The Republic of Indonesia

Badan Meteorologi, Klimatologi, dan Geofisika

The Project of Capacity Development for the Implementation of Climate Change Strategies Phase 2 Final Report regarding Capacity Building on Long-Term Climate Change Projections

April 2023

Japan International Cooperation Agency

Japan Meteorological Business Support Center

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Abbreviations

Abbreviation	Terms
APIK	Adaptasi Perubahan Iklim dan Ketangguhan (Climate Change Adaptation and Resilience)
ATR/BPN	Kementerian Agraria dan Tata Ruang / Badan Pertanahan Nasional (Ministry of Agrarian Affairs and Spatial Planning / National Land Agency)
AWS/ARG	Automatic Weather Station/Automatic Rain Gauge
BAPPENAS	Badan Perencanaan Pembangunan Nasional (National Development Planning Agency)
BMKG	Badan Meteorologi, Klimatologi, dan Geofisika (Meteorological, Climatological and Geophysical Agency)
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CPC	NOAA, Climate Prediction Center
CPD	JMA, Climate Prediction Division
DJF	December, January, February
DS	Downscaling
ECMWF	European Centre for Medium-Range Weather Forecasts
ENSO	El Niño-Southern Oscillation
ERA5	ECMWF reanalysis v5
FAO	Food and Agriculture Organization
GCM	Global Climate Model
	General Circulation Model
GrADS	Grid Analysis and Display System
HPC	High Performance Computer
IOD	Indian Ocean dipole
IPCC	Intergovernmental Panel on Climate Change
ITB	Institut Teknologi Bandung (Bandung Institute of Technology)
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JAXA	Japan Aerospace Exploration Agency
JCC	Joint Coordinating Committee
JJA	June, July, August
JMA	Japan Meteorological Agency
MRI	Japan Meteorological Agency, Meteorological Research Institute
MRI-CGCM3	MRI Coupled General Circulation Model ver.3
KLHK	Kementerian Lingkungan Hidup dan Kehutanan (Ministry of Environment and Forestry)
MASP	Ministry of Agrarian and Spatial Planning

MIROC	Model for Interdisciplinary Research on Climate
MJO	Madden Julian Oscillation
NARO	National Agriculture and Food Research Organization
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NHRCM	Nonhydrostatic Regional Climate Model
NIES	National Institute for Environmental Studies
NOAA	National Oceanic and Atmospheric Administration
PIKAM	Pusat Iklim, Agroklimat dan Iklim Maritim (Center for Climate, Agroclimate and Maritime Climate)
PIKU	Pusat Perubahan Iklim dan Kualitas Udara (Center for Climate Change and Air Quality)
RAN-API	National Action Plan on Climate Change Adaptation
RAN-GRK	National Action Plan for Greenhouse Gas Emission Reduction
RPJMN	Rencana Pembangunan Jangka Menengah Nasional (National Medium Term Development Plan)
SST	Sea Surface Temperature
SYNOP	Surface Synoptic Observations
TCC	Tokyo Climate Center
USAID	United States Agency for International Development
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WRF	Weather Research & Forecasting (NCAR)

INDONESIA

PROVINCES OF INDONESIA

1. ACEH	16. KALIMANTAN TIMUR
2. BALI	17. LAMPUNG
3. BANGKA-BELITUNG	18. MALUKU
4. BANTEN	19. MALUKU UTARA
5. BENGKULU	20. NUSA TENGGARA BARAT
6. GORONTALO	21. NUSA TENGGARA TIMUR
7. IRIAN JAYA	22. RIAU
8. JAKARTA	23. SULAWESI SELATAN
9. JAMBI	24. SULAWESI TENGAH
10. JAWA BARAT	25. SULAWESI TENGGARA
11. JAWA TENGAH	26. SULAWESI UTARA
12. JAWA TIMUR	27. SUMATERA BARAT
13. KALIMANTAN BARAT	28. SUMATERA SELATAN
14. KALIMANTAN SELATAN	29. SUMATERA UTARA
15. KALIMANTAN TENGAH	30. YOGYAKARTA

Legend:
- ⊙ National capital
- ⊚ Provincial capital
- ○ Town, village
- International boundary
- Provincial boundary
- Main road
- Secondary road
- Railroad
- ✈ Major airport

0   250   500   750 km
0   250   500 mi

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

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January 2004

Department of Peacekeeping Operations
Cartographic Section

Local Administrative Unit	
1st	Province (Provinsi)
2nd	Regency (Kabupaten)
	City (Kota)
3rd	District (Kecamatan)
	Village (Kelurahan/Desa)

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1. Outline of the Project

Climate matters in Indonesia have become gradually significant, e.g., change of annual precipitation patterns, and especially in southern region of equator, longer dry season, decrease of precipitation, shorter rainy season, frequent torrential rain, etc. become risks supposed to be caused by climate change. Severer damages by natural disasters and increase of their frequency bring economic stagnation, escalation of poverty, increase of social and economic damages, and these serious risks threaten economic growth in Indonesia. Considerations for risks and vulnerability brough by climate change are indispensable when planning and implementations of the development plans for spatial planning and policy making in national/regional levels. In each sector, mainstreaming of climate change action plans is strongly required.

JICA had implemented technical cooperation project "Project of Capacity Development for the Implementation of Climate Change Strategies" (hereinafter referred to as "Phase 1") for 5 years from October 2010 with the National Development Planning Agency (hereinafter referred to as "BAPPENAS") and other governmental agencies. In 'Phase 1', JICA had implemented comprehensive support to encourage countermeasures for climate change, mainstreaming of climate change in Medium-Term National Development Plan (RPJMN), strengthen ability and structures to develop adaptation plans in agricultural sector, and technical skill transfer for formulation of GHG Inventory. As outputs of the 'Phase 1', the Regional Action Plan for Greenhouse Gas Emission Reduction (RAD-GRK) were promoted under the National Action Plan to reduce Greenhouse Gas Emissions (RAN-GRK). The National Action Plan for Climate Change Adaption (RAN-API) was formulated and implementation of RAN-API and RAN-GRK were notified on RPJMN2015-2019, and JICA supported mainstreaming of climate change action plans of Indonesian governments through the 'Phase 1' project.

"Project of Capacity Development for the Implementation of Climate Change Strategies Phase 2" (hereinafter referred to as "Phase 2") is the project that follows outputs of 'Phase 1' and targets (1) monitoring and evaluation of mitigation actions of RAN-GRK, (2) implements adapting action plans of RAN-API in regional level (mainstreaming of adaptation plans for development plans and space planning) and enhances monitoring and evaluation ability in agencies in national levels and in regional government sectors.

Agency for Meteorology, Climatology and Geophysics (hereinafter referred to as "BMKG"), one of the implementing bodies of 'Phase 2', is a responsible agency for climate change projections, providing this information to related agencies, i) needs experiences and enhancement of technical skills for researches using climate model outputs, ii) implements downscaling of climate projection models cover the whole Indonesia and iii) utilizes downscaled climate projection data. This project aims technical skill transfer for downscaling of Global Climate Model and utilization of downscaled data through training and technical supports for BMKG staff members in Indonesia and in Japan.

1.1 Project Purpose
The purpose of this project targets the achievement of output 2-2 (the enhancement of technical

skills for seasonal prediction and climate projection) in the 'Phase 2' project agreed between JICA and 4 implementing bodies and also aims to contribute to the achievement of the overall goal of the project. In particular, this project aims to enhance the ability of BMKG for (1) supporting the implementation of downscaling of Global Climate Model in high resolution, (2) developing utilization of downscaled climate model data, and (3) supports activities for applying climate change prediction data to plans in pilot areas and targets technical skill transfer for mainstreaming climate change adaptation plan on development plans through BMKG activities.

1.2   Goals

[Overall Goal]

Climate change plans are properly promoted and mainstreamed in Indonesia's National Development Plan to support low carbon and green economic development.

[Project Goal]

Capacities of the key ministries and local government for the climate action cycle (policy assessment, development of framework, development of process and methods, plan, implementation, monitor, and evaluation) are improved.

1.3   Outputs

Output 1   Implementation of climate change mitigation actions under RAN-GRK and the National Determined Contribution (NDC) and support for Low Carbon Development (LCD) and Green Economic Development in the next RPJMN 2020-2024 is strengthened.

Output 2   National Action Plans on Climate Change Adaptation (RAN-API) as the basis for climate change adaptation (CCA) policies and programs in the next RPJMN is reinforced and reformed.

1.4   Activities

[Activities for Output 1]

1-1.   Develop and advance MER system for the government and non-governmental/private sector intervention under RAN-GRK mechanism (BAPPENAS)

1-2.   Investment for NDC (BAPPENAS)

[Activities for Output 2]

2-1.   Review current RAN-API (BAPPENAS)

2-2.   Predict seasonal change and project climate change (BMKG)

2-2-1.   Review the status of seasonal prediction and/or climate change projection to support vulnerability and/or risk assessments at the national level and Pilot Site(s).

2-2-2.   Identify gaps and priority areas for further improvement of seasonal prediction and/or climate change projection to support vulnerability and/or risk assessments at the national level and Pilot Site(s).

2-2-3.   Strengthen capacities in the priority areas, as identified in the Activity 2-2-2, for BMKG

and its concerned local officers to conduct seasonal prediction and/or climate change projection to support vulnerability and/or risk assessments at Pilot Site(s).

2-2-4. Conduct seasonal prediction and/or climate change projection to support vulnerability and/or risk assessments at Pilot Site(s) according to the needs of users, such as MASP and relevant local governments.

2-2-5. Complete lessons learned from Activities 2-2-1 to 2-2-4 and share with stakeholders, including other local officers of BMKG, for the enhancement of the capacity at the national level.

2-2-6. Establish collaboration with RAN-API's secretariat and APIK-USAID project.

2-3. Strengthen Climate Vulnerability Index assessment for improving National Adaption Plan (KLHK)

2-4. Integrate CCA into a spatial plan (MASP)

1.5 Target Area
- Whole area of Indonesia
- Pilot Area (West Java, Semarang city of Central Java)

1.6 Relative Ministries and Agencies
- National Development Planning Agency (BAPPENAS)
- Ministry of Environment and Forestry (KLHK)
- Ministry of Agrarian Affairs and Spatial Planning (ATR)
- Agency for Meteorology, Climatology and Geophysics (BMKG)

2. Work Plan

2.1 Basic Policy of the Project

BAPPENAS, the project implementation organization, has required 5km resolution downscaling of the climate model covering the whole of Indonesia since the beginning of project phase 2, to use these downscaled data to develop climate change mitigation and adaptation plans in pilot areas by BAPPENAS and relevant governmental bodies.

There are two types of downscaling of Global Climate Model, i.e. dynamical downscaling and statistical downscaling. The dynamical downscaling calculates future climate parameters based on elevations and surface conditions (vegetation, terrain, heat flux, etc.) with the resolution of Global Climate Model. The dynamical downscaling requires a high-performance computer with a huge storage, climate model for local level downscaling and it takes several months to complete 10- to 20-year downscaling. On the other hand, statistical downscaling calculates climate projection data with historical observation data and a high-resolution distribution map of normal instead of using direct/physical process. Statistical downscaling is suitable to evaluate the trend of means and variations and is applicable to various GCM models and scenarios. Statistical downscaling has a variety of applications.

This project aims at implementing high resolution dynamical and statistical downscaling for BMKG, technology transfer to produce and share information that BAPPENAS and other agencies require, and capacity building to utilize the data.

Policy 1	Technology transfer for dynamical downscaling and utilization of downscaled data

Implementing high resolution (5 km) downscaling data covering whole Indonesia is the most prioritized requirement for the project by BAPPENAS and other organizations. Dynamical downscaling covering the whole Indonesian area requires huge computer power and several months of calculation period. In 2019, BMKG researchers implemented 20-year downscaling from 1981 to 1990 and 2081 to 2090 using Earth Simulator (one of the most powerful computers in Japan, managed by JAMSTEC) as part of Phase 1. The calculation took about 4 months.

As 'Policy 1', the JICA expert team proposed that BMKG experts implement 20-year 5km downscaling from 1991 to 2000 and from 2091 to 2100 in MRI in cooperation with MRI and JAMSTEC.

However, due to the COVID-19 pandemic, the BMKG experts could not be invited to Japan and the planned 20-year dynamical downscaling could not be implemented. As an alternative plan, it was planned that JICA experts would implement dynamical downscaling using ES with the cooperation of MRI and send the downscaled data to BMKG. When bans on overseas travel are lifted, experts will provide training on the use of HPC as described in Policy 3, dynamical downscaling, and data analysis. In 2021, a domestic training course to utilize downscaled data will be implemented with MRI.

In addition, the training for BMKG staff in Japan is scheduled to be conducted in 2022. Since BMKG staff are not able to come to Japan due to the COVID-19 pandemic in 2020, the JICA expert team will

carry out the downscaling in Japan. To assist the BMKG staff in acquiring the techniques, three steps of training are planned, 1) to carry out OJT when JICA experts travel to Indonesia for installation and setting-up of HPC in 2021, 2) to assist remotely, and 3) to train BMKG staff in Japan. Training in Japan in 2022 for BMKG staff is necessary, because it is very effective to be trained in person by the experts at MRI, NARO, and the University of Tsukuba, however, considering the current pandemic situation, the training period will be shortened.

Policy 2	Technology transfer for statistical downscaling and utilization of downscaled data

The National Agriculture and Food Research Organization (NARO) of Japan provided BMKG with statistical downscaling of Global Climate projection data during the feasibility study for Agri-insurance conducted by Sonpo-Japan Inc. in 2015. The statistical downscaling method employed in the project is the non-parametrical bias correction method using historical observation data and distribution map of meteorological factors' normal, and NARO provided basic lectures and exercises to BMKG to share technical skills. In recent years, NARO conducted statistical downscaling (1- to 5-km resolution) in Japan in SI-CAT (Social Implementation Program on Climate Change Adaptation Technology) project supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan, and various GCM and scenarios to implement cross-model/scenario statistical downscaling is made accessible. Under NARO's cooperation, the 5-km resolution statistical downscaling with RCP 8.5 scenario is planned with MRI-GCM projection to provide the downscaled data for BAPPENAS and other organizations in 2020. In 2021, it is planned statistical downscaling with other GCMs and scenarios in cooperation with NARO.

Policy 3	Procurement of HPC and technology transfer for the implementation of dynamical downscaling

The project plans to procure 2 (two) sets of high-performance computers (HPC) and data storage (HDD) to conduct local dynamical downscaling including western Java (pilot area). To use NHRCM: MRI's dynamical downscaling model and MRI-GCM, it is necessary for BMKG to obtain MRI's agreement with MRI experts' assistance. In the original plan, BMKG experts were to install NHRCM in the procured HPC in cooperation with MRI to develop/modify scripts and to execute NHRCM for pilot areas. However, due to the COVID-19 pandemic, installation of NHRCM, development of scripts, and experimental execution of NHRCM will be carried out by JICA experts. During the installation and calculation, it is planned experts would prepare documents, lecture materials for installation, developing scripts, and evaluation of downscaled data. Following the completion of dynamical downscaling mentioned in 'Policy 1', experts will bring HPCs and HDDs downscaled data, training materials to Indonesia, and implement training and exercises on NHRCM installation, modification of scripts, execution of the model, and evaluation of projected data. After the installation of HRCs and HDDs in BMKG in 2021, BMKG experts will carry out dynamical downscaling for pilot areas with JICA experts' support.

| Policy 4 | Specialized Downscaling for a research theme |

While dynamical and statistical downscaling mentioned in 'Policy1' and 'Policy 2' cover the whole of Indonesia, the statistical downscaling results are used for policymaking against climate change in smaller areas. During the domestic training in Japan in 'Phase 1', BMKG experts studied practical statistical downscaling techniques with Prof. Kusaka at Tsukuba University. Prof. Kusaka has studied the impacts of climate change and urbanization on future change of precipitation and temperature in southeast Asian megacities including Tokyo, Manila, Hanoi, and Kuala Lumpur. In this project, BMKG experts will carry out statistical downscaling in specific areas or cities as cooperative research with Prof. Kusaka.

2.2 Project Implementation

(1) Duration of the project and expert assignment

The planned period of the project was 1 year and 9 months (from July 2020 to February 2022). However, due to travel restrictions and difficulties on on-site activities to prevent COVID-19 infection, activities of the project were implemented separately in Indonesia and in Japan and cooperation works were implemented through the Inter-Net and dynamical down scaling of Global Climate Model (MRI-AGCM) was implemented by Japanese experts and remotely by BMKG members. Parts of project activities, especially on the job trainings (face to face technical skill transfer) had not been implemented and technical skill transfers were not enough to achieve project purposes. The project period of the umbrella project 'The project of Capacity Development for the Implementation of Climate Change Strategies Phase 2' was extended from 3 months to 3 months and 10 months after the amendment of R/D. Along the extension of the umbrella project, the project period was extended from 1 year and 9 months to 2 years and 11 months (from July 2020 to April 2023). In 2022, restrictions and limitation of activities between and in both countries were gradually alleviated and onsite activities resumed with experts dispatch to Indonesia from February 2022.

Experts assigned to the project was listed in Table 1. The original assignment plan and extended assign plan and results of expert assignment are of and results are attached as appendix A.

Table 1 Results of Expert Assignment

Name	expertise	Assignment (Indonesia)	Assignment (Japan)
Michihiko TONOUCHI	Statistical downscaling	1.37 M/M [2]	3.55 M/M
Koichi KURIHARA	Climate projection	3.03 M/M [3]	4.20 M/M
Masaru CHIBA	Dynamical downscaling 1	1.87 M/M [2]	4.80 M/M
Hiroshi SATODA	Dynamical downscaling 2	1.07 M/M [1]	3.90 M/M

M/M: Input Man Month

[x]: Times of on-site activity

(2)　Working Group

Activities of the project have been mainly implemented by Working Groups (WGs). WG1, 2, 3 and 4 were coordinated and activities of each WG are as follows.

Table 2 Working Group Activities

WG1	Technical transference for dynamical downscaling and for utilization of downscaled data. Provision of hardware for dynamical downscaling, including HPC procurement, NHRCM installation and dynamical downscaling for specific area with another scenario and models.
WG2	Technical transference for statistical downscaling and for comparing multi models and scenarios. (supported by Dr. Nishimori of NARO)
WG3	High resolution downscaling targets practical issues. (co-research with prof. Kusaka and Mr. Asano of Tsukuba university)
WG4	Technical skill transfer and support for long-term forecasts (continues from the Agri-insurance project by Dr. Kurihara)

Working members were appointed and members of each working group members at the end of the project was shown in Table 3.

Table 3 Working Group Member List

Output	WG members of BMKG	WG members of JICA
Coordinate project	Dr. Ir. Dodo Gunawan Kadarsah	JICA project tea Mr. Michihiko TONOUCHI (Team leader)
Output 1 (Dynamical Downscaling)	Apriliana Rizqi Fauziah Agus Savana (manager)	Mr. Hiroshi SATODA Mr. Osamu CHIBA
Output 2 (Statistical Downscaling)	Dyni Frina Meisda Muhammad Sudirman Agus Savana (manager)	Mr. MichihikoTONOUCHI Dr. Motoki NISHIMORI (NARO)
Output 3 (Co-research Downscaling)	Trinah Wati	Mr. Michihiko TONOUCHI Mr. Yuki ASANO (Tsukuba university)
Output 4 (Long Range Forecasting)	Supari (leader) Adi (manager, climate outlook) Rama, Rosi (seasonal forecast evaluation, monsoon variability) Novi, Damiana (S2S prediction) Amsari, Ridha, Ayu (ENSO, IOD)	Dr. Koichi KURIHARA

(3)   Project Activities

This project was implemented as a part of the JICA "phase 2" project, and its activities based on Outputs are as follows.

Activity 1-1   Develop and advance MER system for government and non-state actor/private sector intervention under RAN-GRK mechanism (BAPPENAS)

Activity 1-2   Investment for NDC (BAPPENAS)

Activity 2-1   Review current RAN-API (BAPPENAS)

Activity 2-2   Predict seasonal change and project climate change (BMKG)

Activity 2-3   Strengthen Climate Vulnerability Index assessment for improving National Adaptation Plan (KLHK)

Activity 2-4   Integrate CCA into Spatial Plan (MASP(ATR))

This project targets "Activity 2-2" with BMKG and its plan and results are as follows.

Activity 2-2-1   Review the status of seasonal prediction and/or climate change projection to support vulnerability and/or risk assessments at the national level and Pilot Site(s). (Completed)

The project reviewed the above status, and the followings were key findings.

- BMKG conducted a variety of climate projections. However, BMKG doesn't have consistent time series data of climate projection until 2100 and is not high-resolution data for nationwide.

- The JICA agriculture insurance project worked on seasonal prediction, historical data archive and its quality check with BMKG. Several topics of seasonal prediction in JICA Agriculture Insurance-BMKG cooperation and historical data archive/quality check are expected to be continued in JICA Climate Change Strategies Project.

Activity 2-2-2   Identify gaps and priority areas for further improvement of seasonal prediction and/or climate change projection to support vulnerability and/or risk assessments at the national level and Pilot Site(s). (Completed)

JICA Project conducted several discussions to determine potential support for BMKG and identified gaps and priority areas on it.

- The priority for climate projection was having a high-resolution downscaling complete a period toward 2100 at least for one method, dynamical method, or statistical method, and one scenario (RCP8.5 or 4.5) and providing it properly for other stakeholders such as BAPPENAS, KLHK, ATR, Ministry of Finance. Furthermore, it would be better to produce both RCP8.5 and RCP4.5 if the resources allow it. With regards to the high-resolution climate projection, BAPPENAS requested BMKG to provide climate projection with high-resolution in 2020-2045 for the entire Indonesia.

- For the seasonal prediction, it was focused on long term (up to 1 year ahead) seasonal prediction and prediction with good accuracy to fulfill those needs by the other Counterpart. By reviewing the results of the JICA agriculture project, BMKG wished to continue several

seasonal prediction activities namely: seasonal forecast evaluation; Monsoon variability study; S2S prediction study; IOD forecast evaluation and one-year forecast study as a new topic in this project.

Activity 2-2-3   Strengthen capacities in the priority areas, as identified in the Activity 2-2-2, for BMKG and its concerned local offices to conduct seasonal prediction and/or climate change projection to support vulnerability and/or risk assessment at Pilot Site(s). (Completed)

- For assisting BMKG target on climate projection towards 2100 with RCP8.5 and RCP4.5 (if possible), JICA ICCS 2 project with short-term experts started to work for fulfilling the dynamical downscaling for near-future period (2034-2058) and for future period (2071-2100). Additionally, post processing methods, evaluation of downscaled data and calculate various indexes (frequency of heavy rain, dry spells and so on) were developed. For the project with RCP4.5, BMKG can do by High Performance Computer provided by the project. It aims to cover the hotspots at first due to the size of the nation.

- The statistical downscaling data (RCP 2.6, 4.5, 6.0 and 8.5, from 2006 to 2100) was shared and methods of statistical downscaling using historical observation data were shared and exercised. BMKG tried statistical downscaling to cover the period originally asked by BAPPENAS (2006-2100) and evaluated.

- The JICA expert with BMKG jointly conducted activities/studies on key topics on seasonal predictions by monthly meetings. These meetings are to share and consult the progress of each topic.

- The JICA experts shared a guideline to analyze dynamical and statistical downscaling data and provide technical assistance for BMKG Officers especially for post processing to produce detailed climate projection data. In particular, during their visit in July/August 2022, the JICA experts surveyed the requirements of ATR and BAPPENAS for climate change projection. They developed a guideline regarding the methods to develop products that meet their specific requirements from the downscaled climate change projections and shared the guideline with BMKG.

- JICA Short-term Experts visited Jakarta three times in January-March 2021, July-August 2022, and February-March 2023 to conduct capacity building for BMKG members such as climate model installation and share the data & script as well to implement climate projection and seasonal prediction.

- JICA successfully shipped an HPC to BMKG in September 2022 and the HPC was installed in BMKG's server room. Working Group 1 members started to implement dynamical downscaling using the HPC.

- The JICA project and BMKG conducted workshops in Bandung on 1-3 November 2022 and Semarang on 15-17 November 2022, respectively to deliver results of Climate Projection and Seasonal Prediction. The workshop was attended by local departments of West Java, f Bandung City, Central Java, Semarang City and other local organizations including NGOs. In

these workshops, the JICA short-term experts made presentations on "Overview of the Project" "Climate Change and Climate Modelling" and "Project Overview -Seasonal Prediction- "

Activity 2-2-4   Conduct seasonal prediction and/or climate change projection to support vulnerability and/or risk assessments at Pilot Site(s) according to the needs of users, such as ATR and relevant local government. (Completed)

- JICA project supported by Japanese researchers implemented the dynamical downscaling for BMKG because BMKG officers could not go to Japan due to the COVID-19 pandemic.
- Dynamical downscaling RCP8.5 for entire Indonesia for the near future period (2035-2058) was completed in FY2020 (and future period (2071-2100) conducted by The JICA agriculture insurance project). The data were sent to Indonesia and BMKG officers, who started their analysis.
- Some studies of seasonal prediction were completed. BMKG released a one-year forecast as the climate outlook. In the process, Japanese experts provided consultation and information regarding the study.
- Additionally joint co-research by the Japanese expert and BMKG officer for downscaling 1-2 km was completed. Japanese researchers and BMKG have targeted Jakarta as a pilot area to study flood events in early 2021 as the topic. Japanese researchers trialed the simulation to see the impact of global warming and urbanization. BMKG members assisted the simulation by providing the station data and land use coverage in Jakarta and its surroundings as input. The result has been shared at open Seminar Workshop in Jakarta by Mr. Asano in March 2023.
- BMKG supported by JICA short-term experts conducted statistical downscaling with 25KM resolution with several scenarios (RCP2.6, RCP4.5, RCP6.0, RCP8.5) for whole Indonesia in 2022. The data is now available in BMKG.

Activity 2-2-5   Compile lessons learned from the Activities 2-2-1 to 2-2-4 and share with stakeholders, including other local offices of BMKG, for the enhancement of the capacity at the national level. (Completed)

- Japanese experts provided advice and information at several "Dry season/Wet season preparation meetings", which were attended by BMKG seasonal forecasters and researchers/professors outside BMKG.
- The JICA project and BMKG have conducted the workshop in Bandung on 1-3 November 2022 and Semarang on 15-17 November 2022 to deliver results of Climate Projection and Seasonal Prediction. The workshop was attended by local departments of West Java, Bandung City, Central Java, Semarang City and other local organizations including NGOs.
- The climate field school for the application of weather/climate information, organized by BMKG in cooperation with the local organization, was held in Medan on 21-22 August 2022 and was attended by stakeholders including Sharing projection data and data archived to stakeholders were required and BMKG shared the data through data provision server to users contracted with BMKG. Improvement of Climate Change Information System (CCIS) had

been conducted to share projection and data archived.ng tea/coffee producers and makers. The application of seasonal forecast was lectured by the JICA expert.

- BMKG held the national forecaster meeting for the preparation of the wet season 2022/23 in Lombok Island on 2-4 August 2022. The meeting was attended by BMKG local offices over the nation and the results of the Seasonal Prediction were delivered and the climate change issues were lectured by the JICA experts.

- Sharing projection data and data archived to stakeholders were required and BMKG shared the data through data provision server to users contracted with BMKG. Improvement of Climate Change Information System (CCIS) had been conducted to share projection and data archived.

- BMKG jointly with JICA conducted an Open Seminar to share climate projection data and its utilization. In the seminar, both Indonesian research and Japanese researchers shared their experience regarding climate data utilization.

(4)   Procurement

Through the project, items listed in Table 2-4 were procured and handed over to BMKG at the end of the project. Photos of equipment handed over was shown in Figure 1.

Table 4 Items Procured through the Project.

No.	Item	Qty	Description	Purpose	Place
1	HPC	2(J)	DELL PowerEdge R440	High performance PC for dynamical downscaling	BMKG server room
2	Modem	2(J)	Disk enclosure with hard disks (4TB x 12) QNAP TLR1200CRN4012	RAID5, data storage	BMKG server room
3	Laptop PC	2(J)	Laptop PC Panasonic CF-SV8	Remote operation of HPC	BMKG server room
4	Power supply unit	1(I)	APC AP9559 x1, with 2 VGA Cables (3meter)	Power Supply unit	BMKG server room
5	CCIS server software	1(I)	CCIS software development, trainings in Jakarta	Update and renovation of CCIS software	BMKG Bandon
6	Laptop PC	2(I)	ASUS ASUS ROG Flow X13 GV301RC-R735A6T-O	Development and remote operation of CCIS server	BMKG Bandon

(I) Purchased in Indonesia

(J) Purchased in Japan
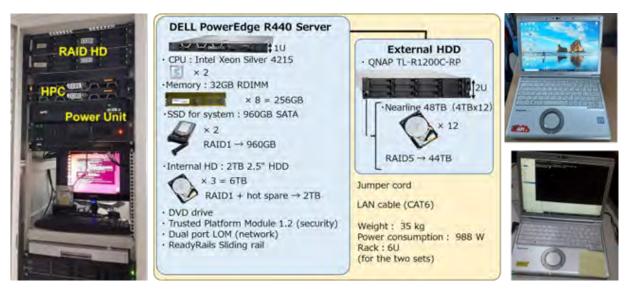
Fig 1 Items Procured
(left: HPC [item no. 1, 2, 4], middle: Spec of HPC, right: operation PCs [3])

Development and rehabilitation of CCIS sever (the previous CCIS server was developed from 2012 to 2014 by BMKG to manage and utilize data to outside users. The previous CCIS server was suspended because of software problems infected with computer virus.) to share historical data BMKG observed, and projection data calculated through WG1 activities was developed. Development/Rehabilitation of the CCIS server is i) software development, ii) trainings in BMKG for operation/maintenance and iii) procurement of laptop PCs to develop and operate CCIS.

Fig 2 Images of CCIS servers

Development of CCIS was finished at the end of March 2023, and trainings for BMKG staff members were conducted in April 2023.

Fig 3 Trainings of CCIS for BNKG (April 2023)

(5)   Products

WG 1 (dynamical downscaling) implemented dynamical downscaling of MRI-AGCM RCP8.5 scenario data using earth simulator in 2019, 2020 and 2021. Dynamical downscaling of 'Future projection' and 'present' (hindcast) data was implemented as activities of the 'Project of Capacity Development for the Implementation of Agricultural Insurance Products, and dynamical downscaling of 'near future projection data) was implemented under this project in 2020 and 2021.

Details of dynamical downscaling data was shown in Figure 4 and further information was reported in chapter 3-2-1. All data (including full layers data) were handed over to BMKG in HD and set in BMKG server storages.
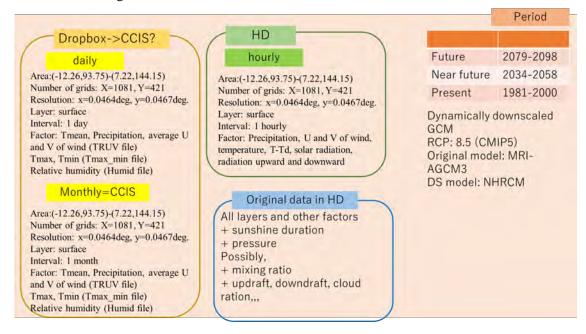
Fig 4 Downscaled data developed through the project (dynamical downscaling)

MRI-CGCM	
hindcast	1961-2005
projection	2006-2100
RCP	2.6,4.5,6.0,8.5
	CMIP5

monthly

Crop area:(-15.14,90.0)-(10.65,150.75)
Number of grids: X=55, Y=24
Resolution: x,y=1.125deg
Layer: surface
Interval: 1 month
Factor: Tmax, Tmin, Precipitation, average wind speed, humidity

Daily

Crop area, Number of grids, Resolution, Layer, factor: ditto
Interval: 1 day

d4PDF	
hindcast	1991-2010
2Kprojection	2031-2060
4Kprojection	2071-2100
GCM	CC, GF, HA, MI, MP, MR
member	9 (2K), 15(4K) for each GCM
	100 (hindcast)

monthly

Area:(-15.44,90.0)-(10.95,150.75)
Number of grids: X=109, Y=48
Resolution: x,y=0.5625deg
Layer: surface
Interval: 1 month
Factor: Tmean, precipitation, average wind speed, humidity

Remark: Daily data is shared on DIAS(Japanese) site. downloading/sharing data is not scheduled.

BMKG data

SYNOP:
Interval: 1 day
Factor: Tmax, Tmin, precipitation
Period: 1981-2020

SACAD:
Interval: 1 month
Resolution: 25km
Factor: Tmax, Tmin, precipitation
Period: 1981-2010(?)

Fig 5 Downscaled data developed through the project (statistical downscaling)

WG2 (statistical downscaling) developed statistical downscaling methos from original Global Climate Model data using observation stations data and/or special average mesh data collected/developed by BMKG mainly for monthly data, partly for daily data.

For statistical downscaling activities, daily and monthly data of MRI-CGCM data was shared to BMKG shown in Figure 5 and used for statistical downscaling. Additionally, in order to compare differences between GCMs, d4PDF data (pseudo global warming experiments data) were shared to BMKG and comparison of results of GCMs were implemented.

In February 2022, users meeting between BMKG and projection data users (related organizations) were held and requirements of users are categorized shown in Fig. 6. These results were reflected for rehabilitation of CCIS server mentioned in previous section and CCIS was designed to have functions and developed to share the data.

Factor
Rainfall
Temperature
Humidity
Wind

Statistic data
Annual average/total
Annual variability
Monthly average/total
Monthly variability

Average: temperature, wind, humidity
Total: rainfall

Rainfall
Number of day (>=60mm/day)
Probability of extreme rainfall (%)
Number of day (<5mm/day) <dry spell>

Temperature
Number of extreme temperature

Temperature
2 climate period

Format
Raster map

Resolution
25km
5km

Spatial
National
Province
Regency
City
Detail

Fig 6 Requirements from users (Feb. 2022)

(6)   Final Meeting and Open Seminar

As a final reporting of the project, 'Final Meeting' was held in the morning of 6th of March 2023 and 'Open seminar' to share latest knowledge and information related climate change in Indonesia in the afternoon of March 2023. Agenda of the meeting and seminar was shown in Figure 7 and presentation materials were reported in DVD with digital files of the project completion report.

Time	Topic	Speaker
09.00 – 09.15	Registration of the participants	
09.15 – 09.20	Opening Remarks	JICA
09.20 – 09.35	Project Outline and Achievement of the Project	Mr. Michihiko Tonouchi (JICA Experts Team Leader)
09.35 – 09.55	Activity 1a: Dynamical Downscaling	WG 1
09.55 – 10.15	Activity 1b: Statisical Downscaling	WG 2
10.15 – 10.30	Activity 1c: High Resolution Downscaling	WG 3
10.30 – 11.20	Activity 2: Long Range Forecasting	WG 4
11.20 – 11.50	Discussion	
11.50 – 12.00	Closing Remarks	

Time	Topic	Speaker
13.00 – 13.15	Registration	
13.15 – 13.30	Introduction of Participants and Opening Session of the Seminar	JICA and BMKG
13.30 – 13.35	Photo Session	
13.35 – 13.50	Climate Projection Data Availability	Kadarsah, M.Si
13.50 – 14.10	Climate Projection by Statistical Downscaling in Indonesia and Agriculture	Dr. Motoki Nishimori NARO
14.10 – 14.25	Climate Change and Affection on Agriculture in Indonesia	Ministry of Agriculture
14.25 – 15.00	Climate Projection considering Urbanization for 2045 Jakarta	Prof. Hiroyuki Kusaka Tsukuba University
15.00 – 15.10	Climate Change Research in Indonesia	Climate Change Center ITB
15.10 – 15.20	Climate Change Research in Indonesia	CCROM IPB
15.20 – 15.55	Discussion	Moderator: Dr. Amsari Mudzakir Setiawan
15.55 – 16.00	Closing	

Fig 7 Agenda of 'final-meeting' and 'Open-seminar'

Through WG activities, WG meetings, discussions, exercises were held, and these were listed in Table 5.

Table 5 Workshops, Forums, Seminars and Meetings

<WG1>

Date	Meetings	participants	number	themes
2021.09.22	WG1 meeting	WG1 team, JICA team	10	progressive reports and discussopn of next activities
2021.11.8	WG1 meeting	WG1 team, JICA team	10	progressive reports and discussopn of next activities
2021.12.14	WG1 meeting	WG1 team, JICA team	9	progressive reports and discussopn of next activities
2022.02.02	WG1 meeting	WG1 team, JICA team	10	progressive reports and discussopn of next activities
2022.03.01	WG1 meeting	WG1 team, JICA team	3	progressive reports and discussopn of next activities

\<WG2\>

Date	Meetings	participants	number	themes
2021.06.14	WG2 meeting	WG2 team, JICA team	8	Sharing MRI-AGCM data and scripts
2021.07.13	WG2 meeting	WG2 team, JICA team	8	Sharing grads scripts for MRI-4-scenarios-GCM, d4PDF
2021.09.21	WG2, WG3 meeting	WG2, WG3 team, JICA team	10	progressive reports and discussopn of next activities
2021.11.5	WG2, WG3 meeting	WG2, WG3 team, JICA team	10	progressive reports and discussopn of next activities
2021.11.18	WG2 meeting	WG2 team, JICA team	8	Sharing grads scripts for MRI-4-scenarios-GCM, d4PDF
2022.02.02	WG2 meeting	WG2 team, JICA team	8	Sharing grads scripts for MRI-4-scenarios-GCM, d4PDF
2022.02.16	WG2 meeting	WG2 team, JICA team	8	Evaluation of MRI-AGCM 4 scenarios
2022.02.22	WG2 meeting	WG2 team, JICA team	8	trend analysis (temperature and precipitation) at whole BMKG staions,
2022.03.01	WG2 meeting	WG2 team, JICA team	8	trend analysis (temperature and precipitation) at whole BMKG staions, sharing statistical DS tools
2022.03.10	WG2 meeting	WG2 team, JICA team	8	trend analysis (temperature and precipitation) at whole BMKG staions

＜WG3＞

Date	Meetings	participants	number	themes
2021.06.29	DS jlint eeting	BMKG, Tsukuba university, JICA-project-office	12	dicsussion on high resolution DS
2021.09.21	WG2,3-meeting	MRI-GCM grads scripts sharing	10	Sharing MRI-GCM visualization tools and manuals
2021.11.5	WG3 meeting	WG3 team	5	Progressive report and discussion for next activities
2022.02.8	WG3 meeting	WG3 team	2	Progressive report and discussion for next activities
2022.03.8	WG3 meeting	WG3 team	2	Progressive report and discussion for next activities
2022.03.29	WG3 meeting	WG3 team	2	Progressive report and discussion for next activities

<WG4 Workshop, Forum, Seminar>

NO	Year.Month.Date	会合 (Meetings)	参加者 (Participants)	内容等 (Contents of the meeting)
1	2021.03.12	National Climate Outlook Forum（NCOF）	BMKG and seasonal forecast expets	To discuss and prepare 2021 Dry season forecast
2	2021.03.18	National Climate Forum for User	BMKG and seasonal forecast users	To explain 2021 Dry season forecast
3	2021.07.29	National Climate Expert Forum（NCEF）	BMKG and seasonal forecast experts	To discuss 2021/22 Wet season forecast
4	2021.08.27	National Climate User Forum	BMKG and seasonal forecast users	Meeting wih seasonal forecast users
5	2021.11.17	Focus Group Disscussion	Seasonal forecast experts from BMKG and Mlaysia met office	To share information on Climate Variability and Climate Services in Southeast Asia
6	2022.02.15	National Climate Expert Forum	BMKG and seasonal forecast experts	To discuss 2022 Dry season forecast
7	2022.02.22-26	National Climate meeting	BMKG seasonal forecasters	Seasonal forecast meeting for Dry season 2022
8	2022.08.02-05	Wet season forecast meeting(Lombok)	BMKG seasonal forecasters	To prepare for wet season 2022/23 forecast
9	2022.08.20-21	Climate Field School(Medan)	BMKG and users(Tea/coffee producers)	Climate Field school for tea/coffee production
10	2022.11.01-03	Workshop of Climate Projection and Seasonal Prediction in Bandung	BMKG and local organizations	Lectures on climate change/seasonal forecas by JICA experts and WG4 members
11	2022.11.15-17	Workshop of Climate Projection and Seasonal Prediction in Sumarang	BMKG and local organizations	Lectures on climate change/seasonal forecas by JICA experts and WG4 members
12	2023.01.25	The Focus Group Discussion　-ENSO Forecast Devlopment	BMKG and seasonal forecast/ENSO forecast expert	Discussion and lecture on ENSO monitoring and forecast

<WG4 Meeting>

	Date	Meetings	Participants	Contents of Meeting
1	2020.10.13	Kick-off Meeting	WG4 members, Project Expert	JICA hosted Kick-off Meeting
2	2020.10.20	WG4 Monthly meeting	WG4 members, Project Expert	To prepare Work Plan for Target 4
3	2020.11.24	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
4	2020.12.22	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
5	2021.02.03	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
6	2021.03.04	JICA/BMKG Joint meeting	JICA, BMKG, JMBSC	Progressive report and Work Plan for 2021
9	2021.04.06	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG activities
10	2021.04.14	JICA/BMKG Joint meeting	JICA, BMKG, JMBSC	Joint meeting
11	2021.05.19	The Second JCC	JICA, Related Organizations, JMBSC	The Second JCC
12	2021.05.25	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
13	2021.06.24	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
14	2021.07.28	WG4 Monthly meeting	WG4 members, Project Expert	Same as above

<WG4 Meeting> (Continue)

17	2021.08.31	Technical Working Group Discussion	JICA, BMKG, JMBSC	Joint meeting
18	2021.09.02	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
19	2021.09.17	WG4 Monthly meeting	WG4 members, Project Expert	Preparing mid-term reports
20	2021.09.27	JICA/BMKG joint meeting	JICA, BMKG, JMBSC	JICA/BMKG joint meeting for mid-term reporting
21	2021.10.12	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
23	2021.11.23	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
24	2021.12.15	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
25	2022.02.03	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
26	2022.02.10	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
28	2022.02.15	WG4 Monthly meeting	WG4 members, Project Expert	To disscuss work plan among others
30	2022.03.02	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
31	2022.04.13	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
32	2022.05.22	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
33	2022.06.29	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
34	2022.07.18	WG4 Monthly meeting	WG1,2,3 and 4, Project Expert	To report and share the progress of WG activities
38	2022.08.24	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
39	2022.09.14	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
40	2022.10.28	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
43	2023.01.18	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
45	2023.02.14	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
46	2023.02.27	WG4 meeting	WG4 members, Project Expert	To prepare for the final report meeting and for Complete report of WG4
47	2023.02.28	WG4 meeting	WG4 members, Project Expert	Same as above
48	2023.03.02	WG4 meeting	WG4 members, Project Expert	Speach reheasal for the final report meeting
49	2023.03.03	WG4 meeting	WG4 members, Project Expert	Same as above
50	2023.03.06	Final report meeting	JICA/BMKG project PhaseII members	Report to JICA/BMKG
51	2023.03.06	Open seminor	JICA/BMKG and related organizations	Lectures by experts on climate change issues
52	2023.03.10	WG4 meeting	WG4 team, JICA	Wrap-up for WG4 Activity
53	2023.03.20	WG4 meeting	WG4 team, JICA	Preparation of WG4 final report

3. Project Activities

As mentioned in Section No.2, this project conducts high-resolution downscaling in dynamical and statistical and aims to build the capacity of BMKG for technical skill transfer and data usage with developing and sharing information demanded from operational organizations such as BAPPENAS.

Methods of the downscaling in this project are composed of dynamical, statistical, and high-resolution downscaling, outputs regarding the downscaling are divided into three parts; Output 1a as dynamical downscaling, Output 1b as statistical downscaling, and Output 1c as high-resolution and reported them respectively. Moreover, the long-range forecast which is also an output of this project is Output 2. Each output working group is organized as WG1 is Output 1a, WG2 is Output 1b, WG3 is Output 1c, and WG4 is Output 2.

3.1 Activity for Output 1a (Dynamical Downscaling)

3.1.1 Background on Output 1a

In Indonesia, it is concerned that the growing severity and increasing frequency of the disaster associated with future climate change may become a major risk.

Therefore, it is important to mainstream climate change in developing and implementing national and regional development plans, space plans, sectoral policies, considering the effects and regional and sectoral vulnerability of climate change.

The regional scale (resolution of about 5 km) climate change projection is required to evaluate the increasing severity and frequency of the disaster associated with future climate change and to use the knowledge for regional development plans and policymaking. In order to carry out the required detailed climate change projection, it is necessary (i) to cut out boundary conditions (the data with which downscaling are carried out) from global climate model projection (ii) to execute a regional climate model, which is able to consider more detailed topography, and effects of land process and distribution of sea surface temperature to carry out a regional projection of present and future climate change (dynamical downscaling). Also, it is necessary (i) to evaluate the representation of the present climate and future projections, (ii) to compile information for impact assessment of climate change and provide for relevant agencies in charge of measures against climate change.

In this project, the dynamical downscaling was carried out from projections with MRI Atmospheric Global Climate Model (MRI-AGCM) with RCP 8.5 scenario using Non-Hydro Regional Climate Model (NHRCM). The difference of resolution between AGCM and NHRCM is shown in Figure 8 NHRCM, with higher resolution than AGCM, expresses the decrease of the surface temperature in the mountains in Bali better.
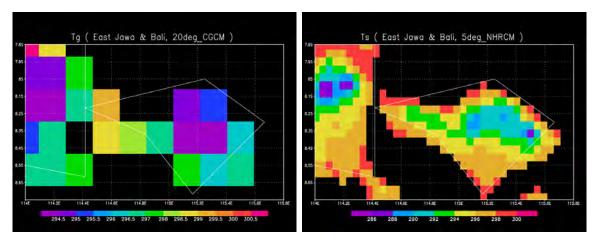
Fig 8 Comparison between AGCM and NHRCM in Terms of the Surface Temperature

Left: AGCM (20 km resolution), Right: NHRCM (5 km resolution).

The white lines indicate the coastline of Eastern Java and Bali Island. The colored meshes indicate the surface temperature computed with each model.

In this project, projections with AGCM and NHRCM were carried out for the periods of "Present (1980 - 2000)", "Near Future (2036 - 2055)" and "Future (2080 - 2010)" respectively that enables temporal regional climate change projection in Indonesia with RCP8.5 scenario (IPCC's highest emission scenario).

3.1.2 Challenges Related to Output 1a

BMKG, which is one of the operational organizations of this project, is in charge of application of climate models, implementation of downscaling of climate change in Indonesia, and application of downscaled data. However, BMKG does not possess the necessary computation resources and lacks experience and technologies to carry out dynamical downscaling and utilize the results.

Therefore, it is necessary to provide BMKG with capacity building to carry out dynamical downscaling and its application through training for BMKG staff in Indonesia and Japan.

3.1.3 Activity Details for Output 1a

In Output 1a, the following targets and activity plans were set in accordance with "Policy 1: Dynamical downscaling and utilization of downscaled data" and "Policy 3: Procurement of HPC and technical skill transfer for implementation of dynamical downscaling."

(1) 5-km dynamical downscaling for the whole area of Indonesia

a) Target

The target is to complete the 5-km dynamical downscaling for the whole area of Indonesia for the periods of "Present (1981 - 2000)", "Future (2080 - 2100)" as well as "Near-Future (2036 - 2055)", and to check their qualities.

b) Activity Plan

It was planned to carry out the downscaling from the 20-km AGCM projections with the non-hydro regional climate model (NHRCM) developed by MRI, in cooperation with Area Theme C: Integrated

Climate Change Projection of the Integrated Research Program for Advancing Climate Models (TOUGOU C), with the Earth Simulator of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

Japanese experts carried out the downscaling in place of BMKG experts, who were unable to visit Japan due to the COVID-19 pandemic, and parts of projections were sent to BMKG and analyzed by the BMKG experts.

(2)   Policy 3: Procurement of HPC and Technical Skill Transfer for Implementation of Dynamical Downscaling

a)   Target

The target is to procure the high-performance PCs (HPC) that will enable further dynamical downscaling in Indonesia and laptop PCs that will be used to make a presentation of the analyses to relevant agencies; and to complete the installation of NHRCM programs and scripts in the HPCs, and the 5-km downscaling projections and other relevant data in the HPCs.

b)   Activity Plan

HPC specifications that are needed to run NHRCM were determined following the expertise of MRI researchers and considering its use in Indonesia, and the procurement process was carried out. JICA experts, in place of BMKG staffers who were unable to visit Japan, installed NHRCM into HPC.

3.1.4   Progress for Output 1a

All activities of Output 1a were successfully completed as planned as follows.

(1)   Dynamical Downscaling and Utilization of Downscaled Data

All planned dynamical downscaling projections were completed successfully for the RCP8.5 scenario and the area of the whole of Indonesia. The results are shown in the figure below.

The results of projection were stored in HPC and transported to BMKG with HPC.
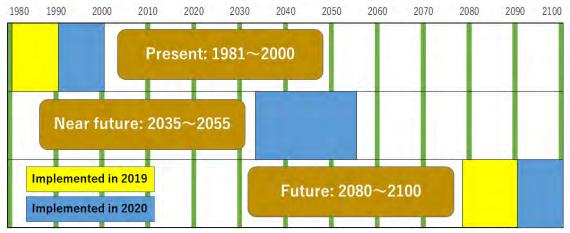
Fig 9 Results of 5-km Dynamical Downscaling

Some of the calculation results (surface temperature, wind, precipitation, etc.) were sent to BMKG in advance for their analysis. The analysis results were published in the Annual Report of the Integrated Research Program for Advancing Climate Models (TOUGOU) 2020.

(2)   Procurement of HPC and Technical Skill Transfer for Implementation of Dynamical Downscaling

HPC and laptop PCs for the presentation of the evaluation results were procured, as shown in the figure below. They were temporarily installed in the server room of the Meteorological Research Institute, and the installation of OS, NHRCM, and data was completed.

In determination of the specifications of the HPC, requirements of the processor and memory were considered to carry out further high-resolution downscaling, and the external storage was selected so that the 5-km downscaling projections can be stored. Considering the use in Indonesia, two sets of HPCs were procured for redundancy, and general-purpose parts of HDD were selected so that replacements can be easily purchased in Indonesia. Furthermore, the Linux OS (Cent OS 7) which is used in BMKG was adopted. It is expected that this HPC is capable of conducting activities of Output 1b (Statistical downscaling) as well.

The laptop PCs were procured which have the multilingual OS and applications, US keyboard and many output terminals as well as shock resistance, considering the use to make briefings to relevant organizations.

It was planned that these devices would be transported and installed in BMKG during the JICA experts' travel to Indonesia. Importation procedures on the Indonesian side took more time than expected, and the equipment was delivered to BMKG on 25 August 2022.
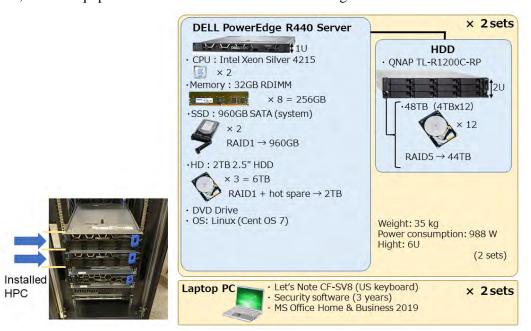
Fig 10 Specifications and Installation of HPC and Laptop PC

(3)   Support for Capacity Building to Use Downscaled Data

To strengthen the capacity of Indonesian government agencies, including BMKG, to use the results of downscaling to consider climate change adaptation measures, JICA experts conducted.

- JICA experts developed materials to introduce the counterparts such as BMKG and BAPPENAS Japan's case studies on adaptation measures to climate change using the results of

dynamical downscaling.

- With the support of the local project office, specific needs for downscaling data that relevant ministries such as BAPPENAS and ATR have been identified, and data and analysis tools to enable BMKG to meet those needs were developed.
- They held regular working group meetings with BMKG officers (22 September, 8 November, 14 December 2021, 2 February, 1 March and 27 June 2022) to carry out the following activities:
  - ➢ The data processing environment at BMKG, including the operating system and software BMKG uses, and the staff's skills were confirmed.
  - ➢ As the provided hourly data proved to be too large and complicated to use, daily and monthly averages were created and shared using the online file-sharing system Dropbox. In addition, relative humidity data were additionally provided in response to requests from relevant ministries for the downscaled data.
  - ➢ The Japanese experts developed and provided scripts for analyzing and charting these data and supported the data analysis work by BMKG.
  - ➢ Items to be analyzed were surveyed based on the needs of the relevant governmental agencies.
  - ➢ Items to be discussed in the workshops for BMKG's local staff and local government officials were considered.

As a result of these developments, the expert team developed a guideline for producing information the relevant agencies need using the dynamical and statistical downscaling products. The guideline was submitted to BMKG counterpart on 29 August 2022 during the expert's visit.

The expert assisted the BMKG's application for MRI to lend NHRCM. The director of MRI granted the permission dated 2 September 2022.

(4)   Seminars for BMKG staff and local government officials

The expert conducted seminars for BMKG staff and local government officials regarding the fundamentals of global warming and regional climate change projections in the vicinity of Indonesia with the following schedule:

4 August 2022: BMKG's rainy season forecast meeting

2 November 2022: Seasonal prediction workshop in West Java

In the seminars, the expert made a presentation on the principles of global warming, climate change in the past, methods of global warming projection, global warming projections according to emission scenarios, regional global warming projections in the vicinity of Indonesia, referring to the sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC).

(5)   Development of programs and manuals for the analysis of the projection

In downscaling from a horizontal resolution of 20 km to 5 km, data is output every hour to calculate the daily maximum and minimum temperatures. The volume of such hourly data was so large that it was difficult for BMKG to process the data. For this reason, the Japanese experts created daily, monthly, and yearly average files to facilitate analysis by BMKG. In processing the averages, the maximum and

minimum temperatures were also calculated simultaneously. As described in (3), the Japanese experts provided these products to BMKG.

Data analysis was performed using a drawing software called Grads. The Japanese experts created a script that summarized the Grads commands necessary for the analysis and provided it to BMKG.

The Japanese experts created programs to calculate extreme events (e.g., precipitation periods, no precipitation periods, etc.) using daily average data and also created an HTML script to display the frequency distribution of occurrence in the present, near future, and future periods, which was provided to BMKG.

The programs for the above analyses were developed in Fortran, Grads script, and HTML script. The Japanese experts provided all these programs and scripts to BMKG and explained how to use them. BMKG counterparts are using the provided programs with modifications according to their purposes.

(6)   Analysis of the downscaled climate change projection

Indonesia, the tropical maritime continent, is one of the most vulnerable countries to climate-related disasters. Rainfall is a parameter that interacts with many living sectors of the population, and much of the effort on weather and climate prediction and analysis in Indonesia is focused on precipitation and its related information. BMKG team has analyzed the past state and multiple future periods over Indonesia based on the modeling process using the Non-Hydrostatic Regional Climate Model (NHRCM) developed by the scientists at Japan's Meteorological Research Institute (MRI).

NHRCM data was used to analyze rainfall, maximum temperature, and minimum temperature for past and future periods. Below is the detail of the NHRCM data

- Using NHRCM - AGCM 20 km as forcing
- Downscale to 5x5 km resolutions (1081 x 421 grid point)
- Cover whole Indonesia and surrounding continent area (longitude 93.76 to 144.15 decimal degrees East dan latitude 12.26 decimal degrees South to 7.23 decimal degrees in the North)
- Experiment:
  - ➢ August 1981 – September 2001 for present
  - ➢ August 2034 – September 2059 for near future
  - ➢ August 2079 – September 2099 for future
- Both future simulations utilize the climate change RCP8.5 scenario
- The first month of each simulation was ignored and considered as the model spin-up time

a)   Analysis for past period
Comparison with observation

The result of the past simulations was compared with the CHIRPSv2.0 gridded dataset (representing rainfall observation reference) with a 0.05-degree resolution for rainfall comparison and the ERA5 reanalysis dataset (representing temperature observation reference) with a 0.3-degree resolution for temperature comparison.
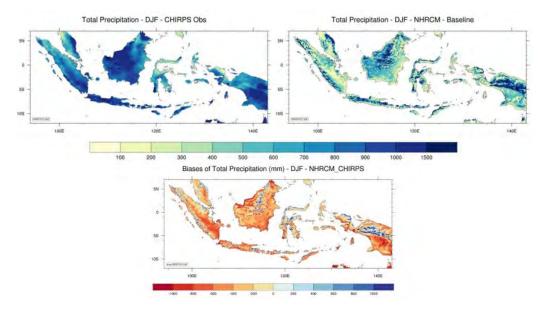
Fig 11 Precipitation (NHRCM) vs CHIRPSv2.0 in DJF

(Upper left) CHIRPS Observation, (Upper right) NHRCM simulation, (Lower) Difference

Precipitation simulation during the past period (1981-2000) for the December-January-February (DJF), as well as the CHIRPS observation data and their differences for the respective period, is shown in Fig. AA. In general, NHRCM shows an almost uniform underestimation of the observational reference. Besides, the spatial pattern of the NHRCM simulation result proves to be more heterogeneous in terms of representing the topography in Indonesia. The mountain range over Sumatra, Borneo, Java, Celebes, and New Guinea is analogous to the spatial rainfall pattern. NHRCM simulation also tends to overestimate precipitation over these mountainous regions while underestimating rainfall over lower altitudes and flatlands. NHRCM simulation has a strong sense in presenting the rain shadow effect, which leads to higher precipitation in front of the mountain but dryer in its backside, as in DJF, the wind dominantly came from the northern hemisphere.
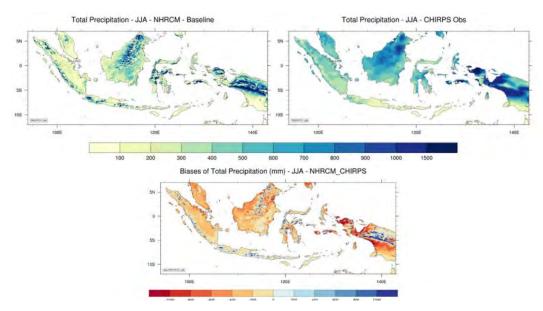
Fig 12 Precipitation (NHRCM) vs CHIRPSv2.0 in JJA

(Upper left) NHRCM simulation, (Upper right) CHIRPS Observation, (Lower) Difference

Precipitation simulation during the past period (1981-2000) for the June-July-August (JJA), as well as the CHIRPS observation data and their differences for the respective period, is shown in Upper Figure. It is still shown that NHRCM simulation can still capture the spatial pattern of precipitation compared to the CHIRPS observation while representing a better pattern with respect to topography. In general, NHRCM produces underestimated precipitation over the whole region of Indonesia. Meanwhile, it still produces overestimated rainfall over mountainous regions, as mentioned in the DJF part. As mentioned, NHRCM has a strong sense of presenting a rain shadow effect, which leads to higher precipitation in front of the mountain but dryer in its backside, as in JJA, the wind dominantly came from the southern hemisphere.
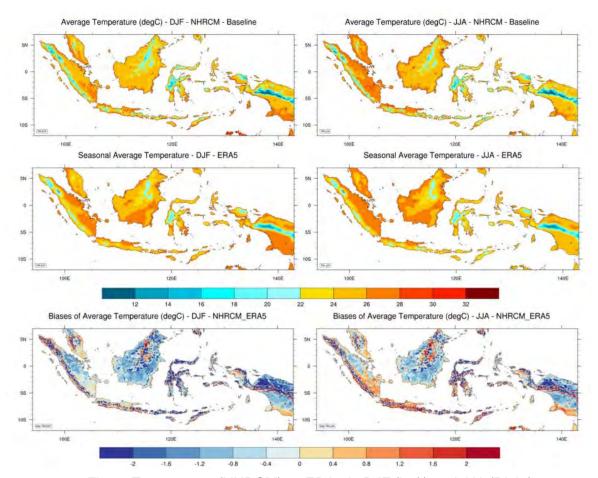
Fig 13 Temperature (NHRCM) vs ERA5 in DJF (Left) and JJA (Right)

The NHRCM simulation during the past period can reproduce the spatial pattern of the ERA5 observational reference. The difference between NHRCM and ERA5 is apparent in spatial resolution, as NHRCM simulation has a higher resolution of 5x5 km. The figures show that NHRCM simulation produces a better spatial representation concerning topographical distribution. Such a feature prevails in both DJF and JJA seasons. However, over the mountainous regions, NHRCM simulation tends to produce a significant cold bias (up to 2 degrees Celsius differences). It can be inferred that the model is less skillful over the area or that the reanalysis data does not correctly represent the temperature over the mountain area due to its limitation. This is something that should be confirmed with several samples of in-situ observation. A warm bias is also detected in the JJA season over lower lands in Java, ranging from 0.8 to 1.6 degrees. Such biases should be considered in performing future analyses.
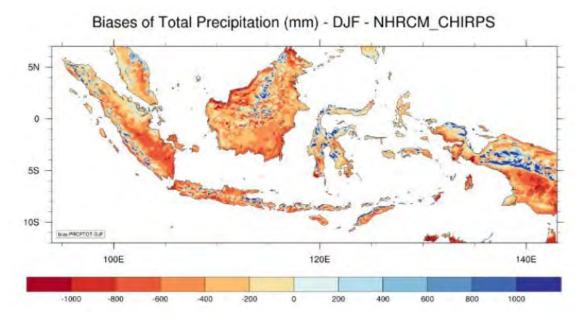
Fig 14 Precipitation biases between NHRCM and CHIRPS in DJF

NHRCM simulation also tends to overestimate precipitation over these mentioned mountainous regions while underestimating rainfall over lower altitudes and flatlands. NHRCM simulation has a strong sense in presenting the rain shadow effect, which leads to higher precipitation in front of the mountain but dryer in its backside, as in DJF, the wind dominantly came from the northern hemisphere.
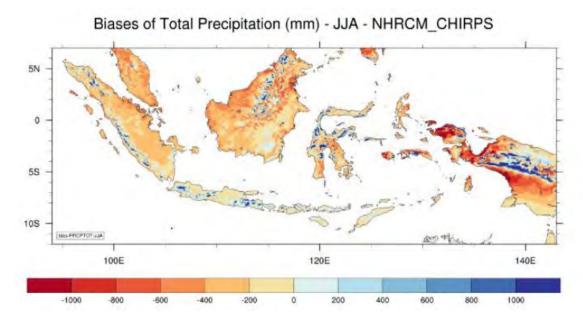
Fig 15 Precipitation biases between NHRCM and CHIRPS in JJA

In general, NHRCM produces underestimated precipitation over the whole region of Indonesia. Meanwhile, it still produces overestimated rainfall over mountainous regions, as mentioned in the DJF part. As mentioned, NHRCM has a strong sense in presenting the rain shadow effect, which leads to higher precipitation in front of the mountain but dryer in its backside, as in JJA, the wind dominantly

came from the southern hemisphere.

Comparison with BMKG Local Stations

In situ observations were compared with NHRCM over Java Island using BMKG Local Stations. We chose only Java Island because the data availability was better than in other regions.
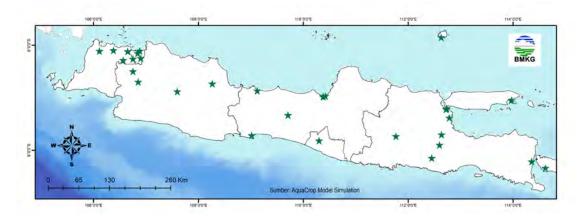
Fig 16 BMKG Local stations

Precipitation

Comparison of daily precipitation between observation and NHRCM data. Trends were plotted for baseline, near future, and future. Below are some examples of the trend in West Java and Central Java.
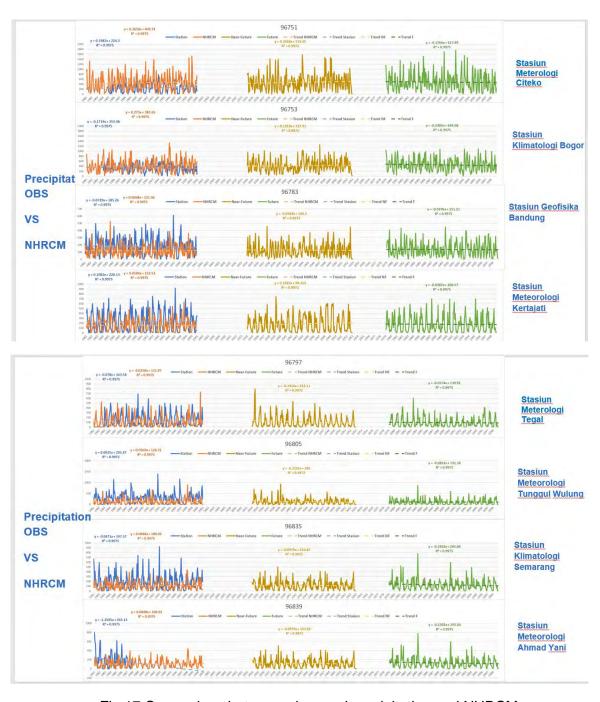
Fig 17 Comparison between observed precipitation and NHRCM:
(Upper) West Java, (Lower) Central Java

For easier checking, all collected data are shown by the map, for precipitation dominated by red color. It means the model underestimated precipitation more than observations. But some areas show green, which means overestimated. The blue points are plotted on the mountainous region, and the red points are generally located on flatland. The result agrees with Chirps and NHRCM bias analysis, which has been done in the previous explanation.
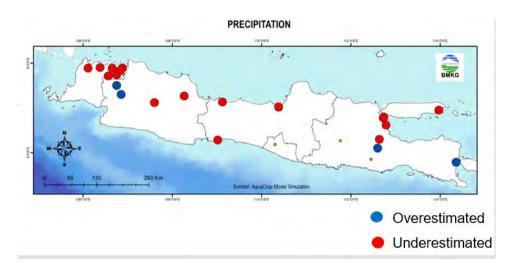
Fig 18 Comparison between observed precipitation and NHRCM in Java Island

Temperature

The daily temperature was compared between observation and NHRCM data. The trends from baseline, near future, and future are plotted. Below are some examples of the trend in West Java and Central Java.

Fig 19 Comparison between observed temperature and NHRCM: (Upper) West Java, (Lower) Central Java
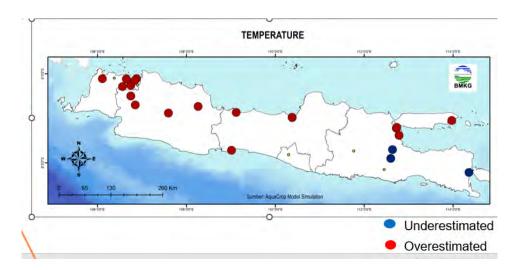
Fig 20 Comparison between observed temperature and NHRCM in Java Island

Almost every station has a lower bias, and only three stations in East Java have a higher bias. This result agrees with previous analysis using Era5 that mountainous regions tend to produce a cold bias (blue color).

Maximum Temperature

The daily maximum temperature was compared between observation and NHRCM data. The trends from baseline, near future, and future are plotted. Below are some examples of the trend in West Java and Central Java.
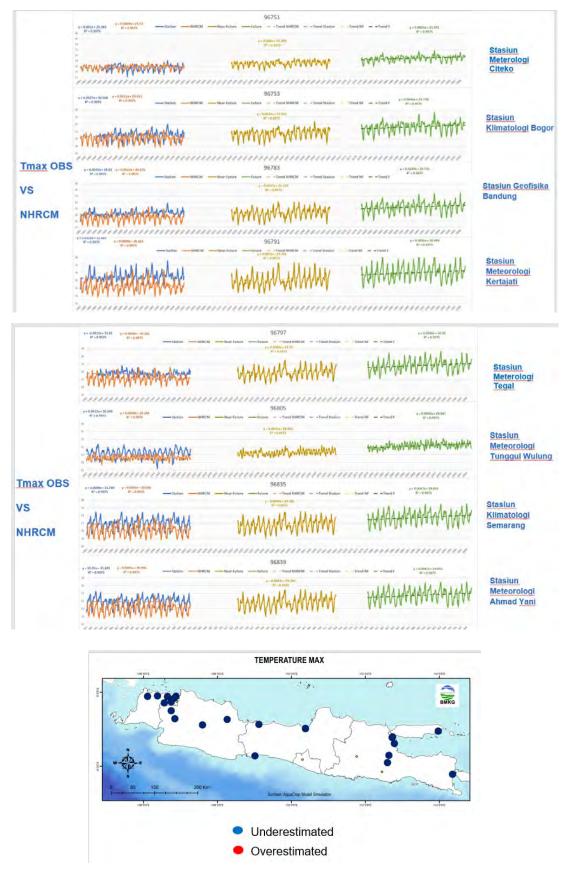
Fig 21 Comparison between observed maximum temperature and NHRCM: (Upper) West Java, (Center) Central Java, Bias distribution in Java Island

The maximum temperature plot is dominated by blue color. It means the model underestimated the maximum temperature from observations.

Minimum Temperature

The daily minimum temperature was compared between observation and NHRCM data. The trends from baseline, near future, and future are plotted. Below are some examples of the trend in West Java and Central Java.
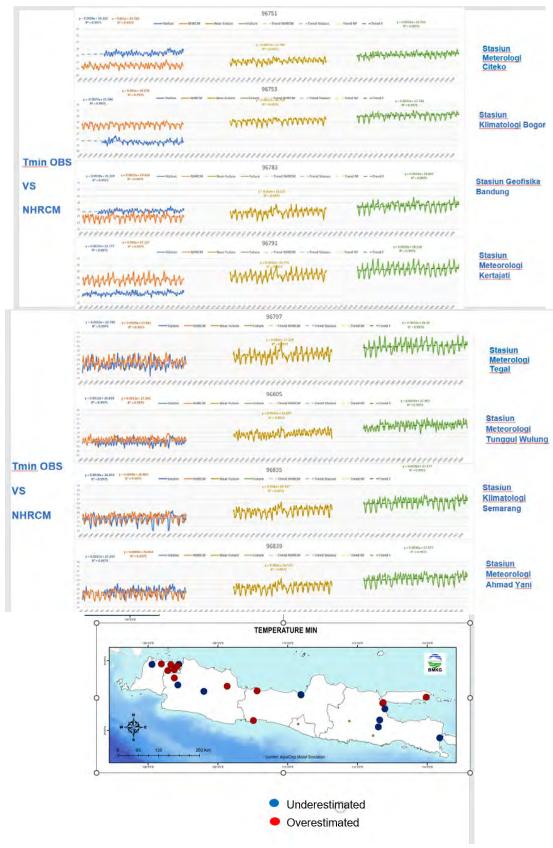
Fig 22 Comparison between observed minimum temperature and NHRCM:
(Upper) West Java, (Center) Central Java, Bias distribution in Java Island.

The plots of minimum temperature show various results. Mountainous regions tend to have cold

bias, but some points on flatlands also produce cold bias.

b)   Analysis for future period
Probability Distribution Function
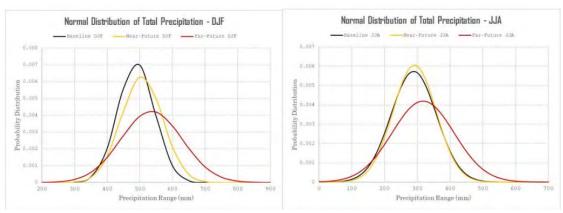
Fig 23 Probability Distribution Function of precipitation (Left) DJF, (Right) JJA

The probability distribution function of the whole Indonesian area by averaging the domain area used in NHRCM (1081 x 421 grid points) for the whole 20 years of past simulation (black line) and future simulations (gold and dark red) was calculated. Both seasons, DJF and JJA, are projected to have higher precipitation in the mean value, with the increase of the mean value in DJF being higher.

In the near-future period, the mean precipitation is projected to increase from around 480 mm to 510 mm during DJF, which is around a 30 mm rise, and for JJA, the increase in the mean is not very significant. As for the far-future period, the mean precipitation is projected to increase from around 480 mm to 540 mm during DJF, around a 60 mm rise. The far-future mean precipitation is projected to increase from around 290 mm to 320 mm during the JJA season, which is around a 30 mm rise, in contrast to the less significant expected mean change during the near-future period.

The spread of the curve is also another thing to be noted. Both curves of the future period precipitation (gold and dark red) in DJF appear to be lower and wider compared to the past period (black), with the far-future period having a more significant shift toward the extremes. This means that in the future, the state of the DJF precipitation will have a higher chance of extreme events related to higher cumulative precipitation, as shown by the reach of the curve to the right side.

In JJA, however, the curve becomes slightly narrower, albeit not very significant in the near-future period. On the other hand, there is a tendency for an increase in mean value and the reach of the curve for the far-future period. This type of change can provide a different impact which depends on the condition during the JJA season of a specific area. An area with a wet JJA season could experience a wetter anomaly, while another area with a dry JJA season could benefit from the additional water supply.

The shift of the mean rainfall and the curve's movement towards extremes must be alerted to stakeholders and policymakers of various sectors. It should be noted that this is an average for the whole Indonesia region, which has various types of rainfall patterns. A more specific probability distribution analysis over a localized region would give more insight into local adaptation strategy.

Projection Changes
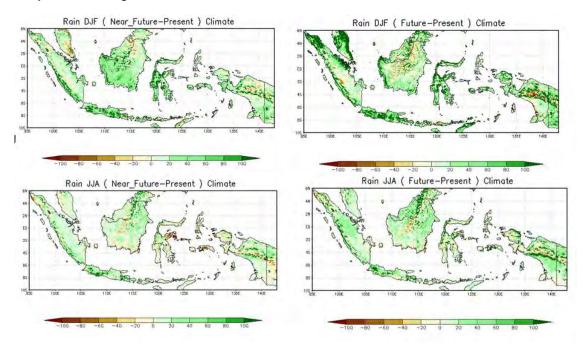
Fig 24 Changes in projected seasonal precipitation
(upper left) near-future in DJF, (upper right) end-of century in DJF,
(lower left) near-future in JJA, (lower right) end-of century in JJA

The seasonal precipitation change figures show a dominant green color for DJF, which means in the future, precipitation in the rainy season will increase. But some regions will decrease, like the central part of Sumatra, Borneo, and New Guinea. Java and Celebes are dominant increasing, which suggests a wet get wetter (influenced by Indo-Australian monsoon). Some areas that are decreasing in the near future will get drier in the future.

In the JJA season, similar to DJF but slightly different, dominantly by soft green and soft brown, which means the number of changes is not big. In the future exhibits a much more significant increase or decrease (suggest a dry get drier and a wet get wetter). Take notice that the significant change in both seasons implies a higher risk from the change in the climate parameter.
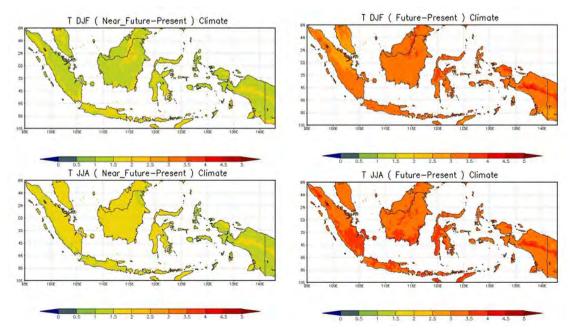
Fig 25 Changes in projected seasonal temperature
(upper left) near-future in DJF, (upper right) end-of century in DJF,
(lower left) near-future in JJA, (lower right) end-of century in JJA

Both DJF and JJA in the near and far future are projected to increase uniformly over the whole of Indonesia. Near future increases around 1 ℃ to 2 ℃, and far future increases around 3 ℃ to 4 ℃. JJA tends to have higher increases than DJF in the near and far future. A significant increase is also shown over the mountain range of New Guinea, having a further impact on the tropical ice sheet.

Climate Indices

With help from Japan Expert to make climate indices and display using html (http://13.230.234.238/NHRCM/index.html). Climate indices contain information about climate extremes for each period and the changes. The calculation of climate extreme using NHRCM daily data and calculating into some indices.

- Climate extreme indices are listed as follows:
- TXx, Monthly maximum value of daily maximum temperature
- TNx, Monthly maximum value of daily minimum temperature
- TXn, Monthly minimum value of daily maximum temperature
- TNn, Monthly minimum value of daily minimum temperature
- TN10p, Percentage of days when TN < 10th percentile
- TX10p, Percentage of days when TX < 10th percentile
- TN90p, Percentage of days when TN > 90th percentile
- TX90p, Percentage of days when TX > 90th percentile
- DTR, Daily temperature range: Monthly mean difference between TX and TN
- Rx1day, Monthly maximum 1-day precipitation
- Rx5day, Monthly maximum consecutive 5-day precipitation

- SDII Simple precipitation intensity index: Let RRwj be the daily

- Rnnmm Annual count of days when PRCP≥ nnmm

- Rnnmm Annual count of days when PRCP≥ nnmm

- Rnnmm Annual count of days when PRCP≥ nnmm

- CDD. Maximum length of dry spell, maximum number of consecutive days with RR < 1mm

- CWD. Maximum length of wet spell, maximum number of consecutive days with RR ≥ 1mm

- R95pTOT. Annual total PRCP when RR > 95p

- R99pTOT. Annual total PRCP when RR > 99p

- PRCPTOT. Annual total precipitation in wet days

Below is the display window of extreme indices draw in html.
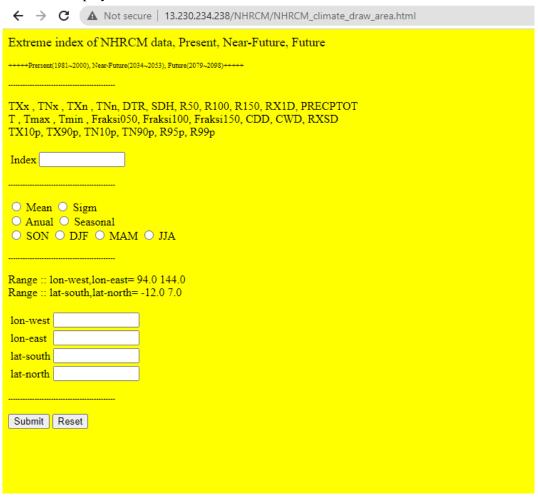
Fig 26 Display window of extreme indices

c)	Analysis of climate extreme

Precipitation total (annual)
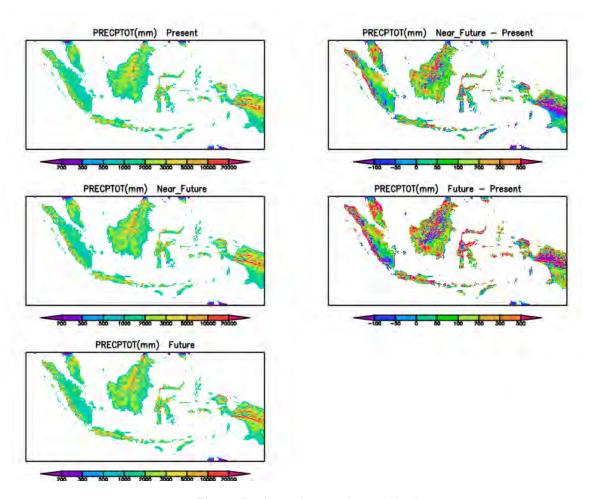
Fig 27 Projected annual precipitation
(Left column, top to bottom) present climate, near-future, and end-of century,
(Right column, top to bottom) difference of near-future, and end-of century projections
from the present climate

The HTML link displays climate extreme analysis and climate parameters (seasonal or annual). Baseline, Near Future, and Far future for precipitation are slightly the same. Mountainous regions show higher precipitation, and flatlands show lower precipitation. Near future projected increasing in mountainous regions and decreasing in flat land. Far future projects a wet getting wetter and a dry getting drier.
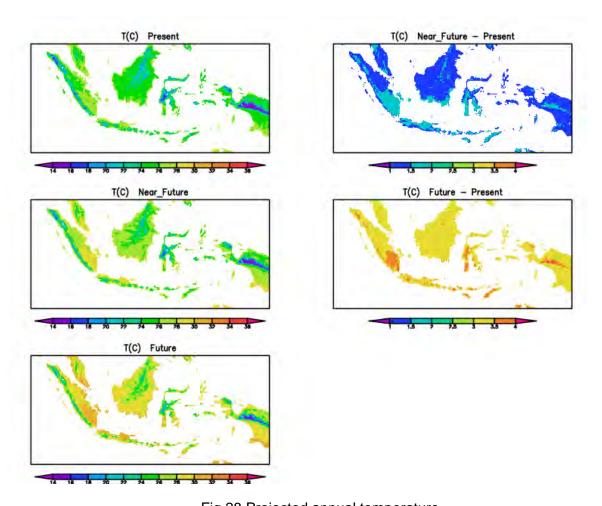
Fig 28 Projected annual temperature
(Left column, top to bottom) present climate, near-future, and end-of century,
(Right column, top to bottom) difference of near-future, and end-of century projections
from the present climate

NHRCM draws the mountainous regions well with lower temperatures. The southern region is experiencing hotter temperatures than the northern region. Both periods are increasing. Near future, it will increase by 1.5 ℃ - 2.5 ℃ (higher than seasonal temperature). Far future increases 3 ℃ - 4 ℃. A significant change over mountainous regions both in the near and far future.

R50 (annual)
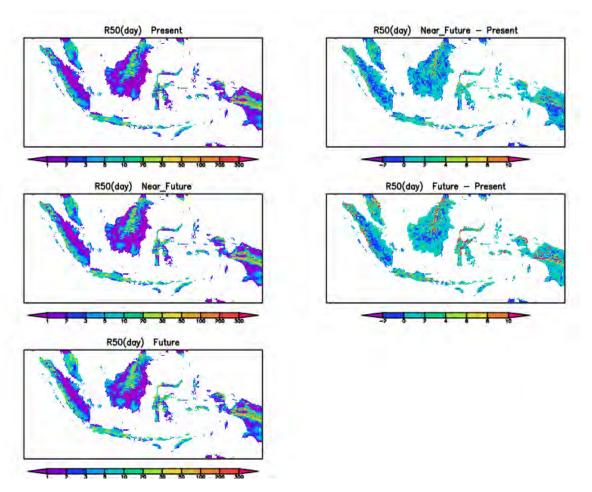
Fig 29 Projected number of daily precipitation ≥50mm (R50)
(Left column, top to bottom) present climate, near-future, and end-of century,
(Right column, top to bottom) difference of near-future, and end-of century projections
from the present climate

The number of days when the daily precipitation is 50 mm and more is more frequent in mountainous regions. Near Future: some regions are constant, and some regions increase, especially mountainous regions around 2-10 days. Far Future: similar to near Future but more frequent than the constant change.

Monthly maximum value of daily maximum temperature (TXx)
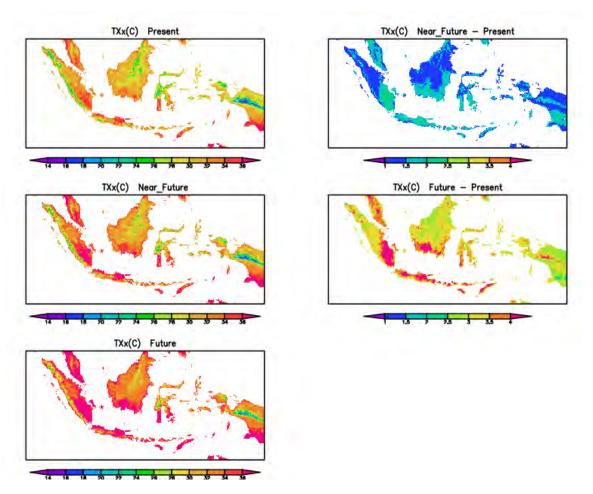
Fig 30 Projected monthly maximum value of daily maximum temperature (TXx)
(Left column, top to bottom) present climate, near-future, and end-of century,
(Right column, top to bottom) difference of near-future, and end-of century projections
from the present climate

Both periods are increasing. The southern region is experiencing hotter temperatures than the northern region. Near future 1.5 ℃ - 3 ℃ and Far Future 2.5 ℃ - >4 ℃. A significant change over mountainous regions both in the near and far future.

Monthly minimum value of daily minimum temperature (TNn)
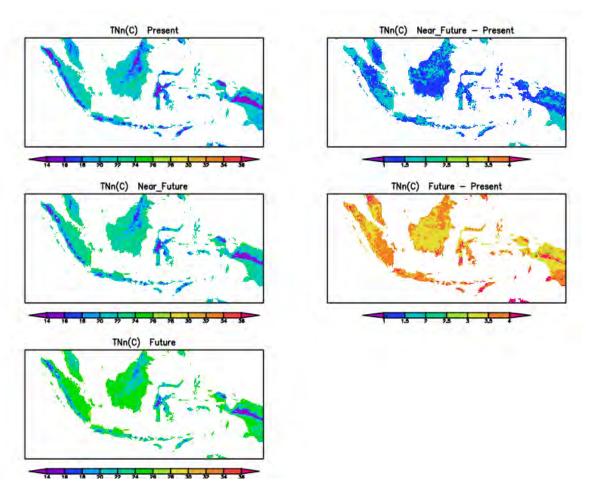
Fig 31 Projected monthly minimum value of daily minimum temperature (TNn)
(Left column, top to bottom) present climate, near-future, and end-of century,
(Right column, top to bottom) difference of near-future, and end-of century projections
from the present climate

Both periods are increasing. Near future 1.5 ℃ - 2 ℃ and Far Future 3 ℃ - >4 ℃. A significant change over mountainous regions both in the near and far future.

Maximum length of dry spell, maximum number of consecutive days with RR < 1mm (CDD)

Maximum length of dry spell, maximum number of consecutive days with RR < 1mm (CDD)
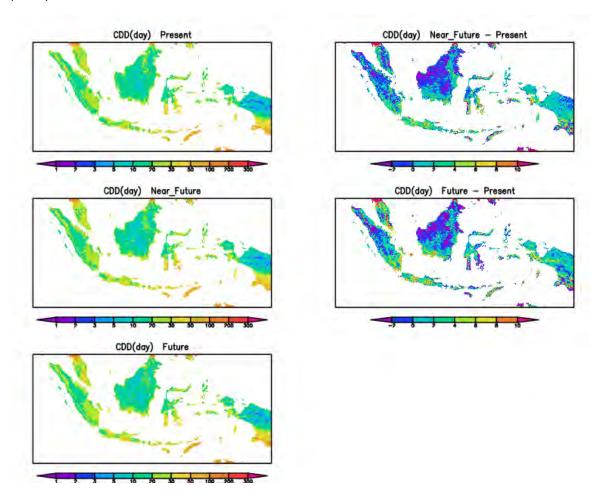
Fig 32 Projected Maximum length of dry spell, maximum number of consecutive days with RR < 1mm (CDD) (Left column, top to bottom) present climate, near-future, and end-of century, (Right column, top to bottom) difference of near-future, and end-of century projections from the present climate

Both Near and Far future, 2-100 days CDD events. CDD is projected longer in the southern part and shorter in the northern parts. Some shorter CDD in the near future will become longer in the far future, like south Sumatra, south Kalimantan, South Sulawesi, and Central Papua.

6. Maximum length of wet spell, maximum number of consecutive days with RR ≥ 1mm (CWD)
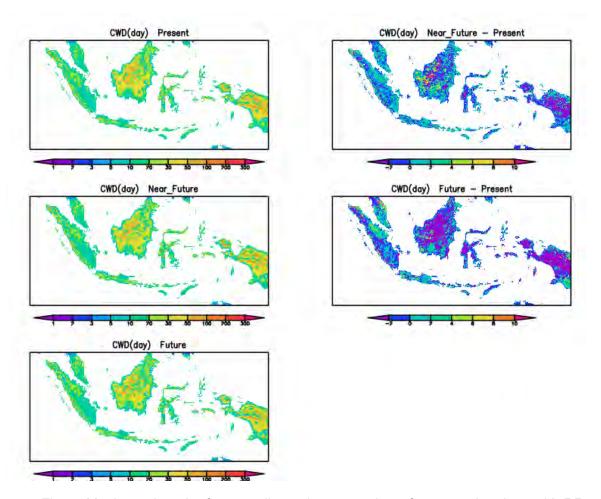
Fig 33 Maximum length of wet spell, maximum number of consecutive days with RR ≥ 1mm (CWD) (Left column, top to bottom) present climate, near-future, and end-of century, (Right column, top to bottom) difference of near-future, and end-of century projections from the present climate

Both Near and Far future, 10-200 days CWD events. CWD projected longer on central Kalimantan and Papua. Some areas will get longer CWD in Near Future but are projected to be shorter in Far Future.

In addition to working on climate extremes with the output displayed in HTML, the processing is also carried out with the output netcdf (.nc). The result of netcdf information display in CCIS developed by CCIS Team.

Result of Analysis:
➤ NHRCM simulations could represent the seasonal precipitation over Indonesia quite well, although with some deficiencies. NHRCM tends to overestimate precipitation over mountain ranges while underestimating precipitation over lowlands. NHRCM also has some cold biases in several areas. The NHRCM simulation results have superiority in reproducing the spatial features of topography patterns for both precipitation and temperature.

- Future projections by NHRCM show varying changes in precipitation in terms of seasonality, spatial distribution, intensity, and annual pattern. One can expect a more significant change in the far-future period, in which precipitation distribution shifts more towards the extremes. On a side note, changes in rainfall conform to the wet-get-wetter and dry-get-drier tendencies, particularly for areas with distinct wet and dry seasons.
- Extreme events of precipitation and temperature increase during the far-future period. Short-term heavy precipitation, a heatwave risk should also be anticipated and to be alerted stakeholders and policymakers of various sectors.
- All in all, the future simulation results from NHRCM simulations imply incoming threats and opportunities from the changing climate under global warming.

(7)   Dissemination of the climate change products

a)   Workshop "Climate Projection and Seasonal Prediction"

This activity is initiated by BMKG and coordinated with all participants through BMKG Local Office and Local Government. This workshop was held in two regions West Java (1-3 November 2022) and Central Java (15-17 November 2022). This meeting aims to enhance the capacity of the local BMKG Office to provide climate projection and seasonal prediction and enhance understanding of climate data (Climate Projection and Seasonal Prediction) utilization for stakeholders.

[Bandung]

The 1st day of the meeting was held for stakeholders. The BMKG team presented in the afternoon session about Climate projections and their utilization. There were three presentations:
- Climate projection data availability status.
- Climate projection data utilization for Crops.
- Climate projection data utilization for hydrometeorological disaster: Flood & Drought.

2nd day of Training made for BMKG Local Office. The Climate Change team conducted the Training. The morning session was used for Theory, and the afternoon session for practice. Material of presentation
- Climate Change and Model (JICA Expert)
- Basic theory of climate projection
- Climate projection data availability and data processing Capacity building for extreme index projection using climpact
- Climate Data projection utilization capacity building for crop productivity
- Climate Data projection utilization capacity building for hydrometeorology Disaster

3rd day of the meeting was made for the Seasonal Prediction team

[Semarang]

The concept and material meeting for Semarang are the same as Bandung. But for climate change team gave the Training on 3rd day of the meeting.

b)   Training Course in Japan

The BMKG team (climate change team of 3 people and seasonal prediction team of 3 people) got a

training course in Japan from 4-17 December 2022. The 1st week of training was held basically in the Tsukuba area. We visited: JICA Tsukuba, MRI, NARO, Ibaraki University, Tsukuba University.

- Lecture & Workshop: Global Warming Projection Data JICA: Dr. Murata (5 December 2022),
- Lecture: Change of Water Resource Variations Due to Global Warming: Dr. Endo (6 December 2022)
- Lecture: Change of Water Resource Variations Due to Global Warming: Dr. Endo (6 December 2022)
- Lecture & Workshop: Statistical Downscaling Using CMIP6: Dr. Nishimori (7 December 2022)
- Lecture & Workshop: Statistical Downscaling Using CMIP6: Dr. Nishimori (7 December 2022)
- Lecture: How to Project Future Climate by Dynamical Downscaling Method: Prof. Kusaka (8 December 2022)
- Workshop: Identifying a new normal in regional climate under global warming with dynamical downscaling: Dr. Doan (8 December 2022)
- Lecture: Climate Change Adaptation Process in Various Sectors: Prof. Tamura (9 December 2022)
- In the 1st week, the BMKG team also made a presentation about the result of Working Group 1 in MRI and Tsukuba University.

The 2nd week was held in JICA Tokyo, JAMSTEC, and Tokyo Climate Center, JMA. The training focuses on Seasonal prediction.

In the wrap-up evaluation, each trainee made a presentation about what has been done for analysis, what has been learned in the training, and what will be the future plan.
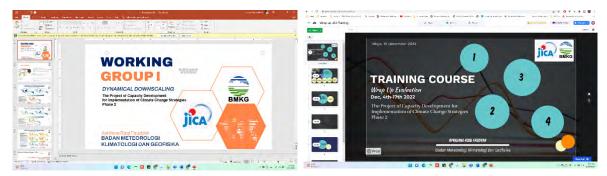
Fig 34 Presentation materials of the training course

c) Climate Change Information System (CCIS)

Through the project, the Climate Change Information System (CCIS) was rehabilitated and reactivated to share historical observation data and future projection data to users. (The original CCIS server was developed in 2015, but due to malware infection, services stopped.)

The CCIS server provides historical observation data quality checked by BMKG as (i) trends of temperature, precipitation and other factors, (ii) distribution map of factors covering whole Indonesia or focused on smaller areas and (iii) various climate indexes mentioned in <climate index section> in page 33 to 34. CCIS also provides future projection data as trends, distribution maps, climate indexes

and (iv) difference maps between present and future or present and near future.

In order to use CCIS server, a user has to subscribe from a user subscription page and get an allowance from administrator of the CCIS. At present, BMKG is going to consider to who BMKG allows access and what kind of data BMKG opens based on BMKG data open policy. However, considering, the 1ˢᵗ CCS stopped due to malware infection, and if data access becomes bigger, 1 server would not be able to afford such requests, the project experts recommended that for the first stage, (i) users should be limited inside of BMKG officers. And when BMKG opens the CCIS, (ii) BMKG is recommended to host the server in outside warehouse or clouds services who provide enough data security and road balance services for increase of data requests. A copy of subcontract agreement and outline of the CCIS system was attached in appendix.

Fig 35 CCIS website

3.1.5 Future Activity Plan

After all activity we have been done, we will continue our activities like:
- Improving skills in Climate Change Analysis.
- Continuing analysis of the result of NHRCM and applying it to various sectors.
- Conducting CMIP6 downscaling and higher resolution downscaling both in Dynamical and Statistical Downscaling using HPC.
- Publishing paper about climate downscaling activity.
- Identify necessary climate projection from Stakeholders, Ministries, and Users.
- Strengthen the capacity of BMKG headquarter and local office, especially in providing climate projection and seasonal prediction.
- Support the Indonesia government's efforts to reduce greenhouse gasses emissions.

3.2　Activity for Output 1b (Statistical Downscaling)

3.2.1　Background on Output 1b

As mentioned in Output 1a, climate maters in Indonesia become gradually significant, and severe damages caused by natural disasters and increase of their frequency should cause economic stagnation, escalation of poverty, increase of social/economical damage, that is, these serious risks will threaten economic growth in Indonesia. Therefore, consideration for risks and vulnerability brought from climate change is indispensable when considering and implementing development plans of spatial planning and policymaking.

Dynamical downscaling of climate projection (Output 1a) is the most reliable projection data calculated in scientifically pertinent way (considering physical processes of the atmosphere, marine, mutual interactions, condition of sea/land surface, and so on). However, since high resolution dynamical downscaling requires huge computing power and human resources (time, knowledge for modeling, and computing technology), it is difficult to implement them which cover the whole Indonesian area promptly and needs to prepare enough human/computer resources.

As an alternative way to make up for such shortcomings, statistical downscaling of climate projection data is often used for lots of research to roughly estimate the affections/trends of climate change. The target of Output 1b is to transfer technical skills/knowledge on statistical downscaling of climate projection data. Differences between dynamical downscaling and statistical downscaling are organized as follows.

<Dynamical Downscaling and Statistical Downscaling>

Scientifically accurate climate projection data for the smaller area (for example 5km resolution) is produced by dynamical downscaling with a regional climate model (e.g., NHRCM by MRI) considering external forcing parameters (Representative Concentration Pathways, etc.), atmosphere/marine interactions, meteorological dynamical/physical processes and boundary conditions (roughness, elevation, etc.). As such high-resolution dynamical downscaling requires huge computing resources, if we need to obtain results for various scenarios or to customize to user's requirements, it is impossible to implement them by dynamical downscaling without proper resources. Thus, in order to respond to such requirements, statistical downscaling which adjusts results of dynamically downscaled data and interpolates using higher resolution geographical data is used as an alternative way.

Differences between both methods are;
- Dynamical downscaling includes physical, boundary conditions and interactions as programing source code
- Statistical downscaling includes such relationship statistically based on relationships between model outputs and observation data

When we estimate differences between present and future, trends in future or differences caused by a special resolution would be responded by statistical downscaling, as an outline of trends and differences. On the other hand, in order to consider boundary conditions (elevation, geographical features <cities, mountains, valley, channels, etc.>) or evaluate effects by 10km resolution phenomenon,

dynamical downscaling is the only way to respond correct answers for them.

When we evaluate the 10km resolution phenomenon, for example, precipitation differences between the east side and west side of Bali, we need to implement dynamical downscaling in higher resolution for several years. We try to find differences between the original coarse resolution model and higher resolution model and to reflect these differences to climate projection data through other methods; statistical adjustment or qualitative presumption.

3.2.2   Challenges Related to Output 1b

As results of Output 1a, 5km resolution dynamical downscaled data for present, near-future and future were already prepared and the following activities of Output 1a are scheduled.

1) Comparison between 'present' and 'near-future' or 'future'
2) Analysis for findings by higher resolution downscaling (from 20km to 5km resolution downscaling)

Additionally, when we share downscaled data to other agencies, following supports would be needed,

3) Technical skill transfer on the usage of software, programing skills to cut out required factor/period/area data from original dataset and on statistical bias correction of original data.
4) Technical skill transfer to calculate other factors required, for example precipitation in basins, wave height estimate, expected values associated with return period.

And following requirements may be raised for further considerations,

5) Seamless trend analysis from 2000 to 2100
6) Comparison between different scenarios and/or different GCM models

1), 2) and 3) are proposed to be implemented in Output 1a activities and 4), 5) and 6) are in Output 1b activities.

3.2.3   Activity Details for Output 1b

For development and technical skill transfer on statistical downscaling, the project contracted a cooperation research contract with Dr. Nishimori of "the National Agriculture and Food Research Organization" (NARO) and the consultant team proposed the cooperation research plan at the kick-off meeting held on 13th of October 2020 to BMKG and both agreed to the plan. Technical skill transfer for statistical downscaling has been done in the following 3steps (data collection, experiment at pilot sites, expansion to whole Indonesian area). In 2021, statistical downscaling started through step1 [data collection for pilot areas] by BMKG, step 2 [development of statistical DS] by Dr. Nishimori. Data collection for the pilot areas, west Java, and JDK, shared with Dr. Nishimori in early 2021, and results of experimental statistical downscaling were implemented, and the results were reported at the Autumn academic meeting of the Japan Meteorological Society by Dr. Nishimori and BMKG-co-authors.

(1)   Step 1: Data Collection for pilot areas by BMKG

<SYNOP stations> shared on 12th of October 2020

• Temperature (daily mean, daily maximum, daily minimum), daily precipitation, sunshine

duration

- Central Java: 5, West Java: 4, DKI Jakarta: 3, 1991-2010

<Map average data> shared on 1st of February 2021

- Monthly maximum temperature, minimum temperature, mean temperature, precipitation data from 1981 to 2010
- Monthly average for 1981 to 2010 in NetCDF and CSV format

Filename	Compressed ...	Original Size	Compr...	File Type	Modified Date
..					
rr_java_1981-2010.nc	114,489	414,360	72%	NC ファイル	2021-01-25 PM 01:33:46
rr_java_climat.nc	5,180	16,052	68%	NC ファイル	2021-01-25 PM 01:31:20
tg_java_1981-2010.nc	105,888	414,364	74%	NC ファイル	2021-01-25 PM 01:37:18
tg_java_climat.nc	4,756	16,052	70%	NC ファイル	2021-01-25 PM 01:37:46
tn_java_1981-2010.nc	106,646	414,364	74%	NC ファイル	2021-01-25 PM 03:08:48
tn_java_climat.nc	4,783	16,052	70%	NC ファイル	2021-01-25 PM 03:08:42
tx_java_1981-2010.nc	107,303	414,364	74%	NC ファイル	2021-01-25 PM 02:53:50
tx_java_climat.nc	4,754	16,052	70%	NC ファイル	2021-01-25 PM 02:53:44

Filename	Compressed ...	Original Size	Compr...	File Type	Modified Date
..					
rr_SACAD_Climatology.csv	5,598	15,052	63%	Microsoft Excel CS...	2021-02-01 AM 09:1
rr_SACAD_montly.csv	104,293	313,409	67%	Microsoft Excel CS...	2021-01-25 PM 03:1
tg_SACAD_Climatology.csv	4,657	16,824	72%	Microsoft Excel CS...	2021-01-29 PM 04:1
tg_SACAD_montly.csv	104,469	432,401	76%	Microsoft Excel CS...	2021-01-25 PM 03:1
tn_SACAD_Climatology.csv	4,651	16,476	72%	Microsoft Excel CS...	2021-01-29 PM 04:1
tn_SACAD_montly.csv	103,668	420,953	75%	Microsoft Excel CS...	2021-01-25 PM 03:1
tx_SACAD_Climatology.csv	4,782	17,213	72%	Microsoft Excel CS...	2021-01-29 PM 07:5
tx_SACAD_montly.csv	107,820	436,192	75%	Microsoft Excel CS...	2021-01-25 PM 03:1

Fig 36 Collected Data (pilot area)

bujur	lintang	Jan-81	Feb-81	Mar-81	Apr-81	May-81	Jun-81	Jul-81
114.375	-8.625	22.82	22.9	22.99	23.04	22.55	22.69	22.45
113.625	-8.375	22.27	22.37	22.7	22.82	22.33	22.32	21.87
113.875	-8.375	20.41	20.57	20.65	20.81	20.39	20.44	20.35
114.125	-8.375	21.7	21.79	21.97	22.12	21.73	21.78	21.58
114.375	-8.375	22.72	22.75	22.98	23.11	22.74	22.79	22.51

WMO ID	DATA TIMESTAMP	TEMP AV(	TEMP MA	TEMP MI	RAINFALL	SUNSHINE HOUR
96797	1991-01-01 00:00:00.0 +0:00	25.8	30.7	23	19	75
96797	1991-01-02 00:00:00.0 +0:00	25.6	30	23.2	17.5	66
96797	1991-01-03 00:00:00.0 +0:00	27.3	30.5	24.5	21.6	100
96797	1991-01-04 00:00:00.0 +0:00	27.2	31.2	23.7	2.5	56
96797	1991-01-05 00:00:00.0 +0:00	26.2	31.6	23.8	51	94

Fig 37 Examples of Data (above: mesh data, below: station data)

Fig 38 An Example of the Statistical Downscaling (West Java)

(2)   Step 2: Preparatory analysis (Dr. Nishimori)

As a preparatory analysis, Dr. Nishimori implemented statistical downscaling using the Gaussian-type method (Wilby, 2004) and CDF method using collected observation data and mesh data.

<Gaussian-type downscaling> =in case of monthly data=

Firstly, basic statistical parameters, average <To> and standard deviation σ(To), are calculated from monthly observation data. And then average <Ts> and standard deviation σ(Ts) of hindcast data at the observation points are calculated from hindcast data interpolated grid points or stations data using a weight of special distance from hindcast monthly data.

Here, future projection data <T> is statistically estimated by the following equation;

$$T = \frac{\sigma(To)}{\sigma(Ts)}(Ts - <Ts>) + <To>$$

When there is no observation data at station x, <Tx> and σ(Tx) is interpolated from nearby stations <Toi> and σ(Ti) (i=1,2,,,). (Fig. 39)

Gaussian type downscaling based on the idea, which data distribution is subject to normal distribution (Gaussian distribution), therefore, when the distribution pattern is different from the normal distribution, data modification that transforms to the normal distribution pattern is implemented. At this research, monthly precipitation was transformed to cubic-square data and statistically downscaled.

On the other hands, CDF does not require specific distribution patterns and is often used for bias correction for precipitation forecasts with numerical weather prediction (NWP) models (In general, NWP forecasts outputs smaller values to actual precipitations).

CDF downscaling is implemented as the following processes:
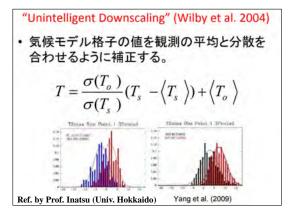
1)   sort observation data Oi from big data to small data

2)   sort hindcat data Hi from big data to small data

3)   calculate bias CDFi (=Oi-Hi) between Oi and Hi sorted each by each

4)   dort projection data Pi from big data to small data

5)   using CDFi, adjust sorted projection data Pi (=Pi+CDFi)

6)   re-sort CDFi according to year and month

When the numbers of Oi, Hi, and Pi are different, values of Oi, Hi, and Pi are normalized from 0 to 1

and CDFi is calculated and adopted (Fig. 40). Not being accepted to share the analysis kit, the expert team developed a tool for statistical downscaling with MRI-AGCM and shared techniques to use the tool in March 2022. Practical training with the tool will be conducted later to realize technical transference. Moreover, remote lectures on statistical downscaling by Dr. Nishimori are planned for August 2022.

Statistical downscaling for Jakarta with developing a simple kit with MS Excel was lectured by using SYNOP observation data, meshed observation data, and climate model mesh data on 22 February 2022. With this example, a practical process of statistical downscaling will be lectured later.

Additionally, the expert team has developed software that enables to conduct the downscaling with programming and plans to lecture a use of this software. Since several downscaling can be conducted by these methods, the expert team will evaluate the statistical downscaling with counterparts through web meetings after onsite activity conducted from February to March 2022. BAPPENAS has requested 5km statistical downscaling, however, mesh value with 5km resolution is needed. Therefore, BMKG plans to consider obtaining the mech value to realize the request later.

Fig 39 Gaussian Type Correction

Fig 40 CDF Method
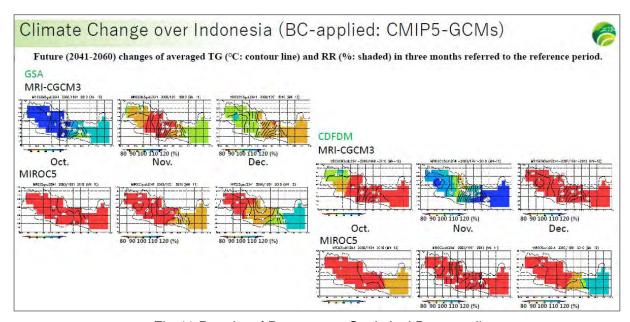
Fig 41 Results of Preparatory Statistical Downscaling

(3)   Step 3: Expand Statistical Downscaling to Whole Indonesian Area
-    BMKG adapts statistical downscaling tool to whole Indonesian area
-    WG evaluates results of statistical downscaling through web meetings

For interpolation from mesh data into point data, and vice versa, the following method is used.

The statistical equation of downscaling is fixed comparing historical observation data and climate projection data. In order to calculate a value at the observation point, the value is interpolated using values at near 4 grid points (g1, g2, g3, g4) and weighting function, i.e., reciprocal value of distance (l1, l2, l3, l4). Here, values at grid point are a deviation from the average of climate projection data (not values themselves of climate projection) (Fig. 42).
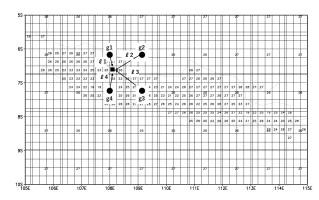
Fig 42 Interpolation of Grid Data to the Point

(4)   Matters on the Statistical Downscaling

Through a preparatory survey of statistical downscaling by NARO, results of statistical downscale showed two matters as follows,

(i)   precipitation trend from present to near-future differs between MIROC and MRI,

(ii)   statistically downscaled projection data showed a wider variety using the Gaussian-type method for precipitation data.

The 1st matter comes from characteristics of GCM models themselves, and WG needs to check the characteristics of each model and need to compare the results of multi models. The 2nd matter comes from differences in precipitation distribution patterns from normal distribution patterns. For judging the appropriateness of the Gaussian-type method for precipitation downscaling, check for distribution patterns (it follows gamma function, does not follow exponential distribution pattern before implementing statistical downscaling by Gaussian methods. (in such a case, CDF should be used).

The tool for statistical downscaling mentioned above can correct values with Gaussian type or CDF, however, when precipitation is corrected by Gaussian type and the distribution pattern of precipitation at the target point is the exponential (decreasing monotonously), its estimation accuracy can be dropped. The expert shared this information with counterparts in February 2022.
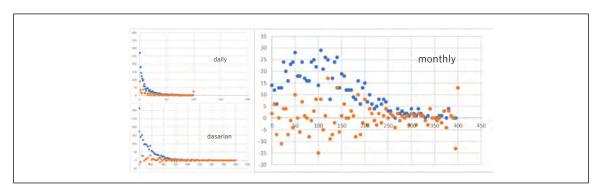
Fig 43 Distribution Pattern of Precipitation
(left top: daily, left bottom: seasonal, right: monthly)

(5)   Approaches to respond requests from users

BMKG received various requests from projection data users, such as "high resolution downscaling in 5km resolution of RCP 4.5 scenario", "precise projection data in city size level at 2045" and so on. If BMKG can implement dynamical downscaling to meet their requirements, BMKG can meet such requests, however, it is impossible both from computer power, time, and researchers capacities. And statistical downscaling shows more precise downscaled information, however, it is calculated from GCM model and monthly average data and it could not add new findings beyond GCM original data and following GCM characteristics. From this point of view, WG should check characteristics of original GCM models and tend of 4 scenarios, for responding to various questions.

As the first approach to the understanding of MRI-AGCM models, WG2 shared 1961-2005 hindcast data and 2006-2100 projection data of MRI-AGCM3 models in 4 scenarios (RCP 2.6, 4.5, 6.0 and 8.5) monthly data (convert Indonesian area in 100km resolution) and developed scripts to draw differences between periods (including seamless comparison for a year) and scenarios. WG2 started the comparison of GCM models between periods and scenarios and is going to summarize them by around the end of March 2022.

Tool 1. Make differences between periods

C:¥home¥JICA_BMKG_2020¥statistical-DS¥Script¥mri-cgcm_monthly>grads

```
ga-> Diff_between_age.gs                                    <-try 'Diff_between_age.gs'
**********************************************              If there are not enough parameters, explanation how to
**********************************************              put information to the script will appear.
 Usage :: run Script/Diff_between_age.gs elm  rcp  mmm  ybs  ybe yas yae
 Purpose:: Draw difference between two ages(yas-yae) - (ybs- ybe) )
   elm :: Humidity, Tmax, Tmin, Wind, Rain)
   rcp :: Senario ( 26, 45, 60, 85 , hindcast)
   mmm :: month( Jan, Feb,,,,,,Dec)
   ybs :: Year start ( must be larger than 2005 forrcp=26,45,60,85 )
   ybe :: Year end ( must be smaller than 2006 for rcp=hindcast )
   yas :: Year start ( must be larger than 2005 forrcp=26,45,60,85 )
   yae :: Year end ( must be smaller than 2006 for rcp=hindcast )
**********************************************
**********************************************
ga-> Diff_between_age.gs Rain 85 Jan 2006 2025 2080 2099   <- This command displays,
tybs,tybe = 1 229
tyas,tyae= 889 1117                                         difference of monthly
ctl    = pr85_2006-2100.ctl                                 precipitation between
vari   = pr_85                                              future(2080-2099) and
No hardcopy metafile open                                   present (2006-2025) on
All files closed; all defined objects released;            RCP 8.5 scenario
All GrADS attributes have been reinitialized
Warning: OPTIONS keyword "template" is used, but the
   DSET entry contains no substitution templates.
ga->
```

作図ツールの共有

説明資料の作成に
なれる
Arc-GISも検討中

対象ファイルを変えることで（現在は、MRI-CGCM,4シ
ナリオ）、力学的DS、統計的DSデータに横展開できる

Diff Rain_RCP85(Jan (2080-2099) – (2006-2025))

Fig 44 Script for Drawing the Difference between Periods

Tool 2. Make differences between scenarios

C:¥home¥JICA_BMKG_2020¥statistical-DS¥Script¥mri-cgcm_monthly>grads

```
ga-> Diff_between_RCP.gs                                    <-try 'Diff_between_RCP.gs'
**********************************************              If there are not enough parameters, explanation how to
**********************************************              put information to the script will appear.
 Usage :: run Script/Diff_between_RCP.gs elm  rcp1 rcp2  mmm  ybs  ybe
 Purpose:: Draw difference between two RCP( & mean (rbs - ybe) )
   elm :: Humidity, Tmax, Tmin, Wind, Rain)
   rcp1 :: Senario ( 26, 45, 60, 85 )
   rcp2 :: Senario ( 26, 45, 60, 85 )
   mmm :: month( Jan, Feb,.....,Dec))
   ybs :: Year start ( must be larger than 2005 for rcp=26,45,60,85 )
   ybe :: Year end  ( must be smaller than 2006 for rcp=hindcast )
**********************************************
ga-> Diff_between_RCP.gs Rain 45 85 Dec 2026 2045          <- This command displays,
tybs,tybe = 252 480
ctl1 = pr45_2006-2100.ctl                                  difference of monthly
ctl2 = pr85_2006-2100.ctl                                  precipitation between
vari1 = pr_45,1                                            RCP 4.5 and 8.5 in
vari2 = pr_85,2                                            January between 2026 to
No hardcopy metafile open                                  2045
All files closed; all defined objects released;
All GrADS attributes have been reinitialized
Warning: OPTIONS keyword "template" is used, but the
   DSET entry contains no substitution templates.
Warning: OPTIONS keyword "template" is used, but the
   DSET entry contains no substitution templates.
ga->
```
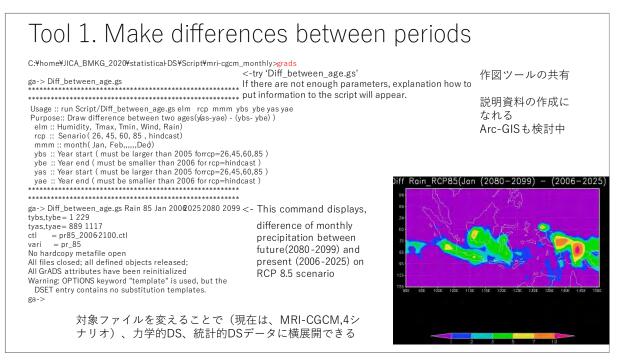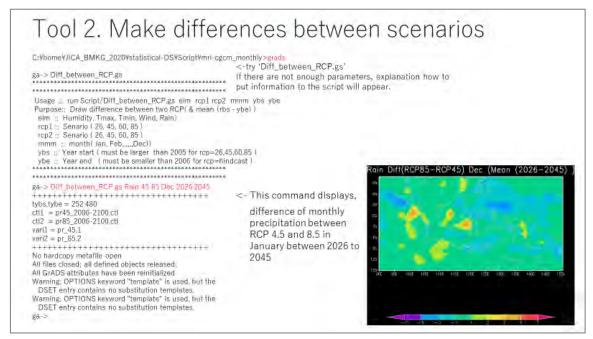
Rain Diff(RCP85-RCP45) Dec (Mean (2026-2045))

Fig 45 Scripts and Results to Draw Difference between Scenarios

Additionally, to check differences of precipitation in December of near future between MIROC and MRI model, monthly data of d4PDF data also shared to WG2 and scripts to analyze differences are developed. After a comparison of MRI-AGCM scenarios, WG2 is going to compare differences between GCM models in the near future and the future until the end of March 2022.
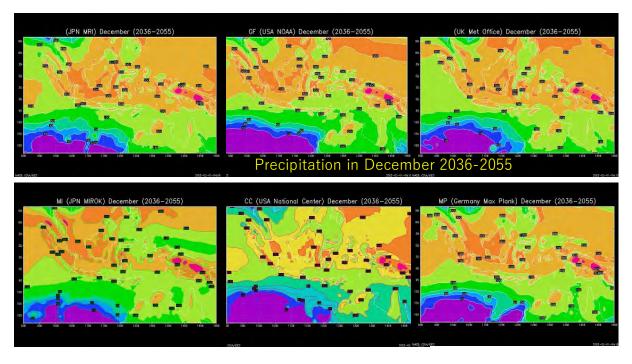
Fig 46 Monthly precipitation in December (2036-2055)
Above: MR, GF, HA, below: MI, CC, MP (abbreviations shown in Table 6)

Table 6 Global Climate Models (GCMs) used by the d4PDF Data

Global Climate Model	Abb.	Developer
CCSM4	CC	National Center for Atmospheric Research (USA)
GFDL-CM3	GF	NOAA Geophysical Fluid Dynamics Laboratory (USA)
HadGEM2-AO	HA	Met Office Hadley Centre (UK)
MIROC5	MI	AORI, NIES, JAMSTEC (Japan)
MPI-ESM-MR	MP	Max Planck Institute for Meteorology (Germany)
MRI-CGCM3	MR	Meteorological Research Institute (Japan)

These data also cover the Indonesian area and statistical downscaling using d4PDF data might have a possibility if statistical downscaling is implemented smoothly. Numbers of GCM models and ensembles are as follows and outline of the d4PDF data is shown in Fig. 47,48.

+4K: target 2090:   6 models (USA:2, JPN:3, UK:1) x 15 ensembles

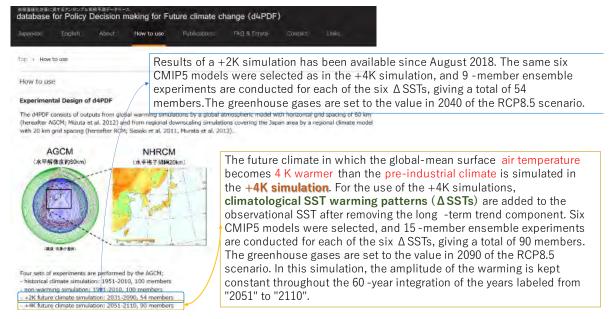+2K: target 2040:   6 models (USA:2, JPN:3, UK:1) x 9 ensembles

61

d4PDF

http://www.miroc-gcm.jp/~pub/d4PDF/design_en.html

Results of a +2K simulation has been available since August 2018. The same six CMIP5 models were selected as in the +4K simulation, and 9 -member ensemble experiments are conducted for each of the six ΔSSTs, giving a total of 54 members.The greenhouse gases are set to the value in 2040 of the RCP8.5 scenario.

The future climate in which the global-mean surface air temperature becomes 4 K warmer than the pre-industrial climate is simulated in the **+4K simulation**. For the use of the +4K simulations, **climatological SST warming patterns（ΔSSTs）** are added to the observational SST after removing the long -term trend component. Six CMIP5 models were selected, and 15 -member ensemble experiments are conducted for each of the six ΔSSTs, giving a total of 90 members. The greenhouse gases are set to the value in 2090 of the RCP8.5 scenario. In this simulation, the amplitude of the warming is kept constant throughout the 60 -year integration of the years labeled from "2051" to "2110".

Fig 47 Outline of d4PDF Data

The greenhouse gases are **set** to the value **in 2090 of the RCP8.5**

climatological SST warming patterns (ΔSSTs) are added to the observational SST

Annual Report on Atmospheric and Marine Environment Monitoring Data
https://www.jma.go.jp/jma/en/Activities/cc.html

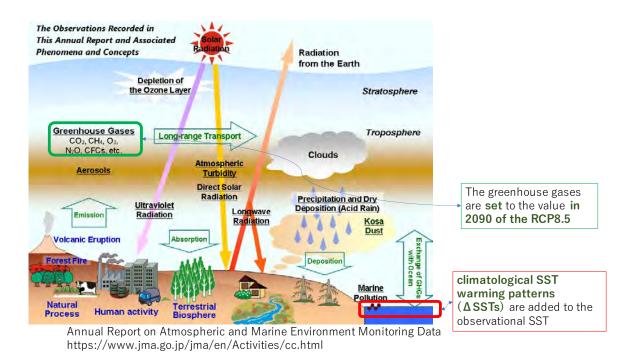Fig 48 Parameters Considered in d4PDF Dataset

(6) Results of preparatory check

<Characteristics of Scenario in near future and future in MRI-CGCM>

Before downscaling, we need to see an overview of the original MRI output data. The sample location is one point in Jakarta (-6.15, 106.75). MRI data of rain and humidity parameters show variations in changes in the period 2005-2100 in all RCP scenarios. RCP8.5 shows a more significant trend of increasing rainfall compared to other RCPs but for the humidity parameter, RCP8.5 showed a

more pronounced trend of decreasing compared to other RCPs. speed parameters, at the sample point shows a small variation of changes in the 2005-2100 period in the entire RCP.
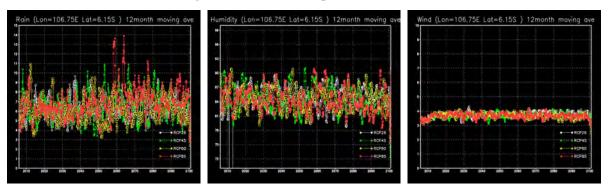

Fig 49 Trend of original data MRI
(left: rain, center: humidity, right: wind)

The picture below shows that output of NHRCM for the maximum and minimum temperature parameter, at the sample point shows a clear variation of changes in the overall RCP. RCP8.5 shows a tendency to increase the maximum temperature which is higher than other RCPs. For the original NHRCM data output, the minimum temperature increase at RCP8.5 showed the most significant results among other parameters and other RCPs.

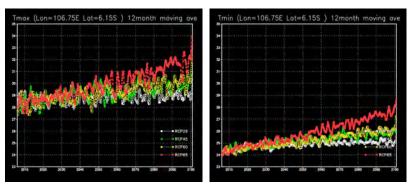Fig 50 Trend of original data MRI
(left: temp.maximum, right: temp.minimum)

<Differences between periods>

According to the analysis of 5km dynamical downscaling, Java, south Sumatra, and Papua, precipitation in wet seasons increases and dry area becomes drier (wet-get-wetter tendency and the dry-get-drier tendency).

In the MRI-AGCM model, the tendency mentioned above is analyzed as precipitation increases in Papua and decreases in west Papua and northern Sulawesi, however, significant increase of precipitation in Java, south Sumatra, south Kalimantan, and south Sulawesi is not analyzed apparently. For monthly comparison, precipitation increases in January are shown but not clear in December.
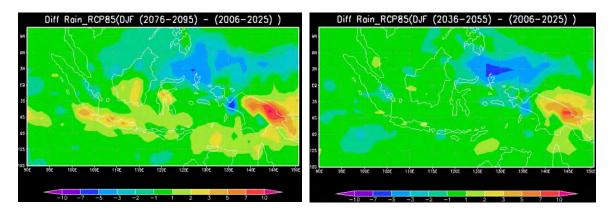
Fig 51 Change of Precipitation in DJF (by Different Periods)
(left: 2076-2095, right: 2036-2055 to present <2006-2025>)

<Difference between scenarios>

In RCP 8.5 and 4.5 scenarios, precipitation increases in Java, south Sumatra in DJF especially in Dec. and Jan, however, it's not significant in RCP 2.6. Precipitation change in the near future does not show an apparent trend and precipitation increase becomes apparent after 2050 in RCP 4.5 and 8.5 scenarios.

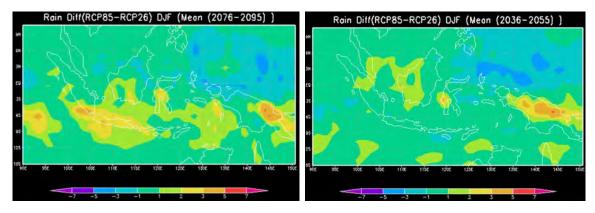Fig 52 Change of Precipitation in DJF (by Different Scenarios; RCP8.5 and RCP 2.6)
(left: Future, right: Near future)

<Comparison between observation data and MRI original data>

Fig 53 Trend comparison of monthly rainfall between model NHRCM
in the near future period and observation data

The results of the rainfall parameter seem difficult to explain because the result is so varied, and this is different from the temperature parameter which is clearly the difference between the observed temperature and the temperature of the MRI model. The similarity between the rainfall parameter shown by the observation data and the MRI data is that there is a slight increase in the trend value.

The figure above shows that the difference between NHRCM model rainfall and BMKG observational rainfall very variety. In some regions, baseline data is overestimated and in some regions baseline data is underestimated. Rainfall trends also show varied results, in some regions showing an increasing trend and some regions showing a decreasing trend.
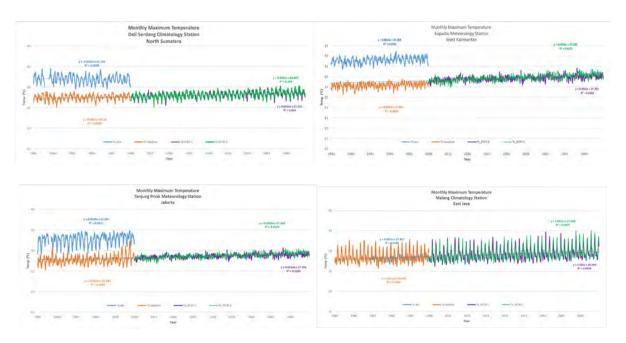
Fig 54 Trend comparison of monthly maximum temperature between model NHRCM
in the near future period and observation data

In figure 54 shows that, generally, the monthly maximum temperature from the model has underestimated result than observation except in Malang, East Java. In the near future period, RCP4.5 and RCP8.5 have similar results while both of the scenarios are unclearly significant.

Maximum temperature baseline data generally show underestimate result when compared to observational data. In the near future period, the maximum temperature trend shows an increasing trend, this happens in both RCP4.5 and RCP8.5 scenarios, the increasing trend of maximum temperature shows less significant results compared to the observed maximum temperature.

Fig 55 Trend comparison of monthly minimum temperature between model NHRCM
in the near future period and observation data

Based on the figure above, it can be seen that in general the monthly minimum temperature of the model (baseline) shows an overestimated result compared to observations. There is anomaly in Tanjung Priok, Jakarta. Observation data is a little higher than the model because the observation field in Tanjung Priok moves to different places. Temperature trend in the near future period, RCP4.5 and RCP8.5 have the same results while both scenarios show an increasing trend.

<Comparison between normal period >

Indonesia has a large area with very varied rainfall patterns, for rainfall parameters, one sample station can only represent a small area, a lot of sample stations are needed to get more accurate results. Indonesia generally has two seasons, rainy seasons and dry seasons. However, the distribution of rainfall in each region in Indonesia varies due to a lot of factors. For example, in December, areas on the island of Java started to enter the rainy season, while several other areas in Indonesia are to be still dry. This shows that when the rainy season has entered, not all regions in Indonesia will have the rainy season at the same time. There are three types of pattern in rainfall in Indonesia, equatorial pattern, monsoon pattern and anti-monsoon pattern (local pattern).
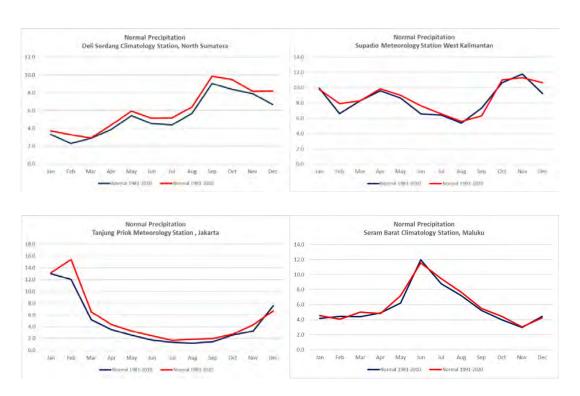

Fig 56 Comparison between monthly rainfall normal period 1981-2010 and
new normal 1991-2020 observation data BMKG

In figure above, it shows the distribution of the average monthly rainfall data, BMKG generally divides the territory of Indonesia into 3 rainfall patterns, monsoon, equatorial and local. All types of precipitation in Indonesia (Monsoon, Equatorial and Local) have a similar pattern between the new normal period 1991-2020 and old normal period 1981-2010. Normal precipitation 1991-2020 usually little bit higher than 1981-2010.

The picture above explains the difference between normal rainfall of the new normal period (1991-2020) and rainfall of the old normal period (1981-2010). All types of rainfall in Indonesia have the same pattern between the new normal and the old normal. The difference in rainfall in the new normal and old normal periods very variety in all BMKG observation stations.
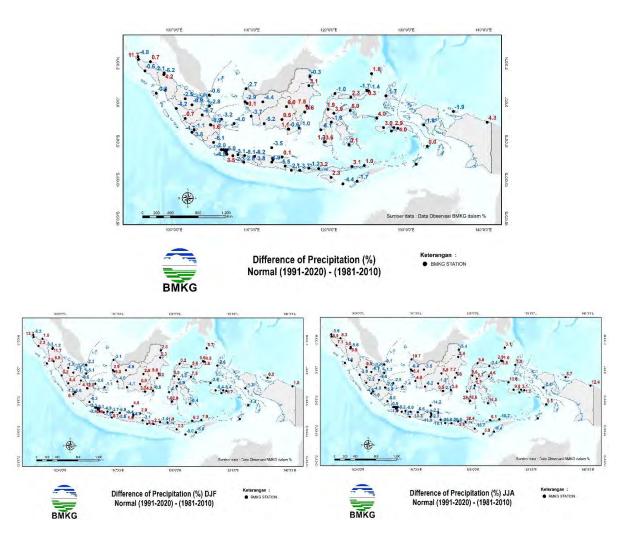

Fig 57 Difference of Precipitation (%) between period normal all season (above), DJF season (left) and JJA season (right).

Based on the picture above, the rainfall parameters from 94 BMKG stations in Indonesia show different results, some stations have increased and others decreased. The difference in rainfall between the new normal (1991-2020) and the old normal (1981-2010) it can be seen that there are 53 stations that have decreased and only 41 have increased. Most of all monsoonal type of rainfall in JJA period has decreased, the local type of rainfall in JJA periode has increased and most of equatorial type also increased. In the DJF period 50% of stations have increased and 50% has decreased.
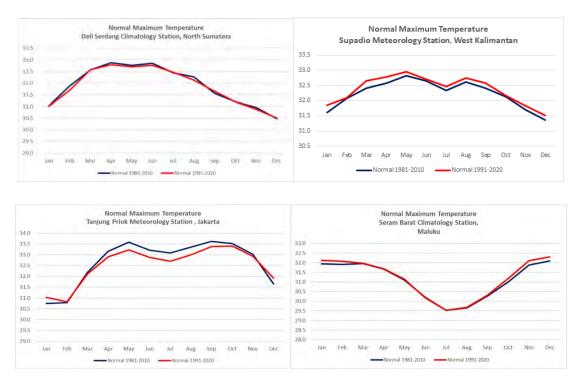
Fig 58 Comparison between maximum temperature normal period 1981-2010 and
new normal 1991-2020 observation data BMKG

Normal Maximum Temperature has a similar pattern between 1991-2020 period and 1981-2010 period. Normal Maximum Temperature in 1991-2020 period is usually a little bit higher than 1981-2010 period.

The maximum temperature in the new normal shows the same pattern as the maximum temperature in the old normal. In general, the maximum temperature in the new normal has a higher temperature than the maximum temperature in the old normal. There is an anomaly at the BMKG Tanjung Priuk station, DKI where the maximum temperature in the old normal period is higher than the new normal. The maximum temperature difference between the two normal periods is not very significant.
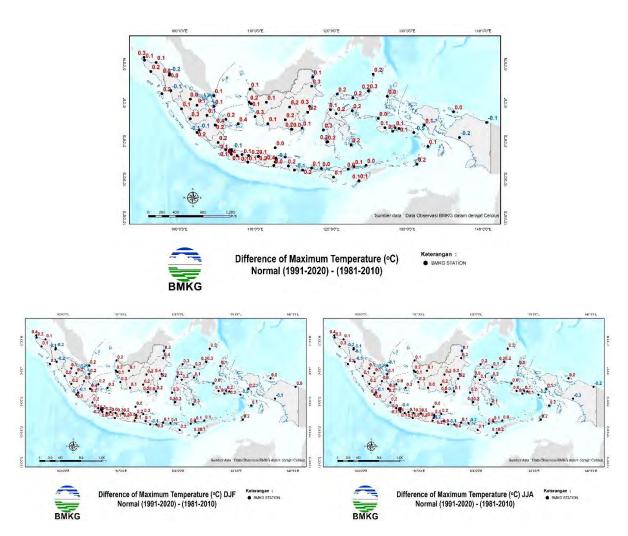
Fig 59 Difference of Maximum Temperature (ºC) between period normal all season (above), DJF season (left) and JJA season (right)

Based on the figure above, most BMKG stations show an increase for maximum temperature in all seasons, DJF season and JJA season. Highest increases for maximum temperature occur in 4 stations, around 0.4 ºC. The Increase of Indonesia average from 98 stations for maximum temperature is 0.1 ºC. In the DJF and JJA season, the highest increase for maximum temperature occurs in 3 stations, around 0.5 ºC (East Java). The Increase of Indonesia average from 98 stations for maximum temperature is 0.1 ºC.
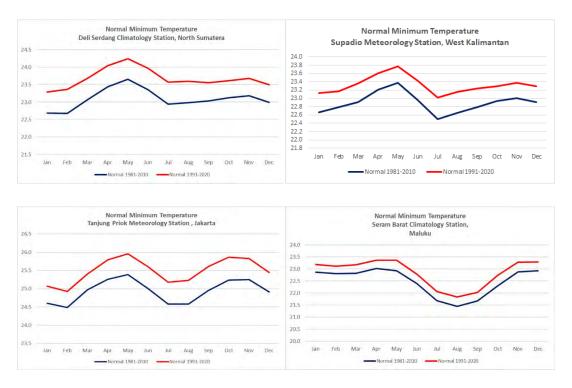
Fig 60 Comparison between minimum temperature normal period 1981-2010 and
new normal 1991-2020 observation data BMKG

Figure 60 shows Normal Minimum Temperature has a similar pattern between 1991-2020 and 1981-2010. Normal Minimum Temperature 1991-2020 higher than 1981-2010. Several stations has clearly significant between two period.

The minimum temperature in the new normal shows the same pattern as the minimum temperature in the old normal. In general, the maximum temperature in the new normal has a higher temperature than the minimum temperature in the old normal. The difference in minimum temperature between the two periods is very clear and significant among other parameters (maximum temperature and rainfall).
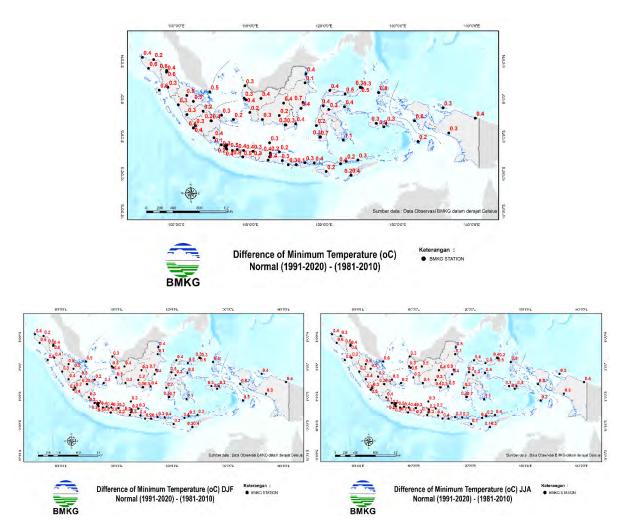
Fig 61 Difference of Minimum Temperature (°C) between period normal all season (above), DJF season (left) and JJA season (right)

In Figure 61, it can be seen that all BMKG stations have a minimum temperature increase in the all-season and DJF and JJA seasons. The highest minimum temperature increase occurred in Beto Ambari, Baubau (Southeast Sulawesi) at around 1.1 °C. The average increase in Indonesia from 92 stations for the minimum temperature is 0.4 °C. There is no difference in the increasing minimum temperature between DJF season, JJA season, and all seasons.

<Result of Statistical Downscaling>

Downscaling is done to obtain climate parameter values at a smaller or closer scale. The figure below shows the distribution of rainfall from the original MRI data (left), the distribution of rainfall from BMKG observation data (top center), the distribution of rainfall from the SACAD grid data (bottom center), and the corrected distribution of rainfall (right). From the figure, it can be seen that the distribution of rainfall from the original MRI data is unable to capture the area of Java Island in high mountainous areas. The distribution of rainfall from SACAD data has better resolution, so the distribution of rainfall follows the altitude pattern where there is high rainfall in mountainous areas and low rainfall in rain shadow areas. Corrected rainfall distribution using BMKG observation data or

72

SACAD data produces a similar distribution pattern, where the corrected rainfall distribution is higher than the observation data.
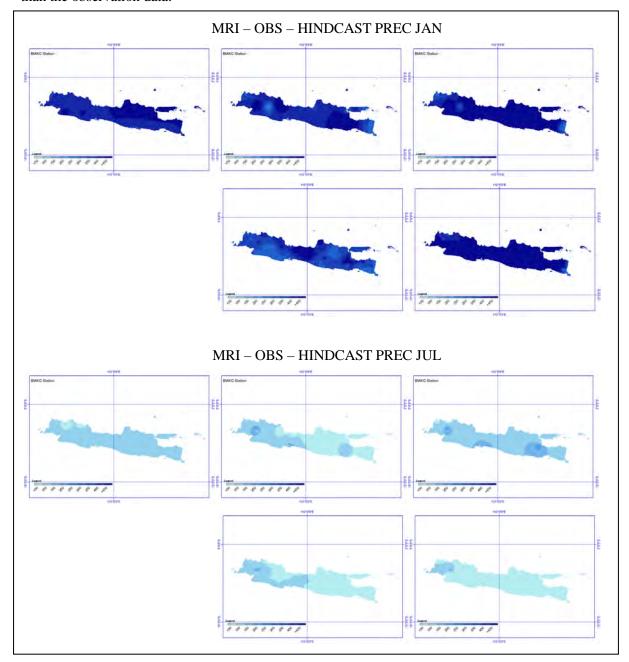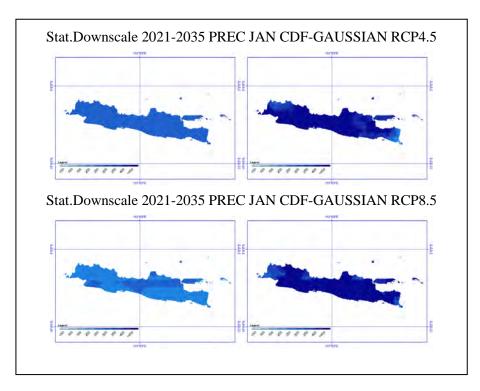

Fig 62 Maps of original MRI (left), observation (center) and
hindcast correction (right) for rainfall parameter.

The figure below shows the distribution of rainfall in future periods using CDF (left) and Gaussian (right) methods, as well as using RCP4.5 (top) and RCP8.5 (bottom) scenarios. The rainfall distribution between the two methods shows very different results, and does not show a rainfall pattern in the Java region. The CDF results for RCP4.5 only produce a certain range of rainfall values, which is (250-300 mm). From this figure, it can be concluded that statistical downscaling is able to produce certain values, but the results obtained are not reliable.
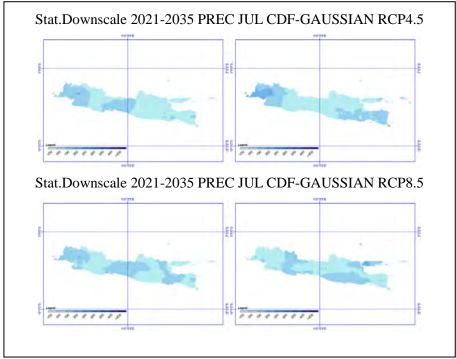
Fig 63 Maps of distribution of rainfall in future periods using CDF (left) and Gaussian (right) methods

The figure below shows the distribution of maximum temperature from the original MRI data (left), the distribution of maximum temperature from BMKG observation data (top center), the distribution of maximum temperature from the SACAD grid data (bottom center), and the corrected distribution of maximum temperature (right). From the figure, it can be seen that the distribution of maximum temperature from the original MRI data is unable to capture the area of Java Island in high mountainous

areas. The distribution of maximum temperature from SACAD data has a better resolution, so that the maximum temperature distribution follows the elevation pattern where the maximum temperature in highlands or mountains is lower than in lowlands. Corrected distribution of maximum temperature using BMKG observation data or SACAD data produces a similar distribution pattern where the corrected distribution of maximum temperature is higher than the observation data

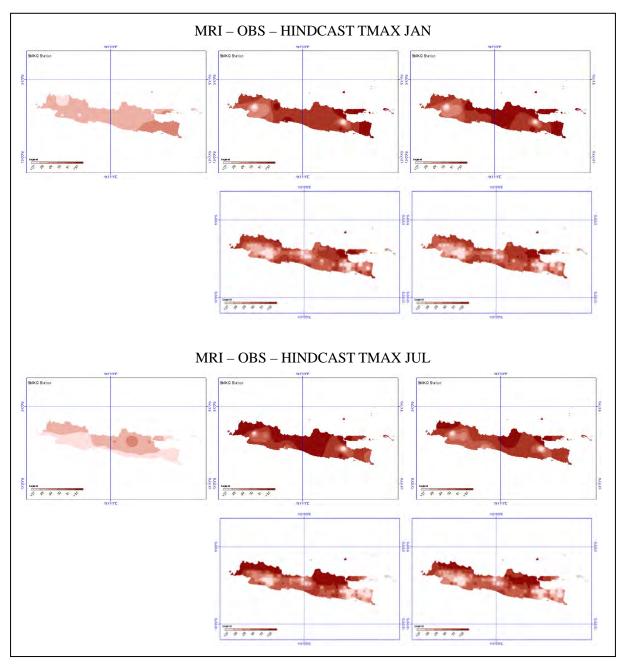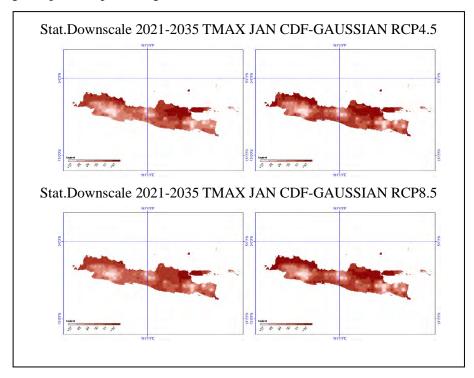Fig 64 Maps of original MRI (left), observation (center) and hindcast correction (right) for Tmax parameter.

The figure below shows the distribution of maximum temperature in the future period using the CDF (left) and Gaussian (right) methods, as well as using the RCP4.5 scenario (top) and the RCP8.5 scenario (bottom). The distribution of maximum temperature between the two methods shows very different

results. The distribution of maximum temperature does not show the pattern of maximum temperature in the Java Island region. The CDF result for RCP4.5 only produces a certain range of maximum temperature, which is (<27 ℃) - (>32 ℃). From the figure, it can be concluded that statistical downscaling is capable of producing certain values, but the results obtained are not reliable.
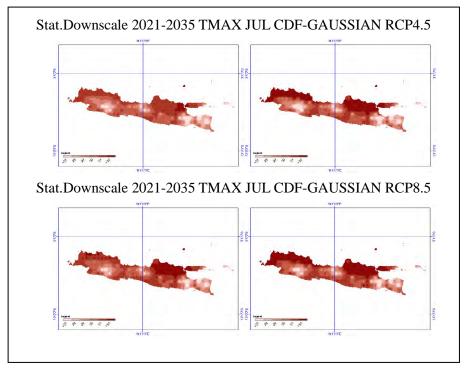

Fig 65 Maps of distribution of Tmax in future periods using CDF (left) and Gaussian (right) methods

The figure below shows the distribution of minimum temperature from the original MRI data (left), the distribution of minimum temperature from BMKG observation data (top center), the distribution of minimum temperature from the SACAD grid data (bottom center), and the corrected distribution of minimum temperature (right). From the figure, it can be seen that the distribution of minimum temperature from the original MRI data is unable to capture the area of Java Island in high mountainous areas. The distribution of minimum temperature from SACAD data has a better resolution, so that the minimum temperature distribution follows the elevation pattern where the minimum temperature in highlands or mountains is lower than in lowlands. Corrected distribution of minimum temperature using BMKG observation data or SACAD data produces a similar distribution pattern where the corrected distribution of minimum temperature is higher than the observation data.
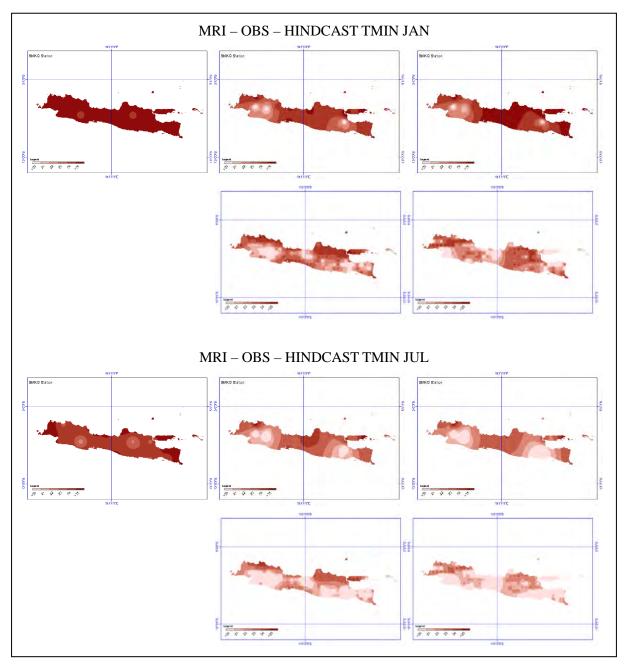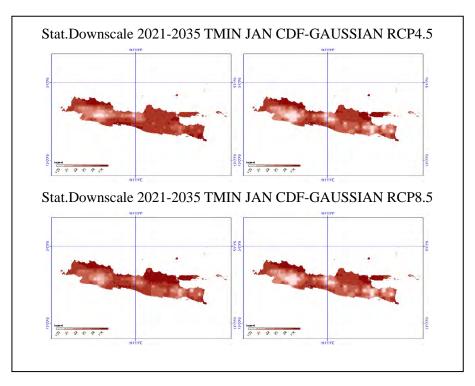
Fig 66 Maps of original MRI (left), observation (center) and
hindcast correction (right) for Tmin parameter.

The figure below shows the distribution of minimum temperature in the future period using the CDF (left) and Gaussian (right) methods, as well as using the RCP4.5 scenario (top) and the RCP8.5 scenario (bottom). The distribution of minimum temperature between the two methods shows very different results. The distribution of minimum temperature does not show the pattern of minimum temperature in the Java Island region. The CDF result for RCP4.5 only produces a certain range of minimum temperature, which is (<20 ℃) - (>25 ℃). From the figure, it can be concluded that statistical downscaling is capable of producing certain values, but the results obtained are not reliable.

Stat.Downscale 2021-2035 TMIN JAN CDF-GAUSSIAN RCP4.5

Stat.Downscale 2021-2035 TMIN JAN CDF-GAUSSIAN RCP8.5

Stat.Downscale 2021-2035 TMIN JUL CDF-GAUSSIAN RCP4.5

Stat.Downscale 2021-2035 TMIN JUL CDF-GAUSSIAN RCP8.5
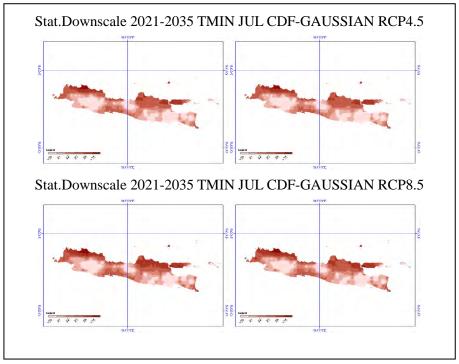
Fig 67 Maps of distribution of tmin in future periods using CDF (left) and
Gaussian (right) methods

(7)   Statistical downscaling of CMIP6 data

In the "Climate Change Capacity Enhancement Phase 2," with technical support from Dr. Motoki Nishimori, Senior Researcher, Head of Impact Prediction Unit, Climate Change Response Research Area, Research Center for Agricultural and Environmental Change, National Agriculture and Food Research Organization (NARO, formerly National Institute of Agro-Environmental Sciences),

statistical downscaling software of gaussian and CDF type was developed and shared with counterparts. Statistical DS was performed on MRI-AGCM data from CMIP5 and 2K and 4K data from d4PDF experiments. BMKG strongly requested that statistical downscaling be performed on the CMIP6 data later in the project, although statistical DS was performed on the

To meet this demand, the ESGF website (https://aims2.llnl.gov/search) Mr. Nishimori of NARO provided us with a method for downloading CMIP6 data from the ESGF website. In addition to downloading these data stored in NetCDF format, we prepared a manual on using Grads to cut out and draw the data for the Indonesian region and transferred the technology in March 2023.

Since the data for the MRI-AGCM and MIROC models at the above sites are for the same 1.25-degree lattice as CMIP5, the statistical DS software created for CMIP5 is expected to be used without modification.

Other pages of ESGF also contain higher resolution 25 km mesh data, which can be downloaded, cropped, and statistically downscaled like the CMIP6 data. With the data mentioned above download manual and the newly transferred statistical downscaling package, BMKG can perform statistical downscaling of CMIP6 data.
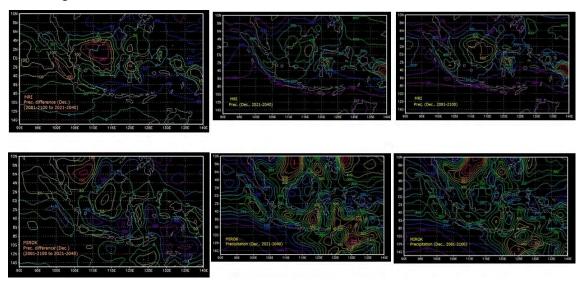
Fig 68 Example of CMIP6 data comparison
(top: MRI, bottom: MIROK, monthly precipitation from December to February)

3.2.4   Progress for Output 1b

Statistical downscaling is a method of statistically correcting coarse-resolution climate model data for bias or fitting the distribution function of observations using actual values. In this project, BMKG collected the observations, and a team of experts shared the climate model data in cooperation with NARO and others. Various downscaling was performed mainly for monthly statistics using statistical downscaling methods based on the Gauss distribution and CDF.

The observational data collected by BMKG consisted of data from BMKG manned stations for 1981-2020 and mesh reanalysis values called SACAD for 1981-2010. Statistical downscaling using the mesh data was performed for the following areas, which are pilot districts.

SYNP Central Java, West Java, Jakarta Special Municipality (DKL)

Statistical downscaling was conducted for about 90 manned stations throughout Indonesia (Figures 53 and 54). By examining the differences between the 1981~2010 average and the 1991~2020 average at the manned stations, we analyzed the changes in temperature and precipitation between 1981~1990 and 2011~2020. The results show an upward trend in temperature over almost all of Indonesia, and the precipitation trend is unclear at this time.

Statistical downscaling is useful for bias correction of point data. On the other hand, since the distribution function of daily precipitation deviates from a normal distribution, statistical downscaling could be more accurate. Statistical downscaling is considered adequate for comparing summaries monthly. In addition, the accuracy of statistical downscaling is highly dependent on the referenced data, so higher resolution mesh data is required (statistical downscaling of monthly mean values on a 5 km mesh requires mesh data of similar resolution), reanalysis using GSMaP and BMKG observation data provided by JAXA. By utilizing these data, high-resolution statistical downscaling can be performed.

Table 7 WG2 Meetings

Date	Meetings	participants	number	themes
2021.06.14	WG2 meeting	WG2 team, JICA team	8	Sharing MRI-AGCM data and scripts
2021.07.13	WG2 meeting	WG2 team, JICA team	8	Sharing grads scripts for MRI-4-scenarios-GCM, d4PDF
2021.09.21	WG2, WG3 meeting	WG2, WG3 team, JICA team	10	progressive reports and discussopn of next activities
2021.11.5	WG2, WG3 meeting	WG2, WG3 team, JICA team	10	progressive reports and discussopn of next activities
2021.11.18	WG2 meeting	WG2 team, JICA team	8	Sharing grads scripts for MRI-4-scenarios-GCM, d4PDF
2022.02.02	WG2 meeting	WG2 team, JICA team	8	Sharing grads scripts for MRI-4-scenarios-GCM, d4PDF
2022.02.16	WG2 meeting	WG2 team, JICA team	8	Evaluation of MRI-AGCM 4 scenarios
2022.02.22	WG2 meeting	WG2 team, JICA team	8	trend analysis (temperature and precipitation) at whole BMKG staions,
2022.03.01	WG2 meeting	WG2 team, JICA team	8	trend analysis (temperature and precipitation) at whole BMKG staions, sharing statistical DS tools
2022.06.27	WG2 meeting	WG2 team, JICA team	8	statistical downscaling (daily data) lecture and exercise
2022.08.31	WG2 meeting	WG2 team, JICA team	8	statistical downscaling (daily data) lecture and exercise
2022.11.15	WG2 meeting	WG2 team, JICA team	8	summarize statistical downscaling
2023.02.13	WG2 meeting	WG2 team, JICA team	8	final meeting presentation meeting
2023.02.28	WG2 meeting	WG2 team, JICA team	8	final meeting presentation meeting
2023.03.01	WG2 meeting	WG2 team, JICA team	8	CMIP6 data download and visualization

Due to travel and activity restrictions imposed by COVID-19, the project activities were mainly remote, especially in the first half of the project. However, by sharing statistical downscaling tools, holding net meetings (Table 7) as needed, explaining how to use them, and conducting exercises, we were able to Basic technology transfer was implemented. These were mainly due to the human connections and mutual understanding between BMKG and the expert team that continued from Phase 1, and it was found that considerable activities could be carried out even remotely if there was a sufficient mutual understanding between the counterpart in charge of the project and the expert team. However, on-the-job training in the field was still crucial for detailed technology transfer and tool modification. In the future, on-site activities once or twice a year will be essential for technology transfer. Still, it is also possible for BMKG to conduct technology transfer while utilizing remote activities.

3.2.5　Future Activity Plan

We shared the statistical downscaling packages by Gaussian-type and CDF, and evaluated the statistical downscaling in West Java, mainly using the BMKG observation data.

Statistical downscaling is a convenient method that allows downscaling of data from various models and scenarios with a small amount of computer resources and time. With actual conditions (point data or mesh data), future climate changes can be calculated. On the other hand, the Gaussian-type method assumes that the distribution function is normally distributed, while CDF does not specify a distribution function but has some weaknesses in statistical estimation methods, such as the fact that the actual situation pulls estimates if the data range or extreme values of the climate model and actual condition differ significantly.

Through this project, basic knowledge and tools for statistical downscaling were shared with BMKG. If BMKG can develop higher-resolution mesh data in the future, statistical downscaling over Indonesia can be easily performed. However, since it is a statistical method, it is appropriate to perform downscaling for a certain period, such as a season or a month. By preparing mesh data, statistical downscaling is expected to be utilized as a simple downscaling method.

Since the resolution of the original climate model in CMIP6 is about 30 km, and statistical downscaling is effective for bias correction and interpolation using climate values, it will be used to get an overview of each model and scenario, as described in Chapter 4. Using this method to respond to various user requests is considered appropriate.

3.3　Activity for Output 1c (Experimental Downscaling)

3.3.1　Background on Output 1c

The project targets high resolution downscaling, covers whole Indonesian area through output 1a (dynamical downscaling) and output 1b (statistical downscaling), and analyze future climate change and trend from present to future. Results of 5km downscaling can analyze few tens km resolution phenomenon, however, for more minute phenomenon, i.e. convective convection rains brought by small cumulonimbus, precise downscaling would be required.

In Indonesia, inundation in cities with local rivers by regional torrential rains or overflow of rivers by continuous rains or tidal change in mega cities like Jakarta, frequently occur recently. In order to analyze such smaller size events in future, precise downscaling in 500m or 1km resolution should be implemented and future projections of such events are strongly requested from other agencies (ATR, etc.) in order to contribute for decision and policy making considering climate change.

3.3.2　Current issues related to Outcome 1c

In the "Phase 1 Project" that preceded this project, with the guidance and cooperation of Professor Hiroyuki Kusaka of the Center for Computational Science at the University of Tsukuba and others, mechanical downscaling using the WRF model (an open-source weather model provided by NCAR in the United States) in BMKG was implemented, and technology was transferred. In the Phase 2 project,

we also carried out the downscaling of the Tsukuba area. In the Phase 2 project, with the cooperation of the University of Tsukuba, we also transferred high-resolution city-level climate model downscaling technology to BMKG.

3.3.3 Activity Details for Output 1c

During the preliminary study phase with the University of Tsukuba, it was decided that the joint research theme would be to estimate more realistic future changes that cannot be assessed by climate change models alone by considering both climate change and thermal environmental changes due to urbanization for Jakarta.

In 2020, due to travel restrictions to prevent transmission of the novel coronavirus and restrictions on research activities at the university, specific activities could not be carried out, and collaborative research had not been initiated until FY2021. The procedures for the joint research are as follows.

- Japanese side presents requirements for skills, knowledge, etc., required for joint research.
- Recommendation of BMKG side collaborators and discussion with Univ. of Tsukuba
- Establish targets and protocols for collaborative research

Joint research was conducted as an activity of WG3, and when necessary, joint meetings were held with other WGs to address issues with the cooperation of other WGs. WG meetings are shown in Table 8.

Table 8 WG3 Meetings

Date	Meetings	participants	number	themes
2021.06.29	DS jlint eeting	BMKG, Tsukuba university, JICA-project-office	12	dicsussion on high resolution DS
2021.09.21	WG2,3-meeting	MRI-GCM grads scripts sharing	10	Sharing MRI-GCM visualization tools and manuals
2021.11.5	WG3 meeting	WG3 team	5	Progressive report and discussion for next activities
2022.02.8	WG3 meeting	WG3 team	2	Progressive report and discussion for next activities
2022.03.8	WG3 meeting	WG3 team	2	Progressive report and discussion for next activities
2022.03.29	WG3 meeting	WG3 team	2	Progressive report and discussion for next activities
2022.06.27	WG3 meeting	WG3 team	2	Progressive report and discussion for next activities
2022.08.31	WG3 meeting	WG3 team	2	Hindcast data evaluation and discussion for next activities
2022.11.15	WG3 meeting	WG3 team	2	2045 heavy rain event simulation and discussion for next activities
2023.02.13	WG3 meeting	WG3 team	2	2045 heavy rain event simulation and discussion for next activities

(1) Activities through March 2022

At the joint-meeting held on 13rd of March 2021, (i) Tsukuba-university showed results of past researches for megacities in south-east Asian countries, (ii) attendees discussed target cities, target periods, target meteorological factors, and (iii) Japanese side requested BMKG to nominate co-researchers. For nomination of co-researchers, BMKG requested skill and knowledge required for co-researchers, and Japanese side replied to as follows,

i. familiar to LINUX OS
ii. having interest (hopefully knowledge) in climate change and urbanization effect
iii. hopefully experiences for WRF model
iv. review papers regarding precise downscaling in Asian big cities by prof. Kusaka

In June, BMKG requested to hold a meeting to discuss details of the co-research and WG3 meeting was held on 29th of June 2021 with participants as follows.

BMKG:　Mr. Kadarsah, Mr. Donaldi, Ms. Trinah, Mr. Ferdika Amsal (Sorbonne Université)、Mr. Jose Rizal (climate model, WRF, IPCC), Mr. Agus, Ms. Nurdeka, Mr. Tyas Rahmdar (R&D), Mr. Kawtsar (JICA project office)
Tsukuba university:　Prof. Kusaka, Mr. Asano,
JMBSC:　Mr. Tonouchi, Mr. Satoda, Mr. Kobayashi

At the meeting following terms were agreed.
<target of research>
+ Target city and year: Jakarta, 2045 (100 years anniversary year of Indonesia)
+ Target theme: heavy rain events considering global warming and urbanization effect <heat emission from city> (1km resolution)
+ Co-researchers: BMKG: Ms. Trinah, Mr. Donaldi, Tsukuba University: Mr. Asano
<preparation by BMKG>
+ land use data, heat emission data for Jakarta (covers simulation area shown in Fig. 3-3-1) at present and at 2045
+ list up dates of past heavy rain events in Jakarta and collect observation data (precipitation, temperature, wind)
+ recommend an appropriate GCM which shows good reproducibility of actual meteorological phenomenon from experiences of the CORDEX-SEA project
<preparation by Tsukuba university>
+ Reproducibility experiments, evaluations with historical observation data and re-analysis data
+ experiments and selection of boundary conditions, physical parameterization schemes, GCM models
+ collect geophysical data, land use data, heat emission data from database of laboratories

In regards with appropriate GCM model for Indonesian region, BMKG recommended GFDL based on experiments of CORDEC-SEA projects. GCM models experimented in CORDEX-SEA project were as follows,

CNRM-CM5 (Voldoire et al., 2013), CSIRO-Mk3.6.0 (Jeffrey et al., 2013), EC-Earth (Hazeleger et al., 2012), IPSL-CM5A-LR (Dufresne et al., 2013), GFDL-ESM2M (Dunne et al., 2012), and MPI-ESM-MR (Giorgetta et al., 2013)

Progressives of research were reported, maters were discussed and project plans were updated at WG3 meetings regularly held (in 2 or 3 monthly basis). Progressives of simulations at Tsukuba university ware reported by Mr. Asano at the meeting held in 8th of February 2022, as follows,

hindcast experiments were implemented for heavy rain event on Jan 16-18, 2013

through evaluation with actual observation data, appropriate 2 re-analysis models, 3 boundary

conditions, 3 micro physical parameters were selected.

reproductivity experiments confirmed that experiment results showed minute precipitation distribution patterns correctly caused by cumulative clouds.

Additionally, Mr. Asano explained reasons why ensemble downscaling was tried to ensure reliable downscaling. After ensemble experiments for hindcast data, WG3 tried to apply these conditions for projection ensemble runs. After the meeting, BMKG shared observation data in Jakarta area (precipitation, temperature, wind and weather during heavy rain events) and land use data in shape file formats.

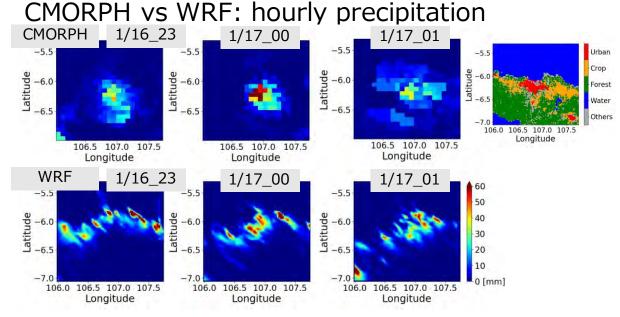# CMORPH vs WRF: hourly precipitation

Fig 69 Results of preparatory experiment on past heavy rain events
(above: precipitation observed by satellite<TRIM>, below: simulation results)

(2)   Verification of reproducibility through ensemble experiments (April-November 2022)

Hindcast experiments (reproduction experiments using past analysis values) of heavy rainfall cases were conducted at several objective analysis sites, boundary conditions, and physical processes shown in Table 8. Comparison and verification with actual rainfall distributions (observed data from the Tropical Rainfall Measuring Mission [TRMM]) were conducted to compare models and conditions with high reproducibility. Since simulations are more reliable when evaluated based on results computed under multiple conditions rather than results from a single climate model, boundary condition, or physical process, four initial conditions, three cloud physical processes (WSM6, WDM6, and Thompson), and two boundary layer PBL schemes (Planetary Boundary Layer scheme: parameterization of vertical heat, water vapor, etc.) were simulated for urbanized and non-urbanized precipitation for each of them.

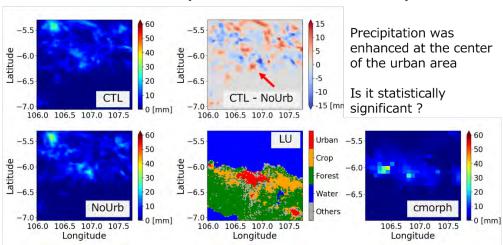Table 9 Urbanization Unsubsidized Simulation 1 (April-August 2022)

Initial value (reanalysis value name and initial time)	cloud physics	PBL Scheme
FNL: 2007-01-31 18 UTC FNL: 2007-02-00 00 UTC FNL: 2007-02-00 00 UTC ERA5: 2007-02-00 00 UTC	WSM6 WDM6 Thompson	YSU ACM2

FNL and ERA5 are names of initial value analysis models

FNL: Operational Global Analysis data provided by NCEP (USA)

ERA5: 5th generation global reanalysis data provided by ECMWF (Europe)

Ensemble mean (2007-02-01_18 UTC)

Precipitation was enhanced at the center of the urban area

Is it statistically significant ?

Ensemble mean (Cumulative precipitation)

Precipitation was enhanced over the urban area

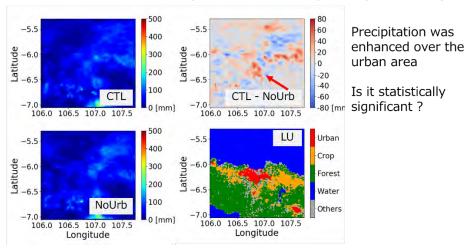Is it statistically significant ?

Fig 70Effect of urbanization on precipitation (all averaged in ensemble)

(Top: 1-hour precipitation at 18 UTC; Bottom: accumulated precipitation; CTL: with cities; NoUrb: without cities; LU: land use status; CTL-Nourb: difference in precipitation with and without cities; data from 8/31/2022)

Figure 70 compares precipitation amounts for the "with-city (CTL)" and "without-city (NoUrb)" cases (precipitation amounts are the average of simulation results for 4x3x2=24 cases). The above figure compares precipitation totals from 2/1~2, when rainfall was heaviest (18 UTC on 2/1/2007, or 1:00 AM on 2/2 in Jakarta), and for the period from 2/1~2. Here, NoUrb is calculated by replacing the urban area shown in red in the CTL figure with Crop (agricultural land).

In the simulation results, areas of increased precipitation appear on the slightly mountainous side of the urban area that makes up Jakarta, suggesting that the city enhances the convergence around the urban area and that precipitation in the urban area increases.

In August-December 2022, three heavy rainfall cases (2007/2, 2013/1, and 2015/2), three initial values for each heavy rainfall case, two analytical values (FNL and ERA5), two cumulus parameterizations, three cloud physics processes, and three PML schemes for a total of 324 cases, were subjected to similar Ensemble experiments were conducted to select appropriate parameters and schemes and to reproduce them in ensemble experiments.

Table 10 Urbanization Unsubsidized Simulation 2 (August-December 2022)

case	2007-02, 2013-01, 2015-02
initial time	3 times for each event
Data	FNL, ERA5
cu physics	Kain Fritsch, New Tiedtke
mp physics	Thompson, WDM6, WSM6
pbl physics	ACM2, YSU, MYNN25

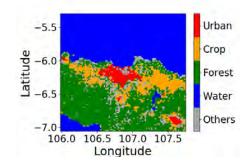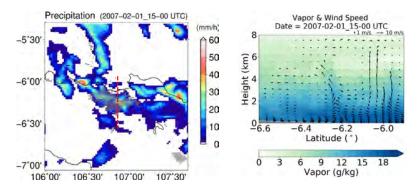| Case	2007-Feb-01, 2007
initial time	2007-Feb-01 00 UTC
analysis data	FNL
cu physics	New Tiedtke
mp physics	WDM6
pbl physics	YSU

Fig 71 Effect of urbanization on precipitation (example of analysis)

(left) Precipitation Map, Vertical Vapor profile (15UTC of 2007-Feb-01)

Fig 72 Impact of urbanization on precipitation
(left: precipitation distribution, right: vertical cross section, 2022/11/30 data)

Figure 71 shows the simulated 1-hour precipitation and vertical cross section at 15 UTC (22:00 local time) for the heavy rainfall case on 2/1/2007 under the FNL, New Tiedtke, WDM6, and YSU conditions, which are well reproduced in the unobservable experiment. It can be seen that over the city of Jakarta, winds from the ocean and land converge to form an updraft, which tilts toward the south toward the sky and forms an area with high water vapor content. The clouds that are bringing rainfall are mainly in the upwelling area around latitude -6.0 degrees in the figure on the right, and it can be inferred that the exhaust heat brought by Jakarta strengthens the upwelling above it, a process that enhances precipitation to the south of Jakarta.

(3)   Impact of Urbanization and Global Warming on Rainfall in Jakarta

Initially, from December 2022 to February 2023, we used a combination of models and parameters that fit well with the heavy rainfall case of 2007/2/1 in experiments (1) and (2) to see how rainfall in Jakarta would change under 2045 weather conditions (2°C rise scenario).

For the warming experiment, simulations were conducted using the methods shown in Table11. Specifically, the simulations were performed by adding the difference between the future (2036-2055) and current (2000-2019) monthly components of the climate model to the initial conditions of the event of interest, which were defined as future climate conditions. Simulations were conducted with several climate models, and the results using GFDL (USA) as an example are shown in Figure 74.

In addition, the Jakarta area is expected to expand further in the future. To examine these effects, an experiment was also conducted on the future urban impact (Figure 73), which assumes that the urban area will expand approximately twice as much.

Table 11 Methods of Pseudo-Warming Experiments

$$var_{event,\ FC} = var_{event,\ PC} + \Delta var$$

$$\Delta var = var_{twenty-year\ monthly\ mean,\ FC} - var_{twenty-year\ monthly\ mean,\ PC}$$

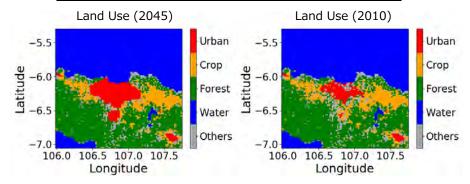| Variables	ts, ta, hum, u, v, gph
scenario	RCP8.5
Future Climate	2036-2055
Present Climate	2000-2019
GCM	CNRM-CM5
	CSIRO-Mk3-6-0
	GFDL-ESM2M
	MPI-ESM-MR

Fig 73 Future urban area (left: 2045, almost double the current area; right: current)

The Impact of Pseudo-Warming

Simulations were performed in the future (after pseudo-warming) and in the present, with the urban area remaining as it is today. The characteristics of the results are as follows.

- Overall, the area of intense rainfall will expand, and the area of intense rainfall will move to the northwest.
- The area of northwesterly winds from the sea to land narrows, and the line of convergence with the southerly winds from land to sea shifts seaward
- The upwelling area formed over the city has also moved seaward and is almost integrated with the upwelling area over the ocean analyzed over the sea in Figure 72.
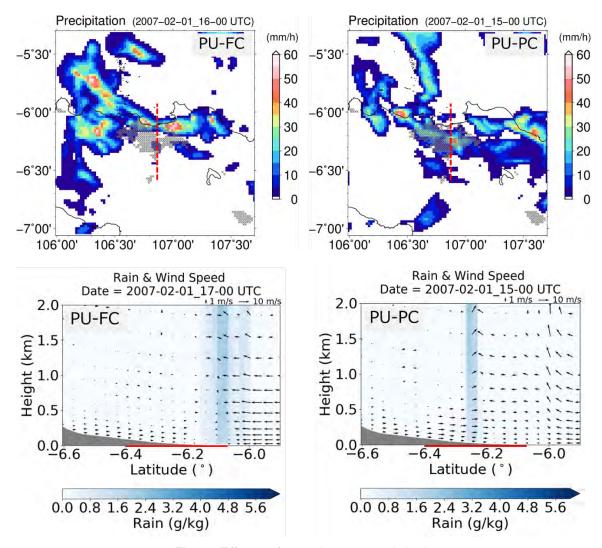
Fig 74 Effects of warming on precipitation

(left: after warming, right: present climate, urban area is present)

(Top: precipitation distribution, Bottom: vertical wind and precipitation, 1-hour precipitation

(2007-Feb-01 15UTC)

The experimental results suggest that the overall increase in air temperature and water vapor content due to climate change has expanded the area of intense rainfall and that the higher air temperature and water vapor content over the sea has enhanced convection over the sea, resulting in a shift of the upwelling area formed over Jakarta to the seaside. While it is reasonable to some extent that warming increases the amount of water vapor in the air and expands the area of intense rainfall, there are several issues to be considered regarding the shift of the area of intense rainfall toward the coastline, such as the resolution of the climate model being only a few tens of kilometers and reflecting detailed ocean-land distribution and water vapor distribution, etc., and verification with more cases is necessary. It is necessary to verify the results using a more significant number of cases.

Figure 75 compares precipitation under warming climate conditions in 2045, under current and future urban areas (Figure 73). As shown in Figure 74, warming has shifted the precipitation area

seaward, but further expansion of the urban area has further enhanced the updrafts in the urban area, shifting the marine rainfall area to the urban side.

This detailed downscaling showed that urbanization enhances intense rainfall areas over cities while warming enhances precipitation over the ocean. It is necessary to evaluate the effects of future climate change on many more cases.
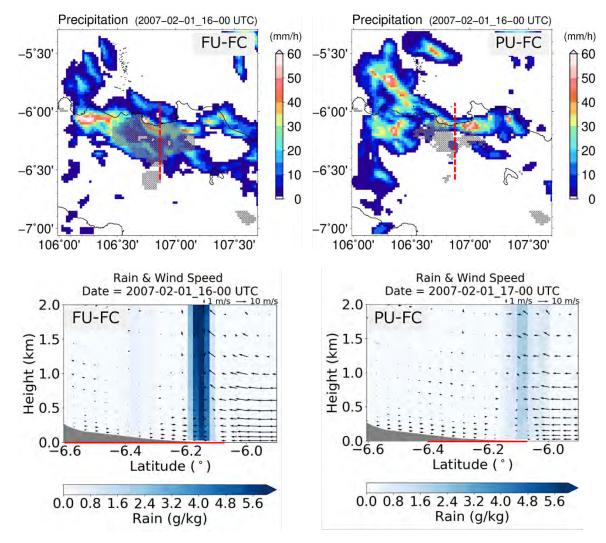

Fig 75 Impact of further urbanization on precipitation
(left: urban area expansion, right: current city)
(Top: precipitation distribution, Bottom: vertical wind and precipitation, 1-hour precipitation
(2007-Feb-01 15UTC)

3.3.4   Achievement of Outcome 1c

In collaboration with the University of Tsukuba, downscaling of the climate model was conducted using the WRF model in the following process.

Extraction of past heavy rainfall cases

Reproducibility calculations using multiple reanalysis values, convection schemes, and cloud physics processes for heavy rainfall cases (including evaluation of the reliability of reproducibility

through ensemble experiments) and evaluation with actual conditions.

Using optimal schemes, cloud physics processes, etc., replicate experiments for Jakarta in 2045 for no city, current Jakarta, and future Jakarta (assumed to be twice as large as current) under conditions of a 2°C increase, with the current climate.

- Assessing the effects of urbanization, global warming, and urbanization and global warming
- Although the implementation was quite research-oriented and not all of the techniques could be transferred to BMKG, we could share what procedures were used to perform the simulations.

3.3.5　Future Activity Plans

This activity allowed us to share with BMKG our process for conducting thematic global warming impact assessments. Although it was pretty advanced, and we could not directly transfer the technology to BMKG, setting research themes and scientific approaches on them is an asset to BMKG.

Regarding climate change assessment, the main activity of Activity 1a and 1b is to create a database covering the whole of Indonesia. On the other hand, it is expected that more and more requests will be made for thematic data for climate change measures, such as the request for climate change projections for Jakarta in 2045, the 100th anniversary of the country's founding, in this project. It is also necessary to strengthen BMKG's ability to respond to these requests.

The technical level required to meet these demands is relatively high, and it takes work to meet them with BMKG's current structure. To fill these gaps, collaboration with research institutions and active human resource exchange is considered a highly effective approach. Specifically, conducting joint research with overseas research institutions, including those in Japan, as was done in Activity 1c, or utilizing BMKG's efforts to dispatch young staff overseas and have them obtain degrees, are considered practical approaches,

Indonesia plans to relocate its capital to Kalimantan, and the proposed relocation site is mostly forest. Observation and evaluation of the impact of the emergence of a large city here on the climate is an excellent research theme for Japanese research institutions, and the Kusaka Laboratory at the University of Tsukuba has shown strong interest in these observations, analysis, and simulations. Continuing the analysis of future precipitation variability in Jakarta and researching climate change related to the relocation of the new capital in collaboration with Japanese research institutions is one of the promising themes for technical cooperation in climate change and should be actively considered for implementation in the future.

3.4 Activity for Output 2 (Strengthening the Capacity of Long-Range Forecasts)

3.4.1 Background on Output 2

Consisting of five major islands and more than 13,000 islands, Indonesia is characterized by a varied climate that includes remarkable dry and rainy seasons. Usually, the dry season is from July / August to October, and the rainy season is from October to January / February. However, the year-to-year and regional fluctuations are quite large.

Factors affecting weather and climate variability in Indonesia include the El Niño-Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), the Sea Surface Temperature (SST) near Indonesia, the Asian-Australian monsoon, and the Madden-Julian Oscillation (MJO), one of the tropical atmospheric fluctuations. In addition, progressing global warming is gradually increasing its role as a key factor in Indonesia's climate change and variable characteristics.
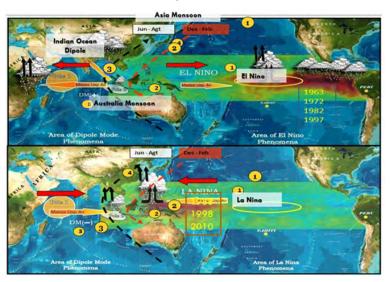

Fig 76 Major climate drivers (BMKG)

In this way, Indonesia's weather and climate are characterized by these various climatic factors and geographical and topographical factors.   BMKG has used 342 Seasonal Zones (ZOM)" and 65 Non-seasonal Zones (Non ZOM) for long range forecasts (seasonal forecasts) and has issued long range forecasts for each region based on the fluctuation characteristics of these factors. BMKG started to use new forecast zones, that is a) Regions with at least 2 seasons in a year (615 ZOM) and b) Regions with 1 season in a year (108 ZOM) when BMKG started use of new climate normal (using 30 years of data from 1991 to 2020).
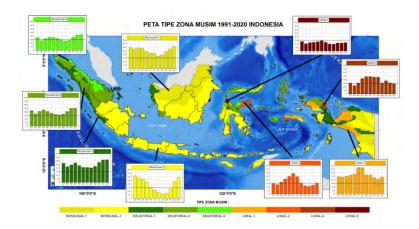
Fig 77 Climate regions in Indonesia (BMKG)

3.4.2 Challenges Related to Output 2

(1) Long-Range Forecast of BMKG

BMKG issues 10-day, one-month forecasts, three-month forecasts, and seasonal forecasts for the rainy and dry seasons based on dynamical ensemble forecast materials provided by European Centre for Medium-Range Weather Forecasts (ECMWF) and forecast guidance created by BMKG, and monitoring and diagnostic activities for ENSO, IOD, the Asian-Australian monsoon, etc.

In addition, BMKG uses forecast data from other national meteorological/hydrological centers (NMHCs) such as CPC (Climate Prediction Center)/ NOAA, TCC (Tokyo Climate Center)/ CPD (Climate Prediction Division)/ JMA (Japan Meteorological Agency) for forecasting.

Moreover, BMKG is working with Bandung University of Technology (ITB) to develop a multi-model ensemble (MME) method for seasonal prediction with the aim of introducing it into forecasting operation within a few years, as well as utilizing empirical and statistical prediction methods.
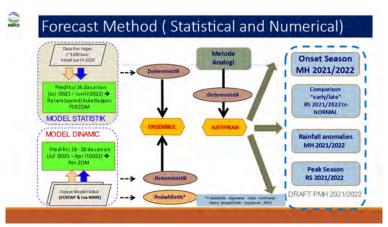

Fig 78 Flowchart of producing seasonal forecast (BMKG)

(2) Long-Range Forecasting Issues (Challenges)

As mentioned above, BMKG has been developing and operating its own forecasting method, utilizing the latest knowledge from advanced climate centers, and has been issuing long range forecasts for 1, 3, and 6 months ahead. It should be noted that BMKG started to provide '1-year climate outlook'

to the government agencies in 2022, responding to the request from the government agency.

On the other hand, there is a strong demand from users for more accurate forecasts, especially for the start/end of the rainy season. For the agricultural sector, it is important to forecast the start or end of the rainy season for planting major crops such as paddy rice, soybean, and corn.

In order to improve the accuracy of seasonal forecasts, it is necessary to understand more precisely the factors that cause fluctuations in precipitation during the dry and rainy seasons. In addition, as socio-economic damages caused by heavy rains have increased in recent years, there is a growing demand for weather information that contributes to disaster prevention measures.

Furthermore, as concerns about the impact of global warming on social and economic activities are gradually intensifying, it is requested for BMKG to provide "longer-term climate information" in order to formulate a long-term national plan for social and economic activities in Indonesia.

3.4.3   Activity Details for Output 2
Based on the current situation and issues surrounding BMKG mentioned above, we worked on the following activities.

(1)   Activity Goals
We will support technology transfer, research and development related to the enhancement of seasonal forecasts and contribute to the improvement and strengthening of seasonal forecasts at BMKG.

(2)   Establishment of a working group and consideration of specific issues
JICA experts have held regular online meetings with BMKG representatives to discuss specific issues and responsibilities. Based on the discussions at the meeting and the results of the Meteorological Observation Data Evaluation Capacity Enhancement Project of the Indonesian "Agricultural Insurance Implementation Capacity Improvement Project", the following five issues were addressed (Table 12). These issues were tackled by junior BMKG staff, and BMKG senior staff and JICA experts shared the responsibility of the survey and provided technical advice to the juniors.

Table 12 WG4 Main Tasks and Working Group Members

課題（Tasks）	担当（Staff）
（1）BMKG季節予報の精度評価（BMKG seasonal forecast evaluation）	（BMKG） Supari Adi Amsari Rosi Damiana Rama Ridha Ayu （JICA expert） Kuirhara
（2）インドネシアモンスーンの変動特性の調査（Monsoon variability study）	
（3）1カ月先までの大雨の予測可能性調査（S2S prediction study）	
（4）エルニーニョ南方振動（ENSO）／インド洋ダイポールモード（IOD）影響調査（ENSO and IOD impact study）	
（5）気候の1年予報の調査（1 year climate outlook study）	

a)   BMKG Seasonal Forecast Evaluation
- Evaluate BMKG's seasonal forecasts and identify issues to improve forecasts.

- Evaluate the accuracy of seasonal forecasts through the end of 2020.
- As an expected result, it will be possible to confirm the accuracy of seasonal forecasts and issues that require technical improvement.

b)   Monsoon variability study

- To investigate the characteristics of Indonesian monsoon and associated precipitation fluctuations, including long-term trend analysis, with a particular focus on the start/end of the monsoon, the length and shortness of the monsoon period, and the total monsoon precipitation.
- For pilot areas such as West Java Province, to collect precipitation data from about 40 years from 1981 to the present and conduct the above analysis.
- As an expected outcome, it will be possible to further understand the variability characteristics of monsoon and precipitation, which are related to socio-economic activities in Indonesia. It will also contribute to efforts to improve the accuracy of seasonal forecasts. In addition, it contributes to the improvement of weather information provided by BMKG.

c)   Sub-seasonal to Seasonal(S2S) prediction study

- To investigate the predictability of heavy rain about one month ahead, by using the forecast data of the numerical forecast models of the ECMWF (European Medium-Range Forecast Center) and JMA (Japan Meteorological Agency),
- The target area will be selected from West Java Province and areas where heavy rains have occurred in the past few years.
- As an expected outcome, understanding of the predictability of heavy rainfall, which has a significant impact on citizens' lives, will be advanced. It also contributes to improving the accuracy of weather prediction information provided by BMKG.

d)   ENSO and IOD Impact Assessment

- To evaluate the impact on precipitation changes in Indonesia, in addition to evaluating ENSO and IOD forecasts, which are one of the basic information for seasonal forecasts.
- As an expected result, we can confirm the challenges for improving seasonal forecasting technology.

e)   1 year climate outlook study

- To investigate what information is required for climate information one year ahead requested by government agencies such as BAPPENAS.
- To investigate what kind of information can be provided based on the accuracy of the information, in addition to collecting information such as precedents of meteorological organizations around the world,
- As an expected result, it can meet the requests of government agencies such as BAPPENAS. It will also contribute to the expansion of BMKG's climate information.

(3)   Activities of JICA Experts

Regarding the issues mentioned in the previous section, JICA provided the following data/information and technical advice.

- Introduction to JMA's latest 6-month forecast materials (6-month forecast by day) available for S2S surveys.
- Introduction to IOD Monitoring Data in JMA
- Introduction to JMA's Asia-Australia monsoon data
- Examples of one-year forecasts from global meteorological organizations
- In addition, information and materials necessary for the investigation and technical advice were provided.

3.4.4   Progress for Output 2

The implementation plan of WG4 is shown in Figure 79. From the start of the project until December 2021, due to the spread of COVID-19, JICA experts were unable to visit BMKG to provide information and advice directly. During this period, WG4 held regular online meetings to exchange information on the progress of the survey and to provide advice from JICA experts as necessary. Since January 2022, JICA experts have conducted three field activities (January-March 2022, July-August 2022, and February-March 2023). In these onsite activities, we examined and confirmed the progress of WG4 tasks and future initiatives, and prepared reports. JICA experts also attended workshops/forums and gave lectures on seasonal forecasts and climate change issues.

Table 13 shows the status of JICA experts giving lectures related to seasonal forecasts during the project activity period, and Table 14 shows the status of WG4 meetings.
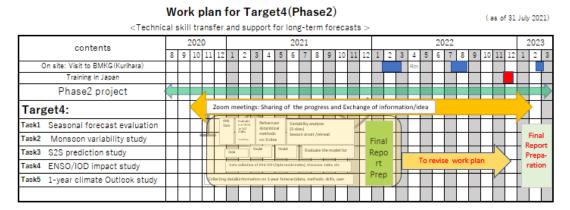

Fig 79 Implementation Plan

Table 13 Workshops, Forums, and Seminars (October 2020 to March 2023)

NO	Year.Month.Date	会合 （Meetings)	参加者 （Participants)	内容等 （Contents of the meeting)
1	2021.03.12	National Climate Outlook Forum （NCOF）	BMKG and seasonal forecast expets	To discuss and prepare 2021 Dry season forecast
2	2021.03.18	National Climate Forum for User	BMKG and seasonal forecast users	To explain 2021 Dry season forecast
3	2021.07.29	National Climate Expert Forum（NCEF）	BMKG and seasonal forecast experts	To discuss 2021/22 Wet season forecast
4	2021.08.27	National Climate User Forum	BMKG and seasonal forecast users	Meeting wih seasonal forecast users
5	2021.11.17	Focus Group Disscusion	Seasonal forecast experts from BMKG and Mlaysia met office	To share information on Climate Variability and Climate Services in Southeast Asia
6	2022.02.15	National Climate Expert Forum	BMKG and seasonal forecast experts	To discuss 2022 Dry season forecast
7	2022.02.22-26	National Climate meeting	BMKG seasonal forecasters	Seasonal forecast meeting for Dry season 2022
8	2022.08.02-05	Wet season forecast meeting(Lombok)	BMKG seasonal forecasters	To prepare for wet season 2022/23 forecast
9	2022.08.20-21	Climate Field School(Medan)	BMKG and users(Tea/coffee producers)	Climate Field school for tea/coffee production
10	2022.11.01-03	Workshop of Climate Projection and Seasonal Prediction in Bandung	BMKG and local organizations	Lectures on climate change/seasonal forecas by JICA experts and WG4 members
11	2022.11.15-17	Workshop of Climate Projection and Seasonal Prediction in Sumarang	BMKG and local organizations	Lectures on climate change/seasonal forecas by JICA experts and WG4 members
12	2023.01.25	The Focus Group Discussion –ENSO Forecast Devlopment	BMKG and seasonal forecast/ENSO forecast expert	Discussion and lecture on ENSO monitoring and forecast

Table 14 List of WG4 Meetings (October 2020 to March 2023)

	Date	Meetings	Participants	Contents of Meeting
1	2020.10.13	Kick-off Meeting	WG4 members, Project Expert	JICA hosted Kick-off Meeting
2	2020.10.20	WG4 Monthly meeting	WG4 members, Project Expert	To prepare Work Plan for Target 4
3	2020.11.24	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
4	2020.12.22	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
5	2021.02.03	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
6	2021.03.04	JICA/BMKG Joint meeting	JICA, BMKG, JMBSC	Progressive report and Work Plan for 2021
9	2021.04.06	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG activities
10	2021.04.14	JICA/BMKG Joint meeting	JICA, BMKG, JMBSC	Joint meeting
11	2021.05.19	The Second JCC	JICA, Related Organizations, JMBSC	The Second JCC
12	2021.05.25	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
13	2021.06.24	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
14	2021.07.28	WG4 Monthly meeting	WG4 members, Project Expert	Same as above

17	2021.08.31	Technical Working Group Discussion	JICA, BMKG, JMBSC	Joint meeting
18	2021.09.02	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
19	2021.09.17	WG4 Monthly meeting	WG4 members, Project Expert	Preparing mid-term reports
20	2021.09.27	JICA/BMKG joint meeting	JICA, BMKG, JMBSC	JICA/BMKG joint meeting for mid-term reporting
21	2021.10.12	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
23	2021.11.23	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
24	2021.12.15	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
25	2022.02.03	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
26	2022.02.10	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
28	2022.02.15	WG4 Monthly meeting	WG4 members, Project Expert	To disscuss work plan among others
30	2022.03.02	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
31	2022.04.13	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
32	2022.05.22	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
33	2022.06.29	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
34	2022.07.18	WG4 Monthly meeting	WG1,2,3 and 4, Project Expert	To report and share the progress of WG activities
38	2022.08.24	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
39	2022.09.14	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
40	2022.10.28	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
43	2023.01.18	WG4 Monthly meeting	WG4 members, Project Expert	Same as above
45	2023.02.14	WG4 Monthly meeting	WG4 members, Project Expert	To report and share the progress of WG4 activity
46	2023.02.27	WG4 meeting	WG4 members, Project Expert	To prepare for the final report meeting and for Complete report of WG4
47	2023.02.28	WG4 meeting	WG4 members, Project Expert	Same as above
48	2023.03.02	WG4 meeting	WG4 members, Project Expert	Speach reheasal for the final report meeting
49	2023.03.03	WG4 meeting	WG4 members, Project Expert	Same as above
50	2023.03.06	Final report meeting	JICA/BMKG project PhaseII members	Report to JICA/BMKG
51	2023.03.06	Open seminor	JICA/BMKG and related organizations	Lectures by experts on climate change issues
52	2023.03.10	WG4 meeting	WG4 team, JICA	Wrap-up for WG4 Activity
53	2023.03.20	WG4 meeting	WG4 team, JICA	Preparation of WG4 final report

A summary of the activities for the five tasks is shown below (See the appendix for detailed reports):

(1)   Task1 Seasonal Forecast Evaluation

Objective

To evaluate seasonal forecasts (forecasts of the start of the rainy and dry seasons) using data from 2012 to 2020, and to clarify issues for improving forecasts.
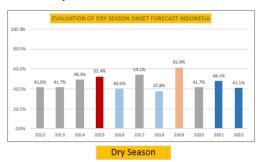
Result

- BMKG seasonal forecasts for the onset of wet/dry season perform better than Climate forecasts. (Note: Climate forecast is that onset of dry/wet season is always forecasted as 'near normal.')
- The forecast for the start of the rainy season performs better than the forecast for the start of the dry season (Figure80).
- In Bali (Bali Nusra) and Papua (Maluku Papua), the forecast accuracy of the start of the dry season has been on an upward trend over the past decade (Fig. 81).
- Forecast results suggest a relationship between dry/wet season onset and ENSO/IOD.
- There are regional differences in forecast accuracy, and the northern Indonesia region and areas near the equator need further improvement of forecasts (Fig. 82).

Achievements

The technical level of dry/rainy season forecasting for the dry/dry season onset were confirmed. It was found that the year-to-year fluctuation of forecasting skills is related to factors such as ENSO. In addition, it was found that forecast accuracy improved over the last decade in some regions.

Future Initiatives

In this forecast evaluation survey, we conducted a forecast evaluation using the average year values from 1981~2010. Currently, forecasts are made using statistical values from 1991 to 2020, when the date quality has improved. Therefore, we will verify the forecast using the new normal-year data and compare it with the current results. In addition, we aim to further improve forecasting skills by applying the relationship between ENSO/IOD and precipitation variability revealed in this survey. Furthermore, efforts will be made to utilize the results in the implementation of forecast commentary based on forecast accuracy.
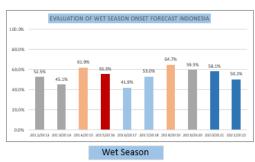

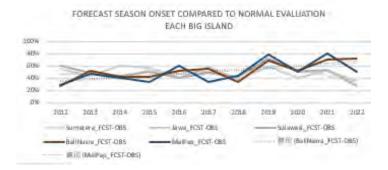Fig 80 Annual variation in accuracy rate of Dry/Wet season onset forecast

Fig 81 Change in accuracy rate by island in the forecast for the dry season onset

Fig 82 Accuracy rate of Dry/Wet season onset forecast in forecast regions

(2)   Task 2 Monsoon variability study

Objective

To characterize the variability of the start of the dry/wet season and the variation in total precipitation for the pilot regions of Bandung and Semarang (Fig.83).

Result

- JATENG_24(Semarang region) has a longer dry season and a shorter rainy season compared to JABAR_31(Bandung region). Furthermore, JATENG_24 shows an earlier onset of dry season in April and a later onset of rainy season in November compared to JABAR_31, which shows these seasons in May and October, respectively.

- In the present study both regions showed a trend of shortening the dry season and extending the wet season. Also, total precipitation in the dry season showed a downward trend, and total precipitation in the wet season an upward trend (Figs.84 and 85).

- El Niño affects rainfall patterns in both regions, particularly in their dry seasons (Figs. 86 and 87). Precipitation tends to decrease during El Nino events. This tendency is particularly pronounced during the dry season. JABRA_31 shows a reduction in rainfall during both the dry and rainy seasons, while JATENG_24 shows no reduction in rainfall from January to April, which is within its wet season. In JABAR_31, El Niño results in changes in the onset and duration of the seasons, such as the addition of periods in the dry season and the reduction of periods in the rainy season.

- Impacts of La Niña events are not so clear as those of El Nino. During La Nina events rainfall

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tends to increase especially in the wet season. Strong La Niña shows mixed results, while moderate and weak La Niña have almost no impact on the regions.

Achievements

The characteristics of precipitation variability in dry and wet monsoons in the pilot area, especially those associated with ENSO variability, were clarified.

Future Initiatives

Similar surveys will be conducted in other forecast zones (ZOMs) to clarify the characteristics of overall monsoon variability in Indonesia. In addition to ENSO, we will investigate how it relates to large-scale atmospheric and oceanic variability such as IOD. Efforts will be made to improve the seasonal forecast of BMKG.

Fig 83 Annual variation in precipitation in Bandung (Left) and Semarang (Right) forecast area
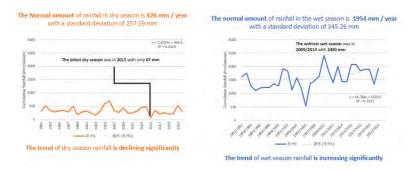
Fig 84 Annual variation in total rainfall in Bandung during Dry/Wet seasons
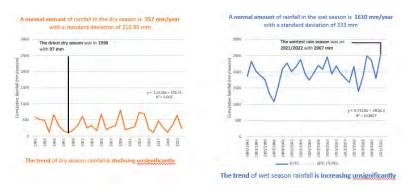
Fig 85 Annual variation in total rainfall in Semarang during Dry (left)/ Wet (Right) seasons
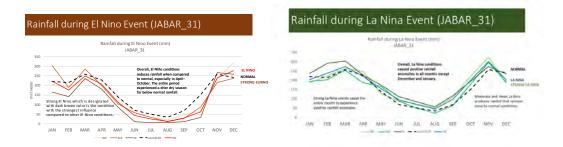
Fig 86 Seasonal changes in precipitation during ENSO (Bandung)
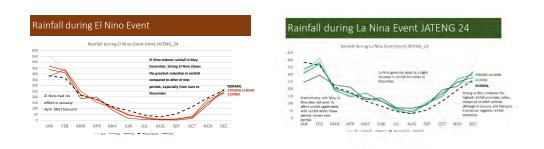

Fig 87 Seasonal changes in precipitation during ENSO (Semarang)

(3)   Task 3 Sub-Seasonal to Seasonal Prediction Study

Purpose

To investigate the predictability of extreme events such as heavy rain and drought condition about one month ahead, using outputs of the numerical forecast models of the ECMWF (European Medium-Range Forecast Center). Predictabilities in the dry season (May to August) are studied.

Result

- Predictability studies were done for the dry season with four different lead times using 20 years (2002 to 2021) of verification data (Fig. 88). MSSS and BR score are calculated to study predictability.
- Higher predictability is found in July compared to other months (Figs. 89 and 90).
- Case studies were done for extreme events (Fig. 91). In the case of August 2022, it showed high predictability with 4 weeks lead time to predict dry and wet condition, suggesting forecasts could be applicable for extreme weather condition cases.

Achievements

It was discovered that sub-seasonal predictions have the potential to provide earlier information on the potential for extreme events, although it still needs to be improved for accurate predictions.

Future Initiatives

In the future study, studies using other forecast models will be explored to find most suitable one for Indonesian regions. Studies for the other season is also needed. Moreover, studies in the presence of MJO and ENSO are essential.

Fig 88 Prediction Issued
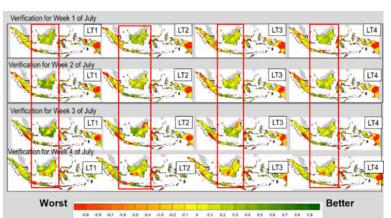date and target week
illustration

Fig 89 Spatial Analysis for MSSS in July
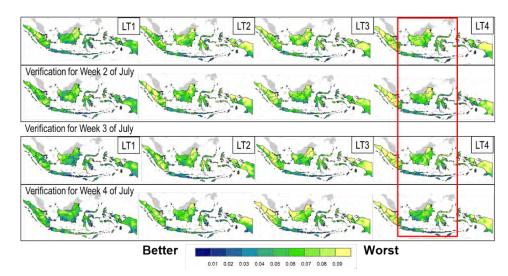(2002 - 2021)

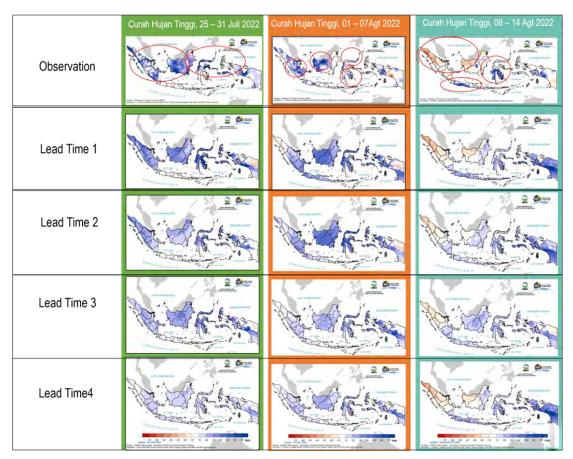Fig 90 Spatial Analysis for BS in July (2002 - 2021)

Fig 91 Sub-seasonal predictability in three case studies of the impact of extreme events

(4)　　Task 4 ENSO/IOD impact study

Task 4.1 The Impact of ENSO on Rainfall Variability in Indonesia

Purpose

BMKG has produced new climate normals based on the dataset from 1991 to 2020. Study of ENSO impacts on rainfall over Indonesia was conducted using these new normals and the historical dataset. bootstrap percentile method was used to evaluated ENSO impacts.

Result

- During the June-July-August period in El Niño years negative anomalies of seasonal precipitation were shown in the majority of areas across Indonesia while northeastern regions show above normal precipitation (Fig. 92Left). During the September-October-November Most regions show significant below normal precipitation (Fig. 92Right). The areas with negative anomalies of magnitude greater than 60% were shown in the southern part of Sumatra, Java, Bali, Nusa Tenggara, etc.

- During the June-July-August period in La Niña years, positive anomalies of seasonal precipitation were shown in the majority of areas across Indonesia (Fig. 93Left). Areas recording positive anomalies of magnitude greater than 80% widened until the southern part of Sumatra, the southern to the central part of Kalimantan, the northern part of Sulawesi, and the southern part of Maluku.

- During the September-October-November period, wet conditions show throughout the country

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(Fig.93Right). The areas with positive anomalies of magnitude greater than 80% were shown in the southern part of Sumatra, Java, Bali, Nusa Tenggara, the eastern part of Kalimantan, and the central part of Sulawesi.

Achievements

ENSO impacts over Indonesian rainfall were evaluated for the June to November period using new normal data. It was found ENSO Impacts, dry condition during El Nino and wet condition during La Nina, seemed most widely developed during August to September. it can be concluded that some areas in the south of the equator experience decrease rainfall of over 60% during the El Niño event on JJA-SON. And some areas experience increase rainfall of over 80% during the La Niña event on ASO-SON.

Future Initiatives

Further studies for other period of the year need to be done. Moreover, study and works should be conducted for these results being installed on operational early warning and heavy rainfall warning system.
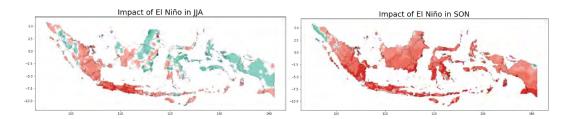

Fig 92 Impact of El Niño event on rainfall variability in JJA (Left) and SON(Right) periods in Indonesia
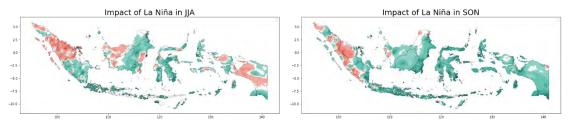

Fig 93 Impact of La Niña event on rainfall variability in JJA(Left) and SON(Right) periods in Indonesia

Task 4.2 Improvement of Indian Ocean Dipole Mode (IOD) Monitoring and Forecast

Purpose

ENSO and IOD are most important driving forces on the Indonesian climate conditions. Their forecast information from world climate centers such as TCC (Tokyo climate center)/JMA are used for monitoring and forecasting them for operational seasonal forecast activities in BMKG. JMA's ENSO Forecast Skills Survey was conducted on an agricultural insurance project[1]. A similar approach was used to investigate the JMA forecasting skills of IOD indices. Moreover, IOD impacts on precipitation

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[1] The Republic of Indonesia Project of Capacity Development for the Implementation of Agricultural Insurance - Capacity Development on Meteorological and Climate Data Analysis for the Agricultural Insurance, Completion Report, October 2020

variability in Indonesia were studied.

Result

a) JMA IOD Index Forecast Evaluation

- JMA's IOD index forecasts were evaluated using statistical methods (Pearson Correlation and Mean Square Skill Score (MSSS)).
- For forecasts one to three months ahead, the forecasts and observations were highly correlated and the MSSS was positive (Fig.94).
- By season, the forecast for January to March is less correlated than for other seasons (Fig. 95) possibly representing so-called Spring barriers. The accuracy of the forecast appears to depend on the season, and the factors that contribute to this need further investigation.

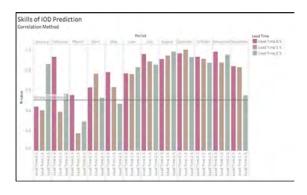Fig 94 Performance of IOD predictions Issued by JMA

Fig 95 Performance of IOD predictions Issued by JMA using Correlation Method

b) Impact of IOD events on Indonesian Rainfall

- Bootstrapping method was used to analyze the impact of IOD on rainfall in Indonesia.
- In general, positive/negative IOD has a significant impact on rainfall over Indonesia during JJA(June-July-August) Period, especially for some parts of Sumatera, Java, Bali NTB and NTT (Fig. 3-4-21). Rainfall during positive IOD in the JJA period tends to decrease in some parts of Sumatera and Java while it tends to increase in some parts of Kalimantan, Sulawesi and Papua. During negative IOD rainfall tends to increase in most parts of Indonesia except in northern Sumatera and Papua.
- Positive/negative IOD significantly impacts rainfall over Indonesia during SON Period, especially for the southern part of Sumatera, Java, Bali, NTB and NTT, Kalimantan, Sulawesi, and Maluku (Fig.97). Rainfall in SON period tends to decrease in most parts of Indonesia

during positive IOD while it tends to increase in most parts of Indonesia during negative IOD.

- It is noted that impacts of IOD in northern Sumatera are a little different from other parts of Indonesia. It tends to be below normal in JJA and SON during negative IOD.
- Impacts of Pure IOD, IOD conditions without ENSO events, are also investigated. Results are similar to impacts of IOD mentioned above.
- Timeseries of rainfall during positive/negative IOD for pilot regions are shown in Figure 98 (Central Java) and Figure 99 (West Java). Since IOD general becomes evident during dry season in Indonesia, its impacts on rainfall, drier condition during positive IOD and wetter conditions during negative IOD, are clearly apparent in the dry season at the regions.
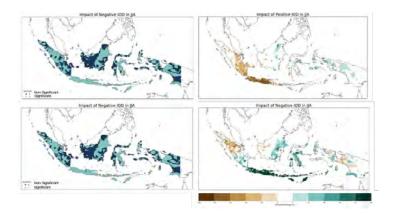

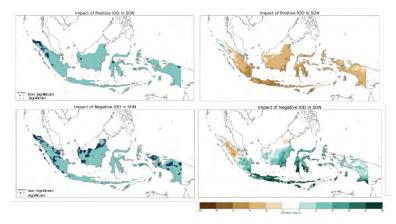Fig 96 Impact of IOD events on Indonesian Rainfall During JJA

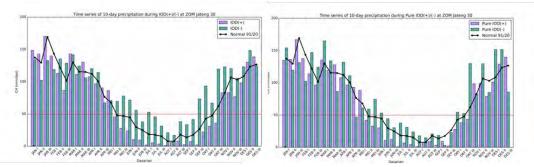Fig 97 Impact of IOD events on Indonesian Rainfall During SON

Fig 98 Time Series of 10-day Precipitation during Positive/Negative IOD
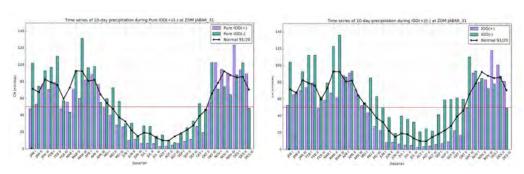at Central Java_30 Region

Fig 99 Time Series of 10-day Precipitation during Positive/Negative IOD
at West Java_31 Region

Achievement

- IOD Prediction issued by JMA that is used for BMKG seasonal forecasts as one of main information was evaluated. It was found that it has a good prediction on forecasting 1 to 3 months ahead.

- It was found that IOD on rainfall amounts in Indonesia were clarified for dry season. In general, Indonesia's rainfall during the positive IOD decreased and vice versa. However, some regions experienced different impacts.

Future plan

- In the next project, we could evaluate the six months IOD and ENSO forecasts issued by JMA. This information will assist the BMKG forecaster in predicting seasonal rainfall and the season onset.

(5)   Task 5 1 Year Climate Outlook Study

Purpose

Since there is a strong request from Indonesian government agencies for a one-year forecast, a study on issues for providing climate projections up to one year ahead was conducted.

Results

BMKG produced one year climate outlook 2022 as well as the one for 2023. BMKG used existing seasonal forecast techniques (a combination of dynamical and statistical methods) to create climate projections up to one year ahead (Fig. 100). It is noted information on ENSO and IOD prediction up

to one year ahead were main factors for producing one year outlook (Fig. 101). Outlook of annual rainfall (Fig. 102) as well as monthly rainfall over Indonesia among others was produced.
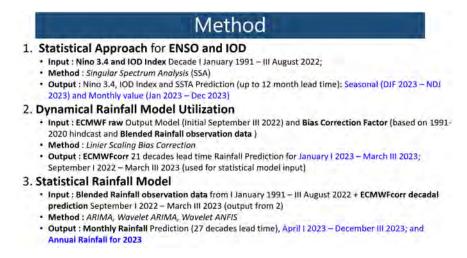

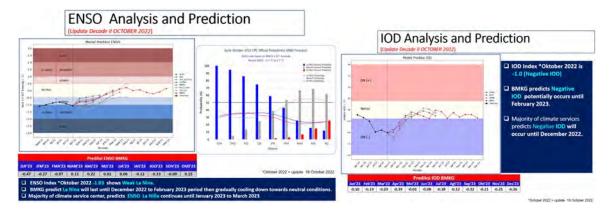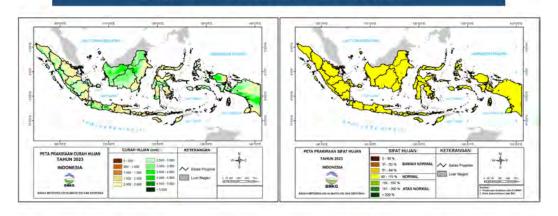Fig 100 The method for one year climate outlook 2023 (BMKG)

Fig 101 ENSO Analysis and Prediction (left) compared with Probabilistic ENSO Forecast (middle); IOD Analysis and Prediction for One Year Climate Outlook 2023 (right)

2023 Annual Rainfall Prediction Map   2023 Annual Rainfall Anomaly Prediction Map

Fig 102 Annual Rainfall Prediction for 1year climate outlook 2023 (BMKG)

Achievements

- One Year Climate Outlook was prepared to respond to the request from the government through the Ministry of National Development Planning of the Republic of Indonesia and other sectoral ministries
- It is made based on combined dynamical and statistical methods to see the climate conditions (drier or wetter) in the next year
- The outlook is used as a reference and consideration in designing plans for next year by several sectors
- It became evident that for long-term forecasting efforts, it is important to consider what climate change factors will dominate the year ahead (e.g., the presence or absence of ENSO and IOD, and their phases).

Future Initiatives

Actions that need to be done for further improvement in the future are such as:

- Outlook Evaluation based on Hindcast and Verification
- Collaboration with other agencies such as Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and Meteorological Research Institute (MRI) – Japan Meteorological Agency (JMA) for Multi Years/Decadal Climate Prediction
- Artificial Intelligence /Machine Learning approach for multi years climate outlook

(6)   Provision of survey-related materials by JICA experts

JICA experts provided materials and information necessary for the investigation and gave advice on the survey as shown below.

- Introducing JMA's latest 6-month forecast data by 6-month forecast data
- Examples of one-year forecasts from global meteorological organizations
- Introduction to IOD Monitoring and forecast in JMA

- Comparison of observations with JMA ENSO forecasts (NINO3, NINO3.4, NINO4) over the past three years

(7) Lectures and provision of information at Workshop/Forum/seminar

JICA experts attended BMKG meetings associated with seasonal forecast preparation meetings and made lectures and/or provision of information (See Table 13). Through lectures at seasonal forecasting meetings and seminars, technology related to seasonal forecasting was transferred.

- Provision of information at the dry/wet season forecast preparation meetings in March, July and August 2021, February and August 2022
- Seasonal forecast lecture at Climate Field School (Medan, August 2022) organized by BMKG
- Seasonal forecast lecture at the workshops organized by BMKG (Bandung and Semarang, November 2022)

(8) Training in Japan (December 2022)

6 BMKG participants attended the trainings at JAMSTC and JMA and had lectures and practical training on methods for diagnosing and monitoring the climate system and seasonal forecasting as well as ENSO forecast. At the training, each person of WG4 reported on their research studies and received advice from JAMSTEC and JMA experts on how to promote future surveys.

3.4.5 Future Action Plan

Regarding future efforts, the individual issues are addressed in Section 3.4.4.

It is noted government agencies and industries have requested that the accuracy of seasonal forecasts be improved, and the forecast period be extended. BMKG started to provide 1 year climate outlook in 2021, while the request for extension of the forecast period (up to 1 to 2years) still continues. In addition, there is a concern that heavy rain disasters will increase due to the progress of global warming in the future.

Accordingly, the following items are listed as issues to be tackled in the future.

- To improve the accuracy of seasonal forecasts and continue to advance forecasts that meet the needs of various users,
- To further study on prediction of the possibility of heavy rain about one month ahead,
- To promote research on climate projections up to 1~2 years in advance, which is strongly requested by government agencies

These issues are quite challenging, but BMKG should continue to address them in response to the strong demands and expectations of government agencies, industries and the public of Indonesia.

3.5 Training in Japan
3.5.1 Training Outline
(1) Name of the training course

TRAINING IN JAPAN FOR ENHANCING ABILITIES FOR METEOROLOGICAL/ CLIMATOLOGICAL DATA USAGE

Course number: 201500577J012

(2)   Duration of the training course

5 December 2022 – 16 December 2022

(3)   Number of the trainees

Six (6) staff members of Badan Meteorologi, Klimatologi, dan Geofisika (BMKG)

The list of the trainees is shown in Appendix A.

3.5.2   Contents of the Training

(1)   Purpose and goals

The objectives of this training are as follows:

- To acquire data application techniques for dynamical downscaling, statistical downscaling, and downscaling that takes into account the effects of urbanization.
- Acquisition of knowledge and know-how necessary to utilize and reflect the results of climate change projections in the formulation and implementation of policies and measures in Indonesia.
- Improvement of seasonal forecasting techniques through practical training in the use of iTacs operated by the Japan Meteorological Agency.

(2)   Expected output of the training course

a)   Assignments of the trainees in the workplace

The target participants of this training course are staff members of BMKG who are in charge of providing forecast information that contributes to mid-term plans formulated by relevant ministries and agencies using global warming forecasting products and who are in charge of preparing and announcing seasonal forecasts.

b)   Professional tasks the trainees cope with and their present skill level

In their daily work, the trainees are engaged in charting and providing grid data from global warming prediction products to related organizations. Still, they need to gain knowledge of how such products are created and how the information they provide is used for climate change mitigation measures. Therefore, it is necessary to learn the basics of climate models and examples of using global warming prediction information in Japan through this training course. In addition, there needs to be more knowledge necessary to conduct seasonal forecasting operations using advanced climate system analysis tools and learn the latest knowledge and technology.

c)   Expected achievements

The objectives of this training course are for trainees (1) to acquire the ability to provide appropriate explanations of the characteristics and limitations of products in the provision of downscaled global warming forecast information based on the needs of relevant government agencies and (2) to acquire the knowledge and skills necessary to conduct seasonal forecasting operations using advanced climate system analysis tools.

(3)   Schedule of the training course

Table 15 The Schedule of the Training Course

PROJECT OF CAPACITY DEVELOPMENT FOR THE IMPLEMENTATION OF CLIMATE CHANGE STRATEGIES PHASE II IN THE REPUBLIC OF INDONESIA
TRAINNIG IN JAPAN FOR ENHANCING ABILITIES FOR METEOROLOGICAL /CLIMATOROLOGICAL DATA USAGE   JICA

as of 7/Nov/2022

No.	date	day	Trainings in Japan for weather forecasting 6 members	Lecturer	Venue	Stay
1	3-Dec	Sat	Transfer to Soekamo-Hatta Intl. Airport			
2	4-Dec	Sun	Travel Jakarta to Tokyo, Tsukuba			Tsukuba, baraki pref.
3	5-Dec	Mon	Breefing and orientation	JICA	JICA Tsukuba	JICA Tsukuba, Ibaraki pref.
			Lecture & Workshop: Global warming projection data	Dr. Murata	JMA-MRI	
4	6-Dec	Tue	Lecture: Change of water resource variations due to global warming	Dr. Nakaegawa	JMA-MRI	JICA Tsukuba, Ibaraki pref.
			Lecture: Change of monsoon variations due to global warming	Dr. Endo	JMA-MRI	
5	7-Dec	Wed	Lecture & Workshop: Statisitical downscaling	Dr.Nshimori	NARO	JICA Tsukuba, Ibaraki pref.
			Lecture & Workshop: Statistical downscaling using CMIP6			
6	8-Dec	Thu	Workshop: Review of precise downscaling	Dr.Doan	Tsukuba Univ.	JICA Tsukuba, Ibaraki pref.
			Lecture: Climate change at megacities in Southeast Asia	Prof. Kusaka	Tsukuba Univ.	
7	9-Dec	Fri	Travel: Tsukuba to Mito, Ibaraki pref.			
			Lecture: Climate change adaptation process in various sector	Prof. Tamura	Ibaraki Univ.	JICA Tsukuba, Ibaraki pref.
			Travel: Mito to Tsukuba			
8	10-Dec	Sat	Documentation			JICA Tsukuba, Ibaraki pref.
9	11-Dec	Sun	Documentation			JICA Tsukuba, Ibaraki pref.
10	12-Dec	Mon	Travel: Tsukuba to Yokohama, Kanagawa pref.			
			Lecture & Workshop: Long range forecasting on SST	Dr. Doi	JAMSTEC	JICA Tokyo, Tokyo
			Lecture: Long range forecasting on ENSO and Dipole mode			
10	13-Dec	Tue	Lecture: Outline of TCC, El Nino and seasonal forecasting (1)	JMA	JMA-TCC	JICA Tokyo, Tokyo
			Lecture: El Nino and seasonal forecasting (2)	JMA	JMA-TCC	
11	14-Dec	Wed	Workshop: training on ITACS (Interactive Tool for Analysis of the Climate System)	JMA	JMA-TCC	JICA Tokyo, Tokyo
			Study visit: Operation room etc. of JMA	JMA	JMA-TCC	
12	15-Dec	Thu	Preparation for wrap-up evaluation	JMBSC	JICA HQ	JICA Tokyo, Tokyo
			Wrap-up evaluation	JICA/JMBSC	JICA HQ	
13	16-Dec	Fri	Completion ceremony	JICA	JICA HQ	JICA Tokyo, Tokyo
14	17-Dec	Sat	Transfer to Nanita Intl. Airport			
			Back to Jakarta from Tokyo			

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(4)   Syllabus

Title	Dynamical Downscaling of Climate Change in Southeast Asia: Fundamentals and Applications	
Date	5 December (Mon) 14:00 – 16:00	Two hours
Lecturer	MURATA Akihiko (MRI)	
Content	The dynamical downscaling of climate change in Southeast Asia using a regional climate model is introduced. First, fundamental items on dynamical downscaling, such as regional climate models and experimental designs, are explained. Next, examples of studies related to regional climate change projections over Southeast Asia are introduced. Finally, methods of analysis using downscaled data are described. Trainees asked questions about the method of bias correction used in the analysis, and the trainer explained the methods.	
Aims of the lecture	To learn the fundamentals of dynamical downscaling techniques with the climate model and analysis techniques.	

Title	Future changes in water under a changing climate	
Date	6 December (Tue) 10:00 – 12:00	Two hours
Lecturer	NAKAEGAWA Toshiyuki (MRI)	
Content	The first topic is about future projections of water, including water resources, drought, and flood under a changing climate: The fundamental approach in our research program is explained with numerical global climate models and experiment setups such as emission scenarios. Land surface models in climate models are introduced since they are key to water-relevant projections. The future water changes, both global and in Indonesia, are shown. The second topic is the latest IPCC AR6 WGI. We will scan the full report of IPCC AR6 WGI by focusing on the descriptions of Indonesia. The full report of the IPCC AR6 WGI comprises 2409 pages, and most people need help reading these contents. Therefore, most people read Summary for Policymakers or SPM, composed of 32 pages. However, SPM does not provide sufficient information for domestic policymakers due to the limited information about global-to-regional scale contents. The descriptions of Indonesia in the full report of the IPCC AR6 WGI are provided, and we will discuss them from multiple viewpoints..	
Aims of the lecture	To learn the projected changes in water resources with climate change and the projections for the Indonesian region as described in IPCC AR6 WG I.	

Title	Future projection of monsoon changes under global warming	
Date	6 December (Tue) 14:00 – 16:00	Two hours
Lecturer	ENDO Hirokazu (MRI)	
Content	The lecturer will talk about two topics. The first topic is "global warming projections by climate models." It will provide basic knowledge of future climate changes projected by climate models during the twenty-first century, especially focusing on precipitation changes. The second topic is "future changes in monsoon projected by climate models." It will include the basics of monsoon phenomena, projected future changes in global and regional monsoons, and the mechanism of future changes in monsoon precipitation. The presentation materials are mainly based on the 6th Intergovernmental Panel on Climate Change (IPCC) assessment report published in 2021 and recent research papers.	
Aims of the lecture	To learn the outline of global warming projection with the climate model and projected changes in the monsoon.	

Title	Statistical downscaling	
Date	7 December (Wed) 10:00 - 12:00, 13:30 – 16:30	Five hours
Lecturer	Dr. NISHIMORI Motoki (NARO)	
Content	The subject of this training is bias correction and statistical downscaling (BCSD) of climate model output for future precipitation changes over the Indonesian region. The trainees will also present the results using CMIP5-catalogued GCMs, and the new CMIP6-GCM results will be presented here. In addition, an overview of our NIAES/NARO research for climate impacts and adaptations and its relevance to the atmospheric-ocean interaction system in agricultural production in Indonesia. Through this training, it is expected that mutual understanding of climate and air-sea interaction system changes in the Asia-Pacific region and their agricultural impacts will be enhanced.	
Aims of the lecture	To learn the outline of the statistical downscaling techniques and bias correction methods and their application for agriculture.	

Title	Effects of urbanization and climate change on heavy rainfall in Jakarta	
Date	8 December (Thu) 10:00 – 12:00	Two hours
Lecturer	ASANO Yuki (University of Tsukuba)	

Content	Urbanization enhances the rainfall with lower convergence zone due to lower northerly wind.
	Due to global warming, the precipitation area in Jakarta has shifted northward.
	The magnitude of urbanization effects is almost the same between present conditions and future projections.
Aims of the lecture	To understand the effects of urbanization on the regional circulation and strong short-term rainfall in the vicinity of Jakarta in the warming condition.

Title	Dynamical downscaling	
Date	8 December (Thu) 14:00 – 15:00	One hour
Lecturer	Professor KUSAKA Hiroyuki (University of Tsukuba)	
Content	Dynamical downscaling methods, including the one that used the pseudo-global warming method, are introduced, and some examples of the impact of physical schemes on rainfall simulation are shown.	
	In addition, a diurnal variation of rainfall in Indonesia simulated with the dynamical downscaling techniques is introduced.	
Aims of the lecture	To learn the dynamical downscaling techniques with the pseudo-global warming method and know the diurnal rainfall variations in Indonesia.	

Title	Identifying a new normal in regional climate under global warming with dynamical downscaling	
Date	8 December (Thu) 15:00 – 16:30	1.5 hours
Lecturer	Dr. DOAN Quang Van (University of Tsukuba)	
Content	Future precipitation projection is discussed, especially in cities with the pseudo-global warming approach.	
	Weak convections will be suppressed for stronger convections to grow.	
	The diurnal temperature range will decrease with global warming, possibly because the increase in cloud amount causes under-warming of Tmax.	
Aims of the lecture	To understand the change in the development of convection and trends in temperature associated with global warming.	

Title	Climate change adaptation process in various sectors	
Date	9 December (Fri) 10:00 – 12:00	Two hours
Lecturer	Professor TAMURA Makoto (Ibaraki University)	

Content	1) Challenges of Ibaraki Local Climate Change Adaptation Center (iLCCAC)
	Ibaraki Local Climate Change Adaptation Center (iLCCAC) was established at Ibaraki University on 1 April 2019, after the climate change adaptation act was enacted in 2018, to address the impacts of climate change. The speech presents several challenges of iLCCAC and discusses how to promote local adaptations.
	2) Coastal Adaptation Mixing Gray and Green Infrastructures to Climate Change in Vietnam and the world
	Sea level rise (SLR) due to climate change may threaten humans who live near the coastal areas. To adapt to climate change, examining the economic damage and cost of coastal protection is important. Coastal areas can be protected more efficiently and economically if adaptation combines planting mangrove forests and constructing dikes along the tropical and subtropical coastline. This study tries to examine them and propose desirable adaptations.
Aims of the lecture	To learn the outline of the index type agriculture insurance. To understand the design of the insurance, necessary data and their effects.

Title	ENSO/IOD prediction study based on the JAMSTEC Prediction system
Date	12 December (Mon) 11:00 – 13:30 1.5 hours
Lecturer	Doi Takeshi (JAMSTEC Senior Researcher)
Content	JAMTEC has been providing ENSO two-year forecasts every month. The forecast system of ENSO/IOD and some forecast results are lectured.
Aims of the lecture	Learning the ENSO prediction methods and the IOD prediction is harder than the ENSO prediction. To understand that the ENSO prediction has a room to improve.

Title	Discussion on BMKG one-year Outlook
Date	12 December (Mon) 13:00 – 14:30 1.5 hours
Lecturer	Doi Takeshi (JAMSTEC Senior Researcher)
Content	One-year climate outlook by BMKG is reported by one of the participants and followed by an exchange of opinions/questions among the lecturer and participants for improving it.
Aims of the lecture	To understand the issues to improve BMKG's one-year seasonal outlook.

Title	Visiting Earth Simulator

Date	12 December (Mon) 15:00 – 16:00	One hour
Lecturer	Doi Takeshi (JAMSTEC Senior Researcher)	
Content	Participants visited JAMSTEC Earth Simulator, which was used for global warming simulation at the current JICA project.	
Aims of the lecture	To learn the supercomputer's capacity to produce the climate change projections in this project.	

Title	Introduction: Outline and scope of the Training Seminar and Introduction of the Tokyo Climate Center (TCC)	
Date	13 December (Tue) 10:00 – 10:30	0.5 hour
Lecturer	TAKAHASHI Kiyotoshi (Scientific officer, Climate Prediction Division（CPD）/JMA）	
Content	The outline of this seminar and various functions of TCC as RCC are introduced briefly.	
Aims of the lecture	To learn the outline of the TCC's services.	

Title	Lecture: TCC web content and tools	
Date	13 December (Tue) 10:30 – 11:15	0.75 hour
Lecturer	NATORI Hiroaki, Forecaster, CPD, JMA	
Content	Climate information, products, and tools on the TCC website are introduced.	
Aims of the lecture	To learn about information and material available from the TCC website and analysis tools.	

Title	Lecture: Introduction to Seasonal Forecasts	
Date	13 December (Tue) 11:15 – 12:00	0.75 hour
Lecturer	NATORI Hiroaki, Forecaster, CPD, JMA	
Content	A brief introduction on the practices and the climate dynamics for a seasonal forecast by JMA.	
Aims of the lecture	To understand the outline of JMA's seasonal prediction services.	

Title	Lecture: ENSO and IOD	
Date	13 December (Tue) 13:00 – 14:00	One hour
Lecturer	UMEDA Takafumi, Head, Center for Information on Climate Extremes, CPD, JMA	
Content	The occurrence mechanism and predictability of each ENSO and IOD are explained.	
Aims of the lecture	To understand the mechanism of ENSO and IOD and their predictability.	

Title	Lecture: Effective use of Long-Range Forecast	
Date	13 December (Tue) 14:00 – 14:40	0.66 hour
Lecturer	Oikawa Yoshinori, Manager for mid-to long-term forecast, CPD, JMA	
Content	Among prospective users of long-range forecasts are industries including but not limited to agriculture, commerce, and apparel. The topic discussed in this lecture is how seasonal forecasts can benefit these industries.	
Aims of the lecture	To understand the use of seasonal forecasts for socio-economic activities.	

Title	Lecture: Monitoring of Climate and Climate System	
Date	13 December (Tue) 14:40 - 15:30	0.83 hour
Lecturer	SATO Hitoshi, Forecaster, CPD, JMA	
Content	Products on the TCC website and activities at JMA for monitoring climate and climate systems are introduced briefly.	
Aims of the lecture	To understand the purpose of the climate monitoring activities and products the TCC website disseminates.	

Title	Lecture: Climate Change Monitoring, Future Projections, and Introduction to IPCC AR6	
Date	13 December (Tue) 15:30 - 16:30	One hour
Lecturer	WAKAMATSU Shunya, Scientific Officer, CPD, JMA	
Content	This lecture explains the importance of climate change monitoring and future projection and briefly introduces IPCC AR6 reports.	
Aims of the lecture	To understand the importance of climate change projection and learn the outline of AR6.	

Title	Exercise: Introduction and operation of iTacs (Basic)	
Date	14 December (Wed) 10:00 – 12:00	Two hours
Lecturer	YAMAMOTO Kosuke, Scientific Officer, CPD, JMA	
Content	This lecture aims to deepen understanding of the climate system through learning the iTacs operation, a web application developed by TCC/JMA.	
Aims of the lecture	To learn basic features of iTacs analysis functions.	

Title	Exercise: Introduction and operation of iTacs (Advanced)	
Date	14 December (Wed) 13:00 – 15:30	2.5 hours
Lecturer	TAKEMURA Kazuto, Scientific Officer, CPD, JMA	

Content	This lecture aims to deepen understanding of the climate system through learning the iTacs operation, a web application developed by TCC/JMA.
Aims of the lecture	To learn advanced features of iTacs analysis functions.

Title	Presentation: Latest status on BMKG climate services (an open session to JMA staff members)	
Date	14 December (Wed) 15:30 – 16:30	One hour
Lecturer	Experts for seasonal forecast/ENSO forecast from CPD/JMA	
Content	Brief introduction of the present study activity by the BMKG participants followed by discussion and advice by JMA experts.	
Aims of the lecture	To obtain useful information and advice for the trainees' future activities.	

Title	Visiting Forecast Operation Room	
Date	14 December (Wed) 15:30 – 16:30	One hour
Lecturer	TAKAHASHI Kiyotoshi, Scientific officer, CPD, JMA	
Content	Visiting the JMA operation room (Observation and forecasts) to learn the daily operations of JMA after watching a video movie explaining JMA's daily activities.	
Aims of the lecture	To learn JMA's operational observation and forecast services.	

3.5.3 Evaluation of the training course

(1) Lectures

In this training course, lectures were given on the following four technology transfer items:

(1) Dynamical downscaling

(2) Statistical downscaling

(3) Global warming prediction taking into account the effects of urbanization in the Jakarta area.

(4) Improvement of seasonal forecasting in the Indonesian region

For (1), the trainees presented the status of BMKG's efforts in the Meteorological Research Institute (MRI), and the lecturer gave lectures on the basics of global warming prediction using climate models, major conclusions of the IPCC Sixth Assessment Report, and changes in the monsoon and hydrological cycle associated with global warming. A lively Q&A session followed the lectures.

Regarding (2), at the Research Center for Agro-Environmental Change, National Agriculture and Food Research Organization (NARO), participants learned about evaluation methods for future precipitation changes in the Indonesian region through lectures on statistical downscaling methods and bias correction of climate model outputs. In addition to the results using GCMs registered in CMIP5, new CMIP6-GCM results and the relationship between agricultural production and atmosphere-ocean interaction system in Indonesia were discussed in the lecture.

Regarding (3), a lecture was given on dynamical downscaling incorporating pseudo-warming

methods at the Division of Climate Change and Global Environment Research, Research Center for Computational Science, University of Tsukuba, and the results of the evaluation of diurnal variability of precipitation were presented as a part of this process.

The lecture also discussed the domestic policy framework for using these forecast results to contribute to planning adaptation measures in the agricultural sector and other areas and examples of using forecast information.

Regarding (4), the participants learned in JAMSTEC about ENSO and IOD, which are essential for seasonal forecasting and play an important role in Indonesia's weather variability and also learned about the forecasting methods and examples of long-term forecasts up to two years ahead. In addition, the trainees received valuable knowledge and advice on the one-year forecast (outlook) that BMKG had started and had discussions on how to improve it in the future. During the training in JMA, the trainees received lectures on techniques for monitoring and analyzing the climate system, which are indispensable for seasonal forecasting. Furthermore, the trainees, who have been working on research activities to improve seasonal forecasting in this project, reported their findings to the Climate Prediction Division staff in an open seminar and received various advice for the future progress of the research.

(2) Exercises, discussions, and presentations

In this training course, the trainees gave presentations to the lecturers on their approaches to dynamical downscaling and statistical downscaling in BMKG and received comments from the lecturers as appropriate. The trainees and lecturers engaged in lively discussions and asked questions.

The trainees spent a full day practicing (basic and advanced) the monitoring and analysis of actual conditions, which are indispensable for seasonal forecasting, using the JMA's iTacs (climate system analysis tool) to learn analysis and monitoring techniques. Several Climate Prediction Division staff members provided one-on-one guidance during the practical training to ensure that all trainees mastered the techniques.

Each trainee compiled the training results into a future activity plan presented at the final evaluation meeting. After returning to Indonesia, the results will be shared at the BMKG debriefing session.

(3) Technical visits

In JAMSTEC, the trainees toured the Earth Simulator, which is used to calculate the global warming prediction information for this project. The participants reaffirmed their understanding that using such a supercomputer is indispensable for detailed climate change prediction in the future. At the Japan Meteorological Agency, they visited the observation and forecasting field office to observe actual forecasting work in progress.

(4) Duration, arrangements, and contents of the lectures

The training period was allotted five days for climate change forecasting and three days for seasonal forecasting, and the training, including the preparation of an action plan, lasted two weeks. To allow trainees to concentrate on each topic, the first half of the training was devoted to climate change and

the second half to seasonal forecasting.

(5) Textbooks, equipment, and facilities

Training materials were provided in advance and distributed to trainees in print whenever possible. This gave the trainees an overview of the lecture content before the training. Presentation materials of lecturers were also provided as files and distributed to trainees after the training.

(6) Level of achievement

In this training course, the achievement level against the achievement target is as follows.

[Dynamical Downscaling]

- The trainees achieved the following objectives at the Meteorological Research Institute.
- They understood the fundamentals and analytical methods of dynamical downscaling using climate models.
- They understood the projected changes in water resources and monsoon changes associated with climate change and the projected results for Indonesia as described in IPCCAR6.

[Statistical Downscaling]

- In the National Agriculture and Food Research Organization (NARO), the trainees learned about statistical downscaling techniques and bias correction methods and understood their application in the agricultural sector.

[Global Warming Prediction with the Effects of Urbanization]

- The trainees achieved the following objectives at the Center for Computational Science and Technology, University of Tsukuba.
- They understood the effects of urbanization on local circulation and short-term rainfall around Jakarta during the warming condition.
- They learned about the dynamical downscaling method using the pseudo-global warming method and obtained knowledge about the resulting diurnal variability of precipitation in Indonesia.
- They understood the changes that appear in the development of convection and the trend of temperature change during global warming.

[Seasonal Forecasting]

- The trainees understood the predictability of ENSO and IOD in JAMSTEC. They clarified issues for future improvement of one-year forecasting, which BMKG is working on.
- In the JMA training program, they acquired the skills to analyze and use the information and materials necessary for monitoring, diagnosing, and forecasting the climate system using the analysis tools (iTacs) provided by TCC.
- They received advice from the JMA on further developing the research agenda the trainees are working on in this project.

3.5.4 Trainees

(1) Qualification

The six trainees provided global warming projection information for Indonesia's mid-term planning and seasonal forecasting. They will be able to apply the content of the training to their work after returning to their home countries. A list of trainees is attached as Appendix B.

(2) Trainees' initiative for the course

The trainees could actively participate in the training because they all had practical experience, used data from the training institute daily, and had sufficient communication skills in English. In addition, each trainee had prepared a presentation on the data evaluation in their work, which enabled the training on the specific use of the forecasting results.

3.5.5 Use of takeaways

(1) Experience acquired in the training course

The trainees will bring back the results obtained from the training course to BMKG and the training materials, which will be shared and utilized within BMKG through debriefing sessions upon their return. In addition, since they were able to build a human network with each research institute, they will continue to share necessary data by exchanging information through e-mail and other means.

(2) Future use of the experience

Each trainee presented the results obtained from the training as an action plan at the final evaluation meeting. The action plan summarized the activities that had been conducted so far, what they had learned in this training program, and how the training results should be used in their work in the short term and the long term in BMKG's work.

It is planned that the trainees will make the same presentations at the debriefing session after returning to Indonesia.

3.5.6 Other remarks

The trainees paid a courtesy visit to Mr. Obayashi, Deputy Director General of the Japan Meteorological Agency (JMA), and had a chance to talk with him. The trainees expressed their gratitude for the training at the JMA. Mr. Obayashi encouraged the trainees to continue working together to expand and improve meteorological services and expressed his expectations for their future activities. The meeting was very encouraging for the trainees, even though it lasted only briefly.

4. Recommendations for achieving the Overarching Objective

The [Overall goal] of the " Project of Capacity Development for Implementation of Climate Change Strategies in Indonesia Phase 2 - Capacity Development for Climate Change Projection " is " Climate change plans are properly promoted and mainstreamed in Indonesia's National Development Plan to support low carbon and green economic development." and the [Project goal] is "Capacities of the key ministries and local government for the climate action cycle (policy assessment, development of framework, development of process and methods, plan, implementation, monitor, and evaluation) are improved."

The project aims to strengthen the capacity of the BMKG in charge of climate change and long-term forecasting, which is an input to climate change measures.

BMKG, the counterpart of BMKG, is the government agency responsible for providing observations, forecasts, and warnings about Indonesia's meteorological, geological, and oceanic phenomena. The Climate Change Department is accountable for delivering mid- to long-term forecasts (generally one-week ahead forecasts to seasonal forecasts) and information on climate change.

The BMKG Climate Center, the direct counterpart department, is divided into two sections: Climate Projection and Climate variability. The former is responsible for climate change over several years to decades, and the latter for long-term forecasts over ten days to two years. To achieve the high-level goal of "mainstreaming climate change in national planning," the following directions concerning "climate variability" and "long-term forecasting" are recommended.

For "climate change," knowledge sharing and software (NHRCM, WRF) sharing were conducted through dynamic downscaling, and HPC, which enables dynamic downscaling for a certain period (several years) in a specific area (e.g., western Java), was also introduced through this project. HPC was also introduced through this project. In addition, a statistical downscaling tool that can perform downscaling with a certain degree of accuracy on a monthly basis was shared, allowing for the statistical downscaling of multiple GCM data.

Climate change models are updated with model calculations at approximately five-year intervals, with the most current version being CMIP6. BMKG will be required to conduct downscaling using CMIP6 data and provide the results. Based on the technology transferred by this project and the computer capabilities of BMKG, a practical approach would be as follows.

- Statistical downscaling is performed on the CMIP6 model data available on the NASA website, etc., to understand the regional and seasonal climate variability characteristics for each factor.
- Conduct a needs assessment on the provision and use of climate change data with relevant ministries and local governments in Indonesia to understand the social impact of climate change.
- Conduct mechanistic downscaling focused on specific areas and periods, based on climate factors that will change significantly in the future and the magnitude of the impact.

The high-resolution dynamical downscaling across Indonesia conducted in this project requires the use of significant computational resources in Japan and international efforts such as CORDEX, and to make these efforts effective, based on the assets of this project, using the approach described above, it is hoped that the project will continue its efforts on climate change.

In addition, while joint research was conducted with the University of Tsukuba for Outcome 1c, future activities in collaboration with Japanese research institutions will provide BMKG with an adequate opportunity to learn new skills. The assessment of the impact of climate change and anthropogenic landform alteration is an essential issue for BMKG, and the direction of joint observation, analysis, and research through initiatives such as SATREPS is a high-quality research theme for Japanese researchers as well. It is also essential to make use of the assets of this human exchange and to promote the initiative while receiving advice from leading researchers.

BMKG has made several efforts to address long-term forecasting issues and has been able to conduct pilot projects for long-term forecastings, such as using JMA's "iTacs" for current status assessment, S2S forecasting, and one-year forecasting using ENSO forecasting. The S2S forecast, for which the MJO is expected to provide superior forecast accuracy to a certain degree, is expected to be achieved by collaborating with leading research institutes in the field. From either perspective, it is important to constantly exchange information with overseas researchers and research institutions and work together to improve the information.

A schematic diagram summarizing the above is shown in Figure103.
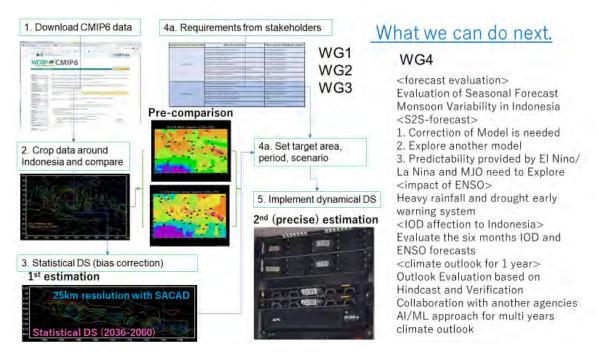
Fig 103 Direction of Climate Change Data DS (to achieve higher-level targets)

5. Summary of the Project

BMKG has developed capacities for climate projection activities, i.e. collect observation data, check data quality of them, evaluate projection/hindcast data and evaluate long range forecasts, high resolution climate projection data, through Phase I and 'Agricultural Insurance Project' of Phase II. BMKG leveled up skills and produced various products, however, requirements from stakeholders became widely and precisely, i.e. higher resolution downscaled data covering whole Indonesia, requirements for various factors (not simple factors, but complex indexes for example strong precipitation possibility, Consecutive Dry spell Days, etc). In order to respond to such requirements from stakeholders, BMKG needs further capacity developments, and these are (i) foster core meteorologists/climatologists respond to high end requirements, (ii) support high performance computer resources for simulation of climate projections and (iii) support linkages with cutting edge researchers.

For taking care of theme (i), during the project, the project team coordinated 4 working groups to implement technical skill transfers. Core members of each working group firstly studied technical skills/procedures, they shared them to members of WG and finally WGs tackled tasks. This structure worked well especially in WG2 activities (output 1b: statistical downscaling). On the other hand, due to restrictions by COVID-19 pandemic, on site activities in Indonesia and Japan had been restricted and on-site activities or trainings in Japan were only implemented in the last year. For output 1a (dynamical downscaling) and 1c (high resolution downscaling), requirements for technical skill transfer were relatively higher and enough lectures/exercises had not been implemented due to these restrictions, even though, remote technical skill transfers (core activities of output 1a and 1c) were implemented through the Internet, and main simulations were implemented by Japanese experts. For output 2 activities (long range forecasting), WG4 tried and implemented each research activities using JMA information system and database, it reduced time and efforts to prepare basic data and materials, and WG4 can developed and implemented researches effectively even thorough remote activities.

For theme (ii), the project team coordinated high specification computers, namely 'Earth Simulator' of JAMSTEC for output 1a dynamical downscaling and Tsukuba university HPC for output 1c high resolution downscaling to implement long term and high-resolution downscaling. For theme (iii), the project team coordinated linkage and supports with academic fields, for output 1a JMA MRI, for 1b NARO, for 1c Tsukuba university and for 2 JMA climate division and implemented/supported WG activities.

BMKG has human resources and team structures to implement tasks based on SOPs (manuals, guidelines) with data sources shared. when a project can prepare and clarify these processes and supports technical skills and data, BMKG implements tasks effectively. However, recently and in future, requirements from stakeholders would become higher and more complicated, and in order to respond to these requirements, much core researchers well trained and has enough skills would be required. For growing such core researchers, BMKG should strengthen partnerships with laboratories, universities and JMA further and possibly BMKG sends young researchers to Japan and study with researchers through master or/and doctor courses in universities, and use their database and skills shared. And these

core researchers lead BMKG activities sharing their knowledge to BMKG officers. Additionally, BMKG would better strengthen cooperation activities with JMA in long range forecasting.

Through Phase I and Phase II projects, BMKG, Japanese researchers and JMA officers have developed capacities and personnel network between them had been strengthened. These networks supported remote activities very well even during COVID-19 pandemic situations, and the project implemented lots of activities. These networks and personnel linkages would work well, even after the Phase II project, and BMKG can continues development of technical skills using such frames and is expected to continue them.

From view point of technical skill transfer, linkage with Japanese researchers can support BMKG activities, however, in order to achieve the project goal 'Capacities of the key ministries and local government for the climate action cycle (policy assessment, development of framework, development of process and methods, plan, implementation, monitor, and evaluation) are improved', activities to share projection data, discuss matters and prepare adaptation plans, in local areas with stakeholders by BMKG officers, are needed. Due to restrictions of COVID-19 pandemic, few feasible activities were implemented in the last 1 year, but not enough experiences had not been tried and activities were not sophisticated.

For contributing for adaptation planning for climate change in local areas, enhancing communication skills of BMKG to (i) share climate projection data and to (ii) transfer usage of these data and to (iii) plan countermeasures through discussion with users are required. In such activities, BMKG has to consider not what kind of information BMKG can share but what kind of information users require to BMKG. These approaches would start from communications/researches with users, and BMKG customizes data to users, then discusses usage of them and develops plans together.

BMKG has implemented Field-climate-schools (user-oriented communication frames) with local governments and framers and BMKG rehabilitated CCIS server to share data to outside users. BMKG is expected to enhance skills for communication with users, customize data and support local adaptation plannings, based on existing frames and develop them in next phases.

Appendix

A) Expert assignment plan and record

B) Permission of use of NHRCM

C) Contract and final report of the development of CCIS

D) Study report: Non-hydrostatic regional climate model (MRI-NHRCM) simulation of near and far future precipitation and temperature over Indonesia (Output 1a)

E) Study report: Future changes in monsoon climate in Java, Indonesia, by using bias correction and statistical downscaling methods (Output 1b)

F) Open seminar material: Climate projection data downscaling and its utilization (Output 1c)

G) Reports/materials for Long-range forecast (Output 2)

Shared data

[Dynamical downscaling]

Present: 1981-2000

Near future: 2034-2058

Future: 2079-2098

GCM: RCP: 8.5 (CMIP5)

Original model: MRI-AGCM3

DS model: NHRCM

[Daily data]

Area: (-12.26,93.75)-(7.22,144.15)

Number of grid: X=1081, Y=421

Resolution: x=0.0464deg, y=0.0467deg.

Variables: Surface, Tmean, Precipitation, average U and V of wind (TRUV file), Tmax, Tmin (Tmax_min file), Relative humidity (Humid file)

[Monthly data]

Area: (-12.26,93.75)-(7.22,144.15)

Number of grid: X=1081, Y=421

Resolution: x=0.0464deg, y=0.0467deg.

Variables: Surface, Tmean, Precipitation, average U and V of wind (TRUV file), Tmax, Tmin (Tmax_min file), Relative humidity (Humid file)

[Hourly data]

Area: (-12.26,93.75)-(7.22,144.15)

Number of grid: X=1081, Y=421

Resolution: x=0.0464deg, y=0.0467deg.

Variables: Surface, Precipitation, U and V of wind, temperature, T-Td, solar radiation, radiation

upward and downward

[Original data]

All layer data, hourly

Variables: sunshine duration, pressure, mixing ratio, updraft, downdraft, cloud ration, shortwave radiation, longwave radiation, etc

[Statistical downscaling]

[MRI-CGCM]

hindcast:1961-2005

projection: 2006-2100

RCP scenario: 2.6, 4.5, 6.0, 8.5

Area: (-15.14,90.0)-(10.65,150.75)

Number of mesh: X=55, Y=24

Resolution: x,y=1.125deg

Interval: 1 month, 1day

Variables: Surface, Tmax, Tmin, Precipitation, average wind speed, humidity

[d4PDF]

Hindcast: 1991-2010

2K-projection: 2031-2060

4K-projection: 2071-2100

GCM: CC, GF, HA, MI, MP, MR

Member: 9(2K), 15 (4K) for each GCM

100 (hinddast)

Area: (-15.44,90.0)-(10.95,150.75)

Number of mesh: X=109, Y=48

Resolution: x,y=0.5625deg

Interval: 1 month

Variables: Surface, Tmean, precipitation, average wind speed, humidity

[SYNOP]

Interval: 1 day

Variables: Tmax, Tmin, precipitation

Period: 1981-2020

[SACAD]

Interval: 1 month

Resolution: 25km

Variables: Tmax, Tmin, precipitation

Period: 1981-2010

Assignment Plan/ Assignment Record (Original)

Project tytle: 'The Project of Capacity Development for the Implementation of Climate Change Strategies Phase 2 – Capacity Building on Long-Term Climate Change Projections'

[Activity on site]

	Name	expertise	term	travel	Contract period 2020 / 2021 / 2022	days of assign	M/M	備考
1	Michihiko TONOUCHI	statistical downscasling	Plan	10	(10日) (14日) (21日) (10日)	79	2.63	
			Record	2				
2	Kouichi KURIHARA	Climate projection	Plan	11	(28日) (28日) (28日) (21日) (10日)	143	4.77	
			Record	3				
3	Masaru CHIBA	dynamical downscaling	Plan	11	(21日) (28日) (28日) (28日) (14日)	119	3.97	
			Record	3				
						341	11.37	

Statistical downscaling
dynamical downscaling
procurement of H/C, install RNHCM install RNHCM downscaling transport setting in BMKG
Usage of climate change projection data
ramadan (4/13-5/12?)

[Activity in Japan]

	Name	expertise	term	travel	Contract period 2020 / 2021 / 2022	days of assign	M/M	備考
1	Michihiko TONOUCHI	statistical downscasling	Plan		Statistical downscaling (7日) (10日) co-research with Tsukuba Univ, adaptation plan training in Japan (3日) (3日) (5日) (5日) completion report (3日)	36	1.80	
			Record					
2	Kouichi KURIHARA	Climate projection	Plan		progressive report (3日) training in Japan (3日) completion report (3日)	9	0.45	
			Record					
3	Masaru CHIBA	dynamical downscaling	Plan		dynamical downscaling (5日) (5日) (5日) specific downscaling (6日) folowup for dynamical downscaling (5日) (3日)	44	2.20	個人の補強
			Record					
						89	4.45	
						430	15.82	

Training in Japan (Tsukuba Univ.)
Training in Japan (Adaptation)

Remarks: Assignment Plan (Gray)
Assignment Record (black)
Company's burden (diagonal line)

Appendix A

Assignment Plan/ Assignment Record (Achievement)

Project title: 'The Project of Capacity Development for the Implementation of Climate Change Strategies Phase 2 – Capacity Building on Long-Term Climate Change Projections'

Remarks: Assignment Plan (Gray); Assignment Record (black); Company's burden (diagonal)

Meteorological Research Institute
1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan
Phone +81-29-853-8716
Fax +81-29-853-8545

2 September 2022

Dr. Dodo Gunawan

Director, Center for Climate Change Information

Agency for Meteorology Climatology and Geophysics
(BMKG)

The Republic of Indonesia

Dear Dr. Gunawan,

I refer to your letter dated 1 August 2022 seeking permission to use the Non-Hydrostatic Regional Climate Model (NHRCM) developed by the Meteorological Research Institute (MRI) of the Japan Meteorological Agency (JMA). I am pleased to inform you of approval for the group users mentioned in the letter to use the NHRCM for the purposes and under the terms and conditions described in the letter. The contact person at the MRI for this matter is as follows:

Dr. Akihiko Murata
Department of Applied Meteorology Research

Phone: +81 29 853 8732
E-mail: amurata@mri-jma.go.jp

I sincerely hope that the NHRCM will contribute to the success of the research project on regional climate downscaling in Indonesia.

Yours sincerely,

Mr. Takayuki Matsumura

Director-General
Meteorological Research Institute
Japan Meteorological Agency

Contract Agreement
between
Japan Meteorological Business Support Center (JMBSC)
and
PT MANDIRI CReASINDO

on
Development of Climate Change Information System (CCIS)
for

Project of Capacity Development for Implementation of
Climate Change Strategies in Indonesia Phase 2 –
Capacity Development for Climate Change Projection

22nd January 2023

CONTRACT AGREEMENT

This CONTRACT AGREEMENT (hereinafter referred to as "Agreement") is entered into on the date signed by and between:

Japan Meteorological Business Support Center, a corporation organized and existing under the laws of the Japan having its registered office at 3-17 Kanda-Nishikicho, Chiyoda-ku, Tokyo, 101-0054 Japan (hereinafter referred to as "JMBSC")

and

PT MANDIRI CReASINDO, a company organized and existing under the laws of Republic of Indonesia having its registered office at Jl. Kalasan No.1, Menteng Jakarta Pusat 10320 DKI Jakarta Indonesia (hereinafter referred to as "Subcontractor")

RECITALS

WHEREAS, JMBSC has entered into this Agreement on the "Development of Climate Change Information System for the Project of Capacity Development for Implementation of Climate Change Strategies in Indonesia Phase 2 – Capacity Development for Climate Change Projection"
and
WHEREAS, the Subcontractor has agreed to perform its obligations as specified in this Agreement.

NOW, THEREFORE, in consideration of the mutual representations, warranties, promises, covenants, and agreements set forth herein, the receipt and sufficiency of which is hereby acknowledged, each of JMBSC and the Subcontractor agrees as follows:

SECTION 1   INCLUSIONS
1.1   "Agreement" means this Agreement together with the Appendices; all of which constitute and shall be read and construed as, the entire agreement with respect to the subject matter contained herein. The Appendices shall be as follows:

SECTION 2   SCOPE OF WORKS
2.1   The Subcontractor shall fulfill the development items as follows:
2.1.1   The development items include "Design", "Prototyping", "Initial development" and "Installation" for stable and functional software of the Climate Change Information System (hereinafter referred to as "CCIS") running on the components operationally.

2.2   The Subcontractor shall submit documents related to the CCIS and lectures necessary for its operation and maintenance.

JMBSC Japan Meteorological Business Support Center (JMBSC)
3-17 Kanda-Nishikicho, Chiyoda-ku, Tokyo, 101-0054 Japan

2.3   All development works shall be performed in compliance with the specification shown in Appendix 1 of this Agreement.

2.4   All development works, submission of documents, and lectures for operation and maintenance shall be completed by 31st March 2023.

SECTION 3   QUOTATION AND PAYMENT CONDITION

3.1   JMBSC shall pay a down payment and a completion payment based on the Quotation shown in Appendix 2 of this Agreement to the Subcontractor.

3.2   The down payment and the completion payment are 50% of the total costs in the Quotation shown in Appendix 2, respectively. The down payment procedure shall be done based on the invoice based on the agreement of this contract, and the completion of payment shall be done based on the invoice with inspection reports authorized by JMBSC on the acceptance test for the CCIS development.

3.3   All expenses, taxes, delivery, and workers' accommodation fees shall be contained in the Quotation and shall not be separately charged to JMBSC.

3.4   All payments by JMBSC shall be payable upon issuance of Invoice from the Subcontractor.

3.5   The Subcontractor shall issue a receipt addressed to JMBSC on the reception of the payment.

SECTION 4   DISPUTE RESOLUTION

4.1   Any modification of this Agreement shall be subject to the written consent of both JMBSC and the Subcontractor.

4.2   JMBSC and the Subcontractor agree to make the best effort to solve amicably any dispute, controversy, or difference arising out of, in connection with, or resulting from this Agreement.

JMBSC Japan Meteorological Business Support Center (JMBSC)
3-17 Kanda-Nishikicho, Chiyoda-ku, Tokyo, 101-0054 Japan

IN WITNESS WHEREOF, JMBSC and the Subcontractor have caused this Agreement to be signed and delivered by their respective duly authorized representatives as of the date first above written.

Japan Meteorological Business Support Center (JMBSC)

By   :

Name :   Michihiko Tonouchi
Title   :   Project Manager
Email :   tono@jmbsc.or.jp
Date   :   22/ Jan./ 2023

PT MANDIRI CReASINDO

By   :

Name :   Irman Irawan, S.Si
Title   :   Director
Email :   irman@mcreasindo.com, irmanirawan@gmail.com
Date   :   22 - January- 2023

[Witness]
Badan Meteorologi, Klimatologi, dan Geofisika (BMKG)

By   :

Name :   Kadarsah
Title   :   Coordinator for Climate Change Analysis
Email :   kadarsah@bmkg.go.id, kadarsah@gmail.com
Date   :   22 January 2023

JMBSC Japan Meteorological Business Support Center (JMBSC)
3-17 Kanda-Nishikicho, Chiyoda-ku, Tokyo, 101-0054 Japan

Appendix 1

Specification of

Development of Climate Change Information System for the Project of Capacity Development for Implementation of Climate Change Strategies in Indonesia Phase 2 – Capacity Development for Climate Change Projection"

In accordance with the Terms of Reference that we observe that:

Basic Data Used

The Meteorology, Climatology and Geophysics Agency has the following duties: to carry out government duties in the fields of Meteorology, Climatology, Air Quality and Geophysics in accordance with the provisions of the applicable laws and regulations. In order to provide information on climate change that can be used by experts to analyze climate change comprehensively.

Technical Standards

The technical standards for the climate change system information system are following:
   a. Application models : *Web-based*
   b. Programming language:
      - Front-end : codeigniter
      - Back-end : codeigniter
   c. Database : Mysql
   d. Access rights: - Administrator, - Users
   e. User: Badan Meteorologi, Klimatologi dan Geofisika

Scope of work

Scope of work Development of climate change system information system, namely:
   1. Collecting Data
      Is a stage in collecting climatological data needed to make normal data for Indonesia
   2. Quality Control
      Is the stage in carrying out quality control of the data that will be used to create normal Indonesian data so that the data to be generated is valid
   3. Normal Data Creation
      This is the stage for making normal data for Indonesia

4. Ingesting Data

   Is the stage of entering normal data into the RDMS system

5. Development of a Front End climate change system information system

6. Development of Back End climate change system information system

7. Climate Projection Data Sharing Module (Downscaled data from JICA-BMKG project)

8. The system will be created on the Dev Server

9. Migration from Dev Server to Live server

Modules

Making the modules as follows:

Backend

A. Backend User Registration Module

B. Backend User Login Module

C. Dashboard Module

   ✓ Provides a summary feature of the number of annual users in the last 5 years

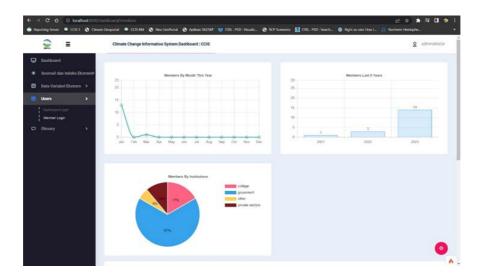   ✓ Provides a summary feature of the number of monthly users in the current year

   ✓ Provides a summary feature of the number of users by category

   ✓ Provides display in graphical / tabular form

   ✓ Provides export facility to png

D. Backend user data input module

Frontend

E. Frontend climatology data visualization module

F. Frontend User Registration Module

G. Climate Projection Data Sharing to registered users

H. Frontend User Login Module

   ✓ Provide login for user

Training

- Provide front-end operational training with a minimum of 10 participants for 2 days

- Back-end training with a minimum of 10 participants for 2 days

- Training is held offline at the BMKG Office or at a place provided by the BMKG

JMBSC Japan Meteorological Business Support Center (JMBSC)
3-17 Kanda-Nishikicho, Chiyoda-ku, Tokyo, 101-0054 Japan

Appendix 2

Quotation

No	Work item	Cost (Rp)
1	OS on New Server Installation	1.000.000
2	Webserver Installation	1.000.000
3	Configuration Webserver	1.000.000
4	MySQL DB Installation	1.000.000
5	Configuration of MySQL DB	1.000.000
6	Installation of MAP For Web Server	1.000.000
7	Configuration of MAP For Web Server	1.000.000
8	Installation of FTP server	1.000.000
9	Installation of Remote Application	1.000.000
10	Collecting Data to Create Normal Data	1.000.000
11	Create Normal Data	10.000.000
12	QC Normal Data	10.000.000
13	Ingesting Normal Data into DB On Live Server	10.000.000
14	Developing Website on Dev server	70.000.000
15	Migration To Operational Server	20.000.000
16	Testing and Debugging New Web on Operational Server	14.000.000
17	Sharing Knowledge	6.000.000
18	Operational Laptops to support the CCIS Server - 2 units ASUS RoG flow Z13	50.000.000
	Total	200.000.000

FINAL REPORT

Development of Climate Change Information System (CCIS) for

Project of Capacity Development for Implementation of Climate Change Strategies in Indonesia Phase 2 – Capacity Development for Climate ChangeProjection

31st March 2023

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PT. MANDIRI CReASINDO
Information Technology, Design Printing & Trading

INTRODUCTION

The Meteorology, Climatology and Geophysics Agency has the following duties: to carry out government duties in the fields of Meteorology, Climatology, Air Quality and Geophysics in accordance with the provisions of the applicable laws and regulations. In order to provide information on climate change that can be used by experts to analyze climate change comprehensively.

The Climate Change Information System or Climate Change Information Services (CCIS) is a central gateway to climate change information developed by BMKG Climate Change Information Center. These services support coping policies and adaptation of various sectors affected by Climate Change. The development of CCIS is the results from JICA and BMKG cooperation within Project of Capacity Development for Implementation of Climate Change Strategies in Indonesia Phase 2 – Capacity Development for Climate Change Projection.

CCIS system that has been developed is using web-based form to disseminate information related to Climate Change particularly information regarding extreme values, whether present condition, near future projection, and future projection.

CCIS Web

1. MODULES BACKEND

A. Backend User Registration Module

This module function is to add new user, because the system restricted only registered user can view and download the data.
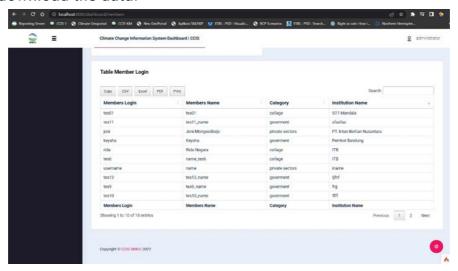
Figure 1. Backend User Registration form

B. Backend User Login Module

This module has function to login in the CCIS web and use all the function within the web.
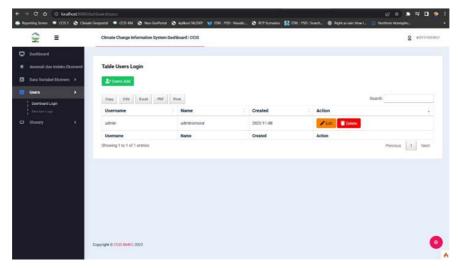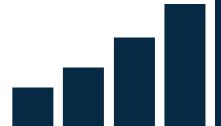
Figure 2. Backend user login module

CCIS Web

1. MODULES BACKEND

C. Dashboard Module

a. Provides a summary feature of the number of annual users in the last 5 years

Figure 3. Summary in yellow box

b. Provides a summary feature of the number of monthly users in the current year
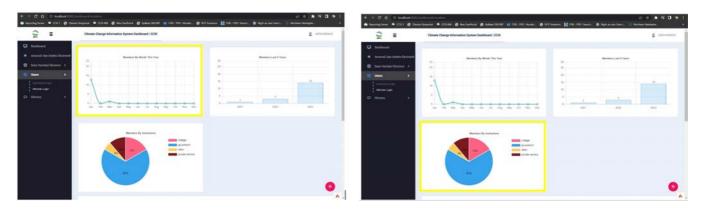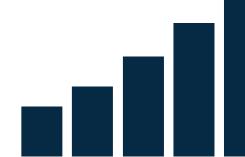
Figure 4. Summary in yellow box

CCIS Web

1. MODULES BACKEND

C. Dashboard Module

c. Provides display in graphical / tabular form
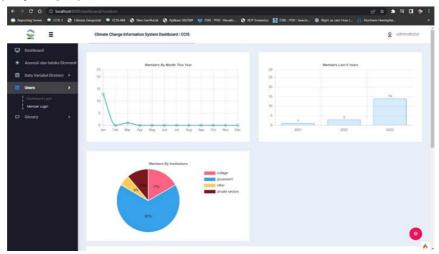
Figure 5. Display in graphical and tabular

d. Provides export facility to png
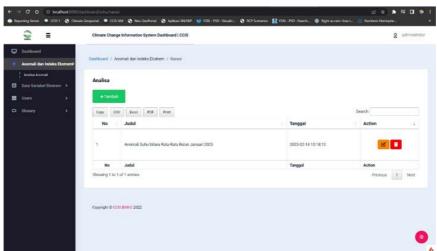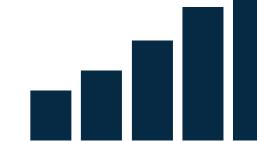
Figure 6. Export Facility

CCIS Web

1. MODULES BACKEND

D. Backend User Data Input Module
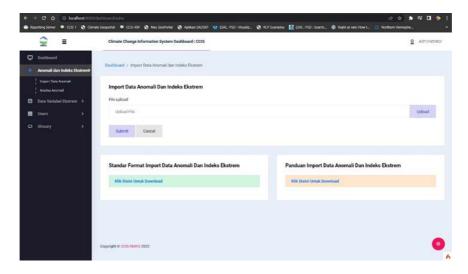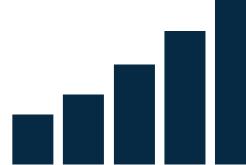
Figure 7. User Data Input

CCIS Web

2. MODULES FRONTEND

A. Frontend Climatology Data Visualization Module

There are four (4) main module in the CCIS web, which are: Anomali dan Indeks Ekstrim, Variabel Ekstrim, Data Proyeksi Iklim, and Glossary

Figure 8. CCIS main page and its modules

B. Frontend User Registration Module

Figure 9. User registration form

CCIS Web

2. MODULES FRONTEND

C. Climate Projection Data Sharing to Registered Users

This module is consist of projection data, user can create a map based on extreme variables projection and save the map into image.
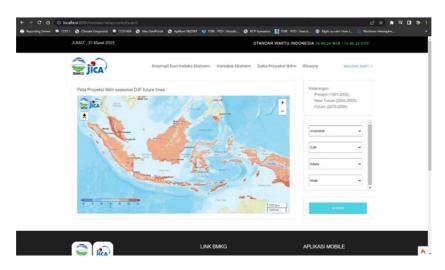
Figure 10. Projectin data sharing module

D. Frontend User Login Module
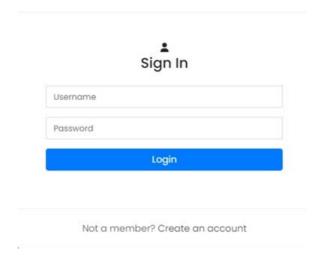
Figure 11. Login Form for registered user

Training

- Provide front-end operational training with a minimum of 10 participants for 2 days
- Back-end training with a minimum of 10 participants for 2 days
- Training is held offline at the BMKG HQ Office in Jakarta.

Laptop Used For Developing

To develop the CCIS web, highperformance PC or laptops are needed. In this case, the development of CCIS web is using high performance laptop.

Figure 12. Laptop used to developed CCIS

Work Schedulle

This project is completed in accordance with the time line of work schedule.

No	Activity	month		
		1	2	3
1	Website/Portal implementation (coding).	■	■	
2	Website/Portal Installation	■	■	
3	Test Website/Portal			■
4	Training			■

Table 1. Project time line

e. 令和2年度研究成果

1. Non-Hydrostatic Regional Climate Model (MRI-NHRCM) Simulation of Near and Far Future Precipitation and Temperature over Indonesia

Ganesha Chandrasa
BMKG, Indonesia

1.1. Introduction

Indonesia, located in the tropical maritime continent, is one of the most vulnerable countries to climate-related disasters. There is also a potential for high economic loss from climate risk in the future, concerning the impact of global climate change. Low to middle-class economy is especially exposed to the danger, specifically those who live in areas with hazards of drought, flood, landslide, and coastal inundation. Such events will bring a negative impact on economic growth by disturbing climate-sensitive sectors such as agriculture and fisheries as well as increasing the risk of disaster for other prone sectors. In this case, rainfall, in particular, is a parameter that interacts with many living sectors of the population and much of the effort on weather and climate prediction and analysis in Indonesia is focused on precipitation and its related information.

The maritime continent area is a region comprised of a densely populated chain of islands of various sizes. Among its unique features is the large influence exerted by islands on local atmospheric dynamics. The sea surrounding the islands plays an important role in the regional ocean-atmosphere interaction, so that short to long-term atmosphere and climate conditions are highly dependent on the state of the sea. The spatial variability of rainfall in the Indonesian islands is highly heterogeneous, mainly due to the diurnal cycle of convection which occurs between the inland mountain and flat coastal areas, that is caused by different properties of heat reserve between land and sea.

To address these issues, this study has conducted an analysis on the climate at the past state and multiple future periods over Indonesia based on the modeling process using the Non-Hydrostatic Regional Climate Model (NHRCM) developed by the scientists at Japan's Meteorological Research Institute (MRI). This high-resolution regional climate modeling effort is expected to resolve local scale phenomena as well as the impact of variation in topography towards the state of the atmosphere, and particularly, the variability in rainfall.

1.2. Methodology

Simulations were done by using NHRCM (Saito et al., 2006; Sasaki et al., 2008) at approximately 5x5 km resolution. The total grid size (the dimension) of the simulation output is 1081 x 421 grid points. These simulations are forced using the MRI-AGCM boundary condition with a coarser resolution (20x20 km).

The domain of this simulation is set to cover the whole of Indonesia and its surrounding maritime continent area. The simulation domain stretch from 93.76 to 144.15 decimal degrees East (of longitude) and –12.26 decimal degrees in the South to 7.23 decimal degrees in the North (of latitude).

The whole experiment is designed to separate different normal period into different time-slice. The past period simulation covers the time from August 1981 to September 2001. The near-future period simulation covers the time from August 2034 to September 2055. The far-future period simulation covers the time from August 2079 to September 2099. The first month of each simulation was ignored and considered as the model spin-up time (Zhong et al., 2007).

Both future simulations utilize the climate change RCP8.5 scenario (Riahi et al., 2007) based on the change in the greenhouse gasses concentration (Meinshausen et al., 2011). The result of the past simulations was compared to the CHIRPSv2.0 gridded dataset (representing rainfall observation reference) with the 0.05-degree resolution (Funk et al., 2015) for the purpose of rainfall comparison and ERA5 reanalysis dataset (representing temperature observation reference) with 0.3-degree

Ⅲ．研究成果の詳細報告

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resolution (Hersbach et al., 2020) for the purpose of temperature comparison.

1.3. Results and Discussion

1.3.1. Precipitation

Precipitation simulation during the past period (1981–2000) for the December-January-February (DJF) as well as the CHIRPS observation data and their differences for the respective time period is shown in Fig. 1. In general, NHRCM shows almost uniform underestimation towards the observational reference. Besides, the spatial pattern of the NHRCM simulation result proves to be more heterogeneous, in terms of representing the topography in Indonesia. The mountain range over Sumatra, Borneo, Java, Celebes, and New Guinea are represented analogously with the spatial rainfall pattern. NHRCM simulation also tends to overestimate precipitation over these mentioned mountainous regions while underestimating rainfall over lower altitudes and flatlands. NHRCM simulation has a strong sense in presenting the rain shadow effect which leads to higher precipitation in front of a mountain but dryer in the backside of the mountain, as in DJF, the wind dominantly came from the northern hemisphere.
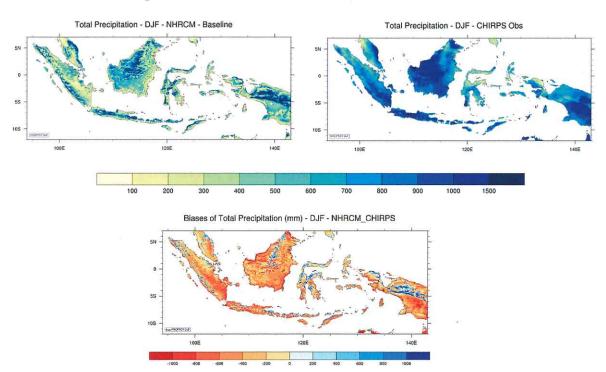
Figure 1. Normal average (1981–2000) of total DJF precipitation of NHRCM's baseline simulation (top left) and CHIRPS (top right). The difference of both data is shown as bias values in millimeters (bottom).

Precipitation simulation during the past period (1981–2000) for the June-July-August (JJA) as well as the CHIRPS observation data and their differences for the respective time period is shown in Fig. 2. It is still shown that NHRCM simulation can still capture the spatial pattern of precipitation compared to the CHIRPS observation while representing a better pattern with respect to topography. In general, NHRCM produce underestimate precipitation over the whole region of Indonesia. Meanwhile, it still produces overestimate rainfall over mountainous regions as mentioned in the DJF part. As mentioned, NHRCM has a strong sense in presenting rain shadow effect which leads to higher precipitation in front of mountain but dryer in the backside of the mountain, as in JJA, the wind dominantly came from the southern hemisphere.

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Total Precipitation - JJA - NHRCM - Baseline

Total Precipitation - JJA - CHIRPS Obs

Biases of Total Precipitation (mm) - JJA - NHRCM_CHIRPS
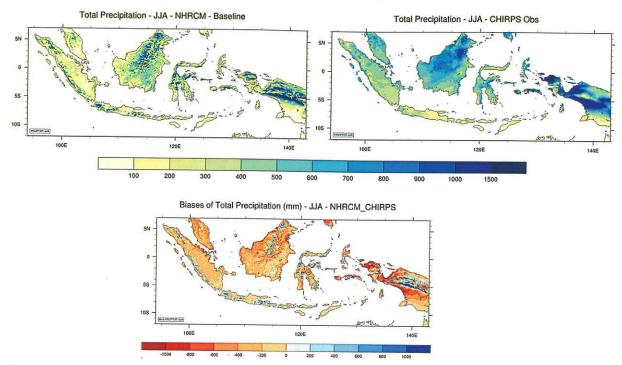
Figure 2. Normal average (1981–2000) of total JJA precipitation of NHRCM's baseline simulation (top left) and CHIRPS (top right). The difference of both data is shown as a bias value in millimeters (bottom).

Future climate projections (2035–2054 and 2079–2098) from NHRCM simulations suggest a distinct trend between different seasons over Indonesia. Fig. 3 shows the supposed normal condition as well as the difference in precipitation between the future and past periods in spatial distribution. The difference is calculated by subtracting the precipitation from both future periods with past precipitation for DJF and JJA seasons.

During DJF season, simulation results display a dominant green color for most of the Indonesian area, indicating an increase in total precipitation amount in the future. Some regions are experiencing a decrease such as the central part of Sumatra, Borneo, and New Guinea. The brownish color indicates that the precipitation will be reduced in the future, as explained in the legend. Meanwhile, the whole Java and Celebes are dominated by a trend of increase. This pattern suggests a wet-get-wetter tendency for the area heavily influenced by the Indo-Australian monsoon. On the other hand, during the JJA season, there seems to be a distinct difference between the northern and southern parts of the domain. Java, which is located in the southern hemisphere will experience a decrease. The northern part of Sumatra, Borneo, Celebes, and New Guinea are consistently having an increase in precipitation. This pattern suggests a dry-get-drier tendency for the area heavily influenced by the Indo-Australian monsoon. The prominent difference between the two future periods is in the intensity of the changes. The far-future period exhibits a much more significant increase (or decrease), implying a higher risk from the change in the climate parameter.
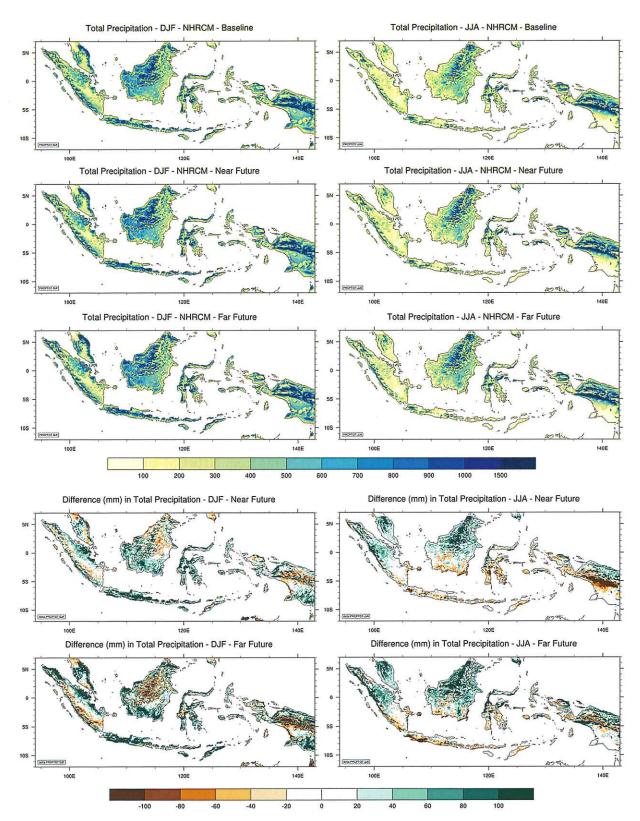
Figure 3. Seasonal cumulative rainfall of the NHRCM simulations. The baseline period is displayed at the top row. The second row shows the near-future period. The third row shows the far-future period. The two rows at the bottom are the difference between the future periods (near-future at the fourth row and far-future at the bottom row) and the baseline period. Left and right columns present the seasons of DJF and JJA respectively.

Next analysis was done by calculating the probability distribution function of the whole Indonesian area (as shown in Fig. 4) by averaging the domain area used in NHRCM (1081 x 421 grid points) for the whole 20 years of past simulation (black line) and future simulations (gold and dark red). Both seasons, DJF and JJA, are projected to have higher precipitation in the mean value, with the increase of the mean value in DJF is higher.

In the near-future period, the mean precipitation is projected to increase from around 480 mm to 510 mm during DJF, which is around a 30 mm rise, and for JJA, the increase in the mean is not very significant. As for the far-future period, the mean precipitation is projected to increase from around 480 mm to 540 mm during DJF, which is around a 60 mm rise. The far-future mean precipitation is projected to increase from around 290 mm to 320 mm during the JJA season, which is around a 30 mm rise, in contrast to the less significant expected mean change during the near-future period.

The spread of the curve is also another thing to be noted. Both curves of the future period precipitation (gold and dark red) in DJF appears to be lower and wider in comparison to the past period (black), with the far-future period having a more significant shift toward the extremes. This means that in the future, the state of the DJF precipitation will have a higher chance of extreme events related to higher cumulative precipitation, as shown by the reach of the curve to the right side.

In JJA, however, the curve becomes slightly narrower albeit not very significant in the near-future period. On the other hand, for the far-future period, there is a tendency for an increase in mean value and the reach of the curve. This type of change can provide a different impact which depends on the condition during the JJA season of a specific area. An area with a wet JJA season could experience a wetter anomaly, while another area with a dry JJA season could benefit from the additional supply of water.

The shift of the mean rainfall and the movement of the curve towards extremes are something to be alerted of for stakeholders and policymakers of various sectors. It should be noted that this is an average for the whole Indonesia region, which has various types of rainfall patterns. A more specific analysis of probability distribution over a localized region would give more insight into local adaptation strategy.
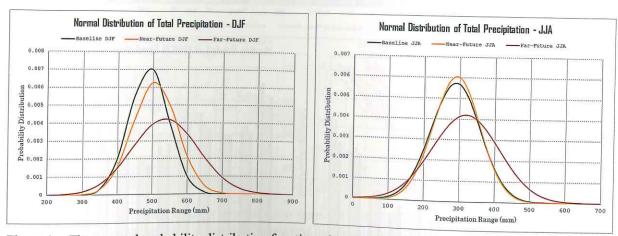
Figure 4. The seasonal probability distribution function of NHRCM simulations for DJF (left) and JJA (right).

The precipitation annual pattern based on the monthly cumulative rainfall from three different areas is examined and is shown in Fig. 5. The first is the whole domain of NHRCM while others are the island of Java and Borneo. Java is the center of population activity in Indonesia, in which the capital city Jakarta is located, while also serve as the primary region of economic and agriculture sectors. Borneo is expected to be a developing region, where the future capital city is located and the designated area of a so-called national "food estate" project. The rainfall pattern over Java is highly affected by the Indo-Australian monsoon (dry season in midyear and wet season at the beginning/end

of the year), while Borneo has a more heterogeneous climate (Aldrian and Susanto, 2003).

There are no significant changes in rainfall patterns for the whole region of Indonesia, as the peak of rainfall is still expected to be still in January. It is projected that there would be a slight increase almost over all months in the future. This is especially prevalent for the far-future period in which the area experiences an increase, with the month of April and December having the most significant increase.

In Java, it is clear that the tendency of wet-get-wetter and dry-get-drier as an impact of climate change is present. For the near-future period, the monsoonal wet season (around DJF) will experience an increase in rainfall and vice versa (decrease during JJA), and the onset of the rainy season is still expected to be around November and peaking in January. Meanwhile, for the far-future period, there seems to be a shift in the peak of the rainy season from January-February to the months of March-April. The wet-get-wetter and dry-get-drier tendency are also prominent particularly during the JJA period of the dry season. One can expect a much more severe dry condition during the dry season in the far-future period.

Borneo, on the other hand, has a tendency of increasing rainfall throughout the year, as also seen in the pattern of the whole Indonesia domain. A two-peak of monthly rainfall is still relevant in the near-future period. In the far-future period, there is a significant increase in total monthly precipitation during December and January, which can be expected as the peak of the rainy season.
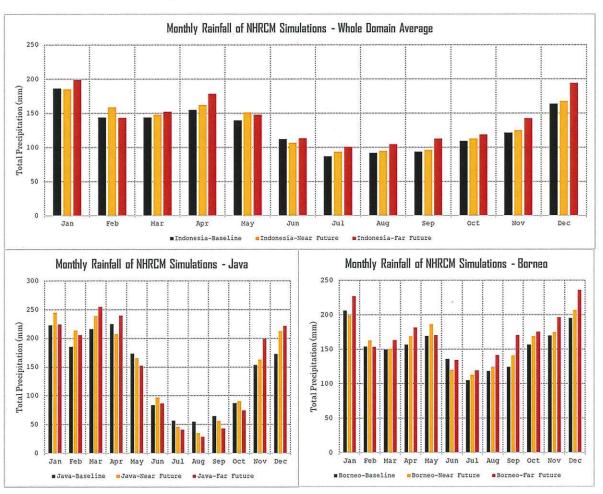
Figure 5. Monthly total precipitation over three different area-averaged regions, whole NHRCM simulation domain (top), Java (bottom left), and Borneo (bottom right).

One of the many indicators of climate extremes is the maximum daily rainfall. Here, the maximum annual daily rainfall for both the past and future simulations are presented. Fig. 6 displays the normal average of annual maximum daily rainfall, and the predominant red color shows that the increase in the amount of rainfall in the future could pose a threat to the rising intensity of heavy rainfall.

It is apparent that, in both future periods, there is a higher risk of extremes related to the intensity of daily rainfall, with the far-future period simulation results displays a higher threat, considering the projected significant increase compared to the near-future period. Such conditions could lead to a flash flood event which would heavily impact the society and economy.

The locations in which a higher risk is expected are almost similar in both the near-future and far-future period, given a considerable difference in the intensity of the changes. Areas that are supposed to have a higher risk from the increase in the daily maximum rainfall consist of the west and east coast of Sumatra, the whole of Java Island particularly the inland part, the Lesser Sunda Islands, almost all of Celebes, the southern part of the Moluccas, coastlines of Borneo, and the inland mountainous part of New Guinea. Again, the pattern over Java Island is to be highly anticipated as it is the center of national economic activity as well as where the population is focused.
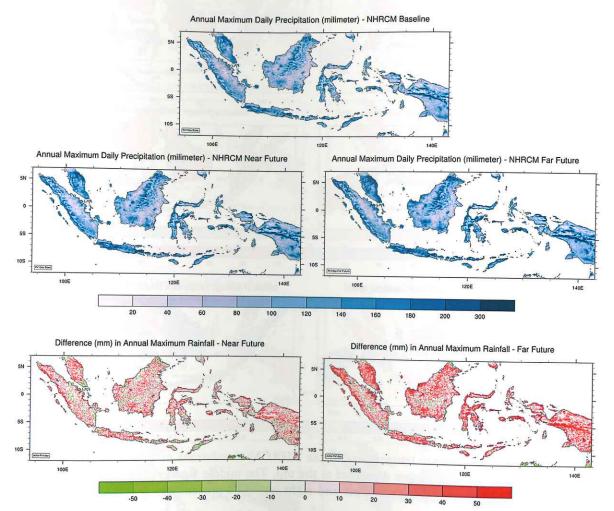
Figure 6.   Yearly maximum of daily precipitation from the NHRCM simulations. The baseline period is at the top. The near-future period is at the middle left and the far-future period is at the middle right. The bottom figures are the difference between the future periods (near-future at the left and far-future at the right) and the baseline period.

1.3.2. Temperature

The next feature to be examined from the model simulation is the near-surface temperature. Figure 7 shows the comparison of temperature in two seasons compared to the reanalysis data of ERA5. The NHRCM simulation during the past period can clearly reproduce the spatial pattern of the ERA5 observational reference. The difference between NHRCM and ERA5 is apparent in terms of the spatial

resolution, as NHRCM simulation has a higher resolution of 5x5 km. The figures show that NHRCM simulation produces a better spatial representation with respect to topographical distribution. Such a feature prevails in both DJF and JJA seasons.

However, over the mountainous regions, NHRCM simulation tends to produce a significant cold bias (up to 2 degree Celsius differences). It can be inferred that the model is less skillful over the area, or, that the reanalysis data simply does not represent the temperature over the mountain area correctly, due to its limitation. This is something that should be confirmed with several samples of in-situ observation. A warm bias is also detected in the JJA season over lower lands in Java, ranging from 0.8 to 1.6 degrees. Such biases should be considered in performing future analysis.
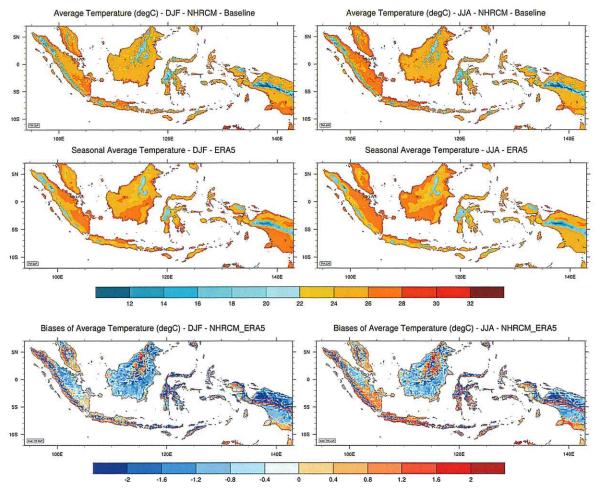
Figure 7. The seasonal average temperature of the NHRCM simulations as compared with the ERA5 reanalysis. The model simulations are displayed at the top. The middle figures show the reference ERA5 dataset. The bottom figures are biases. Left and right columns present the seasons of DJF and JJA respectively.

The near-future temperature over Indonesia during both DJF and JJA seasons is projected to increase uniformly over the whole Indonesia region (Fig. 8). The amount of increase is around 1℃ to 2℃, with the JJA season (monsoonal dry season), tends to have a higher increase particularly over the southern part of the domain. A significant increase is also shown over the mountain range of New Guinea, giving a further impact on the tropical ice sheet.

Similarly, the same tendency is also shown in the far-future simulation results, in which the seasonality and spatial distribution is nearly identical to the near-future results. The difference is in the range in the amount of increase, which is around 3℃ to 4℃, with the highest increase is, again, projected to be over the inland mountain range in New Guinea.

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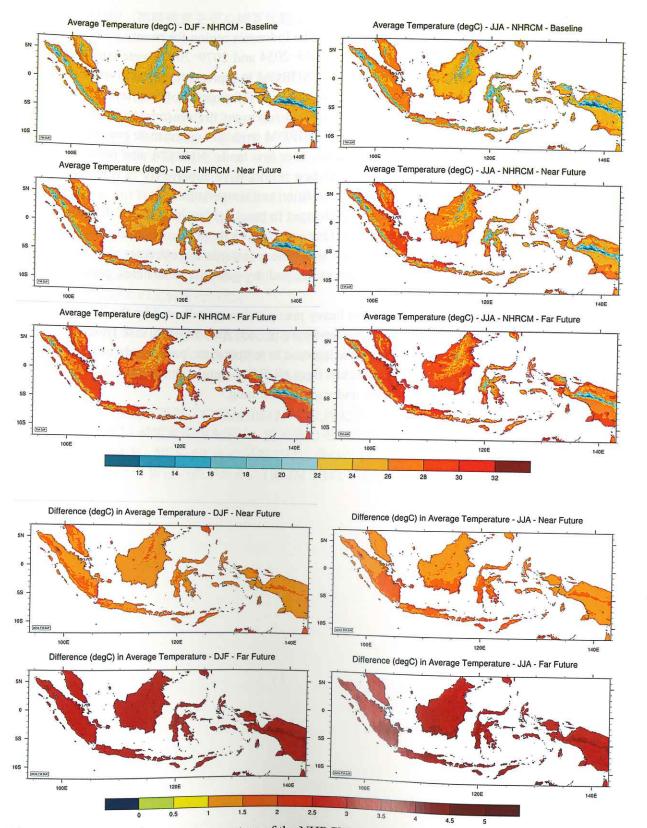
Figure 8. The seasonal average temperature of the NHRCM simulations. The baseline period is displayed at the top row. The second row shows the near-future period. The third row shows the far-future period. The two rows at the bottom are the difference between the future periods (near-future at the fourth row and far-future at the bottom row) and the baseline period. Left and right columns present the seasons of DJF and JJA respectively.

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1.4. Concluding Remarks

In this analysis, 5x5 km NHRCM simulations over the Indonesia region for twenty years in the past (1981–2000) and forty years (total) in the future (2035–2054 and 2079–2098) were conducted. The experiment was done in order to justify the skill of NHRCM in representing past climate in higher spatial resolution as well as providing future climate projection information of Indonesia.

The results indicate that NHRCM simulations could represent the seasonal precipitation over Indonesia quite well, albeit with some deficiencies. NHRCM tends to overestimate precipitation over mountain range while underestimating precipitation over low lands. NHRCM also possesses some cold biases in several areas. The NHRCM simulation results have superiority in reproducing the spatial features of topography pattern for both precipitation and temperature.
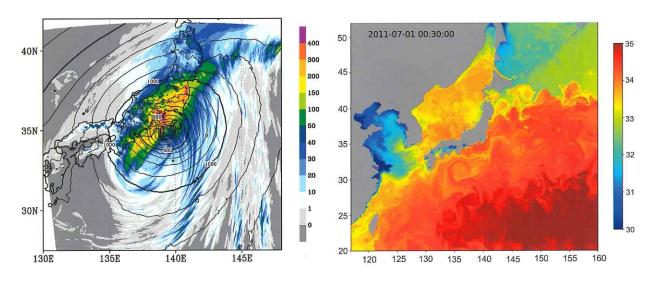
Future projections by NHRCM show varying changes in precipitation in terms of the seasonality, spatial distribution, intensity, and annual pattern. One can expect a more significant change in the far-future period, in which precipitation distribution shifts more towards the extremes sides. On a side note, changes in rainfall conform to the wet-get-wetter and dry-get-drier tendencies, particularly for areas with distinct wet and dry seasons.

There is also an increased risk of short-term heavy precipitation as indicated by the increase in the daily rainfall, with higher intensity during the far-future period. An additional risk from heatwaves should also be anticipated as an impact from the increase in temperature, particularly in the far future time range. All in all, the future simulation results from NHRCM simulations imply incoming threats and opportunities from the changing climate under global warming.

統合的気候モデル高度化研究プログラム
Integrated Research Program for Advancing Climate Models (TOUGOU)

統合的気候モデル高度化研究プログラム 領域テーマC 統合的気候変動予測

令和2年度研究成果報告書

日本域の高解像度大気モデル（左）と高解像度海洋モデル（右）による地球温暖化研究の展開

左：領域気候モデル（NHRCM, 2km 水平解像度）2019 年台風第 19 号（ハギビス）のシミュレーション。等値線と陰影は、それぞれ、気圧（hPa）と降水（mm/ 日）。

右：水平解像度 2 km の領域海洋モデル（JPN）による過去再現実験結果。表示は塩分（psu）。

令和3年4月
文部科学省研究開発局

一般財団法人 気象業務支援センター
国立大学法人東海国立大学機構名古屋大学
国立研究開発法人海洋研究開発機構
国立大学法人北海道大学
国立大学法人東北大学

Future changes in monsoon climate in Java, Indonesia, by using bias correction and statistical downscaling methods

*Motoki NISHIMORI (NARO), Michihiko Tonouchi, Hiroshi Satoda (JMBSC)
and Dodo Gunawan (BMKG)

1. Introduction

The climate of Indonesia located under the equator is predominated by the monsoon of both northern and southern hemispheres. Climate changes in Indonesia would affect not only agricultural production but also the whole economy. The future climate changes were projected by GCM simulation, but the geographical features of Indonesia are very complicated. Therefore, various types of downscaling methods involving RCM simulations are necessary to find detailed changes in the monsoon climate over Indonesia. In this study, we aim to clarify the future climate change of Java Island. Various types of bias correction (BC) methods combined with the statistical downscaling/spatial disaggregation (SD) method are applied.

2. Data and methods

We mainly used the historical data set for 20 years (1991-2010) data at 12 SYNOP stations over the central and western Java Island provided by BMKG. Temperature (daily mean (TG), daily maximum, daily minimum), daily precipitation (RR), and sunshine duration are stored. Monthly maximum temperature, minimum temperature, mean temperature, precipitation data from 1981 to 2010 to interpolate the BC station dataset to a gridded one. We use two BC methods for CMIP-5 GCM output, the gaussian-type scaling method (GSA)[1] and the cumulative distribution function-based downscaling method (CDFDM)[2]. In this analysis, only the BC and SD results of historical and RCP8.5 runs of the MRI-CGCM3 were shown.

3. Results and discussions

Figure 1 shows the seasonal change of monthly rainfall amount over the reference period (1991-2010). Though the seasonal change and amount of rainfall derived from MRI-CGCM3 were different from the observed one, both GSA and CDFDM were well captured the seasonal characteristics of the observed climate. The geographical distribution of near future (2041-2060) changes were different in each BC method. The result of GSA was quite like the GCM original output (upper panel of Fig.2) in that, the rate of TG increase was almost 1.45°C, and the RR slightly decreased over the northern side of Java. But those for CDFDM were different for TG and RR, which show

relatively higher TG (+1.7°C) and quite over-estimated (over 110%) for RR. Two reasons for these different results are presumed; the total number of SYNOP stations applied to CDFDM is too small, and another is the GSA method applied only to monthly data.
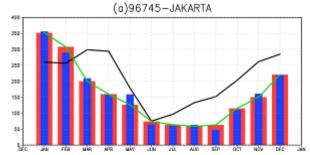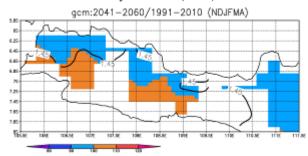
Fig.1 Seasonal change of the amount of monthly rainfall at Jakarta over the reference period (1991-2010). The red (black) line shows the data from observation (GCM: MRI-CGCM3), and the red (blue) bar shows after bias correction by CDFDM (GSA).
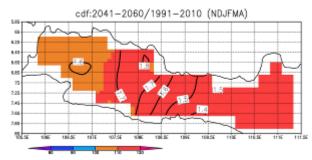
Fig. 2 Future (2041-2060 average) changes of averaged TG (contour line) and RR in the monsoon rainy season (Nov.-Apr.) referred to the reference period.

References:

Future changes in monsoon climate in Indonesia by using bias correction and downscaling methods

Motoki Nishimori (NIAES/NARO)

Michihiko Tonouchi, Hiroshi Satoda (JMBSC),

Kadarsah, Agus Sabana and Dodo Gunawan (BMKG)

National Agriculture and Food Research Organization
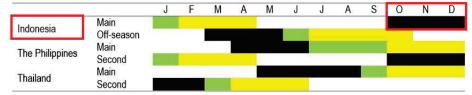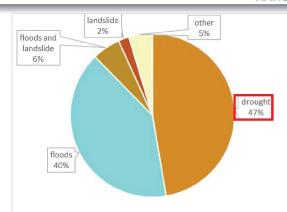
Introduction-1

- The climate of Indonesia which is located under the equator is predominated by the monsoon of both northern and southern hemispheres.

- The future climate changes were projected by GCM simulation, but the geographical features of Indonesia are very complicated.

Introduction-2

- Climate changes in Indonesia would affect not only agricultural production but also the whole economy.

- Drought is the natural factor that most affects agriculture in Indonesia. ➡️

- The amount of precipitation, especially during the onset of the monsoon, is of vital importance for rice cultivation in Indonesia. ⬇️

Crop calendar of rice in Indonesia, the Philippines, and Thailand. The colors black, green, and yellow indicate sowing, growing, and harvesting seasons respectively (Cortes and Otadoy, 2020, Source: FAO).
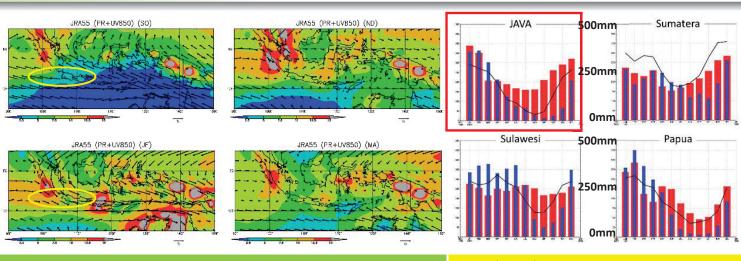
Percentage of affected farmland area by factor * Prepared by SOMPO Risk Management based on data from BNPB, National Disaster Management Agency of IDN.

2

Climate over Indonesia (1986-2005observed: JRA55)

Change to (Nov.-Dec.) and intensification (Jan.-Feb.) of westerly winds are the keys to the onset and persistence of monsoon precipitation over Java Island.

- : OBS (JRA55), ■MRI-CGCM3, ■MIROC5
Seasonal Changes of Rainfall over major Indonesian regions. Most of Indonesia has a distinct wet and dry season.
MRI-CGCM3 (MIROC-5) tends to under (over)-estimate precipitation, respectively.

3

Aim and Scope of this Research

- In this study, we aim to clarify the future climate change of Java Island, Indonesia.
- Various types of bias correction (BC) methods combined with the statistical downscaling/spatial disaggregation (SD) method are applied.

* In this presentation we will first review the seasonal changes in monsoon precipitation throughout the year and then focus on the onset period.

Data Setting

1. 12 station Daily data (1991-2010) over west-mid Java Island area

2. GPV of GCM's output (RCP8.5 of MRI-CGCM3 & MIROC-5) of climate values were interpolated into the 12 stations.

3. Both GSA (Gaussian-type Scaling Analysis: Nishimori et al, 2019) and CDF (Cumulative Distribution Function dowmscaling method: Iizumi et al. 2012) are applied **daily-scale** surface air temperatures and precipitation.

Jakarta

Cirebon

Bogor/Citeko

Tegal

Semarang

Bandung

4
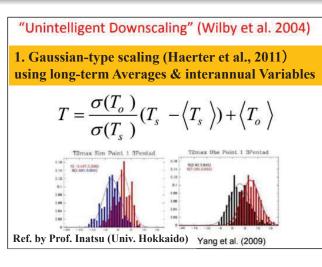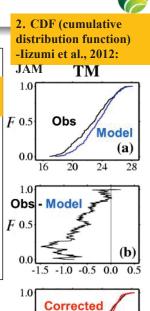
Statistical Downscaling
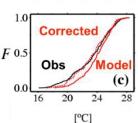
* The basic concept of our Statistical Downscaling method is a combination of Bias-Correction and Spatial Disaggregation
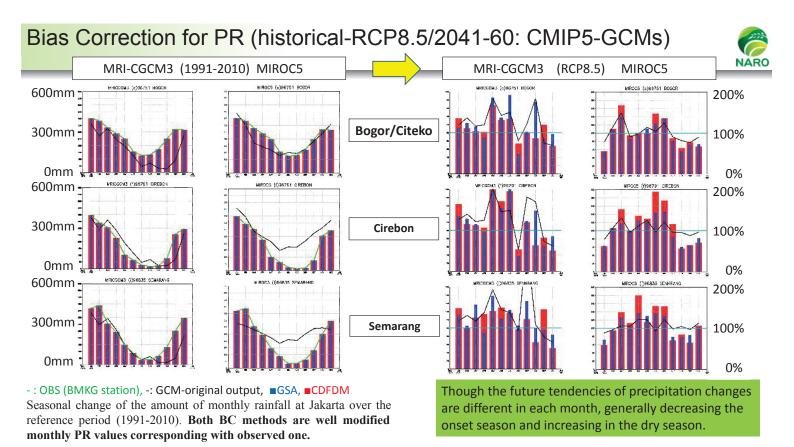
Our strategy of Statistical Downscaling of GCM-derived Climate Projection data over Indonesian (Java) region

"Unintelligent Downscaling" (Wilby et al. 2004)

1. Gaussian-type scaling (Haerter et al., 2011) using long-term Averages & interannual Variables

$$T = \frac{\sigma(T_o)}{\sigma(T_s)}(T_s - \langle T_s \rangle) + \langle T_o \rangle$$

T2max Sim Point 1 3Pentad / T2max Obs Point 1 3Pentad

Ref. by Prof. Inatsu (Univ. Hokkaido)   Yang et al. (2009)

2. CDF (cumulative distribution function) –Iizumi et al., 2012:

JAM   TM
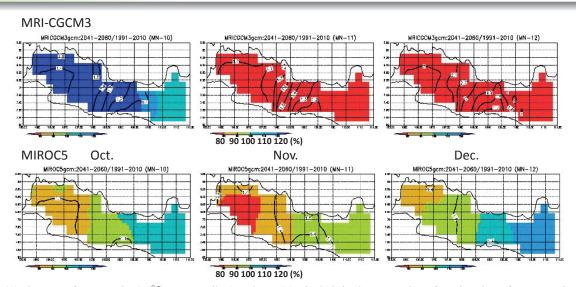
0. Delta method (BC by using only long-term average)
1. Gaussian-type scaling approach (GSA)
2. CDF method

Bias Correction for PR (historical-RCP8.5/2041-60: CMIP5-GCMs)

- : OBS (BMKG station), -: GCM-original output, ■GSA, ■CDFDM

Seasonal change of the amount of monthly rainfall at Jakarta over the reference period (1991-2010). **Both BC methods are well modified monthly PR values corresponding with observed one.**

Though the future tendencies of precipitation changes are different in each month, generally decreasing the onset season and increasing in the dry season.

Climate Change over Indonesia (RCP8.5/2041-60: CMIP5-GCMs)
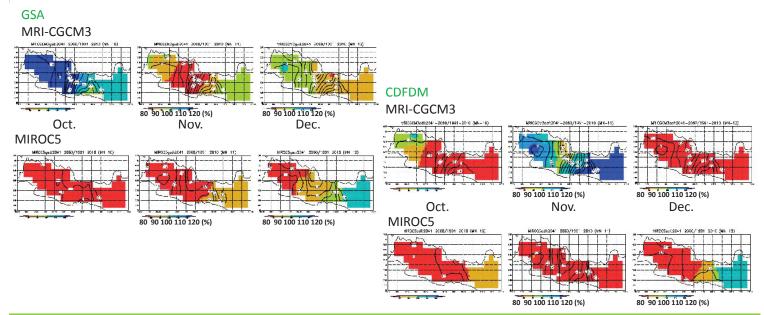
Future (2041-2060) changes of averaged TG (℃: contour line) and RR (%: shaded) in three months referred to the reference period (1991-2010).

There is general agreement that precipitation at the onset of the monsoon is likely to decrease in the future

Climate Change over Indonesia (BC-applied: CMIP5-GCMs)
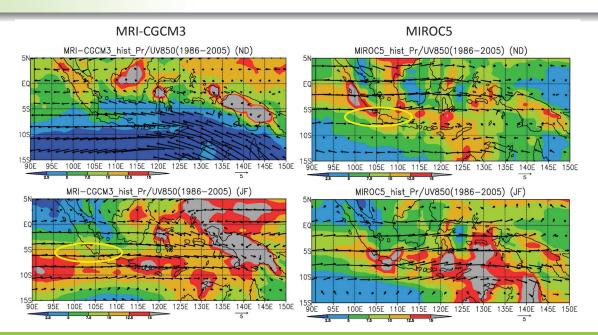
Future (2041-2060) changes of averaged TG (℃: contour line) and RR (%: shaded) in three months referred to the reference period.

GSA
MRI-CGCM3

Oct. Nov. Dec.

MIROC5

CDFDM
MRI-CGCM3

Oct. Nov. Dec.

MIROC5

While there is general agreement that precipitation at the onset of the monsoon is likely to decrease in the future, depending on the BC method, the trend of precipitation change may differ from that of the GCM itself.

Climate over Indonesia (1986-2005simulated: CMIP5-GCMs)

MRI-CGCM3 MIROC5

In the first place, the seasonal progression of the monsoon is different between the two climate models !!

Summary, Discussion and Future Tasks

BMKG

- Though the seasonal change and amount of rainfall derived from CMIP5-GCMs were different from the observed one, both GSA and CDFDM were well captured the seasonal characteristics of the observed climate.
- Though the future tendencies of precipitation changes (RCP8.5; 2041-2060) are different in each month, generally decreasing in the onset season and increasing in the dry season.
- While there is generally coincidence that precipitation at the onset of the monsoon is likely to decrease in the future, depending on the BC method, the trend of precipitation change may differ from that of the GCM itself.

(Q) In the first place, does it make sense to correct only the precipitation values in two climate models with different seasonal atmospheric circulation related with monsoon?
(A) Necessity of applying empirical methods that can account for variations in the circulation field
(Q) Isn't it problematic to apply a Gaussian standard deviation to daily precipitation?
(A) Does it seem like that a 10-day average would be manageable?

In this case, we only looked at the results of daily data aggregated into monthly data, but according to BMKG's definition of the monsoon onset, we need to look at 10-days of data.
- The definition of the monsoon onset of BMKG is when 10-days precipitation > 50 mm continues for three times in a row.

10

March 6th, 2023 @BMKG, Jakarta, Indonesia

Climate Projection Data Downscaling and its Utilization

Climate projection considering urbanization for 2045 Jakarta

Yuki Asano (Univ. of Tsukuba)

Heavy rain in Future Jakarta

Jakarta has heavy rain events under present climate

Indonesiaexpat (https://indonesiaexpat.id/news/jakarta-floods-return-to-claim-lives/)

Future heavy rain is enhanced by
       urban development and/or climate change?
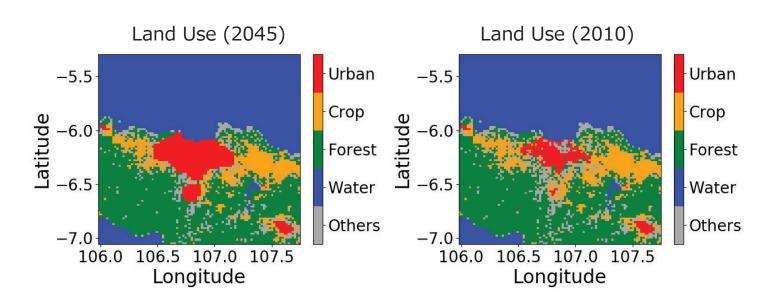
Pseudo Global Warming (PGW) Experiment

$$var_{event, FC} = var_{event, PC} + \Delta var$$

$$\Delta var = var_{twenty-year\ monthly\ mean, FC} - var_{twenty-year\ monthly\ mean, PC}$$

Variables	ts, ta, hum, u, v, gph
Scenario	RCP8.5
Future Climate	2036-2055
Present Climate	2000-2019
GCM	CNRM-CM5
	CSIRO-Mk3-6-0
	GFDL-ESM2M
	MPI-ESM-MR
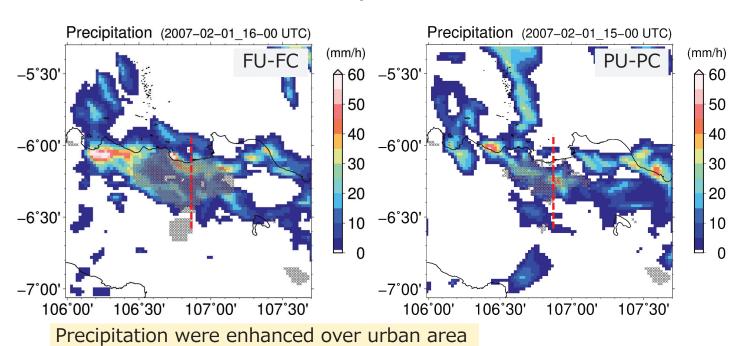
Assumption of Urban Area Expansion (UE)

Land Use (2045)   Land Use (2010)
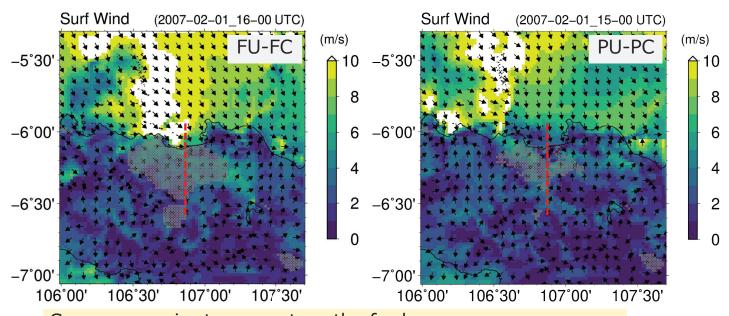
Model Configuration

Model	WRF v4.2.2
case	2007-Feb-01, 2007
Δx (d01, 02, 03)	18, 6, 2 km
initial time	2007-Feb-01 00 UTC
IC・BC	FNL
cu physics	New Tiedtke
mp physics	WDM6
pbl physics	YSU

PGW+UE Effect: Hourly Prec (@2007-Feb-01 15UTC)

Precipitation were enhanced over urban area
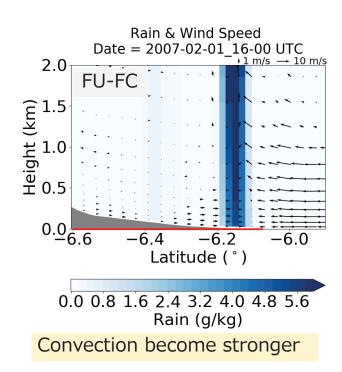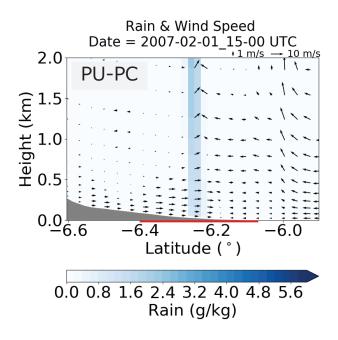
PGW+UE Effect: Surf Wind (@2007-Feb-01 15UTC)
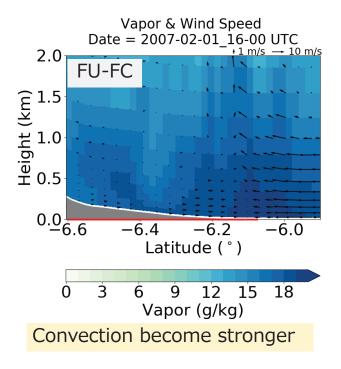
Convergence is stronger at north of urban areas
Easterly winds were slightly stronger in FC than those in PC

PGW+UE Effect: Rain & Wind (@2007-Feb-01 15UTC)

Convection become stronger

PGW+UE Effect: Vapor & Wind (@2007-Feb-01 15UTC)

Vapor & Wind Speed
Date = 2007-02-01_16-00 UTC

FU-FC

Convection become stronger

Vapor & Wind Speed
Date = 2007-02-01_15-00 UTC

PU-PC
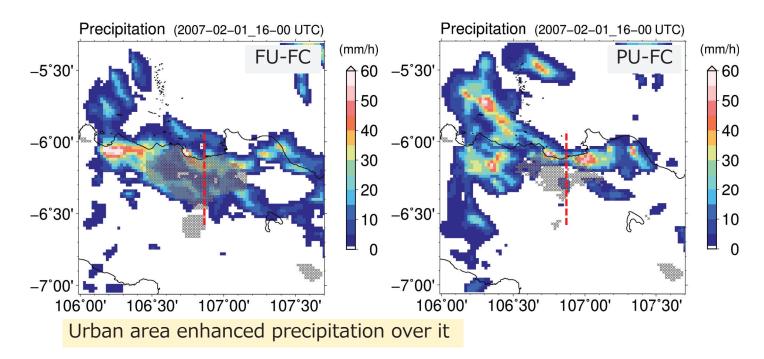
Urban Expansion Effect

Future Urban (FU) & **Future Climate (FC)**
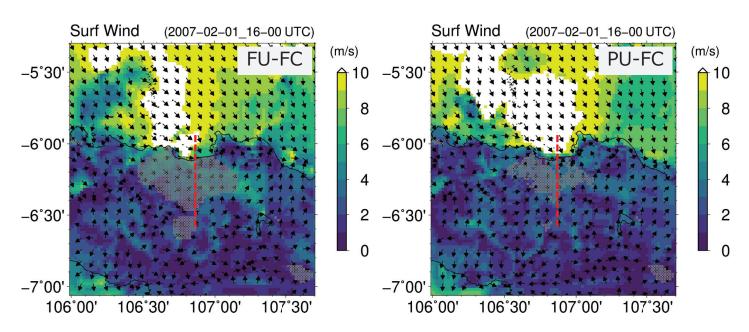
VS

Present Urban (PU) & **Future Climate (FC)**
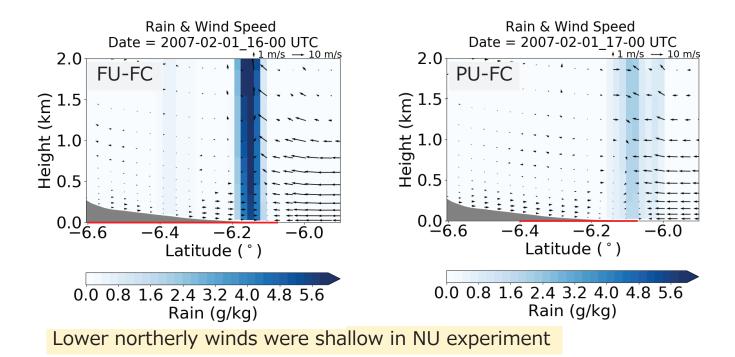
UE Effect: Hourly Prec (@2007-Feb-01 15UTC)

Urban area enhanced precipitation over it
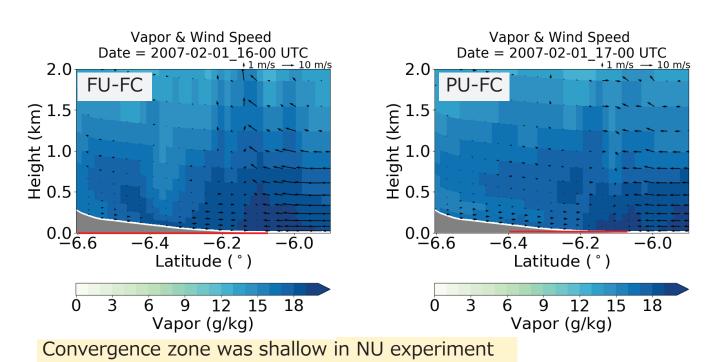
UE Effect: Surf Wind (@2007-Feb-01 15UTC)

UE Effect: Rain & Wind (@2007-Feb-01 15UTC)

Lower northerly winds were shallow in NU experiment

UE Effect: Vapor & Wind (@2007-Feb-01 15UTC)

Convergence zone was shallow in NU experiment
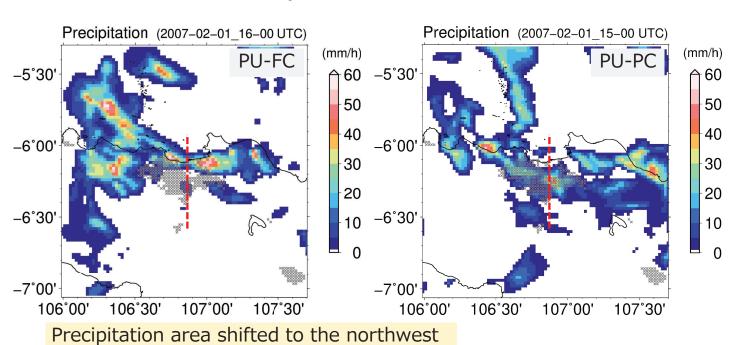
Pseudo Global Warming Effect

Future Urban (FU)
&
Future Climate (FC)
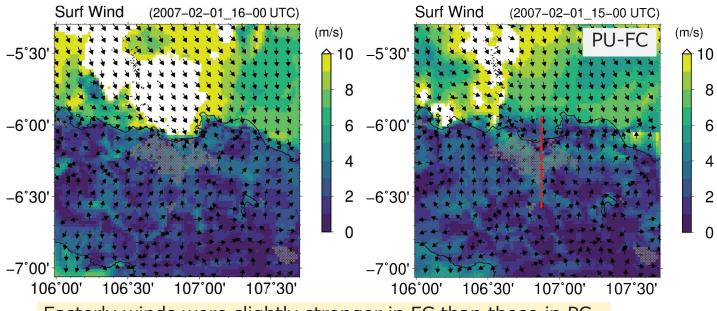
VS

Present Urban (PU)
&
Present Climate (FC)

PGW Effect: Hourly Prec (@2007-Feb-01 15UTC)

Precipitation area shifted to the northwest
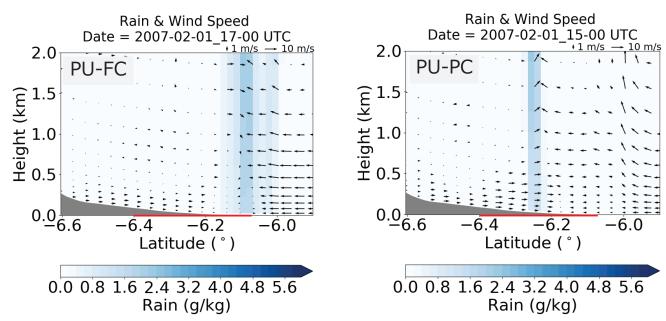
PGW Effect: Surf Wind (@2007-Feb-01 15UTC)
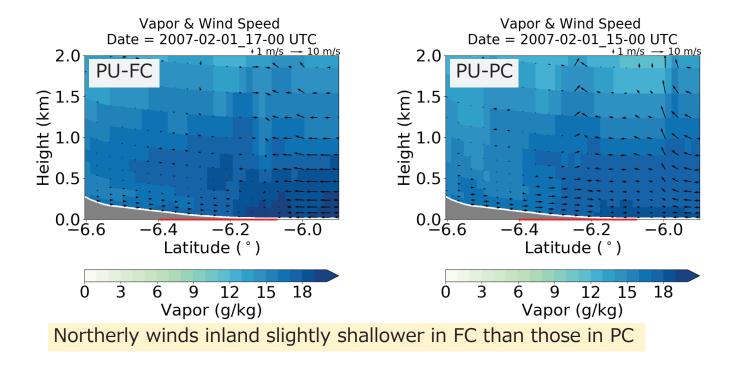
Easterly winds were slightly stronger in FC than those in PC

PGW Effect: Rain & Wind (@2007-Feb-01 15UTC)

Northerly winds inland slightly shallower in FC than those in PC

PGW Effect: Vapor & Wind (@2007-Feb-01 15UTC)

Northerly winds inland slightly shallower in FC than those in PC

Summary

◇ We conducted Pseudo Global Warming & Urban Expansion experiment to reveal future changes in heavy rain in Jakarta.

◇ The future heavy rain was enhanced by the urban expansion.

◇ Climate change due to global warming has shifted precipitation areas to the northwest.

Final report of JICA project

The Project of Capacity Development for Implementation of Climate Change Strategies Phase 2 in the Republic of Indonesia

Target 4: Technical skill transfer and support for long-term forecasts (continues from Agri-insurance project)

Supari PhD

Adi Ripaldi

Amsari Mudzakir Setiawan

Damiana Fitria Kussatiti

Novi Fitrianti

Ridha Rahmat

Rosi Hanif Damayanti

Dyah Ayu Kartika

Muhammad Agfi Isra Ramadhan

Center For Climate Change Information, BMKG

Table of contents

Ⅰ. Seasonal Forecast Evaluation
Evaluation on Seasonal Forecast in 342 ZOM8110

Muhammad Agfi Isra Ramadhan and Rosi Hanif Damayanti

Introduction
Background :

The Indonesian Meteorological, Climatological, and Geophysical Agency (BMKG) provide seasonal forecasts consisting of two predictions that cover the next 6 months after their release. These forecasts are based on collaboration between the headquarters and regional climate stations, with the wet season prediction released in October and the dry season prediction released in March. This biannual forecasting process involves the headquarters providing data, methods, and forecast models while regional climate stations choose suitable models for their area. After the selection process, both parties justify and agree on the final prediction. These forecasts are essential for planning and management purposes, especially for agriculture and disaster management sectors.

(BMKG) produces a range of seasonal forecasts that provide valuable information for the country. These forecasts include the Seasonal Onset, The Seasonal Onset Compared to Normal 1981 - 2010. The Seasonal Anomaly and the Seasonal Peak forecast. BMKG uses a system of classification based on the characteristics of climate to simplify the forecasting of the onset of seasons in different areas. This system divides the regions in Indonesia into two categories, namely Climate Region / Zona Musim (ZOM) and Non-Climate Region / Non-Zona Musim (Non-ZOM). Based on the previous normal data (1981 – 2010), there are 342 ZOMs and 65 Non-ZOMs. ZOM refers to an area with a distinct wet and dry season, while the Non-ZOM has an unclear distinction between the two. Since 2000, BMKG has been predicting the onset of seasons in each district using this classification system. BMKG uses the mapping of ZOM to predict the onset of seasons in each district that has a similar climate pattern. This helps to improve the accuracy of forecasts and enables better planning for various sectors that are dependent on weather conditions.

This study aims to evaluate seasonal forecasts in Indonesia, especially the seasonal onset forecast and seasonal onset forecast compared to normal from 2012 – 2022 that had been released by BMKG. Ultimately, our goal is to gain insights into the unique characteristics of seasonal forecasts in Indonesia and gather insights on the quality of the data and methods utilized for seasonal forecasting, in the hope of improving future forecast products by the BMKG. Accurate forecasting can enhance BMKG's services to the public, particularly in the agriculture sector. Therefore, the hope is that by improving the forecasting process, the BMKG can better support and benefit the public in this field.

Data and Method

This study utilized a set of data to investigate the onset of dry and wet seasons in Indonesia. The data used included the Dry Season Onset (Forecast And Observed) and the Wet Season Onset (Forecast And Observed) from 2012-2022 in 342 ZOM 1981 – 2010, which were released and evaluated by the BMKG. The forecasting models used are a combination of dynamic models which are ECMWF and CFS and statistical models namely ARIMA, ANFIS, WAVELET ARIMA, and WAVELET ANFIS which chose based on the best model that represents a ZOM. Additionally, the study also incorporated the Normal Season Onset from the BMKG observational dataset for both dry and wet seasons, which covered the period from 1981-2010.

BMKG uses a 10-day period called "dekad" to forecast seasons, dividing each month into three periods. Season onset is determined by a scientific approach using precipitation thresholds. Wet season onset is declared when precipitation for three consecutive dekads is >50mm per dekad or cumulative precipitation for those three dekads is >150mm. Dry se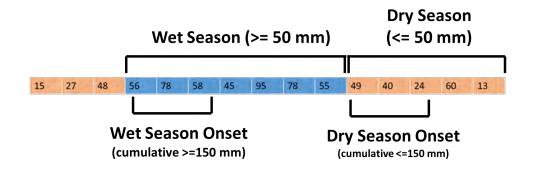ason onset is declared when precipitation for three consecutive dekads falls below 50mm or cumulative precipitation for those three dekads is less than 150mm.

Figure 1. Defining dry and wet season onset in Indonesia

To evaluate these data we are using a contingency table to assess the accuracy of the forecast in comparison to the observed onset. The contingency table shown in Table 1 provides a comprehensive summary of the accuracy of the forecast by comparing the forecasted onset with the observed onset. In the contingency table, the observed onset is listed in the rows, while the forecasted onset is listed in the columns.

Season's onset forecast data from BMKG and observed season's onset data for both the wet and dry seasons are transformed into categorical data with three categories: Near Normal (NN), where season's onset of forecast and observation only differs by +/-1 dasarian (dekad), Earlier than Normal (E), where season's onset of forecast and observation differs by 2 or more dasarian (dekad), and Later Than Normal (L) where differs 2 or more dasarian (dekad) later than normal. For cases where the season's onset cannot be determined (Undefined Observed Onset) is not counted. This case can occur if in one year there is no clear season's onset like there is no dry season since high rainfall occur all year long (wet season all year long). Using the 3x3 contingency table, we compute the score and hit rate from the data that have been transformed to category data. Hit score is a statistical measure used in the evaluation of seasonal onset forecasting. It is calculated by dividing the number of true positives by the sum of true positives and false negatives.

The Season Onset Evaluation is the process of comparing the forecasted onset of a season to the observed onset of that season. If the difference between the forecasted onset and the observed onset is within one dekad, it will be counted as accurate and assigned a value of 1. However, if there is a difference of two or more dekads between the forecasted onset and the observed onset, it will be counted as inaccurate and assigned a value of 0. Instances, where the onset is undefined or not observed, will not be counted and will appear as blank in the evaluation.

Table 1. 3 x 3 Contingency Table for Verification of Season's Onset Forecast

SCORE	Observed E	Observed NN	Observed L
Forecast E	1	0	0
Forecast NN	0	1	0
Forecast L	0	0	1

Hit score is a commonly used metric in assessing the accuracy of seasonal onset forecasts and observations. This score is calculated using a formula that takes into account the number of times a forecast correctly predicted the onset of a season, as well as the number of times an observation accurately captured the onset. A high hit score indicates a strong agreement between the forecast and observation, suggesting a high level of accuracy in predicting seasonal onset. Conversely, a low hit score implies a lack of agreement between the forecast and observation, indicating a lower level of accuracy.

$$hit\ score = \frac{correct\ forecast}{total\ forecast}$$

To gain a more comprehensive understanding of seasonal forecasts in Indonesia, we are not only evaluating the country's forecast as a whole, but we are also dividing the analysis based on the major islands of Sumatera, Jawa, Kalimantan, Sulawesi, Bali Nusra (Bali and Nusa Tenggara), and Malpap (Maluku Papua) shown in Figure 2. By doing so, we can observe the spatial distribution of the averages for each ZOM during both the wet and dry seasons. Additionally, we are comparing the results to those obtained using normal data to identify any potential anomalies or variations.
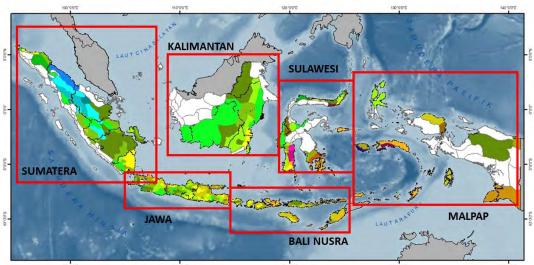

Figure 2. Big Island in Indonesia

Results and Future Tasks
Evaluation of Seasonal Onset Forecast Compared to Normal

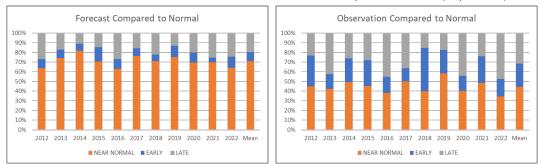Distribution of Seasonal Onset Forecast and Observation Compared to Normal (Dry Season)

Figure 3. Distribution of seasonal onset forecast and observation compared to normal for dry season

Dry season onset forecast and observation conditions are compared in Figure 3. On average, Near Normal is the dominant forecast condition (71%), followed by Later than normal (21%) and Earlier than normal (9%). However, observations are more diverse, with Near Normal being the largest (42%), followed by Later than normal (29%) and Earlier than normal (22%). In some years, observations show less Near Normal conditions and more early dry season conditions compared to the forecast. Meanwhile, Figure 4 shows the wet season onset forecast and observation conditions, which are more varied compared to the dry season. On average, Near Normal is the dominant forecast condition (61%), followed by Late (25%) and Earlier than normal (14%). However, observations show different conditions, with Near Normal being the largest (40%), followed by Late than normal (36%) and Earlier than normal (21%). Wet season onset forecasts are able to see variations in the beginning of the season, although some difficulties still exist in some years.
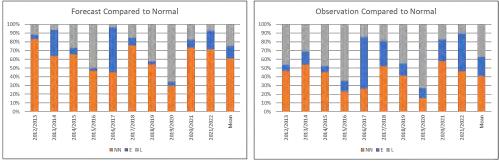
Distribution of Seasonal Onset Forecast and Observation Compared to Normal (Wet Season)

Figure 4. Distribution of seasonal onset forecast and observation compared to normal for wet season

Figure 5. Forecast and observation result near normal for dry season and wet season

Focusing on the Near Normal Seasonal Onset condition in Figure 5 reveals notable differences between the dry and wet seasons. In the dry season, the forecast value compared to the norm (65% - 90%) is much higher than the observation value (34% - 58%). On average, there is a 31% difference between the forecast and observation, with a correlation of 0.55. Meanwhile, for the wet season, the difference between the forecast and observation is smaller, with a 10-year average difference of 22% and a high correlation pattern of 0.9.
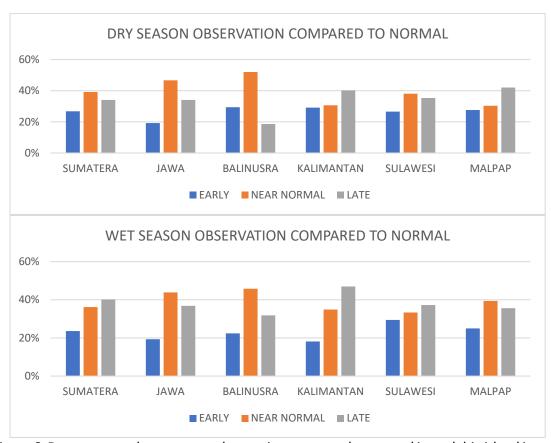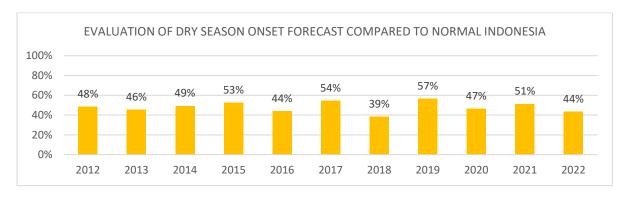
Figure 6. Dry season and wet season observation compared to normal in each big island in Indonesia

Figure 6 displays the average dry season observation compared to normal over ten years, revealing unique conditions on each major island. Sumatra and Sulawesi have balanced Early, Near Normal, and Late conditions, while Java and Bali Nusra have Near Normal dominance. Kalimantan and Malpap produce the beginning of the dry season late compared to the normal more than other phases. The average wet season onset observation compared to normal reveals regional differences.

Sumatra, Kalimantan, and Sulawesi consecutively phase from late than normal, near normal, and earlier than normal, while Java, Bali Nusra, and Malpap respectively show near normal, late than normal, and earlier than normal. No period in any region exceeds 50%.
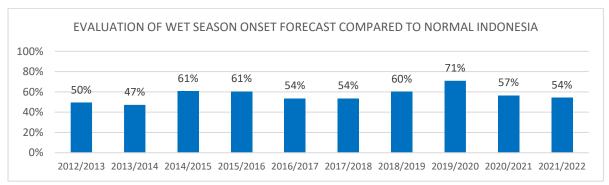
Figure 7. Evaluation of dry and wet season onset forecast compared to normal Indonesia

In Figure 7, evaluation values are presented for early dry season and early wet season forecasts from 2012-2022 compared to normal conditions. Dry season forecast evaluation values range from 40%-60% over the period, with the highest hit value of 57% in 2019 and the lowest value of 39% in 2018. Wet season forecast values compared to the norm range from 50%-60%, with the highest value in 2019-2020 at 71% and the lowest in 2013-2014 at 47%. This indicates that the wet season forecast is slightly better than the dry season forecast, which appears stagnant, possibly due to the dry season's sensitivity to global climate or intra-seasonal variability.
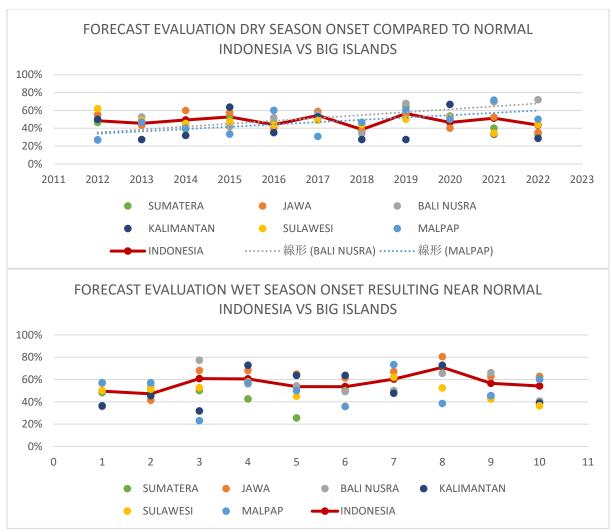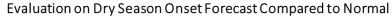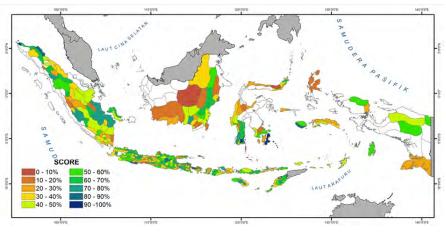
Figure 8. Evaluation of dry season onset forecast compared to normal Indonesia and Indonesia's Big Island (top) and wet season onset forecast compared to normal Indonesia and Indonesia's Big Island (bottom)

Figure 8 compares dry and wet season onset forecasts to normal for Indonesia and its major islands. Indonesia falls in the middle, while Kalimantan and Maluku Papua typically have the worst predictions. Java and Sulawesi produce consistent, often better, forecasts. Positive trends in the evaluation of the dry season can be seen in Maluku Papua and Bali Nusra. In the evaluation of wet season onset forecasts, Java consistently scores above 60%, while other regions vary yearly. No major island has shown a positive trend over the past decade. Figures 9 and 10 show hit score distributions. The equator produces the lowest scores for dry and wet season onset forecasts, while southern Indonesia scores better. Java is the only region consistently scoring in the 50%-90% range for wet season onset forecasts. The best overall score range is 40%-70%, with more members for the wet season range. Wet season forecasts also have a larger percentage of ZOMs with scores >80%, with 16 compared to 10 for the dry season.

Evaluation on Dry Season Onset Forecast Compared to Normal
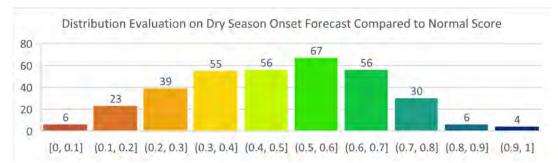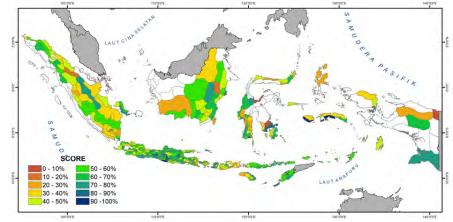
Figure 9 Spatial distribution and graph distribution of evaluation on dry season onset forecast compared to normal

Evaluation on Wet Season Onset Forecast Compared to Normal
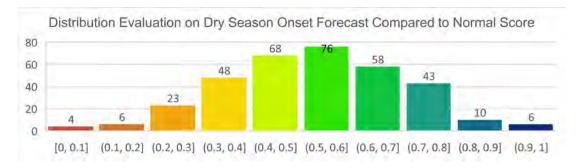
Figure 10.   Spatial distribution and graph distribution of evaluation on wet season onset
forecast compared to normal

Evaluation of Seasonal Onset Forecast
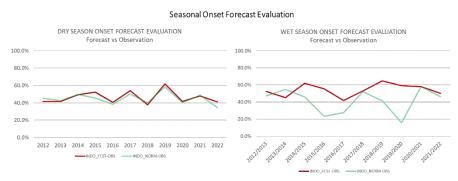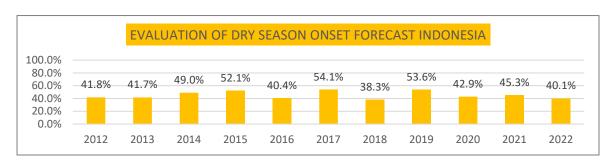
Figure 10.   Spatial distribution and graph distribution of evaluation on wet season onset
forecast compared to normal

In the dry season onset forecast evaluation (figure 10), it can be seen that the BMKG's predicted value and the normal predicted value are almost the same in the range of 40% - 60%. The two prediction values are very similar with a 10-year average difference between them of only ±1%. Meanwhile, in the evaluation of the wet season onset forecast, there is a significant difference between the BMKG prediction and the normalized prediction. The largest gaps between predictions and predictions using the normals are in the 2015/2016 period with a difference of 32% and 2019/2020 with a difference of 44%.
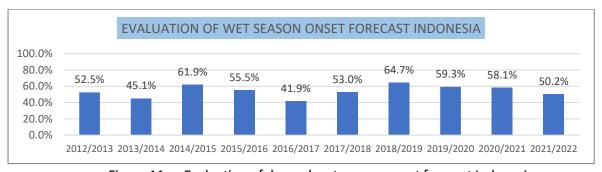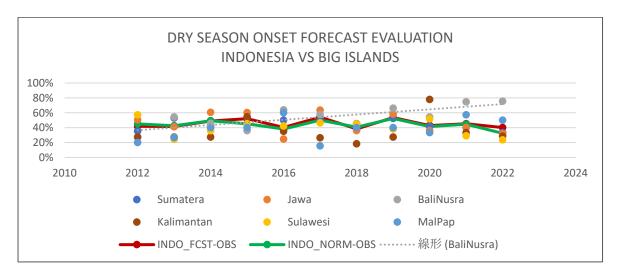
Figure 11.   Evaluation of dry and wet season onset forecast Indonesia

The evaluation of seasonal onset forecasts in the dry season and wet season is shown in the two graphs Figure 11 above. In general, it can be seen that the predicted value of the beginning of the rainy season is slightly better than the prediction of the beginning of the dry season with an average difference between the two being 9% better for the wet season. In the dry season onset forecast, the forecast range for the last 10 years is in the range of 40% - 55%, with the lowest forecast value in 2018, while the highest forecast value is in 2017. Meanwhile, in the wet season onset forecast, the forecast range over the past 10 years is in the range of 40% - 65%, with the dominance of wet season forecast results being above 50%.   Just like the dry season onset forecast, the wet season onset forecast tends to fluctuate in the last 10 years and for the last four years shows a downward trend.

For the dry season onset forecast evaluation between Indonesia's forecast (Figure 12), generally the Indonesian forecast is at the middle value compared to the other islands, as is the Indonesian forecast using normalized data. For the forecast evaluation of each island, the percentage spread across all islands each year is relatively large with a range of 40%. Some islands produce poor percentages each year, such as the islands of Kalimantan, Sulawesi, and Maluku Papua, which most years are in the range below 50% and worse than the national percentage. Some regions are better at predicting dry season onset, such as the BaliNusra region, which is often above 50%, better than the national percentage, and has a significant positive trend increase in the last 10 years.
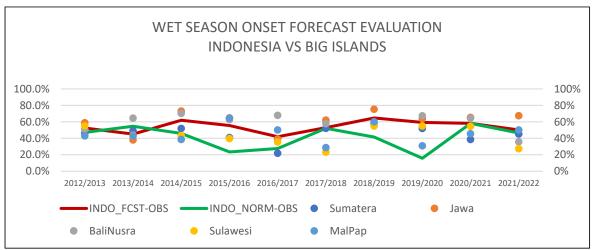
Figure 12. Dry season onset forecast (top) and wet season onset forecast (bottom) evaluation in Indonesia and its big island

Meanwhile, the evaluation of the wet season onset forecast shows more varied results. The national forecast evaluation is still the middle value compared to each island. Meanwhile, if we look at the evaluation of the national forecast using the normals, it can be seen that in many years the wet season onset forecast results are very poor. This is especially clear in the years 2015/2016, 2018/2019, and 2019/2020 where the forecasts using normals are the worst forecasts compared to the national and all islands with a small percentage. For the evaluation on each island, the whole island does not show consistent values each year with fluctuating percentages. Some areas dominated by forecasts with values >60% include Java and BaliNusra.
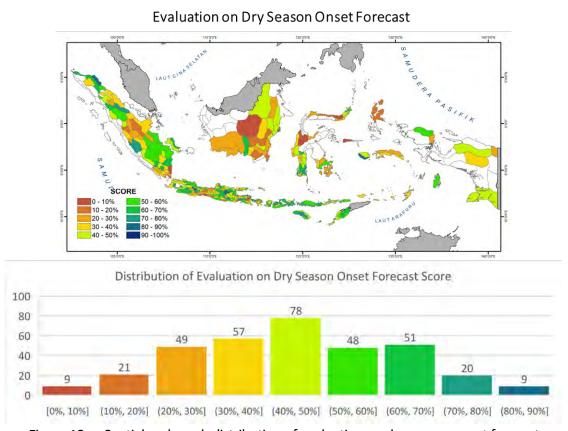
Figure 13.   Spatial and graph distribution of evaluation on dry season onset forecast

The dry season onset displays spatial heterogeneity, as depicted in Figure 13 In comparison to the normal onset, the equatorial Indonesian region (including Sumatra, Kalimantan, Sulawesi, and Maluku islands) exhibits the poorest forecast evaluation scores (0-40%). Additionally, central Java exhibits subpar scores, while southern Sumatra, western and eastern Java, Bali, and Nusa Tenggara attain relatively higher scores. The distribution score ranges from 40% to 50%, with only 9 ZOM surpassing a score of 80%.

The wet season onset evaluation (Figure 14) displays superior spatial and distributional scores in comparison to the dry season onset. The equatorial regions, including Kalimantan, Sulawesi, Maluku, and Papua, exhibit the lowest scores (10-30%), along with southern Sumatra. Conversely, central Java, Bali, and Nusa Tenggara manifest higher scores (50-90%). The highest score in the distribution ranges from 40-50%, while the highest distribution score ranges from 40-70%. The wet season onset forecast outperforms the dry season onset, with 21 ZOM surpassing a value of 80%.

Evaluation on Wet Season Onset Forecast
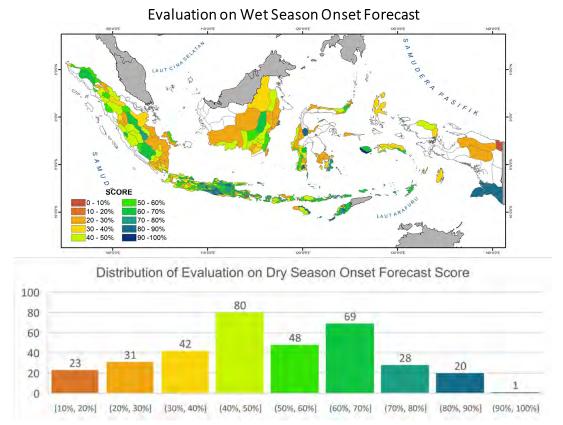
Figure 14.   Spatial and graph distribution of evaluation on wet season onset forecast

Conclusion

In conclusion, the study compared the dry season onset forecast and observation conditions with the wet season onset forecast and observation conditions in Indonesia. The results showed that the Near Normal condition was the dominant forecast condition for both dry and wet seasons, with the wet season showing more variation in the beginning of the season. The study also revealed that there were notable differences between the dry and wet seasons, with the dry season forecast value compared to the norm being much higher than the observation value. The average wet season onset observation compared to the normal revealed regional differences, with Sumatra, Kalimantan, and Sulawesi showing late, near normal, and earlier than normal phases. In contrast, Java, Bali Nusra, and Malpap showed near normal, late than normal, and earlier than normal phases. The study also evaluated the dry and wet season onset forecast compared to normal conditions and found that the wet season forecast was slightly better than the dry season forecast. Finally, the study compared the evaluation of dry and wet season onset forecasts for Indonesia and its major islands and found that Java consistently scored above 60%, while other regions varied yearly. The equator produced the lowest scores for dry and wet season onset forecasts, while southern Indonesia scored better. The study provides important insights into the onset of the dry and wet seasons in Indonesia and can help improve forecasting models and decision-making processes.

Future Task

Over the past decade, the BMKG's seasonal forecasts have been subject to limitations stemming from the availability of datasets and methodologies. Moreover, the forecasting process and algorithms have not been refined, and there has been insufficient analysis of the local climate conditions in the relevant regions. This evaluation aims to highlight these shortcomings, with the expectation that it will catalyse an improvement in the quality of BMKG's seasonal forecasts going

forward. The following research paragraph proposes three future plans to enhance the accuracy of early season predictions using ZOM. The first plan is to disseminate the new ZOM9120 that uses the normal 1991-2020 compared to the outdated ZOM8110. The new ZOM incorporates better datasets and methods, which are expected to provide more reliable results. The second plan is to compare the performance of the ZOM 9120 with ZOM 8110 to identify the strengths and limitations of each model. Lastly, the research proposes to improve the evaluation process by implementing various methods such as machine learning and deep learning. These methods are expected to improve the accuracy of early season predictions, which can provide valuable insights for decision-makers in various industries.

Ⅱ. Monsoon variability study
Case Study on Dry and Wet Season's Rainfall Variability
Muhammad Agfi Isra Ramadhan and Rosi Hanif Damayanti

Introduction
Background

  Indonesia's climate diversity is caused by its strategic geographical location in the tropics, between the Asian and Australian Continents, the Pacific and Indian Oceans, and passed by the equator [1]. Global phenomena such as El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) and regional phenomena such as Asia-Australia monsoon wind circulation, Inter Tropical Convergence Zone (ITCZ), and sea surface temperature conditions also affect Indonesia's climate. ENSO is a global ocean-atmosphere interaction system that causes sea surface temperature anomalies in the Equatorial Central Pacific.

  El Niño occurs when there is a positive temperature anomaly and La Niña occurs when there is a negative anomaly. ENSO is a cyclical pattern of climate variability in the eastern equatorial Pacific, that is characterized by anomalies in both sea surface temperature (SST; referred to as El Niño and La Niña for warming and cooling periods, respectively) and sea-level pressure (Southern Oscillation) [2]. Some paper stated that Indonesian rainfall is coherent and strongly correlated with ENSO variations in the Pacific basin [3,4]. However, the impact of El Niño and La Niña is not evenly distributed across Indonesia due to its vastness and each region has its own characteristics thus should be investigated individually [5].
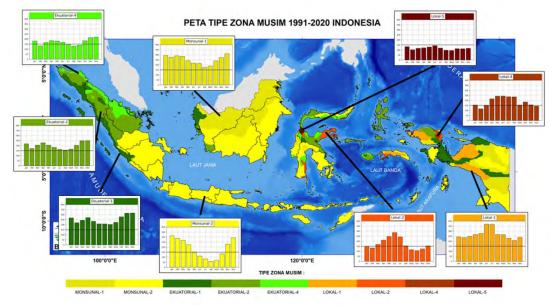
Figure 1. Indonesia climate region (Zona Musim or ZOM) Map

  Since 2022, BMKG has released a new climate region or Zona Musim (ZOM) [6] that divided Indonesia into 699 ZOMs based on the normal rainfall for the 1991-2020 period (Figure 1). These zones are categorized into three types of seasonal zones: Monsoonal, Equatorial, and Local. The Monsoonal ZOM type has an annual rainfall pattern with one period of highest rain and one period of lowest rain, with the highest rainfall occurring during the Asian monsoon period. Monsoonal ZOMs are further divided into Monsoonal-1 and Monsoonal-2 sub-types, which have only one season and two seasons respectively. The Equatorial ZOM type has an annual rainfall pattern with two rain peaks

and consists of Equatorial-1, Equatorial-2, and Equatorial-4 sub-types, with one, two, and four seasons respectively. The Local ZOM type has an annual rainfall pattern different from the monsoon and equatorial types, with one period of high rainfall and one period of low rainfall, but the highest rainfall does not occur during the Asian monsoon period. The Local ZOM type consists of Local-1, Local-2, Local-4, and Local-5 sub-types, with one, two, four, and only dry season periods respectively.

This unique regional climate variability in Indonesia presents a challenge for BMKG to provide accurate and comprehensible climate information, crucial for policy-making across sectors to improve welfare. Therefore, it is imperative to enhance climate forecast accuracy by analyzing climate variability patterns and their atmospheric-oceanic drivers. This study focuses on analyzing dry and wet season variability in JABAR 31 ZOM and JATENG 24, with a monsoonal climate type, as a pilot project to the other 697 ZOMs.

Data and Method

This study employs several datasets to investigate the variability of precipitation in ZOM JABAR 31 and ZOM JATENG 24, located in the center of West Java and in the central north of Central Java, respectively shown in figure 2. Each of ZOM has Monsoonal-2 type which has one wet season peak and one dry season peak. Precipitation data from 1991-2022 are obtained in dekad format, utilizing a gridded dataset that blends observations with CHIRP satellite data. Additionally, the onset of the dry and wet seasons during the same period is analyzed, as well as the normal precipitation during 1991-2020 and the normal onset of the dry and wet seasons from 1981-2010.
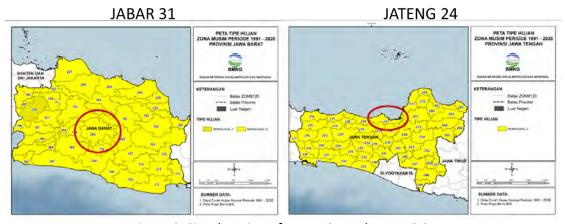
Figure 2. Sites location of JABAR 31 and JATENG 24

Furthermore, the Oceanic Niño Index (ONI) [7], a widely used indicator of the El Niño-Southern Oscillation (ENSO), is used as an external forcing to provide a comprehensive understanding of the precipitation variability in the aforementioned ZOMs. The Oceanic Niño Index (ONI) showed in figure 3 is currently the prevailing standard used by NOAA to classify El Niño (warm) and La Niña (cool) events in the eastern tropical Pacific. The ONI calculates the running 3-month mean SST anomaly for the Niño 3.4 region, which is between 5oN-5oS and 120º-170ºW. To be classified as an event, five consecutive overlapping 3-month periods should have anomalies that are at or above +0.5º for warm (El Niño) events or at or below -0.5 anomaly for cool (La Niña) events. The threshold is further categorized into Weak (0.5 to 0.9 SST anomaly), Moderate (1.0 to 1.4), Strong (1.5 to 1.9), and Very Strong (≥ 2.0) events. To be classified as weak, moderate, strong or very strong, an event must meet or exceed the threshold for at least three consecutive overlapping 3-month periods, as required for the purpose of this report.
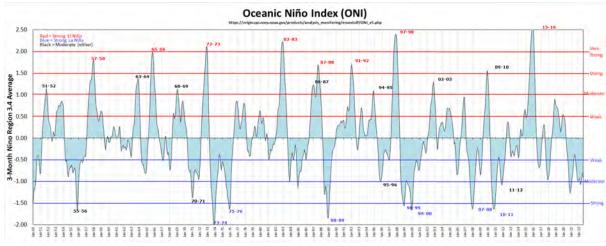
Figure 3. Oceanic Niño Index

The method that used in this study, firstly involved calculating the observed rainfall value in ZOM JABAR 31 and ZOM JATENG 24. This was done using the average rainfall value from all of the grids in each ZOM. The observed dry season onset and retreat were identified using the criteria defined by BMKG. The dry season onset was defined as less than 50mm/dasarian, followed by two dekad after that, while dry season retreat was defined as 1 dekad before the next wet season onset. Similarly, the observed wet season onset and retreat were identified using the criteria defined by BMKG, with the wet season onset defined as rainfall more than 50 mm/dekad followed by two dekad, and wet season retreat defined as 1 dekad before the next dry season onset.

Standard deviation was used to analyze the variation of observed dry and wet season onset and retreat to its normal in ZOM JABAR 31 and JATENG 24.

$$\sigma = \sqrt{\frac{\sum(x - \mu)^2}{N}}$$

σ : standard deviation

x : value of each data

μ : mean

N : number of data

Additionally, standard deviation and coefficient of variation were used to analyze dry and wet season's cumulative rainfall in ZOM JABAR 31 and ZOM JATENG 24.

$$CV = \frac{\sigma}{\mu}$$

CV : coefficient of variation

σ : standard deviation

μ : mean

Linear regression was also used to analyze the trend of dry and wet season's cumulative rainfall in ZOM JABAR 31 and ZOM JATENG 24 from 1991 – 2021.

$$y = ax + b$$

y : dependent variable

x : independent variable

a : slope or gradient (increasing / decreasing rate)

b : y-intercept (level of y when x is 0)

The Mann-Kendall Trend Test was used to test the trend of dry and wet season's cumulative rainfall in ZOM JABAR 31 and ZOM JATENG 24 during 1981-2021, with a significance level of 95%. Finally, composite and average of ENSO phenomenon were used to analyze the relation between rainfall and ENSO during 1991 – 2019.

Results and Future Tasks
Results
a) ZOM JABAR 31

Table 1. Dry Season Onset Variation ZOM JABAR 31

Dry Season (JABAR 31)		
Standard Deviation	3.1	
Onset (Dekad)	Count	Total
JAN I	1	
JAN II	0	
JAN III	0	
FEB I	0	
FEB II	0	
FEB III	1	
MAR I	0	17
MAR II	0	
MAR III	0	
APR I	1	
APR II	1	
APR III	6	
MAY I	7	
MAY II	6	Normal
MAY III	3	
JUN I	2	8
JUN II	3	
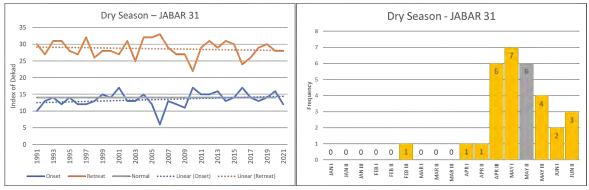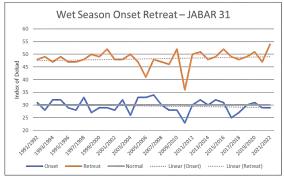
Figure 4. Variation (left) and distribution (right) of dry season onset in ZOM JABAR 31 compared to its normal condition

The dry season onset in JABAR 31 varies greatly, ranging from 2 to 17 decades with a standard deviation of 3.1, as shown in table 1 and figure 4. In terms of early onset, the furthest was in 2006 (JAN I), which was 13 dekad earlier than the norm, while the furthest late onset was in 2016 (JUN II), which was 3 decades late compared to the norm. When compared to the norm, early onset dominates with 17 decades, while late onset has only 8 decades and normal onset has 6 decades. The longest dry season occurred in 1997 for 28 dry season periods, while the shortest was in 2010 for only 6 dekad. Analysis of the period and trend of dry season onset and retreat shows a tendency towards a shorter dry season period from 1991-2021.

Table 2. Wet Season Onset Variation ZOM JABAR 31

Wet Season (JABAR 31)		
Standard Deviation	2.6	
Onset (Dekad)	Count	Total
AUG II	1	
AUG III	0	
SEP I	1	
SEP II	1	15
SEP III	2	
OCT I	5	
OCT II	5	
OCT III	4	Normal
NOV I	3	
NOV II	5	
NOV III	3	12
DEC I	1	
DEC II	0	
DEC III	0	
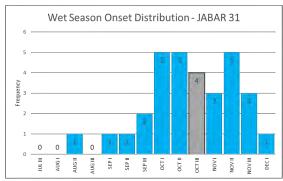
Figure 5. Variation (left) and distribution (right) of wet season onset in ZOM JABAR 31 compared to its normal condition

Table 2 and figure 5 display the wet season onset conditions, which have a lower standard deviation than the dry season onset at 2.6. The furthest wet season onset from normal occurred in 2011/2012 in AUG II, 7 dekad earlier than usual, while the latest dry season onset from normal occurred in 2007/2008 in DEC I, 4 dekad later than usual. Earlier than normal conditions dominate

with 15 events, followed by later than normal conditions with 12 events, and 4 years with normal conditions. The wet season onset varies between dekad 22-32, and the wet season retreat varies between dekad 36-52 (dekad 16 in the following year). The longest period occurred in 2009/2010 with 25 dekadal periods, while the shortest period occurred in 2005/2006 with 9 decadal periods. The trend shows that the wet season period is increasing over the years.

Table 3. JABAR 31 Rainfall

JABAR-31 Rainfall	Dry Season	Wet Season
Normal (1991-2020)	324	1545
Standard of Variation	132.11	384.62
Coefficient of Variation	0.40	0.24
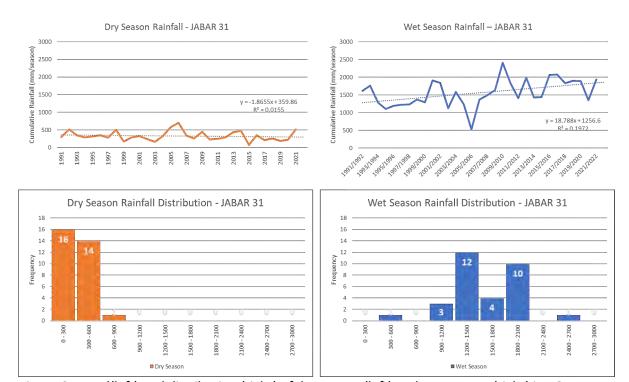
Figure 6. Trend(left) and distribution (right) of dry season (left) and wet season (right) in ZOM JABAR 31

Rainfall in ZOM JABAR 31 is summarized in table 3 and figure 6 Normal rainfall for the dry season is 324 mm and for the wet season is 1545 mm, with variations of 132.11 mm and 384.62 mm, respectively. The dry season mostly has rainfall in the range of 0 - 300 mm for 16 years, with the lowest CH value in 2015 (67 mm, -80% anomaly). Wet season rainfall is mostly in the range of 1200 - 1500 mm for 12 years, with the highest CH value in 2019 - 2020 (2460 mm, +60% rainfall). Trends show a significant decrease for the dry season and a significant increase for the wet season.

Table 4 El Niño effect in JABAR 31

| El Niño | Event | Prec | Normal Onset | Observed | | Period |
				Onset	Retreat	
Dry Season	WE	441	14	12	31	21
	ME	326	14	12	30	19
	SE	213	14	12	31	20
	Norm 9120	324	14	16	29	16
Rain Season	WE	1483	30	32	48	17
	ME	1545	30	31	50	20
	SE	1638	30	32	49	19
	Norm 9120	1545	30	24	49	20
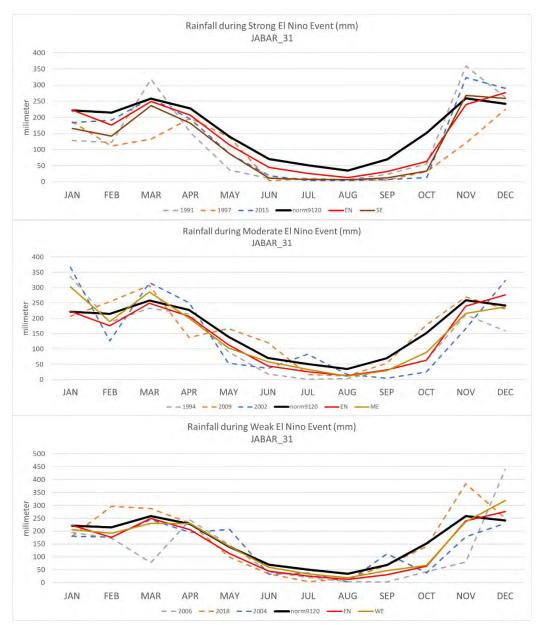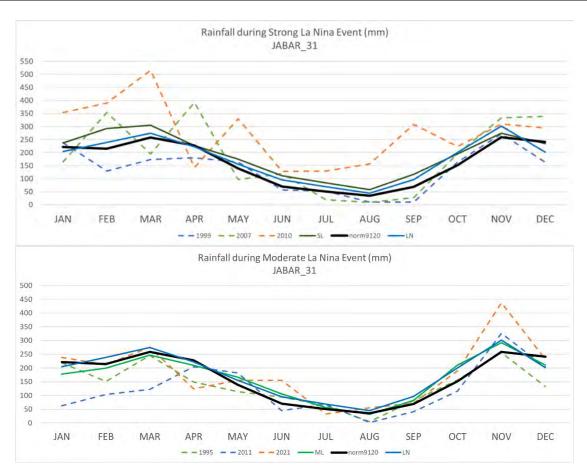
Figure 7 Rainfall during Strong El Niño (Top), Rainfall during moderate El Niño (Middle), Rainfall during weak El Niño (Bottom)

El Nino impacts rainfall and seasonal conditions in JABAR 31. Figure 7 shows that it reduces rainfall in the range of -10mm to -88mm per month on average, with strong El Nino having the most significant effect. Rainfall is below normal for all months, except November. Moderate and weak El Nino have little impact, except from January to April. However, all El Nino phases reduce rainfall from June to November. El Nino also affects the season, causing an earlier start and longer dry season period during the dry season, and a later start and slightly shorter rainy season period during the wet season, according to Table 4.

Table 5 La Niña effect in JABAR 31

| La Niña | Event | Prec | Normal Onset | Observed | | Period |
				Onset	Retreat	
Dry Season	**WL**	335	14	14	27	15
	ML	261	14	15	28	14
	SL	310	14	15	26	13
	Norm 9120	324	14	14	30	16
Rain Season	**WL**	1593	30	28	47	20
	ML	1472	30	29	48	20
	SL	1490	30	27	49	23
	Norm 9120	1545	30	30	50	20

Rainfall during Strong La Nina Event (mm) JABAR_31


Rainfall during Moderate La Nina Event (mm) JABAR_31
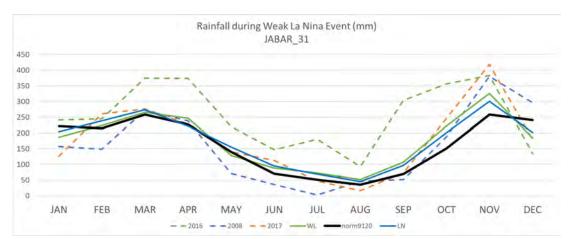
Figure 8 Rainfall during Strong La Niña (Top), Rainfall during moderate La Niña (Middle), Rainfall during weak La Niña (Bottom)

La Nina conditions do not show a significant increase in rainfall compared to the norm, as depicted in Figure 8. Moderate La Nina and Weak La Nina phases also show close to normal average rainfall. Strong El Nino conditions may have above-normal average rainfall, but some years, such as 1999 and 2007, show inconsistency in the influence of this phase on rainfall. Strong La Nina in 2010 and Weak La Nina in 2016 produced very high rainfall anomalies. However, the influence of La Nina on seasonal conditions in the JABAR 31 region is not significant, as shown in table 5. There is no significant change in the beginning and period of each season, except for the Strong La Nina event, which has a shorter dry season period due to the earlier end of the dry season and a longer rainy season period due to the earlier start of the wet season.

b) ZOM JATENG 24

Table 6 Dry Season Onset Variation ZOM JATENG 24

Dry Season (JATENG 24)		
Standard Deviation	3.3	
Onset (Dasarian)	Count	Total
MAR II	2	
MAR III	1	11
APR I	3	
APR II	5	
APR III	6	Normal
MAY I	4	
MAY II	4	
MAY III	0	
JUN I	1	
JUN II	2	
JUN III	1	15
JUL I	0	
JUL II	0	
JUL III	1	
AUG I	1	
AUG II	0	

AUG III	0
SEP I	0
SEP II	0
SEP III	0
OCT I	1
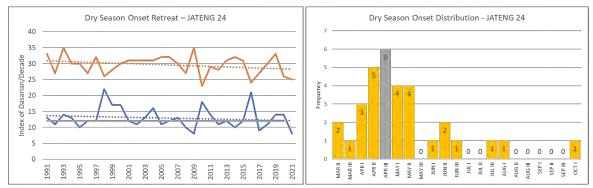
Figure 9 Variation (left) and distribution (right) of dry season onset in ZOM JATENG 24 compared to its normal condition

Table 6 and Figure 9 illustrate the dry season onset and retreat in ZOM JATENG 24. The variability in JATENG 24 is quite substantial with a standard deviation of 3.3 dekad. Moreover, the farthest occurrence of delayed onset from normal was in 2016, specifically in the OCT I decad, resulting in a delay of 16 dekad from the norm. Similarly, the farthest event of an early onset was observed in 2009, precisely in the MAR II decad, with a deviation of 5 dekad from the norm. Late onsets were prevalent from 1991-2021, with 15 instances, followed by early onsets, which occurred 11 times. From the trends in dry season onset and retreat, it can be observed that the dry season period in JATENG 24 is decreasing every year.

Table 7 Wet Season Onset Variation ZOM JATENG 24

| Wet Season (JATENG 24)		
Standard Deviation	3.0	
Onset (Dasarian)		
AUG III	1	
SEP I	1	
SEP II	1	
SEP III	2	12
OCT I	4	
OCT II	2	
OCT III	1	
NOV I	5	Normal
NOV II	6	
NOV III	4	
DEC I	2	14
DEC II	0	
DEC III	2	
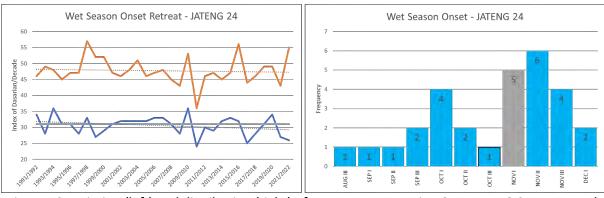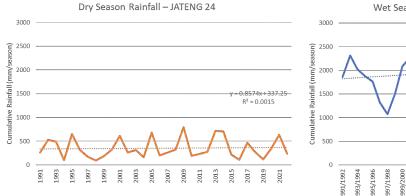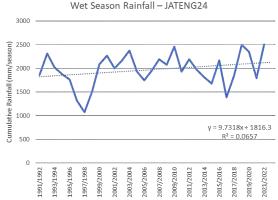
Figure 10 Variation (left) and distribution (right) of wet season onset in ZOM JATENG 24 compared to its normal condition
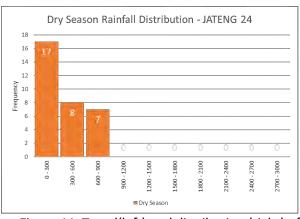
Table 7 and figure 10 illustrate the wet season onset and retreat in ZOM JATENG 24, which shows a standard deviation of 3.0 that is not significantly different from the dry season. The earliest value occurred in August III of 2011/2012 with a deviation of 7 dekad from the norm, while the farthest value in late than normal condition is 3 dekad from the norm in December I of 2009/2010. Late than normal conditions dominate the wet season onset with 14 dekad compared to the norm, followed by 12 dekad of earlier than normal conditions, and 5 dekad of normal conditions. There appears to be a slight trend of increasing the rainy season period in JATENG 24 from year to year based on the wet season onset and retreat conditions.

Table 8. JABAR 31 Rainfall

Rainfal JATENG-24	Dry Season	Wet Season
Normal (1991-2020)	346	1610
Standard Deviation	209.87	333.44
Coefficient of Variation	0.58	0.20
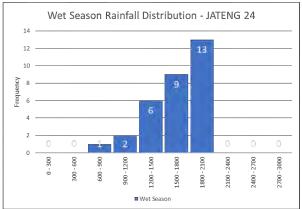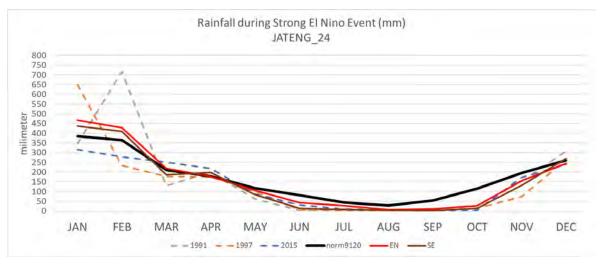
Figure 11. Trend(left) and distribution (right) of dry season (left) and wet season (right) in ZOM JATENG 24

Table 8 and Figure 11 illustrate that the average rainfall in JATENG-24 during the dry season is typically around 346mm, while during the wet season it's around 1610mm. The variability in rainfall during the dry season in this region is quite substantial, with a standard deviation of 209.87 and a coefficient of variation of 0.58. In contrast, the variability during the wet season is much smaller, with a standard deviation of 333.44 and a coefficient of variation of only 0.20. During the dry season, the rainfall distribution ranges from 0 to 300mm for 17 years, with the lowest rainfall recorded in 1998. In contrast, the wet season rainfall distribution is much narrower, ranging from 1800 to 2100mm, with the highest rainfall recorded in 2021. Over the period from 1991 to 2022, there has been a slight downward trend in dry season rainfall, although this trend is not statistically significant. Conversely, there has been a slight upward trend in wet season rainfall, which is also not statistically significant.

Table 9 El Niño effect in JATENG 24

| El Niño | Event | Prec | Normal Onset | Observed | | Period |
				Onset	Retreat	
Dry Season	**WE**	332	12	12	31	20
	ME	386	12	11	32	22
	SE	215	12	12	32	21
	Norm 9120	346	12	12	30	19
Rain Season	**WE**	1210	31	32	47	16
	ME	1465	31	33	49	17
	SE	1374	31	33	53	21
	Norm 9120	1610	31	31	48	17

In JATENG 24, the impact of El Nino differs slightly from JABAR 31. Figure 12 shows that El Nino does not typically reduce rainfall in this area from January to April, and in some El Nino years, rainfall tends to be higher than normal during this period. However, from May to December, there is a reduction in rainfall, with the strongest influence seen in the Strong El Nino phase. The Weak El Nino phase tends to produce rainfall that is close to normal. Table 9 shows that El Nino events, especially Strong El Nino, result in a 37% decrease in rainfall during the dry season, and a 15% decrease during the wet season. Strong El Nino also causes an additional dry and wet season period compared to the norm. Other El Nino phases also cause a decrease in rainfall, but there is no change in the seasonal period compared to the normal.
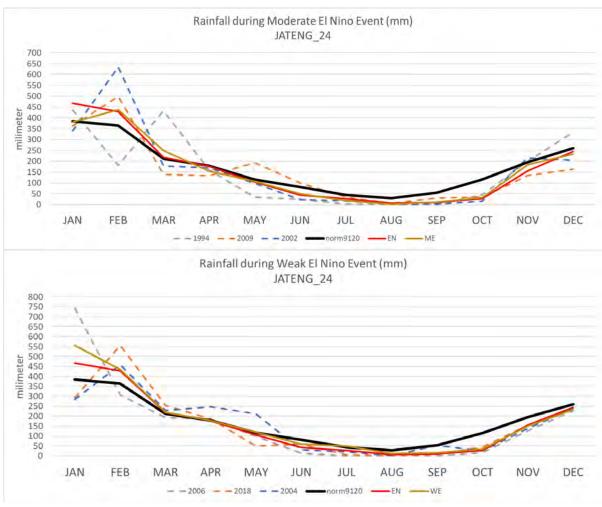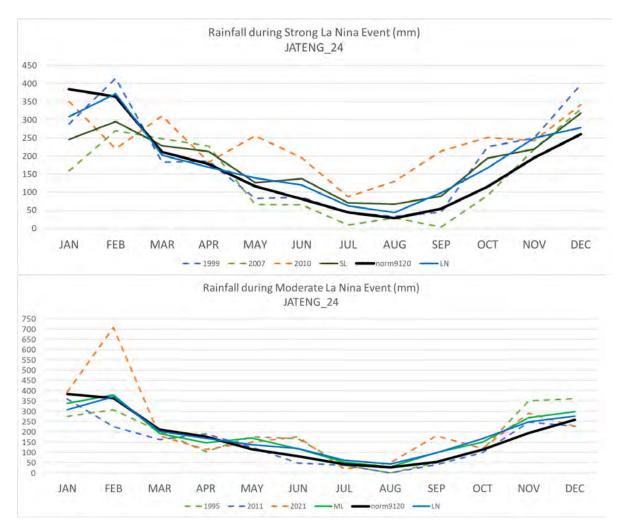
Figure 12 Rainfall during Strong El Niño (Top), Rainfall during moderate El Niño (Middle), Rainfall during weak El Niño (Bottom) in JATENG 24

La Nina has a similar effect in JATENG 24 as in JABAR 31 (Figure 13). It doesn't significantly impact rainfall from January to May but leads to a slight increase in rainfall from May to December. Strong La Nina causes a considerable increase in rainfall from March to December, but the results are inconsistent in sample years. Only in 2010, did rainfall show a large positive anomaly, while in other

years, it remained close to normal. Rainfall in La Nina Moderate and Weak phases also remained close to normal. Strong La Nina (2010) and Weak La Nina (2016) resulted in increased rainfall in several months in this region, similar to JABAR 31. In Strong La Nina, there's an average 22% increase in rainfall with an additional rainy season period in JATENG 24.

Table 10. La Niña effect in JATENG 24

| La Niña | Event | Prec | Normal Onset | Observed | | Period |
				Onset	Retreat	
Dry Season	**WL**	379	12	14	28	15
	ML	409	12	13	28	17
	SL	185	12	19	27	8
	Norm 9120	346	12	12	30	19
Rain Season	**WL**	1708	31	29	45	17
	ML	1678	31	29	47	17
	SL	1973	31	28	46	20
	Norm 9120	1610	31	31	47	17

Rainfall during Strong La Nina Event (mm) JATENG_24


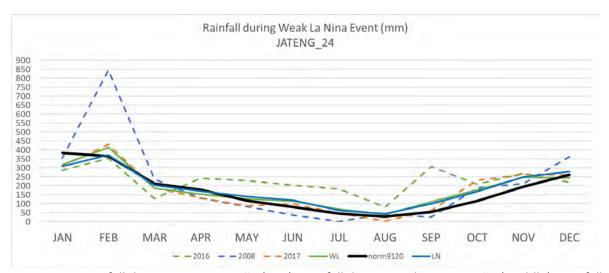Rainfall during Moderate La Nina Event (mm) JATENG_24

Figure 13 Rainfall during Strong La Niña (Top), Rainfall during moderate La Niña (Middle), Rainfall during weak La Niña (Bottom) in JATENG 24

Summary

JATENG_24 and JABAR_31 are two regions in Indonesia that experience distinct rainfall patterns. JATENG_24 has a longer dry season and a shorter rainy season compared to JABAR_31. Furthermore, JATENG_24 experiences an earlier onset of dry season in April and a later onset of rainy season in November compared to JABAR_31, which experiences these seasons in May and October, respectively. Both regions exhibit a significant difference in the amount of rainfall during the dry season (~400 mm) and wet season (~1500-1600 mm).

This study found that both JABAR_31 and JATENG_24 are undergoing a reduction in the duration of the dry season and an increase in the duration of the wet season. In addition, there is a declining trend in dry season year-to-year rainfall and an increasing trend in wet season year-to-year rainfall in both regions. El Niño, a climate phenomenon that results in warmer sea surface temperatures in the Pacific Ocean, affects rainfall patterns in both JABAR_31 and JATENG_24, particularly in their dry seasons. However, JATENG_24 experiences no reduction in rainfall from January to April, which is within its wet season. In JABAR_31, El Niño results in changes in the onset and duration of the seasons, such as the addition of periods in the dry season and the reduction of periods in the rainy season. On the other hand, JABRA_31 experiences a reduction in rainfall during both the dry and rainy seasons due to El Niño.

La Niña, a climate phenomenon that results in cooler sea surface temperatures in the Pacific Ocean, has no significant impact on the rainfall patterns and seasonal variability in both regions. However, strong La Niña shows mixed results, particularly within the sample, while moderate and weak La Niña have almost no impact on the regions. In conclusion, JATENG_24 and JABAR_31 experience distinct rainfall patterns and are affected differently by climate phenomena such as El Niño and La Niña.

Future Task

The high variation of rainfall in each ZOM makes each region unique. From two regions with the same climate type, located on one island with a relatively close regional position, there are differences between the two, let alone regions with other climate types that are already much different from the pattern alone. Some regions have their own characteristics, sometimes not influenced by global climate factors but strongly influenced by local factors. Knowing the variability of each region is one of the important first steps to improve the quality of forecasts.

The current study represents a preliminary investigation into the rainfall variability of the ZOM region, and as such, there is much room for further research in this area. To this end, future plans include an assessment of the remaining 699 ZOMs, in order to better understand the overall pattern of rainfall variability in the region. Additionally, we will seek to explore potential linkages between ZOMs and other climatic parameters, such as the Indian Ocean Dipole (IOD) and the Inter-annual Oscillation (IAO). By incorporating the results of this research into the justification process of seasonal forecasting, we hope to provide more accurate and reliable predictions of future rainfall patterns in the ZOM region, which will be of great value to policymakers, resource managers, and stakeholders.

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Ⅲ. Sub-Seasonal to Seasonal Prediction Study

Novi Fitrianti and Damiana Fitria Kussatiti

Introduction

There are two terms of forecast time range that are already known by the weather and climate community. These are short-to-medium range forecast and long-range forecast. Traditionally, short-to medium time range is referred to as weather forecast covers the time range out to 14 days (up to 2 weeks) meanwhile long range forecast or climate forecast starts at a seasonal timescale and extends out (up to 3 – 6-month) [1]. For many years these two-time scale has been operational in some region while the extended-range forecasting timescales which in between this two-time scale, encompassing forecast ranges from 14 days to 60 days has minimal attention than medium range and seasonal prediction since it is notably difficult to provide skillful at this time range.

Sub-seasonal forecasting sits between weather and climate time scales, defined as the time range between two weeks to two months. This time range forecasting, also known as the extended-range timescale, is considered to bridge the gap between weather forecasts and monthly or seasonal outlooks [2]. There is a growing understanding of the necessity and the potential value of forecasts on the sub-seasonal timescale, which is the frontier of forecasting science. In short-term decision-making, weather forecasts are applicable, such as early warning and evacuation. In contrast, the seasonal outlook is useful as an adaptive strategy, mainly concerned with possible risks of extreme events. In other hand, sub-seasonal prediction can allow users to carry out mitigation, giving more time for preparedness activities and evacuation to reduce the risk of damage or loss of extreme events

In climate services, BMKG (Indonesian Agency of Meteorology, Climate and Geophysics) had provided 10-days basis forecast by using S2S model predictions since 2015. However, the validation of this prediction has not been carried out yet. The absence of validation in sub-seasonal prediction underlies this study. In addition, this case study is a component of JICA's key-activity (Climate change project Phase 2) project, Enhancing Seasonal Forecast; it is intended that by participating in this endeavor, BMKG would gain more credibility in its ability to offer the community trustworthy and practical climate information services.

Data and Method

We used the CPC Global Unified Gauge-Based Analysis of Daily Precipitation data provided by the NOAA PSL, Boulder, Colorado, USA, from their website at https://psl.noaa.gov to make the analysis product [3][4], which we later coupled with the rain-daily gauge's rainfall observations data. The BMKG database center, which receives daily updates in real-time from more than 7000 rain gauges around Indonesia, was used to collect the observational data. Daily CPC analysis data are preferable at illustrating Indonesia's rainfall when compared to other satellites and re-analysis data [5]. For this research, we also need daily climatological data (1991 to 2020) and CPC data, which are accessible from 1979 but have a 3-day delay or are not real-time data.

Across Indonesia, there are in addition up to 7000 rain gauge data networks. Nevertheless, not each of these rain gauges is accessible or functional. There are daily variations in the number of active rain gauges,

which is over 3000. Furthermore, Indonesia has a diverse distribution of rain gauges. Whereas in Papua, the network of rain gauges is less dense, we discovered that Java has a dense network (Figure 1). As a result, we combined data from CPC grids and rain gauge points using a geostatistical approach. The geostatistical method "Kriging External Drift" (KED) is used in this blending process. The external drift method is a particular case of universal kriging. The geo-statistical method is similar to that adopted by BMKG. We here use different input data to blend with rain-gauge data. The analysis product used by BMKG uses different data sources to provide rainfall anomalies, while in this experiment, we use the same data source. We exploited CPC gridded data since it available from 1979.
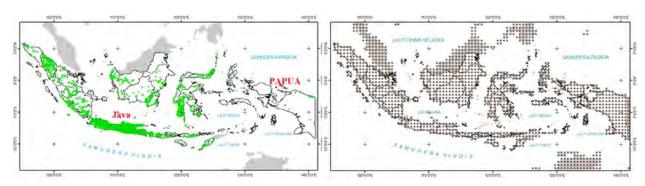
Figure 1. (a) left – rain-gauge distribution over Indonesia, (b) right – CPC gridded data

Nowadays, there are 11 operational research and centers who provided forecast and reforecast model data for sub-seasonal prediction which three of them took charge to archive S2S predictions (Table 1 and Table 2). Ten models are now accessible in the public S2S project database. This database is a crucial resource for improving understanding of the S2S time-scale.

Table 1. The three institutions responsible as archiving centers

Instituion	Start	Website
ECMWF	May 2015	https://apps.ecmwf.int/datasets/data/S2S
CMA (China Meteorological Adminstration)	Nov 2016	https://S2S.ecmwf.int
IRI (International Research Institute Data Library)	Nov 2016	https://iridl/ldeo.columbia.edu/SOURCES/.ECMWF/.S2S

Table 2. 11 institutions provide S2S predictions

institution	Country
The Australian Bureau of Meteorology (BoM)	Australia
The China Meteorological Administration (CMA)	China
The European Centre for MediumRange Weather Forecasts (ECMWF)	UK
Environment and Climate Change Canada (ECCC)	Canada
The Institute of Atmospheric Sciences and Climate of the National Research Council (CNR-ISAC)	Italy
The Hydrometeorological Centre of Russia (HMCR)	Rusia
The Japan Meteorological Agency (JMA)	Japan
The Korea Meteorological Adminstration (KMA)	Korea

Météo − France/Centre National de Recherche Meteorologiques (CNRM)	Fance
The National Centers for Environmental Prediction (NCEP)	USA
The Met Office (UKMO)	UK

The duration of the available reforecast data for the previous 20 years is used to make the most recent ECMWF predictions, which are made twice a week on Mondays and Thursdays with 51 ensemble members. However, for the reforecast, there are just 11 ensemble members available. The reforecast data is designed to calibrate any recently generated predictions to lessen model errors. We employ the hindcast forecast to evaluate the sub-seasonal prediction. Here, we only verify May to July during 2002 – 2021. We use this evaluation method by comparing observations with forecasts made before the target week. A prediction known as Lead-time 1 (LT1) was made on Thursday, three days before the target week. The predictions for Lead Time 2 (LT2), Lead Time 3 (LT3), and Lead Time 4 (LT4) are all made more than a week before the target week. This is depicted in Figure 2.
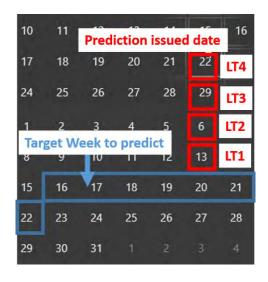
Figure 2. Prediction Issued date and target week illustration

We compare the ensemble mean of total rainfall predictions. Moreover, verification is carried out using the statistical method mean square skill score (MSSS) recommended by WMO for evaluation the deterministic forecast [6]. MSSS value is required and will provide a comparison of forecast performance relative to "forecasts" of climatology. The mean squared error of the forecasts is:

$$MSE_j = \frac{1}{n}\sum_{i=1}^{n}(f_{ij} - x_{ij})^2$$

where x and f denote for continuous deterministic forecasts and time series of observations, respectively. The MSE for climatology can be expressed as:

$$MSE_{cj} = (\frac{n}{n-1})^2 S_{xj}^2$$

$$S_{xj}^2 = \frac{1}{n}\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2$$

The Mean Square Skill Score is therefore given as:

$$MSSS_j = 1 - \frac{MSE_j}{MSE_{cj}}$$

To verify the probability of high rainfall, we use the Brier Score [7]. The Brier score is the mean of squared differences between those predictions and their corresponding event scores. Smaller scores (closer to zero) indicate better forecasts and can be expressed as :

$$Brier\ Score = \frac{1}{N}\sum_{i=1}^{nN}(F_t - O_t)^2$$

- N is the number of events (and, accordingly, predictions) under consideration
- t indexes the events/predictions from 1 to N (the first event, the second event, etc.)
- F_t is the forecast (a probability from 0 to 1) for the t_{th} event
- O_t is the outcome (0 or 1) of the t_{th} event

Result

Evaluation Is carried out from week 1 of May to week 4 of July. By comparing model data with observation data, we equalize the resolution size by gridding the data model, which has a spatial resolution of 1.5 degrees, and changing it to 0.5 degrees in accordance with the resolution of the observation data. According to a spatial analysis, month of May had a high MSSS value during the first week (LT1) throughout most of Indonesia before the skill dropped (LT2 to LT4). In June, elevated MSSS values were also observed during the first two weeks (LT1 and LT2) before declining during the third and fourth weeks. In several locations of Indonesia, we also discovered that the MSSS values were negative during the first week, indicating that the model's error was higher than the climatology's error.

In contrast, the prediction model for July indicates that high skill scores were present not just in the first and second weeks but also up to the fourth week. This demonstrates that the model, even four weeks before to the target week, can accurately estimate the total amount of rainfall. Furthermore, we spot that Papua, one of the biggest islands in the far eastern region of Indonesia, has a substantial inaccuracy even on LT1 and remains consistent up to LT4.

MEAN SQUARE SKILL SCORE
PREDIKSI TOTAL CURAH HUJAN
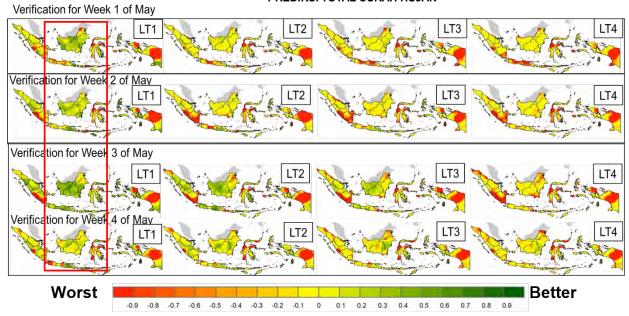
Figure 3. Spatial Analysis for MSSS on May (2002 - 2021)
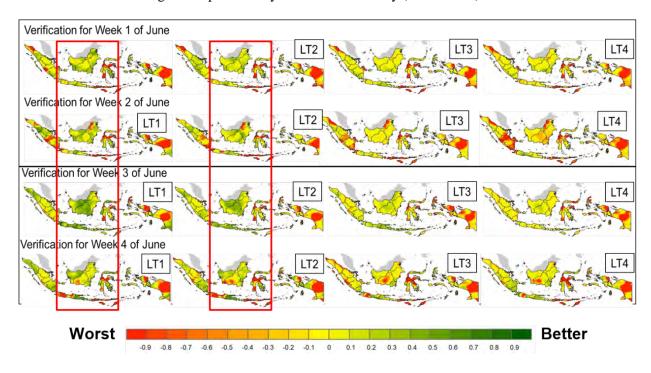
Figure 4. Spatial Analysis for MSSS on June (2002 - 2021)
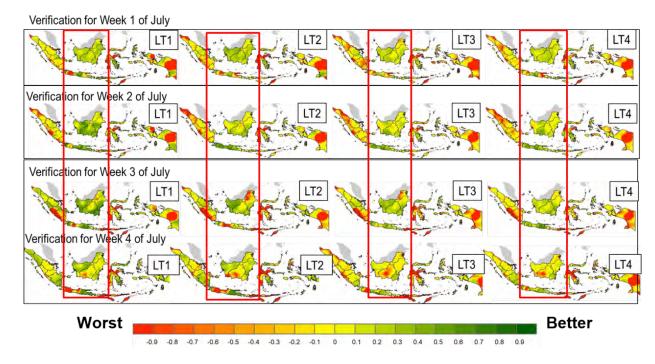
Figure 5. Spatial Analysis for MSSS on July (2002 - 2021)

The quantile 90 series data are used to define high rainfall, and the probability is then determined based on the proportion of members who exceed the quantile 90 threshold. Similar to total precipitation, we also assess the probability of high rainfall from May to July. The verification results demonstrate that in May, the Brier Score (BS) value is close to zero or exhibits great performance, as demonstrated in LT1, where almost all regions of Indonesia have a BS that is close to zero, which then falls spatially in LT2 and LT3. The model performs pretty well, which indicates that the S2S prediction can inform us about intense rainfall three weeks before the event.

While it was observed in June that the BS value was spatially comparable to the May verification at LT1, its performance declined at LT2 to LT4, but we discovered that at LT4 on the island of Java, the BS value was still favorable when compared to other locations. While July's performance is close to that of June's, it is interesting to note that Kalimantan and Sulawesi as well as Java continue to perform well at LT4. This demonstrates that the S2S prediction was able to indicate the possibility of heavy rain four weeks before to the incident.

**BRIER SCORE**
PREDICTION FOR PROBABILITY OF HIGH RAINFALL
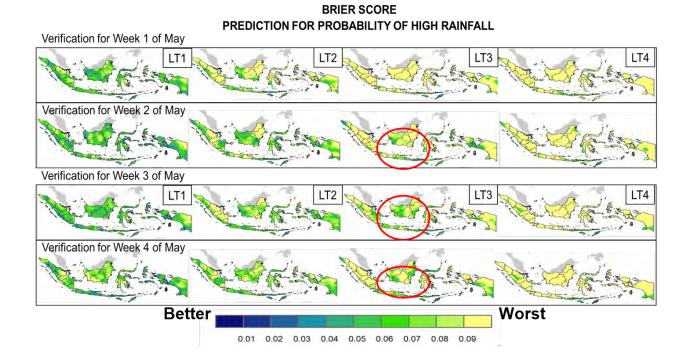
Figure 6. Spatial Analysis for BS on May (2002 - 2021)
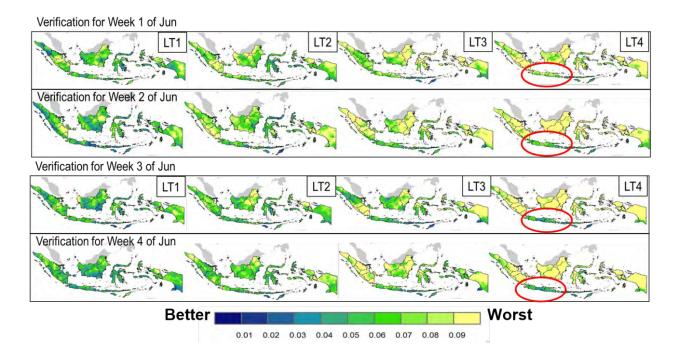
Figure 7. Spatial Analysis for BS on June (2002 - 2021)
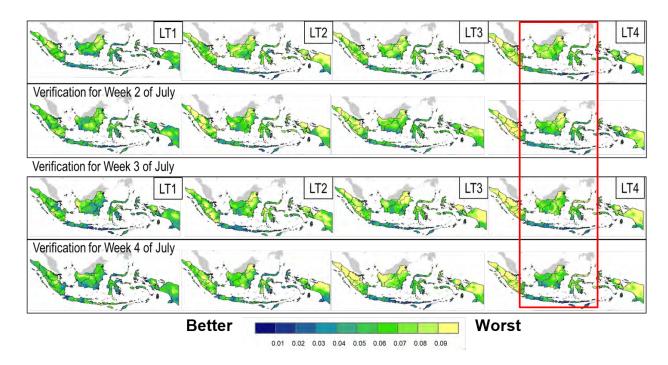
Figure 8. Spatial Analysis for BS on July (2002 - 2021)

In order to demonstrate the predictability of S2S prediction, we show three events in the case study shown in Figure 9 in which a climatic anomaly leads in a hydro - meteorological disaster. It has been demonstrated that the prediction model can accurately predict the occurrence of climate anomalies up to four weeks in advance. We found that the signal is strongest with a one-week lead time and present but weaker at two and three-week lead times. But the model depict the wet and dry condition well in four weeks before the target week.

Figure 9. Sub-seasonal predictability in predicting wet and dry condition

However, this model prediction would not be consistently accurate, we also discovered cases in which the model missed to predict the rainfall, even with a close lead-time, as demonstrated by the study of the third week of July (Figure 11t). This error is due to the strong influence of the sypnotic time scale <7 days, this variance provides a measure of weather disturbances such as the presence of Kelvin waves and equatorial Rossby waves [8][9]. That was a kind of anomaly based on a single day with a very high amount, not precisely what to be expected to predict at a sub-seasonal scale.

According to Indonesia's climate variability, which is significantly impacted by the MJO (Madden Julian Oscillation) and the Inter-annual phenomenon, Indonesia's climate can be predicted on a sub-seasonal scale [10]. The MJO is the most noticeable component of the tropical atmosphere's intra-seasonal (30- to

90-day) variability. This area of Indonesia largely corresponds areas where seasonal predictions or MJO impacts have been established [11][12].

	Heavy rainfall — 25 – 31 Juli 2022	Heavy rainfall — 01 – 07Agt 2022	Heavy rainfall — 08 – 14 Agt 2022
Why was the event a surprise?	Floods, tornadoes, and abrasion due to prolonged moderate to heavy rainfall, overflowing rivers, strong winds, and tidal waves	Floods and landslides caused by moderate to heavy rains, overflowing rivers, and unstable soil conditions were reported by the National Disaster Mitigation Agency (BNPB) in Southeast Sulawesi, Riau Islands, South Sumatra, West and Central Kalimantan, and North Sulawesi.	Floods, landslides and strong winds due to prolonged moderate to heavy rainfall, strong winds and overflowing rivers were reported by BNPB in South Sumatra, West Java, Central Java, East Java, South Sulawesi, Central Sulawesi, Southeast Sulawesi and Gorontalo Provinces in Indonesia
People Exposed	1 -10k people	10 -100k people	1 -10k people
Impacts :	Based on a report by the National Disaster Management Agency, these disasters occurred in the regions of North Sumatra, Riau, South Kalimantan, East Kalimantan, Central Sulawesi, Sulawesi, Gorontalo, Maluku, and North Maluku. In addition, it was reported that 132 residents' houses in Central Maluku were hit by floods caused by heavy rainfall for 2 consecutive days.	On 5-6 August 2022, floods hit the City of Singkawang, Kapuas Hulu and Sambas Regency in West Kalimantan. According to BNPB, the floods occurred due to high rainfall and overflowing rivers. Reports show that 4.2 thousand families (14.4 thousand people) have been affected and 3.2 thousand houses have been damaged along with 1 bridge and 72 public facilities.	Apart from floods and landslides, forest and land fires were also observed in Sumatra and West Kalimantan which were caused by reduced rainfall that week.
Information provided by S2S products :	Model captures rainfall event up to three weeks before — Very high skill for week 1 and 2 and slowly week at week 3 and 4. rainfall anomalies are predicted	High rainfall probability was captures 3 – 4 weeks before but for wider area. — Strongest signal with one to two lead time	The potential for high rainfall has been well predicted by the model, before 3-4 weeks. In addition, the presence of low or below normal rainfall in Sumatra and West Kalimantan was also well predicted by the model.

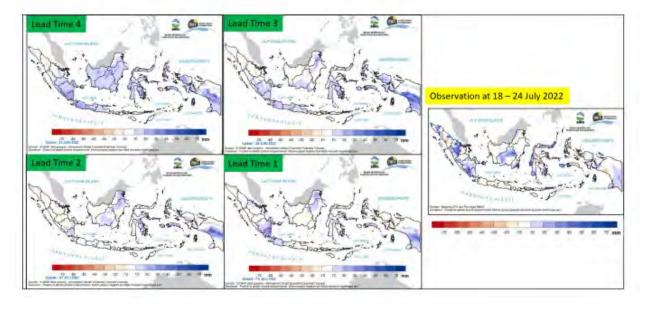Figure 10. Disaster and losses cause by Extreme Events

Figure 11. Sub-seasonal predictability on Week 3 of July

Conclusion

We observed that the model is rather effective in predicting rainfall that occurs during the dry season, according to the results of the study that we conducted from May to July for both predicting total rainfall and predicting the probability of high rainfall. This is demonstrated by the accurate predictions in July, when most of Indonesia, particularly the regions with monsoonal rainfall patterns, where rainfall is more influenced by monsoon winds, is experiencing a dry season. Rainfall in the monsoonal region is lower than normal in July. As a result, the model is able to accurately predict less precipitation, and if extreme events occur during the dry period, the model becomes more sensitive and is able to perform better than it could during the rainy period.

In our analysis, we discovered that sub-seasonal predictions have the potential to provide earlier information on the potential for extreme events, both events that cause reduced rainfall leading to drought events and heavy rainfall events that cause other hydrometeorological disasters. We are aware, however, that these projections need to be improved given the difficulties in producing accurate projections on this time scale. It is potential, however, that this prediction will provide a signal of extreme events 3–4 weeks before when taking into account the potential that is already there, as demonstrated in several case studies. Additionally, this forecast can be used in Indonesian regions where climate variations are caused by sub-seasonal phenomena such as the MJO or interannual phenomena such as El Nino and La Nina.

Discussion and Prospects

Considering we utilized an uncalibrated model in this analysis, we did not use statistical post-processing to reduce bias and root mean square error. We realize that this prediction model need improvement after the third and fourth prediction weeks. The accuracy of this model's regional predictions varies due to Indonesia's extensive geography. We noticed that while certain parts of Indonesia have high skills, others have low skills, such as Papua, which has low skills even in predictions that are close to the target week. Therefore, we recognize that by applying the corrected model, we can offer better climatic services.

We expect that in future initiatives, we will explore other sub-seasonal models, considering that there are 10 research and forecasting centers that provide these forecasts, which are then compared to the models currently used in BMKG operations with the aim of finding the best model for the Indonesian region. Moreover, studies into the model's responsiveness in the presence of the MJO and El Nino/La Nina phenomena are essential due to the lack of studies regarding the predictability of this model in the presence of these phenomena.

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Ⅳ. ENSO/IOD impact study

IV.1   The Impact of ENSO on Rainfall Variability in Indonesia

Dyah Ayu Kartika

1. Introduction

Indonesia is the largest archipelagic country on earth with a geographical location flanked by two oceans (the Indian Ocean and the Pacific Ocean) and two continents (the Asian Continent and the Australian Continent) [1] which results in a seasonal climate, consisting of west and east monsoons. The west monsoon brings the rainy season blowing in October-April, while the east monsoon indicates the opposite.

Rainfall in Indonesia is not only influenced by the rainy season or dry season but also influenced by other climate variability factors, one of which is the El Niño–Southern Oscillation (ENSO) [2]. ENSO, which consists of 3 phases, namely El Niño, Neutral, and La Niña, is widely known by the Indonesian people because it influences rainfall variability in Indonesia. Many studies have been carried out to determine the relationship between El Niño, Neutral, and La Niña and their impact on rainfall variability in Indonesia. The results show that El Niño causes a decrease in rainfall in the Indonesian region, while La Niña causes an increase in rainfall in the Indonesian region [3].

World Meteorological Organization (WMO), a specialized agency of the United Nations whose mandate covers the climatology sector instructs all climatological agencies to update the new climate normal for the period 1991-2020. The new climate normal update is a reference/standard for calculating climate anomalies. With this reference, it can be concluded that climate conditions in one period are hotter or colder. The second objective, climate normal is also widely used, implicitly or explicitly as a prediction that most likely describes climatic conditions at a particular location [4]. So this study is to update the impact of ENSO on the rainfall variability in Indonesia using new normal data from 1991-2020.

2. Data and Method

This study uses the blending of Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) rainfall data with BMKG station rainfall data from 1991-2020. The Nino3.4 Index provided by NOAA can be accessed at https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php.

This study uses the bootstrap percentile method. The percentile bootstrap relies on a simple & intuitive idea: instead of making assumptions about the underlying distributions from which our observations could have been sampled, we use the data themselves to estimate sampling distributions. In turn, we can use these estimated sampling distributions to compute confidence intervals, estimate standard errors, estimate bias, and test hypotheses [5, 6, 7].

The first step to performing the bootstrap percentile method is to create a hypothesis, choose a location point, and choose a specific season. Then determine ENSO years in that season based on Nino3.4 Index provided by NOAA which is shown below and separate rainfall by the ENSO year.

Table 1. Nino3.4 Index provided by NOAA from 1991-2020

Phase	Season	Years
El Niño	JJA	1997, 2002, 2004, 2009, 2015
	JAS	1997, 2002, 2004, 2009, 2015
	ASO	1994, 1997, 2002, 2004, 2006, 2009, 2015, 2018
	SON	1994, 1997, 2002, 2004, 2006, 2009, 2014, 2015, 2018
	OND	1994, 1997, 2002, 2004, 2006, 2009, 2014, 2015, 2018
	NDJ	1994, 1997, 2002, 2004, 2006, 2009, 2014, 2015, 2018
La Niña	JJA	1998, 1999, 2000, 2007, 2010, 2011
	JAS	1995, 1998, 1999, 2000, 2007, 2010, 2011, 2016
	ASO	1995, 1998, 1999, 2000, 2007, 2010, 2011, 2016
	SON	1995, 1998, 1999, 2000, 2007, 2010, 2011, 2016, 2017
	OND	1995, 1998, 1999, 2000, 2005, 2007, 2008, 2010, 2011, 2016, 2017
	NDJ	1995, 1998, 1999, 2000, 2005, 2007, 2008, 2010, 2011, 2016, 2017

Then bootstrap resamples 500 times with returns for a Neutral rainfall season. At each resample, calculate the mean value of the Neutral season and determine the 5th and 95th percentiles of the distribution of the mean values obtained. After that, compare the mean El Niño rainfall and mean La Niña rainfall against those of P5 and P95. And the final step is to conclude the Hypothesis

3. Result

During the June-July-August period in El Niño years (Fig. 1), negative anomalies of seasonal precipitation were shown in the majority of areas across Indonesia. Over the southern part of the country, the situation was even more detrimental, with many areas recording negative anomalies of magnitude greater than 60%, especially in Java. Overall, this part of the study has a similar pattern to the study Supari did in 2017 [8]. During the July-August-September period, dry conditions persisted throughout the country. However, areas recording negative anomalies of magnitude greater than 60% widened until Bali and Nusa Tenggara.

During the August-September-October period in El Niño years, negative anomalies of seasonal precipitation were shown in the majority of areas across Indonesia, except the northern part of Sumatra and the eastern part of Papua. Areas recording negative anomalies of magnitude greater than 60% widened until the southern part of Sumatra, the central part of Kalimantan, the central part of Sulawesi, the northern and the southern part of Maluku, and the central part of Papua. During the September-October-November period, dry conditions still show throughout the country. However, areas recording negative anomalies of magnitude greater than 60% fewer than the August-September-October period. The areas with negative anomalies of magnitude greater than 60% were shown in the southern part of Sumatra, Java, Bali, Nusa Tenggara, a little part of the eastern of Kalimantan, the central to the southern part of Sulawesi, the southern part of Maluku, and the southern part of Papua. Overall, this part of the study persisted to the study Supari did in 2017 [8].

During the October-November-December period in El Niño years, negative anomalies of seasonal precipitation were shown in the majority of areas across Indonesia, except the northern part and central of Sumatra, a smalls area in the northern Kalimantan, the central part of Sulawesi, and the eastern part of Papua. Areas recording negative anomalies of magnitude greater than 60% fewer than the September-October-November

period and only shown in the southern part of Sumatra, the northern and the southern part of Java, small areas in Bali, Nusa Tenggara, and the southern part of Maluku. During the November-December-January period, dry conditions still show throughout the country. However, areas recording negative anomalies of magnitude greater than 60% fewer than the October-November-December period and only shown in small areas in Sumatra and Bali. Positive anomalies of seasonal precipitation began to show in the northern to the southern part of Sumatra, the western part of Java, the western part of Kalimantan, the central of Sulawesi, and the central of Papua.
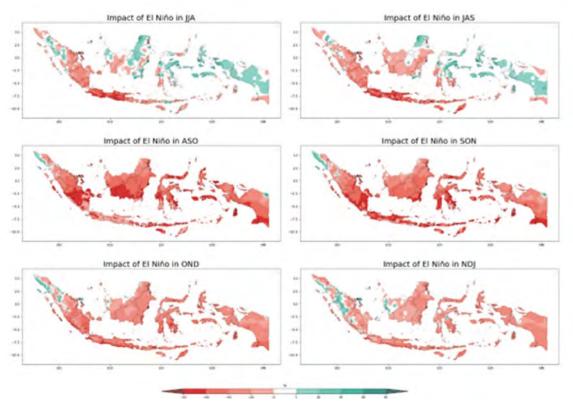
Fig 1. Impact of El Niño event on rainfall variability in Indonesia

During the June-July-August period in La Niña years (Fig. 2), positive anomalies of seasonal precipitation were shown in the majority of areas across Indonesia. Over the southern part of the country, the situation was even more detrimental, with many areas recording positive anomalies of magnitude greater than 80%, especially in the southern part of the equator. During the July-August-September period, wet conditions persisted throughout the country. However, areas recording positive anomalies of magnitude greater than 80% widened until the southern part of Sulawesi, central of Kalimantan, central to the southern part of Sulawesi, and Maluku.

During the August-September-October period in La Niña years, positive anomalies of seasonal precipitation were shown in the majority of areas across Indonesia, except the northern to the southern part of Sumatra, a small area in the southern part of Java and Nusa Tenggara, the eastern part of Kalimantan, a small area in the central and the southern part of Sulawesi, and central and the eastern part of Papua. Areas recording positive anomalies of magnitude greater than 80% widened until the southern part of Sumatra, the southern to the central part of Kalimantan, the northern part of Sulawesi, and the southern part of Maluku.

During the September-October-November period, wet conditions still show throughout the country. However, areas recording positive anomalies of magnitude greater than 80% fewer than the August-September-October period. The areas with positive anomalies of magnitude greater than 80% were shown in the southern part of Sumatra, Java, Bali, Nusa Tenggara, the eastern part of Kalimantan, and the central part of Sulawesi.

During the October-November-December period in La Niña years, positive anomalies of seasonal precipitation were shown in the majority of areas across Indonesia. Areas recording negative anomalies of magnitude greater than 60% fewer than the September-October-November period and only shown in Java, small areas in Bali, Nusa Tenggara, and the southern part of Kalimantan. During the November-December-January period, wet conditions still show throughout the country. However, areas recording negative anomalies of magnitude greater than 60% fewer than the October-November-December period and only shown in small areas in Java, Bali, and Nusa Tenggara. Negative anomalies of seasonal precipitation began to show in the northern to the southern part of Sumatra, the western to the eastern part of Java, the western part of Kalimantan, the central of Sulawesi, and the eastern part of Papua.
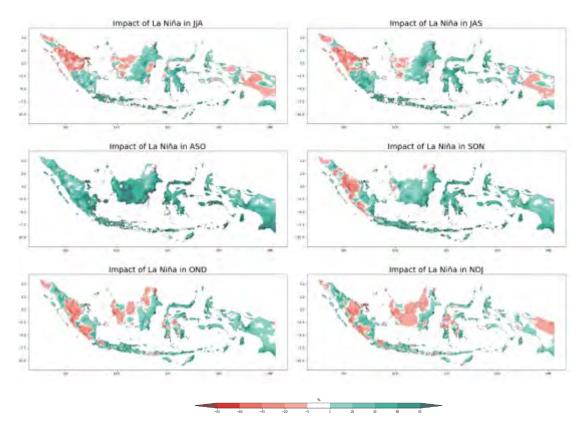
Fig 2. Impact of La Niña event on rainfall variability in Indonesia

4. Conclusion

Based on the results of the analysis that has been carried out above, it can be concluded that some areas in the south of the equator experience decrease rainfall of over 60% during the El Niño event on JJA-SON. And some areas experience increase rainfall of over 80% during the La Niña event on ASO-SON.

5. Future Plan

The future plan for this study is to study for other periods of the year. This is because the present study results were different from the old one by Supari [8].

The Climate Early Warning Sub Division has the latest operational products, namely meteorological drought early warning maps and heavy rainfall early warning maps which are updated every 10 days and released for the first time in 2020. In future studies, it is hoped that an analysis can be carried out regarding the verification of one or both of these maps to determine the skills of operational products.

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Ⅳ. ENSO/IOD impact study

IV.2 Improvement of Indian Ocean Dipole Mode (IOD) Monitoring and Forecast

Ridha Rahmat

(1) Introduction

A. Background

The Indonesian government has always considered the national climate state in the policy-making process, particularly for the sector which is sensitive to the climate, such as agriculture, energy, etc. Since ENSO and IOD strongly drive Indonesian climate, information on that two parameter statuses during the upcoming months or years is crucial for the government to design the following step policy. To support this government strategy, we regularly release the status and ENSO and IOD forecast collected from many climate centers, which are available freely, such as JMA (Japan) and JAMSTEC (Japan) products. In the previous project, we evaluated the ENSO skills issued by JMA. However, the skill of IOD prediction issued by JMA has yet to be done. In this project, we will conduct a simple analysis of the skills of JMA IOD forecasts.

It has been reported in many kinds of literature that the impact of IOD could be spatially coherent over Indonesia, depending on intensity, duration, timing, and the local setting of geography. This study will also analyze the impact of IOD on Indonesian rainfall using the bootstrapping method.

B. Data and Method

Several types of data are used in this study, namely IOD forecast data, IOD reanalysis data from JMA, and rainfall data in Indonesia. The IOD forecast data released by JMA is obtained from the IOD JMA forecast archive file, (data can be accessed via https://ds.data.jma.go.jp/tcc/tcc/gpv/model/CPS2/3-mon/MGPV/YYYYMM/surf_Pss_mb.YYYYMM). where YYYY is input for years and MM is input for months. The data is available from June 2015 to December 2020. This forecast data consists of three lead times. Lead time 0.5; forecasts for the next month, lead time 1.5; forecasts for the next two months, and lead time 2.5; forecasts for the next three months. For more details, please see the following Table.1 illustration.

Table 2.1.1 Illustration of Lead Time JMA ENSO forecast.

Issued Period	Forecast Period			
	Feb	Mar	….	Dec
Jan	Lead Time 0.5	Lead Time 1.5	Lead Time ...	Lead Time 10.5
Feb		Lead Time 0.5	Lead Time 1.5	Lead Time 9.5
⋮			Lead Time 0.5	Lead Time …
Jan				Lead Time …

Historical IOD events from 1991 were obtained from the https://ds.data.jma.go.jp/tcc/tcc/products/elnino/iodevents.html, where Red (blue) bold text indicates positive (negative) **IOD events in concurrence with El Niño (La Niña) events**, while red (blue) background indicates **pure positive (negative) IOD events** Winter, spring, summer, and autumn mean December to February, March to May, June to August, and September to November, respectively. For more details, please see the following table.

Table.2 IOD periods from 1991 to Present

Positive IOD	Negative IOD
summer 1994 - autumn 1994	summer 1996 - autumn 1996
summer 1997 - autumn 1997	summer 1998 - autumn 1998
summer 2006 - autumn 2006	
summer 2007 - autumn 2007	
summer 2008	summer 2010 - autumn 2010
summer 2011 - autumn 2011	
summer 2012 - autumn 2012	summer 2013 - autumn 2013
summer 2015 - autumn 2015	summer 2016 - autumn 2016
summer 2019 - autumn 2019	summer 2020 - autumn 2020
	summer 2021 - autumn 2021 (concurrent La Niña event in autumn)
	summer 2022 - autumn 2022

The rainfall data was obtained by blending Climate Hazards Group InfraRed Precipitation (CHIRPS) with BMKG Station data. The data is available from January 1991 to December 2020. To analyze the skills of JMA IOD forecasts, the Standardized Verification System (SVS) technique for Long-Range Forecast will be applied for this study. That is the **Mean Square Skill Score (MSSS) method** and **Pearson Correlation method**. Meanwhile, **Bootstrapping method** will be used to analyze the impact of IOD on rainfall in Indonesia.

1. **Pearson Correlation**

   The correlation coefficient r is a measure to determine the relationship (instead of difference) between two quantitative variables (interval/ratio). In this study, pearson correlation is used to measure the relationship between IOD forecast data and IOD observation data. Pearson correlation coefficient r for two sets of values, x and y, is given by the formula:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{(\sum(x-\bar{x})^2(y-\bar{y})^2)^{\frac{1}{2}}} \qquad (1)$$

Correlation coefficient r close to positive 1 indicates a strong positive correlation. Its means forecast values similar to observed values. On the other hand, the correlation coefficient is close negative 1 indicates a strong negative correlation. Its means forecast values not similar with observed value.

2. Mean Square Skill Score (MSSS)

Mean Square Skill Score (MSSS) value will provide a comparison of forecast performance relative to forecasts of climatology. The three terms of the MSSS decomposition provide valuable information on phase errors (through forecast/observation correlation), amplitude errors (through the ratio of the forecast to observed variances) and overall bias. MSSS can be calculated using equations:

$$MSSS_j = 1 - \frac{MSE_j}{MSE_{cj}} \qquad (2)$$

where:

MSE_j : Means Square Error of the forecasts.

MSE_{cj}: Means Square Error of the climatology forecast.

Positive MSSS values indicate forecast model performances are better than climatology forecast. On the other hand, negative MSSS values can be interpreted as the climatology model have better performance compared to the forecast model.

3. Bootstrapping Method

Bootstrapping is a data-based simulation method that can be used for statistical inference (Efron and Tibshirani (1998)). Rainfall anomaly is calculated by finding the difference between the total rainfall in each IOD event (positive and negative IOD) and the average total rainfall in the neutral IOD period. The significant level is calculated using the bootstrapping method, with 1000 repetitions, to ensure that the anomaly obtained is statistically robust.

(2) Analysis Results and Discussion
A. Performance of IOD Predictions Issued By JMA

By using the Pearson and MSSS Correlation method, the results of IOD verification for the June 2015 - December 2019 period issued by JMA are as follows:

Figure1. Performance of IOD predictions Issued by JMA

Figure1. shows the results of verification for IOD index issued by JMA. The correlation test shows high correlation of IOD forecast for 1 to 3 months ahead. This means IOD forecast issued by JMA has a high phase similarity with its observational value. Verification using MSSS method also shows similar results with correlation method, where positive MSSS is dominant result. It means IOD Prediction model issued by JMA is better than climatology (in terms of bias magnitude) for 1 to 3 months ahead.

By using the Pearson Correlation, the results of IOD verification for the June 2015 - December 2019 period issued by JMA for each month are as follows:
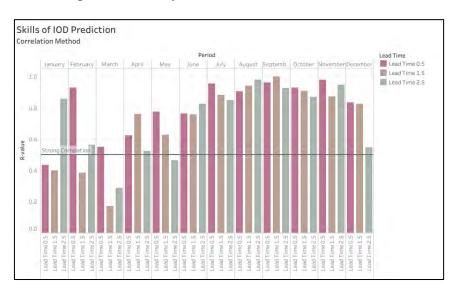

Figure2. Performance of IOD Prediction Issued by JMA using Correlation Method

The results of skill assessment at monthly scale as shown in Figure2. In general, the JMA IOD forecast has good skills except those issued in Jan-March. For Jan-March period, the correlation decreased.

B.   Impact of IOD events on Indonesian Rainfall

1. **Impact of IOD events on Indonesian Rainfall During JJA (June – July – August) Period**
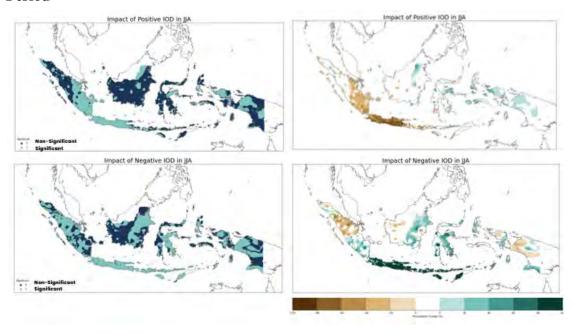
Figure3. Impact of IOD events on Indonesian Rainfall During JJA

In general, positive and negative IOD has a significant impact on rainfall over Indonesia during JJA Period, especially for some parts of Sumatera, Java, Bali NTB and NTT. Indonesia's rainfall during positive IOD in the JJA period decreased, especially for the southern part of Sumatera, Java, Bali, and NTB. However, Indonesia's rainfall during negative IOD in the JJA period increased, especially for the southern part of Sumatera, Java, Bali, NTB, NTT, and Sulawesi.

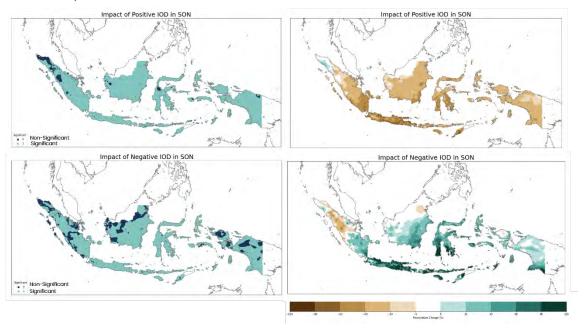2. **Impact of IOD events on Indonesian Rainfall During SON (September – October – November) Period**

Figure4. Impact of IOD events on Indonesian Rainfall During SON

Generally. positive and negative IOD significantly impacts rainfall over Indonesia during SON Period, especially for the southern part of Sumatera, Java, Bali, NTB and NTT, Kalimantan, Sulawesi, and Maluku. Indonesia's rainfall during positive IOD in the SON period decreased, except for the northern part of Sumatra. However, Indonesia's rainfall during negative IOD in the SON period increased, except for the northern part of Sumatra and North Kalimantan.

C. Impact of Pure IOD events on Indonesian Rainfall

1. Impact of Pure IOD events on Indonesian Rainfall During JJA (June – July – August) Period

Figure5. Impact of Pure IOD events on Indonesian Rainfall During JJA

In general, pure positive and pure negative IOD has a significant impact on rainfall over Indonesia during JJA Period, especially for some parts of Sumatera, Java, Bali NTB and NTT. Indonesia's rainfall during positive IOD in the JJA period decreased, especially for the southern part of Sumatera, Java, Bali, and NTB. However, Indonesia's rainfall during negative IOD in the JJA period increased, especially for the southern part of Sumatera, Java, Bali, NTB, NTT, and Sulawesi.

2. Impact of Pure IOD events on Indonesian Rainfall During SON (September – October – November) Period
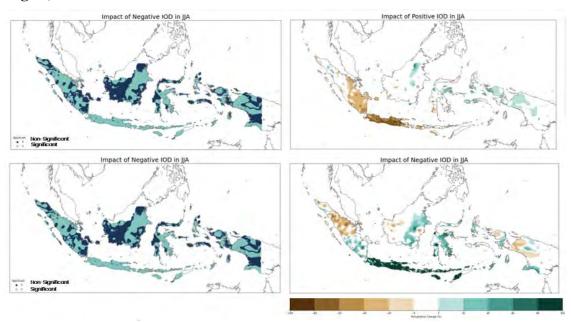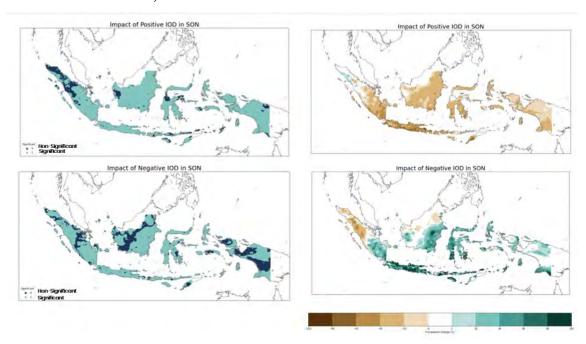

Figure6. Impact of IOD events on Indonesian Rainfall During SON

Generally, pure positive and pure negative IOD significantly impacts rainfall over Indonesia during SON Period, especially for the southern part of Sumatera, Java, Bali, NTB and NTT, Kalimantan, Sulawesi, and Maluku. Indonesia's rainfall during pure positive IOD in the SON period decreased, except for the northern part of Sumatra. However, Indonesia's rainfall during negative IOD in the SON period increased, except for the northern part of Sumatra and North Kalimantan.

D. Time Series of 10-day Precipitation during Positive/Negative IOD
1. Time Series of 10-day Precipitation during Positive/Negative IOD at Central Java 30 Region
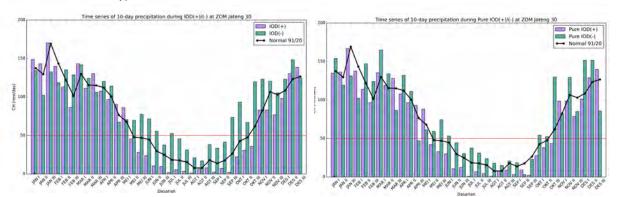
Figure7. Time Series of 10-day Precipitation during Positive/Negative IOD at Central Java_30 Region

Generally, rainfall in Central Java_30 region decreased compared to normal rainfall during positive IOD. Vice versa, rainfall in the Central Java_30 region increased during negative IOD.

2. Time Series of 10-day Precipitation during Positive/Negative IOD at West Java_31 Region
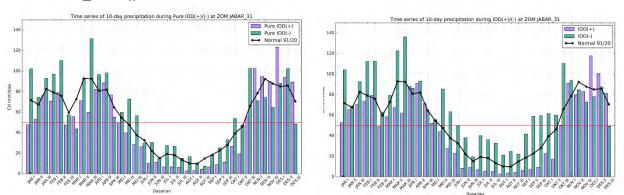
Figure8. Time Series of 10-day Precipitation during Positive/Negative IOD at West Java_31 Region

Generally, rainfall in the West Java_31 region decreased compared to normal rainfall during positive IOD. Vice versa, rainfall in the West Java_30 region increased during negative IOD.

3. Time Series of 10-day Precipitation during Positive/Negative IOD at Aceh_4 Region
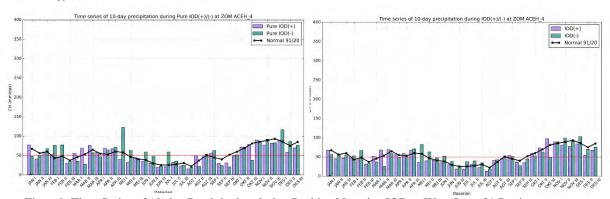
Figure9. Time Series of 10-day Precipitation during Positive/Negative IOD at West Java_31 Region

There is no significant change in rainfall during the negative and positive IOD periods, except on May I-Jul I. During these periods, rainfall in Aceh 4 region decreased compared to normal rainfall during positive IOD; Vice versa, rainfall in the aceh_4 region increased during negative IOD.

E. Atmospheric and Ocean Dynamics Analysis

1. Sea Surface Temperature (SST) During IOD Event.
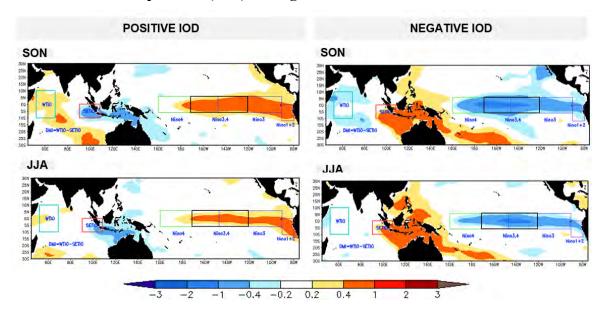
Figure10 SST Anomaly During IOD Event

During the positive IOD, the sea surface temperature (SST) anomaly in the western Indian Ocean is warmer, and SST anomaly conditions in the eastern Indian Ocean are cooler. Furthermore, warm conditions dominate SST conditions in the eastern to central Pacific Ocean. Meanwhile, SST anomaly conditions in Indonesia tend to be cooler. This phenomenon can lead to reduced rainfall in some parts of Indonesia.

While in the negative IOD, the sea surface temperature anomaly (SST) in the western Indian Ocean is cooler, and the SST anomaly in the eastern Indian Ocean is warmer. Furthermore, cooler conditions dominate SST anomaly in the eastern to central Pacific Ocean. Meanwhile, the SST anomaly in Indonesia tends to be warmer. This phenomenon can lead to increase rainfall in some parts of Indonesia.

2. Sea Surface Temperature (SST) During Pure IOD Event.
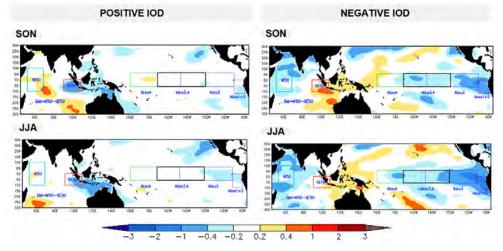
Figure11 SST Anomaly During Pure IOD Event

During pure positive IOD, the sea surface temperature (SST) anomaly in the western Indian Ocean is warmer, and SST anomaly conditions in the eastern Indian Ocean are cooler. Furthermore, warm conditions dominate SST conditions in the eastern to central Pacific Ocean. Meanwhile, SST anomaly conditions in Indonesia tend to be cooler. This phenomenon can lead to reduced rainfall in some parts of Indonesia.

While in pure negative IOD, the sea surface temperature anomaly (SST) in the western Indian Ocean is cooler, and the SST anomaly in the eastern Indian Ocean is warmer. Furthermore, cooler conditions dominate SST anomaly in the eastern to central Pacific Ocean. Meanwhile, the SST anomaly in Indonesia tends to be warmer. This phenomenon can lead to increase rainfall in some parts of Indonesia.

3. Zonal Wind Anomaly (850mb) During IOD Events.
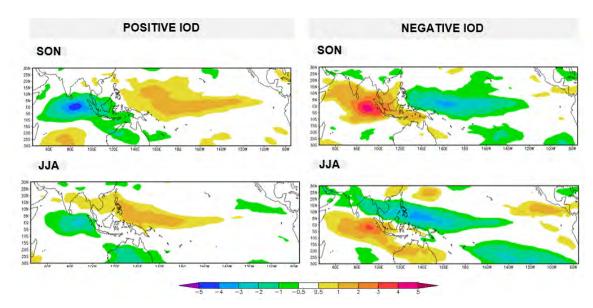
Figure12. Zonal Wind Anomaly During IOD Event

During positive IOD, the zonal wind anomaly in the SON and JJA periods is generally negative, meaning the easterly wind is stronger than the climatology. Meanwhile, during negative IOD, zonal wind anomaly in the SON and JJA periods are generally positive, meaning that the westerly winds are stronger than the climatology.

4. Zonal Wind Anomaly (850mb) During Pure IOD Events.
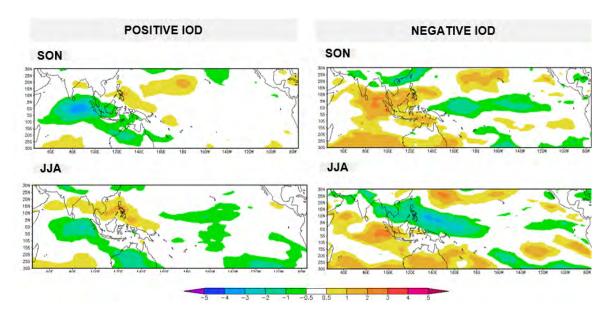
Figure13. Zonal Wind Anomaly During IOD Event

During pure positive IOD, the zonal wind anomaly in the SON and JJA periods is generally negative, meaning the easterly wind is stronger than the climatology. Meanwhile, during negative IOD, zonal wind anomaly in the SON and JJA periods are generally positive, meaning that the westerly winds are stronger than the climatology.

(3) Results and Future Tasks

A. Results
1. IOD Prediction issued by JMA generally has a good prediction on forecasting 1 to 3 months ahead, and Positive MSSS are the dominant result..
2. In general, Indonesia's rainfall during the positive IOD decreased and vice versa. However, some regions experienced different impacts.

B. Future Tasks
In the next project, we could evaluate the six months IOD and ENSO forecasts issued by JMA. This information will assist the BMKG forecaster in predicting seasonal rainfall and the season onset.

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Ⅴ One Year Forecast Study
One Year Outlook Study in Indonesia
(Case Study Climate Outlook 2023)
Amsari M. Setiawan and Adi Ripaldi

1. Introduction

The Indonesia Agency for Meteorology, Climatology and Geophysics (BMKG) regularly disseminate several publications related to climate information such as analysis and prediction of ten days accumulation (decade) rainfall, monthly rainfall, Rain/Dry Season Predictions, and other publications. Start in 2020, the BMKG published Climate Outlook which contains climate prediction information until the end of next year.

One year climate outlook is a special request from the government through the Ministry of National Development Planning of the Republic of Indonesia. This information also requested by other ministries such as the Ministry of Public Works and Public Housing of the Republic of Indonesia, Ministry of Environment and Forestry of The Republic of Indonesia and the Ministry of Agriculture of the Republic of Indonesia.

Climate outlook made to be used as a reference and consideration in designing plans for next year by several sectors in planning, early warning, and early adaptation of national development activities. This outlook also used to provide stakeholders with a general picture of climate conditions in next year as early as possible which can be used as a basis for making policies. Climate outlook information will be supplemented with updated information by the BMKG on the Monthly Prediction and Rain/Dry Season Prediction. The purpose of this study is to describe all the process taken to produce the BMKG one year climate outlook.

2. Data and Method

2.1 Data

Monthly Nino 3.4 and Indian Ocean Dipole (IOD) index from Interactive Tool for Analysis of the Climate System/ iTacs, Japan Meteorological Agency/JMA (https://extreme.kishou.go.jp/tool/itacs-tcc2015/) during January 1991 to August 2022 are applied in Singular Spectrum Analysis (SSA) method (Supari et al, 2019). This data used to produce statistical model prediction, combined with another predictions output provided by various global climate service centers (https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/). Sea Surface Temperature (SST) outlook over Indonesia waters is produced using dynamical model prediction by North American Multi Model Ensembles (NMME) output (Kirtman et. al., 2014). Rainfall dynamical model prediction from European Centre for Medium-Range Weather Forecasts (ECMWF) Bias Corrected Prediction Output Model (ECMWFcorr). Rainfall statistical model predictions are produced based on blended rainfall observation data (BMKG, 2021) from Dasarian or Decade I January 1991 – Dasarian or Decade III August 2022 using Autoregressive Integrated Moving Average (ARIMA), WAVELET - Adaptive Neuro Fuzzy Inference System (ANFIS) and WAVELET-ARIMA (Sonjaya et.al., 2009).
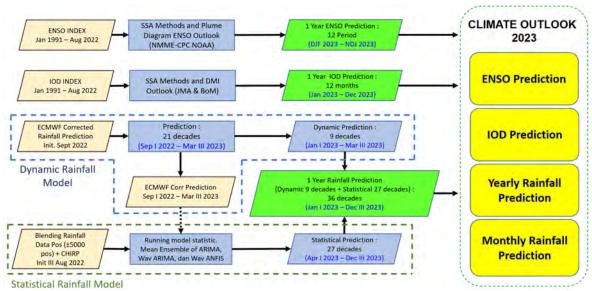
2.2 Method

Figure 1. General flowchart to generate climate outlook information

Nino 3.4 and IOD index decade I January 1991 to decade III August 2022 used as input for SSA model to predict Nino 3.4 and IOD index up to 12-month lead time, seasonal (DJF 2022/23 – NDJ 2023) and Monthly value (Jan 2023 – Dec 2023). This statistical approach was used for ENSO and IOD Prediction in climate outlook. Dynamical rainfall model utilization for one year climate outlook used ECMWF raw output model (initial September III 2022) and bias correction factor (based on 1991-2020 hindcast and blended rainfall observation data). Linier scaling bias correction (Crochemore et. al., 2016) applied on ECMWF output to generate ECMWFcorr rainfall prediction over 21 decades lead time for January I 2023 – March III 2023. While September I 2022 – March III 2023 rainfall prediction used for statistical model input. Statistical rainfall model for extended monthly precipitation outlook provided from blended rainfall observation data from I January 1991 – III August 2022 combined with ECMWFcorr decadal prediction September I 2022 – March III 2023 (output from 2) and processing with ARIMA, Wavelet ARIMA and Wavelet ANFIS. The output from this process is Monthly Rainfall Prediction (27 decades lead time), April I 2023 – December III 2023; and Annual Rainfall for 2023. The general information about these processes can be seen on Figure 1.

3. Result

The Climate Outlook 2023 (BMKG, 2022) was made based on the analysis of climate and global atmospheric dynamics during January-August 2022. The Climate Outlook 2023 consists of three parts:

a. The first part contains predictions for the El-Nino Southern Oscillation (ENSO) and the Indian Oscillation Dipole (IOD) until the end of 2023, along with the outlook for sea surface temperature until May 2023 (Figure 2).

b. The second part contains predictions of 2023 rainfall and its comparison to normal and to 2022 rainfall. This part consists of Annual Rainfall Prediction (Figure 3 left); Annual Rainfall

Anomaly Prediction (Figure 3 right); Monthly Rainfall Prediction (Figure 4); and Monthly Rainfall Anomaly Prediction (Figure 5) for One Year Climate Outlook 2023.

c. The third part, discusses general suggestions for anticipating the 2023 climate impact on development activities in sectors that are closely related and affected by the climate, including the agricultural, forestry, disaster, health, water resources, marine and coastal, and socio-economic sectors.
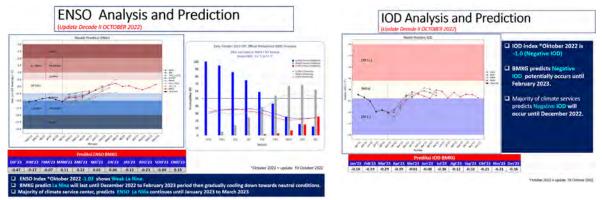
Figure 2. ENSO Analysis and Prediction (left) compared with Probabilistic ENSO Forecast (middle); IOD Analysis and Prediction for One Year Climate Outlook 2023 (right)
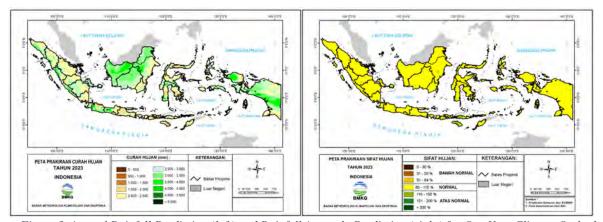
Figure 3. Annual Rainfall Prediction (left) and Rainfall Anomaly Prediction (right) for One Year Climate Outlook 2023
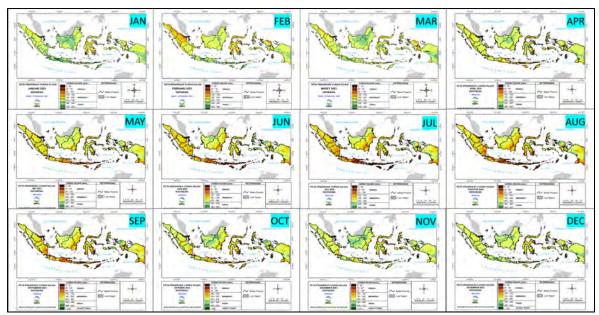
Figure 4. Monthly Rainfall Prediction

The annual rainfall prediction in 2023 are generally will have similar value than its normal. The annual rainfall more than 2500 mm/year potentially occur in Sumatra, especially around the mountainous Bukit Barisan region, Bangka Belitung Islands, South Sumatra, several parts of Banten, West Java, Central Java, few part of Kalimantan, several part of West Sulawesi, South Sulawesi, and Papua. Areas that are predicted to experience rainfall above normal are Jambi, West Java, Java East, few part of East Kalimantan, Bali, West Nusa Tenggara, and few part of Central Sulawesi. On the other side, several areas predicted to experience annual rainfall below normal are located in part of West Papua and a small part of Papua.
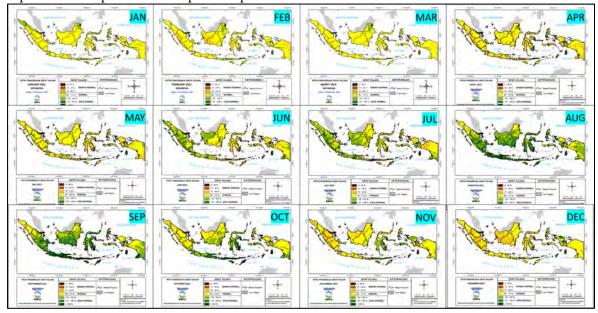
Figure 5. Monthly Rainfall Anomaly Prediction

Monthly rainfall over Indonesia predicted varies from above normal to below normal. Near normal rainfall predicted to be occurs on January to June and October to December 2023. Nevertheless, several areas are predicted to experience rainfall above normal during July to September 2023.

Table 1. Monthly precipitation accumulation prediction value compared with its normal (1991-2020)

| PROVINSI	JAN 2023	JAN NORMAL	FEB 2023	FEB NORMAL	MAR 2023	MAR NORMAL	APR 2023	APR NORMAL	MEI 2023	MEI NORMAL	JUN 2023	JUN NORMAL	JUL 2023	JUL NORMAL	AGT 2023	AGT NORMAL	SEP 2023	SEP NORMAL	OKT 2023	OKT NORMAL	NOV 2023	NOV NORMAL	DES 2023	DES NORMAL
ACEH	260	213	160	163	228	220	233	249	198	202	191	147	182	151	185	180	198	212	241	293	265	329	258	288
SUMATERA UTARA	225	198	145	159	202	200	207	225	187	195	176	141	185	154	204	198	229	241	256	286	268	303	248	281
RIAU	229	212	142	149	209	208	212	227	191	188	166	137	163	132	180	152	192	169	212	221	224	279	217	256
SUMATERA BARAT	282	271	175	211	243	259	230	281	216	208	206	158	206	152	227	172	252	208	259	268	274	333	279	325
KEPULAUAN RIAU	239	222	114	121	166	172	205	197	199	212	197	182	191	173	182	158	175	162	208	221	242	287	246	307
JAMBI	261	253	196	215	234	251	217	251	174	180	156	122	155	120	174	118	185	128	200	193	224	273	224	273
KEP.BANGKA BELITUNG	320	297	185	203	233	248	235	263	201	225	188	166	162	142	174	113	193	112	235	197	278	281	290	347
SUMATERA SELATAN	285	281	228	251	264	281	245	272	193	189	161	135	146	122	156	104	172	113	203	194	248	282	264	311
BENGKULU	304	304	211	248	219	260	221	273	214	218	214	165	218	159	226	176	244	193	267	270	274	347	277	337
LAMPUNG	302	306	245	270	250	277	206	214	166	160	148	110	131	100	125	78	133	87	157	133	191	208	235	286
BANTEN	403	361	349	328	243	269	192	236	183	174	156	115	121	93	121	65	152	84	219	157	258	271	295	344
DKI JAKARTA	369	342	388	375	179	205	153	172	120	117	105	83	110	69	92	48	106	61	149	115	151	156	191	197
JAWA BARAT	370	348	307	328	298	320	232	274	175	175	139	109	105	75	116	53	175	82	246	196	275	319	291	329
JAWA TENGAH	439	411	381	385	316	329	216	259	140	143	104	87	68	51	81	32	125	53	222	163	283	302	330	363
YOGYAKARTA	358	352	328	349	282	309	170	207	96	89	77	53	50	26	59	16	94	32	189	104	257	258	321	332
JAWA TIMUR	337	313	293	294	259	268	173	198	102	99	68	60	41	36	49	18	75	31	146	84	200	195	255	281
KALIMANTAN BARAT	337	329	240	278	286	300	273	291	263	257	262	210	230	188	233	176	260	203	291	303	307	360	308	379
KALIMANTAN TENGAH	304	306	247	279	303	315	274	305	242	243	209	196	182	151	186	127	220	145	278	239	295	313	276	333
KALIMANTAN UTARA	273	246	245	218	280	248	267	264	261	261	238	231	224	223	233	224	245	217	268	274	282	287	266	294
KALIMANTAN TIMUR	274	258	256	236	290	269	255	272	225	235	196	192	178	161	172	135	184	141	232	201	267	264	259	286
KALIMANTAN SELATAN	278	289	228	248	254	271	206	229	173	185	154	174	144	131	145	85	151	88	180	133	220	225	247	299
BALI	395	353	356	325	253	256	158	176	95	104	63	66	49	54	71	28	112	51	185	122	243	211	295	302
NTB	308	280	299	267	209	213	121	141	57	66	26	36	12	26	26	15	60	25	117	56	185	144	237	246
NTT	343	311	339	300	235	238	134	149	70	84	38	48	27	31	36	17	66	26	131	54	205	144	268	273
SULAWESI UTARA	306	260	232	200	221	201	184	193	177	203	179	212	170	160	149	106	150	101	184	148	216	212	229	228
GORONTALO	226	193	155	144	180	167	167	172	156	161	156	170	148	125	129	77	115	70	138	110	150	157	152	164
SULAWESI TENGAH	188	175	162	161	200	194	190	221	187	211	195	226	196	185	187	134	175	117	171	133	172	159	174	175
SULAWESI BARAT	265	246	182	198	216	233	240	261	235	235	214	217	197	156	188	123	185	132	224	187	226	264	221	279
SULAWESI SELATAN	290	273	243	242	271	269	245	309	230	271	207	241	173	171	148	98	153	94	194	130	242	203	252	274
SULAWESI TENGGARA	201	201	179	193	212	222	208	239	190	223	171	213	153	146	133	80	130	69	149	86	186	140	192	187
MALUKU UTARA	227	200	205	185	204	188	190	214	199	203	212	231	203	180	184	132	164	120	162	139	175	175	196	205
MALUKU	237	226	237	228	220	218	196	226	188	226	228	269	213	213	188	150	176	124	173	125	195	162	217	241
PAPUA BARAT	259	247	217	212	217	214	225	263	231	267	245	291	252	280	253	234	249	243	255	252	245	212	239	227
PAPUA	272	277	265	271	279	278	245	276	220	220	212	217	217	235	212	183	209	179	227	209	242	225	257	270

Furthermore, the Climate Outlook of 2023 also provide detailed rainfall prediction for each province in Indonesia, include its comparison with normal. Similar with Figure 4 and Figure 5, Table 1 show monthly rainfall prediction on 2023 which has relatively high spatial and temporal variability. This rainfall prediction and climate outlook information then forwarded using a formal letter from the Head of the BMKG to the president of the Republic of Indonesia and related ministries/institutions (Figure 6)
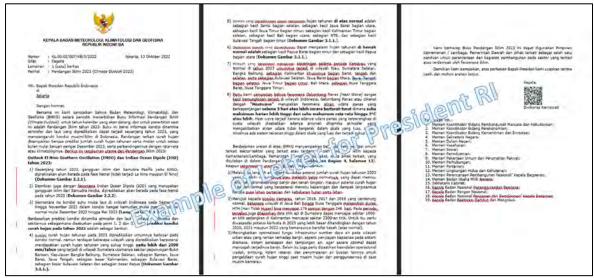

Figure 6. Example letter from BMKG to Republic of Indonesia President

4. Remark

Based on discussion in previous section, several conclusions can be made as follows:

1. One Year Climate Outlook is prepared to supply the request from the government through the Ministry of National Development Planning of the Republic of Indonesia and other sectoral ministries

2. Made based on combined dynamical and statistical methods to see the climate conditions (drier or wetter) in the next year

3. Used as a reference and consideration in designing plans for next year by several sectors, include letter for President

4. Long-term forecast challenge will be heavily dependent by the climate driver force that will dominate the next one year

Beside the conclusion, there are several actions that can be made for further improvement in the future, such as:

a) Outlook Evaluation based on Hindcast and Verification;

b) Collaboration with other agencies such as Japan Agency for Marine-Earth Science and Technology (JAMSTEC) for utilization of Sintex F output and Meteorological Research Institute (MRI) – Japan Meteorological Agency (JMA) for Multi Years/Decadal Climate Prediction, include post processing;

c) Artificial Intelligence /Machine Learning approach for multi years climate outlook

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