Asia and the Pacific

SURVEY ON METEOROLOGICAL SERVICES AND INFRASTRUCTURE IN ASIA AND THE PACIFIC

FINAL REPORT

January 2022

Japan International Cooperation Agency（JICA）

Japan Meteorological Business Support Center
Japan Weather Association
Oriental Consultants Global Co., Ltd.

GE
JR
22-008

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Chapter I Outline of the Survey

I.1 Purpose of the Survey and Background

I.1.1 Background

The importance of National Meteorological Services (NMSs), which are in charge of meteorological observation, forecasting and warning, and information dissemination, is increasing to cope with meteorological phenomena that affect a wide area of the earth, disasters such as heavy rains, floods, windstorms, and storm surges caused by such phenomena, and climate change, which has become increasingly severe in recent years. NMSs are required to continuously implement and enhance their meteorological services by the unified standards established by the World Meteorological Organization (WMO) of the United Nations and under the planning, coordination and guidance of WMO.

However, meteorological observation networks are not sufficiently deployed and maintained in developing countries. NMSs in developing countries do not have adequate systems and capabilities to properly carry out a series of tasks such as collecting observation data, preparing forecasts and warnings, and providing information. For this reason, the Japan Meteorological Agency (JMA) has been working to enhance and improve meteorological services in countries worldwide by participating in the activities of international organizations such as WMO and actively providing technical assistance to developing countries. The Japan International Cooperation Agency (JICA) has also contributed to the strengthening of meteorological observation networks, capabilities of weather analysis, forecasting and warning, and the information dissemination through Yen loan, Grant Aid and Technical Cooperation. Under the Sendai Framework for Disaster Risk Reduction 2015-2030, which was adopted at the Third World Conference on Disaster Reduction in Sendai, Japan in March 2015, the Government of Japan has set a policy to cooperate in strengthening the capacity of NMSs, which is essential to realize and sustain the Sendai Framework for Disaster Reduction 2015-2030. In recent years, new observation equipment/instruments such as automatic weather stations (AWSs) and dual-polarization radars, new systems for weather analysis and forecasting/warning, and information and communication technologies to support these systems have been developed and introduced. NMSs are improving their conventional meteorological services by effectively incorporating these latest systems and technologies into their operations. However, few countries have specific mid- to long-term strategies and have plans to deal with these issues. As a result, new challenges have arisen in these countries, such as insufficient utilization of observation instruments and forecast analysis systems installed with donor supports, difficulties in maintenance and management due to lack of uniformity in the installed instruments, and insufficient assurance of the quality of products from analysis systems. To overcome these challenges, it is necessary to assess the current situation of NMSs in developing countries, identify new technologies to be introduced, analyze the issues from a broad perspective, and consider the direction and contents of future support from a medium- to long-term perspective.

I.1.2 Purpose of the Survey

Taking the situation described in Section 1.1 above into account, the information on the following in the targeting countries that are expected to have cooperation needs is collected: the organizational structure and operational capacity of NMSs; the status of meteorological observation equipment, weather analysis/forecast systems, information and communication systems; and other infrastructure related to meteorological services, as well as the assistance and cooperation of other donors in the field of meteorology. The purpose of the Survey is to analyze expected goals for NMSs in mid- to long-term (5-10 years) and to formulate the JICA's cooperation policy to assist NMSs in realization of these goals in the field of meteorology based on the collected information.

I.1.3 Target Countries

The Survey covered 13 countries, namely Bangladesh, Bhutan, Cambodia, Fiji, Indonesia, Lao PDR, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, and Viet Nam, in which JICA's cooperation activities in the field of meteorology have been carried out in the past or are expected to have cooperation needs in the future. The information was collected through relevant reports, literature, public information such as the Internet, and questionnaire surveys to the NMSs in the target countries. In addition, after consultation with JICA, three countries, Bangladesh, Indonesia and Sri Lanka were selected as the target countries for the field survey. Due to the Covid-19 pandemic, the field surveys were not conducted. Instead, interviews were conducted with NMSs in three countries, and the Japan Meteorological Business Support Center (JMBSC) conducted online interviews with NMS in Mongolia at its own expense.

I.1.4 Institutions Concerned

NMSs involved in this Survey are as follows:

- Bangladesh: Bangladesh Meteorological Department (BMD)
- Bhutan: National Center for Hydrology and Meteorology (NCHM)
- Cambodia: Department of Meteorology (DOM)
- Fiji: Fiji Meteorological Service (FMS)
- Indonesia: Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) (Indonesian Agency for Meteorology, Climatology, and Geophysics)
- Lao PDR: Department of Meteorology and Hydrology (DMH)
- Mongolia: National Agency for Meteorology and Environmental Monitoring (NAMEM)
- Myanmar: Department of Meteorology and Hydrology (DMH)
- Nepal: Department of Hydrology and Meteorology (DHM)
- Pakistan: Pakistan Meteorological Department (PMD)
- Philippines: Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)
- Sri Lanka: Department of Meteorology (DOM)
- Viet Nam: Viet Nam Meteorological and Hydrological Administration (VNMHA)

I.1.5 Survey Period

From 15 February 2021 to 28 January 2022

I.2 Method of the Survey

I.2.1 Implementing Method of the Survey

This Survey was conducted from February 2021 to January 2022. The Survey consisted of (1) preliminary survey in writing, (2) questionnaire survey to each National Meteorological Service (NMS), (3) country interviews, and (4) compilation of survey results. Figure I.2.1-1 shows the overall diagram of the Survey.

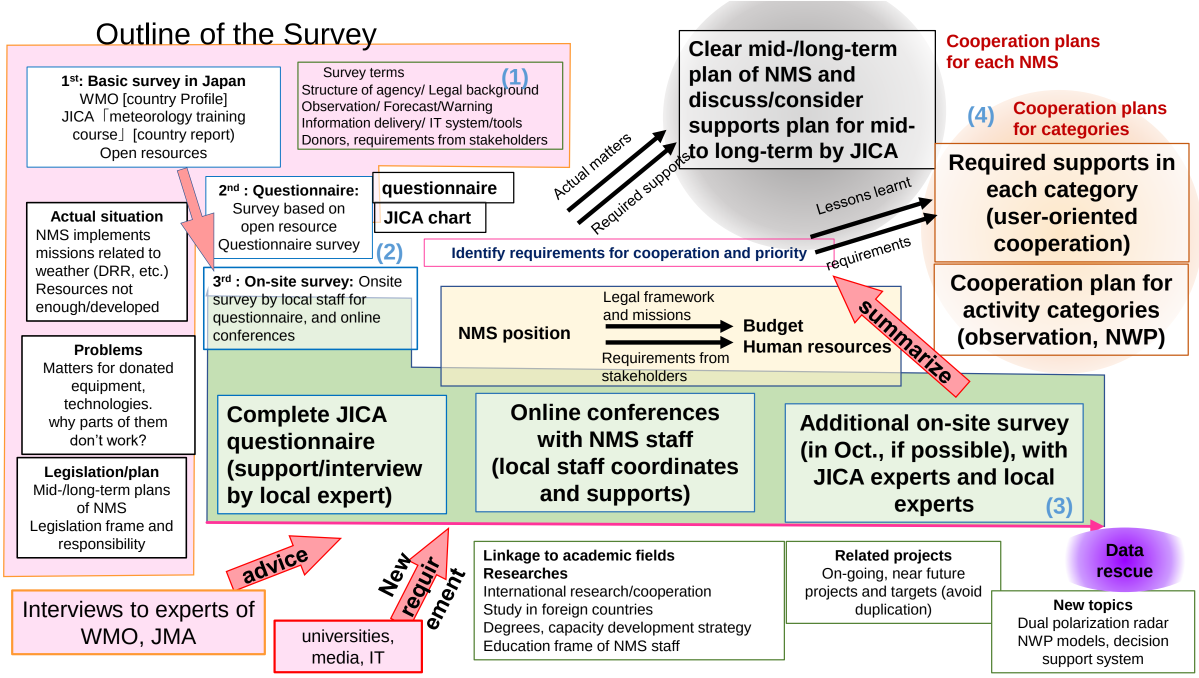

Figure I.2.1-1 Overall diagram of the entire Survey

(1) Preliminary survey in writing (February to March 2021)

The following materials were collected in this Survey in order to assess the current status of the observations, forecasts, information provision, statistics, human resource development, and legal status of NMSs and their organizational structure.

- Web pages of each NMS and published information (reports, medium- and long-term plans, etc.)
- Published information regarding projects by WMO, the World Bank, etc.

In addition, achievements and lessons learned in the field of meteorology within the projects implemented by JICA in the past were reviewed based on materials in the JICA Library and other sources. In collaboration with the Japanese staff at the WMO headquarters (Geneva) and its Regional Office in Singapore, and the World Bank, the status of technical cooperation, meteorological services, structure and human resources, and other donors in each country were surveyed.

As JMA, which has been designated as various world/regional centers, provides cooperation and technical support to NMSs in Asia and the Pacific, the survey team conducted interviews with the following sections: (a) (c) (e) on 18 March 2021: (h) on 25 March: (b) (d) (f) (g) on 26 March 2021 to cover the situation in each country and JMA's cooperation. In addition, the team collected information publicly available as shown in Figure I.2.1-2.

(a) Office of International Affairs

(b) Asia-Pacific Meteorological and Disaster Prevention Center: RSCM Tokyo - Typhoon Center

(c) Climate Prediction Division, Extreme Weather Information Center: Tokyo Climate Center

(d) Coordinator for International Communications of the Information and Telecommunications Infrastructure Division: GISC Tokyo, RTH Tokyo

(e) Observation Development Division: Regional WIGOS Center

(f) Meteorological Satellite Division

(g) Sections in charge of the project for the establishment of a meteorological radar network covering Southeast Asia

(h) Meteorological Instrument Certification Test Center: RIC Tsukuba

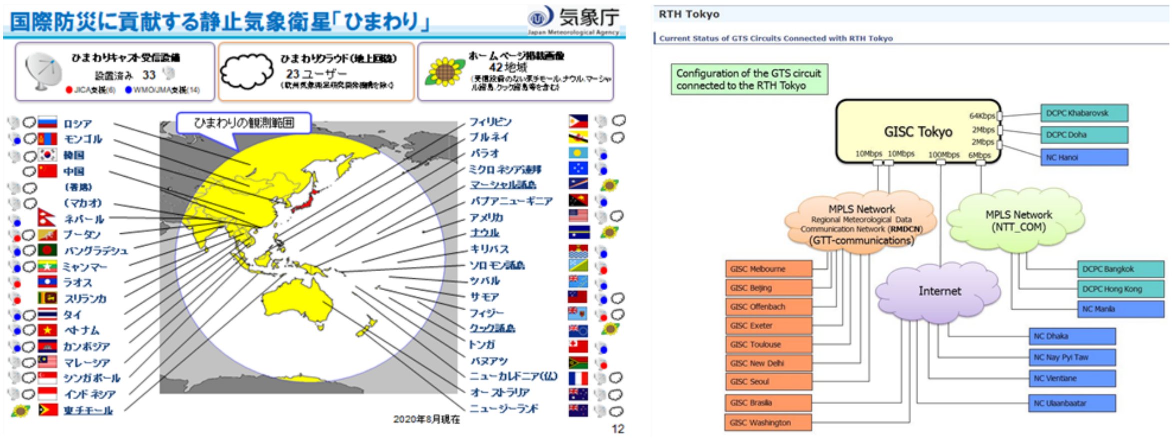

Figure I.2.1-2 Collection of JMA's published information

(Left) Countries using HimawariCast, (Right) Network between GISC Tokyo and each country

In addition, JMA has conducted JICA group training courses on meteorology for NMS staff from various countries, international conferences on meteorological satellite and radar data integration projects, etc. At these training courses and conferences/seminars, participants deliver "Country Reports" (2012-2019). The team reviewed the contents of these reports with the special permission by JMA and analyzed actual situation of each NMS.

These surveys were organized into the following fields. These surveys were organized in the format shown in Figure I.2.1-3, with each team member in charge of a country as shown in Table I.2.2-1.

Areas of the survey

"Disaster Damage Risk", "Legislation and Medium- and Long-Term Planning", "Organization, Budget, and Personnel", "Surface Meteorological Observations", "Radar Observations", "Upper-air Observations", "Meteorological Satellites", "Calibration of Instruments", "International Meteorological Telecommunication System", "Meteorological Forecasting/Infrastructure", "Provision of Meteorological Information", "IT Systems", "Cooperation with Disaster Management Authorities", "Meteorological Statistics", "Other services conducted by NMSs", "Human Resource Development", "Cooperation by

Donors".

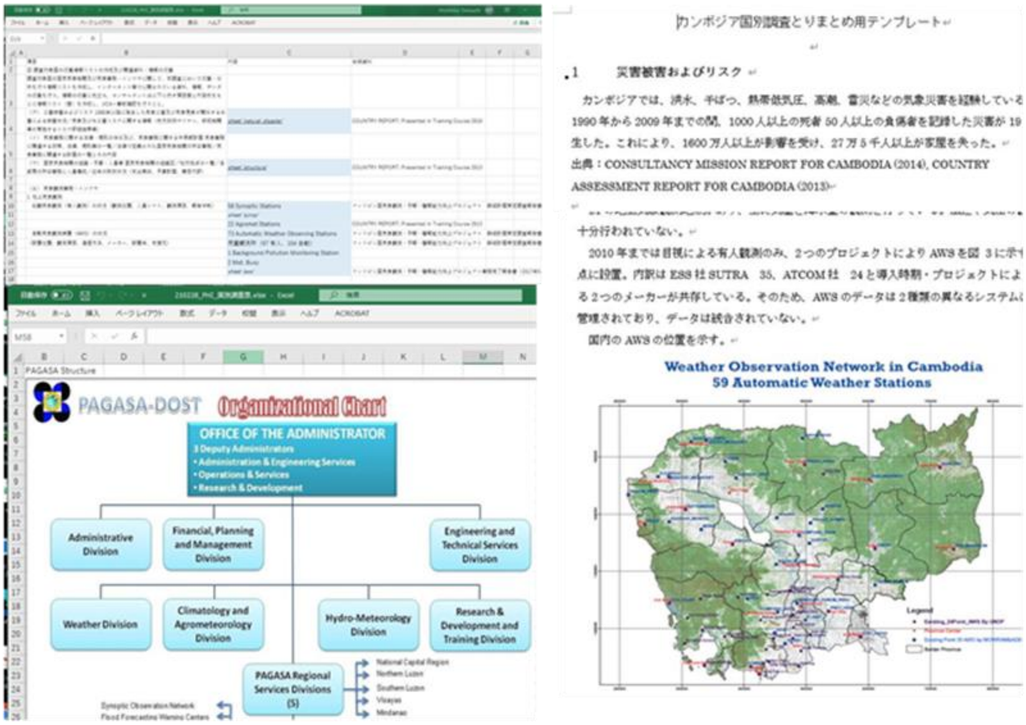

Figure I.2.1-3 Example of survey results by country

(Left) Itemized survey chart, organization chart, (Right) Disaster risk

In addition to the above, the team interviewed Oriental Electronics, Inc., which develops GTS/MSS and HimawariCast receiving systems and provide them to overseas, Japan Radio Co., Ltd., Toshiba Corporation, and Mitsubishi Electric Corporation, which manufacture meteorological radars, as well as Kyoto University, Tsukuba University, and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) which have been conducting international research cooperation. The team interviewed these companies/universities/institutes about the status of their overseas cooperation, challenges, and future directions.

(2) Surveys to each NMS

The domestic survey results by country and by item were summarized in Japanese and English, and additional survey sheets were prepared for items that required further inputs. For these materials, (1) a survey request letter addressed to the Director-General of each NMS (Letter shown in Figure I.2.1-4), (2) a domestic survey summary (Annex 3), (3) a request for the introduction of the person in charge of each NMS to conduct additional surveys (Annex 1), and (4) the current and future priority issues in the next five years of each NMS (Annex 2) were sent out in May 2022 to collect additional information.

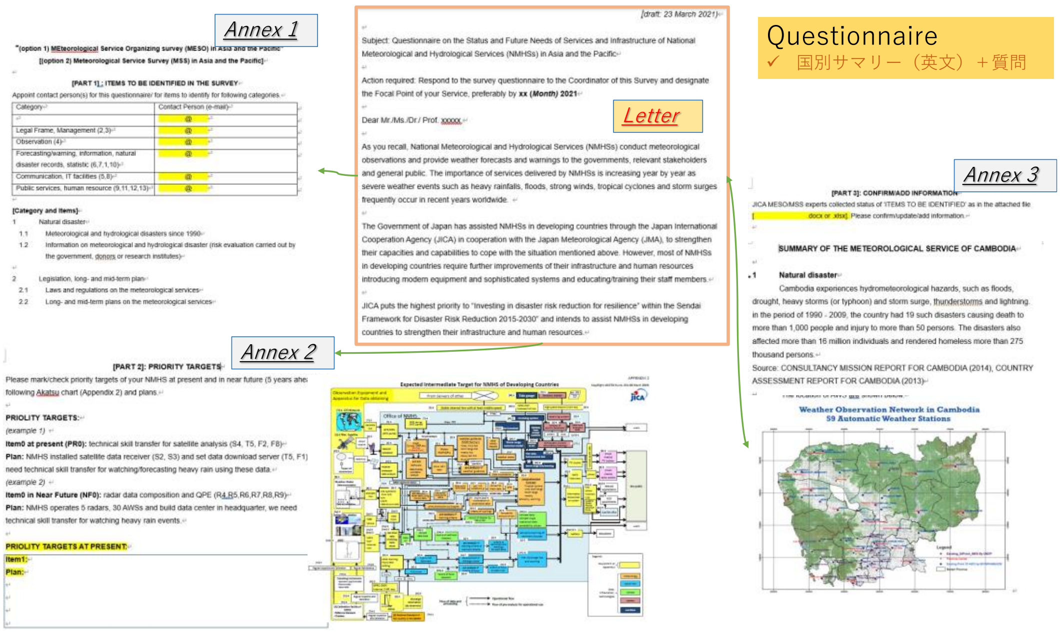

Figure I.2.1-4 Additional survey to each weather station

For those NMSs that did not respond to the questionnaire, the team repeatedly asked them to respond by e-mail or telephone. The responses from each NMS reinforced the domestic survey results.

Additional surveys and analyses were conducted from the "Survey of NMSs", with each field in charge of information collection and analysis.

(3) Online interviews with NMSs

Through the aforementioned country-by-country Survey, a contact person for each field in each country was designated, and additional surveys were conducted directly to the person in charge of each area at each NMS by e-mail or other means. For "surface and upper-air observations", "IT systems" and "meteorological statistics," simple online questionnaire sites were created, and additional information from each NMS was collected.

Because of the travel restrictions due to the Covid-19 and the lockdown in the target countries, it became difficult to conduct the field survey, and detailed country surveys were conducted on a remote basis with local employees.

The procedures for conducting the field survey are as follows: interviews were conducted with NMSs of Sri Lanka, Bangladesh, and Indonesia. Interviews were also conducted with Mongolia, where no projects have been implemented in recent years by JICA, to confirm the current situation and needs.

- Preparation of an inception report summarizing the purpose of the Survey, the results by country, and additional survey items
- Recruitment of local employees for field survey support
- Documentation based on the inception report and the research employment contract with the local employee
- Set up and assist in organizing online interviews by the local employees with the target country's NMSs

and collect materials used/referenced during the interviews

- Follow-up survey on issues that could not be investigated in the interviews
- Preparation of interview reports

(4) Compilation of survey results

Experts of the Survey Team analyzed the results of these surveys in each field to assess the current status and challenges in each country. The current status and challenges of NMSs, as well as key policies for cooperation by JICA, are summarized in Chapter III. All the data and information collected from each country are stored as inner materials in the JICA Headquarters.

In addition, publicity leaflets on "Cooperation in the Field of Meteorology" (A3 version) and "Cooperation in the Field of Meteorology by Region" (A4 version) for Southeast Asia, South Asia and the Pacific have been created. The workflow chart of NMSs of developing countries prepared by JICA has been revised and translated from Japanese into English, French and Spanish.

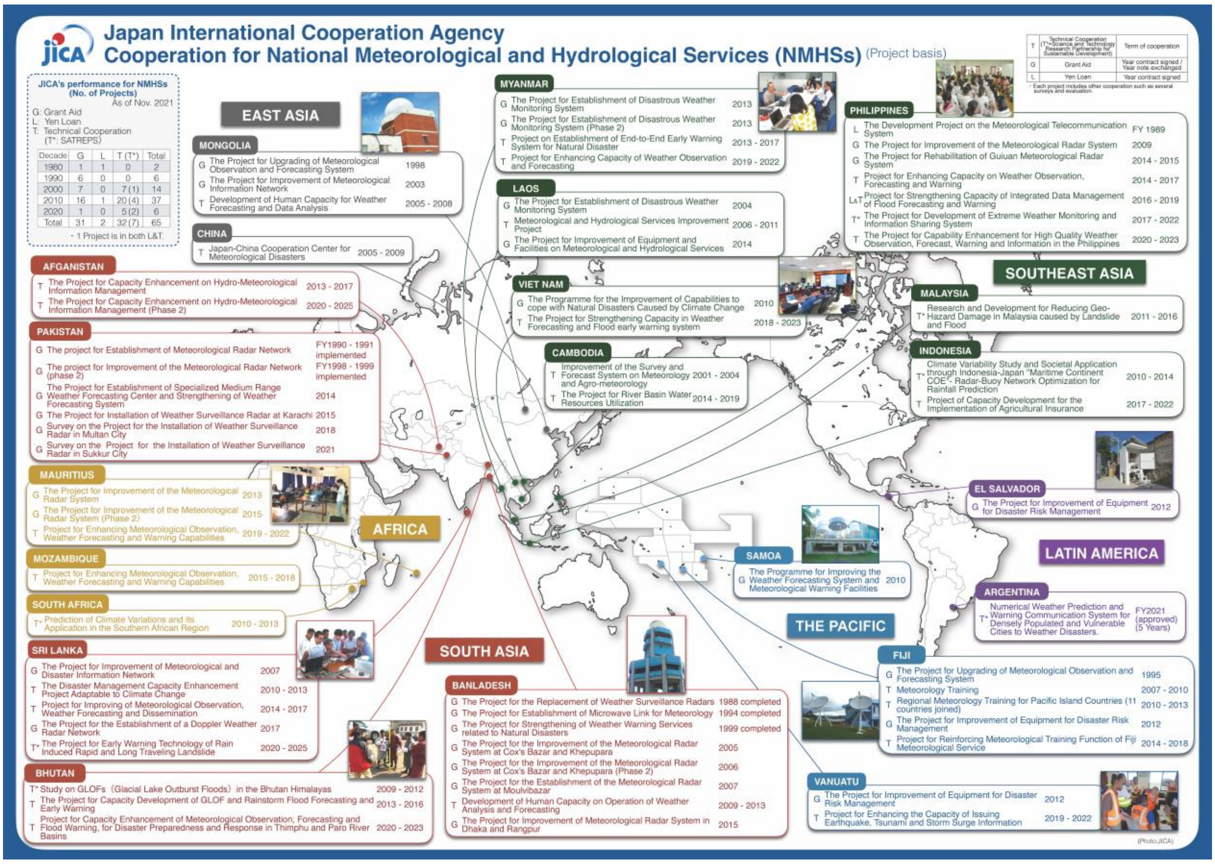

Figure I.2.1-5 Publicity leaflet

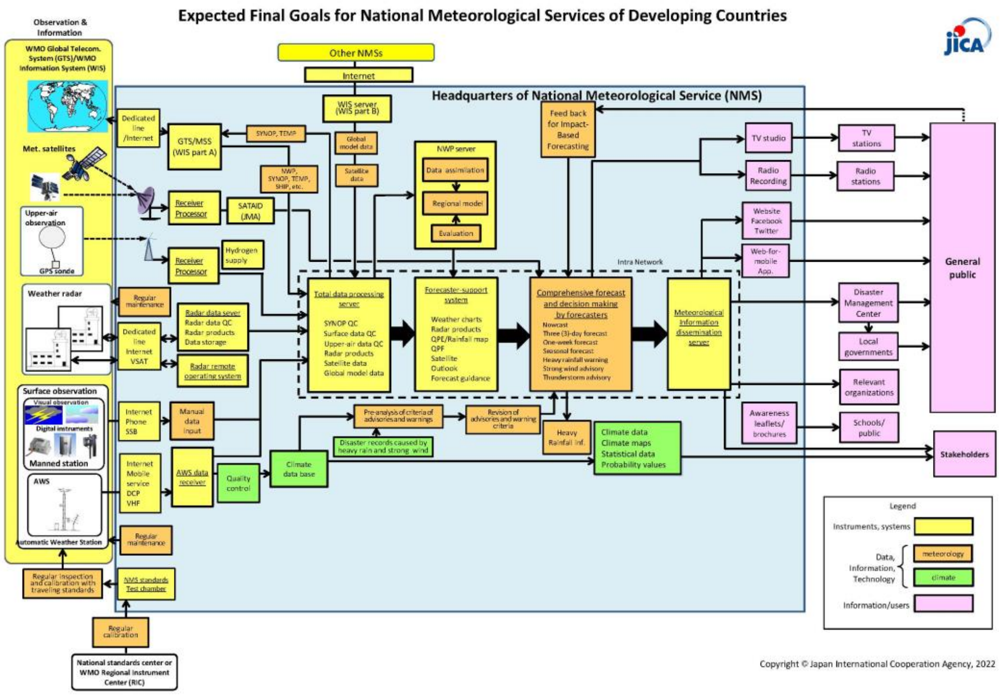

Figure I.2.1-6 Workflow chart of NMSs of developing countries

Table I.2.1-1 Past reports reviewed

Indonesia	Information gathering and confirmation surveys in the field of disaster prevention
Cambodia	Plan to improve agricultural weather forecasting methods
Laos	Meteorological monitoring network improvement plan
	Meteorological and Hydrological Services Improvement Project
	Meteorological and Hydrological System Development Plan
Viet Nam	Basic information collection and confirmation survey on meteorological and hydrological observation, forecasting, and warning services
	Project to Strengthen Operational Capacity of Weather Forecasting and Flood Early Warning System
Myanmar	Natural Disaster Early Warning System Development Project
	Meteorological observation equipment maintenance plan
	Project to Strengthen Meteorological Observation and Forecasting Capabilities
Philippines	Plan for improvement of meteorological communication network
	Meteorological Radar System Development Plan
	Project to improve meteorological observation, forecasting, and warning capabilities
	High-quality weather observation, forecasting, and warning capacity enhancement project
Fiji	Plan for improvement of meteorological observation and forecasting facilities
	Wide-area disaster prevention system improvement plan

	Oceanic State Meteorological Observation Capacity Enhancement Project
Mongolia	Plan for improvement of meteorological observation and forecasting facilities
	Meteorological Information Network Improvement Plan
	Human Resource Development Project for Weather Forecasting and Data Analysis
Bhutan	Project to improve forecasting and warning capacity, including glacial lake outburst floods (GLOFs)
	Project for Strengthening Meteorological Observation, Forecasting and Flood Warning Capacity for Disaster Preparedness and Response in the Thimphu and Paro River Basins
Pakistan	Establishment of the Mid-term Weather Forecast Center and Plan to Strengthen the Weather Forecast System
	Multan Weather Radar Development Plan
	Sackal weather radar maintenance plan
Sri Lanka	Meteorological Information and Disaster Prevention Network Improvement Plan
	Project on Enhancing Disaster Management Capacity in Response to Climate Change
	Project to improve meteorological observation, forecasting, and communication capacity
Bangladesh	Cox's Bazar and Khepupara Weather Radar Development Plan
	Project to improve meteorological observation and forecasting capabilities
	Dhaka and Rangpur Weather Radar Development Plan

I.2.2 The Survey Team Composition

A list of members of the Survey Team and their responsibilities are shown in Table I.2.2-1.

Table I.2.2-1 List of members of the Survey team and their responsibilities

Name	Area of Responsibility	Tasks
Kuniyuki SHIDA	Supervisor / Meteorological Services	Supervision of the entire survey team Country survey: Mongolia Sectoral survey: international and regional trends, laws and medium- and long-term plans, the status of cooperation by donors Field Survey and inception report: Mongolia, Sri Lanka, Analysis of the proposed policy of cooperation in the field of meteorology
Michihiko TONOUCHI	Deputy Supervisor / Information Dissemination / Meteorological Data Management	Support for the overall supervision of the survey team Workplan development and consultations, employment of local staff Country survey: Myanmar, Viet Nam Sectoral survey: human resource development, disaster damage risk Field survey and inception report: Bangladesh Preparation of public relations materials
Soshi IWATA	Surface and upper-air observation	Country survey: Indonesia Field survey: surface observation, upper-air observation, calibration of meteorological instruments

Name	Area of Responsibility	Tasks
Katsuhiro NAGAYA	Meteorological radar observation, operation, and data utilization	Organization of radar meetings and compilation of a report Country survey: Laos, Sri Lanka, Field survey: radar observation Development of Guidelines on dual-polarization radars
Hiroshi SATODA	Weather forecasting and warning / GTS, meteorological satellites	Country survey: Cambodia, Philippines Sectoral survey: international meteorological telecommunication, meteorological satellites, meteorological statistics Field survey and inception report: Indonesia
Mitsuhiro HATTORI	IT infrastructure	Country survey: Fiji Sectoral survey: IT Systems
Keisuke IMADA	Legal system / organizational structure / human resource development	Recruitment of local employees Country survey: Bangladesh, Pakistan Sectoral survey: organization, budget, human resources and cooperation with DRR authorities
Takuya DESHIMARU	International and regional meteorological services / climate change	Country survey: Bhutan, Nepal Sectoral survey: weather forecasting and infrastructure, weather information provision

I.2.3 Work Schedule

The work schedule of the Survey is shown in Table I.2.3-1.

Table I.2.3-1 Work schedule of the Survey

		2021											2022年
		2	3	4	5	6	7	8	9	10	11	12	1
OVERALL ACTIVITIES													
【0-1】	Preparation and discussion of the work plan												
【0-2】	Discussions with JICA for compilation												
【0-3】	C/P-questionnaire												
【0-4】	Local/domestic re-commissioning												
【0-5】	Holding of radar review meetings		△				△						△
	Reports W/P: workplan, P/R: Progress Report, F/R: Final Report	▲ W/P	▽ Radar review meeting				▽ Radar review meeting					▲ F/R(draft)	▽ ▲ adar review meetirF/R
OUTPUT 1													
(1)	International and regional trends												
(2)	Cooperation in the field of meteorology implemented by JICA												
(3)	Resources available for meteorological cooperation in Japan												
(4)	Selection of the target countries and collection of related materials and information												
(a)	Disaster damage and risk												
(b)	Laws and regulations related to meteorological services, and medium- and long-term plans												
(c)	Organization, budget, and personnel of national meteorological organizations												
(d)	Ground-based meteorological observation												
(5)	Radar meteorological observation												
(6)	Upper-air meteorological observation												
(7)	Meteorological satellite observations												
(8)	Calibration of meteorological instruments												
(e)	International meteorological information and communication												
(f)	Meteorological information provision services and infrastructure												
(g)	IT systems												
(h)	Cooperation with disaster prevention-related organizations												
(i)	Operations and infrastructure related to meteorological statistics												
(j)	Other operations carried out by national meteorological organizations												
(k)	Human resource development												
(l)	Cooperation by donors												
(5)	Questionnaire-based survey of national meteorological organizations												
(6)	Selection of target countries for field surveys												
(7)	Preparation of inception reports, including field survey plans												
(2) Field Survey													
(1)	Hearings and field Surveys to NMSs												
(2)	Information Sharing with JICA Field Offices					△							
	Indonesia												
	Sri Lanka												
	Bangladesh												
	Mongolia												
(3) Finalization													
(1)	Current status and challenges of meteorological services and infrastructure												
(2)	Analysis of the draft policy for cooperation in the field of meteorology												
(3)	Analysis of support measures (draft)												
(4)	Management of a study group for the introduction of multi-polarization radar		△				△						△
(5)	Preparation of public relations materials												
(6)	Multilingualization of existing meteorological materials prepared by JICA												
(7)	Preparation of the final report												

Chapter II Results of the Survey on the Cooperation in the Field of Meteorology

II.1 International Trends in the Field of Meteorology

II.1.1 Global Risks

The World Economic Forum (WEF) surveyed leaders in economics, politics, academia and other sectors of society and reported in its Global Risks Report 2021 that "extreme weather events" are highly likely to occur and will have significant negative impacts within the next 10 years. Within the environmental risks, "extreme weather events" (cold fronts, fires, floods, heat waves, windstorms, etc.) will cause loss of human life, damage to ecosystems, destruction of property and/or financial loss at a global scale.

Figure II.1.1-1 Global Risks

In this regard, the National Meteorological Services (NMSs), under the coordination of WMO, are responsible for observation, forecasting/warning and information dissemination of extreme weather events.

II.1.2 Role of National Meteorological and Hydrological Services

"The Role and Operation of National Meteorological and Hydrological Services – A Statement by the World Meteorological Organization for Directors of NMHSs" published by WMO in 2015, presents information on the role and operation of National Meteorological and Hydrological Services (NMHSs) worldwide as follows:

Functions of NMHSs

NMHSs own and operate most of the infrastructure that is needed for providing the weather, climate, water and related environmental services for the protection of life and property, economic planning and development, and for the sustainable exploitation and management of natural resources. Most of the NMHSs:

(a) Develop and distribute forecasts, warnings and alerts for safety of life and property and to support efforts to reduce the impacts of weather, climate, water and related environmental natural hazards;

(b) Provide essential data, information and products necessary for designing/planning, developing and managing infrastructure, settlements and essential sectors such as agriculture, water resources, energy and transport for improving the well being of societies;

(c) Maintain a continuous, reliable and comprehensive historical record of its national weather, climate, water and related environmental data;

(d) Provide relevant advice on weather, climate, water and related environmental issues for decision-making;

(e) Advance science and technology related to weather, climate and water as well as developing and improving their own operations and services through research and development;

(f) Participate in the development, implementation and operation of national multi-hazard early warning systems including those in seismology, volcanic ash monitoring, transboundary pollution, and in ocean-related phenomena such as tsunami;

(g) Fulfill relevant international commitments, including those under the Convention of the World Meteorological Organization, and further national interests through participation in the appropriate international programmes and activities;

(h) Establish and operate observing station networks that gather observations of the earth-atmosphere-ocean system in real time to support the provision of weather, climate, water and related environmental services and research activities including the assessment and projection of climate change;

(i) Establish and operate telecommunication networks for rapid exchange of observation, data and services;

(j) Acquire and operate data-processing and forecasting systems to provide real-time weather, climate, water and related environmental services including warnings and alerts to the public and sectors such as agriculture, water resources, energy, health, shipping, aviation, national defence and environment; and

(k) Acquire and operate a product dissemination system for efficient and effective delivery of information and services to users to enable planning, preparedness and decision-making for socio-economic development.

NMHSs are expected to contribute to:

- Economic and social development activities in their countries;
- International efforts on sustainable development.

Service delivery

NMHSs provide weather, water, climate and related environmental services to a wide range of sectors, including agriculture, water, energy, tourism, transport and health, to assist them in reducing the risks of, and deriving economic benefits from, the associated conditions. The provision of user-targeted products together with their application requires close collaboration between NMHSs and users to enable the integration of user needs in the development of services and facilitate feedback for their improvement. The rapid delivery of warnings and alerts needs close collaboration with the media and telecommunication service providers.

Basic systems that support the delivery of services are:

- Observing and monitoring the atmosphere and related environment;
- National and international exchange of observations, data and products;
- Data processing and forecasting.

Elements required for the successful operation of NMHSs are as follows:

- National legal instruments to define the mission and mandate of NMHSs;
- Impacts of international agreements;
- Governance;
- Partnerships and Cooperation.

The following items are necessary for future development of and opportunities for NMHSs.

- Exploiting greater scientific understanding;
- Exploiting technological advances;
- Education and Training.

II.1.3 WMO Strategic Plan

The outline of the "WMO Strategic Plan 2020-2023" adopted by the WMO at its Eighteenth Congress in 2019 is as follows:

Vision 2030

By 2030, a world where all nations, especially the most vulnerable, are more resilient to the socioeconomic consequences of extreme weather, climate, water and other environmental events; and underpin their sustainable development through the best possible services, whether over land, at sea or in the air.

Overall priorities

- Enhancing preparedness and reducing loss of life, critical infrastructure and livelihood from hydrometeorological extremes;.
- Supporting climate-smart decision making to build or enhance adaptive capacity or resilience to climate risk;
- Enhancing socioeconomic value of weather, climate, hydrological and related environmental services.

Long-term goals and strategic objectives

Goal 1 Better serve societal needs: delivering, authoritative, accessible, user-oriented and fit-for-purpose information and services

Objective 1.1 Strengthen national multi-hazard early warning/alert systems and extend reach to better enable effective response to the associated risks

Objective 1.2 Broaden the provision of policy- and decision-supporting climate information and services

Objective 1.3 Further develop services in support of sustainable water management

Objective 1.4 Enhance the value and innovate the provision of decision-supporting weather information and services

Goal 2 Enhance Earth system observations and predictions: Strengthening the technical foundation for the future

Objective 2.1 Optimize the acquisition of Earth system observation data through the WMO Integrated Global Observing System (WIGOS)

Objective 2.2 Improve and increase access to, exchange and management of current and past Earth system observation data and derived products through the WMO Information System

Objective 2.3 Enable access and use of numerical analysis and Earth system prediction products at all temporal and spatial scales from the WMO seamless Global Data Processing and Forecasting System

Goal 3 Advance targeted research: Leveraging leadership in science to improve understanding of the Earth system for enhanced services

Objective 3.1 Advance scientific knowledge of the Earth system

Objective 3.2 Enhance the science-for service value chain ensuring scientific and technological advances improve predictive capabilities

Objective 3.3 Advance policy-relevant science

Goal 4 Close the capacity gap on weather, climate, hydrological and related environmental services: Enhancing service delivery capacity of developing countries to ensure availability of essential information and services needed by governments, economic sectors and citizens

Objective 4.1 Address the needs of developing countries to enable them to provide and utilize essential weather, climate, hydrological and related environmental services

Objective 4.2 Develop and sustain core competencies and expertise

Objective 4.3 Scale-up effective partnerships for investment in sustainable and cost-efficient infrastructure and service delivery

Goal 5 Strategic realignment of WMO structure and programmes for effective policy- and decision-making and implementation

NMHSs of WMO Members are expected to take this Strategic Plan into account in developing and carrying out their national development, disaster risk reduction, climate services and other relevant strategies on programmes in meteorology, hydrology and related disciplines.

II.1.4 Sustainable Development Goals (SDGs)

It is expected that the actions promoted by WMO and the work of NMSs will contribute to the Sustainable Development Goals (SDGs), which are international goals for a better and more sustainable world by the year 2030, as stated in “2030 Agenda for Sustainable Development” adopted at the UN Summit in 2015 (Table II.1.4-1).

Table II.1.4-1 Sustainable Development Goals and WMO Actions

Sustainable Development Goals (SDGs)	Improve observation and data exchange	Advance targeted research	Improve modeling and forecasts	Improve service quality and delivery	Reduce disaster risks	Strengthen capacity building
1 No Poverty	X	X	X	X	X	X
2 Zero hunger	X	X	X	X	X	X
3 Good health and well¥being	X	X	X	X	X	X
4 Quality Education						X
5 Gender equality					X	X
6 Clean water and sanitation	X	X	X	X	X	X
7 Affordable and clean energy	X	X	X	X	X	X

8 Decent work and economic growth						X
9 Industry, innovation and infrastructure					X	
10 Reduced inequalities						X
11 Sustainable cities and communities	X	X	X	X	X	X
12 Responsible consumption and production						X
13 Climate action	X	X	X	X	X	X
14 Life below water	X	X	X			
15 Life on land					X	
16 Peace, justice and strong institutions						X
17 Partnerships for the goals						X

The contributions of meteorological services to individual development goals are as follows:

Development Goal 1: End poverty

Reducing disaster risk, advancing research and providing information and services for decision-making contribute to development and the elimination of poverty. While not always recognized as poverty-reduction measures, weather, climate and other products and services provide many essential, and often measurable, socio-economic benefits.

Development Goal 2: Zero hunger

Farmers, herders and fishers rely extensively on weather and climate services for anticipating and reducing risks, adapting crops, day-to-day and seasonal agrarian management, and maximizing productivity. Through their increasingly targeted services to the agricultural sector, NMHSs are clearly central to ensuring global food security.

Development Goal 3: Ensure healthy lives and promote well-being for all at all ages

The appearance of mosquitoes, ticks and other insects that transmit many illnesses is frequently influenced by weather, climate and water. Deaths and injuries also result from floods, droughts, heatwaves and air pollution. The forecasts and advice that NMHSs and other service providers deliver to health agencies and to the public help to save lives. (Example: WMO/WHO Atlas of Health and Climate)

Development Goal 5: Achieve gender equality and empower all women and girls

Achieving gender equality and empowering women and girls is essential to meeting the challenges of climate change, disaster risk reduction, and sustainable development.

Development Goal 6: Ensure availability and sustainable management of water and sanitation for all

Observations and information on the hydrological cycle, including wetlands, aquifers, lakes, reservoirs and rainfall, are vital for guiding sustainable water management. The data and analyses provided by NMHSs and other service providers also help to ensure that drinking water is safe and that human activities do not pollute aquatic ecosystems.

Development Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all

The growth in market share by clean energy sources is facilitated by rainfall, sunshine and wind data and forecasts. Weather forecasts also help to protect energy infrastructure from hydrometeorological hazards. (Example: Global Framework for Climate Services (GFCS))

Development Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Severe weather can damage or destroy vulnerable infrastructure, resulting in both economic and human losses. National weather reports protect infrastructure and industry from natural hazards, while climate change scenarios provide guidance on the placement and climate-proofing of infrastructure in coastal and other climate-vulnerable areas. (Example: WMO Severe Weather Forecasting Programme (SWFP))

Development Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

By helping planners to make cities more climate-resilient, national weather and climate services reduce deaths and injuries from hazards, empower the poor and vulnerable, and protect cultural and natural heritage sites. (Example: Response to the Sendai Framework for Disaster Risk Reduction 2015-2030 by multi-hazard warning systems, impact-based forecasting and warnings)

Development Goal 13: Take urgent action to combat climate change and its impacts

The WMO community's challenge is to provide decision-makers with the scientific facts and analyses they need to adapt to climate change impacts and build climate resilience.

Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

WMO, NMHSs and other national entities support international efforts to monitor ocean temperatures, currents, salinity, acidification and surface levels – all major drivers of weather and climate. They also support coastal management and resilience, particularly for Small Island Developing States

(SIDS) and other vulnerable regions. (Example: WMO Coastal Inundation Programme (CIDP))

Development Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

NMHSs monitor the hydrology that shapes the health of freshwater ecosystems, forests and dryland areas. They provide essential data and forecasts that support efforts to combat desertification and restore degraded land and soil, including land affected by drought and floods.

Development Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development

One of the WMO strategic priorities is to strengthen capacity development in order to enhance the capability of NMHSs to fulfill their mandates for providing operational weather, climate and water services (e.g., SDGs, Sendai Framework, GFCS, etc.)

II.1.5 Sendai Framework for Disaster Risk Reduction

"The Sendai Framework for Disaster Risk Reduction 2015-2030," adopted at the Third United Nations World Conference on Disaster Risk Reduction in 2015, sets out the following four priority areas.

Priority 1 Understanding disaster risk,

Priority 2 Strengthening disaster risk governance to manage disaster risk,

Priority 3 Investment in disaster risk reduction for resilience, and

Priority 4 Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

NMHSs can contribute to the fourth priority for action primarily through the enhancement of the Multi-Hazard Early Warning Systems (MHEWSs). MHEWSs will perform the following actions:

- Analyses and assessment of risks involved

NMHSs will contribute to the analyses and assessment of risks of hazards related to weather, climate and water.

- Detection, monitoring, analysis and forecasting the hazards

Hazard specific (e.g., flash floods, storms, tropical cyclones) and sector specific (e.g., agriculture, aviation, humanitarian assistance) early warnings are provided by NMHSs. Therefore, the capacity to issue impact-based forecasts and risk-based warnings needs to be strengthened. Service delivery for DRR in sectors of health, agriculture, land transportation and energy, and in megacities and large urban complexes needs to be improved.

- Dissemination and communication of timely, accurate, actionable, inclusive and authoritative warnings

NMHSs produce forecasts and warnings based on meteorological data and products collected and exchanged through international and domestic communication networks, and provide and disseminate them to relevant domestic agencies, mass media, and the public through various means of communication and dissemination.

- Preparedness and response capabilities

Humanitarian disaster preparedness and response can be improved through collaboration between NMHSs, national disaster management agencies and international humanitarian agencies.

II.1.6 Impact-Based Forecasting

Scientific advance in weather forecasting have afforded the ability to provide reliable warnings of hydrometeorological multi-hazards at an accuracy and lead time that should directly fulfill the mission of NMHSs to provide warnings on hydrometeorological hazards in support of safety of life and mitigation of damage to property. In order for governments, economic sectors and the public to take appropriate actions, they need to know hydrometeorological multi-hazards might have an impact on their lives, livelihoods and property and on the economy.

Many people still lose their lives, and socio-economic costs associated with hydrometeorological hazards continue to rise, due, in part, to a lack of appreciation and understanding of the impacts and consequences of hydrometeorological hazards to well-being.

Therefore, WMO is promoting the "Impact-based Forecasting and Warning Service" to reduce the human, regional and economic damage caused by disasters. This means that NMHSs not only aim to prepare and issue warnings, but to contribute to the prevention and mitigation of disasters by incorporating the impact of hazards into the forecasts and warnings. (Figure II.1.6-1)

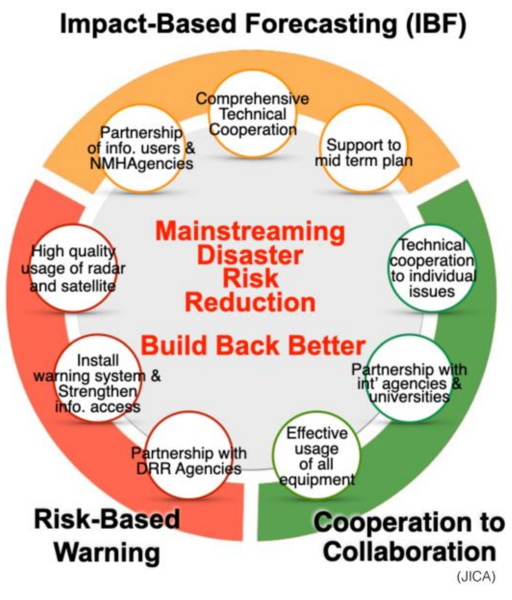

Figure II.1.6-1 Promotion of the Impact-Based Forecasting (IBF)

Currently, only a few NMHSs in developed countries issues impact-based forecasts and warnings. Many NMHSs in developing countries are considering the introduction of such a system but have not yet implemented it, and this should be taken into account when supporting NMHSs in developing countries in the future.

II.1.7 Assistance Provided to Developing Countries by NMSs of Major Developed Countries

The status of assistance provided to developing countries by NMSs of major developed countries in 2019, compiled by the WMO Secretariat is as follows:

[Australia]

- Climate and Oceans Support Program for the Pacific - Phase Two (COSPPac2)
  Target countries: 14 countries in the Pacific, Budget: USD 5.6M, Funding: Australian Government
  Activities: Pacific Sea Level and Geodetic Monitoring Network, seasonal forecasting, monthly climate monitoring bulletin, establishment and operation of Climate Data for Environment (CliDE) database, training
- Papua New Guinea Capacity Development Program (PNGCDP)
  Target country: Papua New Guinea, Budget: USD 1.0M, Funding: Australian Government
  Activities: Provision of new AWSs, restoration of existing observation network, implementation of the PNG National Weather Service Strategic Plan (2019-2023), establishment of a twinning relationship between NWS and the Bureau of Meteorology (Australia) forecasters for mentoring and collaboration purposes, assimilation of observations of PNG for improved NWP guidance, education and training of forecasters.
- Climate Services for Resilient Development in Vanuatu (Van CIS RDP)
  Target country: Vanuatu, Budget: USD 21K, Funding: Green Climate Fund
  Activities: Improvement of climate data records (including data rescue, quality management training), development of climate information services
- Early Warning and Response Systems in the Solomon Islands
  Target country: Solomon Islands, Budget: USD 7K, Funding: Australian Government
  Activities: Assessment of early warnings and provision of advice and training

[Canada]

- Building seamless multi-hazard early warning system under the Climate Risk Early Warning Systems (CREWS) initiative.
  Target countries: Southeast Asia and Small Island Developing States, Budget: CAD 2M, Funding Environment and Climate Change Canada
  Activities: Reduction of human and economic losses associated with meteorological, hydrological and climate-related hazards through strengthening of weather, climatic and water impact-based decision support services to stakeholders, socio-economic sectors and communities.
- Haiti Weather System Program: Climate Services to Reduce Vulnerability in Haiti

Target country: Haiti, Budget: CAD 722K, Funding: Environment and Climate Change Canada
Activities: Rehabilitation of Hydro-meteorological Agencies for the delivery of quality weather, climate and hydrological services including early warnings

[China]

- China Study Tour/First FENGYUN Satellite User Forum: USD 18K
- Short-term training (Total 290 foreign experts)
    - Storm Surge-induced Inundations on the Bay of Bengal and Numerical Prediction Technologies of Ocean Wave Hazards: USD 66K
    - Use of Meteorological Satellite Products and Remote Sensing Technology: USD 101K
    - Assessment of Climate Change Impacts on Agriculture with Remote Sensing Technology: USD 131K
    - Modern Weather Forecast Technologies: USD 31K
    - Climate Change and Climate Information Service: USD 50K
    - Technological Transfer in Coping with Climate Change: USD 79K
    - Economic Development in the Context of Environment and Climate Change for Zanzibar: USD 86K
    - Meteorological Disaster Prevention Technologies: USD 383K
    - Early Warning of Meteorological Disasters: USD 64K
    - Management for Meteorological Officials: USD 84K
    - Disaster Reduction for Indonesia: USD 52K
    - Rainfall Run-off Simulation and Climate Change for Iraq: USD 37K
    - Modern Weather Forecast Technologies: USD 32K
    - Nowcasting Techniques on Severe Convection Weather: USD 61K
    - FENGYUN Satellite Products and Application: USD 67K
    - Application of Meteorological Satellite Products in Weather Forecasting: USD 32K
    - Asian Aviation Hazardous Weather Coordination: USD 38K
- Long-term WMO/China government scholarship (110 scholarship students): USD 1M
- Provision of instruments and equipment
    - Provision of one set of CMACast to Papua New Guinea: USD 71K
    - Provision of 3 sets of satellite data receiver stations to Kyrgyz Republic, Oman and Mozambique: 328K
    - Provision of a CMACast System Service to Laos, Viet Nam, Sri Lanka, Maldives, Malaysia, Nepal, Pakistan: USD 50K.
    - Update of the Meteorological Station in Uzbekistan: USD 57K

[Finland]

Funding: Ministry of Foreign Affairs, Total amount: USD 1M

- Kyrgyzstan: FINKMET II
  Glacier observation with an AWS, unmanned aerial vehicles (UAVs), training on the new air quality observation equipment, training on analysis and reporting of air quality data
- Nepal: FNEP III
  Technical support in radar acquisition process (site selection and evaluation, technical specifications, procurement documents), development of customer management processes, and support in implementation of the World Bank project
- Sudan and South Sudan: FISU II
  Development of the data management system, training on weather forecasting and forecast production
- Tajikistan: FINTAJ II
  Glacier observation with an AWS, UAVs, training on the new air quality observation equipment, training on analysis and reporting of air quality data
- Viet Nam: PROMOSERV III
  Training on weather forecasting process, training on forecaster workstation and forecast production tools (SmartMet), training on customer relationship and management processes
- Viet Nam: PROMOAIR
  Development and training on air quality services for the Vietnam Environmental Administration, capacity building for air quality measurements, modeling and source apportionment
- Viet Nam: SmartMet
  Modernization and installation of weather forecast workstations and production systems (SmartMet) in VNMHA, training on short-range weather forecasts and product development

[France]

- Fellowships, training: 180 persons, Budget: USD 170K, Funding: Météo-France
- Expert missions, Budget: USD 88K, Funding: Météo-France, French embassies
  - Algeria (marine weather forecasting, deep convection prediction, satellite meteorology)
  - Tunisia (deep convection prediction, winter phenomena)
  - Morocco (extreme weather, Information Systems Center)

[Germany]

- Regional NWP COSMO (Consortium for Small-scale Modelling)
  Support for introduction of regional NWP in 17 NMHSs, Budget: USD 91K, Funding: DWD (German Meteorological Service)
  Numerical model training, Budget: USD 26K, Funding: DWD
- Climate predictions (seasonal to decadal) and climate projections for disaster preparedness, Budget: USD 29K, Funding: DWD
- Provision of data and products (for African countries), Budget: USD 87K, Funding: DWD

- Data rescue, digitization and quality control of observational records of 152 stations (32 in Africa, 120 in Central/South America), Budget: USD 98K, Funding: DWD
- GIZ/DWD Project: "Enhancing Climate Services for Infrastructure Investments (CSI)," International Climate Initiative (IKI)
  Target countries: Brazil, Costa Rica, Viet Nam, Nile riparian countries, Budget: USD 56K for DWD
- GIZ/DWD Project: Adaptation of agricultural value chains to climate change (PrAda) in Madagascar
  Target country: Madagascar, Funding: DWD, Budget: USD 56K,

[Hong Kong]

- Workshop on Nowcasting, Seamless Forecasting and Warning Services

[Japan]

Expert missions and training

- Expert mission on the on-site assessment of the technical problems of the weather radar system in Vientiane, Lao PDR
  Budget: USD 35K, Funding: JMA
- JMA Tokyo Climate Center (TCC) Training Seminar on Climate Analysis Information on Extreme Climate Events (for 15 participants from RA II and RA V)
  Budget: USD54 K, Funding: JMA

Training seminars (Budget: USD 133 K, Funding: JMA)

- JMA Technical meeting on a regional weather radar network for Southeast Asia (for 7 participants from RA II and RA V)
- WMO OSCAR/Surface Training Course for the RA II East Asia Subregion (for 16 participants from RA II)
- JMA Weather Radar Seminar (for 14 participants from RA II, RA V and RA VI)

Other education and training events

- WMO/Kyoto University short-term fellowship (for Myanmar and Turkey)
- JICA Knowledge Co-creation Program (Group and Region Focus) for Reinforcement of Meteorological Services (for 9 participants from RA I, RA II and RA V)

[Republic of Korea]

ODA Projects

- Modernization of Forecasting and Warning System for Natural Disaster in Myanmar
  2017-2019, Budget: USD 4M
- Installation of Automatic Weather Observation System in Mongolia
  2017-2019, Budget: USD 3M
- Installation of Automatic Weather Observation System in Cambodia
  2017-2022, Budget: USD 3M

- Support of the GEO-COMPSAT-2A Receiving and Analysis System in Bangladesh
  2017-2021, Budget USD 2.5M

WMO/KMA (Korea Meteorological Administration) Projects

- Coastal Inundation Forecasting Demonstration Project-Fiji
  2016-2020, Budget USD 1.2M
- Modernization of Aviation Meteorological services in Mongolia
  2014-2020, Budget USD 400K
- Climate Data Rescue Project in Uzbekistan (II)
  2019-2021, Budget USD 418K

Training Seminar (Budget: USD 168K**)**

- Radar Operation - 14 trainees / 2 weeks (Myanmar, Senegal, Sri Lanka, etc.)
- Weather Forecasting - 11 trainees / 3 weeks (Mongolia, Viet Nam, Cambodia, etc.)
- Impact of the Natural Disasters on Africa - 2 trainees / 1 week (Nigeria)

[New Zealand]

- Observing Programme Support for Pacific Island Countries & Territories
  Funding: Meteorological Service of New Zealand, Budget: USD 16K
- Severe Weather Forecasting and Disaster Risk Reduction Demonstration Project (SWFDDP)
  Funding: Meteorological Service of New Zealand, Budget: USD 60K
- Nukunonu (Tokelau) AWS installation
  Funding: National Emergency Management Agency, Budget USD 55K
- Development of Pacific competence-based training materials and manuals for Hydrometeorological technicians
  Funding: National Institute of Water and Atmospheric Research, Budget USD 60K

[Norway]

Meteorological Capacity Building Projects

Funding: Norwegian Agency for Development Cooperation (NORAD), Budget: USD 200K

- BMD Bangladesh: "Institutional support and capacity building for mitigation of weather and climate hazards in Bangladesh"
- DMH Myanmar: "Cooperation between DMH Myanmar and Norwegian Meteorological Institute on Capacity Building"
- NHMS Viet Nam: "Cooperation between the National Hydro-Meteorological Service of Viet Nam and the Norwegian Meteorological Institute on Capacity Building."
  Activities: Strengthening of early warning systems and decision making in forecasting and warning services, NWP verification, climate services, and ocean modeling
- Weather and Climate Services in Tanzania and Malawi as Digital Public Goods
  Funding: NORAD, Budget: USD 440K

- Technical Assistance Services to improve the delivery of Meteorological Services in Mozambique" at INAM Mozambique
  Funding: Nordic Development Fund (NDF)/World Bank, Budget USD 120K
- Technical Assistance to upgrade DMH operational weather monitoring and forecasting, service delivery and quality management capabilities
  Funding: WMO/World Bank, Budget USD 50K
- Strengthening the forecasting system for accelerating improvements in quantitative precipitation estimates for flood and landslide early warning in Sri Lanka
  Funding: World Bank, Budget USD 95K

[United Kingdom] (Funding: UK Met. Office, Total budget: USD 1M)

Support through the WMO Voluntary Cooperation Programme (VCP)

- Global Climate Observing System (GCOS) Upper Air Network (GUAN)
  Pacific countries, St. Helena, Seychelles

Support for forecast delivery

- SWFDP Southern Africa, Eastern Africa, Western Africa, Pacific, Bay of Bengal
- NWP model development (Tropical Africa model, 4km resolution): Eastern Africa, Central Africa, Western Africa
- Display of data and products on the Africa Web Viewer (AWV)
- Provision of data and products via EUMETCAST Africa

Climate Data Management

- Support for the development of Climsoft climate database management system (CDMS): African countries

Media/Communications

- TV weather program production/presentation system, Main targets: African countries

Human Resource Development

- MSc fellowships: Papua New Guinea, Ghana, Uganda, Nigeria at Reading University
- Management e-learning: More than 200 participants have completed the course since the 2008

Other key projects

- HIGHWAY, W2SIP, Somalia & South Sudan, CRISPP, Rwanda, Asia Regional Resilience to a Changing Climate, Improving Meteorological Services Mozambique, CONFER, SWIFT, Commonsensing, Technical Assistance to Myanmar

[United States]

- Weather Ready Nations – Impact-Based Forecasting (IBF)
  Target countries: Barbados, El Salvador, Guatemala, Costa Rica, South Africa, Sri Lanka, Indonesia
  Funding: USAID, Budget: USD 2.4M

- Training: Africa and Tropical Training Desks, Pacific Desk
  Funding: Department of State/VCP/USAID, Budget: USD 1.1M
- RANET, Target: Pacific countries
  Funding: Department of State/VCP/USAID, Budget: USD 121K
- Development of improved storm surge modeling in the Caribbean
  Funding: Department of State/VCP/USAID, Budget: USD 200K
- Development of 3D-Printed Automatic Weather Stations (PAWS)
  Funding: USAID, Budget: USD 400K
- V-Lab support - Virtual training program
  Funding: Department of State, Budget: USD 50K

II.1.8 Projects Implemented by WMO

WMO has implemented the following projects with external financial resources:

- Fiji: Coastal Inundation Demonstration Project-Fiji
  Funding: Korea Meteorological Administration (KMA), Budget: USD 1.2M
- Uzbekistan: Climate Data Rescue in Uzbekistan, Phase 2: Digitization
  Funding: KMA, Budget: USD 420K
- Mongolia: Modernization of the Aviation Meteorological Services of Mongolia
  Funding: KMA, Budget: USD 395K
- Tanzania: Enhancing the capacity in provision and utilization of weather and climate services in Tanzania
  Funding: KMA, Budget: USD 99K
- Bhutan: Developing Capacities for Effective Climate Services in Bhutan
  Funding: KMA, Budget: USD 127K
- Southeast Asia: Applying Seasonal Climate Forecasting South East Asia
  Funding: German Ministry for the Environment (BMU), Budget: EUR 8M
- Kenya: WISER AMDAR Kenya
  Funding: UK Foreign, Commonwealth and Development Office (FCDO), Budget: USD500K
- Brazil: Consolidation of Numerical Weather Forecast by INMET
  Funding: Brazil, Budget: USD 7.8M
- Training Programme on Climate Change Adaptation and DRR in Agriculture
  Funding: Italy, Budget: USD 916K
- East Africa: ACREI East Africa - WMO Component
  Funding: Adaptation Fund, Budget: USD 2M
- East Africa: ACREI East Africa - FAO Component
  Funding: Adaptation Fund, Budget: USD 4.7M
- Central Asia: Support implementation of Central Asia Hydrometeorology Modernization Project
  Funding: World Bank, Budget: USD 333K

- Early Warning System - Disaster Risk Reduction
  Funding: USAID, Budget: USD 3.5M
- La Plata Program
  Funding: USAID, Budget: USD 1.5M
- Flash Flood Guidance System (FFGS) Phase III
  Funding: USAID, Budget: USD 5M
- South East Europe: South East Europe MHEWS Phase II
  Funding: World Bank, Budget: USD 900K
- Saudi Arabia: Modernization of PME
  Funding: Saudi Arabia, Budget: USD 1.6M
- Volta Flood and Drought Management
  Funding: Adaptation Fund, Budget USD 7.9M
- Eastern Africa Climate Data Rescue Eastern Africa
  Funding: African Development Bank, Budget: USD 348K
- Latin America: Technical Cooperation for the Assessment of Hydromet Services in Latin America
  Funding: Inter-American Development Bank, Budget USD 333K
- East Africa: WISER HIGHWAY EWS East Africa
  Funding: DFID, Budget: USD 4.1M
- Haiti: Climate Services to Reduce Vulnerability in Haiti
  Funding: Environment and Climate Change Canada (ECCC), Budget: USD 6.5M
- Africa: GFCS Adaptation Programme for Africa Phase II
  Funding: Norwegian Agency for Development Cooperation (NORAD), Budget: USD 36M
- Integrative Health Services
  Funding: WHO, Budget: USD 210K
- Global Polar Observations Predictions and Climate Services
  Funding: ECCC, Budget USD 845K
- WMO HydroHub
  Funding: Swiss Agency for Development and Cooperation (SDC), Budget CHF 2.8M
- Intra-ACP Climate-Services Programme
  Funding: European Commission, Budget EUR 5.5M
- Caribbean Sea: CREWS SIDS-SEA-Caribbean
  Funding: Ministry of Environment and Climate Change Canada (ECCC), Budget: USD 2M
- Pacific CREWS SIDS-SEA-Pacific
  Funding: ECCC, Budget: USD 3.6M
- Southeast Asia CREWS SIDS-SEA-Southeast Asia
  Funding: ECCC, Budget USD 4.4M
- Burkina Faso: CREWS MDTF Burkina Faso_
  Funding: CREWS Multi-Donor TF (CREWS MDTF), Budget USD 2.2M

- Pacific Small Island Developing States: CREWS MDTF Pacific SIDS
  Funding: CREWS MDTF, Budget USD 2.5M
- Democratic Republic of Congo: CREWS_MDTF Democratic Republic of Congo
  Funding: CREWS MDTF, Budget USD 300K
- Niger: CREWS MDTF Niger
  Funding: CREWS MDTF, Budget: USD 250K
- Papua New Guinea: CREWS MDTF Papua New Guinea
  Funding: CREWS MDTF, Budget: USD 1.65M
- Mali: CREWS MDTF Mali
  Funding: CREWS MDTF, Budget: USD 250K
- West Africa: CREWS MDTF West Africa
  Funding: CREWS MDTF, Budget: USD 4M
- Togo: CREWS Togo
  Funding: CREWS MDTF, Budget: USD 1.1M
- Chad: CREWS Chad
  Funding: CREWS MDTF, Budget: USD 1.5M
- ECOWAS: Hydromet institutional development & flood management in ECOWAS
  Funding: World Bank, Budget: USD 189K
- Caribbean: CREWS MDTF Caribbean
  Funding: CREWS MDTF, Budget: USD 2.3M
- Afghanistan: CREWS Afghanistan
  Funding CREWS MDTF, Budget: USD 970K
- Haiti: CREWS MDTF Haiti
  Funding: CREWS MDTF, Budget: USD 1.5M
- Strengthening Capacities in Measuring Early Warning Effectiveness
  Funding: CREWS MDTF, Budget: USD 192K
- Pacific Ocean: CREWS Pacific 2.0
  Funding: CREWS MDTF, Budget: USD 3.4M
- South West Indian Ocean: CREWS South West Indian Ocean
  Funding: CREWS MDTF, Budget: USD 1.75M
- Enhancing the climate science basis of the climate rationale of all GCF funded activities
  Funding: Green Climate Fund (GCF), Budget: USD 1.4M
- Myanmar: Technical assistance for the modernization of the Department of Meteorology and Hydrology (DMH)
  Funding: US Water Conservation Center, Budget: USD 3.4M
- Enhancing Adaptive Capacity of Andean Communities through Climate Services (ENANDES)
  Funding: Adaptation Fund, Budget: USD 7.4M
- Drought information system in southern South America (SISSA)

Funding: EC, Budget: USD 1.3M

- Africa: Focus Africa WMO

  Funding: EC, Budget: EUR 1.1M

- Focus Africa Passthrough

  Funding: EC, Budget: EUR 5.9M

The numbers of fellowships that WMO has awarded to the target countries of this Survey from 2011to 2020 are as follows:

Bhutan	7
Cambodia	0
Fiji	13
Indonesia	8
Laos	1
Mongolia	7
Myanmar	21
Nepal	4
Pakistan	6
Philippines	4
Sri Lanka	15
Vietnam	2

II.1.9 Projects Implemented by the World Bank

The World Bank is implementing the following projects in the South Asia Region and the East Asia-Pacific Region:

[South Asia Region]

- Pakistan: Pakistan Hydrometeorological and Climate Services Project

  Budget: USD 188M

  Activities: 1) Hydrometeorological and climate services (capacity building, observations, data management and forecasting systems, service delivery), 2) Disaster risk management, 3) Emergency response

- Bangladesh: Bangladesh Weather and Climate Services Regional Project

  Budget: USD 127.8M

  Activities: 1) Strengthening of meteorological information service, 2) Strengthening of hydrological information service and early warning systems, 3) Agricultural meteorological information systems development

- Nepal: Building Resilience to Climate Related Hazards

  Budget: USD 31M

  Activities: 1) Institutional strengthening, and capacity building and implementation support of Department of Hydrology and Meteorology (DHM), 2) Modernization of the observation networks and forecasting, 3) Enhancement of the service delivery system of DHM, 4) Creation of an Agricultural Management Information System

- Bhutan: Hydromet Services and Disaster Resilience Regional project
  Budget: USD 3.8M
  Activities: Strengthen hydro-meteorological services and disaster prevention capacity
- Sri Lanka: Climate Resilience Multiphase Programmatic Approach
  Budget: USD 100M
  Activities: 1) Forecasting and early warning of high-impact weather events, floods and landslides; 2) Flood risk mitigation investments in the lower Kelani Basin of; 3) Land acquisition, resettlement assistance and safeguards implementation.

[East Asia and Pacific Region]

- Lao PDR Southeast Asia Disaster Risk Management Project
  Budget: USD 30M
  Activities: Strengthening flood protection and resilient urban planning in Muang Xay, Hydromet modernization and early warning systems
- Marshall Islands: Pacific Resilience project II
  Budget USD 19.6M
  Activities: Strengthening early warning systems, climate resilience investments in shoreline protection, effective response to crises and emergencies
- Pacific Resilience Program
  Budget: USD 9.5M
  Activities: 1) Strengthening early warning, resilience investments and financial protection in Samoa, Tonga and participating countries; 2) Strengthening financial protection in the Marshall Islands and Vanuatu

II.2 Trends in Each WMO Region

II.2.1 WMO Regional Association II (Asia)

The priorities for Regional Association II, as identified at the Asia-Southwest Pacific Joint Management Group meeting held in 2019, are as follows:

1) Impact-based forecasting and warning services - formulate concrete requirements for availability of data to improve forecast quality.
2) Provision of climate information and services and contribution to the Global Framework for Climate Services (GFCS).
3) Strengthening of hydrological services – adequate regional mechanisms for coordination with the Hydrological Assembly.
4) Regional WIGOS Centres, Global/Regional Basic Observing Network (GBON/RBON) and WIS – data sharing and assimilation.
5) Enhancement of capacity in service delivery – more utilization of social media.

6) Implementation of training necessary for the above.

II.2.2 WMO Regional Association V (South-West Pacific)

The priorities of Regional Association V for 2021-2023, as adopted at the eighteenth session of WMO Regional Association V in September 2021, are as follows:

1) Multi-Hazard Early Warning System (MHEWS): Strengthening the national multi-hazard early warning/alert systems.
2) Climate services: Broaden the provision of climate information and services.
3) Hydrological services: Strengthen services in support of flood forecasting, warning and water management.
4) Aviation weather services: Strengthen services in support of aviation weather services.
5) Marine meteorological services: Enhance the value and provision of decision-supporting information and services.
6) WMO Integrated Global Observing System (WIGOS): Optimize the acquisition of Earth-system observation data through WIGOS.
7) WMO Information System (WIS): Improve and increase access to, exchange and management of observation data and derived products through WIS.
8) Global Data -Processing and Forecasting System (GDPFS): Enable access and use of numerical analysis and prediction products from the WMO seamless GDPFS
9) Address the needs of developing countries, especially SIDS to enable them to provide and utilize essential weather, climate, hydrological and related environmental services
   Increase visibility and sustainability of NMHSs in LDCs and SIDS by demonstrating, promoting and communicating the societal-economic value of their weather, climate, water and related environmental observations, research and services.
10) Develop and sustain core competencies and expertise.
11) Strengthen effective partnerships for investment in sustainable and cost-efficient infrastructure and service delivery.

II.3 Resources for Meteorological Cooperation in Japan

II.3.1 Hearing at the Japan Meteorological Agency (JMA)

The Japan Meteorological Agency (JMA) operates a number of regional and global centers, within the framework of WMO, the Intergovernmental Oceanographic Commission of UNESCO and the Intenation Civil Aviation Organization (ICAO) for meteorological observations and telecommunications, weather forecasts, environment, climate, ocean and tsunami as shown in Table II.3.1-1.

Table II.3.1-1 International roles of JMA and their areas of responsibility

Weather monitoring and forecasting	
Operation and data dissemination of geostationary meteorological satellites (1978–)	Asia, Pacific
WMO Global Data-processing and Forecast System (GDPFS) Regional Specialized Meteorological Center (RSMC) (1968–)	East Asia
WMO GDPFS RSMC Tokyo - Typhoon Center (1988–)	East Asia
ICAO Tropical Cyclone Advisory Center (TCAC) (1993–)	Asia, Pacific
ICAO Volcanic Ash Advisory Center (VAAC) (1997–)	Asia, Pacific
WMO GDPFS RSMC on the Provision of Transport Model Products for Environmental Emergency Response (1997–)	Asia, Pacific
Telecommunication and observation systems	
WMO Global Telecommunication System (GTS) Regional Telecommunication Hub (RTH) (1968–)	East Asia
WMO Regional Radiation Center (RRC) of RA II (1965–)	Asia
WMO Regional Instrument Center (RIC) of RA II (1997–)	Asia
GCOS Surface Network (GSN) Monitoring Center (1999–)	World
WMO Regional WIGOS Centre (RWC) of RA II (2021–)	Asia
Global environment and ocean	
WMO Global Atmosphere Watch (GAW) World Data Centre for Greenhouse Gases (WDCGG) (1990–)	World
WMO GAW Quality Assurance/Science Activity Centre (QA/SAC) (1995–)	Asia, Southwest Pacific
WMO GAW World Calibration Centre (WCC) (2002–)	Asia, Southwest Pacific
Tokyo Climate Center (2002–) as WMO Regional Climate Center (RCC) (2009-)	Asia, Pacific
WMO/IOC Integrated Global Ocean Services System (IGOSS) Specialized Oceanographic Center (SOC) (1984–)	Pacific Ocean
Marine observation data collection and archive under MCSS (Marine Climatological Summaries Scheme) (1964–)	Western North Pacific
Tsunami	
Northwest Pacific Tsunami Advisory Center (2005–)	Northwest Pacific

As the centers mentioned above, JMA collaborates with and provides assistance to the NMSs in Asia and the Pacific, interviews were conducted with the relevant offices/centers of JMA.

II.3.2 Hearings at the University

Interviews were conducted with Professor Taiichi Hayashi of Kyoto University's Center for Southeast Asian Studies (CSEAS), who has been conducting observational research in Bangladesh for many years on human resource development in developing countries. A summary of the interviews is as follows:

Interviewee: Hayashi Hayashi, Professor, Center for Southeast Asian Studies, Kyoto University

Date and time of interviews.

- The first session was held at the Japan Meteorological Business Support Center (JMBSC) on Tuesday, 20 April 2021, from 15:30 to 18:00.
- The second session was held at JMBSC (as part of an in-house lecture) on Tuesday, 25, May 2021, from 1:30 p.m. to 3:30 p.m..

Current status of meteorology education in developing countries

In Bangladesh, BMD has established a meteorology training institute. It is positioned similar to JMA's Meteorological College.

About 15 years ago, the Atmospheric Science Research Center was established at the Bangladesh University of Engineering and Technology to provide education in meteorology. The Department of Meteorology and Oceanography has also been established at the University of Dhaka. The Indian Institute of Technology also has a meteorology course. In Bangladesh and Indonesia, journals on meteorology are being published.

At these institutions, BMD staff have received degrees since ten years ago.

Capacity building of NMSs staff

Professor Hayashi has been conducting ongoing research since 2006, deploying self-recording rain gauges in Bangladesh and collecting loggers once a year to analyze heavy rainfall.

A project to deploy a number of AWSs is currently being planned, but the wisdom of NMSs will be needed to maintain these observation systems, especially how to train the staff at the level of weather station chiefs. As local staff can only identify the cause of the problem, AWSs should be deployed and maintained with the maintenance service by the manufacturers.

Current status and proposals for invitations to Japan

Many of the leaders of these universities have degrees from Hokkaido University, Kyoto University, Nagoya University, and Okayama University.

Kyoto University does not have the budget to invite students from developing countries. However, in some cases, each department has invited students from Indonesia and Laos on a personal basis.

It would be desirable if there is a scheme where JICA sponsors students to be enrolled in universities.

Under such circumstances, it is vital to involve developing countries in research activities. It is necessary to put NMS staff not only in assistance to the Japanese scientists but for research.

Tools such as the radars and WRFmodel are available when collaborating with universities. It is crucial to decide on a theme and provide support until a thesis or degree is obtained. The fund scheme of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan expires every five years and is not sustainable.

The Japan Science and Technology Agency (JST) invites young students from overseas to participate in the "Sakura Project," and the Japan Society for the Promotion of Science (JSPS) provides support of JPY 1,200,000 per year for three years as a support program for obtaining a dissertation doctorate.

It is desirable to establish a framework for a project to train meteorologists/engineers in addition to JICA's technical cooperation projects. In such a case, not only tuition fees but also living expenses should be supported.

II.3.3 Discussion at the Meteorological Society of Japan

At the Meteorological Society of Japan 2021 Spring Meeting, a special session on "Current Status and Future Prospects of Assistance to and Cooperation with Developing Countries in the Field of Meteorology" was held to discuss how academic institutions and developing countries should cooperate in the field of meteorology. The main discussions in this session were as follows:

- In the last ten years, the Japan International Cooperation Agency (JICA) has conducted training programs in Japan for technical cooperation projects related to meteorology: NWP models: four times; satellite data: once; disaster management: once; and omnibus training in many other fields: once. The target countries and the number of training times in Japan are Bangladesh: 3; Sri Lanka: 2; and the Philippines: 1. The host institutions are Gifu University: 2; Tsukuba University: 1; Kyoto University: 1; Meteorological Research Institute: 1; Japan Aerospace Exploration Agency (JAXA): 1; and National Research Institute for Earth Science and Disaster Prevention: 1. (Iwata and Hattori)
- As an example of joint research for cooperation and collaboration in atmospheric science research in Southeast Asian countries, the "International Joint Research on Meteorological Disaster Mitigation in Southeast Asia" was conducted as a joint research project by Kyoto University, ITB (Bandung Institute of Technology), and the Meteorological Research Institute of JMA. The goal of the project was to establish a research network and conduct numerical weather prediction experiments in Southeast Asia under international collaboration to develop a decision support system for mitigating weather-related disasters. (Saito)
- In addition, the Project for Strengthening Capacity in Weather Forecasting and flood Early Warning System of JICA for Viet Nam (from 2018) aims to improve the following capabilities: (1) maintenance and calibration of meteorological observation equipment, (2) analysis and quality control of meteorological radar data, (3) monitoring and forecasting of heavy rainfall and typhoons, and (4) information dissemination. The results of the project's first phase were published in a special issue of the Viet Nam Journal of Hydrology and Meteorology in the form of six papers co-authored

by Japanese JICA experts and the staff of the Viet Nam Meteorological and Hydrological Administration. (Saito)

- In Indonesia, a radar network and an ocean observation network have been established within the framework of the Science and Technology Research Partnership for Sustainable Development (SATREPS), information on mitigation of disasters caused by floods and droughts has been issued and a database of past climatic data has been established. As a result, many findings on precipitation processes in the country have been published. (Yamanaka)

The discussions at the session led to the establishment of the International Cooperation Research Study Committee within the Meteorological Society of Japan in December 2021 as a forum for exchanging information and opinions to share experiences, knowledge, challenges, and plans involved in this field.

II.3.4 Projects Implemented by JICA

The past projects implemented by JICA are shown in Table II.3.4-1.

Table II.3.4-1 List of projects implemented by JICA

Name of project	Type	Name of consultants	Period (*1, 2)
Collection and Verification of Meteorological and Disaster Information for Malé Metropolitan Area, Maldives	Basic Survey	Yachiyo Engineering Co., Ltd., Oriental Consultants Global Co., Ltd., Nippon Koei Co., Ltd.	Nov. 2021 - Feb. 2022※2
Detailed Planning Study on the SATREPS System for Weather Forecasting and Disaster Mitigation in Densely Populated Areas Vulnerable to Weather-related Disasters in Argentina (Environmental and Social Considerations) [Stand-alone Type] (Japanese only)	Detailed Survey	Central Consultant Inc.	Sep. 2021 - Nov. 2021※2
Detailed Planning Study (Equipment Procurement Plan) for SATREPS for Densely Populated Areas Vulnerable to Weather-related Disasters in Argentina [Stand-alone Type].	Detailed Survey	Yachiyo Engineering Co., Ltd.	Sep. 2021 - Nov. 2021※2
Detailed Planning Study (Flood Analysis) of SATREPS for Densely Populated Areas Vulnerable to Weather-related Disasters in Argentina [Stand-alone Type].	Detailed Survey	Yachiyo Engineering Co., Ltd.	Sep. 2021 - Nov. 2021※2
Preparatory Survey for the Development of Marine Meteorological Observation System, Viet Nam	Preparatory Survey	International Meteorological Consultant Inc., Weathernews Inc., Alpha Hydraulic Engineer Consultants Co., Ltd.	Jun. 2021 - May 2022※2
Information Collection and Verification Study on Global Meteorological Services and Infrastructure	Basic Survey	Japan Meteorological Business Support Center, Japan Weather Association, Oriental Consultants Global Co., Ltd.	Feb. 2021 - Dec. 2021※2
Capacity Enhancement Project for Hydrological and Meteorological Information Management in Afghanistan (Phase 2)	Technical Cooperation Project	CTI Engineering International Co., Ltd., International Meteorological Consultant Inc.	Oct. 2020 - Oct. 2025※2
Detailed Planning Study (Hydrological and Meteorological Information Management) for the Project on Strengthening Hydrological and Meteorological Information Management (Phase 2), Afghanistan [Stand-alone type].	Detailed Survey	CTI Engineering International Co., Ltd.	Oct. 2019 - Dec. 2019※2

Project for Mainstreaming Disaster Prevention, Fiji	Technical Cooperation Project	Oriental Consultants Global Co., Ltd., Yachiyo Engineering Co., Ltd., PACIFIC CONSULTANTS CO., LTD.	Nov. 2020 - Oct. 2024[※1]
Indonesia Capacity Enhancement for Long-Term Climate Change Prediction in Phase 2 of the Climate Change Response Capacity Enhancement Project	Technical Cooperation Project	Japan Meteorological Business Support Center	Mar. 2020 - Feb. 2022[※2]
Project for Strengthening Capacity for High Quality Meteorological Observation, Forecasting and Warning, Philippines	Technical Cooperation Project	Japan Meteorological Business Support Center	Mar. 2020 - Feb. 2023[※2]
Detailed Planning Study for the Project on Strengthening Capacity for High Quality Meteorological Observation, Forecasting and Warning, Philippines (Meteorological Observation/Pre-warning) [Stand-alone Type].	Detailed Survey	Japan Meteorological Business Support Center	Feb. 2019 - Mar. 2019[※2]
Project for Strengthening Meteorological Observation, Forecasting and Flood Warning Capacity for Disaster Preparedness and Response in the Thimphu and Paro River Basins, Bhutan	Technical Cooperation Project	Earth System Science Co., Ltd., Japan Meteorological Business Support Center, Japan Weather Association	Feb. 2020 - Jan. 2023[※1]
Project for Capacity Building of Human Resources for Climate Change Resilience in the Pacific Region, Samoa	Technical Cooperation Project	Pacific Consultants Co., Ltd., Japan Weather Association, Oriental Consultants Global Co., Ltd.	Jan. 2020 - Jul. 2022[※2]
Preparatory Survey for the Radar Development Project in the Islamic Republic of Pakistan	Preparatory Survey	International Meteorological Consultant Inc.	May 2019 - Jul. 2020[※2]
Capacity Enhancement Project for Meteorological Observation and Forecasting, Myanmar	Technical Cooperation Project	Japan Meteorological Business Support Center, Oriental Consultants Global Co., Ltd.	Mar. 2019 - Jun. 2022[※2]
Detailed Planning Study for the Project on Strengthening Meteorological Observation and Forecasting Capacity in Myanmar (Meteorological Observation and Forecasting) [Stand-alone type]	Detailed Survey	Japan Meteorological Business Support Center	Jul. 2018 - Sep. 2018[※2]
First Detailed Planning Study for the National Capacity Enhancement Project for Disaster Management (Weather Forecasting and Warning), Bhutan [Stand-alone].	Detailed Survey	Japan Weather Association	Feb. 2019 - Mar. 2019[※2]
Capacity Enhancement Project for Meteorological Observation and Forecasting, Mauritius	Technical Cooperation Project	Japan Weather Association, Japan Meteorological Business Support Center	Feb. 2019 - Jun. 2022[※2]
Cambodia Basin Water Resources Utilization Project (Support for Utilization of Meteorological and Hydrological Data) [Independent Type] (in Japanese)	Expert Secondment	Masayuki Kojima	Dec. 2018 - Mar. 2019[※2]
Cambodia Basin Water Resources Utilization Project (meteorological and hydrological observation/water use management) [stand-alone type]	Expert Secondment	Masayuki Kojima	Apr. 2016 - Jul. 2016[※2]
Cambodia Basin Water Resources Utilization Project (Support for improvement and enhancement of meteorological and hydrological observation network) [stand-alone type].	Expert Secondment	Masayuki Kojima	Apr. 2015 - Oct. 2015[※2]
Cambodia Basin Water Resources Utilization Project (Support for Improvement and Strengthening of Meteorological and Hydrological Observation Network) [Stand-alone Type].	Expert Secondment	Masayuki Kojima	Jun. 2014 - Oct. 2014[※2]
Capacity Enhancement of Meteorological Observation Data Evaluation for Agricultural Insurance Capacity	Technical Cooperation	Japan Meteorological Business Support Center	Nov. 2018 - Dec. 2020[※2]

Enhancement Project, Indonesia	Project		
Project for Capacity Enhancement of Meteorological Forecasting and Flood Early Warning System in Viet Nam	Technical Cooperation Project	Japan Meteorological Business Support Center	May 2018 - Dec. 2021[※2]
Capacity Enhancement Project for Meteorological Forecasting and Flood Early Warning System in Viet Nam [Independent Type] (Meteorological Observation and Forecasting/Warning)	Detailed Survey	Japan Meteorological Business Support Center	May 2017 - Jul. 2017[※2]
Preparatory Survey for Multan Weather Radar Development Project, Islamic Republic of Pakistan	Preparatory Survey	International Meteorological Consultant Inc.	Jul. 2017 - May 2018[※2]
Development of a Monitoring and Information System for Extreme Weather in the Philippines	Technical Cooperation Project	Hokkaido University, Tokyo Metropolitan University, Tohoku University	Apr. 2017 - May 2022[※1]
Preparatory Survey for the Development of a Radar System for Meteorological Observation in the Democratic Socialist Republic of Sri Lanka	Preparatory Survey	International Meteorological Consultant Inc.	Feb. 2016 - Dec. 2016[※2]
Meteorological Observation and Forecasting Capacity Improvement Project in Mozambique	Technical Cooperation Project	Japan Meteorological Business Support Center	Mar. 2015 - Aug. 2017[※2]
Follow-up Cooperation for Third Country Training in Meteorology in the Pacific Region (Meteorology) [Independent Type]	Follow-up	Japan Meteorological Business Support Center	Mar. 2015 - Jun. 2015[※2]
Capacity Enhancement Project for Meteorological Personnel Development in the Pacific Region, Fiji (Detailed Planning Study)	Detailed Survey	Koji Kuroiwa	Jun. 2015 (Final Report)
Capacity Building Project for Climate Change Mitigation and Adaptation in Southeast Asia, Thailand	Technical Cooperation Project	Oriental Consultants Global Co., Ltd., Pacific Consultants Co., Ltd., Institute for Global Environmental Strategies	2013 - 2016
Preparatory Survey for the Construction of the Pacific Climate Change Center, Independent State of Samoa	Preparatory Survey	Yamashita Sekkei Inc., PADECO Co., Ltd., EARL Consultants Incorporated	Apr. 2015 - Dec. 2015[※2]
Information Gathering and Verification Study on Disaster Prevention (Meteorological Observation System), Ecuador [Independent Type]	Basic Survey	Japan Weather Association	Oct. 2014 - Nov. 2014[※2]
Information Collection and Verification Study on Disaster Prevention (Warning System/Weather-related Disasters), Ecuador [Independent Type]	Basic Survey	Japan Weather Association	Oct. 2014 - Nov. 2014[※2]
Detailed Planning Study for the Project on Enhancing Comprehensive Data Management Capacity for Flood Forecasting and Warning through Strategic Development of Hydrometeorological Information System (Flood Forecasting and Warning Database), Philippines [Stand-alone type].	Basic Survey	Nippon Koei Co., Ltd.	Sep. 2014 - Nov. 2014[※2]
Project for Capacity Enhancement of Meteorological Observation, Forecasting and Communication, Sri Lanka	Technical Cooperation Project	International Meteorological Consultant Inc., Japan Weather Association, JICA Long-term expert	Sep. 2014 - Aug. 2017[※1]
Project for Capacity Improvement of Meteorological Observation, Forecasting and Warning in the Philippines	Technical Cooperation Project	Japan Meteorological Business Support Center	May 2014 - May 2017[※1]
Preparatory Survey for the Project for the Development of Meteorological Radars in Dhaka and Rangpur,	Preparatory Survey	Japan Weather Association, International Meteorological	Feb. 2014 – Mar. 2015[※2]

Bangladesh		Consultant Inc.	
Preparatory Survey for the Rehabilitation of the Giuang Weather Radar System, Republic of the Philippines	Preparatory Survey	Japan Weather Association, International Meteorological Consultant Inc.	Jan. 2014 - Apr. 2014[※2]
Preparatory Survey for the Radar System Rehabilitation Project in Karachi, Islamic Republic of Pakistan	Preparatory Survey	Japan Weather Association, International Meteorological Consultant Inc.	Dec. 2013 - Feb. 2015[※2]
Project on Climate Change Crisis and Countermeasures in Coral Reef Island Systems, Palau	Technical Cooperation Project	Ryukyu University, Japan Wildlife Research Center, Tokyo Institute of Technology, University of Tokyo, Toho University, Kagoshima University	Apr. 2013 - Mar. 2018[※1]
Project for Capacity Improvement of Meteorological Observation and Forecasting in Bangladesh (5th year) (Calibration and Maintenance of Measuring Instruments) (Small scale)	Technical Cooperation Project	Japan Meteorological Business Support Center	Aug. 2013 - Jan. 2014[※2]
Project for Capacity Improvement of Meteorological Observation and Forecasting in Bangladesh	Technical Cooperation Project	Japan Weather Association, International Meteorological Consultant Inc.	Sep. 2009 - Dec. 2013[※1]
Preparatory Survey for Meteorological and Hydrological System Improvement Project, Lao PDR	Preparatory Survey	Japan Weather Association, International Meteorological Consultant Inc., CTI Engineering International Co., Ltd.	Jul. 2013 - Feb. 2014[※2]
Indonesia Sub-Project 2: Vulnerability Assessment, Indonesia "Capacity Enhancement Project for Climate Change Response	Technical Cooperation Project	Japan Meteorological Business Support Center	Jun. 2013 - Oct. 2013[※2]
Preparatory Survey for the Establishment of the Medium-Term Weather Forecasting Center and the Strengthening of Weather Forecasting System Project, Islamic Republic of Pakistan	Preparatory Survey	International Meteorological Consultant Inc., Japan Weather Association, CTI Engineering International Co., Ltd.	Sep. 2012 - Feb. 2014
Technical Assistance for the Project for Enhancing Meteorological Observation Capacity and Disaster Preparedness in Samoa	Technical Cooperation Project	International Meteorological Consultant Inc., Japan Weather Association (Procurement agent: Japan International Cooperation System)	Dec. 2012 - Oct. 2015
Preparatory Survey for the Project on Improvement of Meteorological Observation and Disaster Preparedness in the Independent State of Samoa (Part 2)	Preparatory Survey	International Meteorological Consultant Inc., Japan Weather Association	Feb. 2010 (Final Report)
Preparatory Survey for the Project for Improvement of Meteorological Observation Equipment in the Republic of the Union of Myanmar	Preparatory Survey	Japan Weather Association, International Meteorological Consultant Inc.	Jun. 2012 - Mar. 2013
Preparatory Survey for the Meteorological Services Project in the Republic of Mauritius	Preparatory Survey	Japan Weather Association, International Meteorological Consultant Inc.	Oct. 2011 - Aug. 2012
Project for Improvement of Meteorological and Hydrological Services in the Lao PDR	Technical Cooperation Project	Japan Weather Association, CTI Engineering International Co., Ltd.	Jul. 2006 - Jan. 2011[※1]
Basic Design Study on the Improvement of Meteorological Monitoring Network in the Lao People's Democratic Republic	Basic Design	Japan Weather Association, Kume Sekkei Co., Ltd.	Jun. 2004 (Final Report)
Basic Design Study on the Development of a Meteorological Radar System for the Republic of the	Basic Design	Japan Weather Association	Jan. 2009 (Final Report)

Philippines			
Preparatory Survey for the Oceanic Region Wide Cooperation Program on Climate Change (Water Resources Management, Meteorological Observation and Disaster Prevention)	Preparatory Survey	Yachiyo Engineering Co., Ltd.	Jun. 2009 (Final Report)
Project for the Japan-China Meteorological Disaster Cooperation Research Center, People's Republic of China	Technical Cooperation Project	University of Tokyo, Japan Weather Association	Dec. 2005 - Jan. 2009※1
Preparatory Survey for the Oceanic Region Cooperative Program on Climate Change (Water Resources Management, Meteorological Observation and Disaster Prevention)	Preparatory Survey	Yachiyo Engineering Co., Ltd.	Jun. 2009 (Final Report)
Human resource development project for meteorological forecasting and data analysis, Mongolia	Technical Cooperation Project	Japan Weather Association	Feb. 2005 - Oct. 2008※1
Basic Design Study for Installation of Meteorological Radar in Moulvibazar, People's Republic of Bangladesh	Basic Design	Japan Weather Association	Feb. 2007(Final Report)
Sri Lanka Basic Design Study for Improvement of Meteorological Information and Disaster Prevention Network	Basic Design	Pacific Consultants Co., Ltd	Jun. 2007 (Final Report)
Basic Design Study on the Radar Installation Project in Cox's Bazar and Khepupara, People's Republic of Bangladesh	Basic Design	Japan Weather Association	May 2005 (Final Report)
Mongolia Basic Design Study for Improvement of Meteorological Information Network	Basic Design	Pacific Consultants Co., Ltd	Feb. 2003 (Final Report)
Socialist Republic of Viet Nam Basic Design Study on Improvement of Meteorological Radar Network	Basic Design	Japan Weather Association	Mar. 2001 (Final Report)
Mongolia Basic Design Study on Natural Disaster Prevention Plan	Basic Design	Japan Weather Association	Jan. 1998 (Final Report)
Republic of the Philippines Basic Design Study on the Improvement of the Seismic and Volcanic Observation Network	Basic Design	Japan Weather Association	Mar. 1998 (Final Report)
Basic Design Study for the Second Meteorological Observation Network in Pakistan	Basic Design	Japan Weather Association	Dec. 1996 (Final Report)
Basic Design Study on the Development of Meteorological Observation and Forecasting System, Republic of Fiji	Basic Design	Japan Weather Association	May 1995 (Final Report)

※1 Period of cooperation (ref.: JICA website)

※2 Period of implementation (ref.: JICA announcements)

Chapter III Analysis of the draft Cooperation Policy of JICA in the Field of Meteorology

III.1 Development and Improvement of Legal Systems, and Medium- and Long-term Plans for Meteorological Services

III.1.1 The Necessity of Developing and Improving Legal Systems, and Medium- and Long-term Plans for Meteorological Services

In many of the target countries, laws and regulations for meteorological services are not in place, resulting in unclear responsibilities of relevant offices, absence of cooperation/coordination among related agencies/institutions, and lack of progress in weather- and disaster-related services. This is one of the reasons why there is a delay in the dissemination of information, and forecasts/warnings are not delivered at the time of disasters, and why such information is not used for evacuation and other activities.

Medium- and long-term plans for meteorological services have not been formulated in many countries. The lack of a clear vision of what should be aimed for makes it difficult to determine issues that need to be resolved or prioritized for action. Lack of clarity on what tasks should be prioritized leads to inefficient budget allocation. Services are implemented in a disjointed manner. The lack of consistency among services results in inefficient operations and the inability to raise funds for maintenance and management due to the lack of unified equipment standards and systems. In addition, establishing an organization and securing the necessary personnel cannot be done in the short term and requires a sustainable budget. These should be done in the medium- and long-term perspective resulting in the necessity of medium- and long-term plans.

The lack of medium- and long-term plans prevents the effective implementation of short-term tasks, makes the expected results ambiguous, and makes it impossible to measure the effectiveness of short-term tasks. For example, when setting warning thresholds, it is desirable to set standards that take into account regional characteristics based on the correlation between past meteorological observation data and disaster records. Because the importance of daily observation data is not recognized and the data are stored, warnings are issued based on uniform standards throughout the country in many countries.

Within the Sendai Framework for Disaster Risk Reduction 2015-2030 formulated at the Third United Nations World Conference on Disaster Risk Reduction in 2015, the promotion of investment in disaster risk reduction for resilience is one of the top priorities, and the establishment of an NMS and the development of meteorological-related laws and plans are essential to realize and sustain it.

The legal status of national organizations and the scope and contents of the services delivered by NMSs differ from one country to another, and the necessary responses to disasters vary depending on the types of disasters and the magnitude of disaster risks. It is necessary to develop a legal system and plans appropriate for each country.

III.1.2 Ways to Cooperate

Development of the legal system

The development of a Meteorological Service Law should be supported to define the legal position of an NMS and to clarify roles and responsibilities of NMS. In Japan, the amendment to the Meteorological Service Law to allow private businesses to issue weather forecasts has led to the provision of detailed and easy-to-understand weather information. It should be noted when NMS lacks sufficient supervisory capacity, there is a possibility that forecasts without technical backing will be issued and cause confusions for users, a permit system should be established, and the types of information that can be issued should be regulated.

Formulation of medium- and long-term plans for NMSs and regulations on meteorological services

NMSs should be supported in formulating medium- and long-term plans, and guidelines/manuals for operation and maintenance of equipment/instruments, meteorological observations, analyses, and forecasting. Issues and priority tasks of NMSs should be clarified so that the limited funds and human resources can be efficiently utilized. NMSs should be supported to effectively use the installed equipment so that engineers and forecasters can properly operate weather radars and other equipment and provide advanced meteorological services.

Strengthening the capacity for operation and management of NMSs

For NMSs to recognize and resolve their issues over the medium and long term, they need to strengthen their medium- and long-term planning capacity. NMSs need the capacity to revise the guidelines and manuals as required. Such capacity should be strengthened by involving the staff of NMSs in the development of laws, plans, and operational rules.

Formulation of disaster management plans involving NMSs

The roles and responsibilities of NMSs in disaster management planning should also be clarified. Issues in the use of meteorological information in disaster management will be reflected in relevant guidelines and manuals. They will be resolved through the process of implementation of medium- and long-term plans of NMSs.

III.2 Surface and Upper-air Observations

III.2.1 Modernization of Surface Observations and the Necessity of Traceability

Many NMSs conduct surface observations at time intervals of three or six hours in accordance with the standards set by WMO, and the observation data are collected at the headquarters for meteorological forecasting and warning, as well as exchanged internationally through GTS for monitoring significant phenomena and as initial values for numerical weather prediction. Observations, and recording and reporting of observed data are stably conducted with human and financial resources of NMSs, and manual observation data is provided to the public as official data in many countries.

The results of continuous and reliable observations are used for real-time applications such as heavy rainfall monitoring, basic data for disaster prevention and climate change. Therefore, it is a critical perspective to evaluate them as one of the strengths of each NMS and promote cooperation that takes advantage of these strengths.

Impact-based forecasting (IBF) promoted by WMO is listed as a priority issue in many countries.

For IBF, it is necessary to introduce, evaluate, operate, and maintain digitalized automatic observation equipment. Assessment of the accuracy, quality control and digitization of observation data, while evaluating the reliable implementation of manual observations and data archive, is essential for the development of basic information on advanced meteorological information required by IBF. In order to introduce automated observations while continuing manual observations, technical cooperation is needed to promote human resource development and technology transfer and encourage digitalization and the shift of personnel from observation to forecasting.

Cooperation Policy

Regular observations and reporting are not performed in many countries in the world except for Asia. For these countries, the following assistance is needed: 1) the provision of observation equipment, and rules, manuals, guidelines and training related to observation, 2) the introduction of NMSs' reference instruments to ensure accuracy, checks using these reference instruments, and 3) the provision of manuals, guidelines and training related to the regular inspection of the equipment.

Many NMSs continuously conduct surface observations, quality management by forecasters and quality control at the time of compiling monthly report, but few NMSs stably conduct quality management. WMO promotes the WIGOS Data Quality Monitoring System (WDQMS), as JMA carries out, as part of the WMO Integrated Global Observing System (WIGOS), which automatically compares the quality of observations with objective analyses by NWP centers. As quality-controlled observation data are indispensable for advancing meteorological information, the first step for cooperation in the field of observation is to evaluate the accuracy of manual observations, control their quality, and prepare manuals and guidelines including the use of WDQMS. The provision of digital Assmann aspiration psychrometer, which has been developed in Japan replacing the Assmann aspiration psychrometer, as a traveling reference standard, can be considered. In addition, it is necessary to continue the periodic accuracy evaluation of the national reference standards in collaboration with RIC Tsukuba operated by the Japan Meteorological Agency. (Cooperation in accuracy evaluation and quality control)

For IBF, it is necessary to improve the accuracy of precipitation prediction by QPE and NWP, and one-hour observation data by automated meteorological instruments is required. Therefore, the next goal is to extend and apply the accuracy above-mentioned evaluation, quality control, and development of manuals and guidelines for manned observatories to automatic meteorological observation instruments. For the maintenance and operation of automatic meteorological instruments, the observational values must be used for monitoring severe weather phenomena, disaster management information, and information dissemination via the web and mobile phones so that the public can realize the necessity of these instruments. When automated observation equipment is deployed, the effort may not be continued if it is not used and publicized. (Cooperation with observation information to be used)

III.2.2 Modernization of Manned Observatories

NMSs in developing countries operate manned stations for meteorological services in their own countries and report SYNOP reports (surface observation reports) to other countries through GTS of WMO.

In many cases, these stations have been using mechanical instruments (anemometers, rain gauges, sunshine gauges, and paper-recording gauges) and mercury barometers and thermometers for many years until now. Mechanical instruments have many problems in terms of accuracy and maintenance. WMO has stated that the manufacture and use of mercury instruments should be stopped according to the Minamata Convention on Mercury adopted in 2017. Therefore, it is urgent to modernize manual observations in developing countries by introducing electric instruments (digital instruments).

With the introduction of electric instruments, observation data can be imported as digital data to PCs and other devices, leading to the automation of part of manual observations. The partial automation of manual observations is not only a technical issue concerning the handling of electric instruments and data quality control but also an issue concerning the staffing and budget allocation of NMSs and the awareness of the staff in charge of observations. It is a subject of careful consideration with the senior staff of NMSs.

Cooperation Policy

It is necessary to install electric instruments in manned stations, maintain the accuracy of observations, carry out quality control of the observed data, develop observation guidelines, and provide essential training to the staff.

If an AWS is installed at a manned station, SYNOP reports can be prepared using AWS, but in this case, it is necessary to pay close attention to the maintenance of the AWS instruments and the quality control the data. For example, it is known that the shelters that house electric thermometers heat up due to solar radiation, resulting in high daytime temperatures and that automatic rain gauges have systematic errors such as low precipitation during heavy rainfall. It is also necessary to conduct these evaluations in cooperation with local staff to make the best use of the past observation data. In many cases, observed data from AWSs installed at manned stations are consolidated on servers at headquarters and cannot be monitored at the stations in the field. This is one of the reasons why AWSs are not regularly inspected and maintained. Therefore, when introducing AWSs, it is necessary to provide advice at the design stage that the observed data can be monitored at the stations in the field.

III.2.3 Proper Deployment and Utilization of AWSs

Many developing countries have installed Automatic Weather Station (AWS) networks with the support of donors to monitor daily weather and small-scale phenomena such as localized heavy rainfall that can cause disasters. AWSs are deployed to complement manual observations. Still, the two are often operated without coordination.

As AWSs supported by multiple donors operates independently, there are still few countries where observational data is integrated and used for monitoring of significant phenomena and assimilation into radar QPE and NWP. Even if equipment with guaranteed accuracy is installed at the time of AWS deployment, regular inspections and quality control are often insufficient, and data archives are often inadequate. One of the reasons for these issues is that each country introduced AWSs as it is used in developed countries, without clearly recognizing the purpose of using AWSs, which are to be used for observations for monitoring and forecasting, and provide observation information to disaster management authorities and the public.

The development and provision of advanced meteorological information for IBF has become a key issue for NMSs and the acquisition of quality-controlled observation data with high spatial resolution is important. Therefore, it is important to recognize the use of AWS data as basic data for the dissemination of advanced meteorological information and to make sure that AWS data will be used by information users. AWS data can be used for various purposes, such as monitoring and forecasting significant meteorological phenomena (heavy rainfall, strong winds, high and low temperatures, etc.), issuing warnings, in situ rainfall data for QPE, initial values for NWP, and service for the public. It is necessary to clarify these purposes and make an appropriate selection of observation elements and the distribution of AWSs.

Cooperation Policy

In deploying AWSs, it is necessary to fully consider the installation purpose as mentioned above. As a standard for considering appropriate distribution; in the case of JMA's AWS network "AMeDAS", one rain gauge is placed every 17 km square and one thermometer/wind vane and anemometer every 20 km square. To monitor local phenomena and to carry out QPE using radar, at least 2,000 rain gauges are required in one radar observation area (assuming a radius of 150 km), and hourly real-time rainfall from these gauges should be collected to the headquarters. According to the results of the quality assessment of AWSs in Indonesia, the correlation of rainfall rapidly decreases when the distance between two observation points exceeds 30 km, and the correlation is even worse in areas where showery precipitation from isolated cumulonimbus clouds is prevailing.

As for the proper deployment and installation of AWSs, one of the themes within the technical cooperation projects is to compare and analyze data from different locations in the evaluation of the accuracy of AWS equipment. For example, it is necessary to analyze proper placement by assuming the number of stations and mutual distance mentioned above or consider it a survey item in the user needs survey.

III.2.4 Discontinuation of Observation Instruments using Mercury

As mentioned in 2.2, according to the Minamata Convention on Mercury, measuring instruments using mercury (glass thermometers, Fortin barometers, etc.) must be disposed of. However, they are still used as working or inspection measuring instruments in many countries.

Cooperation Policy

The alternatives to mercury instruments are electric instruments, provided as AWSs. Therefore, it is practical to actively utilize AWSs provided by each country to replace the mercury instruments. The aforementioned digital Assmann psychrometer can be provided as an effective instrument for non-mercury use.

III.2.5 Strengthening of Upper-air Observation

According to the WMO standard, upper-air observations should be carried two times per day. The observed data are shared with other countries through GTS and used by NWP centers, contributing significantly to improving the accuracy of weather forecasts. On the other hand, it is difficult for the countries conducting the upper-air observations to realize the direct benefit of the observations. Costs of radiosondes and hydrogen generation for balloons are a significant burden to NMSs that leads to reduction of the number of or suspension of upper-air observations.

Cooperation Policy

Upper-air observations for the initial conditions of global NWP models, for monitoring the stability of the atmosphere related to significant phenomena such as heavy rainfall, and as basic data to monitor climate change is highly important. It is necessary to cooperate with international organizations such as the United Nations, the World Bank, and WMO to maintain the upper-air observations. The use of GPS sondes is the mainstream of upper-air observations globally. For example, reception, analysis and reporting systems and consumable sondes were provided to recipient countries including Sri Lanka within the Voluntary Cooperation Programme (VCP) of WMO.

Pilot balloon (PB) observations, in which hydrogen-filled balloons with a diameter of about 50 cm are flown and visually tracked by a theodolite to calculate wind direction and speed at low altitudes, are one type of upper-air observations that are still conducted in developing countries. PB observations have been conducted for many years to observe local low-level winds. It is necessary to thoroughly investigate how the data are used and consider whether to continue or discontinue the PB observations. JMA discontinued PB observations in the 1980s and shifted to the Wind Profiler Radar (WPR) network in 2001, continuously observing upper winds.

In developed countries, observations of upper winds using WPRs and vertical water vapor profile using Water Vapor Lidars are used to improve the forecast accuracy of significant phenomena such as heavy rainfall by assimilating the observed data into the initial conditions of NWP. This can be a new form of cooperation for developing countries that aim to improve forecast accuracy with NWP models. It should be noted that WPRs and Water Vapor Lidars requires the maintenance of these systems, human resources to utilize the data, and facilities such as computers, so it is essential to collaborate with JMA or universities.

III.3 QPE and Exchange of Radar Data with Neighboring Countries

III.3.1 Needs to Support QPE

Some countries have maintained the same radars for more than 20 years, even their functions have deteriorated, while others have stopped operating their radars before they reach the end of their design life. In light of this situation, outcomes of the study on how to provide the developing countries with supports for radars in the future are given below.

The spread of mobile phone networks in developing countries in recent years shows an "uneven development" in which residents far from urban areas can use smartphones, without going through the period when developed countries spent a long time developing the infrastructure of fixed phone networks. The similar process can also be seen in the field of weather radar based on the survey results comparison of the 13 target countries showing that the latest weather radars are being installed in countries with no track record of radar operations, rather than following the various stages followed by developed countries.

The study also showed that the following two aspects are constraints to the development of radar networks in each country as a result of this "uneven development,".

1) To continue using weather radars, users must be aware of the observation accuracy achieved by the entire system and have a maintenance and management system to guarantee the accuracy. In this respect, it differs from smartphones, which can be used as a black box without knowing the communication infrastructure such as base stations.
2) Furthermore, due to "unevenness" in national conditions, different stages of weather radar development may occur between neighboring countries, resulting in data exchange problems.

Based on this background, the following four issues are discussed:

- QPE by weather radars and exchange of weather radar data with neighboring countries,
- Introduction of Dual Polarization Weather Radars and QPE,
- Remote-control monitoring and maintenance of weather radars,
- Consideration of downsizing radar facilities.

These issues are related to the technical and operational aspects, respectively, and will be the key to the future technical cooperation. Figure III.3.1-1 shows these relationships. The yellow boxes indicate the issues to be discussed in this section.

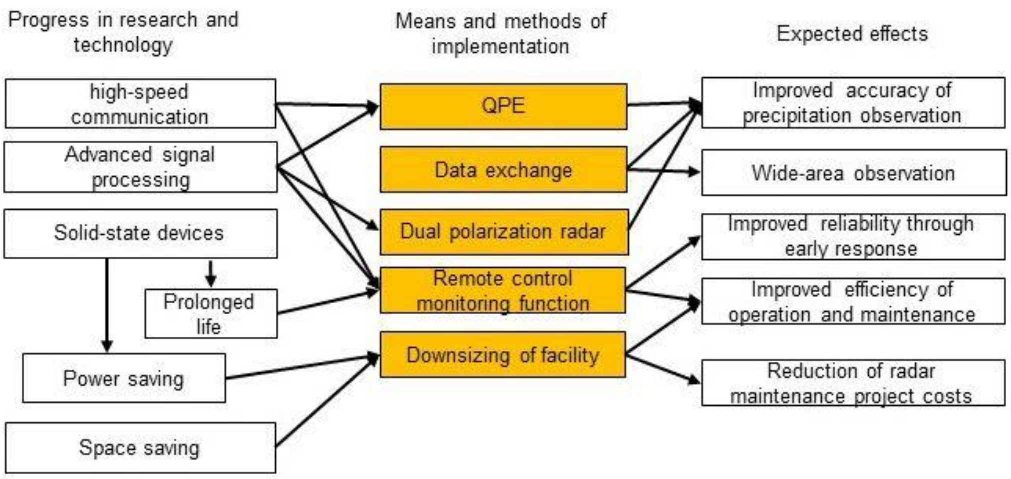

Figure III.3.1-1 Relationships among the issues to be considered in the future technical cooperation on weather radars

III.3.2 QPE with Weather Radars and Technical Cooperation

Precipitation observation by radar provides information on the distribution and movement of rainfall over a wide area. Since radars alone cannot provide quantitative rainfall intensity, the following QPE (Quantitative Precipitation Estimation) techniques are necessary to obtain quantitative and areal rainfall information over the entire country.

1) To monitor the distribution and movement of rainfall over the entire country, it is necessary to remove sufficiently ground clutters and to compose data from multiple radars to get rid of the effect of orographic

radio wave blockage.

2) In most countries surveyed in this study, precipitation intensity is obtained using standard parameters (B=200, β=1.6) from the reflection intensity obtained by radar based on the Z-R relationship. It is a fact that precipitation intensity based on the Z-R relationship does not provide the necessary information for the criteria for issuing heavy rainfall warnings. In addition, radar observation data often do not reflect actual rainfall due to noise caused by topography and abnormal propagation of radio waves.
3) For this reason, the QPE method of obtaining areal rainfall distributions by comparing actual rainfall measurements obtained by automatic rain gauges with radar reflection intensities has been implemented by JMA since the 1980s in Japan (preparation of analytical rainfall). Quantitative rainfall distribution maps can be derived using this method by combining multiple domestic radars or radars from neighboring countries. Based on the distribution maps, quantitative precipitation forecast (QPF) maps can be derived to predict the movement of the rainfall areas.

In some countries, such as Viet Nam, QPE is being realized through JICA's technical cooperation projects, and the results are already being used for weather forecasting and warning. In these countries, the development of QPF has also begun. It is necessary to advance to the stage of providing more accurate rainfall observation information to disaster management authorities. With the development of these technologies, it will be possible to advance to the stage of providing rainfall information derived from QPE and QPF and meteorological and disaster prevention indicators (soil rainfall index as disaster potential, watershed rainfall index, etc.).

As such, QPE and QPF are necessary for each country's forecasting operations and it is required to efficiently transfer the basic technologies for their introduction and utilization, and new technologies related to weather radars to the target countries. Therefore, in addition to the development and expansion of meteorological infrastructures, on-site training programs by short-term experts on QPE and QPF, and training programs in Japan by inviting NMS staff to Japan should be continuously conducted.

III.3.3 Radar Data Exchange and Cooperation with Neighboring Countries

It is useful to exchange radar data with neighboring countries, where domestic weather radars alone are insufficient to carry out observations over a wide area due to topographical conditions or when it is desired to obtain rainfall information for a distant area to monitor approaching typhoons. When exchanging data with these neighboring countries and creating composite maps of radar data over a wide area, it is desirable to exchange rainfall data that have been produce by the highly reliable QPE described in the previous section.

In exchanging data, it is necessary to consider the standardization efforts considered by the Inter-Programme Expert Team on Operational Weather Radar (IPET-OWR) promoted by WMO. The development and operation of QPE technology have been positioned as an essential goal for technology transfer to countries, including those belonging to the Association of Southeast Asian Nations (ASEAN). JMA, in cooperation with ASEAN and the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), has been promoting the development of QPE in Southeast Asia. It is hoped that these efforts will be continued. On the other hand, there are still some issues to be addressed, such as the fact that radar data exchange is not easy in some countries due to data policy constraints.

III.4 Introduction of Dual-Polarization Weather Radars and QPE

III.4.1 Needs for Introduction of Dual-Polarization Weather Radars and QPE

Based on the results of many years of research, the dual-polarization weather radars, deployed by JMA and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in recent years for operational use, has the following advantages over conventional weather radars.

- **More accurate measurements of precipitation intensity**: Using polarization parameters (such as Kdp) that are not attenuated by strong rainfall, it is possible to calculate precipitation with higher accuracy than conventional Z-R relationship.
- **Acquisition of higher quality data**: By using polarization parameters, it is possible to discriminate non-precipitation echoes such as topography, abnormal propagation, and sea clutter.
- **Identification of precipitation particles**: It is expected to improve observation accuracy by identifying bright bands in the cloud.

In Japan and other countries, QPE has been conducted by comparing and calibrating radar observations with automated rain gauges such as AMeDAS. In developing countries, on the other hand, there are challenges that the number of automatic rain gauges is insufficient for QPE or their distribution is uneven in the region even there are sufficient number of rain gauges. In such a situation, there is a possibility to produce high quality QPE using dual-polarization weather radars replacing QPE with rain gauges.

III.4.2 Cooperation Policy for the Introduction of Dual-Polarization Weather Radars and QPE

In developing countries to which JICA has provided weather radars, some radars have been in operation for more than 20 years. Still, these radars are gradually reaching the end of their system lifetimes. In some cases, these radars have reached the end of their service lifetimes and are no longer in operation due to the unavailability of spare parts beyond the planned supply periods. It is hoped that existing weather radars that have reached the end of their service lifetimes will be replaced by solid-state dual-polarization weather radars with low power consumption and fewer consumable parts.

In developing countries as well as in Japan, there are increasing needs for high-quality precipitation information that is necessary for disaster risk reduction and that can be used in daily life. There are needs to replace qualitative heavy rainfall warnings with warnings based on quantitative rainfall information and detailed rainfall information. In response to these needs, the deployment of dual-polarization weather radars and the improvement of the related technical capabilities of NMSs will enable NMSs to provide not only quantitative rainfall distribution maps, for example, but also various disaster prevention parameters (landslide index, flood index, etc.) as the basis for meteorological disaster countermeasures.

In transferring the development and operation technologies of QPE, which is the basis for providing such information, it is necessary to receive guidance from JMA and other related organizations. As for technical cooperation on weather radars with NMSs in Southeast Asia, it is required to consider collaboration under ASEAN and UNESCAP and collaboration among countries.

As a theme for the training in Japan on the weather radars in the technical cooperation projects, it is necessary to enhance the contents on the utilization and maintenance of dual-polarization weather radars in addition to the content on radar data composition.

III.5 Weather Radar Facilities

III.5.1 Requirements for Radar Facilities

When providing support to developing countries for the deployment of weather radars, the following issues should be considered for the facilities.

Facility configuration

Weather radar facilities consist of the radar tower, the machinery room, the observation room, the power supply room, warehouses, toilets, and other living facilities. When a radar facility is constructed adjacent to an existing building such as a meteorological station, consideration should be given to installing ancillary facilities, except for the radar equipment room, within the existing facility. In addition to the space for installation of the equipment, space for maintenance and upkeep, conditions for air conditioning, and security of entry and exit should be taken into consideration to make the space as lean as possible. If the radar is remotely controlled and monitored from the headquarters, an observation room is not necessary at the radar site.

Consideration of seismic strength and wind speed resistance

When designing a dedicated concrete building or a steel tower that can secure the necessary height for observation, the strength of the building or tower should be considered in accordance with the local seismic standards and local conditions such as maximum wind speed. In particular, in the case of dual-polarization weather radars, it is necessary to suppress the swaying and twisting of the tower so that the inclination of the transmitted and received polarization planes remains within the limits even in high winds in order to ensure observation accuracy.

Lightning protection measures

The weather radar requires strict lightning protection measures to prevent operation stoppage during bad weather. Lightning rods should be installed around the radome, and lightning protection measures should be taken for each radar device, power supply, and communication line. When grounding to the ground, each ground wire should be connected to a common installation plate to minimize the electrical resistance between the ground wires.

Waveguide and connecting cable

A waveguide that conducts radio waves is installed between the radar antenna and the transmitting/receiving equipment. The equipment shall be arranged so that the waveguide is not bent, and the attenuation of radio waves in the tube shall be suppressed. Normally, rectangular waveguides are used, but when extending the distance, circular waveguides are used. The length of the waveguide shall be determined within the acceptable loss range calculating the total loss of radio waves from the transmitting/receiving device to the antenna horn. In this case, the radar machine room that houses the transmitting and receiving equipment should be installed as close to the ground as possible.

In the case of outdoor installation, sufficient lightning protection measures shall be taken for signal cables and power cables. For this reason, optical cables should be used for signal cables. In the case of outdoor installation, measures against deterioration due to temperature, humidity, ultraviolet rays, and damages by small animals and insects should also be considered.

Securing the power supply

To ensure stable operation of the radar, uninterruptible power supply equipment such as an engine generator should be provided. When the radar is remotely monitored and controlled, it should be equipped with a function to automatically start and stop the engine generator. Water-cooling or air-cooling of the engine generator shall be considered and will be in suitable for the local conditions.

Facility maintenance and management facilities

When steel towers are used, they should be plated with zinc or other materials to prevent corrosion before assembly. Since maintenance work such as cleaning of the radome and repainting of the steel tower involves work in high places, a work space should be provided around the radome.

Security for facility maintenance

When the radar site is unmanned, security and monitoring equipment such as surveillance cameras, intrusion detection equipment, and fire detection equipment shall be strengthened more than ever before. However, depending on the security situation in developing countries, there may be risks that cannot be handled by these facilities, such as destruction by terrorism, theft, and property damage. In such cases, a manned site with the minimum number of watch personnel would have a deterrent effect on such situations.

Downsizing of Radar Sites

Recent advances in technology have enabled radar equipment, such as transmitters, to save power and space compared to conventional devices. In many JICA projects, antennae have been installed on the concrete towers and the radar equipment rooms have been built underneath. On the other hand, there have been many cases in Japan and other countries where the entire facilities have been downsized by housing the equipment in the containers or the separate buildings. In these cases, the radomes and antennae are installed on the top of the towers, and the waveguides or cables connect the antennae and transmitting/receiving equipment. Figure III.5.1-1 shows a radar tower and a container for the equipment.

Figure III.5.1-1 A radar site with a tower (left: tower, right: ancillary facilities)

Furthermore, as shown in the next section, there is a trend to make radar facilities unmanned and remotely monitor and control them from the headquarters.

III.5.2 Remote Control, Monitoring and Maintenance

In most of the countries surveyed in this Survey, maintenance of meteorological observation equipment and lack of human resources are challenges for NMSs. Especially concerning weather radars, which are expensive as meteorological equipment, the operational status of the radars after their installation will determine the outcomes of the cooperation, and it is time to reconsider the contents of the cooperation.

Reviewing the status of maintenance and operation of the radars installed by JICA projects in each country, observation and maintenance personnel are assigned to the radar sites according to the installation plan, and they perform tasks such as inspection of equipment, replacement of consumables such as transmitter tubes, and troubleshooting, which they learn through on-the-job training. As time passes after installing the radar, each part of the radar deteriorates, the period of radar shutdown becomes longer due to inspections, and the work experience and skills are gradually lost due to personnel transfers during the period.

To cope with these situations, it is necessary to have a system that can constantly monitor the status of the equipment and identify the trend of deterioration so that the deterioration of radar data quality and failures can be detected at an early stage. One of the ways to do this is to monitor the radar remotely. Currently, monitoring the status of and control of devices of weather radars are carried out at the radar sites, and the major radar observation data are transmitted to the radar center at the headquarters. When a radar failure occurs, it is impossible to determine the cause of the failure from the radar observation screen alone, so the radar has been restored through inspection and failure diagnosis at the radar site.

In the future, it is desirable to install a remote monitoring device at the center that can grasp the operational status of each device and meteorological condition. This will allow the center to monitor the radar equipment at all times to determine if the equipment is deteriorating or malfunctioning. In a malfunction, the site will take minimal action and dispatch technicians from the center to repair the equipment.

Ways to cooperate

The following summarizes issues to be considered when cooperating to promote remote monitoring of radar sites.

1) Considering the shortage of radar-related technical personnel in developing countries, the number of personnel and tasks to be assigned to a site should be minimized, and a limited number of technical personnel who can judge the situation should be intensively assigned to the center for optimal allocation of human resources.
2) For this purpose, it is desirable to select a telecommunication line for information transmission between the radar site and the center that can also transmit monitoring information in real-time at the time of system design. In particular, dual-polarization weather radars should monitor various monitoring items in real-time to ensure observation accuracy and detect and respond to faults at the center.
3) There are social and security issues such as communication and public safety in developing countries. Therefore, considering these situations, it is desirable to leave personnel at the radar site for simple inspections and parts replacement.
4) Assuming that no specialized technical personnel are stationed at the radar site, it is necessary to consider the criteria for the staging of failure response (site response, headquarters response, and manufacturer repair), and to consider a periodic maintenance contract that includes on-call (via the Internet) failure diagnosis from the meteorological station to the domestic radar manufacturer.

III.5.3 Display Device Composition

Current status of display devices

The weather radars deployed within JICA projects, various display devices (PCs) have been installed at the radar sites and centers. This is due to the following reasons:

(1) The functions of radar operation monitoring, data/protocol conversion, remote monitoring, and product display (precipitation intensity, wind speed, prediction, etc.) are distributed and placed where necessary.
(2) The hardware and software specifications of these devices are standardized as much as possible, and they are configured to mutually back up their functions in case of individual failures.

On the other hand, it is also common practice to create various products on a Web server for product display and access these products from each display device to display the necessary screens. This also makes it possible to connect LAN of the radar to which the Web server is connected to the operational LAN of NMS and easily display radar products on existing (or newly installed) PCs in each office.

Ways to cooperate

The basic principle of the radar system is to ensure the stable provision of data. In principle, LAN for the radar system should be independent so that access from outside does not affect its operation. In principle, LAN for the radar system should be separated from that for operational use in NMS.

The operation depends on the IT facilities' level and the system administrator's skills when connecting LAN for the radar system and the operational LAN. The configuration should be decided after considering whether network management (e.g., assignment of IP addresses) between the Web server and the client for displaying radar images can be secured in the future.

In determining the contents of radar products, the needs of forecasters for meteorological services and the meteorological information required by related organizations should be considered. In addition, radar products supplied by other donors should be considered, and data should be standardized as much as possible.

III.6 Advanced Utilization of Meteorological Satellite Data, including GSMaP

III.6.1 Necessity of Advanced Utilization of Meteorological Satellite Data

Japan has been operating the Himawari series of geostationary meteorological satellites over the Asia-Pacific region since the first Himawari satellite launched in 1977. The latest Himawari 8/9 satellites have been taking images in visible and infrared 16 channels at a resolution of 0.5 km (visible) and 1 km (infrared) (at the sub-satellite point) every ten minutes.

These observation data, satellite images (Full Disk) are distributed to NMSs in the Asia-Pacific region through communication satellites (HimawariCast) and the Internet (HimawariCloud), together with JMA's Global Spectral Model (GSM) forecast values up to 48 hours ahead, and surface and upper-air observation data in the Asia-Pacific region.

NMSs in the footprint of Himawari satellites utilize these image data to analyze the movement and strength of tropical cyclones several days before they approach and monitor the movement of rapidly developing cumulonimbus clouds to issue early warning disaster management information and a wide range of information essential for the safe operation of aircraft.

Japan has provided NMSs in the Asia-Pacific region with HimawariCast receiving and processing systems and the image visualization tool (SATAID) through JICA and JMA/WMO and has made technology-transfer on satellite image analysis using these systems. In particular, the provision of SATAID has made it possible to comprehensively monitor the meteorological field by superimposing Himawari data, NWP data, surface observations, radar observations, and other data on the same screen, making it an indispensable tool for the preparation of weather forecasts in various countries. As a result of these ongoing activities, Japan has been able to secure a solid relationship of trust and presence in NMSs of the Asia-Pacific countries, despite competition from neighboring countries in the geostationary meteorological satellite services.

However, it has been at least several years since these systems were provided, and support for updating the receiving and analysis systems is required. Furthermore, with the further development of the Internet, support is required to introduce HimawariCloud, which acquires high-resolution satellite data via the Internet. In addition, continued training on the Dvorak method for estimating the strength of tropical cyclones and RGB image analysis for evaluating the distribution of yellow sand and volcanic ash is also required.

SATAID is a software developed by the volunteer staff of JMA, and with the retirement of related core staff, it is becoming difficult to update the software continuously. As a result, it is not possible to adequately respond to user needs, such as utilizing data obtained via HimawariCloud, automating the preparation of routine documents, and flexibly incorporating NWP results. The Japan Aerospace Exploration Agency (JAXA) has been promoting the Global Satellite Mapping of Precipitation (GSMaP) project, which uses low-earth-orbit satellites to monitor quantitative precipitation intensity distribution in real time. If GSMaP data can be displayed with other data in SATAID, SATAID could be a tool to enhance precipitation monitoring operations, especially in developing countries with weak radar networks. However, it is difficult to add such a function to SATAID at present.

Therefore, it is necessary to continue promoting cooperation to support the acquisition and utilization of geostationary meteorological satellite data to ensure disaster management and transport safety in these countries and to maintain Japan's leadership in the field of meteorological satellites in the Asia-Pacific region.

III.6.2 Ways to Cooperate

Updating and upgrading the functions of SATAID

As mentioned above, the provision of SATAID and the transfer of meteorological analysis technology using it are potent means in Japan's technical cooperation. Although it has become difficult for JMA to update SATAID by itself, it is necessary to continue to improve and upgrade SATAID to cope with the next generation Himawari satellites scheduled to be launched in a few years, to cope with the upgrading of the PC environment, and to incorporate new technologies such as GSMaP.

Therefore, it is necessary to establish a foundation for the continued use of SATAID in the Asia-Pacific region by receiving the source code of SATAID from JMA and establishing a fundamental redevelopment of SATAID and unified maintenance and regular update system to incorporate new user needs by specialized software houses. A foundation for the continued use of SATAID in the Asia-Pacific region should be established.

Improving the environment for receiving Himawari data

Several years ago, JICA and JMA, in cooperation with WMO, intensively provided HimawariCast receiving systems to NMSs in the Asia-Pacific region. These systems are gradually becoming obsolete and are in need of renewal. Some neighboring countries are currently operating geostationary meteorological satellites in geostationary orbit near Himawari. There is an undeniable risk that data from satellites of these neighboring countries will be used in place of Himawari date if there is a delay in providing support for replacing aging receiving systems. For this reason, it is necessary to strategically and systematically replace the receiving systems of countries in the region by new ones. In addition, it is important to establish a system to support the countries by replacing malfunctioning parts and updating software even after the provision of the equipment to enhance confidence in Japan.

In recent years, as the Internet becomes more widespread, more and more NMSs are willing to introduce HimawariCloud to acquire higher resolution satellite data via the Internet. It is necessary to support them by providing servers and essential software while considering the communication conditions in the country concerned.

Technology transfer for utilization of satellite data

There is a wide range of analysis techniques using satellite data, such as analyzing tropical cyclones using the Dvorak method, analyzing the distribution of cold air and water vapor using RGB images, and identifying fog, yellow sand and volcanic ash. In addition, it is necessary to acquire new technologies such as the advanced understanding of actual conditions by superimposing NWP data and radar data, and the use of GSMaP to understand the distribution of precipitation outside the radar detection range.

To efficiently transfer the basic and new technologies necessary for these forecasting services to the target countries, it is necessary to continuously conduct on-site training by short-term experts and training in Japan by inviting NMS staff to Japan.

III.7 Improvement of International Meteorological Telecommunication

III.7.1 Necessity of Upgrading International Meteorological Telecommunication

Historical background and future development

The Global Telecommunication System (GTS) is one of the components of the World Weather Watch (WWW) programme, which the World Meteorological Congress approved in April 1963 together with the Global Observation System (GOS) and the Global Data-Processing System (GDPS), and has supported operations among WMO Members for more than 50 years according to the rules of the Manual on GTS.

The basic technology that had realized real-time global data exchange when international data communication was not widely available is "Message Switching" using point-to-point connection and store-and-forward mechanism. The overall structure of GTS is designed to enable global delivery of the highest priority messages such as tsunami warnings within two minutes, and to achieve this, unique functions such as header priority identification, priority queue management, re-routing, and duplicate checking and deletion are introduced.

Even though the communication media has changed from leased lines to network clouds (Frame Relay, MPLS, commercial IP-VPN, Internet VPN), the basic technologies and original functions have been inherited by GTS-MSS (Message Switching System) of each country. GTS-MSSs have been developed by foreign weather system companies which are close to NMSs and have been sold and introduced to various NMSs claiming that they are compliant to WMO technical standards. However, in the first half of the 2000s, many companies began to withdraw from developing these systems because of the small market size and the need to keep up with revisions in technical regulations. In Japan, two companies tried to develop a hardware-oriented minicomputer-based MSS for the Asian market in the 1990s but they gave up due to difficulties in local supports and exports. In its place, a company developed a PC-based MSS with a strong software orientation, which met the objectives of JICA's support for developing countries and was introduced mainly in Asia and the Southwest Pacific.

In the mid-1990's, with the spread of the Internet and the increasing miniaturization and high performance of hardware, data communication and data processing became cheaper and easier to implement using general-purpose technologies, and GTS, which had evolved independently in the meteorological community, could no longer meet the needs of the ICT era. Therefore, WMO developed a plan to construct an information infrastructure based on the requirements of each field of activity for about ten years starting in the late 1990s. This is the WMO Information System (WIS (originally called the Future WMO Information System: FWIS)), which currently consists of the three conceptual elements (Part A to Part C) shown in Figure III.7.1-1.

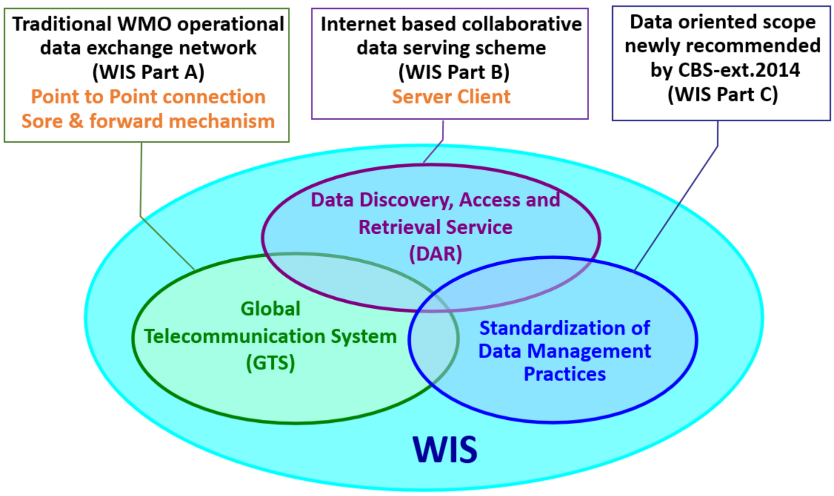

Figure III.7.1-1 Conceptual diagram of WIS

WIS has been in operation since 2012, but the essence of GTS has not changed, although it is within WIS. This is because the data retrieval, direct access, and acquisition based on the Internet general-purpose technology of WIS Part B cannot fully satisfy the real-time capability for routine operations that GTS has inherited.

Currently, WMO's strategy is to move to WIS 2.0 by introducing new mechanisms. The overall concept is based on a shift from push-type delivery of routine data to pull-type acquisition of selected data. This includes the replacement of GTS-based Message Switching with industry-standard data delivery methods and protocols such as Advanced Message Queuing Protocol (AMQP), Secure File Transfer, and Publish/Subscribe Messaging. The WMO transition plan in Table III.7.1-1 shows that GTS will be abolished by 2030 but in reality, it is becoming a "pie in the sky" when considering the transition of all WMO Members, including developing countries.

Table III.7.1-1 Migration plan to WIS2.0

	Projects	Transition	Communication
2020 INFCOM-1EC-73	Demonstration projects established		Outline WIS 2.0 implementation and operation costs for GISCs
2021 Cg-2021 EC-73	Demonstration projects progress report and engage a broader community	Real-time data dissemination with draft message protocols used for 'experimental' data exchange between GISCs and participating WIS Centres	WIS 2.0 engagement with RAs, Activity Areas, and WIS National Focal Points
2022 INFCOM EC-74		WIS 2.0 architecture testing and validation including a subset of GISCs to offer updated WIS Catalogue to support experimental registration of services INFCOM determine how and where the industry should be engaged to support WIS 2.0 implementation	Communication plan for WIS 2.0 implementation published to Members
2023 Cg-19 EC-75	Demonstration projects final report	GISCs confirm procedures for registering services in WIS 2.0 GISCs, with the support of Regional Associations engage the transition of their Area of Responsibility toward WIS 2.0	
2024		Operational WIS 2.0 Catalogue and portal provided by GISCs Old WIS DAR Catalogue 'frozen'. WIS Centres begin to register services in WIS 2.0 Catalogue. Funding options identified to support WIS 2.0 adoption in LDCs and SIDS MSS solutions implementing new message protocols available from the industry	
2026		Original WIS DAR Catalogue deprecated. Rationalized set of data and services migrated from original WIS to WIS 2.0. 70% of GTS routeing table configuration items migrated. GISCs provide service(s) to support the discovery of real-time data from WIS Centres in their AoR that have yet to migrate to new message protocols.	
2030		Migration to use of new message protocols complete - all GTS routeing table configuration items migrated and use of routeing tables deprecated	

Excerpted from https://community.wmo.int/activity-areas/wis/wis2-implementation

As many Global Information System Centers (GISCs) have been established towards WIS 2.0, some neighboring countries have been making efforts to provide supports to developing countries to increase their presence in the region, providing WIS/GTS equipment as well as satellite data receiving systems and forecast-support systems.

Figure III.7.1-2(a), (b) shows the hierarchical structure of the WIS centers and the designated GISCs, respectively.

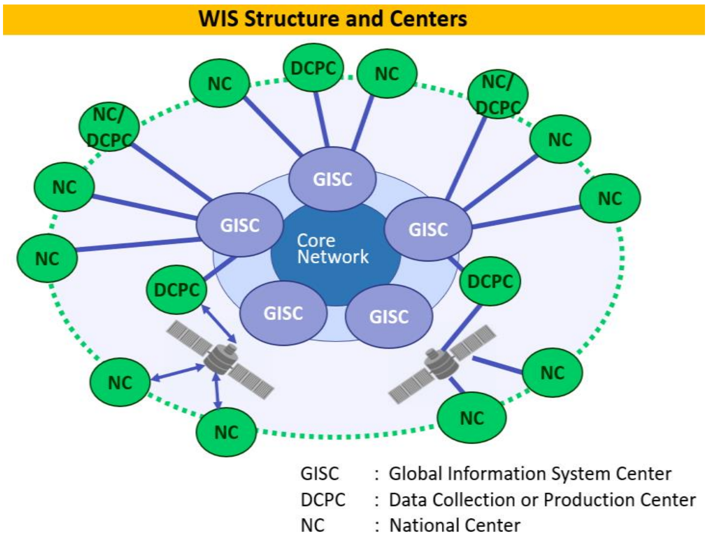

Figure III.7.1-2(a) WIS center hierarchical structure

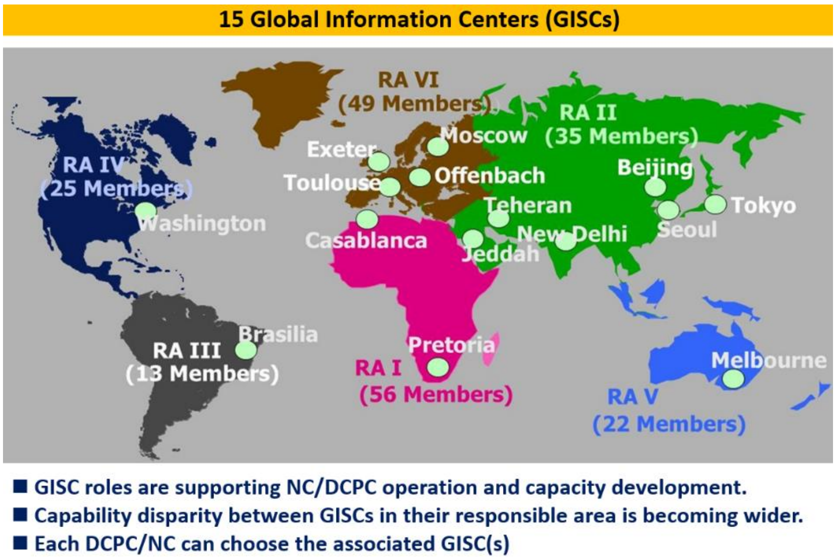

Figure III.7.1-2(b) Designated GISCs

The two driving forces of establishing infrastructure by WMO are WIS and the WMO Integrated Global Observing System (WIGOS), which are expected to work closely together to enhance data management and availability. Under these circumstances, business trends of weather system companies in USA and Europe are as follows:

- These companies have shifted their focus from the development and provision of various systems exclusively for NMSs to the development and provision of a lineup of highly versatile forecast analysis and environmental systems for private meteorological, transportation, energy-related companies and research institutes, not to mention the WIS/GTS system, which is difficult to secure profitability on its own.

- The competition to expand the market is not limited to Europe and Africa but to Asia and Oceania. They are trying to enter the markets in countries in these regions through the intermediary of local ICT-related partner companies and consultants.
- Companies try to make the initial installation costs of the systems relatively low, and they are promoting a method to increase profits through the cost of maintenance and software update contracts. Companies have also strengthened their focus on turnkey systems that can reduce the number of installation days and labor costs at the time of installation.

The volume and format of data should be addressed when considering the future cooperation.

Satellites, radars, and NWP models generate vast amounts of data that never existed before. In addition, even if the size of observation data from AWSs, hydrological and environmental sensors is small, the increasing number of sites and the reporting frequency will lead to a rapid increase in the volume of the data to be processed. These continue to grow significantly faster than the improvement of communication networks and will soon become a severe problem for network distribution, system processing, and storage.

A further complicating factor is the data format: WMO is promoting a migration from the traditional alphanumeric codes (TAC), e.g., SYNOP and TEMP to the table-driven code forms, BUFR and GRIB. But this has not been achieved in many countries, especially in developing countries and this situation is likely to continue for the time being. On the other hand, trials of general open data formats (JSON, CSV, XML, netCDF, HDF, etc.) and discussions on the standardization are in progress at WMO's Commission for Observation, Infrastructure, and Information Systems (INFCOM), mainly by developed countries.

III.7.2 Ways to Cooperate

Integration of international and domestic communication systems

The TCP/IP-based Internet standard technology has made it so easy and inexpensive to build a communication environment that it is said that there is no electronic device that does not communicate. In the past, communication conditions and protocols differed between domestic and international communications, and it was usual to have separate systems. Integration of domestic and international communications should be pursued as this has advantage in maintenance/management and cost.

Major equipment should be duplex to avoid prolonged total failure.

System development and continuous support in line with the actual conditions of developing countries

(1) Support for remote maintenance

In recent years, software lifecycles have become shorter than hardware lifecycles, and OS, middleware, and applications need to be upgraded frequently. While the counterparts should handle minor tasks by remote support or remote training in advance, remote maintenance support from Japan is extremely effective when acute failures or complex tasks are required. A security-conscious remote access environment should be set up at the system installation.

(2) Electric power failure and lightning damages countermeasures

Hardware failures are often caused by electric power failures. Locally procured uninterruptible power supplies (UPSs) with replaceable batteries that can be easily obtained locally should be mandatory. In particular, for critical server and storage systems, UPS with "normal inverter feed system" or "line interactive system" should be selected.

In addition, severe hardware failures due to lightning damages are not uncommon. A dedicated arrester (Lightning Arrester, Surge Protective Device: SPD) should be inserted into the power and signal systems.

(3) Simplifying the intranet

Many NMSs do not have an intranet based on a unified IP address system. There are many cases of confusion due to duplication of Private IP addresses with existing subnets when adding subnets when installing a new system. In addition, tricky IPv4 technologies such as NAT and IP masquerade are often used, but due to the shortage of network engineers in NMSs, subcontracting expenses are often required for setting changes.

Recently, there have been more and more cases where IPv4 packets are encapsulated in IPv6 and WAN is communicated as an IPv6 network (IPv4 over IPv6), and the penetration rate of IPv6 is gradually increasing. However, migrating the entire intranet to IPv6 is still challenging because of the efforts and risks involved.

Considering this situation, adopting IPv6 should be considered to simplify management not to worry about the existing IPv4, such as building a new intranet or a small-scale observation system.

Regardless of IPv4 or IPv6, network design and management are necessary, and it is, therefore, important to o develop engineers within NMSs by establishing a system for technology transfer and training.

WIS/WIGOS, important affinity between communication and observation

(1) Promotion of BUFR foreseeing replacement of measuring instruments

The suspension of delivery of observation reports in Traditional Alphanumeric Codes (TACs) over GTS by China on 1 March 2020 had significant negative impacts on the operations of many developing countries, showing that the prescriptive WMO transition plan cannot be applied to many countries.

Although the reporting TAC (SYNOP and TEMP) will eventually be stopped, no action should be taken to stop it at present, as it is simply reporting the reports converted in BUFR. There is a problem with the simple TEMP conversion to BUFR, and many NWP centers have requested that the simple BUFR conversion be stopped. However, considering the recipient countries that have not yet fully migrated to BUFR, including their domestic use, SYNOP reporting should be continued for the time being as long as it does not cause any problems.

On the other hand, for new BUFR native instruments, it is essential to deliver BUFR reports to enable each country to report observation parameters and elements that TAC cannot report, and there is no need to convert them to TAC for delivery.

(2) Study of an advanced communication system that enables the collection and transmission of heterogeneous AWS data and Automatic Quality Control (AQC)

Different AWS networks have been established independently by different donors in many developing countries, with different data formats and collection methods, making centralized management and sharing impossible.

Some of the latest communication systems of Western weather system companies use add-on converter software to collect AWS data in formats other than the WMO reporting format, perform advanced AQC (not simple screening, but area checking with nearby data and meteorological AI checking) to BUFR conversion, and provide visual web distribution to forecast systems. A condition for this development is the registration of AWSs to WIGOS OSCAR/Surface and the release of the data format. It is expected that WMO will request each donor to meet this condition in the future.

In light of these trends, the future renewal of the integrated communication system in JICA technical cooperation projects should at least consider to establish a system that enables data collection and transmission of AWSs/ARGs provided by JICA, some degrees of AQC and BUFR conversion, and intranet sharing and use.

In addition, the system should be able to support various communication methods such as e-mail, SMS, TCP socket, FTP, etc., to support various AWS data collection.

Development and implementation of projects on rehabilitation of AWSs/ARGs, which have not been able to collect and transmit data due to some failures, may benefit developing countries.

Support for WIS

(1) Upgrade of GTS lines

GTS lines using the TCP socket protocol, which has already been removed from the Manual on GTS, should be upgraded to the WMO-FTP protocol as soon as possible. Developing countries that use leased lines or commercial clouds but face difficulties in terms of operating costs should be supported to migrate to Internet VPNs.

(2) Support for WIS Part B connection with GISC Tokyo

To increase their presence, the support activities of neighboring countries to encourage connection to their GISCs are becoming more prominent.

Developing countries that wish to obtain JMA's NWP products, satellite data, etc. will benefit from connections to GISC Tokyo within the WIS operation. Therefore, technical cooperation projects of JICA should actively support WIS Part B connection to GISC Tokyo in cooperation with JMA. In addition, mutual complementary operational support with HimawariCast and HimawariCloud data distribution should be considered in the Asia-Pacific region.

(3) Cautious response to WIS2.0

WIS2.0 is unlikely to proceed according to the WMO's schedule and should not be hastily targeted in technical cooperation projects. For the time being, it is desirable to monitor the status of the WMO study while receiving information from JMA. In particular, it is necessary to understand the impact of the transition from the existing Store-Forward system to the Advanced Message Queuing Protocol (AMQP) system on developing countries.

III.8 Support using Forecast Analysis and Forecast Support Systems Made by Non-Japanese Suppliers

III.8.1 Needs for Support using Forecast Analysis and Forecast Work Support Systems Made by Non-Japanese Suppliers

In this Survey, it was found that all the countries surveyed use forecast results produced by foreign NWP centers such as Japan, ECMWF, the United States, etc. through the Internet, HimawariCast (JMA's forecast results), etc. and use them to produce short-range forecasts.

It was also found that NMSs in many countries operate the Weather Research and Forecasting (WRF) model, which is a regional model developed by the U.S. National Center for Atmospheric Research (NCAR) and others and made available free of charge, in their own countries and use it for short- range forecasting.

WRF, which requires relatively small computer resources, is widely used for forecasting in developing countries to produce detailed forecasts for the countries by incorporating forecast results produced by foreign NWP centers and their own meteorological observation data. Simply using boundary conditions produced by foreign NWP centers would result in calculations that simply make the NWP center's global model respond to the orography in the country and would not take full advantage of capabilities of WRF. It should be noted that the assimilation of dense observation data in and around the country is necessary to improve the operation and accuracy of WRF.

In addition, whether the forecast results are produced by the NWP center or by a regional model such as WRF for the country, the NWP results contain errors specific to the model used. For this reason, it is essential to compare the forecast results with actual conditions for past cases and to statistically modify the NWP results to produce forecast support materials (guidance).

These systems, such as SmartMet (developed in Finland) and Synergie (developed in France), are used to visualize and display the results of surface, radar and satellite observations as well as NWP results, as weather maps and radar/cloud composite images, in an integrated manner to support efficient forecasting. SATAID, developed in Japan, has similar functions to a certain extent but it is not used as much as other forecast support systems in other countries because it mainly displays Himawari images and Japan's NWP products as it does not have an automatic function for creating routine data/products.

III.8.2 Ways to Cooperate

To fully utilize the WRF model in their forecasting operations, it is important that the countries to be supported fully recognize that it is not sufficient to install computers and obtain boundary conditions from the NWP center and it is necessary to conduct the appropriate assimilation of their own observation data.

Based on this, after checking the operational status of the target country, the technology should be transferred to assimilate not only the data from the NWP center as boundary conditions, but also continuous, asynchronized data such as aircraft observation data and Doppler radar data in the country.

In addition, the development of fundamental observation networks such as AWSs and radar observation and the improvement of data quality management capabilities should be focused so that high-quality observation data can be obtained that will contribute to the improvement of forecast accuracy.

In addition, technology transfer should be made for preparing guidance for processing NWP results into highly accurate forecast support products and supporting the preparation of guidance as integrated forecast information and other products in the forecast support system of the country concerned.

Since SATAID is a crucial software for promoting the utilization of meteorological satellite data of Japan, it is necessary to establish a system for drastic functional improvement and continuous maintenance based on the understanding of user needs.

III.9 Promotion of ICT and DX in National Meteorological Services

III.9.1 Outline of the IT Infrastructure Cooperation Policy

This section describes the cooperation policy for IT infrastructure in ODA projects, focusing on meteorological technical cooperation projects, where cooperation on IT infrastructure is the foundation and prerequisite for "technology implementation" and "delivery of meteorological information/products." Figure III.9.1-1 shows a conceptual diagram of the NMS's IT infrastructure. To use observation data and data transferred from foreign NMSs (left side of the Figure) to provide information to users (right side of the Figure), ideally the following servers should be established: a meteorological data server to store meteorological data; an analysis and processing server to process meteorological data to produce warnings and radar images; and a meteorological data server to transfer data to the users. It is also desirable to equip a server in each department to share data and handle prototype programs for processing. Systems for NWP and general affairs, which some countries already have, are omitted in this section.

While Figure III.9.1-1 shows the ideal situation, Figure III.9.1-2 shows a realistic situation based on this Survey. Each system's capacity may be insufficient for the introduction of new technologies, or may lack necessary functions. Therefore, it is necessary to survey the IT infrastructure in the early stages of the project. The number and skills of personnel as well as the status of hardware and software within NMS should be assessed to determine whether they are sufficient for the introduction of the technology and if not, a reinforcement plan should be formulated. As for the information transmission system, it is necessary to configure the system according to the needs of weather information users. It is desirable to understand the status of the IT infrastructure not only within NMS but also at the users.

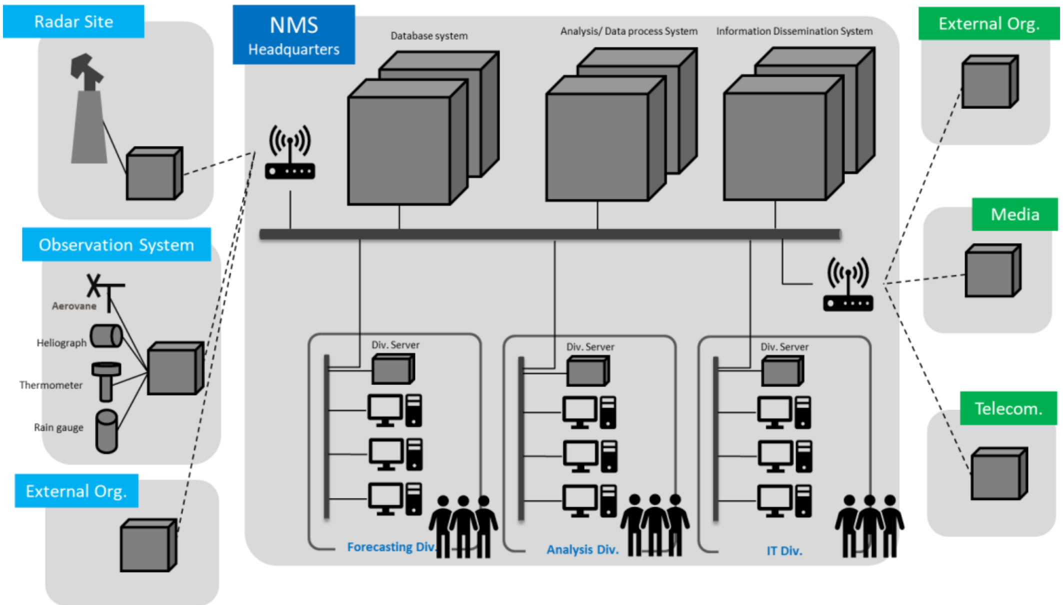

Figure III.9.1-1 Conceptual diagram of the IT infrastructure of NMS (full)

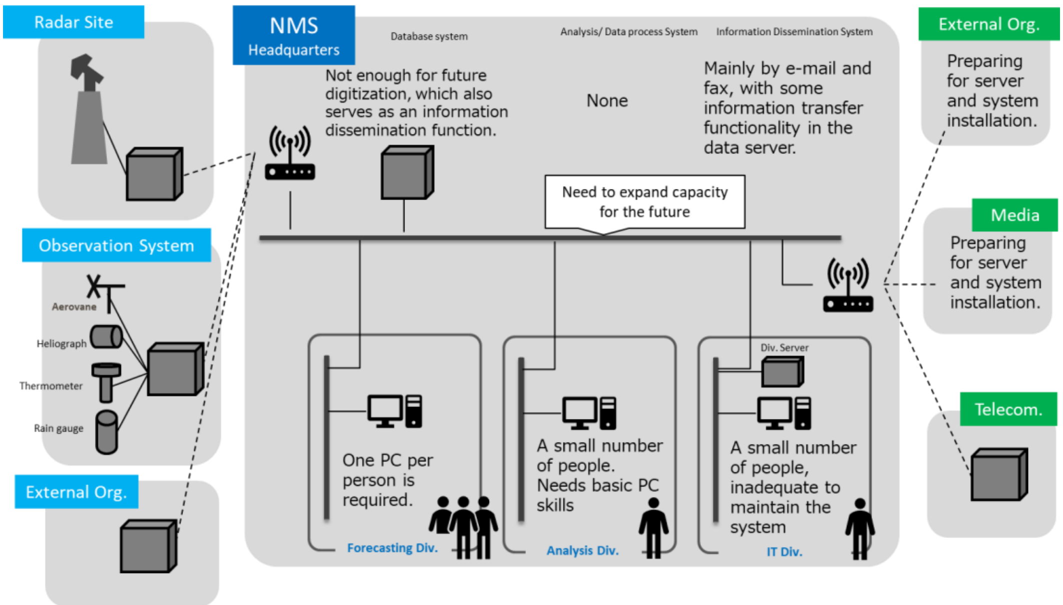

Figure III.9.1-2 Conceptual diagram of the IT infrastructure of NMS (current)

III.9.2 Challenges and Strategies for IT Infrastructure in Technical Cooperation Projects

In implementing technical cooperation projects, it is desirable to have as much information on IT infrastructure as possible. On the other hand, in most cases, detailed information on the IT infrastructure is not disclosed from NMS considering the risk of cyberattacks. In other words, it is impossible for the consultant to collect information regarding configuration charts, specific equipment specifications, and data processing details at the stage of planning a technical cooperation project. Therefore, it is not possible to develop a detailed plan for the IT infrastructure and the IT infrastructure will be provided within the scope of the initial plan and budget after the project starts (Figure III.9.2-1 shows the concept). Once the technical cooperation project has started, NMS regards the consultants as the project implementer, and they can easily collect specific information, enabling them to conduct detailed studies and appropriate planning.

Therefore, it is recommended that the implementation plan for the IT infrastructure be prepared after the beginning of the technical cooperation project. Furthermore, after preparing the implementation plan, the equipment can be estimated and purchased, and the IT infrastructure can be deployed more in line with local conditions and the level of technology for radar technology and forecasting/warning.

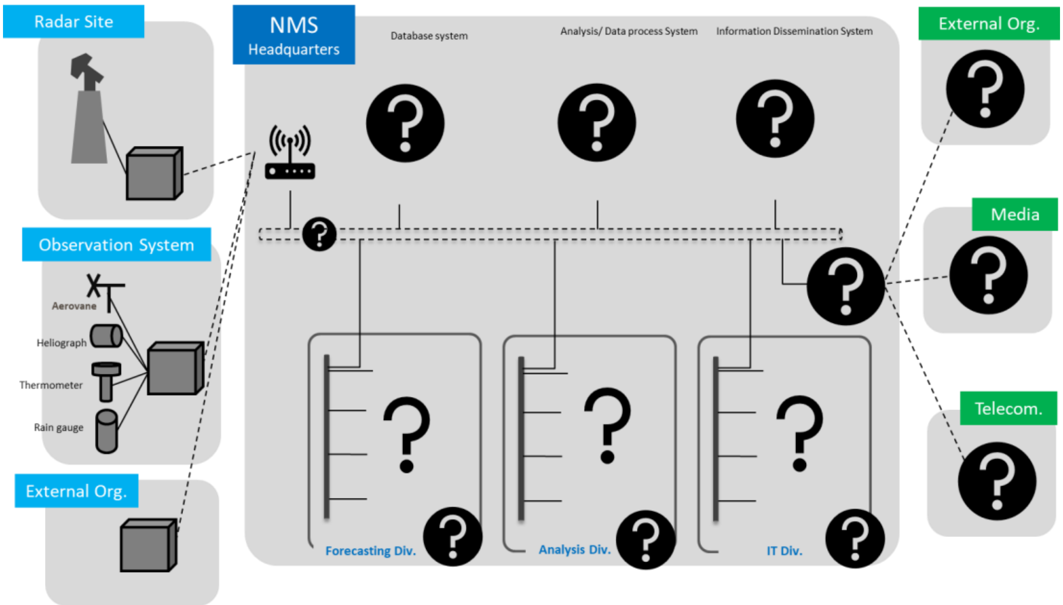

Figure III.9.2-1 Conceptual diagram of the IT infrastructure of NMS (pre-project stage)

III.9.3 Implementation Policy in the Field of IT Infrastructure in Technical Cooperation Projects

As mentioned above, it is desirable to collect as much information on the IT infrastructure, as possible to implement a technical cooperation project. In many cases, sufficient information on IT infrastructure is disclosed when the project begins. It is hoped that this will continue to be the case in the future. However, in some cases, detailed information on the IT infrastructure is not available even after the project begins. In such cases, technologies and IT equipment must be introduced in individual specific technical fields.

When detailed information on IT infrastructure is disclosed, it is necessary to verify whether the NMS's existing IT infrastructure is sufficient for introducing the technology in the project. If the existing IT infrastructure is adequate, it can be implemented using the existing IT infrastructure. If the existing IT infrastructure is inadequate, it is necessary to define the necessary requirements for IT infrastructure for each technology area and consider the IT infrastructure to be implemented as a whole project.

Finally, it is also necessary to consider whether the number and skills of IT engineers/technicians are sufficient. If they are sufficient, the technology transfer can be made as planned; but if they are not sufficient, basic training programs should be conducted. It is also necessary to consider proposing to NMSs to hire specialized IT staff, as necessary. However, it is often reported that the high demand for IT engineers/technicians make it difficult for NMSs to hire IT staff under their salary level. Therefore, it is necessary to outsource IT tasks as necessary. It is necessary for the project staff to collaborate with the NMS staff to define the requirements and review the specifications for outsourcing so that they can outsource and manage the project appropriately. The above discussion is described in Figure III.9.3-1.

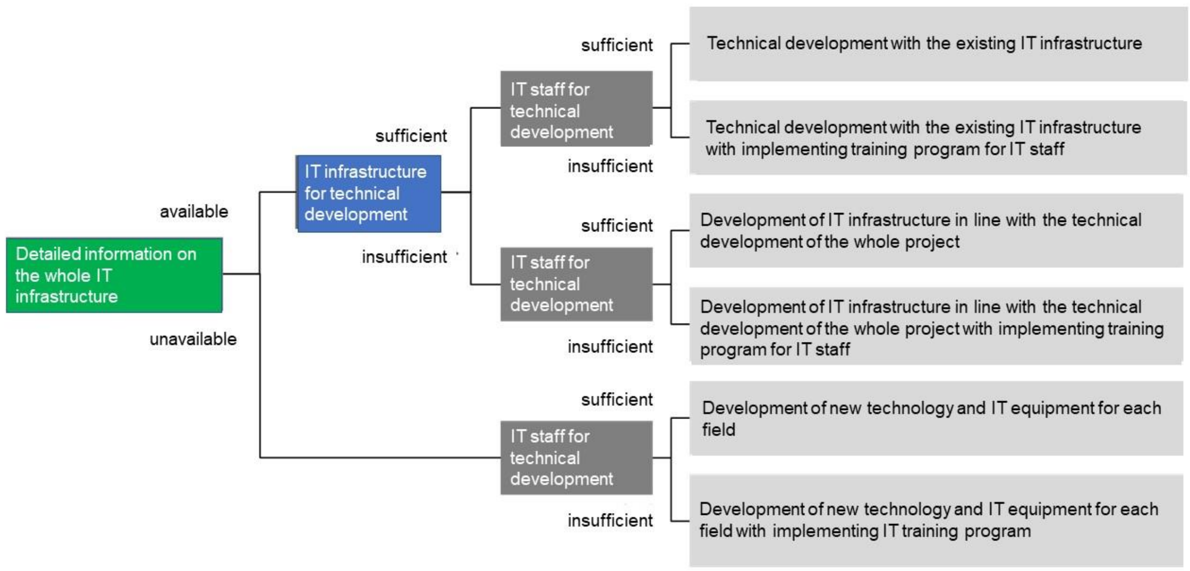

Figure III.9.3-1 Consideration of cooperation policy in the IT infrastructure

III.10 Provision and Disclosure of Meteorological Information to Government Agencies and the General Public

III.10.1 Necessity of Providing and Disclosing Meteorological Information to Government Agencies and the General Public

To reduce the damages caused by disasters, accurate and timely warnings must be issued and the information must be promptly disseminated to disaster management agencies and residents, and used for appropriate disaster management measures such as evacuation and crisis management. In reality, however, meteorological information, including forecasts and warnings , is not sufficiently utilized for evacuation and crisis management in many countries surveyed.

There are various issues in each country; but one of them is that the observation network is insufficiently developed, the accuracy of forecasts is low, and forecasts and warnings are not based on quantitative criteria. During disasters, the observation information cannot be transmitted due to the damages to the equipment. In the case of water level observation in rivers, manual equipment is used, or the observation is conducted visually, and it takes time to collect and utilize data for damage prediction. Even some countries do not have government agencies that specialize in sediment disasters.

Even when accurate and timely warnings are issued, the necessary information is not transmitted to disaster management agencies and residents due to problems in information transmission. Some countries have problems in communicating information from NMSs to disaster management agencies, from central government agencies to local government agencies, and to residents (especially in remote islands and mountainous areas). To cope with these problems, it is necessary to clarify the communication channels in advance and promote cooperation. Depending on the type of the disaster, it may be necessary to issue evacuation orders to residents as soon as possible. Still, inefficient communication channels mean that it takes time to decide on issuing evacuation orders, resulting in delays in information transmission. There are also issues related to equipment, tools, and human resources for information transmission. During a disaster, radio broadcasts may be interrupted, and faxes may be out of service due to power outages, sending and receiving may take a long time or may not be possible. Low processing capability of SMS server can cause delays in transmission. There are situations where information cannot be transmitted outside of working hours due to the lack of manpower for 24-hour/day watch system. The text of weather forecasts is too formal, and TV weather news is difficult to understand as only still images are shown and explanations of the forecast text are read aloud. Easy-to-understand communication of information is required.

Even if accurate and timely warnings are communicated in an easy-to-understand manner, residents do not know how to use the information due to a lack of knowledge and cannot make decisions on evacuation. Another problem is that evacuation sites have not been secured. The local governments' lack of disaster management plans and evacuation plans has prevented them from taking concrete actions.

The roles of NMSs differ from country to country. In some countries, the issuance of forecasts and warnings is the only main emergency response by them. In contrast, in other countries, they coordinate with relevant organizations and communicate information during disasters. It is necessary to resolve the above issues according to the roles of NMSs.

III.10.2 Ways to Cooperate

Establishment of an information distribution system for forecasts and warnings

After clarifying the information distribution channels in the event of a disaster, an information distribution system should be established using tools appropriate to the situation, including a combination of PUSH-type and PULL-type means of communication, multiple layers of transmission, and dedicated lines to major organizations to enable direct distribution of information.

The information distributed needs to be timely and useful for disaster management activities. The weather forecasts of broadcasters could be made to provide dynamic explanations. The text of the forecasts and warnings could be made easier to understand to be linked to decisions on the actions, including evacuation.

Strengthening the capacity of NMSs

In addition to improving communication means and distributed information, it is also necessary to strengthen the capabilities of the personnel who use them. In addition to enhancing their ability to issue warnings, the NMS staff should work with relevant organizations to encourage improvements and improve their systems to mitigate the damages caused by disasters.

For example, cooperation between NMS and DRR authorities (disaster prevention offices and local governments) can be promoted and capacity building can be expected by assigning the staff in charge of disaster management in NMS and dispatching retired NMS staff to DRR authorities. The capacity of NMS's local offices could also be strengthened by encouraging collaboration with local governments and examining the use of meteorological information by residents, which could lead to improvements in the NMS's operations. In countries with challenges in issuing flood forecasts and warnings, cooperation will be promoted with organizations in charge of flood warnings and river administrators to develop a system to share weather information and water level data and set the threshold of warnings from rainfall data.

In addition, through international conferences, regular meetings and training by JICA and WMO, it is also effective to promote technology transfer to carry out meteorological projects in line with WMO's various programmes and promote international cooperation for tsunami damage prevention.

Education for Residents on Disaster Prevention and Mitigation

Since large-scale disasters occur infrequently and extensive damage can be caused by a disaster that no one has ever experienced before, disaster drills and awareness-raising activities should be conducted continuously. It is necessary to inform the public about the characteristics of flash floods and storm surges, what kind of damages they can cause, and how to interpret the warning information to actions such as evacuation. In particular, if the accuracy of the forecasts and warnings is not high enough, disaster prevention activities will often end up in vain, and there is a concern that activities will not be carried out even if forecasts and warnings are issued. Interest should be raised and maintained by sharing examples of past disaster areas and other countries including Japan, using the media, and developing and distributing hazard maps and other information to residents.

III.11 Digitization, Archiving, and Utilization of Past Meteorological Observation Data

III.11.1 Needs for Digitization, Archiving, and Utilization of Past Meteorological Observation Data

Some NMSs have long observation data dating back to the beginning of the 20th century, but much of the data are stored in paper form. Even in countries that have been digitizing their data, the period of digitization is short or not connected to the present, and the automated statistical processing capability has not been fully utilized. In addition, the lack of human resources for information processing and the cost of maintaining expensive equipment are challenges in storing the digitized data.

Digitizing observation data such as temperature and precipitation recorded on paper and storing them as electronic data for machine processing (data rescue) will enable to promptly calculate and publish statistical values, including normal values, monitor climate change, including global warming, utilize the data for assessing the impact of climate change, and conduct advanced information processing and research. It will also enable advanced information processing and research, such as analysis of precipitation leading to disasters and evaluation of the frequency of extreme events (number of days of heavy rainfall, once-in century heavy rainfall, etc.), which are necessary for the development of IBF.

These data can be used in a wide range of areas such as disaster management, food production, social infrastructure and transportation management, water resources and sewerage management, public health, sustainable urban development, and sustainable maintenance of biodiversity and ecosystems.

Therefore, with the support of JICA, it is necessary to digitize the observation data recorded in the paper-based form at NMSs to consolidate the data and prevent the dissipation of paper records.

III.11.2 Ways to Cooperate

Determination of the elements to be digitized and the time frame

Since the digitization work is labor-intensive, JICA experts will consult with NMS to prioritize the target sites (considering the impact of urbanization and importance for disaster management), meteorological elements (temperature and precipitation are the top priority), and the period.

Implementation and quality control of digitization work

Digitizing the data from the handwritten observation logs will be carried out. To avoid the misreading of handwritten records, the same form is entered by multiple people. The input data will be graphed, and AQC will be applied to check the quality of erroneous data.

Local staff will be hired for key-in operations and JICA experts and NMS staff will be in charge of development and technology transfer of process control and quality check scheme.

Storage of digitized observation data

The digitized observation data will be stored using one of climate database management systems assured by WMO. The use of readily available equipment such as Windows PCs will be considered to reduce long-term running costs. JICA experts will procure the necessary equipment and guide the local staff in their work.

Utilization of digitized data

JICA experts will provide training to NMS and ministries related to climate change on how to utilize long-term observation data in climate change monitoring, disaster management, water resources, food production, etc. They will also transfer technology on basic statistics and data analysis methods for climate change monitoring and disaster management.

III.12 Human Resource Development in the Field of Meteorology

III.12.1 Needs for Human Resource Development in the Field of Meteorology

One of the many challenges NMSs face is the inability to maintain and manage observation facilities and communication and information processing systems due to the lack of technically qualified staff. In particular, for NMSs in the least developed countries (LDCs), the shortage of human resources is a serious problem that may make it difficult to continue their services.

In particular, for the operation and maintenance of information and communication infrastructures, such as domestic and international communication networks and various types of computers, it is necessary to secure staff with sufficient knowledge to communicate technical requirements to external hardware and software vendors, since it is too much of a burden for NMSs to regularly employ highly specialized staff.

On the other hand, NMSs in countries with high capacities among the surveyed countries wish to conduct medium- to long-term training to develop senior officials who will lead the operation of NMSs and joint research activities in cooperation with universities and research institutions to cope with high-level technical issues.

There is a need for overseas study schemes in which the target staff can obtain a degree as a result of the training and joint research activities, but the current systems for accepting such staff in Japan is insufficient in terms of both duration and scale of funding.

JICA has been conducting group training programs in meteorology to support various NMSs since 1973. Many participants have become senior officials of NMSs in their countries, and these training programs have a significant factor in enhancing Japan's presence in the field of meteorology. Human resource development is one of the main pillars of JICA's activities, and it is necessary to strengthen human resource development efforts in the field of meteorology.

III.12.2 Ways to Cooperate

Training for NMSs, in particular for those in LDCs, will focus on technology transfer necessary for implementing meteorological services, such as instrument maintenance and calibration techniques for continued observation and analysis and forecasting techniques (satellite image analysis, GPV utilization, guidance development). For this purpose, it is important to continue the JICA group training programs conducted by JMA.

Although ICT is essential for maintaining the services of NMSs, the maintenance of equipment and system development of should be left to local contractors. NMS staff should be trained to identify technical requirements and acquire the skill to document the specifications. It is also preferrable to add a curriculum on basics of ICT to JICA group training programs for meteorological services.

For NMSs with a high level of technology, joint research and technology development should be conducted on individual issues after hearing its technical issues. In cooperation with universities and research institutes, a system should be established to accept NMS staff to study in Japan for several years to obtain a degree as a training goal. In doing so, consideration should be given to providing generous support, including tuition fees and living expenses.

III.13 Recommendations on Cooperation Policies in the Field of Meteorology

This Survey has reviewed the various types of cooperation activities that JICA has implemented, including grant aid, loan assistance and technical cooperation projects, analyzed the current situation and challenges in each field through questionnaires and online interviews with each NMS, and discussed cooperation policies in each field.

Each NMS's trust and expectations for cooperation with Japan are based on their strong confidence in JMA as the global and regional centers and their expectations for Japan's hardware and software technologies and education.

Many countries and organizations (donors) including Japan have assisted targeted countries but there are common challenges: 1) the provided hardware has become a *black box*, and 2) the use of hardware is limited due to the lack of funding for maintenance and repair hence the hardware does not contribute to the effective implementation of meteorological services. One of the reasons for this situation is that investment in disaster risk management to strengthen disaster risk governance is limited to the introduction of hardware, with insufficient budgetary support, human resource development for continuous information dissemination, and enhancement of operational/utilization capacity, lack of support for raising the value of information and operational/educational costs to support budgeting. Therefore, it is important to consider the following viewpoints:

1. The introduction of new equipment should be done with technical cooperation to produce and provide high-quality meteorological information required by information users, which will be made possible by the use of such equipment (<u>from equipment that NMS wants to use</u> to <u>equipment that is necessary for providing meteorological information</u>).
2. Maintenance contracts should be included in the project budget when equipment such as radars, HimawariCast receiving systems and AWSs are provided for the period of five years or so until when the use of such equipment is expected to become operational (<u>support for operating costs</u> until the value of information increases).

On the other hand, according to the questionnaire survey conducted in this Survey, each NMS put the Impact-Based Forecasting (IBF) (see below) as a priority goal. As mentioned above, reviewing <u>the NMS's services from the perspective of IBF (delivery of information that users can use)</u> is an essential issue for future cooperation, and JICA's cooperation policy should also be reviewed from the perspective of IBF.

IBF is promoted by WMO to contribute to SDGs (Sustainable Development Goals) of the 2030 Agenda for Sustainable Development. It will contribute to promote the information delivery for disaster risk reduction including risk information for proactive disaster prevention, monitoring of hazards which cause disasters, and estimation of status of disasters. These are relevant to priority actions "1. Understanding Disaster Risk" and "2 Strengthening Disaster Risk Governance" within JICA's four priority actions for realizing the Sendai Framework for Disaster Risk Reduction 2015-2030.

The roles of NMSs are to conduct Impact-Based Forecasting (IBF), namely forecasting based on what the weather will cause, focusing on *high-impact weather* that significantly affects the safety and economy of a country, and explaining the content of the forecast to policymakers and the public.

For NMSs in developing and semi-development countries, the need to work towards the implementation of IBF is recognized because IBF has become an important matter of significance of NMS's existence, but it has not been implemented yet.

The reason why IBF has not been implemented is that there are not sufficient data on past disasters and quality-controlled meteorological observations during disasters to develop criteria and thresholds, leading to generally vague warning criteria and level thresholds, and the impact of events (flooding and landslides) occurring in response to forecasts cannot be accurately explained. The following measures are considered to be effective for the implementation of IBF.

1. To support the quality control and digital archiving (event data archiving) of past and future weather-related disaster data and meteorological observation data as the basis of IBF as a top priority.
2. To promote continuous support for deploying, operating, and managing more sophisticated surface and radar observation networks necessary for the IBF implementation.
3. To share JMA's experience, which is at the forefront of the world in conducting IBF, with other countries through training and country-specific support opportunities. In some cases, Japan, as a developed country, should host workshops where NMSs in developing countries can meet and exchange information on the theme of promoting understanding of IBF among stakeholders.

The countries covered in this Survey can be divided into two categories: developing and semi-developed countries. In developing countries, many staff are involved in manual observations, and many countries lack the investment for research and development and the human resources to support technological services. In these countries, conventional integrated projects are still necessary. To provide the advanced meteorological information required by IBF, it is necessary to (1) control the quality of observation data and develop basic information through digitization, and (2) introduce, operate, and maintain digital automatic observation equipment. Technical cooperation is required to tackle (1) and (2) in the same way as manual observations, which have been carried out stably in many countries, and to promote human resource development and improvement of operational techniques to encourage "digitalization" and "smooth shift of personnel from observation to forecasting."

Digitalization and human resource development are gradually progressing in semi-developed countries. Technological development for improved information such as radar-based heavy rainfall monitoring (QPE), short-range precipitation forecasting (QPF), and improvement of numerical weather prediction, is a major issue. There is a high demand for studying at and obtaining degrees from Japanese universities as degrees are conditions for promotion in many countries. These countries need the assistance to introduce equipment on specific areas rather than comprehensive cooperation and to establish a system that can continuously support technical cooperation in collaboration with JMA and universities/institutions.

Manual observation is the mainstream, even in many semi-developed countries, and the provision for observers who perform steady work with advanced technology is a challenge. In many countries, steady works such as quality control of observation data and evaluation of NWP models to evaluate advanced technologies, are not performed. It is necessary for the staff in charge of manual observations to combine the archives and evaluation of basic data to introduce the latest technology. It is also necessary to consider efforts to evaluate and support automated observations, which are necessary for advanced meteorological information with highly reliable manual observation data.

Table III.13-1 shows the cooperation policies for developing and semi-developed countries.

Table III.13-1 Cooperation policies for Category 1 (Basic) and Category 2 (Essential)

Current status	Challenges	JICA's cooperation policy for the future
Category 1 (Basic) (developing countries)		**Comprehensive cooperation**
- **Basic observation and forecasting operations are carried out, and warnings for heavy rainfall and typhoons are issued and delivered.** - **Modernization of operations and services is highly dependent on donors.**	- Modernization of observations (from manual to automatic observation instruments, quality control). - Provision of user-oriented and DRR-oriented weather information. - Improvement of technical skills and human resources development in each area. - Increase the visibility of meteorological services within the society and the government.	- Provision of purposely designed equipment (e.g., AWSs). - Implementation of conventional integrated technical cooperation (observation, forecasting, and information delivery). - User- and DRR-oriented forecasting and information delivery including impact-based forecasting (IBF). - Strengthen cooperation with relevant disaster management agencies. - Strengthen organizational structure including budgets, personnel and regulations
Category 2 (Essential) (semi-developed country)		**Dispatch of advisors Individual cooperation by theme**
- **Observation equipment and forecasting systems are deployed with NMS' budget and donors.** - **Modernization of observation and forecasting services are achieved in cooperation with foreign NMSs.** - **Human resources are developed through training within NMS and obtaining degrees in developed countries.**	- Increased demand from society due to increased heavy rainfall events. - There is a mixture of supports from various donors, including local models and forecast support systems from Europe and U.S., invitational training (China and Republic of Korea), technical cooperation through basic agreements (MOUs), etc. It is necessary to improve the technical level of staff and restructure operations. - Although human resources are in place, the number of universities and research institutes in the country is small. It is necessary to introduce advanced technology and develop human resources through cooperation with NMSs, universities, and research	- Introduction of technical cooperation that addresses individual theme and strengthens human resource development. - Cooperation to fully utilize the equipment provided by other donors (e.g., local NWP model). - Strengthen cooperation with universities and research institutes in Japan (dispatch of researchers, long-term training of NMS staff) (e.g., assimilation of observational data). - Dispatch of policy advisors to NMS to improve mid-and long-term operations of NMS

	institutes in developed countries.	

In developing advanced meteorological information, the UK Met. Office operates a regional NWP model in PAGASA and trains PAGASA staff. In some cases, training is provided as a package of the introduction of high-performance computers (HPCs), operation of a regional NWP model, and acceptance of international students. However, as the power supply is not stable in these countries, it is challenging to secure power supply for HPC operation and to cope with equipment failure due to frequent power outages.

In recent years, *cloud computing technology* has made significant progress. JMA has plans to conduct NWP computing on the cloud and NWP data with universities and other research institutes. In line of this trend, the following strategic cooperation policies need to be pursued in the future:

1) To conduct short-range precipitation forecasts by QPF and to run local NWP models (NHM model of JMA and WRF model run by many Japanese universities) on the cloud with the boundary conditions from JMA models to implement technical cooperation and capacity development without the limitation of the unstable power supply and maintenance of the hardware in developing countries;

2) To promote collaboration between NMSs and Japanese universities to conduct joint research activities on short-range heavy rainfalls caused by small-scale rain clouds, which frequently occur in tropical regions and are increasing in Japan in recent years in a cloud environment.