

カンボジア国
土地管理及びインフラ開発のための
電子基準点整備プロジェクト
プロジェクト業務完了報告書
－ 概要版 －

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独立行政法人国際協力機構

株式会社パスコ

1. プロジェクトの概要

1.1. 背景

カンボジアでは、1992 年に土地法が制定され、土地の私的所有制度が導入された。2001 年の同法改正では、土地の私有に対する権利保護が強化された。これにより、土地保有に対する保証制度が強化され、不動産市場が活性化した。しかし、地籍測量の進捗は全土の 6 割程度にとどまっていたことから、測量を迅速化させるための高精度測位環境が求められていた。地籍測量は、国土管理・都市計画・建設省（Ministry of Land Management, Urban Planning and Construction : MLMUPC）の地籍地理総局（General Department of Cadastre and Geography : GDCG）が 2003 年から実施しており、2023 年までにカンボジア全土の土地登記を完了させることを目標としていた。

かかる背景を踏まえて、カンボジア政府は、地籍測量の迅速化と高精度な位置情報サービスの提供能力を向上させるため、電子基準点（Continuously Operating Reference Station : CORS）とデータセンター（Data Center : DC）の整備、運営維持管理のための能力強化、CORS データの利活用促進を目的とした技術協力を日本に要請した。

1.2. 目標

本プロジェクトの目標は、2024 年末までに 5 点の CORS と DC を整備し、地籍測量や工事測量で活用することである。また、プロジェクト終了 3 年後には、CORS が適切に管理・拡張され、地籍測量やインフラ整備に活用されることが期待されている（上位目標）。具体的には、CORS の整備、運営維持管理能力の強化、CORS データの利用促進を行うことで、カンボジアの長期目標である「Cambodia Vision」の実現に寄与することを目指している。

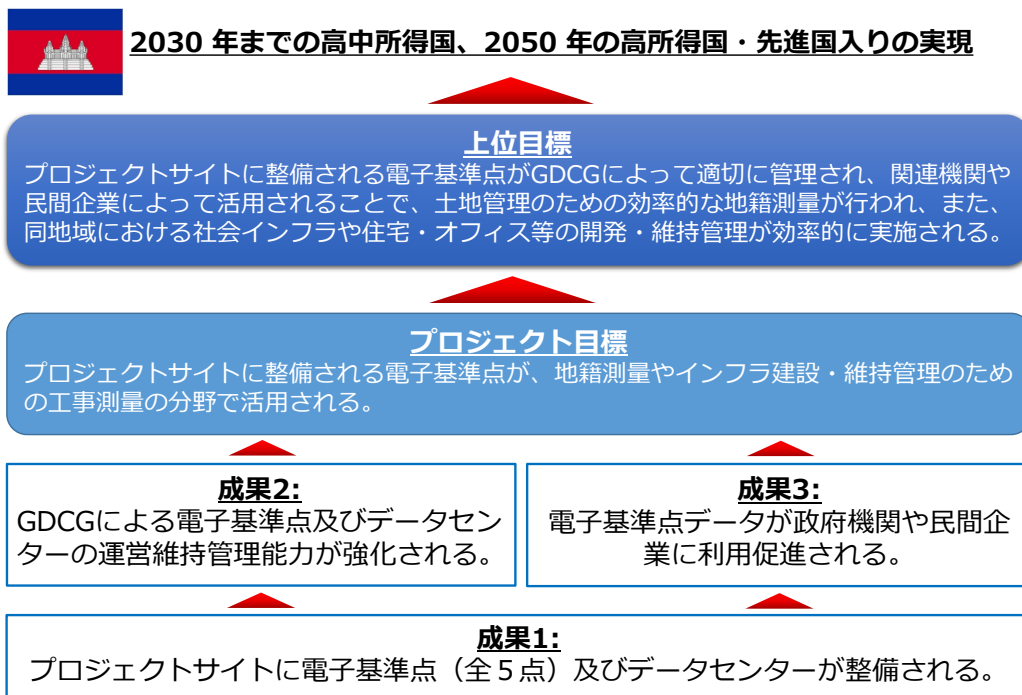


図 1 本プロジェクトの目標及び期待される成果（出典：JPT（Japan Project Team））

2. 活動内容

2.1. プロジェクトフローチャート

プロジェクトの実施フローは以下のとおりである。

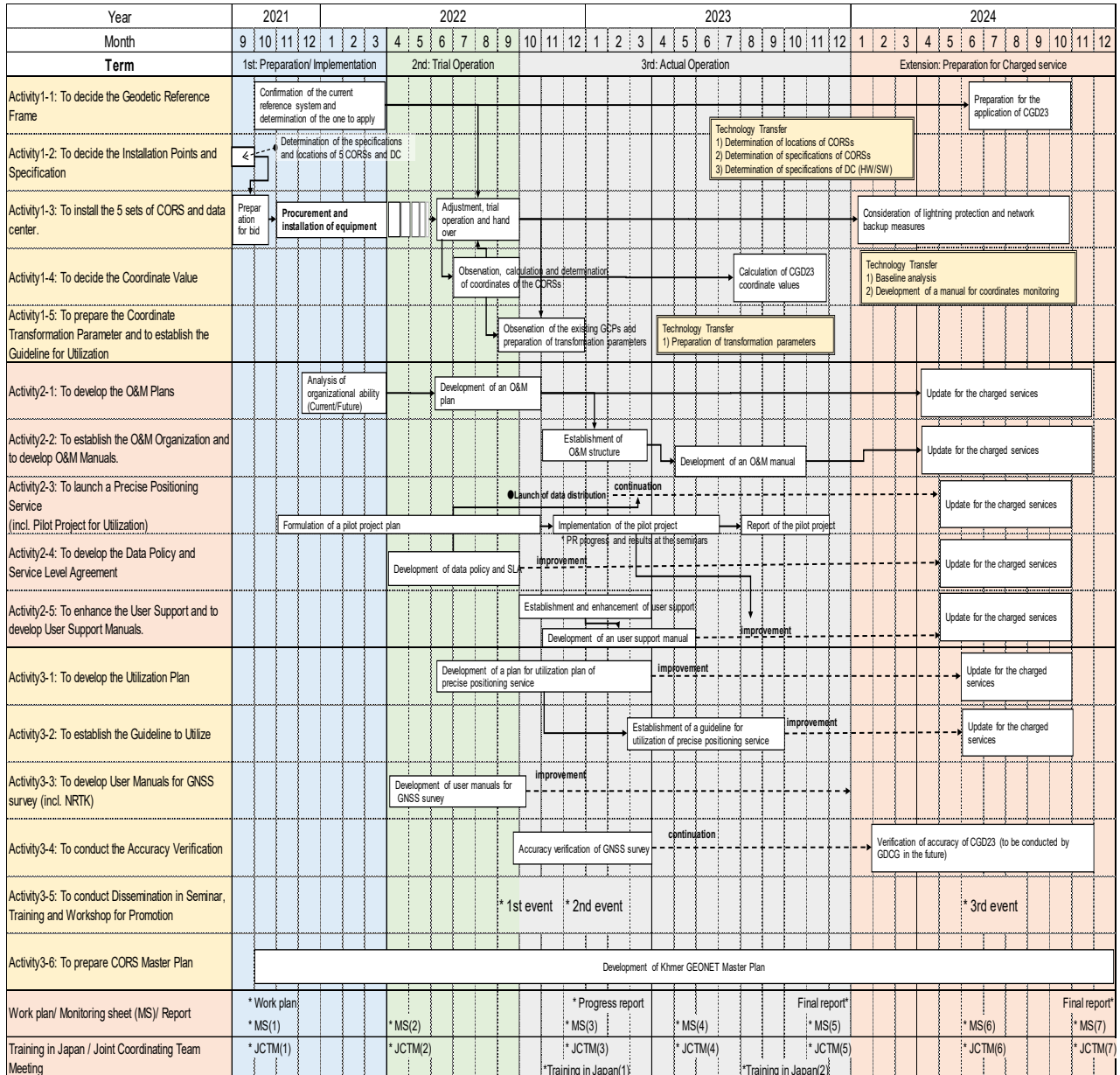


図 2 プロジェクト実施フロー（出典：JPT）

2.2. プロジェクト全体にかかる活動

- **本邦研修の実施:** CORS の運営維持管理や利活用促進に関する技術、知見を習得することを目的として、第1回本邦研修（2022年11月2日～15日）と第2回本邦研修（2023年8月21日～9月2日）を実施した。
- **Joint Coordinating Team Meeting (JCTM) の開催:** 約半年ごとに全7回のJCTMを開催し、各

活動の進捗確認と活動内容の報告、課題の整理と協議、今後の予定の確認、プロジェクトの評価などを行った。



図 3 本邦研修（撮影：JPT）

2.3. 成果 1: CORS 及び DC の整備にかかる活動

- **測地基準系の決定:** CORS に適用する測地基準系を、ITRF2020 を採用した CGD23 とした。ただし、CGD23 を適用するまでは、暫定的に従来の CGD09 の座標値で運用することとした。
- **設置場所と仕様の決定:** 5 点の CORS と DC の設置場所を決定し、仕様を確定した。また、設置場所の選定時に現地踏査を OJT で実施した。
- **設置工事:** Aruna 社への現地再委託によって CORS と DC の設置工事を実施し、検収を完了した。Aruna 社はその後の運営維持管理にも協力した。設置された CORS システムは、「Khmer GEONET」と命名された。
- **座標値の決定:** Bernese ソフトウェアを用いて CORS の座標値を計算した。これにより、高精度な測位を行うための環境が整備された。また、座標計算にかかる技術移転を実施した。
- **座標変換パラメータの策定:** CGD09 と CGD23 の座標変換パラメータを計算した。また、変換パラメータの計算にかかる技術移転を実施した。これにより、既存の測地基準系と CGD23 との互換性を確保した。



図 4 完成した CORS と DC（撮影：JPT）

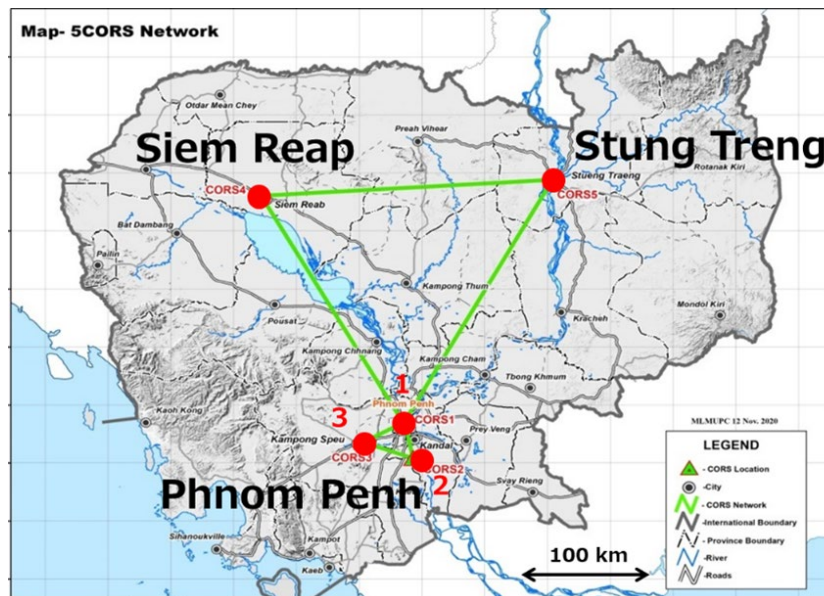


図 5 5 点の CORS の配置（出典：JPT）

2.4. 成果 2: 運営維持管理能力の強化にかかる活動

- **運営維持管理計画の策定:** Khmer GEONET の運営維持管理計画を策定した。計画には、運営維持管理の基本方針、組織体制、マニュアル、資機材保守、人材育成、予算、広報などが記述された。
- **運営維持管理体制の構築:** Khmer GEONET の運営維持管理マニュアルを整備した。マニュアルには、管理体制、通常時・緊急時のレポートラインの枠組み、日報・週報等報告手順及び報告ツールの概要、データバックアップ体制、有償配信サービスの料金体系案等が記述された。
- **データ配信の開始:** 2022 年 10 月に NRTK（Network-Real Time Kinematic）の補正データの配信とユーザー登録を開始した。また、配信データの品質管理にかかる技術移転を実施した。
- **実証事業の実施:** 測量、建設、農業、地籍調査分野で 5 件の実証プロジェクトを実施した。各プロジェクトの成果は、プロジェクトセミナーで発表された。実証事業の実施により、CORS データの有用性が確認された。

- **データポリシーと SLA の策定:** データ配信方法や利用制限などについて示したデータポリシーと、ユーザーにサービスの仕様を示すための SLA（Service Level Agreement）を策定した。
- **ユーザーサポートマニュアルの整備:** ユーザーサポートマニュアルを整備し、サポート体制を強化した。

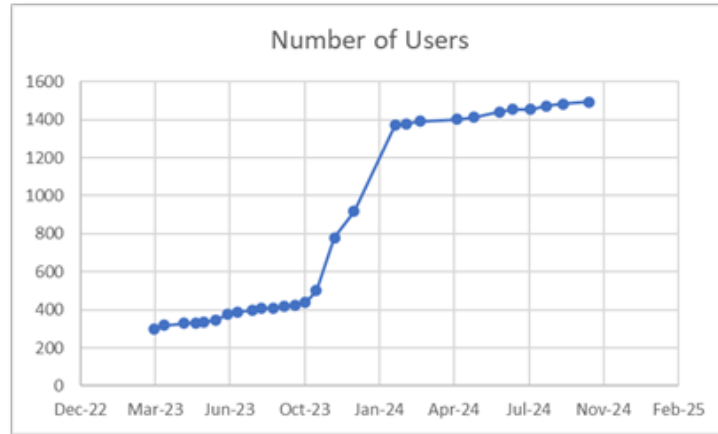


図 6 Khmer GEONET のユーザー登録数の推移（出典：JPT）



図 7 実証プロジェクトの活動（撮影：JPT、CPT（Cambodia Project Team））

2.5. 成果 3: 利活用促進にかかる活動

- **利活用計画の策定:** Khmer GEONET の利活用促進計画を策定した。GDCG が本計画に記載された活動を具体化し実行することで、今後の CORS データの活用が促進される。
- **利活用ガイドラインの整備:** 利活用ガイドラインを作成した。ガイドラインは、ユーザーが CORS データを効果的に利用するための手引書になる。
- **GNSS 測量マニュアルの整備:** Khmer GEONET を用いたスタティック法及び NRTK 法の作業手順、基線解析や網平均計算の精度評価のための指標を記載した、GNSS 測量マニュアルを作成した。
- **精度検証:** スタティック法及び NRTK 法で Khmer GEONET から配信されるデータの精度検証を OJT で実施した。前述したとおり現時点の CORS は CGD09 に基づくものであるため、CGD23 が適用された後に改めて GDCG が精度検証を実施することとした。
- **セミナー等の開催:** セミナーの開催や展示会への出展を行うことで、Khmer GEONET の広報

と利活用促進を図った。セミナーでは GNSS 体験会や実証プロジェクトの成果発表を行うことで、Khmer GEONET が広く周知された。

- マスタープランの策定: カンボジアにおける将来の CORS の姿を見据えた Khmer GEONET マスタープランを策定した。



図 8 (左) Khmer GEONET の Web サイト（出典：<https://khmergeonet.xyz/>）、(右) 利活用事例のリーフレット（出典：CPT）



図 9 セミナーの様子（撮影：JPT）

3. プロジェクトの評価

3.1. 目標の達成度

プロジェクト目標は、地籍測量やインフラ整備で CORS が活用されることで達成された。Khmer GEONET のユーザー数の増加や、Khmer GEONET を利用した地籍調査の加速化が確認された。

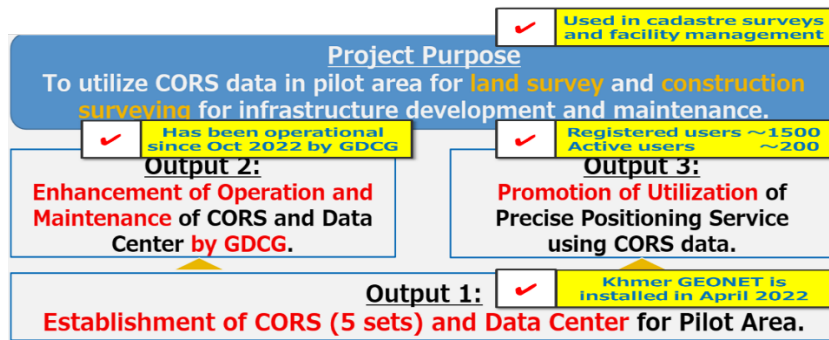


図 10 各成果とプロジェクト目標の達成（出典：JPT）

3.2. DAC 評価 6 基準に基づく自己評価

本プロジェクトの成果を、経済協力開発機構／開発援助委員会（OECD-DAC）の「DAC 評価 6 基準」に基づき、以下のように自己評価した。

- **妥当性 (Relevance) :** 5 点の CORS は、GDCG の地籍調査の迅速化に貢献した。また、実証プロジェクトにより、農業や建設分野での CORS の有用性が確認された。
- **整合性 (Coherence) :** プロジェクト成果はカンボジアの開発協力政策の目標に合致している。また、本プロジェクトで得られた知見は日本の無償資金協力によって 2026 年までに実現予定の CORS 全土整備に役立てられている。加えて、Khmer GEONET によって日本の無償資金協力で供与された GNSS ローパーが有効活用されている。
- **有効性 (Effectiveness) :** 5 点の CORS と DC は計画どおり設置され、ユーザー数は 1,500 名（2024/11 時点）となった。実証プロジェクトの結果、Khmer GEONET が様々な分野における作業の効率化に役立つことが確認された。
- **インパクト (Impact) :** CORS の整備により、地籍調査が迅速化され、土地登記のための測量数が増加した。これにより、公正な社会の発展と国民の財産保全に寄与した。
- **効率性 (Efficiency) :** オンライン会議を活用することで、COVID-19 の影響を最小化し、プロジェクトの活動を効率的に実施できた。
- **持続性 (Sustainability) :** GDCG のスタッフは運営維持管理能力を獲得することができた。本プロジェクト終了後も、Khmer GEONET の運営維持管理にかかる予算と組織改編が承認されることで、プロジェクト成果の持続性が確保される見込みである。

これらの評価に基づき、プロジェクトは全体として成功し、今後の持続的な発展が期待できる。

4. 上位目標達成に向けて

4.1. 取り組むべき課題

1). CGD23 の適用と有償配信の開始

Khmer GEONET は 2022 年 10 月から試験運用を開始し、プロジェクト終了まで無償でサービスを提供した。新しい測地基準系 CGD23 の定義は決定され、プロジェクト期間中に CGD23 の座標計算や座標変換パラメータの技術移転は完了したが、CGD23 の正式な測地基準としての公表準備が整わなかったため、未だ CGD09 が使用されている。GDCG は CGD23 を 2024 年末までに公表し、2025 年 6 月までに適用すると同時に有償配信を開始することを計画している。このためには省令

公布、基準点の成果改定、セミナーやトレーニングの実施など多くの業務が必要となる。

2). 運営維持管理にかかる予算と組織の確保

CORS は国家の測地インフラとして、農業、建設、自動運転などに活用されることで、経済発展や生活向上のために重要な役割を果たす。CORS の運営維持管理に不可欠な予算と体制を確保するために、GDCG は上位省庁にその必要性を適切に説明する必要がある。2025 年度の予算は概ね確保されたが、2026 年度以降の予算確保と体制の確立が求められる。GDCG は、Khmer GEONET の運用セクションの設置により運営維持管理業務の一元化を図る必要がある。

3). 運営維持管理計画、利活用計画、マスタープランの更新と活用

本プロジェクトでは、GDCG が Khmer GEONET に関して実施すべき活動を定めた運営維持管理計画、利活用計画、Khmer GEONET マスタープランを整備した。運営維持管理計画は 5 点の CORS に焦点を当てたものであるため、今後の全土整備に合わせた計画の拡張・改訂が必要となる。利活用計画は、有償配信と全土整備に向けた周知・PR やと利用拡大のための活動と、今後 2 年間の活動スケジュールを含んでいる。この計画の具体化と活動の実施が求められる。Khmer GEONET マスタープランは 2034 年までのカンボジアにおける CORS 整備の方向性を示し、利活用分野、仕様、整備計画、予算確保などについて記述されている。プロジェクト終了後も GDCG が関係省庁と協力して精査・協議し、適宜更新していくことが期待される。

4.2. 上位目標達成に向けた提言

1). 土地管理と土地行政のための効率的な地籍調査の実施に向けて

GDCG は 2002 年からカンボジア全土の地籍調査事業を推進しており、2023 年からの新政権による「デジタル経済・社会の発展」政策により、地籍調査の迅速化とデータ一元管理が実施された。Khmer GEONET の整備と運用もこれらに大きく貢献し、2025 年末までに筆界測量が完了する見込みとなっている。しかし、その後も土地の分合筆や取引が行われるごとに現地での測量作業が必要であり、CORS の活用がその効率化に継続的に寄与する。現在の測量成果には複数の測地基準系によるものが混在しているため、GDCG ができる限り早期に CGD23 を適用するとともに、既存の測地基準に準拠した測量成果を CGD23 に座標変換することで、測地基準系の統一を図ることを提言する。

2). 居住地、商業地での社会インフラの効率的な開発と維持管理の実現に向けて

本プロジェクト期間中、Khmer GEONET のユーザー数は約 1,500 に達し、主に地籍調査の測量作業に利用されている。土地の権利を明確化し、取引を円滑化するために地籍調査は重要であり、この意味で Khmer GEONET はインフラ開発の基盤として機能しているといえる。今後、配信サービスは有償になり、民間企業は利用料を支払ってサービスを利用することになる。ユーザーがコストメリットを感じるためには、安定した高精度の測位データ配信と適切なユーザーサポートが必要となる。これを実現するために、GDCG が運営維持管理マニュアルや GNSS 測量マニュアルに基づくメンテナンスと精度検証、ユーザー対応を確実に実施することを提言する。

3). GDCG による Khmer GEONET の適切な管理に向けて

Khmer GEONET の持続的な運用には、GDCG がシステム全体を適切に管理する必要がある。CORS の全土整備後は CORS の設置数の増加とユーザーの拡大に伴うトラブルの増加が予想されるため、GDCG は必要な予算と人員を確保し十分に備えておかなければならない。また、有償ユーザーを拡大して利用料を得るだけでなく、社会インフラとしての重要性を PR することで、政府内での Khmer GEONET の運営維持管理予算の優先度を上げる努力が必要となる。さらに、業務プロセスの改善による効率化を図ったうえで、増員要求や民間委託を進めることが求められる。その際、増員や民間委託の目的を明確にし、データに基づく根拠を上位省庁に提示することを提言する。

4). カンボジア全土への Khmer GEONET の拡張後に向けて

本プロジェクトでは CORS の全土整備後の運用や利活用促進に向けた活動を実施したが、実際に GDCG が経験したのは 5 点の CORS 設置と運営維持管理である。90 点を超える全土整備後の業務量増加に対応するため、民間企業への業務委託等によって不測の事態に備える体制を早期に構築すること及びそのための予算確保を提言する。また、将来において MADOCA-PPP（通信回線を必要としないで一定の精度でリアルタイム測位を実施できる技術）の併用を検討することも有効であろう。

以上

Site Photos and Description for CORS

CORS Site Name (Long Name):			
CORS Site Name (Short Name):			
CORS Site ID#:			
Location Map		Google Map (Image)	
Sky Visibility or Fisheye Photo		Field Sketch	
North	East	South	West
South	West	North	East
Entrance to The Site		Remarks	

Site Selection Note for CORS (draft)

CORS Information	
CORS Site Name (Long Name)	
CORS Site Name (Short Name)	
CORS Site ID number	
Date of the site selection	
Name who selected the site	
Address	
Circumstance around the CORS	
Ground condition (strength, geology)	
Average temperature and humidity	
Flood frequency and flood depth	
Frequency of Lighting	
Nearby facility that transmits radio waves	
Availability of System Power Supply	
(if Yes) From where, and How far from	
Communication lines (Wired and/or Mobile)	
(Wired) From where, How far from, internet speed	
(Mobile) Which provider, signal condition	
Sky visibility (See Site Description)	
Security	
Others	
Route to the CORS	
Location where vehicles can reach	
Route from vehicles to the CORS	
Others, Remarks	
Land owner and manager information	
Institution name	
Name of the person in charge	
Address	
Phone No.	
Fax No.	
e-mail	
Other related Institutions information (Entry permission, Construction permission, Electric power company, etc.)	
Institution name 1	
Name of the person in charge	
Address	
Phone No.	
Fax No.	
e-mail	
Remarks	
Institution name 2	
Name of the person in charge	
Address	
Phone No.	
Fax No.	
e-mail	
Remarks	
Remarks	

Ver, 24th October 2024

Project on Establishment of Continuously Operating Reference Stations (CORS) for Land Management and Infrastructure Development

Post Processing Manual For Khmer GEONET

Bernese 5.4

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NOTE: The remaining issues are shown below. GDCG should discuss this issue and update this manual.

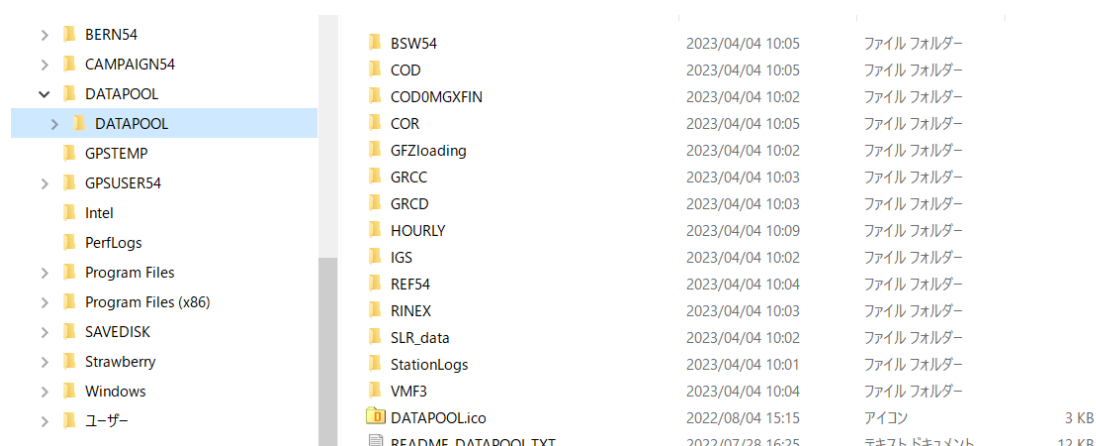
- You will need to edit the instructions for Bernese software updated to Bernese 5.4 or later.
- After CORS is installed throughout Cambodia, it is necessary to record the process of determining its coordinates and the survey network that was calculated.
- Once CORS has been installed throughout Cambodia, it is necessary to decide on the interval at which the coordinate values will be monitored and the observation date for the data used for monitoring. Then use Bernese software to monitor the coordinates at the determined time.

2. Folder structure

2.1. DATAPOOL Folder

The DATAPOOL folder is for placing external local copies.

See [README_DATAPOOL.TXT] for more information.



> BERN54	BSW54	2023/04/04 10:05	ファイル フォルダー	
> CAMPAIGN54	COD	2023/04/04 10:05	ファイル フォルダー	
▼ DATAPOOL	COD0MGXFIN	2023/04/04 10:02	ファイル フォルダー	
> DATAPOOL	COR	2023/04/04 10:05	ファイル フォルダー	
> GPSTEMP	GFZloading	2023/04/04 10:02	ファイル フォルダー	
> GPSUSER54	GRCC	2023/04/04 10:03	ファイル フォルダー	
> Intel	GRCD	2023/04/04 10:03	ファイル フォルダー	
> PerfLogs	HOURLY	2023/04/04 10:09	ファイル フォルダー	
> Program Files	IGS	2023/04/04 10:02	ファイル フォルダー	
> Program Files (x86)	REF54	2023/04/04 10:04	ファイル フォルダー	
> SAVEDISK	RINEX	2023/04/04 10:03	ファイル フォルダー	
> Strawberry	SLR_data	2023/04/04 10:02	ファイル フォルダー	
> Windows	StationLogs	2023/04/04 10:01	ファイル フォルダー	
> ユーザー	VMF3	2023/04/04 10:04	ファイル フォルダー	
	DATAPOOLico	2022/08/04 15:15	アイコン	3 KB
	README_DATAPOOL.TXT	2022/07/28 16:25	テキスト ドキュメント	12 KB

(1) BSW54

This folder is intended to store the ionosphere maps (ION file) and the differential code bias files (DCB file). These files are in Bernese specific formats. These files can be downloaded from the following sites.

Download site: <http://ftp.aiub.unibe.ch/CODE/>

Download site: [Index of /CODE/2023/ \(unibe.ch\)](http://ftp.aiub.unibe.ch/CODE/2023/)

(2) COD

This folder is intended to store the Orbits files, the earth orientation parameters files (EOP file) and the satellite clock corrections files.

This folder is intended to store the files with the analysis center name COD.

These files can be downloaded from the following sites.

Download site of CODE: <http://ftp.aiub.unibe.ch/CODE/>

Download site of

Crustal dynamics data information system: <http://ftp.aiub.unibe.ch/BSWUSER52/>

These file names are [SSSWWWWD.XXX].

SSS: Analysis center name (e.g. COD, IGS)

WWWW: GPS week

D: Day of week (e.g. [0] is Sunday, [6] is Saturday)

XXX: Extension

EOP or ERP: Earth orientation parameters (Convert IERS format (EOP) to Bernese format (ERP))

SUM: Analysis report of GPS week

CLK: Clock correction information of satellite

PRE or SP3: Precise orbit files

[IGS] provides GPS and GLONASS of the precise orbit files in separate files.

The analysis center name of the precise orbit files of GLONASS is IGV.

GPS and GLONASS of the precise orbit files can be merged.

(3) COD0MGXFIN

CODE experimental Multi-GNSS Extension (MGEX) solution, containing GPS, GLONASS, Galileo, Bei Dou, and QZSS.

(4) COR

CODE operational rapid solution, containing GPS, GLONASS and Galileo

(5) GFZ loading

Grid files with crustal deformation corrections from the non-tidal loading models as provided by GFZ Potsdam for atmosphere, ocean and hydrology non-tidal loading effects.

(6) GRCC

These directories are intended to host files which are necessary for Low Earth Orbiter (LEO) data processing. For each LEO satellite a separate folder is foreseen.

(7) GRCD

These directories are intended to host files which are necessary for Low Earth Orbiter (LEO) data processing. For each LEO satellite a separate folder is foreseen.

(8) HOURLY

The same as the RINEX directory but dedicated to hourly RINEX data as used for RTK applications.

(9) IGS

Like the COD folder, this folder is intended to store the Orbits files, the earth orientation parameters files (EOP file) and the satellite clock corrections files in this folder.

This folder is intended to store the files with the analysis center name IGS.

(10) REF54

This folder is intended to store Bernese format files which are useful for several campaigns (e.g. Station coordinate information file (IGS20.CRD) and Velocity information file (IGS20.VEL)).

(11) RINEX

This folder is intended to store GNSS observation data files in RINEX format.

These file names are [TTTTDDDS.YYX].

TTTT: Station name (e.g. PHN1, SIE1)

DDD: Day of year (e.g. [176] is 25th June)

S: Session name (e.g. [0], [2])

YYX: Extension of year and file category

YY: Year (e.g. [22] is 2022)

X: File category

[o]: Observation data such as carrier phase

[n]: Broadcast orbits data of GPS satellites

[g]: Broadcast orbits data of GLONASS satellites

RINEX version 3.02 introduced a new file naming convention.

These file names are [cccc00CCC_R_yyyydddhmm_lll_sss_MO.rnx].

cccc00CCC: 9 characters defining the receiver (proposed usage: four-character site/station code, one-digit number to indicate the monument/receiver at the site, and ISO country code).

R: data source: one of the three items (S from streams, R directly from the receiver, U unknown)

yyyydddhmm: start epoch (specified for the minute)

lll: the intended (nominal) file period (e.g., 01D, 01H, 15M)

sss: the sampling rate of the observations (e.g., 30S, 01S)

MO: data type (indicating the GNSS or M for multi-GNSS) and content (O for observation, N for navigation)

rnx: extension to be used for all RINEX files

(12) SLR_data

This folder is intended to store Satellite Laser Ranging files

(13) Station logs

This folder is intended to store the information files of IGS station.

These files can be downloaded from the following sites.

Download site of the station information: <https://files.igs.org/pub/station/log/>

The coordinates of the observation point, receiver and antenna information can be downloaded from the following site. For example, [IGb14.SNX] is a file that contains information about [IGb14] reference frame.

Download site: <https://files.igs.org/pub/station/coord/>

(14) VMF3

This folder is intended to store the grid files needed for processing using Vienna Mapping Function (VMF3). The grid files can be downloaded from the following sites.

Download site: <http://ggosatm.hg.tuwien.sc.at/DELAY/Grid/VMFG/>

They are not used for the examples but it shall indicate that for other types of files other directories may be created.

2.2. CAMPAIGN Folder

When you create a campaign in Bernese, the campaign folder and subfolders are created. The folder structure when the [INTRO] campaign is created is shown below. These subfolders are for copying the files needed for analysis from the DATAPOOL folder and so on.

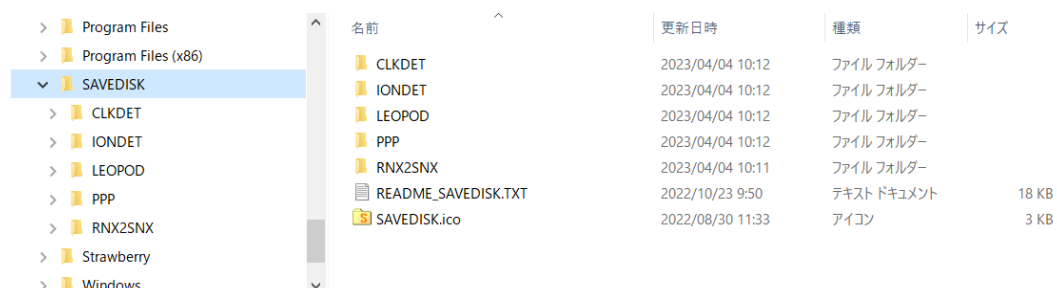


The screenshot shows a Windows Explorer window with the 'INTRO' folder selected in the left pane. The right pane displays a list of subfolders with columns for '名前' (Name), '更新日時' (Last Modified), '種類' (Type), and 'サイズ' (Size).

名前	更新日時	種類	サイズ
ATM	2023/05/15 17:46	ファイル フォルダー	
BPE	2023/05/15 15:02	ファイル フォルダー	
GEN	2023/05/15 17:46	ファイル フォルダー	
GRD	2023/05/15 17:46	ファイル フォルダー	
OBS	2023/05/15 17:46	ファイル フォルダー	
ORB	2023/05/15 17:46	ファイル フォルダー	
ORX	2023/05/15 15:02	ファイル フォルダー	
OUT	2023/05/16 8:57	ファイル フォルダー	
RAW	2023/05/15 17:46	ファイル フォルダー	
SOL	2023/05/15 17:46	ファイル フォルダー	
STA	2023/05/15 17:46	ファイル フォルダー	

2.3. SAVEDISK Folder

The SVEDISK folder is for storing important analysis results. See [README_SAVEDISK.TXT] for more information.



The screenshot shows a Windows Explorer window with the 'SAVEDISK' folder selected in the left pane. The right pane displays a list of files and folders with columns for '名前' (Name), '更新日時' (Last Modified), '種類' (Type), and 'サイズ' (Size).

名前	更新日時	種類	サイズ
CLKDET	2023/04/04 10:12	ファイル フォルダー	
IONDET	2023/04/04 10:12	ファイル フォルダー	
LEOPOD	2023/04/04 10:12	ファイル フォルダー	
PPP	2023/04/04 10:12	ファイル フォルダー	
RNX2SNX	2023/04/04 10:11	ファイル フォルダー	
README_SAVEDISK.TXT	2022/10/23 9:50	テキスト ドキュメント	18 KB
SAVEDISK.ico	2022/08/30 11:33	アイコン	3 KB

Create a subfolder in the SAVEDISK folder with the same name as the campaign folder. Copy important files from [ATM, ORB, OUT, SOL, STA] subfolder in the campaign folder to the [ATM, ORB, OUT, SOL, STA] subfolder in the SVEDISK folder.

3. General files

3.1. A list of general files to be used

A list of General files is shown below.

Filename	Content	Modification	Update from
CONST.BSW	All constants used in the <i>Bernese GNSS Software</i>	No	BSW aftp
IAU2000R06.NUT	Nutation model coefficients	No	—
IERS2010XY.SUB	Subdaily pole model coefficients	No	—
OT_FES2004.TID	Ocean tides coefficients	No	—
TIDE2000.TPO	Solid Earth tides coefficients	No	—
EGM2008_SMALL.GRV	Earth potential coefficients (reduced version, sufficient for GNSS and LEO orbit determination)	No	—
s1_s2_def_ce.dat	S1/S2 atmospheric tidal loading coefficients	No	—

Configuration files located in $\${C}/GLOBAL/CONFIG$

Filename	Content	Modification	Update from
DATUM.BSW	Definition of geodetic datum	Introducing new reference ellipsoid	BSW aftp
GPSUTC.BSW	Leap seconds	When a new leap second is announced by the IERS	BSW aftp
POLOFF.POL	Pole offset coefficients	Introducing new values from IERS annual report (until 1997)	—
SATELLIT_I14.SAT or SATELLIT_I20.SAT	Satellite information file	New launched satellites	BSW aftp
BOXWING.MAC	Definition of orbit model parameters	New launched satellites	BSW aftp
SAT_\${Y}+0.CRX	Satellite problems	Satellite maneuvers, bad data, ...	BSW aftp

The latest general files can be downloaded from the following sites.

Download site: [Index of /BSWUSER54/ \(unibe.ch\)](http://unibe.ch/BSWUSER54/)

Index of /BSWUSER54/

../			
CONFIG/	19-May-2023 01:09	-	
GFZloading/	24-Feb-2021 11:14	-	
MODEL/	11-May-2023 16:13	-	
REF/	19-May-2023 04:56	-	

Copy the downloaded General files to the [C:/BERN54/GLOVAL/GONFIG] or [C:/BERN54/GLOVAL/MODEL] folder.

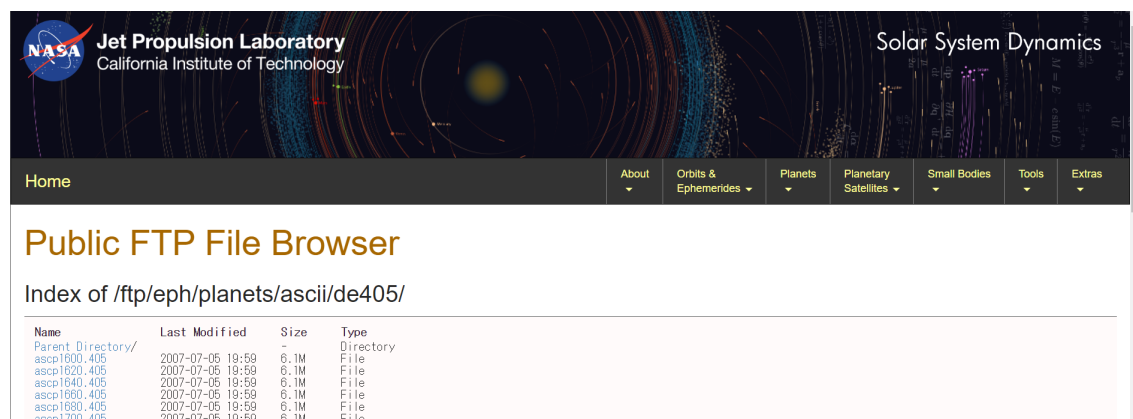
BERN54	名前	更新日時	種類	サイズ
GLOBAL	CONFIG	2023/08/01 15:13	ファイル フォルダー	
CONFIG	MODEL	2023/06/08 16:59	ファイル フォルダー	
MODEL				
MENU				

3.2. Installation of the JPL planetary and lunar ephemerides

Download the JPL planetary and lunar ephemerides from the download site.

See [JPL_EPH.TXT] for more information.

Download site: <https://ssd.jpl.nasa.gov/ftp/eph/planets/ascii/de421/>



Get the following files (in ASCII mode).

- ✓ header.421
- ✓ testpo.421
- ✓ ascp1900.421: covers the time interval between 1900 and 2050
- ✓ ascp2050.421: covers the time interval between 2050 and 2200

Concatenate the JPL planetary and lunar ephemerides files (ASCII files).

Merge [header.421] and [ascp1900.421, ascp2200.421] using a text editor or Windows Command Prompt.

Open a Windows Command Prompt.

[Copy header.421+ ascp1900.421+ ascp2050.421 temp.421]

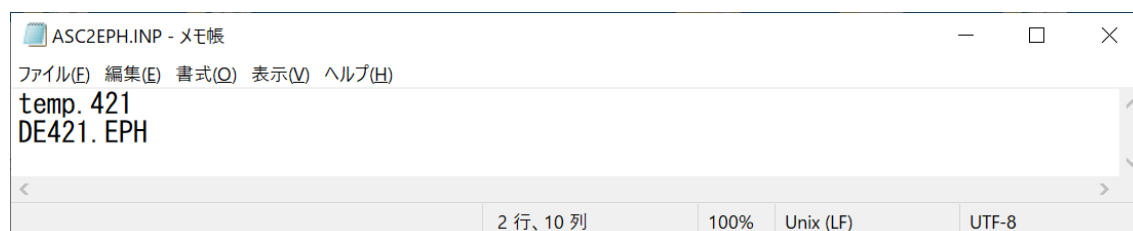
The merged file name is a temporary file name (e.g. temp.421).

Convert the file to binary.

Create an input file [ASC2EPH.INP] using a text editor.

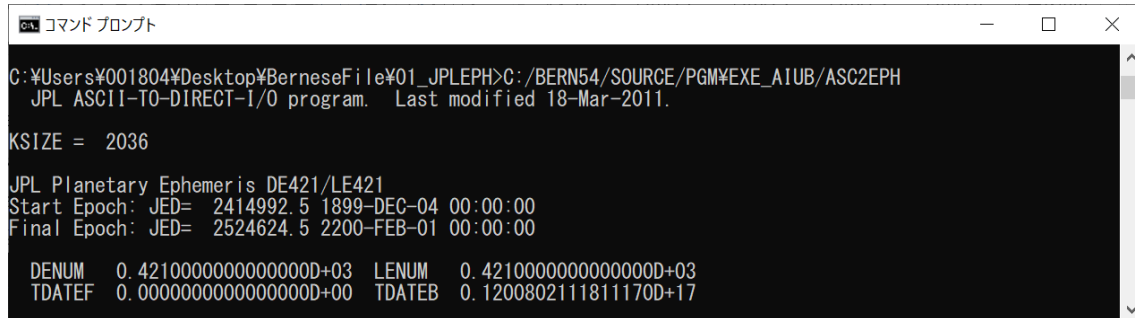
1st line: Filename of the concatenated ASCII file (temp.421),

2nd line: Filename of the resulting binary file [DE421.EPH (JPLEPH)].



Open a Windows Command Prompt. Set the folder where the input file [ASC2EPH.INP] is saved as the current directory.

Execute [C:/BERN54/SOURCE/PGM/EXE_AIUB/ASC2EPH.exe]



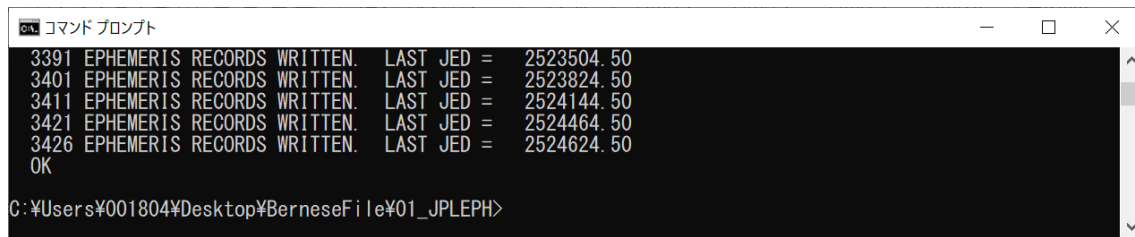
```
コマンド プロンプト
C:\Users\Y001804\Desktop\BerneseFile\Y01_JPLEPH>C:/BERN54/SOURCE/PGM/EXE_AIUB/ASC2EPH
JPL ASCII-T0-DIRECT-I/O program. Last modified 18-Mar-2011.

KSIZE = 2036

JPL Planetary Ephemeris DE421/LE421
Start Epoch: JED= 2414992.5 1899-DEC-04 00:00:00
Final Epoch: JED= 2524624.5 2200-FEB-01 00:00:00

DENUM 0.4210000000000000D+03 LENUM 0.4210000000000000D+03
TDATEF 0.0000000000000000D+00 TDATEB 0.1200802111811170D+17
```

Make sure there are no errors.



```
コマンド プロンプト
3391 EPHEMERIS RECORDS WRITTEN. LAST JED = 2523504.50
3401 EPHEMERIS RECORDS WRITTEN. LAST JED = 2523824.50
3411 EPHEMERIS RECORDS WRITTEN. LAST JED = 2524144.50
3421 EPHEMERIS RECORDS WRITTEN. LAST JED = 2524464.50
3426 EPHEMERIS RECORDS WRITTEN. LAST JED = 2524624.50
OK
C:\Users\Y001804\Desktop\BerneseFile\Y01_JPLEPH>
```

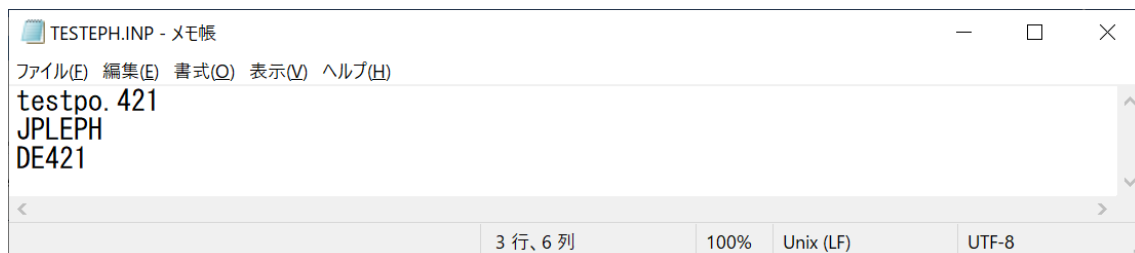
Check the integrity of the file and test the values.

Create an input file [TESTEPH.INP] using a text editor.

1st line: Name of the test-data file from JPL (testpo.421)

2nd line: Name of the binary file to be tested [JPLEPH]

3rd line: DE number of the ephemeris (421)



```
TESTEPH.INP - メモ帳
ファイル(E) 編集(E) 書式(O) 表示(V) ヘルプ(H)
testpo.421
JPLEPH
DE421
3行、6列 100% Unix (LF) UTF-8
```

Set the folder where the input file [TESTEPH.INP] is saved as the current directory.

Execute [C:/BERN54/SOURCE/PGM/EXE_AIUB/TESTEPH.exe]

```

C:\Users\Y001804\Desktop\BerneseFile\Y01_JPLEPH>C:/BERN54/SOURCE/PGM/EXE_AIUB/TESTEPH
JPL TEST-EPHEMERIS program. Last modified March 2013.

 2414992.50    2524624.50    32.00
DENUM  0.4210000000000000D+03
LENUM  0.4210000000000000D+03
TDATEF 0.0000000000000000D+00
  
```

Make sure there are no errors.

```

2800 2500212.5    7    10    6    0.0050445003488    0.0050445003488    0.86736E-18
2900 2503256.5    15    0    2    0.4125495806855    0.4125495806855    0.55511E-16
3000 2506300.5    12    3    5   -0.0061446979927   -0.0061446979927   0.86736E-18
3100 2509343.5     9    11    4   -0.0022391993211   -0.0022391993211   0.43368E-18
3200 2512387.5     3    11    3   -0.3238173037952   -0.3238173037952   0.00000E+00
3300 2515431.5    13    3    5    0.0000054558555    0.0000054558555    0.19566E-18
3400 2518474.5     4     6    3   -2.3518118205103   -2.3518118205103    0.88818E-15
3500 2521518.5     5     6    6    0.0014609478661    0.0014609478661    0.21684E-18
3600 2524562.5     1     7    3   -7.8125572338720   -7.8125572338720    0.00000E+00

C:\Users\Y001804\Desktop\BerneseFile\Y01_JPLEPH>
  
```

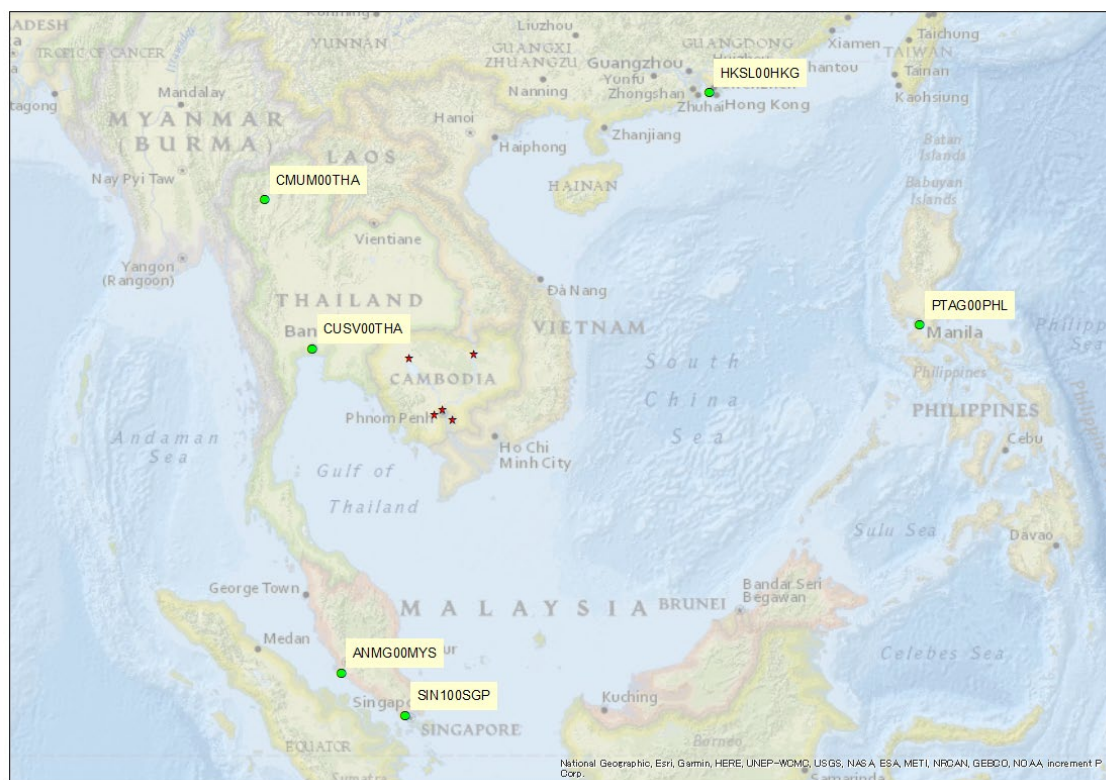
Copy JPLEPH file to the C:/BERN54/GLOBAL/MODEL folder.

Rename [JPLEPH] file to [DE421.EPH] file.

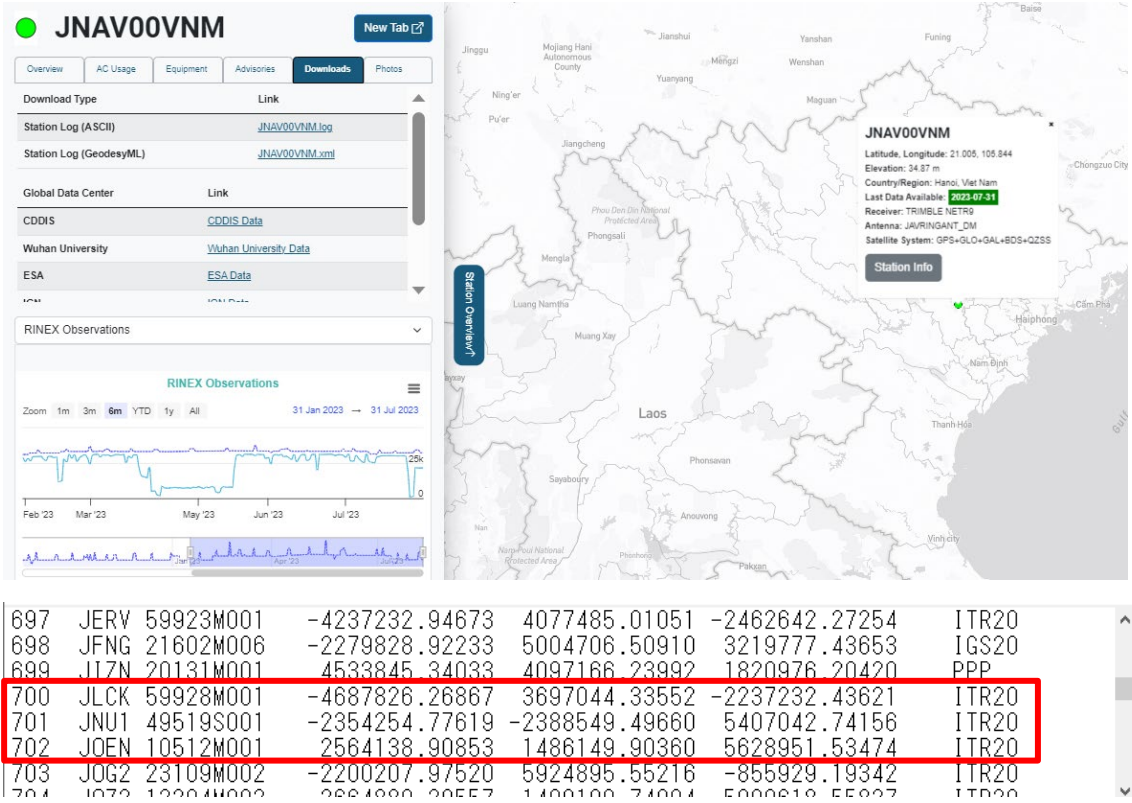


4. IGS Station

Six IGS stations were selected to determine the coordinates of the Khmer GEONET.

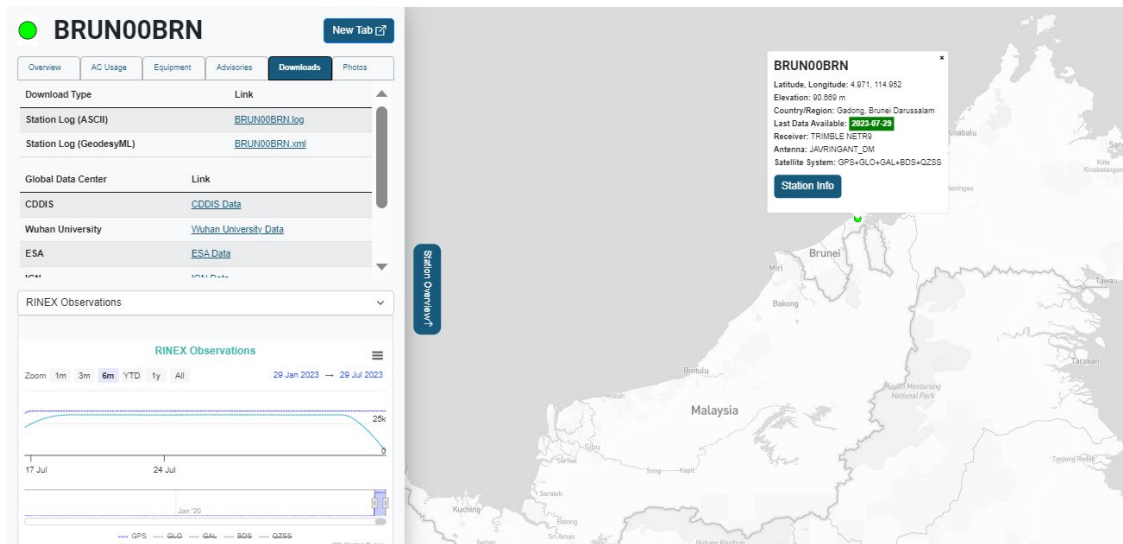


Vietnam's JNAV points could not be used due to missing coordinates in the IGS20.CRD file.



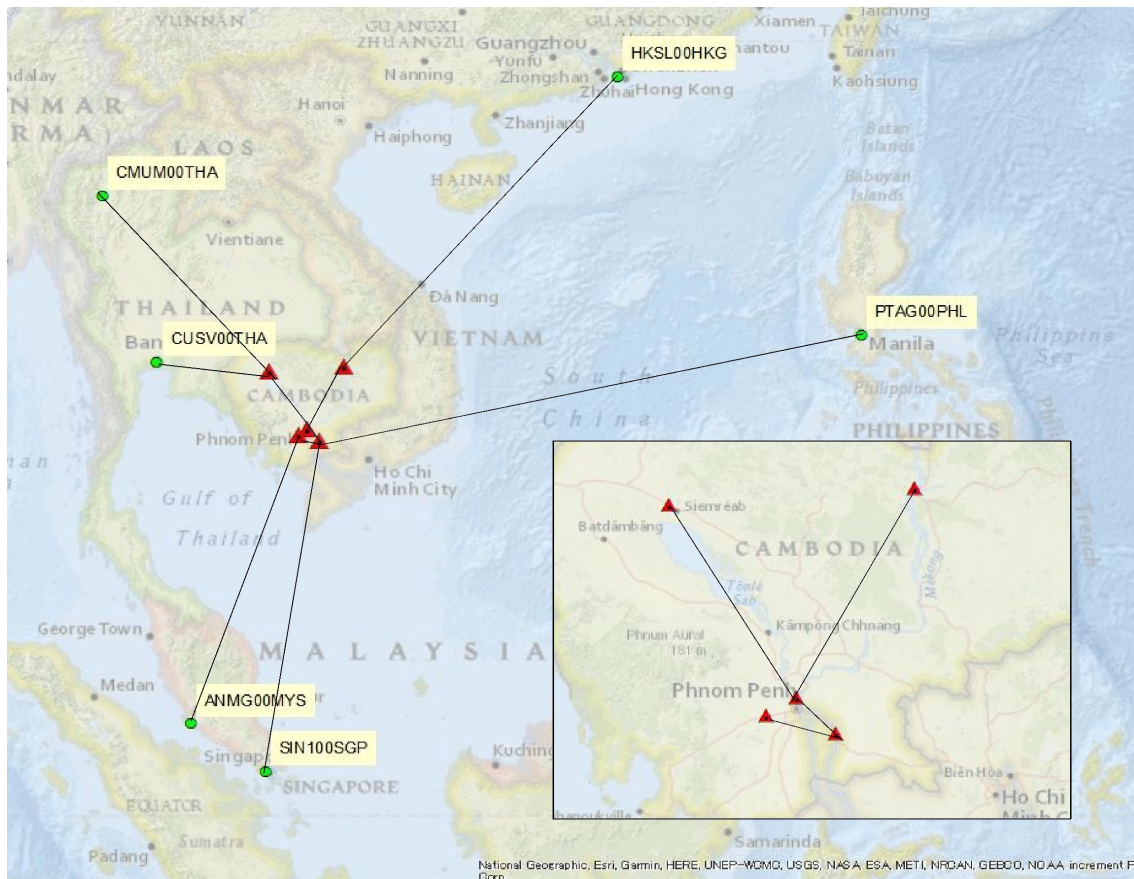
Brunei points have coordinates in the IGS20.CRD file.

However, I couldn't use it because the RINEX file was not archived.



	BREW00USA_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 00:11:56	2.67MB
	BRMG00DEU_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 05:51:46	5.22MB
	BRST00FRA_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 03:59:20	2.75MB
	BRUX00BEL_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 00:15:03	4.78MB
	BSHM00ISR_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 00:16:58	3.85MB
	BUCU00ROU_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 00:51:39	3.97MB
	BZR200ITA_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 00:10:21	2.53MB
	CAS100ATA_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 00:19:37	4.34MB
	CCJ200JPN_R_20231300000_01D_30S_MO.crx.gz	2023:05:11 00:32:07	1.92MB

The network diagram is shown below.

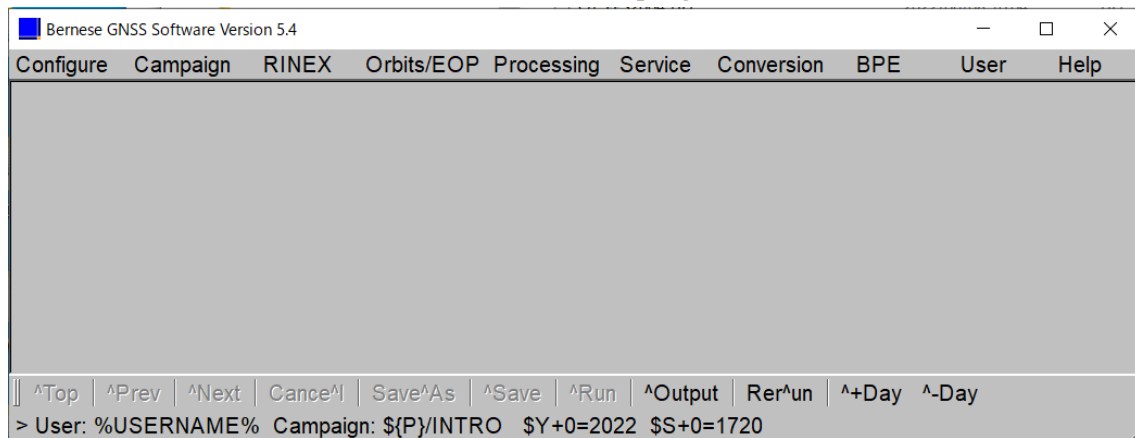


Baseline combinations are shown below.

02:CMUM-10:SIE1
 10:SIE1-03:CUSV
 10:SIE1-09:PNH1
 04:HKSL-11:STG1
 11:STG1-09:PNH1
 09:PHN1-07:KND1
 07:KND1-05:PTAG
 07:KND1-06:SIN1
 07:KND1-08:KPS1
 08:KSP1-01:ANMG

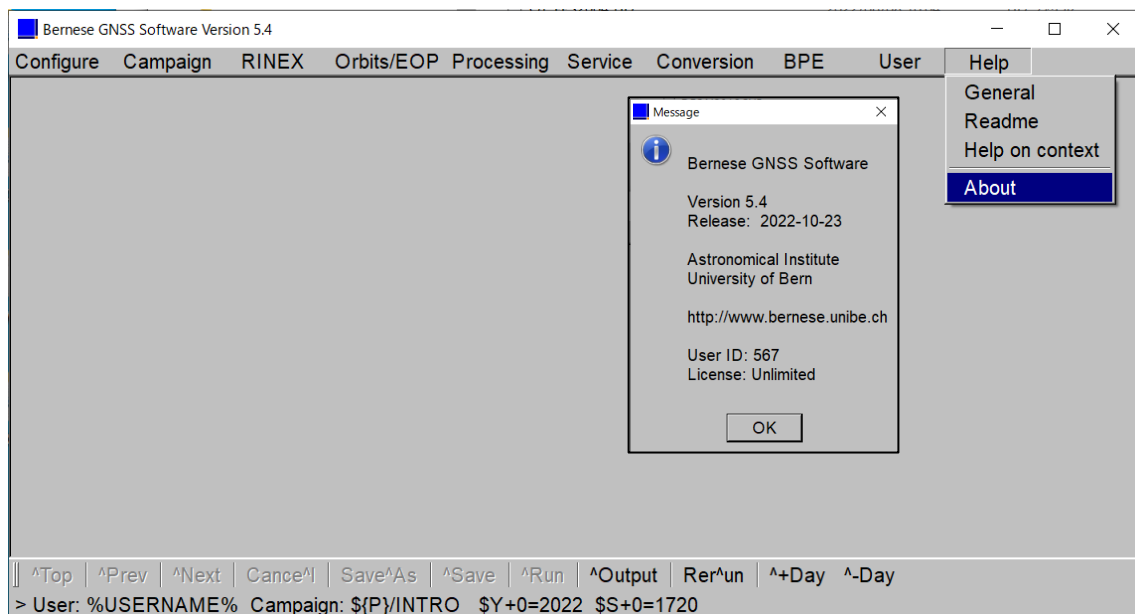
5. Menu

Click [Bernese 5.4 shortcut] to launch the menu program.



Check version and release date.

Bernese software purchased in October 2022 has a release date of 23th October 2022.

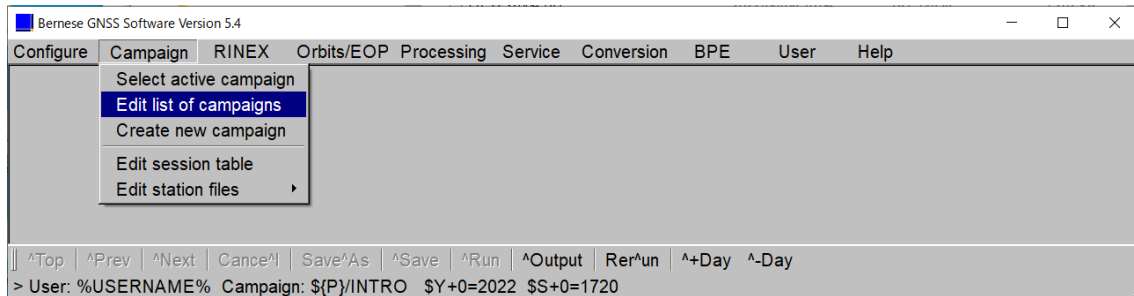


If the version is upgraded, refer to [C:/BERN54/GPS/DOC/README_UPDATE.TXT] and update the version.

6. Campaign setup

6.1. Edit list of campaigns

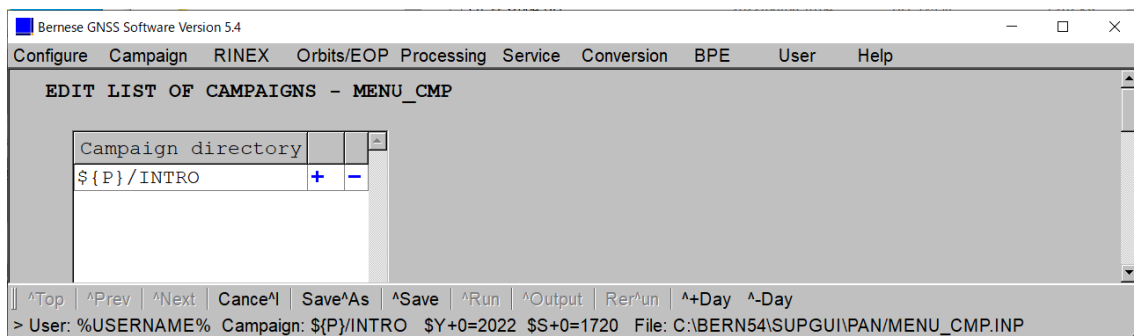
Click [Edit list of campaigns] to display the submenu.



Click [+] to copy the line. Click [-] to delete the line.

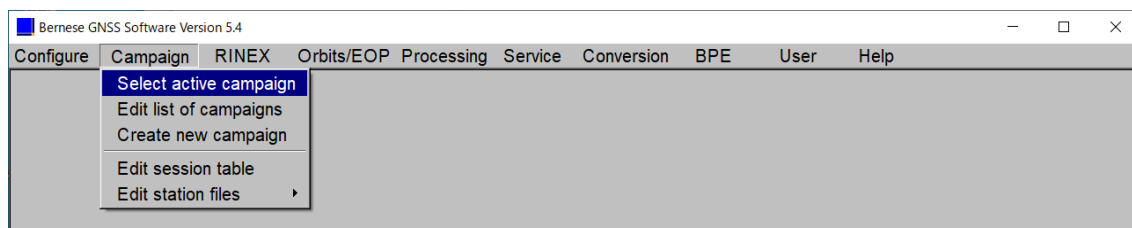
Rename the campaign directory to [\${P}/XXXXX]. [XXXXX] can be named arbitrarily.

Click [^Save] to save your changes.

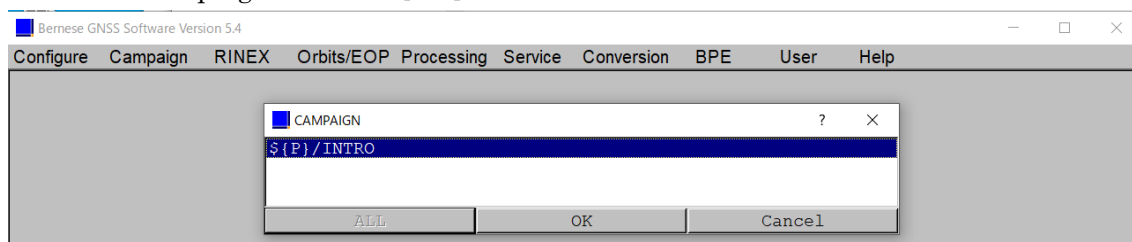


6.2. Select the active campaign

Click [Select active campaign] to display the registered campaign directory.

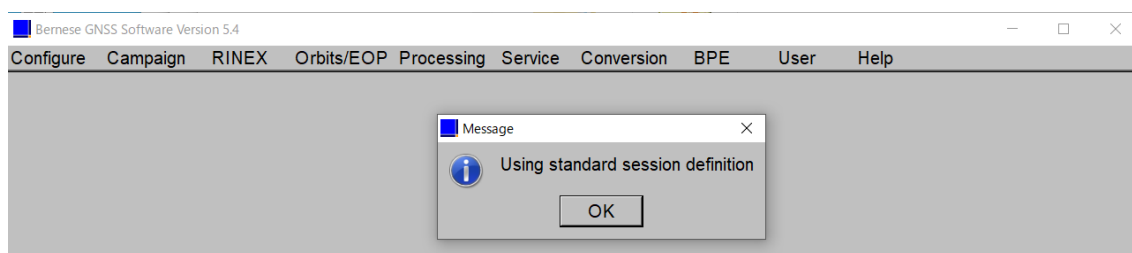
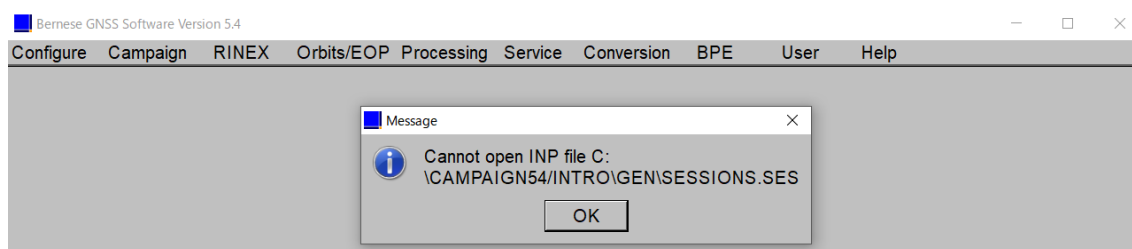


Select the campaign and click [OK].

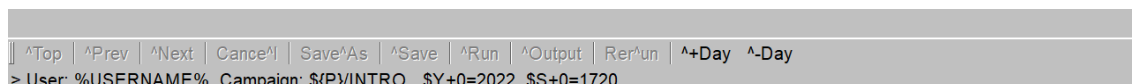


If the Directory is not created, Message will be displayed, but there is no problem.

So press the [OK] button. Then, click [OK] for all.

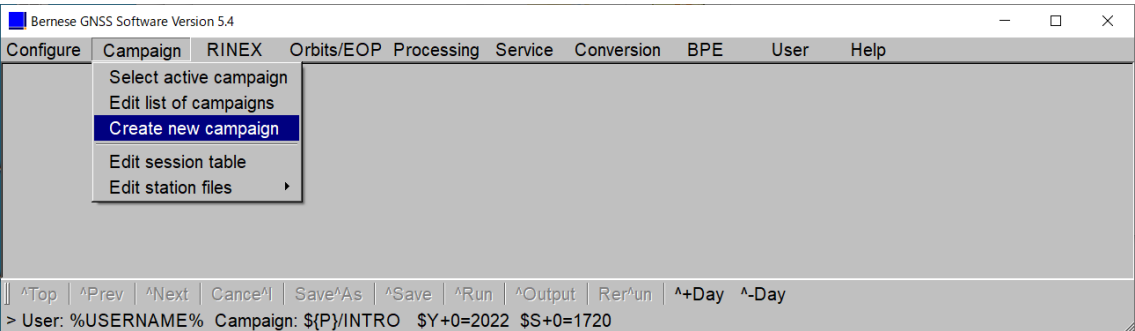


Make sure the selected campaign is displayed at the bottom of the menu screen.

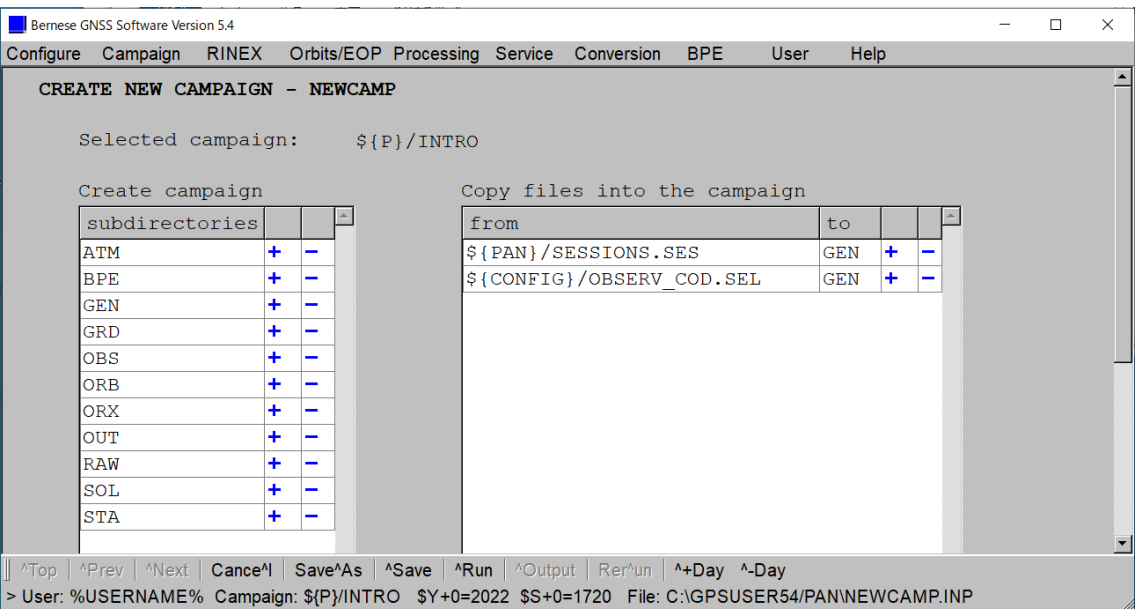


6.3. Create campaign folder

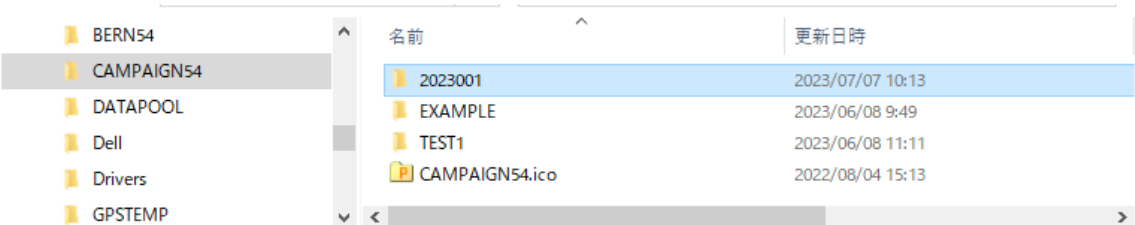
Click [Create new campaign] to display the submenu.



Click [^Run]

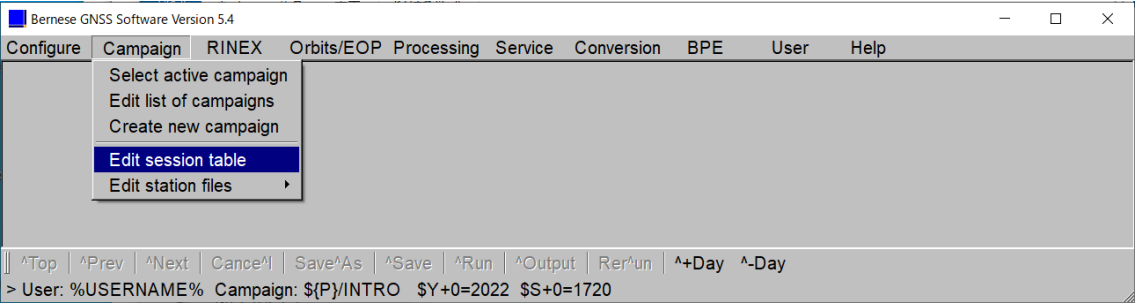


A folder with the campaign name will be created in the CAMPAIGN54 folder.



6.4. Select current session

Click [Edit session table] to display the registered Session table.

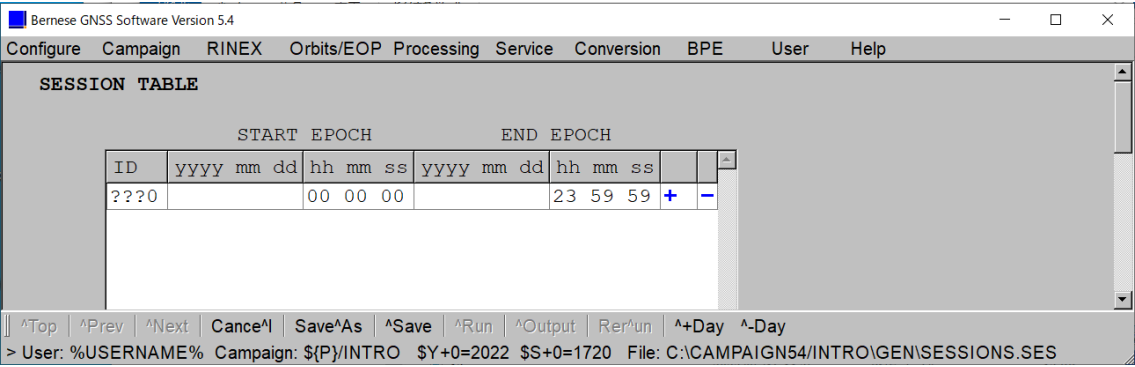


[???] is [Day of year]. It is a total day with 1st-Jan as 1. Set with wildcards.

START EPOCH and END EPOCH dates [yyyy mm dd] are blank.

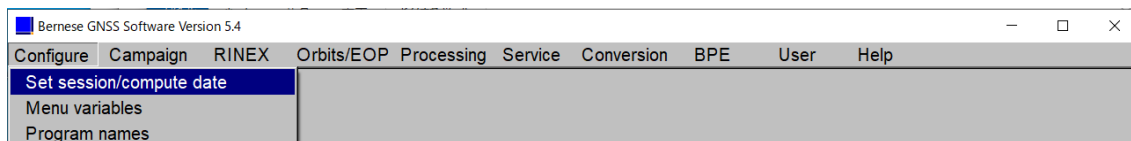
START EPOCH time is 00:00:00. END EPOCH time is 23:59:59.

Click [^Save].



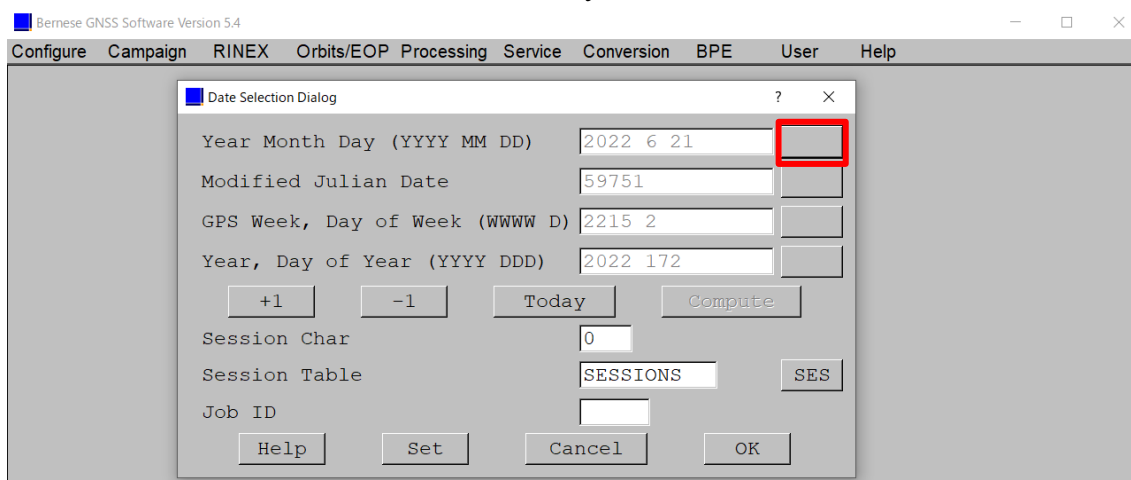
6.5. Baseline processing date setting

Click [Set session/compute date] to display the submenu

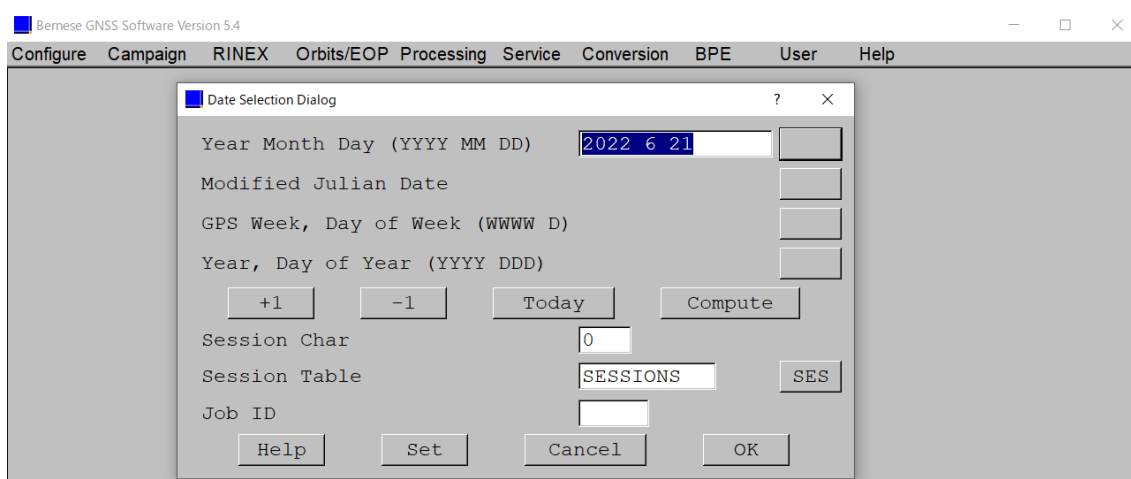


Set by [Year Month Day], [Modified Julian Date], [GPS Week and Day of Week] or [Year and Day of Year].

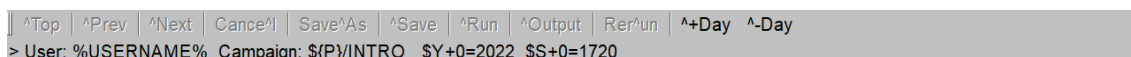
Click the red frame to set in [Year Month Day].



Enter the date and click [OK].



Make sure that the baseline processing date you set is displayed at the bottom of the menu screen.



7. Preparation of observation data, ephemeris data and observation point information

Download the data for analysis from the site of Bern University and Vienna University of Technology.

Download site of Bern University: <http://www.bernese.unibe.ch/>

Download site of Vienna University of Technology:

[Index of /trop_products/GRID/1x1/VMF3/VMF3_OP \(tuwien.ac.at\)](http://www.tuwien.ac.at/index_of/trop_products/GRID/1x1/VMF3/VMF3_OP)

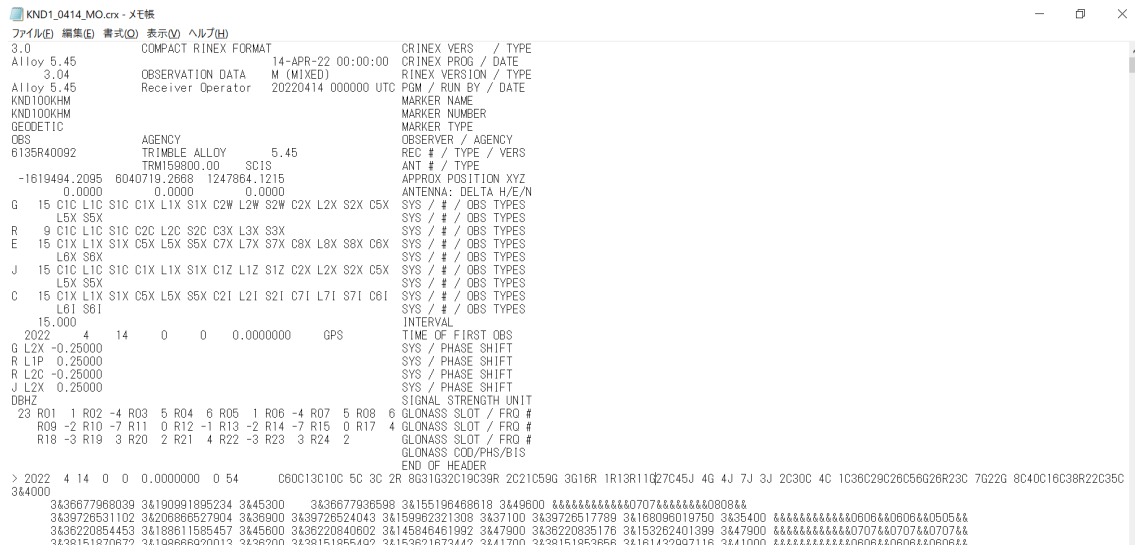
Copy the downloaded data to subfolders of the campaign.

	名前	更新日時	種類	サイズ
▼ INTRO				
ATM	ATM	2023/05/15 17:46	ファイル フォルダー	
BPE	BPE	2023/05/15 15:02	ファイル フォルダー	
GEN	GEN	2023/05/15 17:46	ファイル フォルダー	
GRD	GRD	2023/05/15 17:46	ファイル フォルダー	
OBS	OBS	2023/05/15 17:46	ファイル フォルダー	
ORB	ORB	2023/05/15 17:46	ファイル フォルダー	
ORX	ORX	2023/05/15 15:02	ファイル フォルダー	
OUT	OUT	2023/05/16 8:57	ファイル フォルダー	
RAW	RAW	2023/05/15 17:46	ファイル フォルダー	
SOL	SOL	2023/05/15 17:46	ファイル フォルダー	
STA	STA	2023/05/15 17:46	ファイル フォルダー	
> DATAPOOL				

7.1. RINEX file (Khmer GEONET)

Copy the RINEX file archived by Pivot to [RAW] folder of the campaign.

[KND100KMRxxxxxxxxx_MO.crx]: Compact RINEX format file of the observation data



Since the file name is long, change it to a short file name for BERNESE.

Examples are shown below.

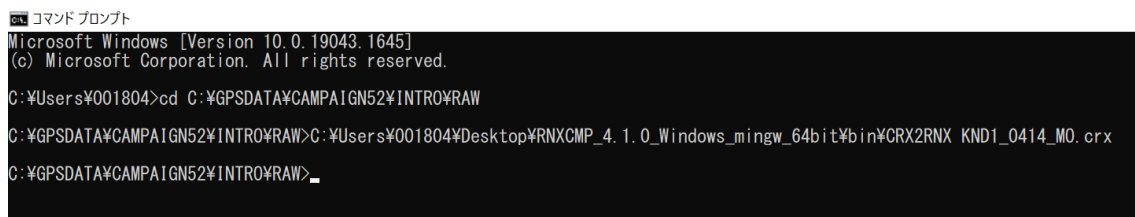
KND11720.crx: Compact RINEX format file of the observation data

Compact RINEX format file is converted to RINEX file format. Use [CRX2RNX.exe] for format conversion.

Open a Windows command prompt. Set the [RAW] folder as the current directory.

Specify the compact RINEX format file to be converted and execute [CRX2RNX.exe].

In addition, specify the directory where [CRX2RNX.exe] was saved and execute it.



[KND11720.rnx]: RINEX format file of the observation data

```
KND1_0419_MO.rnx - メモ帳
ファイル(F) 編集(E) 書式(O) 表示(V) ヘルプ(H)
| 3.04 OBSERVATION DATA M (MIXED) RINEX VERSION / TYPE
Alloy 5.45 Receiver Operator 20220419 000000 UTC PGM / RUN BY / DATE
KND100KHM MARKER NAME
KND100KHM MARKER NUMBER
GEODETTIC MARKER TYPE
OBS AGENCY OBSERVER / AGENCY
6135R40092 TRIMBLE ALLOY 5.45 REC # / TYPE / VERS
TRM159800.00 SC1S ANT # / TYPE
-1619492.9440 6040715.0700 1247864.9000 APPROX POSITION XYZ
0.0000 0.0000 0.0000 ANTENNA: DELTA H/E/N
G 15 C1C L1C S1C C1X L1X S1X C2W L2W S2W C2X L2X S2X C5X SYS / # / OBS TYPES
L5X S5X SYS / # / OBS TYPES
R 9 C1C L1C S1C C2C L2C S2C C3X L3X S3X SYS / # / OBS TYPES
E 15 C1X L1X S1X C5X L5X S5X C7X L7X S7X C8X L8X S8X C6X SYS / # / OBS TYPES
L6X S6X SYS / # / OBS TYPES
J 15 C1C L1C S1C C1X L1X S1X C1Z L1Z S1Z C2X L2X S2X C5X SYS / # / OBS TYPES
L5X S5X SYS / # / OBS TYPES
C 15 C1X L1X S1X C5X L5X S5X C2I L2I S2I C7I L7I S7I C6I SYS / # / OBS TYPES
L6I S6I SYS / # / OBS TYPES
15.000 INTERVAL
2022. 4 19 0 0 0.0000000 GPS TIME OF FIRST OBS
G L2X -.25000 SYS / PHASE SHIFT
R L1P 0.25000 SYS / PHASE SHIFT
R L2C -.25000 SYS / PHASE SHIFT
J L2X 0.25000 SYS / PHASE SHIFT
DBHZ SIGNAL STRENGTH UNIT
23 R01 1 R02 -4 R03 5 R04 6 R05 1 R06 -4 R07 5 R08 6 GLONASS SLOT / FRQ #
R09 -2 R10 -7 R11 0 R12 -1 R13 -2 R14 -7 R15 0 R17 4 GLONASS SLOT / FRQ #
R18 -3 R19 3 R20 2 R21 4 R22 -3 R23 3 R24 2 GLONASS SLOT / FRQ #
GLONASS COD/PHS/BIS
END OF HEADER
> 2022 4 19 0 0 0.0000000 0 56 .000000002000
C60 36676924.46107 190986448.77507 45.100
C13 39951995.54705 208040563.92005 32.400 39951989.88306 16087011
C10 36257146.44507 188800554.36307 45.100 36257132.97708 14599250
R 8 23796338.92206 127428334.40306 36.400 23796344.31306 99110944.74806 36.800
C43 26150543.89505 137422022.53805 35.800 26150545.37106 102620329.33906 37.500
C41 25785958.37905 135508140.45505 35.400 25785967.42206 101189662.40406 40.300
G 3 22583797.96106 118678570.85006 41.700 26150550.30505 136172756.58105 35.400
25785965.14106 134274277.98906 36.900
22583804.75007 9247688
38320699.70305 199545919.94305 35.800 38320685.26606 1543015
END OF HEADER
```

Pivot also allows you to download the RINEX format files [KND11720.23o].

The [KND11720.23o] file can be used as is.

----- Supplementary Explanation -----

The RINEX file has the broadcast ephemeris data.

A description of the broadcast ephemeris data is shown below.

However, BERNESE uses the precise ephemeris data. As a general rule, the broadcast ephemeris data are not used.

[KND100KMRxxxxxxxx_MN.rnx]: RINEX format file of the broadcast ephemeris data

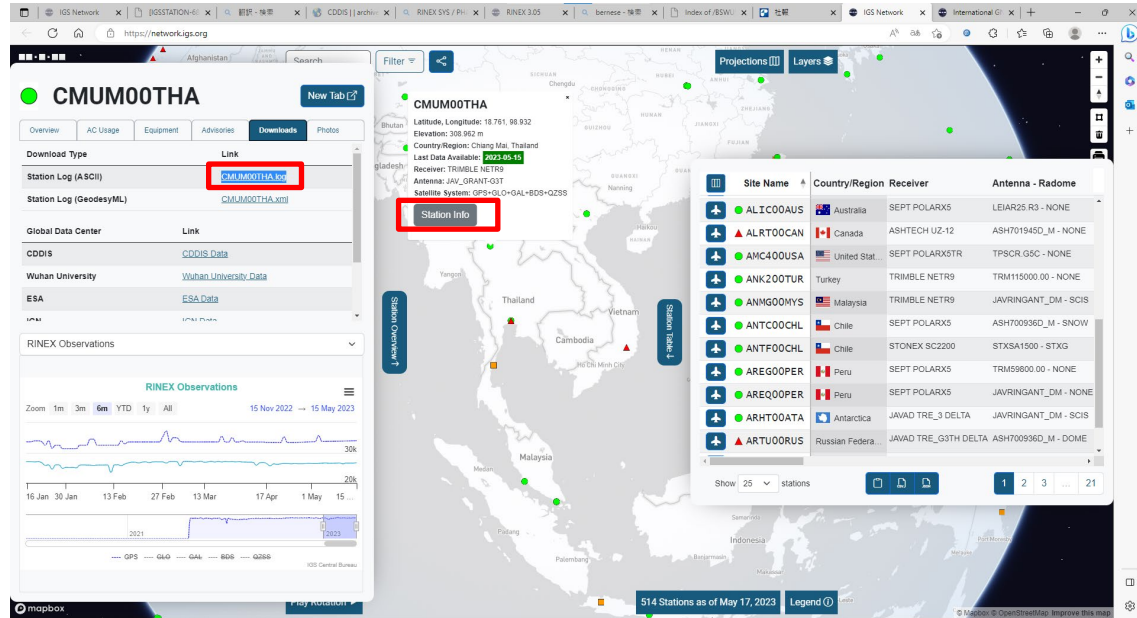
```
KND1_0414_MN.rnx - メモ帳
ファイル(F) 編集(E) 書式(O) 表示(V) ヘルプ(H)
| 3.04 N: GNSS NAV DATA M: MIXED NAV DATA RINEX VERSION / TYPE
Alloy 5.45 Receiver Operator 20220414 000000 UTC PGM / RUN BY / DATE
GPSA .1583D-07 .1490D-07 -.1192D-06 -.1192D-06 IONOSPHERIC CORR
GPSB .1065D+06 .6554D+05 -.1966D+06 -.1966D+06 IONOSPHERIC CORR
GAL .7950D+02 -.1953D-01 .1309D-01 .0000D+00 IONOSPHERIC CORR
QZSA .2328D-07 -.7451D-08 -.4172D-06 -.6557D-06 IONOSPHERIC CORR
QZSB .1229D+06 .6554D+05 -.1180D+07 -.3146D+07 IONOSPHERIC CORR
BDSA .1229D+06 .2906D-06 -.2086D-05 .3099D-05 IONOSPHERIC CORR
BDSB .1700D+06 -.9667D+06 .4588D+07 -.2687D+07 IONOSPHERIC CORR
GPUT -.6519258022D-08 -.168753900D-13 503808 2205 TIME SYSTEM CORR
GAUT -.9313225746D-09 888178420D-15 259200 2205 TIME SYSTEM CORR
BDUT .0000000000D+00 .408562073D-13 14 849 TIME SYSTEM CORR
QZUT -.2793967724D-08 .000000000D+00 528384 2205 TIME SYSTEM CORR
GAGP .4220055416D-08 .577315973D-14 345600 2205 TIME SYSTEM CORR
18 18 2185 7 LEAP SECONDS
END OF HEADER
C60 2022 04 13 23 00 00 -.447384081781D-06 -.150990331349D-12 .000000000000D+00
1000000000000001 1000656250000003 1821147986670008 -.9256626108000001
```

7.2. RINEX file (IGS Station)

7.2.1. Station Information

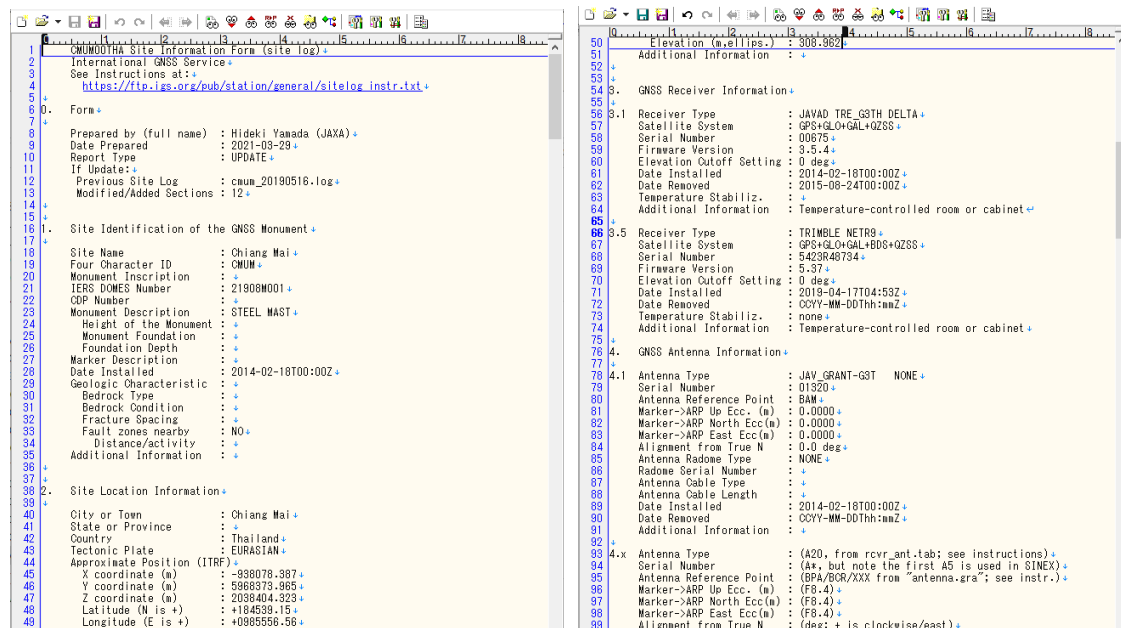
Connect to the IGS website.

IGS website: <https://igs.org/network/>



Select the IGS station mark (●, ▲) and click [Station Info]. ▲ is the point that is not working.

Then click [Station Log (AASCII)] to get information about the IGS station.

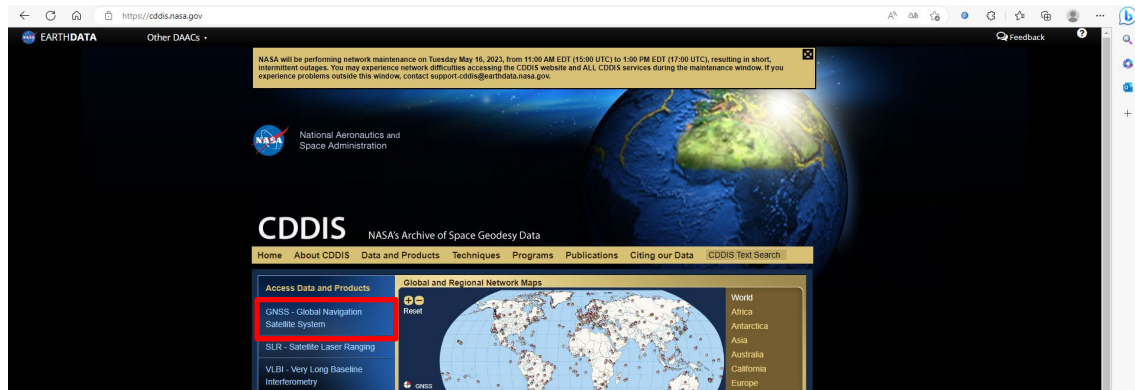


7.2.2. Download RINEX file

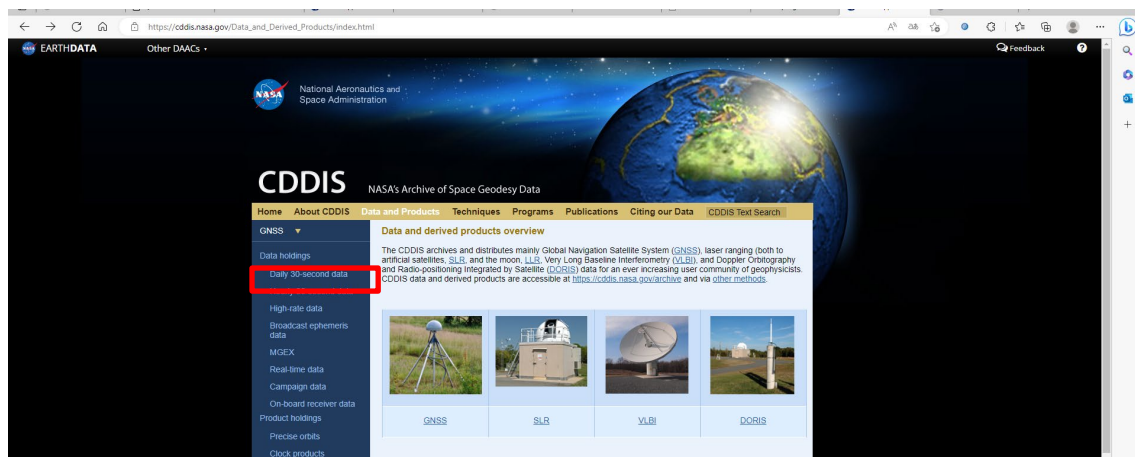
Connect to the NASA website.

NASA's Archive of Space Geodesy Data: [CDDIS | \(nasa.gov\)](https://cdsis.nasa.gov)

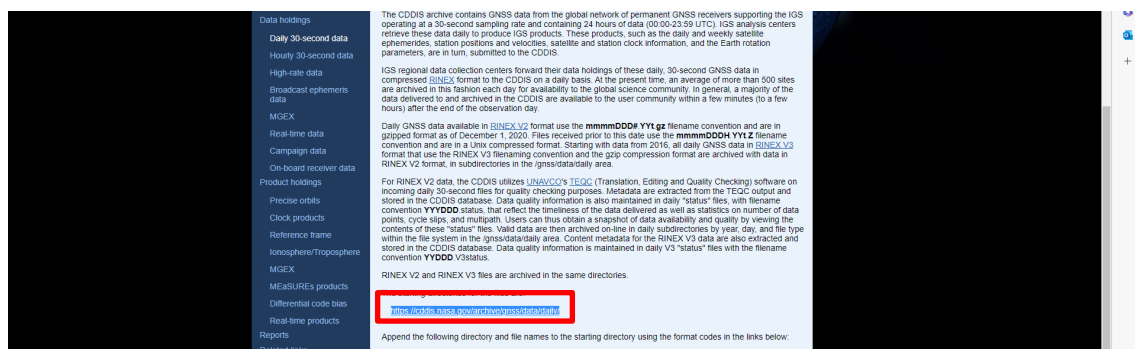
Click [GNSS – Global Navigation Satellite System].



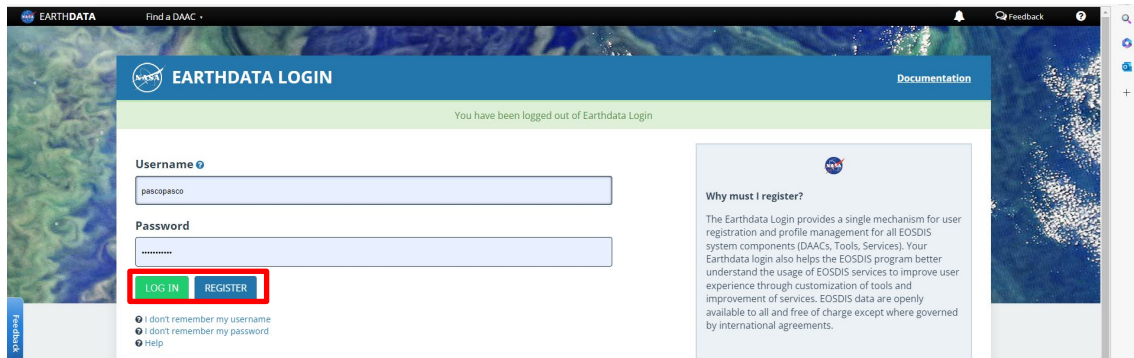
Click [Daily 30-second data].



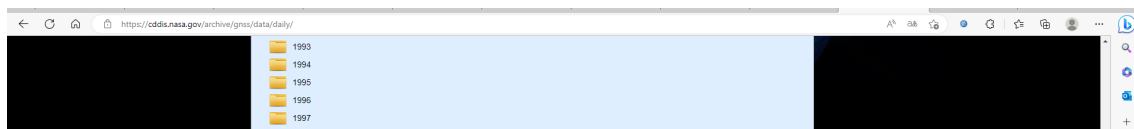
Click [<https://cdsis.nasa.gov/archive/gnss/data/daily/>].



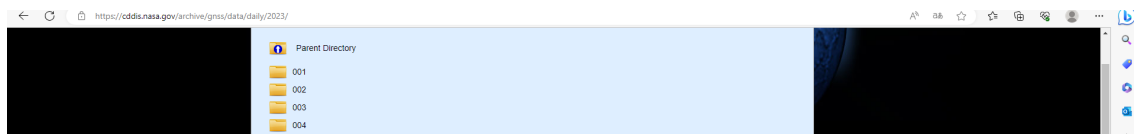
After registering as a user, log in.



Click the year folder of the RINEX file to be used.



Click the day of year folder of the RINEX file to be used.



Click the folder of the RINEX file to be used.

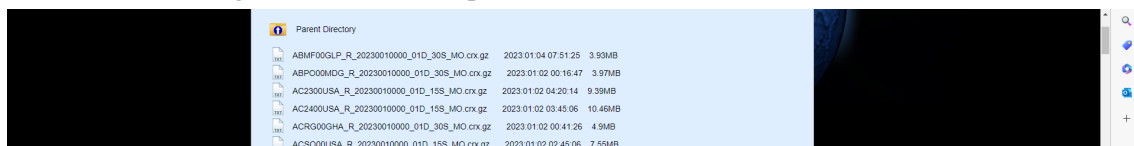
[23d] is compact RINEX format of the observation data.



Download the RINEX file of the IGS station to be used.

Click [23d].

After downloading, convert the compact RINEX format file to RINEX file format.



7.3. Precise orbit files and IGS/IERS pole files

Download the precise orbit files and the IGS/IERS pole files from the download site.

Download site for 2023 data: <http://ftp.aiub.unibe.ch/CODE/2023/>

CGIM1800.23N.Z	04-Jul-2023 06:31	461
CGIM1810.23N.Z	05-Jul-2023 06:37	465
COD00PSFIN_20230010000_01D_01D_ERP.ERP.gz	13-Jan-2023 19:33	546
COD00PSFIN_20230010000_01D_01D_05M_05M.05M.gz	13-Jan-2023 19:33	115K
COD00PSFIN_20230010000_01D_01D_SOL.SNX.gz	13-Jan-2023 19:33	35M
COD00PSFIN_20230010000_01D_01H_GIM.INX.gz	13-Jan-2023 19:33	317K
COD00PSFIN_20230010000_01D_01H_GIM.ION.gz	13-Jan-2023 19:33	61K
COD00PSFIN_20230010000_01D_01H_TRO.TRO.gz	13-Jan-2023 19:33	54K
COD00PSFIN_20230010000_01D_05M_ORB.SP3.gz	13-Jan-2023 19:33	588K
COD00PSFIN_20230010000_01D_05S_CLK.CLK.gz	13-Jan-2023 19:33	16M
COD00PSFIN_20230010000_01D_05S_CLK.CLK.V2.gz	13-Jan-2023 19:33	16M
COD00PSFIN_20230010000_01D_30S_ATT.OBX.gz	13-Jan-2023 19:33	8M

[COD00PSFIN_20yyddd0000_01D_05M_ORB.SP3.gz]: Compressed file of the precise orbit file

[COD00PSFIN_20yyddd0000_01D_01D_ERP.ERP.gz]: Compressed file of the IGS/IERS pole file

[yyyy]: year

[ddd]: Day of year

e.g. [COD00PSFIN_20230010000_01D_05M_ORB.SP3.gz] is the compressed file of the precise orbit file at 1st January 2023

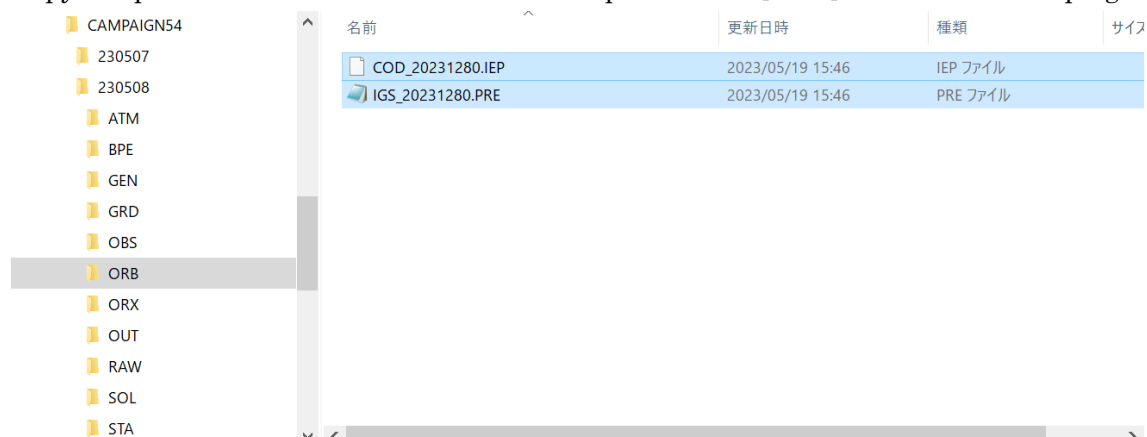
e.g. [COD00PSFIN_20230010000_01D_01D_ERP.ERP.gz] is the compressed file of the IGS/IERS pole file at 1st January 2023

Unzip and rename the file.

From [COD00PSFIN_20yyddd0000_01D_05M_ORB.SP3] to [IGS_yyyddd0.PRE]

From [COD00PSFIN_20yyddd0000_01D_01D_ERP.ERP] to [COD_yyyddd0.IEP]

Copy the precise orbit files and the IGS/IERS pole files to [ORB] folder of the campaign.



7.4. Code bias files

Download the code bias files from the download site.

Download site for 2023 data: <http://ftp.aiub.unibe.ch/CODE/2023/>

[P1C1yyymm.DCB.Z]: Compressed file of the P1C1 code bias file

COD00PSFIN 20231830000 01D 01H GIM.IX.gz	06-Jul-2023	22:36	299K
COD00PSFIN 20231830000 01D 01H GIM.ION.gz	06-Jul-2023	22:36	60K
P1C12301.DCB.Z	04-Feb-2023	05:47	571
P1C12301.F.Z	04-Feb-2023	05:47	325
P1C12301 RINEX.DCB.Z	08-Feb-2023	06:27	6461
P1C12301 RINEX.F.Z	08-Feb-2023	06:27	329
P1C12302.DCB.Z	04-Mar-2023	05:47	568
P1C12302.F.Z	04-Mar-2023	05:47	330
P1C12302 RINEX.DCB.Z	08-Mar-2023	06:23	6499

[P1P2yyymm.DCB.Z]: Compressed file of the P1P2 code bias file

P1C12300.DCB.Z	04-Jul-2023	05:47	300
P1C12300.F.Z	04-Jul-2023	05:47	328
P1C12300 RINEX.DCB.Z	06-Jul-2023	06:31	6564
P1C12300 RINEX.F.Z	06-Jul-2023	06:31	334
P1P22301.DCB.Z	04-Feb-2023	05:47	795
P1P22301 ALL.DCB.Z	04-Feb-2023	05:47	6016
P1P22302.DCB.Z	04-Mar-2023	05:48	778
P1P22302 ALL.DCB.Z	04-Mar-2023	05:48	6190
P1P22303.DCB.Z	04-Apr-2023	05:47	800

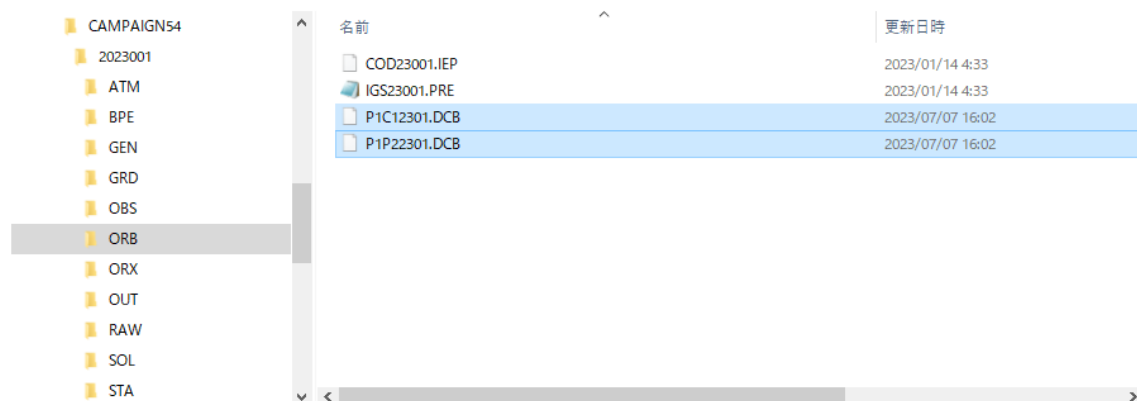
[yy]: Year (20yy)

[mm]: Month

e.g. [P1C12301.DCB.Z] is the compressed file of the P1C1 code bias file at January 2023

e.g. [P1P22301.DCB.Z] is the compressed file of the P1P2 code bias file at January 2023

Unzip and copy the code bias files to [ORB] folder of the campaign.



7.5. Global ionosphere model file

Download the global ionosphere model files from the download site.

Download site for 2023 data: <http://ftp.aiub.unibe.ch/CODE/2023/>

CGIM2000.23N.Z	24-Jul-2023 10:20	466
CGIM2010.23N.Z	25-Jul-2023 06:38	461
CGIM2020.23N.Z	26-Jul-2023 06:36	461
COD00PSFIN_20230010000_01D_01D_ERP.ERP.gz	13-Jan-2023 19:33	546
COD00PSFIN_20230010000_01D_01D_GSB.BIA.gz	13-Jul-2023 14:07	115K
COD00PSFIN_20230010000_01D_01D_SOL.SNX.gz	13-Jan-2023 19:33	35M
COD00PSFIN_20230010000_01D_01H_GIM.ION.gz	13-Jan-2023 19:33	317K
COD00PSFIN_20230010000_01D_01H_GIM.ION.gz	13-Jan-2023 19:33	61K
COD00PSFIN_20230010000_01D_01H_TRG.TRG.gz	13-Jan-2023 19:33	54K
COD00PSFIN_20230010000_01D_05M_ORB.SP3.gz	13-Jan-2023 19:33	588K
COD00PSFIN_20230010000_01D_05S_CLK.CLK.gz	13-Jan-2023 19:33	16M
COD00PSFIN_20230010000_01D_05S_CLK.CLK_V2.gz	13-Jan-2023 19:33	16M

[COD00PSFIN_yyyyddd0000_01D_01H_GIM.ION.gz]: Compressed file of the global ionosphere model file

[yyyy]: year

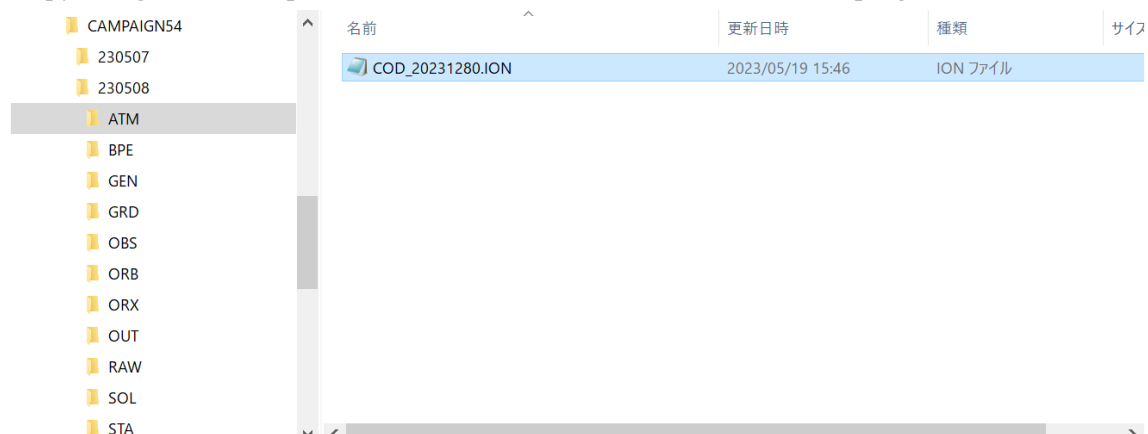
[ddd]: Day of year

e.g. [COD00PSFIN_20230010000_01D_01H_GIM.ION.gz] is the compressed file of the global ionosphere model file at 1st January 2023

Unzip and rename the file.

From [COD00PSFIN_20yyddd0000_01D_01H_GIM.ION] to [COD_yyyyddd.ION]

Copy the global ionosphere model files to [ATM] folder of the campaign.

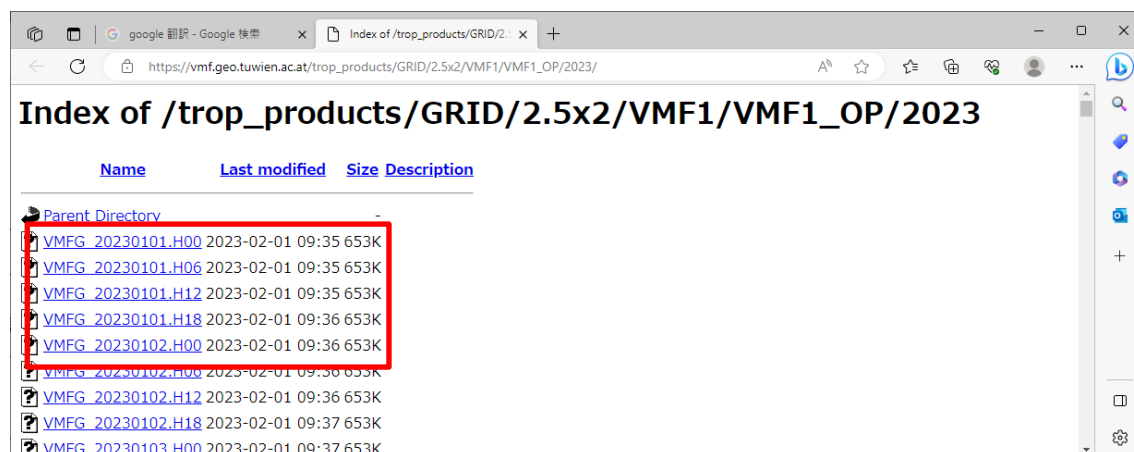


7.6. Tropospheric delay model file (VMF grid data file)

Download the tropospheric delay model files (VMF grid data files) from the download site.

Download site for 2023 data:

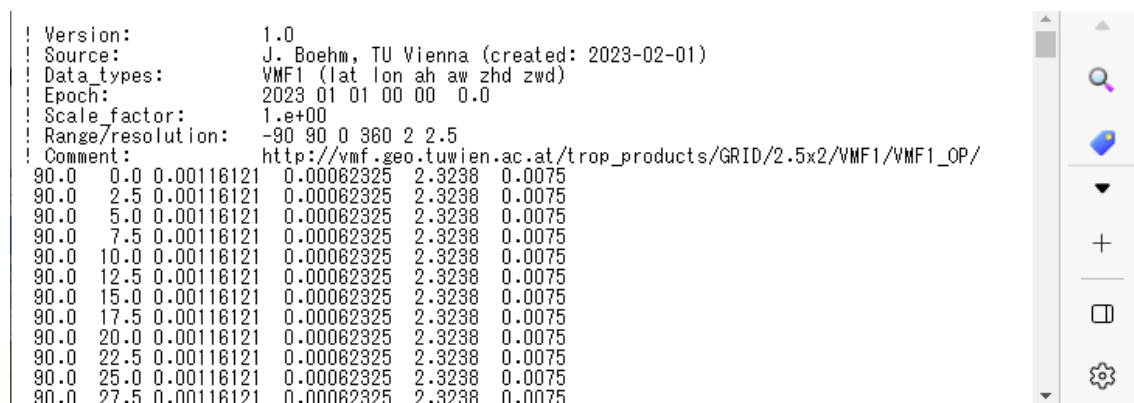
https://vmf.geo.tuwien.ac.at/trop_products/GRID/2.5x2/VMF1/VMF1_OP/2023/



The VMF grid data files are created every 6 hours.

Use 4 files of the day of baseline analysis and the first 1 file of the next day.

Click the file name to see the data.



Merge 5 files using a text editor.

The file name is [VMF_yyyyddd.GRD].

[yyyy]: Year

[ddd]: Day of year

Copy VMF grid data file to [GRD] folder of the campaign.

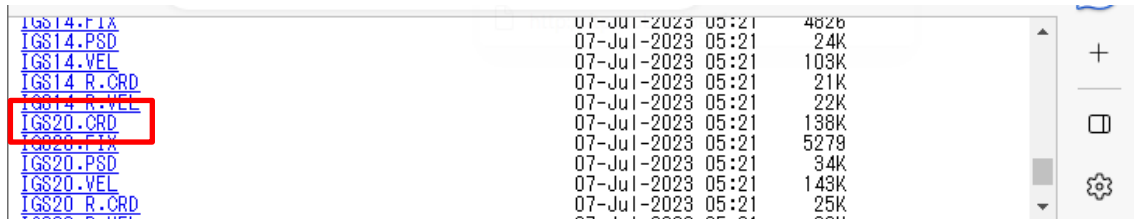
▼	CAMPAIGN54	名前	更新日時	種類	サイズ
>	230507				
▼	230508				
	ATM				
	BPE				
	GEN				
	GRD	VMF_20231280.GRD	2023/07/29 9:55	GRD ファイル	
	OBS				
	ORB				
	ORX				
	OUT				
	RAW				
	SOL				
	STA				

7.7. Observation point coordinate file

7.7.1. Get Coordinate file of IGS Station

Download the IGS station coordinate file [IGS20.CRD] from the download site.

Download site: <http://ftp.aiub.unibe.ch/BSWUSER54/REF/>



IGS14.FIX	07-Jul-2023 05:21	4826
IGS14.PSD	07-Jul-2023 05:21	24K
IGS14.VEL	07-Jul-2023 05:21	103K
IGS14.R.CRD	07-Jul-2023 05:21	21K
IGS14.R.VEL	07-Jul-2023 05:21	22K
IGS20.CRD	07-Jul-2023 05:21	138K
IGS20.FIX	07-Jul-2023 05:21	5279
IGS20.PSD	07-Jul-2023 05:21	34K
IGS20.VEL	07-Jul-2023 05:21	143K
IGS20.R.CRD	07-Jul-2023 05:21	25K
IGS20.R.VEL	07-Jul-2023 05:21	25K

7.7.2. Create Coordinate file

Create coordinate data for the IGS and Khmer GEONET stations using a text editor.

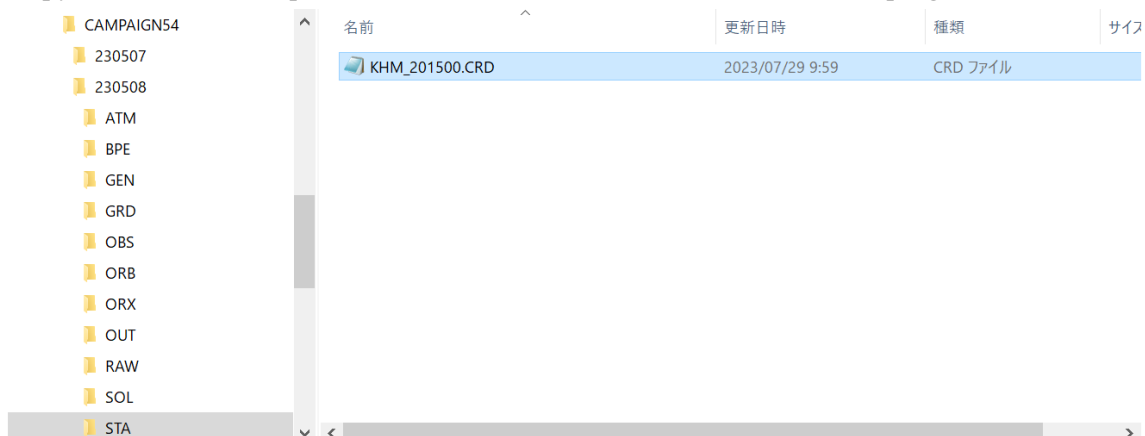
The coordinates of the IGS station are the values of [IGS20.CRD] file.

Coordinates of the Khmer GEONET station can be temporary values, but accurate values are better. For example, use the ITRF2014 values entered in Pivot.

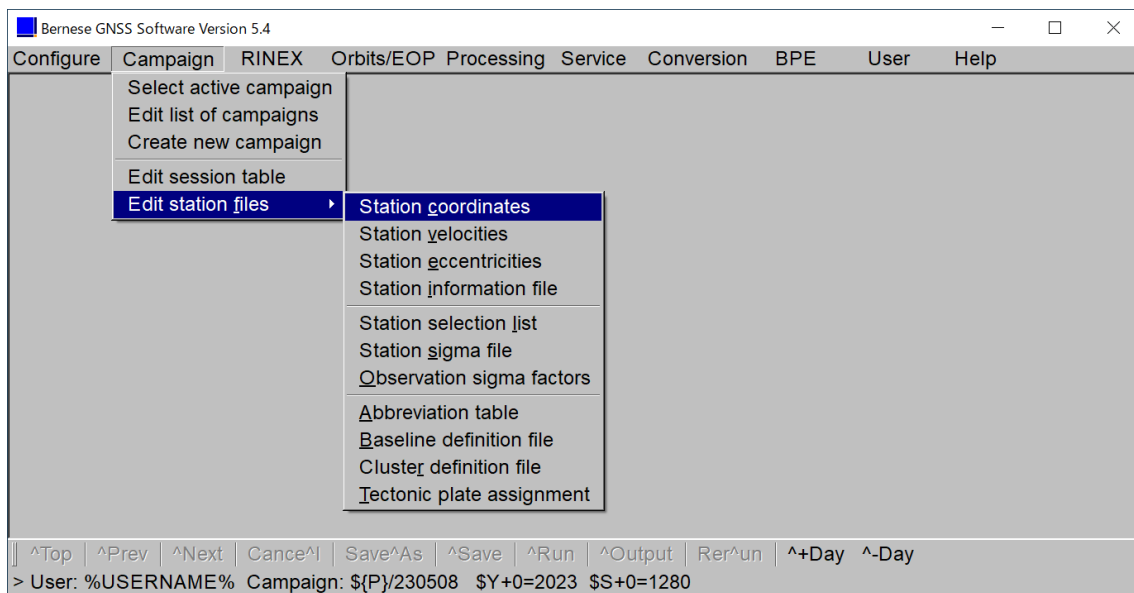
LOCAL GEODETIC DATUM: IGS20							EPOCH: 2015-01-01 00:00:00	
NUM	STATION NAME	X (M)	Y (M)	Z (M)	FLAG	SYSTEM		
1	ANMG	-1270826.89380	6242631.33340	307792.42240	I			
2	CMUM	-938078.34810	5968373.98630	2038404.32190	I			
3	CUSV	-1132914.86460	6092528.56900	1504633.21270	I			
4	HKSL	-2393382.91750	5393860.99760	2412592.23210	I			
5	PTAG	-3184318.71050	5291065.49990	1590418.24380	I			
6	SIN1	-1507972.63360	6195613.86690	148488.03430	I			
7	KND1	-1619492.94400	6040715.07000	1247864.90000				
8	KSP1	-1572714.38600	6050448.84600	1260501.89200				
9	PNH1	-1603672.47300	6038739.32500	1277314.62100				
10	SIE1	-1490303.89300	6024644.81700	1465891.13600				
11	STG1	-1706798.61200	5963096.21200	1481479.65100				

7.7.3. Edit Coordinate file

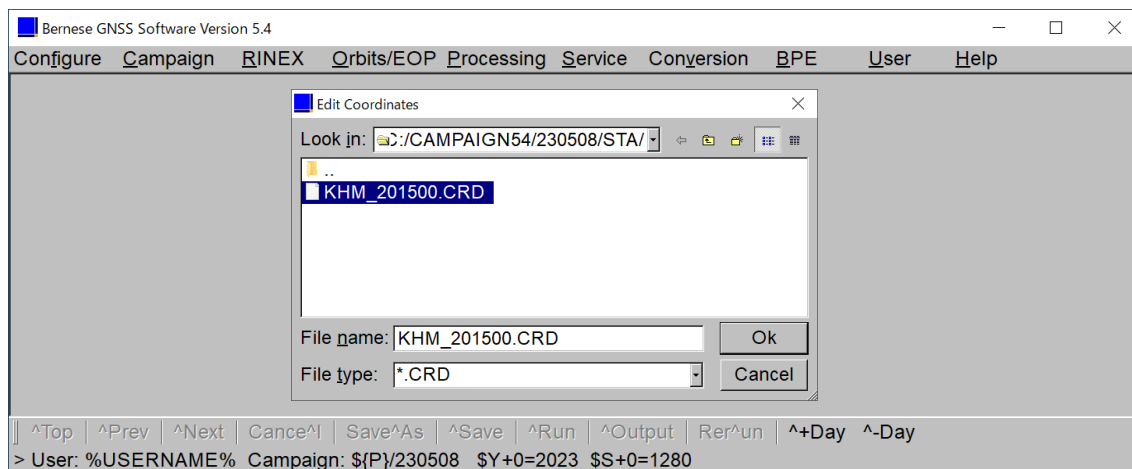
Copy the observation point coordinate file to [STA] folder of the campaign.



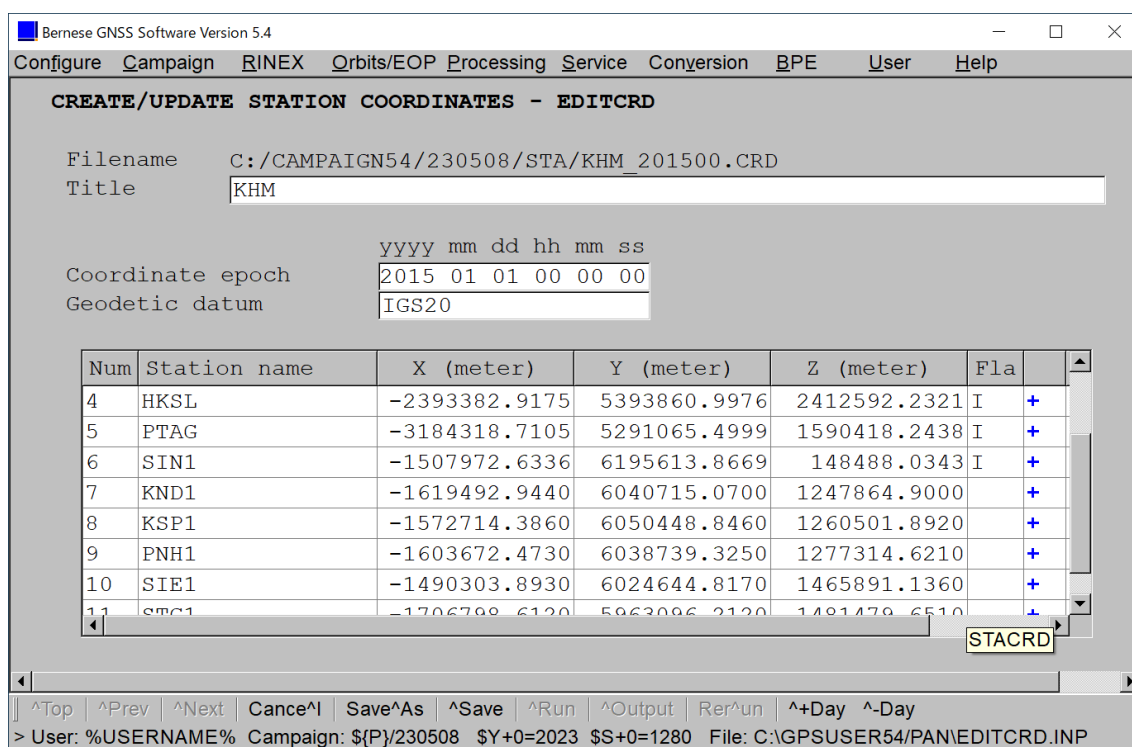
Click [Station Coordinates] to display the submenu.



Select the coordinate file and click [OK].



Enter Title, Coordinate epoch, Geodetic datum, Station name and the coordinate values. Click [^Save].



Title: Can be entered arbitrarily

Coordinate epoch: The year, month, day, hour, and second for which the coordinates were calculated.

Geodetic datum: e.g. IGS20

If you save, they will be sorted by the station name.

LOCAL GEODETIC DATUM: IGS20			EPOCH: 2015-01-01 00:00:00			
NUM	STATION NAME	X (M)	Y (M)	Z (M)	FLAG	SYSTEM
1	ANMG	-1270826.89380	6242631.33340	307792.42240	I	
2	CMUM	-938078.34810	5968373.98630	2038404.32190	I	
3	CUSV	-1132914.86460	6092528.56900	1504633.21270	I	
4	HKSL	-2393382.91750	5393860.99760	2412592.23210	I	
7	KND1	-1619492.94400	6040715.07000	1247864.90000		
8	KSP1	-1572714.38600	6050448.84600	1260501.89200		
9	PNH1	-1603672.47300	6038739.32500	1277314.62100		
5	PTAG	-3184318.71050	5291065.49990	1590418.24380	I	
10	SIE1	-1490303.89300	6024644.81700	1465891.13600		
6	SIN1	-1507972.63360	6195613.86690	148488.03430	I	
11	STG1	-1706798.61200	5963096.21200	1481479.65100		

7.8. Plate definition file

Create the plate definition file using a text editor.

LOCAL GEODETIC DATUM: IGS20

NUM	STATION NAME	VX (M/Y)	VY (M/Y)	VZ (M/Y)	FLAG	PLATE
1	ANMG					EUR
2	CMUM					EUR
3	CUSV					EUR
4	HKSL					EUR
7	KND1					EUR
8	KSP1					EUR
9	PNH1					EUR
5	PTAG					PHIL
10	SIE1					EUR
6	SIN1					EUR
11	STG1					EUR

Copy the plate definition file (KhmrGEONET.PLD) to [STA] folder of the campaign.

CAMPAIGN54

230507

230508

ATM

BPE

GEN

GRD

OBS

ORB

ORX

OUT

RAW

SOL

STA

名前

KHM_201500.CRD

KhmrGEONET.PLD

更新日時

2023/07/29 10:02

2023/07/28 14:22

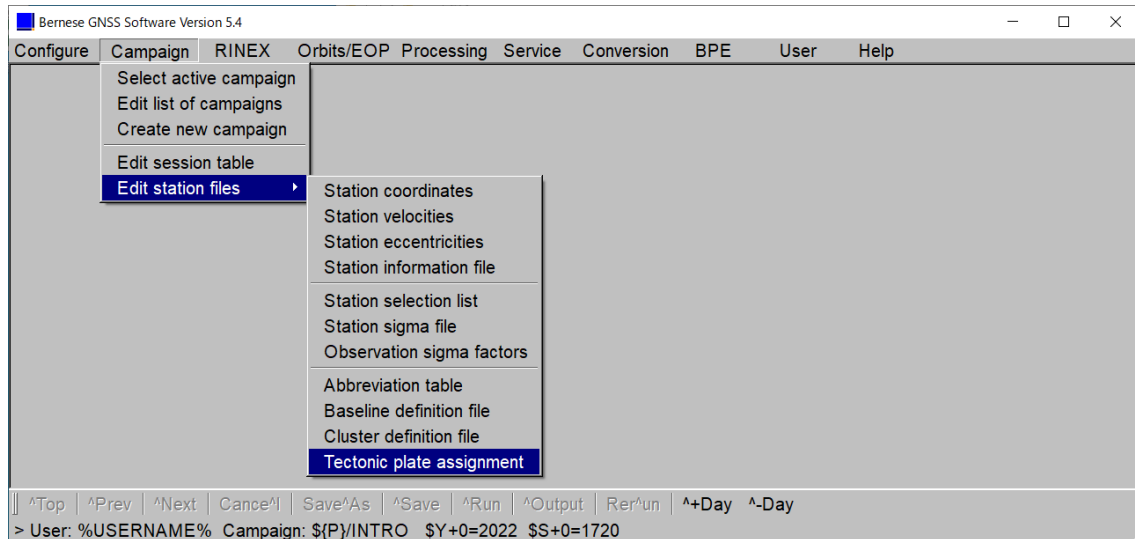
種類

CRD ファイル

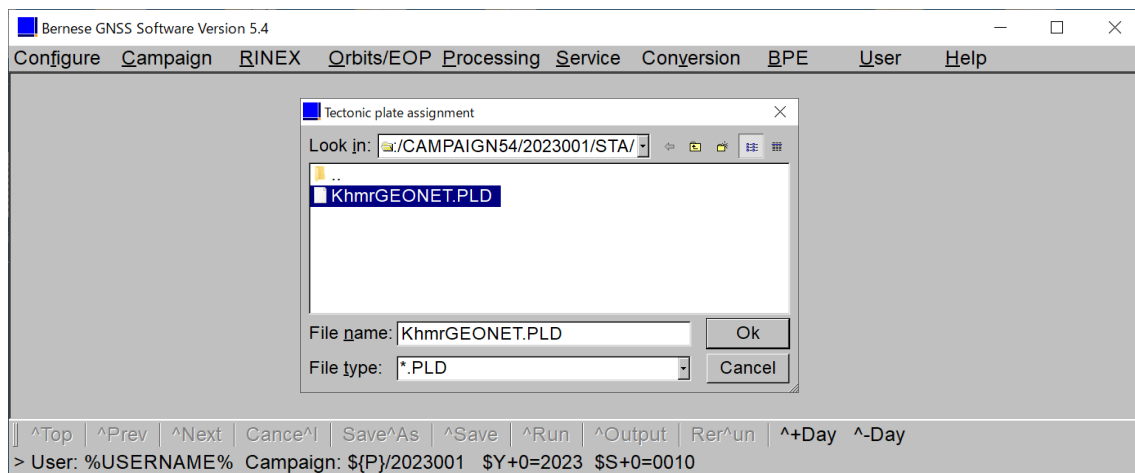
PLD ファイル

サイズ

Click [Tectonic plate assignment] to display the submenu.



Select the plate definition file and click [OK].



Enter Title, Num, Station name and Plate.
Click [Save].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

CREATE/UPDATE TECTONIC PLATE ASSIGNMENT - EDITPLD

Filename C:/CAMPAIGN54/230513C/STA/KhmerGEONET.PLD

Title

Num	Station name	Plate	+	-
1	ANMG	EURA	+	-
2	CMUM	EURA	+	-
3	CUSV	EURA	+	-
4	HKSL	EURA	+	-
7	KND1	EURA	+	-
8	KSP1	EURA	+	-
9	PNH1	EURA	+	-
5	PTAG	PHIL	+	-
10	SIE1	EURA	+	-
6	SIN1	EURA	+	-
11	STG1	EURA	+	-

Available plates

- AFRC = Africa
- ANTA = Antarctica
- ARAB = Arabia
- AUST = Australia
- CARB = Caribbean
- COCO = Cocos
- EURA = Eurasia
- INDI = India
- JUFU = Juan de Fuca
- NAZC = Nazca
- NOAM = North America
- SOAM = South America
- PCFC = Pacific
- PHIL = Philippine

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230513C \$Y+0=2023 \$S+0=1330 File: C:\GPSUSER54\PAN\EDITPLD.INP

Cambodia is on the Sunda plate.

However, Bernese chooses the Eurasian plate.

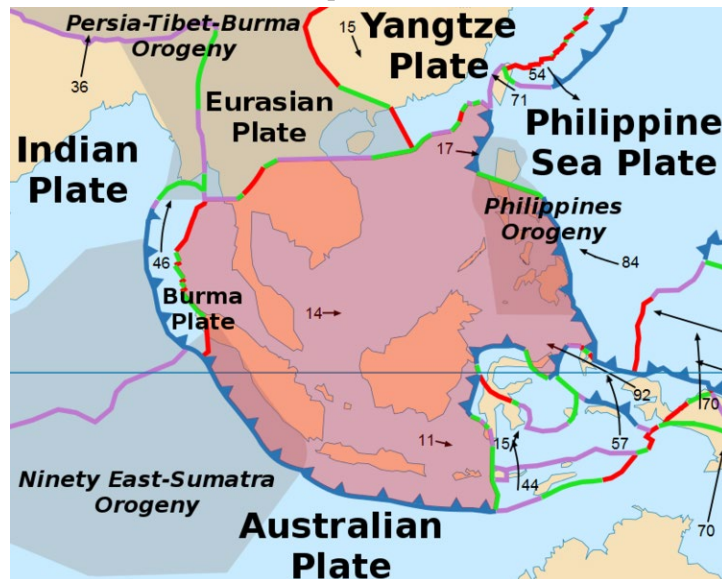


Fig.1 Sunda Plate

https://en.wikipedia.org/wiki/Sunda_Plate#:~:text=The%20Sunda%20Plate%20is%20a%20minor%20tectonic%20plate,movement%20at%2010%20mm%2Fyr%20eastward%20relative%20to%20Eurasia

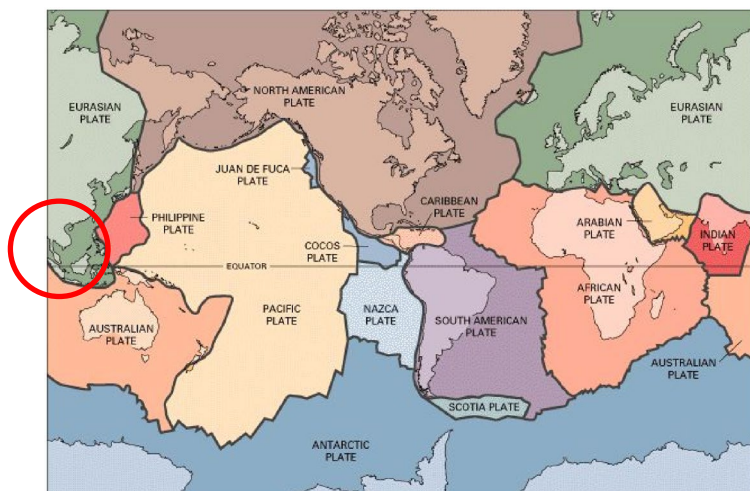
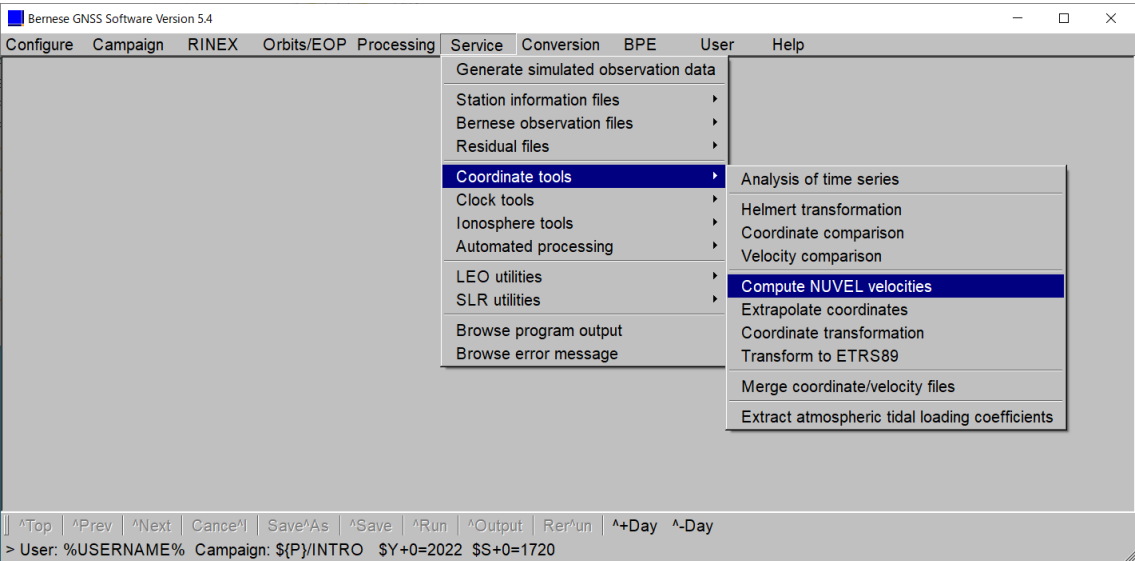


Fig.2 Plate for Bernese

<http://ftp.aiub.unibe.ch/BSWUSER52/STA/plates.pdf>

7.9. Observation point velocities file

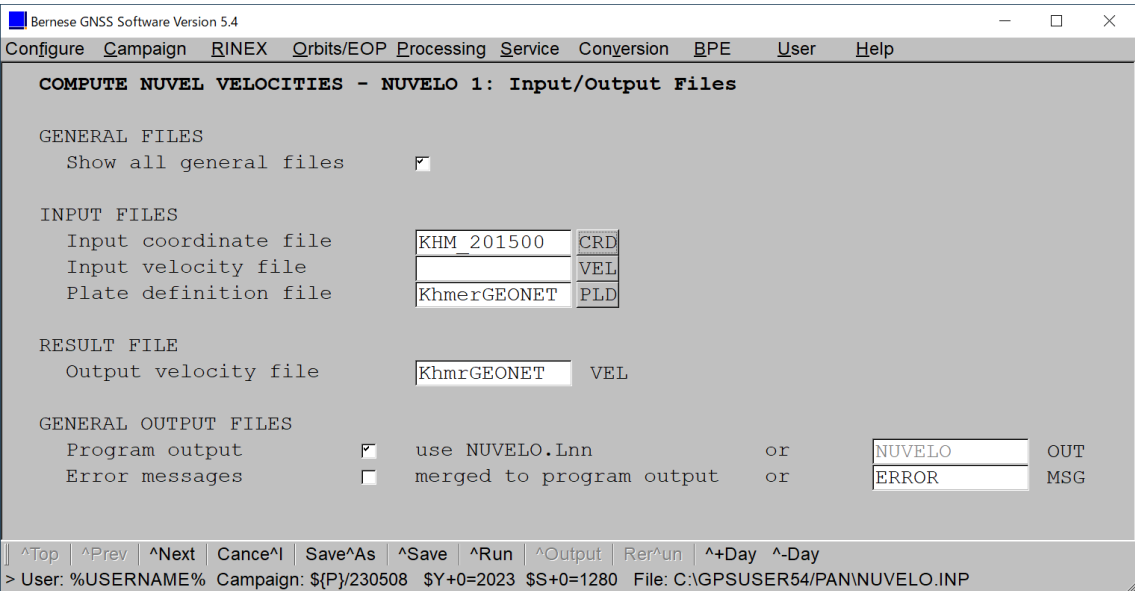
Click [Compute NUVEL velocities] to display the submenu.



Select Input coordinate file and Plate definition file.

Enter the file name of the Output velocity file.

Click [^Next].



Click [^Next].

The screenshot shows the 'NUVELO 1.1: General Files' dialog box in the Bernese GNSS Software Version 5.4. The dialog has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into three sections: 'GENERAL INPUT FILES', 'MENU SETTINGS', and 'TEMPORARY FILES'. In 'GENERAL INPUT FILES', 'General constants' is set to 'CONST' and 'Geodetic datum' is set to 'DATUM', both with 'BSW' buttons. In 'MENU SETTINGS', 'Selected campaign' is '\${P}/INTRO', 'Selected session' is 'year 2022 session 1720', and 'Session table' is '\${P}/INTRO\GEN\SESSIONS.SES'. In 'TEMPORARY FILES', 'Scratch file' is 'NUVELO\$J' with an 'SCR' button. At the bottom, there is a status bar with a menu of shortcuts and a command line showing the current user, campaign, session, and file path.

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

NUVELO 1.1: General Files

GENERAL INPUT FILES

General constants

Geodetic datum

MENU SETTINGS

Selected campaign \${P}/INTRO

Selected session year 2022 session 1720

Session table \${P}/INTRO\GEN\SESSIONS.SES

TEMPORARY FILES

Scratch file

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\NUVELO.INP

Enter Title and select [ALL] for Select station for output file.

Click [^Run].

The screenshot shows the 'NUVELO 2: Options' dialog box in the Bernese GNSS Software Version 5.4. The dialog has the same menu bar as the previous one. The main area has three sections: 'TITLE', 'STATION SELECTION', and 'OPTIONS'. 'TITLE' has a text field with 'khmwe GEONET IGS20'. 'STATION SELECTION' has 'Select stations for output file' set to 'ALL' in a dropdown menu, and 'Stations for velocity computation' with an empty text field and a button. 'OPTIONS' has 'Velocity model' set to 'NUVEL1A' in a dropdown menu. The status bar at the bottom is identical to the previous dialog.

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

NUVELO 2: Options

TITLE

STATION SELECTION

Select stations for output file

Stations for velocity computation

OPTIONS

Velocity model

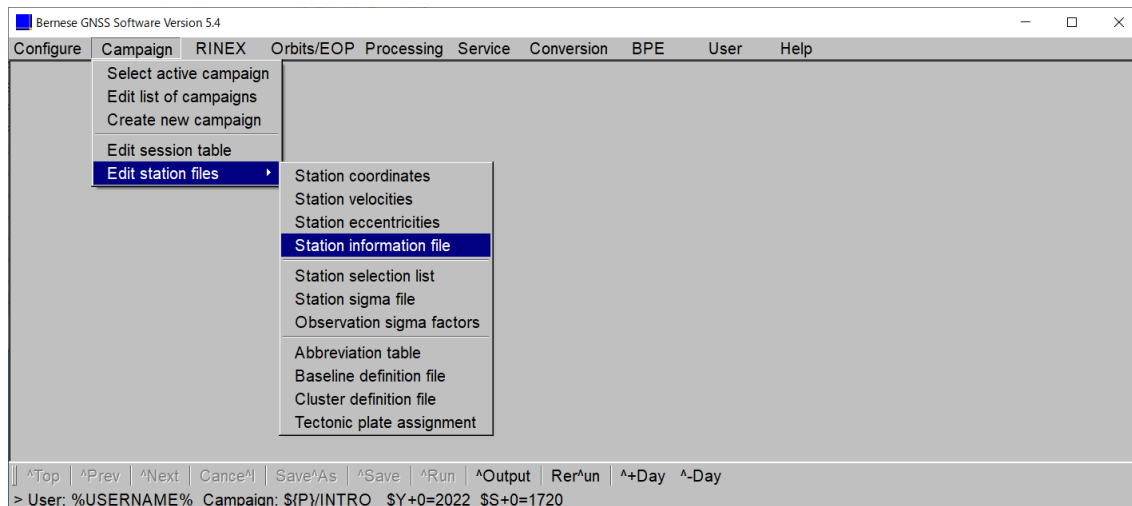
^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\NUVELO.INP

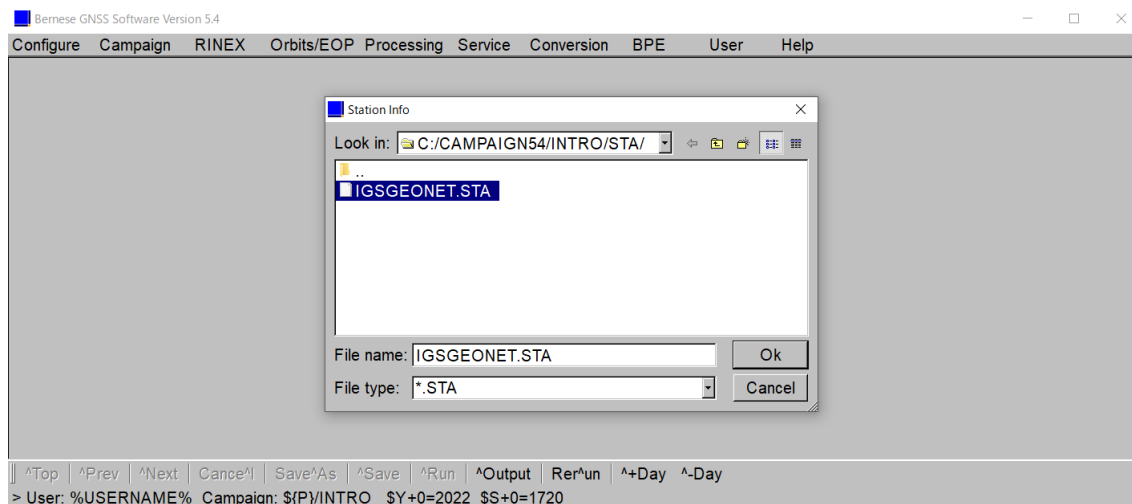
7.10. Station information file

Copy the sample file of the station information file (KHM_20231280.STA) to [STA] folder of the campaign.

Click [Station information file] to display the submenu.



Select the sample file and click [OK].



(1) Type 001

Enter Title, Station name, From, To and Old station name.

Click [^Next].

EDIT STATION INFORMATION FILE - EDITSTA 1: Renaming of Stations (TYPE 001)

Filename: C:/CAMPAIGN54/230508/STA/KHM_20231280.STA
Title: STATION INFORMATION FILE FOR BERNESE GNSS SOFTWARE 5.4
Technique: GNSS

Station name	Flag	from yyyy mm dd hh mm ss	to yyyy mm dd hh mm ss	Old station name	Remark
KND1	001	2023 05 08 00 00 00	2023 05 08 23 59 59	KND1	
KSP1	001	2023 05 08 00 00 00	2023 05 08 23 59 59	KSP1	
PNH1	001	2023 05 08 00 00 00	2023 05 08 23 59 59	PNH1	
SIE1	001	2023 05 08 00 00 00	2023 05 08 23 59 59	SIE1	
STG1	001	2023 05 08 00 00 00	2023 05 08 23 59 59	STG1	
ANMG	001	2023 05 08 00 00 00	2023 05 08 23 59 59	ANMG	
CMUM	001	2023 05 08 00 00 00	2023 05 08 23 59 59	CMUM	
CUSV	001	2023 05 08 00 00 00	2023 05 08 23 59 59	CUSV	
HKSL	001	2023 05 08 00 00 00	2023 05 08 23 59 59	HKSL	
PTAG	001	2023 05 08 00 00 00	2023 05 08 23 59 59	PTAG	
SIN1	001	2023 05 08 00 00 00	2023 05 08 23 59 59	SIN1	

Navigation: ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
Status: > User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PA\EDITSTA.INP

Station name: Station name for Bernese

From: Start time of observation

To: End time of observation

Old station name: Observation point name entered in [Marker Name] of RINEX file

Select PCV correction file.

Enter Station name, From, To, Receiver type, Receiver serial number, Antenna type and Antenna serial number.

Click [^Next].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

EDITSTA 2: Station Information (TYPE 002)

Antenna corrections file to check the entries

from to

Station name	Flag	yyyy mm dd hh mm ss	yyyy mm dd hh mm ss	Receiver type	Receiver serial nbr	Rec #	Antenna typ
KND1	001	2022 06 14 00 00 00	2022 06 21 23 59 59	TRIMBLE ALLOY	6135R40092		TRM159800.0
KSP1	001	2022 06 14 00 00 00	2022 06 21 23 59 59	TRIMBLE ALLOY	6139R40020		TRM159800.0
PNH1	001	2022 06 14 00 00 00	2022 06 21 23 59 59	TRIMBLE ALLOY	6139R40033		TRM159800.0
SIE1	001	2022 06 14 00 00 00	2022 06 21 23 59 59	TRIMBLE ALLOY	6140R40026		TRM159800.0
STG1	001	2022 04 14 00 00 00	2022 06 21 23 59 59	TRIMBLE ALLOY	6135R40098		TRM159800.0
ANMG	001	2022 04 14 00 00 00	2022 06 21 23 59 59	TRIMBLE NETR9	5423R48722		JAVRINGANT_1
CMUM	001	2022 04 14 00 00 00	2022 06 21 23 59 59	TRIMBLE NETR9	5423R48734		JAV GRANT-G
CUSV	001	2022 04 14 00 00 00	2022 06 21 23 59 59	JAVAD TRE_3 DELTA	01926		JAVRINGANT_1
HKSL	001	2022 04 14 00 00 00	2022 06 21 23 59 59	LEICA GR50	1870250		LEIAR25.R4
PTAG	001	2022 04 14 00 00 00	2022 06 21 23 59 59	LEICA GR50	1871663		LEIAR25.R4
SIN1	001	2022 04 14 00 00 00	2022 06 21 23 59 59	TRIMBLE NETR9	5133K77754		LEIAR25.R3

^Top ^Prev ^Next Cancel SaveAs Save Run Output ReRun ^*Day ^Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\EDITSTA.INP

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

Antenna eccentricity

Antenna type	Antenna serial nbr	Ant #	North (m)	East (m)	Up (m)	Azimuth	Long name	Description	Remark
TRM159800.00	SCIS 6201333025		0.0000	0.0000	0.0000				
TRM159800.00	SCIS 6201333023		0.0000	0.0000	0.0000				
TRM159800.00	SCIS 6202333035		0.0000	0.0000	0.0000				
TRM159800.00	SCIS 6202333054		0.0000	0.0000	0.0000				
TRM159800.00	SCIS 6201333020		0.0000	0.0000	0.0000				
JAVRINGANT_DM	SCIS 00449		0.0000	0.0000	0.0000				
JAV GRANT-G3T	NONE 01320		0.0000	0.0000	0.0000				
JAVRINGANT_DM	NONE 00918		0.0000	0.0000	0.0000				
LEIAR25.R4	LEIT 725194		0.0000	0.0000	0.0083				
LEIAR25.R4	LEIT 726458		0.0000	0.0000	0.0000				
LEIAR25.R3	LEIT 09330041		0.0000	0.0000	0.0000				

^Top ^Prev ^Next Cancel SaveAs Save Run Output ReRun ^*Day ^Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\EDITSTA.INP

(3) Type 003

Click [^Next].

The screenshot shows the 'EDITSTA 3: Handling of Station Problems (TYPE 003)' dialog box. It features a table with columns: Station name, Flag, from (yyyy mm dd hh mm ss), to (yyyy mm dd hh mm ss), and Remark. The 'from' and 'to' columns are currently empty. Below the table is a status bar with menu options: ^Top, ^Prev, ^Next, Cance^l, Save^As, ^Save, ^Run, ^Output, Rer^un, ^+Day, ^-Day. The status bar also displays: > User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PA\EDITSTA.INP.

(4) Type 004

Click [^Next].

The screenshot shows the 'EDITSTA 4: Station Coordinate and Velocity Constraints (TYPE 004)' dialog box. It features a table with columns: Station name 1, Station name 2, Relative constr position (North (m), East (m), Up (m)), and Relative constr velocity (North (m), East (m), Up (m)). The 'Station name 1' and 'Station name 2' columns are currently empty. Below the table is a status bar with menu options: ^Top, ^Prev, ^Next, Cance^l, Save^As, ^Save, ^Run, ^Output, Rer^un, ^+Day, ^-Day. The status bar also displays: > User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PA\EDITSTA.INP.

(5) Type 005

Click [^Save].

The screenshot shows the 'EDITSTA 5: Marker Type (TYPE 005)' dialog box. It features a table with columns: Station name, Flag, from (yyyy mm dd hh mm ss), to (yyyy mm dd hh mm ss), Marker type, and Remark. The 'from' and 'to' columns are currently empty. Below the table is a status bar with menu options: ^Top, ^Prev, ^Next, Cance^l, Save^As, ^Save, ^Run, ^Output, Rer^un, ^+Day, ^-Day. The status bar also displays: > User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PA\EDITSTA.INP.

You can also create it using the text editor.

You can also use the existing file.

7.11. Observation point abbreviation file

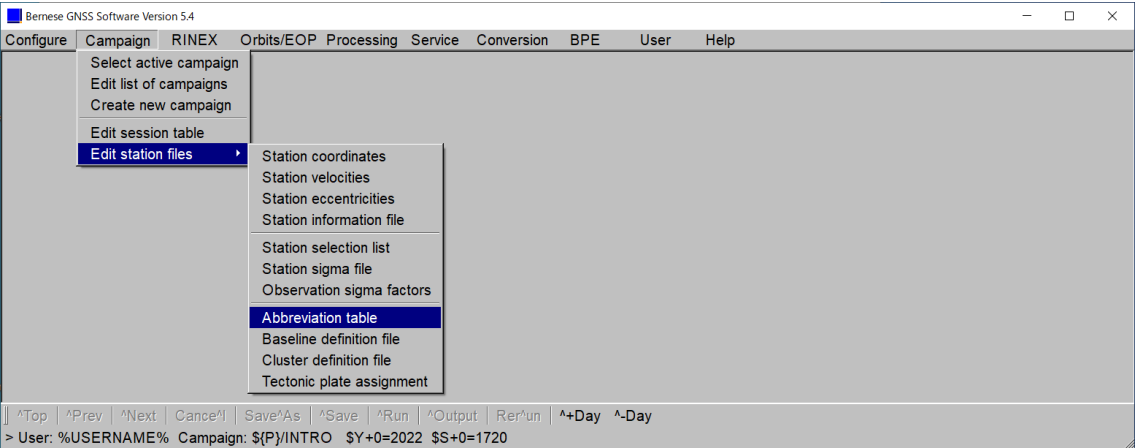
Create the observation point abbreviation file using a text editor.

Khmer GEONET IGS20		16-MAY-23 14:55	
Station name	4-ID	2-ID	Remark
*****	****	**	*****
ANMG	0001	01	
CMUM	0002	02	
CUSV	0003	03	
HKSL	0004	04	
PTAG	0005	05	
SIN1	0006	06	
KND1	0007	07	
KSP1	0008	08	
PNH1	0009	09	
SIE1	0010	10	
STG1	0011	11	

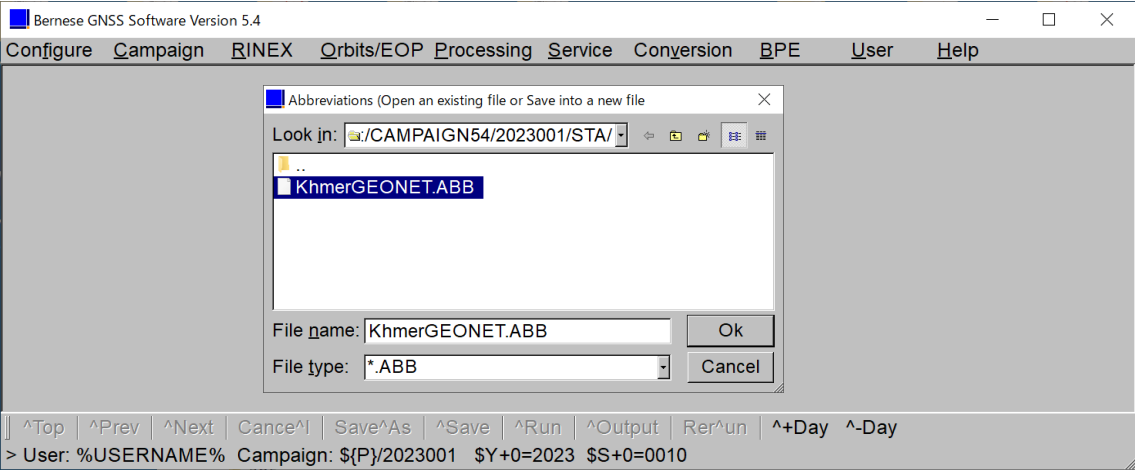
Copy the observation point abbreviation file [KhmerGEONET.ABB] to [STA] folder of the campaign.

CAMPAIGN54	名前	更新日時
2023001		
ATM	KH201500.CRD	2023/07/07 17:39
BPE	KH2023001.STA	2023/07/20 14:44
GEN	KhmrGEONET.PLD	2023/07/14 18:49
GRD	KhmrGEONET.VEL	2023/07/20 14:14
OBS	KhmerGEONET.ABB	2023/07/20 14:48
ORB		
ORX		
OUT		
RAW		
SOL		
STA		

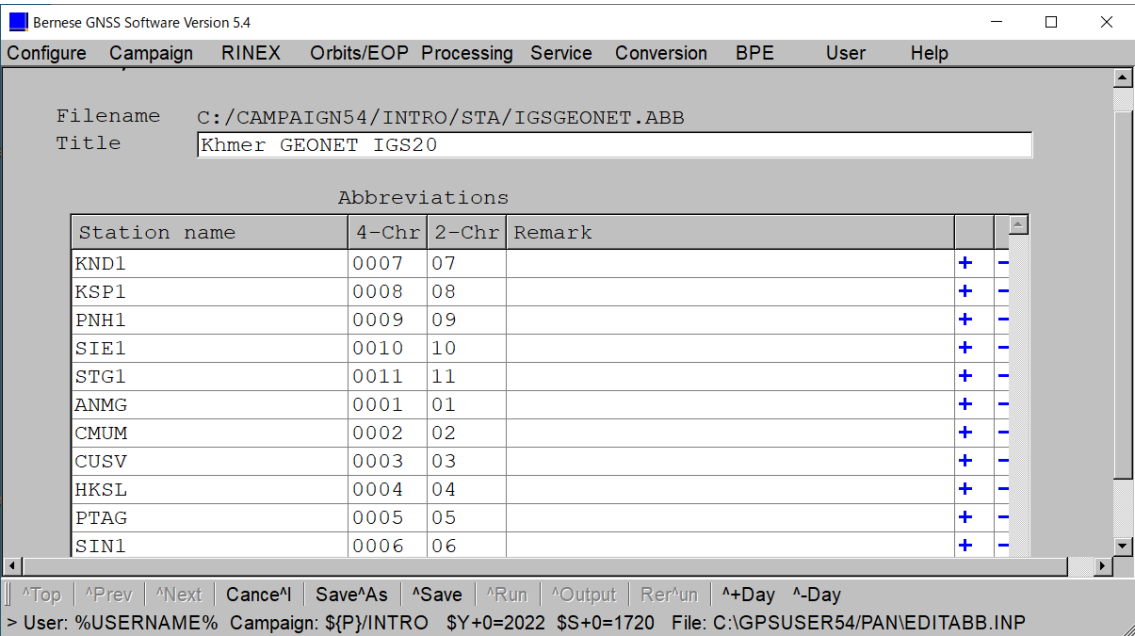
Click [Abbreviation table] to display the submenu.



Select the sample file and click [OK].



Enter Title Station name, Abbreviation (4-Chr) and Abbreviation (2-Chr).
Click [^Save].



You can also create it using the text editor.

You can also use the existing file.

7.12. Ocean tide parameter file

Order the Ocean tide loading provider to calculate by email. You can receive the results by email.

Provider site: <http://holt.oso.chalmers.se/loading/>

Select ocean tide model

A brief description of the ocean tide models can be found [here](#). **Note: Default model is a fake to bar spammers**

FES2014b ▼

What type of loading phenomenon do you consider

- ☒ vertical and horizontal displacements
- ☐ gravity (nm/s^2) and tilt (nrad)

using Greens function

- ☒ elastic (Farrell, 1972)
- ☐ visco-elastic (STW105)

If you have selected vertical and horizontal displacements, you can correct for the [centre of mass motion of the Earth due to the ocean tides](#).

(**NO** means your frame origin is in the solid earth centre,
YES that it is in the joint mass centre of solid earth and ocean.)

Do you want to correct your loading values for the motion?

- ☒ NO
- ☐ YES

Want a plot? Option is available for the ocean models with a grid constant $\geq (1/8)^\circ$

The plots show the grid refinement in the near-field and also the resolution of the coastline.

They are generated for each site that involves the loading post-processor. Notice "Computed by OLMPP" in the result file.

- ☒ NO
- ☐ YES

[Fetch plot here](#) after you received the results. Look for your user name: *name-olapp1.png* *name-olapp2.png* etc.

Also [see the Caption common to all maps](#).

What kind of output format is required?

- ☒ BLQ(normal)
- ☐ HARPOS(... RECENTLY ADDED FEATURE ...)

Gravity loading parameters for [TSOFT](#) and [g-Software](#) can be converted from BLQ with [olgt.pl](#)

Where are your stations?

In the following form, up to one hundred stations can be entered, each station on a separate line.

In the case of displacements, the height of the station above sea level is irrelevant; it is not necessary to specify this parameter at all.

Name of station_____	Longitude (deg)	Latitude (deg)	Height (m)	OR
Name of station_____	X (m)	Y (m)	Z (m)	
// Records starting with // are treated as comments				
//ABCD	4274689.360	2104509.140	4226072.801	
//Onsala	11.9264	57.3958	0.0000	
//ruler.....b<.....<.....<.....				
ANMG	-1270826.89380	6242631.33340	307792.42240	
CMUM	-938078.34810	5968373.98630	2038404.32190	
CUSV	-1132914.06460	6092528.56900	1504693.21270	
HKSL	-2393382.91750	5393860.99760	2412592.23210	
PTAG	-3184318.71050	5291065.49980	1590418.24380	
STW1	-1507972.65380	6195615.88690	148468.03430	
KND1	-1619492.94400	6040715.07000	1247864.90000	
KSP1	-1572714.38600	6050448.84600	1260501.89200	
PNH1	-1803672.47300	6038739.32500	1277314.62100	
STE1	-1490303.89300	6024644.81700	1465891.13600	
STG1	-1706798.81200	5963096.21200	1481479.65100	

Our fixed column layout: [Show example](#)

No blankspace to the left.

24 characters for the station, 25th column blank, then three numerical fields with a width of 16 characters each, no TAB characters please! Each value MUST carry one floating-point dot followed by at least one decimal, but three decimal places (case XYZ) or five (case degrees) are more than sufficient.

On a UNIX/Linux system you can produce station lines for copy-and-paste with

```
printf "%-24s %15.3f %15.3f %15.3f\n" $name $x $y $z
printf "%-24s %15.5f %15.5f %15.5f\n" $name $lon $lat $het
```

What is your e-mail address?

Note: Because of a large amount of misuse we deny requests with return addresses at a couple of notorious domains.

Drift messages, planned outages of service

comments
just for here
and now

Name of station_____	Longitude (deg)	Latitude (deg)	Height (m)	OR
Name of station_____	X (m)	Y (m)	Z (m)	
// Records starting with // are treated as comments				
//ABCD	4274689.360	2104509.140	4226072.801	
//Onsala	11.9264	57.3958	0.0000	
//ruler.....b<.....<.....<.....				
uscl	1762489.87752	-5027632.73924	-3496009.24080	
FBAQ	41732M001	2073316.48913	-5621607.72877	-2182074.32127
SANT	41705M003	1769693.47659	-5044574.30863	-3468320.86540
Onsala	11.9264	57.3958	0.0000	

two words at maximum gully

decimal points mandatory

X Y Z and height in metres: two positions after the decimal point yield sufficient precision

Longitude and latitude in degrees: four positions after the decimal point are required

Create the ocean tide parameter file [XXXXX.BLQ] using a text editor (XXXXX can be named arbitrarily).

[CMC Value] is not entered in the result.

Follow the link below to display [CMC Value].

Enter [CMC Value] by referring to [EXAMPLE.BLQ].

If you have selected vertical and horizontal displacements, you can correct for the [centre of mass motion of the Earth due to the ocean tides](#).
(**NO** means your frame origin is in the solid earth centre,
YES that it is in the joint mass centre of solid earth and ocean.)
Do you want to correct your loading values for the motion?
☒ **NO**

You can obtain CMC parameters in the following two variants

1. **CMC** with a correction for tidal mass conservation (that was the standard upto July 29, 2011)
2. **CMC_MIB** without ('_MIB' signifying the mass imbalance implied)

You can see the adjustment (uniform, co-oscillating slab with cos and sin components) in the [collection of mass imbalances](#). The format is explained as follows:

File	Date	Size
FES2004.cmc	23-Dec-2013 13:22	1.3K
FES2012.cmc	01-Oct-2019 14:07	1.3K
FES2014b.cmc	25-Jan-2018 22:34	1.3K
GOT00.2.cmc	23-Dec-2013 13:22	1.3K
GOT4.7.cmc	23-Dec-2013 13:22	1.3K
GOT4.8.cmc	10-Sep-2018 22:42	1.3K
GOT99.2b.cmc	23-Dec-2013 13:22	1.3K

(a, 1p, t42, 3(2x, 2e12, 4))

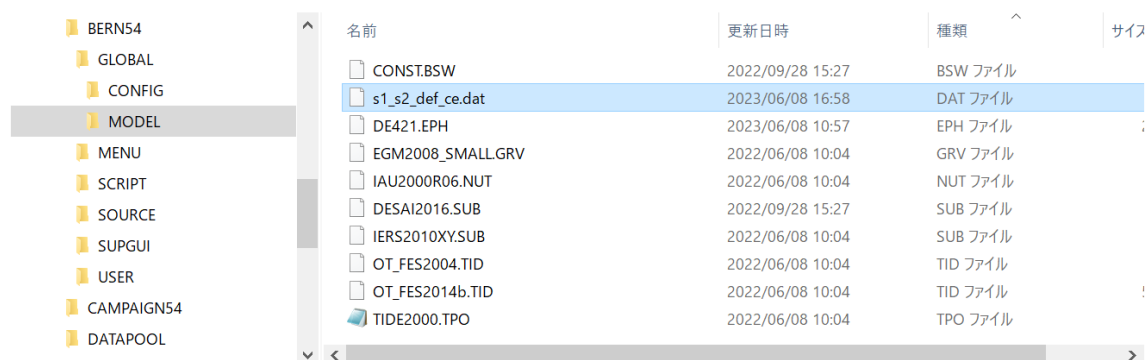
M2	NCDF_FES2014b	-1.2626E-03	-1.6550E-03	-1.3193E-03	8.8426E-04	1.2647E-03	1.5946E-04
S2	NCDF_FES2014b	-2.9698E-04	-6.1631E-04	-7.2190E-04	-3.2153E-04	-3.5852E-05	4.1721E-04
N2	NCDF_FES2014b	-3.9924E-04	-2.7407E-04	-1.4602E-04	1.8052E-04	1.9625E-04	-1.3358E-04
K2	NCDF_FES2014b	-8.5400E-05	1.4051E-04	-1.9055E-04	-1.4918E-04	-8.9350E-05	1.3621E-04
K1	NCDF_FES2014b	-1.2941E-03	4.6763E-03	-2.4561E-03	-1.1950E-03	-1.0583E-03	-2.0408E-03
O1	NCDF_FES2014b	-3.4676E-04	3.4427E-03	-1.4406E-03	-3.9247E-04	-1.1367E-03	-8.0202E-04
P1	NCDF_FES2014b	-3.2342E-04	1.5458E-03	-7.9517E-04	-3.3337E-04	-3.1199E-04	-6.1169E-04
O1	NCDF_FES2014b	-5.1757E-05	5.9627E-04	-2.6681E-04	-4.3339E-05	-2.5553E-04	-5.2304E-05
Mf	NCDF_FES2014b	-5.0623E-04	-6.5222E-05	-2.6106E-04	3.8508E-04	-8.1040E-05	9.1185E-05
Mm	NCDF_FES2014b	-2.7837E-04	1.5729E-06	5.0833E-05	1.9306E-04	-3.8053E-05	1.5211E-05
Ssa	NCDF_FES2014b	-2.2349E-04	-6.5222E-07	1.8577E-04	2.1034E-05	1.5364E-05	1.4517E-05

Copy the ocean tide parameter file to [STA] folder of the campaign.

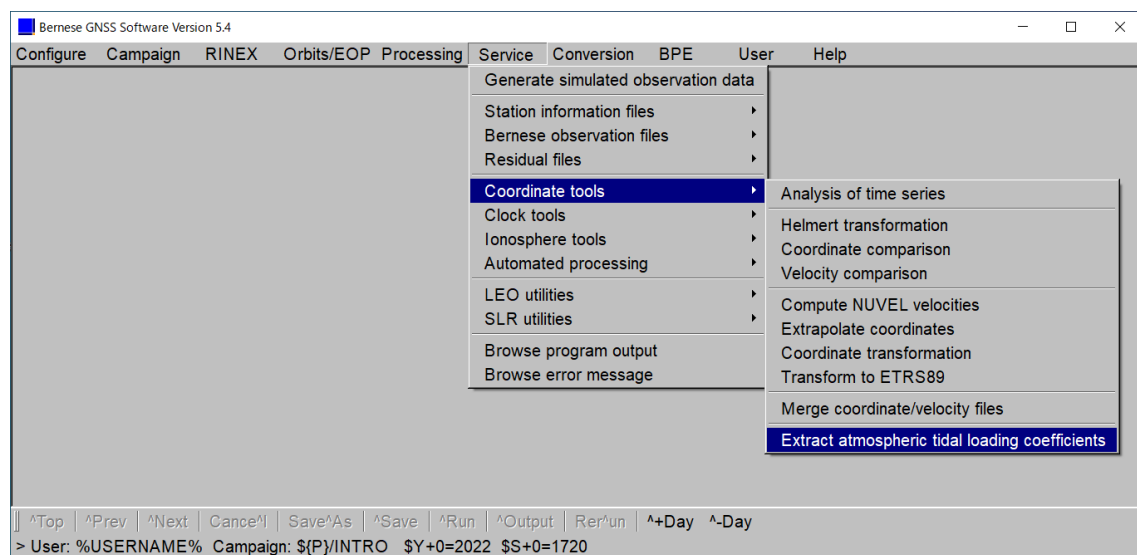
名前	更新日時
KH201500.CRD	2023/07/07 17:39
KH2023001.STA	2023/07/20 14:44
KhmerGEONET.ABB	2023/07/20 14:52
KhmrGEONET.PLD	2023/07/14 18:49
KhmrGEONET.VEL	2023/07/20 14:14
KhmerGEONET.BLQ	2023/07/20 18:39

7.13. Atmospheric tide parameter file

Copy [S1_s2_def_ce.dat] file to [STA] folder of [C:/BERN54/GLOBAL/MODEL].



Click [Extract atmospheric tidal loading coefficients] to display the submenu.



Select Input coordinate file.

Enter the file name of the Output S1/S2 loading coefficient file.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

EXTRACT ATMOSPHERIC TIDAL LOADING COEFFICIENTS - GRDS1S2 1: Filenames

GENERAL FILES

Show all general files ☒

INPUT FILES

S1/S2 loading grid Reference

Input coordinate file

RESULT FILE

S1/S2 loading coeff. ATL

GENERAL OUTPUT FILES

Program output ☒ use GRDS1S2.Lnn or OUT

Error messages ☐ merged to program output or MSG

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\GRDS1S2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GRDS1S2 1.1: General Files

GENERAL INPUT FILES

Geodetic datum

MENU SETTINGS

Selected campaign \${P}/INTRO

Selected session year 2022 session 1720

Session table \${P}/INTRO\GEN\SESSIONS.SES

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GRDS1S2.INP

Enter Title and select [RAY PONTE] for Coefficients form.
Click [^Run].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GRDS1S2 2: Options

TITLE

ADD S1/S2 CENTER OF MASS CORRECTIONS:

Coefficients from Name

CMC-corrections:	X (m)	Y (m)	Z (m)
S1: cos			
sin			
S2: cos			
sin			

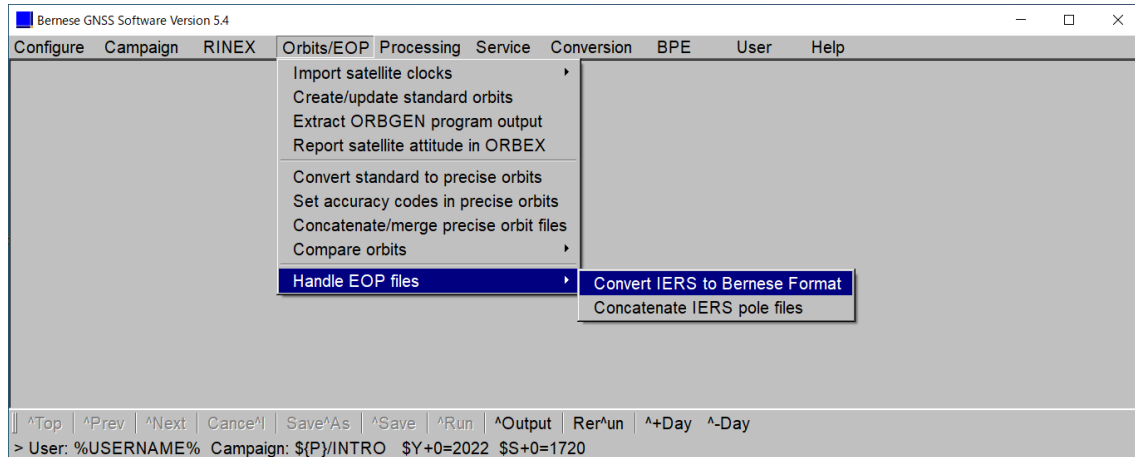
^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230510 \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\GRDS1S2.INP

8. Pole and Orbit Preparation

8.1. Convert IGS/IERS pole file (POLUPD)

Click [Convert IERS to Bernese Format] to display the submenu.



Select Foreign formatted ERP files. Change the extension to [.IEP].

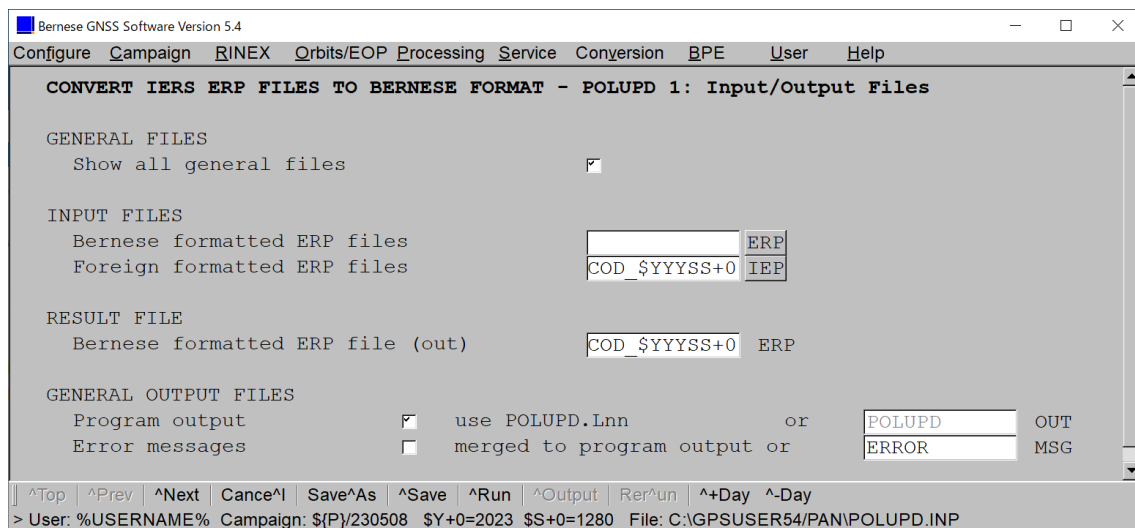
Enter the file name of Bernese formatted ERP file (out).

The name of the Bernese formatted ERP file is [COD_YYYYSS+0.ERP].

YYYY: Year

SS+0: Day of year (e.g. [1760] is 25th June)

Click [^Next].



Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

POLUPD 1.1: General Files

GENERAL INPUT FILES

Pole offset coefficients

GPS-UTC time difference

MENU SETTINGS

Selected campaign

Selected session

Session table

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\POLUPD.INP

Enter Title.

Select Nutation mode [IAU2000R06], [DESA2016] and Sub daily pole mode [IERS2010 V1.2.0].

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

POLUPD 2: Options

HEADER INFORMATION

Title

Nutation model

Subdaily ERP model

Meanpole model

BULLETIN B AS INPUT

Use 1 or 5 day values

OPTIONS

Use ERP rates ☒

Allow double epochs ☒

Include nutation offsets ☒

Use time window ☒

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\POLUPD.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

POLUPD 3: Time Window

TIME WINDOW

☐ Defined by Year and Session identifier

Year Session

☐ Defined by Start and End times

	yyyy mm dd	hh mm ss		yyyy mm dd	hh mm ss
Start	\$YMD_STR+0	00 00 00	End	\$YMD_STR+0	23 59 59

◀ ▶

^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\POLUPD.INP

8.2. Generate Orbit Files (ORBGEN)

Download [SATELLIT_I20.SAT] file and [SAT_2023.CRX] file from the download site.

Download site: [Index of /BSWUSER54/CONFIG/ \(unibe.ch\)](http://unibe.ch/BSWUSER54/CONFIG/)

BOXWING.MAC	28-Jul-2023	22:45	66K
DATUM.BSW	28-Jul-2023	22:45	11K
FREQINFO.FRQ	28-Jul-2023	22:45	17K
GPSUTC.BSW	28-Jul-2023	22:45	1116
OBSERV.SEL	28-Jul-2023	22:45	3040
SATELLIT_I14.SAT	28-Jul-2023	22:45	207K
SATELLIT_I20.SAT	28-Jul-2023	22:45	209K
SATELLIT_M20.SAT	28-Jul-2023	22:45	208K
SAT_2019.CRX	28-Jul-2023	22:45	49K
SAT_2020.CRX	28-Jul-2023	22:45	42K
SAT_2021.CRX	28-Jul-2023	22:45	46K
SAT_2022.CRX	28-Jul-2023	22:45	29K
SAT_2023.CRX	28-Jul-2023	22:45	29K
SAT_GNSS.CRX	28-Jul-2023	22:45	10K

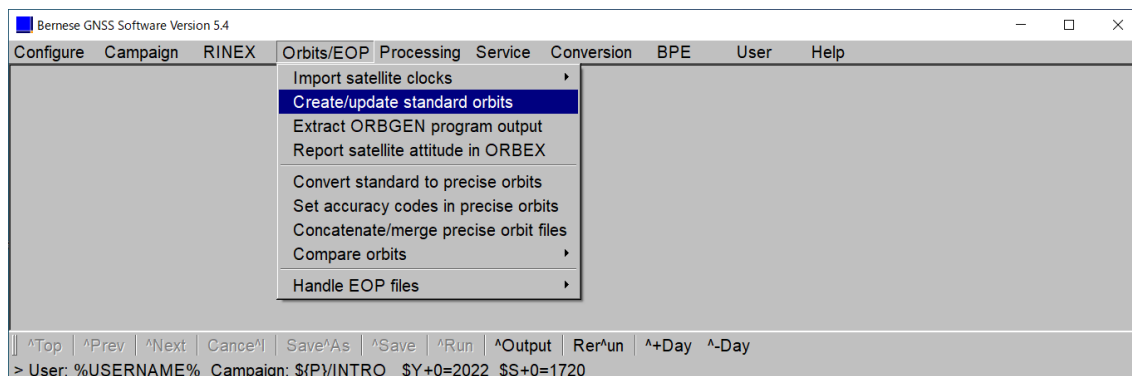
Copy [SATELLIT_I20.SAT] file to [C:/BERN54/GLOBAL/CONFIG] folder.

名前	更新日時
SAT_2017.CRX	2022/06/08 10:04
SAT_2018.CRX	2022/06/08 10:04
SAT_2019.CRX	2022/06/08 10:04
SAT_2020.CRX	2022/06/08 10:04
SAT_2021.CRX	2022/06/08 10:04
SAT_2022.CRX	2022/10/19 15:13
SAT_GNSS.CRX	2022/09/28 15:27
SATELLIT_I14.SAT	2022/09/16 8:15
SATELLIT_M20.SAT	2022/09/28 15:27
SATELLIT_R20.SAT	2022/10/14 7:52
SATELLIT_I20.SAT	2023/07/24 11:14

Copy [SAT_2023.CRX] file to [C:/BERN54/GLOBAL/CONFIG] folder.

名前	更新日時
SAT_2017.CRX	2022/06/08 10:04
SAT_2018.CRX	2022/06/08 10:04
SAT_2019.CRX	2022/06/08 10:04
SAT_2020.CRX	2022/06/08 10:04
SAT_2021.CRX	2022/06/08 10:04
SAT_2022.CRX	2022/10/19 15:13
SAT_2023.CRX	2022/10/19 15:13
SAT_GNSS.CRX	2022/09/28 15:27
SATELLIT_I14.SAT	2022/09/16 8:15

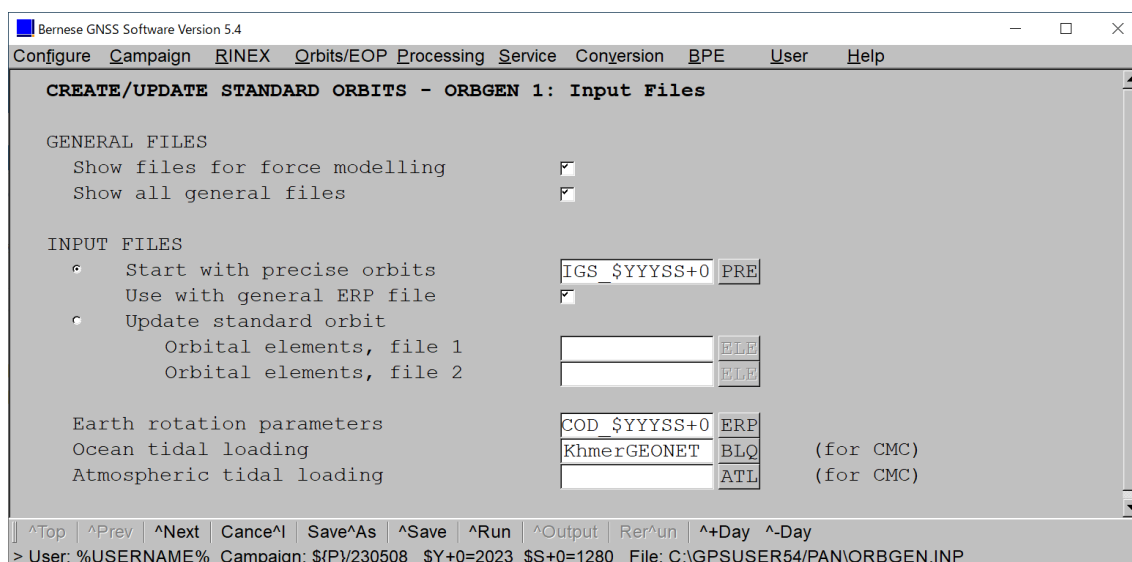
Click [Create/update standard orbits] to display the submenu.



Select Input files.

For Earth rotation parameters file, specify the file created in section 8.1.

Click [^Next].



Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ORBGEN 1.1: Files for Force Modelling

INPUT FILES FOR GRAVITATIONAL FORCE MODELLING

Coeff. of Earth potential	GM2008 SMALL	GRV
Solid Earth tides	TIDE2000	TPO
Ocean tides file	OT FES2014b	TID
Planetary ephemeris	DE421	EPH

INPUT FILES FOR NON-GRAVITATIONAL FORCE MODELLING

Attitude for LEO satellites		ATT
Satellite macro model	BOXWING	MAC
Albedo reflectivity		EXT
Albedo emissivity		EXT

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ORBGEN 1.2: General Files

GENERAL INPUT FILES

General constants	CONST	BSW
Satellite problems	SAT_\$Y+0	CRX
Geodetic datum	DATUM	BSW
Satellite information	SATELLIT I20	SAT
☐ Error if not in satellite information file		
Subdaily ERP model	DESAI2016	SUB
Nutation model	IAU2000R06	NUT
GPS-UTC time difference	GPSUTC	BSW
F10.7 flux index		FLX
☐ Use defaults (FLX=120,AP=15)		

MENU SETTINGS

Selected campaign	\${P}/2023001		
Selected session	year 2023	session	0010
Session table	\${P}/2023001\GEN\SESSIONS.SES		

TEMPORARY FILES

Scratch files	ORBGEN\$J	SCR	ORBGEN\$J	SC2
---------------	-----------	-----	-----------	-----

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Next]

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ORBGEN 2: Result and Output Files

RESULT FILES

Standard orbits

COD_ \$YYYYSS+0

STD

Radiation pressure coeff.

RPR

Residual file

RES

OUTPUT FILES

Summary file

LST

Summary file for IGS-ACC

ORB_ \$YYYYSS+0

LST

Plot file of residuals

PLT

GENERAL OUTPUT FILES

Program output

☐

use ORBGEN.Lnn

or

ORB_ \$YYYYSS+0

OUT

Error messages

☐

merged to program output

or

ERROR

MSG

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ORBGEN 3.1: General Options

TITLE

Khmer GEONET IGS20

TIME FRAME, POTENTIAL AND TIDAL CORRECTIONS

Time frame

GPS

Earth potential degree

12

Ocean tides max degree

8

Apply CMC correction

OTL:

☒

ATL:

☐

Apply antenna offset

☐

SATELLITE SELECTION

ALL SATELLITES

☒ GPS

☒ GLONASS

☐ Galileo

☐ SBAS

☐ BeiDou

☐ QZSS

The satellites in the following list will be

EXCLUDED

Satellite list

EXPERIMENTAL OPTIONS

True attitude modelling of satellites

☒

Print beta angle and attitude switch info to STDOUT

☐

Print Yaw angle to SYSOUT file

☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ORBGEN 3.2: A priori Radiation Pressure Model

NON-CONSERVATIVE FORCES

Solar radiation pressure

NONE

☒ GPS☒ GLONASS☒ Galileo☒ SBAS☒ BeiDou☒ QZSS

Apply partial shadow for LEO

☐

Earth Radiation Pressure

Analytical

☒ Reflected radiation☒ Emitted radiation☒ Numerical interpolation☒ Navigation Antenna Thrust☒ Thermal radiation☒

(defined by macromodel)

Rotation of solar panel

ATT

Only for Jason-2/3

Atmospheric force for LEO

☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ORBGEN 3.3: Numerical Integration

PRINT RESIDUALS

NO

☐ In RSW Coordinates

NUMERICAL INTEGRATION

4

Number of iterations

EQUATION OF MOTION

10

Polynomial degree

00 05 00

Length of interval

(hh mm ss)

VARIATIONAL EQUATIONS

12

Polynomial degree

01 00 00

Length of interval

(hh mm ss)

0

Additional sets

(only relevant for LEO orbits)

☐ Use extended RPR Format

(only intended for LEO orbits)

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Next].

ORBGEN 4: Parameter Selection

DYNAMICAL ORBIT PARAMETERS

Apart from six osculating elements, estimate the following parameters:

Default model ECOM2

Model-specific (default) setup of empirical parameters ☒

Manual selection of parameters and their scaling (for output only):

PAR1	☐	1.0E+7	PAR4	☐	1.0E+7	PAR7	☐	1.0E+7
PAR2	☐	1.0E+7	PAR5	☐	1.0E+7	PAR8	☐	1.0E+7
PAR3	☐	1.0E+7	PAR6	☐	1.0E+7	PAR9	☐	1.0E+7

MODEL	ECOM	ECOM2	ECOM2-D1	ECOM2-YD1	ECOM-TB	ECOM-TBM	RSW	DRSW
PAR1	E30	E30	E30	E30	T30C1b	T30C1b	L30	E30
PAR2	E20	E20	E20	E20	T20S3b	T20S3b	L20	L20
PAR3	E10	E10	E10	E10	T1S2uC1b	T1S2uC1b	L10	L10
PAR4	E3C1u	E3C2u	E3C2u	E3C2u	T3C2uC1b	T3C2uC1b	L3C1u	L3C1u
PAR5	E2C1u	E3C4u	E3C1u	E3C1u	T3C4uC1b	T3C4uC1b	L2C1u	L2C1u
PAR6	E1C1u	E1C1u	E1C1u	E1C1u	T2C2uS2b	T2C2uS2b	L1C1u	L1C1u
PAR7	E3S1u	E3S2u	E3S2u	E3S2u	T3S2uC1b	T3S2uC1b	L3S1u	L3S1u
PAR8	E2S1u	E3S4u	E3S1u	E3S1u	T3S4uC1b	T3S4uC1b	L2S1u	L2S1u
PAR9	E1S1u	E1S1u	E1S1u	E1S1u	T2S2uS2b	T2S2uS2b	L1S1u	L1S1u

E3, E2, E1 axes correspond to D, Y, B, respectively
L3, L2, L1 axes correspond to R, S, W, respectively

> User: %USERNAME% Campaign: \$(P)/230507 \$Y+0=2023 \$S+0=1270 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Next].

ORBGEN 5: Stochastic Pulses and Satellite Accuracy Codes

STOCHASTIC PULSES IN (L3, L2, L1)-DIRECTIONS

Set up based on Orbit midnight

List of satellites

Parameter spacing (hh mm ss)

Orbital elements file

(only used to provide epochs of stochastic pulses)

SATELLITE OPTIONS

Exclude satellites with maneuvers ☐

Use accuracy codes from SP3-file ☒

Exclude sat. with accuracy code 0 ☒

Exclude sat. with acc. code exceeding 99

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Run].

ORBGEN 6: Orbital Arc Definition

ORBITAL ARC DEFINITION

Number of arcs within the time window

Time window to be covered by the standard orbits

☒ Defined by Year and Session identifier

Year Session

☐ Defined by Start and End times

Start End

Start End

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ORBGEN.INP

Click [^Output].

Check the results.

\$(P)/230510B\$OUT\$ORB_20231300.OUT

Station	Arc	Time	Start	End
2		37:47	2023-05-10 16:15:06	2023-05-10 16:52:53
224	1	35:19	2023-05-10 07:22:32	2023-05-10 07:57:51
	2	38:21	2023-05-10 21:26:18	2023-05-10 22:04:39
225	1	36:17	2023-05-10 09:11:22	2023-05-10 09:47:39
	2	39:12	2023-05-10 23:15:11	2023-05-10 23:54:23
227	1	34:15	2023-05-10 00:24:37	2023-05-10 00:58:51
	2	37:26	2023-05-10 14:28:18	2023-05-10 15:05:43
230	1	36:32	2023-05-10 12:39:57	2023-05-10 13:16:29
231	1	35:30	2023-05-10 05:41:03	2023-05-10 06:16:33
	2	38:31	2023-05-10 19:44:49	2023-05-10 20:23:20

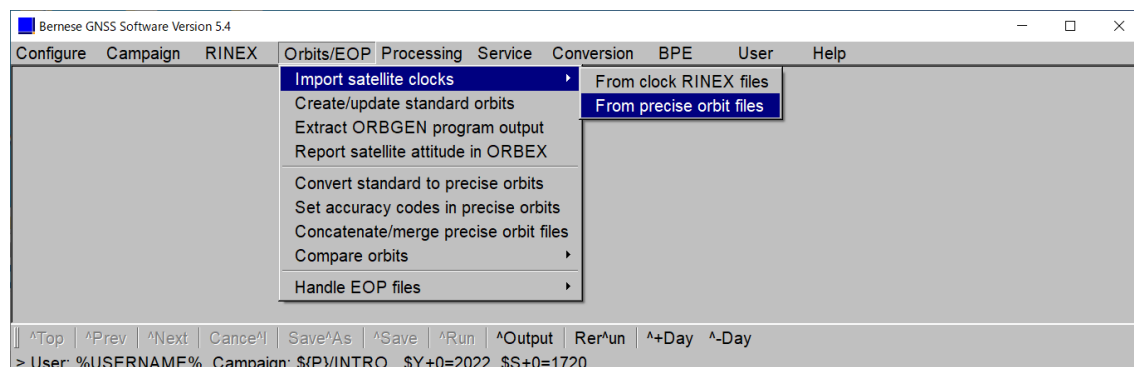
>>> CPU/Real time for pgm "ORBGEN": 0:01:01.500 / 0:01:02.152

>>> Program finished successfully

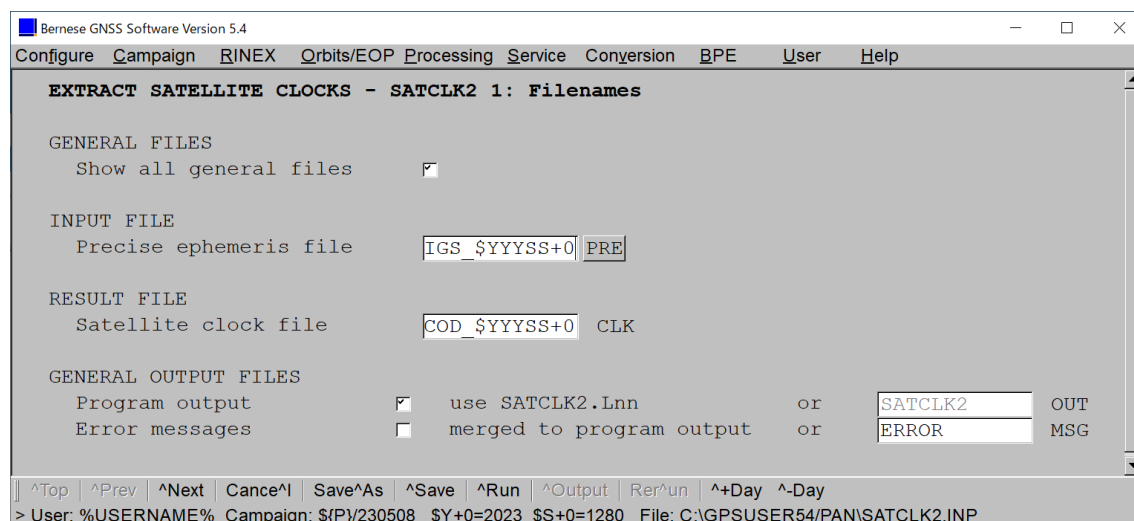
Find next prev Close

8.3. Extract satellite clock corrections

Click [From precise orbit files] to display the submenu.

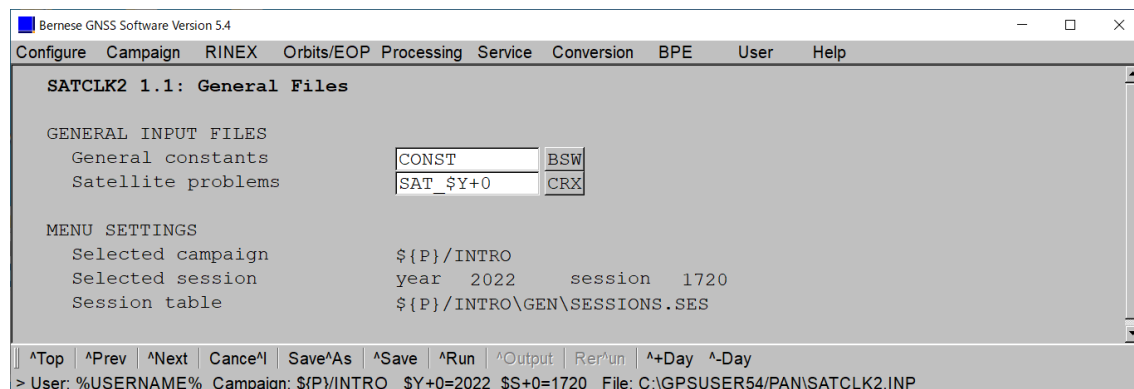


Click [^Next].



Select Satellite problems file.

Click [^Next].



Click [^Next].

The screenshot shows the 'SATCLK2 2: General Options' window in the Bernese GNSS Software Version 5.4. The window has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area contains the following fields and options:

- TITLE**: A text box containing 'Khmer GEONET IGS20'.
- SATELLITE OPTIONS**: A section with a checkbox 'Remove bad satellites' which is checked.
- OPTIONS FOR CLOCKS**: A section with two fields: 'Interval for polynomials' set to '12' and 'Polynomial degree' set to '2'. The unit 'hours' is indicated to the right of the interval field.

At the bottom, there is a status bar with a menu bar: '^Top', '^Prev', '^Next', 'Cancel', 'Save^As', '^Save', '^Run', '^Output', 'Rer^un', '^+Day', '^Day'. Below this is a line of text: '> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\SATCLK2.INP'.

Click [^Run].

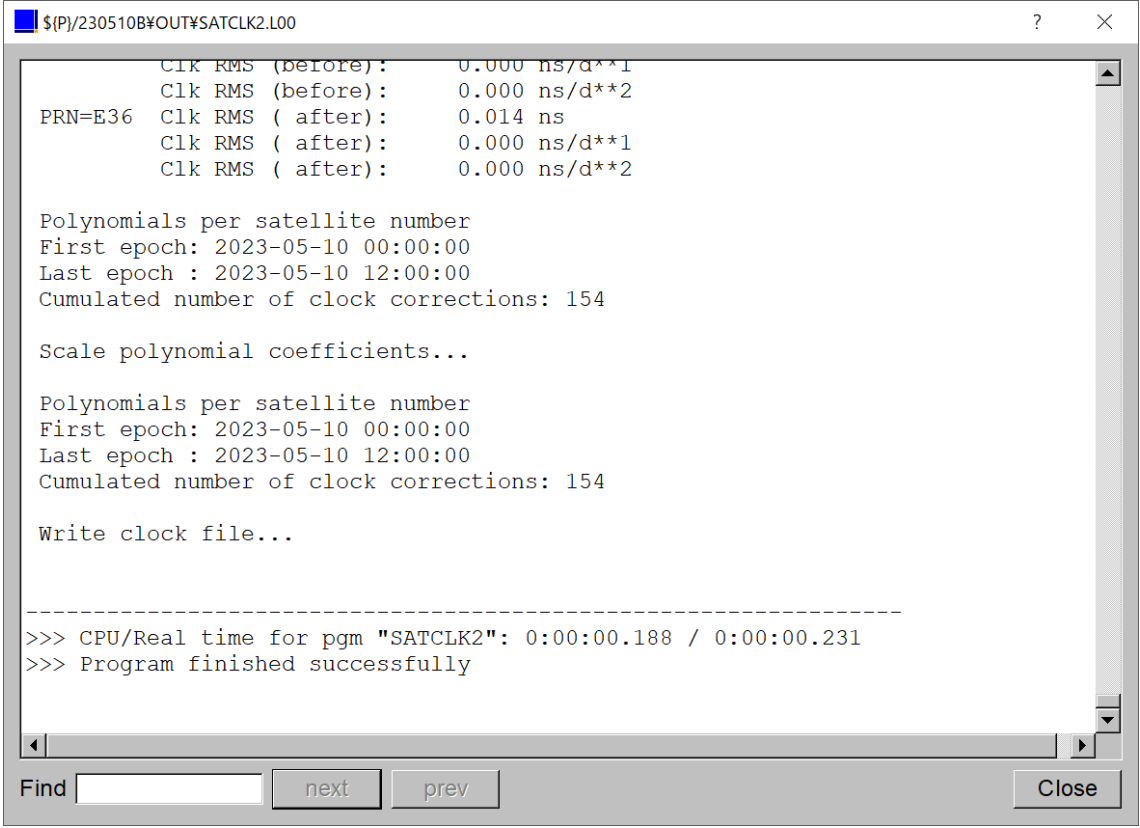
The screenshot shows the 'SATCLK2 3: Observation Window' in the Bernese GNSS Software Version 5.4. The window has the same menu bar as the previous one. The main area contains the following fields and options:

- OBSERVATION WINDOW**: A section with three radio buttons for selection:
 - 'Take all clock records' (unselected).
 - 'Defined by Year and Session identifier' (selected). Below this are two text boxes: 'Year' containing '\$Y+0' and 'Session' containing '\$S+0'.
 - 'Defined by Start and End times' (unselected). Below this are two sets of time selection fields:
 - Start**: Fields for 'yyyy mm dd' (containing '\$YMD_STR+0') and 'hh mm ss' (containing '00 00 00').
 - End**: Fields for 'yyyy mm dd' (containing '\$YMD_STR+0') and 'hh mm ss' (containing '23 59 59').

At the bottom, there is a status bar with a menu bar: '^Top', '^Prev', '^Next', 'Cancel', 'Save^As', '^Save', '^Run', '^Output', 'Rer^un', '^+Day', '^Day'. Below this is a line of text: '> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\SATCLK2.INP'.

Click [^Output].

Check the results.



```
$(P)/230510B#OUT#SATCLK2.L00
Clk RMS (before): 0.000 ns/d**1
Clk RMS (before): 0.000 ns/d**2
PRN=E36 Clk RMS ( after): 0.014 ns
Clk RMS ( after): 0.000 ns/d**1
Clk RMS ( after): 0.000 ns/d**2

Polynomials per satellite number
First epoch: 2023-05-10 00:00:00
Last epoch : 2023-05-10 12:00:00
Cumulated number of clock corrections: 154

Scale polynomial coefficients...

Polynomials per satellite number
First epoch: 2023-05-10 00:00:00
Last epoch : 2023-05-10 12:00:00
Cumulated number of clock corrections: 154

Write clock file...

-----
>>> CPU/Real time for pgm "SATCLK2": 0:00:00.188 / 0:00:00.231
>>> Program finished successfully
```

Find next prev Close

8.4. Convert Bias Corrections from Bias SINEX into Bernese bias Format

Download the Bias Corrections file from the download site.

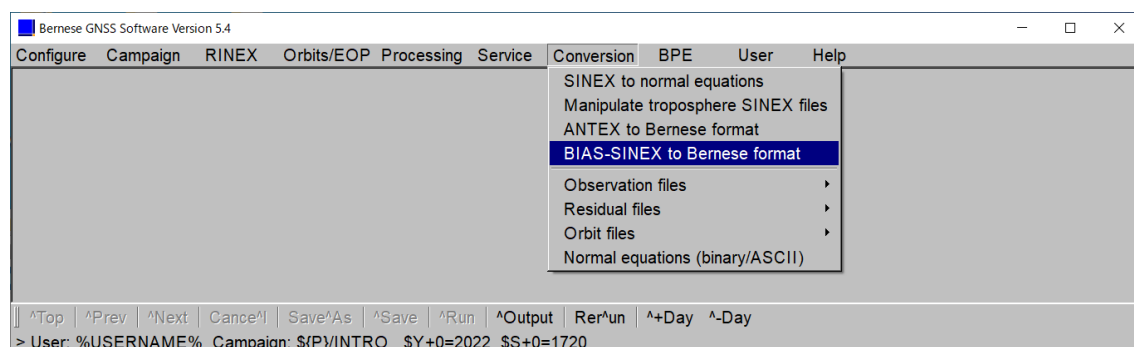
Download site: <http://ftp.aiub.unibe.ch/CODE/2023/>

CGIM1960.23N.Z	19-Jul-2023	06:38	459
CGIM1970.23N.Z	21-Jul-2023	06:37	464
CGIM1980.23N.Z	22-Jul-2023	06:36	461
CGIM1990.23N.Z	23-Jul-2023	06:33	468
C0000PSFIN_20230010000_01D_01D_ERP_ERP.gz	13-Jan-2023	19:33	546
C0000PSFIN_20230010000_01D_01D_OSB.BIA.gz	13-Jul-2023	14:07	115K
C0000PSFIN_20230010000_01D_01D_SOL.SIN.gz	13-Jan-2023	19:33	35M
C0000PSFIN_20230010000_01D_01H_GIM.INX.gz	13-Jan-2023	19:33	317K
C0000PSFIN_20230010000_01D_01H_GIM.ION.gz	13-Jan-2023	19:33	61K
C0000PSFIN_20230010000_01D_01H_TRO.TRO.gz	13-Jan-2023	19:33	54K
C0000PSFIN_20230010000_01D_05M_ORB.SP3.gz	13-Jan-2023	19:33	588K
C0000PSFIN_20230010000_01D_05S_CLK.CLK.gz	13-Jan-2023	19:33	16M
C0000PSFIN_20230010000_01D_05S_CLK.CLK.V2.gz	13-Jan-2023	19:33	16M
C0000PSFIN_20230010000_01D_30S_ATT.OBX.gz	13-Jan-2023	19:33	8M

Copy the Bias Corrections file to [ORB] folder of the campaign.

名前	更新日時	種類	サイズ
COD_20231280.BIA	2023/07/29 10:36	BIA ファイル	
COD_20231280.CLK	2023/07/29 10:34	CLK ファイル	
COD_20231280.ERP	2023/07/29 10:25	ERP ファイル	
COD_20231280.IEP	2023/05/19 15:46	IEP ファイル	
COD_20231280.STD	2023/07/29 10:33	STD ファイル	
IGS_20231280.PRE	2023/05/19 15:46	PRE ファイル	
P1C12305.DCB	2023/07/28 13:51	DCB ファイル	
P1P22305.DCB	2023/07/28 13:52	DCB ファイル	

Click [Bias-SINEX to Bernese format] to display the submenu.



Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

BIAS SINEX to OSB format conversion - BIA2OSB 1: Input/Output Files

GENERAL FILES

Show all general files ☒

Input:

BIAS-SINEX file COD_YYYYSS+0 BIA

Output:

OSB bias file COD_YYYYSS+0 OSB

GENERAL OUTPUT FILES

Program output ☒ use BIA2OSB.Lnn or BIA2OSB OUT

Error messages ☐ merged to program output or ERROR MSG

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\BIA2OSB.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

BIA2OSB 1.1: General Files

GENERAL INPUT FILES

General constants CONST BSW

Satellite information SATELLIT_I20 SAT

MENU SETTINGS

Selected campaign \${P}/INTRO

Selected session year 2022 session 1720

Session table \${P}/INTRO\GEN\SESSIONS.SES

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\BIA2OSB.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

BIA2OSB 2: Options for BIA-SINEX to OSB file format conversion

TITLE KHM

Bias conversion

Use all station biases ☐

Use all satellite biases ☒

Summary file COD_YYYYSS+0 SUM

Biases expected for:

☒ GPS ☒ GLONASS ☒ Galileo

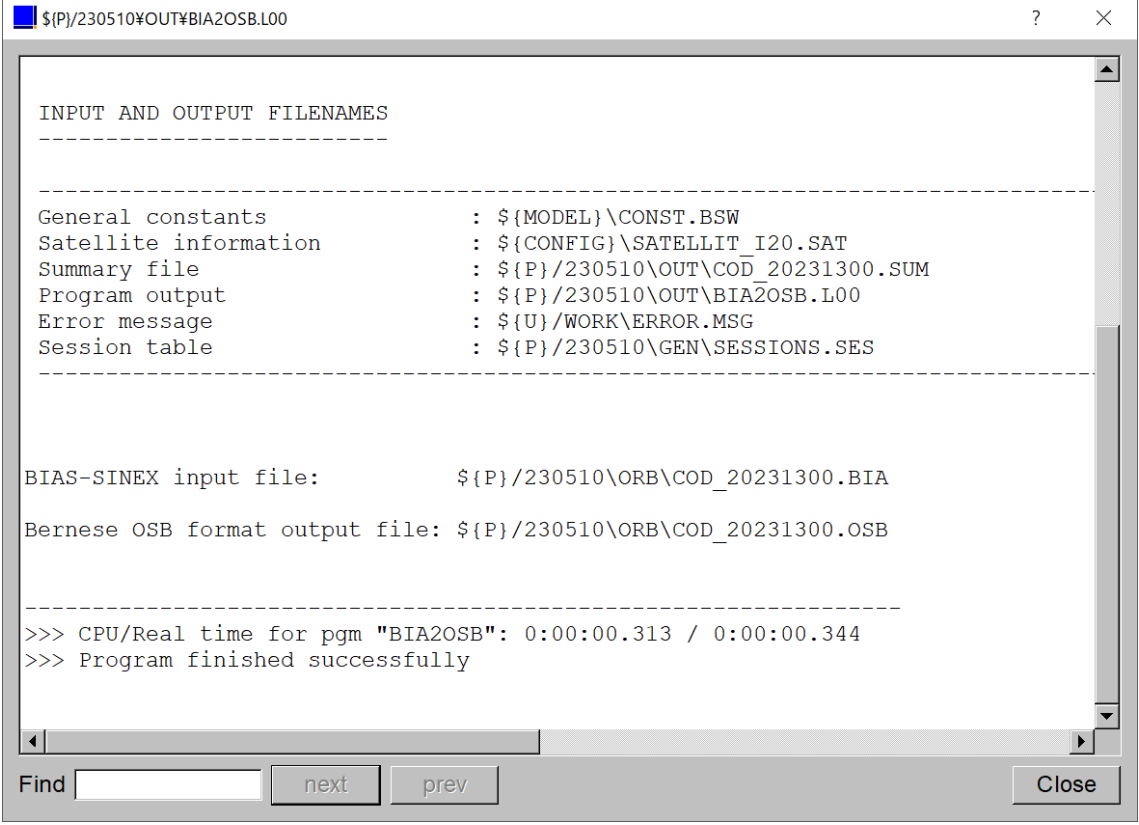
☐ SBAS ☐ BeiDou ☒ QZSS

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\BIA2OSB.INP

Click [^Output].

Check the results.



```
INPUT AND OUTPUT FILENAMES
-----

General constants           : ${MODEL}\CONST.BSW
Satellite information       : ${CONFIG}\SATELLIT_I20.SAT
Summary file               : ${P}/230510\OUT\COD_20231300.SUM
Program output             : ${P}/230510\OUT\BIA2OSB.L00
Error message              : ${U}\WORK\ERROR.MSG
Session table              : ${P}/230510\GEN\SESSIONS.SES
-----

BIAS-SINEX input file:      ${P}/230510\ORB\COD_20231300.BIA
Bernese OSB format output file: ${P}/230510\ORB\COD_20231300.OSB

-----
>>> CPU/Real time for pgm "BIA2OSB": 0:00:00.313 / 0:00:00.344
>>> Program finished successfully
```

Find

9. Baseline Processing

9.1. Extrapolate coordinate file (COOVEL)

Download Post Seismic Deformation corrections file [IGS20.PSD] from the download site.

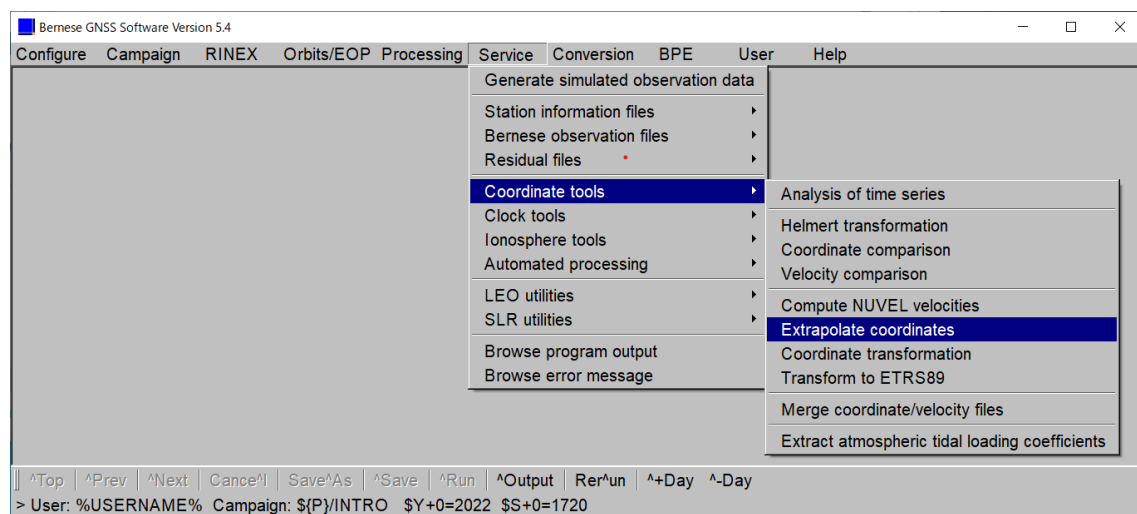
Download site: [Index of /BSWUSER54/REF/ \(unibe.ch\)](http://index.of/BSWUSER54/REF/(unibe.ch))

IGS14.PSD	21-Jul-2023 10:30	24K
IGS14.VEL	21-Jul-2023 10:30	103K
IGS14_R.CRD	21-Jul-2023 10:30	21K
IGS14_R.VEL	21-Jul-2023 10:30	22K
IGS20.CRD	21-Jul-2023 10:30	138K
IGS20.ATX	21-Jul-2023 10:30	5279
IGS20.PSD	21-Jul-2023 10:30	34K
IGS20.VEL	21-Jul-2023 10:30	143K
IGS20_R.CRD	21-Jul-2023 10:30	25K
IGS20_R.VEL	21-Jul-2023 10:30	26K
M20.ATX	21-Jul-2023 10:30	26M
R20.ATX	21-Jul-2023 10:30	30M

Copy Post Seismic Deformation corrections file to [STA] folder of the campaign.

	名前	更新日時
CAMPAIGN54	2023001	
	ATM	
	BPE	
	GEN	
	GRD	
	OBS	
	ORB	
	ORX	
	OUT	
	RAW	
	SOL	
	STA	
	KH201500.CRD	2023/07/07 17:39
	KH2023001.STA	2023/07/20 14:44
	KhmerGEONET.ABB	2023/07/20 14:52
	KhmerGEONET.BLQ	2023/07/20 18:39
	KhmrGEONET.ATL	2023/07/24 10:57
	KhmrGEONET.PLD	2023/07/14 18:49
	KhmrGEONET.VEL	2023/07/20 14:14
	IGS20.PSD	2023/07/25 10:14

Click [Extrapolate coordinates] to display the submenu.



Select Input Coordinate file, Input velocity file and PSD correction.

Enter REFERENCE EPOCH, Output coordinate file and Title.

Click [^Next].

The screenshot shows the 'COOVEL 1: Filenames' dialog box in the Bernese GNSS Software Version 5.4. The dialog has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into several sections: 'GENERAL FILES' with a checked 'Show all general files' checkbox; 'INPUT FILES' with fields for 'Input coordinate file' (KHM_201500), 'Input velocity file' (KhmrGEONET), 'PSD correction (since ITRF14)' (IGS20), and 'Annual/semiannual corrections' (TVC); 'REFERENCE EPOCH' with 'yyyy mm dd' (\$YMD_STR+0) and 'hh mm ss' (00 00 00) fields; 'RESULT FILE' with fields for 'Output coordinate file' (APR_YYYYSS+0), 'Approx. velocities at ref. epoch' (VEL), and 'Stations without PSD corrections' (FIX); 'GENERAL OUTPUT FILES' with checkboxes for 'Program output' (checked) and 'Error messages' (unchecked), and options to 'use COOVEL.Lnn' or 'merged to program output'; and a 'TITLE' field containing 'KHM'. At the bottom, there is a status bar with navigation buttons (^Top, ^Prev, ^Next, Cance^l, Save^As, ^Save, ^Run, ^Output, Rer^un, ^+Day, ^-Day) and a command line: '> User: %USERNAME% Campaign: \${P}/230511 \$Y+0=2023 \$S+0=1310 File: C:\GPSUSER54\PAN\COOVEL.INP'.

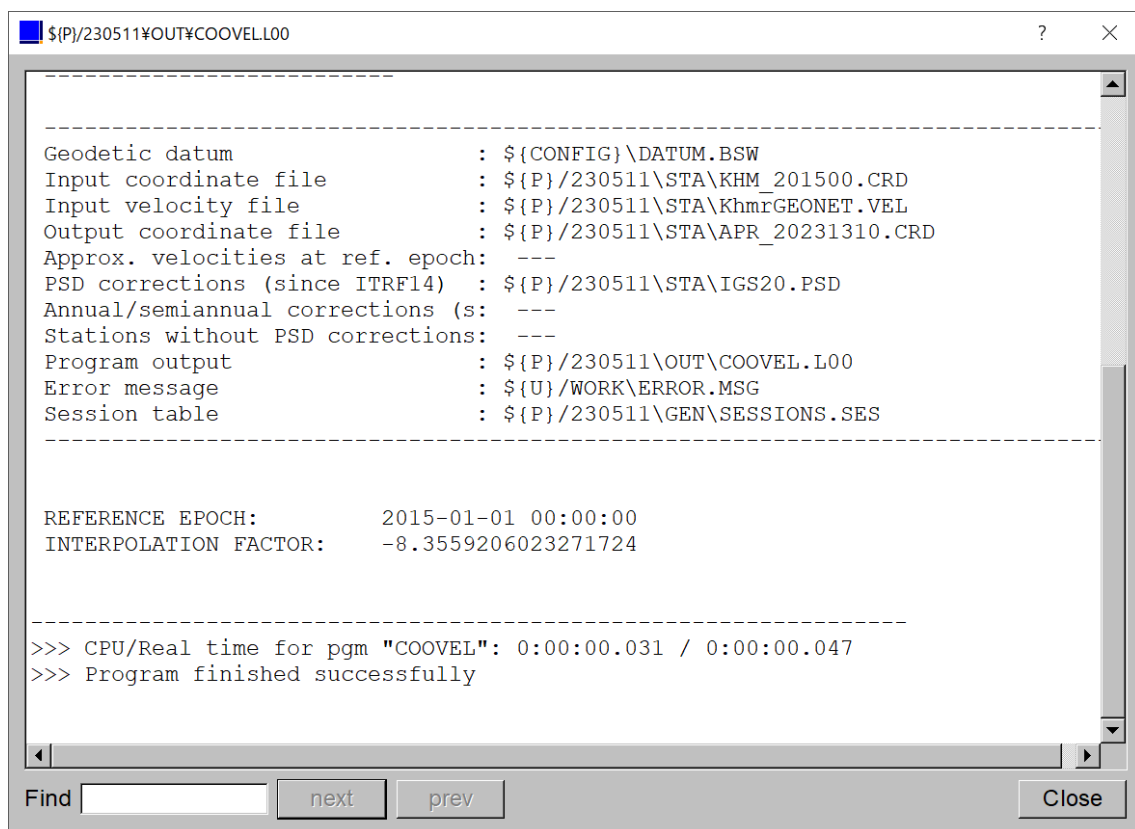
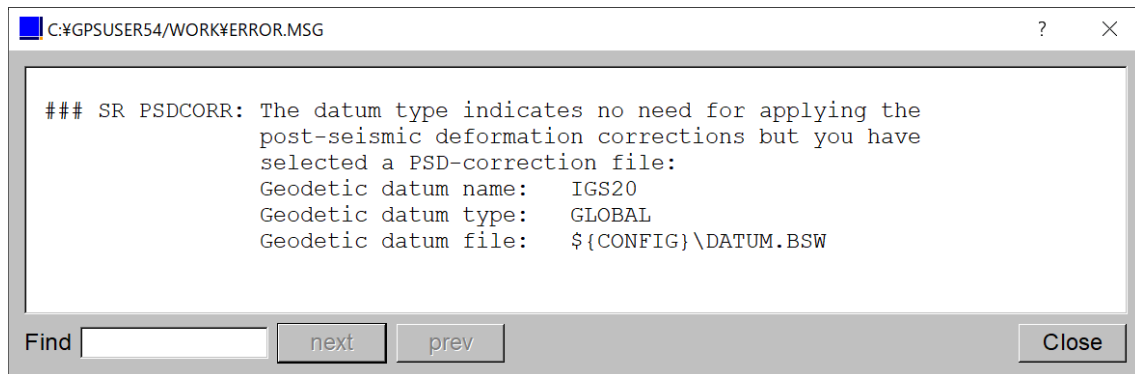
Click [^Run].

The screenshot shows the 'COOVEL 1.1: General Files' dialog box in the Bernese GNSS Software Version 5.4. The dialog has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into two sections: 'GENERAL INPUT FILES' with a 'Geodetic datum' field set to 'DATUM' and a 'BSW' checkbox; and 'MENU SETTINGS' with fields for 'Selected campaign' (\${P}/INTRO), 'Selected session' (year 2022, session 1720), and 'Session table' (\${P}/INTRO\GEN\SESSIONS.SES). At the bottom, there is a status bar with navigation buttons (^Top, ^Prev, ^Next, Cance^l, Save^As, ^Save, ^Run, ^Output, Rer^un, ^+Day, ^-Day) and a command line: '> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\COOVEL.INP'.

Click [^Output].

Check the results.

You can safely ignore this warning.



9.2. Inventory of the unput RINEX files (RNXGRA)

Check the RINEX file header.

Edit the header as shown below.

If you see a warning in the RINEX file during the calculation, it is most likely related to the header and you will need to edit the header.

Here are three examples: Other warnings may also occur.

A) The marker name and marker number should be 4 characters. Give it the same name as the [KhmerGEONET.ABB] file.

```
ANMG0010.rnx - メモ帳
ファイル(F) 編集(E) 書式(O) 表示(V) ヘルプ(H)
3.02 OBSERVATION DATA M: Mixed RINEX VERSION / TYPE
dconv JAXA 20230102 003029 UTC PGM / RUN BY / DATE
ANMG MARKER NAME
ANMG MARKER NUMBER
ANMGKASA JAXA OBSERVER / AGENCY
5423R48722 TRIMBLE NETR9 5.37 REC # / TYPE / VERS
00449 JAVRINGANT_DM SCIS ANT # / TYPE
-1270826.8700 6242631.4460 307792.4399 APPROX POSITION XYZ
0.0000 0.0000 0.0000 ANTENNA: DELTA H/E/N
G 12 C1C L1C S1C C2W L2W S2W C2X L2X S2X C5X L5X S5X SYS / # / OBS TYPES
1行、1列 100% Windows (CRLF) UTF-8
```

```
KhmerGEONET.ABB - メモ帳
ファイル(F) 編集(E) 書式(O) 表示(V) ヘルプ(H)
Khmer GEONET IGS20 20-JUL-23 14:52
-----
Station name      4-ID      2-ID      Remark
*****
ANMG              0001      01      *****
CMUM              0002      02      *****
CUSV              0003      03      *****
HKSL              0004      04      *****
PTAG              0005      05      *****
SIN1              0006      06      *****
KND1              0007      07      *****
KSP1              0008      08      *****
PNH1              0009      09      *****
SIE1              0010      10      *****
STG1              0011      11      *****
1行、1列 100% Windows (CRLF) UTF-8
```


B) If GPS time is not listed in [TIME OF FIRST OBS] and [TIME OF LAST OBS], please edit it so that it is correct.

```

SIN10010.rnx - メモ帳
ファイル(E) 編集(E) 書式(O) 表示(V) ヘルプ(H)
J L6L 0.00000
C1C 0.000 C1P 0.000 C2C 0.000 C2P 0.000
Source NTRIP stream mgex.igs-ip.net/SIN10
Carrier-to-noise-density ratios in [dB-Hz]
All observations are referred to receiver time
2023 01 01 00 00 00.0000000
SYS / PHASE SHIFT
GLONASS COD/PHS/BIS
COMMENT
COMMENT
TIME OF FIRST OBS
END OF HEADER
> 2023 01 01 00 00 00.0000000 0 49
G23 22489295.820 118182066.151 1933.004 43.700 22489306.363 92089911.512
G29 23705529.070 124573515.421 -1949.332 42.900 23705538.578 97070292.988
G02 21443343.266 112685536.806 -2217.223 46.100 .000 .000
1行、1列 100% Windows (CRLF) UTF-8

```

```

ANMG0010.rnx - メモ帳
ファイル(E) 編集(E) 書式(O) 表示(V) ヘルプ(H)
E 12 C1X L1X S1X C5X L5X S5X C7X L7X S7X C8X L8X S8X
J 15 C1C L1C S1C C1X L1X S1X C1Z L1Z S1Z C2X L2X S2X C5X
L5X S5X
C 6 C1L L1L S1L C7L L7L S7L
2023 1 1 0 0 0.0000000 GPS
2023 1 1 23 59 30.0000000 GPS
SYS / # / OBS TYPES
TIME OF FIRST OBS
TIME OF LAST OBS
SYS / PHASE SHIFT
24 R01 1 R02 -4 R03 5 R04 6 R05 1 R06 -4 R07 5 R08 6 GLONASS SLOT / FRQ #
R09 -2 R10 -7 R11 5 R12 -1 R13 -2 R14 -7 R15 1 R16 -1 GLONASS SLOT / FRQ #
R17 4 R18 -3 R19 3 R20 2 R21 4 R22 -3 R23 3 R24 2 GLONASS SLOT / FRQ #
C1C 0.000 C1P 0.000 C2C 0.000 C2P 0.000
GLONASS COD/PHS/BIS
END OF HEADER
1行、1列 100% Windows (CRLF) UTF-8

```

C) If there is no value in PHASE SHIFT, delete it. Do not edit if it contains a value.

```

ANMG0010.rnx - メモ帳
ファイル(F) 編集(E) 書式(O) 表示(V) ヘルプ(H)
E 12 C1X L1X S1X C5X L5X S5X C7X L7X S7X C8X L8X S8X SYS / # / OBS TYPES
J 15 C1C L1C S1C C1X L1X S1X C1Z L1Z S1Z C2X L2X S2X C5X SYS / # / OBS TYPES
L5X S5X SYS / # / OBS TYPES
C 6 C1I L1I S1I C7I L7I S7I SYS / # / OBS TYPES
2023 1 1 0 0 0.0000000 GPS TIME OF FIRST OBS
2023 1 1 23 59 30.0000000 GPS TIME OF LAST OBS
24 R01 1 R02 4 R03 5 R04 6 R05 1 R06 4 R07 5 R08 6 GLONASS SLOT / FRQ #
R09 -2 R10 -7 R11 5 R12 -1 R13 -2 R14 -7 R15 1 R16 -1 GLONASS SLOT / FRQ #
R17 4 R18 -3 R19 3 R20 2 R21 4 R22 -3 R23 3 R24 2 GLONASS SLOT / FRQ #
C1C 0.000 C1P 0.000 C2C 0.000 C2P 0.000 GLONASS COD/PHS/BIS
END OF HEADER
19 行、78 列 100% Windows (CRLF) UTF-8

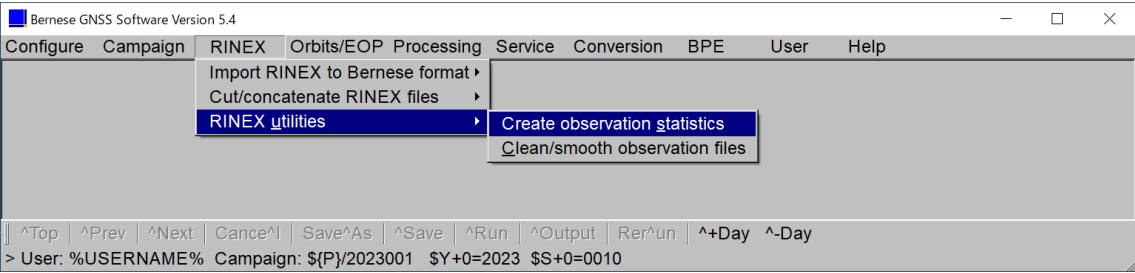
```

```

HKSL0010.rnx - メモ帳
ファイル(F) 編集(E) 書式(O) 表示(V) ヘルプ(H)
C 8 C1I L1I D1I S1I C7I L7I D7I S7I SYS / # / OBS TYPES
DBHZ SIGNAL STRENGTH UNIT
30.000 INTERVAL
2023 01 01 00 00 0.0000000 GPS TIME OF FIRST OBS
2023 01 01 23 59 30.0000000 GPS TIME OF LAST OBS
0 RCV CLOCK OFFS APPL
G L2S -0.25000 SYS / PHASE SHIFT
G L2X -0.25000 SYS / PHASE SHIFT
R L2P 0.25000 SYS / PHASE SHIFT
E L8Q -0.25000 SYS / PHASE SHIFT
24 R01 1 R02 4 R03 5 R04 6 R05 1 R06 4 R07 5 R08 6 GLONASS SLOT / FRQ #
R09 -2 R10 -7 R11 0 R12 -1 R13 -2 R14 -7 R15 0 R16 -1 GLONASS SLOT / FRQ #
R17 4 R18 -3 R19 3 R20 2 R21 4 R22 -3 R23 3 R24 2 GLONASS SLOT / FRQ #
1 行、1 列 100% Windows (CRLF) UTF-8

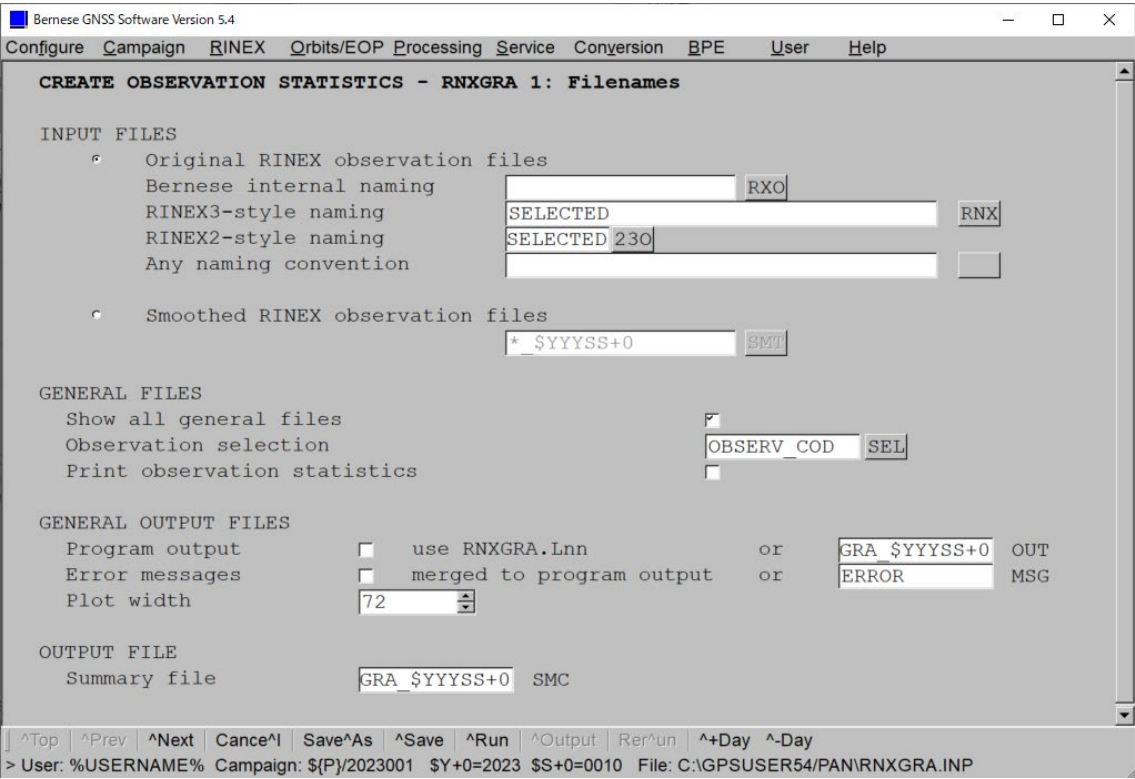
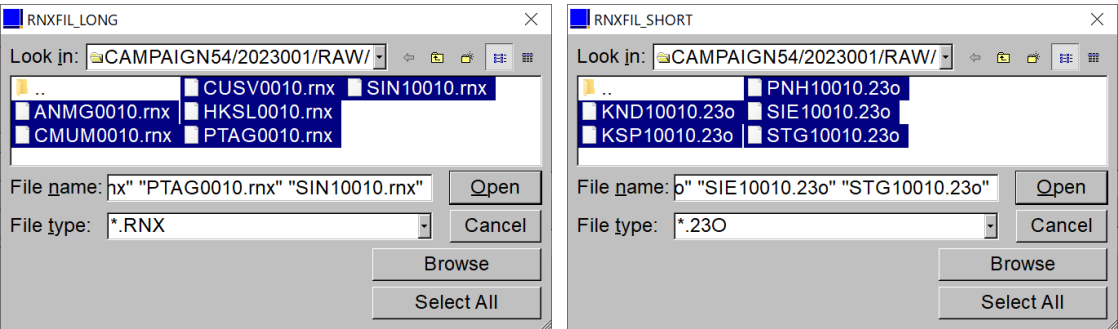
```

Click [Create observation statistics] to display the submenu.



Select RINEX FILES.

Click [^Next].



Click [^Next].

Bernese GNSS Software Version 5.4

Configure

Campaign

RINEX

Orbits/EOP

Processing

Service

Conversion

BPE

User

Help

RNXGRA 1.1: General Files

MENU SETTINGS

Selected campaign

Selected session

Session table

\${P}/2023001

year 2023 session 0010

\${P}/2023001\GEN\SESSIONS.SES

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\RNXGRA.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure

Campaign

RINEX

Orbits/EOP

Processing

Service

Conversion

BPE

User

Help

RNXGRA 2: Options part I

TITLE

KHM

OBSERVATION SELECTION

Use observation window

Measurement type

Frequencies

Minimum s/n ratio requested

Print cycle slip flags

Satellite system

☐

PHASE

BOTH

0

☐

GPS

Galileo

SBAS

GRAPHIC+COUNT

GRAPHIC+COUNT

IGNORE

GLONASS

BeiDou

QZSS

GRAPHIC+COUNT

IGNORE

IGNORE

MAXIMUM NUMBER OF MISSING EPOCHS

Allowed per character

2

(1 chr = 20 minutes)

STATION NAME TRANSLATION

Gather station names from

Station information

Stop if station name not found

MARKER NAME

KHM_YYYYSS+0

STA

☐

LIST OF RINEX FILES

Get a list of RINEX files

☐

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\RNXGRA.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RNXGRA 3: Options part II

SAMPLING

Sampling interval	0	seconds	(0: use all observations)
Offset to full minute	0	seconds	
Sampling tolerance	0.5	seconds	

RULE FOR APPLYING PHASE SHIFT CORRECTIONS FROM HDR ON READING OBSERVATIONS

Phase shift corrections appeared with RINEX version 2.12

Rule AS NEEDED

REJECTION OF FAKE OBSERVATIONS

Maximal freq. considered	0	(0: no rejection)
Tolerance	0	

OTHER RINEX OPTIONS

Change hdr strings to upper case on read	☐
Output errors from input headers	☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\RNXGRA.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RNXGRA 4: Check Content of RINEX Header

Action if marker name doesn't match file name NONE

ACTIONS IN CASE OF MISSING MANDATORY HEADER RECORDS

Missing record: GLONASS SLOT / FRQ #	NONE	(RINEX vers ge 3.01)
Missing record: GLONASS COD/PHS/BIS	SKIP	(RINEX vers ge 3.02)
Missing record: SYS / PHASE SHIFT	NONE	(RINEX vers ge 2.12)
Other missing mandatory records	NONE	

ACTIONS IN SPECIAL SITUATIONS BETWEEN OBSERVATIONS

On epoch events	NONE
On inconsistent header modifications	NONE

NONE : Just continue
WARNING : Write warning and continue
SKIP : Skip file and continue with next file
ERROR : Write error message and stop processing

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\RNXGRA.INP

Check the results.

```

SATELLITE SYSTEM: GALILEO

KND1 | 666567777755666666777888897789****8988888989***998877888888877788888898
KSP1 | 7776677766665666667778888*9999999***688999999****98899999977888888888
PNH1 | 77766777776566666778777789999899998788999999889999*9977888878788888888
SIE1 | 88767776666656666666778889989999*888888889988****8879999985677788778
STG1 | 77766677776666666677767888899999***877889999889****9999999886588888887
ANMG | 788887777766676667577778999886-78888787788877788988*88877778767787766666
CMUM | 64464777677666544445555545557666766776665554556666555545544444444446
CUSV | 667677777766667777766679988*89***87898888887777766589****98977777765
HKSL | 7777797766756655566788887878999888887888888999998989999888766777899899
PTAG | 7777776777787667788779898868889998868889998899988999877789998777789998
SIN1 | 8987888889*889988999998****9*****99*-****9*****988**998**99
-----+-----+-----+-----+-----+
0                                         12                                         24

ANTI-SPOOFING :

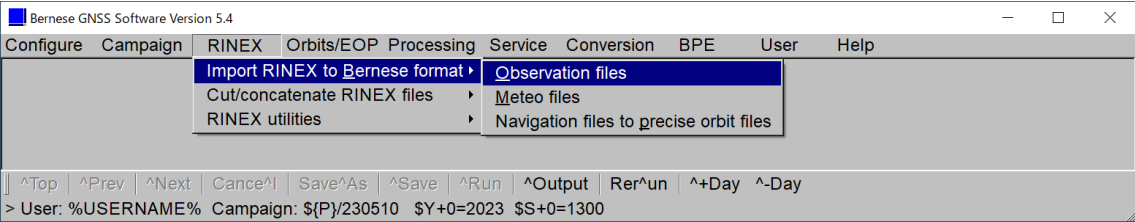
201 | 122222222222222222222222222222221
202 |                                     111222222222222221 1222222
203 |                                     112222222222222222
204 | 11122222222222222222222211122222222222222222
205 |                                     11 112222222222222222222222
207 | 2222222222222211
208 | 111                                     22122222222
209 | 111122222222222222 111222222222222222222222
210 | 1 2222222222222222222222222222222211
211 | 12222222222222222222222222222222222211
212 | 1111 211 112222222222222222222222 111
213 | 222111 111111
215 |                                     11222222222
219 | 1112222222222222222222222211
221 | 22222222222222222222222222221
224 | 1111111122222222222222222222111 111 122222
225 | 111222222222222222222222111122222222
226 | 2222222221111111222222222222221
227 | 22222222222222
230 | 2222222 1
231 | 22222222222222222222222222222211
233 | 2222222222221111222222222222222222
234 | 111112222222222222222222
236 | 2222222222222222222222222222222211
-----+-----+-----+-----+
0                                         12                                         24

-----
>>> CPU/Real time for pgm "RNXGRA": 0:01:38.031 / 0:01:38.750
>>> Program finished successfully

```

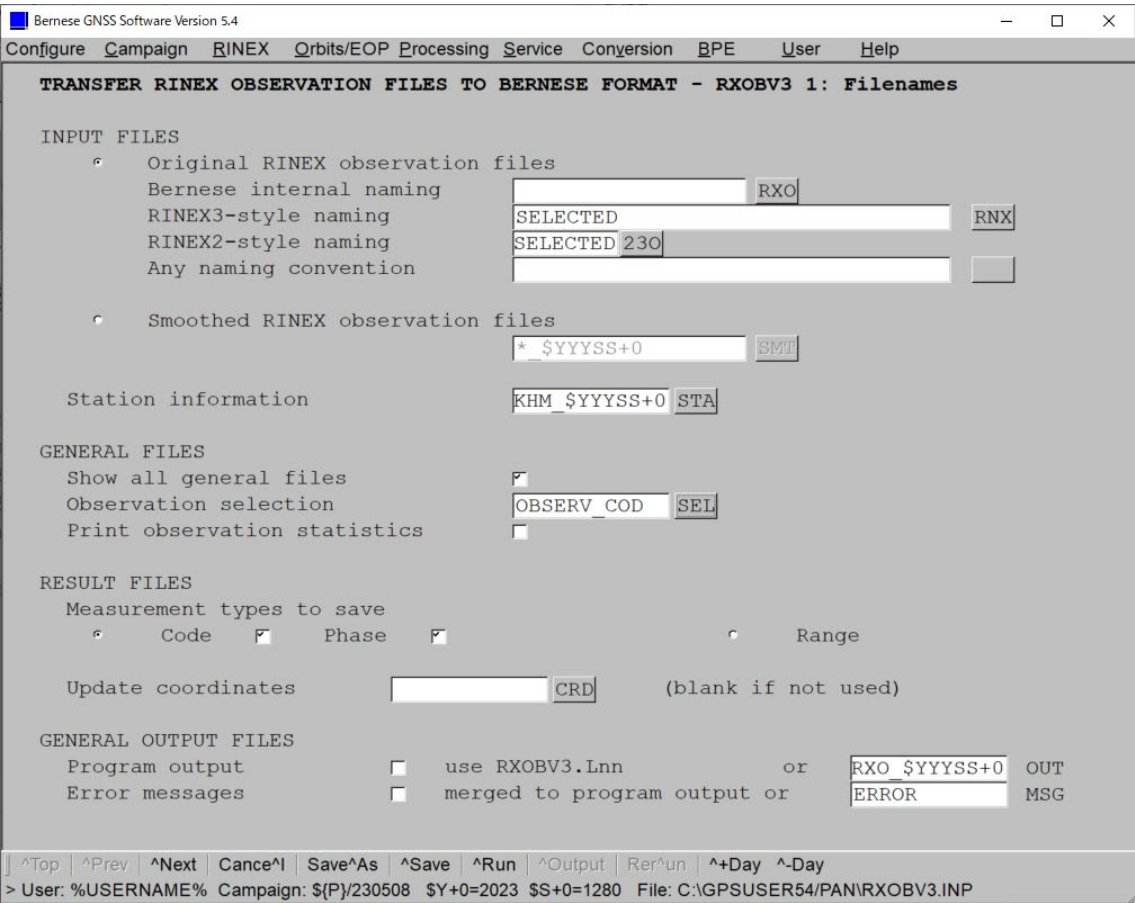
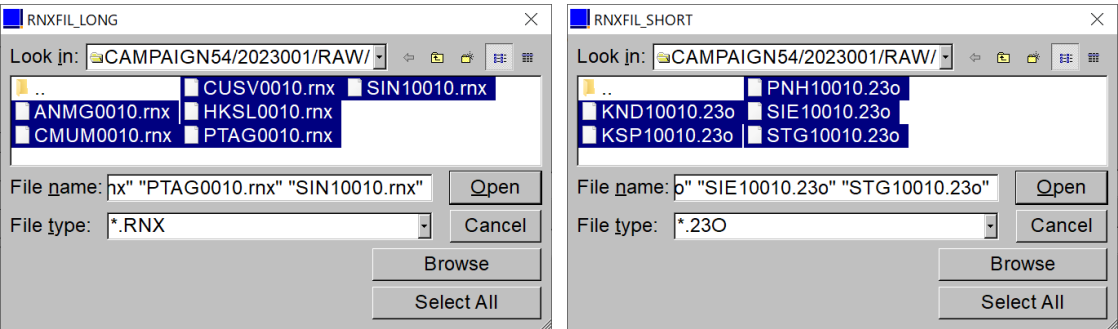

9.3. Converting the Observation from RINEX into Bernese format (RXOBV3)

Click [Import RINEX to Bernese format>Observation files] to display the submenu.



Select all of RINEX files.

Click [^Next].



Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RXOBV3 1.1: General Files

GENERAL INPUT FILES

General constants	CONST	BSW
Satellite information	SATELLIT I20	SAT
Satellite problems	SAT \$Y+0	CRX
Antenna corrections	ANTENNA I20	PCV
GPS-UTC time difference	GPSUTC	BSW
Abbreviation table	KhmerGEONET	ABB
Frequency information		FRQ

MENU SETTINGS

Selected campaign \${P}/230508

Selected session year 2023 session 1280

Session table \${P}/230508\GEN\SESSIONS.SES

TEMPORARY FILES

Scratch files RXOBV3\$J SCR RXOBV3\$J SC1 RXOBV3\$J SC2

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\RXOBV3.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RXOBV3 2: Input Options 1

TITLE KHM

GNSS SELECTION

☒ GPS	☒ GLONASS	☒ Galileo
☐ SBAS	☐ BeiDou	☐ QZSS

STATION NAMES

Gather station names from MARKER NAME

Action if station not in abbreviation list ERROR

SESSION IDENTIFIER

Session ID used for Bernese observation files \$S+0 (blank: AUTO)

OPTIONS

Use observation window	☒
Change hdr strings to upper case on read	☒
Output errors from input headers	☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230507B \$Y+0=2023 \$S+0=1270 File: C:\GPSUSER54\PAN\RXOBV3.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RXOBV3 2.1: Observation Window

OBSERVATION WINDOW

☒ Defined by Year and Session identifier
Year Session

☐ Defined by Start and End times
Start End
Start End

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\RXOBV3.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RXOBV3 3: Input Options 2

SAMPLING
Sampling interval seconds (0: use all observations)
Sampling offset to full minute seconds
Sampling tolerance seconds

RULE FOR APPLYING PHASE SHIFT CORRECTIONS FROM HDR ON READING OBS
Phase shift corrections appeared with RINEX version 2.12
Rule

REJECTION OF FAKE OBSERVATIONS
Maximal freq. considered (0: no rejection)
Tolerance

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\RXOBV3.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure

Campaign

RINEX

Orbits/EOP Processing

Service

Conversion

BPE

User

Help

RXOBV3 4: Input Options 3

SIGNAL STRENGTH REQUIREMENTS

Minimum signal strength

Accept signal strength = 0

Accept cycle slip flags from RINEX

1

☒

☐

REQUIREMENTS REGARDING THE CONTENT OF BERNESE OBSERVATION FILES

Define conditions to write a Bernese obs. file

☐

OPTIONS CONCERNING ANTENNAS

Consider radome code of the antennas

Correct position of radome code

Check antenna correction file for antenna type

Ingnore measurements with antenna calib. method

☒

☒

☒

NONE

else

ERROR

FREQUENCY CHECK FOR SLR

Check frequency information file for frequency

WARNING

ROUNDING OF OBSERVATION EPOCH

Round fractional part of observation time

DONT ROUND

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\RXOBV3.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure

Campaign

RINEX

Orbits/EOP Processing

Service

Conversion

BPE

User

Help

RXOBV3 5.1: Check Content of RINEX Header 1

ACTIONS IN CASE OF INCONSISTENCIES

Station name

Antenna type

Antenna number

Antenna position

Marker type

Receiver type

Receiver number

ERROR

ERROR

WARNING

WARNING

WARNING

WARNING

WARNING

Try also filename

☐

NO_CHECK : No check is done

WARNING : Write warning and continue

SKIP : Skip file and continue with next file

ERROR : Write error message and stop processing

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\RXOBV3.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure

Campaign

RINEX

Orbits/EOP Processing

Service

Conversion

BPE

User

Help

RXOBV3 5.2: Check Content of RINEX Header 2

ADDITIONAL VERIFICATION

Verify station name/number using

☒

MARKER NAME

Verify station name using RINEX filename

☒

HANDLING OF KNOWN INCONSISTENCIES

Accepted station information

CRX

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\RXOBV3.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure

Campaign

RINEX

Orbits/EOP Processing

Service

Conversion

BPE

User

Help

RXOBV3 6: Check Content of RINEX Header 3

Action if marker name doesn't match file name

NONE

ACTIONS IN CASE OF MISSING MANDATORY HEADER RECORDS

Missing record: GLONASS SLOT / FRQ #

NONE

(RINEX vers ge 3.01)

Missing record: GLONASS COD/PHS/BIS

SKIP

(RINEX vers ge 3.02)

Missing record: SYS / PHASE SHIFT

NONE

(RINEX vers ge 2.12)

Other missing mandatory records

NONE

ACTIONS IN SPECIAL SITUATIONS BETWEEN OBSERVATIONS

On epoch events

NONE

On inconsistent header modifications

NONE

NONE : Just continue

WARNING : Write warning and continue

SKIP : Skip file and continue with next file

ERROR : Write error message and stop processing

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

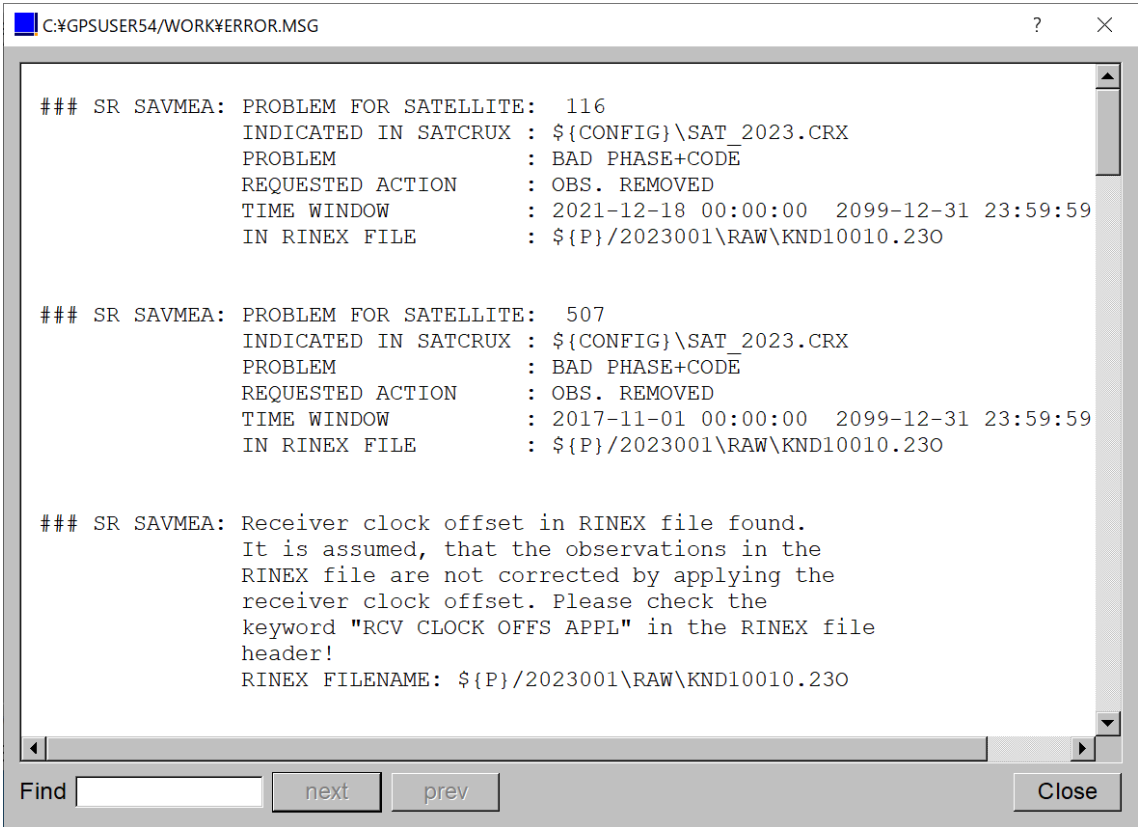
^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\RXOBV3.INP

Click [^Output].

Check the results.

Satellite problem and receiver clock offset warnings are displayed. You can safely ignore this warning.



```
### SR SAVMEA: PROBLEM FOR SATELLITE: 116
      INDICATED IN SATCRUX : ${CONFIG}\SAT_2023.CRX
      PROBLEM              : BAD PHASE+CODE
      REQUESTED ACTION     : OBS. REMOVED
      TIME WINDOW          : 2021-12-18 00:00:00 2099-12-31 23:59:59
      IN RINEX FILE        : ${P}/2023001\RAW\KND10010.230

### SR SAVMEA: PROBLEM FOR SATELLITE: 507
      INDICATED IN SATCRUX : ${CONFIG}\SAT_2023.CRX
      PROBLEM              : BAD PHASE+CODE
      REQUESTED ACTION     : OBS. REMOVED
      TIME WINDOW          : 2017-11-01 00:00:00 2099-12-31 23:59:59
      IN RINEX FILE        : ${P}/2023001\RAW\KND10010.230

### SR SAVMEA: Receiver clock offset in RINEX file found.
      It is assumed, that the observations in the
      RINEX file are not corrected by applying the
      receiver clock offset. Please check the
      keyword "RCV CLOCK OFFS APPL" in the RINEX file
      header!
      RINEX FILENAME: ${P}/2023001\RAW\KND10010.230
```

Find next prev Close

```
$(P)/2023001\OUT#RXOBV3.L01 ? X

3  ${P}/2023001\RAW\PNH10010.230  ${P}/2023001\OBS\00090010.CZH  2880  75206  749
   ${P}/2023001\OBS\00090010.CZO
   ${P}/2023001\OBS\00090010.PZH  2880  75206  749
   ${P}/2023001\OBS\00090010.PZO

4  ${P}/2023001\RAW\SIE10010.230  ${P}/2023001\OBS\00100010.CZH  2879  66353  658
   ${P}/2023001\OBS\00100010.CZO
   ${P}/2023001\OBS\00100010.PZH  2879  66353  658
   ${P}/2023001\OBS\00100010.PZO

5  ${P}/2023001\RAW\STG10010.230  ${P}/2023001\OBS\00110010.CZH  2880  76122  758
   ${P}/2023001\OBS\00110010.CZO
   ${P}/2023001\OBS\00110010.PZH  2880  76122  757
   ${P}/2023001\OBS\00110010.PZO

8  ${P}/2023001\RAW\CUSV0010.RNX  ${P}/2023001\OBS\00030010.CZH  2880  73795  737
   ${P}/2023001\OBS\00030010.CZO
   ${P}/2023001\OBS\00030010.PZH  2880  73795  737
   ${P}/2023001\OBS\00030010.PZO

9  ${P}/2023001\RAW\HKSL0010.RNX  ${P}/2023001\OBS\00040010.CZH  2880  70770  703
   ${P}/2023001\OBS\00040010.CZO
   ${P}/2023001\OBS\00040010.PZH  2880  70559  701
   ${P}/2023001\OBS\00040010.PZO

10 ${P}/2023001\RAW\PTAG0010.RNX  ${P}/2023001\OBS\00050010.CZH  2880  80361  795
   ${P}/2023001\OBS\00050010.CZO
   ${P}/2023001\OBS\00050010.PZH  2880  80051  793
   ${P}/2023001\OBS\00050010.PZO

11 ${P}/2023001\RAW\SIN10010.RNX  ${P}/2023001\OBS\00060010.CZH  2874  89565  884
   ${P}/2023001\OBS\00060010.CZO
   ${P}/2023001\OBS\00060010.PZH  2874  87210  862
   ${P}/2023001\OBS\00060010.PZO

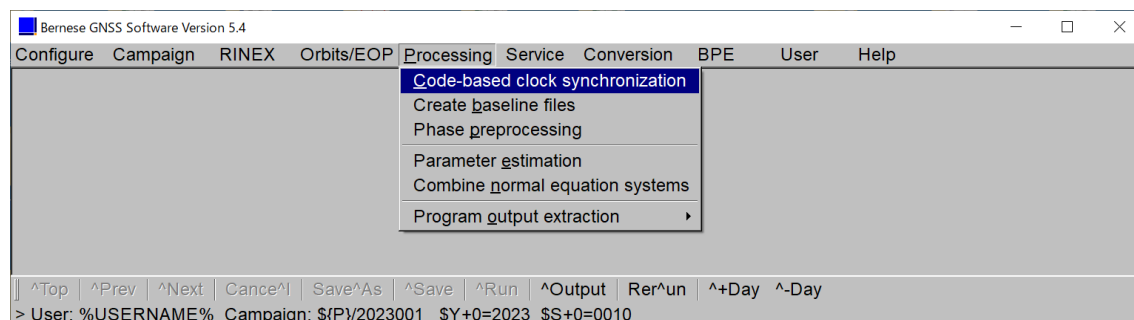
RINEX files not converted to BERNESE observation format:
-----
Num  Rinex file name              Reason
-----

>>> CPU/Real time for pgm "RXOBV3": 0:00:40.766 / 0:00:41.128
>>> Program finished successfully

Find [ ] next prev Close
```

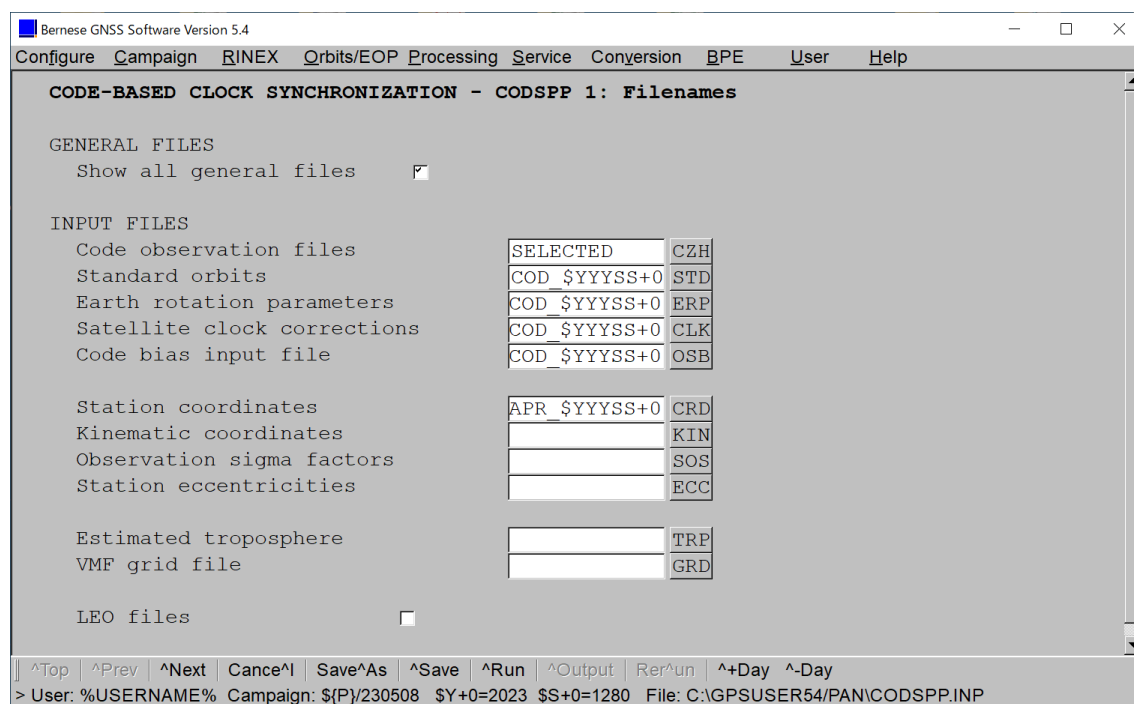
9.4. Receiver clock synchronization (CODSPP)

Click [Code-based clock synchronization] to display the submenu.



Select Standard orbits, Satellite clocks, Code observation files, A priori coordinates, Pole file and Code bias input files.

Click [^Next].



Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

CODSPP 1.1: General Files

GENERAL INPUT FILES

General constants	CONST	BSW
Subdaily ERP model	DESAI2016	SUB
Nutation model	IAU2000R06	NUT
Satellite information	SATELLIT_I20	SAT
Observation selection	OBSERV_COD	SEL
Satellite problems	SAT_\$Y+0	CRX
Station information		STA
Geodetic datum	DATUM	BSW
Antenna corrections	ANTENNA_I20	PCV
Frequency information		FRQ
GPS-UTC time difference	GPSUTC	BSW

☐ Consider antenna rotations

MENU SETTINGS

Selected campaign \${P}/230508

Selected session year 2023 session 1280

Session table \${P}/230508\GEN\SESSIONS.SES

TEMPORARY FILES

Scratch files CODSPP\$J SCR CODSPP\$J SC1 CODSPP\$J SC2

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\CODSPP.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

CODSPP 1.3: Output Files

RESULT FILES

Coordinate results		CRD
Kinematic coordinates		KIN
Residual file		RES
Satellite clock results		CLK
Clock RINEX results		CLK

OUTPUT FILES

Output summary (XYZ coord.) SMC

Output summary (Ell.coord.) SME

GENERAL OUTPUT FILES

Program output ☐ use CODSPP.Lnn or COD \$YYYYSS+0 OUT

Error messages ☐ merged to program output or ERROR MSG

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\CODSPP.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

CODSPP 2: Input Options

TITLE

GNSS SELECTION FOR COMPUTATION OF SYSTEM TIME DIFFERENCE

☒ GPS	☐ GLONASS	☐ Galileo
☐ SBAS	☐ BeiDou	☐ QZSS

PARAMETERS

Frequency	L3	
Clock polynomial degree	E	E: one offset per epoch
Save clock estimates	BOTH	
Estimate coordinates	NO	

ATMOSPHERE MODELS

Troposphere	GPT3
Ionosphere	☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\CODSPP.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

CODSPP 3: Input Options

OBSERVATION SELECTION

Minimum elevation	3	degrees
Sampling interval	1	
Interpolation of clocks allowed over	0	seconds (0:no interpolation)
Observation window	☐	
Use mark flags from observation files	☐	

PRINT OPTIONS

Residuals	☐
Elevations	☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\CODSPP.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

CODSPP 4: Screening Options

ITERATIONS

Max. number of iterations

10

OUTLIER DETECTION

Outlier detection

☒

Max. residual allowed

30.0

meters

Confidence interval

5.0

(in units of one sigma)

Min. degree of freedom

1

Max. RMS of kin. solution

5.0

meters

Mark outliers in obs. files

NO

^Top | ^Prev | ^Next | Cance^l | Save^As | ^Save | ^Run | ^Output | Rer^un | ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\CODSPP.INP

Click [^Output].

Check the results.

```
$(P)/230508%OUT%COD_20231280.OUT ? X

(MARKER)      Y      5963096.18      5963096.18      0.00
              Z      1481479.57      1481479.57      0.00

              HEIGHT      48.60      48.60      0.00
              LATITUDE    13 31 14.274    13 31 14.274    0 0 0.000
              LONGITUDE   105 58 21.175   105 58 21.175    0 0 0.000

CLOCK PARAMETERS:
-----

OFFSET FOR REFERENCE EPOCH:      -0.000000018  SEC

CLOCK OFFSETS STORED IN CODE+PHASE OBSERVATION FILES

RECEIVER UNIT      : 999999
REFERENCE EPOCH    :      2023-05-08  00:00: 0.00

*****
SUMMARY OF BAD OBSERVATIONS
*****

MAXIMUM RESIDUAL DIFFERENCE ALLOWED :      30.00 M
CONFIDENCE INTERVAL OF F*SIGMA WITH F:      5.00

NUMBER OF BAD OBSERVATION PIECES      :      5

NUMB FIL  STATION      TYP SAT      FROM      TO
-----
1  2  CMUM      OUT  11  2023 05 08 11 14 30  2023 05 08 11 14 30
2  2  CMUM      OUT  32  2023 05 08 19 36 30  2023 05 08 19 36 30
3  2  CMUM      OUT   3  2023 05 08 23 40 00  2023 05 08 23 40 00

4  6  SIN1      OUT  13  2023 05 08 04 51 00  2023 05 08 04 51 00
5  6  SIN1      OUT  23  2023 05 08 11 00 00  2023 05 08 11 00 00

-----

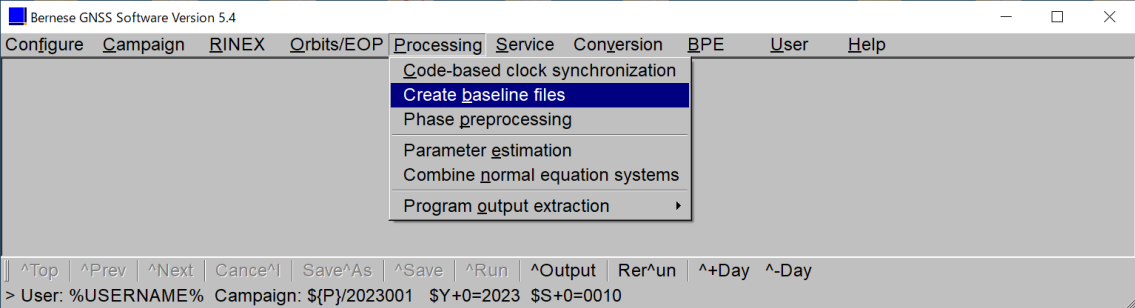
>>> CPU/Real time for pgm "CODSPP": 0:00:31.922 / 0:00:32.500
>>> Program finished successfully

Find [ ] [next] [prev] [Close]
```

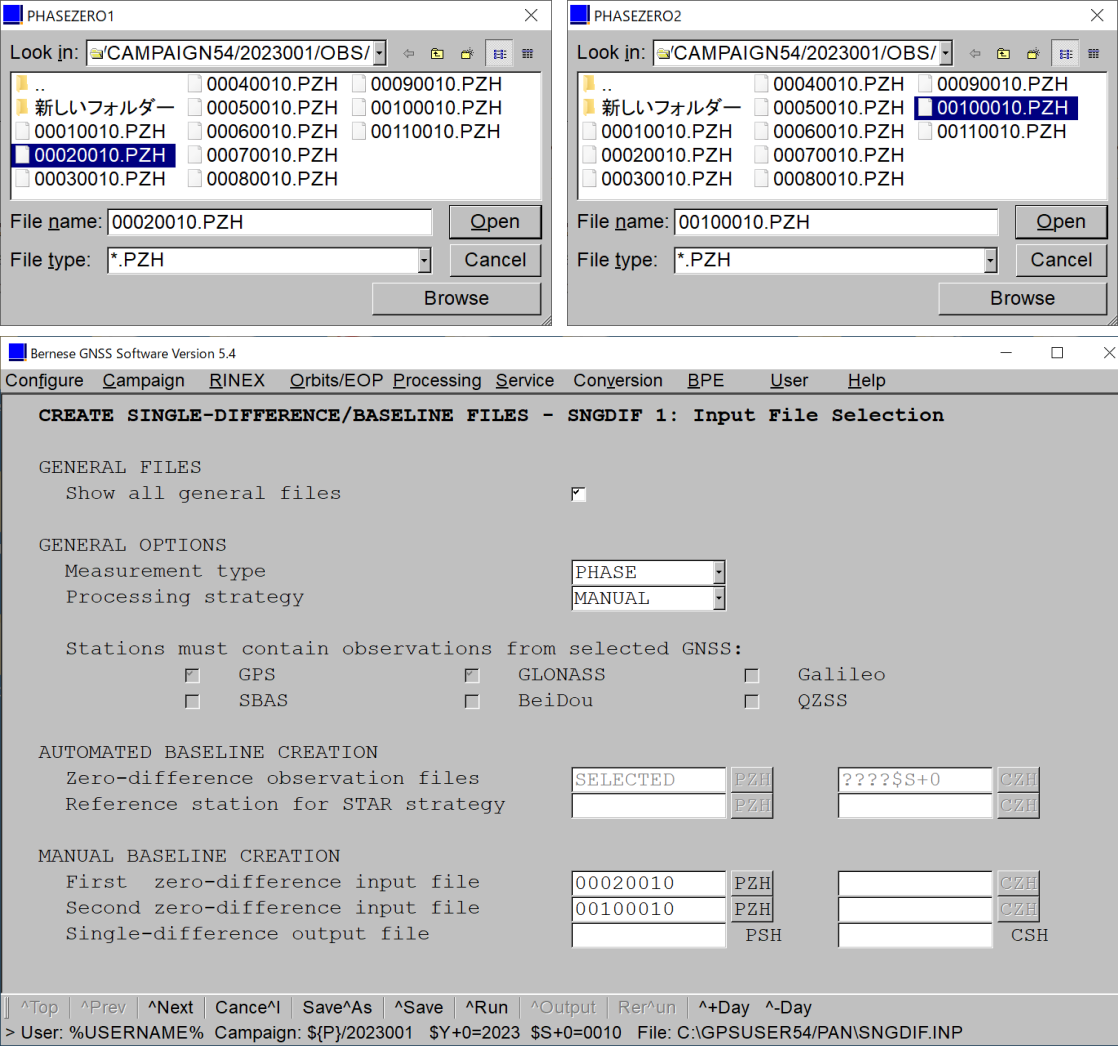
9.5. Single difference (SNGDIF)

Calculate for each baseline.

Click [Create baseline files] to display the submenu.



Click [^Next].



Select Abbreviation table.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

SNGDIF 1.1: General Files

GENERAL INPUT FILES

General constants

SATellite information

Geodetic datum

Abbreviation table

CONST

SATELLIT_I20

DATUM

IGSGEONET

BSW

SAT

BSW

ABB

MENU SETTINGS

Selected campaign

Selected session

Session table

\$(P)/INTRO

year 2022 session 1720

\$(P)/INTRO\GEN\SESSIONS.SES

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\SNGDIF.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

SNGDIF 2: Filenames

INPUT FILES

Station coordinates

Site eccentricities

Predefined baselines

Cluster definition

APR 20230010

CRD

ECC

BSL

CLU

RESULT FILES

Listing of formed baselines

Cluster/baseline assignment

BSL \$YYYS+0

BSL

CLB

(2 digits will be appended)

GENERAL OUTPUT FILES

Program output

Error messages

☒ use SNGDIF.Lnn

☐ merged to program output or

or

SNGDIF

ERROR

OUT

MSG

^Top ^Prev ^Next Cancel^I Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/2023001 \$Y+0=2023 \$S+0=0010 File: C:\GPSUSER54\PAN\SNGDIF.INP

Enter TITLE.

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

SNGDIF 3: Options

TITLE

SIMULTANEOUS OBSERVATIONS

Tolerance to identify observations of one epoch seconds

SETTING OF NEW AMBIGUITIES

Merge ambiguities from input files ☐

After a gap in the observations larger than minutes

If a cycle slip flag in one of the input files ☐

^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^_Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\SNGDIF.INP

Click [^Output].

Check the results.

SNGDIF: INPUT AND OUTPUT OBSERVATION FILE NAMES

0-DIF. HEADER FILE NAMES (INPUT)	0-DIF. OBS. FILE NAMES (INPUT)	NUM

\${P}/2023001\OBS\00020010.PZH	\${P}/2023001\OBS\00020010.PZO	1
\${P}/2023001\OBS\00100010.PZH	\${P}/2023001\OBS\00100010.PZO	2

1-DIF. HEADER FILE NAMES (OUT)	1-DIF. OBS. FILE NAMES (OUT)	NR1	NR2	STAT.

\${P}/2023001\OBS\02100010.PSH	\${P}/2023001\OBS\02100010.PSO	1	2	OK

>>> CPU/Real time for pgm "SNGDIF": 0:00:00.063 / 0:00:00.100

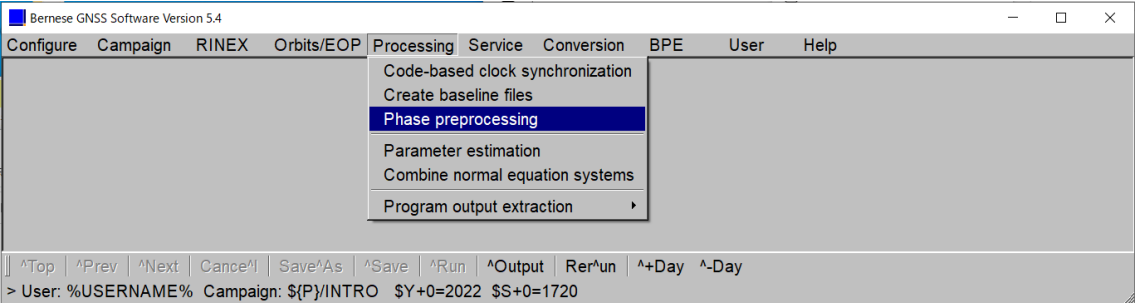
>>> Program finished successfully

Find next prev Close

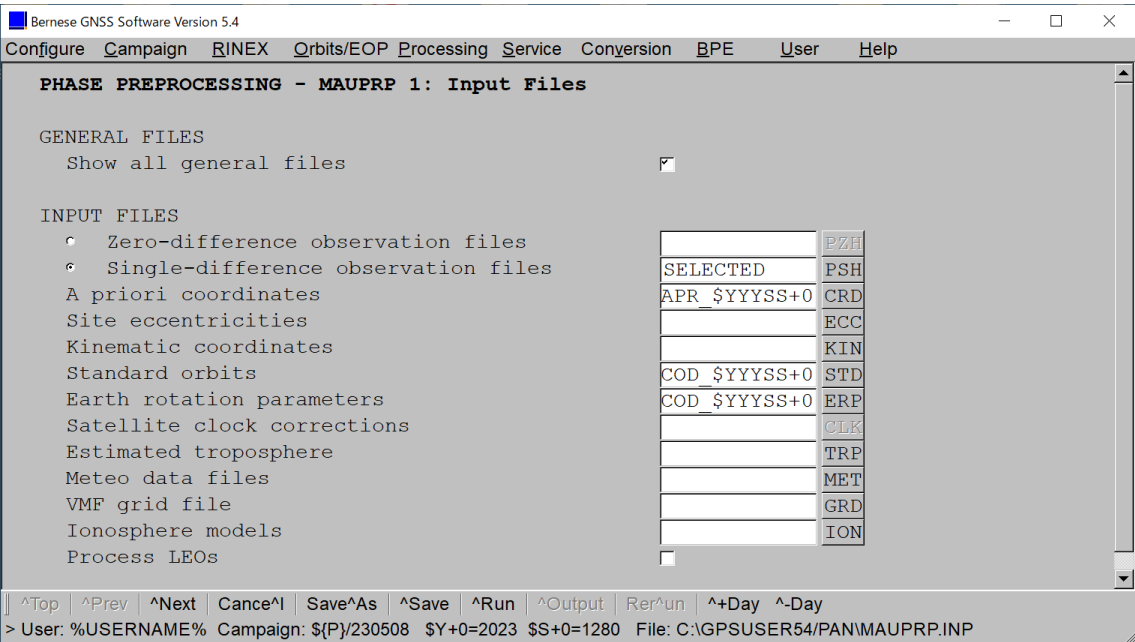
Repeat this calculation to create all required baselines.

9.6. Cycle slip, detection and correction of abnormal values (MAUPRP)

Click [Phase preprocessing] to display the submenu.



Click [^Next].



Select and Check GENERAL INPUT FILES.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

MAUPRP 1.1: General Files

GENERAL INPUT FILES

General constants

Geodetic datum

Subdaily ERP model

Nutation model

Satellite information

Satellite problems

Station information

Antenna corrections

Observation selection

CONST

DATUM

DESAI2016

IAU2000R06

SATELLIT I20

SAT \$Y+0

KHM \$YYYYSS+0

ANTENNA I20

OBSERV_COD

BSW

BSW

SUB

NUT

SAT

CRX

STA

PCV

SEL

☐

Consider antenna rotations

MENU SETTINGS

Selected campaign

Selected session

Session table

#{P}/230508

year 2023 session 1280

#{P}/230508\GEN\SESSIONS.SES

TEMPORARY FILES

Scratch files

MAUPRP\$J

SCR

MAUPRP\$J

SC1

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: #{P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\MAUPRP.INP

If you want to keep the result, enter RESULT FILES.

Click [^Next].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

MAUPRP 2: Output Files

RESULT FILES

Coordinate results

Residual file

CRD

RES

GENERAL OUTPUT FILES

Program output

Error messages

☐

☐

use MAUPRP.Lnn

merged to program output

or

or

MPR_\$YYYYSS+0

ERROR

OUT

MSG

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: #{P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\MAUPRP.INP

- 101 -

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

MAUPRP 3: General Options

TITLE

GENERAL SETTINGS

Screening mode, frequency to check

Max. baseline length to use BOTH mode km

Interpolation of clocks allowed over seconds (0:no interp)

Save screened observation files ☒

ATMOSPHERE MODELS

Troposphere

SAVING COORDINATES

Define the fixed station (blank: automatic selection)

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\MAUPRP.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

MAUPRP 4: Marking of Observations

MARKING OF OBSERVATIONS BEFORE CYCLE SLIP DETECTION

Mark if marking flags in observation file ☐

Mark observations below an elevation of degrees for stations

degrees for LEOs

Minimum time interval accepted for continuous observations seconds

Maximum gap accepted within continuous observations seconds

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\MAUPRP.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

MAUPRP 5: Non-Parametric Screening

GENERAL OPTIONS

Extent of program output SUMMARY

Maximum time interval for polynomial fit 2 minutes

SCREENING ON DIFFERENT DIFFERENCE LEVELS

☐ Original observations from file for ZD-files: zero diff.
Polynomial degree 1 SD-files: single diff.
Discontinuity level 0.4 meters

☒ Differences between satellites for ZD-files: single diff.
Polynomial degree 1 SD-files: double diff.
Discontinuity level 0.01 meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\MAUPRP.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

MAUPRP 6: Epoch-Difference Solution

EPOCH-DIFFERENCE SOLUTION

Frequency for the solution L3 for ZD-files: double diff.
SD-files: triple diff.

Kinematic coordinate estimation ☐

Maximum observed-computed value 0.5 meters (0.0: no check)

RMS limit for epoch diff. solution 0.1 meters (0.0: no check)

RMS limit for epoch solution 1.0 meters (0.0: no check)

☒ A priori coordinate/baseline vector sigmas

X-coordinate 0.1 meters

Y-coordinate 0.1 meters

Z-coordinate 0.1 meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\MAUPRP.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

MAUPRP 8: Cycle Slip Detection/Correction

CYCLE SLIP DETECTION

Extent of program output

Do not accept cycle slip corrections ☐

Minimum size of accepted cycle slip correction cycles

Test only observations with cycle slip flag ☐

L5 is clean except for observations with flags ☐

NO CYCLE SLIP HYPOTHESIS

Sigma for L1 observations meters

Sigma for L2 observations meters

Maximum ionospheric change from epoch to epoch

for single frequency mode (or short bsl.) % of L1 cycles

for combined mode (or long bsl.) % of L1 cycles

use the combined mode value for bsl longer than km

CYCLE SLIP CORRECTIONS

Search width to find L1 cycle slip correction integers

Search width to find L5 cycle slip correction integers

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\MAUPRP.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

MAUPRP 9: Outlier Rejection / Ambiguity Setting

OUTLIER REJECTION

Enable outlier rejection ☒

Mark consecutive outliers up to a time interval seconds

SET UP MULTIPLE AMBIGUITIES

Preserve ambiguities from observation file ☐

If a cycle slip flag in observation file ☐

If no cycle slip correction was possible ☒

After an observation gap larger than seconds

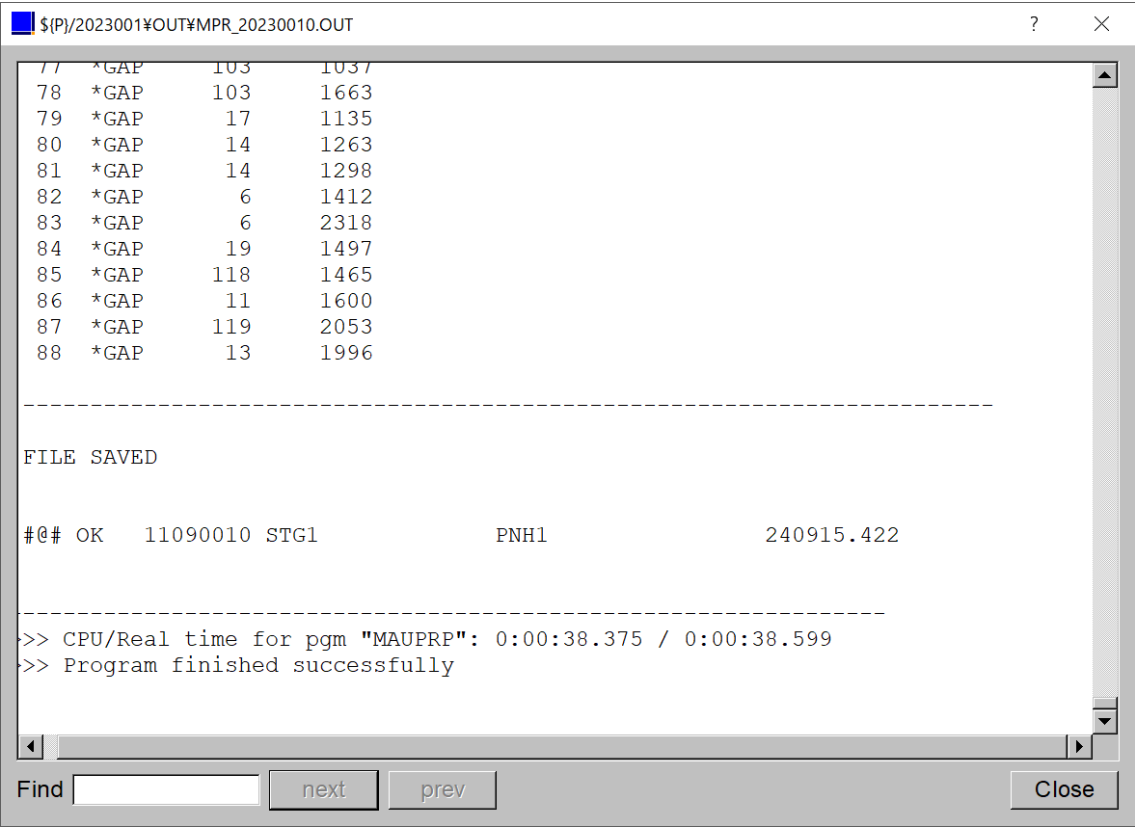
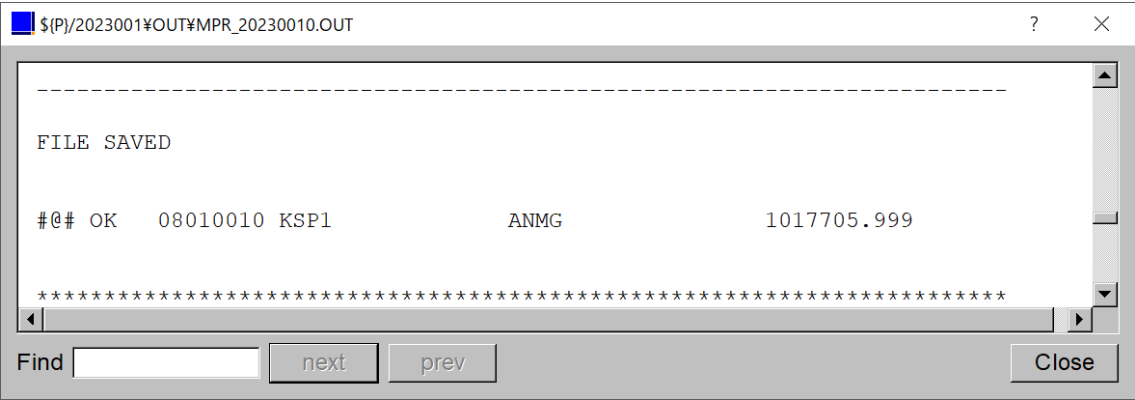
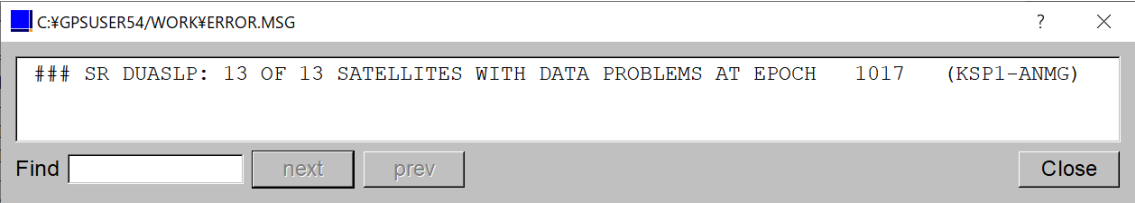
MARKING OF OBSERVATIONS AFTER CYCLE SLIP CORRECTIONS

Minimum observed time interval per ambiguity seconds

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\MAUPRP.INP

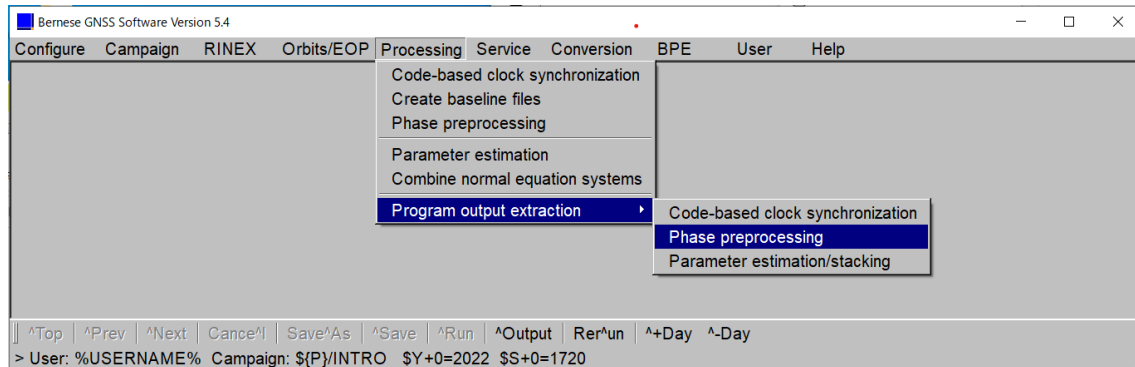
Click [^Output].
Check the results.
Ignore the following warnings.



9.7. About Baseline length (MPRXTR)

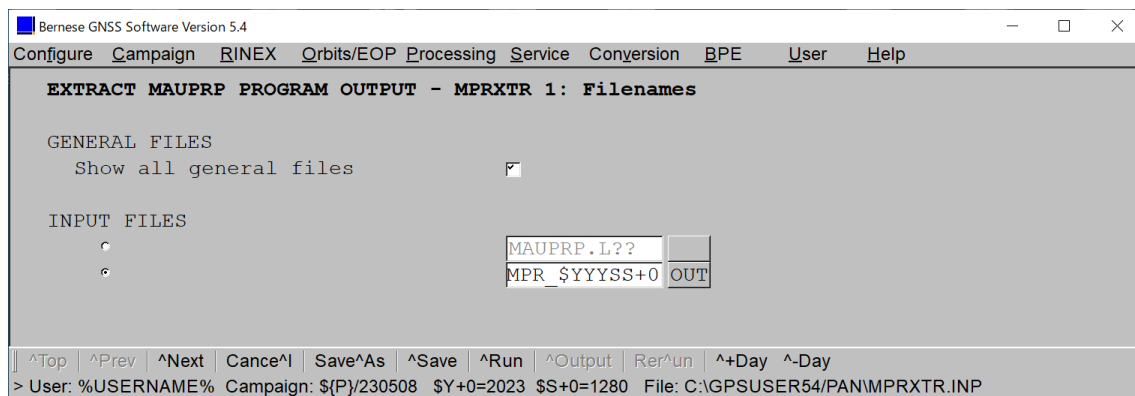
Sort the calculation results by baseline length.

Click [Phase preprocessing] to display the submenu.



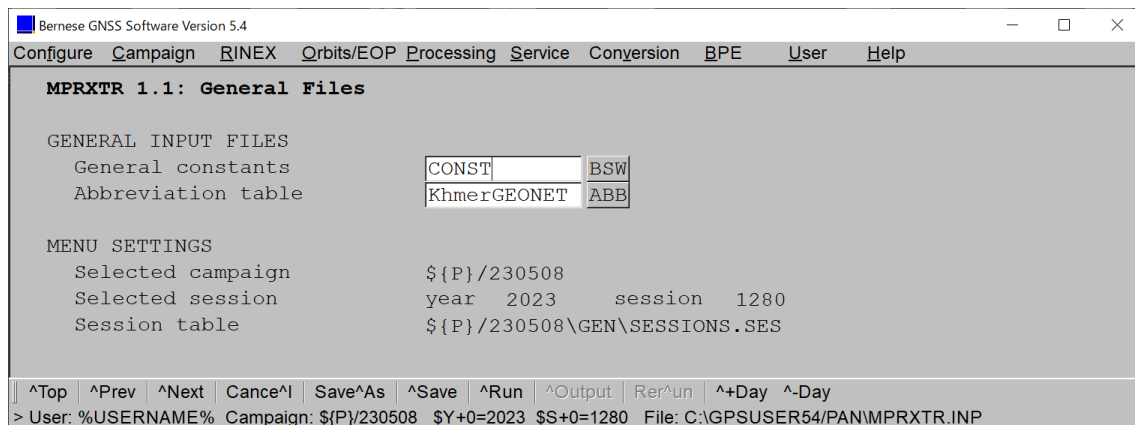
Select INPUT FILERS.

Click [^Next].



Select GENERAL INPUT FILERS.

Click [^Next].



Enter MAUPRP summary file and TITLE.

Click [^Run].

MPRXTR 2: Output Files

OUTPUT FILES

MAUPRP station summary file	MPR \$YYYSS+0	SUM
MAUPRP satellite summary file		SUM (blank: not to be saved)
File deletion list		DEL (blank: not to be saved)
New baseline definition		BSL (blank: not to be saved)

GENERAL OUTPUT FILES

Program output	☒ use MPRXTR.Lnn	or	MPRXTR	OUT
Error messages	☐ merged to program output or		ERROR	MSG

TITLE: KHM

FILE DELETION OPTION

Include in deletion file	BOTH	SINGLE-diff. files only or BOTH, single- and zero-diff. files
--------------------------	------	---

> User: %USERNAME% Campaign: \${P})Save^As\$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\MPRXTR.INP

Click [^Output].

Check the results and the output file [ex. MPR_20230010.SUM].

\$(P)/2023001\OUT\MPRXTR.L02

File	Input files
1	.../2023001\OUT\MPR_20230010.OUT

#@#	OK	02	10	0002	0010	02100010	0010
#@#	OK	04	11	0004	0011	04110010	0010
#@#	OK	07	05	0007	0005	07050010	0010
#@#	OK	07	06	0007	0006	07060010	0010
#@#	OK	07	08	0007	0008	07080010	0010
#@#	OK	08	01	0008	0001	08010010	0010
#@#	OK	09	07	0009	0007	09070010	0010
#@#	OK	10	03	0010	0003	10030010	0010
#@#	OK	10	09	0010	0009	10090010	0010
#@#	OK	11	09	0011	0009	11090010	0010

>>> CPU/Real time for pgm "MPRXTR": 0:00:00.109 / 0:00:00.116
 >>> Program finished successfully

Find

Check the [MPR_20230010.SUM] file.

	名前	更新日時	種類
CAMPAIGN54			
2023001			
ATM			
BPE			
GEN			
GRD			
OBS			
ORB			
ORX			
OUT			
RAW			
SOL			
STA			
	MPR_20230010.SUM	2023/07/27 17:47	SUM ファイル
	MPRXTRJ	2023/07/27 17:47	J ファイル
	MPRXTR.L02	2023/07/27 17:47	L02 ファイル
	MPR_20230010.OUT	2023/07/27 17:41	OUT ファイル
	SNGDIFJ	2023/07/27 17:37	J ファイル
	SNGDIFL17	2023/07/27 17:37	L17 ファイル
	SNGDIFL16	2023/07/27 17:36	L16 ファイル
	SNGDIFL15	2023/07/27 17:36	L15 ファイル
	SNGDIFL14	2023/07/27 17:36	L14 ファイル
	SNGDIFL13	2023/07/27 17:36	L13 ファイル
	SNGDIFL12	2023/07/27 17:35	L12 ファイル
	SNGDIFL11	2023/07/27 17:35	L11 ファイル

MPR_20230010.SUM - Xメモ

ファイル(F)編集(E)書式(O)表示(V)ヘルプ(H)

SUMMARY OF THE MAUPRP OUTPUT FILE

SESS	FIL	OK?	ST1	ST2	L (KM)	#OBS.	RMS	DX	DY	DZ	#SL	#DL	#MA	MAXL3
0010	1	OK	0002	0010	797	32061	15	195	240	115	79	1099	96	50
0010	2	OK	0004	0011	1289	35454	13	165	28	-30	20	872	69	48
0010	3	OK	0007	0005	1769	31397	14	133	175	63	20	1116	74	49
0010	4	OK	0007	0006	1116	34270	14	-69	-517	-208	18	1020	84	48
0010	5	OK	0007	0008	49	35784	14	-10	-6	-3	23	847	88	46
0010	6	OK	0008	0001	1018	34808	12	-19	-498	-128	208	747	84	49
0010	7	OK	0009	0007	33	35130	13	13	-14	-8	12	876	92	50
0010	8	OK	0010	0003	366	34308	11	-34	-481	-159	7	455	63	38
0010	9	OK	0010	0009	220	35213	12	-11	111	12	10	642	89	46
0010	10	OK	0011	0009	241	35998	12	107	-116	-46	24	651	88	50

Tot:	10				690	35998	15	-69	-517	-208	208	1116	96	50

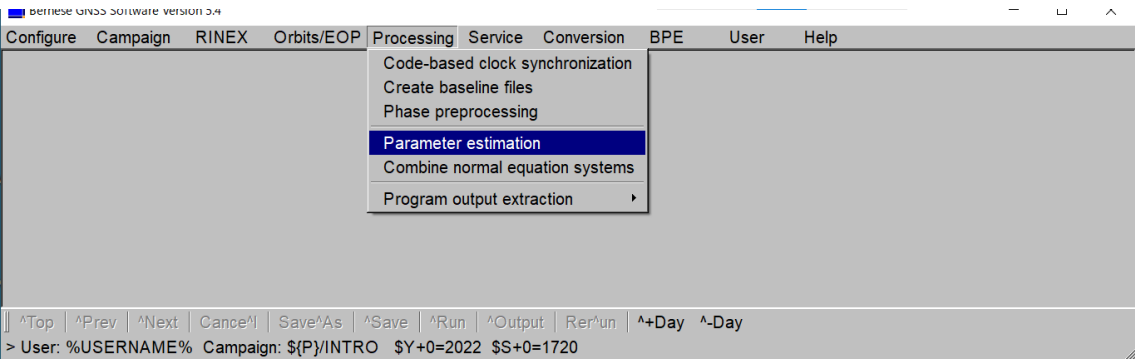
1行、1列100%Windows (CRLF)UTF-8

9.8. Check the data (GPSEST, RMSCHK, SATMRK)

9.8.1. GPSEST

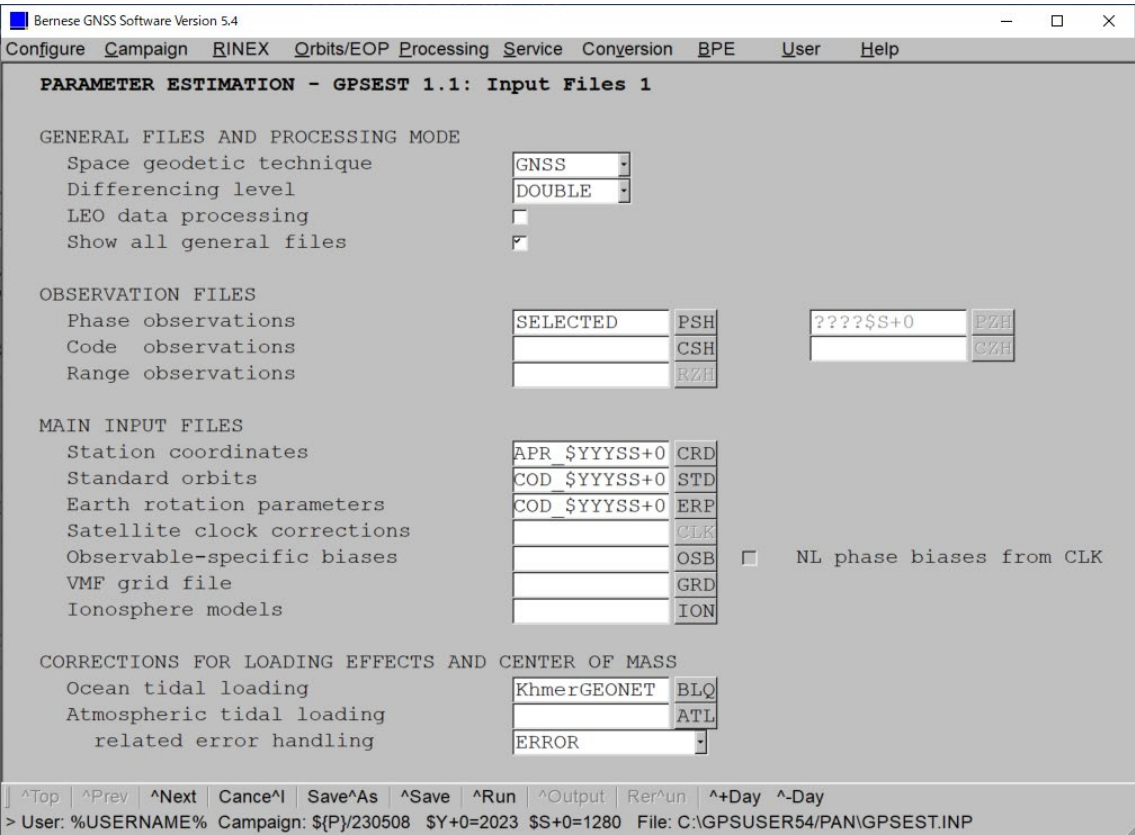
Check data quality.

Click [Parameter estimation] to display the submenu.



Select INPUT FILES

Click [^Next].



Click [^Next].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 1.2: Input Files 2

ADDITIONAL INPUT FILES

Satellite orbit partials		RPR
Clock RINEX file		CLK
Estimated troposphere		TRP
Meteorological data		MET

GRIDDED LOADING PARAMETERS

Atmospheric pressure		GRD
Ocean, non-tidal		GRD
Hydrostatic pressure		GRD

AUXILIARY STATION FILES

Station information		STA
Kinematic coordinates		KIN
Observation sigma factors		SOS
Station eccentricities		ECC

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Select GENERAL INPUT FILES.

Click [^Next].

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GPSEST 1.4: General Files

GENERAL INPUT FILES

General constants	CONST	BSW
Geodetic datum	DATUM	BSW
Antenna corrections	ANTENNA_I20	PCV
Observation selection	OBSERV_COD	SEL
Satellite information	SATELLIT_I20	SAT
Satellite problems	SAT \$Y+0	CRX
Earth potential coefficients	GM2008_SMALL	GRV
Subdaily ERP model	DESAI2016	SUB
Nutation model	IAU2000R06	NUT
SINEX header file		SKL
IONEX control file		SKL
GPS-UTC time difference	GPSUTC	BSW
Frequency information		FRQ

☐ Consider ant. rotations

MENU SETTINGS

Selected campaign	\${P}/INTRO	
Selected session	Year 2022	Session 1720
Session table	\${P}/INTRO\GEN\SESSIONS.SES	

TEMPORARY FILES

Scratch files	GPSEST\$J SCR	GPSEST\$J SC1	GPSEST\$J SC2
---------------	---------------	---------------	---------------

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 2.1: Output Files 1

GENERAL OUTPUT FILES

Program output

☐

use GPSEST.Lnn

or

EDT_YYYYSS+0

OUT

Error messages

☐

merged to program output

or

ERROR

MSG

NORMAL EQUATION SYSTEM

NQ0

STATION- AND SATELLITE-RELATED RESULTS

Station coordinates

CRD

Satellite orbital elements

ELE

Earth rotation parameters

ERP

Earth rotation parameters (IERS)

IEP

ATMOSPHERE-SPECIFIC RESULTS

Troposphere estimates

TRP

Troposphere estimates (SINEX)

TRO

Troposphere slant delays

TRS

Ionosphere models

ION

Ionosphere models (IONEX)

INX

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Enter Observation residuals.

Click [^Next].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 2.2: Output Files 2

ADDITIONAL RESULT FILES

Observable-specific code biases

OSB

Bias SINEX

BIA

Phase center variations (gridded)

PHG

Phase center variations (spherical)

PHH

EPOCH-SPECIFIC RESULTS

GNSS clock corrections

CLK

Clock RINEX

CLK

Kinematic coordinates

KIN

Epoch-wise KIN covariances (LEOs)

COV

AUXILIARY FILES

Observation residuals

EDT_YYYYSS+0

RES

☐

Extended format

Covariance matrix

COV

Covariance matrix wrt coordinates

COV

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.1: General Options 1

TITLE

OBSERVATION SELECTION

GNSS SELECTION

☒ GPS	☒ GLONASS	☒ Galileo
☐ SBAS	☐ BeiDou	☐ QZSS

Frequency/linear combination

PCC applied for MELWUEBB/L4 LC

Elevation cutoff angle degrees

Sampling interval seconds

Tolerance for simultaneity milliseconds

Special data selection

Observation window ☐

OBSERVATION MODELING AND PARAMETER ESTIMATION

A priori sigma of unit weight meters

Elevation-dependent weighting

Type of computed residuals

Correlation strategy

LEO-SPECIFIC SELECTION AND MODELING OPTIONS

Elevation cutoff angle degrees

Elevation-dependent weighting

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/230510B \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2: General Options 2

A PRIORI TROPOSPHERE MODELING

ZPD model and mapping function for GNSS
 for SLR

HANDLING OF AMBIGUITIES

Resolution strategy

Solve ambiguities for

☒ GPS	☒ GLONASS	☒ Galileo
☒ SBAS	☒ BeiDou	☒ QZSS

Consider GPS quarter-cycle biases

Omit AR between subconstellations ☒ (between BeiDou-2 and BeiDou-3)

Save resolved ambiguities ☒

Introduce widelane integers ☐

Introduce L1 and L2 integers ☐

SPECIAL PROCESSING OPTIONS

Stop program after NEQ saving ☒

Activate extended program output ☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 4: Datum Definition for Station Coordinates

DATUM DEFINITION TYPE

- ☐ Free network solution
- ☒ Coordinates constrained WITH FLAG
- ☐ Coordinates fixed FIRST

A PRIORI SIGMAS

North	0.01	meters
East	0.01	meters
Up	0.01	meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 4.1: Datum Definition for Station Coordinates

STATION COORDINATES TO BE CONSTRAINED

- Manual selection CUSV
- List of stations (and sigmas) from file
- Stations with specific flags in CRD file I #: all non-blank

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 5.1: Setup of Parameters and Pre-Elimination 1

STATION-RELATED PARAMETERS		Setup	Pre-Elimination
Station coordinates			NO
Ambiguities			NO
ATMOSPHERIC PARAMETERS			
Site-specific troposphere parameters	☒		NO
Global ionosphere parameters	☐		NO
GLOBAL PARAMETERS			
Orbital parameters	☐	GNSS	NO
	☐	LEO	NO
Earth orientation parameters	☐		NO
Geocenter coordinates	☐		NO
EPOCH PARAMETERS			
Receiver clock offsets	☒		EVERY EPOCH
Satellite clock offsets	☐		EVERY EPOCH
Kinematic coordinates	☐		EVERY EPOCH
Stochastic ionosphere parameters	☒		EVERY EPOCH

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 5.2: Setup of Parameters and Pre-Elimination 2

BIAS PARAMETERS

Setup

Pre-Elimination

Observable-specific code biases

GNSS-specific translation parameters

ANTENNA PHASE CENTER PARAMETERS

Satellite phase center offsets

Satellite phase center variations

Receiver phase center offsets

Receiver phase center variations

PARAMETER SCALING FACTORS

Scaling related to loading effects

Higher-order ionosphere scaling

SLR-RELATED PARAMETERS

Range biases

TIME OFFSET FOR PARAMETER INTERVALS

NO

NO

NO

NO

NO

NO

NO

NO

(hhh mm ss)

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rerun

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 6.1.1: Site-Specific Troposphere Parameters 1

ZENITH PATH DELAY PARAMETERS

Mapping function

Parameter spacing

HORIZONTAL GRADIENT PARAMETERS

Gradient estimation model

Parameter spacing

A PRIORI SIGMAS

Zenith path delay

Horizontal gradients

WET GMF3

04 00 00

CHEN-HERRING

24 00 00

Absolute

Relative

meters

meters

5

5

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rerun

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 6.1.2: Site-Specific Troposphere Parameters 2

STATIONS TO BE EXCLUDED FROM TROPOSPHERE ESTIMATION

Station selection

Station list from file

Manual selection

STATIONS WITH SPECIAL A PRIORI SIGMAS

Station selection

Station list from file

Manual selection

SPECIAL A PRIORI SIGMAS

	Absolute		Relative	
Zenith path delay		meters		meters
Horizontal gradients		meters		meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Output].

Check the results.

\$(P)/2023001\$OUT\$EDT_20230010.OUT

330	3	14	1351	2035	3	-	103	---	REFERENCE	---
432	4	7	1003	1711	3	-	93	---	REFERENCE	---
525	5	26	223	907	3	-	60	---	REFERENCE	---
677	6	7	979	1699	3	-	93	---	REFERENCE	---
768	7	26	199	907	3	-	60	---	REFERENCE	---
843	8	15	2113	2863	3	-	9	---	REFERENCE	---
999	9	26	223	931	3	-	61	---	REFERENCE	---
1128	10	26	223	931	3	-	67	---	REFERENCE	---

>>> CPU/Real time for pgm "GPSEST": 0:00:28.406 / 0:00:28.729

>>> Program finished successfully

Find

Statistics:	

Total number of authentic observations	58194
Total number of pseudo-observations	28
Total number of explicit parameters	1343
Total number of implicit parameters	0
Total number of observations	58222
Total number of adjusted parameters	1343
Degree of freedom (DOF)	56879
A posteriori RMS of unit weight	0.001488 m
Chi**2/DOF	2.21
Total number of observation files	10
Total number of unobserved ambiguities	136
Total number of stations	11

\$\{P\}/2023001\\$\text{OUT}\\$\text{EDT_20230010.OUT}\$? X

Sol	Station name	Typ	Correction	Estimated value	RMS error	A priori
1	CMUM	X	-0.12532	-938078.47342	0.00541	-938078
1	CMUM	Y	-0.00899	5968373.97731	0.00636	5968373
1	CMUM	Z	-0.00837	2038404.31353	0.00527	2038404
1	SIE1	X	0.09340	-1490303.79960	0.00537	-1490303
1	SIE1	Y	-0.01820	6024644.79880	0.00607	6024644
1	SIE1	Z	0.02496	1465891.16096	0.00519	1465891
1	HKSL	X	-0.14082	-2393383.05832	0.00542	-2393382
1	HKSL	Y	-0.05809	5393860.93951	0.00633	5393860
1	HKSL	Z	0.03810	2412582.18400	0.00530	2412582

Find Sol Sta

next

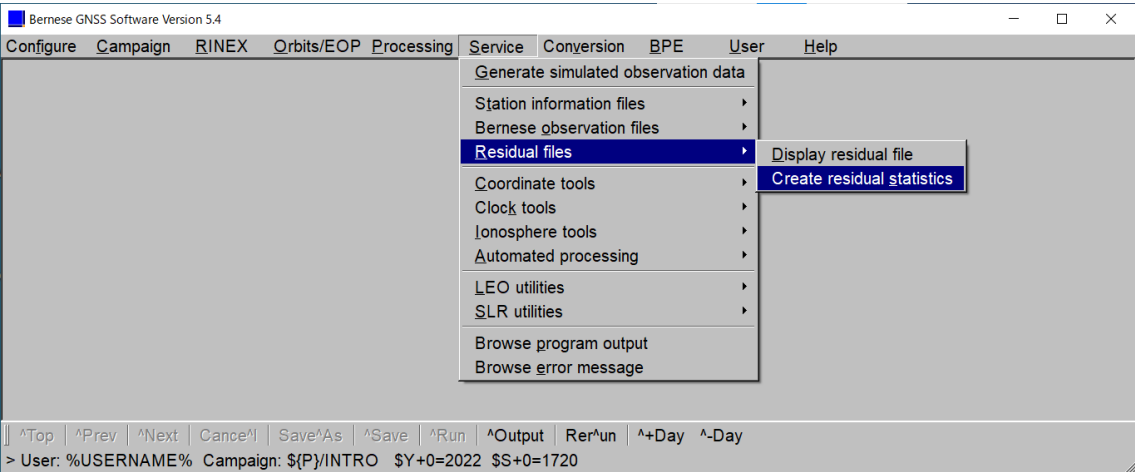
prev

Close

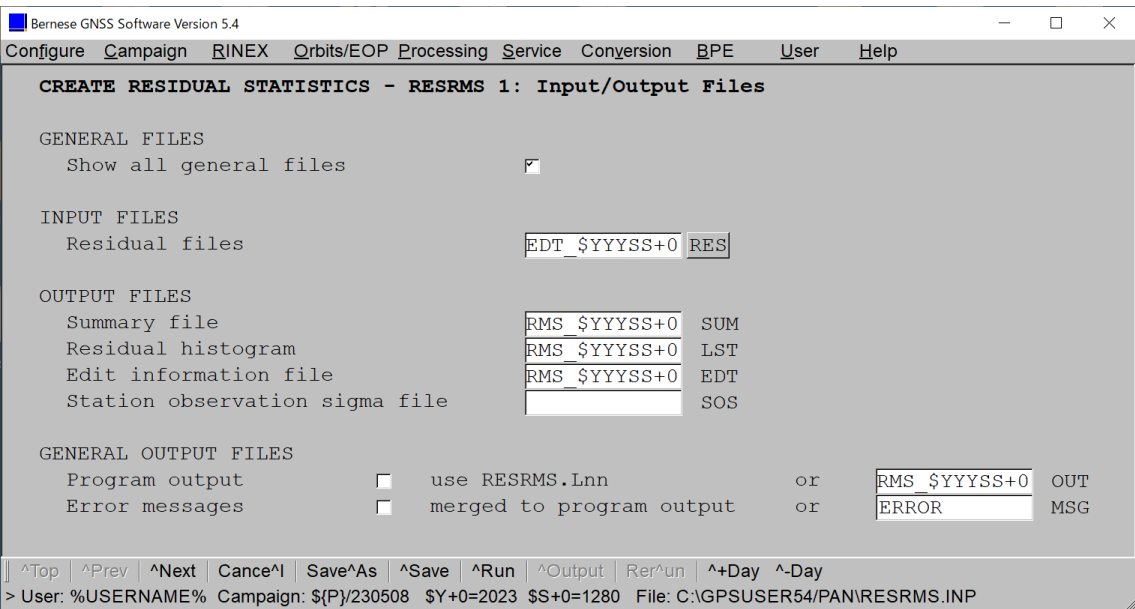
9.8.2. RMSCHK

Examine the residuals file.
Make a list of outliers.

Click [Create residual statistics] to display the submenu.



Select INPUT FILE.
Enter OUTPUT FILE. The Edit information file is used by program SATMRK.
Click [^Next].



Select and Check GENERAL INPUT FILES.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RESRMS 1.1: General Files

GENERAL INPUT FILES

General constants

CONST

BSW

Satellite information

SATELLIT I20

SAT

Abbreviation table

KhmerGEONET

ABE

MENU SETTINGS

Selected campaign

\${P}/230508

Selected session

year 2023

session 1280

Session table

\${P}/230508\GEN\SESSIONS.SES

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\RESRMS.INP

Sampling rate of residual files is 180 seconds.

Enter TITLE.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RESRMS 2: Options

TITLE

KHM

GENERAL OPTIONS

Frequency to check

L3

Sampling interval of residual files

180

seconds

DETECT LARGE RESIDUALS

limit

Phase measurements

☒

0.004

meters

Code measurements

☐

0.004

meters

Range measurements

☐

0.3000

meters

APPLY GNSS-SPECIFIC RESIDUAL FACTOR (EMPTY/DEFAULT IS 1.0)

GPS

1.0

GLONASS

1.0

Galileo

1.0

SBAS

1.0

BeiDou

1.0

QZSS

1.0

DETECT BAD DATA

Minimum continuously observed time interval

361

seconds

Detect ambiguities with few observations

☐

Minimum number of observations per ambiguity

3

Sampling interval for counting the observations

seconds

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\RESRMS.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RESRMS 3: Residual Statistics and Sigma Factors

OPTIONS FOR RESIDUAL HISTOGRAM

Size of histogram50

Bin width for histogram0.1 millimeters

STATION OBSERVATION SIGMA FACTORS

Compute measurement noise fromMEDIAN of residuals

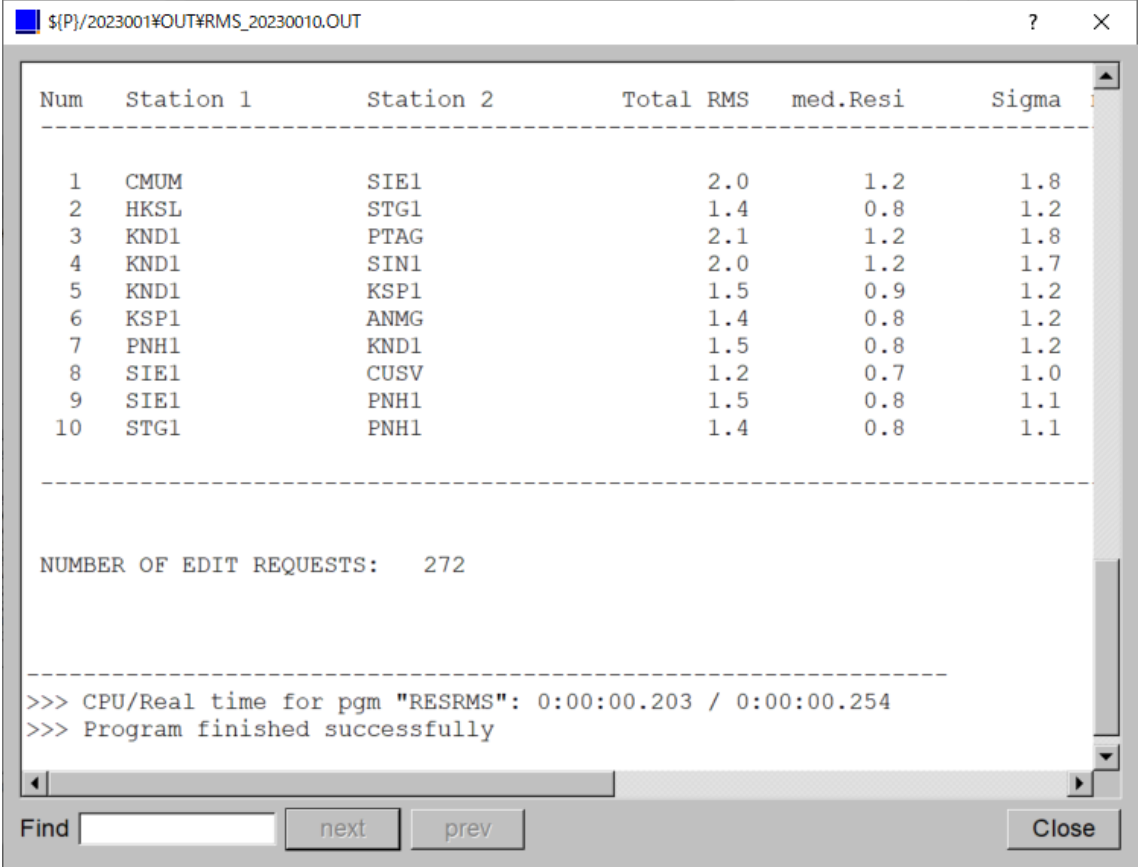
Default sigma factor1.00

New sigma factor	Noise larger than (m)		
1.41	0.005	+	-
1.73	0.010	+	-
2.00	0.015	+	-

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\RESRMS.INP

Click [^Output].
Check the result.



The screenshot shows a terminal window with a title bar containing a file path and standard window controls. The main content area displays a table with 6 columns: Num, Station 1, Station 2, Total RMS, med.Resi, and Sigma. Below the table, it shows the number of edit requests and program execution statistics. At the bottom, there is a search bar and navigation buttons.

Num	Station 1	Station 2	Total RMS	med.Resi	Sigma
1	CMUM	SIE1	2.0	1.2	1.8
2	HKSL	STG1	1.4	0.8	1.2
3	KND1	PTAG	2.1	1.2	1.8
4	KND1	SIN1	2.0	1.2	1.7
5	KND1	KSP1	1.5	0.9	1.2
6	KSP1	ANMG	1.4	0.8	1.2
7	PNH1	KND1	1.5	0.8	1.2
8	SIE1	CUSV	1.2	0.7	1.0
9	SIE1	PNH1	1.5	0.8	1.1
10	STG1	PNH1	1.4	0.8	1.1

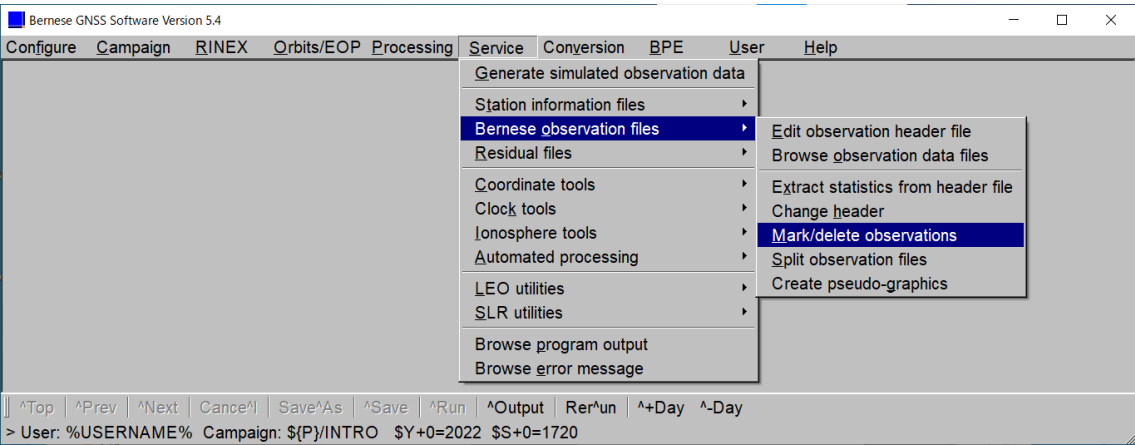
NUMBER OF EDIT REQUESTS: 272

>>> CPU/Real time for pgm "RESRMS": 0:00:00.203 / 0:00:00.254
>>> Program finished successfully

Find next prev Close

9.8.3. SATMRK

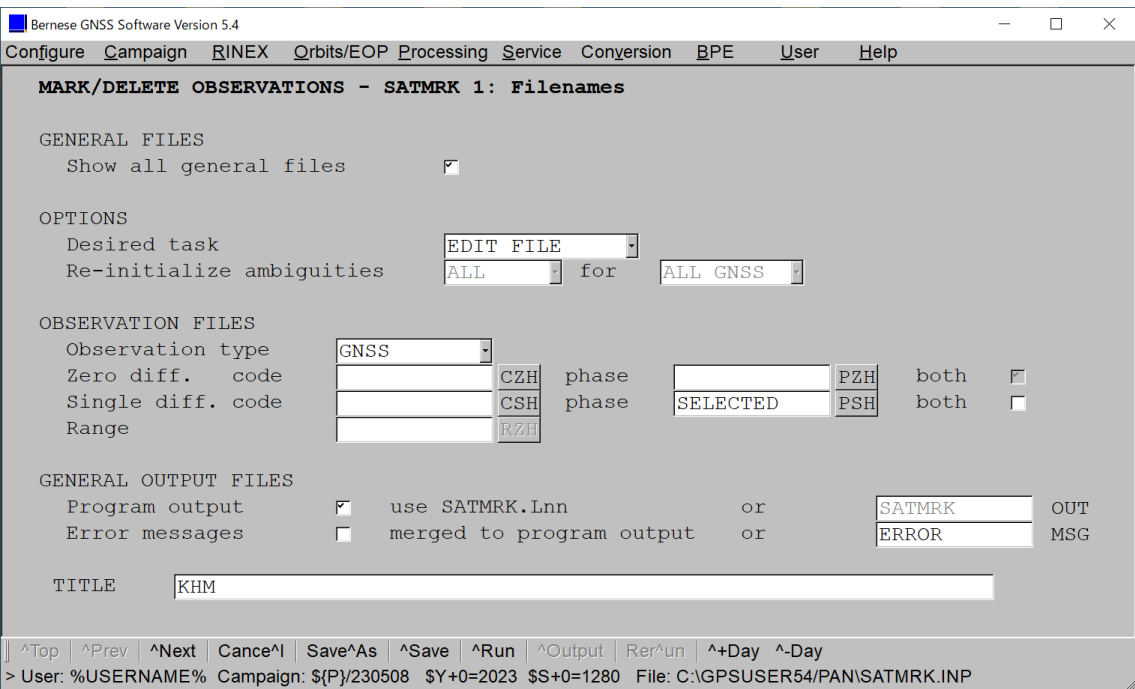
Use the outlier list to flag anomalous data. Data with flags are not used in calculations. Click [Mark/delete observations] to display the submenu.



Select Single Diff. phase file.

Enter TITLE.

Click [^Next].



Select GENERAL INPUT FILES.

Click [^Next].

The screenshot shows the 'SATMRK 1.1: General Files' dialog box in the Bernese GNSS Software Version 5.4. The dialog has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into four sections: 'GENERAL INPUT FILES', 'MENU SETTINGS', 'TEMPORARY FILES', and a status bar. In 'GENERAL INPUT FILES', 'General constants' is set to 'CONST' and 'BSW', and 'Satellite information' is set to 'SATELLIT_I20' and 'SAT'. In 'MENU SETTINGS', 'Selected campaign' is '\$(P)/INTRO', 'Selected session' is 'year 2022 session 1720', and 'Session table' is '\$(P)/INTRO\GEN\SESSIONS.SES'. In 'TEMPORARY FILES', 'Scratch file' is 'SATMRK\$J' and 'SCR'. The status bar at the bottom shows: '> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\SATMRK.INP'. The bottom of the dialog has a row of buttons: '^Top', '^Prev', '^Next', 'Cancel', 'Save^As', '^Save', '^Run', '^Output', 'Rer^un', '^+Day', and '^~Day'.

Select Edit information file.

Click [^Run].

The screenshot shows the 'SATMRK 2: Manual and File Selection' dialog box in the Bernese GNSS Software Version 5.4. The dialog has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into two sections: 'FILE SELECTION' and 'MANUAL SELECTION'. In 'FILE SELECTION', 'Edit information file' is set to 'RMS_\$YYYYSS+0' and 'EDT'. In 'MANUAL SELECTION', 'Type of change' is 'MARK', 'Frequency' is 'L1&L2', and 'Satellite(s)' is 'ALL'. There are two radio buttons: 'From epoch to epoch' and 'Observation window'. The 'Observation window' section has 'Start' set to '\$YMD_STR+0' and 'End' set to '\$YMD_STR+0'. The status bar at the bottom shows: '> User: %USERNAME% Campaign: \$(P)/230513C \$Y+0=2023 \$S+0=1330 File: C:\GPSUSER54\PAN\SATMRK.INP'. The bottom of the dialog has a row of buttons: '^Top', '^Prev', '^Next', 'Cancel', 'Save^As', '^Save', '^Run', '^Output', 'Rer^un', '^+Day', and '^~Day'.

Click [^Output].

Check the results.

\$(P)/2023001\OUT\SATMRK.L02

SUMMARY OF ACTION IN THE OBS. FILE(S): \$(P)/2023001\OUT\RMS_20230010.ED

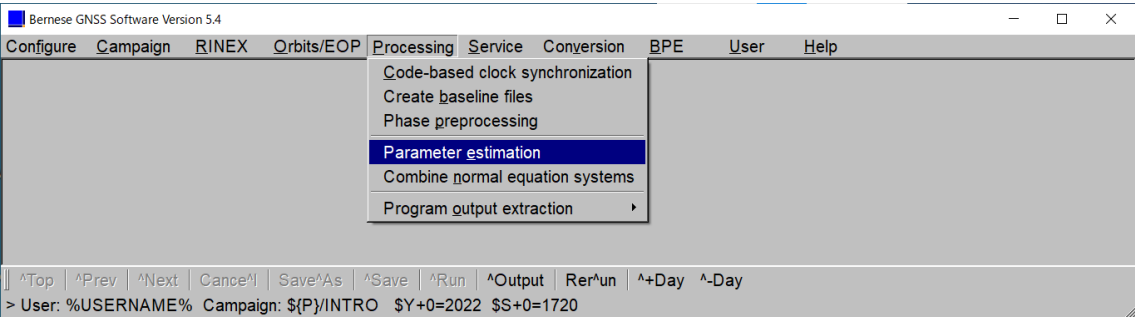
Num	Station name 1	Station name 2	Mea- type	Observations		
				mark	unmark	delete
1	CMUM	SIE1	P :	222	0	0
2	HKSL	STG1	P :	48	0	0
3	KND1	PTAG	P :	298	0	0
4	KND1	SIN1	P :	164	0	0
5	KND1	KSP1	P :	34	0	0
6	KSP1	ANMG	P :	20	0	0
7	PNH1	KND1	P :	42	0	0
8	SIE1	CUSV	P :	0	0	0
9	SIE1	PNH1	P :	54	0	0
10	STG1	PNH1	P :	68	0	0
Total:				950	0	0

>>> CPU/Real time for pgm "SATMRK": 0:00:00.625 / 0:00:00.742
>>> Program finished successfully

Find next prev Close

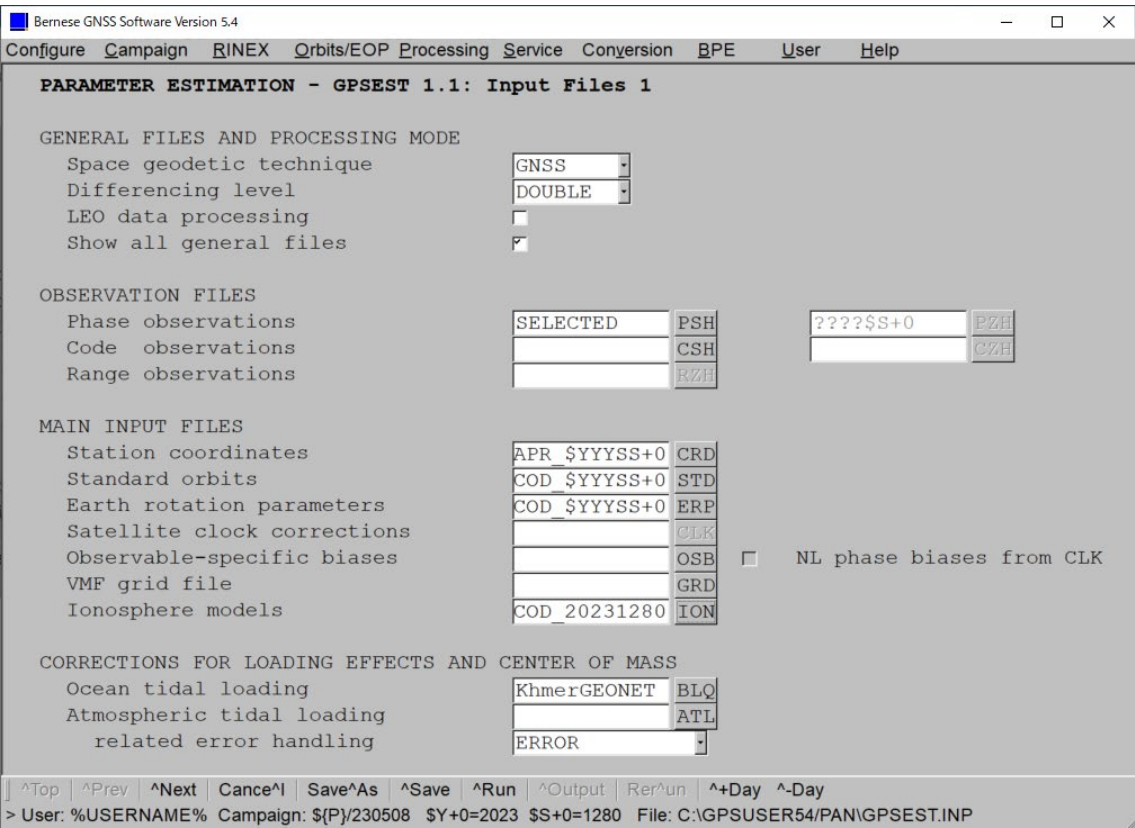
9.9. Coordinate values when Ambiguity is a real number and estimating the amount of atmospheric propagation delay (GPSEST)

Click [Parameter estimation] to display the submenu.



Select INPUT FILES.

Click [^Next].



Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 1.2: Input Files 2

ADDITIONAL INPUT FILES

Satellite orbit partials		RPR
Clock RINEX file		CLK
Estimated troposphere		TRP
Meteorological data		MET

GRIDDED LOADING PARAMETERS

Atmospheric pressure		GRD
Ocean, non-tidal		GRD
Hydrostatic pressure		GRD

AUXILIARY STATION FILES

Station information		STA
Kinematic coordinates		KIN
Observation sigma factors		SOS
Station eccentricities		ECC

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Select GENERAL INPUT FILES.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 1.4: General Files

GENERAL INPUT FILES

General constants	CONST	BSW
Geodetic datum	DATUM	BSW
Antenna corrections	ANTENNA_I20	PCV
Observation selection	OBSERV_COD	SEL
Satellite information	SATELLIT_I20	SAT
Satellite problems	SAT \$Y+0	CRX
Earth potential coefficients	GM2008_SMALL	GRV
Subdaily ERP model	DESAI2016	SUB
Nutation model	IAU2000R06	NUT
SINEX header file		SKL
IONEX control file		SKL
GPS-UTC time difference	GPSUTC	BSW
Frequency information		FRO

☐ Consider ant. rotations

MENU SETTINGS

Selected campaign	\${P}/INTRO	
Selected session	Year 2022	Session 1720
Session table	\${P}/INTRO\GEN\SESSIONS.SES	

TEMPORARY FILES

Scratch files	GPSEST\$J SCR	GPSEST\$J SC1	GPSEST\$J SC2
---------------	---------------	---------------	---------------

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Enter Program output, Station coordinates and Troposphere estimate.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 2.1: Output Files 1

GENERAL OUTPUT FILES

Program output ☒ use GPSEST.Lnn or FLT_YYYYSS+0 OUT

Error messages ☒ merged to program output or ERROR MSG

NORMAL EQUATION SYSTEM NQ0

STATION- AND SATELLITE-RELATED RESULTS

Station coordinates FLT_YYYYSS+0 CRD

Satellite orbital elements ELE

Earth rotation parameters ERP

Earth rotation parameters (IERS) IEP

ATMOSPHERE-SPECIFIC RESULTS

Troposphere estimates FLT_YYYYSS+0 TRP

Troposphere estimates (SINEX) TRO

Troposphere slant delays TRS

Ionosphere models ION

Ionosphere models (IONEX) INX

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Enter Observation residuals.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 2.2: Output Files 2

ADDITIONAL RESULT FILES

Observable-specific code biases OSB

Bias SINEX BIA

Phase center variations (gridded) PHG

Phase center variations (spherical) PHH

EPOCH-SPECIFIC RESULTS

GNSS clock corrections CLK

Clock RINEX CLK

Kinematic coordinates KIN

Epoch-wise KIN covariances (LEOs) COV

AUXILIARY FILES

Observation residuals RES ☐ Extended format

Covariance matrix COV

Covariance matrix wrt coordinates COV

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Sampling interval is 180 seconds.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.1: General Options 1

TITLE KHM

OBSERVATION SELECTION

GNSS SELECTION

☒ GPS ☒ GLONASS ☒ Galileo
☐ SBAS ☐ BeiDou ☐ QZSS

Frequency/linear combination L3
PCC applied for MELWUEBB/L4 LC NEVER
Elevation cutoff angle 5 degrees
Sampling interval 180 seconds
Tolerance for simultaneity 100 milliseconds
Special data selection NO
Observation window

OBSERVATION MODELING AND PARAMETER ESTIMATION

A priori sigma of unit weight 0.001 meters
Elevation-dependent weighting COSZ
Type of computed residuals NORMALIZED
Correlation strategy BASELINE

LEO-SPECIFIC SELECTION AND MODELING OPTIONS

Elevation cutoff angle 0 degrees
Elevation-dependent weighting NONE

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day
> User: %USERNAME% Campaign: \$(P)/230510B \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2: General Options 2

A PRIORI TROPOSPHERE MODELING

ZPD model and mapping function DRY GPT3 for GNSS
MENDES-PAVLIS for SLR

HANDLING OF AMBIGUITIES

Resolution strategy NONE
Solve ambiguities for
☒ GPS ☒ GLONASS ☒ Galileo
☒ SBAS ☒ BeiDou ☒ QZSS

Consider GPS quarter-cycle biases IF INDICATED
Omit AR between subconstellations (between BeiDou-2 and BeiDou-3)
Save resolved ambiguities
Introduce widelane integers
Introduce L1 and L2 integers

SPECIAL PROCESSING OPTIONS

Stop program after NEQ saving
Activate extended program output

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day
> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2.1.1: Extended Program Output Options

INFORMATION RELATED TO OBSERVATIONS

- List of observations given in files ☐
- List of observations used for processing ☐
- Satellite elevations ☐
- Histogram of observations by elevation angle bins ☐
- Histogram of observations by nadir angle bins ☐
- Phase-connected time intervals ☐

INFORMATION RELATED TO ESTIMATED PARAMETERS

- List of all parameters ☐
- Unresolved ambiguities after each iteration step ☐
- Extended summary concerning coordinate parameters ☒
- Extended summary concerning ionosphere parameters ☐
- Extended summary concerning troposphere parameters ☒
- Suppression of output concerning troposphere parameters ☐
- Suppression of output concerning coordinate parameters ☐
- Suppression of output concerning ambiguity parameters ☐
- Suppression of output concerning epoch parameters ☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2.1.2: Extended Program Output Options

OTHER INFORMATION

- Resolved ambiguities from observation files ☐
- Constants, antenna offsets, ionosphere coefficients ☐
- Station eccentricities, receiver information ☐
- Receiver synchronization errors ☐
- RMS of ellipsoidal coordinates and differences ☐
- Slope distances and their RMS ☐
- Statistics on the parameter dimensions ☒

HELMERT TRANSFORMATION OF RESULTING STATION COORDINATES

- Activate Helmert transformation ☐
- Coordinate system for transformation
- Rotation ☒
- Scale ☒

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

A PRIORI SIGMAS is [0.001] meters.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 4: Datum Definition for Station Coordinates

DATUM DEFINITION TYPE

☐ Free network solution

☒ Coordinates constrained

☐ Coordinates fixed

WITH FLAG

FIRST

A PRIORI SIGMAS

North

0.001

meters

East

0.001

meters

Up

0.001

meters

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Enter flag in CRD file.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 4.1: Datum Definition for Station Coordinates

STATION COORDINATES TO BE CONSTRAINED

Manual selection

CUSV

List of stations (and sigmas) from file

STG

Stations with specific flags in CRD file

I

#: all non-blank

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 5.1: Setup of Parameters and Pre-Elimination 1

STATION-RELATED PARAMETERS		Setup	Pre-Elimination
Station coordinates			NO
Ambiguities			EVERY SESSION

ATMOSPHERIC PARAMETERS		Setup	Pre-Elimination
Site-specific troposphere parameters	☒		NO
Global ionosphere parameters	☐		NO

GLOBAL PARAMETERS		Setup	Pre-Elimination
Orbital parameters	☐	GNSS	NO
	☐	LEO	NO
Earth orientation parameters	☐		NO
Geocenter coordinates	☐		NO

EPOCH PARAMETERS		Setup	Pre-Elimination
Receiver clock offsets	☒		EVERY EPOCH
Satellite clock offsets	☐		EVERY EPOCH
Kinematic coordinates	☐		EVERY EPOCH
Stochastic ionosphere parameters	☒		EVERY EPOCH

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 5.2: Setup of Parameters and Pre-Elimination 2

BIAS PARAMETERS		Setup	Pre-Elimination
Observable-specific code biases	☐		NO
GNSS-specific translation parameters	☐		NO

ANTENNA PHASE CENTER PARAMETERS		Setup	Pre-Elimination
Satellite phase center offsets	☐		NO
Satellite phase center variations	☐		NO
Receiver phase center offsets	☐		NO
Receiver phase center variations	☐		NO

PARAMETER SCALING FACTORS		Setup	Pre-Elimination
Scaling related to loading effects	☐		NO
Higher-order ionosphere scaling	☐		NO

SLR-RELATED PARAMETERS		Setup	Pre-Elimination
Range biases	☐		NO

TIME OFFSET FOR PARAMETER INTERVALS (hhh mm ss)

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 6.1.1: Site-Specific Troposphere Parameters 1

ZENITH PATH DELAY PARAMETERS

Mapping functionWET GMF3

Parameter spacing01 00 00 (hh mm ss)

HORIZONTAL GRADIENT PARAMETERS

Gradient estimation modelCHEN-HERRING

Parameter spacing24 00 00 (hh mm ss)

A PRIORI SIGMAS

Absolute

Relative

Zenith path delay

Horizontal gradients

meters

meters

5

5

meters

meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Run].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 6.1.2: Site-Specific Troposphere Parameters 2

STATIONS TO BE EXCLUDED FROM TROPOSPHERE ESTIMATION

Station selectionNONE

Station list from file

Manual selection

STATIONS WITH SPECIAL A PRIORI SIGMAS

Station selectionNONE

Station list from file

Manual selection

SPECIAL A PRIORI SIGMAS

Absolute

Relative

Zenith path delay

Horizontal gradients

meters

meters

meters

meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Output].

Check the results.

\$(P)/2023001%OUT%FLT_20230010.OUT

STG1	0.00037	0.000103	0.28846	0.00010	0.00013	0.00199
STG1	0.00038	0.00096	0.28874	0.00010	0.00016	0.00187
STG1	0.00039	0.00089	0.28524	0.00011	0.00017	0.00205
STG1	0.00040	0.00082	0.28844	0.00012	0.00018	0.00239
STG1	0.00042	0.00075	0.28639	0.00012	0.00019	0.00208
STG1	0.00043	0.00068	0.28938	0.00013	0.00021	0.00240
STG1	0.00044	0.00061	0.30000	0.00014	0.00022	0.00198
STG1	0.00045	0.00054	0.30848	0.00015	0.00023	0.00239
STG1	0.00046	0.00047	0.31661	0.00016	0.00025	0.00365

>>> CPU/Real time for pgm "GPSEST": 0:00:23.828 / 0:00:24.086
>>> Program finished successfully

Find

next

prev

Close

\$(P)/2023001%OUT%FLT_20230010.OUT

Station name	Type	A priori value	Estimated value	Correction	RMS error
CMUM	X	-938078.34810	-938078.38524	-0.03714	0.00134
	Y	5968373.98630	5968373.98433	-0.00197	0.00160
	Z	2038404.32190	2038404.31889	-0.00301	0.00099
	U	308.97625	308.97890	0.00265	0.00164
	N	18.7608772	18.7608772	-0.00410	0.00094
	E	98.9323796	98.9323799	0.03697	0.00132
SIE1	X	-1490303.89300	-1490303.72717	0.16583	0.00126
	Y	6024644.81700	6024644.80889	-0.00811	0.00188
	Z	1465891.13600	1465891.16710	0.03110	0.00094
	U	2.99212	2.95292	-0.03920	0.00195
	N	13.3758579	13.3758583	0.04154	0.00086
	E	103.8942201	103.8942186	-0.15897	0.00122
HKSL	X	-2393382.91750	-2393382.97409	-0.05659	0.00140
	Y	5393860.99760	5393860.97190	-0.02570	0.00160
	Z	2412592.23210	2412592.21199	-0.02011	0.00103
	U	95.26791	95.25976	-0.00815	0.00166
	N	22.3720032	22.3720030	-0.01848	0.00098
	E	113.9279865	113.9279871	0.06209	0.00137

Find

Station name

next

prev

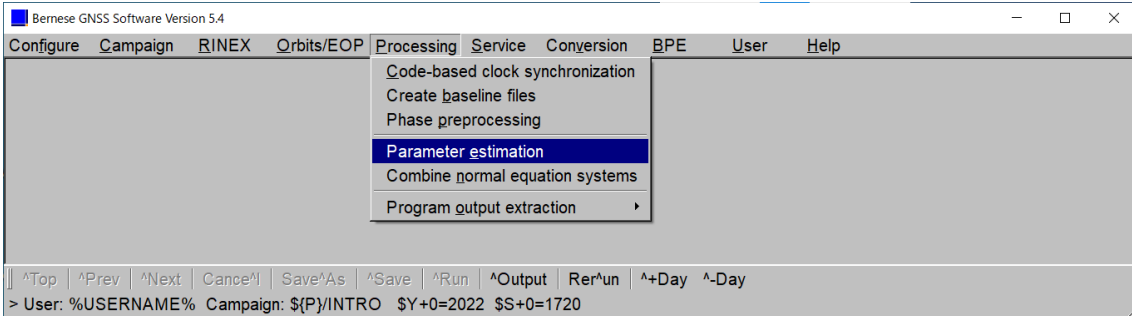
Close

9.10. Ambiguity integerization (GPSEST)

QIF (Quasi Ionosphere Free)

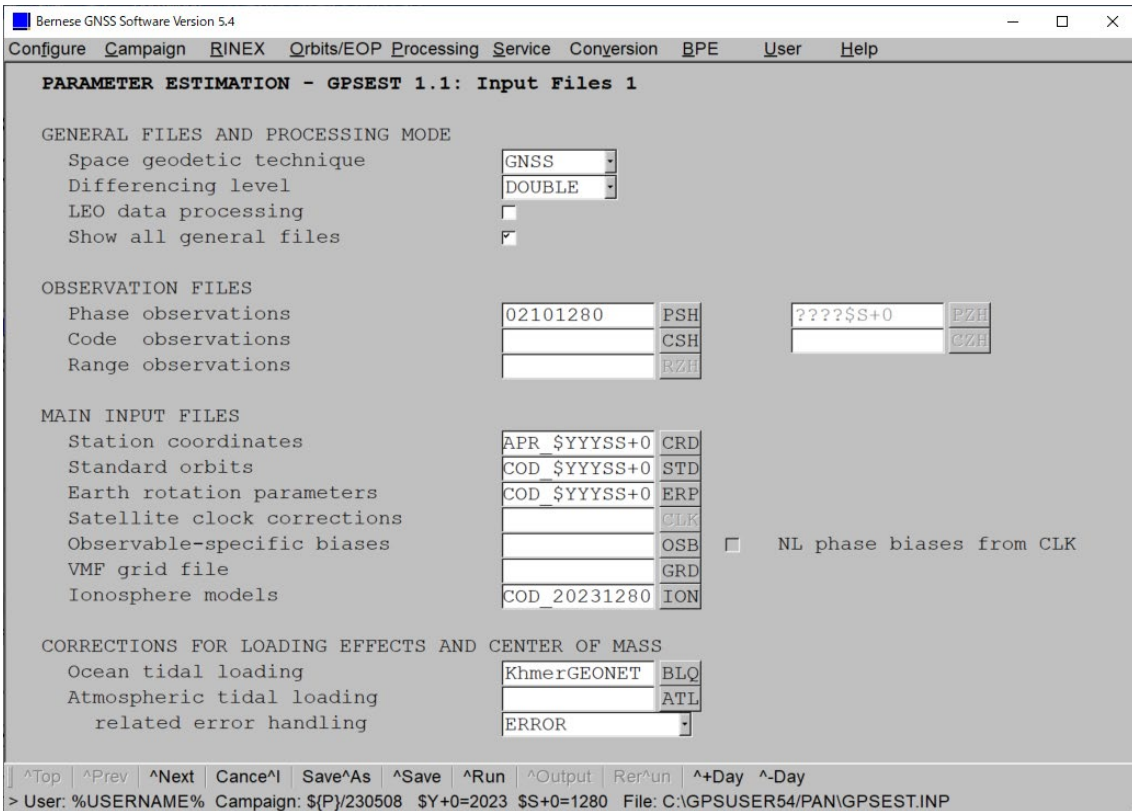
Calculate for each baseline.

Click [Parameter estimation] to display the submenu.



Select Input Files.

Click [^Next].



Select Troposphere estimates.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 1.2: Input Files 2

ADDITIONAL INPUT FILES

Satellite orbit partials		RPR
Clock RINEX file		CLK
Estimated troposphere	FLT_20221720	TRP
Meteorological data		MET

GRIDDED LOADING PARAMETERS

Atmospheric pressure		GRD
Ocean, non-tidal		GRD
Hydrostatic pressure		GRD

AUXILIARY STATION FILES

Station information		STA
Kinematic coordinates		KIN
Observation sigma factors		SOS
Station eccentricities		ECC

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Select GENERAL INPUT FILES.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 1.4: General Files

GENERAL INPUT FILES

General constants	CONST	BSW
Geodetic datum	DATUM	BSW
Antenna corrections	ANTENNA_I20	PCV
Observation selection	OBSERV_COD	SEL
Satellite information	SATELLIT_I20	SAT
Satellite problems	SAT_\$Y+0	CRX
Earth potential coefficients	GM2008_SMALL	GRV
Subdaily ERP model	DESAI2016	SUB
Nutation model	IAU2000R06	NUT
SINEX header file		SKL
IONEX control file		SKL
GPS-UTC time difference	GPSUTC	BSW
Frequency information		FRQ

☐ Consider ant. rotations

MENU SETTINGS

Selected campaign	\${P}/INTRO	
Selected session	Year 2022	Session 1720
Session table	\${P}/INTRO\GEN\SESSIONS.SES	

TEMPORARY FILES

Scratch files	GPSEST\$J SCR	GPSEST\$J SC1	GPSEST\$J SC2
---------------	---------------	---------------	---------------

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Program output is the filename of the result.

The file name is [QXXXX_\$YYYYSS+0.OUT].

[XXXX]: Base line

[\$YYY]: Year

[SS]: Day of year

Click [^Next].

The screenshot shows the 'GPSEST 2.1: Output Files 1' dialog box in the Bernese GNSS Software Version 5.4. The dialog has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into several sections: 'GENERAL OUTPUT FILES' with checkboxes for 'Program output' and 'Error messages', and options to 'use GPSEST.Lnn' or 'merged to program output', and file name fields for 'OUT' (06_YYYYSS+00) and 'MSG' (ERROR); 'NORMAL EQUATION SYSTEM' with a field for 'NQ0'; 'STATION- AND SATELLITE-RELATED RESULTS' with fields for 'CRD', 'ELE', 'ERP', and 'IEP'; and 'ATMOSPHERE-SPECIFIC RESULTS' with fields for 'TRP', 'TRO', 'TRS', 'ION', and 'INX'. At the bottom, there is a status bar with buttons for '^Top', '^Prev', '^Next', 'Cancel', 'Save^As', '^Save', '^Run', '^Output', 'Rer^un', '^+Day', and '^Day', and a text line: '> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP'.

Click [^Next].

The screenshot shows the 'GPSEST 2.2: Output Files 2' dialog box in the Bernese GNSS Software Version 5.4. The dialog has the same menu bar as the previous one. The main area is divided into several sections: 'ADDITIONAL RESULT FILES' with fields for 'OSB', 'BIA', 'PHG', and 'PHH'; 'EPOCH-SPECIFIC RESULTS' with fields for 'CLK', 'CLK', 'KIN', and 'COV'; and 'AUXILIARY FILES' with fields for 'RES', 'COV', and 'COV', and a checkbox for 'Extended format'. At the bottom, there is a status bar with buttons for '^Top', '^Prev', '^Next', 'Cancel', 'Save^As', '^Save', '^Run', '^Output', 'Rer^un', '^+Day', and '^Day', and a text line: '> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP'.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.1: General Options 1

TITLE

OBSERVATION SELECTION

GNSS SELECTION

☒ GPS	☒ GLONASS	☒ Galileo
☐ SBAS	☐ BeiDou	☐ QZSS

Frequency/linear combination

PCC applied for MELWUEBB/L4 LC

Elevation cutoff angle degrees

Sampling interval seconds

Tolerance for simultaneity milliseconds

Special data selection

Observation window ☐

OBSERVATION MODELING AND PARAMETER ESTIMATION

A priori sigma of unit weight meters

Elevation-dependent weighting

Type of computed residuals

Correlation strategy

LEO-SPECIFIC SELECTION AND MODELING OPTIONS

Elevation cutoff angle degrees

Elevation-dependent weighting

^Top ^Prev ^Next Cance^l Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/230510B \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2: General Options 2

A PRIORI TROPOSPHERE MODELING

ZPD model and mapping function

DRY GPT3

for GNSS

MENDES-PAVLIS

for SLR

HANDLING OF AMBIGUITIES

Resolution strategy

QIF

Solve ambiguities for

☒ GPS

☒ GLONASS

☒ Galileo

☐ SBAS

☐ BeiDou

☐ QZSS

Consider GPS quarter-cycle biases

IF INDICATED

☐ (between BeiDou-2 and BeiDou-3)

Save resolved ambiguities

☒

Introduce widelane integers

☐

Introduce L1 and L2 integers

☐

SPECIAL PROCESSING OPTIONS

Stop program after NEQ saving

☐

Activate extended program output

☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/230510B \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2.4: Quasi-Ionosphere-Free Ambiguity Resolution Strategy

OPTIONS AND CRITERIA FOR TESTING

Maximal number of ambiguities fixed per iteration step

1

Search width for pairs of L1 and L2 ambiguities

0.5

WL cycles

Maximal sigma of resolvable NL ambiguities

0.03

NL cycles

Maximal fractional part of resolvable NL ambiguities

0.1

NL cycles

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 4: Datum Definition for Station Coordinates

DATUM DEFINITION TYPE

- ☐ Free network solution
- ☐ Coordinates constrained WITH FLAG
- ☐ Coordinates fixed FIRST

A PRIORI SIGMAS

North	0.001	meters
East	0.001	meters
Up	0.001	meters

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 5.1: Setup of Parameters and Pre-Elimination 1

STATION-RELATED PARAMETERS	Setup	Pre-Elimination
Station coordinates		NO
Ambiguities		NO
ATMOSPHERIC PARAMETERS		
Site-specific troposphere parameters	☐	NO
Global ionosphere parameters	☐	NO
GLOBAL PARAMETERS		
Orbital parameters	☐ GNSS	NO
	☐ LEO	NO
Earth orientation parameters	☐	NO
Geocenter coordinates	☐	NO
EPOCH PARAMETERS		
Receiver clock offsets	☒	EVERY EPOCH
Satellite clock offsets	☐	EVERY EPOCH
Kinematic coordinates	☐	EVERY EPOCH
Stochastic ionosphere parameters	☒	EVERY EPOCH

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 5.2: Setup of Parameters and Pre-Elimination 2

BIAS PARAMETERS

Observable-specific code biases

GNSS-specific translation parameters

Setup

☐

☐

Pre-Elimination

NO

NO

ANTENNA PHASE CENTER PARAMETERS

Satellite phase center offsets

Satellite phase center variations

Receiver phase center offsets

Receiver phase center variations

☐

☐

☐

☐

NO

NO

NO

NO

PARAMETER SCALING FACTORS

Scaling related to loading effects

Higher-order ionosphere scaling

☐

☐

NO

NO

SLR-RELATED PARAMETERS

Range biases

☐

NO

TIME OFFSET FOR PARAMETER INTERVALS

(hhh mm ss)

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 6.7: General Options for Epoch Parameters

OPTIONS SPECIFIC TO EPOCH PARAMETERS

☐

Var-covar wrt epoch parameters

SIMPLIFIED

Sampling interval for resubstitution

seconds

Sampling interval for pre-elimination

seconds

LEO-SPECIFIC

Epochs for var-covar matrix

Print epoch var-covar for

Store covariances in KIN file

4

COORDINATES

☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 6.10: Stochastic Ionosphere Parameters

STOCHASTIC IONOSPHERE PARAMETERS

Elimination of reference ionosphere parameters

Elevation-dependent parameter constraining

Absolute a priori sigma on single difference level

Relative a priori sigma of ionospheric random walk

☐

☒

meters

m/min**1/2

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Check the results.

\$(P)/2023001\OUT\0210_20230010.OUT

Station coordinates and velocities:

Sol	Station name	Typ	Correction	Estimated value	RMS error	A priori
1	SIE1	X	0.22184	-1490303.67116	0.00033	-1490303
1	SIE1	Y	-0.00902	6024644.80798	0.00067	6024644
1	SIE1	Z	0.03362	1465891.16962	0.00030	1465891

>>> CPU/Real time for pgm "GPSEST": 0:00:12.156 / 0:00:12.236

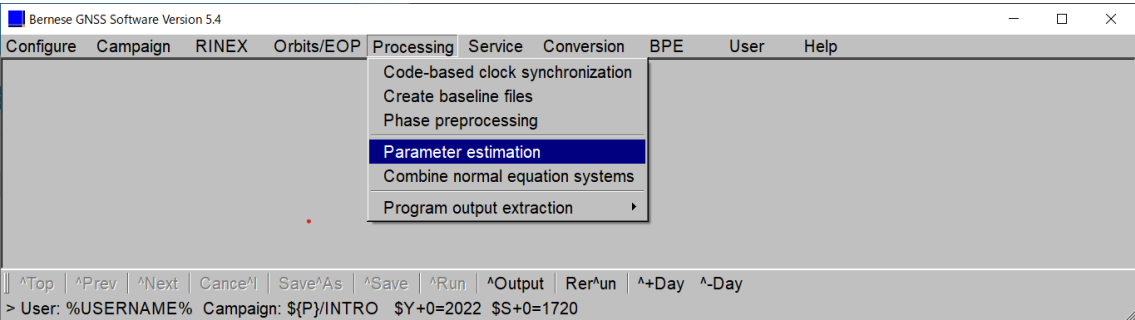
>>> Program finished successfully

Find next prev Close

Repeat this calculation to create all required baselines.

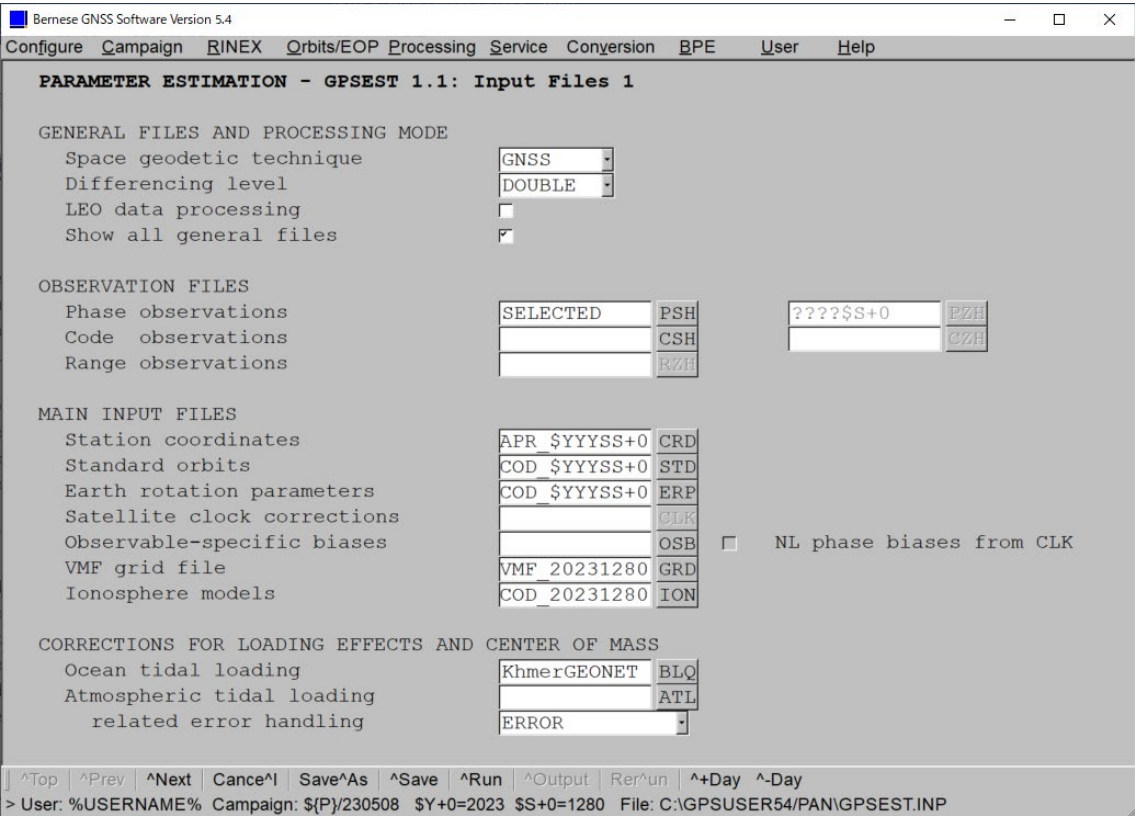
9.11. Creating a normal equation file (GPSEST)

Click [Parameter estimation] to display the submenu.



Select Input Files.

Click [^Next].



Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 1.2: Input Files 2

ADDITIONAL INPUT FILES

Satellite orbit partials		RPR
Clock RINEX file		CLK
Estimated troposphere		TRP
Meteorological data		MET

GRIDDED LOADING PARAMETERS

Atmospheric pressure		GRD
Ocean, non-tidal		GRD
Hydrostatic pressure		GRD

AUXILIARY STATION FILES

Station information		STA
Kinematic coordinates		KIN
Observation sigma factors		SOS
Station eccentricities		ECC

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Select GENERAL INPUT FILES.

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 1.4: General Files

GENERAL INPUT FILES

General constants	CONST	BSW
Geodetic datum	DATUM	BSW
Antenna corrections	ANTENNA_I20	PCV
Observation selection	OBSERV_COD	SEL
Satellite information	SATELLIT_I20	SAT
Satellite problems	SAT \$Y+0	CRX
Earth potential coefficients	GM2008_SMALL	GRV
Subdaily ERP model	DESAI2016	SUB
Nutation model	IAU2000R06	NUT
SINEX header file		SKL
IONEX control file		SKL
GPS-UTC time difference	GPSUTC	BSW
Frequency information		FRQ

☐ Consider ant. rotations

MENU SETTINGS

Selected campaign	\${P}/INTRO	
Selected session	Year 2022	Session 1720
Session table	\${P}/INTRO\GEN\SESSIONS.SES	

TEMPORARY FILES

Scratch files	GPSEST\$J SCR	GPSEST\$J SC1	GPSEST\$J SC2
---------------	---------------	---------------	---------------

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 2.1: Output Files 1

GENERAL OUTPUT FILES

Program output

☐

use GPSEST.Lnn

or

FIX_YYYYSS+0

OUT

Error messages

☐

merged to program output

or

ERROR

MSG

NORMAL EQUATION SYSTEM

FIX_YYYYSS+0

NQ0

STATION- AND SATELLITE-RELATED RESULTS

Station coordinates

CRD

Satellite orbital elements

ELE

Earth rotation parameters

ERP

Earth rotation parameters (IERS)

IEP

ATMOSPHERE-SPECIFIC RESULTS

Troposphere estimates

TRP

Troposphere estimates (SINEX)

TRO

Troposphere slant delays

TRS

Ionosphere models

ION

Ionosphere models (IONEX)

INX

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 2.2: Output Files 2

ADDITIONAL RESULT FILES

Observable-specific code biases

OSB

Bias SINEX

BIA

Phase center variations (gridded)

PHG

Phase center variations (spherical)

PHH

EPOCH-SPECIFIC RESULTS

GNSS clock corrections

CLK

Clock RINEX

CLK

Kinematic coordinates

KIN

Epoch-wise KIN covariances (LEOs)

COV

AUXILIARY FILES

Observation residuals

RES

☐

Extended format

Covariance matrix

COV

Covariance matrix wrt coordinates

COV

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.1: General Options 1

TITLE

OBSERVATION SELECTION

GNSS SELECTION

☒ GPS	☒ GLONASS	☒ Galileo
☐ SBAS	☐ BeiDou	☐ QZSS

Frequency/linear combination

PCC applied for MELWUEBB/L4 LC

Elevation cutoff angle degrees

Sampling interval seconds

Tolerance for simultaneity milliseconds

Special data selection

Observation window ☐

OBSERVATION MODELING AND PARAMETER ESTIMATION

A priori sigma of unit weight meters

Elevation-dependent weighting

Type of computed residuals

Correlation strategy

LEO-SPECIFIC SELECTION AND MODELING OPTIONS

Elevation cutoff angle degrees

Elevation-dependent weighting

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/230510B \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2: General Options 2

A PRIORI TROPOSPHERE MODELING

ZPD model and mapping function for GNSS

for SLR

HANDLING OF AMBIGUITIES

Resolution strategy

Solve ambiguities for

☒ GPS	☒ GLONASS	☒ Galileo
☒ SBAS	☒ BeiDou	☒ QZSS

Consider GPS quarter-cycle biases

Omit AR between subconstellations ☐ (between BeiDou-2 and BeiDou-3)

Save resolved ambiguities ☐

Introduce widelane integers ☐

Introduce L1 and L2 integers ☒

SPECIAL PROCESSING OPTIONS

Stop program after NEQ saving ☒

Activate extended program output ☒

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2.1.1: Extended Program Output Options

INFORMATION RELATED TO OBSERVATIONS

List of observations given in files	☐
List of observations used for processing	☐
Satellite elevations	☐
Histogram of observations by elevation angle bins	☒
Histogram of observations by nadir angle bins	☒
Phase-connected time intervals	☒

INFORMATION RELATED TO ESTIMATED PARAMETERS

List of all parameters	☐
Unresolved ambiguities after each iteration step	☐
Extended summary concerning coordinate parameters	☐
Extended summary concerning ionosphere parameters	☐
Extended summary concerning troposphere parameters	☐
Suppression of output concerning troposphere parameters	☐
Suppression of output concerning coordinate parameters	☐
Suppression of output concerning ambiguity parameters	☐
Suppression of output concerning epoch parameters	☐

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 3.2.1.2: Extended Program Output Options

OTHER INFORMATION

Resolved ambiguities from observation files	☐
Constants, antenna offsets, ionosphere coefficients	☐
Station eccentricities, receiver information	☐
Receiver synchronization errors	☐
RMS of ellipsoidal coordinates and differences	☐
Slope distances and their RMS	☐
Statistics on the parameter dimensions	☒

HELMERT TRANSFORMATION OF RESULTING STATION COORDINATES

Activate Helmert transformation	☐
Coordinate system for transformation	LOCAL
Rotation	☒
Scale	☒

|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

ConfigureCampaignRINEXOrbits/EOP ProcessingServiceConversionBPEUserHelp

GPSEST 4: Datum Definition for Station Coordinates

DATUM DEFINITION TYPE

☐ Free network solution

☒ Coordinates constrained

☐ Coordinates fixed

ALL

FIRST

A PRIORI SIGMAS

North

0.001

meters

East

0.001

meters

Up

0.001

meters

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

ConfigureCampaignRINEXOrbits/EOP ProcessingServiceConversionBPEUserHelp

GPSEST 5.1: Setup of Parameters and Pre-Elimination 1

STATION-RELATED PARAMETERS

Setup

Pre-Elimination

Station coordinates

NO

Ambiguities

AS SOON AS POSSIBLE

ATMOSPHERIC PARAMETERS

Site-specific troposphere parameters

☒

NO

Global ionosphere parameters

☐

NO

GLOBAL PARAMETERS

Orbital parameters

☐ GNSS

☐ LEO

NO

NO

Earth orientation parameters

☐

NO

Geocenter coordinates

☐

NO

EPOCH PARAMETERS

Receiver clock offsets

☒

EVERY EPOCH

Satellite clock offsets

☐

EVERY EPOCH

Kinematic coordinates

☐

EVERY EPOCH

Stochastic ionosphere parameters

☒

EVERY EPOCH

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 5.2: Setup of Parameters and Pre-Elimination 2

BIAS PARAMETERS	Setup	Pre-Elimination
Observable-specific code biases	☐	NO
GNSS-specific translation parameters	☐	NO

ANTENNA PHASE CENTER PARAMETERS		
Satellite phase center offsets	☐	NO
Satellite phase center variations	☐	NO
Receiver phase center offsets	☐	NO
Receiver phase center variations	☐	NO

PARAMETER SCALING FACTORS		
Scaling related to loading effects	☐	NO
Higher-order ionosphere scaling	☐	NO

SLR-RELATED PARAMETERS		
Range biases	☐	NO

TIME OFFSET FOR PARAMETER INTERVALS (hhh mm ss)

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

GPSEST 6.1.1: Site-Specific Troposphere Parameters 1

ZENITH PATH DELAY PARAMETERS		
Mapping function	WET VMF	
Parameter spacing	01 00 00 (hh mm ss)	

HORIZONTAL GRADIENT PARAMETERS		
Gradient estimation model	CHEN-HERRING	
Parameter spacing	24 00 00 (hh mm ss)	

A PRIORI SIGMAS	Absolute		Relative	
Zenith path delay		meters	5	meters
Horizontal gradients		meters	5	meters

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

Click [^Run].

Bernese GNSS Software Version 5.4

ConfigureCampaignRINEXOrbits/EOP ProcessingServiceConversionBPEUserHelp

GPSEST 6.1.2: Site-Specific Troposphere Parameters 2

STATIONS TO BE EXCLUDED FROM TROPOSPHERE ESTIMATION

Station selection

NONE

Station list from file

FIX

Manual selection

STATIONS WITH SPECIAL A PRIORI SIGMAS

Station selection

NONE

Station list from file

SIG

Manual selection

SPECIAL A PRIORI SIGMAS

Absolute

Relative

Zenith path delay

meters

meters

Horizontal gradients

meters

meters

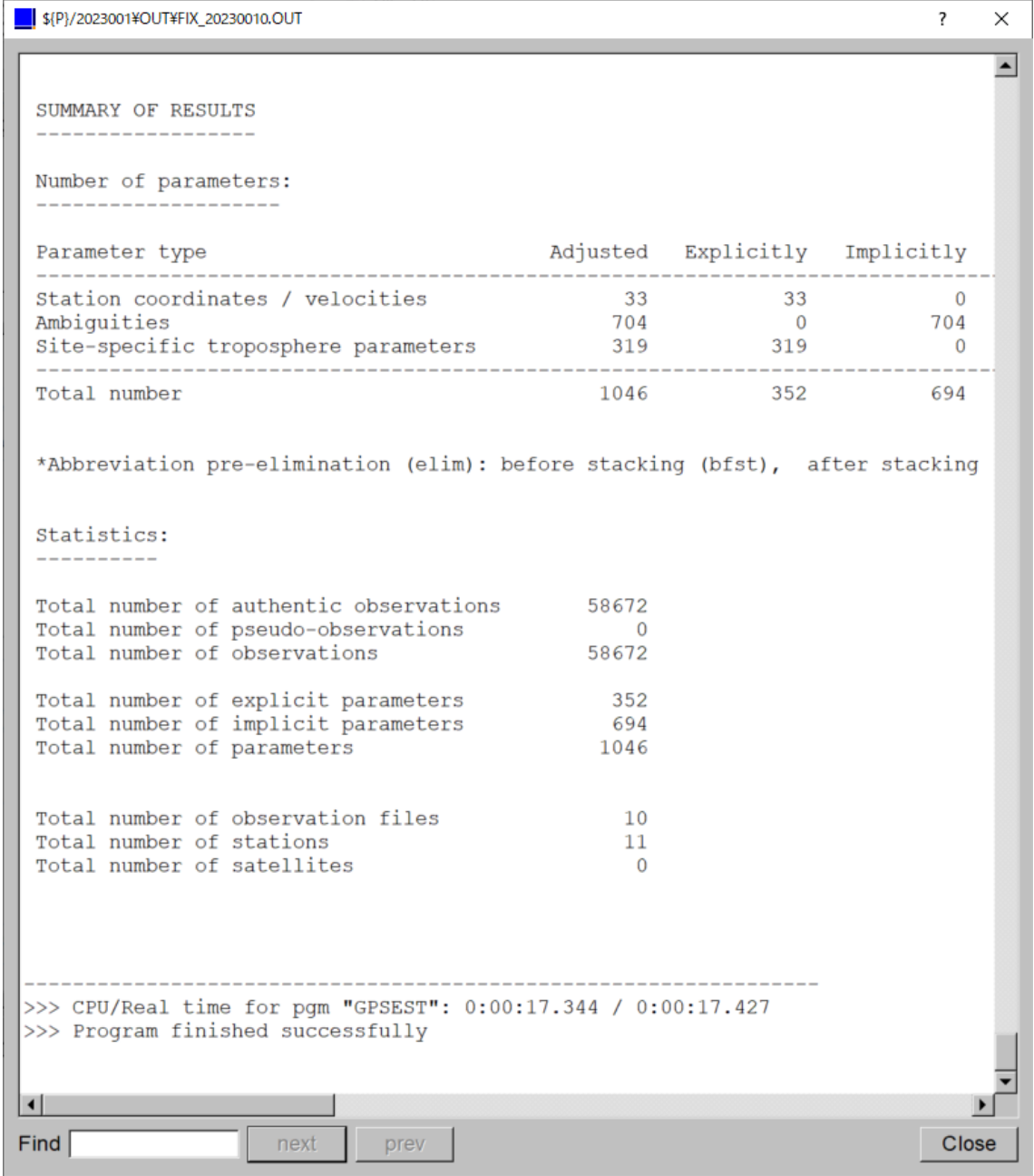
|| ^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\GPSEST.INP

- 148 -

Click [^Output].

Check the results.



```
$(P)/2023001%OUT%FIX_20230010.OUT ? X

SUMMARY OF RESULTS
-----

Number of parameters:
-----

Parameter type                Adjusted  Explicitly  Implicitly
-----
Station coordinates / velocities      33         33         0
Ambiguities                          704         0        704
Site-specific troposphere parameters  319        319         0
-----
Total number                       1046        352        694

*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking

Statistics:
-----

Total number of authentic observations      58672
Total number of pseudo-observations         0
Total number of observations                58672

Total number of explicit parameters         352
Total number of implicit parameters        694
Total number of parameters                 1046

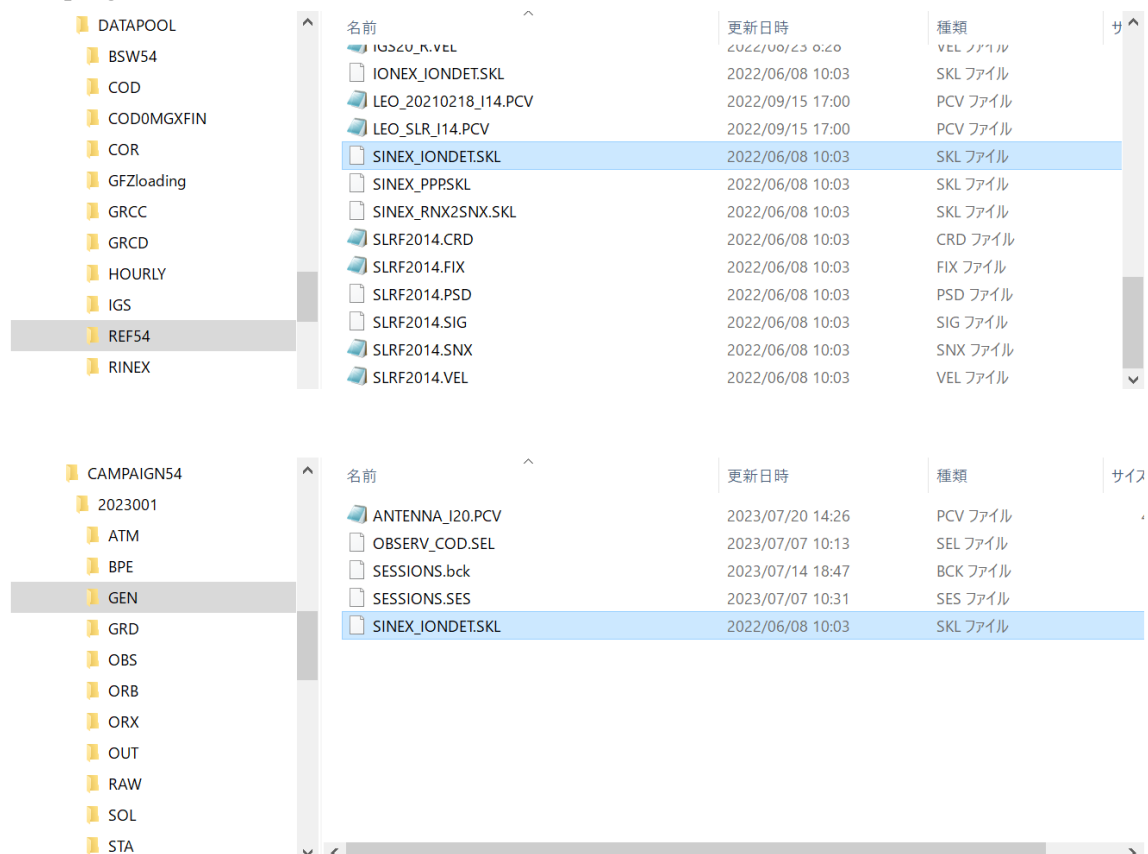
Total number of observation files           10
Total number of stations                   11
Total number of satellites                  0

-----
>>> CPU/Real time for pgm "GPSEST": 0:00:17.344 / 0:00:17.427
>>> Program finished successfully

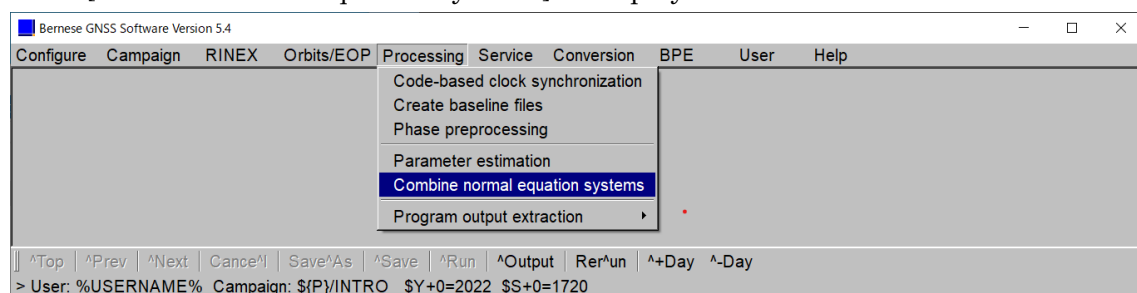
Find  next prev Close
```

9.12. Calculation of coordinate values (ADDNEQ2)

Copy the [SINEX_IONDET.SKL] file of the DATAPOOL folder to [GEN] folder of the campaign.



Click [Combine normal equation systems] to display the submenu.



Click [^Next].

Bernese GNSS Software Version 5.4

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COMBINE NORMAL EQUATION SYSTEMS - ADDNEQ2 1.1: Input Files 1

GENERAL FILES

Show all general files

☒

NORMAL EQUATION SYSTEMS

Normal equations

FIX \$\$\$\$SS+0

NQ0

Variance rescaling factors

WGT

MAIN INPUT FILES

Station coordinates

APR \$\$\$\$SS+0

CRD

Station velocities

VEL

Station information

KHM \$\$\$\$SS+0

STA

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

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ADDNEQ2 1.2: Input Files 2

NEW A PRIORI VALUES

Troposphere estimates

TRP

(parameters are eliminated)

Observable-specific biases

OSB

(a priori is zero if empty)

Earth rotation parameters

ERP

(mandatory if ERPs present)

Geocenter coordinates

GCC

Satellite clock corrections

CLK

Clock RINEX file

CLK

SLR data handling (biases, CoM)

SLR

List of parameter estimates

EST

HEADER AND EPOCH INFORMATION

Ionosphere master file

ION

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rer^un

^+Day

^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Select General Files.
Click [^Next].

Bernese GNSS Software Version 5.4

ConfigureCampaignRINEXOrbits/EOP ProcessingServiceConversionBPEUserHelp

ADDNEQ2 1.3: General Files

GENERAL INPUT FILES

General constants

Geodetic datum

Antenna corrections

Observation selection

Satellite information

Satellite problems

Subdaily ERP model

Nutation model

SINEX header file

IONEX control file

CONST

DATUM

ANTENNA_I20

OBSERV_COD

SATELLIT_I20

SAT_\$Y+0

DESAI2016

IAU2000R06

SINEX_IONDET

BSW

BSW

PCV

SEL

SAT

CRX

SUB

NUT

SKL

SKL

MENU SETTINGS

Selected campaign

Selected session

Session table

\$(P)/230508

Year 2023

Session 1280

\$(P)/230508\GEN\SESSIONS.SES

TEMPORARY FILES

Scratch file

ADDNEQ2\$J

SCR

^Top^Prev^NextCancel^ISave^As^Save^Run^OutputRer^un^+Day^-Day

> User: %USERNAME% Campaign: \$(P)/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

ConfigureCampaignRINEXOrbits/EOP ProcessingServiceConversionBPEUserHelp

ADDNEQ2 2.1: Output Files 1

GENERAL OUTPUT FILES

Program output

Error messages

☐

☐

use ADDNEQ2.Lnn

merged to program output

or

or

FIN_YYYYSS+0

ERROR

OUT

MSG

MAIN RESULT FILES

Normal equations

SINEX with

FIN_YYYYSS+0

NEQ

NQ0

SNX

STATION- AND SATELLITE-RELATED RESULTS

Station coordinates

Station velocities

Satellite orbital elements

Earth rotation parameters

Earth rotation parameters (IERS)

FIN_YYYYSS+0

CRD

VEL

ELE

ERP

IEP

ATMOSPHERE-SPECIFIC RESULTS

Troposphere estimates

Troposphere estimates (SINEX)

Ionosphere models

Ionosphere models (IONEX)

FIN_YYYYSS+0

FIN_YYYYSS+0

TRP

TRO

ION

INX

^Top^Prev^NextCancel^ISave^As^Save^Run^OutputRer^un^+Day^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

ConfigureCampaignRINEXOrbits/EOP ProcessingServiceConversionBPEUserHelp

ADDNEQ2 2.2: Output Files 2

ADDITIONAL RESULT FILES

Geocenter coordinates

Observable-specific biases

Observable-specific biases (SINEX)

Phase center variations (gridded)

Satellite clock corrections

Clock corrections (RINEX)

Data handling (biases, CoM)

GCC

OSB

BIA

PHG

CLK

CLK

SLR

AUXILIARY FILES

Weekly summary

Station residuals

All parameter residuals

Covariance matrix wrt coordinates

Full covariance matrix

Variance rescaling factors, Helmert

List of parameter estimates

SUM

PLT

PLT

COV

COV

WGT

EST

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Enter TITLE.

Click [^Next].

Bernese GNSS Software Version 5.4

ConfigureCampaignRINEXOrbits/EOP ProcessingServiceConversionBPEUserHelp

ADDNEQ2 3.1: Options 1

TITLE

KHM

GENERAL OPTIONS

Maximum number of parameters in combined NEQ

A priori sigma of unit weight

Compute and compare individual solutions

Reference epoch for station coordinates

Stop program after NEQ saving

1000

0.0010 meters

NO

yyyy mm dd

ADD PARAMETERS TO THE SYSTEM

Set up station velocities

Set up Geocenter coordinates

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rerun ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ADDNEQ2 3.2: Options 2

REMOVE STATION PARAMETERS FROM THE SYSTEM

If receiver changes NEVER

If antenna changes NEVER

INPUT FILE OPTIONS

Truncate NEQ station names after position 14 NO

Keep input NEQs in alphabetical order ☐

OUTPUT OPTIONS

Extended output wrt estimated parameters ☒

Extended summary concerning coordinate parameter ☐

Extended summary concerning ionosphere parameter ☐

Extended summary concerning troposphere parameter ☐

Notify station inconsistencies between NEQs ☐

Notify changes due to station information file ☒

Print detailed list of parameter manipulations ☐

Print detailed list on usage of constraints ☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ADDNEQ2 4.1: Parameter Pre-Elimination

STATION-RELATED PARAMETERS

Station coordinates NO exceptions for files station ☐

ATMOSPHERIC PARAMETERS

Troposphere zenith path delays NO ☐

Troposphere gradients NO ☐

Global ionosphere parameters ☐

GLOBAL PARAMETERS

Orbital elements ☐

Plate scaling parameters ☐

Stochastic pulses ☐

Polar motion parameters ☐

Length of day parameters ☐

Universal time parameters ☐

Nutation parameters ☐

Geocenter coordinates ☐

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

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ADDNEQ2 4.2: Parameter Pre-Elimination

BIAS PARAMETERS

Satellite code biases

Receiver code biases

GNSS-specific translations

GNSS-specific ZPD biases

GNSS-specific gradient biases

exceptions for

files

station

ANTENNA PHASE CENTER PARAMETERS

Satellite antenna offsets

Satellite antenna offsets (XY)

Satellite antenna variations

Receiver antenna offsets

Receiver antenna variations

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Re^run

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

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ADDNEQ2 4.3: Parameter Pre-Elimination

HELMERT TRANSFORMATION PARAMETERS

Translation parameters

Rotation parameters

Scale parameters

exceptions for

files

station

PARAMETER SCALING FACTORS

HOI scaling factors

Atmospheric pressure loading

Ocean non-tidal loading

Hydrostatic pressure loading

EPOCH PARAMETERS

Receiver clock offsets

Satellite clock offsets

SLR-RELATED PARAMETERS

Range biases

files

GNSS

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Re^run

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ADDNEQ2 5: Datum Definition for Station Coordinates

DATUM DEFINITION TYPE

☐ Free network solution

☒ Minimum constraint solution

☐ Coordinates constrained

☐ Coordinates fixed

WITH FLAG

MANUAL

MANUAL

MINIMUM CONSTRAINT CONDITIONS

Translation

YES

Rotation

NO

Scale

NO

A PRIORI SIGMAS

North

0.001

meters

East

0.001

meters

Up

0.001

meters

ADVANCED DATUM DEFINITION

☐

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rerun

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ADDNEQ2 5.1: Datum Definition for Station Coordinates

STATIONS CONSIDERED FOR MINIMUM CONSTRAINT CONDITIONS

Manual selection

HKSL

☐

List of stations from file

ITRF14

FIX

☐

Stations with specific flags in CRD file

I

#: all non-blank

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rerun

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

Configure

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Conversion

BPE

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ADDNEQ2 8: Interval Length of Parameters

NEW PARAMETER SPACING

Troposphere zenith path delays

Troposphere gradients

Earth rotation parameters

Nutation parameters

hhh mm ss

REFERENCE EPOCH FOR PARAMETER INTERVALS

yyyy mm dd

hh mm ss

MANUAL DEFINITION OF PARAMETER INTERVALS

yyyy mm dd hh mm ss

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rerun

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Next].

Bernese GNSS Software Version 5.4

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Help

ADDNEQ2 9.1: Options for Atmospheric Parameters

ABSOLUTE CONSTRAINING

Troposphere zenith path delays

Troposphere gradients

Global ionosphere parameters

meters

meters

TECU

RELATIVE CONSTRAINING AND VALIDITY INTERVAL OF CONSTRAINT

Troposphere zenith path delays

Troposphere gradients

Global ionosphere parameters

5

5

meters

meters

TECU

01 00 00

24 00 00

(hh mm ss)

(hh mm ss)

(hh mm ss)

^Top

^Prev

^Next

Cancel

Save^As

^Save

^Run

^Output

Rerun

^+Day

^-Day

> User: %USERNAME% Campaign: \$(P)/INTRO \$Y+0=2022 \$S+0=1720 File: C:\GPSUSER54\PAN\ADDNEQ2.INP

Click [^Run].

The screenshot shows the 'ADDNEQ2 9.2: Options for Troposphere SINEX' dialog box in the Bernese GNSS Software Version 5.4. The window has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into two sections. The first section, 'EXTRACTION OF PARAMETERS FOR TROPOSPHERE SINEX FILE', contains 'Offset' (empty text box), '(hhh mm ss)', 'Time resolution' (01 00 00), and '(hh mm ss)'. The second section, 'ADDITIONAL OPTIONS FOR TROPOSPHERE SINEX FILE GENERATION', contains 'TROPO-SINEX version' (2.00) and 'Time system' (GPS). At the bottom, there is a toolbar with buttons: ^Top, ^Prev, ^Next, Cance^l, Save^As, ^Save, ^Run, ^Output, Rer^un, ^+Day, and ^-Day. Below the toolbar, the status bar displays: '> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PAN\ADDNEQ2.INP'.

Click [^Output].

Check the results.

Ignore the following warnings.

The screenshot shows an error message window titled 'C:\GPSUSER54\WORK\ERROR.MSG'. The window contains three warning messages, each preceded by '### FN D_STACRX:getLongStaId_timint, PG ADDNEQ2 (28-Jul-2023 16:23:44)'. The first message states: 'Empty "Long Name" column for station "ANMG" found in station information file: \${P}/230507\STA\KHM_20231270.STA (short name used instead)'. The second message states: 'Empty "Long Name" column for station "CMUM" found in station information file: \${P}/230507\STA\KHM_20231270.STA (short name used instead)'. The third message states: 'Empty "Long Name" column for station "CUSV" found in station information file: \${P}/230507\STA\KHM_20231270.STA (short name used instead)'. At the bottom of the window, there is a 'Find' text box, 'next' and 'prev' buttons, and a 'Close' button.

\$(P)/INTRO%OUT%FIN_20221720.OUT

*Abbreviation pre-elimination (elim): before stacking (bfst), after stacking

Statistics:

Total number of authentic observations	57958
Total number of pseudo-observations	289
Total number of explicit parameters	352
Total number of implicit parameters	710
Total number of observations	58247
Total number of adjusted parameters	1062
Degree of freedom (DOF)	57185
A posteriori RMS of unit weight	0.001807 m
Chi**2/DOF	3.26
Total number of observation files	10
Total number of stations	11

Find next prev Close

\$(P)/INTRO%OUT%FIN_20221720.OUT

Station coordinates and velocities:

Sol	Station name	Typ	Correction	Estimated value	RMS error	A priori value
1	ANMG	X	-0.00989	-1270827.08669	0.00057	-1270827.07680
1	ANMG	Y	0.00325	6242631.29185	0.00154	6242631.28860
1	ANMG	Z	0.01524	307792.40554	0.00040	307792.39030
1	CMUM	X	-0.00222	-938078.58782	0.00062	-938078.58560
1	CMUM	Y	-0.01692	5968373.96568	0.00208	5968373.98260
1	CMUM	Z	0.00560	2038404.27900	0.00065	2038404.27340
1	CUSV	X	-0.00775	-1132915.05385	0.00061	-1132915.04610
1	CUSV	Y	0.00036	6092528.52756	0.00175	6092528.52720
1	CUSV	Z	0.02484	1504633.15904	0.00047	1504633.13420
1	HKSL	X	-0.00242	-2393383.15912	0.00072	-2393383.15670
1	HKSL	Y	0.00791	5393860.93981	0.00156	5393860.93190
1	HKSL	Z	0.01369	2412592.16829	0.00060	2412592.15460
1	KND1	X	-0.01712	-1619492.96932	0.00070	-1619492.95220
1	KND1	Y	0.06018	6040715.12878	0.00174	6040715.06860
1	KND1	Z	0.02380	1247864.92020	0.00054	1247864.89640
1	KSP1	X	-0.01870	-1572714.41290	0.00063	-1572714.39420
1	KSP1	Y	0.06651	6050448.91111	0.00159	6050448.84460
1	KSP1	Z	0.02204	1260501.91044	0.00049	1260501.88840
1	PNH1	X	-0.01686	-1603672.49806	0.00071	-1603672.48120
1	PNH1	Y	0.06448	6038739.38808	0.00171	6038739.32360

Find next prev Close

10. Calculation result file

10.1. Coordinate file

The coordinate file is [FIN_YYYYSS+0.CRD].

KHM							29-JUL-23 15:09
LOCAL GEODETIC DATUM: IGS20							EPOCH: 2023-05-10 12:00:00
NUM	STATION NAME	X (M)	Y (M)	Z (M)	FLAG	SYSTEM	
1	ANMG	-1270827.02740	6242631.29501	307792.41238	W	GR	
2	CMUM	-938078.54770	5968373.98854	2038404.29516	W	GR	
3	CUSV	-1132915.00378	6092528.54503	1504633.16581	W	GR	
4	HKSL	-2393383.11602	5393860.93838	2412592.17135	W	GR	
7	KND1	-1619492.90963	6040715.07551	1247864.91456	A	GR	
8	KSP1	-1572714.34688	6050448.85813	1260501.90370	A	GR	
9	PNH1	-1603672.43390	6038739.33777	1277314.63722	A	GR	
5	PTAG	-3184318.48024	5291065.63736	1590418.30879	W	GR	
10	SIE1	-1490303.85527	6024644.81426	1465891.14335	A	GR	
6	SIN1	-1507972.76457	6195613.84510	148487.96335	W	GR	
11	STG1	-1706798.57348	5963096.21574	1481479.66509	A	GR	

It is saved in the [STA] folder of the campaign.

230510	名前	更新日時	種類	サイズ
ATM	KhmerGEONET.BLQ	2023/07/20 18:39	BLQ ファイル	10 KB
BPE	IGS20.PSD	2023/07/25 10:14	PSD ファイル	34 KB
GEN	KhmerGEONET.PLD	2023/07/29 10:08	PLD ファイル	2 KB
GRD	KhmerGEONET.ABB	2023/07/29 10:19	ABB ファイル	2 KB
OBS	KHM_201500.CRD	2023/07/29 12:50	CRD ファイル	2 KB
ORB	KhmrGEONETVEL	2023/07/29 14:14	VEL ファイル	2 KB
ORX	KHM_20231300.STA	2023/07/29 14:16	STA ファイル	6 KB
OUT	KhmerGEONET.ATL	2023/07/29 14:21	ATL ファイル	4 KB
RAW	APR_20231300.CRD	2023/07/29 14:30	CRD ファイル	2 KB
SOL	BSL_20231300.BSL	2023/07/29 14:43	BSL ファイル	1 KB
	FLT_20231300.CRD	2023/07/29 14:54	CRD ファイル	2 KB
STA	FIN_20231300.CRD	2023/07/29 15:09	CRD ファイル	2 KB

10.2. Calculation result file

The calculation result file that records RMS etc. is [FIN_YYYYSS+0.OUT].

Station coordinates and velocities:

Sol	Station name	Typ	Correction	Estimated value	RMS error	A priori value	Unit	From	To	M
1	ANMG	X	0.03680	-1270827.02740	0.00062	-1270827.06420	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	ANMG	Y	-0.00748	6242631.29501	0.00197	6242631.30249	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	ANMG	Z	0.06675	307792.41238	0.00048	307792.34563	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	CMUM	X	-0.00188	-938078.54770	0.00064	-938078.54582	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	CMUM	Y	0.01018	5968373.98854	0.00196	5968373.97836	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	CMUM	Z	0.04109	2038404.29516	0.00063	2038404.25407	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	CUSV	X	0.05119	-1132915.00378	0.00062	-1132915.05497	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	CUSV	Y	-0.00651	6092528.54503	0.00160	6092528.55154	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	CUSV	Z	0.02587	1504633.16581	0.00051	1504633.13994	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	HKSL	X	-0.00840	-2393383.11602	0.00077	-2393383.10762	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	HKSL	Y	-0.01612	5393860.93838	0.00180	5393860.95450	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	HKSL	Z	0.03147	2412592.17135	0.00066	2412592.13988	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	KND1	X	0.21822	-1619492.90963	0.00064	-1619493.12785	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	KND1	Y	0.03784	6040715.07551	0.00172	6040715.03767	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	KND1	Z	0.09659	1247864.91456	0.00053	1247864.81797	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	KSP1	X	0.22347	-1572714.34688	0.00065	-1572714.57035	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	KSP1	Y	0.04312	6050448.85813	0.00171	6050448.81501	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	KSP1	Z	0.09289	1260501.90370	0.00049	1260501.81081	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	PNH1	X	0.22345	-1603672.43390	0.00065	-1603672.65735	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	PNH1	Y	0.04443	6038739.33777	0.00165	6038739.29334	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6
1	PNH1	Z	0.09791	1277314.63722	0.00053	1277314.53931	meters	2023-05-10 00:00:00	2023-05-10 23:59:30	6

It is saved in the [OUT] folder of the campaign.

名前	更新日時	種類	サイズ
230510			
ATM			
BPE			
GEN			
GRD			
OBS			
ORB			
ORX			
OUT			
RAW			
SOL			
STA			
FIN_20231300.OUT	2023/07/29 15:09	OUT ファイル	68 KB
FIX_20231300.OUT	2023/07/29 15:07	OUT ファイル	96 KB
Q1109_20231300.OUT	2023/07/29 15:05	OUT ファイル	113 KB
Q1009_20231300.OUT	2023/07/29 15:04	OUT ファイル	119 KB
Q1003_20231300.OUT	2023/07/29 15:04	OUT ファイル	112 KB
Q0907_20231300.OUT	2023/07/29 15:03	OUT ファイル	127 KB
Q0801_20231300.OUT	2023/07/29 15:03	OUT ファイル	103 KB
Q0708_20231300.OUT	2023/07/29 15:02	OUT ファイル	123 KB
Q0706_20231300.OUT	2023/07/29 15:01	OUT ファイル	107 KB
Q0705_20231300.OUT	2023/07/29 15:00	OUT ファイル	105 KB
Q0411_20231300.OUT	2023/07/29 14:58	OUT ファイル	96 KB
Q0210_20231300.OUT	2023/07/29 14:57	OUT ファイル	100 KB

10.3. Calculate latitude, longitude, ellipsoidal height, UTM coordinates, elevation and geoid height

Bernese software cannot calculate latitude, longitude, ellipsoidal height, UTM coordinates, elevation and geoid height.

Therefore, use other coordinate calculation software.

11. Determination of CGD23 coordinates

11.1. Survey to determine CGD23 coordinates

A preliminary calculation of the coordinates of PNH100KHM was performed.

RTX (ITRF2014) was used.

The purpose is to confirm when the coordinate values are stable.

This is to confirm the period when the influence of the ionosphere is small.

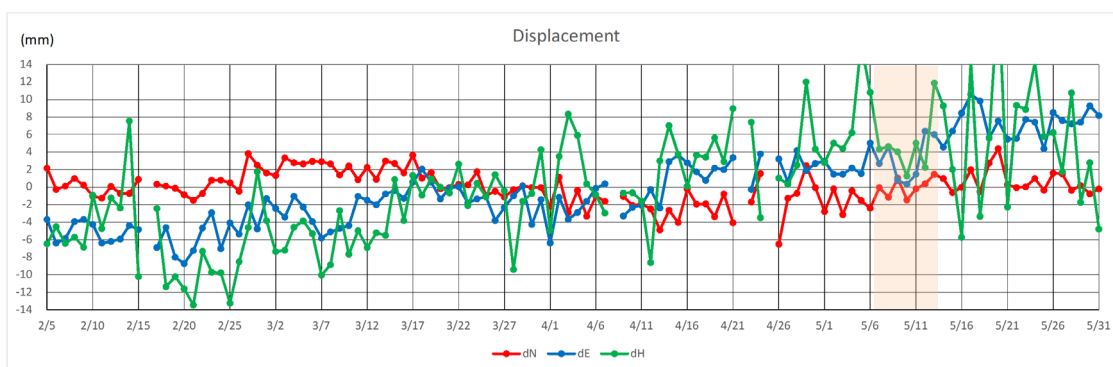
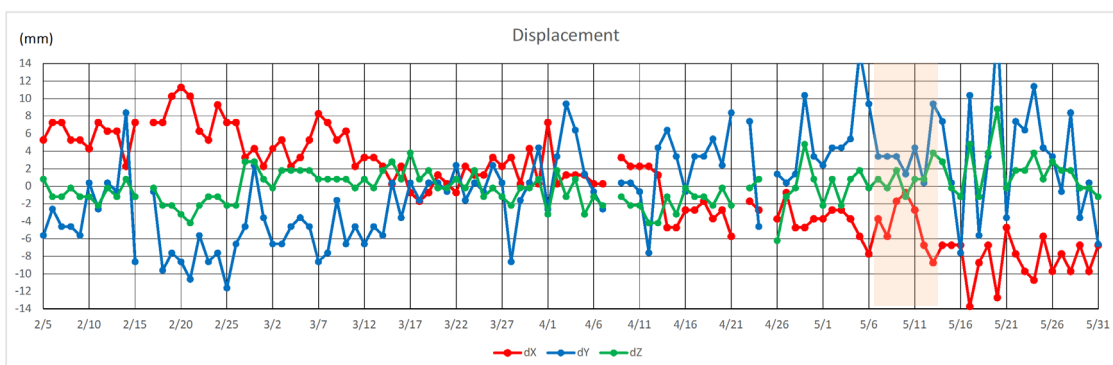
The figure below shows the change in coordinate values from 2/5 to 5/31.

The height component is not stable. It also appears to be on the rise.

It tends to change towards the east. This is roughly consistent with the velocity of crustal movement.

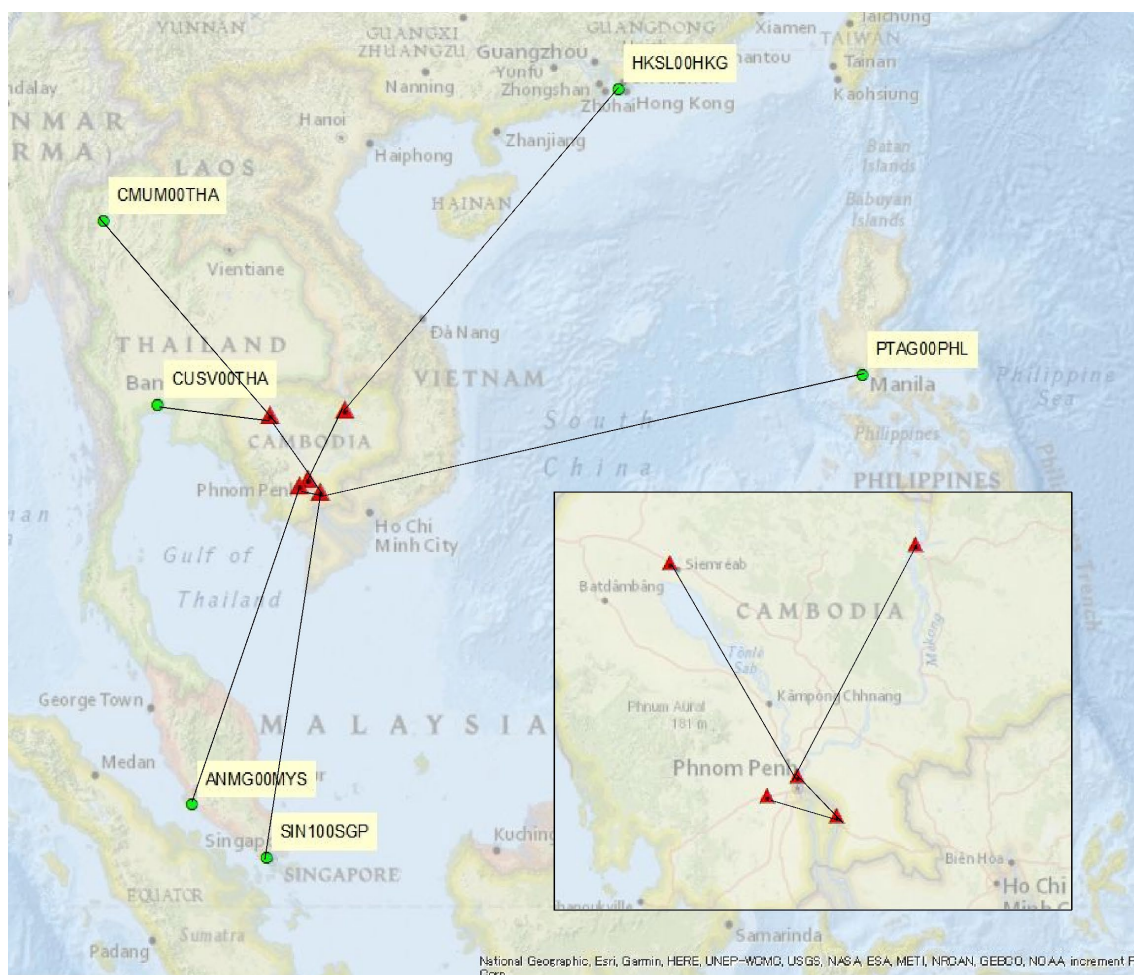
Based on the above, we decided to select the most stable 7-day period, which is the newest period possible.

In other words, the average value of the calculation results from 5/7 (Sun) to 5/13 (Sat) is adopted as the CGD23 coordinates.



11.2. Survey Network for CGD23

As a result of discussion, CGD23 coordinates are decided by the survey network shown below.



11.3. Geodetic Reference System and Map Projection

Let the average value of the results from 5/7 to 5/13 be the CGD23 coordinate of 5-CORS. The median value from 5/7 to 5/13 is 5/10. The epoch is 5/10 at noon (12:00). Since noon (12 o'clock) on May 10th is 129.5 days of the year, calculating the epoch using the following formula yields 2023.355.

$$Epoch = \frac{129.5}{365} = 0.355$$

The Geodetic Reference System and Map Projection is shown below.

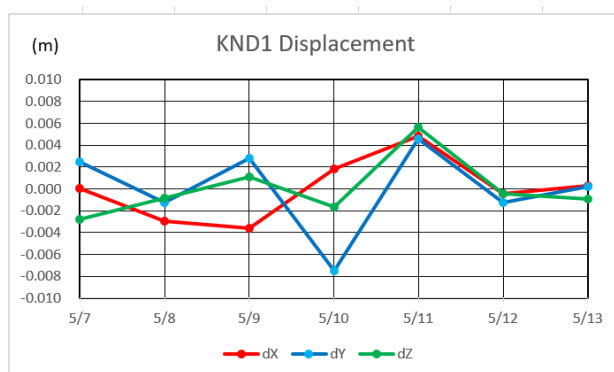
Item	Element
Geocentric Cartesian Coordinate System	ITRF2020 (Epoch 2023.355)
Reference Ellipsoid	GRS 80
Vertical Datum	Mean Sea Level (Haiphong, Vietnam)
Geoid Model	EGM2008
Plane Cartesian Coordinate System	UTM Zone 48 Central Meridian: 105° 00' 00" E Latitude of Origin: 0° 00' 00" N False Easting: 500,000.000 m False Northing: 0.000 m Scale Factor at Central Meridian: 0.9996

11.4. Calculation results from 5/7 to 5/13

11.4.1. KND100KHM

The calculation results for KND100KHM are shown below.

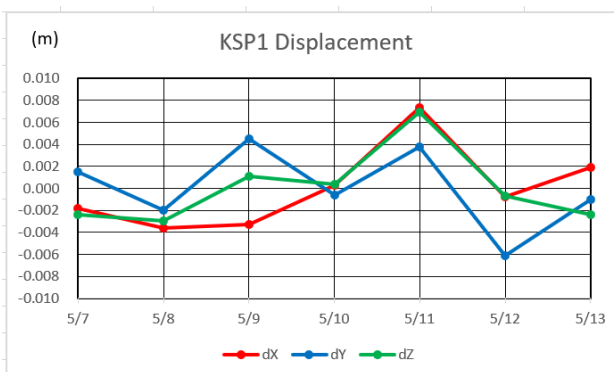
CGD23/ITRF2020 (Epoch2023.355, 2023/05/10)				RMS					Difference from average value		
Name	Date	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)	REMARKS	dX (m)	dY (m)	dZ (m)
KND100KHM	2023/5/7	-1,619,492.911	6,040,715.085	1,247,864.913	0.001	0.002	0.001		0.000	0.002	-0.003
KND100KHM	2023/5/8	-1,619,492.914	6,040,715.082	1,247,864.915	0.001	0.002	0.001		-0.003	-0.001	-0.001
KND100KHM	2023/5/9	-1,619,492.915	6,040,715.086	1,247,864.917	0.001	0.002	0.000		-0.004	0.003	0.001
KND100KHM	2023/5/10	-1,619,492.910	6,040,715.076	1,247,864.915	0.001	0.002	0.001		0.002	-0.007	-0.002
KND100KHM	2023/5/11	-1,619,492.907	6,040,715.088	1,247,864.922	0.001	0.002	0.001	CUSV: No RINEX	0.005	0.005	0.006
KND100KHM	2023/5/12	-1,619,492.912	6,040,715.082	1,247,864.916	0.001	0.002	0.001		0.000	-0.001	0.000
KND100KHM	2023/5/13	-1,619,492.911	6,040,715.083	1,247,864.915	0.001	0.002	0.001		0.000	0.000	-0.001
AVERAGE		-1,619,492.911	6,040,715.083	1,247,864.916							



11.4.2. KSP100KHM

The calculation results for KSP100KHM are shown below.

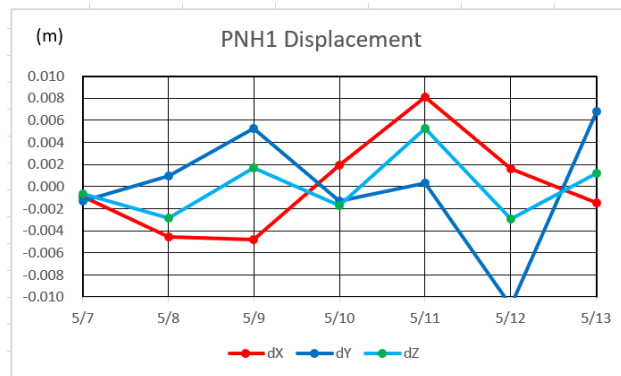
CGD23/ITRF2020 (Epoch2023.355, 2023/05/10)				RMS				Difference from average value			
Name	Date	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)	REMARKS	dX (m)	dY (m)	dZ (m)
KSP100KHM	2023/5/7	-1,572,714.349	6,050,448.860	1,260,501.901	0.001	0.002	0.001		-0.002	0.001	-0.002
KSP100KHM	2023/5/8	-1,572,714.351	6,050,448.857	1,260,501.900	0.001	0.002	0.001		-0.004	-0.002	-0.003
KSP100KHM	2023/5/9	-1,572,714.350	6,050,448.863	1,260,501.904	0.001	0.002	0.000		-0.003	0.004	0.001
KSP100KHM	2023/5/10	-1,572,714.347	6,050,448.858	1,260,501.904	0.001	0.002	0.000		0.000	-0.001	0.000
KSP100KHM	2023/5/11	-1,572,714.340	6,050,448.862	1,260,501.910	0.001	0.002	0.001	CUSV: No RINEX	0.007	0.004	0.007
KSP100KHM	2023/5/12	-1,572,714.348	6,050,448.853	1,260,501.903	0.001	0.002	0.001		-0.001	-0.006	-0.001
KSP100KHM	2023/5/13	-1,572,714.345	6,050,448.858	1,260,501.901	0.001	0.002	0.001		0.002	-0.001	-0.002
AVERAGE		-1,572,714.347	6,050,448.859	1,260,501.903							



11.4.3. PNH100KHM

The calculation results for PNH100KHM are shown below.

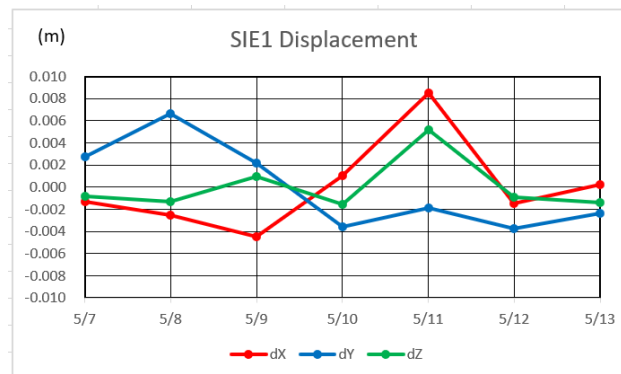
CGD23/ITRF2020 (Epoch2023.355, 2023/05/10)					RMS			REMARKS	Difference from average value		
Name	Date	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)		dX (m)	dY (m)	dZ (m)
PNH100KHM	2023/5/7	-1,603,672.437	6,038,739.338	1,277,314.638	0.001	0.002	0.001		-0.001	-0.001	-0.001
PNH100KHM	2023/5/8	-1,603,672.440	6,038,739.340	1,277,314.636	0.001	0.002	0.001		-0.005	0.001	-0.003
PNH100KHM	2023/5/9	-1,603,672.441	6,038,739.344	1,277,314.641	0.001	0.002	0.000		-0.005	0.005	0.002
PNH100KHM	2023/5/10	-1,603,672.434	6,038,739.338	1,277,314.637	0.001	0.002	0.001		0.002	-0.001	-0.002
PNH100KHM	2023/5/11	-1,603,672.428	6,038,739.339	1,277,314.644	0.001	0.002	0.001	CUSV: No RINEX	0.008	0.000	0.005
PNH100KHM	2023/5/12	-1,603,672.434	6,038,739.328	1,277,314.636	0.001	0.002	0.001		0.002	-0.011	-0.003
PNH100KHM	2023/5/13	-1,603,672.437	6,038,739.346	1,277,314.640	0.001	0.002	0.001		-0.001	0.007	0.001
AVERAGE		-1,603,672.436	6,038,739.339	1,277,314.639							



11.4.4. SIE100KHM

The calculation results for SIE100KHM are shown below.

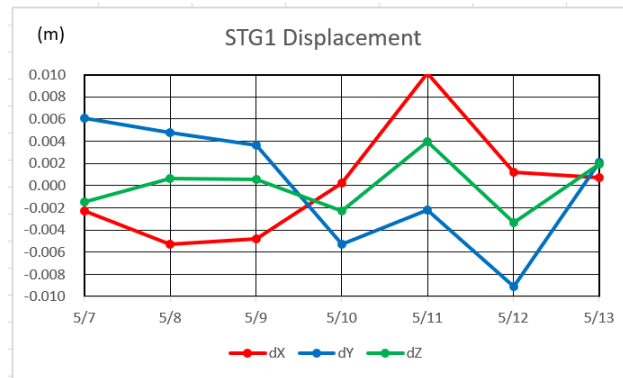
CGD23/ITRF2020 (Epoch2023.355, 2023/05/10)					RMS			REMARKS	Difference from average value		
Name	Date	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)		dX (m)	dY (m)	dZ (m)
SIE100KHM	2023/5/7	-1,490,303.858	6,024,644.821	1,465,891.144	0.001	0.002	0.001		-0.001	0.003	-0.001
SIE100KHM	2023/5/8	-1,490,303.859	6,024,644.824	1,465,891.144	0.001	0.002	0.001		-0.003	0.007	-0.001
SIE100KHM	2023/5/9	-1,490,303.861	6,024,644.820	1,465,891.146	0.001	0.002	0.001		-0.004	0.002	0.001
SIE100KHM	2023/5/10	-1,490,303.855	6,024,644.814	1,465,891.143	0.001	0.002	0.001		0.001	-0.004	-0.002
SIE100KHM	2023/5/11	-1,490,303.848	6,024,644.816	1,465,891.150	0.001	0.002	0.001	CUSV: No RINEX	0.008	-0.002	0.005
SIE100KHM	2023/5/12	-1,490,303.858	6,024,644.814	1,465,891.144	0.001	0.002	0.001		-0.002	-0.004	-0.001
SIE100KHM	2023/5/13	-1,490,303.856	6,024,644.816	1,465,891.143	0.001	0.002	0.001		0.000	-0.002	-0.001
AVERAGE		-1,490,303.856	6,024,644.818	1,465,891.145							



11.4.5. STG100KHM

The calculation results for STG100KHM are shown below.

CGD23/ITRF2020 (Epoch2023.355, 2023/05/10)				RMS					Difference from average value		
Name	Date	X (m)	Y (m)	Z (m)	X (m)	Y (m)	Z (m)	REMARKS	dX (m)	dY (m)	dZ (m)
STG100KHM	2023/5/7	-1,706,798.576	5,963,096.227	1,481,479.666	0.001	0.002	0.001		-0.002	0.006	-0.001
STG100KHM	2023/5/8	-1,706,798.579	5,963,096.226	1,481,479.668	0.001	0.002	0.001		-0.005	0.005	0.001
STG100KHM	2023/5/9	-1,706,798.579	5,963,096.225	1,481,479.668	0.001	0.002	0.000		-0.005	0.004	0.001
STG100KHM	2023/5/10	-1,706,798.573	5,963,096.216	1,481,479.665	0.001	0.002	0.001		0.000	-0.005	-0.002
STG100KHM	2023/5/11	-1,706,798.564	5,963,096.219	1,481,479.671	0.001	0.002	0.001	CUSV: No RINEX	0.010	-0.002	0.004
STG100KHM	2023/5/12	-1,706,798.573	5,963,096.212	1,481,479.664	0.001	0.002	0.001		0.001	-0.009	-0.003
STG100KHM	2023/5/13	-1,706,798.573	5,963,096.223	1,481,479.669	0.001	0.002	0.001		0.001	0.002	0.002
AVERAGE		-1,706,798.574	5,963,096.221	1,481,479.667							



11.4.6. Conclusion

Since the RMS of the results calculated using Bernese software is approximately 2 mm, the daily coordinate values were determined with high accuracy.

The difference from the average value of the daily coordinates is 11 mm in the Y coordinate for PNH100KHM on 5/12, but it is less than 10 mm for other CORS.

Therefore, the CGD23 (Epoch 2023.355) coordinate value, which is the average value from 5/7 to 5/13, was determined with high accuracy.

11.5. 5-CORS CGD23 coordinates

The determined coordinates are shown below.

Name	X (m)	Y (m)	Z (m)
KND100KHM	-1,619,492.911	6,040,715.083	1,247,864.916
KSP100KHM	-1,572,714.347	6,050,448.859	1,260,501.903
PNH100KHM	-1,603,672.436	6,038,739.339	1,277,314.639
SIE100KHM	-1,490,303.856	6,024,644.818	1,465,891.145
STG100KHM	-1,706,798.574	5,963,096.221	1,481,479.667

Name	B (DD MM SS.SSSSS)	L (DDD MM SS.SSSSS)	H (m)
KND100KHM	11 21 29.10724N	105 00 28.29508E	2.021
KSP100KHM	11 28 28.52899N	104 34 14.32999E	23.783
PNH100KHM	11 37 47.13795N	104 52 20.72324E	2.735
SIE100KHM	13 22 33.08881N	103 53 39.19100E	2.986
STG100KHM	13 31 14.27708N	105 58 21.16724E	48.599

Name	N (m)	E (m)	h (m)	Geoid (m)
KND100KHM	1,255,573.579	500,857.576	14.064	-12.043
KSP100KHM	1,268,490.958	453,172.078	37.598	-13.815
PNH100KHM	1,285,616.938	486,093.422	15.770	-13.035
SIE100KHM	1,478,968.366	380,264.014	23.535	-20.549
STG100KHM	1,494,920.523	605,244.625	60.813	-12.214

11.6. Guessing how to obtain Nationwide-CORS coordinates

In a grant aid project, a method for calculating CGD23 coordinates of Nationwide-CORS will be studied.

Let's try to make a guess here.

(A) Consider that the CGD23 coordinate of Nationwide-CORS is calculated based on the 5-CORS coordinate. It may be possible to consider adding an IGS station to the survey network, but basically the 5-CORS coordinate values will be calculated as known coordinate values.

(B) Perform resurvey of 0-1st order control point. This is a necessary survey to check the accuracy of Nationwide-CORS coordinate values and coordinate transformation parameters.

(C) Calculate 0-1st order control point coordinates based on Nationwide-CORS coordinates.

(D) Check the accuracy of Nationwide-CORS coordinate values. In this project, CGD23 coordinates are calculated by resurveying at several 0-1st order control points. Therefore, check the accuracy of the Nationwide-CORS coordinate values by comparing them with the results in (C). If the difference is large, the following causes may be considered, so it is necessary to check the survey data to determine the cause and eliminate the error.

- ✓ Are there any abnormalities in the Nationwide-CORS RINEX data used for calculations?
- ✓ Are there any abnormalities in the survey data for the 0-1st order control point that was resurveyed?
- ✓ Especially in the resurvey data, are there any problems with the input values of the antenna type and antenna bottom height?

(E) Check the coordinate transformation parameters calculated in this project by comparing the CGD09 coordinate of the 0-1st order control point and the CGD23 coordinate that is the result of (C). If the displacement trend is not uniform, it is necessary to create coordinate transformation parameters suitable for the area.

Please refer to the [Coordinate_Transformation_Manual] for the coordinate conversion parameters suitable for each region.

12. Regular monitoring of CORS coordinate values

12.1. Crustal deformation in Cambodia

When we confirmed the crustal deformation in Cambodia over a 14-year period (from 2009 to 2023) using the results of verifying the accuracy of GNSS surveying using CORS data, we found that it was approximately 0.34 m in the east-southeast direction. The displacement rate is approximately 24mm/year.

2023 - 2009	dX (m)	dY (m)	dZ (m)	dN (m)	dE (m)	dU (m)
Max	-0.231	0.004	-0.045	-0.050	0.402	0.082
Min	-0.406	-0.138	-0.143	-0.154	0.224	-0.062
Average	-0.322	-0.034	-0.086	-0.095	0.319	0.030

The crustal deformation of the Sunda plate is 14mm/year in the eastward direction (Fig.1).

Considering the errors in the GNSS measurement of the 0-1st order control point, the results can be considered to be generally consistent with the crustal deformation research of the Sunda plate.

12.2. CORS coordinate values and social activities considering crustal deformation

The CGD23 coordinate value was Epoch2023.355.

In the future, if CORS is installed throughout Cambodia and its operation begins in 2025, the earth's crust will have moved approximately 50 mm east-southeast direction at that point.

If all of Cambodia were to move uniformly in parallel, there would be no problem in continuing to use CGD23. However, if the crust is shifting non-uniformly, it is necessary to revise the coordinate values to CGDxx at some point in time.

On the other hand, if the revision interval is short, the coordinate values and area will fluctuate in a short period of time, causing a problem of confusion in social activities. Therefore, it is better to avoid revising coordinate values in a short period of time.

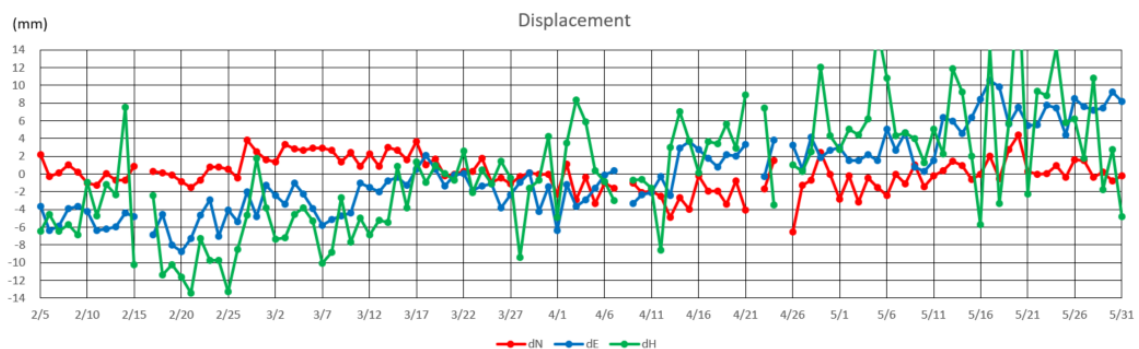
12.3. Regular monitoring of CORS coordinate values

It is important to regularly monitor CORS coordinate values and understand the displacement status of CORS placed throughout Cambodia.

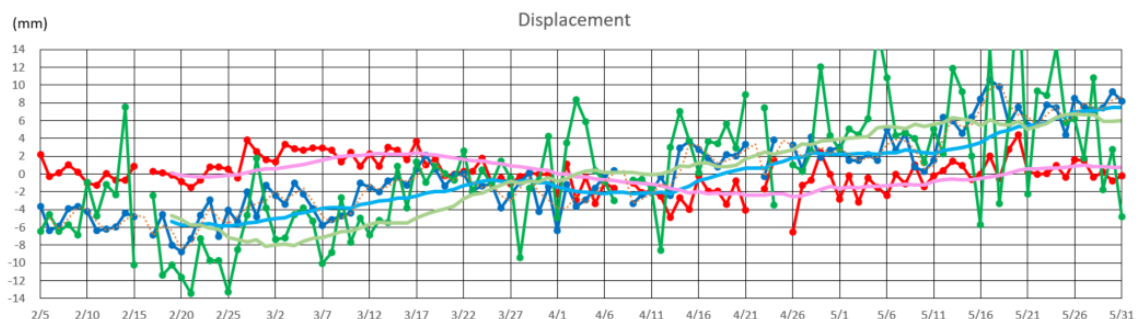
When calculating CORS coordinate values using the Bernese manual, they are calculated at the epoch of the GNSS observation date. We will call these coordinate values "daily coordinates."

If the displacement direction and displacement rate of crustal deformation throughout Cambodia are uniform, it is not necessary to carry out monitoring every day, and it may be possible to monitor it every month. We recommend monitoring at least once a year. At this time, it is better to unify the epoch to January 1st, so calculate the average value for several days before and after so that January 1st is the center.

For example, it is recommended to use the monitoring results calculated every day in a graph like the one shown below for analysis.



The daily difference is about 20 mm due to errors caused by water vapor, the ionosphere, solar activity, etc. Therefore, by analyzing the displacement trend using techniques such as regression calculation and moving average, it is possible to calculate a curve like the one shown below from the above figure.



Then, look at this curve and decide when to revise the coordinates to CGDxx.

As mentioned above, if the interval between revisions is short, there is a risk of

disrupting social activities, so it is basically preferable to use CGD23 coordinate values. The timing to revise the coordinate values is when a large displacement is observed in a short period of time, and when the displacement is uneven depending on the region. For example, in a country like Japan, where the earth's crust is intricately intertwined and earthquakes occur frequently, it is necessary to repeat revisions every time there is a large earthquake.

Cambodia is located on one plate, the Sunda Plate, so we cannot expect large displacement in the short term. If the displacement is uniform at a constant rate, we may consider a proposal to revise it once every quarter century. For this reason, it is necessary to periodically check that the displacement is uniform at a constant rate.

12.4. Future Goals

Manually performing calculations with Bernese software requires a lot of effort and time. Therefore, our future goal is to automate the calculations of the Bernese software and regularly monitor the daily coordinate values.

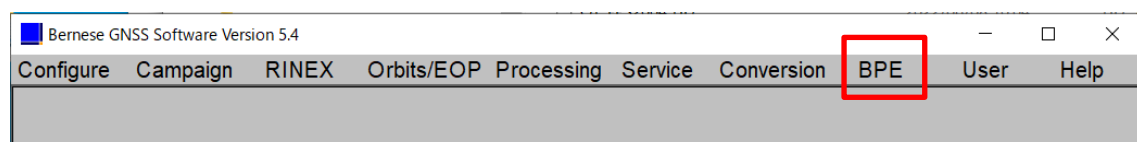
Below are the steps required to automate calculations in Bernese software.

(A) First, understand the process of baseline analysis and coordinate determination in GNSS surveying. After that, learn to calculate coordinate values manually according to this manual. We are currently at this stage in 2023.

(B) The second step is to automate the calculations of the Bernese software. However, the data required for the calculations (such as the precise orbit files available on the University of Bern's website) must be manually downloaded and stored in the designated folder by hand.

We will explain the automatic analysis of Bernese software.

Bernese Software has an automatic analysis function called Bernese Processing Engine (hereinafter referred to as [BPE]).



By defining the analysis procedure etc. in advance in the Processing Control File (hereinafter referred to as "PCF") and starting it, calculations can be performed

automatically. This means that the final solution can be calculated without repeatedly clicking [Run] on the menu screen.

Describe the SCRIPT name that will be executed in the PCF, and BPE executes the SCRIPT files in the order written in the PCF. In the SCRIPT, in addition to commands to run Bernese programs, you can also write commands to change file names and change menu screens. In addition, the PCF can be also described the variable names defined in the PCF, as well as the values and characters set for those variables.

To create CFCs and SCRIPTs, you must know how to run Bernese Software manually.

In other words, as explained in the previous section (A), you first need to improve your skills to be able to find the final solution according to the Bernese Software manual.

Next, the second step is to improve your skills by learning how to create PCFs and SCRIPTs for BPE.

(C) Create a program that automatically collects the data (such as the precise porbit files available on the University of Bern's website) and parameters necessary to find the final solution, and also a program that periodically executes BPE. The final goal is to use this program to build a tool to monitor daily coordinates.

In addition, in order to build the tool, it is necessary to form a team of GNNS survey engineers, IT engineers, system engineers, etc.

Ver. 24th October 2024

Project on Establishment of Continuously Operating Reference Stations (CORS) for Land Management and Infrastructure Development

Coordinate Transformation

Manual for CGD23

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NOTE: The remaining issues are shown below. GDCG should discuss this issue and update this manual.

- After the CGD23 coordinates are registered in Pivot, it is necessary to perform a check survey using NRTK. Please compare the CGD23 coordinate values, which were converted from CGD09 using the coordinate conversion parameters, with the coordinate values obtained by NRTK surveying. If the difference is within an acceptable range, there is no problem with the accuracy of the data being distributed from CORS.
- It is necessary to conduct a check survey after the CORS coordinate values for the entire Cambodia area have been calculated. Calculate the CGD09 coordinate values of CORS across Cambodia using the check survey data. This calculation can be done using TBC software. Next, use CORS for all of Cambodia to calculate the coordinate transformation parameters from CGD09 to CGD23. 5-Compare the coordinate transformation parameters calculated from CORS and the coordinate transformation parameters calculated from CORS for all of Cambodia. If this difference is within an acceptable range, only the coordinate transformation parameters calculated with 5-CORS can be used.
- If there are differences between regions, please refer to this manual and create coordinate transformation parameters suitable for each region. Then, for areas that are not compatible, use the new coordinate conversion parameters to convert CGD09 to CGD23.

1. Introduction

1.1. Introduction

This manual describes the transformation from CGD09 coordinates to CGD23 coordinates. As a reference, it describes how to transform coordinates to CGD23 coordinates from survey results with coordinates older than CGD09 coordinates.

1.2. Structure of the Manual

This manual describes the following items.

1. Geodetic reference system specification
2. Calculation procedure of coordinate transformation parameters
3. Introduction of coordinate transformation methods
4. Calculation methods of coordinate transformation parameters by Helmert transformation using Bernese5.4
5. Procedure of coordinate transformation by Helmert transformation using Bernese5.4
6. Coordinate transformation parameter from CGD09 to CGD23
7. Appendix
 - 1) Study of Coordinate transformation parameters using Khmer GEONET
 - 2) Coordinate transformation method from CGD03 to CGD23
 - 3) Coordinate transformation method of Cadastral survey boundary points
 - 4) Coordinate transformation method from Indian 19XX to CGD23

1.3. Scope of Application

The scope of this manual applies to the following survey results, which are points having CGD09 coordinates.

1. 0 order and 1st order Control Point
2. 2nd and 3rd Order Control Point
3. Cadastral survey boundary points

2. Geodetic Reference System and Map Projection

2.1. CGD23

Table 1 CGD23

Item	Element
Geocentric Cartesian Coordinate System	ITRF2020 (Epoch 2023.355, 10 th May 2023)
Reference Ellipsoid	GRS 80
Vertical Datum	Mean Sea Level (Haiphong, Vietnam)
Geoid Model	EGM2008
Plane Cartesian Coordinate System	UTM Zone 48 - Central Meridian: 105° 00' 00" E - Latitude of Origin: 0° 00' 00" N - False Easting: 500,000.000 m - False Northing: 0.000 m - Scale Factor at Central Meridian: 0.9996
Unit and Notation	Meters, 0,001m

2.2. CGD09

Table 2 CGD09

Item	Element
Geocentric Cartesian Coordinate System	ITRF2005 (Epoch 2009.56, 23 rd July 2009)
Reference Ellipsoid	GRS 80
Vertical Datum	Mean Sea Level (Ha Tien, Vietnam)
Geoid Model	EGM2008
Plane Cartesian Coordinate System	UTM Zone 48 - Central Meridian: 105° 00' 00" E - Latitude of Origin: 0° 00' 00" N - False Easting: 500,000.000 m - False Northing: 0.000 m - Scale Factor at Central Meridian: 0.9996
Unit and Notation	Meters, 0,001m

3. Calculation procedure of coordinate transformation parameters

3.1. Requirements for Calculating Coordinate Transformation Parameters

The requirements for calculating the coordinate transformation parameters are listed below.

- ✓ A point having both CGD09 coordinate values (old coordinate values) and CGD23 coordinate values (new coordinate values) is required.
- ✓ Points with CGD09 coordinate values (old coordinate values) must have no change to the current status and the status at the time of CGD23 coordinate values (new coordinate values) calculation.
- ✓ In addition to the points for calculating the coordinate transformation parameters, a verification point shall be prepared.
- ✓ The point for calculating the coordinate transformation parameters and the verification point shall be re-surveyed to calculate the CGD23 coordinate values (new coordinate values).

3.2. Procedure for Calculating Coordinate Transformation Parameters

A flowchart for calculating the coordinate transformation parameters is shown below.

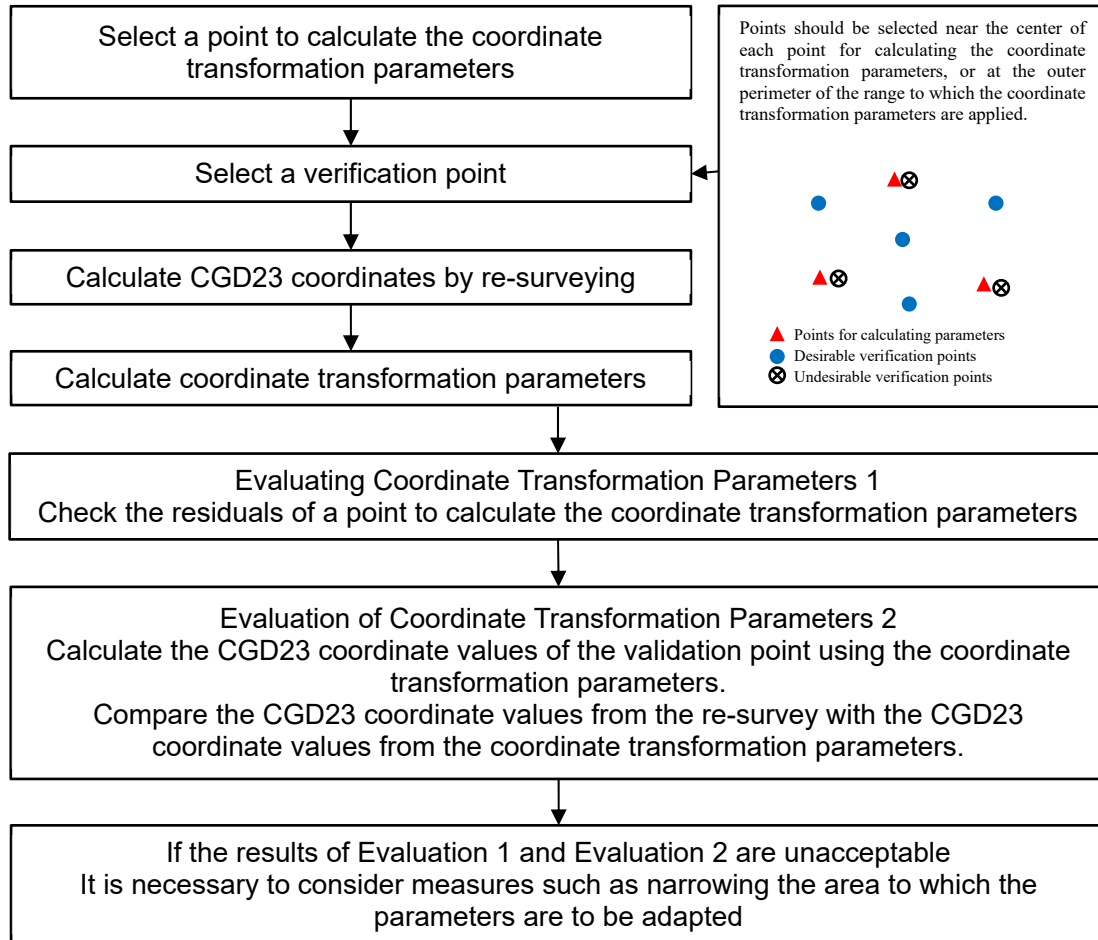


Figure 1 Flowchart

4. Introduction to common coordinate transformation methods

4.1. Helmert Transform

4.1.1. Helmert Transform (3D)

This method should be used when transforming the coordinates of a region with a large area of application, such as a global scale. Using points with both CGD09 coordinate values (old coordinate values) and CGD23 coordinate values (new coordinate values), it estimates the amount of translation from origin, rotation around each axis, and scale factor by the least-squares method. The coordinate transformation parameters from CGD09 to CGD23 coordinate values were calculated by this method. The conversion equations are shown below.

$$\begin{bmatrix} X_{CDG23} \\ Y_{CDG23} \\ Z_{CDG23} \end{bmatrix} = \begin{bmatrix} dx \\ dy \\ dz \end{bmatrix} + (1 + s) \cdot \begin{bmatrix} 1 & -r_z & r_y \\ r_z & 1 & -r_x \\ -r_y & r_x & 1 \end{bmatrix} \cdot \begin{bmatrix} x_{CDG09} \\ y_{CDG09} \\ z_{CDG09} \end{bmatrix}$$

X_{CGD23} : X value of CGD23 coordinate

Y_{CGD23} : Y value of CGD23 coordinate

Z_{CGD23} : Z value of CGD23 coordinate

dx : Amount of translation from origin
in x – axis direction

dy : Amount of translation from origin
in y – axis direction

dz : Amount of translation from origin
in z – axis direction

s : Scale factor

r_x : Amount of rotation around x – axis

r_y : Amount of rotation around y – axis

r_z : Amount of rotation around z – axis

X_{CGD09} : X value of CGD09 coordinate

Y_{CGD09} : Y value of CGD09 coordinate

Z_{CGD09} : Z value of CGD09 coordinate

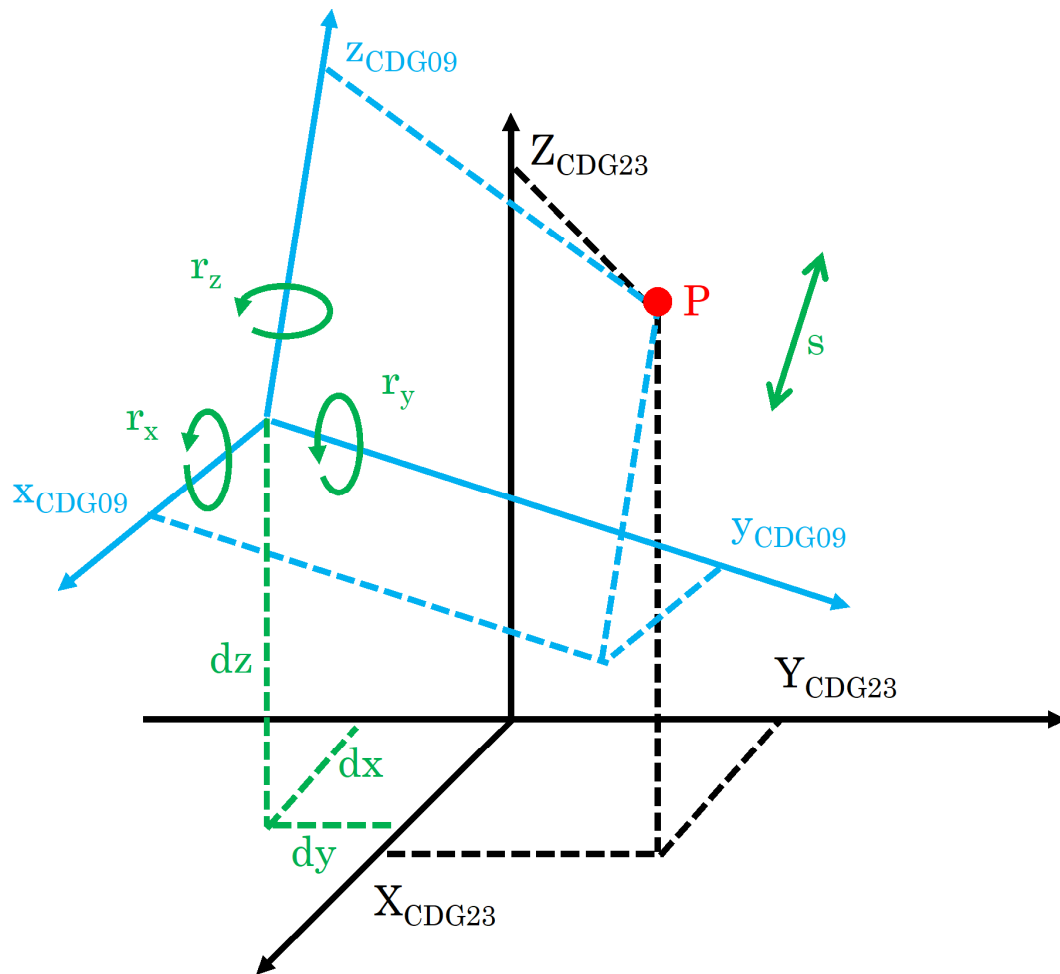


Figure 2 Helmert Transform (3D)

4.1.1. Helmert Transformation (2D)

In general, when transforming the coordinates of an area with a small area of application, the coordinates are transformed by dividing them into horizontal position coordinates and elevation coordinates. The Helmert transformation (two-dimensional) is a method of transforming coordinates for horizontal position coordinates using the amount of translation from origin, rotation, and scale factor. Using points with both CGD09 coordinate values (old coordinate values) and CGD23 coordinate values (new coordinate values), the amount translation from origin, rotation, and scale factor are estimated by the least-squares method. The transformation formula is shown below.

$$\begin{bmatrix} X_{CGD23} \\ Y_{CGD23} \end{bmatrix} = \begin{bmatrix} dx \\ dy \end{bmatrix} + s \cdot \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix} \cdot \begin{bmatrix} x_{CGD09} \\ y_{CGD09} \end{bmatrix}$$

X_{CGD23} : $X(N)$ value of CGD23 coordinate

Y_{CGD23} : $Y(E)$ value of CGD23 coordinate

dx : Amount of translation from origin in $x(N)$ – axis direction

dy : Amount of translation from origin in $y(E)$ – axis direction

s : Scale factor

θ : Amount of rotation

X_{CGD09} : $X(N)$ value of CGD09 coordinate

Y_{CGD09} : $Y(E)$ value of CGD09 coordinate

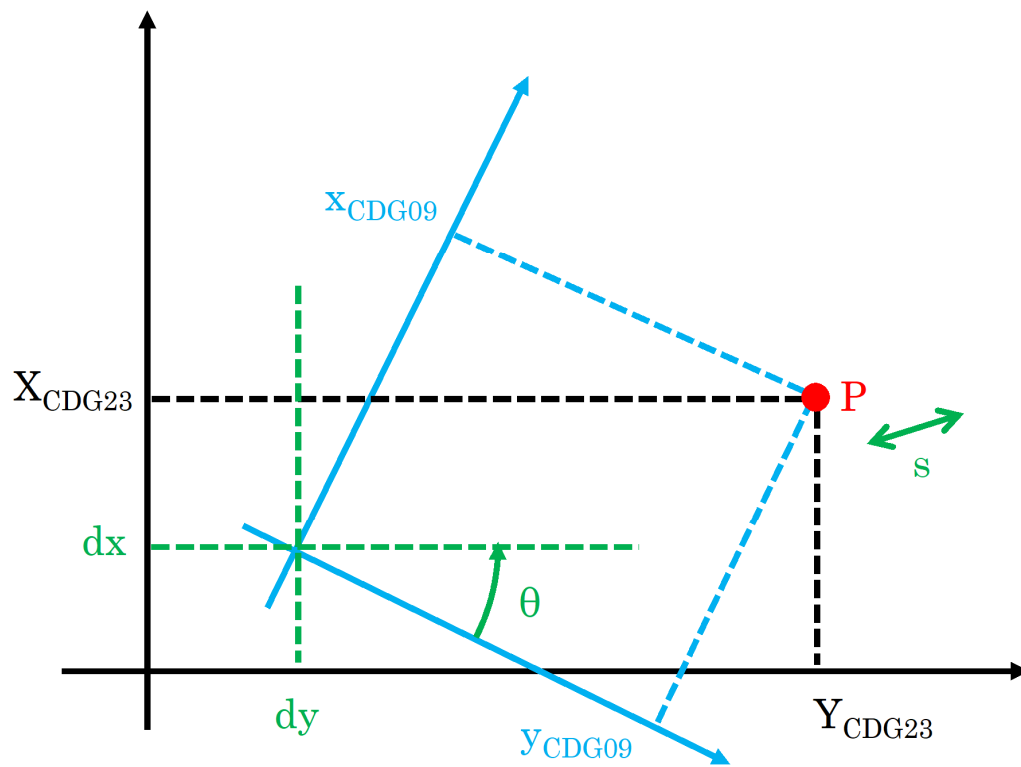


Figure 3 Helmert Transformation (2D)

4.2. Affine Transformation

In general, when transforming the coordinates of an area with a small area of application, the coordinates are transformed by dividing them into horizontal position coordinates and elevation coordinates.

The affine transformation is a method of transforming coordinates for horizontal position coordinates using the amount of translation from origin, rotation of each axis, and scale factor. Using points with both CGD09 coordinate values (old coordinate values) and CGD23 coordinate values (new coordinate values), the amount translation from origin, rotation of each axis, and scale factor are estimated by the least-squares method.

The transformation formula is shown below.

$$\begin{bmatrix} X_{CGD23} \\ Y_{CGD23} \end{bmatrix} = \begin{bmatrix} dx \\ dy \end{bmatrix} + \begin{bmatrix} s_x \cdot \cos \theta_x & -s_y \cdot \sin \theta_y \\ s_x \cdot \sin \theta_x & s_y \cdot \cos \theta_y \end{bmatrix} \cdot \begin{bmatrix} x_{CGD09} \\ y_{CGD09} \end{bmatrix}$$

X_{CGD23} : $X(N)$ value of CGD23 coordinate

Y_{CGD23} : $Y(E)$ value of CGD23 coordinate

dx : Amount of translation from origin in $x(N)$ – axis direction

dy : Amount of translation from origin in $y(E)$ – axis direction

s_x : Scale factor of x – axis

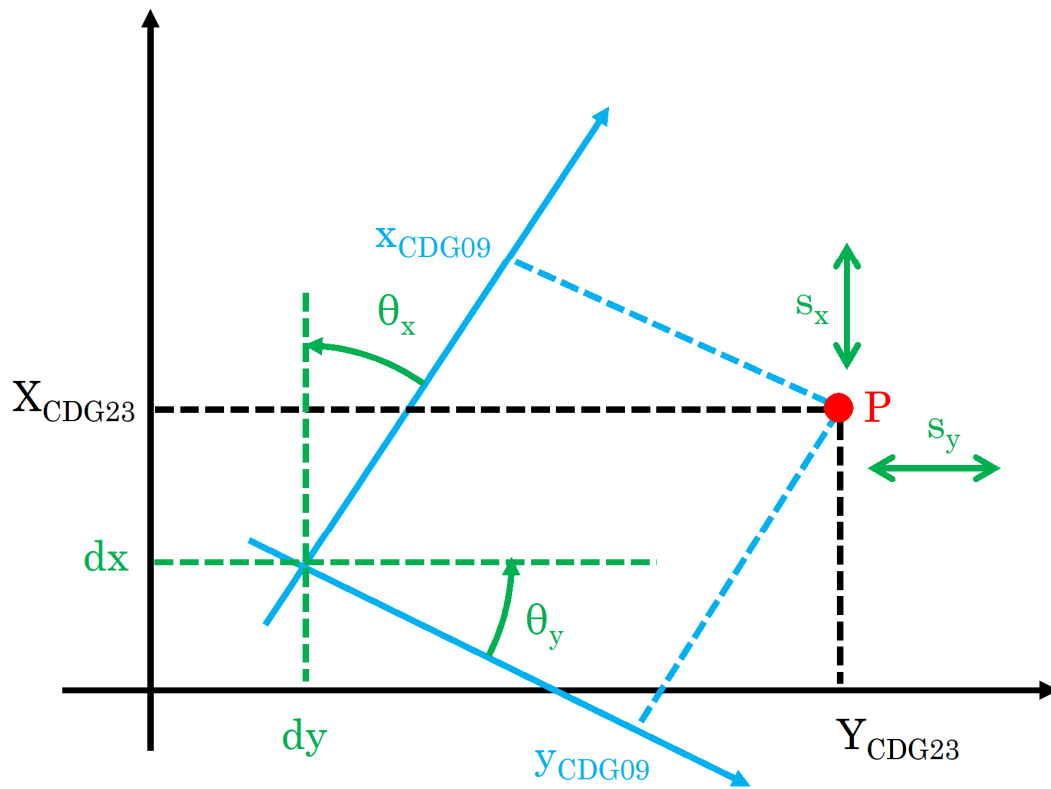
s_y : Scale factor of y – axis

θ_x : Amount of x – axis rotation

θ_y : Amount of y – axis rotation

X_{CGD09} : $X(N)$ value of CGD09 coordinate

Y_{CGD09} : $Y(E)$ value of CGD09 coordinate

**Figure 4 Affine Transformation**

4.3. Method by weighted interpolation

The weighted interpolation is a method for conducting the coordinate transformation to calculate the correction amount for coordinate transformation by weighting the reciprocal of the distance between the point with both CGD09 coordinate values (old coordinate values) and CGD23 coordinate values (new coordinate values) and the point for which the coordinate transformation is performed. This method is used to calculate coordinate transformation parameters adapted to each region.

The calculation formula is shown below.

$$X_{CGD23} = X_{CGD09} + \frac{\sum_{i=1}^n dx_i \cdot P_i}{\sum_{i=1}^n P_i} \quad Y_{CGD23} = Y_{CGD09} + \frac{\sum_{i=1}^n dy_i \cdot P_i}{\sum_{i=1}^n P_i}$$

$$H_{CGD23} = H_{CGD09} + \frac{\sum_{i=1}^n dh_i \cdot P_i}{\sum_{i=1}^n P_i}$$

X_{CGD23} : $X(N)$ value of CGD23 coordinate of point A

Y_{CGD23} : $Y(E)$ value of CGD23 coordinate of point A

H_{CGD23} : Elevation value of CGD23 coordinates at point A

X_{CGD09} : $X(N)$ value of CGD09 coordinate of point A

Y_{CGD09} : $Y(E)$ value of CGD09 coordinate of point A

H_{CGD09} : Elevation value of CGD09 coordinates at point A

$dx_i = x_{Bi \text{ CGD09}} - x_{Bi \text{ CGD23}}$:

Correction amount for coordinate transformation of $X(N)$ coordinate of point B_i

$dy_i = y_{Bi \text{ CGD09}} - y_{Bi \text{ CGD23}}$:

Correction amount for coordinate transformation of $Y(E)$ coordinate of point B_i

$dh_i = h_{Bi \text{ CGD09}} - h_{Bi \text{ CGD23}}$:

Correction amount for coordinate transformation of elevation value of point B_i

$$P_i = \frac{1}{S_i} = \frac{1}{\sqrt{(x_{Bi \text{ CGD09}} - x_{CGD09})^2 + (y_{Bi \text{ CGD09}} - y_{CGD09})^2}} : \text{weight}$$

S_i : Horizontal distance between point B_i and point A

$x_{Bi \text{ CGD23}}$: $X(N)$ value of CGD09 coordinate of point B_i

$y_{Bi \text{ CGD09}}$: $Y(E)$ value of CGD09 coordinate of point B_i

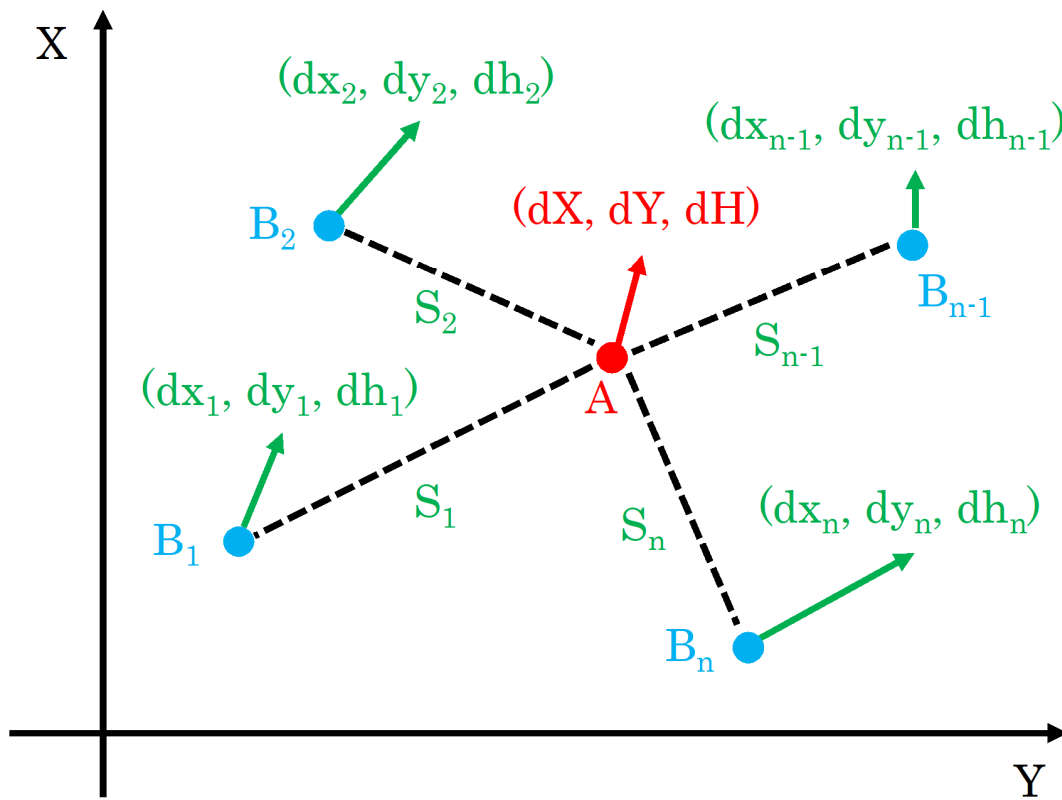


Figure 5 Method by weighted interpolation

4.4. Bilinear transformation method with linear interpolation

Coordinate transformation correction amount calculated from points having both CGD09 coordinate values (old coordinate values) and CGD23 coordinate values (new coordinate values) are distributed on a mesh. The method, which is calculating the coordinate transformation correction amount for an arbitrary point in a mesh by linear interpolation and then transforming the coordinates of that point, is called the bilinear transformation method. This method is used to calculate coordinate transformation parameters adapted to each region. And this method is also suitable for providing users with regionally adapted coordinate transformation parameters and for creating program of calculation formula.

The calculation formula is shown below.

$$\begin{bmatrix} X_{CGD23} \\ Y_{CGD23} \\ H_{CGD23} \end{bmatrix} = \begin{bmatrix} X_{CGD09} \\ Y_{CGD09} \\ H_{CGD09} \end{bmatrix} + \begin{bmatrix} \frac{y_2 - Y_{CGD09}}{y_2 - y_1} \left(\frac{x_2 - X_{CGD09}}{x_2 - x_1} \cdot dx_{11} + \frac{X_{CGD09} - x_1}{x_2 - x_1} \cdot dx_{21} \right) + \frac{Y_{CGD09} - y_1}{y_2 - y_1} \left(\frac{x_2 - X_{CGD09}}{x_2 - x_1} \cdot dx_{12} + \frac{X_{CGD09} - x_1}{x_2 - x_1} \cdot dx_{22} \right) \\ \frac{y_2 - Y_{CGD09}}{y_2 - y_1} \left(\frac{x_2 - X_{CGD09}}{x_2 - x_1} \cdot dy_{11} + \frac{X_{CGD09} - x_1}{x_2 - x_1} \cdot dy_{21} \right) + \frac{Y_{CGD09} - y_1}{y_2 - y_1} \left(\frac{x_2 - X_{CGD09}}{x_2 - x_1} \cdot dy_{12} + \frac{X_{CGD09} - x_1}{x_2 - x_1} \cdot dy_{22} \right) \\ \frac{y_2 - Y_{CGD09}}{y_2 - y_1} \left(\frac{x_2 - X_{CGD09}}{x_2 - x_1} \cdot dh_{11} + \frac{X_{CGD09} - x_1}{x_2 - x_1} \cdot dh_{21} \right) + \frac{Y_{CGD09} - y_1}{y_2 - y_1} \left(\frac{x_2 - X_{CGD09}}{x_2 - x_1} \cdot dh_{12} + \frac{X_{CGD09} - x_1}{x_2 - x_1} \cdot dh_{22} \right) \end{bmatrix}$$

X_{CGD23} : $X(N)$ value of CGD23 coordinates of point A

Y_{CGD23} : $Y(E)$ value of CGD23 coordinates of point A

H_{CGD23} : Elevation value of CGD23 coordinates at point A

X_{CGD09} : $X(N)$ value of CGD09 coordinates of point A

Y_{CGD09} : $Y(E)$ value of CGD09 coordinates of point A

H_{CGD09} : Elevation value of CGD09 coordinates at point A

$dx_{ij} = x_{Bij\ CGD09} - x_{Bij\ CGD23}$: Correction amount for coordinate transformation of $X(N)$ coordinate of point B_{ij}

$dy_{ij} = y_{Bij\ CGD09} - y_{Bij\ CGD23}$: Correction amount for coordinate transformation of $Y(E)$ coordinate of point B_{ij}

$dh_{ij} = h_{Bij\ CGD09} - h_{Bij\ CGD23}$: Correction amount for coordinate transformation of elevation value of point B_{ij}

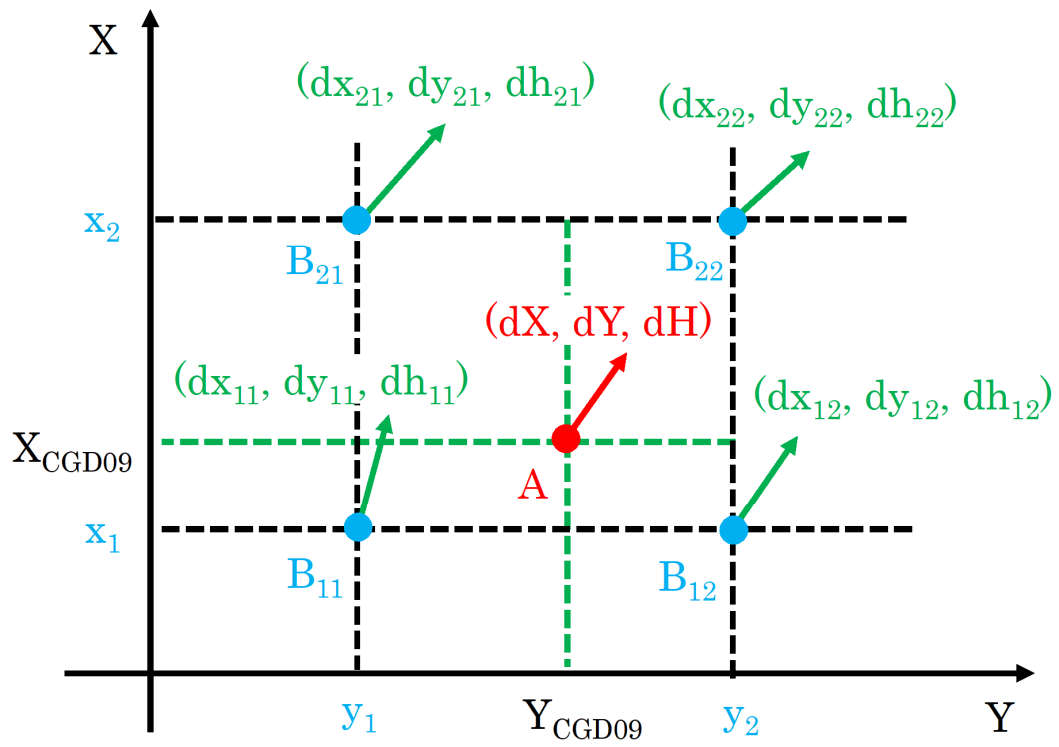


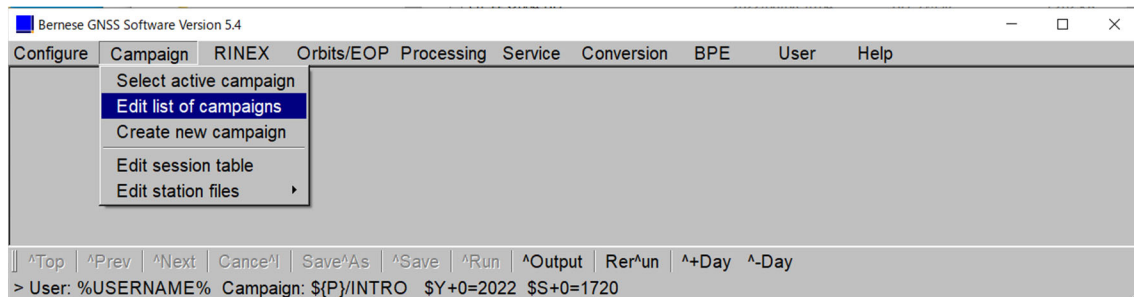
Figure 6 Bilinear transformation method with linear interpolation

5. Coordinate Transformation

5.1. Create a campaign and the point coordinate files

5.1.1. Edit list of campaigns

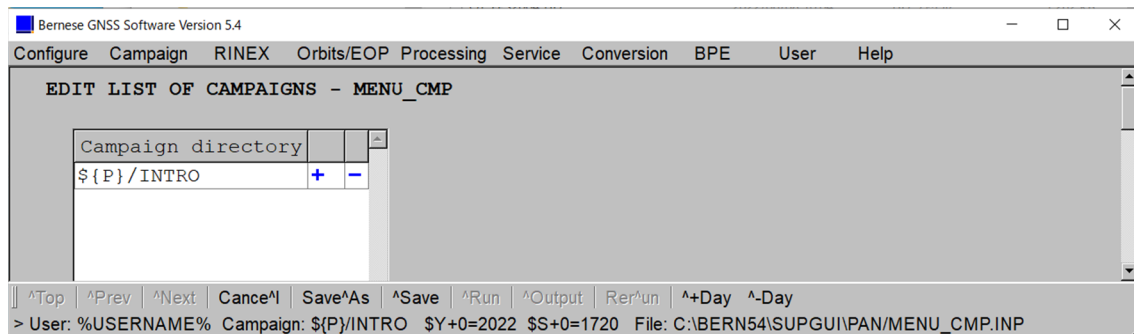
Click [Edit list of campaigns] to display the submenu.



Click [+] to copy the line. Click [-] to delete the line.

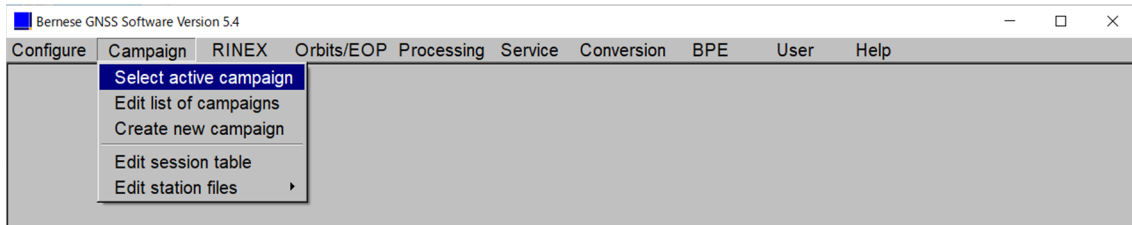
Rename the campaign directory to [\${P}/XXXXX]. [XXXXX] can be named arbitrarily.

Click [^Save] to save your changes.

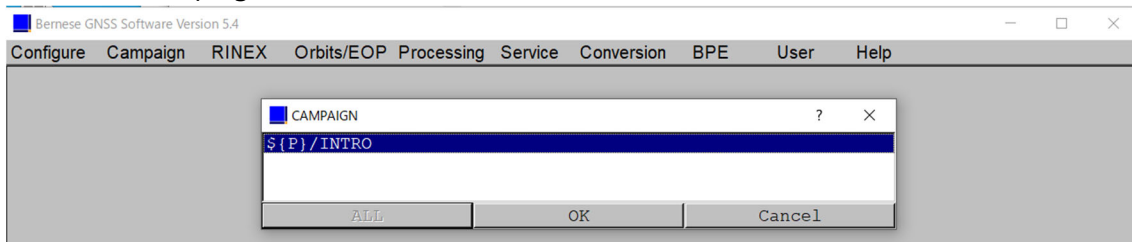


5.1.2. Select the active campaign

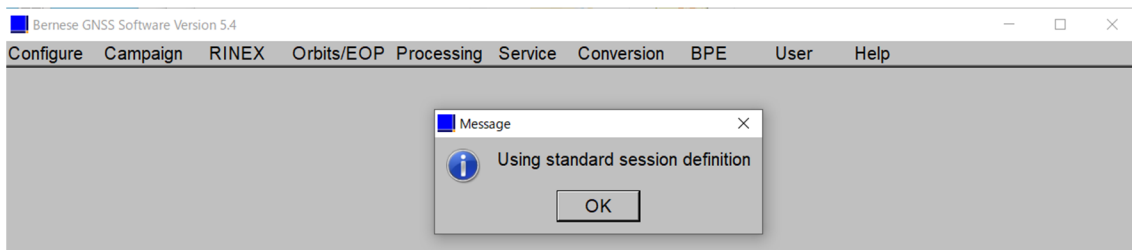
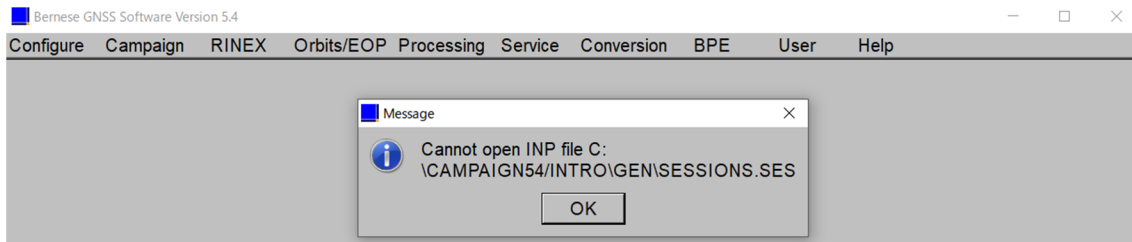
Click [Select active campaign] to display the registered campaign directory.



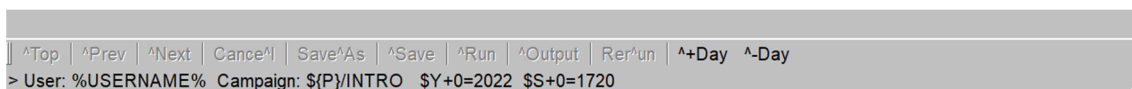
Select the campaign and click [OK].



If the Directory is not created, Message will be displayed, but there is no problem. So press the [OK] button. Then, click [OK] for all.

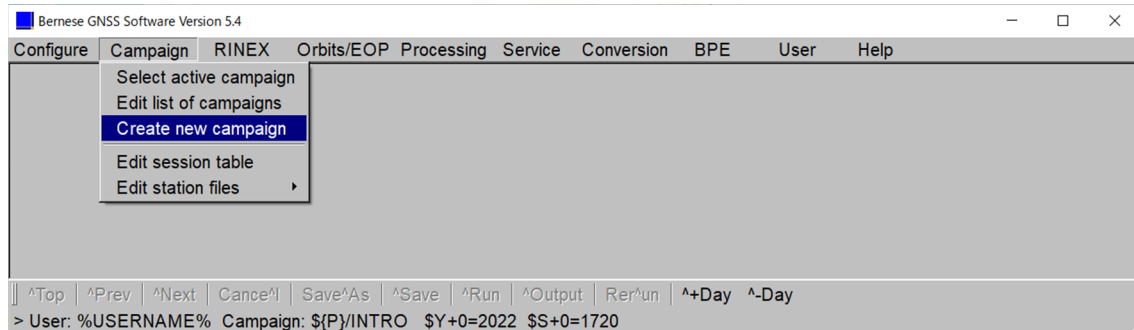


Make sure the selected campaign is displayed at the bottom of the menu screen.

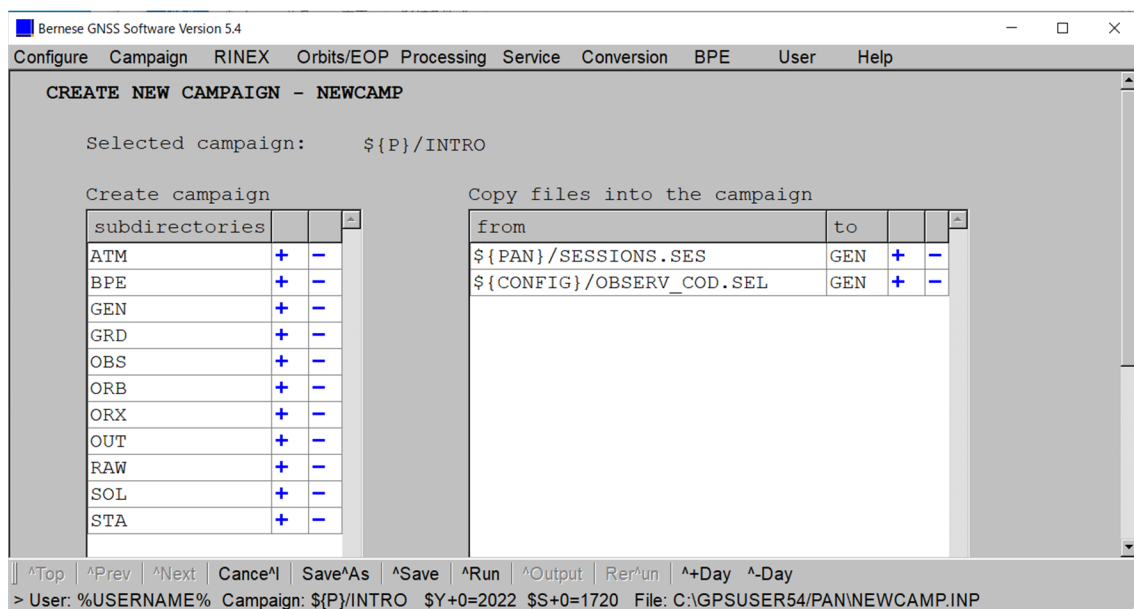


5.1.3. Create campaign folder

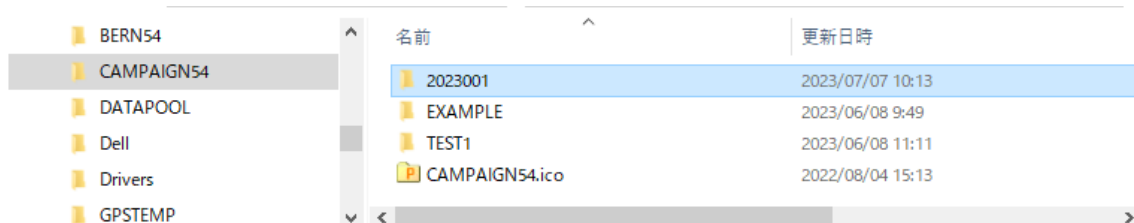
Click [Create new campaign] to display the submenu.



Click [^Run]

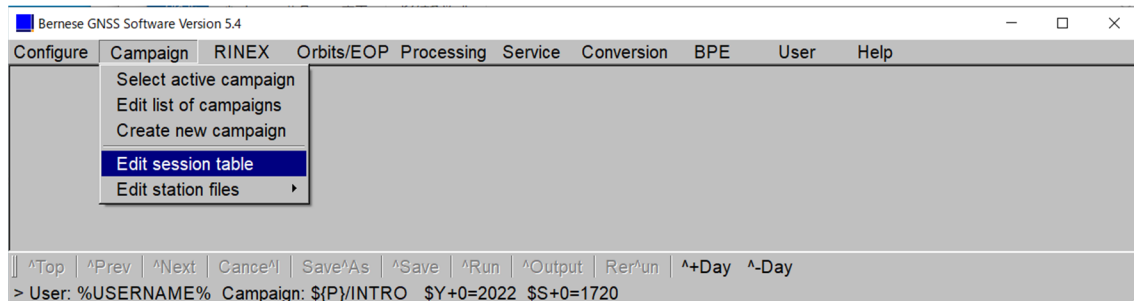


A folder with the campaign name will be created in the CAMPAIGN54 folder.



5.1.4. Select current session

Click [Edit session table] to display the registered Session table.

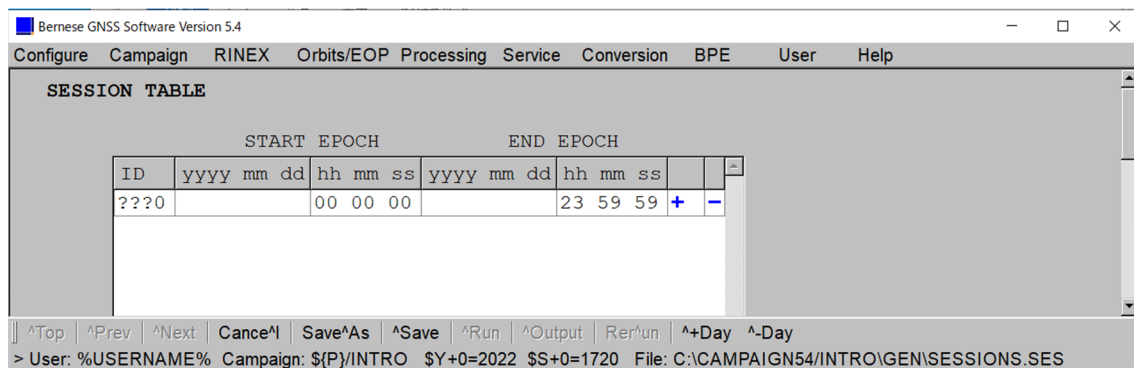


[???] is [Day of year]. It is a total day with 1st-Jan as 1. Set with wildcards.

START EPOCH and END EPOCH dates [yyyy mm dd] are blank.

START EPOCH time is 00:00:00. END EPOCH time is 23:59:59.

Click [^Save].



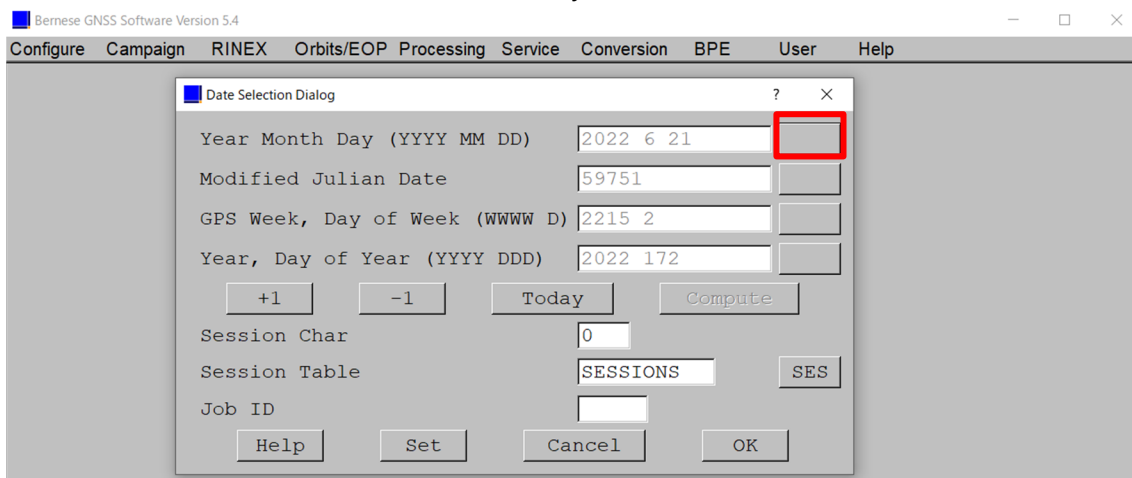
5.1.5. Calculation date setting

Click [Set session/compute date] to display the submenu

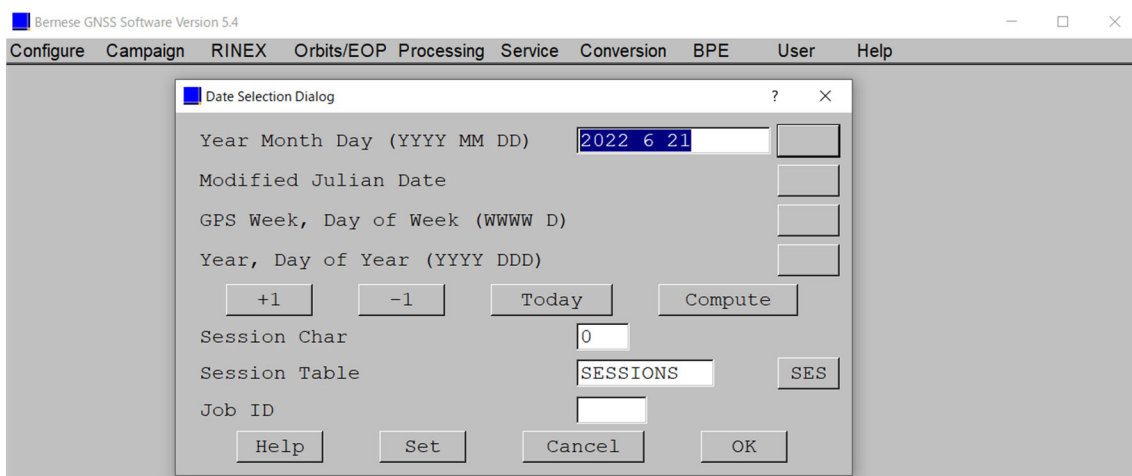


Set by [Year Month Day], [Modified Julian Date], [GPS Week and Day of Week] or [Year and Day of Year].

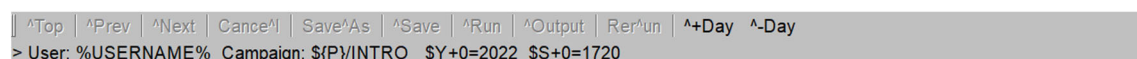
Click the red frame to set in [Year Month Day].



Enter the date and click [OK].



Make sure that the baseline processing date you set is displayed at the bottom of the menu screen.



5.1.6. Create the point coordinate file

Create the point coordinate files using a text editor. (e.g. CGD23.CRD and CGD09.CRD)

LOCAL GEODETIC DATUM: IGS20			EPOCH: 2015-01-01 00:00:00			
NUM	STATION NAME	X (M)	Y (M)	Z (M)	FLAG	SYSTEM
1	ANMG	-1270826.89380	6242631.33340	307792.42240	I	
2	CMUM	-938078.34810	5968373.98630	2038404.32190	I	
3	CUSV	-1132914.86460	6092528.56900	1504633.21270	I	
4	HKSL	-2393382.91750	5393860.99760	2412592.23210	I	
5	PTAG	-3184318.71050	5291065.49990	1590418.24380	I	
6	SIN1	-1507972.63360	6195613.86690	148488.03430	I	
7	KND1	-1619492.94400	6040715.07000	1247864.90000		
8	KSP1	-1572714.38600	6050448.84600	1260501.89200		
9	PNH1	-1603672.47300	6038739.32500	1277314.62100		
10	SIE1	-1490303.89300	6024644.81700	1465891.13600		
11	STG1	-1706798.61200	5963096.21200	1481479.65100		

5.1.7. Edit Coordinate file

Copy the point coordinate files to [STA] folder of the campaign.

CAMPAIGN54

230507

230508

ATM

BPE

GEN

GRD

OBS

ORB

ORX

OUT

RAW

SOL

STA

名前

更新日時

種類

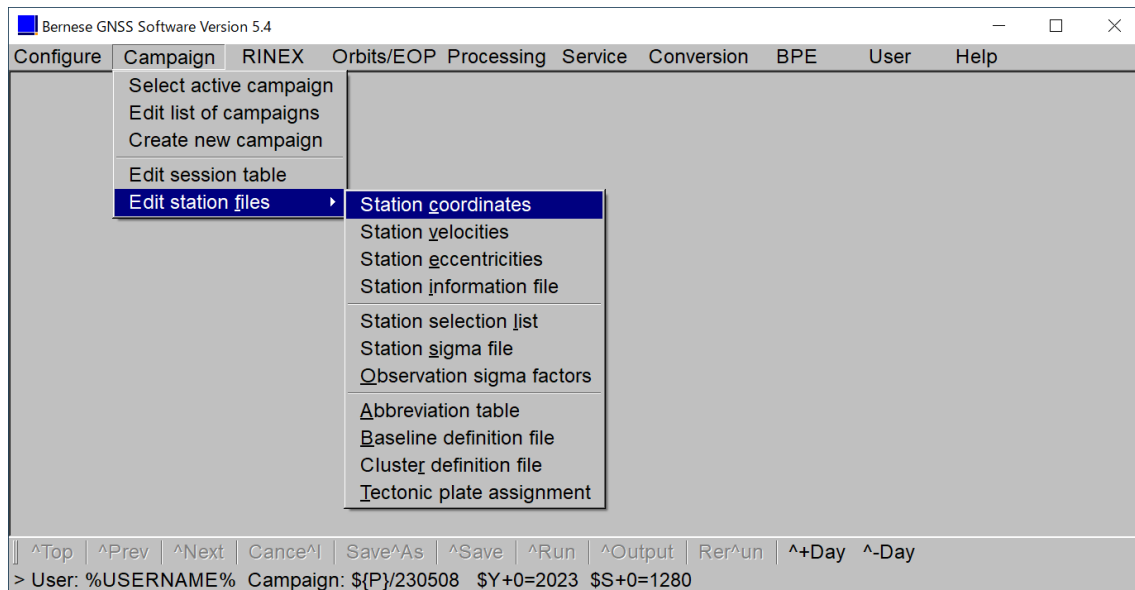
サイズ

 KHM_201500.CRD

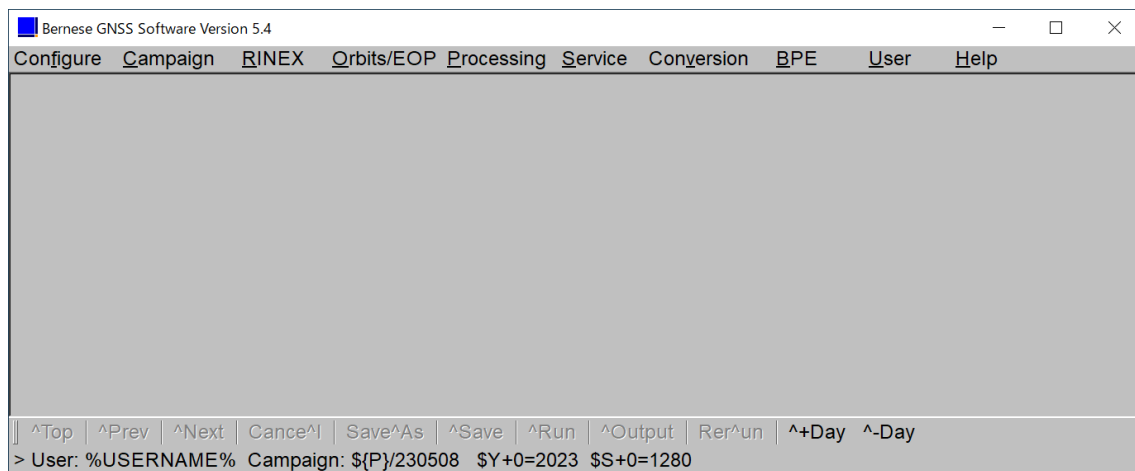
2023/07/29 9:59

CRD ファイル

Click [Station Coordinates] to display the submenu.



Select the coordinate file and click [OK].



Enter Title, Coordinate epoch, Geodetic datum, Station name and the coordinate values.
Click [^Save].

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CREATE/UPDATE STATION COORDINATES - EDITCRD

Filename: C:/CAMPAIGN54/230508/STA/KHM_201500.CRD

Title: KHM

Coordinate epoch: 2015 01 01 00 00 00

Geodetic datum: IGS20

Num	Station name	X (meter)	Y (meter)	Z (meter)	Fla
4	HKSL	-2393382.9175	5393860.9976	2412592.2321	I
5	PTAG	-3184318.7105	5291065.4999	1590418.2438	I
6	SIN1	-1507972.6336	6195613.8669	148488.0343	I
7	KND1	-1619492.9440	6040715.0700	1247864.9000	
8	KSP1	-1572714.3860	6050448.8460	1260501.8920	
9	PNH1	-1603672.4730	6038739.3250	1277314.6210	
10	SIE1	-1490303.8930	6024644.8170	1465891.1360	
11	STC1	-1706708.6120	5863096.2120	1481478.6510	

STACRD

^Top ^Prev ^Next Cancel^I Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: \${P}/230508 \$Y+0=2023 \$S+0=1280 File: C:\GPSUSER54\PA\EDITCRD.INP

Title: Can be entered arbitrarily

Coordinate epoch: The year, month, day, hour, and second for which the coordinates were calculated.

Geodetic datum: e.g. IGS20

Refer to the following website for Transformation Parameters between ITRF Solutions.

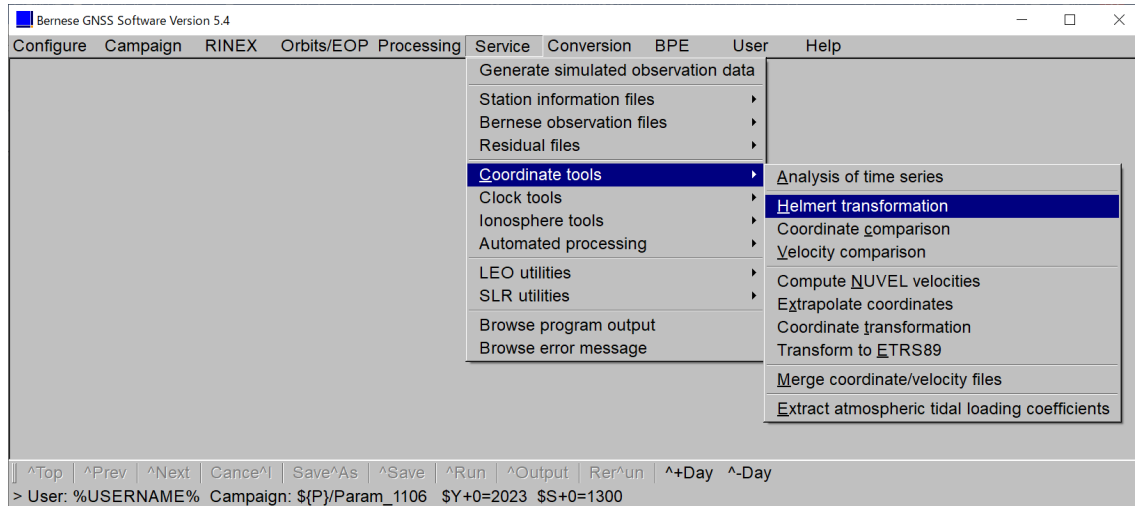
Transformation Parameters between ITRF Solutions website:

<https://itrf.ign.fr/en/solutions/transformations>

5.2. Helmert transformation (HELMR1)

Calculation of transformation parameters from CGD09 to CGD23 is shown below.

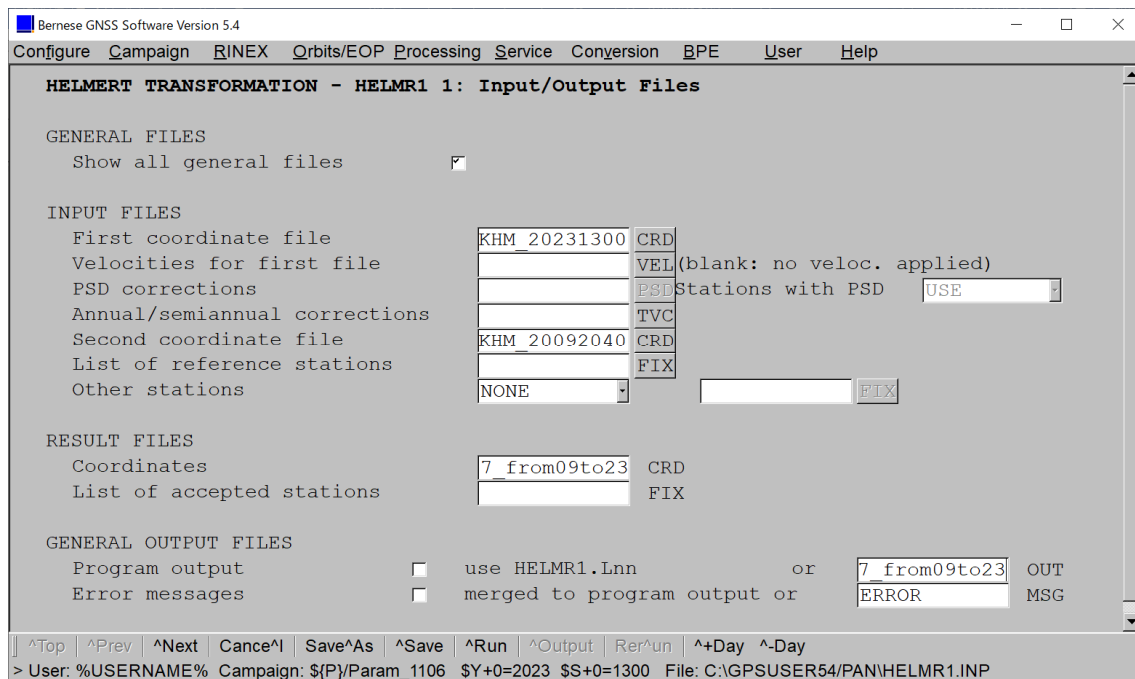
Click [Helmert transformation] to display the submenu.



Select Input files ([First] is [To], [Second] is [From]).

Enter the file name of Result coordinates file and Output file.

Click [^Next].



Click [^Next].

The screenshot shows the 'HELMR1 1.1: General Files' dialog box in the Bernese GNSS Software Version 5.4. The dialog has a menu bar with 'Configure', 'Campaign', 'RINEX', 'Orbits/EOP', 'Processing', 'Service', 'Conversion', 'BPE', 'User', and 'Help'. The main area is divided into sections: 'GENERAL INPUT FILES' with fields for 'General constants' (CONST) and 'Geodetic datum' (DATUM), both set to 'BSW'; 'MENU SETTINGS' with 'Selected campaign' set to '\${P}/Param_1106', 'Selected session' set to 'year 2023 session 1300', and 'Session table' set to '\${P}/Param_1106\GEN\SESSIONS.SES'; and 'TEMPORARY FILES' with 'Scratch file' set to 'HELMR1\$J' and 'SCR'. At the bottom, there is a status bar with a menu of shortcuts: '^Top', '^Prev', '^Next', 'Cancel', 'Save^As', '^Save', '^Run', '^Output', 'Rer^un', '^+Day', and '^Day'. The status bar also displays: '> User: %USERNAME% Campaign: \${P}/Param_1106 \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\HELMR1.INP'.

Enter Title.

Select [STATION SELECTION].

✓ Manual station selection

Select [HELMERT TRANSFORMATION].

✓ System of transformation: LOCAL (N, E, U) or GEOCENTRIC (X, Y, Z)

✓ Parameters to be computed: 3 parameters or 7 parameters

Click [^Next].

The screenshot shows the 'HELMR1 2: Options for Helmert Transformation' dialog box in the Bernese GNSS Software Version 5.4. The dialog has the same menu bar as the previous one. The main area contains: 'TITLE' with a text field containing 'KHM'; 'STATION SELECTION' with two radio buttons, 'Automatic station selection (all stations or selection from file)' and 'Manual station selection', where 'Manual station selection' is selected; 'HELMERT TRANSFORMATION' with 'System of transformation, LOCAL (N,E,U) or GEOCENTRIC (X,Y,Z)' set to 'XYZ' and 'Unit of residuals (meter or millimeter)' set to 'M'; and 'Parameters to be computed' with a table of checkboxes: 'shift 1' (checked), 'rot 1' (checked), 'shift 2' (checked), 'rot 2' (checked), 'shift 3' (checked), 'rot 3' (checked), and 'scale' (checked). At the bottom, the same status bar is present, displaying the same user, campaign, and file information.

Input [STATION SELECTION].

- ✓ [Blank], [M] or [E]
- ✓ Click [^Next].

HELMR1 2.1: Manual Station Selection

MANUAL STATION SELECTION
 Selection: blank = use for transformation
 M = residuals only
 E = not used

Station name	Flg1	Flg2	Selection
0005	K	K	M
0011	K	K	M
0019	K	K	M
002A	K	K	M
022A	K	K	M
KAND	K	K	M
KND1	C	C	
KSP1	C	C	
PNH1	C	C	
SIE1	C	C	
SIEM	K	K	M
STG1	C	C	

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
 > User: %USERNAME% Campaign: \${P}/Param_1106 \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\HELMR1.INP

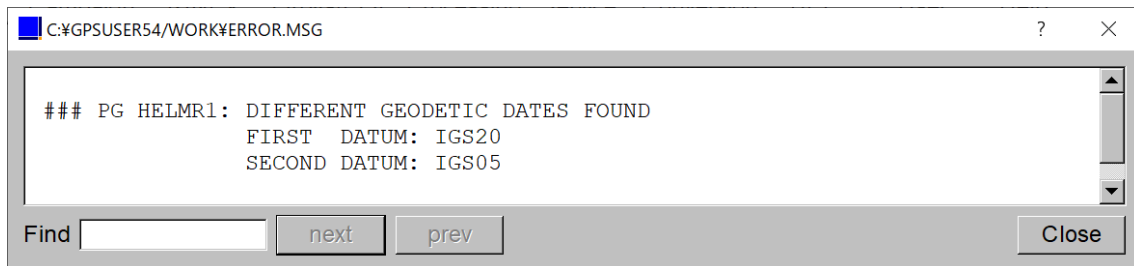
Click [^Run].

HELMR1 3: Outlier Rejection

OUTLIER REJECTION
 Enable outlier rejection ☒
 Maximal number of stations being rejected
 Outlier criteria north component millimeters
 east component millimeters
 up component millimeters
 List of rejected stations FIX

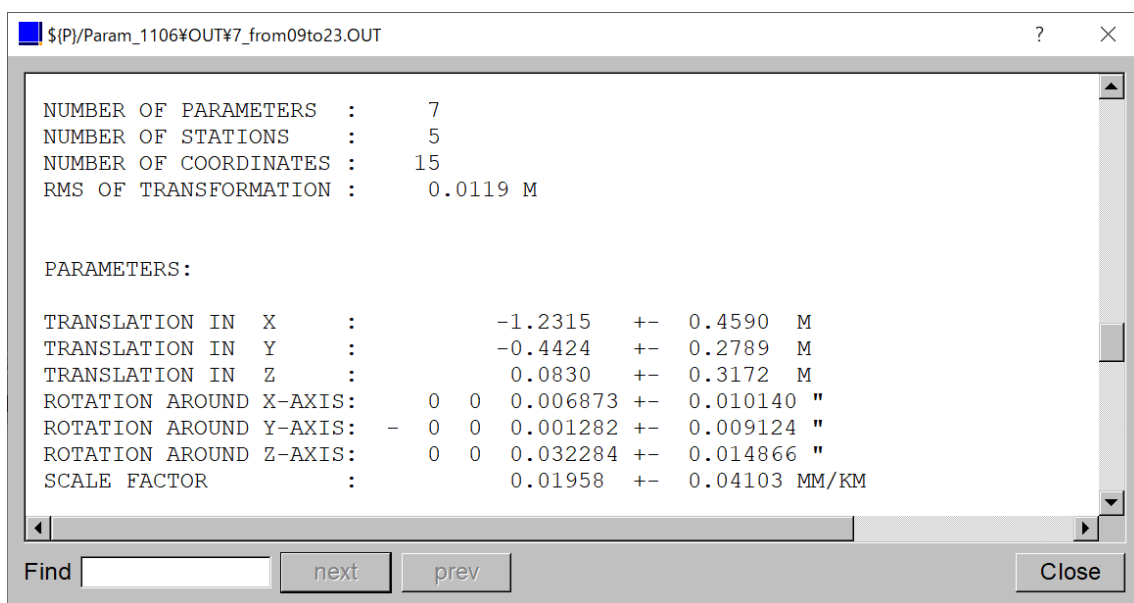
^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day
 > User: %USERNAME% Campaign: \${P}/Param_1106 \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\HELMR1.INP

You can safely ignore this warning.



You can see the calculation result by clicking [Output].

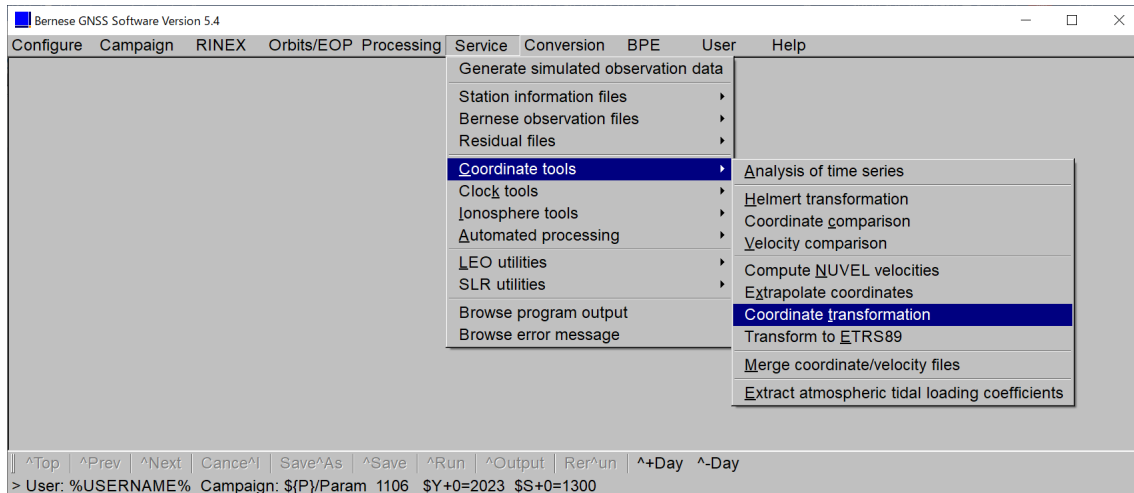
Also, the calculation result is saved in [OUT] of the campaign.



5.3. Coordinate transformation

Transform the coordinates using the parameters obtained in section [5.2.].

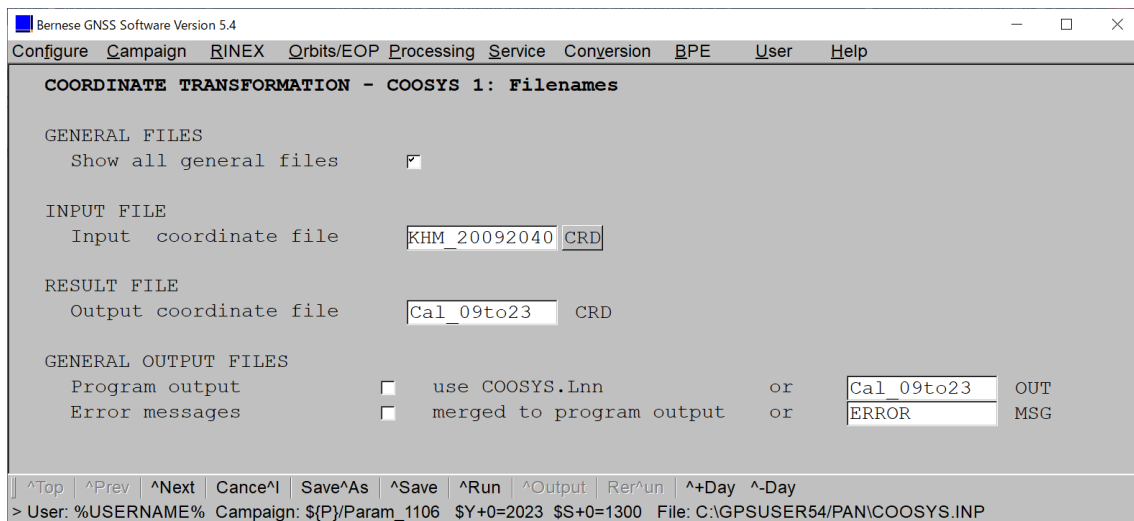
Click [Coordinate transformation] to display the submenu.



Select Input file [From].

Enter the file name of Result file [To] and Output file.

Click [^Next].



Click [^Next].

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COOSYS 1.1: General Files

GENERAL INPUT FILES

General constants	CONST	BSW
Geodetic datum	DATUM	BSW

MENU SETTINGS

Selected campaign	{P}/Param_1106	
Selected session	year 2023	session 1300
Session table	{P}/Param_1106\GEN\SESSIONS.SES	

TEMPORARY FILES

Scratch file	COOSYS\$J	SCR
--------------	-----------	-----

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: {P}/Param_1106 \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\COOSYS.INP

Enter Title and 7 parameters.

For scale, input [s] of (1+s).

Click [^Run].

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Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

COOSYS 2: Options

TITLE KHM

TRANSFORMATION PARAMETERS

Shift X	-1.2315	meters	Rot X	+0.006873	arcseconds
Shift Y	-0.4424	meters	Rot Y	-0.001282	arcseconds
Shift Z	+0.0830	meters	Rot Z	+0.032284	arcseconds
Scale	0.01958	parts per million			

^Top ^Prev ^Next Cancel Save^As ^Save ^Run ^Output Rer^un ^+Day ^-Day

> User: %USERNAME% Campaign: {P}/Param_1106 \$Y+0=2023 \$S+0=1300 File: C:\GPSUSER54\PAN\COOSYS.INP

Click [^Output].

Check the results.

The calculation result is saved in [STA] of the campaign.

6. Coordinate transformation parameter

6.1. Coordinate transformation parameters from CGD09 to CGD23 (7 parameters)

Coordinate transformation parameters were calculated using CGD09 and CGD23 coordinates of Khmer GEONET (5 points). 7 parameters of dX, dY, dZ, Rx, Ry, Rz and Scale are calculated.

6.1.1. 7 parameters

(A) Geocentric (X, Y, Z)

Element	Parameter	Unit
dX	-1.2315	m
dY	-0.4424	m
dZ	+0.0830	m
R _x	+0.006873	arc second
R _y	-0.001282	arc second
R _z	+0.032284	arc second
Scale	0.01958	mm/km (ppm), [s] of (1+s)

(B) Local (N, E, U)

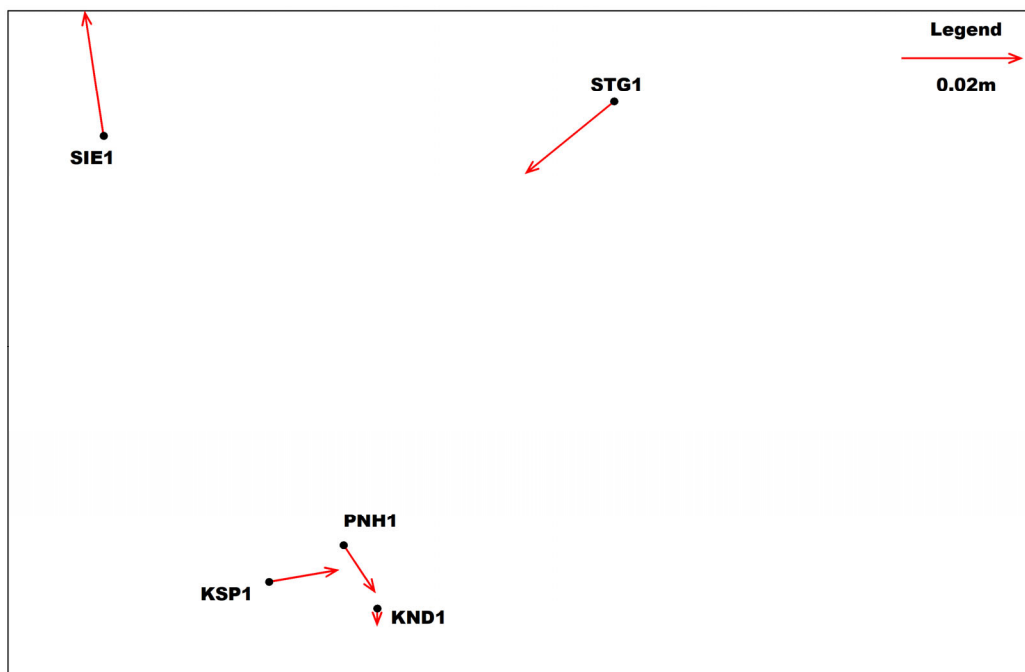
Element	Parameter	Unit
dN	-0.0905	m
dE	+0.3087	m
dU	+0.0330	m
R _N	-0.032184	arc second
R _E	+0.006314	arc second
R _U	-0.003929	arc second
Scale	0.01958	mm/km (ppm), [s] of (1+s)

6.1.2. Evaluating Coordinate Transformation Parameters (Residual check)

(1) Table of residual

Name	Residual					
	dX (m)	dY (m)	dZ (m)	dN (m)	dE (m)	dU (m)
KND1	0.001	-0.007	-0.005	-0.003	0.000	-0.008
KSP1	-0.012	0.002	0.003	0.002	0.011	0.005
PNH1	-0.006	0.004	-0.007	-0.008	0.005	0.004
SIE1	0.005	-0.005	0.020	0.021	-0.003	-0.001
STG1	0.012	0.007	-0.011	-0.012	-0.014	0.000

(2) Vector of residual (dN, dE)



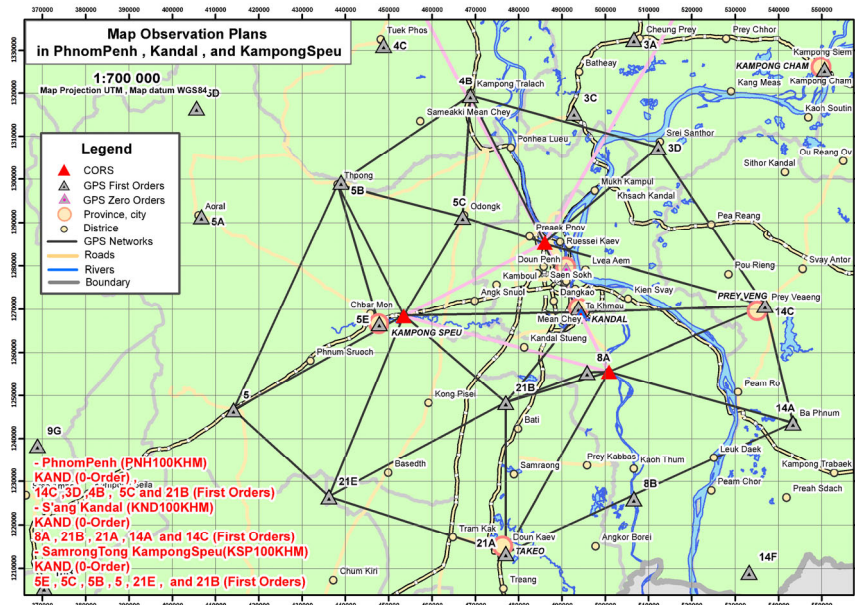
(3) Evaluation

The maximum value is the residuals in the north direction (21 mm) at SIE1, which is sufficiently small. Therefore, the calculated coordinate transformation parameters can be used as the adopted values.

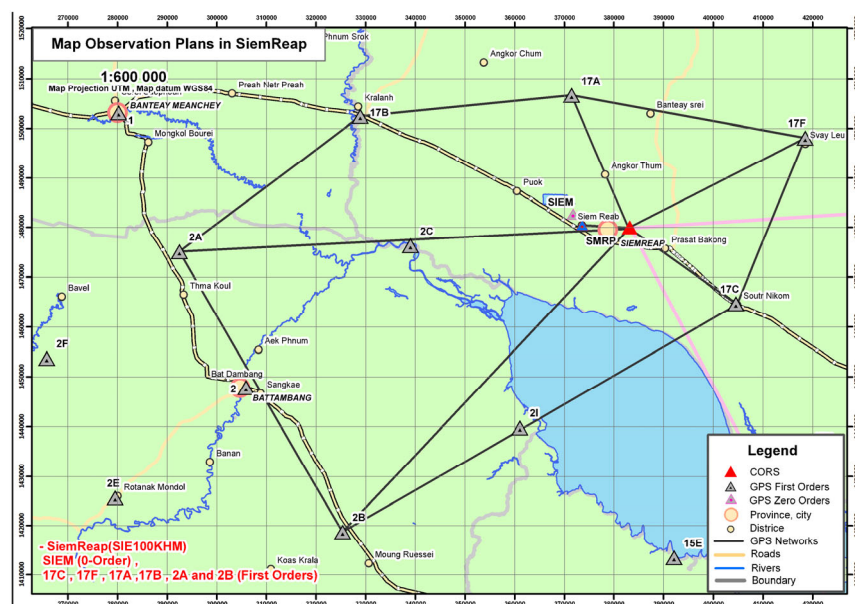
6.1.3. Evaluating Coordinate Transformation Parameters (Compare the coordinate values from the re-survey with the coordinate values from the coordinate transformation parameters)

(1) Re-survey network

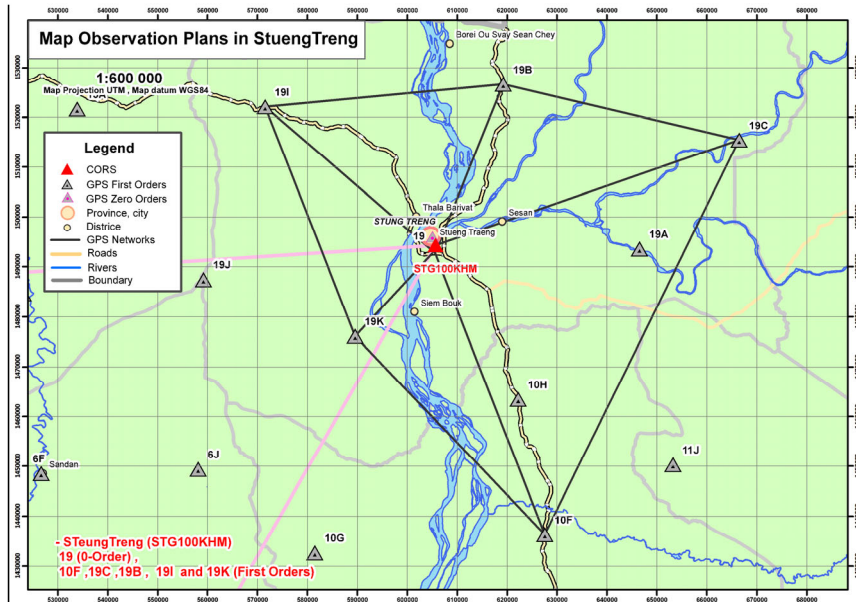
(A) Phnom Penh, Kandal and Kampong Speu (Re-survey was conducted in June 2022)



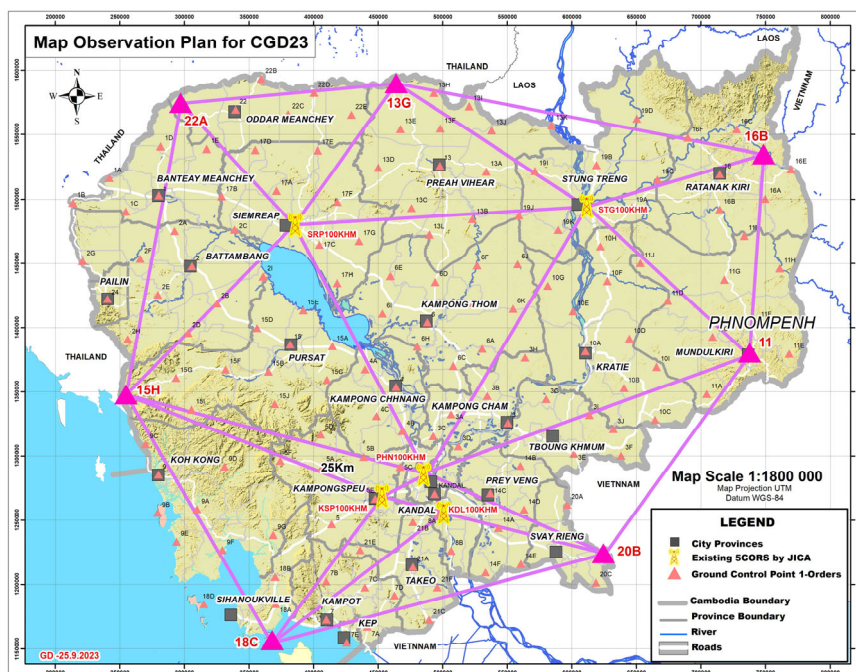
(B) Siem Reap (Re-survey was conducted in June 2022)



(C) Stueng Treng (Re-survey was conducted in June 2022)



(D) Near the national boundary (Re-survey was conducted in September 2023)

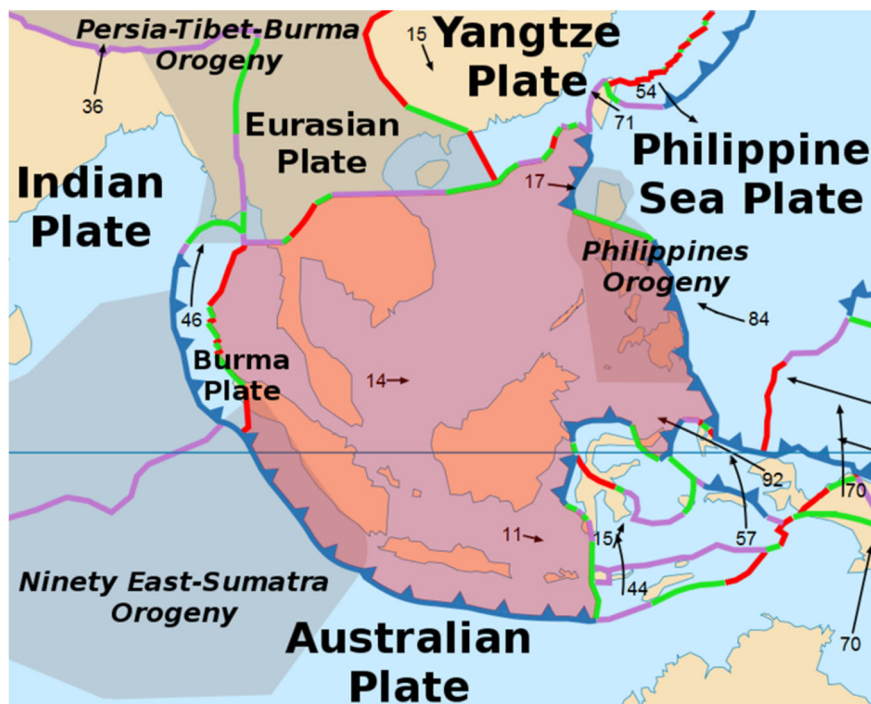


(2) Displacement amount from CGD09 to CGD23

(A) Displacement amount

The difference between the CGD09 and CGD23 coordinates is shown in the table below. Since the transformation parameters between geodetic reference systems (between ITRF2005 (CGD09) and ITRF2020 (CGD23)) are minute, the values shown in the table below are the displacements generated from survey errors and crustal deformation.

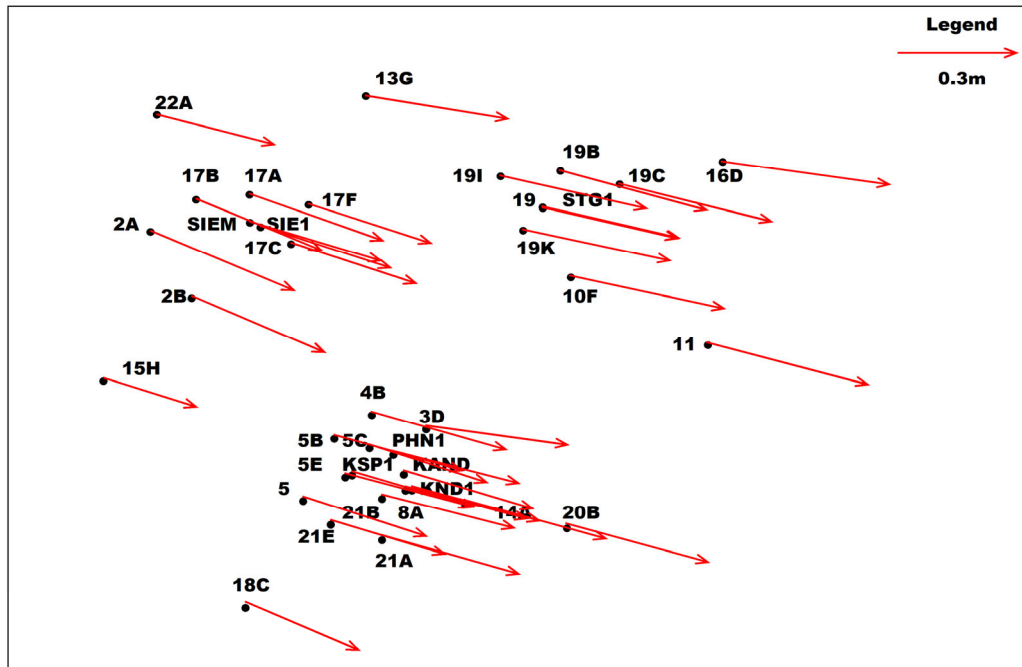
During the 14 years period, the land was displaced approximately 0.1m to the south and 0.3m to the east, resulting in a displacement of approximately 0.3m in the east-southeast direction. The height is about 0.03m, and there is a tendency toward micro uplift. The displacement rate of horizontal displacement is about 0.02m/year. According to the figure below, the displacement of the Sunda plate is in the east direction and its displacement speed is 0.014m/year, which is consistent with the plate motion.



https://en.wikipedia.org/wiki/Sunda_Plate#:~:text=The%20Sunda%20Plate%20is%20a%20minor%20tectonic%20plate,movement%20at%2010%20mm%2Fyr%20eastward%20relative%20to%20Eurasia

Name	CGD23 - CGD09					
	dX (m)	dY (m)	dZ (m)	dN (m)	dE (m)	dU (m)
(A) Phnom Penh, Kandal and Kampong Speu						
000500KHM	-0.303	-0.011	-0.092	-0.103	0.296	0.044
003D00KHM	-0.316	-0.138	-0.062	-0.050	0.341	-0.062
004B00KHM	-0.334	-0.002	-0.082	-0.098	0.323	0.064
005B00KHM	-0.306	-0.051	-0.087	-0.091	0.308	0.009
005C00KHM	-0.292	-0.002	-0.085	-0.098	0.283	0.053
005E00KHM	-0.296	-0.066	-0.085	-0.086	0.303	-0.005
008A00KHM	-0.301	-0.007	-0.072	-0.084	0.293	0.056
014A00KHM	-0.344	-0.028	-0.090	-0.100	0.339	0.045
021A00KHM	-0.328	-0.043	-0.093	-0.100	0.329	0.024
021B00KHM	-0.319	-0.035	-0.079	-0.087	0.318	0.031
021E00KHM	-0.284	-0.003	-0.077	-0.089	0.275	0.051
KAND00KHM	-0.300	-0.081	-0.101	-0.099	0.310	-0.021
(B) Siem Reap						
002A00KHM	-0.346	-0.031	-0.143	-0.154	0.343	0.015
002B00KHM	-0.323	-0.019	-0.135	-0.145	0.318	0.025
017A00KHM	-0.326	-0.014	-0.107	-0.121	0.320	0.038
017B00KHM	-0.303	-0.028	-0.125	-0.133	0.300	0.013
017C00KHM	-0.294	-0.064	-0.104	-0.105	0.300	-0.014
017F00KHM	-0.290	-0.054	-0.099	-0.102	0.294	-0.003
SIEM00KHM	-0.315	-0.035	-0.092	-0.101	0.314	0.018
(C) Stueng Treng						
001900KHM	-0.338	-0.016	-0.067	-0.082	0.329	0.059
010F00KHM	-0.374	-0.035	-0.073	-0.085	0.369	0.050
019B00KHM	-0.354	-0.041	-0.092	-0.102	0.353	0.035
019C00KHM	-0.358	-0.080	-0.097	-0.098	0.366	0.002
019I00KHM	-0.360	-0.016	-0.067	-0.084	0.351	0.064
019K00KHM	-0.357	-0.035	-0.069	-0.081	0.354	0.047
(D) Near the national boundary						
01100KHM	-0.398	-0.014	-0.091	-0.109	0.386	0.082
13G00KHM	-0.344	-0.031	-0.045	-0.058	0.341	0.044
15H00KHM	-0.231	0.004	-0.062	-0.075	0.224	0.040
16D00KHM	-0.406	-0.045	-0.046	-0.060	0.402	0.065
18C00KHM	-0.273	-0.033	-0.115	-0.121	0.273	0.011
20B00KHM	-0.336	-0.061	-0.096	-0.100	0.341	0.016
22A00KHM	-0.289	-0.007	-0.062	-0.076	0.282	0.042
Khmer GEONET						
KND100KHM	-0.311	-0.022	-0.079	-0.090	0.307	0.043
KSP100KHM	-0.295	-0.037	-0.087	-0.093	0.295	0.020
PNH100KHM	-0.304	-0.035	-0.076	-0.083	0.302	0.027
SIE100KHM	-0.313	-0.037	-0.100	-0.108	0.312	0.015
STG100KHM	-0.335	-0.016	-0.065	-0.080	0.326	0.060
Max	-0.231	0.004	-0.045	-0.050	0.402	0.082
Min	-0.406	-0.138	-0.143	-0.154	0.224	-0.062
Average	-0.322	-0.034	-0.086	-0.095	0.319	0.030

(B) Displacement vector (dN, dE)



(3) Comparison between re-survey and transformation results using parameters

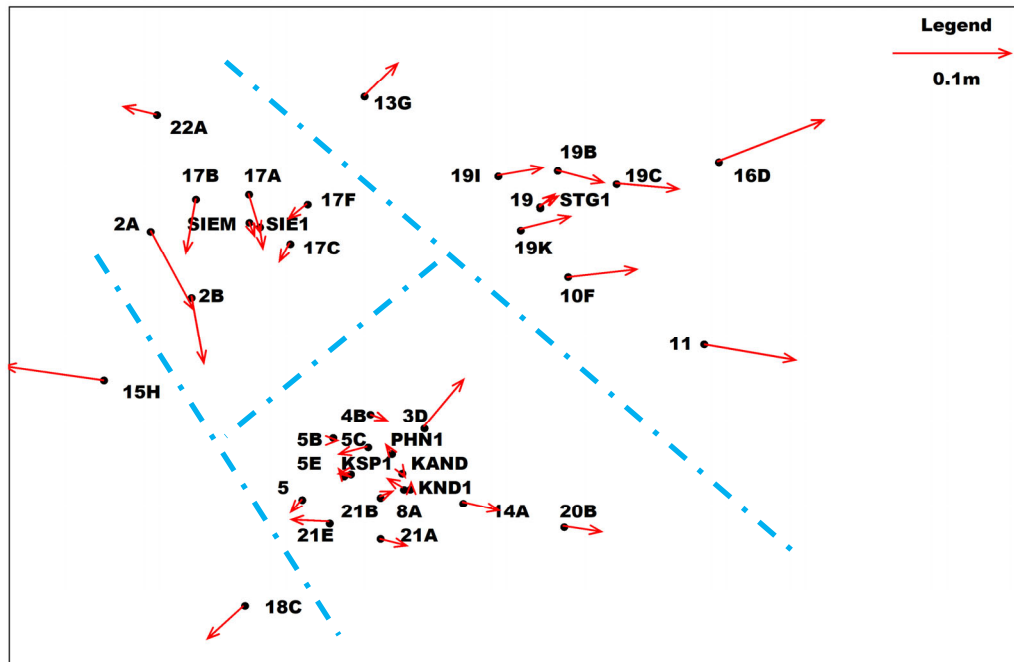
(A) Comparison of tables

Having compared the results of the Re-survey and the parameter-based transformations, the following characteristics were found.

- 2A, 3D, 11, 15H, 16D, 19C are singular points because their differences are larger than the other points. It is recommended to conduct further inspection survey after CORS is installed throughout Cambodia.
- Except for the above points, the difference is less than about 50 mm.
- In the Phnom Penh, Kandal and Kampong Speu region, the difference between the Re-survey and transformation results is small.
- In the Siem Reap region, the Re-survey results are located to the south.
- In the Stueng Treng region, Re-survey results are located to the eastern.
- Near the western coast area, the Re-survey results are located on the west side, but cannot be determined because 15H is a singularity.

Name	dX (m)	dY (m)	ReSurv. - Param.			
			dZ (m)	dN (m)	dE (m)	dU (m)
(A) Phnom Penh, Kandal and Kampong Speu						
000500KHM	0.002	0.031	-0.007	-0.013	-0.010	0.027
003D00KHM	-0.004	-0.112	0.020	0.041	0.033	-0.100
004B00KHM	-0.024	0.030	0.001	-0.006	0.015	0.034
005B00KHM	0.001	-0.014	-0.003	0.000	0.002	-0.014
005C00KHM	0.017	0.031	-0.002	-0.007	-0.024	0.024
005E00KHM	0.011	-0.029	-0.001	0.005	-0.003	-0.030
008A00KHM	0.009	0.023	0.012	0.008	-0.014	0.023
014A00KHM	-0.032	-0.005	-0.007	-0.007	0.031	0.002
021A00KHM	-0.020	-0.010	-0.008	-0.007	0.023	-0.006
021B00KHM	-0.011	-0.002	0.005	0.005	0.012	0.002
021E00KHM	0.022	0.036	0.008	0.002	-0.031	0.030
KAND00KHM	0.010	-0.051	-0.017	-0.006	0.003	-0.054
(B) Siem Reap						
002A00KHM	-0.042	0.024	-0.062	-0.069	0.035	0.019
002B00KHM	-0.019	0.033	-0.053	-0.059	0.010	0.024
017A00KHM	-0.017	0.029	-0.028	-0.035	0.010	0.025
017B00KHM	0.003	0.021	-0.045	-0.048	-0.008	0.008
017C00KHM	0.016	-0.025	-0.024	-0.018	-0.009	-0.033
017F00KHM	0.021	-0.018	-0.020	-0.014	-0.016	-0.026
SIEM00KHM	-0.007	0.009	-0.012	-0.014	0.005	0.007
(C) Stueng Treng						
001900KHM	-0.016	-0.007	0.009	0.009	0.017	0.000
010F00KHM	-0.052	-0.028	0.004	0.007	0.057	-0.012
019B00KHM	-0.030	-0.034	-0.017	-0.011	0.039	-0.028
019C00KHM	-0.031	-0.080	-0.022	-0.005	0.052	-0.071
019I00KHM	-0.039	-0.002	0.009	0.007	0.038	0.011
019K00KHM	-0.036	-0.023	0.008	0.011	0.042	-0.010
(D) Near the national boundary						
01100KHM	-0.070	-0.022	-0.014	-0.013	0.074	-0.003
13G00KHM	-0.027	-0.003	0.031	0.029	0.028	0.012
15H00KHM	0.067	0.067	0.023	0.012	-0.080	0.054
16D00KHM	-0.073	-0.057	0.027	0.035	0.086	-0.025
18C00KHM	0.027	0.018	-0.027	-0.029	-0.030	0.006
20B00KHM	-0.019	-0.049	-0.013	-0.005	0.032	-0.044
22A00KHM	0.018	0.046	0.016	0.007	-0.028	0.044
Khmer GEONET						
KND100KHM	-0.001	0.007	0.005	0.003	0.000	0.008
KSP100KHM	0.012	-0.002	-0.003	-0.002	-0.011	-0.005
PNH100KHM	0.006	-0.004	0.007	0.008	-0.005	-0.004
SIE100KHM	-0.005	0.005	-0.020	-0.021	0.003	0.001
STG100KHM	-0.012	-0.007	0.011	0.012	0.014	0.000
Max	0.067	0.067	0.031	0.041	0.086	0.054
Min	-0.073	-0.112	-0.062	-0.069	-0.080	-0.100
Average	-0.009	-0.005	-0.006	-0.005	0.011	-0.003

(B) Difference vector (dN, dE)



(4) Evaluation

Except for the singular points (2A, 3D, 11, 15H, 16D, 19C), the difference between the Re-survey and parameter-based transformation results is about 50 mm, which is within the range of no practical influence. Therefore, the calculated coordinate transformation parameters can be used as the adopted values.

6.2. Coordinate transformation parameters from CGD09 to CGD23 (3 parameters)

Coordinate transformation parameters were calculated using CGD09 and CGD23 coordinates of Khmer GEONET (5 points). 3 parameters of dX, dY and dZ are calculated. The difference between the value calculated by the coordinate transformation using 7 parameters and using 3 parameters is about 30 mm. If the GDCG can accept the difference, it would be possible to perform coordinate transformations using 3 parameters for such as cadastral survey boundary points.

6.2.1. 3 parameters

(A) Geocentric (X, Y, Z)

Element	Parameter	Unit
dX	-0.3116	m
dY	-0.0294	m
dZ	-0.0814	m
R _x	0.000000	arc second
R _y	0.000000	arc second
R _z	0.000000	arc second
Scale	0.00000	mm/km (ppm), [s] of (1+s)

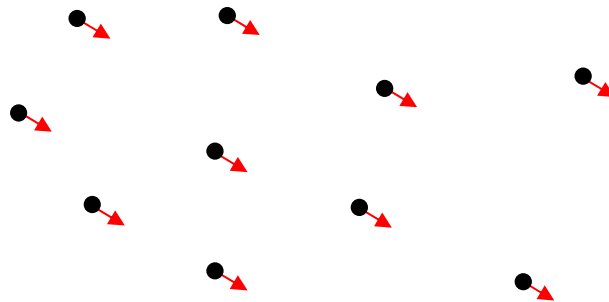
(B) Local (N, E, U)

Element	Parameter	Unit
dN	-0.0905	m
dE	+0.3087	m
dU	+0.0330	m
R _N	0.000000	arc second
R _E	0.000000	arc second
R _U	0.000000	arc second
Scale	0.00000	mm/km (ppm), [s] of (1+s)

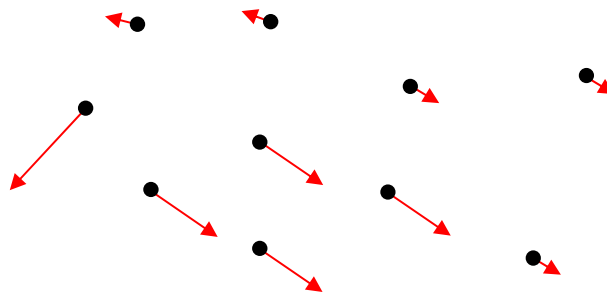
7. Coordinate transformation parameters adapted for each region

7.1. Cases where coordinate transformation parameters adapted to each region are required

Compare the old and new coordinate values of CGD09 and CGD23 of 0-1st order control point (or Nationwide-CORS). As shown in the figure below, if the size of difference vector is small and the results are in the same direction, you only need to apply one coordinate transformation parameter.

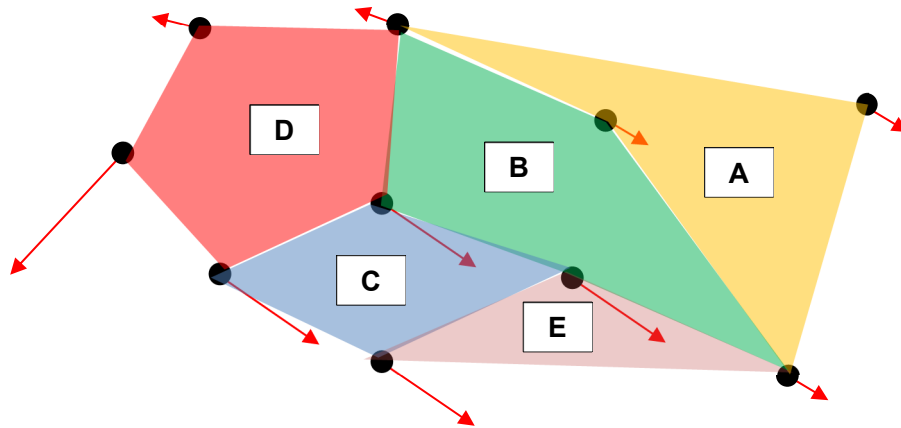


As shown in the figure below, if the size of the difference vector is large or if there is a region facing in a different direction, it is necessary to calculate coordinate transformation parameters adapted to that region.



7.2. Determine the region for calculating coordinate transformation parameters

For example, in the case of the figure below, the area for calculating the coordinate transformation parameters is determined as A to E.



(A) Although some vectors have different directions, the size of the vectors is within the error range, so it can be determined that the area is already compatible.

(B) Since it is adjacent to an area where the vector size is large, this area is treated as one block.

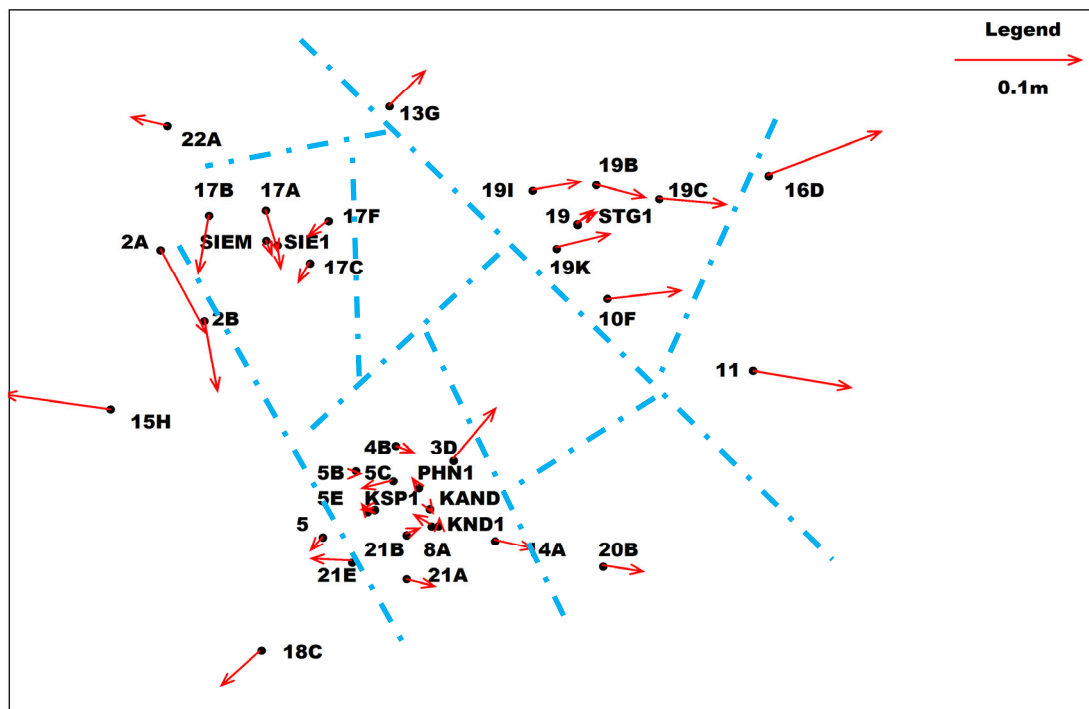
(C) Since the direction of the vectors is the same and the size of the vector is large, this area is treated as one block.

(D) The direction of the vectors is different, the size of the vector is large, and it is adjacent to an area where the size of the vector is small, so this area is treated as one block.

(E) This area has the same tendency as B. However, the point on the southwest side is expected to have a negative effect on block B, so the block is divided.

7.3. Reference example of region for calculating coordinate transformation parameters

The figure below is a simulation based on the results when calculating 5-CORS. The Nationwide-CORS calculation results are expected to be even more accurate, so they are used as a reference example. The light blue dotted line shows the divided areas.



7.4. How to calculate coordinate transformation parameters

(A) Helmert Transform (3D)

Please use software such as Bernese, TBC, MAGNET, etc.

(2) Helmert Transformation (2D)

This is explained in Appendix 3 at the end of this manual.

8. Appendix 1

8.1. Study of Coordinate transformation parameters using Khmer GEONET

The following two patterns were studied and the calculation method for the coordinate transformation parameters was determined. The requirements for the determined calculations were shown below.

- (1) As a result of the study, it was determined to use the five Khmer GEONET points.
- (2) As a result of the study, it was determined that the coordinate transformation parameters shall be 7 parameters.

8.1.1. Comparison of the calculation of coordinate transformation parameters using Khmer GEONET (5 points) only and the using Khmer GEONET (5 points) and 0-1st Order Control Point (32 points)

- (1) Calculating coordinate transformation parameters using Khmer GEONET (5 points)
Refer to section 6.1.
- (2) Calculating coordinate transformation parameters using Khmer GEONET (5 points)
and 0-1st Order Control Point (32 points)

(A) Geocentric (X, Y, Z)

Element	Parameter	Unit
dX	-0.2670	m
dY	-0.7998	m
dZ	+0.0160	m
R _x	+0.007466	arc second
R _y	+0.004936	arc second
R _z	+0.005373	arc second
Scale	0.11205	mm/km (ppm), [s] of (1+s)

(B) Local (N, E, U)

Element	Parameter	Unit
dN	-0.0950	m
dE	+0.3196	m
dU	+0.0292	m
R _N	-0.004626	arc second
R _E	+0.008481	arc second
R _U	-0.003957	arc second
Scale	0.11205	mm/km (ppm), [s] of (1+s)

(3) Comparison table

The table below shows the comparison results of coordinate transformation using parameters calculated by Khmer GEONET (5 points) only and the parameters calculated by Khmer GEONET (5 points) and 0-1st Order Control Point (32 points).

7 parameter (37 Point) - 7 parameter (5 Point)						
Name	dX (m)	dY (m)	dZ (m)	dN (m)	dE (m)	dh (m)
(A) Phnom Penh, Kandal and Kampong Speu						
000500KHM	-0.006	0.007	-0.016	-0.018	0.004	0.005
003D00KHM	-0.011	-0.009	-0.014	-0.013	0.013	-0.009
004B00KHM	-0.009	-0.003	-0.011	-0.010	0.009	-0.003
005B00KHM	-0.008	0.002	-0.012	-0.012	0.007	0.001
005C00KHM	-0.009	-0.002	-0.014	-0.014	0.009	-0.003
005E00KHM	-0.008	0.002	-0.016	-0.017	0.007	0.001
008A00KHM	-0.010	-0.006	-0.018	-0.017	0.012	-0.006
014A00KHM	-0.014	-0.013	-0.021	-0.019	0.016	-0.013
021A00KHM	-0.009	-0.003	-0.021	-0.020	0.010	-0.004
021B00KHM	-0.010	-0.003	-0.018	-0.017	0.011	-0.004
021E00KHM	-0.007	0.003	-0.019	-0.020	0.006	0.001
KAND00KHM	-0.011	-0.005	-0.016	-0.015	0.012	-0.005
(B) Siem Reap						
002A00KHM	0.002	0.022	0.008	0.003	-0.007	0.023
002B00KHM	0.000	0.019	0.002	-0.002	-0.005	0.018
017A00KHM	-0.003	0.010	0.009	0.007	0.001	0.013
017B00KHM	-0.001	0.016	0.010	0.006	-0.002	0.018
017C00KHM	-0.005	0.006	0.004	0.002	0.004	0.007
017F00KHM	-0.006	0.003	0.007	0.006	0.005	0.006
SIEM00KHM	-0.003	0.011	0.007	0.005	0.001	0.013
(C) Stueng Treng						
001900KHM	-0.016	-0.025	0.001	0.005	0.022	-0.018
010F00KHM	-0.018	-0.027	-0.005	0.000	0.024	-0.021
019B00KHM	-0.017	-0.026	0.004	0.009	0.023	-0.019
019C00KHM	-0.019	-0.034	0.002	0.008	0.028	-0.026
019I00KHM	-0.014	-0.019	0.005	0.009	0.019	-0.012
019K00KHM	-0.015	-0.022	0.000	0.004	0.021	-0.016
(D) Near the national boundary						
01100KHM	-0.023	-0.043	-0.013	-0.005	0.035	-0.036
13G00KHM	-0.007	-0.004	0.014	0.014	0.008	0.002
15H00KHM	0.003	0.029	-0.002	-0.008	-0.009	0.027
16D00KHM	-0.023	-0.046	0.001	0.010	0.035	-0.036
18C00KHM	-0.003	0.014	-0.023	-0.025	0.000	0.010
20B00KHM	-0.017	-0.025	-0.024	-0.020	0.023	-0.024
22A00KHM	0.002	0.021	0.017	0.012	-0.006	0.024
Khmer GEONET						
KND100KHM	-0.011	-0.007	-0.018	-0.017	0.013	-0.008
KSP100KHM	-0.009	0.001	-0.015	-0.015	0.008	0.000
PNH100KHM	-0.010	-0.004	-0.015	-0.014	0.011	-0.004
SIE100KHM	-0.003	0.009	0.007	0.005	0.001	0.011
STG100KHM	-0.016	-0.025	0.001	0.006	0.023	-0.018
Max	0.014	0.014	0.014	0.014	0.035	0.027
Min	-0.025	-0.025	-0.025	-0.025	-0.009	-0.036
Average	-0.005	-0.005	-0.005	-0.005	0.011	-0.003

(4) Results of consideration

The difference between the results using parameters calculated by Khmer GEONET (5 points) only and the parameters calculated by Khmer GEONET (5 points) and 0-1st Order Control Point (32 points) in the east-west direction is about 35 mm, and the maximum difference between those two in the height direction is about 35 mm. Therefore, whether the calculation is performed with 5 points or 37 points, the difference is only about 35 mm. Although characteristic trends were observed depending on the regions (Phnom Penh, Siem Reap, Stung Treng, and coastal areas), the values are so small that there is no practical problem.

Therefore, it was determined to use Khmer GEONET (5 points) for the coordinate transformation parameters, since there was no difference to calculate the coordinate transformation parameters between using Khmer GEONET (5 points) only and using Khmer GEONET (5 points) and 0-1st Order Control Point (32 points).

8.1.2. Comparison of coordinate transformation parameters calculated using Khmer GEONET (5 points) (7 parameters) and using Khmer GEONET (5 points) (3 parameters)

(1) Coordinate transformation parameters calculated using Khmer GEONET (5 points) (7 parameters)

Refer to section 6.1.

(2) Coordinate transformation parameters calculated using Khmer GEONET (5 points) (3 parameters)

Refer to section 6.2.

(3) Comparison table

The table below shows the comparison results of coordinate transformation using parameters calculated by Khmer GEONET (5 points) (7 parameters) and Khmer GEONET (5 points) (3 parameters).

Name	3 parameter (5 Point) - 7 parameter (5 Point)					
	dX (m)	dY (m)	dZ (m)	dN (m)	dE (m)	dh (m)
(A) Phnom Penh, Kandal and Kampong Speu						
000500KHM	-0.007	0.013	0.004	0.001	0.003	0.014
003D00KHM	0.000	-0.003	0.001	0.001	0.000	-0.003
004B00KHM	-0.002	0.003	0.002	0.002	0.001	0.003
005B00KHM	-0.005	0.008	0.003	0.001	0.003	0.009
005C00KHM	-0.003	0.004	0.002	0.001	0.002	0.005
005E00KHM	-0.005	0.008	0.003	0.001	0.003	0.010
008A00KHM	-0.002	0.001	0.003	0.003	0.002	0.002
014A00KHM	0.000	-0.006	0.002	0.003	0.001	-0.005
021A00KHM	-0.004	0.004	0.004	0.003	0.003	0.006
021B00KHM	-0.004	0.004	0.003	0.002	0.003	0.005
021E00KHM	-0.006	0.010	0.004	0.001	0.003	0.012
KAND00KHM	-0.002	0.001	0.003	0.003	0.001	0.002
(B) Siem Reap						
002A00KHM	-0.008	0.026	0.000	-0.006	0.002	0.027
002B00KHM	-0.008	0.023	0.001	-0.004	0.002	0.024
017A00KHM	-0.003	0.014	-0.002	-0.005	0.000	0.014
017B00KHM	-0.006	0.020	-0.001	-0.006	0.002	0.020
017C00KHM	-0.002	0.010	-0.001	-0.004	0.000	0.009
017F00KHM	-0.001	0.007	-0.002	-0.003	-0.001	0.007
SIEM00KHM	-0.004	0.015	-0.001	-0.004	0.001	0.015
(C) Stueng Treng						
001900KHM	0.010	-0.020	-0.005	0.000	-0.004	-0.022
010F00KHM	0.010	-0.022	-0.004	0.002	-0.004	-0.024
019B00KHM	0.012	-0.022	-0.006	0.000	-0.005	-0.025
019C00KHM	0.015	-0.029	-0.006	0.002	-0.006	-0.033
019I00KHM	0.009	-0.015	-0.005	0.000	-0.005	-0.017
019K00KHM	0.009	-0.017	-0.004	0.001	-0.004	-0.019
(D) Near the national boundary						
01100KHM	0.016	-0.037	-0.004	0.005	-0.004	-0.040
13G00KHM	0.005	-0.001	-0.005	-0.004	-0.004	-0.003
15H00KHM	-0.014	0.034	0.004	-0.004	0.006	0.036
16D00KHM	0.021	-0.041	-0.008	0.003	-0.008	-0.046
18C00KHM	-0.012	0.022	0.007	0.002	0.007	0.025
20B00KHM	0.005	-0.017	0.002	0.005	-0.001	-0.017
22A00KHM	-0.005	0.024	-0.003	-0.008	0.000	0.023
Khmer GEONET						
KND100KHM	-0.002	0.000	0.003	0.002	0.002	0.001
KSP100KHM	-0.005	0.007	0.003	0.001	0.003	0.008
PNH100KHM	-0.002	0.002	0.002	0.001	0.001	0.003
SIE100KHM	-0.003	0.013	-0.001	-0.004	0.000	0.013
STG100KHM	0.010	-0.020	-0.005	0.001	-0.004	-0.022
Max	0.021	0.034	0.007	0.005	0.007	0.036
Min	-0.014	-0.041	-0.008	-0.008	-0.008	-0.046
Average	0.000	0.001	0.000	0.000	0.000	0.000

(4) Results of consideration

The difference between the east-west and north-south directions is less than 8 mm. The maximum difference in both height directions near the border is about 40 mm. And the difference between in both height direction at Stung Treng is about 30 mm. Thus, whether 7 or 3 parameters are used, the difference in the horizontal direction is only about 10 mm, and the difference in the height direction is only about 40 mm.

Although the characteristic trend was observed depending on the regions (Phnom Penh, Siem Reap, Stung Treng, and coastal areas), these values are so small that there is no practical problem.

Therefore, it was judged that there is no difference between the results of the coordinate transformation using 7 parameters calculated using Khmer GEONET (5 points) and the results of the transformation using 3 parameters calculated using Khmer GEONET (5 points), and it was determined to use 7 parameters calculated by the Khmer GEONET (5 points) as the transformation parameter.

In the case of transforming survey results without elevation information from CGD09 to CGD23, it can be said that 3 parameters can work without causing any practical problems.

8.2. Transformation parameter from CGD03 to CGD23

The coordinate transformation method from CGD03 to CGD23 is shown below.

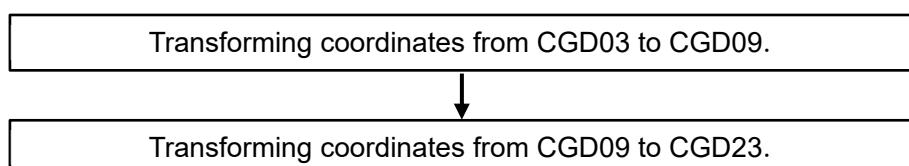
8.2.1. Content of CGD03

Item	Element
Geocentric Cartesian Coordinate System	ITRF2000 (Epoch 1998.90, 24 th October 1998)
Reference Ellipsoid	GRS 80
Vertical Datum	Mean Sea Level (Vietnam)
Geoid Model	EGM2008
Plane Cartesian Coordinate System	UTM Zone 48 - Central Meridian: 105° 00' 00" E - Latitude of Origin: 0° 00' 00" N - False Easting: 500,000.000 m - False Northing: 0.000 m - Scale Factor at Central Meridian: 0.9996
Unit and Notation	Meters, 0,001m

8.2.2. Transformation parameter from CGD03 to CGD23

Calculate using one of the methods below.

- (A) The coordinate transformation parameters from CGD03 to CGD09 were already calculated in 2005. Therefore, as shown in the flowchart below, it is recommended to perform the coordinate transformation from CGD03 coordinate values to CGD09 coordinate values using the above coordinate transformation parameters, and then calculate the CGD23 coordinate values using the transformation parameters from CGD09 coordinate values to CGD23 coordinate values.



Below are the coordinate transformation parameters from CGD03 to CGD09.

Element	Parameter	Unit
dX	-0.231	m
dY	-0.040	m
dZ	-0.114	m
R _x	-0.00722	arc second
R _y	+0.02434	arc second
R _z	-0.03011	arc second
Scale	+0.034	mm/km (ppm), [s] of (1+s)

(B) When calculating the coordinate transformation parameters from CGD03 to CGD23 First, prepare the CGD03 and CGD23 coordinate values for the 0-1st Order Control Point (32 points). Note that the CGD03 coordinate value for Khmer GEONET (5 points) has not been calculated. Next, the coordinate transformation parameters are calculated using Bernese software, etc. It is desirable to evaluate the accuracy of the calculation results by using several of the 32 points as verification points.

8.3. Transformation for Boundary points

Boundary points do not have elevation values. Therefore, it is not possible to calculate the coordinate values of CGD23 using the Helmert transformation (3D) method.

Therefore, the coordinate values of CGD23 should be calculated using one of the methods shown below.

- (1) Prepare the CGD09 (or CGD03) and CGD23 coordinates of 0-2nd order control points installed around the Boundary points.
- (2) Calculate coordinate transformation parameters using one of the following methods from these control points.
 - ✓ Calculate using Helmert Transformation (2D). This is the method shown in section 4.1.1.
 - ✓ Calculate using Affine Transformation. This is the method shown in section 4.2.
 - ✓ Calculate using Method by weighted interpolation. This is the method shown in

section 4.3.

- ✓ A method of creating mesh-like (grid-like) coordinate transformation parameters using Method by weighted interpolation, etc., and calculate using Bilinear transformation method with linear interpolation. This is the method shown in section 4.4.
 - ✓ If the parameters used to calculate the CGD23 coordinate values of 0-2nd order control points are 3 parameters, you can use the parameters dN and dE to perform parallel translation.
- (3) Calculate the CGD23 coordinate values of the Boundary points using the coordinate transformation parameters obtained above.

8.4. Transformation parameter from Indian 19XX to CGD23

8.4.1. Control points

The coordinate transformation parameters from Indian1916 to CGD03 and from Indian1954 to CGD03 were already calculated in 1998.

(A) From Indian 1916 to CGD03

✓ 3 parameters

Element	Parameter	Unit
dX	+202.548	m
dY	+877.524	m
dZ	+320.787	m
R _x	0.00000	arc second
R _y	0.00000	arc second
R _z	0.00000	arc second
Scale	0.000	mm/km (ppm), [s] of (1+s)

✓ 10 parameters

Element	Parameter	Unit
dX	+202.177	m
dY	+876.634	m
dZ	+320.511	m
R _x	-10.33655	arc second
R _y	-6.94679	arc second
R _z	+20.75746	arc second
Scale	-18.364	mm/km (ppm), [s] of (1+s)
Centroid X	-1620202.016	m
Centroid Y	+6037591.585	m
Centroid Z	+1257548.565	m

(B) From Indian 1954 to CGD03

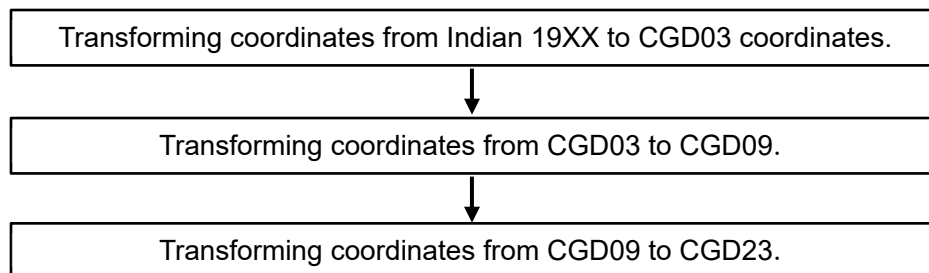
✓ 3 parameters

Element	Parameter	Unit
dX	+179.237	m
dY	+874.349	m
dZ	+308.080	m
R _x	0.00000	arc second
R _y	0.00000	arc second
R _z	0.00000	arc second
Scale	0.000	mm/km (ppm), [s] of (1+s)

✓ 10 parameters

Element	Parameter	Unit
dX	+179.237	m
dY	+874.349	m
dZ	+308.080	m
R _x	-4.75420	arc second
R _y	-27.60029	arc second
R _z	+15.65364	arc second
Scale	+93.654	mm/km (ppm), [s] of (1+s)
Centroid X	-1623986.360	m
Centroid Y	+6040009.771	m
Centroid Z	+1241333.247	m

Therefore, as shown in the flowchart below, coordinate transformation is firstly performed from Indian19XX coordinate values to CGD03 coordinate values using the following coordinate transformation parameters. Next, it is recommended to perform a coordinate transformation from CGD03 coordinate values to CGD09 coordinate values and then calculate the CGD23 coordinate values using the coordinate transformation parameters from CGD09 to CGD23 coordinate values.



Firstly, prepare the Indian19XX and CGD23 coordinate values of the 0-2nd Order Control Point, when you calculate the coordinate transformation parameters from Indian19XX to CGD23 or in case the coordinate transformation parameters from Indian19XX to CGD03 have not been calculated. Note that the Indian19XX coordinate values for Khmer GEONET (5 points) are not calculated. Next, coordinate transformation parameters are calculated using Bernese software. It is desirable to evaluate the accuracy of the calculation results by using several points as verification points.

8.4.2. Topographic map

Topographic maps created using a geodetic reference system such as Indian 19XX are small-scale topographic maps, so they do not require high-precision coordinate transformation.

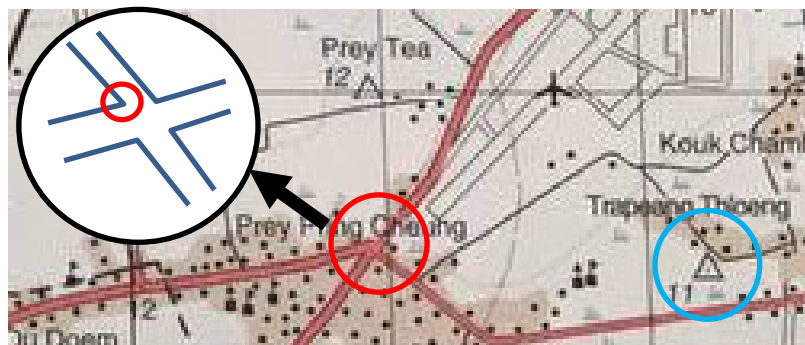
In the Japanese survey manual, the accuracy of topographic maps (at map information level 5,000) is defined as follows.

- ✓ Standard deviation of horizontal position: 3.5m or less ($1-\sigma$)
- ✓ Standard deviation of spot height elevation: 1.66m or less ($1-\sigma$)
- ✓ Standard deviation of contour line elevation: 2.5m or less ($1-\sigma$)

Therefore, the coordinate transformation parameters may be the amount of translation (dN, dE, dU), and an accuracy of about 1m-2m is considered sufficient.

The method for determining the coordinate transformation parameters is shown below.

- (1) Select points for calculating the coordinate transformation parameters.
 - ✓ For horizontal measurement positions, we recommend the corners of road intersections.
 - ✓ Choose a location that hasn't changed from the old road.
 - ✓ For the height measurement position, measure at a point where the elevation value is known.



- ✓ Select multiple points within the target area of the coordinate transformation. An example is shown below.
 - (a) Phnom Penh area: Horizontal (2 points) and height (2 points)
 - (b) Siem Reap: Horizontal (2 points) and height (2 points)
 - (c) Stung Treng: Horizontal (2 points) and height (2 points)

- (2) Use the NRTK or Single RTK methods to measure the coordinates of clear features.
- (3) Read the coordinates of Indian19XX from the topographic map.
- (4) Compare the coordinates of Indian19XX with the coordinates of CGD23. The average value of these differences is the coordinate transformation parameter (the amount of parallel displacement).

9. Appendix 2

9.1. Error Theory

Measured values always include errors. The value obtained by subtracting the true value L_0 from the measured value L is the error ε .

$$\varepsilon = L - L_0$$

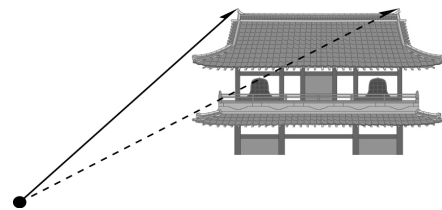
9.1.1. Type of error

Errors are classified into three types.

- (A) Large error (negligence)
- (B) Systematic error
- (C) Random error

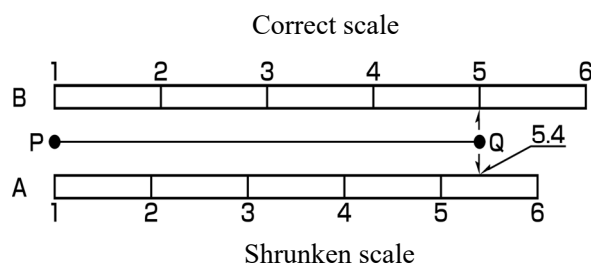
(A) Large error (negligence)

For example, human errors include measuring the wrong target or recording an angle of 124° as 214° by mistake. These are extremely large and can be found immediately.



(B) Systematic error

For example, if you measure distance using a shrunken scale, the distance will be measured to be longer than the actual length. In the example shown in the figure, when the distance between PQ is measured using a shrunken scale A , the measured distance is 5.4. The distance measured on the correct scale B is 5.0, so it is 0.4 longer.

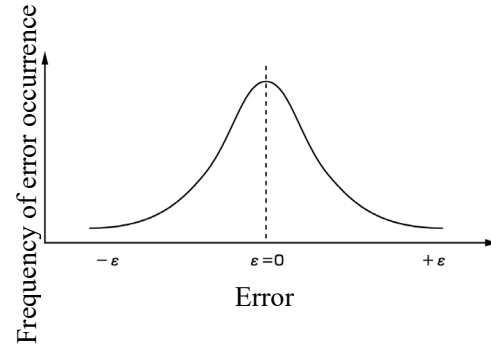


Since the cause of systematic errors is known, correct values can be determined by correction.

(C) Random error

Even after excluding large errors (negligence) and systematic errors, errors still remain. This is called a random error. The random errors are relatively small, and each value appears to be irregular, but there are some regularities as shown below.

- ✓ The number of small errors is greater than the number of large errors.
- ✓ The number of errors with equal amounts and opposite signs is equal
- ✓ Very large errors rarely occur



In other words, the size of random errors and their frequency of occurrence are normally distributed. First, discover and eliminate large errors (negligence). Next, correction is performed to eliminate systematic errors. Finally, analyze the random errors and calculate the most probable value. One method for analyzing random errors is the least squares method. The least squares method is a method of calculating the most probable value so that the sum of squared errors is minimized.

$$\epsilon_1^2 + \epsilon_2^2 + \epsilon_3^2 + \dots = \text{Minimum}$$

9.1.2. Precision and Accuracy

(A) Precision

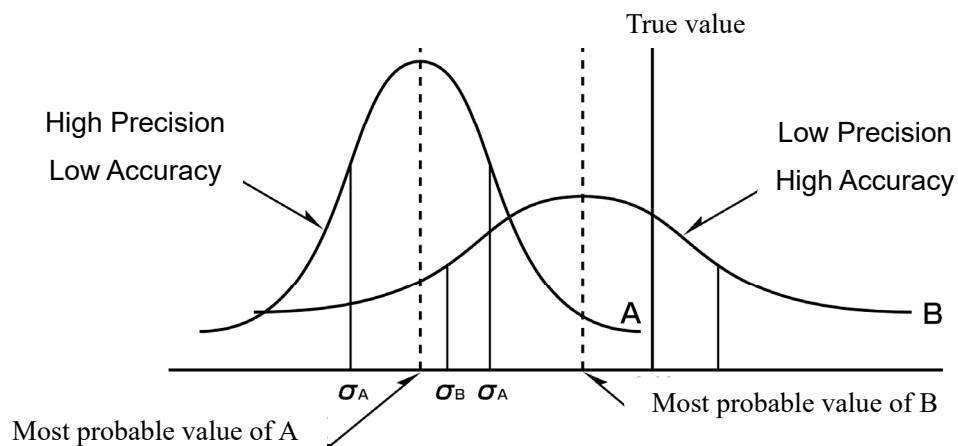
Represents the degree of dispersion of observed values.

The smaller the standard deviation σ , the better the precision.

(B) Accuracy

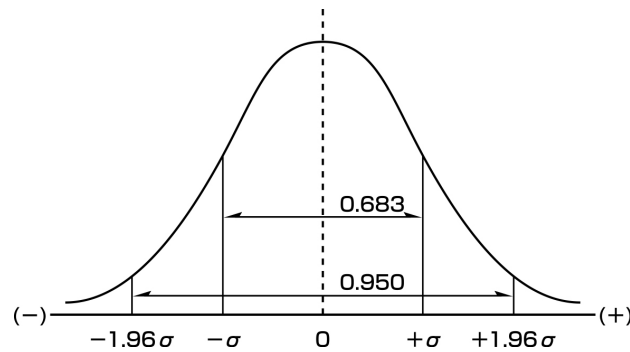
Represents the difference between the observed value and the true value.

Even if the precision is high, observed values with low accuracy cannot be used.



9.1.3. Degree of reliability

When the error is normally distributed as shown in the figure below, the probability of a measured value falling within the standard deviation σ is approximately 68%.



The relationship between range and probability is shown below.

1.00 $\times\sigma$ (standard deviation)	Approximately 68%
1.96 $\times\sigma$ (sometimes called 2 σ)	Approximately 95%
	International standards often use 95% probability
2.58 $\times\sigma$ (sometimes called 3 σ)	Approximately 99%

10. Appendix 3

10.1. Calculate Helmert Transformation (2D) in Excel

10.1.1. Least Squares Method

The principle of the least squares method is [a method for estimating the most probable value that minimizes the sum of the squares of errors (residuals)].

10.1.2. Least Squares Method Using Observation Equations

(A) Observation Equation

It is theoretically known that a certain relational equation holds between m unknown quantities $X_1, X_2, \dots, X_m$ and n measured values $l_1, l_2, \dots, l_n$. The equation that expresses this kind of relationship is called the observation equation. Here, $n > m$ must be satisfied.

$$\left. \begin{aligned} l_1 &= f_1(X_1, X_2, \dots, X_m) \\ l_2 &= f_2(X_1, X_2, \dots, X_m) \\ &\vdots \\ l_n &= f_n(X_1, X_2, \dots, X_m) \end{aligned} \right\} \dots (1) \text{ Observation Equation}$$

When the relationship in equation (1) holds, equation (2) is called a mathematical model.

$$l_i = f_n(X_1, X_2, \dots, X_m) \dots (2)$$

Before calculating with the least squares method, each mathematical model must be given.

However, since there are always errors in observations and measurements, equation (1) does not hold true strictly.

Here, let l_n^b be the value obtained by observing l_n .

l_n^b includes observation errors (random errors).

If we can obtain the most probable value l_n^a (adjusted value, most probable value) by adding an unknown correction amount v_j to the observed value, the following formula holds.

$$l_n^a = l_n^b + v_j \dots (3)$$

Since equation (2) is generally nonlinear with respect to the unknown quantity x_j , it is linearized using Taylor's expansion formula.

Therefore, let x_i^o be the approximate value of x_j . x_i^o is calculated or estimated in advance by some method.

x_i^a is the most probable value of x_j determined by the least squares method, and if the unknown correction amount to be added to x_i^o is Δx_j , the following formula holds true.

$$x_i^a = x_i^o + \Delta x_j \quad (j = 1, 2, \dots, m) \quad \dots (4)$$

Δx_j is assumed to be a small amount. If we perform Taylor expansion on the right side of equation (2) and find the first term, we get the following equation.

$$f_i(x_1^a, x_2^a, \dots, x_m^a) = f_i(x_1^o, x_2^o, \dots, x_m^o) + \left(\frac{\partial f_i}{\partial x_1}\right)_o \Delta x_1 + \left(\frac{\partial f_i}{\partial x_2}\right)_o \Delta x_2 + \dots + \left(\frac{\partial f_i}{\partial x_m}\right)_o \Delta x_m \quad \dots (5)$$

Here, equation (6) is calculated by partially differentiating f_i and using the approximate value x_j^o as the value of x_j , and will be expressed as equation (7).

$$\left(\frac{\partial f_i}{\partial x_1}\right)_o \quad (j = 1, 2, \dots, m) \quad \dots (6)$$

$$\left(\frac{\partial f_i}{\partial x_1}\right)_o = a_{ij} \quad \dots (7)$$

And we will express equation (2) as equation (8) or equation (9).

$$l_i^a = l_i^b + v_i = f_i(x_1^o, x_2^o, \dots, x_m^o) + \sum_{j=1}^m a_{ij} \Delta x_j \quad \dots (8)$$

$$l_i^o = f_i(x_1^o, x_2^o, \dots, x_m^o) \quad \dots (9)$$

Then, the correction amount v_j to be added to the observed value is given by equation (10).

$$v_i = \sum_{j=1}^m a_{ij} \Delta x_j + (l_i^o - l_i^b) \quad \dots (10)$$

As shown in the above equation, the equation that holds true between the correction amount v_j to be added to the observed value and the unknown parameter Δx_j included in the mathematical model is called the observation equation.

Here, the unknown quantities are v_j and Δx_j , and the known quantities are a_{ij} , l_j^o , and l_j^b . Also, if Δx_j is expressed as x_j , the entire observation equation becomes the following equation.

$$\left. \begin{aligned} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1m}x_m + (l_1^o - l_1^b) &= V_1 \\ a_{11}x_1 + a_{12}x_2 + \cdots + a_{1m}x_m + (l_1^o - l_1^b) &= V_1 \\ &\vdots \\ a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nm}x_m + (l_n^o - l_n^b) &= V_n \end{aligned} \right\} \cdots (11)$$

(B) Representation of observation equation by matrix

It is convenient to use matrices to find solutions to these equations and to examine the standard deviation of the solution functions. To do this, we rewrite equation (10) into a vector or matrix representation.

First, let us express the collection of observed quantities and unknown quantities as a column vector using the following equation.

$$L_b = \begin{pmatrix} l_1^b \\ l_2^b \\ \vdots \\ l_n^b \end{pmatrix}, L_a = \begin{pmatrix} l_1^a \\ l_2^a \\ \vdots \\ l_n^a \end{pmatrix}, X_o = \begin{pmatrix} X_1^o \\ X_2^o \\ \vdots \\ X_n^o \end{pmatrix}, X_a = \begin{pmatrix} X_1^a \\ X_2^a \\ \vdots \\ X_n^a \end{pmatrix}, V = \begin{pmatrix} V_1 \\ V_2 \\ \vdots \\ V_n \end{pmatrix} \cdots (12)$$

Here, the symbol a means adjusted value. b is the observable quantity, and uses the initials of the German word Beobachtung. v and V are correction values, using the initial letters of the German word Verbesserung. These are commonly used symbols.

In order to find the most probable value of the unknown quantity X_a , the correction value X added to the approximate value X_o is expressed by the following formula.

$$X = X_a - X_o \cdots (13)$$

Let $L_o = (l_1^o, l_2^o, \cdots, l_n^o)$ represent the vector whose elements are equation (9) calculated from the approximate value of X . Also, it is expressed as $L_o - L_b = L$.

Here, if equation (11) is expressed as a matrix, it becomes the following equation.

$$L_a = F(X) \cdots (14)$$

On the other hand, since $L_a = L_b + V, X_a = X_o + V$, equation (14) becomes equation (15).

$$L_b + V = F(X_o + X) \cdots (15)$$

X is the unknown correction amount that we ultimately want to find. Generally, if the approximate value of X_o is close to the most probable value, the amount of correction is small. Therefore, using up to the first-order terms of the Taylor expansion, it can be expressed as the following equation.

$$L_b + V = F(X_o) + AX \cdots (16)$$

However, A is a matrix called a coefficient matrix or a design matrix. Its elements are as follows.

$$a_{ij} = \frac{\partial l_i^o}{\partial x_j^o}, \quad \text{or} \quad A = \frac{\partial L}{\partial X} = \frac{\partial F}{\partial X} \cdots (17)$$

Here. Since $F(X_o) = L_o, L = L_o - L_b$, equation (16) becomes the following equation.

$$V = AX + (L_o - L_b) = AX - L \cdots (18)$$

Equation (18) is an observation equation that expresses equation (11) in a matrix.

$$\text{Observation Equation Model } V = AX - L$$

(D) Weights

The previous formulas are for the case where n observations are mutually independent, and all observation precision is equal.

Here, consider the case where the variances of observed values $\sigma_1^2, \sigma_2^2, \dots, \sigma_n^2$ are generally different. First, using the variance σ_o^2 of the unknown unit weights (also called unit weight variance) and the weights P_i , equation is expressed as follows.

$$\sigma_i^2 = \frac{\sigma_o^2}{P_i} \quad (i = 1, 2, \dots, n) \cdots (19)$$

Multiplying both sides of equation (11) by $\sqrt{P_i}$ yields the following equation.

$$v_i^o = \sum_{j=1}^m \sqrt{P_i} a_{ij} X_j + \sqrt{P_i} (l_i^o - l_i^b) \cdots (20)$$

However, if equation (21) holds true, the variance of $\sqrt{P_i} (l_i^o - l_i^b)$ is all equal to σ_o^2 .

$$v_i^o = \sqrt{P_i} v_i \cdots (21)$$

In other words, equation (21) is an observation equation with equal precision.

(D) Matrix representation of weights

When expressing weights as a matrix, if the observations are mutually independent, the weight matrix P becomes a diagonal matrix with $P_i = P_{ii}$ as the diagonal elements, as shown below.

$$P = \begin{pmatrix} P_{11} & 0 & \cdots & 0 \\ 0 & P_{22} & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & P_{nn} \end{pmatrix}, \quad \text{and } P^{\frac{1}{2}} = \begin{pmatrix} \sqrt{P_{11}} & 0 & \cdots & 0 \\ 0 & \sqrt{P_{22}} & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & \sqrt{P_{nn}} \end{pmatrix} \cdots (22)$$

(E) Observation equation considering weights

Considering the weight from the above results, both sides of the observation equation (18) are multiplied by $P^{\frac{1}{2}}$, and it is expressed as the following equation.

$$P^{\frac{1}{2}} A X + P^{\frac{1}{2}} L = P^{\frac{1}{2}} V = V_o \cdots (23)$$

(F) Once again, about the least squares method

In the discussion so far, the diagonal matrix of the product of a matrix and its transposed matrix is the sum of squares.

As mentioned above, the least squares method is a method for estimating the most probable value that minimizes the sum of squared errors.

Therefore, the product of the error (residual) matrix and its transposed matrix can be differentiated and set to 0.

(G) Sum of squared errors (residuals)

V is the residual vector (matrix). To find the sum of the squares of each element of this vector (matrix), multiply the residual matrix V by its transposed matrix (matrix) V^T .

Since P is a diagonal matrix, keeping in mind that $P^T = P$, the following equation holds.

$$\left(P_z^{-1}V\right)^T P_z^{-1}V = V_o^T V_o = V^T \left(P_z^{-1}\right)^T P_z^{-1}V = V^T P V \dots (24)$$

Therefore, using the observation equation (18), the sum of squared errors (residuals) can be expressed as follows.

$$\begin{aligned} V^T P V &= (AX + L)^T P (AX + L) = (L^T + X^T A^T) P (AX + L) \\ &= X^T A^T P A X + X^T A^T P L + L^T P A X + L^T P L \end{aligned}$$

Here, since $P^T = P$, $L^T P A X = (X^T A^T P^T L)^T = (X^T A^T P L)^T$.

Continuing the previous equation, we can transform it into the following equation.

$$\begin{aligned} V^T P V &= (AX + L)^T P (AX + L) = X^T A^T P A X + 2X^T A^T P L + L^T P L \\ &= X^T N X + 2X^T U + L^T P L \dots (25) \end{aligned}$$

However, N and U are as follows.

$$\left. \begin{aligned} N &= A^T P A \\ U &= A^T P L \end{aligned} \right\} \dots (26)$$

(H) Derive a normal equation by minimizing the sum of squared errors (residuals)

$V^T P V$ is the sum of the squares of the residuals. To minimize this, [The derivative with respect to the elements of X is equal to 0].

Therefore, keeping in mind that $L^T P L$ does not include the most probable value vector X , differentiating equation (25) with respect to X yields the following equation.

$$\frac{1}{2} \cdot \frac{\partial(V^T P V)}{\partial X} = \frac{1}{2} \cdot \frac{\partial(X^T N X)}{\partial X} + \frac{\partial(X^T U)}{\partial X} + \frac{1}{2} \cdot \frac{\partial(L^T P L)}{\partial X} = 0 \dots (27)$$

Here, using the matrix differential formula, we get the following.

$$\frac{1}{2} \cdot \frac{\partial(X^T N X)}{\partial X} = X^T N, \quad \frac{\partial(X^T U)}{\partial X} = U^T \quad \dots \quad (28)$$

Therefore, the following equation holds.

$$NX + U = 0 \quad \dots \quad (29)$$

Or

$$A^T P A X + A^T P L = 0 \quad \dots \quad (30)$$

Equations (29) and (30) are called [Normal equations].

(I) Find the most probable value

The most probable value is calculated using equation (29).

$$\begin{aligned} NX + U &= 0 \\ NX &= -U \end{aligned}$$

Multiplying both sides by the inverse matrix N^{-1} of N yields the following.

$$\begin{aligned} N^{-1}NX &= -N^{-1}U \\ X &= -N^{-1}U \quad \dots \quad (31) \end{aligned}$$

In other words, with the matrix solution method, you can obtain a solution as if you were solving a linear equation.

Alternatively, use equation (30) to calculate as follows.

$$\begin{aligned} A^T P A X + A^T P L &= 0 \\ A^T P A X &= -A^T P L \\ X &= -(A^T P A)^{-1} A^T P L \quad \dots \quad (32) \end{aligned}$$

10.1.3. Calculate Helmert Transformation (2D) in Excel

(A) Helmert Transformation (2D) calculation formula

$$\begin{bmatrix} X_{CGD23} \\ Y_{CGD23} \end{bmatrix} = \begin{bmatrix} dx \\ dy \end{bmatrix} + s \cdot \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix} \cdot \begin{bmatrix} x_{CGD09} \\ y_{CGD09} \end{bmatrix} \quad \cdots (33)$$

X_{CGD23} : $X(N)$ value of CGD23 coordinate

Y_{CGD23} : $Y(E)$ value of CGD23 coordinate

dx : Amount of translation from origin in $x(N)$ – axis direction

dy : Amount of translation from origin in $y(E)$ – axis direction

s : Scale factor

θ : Amount of rotation

X_{CGD09} : $X(N)$ value of CGD09 coordinate

Y_{CGD09} : $Y(E)$ value of CGD09 coordinate

To simplify the explanation, equation (1) is expressed as follows.

$$\begin{bmatrix} X_a \\ Y_a \end{bmatrix} = \begin{bmatrix} C \\ D \end{bmatrix} + \begin{bmatrix} A & B \\ -B & A \end{bmatrix} \cdot \begin{bmatrix} x_b \\ y_b \end{bmatrix} \quad \cdots (34)$$

$$A = s \cdot \cos \theta$$

$$B = -s \cdot \sin \theta$$

$$C = dx$$

$$D = dy$$

(B) Observation equation

The observation equation is as follows.

$$V = AX - L$$

First, transform the Helmert Transformation (2D) formula to create each matrix such as design matrix A .

Equation (34) can be transformed as follows.

$$\begin{aligned} X_a &= Ax_b + By_b + C \\ Y_a &= -Bx_b + Ay_b + D \quad \cdots (35) \end{aligned}$$

The most probable values of X_a and Y_a include errors (residuals) VX_a and VY_a , so equation (35)

becomes as follows.

$$\begin{aligned} X_a + VX_a &= Ax_b + By_b + C \\ Y_a + VY_a &= -Bx_b + Ay_b + D \quad \cdots (36) \end{aligned}$$

$$\begin{aligned} VX_a &= Ax_b + By_b + C - X_a \\ VY_a &= -Bx_b + Ay_b + D - Y_a \quad \cdots (37) \end{aligned}$$

Rearrange equation (37) to make it easier to understand.

$$\begin{aligned} VX_a &= Ax_b + By_b + C - X_a \\ VY_a &= Ay_b - Bx_b + D - Y_a \quad \cdots (38) \end{aligned}$$

The unknown quantities we want to calculate are A, B, C , and D .

Therefore, the unknown quantity matrix X is as follows.

$$X = \begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} \quad \cdots (39)$$

Since there are no unknown quantities in the terms X_a and Y_a , this becomes the matrix L , which is expressed by the following equation.

$$L = \begin{bmatrix} X_a \\ Y_a \end{bmatrix} \quad \cdots (40)$$

Since there are n pieces of data to be given, the matrix L is as follows.

$$L = \begin{bmatrix} X_{a1} \\ Y_{a1} \\ X_{a2} \\ Y_{a2} \\ \vdots \\ X_{an} \\ Y_{an} \end{bmatrix} \quad \cdots (41)$$

Equation (38) is expressed as the following equation using the error (residual) vector V and the unknown quantity vector X .

$$V = F(X) \quad \dots (42)$$

Also, the elements of design matrix A are equation (17).

$$\forall a_{ij} = \frac{\partial l_i^o}{\partial x_j^o}, \quad \text{or} \quad A = \frac{\partial L}{\partial X} = \frac{\partial F}{\partial X} \quad \dots (17)$$

Create a design matrix A from equations (6) and (10) using the following equation.

$$A = \frac{\partial F}{\partial X} \quad \dots (43)$$

$$A = \frac{\partial F(X)}{\partial A} + \frac{\partial F(X)}{\partial B} + \frac{\partial F(X)}{\partial C} + \frac{\partial F(X)}{\partial D} \quad \dots (44)$$

$$A = \begin{bmatrix} x_b & y_b & 1 & 0 \\ y_b & -x_b & 0 & 1 \end{bmatrix} \quad \dots (45)$$

Since there are n pieces of data to be given, the design matrix A is as follows.

$$A = \begin{bmatrix} x_{b1} & y_{b1} & 1 & 0 \\ y_{b1} & -x_{b1} & 0 & 1 \\ x_{b2} & y_{b2} & 1 & 0 \\ y_{b2} & -x_{b2} & 0 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{bn} & y_{bn} & 1 & 0 \\ y_{bn} & -x_{bn} & 0 & 1 \end{bmatrix} \quad \dots (46)$$

Expressing the observation equation using equations (39), (41), and (46), it becomes the following equation.

$$V = AX + L = \begin{bmatrix} x_{b1} & y_{b1} & 1 & 0 \\ y_{b1} & -x_{b1} & 0 & 1 \\ x_{b2} & y_{b2} & 1 & 0 \\ y_{b2} & -x_{b2} & 0 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{bn} & y_{bn} & 1 & 0 \\ y_{bn} & -x_{bn} & 0 & 1 \end{bmatrix} \begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} + \begin{bmatrix} X_{a1} \\ Y_{a1} \\ X_{a2} \\ Y_{a2} \\ \vdots \\ X_{an} \\ Y_{an} \end{bmatrix} \quad \dots (47)$$

(C) Calculation of unknown quantity

The unknown quantity is calculated using the normal equation (32).

$$\begin{aligned} A^T P A X + A^T P L &= 0 \\ A^T P A X &= -A^T P L \\ X &= -(A^T P A)^{-1} A^T P L \quad \dots (32) \end{aligned}$$

To make the explanation easier to understand, we will consider the weight matrix P as a unit matrix as shown below. In other words, assume that all input data has equal precision.

$$P = \begin{bmatrix} 1 & 0 & \dots & 0 & 0 \\ 0 & 1 & \dots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \dots & 1 & 0 \\ 0 & 0 & \dots & 0 & 1 \end{bmatrix} \quad \dots (48)$$

Expressing equation (32) using equations (39), (41), (46), and (48) yields the following equation.

Note that equation (32) is transformed on the condition that the weight matrix P is a unit matrix.

$$\begin{aligned} \begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} &= - \left(\begin{bmatrix} x_{b1} & y_{b1} & x_{b2} & y_{b2} & \dots & x_{bn} & y_{bn} \\ y_{b1} & -x_{b1} & y_{b2} & -x_{b2} & \dots & y_{bn} & -x_{bn} \\ 1 & 0 & 1 & 0 & \dots & 1 & 0 \\ 0 & 1 & 0 & 1 & \dots & 0 & 1 \end{bmatrix} P \begin{bmatrix} x_{b1} & y_{b1} & 1 & 0 \\ y_{b1} & -x_{b1} & 0 & 1 \\ x_{b2} & y_{b2} & 1 & 0 \\ y_{b2} & -x_{b2} & 0 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{bn} & y_{bn} & 1 & 0 \\ y_{bn} & -x_{bn} & 0 & 1 \end{bmatrix} \right)^{-1} \\ &+ \begin{bmatrix} x_{b1} & y_{b1} & x_{b2} & y_{b2} & \dots & x_{bn} & y_{bn} \\ y_{b1} & -x_{b1} & y_{b2} & -x_{b2} & \dots & y_{bn} & -x_{bn} \\ 1 & 0 & 1 & 0 & \dots & 1 & 0 \\ 0 & 1 & 0 & 1 & \dots & 0 & 1 \end{bmatrix} P \begin{bmatrix} X_{a1} \\ Y_{a1} \\ X_{a2} \\ Y_{a2} \\ \vdots \\ X_{an} \\ Y_{an} \end{bmatrix} \quad \dots (47) \end{aligned}$$

Create a Helmert Transformation (2D) calculation tool using equation (49).

If the number of points to be calculated is small, Excel may be used, but if there are many points to be calculated, we recommend creating an application using programming.

(D) Explanation of Excel VBA macros

Matrix calculations were created using Excel functions.

The routine to assign values to cells was created using VBA macros.

(i) Main routine

This is the main routine that erases previous calculations and executes each subroutine.

```
Sub HelmSimple()
    Sheets(Array("P", "A", "AT", "L", "PL", "ATPL", "PA", "ATPA")).Select
    Cells.Select
    Selection.ClearContents

    Call INdat
    Call make_P
    Call make_A
    Call cal_AT
    Call make_L
    Call cal_PL
    Call cal_ATPL
    Call cal_PA
    Call cal_ATPA
    Sheets("OUTPUT").Select
End Sub
```

Delete the previous calculation.

Execute the subroutines in order and display the OUTPUT sheet at the end.

(ii) Create INPUT data

Enter the point name, coordinates before transformation, coordinates after transformation, and weight (variance) on the INPUT sheet. However, since the condition is that they all have equal precision, the input value of the weight is set to 1. These are entered manually. Also, the explanation of the weight matrix will be omitted from now on.

	A	B	C	D	E	F	G						
1	Name	From		To		Weight							
2		Xb	Yb	Xa	Ya	sigma Xb	sigma Yb						
3	5	1246699.207	414116.026	1246699.104	414116.322	1.000	1.000						
4	3D	1307397.722	512230.914	1307397.672	512231.255	1.000	1.000						
5	4B	1319439.481	468822.901	1319439.383	468823.224	1.000	1.000						
6	5B	1299339.345	438998.827	1299339.254	438999.135	1.000	1.000						
7	5C	1291290.984	467060.518	1291290.886	467060.801	1.000	1.000						
8	5E	1266636.714	447804.803	1266636.628	447805.106	1.000	1.000						
9	8A	1255466.677	495800.431	1255466.538	495800.724	1.000	1.000						
OUTPUT		INPUT	P	A	AT	L	PL	ATPL	PA	ATPA	ATPA-1	X	(+)

Read the input data from the INPUT sheet and write it to the OUTPUT sheet.

```
Sub INdat()
    Dim ID(4999)
    Dim Xa(4999) As Double
    Dim Ya(4999) As Double
    Dim Xb(4999) As Double
    Dim Yb(4999) As Double

    i = 1
    Do While Not Sheets("INPUT").Cells(i + 2, 1).Value = 0
        ID(i) = Sheets("INPUT").Cells(i + 2, 1).Value
        Xb(i) = Sheets("INPUT").Cells(i + 2, 2).Value
        Yb(i) = Sheets("INPUT").Cells(i + 2, 3).Value
        Xa(i) = Sheets("INPUT").Cells(i + 2, 4).Value
        Ya(i) = Sheets("INPUT").Cells(i + 2, 5).Value
        i = i + 1
    Loop
    N = i - 1
```

Read the input value from the INPUT sheet.

Count the number of data and write it to the OUTPUT sheet.

```
Sheets("OUTPUT").Cells(2, 9).Value = N
For i = 1 To N
    Sheets("OUTPUT").Cells(i + 5, 1).Value = ID(i)
    Sheets("OUTPUT").Cells(i + 5, 2).Value = Xb(i)
    Sheets("OUTPUT").Cells(i + 5, 3).Value = Yb(i)
    Sheets("OUTPUT").Cells(i + 5, 4).Value = Xa(i)
    Sheets("OUTPUT").Cells(i + 5, 5).Value = Ya(i)
Next i
End Sub
```

Write the input values to the OUTPUT sheet.

	A	B	C	D	E	F	G	H	I
1	Parameter	A	B	C	D	S	θ		data
2		1.000000033	0.000000003	-0.146	0.310	1.0000000328	0.00000		25
3									
4	Name	From	To			To (cal)			
5		Xb	Yb	Xa	Ya	Xa	Ya	dX	dY
6	5	1246699.207	414116.026	1246699.104	414116.322	1246699.103	414116.346	-1	24
7	3D	1307397.722	512230.914	1307397.672	512231.255	1307397.621	512231.237	-51	-18
8	4B	1319439.481	468822.901	1319439.383	468823.224	1319439.380	468823.222	-3	-2
9	5B	1299339.345	438998.827	1299339.254	438999.135	1299339.243	438999.147	-11	12
10	5C	1291290.984	467060.518	1291290.886	467060.801	1291290.882	467060.839	-4	38
11	5E	1266636.714	447804.803	1266636.628	447805.106	1266636.611	447805.124	-17	18
12	8A	1255466.622	495800.431	1255466.538	495800.724	1255466.519	495800.753	-19	29
13	14A	1243671.556	543377.087	1243671.456	543377.426	1243671.453	543377.411	-3	-15
14	21A	1212405.807	477047.002	1212405.707	477049.291	1212405.702	477049.314	-E	-7

(iii) Create weight matrix P

Matrix P is a unit matrix, so its explanation will be omitted.

```
Sub make_P()
    Dim Wx(5000) As Double
    Dim Wy(5000) As Double
    Dim P(5000, 5000) As Double

    i = 1
    Do While Not Sheets("INPUT").Cells(i + 2, 1).Value = 0
        Wx(i) = Sheets("INPUT").Cells(i + 2, 6).Value
        Wy(i) = Sheets("INPUT").Cells(i + 2, 7).Value
        i = i + 1
    Loop
    N = i - 1

    For i = 1 To (N * 2) Step 2
        P(i, i) = 1 / Wx((i + 1) / 2) ^ 2
        P(i + 1, i + 1) = 1 / Wy((i + 1) / 2) ^ 2
    Next i
    For i = 1 To N * 2
        For j = 1 To N * 2
            If i = j Then
                Sheets("P").Cells(i, j).Value = P(i, j)
            Else
                Sheets("P").Cells(i, j).Value = 0
            End If
        Next j
    Next i
End Sub
```

	A	B	C	D	E	F	G	H	I
1	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
2	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
3	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
4	0.000E+00	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00	0.000E+00
7	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	0.000E+00	0.000E+00
8	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00	0.000E+00
9	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+00
10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
OUTPUT INPUT P A AT L PL ATPL PA ATPA ATPA-1 X (+)									

(iv) Create design matrix A

Create a design matrix of equation (46) and write it on sheet A.

$$A = \begin{bmatrix} x_{b1} & y_{b1} & 1 & 0 \\ y_{b1} & -x_{b1} & 0 & 1 \\ x_{b2} & y_{b2} & 1 & 0 \\ y_{b2} & -x_{b2} & 0 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{bn} & y_{bn} & 1 & 0 \\ y_{bn} & -x_{bn} & 0 & 1 \end{bmatrix} \cdots (46)$$

Sub make_A()

Dim Xb(4999) As Double

Dim Yb(4999) As Double

i = 1

Do While Not Sheets("INPUT").Cells(i + 2, 1).Value = 0

Xb(i) = Sheets("INPUT").Cells(i + 2, 2).Value

Yb(i) = Sheets("INPUT").Cells(i + 2, 3).Value

i = i + 1

Loop

N = i - 1

For i = 1 To N

j = 2 * i - 1

Sheets("A").Cells(j, 1).Value = Xb(i)

Sheets("A").Cells(j, 2).Value = Yb(i)

Sheets("A").Cells(j, 3).Value = 1

Sheets("A").Cells(j, 4).Value = 0

Sheets("A").Cells(j + 1, 1).Value = Yb(i)

Sheets("A").Cells(j + 1, 2).Value = -Xb(i)

Sheets("A").Cells(j + 1, 3).Value = 0

Sheets("A").Cells(j + 1, 4).Value = 1

Next i

End Sub

Read the elements of the design matrix from the INPUT sheet.

Rearrange the elements of the design matrix and write them on sheet A.

	A	B	C	D	E	F	G	H
1	1246699.207	414116.026	1	0				
2	414116.026	-1246699.207	0	1				
3	1307397.722	512230.914	1	0				
4	512230.914	-1307397.722	0	1				
5	1319439.481	468822.901	1	0				
6	468822.901	-1319439.481	0	1				
7	1299339.345	438998.827	1	0				
8	438998.827	-1299339.345	0	1				
9	1291290.984	467060.518	1	0				
10	467060.518	-1291290.984	0	1				
11	1266636.714	447804.803	1	0				
12	447804.803	-1266636.714	0	1				
13	1255466.622	495800.431	1	0				
14	495800.431	-1255466.622	0	1				

(v) Create a transposed matrix of design matrix A

Create the transposed matrix A^T of the design matrix in equation (46) and write it on the A^T sheet.

$$A^T = \begin{bmatrix} x_{b1} & y_{b1} & x_{b2} & y_{b2} & \cdots & x_{bn} & y_{bn} \\ y_{b1} & -x_{b1} & y_{b2} & -x_{b2} & \cdots & y_{bn} & -x_{bn} \\ 1 & 0 & 1 & 0 & \cdots & 1 & 0 \\ 0 & 1 & 0 & 1 & \cdots & 0 & 1 \end{bmatrix}$$

Sub cal_AT()

N = 2 * Sheets("OUTPUT").Cells(2, 9).Value

Read the number of data N from the OUTPUT sheet.

Since the number of rows of design matrix A is twice the number of data N, the number of columns of the transposed matrix is 2×N.

Sheets("AT").Select

Range(Cells(1, 1), Cells(4, N)).Select

NN\$ = Trim(Str(N - 1))

at\$ = "=TRANSPOSE(A!RC:R[" & NN\$ & "]C[3])"

Calculate the transposed matrix at\$ of design matrix A using the Excel function TRANSPOSE and write it on the AT sheet.

Selection.FormulaArray = at\$

End Sub

A1		{=TRANSPOSE(A!A1:D50)}					
	A	B	C	D	E	F	G
1	1246699.207	414116.026	1307397.722	512230.914	1319439.481	468822.901	1299339.345
2	414116.026	-1246699.207	512230.914	-1307397.722	468822.901	-1319439.481	438998.827
3	1	0	1	0	1	0	1
4	0	1	0	1	0	1	0
5							

(vi) Create matrix L

Create a matrix L and write it to the L sheet.

$$L = \begin{bmatrix} X_{a1} \\ Y_{a1} \\ X_{a2} \\ Y_{a2} \\ \vdots \\ X_{an} \\ Y_{an} \end{bmatrix} \cdots (41)$$

Sub make_L()

Dim Xa(4999) As Double

Dim Ya(4999) As Double

i = 1

Do While Not Sheets("INPUT").Cells(i + 2, 1).Value = 0

Xa(i) = Sheets("INPUT").Cells(i + 2, 4).Value

Ya(i) = Sheets("INPUT").Cells(i + 2, 5).Value

i = i + 1

Loop

N = i - 1

For i = 1 To N

j = 2 * i - 1

Sheets("L").Cells(j, 1).Value = Xa(i)

Sheets("L").Cells(j + 1, 1).Value = Ya(i)

Next i

End Sub

Read the elements of matrix L from the INPUT sheet.

Write the elements of matrix L in order on sheet L.

	A	B	C	D	E	F	G	H
1	1246699.104							
2	414116.322							
3	1307397.672							
4	512231.255							
5	1319439.383							
6	468823.224							
7	1299339.254							
8	438999.135							
9	1291290.886							
10	467060.801							
11	1266636.628							

(vii) Compute the product of matrix P and matrix L

Matrix P is a unit matrix, so its explanation will be omitted.

```
Sub cal_PL()
    N = 2 * Sheets("OUTPUT").Cells(2, 9).Value
    Sheets("PL").Select
    Range(Cells(1, 1), Cells(N, 1)).Select
    NN$ = Trim(Str(N - 1))
    pl$ = "=MMULT(P!RC:R[" & NN$ & "]C[" & NN$ & "],L!RC:R[" & NN$ & "]C)"
    Selection.FormulaArray = pl$
End Sub
```

(viii) Compute the product of matrix A^T and matrix PL

The matrix $A^T PL$ is as follows.

$$A^T PL = \begin{bmatrix} x_{b1} & y_{b1} & x_{b2} & y_{b2} & \cdots & x_{bn} & y_{bn} \\ y_{b1} & -x_{b1} & y_{b2} & -x_{b2} & \cdots & y_{bn} & -x_{bn} \\ 1 & 0 & 1 & 0 & \cdots & 1 & 0 \\ 0 & 1 & 0 & 1 & \cdots & 0 & 1 \end{bmatrix} P \begin{bmatrix} X_{a1} \\ Y_{a1} \\ X_{a2} \\ Y_{a2} \\ \vdots \\ X_{an} \\ Y_{an} \end{bmatrix}$$

```
Sub cal_ATPL()
    N = 2 * Sheets("OUTPUT").Cells(2, 9).Value
```

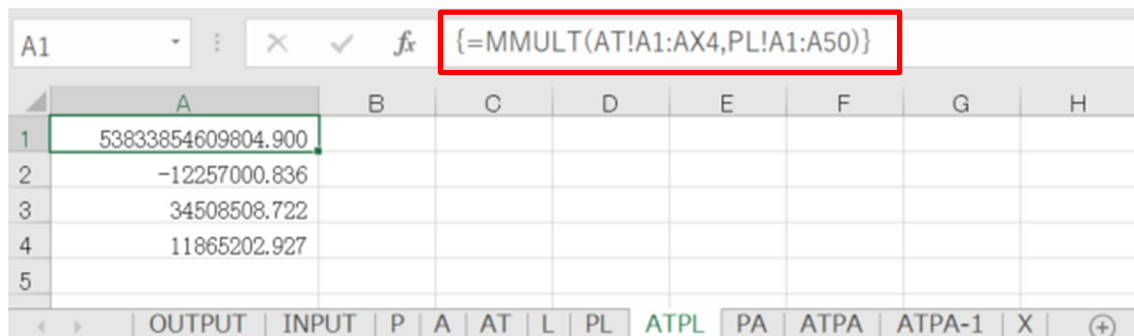
Read the number of data N from the OUTPUT sheet.
The number of rows in the matrix $A^T PL$ is twice the number of data N.

```
    Sheets("ATPL").Select
    Range(Cells(1, 1), Cells(4, 1)).Select
    NN$ = Trim(Str(N - 1))
```

```
    atpl$ = "=MMULT(AT!RC:R[3]C[" & NN$ & "],PL!RC:R[" & NN$ & "]C)"
```

```
    Selection.FormulaArray = atpl$
End Sub
```

Calculate the product atpl\$ of matrix AT and matrix PL using the Excel function MMULT. Write on the ATPL sheet.



(ix) Compute the product of matrix P and matrix A

Matrix P is a unit matrix, so its explanation will be omitted.

```
Sub cal_PA()
N = 2 * Sheets("OUTPUT").Cells(2, 9).Value
Sheets("PA").Select
Range(Cells(1, 1), Cells(N, 4)).Select
NN$ = Trim(Str(N - 1))
pa$ = "=MMULT(P!RC:R[" & NN$ & "]C[" & NN$ & "],A!RC:R[" & NN$ & "]C[3])"
Selection.FormulaArray = pa$
End Sub
```

(x) Compute the product of matrix A^T and matrix PA

The matrix $A^T PA$ is as follows.

$$A^T PA = \begin{bmatrix} x_{b1} & y_{b1} & x_{b2} & y_{b2} & \cdots & x_{bn} & y_{bn} \\ y_{b1} & -x_{b1} & y_{b2} & -x_{b2} & \cdots & y_{bn} & -x_{bn} \\ 1 & 0 & 1 & 0 & \cdots & 1 & 0 \\ 0 & 1 & 0 & 1 & \cdots & 0 & 1 \end{bmatrix} P \begin{bmatrix} x_{b1} & y_{b1} & 1 & 0 \\ y_{b1} & -x_{b1} & 0 & 1 \\ x_{b2} & y_{b2} & 1 & 0 \\ y_{b2} & -x_{b2} & 0 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{bn} & y_{bn} & 1 & 0 \\ y_{bn} & -x_{bn} & 0 & 1 \end{bmatrix}$$

```
Sub cal_ATPA()
N = 2 * Sheets("OUTPUT").Cells(2, 9).Value
Sheets("ATPA").Select
Range(Cells(1, 1), Cells(4, 4)).Select
```

Since Helmert Transformation (2D) has 4 unknown quantities, the matrix $A^T PA$ has 4 rows and 4 columns.

```
NN$ = Trim(Str(N - 1))
```

```
atpa$ = "=MMULT(AT!RC:R[3]C[" & NN$ & "],PA!RC:R[" & NN$ & "]C[3])"
```

```
Selection.FormulaArray = atpa$
End Sub
```

Calculate the product atpa\$ of matrix AT and matrix PA using the Excel function MMULT. Write on the ATPA sheet.

A1		X		f		{=MMULT(AT!A1:AX4,PA!A1:D50)}	
	A	B	C	D	E	F	
1	5.383E+13	0.000E+00	3.451E+07	1.187E+07			
2	0.000E+00	5.383E+13	1.187E+07	-3.451E+07			
3	3.451E+07	1.187E+07	2.500E+01	0.000E+00			
4	1.187E+07	-3.451E+07	0.000E+00	2.500E+01			
5							

(xi) Compute the inverse of $A^T P A$

The inverse matrix of matrix $A^T P A$ is as follows.

$$(A^T P A)^{-1} = \left(\begin{bmatrix} x_{b1} & y_{b1} & x_{b2} & y_{b2} & \cdots & x_{bn} & y_{bn} \\ y_{b1} & -x_{b1} & y_{b2} & -x_{b2} & \cdots & y_{bn} & -x_{bn} \\ 1 & 0 & 1 & 0 & \cdots & 1 & 0 \\ 0 & 1 & 0 & 1 & \cdots & 0 & 1 \end{bmatrix} P \begin{bmatrix} x_{b1} & y_{b1} & 1 & 0 \\ y_{b1} & -x_{b1} & 0 & 1 \\ x_{b2} & y_{b2} & 1 & 0 \\ y_{b2} & -x_{b2} & 0 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{bn} & y_{bn} & 1 & 0 \\ y_{bn} & -x_{bn} & 0 & 1 \end{bmatrix} \right)^{-1}$$

Calculate the inverse matrix from the matrix $A^T P A$ using the Excel function MINVERSE and write it on the ATPA-1 sheet.

A1		✕ ✓ fx		{=MINVERSE(ATPA!A1:D4)}										
	A	B	C	D	E	F								
1	1.757E-12	2.706E-27	-2.426E-06	-8.340E-07										
2	2.772E-27	1.757E-12	-8.340E-07	2.426E-06										
3	-2.426E-06	-8.340E-07	3.784E+00	0.000E+00										
4	-8.340E-07	2.426E-06	0.000E+00	3.784E+00										
5														
		OUTPUT	INPUT	P	A	AT	L	PL	ATPL	PA	ATPA	ATPA-1	X	⊕

Parameters A, B, C, and D of Helmert Transformation (2D) are unknown quantity matrix X, which is expressed by the following equation.

$$X = \begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} \quad \dots \quad (39)$$

Matrix X is the product of the inverse of matrix $A^T P A$ $(A^T P A)^{-1}$ and matrix $A^T P L$.

$$X = -(A^T P A)^{-1} A^T P L$$

Calculate the product using the Excel function MINVERSE and write it on the ATPA-1 sheet.

Figure 10: The screenshot shows the Excel formula bar with the formula `=MMULT('ATPA-1'!A1:D4,ATPL!A1:A4)` entered. The spreadsheet displays the results of the matrix multiplication in the range A1:A4, with values 1.0000000328, 0.0000000032, -0.1459287703, and 0.3100314215.

(xiv) Create an OUTPUT sheet

A formula is written in the cell so that each element (coordinate transformation parameter) of the calculated unknown quantity matrix X is assigned from the X sheet to the OUTPUT sheet.

B2 fx =X!A1

	A	B	C	D	E	F	G	H	I
1	Parameter	A	B	C	D	S	θ		data
2		1.000000033	0.000000003	-0.146	0.310	1.0000000328	0.00000		25
3									
4	Name	From		To		To (cal)			
5		Xb	Yb	Xa	Ya	Xa	Ya	dX	dY
6	5	1246699.207	414116.026	1246699.104	414116.322	1246699.103	414116.346	-1	24
7	3D	1307397.722	512230.914	1307397.672	512231.255	1307397.621	512231.237	-51	-18
8	4B	1319439.481	468822.901	1319439.383	468823.224	1319439.380	468823.222	-3	-2
9	5B	1299339.345	438998.827	1299339.254	438999.135	1299339.243	438999.147	-11	12
10	5C	1291290.984	467060.518	1291290.886	467060.801	1291290.882	467060.839	-4	38
11	5E	1266636.714	447804.803	1266636.628	447805.106	1266636.611	447805.124	-17	18
12	8A	1255466.622	495800.431	1255466.538	495800.724	1255466.519	495800.753	-19	29

OUTPUT INPUT P A AT L PL ATPL PA ATPA ATPA-1 X

A formula is written in the cell to coordinate transform the input value using the calculated coordinate transformation parameters.

F6 fx =\$B\$2*B6+\$C\$2*C6+\$D\$2

	A	B	C	D	E	F	G	H	I
1	Parameter	A	B	C	D	S	θ		data
2		1.000000033	0.000000003	-0.146	0.310	1.0000000328	0.00000		25
3									
4	Name	From		To		To (cal)			
5		Xb	Yb	Xa	Ya	Xa	Ya	dX	dY
6	5	1246699.207	414116.026	1246699.104	414116.322	1246699.103	414116.346	-1	24
7	3D	1307397.722	512230.914	1307397.672	512231.255	1307397.621	512231.237	-51	-18
8	4B	1319439.481	468822.901	1319439.383	468823.224	1319439.380	468823.222	-3	-2
9	5B	1299339.345	438998.827	1299339.254	438999.135	1299339.243	438999.147	-11	12
10	5C	1291290.984	467060.518	1291290.886	467060.801	1291290.882	467060.839	-4	38
11	5E	1266636.714	447804.803	1266636.628	447805.106	1266636.611	447805.124	-17	18
12	8A	1255466.622	495800.431	1255466.538	495800.724	1255466.519	495800.753	-19	29

OUTPUT INPUT P A AT L PL ATPL PA ATPA ATPA-1 X

A formula is written in the cell to calculate the difference (residual) between the input value and the calculated value.

H6	X		✓	f_x	=(F6-D6)*1000											
	A	B	C	D	E	F	G	H	I							
1	Parameter	A	B	C	D	S	θ	data								
2		1.000000033	0.000000003	-0.146	0.310	1.0000000328	0.00000	25								
3																
4	Name	From	To		To (cal)											
5		Xb	Yb	Xa	Ya	Xa	Ya	dX	dY							
6	5	1246699.207	414116.026	1246699.104	414116.322	1246699.103	414116.346	-1	24							
7	3D	1307397.722	512230.914	1307397.672	512231.255	1307397.621	512231.237	-51	-18							
8	4B	1319439.481	468822.901	1319439.383	468823.224	1319439.380	468823.222	-3	-2							
9	5B	1299339.345	438998.827	1299339.254	438999.135	1299339.243	438999.147	-11	12							
10	5C	1291290.984	467060.518	1291290.886	467060.801	1291290.882	467060.839	-4	38							
11	5E	1266636.714	447804.803	1266636.628	447805.106	1266636.611	447805.124	-17	18							
12	8A	1255466.622	495800.431	1255466.538	495800.724	1255466.519	495800.753	-19	29							
OUTPUT INPUT P A AT L PL ATPL PA ATPA ATPA-1 X +																

(ii) Activate the OUTPUT sheet.

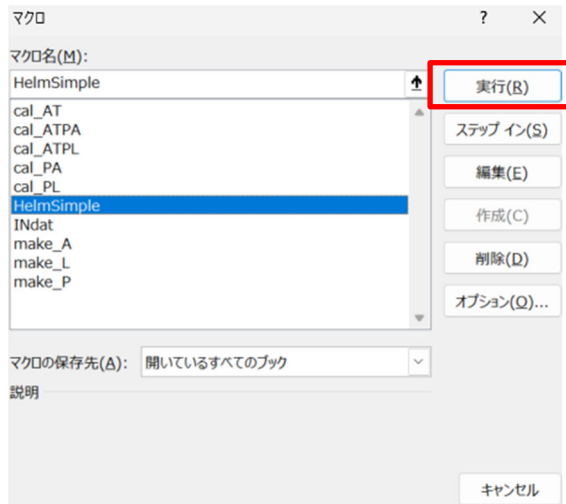
If there are numbers in the yellow cells, delete them.

	A	B	C	D	E	F	G	H	I
1	Parameter	A	B	C	D	S	θ		data
2		1.000000033	0.000000003	-0.146	0.310	1.0000000328	0.00000		
3									
4	Name	From		To		To (cal)			
5		Xb	Yb	Xa	Ya	Xa	Ya	dX	dY
6						-0.146	0.310	-146	310
7						-0.146	0.310	-146	310
8						-0.146	0.310	-146	310
9						-0.146	0.310	-146	310
10						-0.146	0.310	-146	310
11						-0.146	0.310	-146	310
12						-0.146	0.310	-146	310
13						-0.146	0.310	-146	310

(iii) Please display the macro.

ファイル ホーム 挿入 ページレイアウト 数式 データ 校閲 表示 自動化 ヘルプ									
既定 標準 改ページ プレビュー ユーザー設定のビュー シートビュー ブックの表示 表示 100% 選択範囲に合わせて 拡大/縮小 ズーム 新しいウィンドウを開く 整列 ウィンドウの切り替え マクロ									
J30									
	A	B	C	D	E	F	G	H	I
1	Parameter	A	B	C	D	S	θ		data
2		1.000000033	0.000000003	-0.146	0.310	1.0000000328	0.00000		
3									
4	Name	From		To		To (cal)			
5		Xb	Yb	Xa	Ya	Xa	Ya	dX	dY
6						-0.146	0.310	-146	310
7						-0.146	0.310	-146	310

(iv) Run the [HelmSimple] macro.



(v) Please check the residuals.

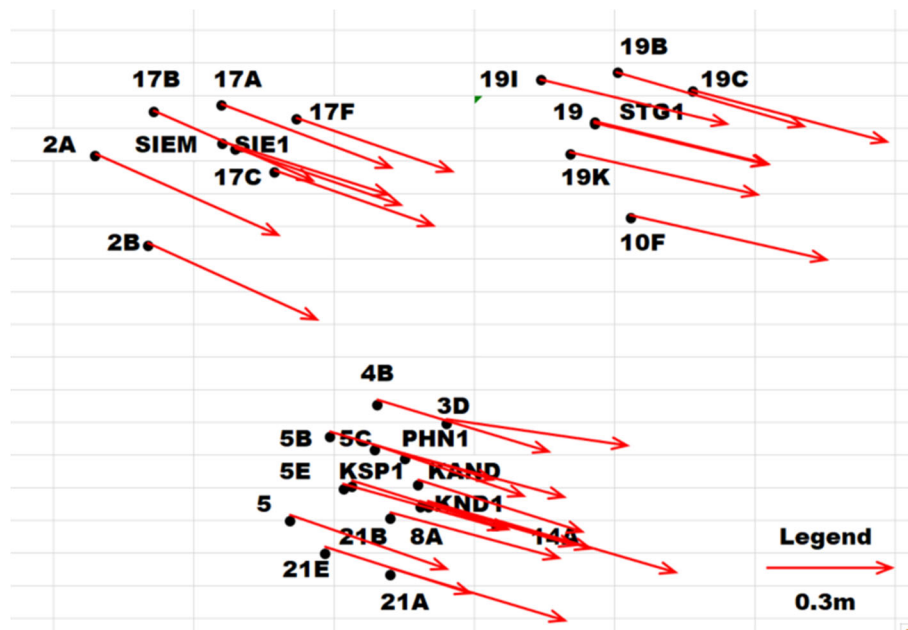
	A	B	C	D	E	F	G	H	I
1	Parameter	A	B	C	D	S	θ		data
2		1.000000033	0.000000003	-0.146	0.310	1.0000000328	0.00000		25
3									
4	Name	From		To		To (cal)			
5		Xb	Yb	Xa	Ya	Xa	Ya	dX	dY
6	5	1246699.207	414116.026	1246699.104	414116.322	1246699.103	414116.346	-1	24
7	3D	1307397.722	512230.914	1307397.672	512231.255	1307397.621	512231.237	-51	-18
8	4B	1319439.481	468822.901	1319439.383	468823.224	1319439.380	468823.222	-3	-2
9	5B	1299339.345	438998.827	1299339.254	438999.135	1299339.243	438999.147	-11	12
10	5C	1291290.984	467060.518	1291290.886	467060.801	1291290.882	467060.839	-4	38

(vi) Enter the [Name] and [From] coordinates of the point you want to calculate in the blank line.
The F and G columns of To(cal) contain function expressions. Please copy and paste.

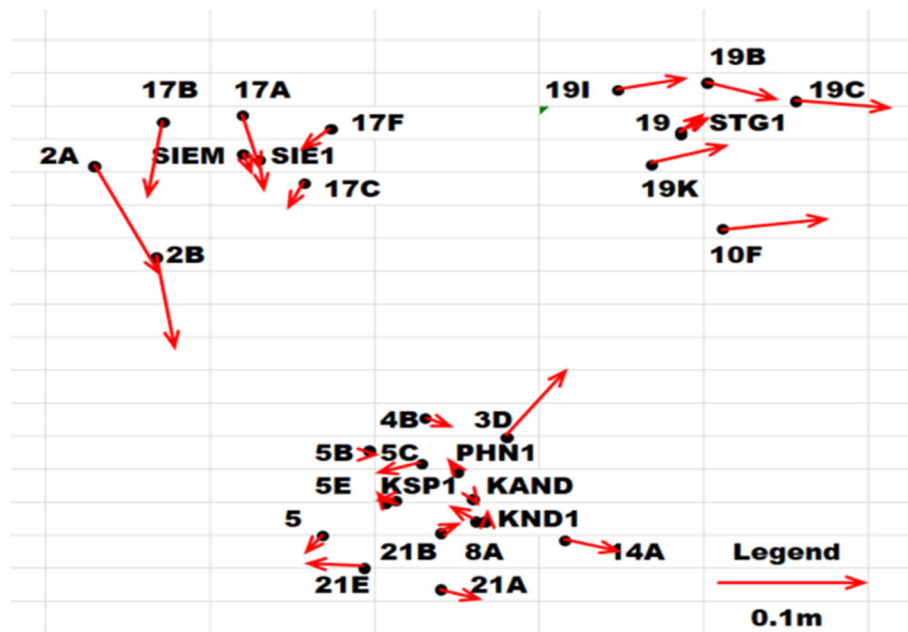
F32								
=B\$2*B32+\$C\$2*C32+\$D\$2								
1	A	B	C	D	E	F	G	H
2	Parameter	A	B	C	D	S	θ	data
3		1.000000033	0.000000003	-0.146	0.310	1.0000000328	0.00000	25
4	Name	From		To		To (cal)		
5		Xb	Yb	Xa	Ya	Xa	Ya	dX
27	19B	1526713.789	619234.711	1526713.687	619235.064	1526713.695	619235.036	8
28	19C	1515439.370	666483.980	1515439.272	666484.346	1515439.276	666484.307	4
29	19I	1522111.940	571499.692	1522111.856	571500.043	1522111.846	571500.016	-10
30	19K	1476143.796	589528.291	1476143.715	589528.645	1476143.700	589528.616	-15
31								
32	11	-1839913.079	5951524.913			-1839913.266	5951525.424	
33	13G	-1564781.402	5978301.106			-1564781.580	5978301.617	
34	15H	-1376009.753	6081806.563			-1376009.925	6081807.077	
35								

10.1.4. Example of calculating parameters adapted to each region

The figure below shows the displacement vector from CGD09 to CGD23.



The figure above looks like the same displacement vector because the amount of displacement is large. Therefore, the figure below shows the characteristics of the displacement trend at each point by excluding the average value of the displacement vector from the figure above.



It can be seen that the characteristics are different in each region of Phnom Penh, Siem Reap, and Stung Treng.

Therefore, coordinate transformation parameters are calculated for each region of Phnom Penh, Siem Reap, and Stung Treng.

(A) Phnom Penh

Name	Whole Area		Each Region	
	Helmert2D Residual		Helmert2D Residual	
	dN (mm)	dE (mm)	dN (mm)	dE (mm)
5	-1	24	7	-2
3D	-51	-18	-28	-21
4B	-3	-2	22	-15
5B	-11	12	10	-8
5C	-4	38	15	25
5E	-17	18	-4	0
8A	-19	29	-9	23
14A	-3	-15	4	-9
21A	-5	-7	-5	-17
21B	-16	4	-8	-7
21E	-15	45	-13	25
KAND	-4	12	10	6

(B) Siem Reap

Name	Whole Area		Each Region	
	Helmert2D Residual		Helmert2D Residual	
	dN (mm)	dE (mm)	dN (mm)	dE (mm)
2A	57	-28	8	-22
2B	47	-2	17	19
17A	26	-3	-1	-18
17B	37	16	-3	8
17C	8	19	-1	13
17F	7	25	-3	6
SIEM	5	3	-18	-4

(C) Stung Treng.

Name	Whole Area		Each Region	
	Helmert2D Residual		Helmert2D Residual	
	dN (mm)	dE (mm)	dN (mm)	dE (mm)
19	-13	-4	-7	24
10F	-12	-43	-6	-16
19B	8	-28	14	1
19C	4	-39	9	-10
19I	-10	-27	-3	2
19K	-15	-29	-8	-1

The residual error when calculated for each region is smaller than when calculated for the whole area. In other words, the parameters are adapted to each region by the amount of the reduced residual.

**Project on Establishment of Continuously Operating Reference Stations
(CORS) for Land Management and Infrastructure Development**

Operation and Maintenance Plan for the Khmer GEONET

18 November 2024

**GENERAL DEPARTMENT OF CADASTRE AND GEOGRAPHY OF
MINISTRY OF LAND MANAGEMENT, URBAN PLANNING AND
CONSTRUCTION OF
KINGDOM OF CAMBODIA**

JAPAN INTERNATIONAL COOPERATION AGENCY

PASCO CORPORATION

Record of Updating

25 September 2023	Version 0.1 the first draft
2 November 2023	Version 0.2 the second draft
3 May 2024	Version 1.0 towards the Paid-Service
18 November 2024	Version 1.1 End of the Project

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Acronyms and Abbreviations

No.	Abbreviation	Official Name
1	CORS	Continuously Operating Reference Stations
2	DPM	Deputy Prime Minister
3	GDCG	General Department of Cadastre and Geography
4	GNSS	Global Navigation Satellite System
5	GPS	Global Positioning System
6	JICA	Japan International Cooperation Agency
7	Khmer GEONET	Khmer GNSS Earth Observation Network System
8	MEF	Ministry of Economy and Finance
9	MLMUPC	Ministry of Land Management, Urban Planning and Construction
10	RGC	Royal Government of Cambodia

CHAPTER 1. Planning of Operation and Maintenance for the Khmer GEONET

1.1. Outline of establishment of the Khmer GEONET

The Khmer GEONET <<https://khmergeonet.xyz>> has been established under the “Project on Establishment of Continuously Operating Reference Stations (CORS) for Land Management and Infrastructure Development” between the Ministry of Land Management, Urban Planning and Construction (MLMUPC) and Japan International Corporation Agency (JICA). This is a JICA Technical Transfer Project with the period from August 2021 to December 2024.

The General Department of Cadastre and Geography (GDCG) under MLMUPC is the responsible agency in Cambodia for whole operation and maintenance for the Khmer GEONET. The construction of five stations and establishment of the Data Center have generally completed in April 2022. All equipment has been handed over from JICA to MLMUPC / GDCG on 6th December 2022.

The Khmer GEONET will start the Paid-Service on **Wednesday, 25th June 2025**.

1.2. Objective of the O & M Plan for the Khmer GEONET

This document describes the essential plan for the operation and maintenance (O & M) of hardware / software, organization and partnerships for the Khmer GEONET, which consists of five (5) stations and one (1) Data Center (as of November 2024).

1.3. Overview of the O & M Plan for the Khmer GEONET

The plan is separated into the mainly three phases: Phase 1 Towards Stable Paid-Service, Phase 2 Smooth Expansion to Whole Country, and Phase 3 Sustainable O & M of the Khmer GEONET. Phase 1 is targeting the establishment of stable service of the Khmer GEONET until the end of the JICA Technical Transfer Project, December 2024.

Phase 2 is targeting the smooth integration with the JICA Grant Aid Project for the nationwide CORS network which will be completed in **March 2026**.

Phase 3 is targeting the sustainable activities of the Khmer GEONET since April 2026, after the completion of the JICA Grant Aid Project.

Please see the attached “Roadmap of the Operation and Maintenance Plan for the Khmer GEONET” for the summary of the progress.

CHAPTER 2. Tasks of the O & M Plan for the Khmer GEONET

2.1. Tasks of Phase 1 Towards Stable Paid-Service

The task list of Phase 1 is shown as below.

Table 2-1 Task List of Phase 1 Towards Stable Paid-Service

#	Tasks
1-1	Management Policy
1-2	Organizational Structure
1-2-1	Organizational Structure: O & M Office
1-2-2	Organizational Structure: Registration Service Office
1-2-3	Organizational Structure: Technical Inspection Office
1-2-4	Organizational Structure: Staff of the O & M Office
1-3	O & M Manuals and Reporting App for Data Center Operators
1-4	O & M Manuals and Reporting App for On-site Station Staff
1-5	Public-Private Partnership
1-6	Human Resources Development
1-7	Equipment Planning & Updating for 5 Stations and the Data Center
1-7-1	Equipment Planning for 5 Stations and 1 Data Center
1-7-2	Updating of Batteries for 5 Stations
1-8	Budget Planning for Fiscal Year 2024 & 2025
1-8-1	Budget Planning for Fiscal Year 2024
1-8-2	Budget Planning for Fiscal Year 2025
1-9	Start of the Paid-Service
1-10	Public Relations

2.1.1. Task 1-1 Management Policy

This task is the establishment of a basic policies including the Paid-Service for Khmer GEONET. The expected users are Government/International Project, Academia, Private Company, and so on.

The DRAFT Paid-Service Plan (Price List, User Category, Service Type) has been submitted to MLMUPC and MEF in June 2023. It will be approved by MEF and other line ministries in

advance of the start of the Paid-Service.

2.1.2. Task 1-2 Organizational Structure

This task is the establishment of the official Section / Office with staff as the responsible framework for the Khmer GEONET services.

2.1.2.1. Task 1-2-1 Organizational structure: O & M Office

GDCG has proposed a new O & M Office for Khmer GEONET.

It will be reviewed in the fiscal year 2025.

2.1.2.2. Task 1-2-2 Organizational Structure: Registration Service Office

GDCG has proposed a new Registration Service Office for Khmer GEONET.

It will be reviewed in the fiscal year 2025.

Registration of Surveyors has been announced and started in March 2024. The qualification test of surveyor will be conducted after consideration of the registration.

Licensing of Survey Company will be announced and started after the preparation of the qualification test. The survey company must have the registered and licensed (qualified) surveyors.

2.1.2.3. Task 1-2-3 Organizational Structure: Technical Inspection Office

GDCG has proposed a new Technical Inspection Office for Technical Inspection for Surveying Equipment.

It will be reviewed in the fiscal year 2025.

2.1.2.4. Task 1-2-4 Organizational Structure: Staff of the O & M Office

GDCG has proposed the staff of the new O & M Office for Khmer GEONET. The organizational structure would have the three categories of official staff:

1. Manager (High level decision making)
2. Supervisor (Department)
3. DC Operator (Data Center & 1 Station)

Besides, the on-site level (4 Stations) has one category of official staff:

1. Station Staff (District/Provincial Offices)

This proposal of the organizational structure has already been submitted. The approval line is: Department -> GDCG -> Under Secretary of State -> Secretary of State -> Minister of MLMUPC (= Deputy Prime Minister, as of November 2024).

The organization is provisionally named “Khmer GEONET Data Center” under the Geography Department of GDCG.)
It will be reviewed in the fiscal year 2025.

2.1.3. Task 1-3 O & M Manuals for Data Center Operators

The Japanese Project Team (JPT) and Aruna Technology Ltd. (Aruna) has been consulted with Cambodian Project Team (CPT, that is, GDCG) about the O & M manuals for Data Center Operators: GNSS-Receiver, Software (Trimble Pivot Platform, Bernese GNSS Software, etc.), Communication / Network / Power Supply. Moreover, Daily/Monthly/Yearly Tasks (storage and backup of data, calculation of coordinates, etc.) are also considered. All the documents should be shared on-line (Telegram, Private Google Drive, Data Center Server).

The O & M Manual has been translated from English to Khmer.

These documents and report formats will be updated based on experiences.

2.1.4. Task 1-4 O & M Check List & Report Format for On-site Maintenance

The reporting tool for station maintenance should be shared on-line. GDCG has developed a smartphone app based on ArcGIS Survey123, ArcGIS Field Maps and ArcGIS Dashboards for information management. All the report should be shared through Telegram and archived in the GDCG Server (Synology NAS). Backup tape is also stored at the other building in case of contingency situation (once in a month).

The O & M Manual has been translated from English to Khmer.

The tools will be updated based on experiences.

2.1.5. Task 1-5 Public-Private Partnership

Outsourcing of a part of O & M activities from GDCG to the private company (ex. Aruna) is important. The contract between GDCG and private company for hardware maintenance and necessary support will be processed in fiscal year 2025.

The budget for O & M for the fiscal year 2025 will be finally approved by the Parliament by December 2024.

2.1.6. Task 1-6 Human Resources Development

Capacity development of engineers for the O & M of 5 CORS should be conducted after the approval of the Paid-Service plan / the organizational structure, and before the start of the Paid-

Service.

2.1.7. Task 1-7 Equipment Planning & Updating for 5 Stations and the Data Center

2.1.7.1. Task 1-7-1 Equipment Planning for 5 Stations and 1 Data Center

In case of machine troubles, an equipment plan should be prepared for operation continuity, update of hardware/software, and others for the 5 Stations and the Data Center. **(Completed)**

2.1.7.2. Task 1-7-2 Updating of Batteries for 5 Stations

Each Station has three units of battery. The batteries should be checked after two years (from April 2022) to see if it is necessary to change them at that time or their life can be extended.

Example: The maximum cost might be:

$(\text{USD}150/\text{unit}) \times (3 \text{ units/station}) \times 5 \text{ stations} = \text{USD } 2,250$

The unit price USD 150 includes transportation fees.

2.1.8. Task 1-8 Budget Planning for Fiscal Year 2024 & 2025

2.1.8.1. Task 1-8-1 Budget Planning for Fiscal Year 2024

The budget for the Khmer GEONET in the fiscal year 2024 (January - December 2024) have been submitted to MLMUPC from GDCG in March/April 2023. It has been discussed and approved in July/August 2023 at MEF. After that, it has been finally approved by the Parliament by December 2023. **(Completed)**

2.1.8.2. Task 1-8-2 Budget Planning for Fiscal Year 2025

GDCG have prepared a draft budget plan for the Khmer GEONET in the fiscal year 2025 (January - December 2025) by March/April 2024 to submit as a part of the Annual National Budget in 2025. It has been discussed by MLMUPC and MEF at the meeting on 5th July 2024 and after. The budget for O & M for the Khmer GEONET in the fiscal year 2025 will be finally approved by the Parliament by December 2024.

2.1.9. Task 1-9 Start of the Paid-Service

The Khmer GEONET will start the Paid-Service on **25th June 2025** (re-changed from 26 June 2024). Khmer GEONET Website has already been developed. The collaboration with Cambodia Data Exchange Platform (CamDX) will be added for payment method.

2.1.10. Task 1-10 Public Relations

For value adding and sustainability of the Khmer GEONET, number of users is an important monitoring index. Promotion activities are necessary.

The results of the pilot projects can be used as the PR materials for the current / future users of the Khmer GEONET.

The 3rd Seminar has successfully been conducted on 5th June 2024. The materials (agenda, leaflet for the Khmer GEONET, presentations, etc.) are shared among participants. **(Completed)**

2.2. Tasks of Phase 2 Smooth Expansion to Whole Country

The task list of Phase 2 is shown as below.

Table 2-2 Task List of Phase 2 Smooth Expansion to Whole Country

#	Tasks
2-0	Start of the Paid-Service
2-1	JICA Grant Aid for the Nationwide CORS Network
2-2	Updating of Batteries for the Nationwide CORS Network
2-3	Updating of Software
2-4	Public-Private Partnership
2-5	Human Resources Development
2-6	Equipment Planning
2-7	Budget Planning
2-8	Public Relations
2-9	Registration as the International GNSS Service (IGS) Station

2.2.1. Task 2-1 JICA Grant Aid for the Nationwide CORS Network

The contract has been concluded on 14th March 2024.

The construction will complete by **March 2026** (planned two years from the contract).

(Total number of stations are under adjustment (as of November 2024).)

2.2.2. Task 2-2 Updating of Batteries for the Nationwide CORS Network

Each Station has three units of battery. Basically, the batteries should be checked after two years (from the set-up at the station) to see if it is necessary to change them at that time or their life can be extended.

Because of the variety of each on-site situation, the lifetimes of batteries may be different from each other.

2.2.3. Task 2-3 Updating of Software

Updating of software should be considered well in advance of the expiration.

For example:

Pivot (expire on 31 May 2027),

Bernese,

Network software,

Internet Security (Anti-Virus software, Firewall, etc.),

Microsoft Operation Software (Windows),

Microsoft Office (Excel, Word),

ArcGIS, etc.

2.2.4. Task 2-4 Public-Private Partnership

Outsourcing of a part of O & M activities from GDCG to the private company should be prepared.

2.2.5. Task 2-5 Human Resources Development

Capacity development of engineers for O & M of Nationwide CORS Network with the Data Center should be conducted.

2.2.6. Task 2-6 Equipment Planning

In case of machine troubles, an equipment plan should be prepared for operation continuity, update of hardware/software, and others for the Nationwide CORS Network with the Data Center. For reasonable planning, the evidence/experience, such as past accident records, should be considered.

2.2.7. Task 2-7 Budget Planning

Every year, GDCG shall prepare a draft budget plan by March/April to submit as Annual National Budget on the next fiscal year (January - December) for the Nationwide CORS Network with the Data Center.

2.2.8. Task 2-8 Public Relations

Goal setting (how many users are registered until when?) is important for promotion.

For example, increase users up to 1,000 registrations at the end of 2026, hopefully.

2.2.9. Task 2-9 Registration as the International GNSS Service (IGS) Station

It should be considered that how many stations of the Khmer GEONET might be aiming to register as International GNSS Service (IGS) stations. The target year should be also considered.

2.3. Tasks of Phase 3 Sustainable O & M of the Khmer GEONET

The task list of Phase 3 is shown as below.

Table 2-3 Task List of Phase 3 Sustainable O & M of the Khmer GEONET

#	Tasks
3-1	Updating of Hardware (GNSS Receiver, Antenna, UPS, etc.)
3-2	Updating of Storage, Server, etc.
3-3	Updating of Software
3-4	Human Resources Development
3-5	Future expansion of the Khmer GEONET

2.3.1. Task 3-1 Updating of Hardware (GNSS Receiver, Antenna, UPS, etc.)

Lifetime of hardware expects 10 years or more. The plan and budget for updating of the Nationwide CORS Network should be prepared well in advance.

Hopefully, the updating of each Stations might be one by one, not simultaneously.

2.3.2. Task 3-2 Updating of Storage, Server, etc.

Lifetime of PC at the Data Center will be expected around 3 years or more. The plan and budget for updating of the PCs at the Data Center should be prepared well in advance.

2.3.3. Task 3-3 Updating of Software

Lifetime of Software at the Data Center will be expected around 3 years or more. The plan and budget for updating of the software at the Data Center should be prepared well in advance.

2.3.4. Task 3-4 Human Resources Development

Capacity development of engineers for O & M of the Nationwide CORS Network with the Data Center is inevitable.

Hardware/software are progressed and changed. The Khmer GEONET should catch up and adapt the latest technology as needed.

2.3.5. Task 3-5 Future expansion of the Khmer GEONET

In future, the additional deployment of Stations for the Khmer GEONET will be considered. Demand and use case for the Khmer GEONET should be developed, adding to the cadastral survey.

[End of the Document]

					2024												2025				2026				Remark
Phase		Contents	Responsible Organization	Progress	1	2	3	4	5	6	7	8	9	10	11	12	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12	
Phase 1: Towards Stable Paid-Service (The Project completion in December 2024)																									
1-1	Management Policy	Establishment of a basic policies including the paid-services for Khmer GEONET (users: Government / International Project, Academia, Private Company, etc.) The DRAFT <u>Paid Service Plan (Price List, User Category, Service Type)</u> has been submitted to MLMUPC and MEF in June 2023. It will be approved by MEF and other line ministries in advance of the start of the paid-service.	CPT, MLMUPC, MEF	80%																					
1-2-1	Organizational Structure: O & M Office	GDCG has proposed a new O & M Office for Khmer GEONET. It will be reviewed in the fiscal year 2025.	CPT, MLMUPC	50%																					
1-2-2	Organizational Structure: Registration Service Office	GDCG has proposed a new Registration Service Office for Khmer GEONET. It will be reviewed in the fiscal year 2025. Registration of Surveyors has been announced and started in March 2024. (The qualification test of surveyor will be conducted after consideration of registration.) Licensing of Survey Company will be announced and started after the preparation of the qualification test . (The survey company must have the registered and licensed (qualified) surveyors).	CPT, MLMUPC	50%																					
1-2-3	Organizational Structure: Technical Inspection Office	GDCG has proposed a new Technical Inspection Office for Technical Inspection for Surveying Equipment. It will be reviewed in the fiscal year 2025.	CPT, MLMUPC	50%																					
1-2-4	Organizational Structure: Staff of the O & M Office	GDCG has proposed the staff of the new O & M Office for Khmer GEONET: 1. Manager (High level decision making) 2. Supervisor (Department) 3. DC Operator (Data Center & 1 Station) On-site Level (4 Stations): 1. Station Staff (District/Provincial Offices) It will be reviewed in the fiscal year 2025.	CPT, MLMUPC	80%																					
1-3	O & M Manuals and Reporting App for Data Center Operators	GDCG: Operation records/archives are shared on-line (Smartphone App developed by GDCG based on ArcGIS Survey123 and ArcGIS Dashboards, Telegram) JPT: The O & M Manual has been translated from English to Khmer. Aruna: Manuals for GNSS-Receiver, Software (Pivot, etc.), Communication/Network, Power Supply.	CPT, JPT, Private Company	90%																					
1-4	O & M Manuals and Reporting App for On-site Station Staff	GDCG: Operation records/archives are shared on-line (Smartphone App developed by GDCG based on ArcGIS Survey123 and ArcGIS Dashboards, Telegram). JPT: The O & M Manual has been translated from English to Khmer.	CPT, JPT	90%																					
1-5	Public-Private Partnership	Outsourcing of a part of O & M activities from GDCG to the private company (e.g. Aruna) The contract between GDCG and private company for hardware maintenance and necessary support will be processed in fiscal year 2025.	CPT, Private Company	70%																					
1-6	Human Resources Development	Capacity development of engineers (at District / Provincial office) for the O & M of 4 CORS (except PNH1 (MLMUPC)).	CPT	70%																					
1-7-1	Equipment Planning for 5 Stations and 1 Data Center	In case of machine troubles, operation continuity, update of hardware/software, and others	CPT, JPT	100%																					
1-7-2	Updating of Batteries for 5 Stations	(USD150/unit) x (3 units/station) x 5 stations – Test the batteries after two years (from April 2022) to see if it is necessary to change them at that time or their life can be extended. – The unit price includes transportation fees.	GDCG, Private Company	0%																					
1-8-1	Budget Planning for Fiscal Year 2024	GDCG shall prepare a draft budget plan by March/April 2023 to submit as Annual National Budget.	CPT, JPT, Private Company	100%																					
1-8-2	Budget Planning for Fiscal Year 2025	GDCG have prepared a draft budget plan by March/April 2024 to submit as Annual National Budget in 2025. It has been discussed by MLMUPC and MEF at the meeting on 5th July 2024 and after. The budget for O & M for the Khmer GEONET in the fiscal year 2025 will be finally approved by the Parliament by December 2024.	CPT, Private Company	90%																					
1-9	Start of the Paid-Service	It is re-planned to start on 25th June 2025 . Khmer GEONET Website has been developed. The collaboration with Cambodia Data Exchange Platform (CamDX) will be added for payment method.	CPT	60%																					
1-10	Public Relations	The 3rd Seminar has been completed as scheduled on 5 June 2024. Explanatory materials (leaflet) have been distributed.	CPT, JPT	100%																					
Phase 2: Smooth Expansion to Whole Country (Grant Aid Project completion in March 2026)																									
2-0	Start of the Paid-Service	It is re-planned to start on 25th June 2025 . Khmer GEONET Website has been developed. The collaboration with Cambodia Data Exchange Platform (CamDX) will be added for payment method.	GDCG	60%																					

					2024												2025				2026				Remark
Phase		Contents	Responsible Organization	Progress	1	2	3	4	5	6	7	8	9	10	11	12	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12	
2-1	JICA Grant Aid for Nationwide CORS Network	The contract has been concluded in March 2024. The construction will complete by March 2026 (planned two years from the contract).	GDCG, Joint Venture (JV)	10%																					
2-2	Updating of Batteries for Nationwide CORS Network	3 batteries for each Station (every 2 years?)	GDCG	0%																					
2-3	Updating of Software	Pivot (expire on 31 May 2027), Bernese, Network software, Internet Security (Anti-Virus software, Firewall, etc.), Microsoft Operation Software (Windows), Microsoft Office (Excel, Word), ArcGIS, etc.	GDCG, Private Company	0%																					
2-4	Public-Private Partnership	Outsourcing of a part of O & M activities from GDCG to the private company	GDCG	0%																					
2-5	Human Resources Development	Capacity development of engineers for O & M of the Nationwide CORS Network	GDCG	0%																					
2-6	Equipment Planning	In case of machine troubles, operation continuity, update of hardware/software, and others	GDCG	0%																					
2-7	Budget Planning	Every year, O & M for the Nationwide CORS Network.	GDCG	0%																					
2-8	Public Relations	Goal Setting: How many users are registered until when?	GDCG	0%																					
2-9	Registration as the International GNSS Service (IGS) Station	Goal Setting: How many stations of Khmer GEONET are registered as IGS stations until when?	GDCG	0%																					
Phase 3: Sustainable O & M of Khmer GEONET (the Nationwide CORS Network from April 2026)																									
3-1	Updating of Hardware (GNSS Receiver, Antenna, UPS, etc.)	Lifetime of Hardware expects 10 years or more. Plan and prepare budget in advance. Hopefully the updating of the Nationwide CORS Network might be one by one, not simultaneously.	GDCG	0%																					
3-2	Updating of Storage, Server, etc.	Lifetime of PC expects 3 years or more. Plan and prepare budget in advance.	GDCG	0%																					
3-3	Updating of Software	Lifetime of Software expects 3 years or more. Plan and prepare budget in advance.	GDCG	0%																					
3-4	Human Resources Development	Capacity development of engineers for O & M of the Nationwide CORS Network	GDCG	0%																					
3-5	Future expansion of the Khmer GEONET	Next stage after the JICA Grant Aid for Nhaiione CORS Network	GDCG	0%																					