SIRGAS

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GUIDE03 PROCESSING GUIDELINES FOR THE SIRGAS ANALYSIS CENTERS

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DOCUMENT CHANGE LOG

Version 3.0, 12.2021

(Previous edition: Version 2.2, 03.2017)

12.2021: *A detailed update of the SIRGAS guides prior to the current ones is made. Of the four existing guides:*

1. *Guide for the installation of SIRGAS-CON stations*
2. *Procedure to register a new station in the SIRGAS-CON network*
3. *Guide for the coordination of SIRGAS-CON*
4. *Guide for SIRGAS Analysis Centers*

The order is changed and they are generated in 3 new guides:

1. *Guide01 Coordination of the SIRGAS Network*
2. *Guide02 Installation, operation and registration of SIRGAS-CON stations*
3. *Guide03 Processing guidelines for SIRGAS-CON analysis centers*

A general review of the content is made, internet links and additional details related to the Analysis Centers, the structure of SIRGAS and Working Group I are updated. Most of the texts prepared in previous versions by L. Sánchez, C. Brunini, S. Costa , V. Mackern and V. Cioce remains. As of this version, the writing team is indicated in the source of this document..

03.2017: *The National GNSS Data Processing Center of the National University (Costa Rica) has been updated to become an official SIRGAS processing center. Update of some Internet links. IGS14 was included as a reference frame.*

08.2013: *Processing characteristics have been adapted to the new IERS and IGS standards; the delivery of loosely constrained daily solutions was defined together with the usual weekly solutions; the Military Geographical Institute of Chile was added as an official SIRGAS processing center, and the National GNSS Data Processing Center of the National University (Costa Rica) also added as a new experimental processing center.*

07.2011: *Replacement of "CPAGS-LUZ: SIRGAS GNSS Processing and Analysis Center at the Laboratory of Physical and Satellite Geodesy of the University of Zulia (Venezuela)" with "CPAGS-LUZ: GNSS SIRGAS Processing and Analysis Center of the University of Zulia (Venezuela)".*

01.2011: *The formalization of the IGN-Ar and INEGI processing centers has been included.*

09.2010: *The new SIRGAS FTP server has been included.*

01.2010: *The formalization of the CEPGE-Ec, SGM-Uy and CPAGS-LUZ processing centers has been included.*

10.2009: *Instructions were included to define the geodetic datum in the SIRGAS-CON network weekly solutions.*

04.2009: *The Laboratory of Physical and Satellite Geodesy of the University of Zulia (LGFS-LUZ) and the Military Geographic Service of Uruguay (SGM-Uy) have been added as new experimental processing centers.*

01.2009: *The Military Geographical Institute of Ecuador (IGM-Ec) has been added as a new experimental processing center.*

The objective of this document is to establish the general indications to be followed by the SIRGAS Analysis Centers (official Processing Centers, Experimental Processing Centers and Combination Centers) for the weekly processing of the SIRGAS continously operating network (SIRGAS-CON). It has been prepared by the SIRGAS-GTI and complemented with recommendations made by various colleagues. SIRGAS appreciates this valuable collaboration.

In order to keep this document up-to-date, you are cordially invited to send your comments, questions or suggestions to the chair of SIRGAS-GTI, whose contact details may be found at https://sirgas.ipgh.org/.

Related documents:

- Guide01 SIRGAS Network Coordination
- Guide02 Installation, Operation and Registration of SIRGAS-CON Stations

1. INTRODUCTION

One of the most important aspects to achieve international geodetic standards in relation to the materialization and densification of modern geodetic frames[1][2], are the routines and characteristics of the geodetic network processing, in this case the SIRGAS Continuously Operating Network (SIRGAS-CON).

Based on **"Guide01 SIRGAS Network Coordination"** which establishes the components making up the SIRGAS-CON network, their responsibilities and interaction, and **"Guide02 Installation, Operation and Registration of SIRGAS-CON Stations"**, this document presents the standars, guidelines, recommendations and commitments to process SIRGAS-CON. It is suggested that any organization interested in becoming a SIRGAS-CON analysis center, previous to the application review the above guidelines to familiarize yourself with the organizational structure of SIRGAS.

2. ORGANIZATIONAL STRUCTURE OF THE SIRGAS-CON NETWORK

The activities related to SIRGAS-CON network processing is carried out by the SIRGAS Analysis Centers, coordinated by the SIRGAS Working Group I (Reference System), known as SIRGAS-GTI. The set of GNSS stations making up the network is accordingly grouped into two networks:

1. A continental coverage network (SIRGAS-C, Core), as the primary densification of the ITRF (International Terrestrial Reference Frame) on the American continent, including stable stations featuring optimal operations which are able to guarantee the consistency, durability and precision of the reference frame over time. This network is considered the primary SIRGAS-CON network.
2. National reference networks (SIRGAS-N, National) that densify the continental network and provide access to the reference frame at both national and local levels. Both the continental and national networks share the same characteristics and quality standards, as each station is processed by at least three Analysis Centers.

The stations provide their data through the SIRGAS National Data Centers, whose interaction with the Local Processing Centers and the Combination Centers, including how this is coordinated between them and the generation of the final SIRGAS-CON products, is shown in Figure 1.

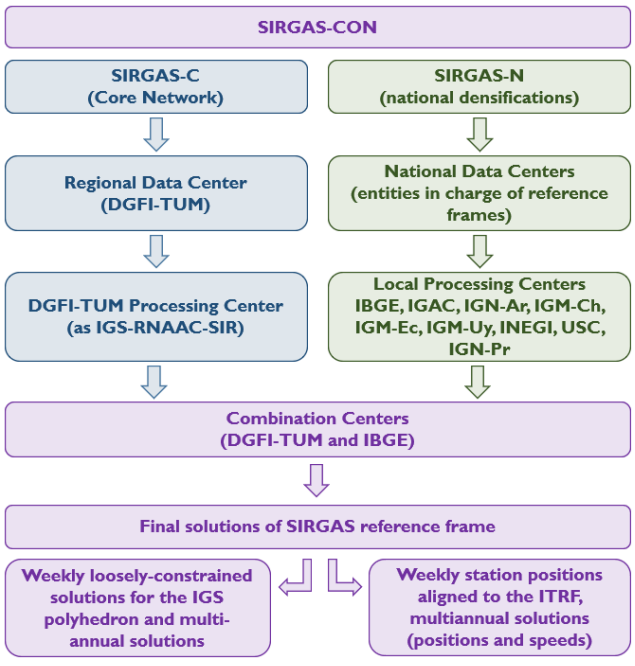

Figure 1: Flow diagram for processing the SIRGAS-CON network.

GNSS observations recorded by the SIRGAS-CON stations are given in standard RINEX format, and are stored long-term by the Regional Data Center operated by the DGFI-TUM (Deutsches Geodätisches Forschungsinstitut der Technischen Universität München) in the case of the continental network (SIRGAS-C), while The National Data Centers are responsible for safeguarding the data provided by SIRGAS-N national network, according to the provisions enshrined in "**Guide01 SIRGAS Network Coordination"**

The continental SIRGAS-C network is processed by the IGS Regional Network Associate Analysis Centre for SIRGAS (IGS-RNAAC-SIR), while the national networks are calculated by the Local Processing Centers(CPL). Daily and weekly loosely-constrained solutions created by these centers are combined with the corresponding solutions created for the continental network in order to ensure the consistency of the coordinates and velocities of all the continuous operation stations included in SIRGAS.

3. GENERAL DESCRIPTION OF THE RESPONSABILITIES OF A SIRGAS ANALYSIS CENTER

The steps of data processing are, in general, those shown in the following image:

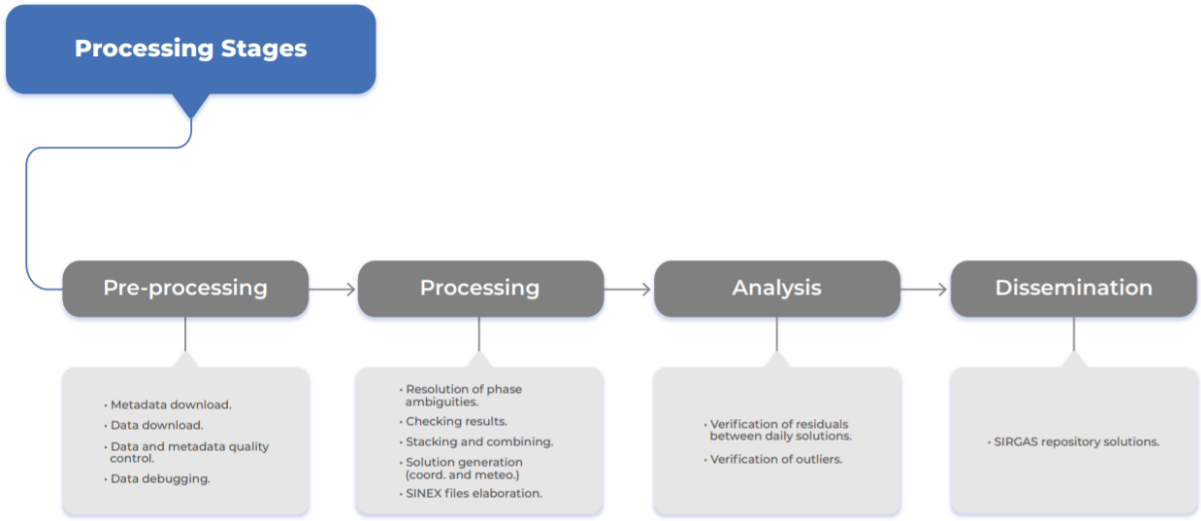

Figure 2: Processing steps. Sources:[1]

The essential activities required of a SIRGAS Analysis Center to carry out these stages include:

1. Downloading the GNSS observation files in RINEX format from the Data Centers, which requires the corresponding accesses managed by the SIRGAS-GTI to be enabled.
2. Verification of the correspondence between the number of stations assigned, the number of sessions available out and the RINEX files available.
3. Downloading the input data necessary for processing (orbits, EOP (Earth Orientation Parameters), models for bias reduction, etc.); more details at http://www.igs.org/products [3].
4. Preparation of the processing according to the software characteristics; the task involves adapting the processing platform and organizing the observation files as well as the inputs according to software requirements.
5. Processing of GNSS measurements and carrying out the quality control of the results (daily and weekly loosely-constrained solutions) for subsequent distribution among the Combination Centers.
6. Implement changes reported by the Network Coordinator, regarding station metadata updates.
7. Subscribe to the SIRGAS Mail (see instructions at http://sirmail.dgfi.tum.de [4]) as this is the channel for disseminating information related to the status and possible changes in the configuration of the SIRGAS-CON stations.

8. Subscribe to the IGS Station Exploder and the IGS Mail Exploder to stay informed about changes in the IGS global stations and receive announcements of relevance to the IGS community. Instructions for subscribing to these two mail exploders are described at http://www.igs.org/mail [5]
9. Notifying any eventualities that may arise during the processing stages and preparation of activity reports at the request of SIRGAS-Working Group I.
10. In those cases where the Analysis Center also participates as a Data Center, it should also follow the indications established in **"Guide02 Installation, Operation and Registration of SIRGAS-CON Stations".**
11. The allocation of functions to the different members of the SIRGAS Analysis Center is made purely on the basis of its internal organization. However, the following posts must be designated as a matter of course:
    a) A person in charge or a coordinator with the full-time responsibility of ensuring the normal development of the activities to be carried out.
    b) A main assistant on a part-time basis to perform intermediate or support tasks as required for weekly network processing, also able to replace the person in charge in case of their absence.
    c) An alternative assistant on a part-time basis to help with technology-related tasks and keep information up-to-date as required to maintain infrastructure (equipment and software), connectivity, data storage, access management and others.
12. It should be clarified that the products created by the Analysis Centers (official and experimental) within the SIRGAS framework are completely free and must be made available to those requesting it. This policy must be accepted and practiced by the entities or institutions collaborating with and making up SIRGAS.

4. INSTRUCTIONS FOR EXPERIMENTAL ANALYSIS CENTERS

SIRGAS Analysis Centers are responsible for performing tasks related to the rigorous processing of the GNSS observations registered by the set of stations in the SIRGAS-CON network, coordinated by the SIRGAS-GTI. Any academic, scientific or governmental entity working in any member country, may set up an Analysis Center after evaluating the availability of all the resources required as regards feasibility criteria, and may rely at all times on the support and technical advice provided by SIRGAS.

The following guidelines are intended to orient the process to evaluate and take a decision about the effective installation of a SIRGAS Analysis Center, thus ensuring its permanence over time, given the level of commitment involved.

1. **Human resources:** the set of fundamental activities that are carried out by the SIRGAS Analysis Centers are routine; hence the automation of the processes is convenient. Consequently, a small number of members can be held responsible without undermining the assignments of the entity where they work. Provided that the functions are clearly identified, the human resource of the Analysis Center can be made up of a minimum of three (3) members, thus guaranteeing its continuous operation.

   The skills and abilities required by the members of a SIRGAS Analysis Center are indicated below, and a training plan will be designed by the SIRGAS-GTI according to these:

   a) Basic training (minimum) in geodesy, surveying and/or cartography.
   b) Working knowledge of aspects related to GNSS fundamentals and applications.
   c) Experience in the treatment and processing of GNSS observations.
   d) Use of a programming language (desirable).
   e) Minimum skills in the use of databases, networks, communication protocols.
   f) Management of office automation packages (e.g., Microsoft Office or its equivalent in Linux).

2. **Material resources:** A SIRGAS Analysis Center must have at least one (1) high-performance processor, capable of processing the high volume of GNSS data typical of the set of SIRGAS-CON stations that it will be running. This task must be carried out according to the work schedule established by the SIRGAS-GTI, so that the sending of solutions to the Combination Centers is not delayed by computational limitations. In addition, there must be a good enough Internet connection to allow the data and information typical of weekly network processing functions to be downloaded and sent.

   Based on current experiences in managing SIRGAS Analysis Centers, the hardware must at a minimum be made up of an I7 processor with 8 GB RAM. The selection of the operating system (i.e., Linux or Windows) is up to the Analysis Center. If Windows is chosen, version 7 onwards is recommended, always with strict adherence to the conditions governing user licenses.

   Physical space and other infrastructure requirements must be sufficient to house the computer equipment and facilitate the work of the calculators without creating further demands.

3. **Processing software:** The high quality standards pursued by the continental geodetic reference frame require the use of scientific processing platforms able to rigorously treat GNSS observations based on current geodetic estimation conventions and standards.[6]. The choice of software is at the discretion of the respective Analysis Center, however, the above, as a guideline, are shown below some examples of scientific software, used by different organizations and institutions at an international level in spatial geodesy:

   - Bernese GNSS Software [7]
   - GAMIT(GNSS at MIT)-GLOBK(Global Kalman filter)[8]
   - PANDA (Positioning And Navigation Data Analyst) [9]
   - Gipsy Oasis [10]
   - NAPEOS (Navigation Package for Earth Orbiting Satellite)[11]
   - MicroCosm [12]

   However, an Analysis Center may implement another processing platform, which is not ruled out as long as it meets the processing requirements of the SIRGAS-CON network. The Analysis Center or the institution hosting it are responsible for arranging the necessary licenses and permits with the providers of any of the processing platforms to be used, as well as their respective updates.

4. **Institutional support:** The academic, scientific or governmental entity where an Analysis Center is installed will be liable to SIRGAS, for contributing to the maintenance of the continental geodetic reference frame with everything that this task implies. Hence, the institutional support, in terms of the provision of inputs and facilities offered to help with attending the scientific-technical events organized annually by SIRGAS, is extremely important to ensure the optimal fulfillment of the center's functions.

4.1. PROCEDURE TO SET UP AN EXPERIMENTAL ANALYSIS CENTER

Once the feasibility of operating a SIRGAS Analysis Center has been evaluated as described in the previous item, the interested party must express their clear and voluntary desire to cooperate with SIRGAS in the long term. They must do so in line with the instructions, standards and conventions defined by SIRGAS to permanently maintain the quality of the products created by the SIRGAS-CON network, endorsed by their country's National Representative to SIRGAS.

Each candidate SIRGAS Analysis Center must pass a trial period (generally one year) in which it adapts its processing routines to the procedures specified by SIRGAS and verifies that it is capable of meeting the performance standards and the quality of its results, in strict adherence to the SIRGAS-GTI indications. During this trial period, the candidate SIRGAS Analysis Center is called Experimental Analysis Center and may become an Official Analysis Center once it has successfully passed the trial period. In view of the above, the steps to follow for the installation of an Experimental Analysis Center are as follows:

1. Contact the Chair of the SIRGAS-GTI, formally stating the willingness to set up an Experimental Analysis Center. This communication, in addition to indicating the name and contact information of the person responsible (address, email, telephone), must be accompanied by a letter of support issued by the corresponding entity and a letter of endorsement signed by their country's National Representative to SIRGAS.
2. Indicate the software to be used for GNSS data processing, which must have the ability to implement rigorous calculation strategies in line with SIRGAS standards (see Item 5). The SIRGAS-GTI reserves the right to request information on software licensing and conditions of use from the entity applying.
3. Propose a set of SIRGAS-CON stations to start the series of processing tests with a view to moving into the training and adaptation phase for rigorous processing according to SIRGAS standards. The selection of stations can be prepared with help from the SIRGAS-GTI Chair.
4. Propose a three-character code to identify the Experimental Center, for example, USC for "Universidad de Santiago de Chile".
5. Indicate the GPS week from which functions as an experimental center would begin.
6. Express to the Chair of SIRGAS-GTI the need for specific training associated with the management of the SIRGAS Analysis Centers, which allowed the planning and implementation of such activity.

4.2. START OF OPERATIONS AT AN EXPERIMENTAL ANALYSIS CENTER

Once the SIRGAS Executive Committee has accepted the proposal to set up an Experimental Analysis Center, the Chair of the SIRGAS-GTI will contact the person in charge to coordinate the following actions:

1. Based on the processing tests considering the set of stations as indicated in **Item 3** in the previous point, the SIRGAS-GTI Chair will make the final assignment of the stations to be in the charge of the new Experimental Analysis Center. In this sense, the distribution will meet the criteria regarding the inclusion of SIRGAS-CON stations in the same number of individual solutions.
2. During the evaluation period, the experimental center's activities will be governed by this guide (see **Item 5**) and other instructions provided by the SIRGAS-GTI.
3. The evaluation of the experimental center's performance is the responsibility of the SIRGAS-CON Analysis Coordinator and includes aspects such as punctuality when sending solutions, optimal implementation of the SIRGAS processing strategy, the capacity to solve issues related to the operations of an Analysis Center, and the quality and consistency of the solutions created.
4. The Analysis Coordinator will prepare partial reports for the SIRGAS-GTI on the performance of the experimental center, based on the routine evaluation indicated in the previous item. From these reports, the Chair of the SIRGAS-GTI will inform the experimental center of those aspects that must be improved.
5. At the end of the trial period, the Chair of SIRGAS-WGI, in agreement with the SIRGAS Executive Committee, decides whether the experimental center is in a position to become an official center.
6. In view of the foregoing, the entity hosting the experimental center must issue a letter of commitment with SIRGAS in which it guarantees to support its operation and continuity, in line with SIRGAS standards.
7. The SIRGAS-GTI is empowered to drive and propose that an experimental center that satisfies SIRGAS standards in full. be made official without fulling the one-year period stipulated.

5. INSTRUCTIONS FOR ANALYSIS CENTERS

The processing, analysis and creation of primary products based on the geodetic infrastructure represented through SIRGAS-CON, are carried out on a weekly basis, in compliance with instructions which have been especially formulated according to the latest standards in matters of geodetic calculation as per IERS (International Earth Rotation and Reference Systems Service) and IGS (International GNSS Service) standards and conventions.

Processing Centers calculate daily loosely-constrained solutions for the coordinates of the SIRGAS-CON stations assigned, producing a weekly loosely-constrained solution after combining the seven daily solutions corresponding to a GPS week. For this, there are minimum requirements for calculating the network, presented below. The Atmospheric Analysis Centers, for their part, use the results derived from the GNSS processing, so that they are also governed in the first instance by the same calculation strategy.

The weekly processing of the SIRGAS-CON network presents the following general characteristics:

1. Original GNSS observations: for processing purposes, at least the GPS constellation will be taken into account, ideally the GPS+GLONASS combination.
2. Derived GNSS observations: they are given by forming the linear combination L3 (Ionosphere-free combination) from the observables L1 and L2. This in turn allows for the reduction of the first order effect caused by ionospheric refraction.
3. Number of observation sessions: the results must be calculated on the basis of multisession processing, where the seven daily sessions (i.e., with a 24-hour extension) carried out by the stations are independently calculated. Considering the operation of the stations, in those cases where the full number of sessions is not available, all available sessions should be considered.
4. Sampling interval for GNSS observations: 30 seconds.
5. Elevation mask: 3°.
6. Weighting of observations: this is based on elevation, so that the lower the elevation, the lower the weighting. Analysis Centers unable to include this type of weighting must use a 15° elevation mask.
7. Known parameters in adjustment: the satellite orbits, corrections to satellite clocks, and EOP earth orientation parameters (Earth Orientation Parameters) contained in the final IGS solutions are introduced. These products are available at http://www.igs.org/products/data [3].
8. Modeling of the Earth's gravitational field: should any stage of the processing require the use of a global gravity model, this should be the EGM2008. [13]
9. Use of the most recent recent model of absolute values of the corrections to the phase center variations (PCV) of the GNSS antennas published by the IGS, including those dependent on the elevation and arrival azimuth of the satellite signal. This model is available at https://files.igs.org/pub/station/general/pcv_archive/[14]
10. The combination of antennas with protective covers (radomes) must be strictly considered when applying the corrections to the PCV. The identification of the equipment (receiver+antenna+radome) used to perform the processing must coincide exactly with the content of the station log files, as per ftp://ftp.sirgas.org/pub/gps/DGF/station/log.[15]
11. When the operator or person in charge of a station uses the relevant channels as established in **"Guide02 Installation, Operation and Registration of SIRGAS-CON Stations"** to notify changes in the antenna and/or radome, an operation that can happen any day of the week, the Analysis Centers must take into account for processing the largest number of observation sessions, discarding all other sessions.
12. The correction for the effect of the displacement of the mean phase center of the transmitting antenna with respect to the center of mass of the Phase Center Offset (PCO) satellite, must be done on the basis of the absolute calibration values in the direction of the Z axis, contained in the same IGS model as the one giving the PCVs of the receiving antennas, available at https://files.igs.org/pub/station/general/pcv_archive/ .[14]

13. Oceanic tidal loading effect: the periodic movement of the seasons caused by oceanic tides on land (elastic response of the earth's crust to oceanic tides) must be corrected. These corrections should be estimated using the most recent version of the FES ocean tidal model, drawn up by Bos and Scherneck in http://holt.oso.chalmers.se/loading.[16] In the option "Do you want to correct your loading values for the motion?", answer "NO", as this correction is already included in the final IGS orbits used for SIRGAS processing.

14. Atmospheric tide loading effects: the tidal component must be corrected (elastic response of the earth's crust to the variable distribution of atmospheric pressure caused by the direct gravitational attraction (i.e., tides) of the Sun and Moon on atmospheric masses). The reduction can be applied considering the tidal harmonics S_1 and S_2, according to the model drawn up by van Dam, T. and R. Ray.[17]

15. Non-tidal loading effects: in general, non-tidal oceanic and atmospheric loading effects (non-tidal) should not be reduced during processing. These must be completely contained in the solutions generated by the Analysis Centers, so that they can be identified in the time series of the station coordinates for their adequate treatment. This also applies to hydrological loading effects.

16. Refraction in the neutral atmosphere: the delay of the GNSS signal caused by refraction during its passage through the neutral atmosphere (troposphere and stratosphere) should be treated as follows:

    a) The hydrostatic component in the direction of the zenith (Zenith Hydrostatic Delay - ZHD) is modeled from the coefficients of the VMF (Vienna Mapping Function) at one-hour intervals for each day and each site. The coefficients of this modern mapping function are based on the data flow of the numerical weather prediction model managed by the ECMWF (European Center for Medium-Range Weather Forecasts), and are available in global meshes with a certain spatial and temporary resolution at https://vmf.geo.tuwien.ac.at/trop_products/GRID/.[18]

    b) The non-hydrostatic component in the direction of the zenith (Zenith Wet Delay) is estimated, with intervals of one hour at the same time as the station coordinates, obtaining a total of twenty-four correction factors for each day and for each site. The necessary a priori values are also obtained from the VMF.

    c) It is advisable to consider horizontal gradients to reduce the effect of the azimuthal asymmetry of the atmosphere, in which case the Chen and Herring model should be applied.[19]

17. The strategy to resolve ambiguities in carrier phases must lead to their fixation in integer terms (i.e., fixed solution).

18. The solutions generated in terms of normal equations are only for the station positions, meaning that the parameters associated with the delay in the neutral atmosphere and the solution of ambiguities must be pre-eliminated (subtracted from the normal equations) from the daily solutions.

19. For the combination of daily solutions, the stations with a root mean square error (1σ) greater than 10 mm in the N-E component, and more than 20 mm in the Up component, are eliminated from normal equations.

20. When there is inconsistency in a station due to changes in equipment, such as the receiver or antenna, this should be kept for as many days as possible using similar equipment.

21. Both the daily and weekly solutions must be made available in SINEX (Solution (Software/technique) INdependent EXchange Format format), and contain the positions calculated in the solution, the corresponding variance-covariance matrix and all constraints used a priori to calculate the solution. This means that the necessary statistical information must be included (e.g., number of observations, number of unknowns, variance, etc.) to draw up the combination of the individual solutions based on the normal equations.

22. Since the daily and weekly solutions must be loosely-constrained, it is recommended that a prior variance factor equal to ±1 m be introduced for the coordinates of all processed stations. If this is not possible, the SINEX files created should contain all the constraints applied to calculate the individual solutions.

23. All the results are expressed in the same reference system, frame and epoch in which the GNSS orbits are given. The calculations and presentation of results must be advanced in GPS time.
24. The characteristics of the processing not explicitly mentioned in this section are at the discretion of the Analysis Centers, in line with IERS[20] and IGS[2] standards and conventions.
25. The Analysis Centers must prepare a report in text format specifying which stations were not included in the solution, either because they were inactive, or because they presented low-quality observations, or because of any other processing-related developments. The text file must be saved in a *.REP extension format.

```
Processing Center:    USC
Week:                 2152
Processed on:         4/30/2021
RINEX download on:    4/29/2021

RINEX not found:

Excluded stations:
```

*Figure 3: Text file format *.REP*

26. All the information related to processing aspects and the stations processed must be kept up-to-date together with the respective processing log file.
27. Any variant tending to improve the quality of the determinations may be implemented only for evaluation purposes, without this implying any interference with the processing schedule defined by the SIRGAS-GTI. For the determinations to be adopted by the SIRGAS Analysis Centers, the pertinent reference must communicate to the SIRGAS-GTI chair. In this sense, the results presented must comply explicitly with the indications presented in this document.

However, in order to optimize resources in the centers, the suggestion is to carry out seven-day processing in parallel mode, rather than sequentially. It is also recommended that processing be optimized to allow the software to use all the computer equipment cores available.

6. RESULTS PROCESSING AND RECORDING SCHEDULE

The processing schedule should be the following:

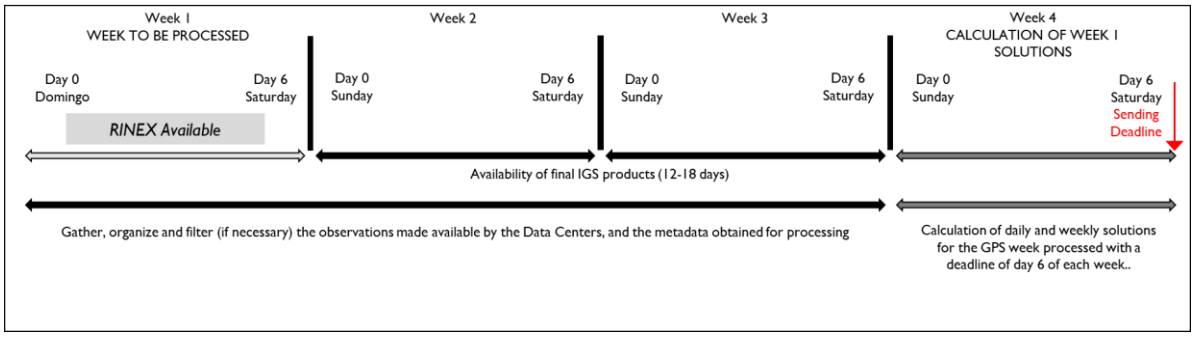

Figure 4: Processing Schedule.

The SIRGAS Analysis Centers (official and experimental) must follow a schedule of activities encompassing all the SIRGAS-CON processing stages until the timely sending of the individual loosely-constrained solutions, in order to guarantee that:

1. The Combination Centers can draw up weekly IGS-adjusted results able to support all the technical and scientific work in the fields of geodesy, surveying, geomatics, engineering, and other disciplines requiring precise positioning.
2. The IGS-RNAAC-SIR can create the SIRGAS contribution required to draw up the IGS global polyhedron.
3. In a period of four weeks, which includes the observation period carried out by the SIRGAS-CON stations, the Analysis Centers must:

    a) Collect, organize and review the GNSS observations in RINEX format registered by the SIRGAS-CON stations assigned to the center, and made available by the Data Centers. This is for the GPS week to be calculated.

    b) Obtain the basic inputs for processing, i.e., IGS products (final orbits, derived from ERP satellite clocks), global VMF and TEC (total electron content) meshes for ionospheric reduction, and other inputs according to the processing platform used. There are files available thirteen (13) days after the observation date (in the case of IGS products), which means that the SIRGAS-CON processing will be yielding results referring to the three (3) weeks prior to the calculation date.

    c) Calculation of daily and weekly loosely-constrained solutions for the set of SIRGAS-CON stations assigned to the Analysis Center. This stage includes obtaining a weekly solution (combination of the seven daily solutions) for the station coordinates and creating the SINEX files containing them, together with the corresponding variance-covariance matrix, both for the weekly solution and for each daily solution. The activity planning should envisage carrying out this stage during the fourth week of the schedule.

Below is an example of the schedule:

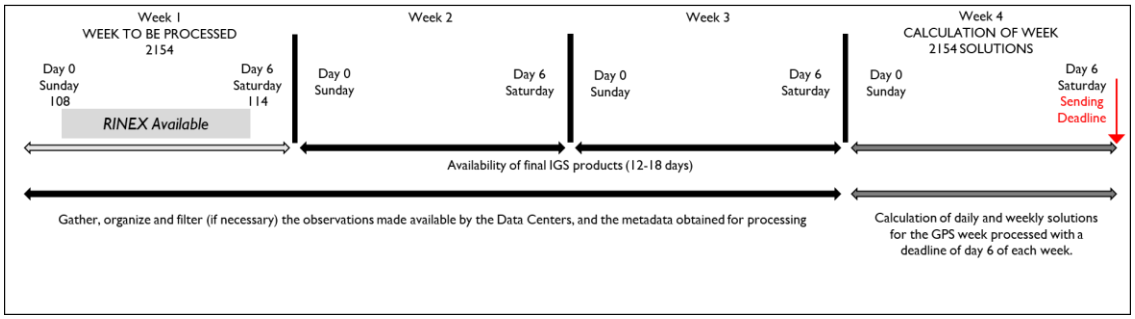

Figure 5: Processing Example Schedule

Note:

The SIRGAS-CON Network Coordinator will be in charge of providing the Analysis Centers with input files intended to reduce bias regarding the estimates. These are not offered under a periodic regime by international services, but given how relevant they are for obtaining reliable results, they require the strictest uniformity to be followed in obtaining them. This is the case of the correction values for oceanic and tidal atmospheric loads, the PCV for transmitting and receiving antennas, the list of stations (*.STA in the case of Bernese GNSS Software), etc.

Any processing irregularity, inconsistency or problem must be notified to the SIRGAS-GTI Chair, which will allow the necessary measures to be taken so as not to affect the workflow from the other Analysis Centers.

d) The daily and weekly loosely-constrained solutions created individually by each Processing Center must be sent to the Combination Centers no later than Friday of each week. There are specific directories enabled for this purpose on the DGFI-TUM's FTP server which houses all SIRGAS-related information. The access data are only provided by the SIRGAS-GTI. On this point:

i. Daily and weekly files in SINEX format (*.SNX) must be compressed in gz format, according to the following nomenclature:

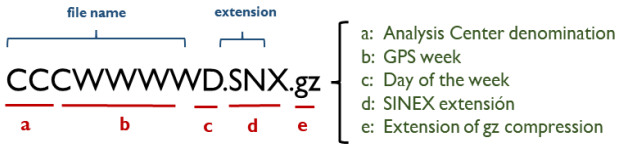

*Figure 6: Filename in *.SNX format*

ii. Daily output files generated by the software using the parameters associated with the delay in the neutral atmosphere, i.e., ZHD, ZWD, ZTD and horizontal gradients, must be sent in gz compressed format, as follows:

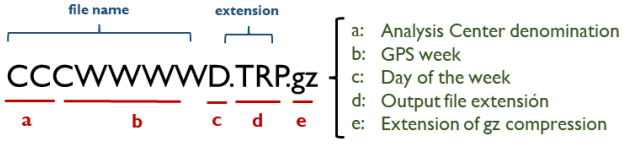

*Figure 7: Filename in *.TRP format*

iii. In this way, each Processing Center will deliver seven (7) *.SNX files, seven (7) *.TRP files and one (1) *.REP file. This comes to a total of fifteen (15) files containing the solutions associated with the set of stations assigned, as shown below.

SINEX	TRP
Station coordinates, variance-covariance matrix and statistical information of interest: number of observations, unknowns, degrees of freedom, etc.	Hourly values of the ZHD, ZWD, ZTD and horizontal gradients of all the stations contained in the solution

*for more information on the description of the SINEX format, see https://www.iers.org/IERS/EN/Organization/AnalysisCoordinator/SinexFormat/sinex.html.[21]

The identification codes of the existing SIRGAS Analysis Centers are:

ID	ANALYSIS CENTER:	TYPE	COUNTRY
CHL	Instituto Geográfico Militar, Chile	LPC	Chile
DGF	Deutsches Geodätisches Forschungsinstitut - TUM	LPC/CC/ IGS-RNAAC-SIR	Germany
ECU	Centro de Procesamiento de Datos GNSS del Ecuador - IGM	LPC	Ecuador
GNA	Instituto Geográfico Nacional, Argentina	LPC	Argentina
IBG	Instituto Brasileiro de Geografia e Estatistica	LPC/CC	Brazil
IGA	Instituto Geográfico Agustín Codazzi	LPC	Colombia
INE	Instituto Nacional de Estadística y Geografía	LPC	Mexico
URY	Instituto Geográfico Militar, Uruguay	LPC	Uruguay
USC	Centro de Procesamiento y Análisis Geodésico de la USACH	LPC	Chile
PER	Instituto Geográfico Militar, Perú	EPC	Peru
CRI	Instituto Geográfico Nacional, Costa Rica	EPC	Costa Rica

Table 1: Analysis Center Codes

7. INSTRUCTIONS FOR COMBINATION CENTERS

There are two Combination Centers; the IBGE is the primary one and the DGFI-TUM acts as the IGS-RNAAC-SIR. Their operation is supervised by the SIRGAS-GTI Chair. Both carry out the SIRGAS-CON combination or adjustment process by applying the same methodology and using the same set of individual loosely-constrained solutions supplied by the Local Processing Centers, so that the network's final solution for a specific week is double checked. The stations' coordinates, coming from the combination made by these centers, are equivalent.

The individual solutions obtained by the Local Processing Centers must be available for their combination at the beginning of the fourth week following the observation date, according to the indications in **Item 6** concerning the activity schedule. If any are unavailable, they will not be included in the combined weekly solution and the Analysis Center must report what happened.

In general, the combination strategy consists of:

1. A review of the solutions available for the combination regarding the completeness of the SINEX format and the possibility of obtaining completely unconstrained normal equations. For this purpose, it is necessary to remove the constraints included in the calculation of individual solutions.
2. The verification of the station names, which must match their identification (a four-character code + DOMES Number) contained in the IERS database.[22] If inconsistencies occur, the relevant stations should be renamed.
3. A comparison between the positions contained in the different SINEX files to identify any possible discrepancies between the individual solutions.
4. A determination of relative weights (or variance factors) between the individual solutions to compensate for possible differences between the stochastic models. This procedure can be advanced by adjusting the individual solutions to the same reference frame, for example, the ITRF stations included in SIRGAS-CON.

5. Identification of gross errors in the stations' coordinates and reduction of these before advancing the combination. This identification can be carried out by generating time series for the coordinates and by comparing individual solutions.
6. Combination of individual normal equations and analysis of position repeatability residuals to identify new gross errors or discrepancies. This and the two previous steps must be repeated iteratively until the results of the combination are satisfactory. Stations with a root mean square (RMS) greater than 10 mm in the N-E component, and more than 20 mm at altitude, are eliminated from normal equations.
7. The comparison between the individual solutions and the combined one, and the preparation of a report describing the main results (relative weights) must be made available together with the results of the combination.
8. Communication with the SIRGAS-GTI Chair to report irregularities, inconsistencies or problems in the combination.
9. The Combination Centers must offer the following products, using the nomenclature indicated:

   a) A weekly loosely-constrained solution for station positions in SINEX format and the combination report.

   Example:

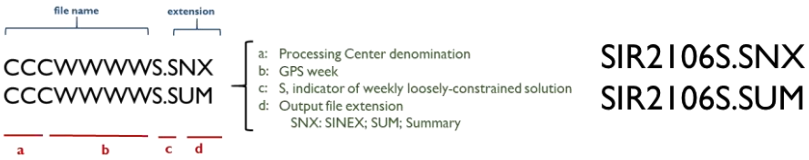

Figure 8: SINEX file and report for weekly loosely-constrained solution

   b) A weekly station position solution aligned to the ITRF via the IGS reference frame in SINEX format and as a list of station positions, made available to users on the https://sirgas.ipgh.org/[23].

   Example:

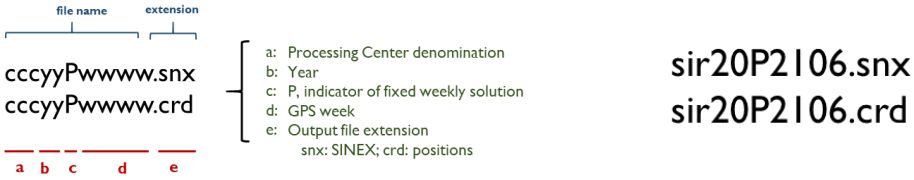

Figure 9: SINEX file, coordinates file and fixed weekly solution report

8. INSTRUCTIONS FOR THE MATERIALIZATION OF THE GEODETIC DATUM

The following instructions for the materialization of the geodetic datum in the weekly solutions of the SIRGAS-CON network were issued at the SIRGAS 2009 Meeting, held in Buenos Aires, Argentina.

1. The highest quality global IGS stations will be used as fiducial stations (currently, those from the IGb14 implementation as of May 17, 2020, GPS week 2106) included in the SIRGAS-CON network.
2. The values resulting from the weekly combinations of the IGS (igsyyPwwww.snx, yy = year, wwww = GPS week) will be adopted as reference coordinates for the fiducial stations. Positions for a standard epoch corrected with constant velocities will explicitly not be used.

3. The prior standard deviation assigned to the reference coordinates within the fit must be equivalent to the standard deviation estimated by the processing program for the station positions. With Bernese GNSS Software v5.2 or later, ±1E-04 m should be used.
4. These instructions will be reviewed and duly updated whenever a new ITRF/IGS solution becomes available.

9. USE OF SIRGAS MAIL

SIRGAS Mail is the channel established by SIRGAS to transmit all the information related to SIRGAS-CON stations. The station operator or manager, as well as any member of the SIRGAS community, may register by following the instructions given in http://sirmail.dgfi.tum.de/.[4]

The type of information generally disclosed through SIRGAS Mail covers the following: the incorporation or removal of stations from the network; changes or updates to instruments and the ensuring log file adaptation; reports on any tracking problems or inconsistencies in observations, SIRGAS-CON solutions, SIRGAS events, etc. Hence the importance of subscribing to the contact list.

For the purposes of operating a SIRGAS station, t**he use of the SIRGAS Mail is mandatory for the operator or person in charge** when any of the events listed below occurs:

1. Sending reports from the Combination Centers
2. Sending reports from the IGS Analysis Centers.
3. Changes in the designation of stations assigned to centers.
4. Designation of new stations assigned to centers.
5. Relevant geodetic information that the center considers should be shared.

10. DATA POLICY

The solutions generated by the Analysis Centers (in the form of coordinates and velocities, SINEX files, time series for the coordinates of the stations, etc.) are completely free of charge and available to anyone who requires them. However, both the Analysis Centers and the Regional Data Center are not authorized to deliver the observations of the SIRGAS-CON stations to third parties. For this purpose, the parties interested should directly contact those responsible (Operator Center and/or National Data Center) at the corresponding stations. This data policy must be accepted and respected by each academic, scientific or governmental entity wishing to work with SIRGAS.

11. SERVICE FOR ANALYSIS CENTERS

Any inquiry or request for information by the operator or person in charge of the station regarding the contents of this document may be channeled through the SIRGAS Working Group I, by contacting the Chair of the Working Group and/or the SIRGAS-CON Network Coordinator. Their email addresses are listed in https://sirgas.ipgh.org/[23].

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13. ACRONYMS

ARP: Antenna Reference Point

CAA: Atmospheric Analysis Centers

CC: Combination Centers

CEP: Experimental Processing Centers

CND: National Data Centers

CO: Operator Centers

CODE: Center for Orbit Determination in Europe

CORS: Continuously Operating Reference Station

CPL: Local Processing Centers

CRD: Regional Data Center

EOP: Earth Orientation Parameters

ERP: Earth Rotation Parameter

FTP: File Transfer Protocol

GNSS: Global Navigation Satellite System

HTTPS: HyperText Transfer Protocol Secure

IERS: International Earth Rotation and Reference Systems Service

IGS: International GNSS Service

ITRF: International Terrestrial Reference Frame

NRP: North Reference Point

PCO: Phase Center Offset

PCV: Phase Centre Variation

PRN: Pseudorandom noise

RINEX: Receiver Independent Exchange Format

SINEX: Solution (Software/technique) INdependent EXchange Format

RMS: Root Mean Square

TEC: Total Electron Content

VMF: Vienna Mapping Function

CHL: Instituto Geográfico Militar, Chile (Military Geographical Institute, Chile)

CRI: Instituto Geográfico Nacional, Costa Rica (National Geographic Institute, Costa Rica)

DGF: Deutsches Geodätisches Forschungsinstitut - TUM

ECU: Centro de Procesamiento de Datos GNSS del Ecuador – IGM (Ecuador GNSS Data Processing Center – IGM)

GNA: Instituto Geográfico Nacional, Argentina (National Geographic Institute, Argentina)

IBG: Instituto Brasileiro de Geografia e Estatistica (Brazilian Institute of Geography and Statistics)

IGA: Instituto Geográfico Agustín Codazzi, Colombia (Agustín Codazzi Geographic Institute, Colombia)

INE: Instituto Nacional de Estadística y Geografia, México (National Institute of Statistics and Geography, México)

PER: Instituto Geográfico Militar, Perú (Military Geographical Institute, Peru)

URY: Instituto Geográfico Militar, Uruguay (Military Geographical Institute, Uruguay)

USC: Centro de Procesamiento y Análisis Geodésico de la USACH, Chile (Processing Center and Geodesic Analysis of the USACH, Chile)