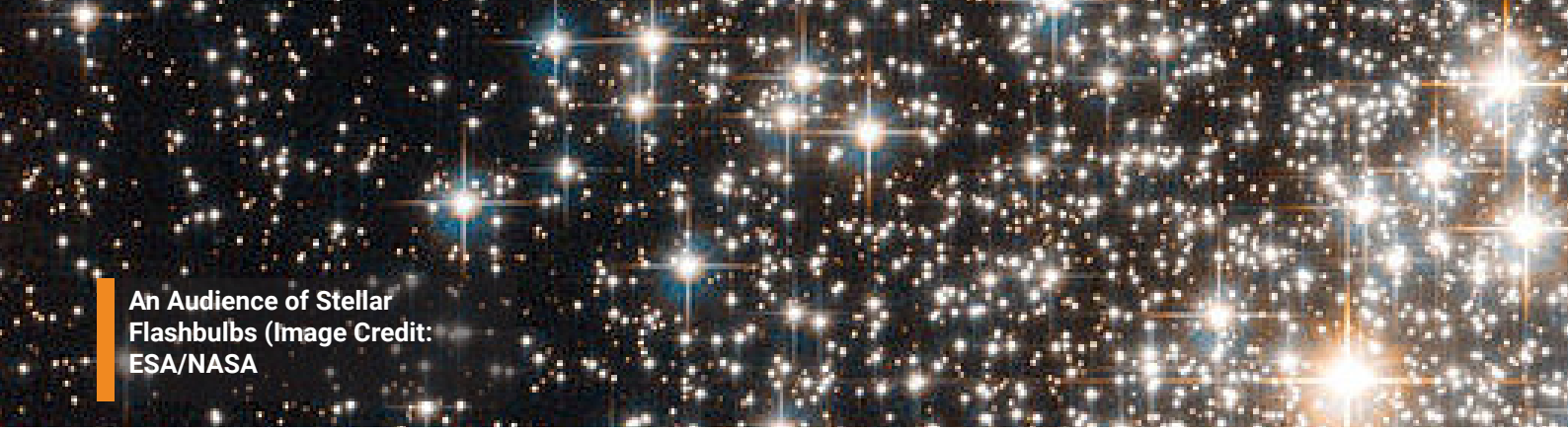
Summary Recommendations of the IGS 2022 Virtual Workshop

27 June to 1 July
Convened Virtually and Hosted by
UNAVCO and UCAR
Boulder, Colorado, USA

IGS INTERNATIONAL GNSS SERVICE



An Audience of Stellar Flashbulbs (Image Credit: ESA/NASA

Editors

IGS Central Bureau

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The IGS is a service of Global Geodetic Observing System International Association of Geodesy International Union of Geodesy and Geophysics

IGS INTERNATIONAL GNSS SERVICE

The International GNSS Service (IGS) ensures open access, high-quality GNSS data products that enable access to the definitive global reference frame for scientific, educational, and commercial applications.

IGS is a Network Member of International Council for Science - World Data System

ICSU WORLD DATA SYSTEM IUGG IAG GGOS Global Geodetic Observing System

Sponsorship is acknowledged. A portion of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004)

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Mountains in Boulder, Colorado, USA (Photo by Braden Collum on Unsplash)

Mission

The International GNSS Service provides, on an openly available basis, the highest-quality GNSS data, products and services in support of the terrestrial reference frame, Earth observation and research; positioning, navigation and timing; and other applications that benefit science and society.

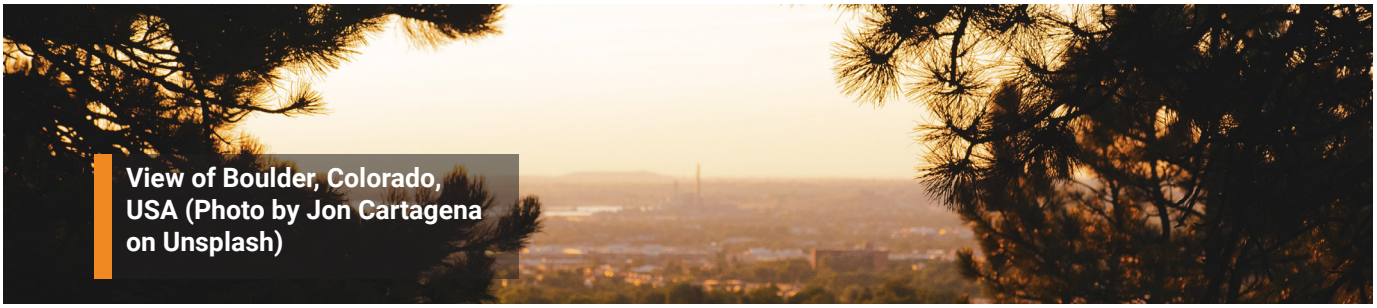
Vision

A better understanding of the Earth through the application of GNSS

Organizational Values

Fundamental to the IGS are key values that are shared across the organization, these are:

- Advocacy of an open data policy, with data and products openly available,
- Welcome contributions from and participation with all organizations,
- Effective reliability through the redundancy of IGS components,
- Technical evolution through “friendly competition”,
- Dedicated engagement with policy entities to raise mutual awareness of IGS and geodesy in general.



View of Boulder, Colorado, USA (Photo by Jon Cartagena on Unsplash)

About the IGS 2022 Virtual Workshop

"Science from Earth to Space"

Our planet is dynamic and ever-changing, and so it seems, is our IGS Workshop planning process, as well. Due to circumstances beyond our control, the IGS needed to move our 2022 Boulder Workshop to a fully virtual format.

We used this change of circumstances to help us refocus the IGS Workshop back to being just that – a community workshop. We operated on a compressed schedule to try to be inclusive to as many time zones as possible, and condensed our workshop program to aspects that are the most critical to the function of our Service, specifically a small number of keynote presentations by luminaries and innovators in our community, supported by a comprehensive agenda of working group and/or topical collaboration sessions. The emphasis was on bringing our community together to discuss key issues and brainstorm the next steps toward a multi-GNSS IGS in service to our global community.
The virtual workshop took pkace the week of 27 June to 1 July, 2022. Key changes included:

- Live Keynote presentations
- Targeted Working Group and topical splinter sessions convened by IGS Working Group Chairs and community leaders
- No Plenaries/Poster sessions, but are effectively already taking place (virtually) via the Tour de l'IGS Mini Workshop Series

Future accompanying events to this workshop include Additional/ enhanced sessions at the December 2022 AGU Fall Meeting for in-person presentations, an Open Associate Member and Working Group Meeting, and 2022 Workshop networking event.

We hope that this new workshop program will help the IGS workshop return to its unique place among our regular meetings, adding value and impact to our profession.

IGS At A Glance

The International GNSS Service (IGS, where GNSS stands for Global Navigation Satellite Systems) is the world's largest GNSS organization, with an over twenty-five years of history of advocating for and providing freely and openly available high-precision GNSS data and products. The IGS consists of over 300 Associate Members (AM), representing over 45 countries and over 200 contributing organizations.

As of early 2021, the IGS consists of over 300 Associate Members, representing over 45 countries. The 36-member IGS Governing Board guides the coordination of over 142 contributing organizations participating within IGS, including 108 operators of GNSS network tracking stations, 6 global Data Centers, 13 Analysis Centers, and 4 product coordinators, 21 Associate Analysis Centers, 23 regional/project Data Centers, 14 technical Working Groups, two active pilot projects (i.e., Multi-GNSS and Real-time), and the Central Bureau.

IGS is a voluntary federation of self-funded agencies, universities, and research institutions all over the world, working together to provide the highest precision GNSS satellite orbits in the world. Access to very high precision products is provided freely and openly for scientific advancement and public benefit. IGS data and analysis products support a wide variety of applications that touch millions of users in virtually all segments of the global economy.

IGS products support access to and realization of the International Terrestrial Reference Frame, providing support for geodetic research and scholarly applications. Furthermore, IGS Working Groups and Pilot Projects work for the continuous development of new and improved applications and products. As a technical service of the International Association of Geodesy, IGS functions as a component of the IAG Global Geodetic Observing System (GGOS) and a network member of the International Science Council's World Data System.

1,428 IGS MAIL SUBSCRIBERS

500+ Worldwide Reference Stations in over **100** countries

300+ Associate Members

142 Contributing Organizations

Providing Data & Products from over **145** Satellites in **4** Global & **2** Regional Constellations

108 Agencies operating GNSS Network Tracking Stations

23 Regional/Project Data Centers

21 Associate Analysis Centers

14 Technical Working Groups

13 Analysis Centers

11 TB (135 million files) over the last 5 years

6 Global Data Centers

Analysis Center Coordinator and Reference Frame

Working Group/Session Chair(s):

Salim Masoumi, Thomas Herring, Paul Rebischung

Rapporteur:

Salim Masoumi

Participants:

~126 Participants

Discussion Highlights:

- IGS Repro3 outcomes and feedback to ACs:
  - IGS Repro3 reference frame outcomes
  - IGS Repro3 orbit/clock/bias combination outcomes
  - Assessment of IGS Repro3 orbits using SLR observations
  - PPP validation of the IGS Repro3 products
- Analysis Center Contributions to the IGS:
  - Establishing an IGS Analysis Center in Japan
- Review of SINEX/orbits/clock alignments for IGS products
- Transition to ITRF2020 and Repro3-standard products:
  - Preparation and implementation of the IGS20/ig20.atx framework
  - Schedule and timeline for the transitions

Key Issues:

- IGS third reprocessing effort (Repro3)
- Transition to ITRF2020
- Review of SINEX/orbits/clock alignments for IGS products
- Multi-GNSS combinations

Emerging Ideas:

- Emerging area of research to improve position estimates and reduce spurious signals in the IGS time series as set in the workshop recommendations

- Investigate terrestrial scale [rate] differences between GNSS and other space geodetic techniques
- Areas of research to mitigate the impact of offsets on the long-term stability of the ITRF as set in the recommendations
- Update of the IGS ACC charter

Major Accomplishments since the Wuhan workshop, and progress on Wuhan (and earlier) workshop recommendations:

- Establish the repro3 models and standards as soon as possible
    - Completed
- Work closely with the AWG on ANTEX file to be used for repro3
    - Completed
- Work towards Multi-GNSS IGS combined products
    - Multi-GNSS combinations (GPS+GALILEO+GLONASS) were completed for repro3; work towards an operational Multi-GNSS combination is in progress and a Multi-GNSS task force was proposed by the Multi-GNSS working group to consolidate the different activities
- Products and formats
    - Formalize an in-house data format for satellite quaternions
        - Completed
    - Use long names for repro3/operational products (MM, in consultation with the IC/DC)
        - Completed for repro3, work in progress as part of the transitions to IGS20 and repro3 standards
    - Determine a clear recommendation for users in case 24h day boundary epochs are added into clock files (Stefan)?
        - 24h day boundary epochs are not added to clock files at the moment.

Recommendations (please include a projected timeline, if possible):

Reference Frame Recommendations:

- Understand higher precision of TUG station position estimates compared to other ACs.
- Aim at further reducing spurious periodic signals in IGS station position time series, by further advances in orbit and tide modeling.
- Investigate terrestrial scale [rate] differences between GNSS and the other space geodetic techniques.
- Aim at mitigating the impact of offsets on the long-term stability of the ITRF by:
    - Investigating in situ antenna calibrations, either absolute or relative;

    - Considering next generation of station installations, less subject to environmental errors;
    - Limiting equipment changes at RF stations.
- Finalize and publish IGS20/igs20.atx by July 22, 2022.

ACC Recommendations:

- Publish the Repro3 combined orbit/clock/bias products along with reference attitudes.
- Consolidate and formalize the assessments of the Repro3 orbits/clock/bias products.
- Work with the Multi-GNSS working group for a Multi-GNSS combination task force; BDS processing.
- Update of the ACC charter, specifically on the process for becoming an IGS AC, but also on the operational model of the ACC (and potentially on its relationship with the Multi-GNSS working group and Multi-GNSS combination task force).
- Decision on CoM vs CoF issue, and recommendation on SINEX/orbit/clock alignment strategies.
- Coordination between ACs and Data Centres for the transition to long filenames.

RF/ACC Recommendations:

- Transition of the IGS products to IGS20/igs20.atx and the repro3-standards (and long filenames) with trial period August-September 2022, and the final switch October 2022. The trial period was further extended post workshop, with the final switch occurring at the end of November 2022.

Which of the IGS 2021+ Strategic Plan Goals and Objectives is your group addressing?

GOALS	OBJECTIVES	STATUS
Goal 1 Multi-GNSS Technical Excellence	Identify impediments to Multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages	Directly working on this objective
	Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components	Directly working on this objective
	Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS	Directly working on this objective

GOALS	OBJECTIVES	STATUS
	Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration	Directly working on this objective
Goal 2 Outreach and Engagement	Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors	Directly working on this objective
	Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications	Indirectly contributing to this objective
	Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists	Indirectly contributing to this objective
	Advocating for standardization and interoperability essential to organizational sustainability and user community engagement	Directly working on this objective
Goal 3 Sustainability and Resilience	Facilitating integration and evolution as both a collaborative research program and operational service	Directly working on this objective
	Coordinating technological and geographical infrastructural innovation and diversity	Indirectly contributing to this objective
	Incubating organizational sustainability and resilience through personnel redundancy and modularity	Directly working on this objective
	Advocating for open access geodetic and Multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas	Indirectly contributing to this objective

At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

Maintaining and improving the IGS contribution to the ITRF, and the access to the ITRF for users of the IGS products, through improvements in the modeling, as well as Multi-GNSS inclusion

What impediments do you think are preventing the group from successfully realizing its recommendations?

Resources are a limiting factor, as the ACC/RF are performing operational routine combinations as well as developments required with the inclusion of Multi-GNSS as well as constantly changing standards and data formats.

Antenna

Working Group/Session Chair:

Arturo Villiger

Rapporteur:

Arturo Villiger

Participants:

~117 Participants

Discussion Highlights:

- Presentation of the planned MGEX extension for the IGS20 ANTEX file
- New project lead for the IGS AWG RingAnt Calibration project

Major Accomplishments since the Wuhan workshop, and progress on Wuhan (and earlier) workshop recommendations:

- Creation of the IGS20 ANTEX file including multiGNSS receiver antenna calibrations
- Start of project ring calibration
- Creation of a small discussion group for the next ANTEX file format

Recommendations (please include a projected timeline, if possible):

- The IGS20 ANEX file shall be extended with BeiDou, IRNSS, and QZSS using, if available, chamber calibrated satellite antenna pattern provided by the system provider. If the phase variation pattern is not available then a zero pattern will be added (with extended nadir angle for LEO POD)
- The listing of receiver and antenna names and ANTEX entries shall be restricted: 1) only geodetic antenna and receivers if the corresponding antenna pattern is provided 2) for coordination of antenna and receiver naming scheme for antenna calibration facilities and regional networks connected to the IGS (e.g., EUREF, SIRGAS, …)
- The IGS AWG entourages the change of lead of the project “Ring-Ant” and supports this project as a crucial part of the antenna calibration comparison / validation activities

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At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

The main target of the AWG is to provide the antenna calibrations associated with the IGS realization to the user community and coordinate activities between calibration facilities as well as antenna related work.

What impediments do you think are preventing the group from successfully realizing its recommendations?

There are many open points and only limited capacity (time availability)

Clock Products

Working Group/Session Chair:

Michael J. Coleman

Rapporteur:

Michael J. Coleman

Participants:

~90 Participants

Discussion Highlights:

- Multi-GNSS Clock Combination
- Clock RINEX File Format Updates
- IGS Leap Second Position

Emerging Ideas:

- Change antenna phase center records in ClockEx file to meters from millimeters.

Any changes or updates to the group's charter, goals, or objectives? If yes, please describe:

The WG charter was updated in 2019 and has been submitted to the CB for posting on the website. There are a number of membership updates over the past few years.

Recommendations (please include a projected timeline, if possible):

- In conjunction with Bias & Calibration WG as well as PPP-AR WG, we recommend discussing the need for multiple clock files depending on signal frequency combination.

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At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

The present goal of this WG is the development and publication of Multi-GNSS clock products in combination with combined bias products. This group will continue to advise relevant IGS subgroups on the interests of clock product users and clock solutions so that the most appropriate products are ultimately generated and disseminated.

What impediments do you think are preventing the group from successfully realizing its recommendations?

The effect of clock biases on several different methods and measurements makes this group's subject area an important intersection for discussion and planning. Because there are several stakeholders, there is a need to collaborate across working groups that is not ordinarily done at any IGS meeting or workshop.

GNSS Monitoring (IGMA), Site Log Manager, and GeodesyML

Session Chairs:

Allison Craddock, Tim Springer, Robert Khachikyan, Brian Kohan, and Markus Bradke

Rapporteur:

Allison Craddock

Participants:

~118 participants

Discussion Highlights:

- International GNSS Monitoring and Assessment update
- Premiere of the new IGS Site Log Manager (SLM 2.0)
- Update from the recently revived metadata ad-hoc task group, and GeodesyML implementation information, including how site log information can be represented using GeodesyML
    - GA and ROB already use GeodesyML operationally
    - New features to include FAIR principles and move away from free-text in favor of creating code lists.

Key Issues:

- IGMA was significantly delayed by the COVID-19 pandemic, it is expected that this group's work will resume by the next ICG meeting, scheduled for October 2022.

Emerging Ideas:

- Defining standardized ways to exchange metadata, such as using RSS feeds, between different organizations
- Linking other instruments/domains, such as seismometers, InSAR corner reflectors.
- Checking incorporation of SensorML

Any changes or updates to the group's charter, goals, or objectives? If yes, please describe:

Metadata ad-hoc task group was revived, with the goal to assist with successful development of SLM and eventual integration of GeodesyML.

Infrastructure Committee, Data Centers, RINEX

Coordinators/Working Group Chair:

Markus Bradke (ICC), Benjamin P. Michael (DCC), Ignacio Romero (RINEX WG chair)

Session Chairs:

Markus Bradke, Benjamin P. Michael, Ryan Ruddick, Wolfgang Söhne

Rapporteur:

Markus Bradke

Participants:

~134 participants

Discussion Highlights:

- An online poll asked participants to answer a series of questions on the future direction of the IGS infrastructure. 80% of attendees participated and contributed 3348 responses.
- Climate change, hazard monitoring and emergence of telecommunication standards were identified as key societal and scientific drivers that will impact on the future direction of the IGS infrastructure.
- There was very strong agreement that the existing network needs to expand to better support existing and emerging community needs.
- There was strong desire to implement modern ways of accessing the IGS data (i.e., APIs) and investigate a more cloud native approach to data storage.
- There was support to investigate a higher tier of data center (global archive) which would set mandatory requirements such as quality control, data synchronization and some form of service level agreement with the IGS.

Key Issues:

- There is no set of minimum requirements that a global data center needs to comply with (accept file uploads, file quality control, etc.).
- Information Security is underestimated and needs to be continuously addressed (e.g., use of unencrypted protocols).

- Improvement on a fully Multi-GNSS network is needed since only 150 of the 512 stations track all signals (e.g., dual-frequency BDS-3).

Major Accomplishments since the Wuhan workshop, and progress on Wuhan (and earlier) workshop recommendations:

2017 Paris

- **2017-1.** To implement a Station product participation table for the IGS station webpage to show each station inclusion in the different IGS products
- **2017-2.** To create a way forward to provide at least weekly positions for ALL IGS network station
- **2017-3.** To investigate and create a plan of what to do with parallel station installation data when upgrading antennas
- **2017-4.** To support the Antenna WG in the new test activity to check available individual antenna calibrations in the existing IGS stations
- **2017-5.** To request NSWE pictures from station antennas especially for those that do provide individual antenna calibrations
- **2017-6.** To request antenna's ground plane distance to the ground (local height) (< 10cm accuracy)

2018 Wuhan

- **2018-1.** To implement IGS Global/Regional DC data/performance checks at the IC
- **2018-2.** To implement across IGS DCs that For each high-rate site 96 sub-hourly files ⇒ 1 daily high-rate tar file
- **2018-3.** To prepare the necessary Terms of Reference and Charter changes to end the DC WG and to create the DC Coordinator position
- **2018-4.** To coordinate DC, IC and NC so as to move away from Z compression for all IGS files (data and products) and into using gzip (.gz)
- **2018-5.** To integrate at the DCs data prior to 2016 in MGEX campaign directories into main GNSS directory structures
- **2018-6.** To prepare and integrate GLONASS data and products into the regular GNSS directory structure (Al for Pat)
- **2018-7.** To prepare and integrate MGEX data and products into the regular GNSS directory structure

Legend:

Partially Implemented **Fully Implemented** **Not Implemented**

Any changes or updates to the group's charter, goals, or objectives? If yes, please describe:

- Role of the Infrastructure Committee chair changed to a coordinator role
- Implementation of the Data Center Coordinator role

Recommendations (please include a projected timeline, if possible):

1. Following input from the community at the 2022 workshop, develop a roadmap to enhance the IGS tracking network to meet the shifting user needs. [2021+ direct alignment - 1.1, 1.2, 1.3, 2.1, 2.4, 3.1, 3.2] (6-12 months)
2. Advocate for the importance of Information security across the IGS to improve the resilience of the infrastructure and increase trust and confidence in our data and products. [2021+ direct alignment - 3.1, 3.2] (6-12 months develop plan and continuous review- security risks don't go away)
3. Explore modern standards, data storage and access methodologies to improve the FAIRness of the IGS data and metadata. [2021+ direct alignment - 2.4, 3.4] (6 - 24 months)
    a. Cloud-based storage formats
    b. API
    c. Implementing GeodesyML across networks/databases
4. Develop a proposal to investigate a higher tier of data center (global archive) which would set mandatory requirements such as quality control, data synchronization and some form of service level agreement with the IGS. [2021+ direct alignment - 3.1, 3.2, 3.4] (12 - 24 months)
5. Actively engage with all working groups to support them in accessing the data and products needed to succeed in their objectives. (continuous)

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At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

To coordinate, sustain and enhance the global IGS infrastructure to ensure the community has secure and easy access to the highest quality Multi-GNSS observation data and accurate station metadata.

What impediments do you think are preventing the group from successfully realizing its recommendations?

- Limited resources
- The voluntary nature of the IGS infrastructure presents a risk to the continuous availability of the data
- Getting the community to support realizing its recommendations

What is one thing that your group members wish the public knew about the IGS?

If you search for independent data and products all around the globe for all four global GNSS systems, the IGS is definitely the right place - so do support our activities.

Ionosphere

Working Group Chair:

Andrzej Krankowski

Session Chairs:

Andrzej Krankowski, Manuel Hernandez Pajares, Ningbo Wang, Iurii Cherniak, Adam Fron, Kacper Kotulak

Rapporteur:

Andrzej Krankowski

Participants:

~61 participants

Discussion Highlights:

- A progress within the real-time global ionospheric maps have been discussed – performance of the two independent IGS combined real-time products has been presented.
- The ROTI ionospheric fluctuation product development towards covering the southern hemisphere and equatorial region has been presented.
- A progress within the cooperation between IGS and IRI groups regarding the development of the VTEC maps as an input for the GIRO GAMBIT system.
- First results of the simultaneous ionospheric observations with GNSS and LOFAR systems have been presented.

Key Issues:

- IGS real-time service for global ionospheric total electron content modeling
- IGS ROTI Maps: Current Status and Its Extension towards Equatorial Region and Southern Hemisphere
- Towards Cooperative Global Mapping of the Ionosphere: Fusion Feasibility for IGS and IRI with Global Climate VTEC Maps
- Cooperation with International LOFAR Telescope (ILT) for potential synergies
- From the VTEC GIMs to the Storm Index GIMs.
- The VTEC GIMs as a reliable source of VTEC gradient information.
- Influence of the temporal resolution in the VTEC GIM performance

Emerging Ideas:

- Moving toward real-time multi-constellation ionosphere products including VTEC maps, ROTI maps, scintillation products.

Major Accomplishments since the Wuhan workshop, and progress on Wuhan (and earlier) workshop recommendations:

- Further expansion of the real-time global ionospheric maps has been achieved – currently two IGS combined real-time products are available (results published in three papers)
- ROTI Northern-hemisphere polar maps are being supplemented with products covering also Southern hemisphere and equatorial region (results published in six papers)
- Four manuscripts concerning cooperation with ILT and IRI communities have been published in high impact factor peer-reviewed journals.

Recommendations (please include a projected timeline, if possible):

- Continuation of work on IGS real-time service for global ionospheric total electron content modeling.
- Preparation of final version of IGS ROTI maps extension towards low latitudes and Southern Hemisphere.
- Continuation of cooperation with IRI and ILT communities.
- Close cooperation with the Real-Time Working Group in order to elaborate full real-time VTEC and ROTI products.

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Goal 3 Sustainability and Resilience	Facilitating integration and evolution as both a collaborative research program and operational service	Directly working on this objective
	Coordinating technological and geographical infrastructural innovation and diversity	Directly working on this objective
	Incubating organizational sustainability and resilience through personnel redundancy and modularity	Not Applicable
	Advocating for open access geodetic and Multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas	Indirectly contributing to this objective

At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

Providing highest possible quality ionospheric products for the geodetic and other science communities, industry, and various other users

What impediments do you think are preventing the group from successfully realizing its recommendations?

There are no particular impediments. The group is continuously improving the quality of the provided products.

What is one thing that your group members wish the public knew about the IGS?

Dedication and selflessness of the researchers participating in international collaborations.

Multi-GNSS

Working Group Chair:

Oliver Montenbruck

Session Chairs:

Oliver Montenbruck, Peter Steigenberger, Gustavo Mansur, Salim Masoumi, Jianghui Geng, Guo Chen

Rapporteur:

Oliver Montenbruck

Participants:

~166 participants

Major Accomplishments:

- Routine generation of Multi-GNSS orbit and clock products for up to 5 constellations by 7 MGEX ACs
- MGEX website transition and maintenance
- RINEX 4 navigation file format definition and product
- Satellite metadata file maintenance

Key Topics:

- Transfer of MGEX products to standard IGS product directory
- Multi-GNSS product combination
    - Orbit/clock product comparison and required harmonization
    - Review of past work on orbit/clock combination (ACC, GFZ, Wuhan Univ., iGMAS) and
    - Discussion of preferred concept for Multi-GNSS orbit combination (constellations, Helmert transformation, VCE, EOPs, weighting)
    - Discussion of clock combination concept (system time, GLONASS handling)
- Metadata SINEX file
- IGS support for GPS L1/L5 users

Discussion Highlights:

- General agreement to full integration of MGEX products into standard directory branch
- Various discussions on possible extensions of current satellite metadata format (clock type, box-wing model parameters, yaw rate). Feasibility/benefit to be assessed. Current contents well received by user community.
- User interest in GPS L1/L5 products is recognized, but varying opinions on preferred approach (bias file for time varying offset between L1/L2 clock and L1/L5 vs. dedicated L1/L5 clock product)
- Lively and controverse discussion on need for coordination/harmonization of concurrent product combination activities within different IGS entities and the range of supported constellations (GGG vs full MGEX)

Recommendations (please include a projected timeline, if possible):

- Relocate all MGEX products to standard IGS products directory
    - Notes: currently products implementation by all DCs coordinated by DCC (Pat and Markus); target date for completion 30 Sep 2023; 2 months lead notice to all users via IGS mail
- Request GB approval for Satellite Metadata SINEX File Format and Product
    - Notes: standardized I/F for satellite metadata for ACs and IGS users, maintained by DLR/GSOC, prototype available from files.igs.org/pub/station/general/ or igs.org/mgex since Jan 2021
- Establish a Task Force to define and implement a tool chain for Multi-GNSS orbit/clock/ (bias, SINEX, EOP) combination and to establish an operational product
    - Notes: taskforce to be composed of interested IGS specialists/volunteers/stakeholders to coordinate concurrent activities of different IGS entities with the ultimate goal of generating comprehensive multi-constellation products in accord with Strategic Plan
- Study options for supporting the GPS L1/L5 user community through dedicated IGS clock or bias products

Which of the IGS 2021+ Strategic Plan Goals and Objectives is your group addressing?

GOALS	OBJECTIVES	STATUS
Goal 1 Multi-GNSS	Identify impediments to Multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages	Not Applicable

GOALS	OBJECTIVES	STATUS
Technical Excellence	Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components	Directly working on this objective
	Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS	Directly working on this objective
	Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration	Not Applicable
Goal 2 Outreach and Engagement	Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors	Not Applicable
	Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications	Not Applicable
	Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists	Not Applicable
	Advocating for standardization and interoperability essential to organizational sustainability and user community engagement	Directly working on this objective
Goal 3 Sustainability and Resilience	Facilitating integration and evolution as both a collaborative research program and operational service	Not Applicable
	Coordinating technological and geographical infrastructural innovation and diversity	Not Applicable
	Incubating organizational sustainability and resilience through personnel redundancy and modularity	Not Applicable

GOALS	OBJECTIVES	STATUS
	Advocating for open access geodetic and Multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas	Directly working on this objective

Precise Point Positioning with Ambiguity Resolution (PPP-AR)

Working Group Chair:

Jianghui Geng

Session Chairs:

Jianghui Geng, Sylvain Loyer, André Hauschild, Peter Steigenberger, Oliver Montenbruck, Zhiguo Deng, Patrick Dumitraschkewitz

Rapporteur:

Jianghui Geng

Participants:

~163 participants

Discussion Highlights:

- Clock/bias combination
  - An operational clock/bias combination process to cross-validate AC bias products
  - Statistics and PPP-AR results illustrated online
- Day boundary discontinuities
  - Reduce day boundary discontinuities of clocks using the integer clock properties
- BDS/QZSS and multi-frequency phase biases
  - Only GFZ and Wuhan provide BDS-2/3 phase biases at the moment
  - GPS L5 as well as all third frequencies for Galileo and BDS

Key Issues:

- Progress of the PPP-AR WG since 2018 Wuhan workshop
- New conventions to be applied to the bias generation
  - Satellite attitude quaternions
  - Antenna PCOs applied to the DCB and Melbourne-Wübbena observable
- Bias products at representative ACs
- Promotion of bias combination
- Roadmap to Multi-GNSS & multi-frequency phase bias products

Emerging Ideas:

- A consensus is needed for the Keyword denoting whether antenna phase centers (APCs) have been applied or not
- Consistent standard and modeling of group-delay variation patterns
- Temporal resolution should be at least equal to the clocks temporal resolution to avoid interpolation problems

Major Accomplishments since the Wuhan workshop, and progress on Wuhan (and earlier) workshop recommendations:

- Promote the recognition of providing satellite attitude quaternions and correcting for PCOs by ACs
- Inspire more ACs to provide phase bias products, especially for BDS and QZSS
- A preliminary consensus on establishing routine combination process for validation and online promotion

Recommendations (please include a projected timeline, if possible):

- Encourage more ACs to provide quaternions whose temporal resolution should be at least equal to that of the clocks and number of decimal digits should be properly set
- Antenna PCO should be considered in DCB and Melbourne-Wübbena computations
- Routine clock/bias combination and visualization online to cross-validate AC products
- Consistent standard and modeling of group-delay variation patterns
- Study how to reduce and calculate day boundary discontinuities of integer clocks and their impact on time transfer
- Study how to produce high-quality BDS/QZSS phase bias products

Which of the IGS 2021+ Strategic Plan Goals and Objectives is your group addressing?

GOALS	OBJECTIVES	STATUS
Goal 1 Multi-GNSS	Identify impediments to Multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages	Indirectly contributing to this objective

GOALS	OBJECTIVES	STATUS
Technical Excellence	Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components	Directly working on this objective
	Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS	Directly working on this objective
	Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration	Directly working on this objective
Goal 2 Outreach and Engagement	Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors	Indirectly contributing to this objective
	Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications	Directly working on this objective
	Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists	Indirectly contributing to this objective
	Advocating for standardization and interoperability essential to organizational sustainability and user community engagement	Indirectly contributing to this objective
Goal 3 Sustainability and Resilience	Facilitating integration and evolution as both a collaborative research program and operational service	Directly working on this objective
	Coordinating technological and geographical infrastructural innovation and diversity	Indirectly contributing to this objective
	Incubating organizational sustainability and resilience through personnel redundancy and modularity	Indirectly contributing to this objective

GOALS	OBJECTIVES	STATUS
	Advocating for open access geodetic and Multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas	Indirectly contributing to this objective

At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

Support high-precision scientific applications requiring globally applicable point positioning technique and rapid access to the international terrestrial reference frame.

What impediments do you think are preventing the group from successfully realizing its recommendations?

Limited resources in some ACs to provide extra satellite products. Insufficient software which requires great efforts and manpower to improve to Multi-GNSS and multi-frequency capability.

What is one thing that your group members wish the public knew about the IGS?

The IGS members work on a best effort and voluntary basis for the benefit of society. This work is expected to be recognized by the academic community and acknowledged in their publications.

Real-Time

Working Group Chair:

André Hauschild

Session Chairs:

Manuel Hernandez Pajares, André Hauschild, Qi Liu, Tomasz Hadas, Xinyuan Jiang, Attila Komjathy

Rapporteur:

Manuel Hernandez Pajares, André Hauschild

Participants:

~169 participants

Discussion Highlights:

- Summary of previous activities from past workshop (10 Minutes)
- Presentations (10 + 5 min) on scientific use cases for real-time products (60 Minutes)
    - Qi Liu, Manuel Hernandez Pajares (UPC)
      "The cooperative IGS RT-GIMs: a global and accurate estimation of the ionospheric electron content distribution in real-time"
    - Tomasz Hadas (UPWR)
      "Overview of real-time GNSS meteorology: ZTD accuracy, horizontal gradients, low-cost receivers"
    - Xinyuan Jiang (GFZ)
      "Real-Time GNSS processing for geohazard early warning: implementation in the EWRICA project"
    - Attila Komjathy (JPL)
      "Ionospheric Detection of the 2022 Tonga Event Using Real-Time GDGPS Observations"
- Roadmap for future IGS real-time activities for 1,3,5 years (20 Minutes)
    - Roadmap items ready for recommendation:
        - Extend IGS-SSR format with new messages for attitude and SRP(APC)/CoM offset (1 year)
        - Define an agreed format and broadcast the RMS map associated to the RT-VTEC product (3 years)
    - Potential roadmap items which need further discussion:
        - Extend IGS-SSR format with new messages for PCV/GDV (3 years)

        - Define an agreed format and broadcast a satellite-dependent slant TEC
          (potential indicators about Slant TEC or Vertical TEC, global VTEC or regional VTEC with sector identifier or spatial range and interval, might be considered) (3-5 years)
    - Further ideas for roadmap from brainstorming during zoom call:
        - Multi-layer RT-VTEC
        - Phase biases for PPP-AR
        - Real-time solar Xray GNSS signal reduction monitoring
        - GNSS signal interference monitoring
        - Message troposphere corrections/estimations
        - Real-Time GNSS-based Integrated Water Vapour (IWV)
        - Integrity messages
        - Potential of using Starlink for correction dissemination
        - For earthquake applications: standard format for station movements
        - Real Time Crustal Deformation Monitoring
        - Real-time time/clock synchronization

Major Accomplishments since the Wuhan workshop, and progress on Wuhan (and earlier) workshop recommendations:

- New experimental Real-Time Ionospheric Combination Product
  (co-operation with IONO-WG)
- Extension of BKG combination to include Galileo and Beidou
  (in addition to GPS & GLONASS)
- Monitoring of AC streams and BKG combination streams extended to cover Galileo (in addition to GPS & GLONASS)
- Improved Broadcast Ephemeris Quality in IGS Combined Streams
- Broadcaster Guidelines released
  (co-operation with infrastructure committee)
- IGS-SSR Multi-GNSS Standard
  released as alternative to RTCM-SSR
- Survey for improved IGS-SSR ionosphere messages (co-operation with IONO-WG)
- Transition to IGS-SSR for the RTS combination and AC products
- Combination performance improvements
- Excluding incompatible solutions from ESOC combination
- Alignment of APC reference points to use single-frequency APC
- Transition to receiver-generated Multi-GNSS RTCM-MSM streams
- Long mountpoint names for all observation/product streams
- Deactivation of CB Caster and Transition to UCAR Caster
- New AC (SHAO, China) & station contributor (USACH, Chile)
- Transition to IGS-SSR for the RTS combination and AC products

- Combination performance improvements
- Excluding incompatible solutions from ESOC combination
- Alignment of APC reference points to use single-frequency APC
- Transition to receiver-generated Multi-GNSS RTCM-MSM streams
- Long mountpoint names for all observation/product streams
- Deactivation of CB Caster and Transition to UCAR Caster
- New AC (SHAO, China) & station contributor (USACH, Chile)

Recommendations (please include a projected timeline, if possible):

1. Extend IGS-SSR format with new messages for GNSS satellite attitude and SRP(APC)/CoM offsets (1 year)
2. Define an agreed format and broadcast the RMS map associated to the RT-VTEC product (3 years)
3. Define a roadmap for future IGS real-time activities based on feedback from virtual workshop (by end of 2022)

Which of the IGS 2021+ Strategic Plan Goals and Objectives is your group addressing?

GOALS	OBJECTIVES	STATUS
Goal 1 Multi-GNSS Technical Excellence	Identify impediments to Multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages	Directly working on this objective
	Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components	Directly working on this objective
	Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS	Directly working on this objective
	Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration	Directly working on this objective
Goal 2 Outreach	Facilitating collaborations with stakeholder organizations and groups to diversify and	Directly working on this objective

GOALS	OBJECTIVES	STATUS
and Engagement	increase participation of IGS users and contributors	
	Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications	Directly working on this objective
	Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists	Indirectly contributing to this objective
	Advocating for standardization and interoperability essential to organizational sustainability and user community engagement	Not Applicable
Goal 3 Sustainability and Resilience	Facilitating integration and evolution as both a collaborative research program and operational service	Not Applicable
	Coordinating technological and geographical infrastructural innovation and diversity	Directly working on this objective
	Incubating organizational sustainability and resilience through personnel redundancy and modularity	Indirectly contributing to this objective
	Advocating for open access geodetic and Multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas	Directly working on this objective

At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

The IGS through its real-time working group (RTWG) is dedicated to provide open data, open products and open standards for real-time users to the GNSS community. The RTWG aims at maintaining high quality data and providing high precision products that are state-of-the-art. It supports their dissemination by improving existing data formats or by developing new standards. The RTWG provides a forum to discuss the development of new methods and algorithms, for example, to improve the performance

of precise point positioning (PPP) techniques in terms of convergence, accuracy and reliability.

What impediments do you think are preventing the group from successfully realizing its recommendations?

The working group has achieved the majority of the goal from the previous workshop in Wuhan. A continuing impediment is that providing real-time corrections as a service free of charge is still perceived as a competition to commercial service providers by some. This might be overcome by emphasizing that the IGS real-time activities are targeted at scientific applications.

Satellite Vehicle Orbit Dynamics

Working Group Chair:

Tim Springer

Session Chairs:

Tim Springer, Rolf Dach, Florian Dilssner

Rapporteur:

Tim Springer, Rolf Dach

Participants:

~84 participants

Discussion Highlights:

- The REPRO3 results show significant orbit model improvements compared to the REPRO2 results thanks to the efforts of all the participating ACs
    - Direct orbit comparisons clearly improved
    - Significant reduction of systematic orbit differences
    - Much improved behavior of the Z-Geocenter and ERPs
- New satellites pose new challenges (GPS III, Galileo FOC)
- Presentations will be made available

Key Issues:

- Reduction, and ideally, removal of orbital periods in the GNSS time series by improving the satellite orbit models
- Handling of ERP rates to be revised in order to establish a more stable quasi-inertial frame (GCRF) for orbit modeling
    - See Beutler et.al. 2016 (IGS Workshop, Sydney)
- Modeling of GPS Block III and Galileo FOC can and need to be improved

Emerging Ideas:

- GNSS SVOD Capacity Development
    - Share and compare orbit models
    - At least make a central depository of relevant publications and models

    - Activities at DLR, ESA, JAXA, JPL, UCL, any others?
- ERP file format harmonization and enhancement of number of digits
- Attitude output (ORBEX format) from all ACs

Recommendations (please include a projected timeline, if possible):

- Improve orbit modeling of the GNSS satellites in the operational products, in particular
    - the GPS Block IIIA satellites
    - the GALILEO FOC satellites (If possible, also the two eccentric satellites)
- Improve orbit quality of the remaining GNSS satellites to bring them to a similar level as the operational products so that they can be included (in particular BDS)
- For next reprocessing the downweighting of known poorly behaving satellites should be considered
    - the GPS satellites with attitude thruster firings (loss of momentum wheels)
    - but also, some GLONASS and other issues
- Develop, share and compare GNSS Orbit Models
    - At least make a central depository of relevant publications and models
    - Activities at DLR, ESA, JAXA, JPL, UCL, any others?
- Harmonize the attitude models used amongst ACs

Which of the IGS 2021+ Strategic Plan Goals and Objectives is your group addressing?

GOALS	OBJECTIVES	STATUS
Goal 1 Multi-GNSS Technical Excellence	Identify impediments to Multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages	Directly working on this objective
	Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components	Directly working on this objective
	Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS	Directly working on this objective

GOALS	OBJECTIVES	STATUS
	Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration	Indirectly contributing to this objective
Goal 2 Outreach and Engagement	Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors	Directly working on this objective
	Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications	Indirectly contributing to this objective
	Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists	Indirectly contributing to this objective
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Goal 3 Sustainability and Resilience	Facilitating integration and evolution as both a collaborative research program and operational service	Directly working on this objective
	Coordinating technological and geographical infrastructural innovation and diversity	Indirectly contributing to this objective
	Incubating organizational sustainability and resilience through personnel redundancy and modularity	Not Applicable
	Advocating for open access geodetic and Multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas	Directly working on this objective

At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

GNSS orbit modeling is the fundamental base for the successful application of GNSS for all science, engineering and society.

What impediments do you think are preventing the group from successfully realizing its recommendations?

Detailed knowledge of the metadata of the GNSS satellite is essential (elements like dimensions, materials, properties, attitude, antenna locations, center of mass, etc. etc.).

What is one thing that your group members wish the public knew about the IGS?

Space is hard! IGS has a lot to do with space!
IGS is not routine, it may be operational but it requires a lot of research!
Friendly competition!

Tide Gauge

Working Group Chair:

Tilo Schöne

Session Chair:

Tilo Schöne, Elizabeth Prouteau

Rapporteur:

Tilo Schöne

Participants:

~49 participants

Discussion Highlights:

- Understanding sea level change and coastal hazards requires a stable reference frame and GNSS@TideGauge time series
- Community appreciates SONELs capability for displaying time series from different solutions/ACs
    - more efforts are needed to (study and) explain differences between solutions at a specific site
- Can we provide better service to non-IGS users, non-GNSS experts?
    - comparison of solutions
    - combination of TIGA-repro3 (GFT and UoL are not in the IGS-repro3 solution)
    - Outreach at sea level conferences

Key Issues:

- Review the status (e.g., coverage) of the TIGA-repro3 contribution, do we meet the requirements of the community (coverage, stability, “products”)
- Need of a dedicated TIGA combination (e.g., with ULR, GFZ, UoL, …)
- Discuss ways to improve the situation with leveling TGBM/ARP
- Impact of Multi-GNSS combinations on long-term homogeneity of the vertical of GPS-only time series (req. sub-mm/a) at tide gauges

Emerging Ideas:

- Work with GLOSS-GE to get feedback for the QoS, define more stations, and connect to the TG community
- Work with IAPSO/CMSLT (President: Gary Mitchum)
    - to define and (later) provide a better service to non-expert GNSS users of time series and trends (what are and why we have different solutions and results)
    - analyze the impact in respect the sea level change estimates
    - Develop a test strategy for time series of GNSS@TG
    - CMSLT plans establishing a working group on GPS/GNSS datums, which will provide an excellent forum to get both communities together
- Develop a “How-to” for the IHO-TWCWG (action item from last GLOSS-GE)
- Guidelines for TIGA-labeled stations should be renewed
    - beyond the IGS CORS Guidelines, reflecting the way of the ARP to the TGZ
    - IOC manuals on Sea Level (IOC Manuals and Guides No. 14: Volumes I–V), especially IV

Major Accomplishments since the Wuhan workshop, and progress on Wuhan (and earlier) workshop recommendations:

- University of La Rochelle and GFZ Potsdam processed large networks of GNSS@TG stations in IGS-repro3, UoLuxembourg plans a dedicated repro3 effort for TIGA
- Results (time series) are (or soon will be) available at the SONEL.ORG
    - TIGA/GFZ-repro3: doi 10.5880/GFZ.1.1.2022.001
    - SONEL ULR7 plans also a DOI
- SONEL acts also as TIGA-WG DC and hosts TIGA-NC
- Collected number of levelling ties increased at SONEL, also integration with PSMSL/IGS
- different studies using results from TIGA solutions
- SONEL provides an excellent service for the GLOSS, TIGA, and sea level community
- TIGA NC at SONEL provides an excellent service to keep the network up-to-date and growing

Recommendations (please include a projected timeline, if possible):

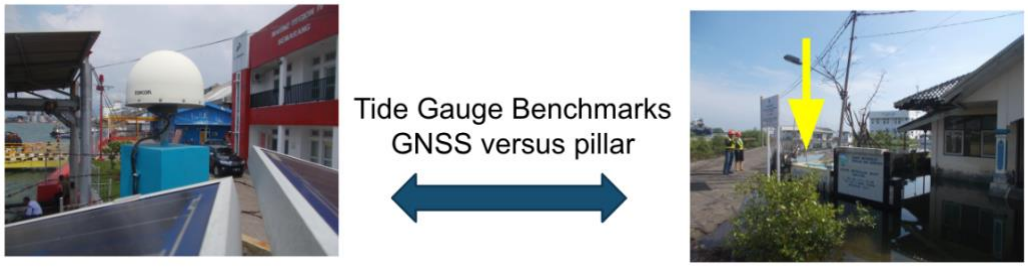
- Non-expert community needs guidelines for the understanding of jumps, drifts, non-congruent GNSS time series from individual solutions

What impediments do you think are preventing the group from successfully realizing its recommendations?

- Decline in number of GNSS@TG stations
- many legacy receivers, delivering GPS-only/RINEX2/spurious data/…
- still leaking sufficient levelling information for >50% of the stations
- need more groups processing TIGA and GNSS@TG stations during repro's

What is one thing that your group members wish the public knew about the IGS?

- IGS provides a service essential to the sea level community by providing the frame where we can study sea level rise, regardless we live in a GIA- or subsidence-prone region.
- GNSS at radar altimetry satellites provides more stable orbits, thus, homogeneous time series of sea level change and results homogeneous to GNSS@TG
- GNSS is increasingly used by the tide gauge community to complement the tide gauge benchmark network and provide stable reference for the TGZ control



Troposphere

Working Group Chair:

Sharyl Byram

Session Chairs:

Sharyl Byram, Jan Dousa, Johnathan Jones

Rapporteur:

Sharyl Byram

Participants:

~60 participants

Discussion Highlights:

- Jan Dousa: “Real-time troposphere monitoring at GOP”
- Jonathan Jones: “GNSS Meteorology at the Met Office”
- Sharyl Byram (session chair)
    - Working Group Presentation and Discussion
    - Charter updates via mailing list
    - IGS Final Troposphere Estimates: status report
    - Updates to FTEs
    - Looking Forward: Recommendations

Key Issues:

- Repro3 processing
- Multi-GNSS testing

Any changes or updates to the group’s charter, goals, or objectives? If yes, please describe:

Charter updates to be discussed via TWG mailing list. Discussion began during IGS WS week.

Recommendations (please include a projected timeline, if possible):

- Test newer troposphere models in final troposphere estimates
  - GMF currently in use
  - Test VMF. Concern with discontinuities between 6-hour releases
  - Investigate other models as well
- Repro 3 reprocessing
  - Investigate suitability of Repro3 combination productions for troposphere reprocessing
  - If suitable, begin troposphere Repro3 reprocessing and evaluation of quality
- Multi-GNSS investigation
  - Begin testing production and analysis quality of a Multi-GNSS final troposphere product
  - Quality analysis of combined observations as well as evaluate individual constellation inclusion

Which of the IGS 2021+ Strategic Plan Goals and Objectives is your group addressing?

GOALS	OBJECTIVES	STATUS
Goal 1 Multi-GNSS Technical Excellence	Identify impediments to Multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages	Directly working on this objective
	Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components	Not Applicable
	Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS	Not Applicable
	Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration	Indirectly contributing to this objective
Goal 2 Outreach	Facilitating collaborations with stakeholder organizations and groups to diversify and	Not Applicable

GOALS	OBJECTIVES	STATUS
and Engagement	increase participation of IGS users and contributors	
	Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications	Not Applicable
	Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists	Not Applicable
	Advocating for standardization and interoperability essential to organizational sustainability and user community engagement	Directly working on this objective
Goal 3 Sustainability and Resilience	Facilitating integration and evolution as both a collaborative research program and operational service	Indirectly contributing to this objective
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	Incubating organizational sustainability and resilience through personnel redundancy and modularity	Not Applicable
	Advocating for open access geodetic and Multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas	Not Applicable

At this point in its development, what does the group think its major purpose is, in the IGS and in the greater geodesy community?

Provide and improve the high-quality troposphere estimates used for GNSS processing as well and countless atmospheric and weather-related science applications

What impediments do you think are preventing the group from successfully realizing its recommendations?

Lack of active participation in carrying out recommendations via projects and putting in time. Lots of great ideas come from the working group but very little offers of performing the work to make the ideas a reality.

2022 Workshop Participants.

(Note: Verbal consent was given to use this photograph)

Looking Forward

Thank you to everyone who attended our first-ever virtual community workshop. The past 2 years have been filled with uncertainty regarding travel and gatherings, and we appreciate everyone who made accommodations and modifications in order to ensure that the spirit of community and collaboration that makes IGS Workshops so special is sustained.

We would also like to thank our colleagues at UNAVCO and UCAR for their enduring commitment to holding this workshop, despite multiple setbacks and unforeseen challenges.

We encourage all session participants to consider how the work discussed this week can support implementation of the IGS 2021+ Strategic plan, which presents a forward-looking strategy addressing the role of IGS as facilitator, incubator, coordinator, and advocate working towards three major goals in service to our community and beyond.

Presentations for this workshop can be found at igs.org/workshop/presentations. Keynote and the Site Log Manager 2.0 Demo videos can be found on our YouTube Channel: youtube.com/igsorg

We hope to see you all in-person at the **IGS 2024 Workshop** in Bern, Switzerland, hosted by the Astronomical Institute, University of Bern (AIUB).

Together, we can build a strong, sustainable, and resilient Multi-GNSS future for our community and the public we serve.

Special Thanks

Scientific Organizing Committee

- Jan Weiss (Chair, UCAR, USA)
- Frederick Blume (UNAVCO, USA)
- Rui Fernandes (University of Beira Interior, Portugal)
- Jianghui Geng (Wuhan University, China)
- Rolf Dach (University of Bern, Switzerland)
- Arturo Villiger (University of Bern, Switzerland)

Central Bureau

- Allison Craddock (Director)
- Mayra Oyola (Deputy Director)
- Ashley Santiago (Product Strategist)
- Robert Khachikyan

Local Organizing Committee

- Frederick Blume (Co-chair, UNAVCO, USA)
- John Braun (Co-chair, UCAR, USA)
- Melissa Weber (UNAVCO, USA)
- Taunia Medina (UNAVCO, USA)
- Jennifer Marrow (UNAVCO, USA)

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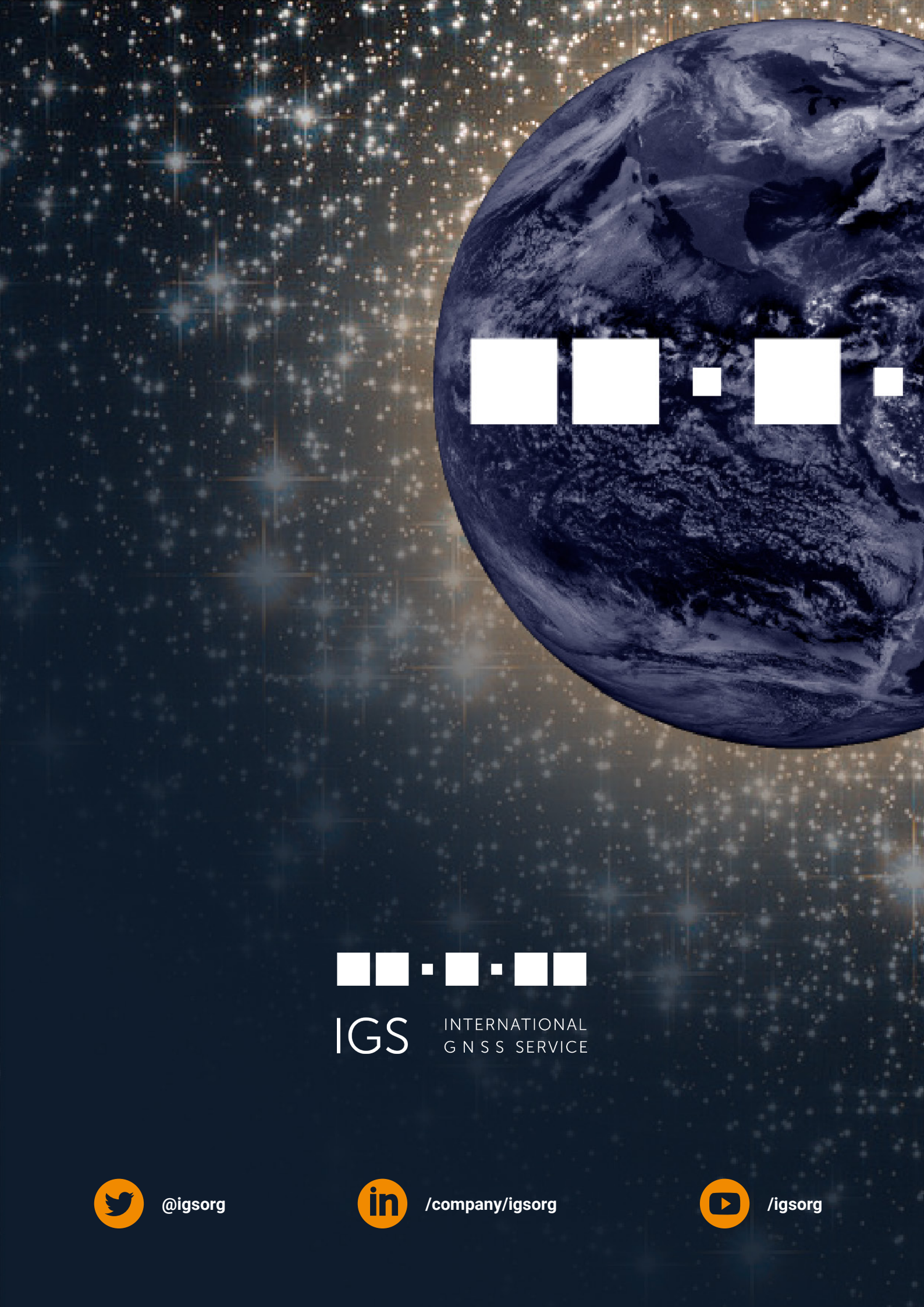
- Judy Donato (UNAVCO's Director of Business Affairs)
- Donna Charlevoix (UNAVCO's Director for Education and Community Engagement)



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