IGS Constellations

The Newsletter of the International GNSS Service

Issue 6 | December 2022

(Banner Image Source: ESA, Florian Dilssner)

Benefits of Galileo satellite metadata for the ITRF2020 realization recognized by the United Nations

by Francisco Gonzalez and Florian Dilssner, ESA

The International GNSS Service (IGS) relies on spacecraft metadata from the GNSS system providers to ensure the highest possible accuracy and robustness of IGS products. Some of those metadata such as the solar radiation pressure and antenna phase center parameters can be estimated from the global GNSS tracking data. The disadvantage of empirically determined parameters, however, is that they tend to absorb the effects of other un-modelled or mis-modelled processes, for example, Earth rotation or geocenter motion.

The importance of metadata for Galileo was already recognized by the scientific community in the early stages of the development of the Galileo project. In 2011, the Galileo scientific advisory committee elaborated a first metadata list which was additionally endorsed by the IGS governing board. The list was formally requested to the Galileo project, paving the way to compile and release the information. In 2016, after a lengthy careful in-orbit validation campaign, the Galileo metadata information was released through a dedicated site. Updates followed each satellite launch.

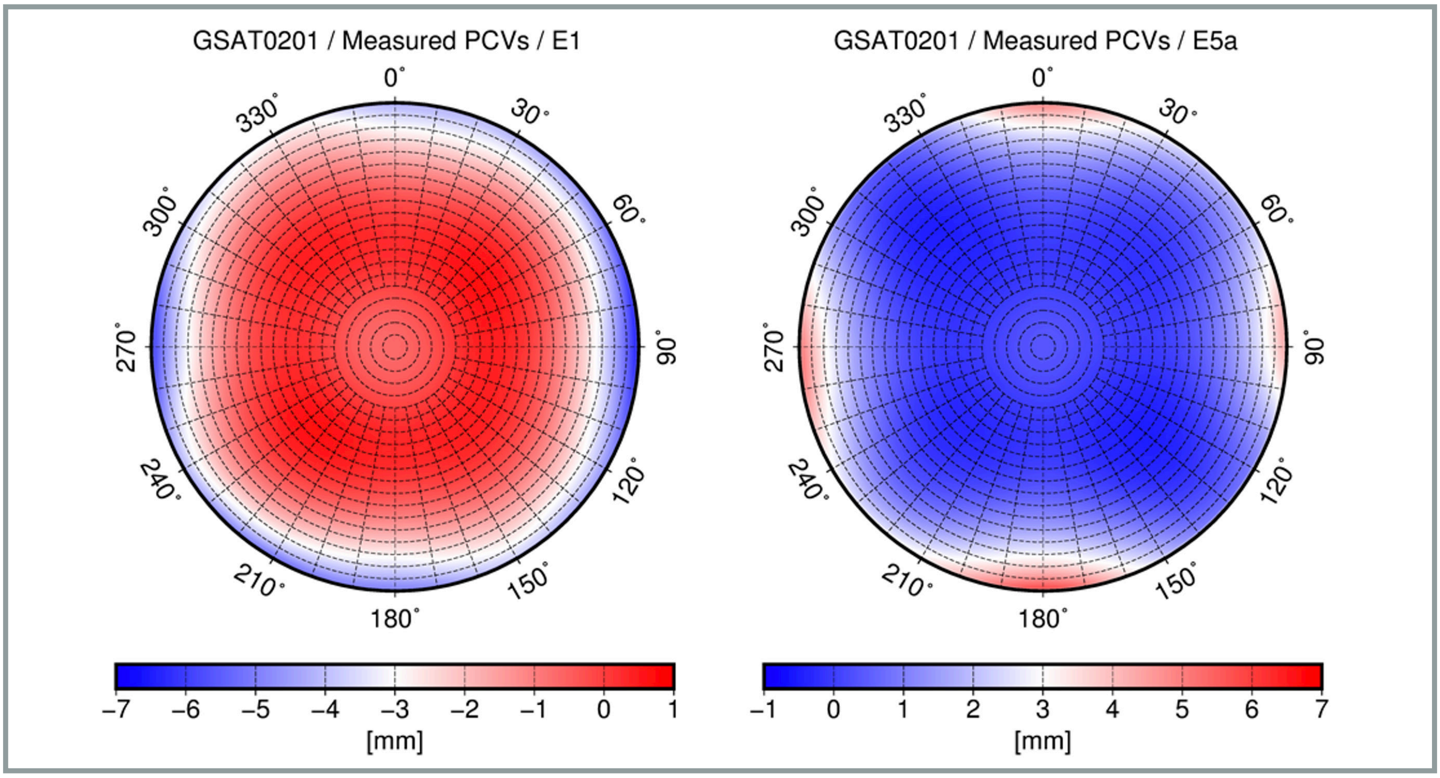

Figure 1: Satellite antenna phase centre variations measured on the Galileo satellite GSAT0201 for E1 (left) and the E5a (right) frequency. Credits: ESA, Florian Dilssner.

One of the main benefits discussed in support of the release was the positive impact on the ITRF scale and thus on satellite altimetry which is critical for water rise measurements and global warming monitoring. Today, ten years later and after the constellation became fully operational, this early vision has come to fruition and was recognized by the United Nations (UN) at the 16th meeting of the International Committee on Global Navigation Satellite Systems in October 2022 by acknowledging that Galileo metadata was used in determining the scale of the GNSS/IGS reference frame in the Repro3 solution, which contributed to the realization of ITRF2020.

Figure 2: Galileo FOC FM2 lowered for mass property test. Credits: ESA-Anneke Le Floc'h

Further improvements will be possible with even better information on the satellite model. As highlighted by the UN join statement, satellite metadata information such as physical and geometrical properties related to the shape, mass, optical properties, dimensions, and locations of radiating antennas permits improved orbit modelling, which in turn increases the accuracy of satellite ephemerides and clock correction determination. The definition of the satellite model in 2011 was elaborated when a priori models were seldomly used in the IGS, while after the release of the metadata information it has become a common practice. The ESA Galileo project is already preparing an update for agreement in the Galileo Programme to implement this recommendation and we look forward to seeing further benefit on the ITRF scale with additional information and a longer data period.

Towards Near-Real Time Detection of Tsunamis

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Tsunamis are natural hazards with high socio-economic impact, but their early detection remains a challenge, due to open ocean buoys failing. However, tsunamis often trigger gravity waves (GWs) that enter the Earth's ionosphere causing electron density perturbations within minutes. Ground-based Global Navigation Satellite System (GNSS) receivers are sensitive to fractional changes in electron density caused by tsunamis, making GNSS ionospheric observations an ideal augmentation system of the open ocean buoy network. A new era of space-based GNSS Tsunami Early Warning Systems (GTEWS) emerged using the world-wide GNSS network to demonstrate tsunami detections at post-processed mode. However, to reduce disaster risk and help contribute to disaster preparedness with better mitigation and response plans, tsunamis must be detected, monitored, and characterized in near-real time (NRT) from space. The steps towards accomplishing these societal needs include the development of an NRT GTEWS software capable of inferring tsunami properties using space-based and ground-based GNSS observables.

The science community has come long way in developing operational NRT GTEWS, and an example of such systems include NASA/JPL's GNSS-based Upper Atmospheric Real-time Disaster Information and Alert Network (GUARDIAN). It uses globally distributed GNSS receivers that monitor the ionosphere every second everywhere under all weather conditions. GUARDIAN has been successfully used to detect the January 2022 Tonga volcanic eruption and a plethora of tsunami events. The next step to NRT GTEWS is to implement Artificial Intelligence (AI) algorithms trained on ionospheric disturbances caused by tsunamis to introduce an autonomous NRT tsunami detection. Finally, NRT GTEWS should be able to also infer the properties of the detected tsunamis based on the associated ionospheric disturbances. To accomplish such a task, the science community needs to first understand how tsunamis dynamically couple with the Earth's lower atmosphere prior to reaching the ionosphere, investigate the detectability thresholds of tsunamis (including meteotsunamis) in the ionosphere, and finally develop inversion softwares capable of estimating tsunami wave heights. The use of neutral atmosphere high vertical resolution temperature measurements is necessary to study the tsunami-generated GWs so that we fill in the knowledge gaps of existing tsunami modeling in the ionosphere. Such research will potentially spur the development of new and innovative tsunami inversion techniques, which are key to further improve the information provided early-warning systems for communities at risk from meteotsunamis/tsunamis and sustainably reduce damage to life and property.

Creation of a new ICG Task Force, "Applications of GNSS for Disaster Risk Reduction"

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This October 2022, all attendees of the 16th meeting of the International Committee on GNSS (ICG) have reached a consensus on the need to create a new ICG Task Force (TF): "Applications of GNSS for Disaster Risk Reduction". Originating from the ICG Workings Groups (WGs) D (Reference Frames, Timing, and Applications) and B (Enhancement of GNSS Performance, New Services and Capabilities), this TF is to be co-chaired between the two WGs, by three ICG members, one of which is to be IGS.

The goal of the TF is to establish new collaborations – between international organizations, space agencies, member countries, and GNSS/RNSS providers – on the topic of using GNSS for disaster risk reduction and natural hazard early warning systems. The scope of activities for this TF includes (1) fostering international recommendations and policies, (2) developing solid science connections to the strategic plans of relevant space agencies and GNSS/RNSS providers, and (3) facilitate collaboration on the development of operational tools.

Four main techniques of interest have been identified. GNSS Reflectometry (GNSS-R) probes the surface conditions, in terms of soil moisture; this applies particularly well to wildfires, flooding, and tsunamis. GNSS Radio Occultation (GNSS-RO) probes the vertical structure of the atmosphere from the surface to mid-stratosphere (40 km), in terms of temperature and moisture, with very high resolution (100 m); this applies particularly well to wildfires, storms, and volcanic eruptions. GNSS Polarimetric RO (GNSS-PRO) extends the capacities of GNSS-RO by allowing the simultaneous measurement of heavy precipitation (in addition to temperature and moisture). GNSS Ground-Based Ionospheric TEC (GNSS-TEC) probes the ionosphere (100-600 km), in terms of Total Electron Content; this applies to any natural disaster creating atmospheric waves propagating vertically (such as tsunamis, volcanic eruptions, and earthquakes), but also to space weather events (such as coronal mass ejections).

A prime example of GNSS-TEC efforts is the GNSS Upper-Atmospheric Real-time Disaster Information and Alert Network (GUARDIAN) system, leveraging the Global Differential GPS (GDGPS) network, managed by NASA's Jet Propulsion Laboratory (JPL). This system (1) collects high-rate ground-based GNSS data in real time from multiple networks of GNSS stations around the world (a majority of which coming from the International GNSS Service network), (2) produces TEC time series, and (3) provides them to the community through a user-friendly web interface. This allows users to monitor the ionosphere in near-real-time, and has for future objective to be linked to other early warning systems – especially for tsunamis.

During ICG-16, a several ICG members have already expressed interest in contributing to these efforts, including volunteer co-chairs. We are currently reaching out to more members of the GNSS community to gather an initial roster of participants. We encourage interested parties to contact the IGS Central Bureau (at cb@igs.org) to join this TF. Regular meetings will start in 2023, beginning with the collaborative definition of more precise goals and means of functioning. Going forward, we hope to help coordinate efforts for the benefit of the populations at risk worldwide.

Acknowledgement: The GUARDIAN research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).

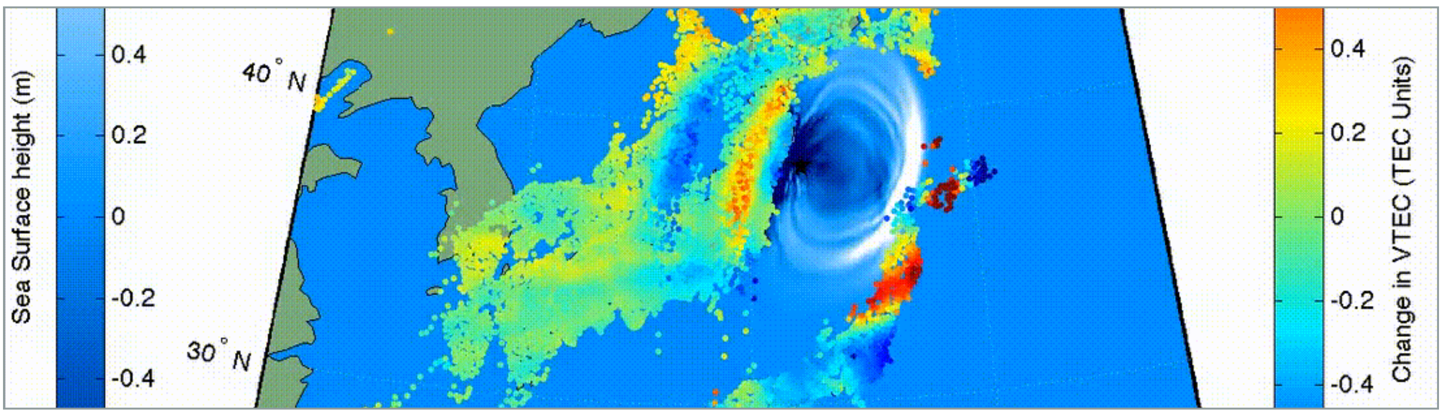

Figure 3: Ionospheric TEC and sea surface height map for the 2011 Tōhoku-Oki event (Galvan et al., 2012, DOI 10.1029/2012RS005023)

AGU Geodesy Section Award

The IGS Central Bureau extends heartfelt congratulations to our current IGS Reference Frame Coordinator, Paul Rebischung, on winning the AGU Geodesy Section Ivan I. Mueller Award for Distinguished Service and Leadership!

Each year, AGU sections recognize those who "dedicated themselves to advancing Earth and space sciences" and grants awards based on their "meritorious work or service toward the advancement and promotion of discovery and solution science."[1] "The Ivan I. Mueller Award for Distinguished Service and Leadership is presented annually and recognizes significant achievements in service to, or leadership in, the geodesy community by a mid-career or senior scientist."[2] This award is named in honor of Ivan I. Mueller, who also happens to be one of the founders of the IGS as head of the IGS Planning Committee from 1989-1991 and served the IGS Governing Board as the IAG Representative from 1993-1999.

Rebischung's contributions to the IGS and geodetic community are extensive, including substantial contributions towards IGS Reference Frame products as well as the Reference Frame working group. "The IGS contribution to the ITRF, and in particular the Repro3 time series of station positions and Earth Rotation Parameters are fundamental and of high quality, thanks to Paul's dedication and excellence in forming the IGS products that have greatly benefited the latest versions of the ITRF, the ITRF2020." says Zuheir Altamimi, current IAG President, Research Director at Institut National de l'Information Géographique et Forestière (IGN).

The IGS would also like to recognize and congratulate former IGS Governing Board member and former IAG President, Harald Schuh, on also winning the AGU Geodesy Section Ivan I. Mueller Award for Distinguished Service and Leadership.

"It is particularly meaningful to me to receive an award bearing the name of Ivan I. Mueller, one of the founders of the IGS. I am certainly honored that my contribution to the IGS and the geodesy community is recognized, but my true honor is simply to be a part of this global, highly stimulating and successful collaboration named IGS. I am looking forward to pursuing this collective, enriching adventure for the years to come!"

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[1] Lozier, S. & Myles, L. T. 2022 AGU Section Awardees and Named Lecturers. Eos (2022). Available at: https://eos.org/agu-news/congratulations-to-the-2022-agu-union-medal-award-and-prize-recipients. (Accessed 21st November 2022)
[2] Ivan I. Mueller award. AGU Available at: https://www.agu.org/Honor-and-Recognize/Honors/Section-Awards/Mueller-Award. (Accessed: 21st November 2022)

Upcoming Events

11 December 2022
IGS 5th AM/WG Open Meeitng (Hybrid)

12 - 16 December
AGU Fall Meeting 2022

12 December
IAG Dinner

CREDITS
Newsletter created and edited by the IGS Central Bureau at NASA Jet Propulsion Laboratory, California Institute of Technology. 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).

Government sponsorship is acknowledged.