IGS Constellations

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(Banner Image Source: U.S National Oceanic and Atmospheric Administration (NOAA))

Real-Time High-Rate Ionospheric Monitoring of Natural Hazards Demonstrated by the Hunga Tonga Eruption

by Léo Martire, Siddharth Krishnamoorthy, Attila Komjathy

Following a series of relatively weak eruptions starting in December 2021, the submerged Hunga volcano in the Kingdom of Tonga produced an extremely large and energetic eruption on the January 15, 2022. The cataclysmic energy release caused unprecedented signals in the atmosphere, ocean, and solid Earth, which circumnavigated the globe multiple times. Audible sound was heard over thousands of kilometres, while both volcanic ash and tsunami waves ravaged the islands that make up Tonga.

Seismic waves from the eruption coupled into the atmosphere, atmospheric waves coupled with the ground and caused meteotsunamis in the ocean, and the tsunami waves produced acoustic-gravity waves in the atmosphere. Atmospheric waves also disturbed the ionized plasma of the ionosphere, the effect of which was observable via measurements derived using Global Navigation Satellite Systems (GNSS) satellites.

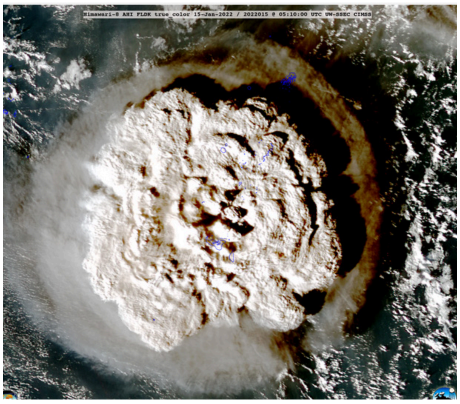

Figure 1 JMA Himawari-8 True Color RGB image (Source: CIMSS, University of Wisconsin-Madison)

The integrated ionospheric electron density per unit area between a GNSS satellite and a fixed ground station, also known as total electron content (TEC), can be derived by computing the phase delay of radio signals between satellites and receivers. Thanks to a wide coverage of ground-based GNSS receivers worldwide constantly monitoring the multiple GNSS constellations[1] orbiting Earth, thousands of receiver-transmitter links are readily available. As a result, one can obtain dense maps of TEC, which can be used to highlight potential ionospheric disturbances.

In particular, the Global Differential GPS network, managed by NASA's Jet Propulsion Laboratory (JPL), collects GNSS data in real time and at the high rate of one sample per second. The GDGPS network sources data from GNSS stations around the world, established both by JPL and by non-JPL entities such as the International GNSS Service (IGS). In the particular case of the Tonga eruption, the stations in the GDGPS network allowed for the real-time monitoring of the ionospheric disturbances following the eruption.

The direct signal from the volcano arrived in the ionosphere merely five minutes after the main explosive event, causing perturbations of more than 6 TECU[2] peak-to-peak, i.e., more than 60 times the usual background perturbation level during quiet geomagnetic conditions. The waves then travelled radially away from the volcano at speeds ranging from 270 m/s to 470 m/s, were clearly seen as far as 10000 km away, and were reported globally. The main signal, which reached the West coast of the USA at a 1 TECU level, was seen circumnavigating the globe alongside its lower-atmospheric acoustic counterpart close to the Earth's surface. Perturbations of lower amplitude were also recorded by the GDGPS network, and are most likely caused by further interactions of the atmospheric wave and tsunami with the upper atmosphere – though further analysis is pending at this time. [Continue on the next page]

[1] Namely: BeiDou, Galileo, GLONASS, and GPS.

[2] 1 TECU = 1016 electrons/m2.

Due to the Hunga volcano being so close to their territories, the sound of the eruption was unfortunately the earliest warning the people of Tonga could benefit from. However, for distant locations, monitoring the ionosphere remains a viable augmentation to natural hazard early-warning systems. Indeed, while seismic networks provide a near-instantaneous response, they often lack accuracy in determining the magnitude of a disaster; moreover, DART buoys offer a direct measurement of tsunami waves, but are only sparsely distributed along coasts. In contrast, the ionosphere reacts relatively early to hazards, and the magnitude of TEC perturbations is often directly correlated to the events themselves (e.g., tsunami waves). Additionally, measurements are typically available over a horizon ranging up to 1000 km away from ground stations.

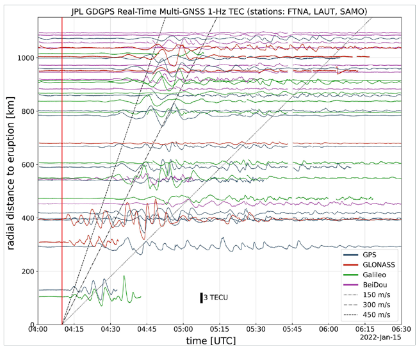

Figure 2 Tonga Eruption Atmospheric Wave. (Source: NASA/JPL-Caltech/GDGPS)

Leveraging the GDGPS network, JPL is currently developing the GNSS Upper-Atmospheric Real-time Disaster Information and Alert Network (GUARDIAN), with the goal of providing a user-friendly interface for ionospheric monitoring and early warning.

Developed under GDGPS and NASA ROSES Earth Surface and Interior and GNSS Research Team Program support.

From the GB Corner

by Mayra Oyola

Figure 3 IGS 58th Governing Board Virtual Meeting

Throughout the COVID-19 pandemic, a major Governing Board (GB) concern was how to support IGS data and products dissemination -- especially during the quarantine lockdown periods when people could not access their respective labs and offices due to global COVID-19 mandates. Despite travel and access limitations, the IGS has continued to support all data and product dissemination with no interruptions. On the administrative side, the Central Bureau has worked to ensure effective governance support through regular virtual GB meetings, accommodating for various time zones and technology bandwidths, and adopting a condensed "live" session with additional items for asynchronous "homework." Through collective efforts and innovative solutions, this has ensured the completion of the IGS Third Reprocessing Campaign (repro3), which supported the development of the ITRF2020.

During the last year, the GB developed and published the new IGS 2021+ Strategic Plan, and is actively promoting revisions to component Charters that are in alignment with the new IGS Goals and Objectives. Similarly, GB members have led the creation and dissemination of the new formats and guidelines, such as RINEX 4.0, the upcoming GDPR Guidelines for the IGS and the new Guidelines for IGS Real-Time Broadcasters and Stations.

As another step towards achieving objectives of the new Strategic Plan, the GB has established the Committee on Sustainable Working Group Governance, which is currently working on creating new guidelines and policies to improve working group activities and management. GB Members have led an Analysis Center (AC) Capacity Development Study to provide updated and transparent guidance to current and future ACs.

The GB also serves as a driving force to sustain and rebuild for robustness, resilience, and alignment/interoperability of IGS resources with other community resources, evaluate the services that the IGS provides and identify new online tools for the community. In 2021, this led to the development of a new IGS network station individual pages and the new on Site Log Manager "SLM 2.0" which will be available later this year, and whose code will be openly available to everyone in the scientific community.

[To continue reading this article, visit From the GB Corner full article on igs.org.]

Women's History Month and International Women's Day 2022

by Ashley Santiago

In celebration of Women's History Month and International Women's Day 2022, the International GNSS Service (IGS) joined the global community by profiling five women in the IGS community who are making contributions to global geodesy for the greater good.

This year's International Women's Day (#IWD) theme is "Gender equality today for a sustainable tomorrow." The United Nations (UN) has observed International Women's Day since 1975, with this year's goal to: "Continuing to examine the opportunities, as well as the constraints, to empower women and girls to have a voice and be equal players in decision-making related to climate change and sustainability is essential for sustainable development and greater gender equality." (United Nations, 2022) Recently, many countries/regions and organizations have extended IWD celebrations throughout the entire month of March, now known as Women's History Month (#WHM).

To meet our featured women for Women's History Month, visit the Women's History Month 2022 and International Women's Day news article on igs.org.

IGS Stations Highlight

by Ryan Ruddick

Geoscience Australia, with support from the local Land and Survey Ministries, coordinates a network of continuously operating reference stations across the Pacific. This network was established as part of the Australian Government's Climate and Oceans Support Program in the Pacific to support the generation of accurate sea level records in the Pacific. The benefits of the data from the network is now being realised for a number of other scientific and societal applications, including the modernisation and alignment of local geodetic datum's with the global geodetic reference frame.

Recently there has been a lot of interest in the data from stations in Nuku'alofa, Tonga (TONG00TON) and Apia, Samoa (SAMO00WSM), which observed the Hunga Tonga-Hunga Haa'pai eruption in January this year.

The stations, which have been part of the IGS network since 2015, will be upgraded this year to improve their resilience and ensure they are able to better support disaster risk reduction and recovery activities.

Site ID: **TONG00TON**
Location: **Nuku'alofa, Tonga**
Established: **2002**
Data Centre: **GA, CDDIS**

Site ID: **SAMO00WSM**
Location: **Apia, Samoa**
Established: **2001**
Data Centre: **GA, CDDIS**

Welcome to the #IGSNetwork!

These new stations above (AC2300USA, ACSO00USA, KSU100USA, P04300USA, P05100USA, P05300USA, P38900USA, and P80200USA) are providing real-time data to the BKG caster. We anticipate the real-time data will eventually be available from the CDDIS and UCAR casters as well. We appreciate UNAVCO for providing the data.

These two stations on the right (AC2400USA and IITK00IND) are providing real-time data to the BKG and CDDIS casters. We appreciate the Indian Institute of Technology Kanpur and UNAVCO for providing this data to the IGS.

For more information, visit the Network page on igs.org.

IGS 2022 Workshop Going Virtual!

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, we will unfortunately need to move our 2022 Workshop to a fully virtual format.

While we will all miss seeing each other in person, we will use this change of circumstances to help us refocus the IGS Workshop back to being just that – a community workshop. We will be operating on a compressed schedule to try to be inclusive to as many time zones as possible, and condensing 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 will be 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.

To learn more, visit the IGS 2022 Virtual Workshop event page on igs.org.

Upcoming Events

Last week of April
Tour de l'IGS 4th Stop

First week of May
IGS Governing Board Meeting

27 June - 1 July
IGS 2022 Virtual Workshop

CREDITS
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