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INVITED TALK

Real-Time Ionospheric Monitoring of the 2022 Tonga Eruption

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1 Introduction

Following a series of relatively weak eruptions starting in December 2021, the submerged Hunga Tonga volcano in the Kingdom of Tonga produced an extremely large and energetic eruption on 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.

2 Acoustic-Gravity Waves

This event excited a multitude of waves in the Earth's atmosphere. A large-amplitude guided atmospheric surface wave (Lamb wave) was produced after the initial shock, and acoustic-gravity waves followed the rising of the volcanic plume. The tsunami caused by the eruption also produced additional gravity waves. Travelling up, these atmospheric waves disturbed the ionized plasma of the ionosphere. Fortunately, the ionospheric total electronic content (TEC) can be derived from ground tracking of Global Navigation Satellite Systems (GNSS) signals [1].

3 GDGPS and GUARDIAN Near-Real-Time Monitoring

Several networks of ground-based GNSS receivers (*e.g.*, the International GNSS Service – IGS) constantly monitor the multiple GNSS constellations orbiting Earth (*e.g.*, BeiDou, Galileo, GLONASS, and GPS), and therefore ensure a worldwide coverage for mapping perturbations in electron densities in the ionosphere. In particular, the Global Differential GPS (GDGPS) network, managed by NASA's Jet Propulsion Laboratory (JPL), streams high-rate GNSS data in real-time from a set of over 200 ground stations, 70 of which are distributed around the Pacific Ring of Fire. Leveraging this capability, JPL is actively developing the GUARDIAN (GNSS-based Upper-Atmospheric Disaster Information and Alert Network) system, its goal being to provide time series of natural-hazard-driven TEC perturbations in near-real-time to a broad audience *via* a publicly-accessible and user-friendly website [2].

4 Results

We present the state of the ionosphere after the Hunga Tonga eruption, as computed from the GDGPS-derived real-time data. We identify the different travelling ionospheric disturbances and attempt to associate them with the various atmospheric waves excited by the volcano. Furthermore, using calibrated absolute TEC derived from JPL's global ionospheric mapping software (GIM), we evaluate the non-linear and long-lasting effects of the eruption on the ionosphere above Tonga. Finally, we also report recent progress made on the development of the GUARDIAN system, and compare its real-time performance to the traditional post-processing of RINEX files.

References

[1] P. J. Teunissen and O. Montenbruck, *Springer Handbook of Global Navigation Satellite Systems*, vol. 18. Cham: Springer International Publishing, 12 2017.

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