Extreme Space Weather Impact on GNSS

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Extended Abstract

The U.S. Global Positioning System (GPS) has generated a multi-billion dollar industry with hundreds of millions of users worldwide. New Global Navigation Satellite System (GNSS) constellations and capabilities are emerging from Europe, Russia and China. By the end of this decade there will be more than 150 navigation satellites transmitting more than 400 multi-frequency signals. The global coverage and positioning accuracy (and new GNSS user services) enabled by these advances will be unprecedented and ubiquitous. Positioning accuracies are approaching the threshold of sub-centimetre globally, with a multitude of new services supporting everything from precision timing to autonomous platforms and drones. It is important to ensure that current and future GNSS services are robust and reliable during severe space weather.

The rapid development of new GNSS capabilities requires ongoing investigations by space weather researchers to quantify, predict and mitigate potential impacts on the integrity, accuracy and reliability of evolving user applications. Characterization of ionospheric phenomena resulting from space weather events is key to such studies, with full knowledge of ionospheric plasma distribution translating directly into effects on GNSS signal propagation and associated user applications. GNSS simulation tools which account for the full range of ionospheric propagation conditions are typically employed in such investigations. It is critically important to ensure that these tools include state-of-the-art current and future GNSS receiver designs and navigation algorithms in order to determine extreme impacts on users. For example, the largest magnitude ionospheric propagation errors may be readily rejected as outliers with minimal user impact while smaller signal perturbations may skew navigation solutions over time beyond acceptable error bounds.

In this presentation we quantify extreme impacts of space weather, via ionospheric phenomena, on GNSS users. We apply models of known ionospheric phenomena – such as aurora, polar patches and storm-enhanced density – in our GNSS hardware and software simulations to generate extreme impact on marine, aviation, and surveying applications. Simulations include 1) large-scale phenomena specification and structures within, both spatially and temporally, and 2) small-scale irregularity specification affecting GNSS signal propagation. Impacts are quantified at the receiver tracking level and in terms of observation/positioning accuracy and navigation integrity. Results are considered in context of current global user standards and needs, and in context of near-future GNSS developments and technological advances.