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Quantifying the socioeconomic impacts of Space Weather in Europe: How costly is the effect of Medium Scale Traveling Ionospheric Disturbances on GNSS positioning?

S. Mainella*(1), P. Vermicelli (2), and J. Urbar(3)

(1) Istituto Nazionale di Geofisica e Vulcanologia (INGV), Rome, Italy; e-mail: sara.mainella@ingv.it;
(2) SpacEarth Technology Srl, Rome, Italy; e-mail: pietro.vermicelli@spacearth.net
(3) Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague Czech Republic; e-mail urbar@ufa.cas.cz

In our previous report [1], we were able to identify which ground-based and space-borne infrastructures are vulnerable to upper atmospheric phenomena (UPA) and critically compare the corresponding socioeconomic estimates available in the literature. This becomes a matter of concern, given the escalating dependence of modern society on technologies susceptible to such space weather events.
We concluded that the costs associated with the risks posed by UPA to critical space-borne and ground-based are high and that the literature focuses mainly on events with low return probabilities (1-30, -100-, or -1000-years events, as defined in [2]). Finally, we stated that the science of the quantification of the socioeconomic impacts of the UPA is not yet mature: It lacks important modeling information, also because of modern society's lack of experience with extreme events, and, as a result, it relies often on qualitative assumptions [3]. To avoid these pitfalls and given the approaching peak sunspot activity of the current solar cycle in 2025, we have decided to analyze UAP that occur during moderate space weather events and whose occurrence and propagation forecast are the object of increased attention and study, for example, within the EU-funded (GA 101081835) T-FORS project. These UPA are the Traveling Ionospheric Disturbances (TIDs), and their relevance in the context of a socioeconomic impacts assessment is secured by their status as "silent killer of the accuracy" of a fundamental service like the GNSS precise positioning with PPP or RTK techniques.

To prove our point, we outline a case study. The St. Patrick's Day storm on March 17, 2015, was the most intense geomagnetic storm of the 24th solar cycle; characterized by a Dstmin index ~-226nT, it is an event with a once-a-year occurrence probability [2], i.e., a moderate one. Poniatoski et al. [4] looked at how Medium-Scale TIDs (MSTIDs) degraded the kinematic PPP of GNSS stations across central Europe. They observed a clear decrease in position accuracy far worse than 1.5 m for all the components during the main phase of the storm in which high-intensity MSTIDs occurred. The observed decreased accuracy was so severe that determining the position was impossible for more than three hours. Given that the positioning accuracy required, for example, by most GNSS applications and technologies in precision agriculture (PA) is <1m [5] and that the cost of a GNSS outage for an hour to this sector is ~€200K (authors' estimates), we can estimate the cost of the St. Patrick's Day storm for the PA sector as €600K. By extrapolating from this example, we can answer our question of how costly the impact of MSTIDs on GNSS positioning would be. We will start by drafting a more general assessment of the decrease in position accuracy and the time extension to be expected under different storm scenarios. From there, we will achieve our goal by combining that information with the GNSS requirements across several sectors and relying on existing techniques [3] to estimate the socioeconomic costs of GNSS outages caused by MSTIDs.

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