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Impact of geomagnetic storms and ionospheric disturbances on mid-latitude station's coordinates using static and kinematic PPP

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Geomagnetic storms can cause irregularities in the ionospheric electron density, which can affect GNSS positioning and even cause signal's scintillations. The first order ionospheric effect can be eliminated through an ionosphere-free solution, but higher order terms remain and may cause artificial coordinate variations to be considered in precise GNSS applications.

In this study, we investigate effects of severe space weather events on coordinate estimation using Precise Point Positioning (PPP) in mid-latitude region (Sarajevo, Bosnia and Herzegovina) and the significance of remaining high-order ionospheric (HOI) terms. The analysis covers the periods March 2015 and September 2017, when the strongest geomagnetic storms of the solar cycle 24 occurred. These periods represent different years of solar cycle with a different level of solar activity, which reached its maximum in April 2014. Solar activity level and conditions in the Earth's magnetic field were described with solar and geomagnetic indices. Ground based GNSS (GPS+GLONASS) observations of the European Permanent Network (EPN) station SRJV were applied to calculate the total electron content (TEC) in the ionosphere and perform coordinate estimation. Two PPP methods were used: static PPP, providing daily-based results, and Pseudo–Kinematic PPP with 300 s sampling interval to observe coordinate variations. Data were processed with and without applying HOI corrections using Bernese v.5.2 GNSS scientific software package. The HOI delays were obtained by difference between the results of these two approaches. Positioning results were compared to the weekly combined EPN position solutions.

Results showed that the solar activity level was generally higher during March 2015, except for a few days before the geomagnetic storm in September 2017, when it significantly increased. Severe disturbances were observed in Earth′s magnetic field for both study cases. They caused sudden variations of the ionospheric TEC, which were twice greater during the storm in March 2015. Resulting coordinate differences were at the cm-level in the static and at the dm-level in the kinematic PPP. Standard deviations of coordinate components (north, east, up) were at mm-level for the static and cm-level for the kinematic approach, while up components showed averagely twice higher deviations than the north and east components. Analysis showed that the coordinate variations, standard deviations and HOI values were greater during March 2015, for both PPP strategies, and the TEC variations were more pronounced as well. This could be related to the influence of a different phase of solar cycle, despite the occurrence of severe geomagnetic storms.