Space weather effects of the 6 September 2017 X-class solar flares

Y. Yasyukevich[1], E. Astafyeva[2], A. Padokhin[3], V. Ivanova[1], S. Syrovatskii[1,3], and A. Podlesnyi[1]

1 - Institute of Solar-Terrestrial Physics SB RAS, Irkutsk, Russia,

2 - Institut de Physique du Globe de Paris (IPGP), Paris Sorbonne Cité, University, Paris, France,

3 - Faculty of Physics, Lomonosov Moscow State University, Moscow, Russia

Solar flares (SFs) are the most intensive "disturbers" of the space weather. The increased level of extreme ultraviolet (EUV) and of X-ray radiation results in ionization in the ionosphere on the sunlit side of the Earth and causes absorption in the lower ionospheric D layer, which lead to degradation or complete absorption of high-frequency signals. The current 24th solar cycle began in December 2008 and is now decreasing in intensity and heading toward the solar minimum. However, despite the low solar activity period, a series of powerful SFs occurred in September 2017. On 6 September 2017, the Sun emitted two significant solar flares. The first SF, classified X2.2, peaked at 09:10 UT. The second one, X9.3, which is the most intensive SF in the current solar cycle, peaked at 12:02 UT and was accompanied by solar radio emission. We study ionospheric response to the two X-class SFs and their impact on the Global Navigation Satellite Systems and high-frequency (HF) propagation.

We used data of X-ray flux measured by GOES-13, Solar radio emission from San Vito radiospectrograph of Radio Solar Telescope Network, SOHO/SEM EUV flux at 0.1–50 nm and at 26–34 nm, ionospheric total electron content (TEC) as well as phase measurements from GPS/GLONASS networks, vertical TEC from Madrigal database, geostationary TEC based on Beidou-GEO measurements, Oblique-incidence HF-ionosonde sounding.

In the ionospheric absolute vertical TEC, the X2.2 SF caused an overall increase of 2–4 TECU on the dayside. The X9.3 SF produced a sudden increase of ~8–10 TECU at midlatitudes and of ~15–16 TECU enhancement at low latitudes. These vertical TEC enhancements lasted longer than the duration of the EUV emission. In TEC variations within 2–20min range, the two SFs provoked sudden increases of ~0.2 TECU and 1.3 TECU. Variations in TEC from geostationary and GPS/GLONASS satellites show similar results with TEC derivative of ~1.3–1.7 TECU/min for X9.3 and 0.18–0.24 TECU/min for X2.2 in the subsolar region. Further, analysis of the impact of the two SFs on the Global Navigation Satellite Systems-based navigation showed that the SF did not cause losses-of-lock in the GPS, GLONASS, or Galileo systems, while the positioning error increased by ~3 times in GPS precise point positioning solution. Based on our results, and comparing to previous works where even 4,000–12,000 sfu caused degradation of GNSS signals, nowadays SFs seem to be less threatening for the GNSS operation. The two X-class SFs had an impact on HF radio wave propagation causing blackouts at <30 MHz in the subsolar region and <15 MHz in the postmidday sector.