Solar flare effect on the ionospheric current in the polar region: a new phenomena

Masatoshi Yamauchi1, Magnar Johnsen2, and Carl-Fredrik Enell3

1Swedish Institute of Space Physics, Kiruna, Sweden (m.yamauchi@irf.se)
2Tromsø Geophysical Observatory (TGO), UiT the Arctic University of Norway, Tromsø, Norway
3EISCAT Scientific Association Headquarter, Kiruna, Sweden

Solar flares are known to enhance the ionospheric electron density in the D- and E-region, enhancing twin vortex pattern in the dayside (e.g., Curto et al., 1994). The geomagnetic deviation due to this current system is called as "crochet" or "SFE (solar flare effect)". For X-flares, the crochet is easily detected as an enhancement in ASY-D index (Sing et al., 2012). Since the effect is expected stronger at low solar zenith angles where solar radiation is high, high-latitude behavior (> 70° geographic latitudes: GGLat) has not been well studied and simply assumed as minor (such as weak return current).

However, the X flares on 6 September 2017 (X2.2 at 9 UT and X9.3 at 12 UT), caused large non-substorm geomagnetic disturbances at high latitudes, lasting much longer than the burst of electron density enhancement in the the D- and E-region (Yamauchi et al., 2018). Both the polarity and duration turned out to be different from mid-latitude crochet which is characterized by short-lived (< 30 min) dH<0: dH is positive for over 5 hours with much higher amplitude than the crochet although the event took place near equator. In addition, this dH showed oscillations on the order of 30 minute. Since the X-ray intensity during 12-17 UT was higher than X-flare criterion until 17 UT, this long-lasting dH>0 with peak at 74-75 GGLat must also be caused by the X-flare. The EISCAT radar data showed strong enhancement of convection lasting hours after the flare onset and relevant bursty (< 10 min) enhancement of the electron density. This is consistent with long-lasting positive dH. On the other hand, density oscillation period is about 15 min and different from the oscillation period of dH.

Using Norwegian geomagnetic chain and EISCAT data, we examined X flares (> X2.0) for past two solar cycles, and found that (1) dH>0 at > 70 GGLAT with dH<0 (and positive ASY-D change is quite common) at lower latitude, (2) duration of crochet (dH<0) is shorter at higher latitude as the start timing and amplitude of dH>0 becomes earlier and larger at higher latitude, (3) at some latitude, crochet (dH<0) disappears and dH>0 dominates the entire period much longer than the crochet, and (4) electron density enhancement is spike-like no matter the duration of X-flare. We interpret this long-lasting dH>0 is caused by independent mechanism from crochet.

Reference