Ionospheric Variability due to Solar Flares

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There are a myriad of mechanisms that produce variability in the ionosphere. The focus here is on the variability introduced on the ionosphere from solar flares. With durations ranging from minutes to hours, solar flares provide strong impulsive radiation and energy injection to the sunlit upper atmosphere. The increased level of X-ray and extreme ultraviolet (EUV) radiation leads to sudden changes in ionization in the lower layers of the ionosphere. The global network of GNSS receivers can be used to monitor changes in the total electron content (TEC), and because GNSS is extremely sensitive at measuring the changes in TEC, the temporal, latitudinal, and solar zenith dependencies following solar flares can be studied in detail. Changes in electron density and temperature as a function of height can be monitored by incoherent scatter radars. We focus here on the four significant X class flares that occurred between 6-10 September 2017. These flares are listed in Table 1.

TABLE 1. X-Class Flares in September 2017.

Flare Size	Date	Day of Year	Start Time	Maximum	Stop Time
X9.3	2017/09/06	249	11:53	12:02	12:10
X8.2	2017/09/10	253	15:35	16:06	16:31
X2.2	2017/09/06	249	08:57	09:10	09:17
X1.3	2017/09/07	250	14:20	14:36	14:55

Figure 1 shows the impact on the ionosphere following the X9.3 solar flare on 2017/09/06. In this case, a low-pass Savitzky-Golay low pass filter using a 1 hour window was applied to the data. The area in shadow represents that area in night. The effect of the enhanced ionization due to the solar flare is clearly visible, and is of the order of 1 TEC unit, covering the entire sunlit part of the globe. The time period shown is close to the maximum time of this solar flare.

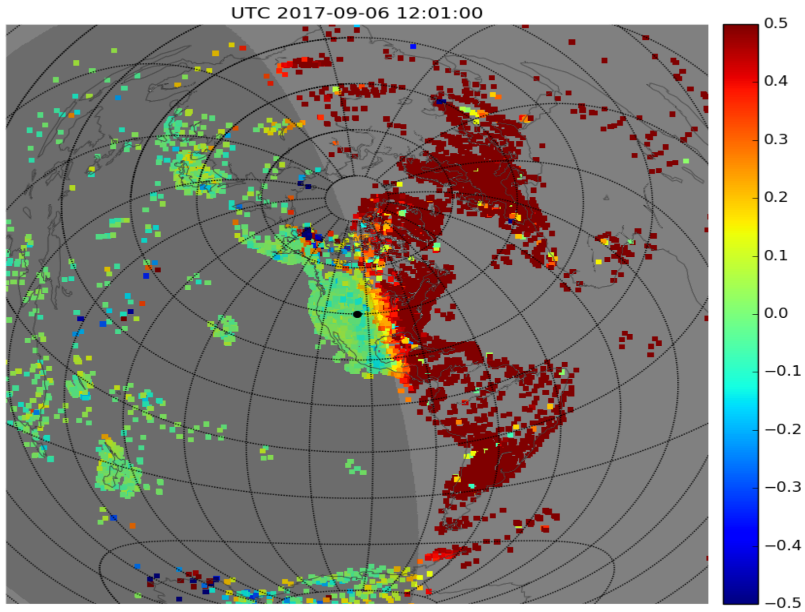

Figure 1. Increased TEC observed over entire sunlit region on 6 September 2017.

The Millstone Hill incoherent radar captured some of these September flares including the ones on the 6th and 10th. An increase in the E-region and F1-region electron density was clearly visible in the incoherent scatter measurements. The radar was also collecting plasma line data throughout this time period, providing highly accurate absolute electron density observations at certain altitudes. Radar observations show also clear changes in the ion drift and plasma temperatures associated with sudden energy injection by the flares. We will present an overview of the data gathered during these solar flares.