Final Report for Grant number NAG5-13507

Project Title: Ionospheric Response to Short Term Variations in the Solar Flux

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As a result of this effort, there is now a significantly better understanding of how to use full disk solar irradiance measurements, such as those from TIMED/SEE to improve models of the ionosphere and how much improvement such measurements can provide. We have also enhanced the understanding of the dependence of the ionosphere on geomagnetic activity.

The three most important results from the research effort:

1. Total electron content (TEC) is influenced as much by the random (non-periodic) variations in the Solar soft X-ray irradiances during the previous three days as it is by the periodic, 27 day solar cycle

2. Peak electron densities (f_oF2) are best correlated with Solar soft X-rays for time scales of < 27 days, but best correlated with Solar extreme ultraviolet (EUV) at longer time scales

3. TEC at the equator shows a clear correlation with geomagnetic activity (Dst) even during quiet conditions

are discussed in more detail below.

1. Total electron content (TEC) is influenced as much by the random (non-periodic) variations in the Solar soft X-ray irradiances during the previous three days as it is by the periodic, 27 day solar cycle

The Total Electron Content (TEC) measurements are correlated with the random variations in full disk solar irradiance one each of the three previous days, as shown in Figure 1. The magnitude of this effect is as large as that of the 27 day period of the Sun's irradiance. Significant correlations are seen well beyond the recombination time for the ionosphere, which is less than a day. Although the observations analyzed do not provide the reason for the persistence of the correlations, changes in the neutral density and composition which lag solar changes by approximately one day and may be responsible. These results are based on comparisons of TEC from an equatorial station in the American sector (Jicamarca, Peru).

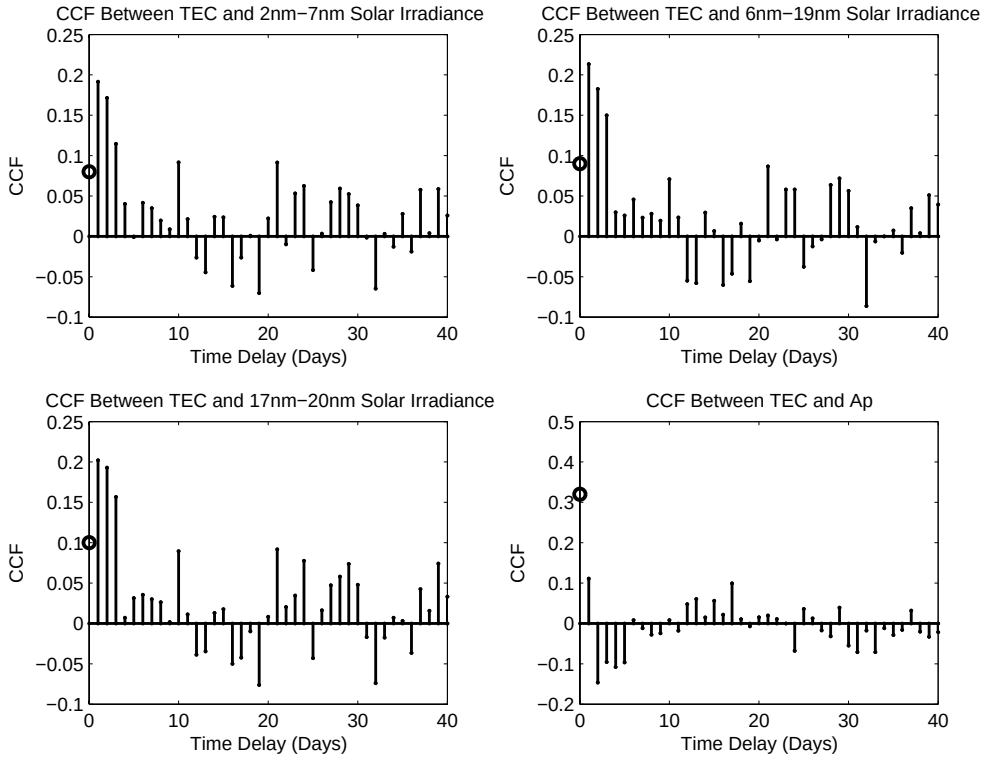

Figure 1. Cross-correlation of the TEC with the solar soft X-rays and Ap after removing the periodic variations and the autocorrelations within each set of data. A CCF value of 1.0 would indicate a perfect correlation between two signals in the comparison, and values of less than 0.087 are below the noise level. These values indicate significant correlations between the TEC and the X-ray irradiances on the previous 1-3 days still exist.

2. Peak electron densities (f_oF2) are best correlated with Solar soft X-rays for time scales of < 27 days, but best correlated with Solar extreme ultraviolet (EUV) at longer time scales

Soft X-rays show similar or higher correlation with f_oF2 at short timescales (27 days or less) than EUV does (Figure 2), although the correlation with EUV is higher for longer periods (Figure 3). For the short-term variations, both SNOE and TIMED observations have a higher correlation in the morning (~0.46) than in the afternoon (~0.1). In the afternoon, SNOE observations have a higher correlation (~0.2) with foF2 than the TIMED observations (~0.1 correlation), which may be due to differences in the solar cycle. At morning times, foF2 has a ~27-day variation, consistent with the solar rotation rate. After noon, but not in the morning, a ~13.5-day variation consistently appears in foF2. This ~13.5-day variation is attributed to geomagnetic influences.

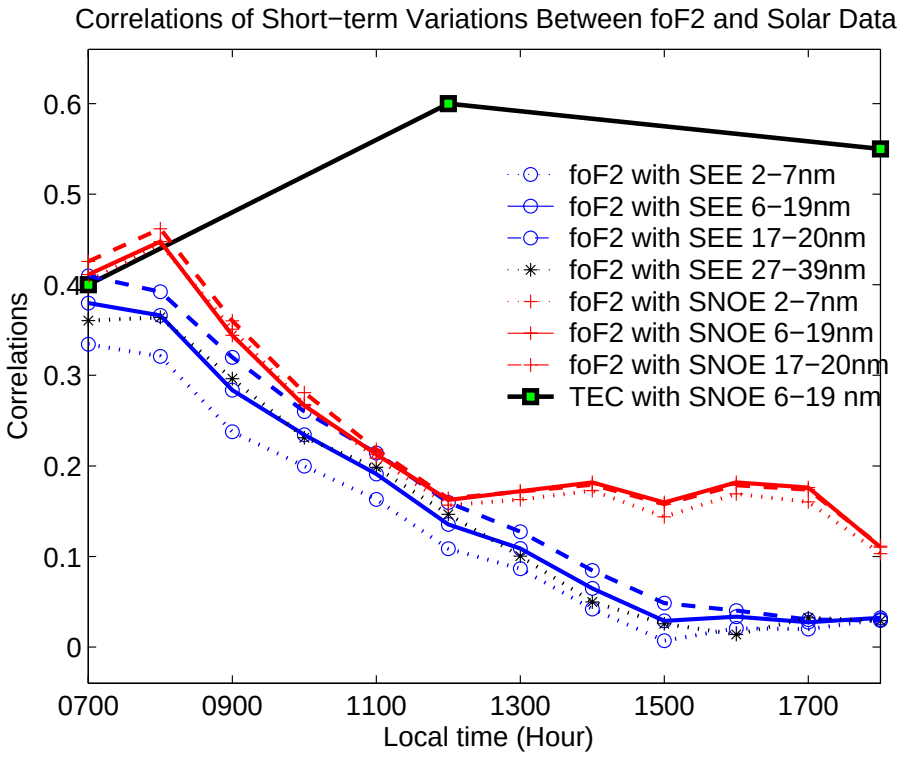

Figure 2. Correlations of short-term variations (27 day and less) in the daily solar irradiances and hourly f_oF2 data. For comparison TEC from GPS observations are also shown, which shows an opposite trend and higher correlations than f_oF2 with solar irradiance.

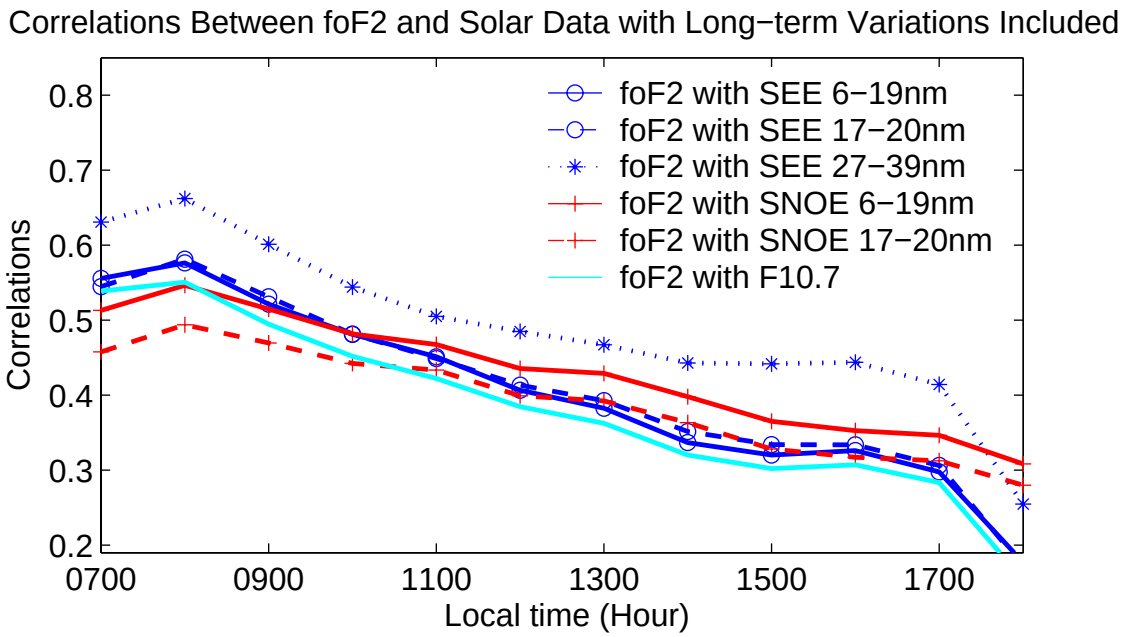

Figure 3. Correlations between solar irradiances and f_oF2 when the long term (> 27 day) changes are included.

3. TEC at the equator shows a clear correlation with geomagnetic activity (Dst) even during quiet conditions

The total electron content (TEC) at an equatorial station in the American sector (Jicamarca, Peru) shows clear correlations with the Dst index, a proxy for equatorial geomagnetic activity even during magnetically quiet times. At time scales of 2-3, 3-5, 5-9 and 9-11 days, there are significant correlations (~ 0.4 at local noon, when all the data are included, as shown in Table 1) between TEC and Dst. These correlations increase from morning to afternoon, as shown in Figure 4. Even during geomagnetically quiet times (Dst > -20), a clear correlation, 0.21, which exceeds the 95% confidence level of 0.14 for the 2-3 and 3-5 day periods, is seen between TEC and Dst at the shortest time scale examined. (The 95% confidence level is 0.24 for 5-9 and 9-11 days results.) As geomagnetic activity increases, the correlations increase rapidly. When moderate levels of geomagnetic activity (Dst > -50) are included for observations at local noon, distinct correlations (~0.3) are seen and persist for all but the longest time scale; with higher levels of geomagnetic activity included there are distinct correlations at all the time scales examined . The presence of a significant correlation during quiet conditions and persistence of the correlation at moderate levels of activity are both unexpected.

Table 1. Cross correlations between TEC and Dst at noon time under different geomagnetic conditions

Periods	Dst>-20	Dst >-50	Dst all
2-3 day	0.21545	0.36864	0.43005
3-5 day	0.15581	0.30953	0.41464
5-9 day	0.14066	0.30759	0.45501
9-11 day	0.16629	0.19556	0.30294

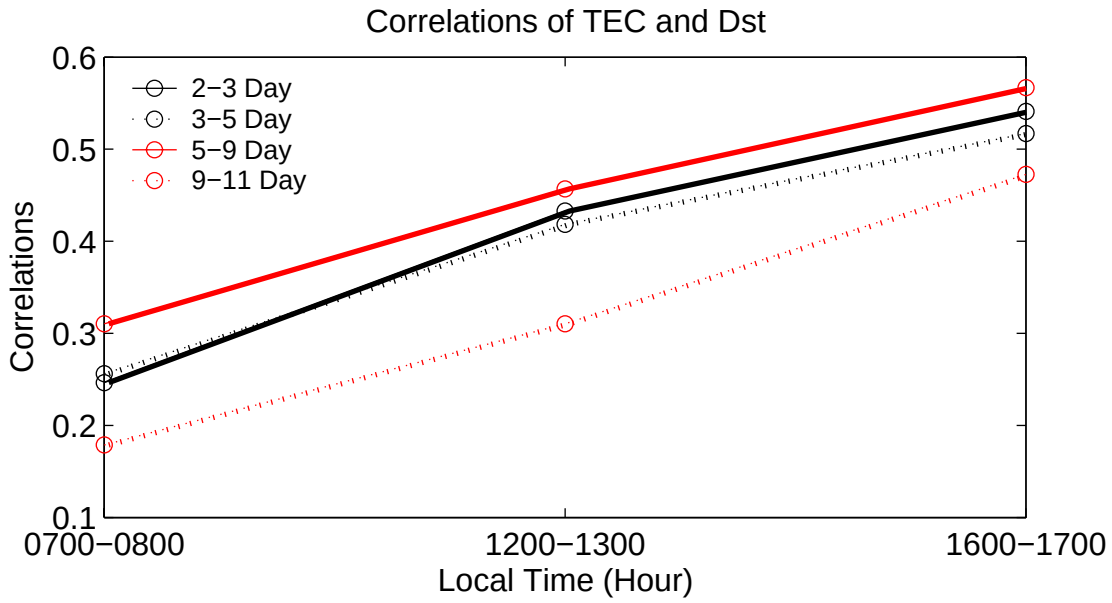

Figure 4. Correlations between Dst and TEC at Ancon, Peru as a function of local time.

Three papers were completed under this effort:

Wang, X., Q. Sun, R. Eastes, B. Reinisch, and C. E. Valladares, Short-term relationship of Total Electron Content (TEC) with geomagnetic activity in the Equatorial region (in review).

Wang, X., R. Eastes, B. W. Reinisch, S. Bailey, C. E. Valladares, and T. Woods (2007), Short-term relationship between solar irradiances and equatorial peak electron densities, *J. Geophys. Res.*, 112, A06310, doi:10.1029/2006JA012128.

Wang, X., R. Eastes, S. Weichecki Vergara, S. Bailey, C. Valladares, and T. Woods (2006), On the short-term relationship between solar soft X-ray irradiances and equatorial total electron content (TEC), *J. Geophys. Res.*, 111, A10S15, doi:10.1029/2005JA011488.