EUV irradiance monitoring and forecasting of strong and extreme solar events from polar cap observations of TEC

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Abstract

The F-region above 270 km is sunlit at all local times and seasons at latitudes higher than 75 degrees in the polar cap. This gives a direct indication of the effect of solar EUV activity at the dayside of the Earth. GNSS slant-TEC measurements covering the local time sector from 9:00 to 15:00 LT reveal primarily the changes in the solar EUV irradiance. The main error source in the TEC observations here originates primarily from polar cap patches moving towards the night sector and varying plasma decay rates. Applying a running one-hour average filters out most of the changes caused by polar cap patches. In this study, observations from the polar cap GNSS station in Thule, Greenland, (at a latitude of 76.5 degrees) have been used to identify and forecast enhanced solar EUV activity. The results have been compared with measurements from the SORCE satellite in the frequency range from 100 to 120 nm. The monitored enhanced TEC-values and derived solar irradiances (mostly due to flares and CMEs) occurred minutes after they were observed at the sun, which shows the strong forecast capability of technique. Most of the observed phenomena, which propagated towards Earth, impacted a few days later the magnetosphere-ionosphere system. We studied a 4-year data set (2012 - 2015) of slant-TEC observations derived from the Thule GNSS station and compared the data sets with observations from the SORCE satellite of solar EUV emissions. The statistical correlation coefficient between the two data set became 0.7. Both data sets identified clearly the 27-day variations in the solar spectral irradiance for wavelengths in the EUV spectrum (with amplitudes of 10-15 TECU). The polar cap EUV index showed also higher mean-TEC variability near the equinoxes and in summer-time. During summer, the F-region cross-field plasma diffusion rates are increased when an underlying conductive E-layer is present. During the winter, the insulating E-layer slows the F-layer plasma decay rate, thereby allowing F-layer structures to survive significantly longer.

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EUV irradiance monitoring and forecasting of strong and extreme solar events from polar cap TEC observations

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Abstract

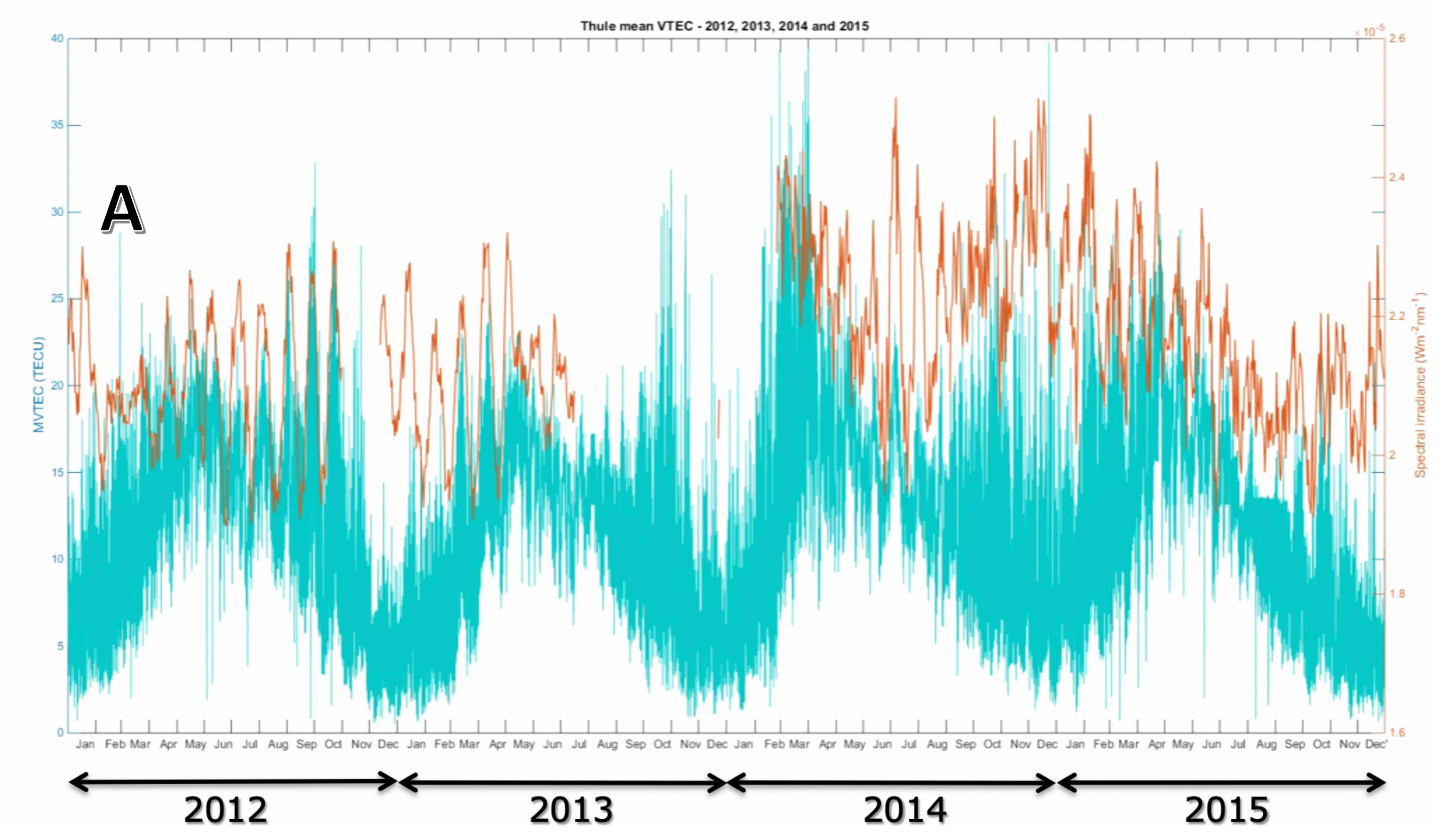
The F-region above 200 km altitude is sunlit all year long in the local time sector from 9:00 to 15:00 LT for latitudes higher than 75 degrees in the polar cap. This gives a direct indication of the effect of solar EUV activity on the dayside of the Earth. GNSS vertical TEC measurements covering this local time sector (**A**) reveal the changes in the solar EUV irradiance (**B**, **C**). The main error source in the TEC observations originates primarily from polar cap patches moving towards the night sector and varying plasma decay rates. Applying a running one-hour average filter eliminates most of the changes caused by polar cap patches.

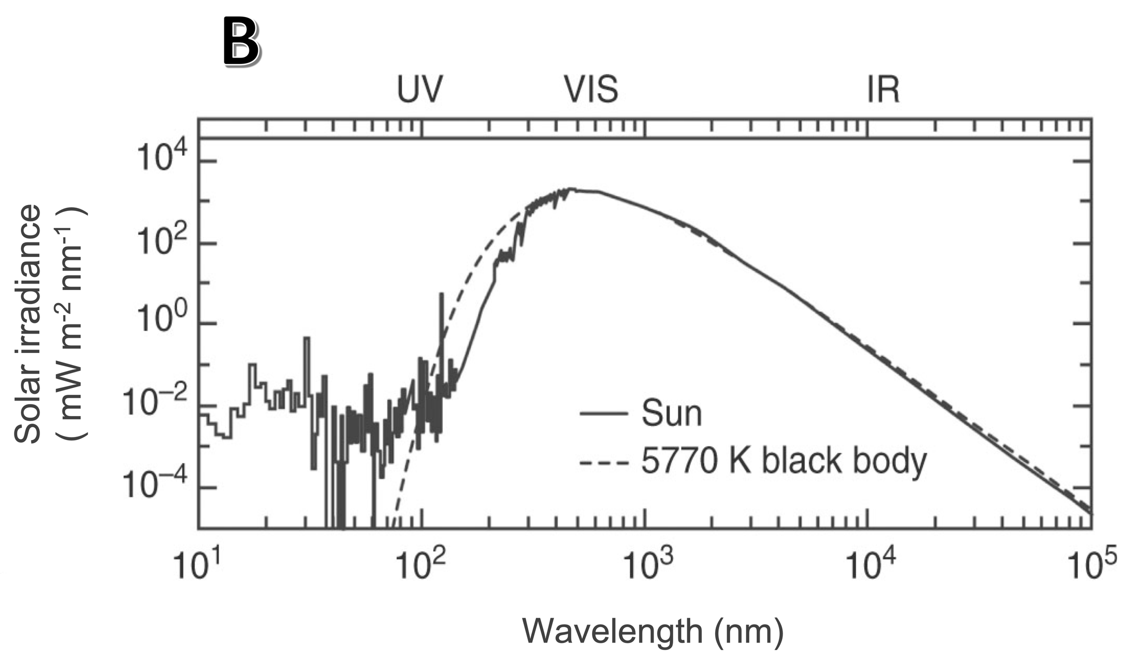
In this study, observations from the polar cap GNSS station in Thule, Greenland (**E**), (at a latitude of 76.5 degrees) have been used to identify and forecast enhanced solar EUV activity. The results have been compared with measurements from the SORCE satellite in the wavelength range from 100 to 120 nm. The monitored enhanced TEC-values and derived solar irradiances (mostly due to flares) occurred minutes after they were observed at the sun, which shows the strong forecast capability of the technique. Most of the observed phenomena, which propagated towards Earth, impacted a few days later the magnetosphere-ionosphere system.

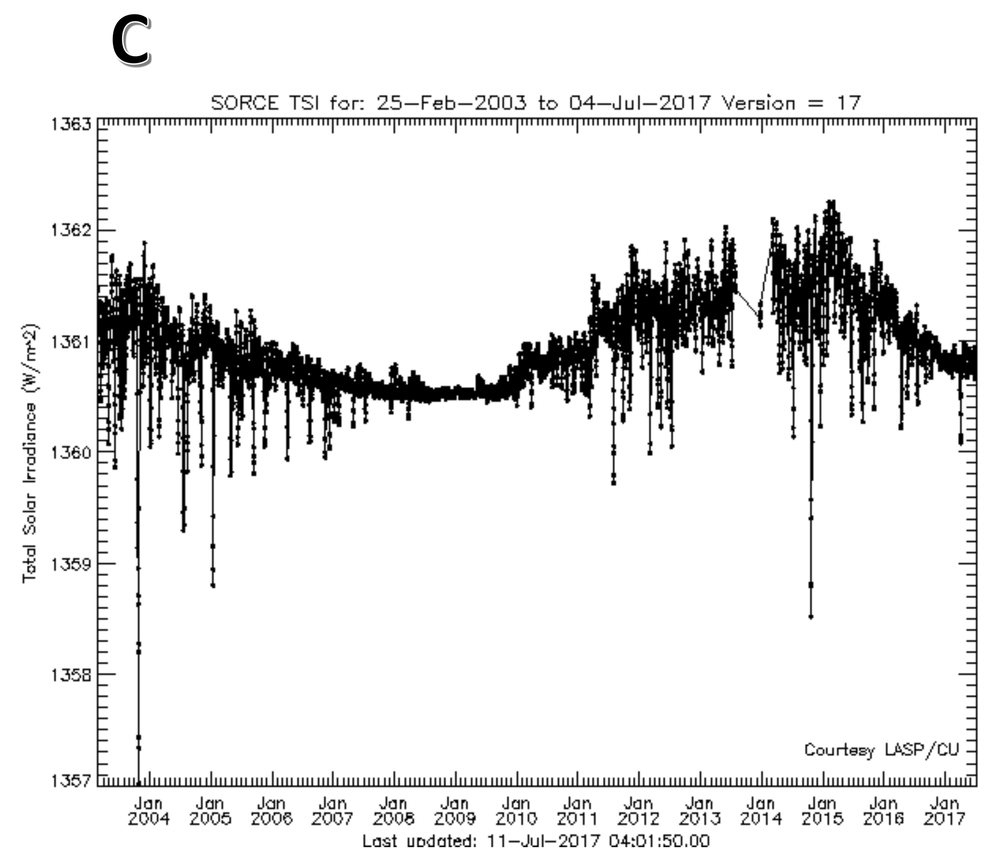
We studied a 4-year data set (2012 - 2015) of vertical TEC observations derived from the Thule GNSS station and compared the data sets with observations from the SORCE satellite of solar EUV emissions. The statistical correlation coefficient between the two data set became 0.75 (**D**).

Both data sets identified clearly the about 26-day variations in the solar spectral irradiance for wavelengths in the EUV spectrum (with amplitudes of 10-15 TECU) (**F**, **G**). The polar cap EUV index showed also higher mean-TEC variability near the equinoxes and in summer-time. During summer, the F-region cross-field plasma diffusion rates are increased when an underlying conductive E-layer is present. During the winter, the insulating E-layer slows the F-layer plasma decay rate, thereby allowing F-layer structures to survive significantly longer.

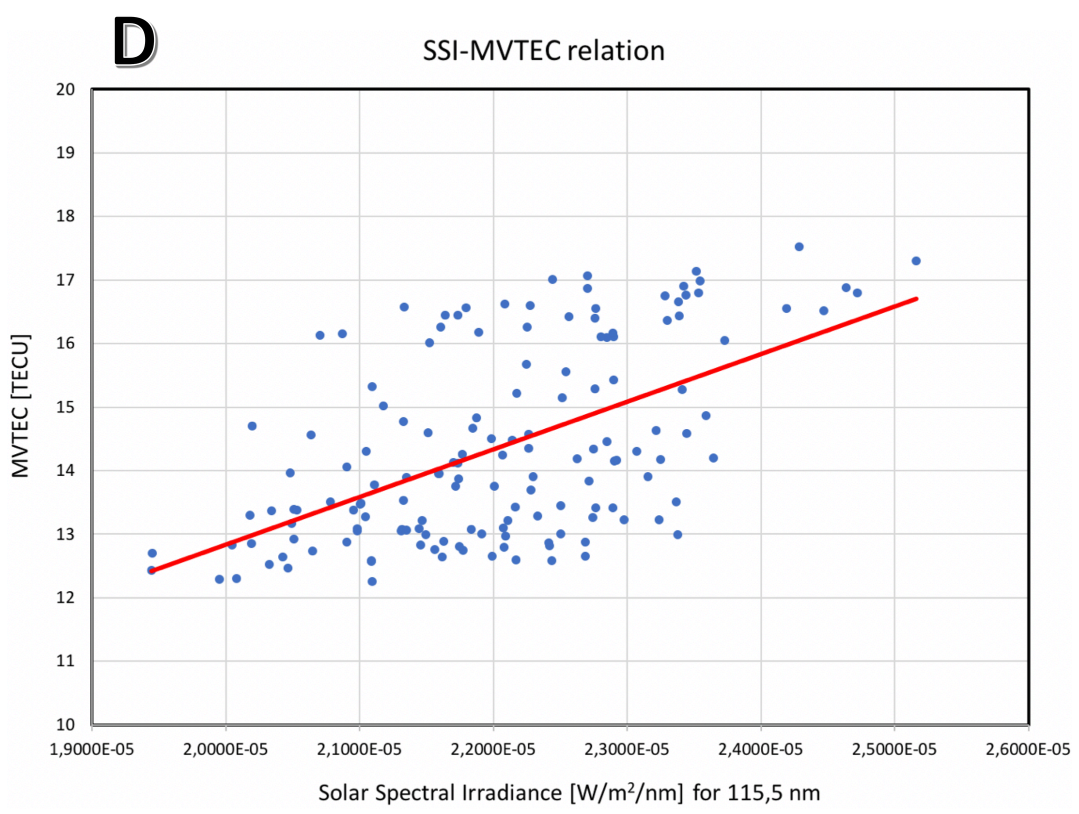
5-minute resolution MVTEC time-series and hourly 115 nm SSI time-series for the years 2012, 2013, 2014, 2015

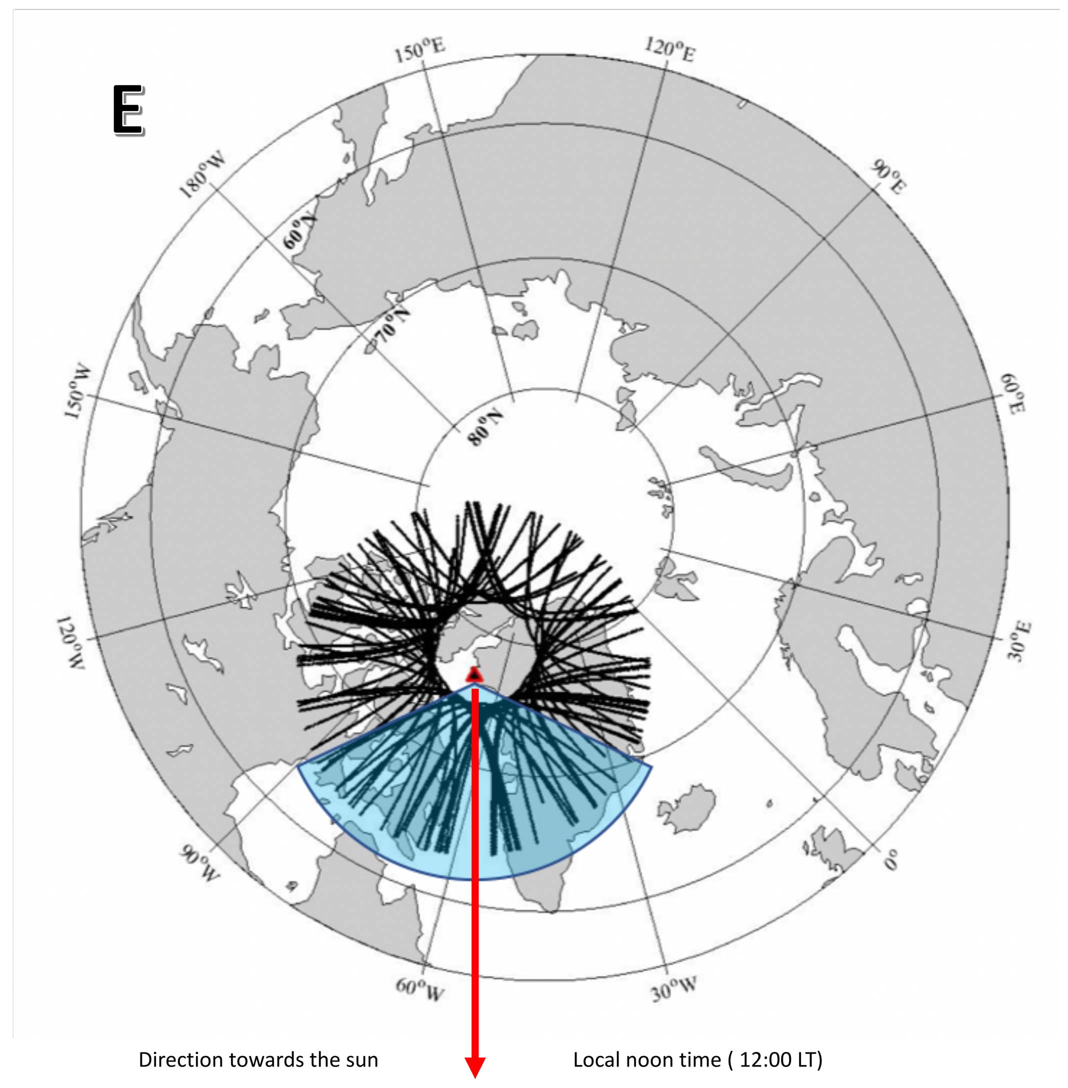


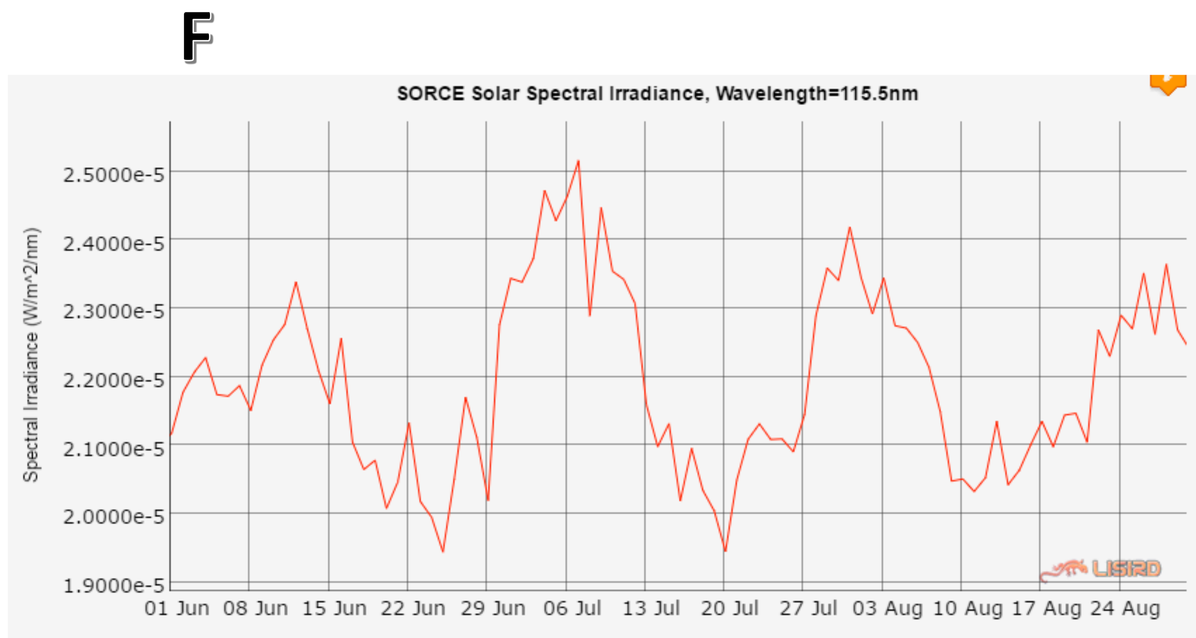


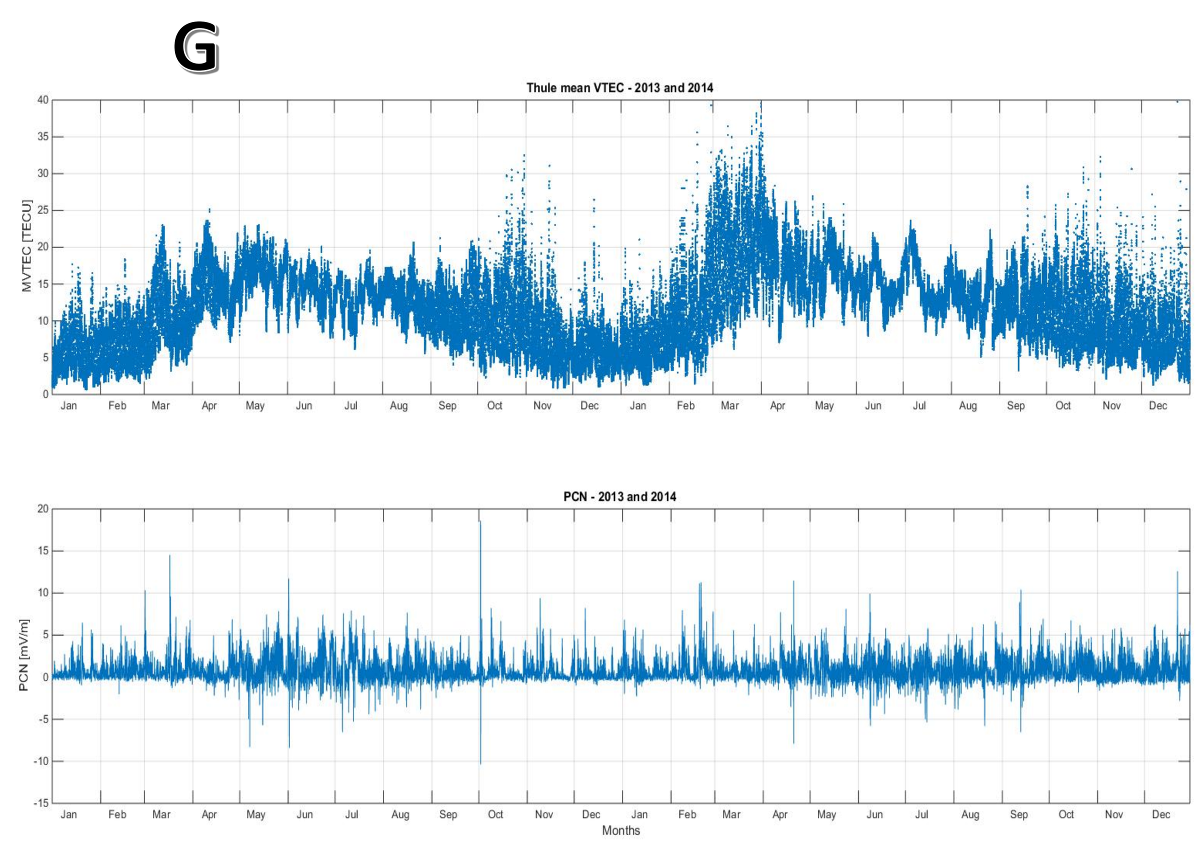


Scatter-plot showing the relation between MVTEC and SSI and the linear trend (R=0.75) for the summer period of 2014 (May-September)









Three distinct processes shape the VTEC time-series:

1. Solar wind and celestial: Semi-annual and annual variation of geomagnetic activity due to the varying angle between the southward component of IMF with the magnetosphere and the tilt of the Earth in orbital plane around the sun (23.4 degrees).
2. Solar EUV radiation: Solar irradiance variations. The period of the VTEC anomalies appear to be just a few days less than a month (**G**), which potentially could indicate a good correlation with the about 26-day synodic solar rotation (**F**).
3. Combination of solar EUV and E-layer: Primarily solar EUV-induced. But a significant secondary effect, related to F-layer cross-field plasma diffusion rates and E-layer conductivities, plays an important role. Horizontally structured F-layer decay points towards the physical mechanisms behind this decay in the polar cap, including the effects of a conducting E-layer.