Observations and Modeling of the Ionospheric Topside Response to the Moon's Shadow During Solar Eclipses

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November 21, 2022

Abstract

In previous work (Hairston et al., GRL doi 10.1029/2018GL077381, 2018) we showed the topside F-layer (˜850 km) electron temperatures measured by two DMSP spacecraft as they flew through the Moon's shadow during the 21 August 2017 eclipse exhibited a series of non-uniform, banded decreases rather than a broad and smooth temperature decrease. We found that making a "mask" of the shadow of the Moon eclipsing the existing active regions on the sun's surface created a pattern on the ionosphere showing where the gradient of the EUV from the active regions was greatest. The complex pattern of these areas from the mask at the F-peak altitude at 300 km corresponded to the areas in the topside F-layer where the DMSP observed the bands of cooled electrons. We have expanded this work to examine about a dozen other eclipses including the most recent 21 June 2020 eclipse. We repeatedly observed the same banded pattern in the electron temperatures in almost all the DMSP eclipse passes, thus demonstrating this is a repeatable phenomenon. Since the DMSP series of spacecraft form a constellation of four operational satellites with the same plasma instrument package making multiple measurements of the shadow at different local times, and sometimes within 10-15 minutes of each other, we can use these observations to map the shape and evolution of these cooling band patterns as the eclipse's shadow passes over the Earth's ionosphere. Here we will present our first detailed analysis of the two eclipses that occurred on 20-21 May 2012 and 2 July 2019. Both these eclipses have passes through the duskside by two spacecraft within a few minutes of each other, thus allowing us to examine the evolution of the pattern. We are using these events to determine the empirical patterns seen in the electron temperatures decreases during eclipses and to explore the mechanism causing the cooling of the plasma and how it is transported from the F-peak region to the topside ionosphere.

SA018-07

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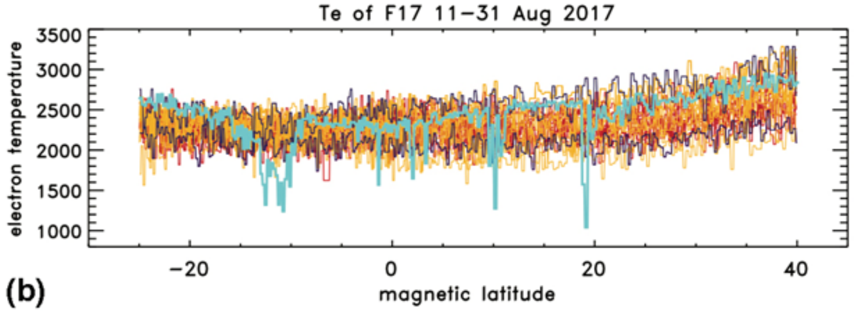
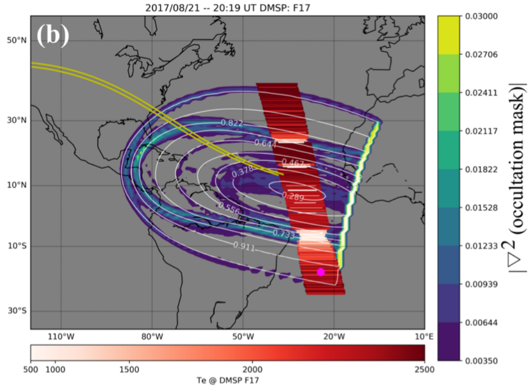
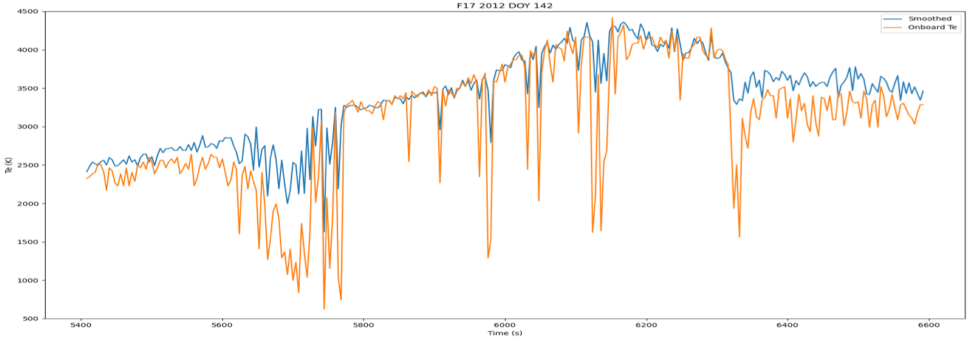
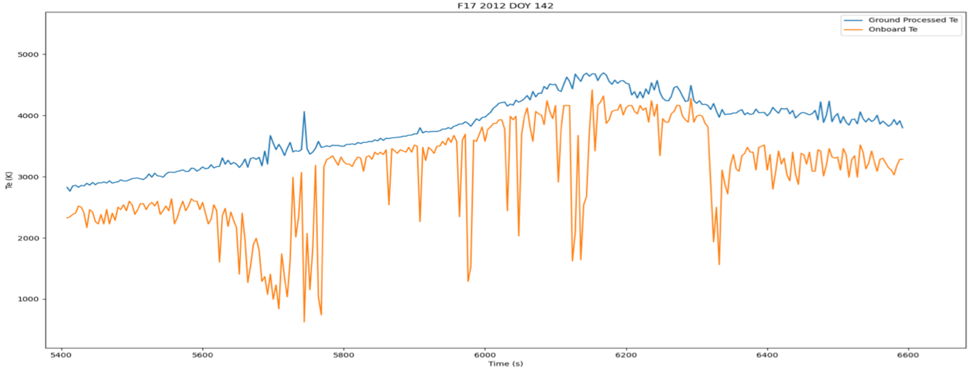








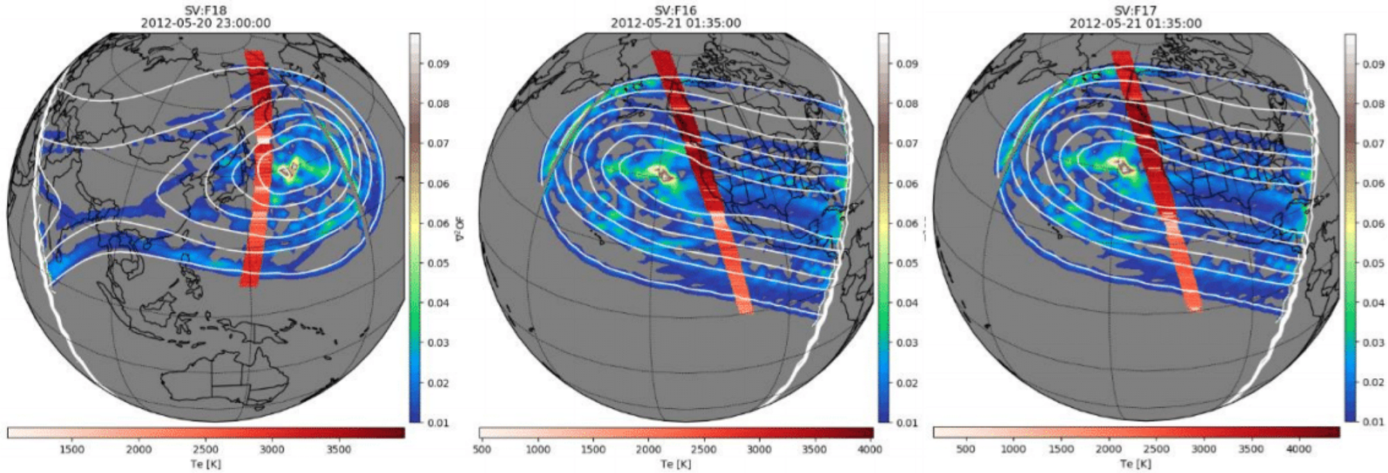
F17 eclipse pass on 21 May 2012

This worked started with the 21 August 2017 eclipse (above) where DMSP observed strange dips in the electron temperatures at 850 km that matched the regions of large gradient in the EUV from the moon's shadow.

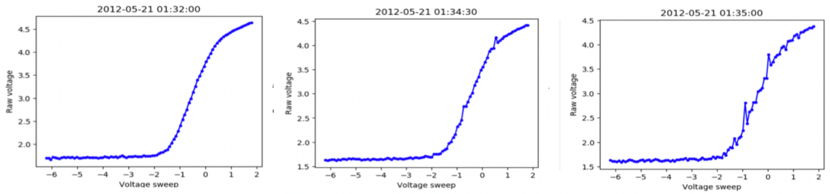
Further examination of over a dozen eclipses showed similar patterns in the electron temperature in the moon's shadow.

Work on these other eclipses (right) showed that the dips in the electron temperatures were likely an artifact of the data reduction algorithm dealing with noisy sweeps from the Langmuir probe.

The temperature "dips" were caused by noisy data in the Langmuir probe sweeps and these regions of still correspond to the regions of large gradients in the EUV from the sun caused by the moon's shadow (seen here in the May 2012 eclipse). We identified three types of anomalous behavior of the plasma instruments that occurred during the eclipse.

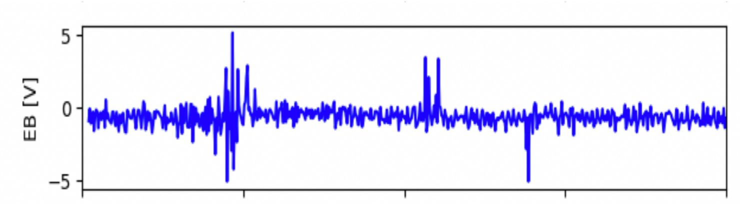


Noisy data in the Langmuir probe sweeps



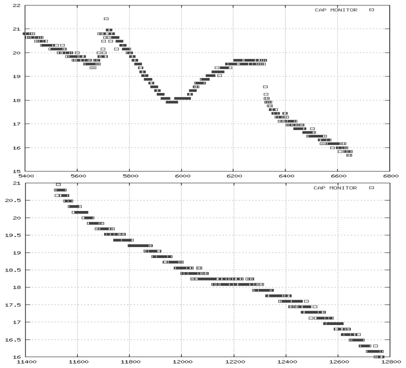
Normal smooth Langmuir probe sweep (left) gives nominal electron temperatures. The slightly noisy (center) and very noisy (right) sweeps in the EUV gradient region give the erroneous low electron temperatures.

High energy ions/electrons in the RPA

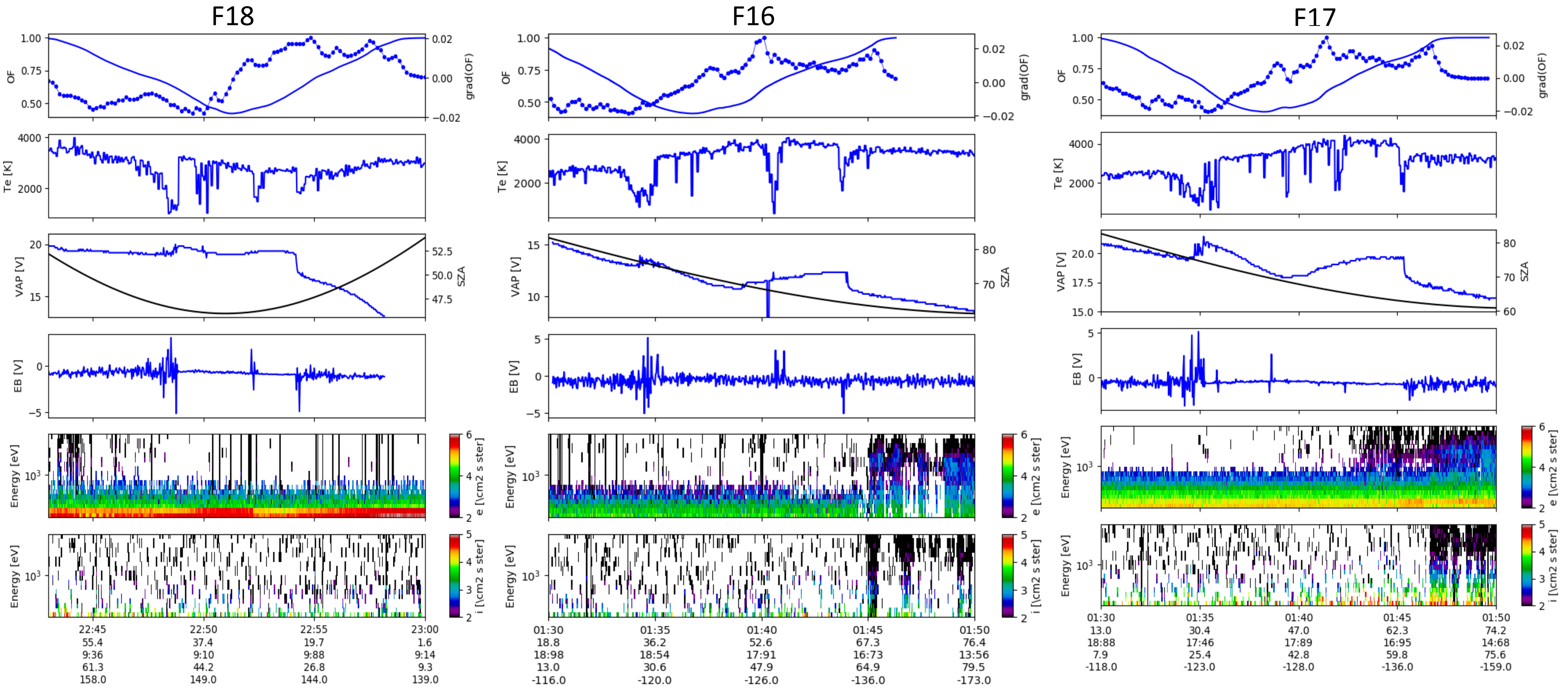


The retarding potential analyzer (RPA) samples high energy ions and electrons every two seconds and it observes high energy bursts in the regions of high EUV gradients.

Anomalous spacecraft charging



Bottom plot shows the spacecraft charges less negative (sign flipped here) as it moves northward in a nominal pass. Top plot shows an unexplained increase in negative charging in the eclipse's shadow.



Something is affecting the ionosphere in the eclipse shadow, but our instruments are not designed to detect whatever this is directly, so we are puzzled. All three spacecraft observed similar responses as they passed through the May 2012 eclipse shadow at two different times and three different locations. With multiple sets of observations from these and other eclipses we hope to be able to track down the causes.