Van Allen Probes Intercalibration between HOPE and RBSPICE for Protons

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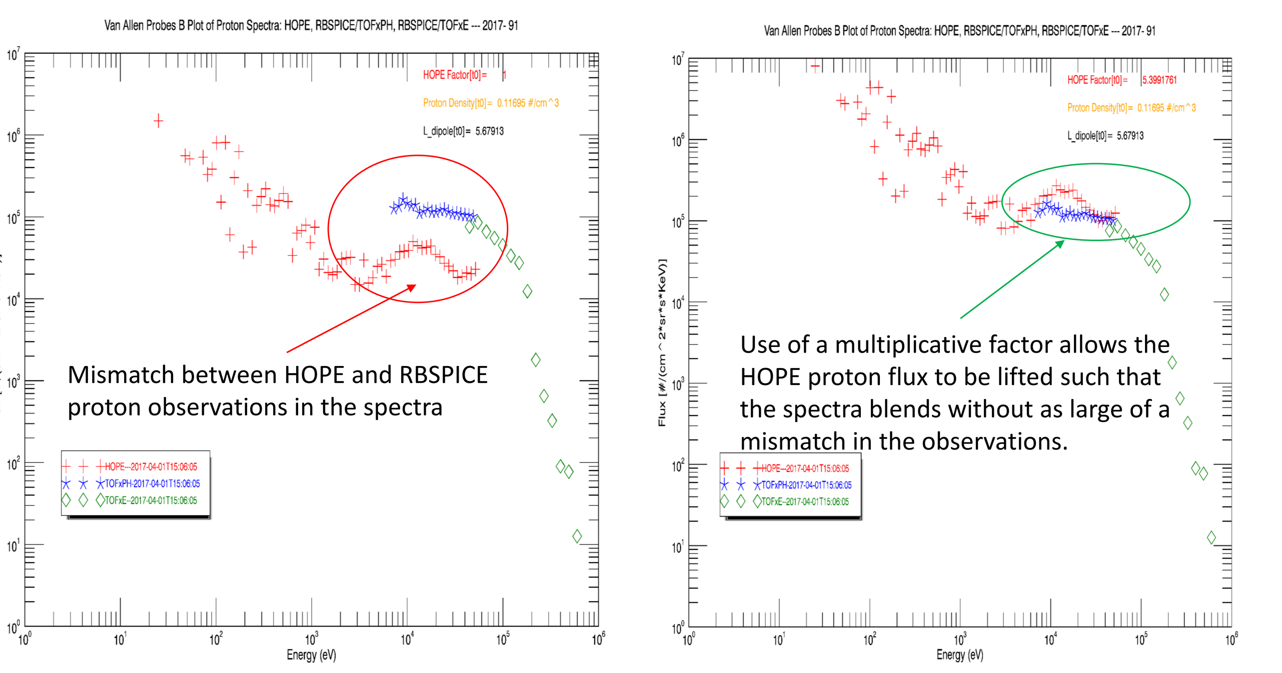
Abstract: Observations of energetic protons from the Van Allen Probes HOPE and RBSPICE have overlapping energy channels at the high end of HOPE and low end of RBSPICE. Evaluation of the data has shown that there is a variable factor which is required to allow the observations to match properly in a spectra. This poster presents an algorithm for the calculation of a modification factor that provides a proper correction to the observations such that observed spectra properly match at the overlapping energy channels. Analysis of this modification factor as a function of Spacecraft (A or B), L, and MLT is provided to guide the use of the data for global modelers. Finally we present interesting observations of the spectra showing bump on tail distributions as well as double bump on tail distributions.

HOPE vs RBSPICE data

HOPE energy channels provide observation of proton spectra with 72 energy channels from 25 eV to 52 KeV.
RBSPICE has two specific data products used in this analysis
RBSPICE/TOFxPH protons has 20 energy channels from 7 KeV to 49 KeV.
RBSPICE/TOFxE protons has 14 energy channels from 45 KeV to 600 KeV

The overlap of HOPE and RBSPICE energy channels occurs with the upper HOPE energy channels overlapping the RBSPICE/TOFxPH energy channels and the bottom two energy channels of the RBSPICE/TOFxE product.
The following spectra show the proton spectra taken for specific times showing the disconnect between the HOPE and RBSPICE proton flux.



Algorithm to modify the Omni Flux from HOPE and RBSPICE so spectrum are "aligned"

A simple algorithm for spin by spin match of the proton spectra between the HOPE OMNI upper energy channels and the TOFxPH upper energy channels. This provides a spin by spin direct observation of the necessary changes required to match the spectra and get a reasonable agreement between the two data sets.
Simple algorithm which works most of the time $R_E > 3.5$ and somewhat when $R_E < 3.5$ (Note that the TOFxPH data lower energy channels suffer from contamination due to accidentals from high density plasma in the plasmapause, this can be noticed when the lowest HOPE flux is exceptionally high and the low end of the RBSPICE TOFxPH flux becomes significantly higher than the HOPE data)
Calculate average OMNI flux of the top 3 HOPE energy channels minus 1, i.e.

E_{mid_68}= 32724.5+-2454.34 eV; E_{mid_69}= 38130.1+-2859.76 eV; E_{mid_70}= 44428.7+-3332.15 eV

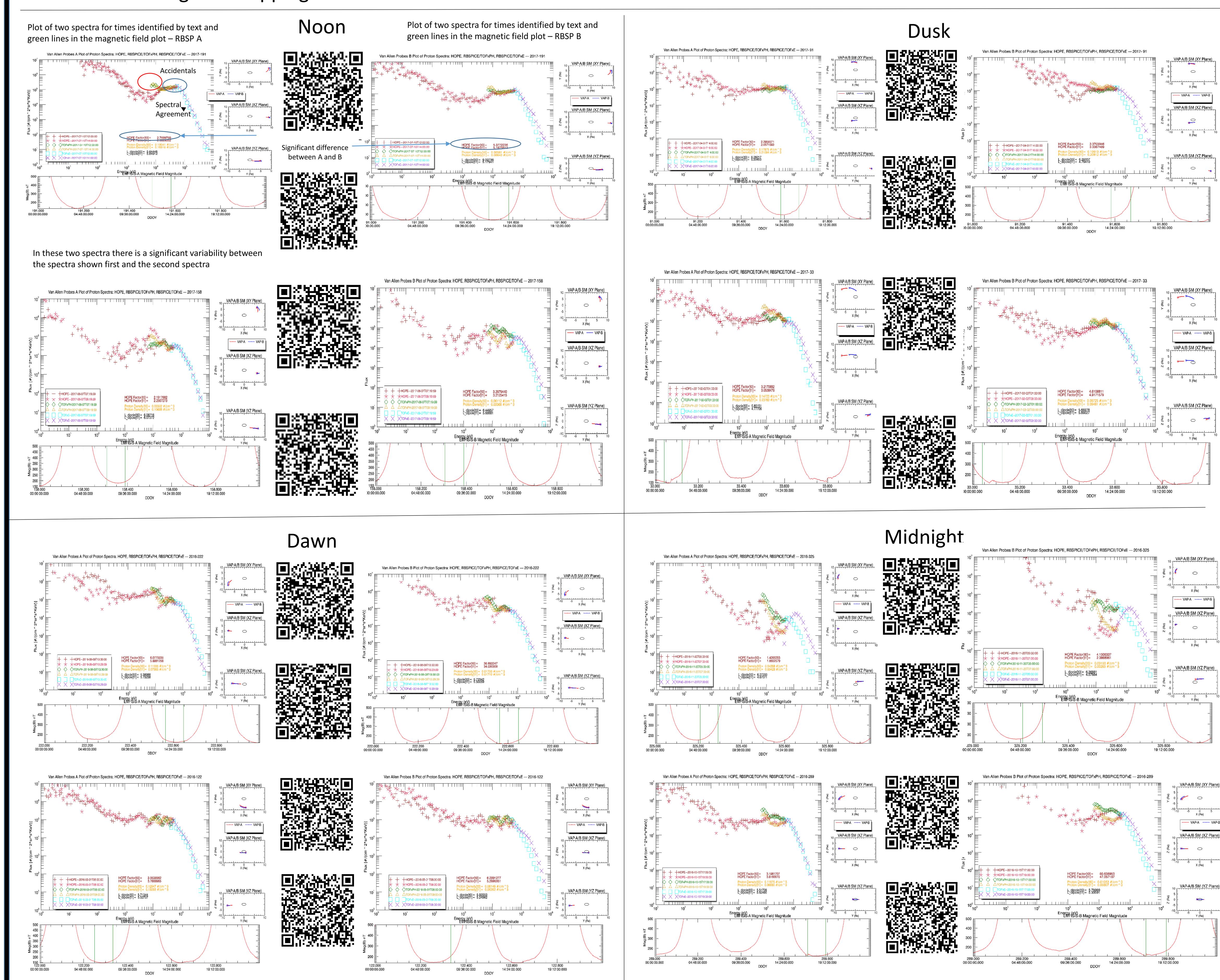
Calculate average ONNI flux of the top 3 RBSPICE/TOFxPH_H_HELT energy channels minus 2, i.e.

E_{mid_15}= 32873.0+-3266.84 eV; E_{mid_16}= 36310.6+-3608.46 eV; E_{mid_17}= 40107.7+-3985.81 eV

Calculate the ratio of TOFxPH to HOPE, .i.e $r = \langle f_{tofxph}\rangle / \langle f_{HOPE}\rangle$ assuming the slight mismatch of energies passbands is a second order effect that doesn't significantly effect this calculation and exists within the statistical Poisson error bars.
Multiply the HOPE ONNI Flux matrix by R – this is identified in plots as the HOPEMOD factor.

HOPE and RBSPICE Observations

The following plots provide a sample of the use of the modification algorithm for variations in MLT and for each spacecraft. Several of these plots show examples of the higher TOFxPH (low energy channels) higher flux due to accidentals. Note that most of these times were chosen during RBSP lapping events where KP < 4



Discussion of interesting Spectra and Consequences for Modelers

As can be seen in the spectra and associated movies there are different characteristics to these spectra that have been observed as the movies are generated. We note that at this time these spectra observations are anecdotal and more study will occur over the next months and more completely presented at AGU.

All the spectra presented in the upper right of this poster were measured during fairly quiet time conditions after the magnetosphere had time to relax to a more steady state condition.

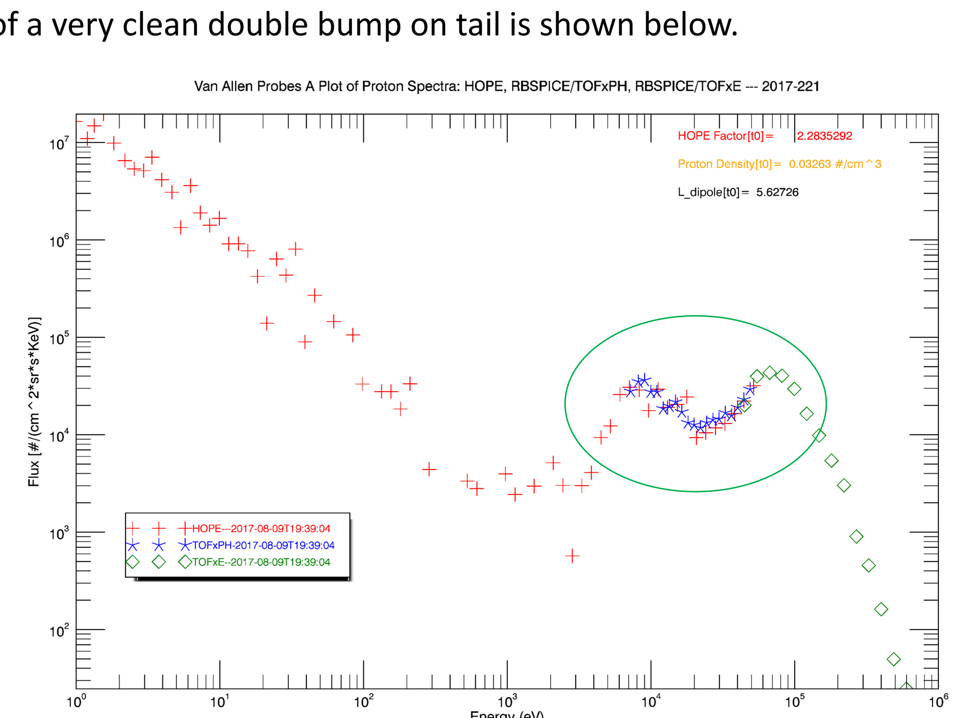
Noon
The spectra observed in the noon to dusk sector generally show a bump on tail distribution that has been noted in multiple publications going all the way back to the original observations off ring current particles in the 1960's. The dip in the flux seems to occur in the range of 1 KeV to 10 KeV.

Dusk
The spectra observed in the dusk to midnight sector also includes a bump on tail distribution although in many instances (as can be seen in the upper right) there is observed a very flat distribution from less than 1 KeV upwards through the TOFxPH energy range.

Midnight
The midnight to dawn sector seems to have the most observed variability in the spectra during quiet time including a nominal Maxwellian distribution, bump on tail, and double bump on tail.

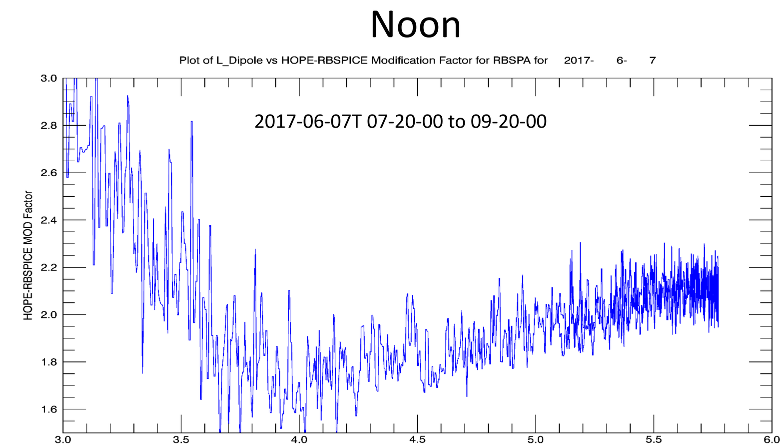
Dawn
The dawn to noon sector seems to be the interesting place in which a large number of the observed spectra are represented by a double bump on tail indicating that there is a significant amount of free energy available for the generation of wave modes at many different characteristic frequencies. An example of a very clean double bump on tail is shown below.

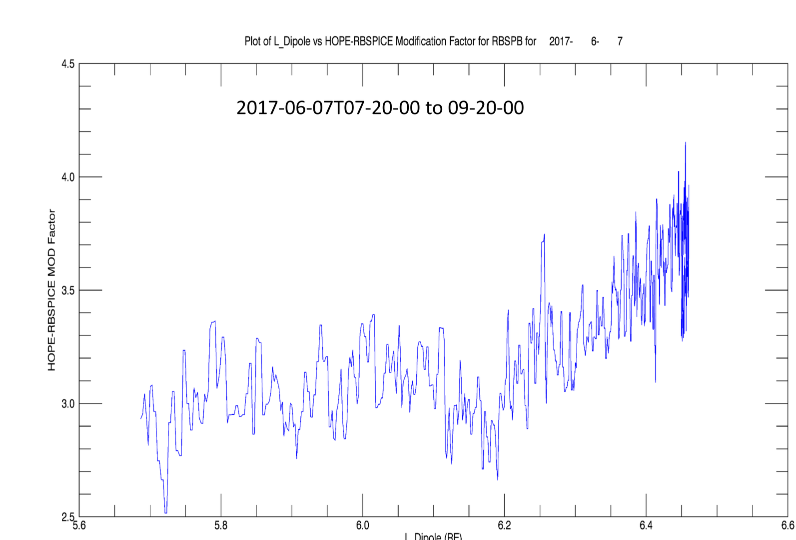
Double bump on tail spectral image. Question for future work is to identify how frequent such spectra are observed throughout the RBSP mission and the nature of any wave activity that occurs during the timeframe of observation.



Modification factor versus L and MLT

Noon



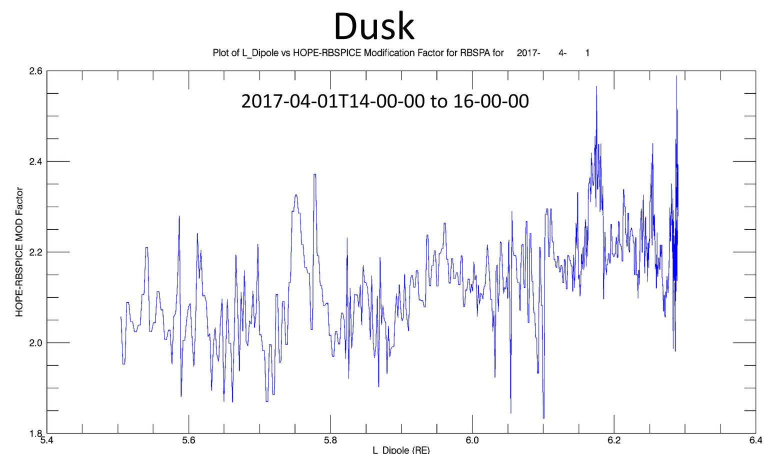


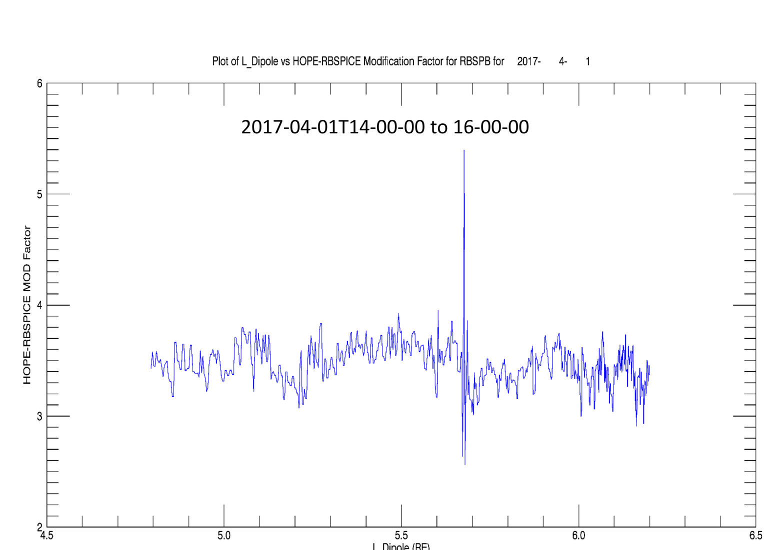
We first note that a complete study of the dependence of the modification factor with L and MLT has not been done. Plotted to the left and right are the RBSP A and RBSP B values of the modification factor for a select number of apogee passes.

We first note that there is significant variability in the value of the modification factor between RBSP A and RBSP B.

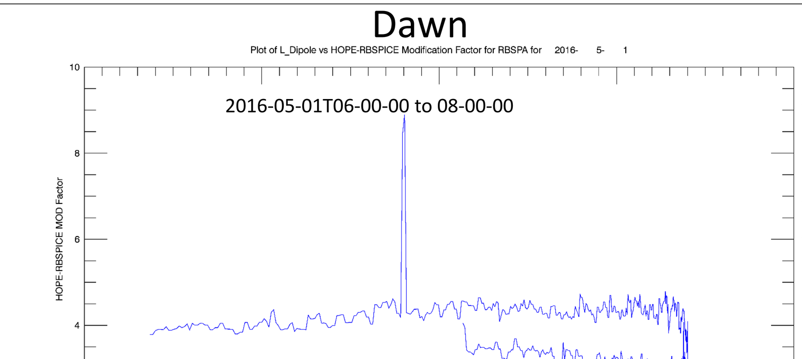
The L variation is difficult to quantify at this time although future work will attempt to do a statistical evaluation of these factors.
There are occasional times when the modification factor is fairly constant and then has a significant change over one or two spins and then back to the previous value as seen for A on 2016-05-01. One such even (note shown) that occurs is during a substorm injection on 2017-2-2 around 0145 and occurs just prior to a significant Ground MIE that occurs in the pre-midnight sector.

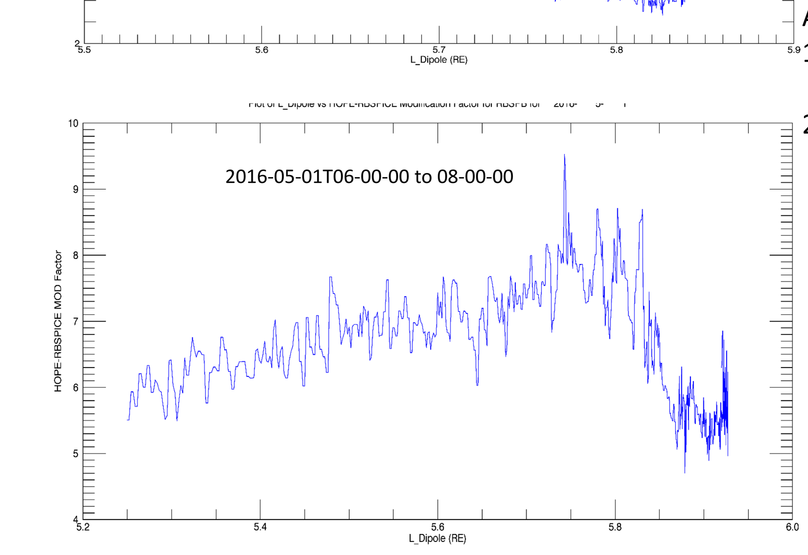
Dusk





Dawn

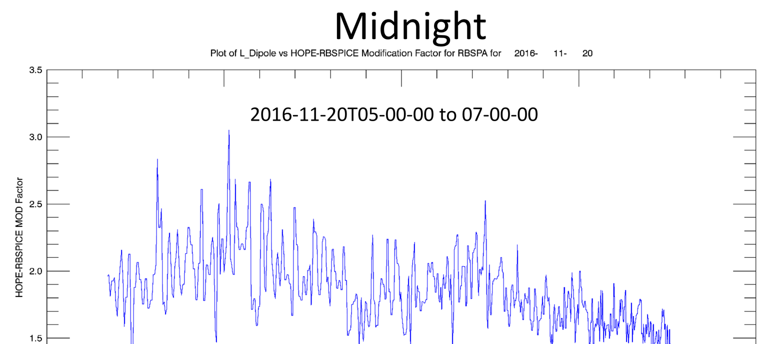


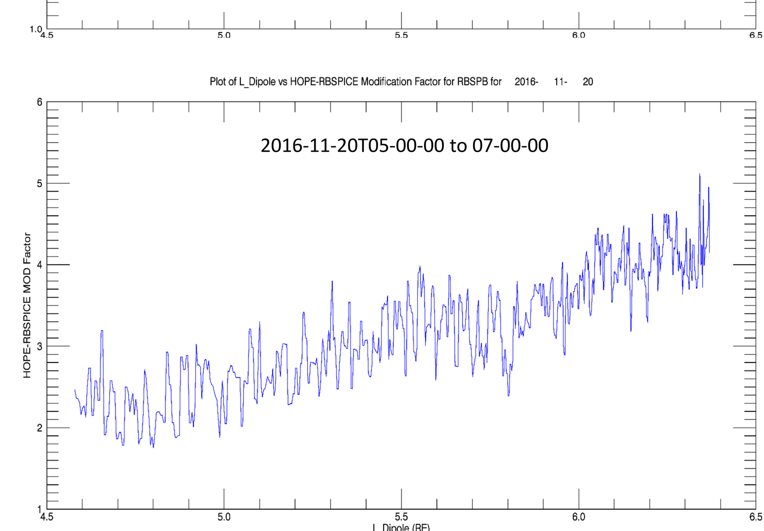


Several of these plots include inbound and outbound sectors and it is noteworthy that the modification factor is not symmetric across apogee which implies there is a strong MLT dependence on the value of this factor.

Additional Future Work items:
1) Spacecraft location with respect to the ecliptic plane.
2) Spacecraft location with respect to the plasmapause and the association of the modification factor with respect to the total plasma and/or neutral density.

Midnight





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