

The Ring Current Response to Different Storm Drivers Using Van Allen Probe Observations

Introduction / Motivation

- The ring current responds differently to the different solar and interplanetary storm drivers such as coronal mass ejections, (CMEs), stream interaction regions (SIRs) and other structures.
- The resulting changes in the ring current pressure alter the global magnetic field, which affects the transport of the radiation belts. In order to determine the field changes during a storm it is necessary to understand the development of the particles that contribute to the ring current.
- The source population of the storm time ring current is the night side plasma sheet. However, it is not clear how these convecting particles affect the storm time ring current pressure development.
- We use Van Allen Probe observations to build a statistical picture of the ring current pressure development through different storm phases at different L-shell values and magnetic local times as they are related to different interplanetary drivers, CMEs and SIRs.

Instrumentation and Data

Van Allen Probes A & B

HOPE – H+ & O+ < 60 keV. The pressure calculated from the HOPE data was used with a multiplied factor of 2 to agree with measurements from other instruments.

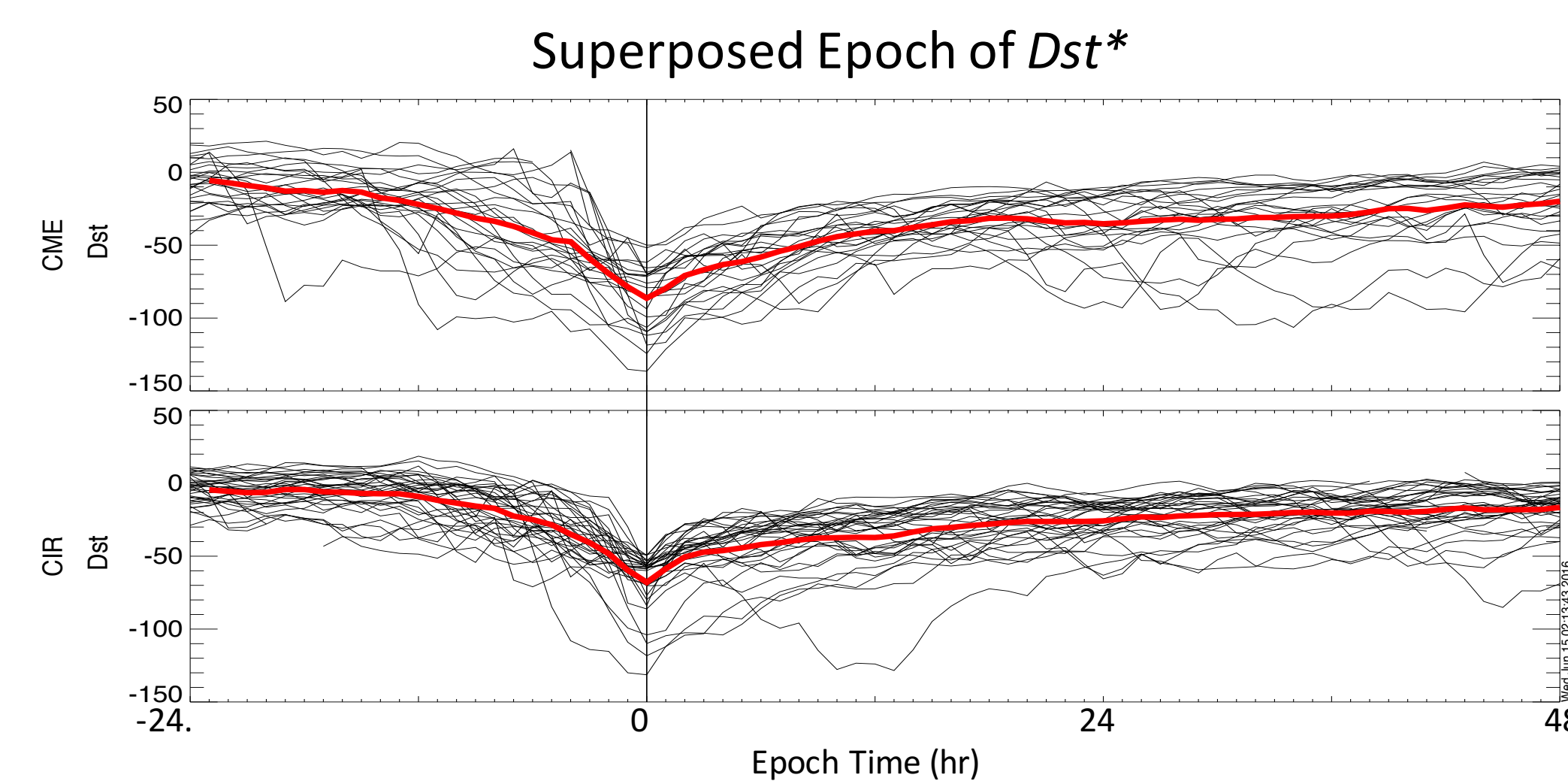
RBSPICE – H+ & O+ 60-600 keV for H+ and 120-1100 keV for O+. Pressure calculated with by Energy (xE) RBSPICE Level 3 PAP. A fit is used to estimate the pressure contribution from the O+ energies between HOPE and the RBSPICE xE measurement.

Geomagnetic Storms

A list of geomagnetic storms during the VAP era was compiled with the selection criteria requiring a single identifiable storm driver, and ones that do not feature a strong double dip feature. If a second drop in the Dst^* occurs during the recovery phase it is neglected.

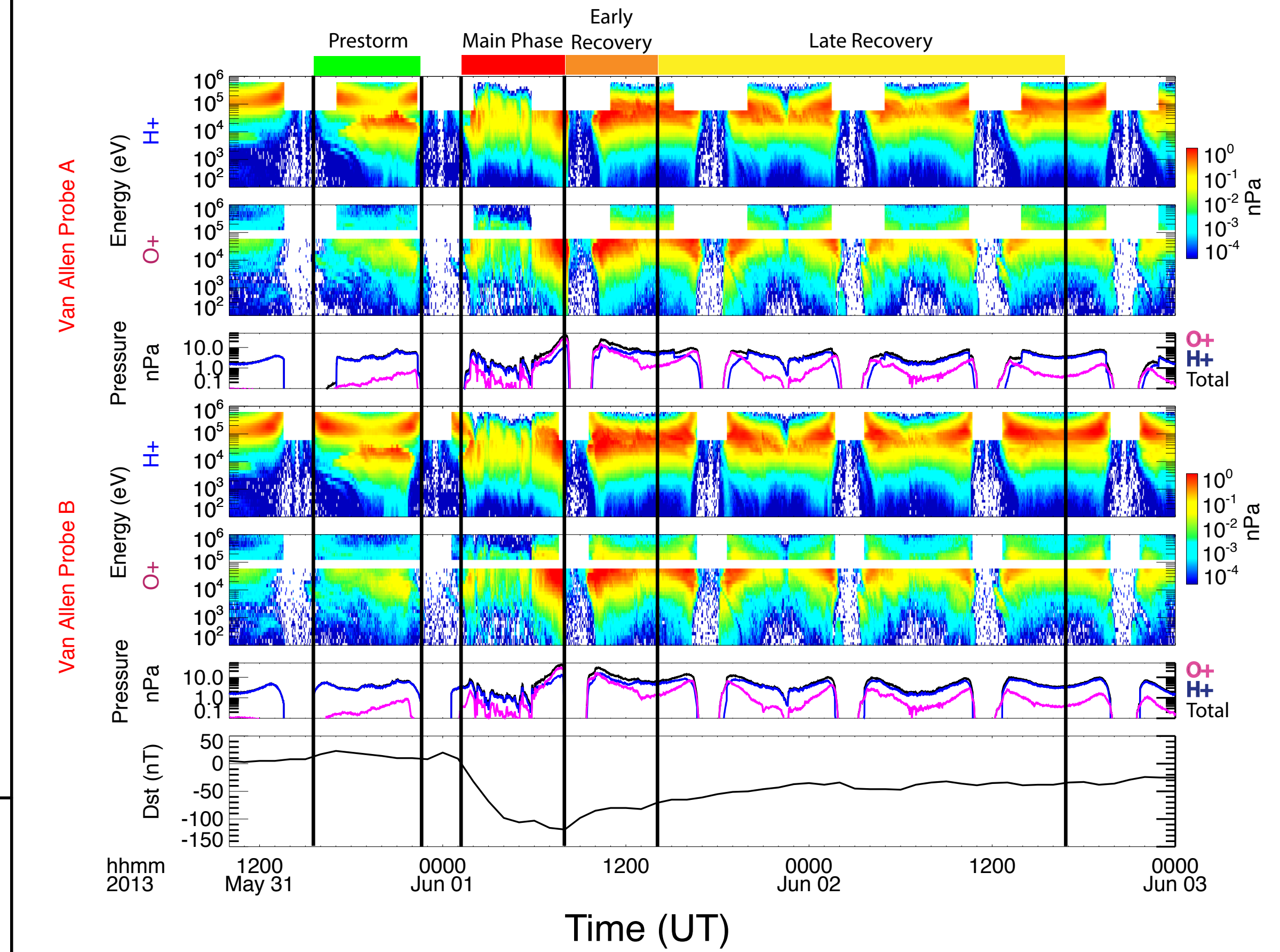
Storm Selection

Below are the Dst^* responses of the storms meeting the above criteria for selection from 2013-2016. The individual storm drivers were determined with WIND and/or ACE data along with the Richardson/Cane Near Earth ICME List and “The Weekly” write-ups from the NOAA Space Weather Prediction Center.



Statistics of Storms Used		
Storm Driver	ICMEs	SIRs
Average min Dst^*	-84.7	-67.3
Storms between -50 and -80	12	29
Storms between -80 and -120	11	5
Storms between -120 and -150	2	1

Storm Time Pressure Calculations



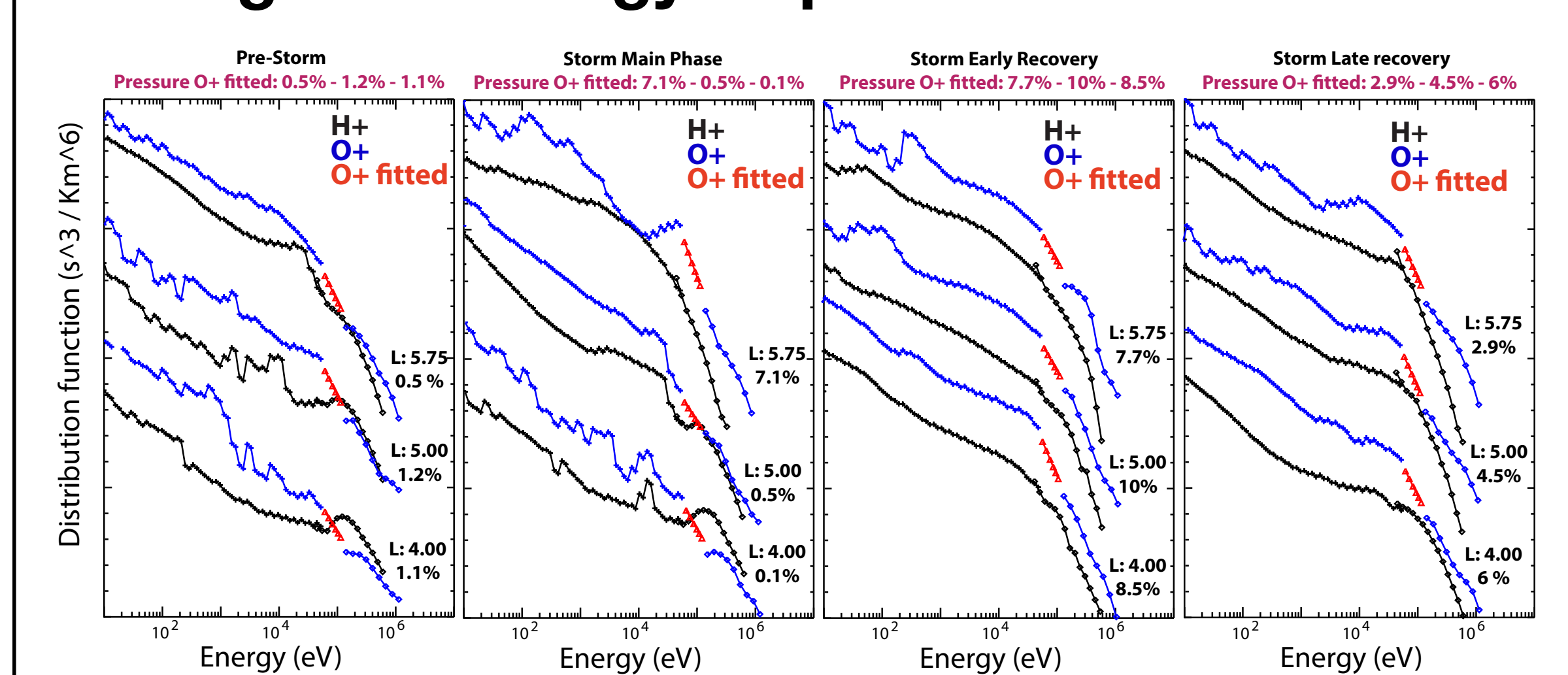
Shown above is a sample storm from our storm list. The average kinetic pressure spectra and total pressure are calculated for each spacecraft with HOPE and RBSPICE data. The average pressure is calculated by integrating the differential particle flux, J .

For the statistical study on the ring current pressure development we performed a superimposed epoch analysis of the ring current pressure development during each phase of the storm. The storm phases are defined as:

- Prestorm** – 9 hour period (1 orbit) before the onset was determined to start.
- Main Phase** – after the onset and once the Dst^* started to significantly decrease until the min Dst^* was reached.
- Early Recovery** – From minimum Dst^* to 8 hours later.
- Late Recovery** – From the end of the early recovery until the Dst^* returned to 20% of min Dst^* .

The pressure is then binned for every storm by phase, MLT, and L-shell to build an average statistical picture of the ring current by aggregating these individual storms.

Fitting the “Energy Gap” in O+



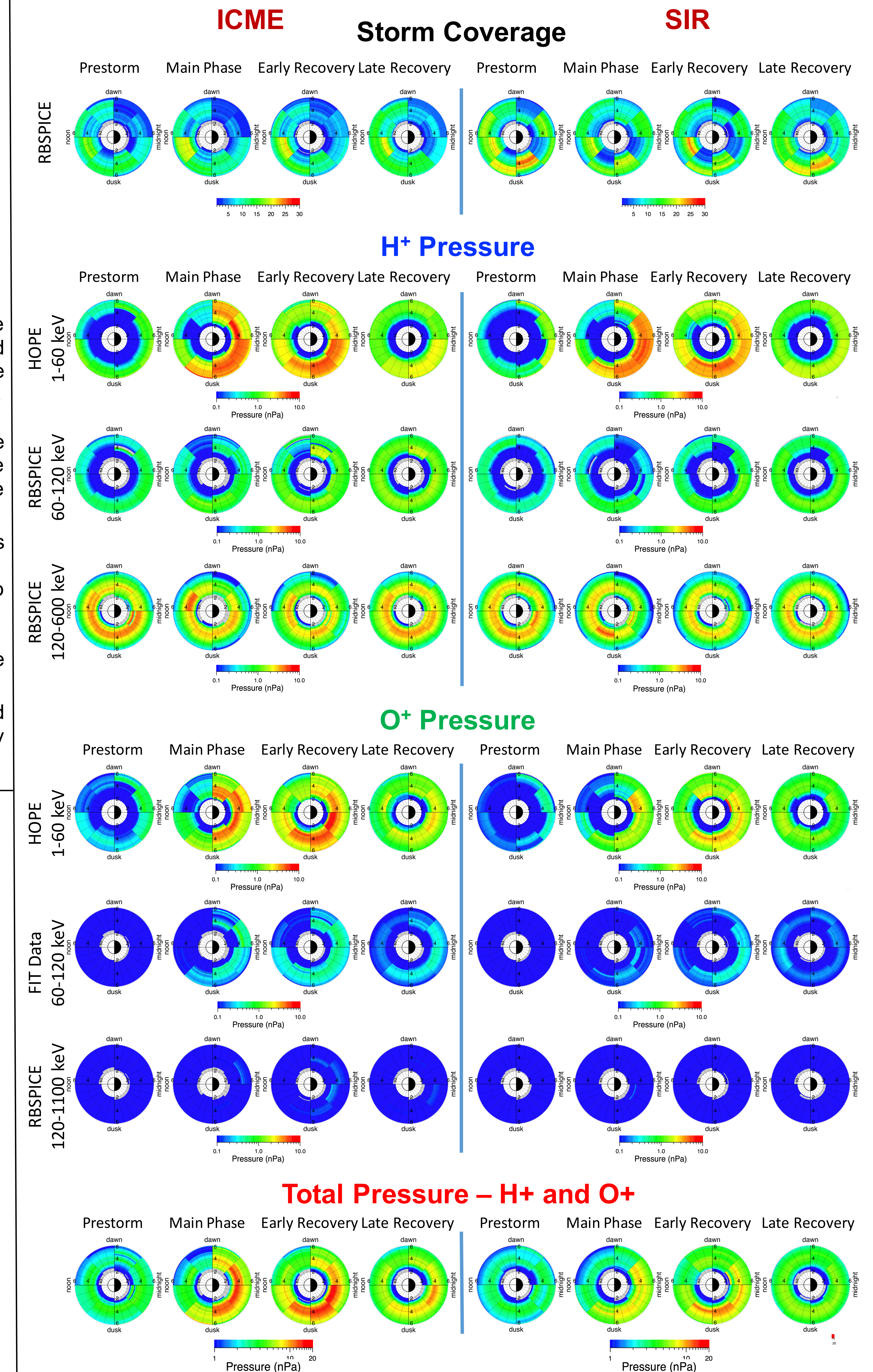
- The O+ spectra in the ~60–120 keV energy range are not consistently measured by the RBSPICE instrument. Therefore, in order to account for the pressure contribution of these populations throughout the statistical study, a linear fit in log-log space of the distribution function is used instead. Using this fit an estimated flux is calculated and then the corresponding pressure.
- Shown above are examples of the fitted data (red symbols) for three L shells and for the different phases of the June 1st, 2013 storm. Also, the fraction of the deduced pressure over the total pressure is indicated.

Observed Storm Time Ring Current Pressure

Combining the individual storm pressure calculations with a binned average pressure in MLT and L in different storm phases, provides a statistical overview of the ring current pressure development in the inner magnetosphere through the storm phases.

The average Pressure vs. MLT vs. L shell vs. Storm-phase plots shown below

- The contribution of different populations (energy/species) is shown.
- The ring current pressure development during ICMEs and SIRs is compared.



Summary of Observations

H+

- Lower energy (1-60 keV) H+ ring current is greatly enhanced during the main phase of both ICME and SIR storms, primarily on the dusk side showing evidence of strong convection. As the storm progresses more ring current is built up into the post noon sector, but never forming a symmetric ring current. ICMEs generate a slightly larger ring current and reaching lower L.

- Middle energy (60-120 keV) H+ ring current sees an enhancement during the main phase in dusk side as evidence of convection and the formation of a more asymmetric ring current. This ring current becomes enhanced and symmetric in the recovery phase. The ICME ring current is slightly stronger and reaching slightly lower L again.

- The high energy (120+ keV) H+ ring current decreases in the main and early recovery phases before being enhanced in the late recovery phase showing evidence of possible adiabatic effects or radial diffusion.

O+

- The low energy (1-60 keV) oxygen is enhanced considerably more by ICMEs than SIRs in the main and early recovery phases. This enhancement is strongly asymmetric and located on the night/dusk side. The ring current becomes more symmetric in the late recovery phase.

- The fit data primarily follows the trend of the low energy O+ as one would expect. It does not appear to be a significant source of ring current pressure during the main phase.

- The high energy (120+ keV) oxygen barely registers any pressure before, during, or after the storm period for either storm driver.

Conclusions

Total Ring Current

- The total ring current is mainly symmetric pre-storm with the strongest contribution being the high energy H+.

- The main phase sees a significant increase in the low and middle energies.

- The large difference between the intensity of ICME and SIR responses in the main and early recovery phase is driven by how the low energy O+ ring current responds to these drivers.

- The late recovery phase becomes more symmetric. The difference between the ICME and SIR drivers in this phase is still driven by the Low energy O+.