University of New Hampshire

SM11A-2139

Storm Time Ring Current Dynamics and Response to CMEs and SIRs Using Van Allen Probes Observations and CIMI Simulations

S. Bingham[1], C. G. Mouikis[1], L. M. Kistler[1], M.-C. Fok[2], A. Glocer[2], C. Farrugia[1], M. Gkioulidou[3], H. Spence[1]

[1]SSC, Eos, Univ. of New Hampshire, Durham, USA, [2]NASA Goddard Space Flight Center, Greenbelt, Maryland, USA, [3]JHU/APL, MD, USA

AGU FALL MEETING
San Francisco | 12–16 December 2016

Motivation and Introduction

- The **storm time ring current alters the global magnetic field**, and **introduces sources for electromagnetic ion cyclotron (EMIC) wave generation**.
- Characterizing the response of the ring current to interplanetary coronal mass ejections (**ICMEs**) and stream interaction regions (**SIRs**) will provide a better understanding of how solar and interplanetary structures affect the inner magnetosphere.
- Using Van Allen Probes observations, we develop a statistical spatial ring current model of the ring current pressure, the pressure anisotropy, and the properties that can lead to EMIC wave generation during storm phases for ICMEs and SIRs.
- This statistical model is compared to the results of CIMI simulations of CMEs and SIRs using superposed epoch solar wind conditions of the storms used in the statistical study.

Instrumentation and Data

Van Allen Probes A & B

<u>HOPE</u> – 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.

<u>RBSPICE</u> – H^+ & O^+ > 60 keV.

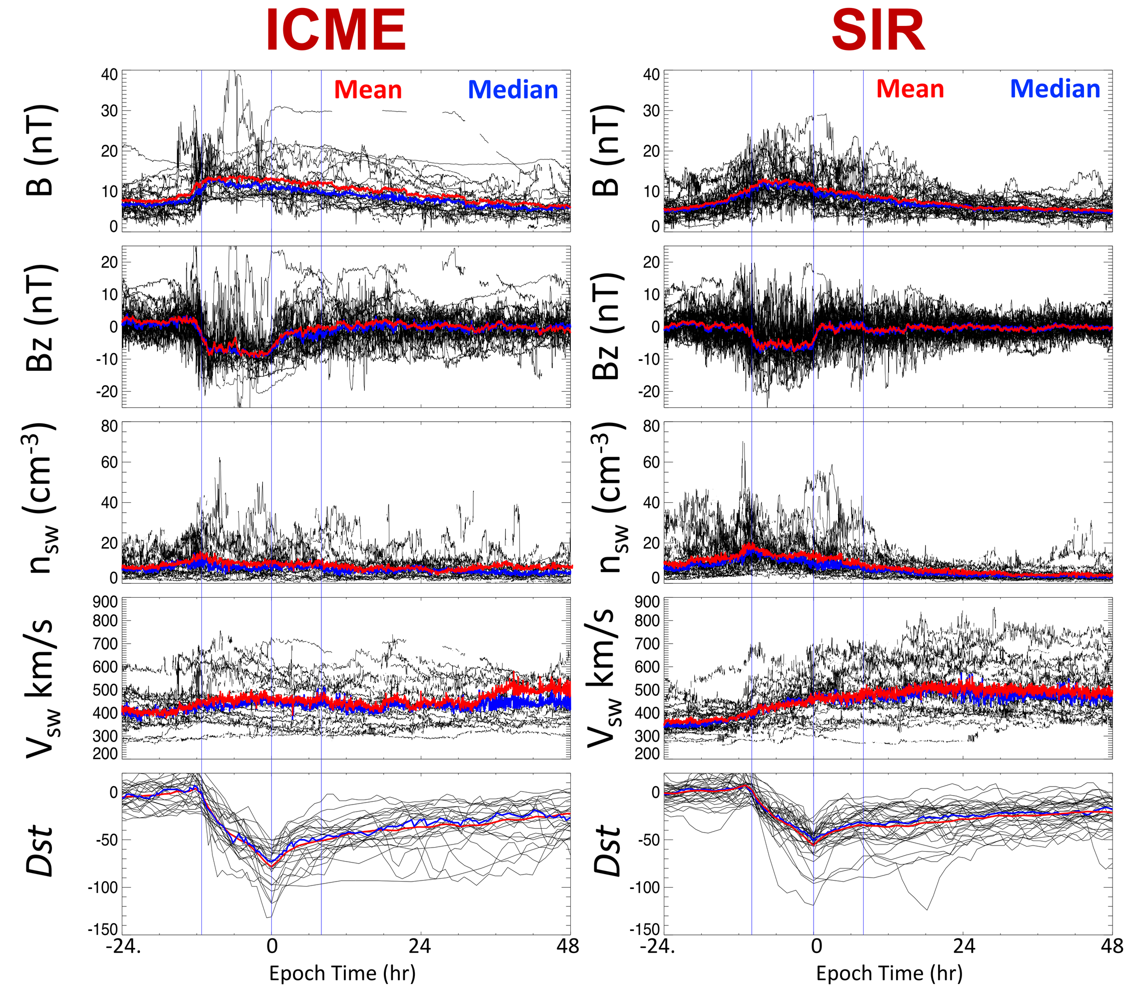
<u>EMFISIS</u> – local magnetic field.

<u>NURD</u> – electron number density from Neural-network-based Upper hybrid Resonance Determination [Zhelavskaya et al. 2016].

Geomagnetic Storms

35 SIR/CIR and 25 ICME Storms are identified between 2013-02-01 and 2016-04-16 with a minimum *Dst* between -50 nT and -120 nT.

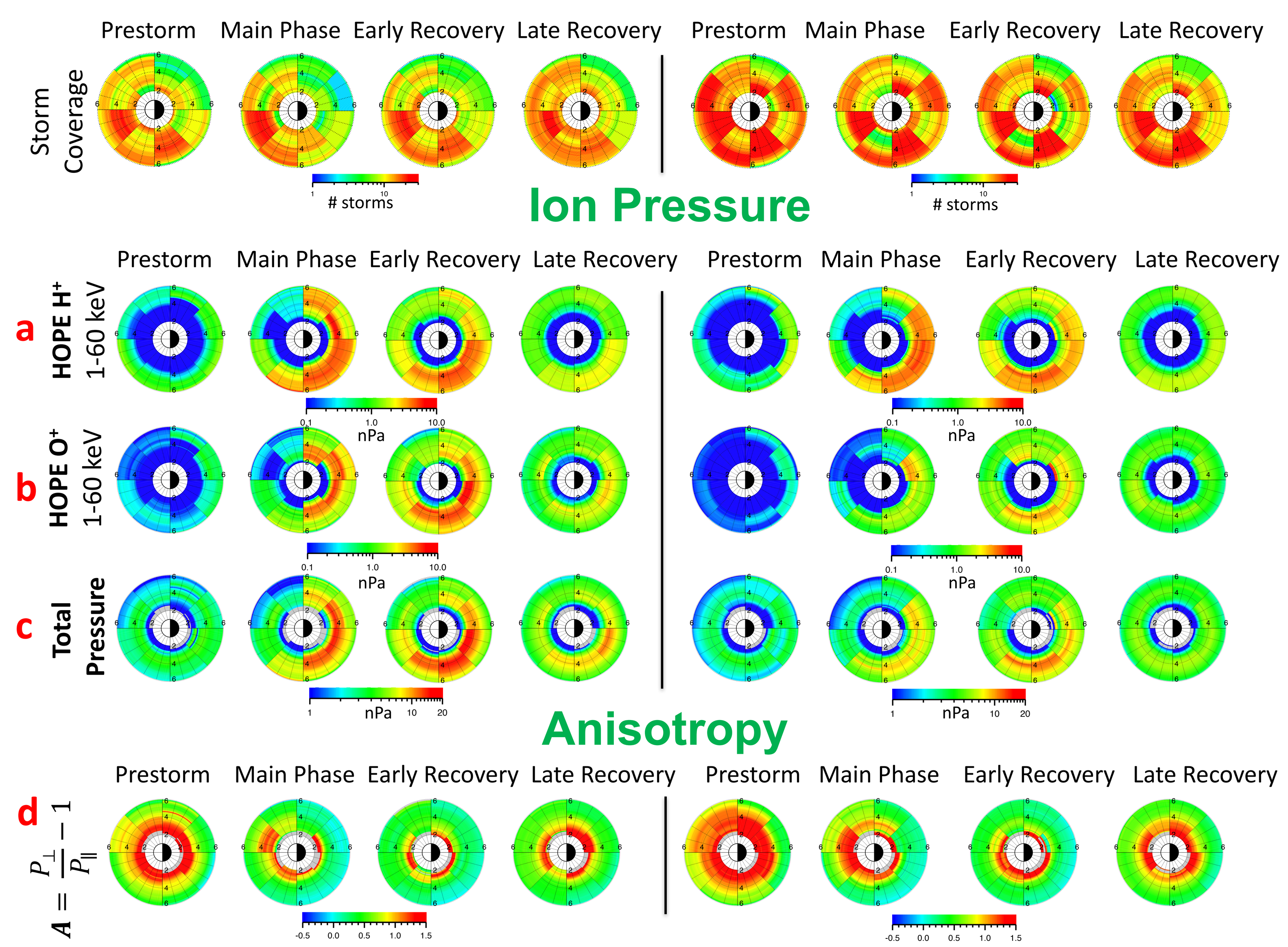
Epoch solar wind conditions of Storms in study



Shown above are the **storm phase normalized superposed epoch solar wind data** for the 25 ICME and 35 SIR storms used in the statistical study.

The median values are used as inputs for the CIMI simulation of the ring current.

Empirical Model of the Storm Time Ring Current Pressure Development for CMEs and SIRs



Individual storm pressure calculations from VAPs are binned in MLT and L for the different storm phases for ICMEs - SIRs

(a) 1-60 keV H^+ : Pressure is greatly enhanced during the main and early recovery phases of both ICME and SIR storms peaking with a pressure around 10 nPa. The pressure peak is asymmetric demonstrating the buildup of the partial ring current.

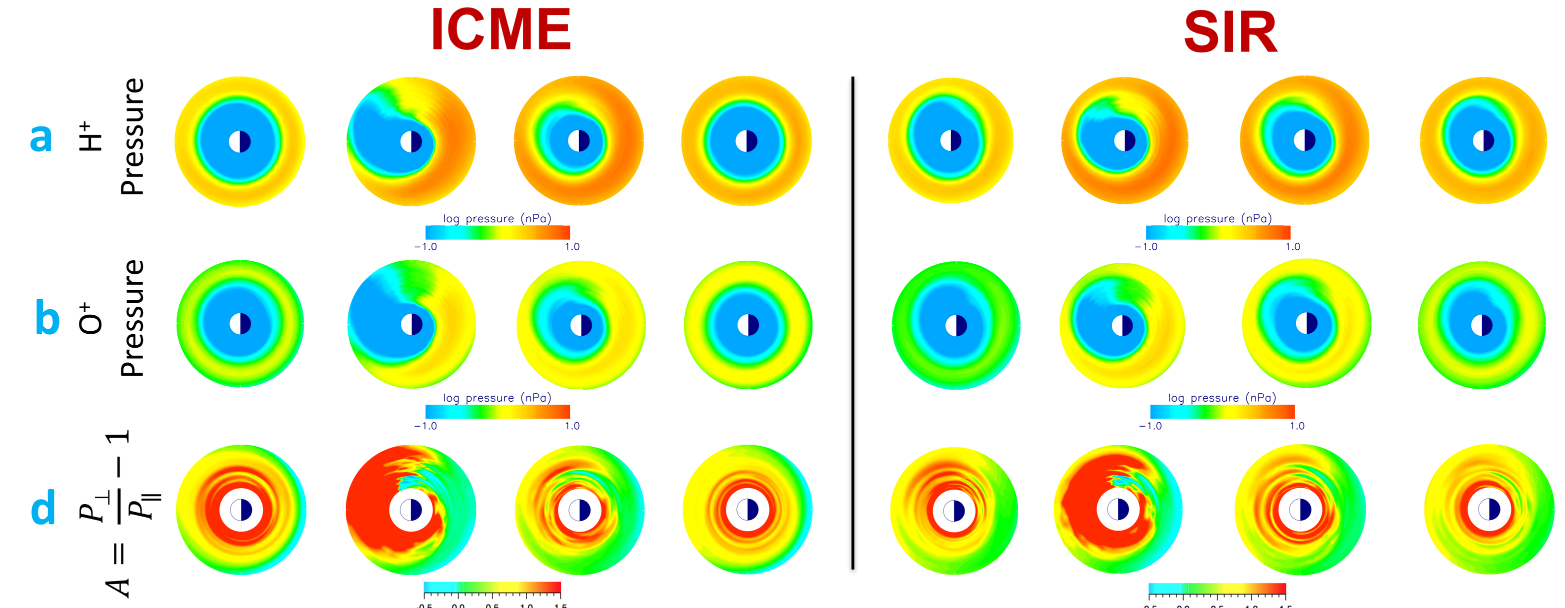
(b) 1-60 keV O^+ : Pressure is enhanced considerably more by ICMEs than SIRs in the main and early recovery phases.

(c) Total Pressure: Stronger pressure enhancement is seen in ICMEs. **Comes primarily from the higher O^+ contribution**.

(d) Anisotropy: Decreases during the main phase in regions where ions drift in on open drift paths reach.

CIMI Simulation Comparisons

The Comprehensive Inner Magnetosphere-Ionosphere Model (CIMI) [Fok et al. 2014] is used with the median ICME and SIR solar wind superposed epoch of the storms selected for this study (shown to the left).



- The H^+ main phase pressure increases in both ICMEs and SIRs to a similar ~10 nPa in agreement with the VAPs observations.
- The main phase ICME convection pattern is similar to the VAP observations.
- The O+ pressure is underestimated during all storm phases for both ICMEs and SIRs indicating a discrepancy in the O+ source.
- A much higher anisotropy, compared to observations, during the main phase of both ICME and SIR storms is predicted.

Summary

- This statistical study shows the main difference between the CME and SIR ring current pressure is that the **O^+ contribution is significantly higher on the duskside during ICME storms**.
- Comparing our statistical results to CIMI simulations shows comparable pressures during storm times but does not show the O^+ pressure difference between drivers.
- By evaluating a threshold linear theory based equation for EMIC wave generation we create a statistical picture for the properties that drive wave generation during storm times.
- We observe an increased likelihood of EMIC wave generation on the duskside during storm times, **with the greatest increase in SIRs during the recovery phases**.

Storm Time EMIC Wave Generation – Linear Theory Conditions

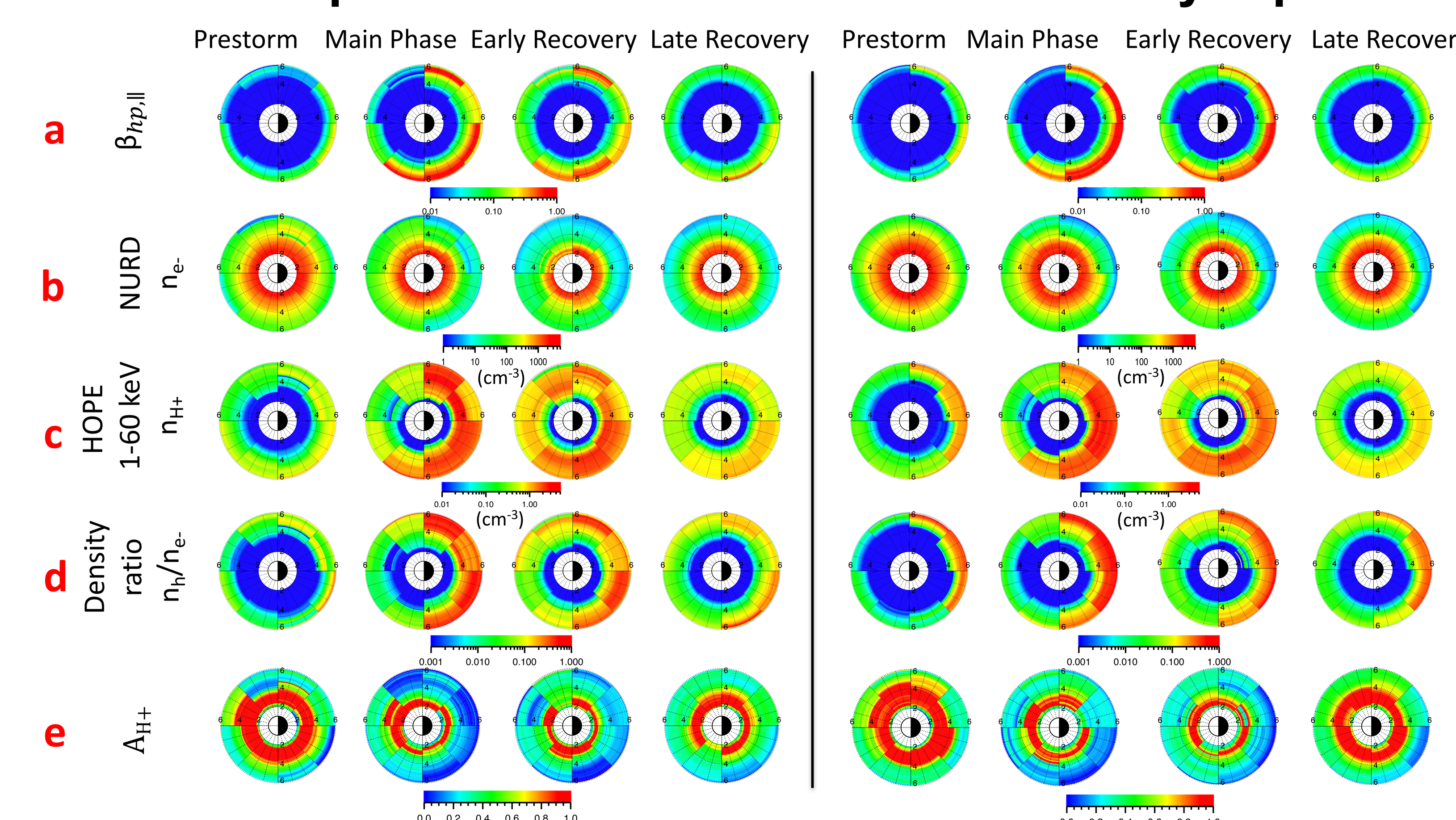
- We apply a threshold equation [Blum et al. 2009], which uses linear Vlasov theory to predict if conditions are favorable to excite EMIC waves.
- To do this we compare the storm time development of the <u>growth parameter</u> **Σ** to the <u>theoretical instability threshold</u> **S** for ICMEs and SIRs.

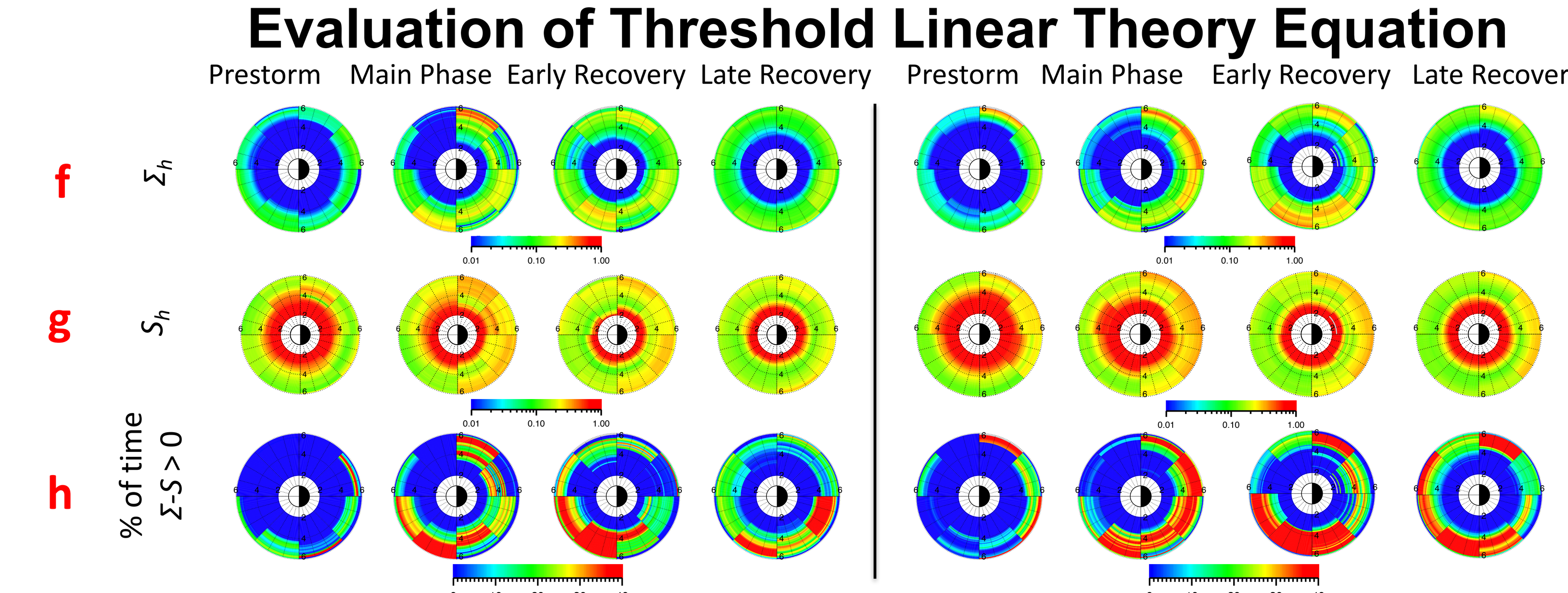
$$\Sigma_h = \left(\frac{T_{\perp,h}}{T_{\parallel,h}} - 1\right)\beta_{\parallel h}^{\alpha} \qquad S_h = \sigma_0 + \sigma_1 ln\left(\frac{n_h}{n_e}\right) + \sigma_2\left[ln\left(\frac{n_h}{n_e}\right)\right]^2$$

$$\alpha_h = a_0 - a_1 ln\left(\frac{n_h}{n_e}\right) - a_2\left[ln\left(\frac{n_h}{n_e}\right)\right]^2$$

with all proton quantities referring to the **hot proton population** (1-60 keV).

- If **Σ – S > 0**, then it is predicted that the H^+ anisotropy is sufficient to excite EMIC waves.
- Below is the statistical picture of the values comprising the linear theory equation for EMIC wave generation as measured by VAPs (**panels a – d**), and the percentage of time that the observational EMIC growth parameter exceeds the instability threshold (**panel** h) for ICME and SIR storms.





- During the main and early recovery phases for both ICMEs and SIRs, according to linear theory, there is a high likelihood of EMIC wave generation in the dusk region (**Panel h**). This matches observational results of storm time EMIC waves from Saikin et al. 2016.
- The nightside main phase areas where Σ - S > 0 (**Panel h**) are mainly driven by a observed high $\beta_\parallel$ (**Panel a**), while the anisotropy is fairly low (**Panel e**).
- In the recovery phase, duskside and dayside anisotropy increases, while $\beta_\parallel$ remains elevated, making them ideal locations for wave activity.
- During the recovery periods, **SIRs show an increased likelihood of satisfying the wave generation equation on the dusk and afternoon sectors**.

References

Zhelavskaya, I. S., M. Spasojevic, Y. Y. Shprits, and W. S. Kurth (2016), Automated determination of electron density from electric field measurements on the Van Allen Probes spacecraft, J. Geophys. Res. Space Physics, 121, 4611–4625, doi:10.1002/2015JA022132

Fok, M.-C., N. Y. Buzulukova, S.-H. Chen, A. Glocer, T. Nagai, P. Valek, and J. D. Perez (2014), The Comprehensive Inner Magnetosphere-Ionosphere Model, J. Geophys. Res. Space Physics, 119, 7522–7540, doi:10.1002/2014JA020239.

Blum, L. W., E. A. MacDonald, S. P. Gary, M. F. Thomsen, and H. E. Spence (2009), Ion observations from geosynchronous orbit as a proxy for ion cyclotron wave growth during storm times, J. Geophys. Res., 114, A10214, doi:10.1029/2009JA014396.

Saikin, A. A., J.-C. Zhang, C. W. Smith, H. E. Spence, R. B. Torbert, and C. A. Kletzing (2016), The dependence on geomagnetic conditions and solar wind dynamic pressure of the spatial distribu- tions of EMICwaves observed by the Van Allen Probes, J. Geophys. Res. Space Physics, 121, 4362–4377, doi:10.1002/ 2016JA022523.Received