Van Allen Probe Observations of Chorus Growth, Source, Seed, and Relativistic Electrons During ICME and CIR Storms

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Poster #10

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Motivation and Introduction

- Understanding the variability of the outer radiation belt during geomagnetic storms remains one of the outstanding problems in magnetospheric physics.
- Whistler mode chorus waves can play an important role in accelerating "seed" electron populations (100s of keV) to relativistic energies in the outer radiation belt during storm times.
- Discrepancies in typical characteristic solar wind features of ICMEs and CIRs generate differences in convection, plasma sheet source electron populations that drive chorus waves, and the seed electron populations.
- Using a Linear Theory proxy we have conducted a statistical study in MLT/L during each storm phase of the parameters that drive chorus waves by using plasma data from the Van Allen Probes (VAPs) spacecraft. This inferred growth rate is compared to VAP measured chorus wave power.
- We have used VAP data to create a superposed epoch of average flux levels at 300 keV, 1 MeV and 4 MeV data vs L for ICMEs and CIRs to study the development of the seed and relativistic electrons.

Data and Storm Selection

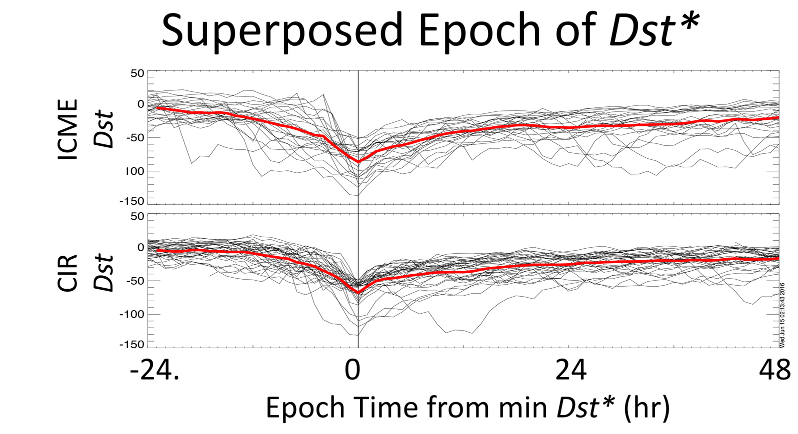
Van Allen Probes A & B

- **HOPE** – e^- < 60 keV.
- **MagEIS** – e^- 30 keV – 4 MeV.
- **EMFISIS** – magnetometer and waves instrument

Storm Selection

- 25 ICME and 35 SIR/CIR Storms are identified between 2013-02-01 and 2016-04-16 with a minimum *Dst** between -50 and -150 nT.
- Storms required a single identifiable driver (ICME/CIR) and periods after the start of a second dip in *Dst* were not used.

Superposed Epoch of *Dst**



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

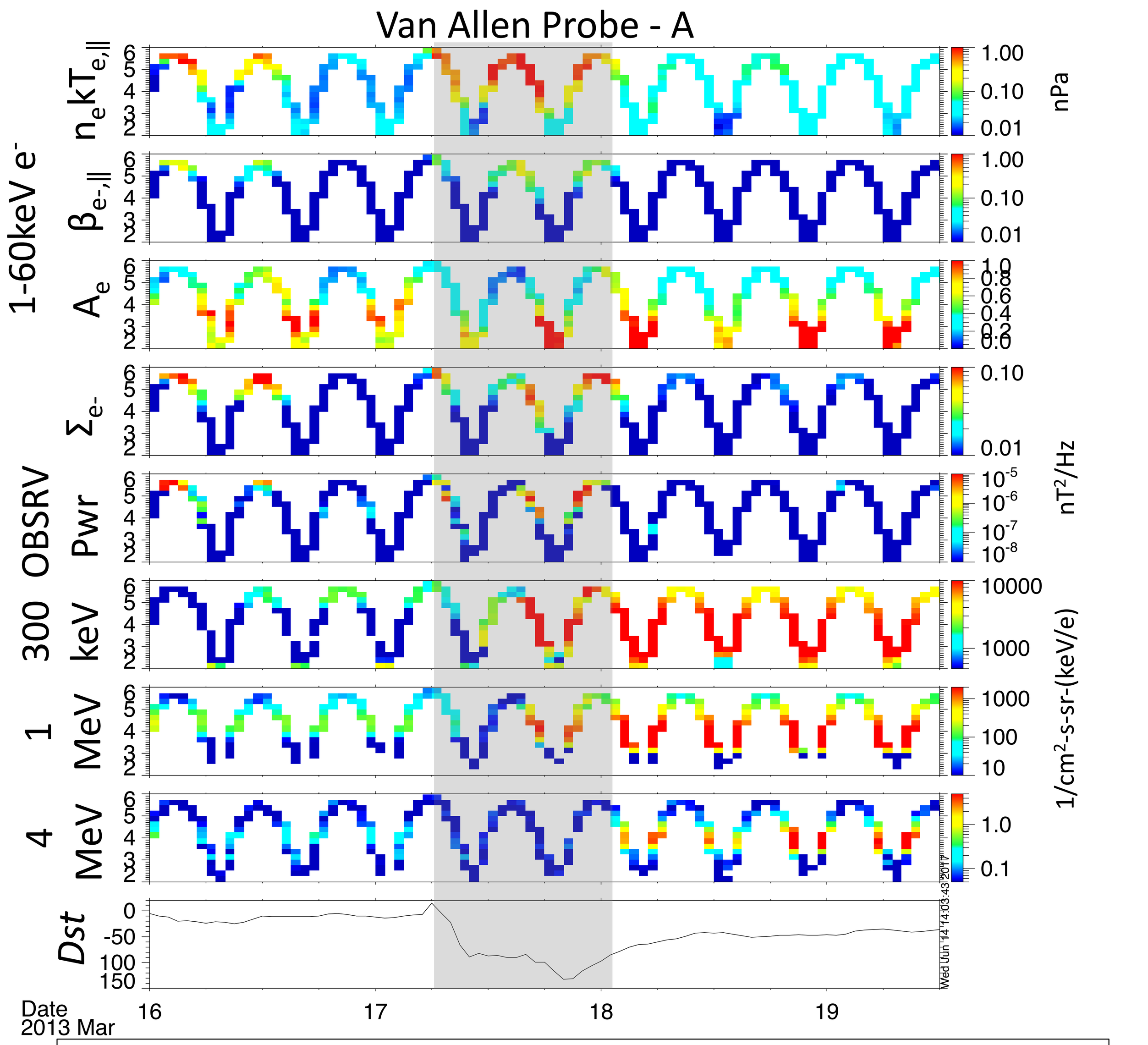
Chorus Wave Proxy-Single Storm

- MacDonald et al. 2008 – Developed a linear theory proxy based on plasma measurements to predict Chorus wave growth rates.
- Inferred Chorus Growth rate, Σ_e, with hot (1-60 keV) electron anisotropy and hot electron parallel plasma beta:

$$\Sigma_e = \left(\frac{T_{e,\perp}}{T_{e,\parallel}} - 1\right)\beta^{\alpha}_{e\parallel} \qquad \beta^{\alpha}_{e,\parallel} = \frac{n_e k T_{e,\parallel}}{B^2/2\mu_0}$$

- March 17th storm was shown to have MeV enhancements via chorus acceleration of lower energy e^- [Boyd et al 2014, Li et al. 2014].

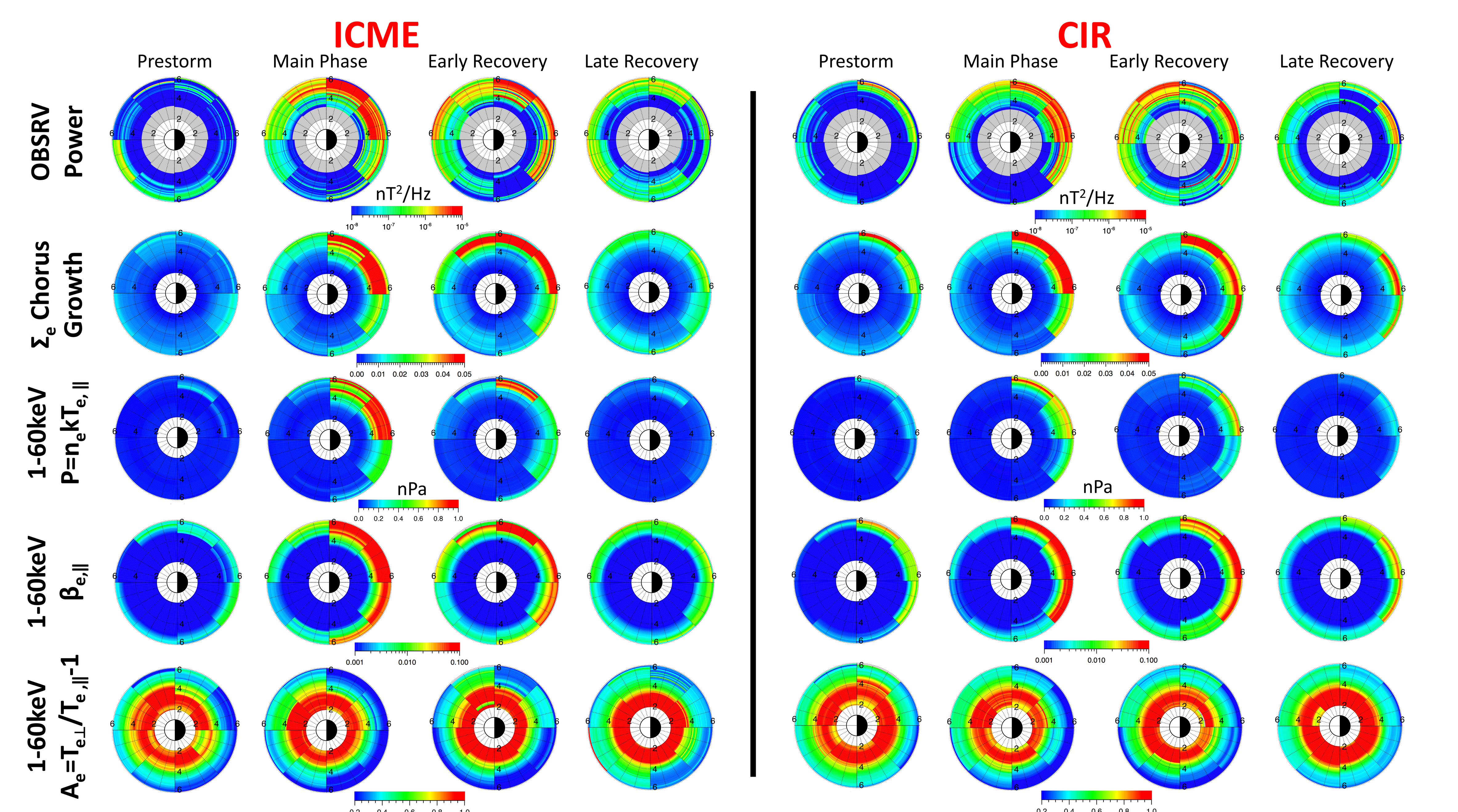
Van Allen Probe - A



Overlap of elevated $\beta_{e,\parallel}$ and A_e leads to higher chorus growth rate Σ_e and measured wave power. Wave activity with enhanced seed e^- leads to RB enhancement.

Chorus Wave Proxy & Measurements-Statistical Study

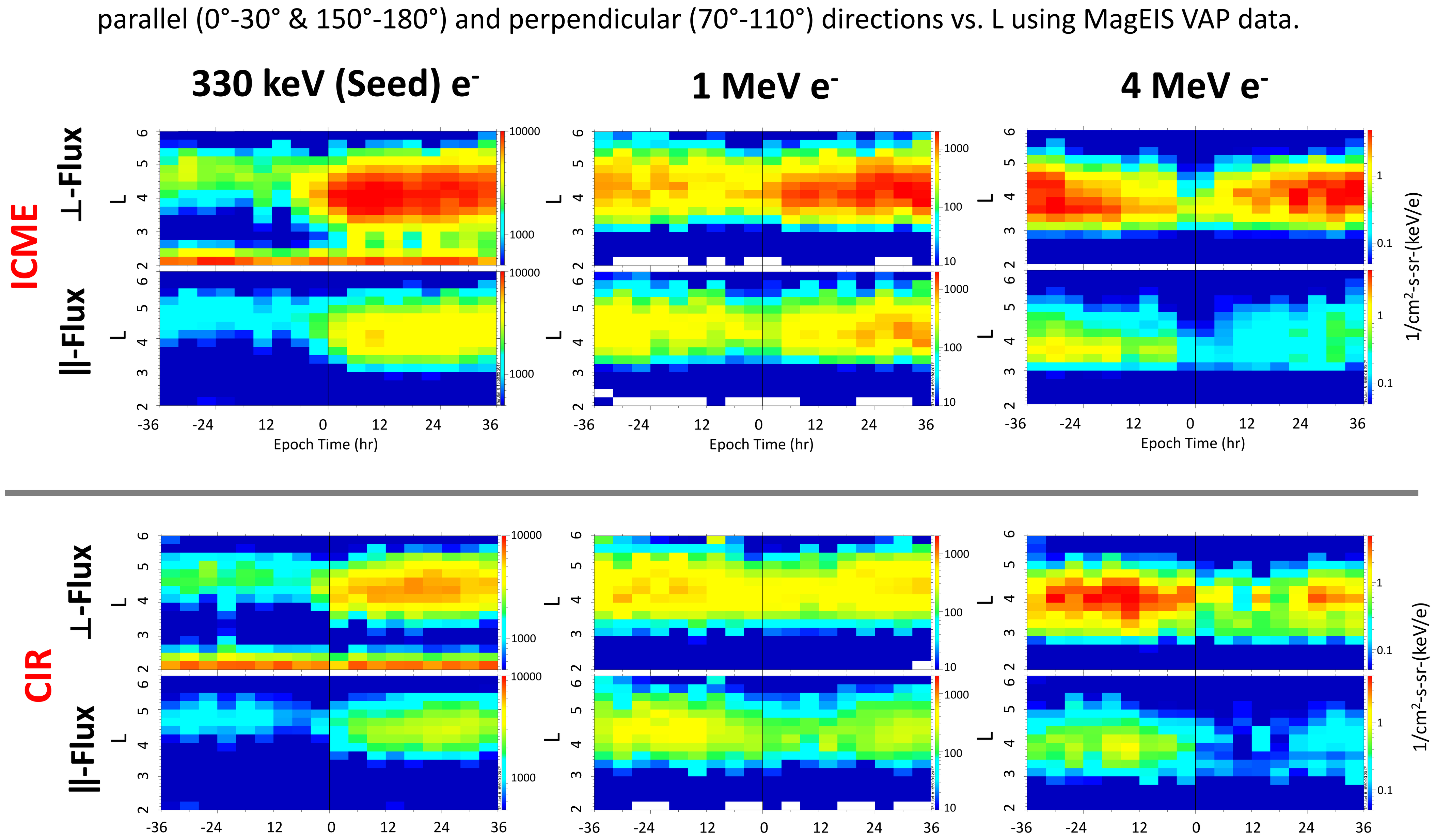
- Using chosen 25 ICME & 35 CIR storms we map the average conditions for each individual term that comprises the linear theory proxy for chorus wave growth, the inferred growth rate, and the measured wave power in MLT and L by storm phase and driver.



- Main phase convection drives electrons eastward, increasing pressure and plasma beta, which drives growth rate/wave power.
- Electrons drift further eastward in recovery periods, expanding chorus activity in MLT.
- Electron anisotropy drops during main phase in regions accessed by fresh electrons driven by convection.
- Electron Anisotropy increases during recovery phases.
- Inferred chorus growth rate compares well with measured wave power.
- Similar inferred growth rate and observed wave power for ICMEs and CIRs.

Superposed Epoch Seed Population and Radiation Belt Response

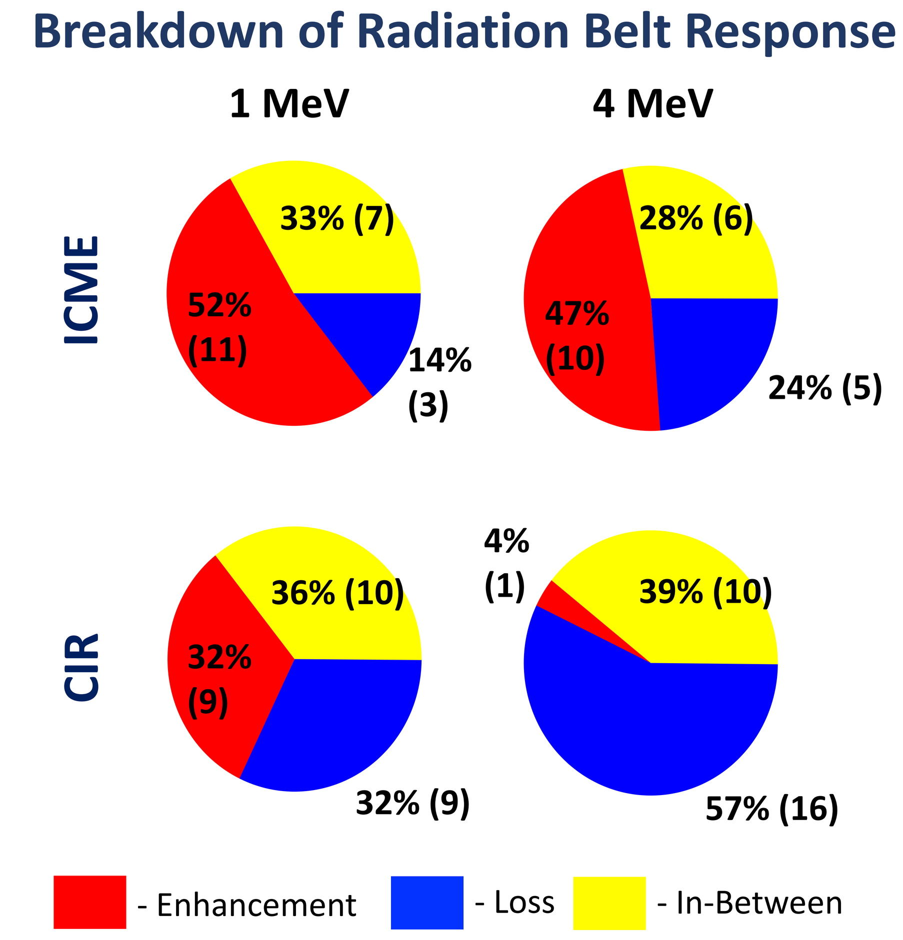
- Using chosen ICME/CIR storms - created a superposed epoch (t=0 at *Dst** min) of average seed and relativistic electron flux levels in the parallel (0°-30° & 150°-180°) and perpendicular (70°-110°) directions vs. L using MagEIS VAP data.



Observations

- Significantly stronger enhancement of seed population in ICME storms.
- Much more likely to see enhancement in 1 and 4 MeV e^- during our ICME storms.
- Enhancement in 4 MeV e^- is almost entirely in perpendicular direction.
- CIR storms have fewer enhancements 4 MeV e^- than 1 MeV e^-.
- ICMEs do not show the same feature, and 1 MeV e^- response is similar to 4 MeV e^-.

Breakdown of Radiation Belt Response



- Percentage of storms showing 1 MeV or 4 MeV e^- **loss** (Flux drop by a factor of 2), **enhancements** (Flux increased by a factor of 2) or **in-between**.
- Average flux between L of 3.5-5 from 1.5 to .5 days before min *Dst** are compared to those .5 to 1.5 post min *Dst** to determine response.

Summary/Conclusions

- Mapped the plasma parameters in MLT/L that drive chorus waves during different storm phases for ICMEs and CIRs.
- Showed that **chorus wave activity increases across** the **dayside as** the **storm progresses and source e^- drift further in MLT**.
- Our **ICME and CIR storms have similar levels of chorus wave activity** as measured by EMFISIS and the linear theory proxy.
- Inferred chorus growth rate driven by $\beta_{e,\parallel}$ in storm times.
- **Measured wave activity compares well to inferred growth rates.**
- **Seed electron population** sees a much **stronger enhancement for our ICME storms over CIRs.**
- The **average 1 MeV and 4 MeV response** is **more likely to be an enhancement for our ICME storms over our CIR** storms.
- Our **CIR storms** see **very few 4 MeV enhancements**.
- The enhanced seed population in our ICME storms could help explain the greater likelihood of an outer RB enhancement.
- Enhancements of the 4MeV e^- are mainly in the $\perp$ - direction.

References

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