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A new statistical model for plasmaspheric hiss and its effect on electron losses

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(1) British Antarctic Survey, UK

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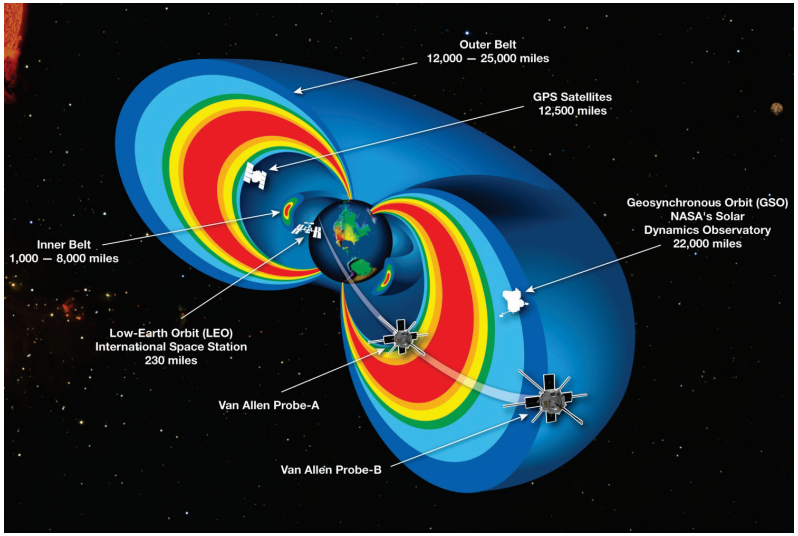
Van Allen Radiation Belts

- Risk for spacecraft
- Danger for humans in space
- Inner belt: stable
- Outer belt: highly variable
- Main cause for variability: Plasma waves



Source: NASA

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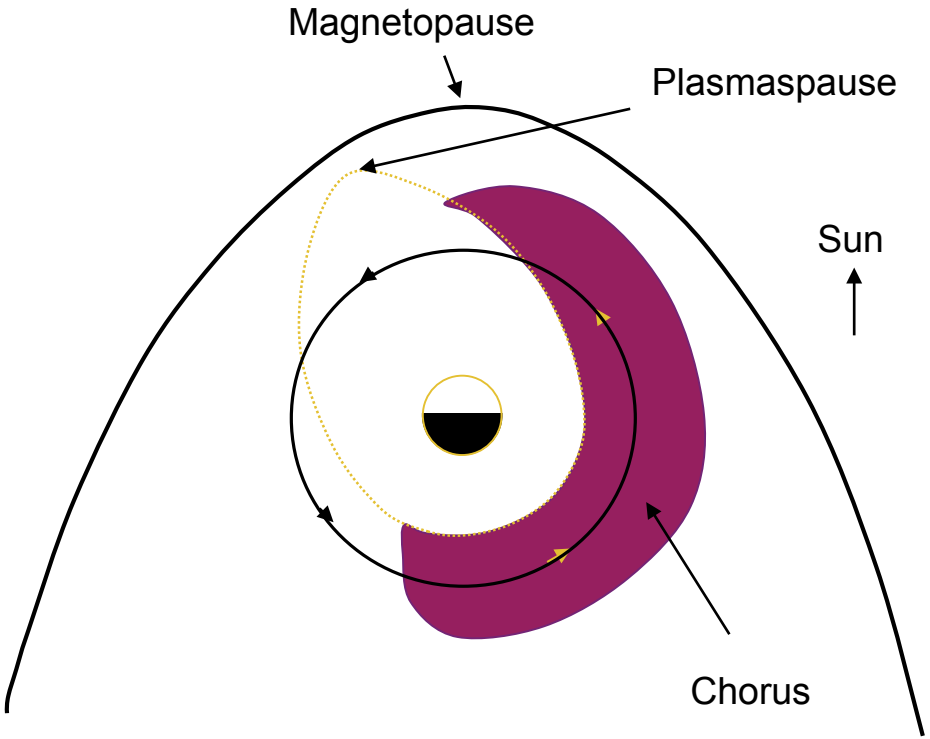
Types of plasma waves

- *Chorus waves*:
  - Major cause of acceleration and loss



Types of plasma waves

- *Chorus waves*:
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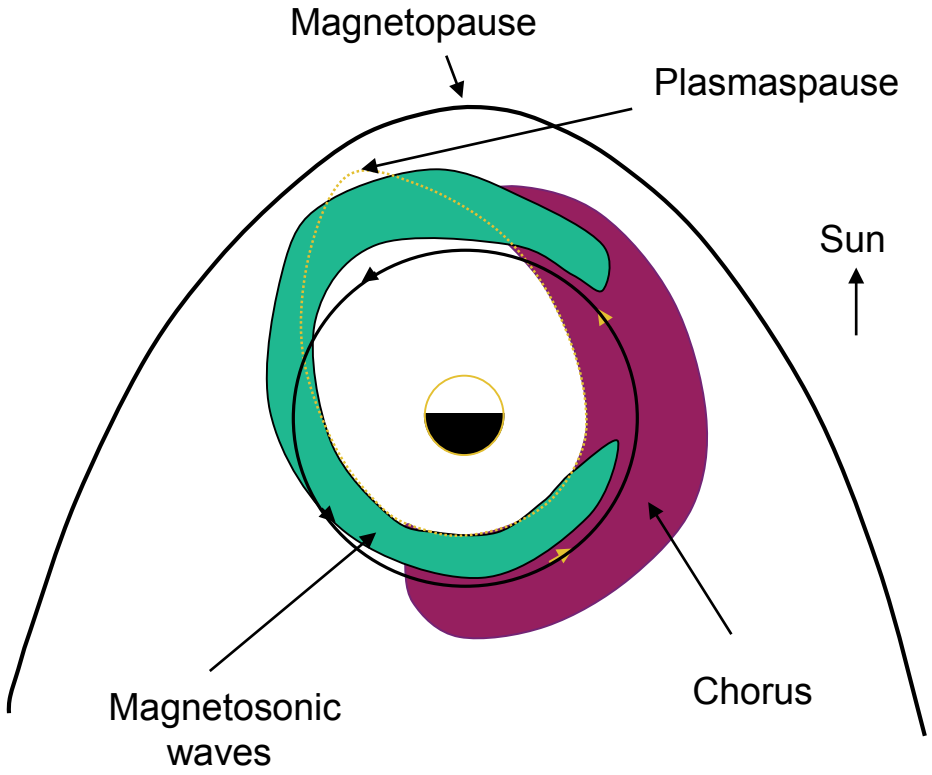
- *Magnetosonic waves*:
  - May be an important acceleration mechanism



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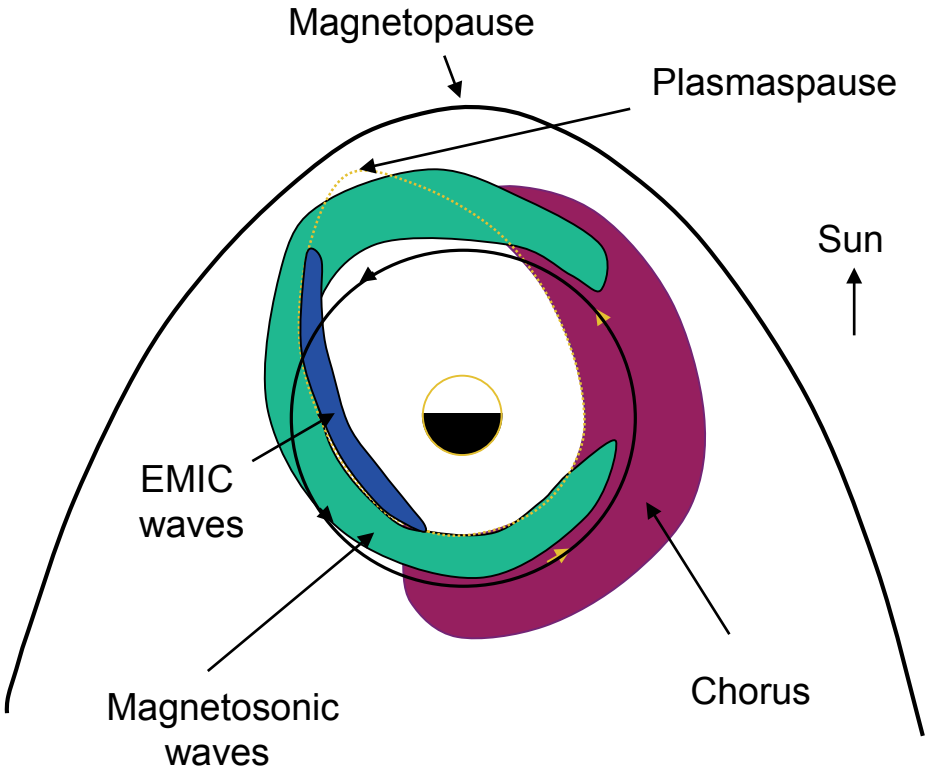
  - Losses of ultrarelativistic electrons at low pitch-angles



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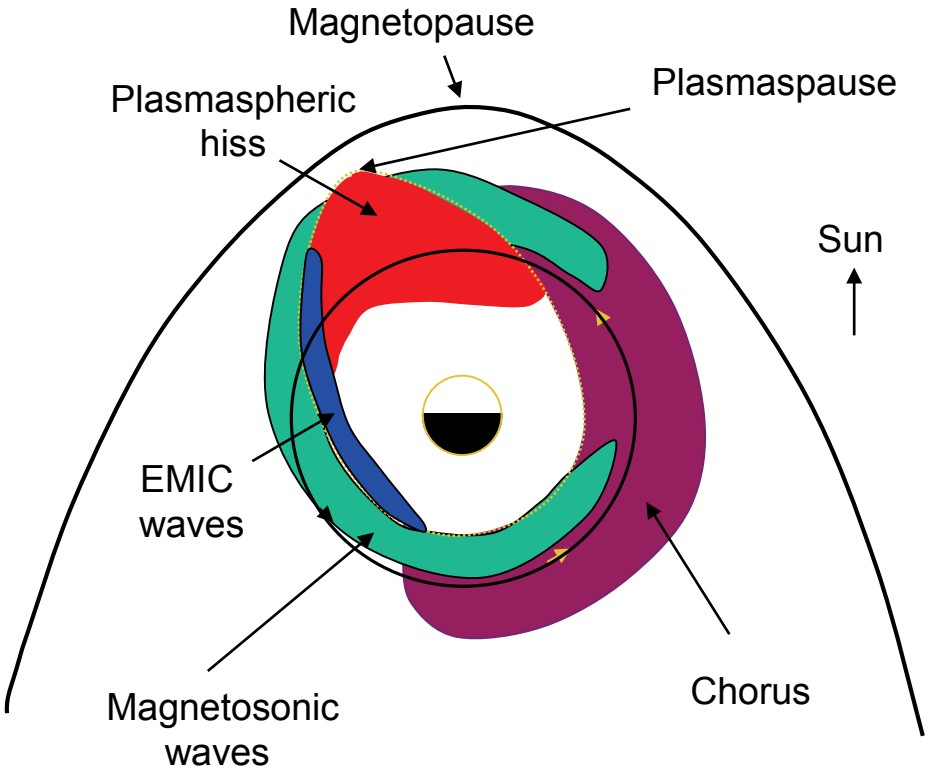

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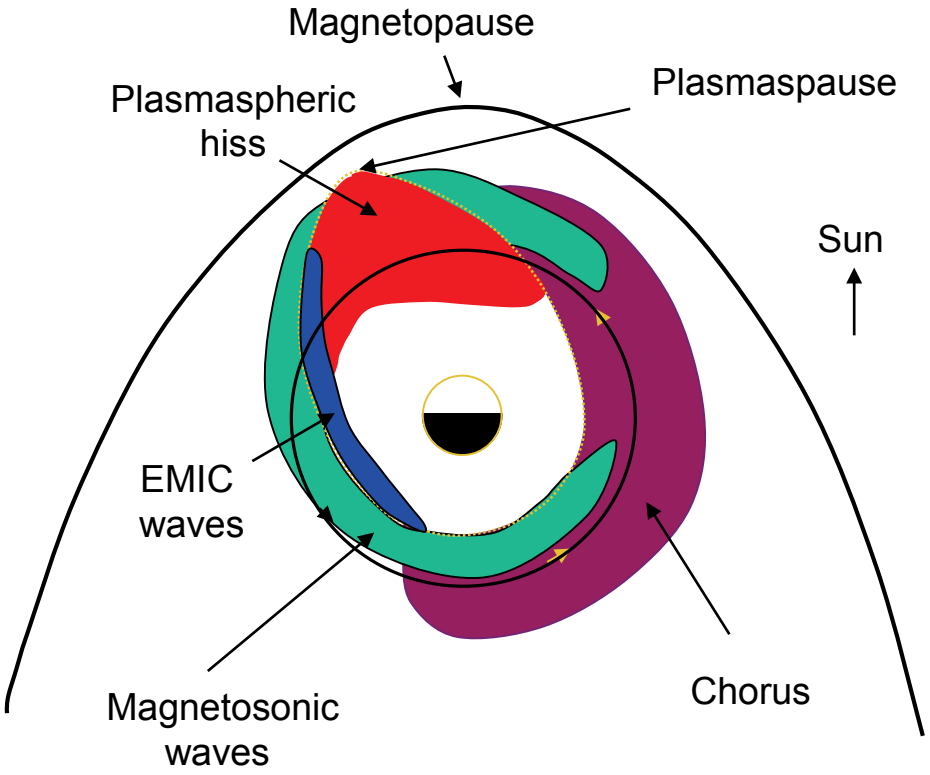

Objective of Study: Determine the effectiveness of hiss

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Modelling the Radiation Belts

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BAS Radiation Belt Model

- Fokker-Planck Equation

$$\frac{\partial f}{\partial t} = L^2 \frac{\partial}{\partial L}\left(\frac{D_{LL}}{L^2}\frac{\partial f}{\partial L}\right)\Bigg|_{\mu J} + \frac{1}{g(\alpha)}\frac{\partial}{\partial \alpha}\left(g(\alpha)D_{\alpha\alpha}\frac{\partial f}{\partial \alpha}\right)\Bigg|_{EL} + \frac{1}{A(E)}\frac{\partial}{\partial E}\left(A(E)D_{EE}\frac{\partial f}{\partial E}\right)\Bigg|_{\alpha L} - \frac{f}{\tau(\alpha, E)}$$

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Radial transport

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Radial transport Pitch angle diffusion

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Radial transport Pitch angle diffusion Energy diffusion

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Radial transport | Pitch angle diffusion | Energy diffusion | Losses

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Radial transport | Pitch angle diffusion | Energy diffusion | Losses

- Drift & bounce averaged diffusion coefficients D_{LL}, $D_{\alpha\alpha}$, D_{EE} are activity, location and energy dependent

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Radial transport | Pitch angle diffusion | Energy diffusion | Losses

- Drift & bounce averaged diffusion coefficients D_{LL}, $D_{\alpha\alpha}$, D_{EE} are activity, location and energy dependent

- Calculate $D_{\alpha\alpha}$ and D_{EE} with PADIE diffusion code [Glauert and Horne, 2005]

- Requires wave spectral data -> Wave model

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New Plasmaspheric Hiss Model

- Wave spectral data from seven different satellites: CRRES, Double Star TC1, Dynamics Explorer 1, Cluster 1, THEMIS A, D, and E

- Derived statistical model for plasmaspheric hiss:
  - Frequency range covered: 100 Hz – 4 kHz
  - 12 levels of L* covering 1.5 < L* < 7.0 (in steps of 0.5 L*) Includes hiss in plumes
  - 24 levels of MLT
  - 10 levels of geomagnetic latitude covering $3° < \lambda_m < 60°$ (in steps of 6 °)
  - 6 levels of geomagnetic activity (AE)

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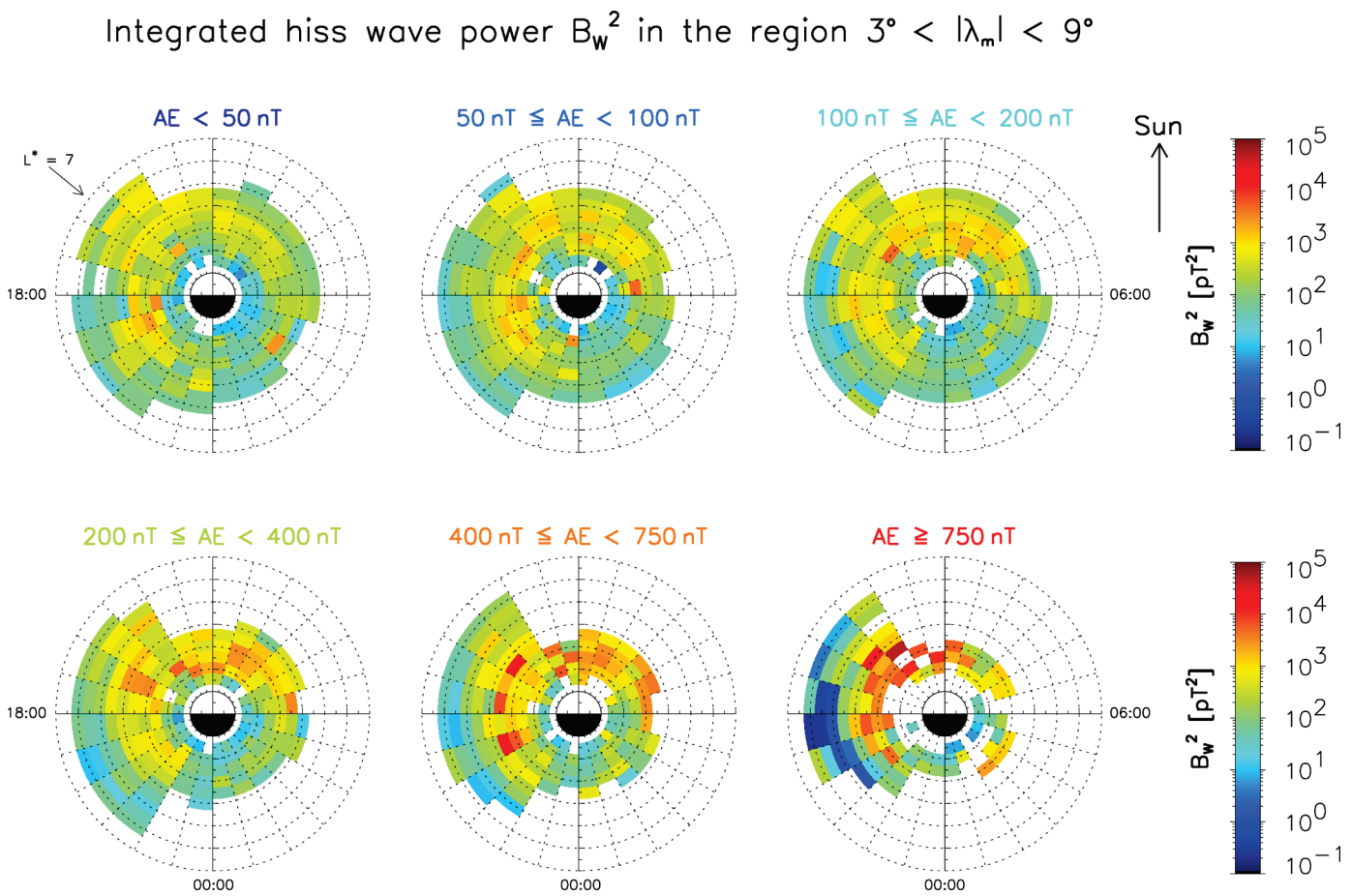
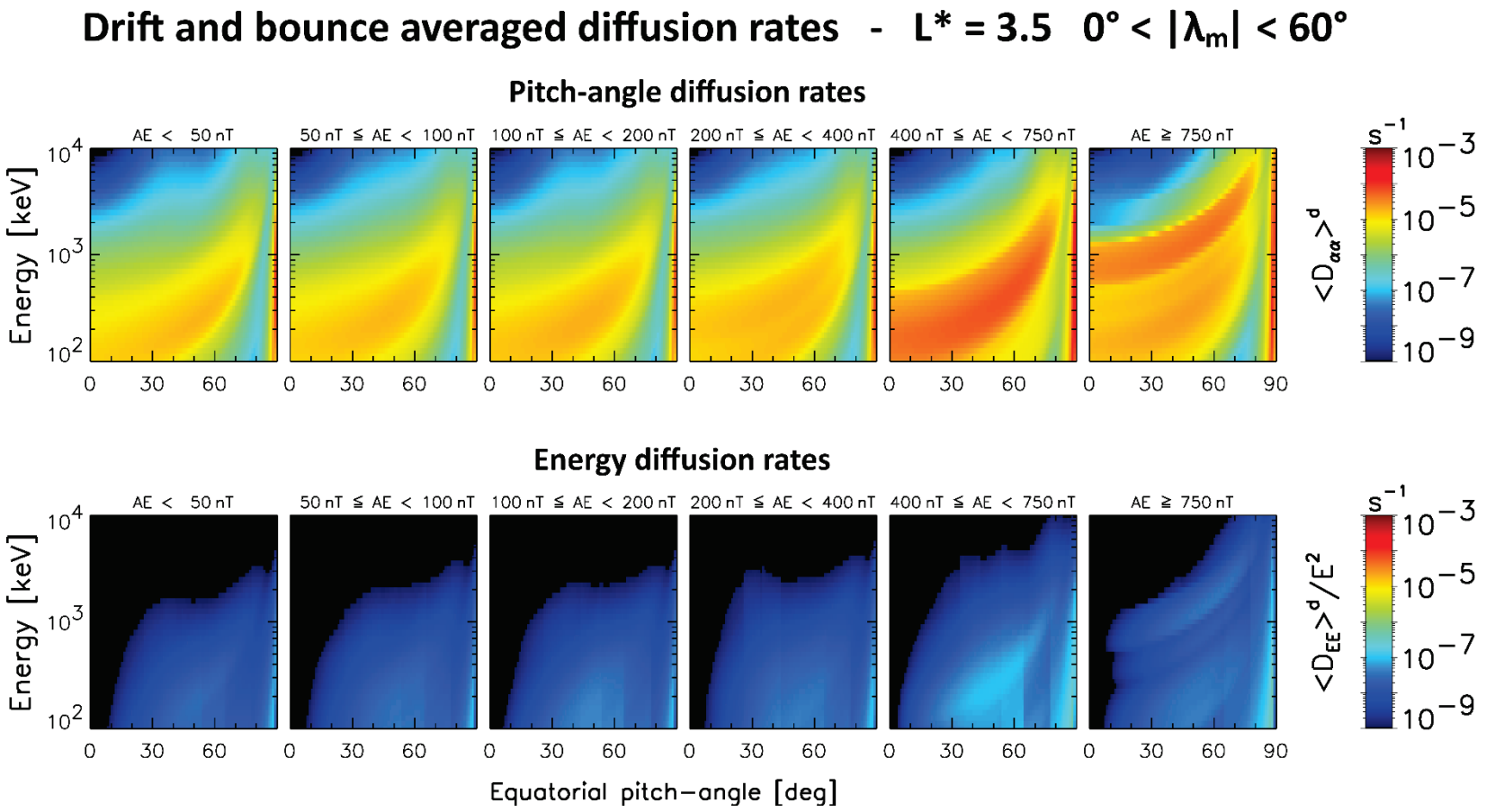
Plasmaspheric Hiss – Wave Power

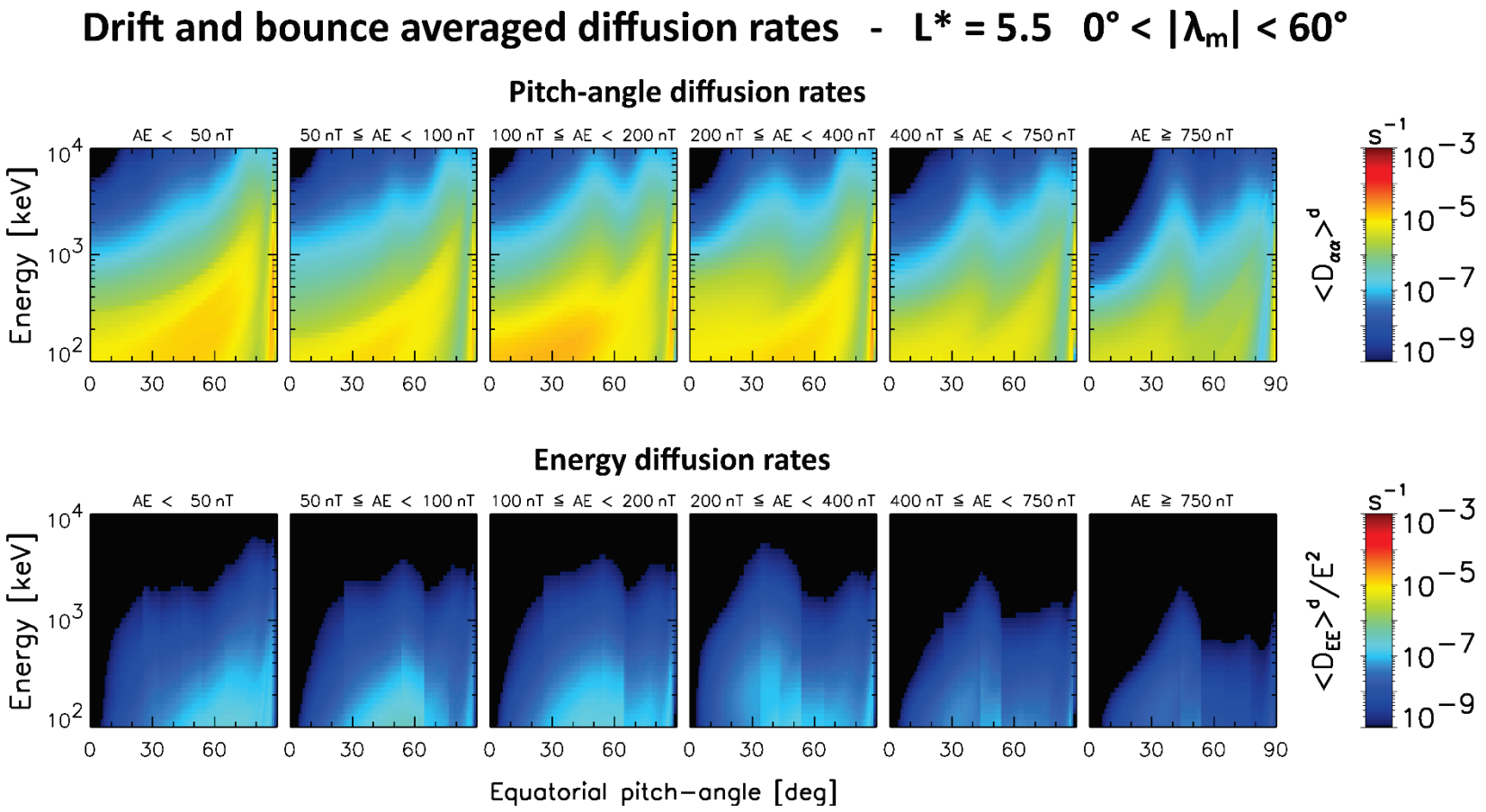


Diffusion Rates

Drift and Bounce Averaged Diffusion Rates



Drift and Bounce Averaged Diffusion Rates



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Electron Flux

- Selected Van Allen Probes period:
  03 March 2015 – 31 March 2015 (St. Patrick‘s day storm)

- BAS RBM driven by:
  - Brautigam & Albert radial diffusion coefficients
  - Our most recent lower and upper band chorus wave model
  - Our most recent EMIC wave model
  - Presented plasmaspheric hiss wave model

- Initial and Boundary conditions derived from VAP data

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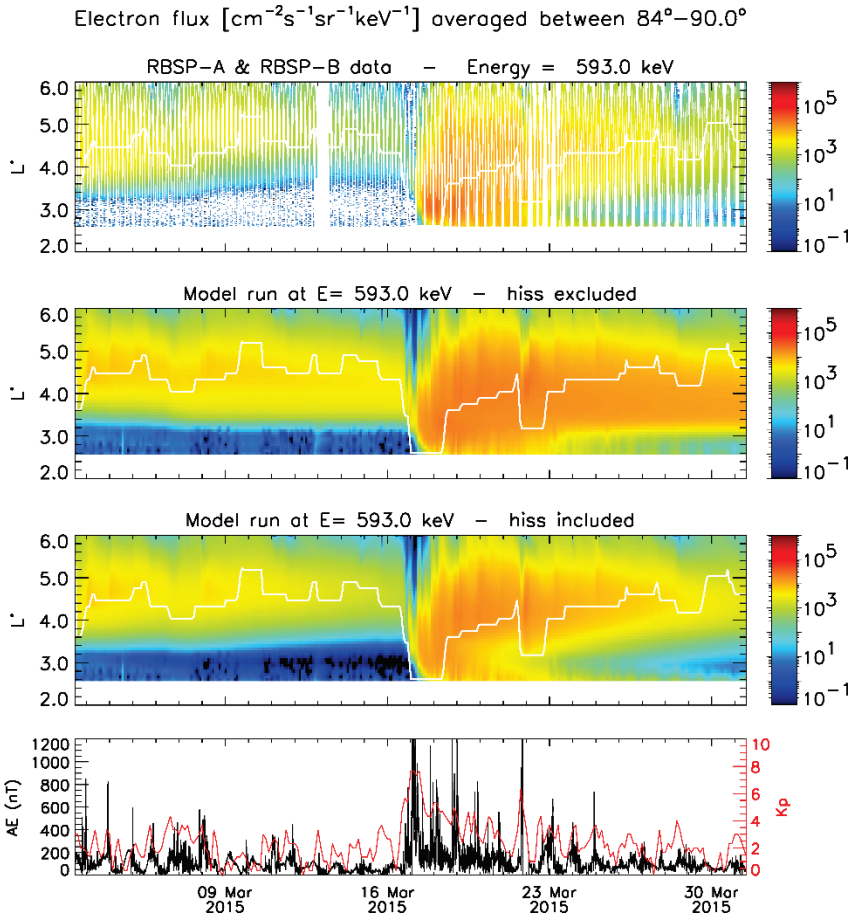
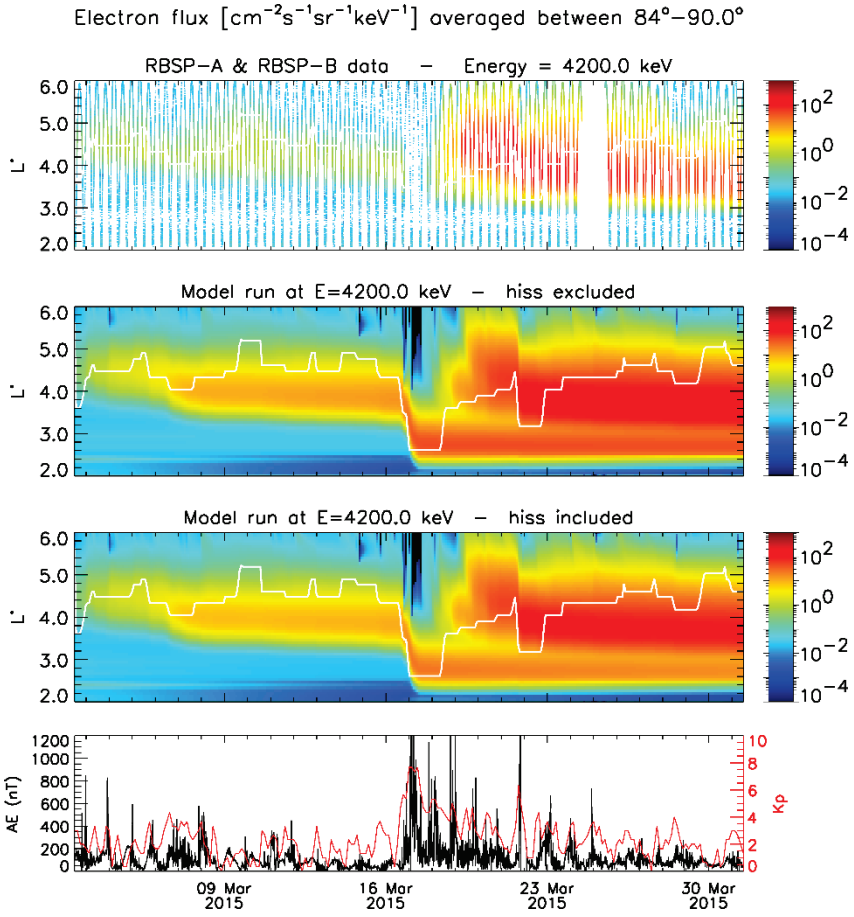
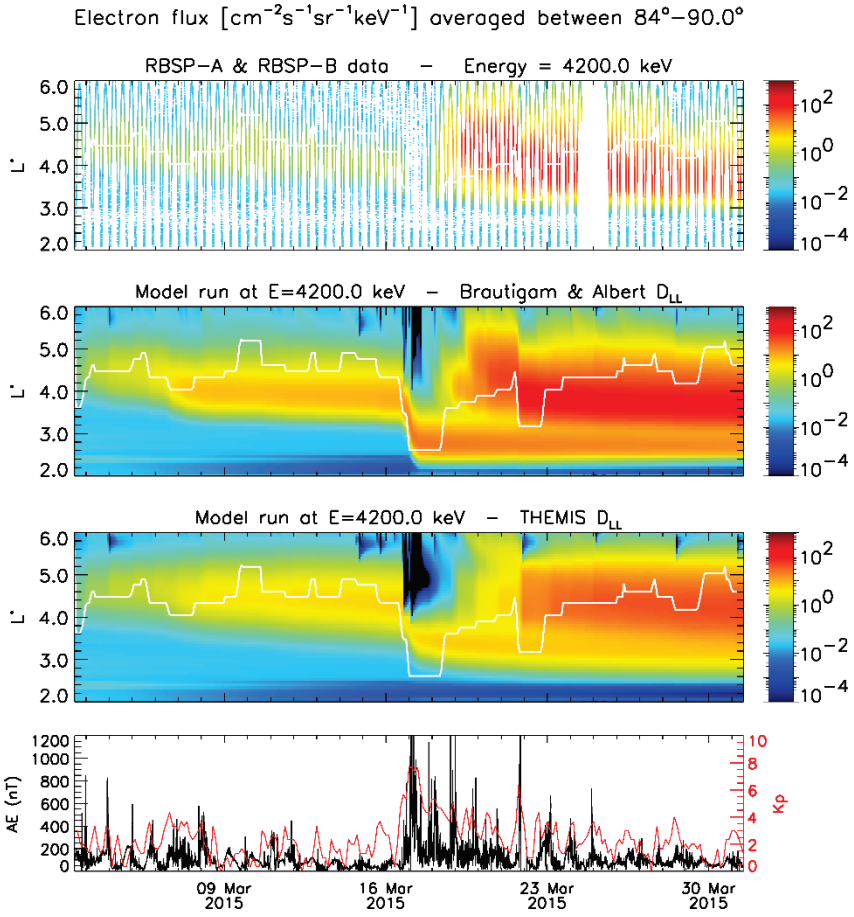
90° Electron Flux – 593 keV



90° Electron Flux – 4200 keV



90° Electron Flux – 4200 keV – D_{LL} Comparison



Summary and Conclusions

- Developed statistical hiss wave model based on data from 7 satellites.
- Considerably improved resolution of L*, MLT, and geomagnetic activity
- Hiss provides good agreement with VAP data between 100 keV and 1 MeV
- There are issues for E > 2 MeV at low L*
- Indications that radial diffusion too strong inside the plasmapause at high energies
- Is there evidence for reduced ULF wave power inside the plasmapause?

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Acknowledgements

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