Global Model of Lower Band and Upper Band Chorus from Multiple Satellite Observations

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Introduction

- Gyroresonant wave particle interactions with whistler mode chorus play a key role in radiation belt dynamics

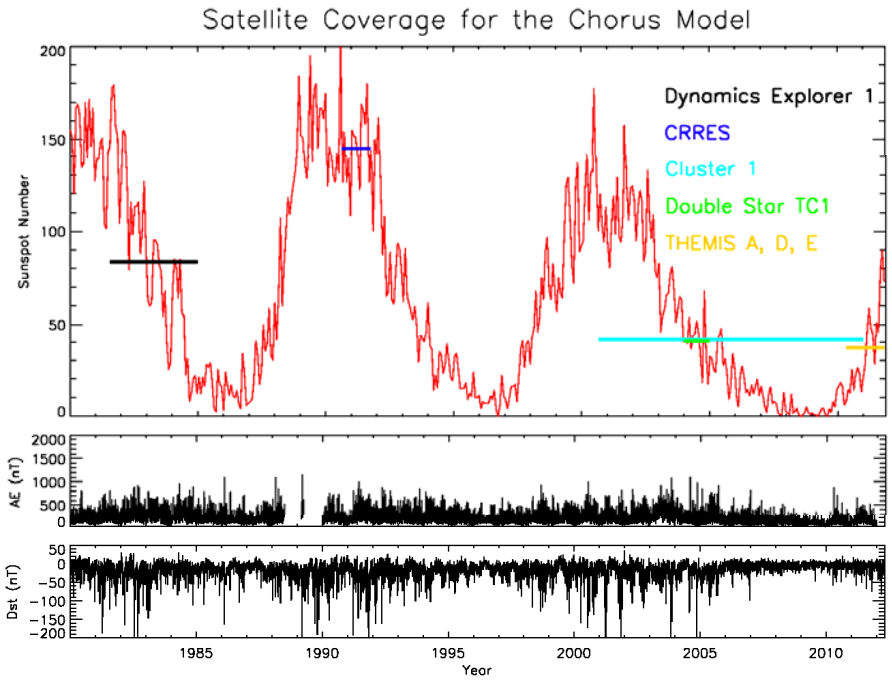
- Knowledge of the variability of the chorus wave power as a function of location and geomagnetic activity, required for computation of pitch angle and energy diffusion rates, is thus a critical input to radiation belt models

VLF Wave Database

- To improve our radiation belt models and forecasts for SPACECAST we have developed a large database of VLF waves

- We use data from 5 satellites:
  - Dynamics Explorer 1
  - CRRES
  - Cluster 1
  - Double Star TC1
  - THEMIS

- Database covers all the different phases of the solar cycle



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Magnetic Coordinates

- Radiation belt models calculate the phase space density as a function of energy, pitch angle, L* and time.
- L* is related to the third adiabatic invariant, Φ (Roederer, 1977)
- We develop our new global model as a function of L*, MLT and λ_m
- Calculate L*, MLT and λ_m using the ONERA-DESP library v4.2 (Boscher et al., 2008)
- The IGRF field at the middle of the appropriate year and the Olson-Pfitzer quiet time model (Olson and Pfitzer, 1977)

Wave Database

- For each satellite we bin the average wave intensity and number of samples as a function of
  - Frequency (13 variable and 8 fixed frequency bands)
  - L*
  - MLT
  - MLAT
  - Location with respect to the plasmapause
  - Magnetic activity

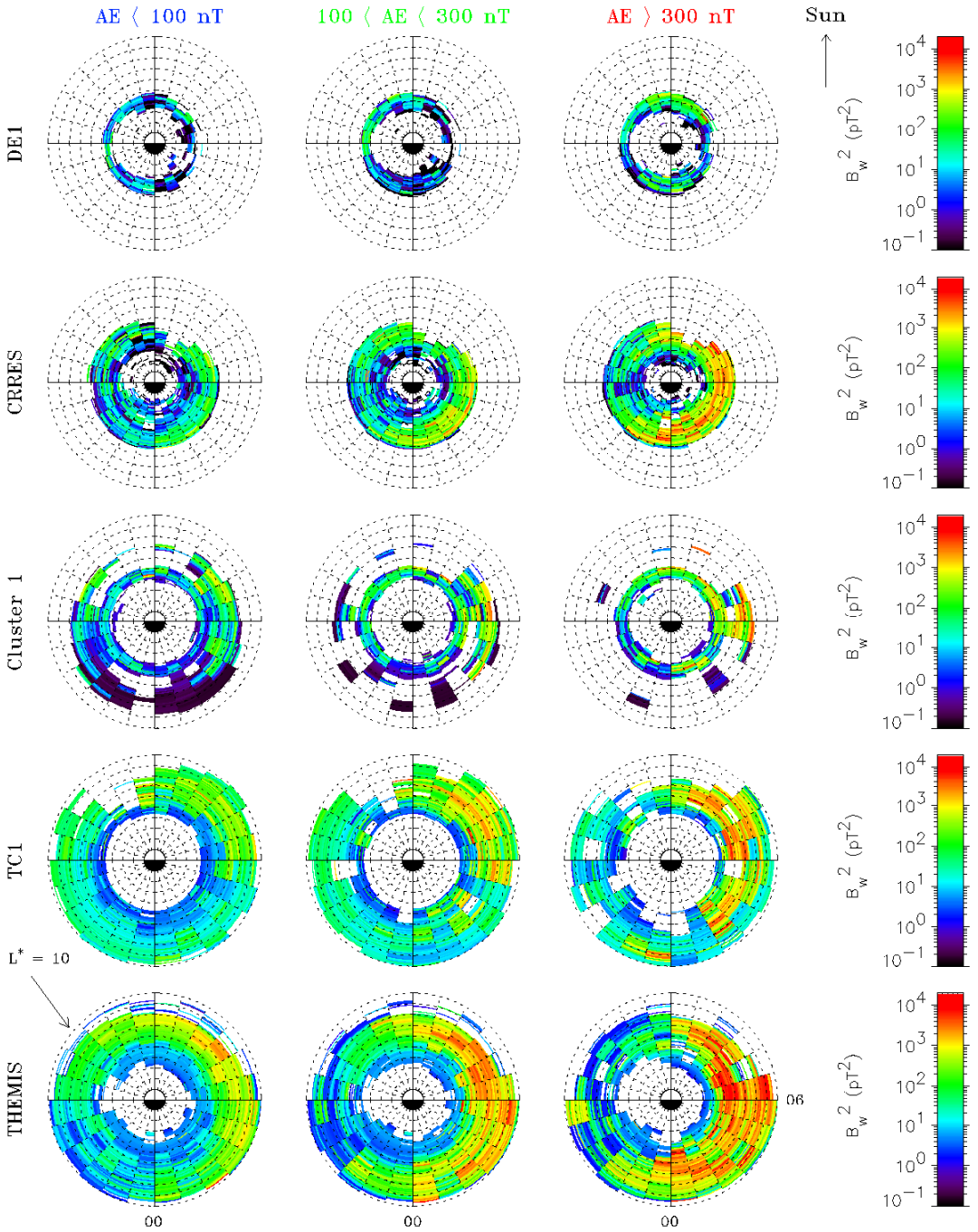
Statistical Analysis

- Here we conduct a statistical analysis of the average wave intensities of lower (0.1fce < f < 0.5fce) and upper (0.5fce < f < fce) band chorus as a function of spatial location and geomagnetic activity

- We split the magnetic activity into three levels which we define as
  - Quiet AE < 100 nT
  - Moderate 100 < AE < 300 nT
  - Active AE > 300 nT

Equatorial Lower Band Chorus

- Average wave intensity outside the plasmapause as a function of L* and MLT for the region $-15^o < \lambda_m < 15^o$
- Lower band chorus is substorm dependent
- Largest intensities are seen during active conditions primarily on the dawn-side



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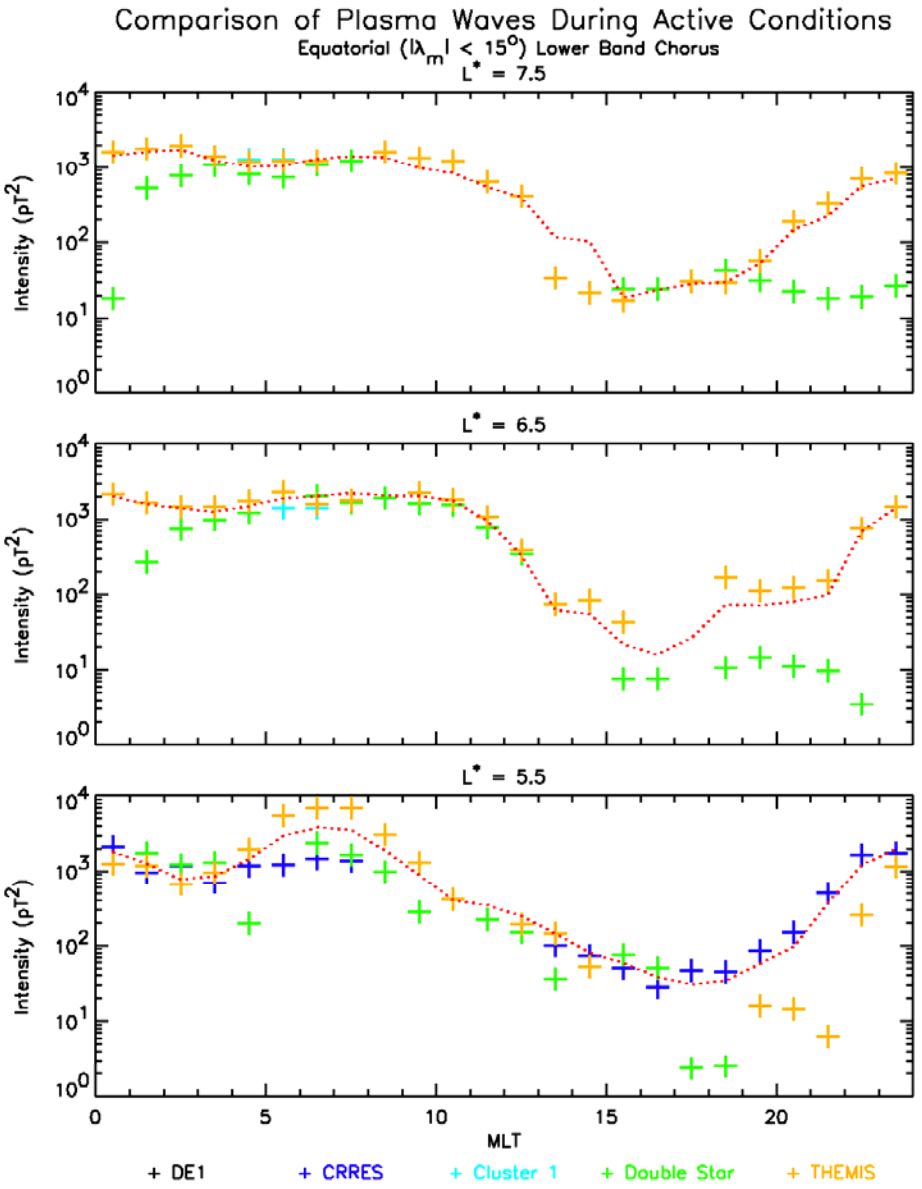
Inter-comparison of Wave Data

- At L*= 6.5 and 7.5 there is good agreement, largely to within a factor of 2 or so between the THEMIS and Double Star TC1 data between 0200 and 1900 MLT

- At L*= 5.5 there is slightly more scatter but generally good agreement between the CRRES, THEMIS and Double Star TC1 values between 0200 and 1600 MLT



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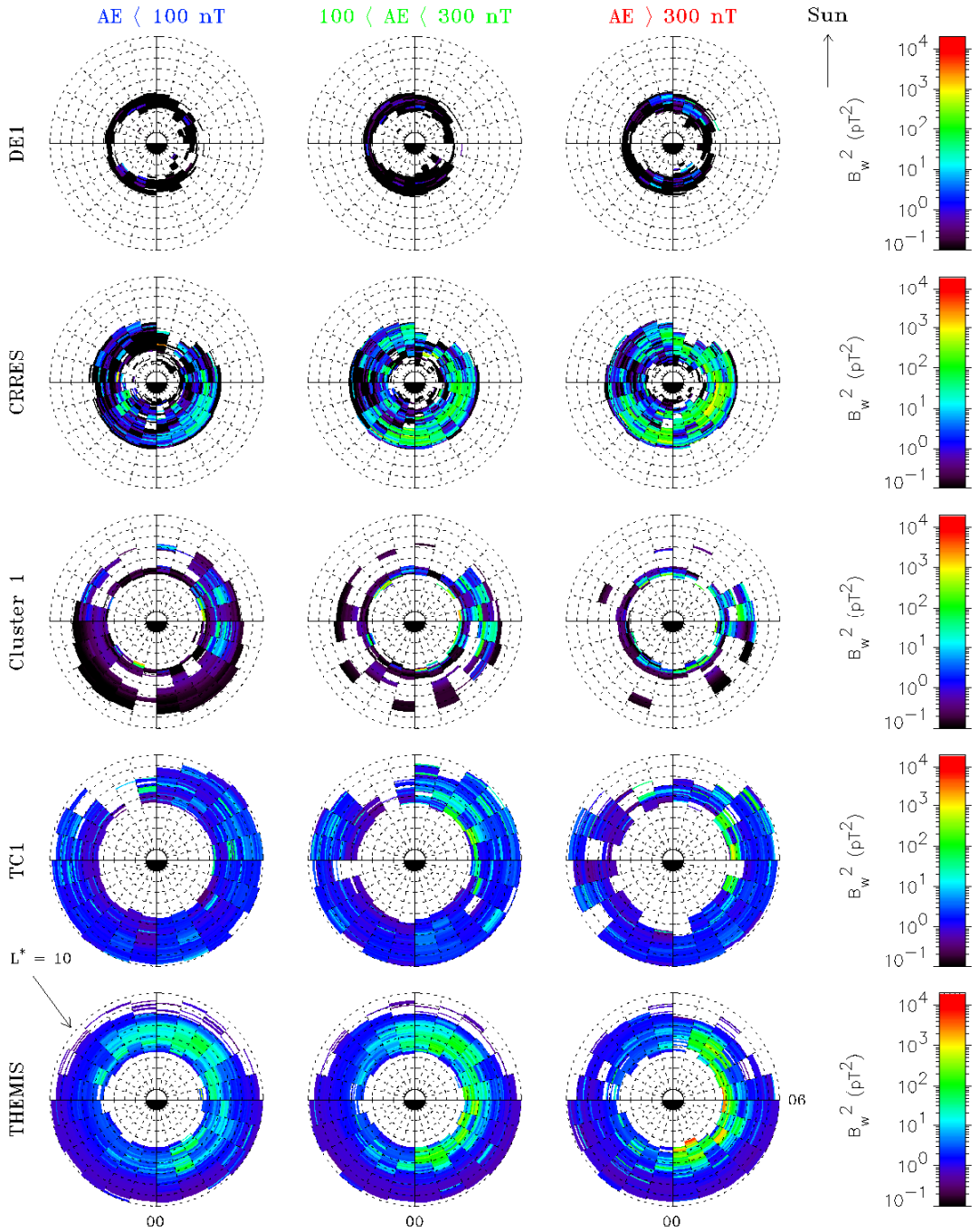
Equatorial Upper Band Chorus

- Upper band chorus is also substorm dependent but much weaker and less extensive
- Largest intensities are again seen during active conditions on the dawn-side



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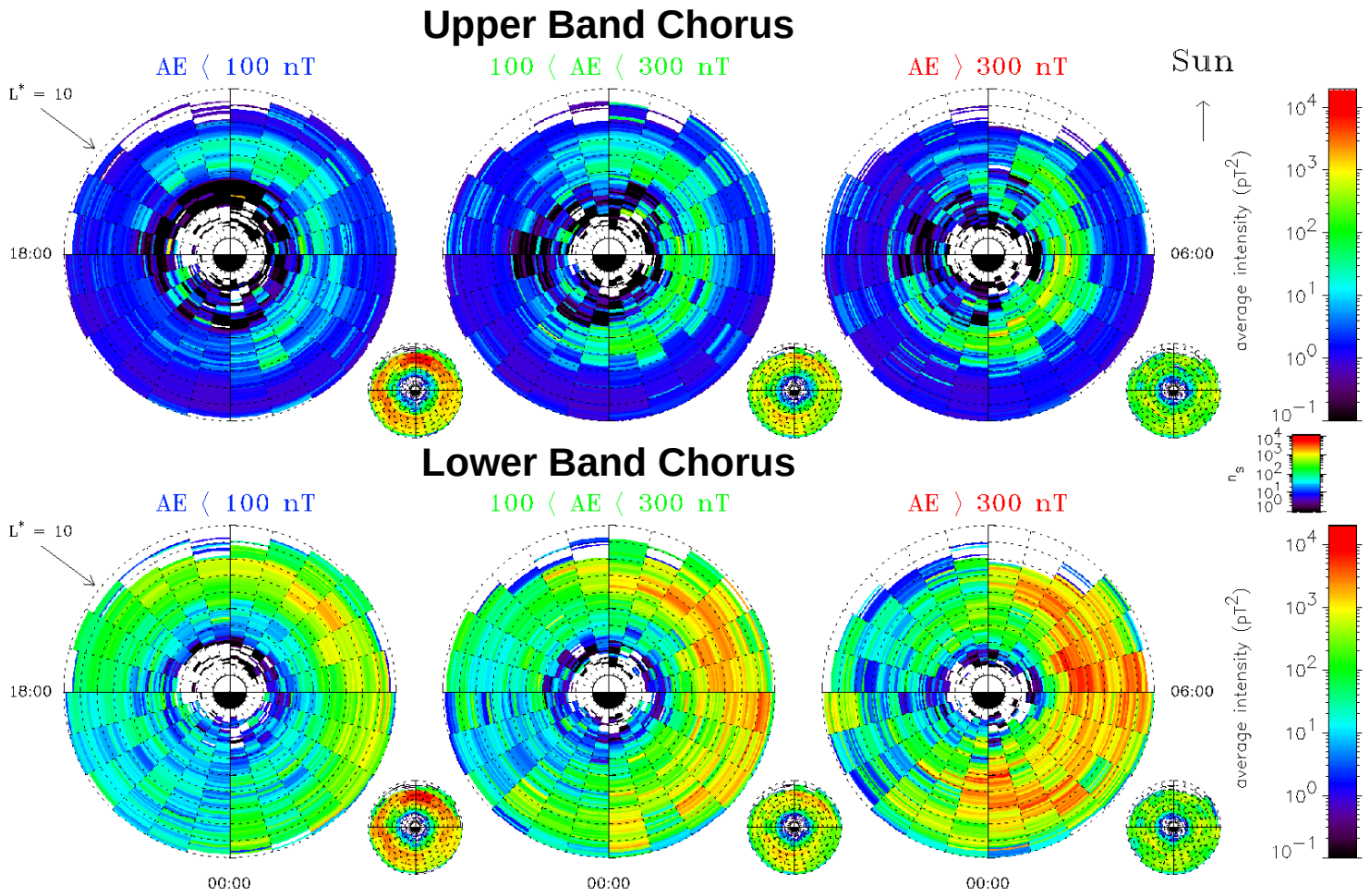
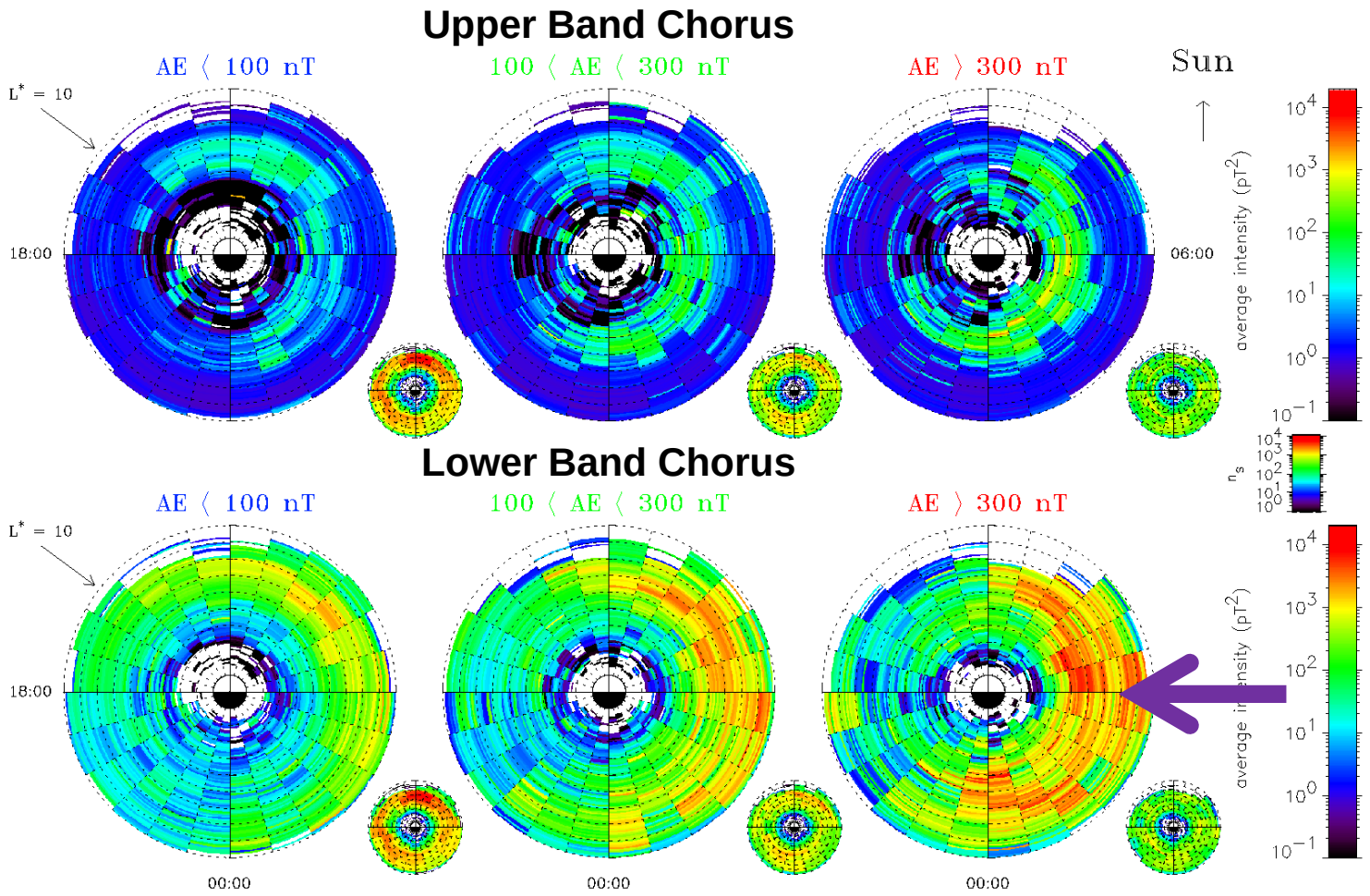
Combined Global Model of Equatorial Chorus



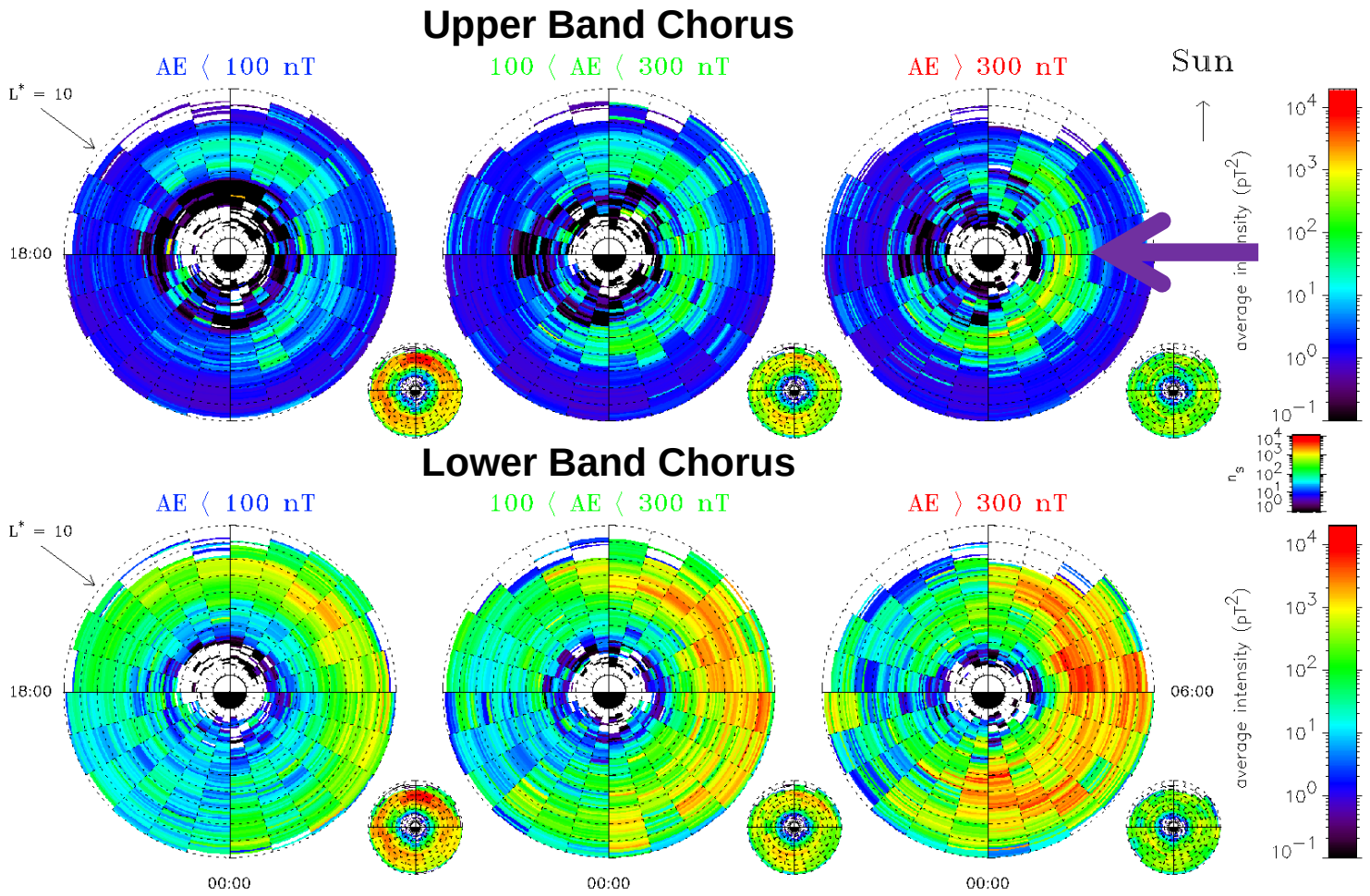
- Combined coverage extends from the plasmapause out to L* = 10

Combined Global Model of Equatorial Chorus



- Waves are strongest in the lower band during active conditions, with intensities of the order of 2000 pT^2 in the region $4 < L^* < 9$ from 23-12 MLT

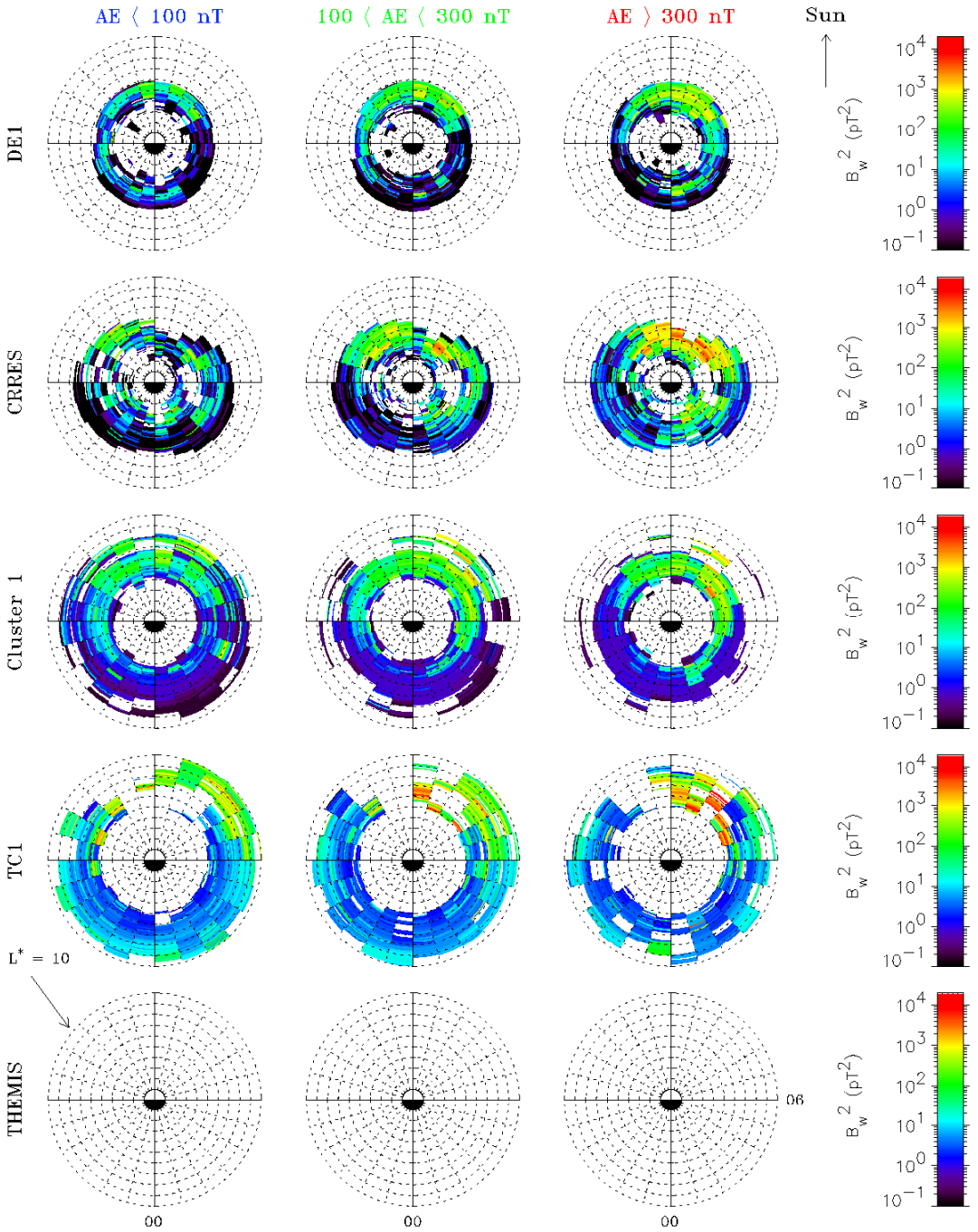
Combined Global Model of Equatorial Chorus



- Waves are weaker in the upper band, with largest intensities of the order a few hundred pT^2 during active conditions from $4 < L^* < 7$ from 22-11 MLT

Mid-Latitude Lower Band Chorus

- Mid-latitude lower band chorus is also substorm dependent
- Waves most intense on the dayside during active conditions
- Little or no activity on the night-side



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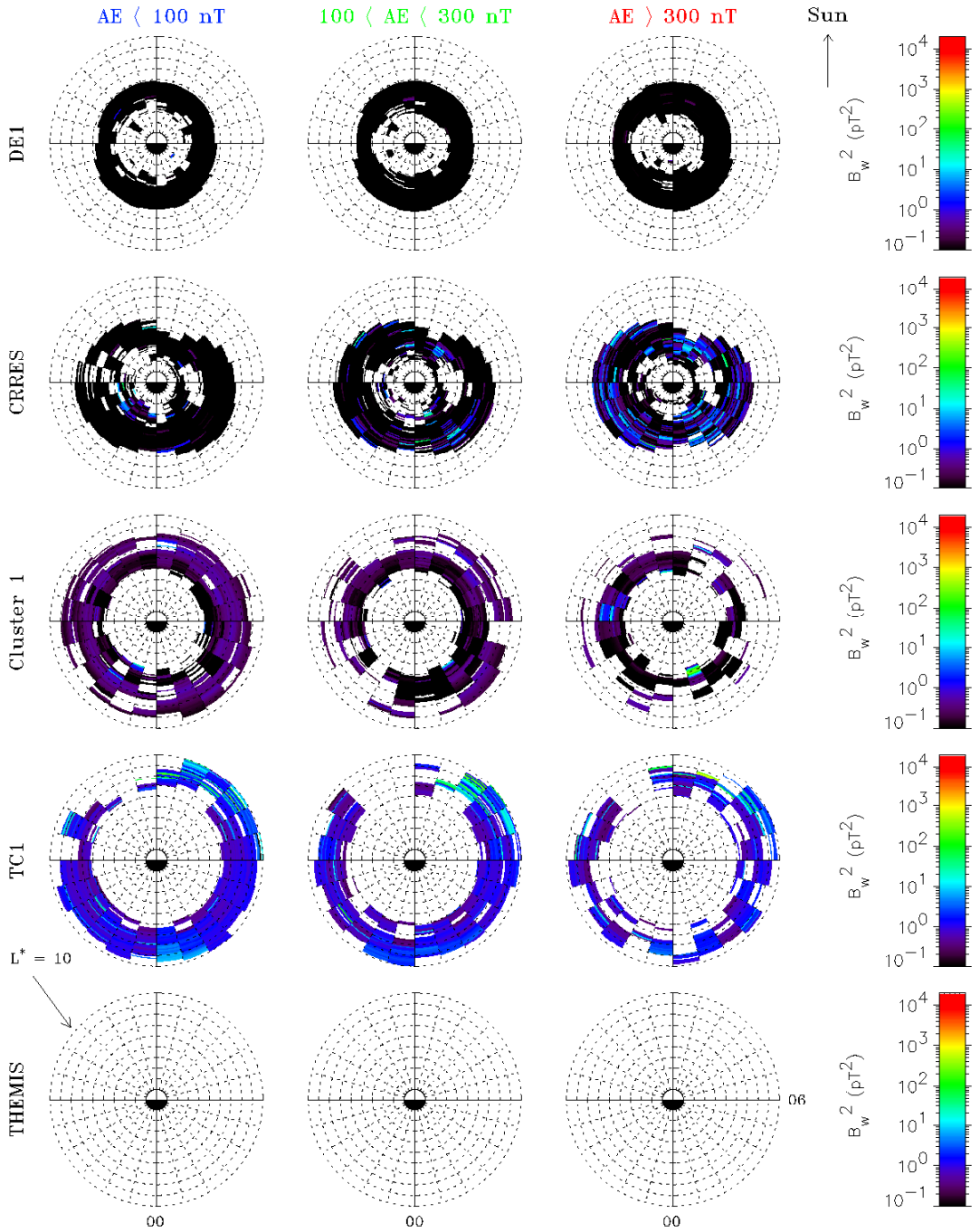
Mid-Latitude Upper Band Chorus

- Little or no mid-latitude chorus in the upper band detected by any of the 5 satellites.
- Data at background levels



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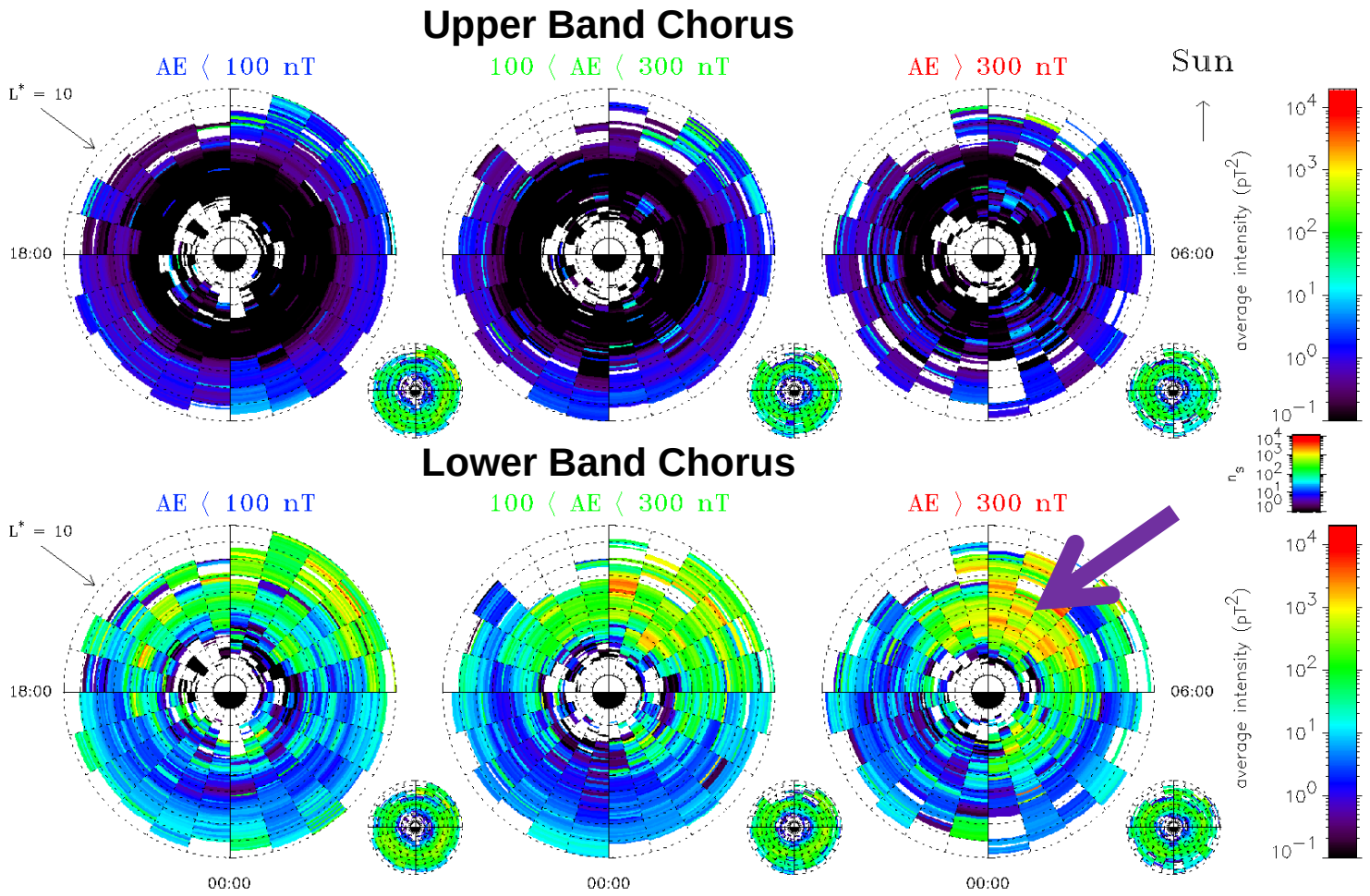
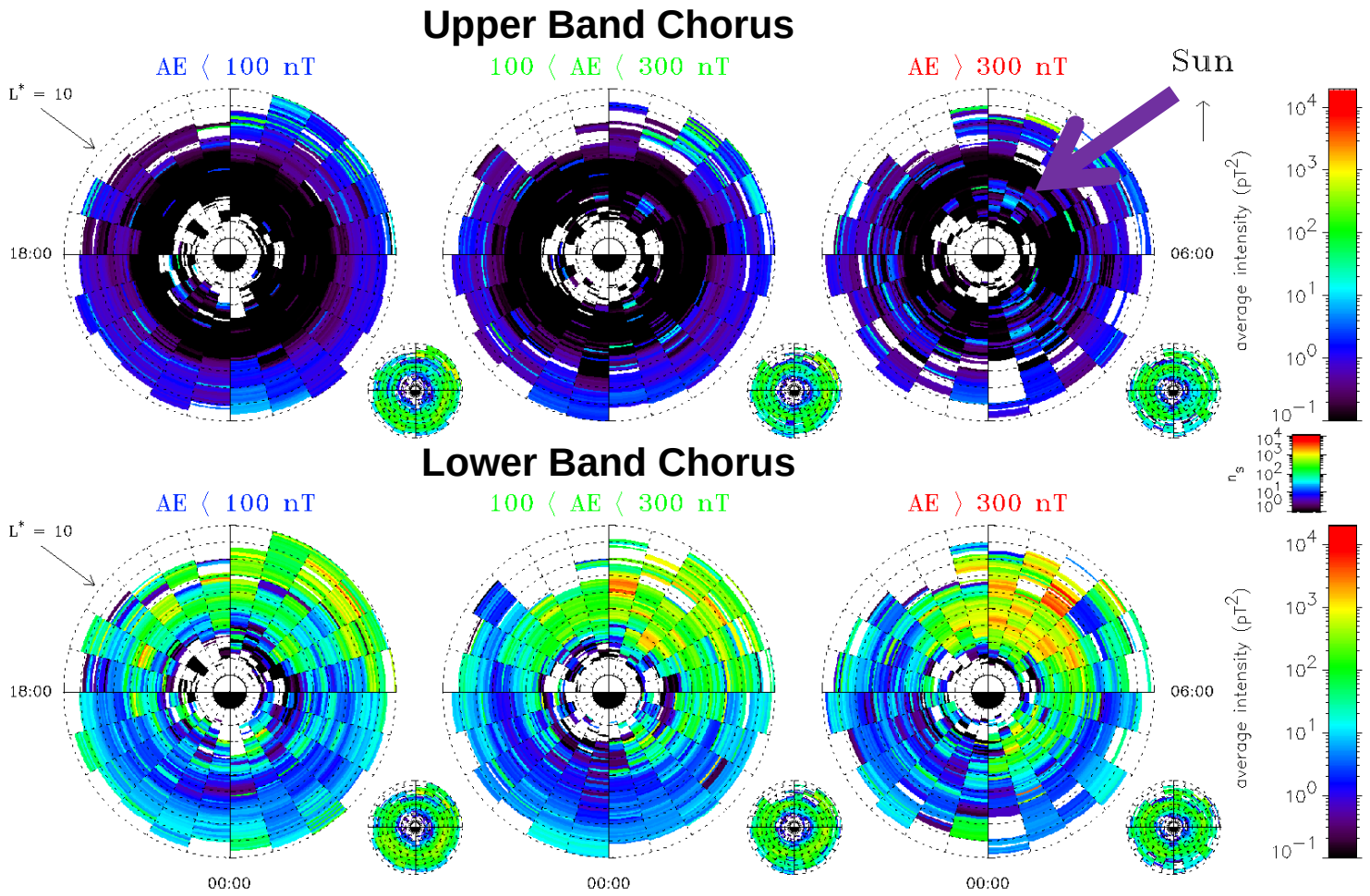
Combined Global Model of Mid-Latitude Chorus



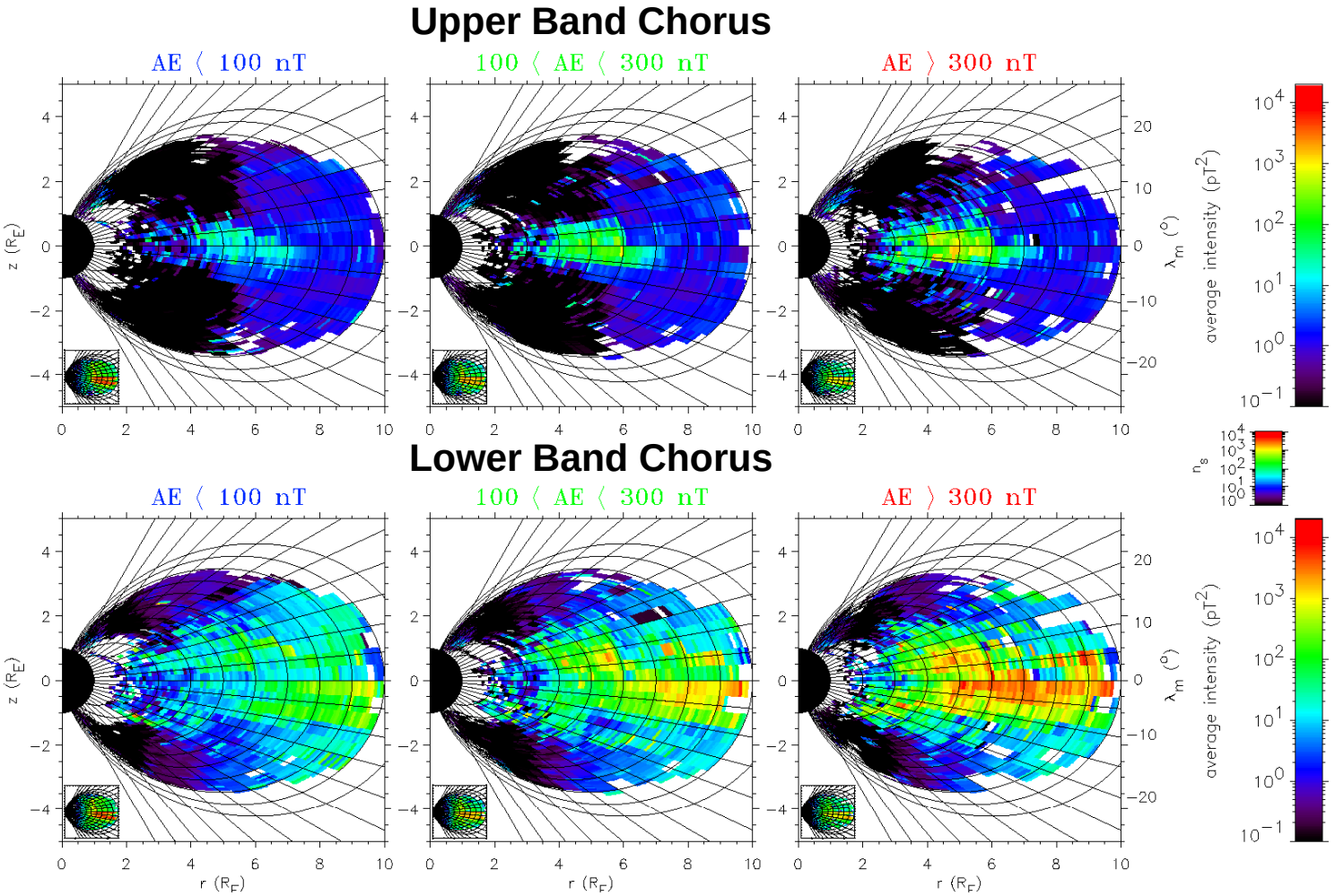
- Waves strongest in the lower band, with intensities of the order 2000 pT^2 during active conditions from $4 < L^* < 9$ but restricted to 07-13 MLT

Combined Global Model of Mid-Latitude Chorus



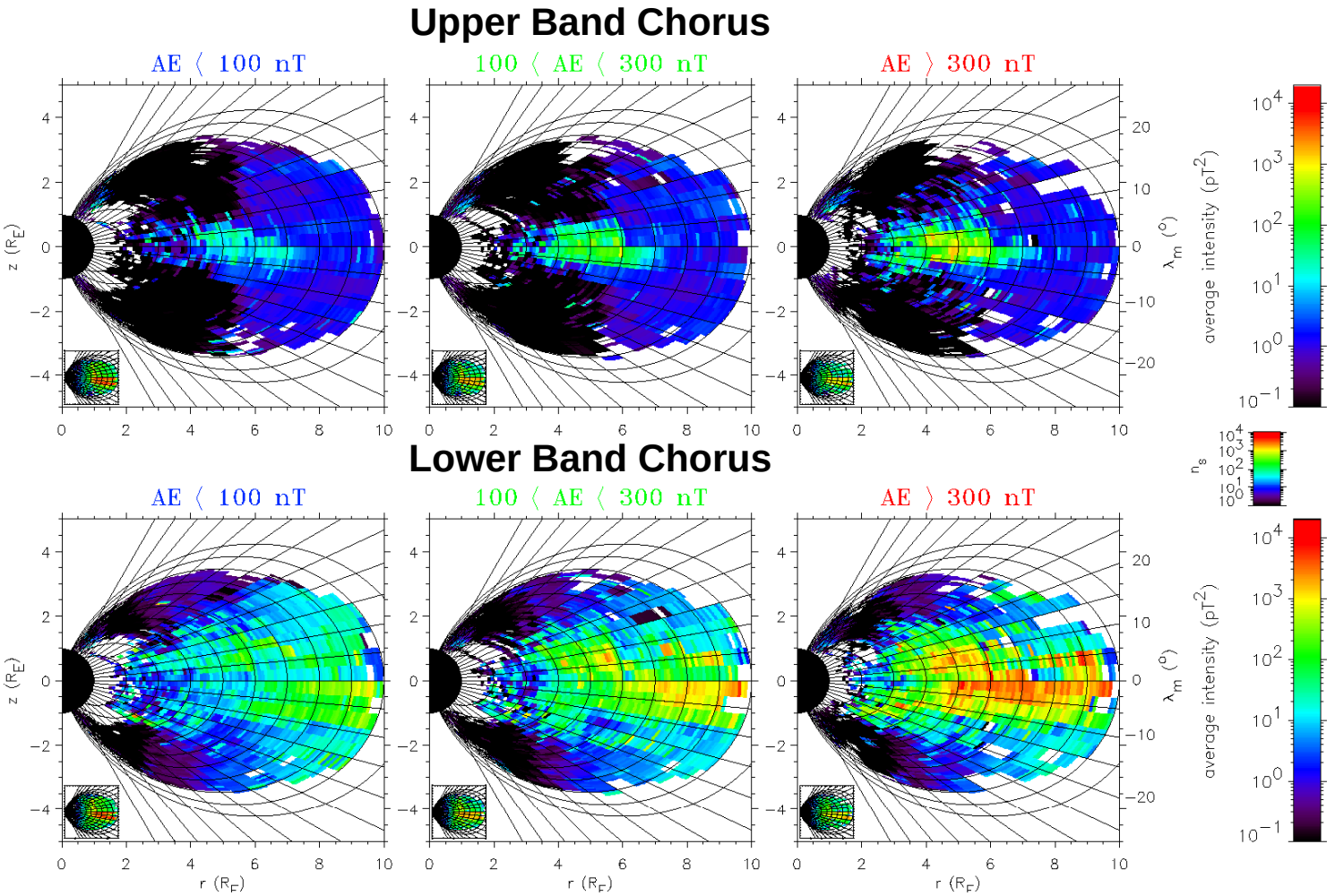
- Little or no upper band chorus at mid-latitudes, with observed intensities close to background levels

Combined Global Model of Nightside Chorus



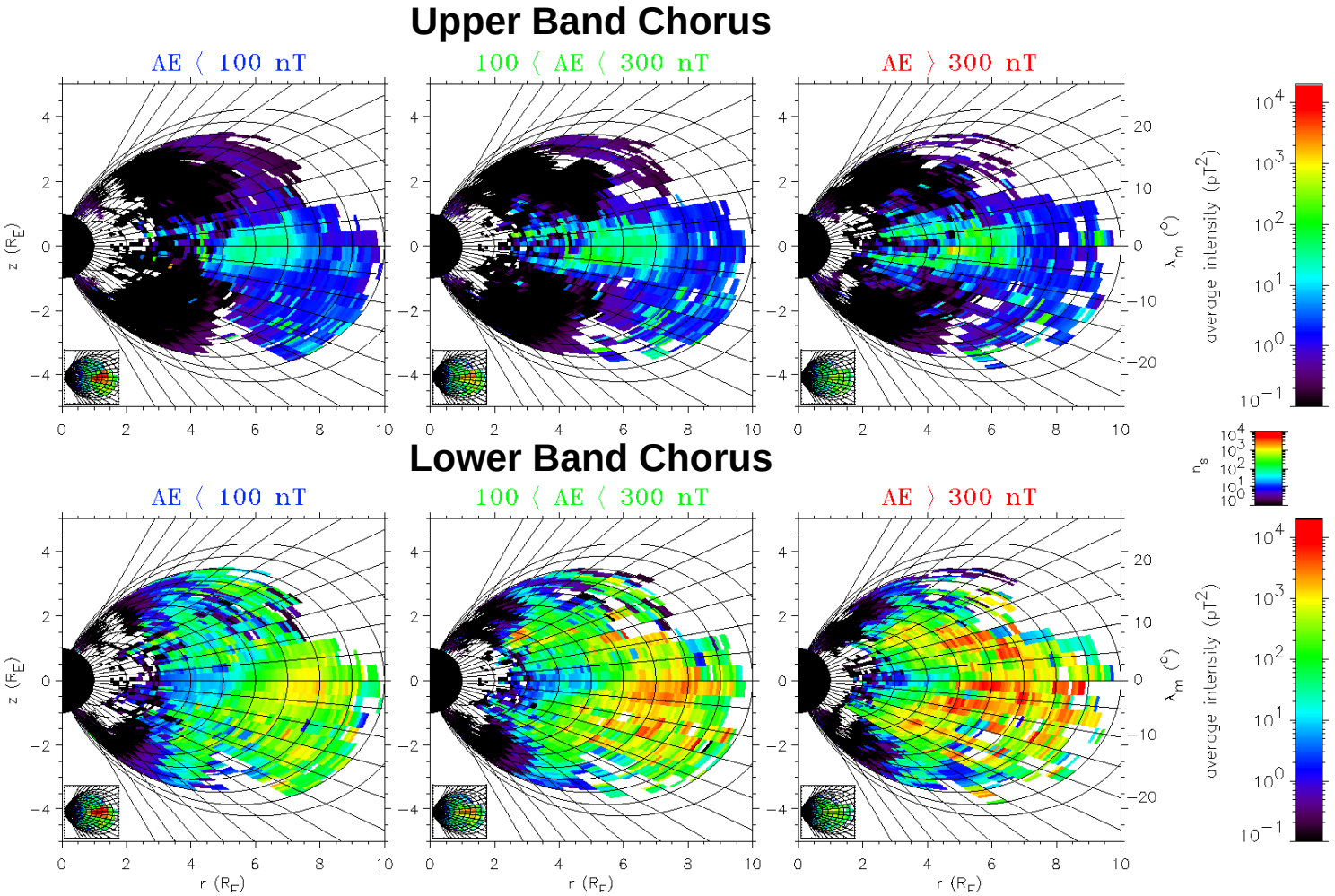
- On the nightside lower band chorus intensities are strongest during active conditions in the region $4 < L^* < 10$ and are confined to $|\lambda_m| < 12^o$

Combined Global Model of Nightside Chorus



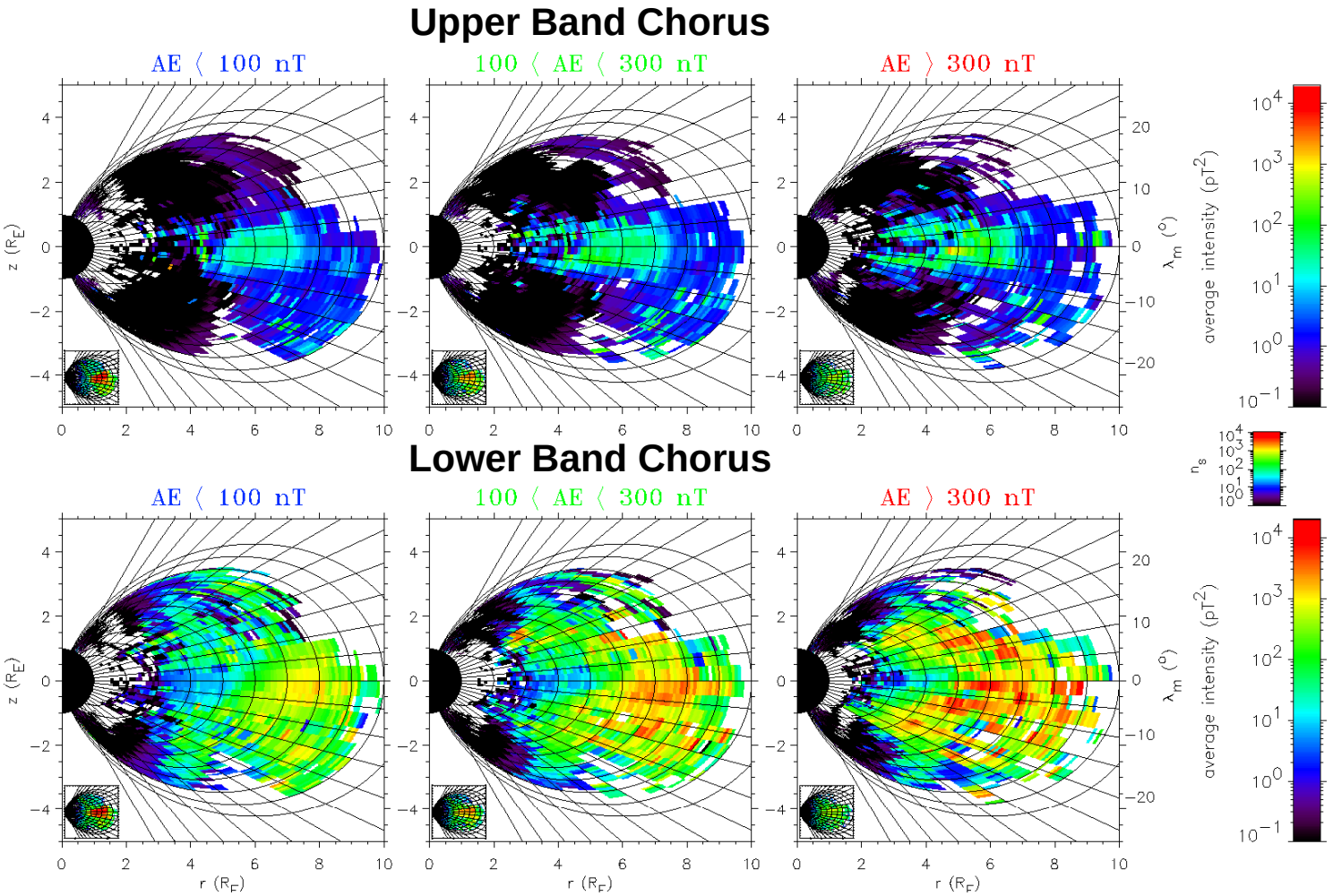
- Nightside upper band chorus intensities are strongest during active conditions in the region $4 < L^* < 7$ and are confined to $|\lambda_m| < 6^o$

Combined Global Model of Dayside Chorus



- On the dayside lower band chorus intensities are strongest during active conditions in the region 4 < L* < 9 and extend to higher latitudes

Combined Global Model of Dayside Chorus



- Dayside upper band chorus intensities are weaker and are confined to $|\lambda_m| < 6^o$

Conclusions

- Our new global model of whistler mode chorus extends the coverage and improves the statistics of existing models. The principle conclusions are:
    - Equatorial chorus is strongest in the lower band during active conditions with peak intensities of the order 2000 pT^2 in the region $4 < L^* < 9$ in the region 23-12 MLT
    - Mid-latitude chorus is strongest in the lower band during active conditions with peak intensities of the order 2000 pT^2 in the region $4 < L^* < 9$ between 07-14 MLT
- We have developed a VLF wave database using data from five satellites. The resulting models of whistler mode chorus and other wave modes will be used to improve our radiation belt models and forecasts

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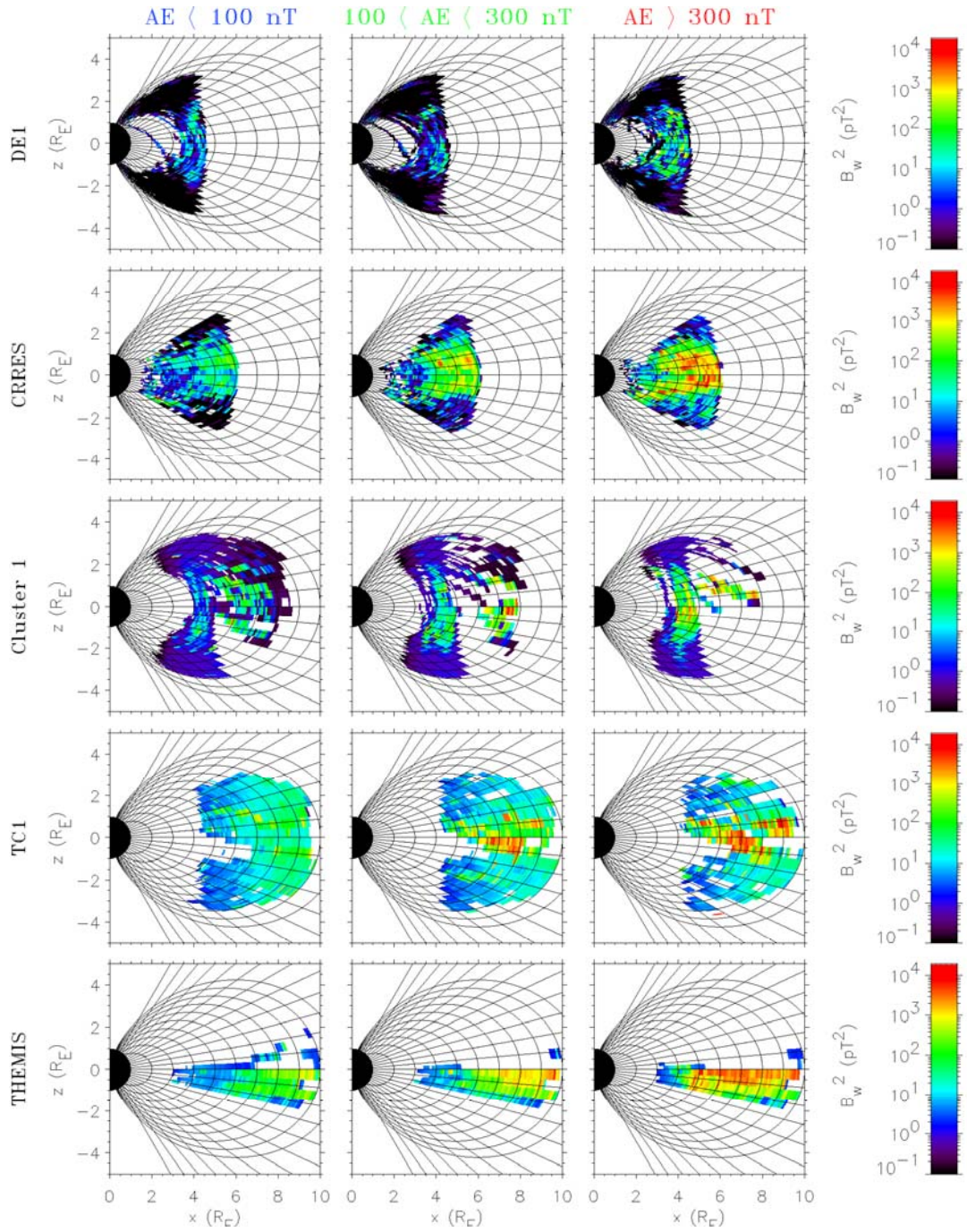
Nightside Lower Band Chorus

- Average wave intensity outside the plasmapause as a function of L* and λ_m for the region 21 – 06 MLT
- Strongest emissions confined to within 10^o of the equator



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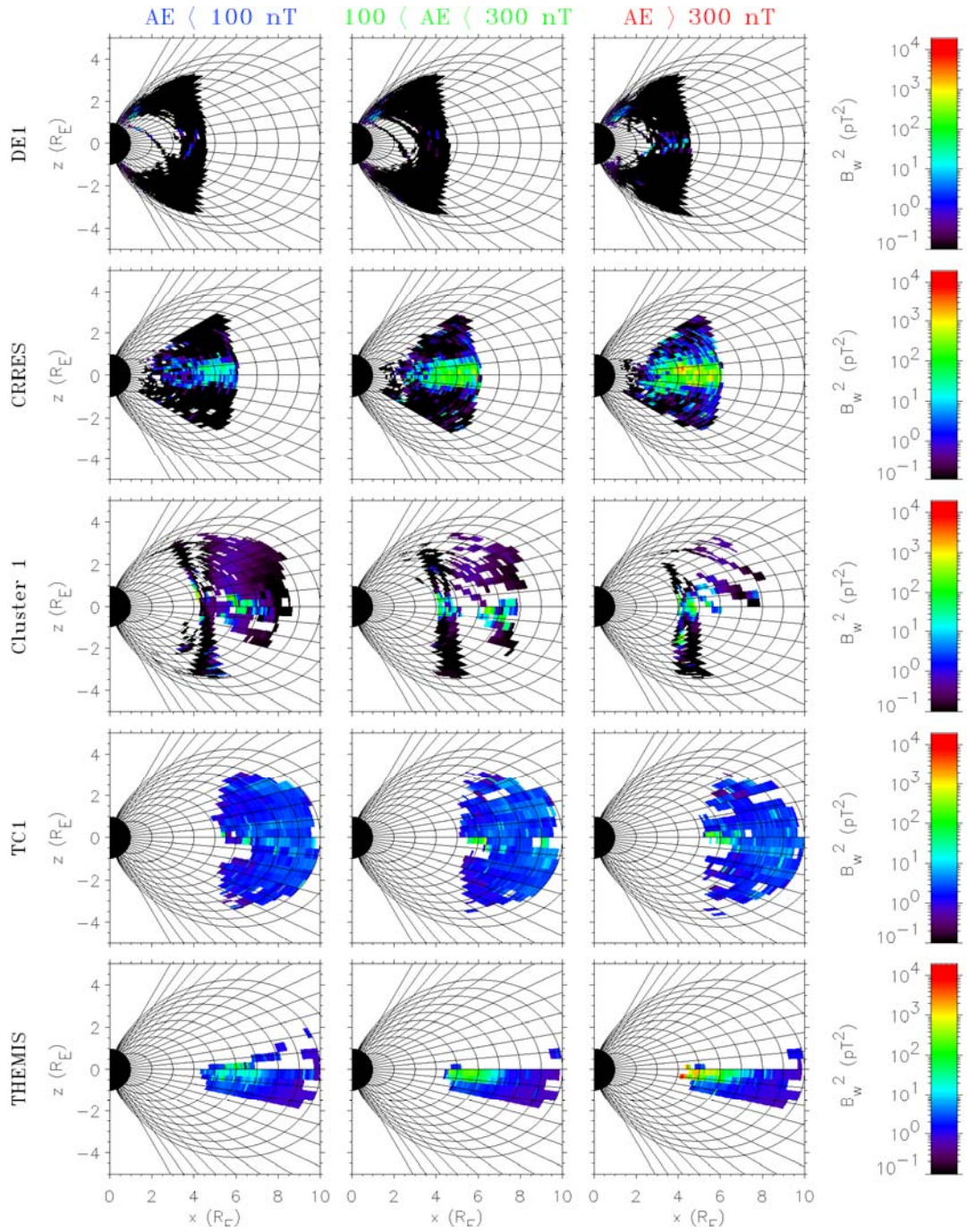
Nightside Upper Band Chorus

- Strongest emissions more tightly confined to within 5^{o} of the equator



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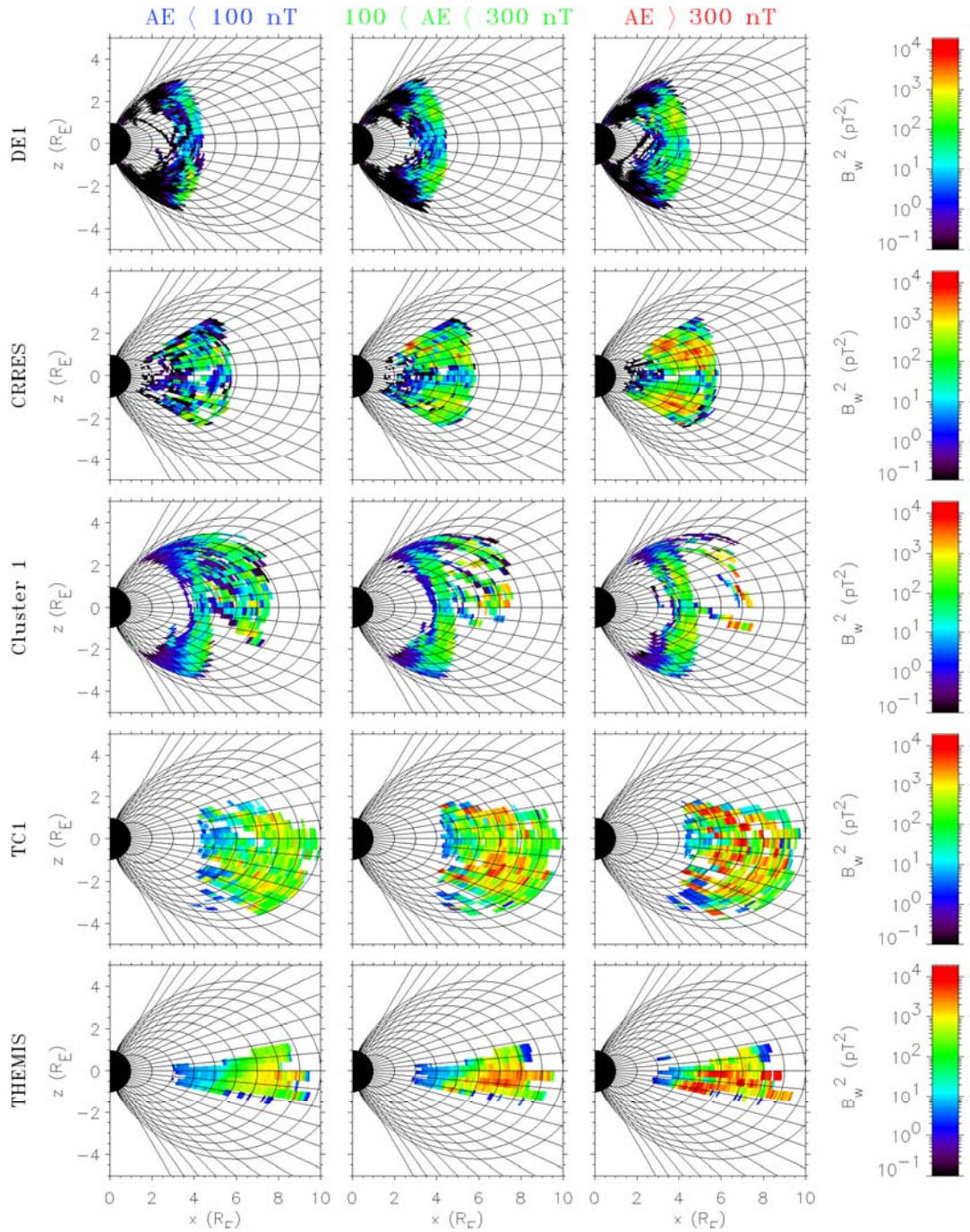
Dayside Lower Band Chorus

- Average wave intensity outside the plasmapause as a function of L* and λ_m for the region 06 – 15 MLT
- Strongest emissions extend to higher latitudes



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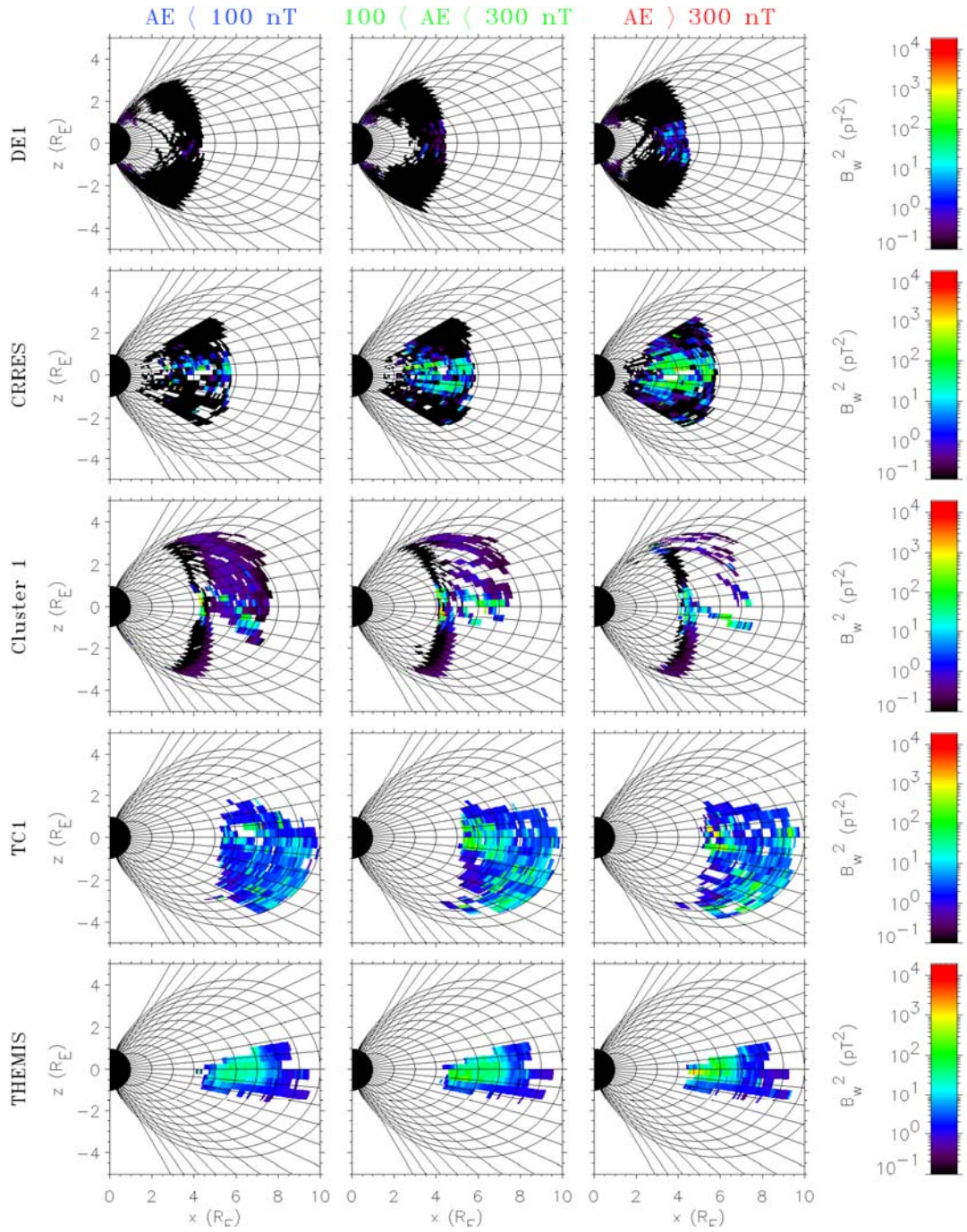
Dayside Upper Band Chorus

- Dayside upper band chorus is much weaker and less extensive being confined to within about 5º of the magnetic equator



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