Storm-time Evolution and Empirical Modelling of the Equatorial Electron Pitch Angle Distributions in Earth's Outer Radiation Belt

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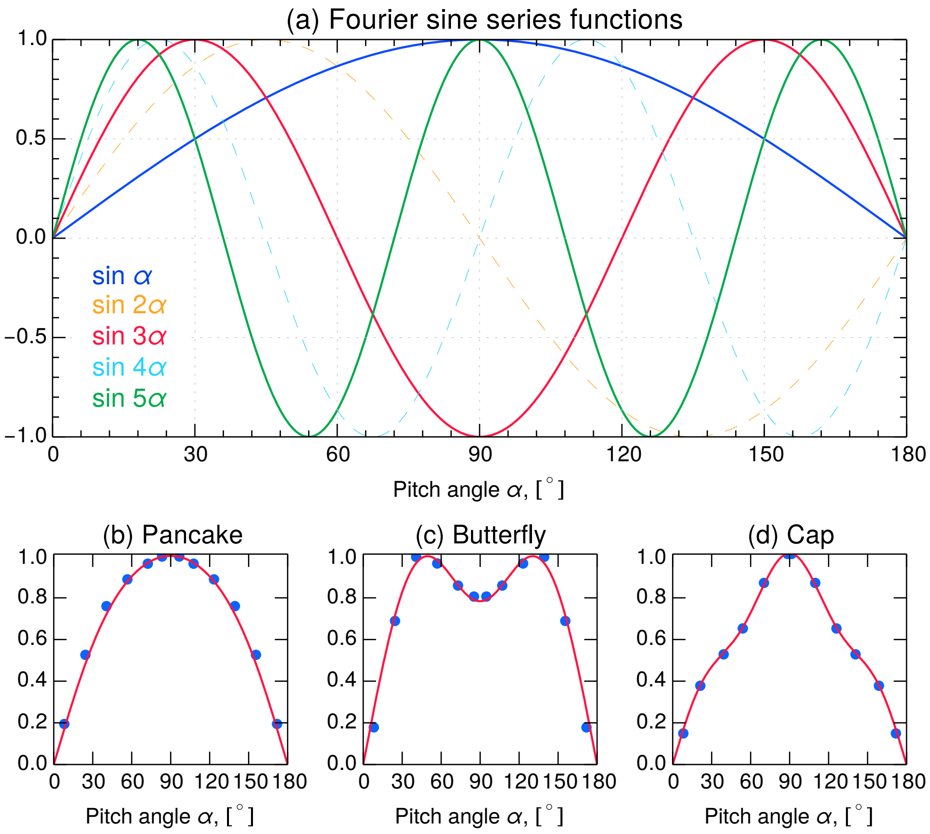
Pitch Angle Distributions



A1 ~ pancake
A3 ~ butterfly
A5 ~ cap

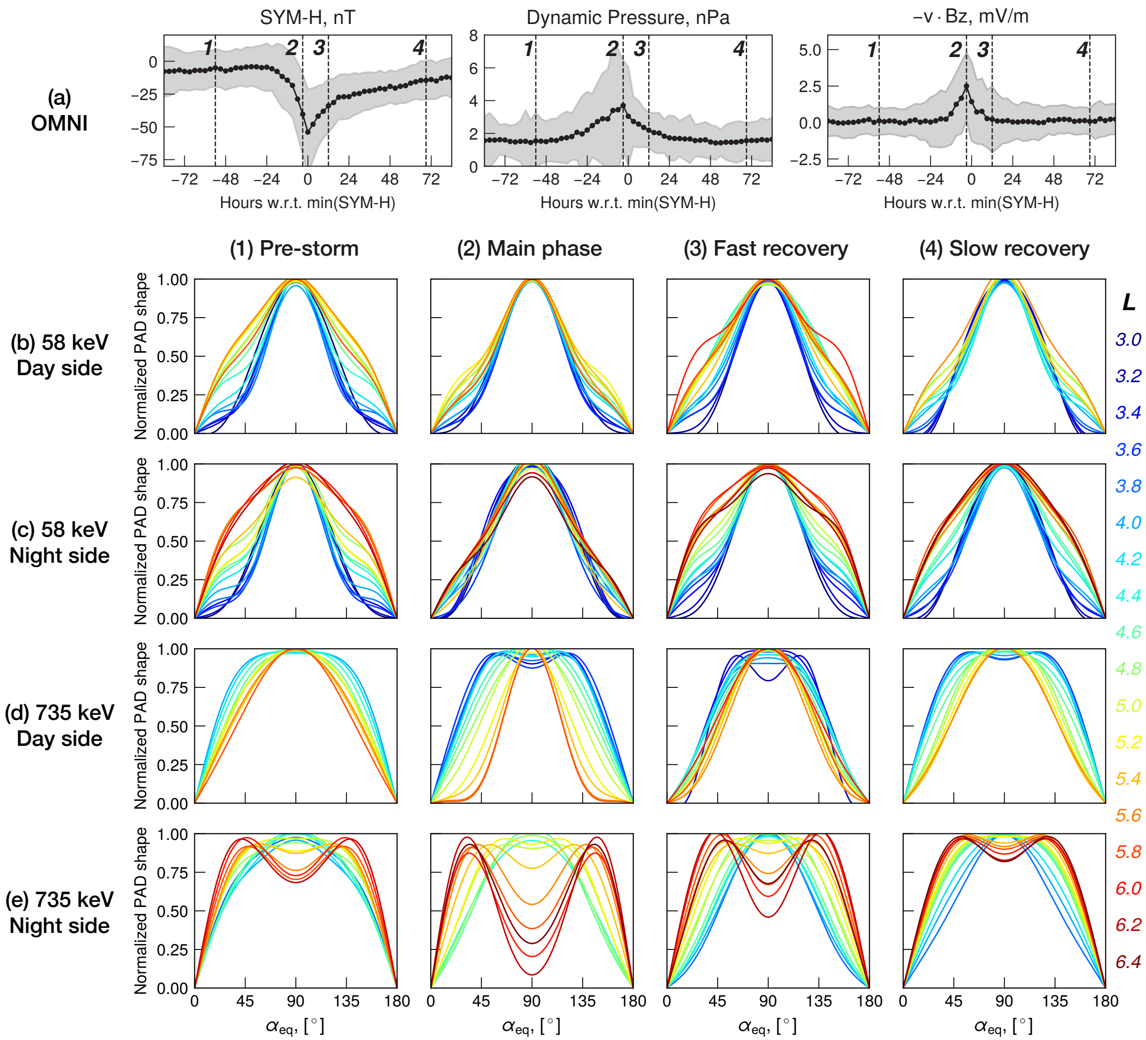
- Equatorial electron PADs can be well approximated using Fourier sine series expansion to degree 5:

$$j(\alpha) = A_0 + A_1 \sin\alpha + A_3 \sin 3\alpha + A_5 \sin 5\alpha$$

- Coefficients before the second and fourth harmonics are not used, because they represent asymmetric terms
- In order to remove flux levels, we normalize each PAD measured by the Van Allen Probes using:

$$\tilde{A}_i = \frac{A_i}{j_{max} - A_0}, i = \{1, 3, 5\}$$

Superposed PAD shapes

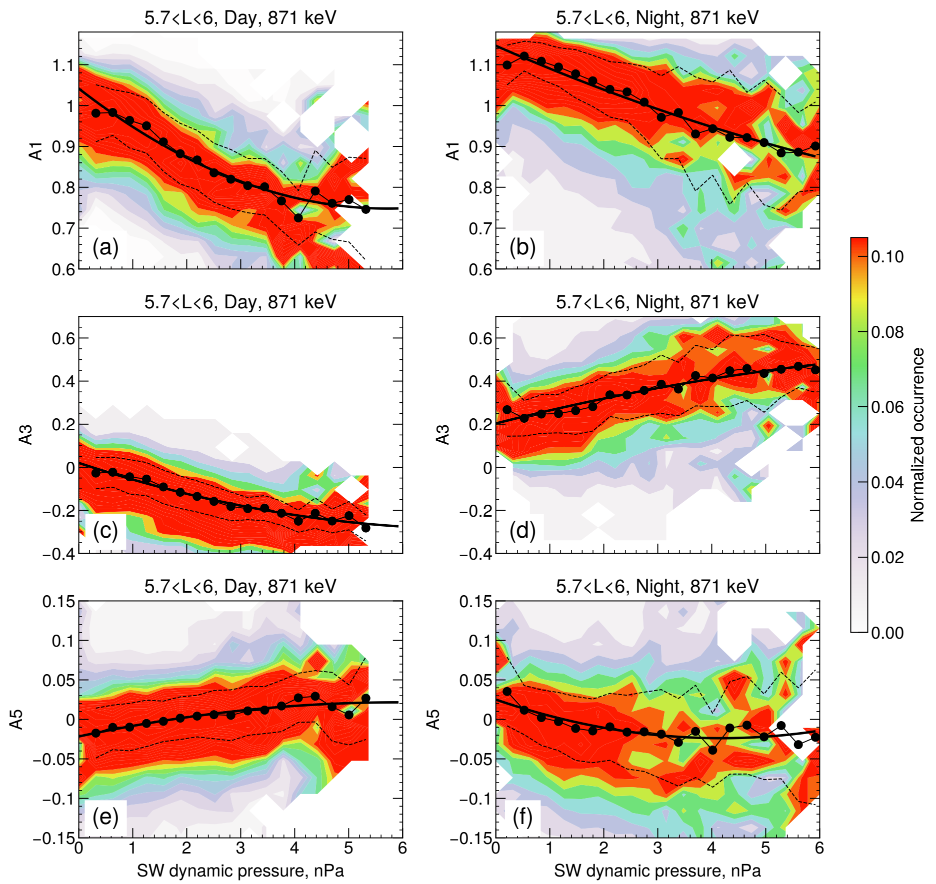


At lower energies, PADs are quite stable throughout the geomagnetic storms

At higher energies,

- At day side MLT, pancake PADs become steeper around the main phase
- At night side, the butterfly distributions become more pronounced

Generalized dependence on Pdyn



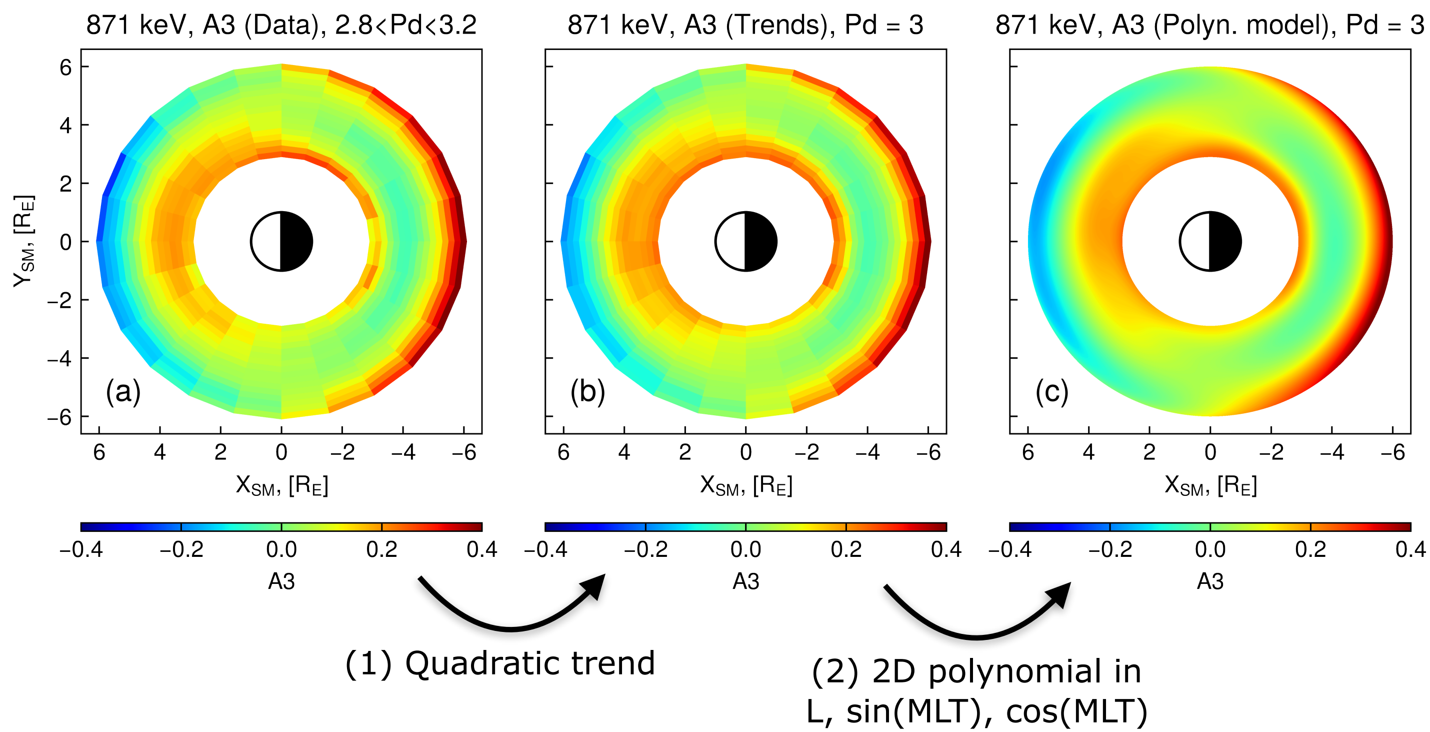
Normalized occurrence plots of the pancake (A1), butterfly (A3) and cap (A5) coefficients based on Pdyn for L>5.7

- We now analyze, whether we can draw a generalised dependence of the A1, A3 and A5 coefficients on activity
- At each bin of 0.2L x 1hr MLT, we fit the quadratic dependence on dynamic pressure:

$$A_i = c_0 \mathrm{Pdyn}^2 + c_1 \mathrm{Pdyn} + c_2$$

- One can see that there is a strong dependence on Pdyn, and the values coincide with our previous analysis
- We now need to introduce a dependence on L and MLT.

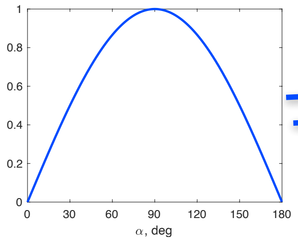
Model setup



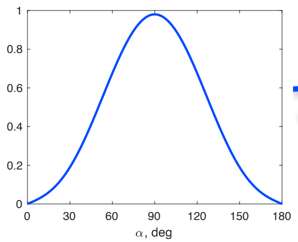
We get a model that has a continuous dependence on L, MLT and dynamic pressure, for each energy channel

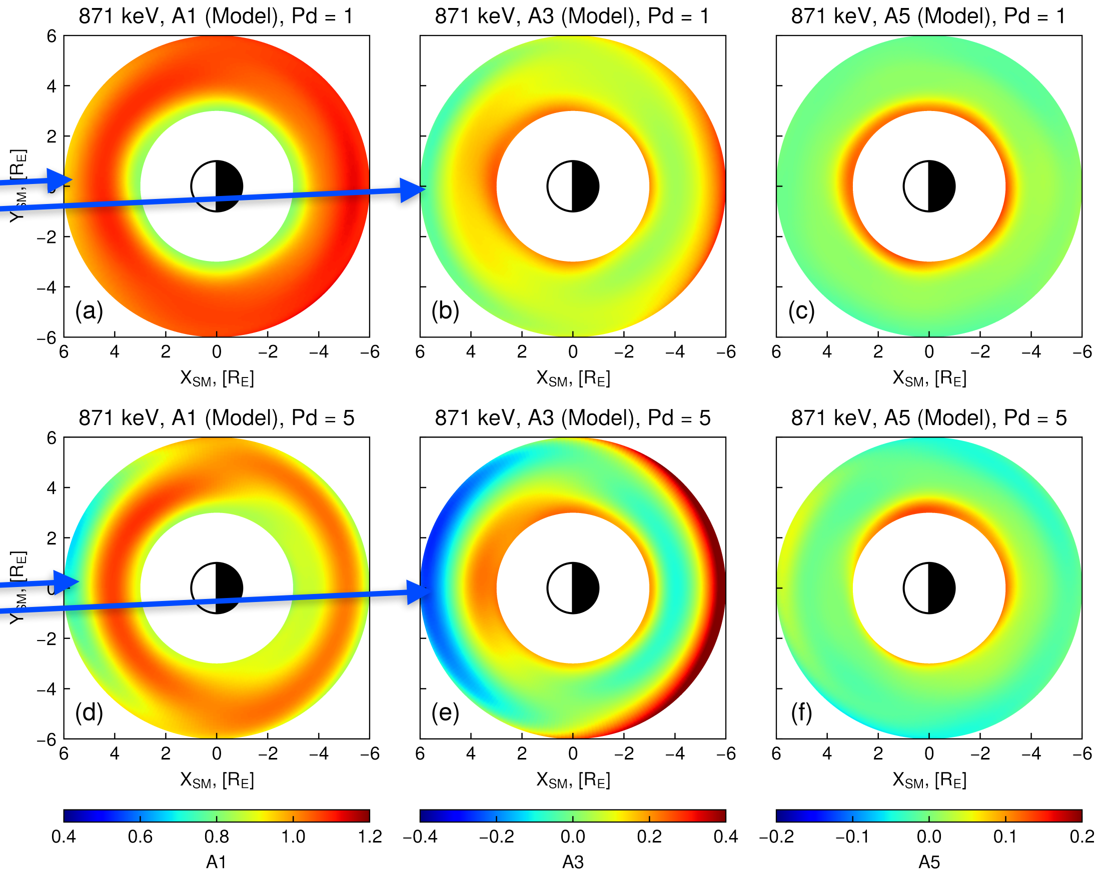
Model dependence on dynamic pressure

Dayside/ Quiet



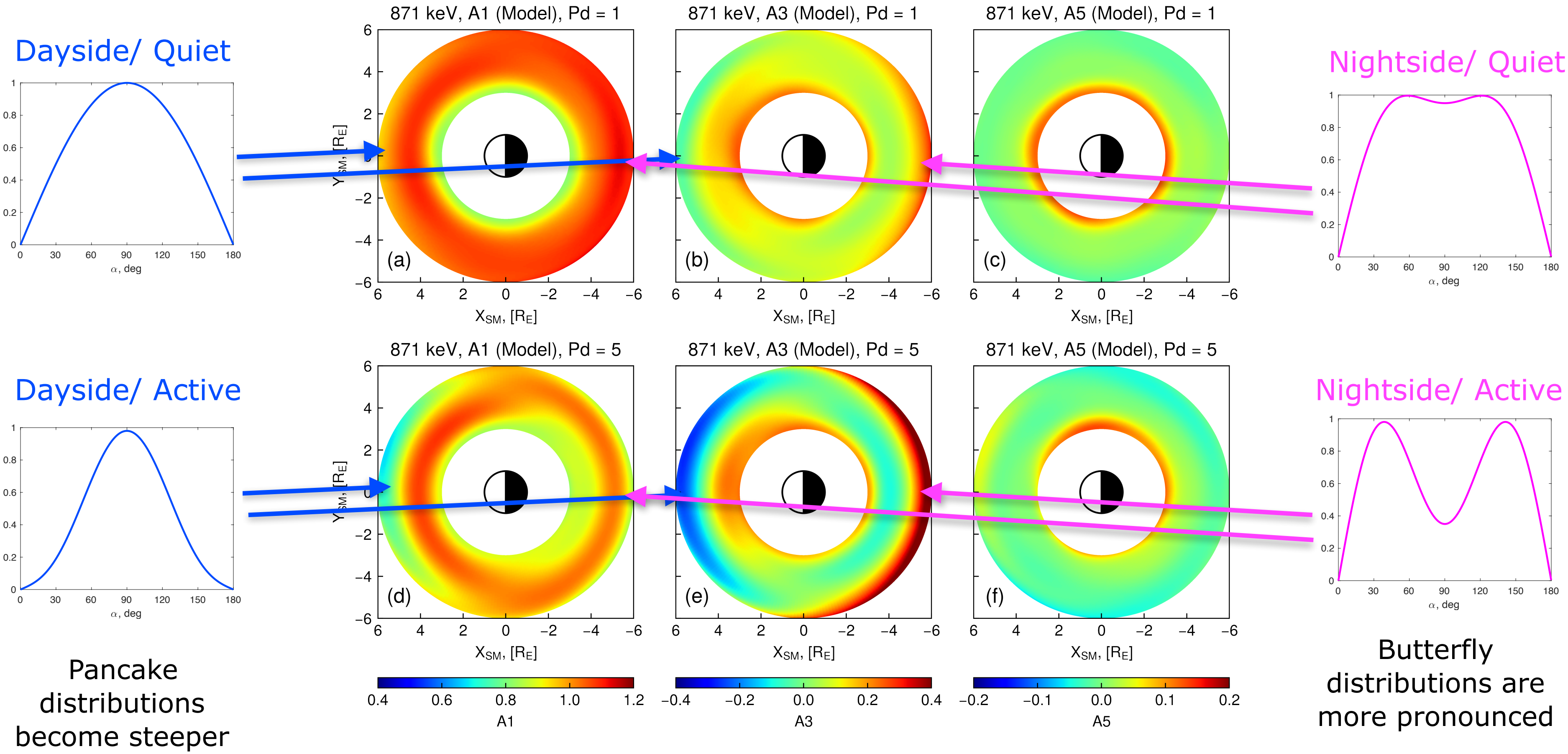
Dayside/ Active





Pancake distributions become steeper

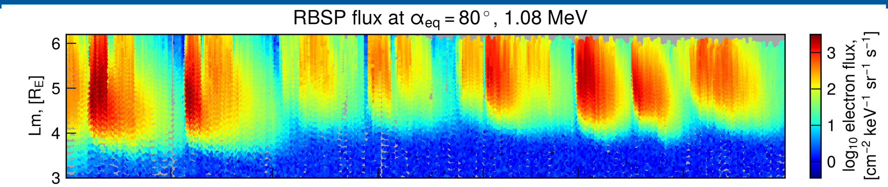
Model dependence on dynamic pressure



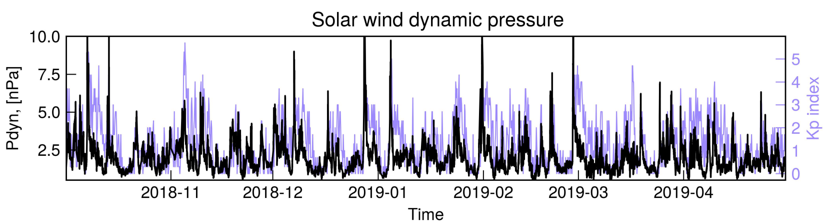
This agrees well with the superposed epoch analysis.

The model reproduces the activity dependence well.

Model validation: 1 MeV



- We use two directional flux measurements at low pitch angles to reconstruct flux values at 90 degrees equatorial p.a.
- We use 2 lowest MagEIS pitch angles, 8 and 17 degrees
- By having 2 observations, we can reconstruct both A0 that we previously omitted, and the normalization factor
- We also reconstruct the equatorial 90-degrees flux using the standard sine approximation
- The skill score (improvement in performance) of our Fourier-based model compared to the standard approach is 92%.



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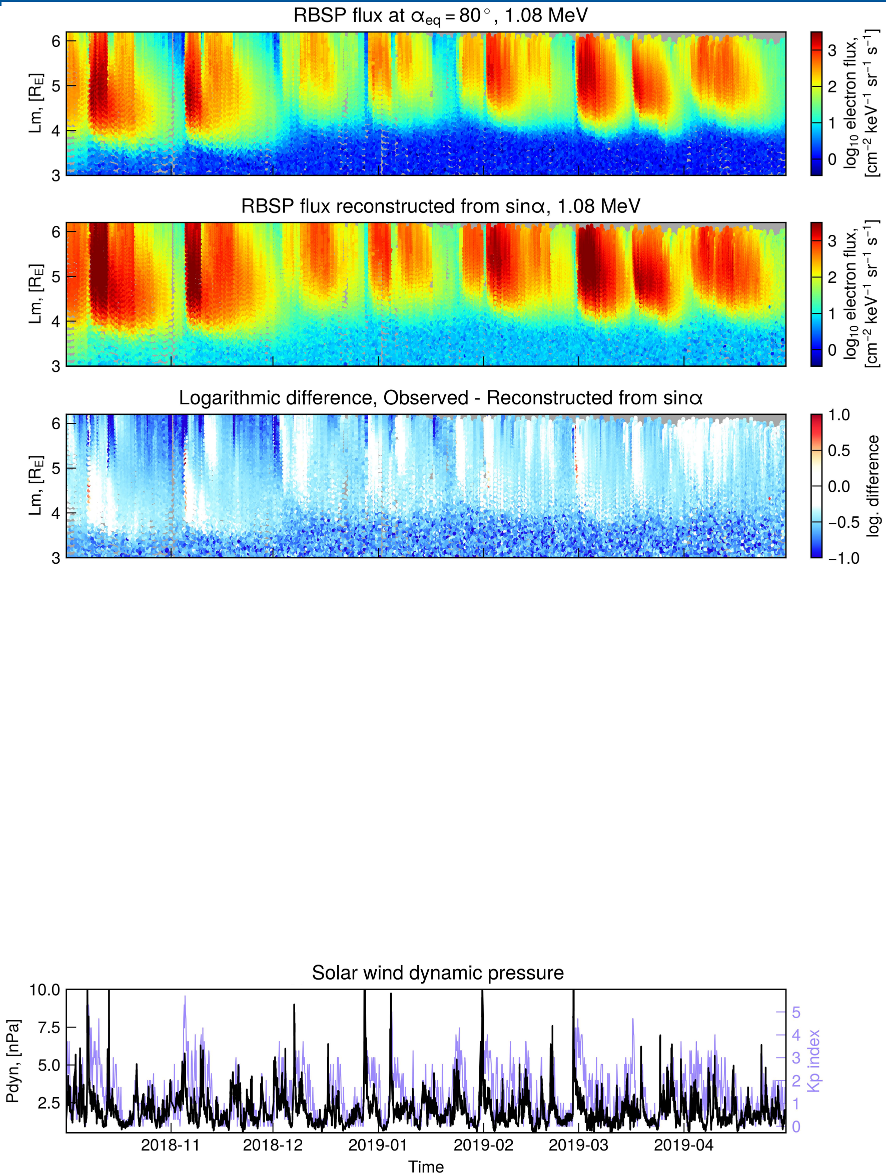

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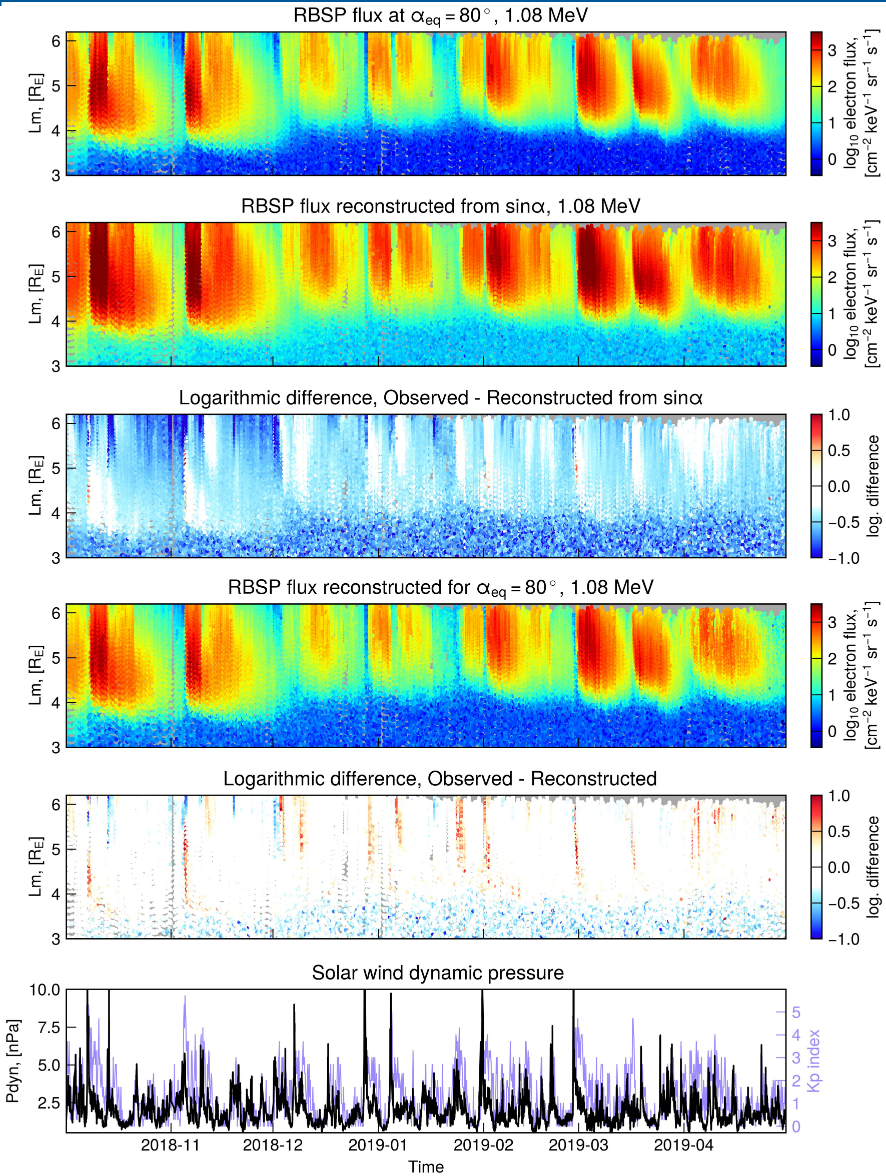

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Conclusions

- Pitch angle distributions in the outer radiation belt region can be well approximated by a Fourier series expansion up to degree 5
- Storm-time evolution of PADs was investigated in terms of L-MLT variation
- A simple polynomial model, based on dynamic pressure, is developed. It reproduces the PAD behaviour in the outer belt well
- The model can be used to reconstruct the full equatorial PADs from LEO data. It outperforms the standard sine approximation by 92%
- The model can also be used to reconstruct equatorial PADs from omni-directional measurements, for instance, at MEO orbits.

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