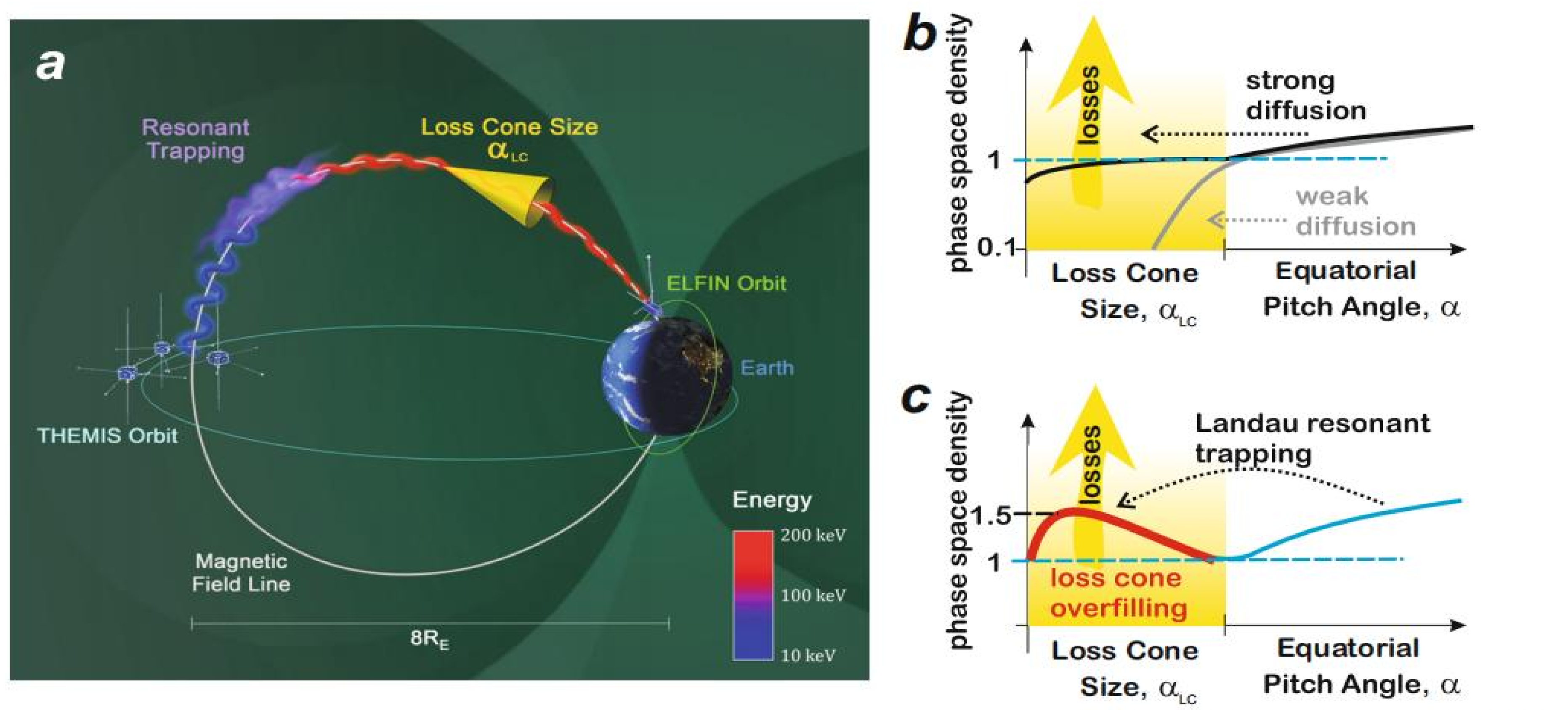
A statistical study of superfast atmospheric precipitation of radiation belt electrons observed by POES satellites

Deyu Guo[1,2] (guodeyu@whu.edu.cn), Zheng Xiang[1], Binbin Ni[1,3], Yangxizi Liu[1]

1 Department of Space Physics, School of Electronic Information, Wuhan University, Wuhan, China.
2 Now visiting GFZ German Research Centre for Geosciences, Potsdam, Germany.
3 Chinese Academy of Sciences Center for Excellence in Comparative Planetology, Hefei, China.

Introduction—Electron Superfast Precipitation



This figure is adopted from Zhang et al. (2022).

Opposite diffusion limits in quasi-linear diffusion theory:

1. Weak diffusion (the grey line in panel b, nearly empty loss cone), electrons are slowly scattered into the loss cone over a period longer than their bounce period.
2. Strong diffusion (black line in panel b), electrons are scattered into the loss cone quicker than loss to atmospheric, but flux in loss cone is still smaller than outside).

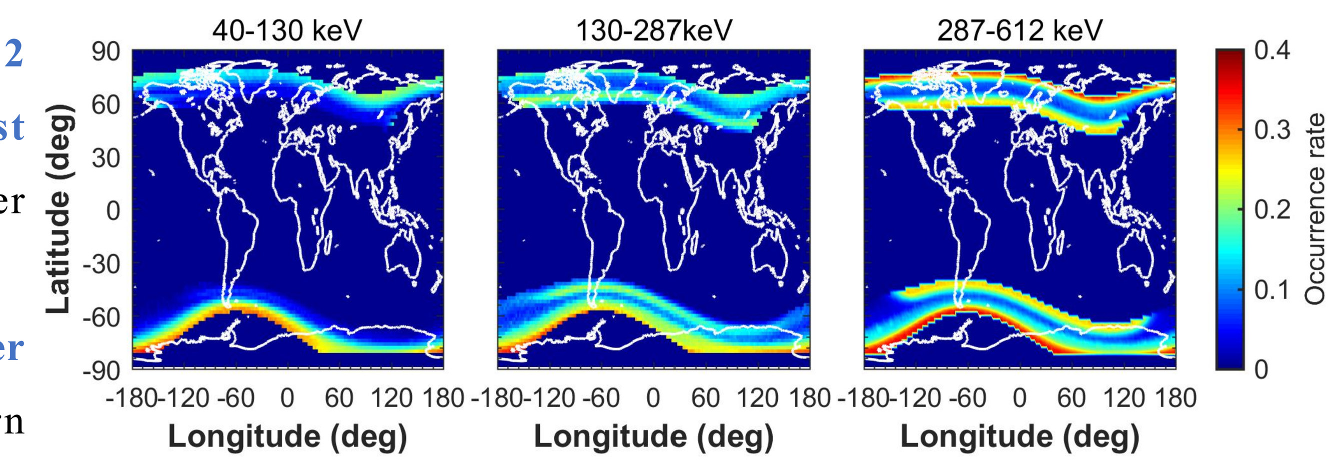
In summary, **according to quasi-linear theory**, flux gradient is needed for diffusion. Thus, **electron fluxes inside the loss cone cannot exceed the fluxes outside the loss cone!**

- By ELFIN observation and **nonlinear wave-particle** interaction simulation, Zhang et al. (2022) demonstrate that Landau resonant trapping between electrons and oblique whistler waves **can cause electron superfast precipitation (but cannot above 300 keV)**, **namely fluxes inside loss cone greater than trapped fluxes.**

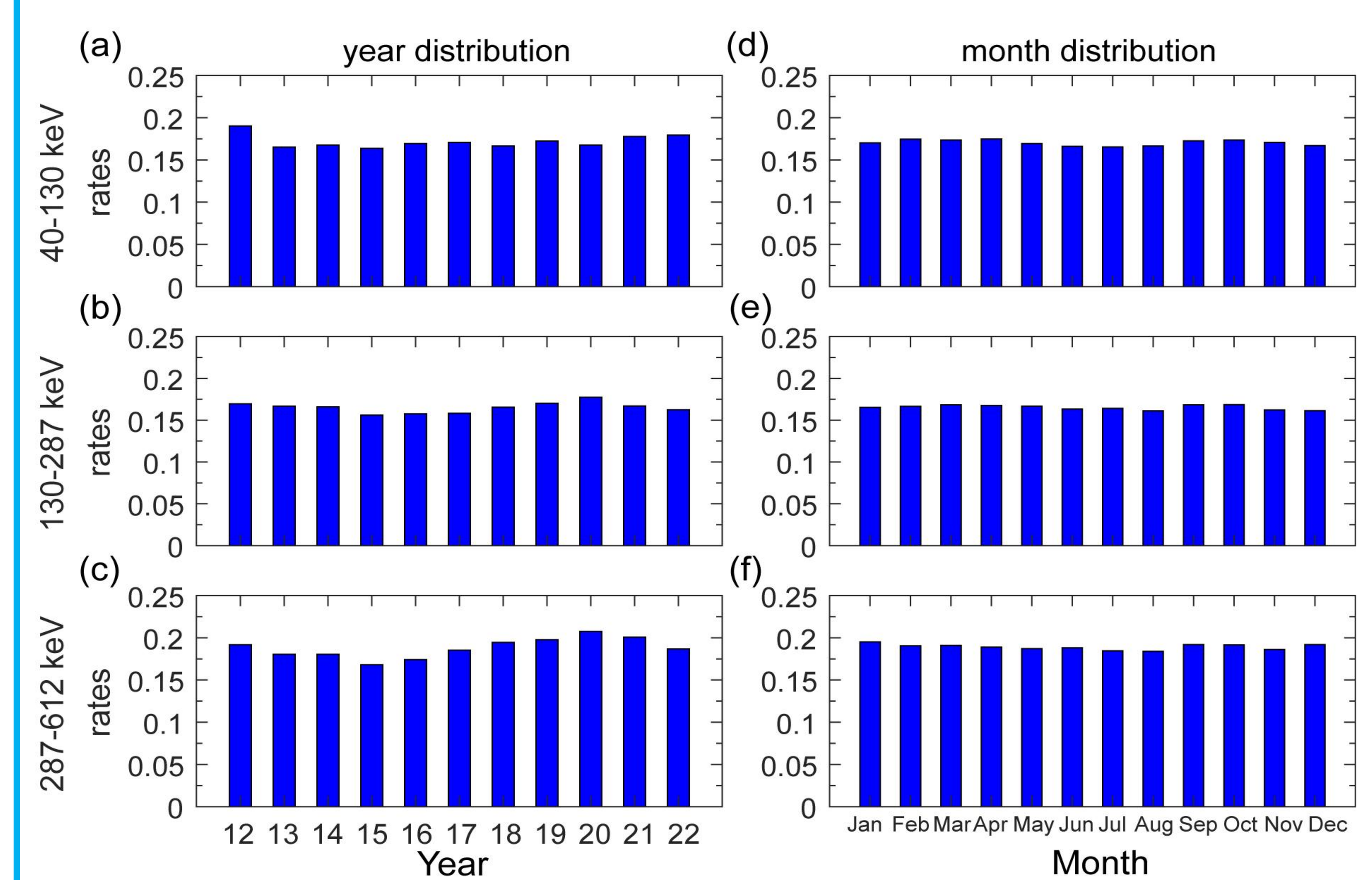
Question: What are the distribution and characteristics of electron superfast precipitation?

Geographical and Spatiotemporal distribution

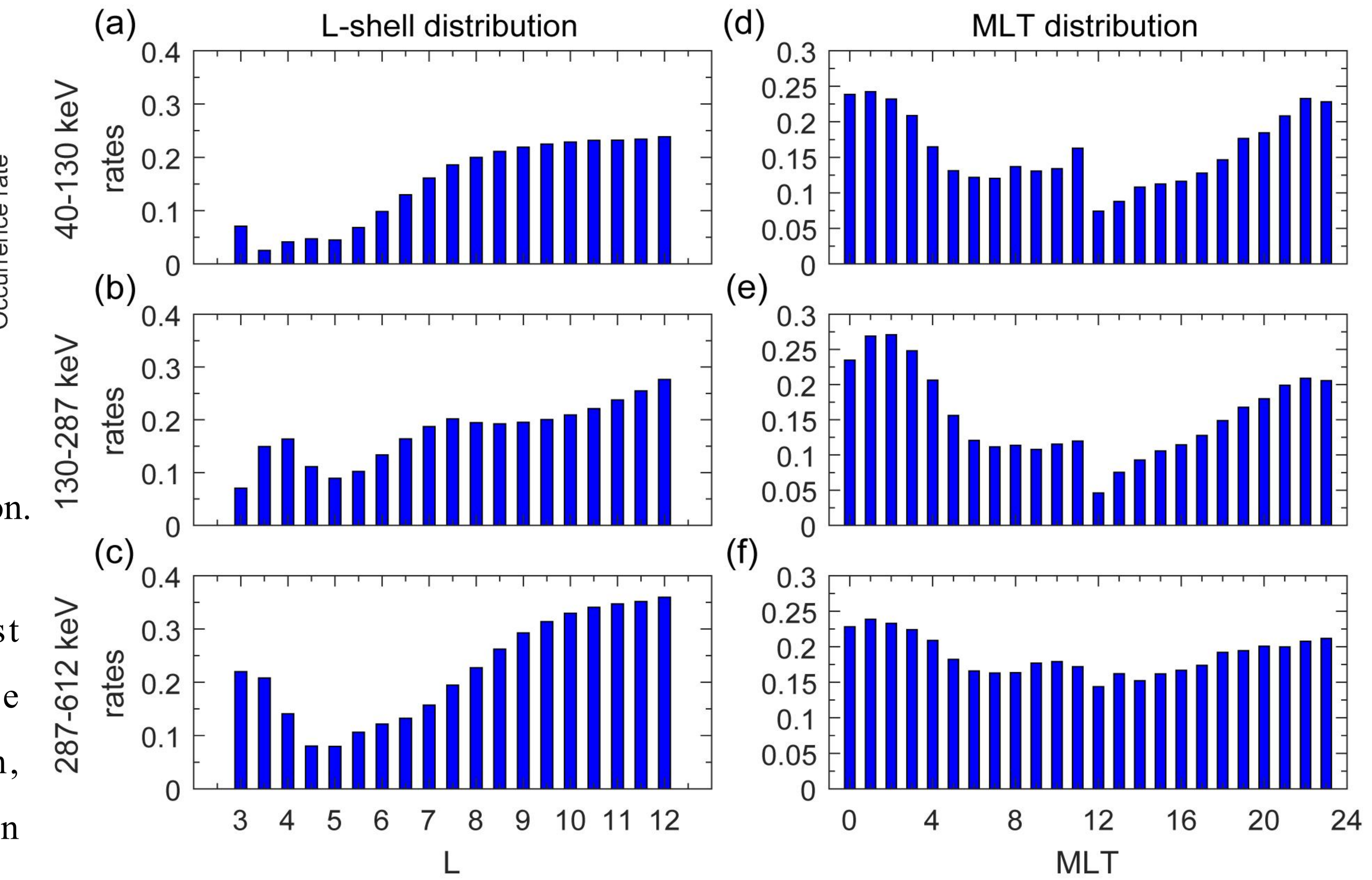
- Unlike Zhang et al. (2022), **287-612 keV electrons also exist superfast precipitation** and even have higher occurrence rates than other energies.
- The **southern hemisphere** has **higher** occurrence rates than the northern hemisphere.



Binned by 2°×2°, and excluded regions with fewer than 1000 valid observation.



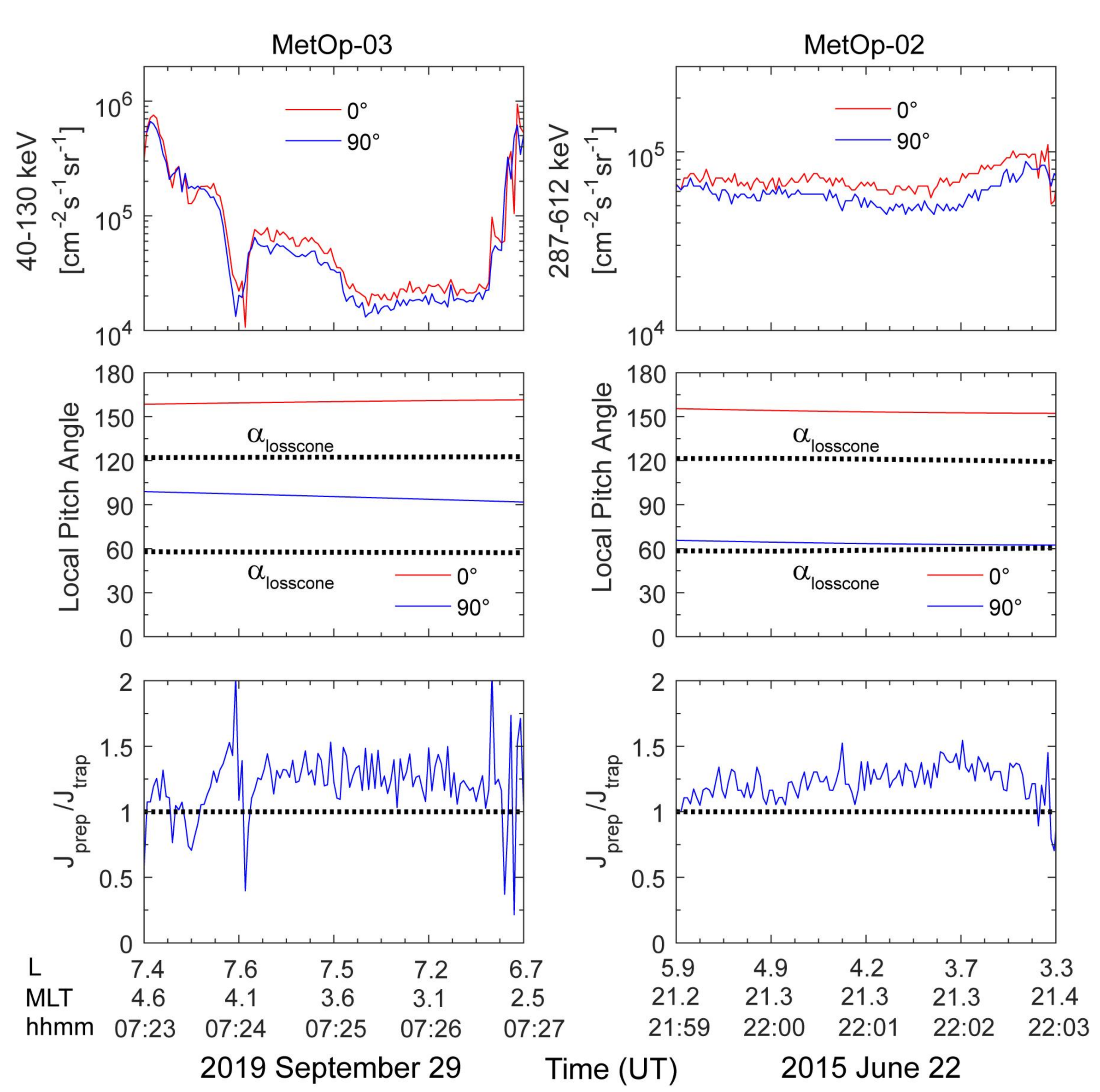
- The occurrence rates of superfast precipitation are almost the same regardless of the year and month, suggesting that superfast precipitation is **not influenced by the solar cycle or seasonal variation**.
- For different years, months, and energy ranges, the occurrence rates of electron superfast precipitation are **greater than 15%**, showing that this phenomenon is **common** and worthy of investigation.



Excluded regions with L>12 since the number of efficient points was smaller than 10000.

- Electron superfast precipitation mainly occurred **in high L-shell**.
- For 40-130 keV and 130-287 keV electrons, superfast precipitation has **higher** occurrence rates in **nightside than dayside**. However, for 287-612 keV electrons, the difference in occurrence rates between dayside and nightside is not significant, implying that **different mechanisms might be responsible for different energy electrons** (perhaps caused by current sheet scattering?).

Statistical Standards, Examples, and Geographical distribution



Processed data (at 2s resolution) of POES and MetOp satellites (From 2012.10.13- 2022.12.31) are used in this study, which provide four energy ranges of trap/precipitation electron flux (>40, >130, >287, and >612 keV).

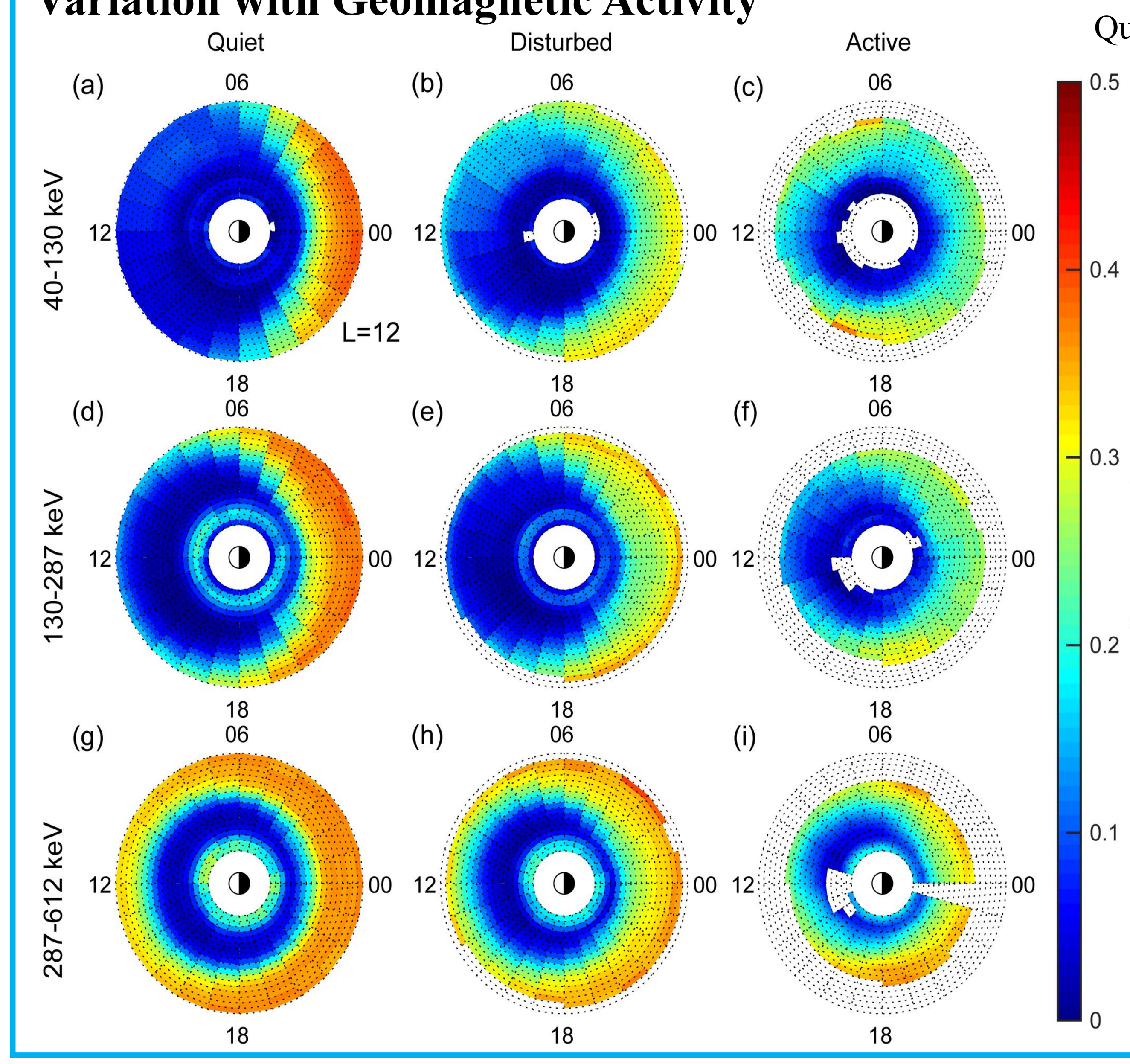
A valid observation point must satisfy:

1) L-shell is smaller than magnetopause location (calculated by model of Shue et al. 1998).
2) Observed pitch angle of 0° telescope must be within the bounce loss cone (calculated by IRBEM library). Meanwhile, observed pitch angle of 90° telescope must be outside the bounce loss cone.
3) Trapped flux larger than 0 and the ratio between precipitation and trapped flux (J_{prep}/J_{trap}) larger than 0.05.
4) To reduce the effect of protons, we only considered the points in outer radiation belt with L≥3.

On this basis, J_{prep}/J_{trap}>1 is considered as a superfast precipitation point.

Variation with Geomagnetic Activity

Quiet: Kp≤2; Disturbed: 2<Kp≤4; Active: 4<Kp



Excluded regions with fewer than 1000 valid observation points.

- Accompanied by the enhancement geomagnetic activity, occurrence rates decrease and superfast precipitation are more likely to occur on the dusk and dawn sides.
- For 287-612 keV electrons, superfast precipitation has higher occurrence rates (>~20%) at high L-shell (L>~9) overall MLT regions during quiet time. With increasing geomagnetic activity, occurrence rates also decrease and high occurrence rate regions also **move to the dusk and dawn sides**.

References

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Contact information

Email: guodeyu@whu.edu.cn
Skype: Deyu Guo
My wechat: