Dependence of energetic proton precipitation equatorward of the isotropy boundary on geomagnetic activity and solar wind dynamic pressure

N.V. Semenova[1], T.A. Yahnina[1], A.G. Yahnin[1], A.G. Demekhov[1,2]

[1] *Polar Geophysical Institute, Apatity*

[2] *Institute of Applied Physics, Nizhny Novgorod*

Introduction

The Ion-Cyclotron (IC) instability in the near-Earth equatorial magnetosphere develops due to transverse anisotropy of ring current/plasma sheet protons (E=10-100 keV) and leads to growth of EMIC waves in the frequency range from tenths to several Hz (Pc1 range). As the result of the interaction with EMIC waves, energetic protons (and, as suggested, relativistic electrons) are scattered into the loss cone, that is, precipitate.

Energetic Proton Precipitation (EPP) equatorward of the isotropy boundary is believed to be an indicator of the IC interaction (e.g., Yahnina et al 2000, 2003; Sakaguchi et al., 2007; Sandanger et al., 2007; Carson et al., 2010; and many others).

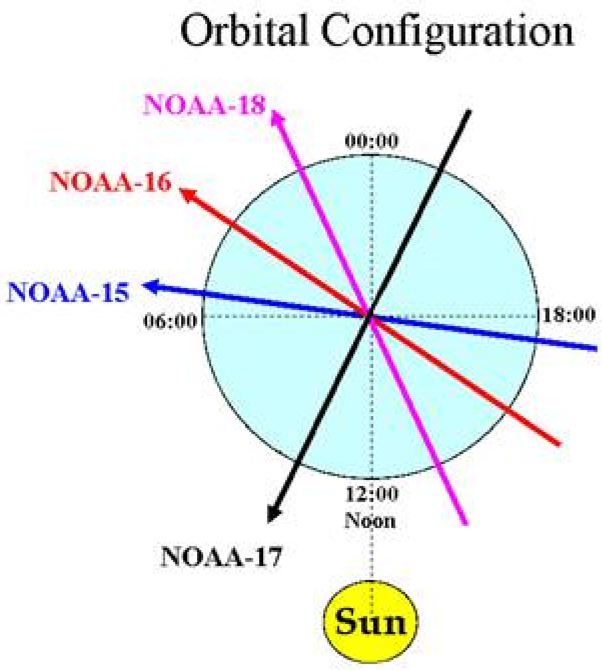
In this study, we will consider the dependence of the EPP occurrence distribution on geomagnetic conditions and compare this distribution with that obtained for EMIC waves in the magnetosphere.

NOAA POES

We will discuss precipitation patterns related to EMIC waves as they seen onboard low-orbiting satellites (NOAA POES).

NOAA POES have a set of detectors measuring charged particles with energy E>30 keV in two directions: vertical and horizontal.

At L>3, these detectors allow to distinguish between precipitating particles and those trapped at the satellite altitude (~800 km). The latter correspond to the equatorial pitch angle just outside the loss cone.



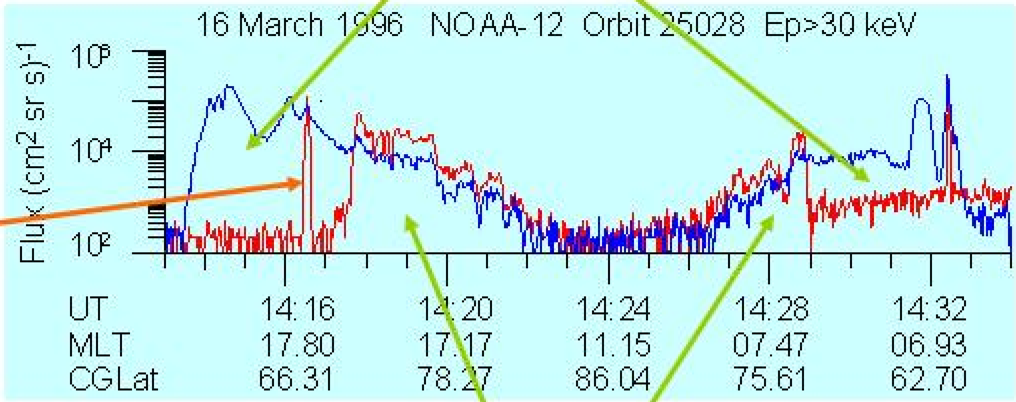
Details of the NOAA particle measurements can be found in Evans and Greer (2004), Robel (2009).

Localized precipitation of energetic protons (LPEP)

Example of the NOAA POES energetic proton data

Empty loss cone region

Localized (in latitude) precipitation of energetic protons within anizotropic zone

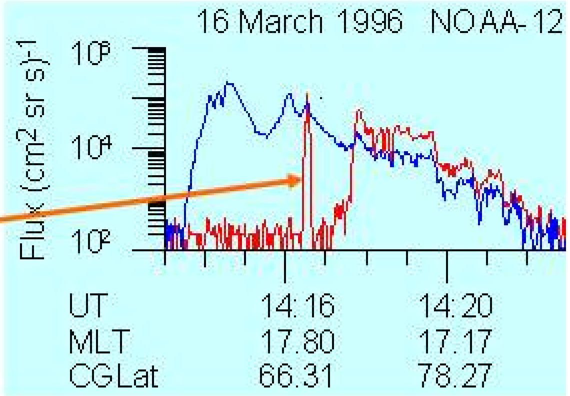


Isotropic precipitation from "low" **B** region (*plasma sheet, outer ring current*)

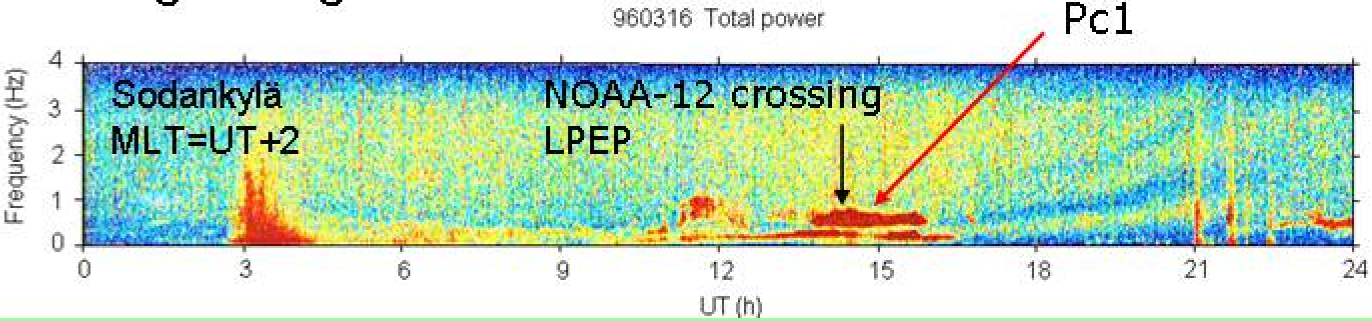
As the Ion-Cyclotron Instability needs the transverse anisotropy of the proton temperature, it seems to be reasonable to search proton scattering signatures in the region, which is equatorward of the isotropy boundary.

Localized precipitation of energetic protons (LPEP) and EMIC waves

Localized (in latitude) precipitation of energetic protons within anizotropic zone

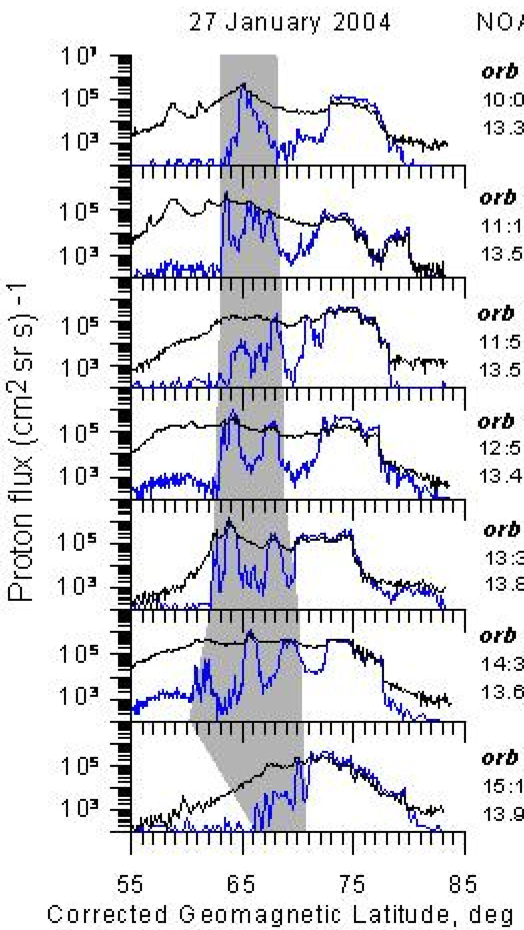


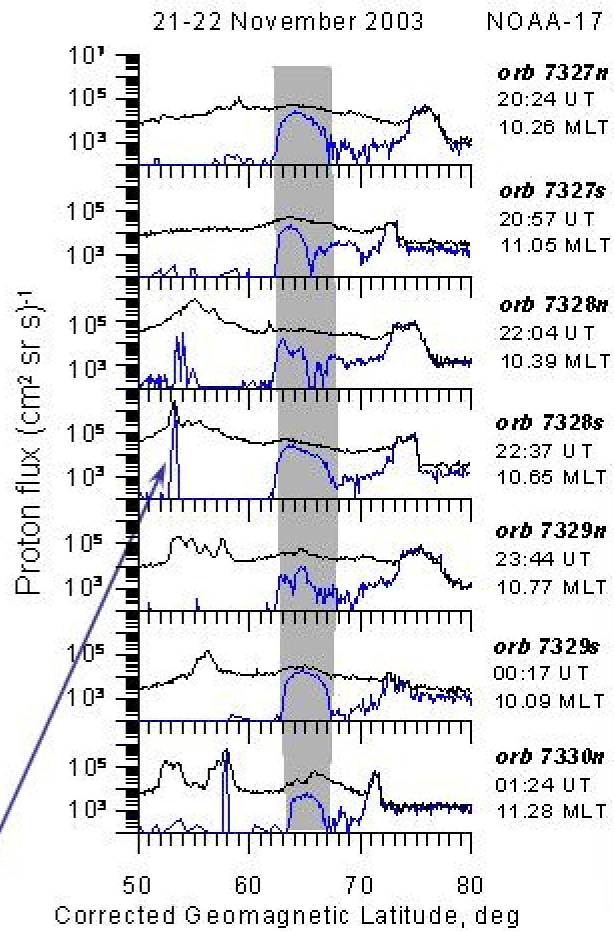
Spectrogram of geomagnetic fluctuations



When the ground station is in the 2-h MLT range from the LPEP location, it registers geomagnetic pulsation Pc1 (EMIC waves) in almost 100% of cases [*Yahnina* et al., 2003].

Dayside sub-oval proton precipitation





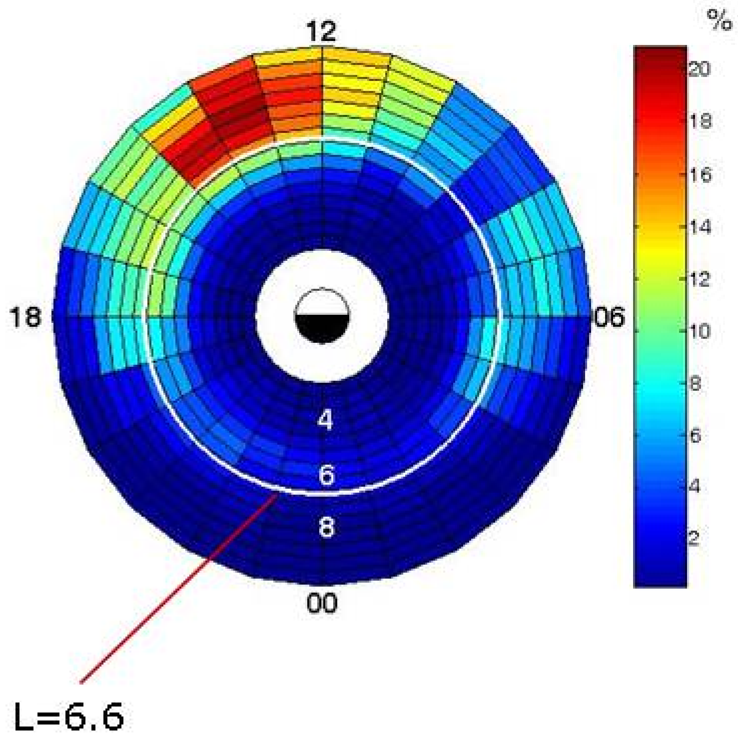
Sequences of passes of the low-orbiting satellites trough the dayside sub-oval region represent the proton precipitation equatorward of the isotropy boundary.

These wide in latitude, structured, long-lived, and variable proton precipitation are observed in ~30% of NOAA orbits in the sub-oval region on the dayside.

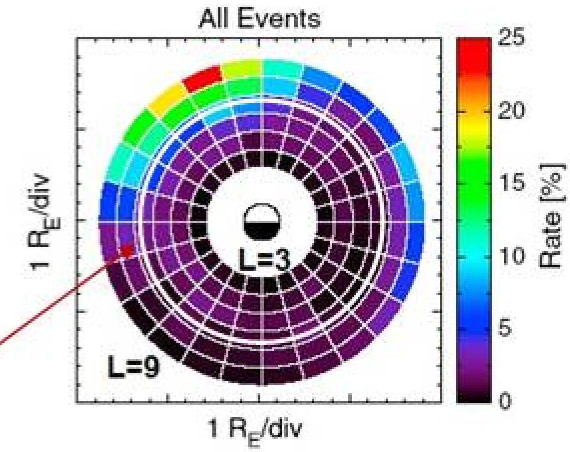
Note: Sometimes LPEP (plasmapause) are also seen during dayside sub-oval precipitation

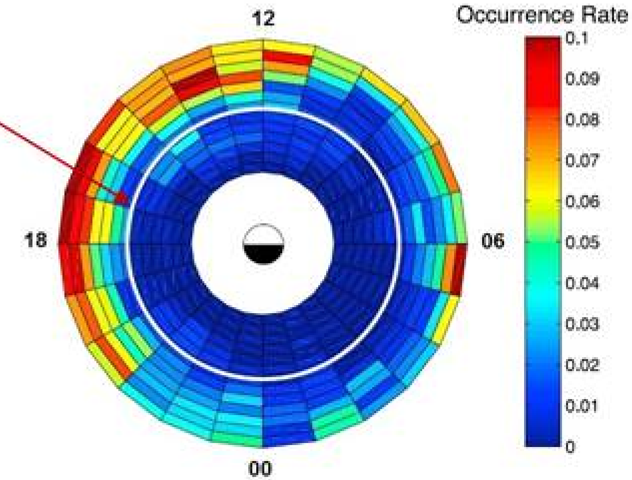
Comparison with the EMIC wave statistics

Global distribution of EPP was constructed for interval from July 01 to December 31, 2005



L=6.6



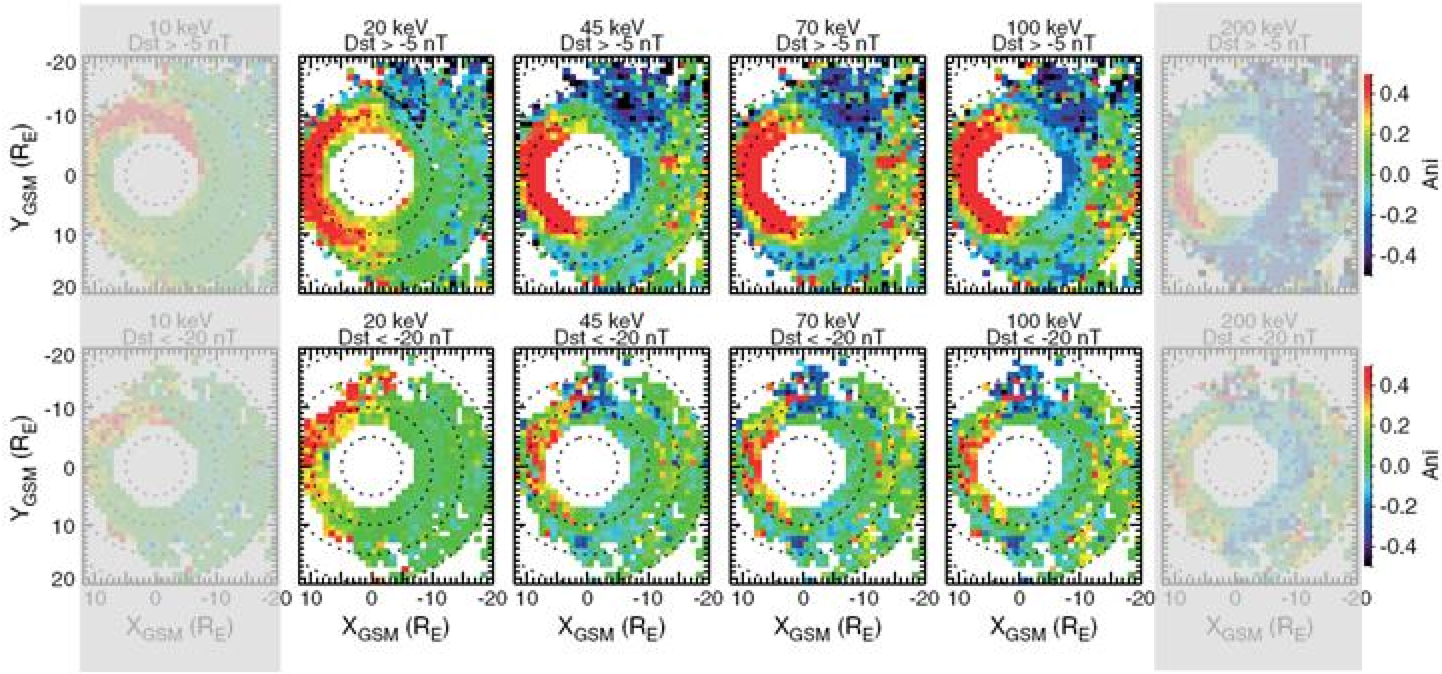


The global distribution of the occurrence of the sub-oval proton precipitation resembles that of the EMIC waves

EMIC wave occurrence [*Usanova* et al., 2012; *Keika* et al., 2013]

The equatorial distributions of median ion anisotropy

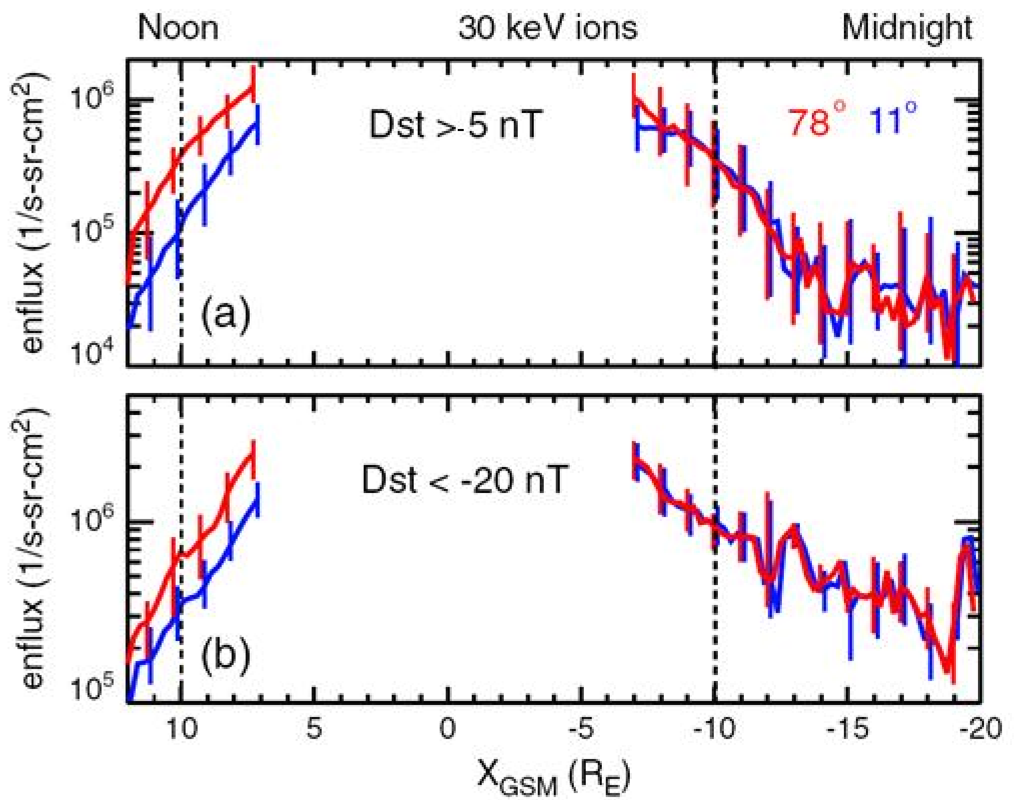
Based on THEMIS measurements from 2007 to 2010.



Wang et al., 2013

The enhanced transverse anisotropy ($A=(T_{\perp}/T_{\parallel})-1 > 0$) of protons is observed on the dayside. This is evidently related to the “drift shell splitting” effect.

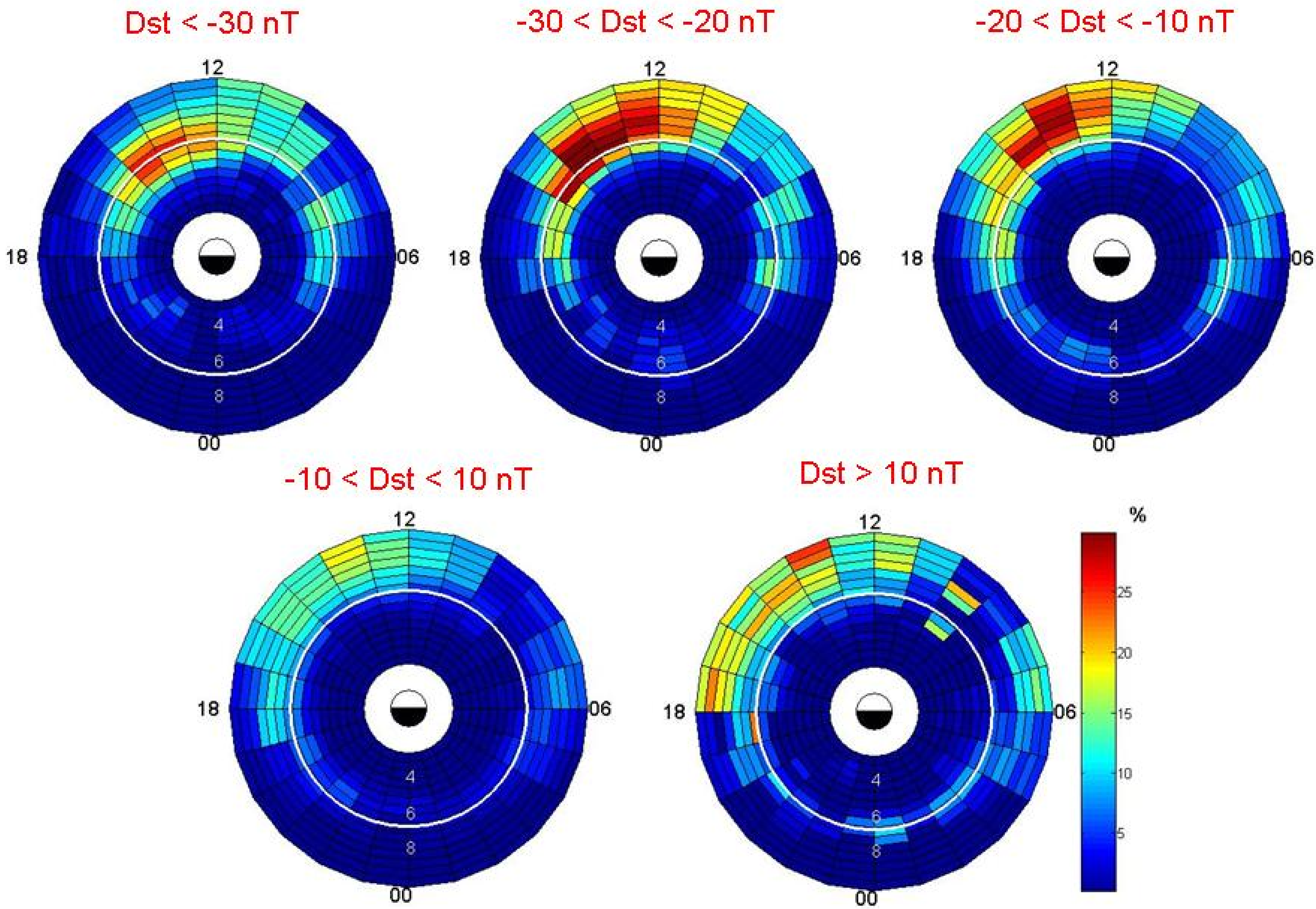
Experimental illustration of the "drift shell splitting" effect



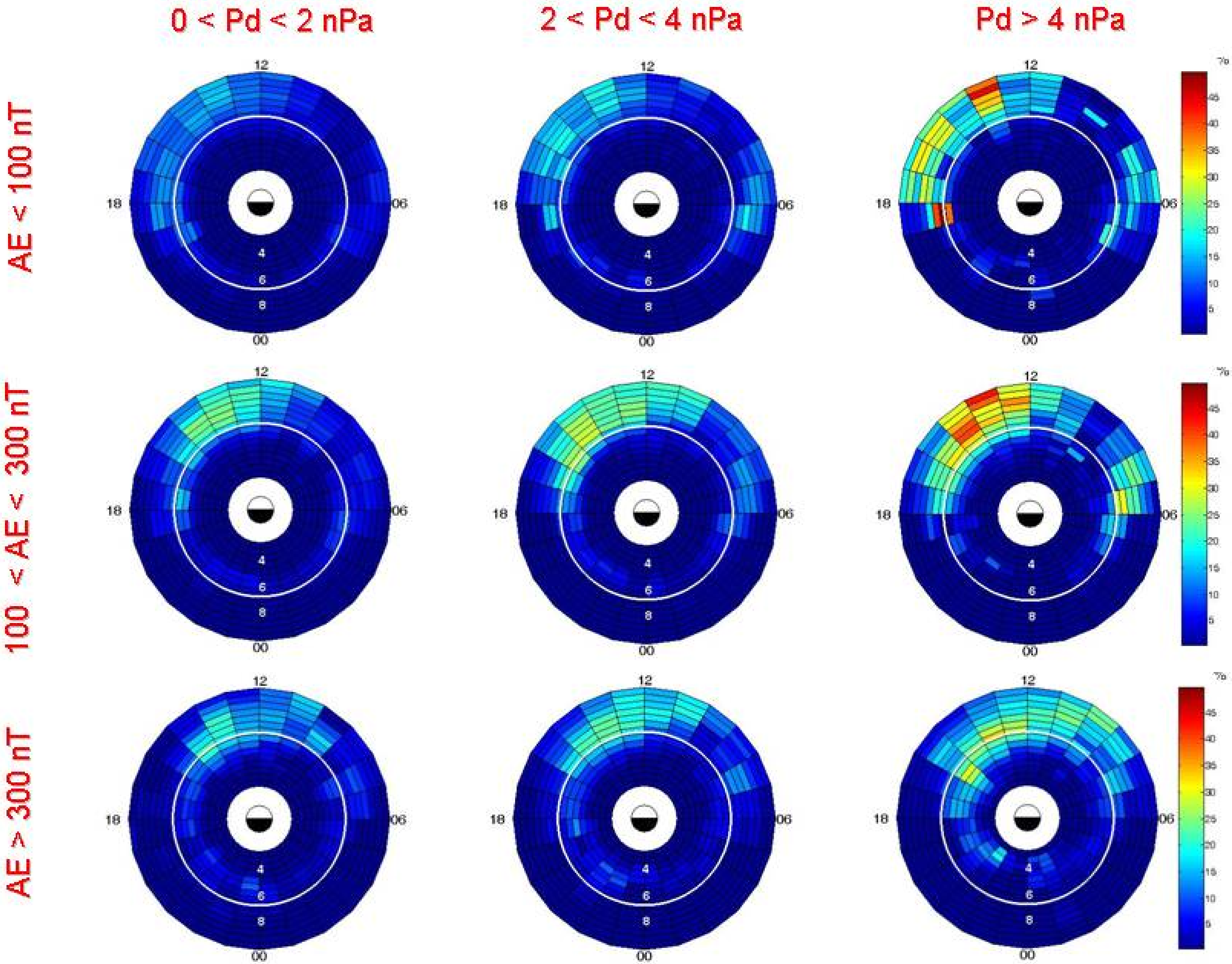
Wang et al., 2013

The anisotropy depends on the radial gradient of the energetic proton flux on the nightside.

Dependence of the sub-oval proton precipitation occurrence rate on Dst index



Dependence on solar wind dynamic pressure and AE-index



Conclusions

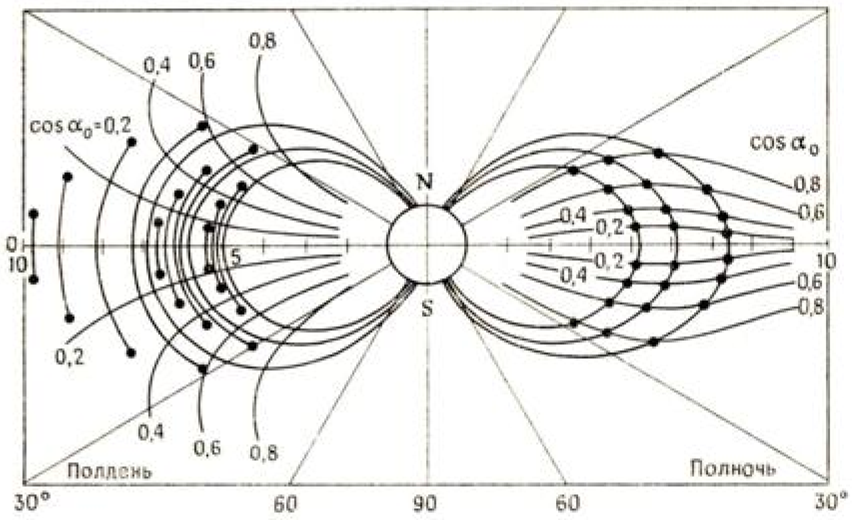
- It has been shown that maximal occurrence rate of precipitations increases with the increase in the solar wind dynamic pressure independently of the geomagnetic activity level.

- The occurrence rate of EPP increases from low to moderate geomagnetic activity, and it decreases during more disturbed periods.

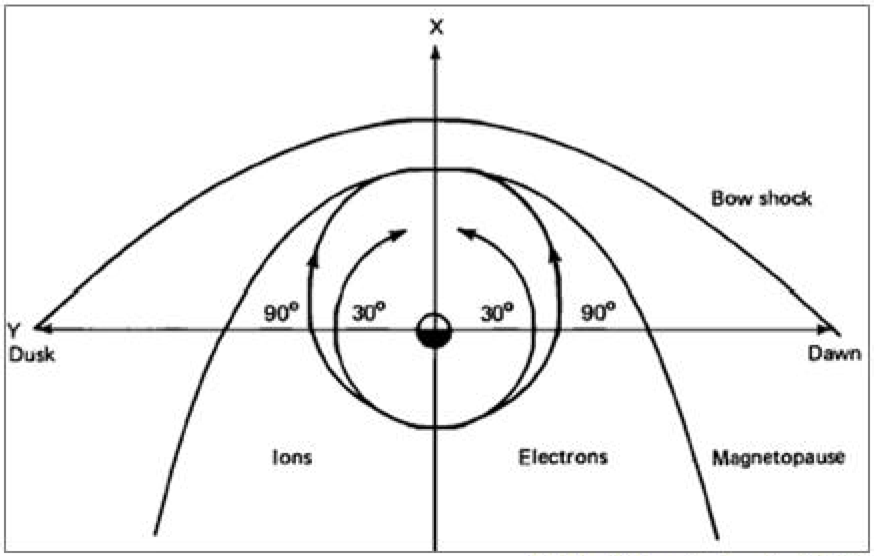
Such behavior can be explained by the effect of the two competitive processes, both of them are due to the nightside injection of energetic protons. On the one hand, the injections lead to growth of particle flux, which, in turn, causes the increase of IC instability increment. On the other hand, the injections lead to the decrease of the radial gradient of the particle flux on the nightside. This results in the decrease of transverse anisotropy of energetic protons on the dayside.

Schematically explanation of the “drift shell splitting” effect

After Roederer, J.G. (1967)



When particles drift around the Earth, conservation of the 1st and 2nd adiabatic invariants means that particles with higher equatorial pitch angles have drift paths further out in L on the dayside than those with lower pitch angles. This leads to transverse anisotropy energetic particles on the dayside.



D.G. Sibeck et al., 1987