Probing storm-time near-Earth magnetotail dynamics using 30 keV proton isotropic boundaries as tracers of precipitating and trapped populations

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Fall AGU meeting, December 11-15, 2017, New Orleans LA, USA

Magnetotail dynamics and low altitude measurements

Determining the **geometry of the Earth's magnetospheric magnetic field** under various solar wind and IMF conditions is crucial for obtaining connections between ionospheric and auroral features and magnetospheric phenomena.

Knowing the configuration of the magnetic field lines is directly related to the understanding of the **magnetic mapping** in different conditions and between different regions of the near-Earth space.

There are not many satellites in the magnetosphere which measure the magnetic field, therefore, magnetic field models are used.

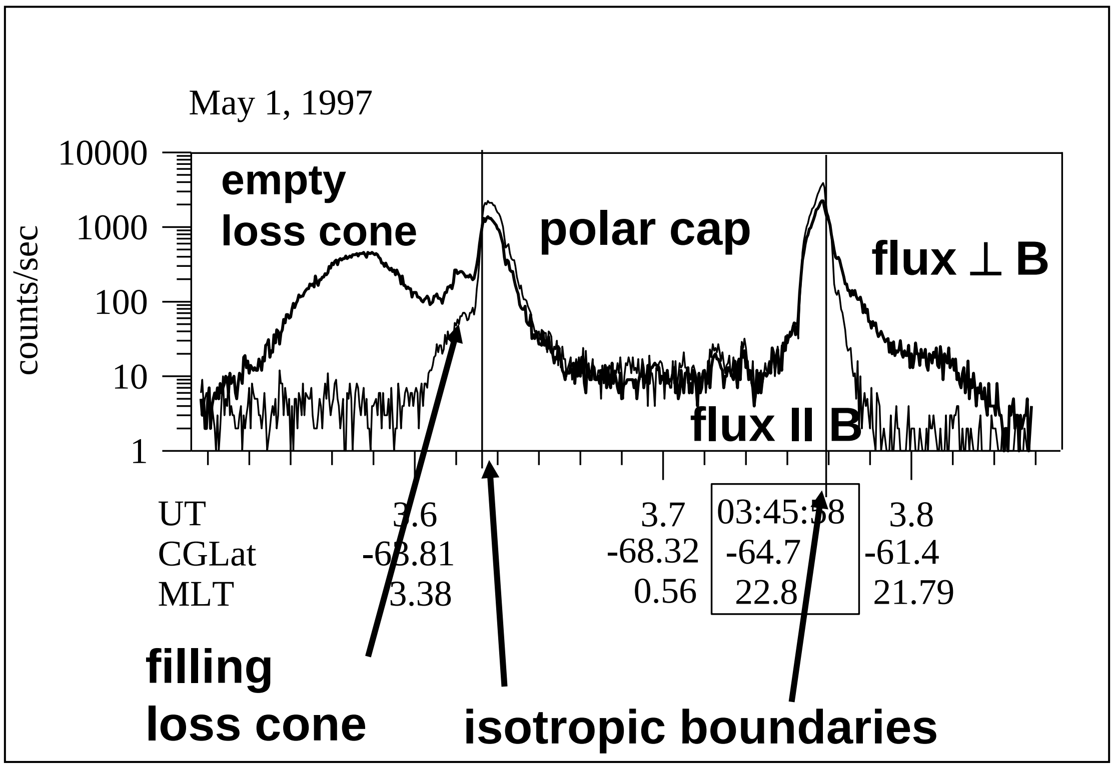
At the same time, there exist **continuous measurements on NOAA satellites**, which can provide, though indirectly, valuable information about the dynamics of the magnetospheric magnetic field, in the magnetotail, in particular.

Isotropic boundary observed at NOAA can serve as an indicator of the magnetotail dynamics if we know the mechanism of its formation.

NOAA POES Instrumentation and data

The NOAA POES spacecraft is on **nearly circular Sun-synchronous polar orbit** at an **altitude of about 800 km** with orbital **period about 102 minutes**, which produces 14.1 orbits per day.

SEM-2 contains **MEPED** which measures (with a **time resolution of 2 s)** the flux of the energetic **protons** and electrons. We work with protons in P1 (30–80 keV).



Detectors in the MEPED:
(1) radially outward measures **precipitating particles** in the central part of the loss cone
(2) perpendicular direction measures **locally trapped** particles outside the loss cone.

- **IBs** observed at all MLTs;
- For same species and energy: IB lat higher around noon than at midnight;
- The higher the energy, the lower the IB latitude

Formation mechanisms of isotropic boundaries

The mostly debated mechanisms of the pitch-angle scattering responsible for the IB formation on the nightside:

1). field-line-curvature (FLC) scattering [e.g., *Sergeev et al.*, 1983, 1993]

2). scattering by electro-magnetic ion cyclotron (EMIC) waves [e.g., *Dubyagin et al.*, 2013, *Liang et al.*, 2014 , *Sergeev et al.*, 2015]

Field-line curvature (FLC) mechanism

For the idealized magnetotail-like configuration, the condition for the loss-cone filling by the FLC-scattering is

$\kappa = \dfrac{R_c}{\rho} \leq 8,$ where $R_c = \dfrac{B_z}{(\partial B / \partial z)}$ is the magnetic field line curvature radius

and $\rho = \dfrac{\sqrt{2mE}}{qB} \sin\alpha$ is the particle gyroradius in the center of the current sheet.

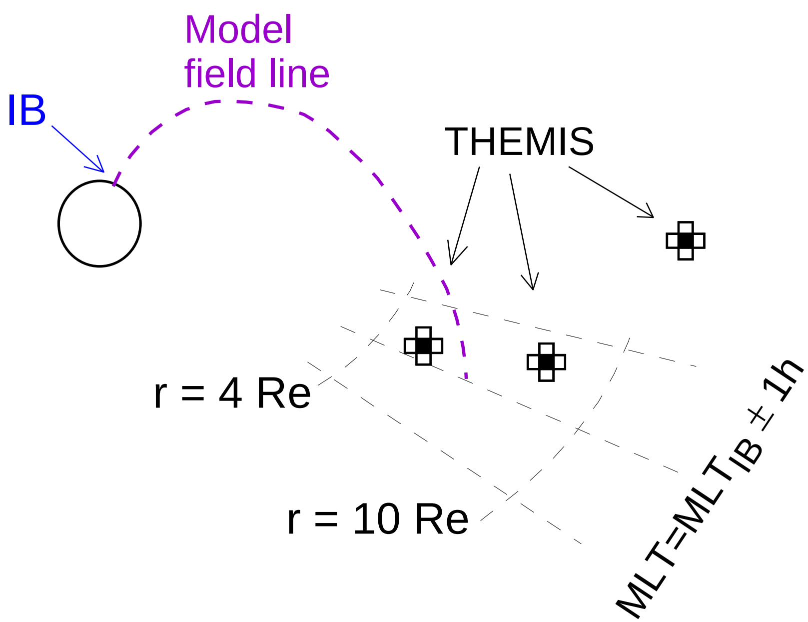
If in some region of magnetotail, the gyration radius of a particle becomes comparable with the field line curvature, a particle is exposed to **pitch angle scattering.**

The nightside IB is interpreted as a boundary between the adiabatic and stochastic particle motion in the tail current sheet and is used to determine the degree of magnetic field stretching in the magnetotail

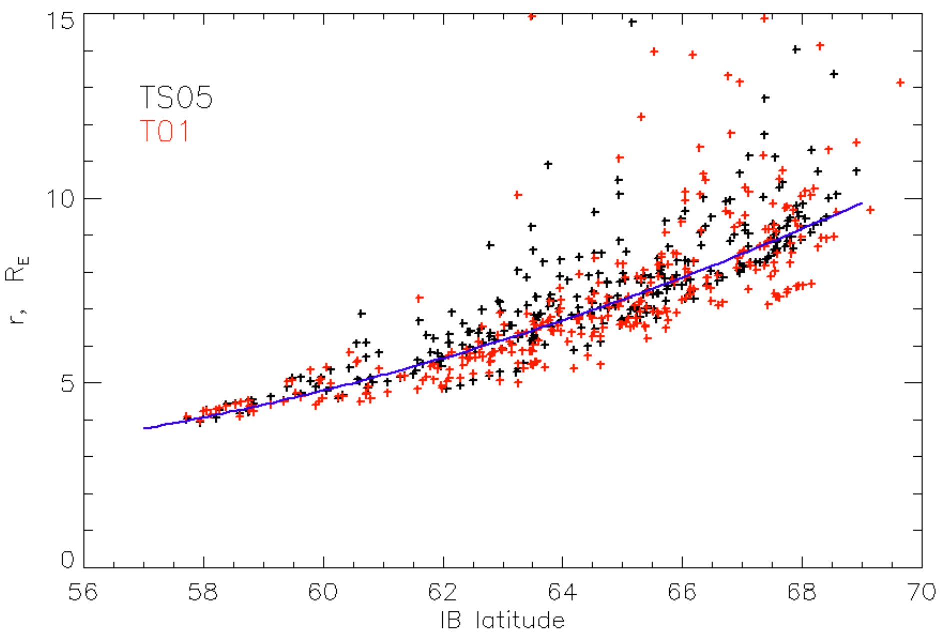
To determine K - parameter

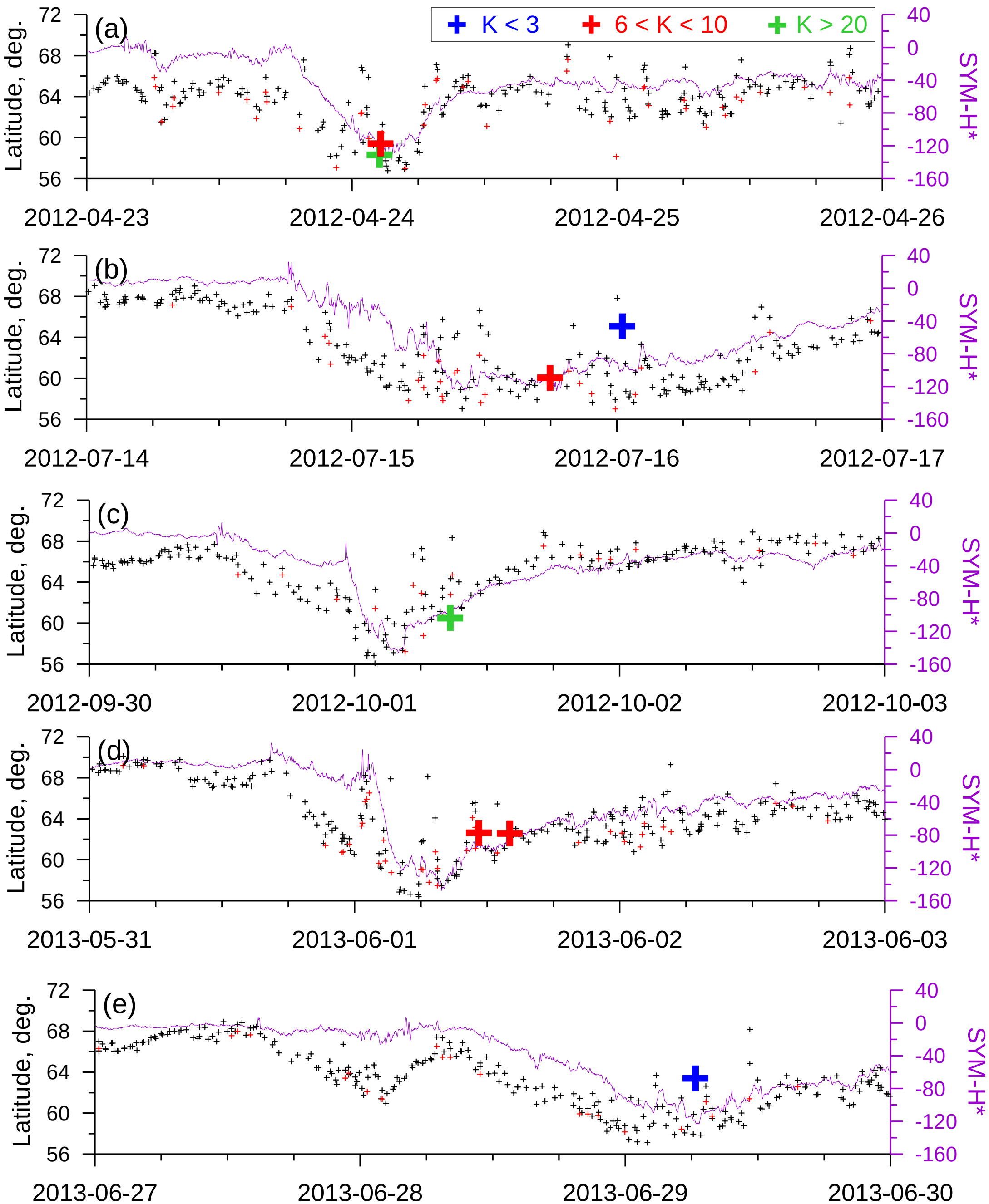
$$\frac{R_C}{\rho} \approx \frac{B_Z}{dBx/dZ} \cdot \frac{eB_Z}{mV} = \frac{eB_Z^2}{mV\, dBx/dZ}$$

To control the model accuracy:
comparison with in situ magnetic field measurements (THEMIS),
near expected IB equatorial projection (r=4-10Re,
same MLT (plus/minus 1 hour)
as observed IB).



Observed IBs projected onto equatorial plane using T01 and TS05 models: between 4 and 10 Re





IB during storms

Concurrent observations **at low-altitudes and in the equatorial magnetosphere**:
THEMIS on the nightside
IBs within 21–03 MLT

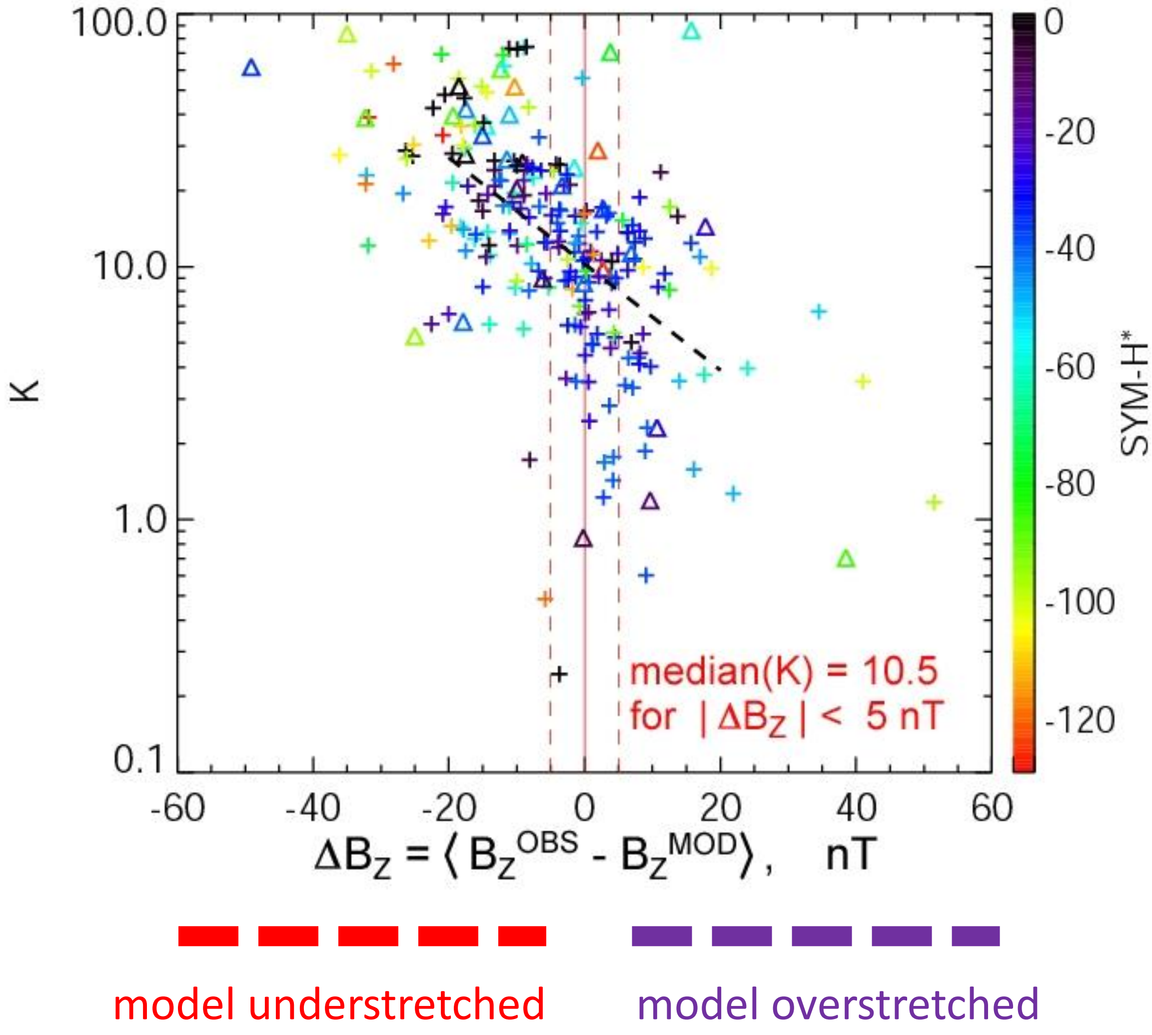
IB latitudes follow the variations of SYM-H closely except for transient periods (IB latitude up and down)

K ≈ 8 (red crosses):
typically found during periods of stable IB location.

K < 3 or K > 20
(green and blue crosses):
during the periods when location of IB underwent fast variations.

Estimated K - parameter correction using THEMIS measurements

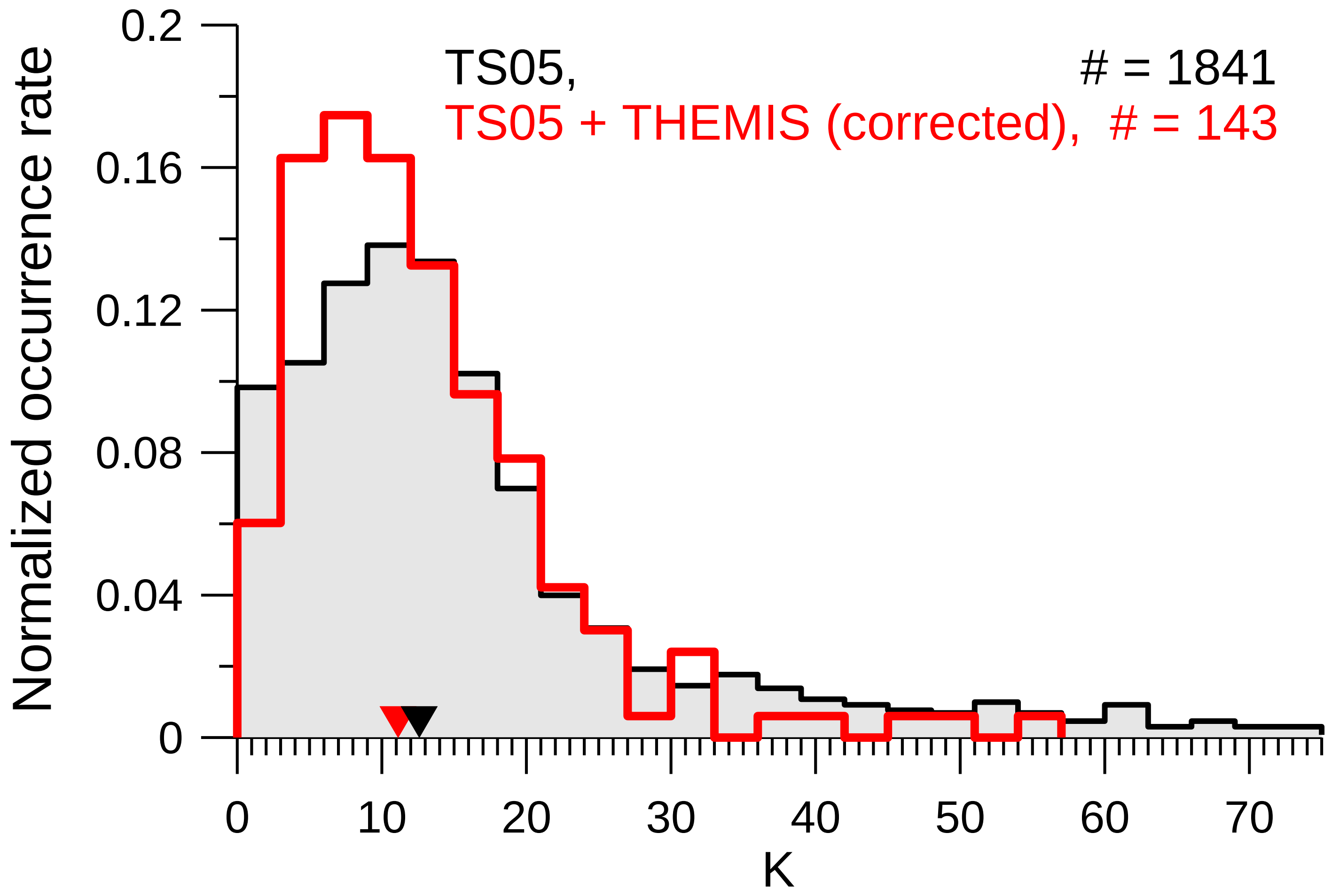
Triangles: storm main phases; **Crosses**: storm recovery phases



ΔBz <0: model Bz > real Bz;
model overestimates K-parameter;
model is understretched;
equatorial projections of IB are closer to Earth than real.
ΔBz >0: opposite
model underestimates K-parameter for such events.

For the events when the TS05 is in a good agreement with magnetic field measurements, the K-distribution, though broad, peaks at K=10.

K-parameter for observed IB field lines by TS05



Although distributions are very broad, they are centered at K=10-13.

Conclusions

- ✓ The latitude of the energetic proton isotropic boundary undergoes dramatic variations and can be as low as at 55 degrees during storm times;

- ✓ In contrast to *Sergeev et al*. [2015], **K>30 was found for only 5% of events.**

- ✓ K-parameter estimation is very sensitive to Bz in equatorial magnetotail. The observations in this region should be used to control the model accuracy

- ✓ No indications were found that the mechanism of the pitch-angle scattering near midnight is systematically different from that during non-storm conditions.

- ✓ The dominant mechanism of isotropic boundary formation is the pitch-angle scattering owning to the curvature of the field lines in the magnetotail current sheet.