Isotropic Boundaries Observed at LEO as a Proxi for SWMF Magnetic Field

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What is it all about? Why it is useful?

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.

The only way to determine the magnetic field configuration in the entire magnetosphere is to use **an existing model – magnetic field from SWMF**.

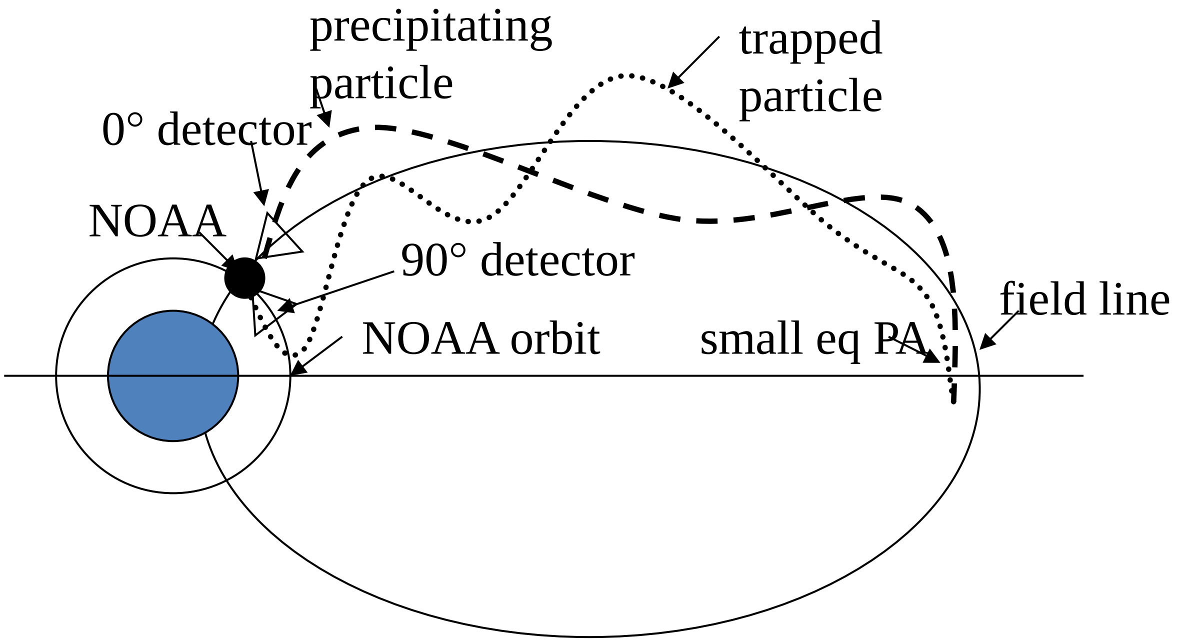
Models need to be validated. There are not so many satellites in the magnetosphere which measure the magnetic field.

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.

NOAA POES measurements

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.

The **MEPED** instrument measures with a **time resolution of 2 s** the differential flux of protons with energies of P1 (30–80 keV), P2 (80–240 keV), P3 (240–800 keV).

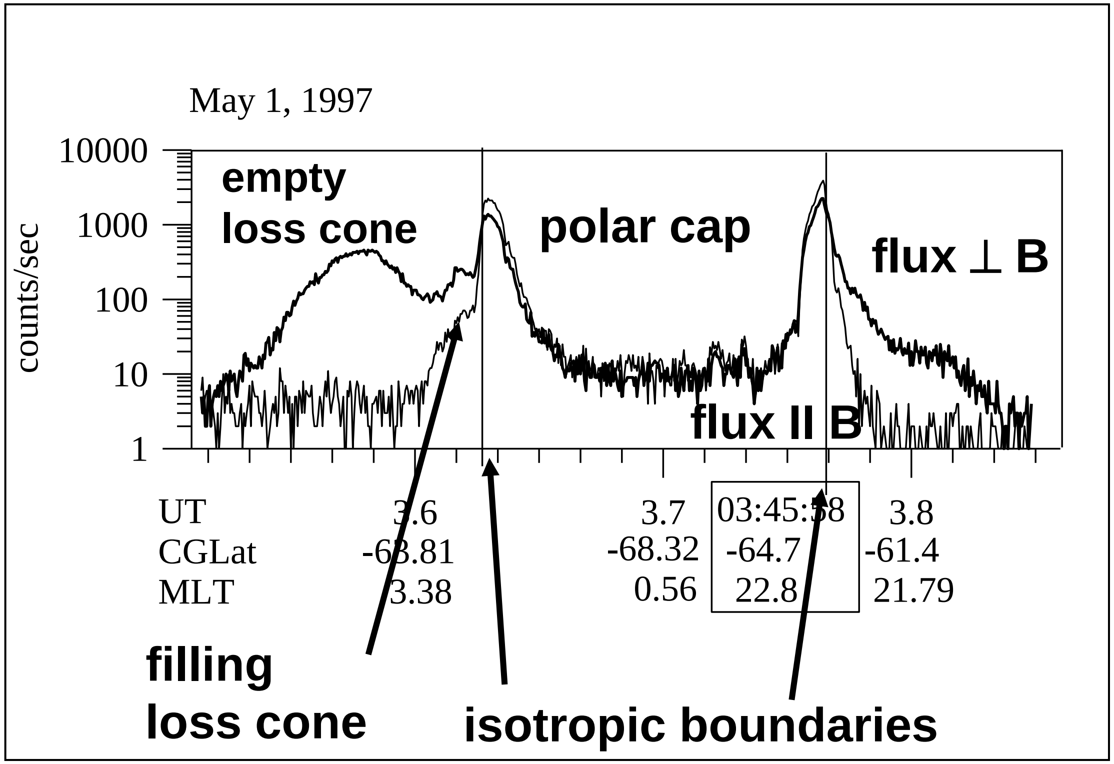


Pair of detectors in the MEPED instrument looking:

(1) radially outward measures precipitating particles in the central part of the loss cone and

(2) perpendicular direction measures locally trapped particles outside the loss cone.

Properties of isotropic boundaries at low altitudes



lat < 60 deg:
- anisotropic PA distr.;
- max flux ⊥ B;
- locally mirroring
- with 90 deg PA.

lat > 60 deg:
- isotropization;
- flux ⊥ B ≈ flux || B;
- precipitation.

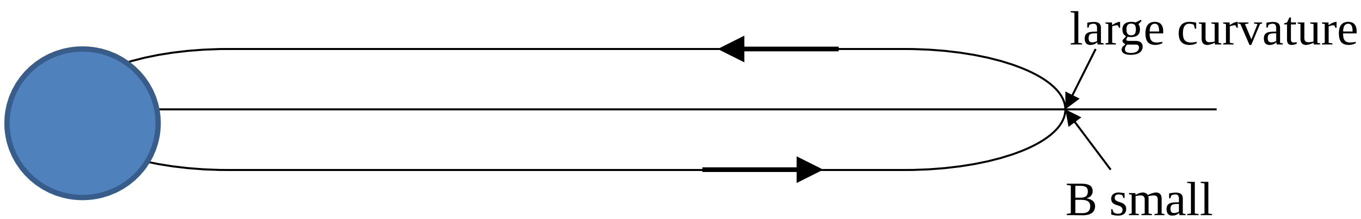
Isotropic boundary (IB) latitude depends on species, E, MLT, activity.

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

- 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;
- Signature of boundary between regions of adiabatic and chaotic particle motion.

Formation mechanism of isotropic boundaries

In the **magnetotail**, the field lines have a large curvature (small radius of curvature) with a small magnetic field strength at the neutral sheet separating opposite fields.



Curvature radius

$$R_c = \frac{B_z}{\left(\partial B / \partial z\right)}$$

Gyration radius

$$\rho = \frac{\sqrt{2mE}}{qB} \sin \alpha$$

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.**

Condition: Rc/ρ = 8.

IB allows to probe the magnetotail configuration remotely (e.g. *Segreev et al*., 1996).

However, recent studies showed that wave-particle interaction cannot be neglected entirely (*Dubyagin et al*., 2013; *Liang et al*., 2014; *Sergeev et al*., 2015)

How to use IB location (latitude, MLT) for SWMF magnetic field validation in the magnetotail?

For post-event analysis (with available magnetic field measurements in the magnetosphere)

1. Identify the **set of events** (or time period, or whatever event(s) is(are) of interest)
2. Obtain the **time-dependent set of IB latitudes** from all NOAA satellites
3. **Simulate events using SWMF** and the models coupled therein to obtain the global magnetospheric magnetic field configurations
4. **Validate the magnetic field output from SWMF** by comparing with all available magnetic field data from the satellites in the magnetotail.
5. For each nightside IB latitude determine **the corresponding magnetic field line** using the SWMF magnetic field and **locate its crossing in the magnetotail at Bmin point and** the corresponding **magnetic field magnitude**;
6. Compute the **corresponding *Rc/ρ*-ratio** for the obtained IB location (for a specific particle energy) in the magnetotail;
7. **Compare** the obtained *Rc/ρ*-ratios with the theoretically determined threshold (***Rc/ρ*=8**) for strong pitch angle scattering;
8. Determine the **actual location in the tail where *Rc/ρ*=8** for a specific event with corresponding magnetospheric magnetic field configuration;
9. Conduct the **validation** for the magnetic field given by SWMF: what magnetic field we Have from SWMF and what from IB: how to improve SWMF field? **Tail current!**

Some demonstrations to start with: Dataset

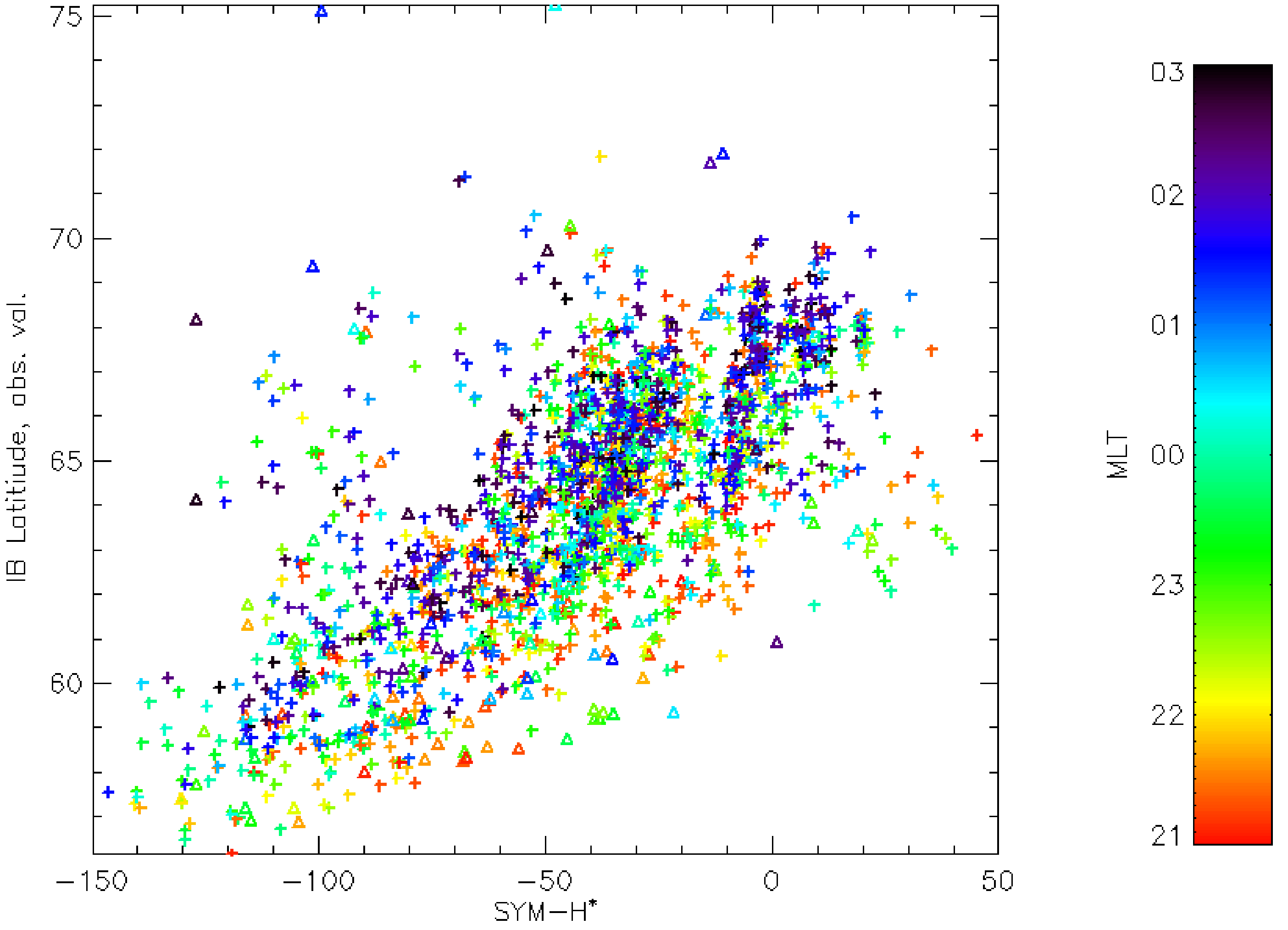
9 moderate storms during 2011-2013 with min SYM-H ~ -100 nT

The data from 7 NOAAPOES satellites are available.
NOAA-15,16,17,18,19, METOP-01,02

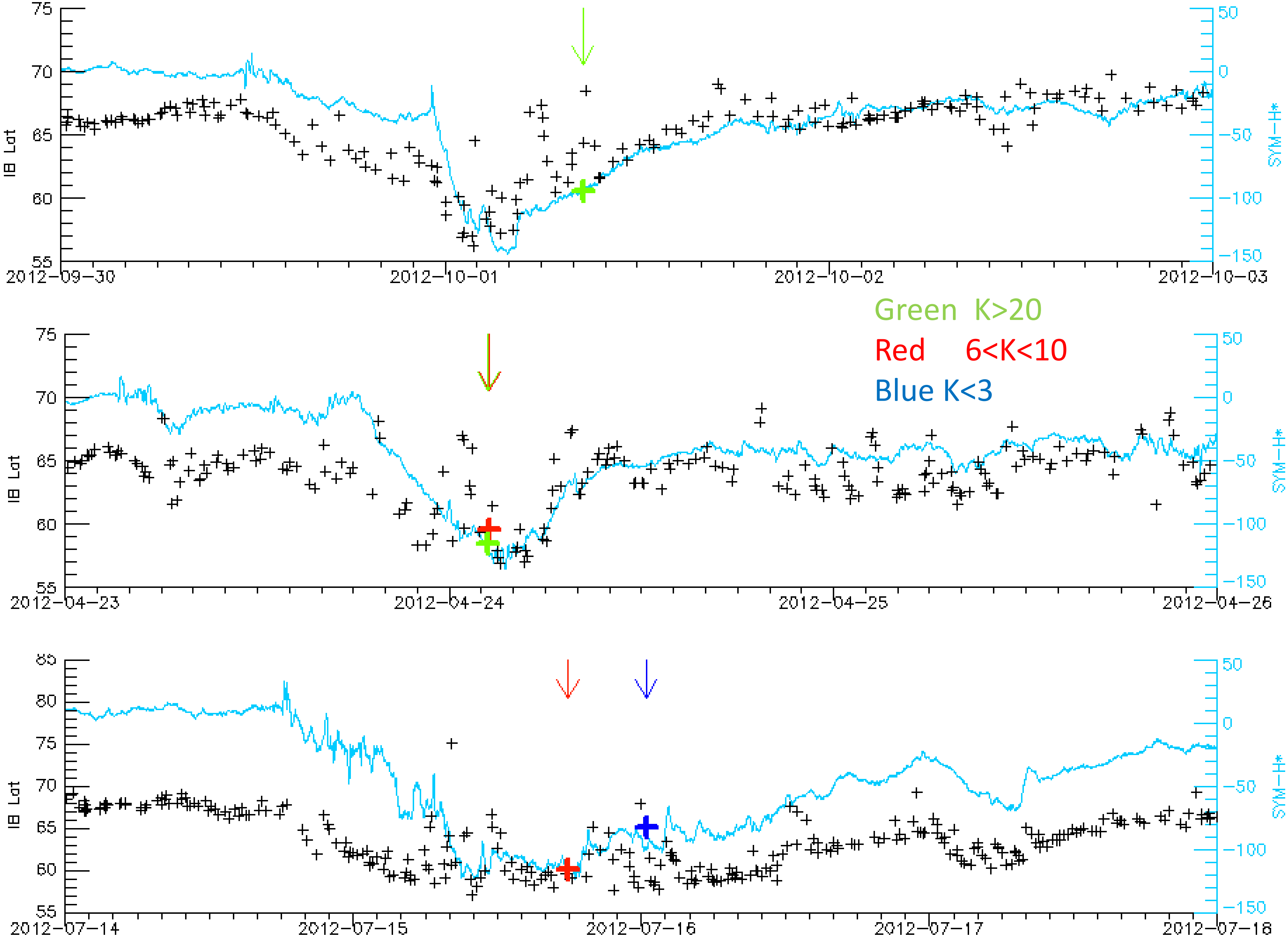
Proton MEPED detectors degraded severely on old satellites.
We use the results of *Asikainen et al*. (2012) and *Sandanger et al*. (2015) to determine the detector low energy limit.

We selected 2274 IBs between MLT 21 - 3 h (near midnight)

IB latitude dependent on Dst (SYM-H)



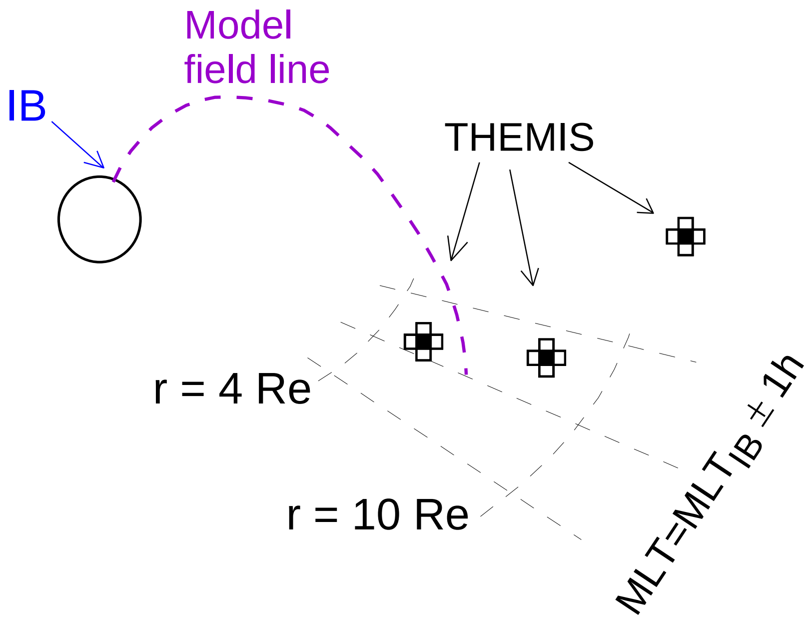
Strong IB latitude dependence on SYM-H index has been previously reported (*Soraas et al*., 2002; *Lvova et al*., 2005; *Asikainen et al*., 2010)

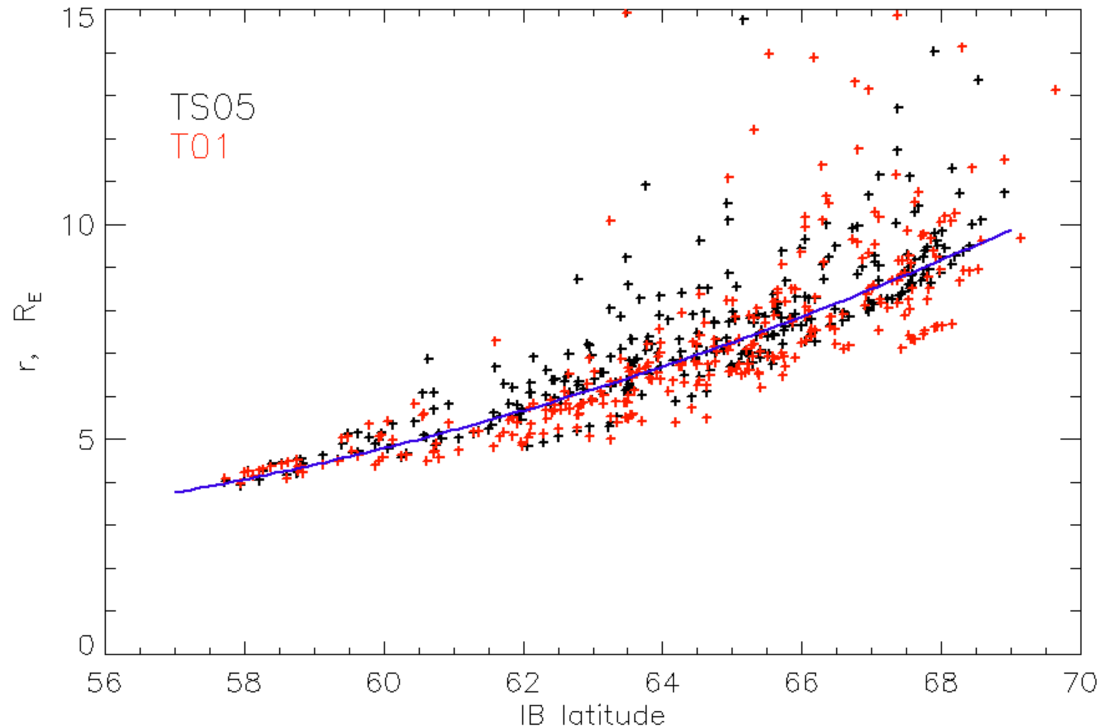


IB Lat
SYM−H*
2012−09−30
2012−10−01
2012−10−02
2012−10−03
2012−04−23
2012−04−24
2012−04−25
2012−04−26
2012−07−14
2012−07−15
2012−07−16
2012−07−17
2012−07−18
Green K>20
Red 6<K<10
Blue K<3

To start with: To determine K - parameter using empirical Tsyganenko models

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).

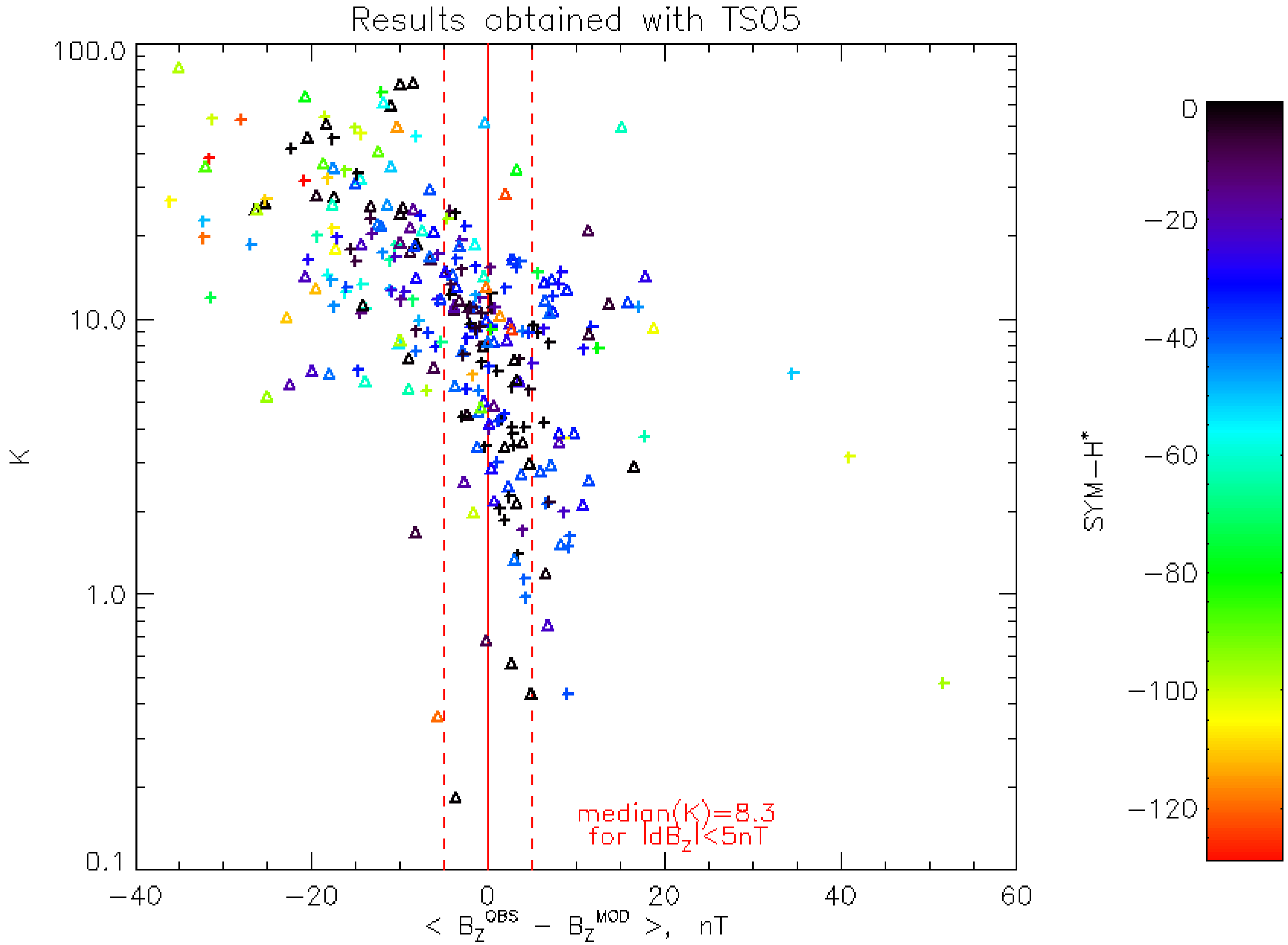




Observed IBs projected onto equatorial plane using T01 and TS05 models:
Most of IBs are located between 4 and 10 Re.

K - parameter and model quality

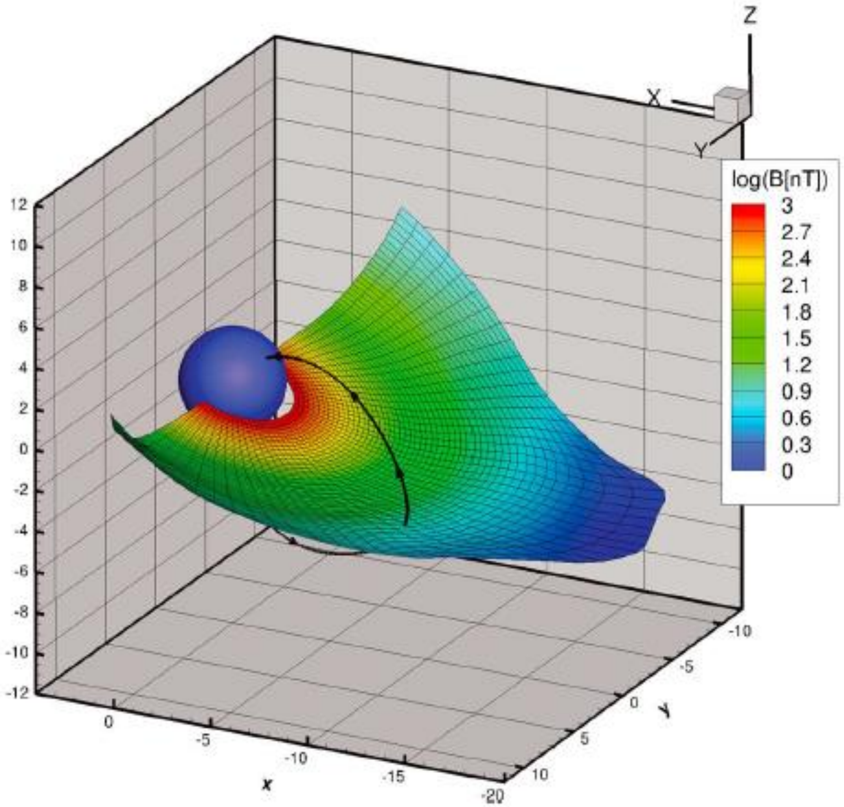
Bz ~ const across a current sheet. Therefore, Delta(Bz) = Bz_obs – Bz_model is an indicator of the model quality. If Delta Bz > 0 , the model configuration is overstretched and K-parameter is underestimated, and vice versa.



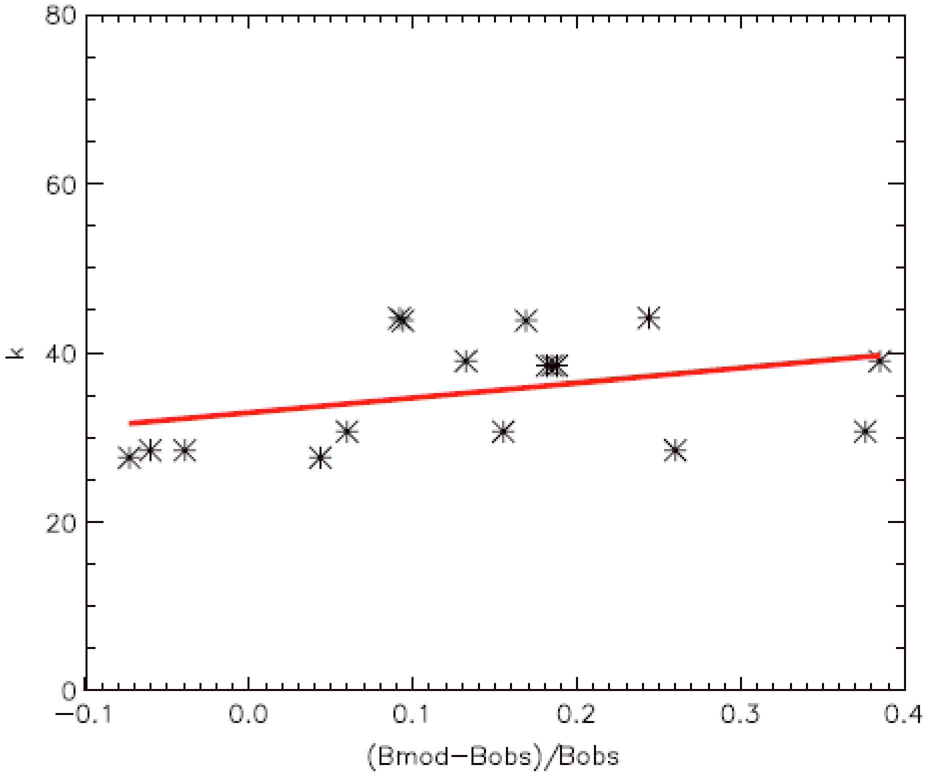
model understretched

model overstretched

Initial SWMF magnetic field validation on February 13, 2009 quiet event



Magnetic field strength at Bmin surface



For IBs with corresponding THEMIS magnetic field measurements

Ilie et al., JGR, 2015

Summary

1. There exist A LOT of **continuous measurements on NOAA satellites**

2. They can be used to probe (indirectly) the dynamics of magnetic field in the tail

3. They can indicate on the dynamics of the tail current in SWMF when the observed and modeled magnetic field are far from each other.

4. Magnetic field line tracing is very sensitive to many factors inside SWMF.
Small changes in IB locations can result in field lines going to very different distances

5. Previous problems: position of dipole axis
Was set at geographic Lon=289.1 deg and Lat=79 deg but for February 13, 2009 event
It is Lon=287.86 deg and Lat=79.96 deg. 1 degree is a lot for field line locations.

6. Usage of IGRF instead of dipole for internal field: Mapping changes very much.

7. Initial results are promising. It was easy to compute IB statistics using Tsyganenko models.

8. If we manage to compute several events with SWMF, it will be a huge step forward
for magnetotail current validation and check for $Rc/\rho = 8$ mechanism validity conditions.

EU H2020 PROGRESS project overview
PRediction Of Geospace Radiation Environment and Solar wind parameterS

ssg.group.shef.ac.uk/progress/html

Participants:

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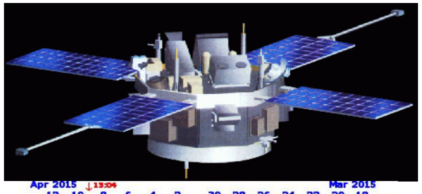
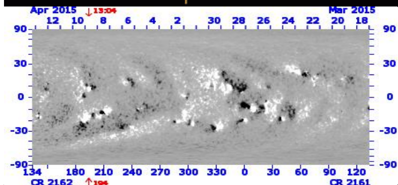
The **overall aim** of the project PROGRESS is to exploit the available spacecraft and ground based data combined with state of art data assimilation methodologies in order to develop an accurate and reliable forecast of space weather hazards.

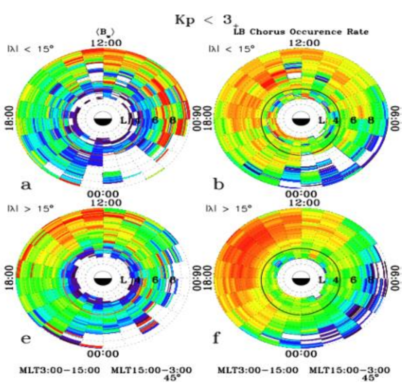
PROGRESS Overview





Solar wind propagation from Sun to L1 (AWSoM/SWIFT)

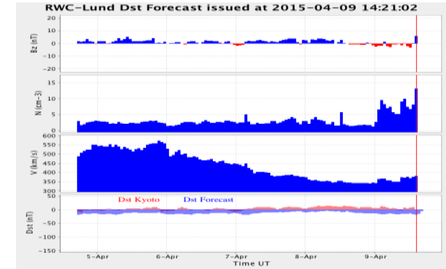
Development of new statistical models

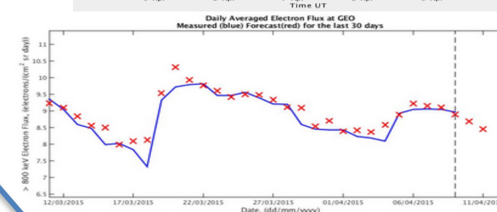


Low energy electron model

Forecast of the Evolution of Geomagnetic indices

Forecast of the high energy electron environment





Fusion of forecast tools