Magnetospheric current systems as inferred from SYM and ASY mid-latitude indices

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European Geosciences Union, General Assembly, Vienna, Austria, 12 – 17 April 2015

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Why to be interested in SYM and ASY indices?

- The interpretation of magnetospheric currents is **difficult but vitally important** because these currents support the distortion the magnetosphere from its quiet-time configuration.

- It is problematic to obtain near-Earth **currents from observations**.
  - Using plasma pressure obtained from particle measurements or ENA imaging
  - Curlometer technique

- **SYM and ASY indices c**omputed from the observations of magnetic field at low latitude ground-based stations: **continuously measured** quantities, which can provide, though indirectly, information about the dynamics of the magnetospheric current systems.

- Since it is impossible to separate the contributions from different current systems from point magnetic field measurements on the ground, **models are needed** where current systems are identified.

- **In the present study** we use empirical magnetic field models to analyze statistically the relative contribution from the different current systems to the symmetric and asymmetric midlatitude indices

SYM and ASY indices: Symmetric part of mid-latitude disturbance field

● **Dst** [*Suigura*, 1964] and **SYM-H** [*Iyemori* , 1990]: measure of the total storm strength.

● Initial interpretation of the depression of the Dst index: effect of the **Symmetric Ring Current (SRC) development.**

● **Dessler-Parker-Sckopke (DPS) relationship** [*Dessler and Parker , 1959; Sckopke*, 1966]: relates total energy content of the plasma within the inner magnetosphere to a magnetic perturbation at the center of the Earth.

● **Other current systems' contributions (significant or largest)** during main phase:
- ***cross-tail current*** [*Alexeev et al., 1996; Dremukhina et al., 1999; Turner et al., 2000; Alexeev et al., 2001; Ohtani et al., 2001; Maltsev, 2004; Ganushkina et al., 2004; Kalegaev et al., 2005]*
- ***partial ring current*** *[Liemohn et al.*, 2001; *Liemohn, 2003]*
- ***substorm current wedge*** [*Friedrich et al., 1999; Munsami , 2000]*.

SYM and ASY indices: Longitudinally asymmetric part of storm-time mid-latitude disturbance field

- extensively studied during the early years of the magnetospheric studies [*Akasofu and Chapman, 1964; Crooker and Siscoe, 1971; Kawasaki and Akasofu, 1971; Fukushima and Kamide, 1973]*
- associated with **development of the Partial Ring Current (PRC)** [*Cummings, 1966; Cahill , 1966]*.

More recent studies

- the asymmetry can be controlled by the **balance between Region 1 and Region 2 field-aligned currents** *[Harel et al*., 1981; *Crooker and Siscoe, 1981; Iyemori , 1990]*,
- still the mid-latitude asymmetry indices are considered as a measure of the PRC intensity [*Weygand and McPherron*, 2006].

- *Fukushima and Kamide [1973*]: **main contribution to the H-component** asymmetry comes from **field-aligned currents** and neither from the ionospheric electrojets nor from the magnetospheric closure current.
- *Shi et al. [2008a, b]:* strong longitudinal asymmetry during the solar wind dynamic pressure enhancement is produced by the combined effect from region 1, 2, PRC, and Chapman-Ferraro currents.

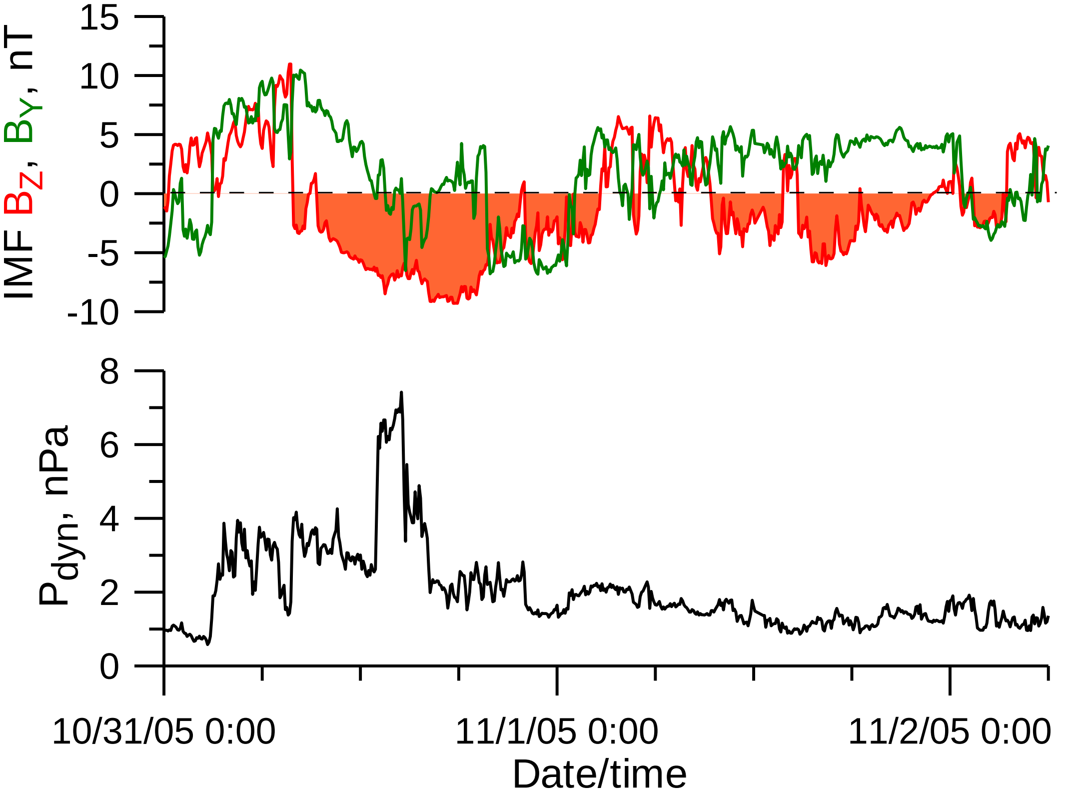
Comparison of model and observed indices: Case study on October 31, 2005

Model SYM and ASY indices, both H- and D- components, were computed using similar procedure that is used for real indices at the World Data Center for Geomagnetism, Kyoto (http://wdc.kugi.kyoto-u.ac.jp/aeasy/asy.pdf (*Iyemori [2010])*

Contribution from the **ground-induced currents of 25%** is taken into account following *Häkkinen et al*. [2002].

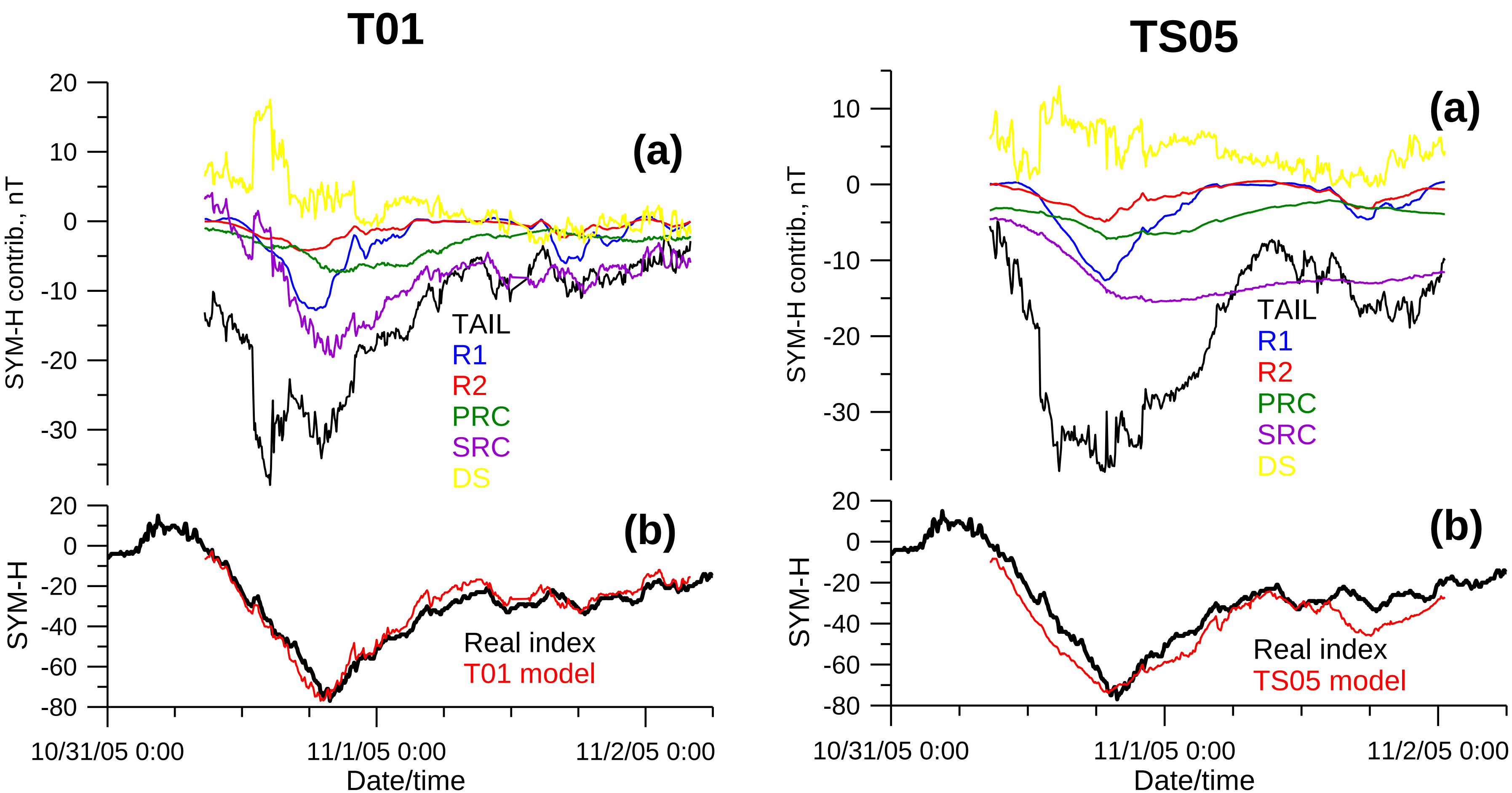
E**mpirical models** which include the **field-aligned currents and dawn-dusk asymmetry** were used:

(1). **T01** [*Tsyganenko*, 2002a, b],;
(2). **TS05** [*Tsyganenko and Sitnov, 2005];*
(3). **TS07** *[Tsyganenko and Sitnov, 2007; Sitnov et al., 2008]*



October 31, 2005: Contributions to SYM-H

Total SYM-H = sum of contributions from current systems

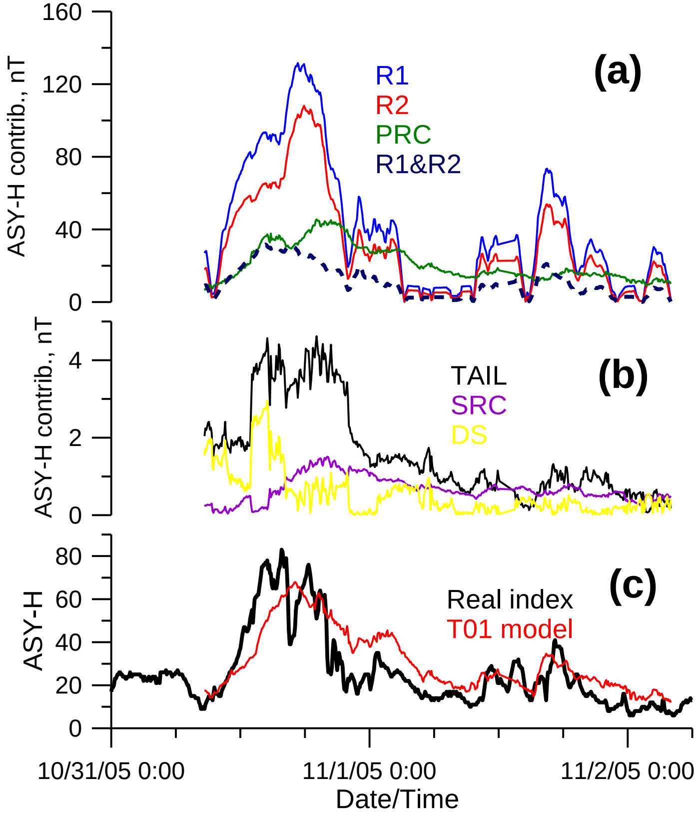


Main contribution comes from **the tail current**
(PRC, R2, and inner TAIL modules in T01 and TS05 models **overlap on the nightside** , the resulting current flows can be completely different than of the TAIL module alone.
Strong contribution from **F1 FAC (not seen in superimposed epoch analysis)**

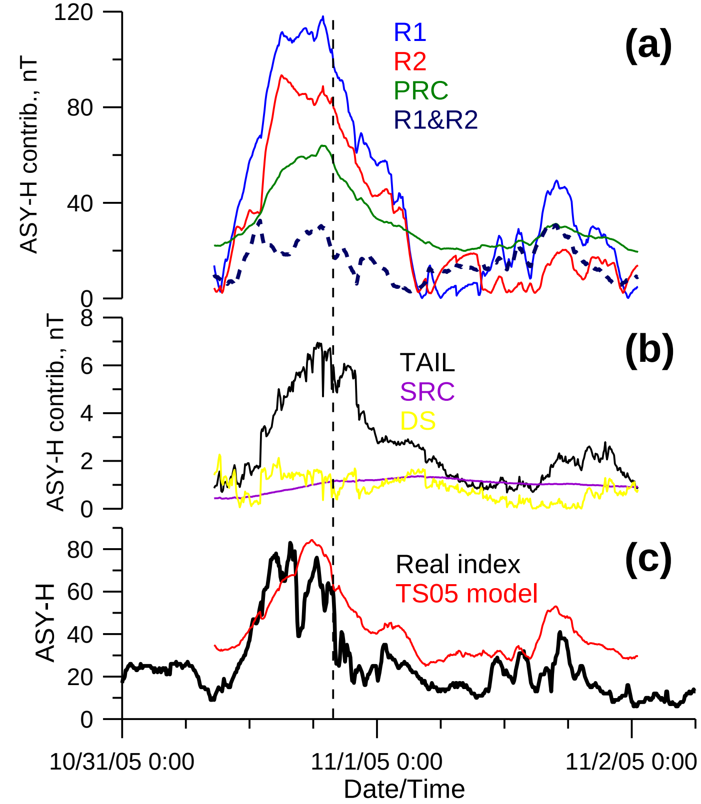
October 31, 2005: Contributions to ASY-H

Total ASY-H ≠ sum of contributions from current systems

T01



TS05



Main contributors: **Partial RC and FACs (o**nly currents closing via the ionosphere give a significant contribution to the ASY-H)

Equatorial part of PRC does not contribute to ASY-H (Tail contribution is small)

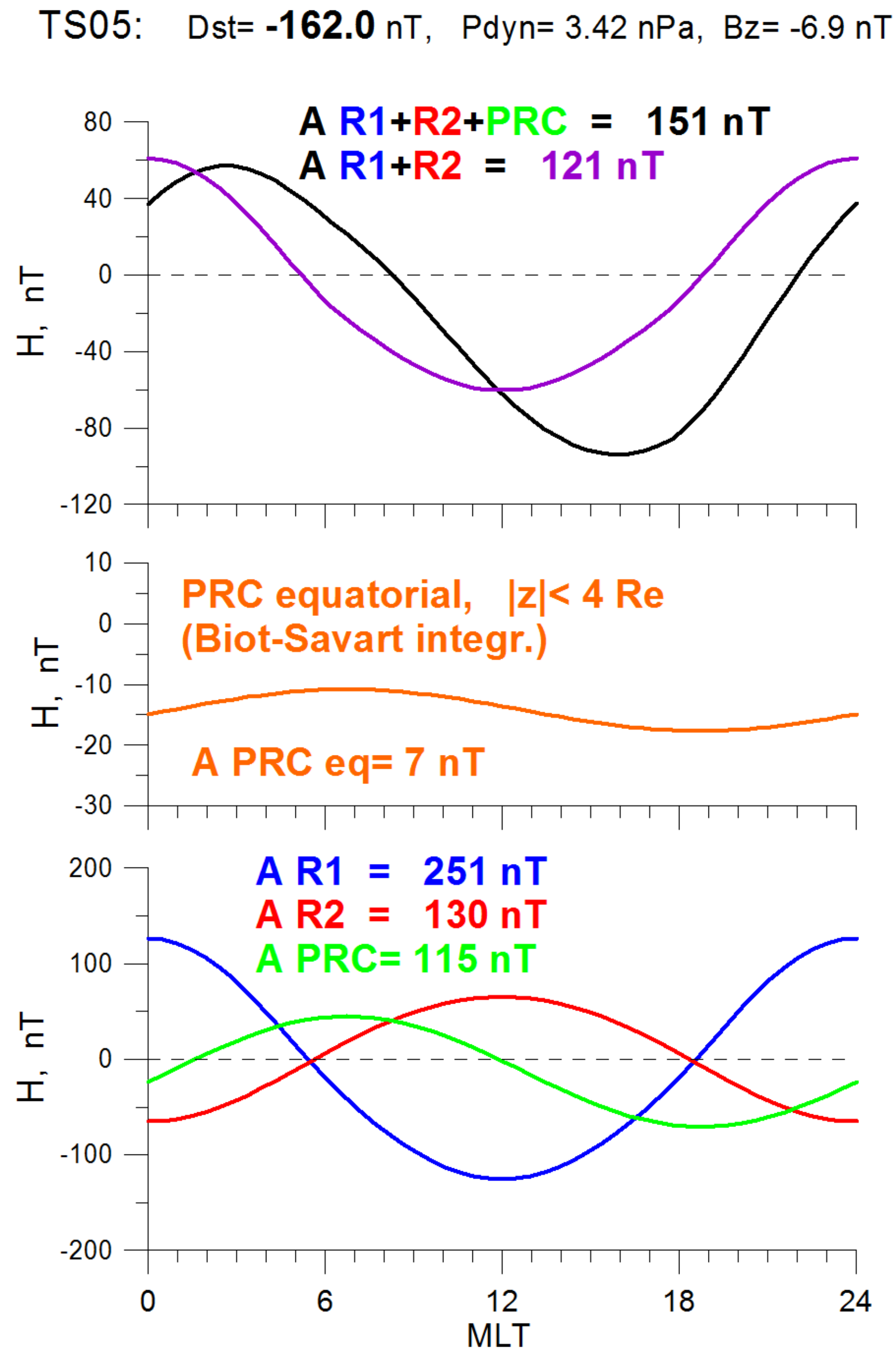
High peaks of FACs but the asymmetries of the R1 and R2 compensate each other.

MLT profiles of currents' contributions to the H component

H-component computed at 40 deg latitude at all MLTs for storm max.
Numbers indicate **max asymmetry**, Hmax-Hmin.

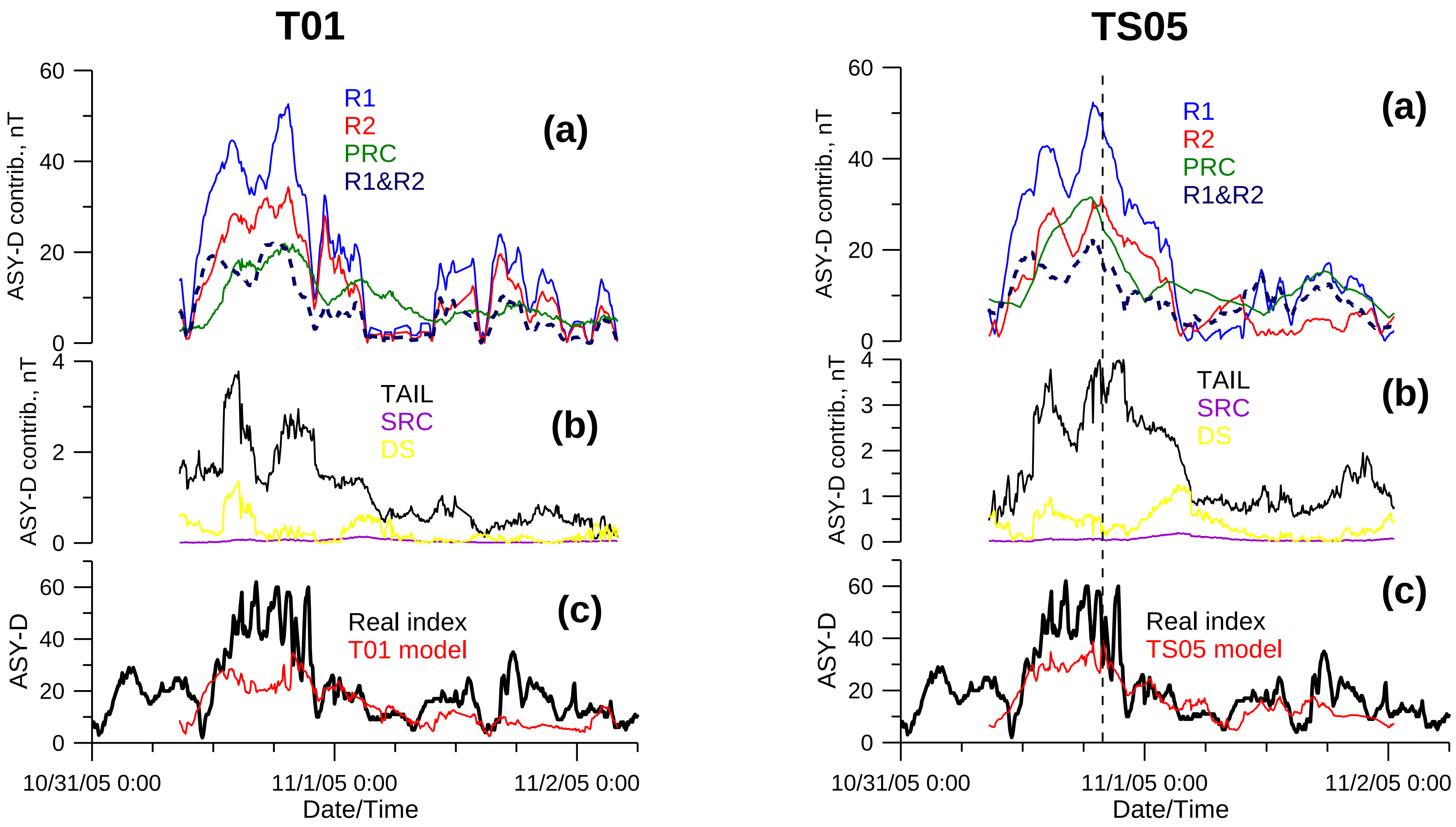
Contribution from **equatorial part of PRC is very small.**

Contribution of R1 FAC is highest but **R1 and R2 compensate** each other.



October 31, 2005, Current contributions ASY-D

Total ASY-D ≠ sum of contributions from current systems



The relative contribution of the different systems to the ASY-D index is similar to that for ASY-H.

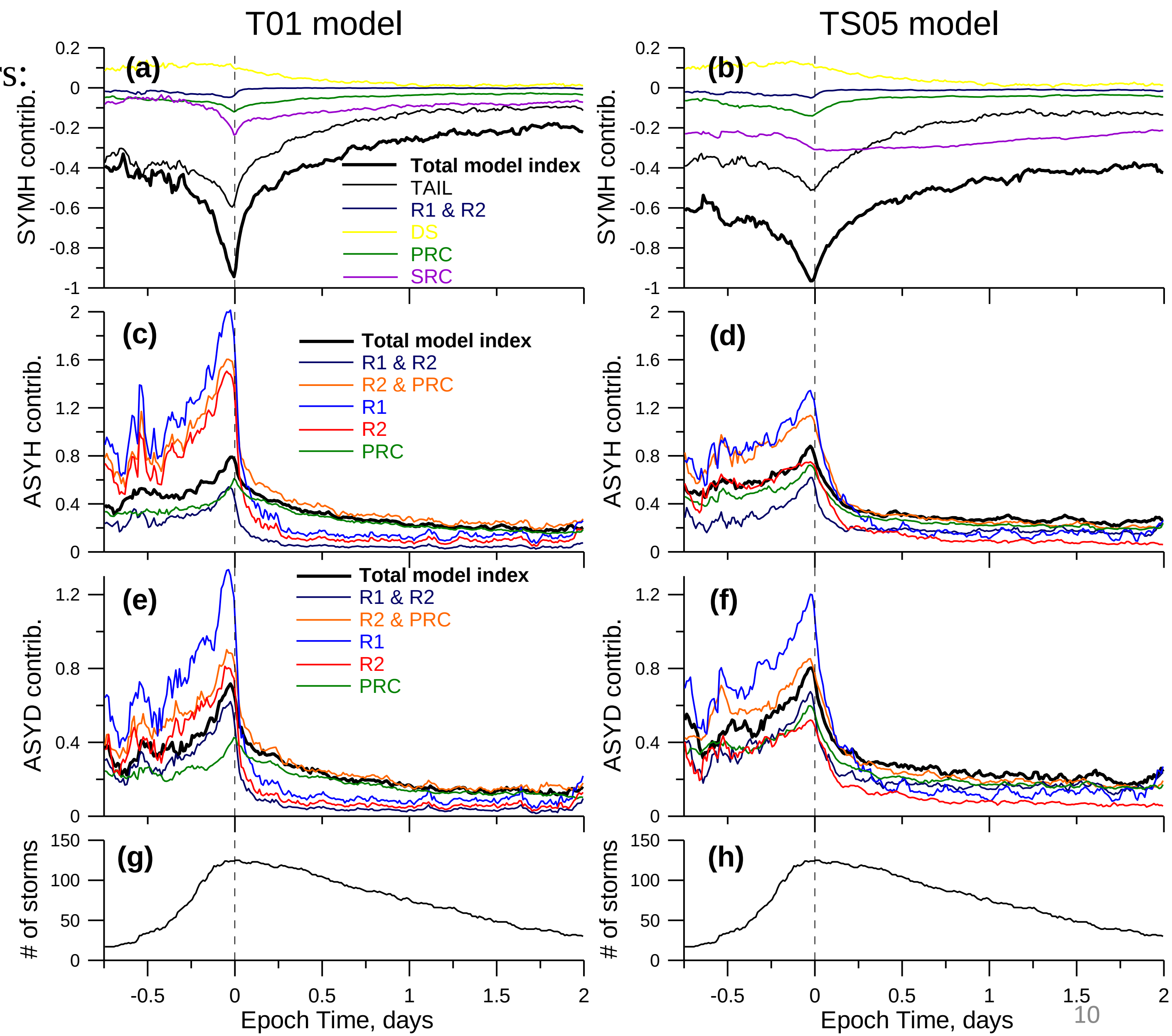
Superposed epoch analysis: All storms, 1995-2004

SYM-H
Main phase contributors:
(1) TAIL module;
(2) SRC module;
(3) PRC,

ASY-H and -D
Comparable contributions from **R1R2 and PRC**

R1 strongest during **main phase, compensated by R2 but not all**

PRC and R2 as one system major contributor during **recovery phase**.



Summary

Although T01 and TS05 show a bit different results, both models are in agreement about the key results.

(1) Cross-tail current gives the dominant contribution to the SYM-H index during storm main phase (model Region 2 FAC, partial ring current, and cross-tail current systems are not spatially demarcated and overlap in the vicinity of geostationary orbit)

(2) Only current systems which close via the ionosphere give a significant contribution to the ASY-H and ASY-D indices. These systems are the partial ring current and Region 1 and 2 FACs.

(3) Equatorial part of PRC does not contribute much to ASY indices (same as cross-tail current does not contribute to ASY indices)

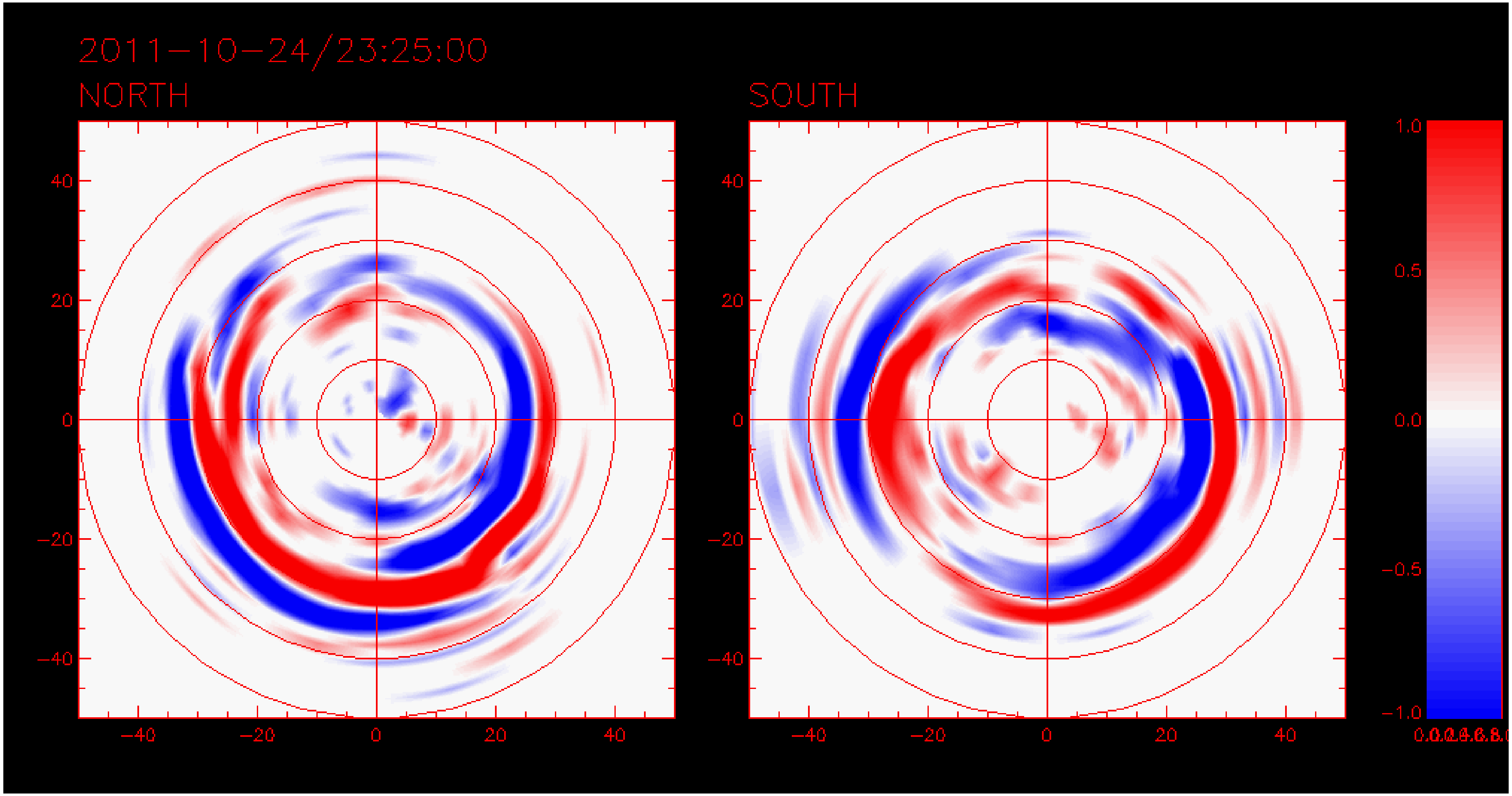
(3) There is not much difference between the relative contribution of the different systems to the ASY-H and to the ASY-D indices.

(4) The Region 1 FAC is the main contributor to the ASY-H and ASY-D indices during storm main phase, Region 2 FAC and partial ring current contributions are not negligible.

Since ASY indices contain mainly contributions from FACs, can they be used as a proxi for FAC variations during storm times?

Computation ASY indices using AMPERE data

http://ampere.jhuapl.edu/



Biot-Savart integration along IGRF field lines from ionosphere to equator.

No ionospheric curents, No magnetospheric closure currents

Comparison with real ground-based data

Disturbance field at the mid-latitude observatories positions
Diamonds - observations
Asterisks - AMPERE integration results
Red – northern hemisphere observatories; Blue - southern
The sign of dD is inversed for observatories in southern hemisphere