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

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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** computed 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].

Empirical 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]
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)
Main contributors: Partial RC and FACs (only 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.
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 proxie 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 currents, 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