GEM Summer Workshop, June 20, 2012

Empirical geomagnetic field modeling

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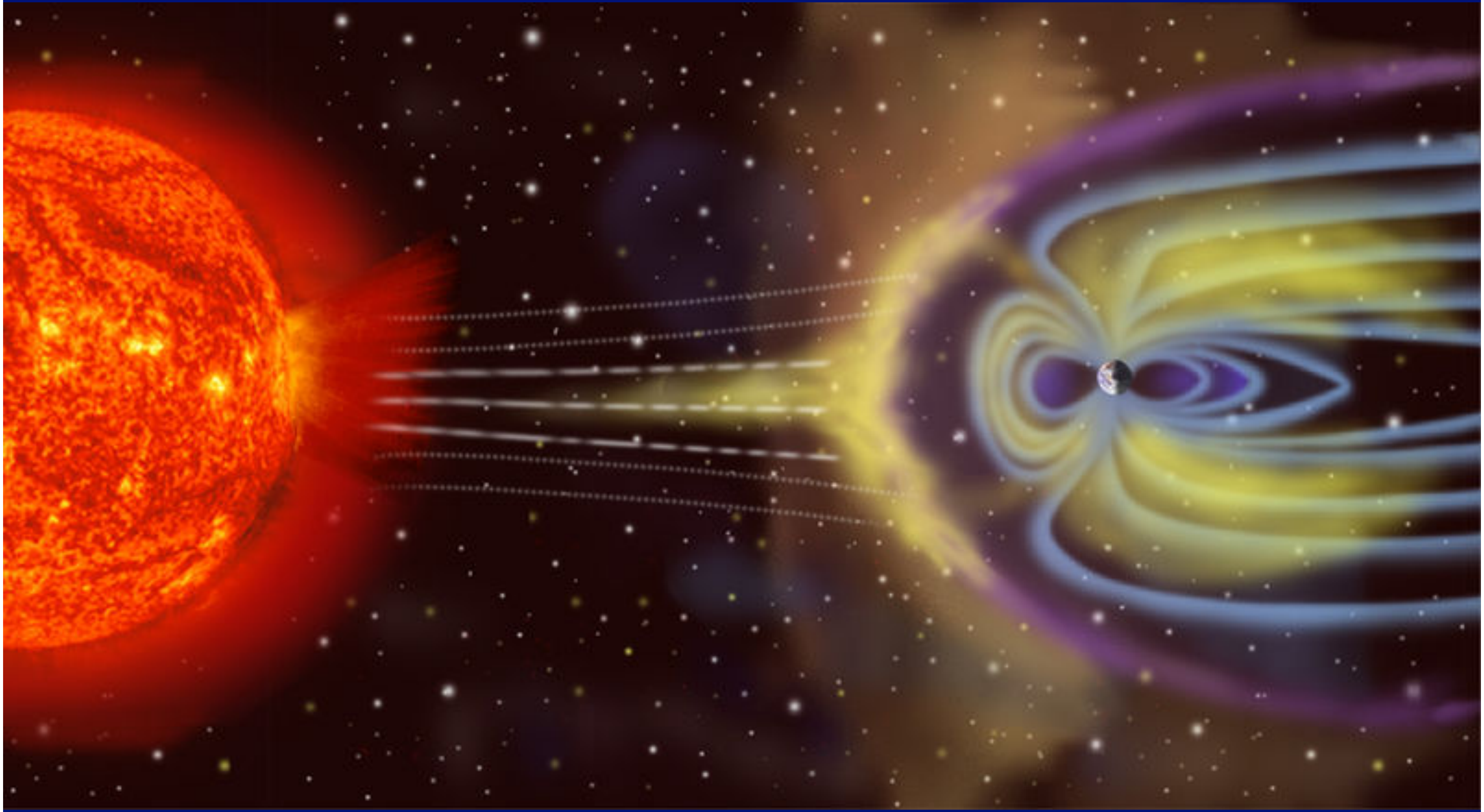
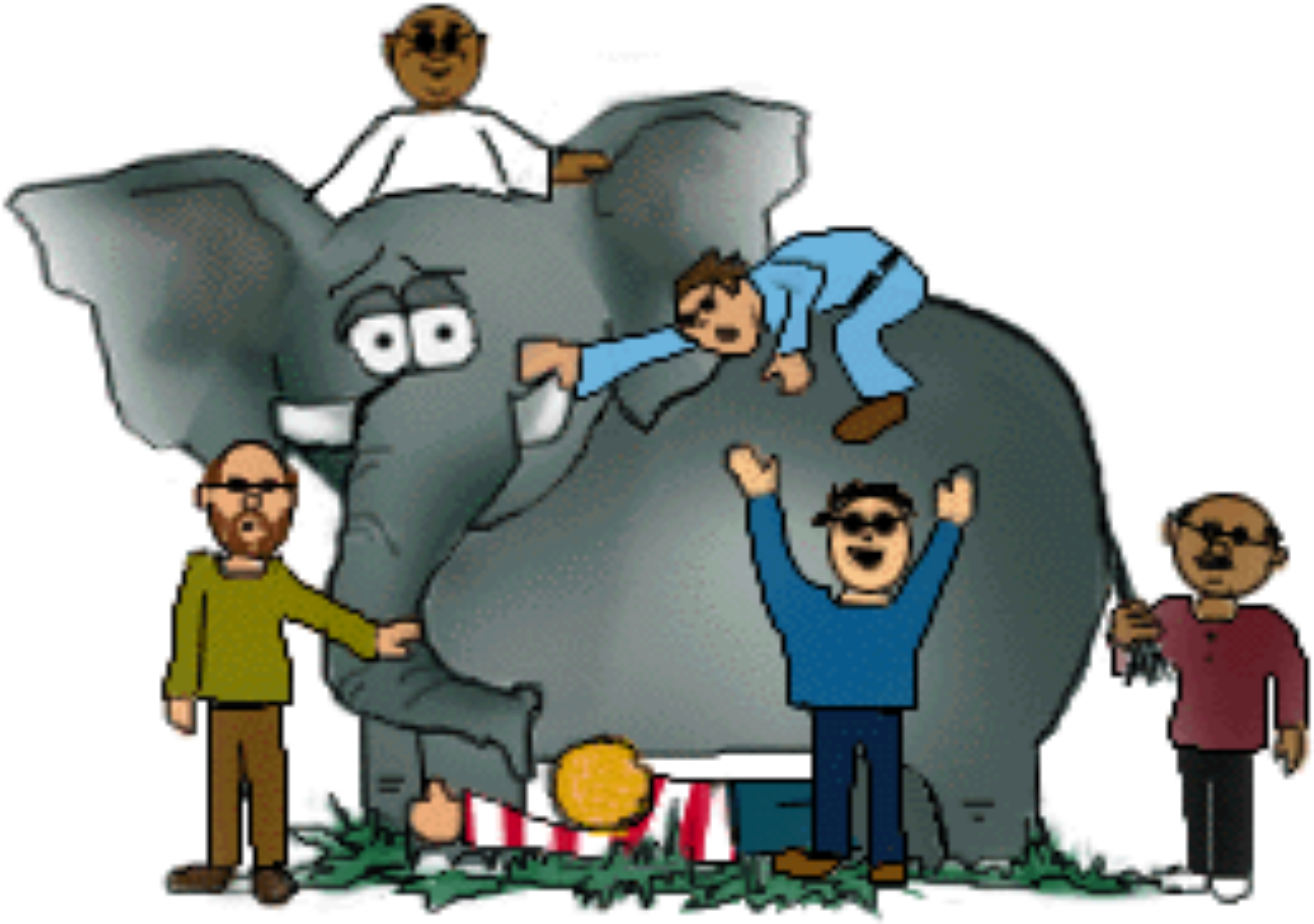
(JHU/APL)

In collaboration with **G. Stephens, A. Ukhorskiy, P. Brandt, B. Anderson, H. Korth, J. Vandegriff, and N. Tsyganenko**

Magnetosphere

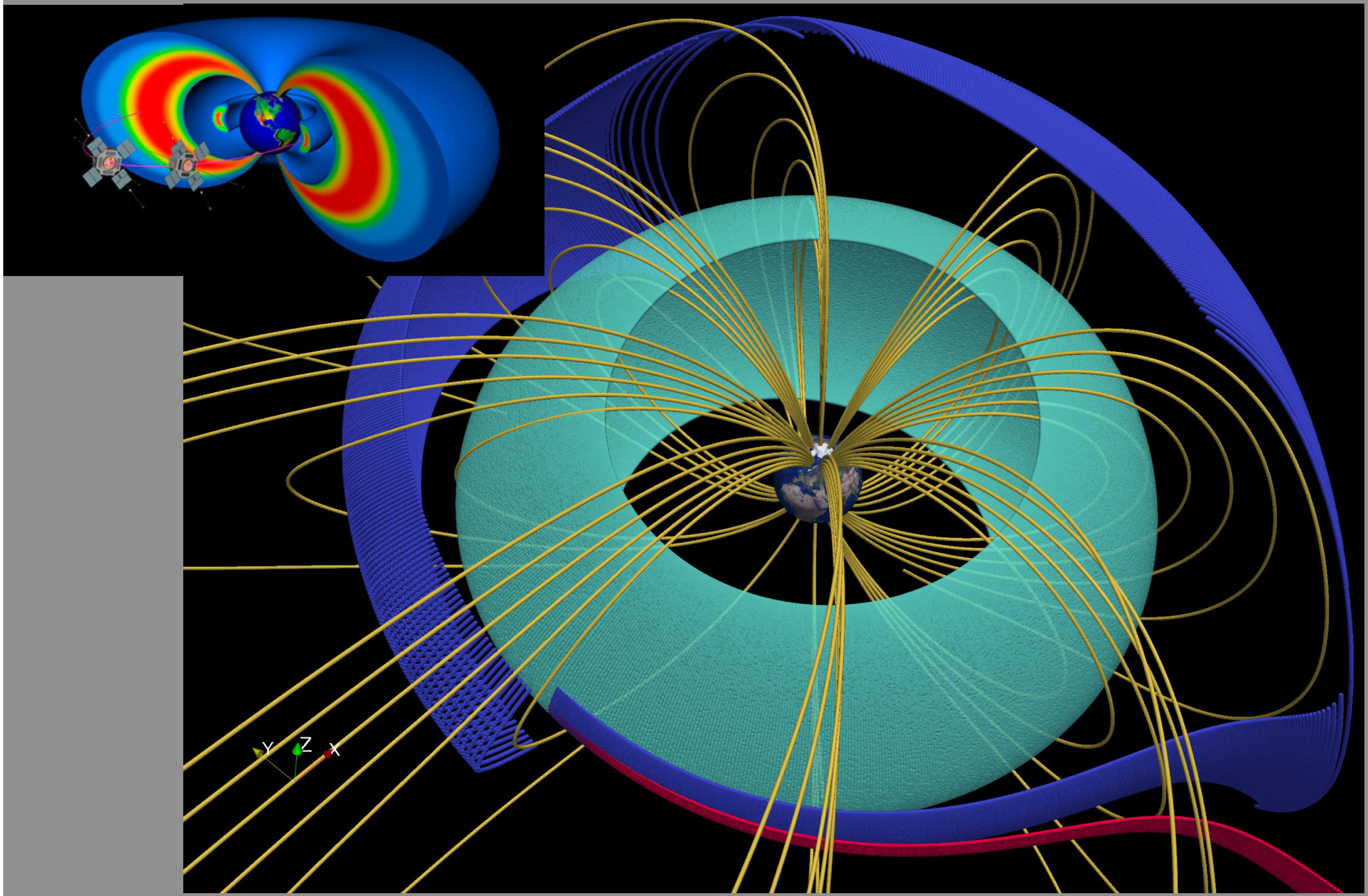


Earth’s magnetosphere - How to get its global picture?



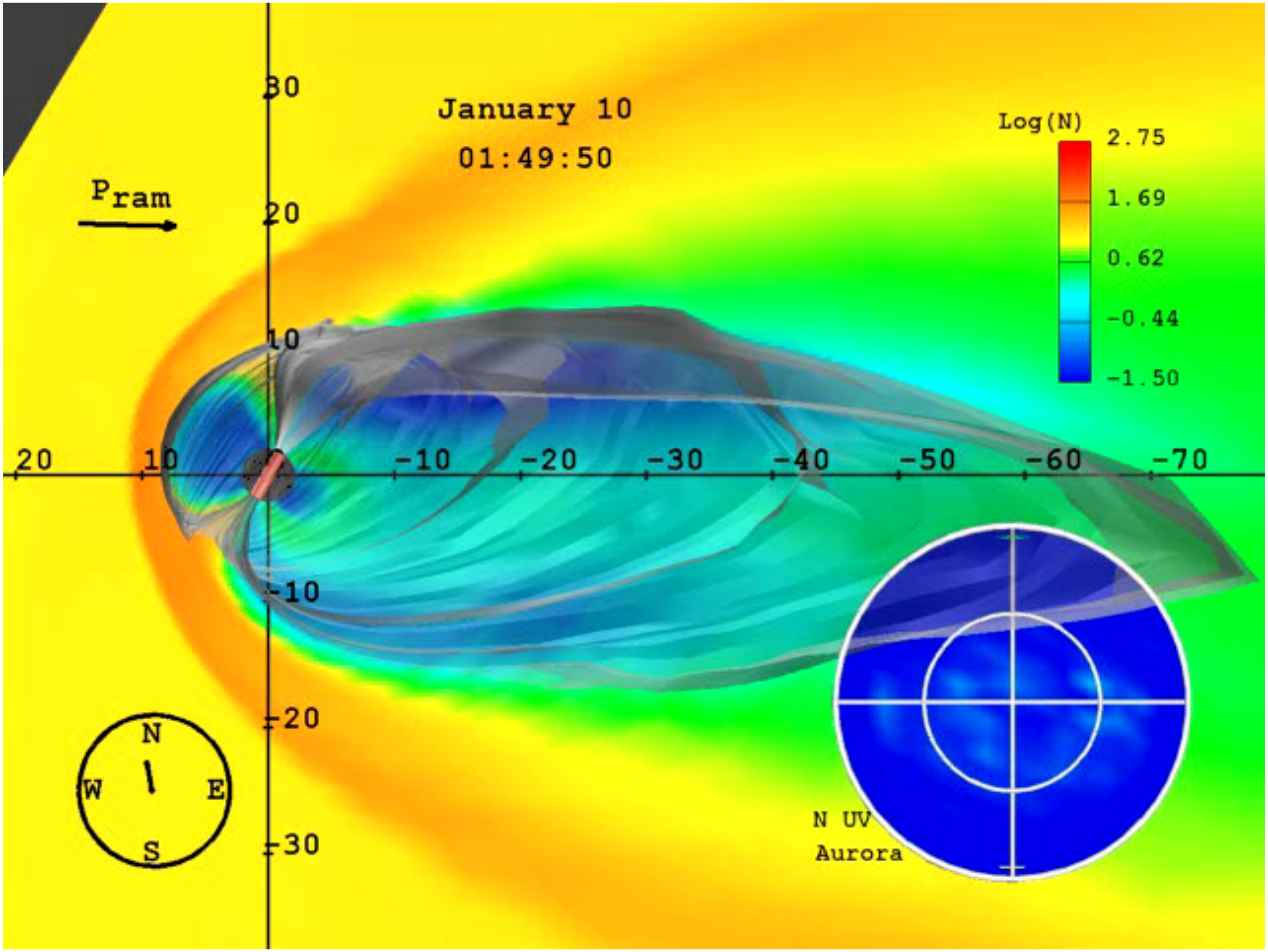
Courtesy David Stern

Space Weather/RBSP: Modern challenge for geomagnetic field modeling



Ukhorskiy et al. [2011]

http://www.bu.edu/cism/CISM_Thrusts/modelsandcoupling.html

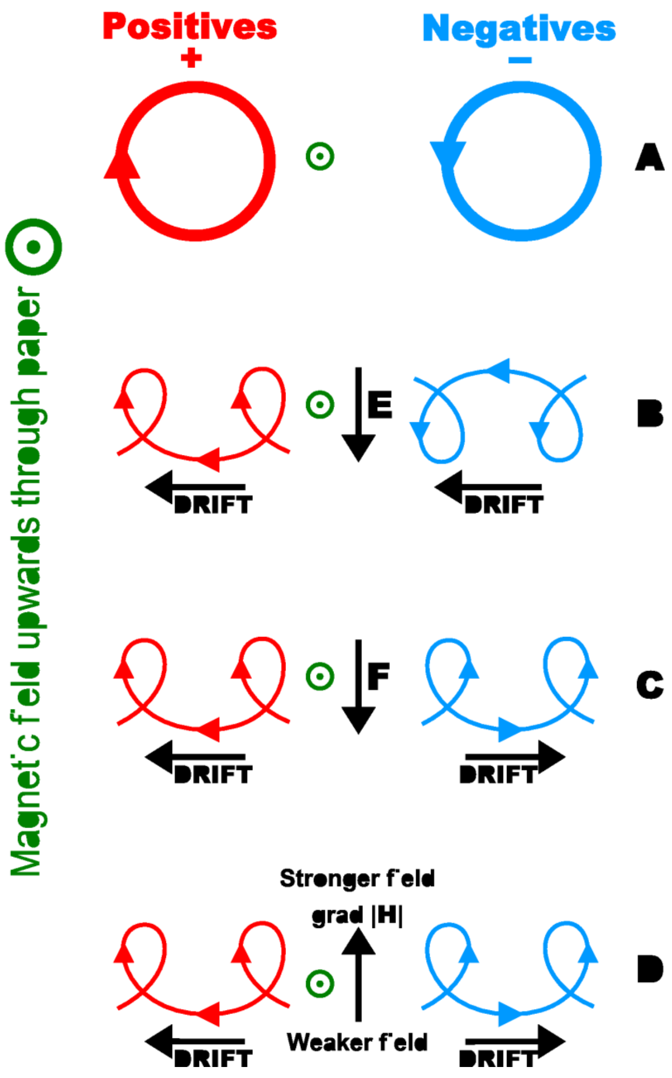


First-principles modeling limitations: MHD

Particle drifts: Curvature and gradient drifts are not described by a single-fluid MHD model

Wave-particle interactions: play very important role as a mechanism of the ring current buildup and decay

MHD equation of state (adiabatic) does not describe plasma kinetics of magnetic storms

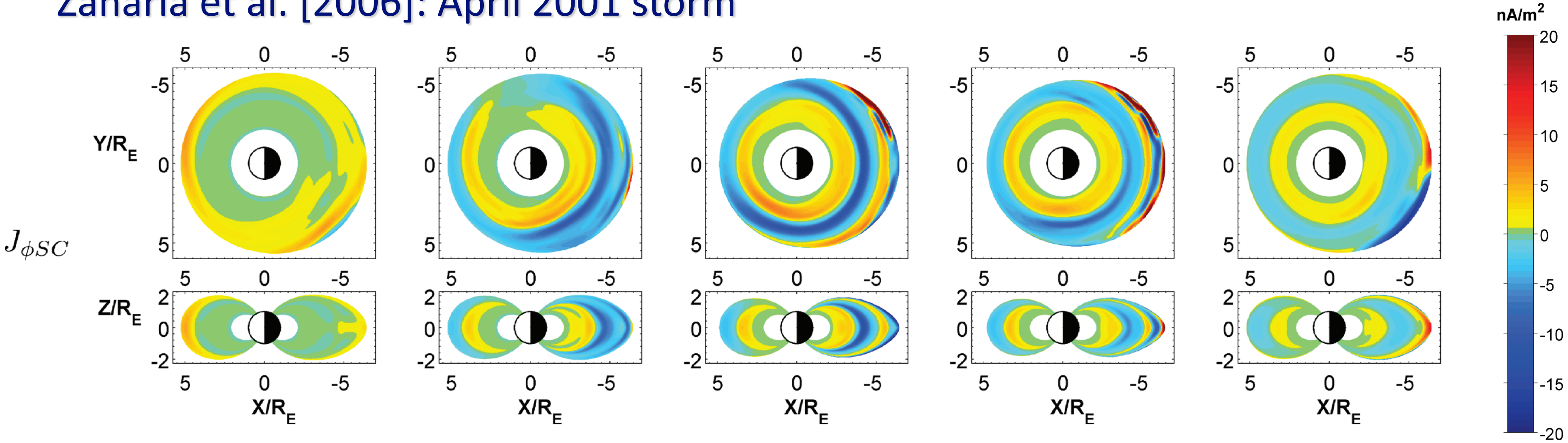


MHD models cannot fully describe the storm-time ring current

Kinetic ring current models

Wolf et al. [1983], Chen et al. [1994], Fok et al. [1995; 2001], Jordanova et al. [1996], Ridley and Liemohn [2002]

Zaharia et al. [2006]: April 2001 storm



Slow-flow approximation

Limited self-consistency

Boundary conditions (often geosynchronous)

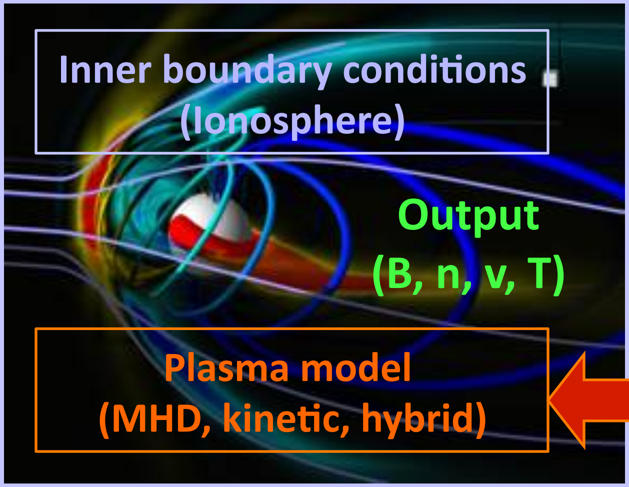
Coupled MHD-Ring current models: De Zeeuw et al. [2004], Toffoletto et al. [2004], Buzulukova et al. [2010], Hu et al. [2010] Zaharia et al [2010], Pembroke et al. [2012]

Is there at present a global first-principle code capable of describing the evolution of the storm-time magnetosphere?

First-principles and empirical approaches

First-principles approach

Solar wind input (B, n, v, T)



Inner boundary conditions (Ionosphere)

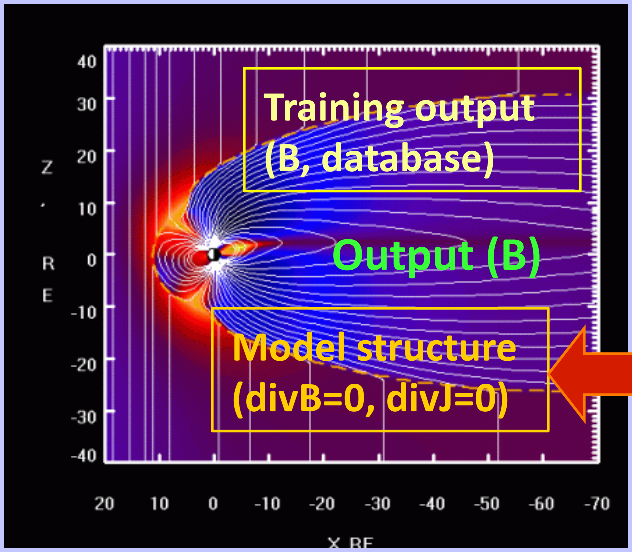
Output (B, n, v, T)

Plasma model (MHD, kinetic, hybrid)

Maxwell and Vlasov equations

Empirical approach

Solar wind input (B, n, v, P)



Training output (B, database)

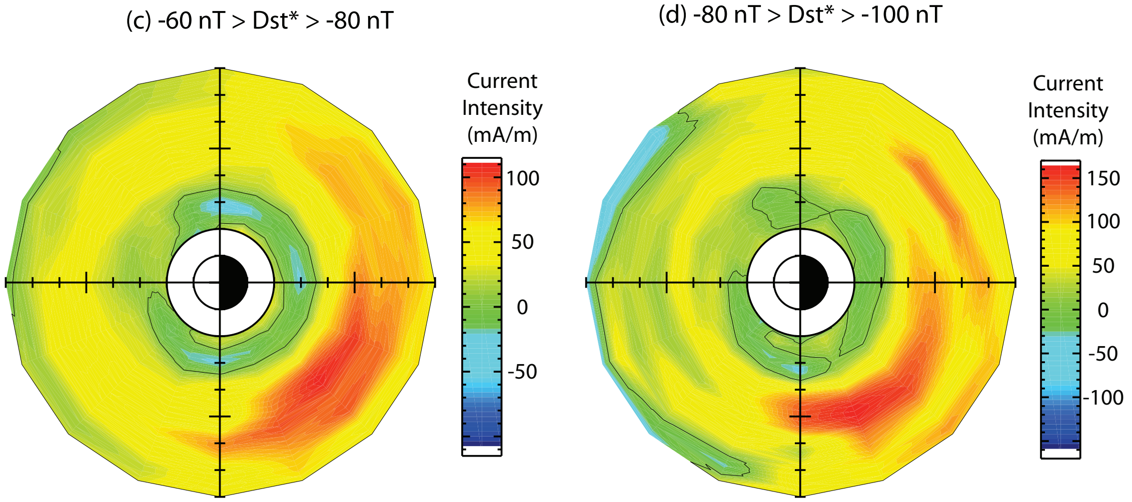
Output (B)

Model structure (divB=0, divJ=0)

Predefined modules or regular expansions

T≤05 and TS07D …Only Tsyganenko models?

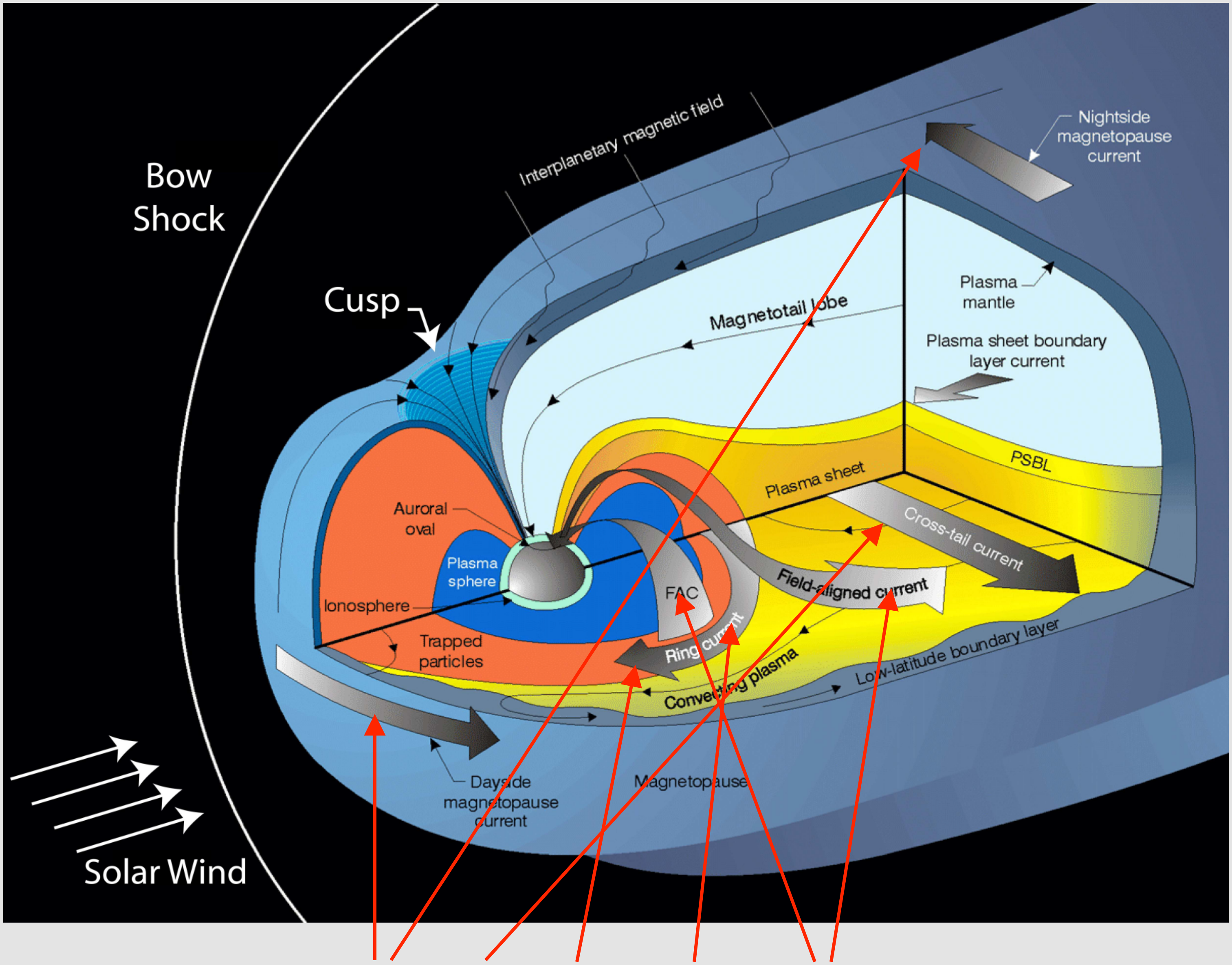
Earlier models: Mead and Fairfield [1975]; Olson and Pfitzer [1977]; Alexeev et al. [1996]
Recent contributions: Le et al. [2004]; Ganushkina et al. [2004]; Zaharia et al. [2005]; Yang et al. [2012]



Equatorial ring current distribution for different activity levels [Le et al., 2004]

Tsyganenko-class models are freely available as open source codes

Classical empirical geomagnetic field models



TS05 model: $\mathbf{B}_E = \mathbf{B}_{CF} + \mathbf{B}_T + \mathbf{B}_{SRC} + \mathbf{B}_{PRC} + \mathbf{B}_{FAC} + \mathbf{B}_{INT}$

TS05 model: Structure

Tail modules

$$\mathbf{B}_T = t_1 \mathbf{B}_T^{(1)} + t_2 \mathbf{B}_T^{(2)}$$

$$A_\phi = \rho \sum_{i=1}^{5} f_i \frac{t_i \sqrt{1 - t_i^2}}{S_i^{(1)} S_i^{(2)}} \qquad t_i = \frac{2b_i}{S_i^{(1)} S_i^{(2)}} \qquad \zeta = \sqrt{z^2 + D^2}$$

$$S_i^{(1)} = \sqrt{(\rho + b_i)^2 + (\zeta + c_i)^2} \qquad S_i^{(2)} = \sqrt{(\rho - b_i)^2 + (\zeta + c_i)^2}$$

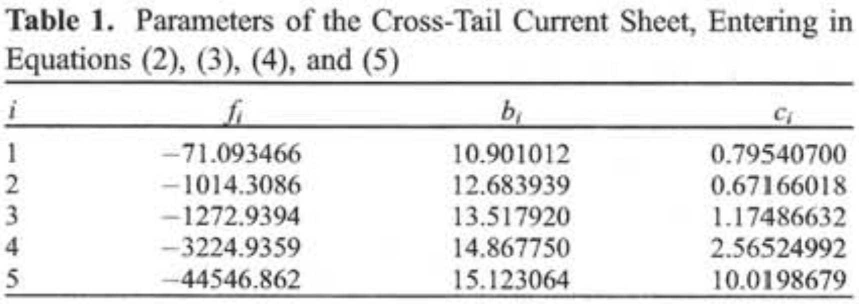
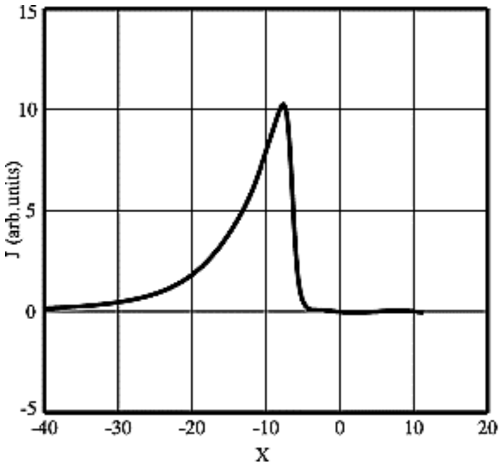


Table 1. Parameters of the Cross-Tail Current Sheet, Entering in Equations (2), (3), (4), and (5)

i	f_i	b_i	c_i
1	−71.093466	10.901012	0.79540700
2	−1014.3086	12.683939	0.67166018
3	−1272.9394	13.517920	1.17486632
4	−3224.9359	14.867750	2.56524992
5	−44546.862	15.123064	10.0198679



Modules are custom-made, sophisticated, but hard to interpret and generalize (to further improve spatial resolution)

TS05 model: Input and data binning

Tail modules $t_1 = t_1^{(0)} + t_1^{(1)} W_{t1} / \sqrt{1 + \left(W_{t1} / W_{t1c} \right)^2} + t_1^{(2)} \left(P_d / P_{d0} \right)^{\alpha 1}$

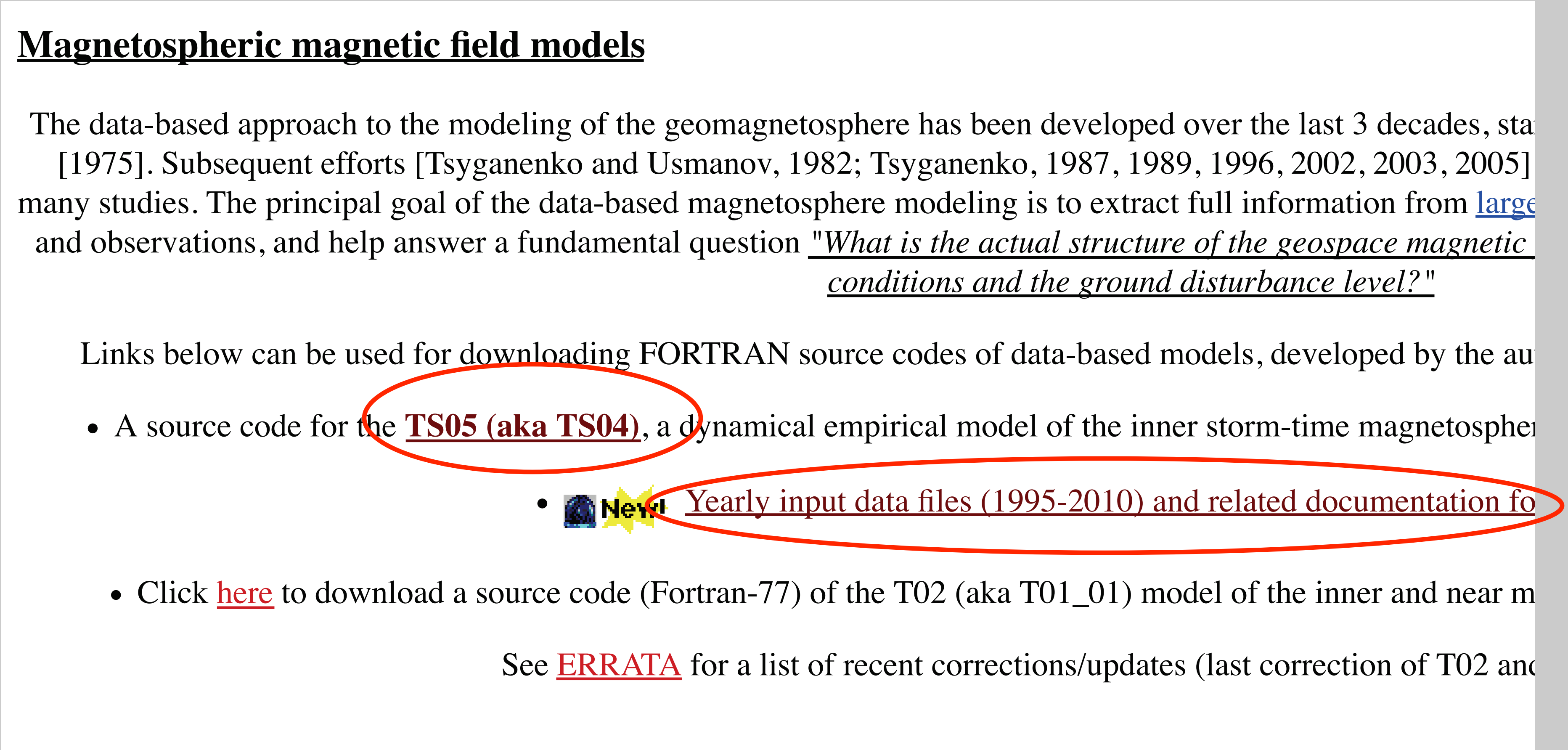
$$W(t) = W_0 + \int_0^t S(\tau) \exp\left[r(\tau - t) \right] d\tau \qquad \frac{dW}{dt} = S - r\left(W - W_0 \right)$$

$$S = a N^{\lambda} V^{\beta} B_s^{\gamma}$$

TS05 binning is "climatological" (several universal response functions). Yet, it is quite sophisticated and it may take into account important solar wind and IMF features.

TS05 model usage

Model website: http://geo.phys.spbu.ru/~tsyganenko/modeling.html



Magnetospheric magnetic field models

The data-based approach to the modeling of the geomagnetosphere has been developed over the last 3 decades, sta
[1975]. Subsequent efforts [Tsyganenko and Usmanov, 1982; Tsyganenko, 1987, 1989, 1996, 2002, 2003, 2005]
many studies. The principal goal of the data-based magnetosphere modeling is to extract full information from large
and observations, and help answer a fundamental question *"What is the actual structure of the geospace magnetic*
conditions and the ground disturbance level?"

Links below can be used for downloading FORTRAN source codes of data-based models, developed by the au

- A source code for the **TS05 (aka TS04)**, a dynamical empirical model of the inner storm-time magnetosphe
  - New! Yearly input data files (1995-2010) and related documentation fo
- Click here to download a source code (Fortran-77) of the T02 (aka T01_01) model of the inner and near m

See ERRATA for a list of recent corrections/updates (last correction of T02 and

Transition to TS07D model: Using huge amount of data to increase resolution and remove model constraints

Data from GOES 12, Imp-8, Polar, Geotail, and Cluster

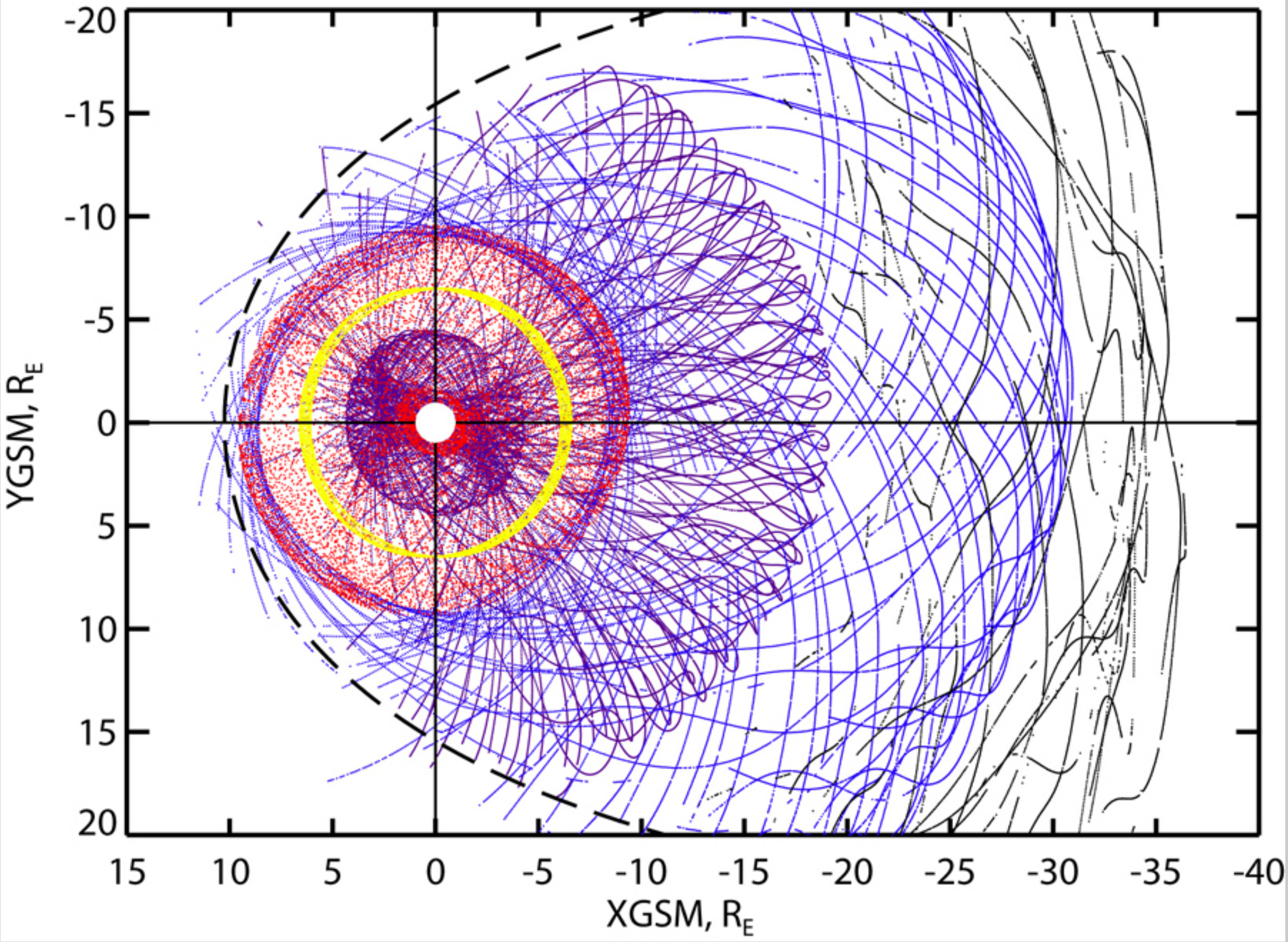
POLAR (red)

GOES-12 (yellow)

Cluster (magenta)

Geotail (blue)

IMP 8 (black)



TS07 model : Spatial structure

$$\mathbf{B}_E = \mathbf{B}_{CF} + \underbrace{\mathbf{B}_T + \mathbf{B}_{SRC} + \mathbf{B}_{PRC}} + \mathbf{B}_{FAC} + \mathbf{B}_{INT}$$

$$\boxed{\mathbf{B}_T = \sum_{n=1}^{N} t_n^{(s)} \mathbf{B}_{Tn}^{(s)} + \sum_{m=1}^{M} \sum_{n=1}^{N} t_{mn}^{(o)} \mathbf{B}_{Tmn}^{(o)} + \sum_{m=1}^{M} \sum_{n=1}^{N} t_{mn}^{(e)} \mathbf{B}_{Tmn}^{(e)}}$$

$$t = t^{(0)} + t^{(1)} \sqrt{P_d},$$

Sample basis function

$$\mathbf{B}_{Tmn}^{(o)} = k_n J_m (k_n \rho) \exp(-k_n \zeta) \left[\cos(m\phi) - \frac{k_n D}{m\zeta} \frac{\partial D}{\partial \phi} \sin(m\phi) \right]$$

$$k_n = n / \rho_0$$

$$\zeta = \sqrt{z^2 + D^2}$$

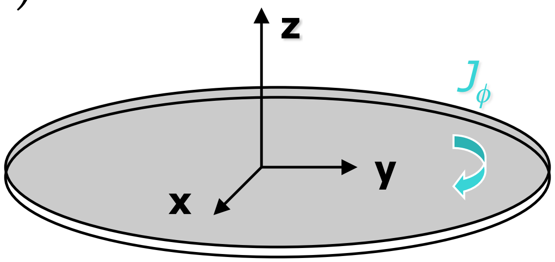
Basic idea: Magnetic field of an axisymmetric current disc [*Tsyganenko*, 1989]

Ampere's equation

$$\frac{\partial}{\partial \rho} \left(\frac{1}{\rho} \frac{\partial}{\partial \rho} (\rho A_\phi) \right) + \frac{\partial^2 A_\phi}{\partial z^2} = J_\phi(\rho) \delta(z)$$

Solution

$$A_\phi(\rho, z) = \int_0^\infty C(k) \exp(-k|z|) J_1(k\rho) \sqrt{k}\, dk$$



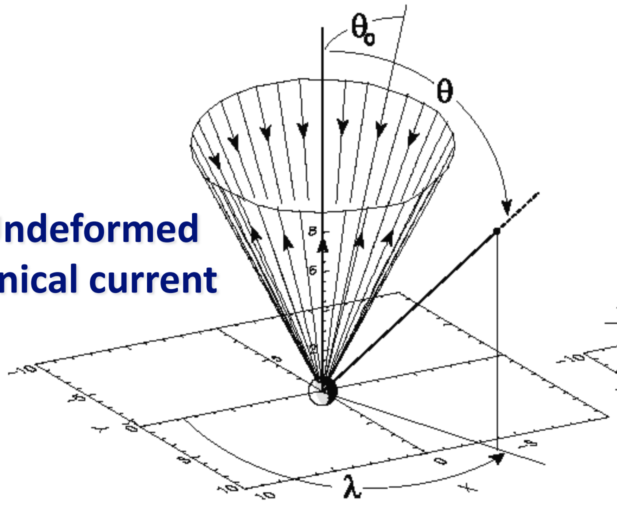
Finite sum form:

$$A_\phi(\rho, z) = \sum_{m=0}^{N} C_m \exp(-k_m |z|) J_1(k_m \rho), \qquad k_m = k_0 + m\Delta$$

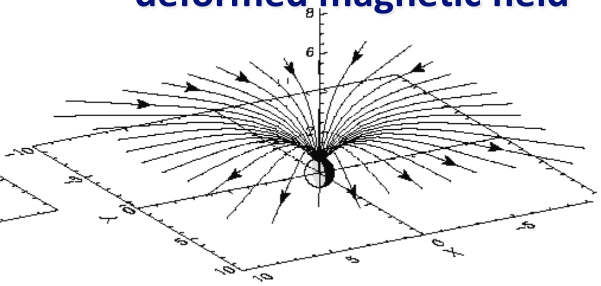
Modeling field-aligned currents

Main module [Tsyganenko, 2002]

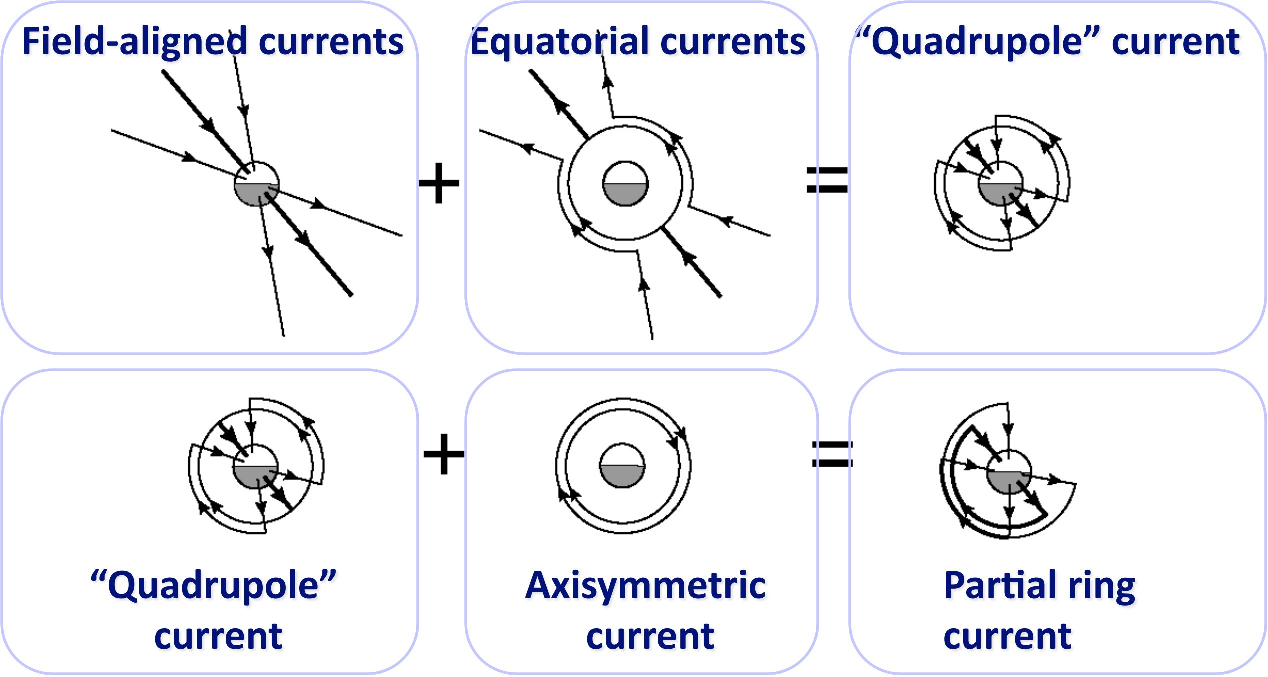
Undeformed conical current



Currents corresponding to deformed magnetic field

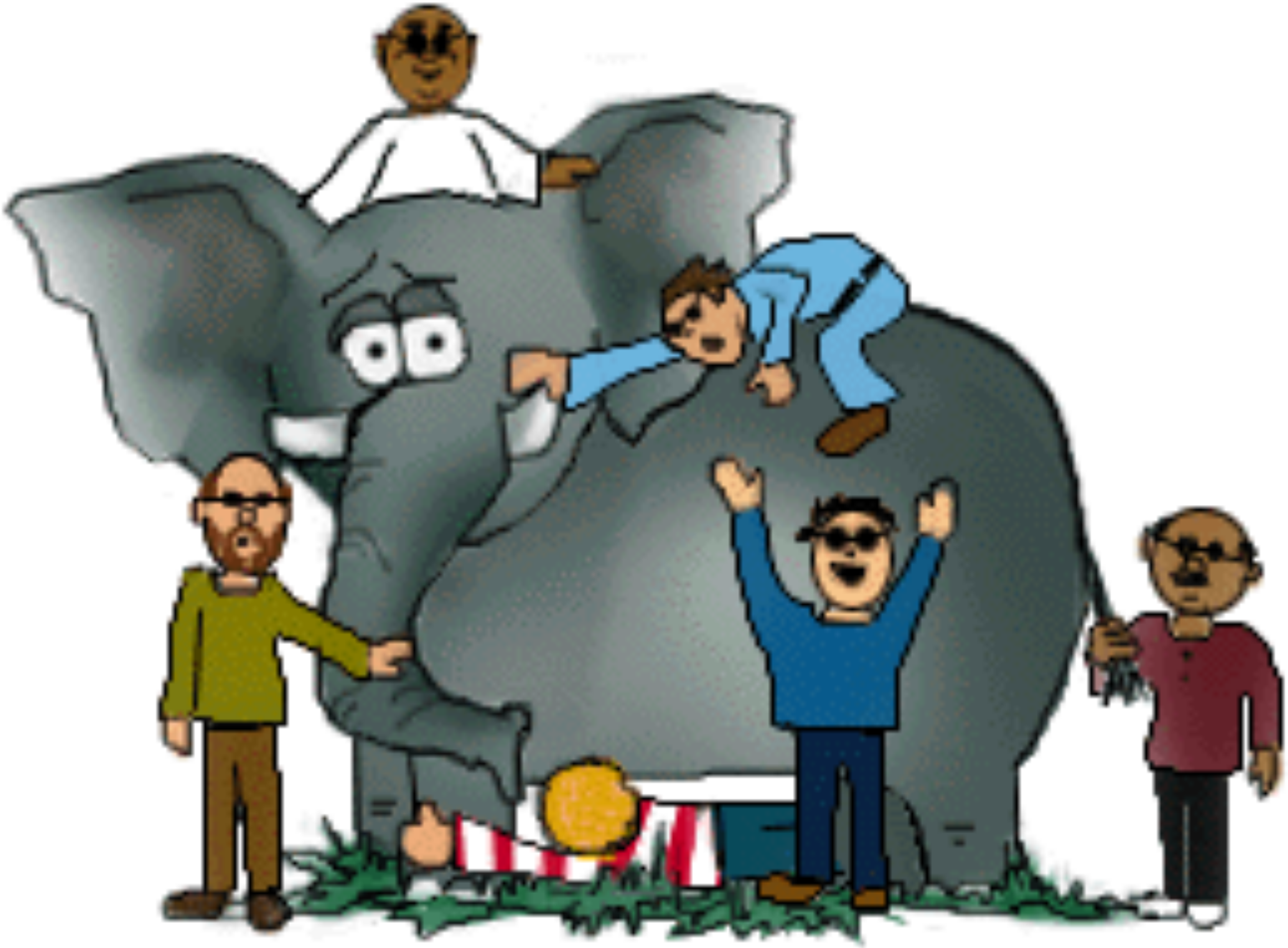


Coupling with equatorial currents



Field-aligned currents + Equatorial currents = “Quadrupole” current

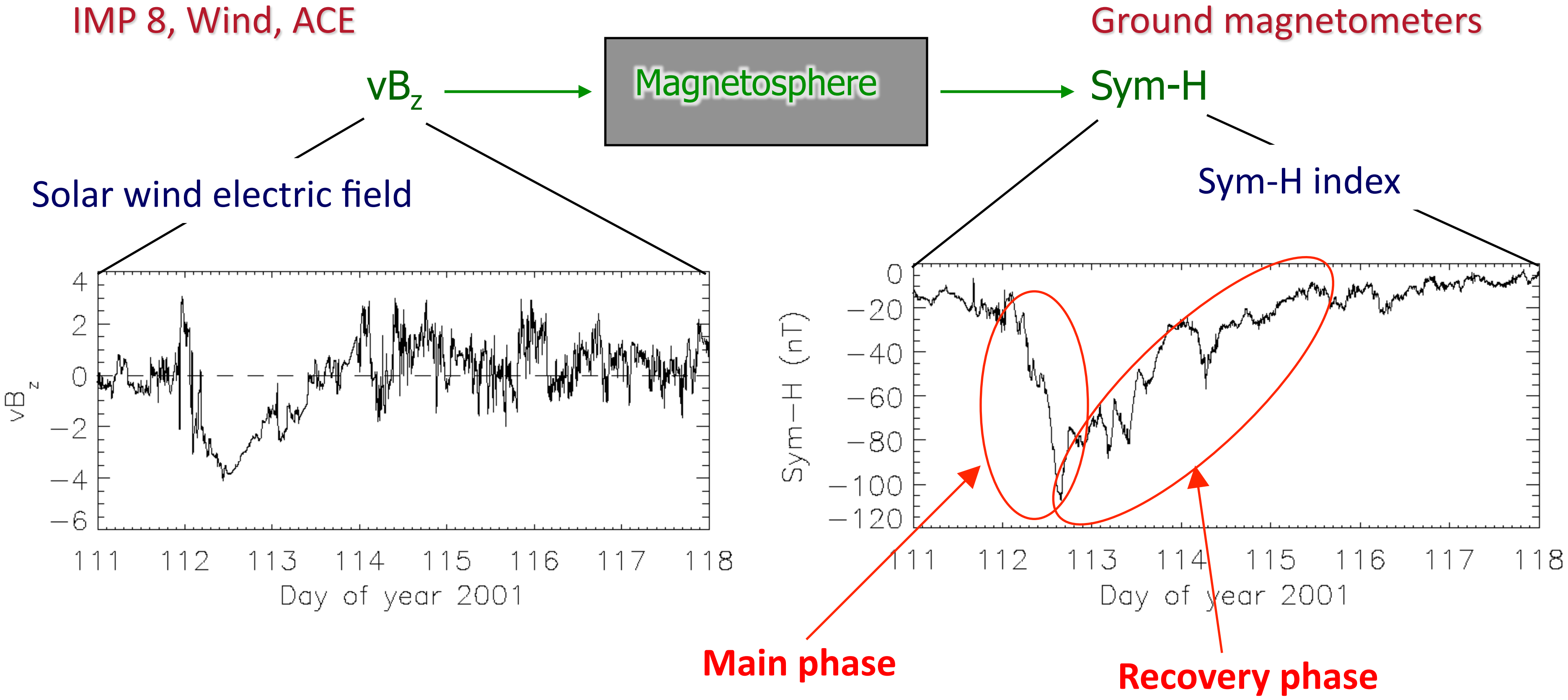
“Quadrupole” current + Axisymmetric current = Partial ring current



It is moving!

TS07D: Dynamical system approach to data mining

Magnetosphere as a black box:



IMP 8, Wind, ACE

vB_z → Magnetosphere → Sym-H

Ground magnetometers

Solar wind electric field

Sym-H index

Main phase

Recovery phase

Burton et al. [1975]: $F\left(vB_z, Sym-H, d\left(Sym-H\right)/dt\right)=0$

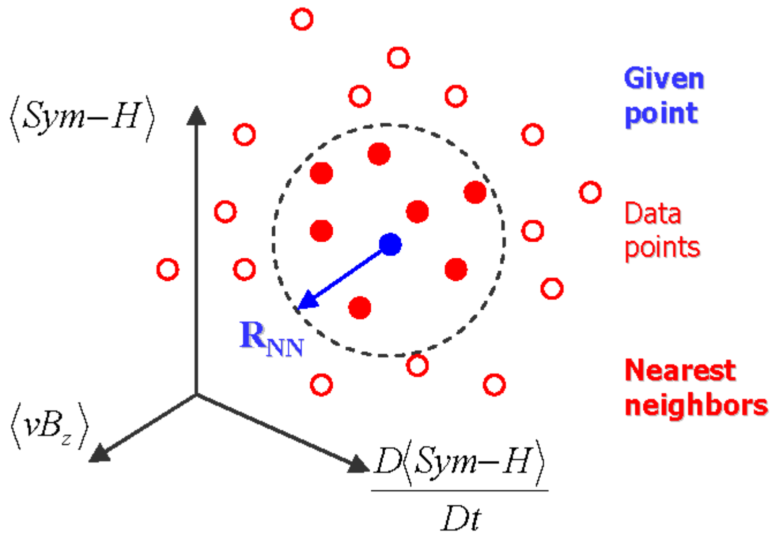
TS07D: Nearest neighbor method

A small subset of the whole database is used to fit the model with data at the time of interest. It consists of points that neighbor the magnetosphere at that time in its state space.

$$\langle vB_z\rangle \propto \int_{-T/4}^{T/4} vB_z \cos(\pi\tau/T)\,d\tau$$

$$\langle Sym-H\rangle \propto \int_{-T/4}^{T/4} Sym-H(t+\tau)\cos(\pi\tau/T)\,d\tau$$

$$\frac{D\langle Sym-H\rangle}{Dt} \propto \int_{-T/4}^{T/4} Sym-H(t+\tau)\sin(2\pi\tau/T)\,d\tau$$



T/4=6 hours – we only consider storm scales

Global parameter state space of the storm-time magnetosphere

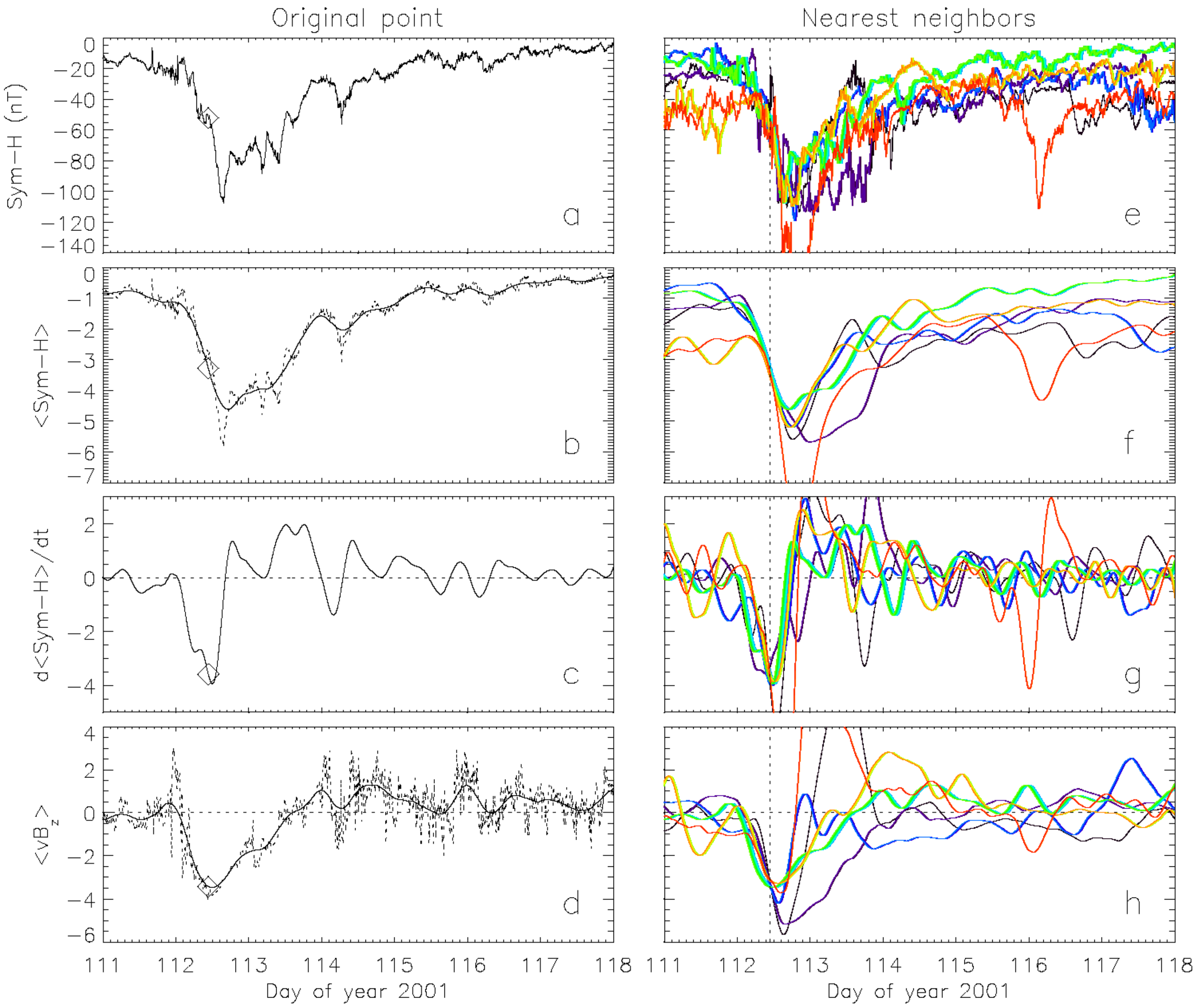
$$\mathbf{G} = \left(\frac{\langle vB_z\rangle}{\sigma(\langle vB_z\rangle)}, \frac{\langle Sym-H\rangle}{\sigma(\langle Sym-H\rangle)}, \frac{D\langle Sym-H\rangle/Dt}{\sigma(D\langle Sym-H\rangle/Dt)}\right)$$

$$\boxed{R = \left|\mathbf{G}_{NN}^{(i)} - \mathbf{G}\right| < R_{NN}}$$

$\mathbf{G}_{NN}^{(i)}$ – nearest neighbors

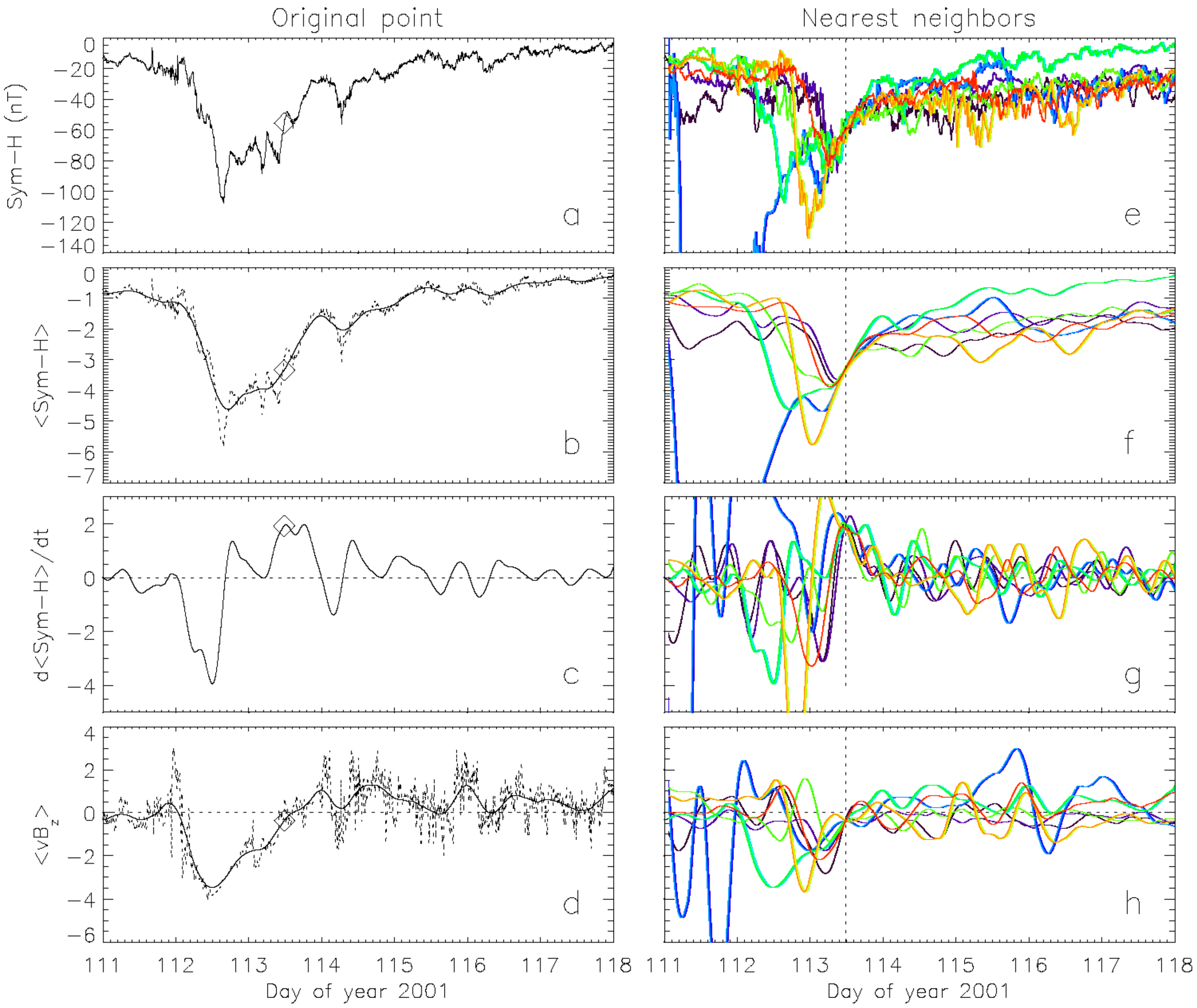
NN technique: April 2001 storm

Sitnov et al. [2008]

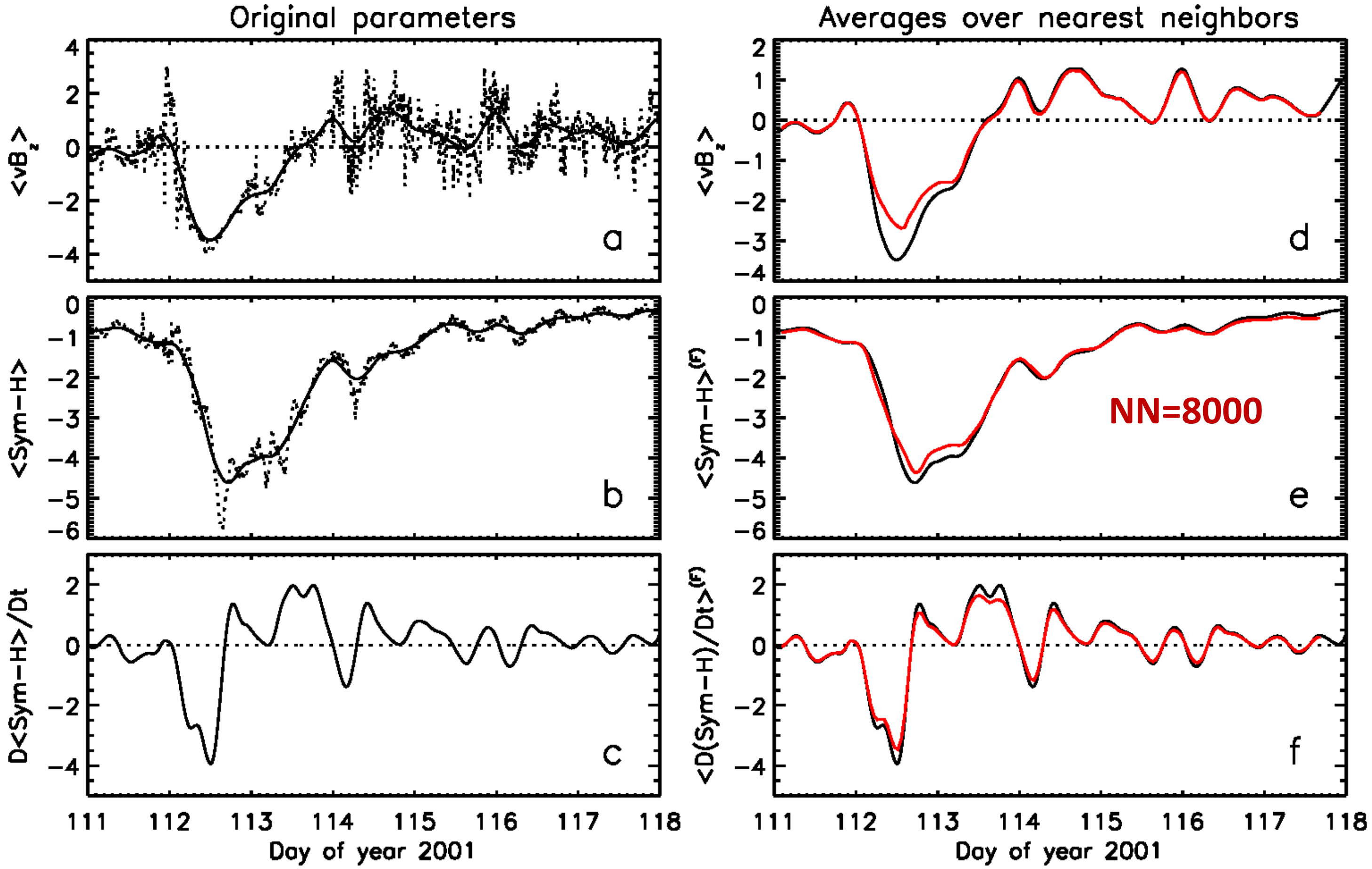


NN technique: April 2001 storm

Sitnov et al. [2008]



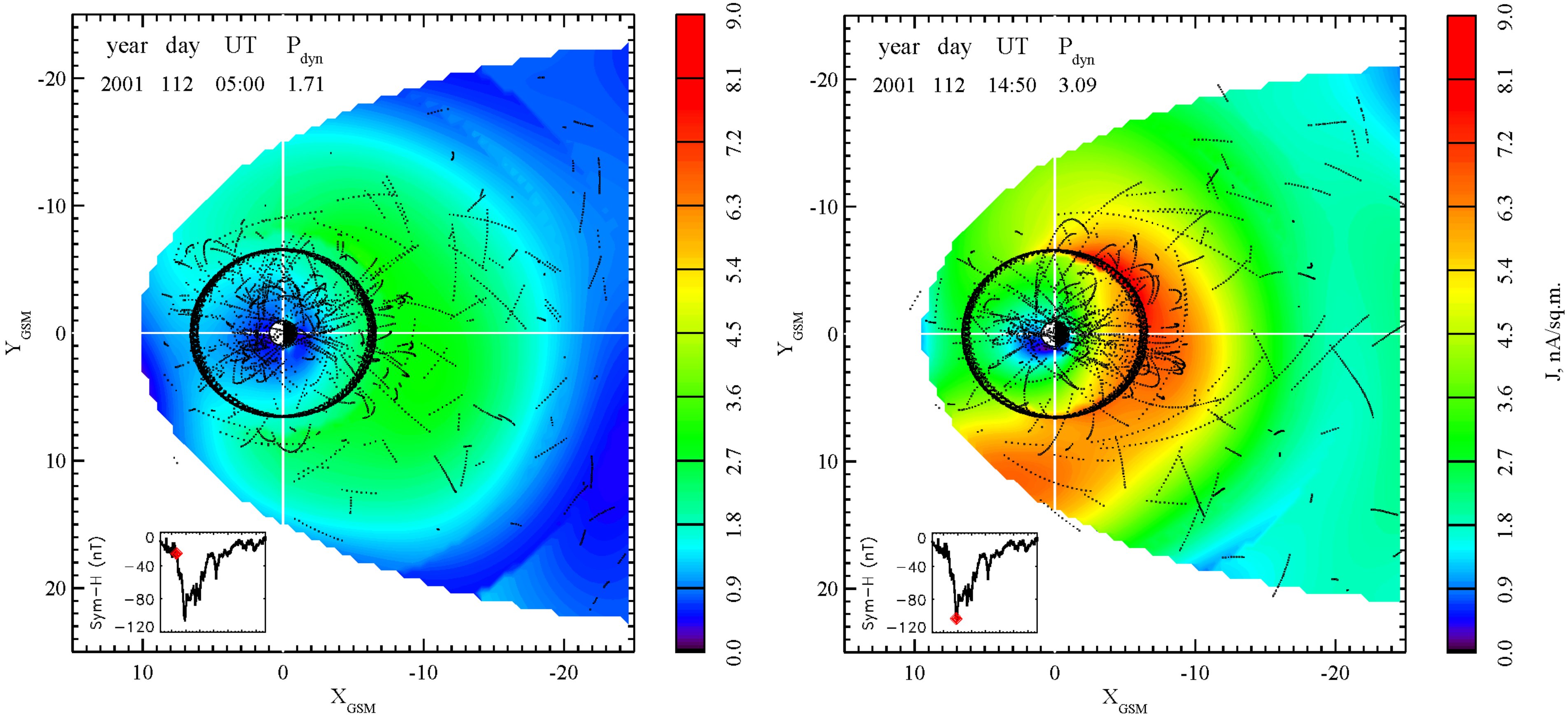
Nearest neighbor selectivity


Original parameters

Averages over nearest neighbors

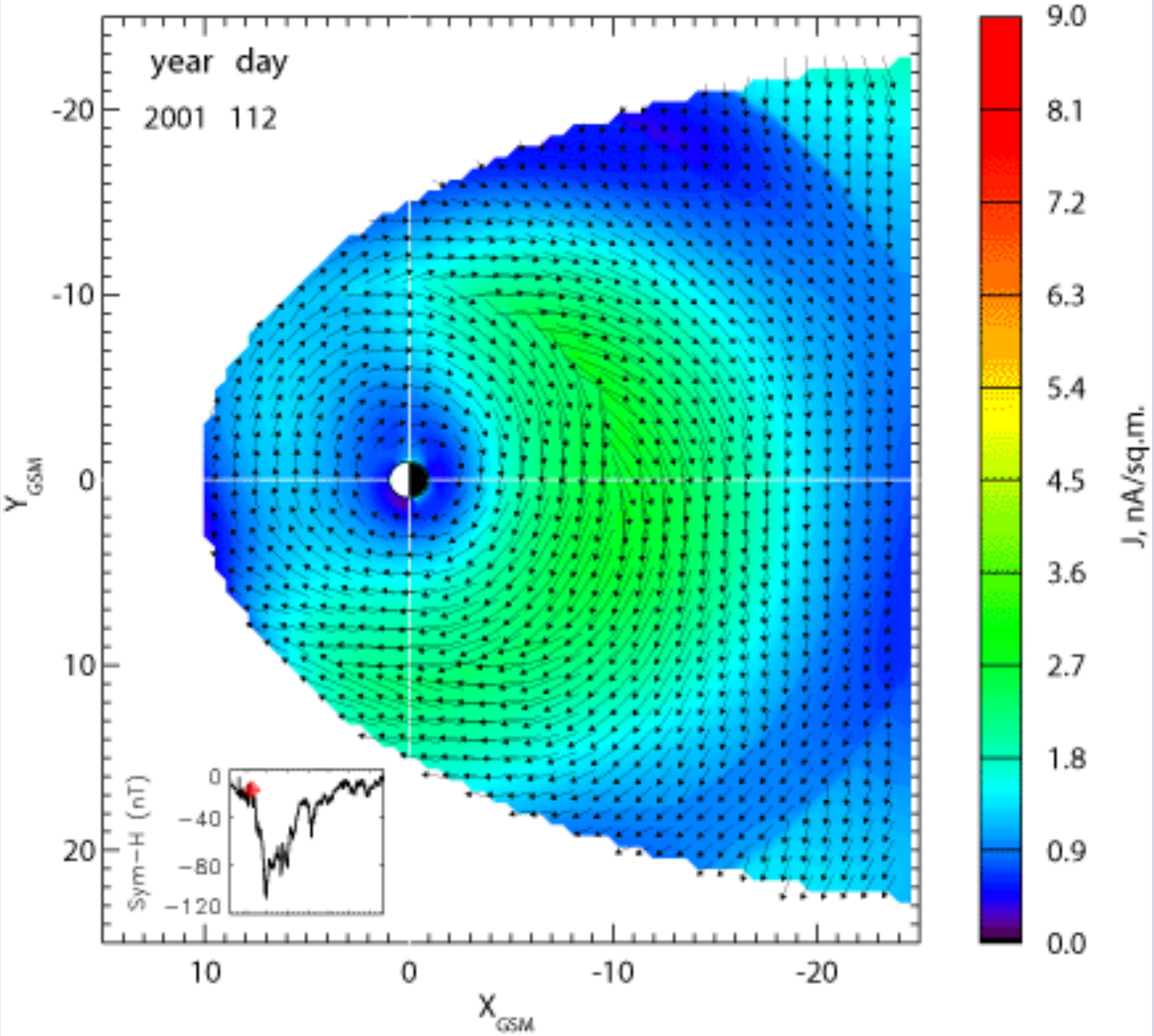
NN algorithm provides a balance between earlier statistical models like T89, 96, 05 (NN=N$_{database}$~10^{6}) and event oriented models (NN<~10).

Instantaneous subsets of magnetic field data



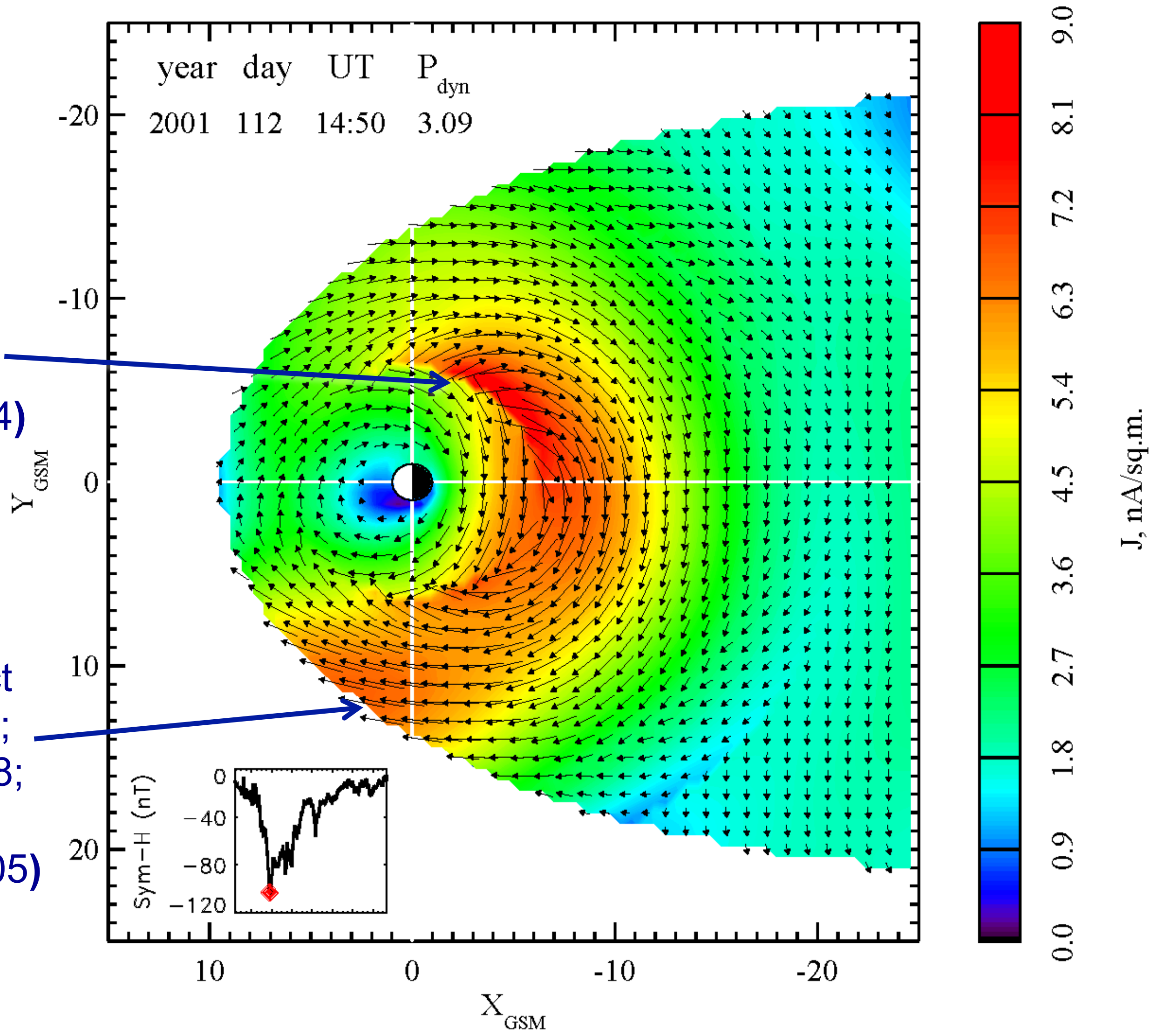
TS07D has 5 global parameters in total: <Sym-H>,D<Sym-H>/Dt, $<vB_z>$ plus P_{dyn} and tilt angle

CME-driven storm: April 21-23, 2001



http://geomag_field.jhuapl.edu/model/

Hook-shaped current



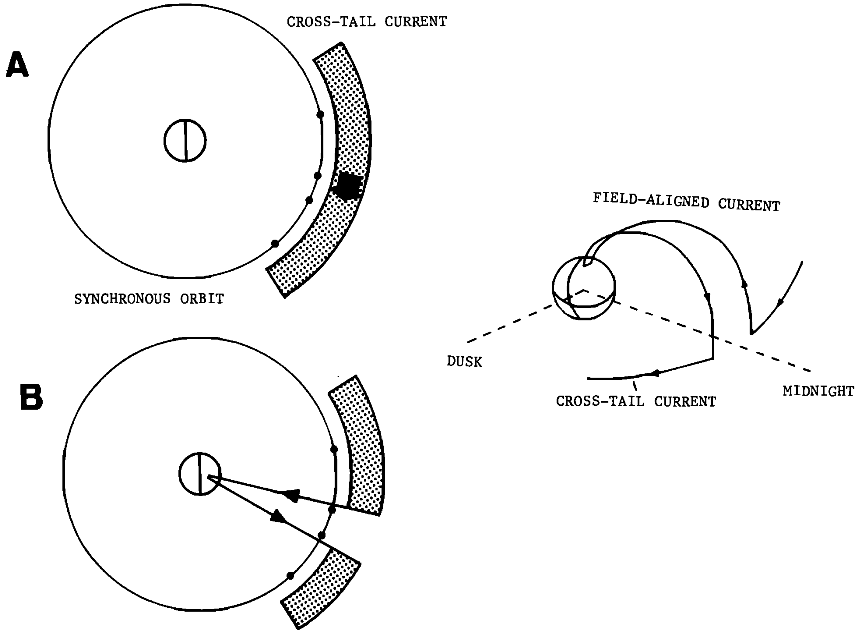
Postmidnight current intensification (Brandt et al., 2002; Ebihara and Fok, 2004)

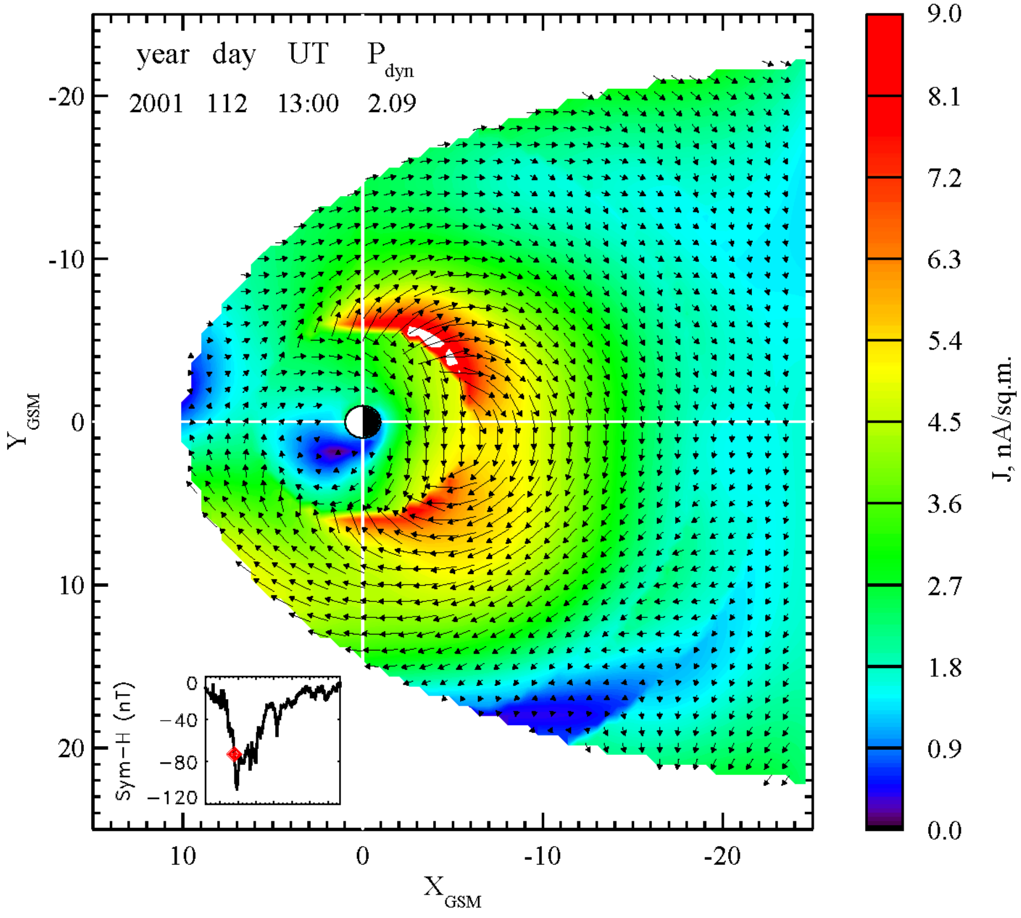
Dayside flow-out effect (Takahashi et al.,1990; Ebihara and Ejiri, 1998; Liemohn et al.1999; Keika et al., 2004, 2005)

In TS07D tail and ring currents constitute the united current system and they differ only by their closure paths (through the ionosphere or the magnetopause)

Ring current bifurcation effect

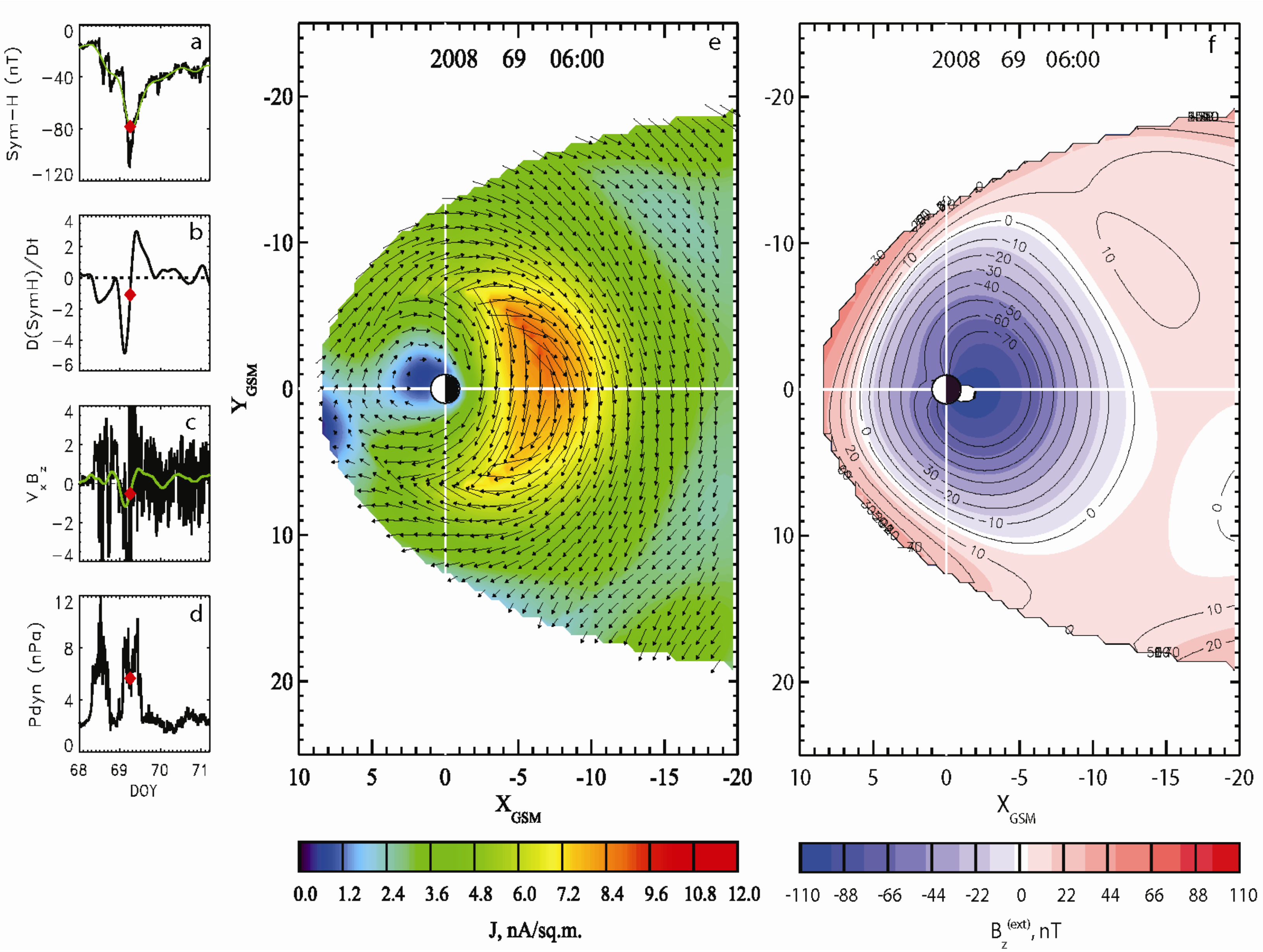
Nagai [1982]



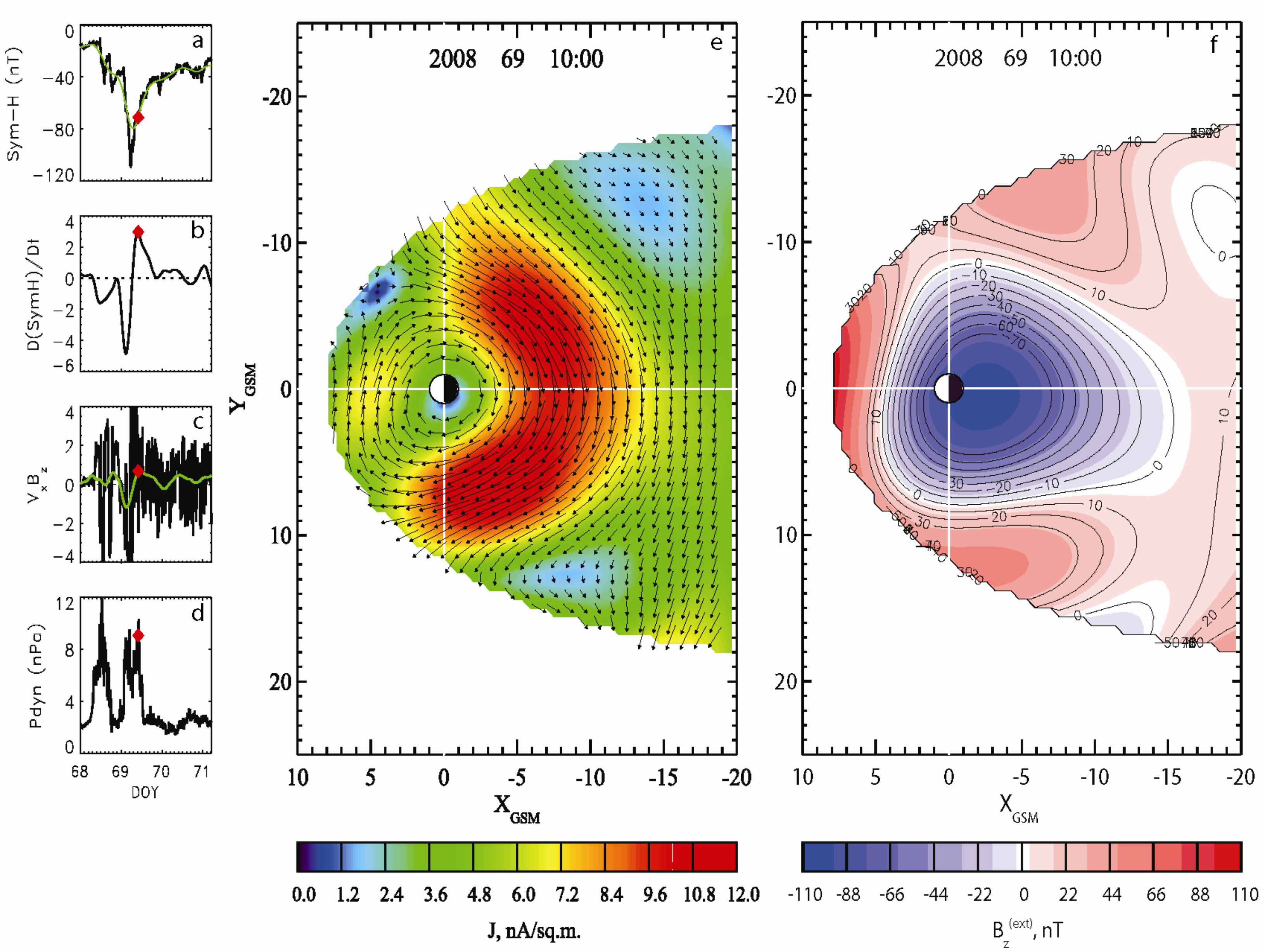


TS07D captures integrated (storm-scale) effects of substorms

March 8-11, 2008 CIR-driven storm: Main phase

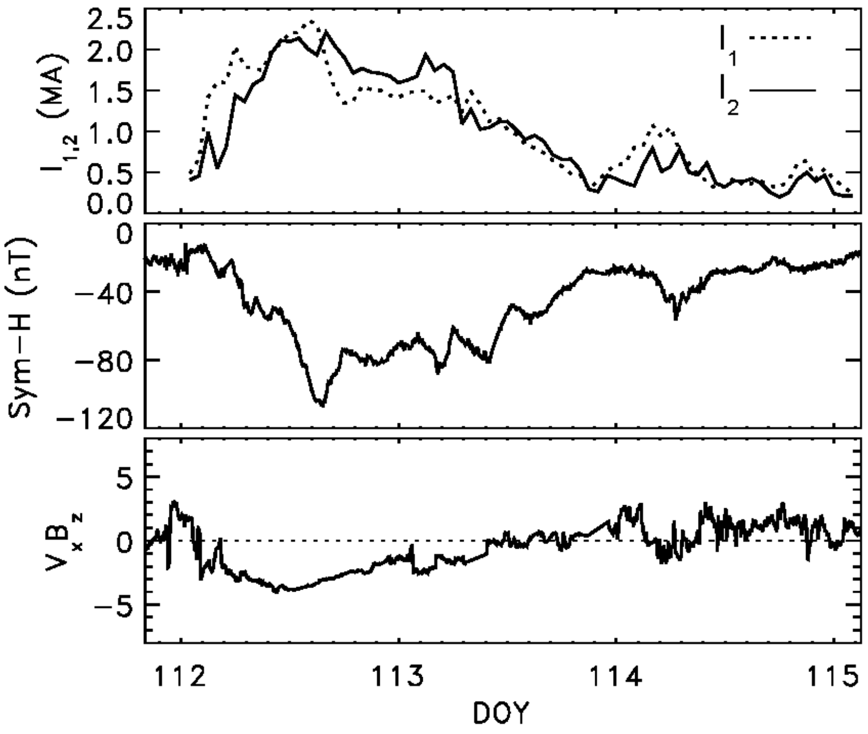


March 8-11, 2008 CIR-driven storm: Recovery phase

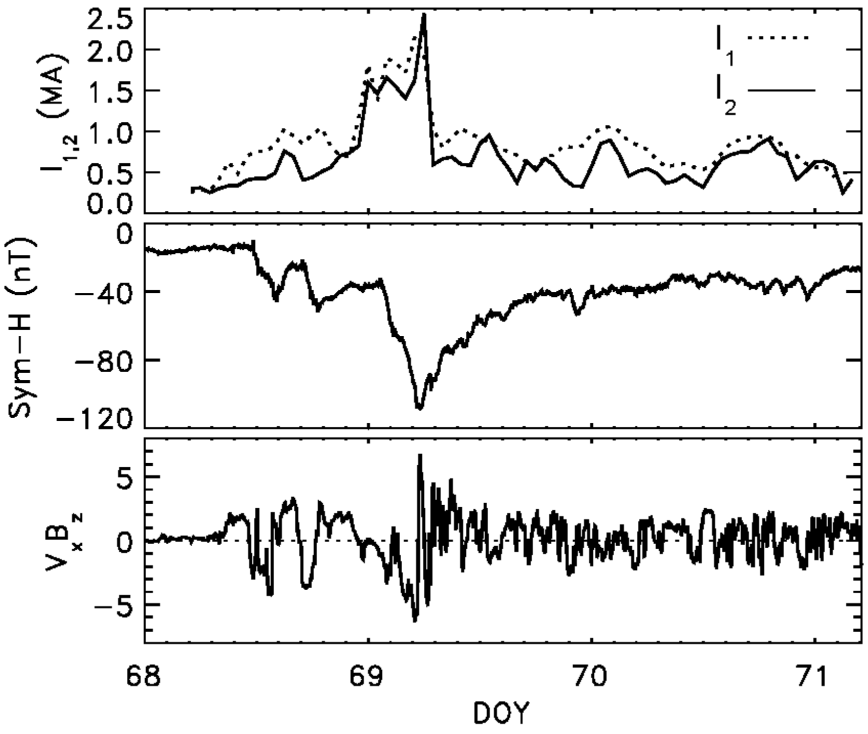


CME- and CIR-driven storms compared

CME-driven April 2001 storm

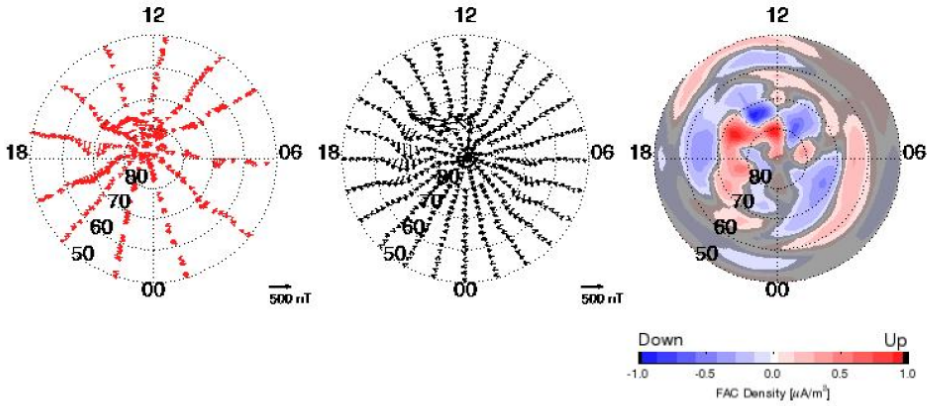


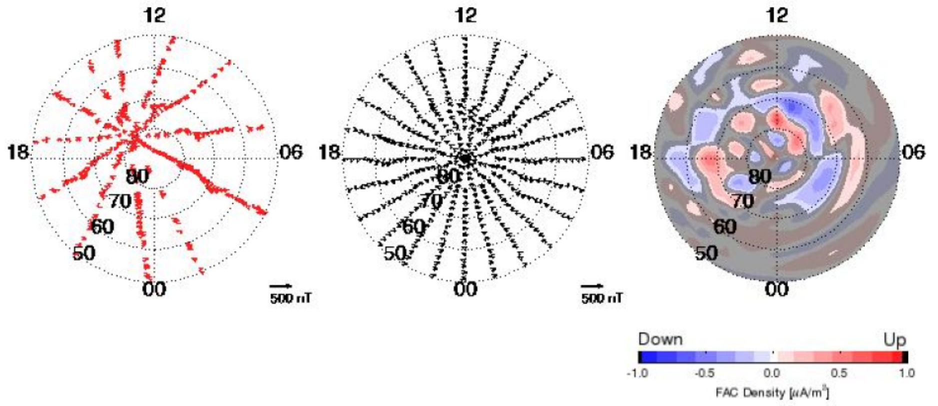
CIR-driven March 2008 storm

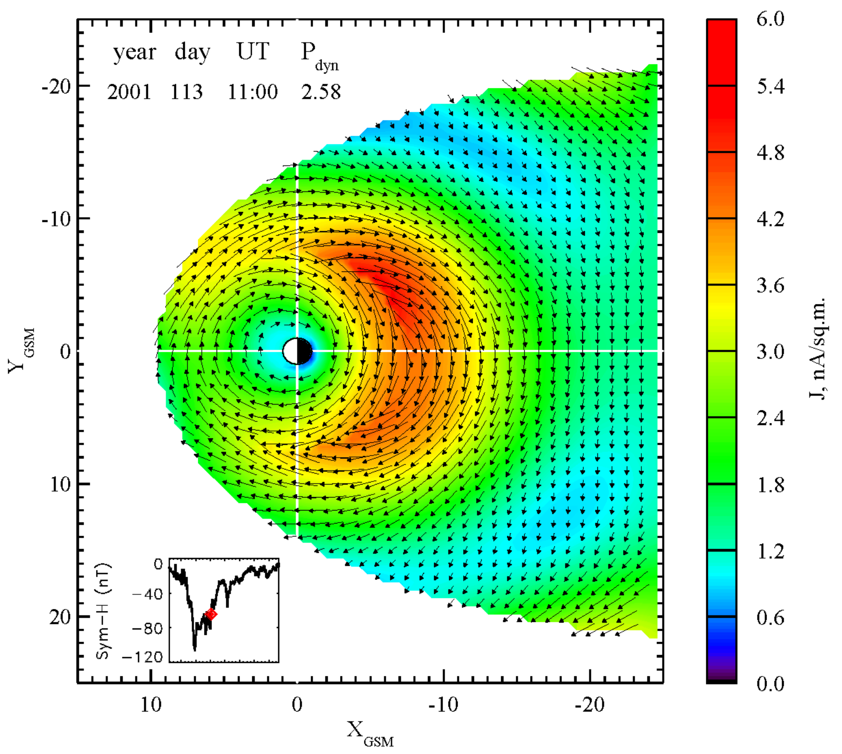


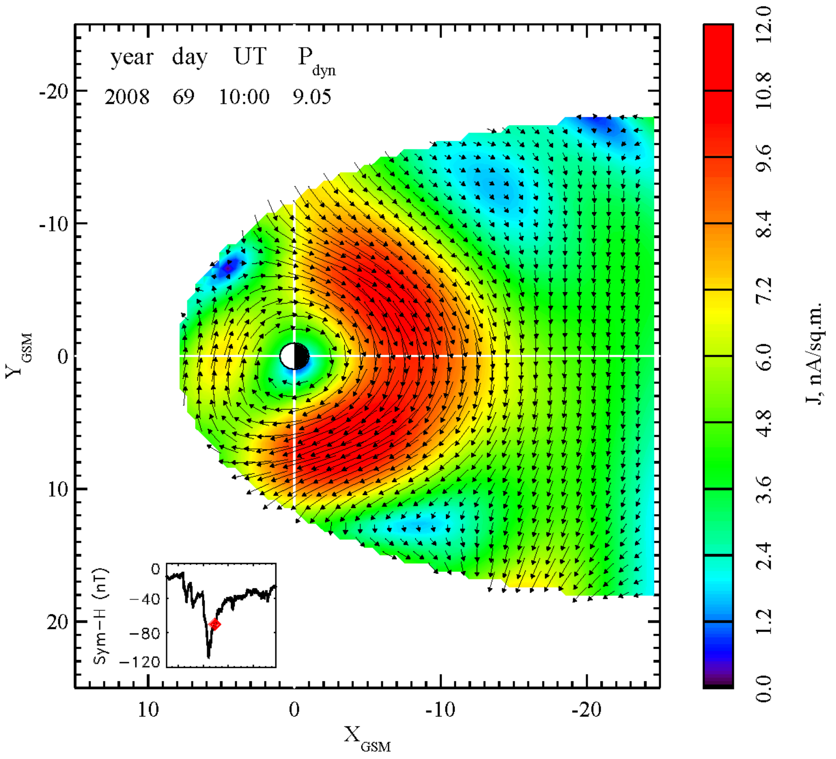
Tail-type storm-time current (instead of PRC) arises when the equatorial current systems are enhanced (by P_{dyn}), while the field-aligned currents are suppressed because of the weak solar wind electric field.

CME- and CIR-driven storms compared

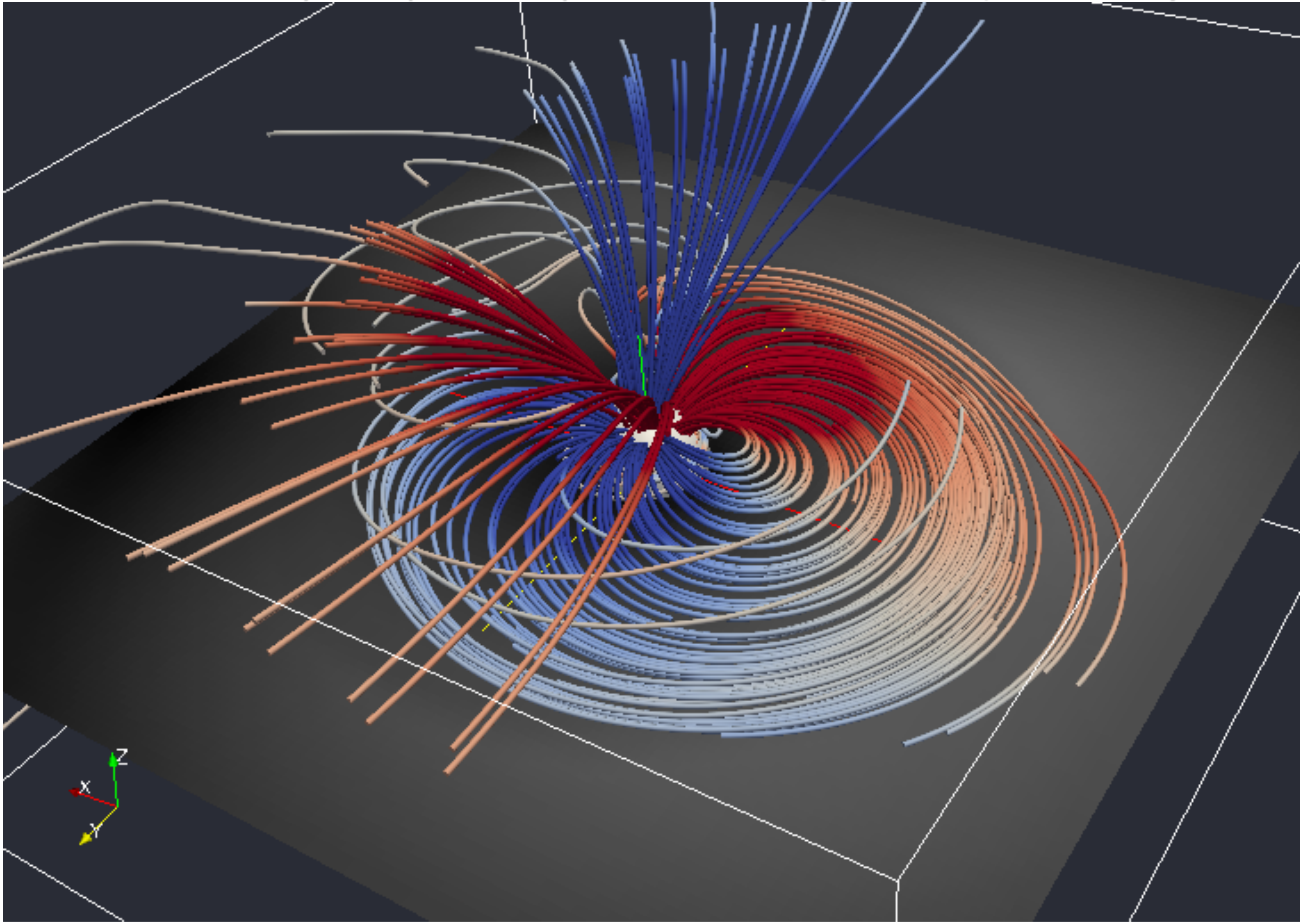

04/23/2001 10:30 - 11:30 UT (North)


03/09/2008 09:30 - 10:30 UT (North)

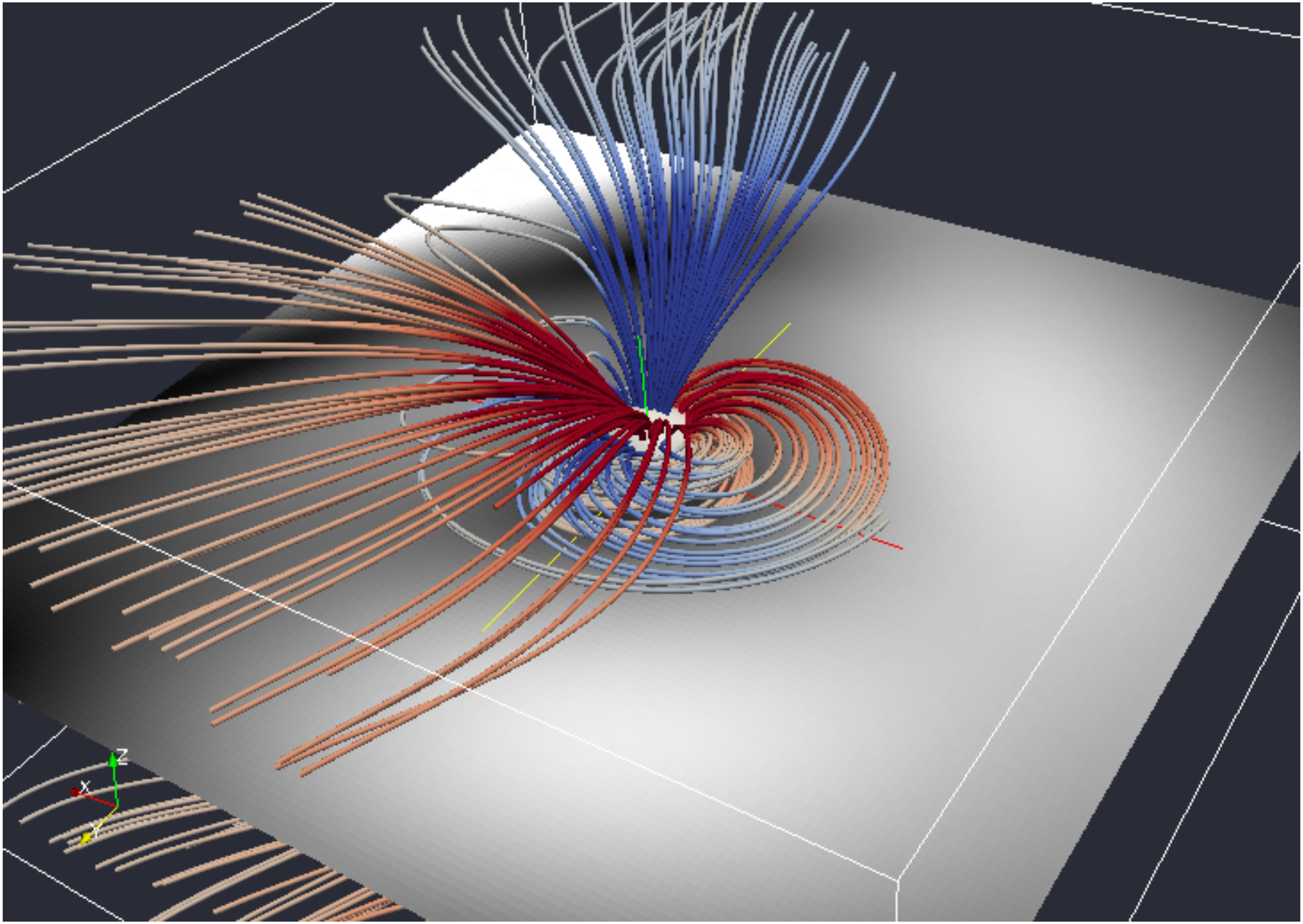




3D current system picture: April 2001 storm (DOY=113; UT=11:00)

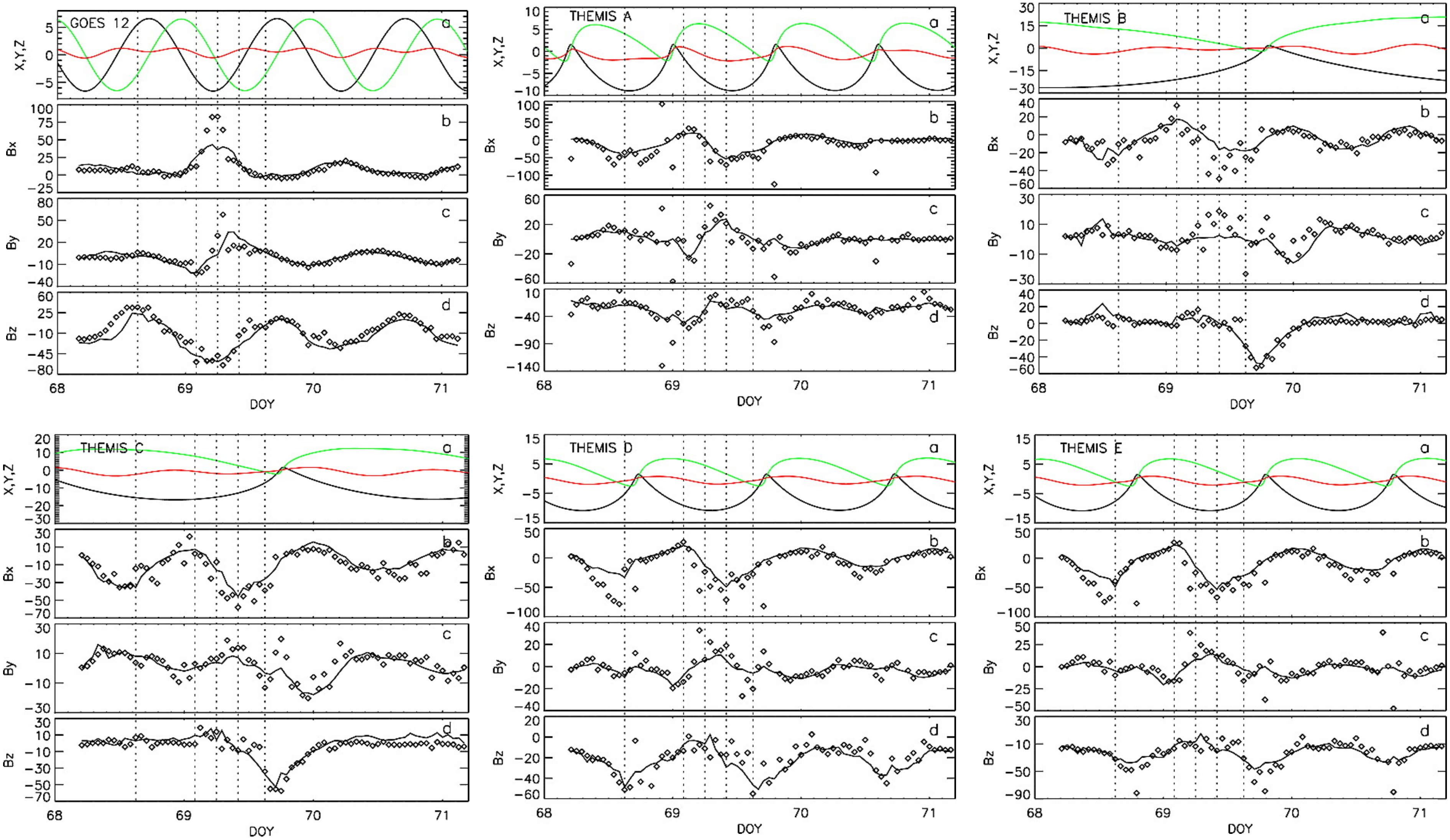


3D current system picture: March 2008 storm (DOY=69; UT=10:00)



TS07D validation example

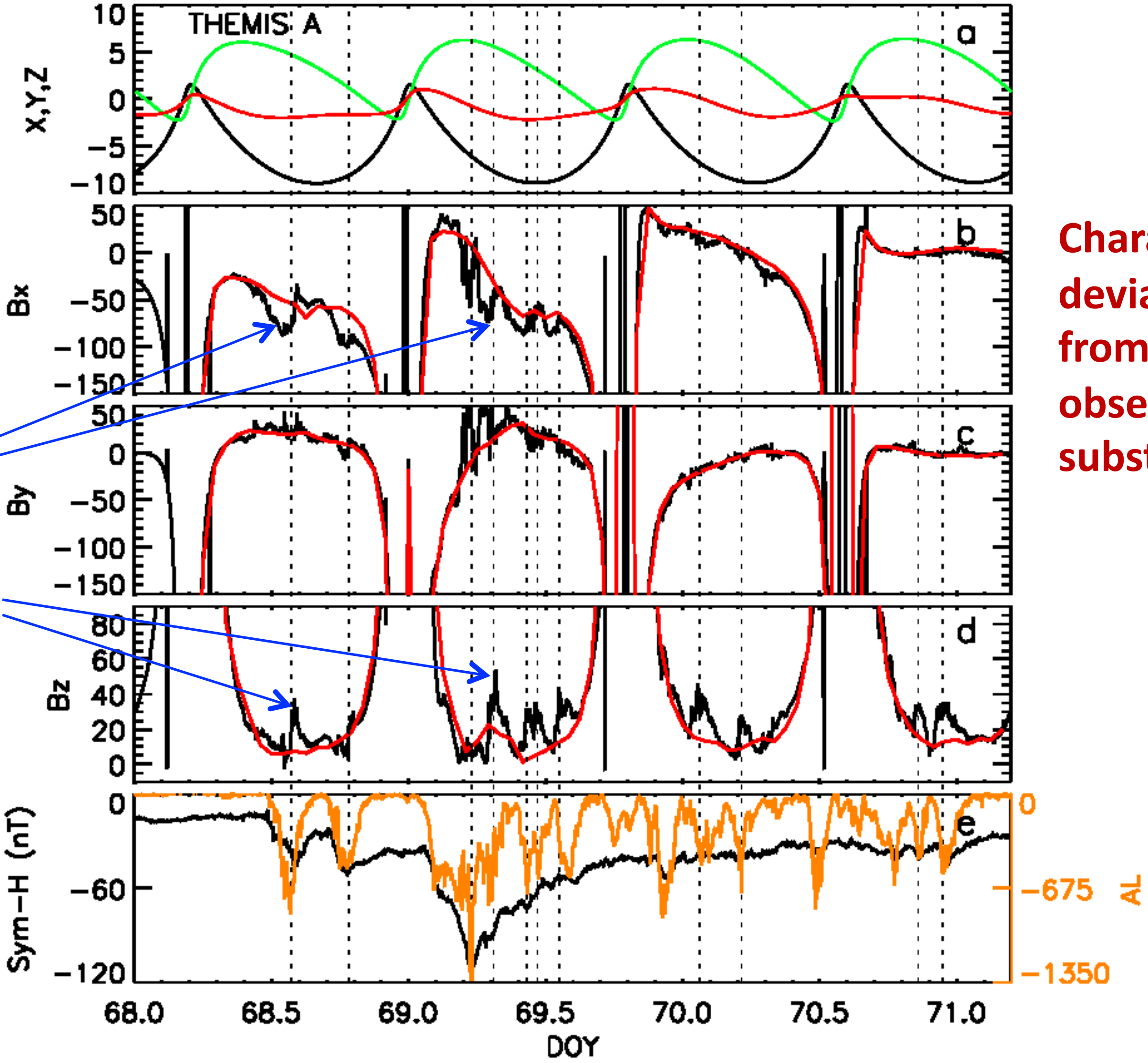
March 8-11, 2008 magnetic storm



The model accurately reconstructs the magnetic field on storm scales everywhere in the magnetosphere (note the spatial separation between the spacecraft shown)

TS07D validation: Substorm effects

March 8-11, 2008 magnetic storm reconstructed using TS07D model



CS thinning

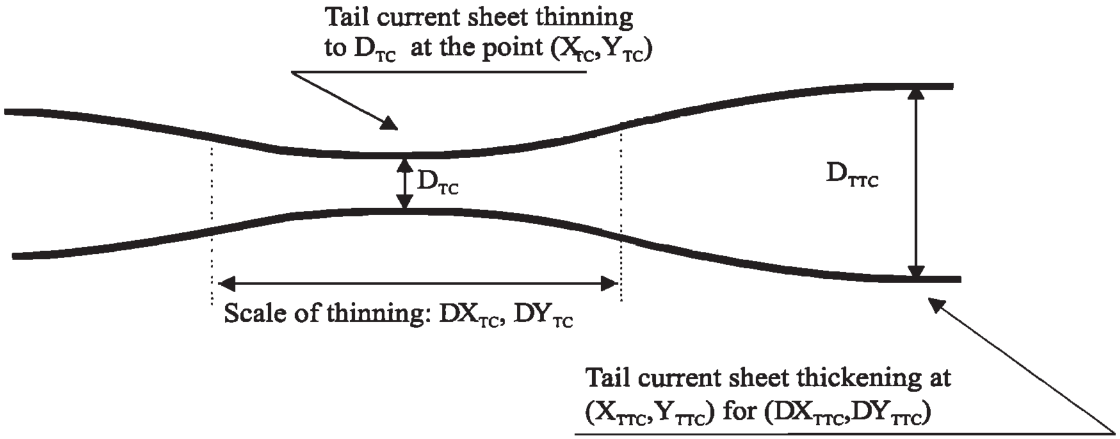
dipolarization

Characteristic deviations of the model from THEMIS data are observed during each substorm

Empirical geomagnetic field modeling: Substorms

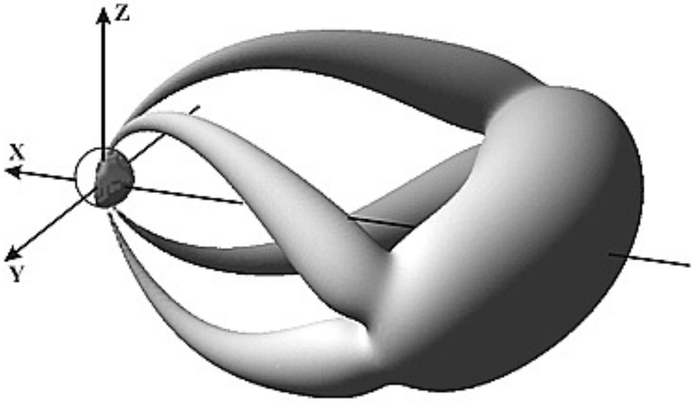
Tail current sheet thinning

Kubyshkina et al. [1999, 2002, 2009, 2011] use thin current sheet module



Dipolarization

Sergeev et al., [2011] based on a new SCW module



Both approaches employ classical custom-tailored modules (T≤05 models)

Both are missing their PRC counterparts (with Region 2-sense FACs)

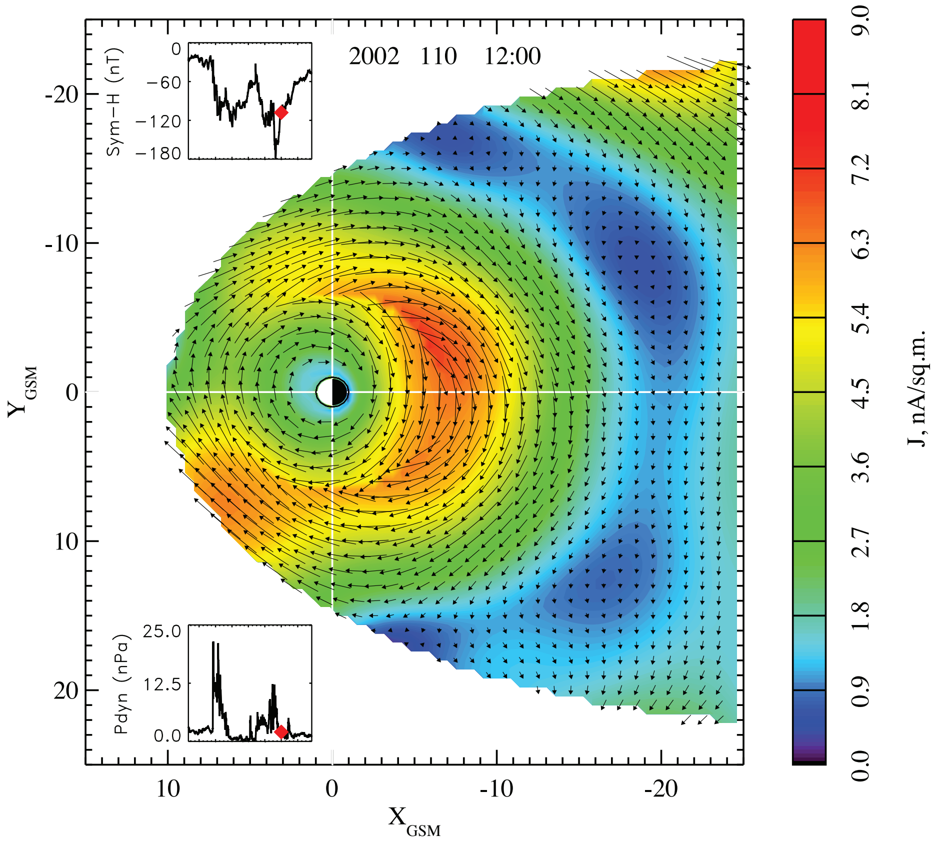
Substorm-time magnetosphere has too many degrees of freedom to match the presently available number of observations

Tsyganenko models compared

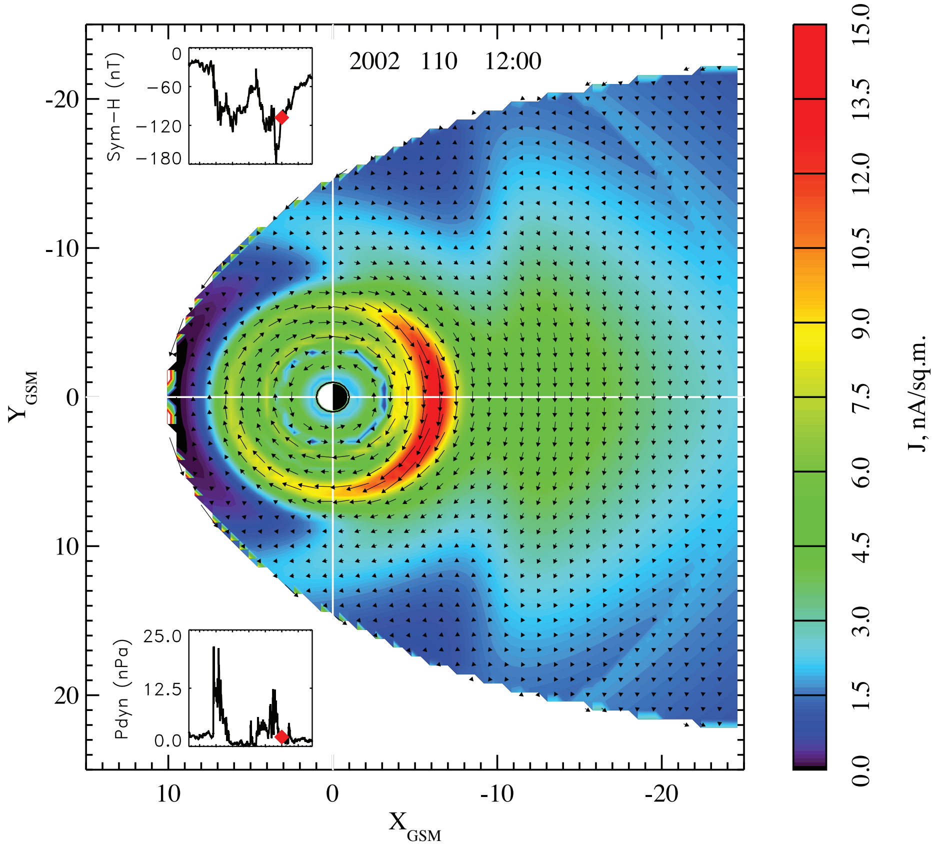
Model	**TS05**	**TS07D**
Structure	Rigid modules	Regular expansions
Data binning method	“Climatology”: Model coefficients are universal functions of the solar wind and IMF parameters	Dynamical: Nearest neighbor approach
Database	$\sim 10^5$ points ($\sim$68% geosynchronous)	$\sim 10^6$ points (weighted to provide even distribution in the magnetosphere)

TS07D versus TS05

TS07D



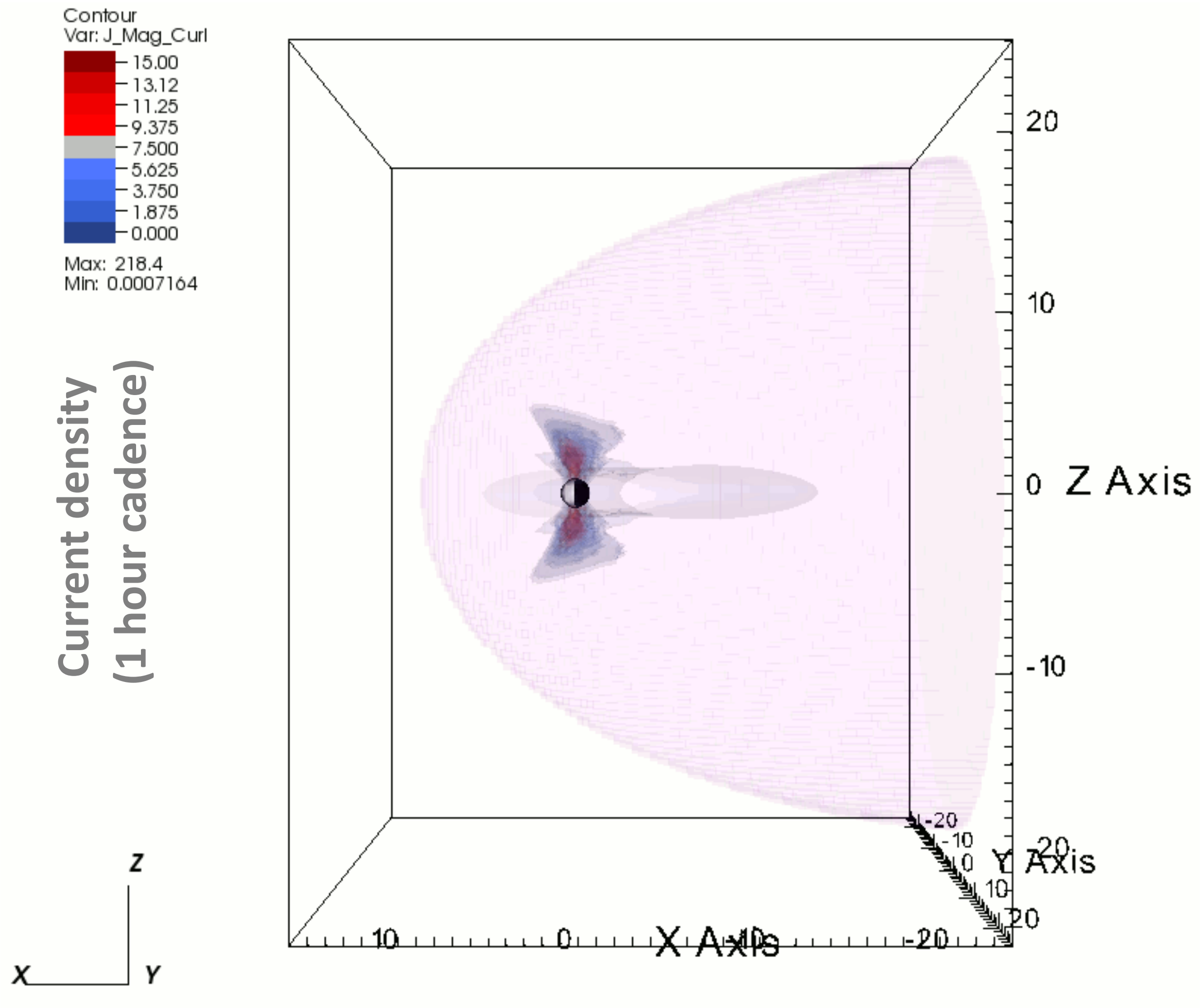
TS05



TS07D is less dependent on pre-defined current modules based on a priori assumptions regarding the morphology of magnetospheric current systems

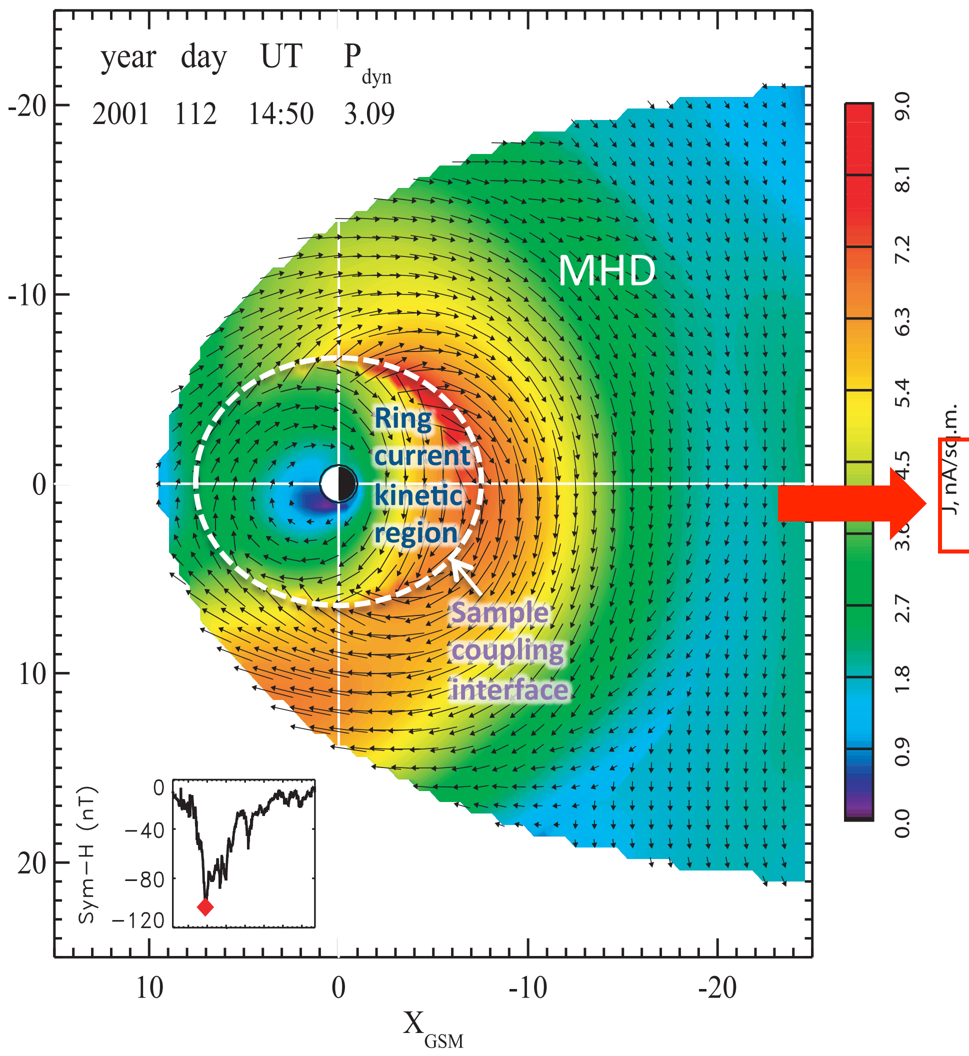
3D dynamical reconstruction of magnetospheric currents

April 17-21, 2002 storm: TS07D 3D visualization



http://sd-www.jhuapl.edu/geostorm/sidecropped.gif

Combining with first-principles models



$$\mathbf{j}\times\mathbf{B} = \nabla p$$

Adjusting storm time scale equation of state

MHD equations

$$\partial\rho/\partial t + \nabla(\rho\mathbf{v}) = 0$$

$$\partial\mathbf{v}/\partial t + (\mathbf{v}\nabla)\mathbf{v} = \rho^{-1}(\mathbf{j}\times\mathbf{B} - \nabla p)$$

$$(\partial/\partial t + \mathbf{v}\nabla)p = -\gamma p\nabla\mathbf{v}$$

$$\mathbf{E} = -\mathbf{v}\times\mathbf{B} + \eta\mathbf{j}$$

Adjusting external boundary conditions

RCM equations

$$(\partial\rho/\partial t + \mathbf{v}_D\nabla)\eta_k = -\eta_k/\tau_k$$

$$\mathbf{j}\times\mathbf{B} = \nabla p$$

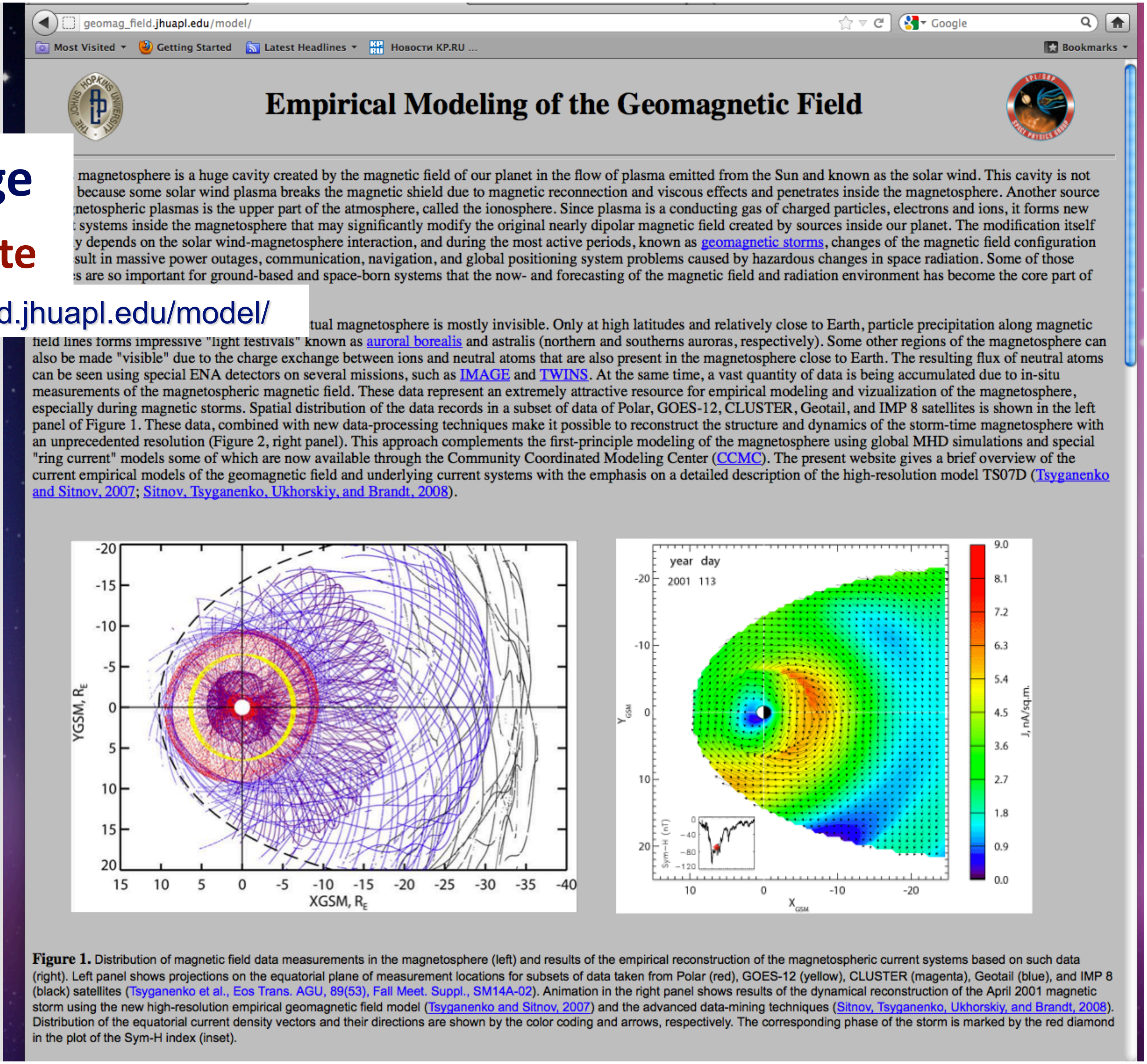
$$pV^{5/3} = (2/3)\sum_k \eta_k|\lambda_k|$$

$$j_{\parallel nh} - j_{\parallel sh} = B_i(\mathbf{B}/B^2)(\nabla V\times\nabla p)$$

TS07D usage

Model website

http://geomag_field.jhuapl.edu/model/



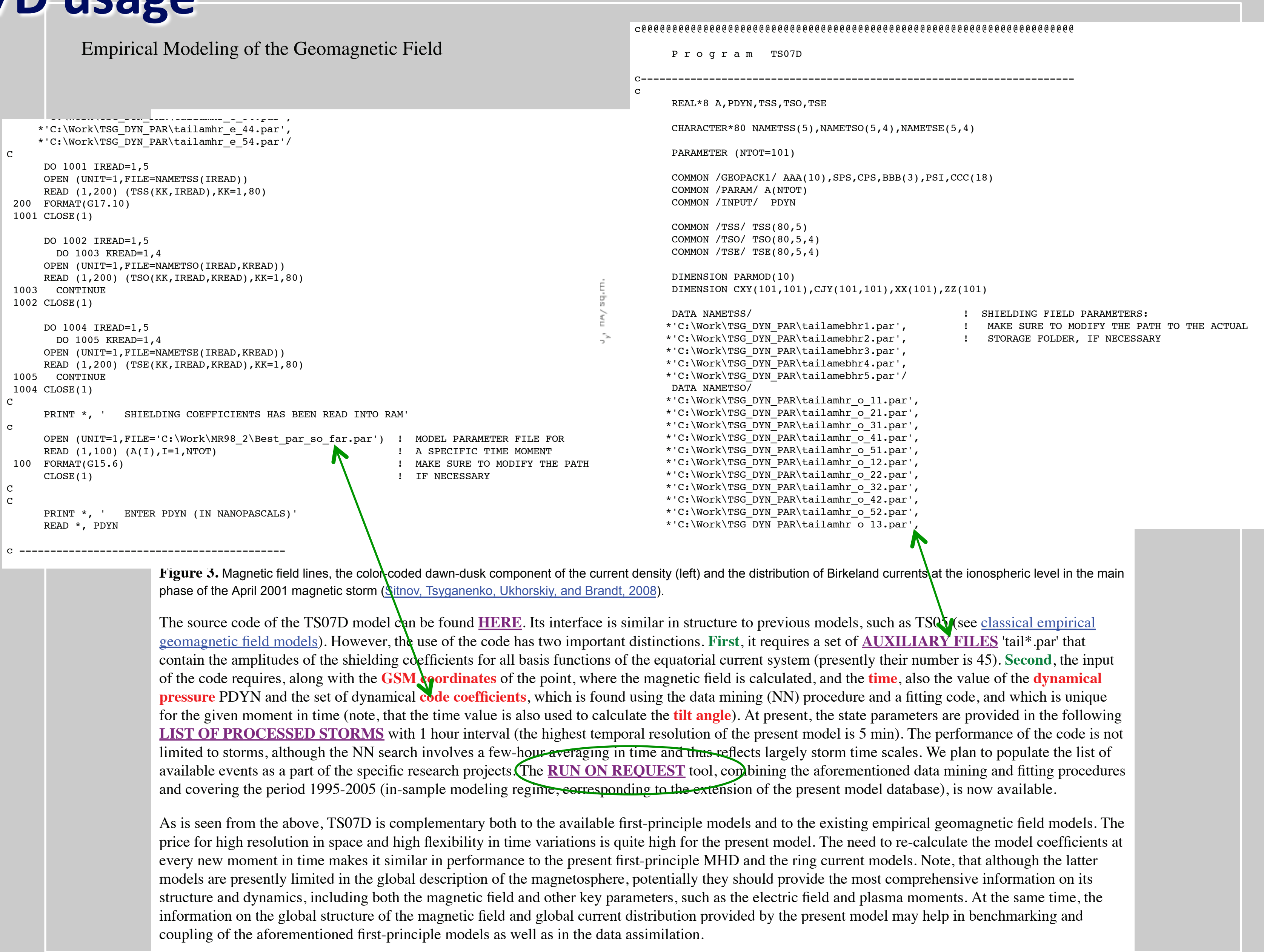
Empirical Modeling of the Geomagnetic Field

magnetosphere is a huge cavity created by the magnetic field of our planet in the flow of plasma emitted from the Sun and known as the solar wind. This cavity is not because some solar wind plasma breaks the magnetic shield due to magnetic reconnection and viscous effects and penetrates inside the magnetosphere. Another source netospheric plasmas is the upper part of the atmosphere, called the ionosphere. Since plasma is a conducting gas of charged particles, electrons and ions, it forms new t systems inside the magnetosphere that may significantly modify the original nearly dipolar magnetic field created by sources inside our planet. The modification itself y depends on the solar wind-magnetosphere interaction, and during the most active periods, known as geomagnetic storms, changes of the magnetic field configuration sult in massive power outages, communication, navigation, and global positioning system problems caused by hazardous changes in space radiation. Some of those s are so important for ground-based and space-born systems that the now- and forecasting of the magnetic field and radiation environment has become the core part of

tual magnetosphere is mostly invisible. Only at high latitudes and relatively close to Earth, particle precipitation along magnetic field lines forms impressive "light festivals" known as auroral borealis and astralis (northern and southerns auroras, respectively). Some other regions of the magnetosphere can also be made "visible" due to the charge exchange between ions and neutral atoms that are also present in the magnetosphere close to Earth. The resulting flux of neutral atoms can be seen using special ENA detectors on several missions, such as IMAGE and TWINS. At the same time, a vast quantity of data is being accumulated due to in-situ measurements of the magnetospheric magnetic field. These data represent an extremely attractive resource for empirical modeling and vizualization of the magnetosphere, especially during magnetic storms. Spatial distribution of the data records in a subset of data of Polar, GOES-12, CLUSTER, Geotail, and IMP 8 satellites is shown in the left panel of Figure 1. These data, combined with new data-processing techniques make it possible to reconstruct the structure and dynamics of the storm-time magnetosphere with an unprecedented resolution (Figure 2, right panel). This approach complements the first-principle modeling of the magnetosphere using global MHD simulations and special "ring current" models some of which are now available through the Community Coordinated Modeling Center (CCMC). The present website gives a brief overview of the current empirical models of the geomagnetic field and underlying current systems with the emphasis on a detailed description of the high-resolution model TS07D (Tsyganenko and Sitnov, 2007; Sitnov, Tsyganenko, Ukhorskiy, and Brandt, 2008).

Figure 1. Distribution of magnetic field data measurements in the magnetosphere (left) and results of the empirical reconstruction of the magnetospheric current systems based on such data (right). Left panel shows projections on the equatorial plane of measurement locations for subsets of data taken from Polar (red), GOES-12 (yellow), CLUSTER (magenta), Geotail (blue), and IMP 8 (black) satellites (Tsyganenko et al., Eos Trans. AGU, 89(53), Fall Meet. Suppl., SM14A-02). Animation in the right panel shows results of the dynamical reconstruction of the April 2001 magnetic storm using the new high-resolution empirical geomagnetic field model (Tsyganenko and Sitnov, 2007) and the advanced data-mining techniques (Sitnov, Tsyganenko, Ukhorskiy, and Brandt, 2008). Distribution of the equatorial current density vectors and their directions are shown by the color coding and arrows, respectively. The corresponding phase of the storm is marked by the red diamond in the plot of the Sym-H index (inset).

TS07D usage



Empirical Modeling of the Geomagnetic Field

```
c@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@

      P r o g r a m   TS07D

c-----------------------------------------------------------------------
c
      REAL*8 A,PDYN,TSS,TSO,TSE

      CHARACTER*80 NAMETSS(5),NAMETSO(5,4),NAMETSE(5,4)

      PARAMETER (NTOT=101)

      COMMON /GEOPACK1/ AAA(10),SPS,CPS,BBB(3),PSI,CCC(18)
      COMMON /PARAM/ A(NTOT)
      COMMON /INPUT/  PDYN

      COMMON /TSS/ TSS(80,5)
      COMMON /TSO/ TSO(80,5,4)
      COMMON /TSE/ TSE(80,5,4)

      DIMENSION PARMOD(10)
      DIMENSION CXY(101,101),CJY(101,101),XX(101),ZZ(101)

      DATA NAMETSS/                                   !  SHIELDING FIELD PARAMETERS:
     *'C:\Work\TSG_DYN_PAR\tailamebhr1.par',          !   MAKE SURE TO MODIFY THE PATH TO THE ACTUAL
     *'C:\Work\TSG_DYN_PAR\tailamebhr2.par',          !   STORAGE FOLDER, IF NECESSARY
     *'C:\Work\TSG_DYN_PAR\tailamebhr3.par',
     *'C:\Work\TSG_DYN_PAR\tailamebhr4.par',
     *'C:\Work\TSG_DYN_PAR\tailamebhr5.par'/
      DATA NAMETSO/
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_11.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_21.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_31.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_41.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_51.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_12.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_22.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_32.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_42.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_o_52.par',
     *'C:\Work\TSG DYN PAR\tailamhr o 13.par',
```

```
     *'C:\Work\TSG_DYN_PAR\tailamhr_e_44.par',
     *'C:\Work\TSG_DYN_PAR\tailamhr_e_54.par'/
C
      DO 1001 IREAD=1,5
      OPEN (UNIT=1,FILE=NAMETSS(IREAD))
      READ (1,200) (TSS(KK,IREAD),KK=1,80)
 200  FORMAT(G17.10)
 1001 CLOSE(1)

      DO 1002 IREAD=1,5
        DO 1003 KREAD=1,4
      OPEN (UNIT=1,FILE=NAMETSO(IREAD,KREAD))
      READ (1,200) (TSO(KK,IREAD,KREAD),KK=1,80)
 1003   CONTINUE
 1002 CLOSE(1)

      DO 1004 IREAD=1,5
        DO 1005 KREAD=1,4
      OPEN (UNIT=1,FILE=NAMETSE(IREAD,KREAD))
      READ (1,200) (TSE(KK,IREAD,KREAD),KK=1,80)
 1005   CONTINUE
 1004 CLOSE(1)
C
      PRINT *, '   SHIELDING COEFFICIENTS HAS BEEN READ INTO RAM'
c
      OPEN (UNIT=1,FILE='C:\Work\MR98_2\Best_par_so_far.par')  !  MODEL PARAMETER FILE FOR
      READ (1,100) (A(I),I=1,NTOT)                             !  A SPECIFIC TIME MOMENT
 100  FORMAT(G15.6)                                            !  MAKE SURE TO MODIFY THE PATH
      CLOSE(1)                                                 !  IF NECESSARY
C
C

      PRINT *, '   ENTER PDYN (IN NANOPASCALS)'
      READ *, PDYN

c ----------------------------------------------
```

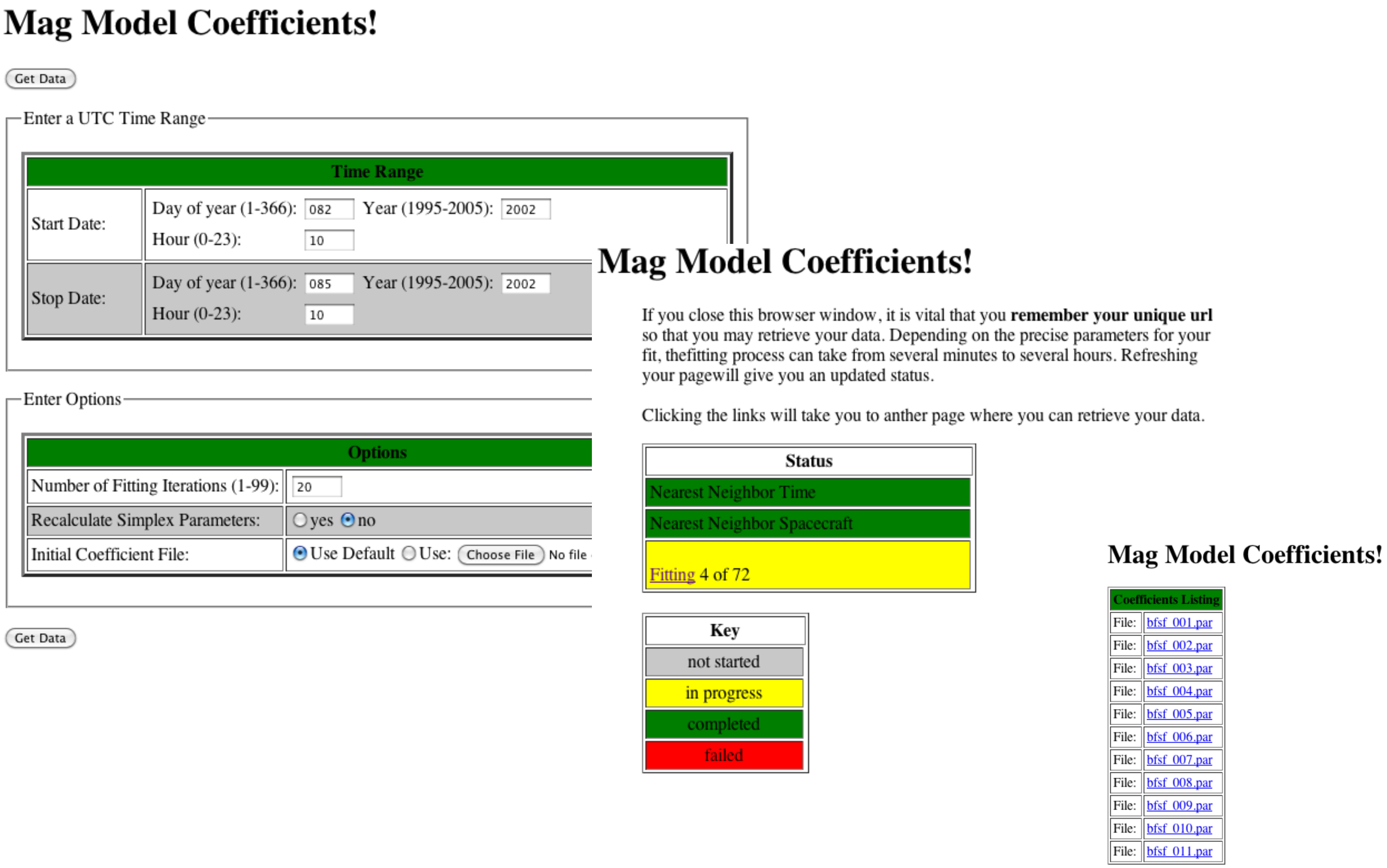
Figure 3. Magnetic field lines, the color-coded dawn-dusk component of the current density (left) and the distribution of Birkeland currents at the ionospheric level in the main phase of the April 2001 magnetic storm (Sitnov, Tsyganenko, Ukhorskiy, and Brandt, 2008).

The source code of the TS07D model can be found **HERE**. Its interface is similar in structure to previous models, such as TS05 (see classical empirical geomagnetic field models). However, the use of the code has two important distinctions. **First**, it requires a set of **AUXILIARY FILES** 'tail*.par' that contain the amplitudes of the shielding coefficients for all basis functions of the equatorial current system (presently their number is 45). **Second**, the input of the code requires, along with the **GSM coordinates** of the point, where the magnetic field is calculated, and the **time**, also the value of the **dynamical pressure** PDYN and the set of dynamical **code coefficients**, which is found using the data mining (NN) procedure and a fitting code, and which is unique for the given moment in time (note, that the time value is also used to calculate the **tilt angle**). At present, the state parameters are provided in the following **LIST OF PROCESSED STORMS** with 1 hour interval (the highest temporal resolution of the present model is 5 min). The performance of the code is not limited to storms, although the NN search involves a few-hour averaging in time and thus reflects largely storm time scales. We plan to populate the list of available events as a part of the specific research projects. The **RUN ON REQUEST** tool, combining the aforementioned data mining and fitting procedures and covering the period 1995-2005 (in-sample modeling regime, corresponding to the extension of the present model database), is now available.

As is seen from the above, TS07D is complementary both to the available first-principle models and to the existing empirical geomagnetic field models. The price for high resolution in space and high flexibility in time variations is quite high for the present model. The need to re-calculate the model coefficients at every new moment in time makes it similar in performance to the present first-principle MHD and the ring current models. Note, that although the latter models are presently limited in the global description of the magnetosphere, potentially they should provide the most comprehensive information on its structure and dynamics, including both the magnetic field and other key parameters, such as the electric field and plasma moments. At the same time, the information on the global structure of the magnetic field and global current distribution provided by the present model may help in benchmarking and coupling of the aforementioned first-principle models as well as in the data assimilation.

RUN-ON-REQUEST application

Location: http://geomag_field.jhuapl.edu/model/ (go to "RUNS ON REQUEST")



Mag Model Coefficients!

Enter a UTC Time Range

Time Range	
Start Date:	Day of year (1-366): 082 Year (1995-2005): 2002 Hour (0-23): 10
Stop Date:	Day of year (1-366): 085 Year (1995-2005): 2002 Hour (0-23): 10

Enter Options

Options	
Number of Fitting Iterations (1-99):	20
Recalculate Simplex Parameters:	○ yes ● no
Initial Coefficient File:	● Use Default ○ Use: Choose File No file

Mag Model Coefficients!

If you close this browser window, it is vital that you **remember your unique url** so that you may retrieve your data. Depending on the precise parameters for your fit, thefitting process can take from several minutes to several hours. Refreshing your pagewill give you an updated status.

Clicking the links will take you to anther page where you can retrieve your data.

Status
Nearest Neighbor Time
Nearest Neighbor Spacecraft
Fitting 4 of 72

Key
not started
in progress
completed
failed

Mag Model Coefficients!

Coefficients Listing	
File:	bfsf_001.par
File:	bfsf_002.par
File:	bfsf_003.par
File:	bfsf_004.par
File:	bfsf_005.par
File:	bfsf_006.par
File:	bfsf_007.par
File:	bfsf_008.par
File:	bfsf_009.par
File:	bfsf_010.par
File:	bfsf_011.par

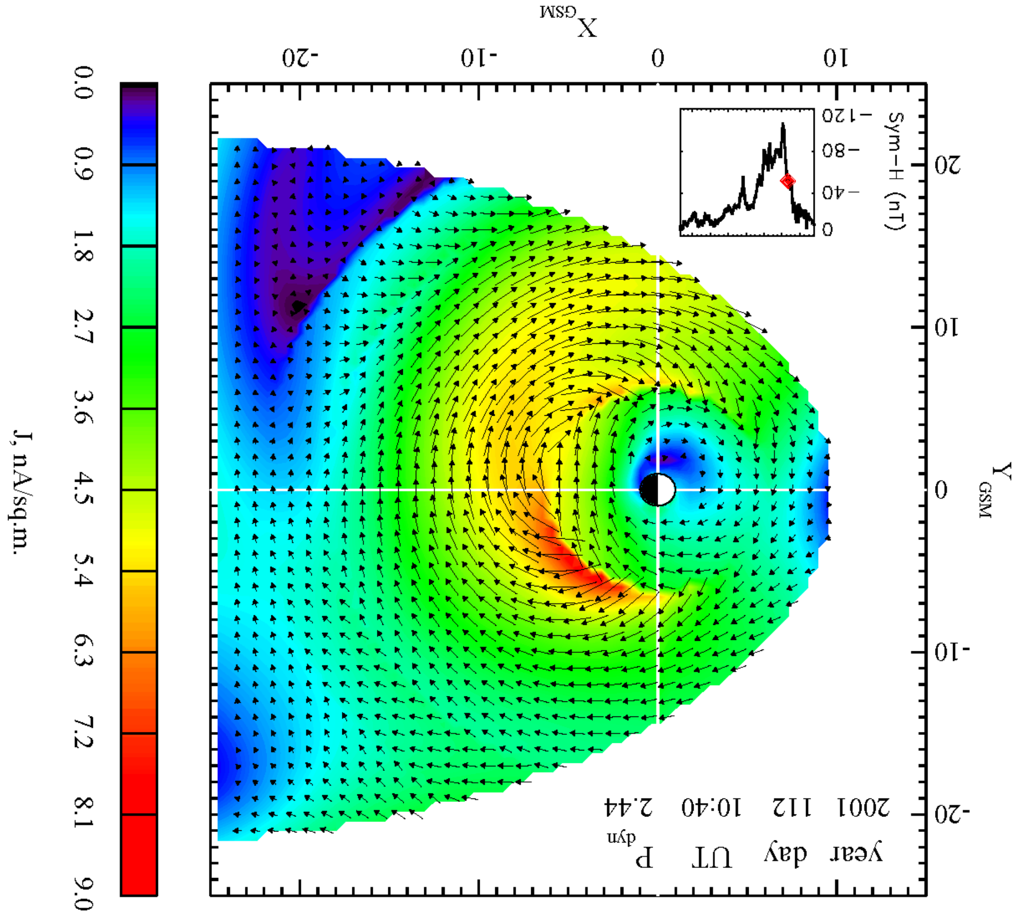
Conclusion

- Modern empirical geomagnetic field modeling opens new opportunities in studies of the magnetosphere.

- The new model, TS07D, is less dependent on assumptions regarding the shape of magnetospheric current systems and modes of their response to solar wind driving. Therefore it allows one to infer both the geometry of the currents and their evolution directly from data.

- This new empirical picture of the magnetic field and underlying electric currents can be used both for conventional applications, such as particle tracing and mapping, and for investigation of the storm-scale current morphology as well as for ingesting additional empirical information into first-principles models.

It looks like an elephant!



David Stern was right…