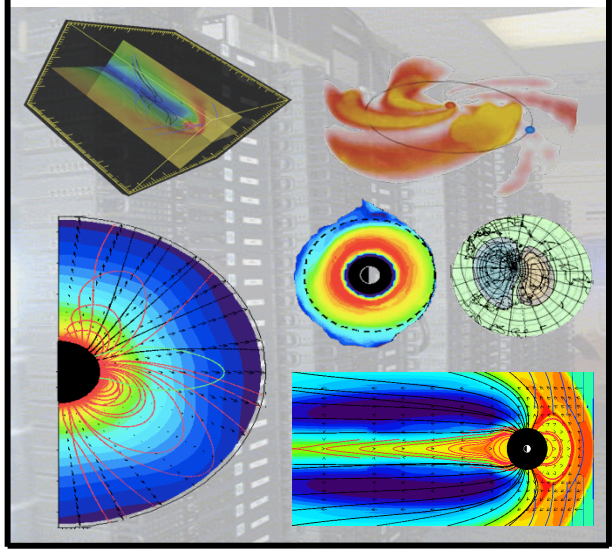
COMMUNITY COORDINATED MODELING CENTER

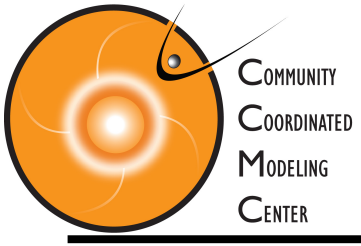


Model Validation

P. MacNeice, A. Taktakishvilli,
L. Rastaetter, A. Pulkkinen,
Y. Zheng, J.S. Shim, M. Kuznetsova

http://ccmc.gsfc.nasa.gov

NASA Goddard Space Flight Center



Overview

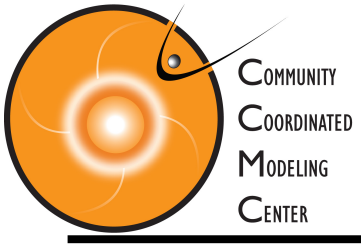
Encompasses 4 types of validation study

1. By the CCMC
2. Based on studies by CCMC users
3. Community-wide Challenges
4. Collaborative Validations
    - CCMC/AFIT - Acebal

Organized by discipline

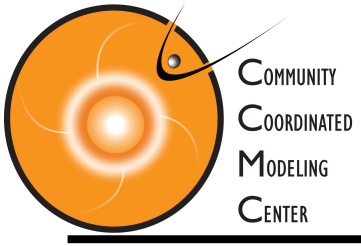
- Solar and Heliospheric – MacNeice, Taktakishvilli, Pulkkinen
- Magnetospheric – Rastaetter, Kuznetsova, Zheng
- Ionospheric and Thermospheric – Shim, Kuznetsova

Emphasize the breath of the overall validation effort.



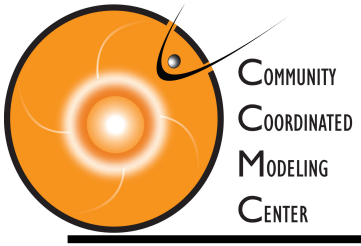
Solar and Heliospheric Models

(With input from Sandro Taktakishvilli and Antti Pulkkinen)



Solar and Heliospheric

- Ambient Models
  - Fieldline Tracing – published Oct. 2011
  - Skill Score Analysis of latest ENLIL (v2.7d) – just begun
  - Heliospheric Tomography – in data collection phase
  - Study by Lan Jian
  - SHINE workshop study – in definition phase
- Transient
  - ENLIL Cone Model
    - 2 CCMC studies published + in preparation
    - 2 studies led by Thea Von Falkenberg
    - Collaborative study with AFIT (Dan Emmons, Ariel Acebal)



Field Line Tracing

Collaborative Validation with AFIT (Brian Elliot and Ariel Acebal)

Concept

- Accurate tracing of fieldlines from Earth to Sun could support improved forecasting of SEPs
- How good are the current generation of operational models at tracing Earth/Sun fieldline connectivity?
  - Can use of ENLIL improve accuracy of fieldline tracing?

Process

- Catalog weak impulsive SEP bursts with clear signatures of coronal origin
- Identify transient brightenings at solar surface consistent with SEP times of flight as marker of Earth connected fieldline footpoint
- Compare this 'observed' fieldline with fieldlines reconstructed from four different models
  1. Parker Spiral
  2. PFSS + Parker Spiral
  3. WSA
  4. WSA/ENLIL

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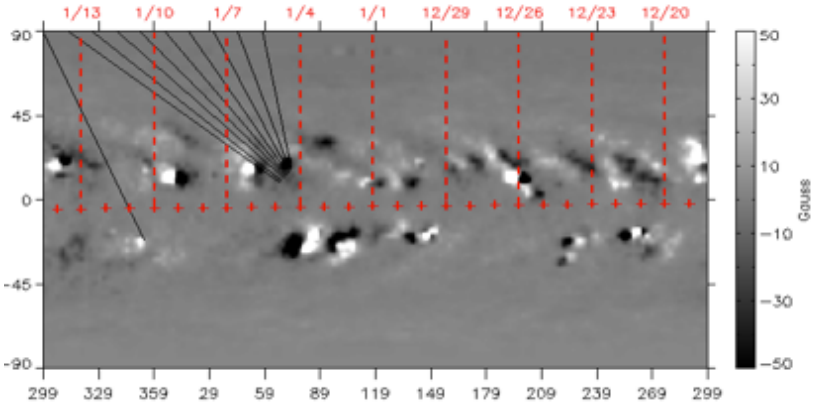
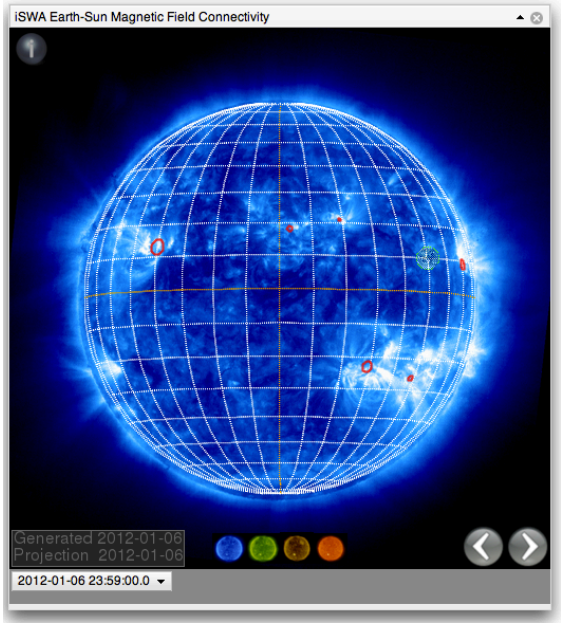
Field Line Tracing



Results

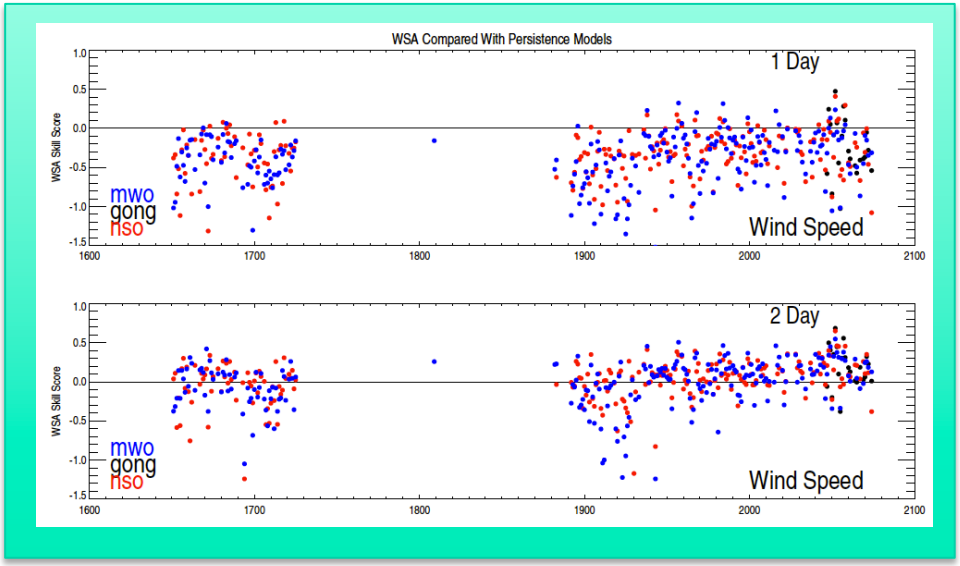
- Difficult to find usable SEP bursts with clear surface points of origin
  - Eventually settled on just 15 events
  - Hopefully SDO's continuous high cadence observations will remedy this
- Typical footpoint location errors average 20-30^{o}
- WSA/ENLIL is no better than the simpler models
- Implies that dominant error is due to coronal model components
  - Current 'potential-like' coronal models produce too little open flux at low latitudes
  - Perhaps due to steady-state nature of current models



ENLIL Next Version

- In January 2010 we were using
  - WSA Version 1.4
  - ENLIL Version 2.6

- In January 2012 we are using
  - WSA Version 2.2
  - ENLIL Version 2.7



- Two weeks ago we received ENLIL V2.7d

- Running validation cases to help Dusan tweak his configuration – initial stage of a more complete skill score validation of WSA/ENLIL

- In the process we will update the published WSA skill score validation

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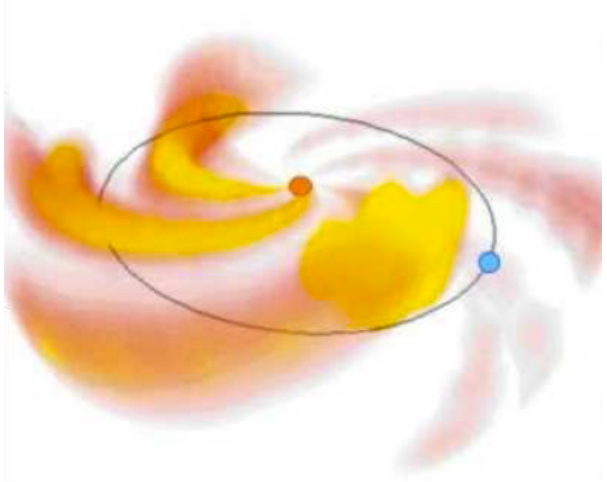
Heliospheric Tomography

- UCSD Model – Jackson et al
- Latest version can forecast wind state up to 3 days ahead
- Uses scintillations of ~ 20 radio source timelines recorded by STELab at 4 sites
- Uses a 3D iterative reconstruction tomography code – iterates in 3 directions, latitude, longitude and time, to create a time dependent source surface boundary solution for density and velocity for a kinematic wind model
- Also constrains reconstruction using ACE data
- The Kinematic wind model
  - assumes radial flow
  - allows for interactions between wind streams by imposing conservation of mass and mass flux, permitting merging of fast streams with slow streams which they overtake.



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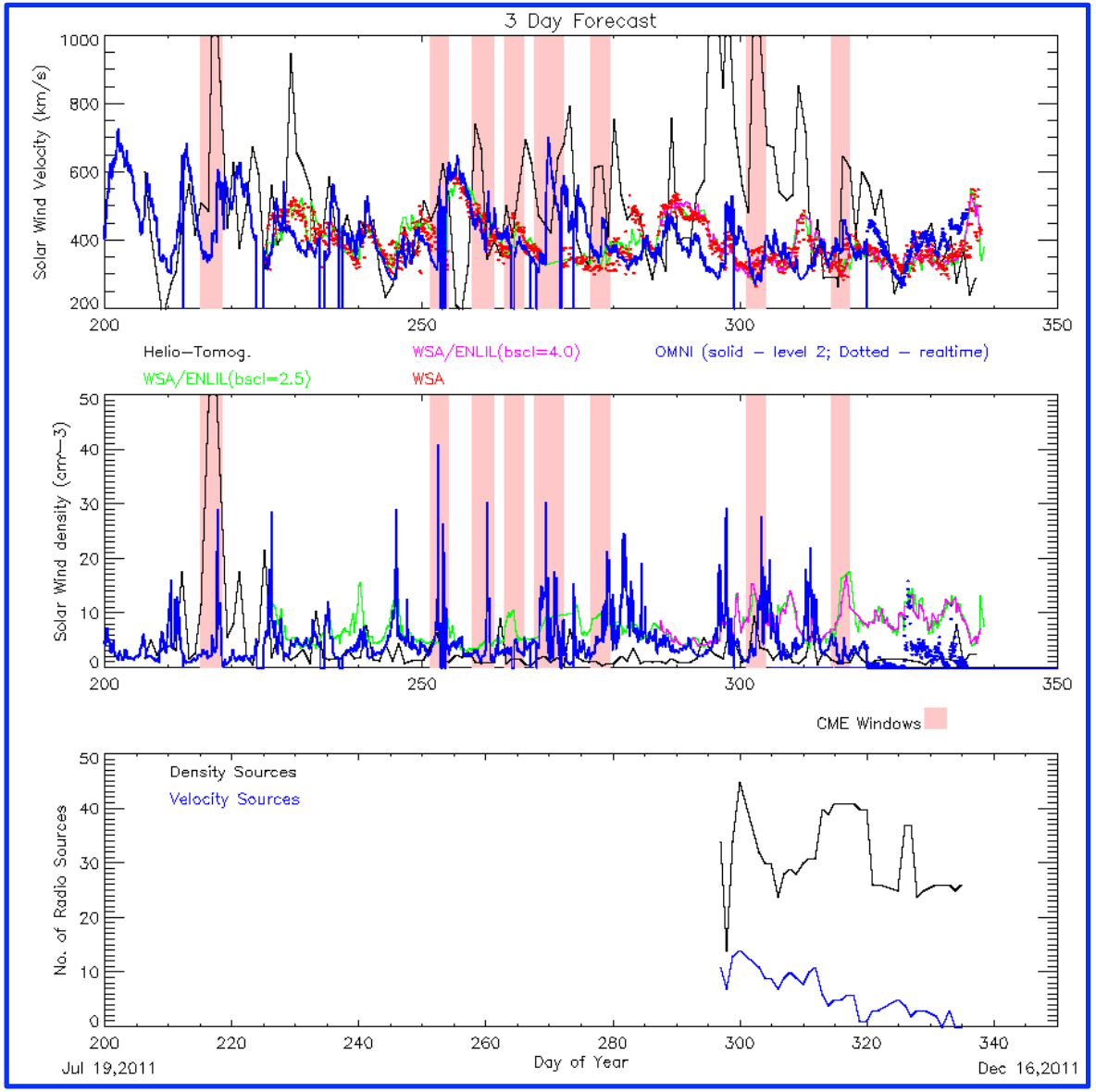
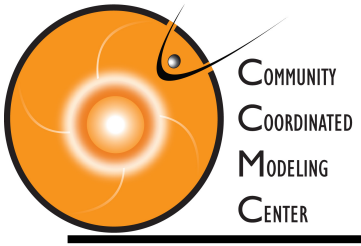
Heliospheric Tomography

- Compare 1,2 and 3 day forecasts for wind speed and density at 1AU from
  - UCSD HelTomo
  - WSA
  - WSA/ENLIL
  - OMNI Data
- Models run > daily since July 2011
- Still in data acquisition phase
- Goal is to complete a skill score analysis





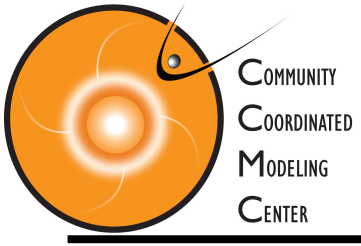
SHINE Workshop Study

Concept

- CCMC mandate to validate models typically has a SW Ops flavor, ie test the forecast of a specific quantity needed at a specific location.
- Research community wants to test models in a more comprehensive way , ie all quantities at all points
- SHINE workshop validation session is an effort to engage the community in a 'science oriented validation'
- Focus is models of corona and inner heliosphere

Process

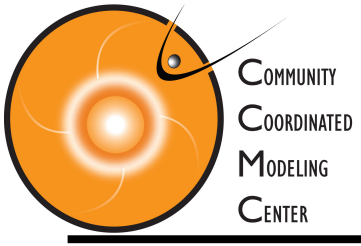
- Pose a set of well defined test calculations
- Define a standard set of model outputs
- Model results posted for comparison at a site to be set up and maintained by the CCMC



SHINE Workshop Study

Status

- Had a very well attended kick-off meeting at SHINE in July 2011.
- Agreed to model ambient corona and inner heliosphere for a CR representative of solar minimum and a second for solar maximum.
- Agreed on set of model diagnostics
  - Discussion emphasized need for comprehensive diagnostic set
- Currently refining the CR selection for solar minimum
  - CR 2058 – 2063 had stable field topology
  - Good imaging and in situ coverage
- Have agreements with Dusan Odstrcil and Sarah Gibson to use their post-processing synthetic image tools.
- Expect to circulate info about CR case and output format requirements within next two weeks.
- Will review results of model runs at follow-on session at SHINE in June



SHINE Workshop Study

Possible Participants

- Corona
  - MHD
    - ✓CORHEL (PredSci)
    - ✓SWMF
    - ✓Wu et al
  - NLFFF
    - ✓Wiegelmann et al
    - ✓McKay, Yeates, Van Ballegooijen
  - Potential
    - ✓WSA(Arge et al)
- Inner Heliosphere
  - ✓ CORHEL (PredSci)
  - ✓ SWMF
  - ✓ ENLIL
  - ✓ Wu et al
  - ✓ WSA (Arge et al)
  - ✓ HelTomo (Jackson et al)
  - ✓ Merkin et al

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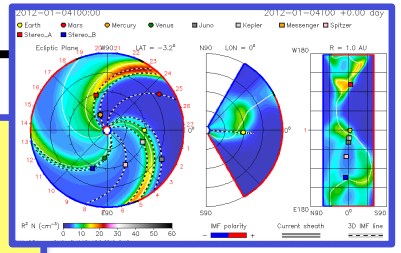
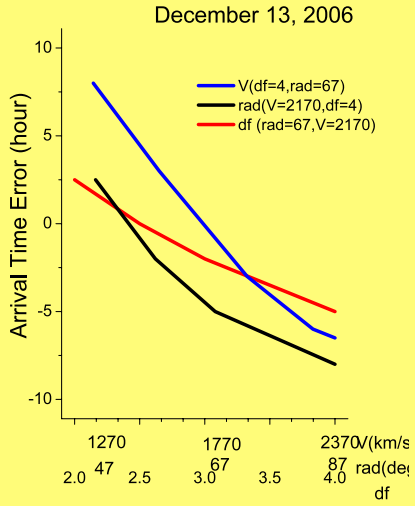
WSA/ENLIL Cone Model Validation



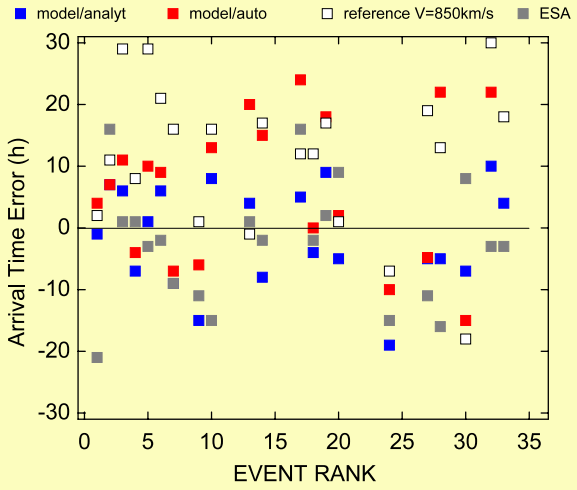
- Dependence of CME shock arrival time error and magnetospheric impact magnitude on the uncertainty in the CME input parameters

Model uncertainties in predictions of arrival of coronal mass ejections at Earth orbit, Taktakishvili, P. MacNeice, D.Odstrcil, Space Weather, 2010.



- Evaluation of WSA/ENLIL cone model performance studying CME events that caused 36 particularly large geomagnetic storms.

Modelling of CMEs That Caused Particularly Large Geomagnetic Storms Using WSA/ENLIL Cone Model, Taktakishvili, Pulkkinen, P. MacNeice, M. Kuznetsova, M. Hesse, D.Odstrcil, *Space Weather, 2011*.



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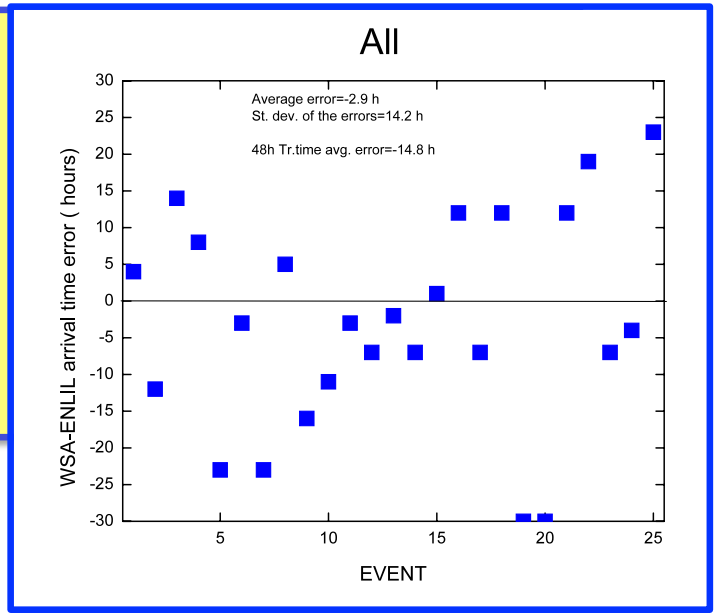
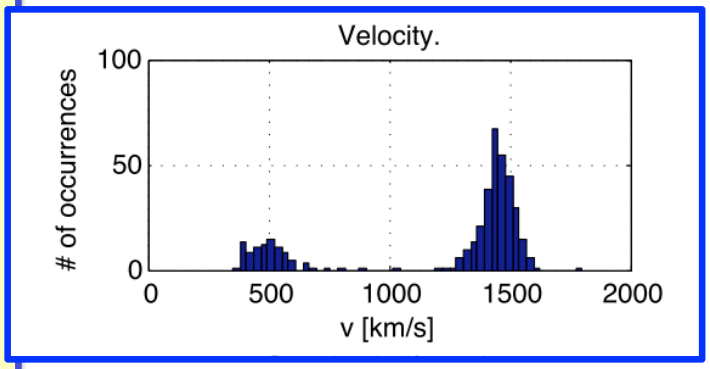
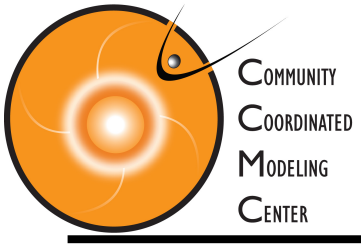
Cone Model Validation

- Validation of Real time WSA-ENLIL cone model run system.
  - *In progress*



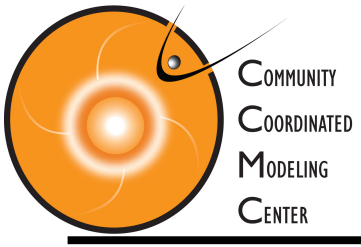
- Ensemble Forecasting of ICME arrival
  - Dan Emmons, Thesis, AFIT.
  - Using automated analysis (Pulkkinen et al., 2010)
  - *In progress*





Magnetospheric Models

(based on info from Lutz Rastaetter, Yihua Zheng, Masha Kuznetsova)



Magnetosphere/ionosphere model validations

Slide Courtesy L.Rastaetter

GEM 2008-2009 Modeling Challenge

- Magnetic field perturbations on the ground

  Pulkkinen et al., Systematic evaluation of ground and geostationary magnetic field predictions generated by global magnetohydrodynamic models, JGR 115, A03206, DOI: 10.1029/2009JA014537, 2010.

- Geosynchronous magnetic fields (SWMF, OpenGGCM at CCMC)

  L. Rastaetter et al. Geospace Environment Modeling 2008–2009 Challenge: Geosynchronous magnetic field. Space Weather 9, S04005 DOI:10.1029/2010SW000617

- DST index (models at CCMC + results submitted by modelers)

  L. Rastaetter et al., Geospace Environment Modeling 2008–2009 Challenge: Dst index, Manuscript in preparation for Space Weather.

Slide Courtesy L.Rastaetter

Web interface for model validation

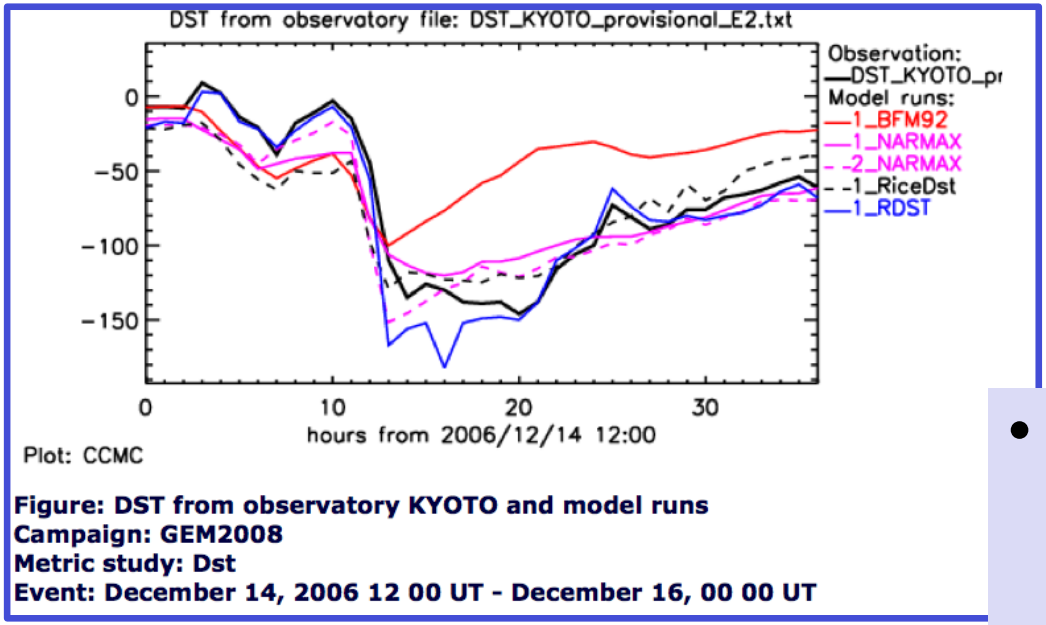


Figure: DST from observatory KYOTO and model runs
Campaign: GEM2008
Metric study: Dst
Event: December 14, 2006 12 00 UT - December 16, 00 00 UT

- Time series data from a wide variety of models and quantities.
- Skill scores computed with plots.

Variable: DST Observation file: DST_KYOTO_provisional_E2.txt

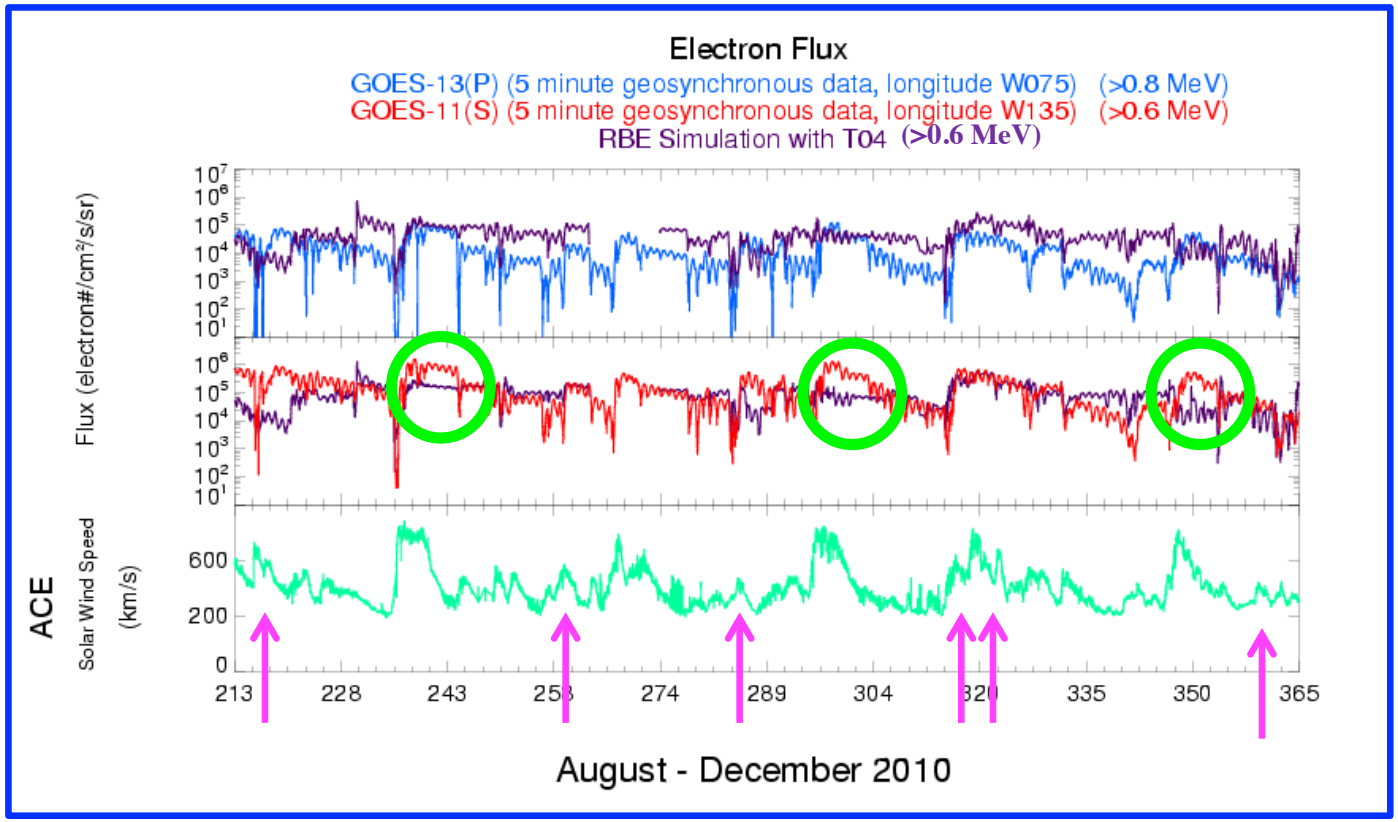
Model_Setting	PredEff	N_region	N_finite	PredYield	MinTimingError	MaxTimingError	Correlation
1_BFM92	-0.111	37	37	0.592	7.000	2.000	0.411
1_NARMAX	0.837	37	37	0.680	4.000	2.000	0.959
2_NARMAX	0.855	37	37	0.866	7.000	7.000	0.946
1_RiceDst	0.791	37	37	0.718	7.000	0.000	0.906
1_RDST	0.899	37	37	1.194	4.000	0.000	0.969

Slide Courtesy Yihua Zheng

Internal validation

RBE

- Validation of Fok Radiation belt model running in realtime
  - Captures the long term trends but struggles during CIRs
  - Need to include wave-particle interactions and magnetic field fluctuations ?



CMES

CIRs

Lee, Zheng, Kuznetsova, et al.

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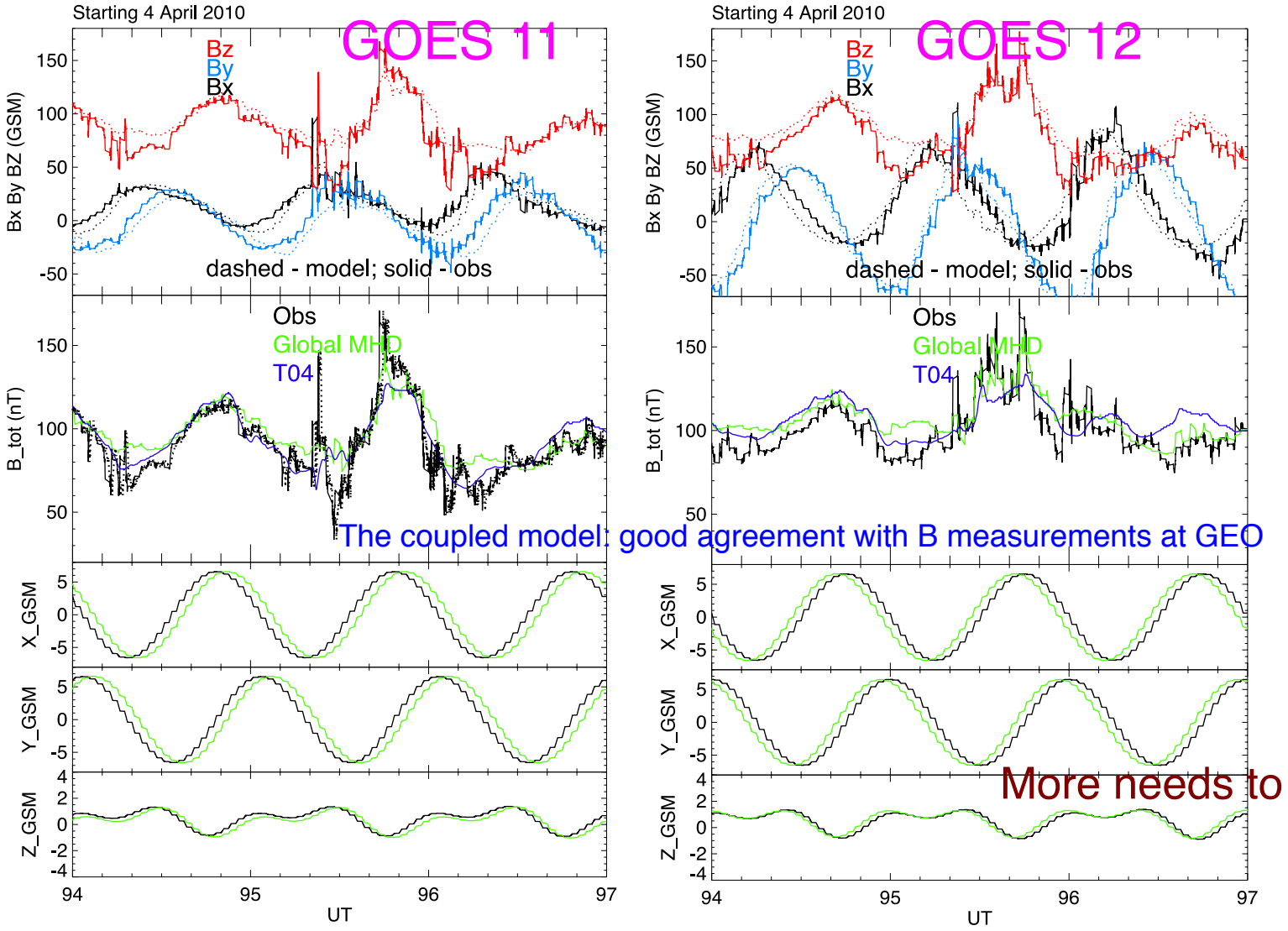
Slide Courtesy Yihua Zheng

Internal Model Validation

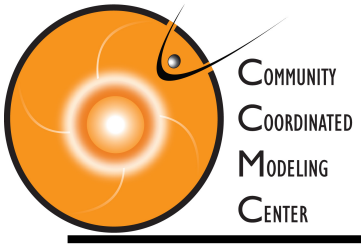
SWMF+RCM+RBE



The coupled model: good agreement with B measurements at GEO

More needs to be done

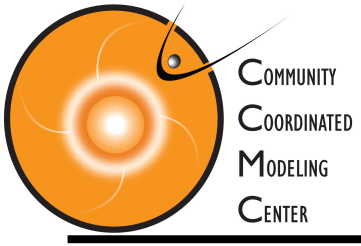
Zheng, Kuznetsova, Rastaetter, et al.



Ionospheric and Thermospheric Models

(based on info from Lutz Rastaetter, Yihua Zheng, Ja Soon Shim)

Much of this covered already in talks by
Barbara Emery
Stan Sazykin
Ariel Acebal
John Retterer (aka Ja Soon Shim)



Slide Courtesy Ja Soon Shim

ITM : Validation Study

- **Published**

  Shim, J. S., et al. (2011), CEDAR Electrodynamics Thermosphere Ionosphere (ETI) Challenge for systematic assessment of ionosphere/thermosphere models: NmF2, HmF2, and vertical drift using ground-based observations, *Space Weather, 9*, S12003, doi10.1029/2011SW000727.

- **Papers to be submitted soon**

  1. Invited article on the 'CCMC IT Challenge' for the AGU monograph on 'Modeling the Ionosphere/Thermosphere System.'
  2. CEDAR ETI Challenge for systematic assessment of IT models: Electron density, Neutral density, NmF2, and HmF2 Using Space Based Observations

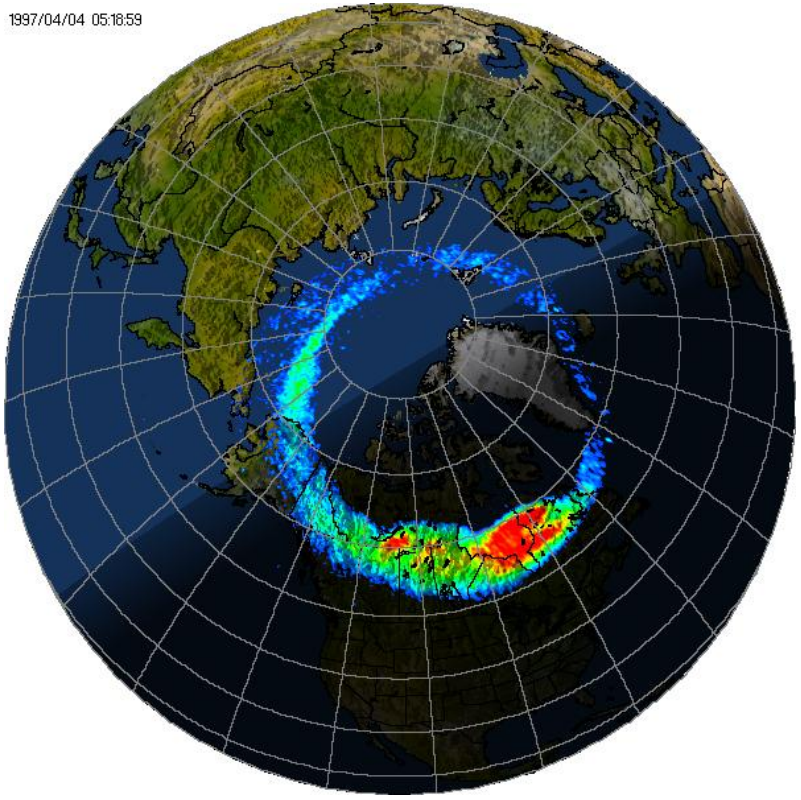
- **Papers in Preparation**

  1. Poynting Flux / Joule Heating along DMSP satellite tracks

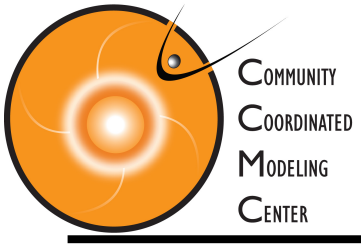
Collaborative model validation with AFIT: Auroral models

Collaboration with Maj. Lane, Lt. Col. Acebal

- Ovation Prime (OP)
- New Hardy (NH)
- Old Hardy (OH)
- SWMF – Fok-RC (SWMF)
- AMIE – (AMIE)



Slide Courtesy Yihua Zheng



Summary

- Extensive list of studies published or in progress
- Validation pace has accelerated considerably over the last two years
- For more specific details, talk to
  - Solar and Helio – Me, Sandro, Antti
  - Magnetospheric – Lutz, Yihua, Masha
  - IT – Ja Soon, Yihua, Lutz