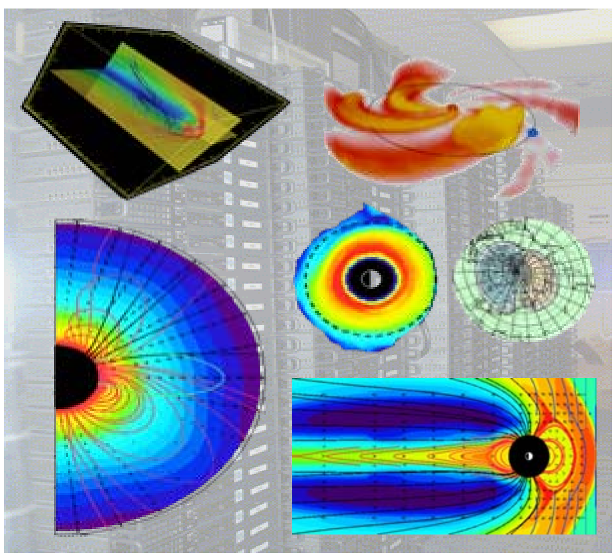
Community
Coordinated
Modeling
Center

CCMC Operations Support, Metrics and V&V Report



M. Kuznetsova, A. Taktakishvili, P. MacNeice
M. Hesse, L. Rastaetter, A. Chulaki

CCMC Workshop,

Arecibo 2007

http://ccmc.gsfc.nasa.gov

CCMC Function

- Provide tool by which science progress at NASA, NSF feeds into Space Weather operations
- Perform independent and unbiased testing and validation of science models with operational benefits

Outline

- Operations Support Activities
- Role of Runs on Request System Users in V&V
- Examples of Metrics and V&V
- Other Metrics Opportunities and Future Plans
- Outlook

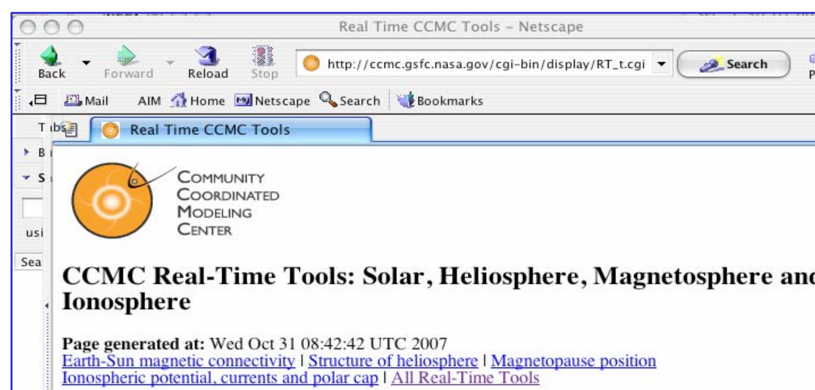
Model Testing and Validation Components

- **Science-based validation**
  - Test model validity
  - Detailed analysis for selected events, broad range of parameters
  - Broad feedback to code developers
  - Essential for further model improvement
- **Metrics**
  - Measure model usefulness for operations in comparison with some simple standard model.
  - Focus on parameters useful for operations
  - Repeatable comparison between model output and measurements.
  - Blind studies
- **Test model robustness**

Operations Support Activities: Model Testing for Operational Environment

- Experimental real-time simulations 24/7
  - http://ccmc.gsfc.nasa.gov
    - BATSRUS/SWMF (2001)
    - Fok ring current (2003)
    - Chain of solar and heliospheric models (WSA, PFSS, ENLIL) (2006)

- Quasi-operational real-time tools (tailored to NOAA SWPC specifications)
  - http://ccmc.gsfc.nasa.gov/cgi-bin/display/RT_t.cgi



L. Rastaetter, P. MacNeice

Operations Support Activities:
R2O Workshop support

- Releases of historic event simulations in "real-time"
  - http://ccmc.gsfc.nasa.gov/R2O

- Expose models to operators
- Help to tailor model output to operator needs
  - Help to define what visualization is useful
  - Help develop templates for future real-time pages
  - Tool for feedback

A. Chulaki, M. Kuznetsiva
L. Rastaetter, P. MacNeice

Role of RoR Users in V&V

2001 – 2003: ~ 200 requests,
2004 – 2005: ~ 400 requests,

2006 – 2007: ~ 1100 requests,

- 60 publication/presentations
- informal feedback from users

Development/utilizing of “ready-for-validation” tools:

- output along trajectories
- time series
- vertical profiles

Simulation setup according to user specifications

ENLIL Background SW Model Metrics

- Comparison of the ENLIL model simulation results with the ACE satellite data.
- Both simulation and observation data are smoothed over 6 hour period for entire CR time interval.
- Mean model as reference

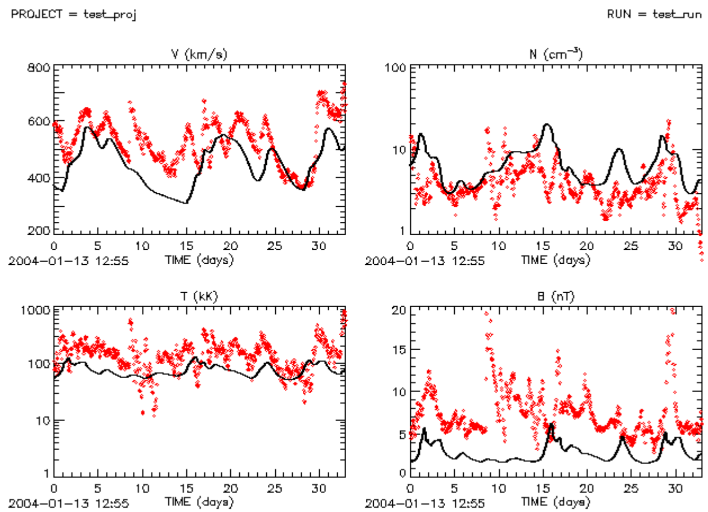
$$M = 1 - \frac{D_{mod}}{D_{mean}}$$

- Skill score calculation for
  - different input coronal models,
  - different observatory magnetograms.

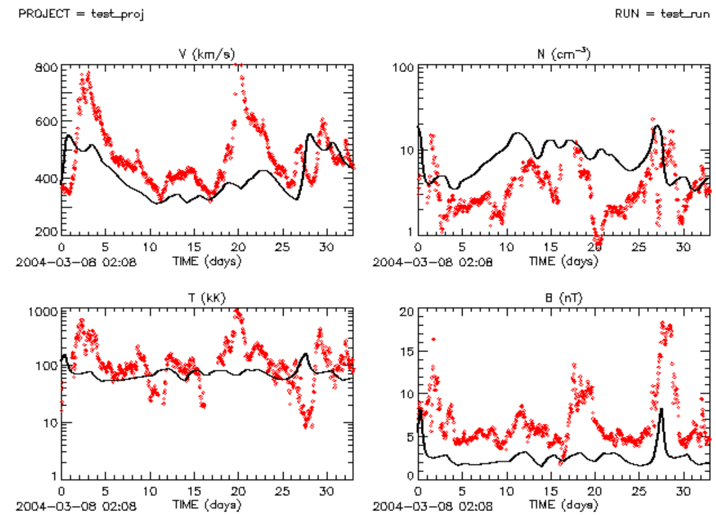
S. Taktakishvili

Comparison of the ENLIL results to the ACE data for the randomly selected CR-s

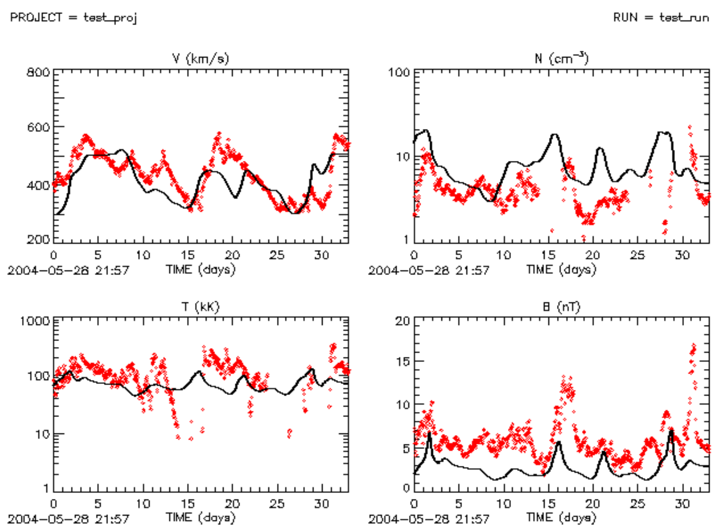
CR 2012



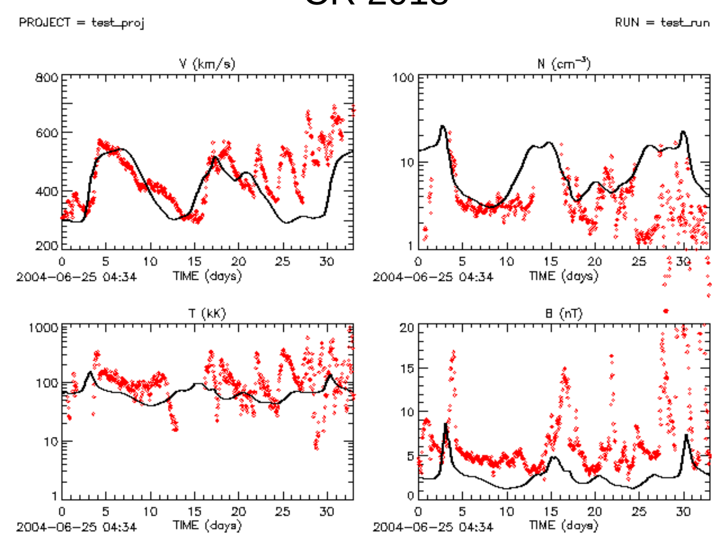
CR 2014



CR 2017



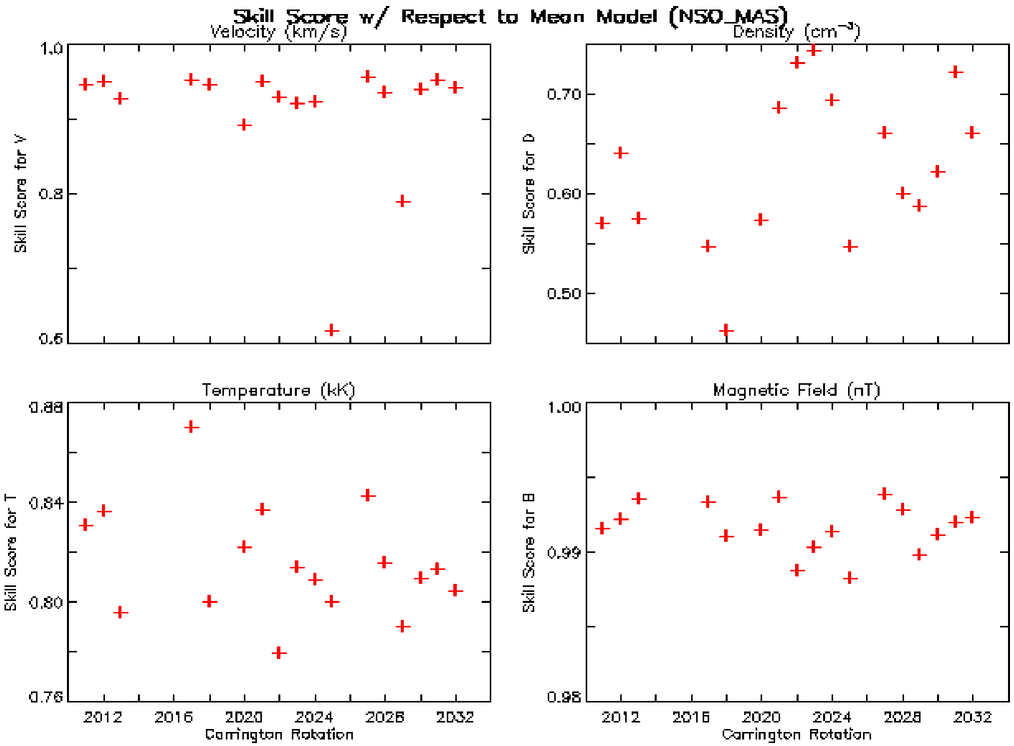
CR 2018



Skill Score statistics
(Skill Score vs CR number)

Coronal model:
MAS

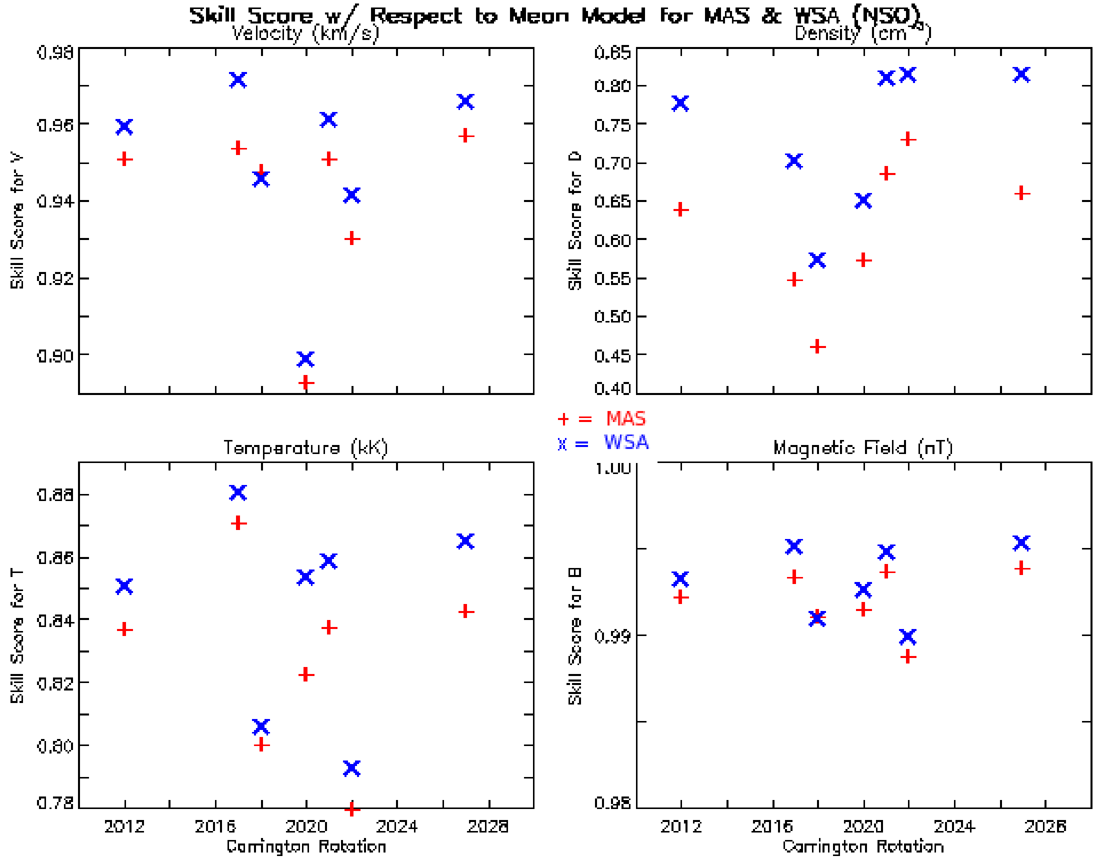
Input magnetogram:
NSO



- Model performs much better than mean model for all parameters.
- Velocity has the highest skill score, followed by magnetic field magnitude, then temperature and density at the end.

S. Taktakishvili

Skill Score for different input solar corona models - MAS and WSA



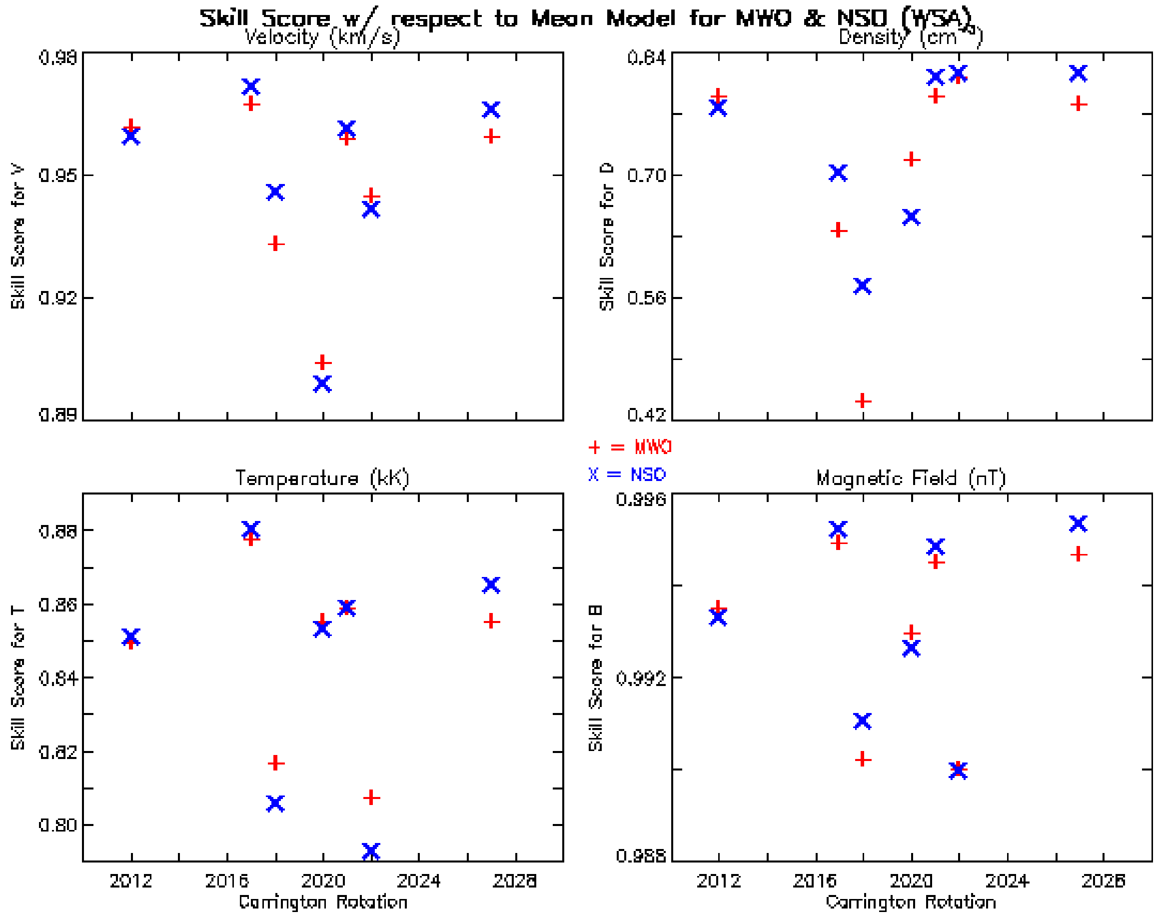
Input magnetogram: NSO

Model performs slightly better for the WSA than for MAS.

S. Taktakishvili

Skill Score for different input magnetograms - MWO and NSO

Input coronal model: WSA

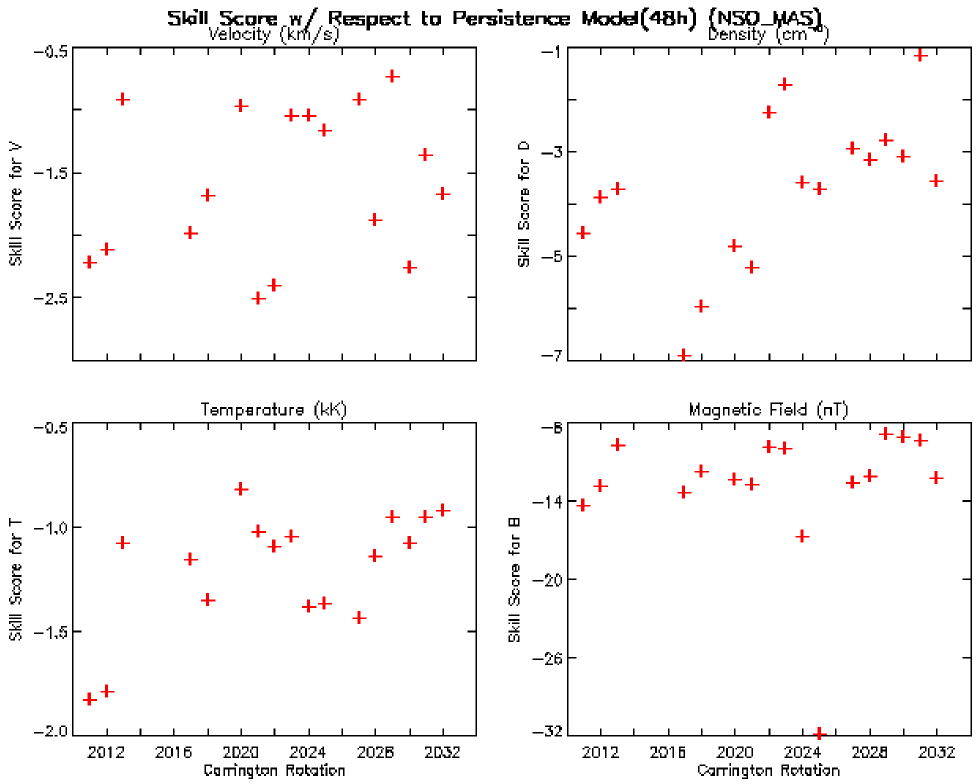


Model performs slightly better for the Kitt Peak Observatory (NSO) than for the Mount Wilson Observatory (MWO) input magnetograms.

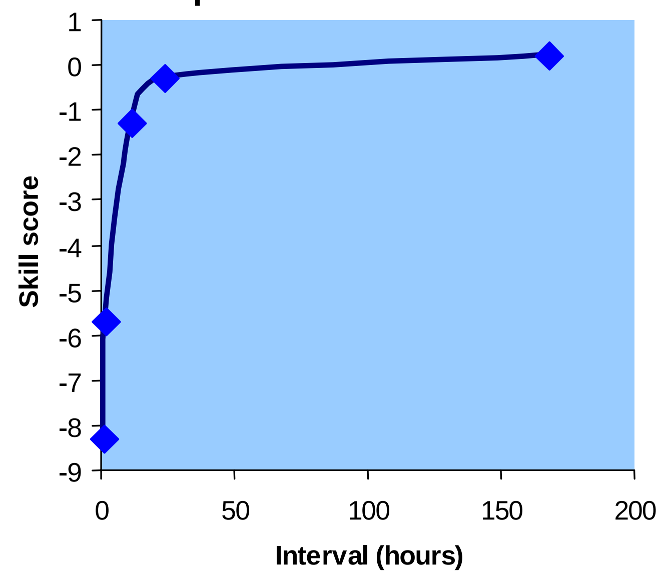
S. Taktakishvili

Skill Score with respect to Persistence Model

Persistence interval 48 hours

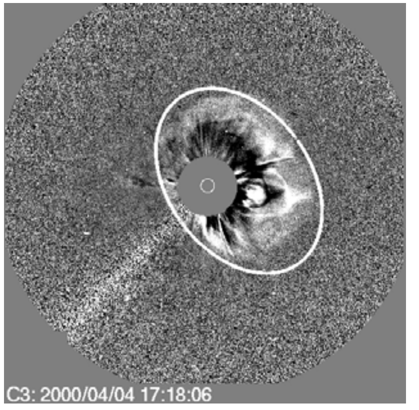


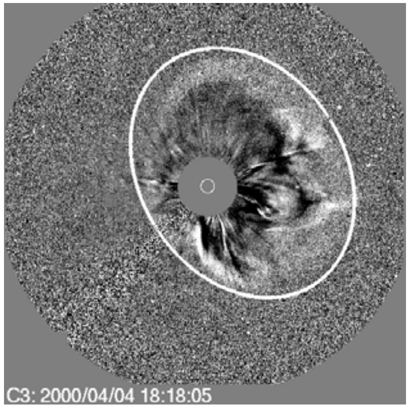
Skill score as a function of persistence interval



S. Francis, S. Taktakishvili

Enlil Cone Model (D. Odstrcil)





Enlil Cone model input is generated using a set of consecutive SOHO LASCO C3 Running Difference images (minimum two)

S. Taktakishvili

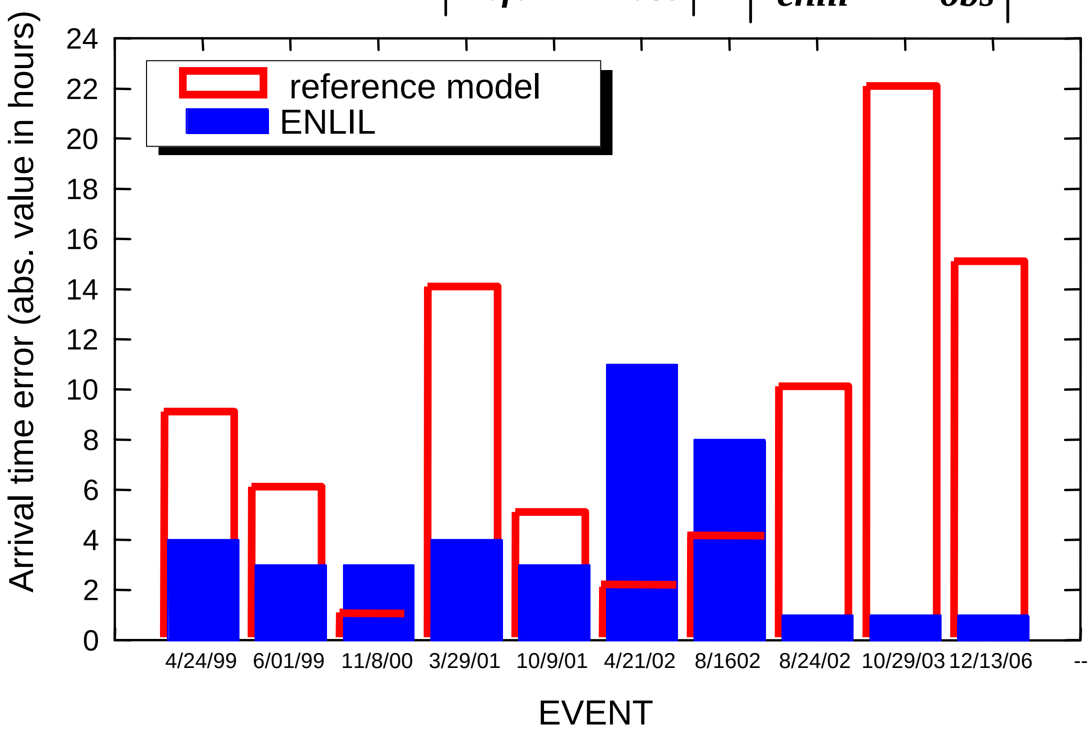
Enlil Cone Model Prediction Validation

- CME **arrival time** prediction
- **Strength** of impact
- **Duration** of activity

- Future plans: Event prediction
  - % of time magnitude exceeds a threshold
  - % of time magnetopause inside geosynch. orbit
  - % of time Bz < 0

ENLIL Cone Model CME arrival time prediction

Shown here: $\left| t_{refer}^{arr} - t_{obs}^{arr} \right|, \left| t_{enlil}^{arr} - t_{obs}^{arr} \right|$



Reference Model: ballistic propagation with the average velocity (average of Halo CME speed from the CME catalogue).

V_{avg}=850 km/s

Average propagation time to the ACE satellite:

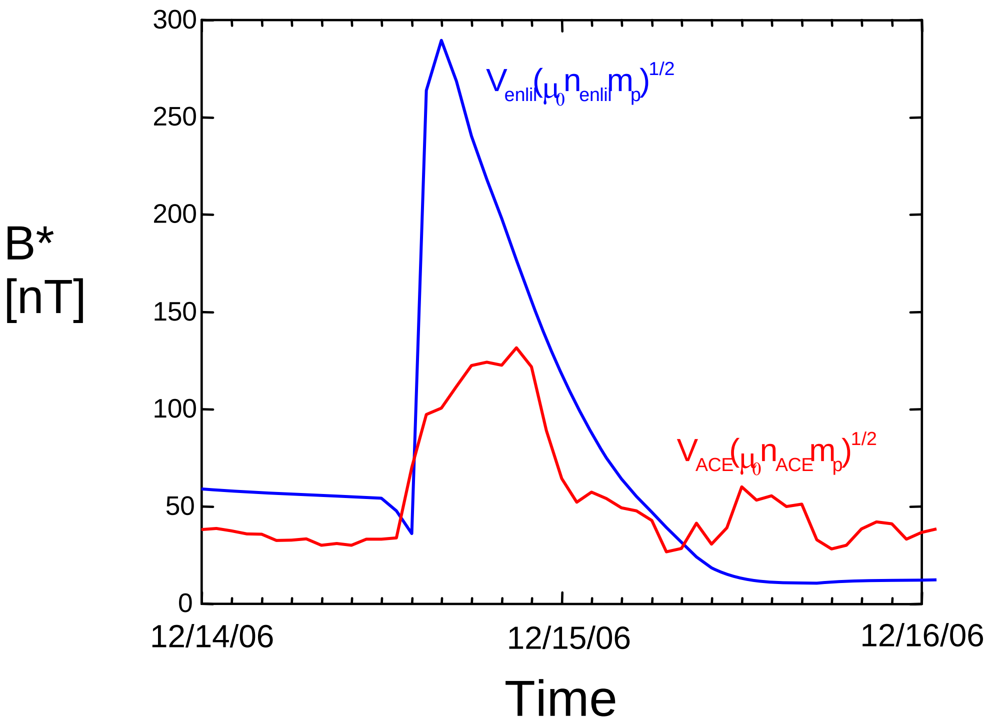
T_{avg} (prop) = 48 hours

Future plans:

- Error bars due to uncertainty in cone model parameters
- Utilize STEREO SWAVES data to better estimate CME speed

S. Taktakishvili,
S. Krog,
P. MacNeice

Strength of Impact



Magnetic field strength required to stop the SW

$$m_p\, n_{sw}\, V_{sw}^2 = (1/\mu_0)\, B^{*2}$$

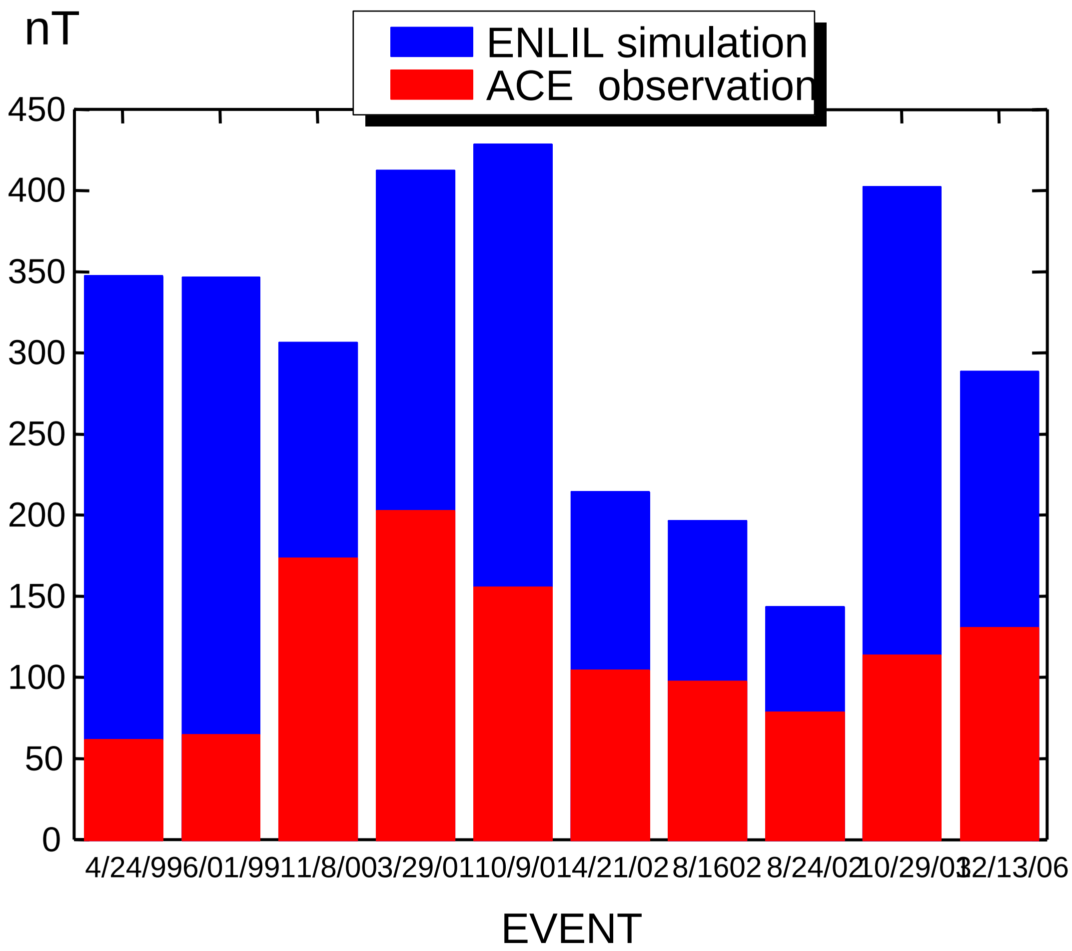
SW ram pressure

Estimated magnetic field at the magnetopause

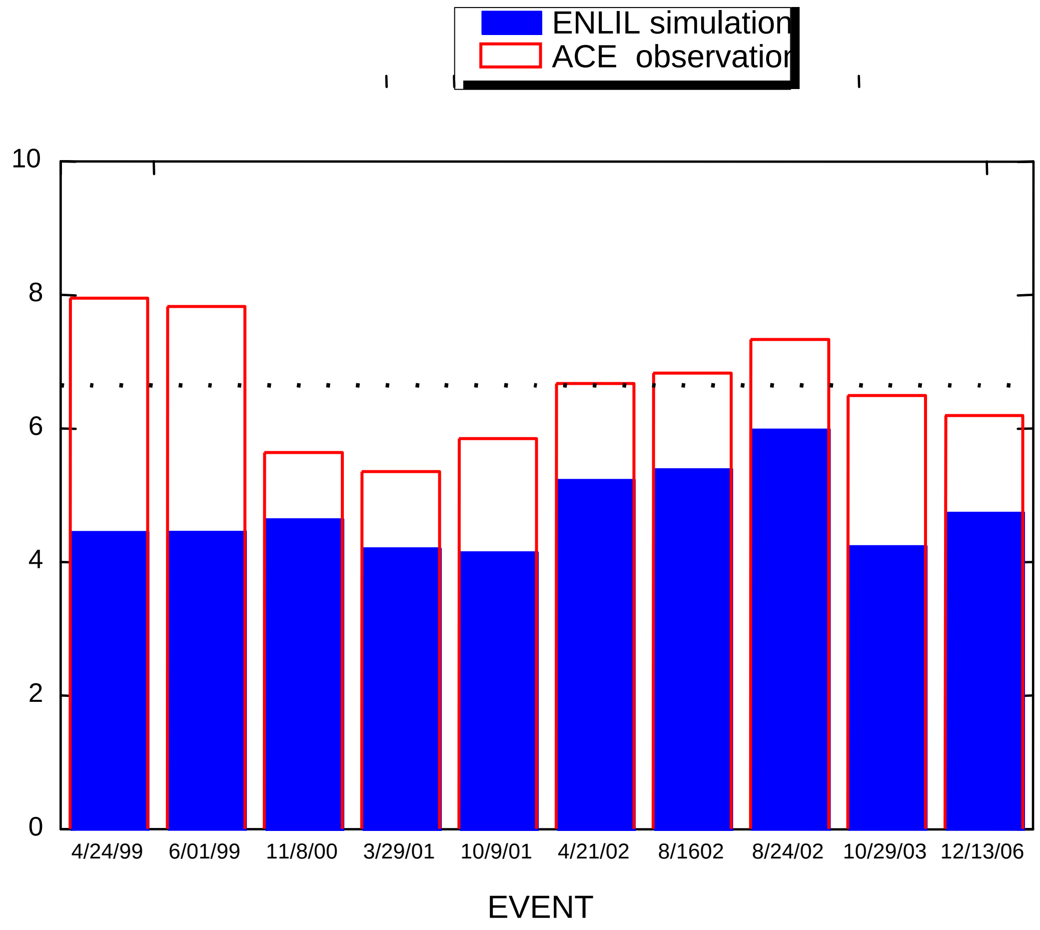
- Future plans: Time intervals of southward (Bz < 0)

S. Taktakishvili

Estimated Maximum Magnetic Field at the Magnetopause



Estimated Minimum Magnetopause Standoff



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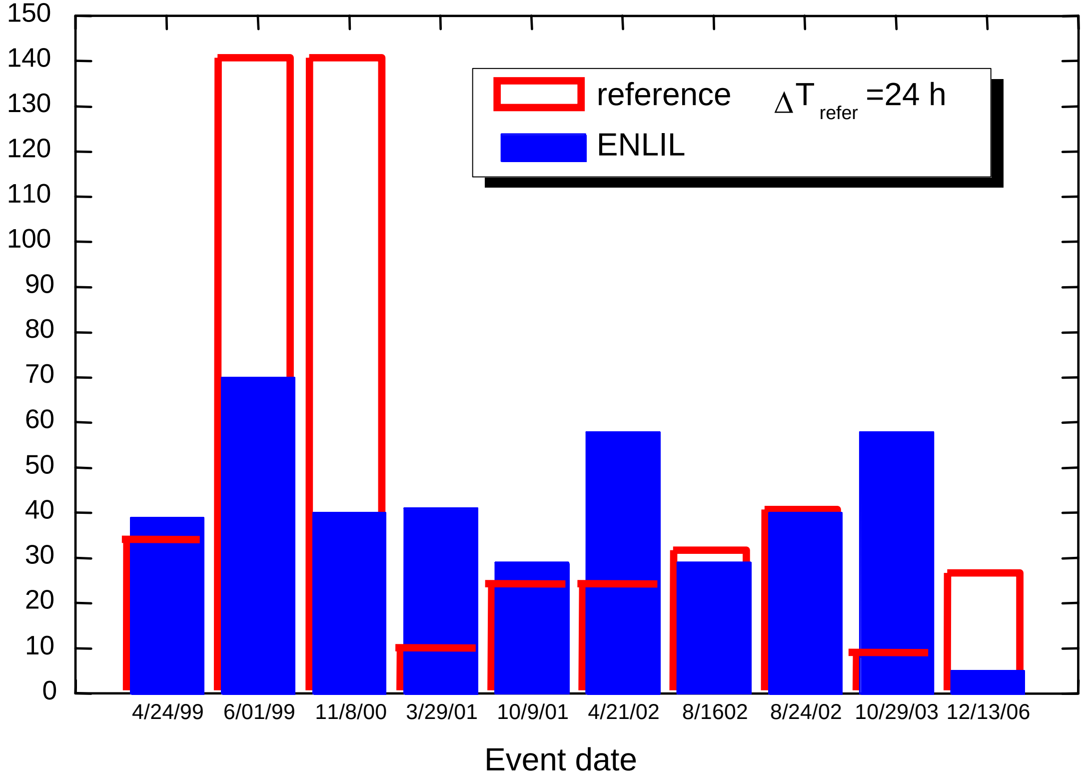
ENLIL Cone Model CME duration time prediction metrics

% Duration time error w/respect to ΔT_{obs}



Reference duration:

Mean duration of the **ram pressure** pulse at ACE observed for 10 studied CME-s:

ΔT_{refer} **= 24 hours**

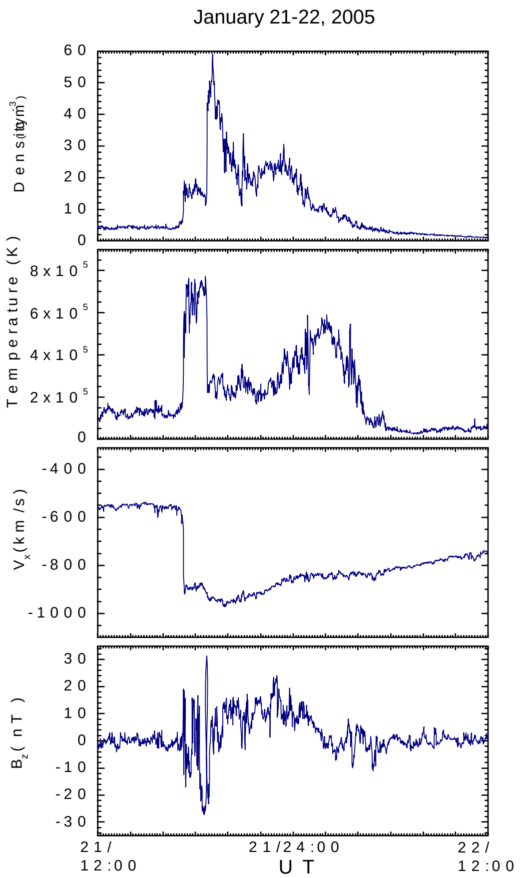
Shown here: $$\frac{|\Delta T_{refer} - \Delta T_{obs}|}{\Delta T_{obs}}, \quad \frac{|\Delta T_{enlil} - \Delta T_{obs}|}{\Delta T_{obs}}$$

S. Taktakishvili

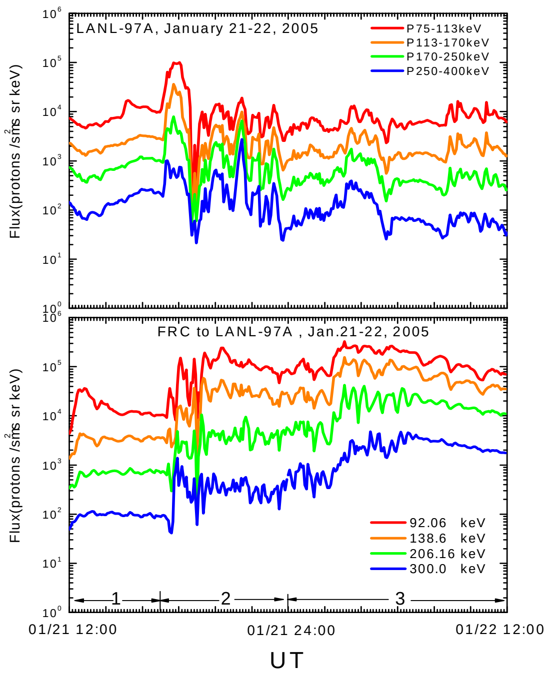
Coupled BATSRUS + Fok RC Models: 1-st event – directly SW driven RC

SW input to BATSRUS model
January 21-22, 2005 “CAWSES” event

LANL-97A observations & FRC model output for proton fluxes for 5 energy channels



Model performance is good (at least qualitatively)



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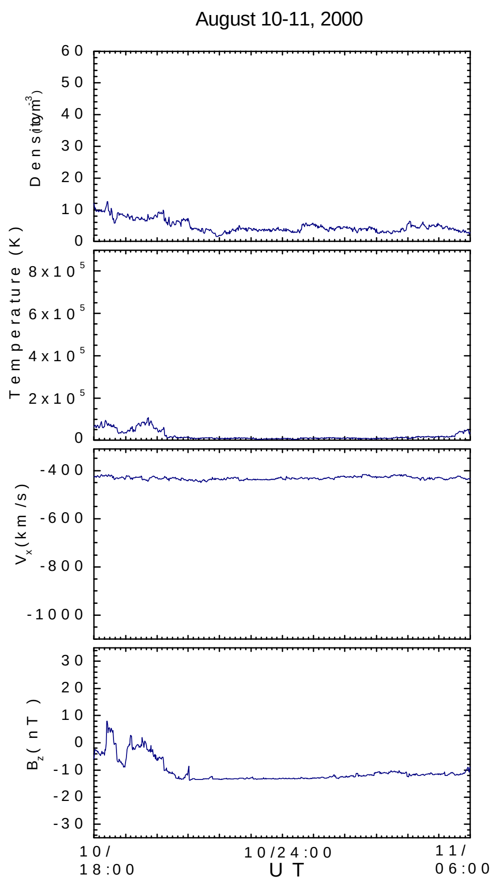
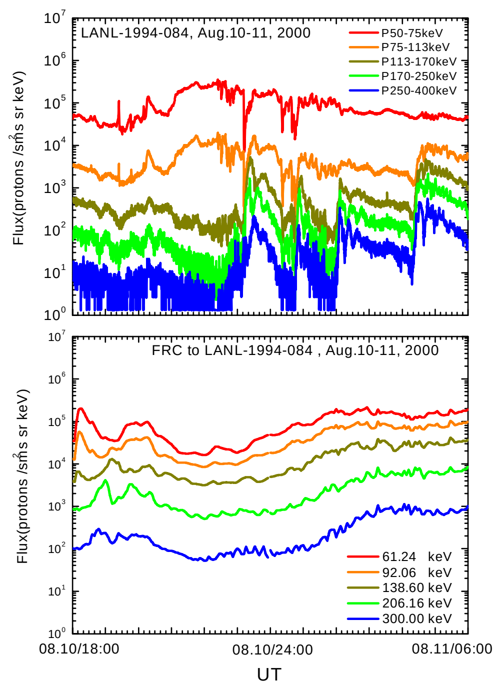
2-nd event – quasi steady Bz<0, “sawtooth” RC oscillations

SW input to BATSRUS model
August 10-11, 2000 event



LANL-1994-084 observations &
FRC model output for proton
fluxes for 5 energy channels

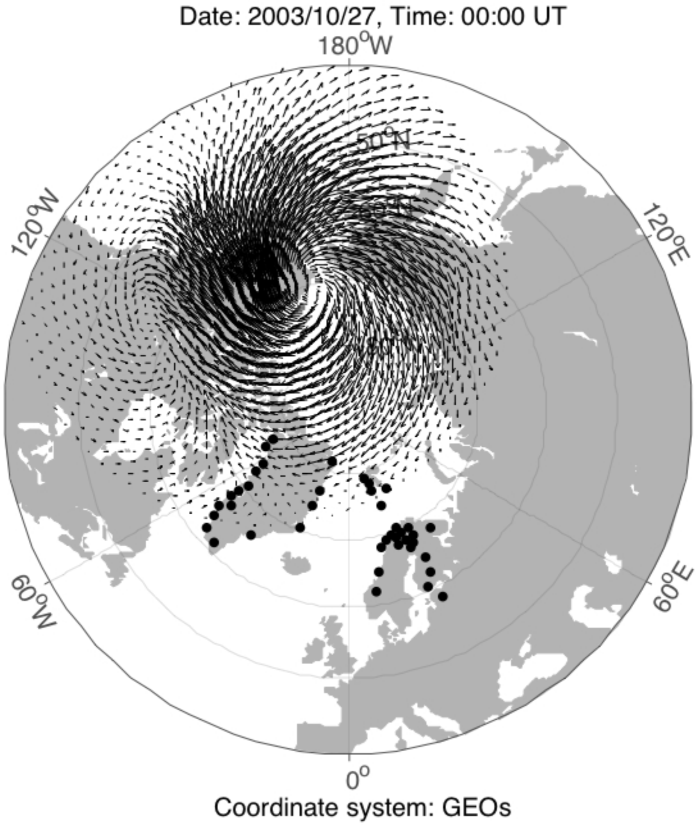


Model response is poor even qualitatively

Some internal dynamics is missing

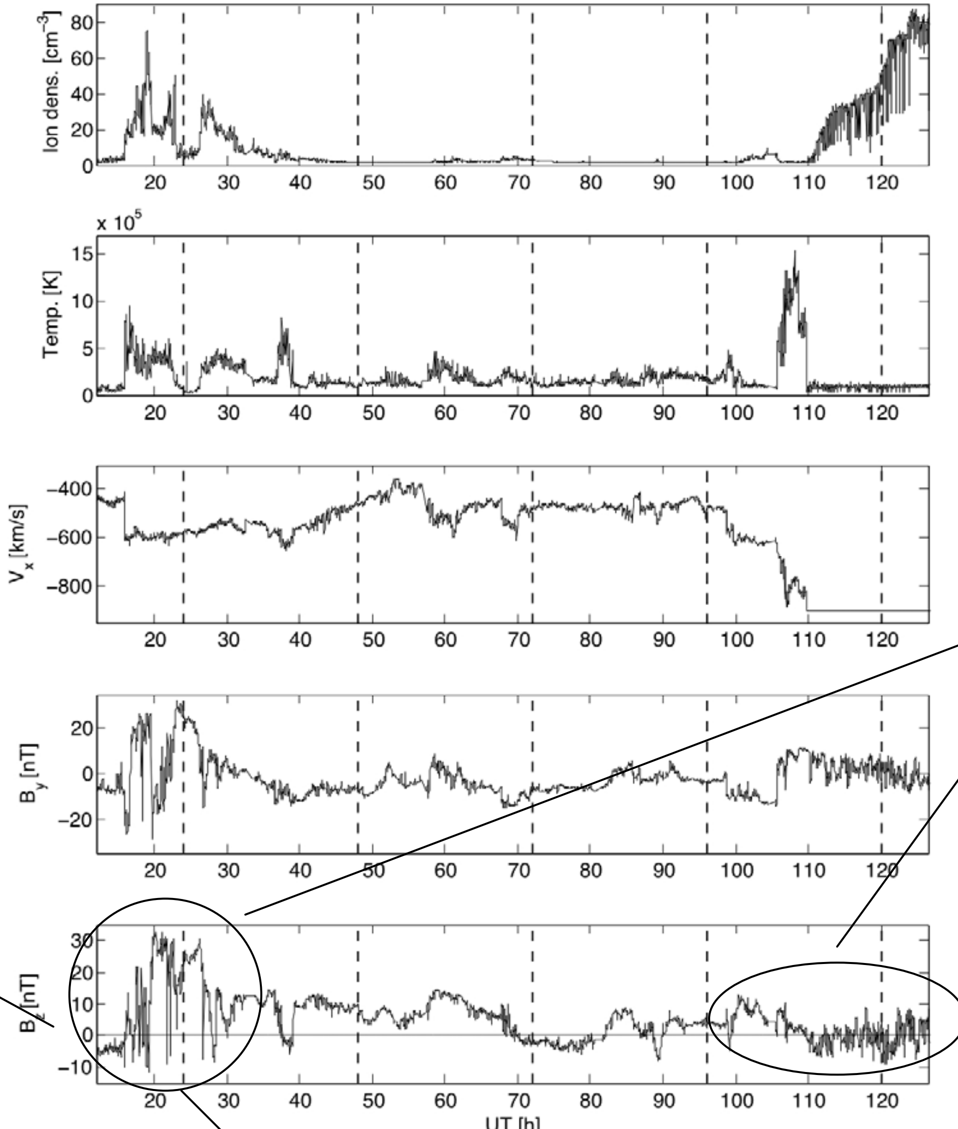
S. Taktakishvili

Oct 24-29, 2003 event - snapshot



A. Pulkkinen

Oct 24-29, 2003 event - the driver



Highly fluctuating IMF

Several moderately negative “sweeps”

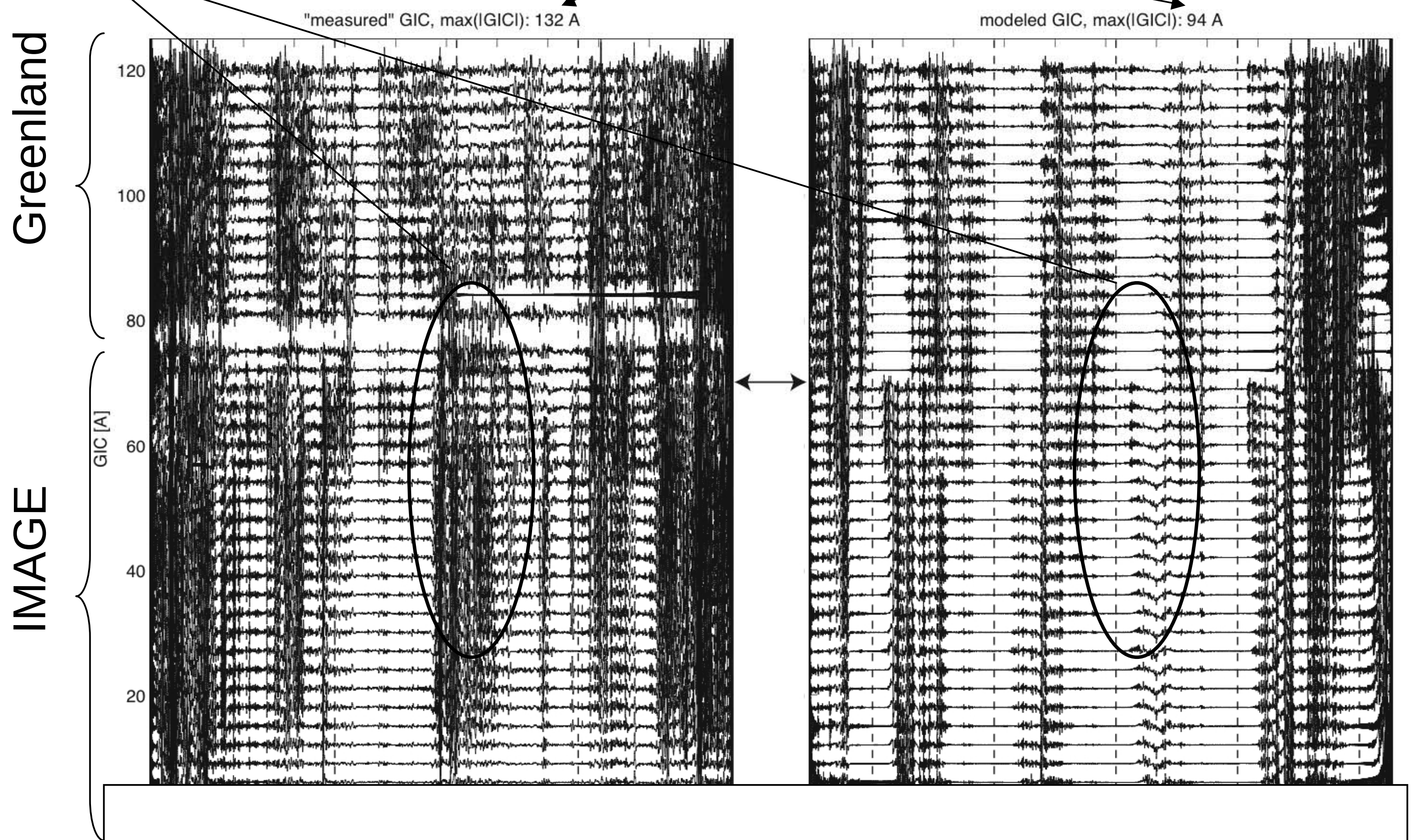
Dashed line: new UT day

A. Pulkkinen

Some (internal?) dynamics missing

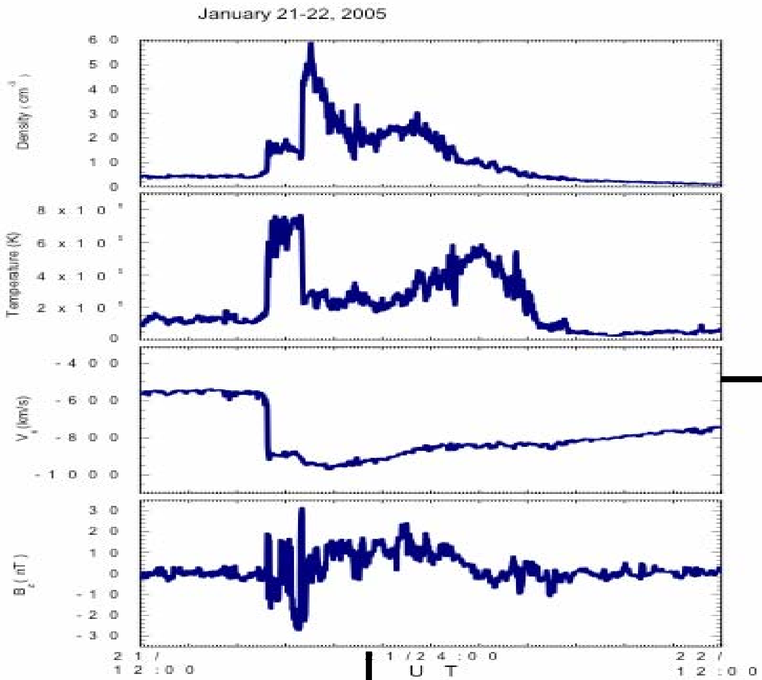
Comparable magnitudes

A. Pulkkinen



However, in general, the qualitative spatiotemporal morphology perhaps surprisingly similar.

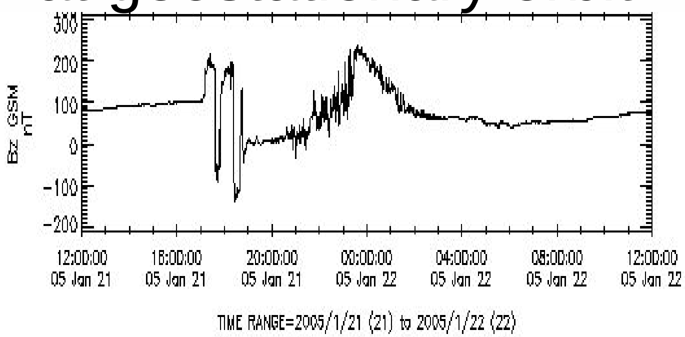
Dynamic Solar Wind Input



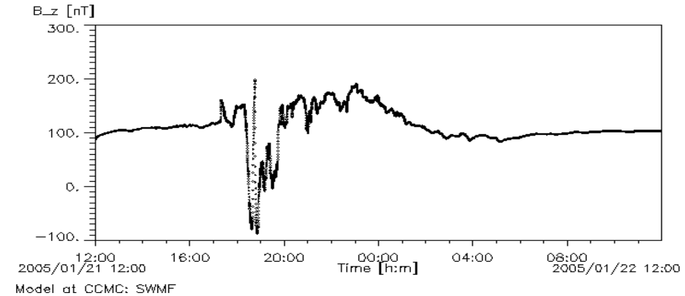
Simulations

QuickTime™ and a
GIF decompressor
are needed to see this picture.

Observations
at geostationary orbit



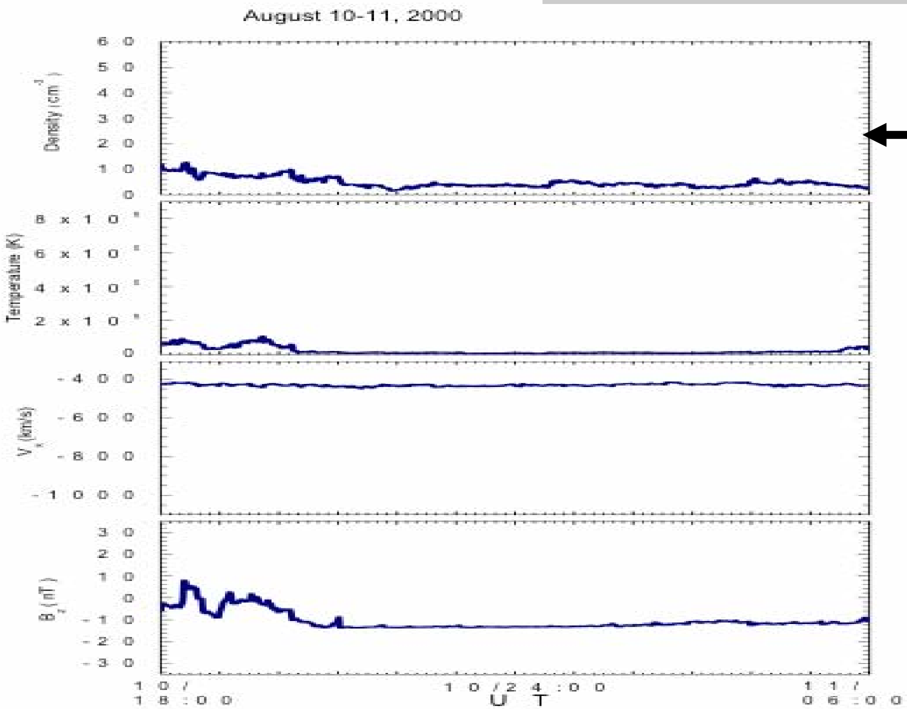
Simulations



Ideal MHD with Numerical Dissipation for Steady Southward IMF Driving

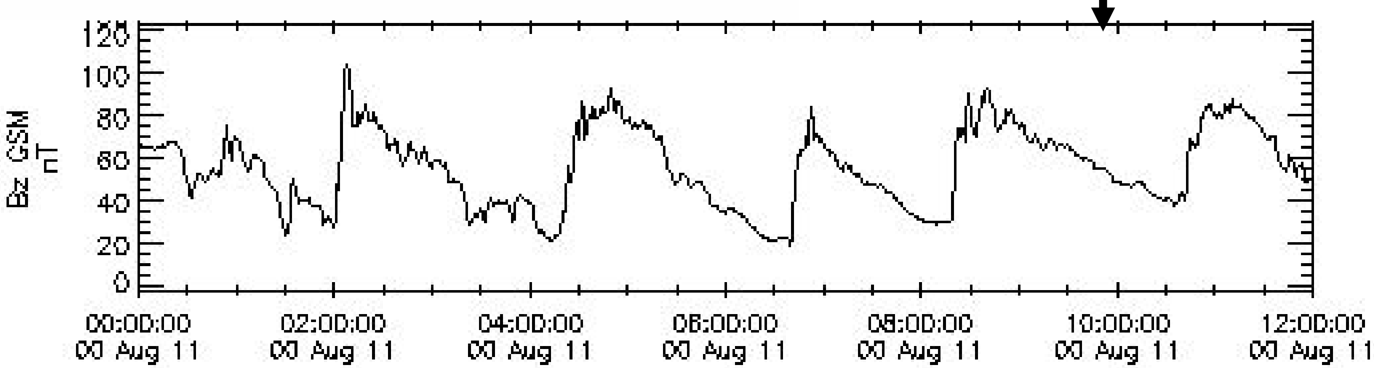
QuickTime™ and a
GIF decompressor
are needed to see this picture.

Steady Solar Wind Input



Input: quasi-steady southward IMF driving

Observations at geostationary orbit (GOES): quasi-periodic oscillations: 2 hours

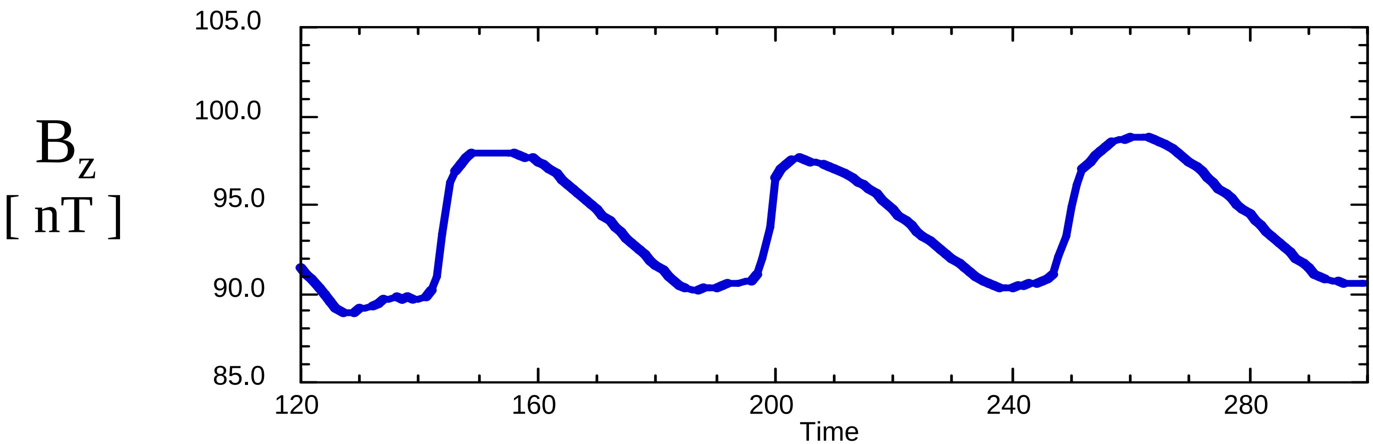


Non-MHD effects are important

Global MHD simulations with kinetic corrections at magnetotail reconnection sites

SW Input: Average SW parameters during August 10, 2000 sawtooth event

Signature at Geostationary Orbit: $X = -6.6\ R_E$, $Z = 0$



M. Kuznetsova

Future Plans

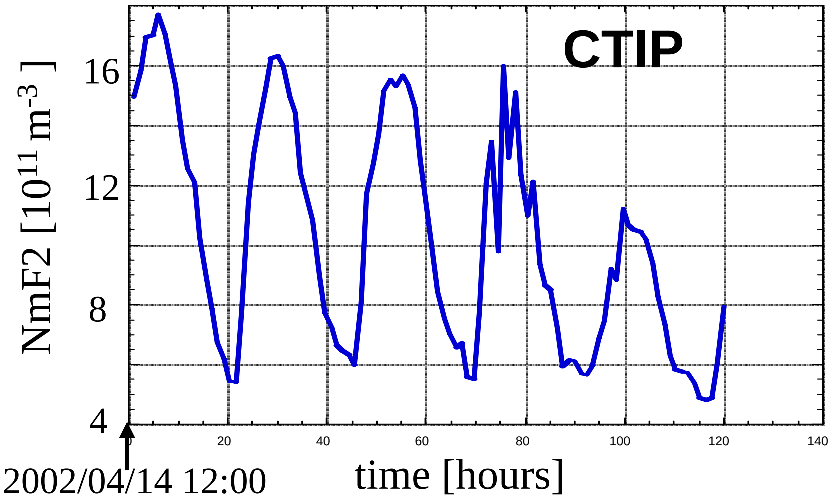
- Continue to follow National Space Weather Program Implementation Plan guidelines.
- Validation of other models (GAIM, AbbyNormal,…). Use Arecibo data.
- Focus on parameters most useful to operations.
- Work with operators to identify suitable visualization.
- Work with operators to identify suitable metrics.
- Explore event prediction metrics.
- Development of reusable V&V and metrics software.
- Expand RoR System to benefit V&V studies.
- Continue working with model developers to improve model performance.

We welcome suggestions!

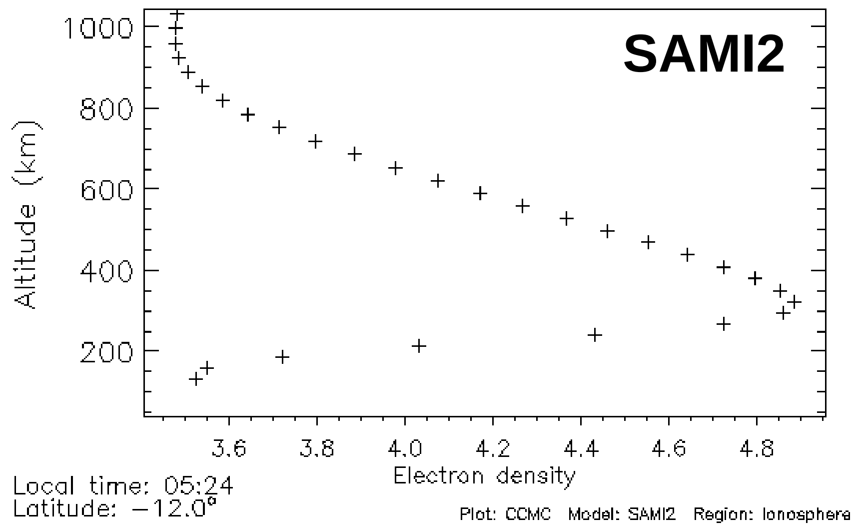
Other Metrics Opportunities. Ionospheric Forecasting.

Electron Density Parameters: Vertical Profiles, NmF2, TEC

Arecibo [18.3, 293.2]



Jicamarca [-11.96, 283.13]

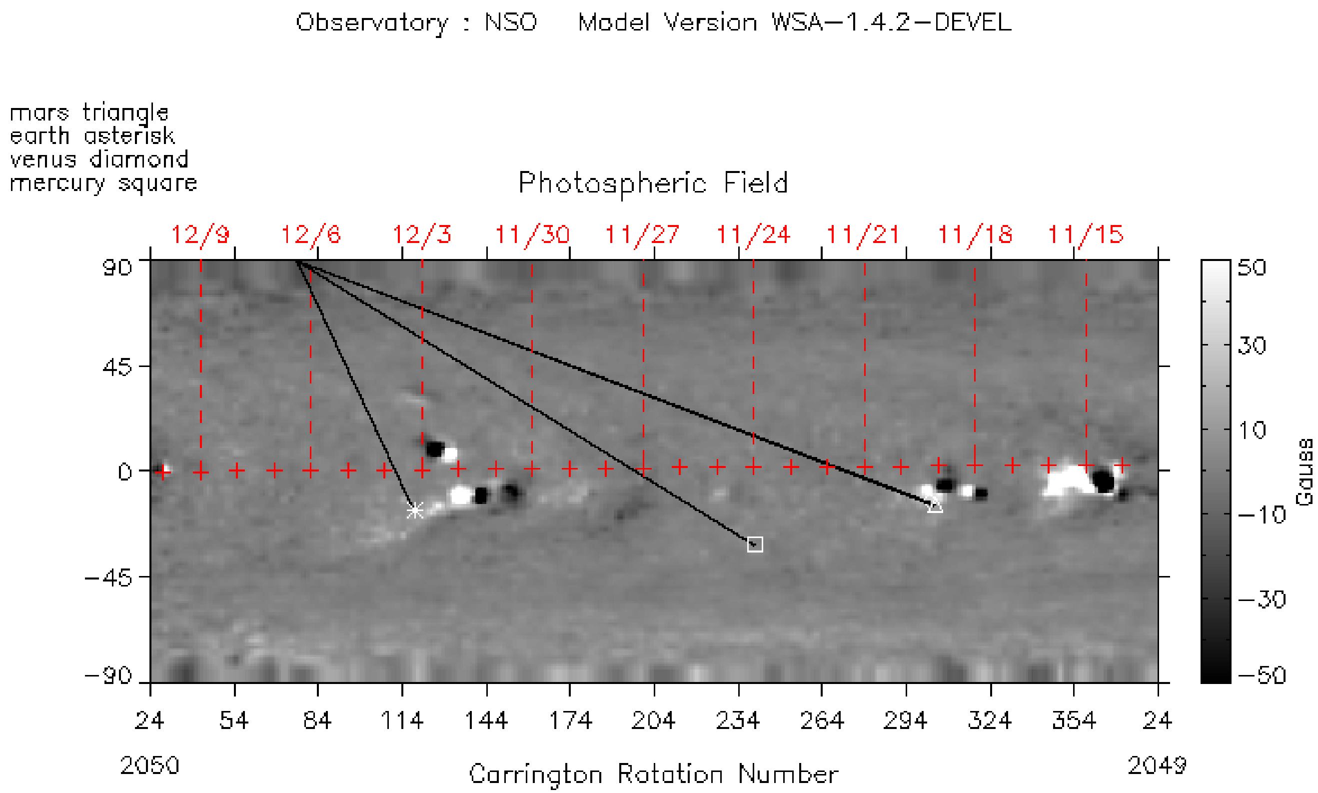


Models: CTIP, SAMI2, GITM2, GAIM

Observations: Incoherent Scatter Radars, GPS, Ionosonds

Supplementary Slides

Solar magnetogram + magnetic connection (WSA, ENLIL)

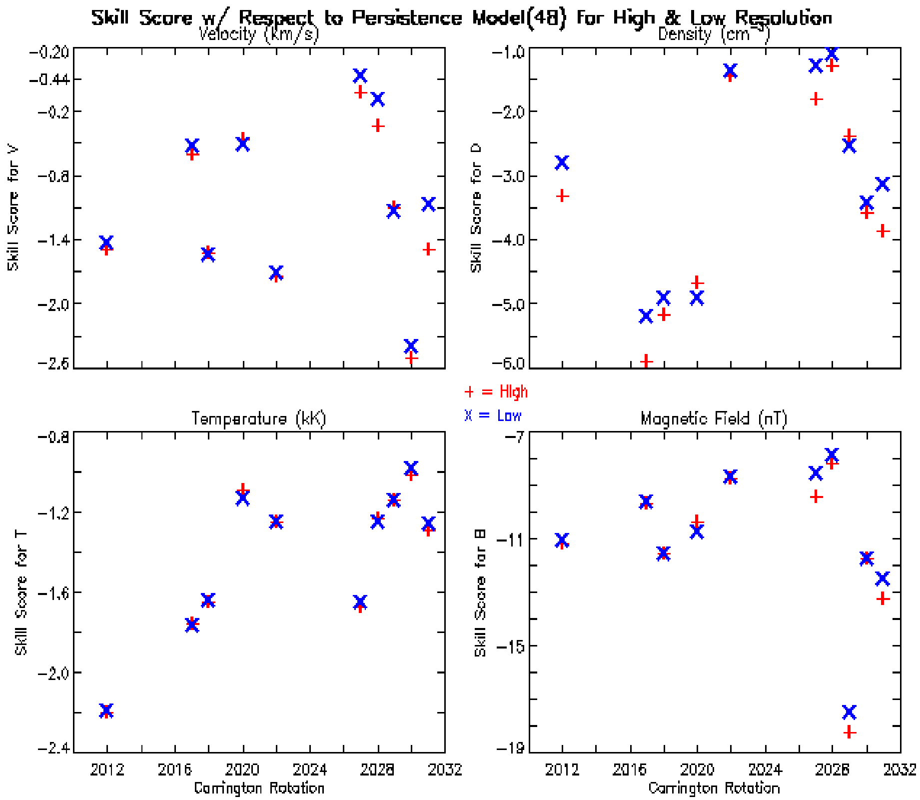


- The sun’s surface magnetic field and an estimate of the footpoints of the fieldlines connecting the 4 inner planets to the sun at a specific time. (Earth is *)
- Future plans: Footpoints on visible disk. Testing & validation.

P. MacNeice, B. Elliott

Metrics: Skill Score for modelling with Low and High spatial resolution

Input model: WSA
Input observ: NSO

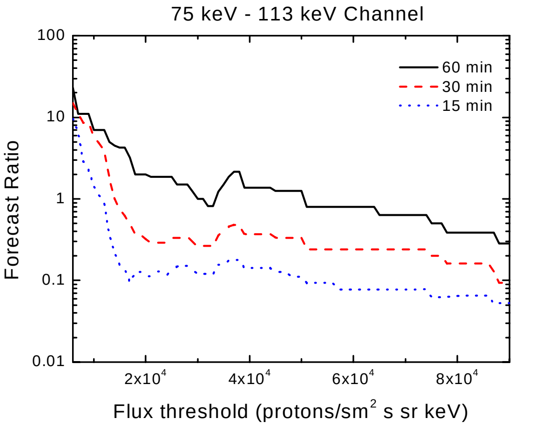


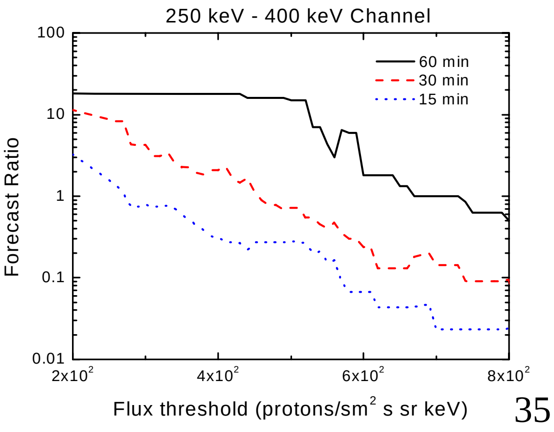
Model performs better for Low spatial resolution than for High spatial resolution simulation. This is true for all the parameters and almost for all simulated CR-s.

Event Prediction Metrics: Forecast Ratio

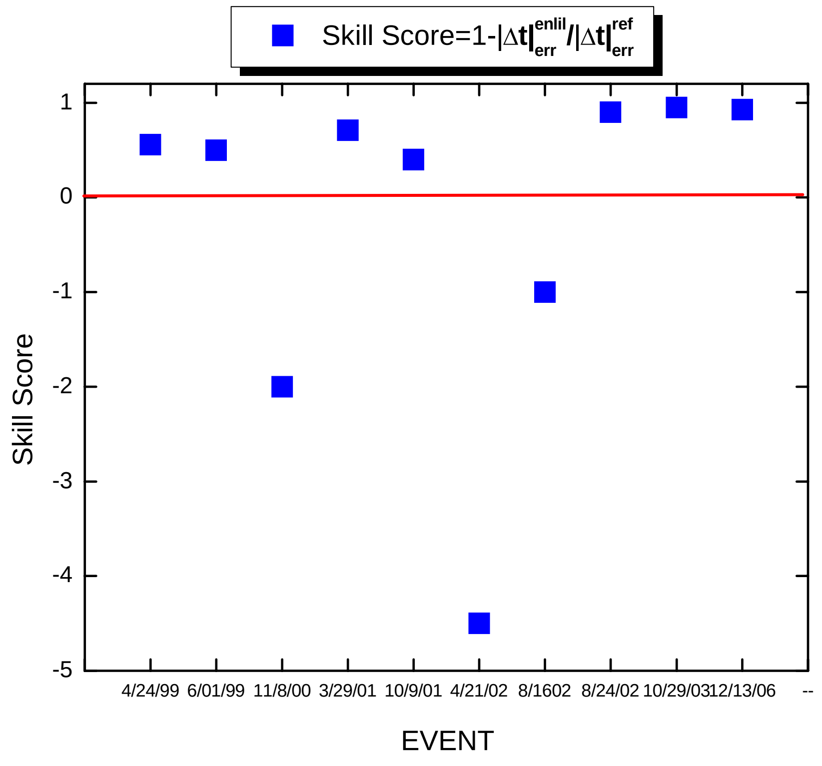
15,30 & 60 min windows,
2 energy channels

- Event: within a forecast window of length ΔT flux exceeds a threshold F_{thr}
- Correct forecast: both model and observation exceed F_{thr} at least once within a window
- False alarm if model predicts $F>F_{the}$ while observed flux never exceeds F_{thr}
- Forecast ratio: $N_{correct}/N_{false}$





ENLIL CME arrival time prediction metrics: Skill Score

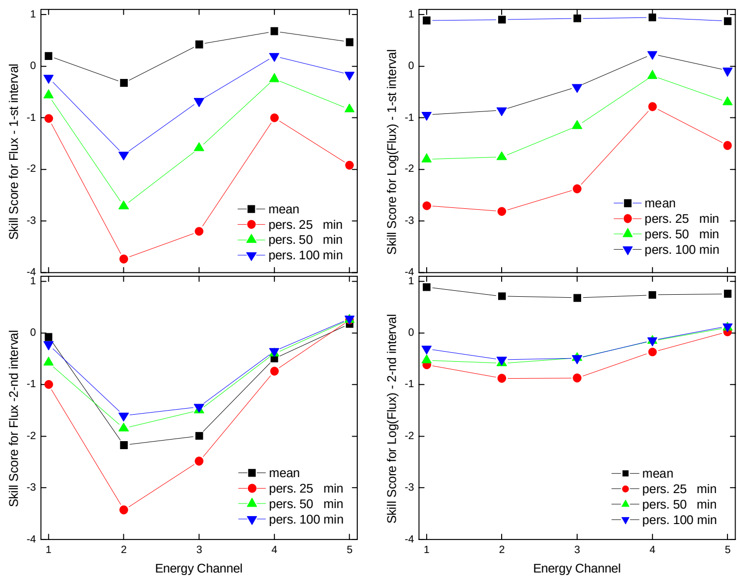


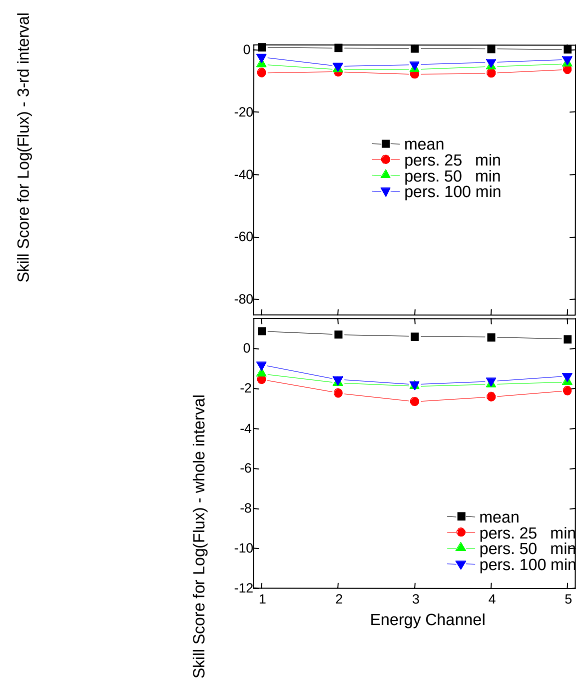
$$Skill\ Score = 1 - \frac{\left| t_{enlil}^{arr} - t_{obs}^{arr} \right|}{\left| t_{refer}^{arr} - t_{obs}^{arr} \right|}$$

Skill Score w/respect to the Mean and Persistence Models

Skill Score for:
1 - pre storm, quiet interval
2 - active interval

Skill Score for:
3 - post active interval &
the whole interval



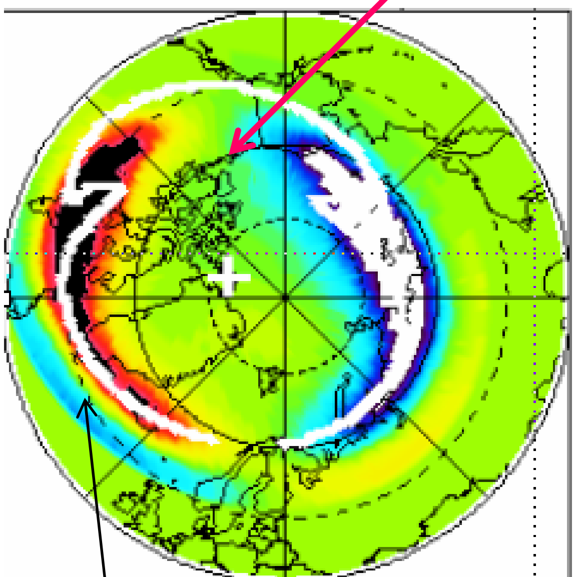


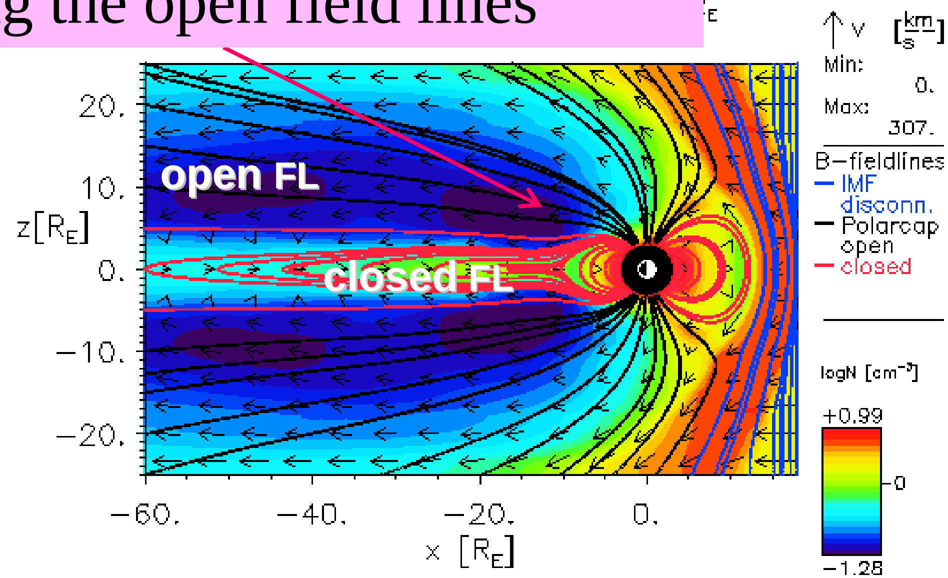
S. Taktakishvili

Polar Cap Boundary

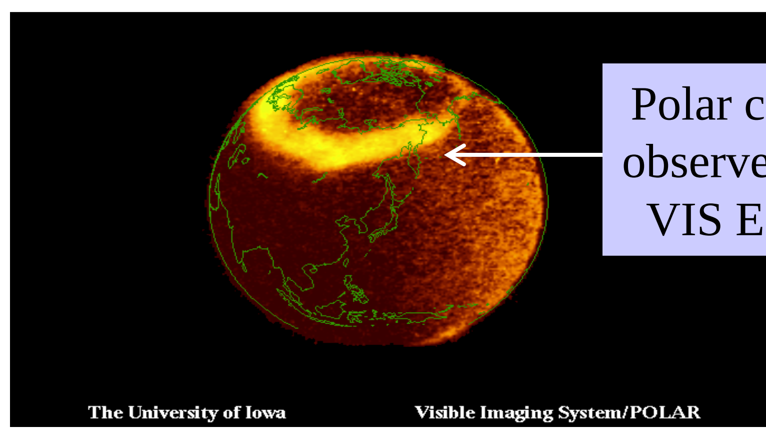
Boundary between open and closed field lines

SEP have free access along the open field lines





Energetic particles precipitation from the tail

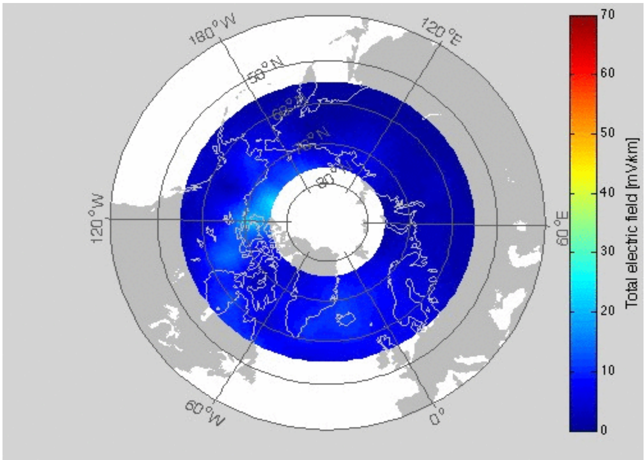


Polar cap boundary observed by POLAR VIS Earth Camera

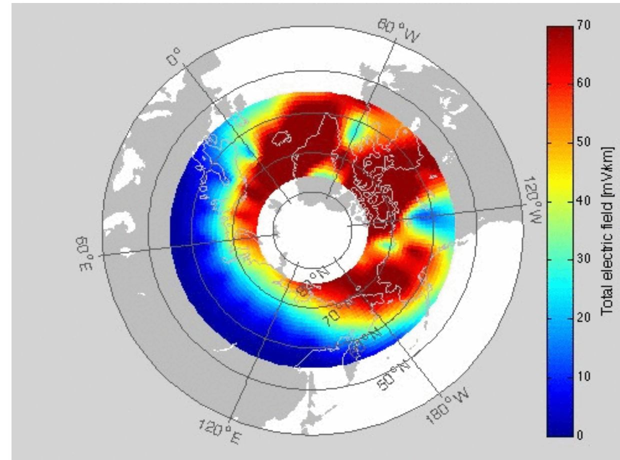
L. Rastaetter

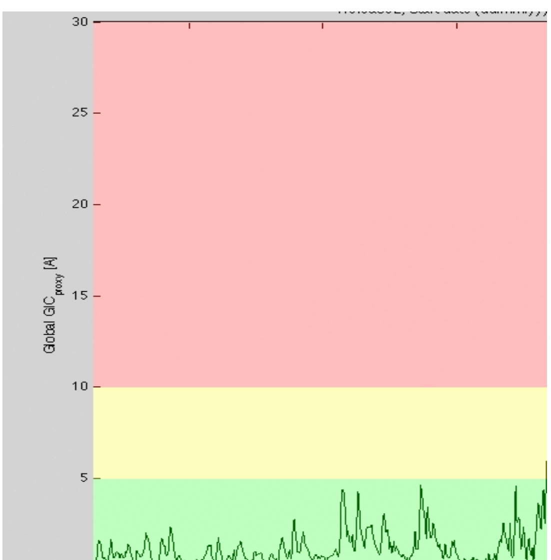
Geomagnetically Induced Total Electric Field (GIE)
Geomagnetically Induced Currents (GIC) Proxy

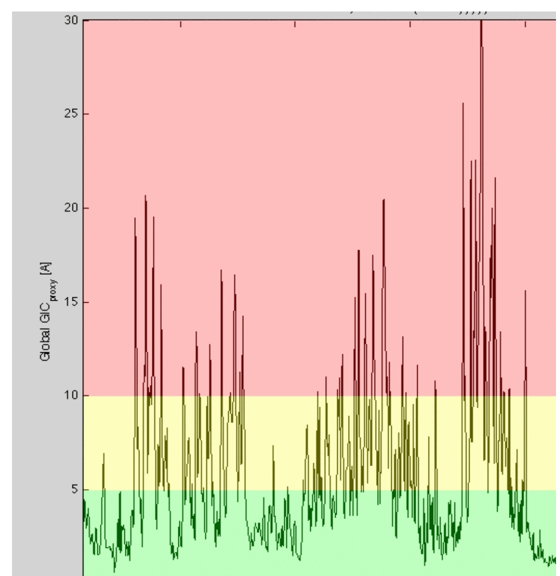
Quiet



Storm

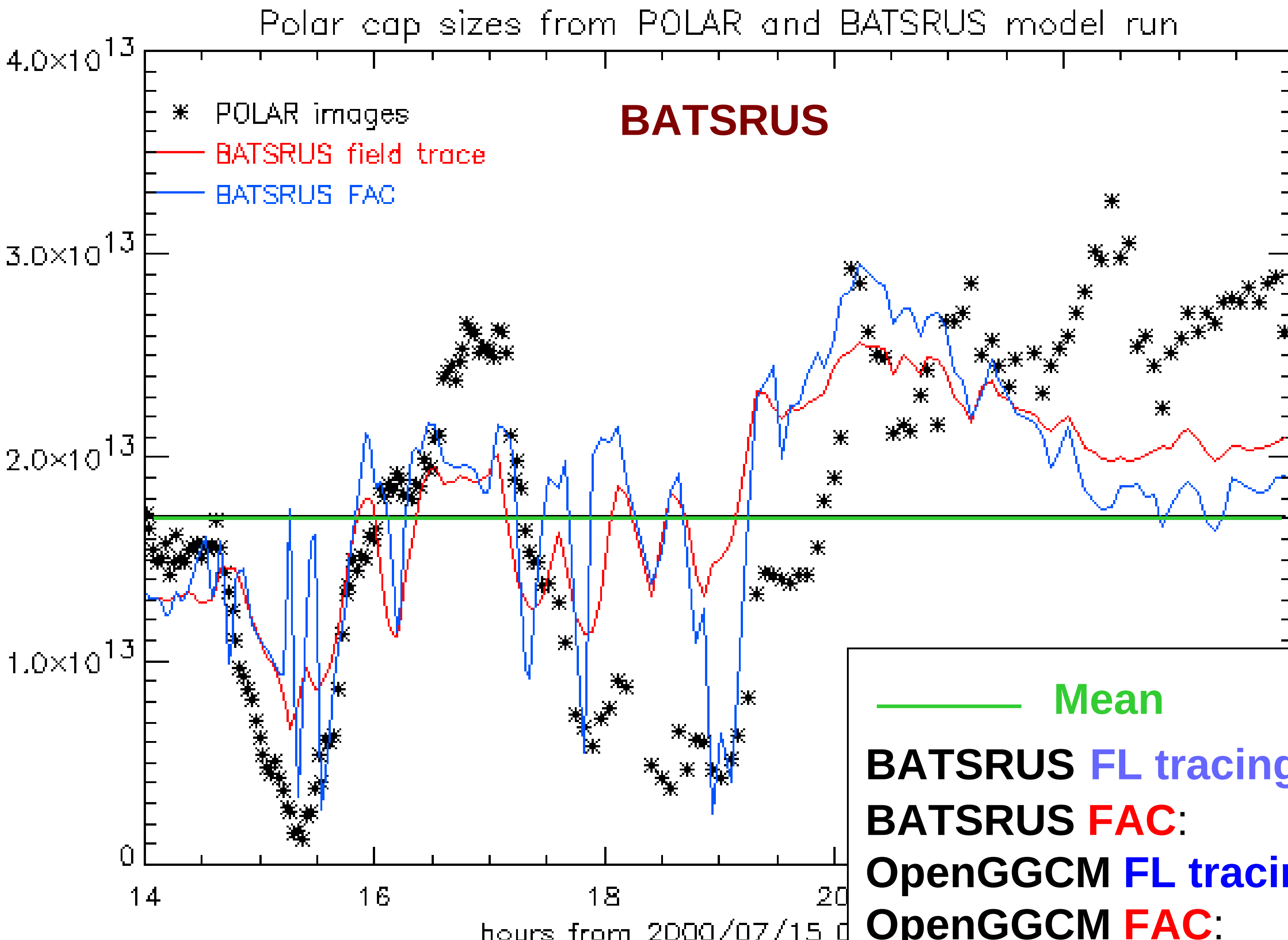






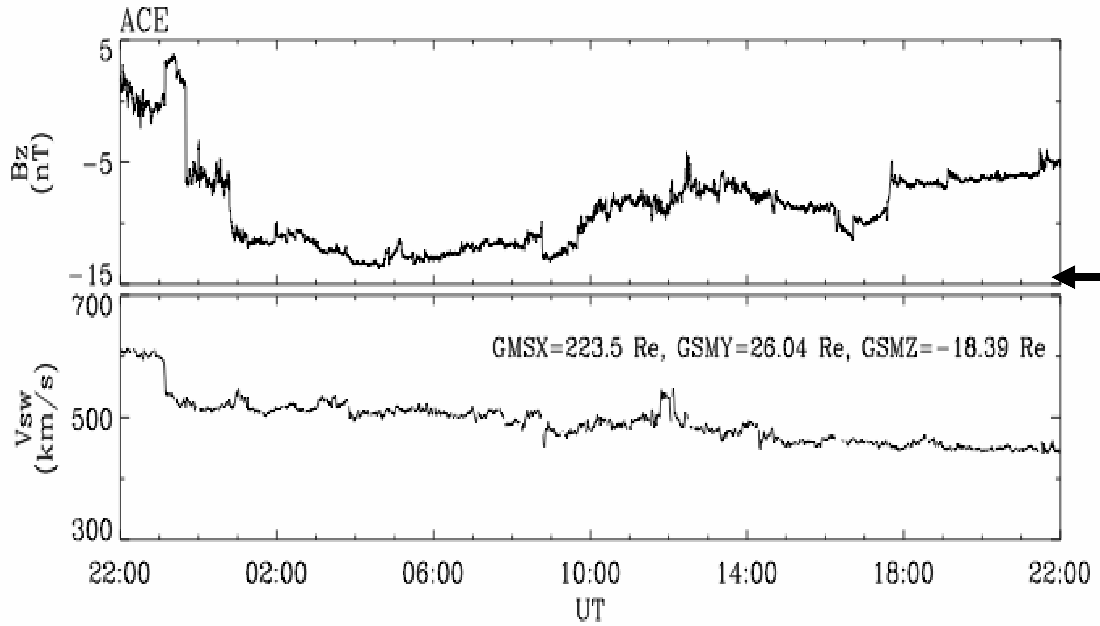
A. Pulkkinen

SEP access to the magnetosphere

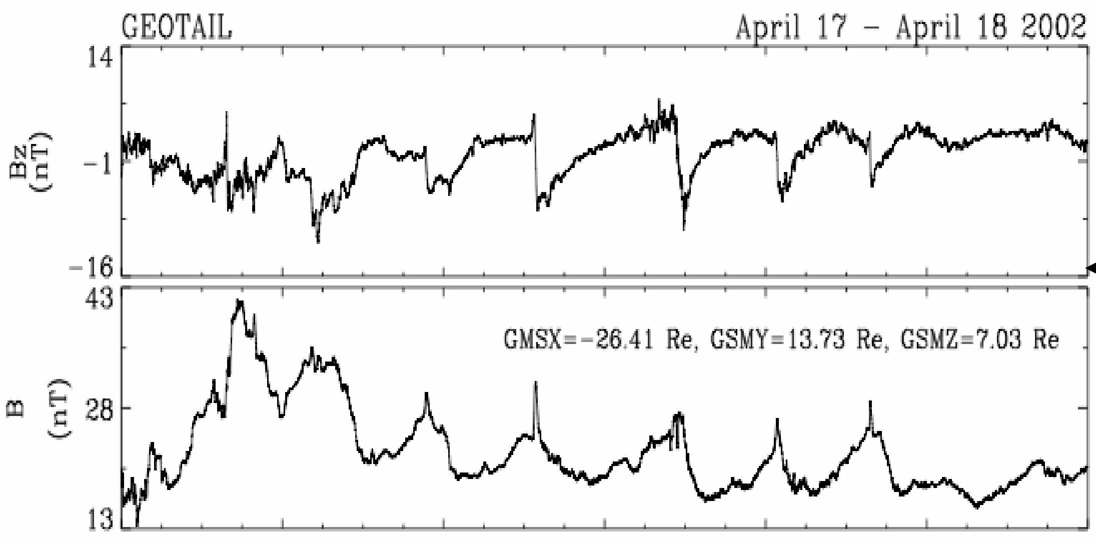


	Skill Score
Mean	
BATSRUS FL tracing:	0.226
BATSRUS FAC:	0.149
OpenGGCM FL tracing:	- 0.137
OpenGGCM FAC:	- 0.252
Weimer-2K FAC:	- 0.473

L. Rastaetter



Input: quasi-steady southward IMF driving



Observations in tail lobes (Geotail): quasi-periodic TCR (multiple plasmoids)

J. Slavin

Global Ionosphere Models

Global Assimilation of Ionospheric Measurements (USU-GAIM, *Schunk et al.*)

USU-GAIM uses a physics-based Ionosphere Forecast Model (IFM).

USU-GAIM assimilates electron density (Ne) profiles from a diverse set of real-time (or near real-time) measurements:

- slant TEC from GPS ground stations via RINEX files,
- bias information for GPS satellites and ground-stations,
- electron density profiles from DISS ionosondes via SAO files

Ionosphere Forecast Model (IFM) needs

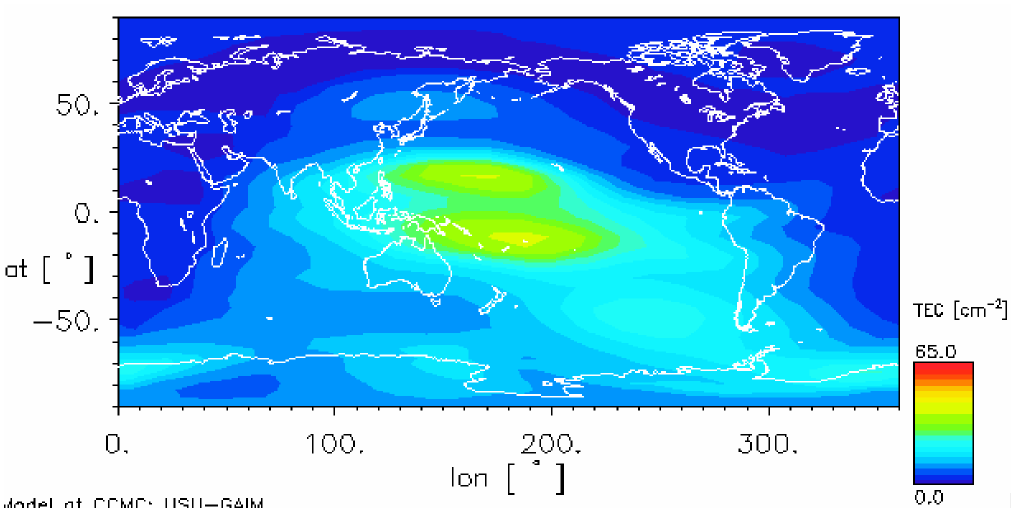
- F10.7, daily Ap, 3-hour Kp indices

` - neutral wind, electric field, auroral precipitation, solar EUV (empirical inputs)

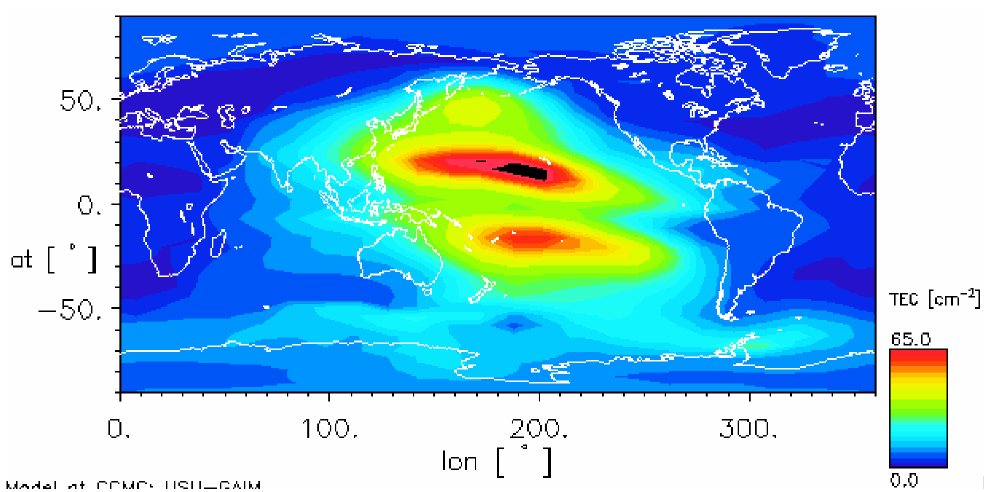
AbbyNormal Model (*Eccles et al.*, Space Environment Corporation) calculates absorption values for HF signals

USU-GAIM Model: Total Electron Content (TEC)

Normal TEC



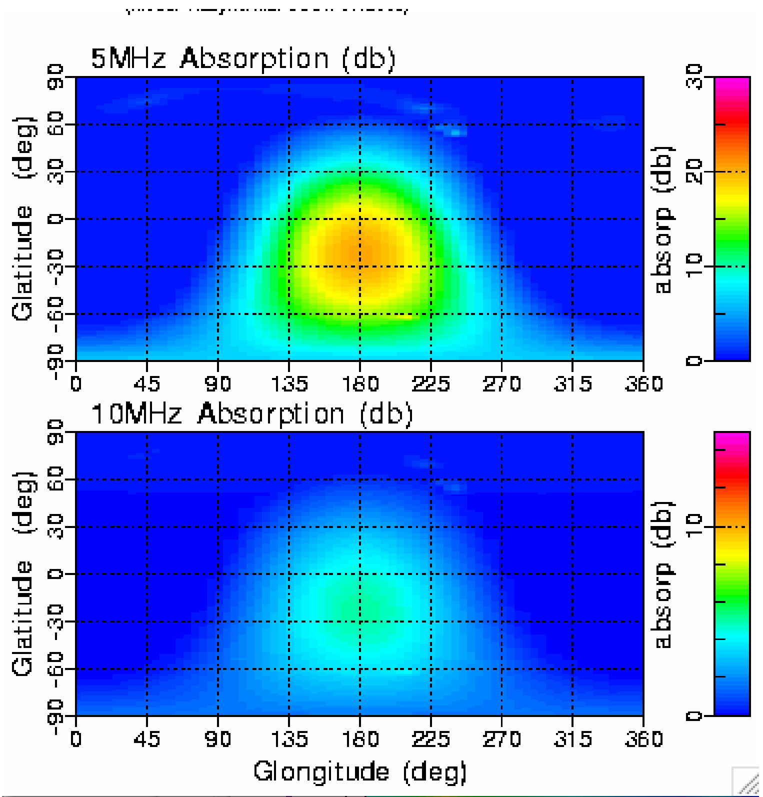
Increased TEC



AbbyNormal Model: Absorption Values for HF Signals

Vertically Integrated Signal Loss in Decibels for 5 and 10 MHz HF Signals

Normal Absoption



Increased Absoption