Potential Space Weather Applications of the Coupled Magnetosphere-Ionosphere-Thermosphere Model

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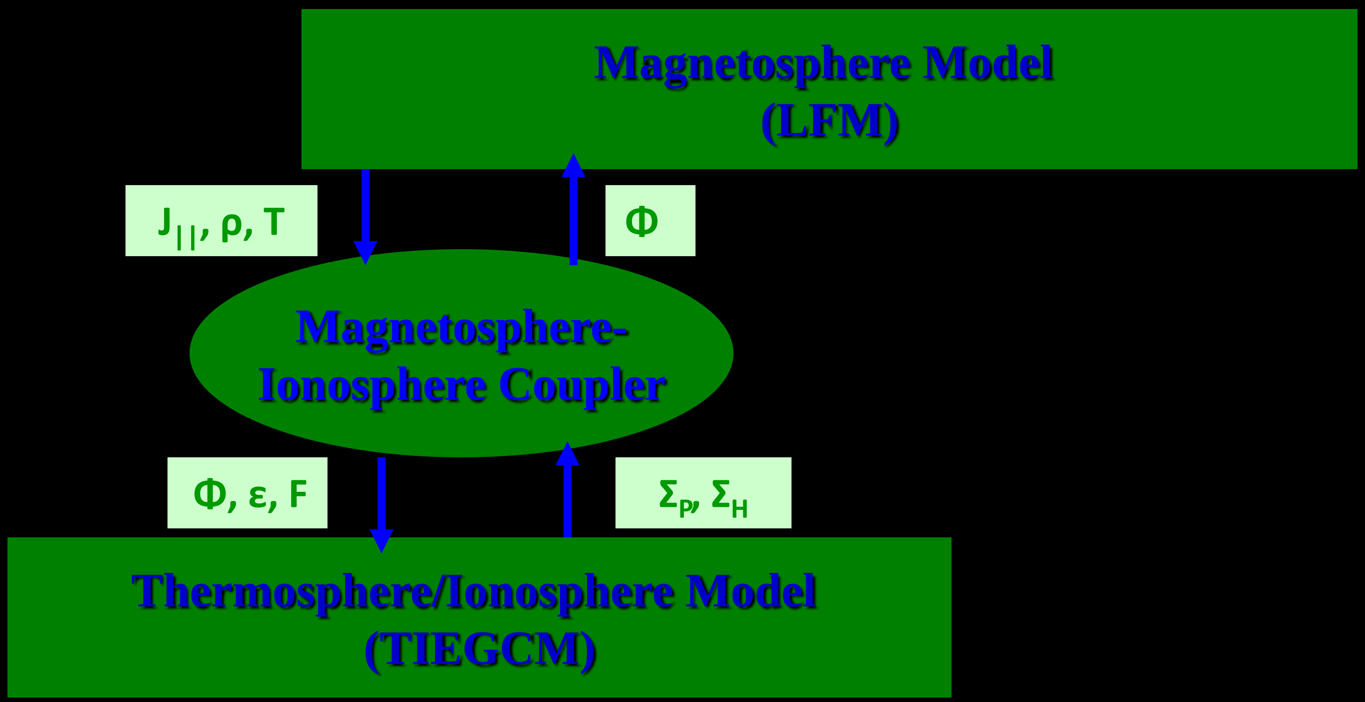
On behalf of the CMIT Development Team

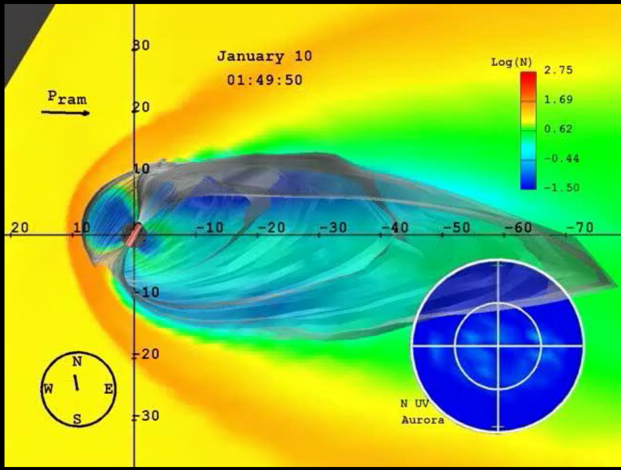
Outline

- CMIT Model Overview
  - LFM, MIX, and TIEGCM Components
    - Inputs/Outputs
  - Resolution and Performance
- Space Weather Applications
  - Long Duration Runs – WHI
  - Geosynchronous Magnetopause Crossing
  - Geosynchronous Magnetic Field Variations
  - Total Electron Content
  - Regional dB/dt

CMIT Model


Magnetosphere Model
(LFM)
J||, ρ, T
Φ
Magnetosphere-
Ionosphere Coupler
Φ, ε, F
ΣP, ΣH
Thermosphere/Ionosphere Model
(TIEGCM)

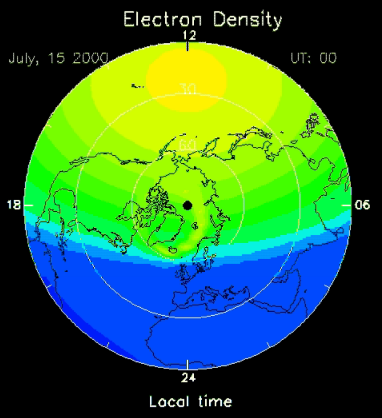
LFM Magnetospheric Model



- Uses the ideal MHD equations to model the interaction between the solar wind, magnetosphere, and ionosphere
  - Computational domain
    - 30 R_E < X < -300 R_E & ±100R_E for YZ
    - Inner radius at 2 R_E
  - Calculates
    - full MHD state vector everywhere within computational domain
  - Requires
    - Solar wind MHD state vector along outer boundary
    - Empirical model for determining energy flux of precipitating electrons
    - Cross polar cap potential pattern in high latitude region which is used to determine boundary condition on flow

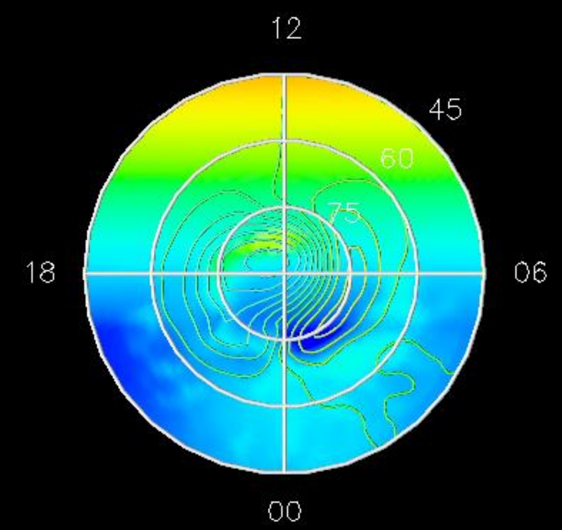
TIEGCM

- Uses coupled set of conservation and chemistry equations to study mesoscale process in the thermosphere-ionosphere
  - Computational domain
    - Entire globe from approximately 97km to 500km in altitude
  - Calculates
    - Solves coupled equations of momentum, energy, and mass continuity for the neutrals and O^+
    - Uses chemical equilibrium to determine densities, temperatures other electrons and other ions (NO^+, O_2^+,N_2^+,N^+)
  - Requires
    - Solar radiation flux as parameterized by F10.7
    - Auroral particle energy flux
    - High latitude ion drifts
    - Tidal forcing at lower boundary



MIX - Electrodynamic Coupler

- Uses the conservation of current to determine the cross polar cap potential
  - Computational domain
    - 2D slab of ionosphere, usually at 120 km altitude and from pole to 45 magnetic latitude
  - Calculates
    - $\nabla\cdot\left(\Sigma_P+\Sigma_H\right)\nabla\Phi=J_{\parallel}\sin\left(\eta\right)$
  - Requires
    - FAC distribution
    - Plasma T and ρ to calculate energy flux of precipitating electrons
    - F107 or conductance

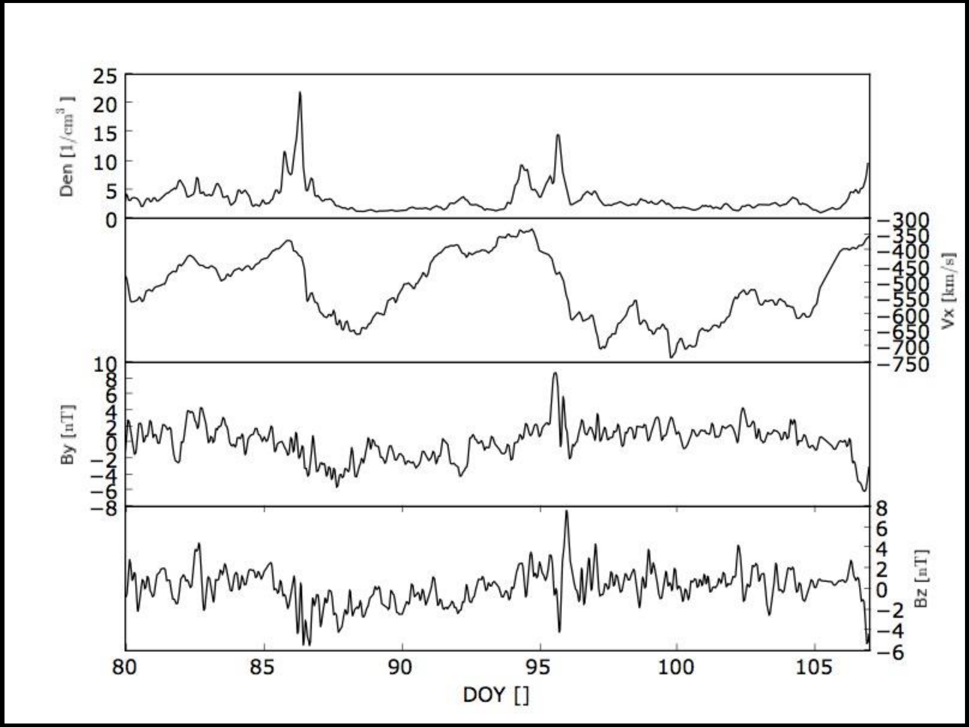


Performance

- CMIT Performance is a function of resolution in the magnetosphere ionosphere system
  - Low resolution
    - 53x24x32 cells in magnetosphere with variable resolution smallest cells ½ RE
    - 5° x 5° with 49 pressure levels in the ionosphere-thermosphere
    - On 8 processors of an IBM P6 it takes 20 minutes to simulate 1 hour
  - Modest resolution
    - 53x48x64 cells in the magnetosphere with variable resolution smallest cells ¼ RE
    - 2.5° x 2.5° with 98 pressure levels in the ionosphere-thermosphere
    - On 24 processors of an IBM P6 it takes an hour to simulate an hour

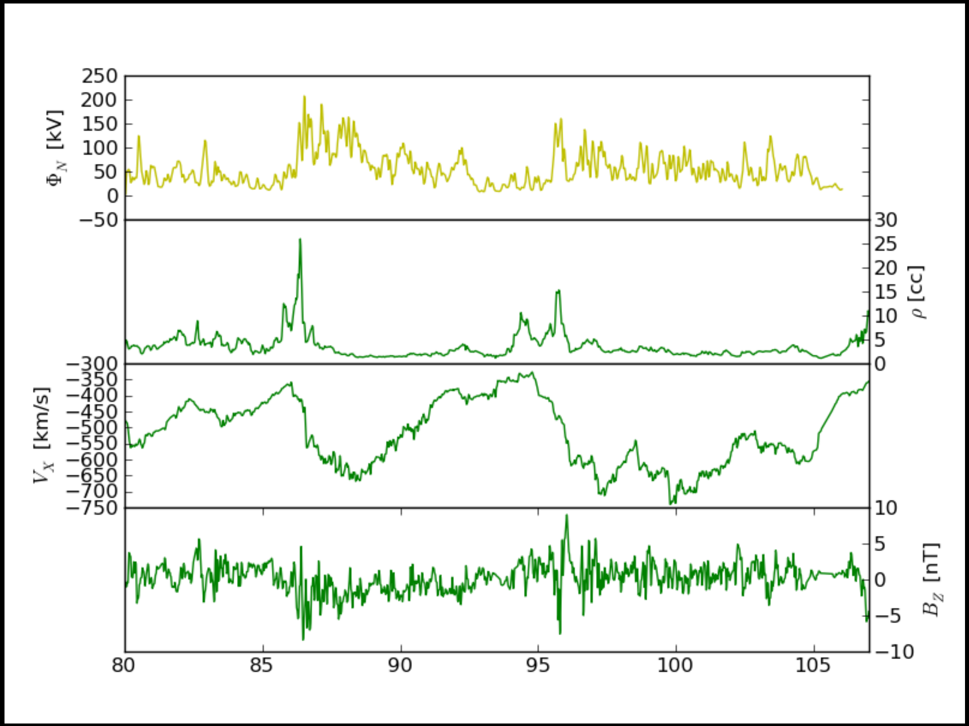
Whole Heliosphere Interval

- As part of IHY the WHI was chosen as a follow on to the WSM
  - Internationally coordinated observing and modeling effort to characterize solar-heliospheric-planetary system
  - Carrington Rotation 2068
    - March 20 – April 16 2008
    - Includes two high speed streams which are part of a co-rotating interaction region

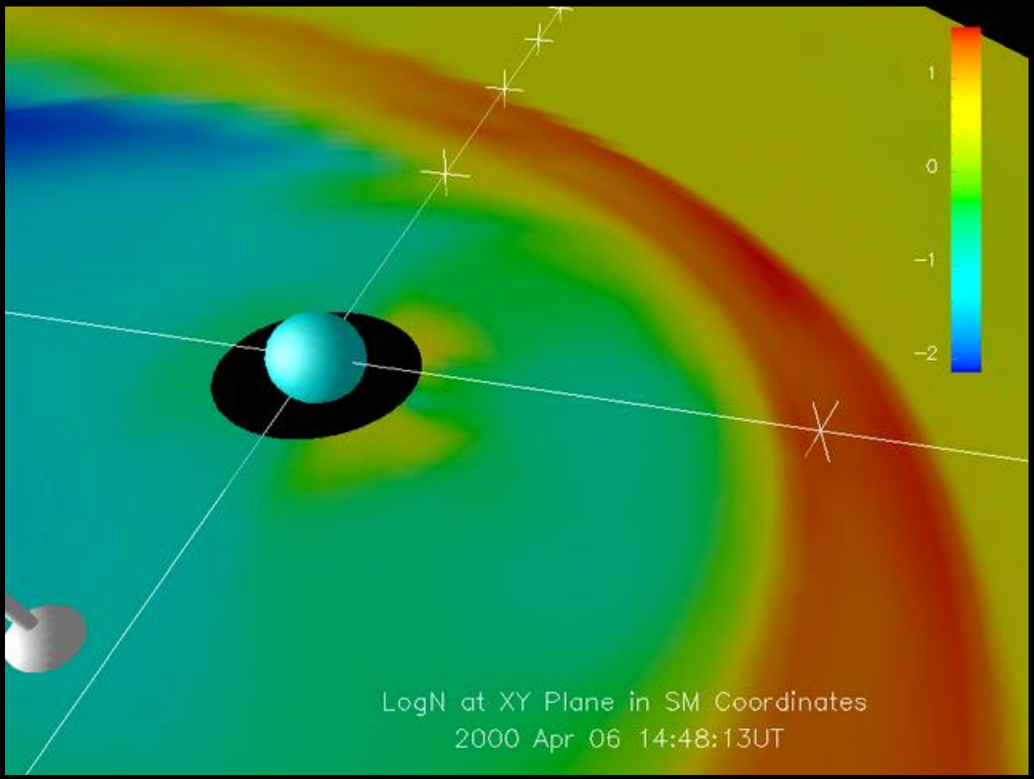


Different Stream Interactions

- Geospace response to each stream had different characteristics
  - Stream 1had prompt rise of Φ while stream 2 had delayed reaction
  - Stream 1 had higher Φ for longer than stream 2 even though Vx was lower
  - BZ plays an important role in determine geoeffectiveness of streams



Magnetopause Crossing Threat Scores

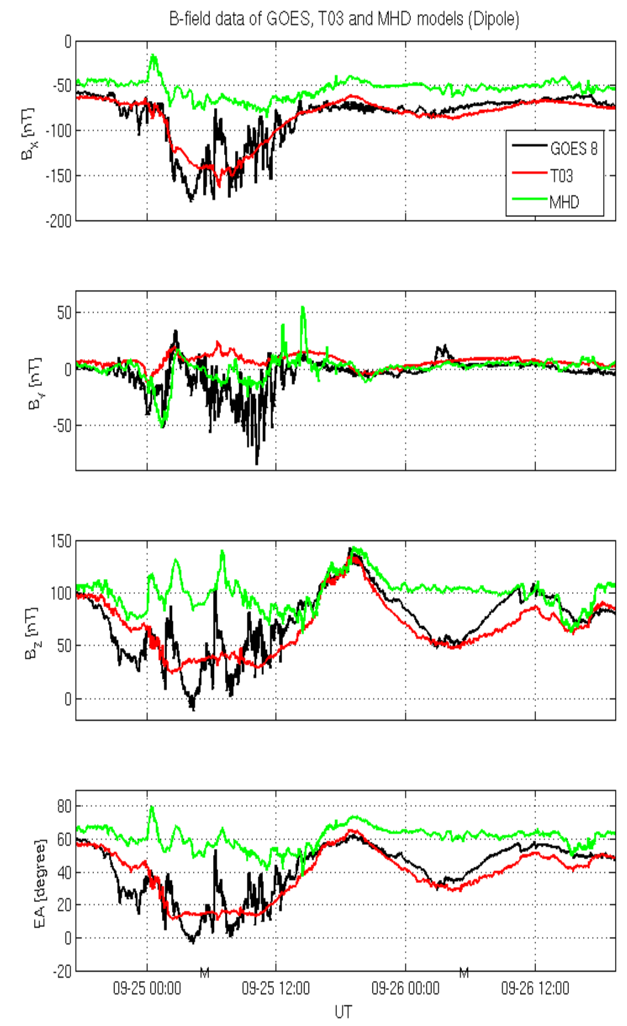


	LFM	RS
A	0.95	0.93
B	1.18	1.28
POD	0.92	0.90
FAR	0.22	0.30
POFD	0.048	0.069
TS	0.73	0.65
TSS	0.87	0.83
MTSS	0.73	0.64
HSS	0.81	0.74

- Using GOES magnetic field data it is possible to detect when the magnetopause is pressed inside geosynchronous orbit during southward IMF
- This is a relatively rare event so TSS, MTSS and HSS are good choice
  - LFM performs better under these circumstances then empirical models

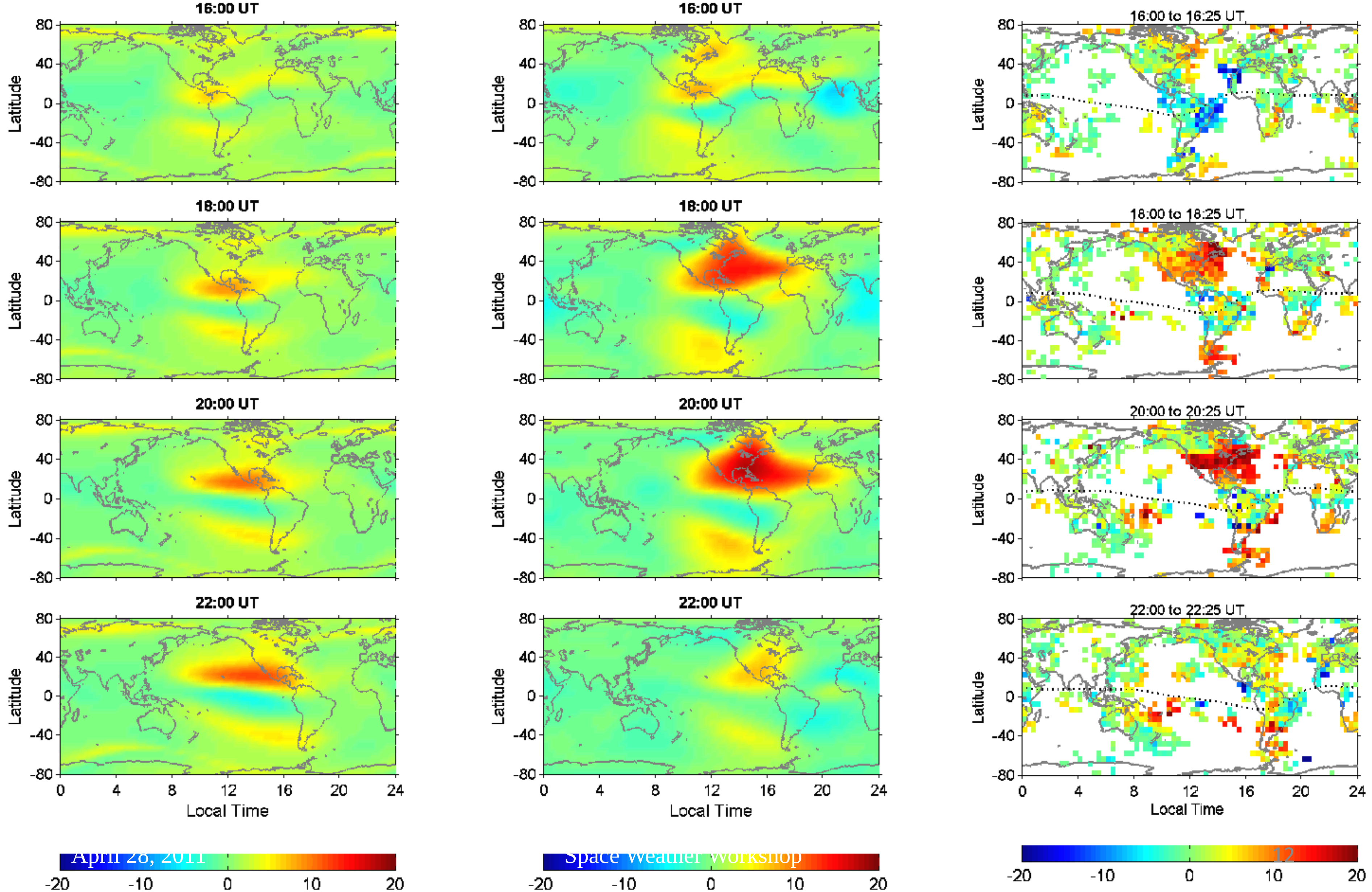
Storm-time Geosync Magnetic Field

- Geostationary fields are scientific metric, especially of interest during storms
- Results for 25 September 1998 Event
  - Data set GOES magnetic field (black)
  - Baseline Model is T03 Storm (red)
  - Test Model is LFM (green)
- Comparison shows that MHD model has much weaker ring current and tail current compared to Tsyganenko especially near midnight and at storm peak

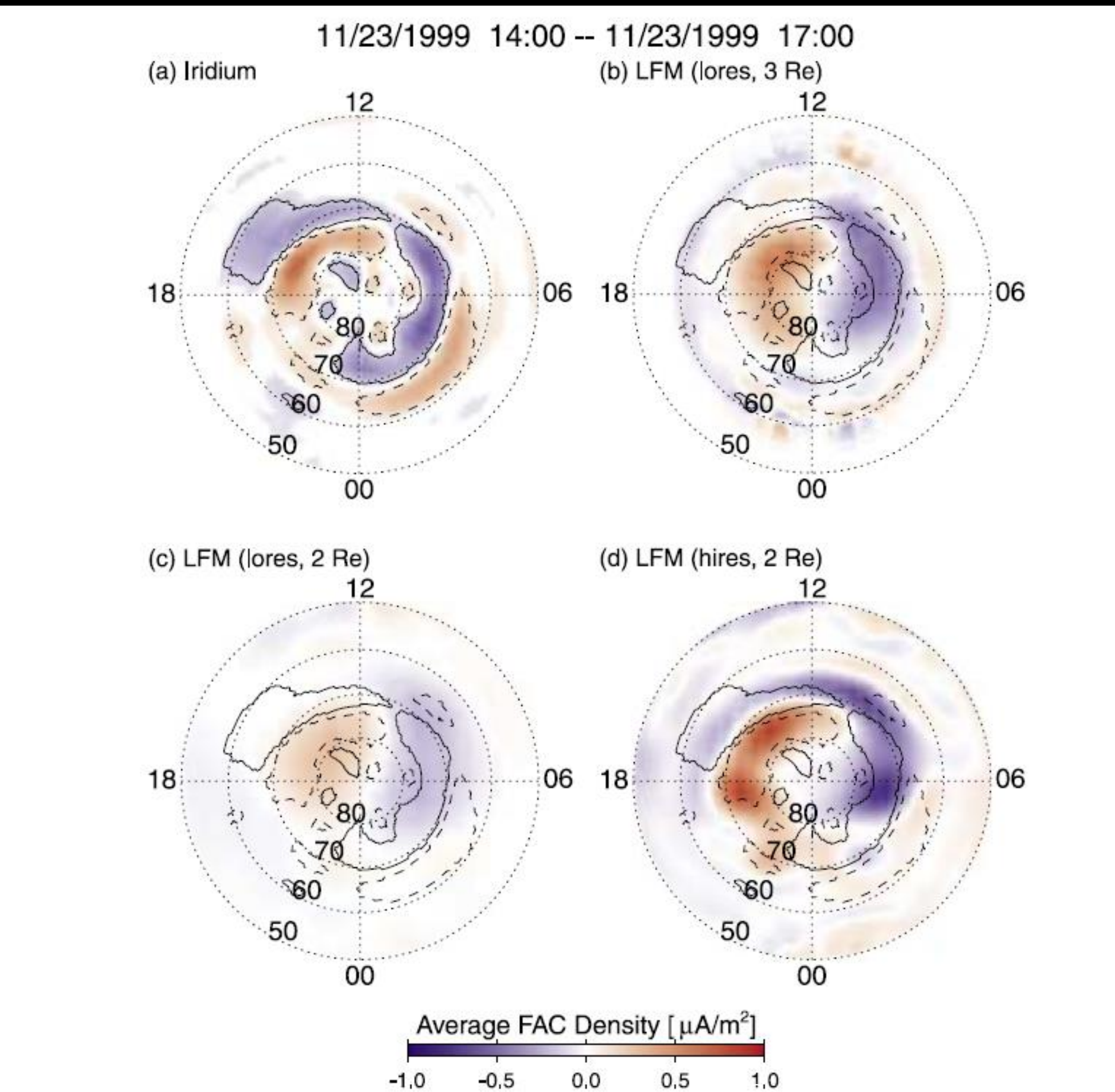


Work by Chia-Lin Huang

The December 2006 “AGU Storm”

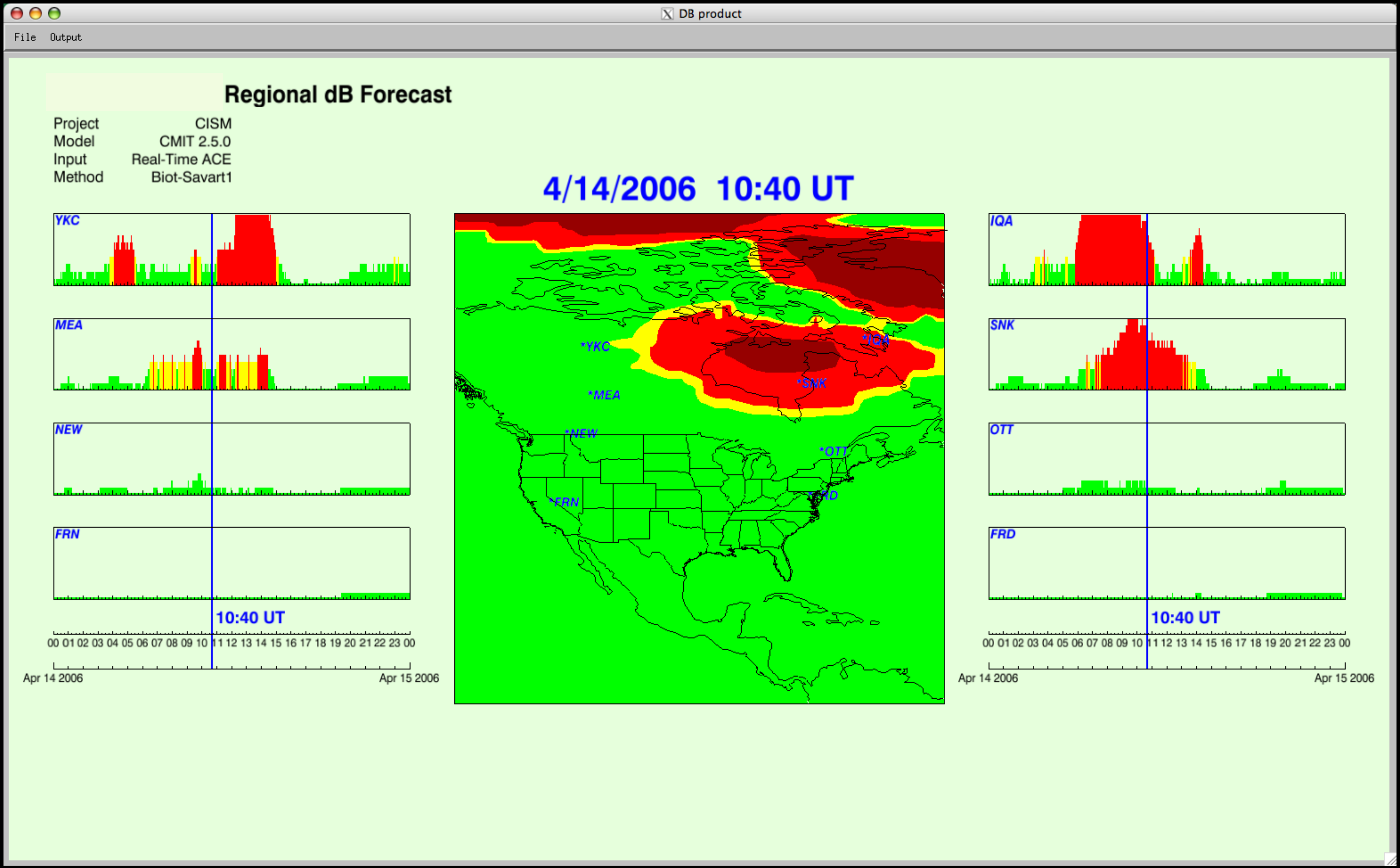


Field Alginged Current Structure

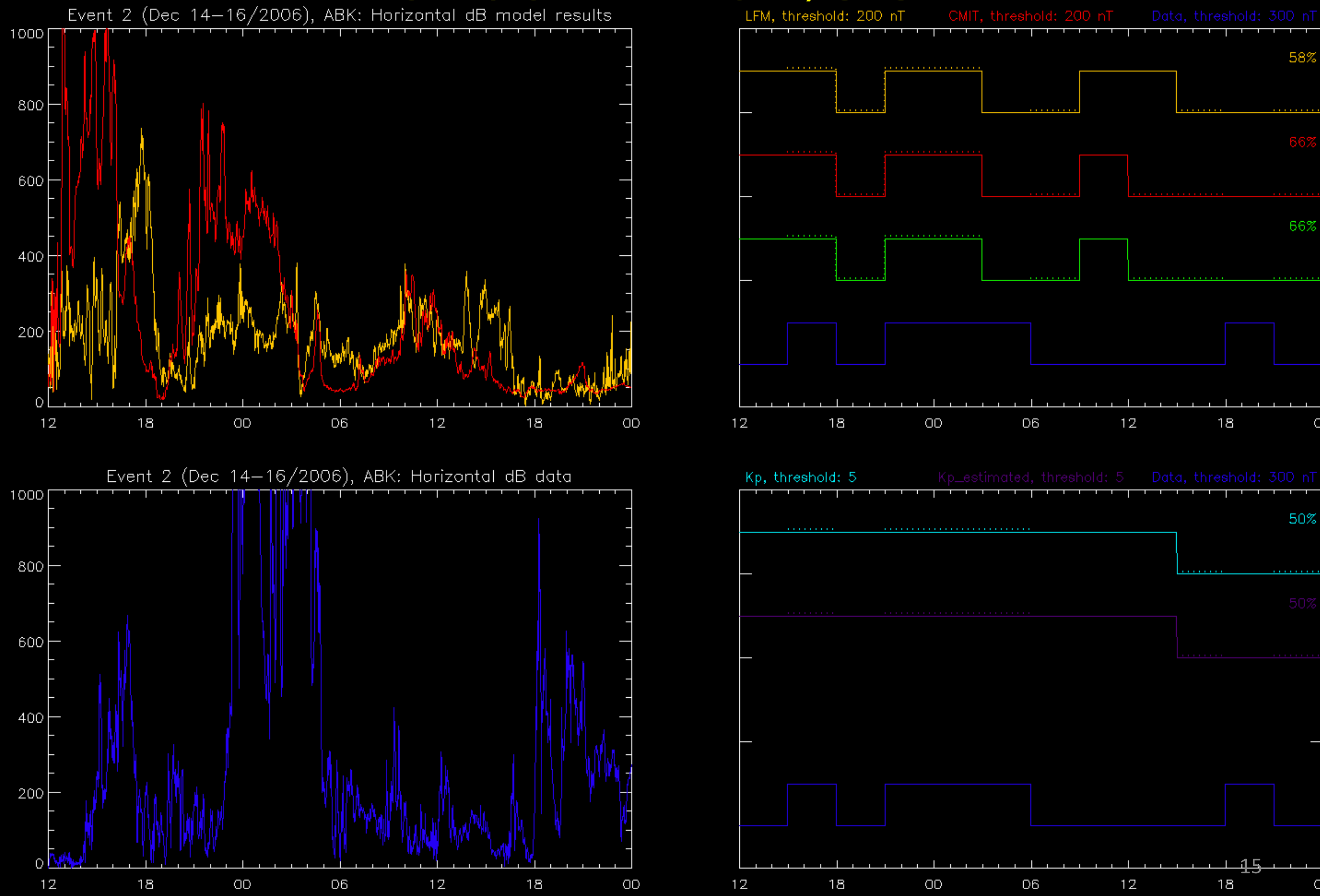


- Comparison of Iridium FAC observations with various resolutions of the LFM simulation results
  - Results show better agreement with boundaries at higher resolution, but with greater magnitude
    - Iridium R1 1.3MA
    - LFM Low 3 1.5MA
    - LFM Low 2 0.8MA
    - LFM High 2 2.5MA

Regional dB/dt tool



dB/dT Analysis



Conclusions

- CMIT has the capability to perform in faster than real time mode for long durations with minimal supervision
- Numerous parameters of interest can be derived from the basic physics parameters output by the model
- It is not perfect, still have areas of improvement
  - Essential to define the right metrics to assess the value using this model adds to forecasts

Backup Slides

Threat Scores

- Threat Score (Critical Success Index)
  - *TS = CSI = hits/(hits+misses+false alarms)*
  - *Range 0 to 1 with 1 perfect and 0 no skill*
  - How well did the forecast 'yes' events correspond to the observed 'yes' events?
  - Measures the fraction of observed and/or forecast events that were correctly predicted.
  - Can be thought of as accuracy when correct negatives are removed from consideration
- True Skill Statistic (Hanssen and Kuipers Discriminant)
  - *TSS = (hits)/(hits+misses) – (false alarms)/(false alarms+correct negs)*
  - *Range -1 to 1 with 1 perfect and 0 no skill*
  - How well did the forecast separate the 'yes' events from the 'no' events?
  - Can be thought of as POD - POFD
  - Uses all elements of the contingency table.
  - For rare events its unduly weighted toward the first term
- Modifed True Skill Statistic
  - *TSS2 = (hits-misses)/(hits+misses) – 2*(false alarms)/(correct negs)*
  - *Range -1 to 1 with 1 perfect and 0 no skill*
  - First term is POD remapped to -1 to 1
  - Second term peanlizes a forecast for large area for rare event