CCMC Workshop Nov 5-8 2007
Arecibo Observatory, Puerto Rico

User needs: ionosphere models
(IPY support)

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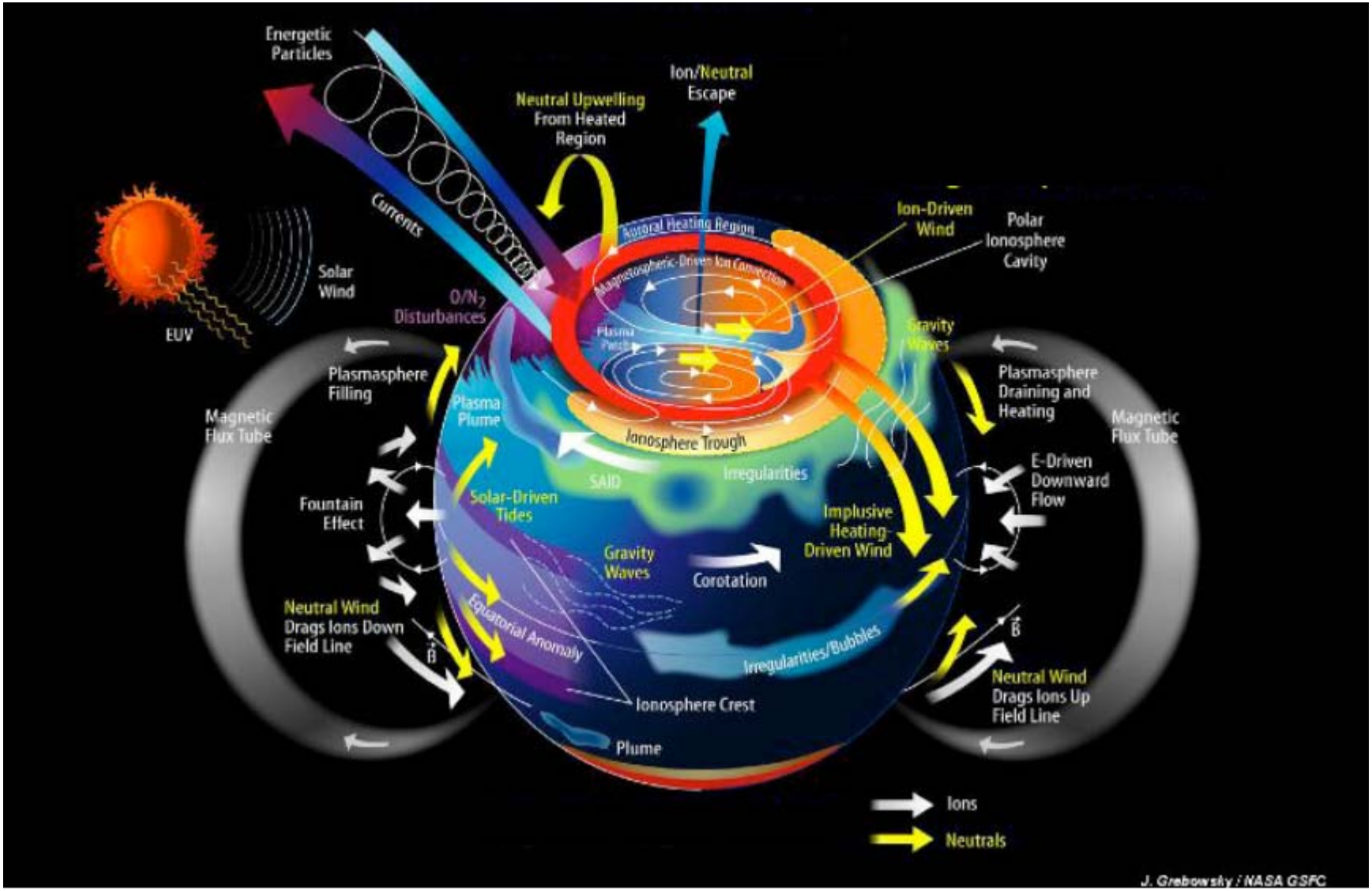
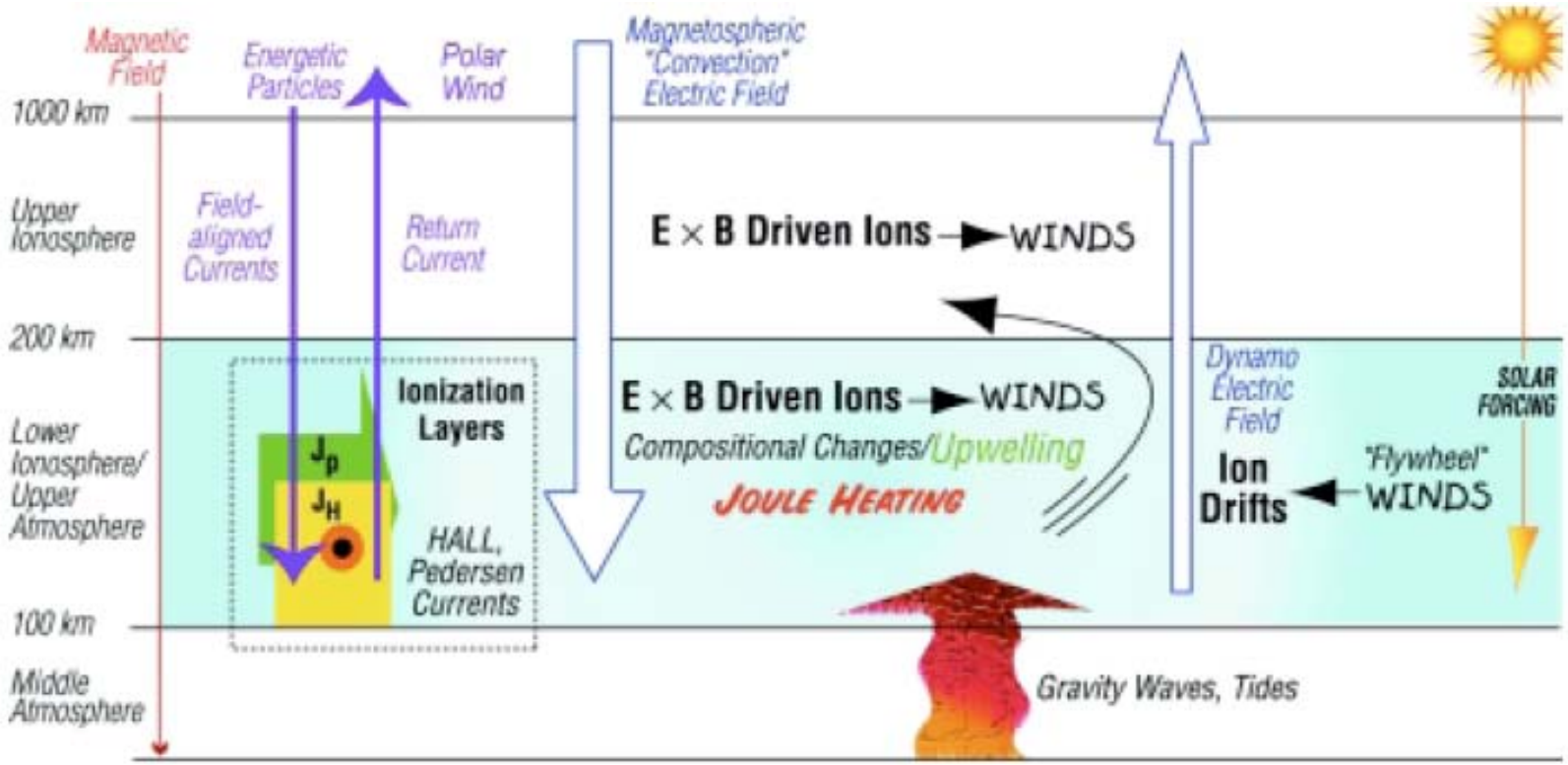
Outline

- The Role Of Modeling
- Modeling In A Scientific Context
- Modeling In An Operational Context
- User Needs

Ionosphere-Thermosphere System



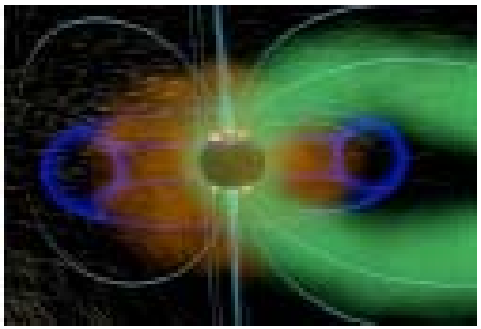
Altitude Regimes



Coupling: changing plasma density changes conductivity which affects the electrodynamics and therefore the plasma state. Changing the neutral distribution function changes the plasma distribution function (via the dynamo) changing the neutral distribution function via ion-neutral coupling (adapted from comments by Heelis, 2007)

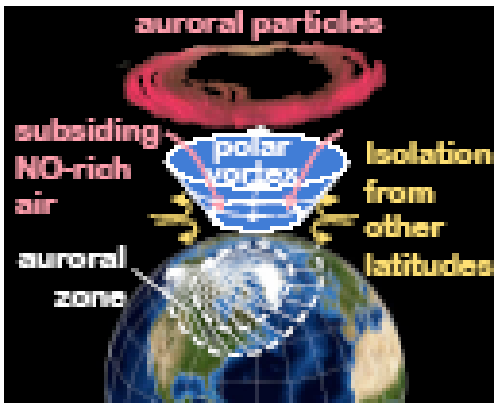
GEC Science and Technology Definition Team Report, 2001 (adpated from Volland 1996)

Science Focus Areas



Mass Exchange

Electrodynamic Coupling



Chemical – Dynamical Coupling

After Thayer, Kozyra, Heelis, Robinson
"Space-Based Ionosphere-Thermosphere Research: The Next Steps"
Manhattan Beach, CA October 2007

"Model Layer"
LWS TR&T Steering Committee Report

LWS Science Architecture Team

- **Sparse data sampling -- ultimate product is physics-based models**
  - **observations to feed models**
  - **large scale linked model development required**
- **Require a multi-year period of simultaneous observations of the whole system to understand the linkages**
- **Follow physical processes from start to finish (e.g. sun to upper atmosphere)**
  - **ensure that all significant links in the chain are identified**
  - **enable a global theory & modeling effort to achieve predictive goals**

LWS Science Architecture Team [2]

Sample problem area treatment

Since observational sampling of the Sun, heliosphere, and geospace is extremely sparse, the SAT adopted the view that the ultimate product of the program would be in physics-based models of the various regions of importance. In this approach, the role of observations is to understand the physical processes so that theory and models can be developed, and, eventually, to drive the models so that nowcasting and predictions can be made. In the words of one attendee at the SAT workshop, "the observations should be made to feed the models."

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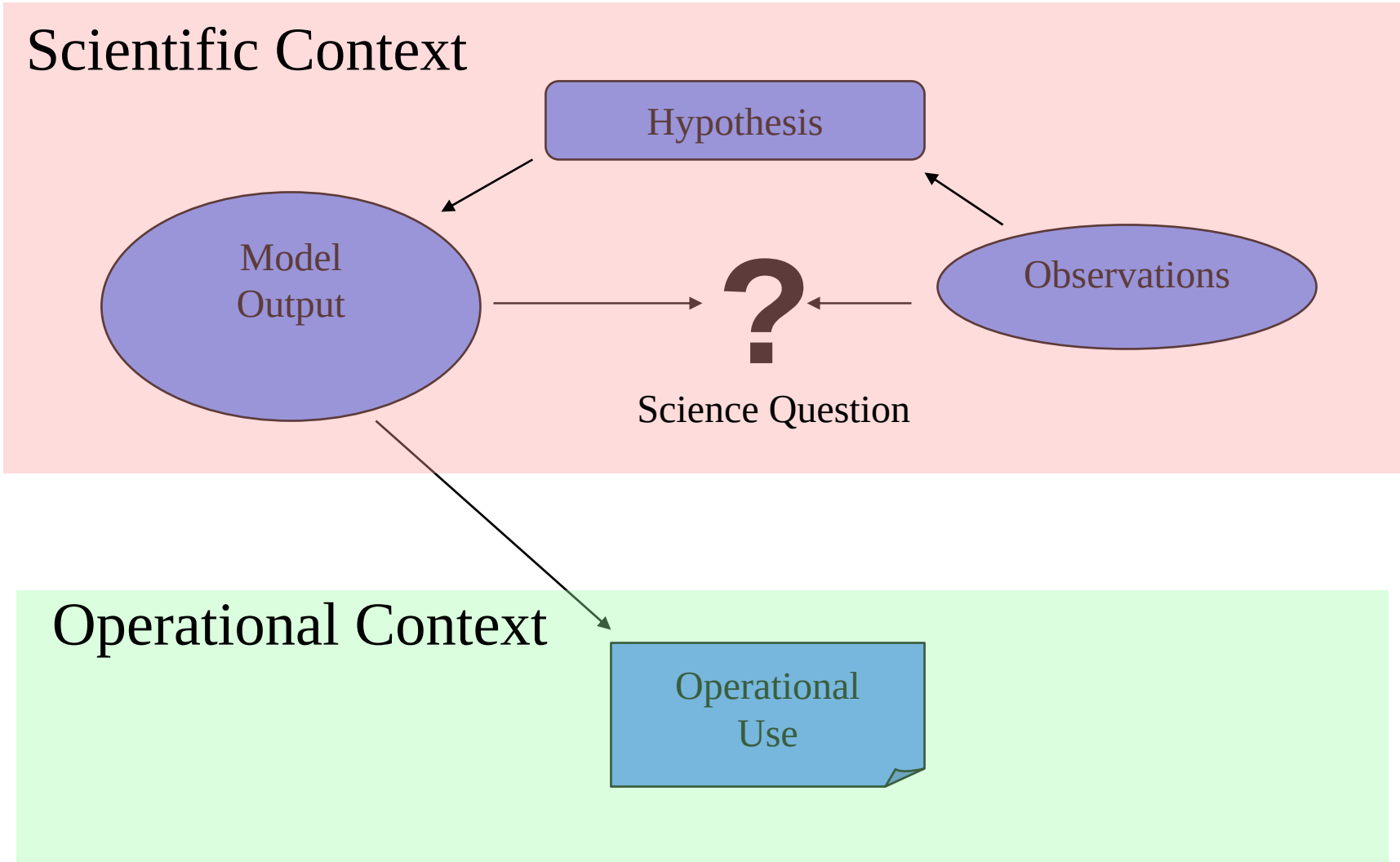
Modeling In Science And Operations



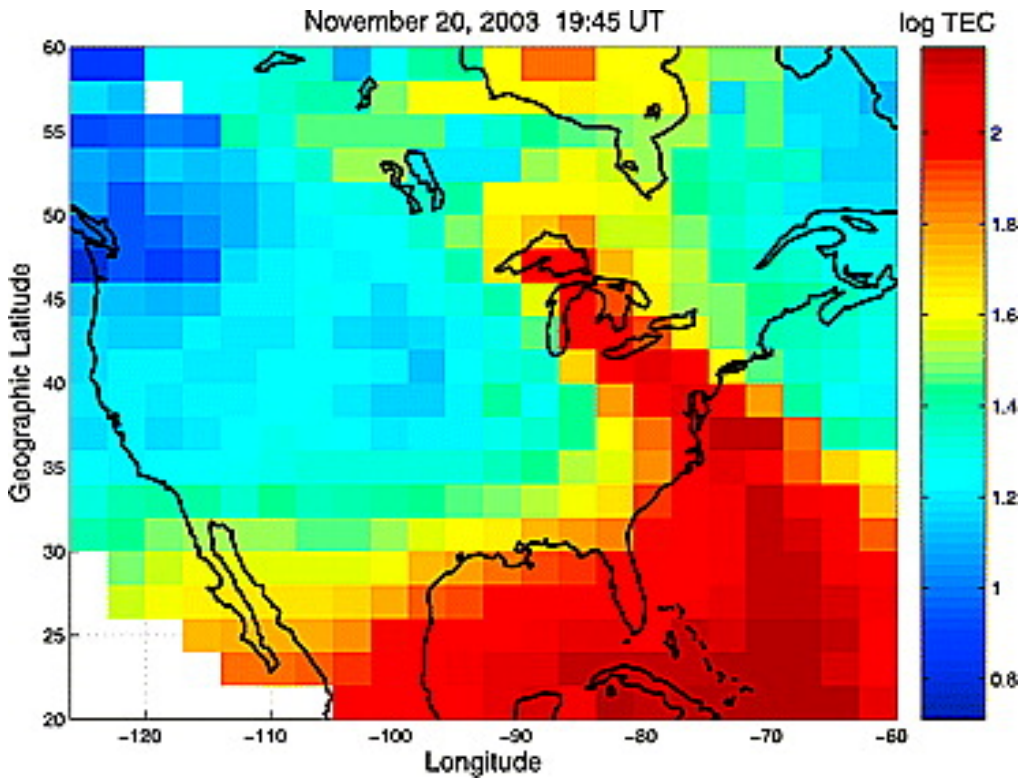
Model Interpretation: What Could Happen/What Did Happen

- CCMC contains large-scale global models
- Spatial and temporal boundary conditions are not fully constrained
- The model physics is approximate
- Agreement with observations is a challenge

- Within the physical domain represented by the model, the model output describes what *could* occur
- Model output may not represent what did occur
- What could occur is very important and *instructive*

Example: Plume formation

Foster et al,
JGR, 2005



GPS TEC data

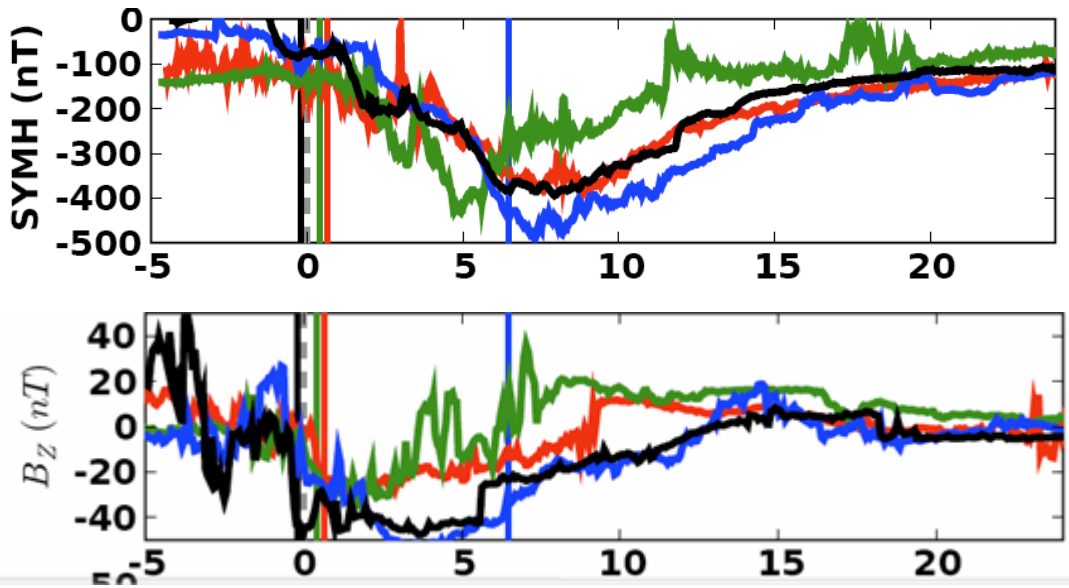
Dusk effect

Two possible interpretations:

- **Entrainment in the two-cell convection pattern**
- **“Polarization terminator”: conductivity changes associated with terminator**

Example: Electric Field "Penetration"

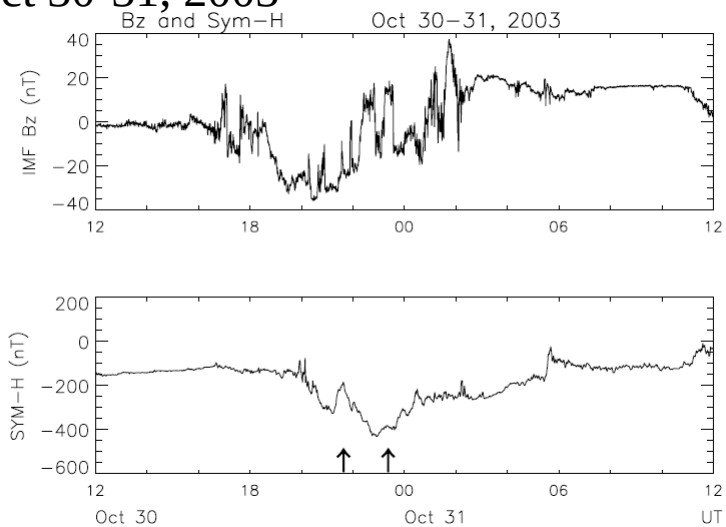
The penetration electric field appears at the equator during a very different phase of the storm for Nov 20 2003



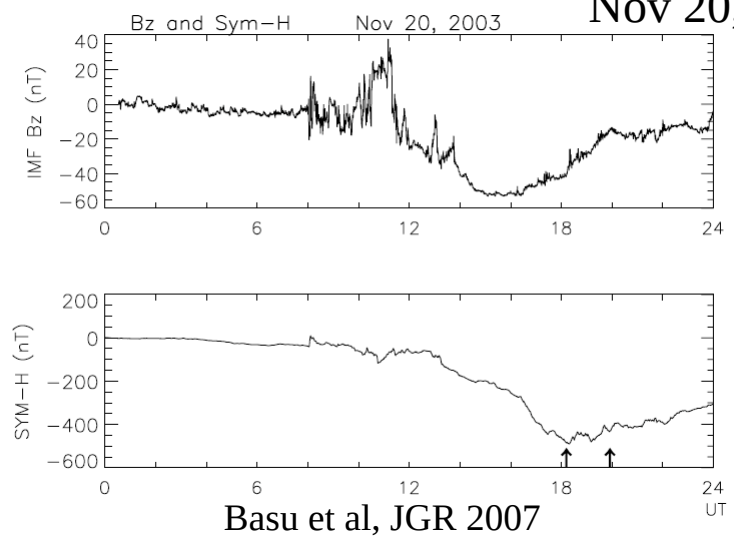
Oct 29 2003
Oct 30 2003
Nov 20 2003
Nov 7 2004

Mannucci et al., final revisions, JGR 2008

Oct 30-31, 2003

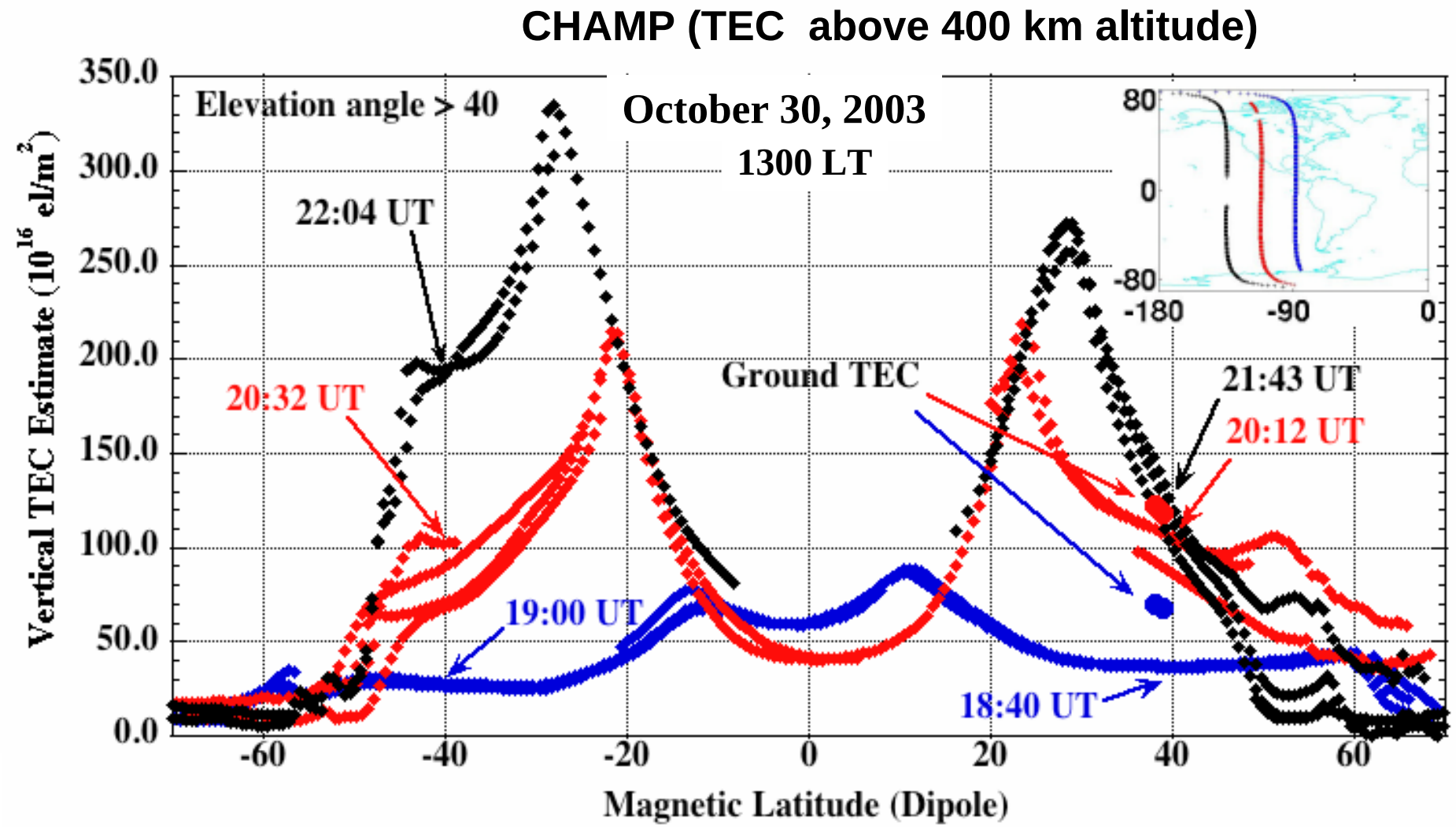


Nov 20, 2003



Basu et al, JGR 2007

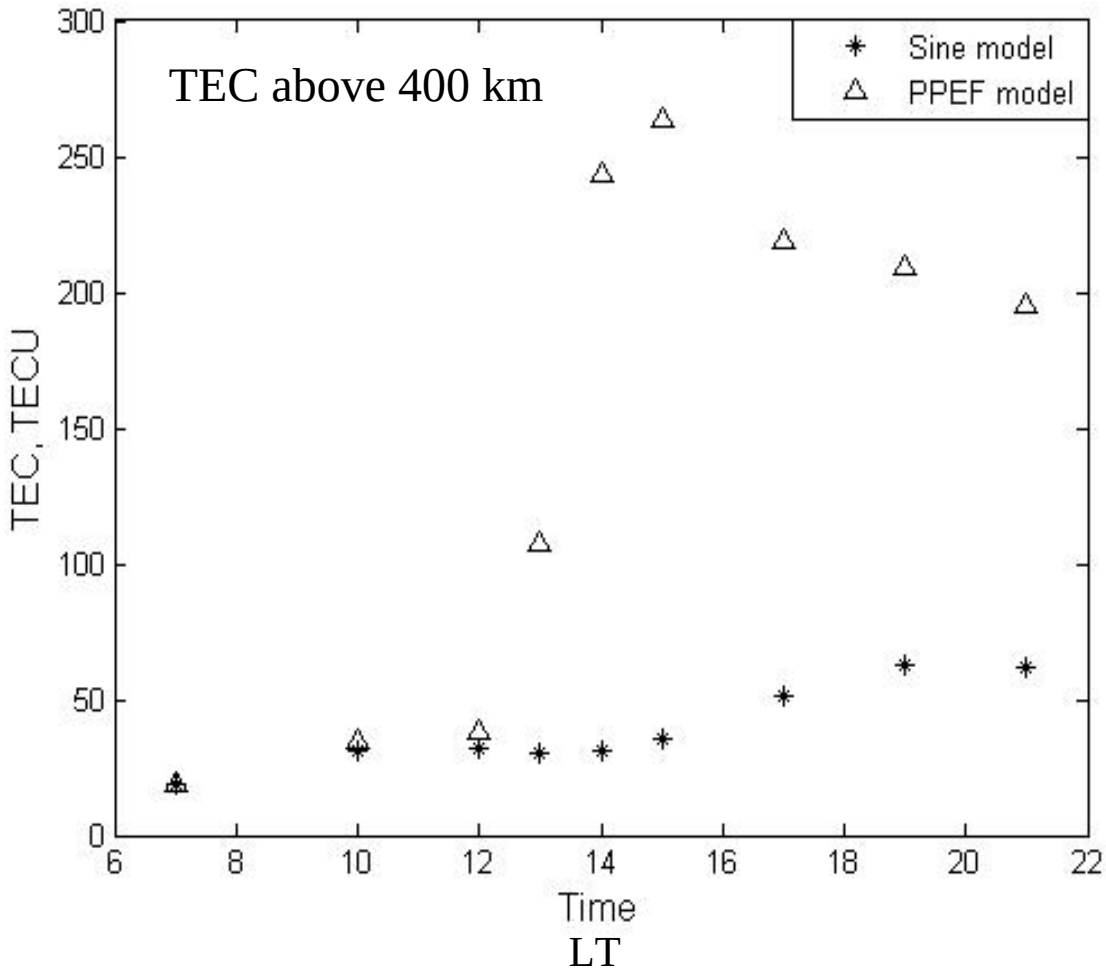
Example: Extreme Electric Field Magnitudes



Mannucci et al., GRL 2005

SAMI2 Model Run

Electric field estimate using CHAMP magnetometer data: **4 mV/m**
Ann. Geophys., 25, 569–574, 2007



Background sinusoid 0.5 mV/m

Enhanced electric field
12 - 14 LT
(single longitude model)

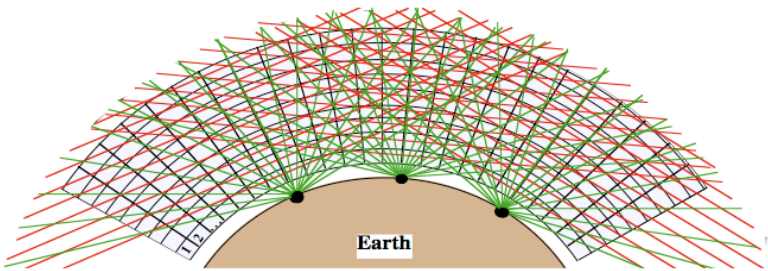
25° Latitude

CHAMP value ~230 TECU

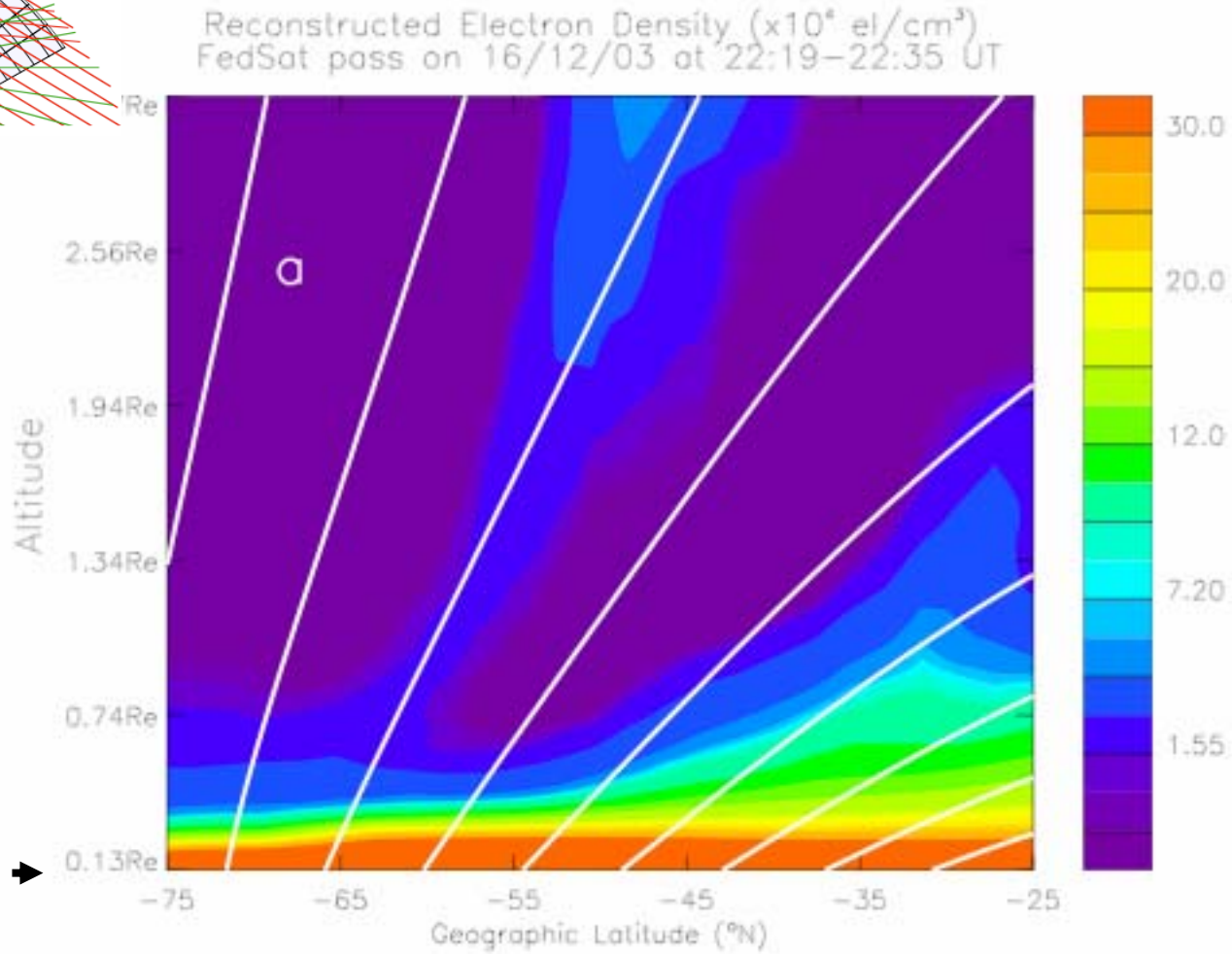
CCMC Version: sinusoidal E with peak value specified

Verkhoglyadova et al., in Coupling Processes in the Equatorial Atmosphere Symposium Proceedings, March 2007

Tomographic Reconstruction of Mass Coupling



Fedsat Low-Earth Orbiting GPS Receiver Tomographic reconstruction of over-satellite TEC



800 km

Yizengaw et al., GRL 2006

Ionospheric Perspective

- **Strongly "driven" system**
  - **Observed state is a consequence of many factors varying in time**
- **Several key inputs are essentially unmeasured**
  - **Global winds, global electric fields, thermospheric composition, conductivities, certain high-latitude inputs**
  - **Complex feedbacks are modifying these "inputs"**
- **The system itself is nearly unobserved**
  - **The "ionospheric disk" has never been observed**
  - **Compare, e.g., to the solar disk**
- **Models are the bridge between scientific hypotheses and observations**
- **Limited observations and limited model constraints are significant challenges to testing our hypotheses**

Modeling For Operations

- **Data assimilation is critical**
- **We use a broad definition of "data assimilation"**
  - **Whatever technique works best**
- **Understanding is subordinate to quantitative accuracy**

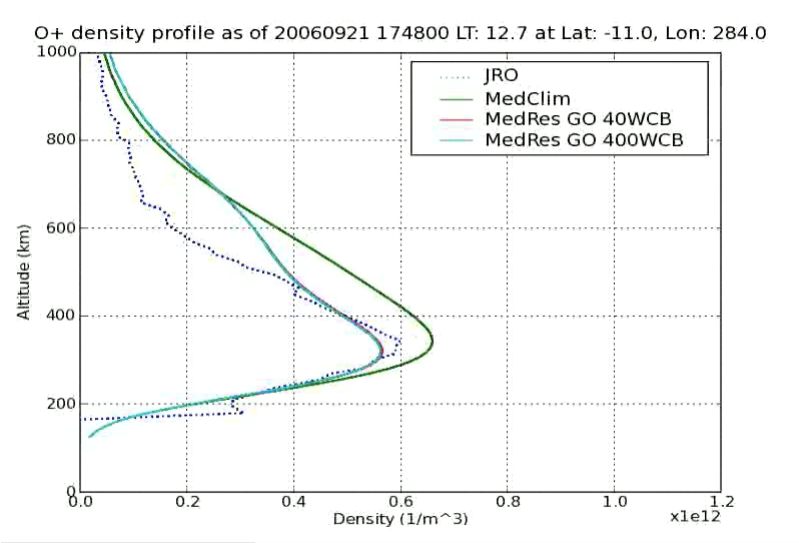
- **USU-GAIM at CCMC is a major accomplishment**

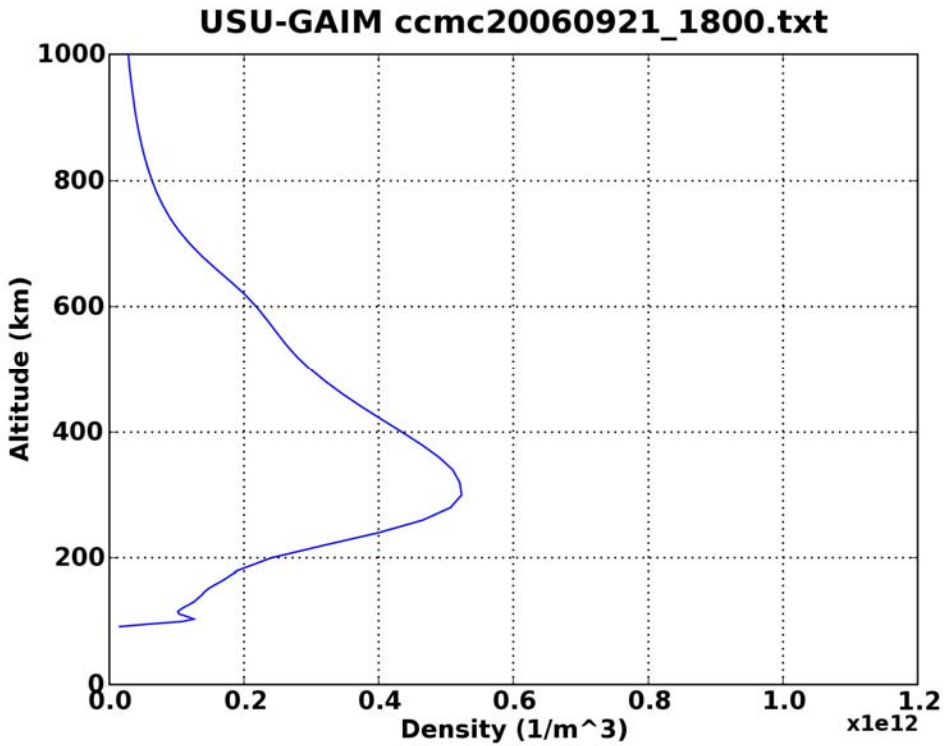
Key Needs For Data Assimilation

- **Where are the data?**
- **What type of data are there?**
- **What do we expect to happen when these data are assimilated?**

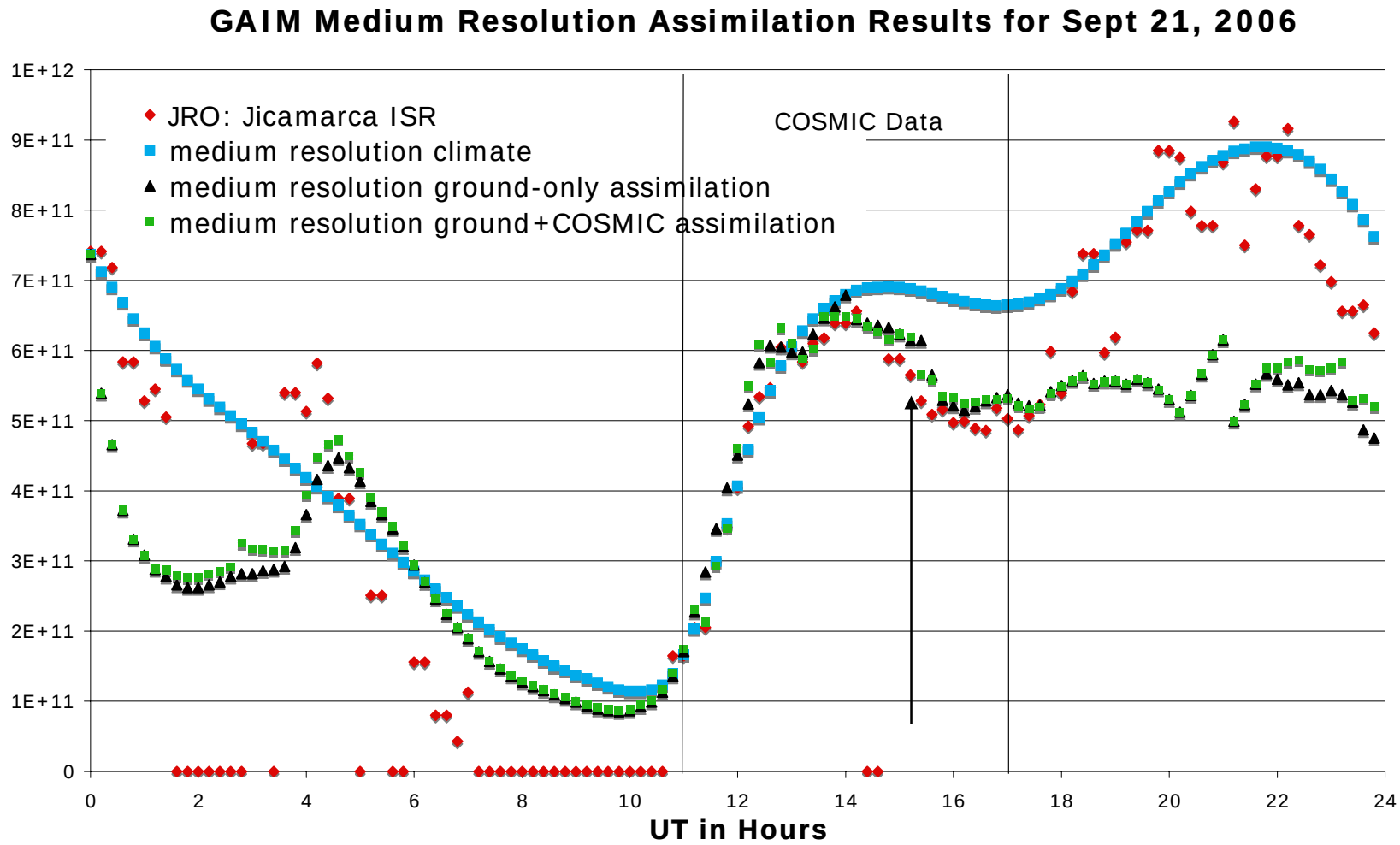
  - **TEC data**
  - **GPS occultation data**
  - **UV radiances**
  - **Beacon TEC data (CERTO, CITRIS)**
  - **Sounders (ground and space)**
  - **In-situ data**
    - **Less useful in an assimilative context**

Data Assimilation Examples



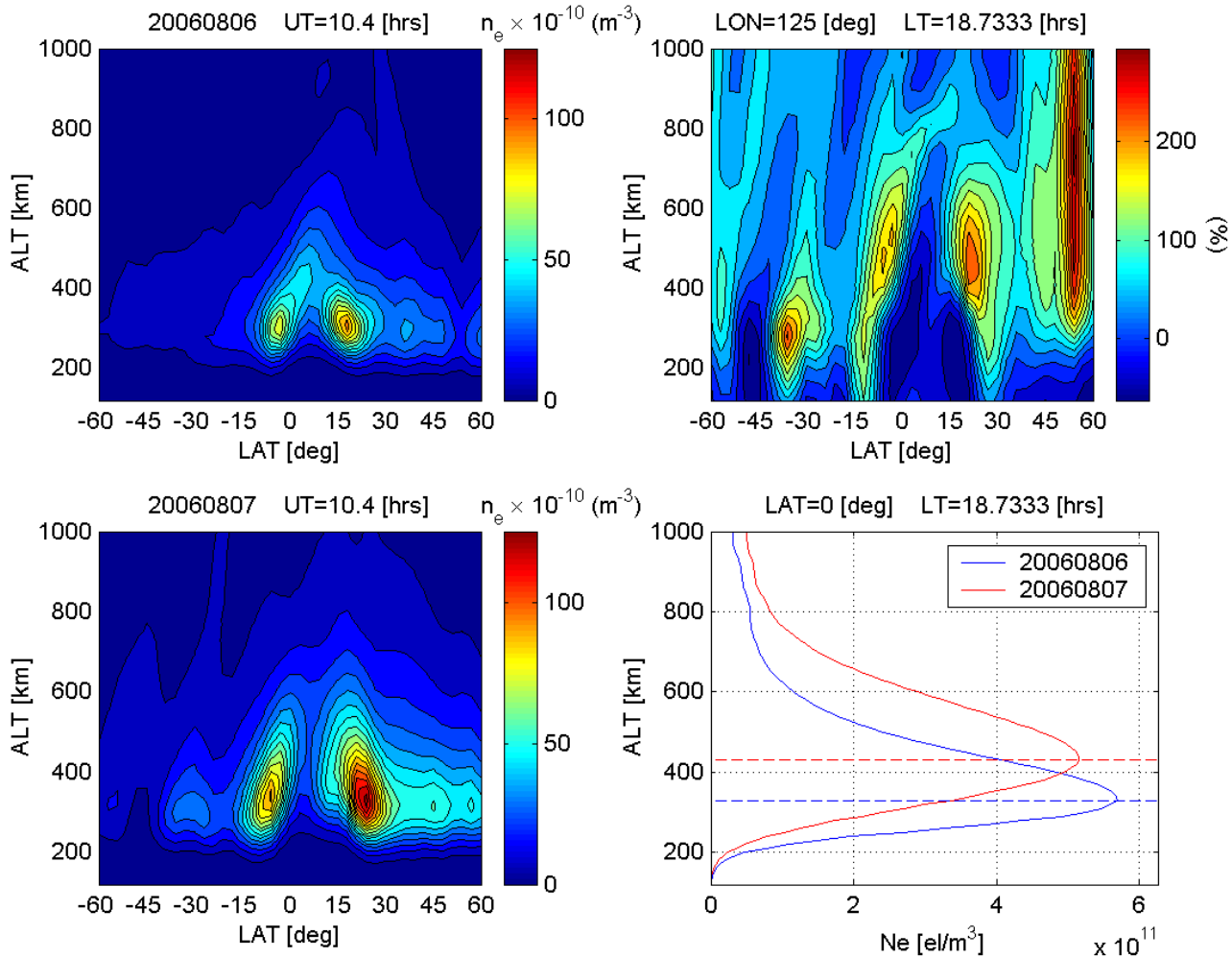


Importance of Data Proximity



Medium resolution GAIM NmF2 with COSMIC data matches well during the dense data period 11-17 UT

JPL/USC GAIM Storm-Time



Inputs: Ground TEC and COSMIC occultation data

Way Forward: Data Assimilation

- **Data assimilation: need to know the locations and times of the data**
- **Select data on/off by some reasonable criteria**
- **Data assimilation is an extremely useful addition to CCMC**

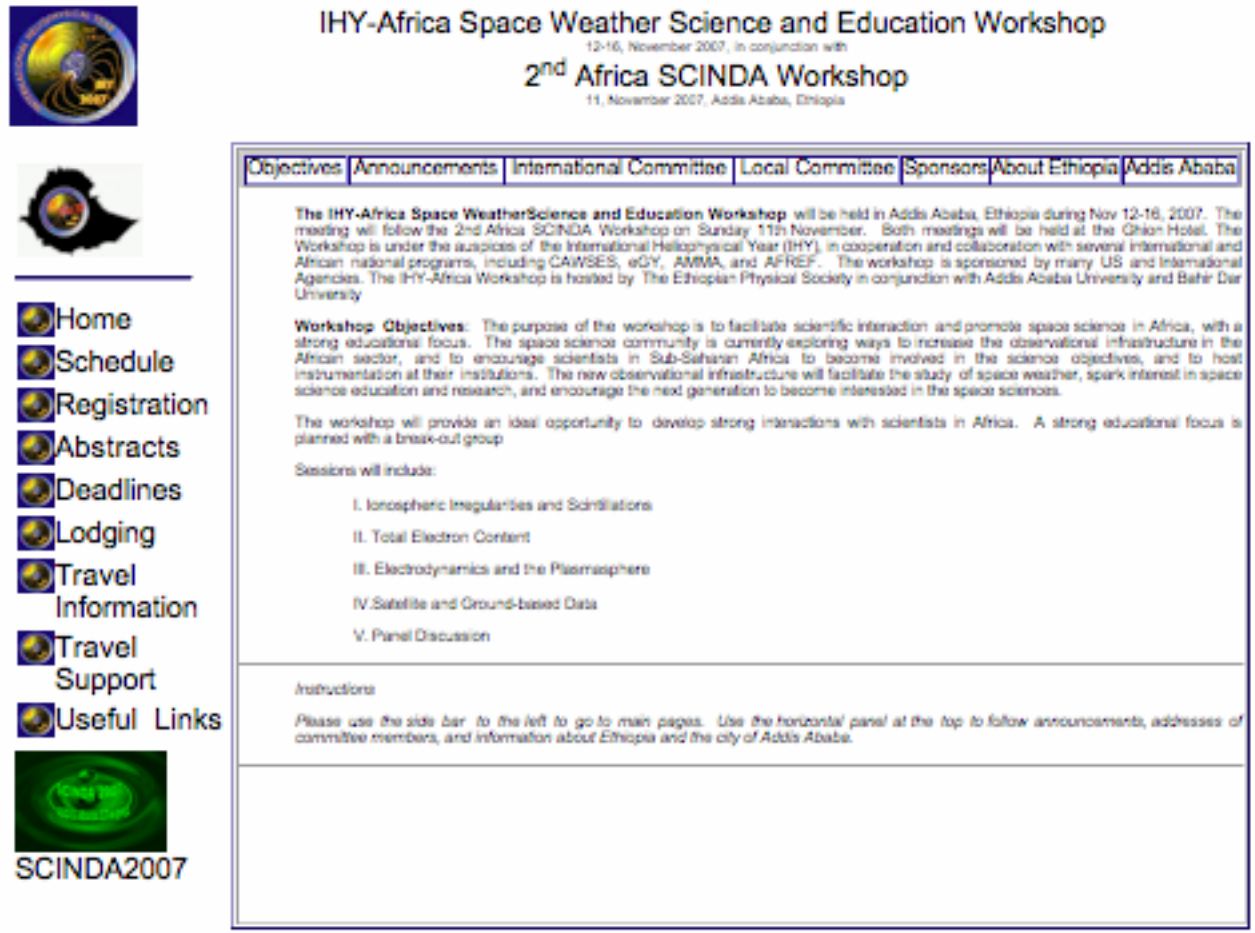
Way Forward: Science

- **Near-term: provide more diagnostic information on the drivers**
  - **Winds, electric fields, etc.**
  - **Multiple output fields**
- **Longer-term: inclusion of carefully tuned case-studies, studies from specific publications, etc.**
  - **Pre and post-tuned runs**
- **Longest-term: modify the drivers, user-tuning**
  - **Difficult in practice**

- **Specific request: AMIE**
- **Coupling (not sure what to say here)**

Way Forward: IPY

- **Outreach, think of the possibilities…**



Summary

- CCMC contains state-of-the-art models of the ionosphere-thermosphere system
- To progress on the scientific side: diagnostics, tuning, AMIE, coupling?
- To progress on the assimilation/operational side: data locations and switches
- Does CCMC address the “valley of death” problem?
  - Transition to operations is past the valley
- NOAA 2-day prediction – encouraging
  - One has to start somewhere (C/NOFS lesson)

BACKUP SLIDES

Closing the loop scientifically

1. Could what the model is describing happen?
2. What did happen?
3. Is the model describing what did happen
    1. If so, then we have closed the loop
    2. But only if we have no free parameters to “tune”
    3. If we have free parameters, then we have learned something about what is possible, but not what actually did occur