Ensemble Modeling with Data Assimilation Models: A New Strategy for Space Weather Specifications and Forecasts

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Science Focus

- **Elucidate the fundamental physical, chemical, and coupling processes that operate in the I-T-E system for a range of *actual, global-scale, space weather events*, including storms & substorms.**

- **Identify the spatial and temporal scales over which mass, momentum, and energy flow in the system.**

- **Determine the effect that *plasma and neutral gas structures (100-1000 km) have on global-scale flows.***

Model Construction

Construct a *Multimodel Ensemble Prediction System (MEPS)* for the Ionosphere-Thermosphere-Electrodynamics (I-T-E) system that will incorporate existing, first-principles-based, data assimilation models with different physics, numerics and initial conditions.

MEPS will allow ensemble modeling with different data assimilation models.

Model Construction

Goal of MEPS is to produce model output that is unbiased together with uncertainties that properly account for the true uncertainty.

Compelling evidence is that different physics, numerics and initial conditions of the contributing individual models provide more useful specifications and forecasts than those obtained from a single model.

National Hurricane Center multi-model ensemble forecast for hurricane Rita.

Data Assimilation Models

GAIM-BL ➔ Mid & Low Latitudes

GAIM-GM ➔ Mid & Low Latitudes

GAIM-4DVAR ➔ Mid & Low Latitudes, with Drivers

GAIM-FP ➔ Mid & Low Latitudes, with Drivers

IDED-DA ➔ High Latitudes, with Drivers

Mid-Low Electro-DA ➔ Ionosphere with Drivers

GTM-DA ➔ Global Thermosphere

- **Global, Regional & Nested GRID Capabilities**
- **GAIM-GM & GAIM-BL are Operational Models**
- **Specifications & Forecasts**

Data Sources for MEPS

Table 1. Data Sources that our new Data Assimilation System will assimilate

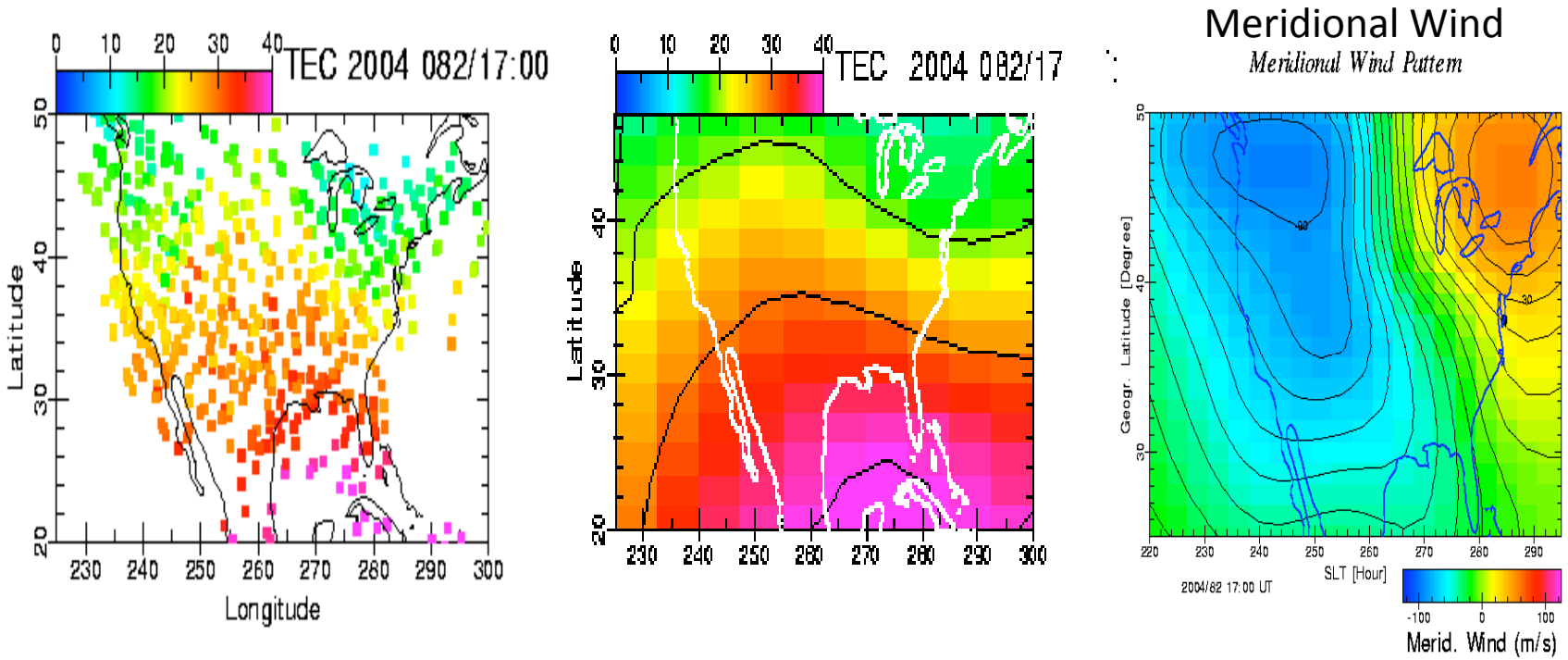
Ionosphere	Electrodynamics	Thermosphere
Ground-Based GPS-TEC	Ground magnetometers	Satellite UV emissions
Satellite-Based GPS Occultation	DMSP cross-track velocities	In situ neutral densities and winds
Ionosonde and Digisonde	SuperDARN line-of-sight velocities	Satellite accelerometer and drag
In situ N_e	Iridium magnetometers	FPI winds
911Å, 1356Å, limb, disk (UV)	ACE IMF, Dst	ISR Neutral parameters
Solar UV, EUV	Solar UV, EUV	Solar UV, EUV

Black: Data sources already being assimilated; Red: New data sources to be assimilated

Ionosphere Reconstructions With Self-Consistent Drivers

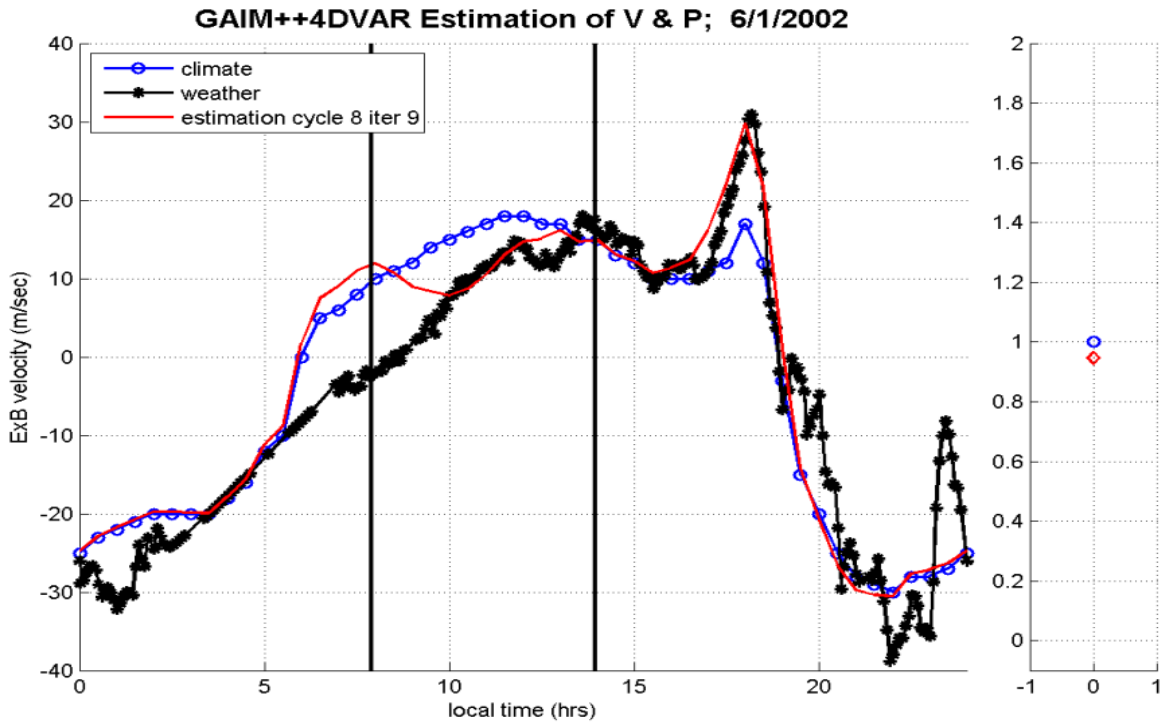
GAIM-FP ➔Regional Run

(Ensemble Kalman Filter)



- **Snapshots of TEC measurements (left)**
- **GAIM-FP reconstruction (middle)**
- **GAIM-FP neutral wind at 300 km (right)**
- **17:00 UT, day 82, 2004**

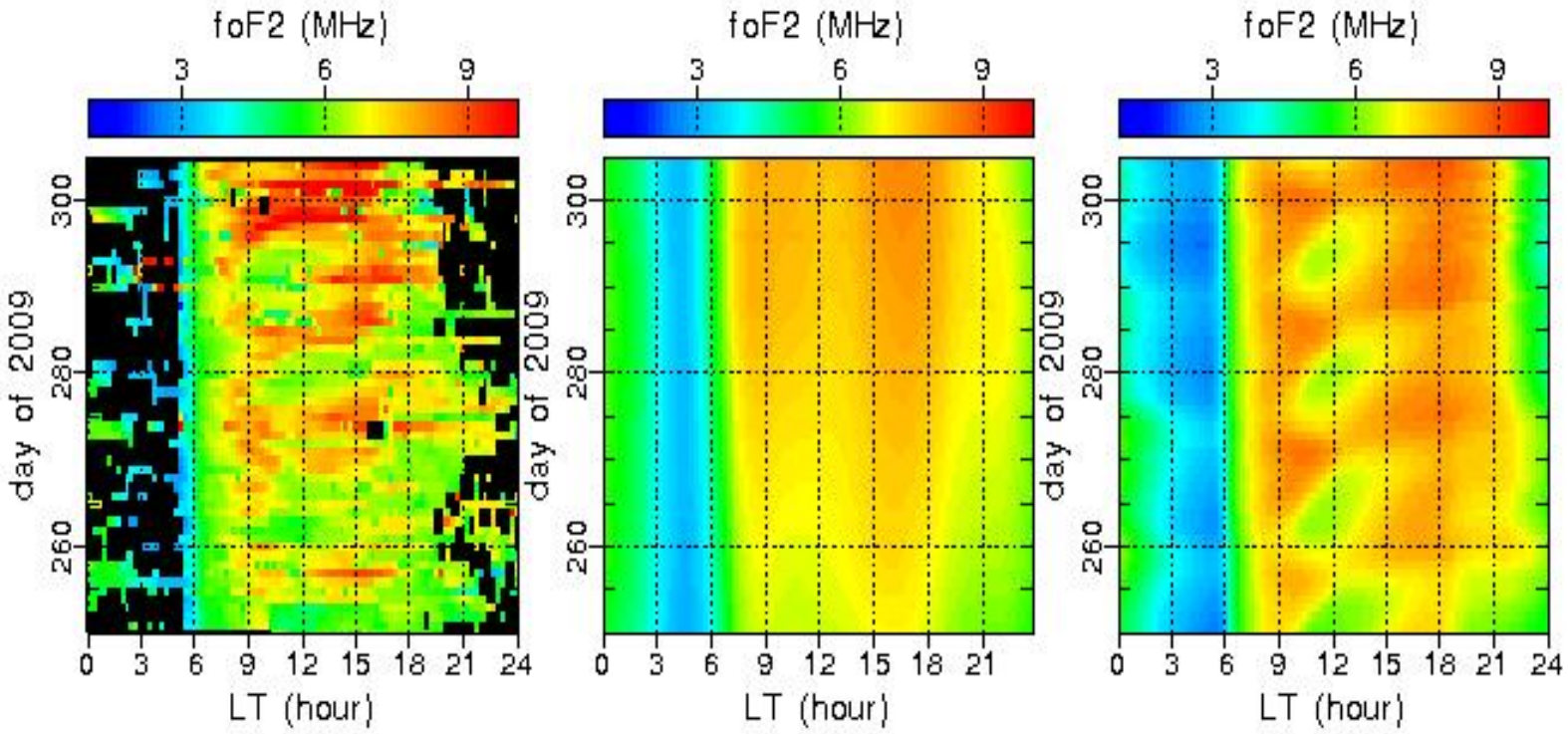
Ionosphere Reconstructions With Self-Consistent Drivers
GAIM - 4DVAR



- **Estimate equatorial electric field/plasma drift, ion production factor, and wind.**
- **Black circles indicate ISR measurements made at the Jicamarca Radio Observatory**
- **Blue curve is an empirical model result**
- **Red curve presents estimated vertical drift and a single-ion production factor**
- **Data assimilation helps GAIM catch the pre-reversal enhancement**

  [Pi et al., 2008].

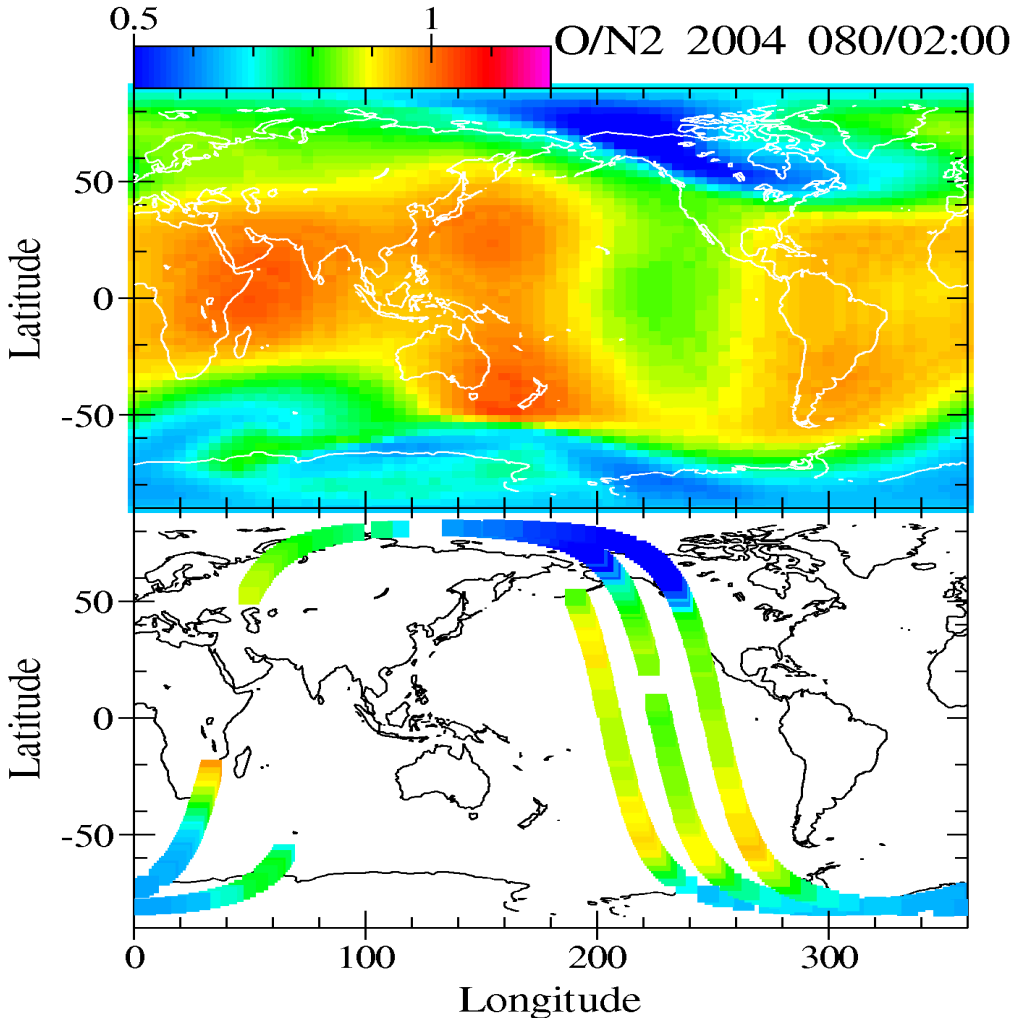
Ionosphere-Electrodynamics Reconstructions (Mid & Low Lat. Electrodynamics – DA)



- **Observed foF_2 at Jicamarca (left)**
- **Modeled foF_2 using Scherliess and Fejer plasma drifts (center)**
- **Derived foF_2 using an ensemble data assimilation model (right)**
- **Captures lunar and solar tides**

(*Eccles et al., 2011*)

Global Thermosphere Reconstructions
GTM-DA
(Ensemble Kalman Filter)



Global O/N_2 reconstruction from an ensemble Kalman Filter GTM-DA run

Synthetic SSUSI O/N_2 observations from 3 DMSP satellites were assimilated

Table 2. Delivery Schedule for Data Assimilation Models

	2013		2014		2015		2016		2017	
GAIM-GM				x						
GAIM-BL				x						
GAIM-FP						x				
GAIM-4DVAR							x			
IDED-DA								x		
GTM-DA									x	
Low-Mid Electrodynamics						x				
MEPS										x

Delivery Includes:

- Data Assimilation Model
- Associated Physics-Based Model
- User's Manuel
- Sample Test Cases (Input Data/Output)
- MEPS Team Support

Summary

- MEPS → ensemble modeling with different data assimilation models
- Data assimilation on multiple spatial & temporal scales
- Wide range of ground and space data
- An important tool for studying basic physics
- Can combine different data sets into a coherent picture
- Fills in regions where there are no data
- Can be used to study unresolved problems
- New approach to specifications and forecasts