Space Weather Forecasting with a Multimodel Ensemble Prediction System (MEPS) of Data Assimilation Models

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MEPS Model

The *Multimodel Ensemble Prediction System (MEPS)* covers the Ionosphere-Thermosphere-Electrodynamics (I-T-E) system and incorporates existing, first-principles-based, data assimilation models with different physics, numerical techniques, and initial conditions.

MEPS allows ensemble modeling with different data assimilation models.

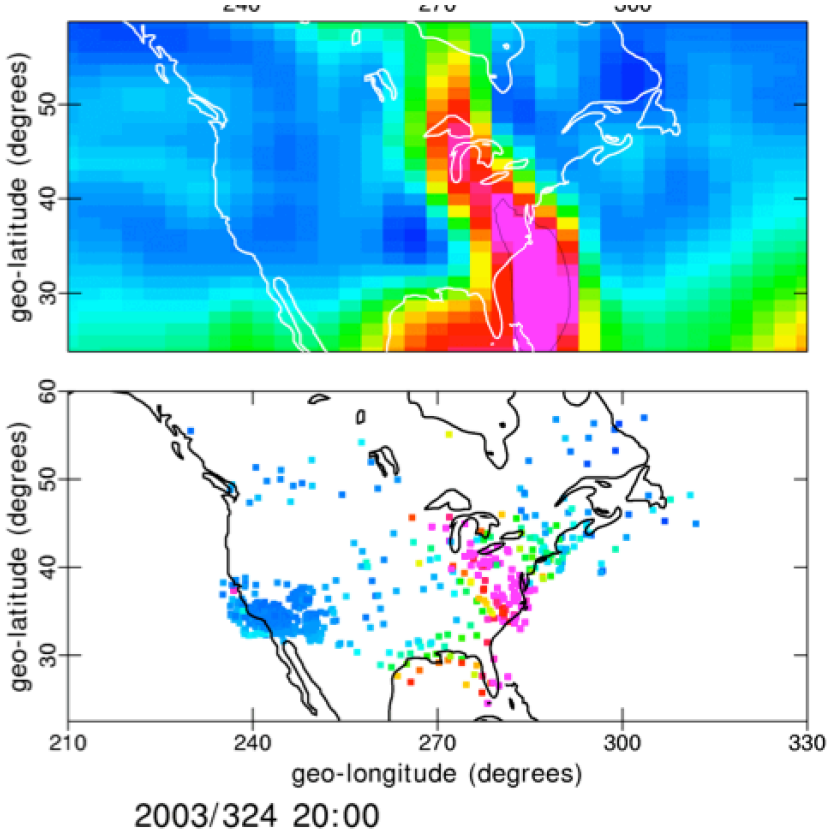
NASA/NSF Space Weather Modeling Collaboration Applications

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

Visualization of the ensemble process at work, meteorology

NASA/NSF Space Weather Modeling Collaboration Applications

Visualization of what ionospheric assimilation can do, and ensemble analysis would do even better.



- **GAIM-GM Reconstruction**
- **Similar Simulations with MEPS**

MEPS 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

Mid-Low Electro-DA ➔ Ionosphere with Drivers

IDED-DA ➔ High Latitudes, with Drivers

GTM-DA ➔ Global Thermosphere

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

MEPS Data Sources

Ionosphere	Electrodynamics	Thermosphere
Ground-Based GPS-TEC	Ground magnetometers	Satellite UV emissions
Satellite-Based GPS Occultation	DMSP cross-track velocities	In situ neutral 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

MEPS Ionosphere Simulation Plan

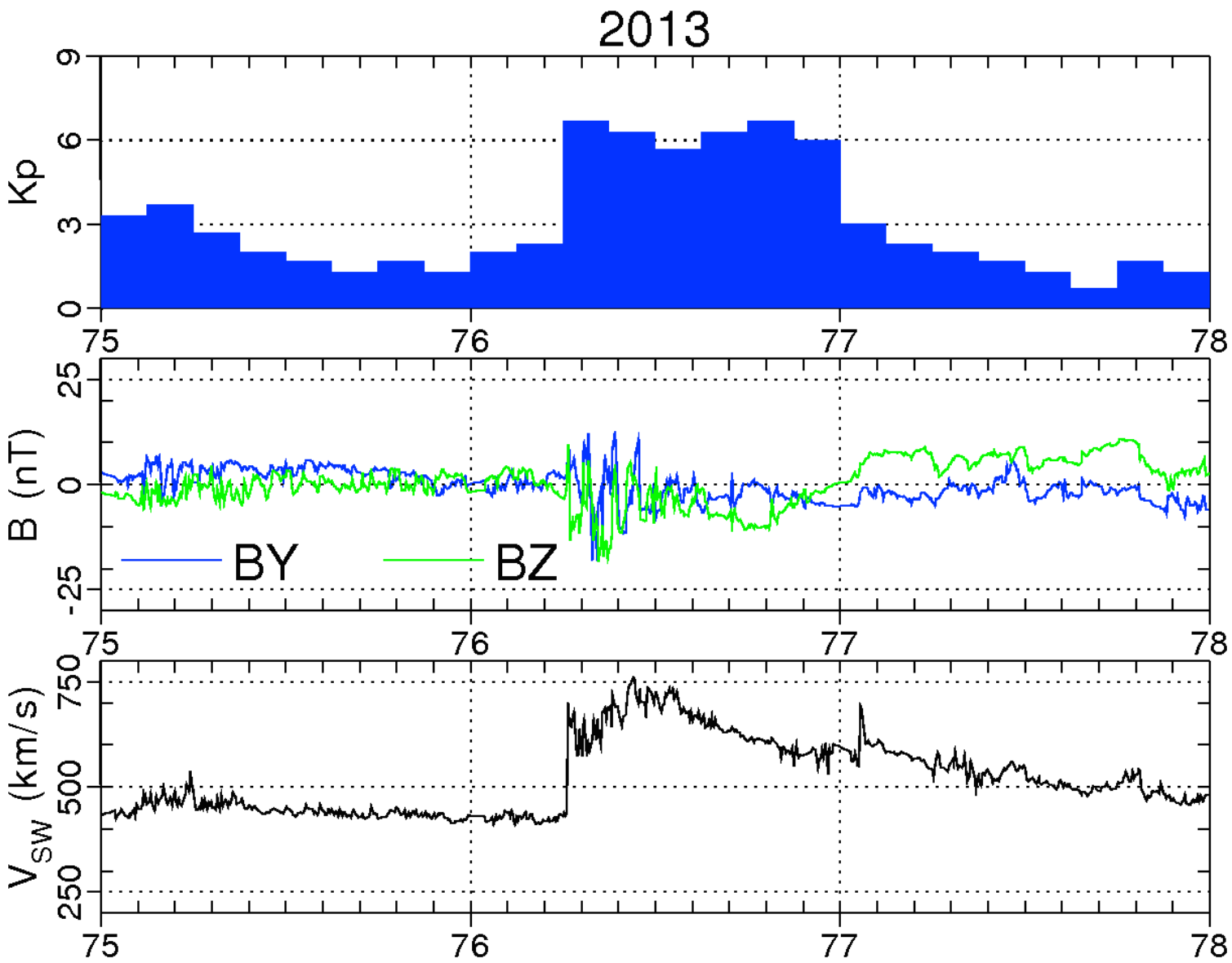
GAIM-BL → Mid & Low Latitudes
GAIM-GM → Mid & Low Latitudes
GAIM-4DVAR → Mid & Low Latitudes, with Drivers
GAIM-FP → Mid & Low Latitudes, with Drivers

BL – Band Limited
GM – Gauss Markov
4DVAR – 4D Adjoint Method
FP – Full Physics

MEPS Ionosphere Simulation Plan

- **Run 4 data assimilation models independently for same case**
- **Run with TEC data from 530 ground GPS receivers**
- **Run with 530 ground GPS receivers & COSMIC occultation data**
- **Run with 530 ground GPS receivers, occultation data, & 80 digisondes**

Goal is to see the differences in the model results and to see how the different models handle the same data type


2013
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6
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76
77
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B (nT)
25
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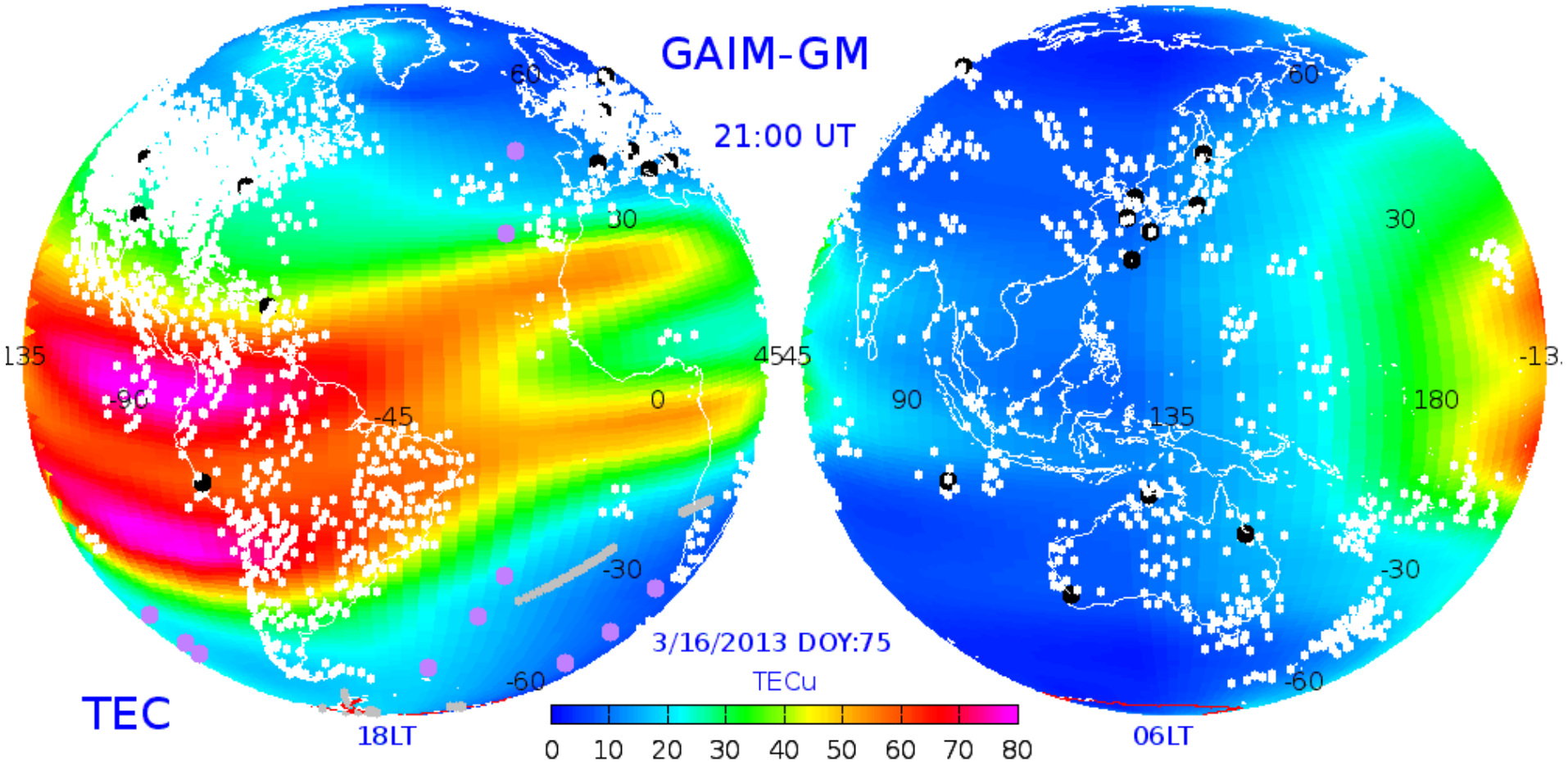
500
750


GAIM-GM
21:00 UT
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30
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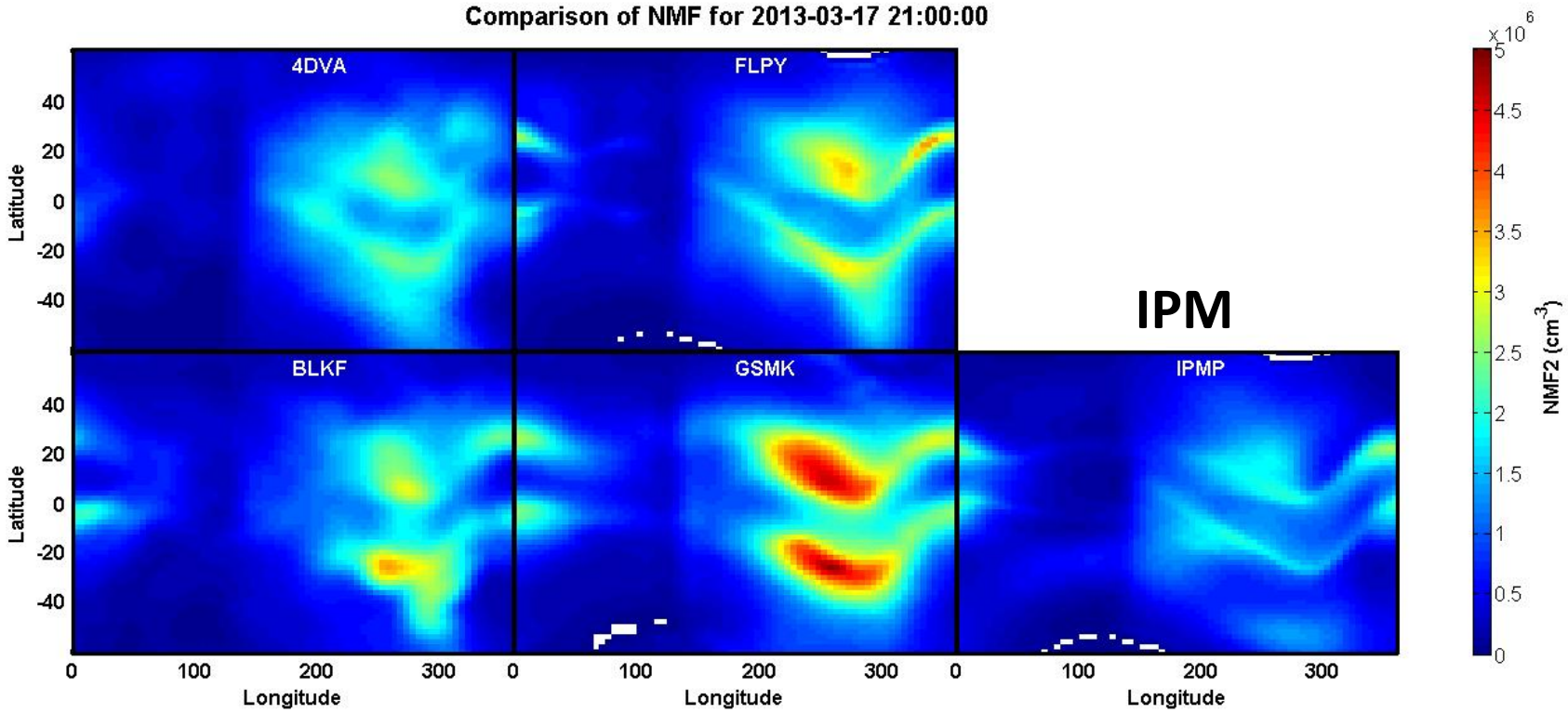
-30
-60
135
90
45
-45
-90
-135
180
-180
3/16/2013 DOY:75
TECu
0 10 20 30 40 50 60 70 80
TEC
18LT
06LT

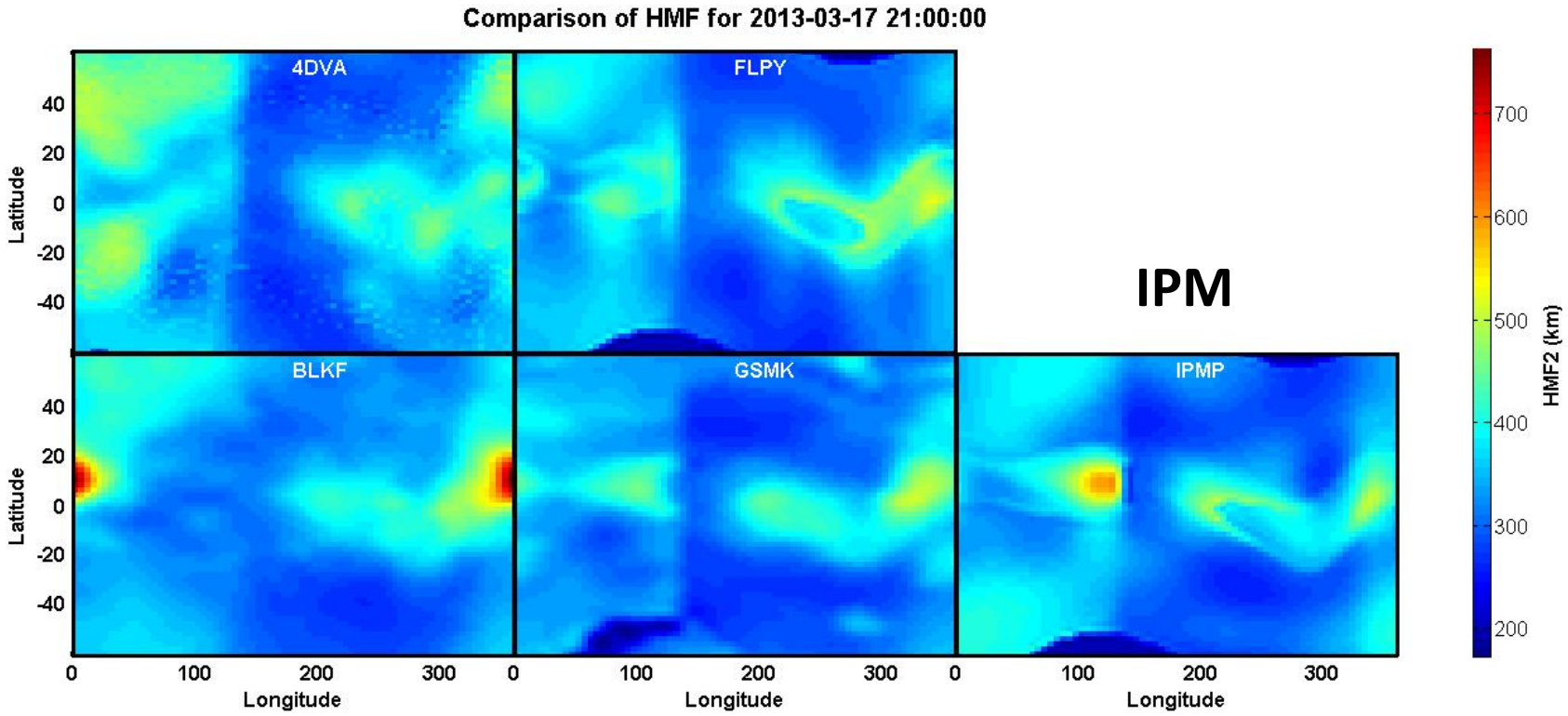
Run the Four Data Assimilation Models with TEC data from 530 ground GPS receivers

NmF2 Comparison for the Storm Day



- Differences in magnitude of the equatorial anomaly.
- Some differences in longitude and width of equatorial anomaly
- Four models show enhanced NmF2 in the southern hemisphere beyond 30° latitude
- IPM is background physics-based model for GAIM-FP

HmF2 Comparison for the Storm Day

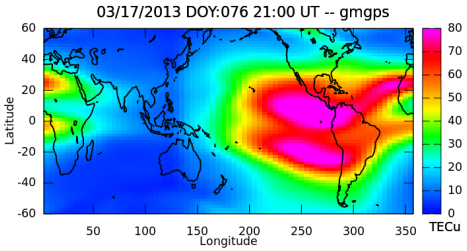
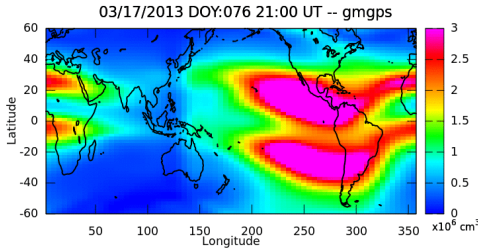
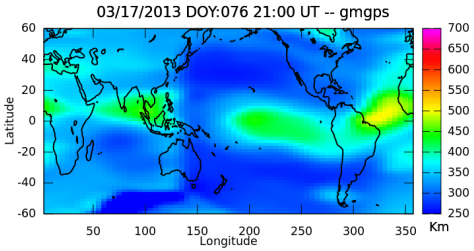
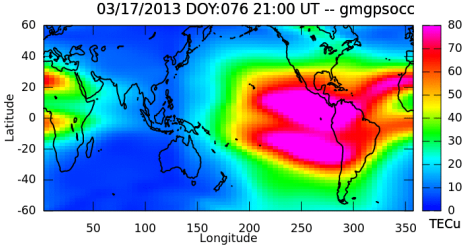
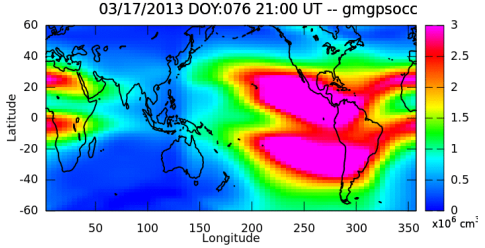
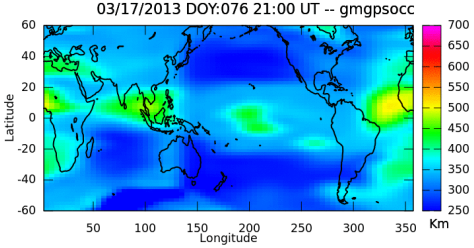
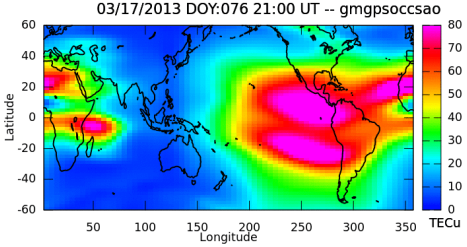
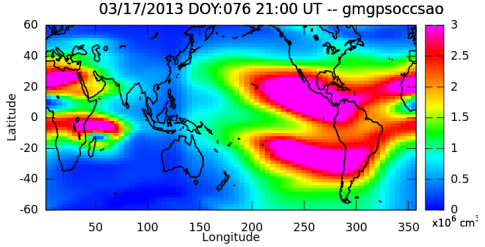
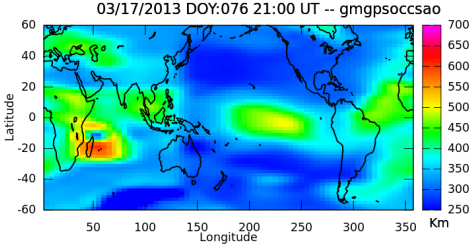


Differences in

- the equatorial region near 0° and 120° longitude
- middle latitudes in the southern hemisphere
- IPM is background physics-based model for GAIM-FP

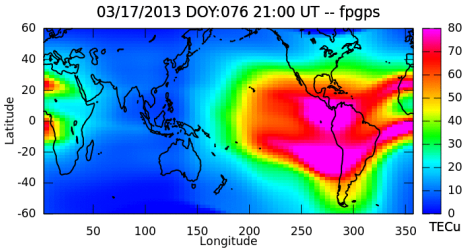
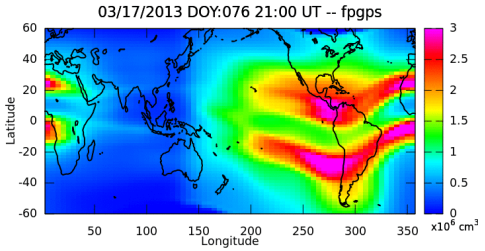
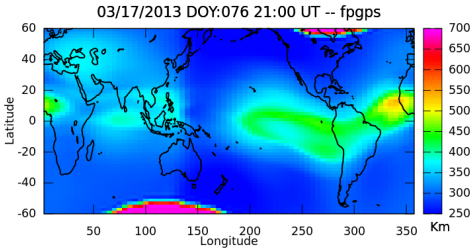
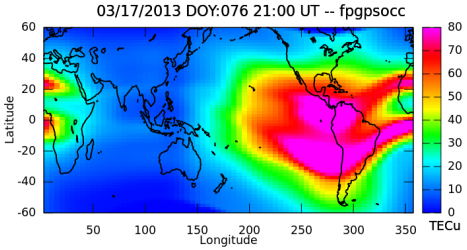
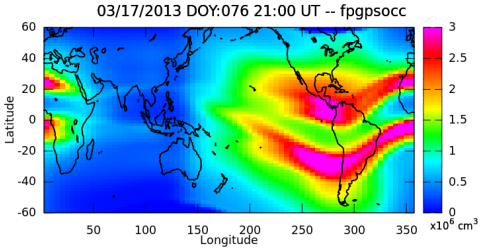
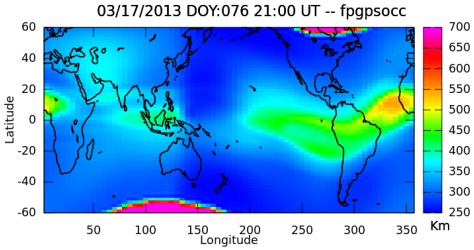
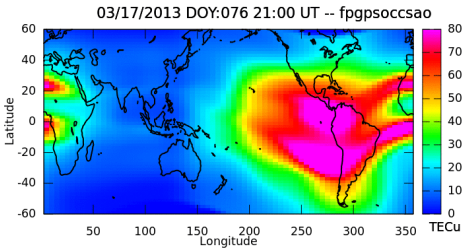
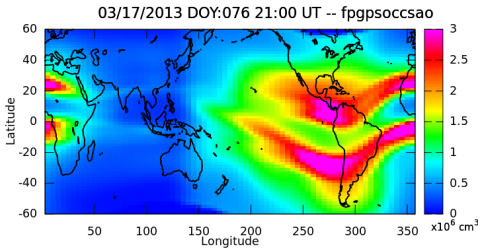
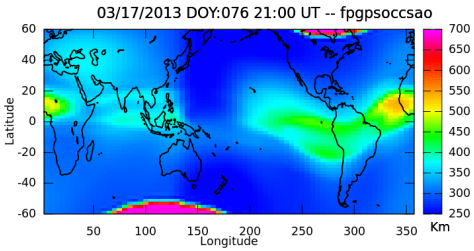
Effect of different data types

GAIM-GM 2013 Day 76 21:00 UT

	TEC	NmF2	hmF2
GPS			
GPS+occ			
GPS + occ + sao			

Storm Day

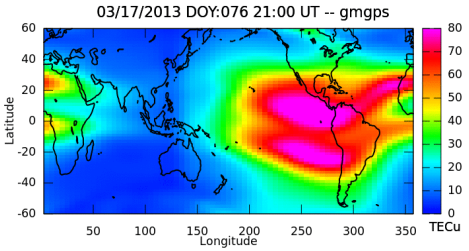
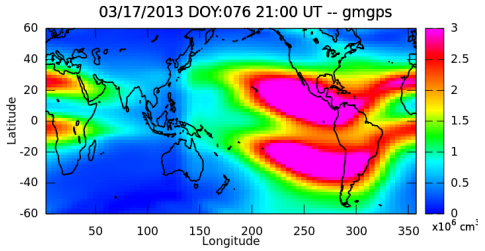
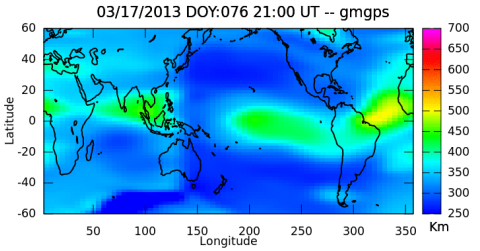
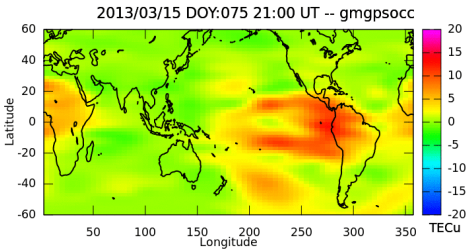
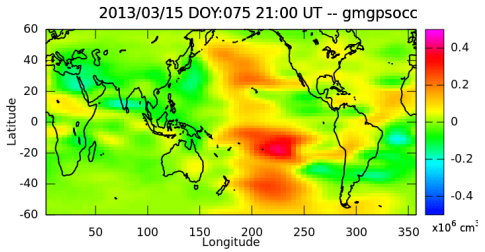
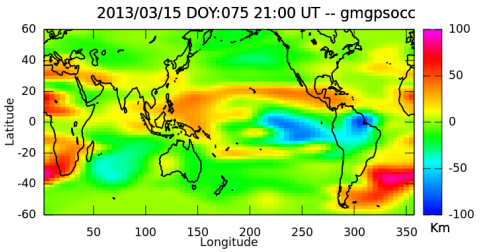
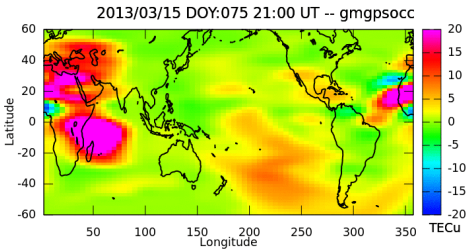
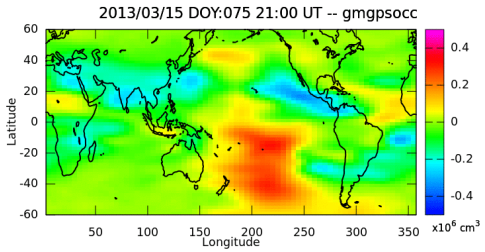
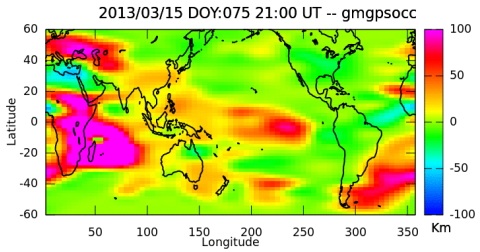
GAIM-FP 2013 Day 76 21:00 UT

	TEC	NmF2	hmF2
GPS			
GPS+occ			
GPS + occ + sao			

Storm Day

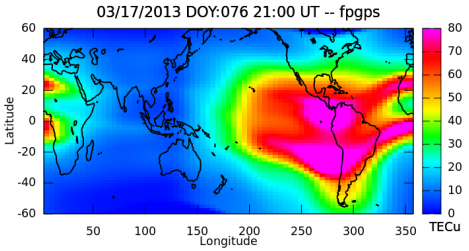
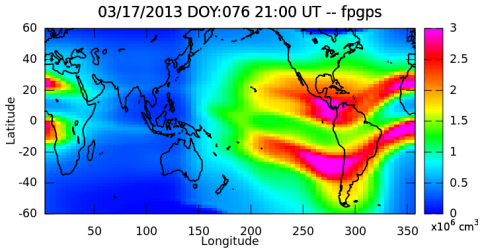
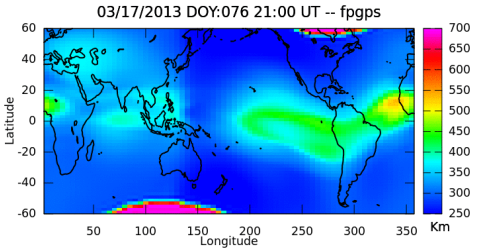
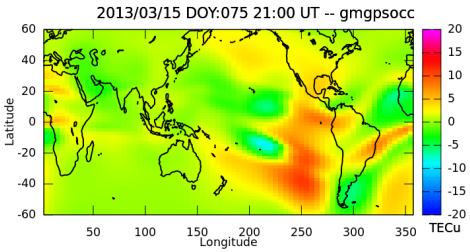
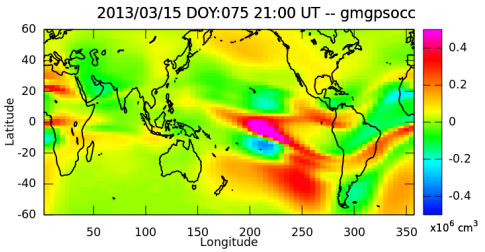
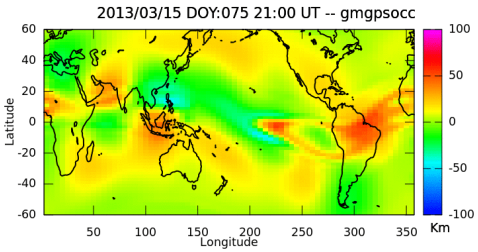
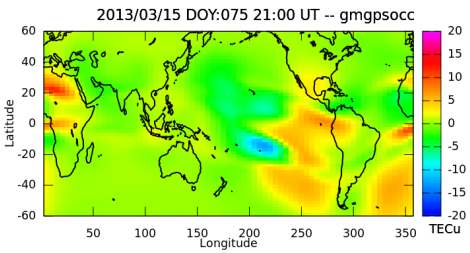
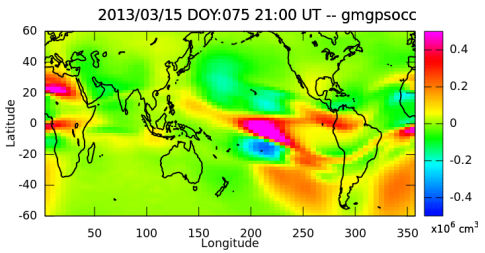
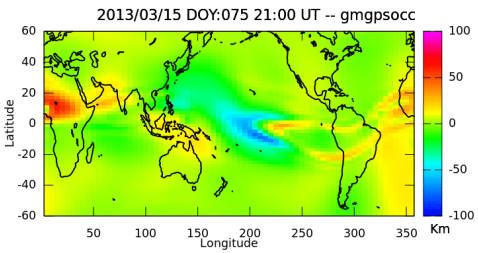
Top row (reconstruction with GPS/TEC data) subtracted from the bottom two rows to better show the effects of the occultation and digisonde data

GAIM-GM 2013 Day 76 21:00 UT Diff

	TEC	NmF2	hmF2
GPS			
GPS+occ			
GPS + occ + sa			

Storm Day

GAIM-FP 2013 Day 76 21:00 UT Diff

	TEC	NmF2	hmF2
GPS			
GPS+occ			
GPS + occ + sa			

Storm Day

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

MEPS Delivery Schedule to CCMC

GAIM-GM ➔ Latest upgraded version delivered March 2016

IDED-DA ➔ High Latitude GAIM, Fall 2016

Mid-Low Electro-DA ➔ Spring 2017

GAIM-FP ➔ Fall 2017

All Deliveries Include:

- **Background ionosphere models**
- **Connections to relevant data sources**
- **USU installation on CCMC computers**
- **User's Manual**