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 Science Focus

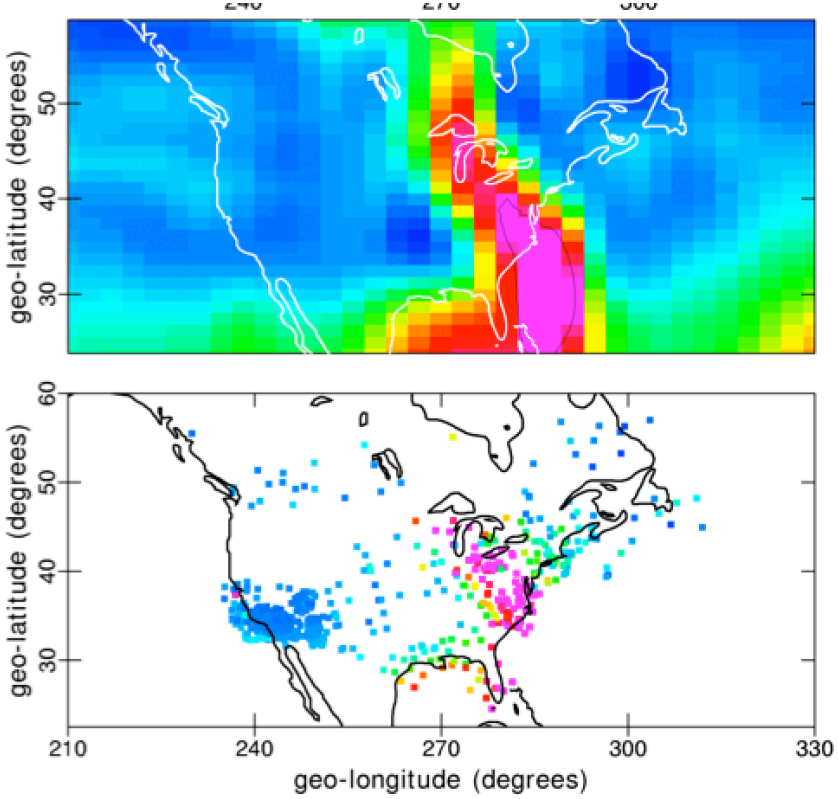
- **Elucidate the fundamental physical, chemical, and coupling processes that operate in the I-T-E system for a range of *actual, global-scale, space weather events*, including storms & substorms.**

- **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.***

NASA/NSF Space Weather Modeling Collaboration Applications

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



- GAIM-GM Reconstruction
- Will redo 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 Initial Simulation Plan

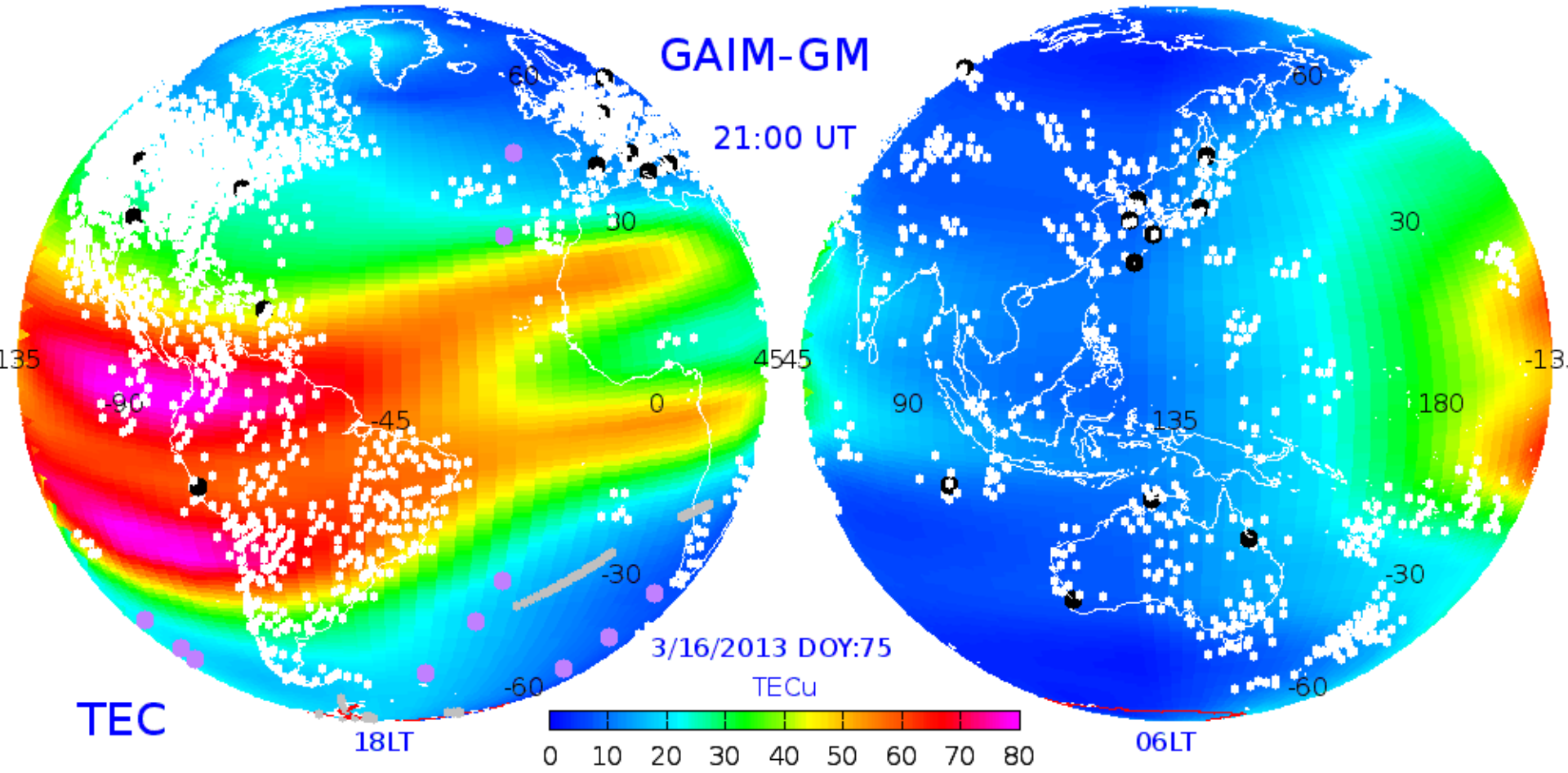
GAIM-BL → **Mid & Low Latitudes**
GAIM-GM → **Mid & Low Latitudes**
GAIM-4DVAR → **Mid & Low Latitudes, with Drivers**
GAIM-FP → **Mid & Low Latitudes, with Drivers**

Ionosphere
Ground-Based GPS-TEC
Satellite-Based GPS Occultation
Ionosonde and Digisonde
In situ N_e
911Å, 1356Å, limb, disk (UV)

MEPS Initial Simulation Plan

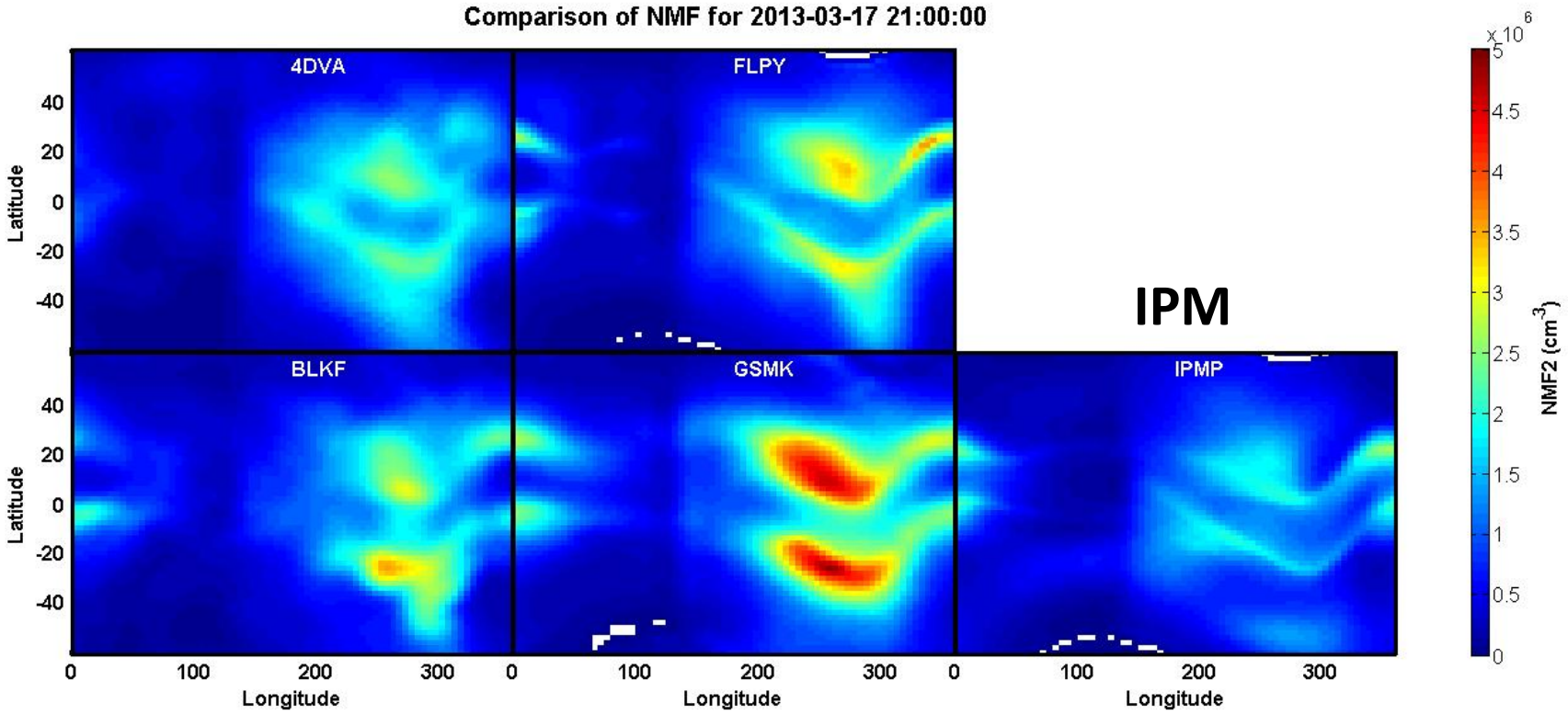
- Run 4 data assimilation models independently for same case
- Run with TEC data from 530 ground GPS receivers
- Run with 530 ground GPS receivers & COSMIC occultation data
- Run with 530 ground GPS receivers, occultation data, & 80 digisondes

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


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

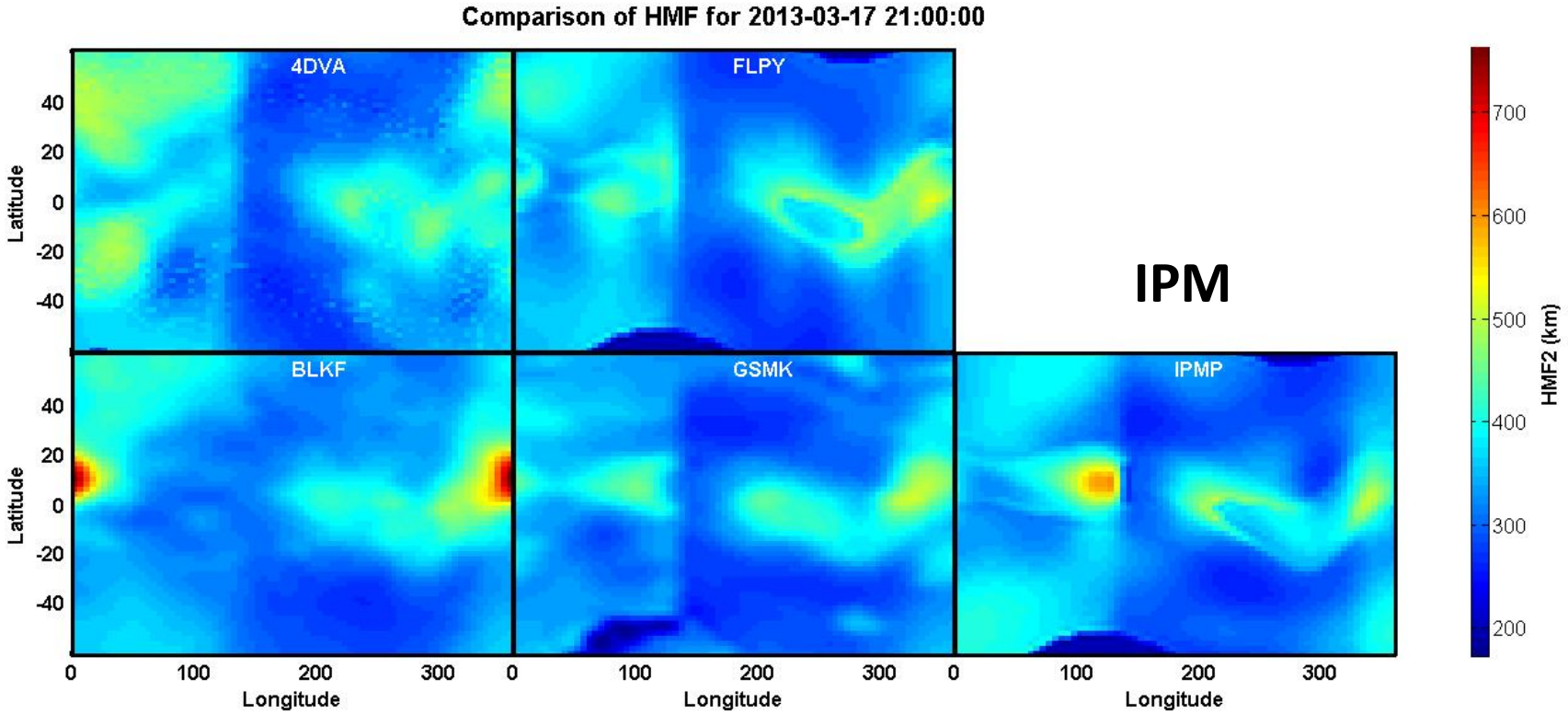
Run the Four Data Assimilation Models with TEC data from 530 ground GPS receivers

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

HmF2 Comparison for the Storm Day



Differences in

- the equatorial region near 0° and 120° longitude
- middle latitudes in the southern hemisphere

GAIM-GM 2013 Day 76 21:00 UT

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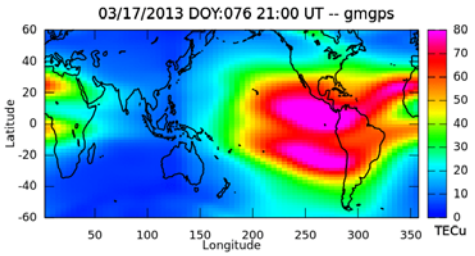
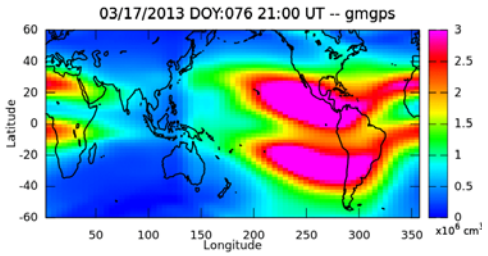
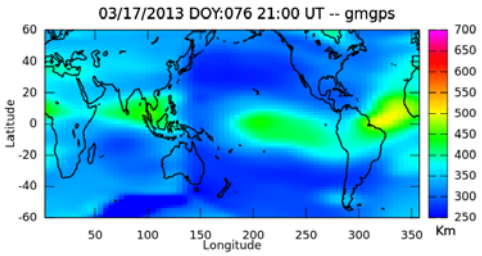
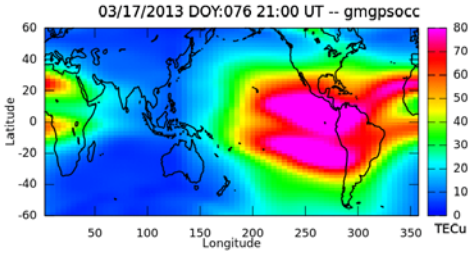
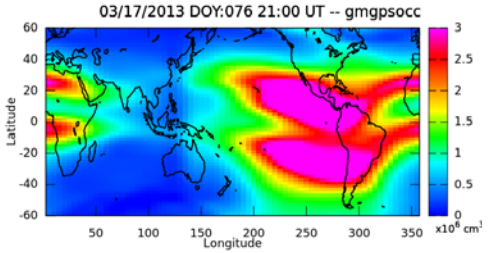
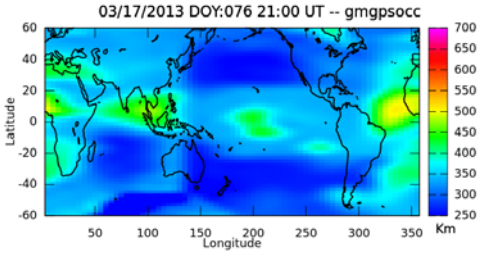
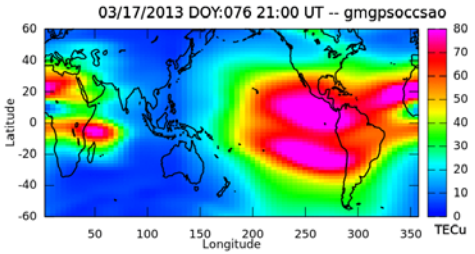
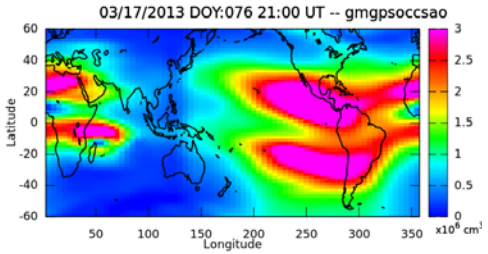
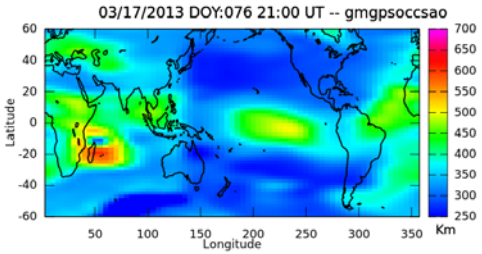
GPS			
GPS+occ			
GPS + occ + sao			

Storm Day

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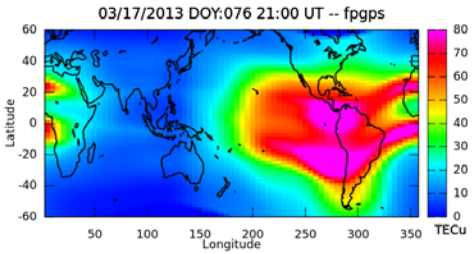
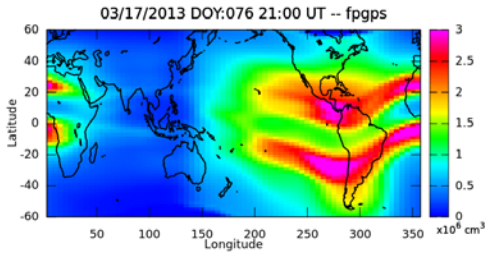
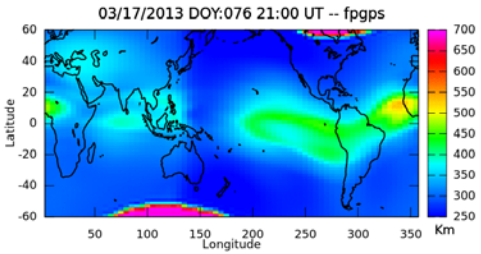
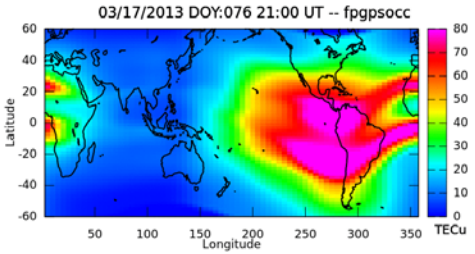
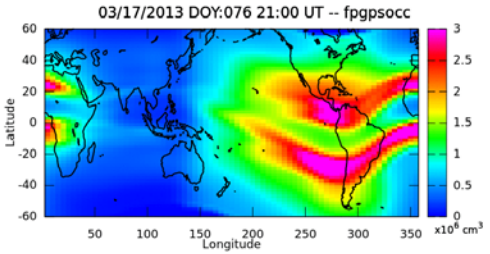
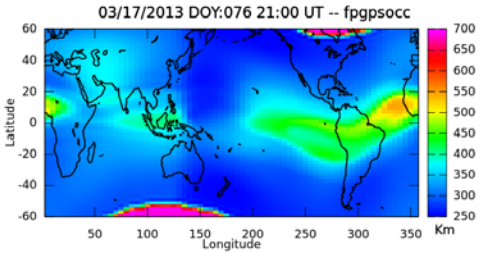
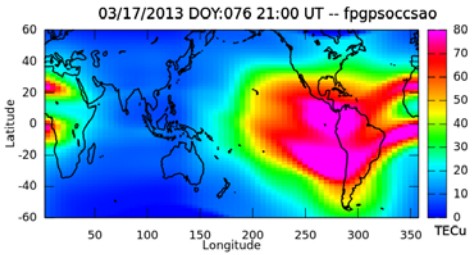
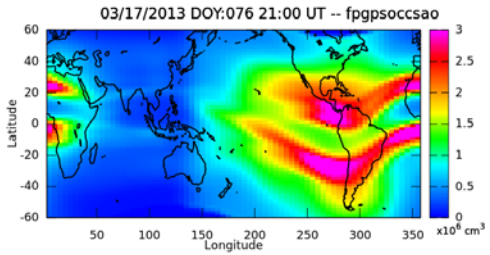
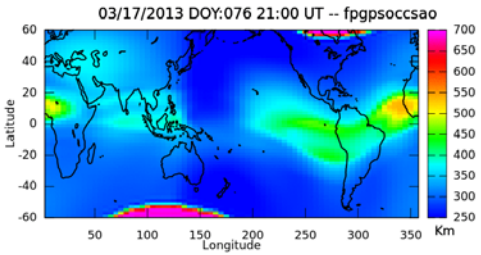
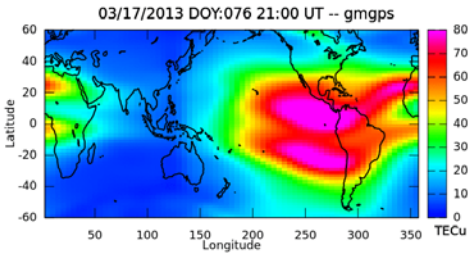
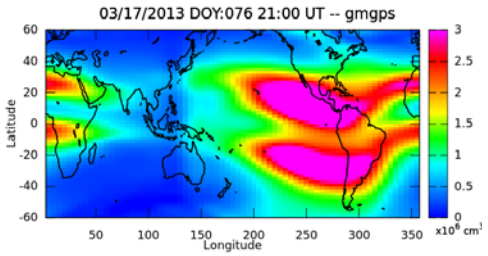
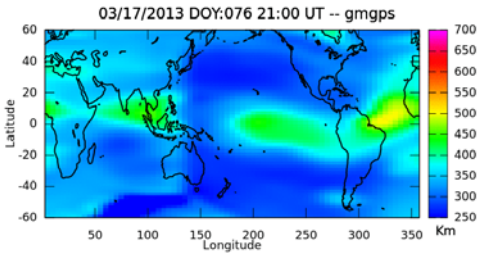
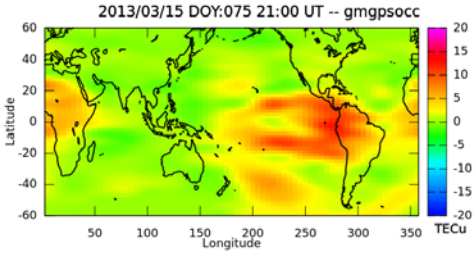
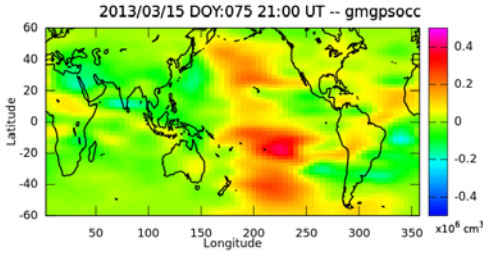
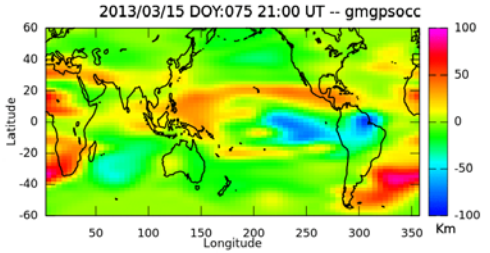
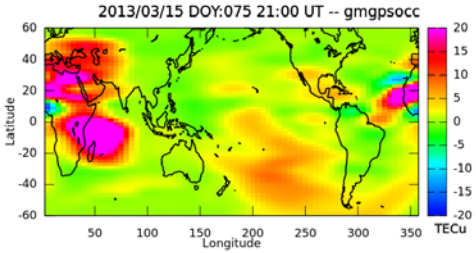
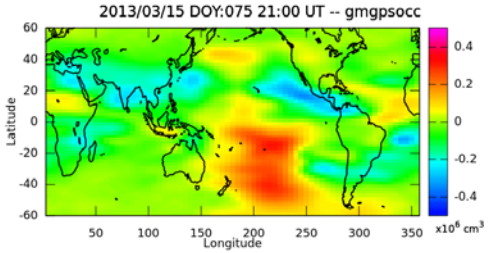
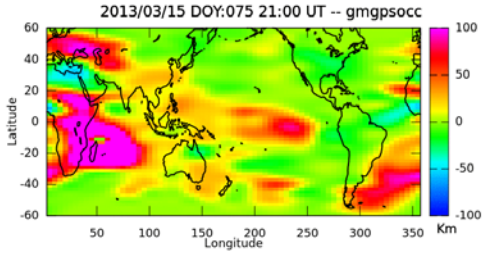
	TEC	NmF2	hmF2
GPS			
GPS+occ			
GPS + occ + sao			

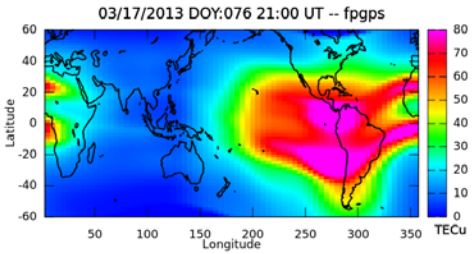
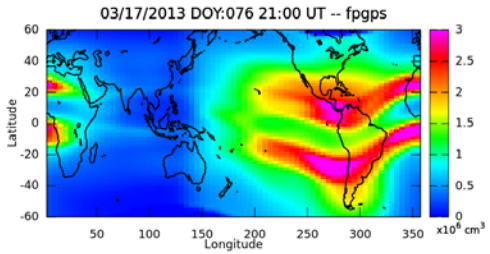
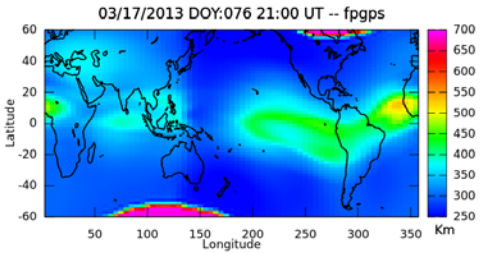
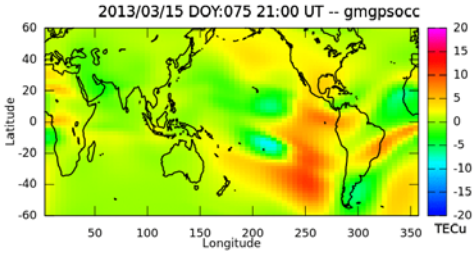
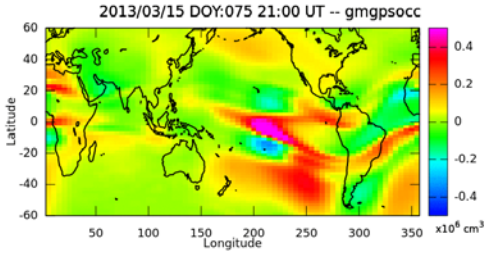
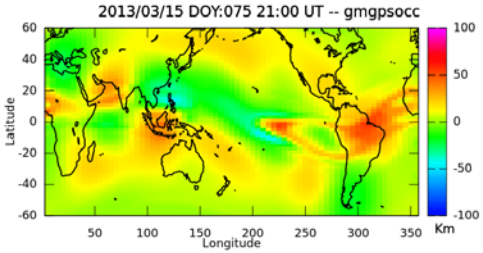
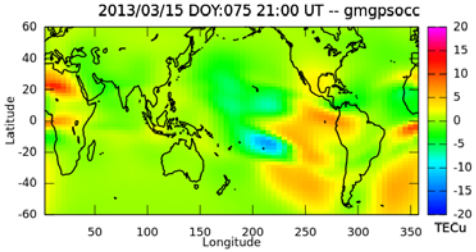
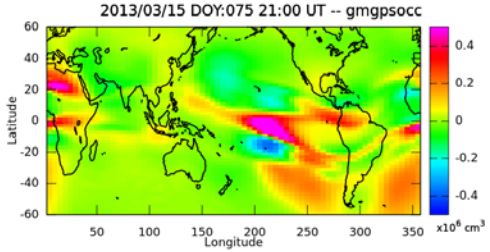
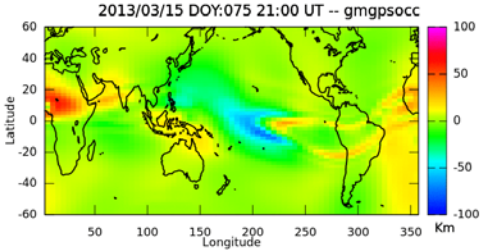
Storm Day

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

Models Display Both Qualitative and Quantitative Differences

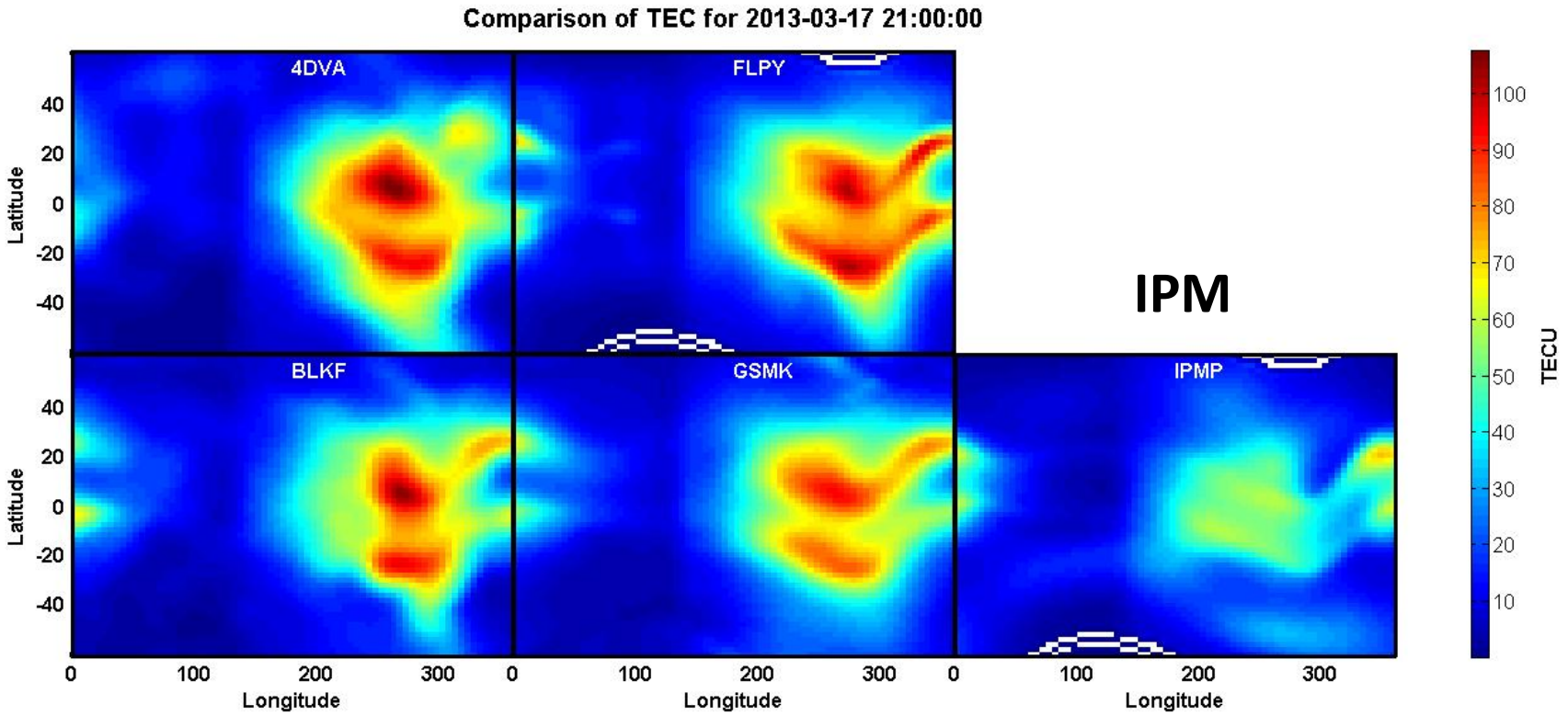
- Different Background Physics-Based Models
- Different Assimilation Techniques
- Different Spatial and Temporal Resolutions
- Different Deduced Electrodynamics Drifts
- Different Deduced Neutral Winds and O/N_2 Ratios

Goal is a Systematic Study to Elucidate Causes of Differences

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

TEC Comparison for the Storm Day



- Agreement in TEC enhancement (magnitude)
- Some differences in the extension and width of equatorial anomaly
  - Four models show enhanced TEC in the southern hemisphere beyond 30° lat
  - Extent of the enhancement

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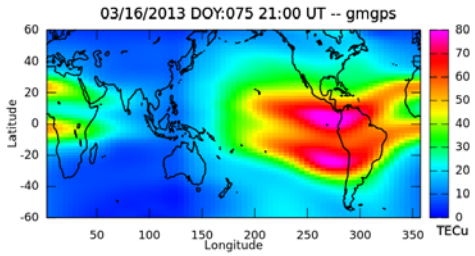
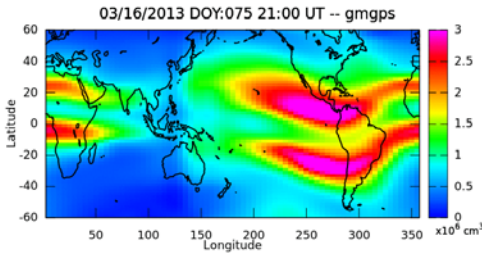
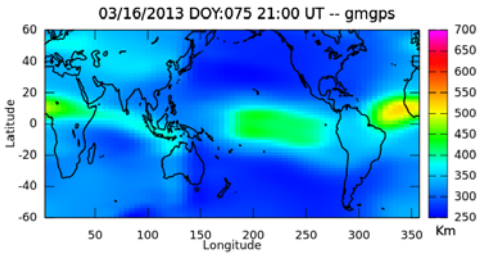
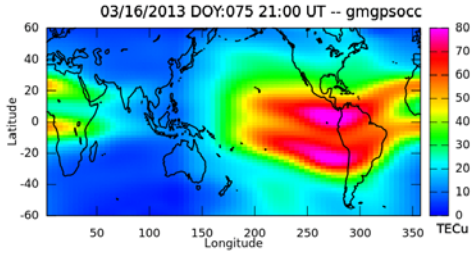
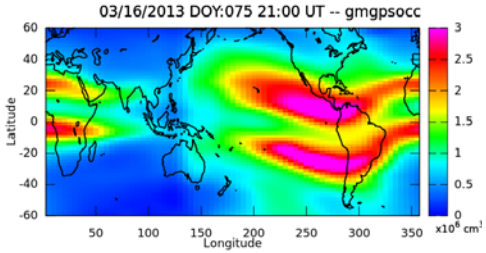
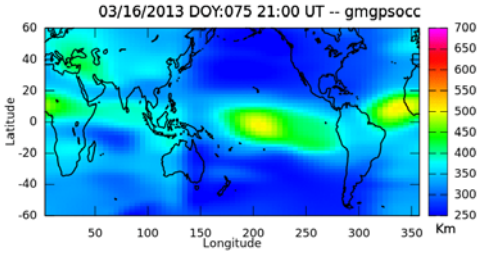
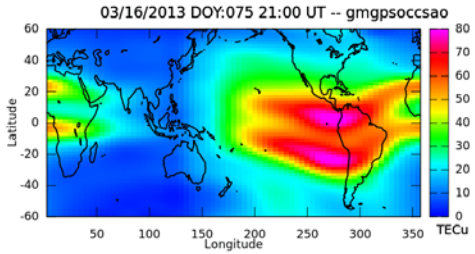
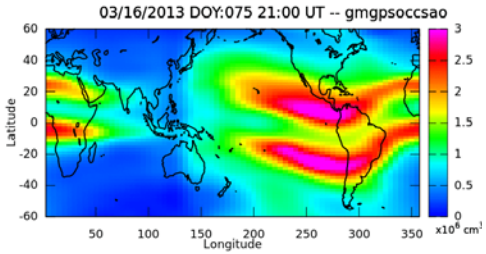
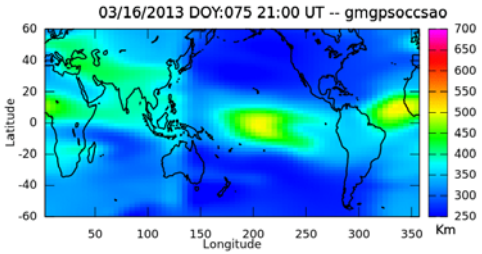
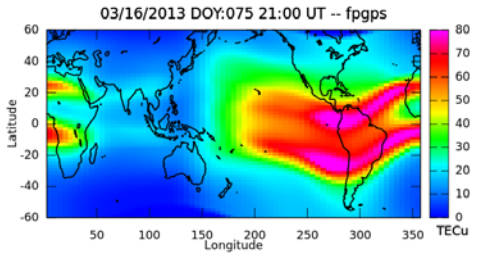
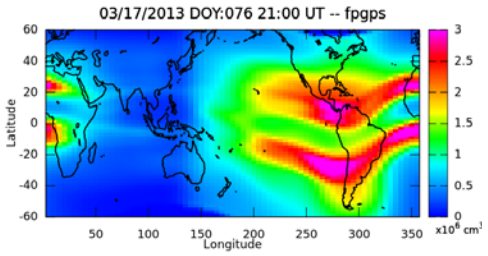
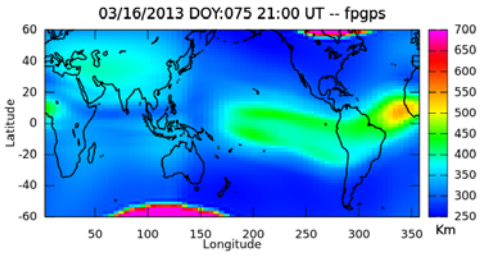
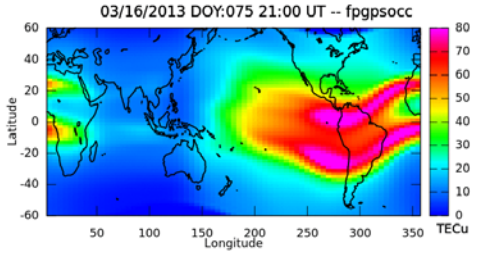
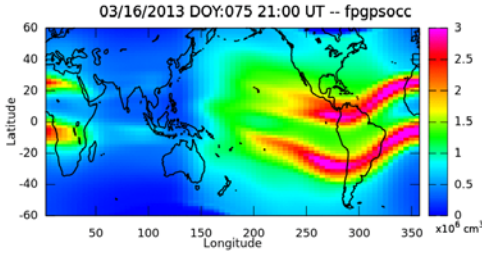
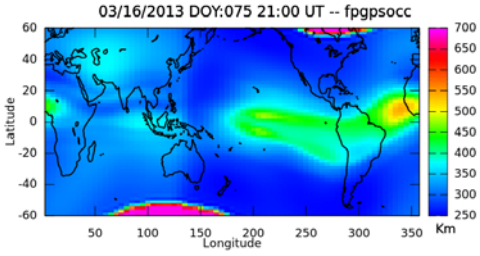
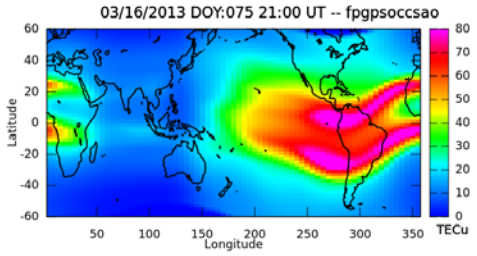
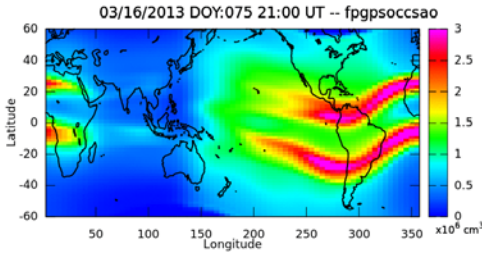
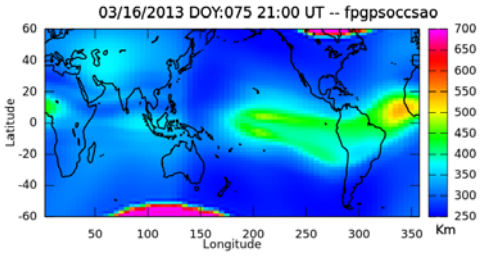
	TEC	NmF2	hmF2
GPS			
GPS+occ			
GPS + occ + sao			

GAIM-FP 2013 Day 75 21:00 UT

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

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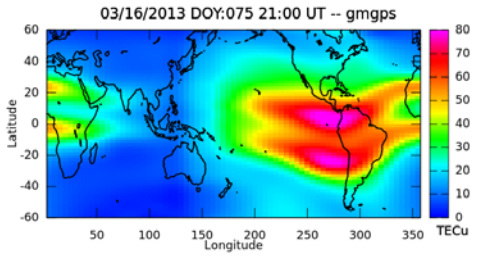
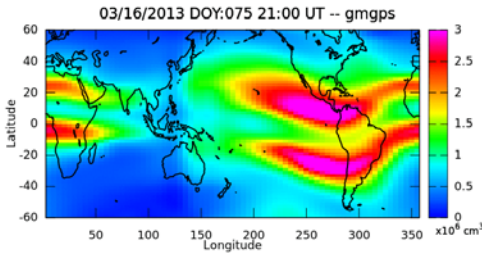
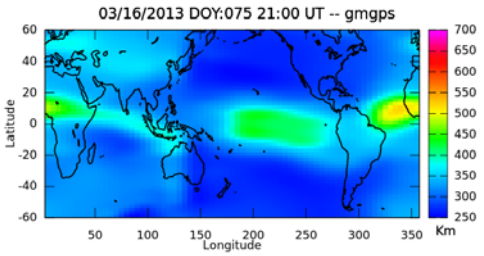
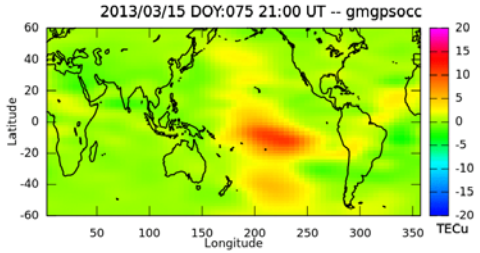
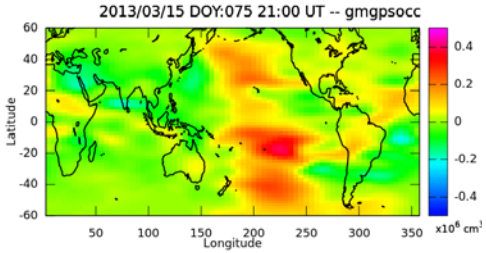
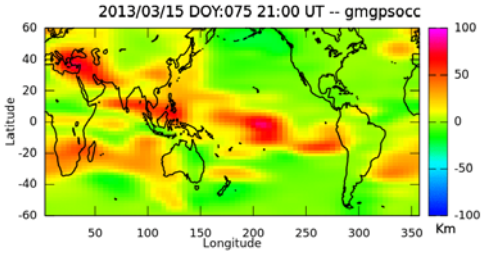
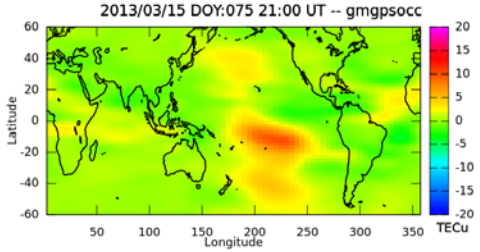
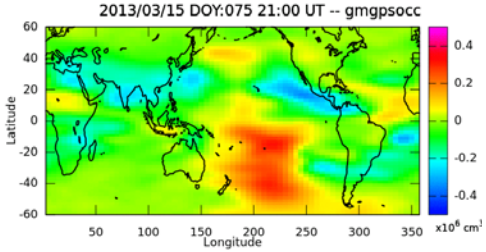
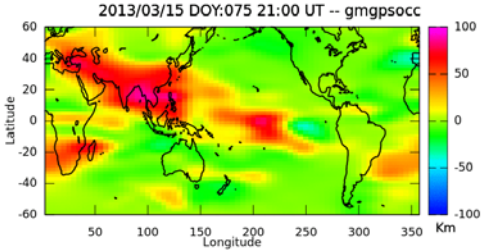
GPS			
GPS+occ			
GPS + occ + sao			

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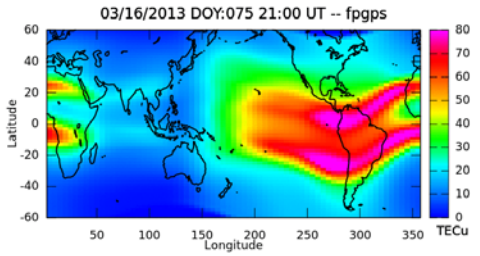
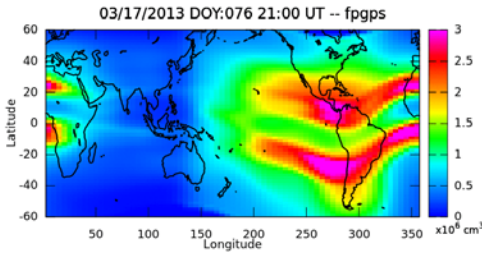
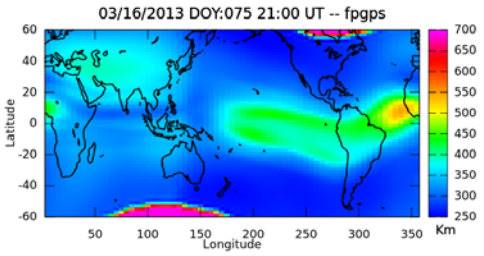
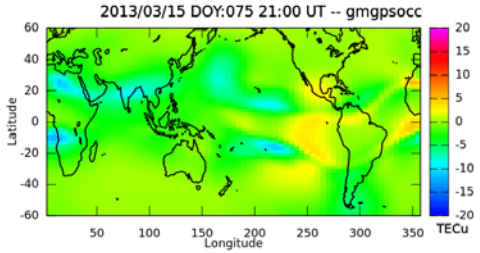
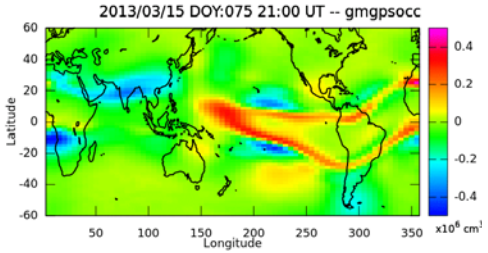
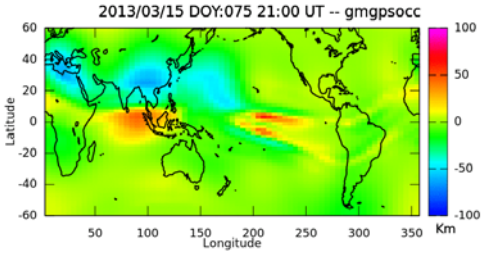
	TEC	NmF2	hmF2
GPS			
GPS+occ			
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