

The USU-GAIM Data Assimilation Models for Ionospheric Specifications and Forecasts

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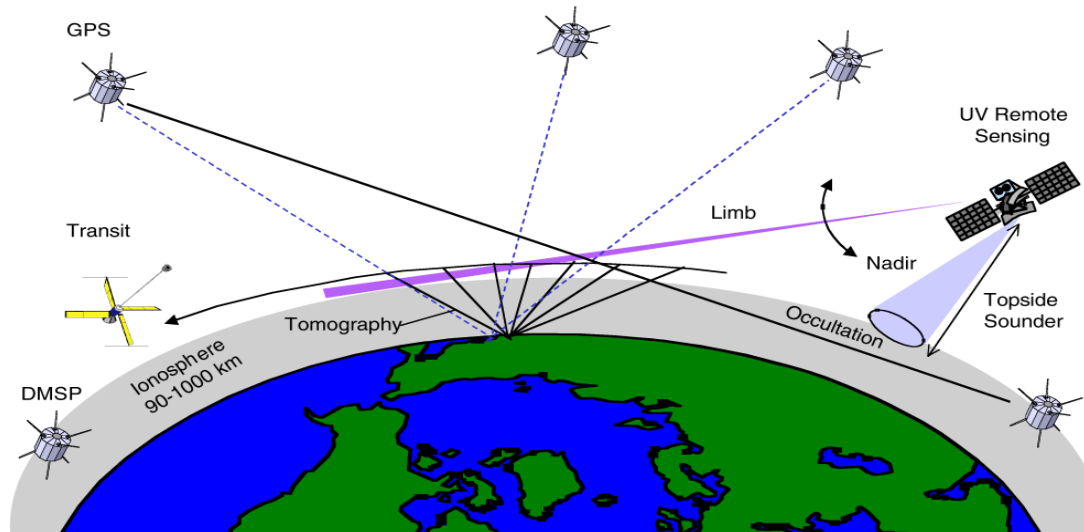
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Brief Overview of USU Data Assimilation Models

- GAIM-GM** → **Mid & Low Latitudes**
- GAIM-FP** → **Mid & Low Latitudes, with Drivers**
- Mid-Low Electro-DA** → **Ionosphere with Drivers**
- GAIM-High Lat** → **High Latitudes with Drivers**
- GTM-DA** → **Global Thermosphere**
- TWAM-DA** → **Thermosphere Wind**

- **All Data Assimilation Models are Physics-Based**
- **Spatial and Temporal Resolutions are arbitrary**

GAIM 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

GAIM-Full Physics

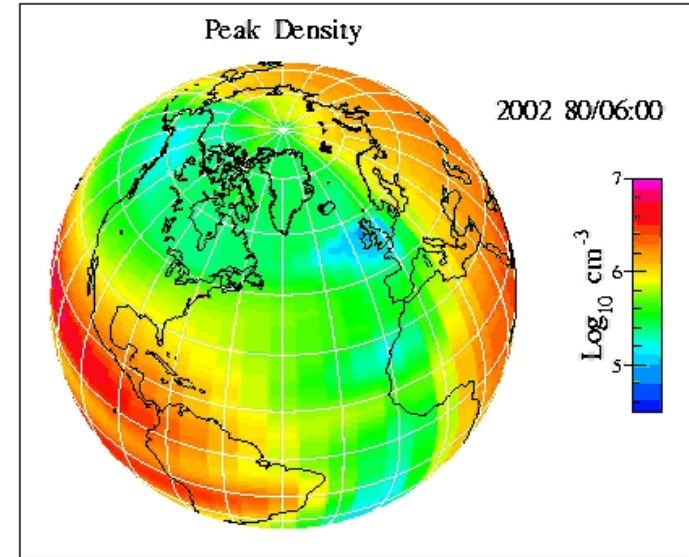
- Ensemble Kalman Filter (24-30 members)
- Physics-based Ionosphere-Plasmasphere Model (IPM)
- 5 Data Sources as shown on previous slide

Additional Data Types that could be assimilated in GAIM-FP:

- Electric Field
- Neutral Wind
- Thermospheric Temperature and Composition
- Etc.

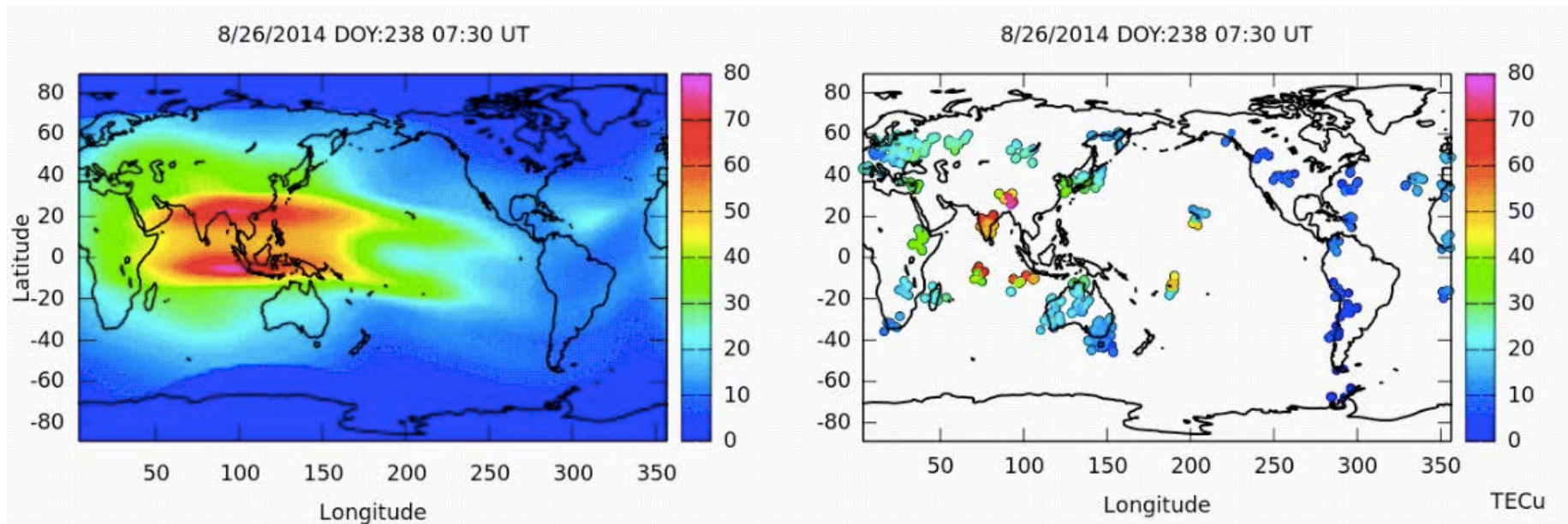
GAIM-FP uses the full physics that is included in the physics-based model (IPM) in the data assimilation scheme

- 90-30,000 km
- Altitude, Latitude, Longitude Grids Set by User
- Six Ion Species (NO^+ , O_2^+ , N_2^+ , O^+ , H^+ , He^+)
- Realistic Magnetic Field (IGRF)
- Some of the Physical Processes included in IPM:
 - Field-Aligned Diffusion
 - Cross-Field Electrodynamical Drifts
 - Thermospheric Winds
 - Neutral Composition Changes
 - Energy-Dependent Chemical Reactions
 - Ion Production due to:
 - Solar UV/EUV Radiation
 - Auroral Precipitation
 - Star Light



GAIM-FP Global Run

- 400 global TEC stations (IGS network) used in real-time at USU Space Weather Center
- Up to 10,000 measurements assimilated every 15- min
- 40-50 Ionosondes/Digisondes

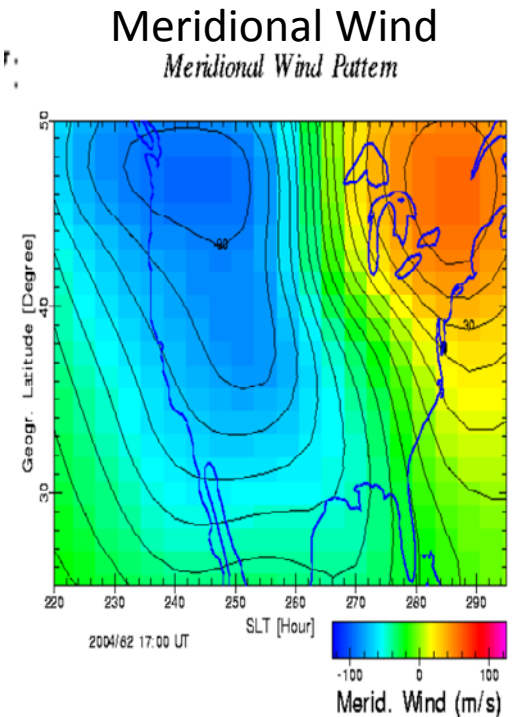
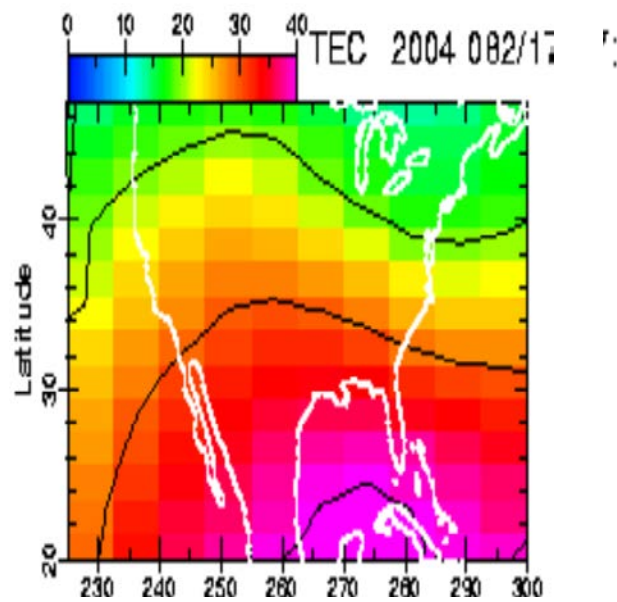
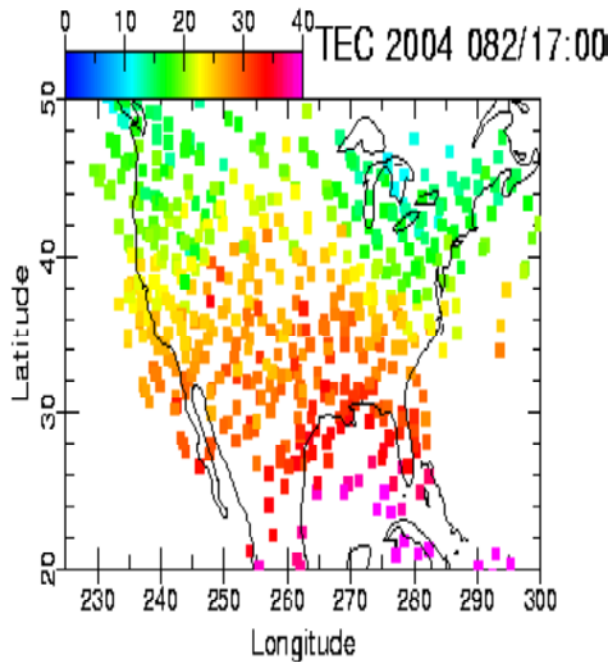


"Bringing The Pieces Together"



Reconstructions With Self-Consistent Drivers

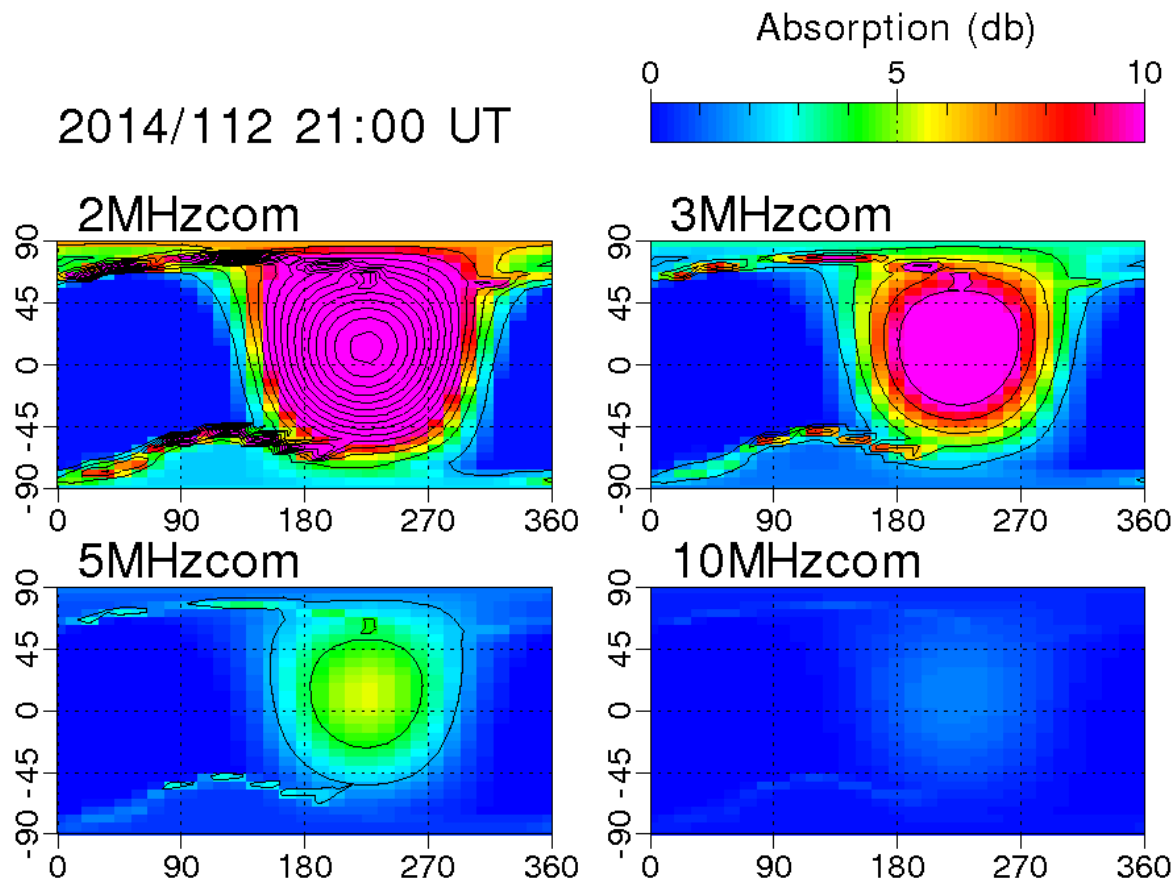
GAIM-FP → Regional Run



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

GAIM Data-Driven D-Region Extension

- Electron density extension down to 40 km altitude
- Uses GOES X-rays and Particles Observations
- Calculates HF Absorption

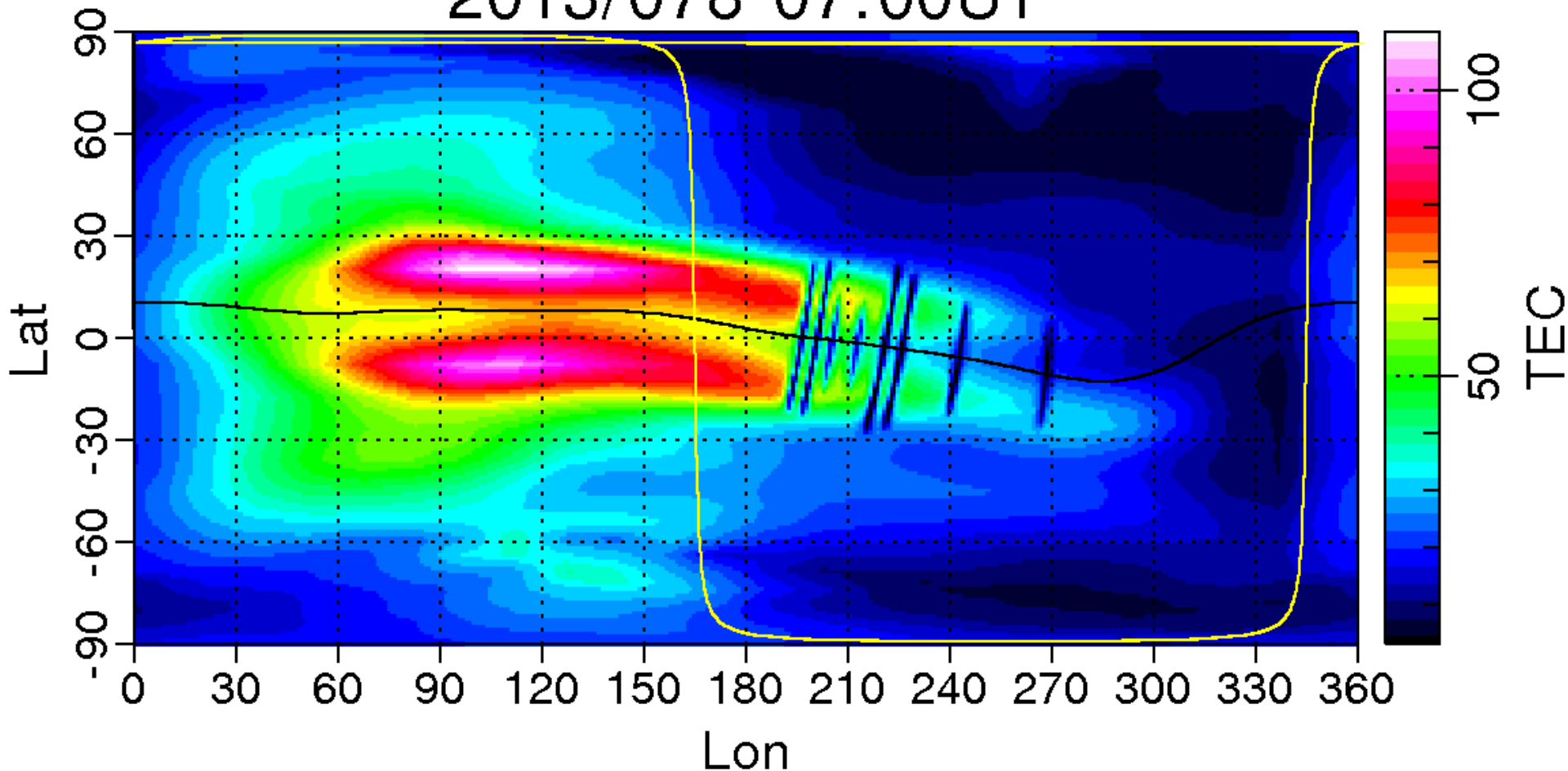


"Bringing The Pieces Together"

Incorporation of Low-Latitude Bubbles into GAIM

SSUSI bubble observations are incorporated into high-resolution GAIM specifications.

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GAIM-FP Output

- **Continuous Reconstruction of Global N_e Distribution**
 - **Ionosphere-Plasmasphere**
 - **D, E, F Regions, Topside and Plasmasphere**
 - **40-30,000 km**
- **Quantitative Estimates of the Accuracy of Reconstruction**
- **Model Drivers**
 - **Electric Fields**
 - **Global Neutral Winds**
 - **Global Neutral Composition**

GAIM-High Latitude

Ensemble Kalman Filter for High-Latitude
Ionosphere Dynamics and ElectroDynamics

High-Resolution Specification of Convection,
Precipitation, Currents & Ionosphere



"Bringing The Pieces Together"



Physics-Based Model Behind GAIM-High Latitude Model

Time-Dependent Ionosphere Model

- 0 3-D Density Distributions (NO^+ , O_2^+ , N_2^+ , O^+ , H^+ , He^+)
- 0 3-D T_e and T_i Distributions
- 0 Ion Drifts Parallel & Perpendicular to B
- 0 Hall & Pedersen Conductances

M-I Electrodynamics Model

- 0 MHD Transport Equations & Ohm's Law
- 0 Alfvén Wave Propagation
- 0 Active Ionosphere
- 0 10 km & 5 sec Resolutions
- 0 Potential, E-field, Currents, Joule Heating

Magnetic Induction Model

- 0 Calculates B Perturbations in Space & on Ground
- 0 Includes Earth's Induction Effect



Data Assimilated by GAIM-High Latitude Model

At High Latitudes it is critical to assimilate observations connected with the drivers

- **Ground Magnetic Data from 100 Sites**
- **Cross-Track Velocities from 4 DMSP Satellites**
- **Line-of-Sight Velocities from 9 SuperDARN Radars**
- **In-situ ΔB from the 66 IRIDIUM Satellites**
- **ACE IMF, solar wind velocity, Kp**



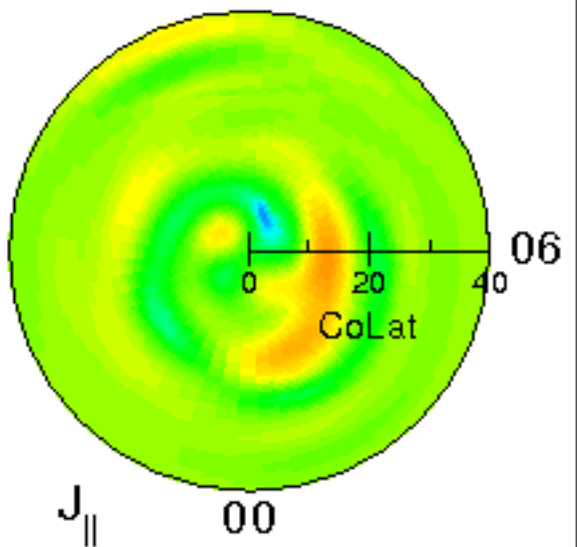
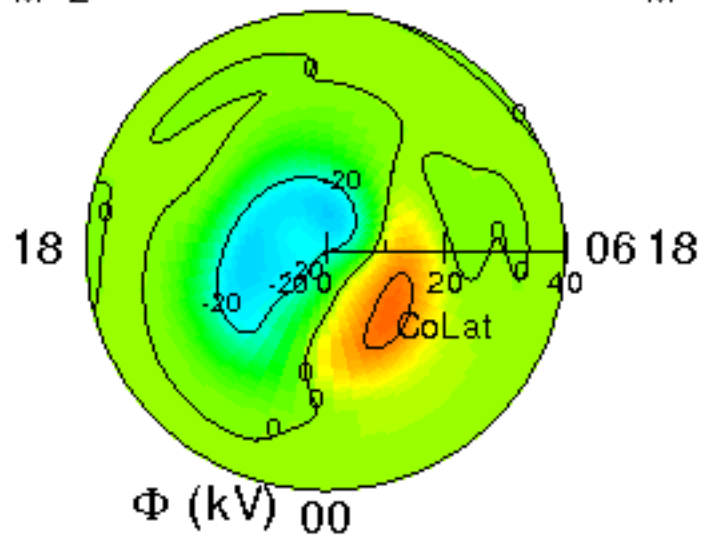
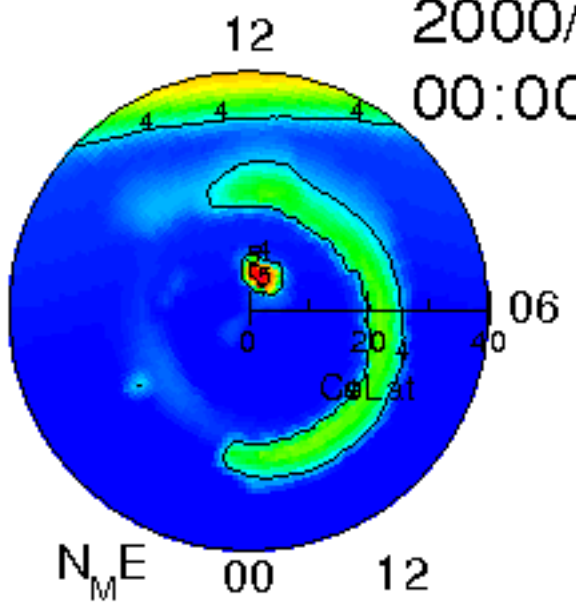
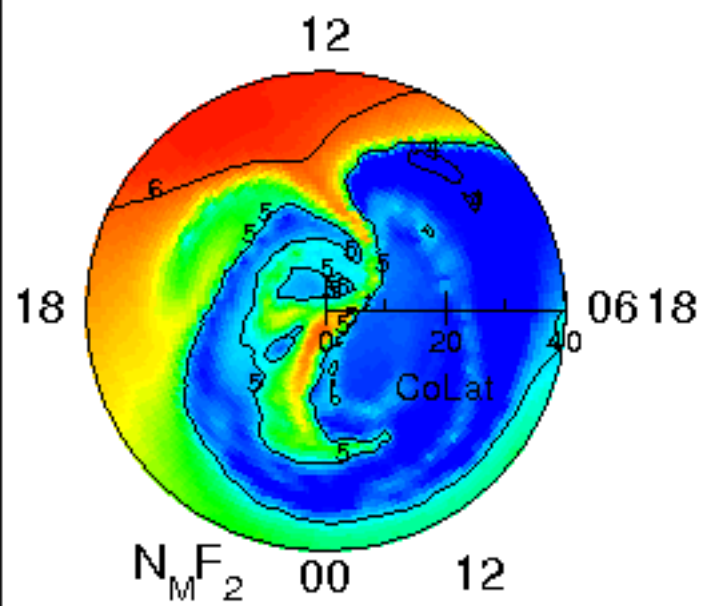
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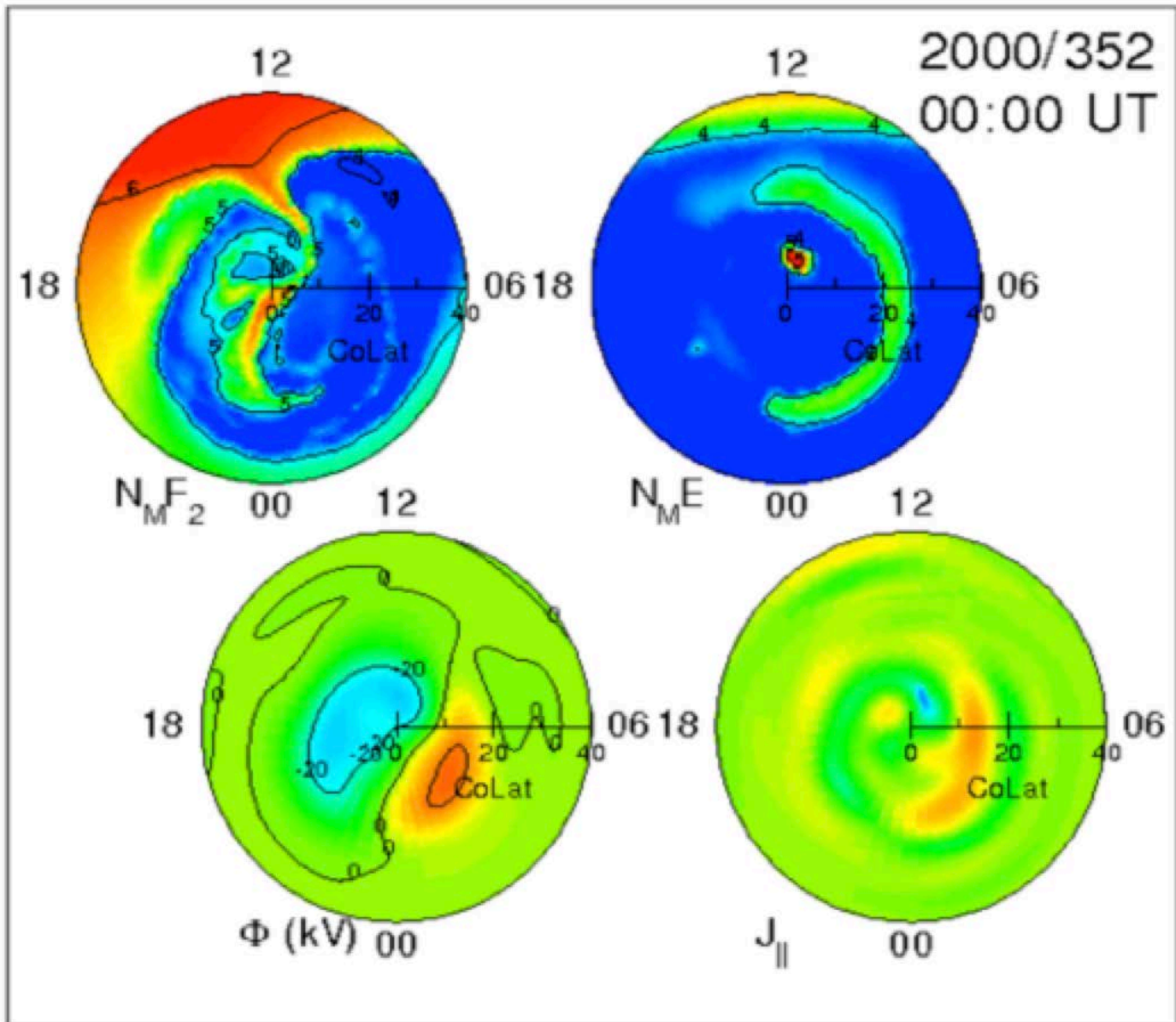


Output of GAIM-High Latitude Model (High Resolution)

- **Electric Potential**
- **Convection Electric Field**
- **Energy Flux and Average Energy of Precipitation**
- **Field-Aligned and Horizontal Currents**
- **Hall and Pedersen Conductances**
- **Joule Heating Rates**
- **3-D Electron and Ion Densities**
- **3-D Electron and Ion Temperatures**
- **TEC**
- **Ground and Space Magnetic Disturbances**

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Operational Models

GAIM-Models are running at

- **AFWA**
- **Northrup Grumman**
- **AFRL**
- **NRL**
- **USU SWC**
- **CCMC**



"Bringing The Pieces Together"

