

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

L. Scherliess, R. W. Schunk, L. C. Gardner, L. Zhu, J.V. Eccles  
and J.J Sojka

Center for Atmospheric and Space Sciences  
Utah State University

Beacon Satellite Meeting  
Trieste  
June 2016

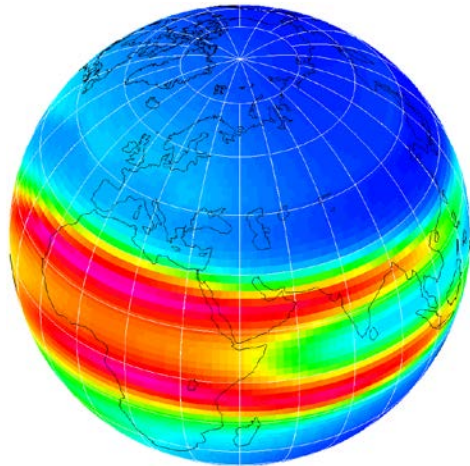


# GAIM Basic Approach

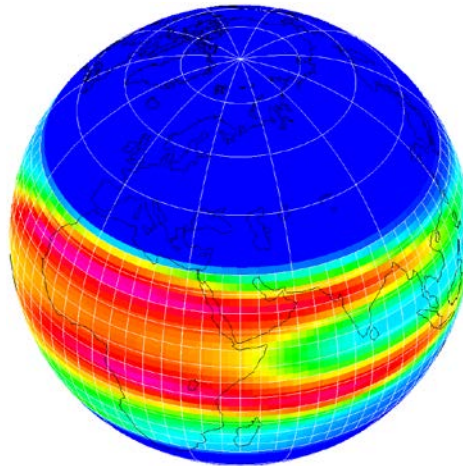
We use physics-based models as a basis for assimilating a diverse set measurements.

GAIM provides specifications on global, regional, or local grids.

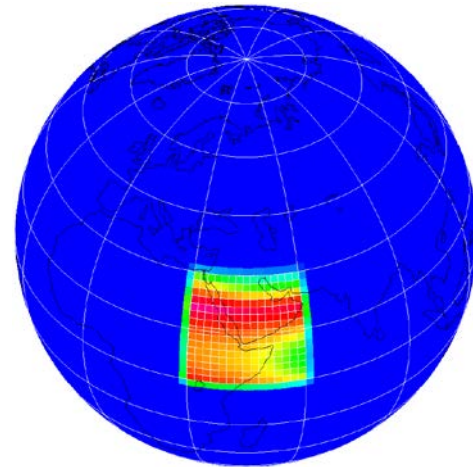
Global



Regional



Local



# 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 Dynamics**

➤ **All Data Assimilation Models are Physics-Based**

# 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 Dynamics**

➤ **All Data Assimilation Models are Physics-Based**

# GAIM-Full Physics

## Low- and Mid-Latitude Ionosphere

Full Physics GAIM uses an **Ensemble Kalman Filter Technique**

Allows to **incorporate ionospheric physics** in data assimilation

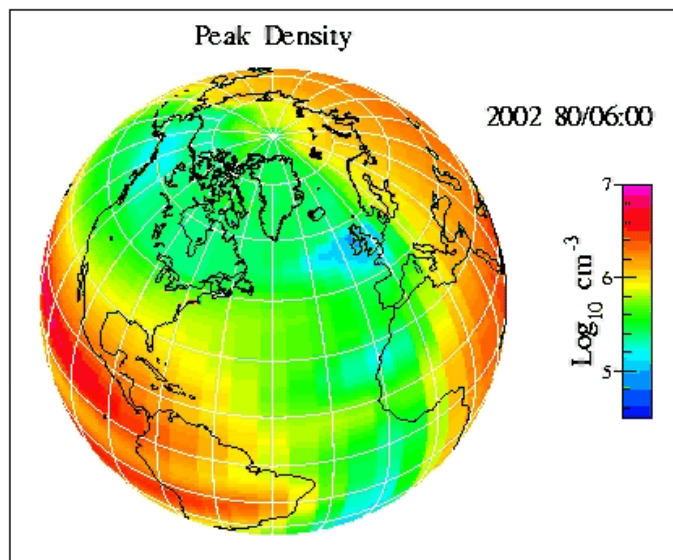
Provides both specifications for the ionospheric plasma densities and drivers:

- Electric Field
- Neutral Wind
- Neutral Composition

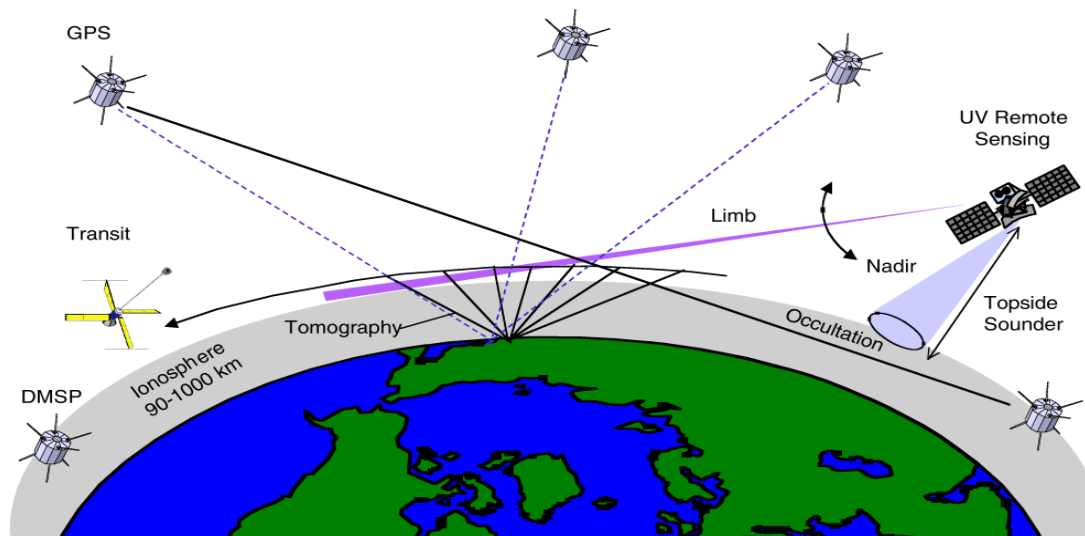
--> **GAIM-FP uses physics-based ionosphere-plasmasphere model (IPM)**

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

- 90-30,000 km
- Six Ion Species ( $\text{NO}^+$ ,  $\text{O}_2^+$ ,  $\text{N}_2^+$ ,  $\text{O}^+$ ,  $\text{H}^+$ ,  $\text{He}^+$ )
- 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 Assimilates Multiple Data Sources



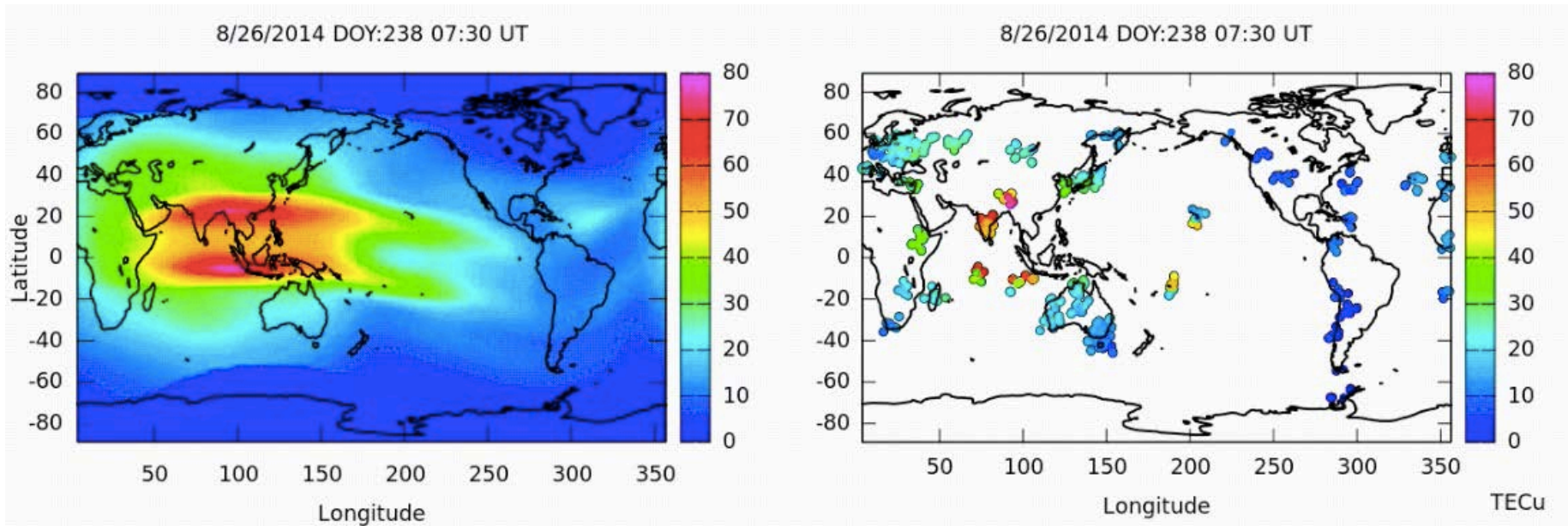
- **Data Assimilated Exactly as They Are Measured**
  - Bottomside  $N_e$  Profiles from Digisondes (~100)
  - Slant TEC from more than 1000 Ground GPS Receivers
  - $N_e$  Along Satellite Tracks (4 DMSP satellites)
  - Integrated UV Emissions (LORAAS, SSULI, SSUSI)
  - Occultation Data (CHAMP, IOX, SAC-C, COSMIC)



"Bringing The Pieces Together"

# GAIM-FP Global Run

- 400 global TEC stations (IGS network) used in real-time at USU Space Weather Center
- 40-50 Ionosondes/Digisondes
- Data are assimilated every 15- min



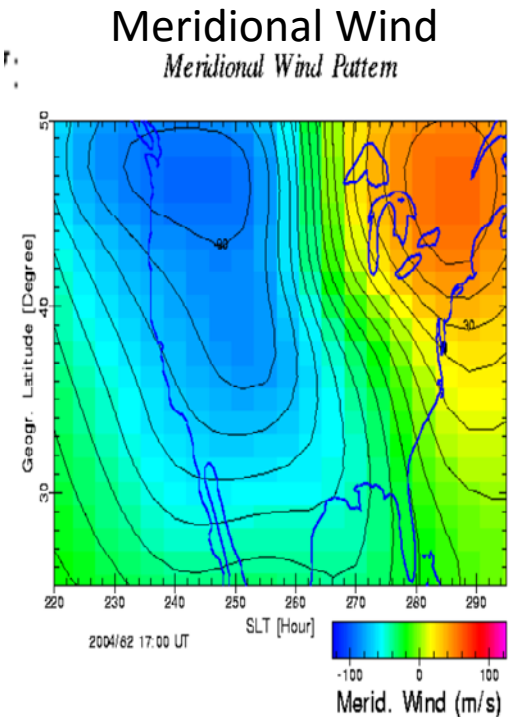
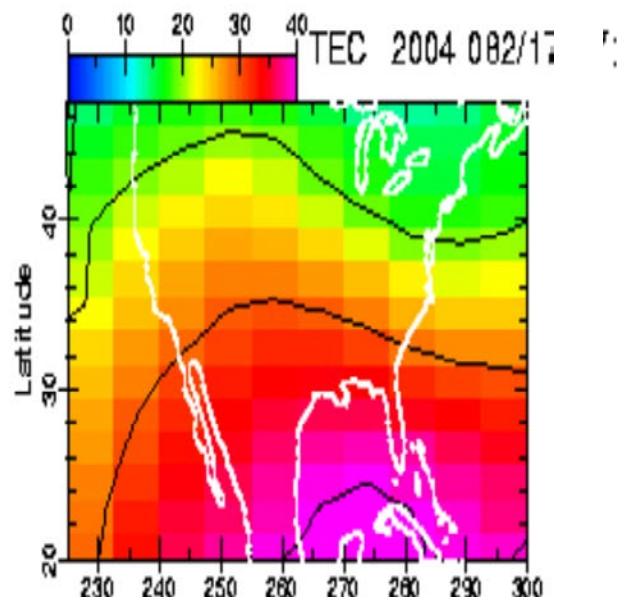
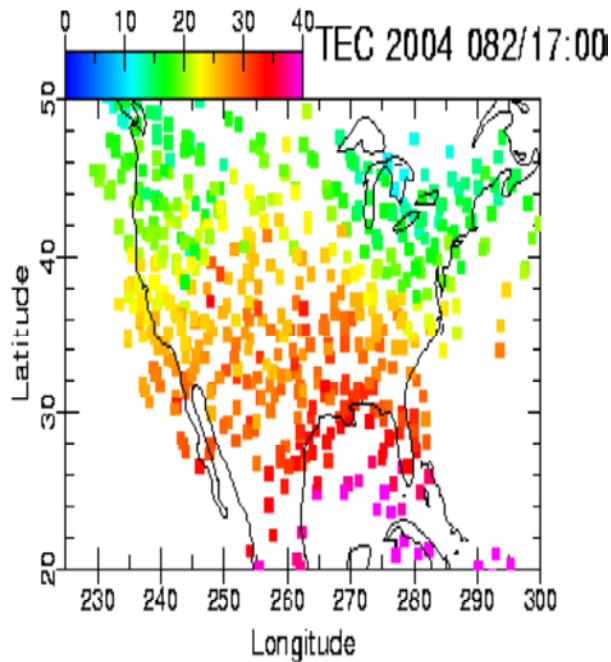
"Bringing The Pieces Together"





# Reconstructions With Self-Consistent Drivers

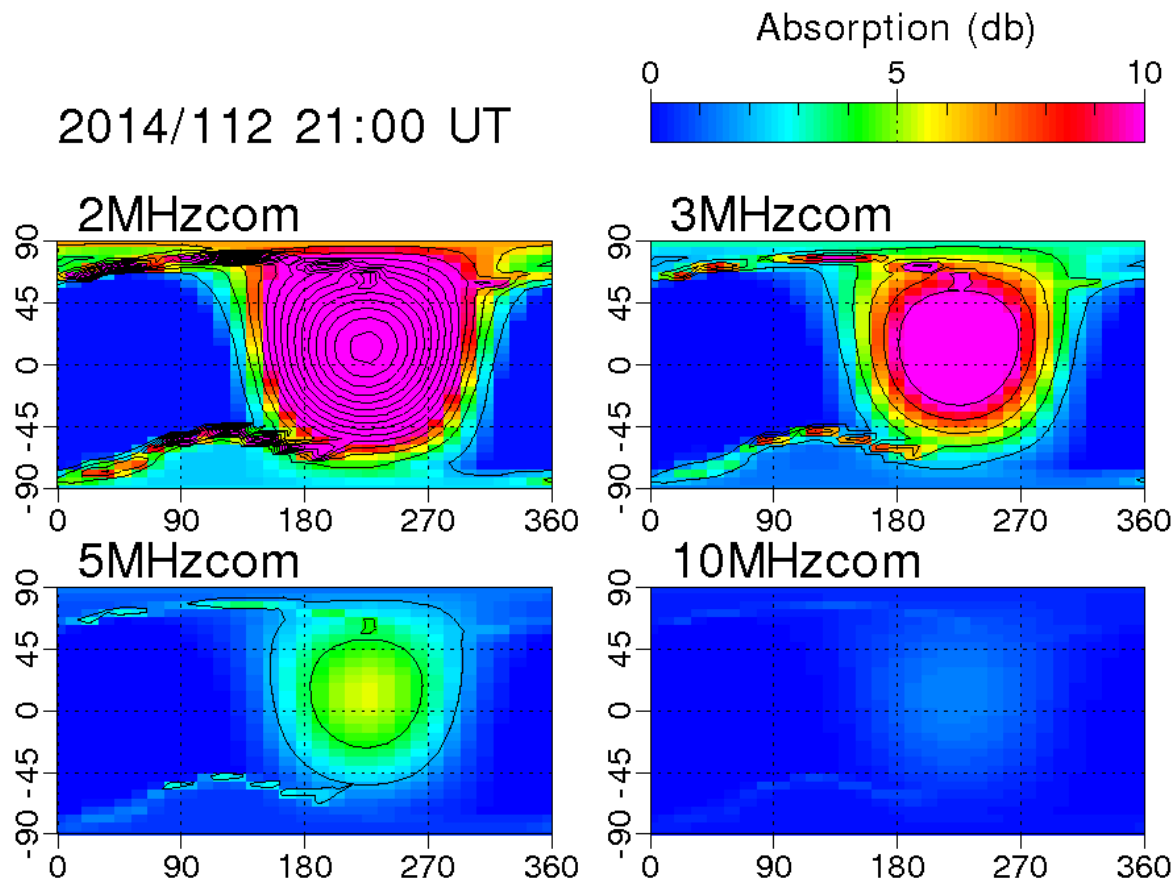
## GAIM-FP → Regional Run



- 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-Ray and Particle Observations
- Calculates HF Absorption

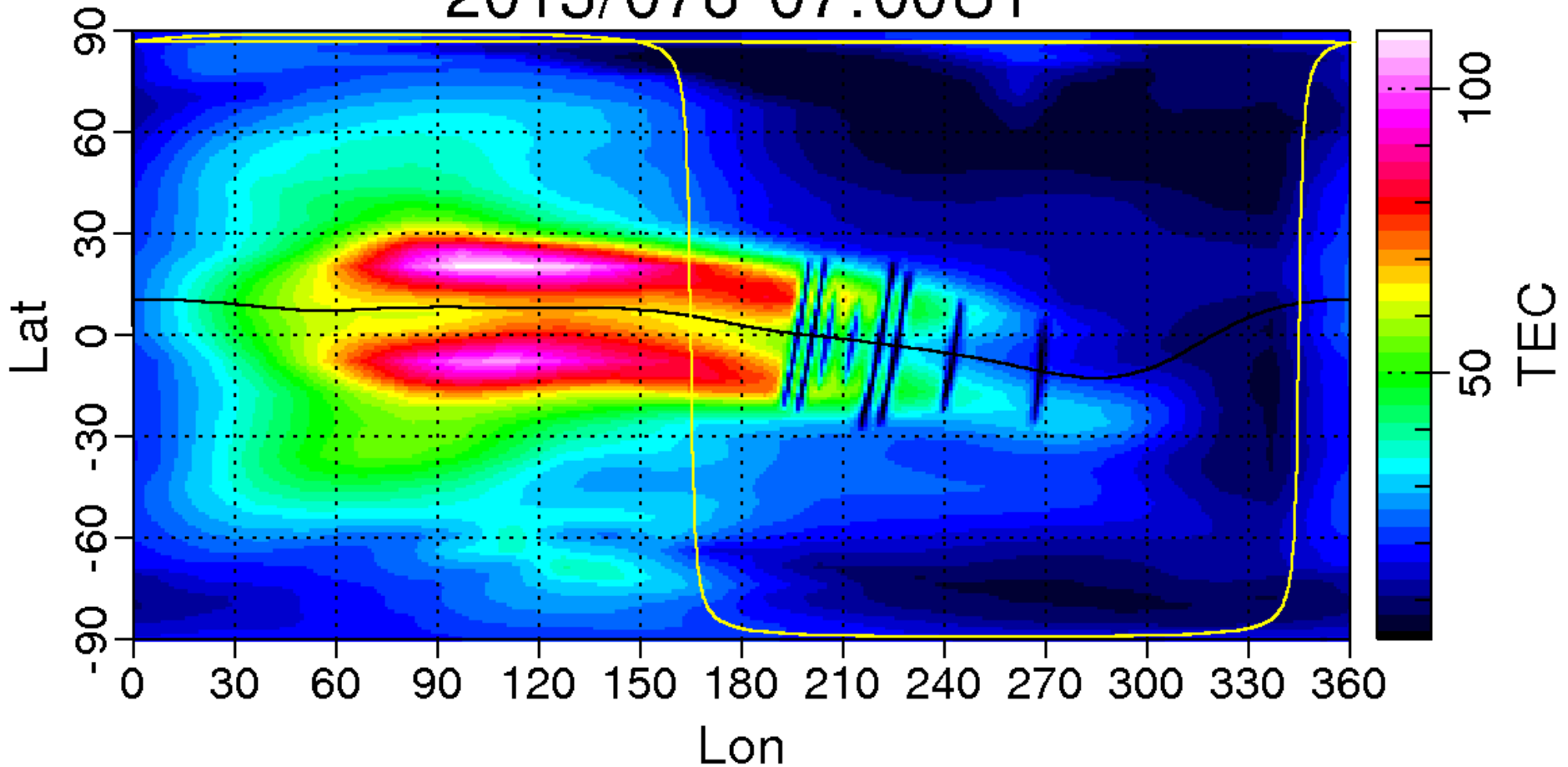


"Bringing The Pieces Together"

# Incorporation of Low-Latitude Bubbles into GAIM

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

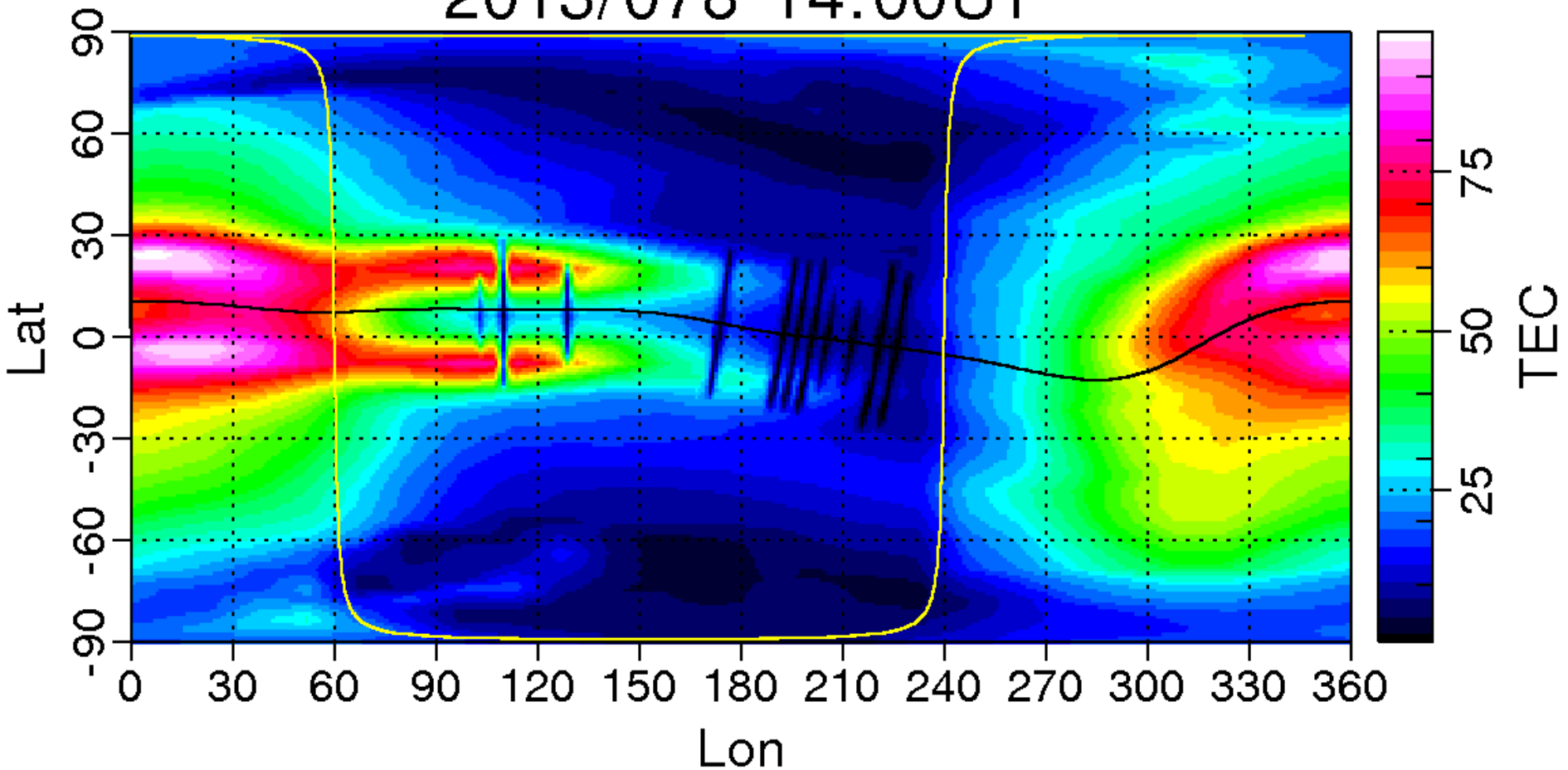
2013/078 07:00UT



# Incorporation of Low-Latitude Bubbles into GAIM

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

2013/078 14:00UT



# 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 ( $\text{NO}^+$ ,  $\text{O}_2^+$ ,  $\text{N}_2^+$ ,  $\text{O}^+$ ,  $\text{H}^+$ ,  $\text{He}^+$ )
- 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 DMSP Satellites**
- **Line-of-Sight Velocities from SuperDARN Radars**
- **In-situ  $\Delta B$  from the 66 IRIDIUM Satellites**
- **ACE IMF, solar wind velocity, Kp**

# 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**



2000/352

00:00 UT

