Multimodel Ensemble Prediction System (MEPS): Ensemble Modeling with Data Assimilation Models for Space Weather Specifications and Forecasts

Science Highlights

Presented by

L. Scherliess

NASA-NSF Space Weather Modeling Collaboration
NASA Ames Research Center, CA
May, 2017

MEPS Science Accomplishments

1. Ensemble Modeling Averaging
2. Improved Statistical Techniques for MEPS
3. Real-Time TWAM
4. Pulsating Geomagnetic Storm
5. Global Data Assimilation Study of Substorms
6. Additional Tasks for IDED-DA
7. Improvements on GAIM-4DVAR

Ensemble Model Averaging

Models Used:

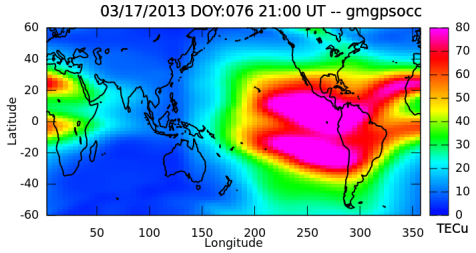
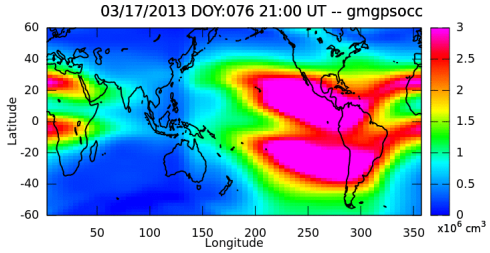
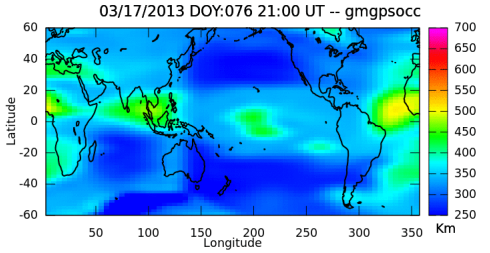
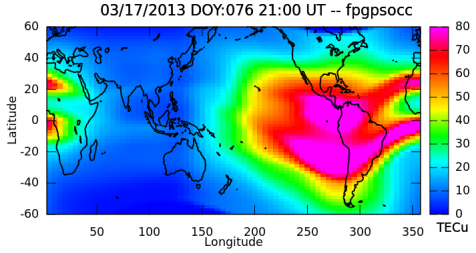
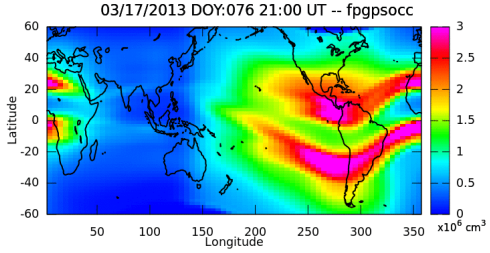
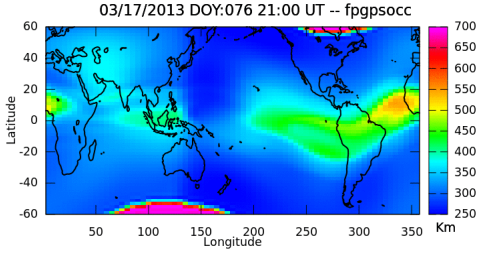
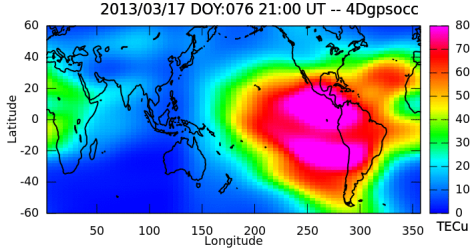
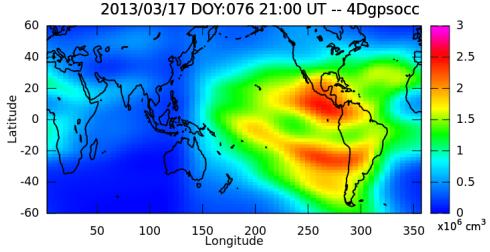
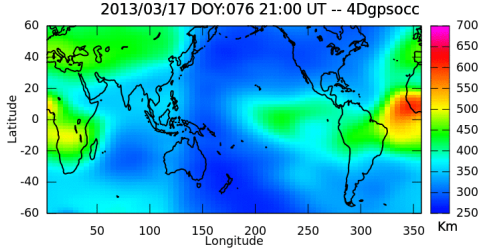
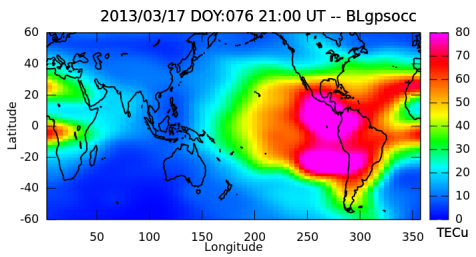
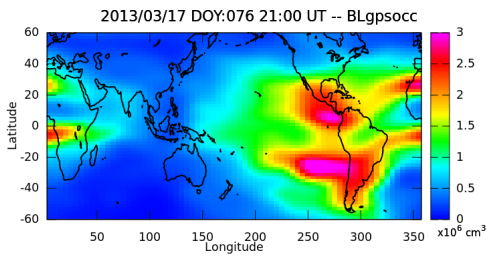
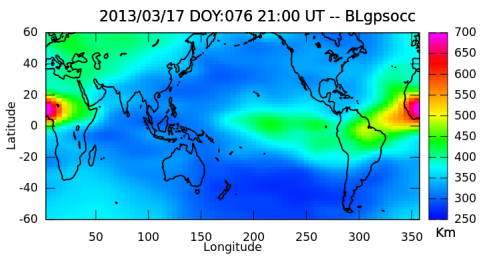
- GAIM-BL → Mid & Low Latitudes
- GAIM-GM → Mid & Low Latitudes
- GAIM-4DVAR → Mid & Low Latitudes, with Drivers
- GAIM-FP → Mid & Low Latitudes, with Drivers
- IFM Physics-Based Model → No DA
- Mid-Low Electro-DA → Ionosphere with Drivers

Data Assimilated:

- Slant TEC from Ground Receivers
- N_e Profiles below F-Region Peak from Digisondes
- COSMIC Occultation Data
- In Situ N_e (SSIES)

Ensemble Model Averaging Example

March 17, 2013 21:00 UT – GPS+OCC

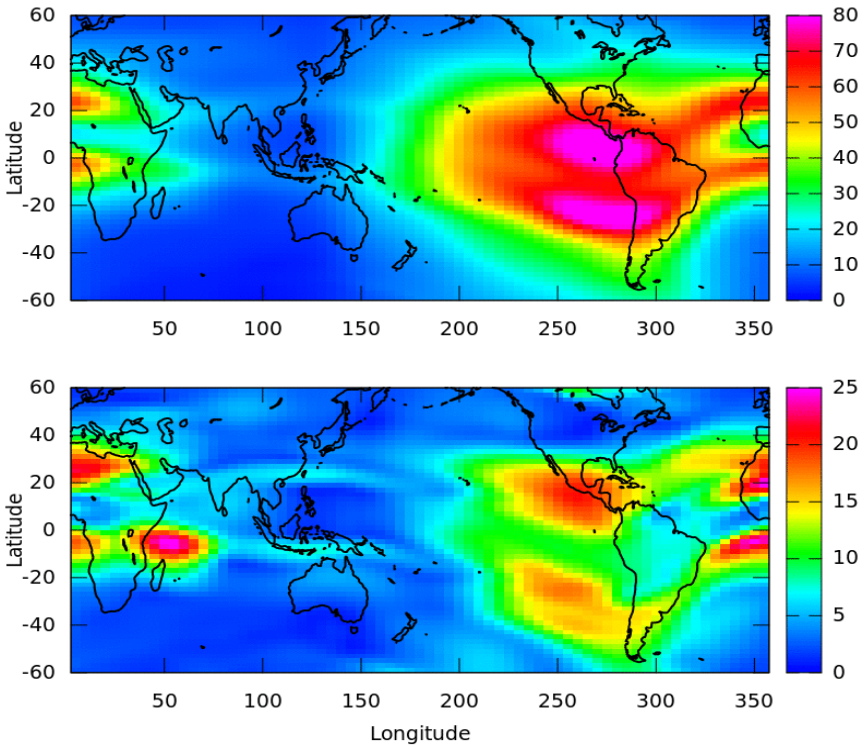
	TEC	NmF2	hmF2
GAIM-GM			
GAIM-FP			
GAIM-4D			
GAIM-BL			

Simple Ensemble Averaging (6 models)

Simple Average:

→ Sum models, divide by total number of models

GPS & Occ



Mean TEC

Standard Deviation

The mean of the Ensemble Performed Better than the Individual Data Assimilation Models!

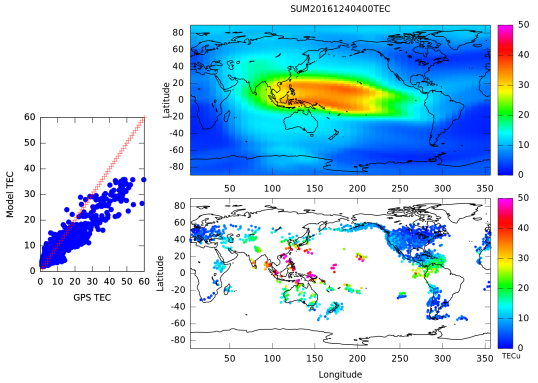
Max TEC below GPS data values → Ensemble is biased low

Improved Statistical Techniques for MEPS Weighted Averages

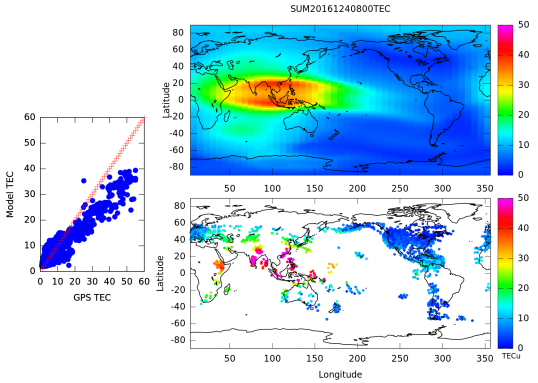
- **Weighted Average –Weights are calculated by comparison of individual model results with GPS TEC data.**
- **6 Data Assimilation Models used in Average**
- **GPS and Occultation Data**
- **Example of May 1-12, 2016 period.**

MEPS Average – Simple

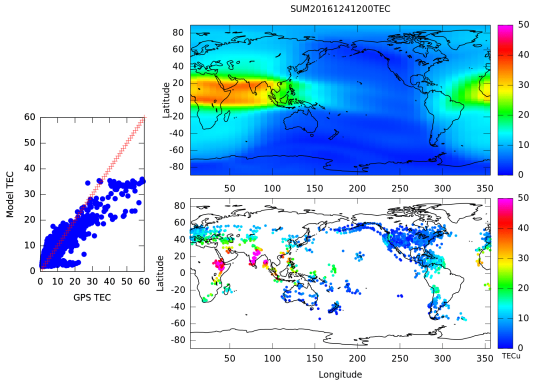
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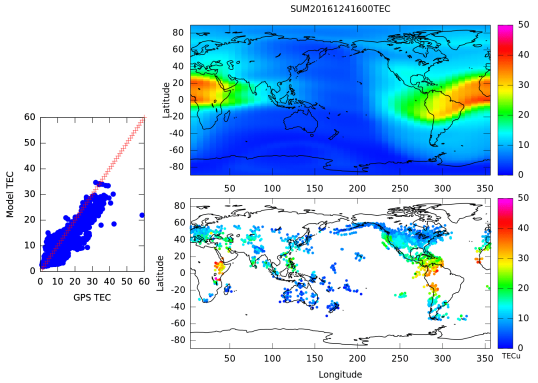


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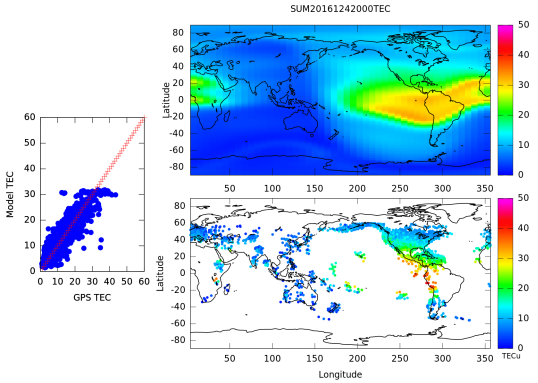


12:00 UT





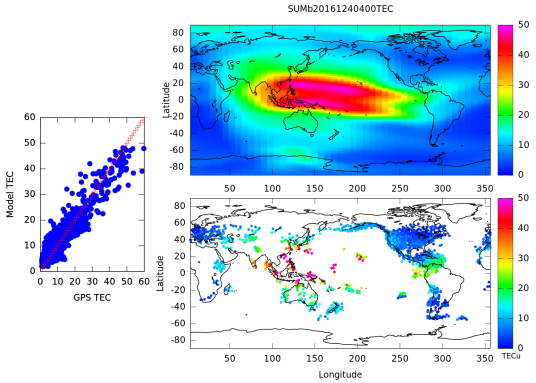
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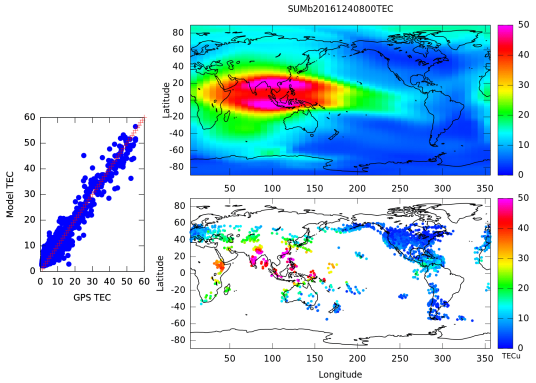
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MEPS Average – Weighted

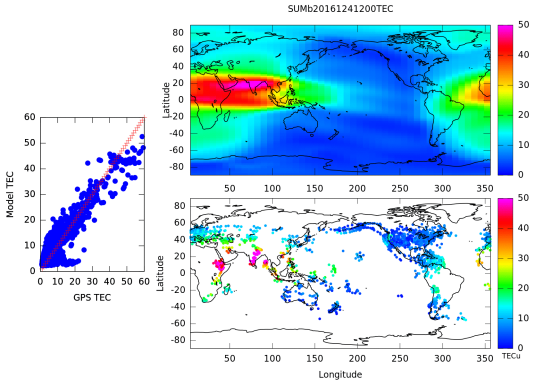
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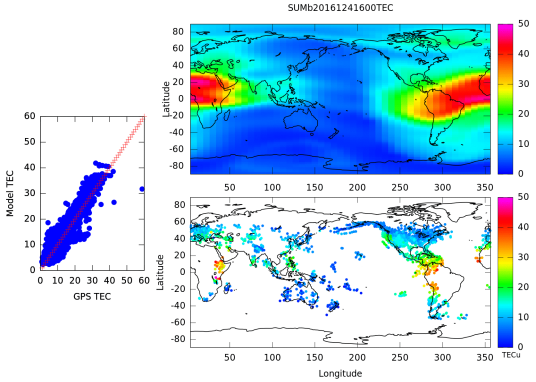


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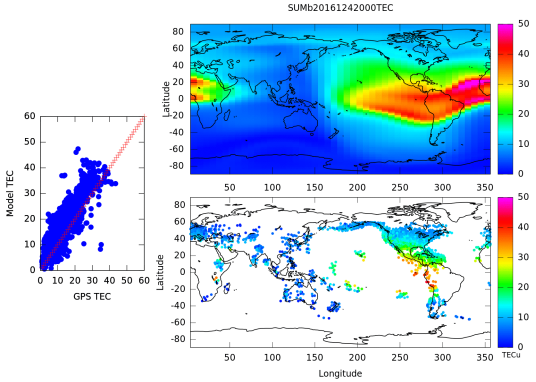


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16:00 UT



20:00 UT

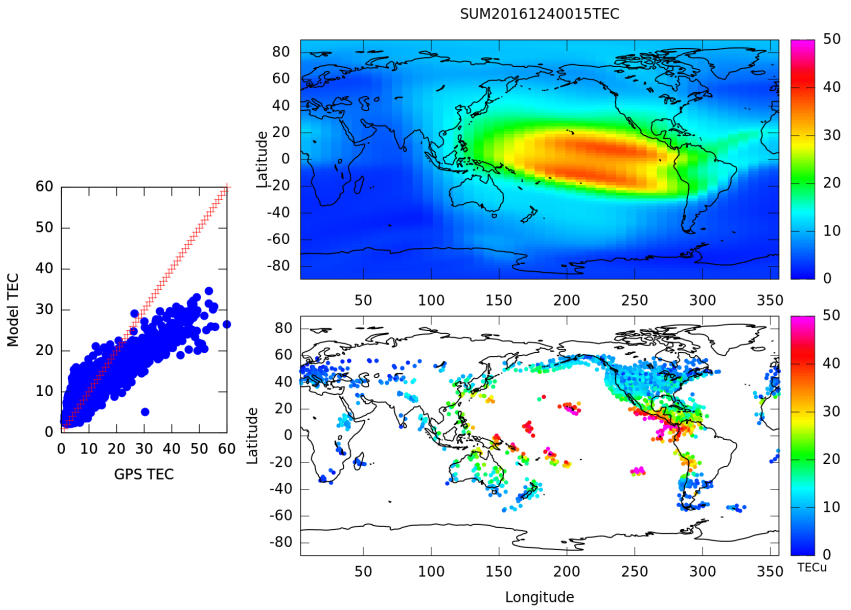
MEPS Averages

Simple

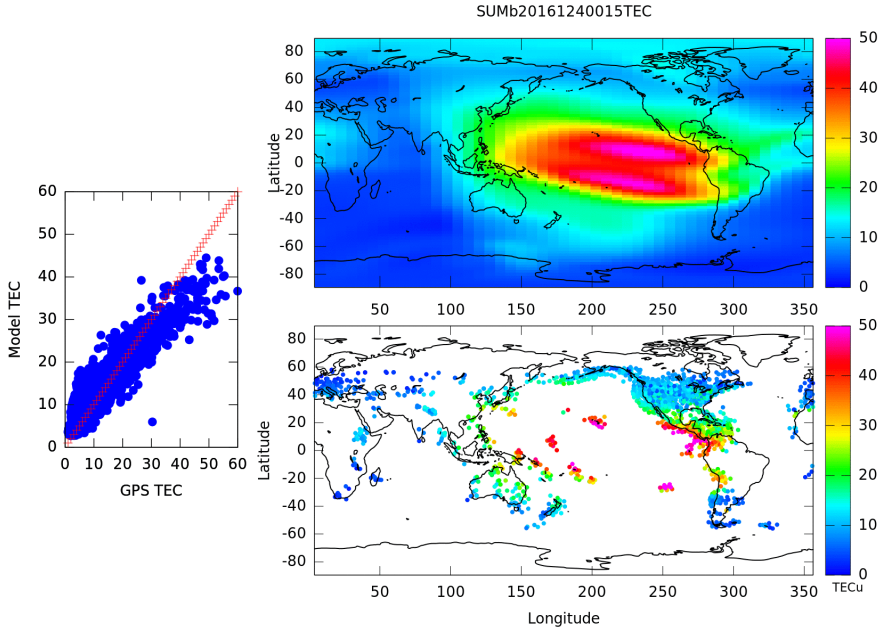
Weighted

MEPS Averages

Simple



Weighted

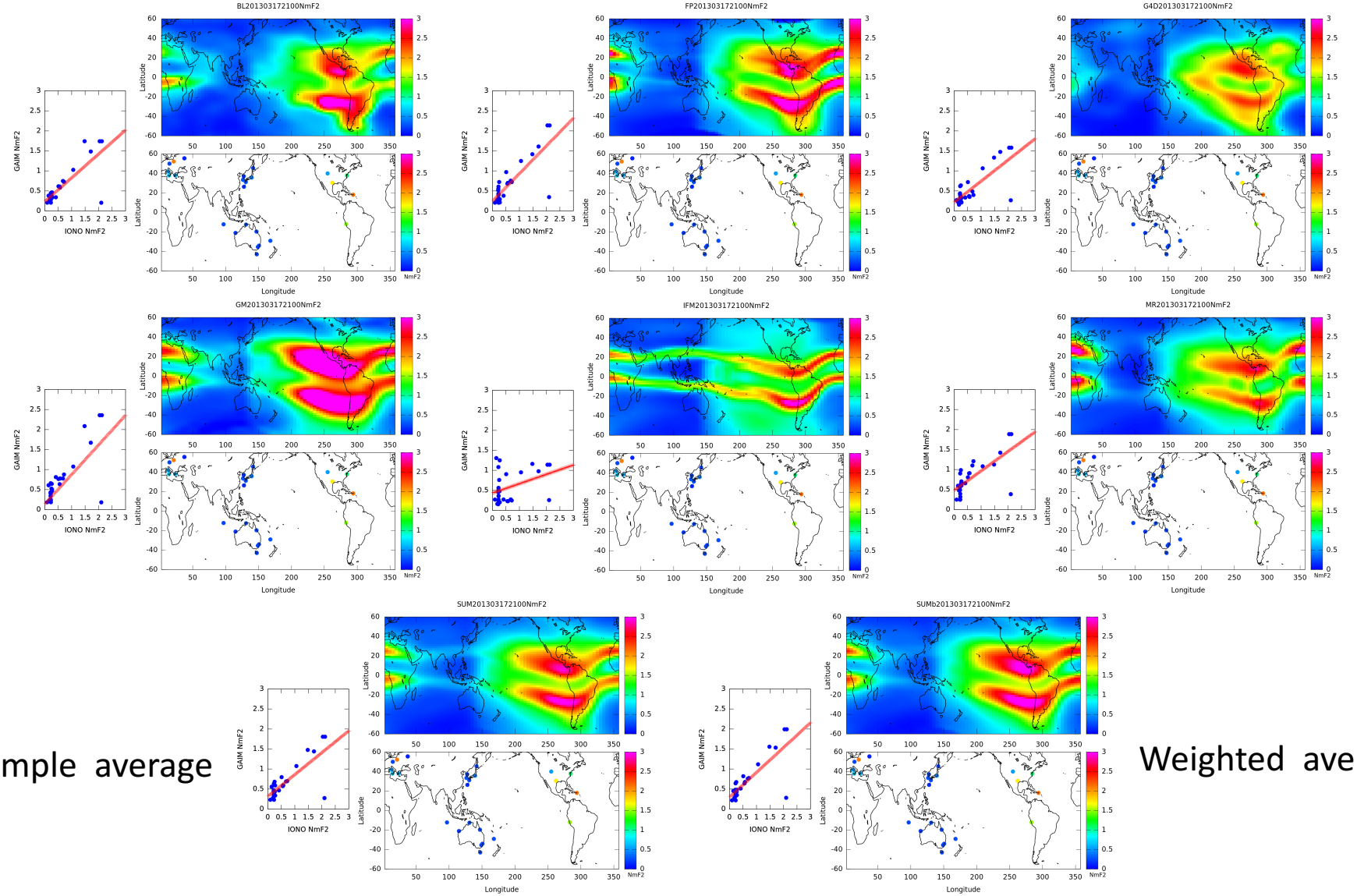


MEPS Averaging - Future

- Work on Improved Averaging Scheme
  - Gridded Weighted Average
- Calculate weights based on standard set of data, not included in assimilation
  - i.e. Cosmic data
- Apply Independent Weights to all Model Variables, i.e. TEC, NmF2, HmF2, electron density ...

Averaging – NmF2

Top 6 panels correspond to individual models

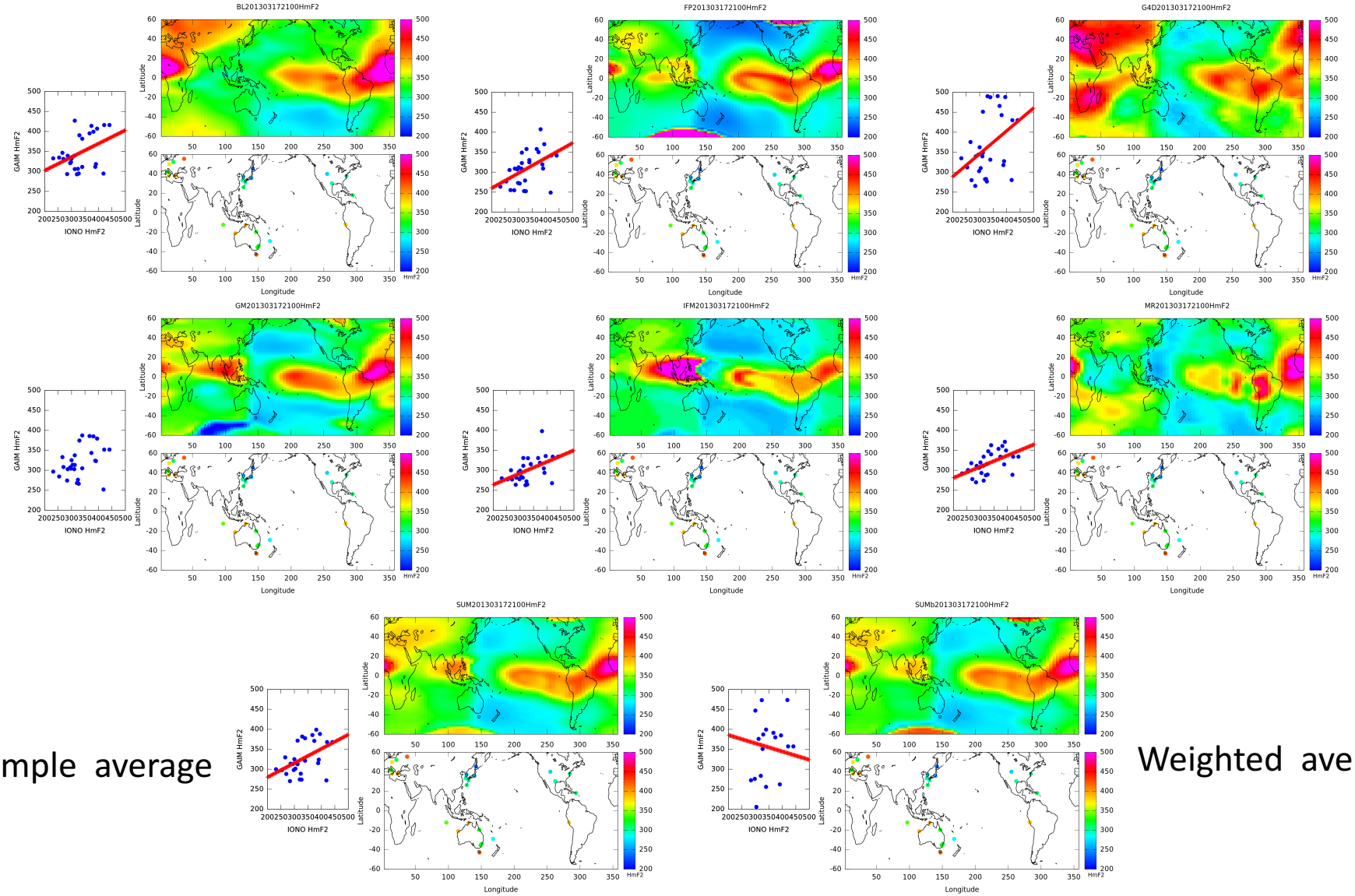


Simple average

Weighted average

Averaging – hmF2

Top 6 panels correspond to individual models



Simple average

Weighted average

Data Assimilation for the Thermospheric Wind

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

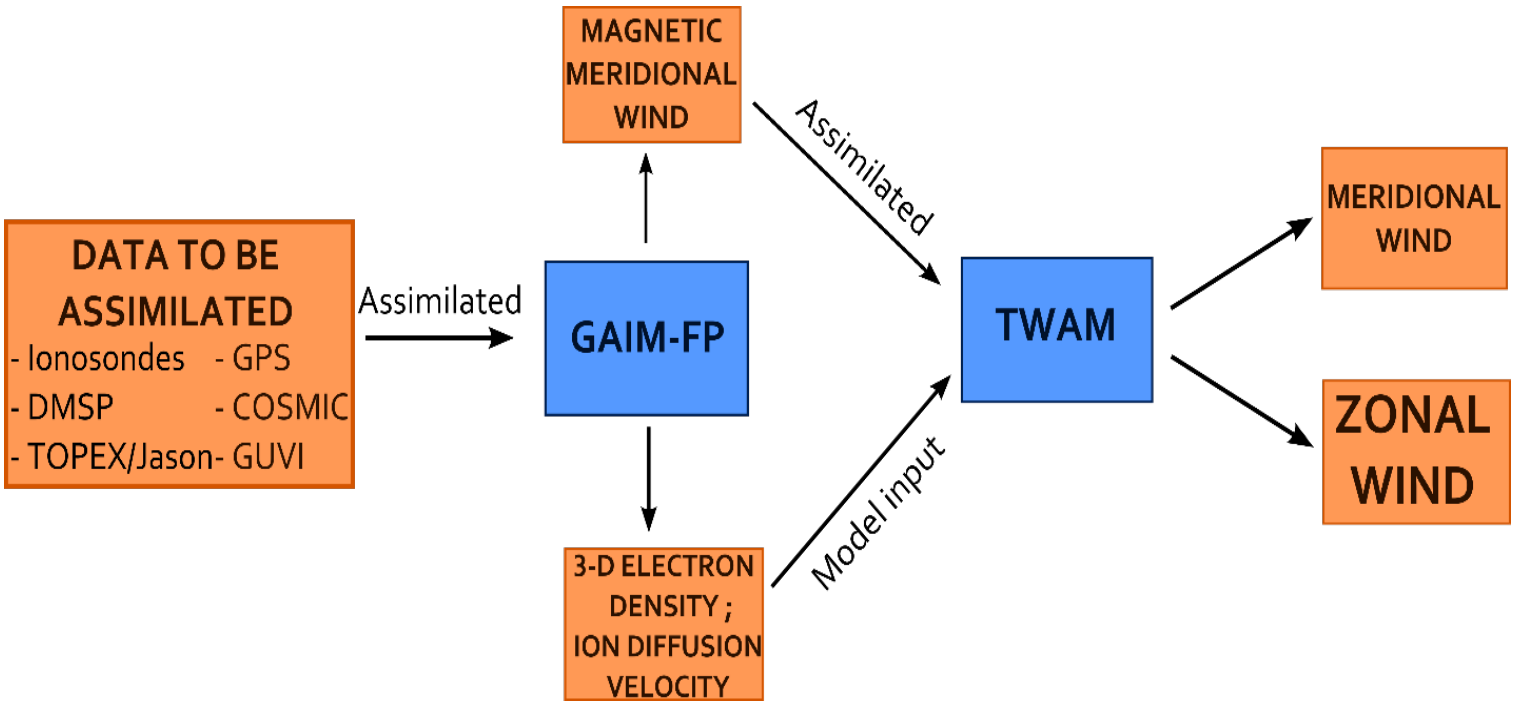
➔ **GAIM-4DVAR and GAIM-FP only provide winds along the geomagnetic meridian.**

TWAM ➔ 3-D Thermospheric Wind

Thermospheric Wind Assimilation Model (TWAM)

TWAM is based on a first-principles model for the thermospheric wind.

Data are assimilated using an implicit Kalman filter technique.



TWAM provides the 3-D thermospheric wind

Lomidze and Scherliess, 2015

Global TWAM Wind Pattern

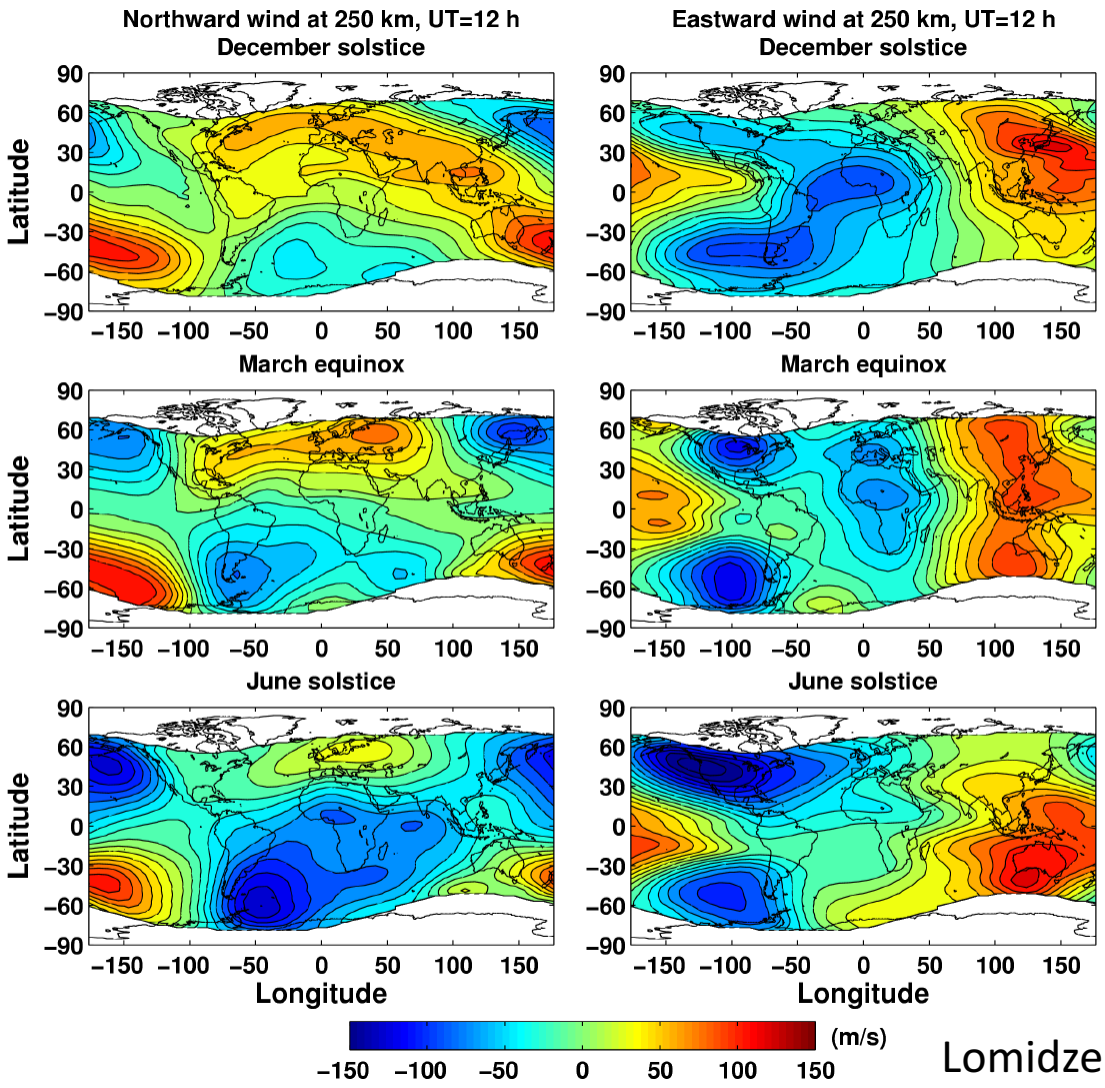
Good agreement with our current understanding of thermospheric dynamics.

Meridional **Zonal**

December Solstice

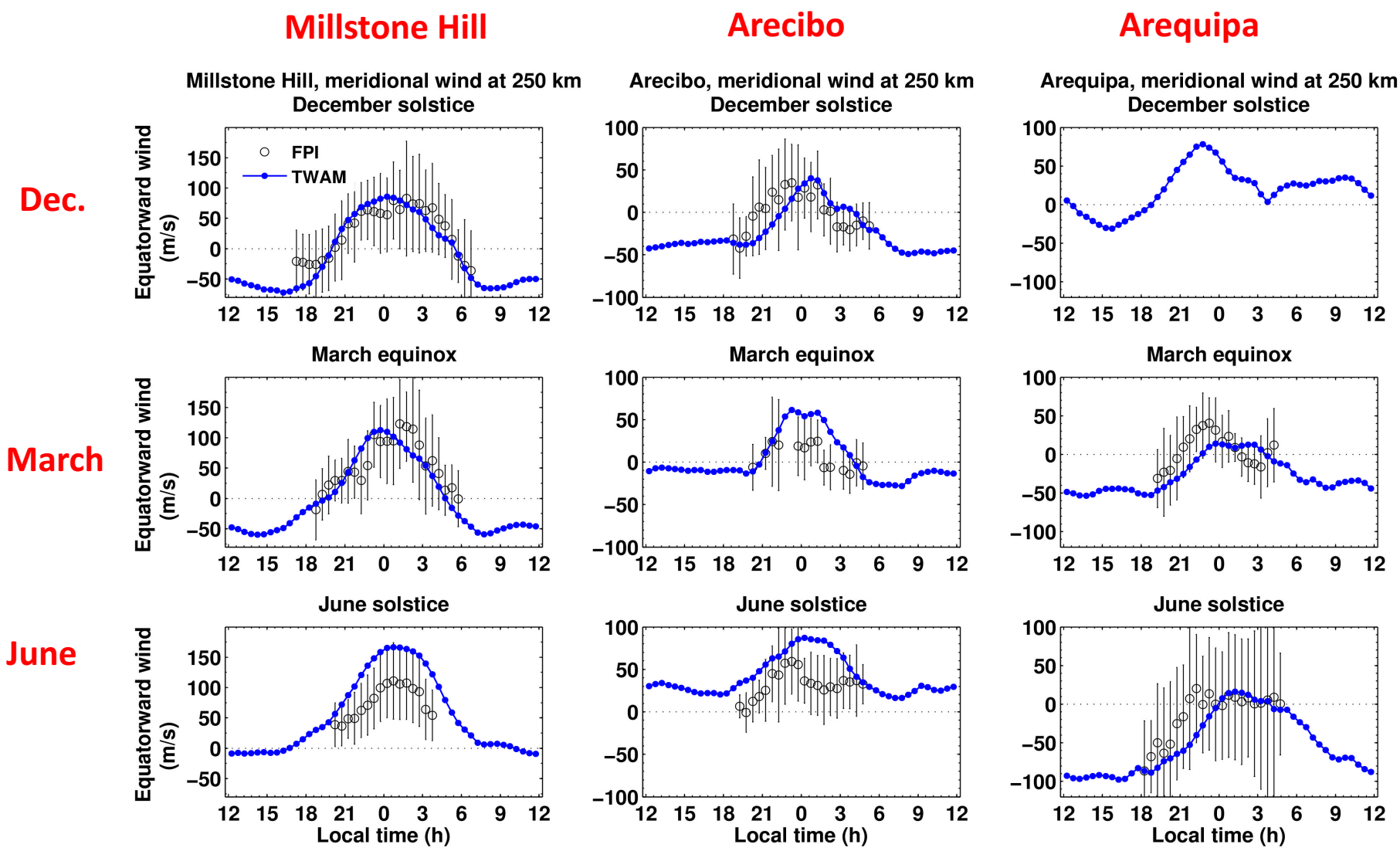
March Equinox

June Solstice



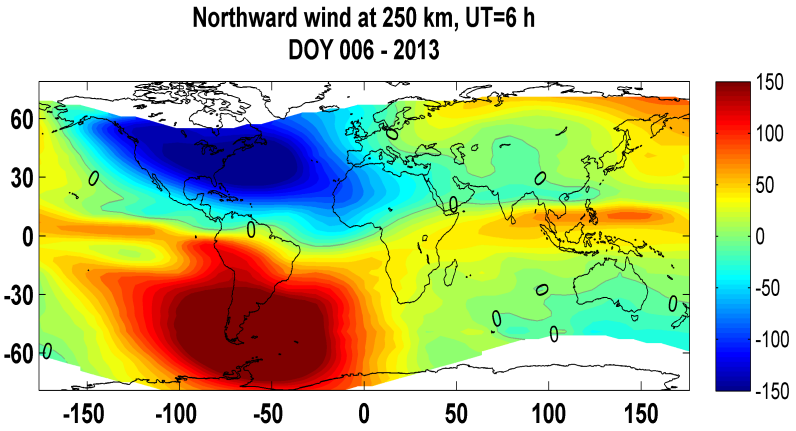
Lomidze and Scherliess, 2015

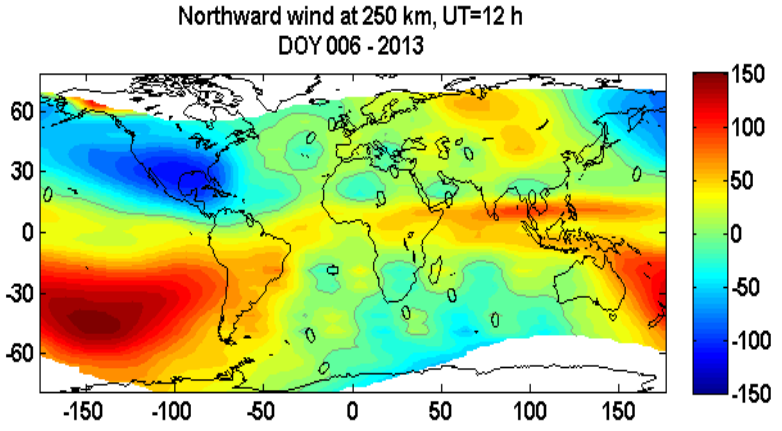
Comparison of TWAM with independent ground-based optical (FPI) data

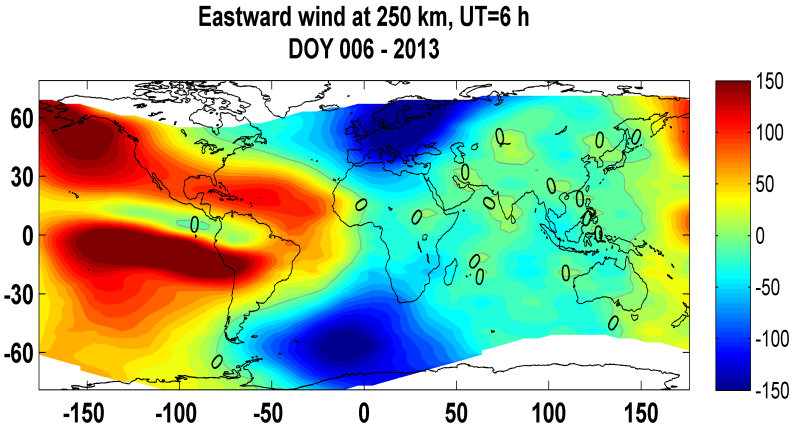


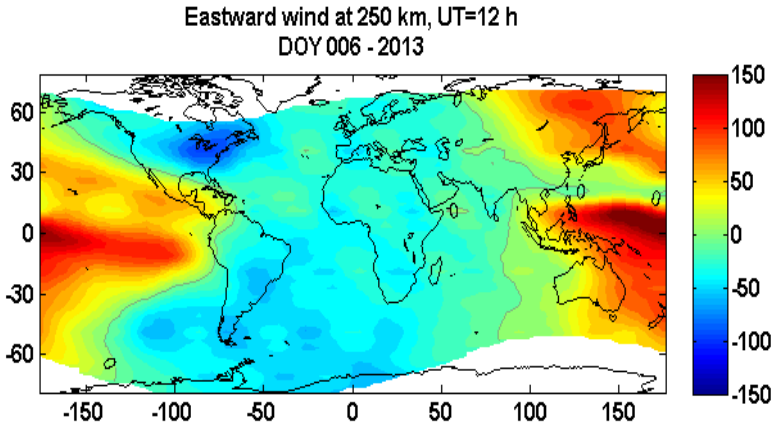
Lomidze and Scherliess, 2015

Day-to-day studies – DOY 6, 2013

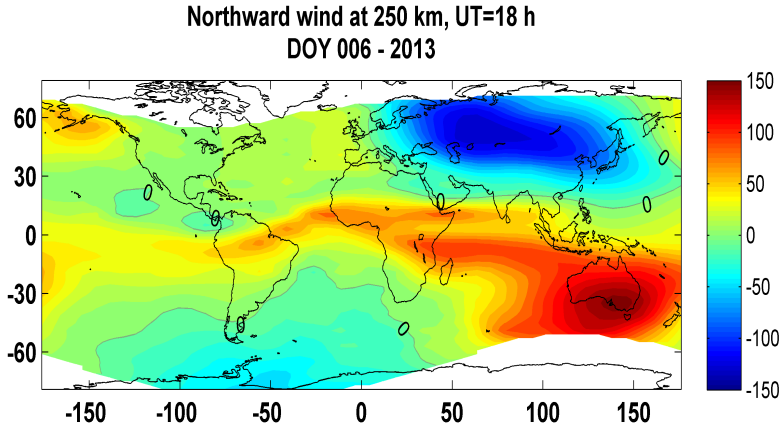


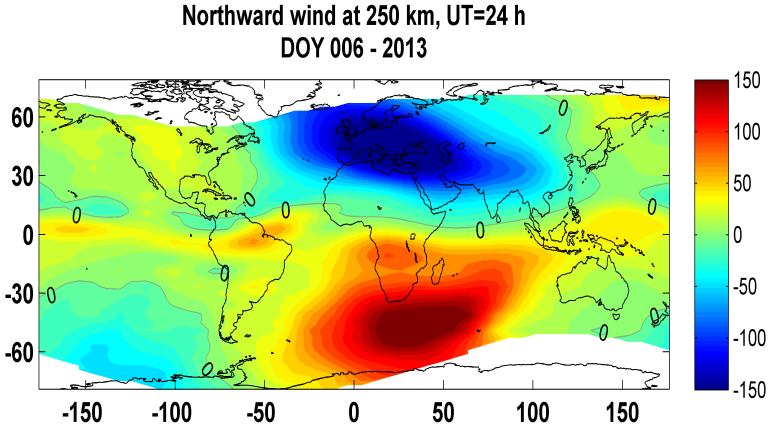


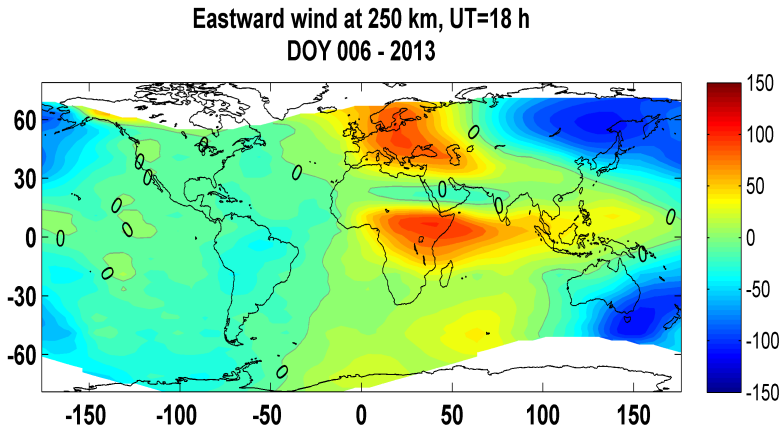


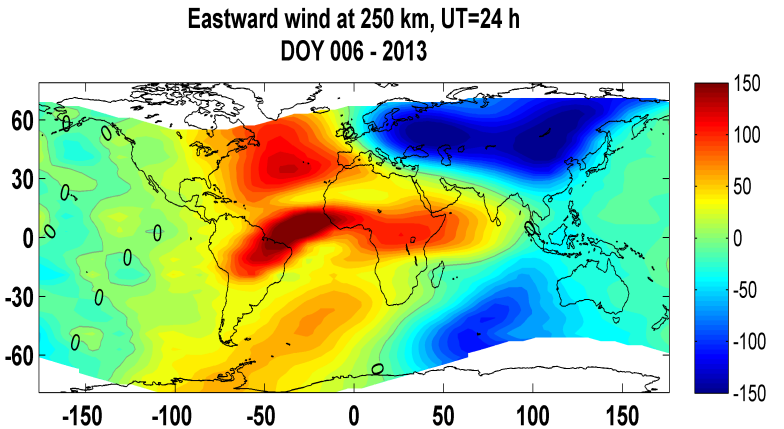


Day-to-day studies – DOY 6, 2013

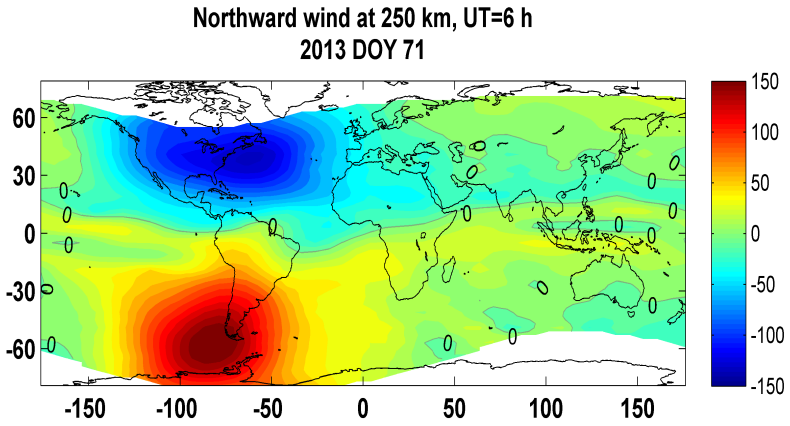


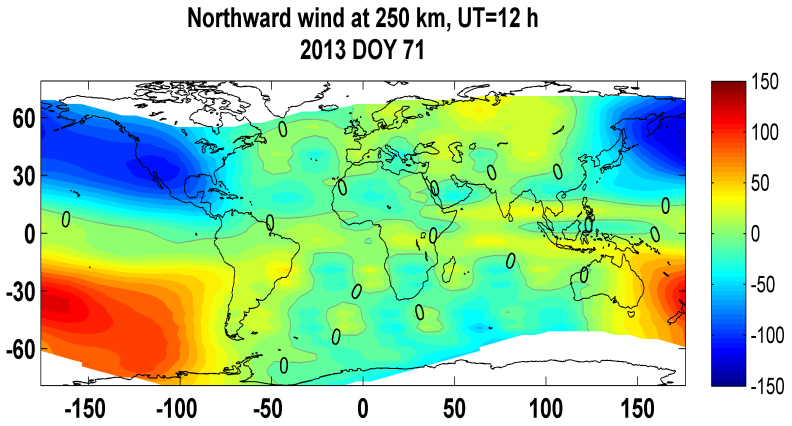


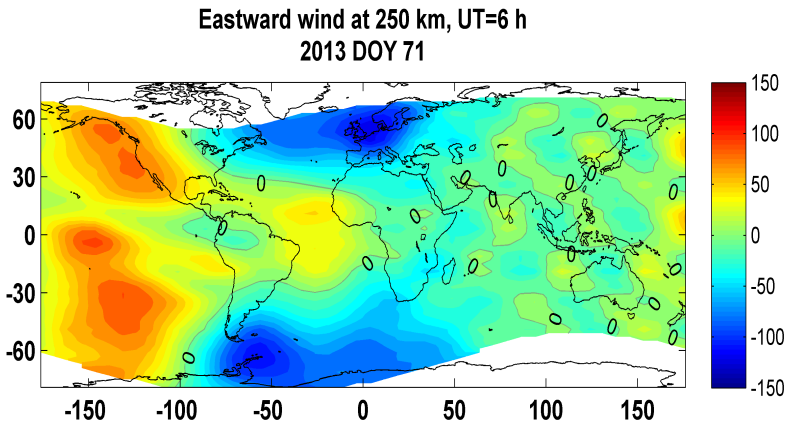


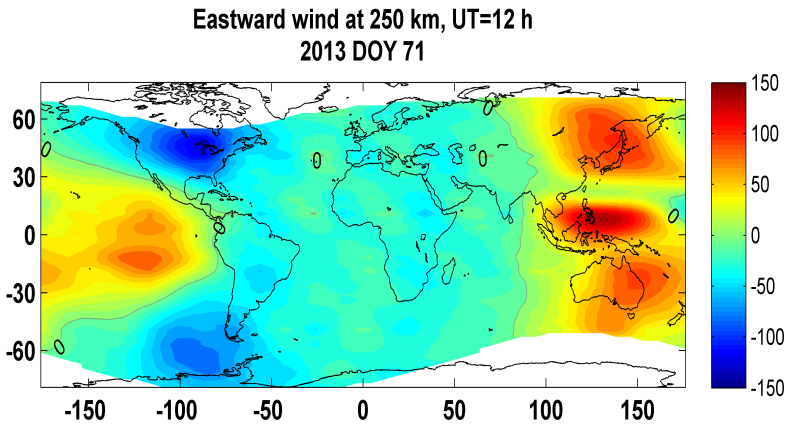


Day-to-day studies, DOY 71, 2013

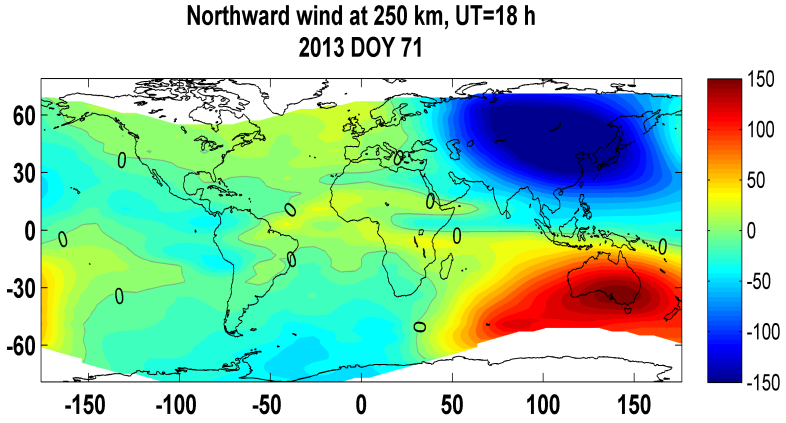


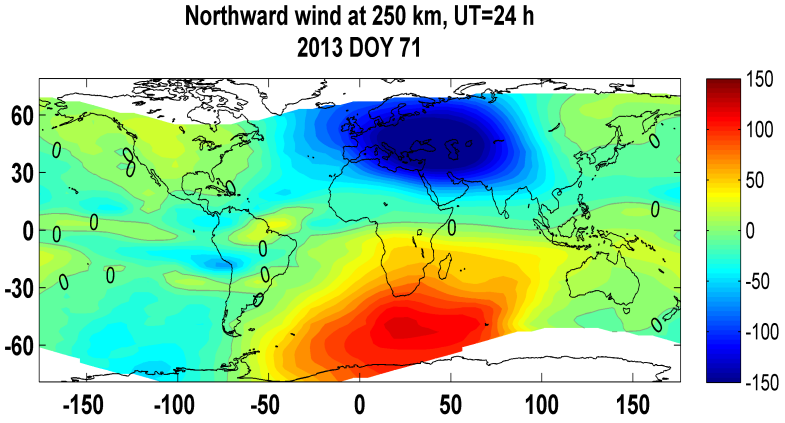


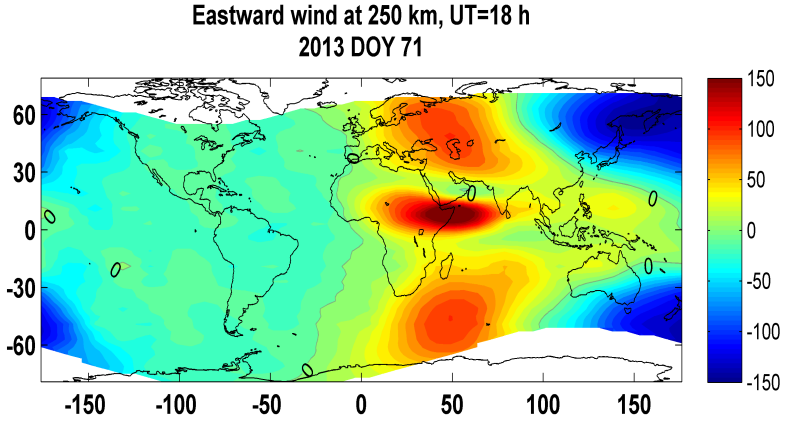


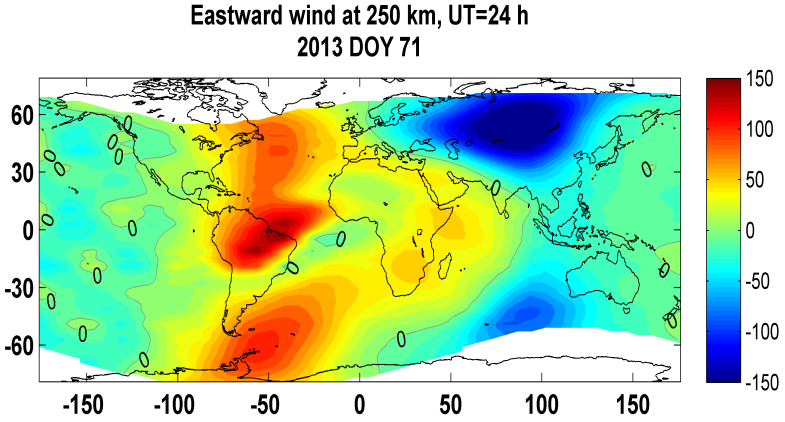


Day-to-day studies, DOY 71, 2013

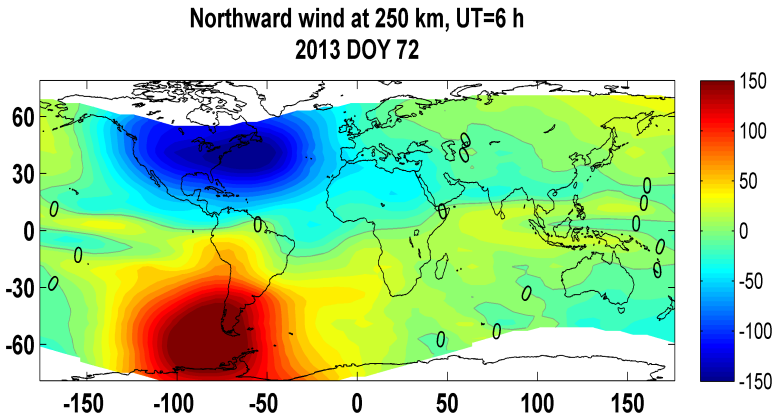


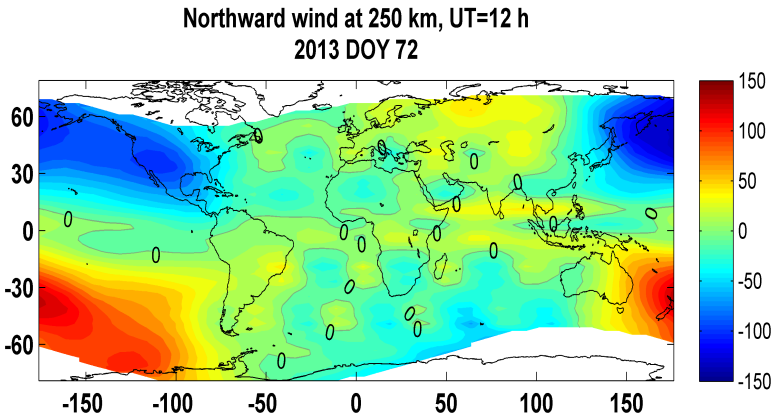


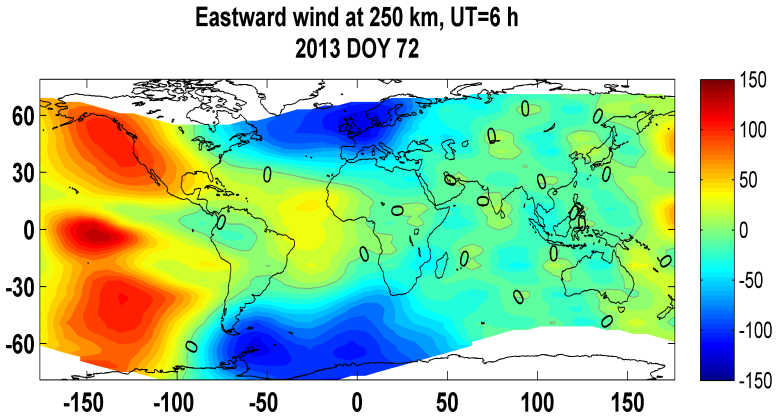


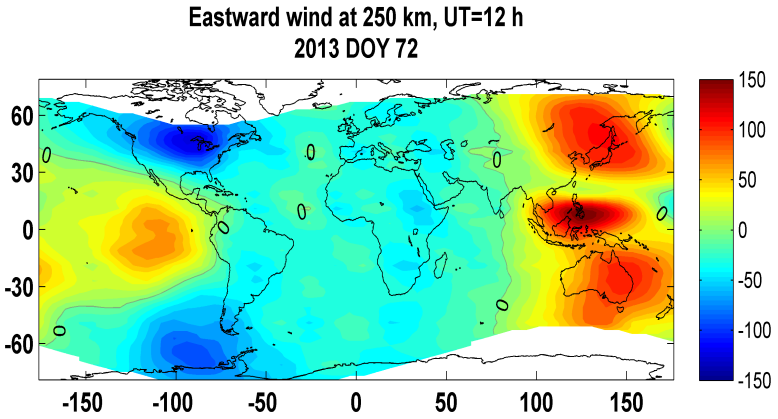


Day-to-day studies, DOY 72, 2013

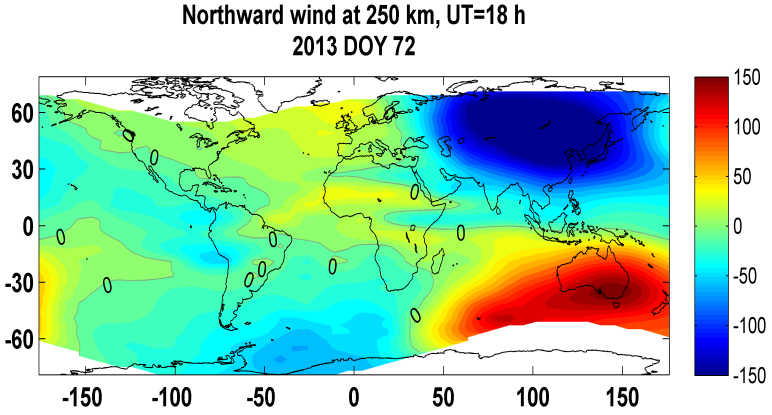


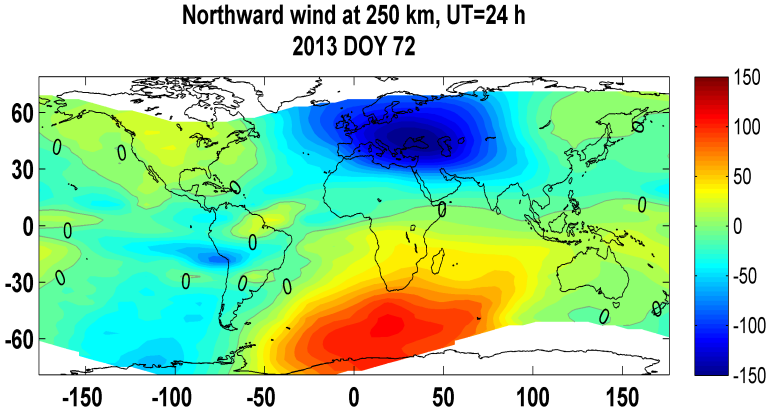


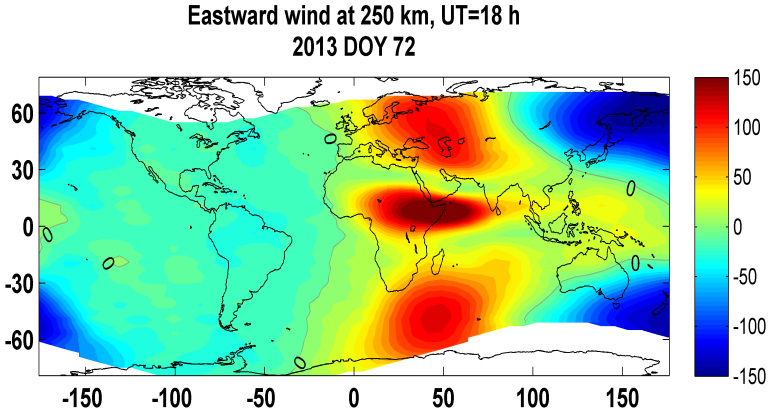


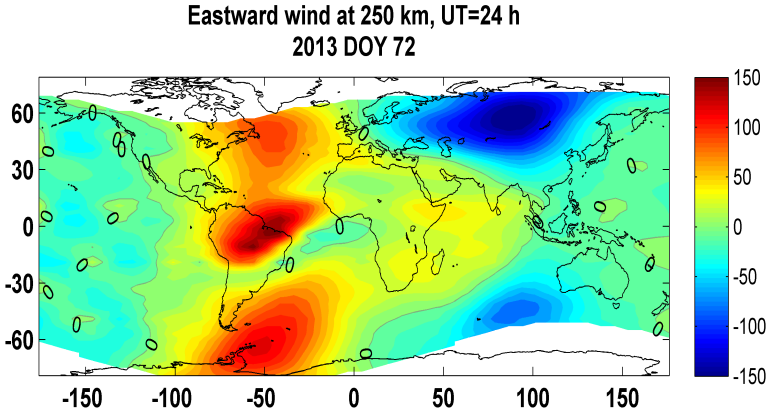


Day-to-day studies, DOY 72, 2013









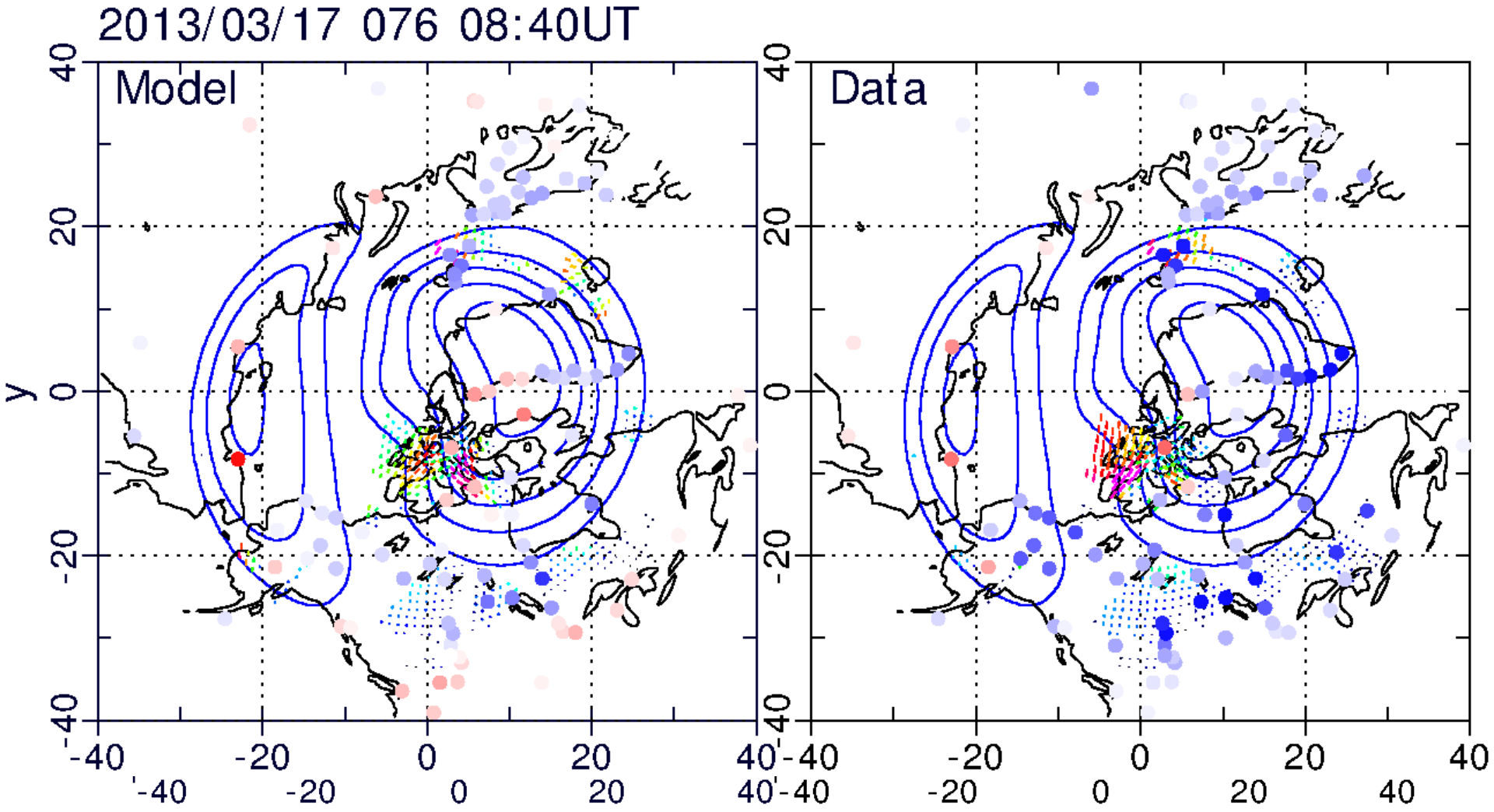
Studies using the High-Latitude Ionospheric Dynamics ElectroDynamics with Data Assimilation (HL-IDED-DA)

Assimilation of Multiple Data-types

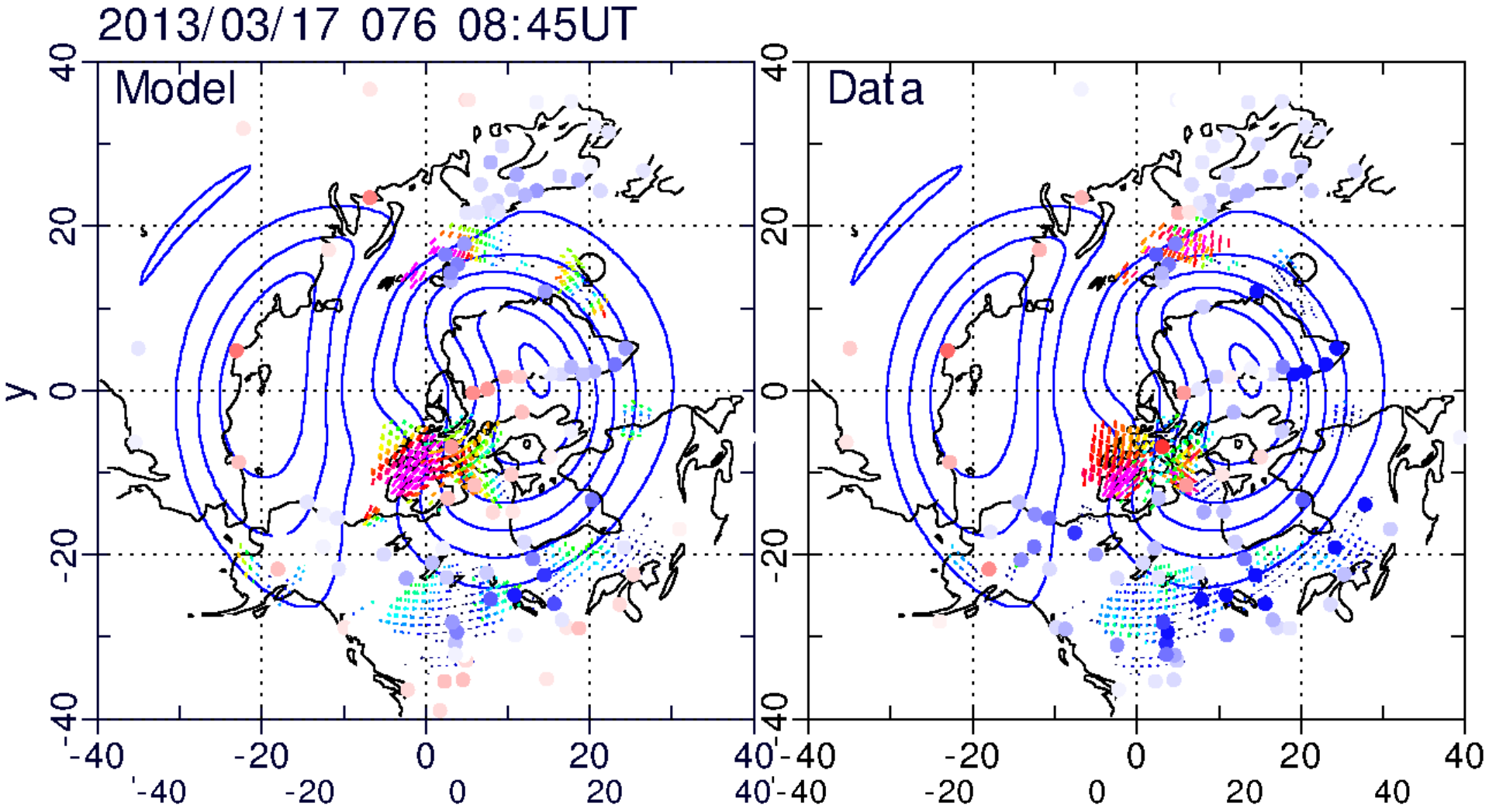
- Assimilating one data type provides the best results for that data type.
- Assimilating several data types is better for representing the complex electrodynamics-ionospheric dynamics system
  - but the results do not reproduce any one data type as well.
    - Instrument errors and interpretation
    - Physics-based model uncertainty
    - Choices in weighting the data types
- Storm of March 17, 2016 (076) follows to show the results using SuperDARN line-of-site and SuperMAG magnetometer deflections.

- In the future we will include AMPERE space-based magnetometers to give greater coverage of polar cap.

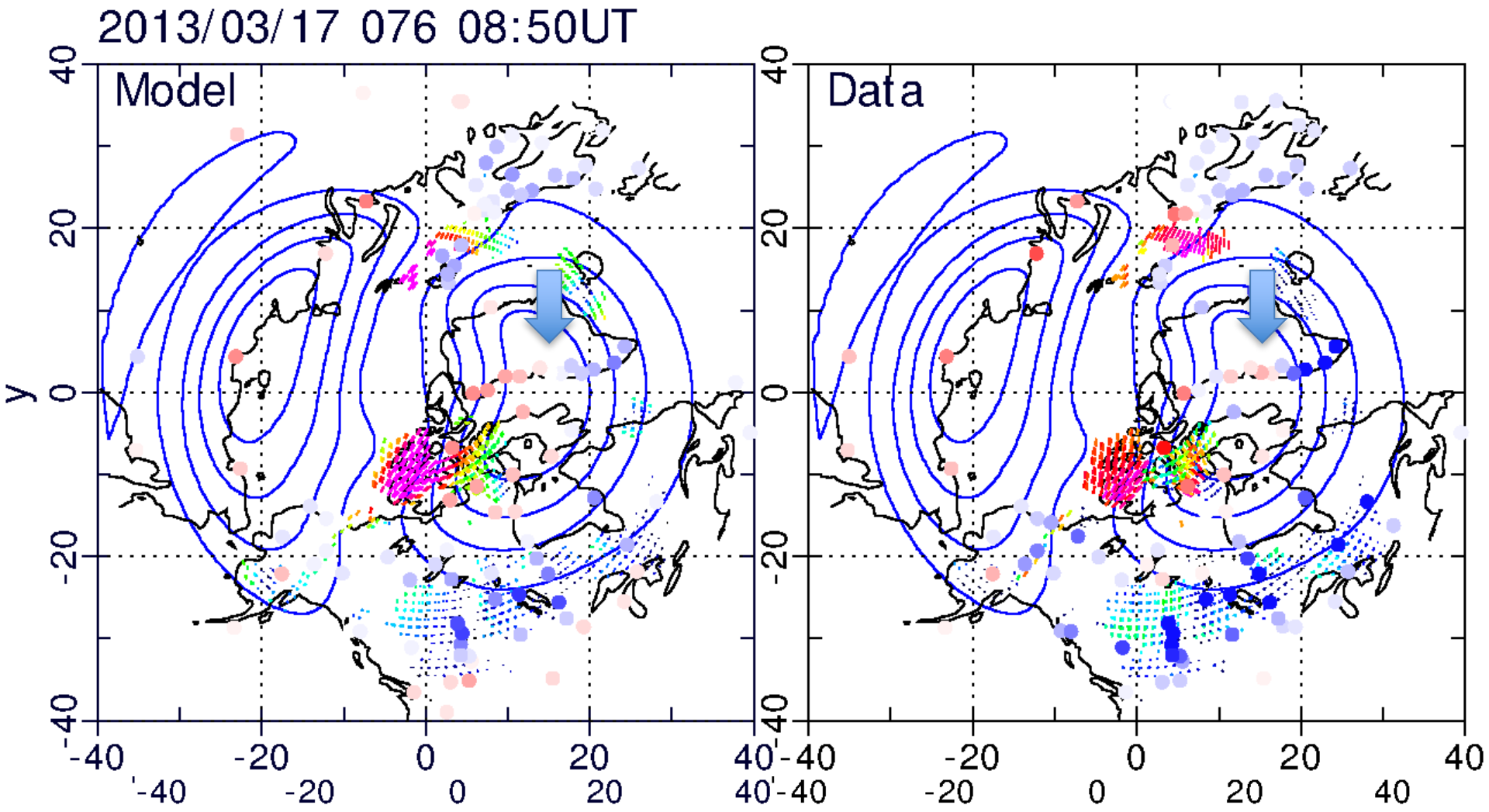
HL-IDED-DA



HL-IDED-DA

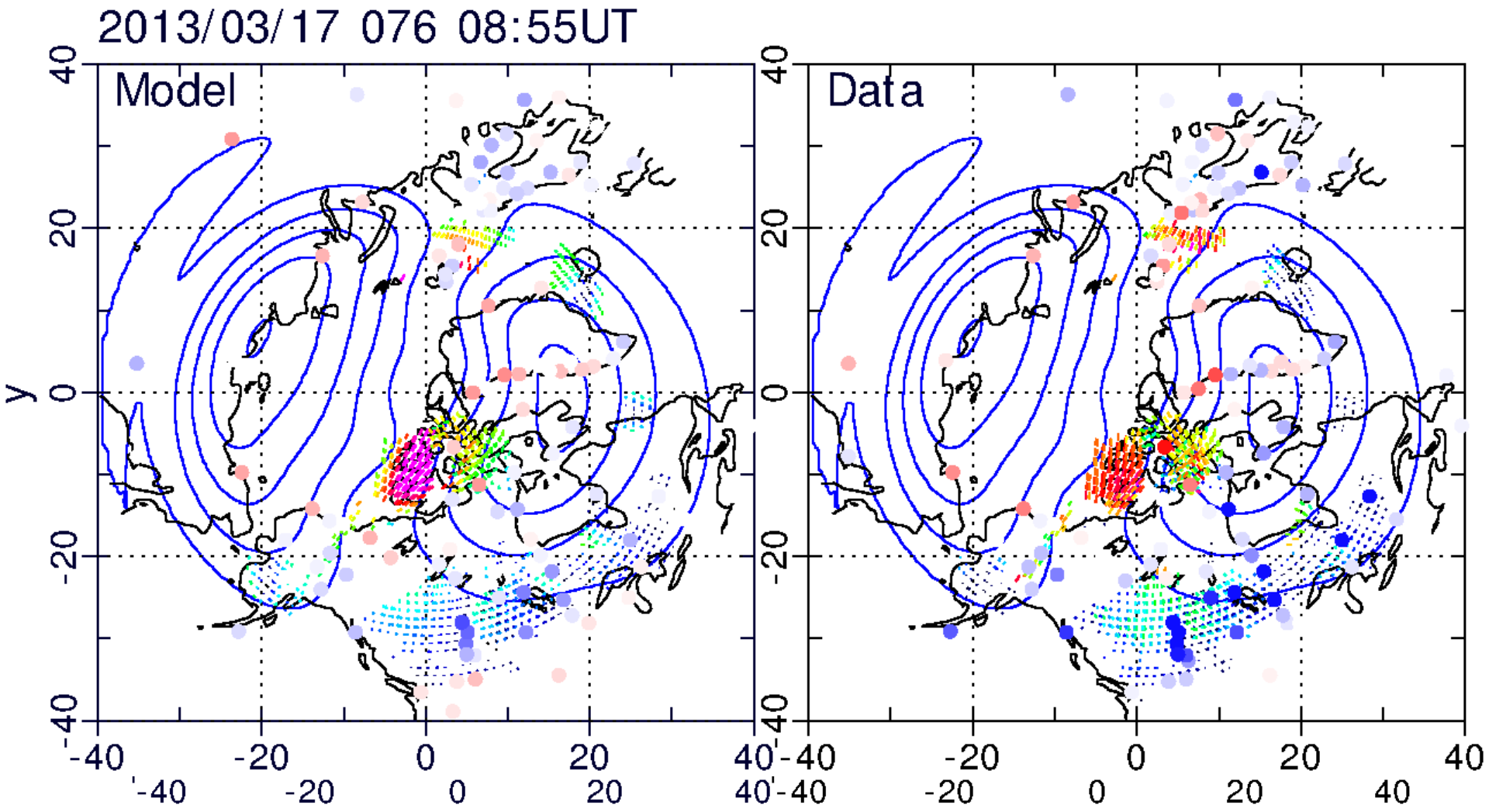


HL-IDED-DA

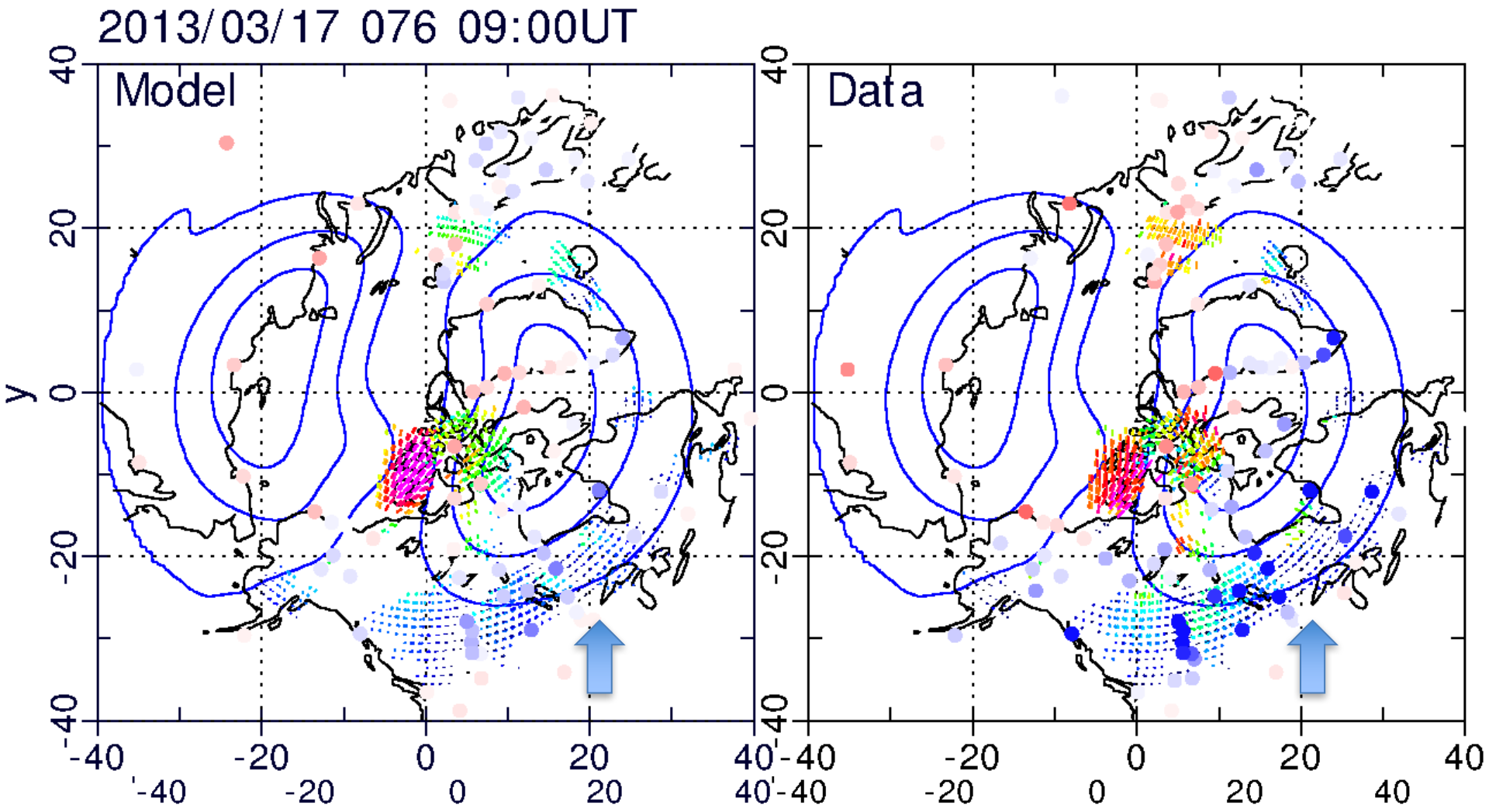


Deflection switch (pink to blue) is captured in cells and throat.
Line-of-sign velocity also reproduced.

HL-IDED-DA

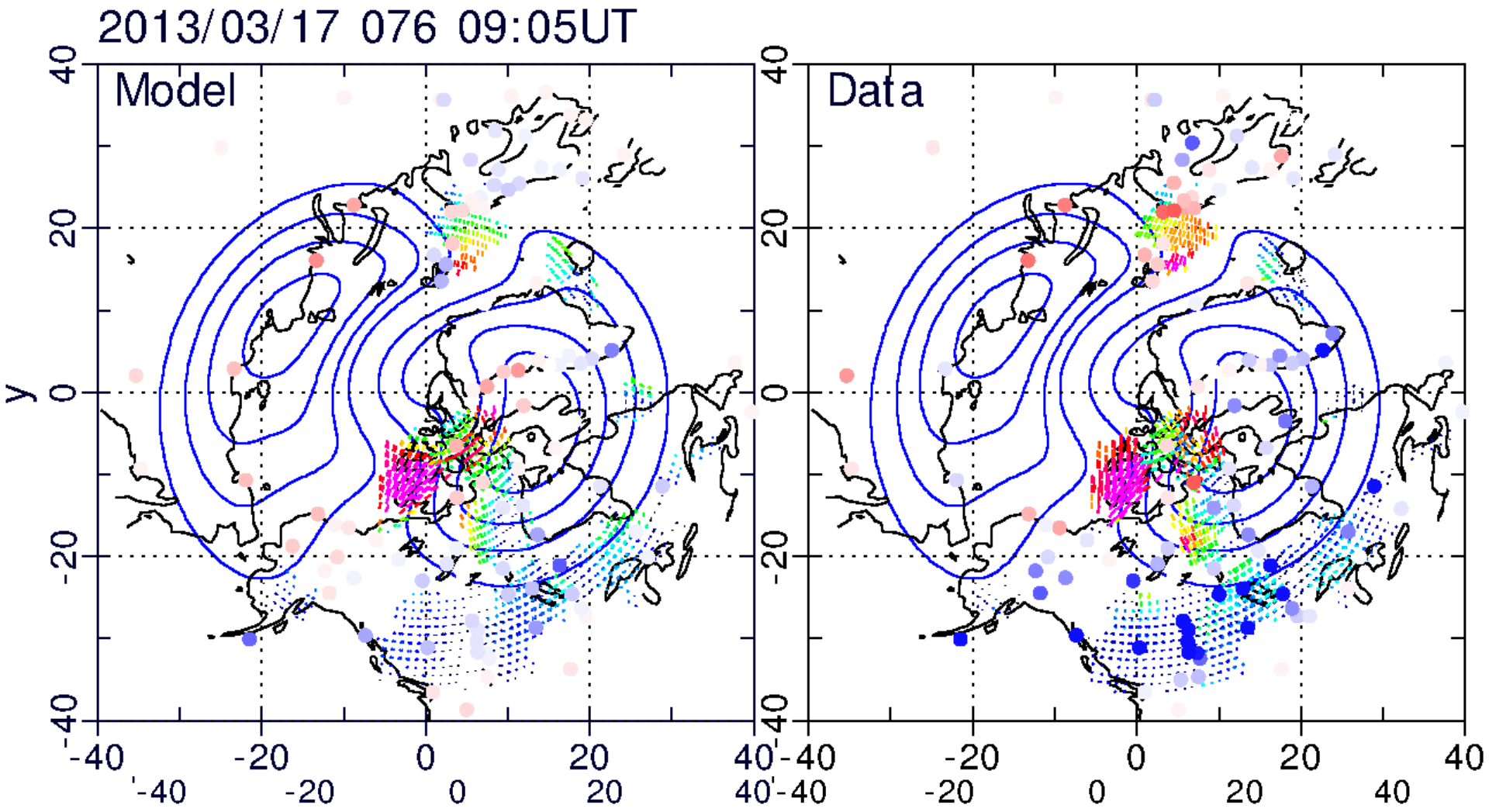


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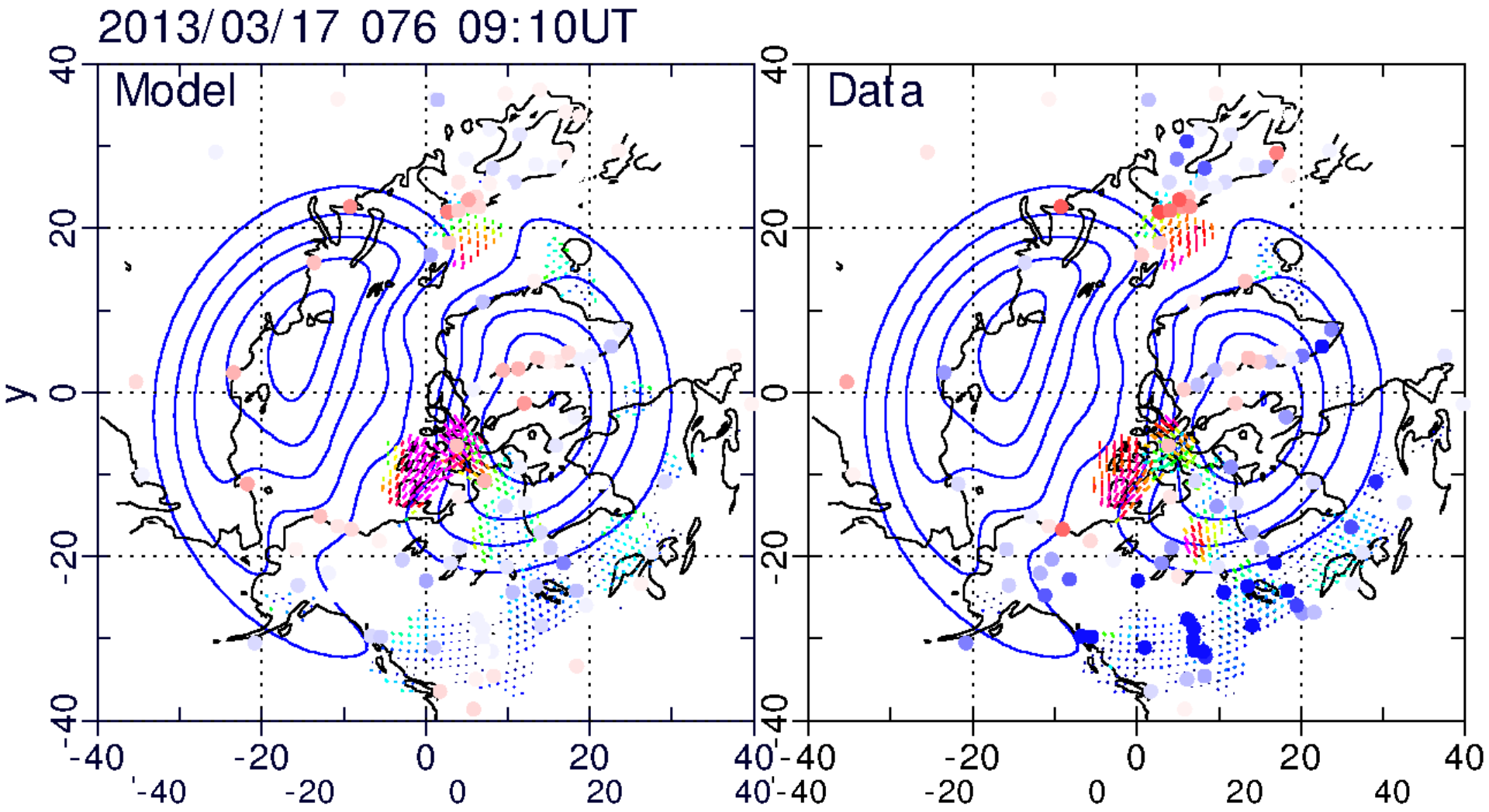


Magnetometer deflects is often underestimated after midnight.

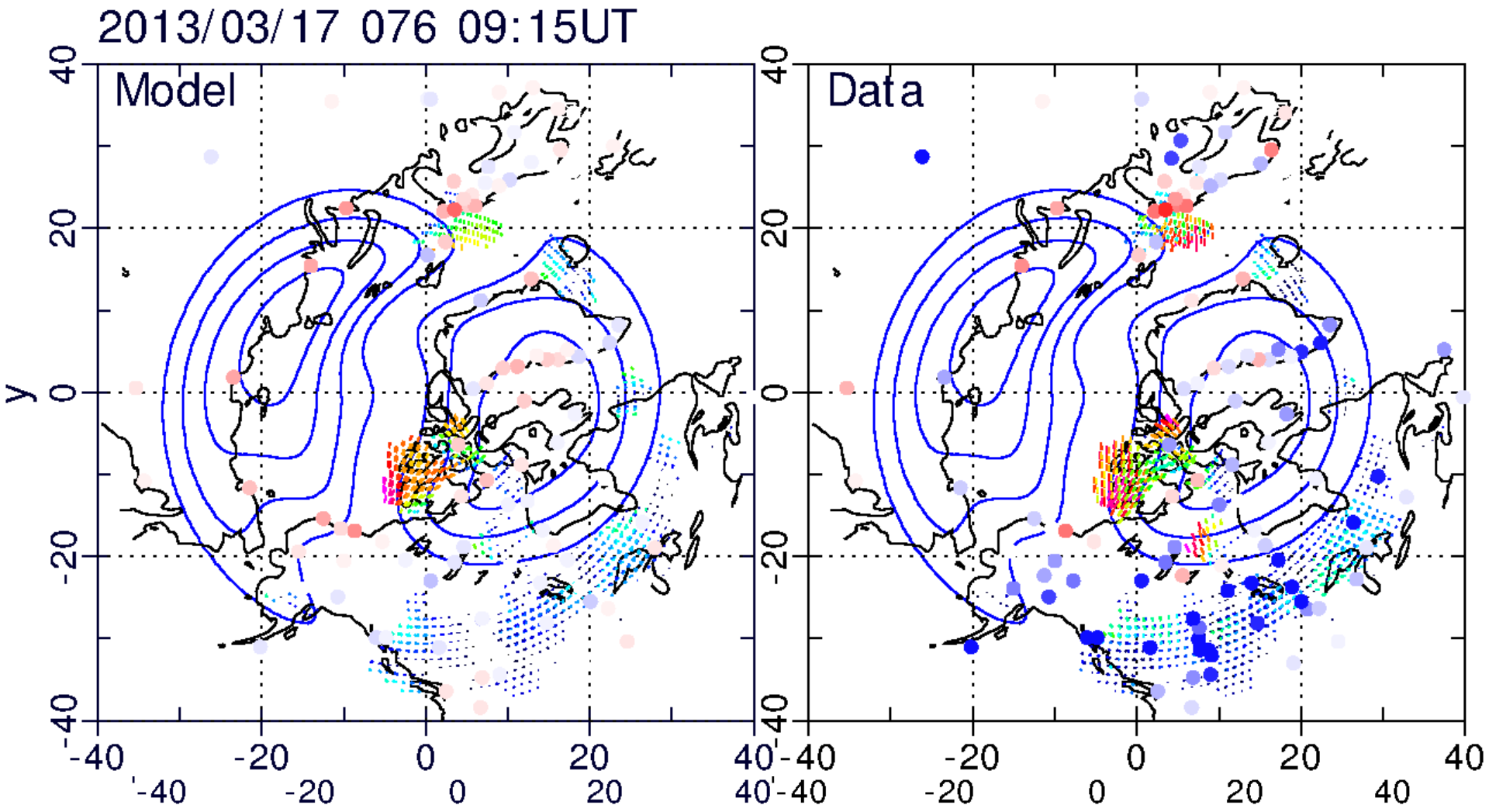
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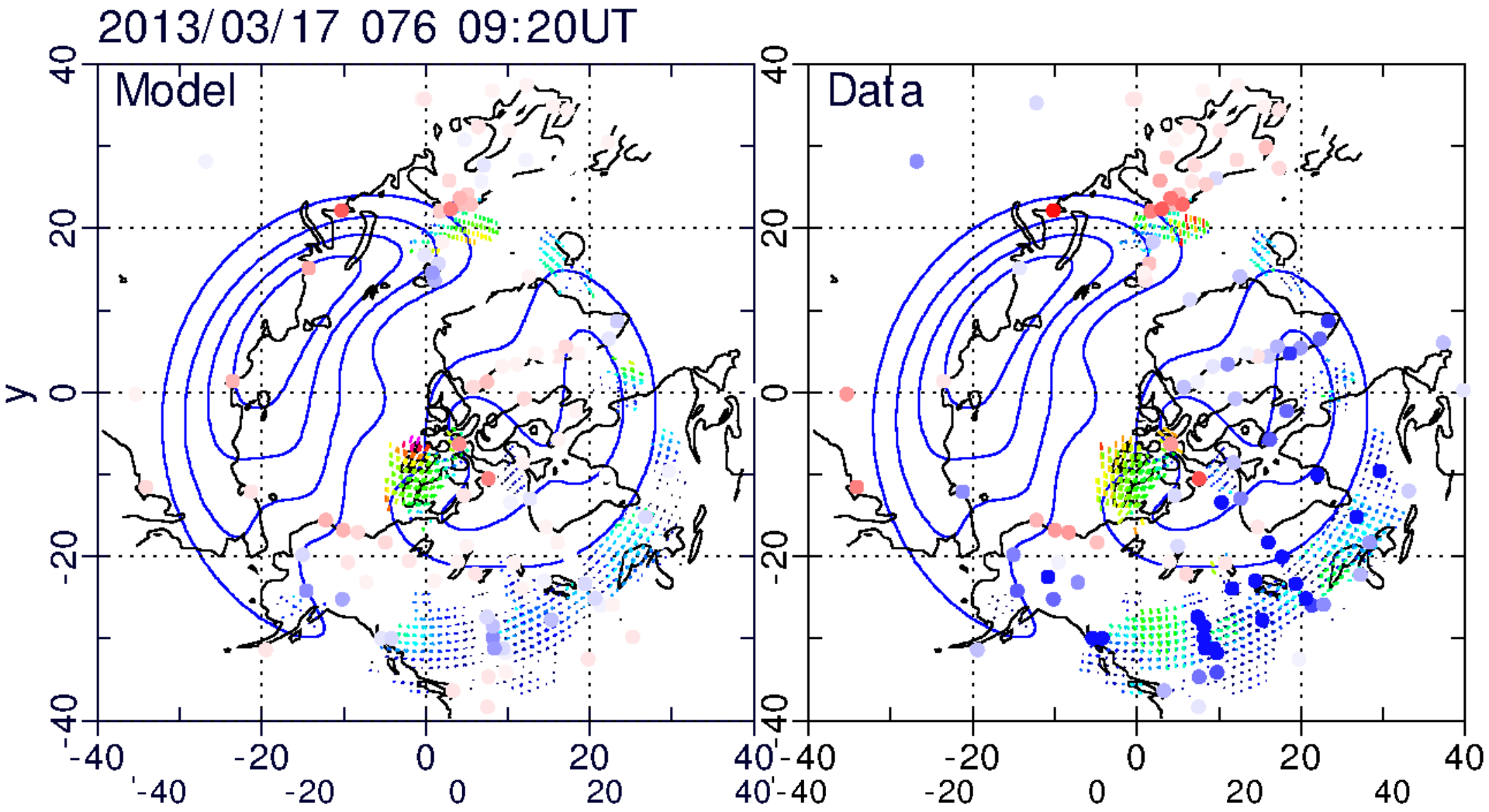
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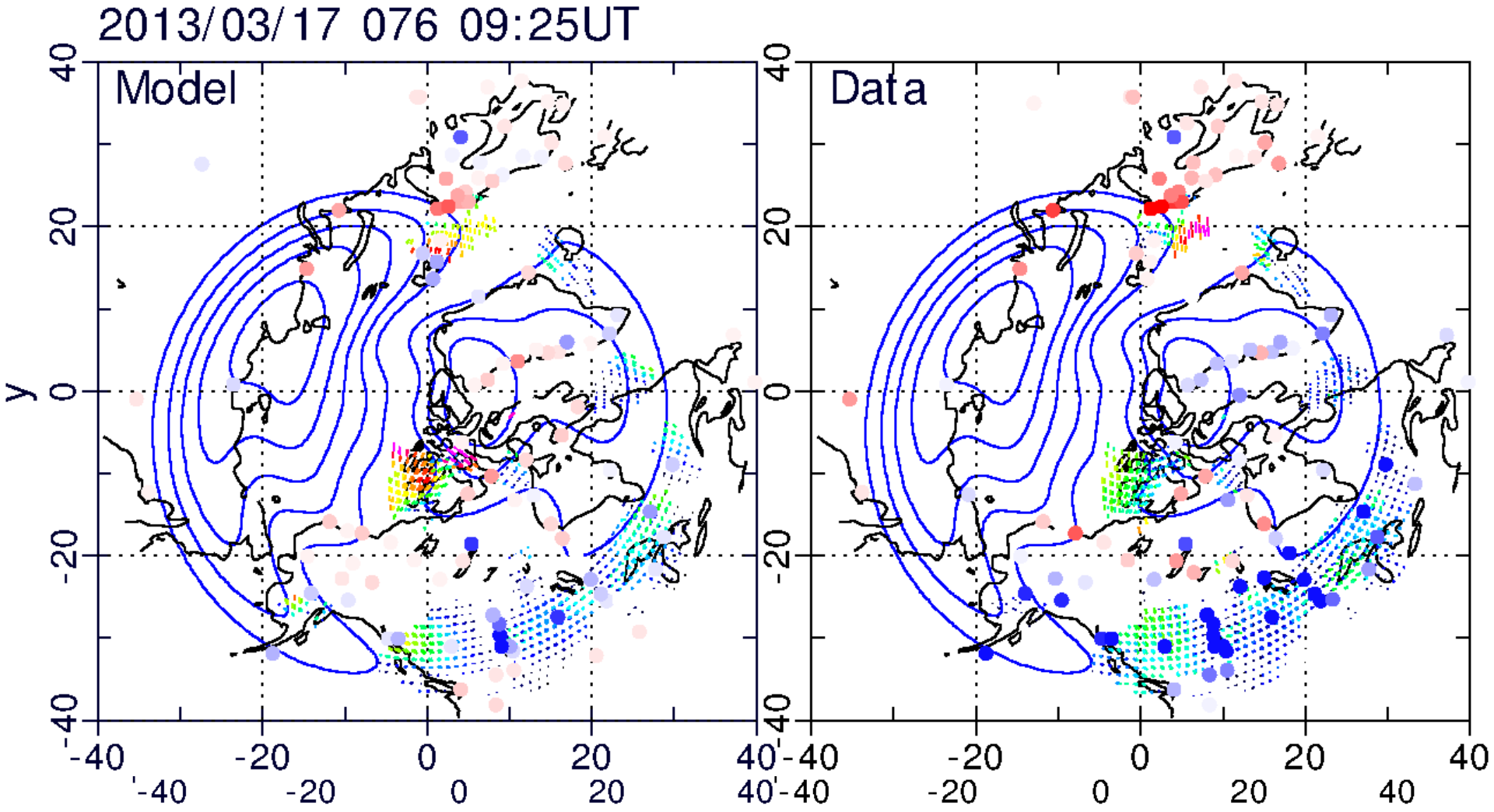
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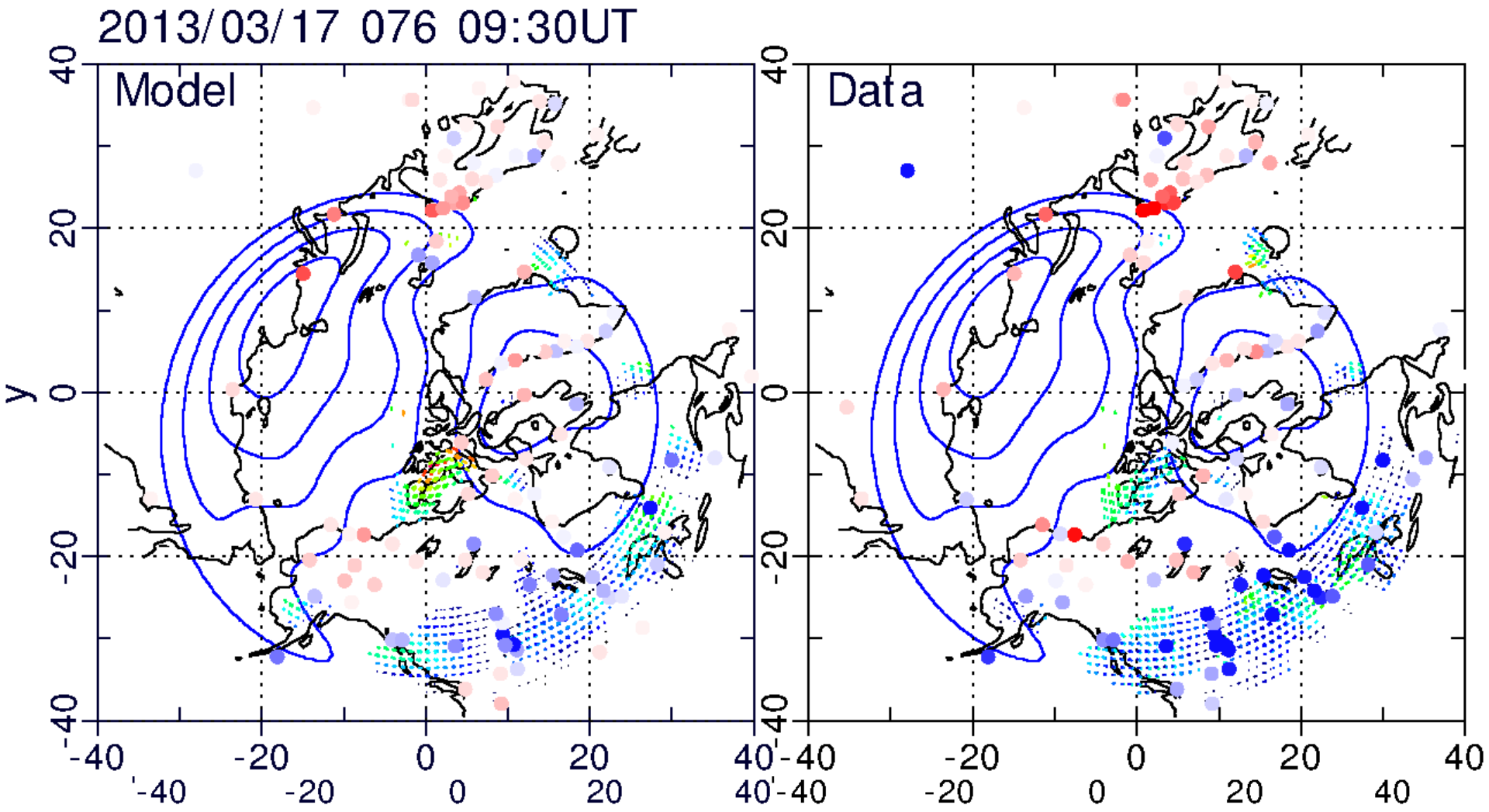
HL-IDED-DA



HL-IDED-DA



HL-IDED-DA



HL-IDED-DA Going Forward

- **Assimilation represents magnetometer deflections and plasma velocities well except in midnight sector.**

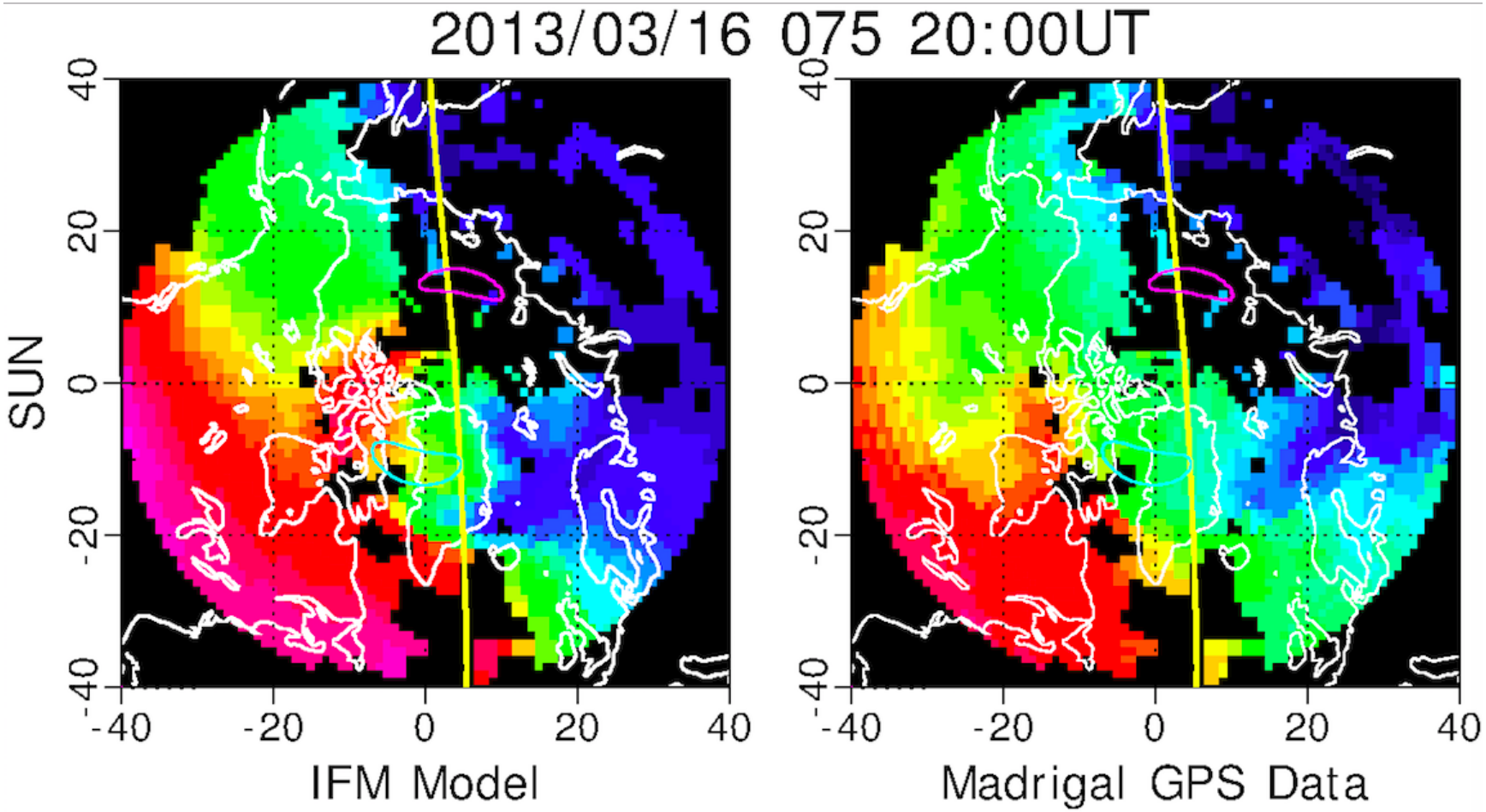
- **Substorm study should help improve midnight results of IDED-DA.**

- **Add IRIDIUM magnetometers to cover data-starved regions (Russia).**

HL-IDED-DA with TEC Maps

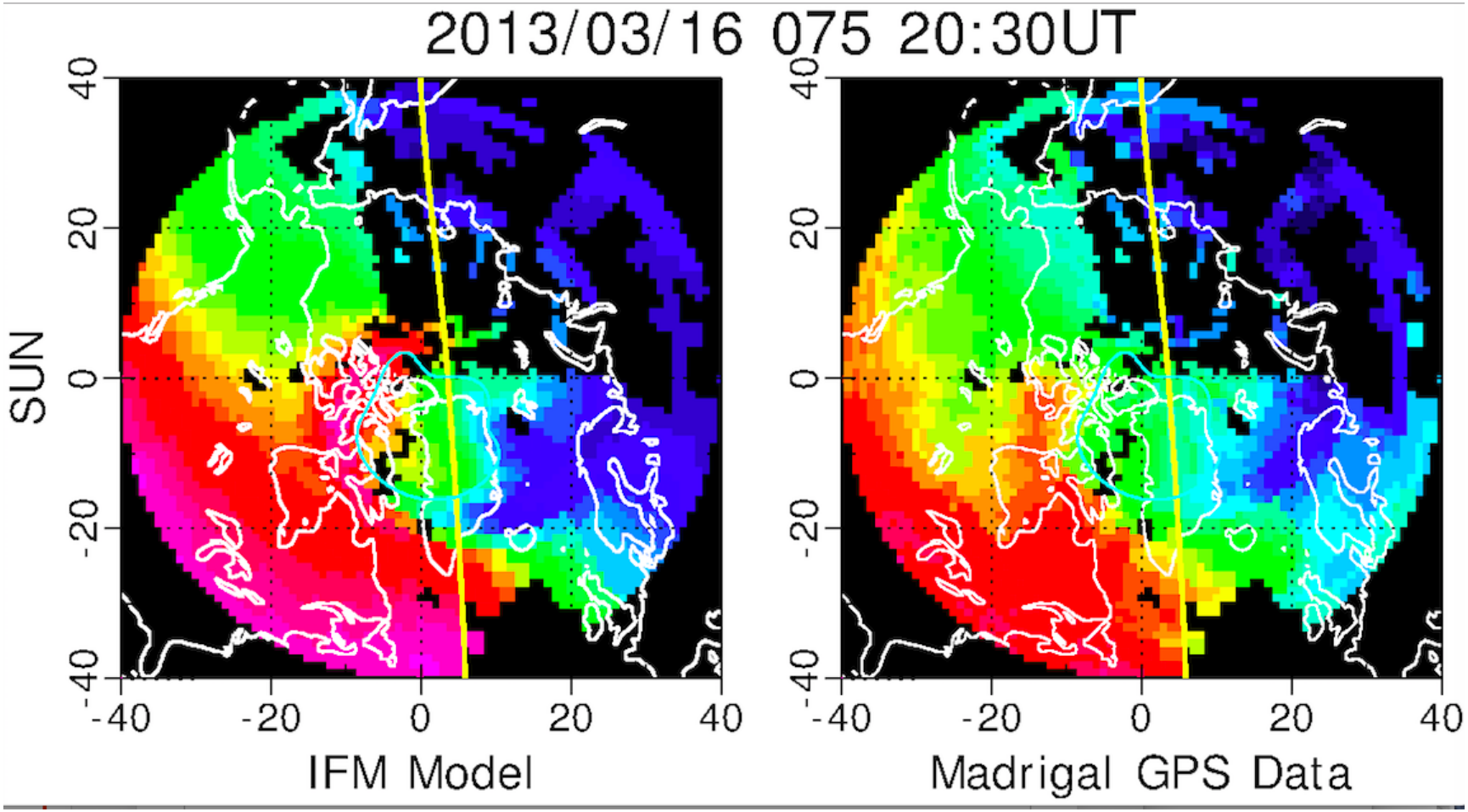
- **Working with TEC data to improve Convection Potential Patters**
  - The TEC patches are structured under the non-linear processes of ionospheric dynamics.
  - Intention is to improve the dayside entrance of plasma into the polar cap.

HL-IDED-DA with TEC Maps



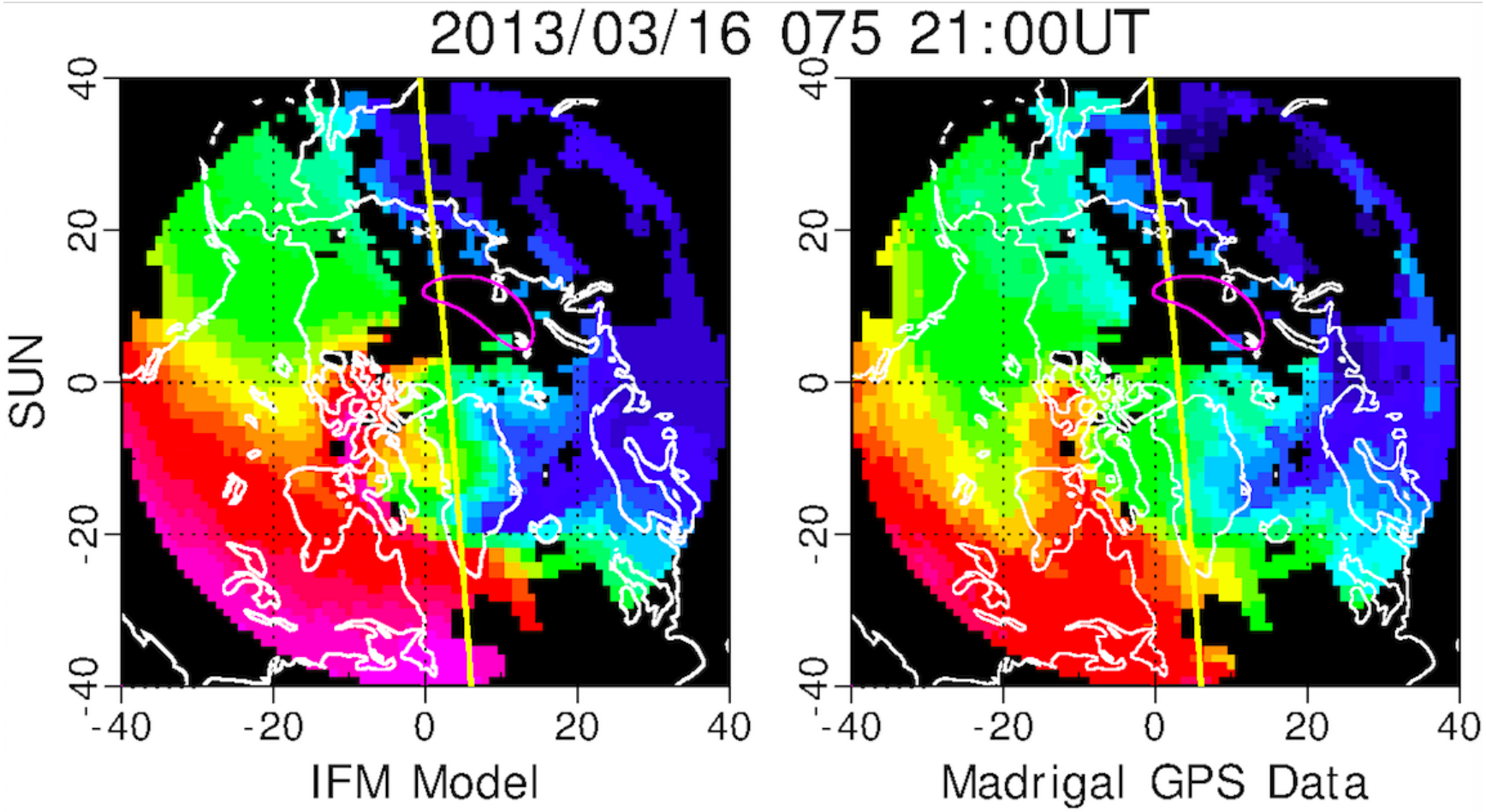
(with high latitude data assimilation)

HL-IDED-DA with TEC Maps



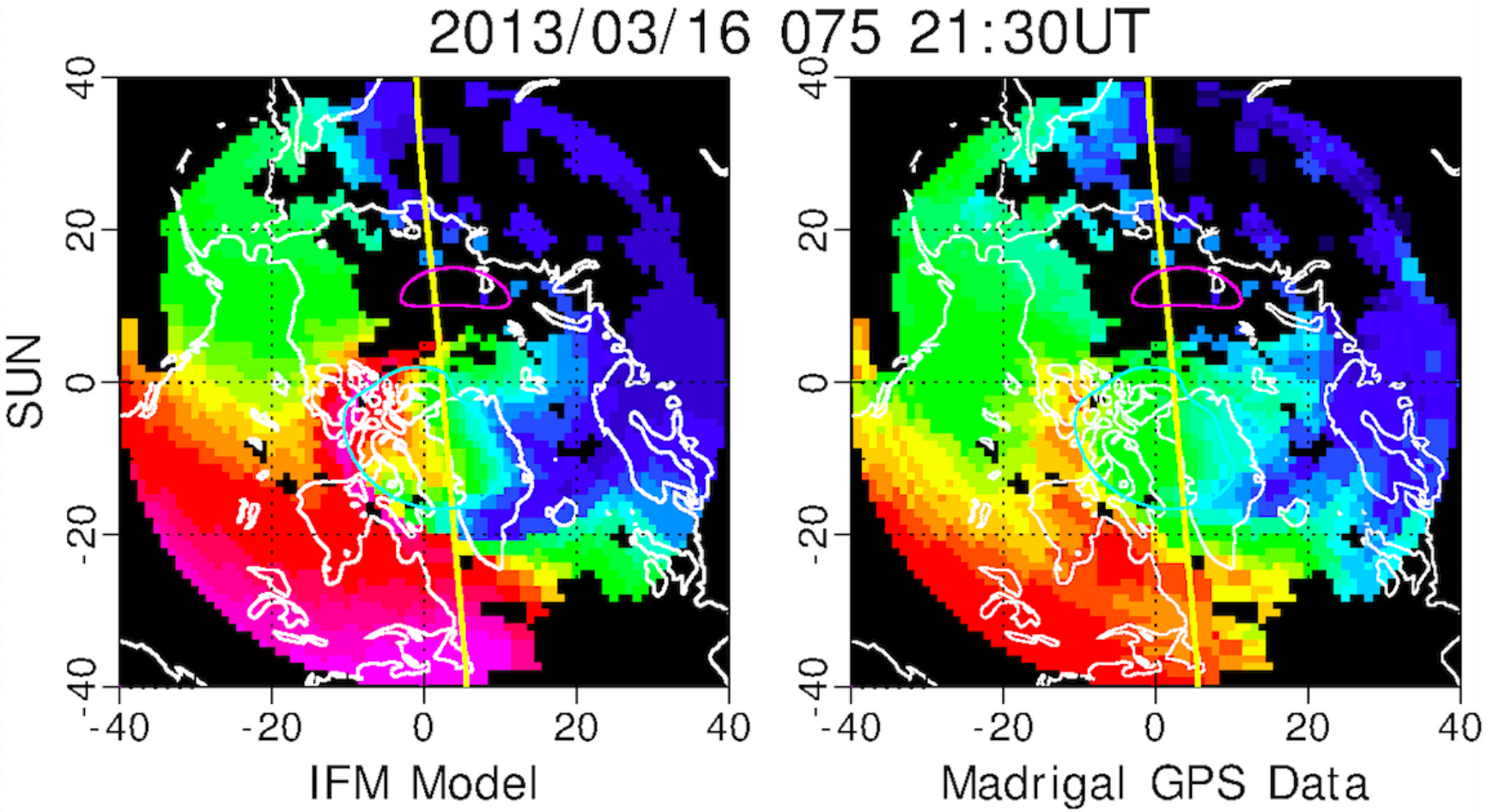
(with high latitude data assimilation)

HL-IDED-DA with TEC Maps



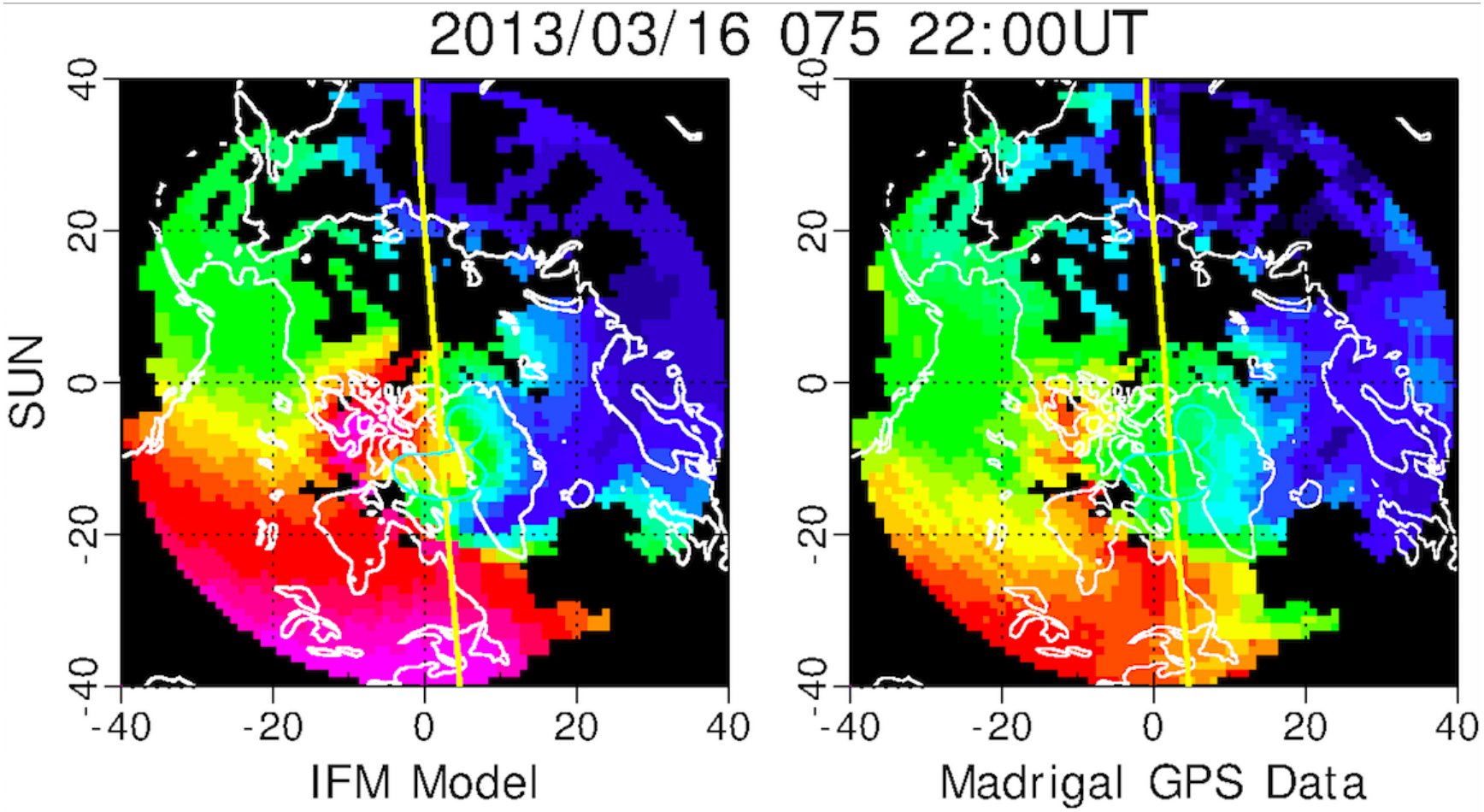
(with high latitude data assimilation)

HL-IDED-DA with TEC Maps



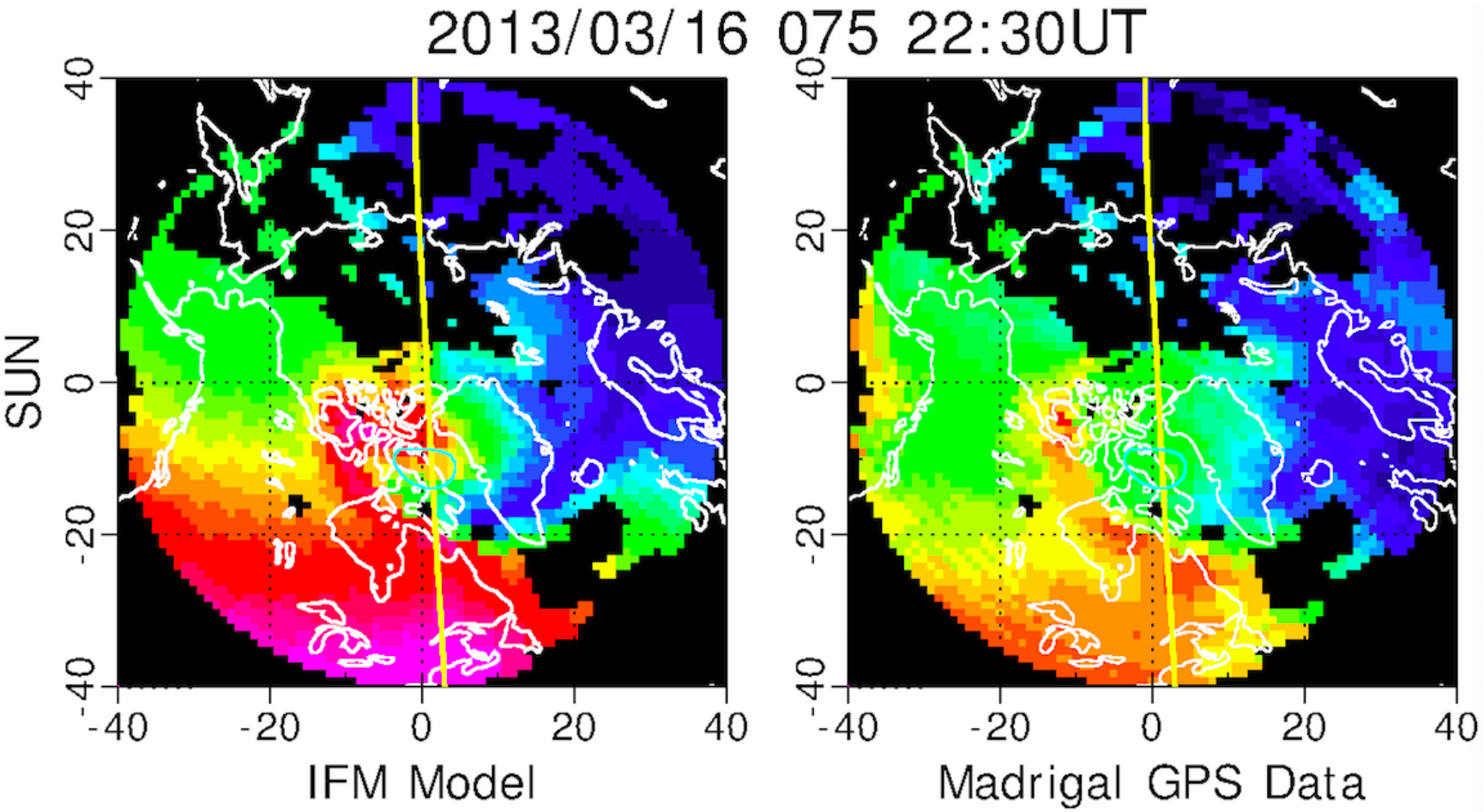
(with high latitude data assimilation)

HL-IDED-DA with TEC Maps



(with high latitude data assimilation)

HL-IDED-DA with TEC Maps



(with high latitude data assimilation)

TEC Use in IDED-DA

- Working for robust method to assimilated TEC entry into polar cap

- Improves the IDED-DA results with respect to ionospheric tongues and patches.