The effect of neutral mass density data assimilation on the quality of the thermosphere-ionosphere estimation

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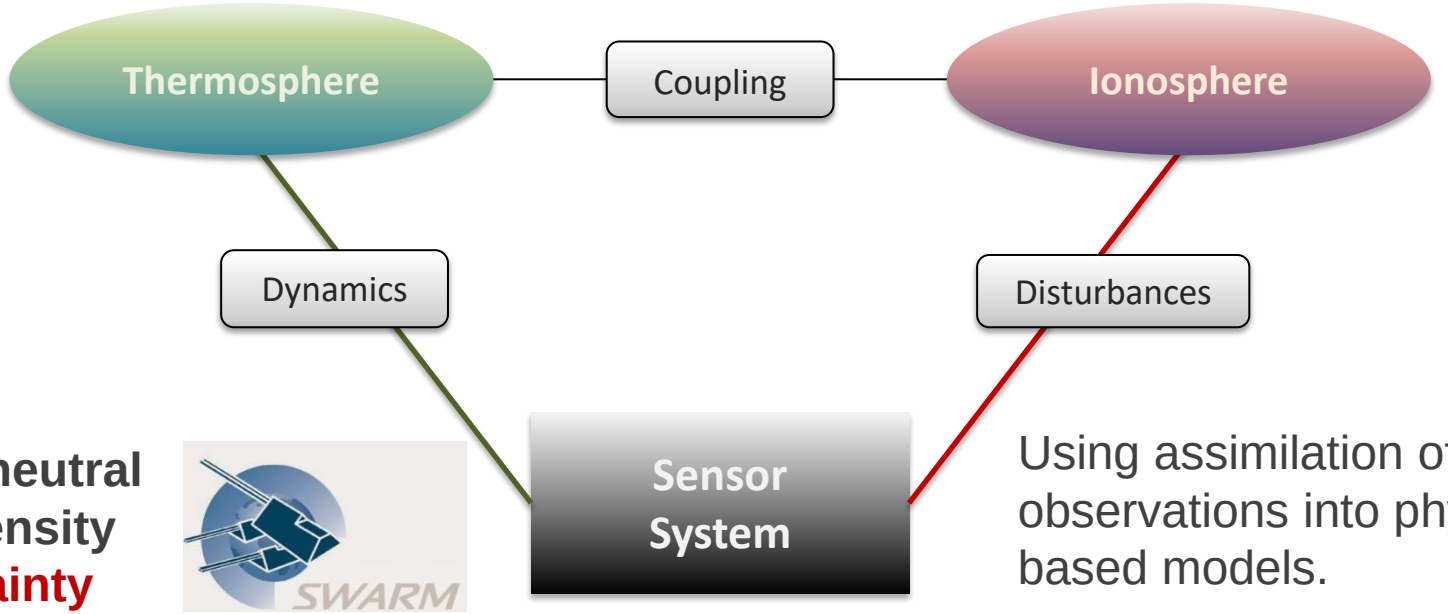
Outline

- Insight II project
- Objective
- Physics-based models: CTIPe and TIE-GCM
- Assimilation schemes: TIDA and DART
- Thermosphere-Ionosphere analysis
- Conclusions

INSIGHT II: Interactions of Low-orbiting Satellites with Surrounding Ionosphere and Thermosphere

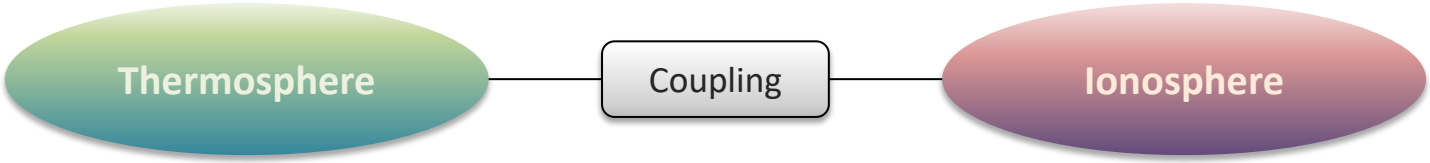


SWARM neutral mass density uncertainty

Using assimilation of observations into physics based models.

Objective

To investigate the **impact of assimilation of in-situ measurements on the Thermosphere-Ionosphere** (TI) system.



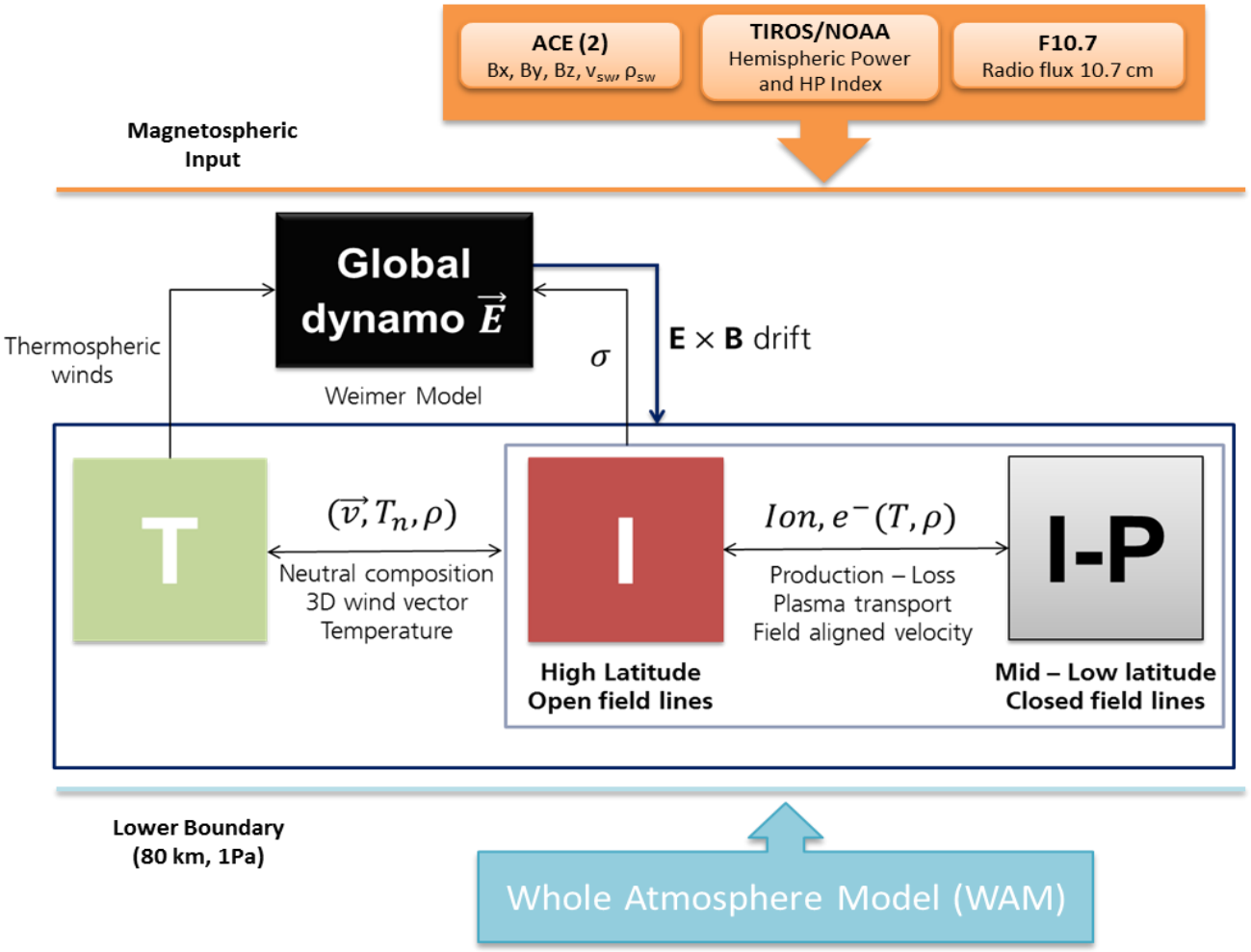
Physics-based model	CTIPe	TIE-GCM
Assimilation Scheme	TIDA	DART
Assimilated parameter	CHAMP **neutral mass density** (ρ)	CHAMP **electron density** (Ne)
Comparison	GRACE-A/B ρ IGS TEC	GRACE-A/B ρ CHAMP ρ and Ne

IGS INTERNATIONAL GNSS SERVICE

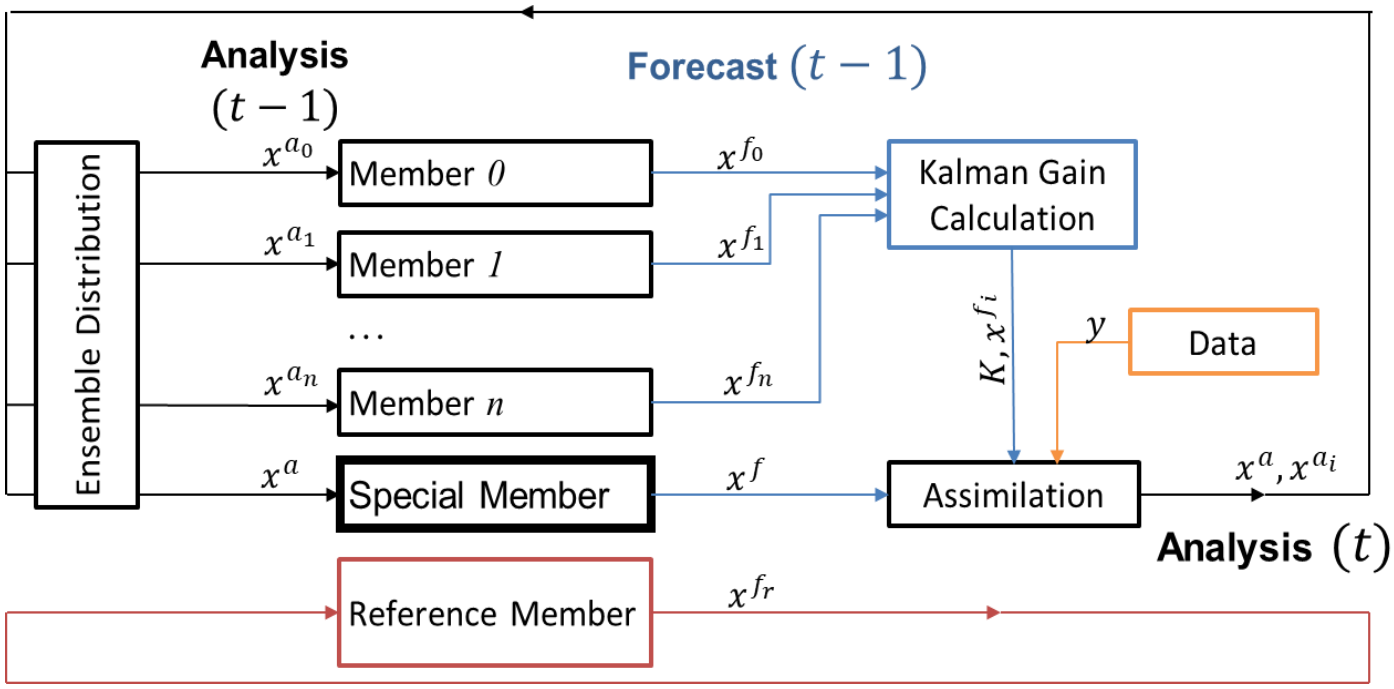
DLR

Physics-based models and Assimilation schemes

Physics-based models: CTIPe



Assimilation Scheme: CTIPe – TIDA (neutral mass density)



State Vector $x = \begin{bmatrix} model\ forcing \\ model\ state \end{bmatrix}$

$$x^a = x^f + K(y - h(x^f))$$
$$y^f = h(x^f)$$

KF update equation

$$x = \{F_{10.7}, |v_{sw}|, \rho_{sw}, B_N, B_\theta, T_n, \gamma_O, \gamma_{O_2}, \gamma_{N_2}, M, U, V\}$$

Model state correction + Forcing estimation

[Codrescu, 2018]

Physics-based models: TIE-GCM

Thermosphere Ionosphere Electrodynamics-General Circulation Model

Magnetic activity
High-lat input
(Kp, IMF)

Solar EUV/FUV
($F_{10.7}$)

Lower atm forcing (tides)
(GSWM, Eddy Diffusion)

Configuration used in this study

$F_{10.7}$ based EUVAC;
Solomon & Qian, 2005;

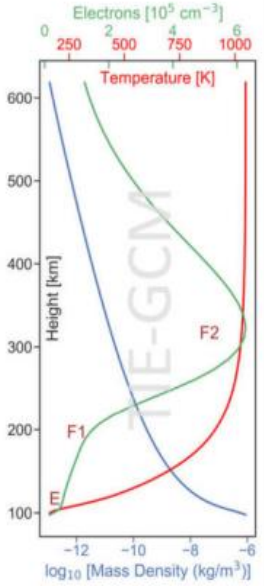
GSWM, Hagan et al., 1999
Eddy, Qian et al., 2009

Heelis et al., 1982;
Weimer 2005;
AMIE (data assimilation);
LFM magnetosphere

TIE-GCM

Low/mid lat electrodynamics:
neutral wind dynamo in
geo-mag apex coordinates.
Richmond et al., 1992; 1995

Latitude x Longitude:
2.5° × 2.5° or 5° × 5°
Height: 29 or 57
constant pressure levels



Neutral Density,
Composition,
Temperature,
Winds,Energy,
Ionosphere (Ne,
TEC), ...

NCAR UCAR HAO

Developed by the High
Altitude Observatory,
Colorado, USA

Assimilation scheme: TIE-GCM – DART (electron density)

Data Assimilation – Ensemble Kalman Filter

NCAR's
Data
Assimilation
Research
Testbed

DART parameters (ensemble size, localisation, assimilation window,...)

Assimilate the obs using the EnKF

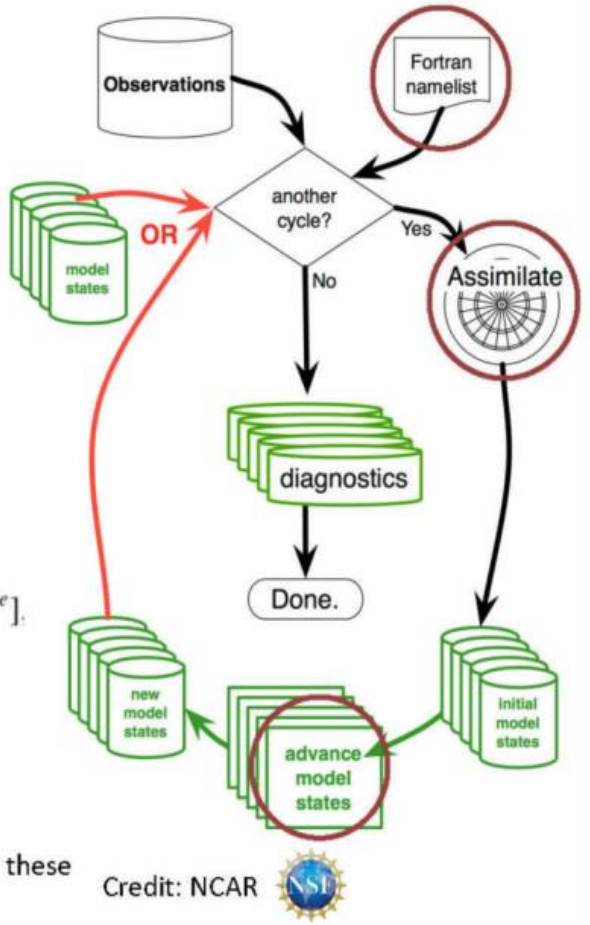
State vector

$$\boldsymbol{x} = [\psi^{Tn}; \psi^{\gamma O}; \psi^{\gamma O^+}; \psi^{\gamma O_2}; \psi^{U}; \psi^{V}; \psi^{Ne}].$$

Advance the model

Diagnostics: explore state before and after assimilation cycle

Integrated the latest TIE-GCM into DART to perform these experiments



Credit: NCAR

[Anderson, 2009]

Thermosphere – Ionosphere

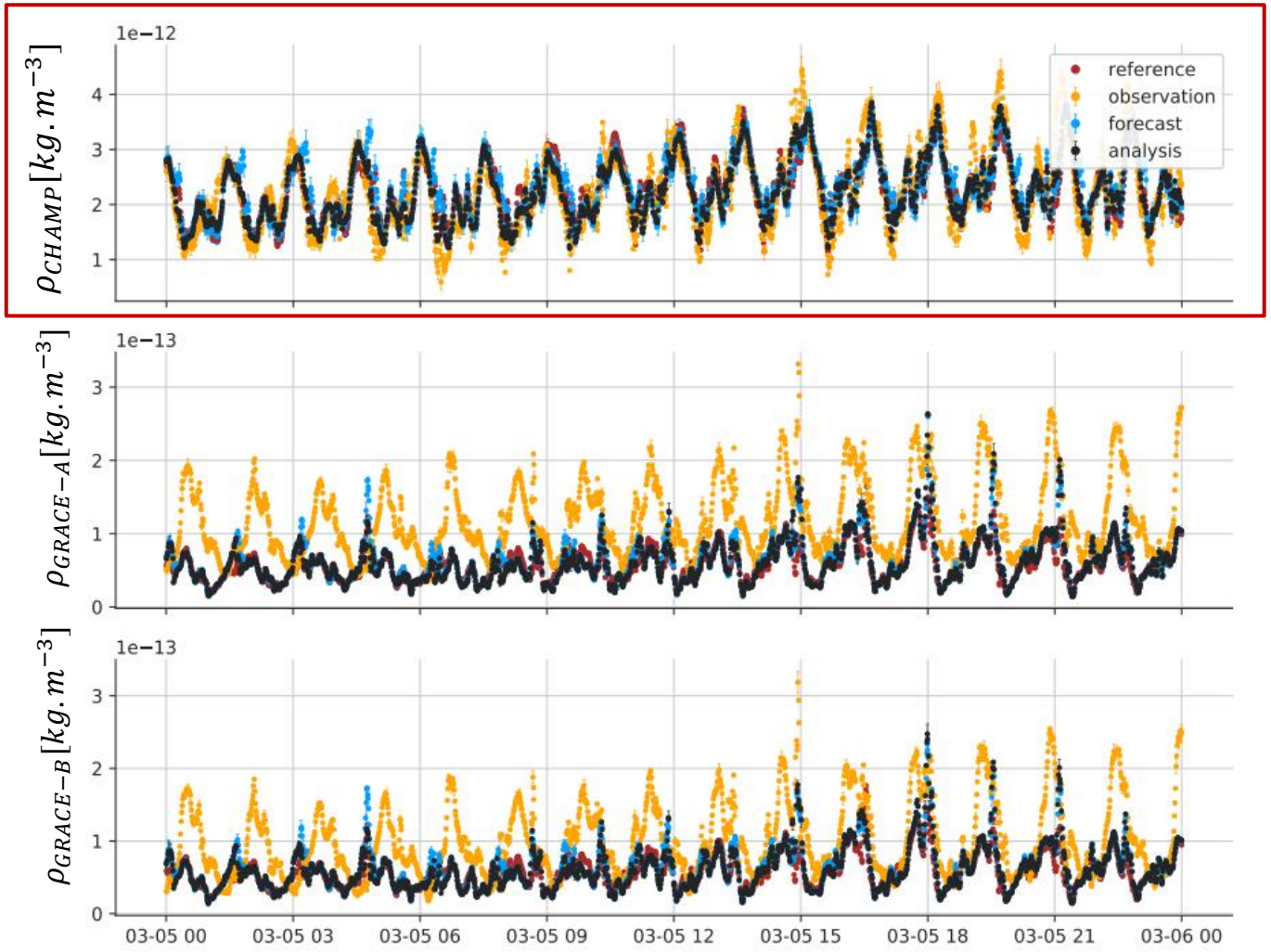
Quiet solar geomagnetic conditions

5 March 2008

Assimilation of neutral mass density into CTIPe

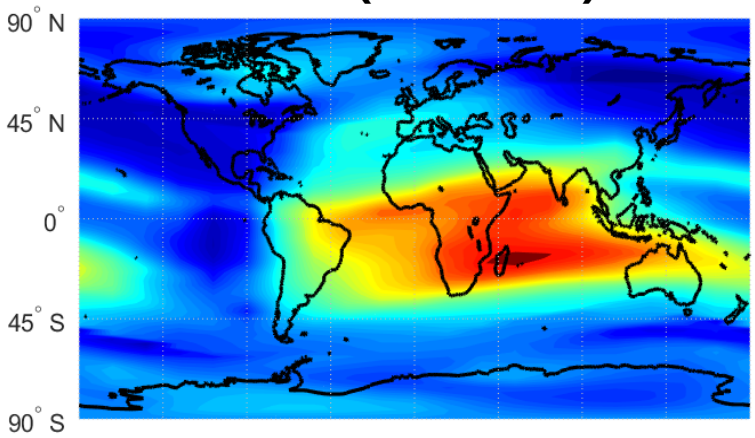
CHAMP

GRACE

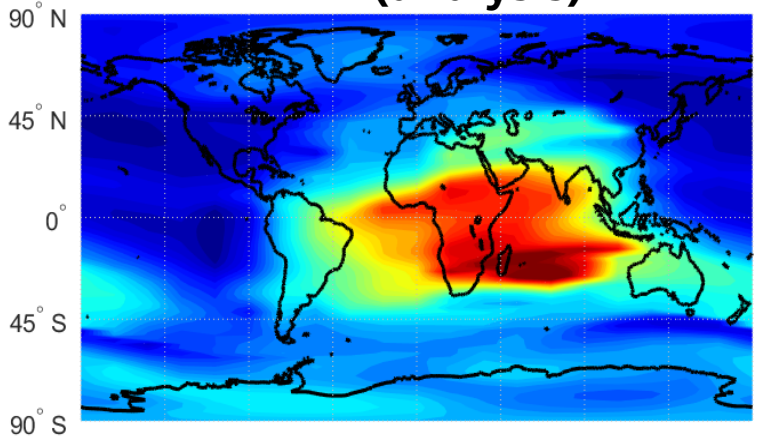


Effect on the Ionosphere: TEC 5.3.2008 12:00

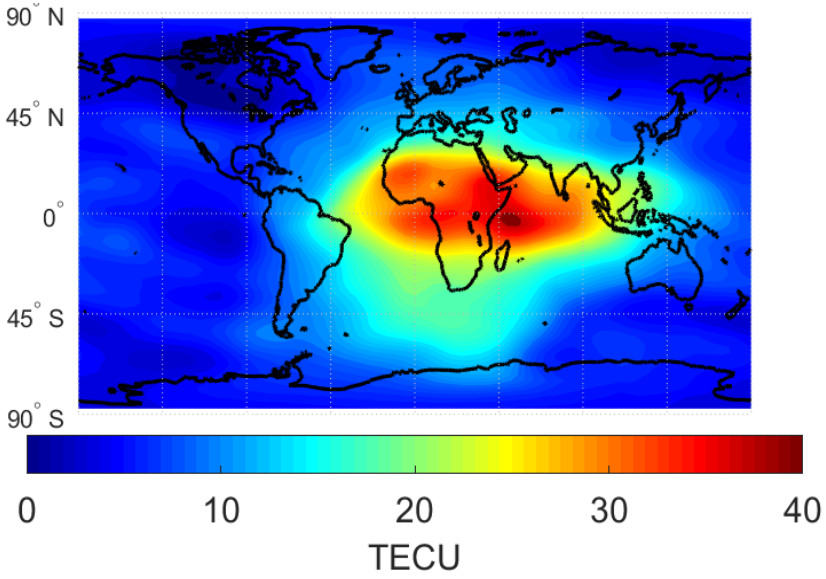
CTIPe (reference)



TIDA (analysis)

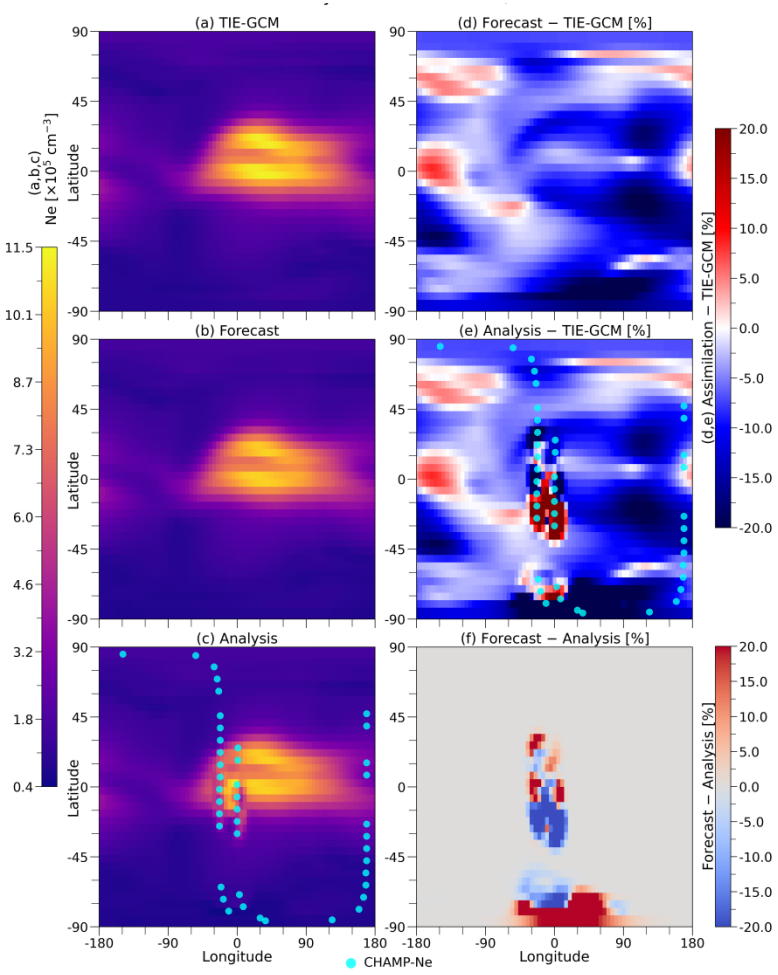


IGS (measurements)



Assimilation of electron density into TIE-GCM

Ne at 12:00 345 km

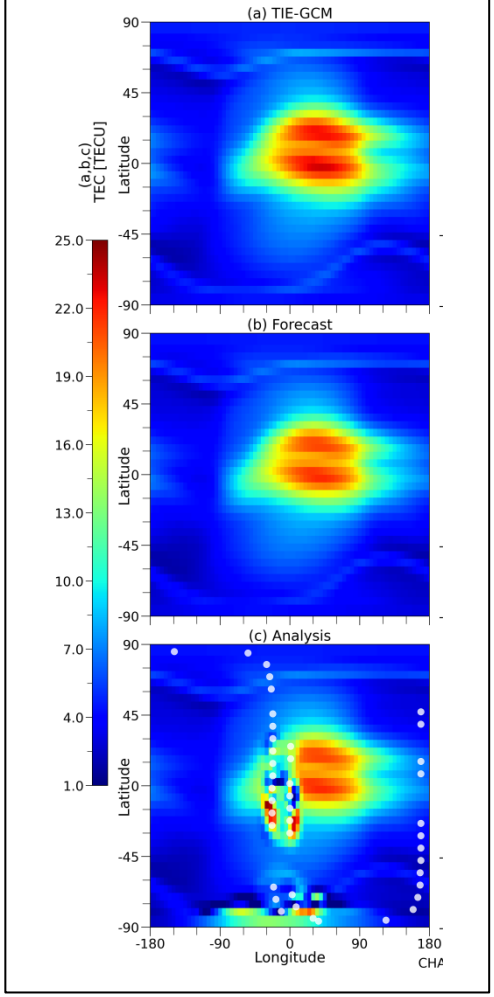


Forecast - Reference

Analysis - Reference

Forecast - Analysis

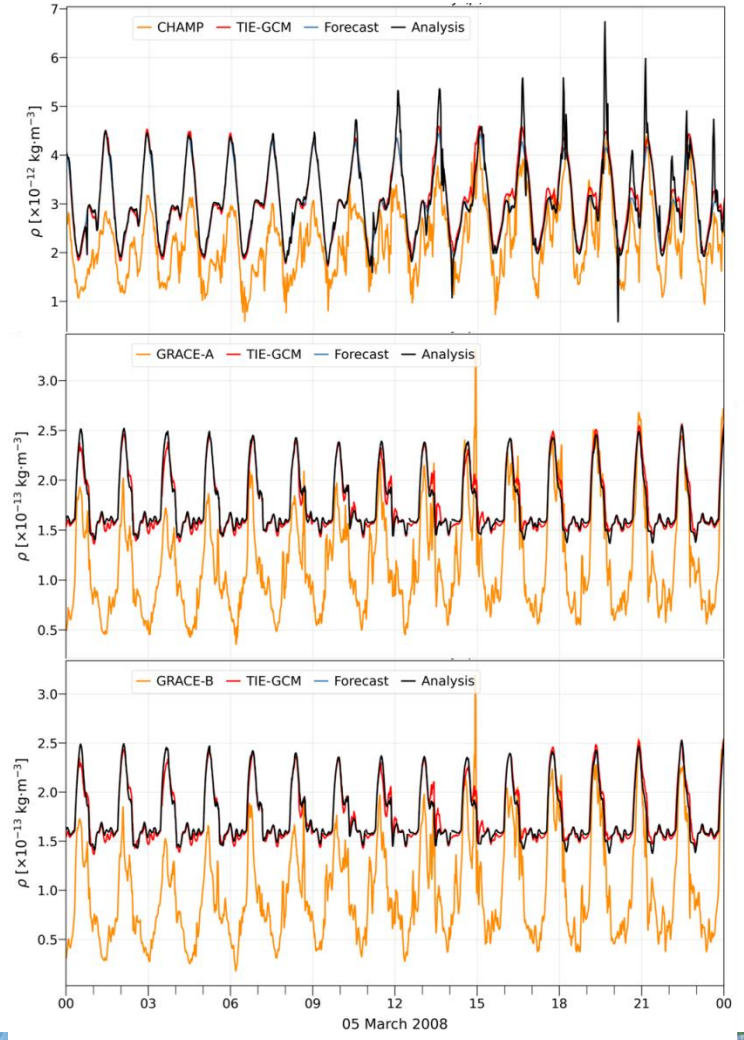
TEC at 12:00



Effect on the thermosphere: CHAMP and GRACE-A/B neutral mass density

CHAMP

GRACE



Reference
Observations
Forecast
Analysis

Conclusions

- In this case study, the **assimilation of both ρ and Ne** during a **geomagneticaly quiet period** is studied. As expected, the results reveal that the assimilation has a bigger impact in the TI state near the assimilated data points.
- In case of ρ, **large biases between model and observations** are visible, which are also partly attributed to calibration errors in the observations. The results indicate only minor improvement of the ρ model estimates through data assimilation during quiet time.
- For the TEC, CTIPe-TIDA shows **significant differences** of the model estimates compared to observations even in larger distances from the assimilated data points. More investigation is needed to determine if the TEC difference between the reference and the analysis are due to assimilation of ρ or the forcing estimation or both.
- More work will follow with different scenarios for both models. Assimilation of different parameters and storm time will be considered.