An Assimilative Version of TIE-GCM using PDAF

Armin Corbin, Kristin Vielberg, Jürgen Kusche

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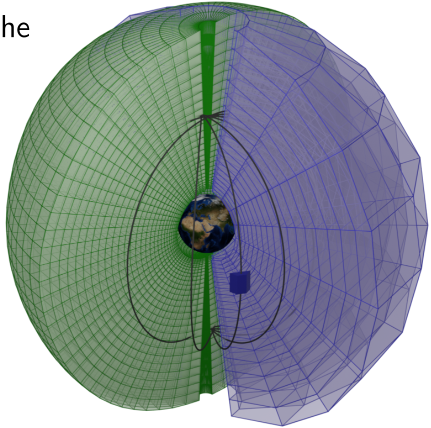

DynamicEarth SPP[1788]

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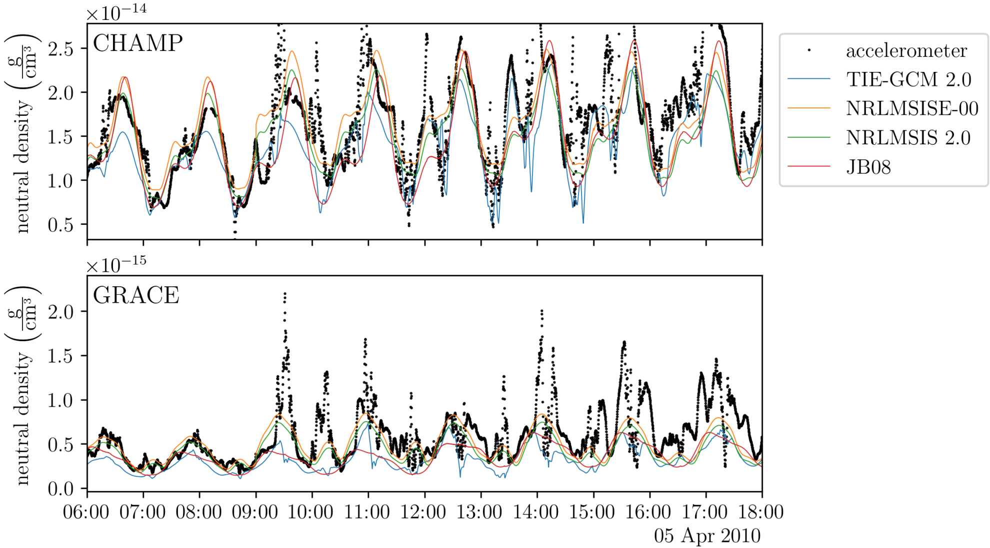
Neutral Density Predictions and Measurements



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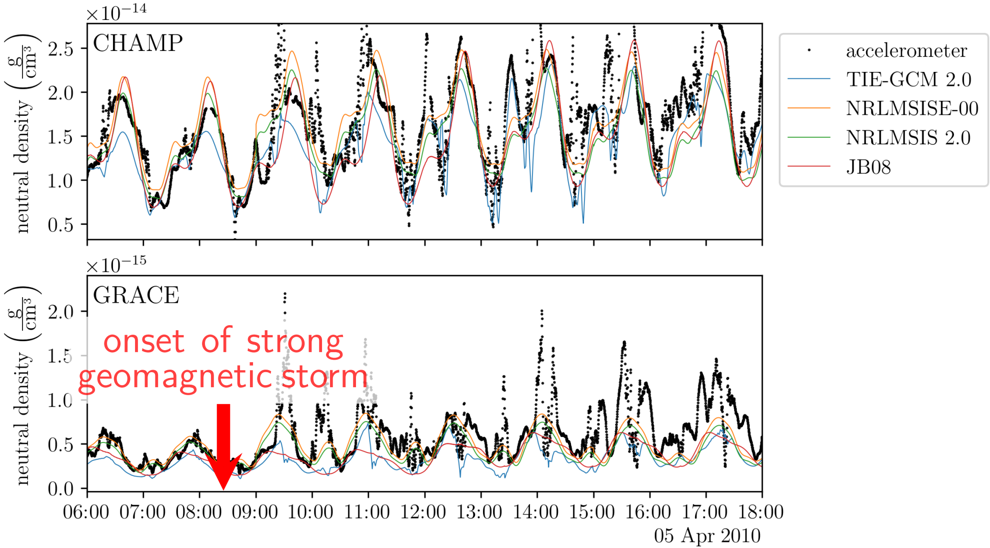
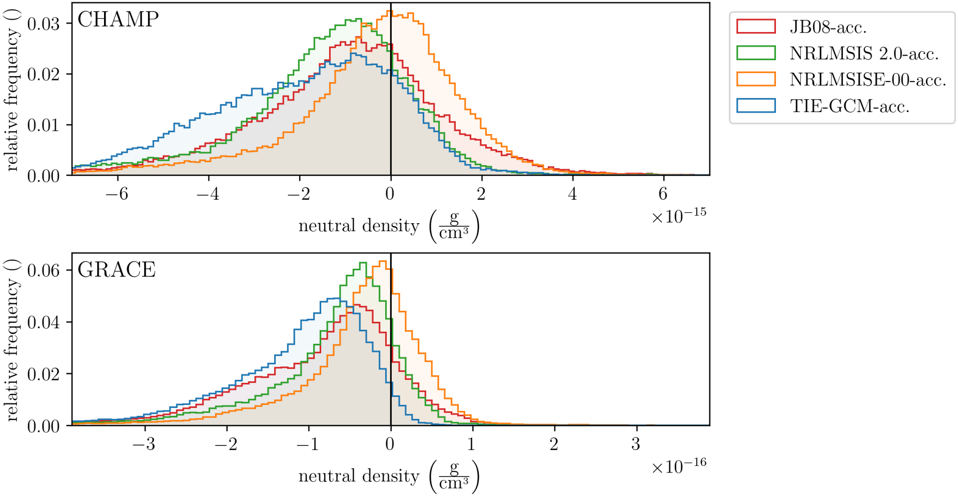


Differences to Measurements between April 27, 2010 and May 10, 2010



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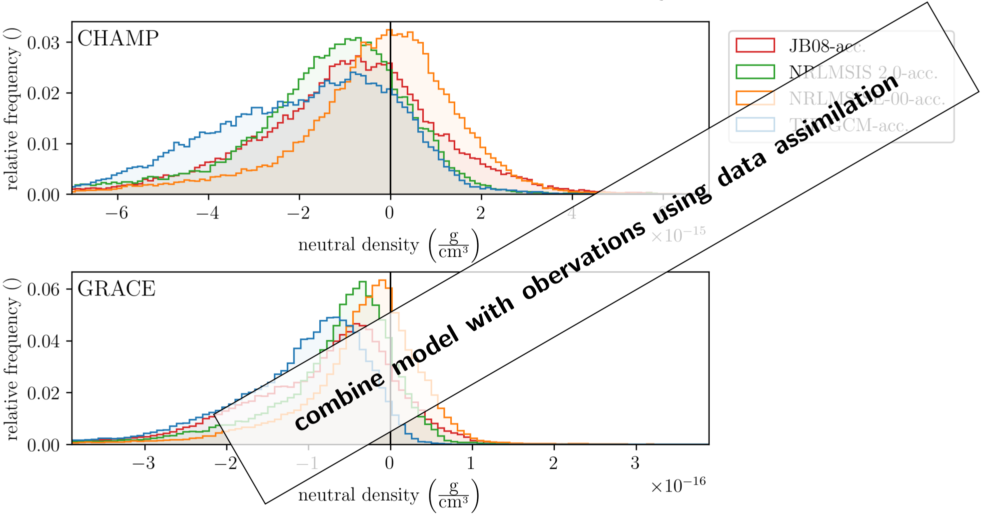


Assimilation Approaches

Observations that have been assimilated into the TIE-GCM

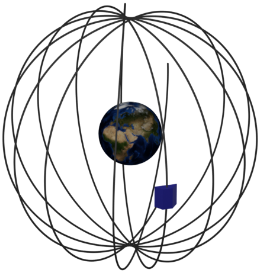
- electron density profiles[1]
- along track accelerometer derived neutral densities[2]

Problem

How can we **globally improve** the prediction of the neutral mass density of the TIE-GCM by assimilating **sparse along track** observations without relying on the correct representation of **long-range correlations** within the ensemble?

[1] e.g., Lee et al., 2012; Matsuo, Lee, and Anderson, 2013; Hsu et al., 2014; Kodikara et al., 2021.
[2] e.g., Matsuo, Lee, and Anderson, 2013; Murray et al., 2015; Sutton, 2018.

Two-Step Assimilation



not to scale

image of Earth: Reto Stöckli, NASA Earth Observatory

Step 1: Calibration of NRLMSIS 2.0

- compute **NRLMSIS 2.0** neutral densities along orbit of **CHAMP**
- calculate **scale factors** between CHAMP accelerometer derived densities[a] and NRLMSIS 2.0 densities
- apply low pass filter to scale factors

[a] Vielberg et al., 2021.

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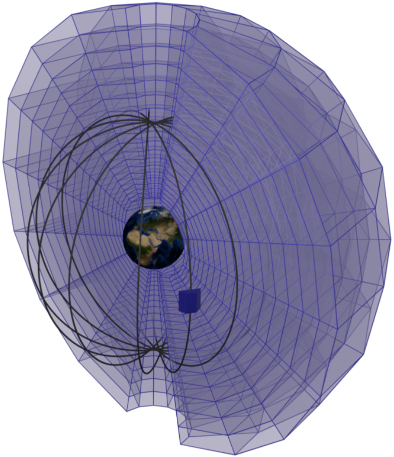

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Step 2: Assimilation of Calibrated Model

- evaluate calibrated **NRLMSIS 2.0** on regular grid

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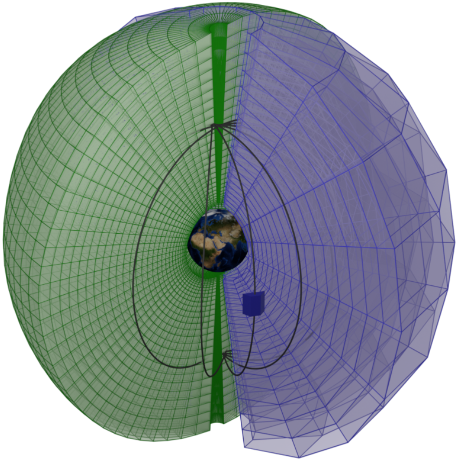

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Step 2: Assimilation of Calibrated Model

- evaluate calibrated **NRLMSIS 2.0** on regular grid
- assimilate this into TIE-GCM

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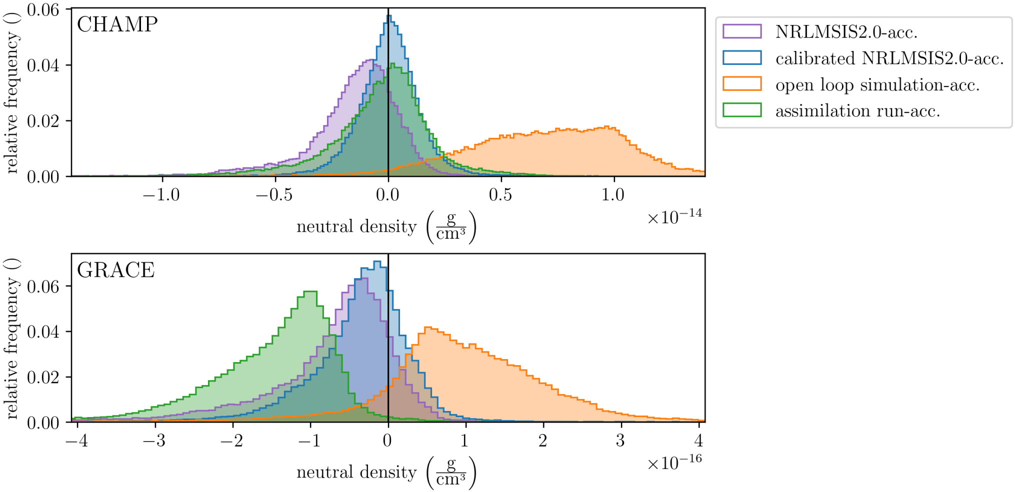
Results



The histograms were calculated using data between April 27, 2010 and May 10, 2010.

Conclusion

- **average difference** between TIE-GCM and accelerometer derived densities along CHAMP orbit is **reduced by two orders of magnitude**
- two-step approach enables **global update of the model state** and localization
- above about 350 km the density is not improved (correction of the first analysis step overshoots the innovation)
- we suspect that **co-estimating calibration parameters** helps to improve the predictions above that altitude

Learn More

Armin Corbin, Jürgen Kusche. *Improving the estimation of thermospheric neutral density via two-step assimilation of in-situ neutral density into a numerical model*, 11 May 2022, PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-1616740/v1]

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Software

Thermosphere Ionosphere Electrodynamics General Circulation Model[3] (TIE-GCM)

- global, physics based model of the upper atmosphere
- ranges from 97 km to about 600 km altitude

Parallel Data Assimilation Framework[4] (PDAF)

- software environment for ensemble data assimilation
- fast since ensemble members are forecasted in parallel

Naval Research Laboratory Mass Spectrometer Incoherent Scatter radar[5] (NRLMSIS 2)

- empirical model of the entire atmosphere
- constructed from observations mainly below 105 km

[1] Qian et al. (2014), [2] Nerger, Tang, and Mu (2020), [3] Emmert et al. (2021)

Scale Factors