PRELIMINARY VALIDATION OF THERMOSPHERE OBSERVATIONS FROM THE TOLEOS PROJECT

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OBSERVATIONS of upper atmospheric neutral mass density (NMD) and wind are critical to understand the coupling mechanisms between Earth's ionosphere, thermosphere, and magnetosphere. The ongoing Swarm DISC (data, innovation, and science cluster) project TOLEOS (thermosphere observations from low-Earth orbiting satellites) aims to provide better calibrated NMD and crosswind data from CHAMP, GRACE, and GRACE-FO (follow-on) satellite missions. The project uses state-of-the-art models, calibration techniques, and processing standards to improve the accuracy of these data products and ensure inter-mission consistency. Here, we present preliminary results of the quality of the data in comparison to the high accuracy drag temperature model DTM2020, and physics-based TIE-GCM (thermosphere ionosphere electrodynamics general circulation model) and CTIPe (coupled thermosphere ionosphere plasmasphere electrodynamics) models.

IMPROVING DATA AVAILABILITY AND QUALITY

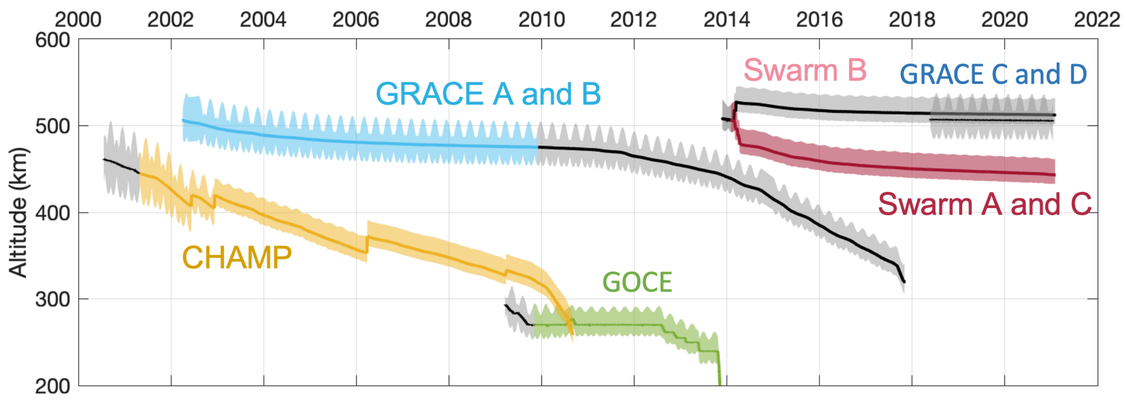

Figure 1: The evolution of the orbital heights of various LEO satellites. The TOLEOS project will develop new data products for CHAMP, GRACE, and GRACE-FO that are currently nonexistent for the time periods in gray. Using improved accelerometer calibration and processing standards, the project will also reprocess the data corresponding to other time periods. The project has processed 10, 16, and 4 years of CHAMP, GRACE-A, and GRACE-FO(C) data to date, respectively.

NEWLY CALIBRATED NEUTRAL MASS DENSITIES

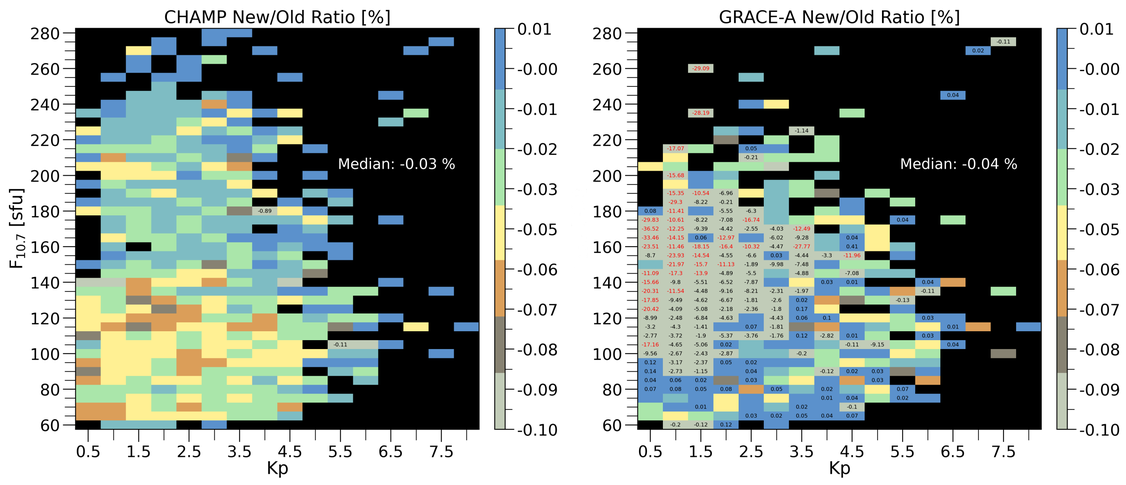

Figure 2: The NMD log-ratio as a percentage between the previous versions and the new TOLEOS versions of (left) CHAMP and (right) GRACE-A as a function of space weather indices Kp and $F_{10.7}$. The log-ratio % is, $[\exp(\langle\ln(\mathrm{New}/\mathrm{Old})\rangle) - 1] \times 100$, where $\langle\rangle$ represent the mean of each bin. The log-ratios beyond the colour-scale are indicated on the respective bins. The CHAMP (GRACE-A) data are for the time period 2001–2010 (2002–2017). In general, the newly calibrated NMDs are less than their previous counterparts. Some large differences in GRACE-A are mainly due to the improvements in radiation pressure modelling.

LONG-TERM DATA-MODEL AGREEMENT

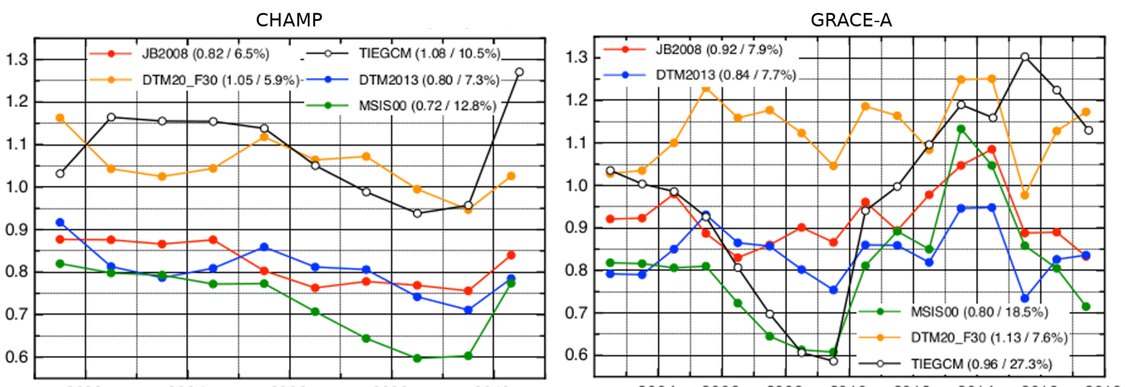

Figure 3: The yearly mean NMD log-ratio $\exp(\langle\ln(\mathrm{Data}/\mathrm{Model})\rangle)$ between the new TOLEOS (left) CHAMP and (right) GRACE-A, and models. JB2008 = Jacchia-Bowman 2008; DTM20-F30 = DTM2020 using solar flux proxy F_{30}; MSIS00 = USA Naval Research Laboratory's mass spectrometer incoherent scatter radar model 2000.

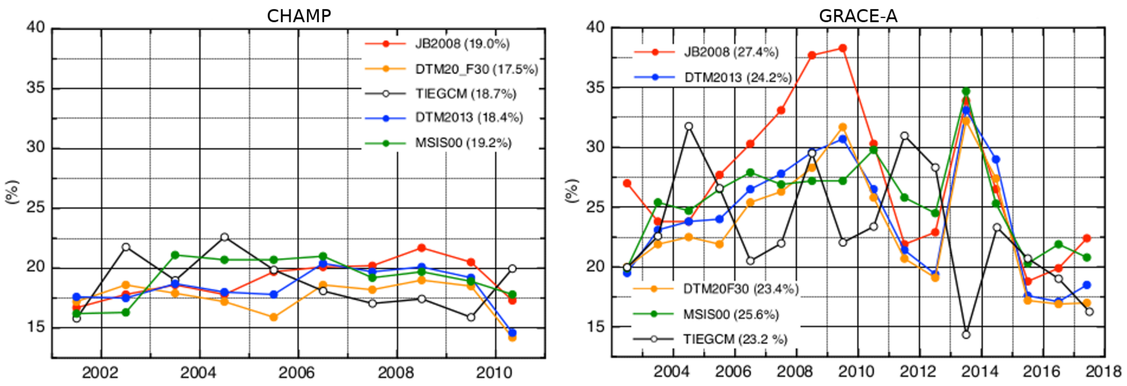

Figure 4: Same as Figure 3 except for standard deviation (σ) of the data-to-model log-ratio as a percentage. In general, σ for the comparison with GRACE-A is about 6% larger than that of CHAMP.

TOLEOS DATA COMPARED WITH PHYSICS-BASED MODELS

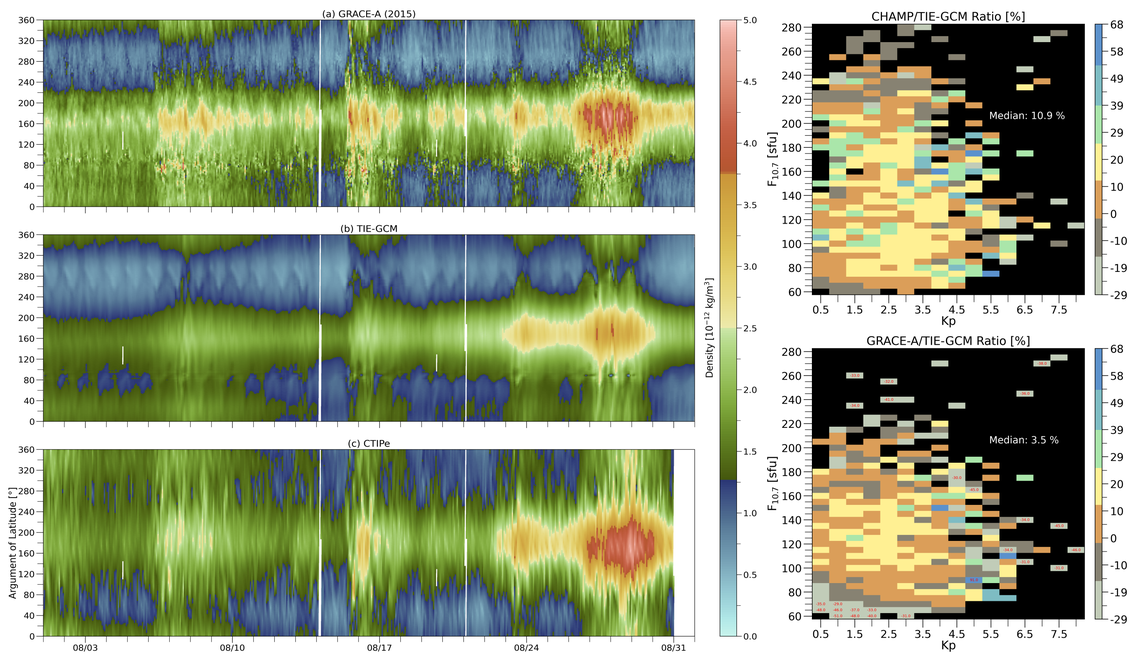

Figure 5: (left) An along orbit comparison of NMD from TOLEOS GRACE-A with physics-based TIE-GCM and CTIPe during 1–31 August 2015. (right) The NMD log-ratio as a percentage between (top) CHAMP and (bottom) GRACE-A, and TIE-GCM as a function of space weather indices Kp and $F_{10.7}$.

CROSSWIND OBSERVATIONS

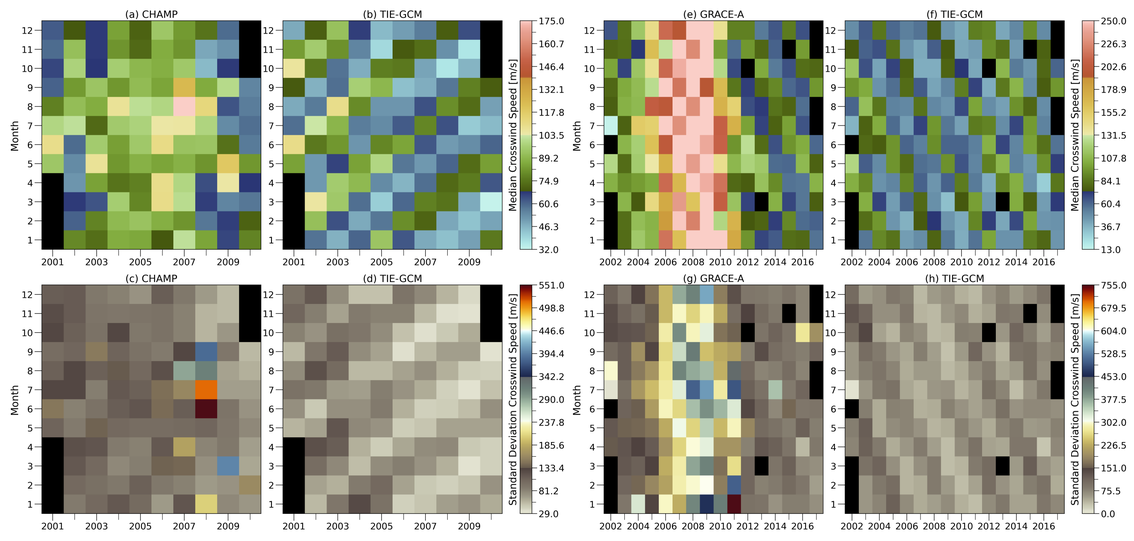

Figure 6: The TOLEOS (a–b) CHAMP and (e–f) GRACE-A monthly median crosswind speeds compared with TIE-GCM. The bottom row gives the standard deviation of crosswind speed in the respective monthly bins. The colour-scales for CHAMP/TIE-GCM and GRACE/TIE-GCM are different.

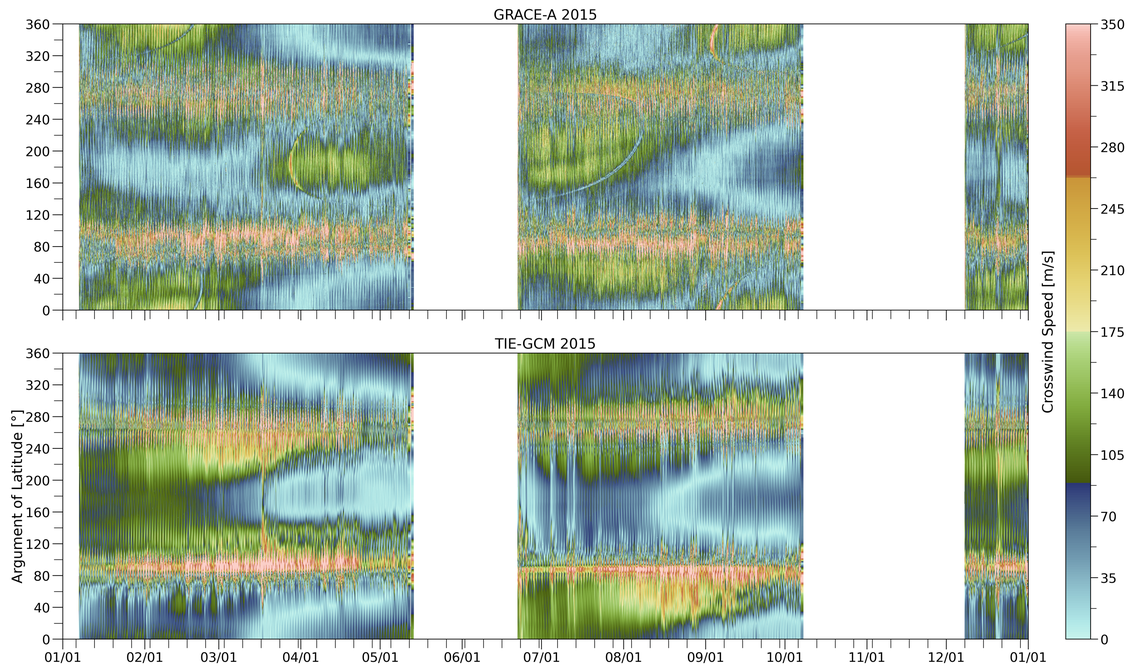

Figure 7: An along orbit comparison of crosswind data from TOLEOS GRACE-A with TIE-GCM during 2015.

CONCLUSIONS

1. Significant improvements gained in the quality of data through better radiation pressure modelling and the use of realistic geometry models.
2. Out of the model comparisons, DTM2020 driven with F_{30} shows the best overall agreement with CHAMP and GRACE-A NMD in terms of log-ratio.
3. In general, the NMD and crosswind data show good agreement with the physics-based models.
4. The solar minimum years 2007–2009 have a significant impact on TIE-GCM's agreement with GRACE-A NMDs.
5. Similarly, GRACE-A crosswind data show significant deviation from TIE-GCM median values.

DATA ACCESS

The NMD and crosswind data, and radiation pressure, aerodynamic and geometry models will be released in summer of 2022 via ESA's PDGS (payload data ground segment; http://swarm-diss.eo.esa.int) and TU Delft's thermosphere database (ftp://thermosphere.tudelft.nl).

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