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Global-scale Observations of the Limb and Disk

Real Time Satellite Drag Prediction using Global-scale Observations of the Limb and Disk (GOLD) Mission Images

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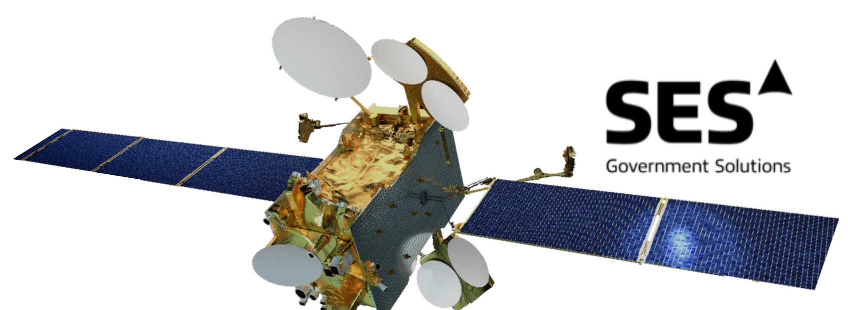
Objective:

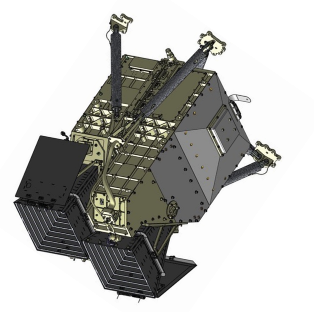
Thermospheric neutral densities depend directly on the temperature and composition. Empirical models of the thermosphere encompass the dependence of temperature on density; consequently, when temperature is known such models may be used to predict densities. NASA's GOLD mission images temperature and composition, the key variables, concurrently at coincident locations on Earth's dayside disk. Comparisons of observations during the recent Space-X storm confirm that observations of the neutral temperatures can be used to specify the neutral densities. Neutral densities derived using GOLD disk temperatures were in excellent agreement with GRACE-FO (500 km) and SWARM-C (460 km) observations of densities. Since it has been previously demonstrated that real-time GOLD temperatures are possible and agree closely with the publicly released (but higher latency) science products, real-time neutral densities could readily be made available for operational use.

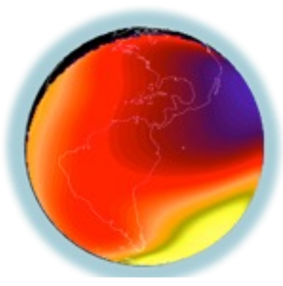
GOLD Mission:

NASA Mission of Opportunity, Imaging Thermosphere-Ionosphere (T-I) System from GEO

- **Motivation for Mission**
  - 'climate' of the T-I system has been characterized using Low Earth Orbiting spacecraft and ground-based data
  - 'weather' of the T-I system, the global spatial and temporal changes, is difficult to quantify using LEO and ground-based data
- **Host Mission**
  - SES-14, in geostationary (GEO) orbit at 47.5 W
- **GOLD Instrument**
  - Two imaging spectrographs observing ~134-160 nm
- **Imaging from GEO characterizes the 'weather' of the T-I system**







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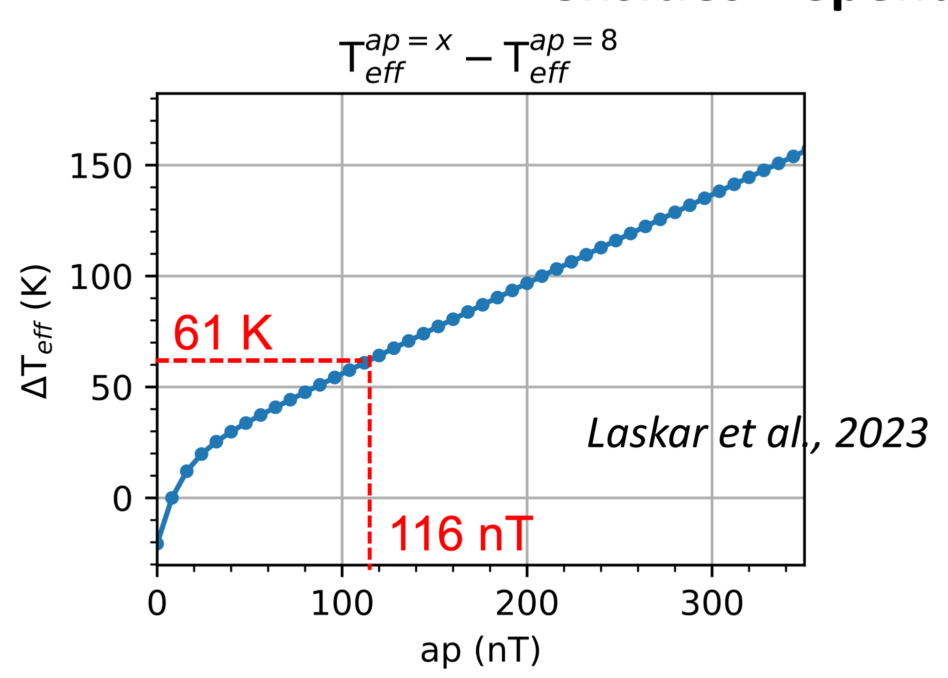
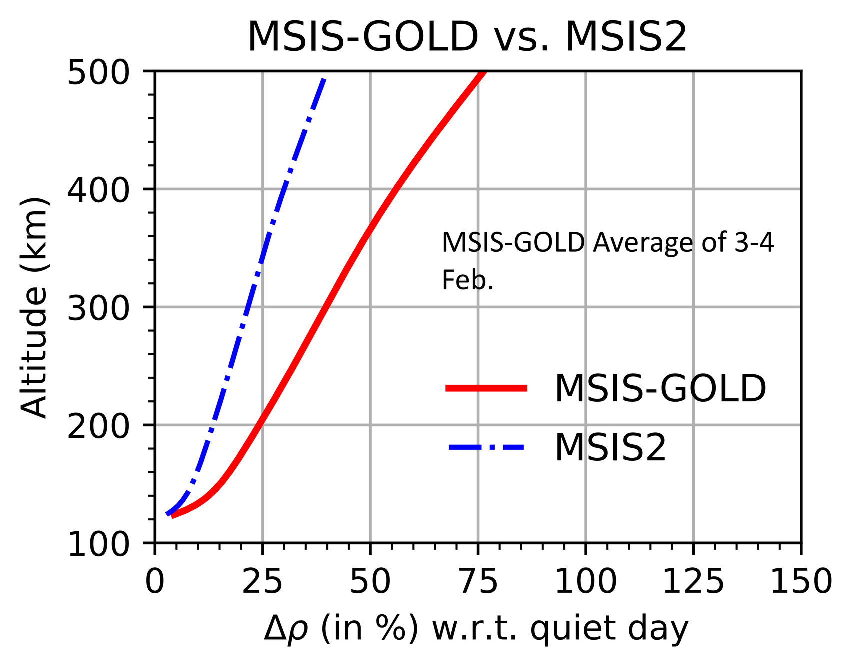
Thermospheric densities (ρ) can be derived from GOLD disk temperatures:

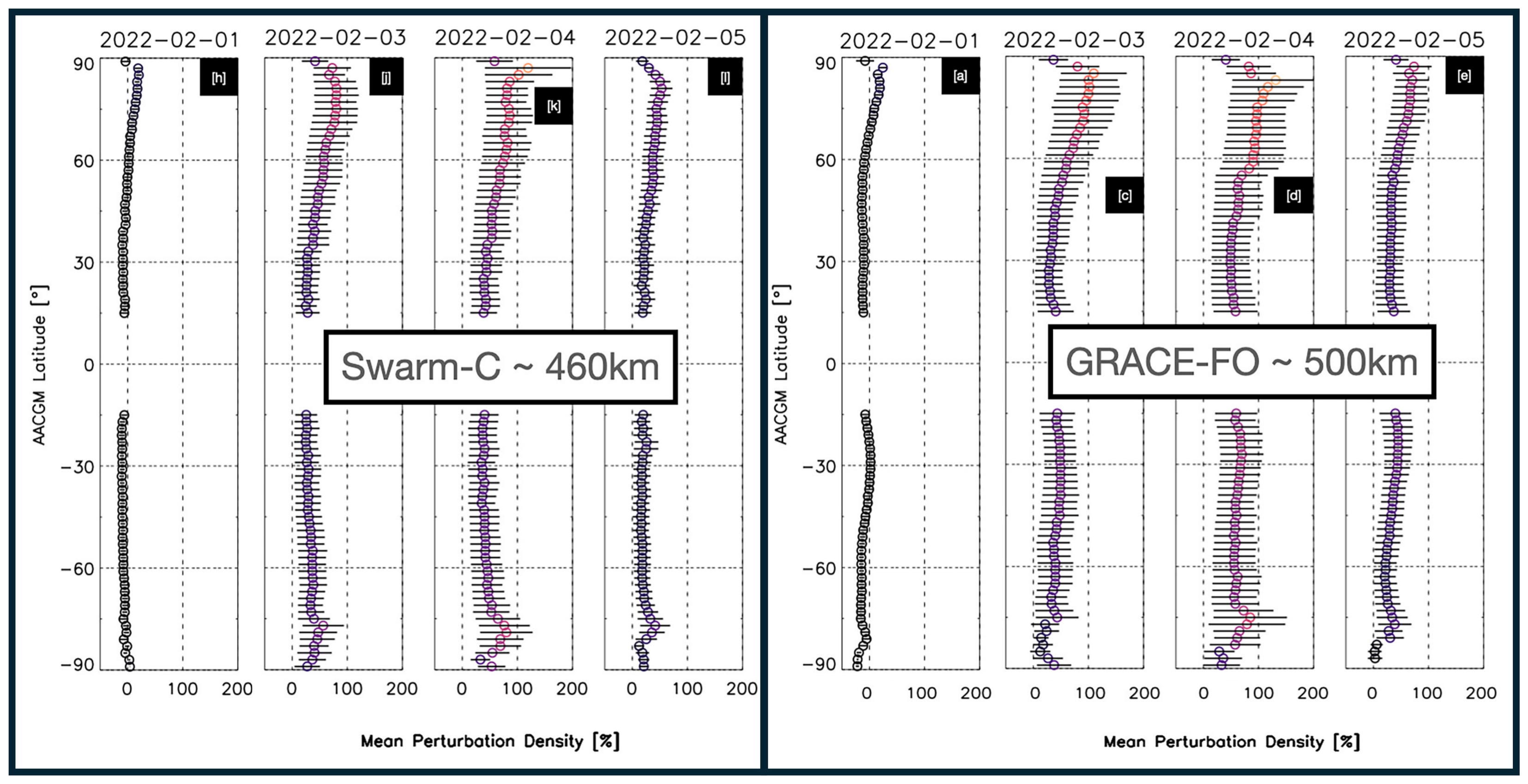
Densities Depend on Temperature





GOLD observed temperature in the lower thermosphere near 150-160 km

Neutral densities determined by nudging the MSIS model (Emmert et al., 2021) with GOLD temperatures



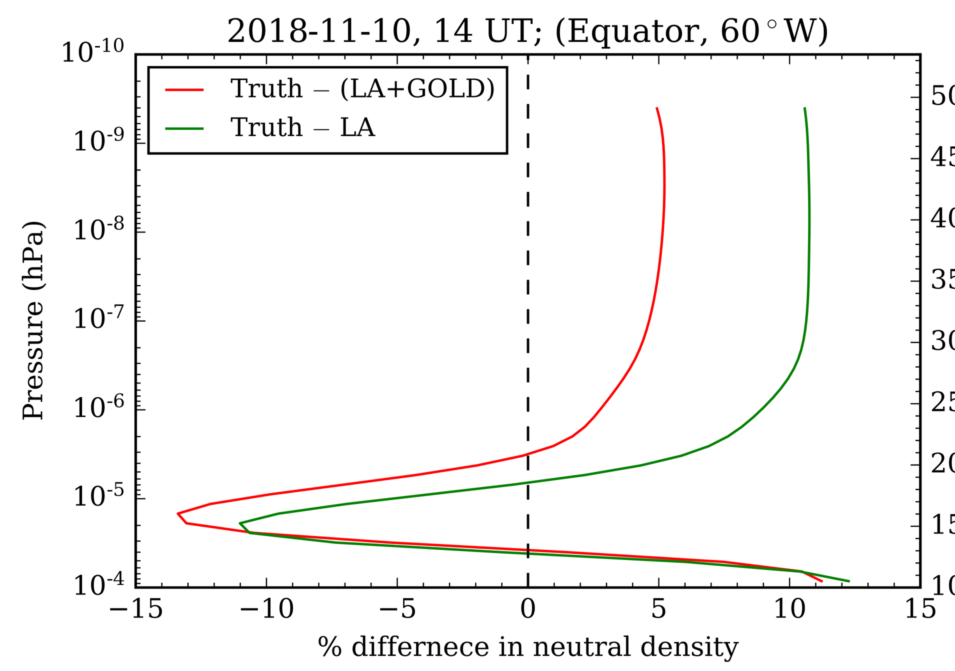
GOLD ρ increase of ~65-75% match GRACE-FO and SWARM-C perturbations (Billett et al., 2024) at 460-500 km

Assimilation of both T and composition data from GOLD would yield greater benefits

Thermospheric densities vary with both temperature and composition, both are available from GOLD.

GOLD data have been successfully assimilated and shown to produce significant improvements. These are most easily seen using simulated observations since the "true" values are known; similar results have been obtained using actual GOLD observations (Laskar et al., 2021; 2022).

Improvements with Assimilation of GOLD Disk Temperatures (Tdisk)

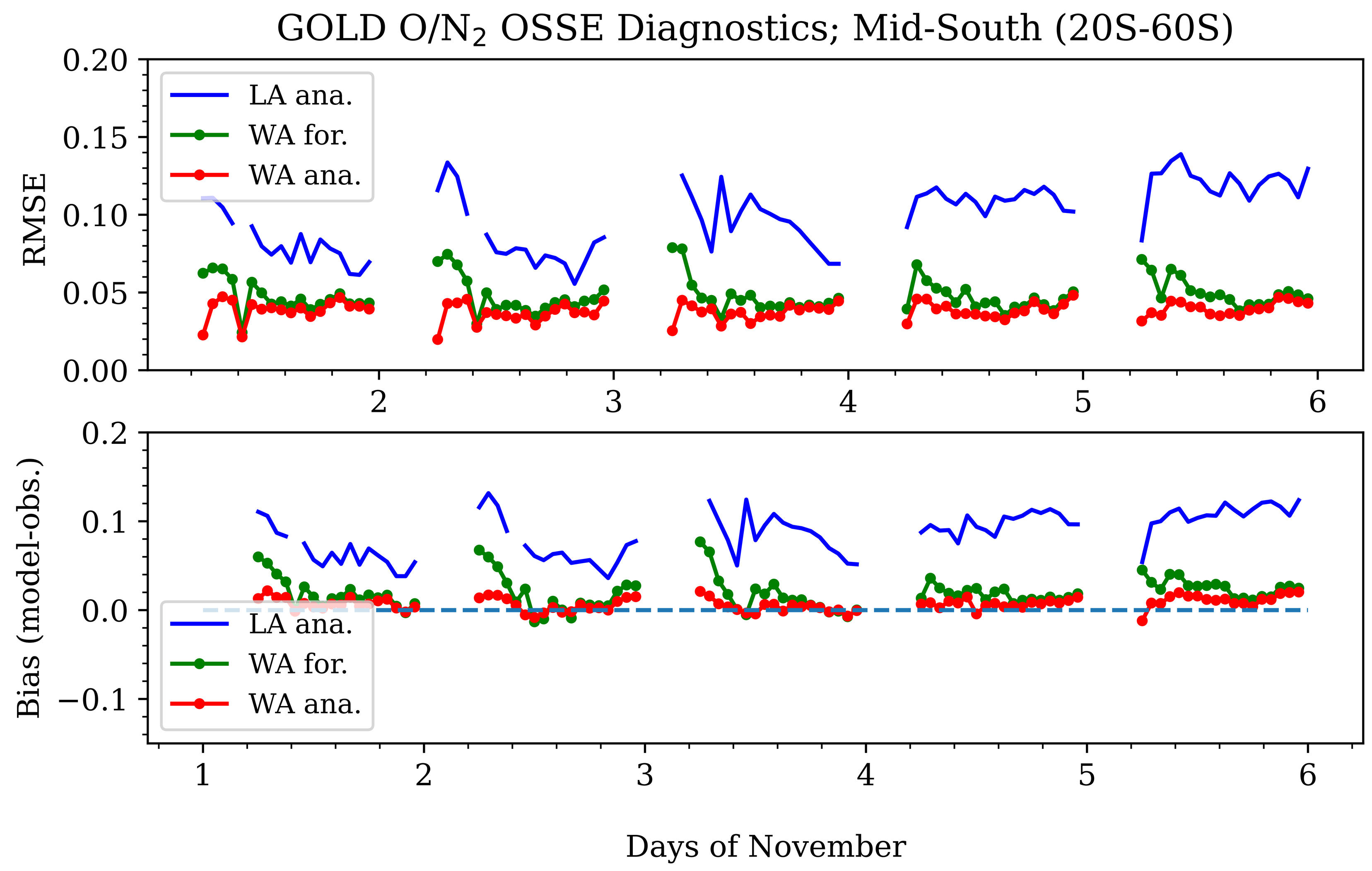


Percentage difference in thermospheric neutral density from Lower Atmosphere (LA) and LA+GOLD OSSEs compared to true-state (Truth).

The 'Truth-(LA+GOLD)' is closer to the 0% at altitudes above about 200 km. Compared to LA experiment there is about 6% improvement in thermospheric neutral density for the LA+GOLD experiment.

Compared to Lower Atmospheric only (LA) assimilation the thermospheric neutral density for the LA+GOLD assimilation improves by a factor of two.

Improvements with Assimilation of GOLD Disk Composition (O/N_2)



Resulting O/N_2 Root Mean Square Error (RMSE) and bias of Whole Atmosphere (WA) analysis (ana.) is better than WA-forecast (for.) or result assimilating only the Lower Atmosphere (LA) analysis

Summary:

- GOLD Real-time data capability is already proven (Codrescu et al., 2021)
- Densities derived using GOLD temperatures and the relationship between density and temperature in an empirical model (e.g., MSIS) agree with those from satellite drag
- Assimilation of both temperature and neutral composition data from GOLD have been accomplished and could provide better ionosphere and thermosphere densities

References:

Codrescu et al., 2021: https://doi.org/10.1029/2020JA027819
Emmert et al., 2021: https://doi.org/10.1029/2020EA001321
Laskar et al., 2021: https://doi.org/10.1029/2021JA030045; Laskar et al., 2022: https://doi.org/10.1029/2021JA030045;
Laskar et al., 2023: https://doi.org/10.1029/2022SW003349
Billett et al., 2024: https://doi.org/10.1029/2023SW003748

Acknowledgements:

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