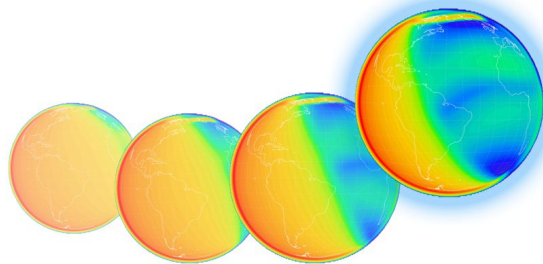


Assimilation of GOLD disk observations in WACCMX+DART for a better thermosphere



Fazlul I. Laskar¹

N. M. Pedatella², M. V. Codrescu³, R. W. Eastes¹, and J. L. Anderson⁴, N. Peterson⁵, & T. E. Berger^{2,5}

email: Fazlul.Laskar@lasp.colorado.edu

¹Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA

²High Altitude Observatory, NCAR-NSF, Boulder, CO, USA

³Vector Space LLC, Boulder, CO, USA

⁴Data Assimilation Research Section, CISL, NSF-NCAR, Boulder, CO, USA

⁵Space Weather Technology, Research, and Education Center, University of Colorado, Boulder, CO, USA

Plan of Talk

1. Introduction

- GOLD mission
- GOLD data assimilations summary (earlier accomplishments)

2. Relative importance of GOLD Tdisk and O/N₂ (present effort)

3. Summary & Future Directions

Introduction: GOLD Mission Overview

- **Host Mission**

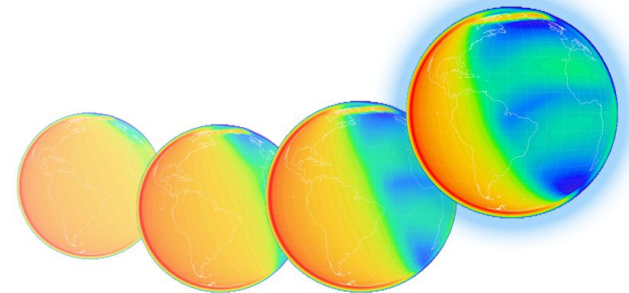
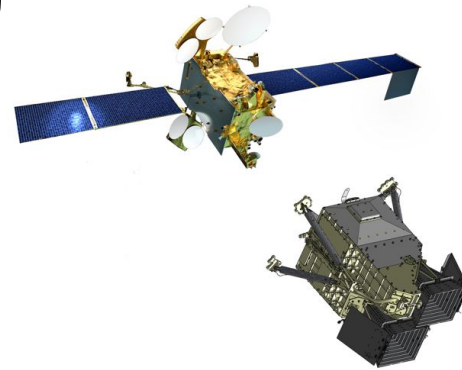
- SES-14, in **geostationary orbit at 47.5°** west (over mouth of the Amazon River)

- **GOLD Instrument**

- Two identical, independent imaging spectrographs covering 132-162 nm

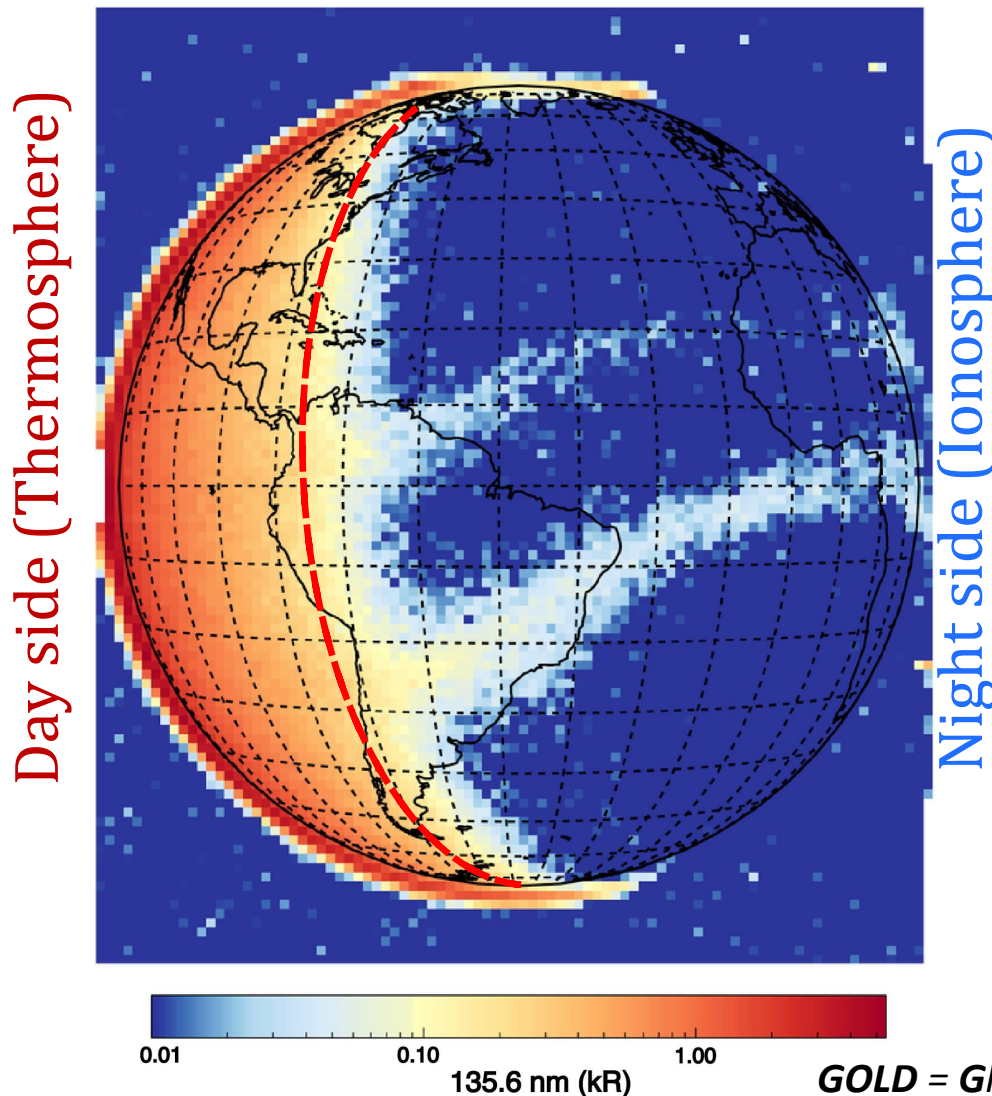
- **Measurements**

- Earth's disk
 - **Tdisk** & O/N₂ - Daytime: from spatial-spectral image cubes of 0-135.6 nm and **N₂-LBH emission**
 - Nmax - Nighttime: from images of 0-135.6 nm emission
- Earth's limb
 - Texo - Altitude profiles of N₂-LBH emission
 - O₂ density profile - Stellar occultations



GOLD Day Disk Observations

GOLD 135.6 nm; 2018-10-15; 21:40-22:10 UT



Dayside (left) - OI-135.6 nm and N_2 -LBH bands emissions are the prominent signals.

N_2 -LBH bands shapes vary with ambient T, giving T_{disk} .

O/ N_2 is retrieved using OI-135.6 and N_2 -LBH bands

Nightside (right) - Ionospheric OI-135.6 nm emissions from radiative recombination.

❑ **Currently GOLD Science data latency is months.**

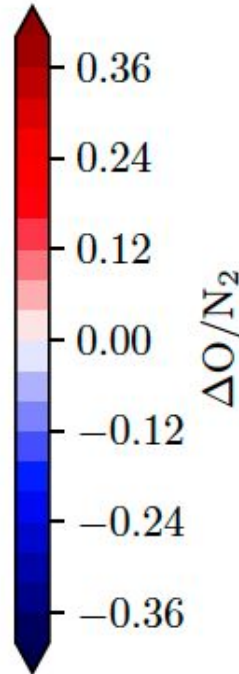
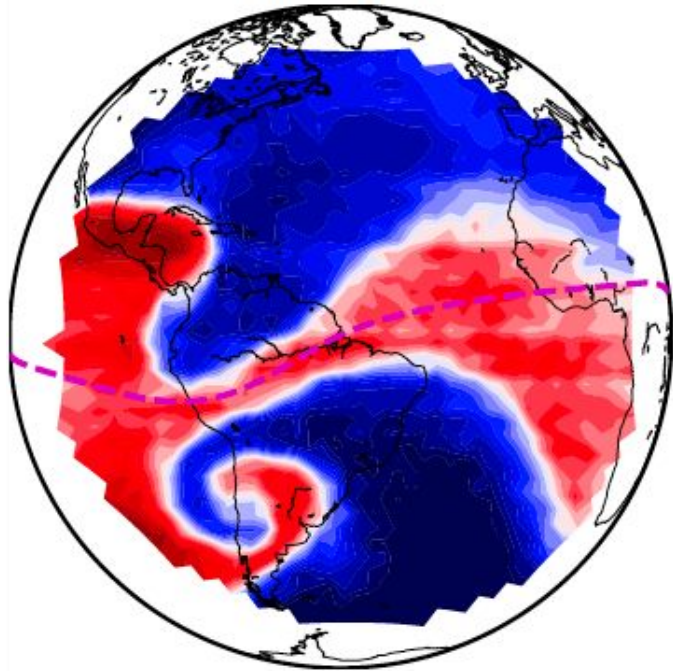
❑ **Operational data with 20-35 minutes latency is possible.**

GOLD = *Global-scale Observations of the Limb & Disk*

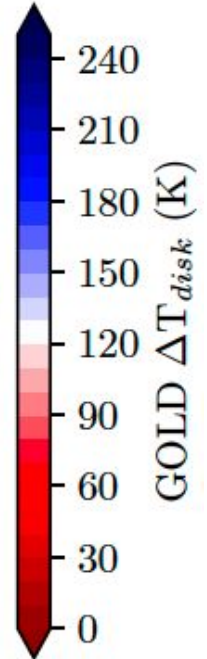
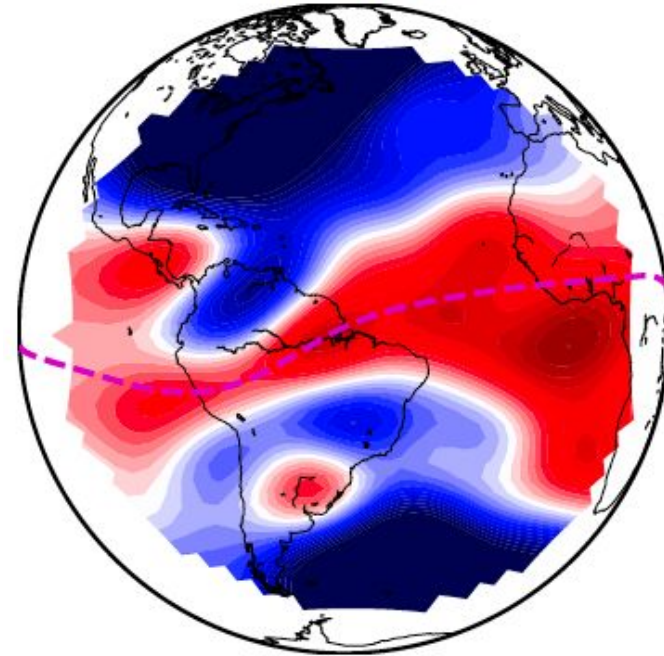
Example of GOLD T_{disk} and O/N_2 during Gannon Storm

Dayside Disk Imaging, ΔT and $\Delta \text{O}/\text{N}_2$ (~160 km)

2024-05-11
UT=14:10



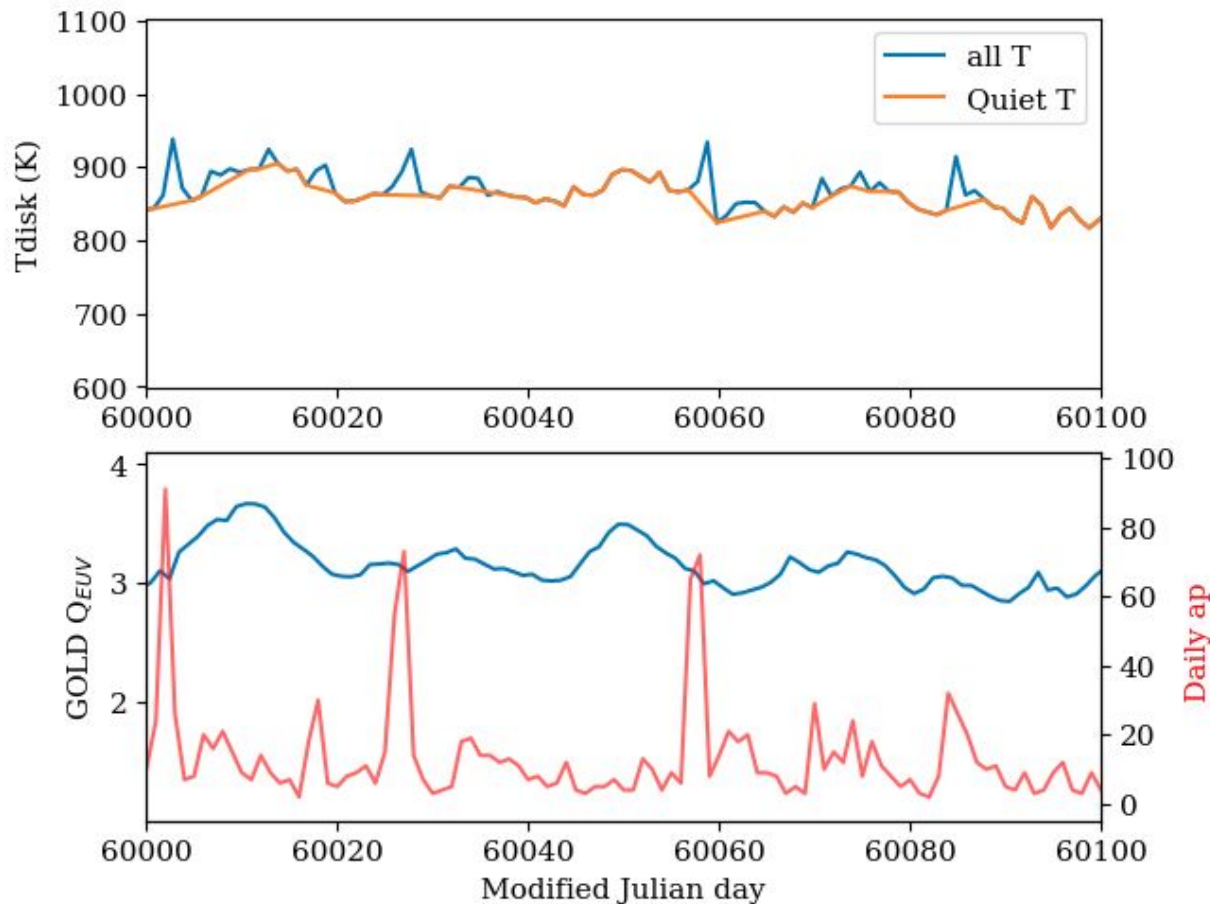
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- A typical half hour image of O/N_2 and T_{disk} retrieved from GOLD radiances.

Evans et al., 2024; GRL

GOLD T_{disk} vs. solar and geomagnetic forcings



- T_{disk} (& O/N_2) responds to both solar and geomagnetic changes.

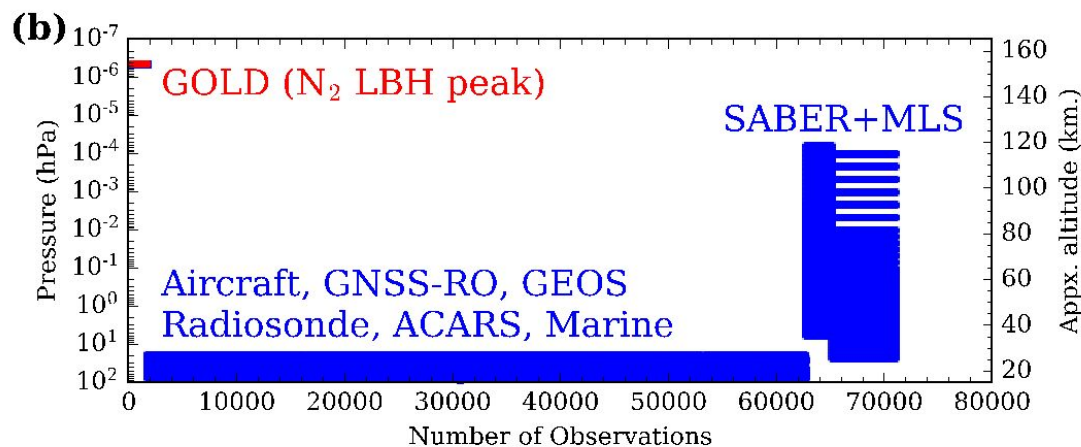
Past Accomplishments in Assimilating GOLD Observations?

Data Assimilation (DA): Data, Model, and Framework

- **Lower atmosphere:**
Meteorological,
TIMED-SABER T, and
Aura-MLS T.

- **Upper atmosphere: GOLD data (T_{disk} or O/N₂); 6 to 23 UT with varying coverage.**

- On an average **~1.5 million observations/day** are assimilated.



- Background model for the assimilation is **WACCMX 2.1**.
- Data Assimilation Research Testbed (**DART**) is used for assimilation.

Past Accomplishments & Future Questions

OSSE: Observing System Simulation Experiment (Synthetic data)

OSE : Observing System Experiment (Actual data)

Experiment	Observation	Validation State/Obs.	References/Results
OSSE	GOLD T_{disk} (Synthetic)	True State	Improved IT-system, <i>(Laskar et al., 2021, JGR)</i>
OSE	GOLD T_{disk} (Real data)	GOLD O/N_2 GPS TEC	Improved IT-system, <i>(Laskar et al., 2022, JGR)</i>
OSSE	GOLD O/N_2 (Synthetic)	True State	Improved IT-system, <i>(Laskar et al., 2024, JGR)</i>

Data Assimilation (DA) system = WACCMX+DART (State estimation)

Future Questions?

- Which one has a greater impact on the IT-system: T_{disk} or O/N_2 ?
- How the actual actual O/N_2 assimilation performs?

OSSE Experiments for relative impact study

Experiments	GOLD Observations Assimilated	Validation State
OSSE 1	T_{disk}	True State
OSSE 2	O/N_2	True State
OSSE 3 (combined)	O/N_2 & T_{disk}	True State
Truth		

OSSE: Observing System Simulation Experiment (synthetic data)

DA System: WACCMX+DART (state estimation)

O/N₂ from OSSE-3 & Lower Atmosphere Only Assimilation

- Whole Atmosphere (WA=GOLD+LA) show improved O/N₂

O/N₂ RMSE: O/N₂ & T_{disk} Combined OSSE 3

□ O/N₂ RMSE is best for the WA-analysis.

T_{disk} RMSE: O/N_2 & T_{disk} Combined OSSE 3

- T_{disk} RMSE is improved for the analysis compared to forecast.

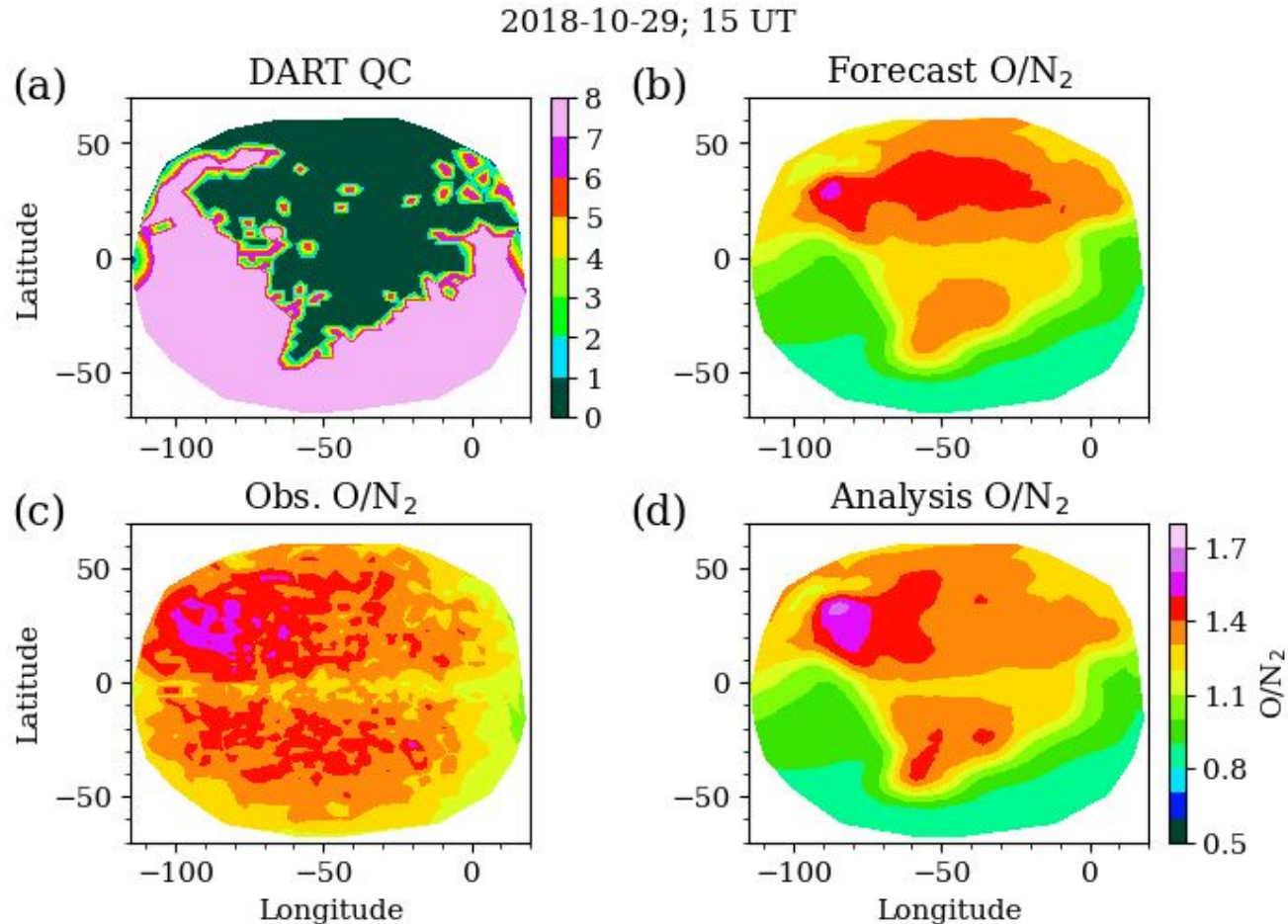
TEC RMSE: O/N_2 & T_{disk} Combined OSSE 3

- TEC RMSE and bias are better for the WA (LA+GOLD).

Which parameter (O/N_2 or T_{disk}) has higher impact?

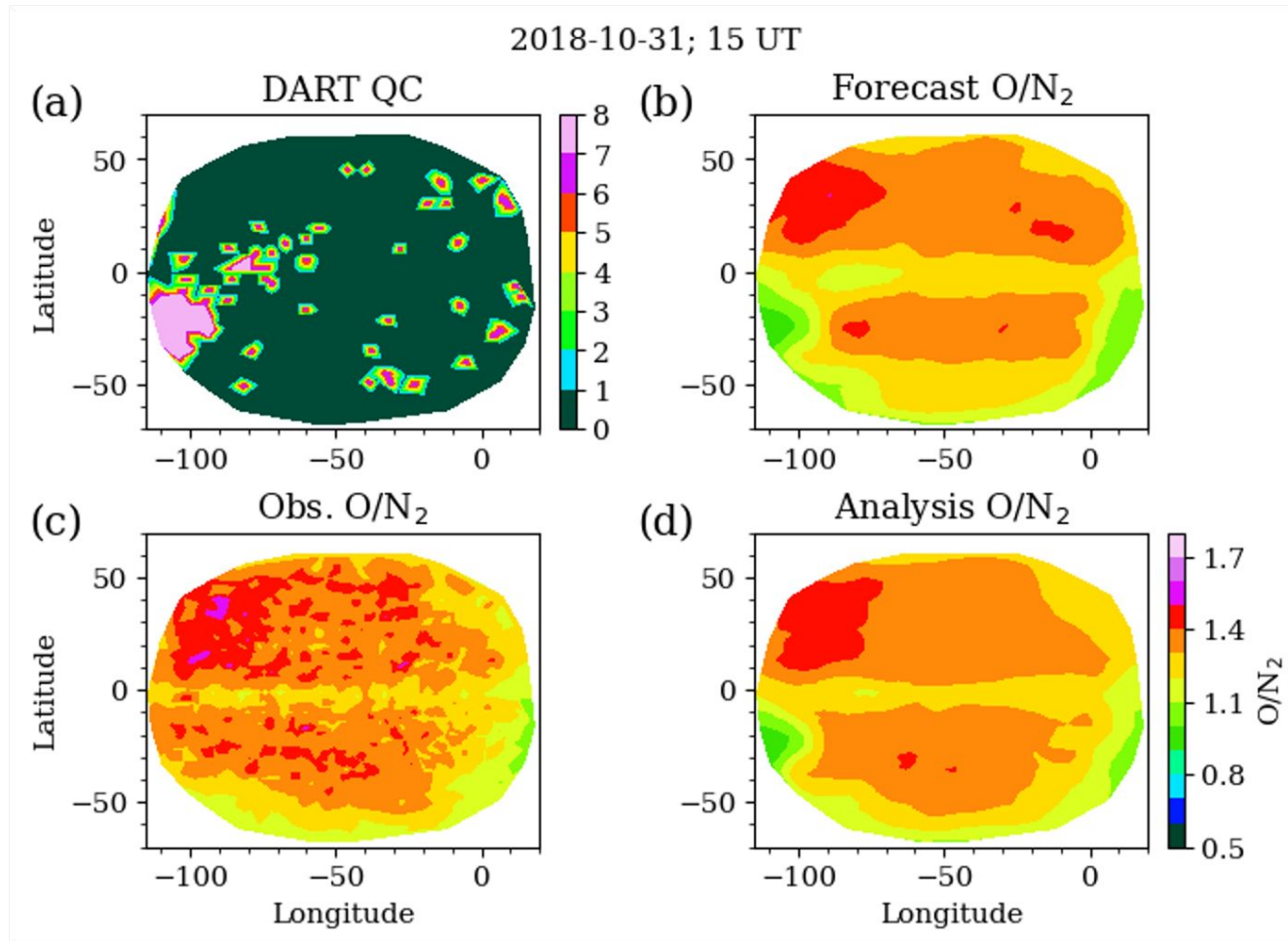
- Neutral density for the combined assimilation is closest to the truth.

GOLD O/N₂ OSE (Real data assimilation)



□ More than 50% data are rejected by the filter.

GOLD O/N₂ OSE (Real data assimilation)



□ Almost 90% data are assimilated.

Summary & Conclusions

- We have obtained improved IT-system by assimilating GOLD T_{disk} .
- Combined (T_{disk} and O/N_2) assimilation improves IT-system better compared to individual assimilation.
- T_{disk} improves thermosphere better compared to O/N_2 .

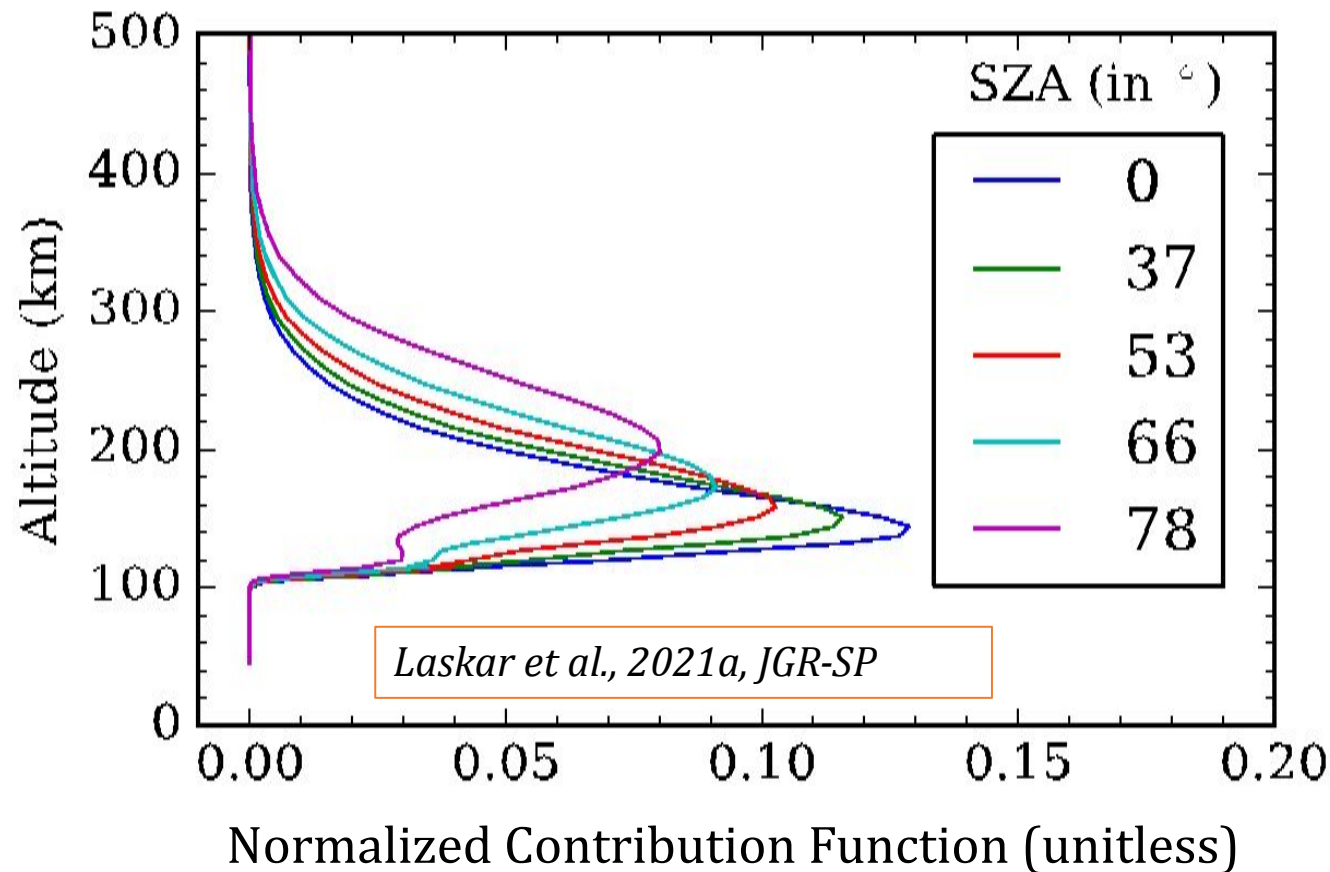
Future Efforts:

- Actual GOLD O/N_2 assimilation (to be continued...).
- Combined assimilation (OSE) of GOLD T_{disk} and O/N_2 for improved Whole-Atmosphere-Ionosphere-Thermosphere (**WAIT**).
- Transfer the knowledge and setup to JEDI-WACCMX, JEDI-WAM, etc.

Thank you!

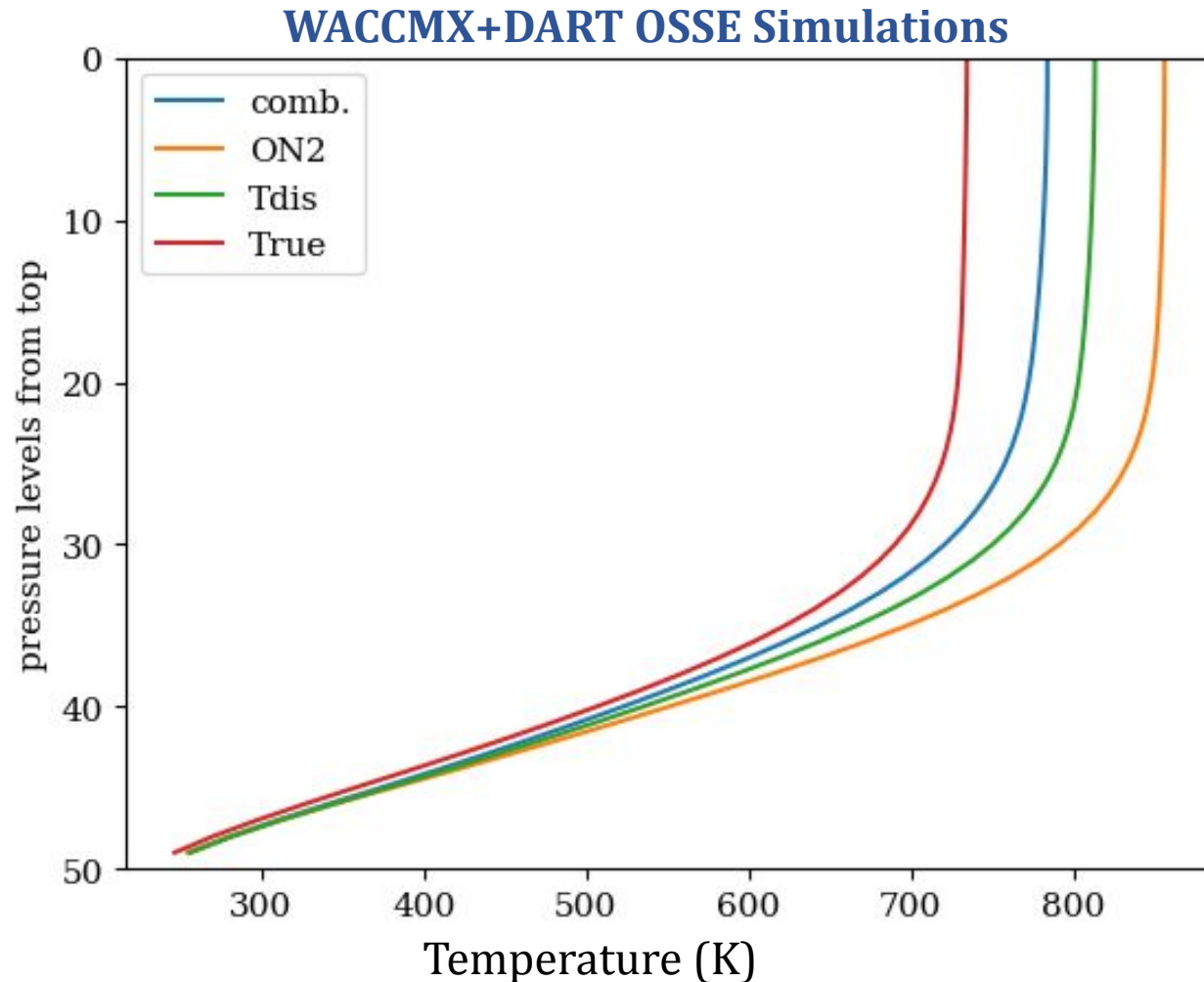
Extra Slides

Contribution Function & Effective Altitude



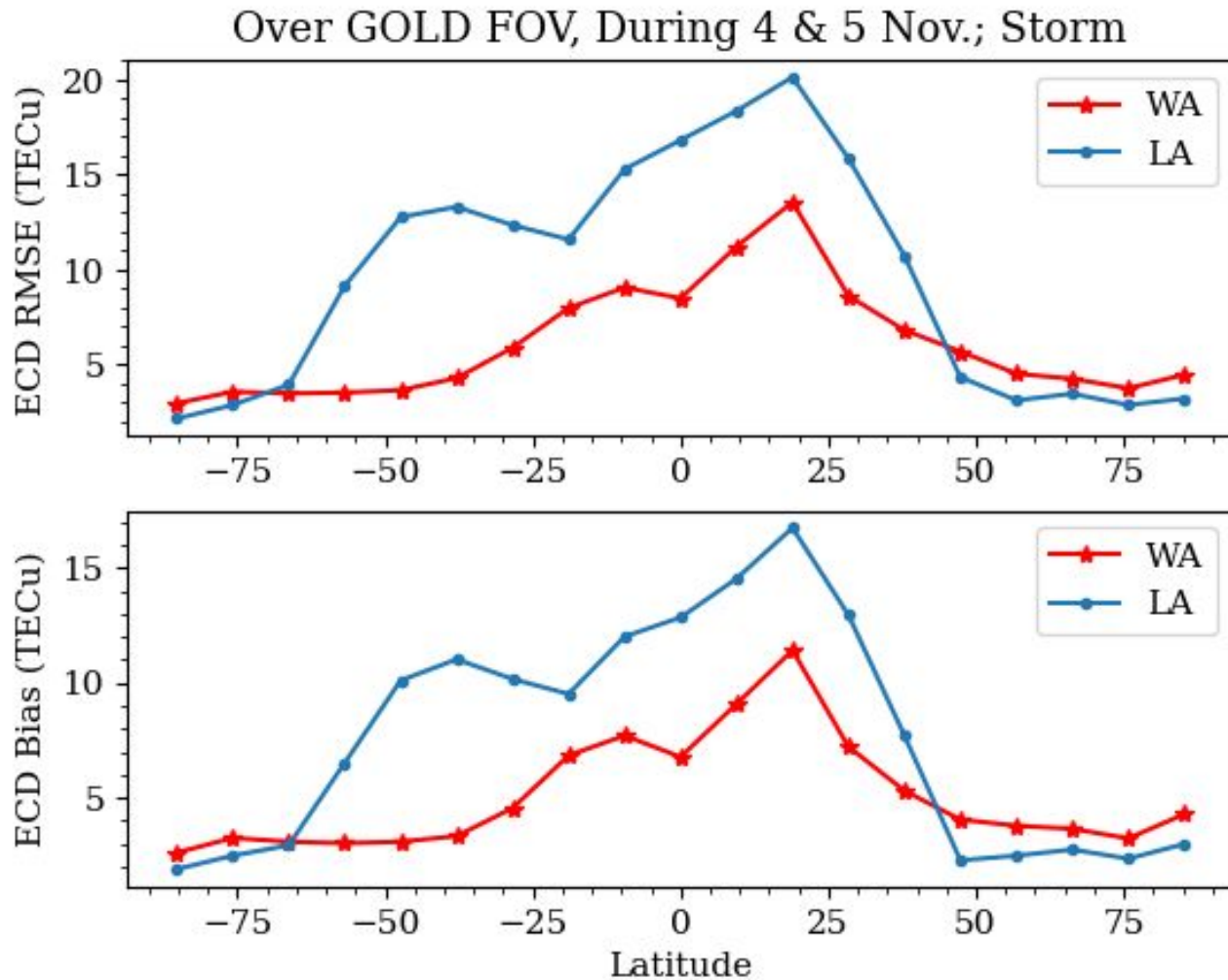
- Contribution Function (CF): It gives an estimate of the representative altitude.
- The peak altitude of the CF varies with SZA and is near **150 km** for SZAs < 50 degrees.

Further Improvement on 4D density: Data Assimilation



Best density estimate will be from data assimilative modelling, e.g., **WACCMX+DART** or, from operational JEDI+WAM-IPE (SWORD-CoE).

TEC RMSE: O/N₂ & T_{disk} Combined OSSE



□ Predicted orbital parameters from Two-Line Element (TLE) data.

2024-05-11

12:10 - 12:33

14:10 - 14:33

16:10 - 16:33

