SWORD Development of JEDI Thermosphere-Ionosphere-Mesosphere Observation Operators

Noah S Peterson[1], Fazlul Laskar[1,2], Mark Miesch[1,3,4], Rebecca Morrison[1], Thomas Berger[1,5]

[1] *University of Colorado Boulder* [2] *Laboratory for Atmospheric and Space Physics* [3] *Cooperative Institute for Research in Environmental Sciences*
[4] *Space Weather Prediction Center* [5] *University of Colorado Boulder, Space Weather Technology, Research, and Education Center*

Introduction

- Space weather phenomena can affect everything from satellite trajectories to power grids .
- With accurate and reliable forecasting, harmful effects can be avoided or mitigated.
- However, accurate and reliable forecasting of space weather events and their severity is quite challenging, as the upper atmosphere is a highly driven, nonlinear system over an immense scale.
- Predictions based solely on physics-based models quickly diverge from reality.
- To improve state estimations and forecast accuracy, data assimilation (DA) techniques integrate observations, model predictions, and their uncertainties.
- At SWORD, we are working to incorporate observations from NASA's GOLD mission and meteor radars into a data assimilation framework called JEDI.

Observation Operator

- Essential DA component that maps from the model state space to the observation space.

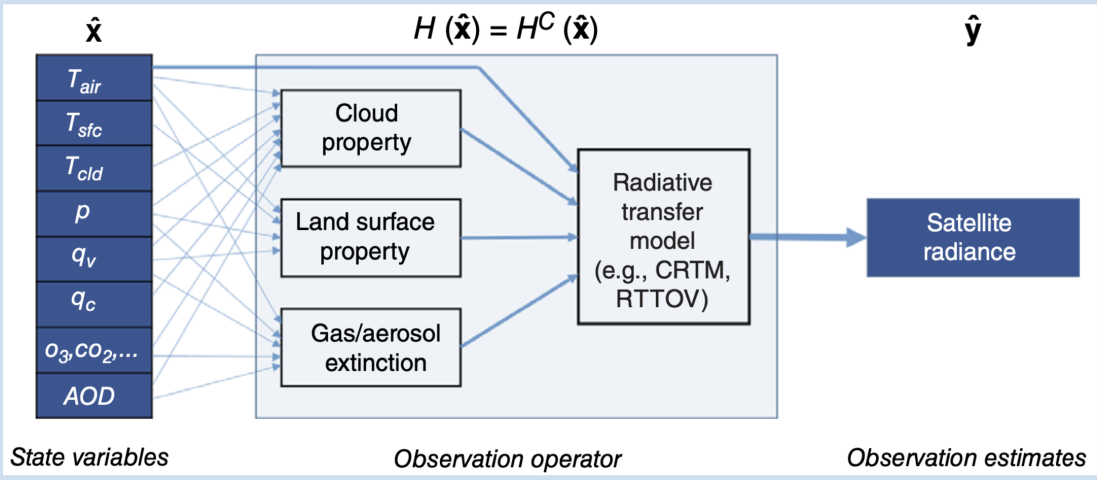

Figure 2: Example observation operator [1].

Observation Type 2: Meteor Radar

- Meteors leave a plasma trail which can be detected and located by radar observatories.
- Tracking the movement of these tails can give insight into the wind patterns of the upper atmosphere.

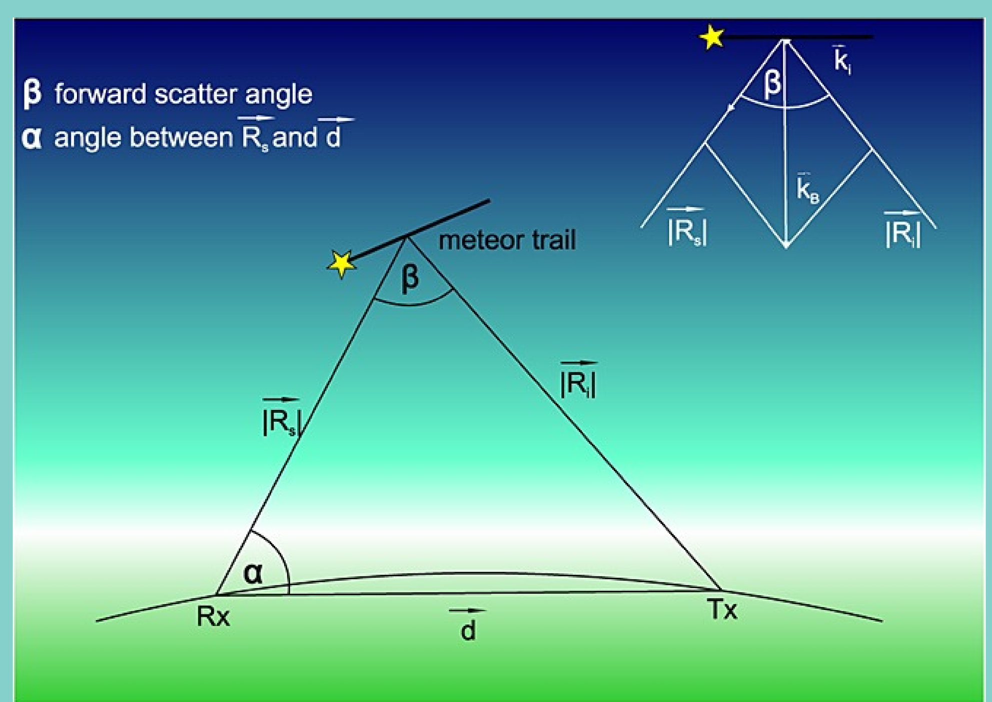

Figure 4: Depiction of meteor plasma trail detection [4].

Data Assimilation

- Data assimilation combines the information of a system model and observations of that system to reduce uncertainty in and improve predictions of the system state.

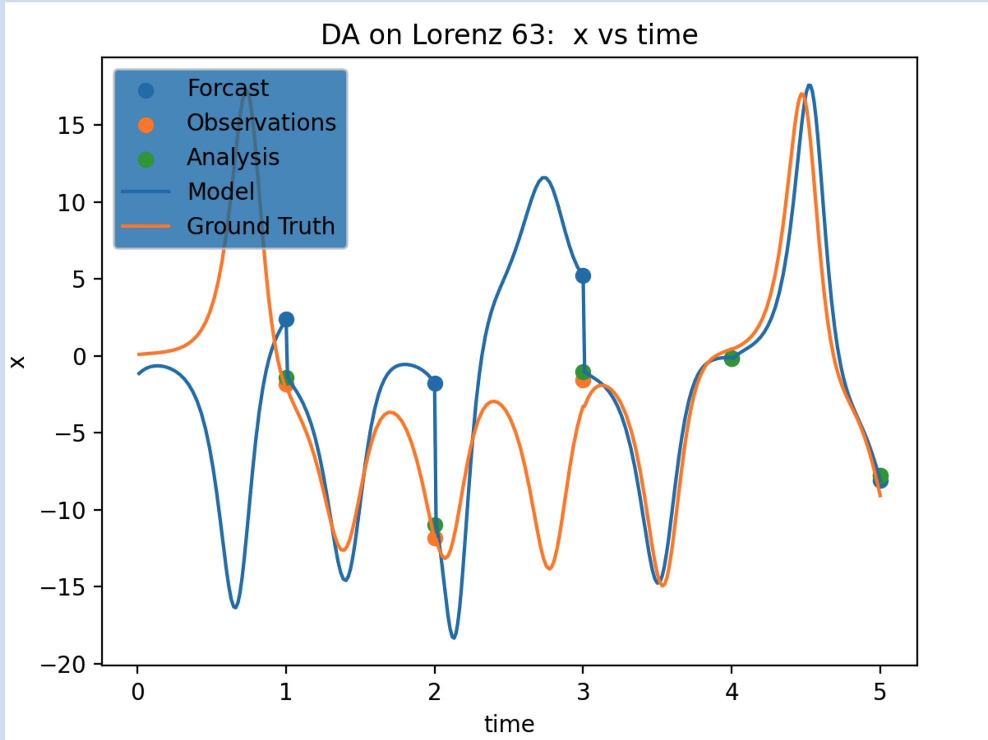

Figure 1: Example of data assimilation performed on the Lorenz-63 model.

Observation Type 1: GOLD TDISK

- Global-scale Observations of Limb and Disk (GOLD).
- Geostationary NASA instrument dedicated to observing the Ionosphere and Thermosphere.
- Takes observations of integrated effective temperature.

$$T_{eff} = \frac{\int_{S_0}^{S_f} CF(\vec{S})T(\vec{S})d\vec{S}}{\int_{S_0}^{S_f} CF(\vec{S})d\vec{S}}$$

- The weighted integration requires a contribution function calculated via the AURIC radiative transfer model.

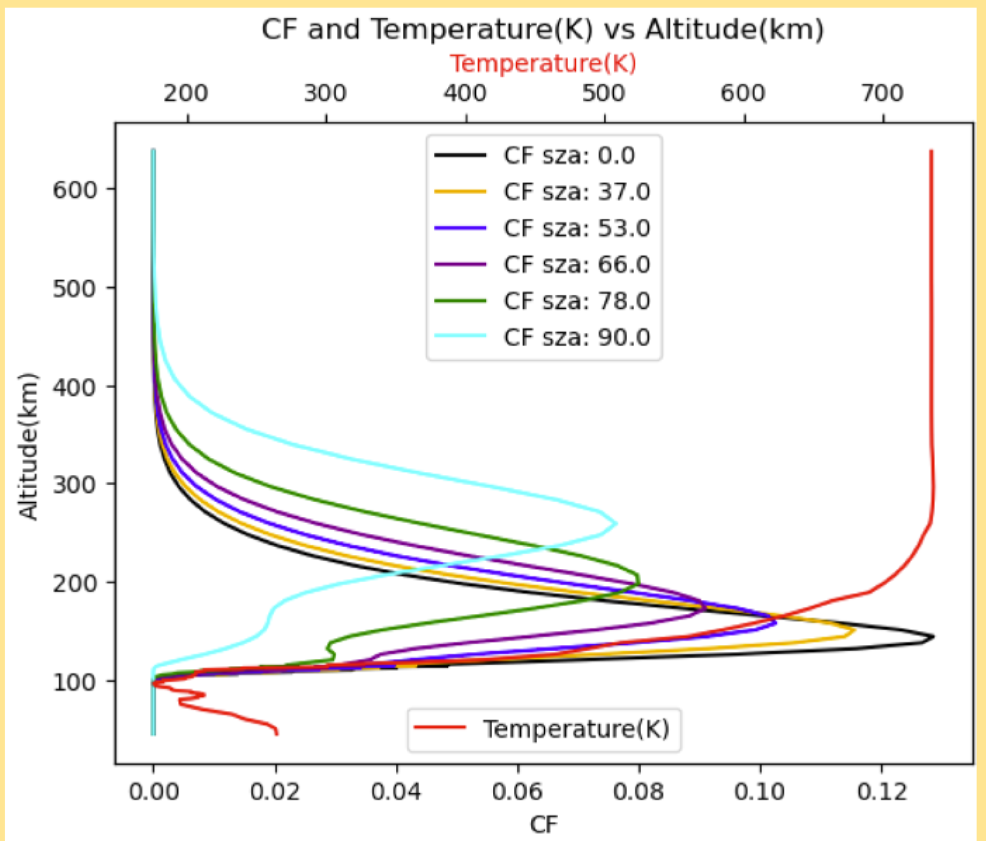

Figure 3: Contribution functions for several solar zenith angles and corresponding averaged global temperature values for solar minima [3].

GOLD Progress

- We recreated the observation operator to ensure understanding of underlying principles.
- We have begun implementation into the JEDI UFO module.

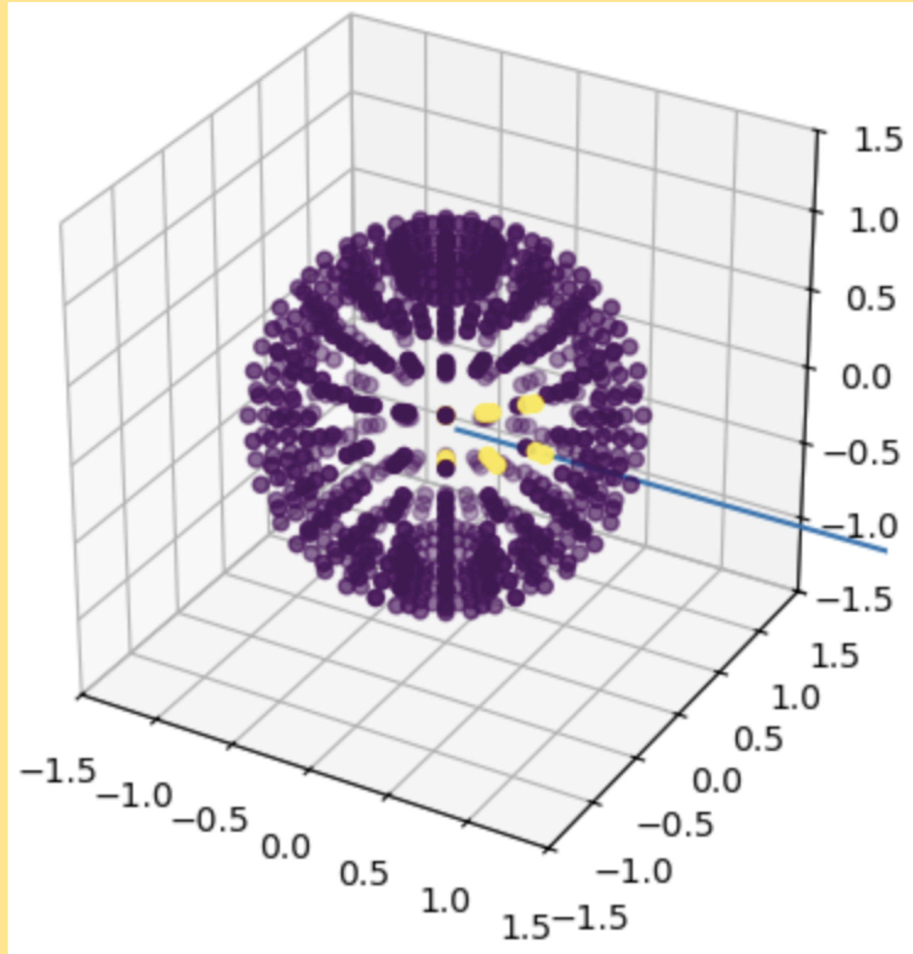

Figure 5: Example geometry and interpolation ray test.

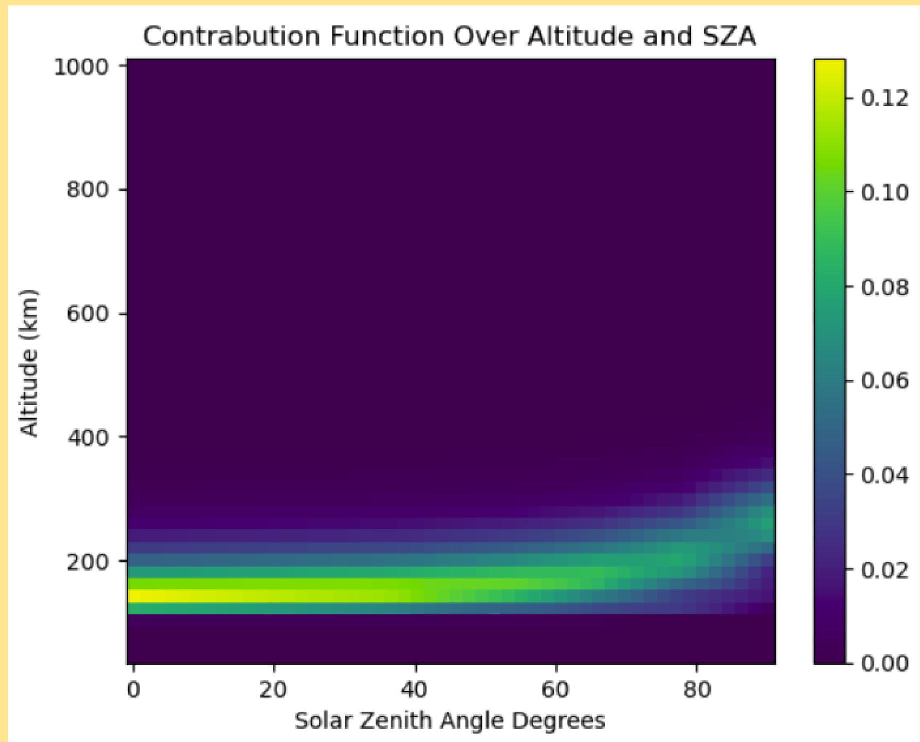

Figure 6: Interpolated contribution function across solar zenith angle and altitude.

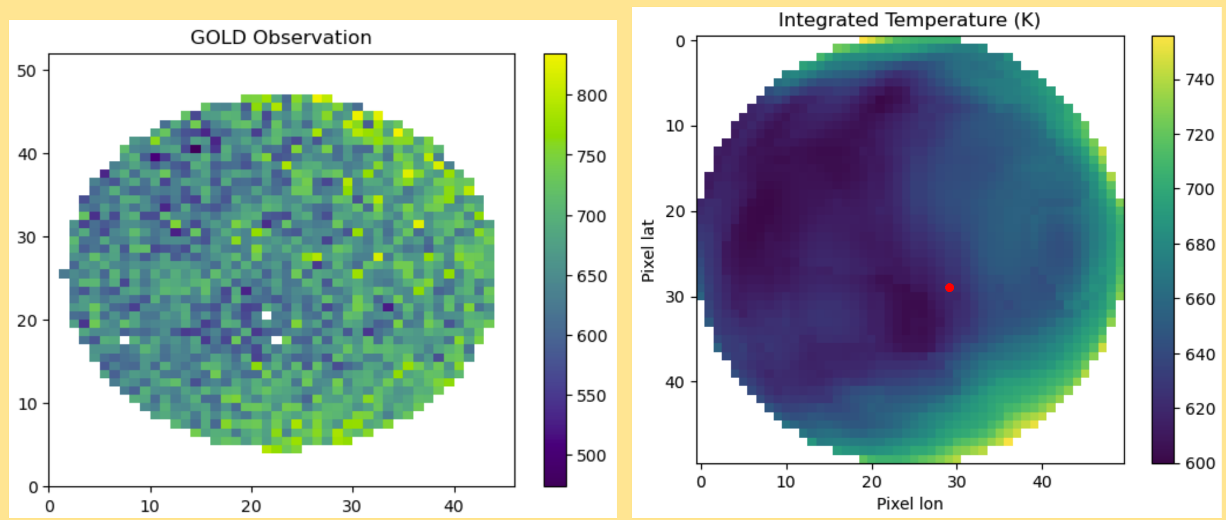

Figure 7: (Left) GOLD TDISK data 11/04/18 1-2 pm UTC. (Right) Output of observation operator using WACCM-X data from 11/04/18 1:40 UTC. The red dot shows the minimum solar zenith point.

Meteor Radar Progress

- We have derived initial algorithms and begun implementation into the JEDI IODA module.

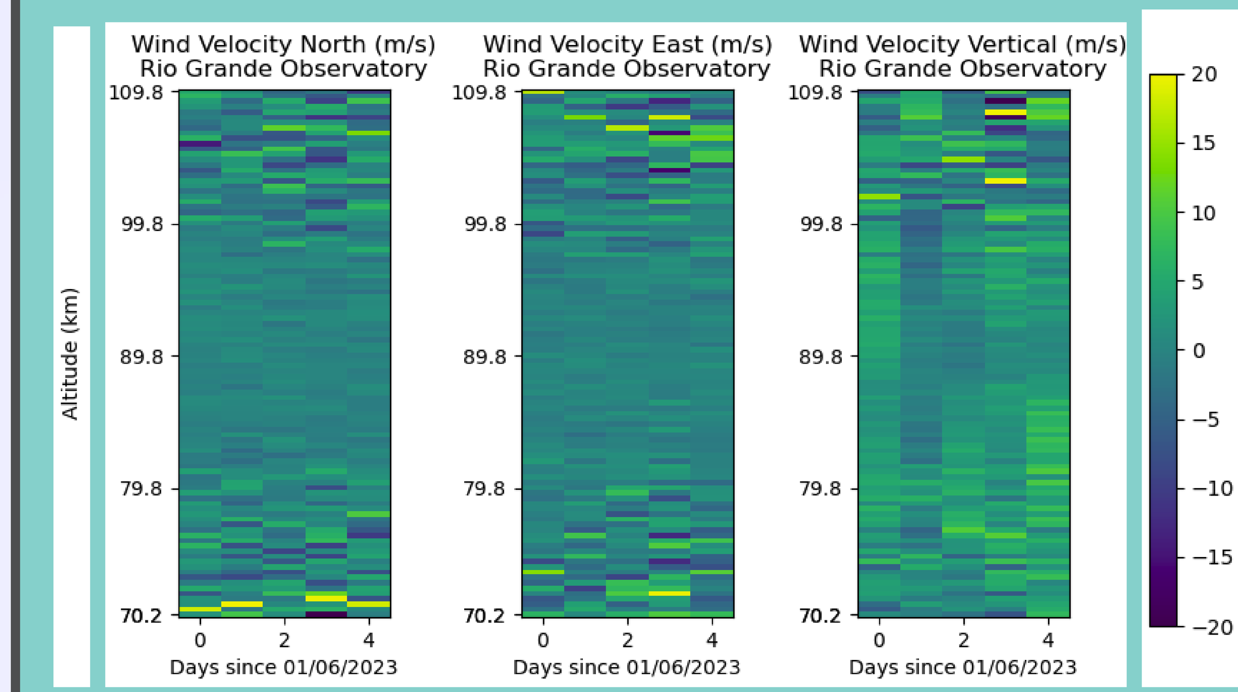

Figure 8: Simple wind approximation from Rio Grande meteor radar observatory.

Future Work

- Complete implementation of both operators and make them available to the community via JEDI repository.
- Begin development of NASA/SABER NO observation operator.
- Conduct validation experiments OSSE and OSE (Observing System Simulation Experiments and Observing System Experiments) to demonstrate the effectiveness of data assimilation for all operators using WACCM-X and possibly FV3/WAM.

References

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