Evaluating the Impact of Data Assimilation on Atmospheric Tidal Modes

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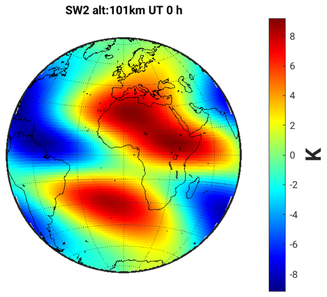
1. Introduction

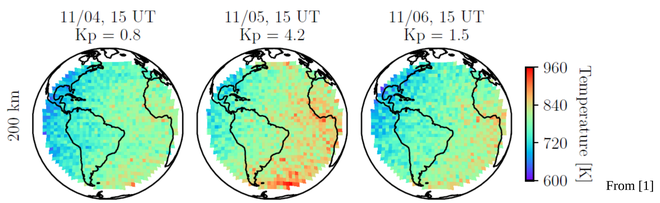
This study aims to address the challenge of accurately capturing the dynamics of Earth's upper atmosphere by exploring how data assimilation of space-based far ultraviolet (FUV) dayglow observations influence the representation of tidal modes in a whole atmosphere model.

Prior work of Cantrall [1] deployed different covariance localization schemes in WDAS ensemble data assimilation experiments with GOLD FUV disk measurements of N2 Lyman-Birge-Hopfield (LBH) bands, however, the effects of covariance localization on tides are not well understood.



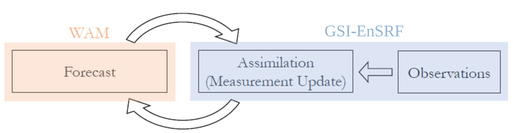
2. Background

- The NASA GOLD mission measures FUV emission from the thermosphere, which can be used to derive thermospheric temperature and composition.



From [1]

- The assimilation of GOLD FUV disk radiance data into WDAS using GSI-EnSRF was shown to impact thermospheric temperature and composition in a whole atmosphere model [1].



- Covariance localization is a technique that limits the influence of distant observations, reducing spurious correlations and improving accuracy by applying a distance-based weighting function.

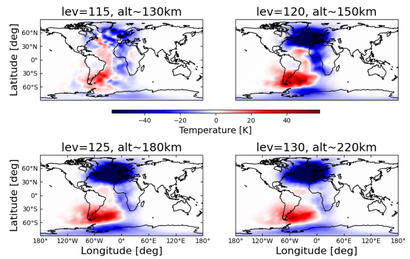
EXPERIMENTS: Within a single measurement update using GSI-EnSRF, three different localization designs are implemented in this study:

1. Horizontal: 5000 km / Vertical: 10 pressure levels
2. No Localization
3. No Horizontal Localization / Vertical: 10 pressure levels*

*Not shown because of small changes

3a. Results – EnSRF Localization Impact

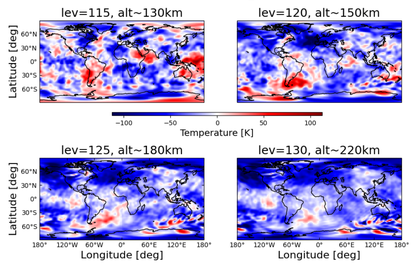
DA Increment Experiment 1



- Experiment 2 yields a much larger and global change due to DA of GOLD data.
- Similar to Exp. 1, Exp. 2 results in more negative increments at the higher altitudes (e.g. altitudes above 180 km).

- Experiment 1 demonstrates the effect of the 5000 km localization on the increments that only center around the US sector.
- The structure and magnitude of the temperature increment have minimal changes below ~150 km.

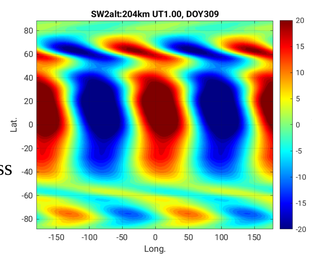
DA Increment Experiment 2



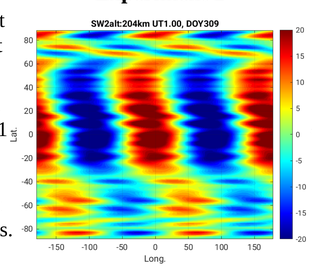
3b. Results – Tidal Mode Decomposition of EnSRF Analysis

- Both experiments are similar in magnitude, but localization slightly reduces the overall magnitude.
- Exp. 1 shows less tidal spatial variability than Exp. 2.
- Exp. 1 has a structural discontinuity not seen in Exp. 2 at 60 deg latitude.
- The localization scheme in Exp. 1 seems to eliminate the tidal structure at the high latitudes.

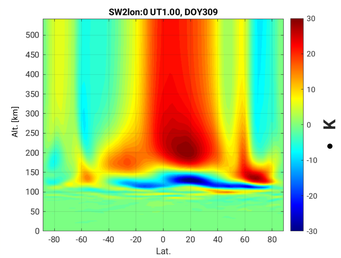
Experiment 1



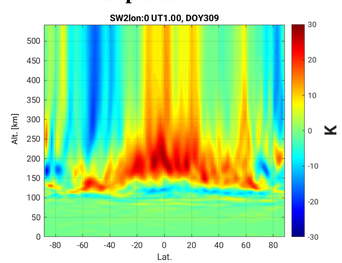
Experiment 2



Experiment 1



Experiment 2

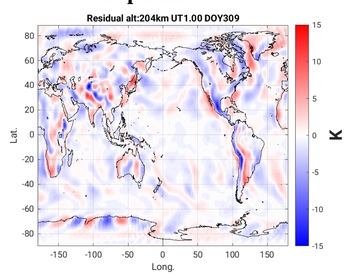


- Both experiments show little impact on the tides at lower altitudes (<90km).
- Similar to the lat-lon plots, Exp. 1 tides have less special variability than Exp. 2.
- Localization completely disregards the lower temperature structure seen in the higher thermospheric altitudes near the mid-to-high latitudes.

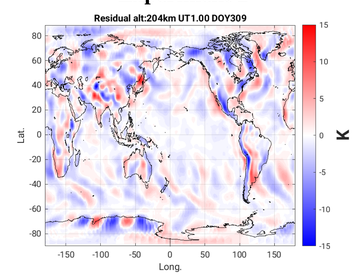
4. Residuals of Tidal Mode Decomposition

- The residual of the tidal mode decomposition is the remainder of the total temperature field when all tides (zonal wavenumbers up to 6) are subtracted out.
- Both Exp. 1 and Exp. 2 have very similar residual magnitudes and structures that resemble the distribution of orographic gravity waves.
- There are distinct additions for Exp. 2 in the northern hemisphere as well as the elongation of some shapes compared to Exp. 1.

Experiment 1



Experiment 2



5. Summary

1. Three different covariance localization schemes are implemented for a single measurement update of the GSI-EnSRF using GOLD irradiance data.
2. The localization scheme (especially in the vertical direction) used in Exp. 2 had large impacts on the DA increments as well as the tidal modes themselves, where more spatial variability of the tidal structures was seen.
3. There are minimal differences in the residual temperature field.

Future Directions:

- Extend the GSI-EnSRF to a full measurement update and forecast cycling. Once completed, experiments using full cycling will be conducted further to quantify the impact of data assimilation on tidal modes.
- Develop a new localization technique that allows maintenance of atmospheric dynamical balance [3] in the GSI-EnSRF so that better insights into the Earth's upper atmosphere can be obtained through observationally constrained whole atmosphere models.

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References

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[3] Thomas, C.A. (2017): Multivariate correlations: Balance operators and variable localization in ensemble data assimilation.