The Impact of Mesospheric Observations on the 2-Day Wave in a Middle Atmosphere Data Assimilation System

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Introduction

The impact of assimilating SABER temperature retrievals on the 2-day wave is investigated using a data assimilation system extending from the ground to the mesopause. The structure and temporal evolution of the 2-day wave is investigated to elucidate the way in which mesospheric observations alter the depiction of the wave.

Model & Data

CMAM-DAS is a 3D-VAR data assimilation system based on CMAM (Polavarapu et.al., 2005), run at T47 horizontal resolution extending from the ground up to 95km. SABER V1.07 (Remsberg et.al., 2008) temperature retrievals have been assimilated for January 2006. In addition, standard meteorological observations in the troposphere and stratosphere have been assimilated up to a height of 45km. SABER observations are assimilated up to a height of 80km, above which the analysis reverts to the background state provided by the model forecasts. To analyze the impact of SABER observations, a control analysis without SABER observations has also been produced.

Methods

- Wavenumber-frequency spectra were computed using Hayashi's formalism (Hayashi, 1971). All spectra were estimated using a smoothed periodogram (1-2-1 smoothing in the frequency domain). Quasi-geostrophic Eliassen-Palm (EP) fluxes for the 2-day wave were computed from wavenumber-frequency cospectra of the meridional heat and momentum flux.
- Time-dependent spectra were computed using a S-Transform based method (Stockwell, 1996). Amplitudes were computed by averaging all amplitudes over the frequency range -0.6cpd to -0.4cpd.
- The meridonal gradient of the quasi-geostrophic potential vorticity (QG-PV) is computed from the monthly mean wind fields. Plots of this quantity can be used to analyze the potential for instability based on the Charney-Stern-Pedlosky instability criterion, which states the meridional gradient of QG-PV must change sign in the region encompassing the flow field for instability to occur (note that this is a *necessary*, not a *sufficient* condition for instability).
- SABER retrievals from 2002 to 2007 were analyzed using the Fast Fourier Synoptic Mapping method (Salby, 1982) over the latitude range 52S to 52N, yielding the evolution of the 2-day wave as observed in the SABER data. This data was kindly provided by Dr. R. Garcia.

Figures

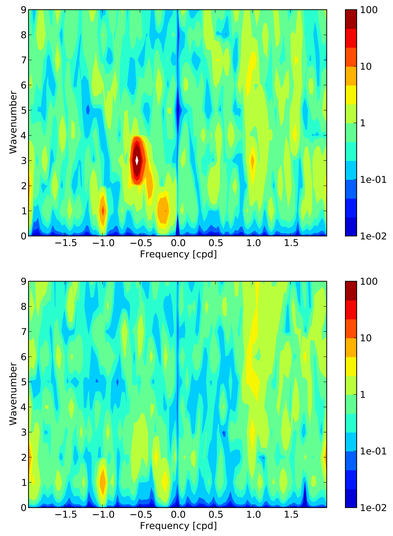

Figure 1: Temperature wavenumber-frequency spectra at 80km, 47S in K^2 day for January 2006 (negative frequencies denote westward propagation).
Top: Analysis with SABER observations
Bottom: Analysis without SABER observations.

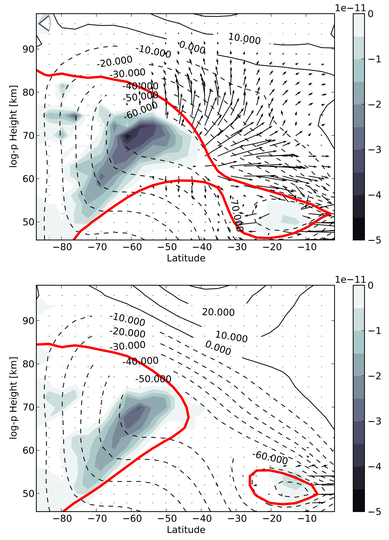

Figure 2: Zonal mean zonal wind in $\frac{m}{s}$ (black contour lines) and meridional QG-PV gradient in $\frac{1}{m\,s}$ (shaded) with EP-flux vectors and critical line (red contour line) for the 2-day wave for January 2006.
Top: Analysis with SABER observations
Bottom: Analysis without SABER observations.

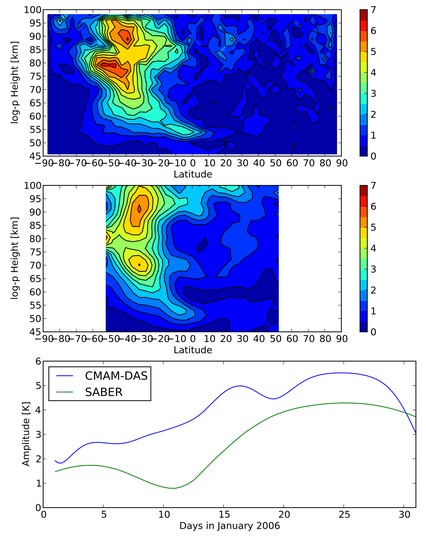

Figure 3: Top: CMAM-DAS 2-day wave temperature amplitude for 22nd of January 2006
Middle: SABER 2-day wave temperature amplitude for 22nd of January 2006 (data courtesy of Dr. R. Garcia)
Bottom: 2-day wave amplitude evolution at 80km averaged over all latitudes between 60S-30S.

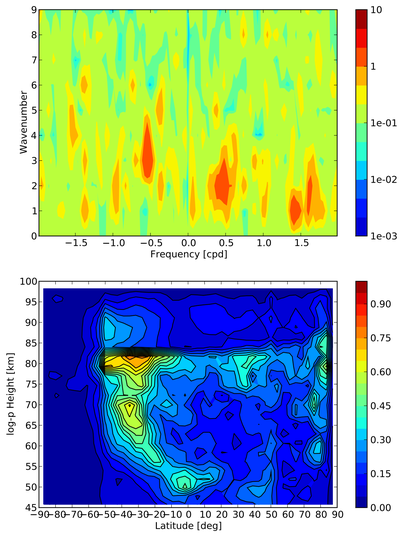

Figure 4: Top: CMAM-DAS temperature analysis increments wavenumber-frequency spectrum at 80km, 47S in K^2 day.
Bottom: Mean 2-day wave amplitude of temperature analysis increments for January 2006.

Results

- Without the assimilation of SABER data, the 2-day wave is not present in the analysis (see Figure 1).
- With SABER data, the 2-day wave is present, with a reasonable meridional structure (see Figures 2, top panel & Figure 3, top and middle panel).
- Though a general agreement can be observed, the 2-day wave analyzed in CMAM-DAS differs from that observed in SABER retrievals in terms of its structure and temporal evolution (see Figure 3).
- The temperature analysis increments show a sizable signal in the 2-day wave frequency range (see Figure 4). Note that no wind increments are produced from temperature observations in the mesosphere.
- The different temporal evolution & structure of the 2-day wave in concert with further analysis of the temperature analysis increments (not shown) indicates that the 2-day wave is likely produced by the model due to changes in the zonal mean zonal wind, not by the action of the analysis increments.

Conclusion

- The 2-day wave found in the CMAM-DAS analysis using SABER observations is likely produced by the model due to the changes in zonal mean zonal wind, not the analysis increments.
- The comparison of the two analyses with & without the assimilation of SABER data hints at model biases in the mesosphere, in the zonal wind field in particular. A likely candidate for the source of this bias is the nonorographic GWD parametrization (see e.g. McLandress and Scinocca, 2004)
- With an improved wind field due to the assimilation of SABER observations, the analysis yields a much more realistic representation of the solstice summer mesosphere.
- This highlights the usefulness of assimilating different sets of observations to study model errors and biases.

References

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