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

Martin Keller

Shuzhan Ren, Saroja Polavarapu,

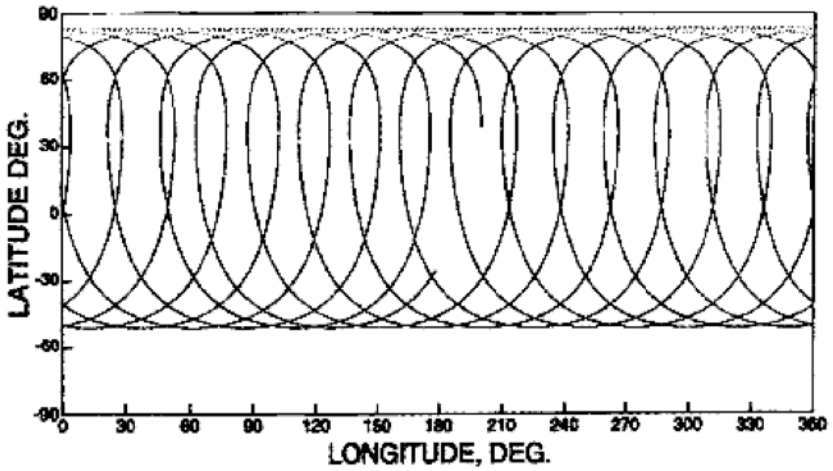
Charles McLandress, Ted Shepherd, Diane Pendlebury

CMAM-DAS:

- 3D-FGAT assimilation system based on CMAM
- CMAM covers the entire middle atmosphere from the ground up to 0.0006hPa, employing physical parametrizations needed to model the upper mesosphere (e.g. Non-LTE radiative transfer, non-orographic gravity wave drag)
- T47 horizontal resolution, ca. 1.5 km vertical resolution in the middle atmosphere
- Tropospheric and stratospheric observations yield no analysis increments in the mesosphere
- Above 10hPa, the only observational constrainta come from AMSU-A measurements
- No mass-wind balance is imposed in the mesosphere

SABER:

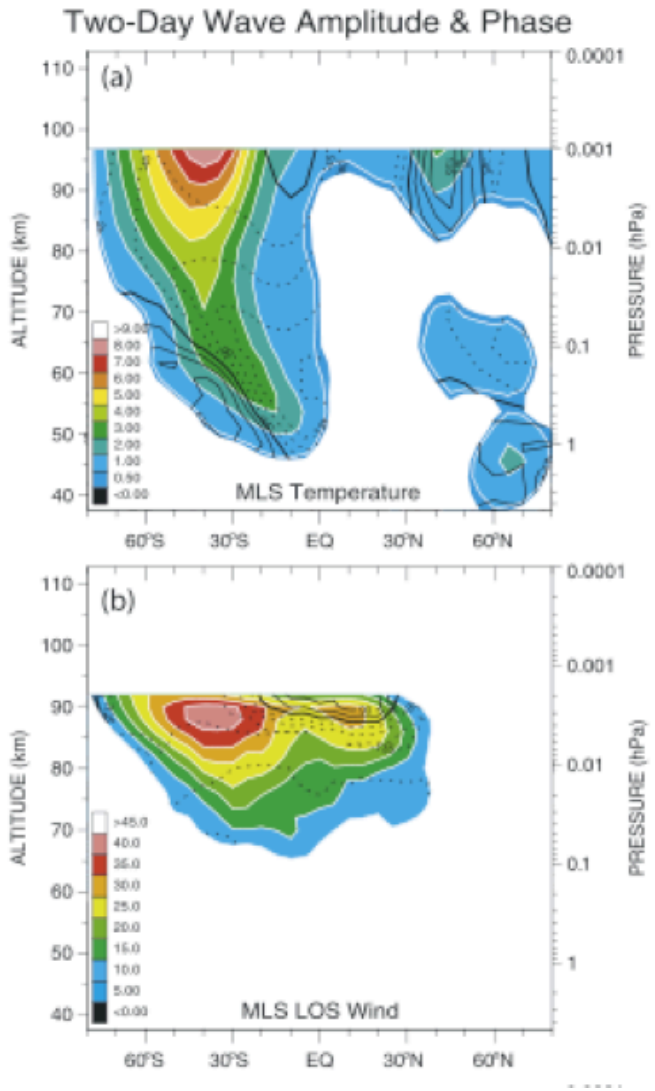
- Limb sounding instrument on board the TIMED satellite
- Temperature profiles are retrieved from 20km to 140km with a vertical resolution of ca. 2km
- The latitudinal coverage extends from 52 degrees to 83 degrees between the northern and southern hemisphere
- The latitudinal coverage flips every 60 days due to yaw cycle maneuvers



The two-day wave is a planetary wave in the extratropical mesosphere.

Its occurrence is restricted to summer solstice conditions and the wave is believed to be forced by baroclinic instability of the mesospheric easterly summer jet.

The two-day wave shows pronounced signals in temperature, meridional and zonal wind, as well as in chemical trace species concentrations.



Taken from Limpasuva, GRL 2005

Without the assimilation of mesosperic observations, the two-day wave is notably absent from analyses produced by CMAM-DAS.

Why is this so and what impact do mesospheric observations have on the depiction of the two-day wave in a middle atmosphere data assimilation system?

Two CMAM-DAS analyses have been produced for January, February and March 2006:

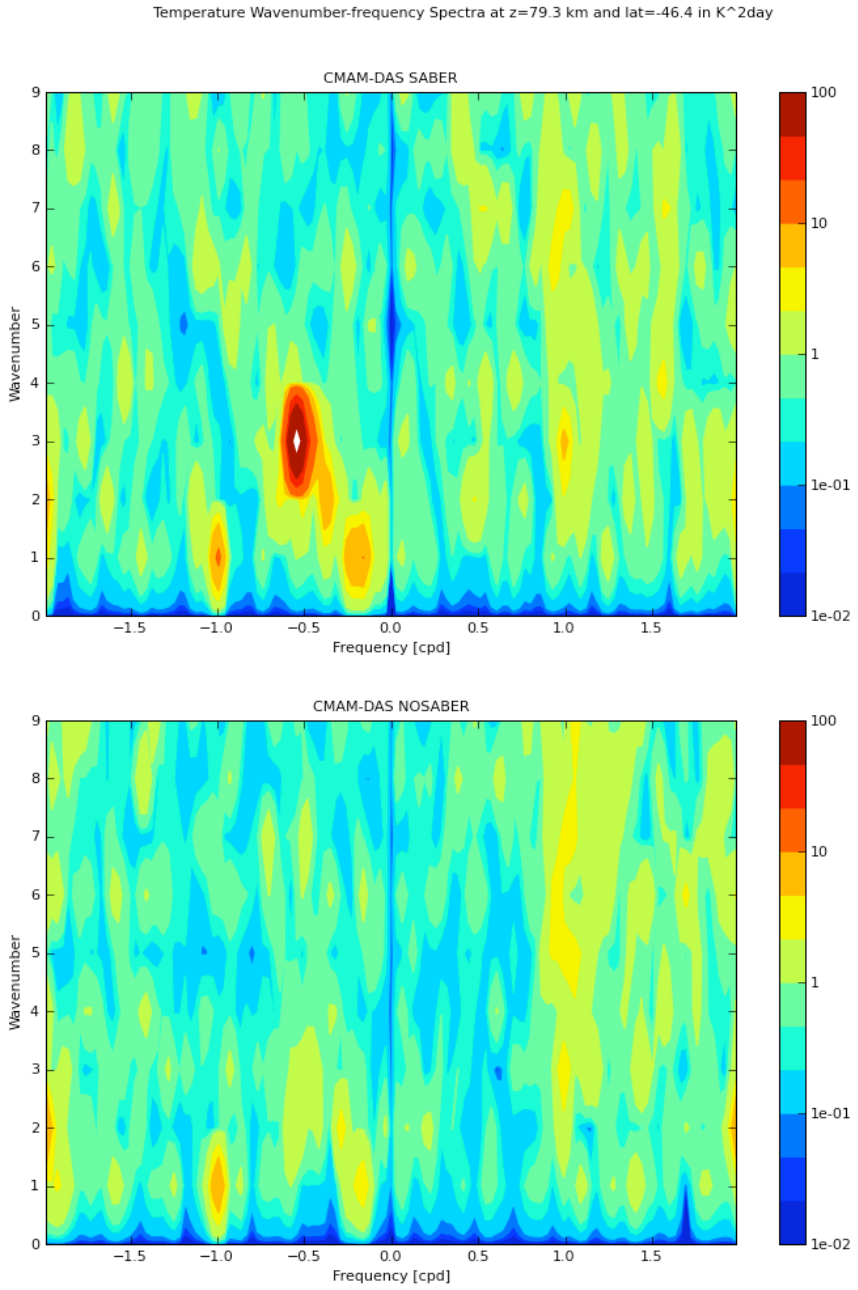
The first analysis has been produced using only standard observations in the troposphere and stratosphere.

The second analysis has been produced assimilating SABER observations in addition to the tropospheric and stratospheric observations.

Temperature wavenumber-frequency spectra for the analysis with (top) and without (bottom) SABER observations.

Negative (positive) frequencies indicate westward (eastward) propagation.

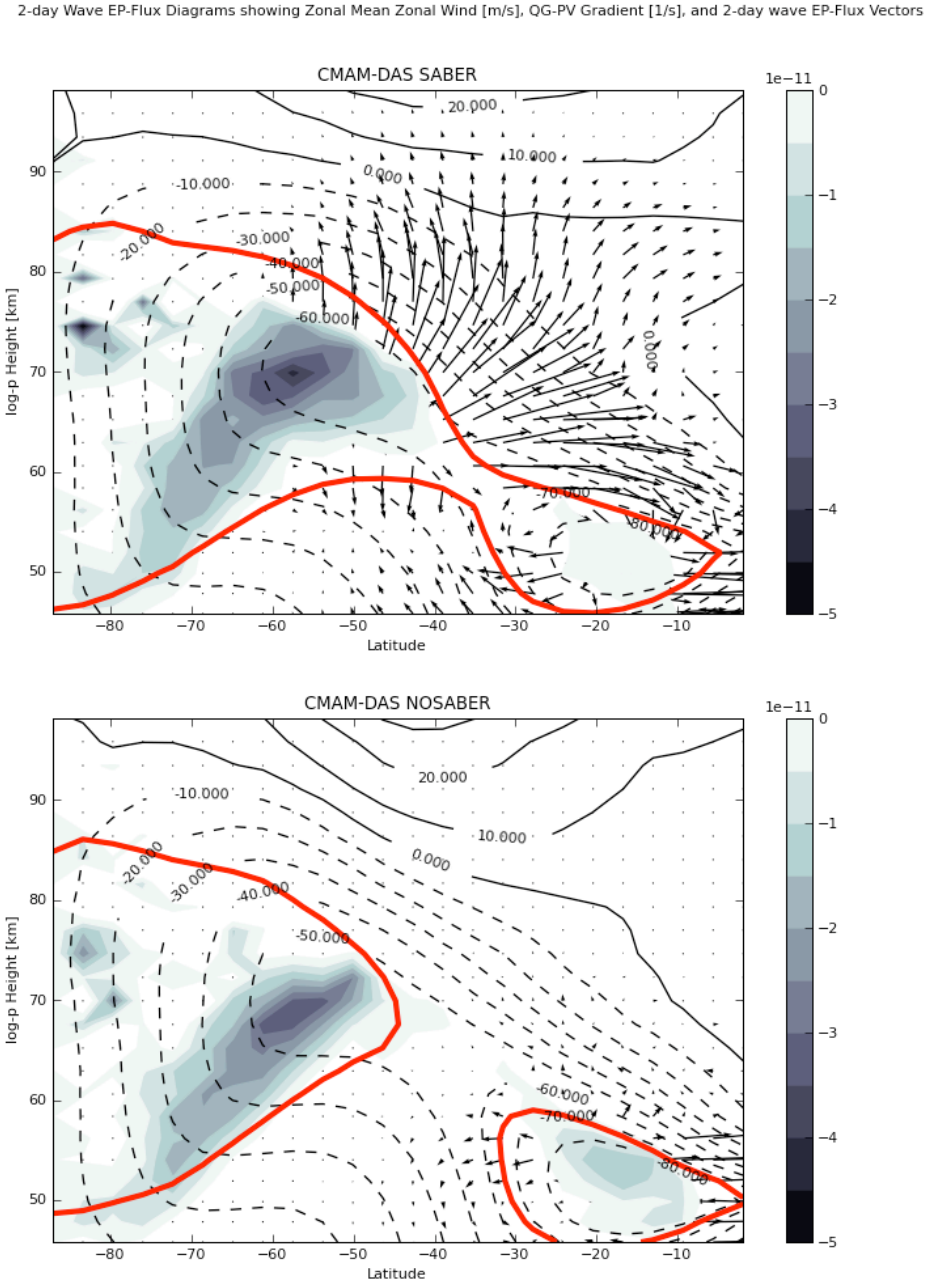
The peak at k=3 and f=-0.5cpd corresponds to the two-day wave.



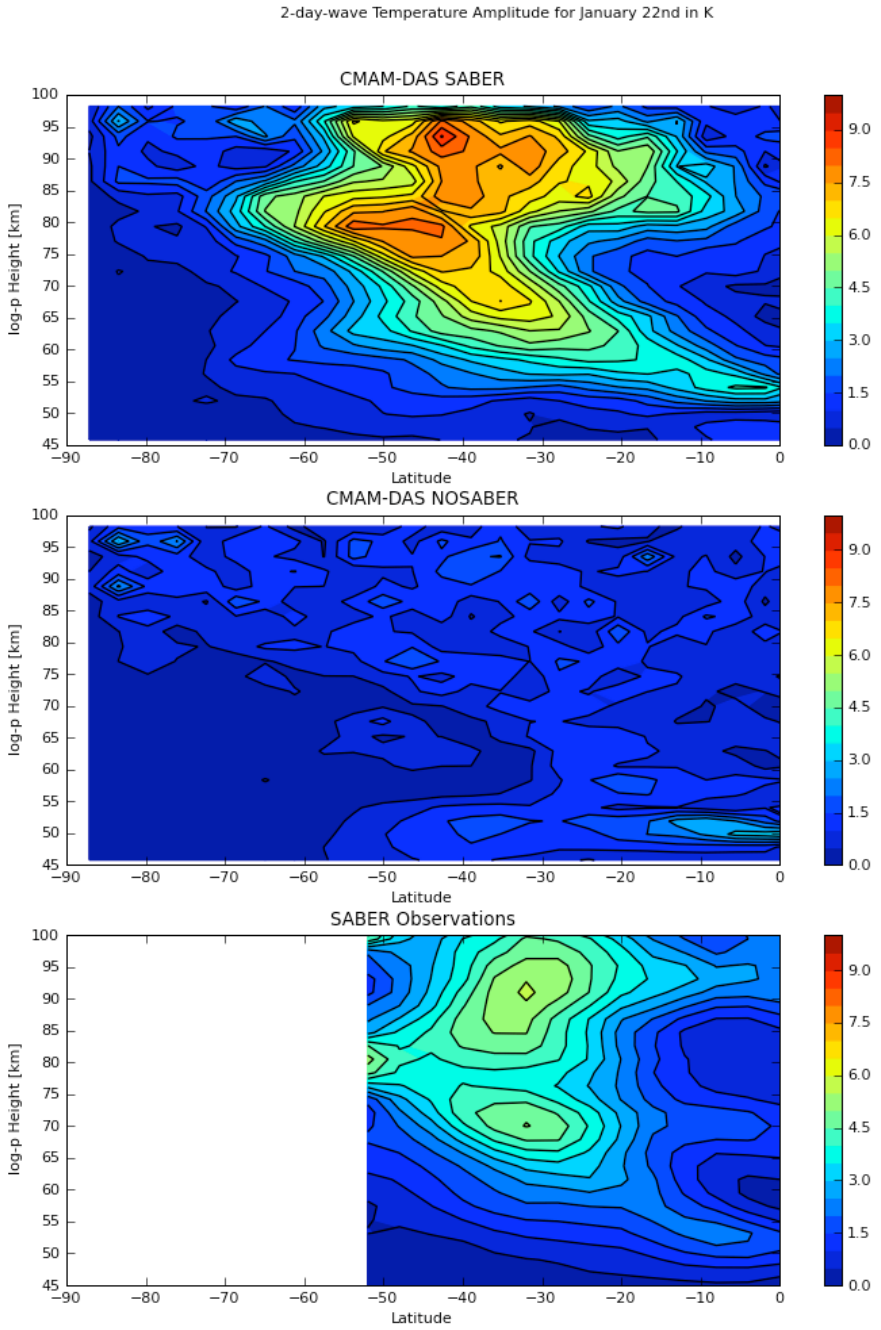
Eliassen-Palm Flux (arrows), zonal mean zonal wind (contours) and meridional QG-PV gradient (filled contours, shown only where negative).

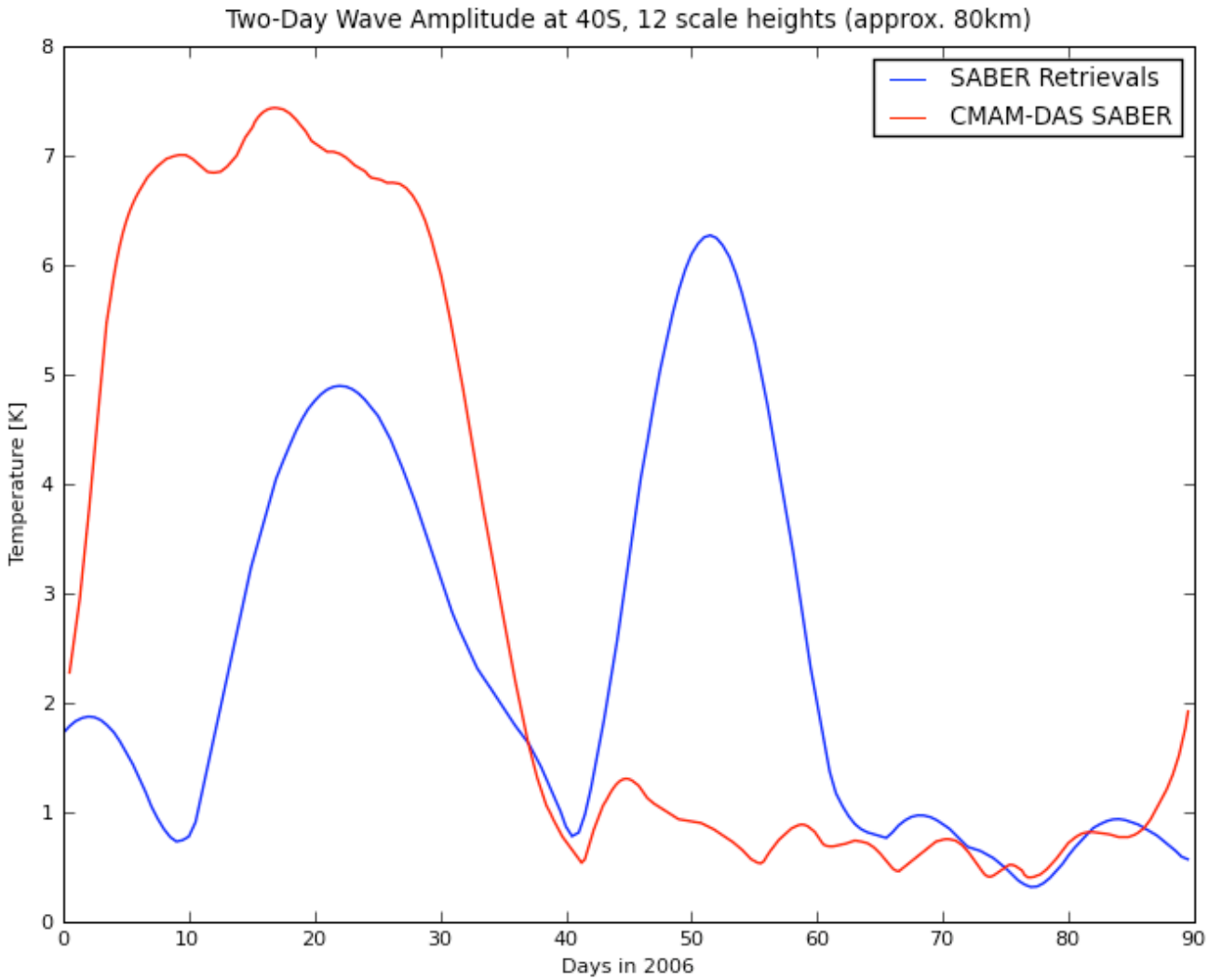
The reversal of the QG-PV gradient is a necessary (not sufficient) condition for baroclinic instability to occur.

EP-Flux vectors pointing out of regions of negative PV gradients are consistent with baroclinic instability.



Two-day wave temperature amplitudes for CMAM-DAS with (top) and without (middle) SABER observations, as well as from SABER retrievals (bottom, data courtesy of Dr. R. Garcia) for January 22nd.





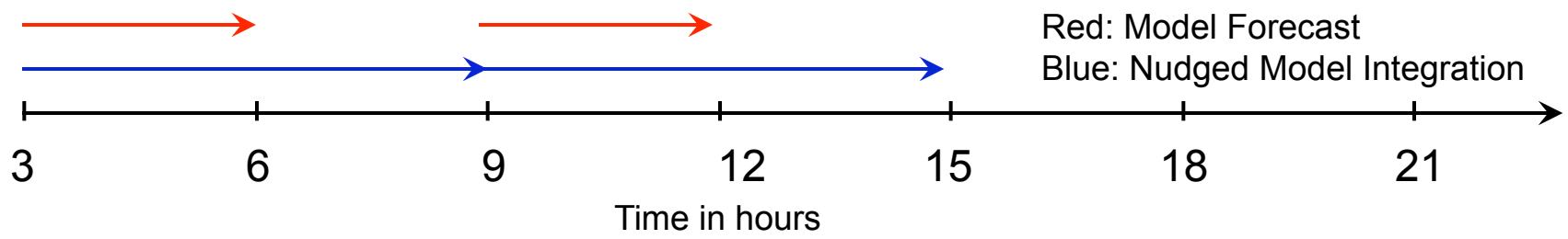
Two-day wave temperature amplitude at 40S, 80km for CMAM-DAS analysis using SABER retrievals and SABER Retrievals (courtesy of Dr. R. Garcia) for January-March 2006.

The assimilation of SABER retrievals leads to the depiction of a two-day wave in CMAM-DAS analyses...why is this so? Two, not necessarilly mutually exclusive, mechanisms could lead to the generation of the wave:

1. The wave is directly introduced by the data assimilation system due to the wave present in the SABER retrievals.
2. The wave is generated internally by the climate model due to the changed zonal mean conditions.

To study how the wave is generated, several additional experiments were conducted.

The CMAM-DAS analysis using SABER retrievals was used as a basis for two nudging experiments. The nudging system was developed at Environment Canada. It is based on the ideas of Incremental Analysis Updating (IAU).

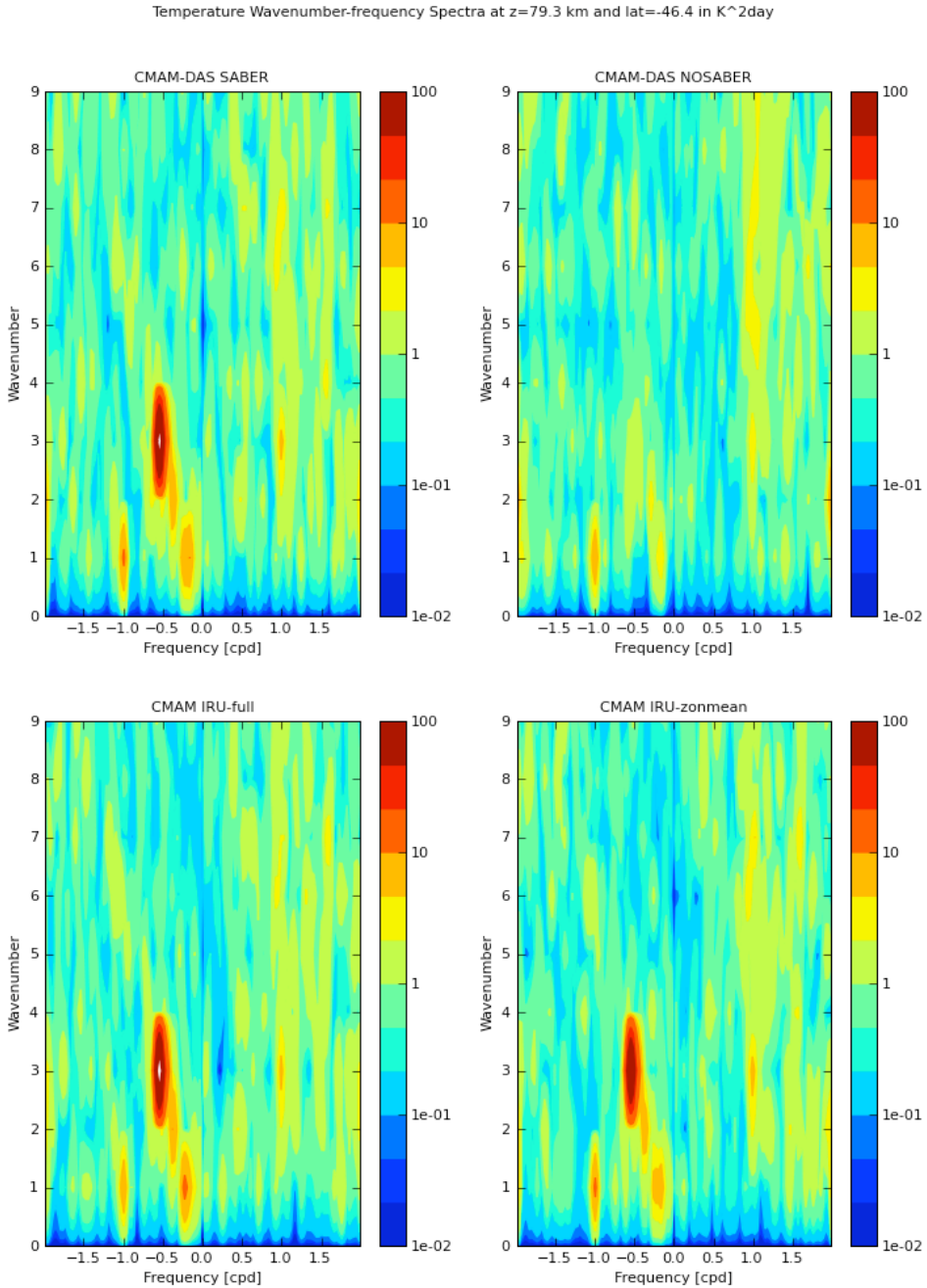


(1) Perform a six hour forecast from a reference
(2) Compute a increment from the difference between the forecast and a prescribed reference state
(3) Rewind the model and integrate for 12 hours using the increment as a model forcing

Two nudging experiments were conducted:

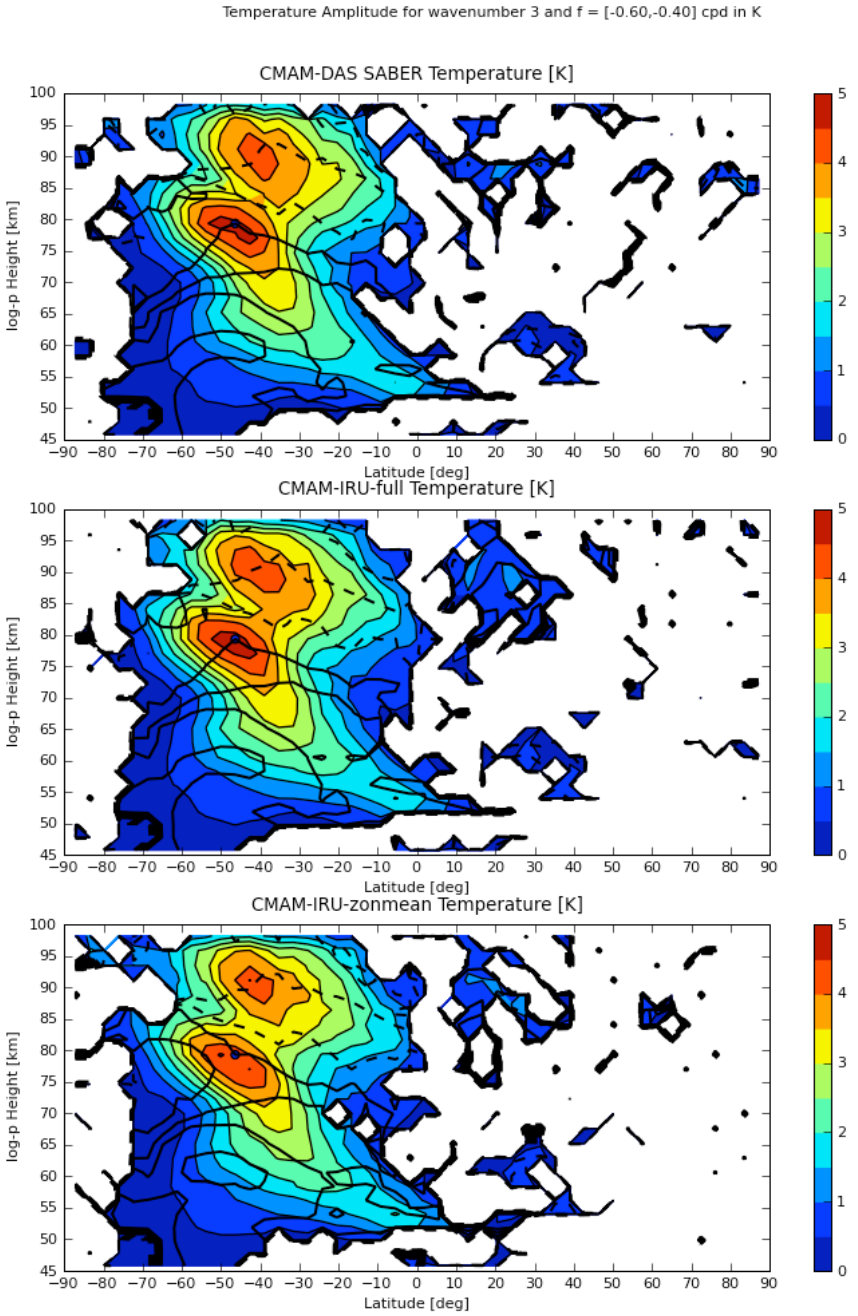
1. The full CMAM-DAS analysis using SABER observations was used as a reference state
2. Only the zonal mean fields were nudged towards the zonal mean of the analysis

So far, the experiments have only been conducted for January 2006.
The second experiment is the key experiment to determine the origin of the two-day wave in the CMAM-DAS analysis.


Temperature Wavenumber-frequency Spectra at z=79.3 km and lat=-46.4 in K^2day
CMAM-DAS SABER
CMAM-DAS NOSABER
CMAM IRU-full
CMAM IRU-zonmean
Wavenumber
Frequency [cpd]
0
1
2
3
4
5
6
7
8
9
−1.5 −1.0 −0.5 0.0 0.5 1.0 1.5
100
10
1
1e-01
1e-02

Temperature amplitude for the two-day wave in the CMAM-DAS SABER analysis (top), the full nudging experiment (middle) and the zonal mean nudging experiment (bottom).

Amplitudes are shown where the coherency-squared with respect to the base point exceeds 0.5. Phase lines with respect to the base point are also shown (25° contour interval)



Summary:

- The assimilation of SABER retrievals leads to the presence of the two-day wave in CMAM-DAS analyses
- The two-day wave present in the analysis is markedly different from the wave present in the SABER retrievals
- Nudging experiments indicate that the wave is generated by the model due to the changed zonal mean fields
- Additionally, the SABER retrievals indicate a strong two-day signal in February 2006, which is absent from the CMAM-DAS analysis