Impact of tropospheric and stratospheric data assimilation on mesospheric prediction

Environment Canada Environnement Canada

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1.Abstract

Numerical experiments are used to assess the potential benefit of the assimilation of tropospheric and stratospheric observations on mesospheric prediction. A simulated atmosphere taken as truth is created using the Canadian Middle Atmosphere Model (CMAM). The truth is sampled at the locations of the measurements from the actual observing system to produce observations which are then assimilated with the CMAM-DAS (Data Assimilation System). Obtained forecasts are compared with the truth and error statistics are calculated. An assessment based on predictability shows that upward propagation of information resulting from the assimilation of tropospheric and stratospheric observations improves the mesosphere in the largest scales (with horizontal wavenumbers less than approximately 10). At the same time, the principle inability of the system to predict mesospheric small scales is demonstrated.

2. CMAM-DAS

- **CMAM model**
  - 71 vertical levels with the lid at 95km.
  - T47 spectral representation
- **Observations**
  - surface obs
  - 1000-10 mb: radiosondes, aircrafts 1000- 1mb : AMSU-A, satellite winds
  - No observations above 1mb
- **Assimilation**
  - 3D-VAR

3. Simulation of observations

- Use a free model simulation as a reference or "truth"
- Sample the "truth" and create "perfect" observations at locations of REAL measurements
- Add random perturbations to perfect observations $\sigma = \sigma_{obs}$

By definition:
Error(t) = Forecast(t) –truth(t)
Error samples are taken from the last 10 days (after the error saturates) of a one month cycle with assimilation every 6 hours (~40 error samples with averaging over 96 longitudes)

4. Zonally averaged January temperature error standard deviations in Kelvin for:

Panel a) shows the minimum error std. dev. that one might expect.

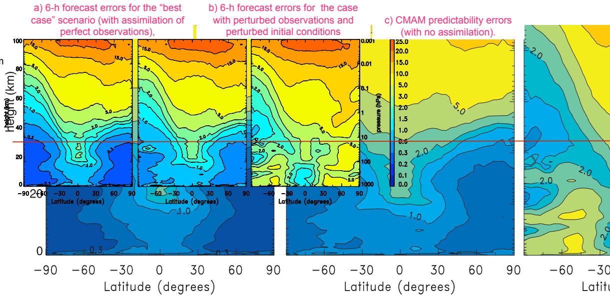
It demonstrates the ability and limitation of a DAS to control forecast errors

It includes the impact of all the components of the 3D-VAR (the minimization, error covariances modeling, balance operator,…) and the observational network

a) 6-h forecast errors for the "best case" scenario (with assimilation of perfect observations),

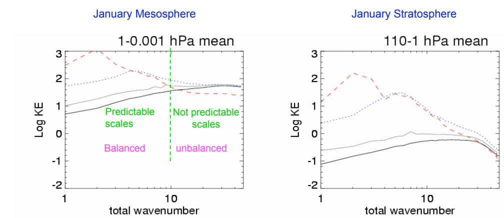
b) 6-h forecast errors for the case with perturbed observations and perturbed initial conditions

c) CMAM predictability errors (with no assimilation).



In the mesosphere, the 6-h forecast error levels from the DA cycle are nearly the same as the predictability error levels (without DA).

5. Kinetic Energy spectra



Only large scales (n>10) are predictable in the mesosphere

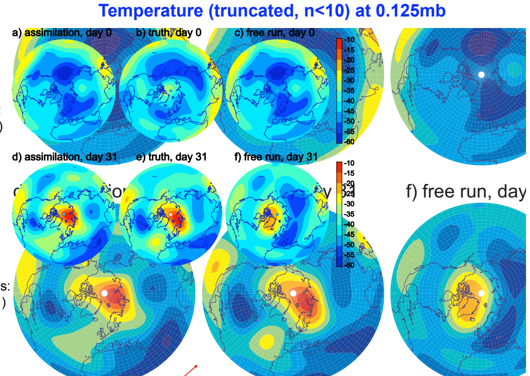
6h-forecast errors from the CMAM-DAS with perfect observations
with perturbed observations
predictability errors of the CMAM
the full states of the CMAM

6. Prediction of mesospheric polar temperatures

Temperature (truncated, n<10) at 0.125mb

Initial state: (January, 1)

After 30 days: (January, 31)

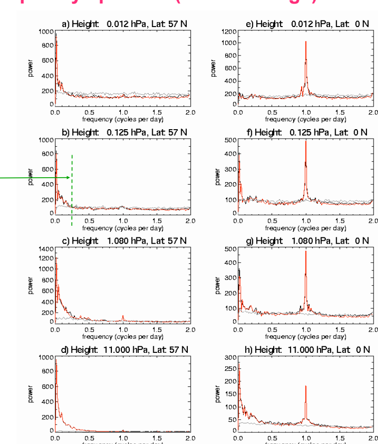


Upward propagation of information from tropospheric and stratospheric measurements results in correctly resolved large scale mesospheric features

7. Temperature frequency spectra (zonal average)

From 2 months time series with 6 hours time step:

Only waves with periods longer than ~5 days are predictable in mesospheric midlatitudes



from the full states of the free CMAM (truth)

6h-forecasts from the CMAM-DAS assimilating perturbed obs

6h-forecast errors from the CMAM-DAS with perturbed observations.

8. Conclusions

The impact of tropospheric and stratospheric observations on mesospheric forecasts is quantified.

- In spite of the inevitable noise accompanying the data assimilation process, information from below still reaches the mesosphere and makes large mesospheric scales predictable.
- The results imply that DA systems with models that incorporate most or all of the mesosphere but do not assimilate mesospheric data may still result in improved mesospheric analyses on large scales (wave numbers smaller than 10 and periods longer than 5 days).
- Comparison of mesospheric analyses from such systems against measurements should be restricted to large scales.
- The inability of the CMAM-DAS (even with a perfect model) to predict small-scale events in the mesosphere and the upper stratosphere is demonstrated. This sets scale-dependent limits on mesospheric predictability from assimilation with the current operational observation network.