Middle Atmosphere Operational Data Assimilation with the Use of Ensembles

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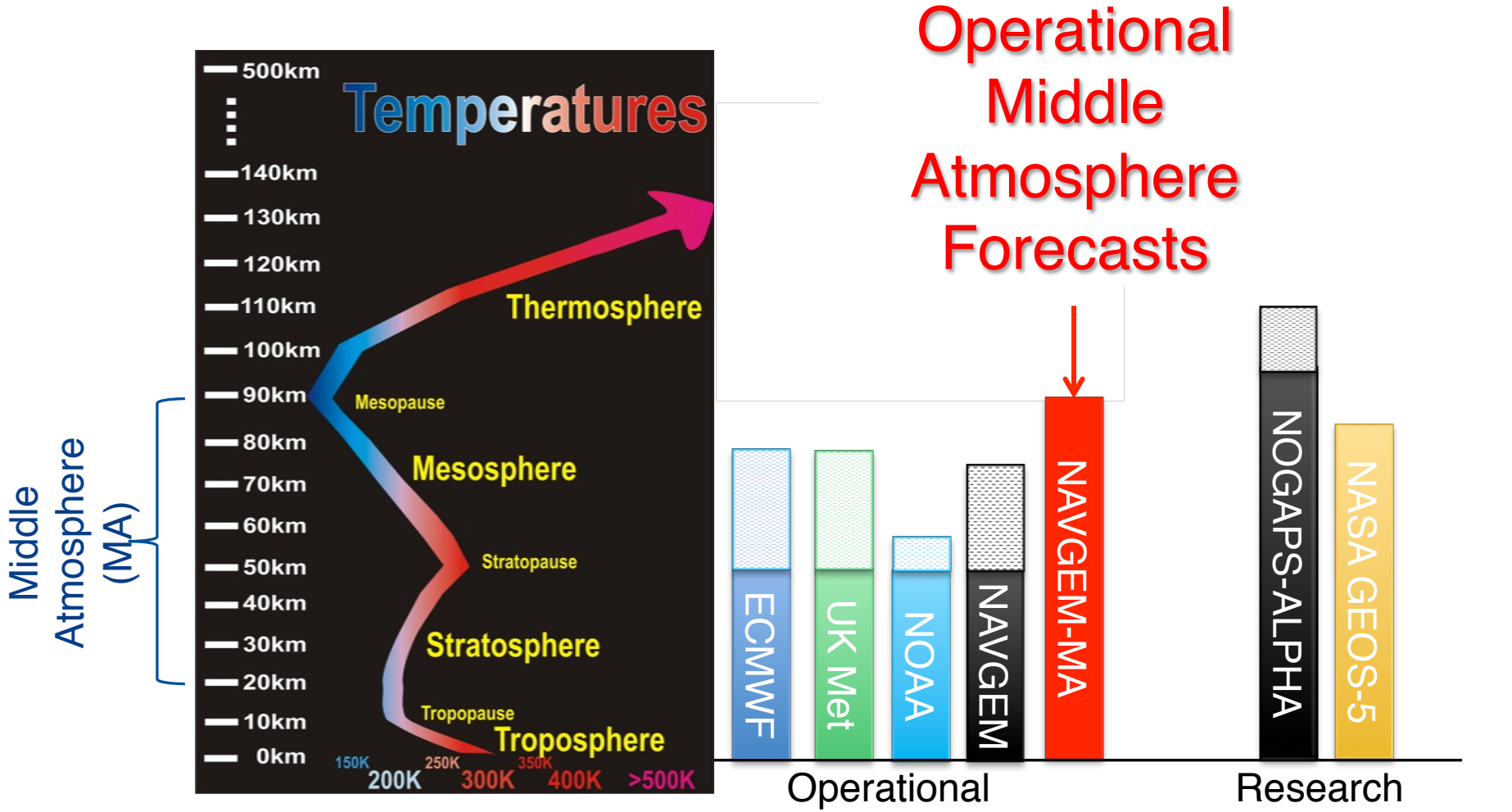
Oral session 9: New observing network, ensemble sensitivity, and new applications
Friday, May 27, 2016 8:00-9:45am

Comparison of Global Modeling



Why is the Navy interested in the MA?

1. Lower Boundary Condition for Space Weather Forecasting
   - Ionospheric models are extremely important for tactical reasons and they require day-to-day forecasts of MA.
2. Assets travelling through and in the Middle Atmosphere encountering complications from dynamics such as large gravity waves
   - Unmanned Aerial Vehicles (UAV) like Global Hawk
   - Space-vehicle takeoff and reentry
   - Hypersonic vehicle testing
3. Desire to make seasonal scale forecasts
   - Many documented cases of long range weather phenomenon initiated or controlled by MA dynamics such as: Sudden Stratospheric Warming (SSW), Quasi Biennial Oscillation (QBO)

Improving Middle Atmosphere Physics

- The current operational forecast model does not include the physics for properly modeling the middle atmosphere.
- Specific focus for improving physics parameterization are:
  a) Diabatic heating due to shortwave ozone and oxygen photolysis;
  b) Longwave ozone and carbon dioxide cooling that accounts for the breakdown of thermodynamic equilibrium above ~70 km;
  c) Heating due to exothermic chemical recombination reactions;
  d) Heating, momentum forcing and mixing due to the dissipation of unresolved gravity waves from both orographic and nonorographic sources;
  e) Downward conduction of heat from thermospheric reservoirs
  f) Generalization of the NRL linearized ozone photochemistry scheme to include diurnal effects above ~50 km.
- Our modeler's have found that by improving the physics they, even with a relatively low horizontal resolution model (T119), can capture many of these phenomenon such as
  - Gravity Waves
  - Sudden Stratospheric Warming (SSW)
  - Quasi Biennial Oscillation (QBO)(increased vertical resolution)

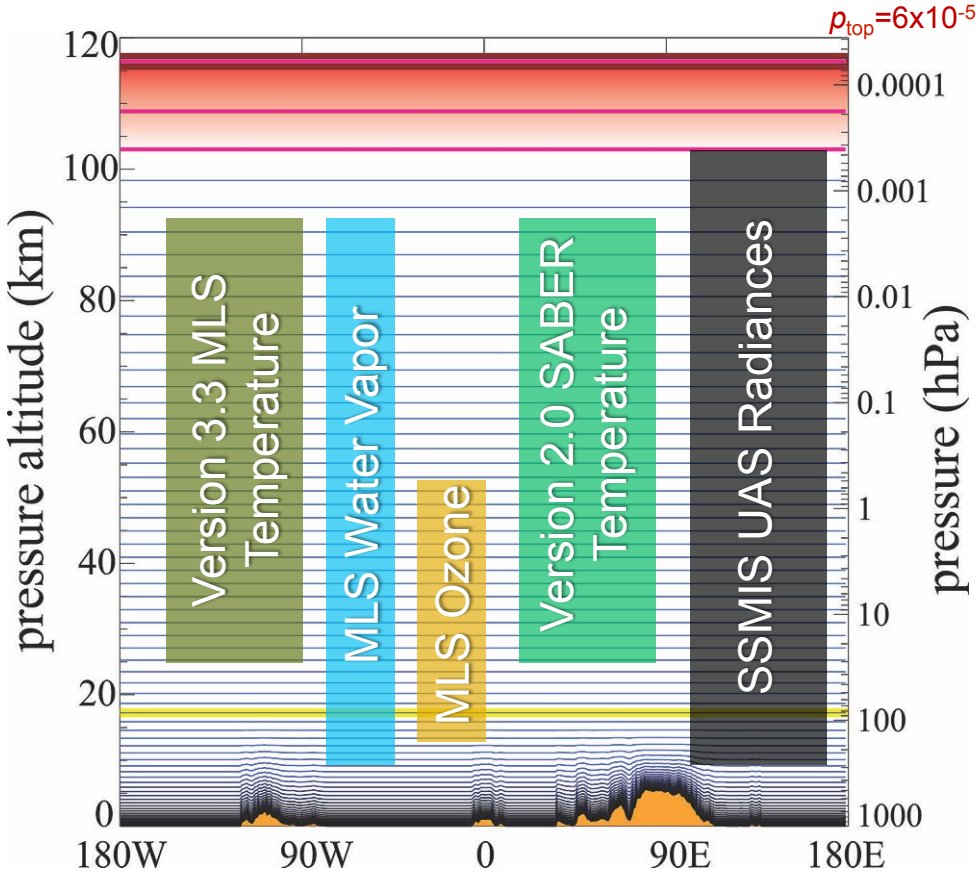
Issues for DA with a MA model

1. Dealing with vastly different dynamical regions
   - Troposphere: Many small scale dynamics
   - Stratosphere: Much larger scales
   - Mesosphere: Small scale dynamics but driven more through chemistry
2. Dealing with vastly different amounts of observations
   - Troposphere: Large amount of observations
   - Stratosphere: Smaller amount of observation
   - Mesosphere: Limited amount of observations
3. Dealing with vastly different regions of model error
   - Tropospheric modeling is very mature
   - Middle atmospheric modeling is still in infancy

- Our 4D-Var TLM was designed for the troposphere. Missing chemical interactions of the MA. Introducing those into the TLM would be quite costly.

Available Sets of MA Observations

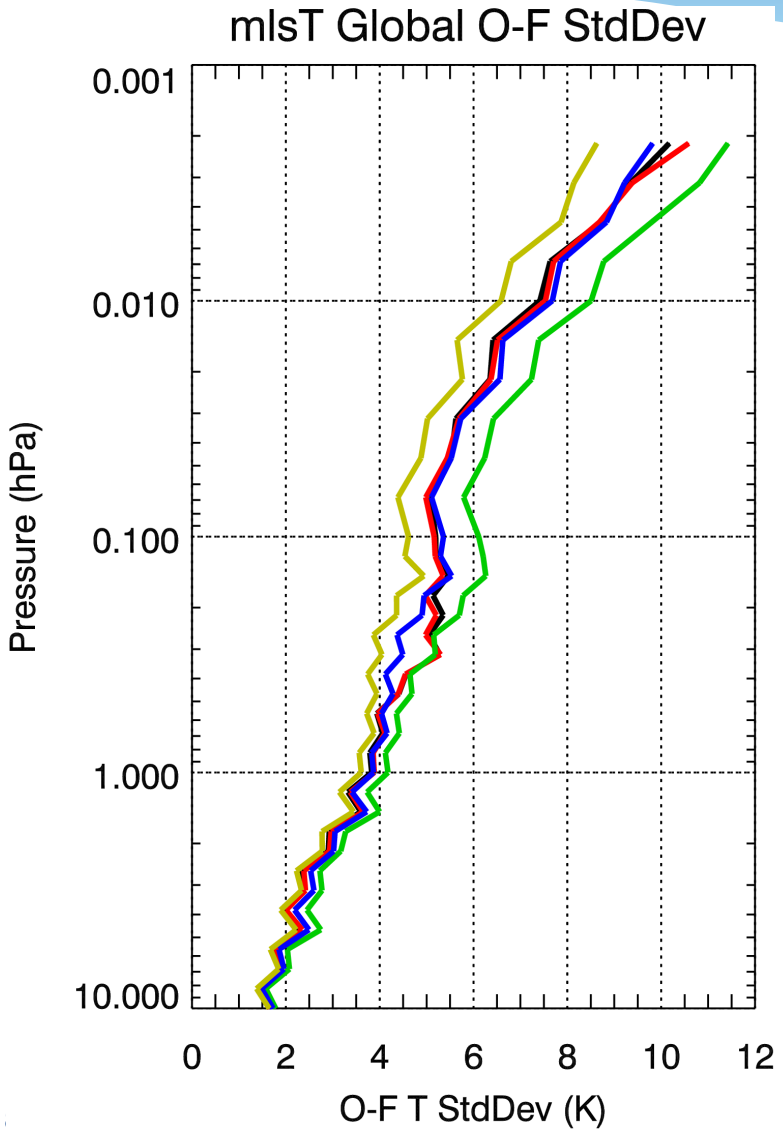
MLS=Microwave Limb Sounder
SABER=Sounding of the Atmosphere Using Broadband Emission Radiometry
UAS=Special Sensor Microwave Imager/Sounder (SSMIS) Upper Atmospheric Sounding



DA systems for the middle atmosphere

1. 4D-Var (Xu et al. 2005)
2. Hybrid 4D-Var →Operational Oct. 2016 (Kuhl et al. 2013)
   - Climatological Pb0 comes from balanced equations (Daley and Barker 2001)
     - Balances were designed for troposphere
     - Those balances breakdown in the MA
   - Flow dependent Pb0 comes from ensemble (nominally 80 members)
     - Ensemble Transform (ET) creates the ensemble (McLay et al. 2010)
     - Simple non-adaptive localization setup
3. 4D Ensemble Var, noTLM/adjoint i.e. ensemble is used for time and spatial correlations (Buehner et al. 2009)

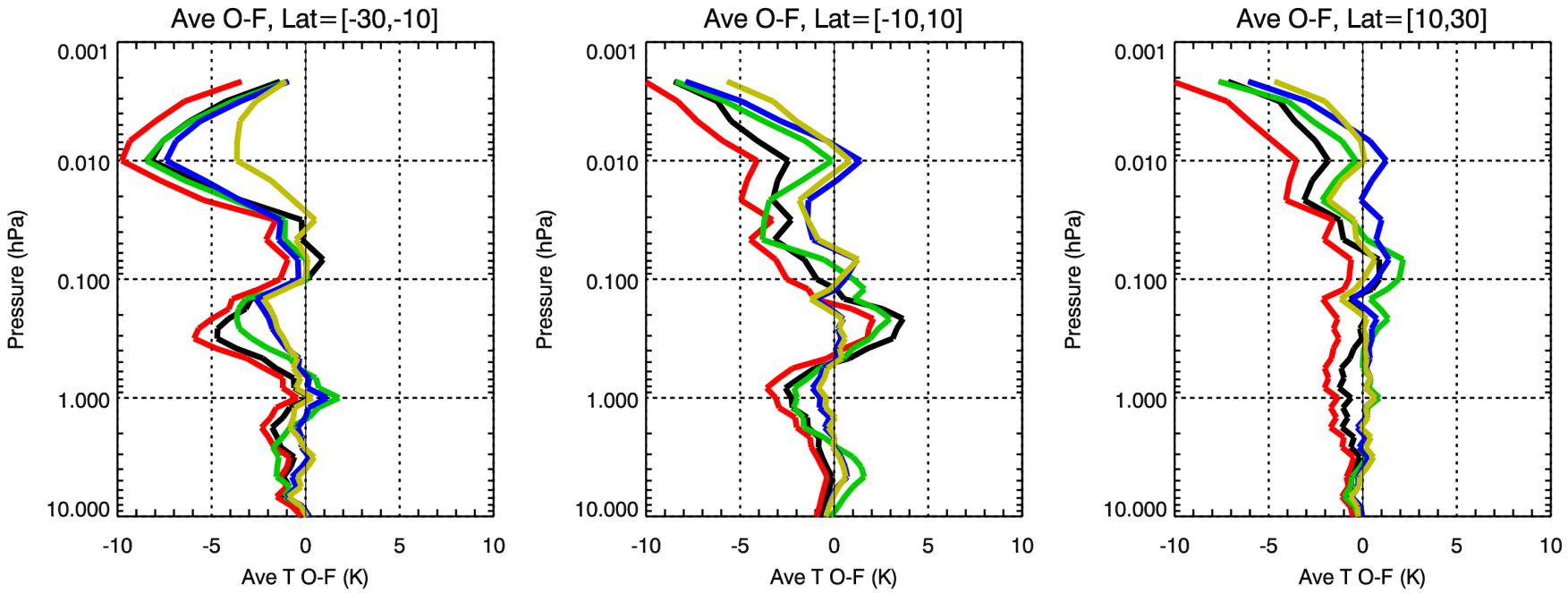
Temperature Forecast Std. Dev. vs MLS



Cycling experiments:
All Forecasts tau=6hr
6/10/2014 to 6/24/2014

4D-Var T119/T47
Hybrid 4D-Var T119/T47 mem=80
4D Ensemble Var T119/T47 mem=200
4DEnsemble Var T119/T119 mem=80
Hybrid 4D-Var T119/T119 mem=80
(ensemble mean background)

Temperature Forecast Bias vs MLS



4D-Var T119/T47

Hybrid 4D-Var T119/T47 mem=80

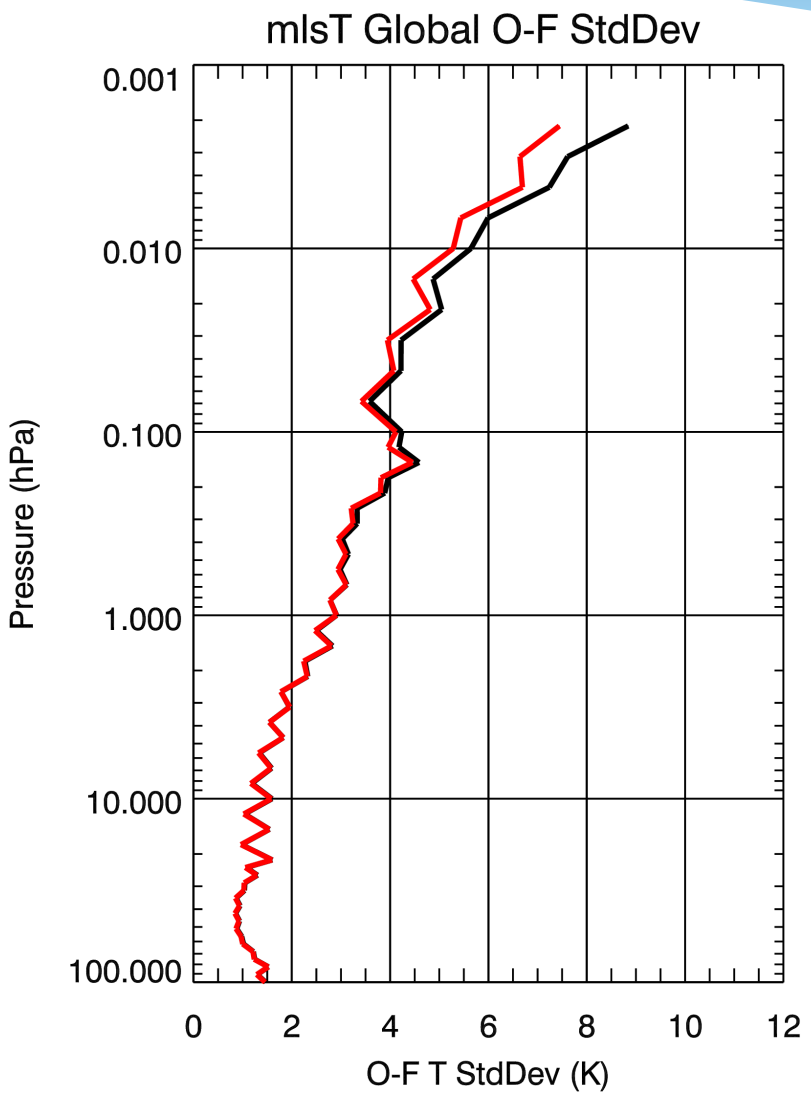
4D Ensemble Var T119/T47 mem=200

4D Ensemble Var T119/T119 mem=80

Hybrid 4D-Var T119/T119 mem=80

(ensemble mean background)

Temperature Forecast Std. Dev. vs MLS

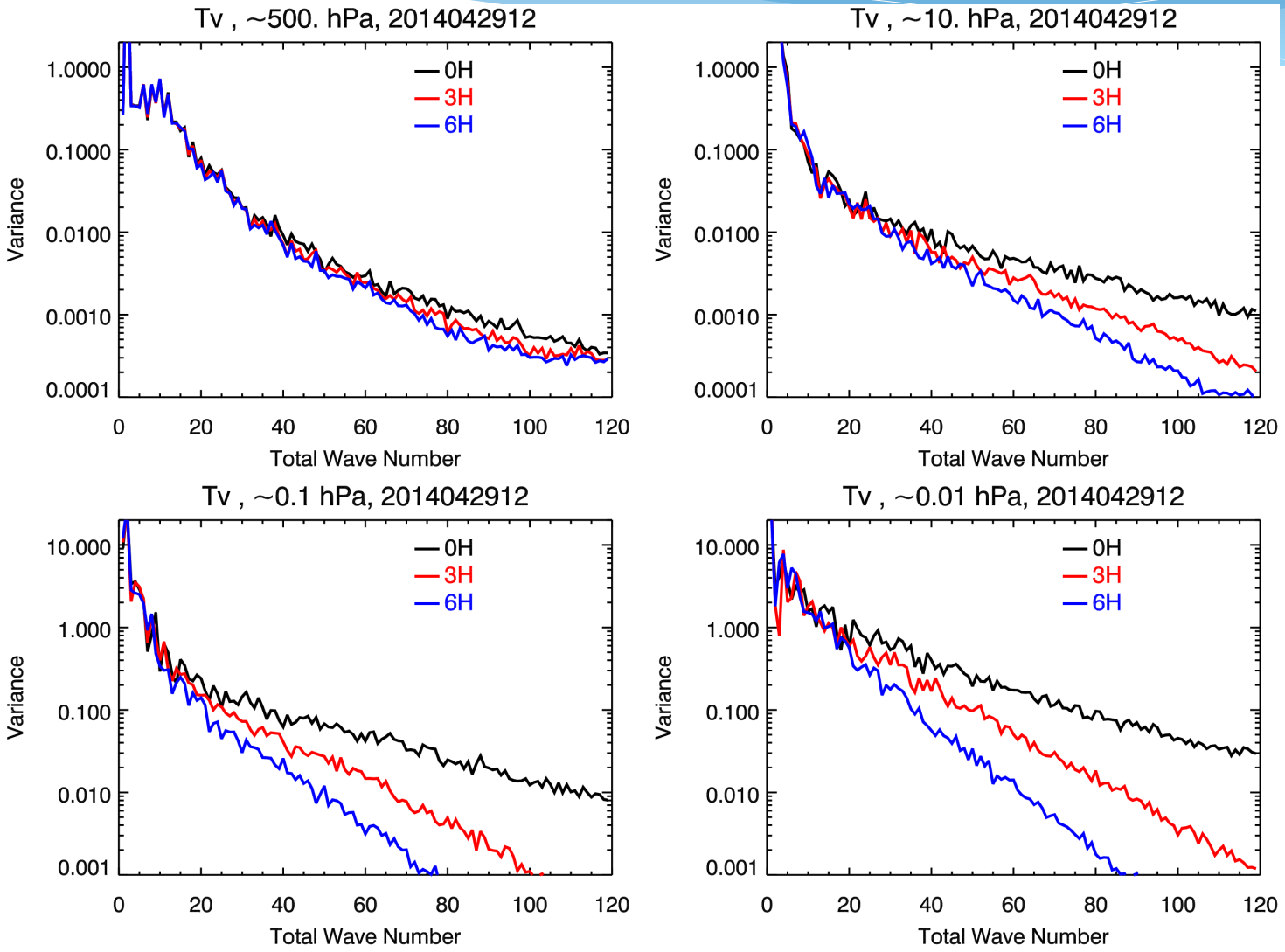


Cycling Experiments:
All Forecasts tau=6hr
5/4/2014 to 5/19/2014

Hybrid 4D-Var T119/T119 mem=80

Hybrid 4D-Var T119/T119 mem=80
(ensemble mean background)

Spectrum of Ensemble Mean Forecasts



Preliminary Conclusions

- Increasing ensemble members from 80 to 200 doesn't seem to help the 4D Ens Var
- Increasing the ensemble resolution to outer-loop resolution seems to improve the 4D Ens Var greatly
- Using the Ensemble Mean as background for Hybrid 4D-Var seems to improve the middle atmosphere
  - As you increase in altitude the ensemble mean spectrum deviates more and more from the analysis (and also the control spectrum)
  - This fall-off of the spectrum seems to improve the analysis and fitting to the observations

References

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Spectrum of Ensemble Mean Forecasts