Raising the model top for an ensemble Kalman filter

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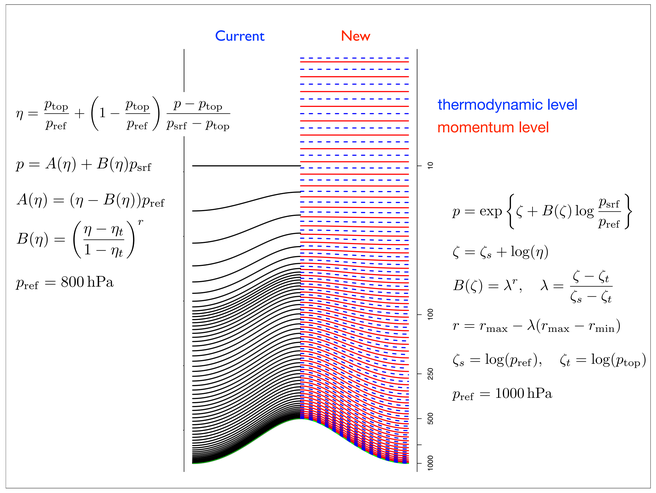
Abstract

Recently, the Canadian Meteorological Center (CMC) introduced a new, staggered, vertical coordinate for the Global Environmental Multiscale model. The new coordinate is thought be more accurate and should facilitate raising the model top further into the stratosphere. As a first step, we raised the model top from 10 hPa (~32 km) to 2 hPa (~43 km) while keeping the horizontal resolution and the number of vertical levels the same as before (400×200 with 58 vertical levels), effectively resulting in slightly reduced vertical resolution. Since the model top has been raised, it has been necessary to change the statistical description of the model error. We moved to a non-separable description provided by the variational system at our center. With the new statistics we have less spread for the wind component and it is evaluated if adding stochastic parameterization can lead to an appropriate increase in ensemble spread. Doubling the ensemble size dealt with the small scales near the surface in the new statistics and also with the low correlations with wind in the stratosphere.

Staggered vertical coordinate



Model error simulation

- different model configuration (Houtekamer et al. 2009).

Deep convection	Kain & Fritsch, Old Kuo	Inverse turbulent Prandtl number	1.0, 0.85
Surface scheme	ISBA, Force-restore	GWD intensity factor	4.0E-6, 1.2E-5
Mixing length	Bougeault, Blackadar	Non-orographic GWD scheme	Hines, None

  - 24 combinations for 4 subensembles.

- Additive isotropic random error.
  - New perturbations are independent for streamfunction, unbalanced divergence, unbalanced temperature, humidity, and unbalanced surface pressure and derived from monthly varying 3D-Var error covariances (Gauthier et al. 1999).

Impact of the higher model top

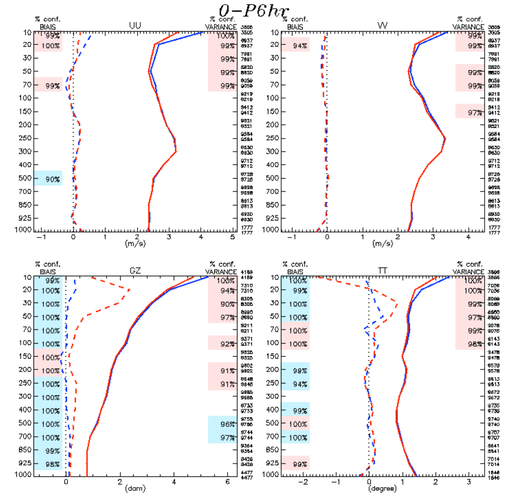
- Additive model errors are generated from streamfunction and unbalanced temperature using separable error description.

Verification against radiosonde observations

GPS up to 30 km
AMSU channels up to 10
Separable model error

Model top at 10 hPa with non-staggered coordinate

Model top at 2 hPa with staggered coordinate



- Improvements are observed mostly above 200 hPa.
- No degradation below 200 hPa is observed even though the vertical resolution is reduced.

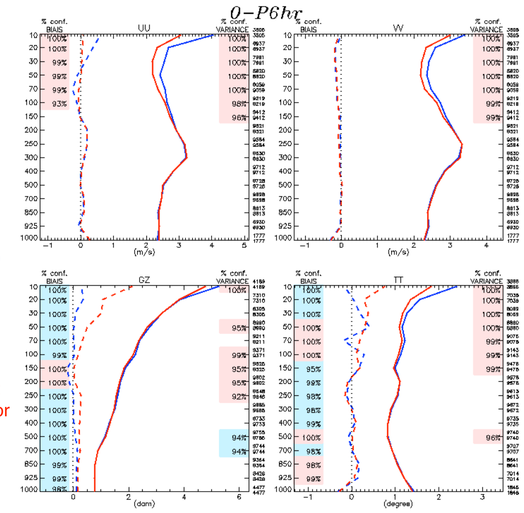
Impact of the additional information

- AMSU channels 11 and 12 are assimilated.
- GPS-RO observations up to 40 km are assimilated.
- A new description of the additive isotropic model error is used.

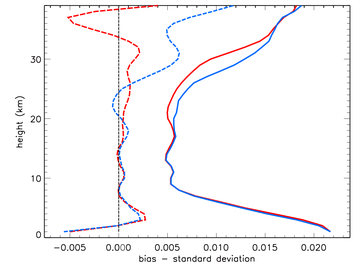
Verification against radiosonde observations

Model top at 10 hPa with non-staggered coordinate
GPS up to 30 km
AMSU channels up to 10
Separable model error

Model top at 2 hPa with staggered coordinate
GPS up to 40 km
AMSU channels up to 12
Nonseparable model error



- More improvements are observed above 200 hPa.



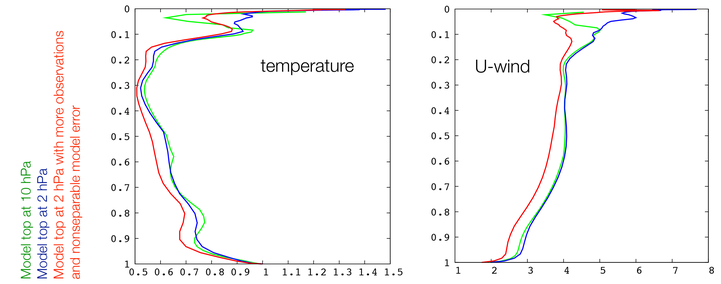
Verification against GPS observations

Model top at 2 hPa with staggered coordinate
GPS up to 30 km
AMSU channels up to 10
Separable model error

Model top at 2 hPa with staggered coordinate
GPS up to 40 km
AMSU channels up to 12
Nonseparable model error

- Improvements above 15 km are observed in the GPS verification but some degradation near the surface is present.

Ensemble spreads



- Ensemble spreads are reduced due to the non-separable additive random error.

Summary and discussion

- Vertical layers of the model are stretched to have the model top at 2 hPa using a recently introduced staggered coordinate.
- Having a higher model top allowed us to assimilate more data.
- It was beneficial to adopt the isotropic perturbation from the variational system for the additive random error even though the ensemble spreads are reduced.
- The changes have positive impact on 6 hour forecasts in the radiosonde and GPS verification.
- Some degradation at the lower levels is present in the GPS verification partly due to the reduced ensemble spread.
- Stochastic kinetic energy backscatter (Shutts 2005) and physical tendency perturbations (Buizza et al 1999) will be considered to recover the reduced ensemble spread.

References

Buizza, R., M. Miller and T. N. Palmer, 1999: Stochastic representation of model uncertainties in the ECMWF ensemble prediction system. *Quart. J. Roy. Meteor. Soc.*, **125**, 2887-2908.

Gauthier, P., M. Buehner and L. Fillion, 1999: Background-error statistics modelling in a 3D variational data assimilation scheme: Estimation and impact on the analysis. *Proc. ECMWF Workshop on Diagnosis of Data Assimilation System*, Reading, United Kingdom, ECMWF, 131-145.

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Shutts, G., 2005: A kinetic energy backscatter algorithm for use in ensemble prediction systems. *Quart. J. Roy. Meteor. Soc.*, **131**, 3079-3102.