

# Raising the model top for an ensemble Kalman filter

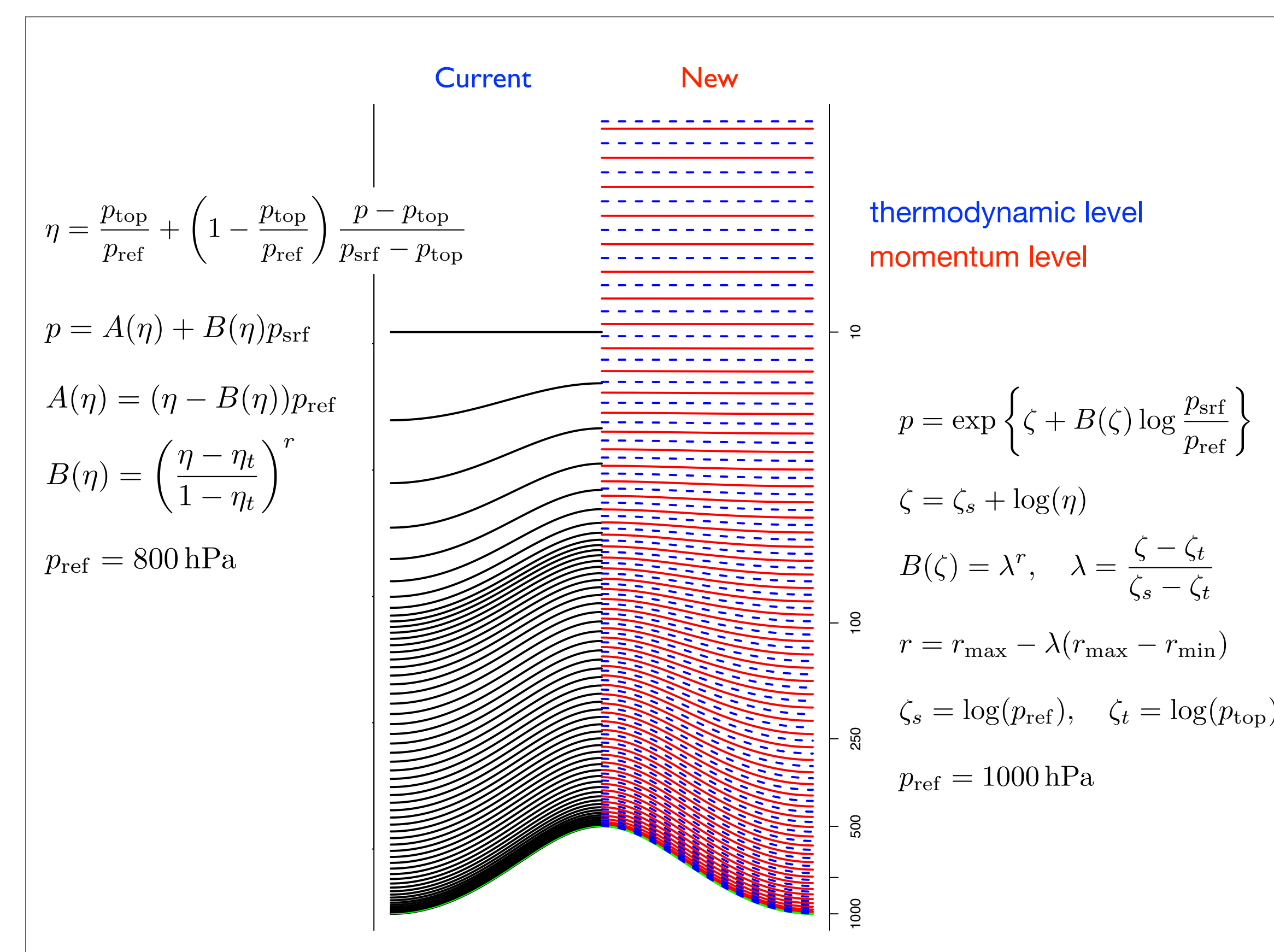
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## Abstract

Recently, the Canadian Meteorological Center (CMC) introduced a new, staggered, vertical coordinate for the Global Environmental Multiscale model. The new coordinate is thought to 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. 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

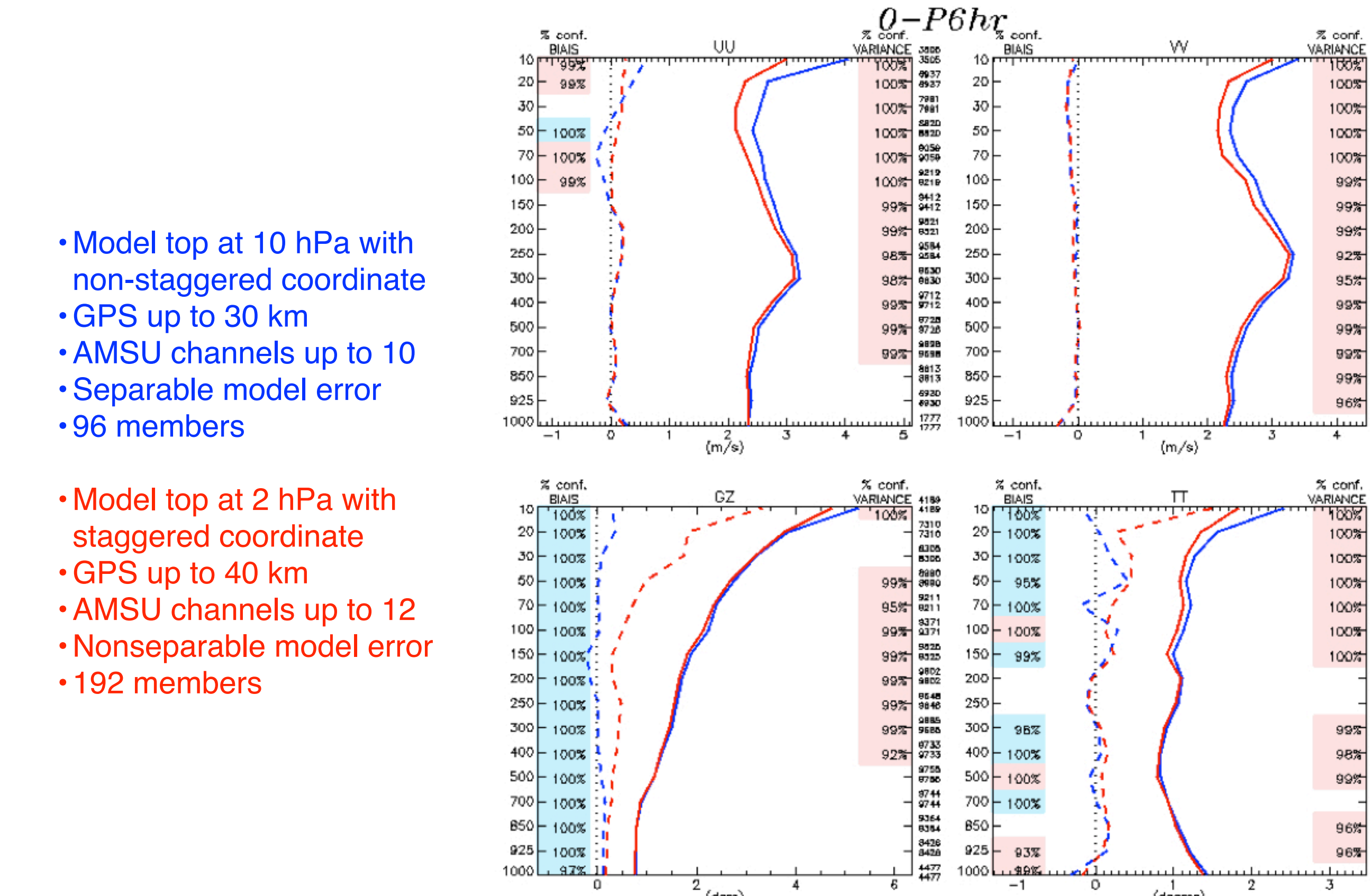
- different model configuration.

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		

- ▶ 24 combinations for 4 subensembles.
- Additive isotropic random error.
  - ▶ New perturbations are independent for stream function, unbalanced divergence, unbalanced temperature, humidity and unbalanced surface pressure, and derived from monthly varying 3D-Var error covariances.
  - ▶ Double the number of ensemble members to represent small scales.

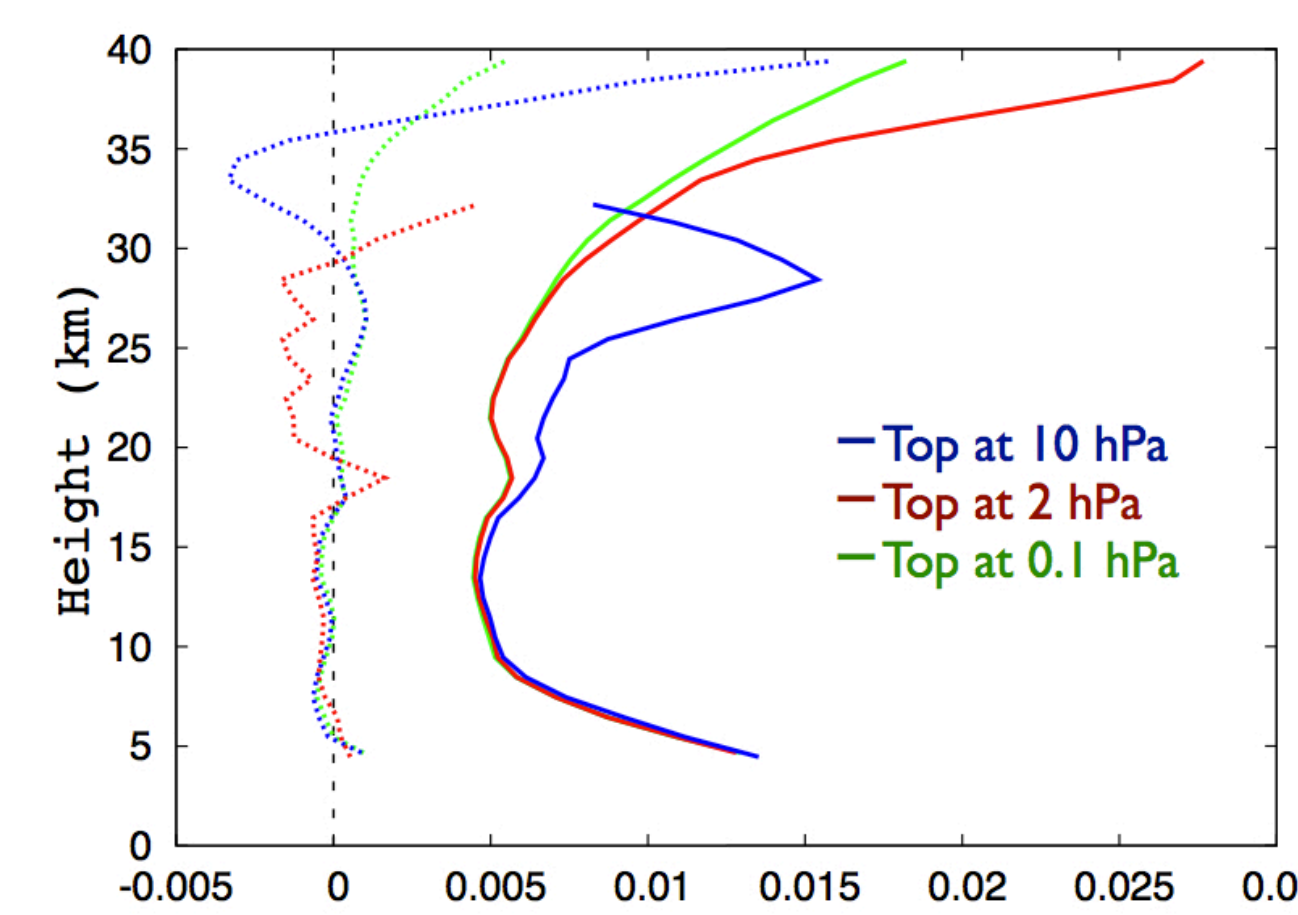
## Impact on 6h forecast of the new configuration

- The dynamics are more realistic in the upper levels.
- AMSU channels up to 12 are assimilated for top at 2 hPa (up to 14 for 0.1 hPa).
- GPS-RO observations up to 40 km are assimilated.
- Non-separable description of the additive isotropic model error.
- Verification against radiosonde observations

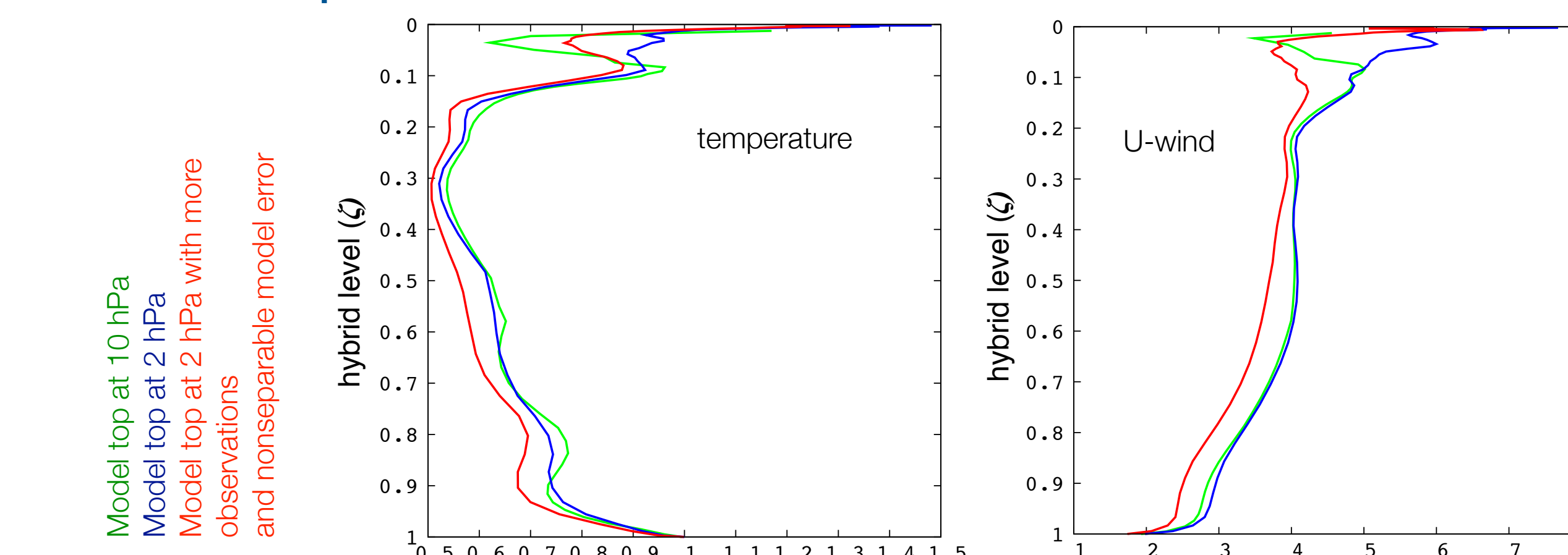


- Overall improvement due to more ensemble members.
- More improvement above 250 hPa due to higher model top.
- No degradation with the same number of ensemble members despite the reduced vertical resolution.

- Verification against GPS observations



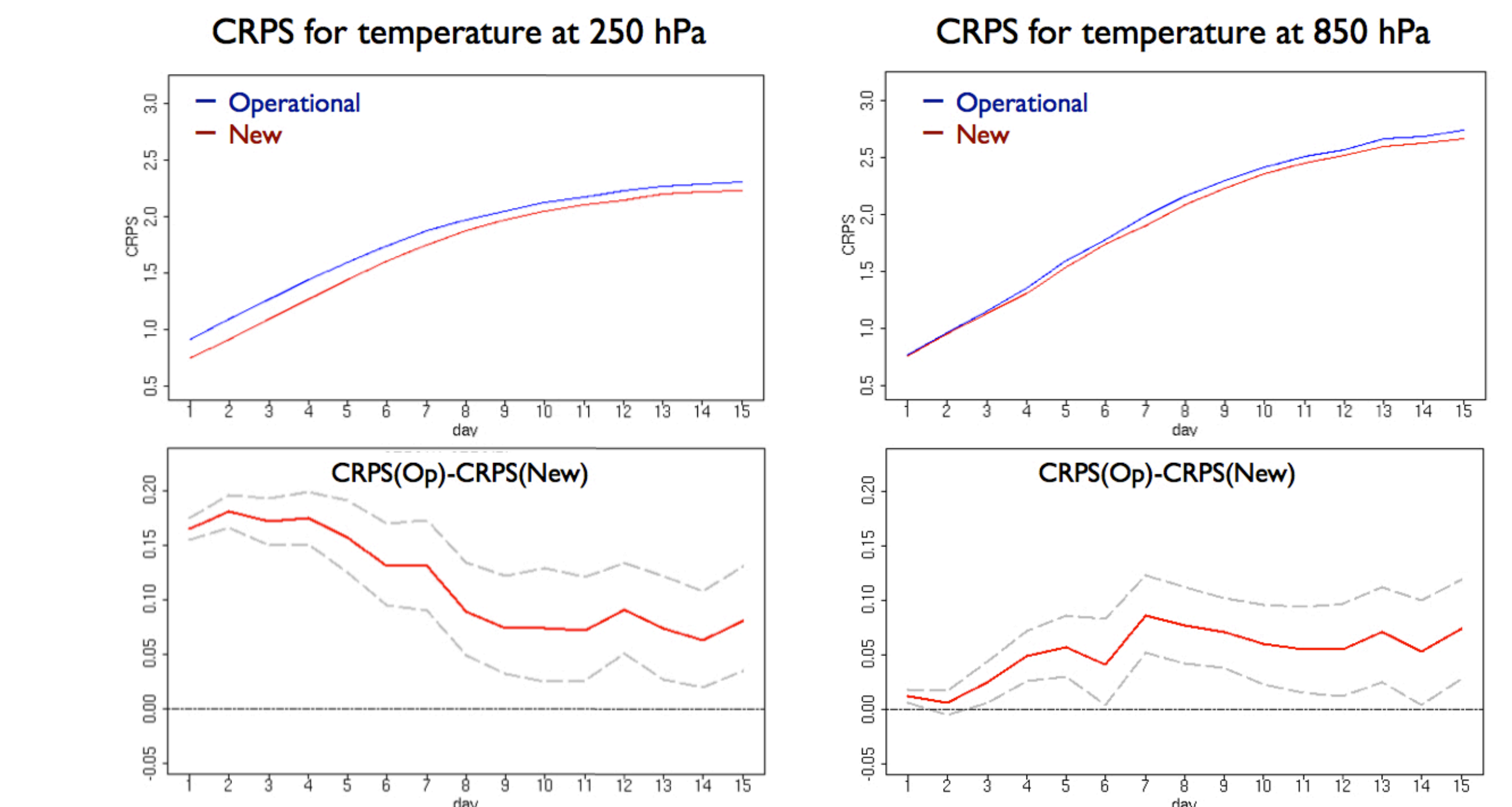
- Ensemble spreads



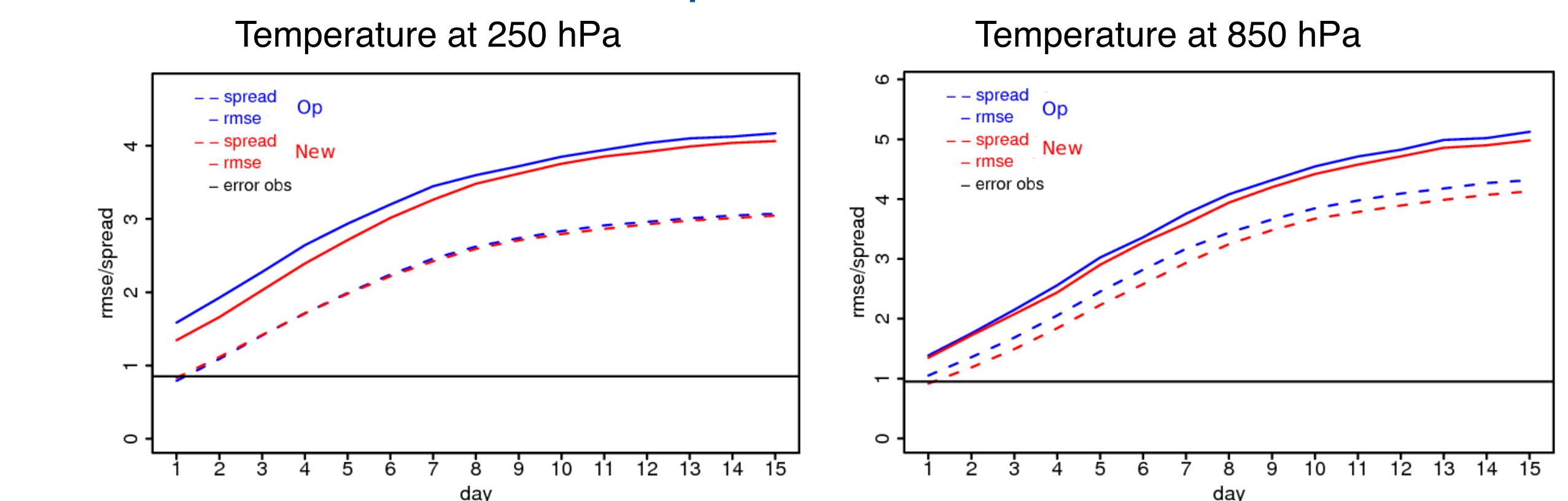
- Ensemble spreads are reduced due to the non-separable additive random error.

## Extended forecast

- Model top at 2 hPa instead of 10 hPa.
- 40 staggered vertical levels instead of 28 non-staggered levels.
- Horizontal resolution of ~66 km instead of ~100 km.
- New radiation scheme and ozone climatology.
- Verification period covers 2009010100 to 2009031512.
- Continuous Ranked Probability Score (CRPS)



- Rms error and ensemble spread



- Improved forecasts throughout the forecast range.
- Significant improvement in the upper layers and less near the surface.
- More improvement in forecast for later days than early days especially at the lower levels maybe due to the improved model dynamics, higher resolution and the propagation from the upper levels.

## 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 and extended forecasts in the radiosonde verification.
- GPS verification shows more improvement in the upper levels as the model top is raised even higher to 0.1 hPa.
- Stochastic kinetic energy backscatter and physical tendency perturbations will be considered to recover the reduced ensemble spread in EnKF to see if it generate further improvement.