ENKF for Global NWP: The experience at ECMWF

5th EnKF workshop

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Thanks to: Jeff Whitaker and many colleagues at ECMWF

ECMWF

Development status of EnKF at ECMWF

- Research activity only, no current plan for operational use
- Uses same model and observation operator as operational 4D-Var system (experimentation performed at lower resolution so far)
- Same observation screening as 4D-Var
- Able to assimilate most observation types (except SCAT and rain-affected radiances)
- Confined to 6-h assimilation window

Research directions pursued so far

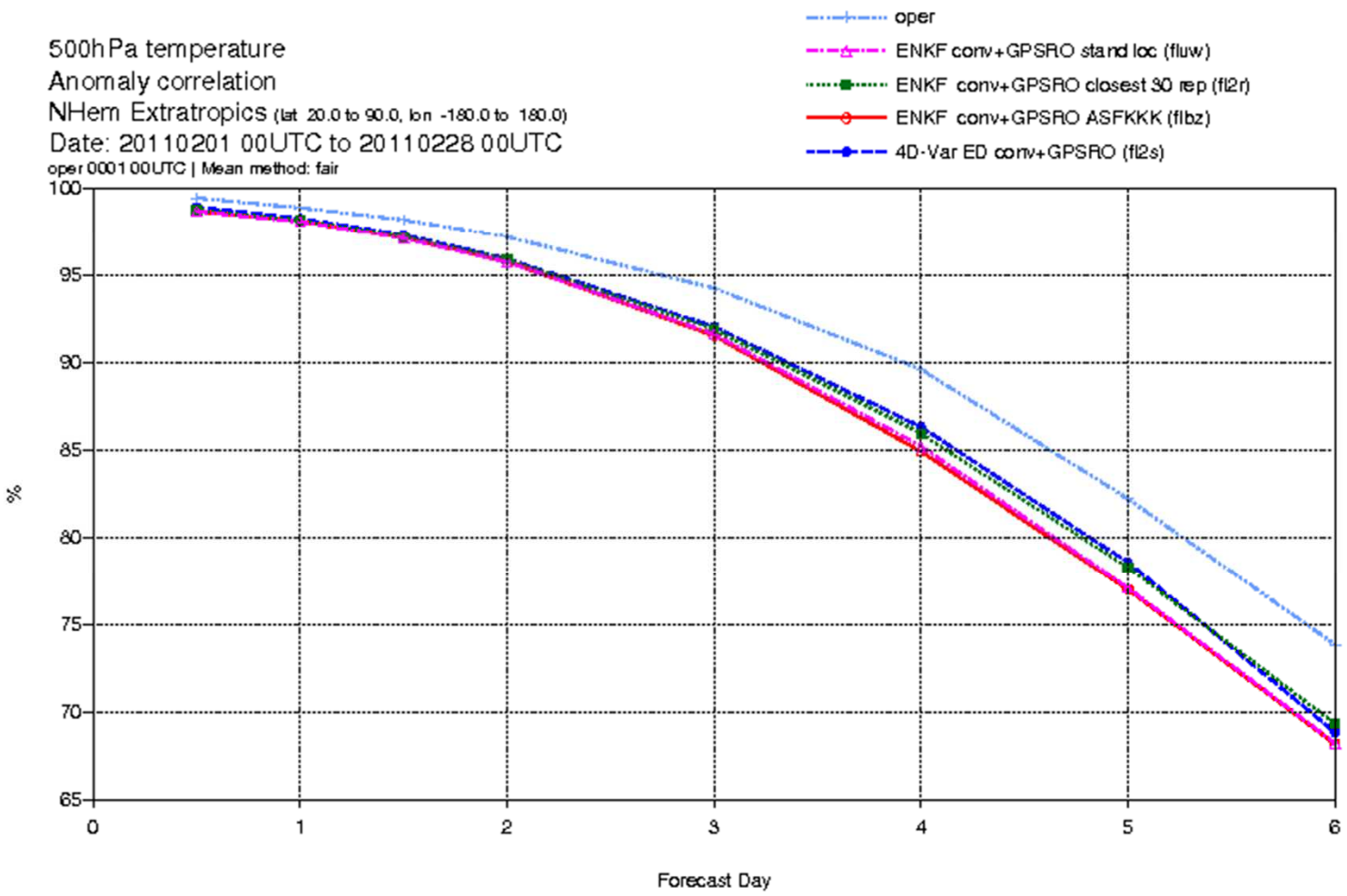
- Covariance Localization (observation selection)
- Various forms of variance inflation
- Imbalances in analysis
- Size of ensemble
- Scale separation

Covariance Localization

- We have experimented with various forms of localization
  - Pure distance based using scale height as vertical distance and Euclidian distance in horizontal, select all observations within cylinder, taper towards edges
  - Select the N closest observations for each report type and variable
  - More complex localization scheme published in literature also taking account of weighting function width for radiance measurements
- No very clear picture has emerged
  - Pure distance based method not very sensitive to selection radius above 1000 km horizontal
  - Vertical localization unavoidable for currently affordable ensemble size
  - Scheme dependence is inconclusive.
- Observation selection very important for cost of ENKF

Localization impact on scores NH

60 member EnKF
Conv. Obs + GPS-RO



Localization impact impact on scores SH

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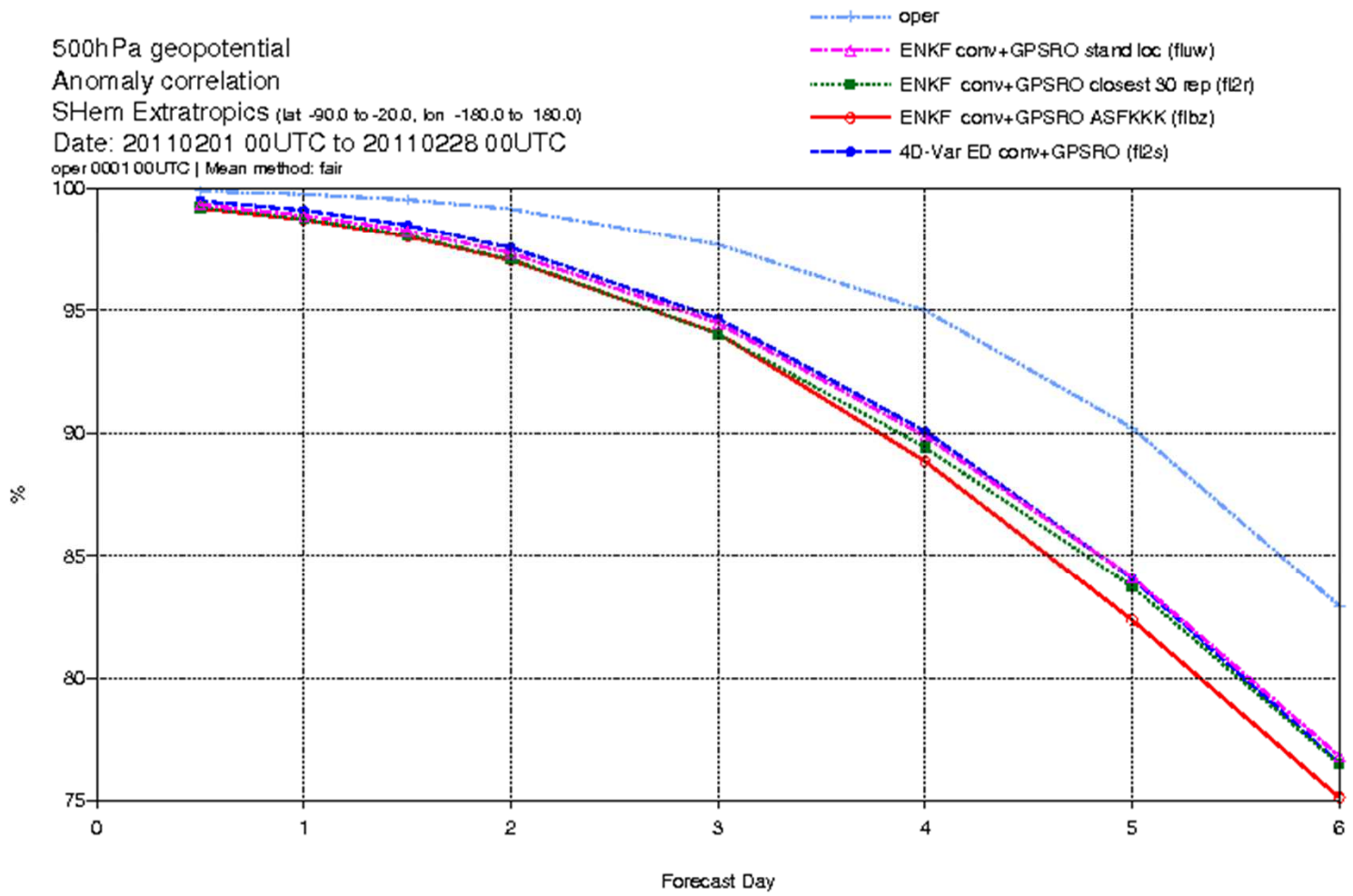


Covariance Inflation

- Without inflation => variance collapse and filter divergence
- Multiplicative inflation
  - Relaxation to prior variance (Whitaker and Hamill - 2012)
- Additive inflation
  - Self evolving using 30h-6h forecasts form ensemble
  - NMC method, scaled 48h-24h forecasts verifying at the same time sampled from operational archive
- Simulate error in forecasts (stochastic physics, backscatter) , similar configuration as in ensemble forecast system
- SST perturbations

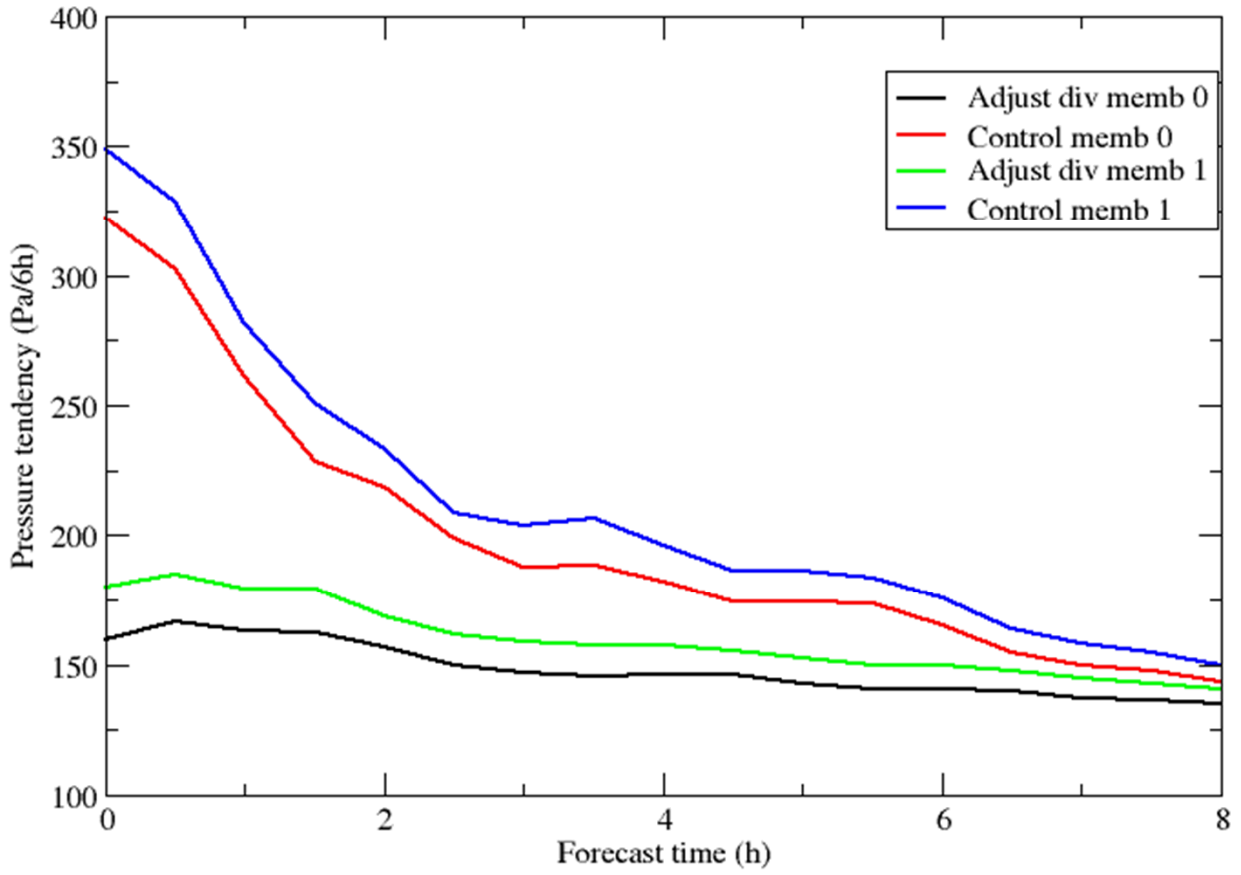
Covariance Inflation results

- Baseline multiplicative inflation (relaxation to prior variance)
- Clear improvement when in combination with additive inflation (NMC or self developing)
- Stochastic physics on top of these adds little (perhaps in the tropics)
- Stochastic physics instead of additive inflation gives worse results
- Additive inflation INSTEAD of multiplicative is not as good as the combination of the two (even when achieving similar spread)
- Results consistent with those obtained by others

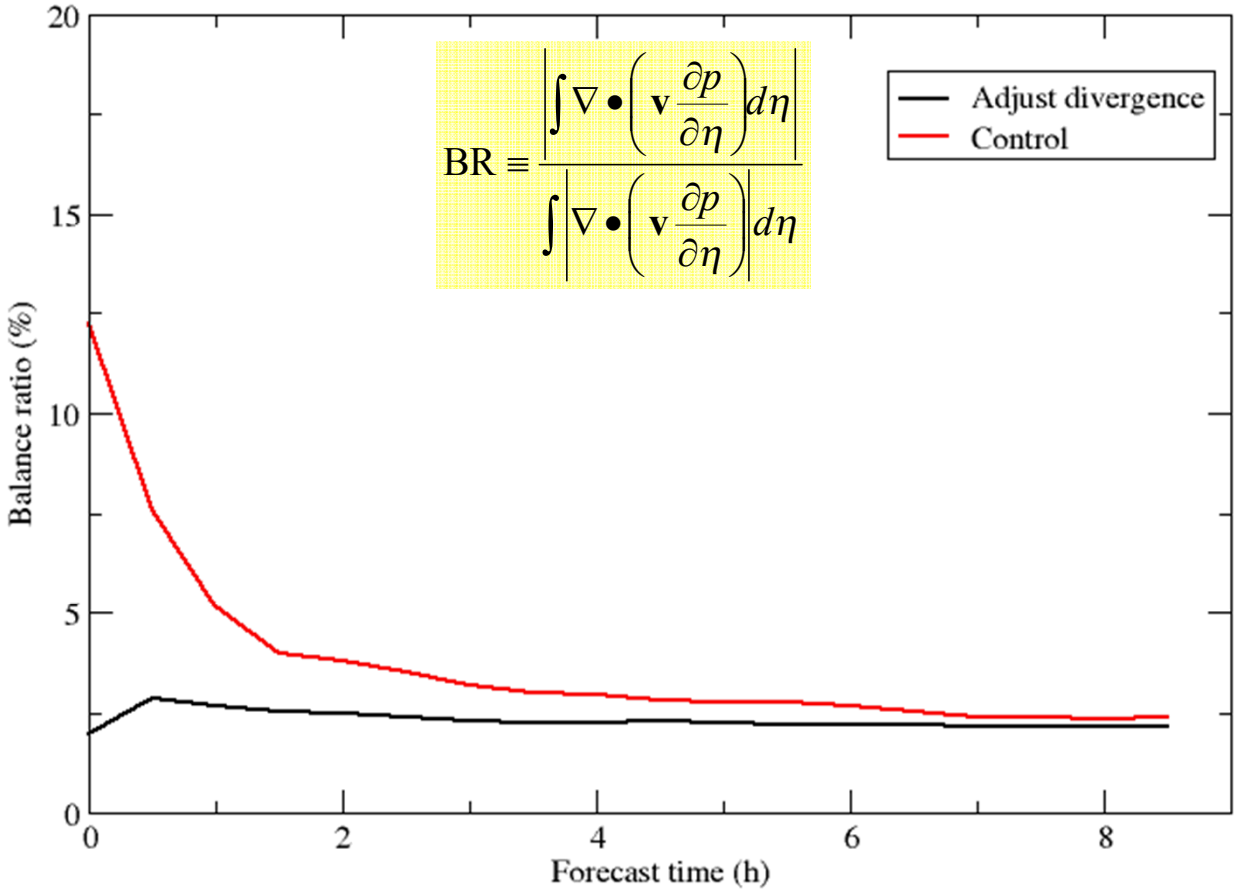
Balance issues

- ENKF produces analysis increments that are not balanced, this is mainly an effect of the localization
- The main imbalance occurs within the vertical column
- Most centres using ENKF also use Digital Filter Initialization (DFI)
- All testing we have done indicate that DFI has a negative impact on forecast quality. We have not tested incremental DFI.
- Analysing the surface pressure tendency and adjusting the divergence within the column gets rid of a lot of the gravity-inertia waves
- Also tried using different analysis variables (normally we use T,u,v,q and ps): this reduced the noise but was detrimental to forecast quality

Absolute surface pressure tendency (global average)



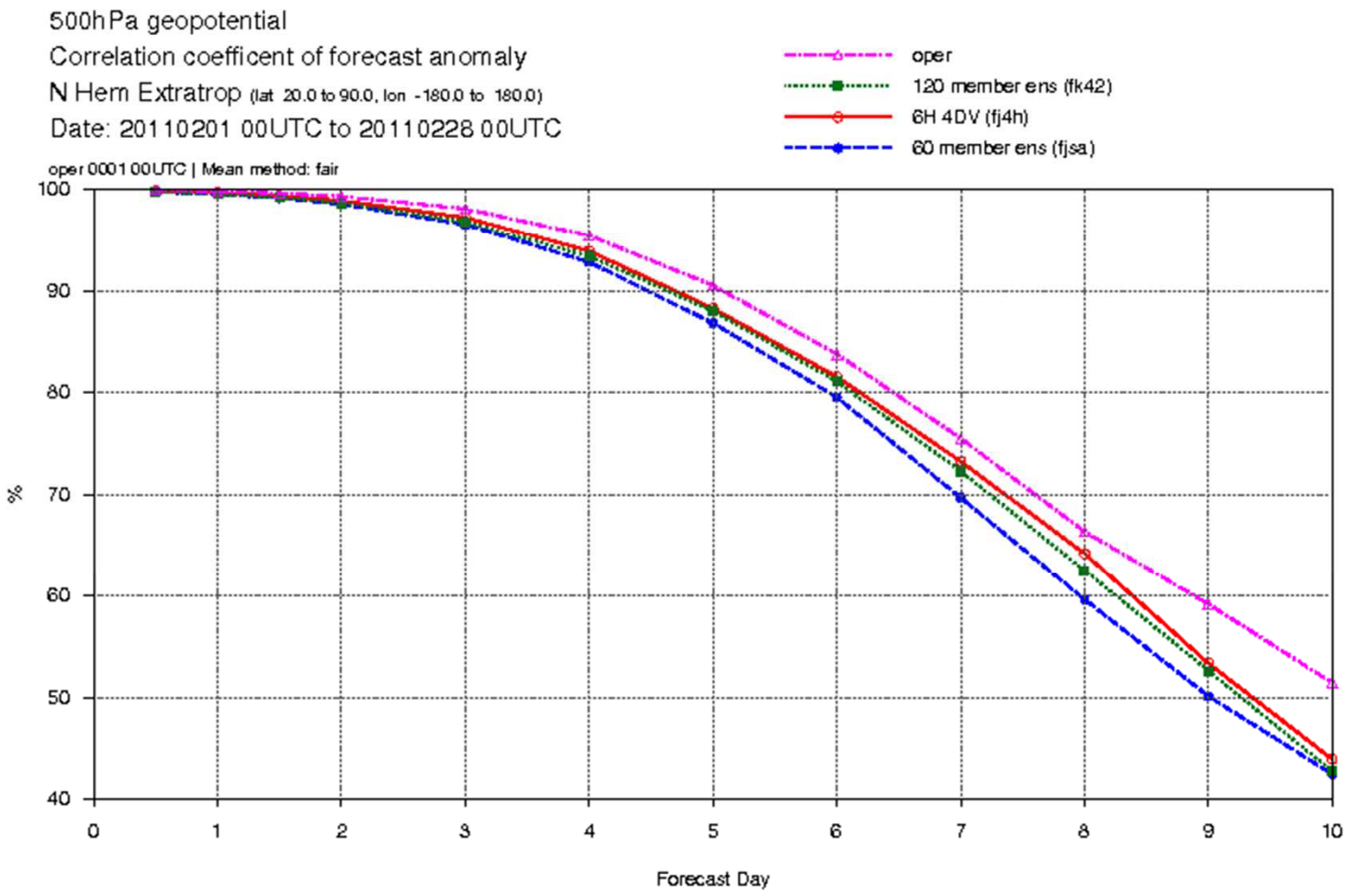
BR showing the effect of cancellation in vertical integration of the continuity equation, 0 total cancellation, 100 none



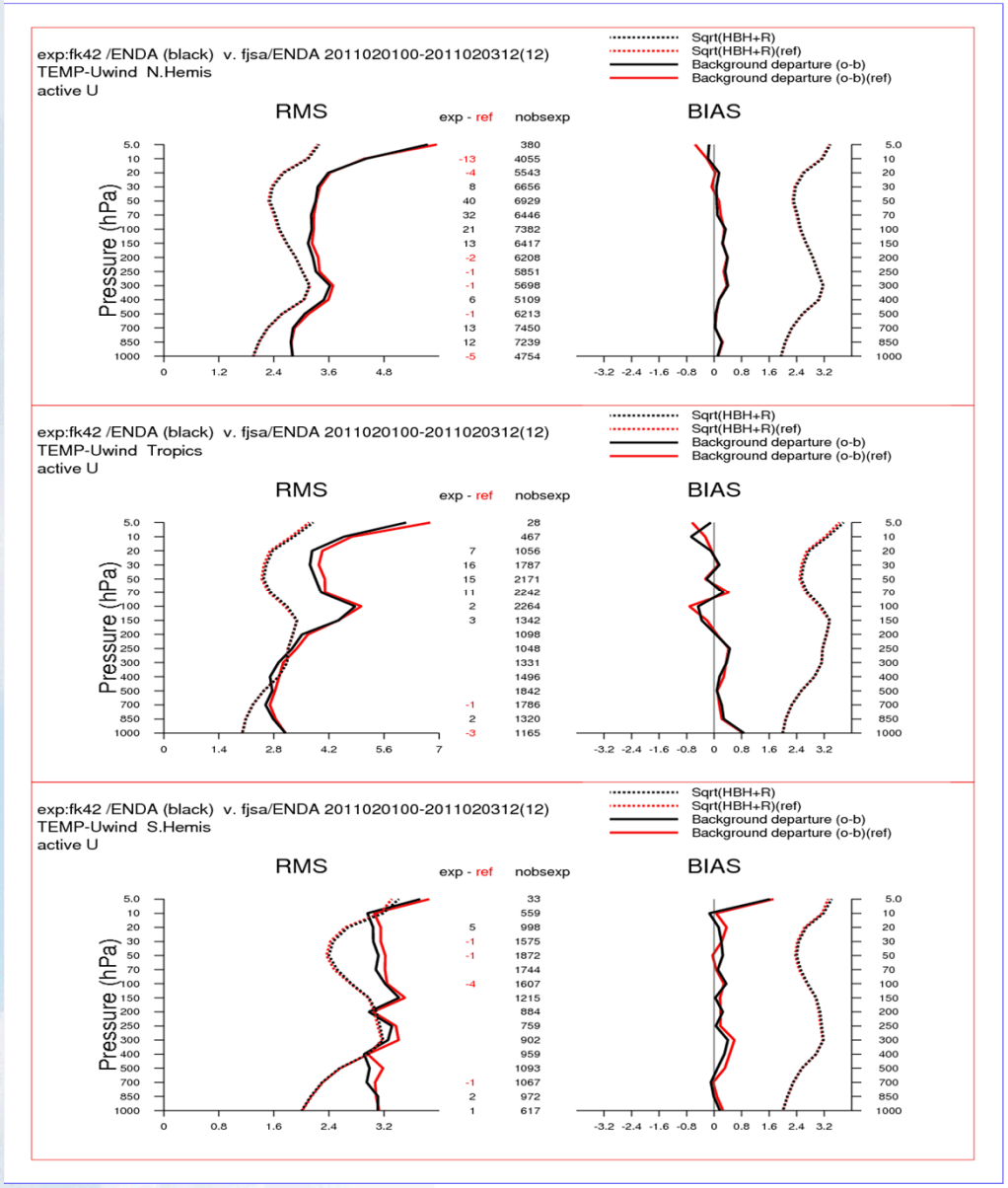
Ensemble size

- Importance of ensemble size
  - Sampling noise
  - Size of subspace for analysis increments
- Tied to localization
- Expensive experimentation, little information in literature for full atmospheric models with comprehensive observation coverage
- One experiment with doubling the ensemble size for 60 to 120 members using the **full observing system**
  - Multiplicative inflation
  - Additive inflation (NMC)
  - Stochastic physics
  - Localization using closest 30 observations for each report type and variable
  - Divergence adjustment

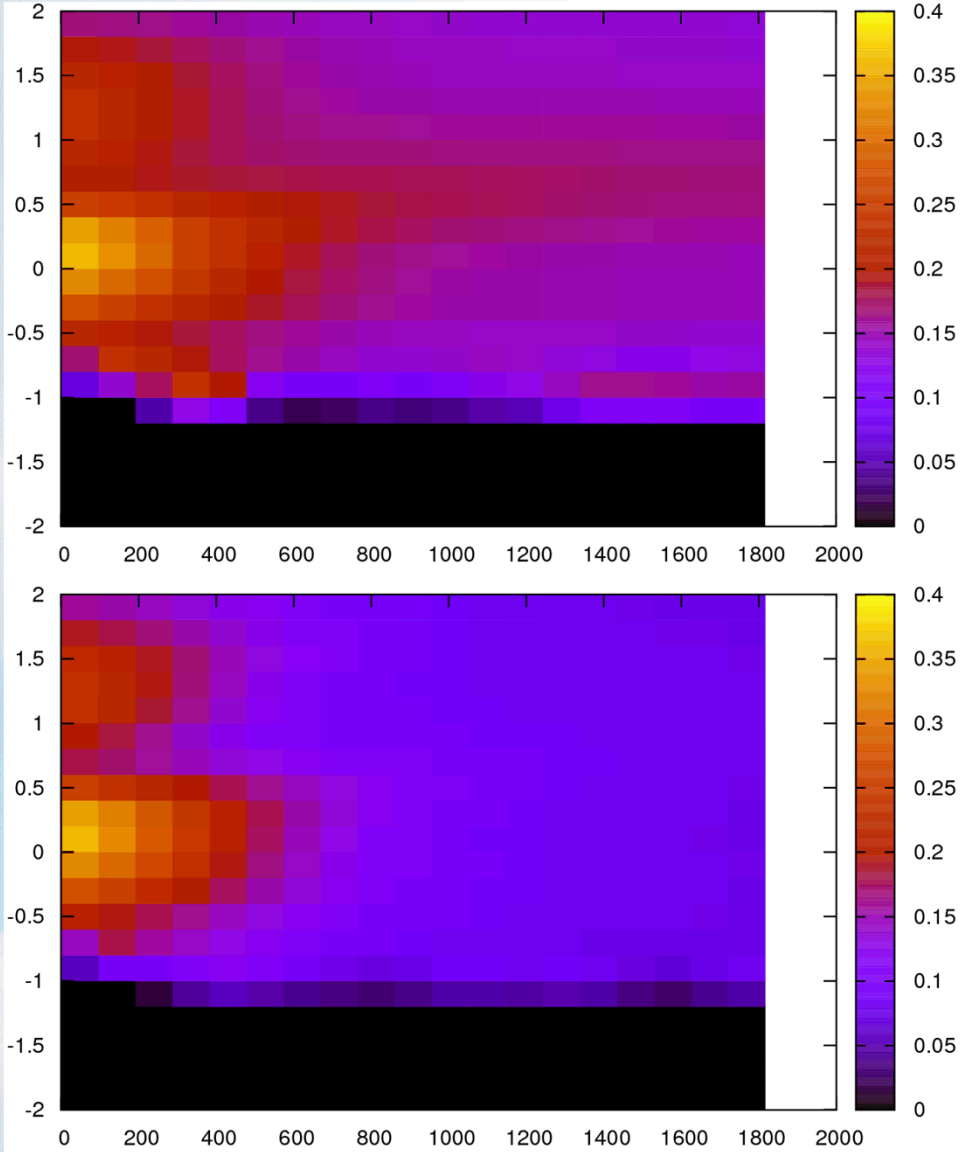
Impact of Ensemble size (all observation types)



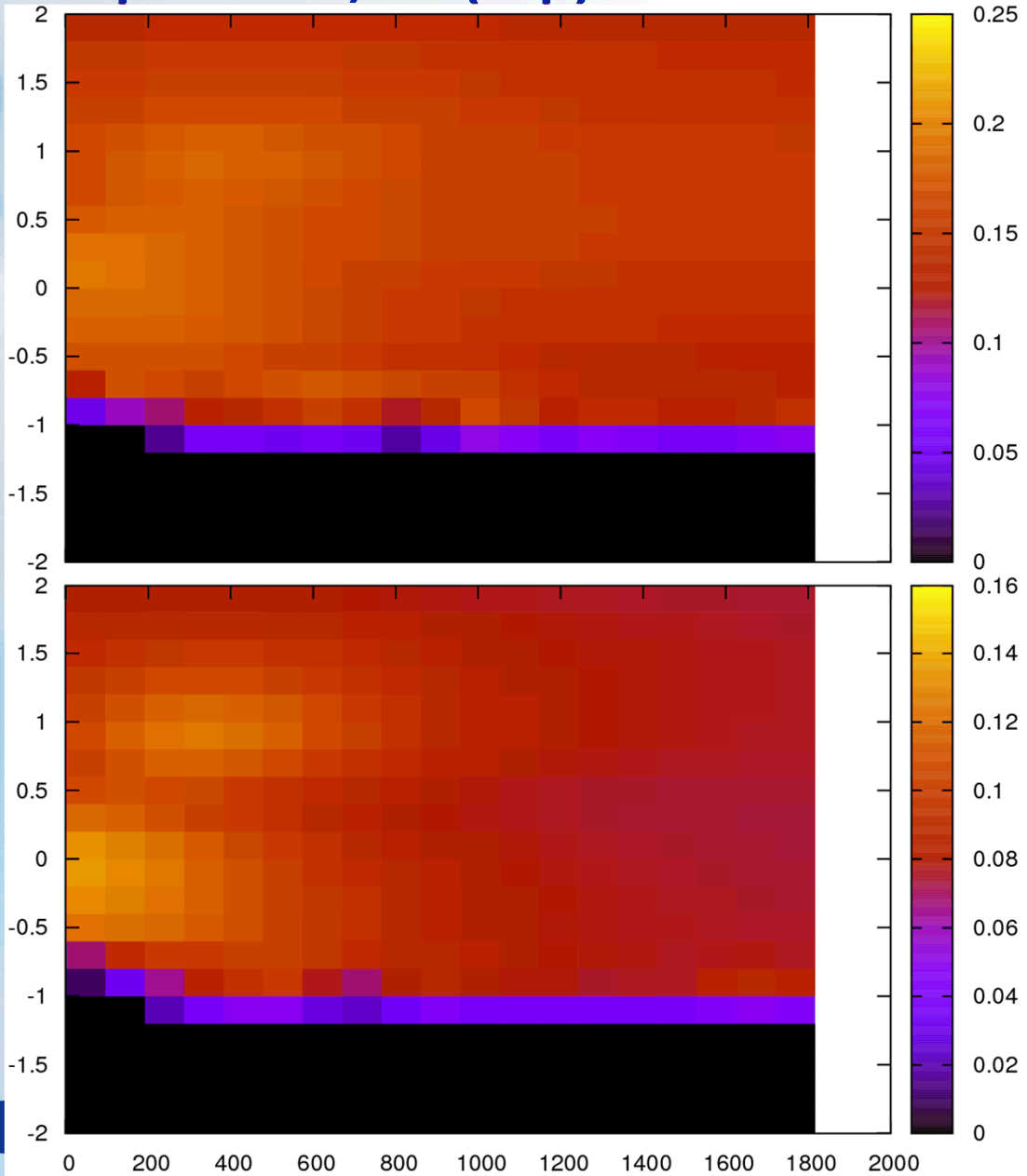
Fit to obs, black 120 members, red 60 members



Absolute correlation between T at 500 mb and Brightness Temperature, 60 (top) and 120 members



Absolute correlation between U at 500 mb and Brightness Temperature, 60 (top) and 120 members (bottom)



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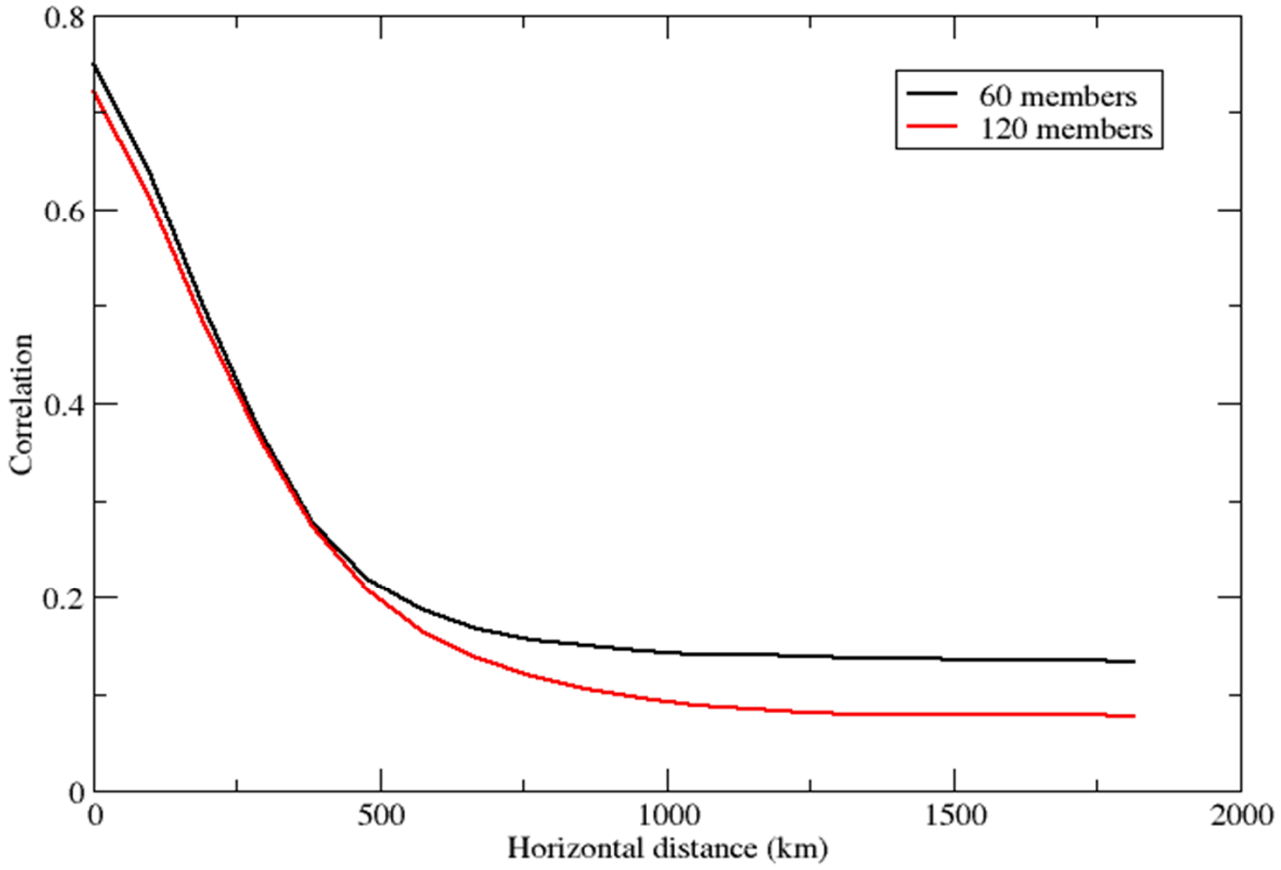
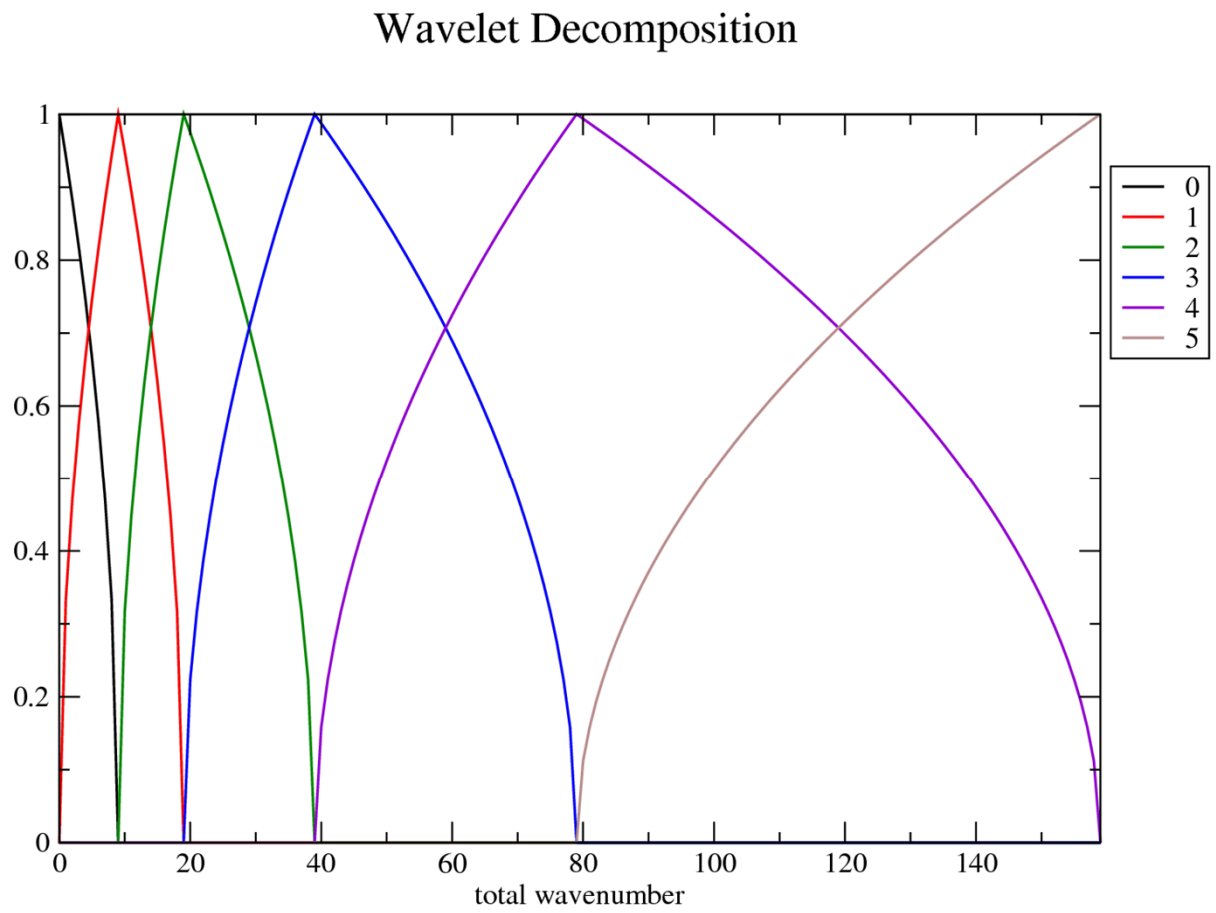
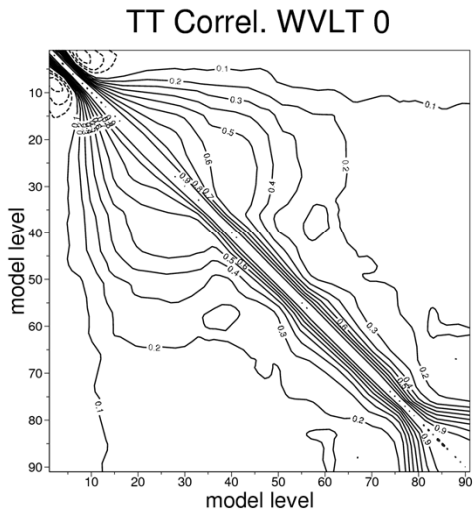
Absolute correlation between model T at 500mb and observations of T at same level

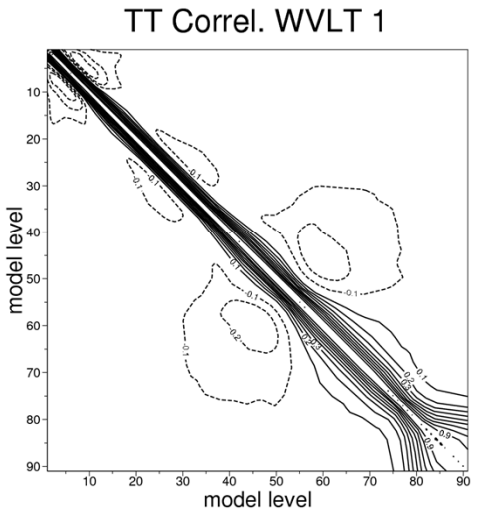


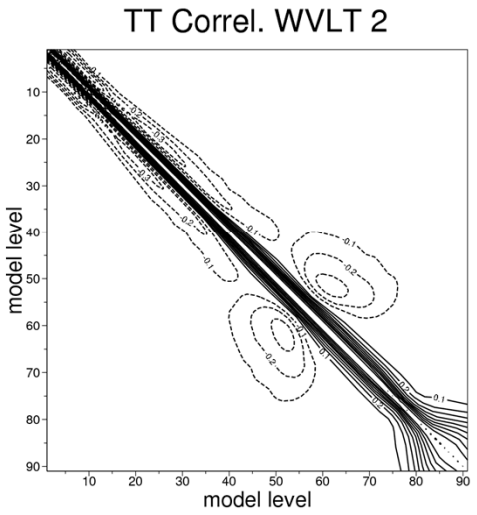
Scale dependent localization

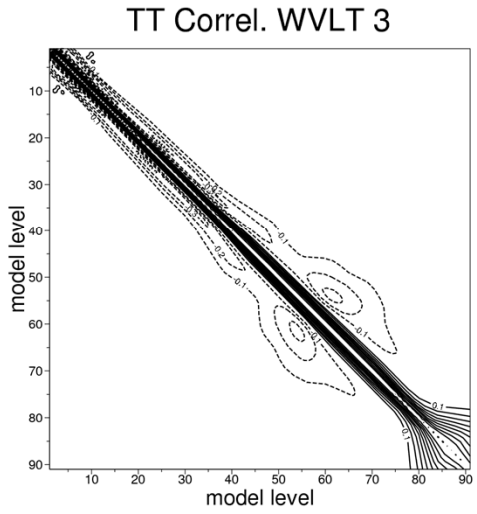


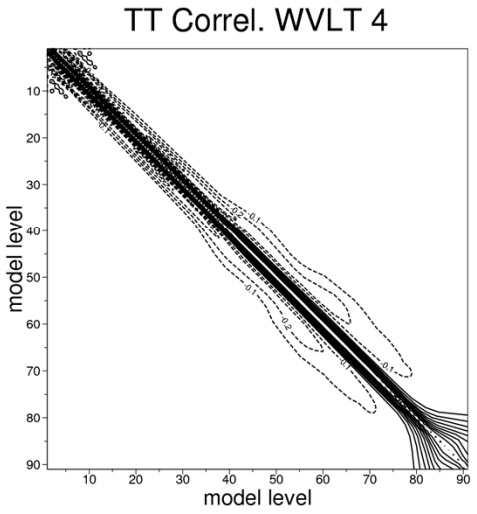
Scale dependent localization

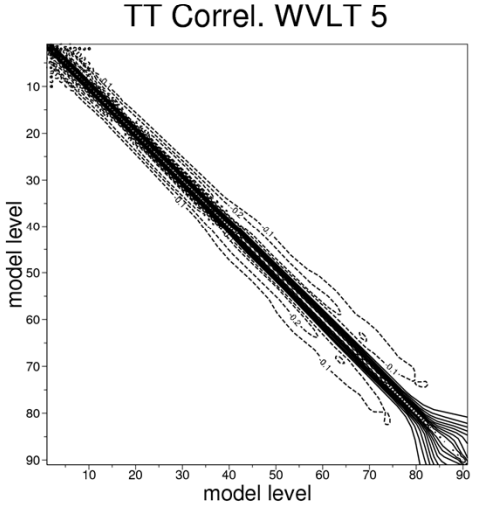












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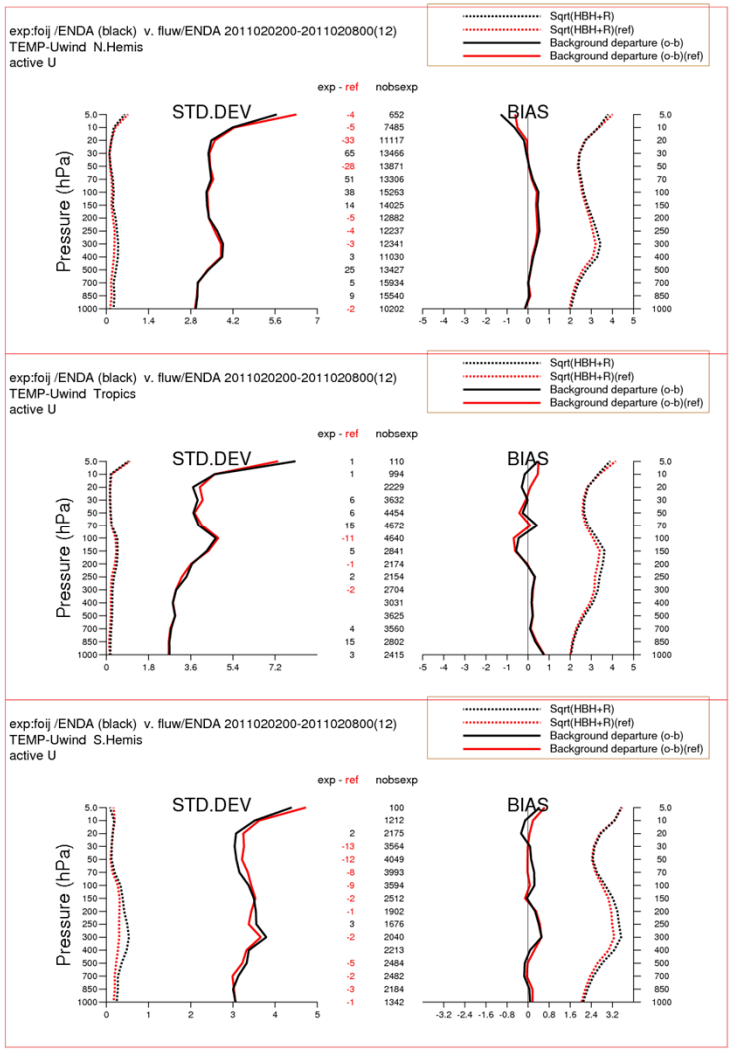
Scale dependent localization

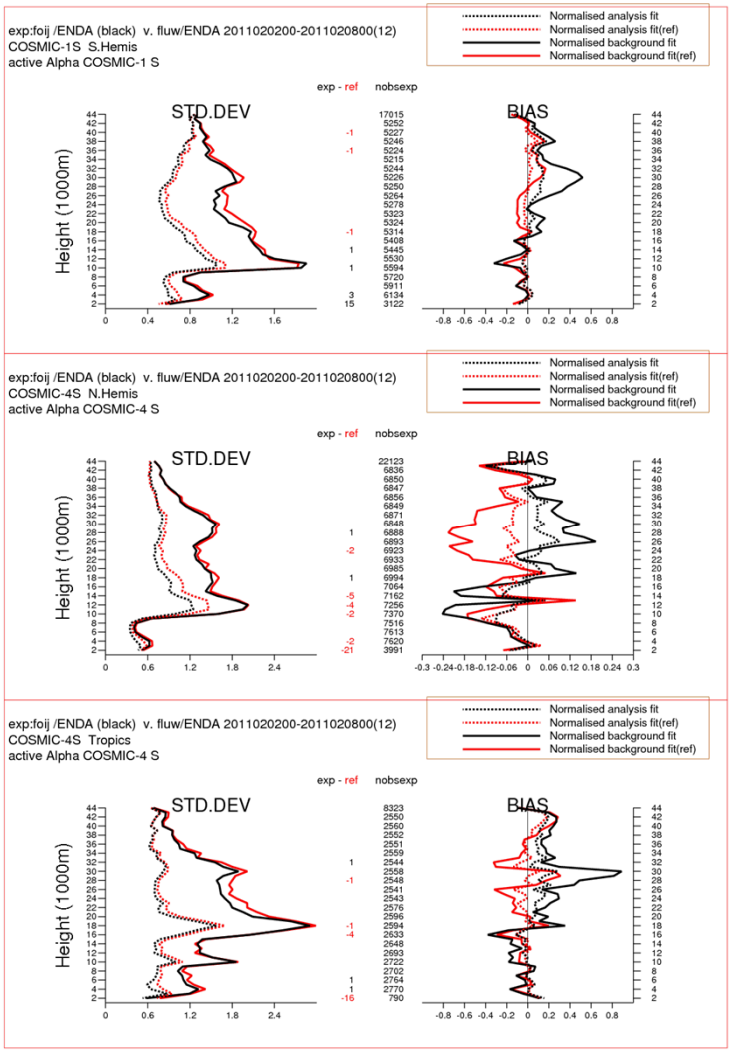
- Perform a wavelet decomposition of background perturbations
- Analyse each wavelet separately with different spatial localizations
- Reconstruct the analysis field summing the wavelet components

Fit to Obs: black Scale dep. Loc. red Standard Loc.

RAOB u-wind



GPS-RO



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Future research directions

- Systematic study of impact of adding satellite observations
  - Localization issues for radiances
  - Observation error retuning for ENKF
- Shorter (3-hour) assimilation window
  - Larger use of continuous observing systems (satellite)
  - More accurate linear evolution of B
- Test of adaptive quality control of observations
- Scale Dependent localization
- Flow-adaptive localization, distance in state-space
- Develop and test adaptive observation bias control