Observation Impact in a Convective-Scale Localized Ensemble Transform Kalman Filter

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Background

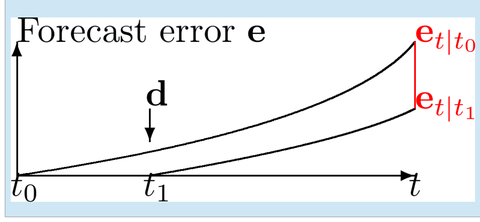
- Knowledge about the impact of observations is crucial to refine and optimize the observing and data assimilation system
- The computational cost of the direct approach to observation impact with data denial experiments is however prohibitively high
- This motivated the development of the Adjoint Forecast Sensitivity to Observation (FSO) tools, which is now implemented at several weather centers
- An adjoint model is not available for the DWD COSMO-DE system, but idealized studies show that ensemble methods can estimate such an impact at a very low computational cost (when the ensemble itself is computed anyway)

Goal

- Estimate the impact of observations (i.e. contribution to the reduction of forecast error) in the future regional ensemble data assimilation system of DWD (KENDA-COSMO)
- Demonstrate the feasibility of the ensemble observation impact estimate in a full NWP system, evaluate the accuracy and investigate limitations
- Perform sensitivity experiments in order to optimize efficiency and accuracy

References: Liu and Kalnay (QJRMS, 2008), Li et al. (QJRMS, 2010), Kalnay et al. (Tellus A, 2012), Sommer and Weissmann (submitted to QJRMS, 2013)

Method



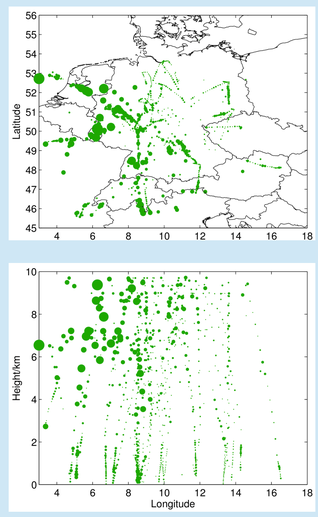
$\mathbf{e}_{t,t_0}$	Error of forecast initialized at t_0
$\mathbf{e}_{t,t_1}$	Error of forecast initialized at t_1
X_f	Forecast ensemble
Y_b	Background ensemble in observation space
$\mathsf{W}(j)$	Weight matrix at grid point j
$\mathsf{R}(j)$	Observation error covariance matrix
$\mathbf{d}$	Observation innovation

Data denial impact $$J = \frac{1}{2}\left(|\mathbf{e}_{t,t_1}|^2 - |\mathbf{e}_{t,t_0}|^2\right)$$

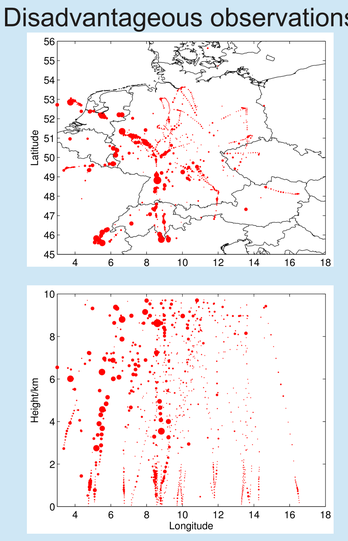
Approximated impact: $$J \approx \frac{1}{2}\frac{1}{N-1}\sum_j \left(\mathbf{e}_f^{\mathbf{d}} + \mathbf{e}_f^{\mathbf{0}}\right)_j \left(\mathsf{X}_f^{\mathbf{d}}\right)_j \left(\mathsf{Y}_b^{\mathbf{d}}\mathsf{W}^{\mathbf{d}}(j)\right)^{\mathsf{T}} \mathsf{R}(j)^{-1}\mathbf{d}$$

Spatial distribution of impact at forecast time 6 hours

Beneficial observations

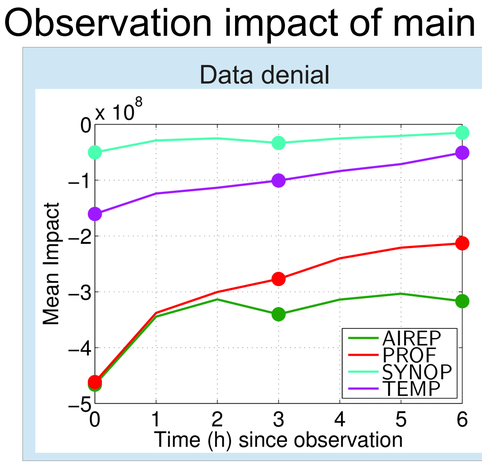


Disadvantageous observations

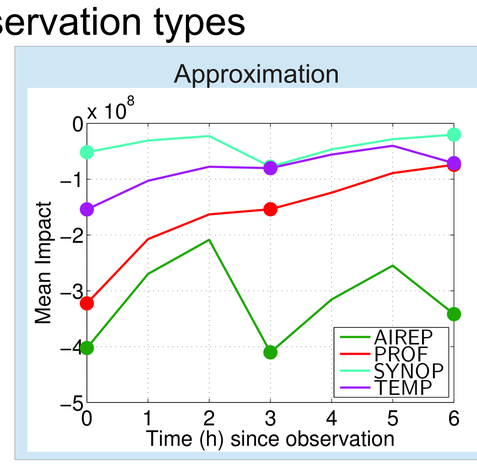


Observation impact of main observation types

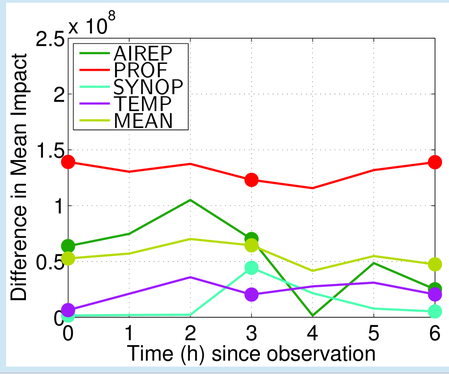
Data denial



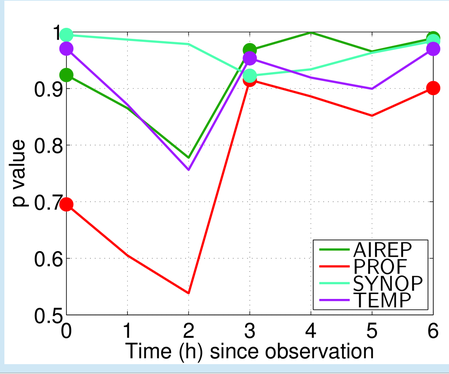
Approximation



Difference Data denial - Approximation

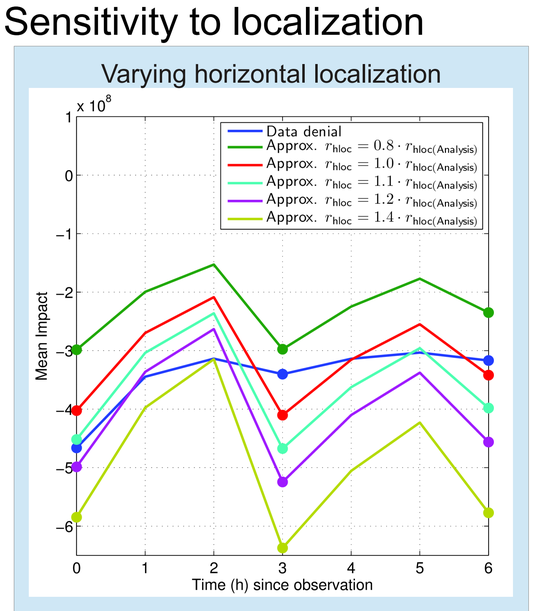


P-values of observed difference

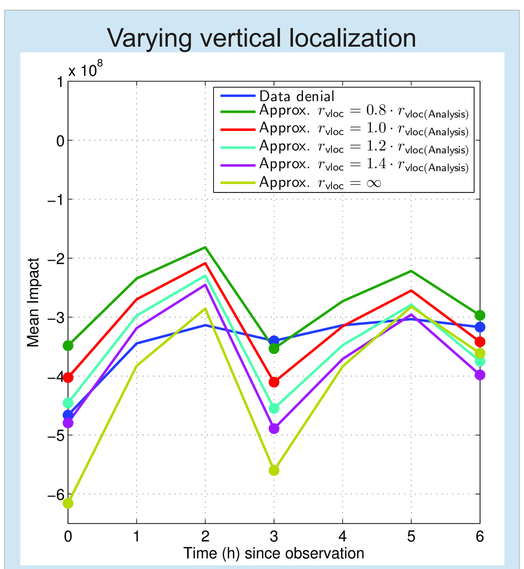


Sensitivity to localization

Varying horizontal localization

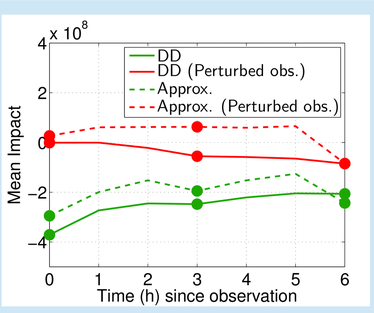


Varying vertical localization

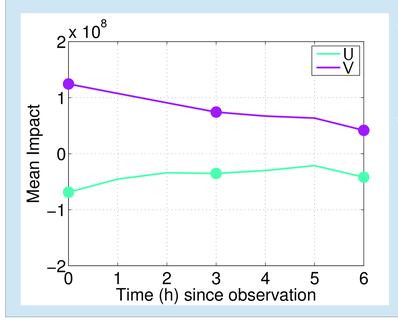


- Localization in impact estimation can be chosen independently from the analysis localization
- In experiments with varying horizontal and vertical localization radii, only shifts but no qualitative changes in the impact estimation were observed
- The optimal configuration was found to be a static localization with the same localization radius as in the calculation of the analysis

Sensitivity to observation perturbations

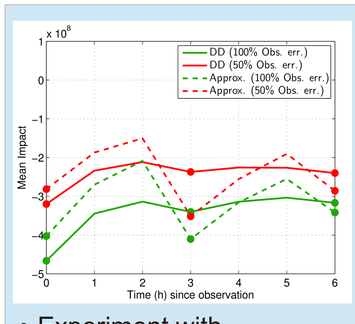


- Experiment with perturbed v-wind observations
- Impact reduction by perturbations in data denial
- Effect of perturbations correctly reproduced in approximation

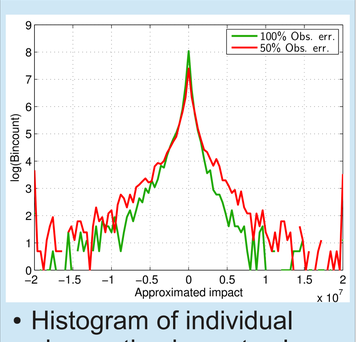


- Approximation allows for an efficient breakdown of total observation impact
- Disadvantageous contribution of v-wind component observation correctly attributed by approximation method

Sensitivity to assumed observation error



- Experiment with unrealistically small observation error (50%)
- Data denial (solid lines) shows reduced impact
- Suboptimal use correctly detected by approximation (dashed lines)



- Histogram of individual observation impact values shows increased spread but...
- … reduced impact in experiment with modified observation error, in agreement with data denial results

Status and outlook

- The method of Kalnay et al. 2012 was applied to a experimental convective-scale data assimilation and forecasting system
- Data denial and sensitivity experiments with 10 6-hourly forecast and assimilation cycles were performed
- In a comparison to data denial experiments, it is demonstrated that the approximation method can efficiently estimate the impact of different conventional observations on a 6h-forecast when averaged over 10 cycles
- The observed differences between approximation and data denial were not statistically significant
- The method was sensitive to perturbations in observation subgroups and suboptimal use of observations
- Best results were achieved with the localization length scale taken equal to the one used in computing the analysis
- In future studies, more extended periods and more complex observation types shall be investigated