# OBSERVATION IMPACT IN A CONVECTIVE-SCALE LOCALIZED ENSEMBLE TRANSFORM KALMAN FILTER

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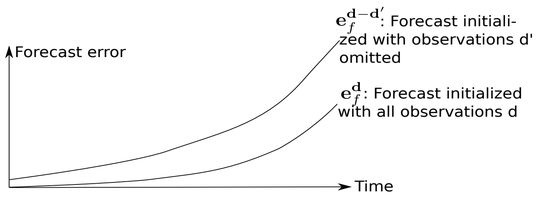
## BACKGROUND

• 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 are 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).

## METHOD

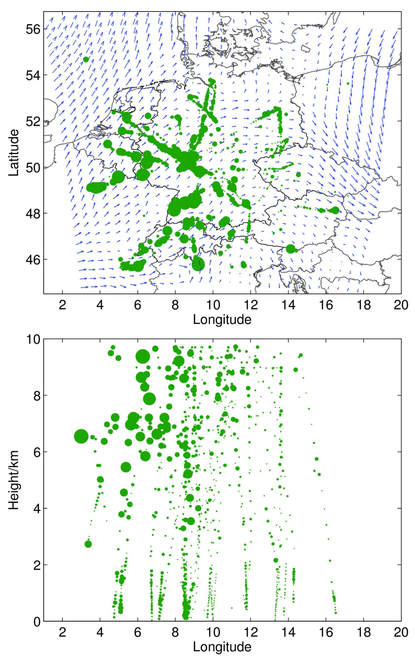



$\mathbf{e}_f^{\mathbf{d}}$ : Error of forecast initizalized with observations d,
$\mathrm{Y}_b$ : Background ensemble perturbations in observation space,
$\mathrm{Y}_f$ : Background ensemble perturbations in observation space,
$\mathrm{W}(j)$ : Weight matrix at grid point $j$,
$\mathrm{R}(j)$ : (Diagonal) observation covariance matrix localized around grid point $j$,
$\mathbf{d}$ : Observation innovation vector.

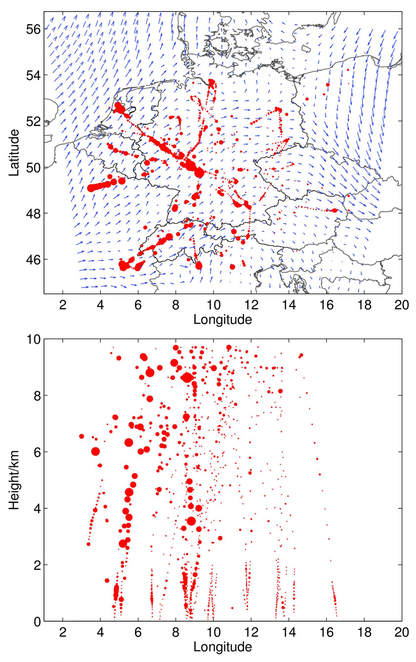
Data denial impact $$J(\mathbf{d}') = \frac{1}{2}\left(|\mathbf{e}_f^{\mathbf{d}}|^2 - |\mathbf{e}_f^{\mathbf{d}-\mathbf{d}'}|^2\right)$$

Approximated impact $$J'(\mathbf{d}') \approx \frac{1}{2}\frac{1}{N-1}\sum_j \left(\mathbf{e}_f^{\mathbf{d}} + \mathbf{e}_f^{\mathbf{d}}\right)_j \left(\mathrm{Y}_f^{\mathbf{d}}\right)_j \left(\mathrm{Y}_b^{\mathbf{d}}\mathrm{W}^{\mathbf{d}}(j)\right)^T \mathrm{R}(j)^{-1}\mathbf{d}'$$

## SPATIAL DISTRIBUTION OF IMPACT AT FORECAST TIME 6H




Beneficial observations




Disadvantageous observations

• The forecast time is 6 h from initialization at 0900 UTC on 8 August 2009

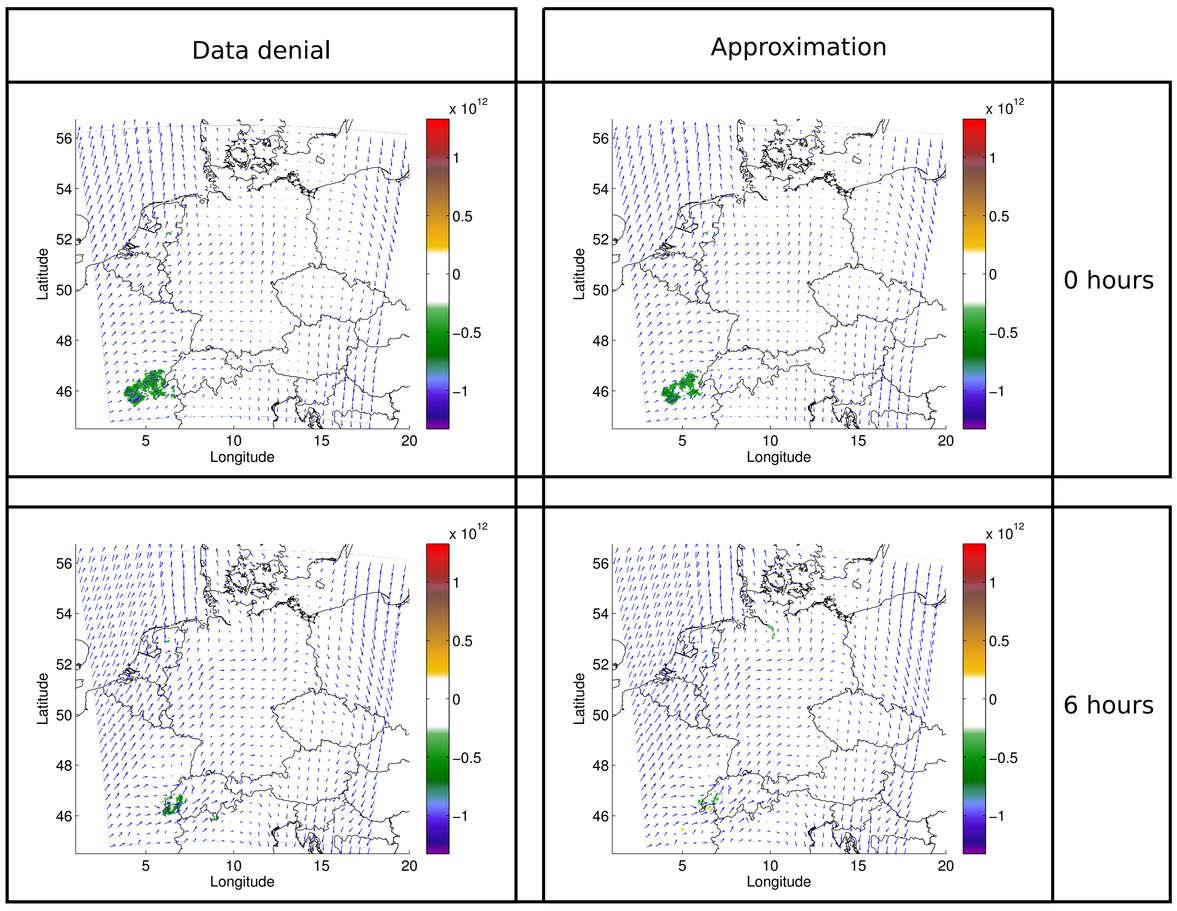
• The marker size is proportional to impact values.

• Ratio of number of beneficial to disadvantageous observations is 54:46.

• No specific region of bad observation impact can be identified at a single point of time.

• Method is required to be averaged over many cycles.

## PROPAGATION OF IMPACT IN SPACE




• The propagation of aircraft impact is well reflected in the approximation.
• In 6 hours, the impact stays within the localization domain, no adaption is therefore needed.

## 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)
• Further refinement of the approximation applying Taylor expansion of observation impact.
• Use verification with observations instead of analysis in model space.
• Consider the value of observations in the combined data assimilation and forecast system.

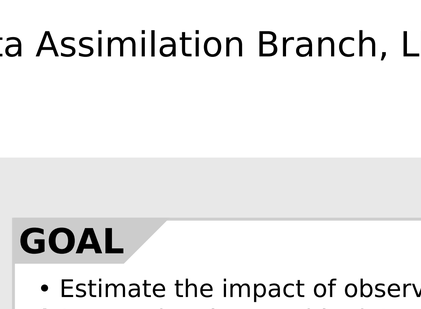
**References**: Liu and Kalnay (QJRMS, 2008), Li et al. (QJRMS, 2010), Kalnay et al. (Tellus A,2012), Sommer and Weissmann (QJRMS, 2014)

## IMPACT OF MAIN OBSERVATION TYPES

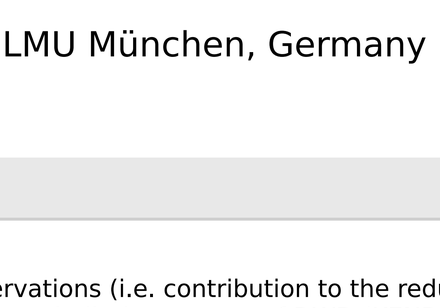

Data denial time series


Approximation time series

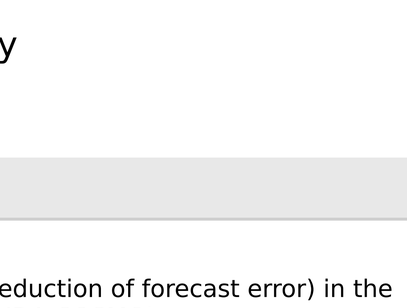

Histogram of approximated impact values




Mean (Verification with analysis in model space)

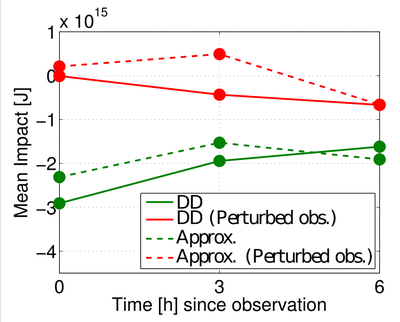



Mean (Verification with observations, refined approximation)

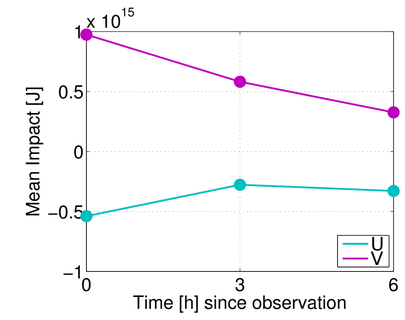



Mean (Verification with observations, original approximation)

## SENSITIVITY TO OBSERVATIONS PERTURBATIONS




Mean impact of unperturbed and perturbed observations

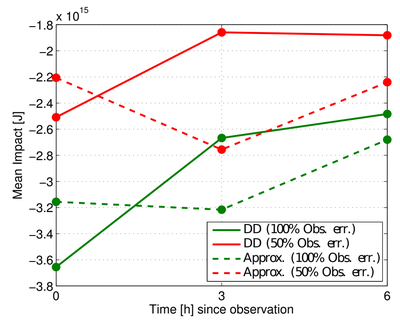



Impact specific to wind components (U: unperturbed, V: perturbed)

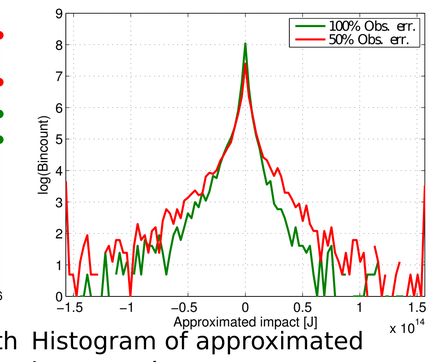
• With perturbations in one wind component (V), the total impact diminuishes both in data denial and approximation

• The approximation correctly associates the disadvantageous impact to the perturbed observations.

## SENSITIVITY TO ASSUMED OBSERVATION ERROR




Mean impact of assimilation with 100% and 50% of operationally used observation error




Histogram of approximated impact values

• An experiment with a reduced (50% of operationally assumed observation error) shows reduced impact.

• This result is well reflected in the approximation.

• The spread in impact values increases as expected.

## STATUS AND OUTLOOK

• The method of Kalnay et al. (2012) was applied to an 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.
• The method has been further improved by using a proper Taylor expansion of data denial observation impact expression.
• Instead of an analysis, independent observations are now used for computing observation impact.
• In future studies, more extended periods and more complex observation types (e.g. satellite observations) shall be investigated.