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The role of observation and background errors for reconstructing localized features from local and non-local observations

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Research at the German Weather Service aims at exploring and optimizing the capabilities of its current and future data assimilation (DA) systems. One focus is the currently developed Ensemble Transform Kalman Filter for which an adaptive localization method has been developed. While a simple empirical version of this adaptive localization has been implemented in the numerical weather prediction model, research aiming at a better understanding of its theoretical basis is carried out.

Another part of research (which is the main topic of this talk) addresses the extent to which spatially localized information can be reproduced by current DA systems. This work assumes that the analysis state is defined as the minimum of a quadratic cost function (which applies to both variational and ensemble DA methods). It is motivated by the large volume of non-local measurements obtained from (mainly space borne) passive remote sensing data. Since these observations can be locally very dense (as for hyperspectral sounders) they could, in principle, provide accurate information about spatially localized atmospheric features if the corresponding observation errors were sufficiently small.

This work discusses how finite observation errors (for given background error statistics) degrade the spatial resolution of the analysis state obtained from such locally dense observations. For this it expands the cost function minimum into a weighted sum over pseudo inverse (PI) solutions each of which corresponds to a different subset of the available observations (i.e., only a subset of the observations is considered for each of these terms, respectively). Observation errors occur only in the weighting factors of this expansion and therefore determine the extent to which observational information is included in the analysis state. More precisely, the weighting factors of the different PIs can be written in terms of normalized observation errors and the determinant of a correlation matrix which characterizes the overlap of the corresponding observation operators. The presented mathematical results are illustrated with a simple model problem which explicitly shows how the reconstruction of a localized feature depends on observation errors as well as the observation operators' overlap.

The findings of this work generally demonstrate that large observation errors do not only decrease the overall weight which the respective observations obtain in the DA process, they especially reduce the DA systems capability to obtain spatially localized information. Small observation errors are particularly important when processing strongly non-local observations as they are typically obtained from passive remote sensing measurements. These have the potential to smear out signals from localized sources over large regions in model space. Generally, observation errors have to be smaller the more the respective observation operators overlap.