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Correction of non-additive errors in variational and ensemble data assimilation using image registration

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It is hard to forecast the position of localized weather phenomena such as clouds, precipitation, and fronts. Moreover, cloudy areas are important since this is where most of the active weather occurs. Position errors, also known as phase or alignment or displacement errors, can have several causes; timing errors, deficient model physics, inadequate model resolution, etc. Furthermore, position errors have been shown to be non-additive and non-Gaussian, which violates the error model most data assimilation methods rely on.

Remote sensing data contain coherent information on the weather development in time and space. By comparing structures in radar or satellite images with the forecast model state it is possible to get information about position errors. We use an image registration (optical flow) method to find a transformation, in terms of a displacement field, that aligns the model state with the corresponding remote sensing data. In particular, we surmise that assimilation of radiances in cloudy areas will benefit from a better aligned first guess. Analysis perturbations should become smaller and be easier to handle by the linearizations in the observation operator.

In the variational setting the displacement field is used as a mapping function to obtain a new, better aligned, first guess from the old one by means of interpolation (warping). To reduce the effect of imbalances, the aligned first guess is not used as is. Instead it is used for generation of pseudo observations that are assimilated in a first step to get an aligned and balanced first guess. This step reduces the non-additive errors due to mis-alignment and is followed by a second step with a standard variational assimilation to compensate for the remaining additive errors.

In ensemble data assimilation a displacement field is estimated for each ensemble member and is used as a distance measure. In areas where a member has a smaller displacement (smaller position error) than the control it is given an increased weight in the subsequent assimilation. It is also possible to first obtain an aligned and balanced first guess based on variational assimilation of super observations from a composite consisting of information from the best member (least position error) in each grid point.

In our ensemble data assimilation experiments we have used a hybrid variational data assimilation that has been developed on top of the HIRLAM variational data assimilation system. It provides the possibility of utilizing, during the data assimilation process, the error-of-the-day structure of the forecast error covariance, estimated from the ensemble of perturbations, at the same time as the full rank of the variational data assimilation is preserved.

Results are presented from experiments done with both variational and ensemble data assimilation systems using synthetic as well as real satellite data from the SEVIRI instrument.