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Rapid observation system experiments for the observation impact in the ensemble space

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We propose a methodology of "rapid observation system experiments" (ROSEs) to make data assimilation experiments comparable. In ROSEs, the analyzed state is not propagated to the next background state. Instead, the next background state is approximated by the state of a base trajectory at the same time, which needs to be constrained. The base trajectory is not affected by the experiments and we therefore generate an analysis without influencing the forecast trajectory. For every experiment, the analysis is based on the same background due to this replacement. Thus, we neglect the influence of old observations on the analysis and the experiments are comparable. As side effect, the ensemble members in the forecast trajectory are traceable and we therefore can examine the behavior of the members in ensemble space. In ensemble Kalman filters, the propagation is the computational more expensive step compared to the analysis update. In our proposed ROSEs, the propagation step is omitted and therefore, the experimentation is sped up compared to observation system experiments (OSEs).

To examine the observation impact, we exploit the ensemble space of ensemble transform Kalman filters (ETKF). The observation impact of the data assimilation on the analyzed variance can be expressed by the degrees of freedom. Here, we propose the degrees of freedom in ensemble space as extension to the existing degrees of freedom definitions. We show that the degrees of freedom in ensemble space can be understood intuitively and that they are computational cheaply to calculate with the eigenvalue decomposition of ETKFs. The degrees of freedom can be seen as potential observation impact on the analysis, which is converted into measurable observation impact with the innovations. The measurable observation impact is naturally described by the analyzed increment in ensemble space, which can reveal connections in the weighting of the ensemble members for different experiments. Thus, the measurable observation impact can be expressed as similarity of the given increment to a reference increment. In ROSEs, the observation impact can not be stated with absolute values because the background covariances are wrongly specified. Instead, we can compare different experiments such that we can state the observation impact by relative values.

In comparison to OSEs, we show that the observation impact can be estimated with our proposed tools, which can also reveal interesting connections between different ensemble members. Thus, they are a promising way to examine the observation impact, especially for ETKFs.