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Measures of observation impact in non-Gaussian data assimilation

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Non-Gaussian/non-linear data assimilation is becoming of increasing interest in the Geosciences. This is due, in part, to the models and the observation operators becoming more non-linear. We set out to answer the following question: what is the effect of relaxing the assumptions of Gaussianity on the observation impact?

Three different metrics are used to define the observation impact: the analysis sensitivity to the observations, relative entropy and mutual information. In this work the analysis is defined as the mean of the posterior distribution given by Bayes' theorem. In Gaussian data assimilation it is known that these three measures tend to be in good agreement, with accurate independent observations which give information about the largest part of the state space having the greatest impact. However when the error statistics, described by the prior and likelihood, are no longer Gaussian this agreement breaks down. This is shown for the idealised case when the prior or likelihood is modelled by a weighted sum of Gaussians. It is seen that the difference in observation impact, when Gaussian approximations are made, for the sensitivity and relative entropy are strongly dependent on the value of the observation. This dependence increases as the prior or likelihood become increasingly non-Gaussian. However, the change in observation impact when Gaussian distributions are assumed is different depending on which metric is used. This hampers conclusions about the effect of non-Gaussian statistics on observation impact. Mutual information, however, remains independent of the value of the observation, and increasing the non-Gaussianity of the prior/likelihood is seen to generally have a smaller effect.

These results are illustrated with simple toy models and the particle filter, which samples the prior and posterior without making any assumptions about their underlying distributions. Conclusions are then made about the appropriateness of each metric for defining the observation impact in non-Gaussian data assimilation.