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Accounting for model error in variational assimilation. A deterministic formulation

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In data assimilation observations are combined with the dynamics to get an estimate of the actual state of a natural system. The knowledge of the dynamics, under the form of a model, is unavoidably incomplete and model error affects the prediction accuracy together with the error in the initial condition. The variational assimilation theory provides a framework to deal with model error along with the uncertainties coming from other sources entering the state estimation. Nevertheless, even if the problem is formulated as Gaussian, accounting for model error requires the estimation of its covariances and correlations, which are difficult to estimate in practice, in particular due to the large system dimension and to the lack of enough observations. Model error has been therefore either neglected or assumed to be an uncorrelated noise. In the present work, an approach to account for a deterministic model error in the variational assimilation is presented. Equations for its correlations are first derived along with an approximation suitable for practical applications. Based on these considerations, a new 4DVar weak-constraint algorithm is formulated and tested in the context of a linear unstable system and of the 3-component Lorenz model which has chaotic dynamics. The results demonstrate that this approach gives superior skill than both the strong-constraint and a weak-constraint variational assimilation which employs the uncorrelated noise model error assumption.