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Impact of nonlinearities and model error on pseudo-inverse calculations

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Pseudo-inverse calculations have been made within the operational and research meteorological communities to identify components of the error in the initial state that are responsible for a significant portion of the forecast error. These calculations are based on the assumptions of a perfect model and linear perturbation growth, conditions not realizable in operational forecasting. In this study, the impact of nonlinearities and model error on pseudo-inverse calculations is investigated within an idealized framework using a simple atmospheric model. Forecasts are run within the perfect and imperfect model frameworks, with initial errors of varying sizes. Model error is introduced by changing the model dissipation terms. It is found that for pseudo-inverses composed of a small subset of the leading SVs, the nonlinear forecast correction is often better than the expected linear correction, indicating the suppression of error growth both inside and outside the pseudo-inverse subspace. As the size of the pseudo-inverse is increased, the nonlinear forecast correction starts to degrade. This forecast degradation coincides with a degradation in the analysis correction. It is possible to improve the forecast by degrading the analysis in the presence of model error, especially when the initial error is very small. However, for initial errors of reasonable magnitude, this is unlikely to happen in instances when the nonlinear forecast correction is better than the linear correction. This suggests that the size of the nonlinear correction relative to the expected linear correction may useful in determining when pseudo-inverse perturbations are likely to have improved the analyses.