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Regularization of singular covariance matrices with graphical models

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Initial state, model error, and observation error are characterized by covariance matrices that are assumed in data assimilation calculations. It is well-known that the covariance significantly affects the assimilation results, but it is not easy to assume the covariance properly from mathematical and numerical viewpoints. Specifically, in order to assume a matrix that is regular (non-singular), we often assume it to (1) be diagonal or (2) have elements represented by a simple analytic function such as Gaussian. Apparently these assumptions neglect spatial covariate structure of dynamic models and observations. The simple assumptions may be brought because the models or observations have larger dimension than the number of time steps available for the models or the observations; sample covariance matrices have ranks less than the time steps which make the matrices singular. In the present study, we examine a method for designing a regular matrix that has a covariate structure derived from model outputs or observations. We apply an idea from graphical models, where conditional independence between the elements of the covariance matrices.