Covariance regularization in inverse space: For large-dimensional matrices

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In data assimilation, covariance matrices are introduced to prescribe weights of initial state, model dynamics, and observation and suitable specification of the covariances is known to be essential for obtaining sensible state estimates. The covariance matrices are specified by sample covariances and assumed covariance structure. Modeling of covariance structure consists of regularization of a sample covariance and constraint of dynamical relationship. Regularization is required for converting the singular sample covariance into non-singular one, removing spurious correlation between variables at distant points, and reducing a required number of parameters that specify the covariances. In past studies, regularization of sample covariances has been carried out in physical (grid) space, spectral space, and wavelet space. We propose a method for covariance regularization carried out in inverse space, in which we use the covariance selection model (the Gaussian graphical model). For each variable we assume neighboring variables: the targeted variable is directly related to the neighbors and is conditionally independent of the variables beyond the neighbors. Conditional independence is expressed by specifying zero elements in the inverse covariance matrix. The non-zero elements are estimated by the maximum likelihood numerically with the Newton method. Appropriate neighbors can be selected with information criterion AIC or BIC. We give an illustrative example and show an application to a sample covariance obtained from sea surface height (SSH) observations.