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Bayesian design of control space in inverse modelling: Application to mesoscale carbon dioxide inversion

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In geophysical inverse modelling, the control space is the set of parameters resolved through the assimilation of observations. We propose a consistent Bayesian formalism to design the discretization of control space over a large dictionary of adaptive multiscale grid representations described by several types of trees. Scale-dependent errors, such as aggregation errors (that lead to representativity errors) are introduced and formulated explicitly. The optimal representation of control space is constructed by optimizing a criterion that accounts for the inversion performance, e.g. the reduction of uncertainty, or the number of degrees of freedom for the signal (DFS) that measures the information gain from observations to resolve the unknown parameters.

The spatiotemporal resolution of carbon source-sink fluxes is a crucial issue in carbon dioxide inversions because of the ill-posedness of the carbon inverse problem. The CO_2 concentration observations are sparse as compared to the high dimensional carbon fluxes. However, this resolution issue is seldom investigated due to the lack of a multiscale framework for analysis. Based on our proposed multiscale formalism, we construct optimal multiscale representations of carbon fluxes for mesoscale inversion and perform inversions using synthetic CO_2 concentration data. Compared with the regular grid at finest scale, optimal representations can have similar inversion performances with much less grid-cells (e.g. 6% of the total number of grid-cells at finest scale). These optimal representations are obtained by maximizing the DFS criterion. DFS is found to be consistent with the root mean square error (RMSE) of carbon fluxes, provided the correlations of the errors of a priori fluxes are physically realistic. Scale-dependent representativity errors are considered for more reliable carbon inversions.