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Data assimilation using spatio-temporal descriptors

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Data assimilation is the process by which numerical model output is fused with observations in order to provide consensus estimates. In a Bayesian framework, this typically consists of constructing a 'process model prior' centred on the numerical model output and an 'observation model' which describes the relationship between the observed variable and the process of interest. This approach, while straightforward and ubiquitous in the geophysical sciences, can lead to erroneous inferences when the numerical output is biased (both spatially and temporally) in an undefined way.

Here we show an alternative way in which to carry out data assimilation, whereby only the spatial and temporal properties of the numerical model are fused with the data. The method, couched in a spatio-temporal Bayesian framework, follows a two-stage approach: (i) Spatio-temporal modelling of the numerical model outputs in order to extract spectral spatio-temporal characteristics which are deemed faithful to the processes of interest (e.g. length scales and marginal variances), and (ii) Spatio-temporal modelling of the processes of interest with informative priors (based on (i)) in order to provide updated estimates. We apply this method to estimating the mass balance of Antarctic ice-sheet processes from multiple observations sources: GRACE, ICESat, ENVISat and GPS data. We show that although this problem is under-determined due to lack of observation diversity, spectral characterisation using the two-stage approach allows us to tease out the individual processes and reduce confounding between the processes whilst concurrently providing inferences which are largely data-driven.