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A Rauch-Tung-Striebel smoother for the interpretation of long time series of ocean observations

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The interpretation of long time series of data in the presence of a model is an important problem both in modern oceanography and in paleoceanography. The adjective "long" refers here to time series extending over a decade or more. In modern oceanography, the problem arises from the analysis of data from the longest instrumental records at coastal and open-ocean stations. In paleoceanography, it arises from the analysis of any sediment record, which may span several thousands of years and even more. The quantitative combination of long ocean records with a circulation model is highly desirable, as it would lead to an interpretation of the data that is consistent with the equations of motion. Methods commonly used to combine records of ocean data with an ocean circulation model are sequential methods and Lagrange multiplier methods. In both cases, the estimation of the uncertainty of the ocean state is an issue, in the former because it may overwhelm the computation and in the latter because it is not part of the solution. Sequential methods appear as particularly attractive for the interpretation of long ocean records given their relatively large uncertainties.

Here we will present a preliminary effort to develop a sequential method (Rauch-Tung-Striebel or RTS smoother) for combining long time series of sea surface temperature (SST) with a model of the circulation in a subtropical gyre. In order to learn about the ultimate capability to develop and apply such a method, a simplified model based on the linearized equations of motion and on the hydrostatic approximation is used. The bottom of the gyre is also assumed to be flat. The advantages of these assumptions are multiple. For example, the motion can then decomposed into vertical modes, where each mode satisfies a set of shallow-water equations for its horizontal structure. This modal decomposition allows the possibility to retain only the leading modes and the effect of various dynamical mechanisms such as Rossby waves to be isolated in the ocean state estimation. Hence the computational load is reduced and physical insight is gained. Furthermore, with a linear model, the estimation of the ocean state is optimal in a probabilistic sense, allowing numerous questions about the data analysis to be answered precisely. The disadvantage of the above assumptions, of course, is a lack of realism. In our presentation, a set of experiments based on idealized but representative records of SST will explore the potential of the RTS smoother to provide a dynamically-consistent interpretation of long time series of ocean observations. Emphasis will be placed on how information from local records propagates horizontally and vertically within the gyre through to the wave motions pertaining to each mode. The influence of data and model errors on the estimated ocean state will also be discussed.