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Jungian data assimilation: Synchronization of truth and model in a stochastic framework

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A new paradigm for data assimilation is the synchronization of a pair of directionally coupled similar dynamical systems, one representing ‘‘truth” and the other representing ‘‘model", with loose coupling through only a small number of variables, and with noise in the coupling channel. Since it has been shown that loosely coupled chaotic systems commonly synchronize in a variety of configurations, despite sensitive dependence on initial conditions, chaos synchronization defines a class of algorithms for data assimilation that extends the standard collection based on 3DVar, 4DVar , and Kalman filtering. The synchronization view is reminiscent of the psychologist Carl Jung’s notion of ‘‘synchronicity" in the relationship between matter and mind.

The present work, which continues a previous talk at EGU 2004 (submitted to Nonlin. Proc. in Geophys.) examines the similarities and differences between the synchronization approach and the traditional approaches. It is shown that optimal synchronization in a system of stochastic differential equations representing a coupled pair of systems with noise in the coupling channel is equivalent to Kalman filtering except in highly nonlinear regions of state space. The criteria that the model state provide the best estimate of the current true state, on the one hand, and that the model converge to truth in the future, on the other, are equivalent except in such highly nonlinear regions. In such regions, where observational noise is sufficient to link model regimes with qualitatively different dynamics, synchronization will improve on Kalman filtering. The synchronization framework provides a theoretical basis and detailed prescriptions for correction techniques such as covariance inflation, that are usually introduced on an ad hoc basis. The general form of the required correction to Kalman filtering is discussed, together with the relationship to the ‘‘ensemble [non-Kalman] filtering ” method, that uses a non-gaussian background pdf in non-linear regions near regime transitions.