On the Problem of Initializing Climate Prediction

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Initialization techniques for seasonal-to-decadal climate predictions fall into two main categories, namely Full Field Initialization (FFI) and Anomaly Initialization (AI). In the FFI case the initial model state is replaced by the best-possible available estimate of the actual state. By doing so the initial error is efficiently reduced but, due to the unavoidable presence of model deficiencies, once the model is let free to run a prediction its trajectory drifts away from the observations no matter how small the initial error is. This problem is partly overcome with the AI where the aim is to forecast future anomalies by assimilating observed climate anomalies on an estimate of the model climate. This way, the initial model state is kept on (or closer to) its own attractor.

The large variety of experimental setups, models and observational networks adopted worldwide make difficult to draw firm conclusions on the respective advantages and drawbacks of the FFI and AI, let alone identifying distinctive lines for improvement. The lack of a unified mathematical framework adds an additional difficulty toward the design of adequate initialization strategies that fit the desired forecast horizon, observational network and model at hand.

In this study we use the notation and concepts of data assimilation theory to propose a unified formalism from which the different initialization approaches can be easily derived and seen as a particular case. Using the idealized coupled dynamics introduced by [1], FFI and AI are compared and studied in a range of different observational and model error scenario, helping clarifying under which conditions one approach outperforms the other. Moreover two advanced formulations of FFI/AI are also proposed to improve the fit to the observations and the bias reduction. Finally, preliminary results using the climate model EC-Earth are used to illustrate the impact of the initialization on climate forecast quality with a state-of-the-art dynamical climate prediction system.

References

[1] Pena M., and E. Kalnay, "Separating fast and slow modes in coupled chaotic systems", *Nonlin. Proc. Geophysics*, **11**, 319–327, 2004.