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A Bayesian approach to test hypotheses about the generation and propagation of systematic decadal climate prediction errors

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The climatology simulated by coupled climate models used in contemporary decadal climate prediction systems is affected by systematic biases compared to observations with respect to mean state, seasonal cycle and interannual internal variability. Decadal climate forecasts with full-field initialized coupled climate models are therefore affected by a systematic growing error signal – so-called drift - that develops due to the adjustment of the simulations from the assimilated state consistent with observations to a state consistent with the biased model's climatology. Model drifts thus reflect a fundamental source of uncertainty in decadal climate predictions.
We propose a state-space model developed within a Bayesian hierarchical framework for a process-oriented statistical assessment of systematic decadal climate prediction errors. Specifically, the state-space model is used to attribute temporal changes observed in the hindcast errors (data) to the "discriminant effects" underlying these changes (process), which include systematic components such as drift and climatological biases in mean state and seasonality. As some parameters of the state-space model are unknown, we formalize a Bayesian modeling strategy with three hierarchical levels (data, process, parameters). The possibility to further account for explanatory effects of local and/or remote co-varying processes renders the proposed state-space model ideal to statistically test specific hypotheses about the generation and propagation of systematic decadal climate prediction errors.
In this contribution, we will illustrate the methodology and propose a few applicative examples that demonstrate how the structural decomposition and Bayesian hierarchical approach envisaged here can help improving our understanding of systematic decadal climate prediction errors.