Correlations versus causality in Stochastic Long-range Forecasting as a Past Value Problem

Lenin Del Rio Amador and Shaun Lovejoy
McGill University, Physics, Montréal, Canada (delrio@physics.mcgill.ca)

Over time scales between 10 days and 10-20 years – the macroweather regime – atmospheric fields, including the temperature, respect statistical scale symmetries, such as power-law correlations, that imply the existence of a huge memory in the system that can be exploited for long-term forecasts. The Stochastic Seasonal to Interannual Prediction System (StocSIPS) is a stochastic model that exploits these symmetries to perform long-term forecasts. It models the temperature as the high-frequency limit of the (fractional) energy balance equation (fractional Gaussian noise) which governs radiative equilibrium processes when the relevant equilibrium relaxation processes are power law, rather than exponential. They are obtained when the order of the relaxation equation is fractional rather than integer and they are solved as past value problems rather than initial value problems.

Long-range weather prediction is conventionally an initial value problem that uses the current state of the atmosphere to produce ensemble forecasts. In contrast, StocSIPS predictions for long-memory processes are “past value” problems that use historical data to provide conditional forecasts. Cross-correlations can be used to define teleconnection patterns, and for identifying possible dynamical interactions, but they do not necessarily imply any causation. Using the precise notion of Granger causality, we show that for long-range stochastic temperature forecasts, the cross-correlations are only relevant at the level of the innovations – not temperatures. Extended here to the multivariate case, (m-StocSIPS) produces realistic space-time temperature simulations. Although it has no Granger causality, we are able to reproduce emergent properties including realistic teleconnection networks and El Niño events and indices.