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Exploiting the atmosphere's memory for monthly, seasonal and interannual temperature forecasting using Scaling LInear Macroweather Model (SLIMM)

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

Traditionally, most of the models for prediction of the atmosphere behavior in the macroweather and climate regimes follow a deterministic approach. However, modern ensemble forecasting systems using stochastic parameterizations are in fact deterministic/ stochastic hybrids that combine both elements to yield a statistical distribution of future atmospheric states. Nevertheless, the result is both highly complex (both numerically and theoretically) as well as being theoretically eclectic. In principle, it should be advantageous to exploit higher level turbulence type scaling laws.
Concretely, in the case for the Global Circulation Models (GCM's), due to sensitive dependence on initial conditions, there is a deterministic predictability limit of the order of 10 days. When these models are coupled with ocean, cryosphere and other process models to make long range, climate forecasts, the high frequency "weather" is treated as a driving noise in the integration of the modelling equations. Following Hasselman, 1976, this has led to stochastic models that directly generate the noise, and model the low frequencies using systems of integer ordered linear ordinary differential equations, the most well-known are the Linear Inverse Models (LIM). For annual global scale forecasts, they are somewhat superior to the GCM's and have been presented as a benchmark for surface temperature forecasts with horizons up to decades.
A key limitation for the LIM approach is that it assumes that the temperature has only short range (exponential) decorrelations. In contrast, an increasing body of evidence shows that – as with the models – the atmosphere respects a scale invariance symmetry leading to power laws with potentially enormous memories so that LIM greatly underestimates the memory of the system.
In this talk we show that, due to the relatively low macroweather intermittency, the simplest scaling models - fractional Gaussian noise – can be used for making greatly improved forecasts. The corresponding space-time model (the ScaLIng Macroweather Model (SLIMM) is thus only multifractal in space where the spatial intermittency is associated with different climate zones. SLIMM exploits the power law (scaling) behavior in time of the temperature field and uses the long historical memory of the temperature series to improve the skill. The only model parameter is the fluctuation scaling exponent, H (usually in the range -0.5 – 0), which is directly related to the skill and can be obtained from the data. The results predicted analytically by the model have been tested by performing actual hindcasts in different 5º x 5º regions covering the planet using ERA-Interim, 20CRv2 and NCEP/NCAR reanalysis as reference datasets. We report maps of theoretical skill predicted by the model and we compare it with actual skill based on hindcasts for monthly, seasonal and annual resolutions. We also present maps of calibrated probability hindcasts with their respective validations. Comparisons between our results using SLIMM, some other stochastic autoregressive model, and hindcasts from the Canadian Seasonal to Interannual Prediction System (CanSIPS) and the National Centers for Environmental Prediction (NCEP)'s model CFSv2, are also shown. For seasonal temperature forecasts, SLIMM outperforms the GCM based forecasts in over 90% of the earth's surface. SLIMM forecasts can be accessed online through the site: http://www.to_be_announced.mcgill.ca.