Is ultra-high model resolution necessary to improve probabilistic predictions?

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Abstract

Beyond timescales of about a week, weather and climate predictions are inherently probabilistic. They are about predicting the probability distributions of future states given initial conditions, boundary conditions, and external forcing. The question is whether one needs ultra-high resolution models to represent such distributions, or whether lower resolution models with deterministic plus stochastic parameterizations of small-scale feedbacks are sufficient for this purpose. From a computational viewpoint, lower resolution models are obviously more attractive. On the other hand one could argue, in the absence of a spectral energy gap and the existence of coherent structures at every scale, that ultra-high resolution is necessary to adequately capture multi-scale interactions and the statistics of extreme values i.e. the tails of the generally non-Gaussian probability distributions.

Comparisons of the probability distributions of daily weather anomalies in long global atmospheric GCM runs made at ECMWF and NCAR at resolutions ranging from T95 (about 130 km) to T2047 (about 6.5 km) are, however, revealing in this regard. The distributions are indeed non-Gaussian, but to an excellent approximation differ only in their widths but not their shapes at the different resolutions. This remarkable result is argued to be consistent with the stochastically generated skewed (SGS) nature of the distributions, and that beyond T511 (about 25 km) the main impact of higher resolution is merely to enhance the effectively stochastic forcing of the large scale eddies by small-scale fluxes. This suggests that a resolution of about T511, utilizing a suitable combination of deterministic and stochastic parameterizations to accurately represent the variances and energy spectra, should be sufficient for extended range weather and climate predictions. For fine scale regional applications, the output of such models could justifiably be downscaled using offline ultra-high resolution regional models. These conclusions will be discussed in the context of ongoing related research in this area.