Geophysical Research Abstracts
Vol. 21, EGU2019-19082, 2019
EGU General Assembly 2019

On the Skewed Nature of Ensemble Forecasts

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It is often not appreciated that an ensemble-mean forecast is generally not the most likely forecast, because the forecast probability distribution is generally skewed. This skew arises from the state-dependence of the unpredictable system dynamics responsible for the spread of the forecast ensemble. Its existence can be demonstrated in even the simplest system with state-dependent noise, even when the initial forecast distribution and the asymptotic (that is, climatological) forecast distributions are both symmetric. In general, the forecast distributions of systems with state-dependent noise must therefore be both skewed and heavy-tailed. This remarkable property not only implies that an ensemble mean forecast is generally biased, but also that the tails of the forecast distribution are strongly asymmetric for positive and negative forecast anomalies. Standard forecast metrics based on second-order moments of the forecast distribution are blind to this important forecast information.

Although forecast distributions may not be Gaussian, the standard deviation has been shown to be a useful indicator of forecast ensemble spread. In the same spirit, we propose the stochastically generated skew (SGS) as a useful metric of both the difference between the ensemble mean forecast and the most likely forecast and the asymmetry of the forecast tails, i.e. of extreme value risks. This is motivated by the facts that 1) the distributions of many geophysical quantities are approximately SGS distributions, 2) Gaussian distributions are a subclass of SGS distributions, and 3) simple analytic expressions exist for the difference between the ensemble-mean and most likely forecast, as well as for the tail asymmetry.