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An alternative interpretation of non-Gaussian Statistics in Geophysical Data

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The statistics of climate variables are often found to be non-Gaussian, and this fact is often attributed to non-linear dynamics. Nonetheless, we find that many features of the non-Gaussian statistics can also be reconciled with linear stochastically perturbed dynamics. A mixture of stochastic noises whose amplitudes are either system state-independent (additive noise) or linearly state-dependent (multiplicative noise) can produce not only symmetric but also skewed non-Gaussian probability distributions if the additive and multiplicative noises are correlated. Furthermore, one expects such correlations from first principles. A generic stochastically generated skewed (SGS) distribution can be derived from the Fokker-Planck equation for a 1-d system. In addition to skewness, all such SGS distributions have power-law tails, and a striking property that the kurtosis K is always greater than 1.5 times the square of the skew S. Remarkably, this K-S inequality is found to be satisfied by circulation variables even in the observed multi-component climate system. This can be understood in terms of a principle of Diagonal Dominance in the equations for the higher statistical moments of multi-component linear systems. The 1-d theory also predicts that fifth moments should be approximately 10 times the skew; this is confirmed to true in long simulations of a simple atmospheric general circulation model. Finally, the theory predicts that the PDFs of climate variables do not merely shift in response to external forcing but also undergo spefic types of changes of shape. This has important implications for the altered likelihood of extreme values under various climate change scenarios.