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Putting Weather back into the Definition of Climate

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For most of the previous century, it was generally clear that "climate" is far more than the "average weather", or even the average weather dressed up with a few supplementary statistics quantifying its variability. Yet towards the end of that century H H Lamb noted that there had been instances where "Climate was sometimes wrongly defined in the past as just 'average weather'." The importance of a clear, agreed definition of climate is stressed, and the slide away from defining climate as the distribution of weather, however measured, is documented. A rather obvious alternative definition from the theory of nonlinear dynamical systems is noted and criticized.

Not only is it the weather that defines climate: it is changes in weather that change climate by altering vegetation and land surface, ice and snow and cloudiness, etc. A clear definition of climate can ease discussions between scientists and statisticians, and avoid needless confusion in discussions beyond (and within) science. An ideal definition would be physically relevant, mathematically coherent and observationally tractable, even if it is impossible to optimize all three properties simultaneously. Further, the definition of climate should allow general utility in decision support and policy making, and ease multi-disciplinary engagement, by avoiding assumptions that presuppose (for example) its application in practice. Defining climate change in relation to changes in averages does, of course, reduce the relevance of climate change to policy makers, as the changes in averages need not reflect impacts on individuals.

Definitions of climate analogous to the (invariant) natural measure of a dynamical system (and distributions of trajectories of initial conditions drawn from this distribution) are proposed and criticized; then contrasted with a definition proposed by Lamb himself. Challenges that terrestrial climate change pose to the vocabulary of the modern theory of nonlinear dynamical systems are noted. It is argued that as models of the Earth System (and of its subsystems) gain skill, these challenges will become policy relevant.

Statistically speaking, changes in the averages and variance of a distribution do not define the distribution, while the distribution does define its moments. This is the case even when the process of interest has no memory. The case for defining climate as a distribution is even stronger when, like in most earth system components, it displays significant decision-relevant correlations in time. (Consider, for instance, the series of events which lead to a "heat wave", or the dependence of droughts on a series of seasons with low rainfall.) It is interesting then that the American Meteorological Society's (AMS) definition of climate has moved from a focus on weather conditions "however they may be expressed" in 1959 toward the current AMS definition "in terms of suitable averages". It is suggested that a definition proposed by Lamb comes close to the mark and can be made mathematically precise so as to capture the essence of the American Meteorological Society's 1959 definition, while many of the definitions stated in this century might profitably be discarded.