Geophysical Research Abstracts
Vol. 19, EGU2017-7313, 2017
EGU General Assembly 2017

Predicting atmospheric states from local dynamical properties of the underlying attractor

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Mid-latitude flows are characterized by a chaotic dynamics and recurring patterns hinting to the existence of an atmospheric attractor. In 1963 Lorenz described this object as: “the collection of all states that the system can assume or approach again and again, as opposed to those that it will ultimately avoid" and analyzed a low dimensional system describing a convective dynamics whose attractor has the shape of a butterfly. Since then, many studies try to find equivalent of the Lorenz butterfly in the complex atmospheric dynamics. Most of the studies where focused to determine the average dimension D of the attractor i.e. the number of degrees of freedom sufficient to describe the atmospheric circulation. However, obtaining reliable estimates of D has proved challenging. Moreover, D does not provide information on transient atmospheric motions, such as those leading to weather extremes. Using recent developments in dynamical systems theory, we show that such motions can be classified through instantaneous rather than average properties of the attractor. The instantaneous properties are uniquely determined by instantaneous dimension and stability. Their extreme values correspond to specific atmospheric patterns, and match extreme weather occurrences. We further show the existence of a significant correlation between the time series of instantaneous stability and dimension and the mean spread of sea-level pressure fields in an operational ensemble weather forecast at lead times of over two weeks. Instantaneous properties of the attractor therefore provide an efficient way of evaluating and informing operational weather forecasts.