Geophysical Research Abstracts
Vol. 13, EGU2011-5455, 2011
EGU General Assembly 2011

Relationship between the predictability limit and initial error in chaotic systems

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The predictability limits of the logistic map and the Lorenz63 model, as a function of the initial error, are calculated by employing the nonlinear local Lyapunov exponent (NLLE), which was recently introduced by the authors to quantitatively determine the predictability limit of chaotic systems. There exists a linear relationship between the predictability limit and the logarithm of initial error. A theoretical analysis performed under the nonlinear error growth dynamics revealed that growth of the mean error enters a nonlinear phase after it reaches a certain critical magnitude, ultimately reaching saturation. For a given chaotic system, if the control parameters of the system are given, then the saturation value of error growth is fixed. The time taken for error growth from the nonlinear phase to saturation is almost constant for various initial errors. The predictability limit is solely dependent on the duration of the phase of linear error growth; consequently, there exists a linear relationship between the predictability limit and the logarithm of initial error. The linear coefficient is related to the largest global Lyapunov exponent: the greater the latter, the more rapidly the predictability limit decreases as increasing logarithm of initial error. If we have prior knowledge of the largest global Lyapunov exponent and the predictability limit corresponding to a fixed initial error, the predictability limit can be extrapolated to various initial errors using the linear relationship between the predictability limit and the logarithm of initial error.