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A new approach to quantify predictability: Nonlinear error growth dynamics

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Measuring quantitatively the predictability of chaotic systems is of practical significance but very complex. In this study, a new theory of nonlinear error growth dynamics and a new concept, the nonlinear local Lyapunov exponent (NLLE), from the theory are introduced to quantify the predictability of chaotic systems. The NLLE, which is a nonlinear generalization to the existing local or finite-time Lyapunov exponents, can characterize the growth rate of initial errors of nonlinear dynamical models without linearizing the governing equations. A saturation theorem of the ensemble mean relative growth of initial error (RGIE) for the chaotic dynamical systems is obtained and the predictability limit can be defined as the time when the RGIE reaches its saturation level. Therefore, quantitative research on the predictability limits of chaotic systems could be really performed based on the new approach. The new approach is employed to quantify the predictability limits of the atmosphere and ocean on various scales and their spatial-temporal structure. Besides, the new theory could also be applied to estimate the predictability of forecast models.