Is Weather Chaotic?
Coexistence of Chaos and Order within a Generalized Lorenz Model

by

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(Last Updated: 2021/03/05)

Abstract

Over 50 years since Lorenz's 1963 study and a follow-up presentation in 1972, the statement ``weather is chaotic'' has been well accepted. Such a view turns our attention from regularity associated with Laplace's view of determinism to irregularity associated with chaos. In contrast to single type chaotic solutions, recent studies using a generalized Lorenz model (GLM, Shen 2019a, b; Shen et al. 2019) have focused on the coexistence of chaotic and regular solutions that appear within the same model using the same modeling configurations but different initial conditions. The results, with attractor coexistence, suggest that the entirety of weather possesses a dual nature of chaos and order with distinct predictability. In recent studies (Shen et al 2021a, BAMS; Shen et al. 2021b), based on the GLM, we illustrate the following two mechanisms that may enable or modulate two kinds of attractor coexistence and, thus, contribute to distinct predictability: (1) the aggregated negative feedback of small-scale convective processes that can produce stable non-trivial equilibrium points and, thus, enable the appearance of stable steady-state solutions and their coexistence with chaotic or nonlinear oscillatory solutions, referred to as the 1^{st} and 2^{nd} kinds of attractor coexistence; and (2) the modulation of large-scale time varying forcing (heating) that can determine (or modulate) the alternative appearance of two kinds of attractor coexistence.

Recently, the physical relevance of findings within Lorenz models for real world problems has been reiterated by providing mathematical universality between the Lorenz and Pedlosky models, as well as amongst the non-dissipative Lorenz model, the Duffing, the Nonlinear Schrodinger, and the Korteweg–de Vries equations (Shen 2020, 2021). Based on our results

obtained using both real world global models and theoretical Lorenz models, we then discuss new opportunities and challenges in predictability research with the aim of improving predictions at extended-range time scales, as well as sub-seasonal to seasonal time scales.