Geostrophic adjustment governing upscale error growth through the atmospheric mesoscales: An analytical model and idealized numerical simulations

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The current literature discussing predictability of atmospheric flow and the nature of the underlying scale interactions considers the problem from two main perspectives. One approach is based on statistical closure models in a homogeneous and isotropic turbulent flow, where the predictability time is determined solely by the background kinetic energy spectrum and not by the underlying dynamical model. An alternative approach is based on results from numerical weather prediction models that suggest that latent heat release associated with deep moist convection is a primary mechanism for small-scale error growth. From this point of view error growth in the atmosphere is an initially localized, highly intermittent phenomenon that expands upscale, leading to a complete loss of predictability on scales below 100 km within a few hours. The error growth process then depends on the underlying dynamics of the respective scale range and the errors in particular have to transition from geostrophically unbalanced to balanced motion while propagating through the mesoscale. In this talk a study will be presented that examines the geostrophic adjustment process as possibly underlying this transition. To that end, an analytical framework for the geostrophic adjustment of an initial pointlike pulse of heat (modeling a convective cloud or an error within the prediction of a cloud) is developed. Spatial and temporal scales of the geostrophic adjustment mechanism are deduced and three characteristics of the solution are shown to be potentially useful for identifying the geostrophic adjustment process in numerical simulations. These three predictions are then tested in the framework of error growth experiments in idealized numerical simulations of a convective cloud field. Three different rotation rates are employed in order to identify the geostrophic adjustment mechanism and allow a quantitative comparison with the predictions of the analytical model. As will be shown, the numerical simulations agree well with the predictions developed from the analytical model. Based on these findings it is suggested that the geostrophic adjustment process governs upscale error growth through the atmospheric mesoscales.

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