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Nonlinear Scale Interaction: A possible mechanism of up-scale error transport attributing to the inadequate predictability of Intra-seasonal Oscillations

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One of the fundamental science questions raised by the Year of Tropical Convection (YOTC) group was that under what circumstances and via what mechanisms water vapor, energy and momentum were transferred across scales ranging from meso-scale to the large (or planetary scale) (The YOTC Science Plan, 2008)? This study has partially addressed the above broad science question by exploring a probable mechanism of error energy transfer across scales in relation to the predictability studies of Intra-seasonal oscillations (ISOs).
The predictability of ISOs being in the dominant planetary scales of wavenumbers 1 – 4 is restricted by the rapid growth and the large accumulation of errors in these planetary / ultra-long waves in almost all medium range forecast models (Baumhefner et al.1978, Krishnamurti et al. 1990). Understanding the rapid growth and enormous build-up of error is, therefore, imperative for improving the forecast of ISOs. It is revealed that while the initial errors are largely on the small scales, maximum errors are appeared in the ultra-long waves (around the tropical convergence zone) within 3-5 days of forecasts. The wavenumber distribution of error with the forecast lead time shows that the initial error in the small scales has already attained its saturation value at these scales within 6-hr forecast lead, whereas that in ultra-long scales is about two order of magnitude smaller than their saturation value. This much amount of error increase in planetary waves cannot be explained simply as a growth of the initial error unless it has been transported from smaller scales. Hence, it has been proposed that the fast growth of errors in the planetary waves is due to continuous generation of errors in the small scales attributing to the inadequacy in representing different physical processes such as formulation of cumulus clouds in the model and upscale propagation of these errors through the process of scale interactions. Basic systematic error kinetic energy and the scale interactions in terms of the wave-wave exchanges among nonlinear triads are formulated and the above hypothesis is tested through a diagnostic analysis of the error energetics in two different model predictions at the lower troposphere (850hPa). It has been revealed that nonlinear triad interactions lead to advection of errors from short and synoptic waves (wave number >10) to long waves (wave numbers 5 – 10) and from long waves to ultra-long waves (wave numbers 1 – 4) and is responsible for the rapid growth of errors in the planetary waves. The continuous generation and then, non-linear propagation of error upto the planetary scales in the course of prediction increase the uncertainty in ultra-long scales which actually inhibit to predict accurately the planetary scale waves in tropics during medium range forecasts. Unraveling this exact mechanism through which upscale transfer of errors take place may help us devising a method to limit the mixing of small scale error with the error in forecast of tropical Intra-seasonal Oscillations and improve the prediction of lower tropospheric ISOs.
Keywords: Predictability, Systematic error energetics, Scale interactions, Triads, Intra-seasonal Oscillations.
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