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Global monsoon: A GCM that does it intraseasonally

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Since the seminal work of Lorenz, chaotic behavior of truncated atmospheric equations bears conceptual grounds in the issue of weather predictability. As for climatic scales, low-order models of the El Niño–Southern Oscillation system show chaotic motions as well. The gap to General Circulation Models (GCMs) has been bridged in conceptual studies using a coarse spatial resolution—but temporally and physically resolved—tropospheric GCM of the Mintz–Arakawa type. Cross sections of its attractor set across the boreal summer hint at a backward running period doubling route ('out of chaos') in the intraseasonal, "40-60 days" active–break cycle of the planetary monsoon system. These dynamics, best visible in global integrals of motion, represent a distinct climatic sub-regime of the seasonal cycle, borne in topological changes between spring and autumn bifurcations. Geometrically, it represents a torus segment in phase space with non-trivial fine structure that is organized via a highly synchronized hierarchy of planetary waves (at lowest possible rational frequency relationships). Planetary teleconnections between individual monsoon branches around the globe are borne in this internal organization. As a sort of degenerate monsoon activity cycle, a slow irregular wander between unstable fixpoints of the summer and winter circulation, which structurally exists for a short period after monsoon retreat (until the winter fixpoint stabilizes), shows the essentials of a Southern Oscillation (SO).

The paper summarizes the AGCM's 'geometry of behavior', its observational analogs, and modifications that arise when coupling it with a thermodynamic mixed-layer ocean (MLO) model. Whereas the intraseasonal activity becomes somewhat attenuated in the coupled model, the AGCM's weak SO becomes enhanced. AGCM solutions are presented under various modifications of forcing, including non-climatological SSTs and changing insolation. The key to this model's qualitatively correct (and quantitatively not unreasonable) intraseasonal dynamics in boreal summer is its high degree of internal synchronization, that is: low–dimensional behavior. These synchronies are established during hard transition into a chaotic July regime, from an orographically excited 'pre-monsoon' oscillation (a standing wave) into the 'interactive' monsoon solution with its inherent tropical–extratropical interactions. Mechanisms and feedbacks are discussed in detail in order to help understanding both essentials of a successful monsoon modelling at intraseasonal scales and consequences of the latter for interannual to centennial variability. First steps to trace the "monsoon climate" solution of the coarse resolution AGCM into higher horizontal resolutions are presented. Though present in the model, a chaotic regime does not appear to be required to explain its interannual variability—in contrast to Lorenz' idea of "chaos & intransitivity" as possible structural causation. The AGCM's 'roulette' effect at monsoon retreat suffices to this end.