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On the origin of atmospheric regime behavior: multiple equilibria or chaotic itinerancy?

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Two hypotheses meant to explain atmospheric regime behavior are known: (i) the multiple equilibria theory, associating circulation regimes with stationary solutions of the equations governing the atmospheric flow, and (ii) the chaotic itinerancy hypothesis, which states that the regimes correspond to ruins of multiple attractors, that coexist when a system parameter is sufficiently disturbed and merge by catastrophic and explosive bifurcations when the parameter is returned to the standard value. These hypotheses are tested in the context of three different spectral T21 models of the wintertime atmospheric circulation over the Northern Hemisphere: A baroclinic, quasi-geostrophic three-level model, a barotropic model, and a ‘pseudo-barotropic’ model, which is constructed from the three-level model by introducing strong internal friction between the levels and switching off the interfacial diabatic heating. After an appropriate tuning of their forcings and parameters, all three models exhibit a reasonable climate and two quite realistic regimes, respectively, resembling the positive and negative phase of the Arctic Oscillation. To test the multiple equilibria hypothesis, steady solutions are computed for all three models. The hypothesis is proven wrong for the three-level model, and there are also some doubts in the case of the other two models. A continuous ‘metamorphosis’ between the pseudo-barotropic and the three-level model is accomplished by a linear interpolation of parameters and forcing fields between these two models. Both local and global bifurcations occurring during this transition to baroclinicity are analyzed in detail, yielding two main results: First, almost all of the multiple steady states of the pseudo-barotropic model owe their existence merely to the fact that the surface friction has generally to be chosen un-

physically weak in barotropic models in order to obtain chaotic behavior. Second, the circulation regimes in both the pseudo-barotropic model and the baroclinic three-level model are proven to emerge from the unification of multiple attractors, which coexist at intermediate strength of baroclinicity and correspond to low- or high-index flow configurations, respectively. The chaoting itinerancy hypothesis is thus corrobated.