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Set-oriented approach for predicting critical transitions in geophysical flows

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The concept of critical transitions is used to describe and analyze the occurrence of sudden changes in the dynamics of complex systems. However, classical mathematical bifurcation theory fails to address such phenomena in time-dependent systems, such as geophysical flows. In order to study critical transitions in nonautonomous systems, we propose to consider trajectories of special time-dependent sets, such as invariant or coherent sets. This set-oriented approach is based on a transfer operator method and provides a computational study of the dynamics on a coarser level. In particular, it outputs a trajectory of subsets of phase space that are representative enough to provide qualitative information regarding the global dynamics of the underlying flow. Spectral properties of the time-dependent transfer operator serve as early warning signals for the bifurcation of these sets. The approach is applied to simple example systems that are motivated by real world phenomena such as polar vortex splitting events.