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Pullback attractor analysis of a periodically forced QG model

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The classical concept of attractor of an autonomous dissipative dynamical system can be generalized to the non-autonomous case by defining a time-dependent attractor in the pullback sense, the so-called pullback attractor (PBA). Here an analysis is presented of the PBAs of a nonlinear, excitable, low-order quasigeostrophic model (representing schematically the wind-driven double-gyre ocean circulation) subject to periodic forcing.

Two general properties of the system's PBAs are first assessed. The PBAs are found to be periodic, even when the single trajectories are chaotic. Moreover, the stroboscopic time average (with the same period of the forcing) of a single chaotic trajectory is found to be equivalent to the ensemble average: this system may therefore be defined as ergodic in the periodic sense.

Synchronization diagrams are then constructed to analyze the structure of PBAs for varying forcing periods. A variety of synchronization properties are revealed by this analysis. Of particular interest is a form of phase locking for which the trajectories evolving from many initial conditions collapse onto one or more single periodic trajectories, sometimes accompanied by regular PBAs. This study provides an a example of how the PBA analysis can reveal hidden, unexpected and fundamental dynamical features of non-autonomous dynamical systems relevant to climate dynamics.