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Methods for detecting saddle points and invariant manifolds from spatio-temporal geophysical data: Comparison and applications to GCM-simulated wind fields

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In dynamical systems saddle points and their invariant manifolds are known to play a crucial role in transport processes. Hence, the knowledge of these objects is of particular importance for the analysis of geophysical systems. Since the relevant data are often only coarsely gridded, the reliable detection of fixed points in spatially discretised vector fields is a problem of contemporary interest.

In this contribution, we thoroughly compare the performance of different dynamical systems methods (finite-time Lyapunov exponents, hyperbolicity times, leaking method) for approximating invariant manifolds and, thus, saddle points from velocity fields with a very simple static approach based on a gradient approximation of the fields at a given time. The results are evaluated with respect to the quality of approximation and the evaluation time, using velocity fields with analytically known saddle points, including a simple sine-cosine flow and a variant of Bower's model of a meandering jet. The quality of the methods is characterised by the largest discretisation step and temporal variation that still yield an identification of the analytically known saddle points.

These methods are then applied to geophysical data: We identify saddle points and

approximate the associated invariant manifolds corresponding to potential transport barriers inside wind fields which have been simulated by the ECHO-GiSP AOGCM. Finally, we discuss whether the consideration of atmospheric chemistry yields a significant shift of these manifolds.