An eddy tracking algorithm from dynamical systems theory

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Abstract

The search for coherent structures in oceanic flows has received an increasing attention in the last decades thanks, in part, to the improvement in ocean observing platforms as well as in the development of reliable ocean modeling systems (Isern-Fontanet et al., 2006; Mendoza and Mancho, 2010). Many works have been devoted to study these structures under a Lagrangian point of view, usually by means of the stretching by advection (Mancho et al., 2008), or by means of the Lyapunov exponents (Hernández-Carrasco et al., 2011).

In this area, not too many works have applied the theory of stationary dynamical systems since the stationary condition is violated in unsteady flows. However, under certain circumstances ocean structures evolve slowly and can be treated as *quasi-stationary.* In such situations, one can identify the structures in the Eulerian framework as stationary fields (snapshots of the time-dependent field), and track them in time to infer their time evolution.

Among the mesoscale structures, one relevant are eddies. Eddies are coherent circular flows, persisting for more than four weeks and with radius larger than 50 km that are present in all oceans (Carton, 2001). They are of key importance in regulating the global climate (Chelton et al., 2011) and their detection is nowadays an active research area. Several works developed different methodologies for the detection and tracking eddies from surface velocities or altimetry data. Fang and Morrow (2003) proposed to search eddies departing from sea surface height anomalies above a particular threshold. Other methods detect eddies by determining closed streamlines and analyzing their curvature (Sadarjoen and Post, 2000), by detecting oscillatory patterns in Lagrangian trajectories (Lilly et al., 2011) or by data mining methods from model velocity data (Petelin et al., 2015) . A large set of methods are based on the Okubo-Weiss parameter derived from a velocity field which is a magnitude that discriminates regions dominated by strain or vorticity.

Here we present a new method for ocean eddy detection that applies concepts from stationary dynamical systems theory. The method is composed of three steps: first, the centers of the eddies are obtained from the fixed points and their linear stability analysis; second, the size of the eddies are estimated from the vorticity profile between the eddy center and its neighboring fixed points and, third, a tracking algorithm connects the different frames. The tracking algorithm has been designed to avoid mismatching connections between different frames. Finally, we obtain a global database of eddies from geostrophic velocities between 1992 and 2012 derived from satellite altimetry and some results have been tested against other available databases.

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