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Zonal jets in the Madagascar plankton bloom

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We study the relation between advection by mesoscale eddies and jets and the remarkable eastward propagation of the Madagascar plankton bloom. Analyzing geostrophic velocity fields from altimetry with state-of-the-art Lagrangian techniques, we find fast coherent zonal jets in the recently discovered South Indian Ocean Countercurrent (SICC) at the exact position of the bloom. The coherent jets have a length of up to 1500km and provide a fast transport to the east.

We use a new simple Lagrangian metric, the Finite-Time Zonal Drift (FTZD) to quantify the zonal transport and find that the jets can partly explain the explosive eastward propagation seen in the evolution of the Madagascar plankton bloom. Numerical experiments with a passive tracer concentration released at a known upwelling region south of Madagascar also supports the hypothesis that an important nutrient source of the plankton bloom could be located in that area. Until now, the reasons for the eastward propagation of the bloom's front remained totally unclear and even a propagation against the mean flow had been suggested.

Moreover, we extract zonal jet-like Lagrangian Coherent Structures (LCS) from fields of the well-established Finite-Time Lyapunov Exponents (FTLE) that can be identified with barriers to meridional transport. Comparing these LCS with fields of chlorophyll concentration of the Madagascar plankton bloom measured by the Sea-viewing Wide Field-of view Sensor (SeaWiFS), we show that the location of jet-like LCS coincide with the boundaries of the plankton bloom, e.g. an LCS prevents cross-transport and confines the bloom to one side of the LCS.

Phytoplankton is one of the few natural tracers that can be used to verify if the ubiquitous zonal mesoscale jets act as transport barriers. In the case of the Madagascar plankton bloom, we find clear evidence that the zonal jets in the SICC indeed represent transport barriers to the ambient flow and shape the northern boundary of the chlorophyll distribution. In other countercurrents, the Atlantic North Equatorial Countercurrent off Brazil and the Pacific North Equatorial Countercurrent off Indonesia, similar plankton patterns with sharp meandering boundaries appear which suggests that the results presented here might be valid more generally.