



## Why separating ocean currents are not steady

Peter Jan van Leeuwen (1) and Will de Ruijter (2)

(1) University of Reading, DARC, Department of Meteorology, Reading, United Kingdom (p.j.vanleeuwen@reading.ac.uk, +441183788905), (2) Institute for Marine and Atmospheric Research Utrecht, Utrecht University, Utrecht, Netherlands (w.p.m.deruijter@uu.nl)

The majority of open ocean currents originate from separating western or eastern boundary currents. All are unsteady and show meandering behaviour and/or eddy shedding. This unsteady behaviour is usually attributed to baroclinic and/or barotropic instability of the flow. However, another candidate for the origin of the unsteady behaviour is the separation process itself.

It has been argued before by Nof and Pichevin (1996) using the zonal momentum balance that retroflecting currents cannot be steady. Also, based on a vorticity argument, basin-wide ocean circulations are unlikely to be steady (see e.g. Pedlosky, 1996). Here, we present an analytic study of the zonal momentum balance integrated over a line from coast to open ocean and show that this balance is highly unlikely to be fulfilled for any steady separating current. The argument is based on an information paradox: the zonal momentum flux in the boundary current is directly related to that in the meandering jet using the steady zonal momentum balance. However, while the former is not dependent on the details of the separation process, but the latter is to a great extend.

An example is the analytical solution by Moore and Niiler (1974) of a steady subtropical gyre, which is shown to be inconsistent with the zonal momentum balance. This leads to the important conjecture that a considerable part of the variability in the World Ocean might be due to the impossibility of a steady separation, not to instability of a free jet.

Nof, D., and T. Pichevin, 1996: The retroflection paradox. *J. Phys. Oceanogr.*, 26, 2344–2358

Moore, D. W., and P. P. Niiler, 1974: A two-layer model for the separation of inertial boundary currents. *J. Mar. Res.*, 32, 457–484.

Pedlosky, J., 1996: *Ocean Circulation Theory*. Springer, 453 pp.

Van Leeuwen, P.J. and W.P.M. de Ruijter 2009: On the steadiness of separating meandering currents, *J. Phys. Oceanogr.*, 39, 437-448.