Accumulation of Neutral Helicity around Islands

Advisor: Geoff Stanley

A parcel of seawater that moves laterally in a loop, while continually finding its level of neutral buoyancy in the vertical, returns to its initial lateral position at a different depth than it started. This phenomenon is called a “neutral helix”, and the vertical distance the “pitch”. This is caused by nonlinearities in seawater’s equation of state and a misalignment of surfaces of constant pressure, salinity, and potential temperature. This effect is locally quantified by the “neutral helicity”. With non-zero neutral helicity, neutral helices are a real phenomenon, and so extended surfaces along which seawater can move while maintaining neutral buoyancy -- “neutral surfaces” -- do not exist.

McDougall and Jackett (2007) speculated that the ocean maintains a small but non-zero neutral helicity so that the dianeutral fluxes associated with neutral helices can be balanced by other processes such as breaking internal waves. But how is neutral helicity destroyed? And how is it generated?

Even in an ocean with zero neutral helicity, Stanley (2019) showed that neutral helices can still exist around islands. Essentially, islands can “hide” some neutral helicity inside them. A preliminary study suggests that the pitch of neutral helices around islands is often much larger than the pitch of a neutral helix of the same lateral size but in the open ocean. This suggests that neutral helicity may be expelled from the open ocean, and fluxed towards the boundaries.

I propose two avenues of study. One is to directly calculate neutral helicity fluxes, and thereby assess its pathways through the ocean. This will involve theoretical development of equations governing neutral helicity, and model analysis to assess realistic fluxes.

Another avenue is a more careful study of the pitch of neutral helices around islands, using the Reeb graph, a tool from topology that helps us classify whether we expect a given island to exhibit a large pitch or not. The topological operation collapses each connected contour of pressure on the surface to a single point. The result is a graph: interior nodes represent saddles of pressure, and leaf nodes represent extrema of pressure. Cycles in the Reeb graph correspond to neutral helices around islands. But islands that are enclosed within a single pressure contour do not create cycles; around these we expect the pitch to be small. The Reeb graph for neutral surfaces is described by Stanley (2019).

Further Reading

McDougall, T.J., Jackett, D.R., 2007. The Thinness of the Ocean in S-θ-p Space and the Implications for Mean Diapycnal Advection. Journal of Physical Oceanography 37, 1714–1732. https://doi.org/10.1175/JPO3114.1

Stanley, G.J., 2019. Neutral surface topology. Ocean Modelling S1463500318302221. https://doi.org/10.1016/j.ocemod.2019.01.008