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Diagnosing neutral density and its associated Ertel's potential vorticity in ocean climate models.

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The definition of surfaces adapted to the study of water masses over the whole water column is a longstanding problem in physical oceanography. A convenient set of surfaces is provided by neutral surfaces, defined such that when water parcels are moved in the neutral surface, they experienceno buoyancy restoring force. Computing such neutral trajectories, Jackett and McDougal (1997) have defined a variable known as neutral density which isosurfaces approximate neutral surfaces. The resulting method and associated algorithm are well suited to the representation of hydrographic datasets over the world's oceans.

We propose a new methodology to define and compute neutral density avoiding the cumbersome calculation of neutral trajectories. The procedure uses a minimization approach to approximate the scalar factor b which relates the gradient of neutral density to the gradient of the locally referenced potential density. The stability and cost efficiency of the resulting algorithm makes it well-adapted to the representation of gridded datasets and ocean climate model outputs. In addition, since our approach does not rely on a previously labelled dataset it can be used to diagnose model outputs for strong climate change scenarios.

Here, we show how the factor b can be used to define the Ertel's potential vorticity associated with neutral density (*neutral potential vorticity*) and its associated fluxes. The method is applied to a 1500-year long simulation of the state-of-the-art global ice-ocean coupled system ORCA2-LIM. With a particular emphasis on the Southern Ocean, we show how isoneutral maps of neutral potential vorticity yield a synthetic

picture of the dynamics and thermodynamics of water mass conversion and their variability.