Geometry and Energetics of Ocean Mesoscale Eddies and Their Rectified Impact on Climate (GEOMETRIC)

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GEOMETRIC is a framework for interpreting and parameterising ocean eddy fluxes that preserves the conservation laws of the unfiltered equations. The framework involves rewriting the residual-mean eddy force as the divergence of an eddy stress tensor to ensure conservation of momentum, and solving a dynamically consistent eddy energy budget. The magnitude of the eddy stress tensor is bounded by the eddy energy, allowing its components to be rewritten in terms of the eddy energy and non-dimensional parameters describing the mean "shape" of the eddies, analogous to eddy ellipses used in observational oceanography. In its simplest form, implementation of GEOMETRIC in an ocean model involves rescaling the Gent and McWilliams eddy diffusivity by the depth-integrated eddy energy, the latter obtained by solving a prognostic eddy energy budget.

GEOMETRIC has three desirable properties: (i) the correct dimensional growth rate for eddy energy the linear Eady model of baroclinic instability; (ii) skilful prediction of eddy diffusivities in numerical simulations of the nonlinear baroclinic instability; (iii) prediction and physical explanation of "eddy saturation”, the relative insensitivity of the volume transport of the Antarctic Circumpolar Current to surface wind forcing.

Initial results from implementation of GEOMETRIC in the NEMO ocean model will be presented, the most pressing issue being accurate modelling of the depth-integrated eddy energy field. In particular, it will be shown that the time-scale over which eddy energy is dissipated is fundamental in setting the strength of the Antarctic Circumpolar Current, the Atlantic Meridional Overturning Circulation, and global ocean heat content. Observation-based estimates suggest that this eddy energy residence time scale is relatively short, of order a few months, with implications for the lateral redistribution of eddy energy through the ocean.