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Towards a potential vorticity based mesoscale closure scheme

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With the advent of high-performance computing, we are now capable of simulating the ocean and climate system on decadal to centennial timescales. However, global and basin-scale simulations still lack the spatial resolution necessary to resolve the mesoscales (hereon referred to as mesoscale-permitting simulations), a scale roughly on the order of O(100 km). Here, we provide a first step towards a potential vorticity (PV) based mesoscale closure scheme in order to improve the representation of mesoscale eddies in such simulations by taking advantage of the thickness-weighted averaged (TWA) framework. In the TWA framework the total eddy feedback can be encapsulated in the Eliassen-Palm (E-P) flux divergence. This implies that mesoscale closure schemes aimed at representing the total eddy feedback should therefore be representing the E-P flux divergence. The TWA framework further elucidates that its divergence is equivalent to the eddy Ertel PV flux. In other words, if one is to parametrize the eddy Ertel PV flux, one has parametrized the total eddy feedback onto the mean flow. Using a 1/12° North Atlantic ensemble simulation with 24 members, which allows us to decompose the mesoscale variability from the forced dynamics, we show that the eddy Ertel PV flux can be related to the local-gradient of mean Ertel PV as an active tracer via an anisotropic eddy diffusivity tensor. What follows is that not only does the tensor bring together the isopycnal thickness skew diffusivity and isopycnic tracer diffusivity, the former known as the Gent-McWilliams (GM) parametrization and latter the Redi parametrization, but also incorporates the eddy momentum fluxes. Although the Redi parametrization has existed longer than GM, there has been much more development in the latter, leaving the Redi diffusivity poorly constrained. Being able to treat GM and Redi simultaneously is another strength of our framework.