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When are eddy tracer fluxes directed down gradient?

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The mechanisms controlling the direction of eddy tracers fluxes are examined using eddy-resolving isopycnic experiments for a cyclic zonal channel and a basin.

Eddy fluxes are directed down gradient on average when either i) there is a Lagrangian increase in tracer variance or ii) there is strong dissipation of tracer variance. The effect of the eddies on the mean tracer evolution can be described through an ensemble of eddies which each have a particular lifecycle. Local examination of the eddy behaviour, such as fluxes, eddy kinetic energy and tracer variance appears complex, although the cumulative time-mean picture has coherence: eddies are preferentially formed in localized regions with downstream growth and increase in tracer variance concomitant with down gradient eddy tracer fluxes, while eventually the eddies decay with a decrease in tracer variance and up gradient eddy tracer fluxes. During spin-up, tracer deformation through flow instability leads to an area-average increase in tracer variance (although locally it is increasing and decreasing with the individual eddy lifecycles) and therefore an implied area-average, down gradient tracer flux. At a steady state, part of the pattern in eddy fluxes simply reflects advection of background tracer variance by the time-mean and eddy flows. The eddy flux becomes more biased to being directed down gradient if there is a strong sink in the tracer, which is likely to be the case for eddy heat fluxes heat along isopycnals outcropping in the mixed layer or for eddy nitrate fluxes along isopycnals intersecting the euphotic zone.