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A new process-based vertical advection/diffusion theoretical model of ocean heat uptake

Gabriel Wolf (1), Remi Tailleux (1), Antoine Hochet (2), David Ferreira (1), Till Kuhlbrodt (1), and Jonathan Gregory (1)

(1) Reading, National Centre for Atmospheric Science, Meteorology, Reading, United Kingdom (g.a.wolf@reading.ac.uk), (2) Scripps Institution of Oceanography, San Diego, USA

Ocean heat uptake is a key process for climate change owing to its control of global mean temperature trends. To understand the underlying internal ocean processes and vertical heat transfer controlling it, ocean heat uptake has been often analysed in terms of the simple one-dimensional vertical advection diffusion model. The standard version of this model, formulated in terms of the horizontally-averaged potential temperature is known to poorly capture important effects such as isopycnal mixing, density-compensated temperature anomalies, meso-scale eddy-induced advection and the depth-varying ocean area.

To overcome this problem a new theoretical model of vertical heat transfer for the ocean heat uptake has been developed in an isopycnal framework that exploits advances achieved in the theory of water masses over the past 30 years or so. The new theoretical model describes the temporal evolution of the isopycnally-averaged thickness-weighted potential temperature in terms of an effective velocity that depends uniquely on the surface heating conditionally integrated in density classes, an effective diapycnal diffusivity controlled by isoneutral and dianeutral mixing, and an additional term linked to the meridional transport of density-compensated temperature anomalies by the diabatic residual overturning circulation. The advantage of the isopycnally-averaged construction over the horizontally-averaged construction is that all the terms that enters it have explicit analytical expressions that are more easily evaluated from observations or model outputs, as well as having clearer physical interpretations.

As a first step, the terms of this new model of ocean heat uptake are evaluated by using a range of different datasets, net surface heat flux products and temporal averages to evaluate their sensitivity to input fields. One key feature of the new model is that its effective velocity and diffusivity are positive over most of the ocean column depth. This is in contrast to the horizontally-averaged construction, in which downwelling and ant-diffusive behavior were occasionally observed in previous studies. The hope is that this insight can then be used to develop an improved representation of ocean heat uptake in simple climate models.