Finescale Water-Mass Variability from ARGO Profiling Floats

Eric Kunze
Applied Physics Lab, University of Washington
1013 NE 40th
Seattle, WA 98105-6698
phone: 206-221-2616   fax: 206-543-6785
e-mail: kunze@apl.washington.edu

LONGTERM GOALS

My longterm goals are understanding the processes responsible for stirring and mixing in the ocean in order to better parameterize their impacts on larger scales.

OBJECTIVES

To obtain a global assessment of mesoscale water-mass variability lengthscales and diffusivities, as well as density ratio statistics from the ARGO profiling float data set.

APPROACH

Mesoscale stirring depends on the eddy field, with eddies acting to stir tracers along isopycnals. In a simple stirring-length framework, horizontal diffusivities K_h depend on rms eddy speed U_{rms} and stirring lengthscale L as $K_h = U_{rms}L$. One signature of eddy stirring in the presence of largescale gradients is water-mass (spice) variability along isopycnals. To estimate the eddy stirring length, ARGO profiling float data were transformed onto σ_θ density coordinates and salinity anomalies S' used as a proxy for water-mass variability. Salinity anomalies S' were combined with 2º×2º gradients on isopycnals $<S_h>$ to determine lengthscales of stirring. The simplest lengthscale estimate, $L = (<S'^2>)^{1/2}/<S_h>$, is prone to overestimation in small mean gradients so an integral estimate of L is obtained from $<S'^2>^{1/2} = \int <S_h(r)> dr$ where the integral runs from 0 to L. This stirring length will be combined with eddy horizontal kinetic energy estimates from the ECCO2 model to produce global estimates of lateral diffusivity to be compared with surface estimates based on satellite altimetry (Ferrari and Nikurashin 2010; Klocker and Abernathy 2014).

Similar methodology may be applied to isopycnal displacements ξ to assess eddy APE variability though internal waves may dominate these statistics away from strong subinertial current systems.

Vertical (density) wavenumber spectra were computed for the water-mass anomalies in the profiles and these correlated as a function of lateral separation Δr and temporal separation Δt. Also in the vertical, density ratio R_ρ statistics have been mapped.

If time permits, we will search the data for outliers in *T,S* and stratification N^2 to map vortices analogous to Meddies. In the Indian, these might include Reddies from the Red Sea in the Arabian Sea (e.g., Shapiro and Meshchankov 1991) and vortices generated by flow of the Antarctic Circumpolar Current past the Kerguelen Plateau (D'Asaro 1988).

WORK COMPLETED

The global ARGO profiling float data set through 2012 has been downloaded from its archive and catalogued. Coherence analysis is complete. Postdoctoral researcher Dr. Cimmaron Wortham, who arrived in September 2013, has nearly completed lengthscale analysis and begun work on figures for at least two anticipated manuscripts.

RESULTS

The coherence of water-mass anomalies extends results of Ferrari and Polzin (2005) in the eastern North Atlantic, that coherence falls to zero at the smallest temporal and horizonal separations resolved (1 day, 5 km) almost everywhere in the ocean, illustrating that *TS* properties are not smooth anywhere.

On the $\sigma_\theta = 27.29$ (*<z>* = 832 m) surface (Fig. 1), stirring lengthscales *L* show global patterns with *L* of O(100-1000 km). Longer stirring lengthscales are concentrated toward the west between 20-50°, as well as along the equatorial Pacific, south of the equator in the Atlantic and Indian but patterns vary with depth. Shorter lengthscales of 100 km are found in the subtropics and poleward of 60°S around Antarctica. Overall, larger lengthscales are associated with stronger mean currents and their associated eddy fields.

mixing length from salinity on $\sigma_\Theta = 27.29\,\mathrm{kg\,m}^{-3}$ (median depth: 832 m)
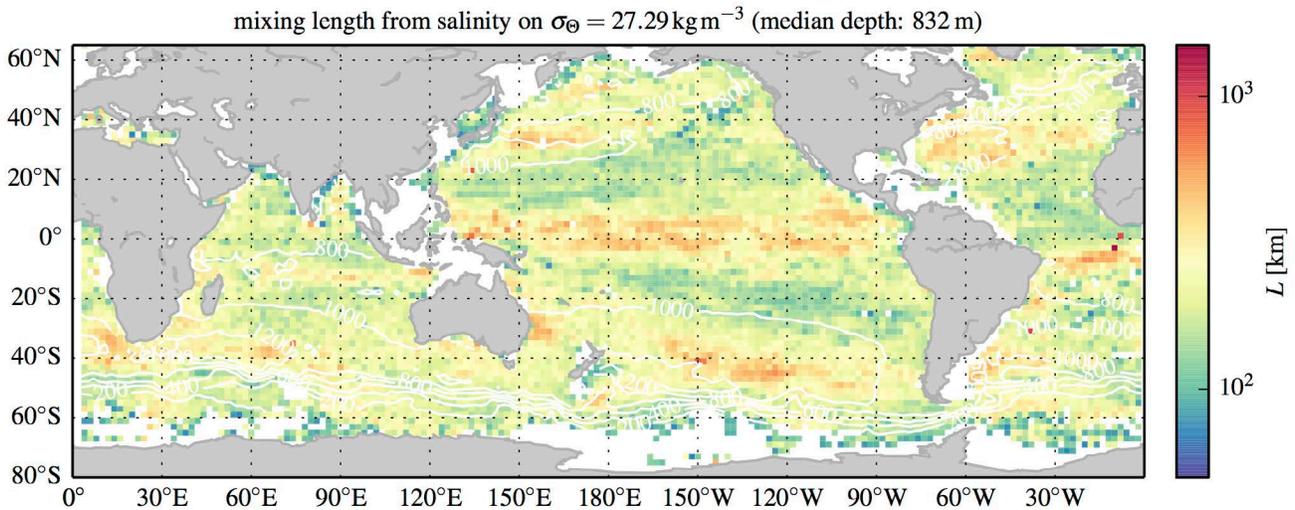
Figure 1: Stirring lengthscales L in 2°×2° squares based on rms salinity anomalies S' on the σ_θ = 27.29 (<z> = 832 m) surface. Color shows lengthscale and white contours mean isopycnal depths <z> in meters.

Meridional sections show strong vertical and zonal coherence of lengthscale statistics (Fig. 2). For example, a local minimum in lengthscale at 40°N extends across the Pacific fro 170°E to 140°W, just north of the Kuroshio extension. The horizontal structure in lengthscale *L* indicates that eddy stirring

lengths are not simply dependent on eddy diameter, which generally decreases monotically with latitude, but also depend on eddy/mean current characteristics and interactions.
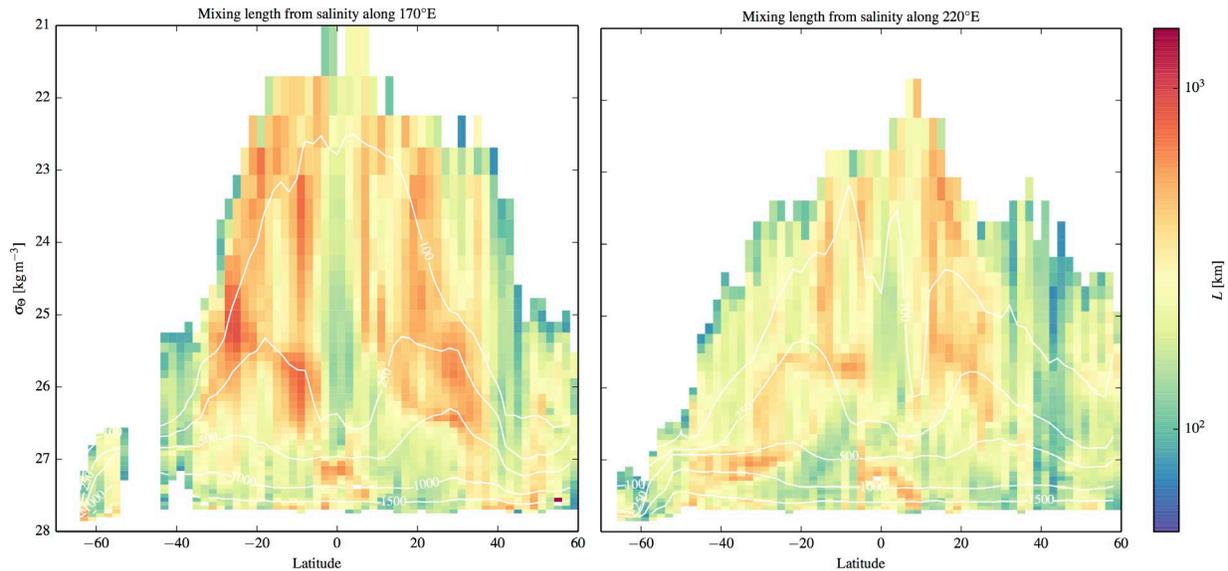
Figure 2: Meridional sections of isopycnal stirring lengthscales L as a function of σ_θ and latitude in the western (left) and eastern (right) Pacific. Color shows lengthscale and white contours average isopycnal depths <z> in meters.

IMPACT/APPLICATIONS

Global mapping of water properties has typically focussed on smoothed basin-scale fields (e.g., You 2002). However, the dramatic increase in available data afforded by the ARGO float array allows mesoscale variances and lengthscales to be examined as well. Water-mass variability on isopycnals provides signatures of stirring that will impact isopycnal mixing, double-diffusive processes and acoustics.

RELATED PROJECTS

This project is examining the global distribution of mesoscale water-mass variability, arising from advection by currents and stirring by eddies, to better characterize lateral stirring on O(100 km) lengthscales. This variability represents the low-wavenumber source for the submesoscale being studied under ONR's Lateral Mixing DRI. For the Lateral Mixing DRI, I have synthesized data from towyo measurements collected by Jody Klymak, Craig Lee, Miles Sundermeyer and myself, as well as autonomous measurements collected by Lou Goodman, during the summer 2010 field campaign in the Sargasso Sea, to produce a spectrum for water-mass variability on isopycnals over horizontal wavelengths of 0.03-30 km (Kunze *et al*. 2014). The submesoscale band represents the forward cascade of variance on lengthscales smaller than the Rossby radiation of deformation so the two lines of research complement each other.

REFERENCES

D'Asaro, E.A., 1988: Geneation of submesoscale vortices – A new mechanism. *J. Geophys. Res.*, **93**, 6685-6693.

Ferrari, R., and K.L. Polzin, 2005: Finescale structure of the *T-S* relation in the eastern North Atlantic. *J. Phys. Oceanogr.*, **25**, 1437-1454.

Ferrari, R., and M. Nikurashin, 2010: Suppression of eddy diffusivity across jets in the Southern Ocean. *J. Phys. Oceanogr.*, **40**, 1501-1519.

Klocker, A., and R. Abernathy, 2014: Global patterns of mesosclae eddy properties and diffusivities. *J. Phys. Oceanogr.*, **44**, 1030-1046.

Kunze, E., J.M. Klymak, R.-C. Lien, R. Ferrari, C.M. Lee, M.A. Sundermeyer and L. Goodman, 2014: Submesoscale water-mass spectra in the Sargasso Sea. *J. Phys. Oceanogr.*, submitted.

Shapiro, G.I, and S.L. Meshchanov, 1991: Distribution and spreading of Red Sea Water and salt lens formation in the northwest Indian Ocean. *Deep-Sea Res.*, **38**, 21-34.

You, Y., 2002: A global ocean climatological atlas of the Turner angle: Implications for double-diffusion and water-mass structure. *Deep-Sea Res. I*, **49**, 2075-2093.