Ocean Sci. Discuss., 7, C471–C474, 2010
www.ocean-sci-discuss.net/7/C471/2010/

Ocean Science Discussions

Interactive comment on "Mixed layer sub-mesoscale parameterization – Part 2: Results for coarse resolution OGCMs" *by* V. M. Canuto and M. S. Dubovikov

Anonymous Referee #2

Received and published: 18 October 2010

Aside from the fact that this paper is difficult to read, as already mentioned by the other reviewer, it is also fundamentally flawed.

This paper purports to extend the previous work on submesoscale parameterizations by the authors in this journal to a form where they may be applied in a coarse-resolution general circulation model. The important process that must occur is that the input and output variables of their parameterization must be averaged over the mesoscale. The authors cite the work of Capet et al. extensively as supporting their procedure.

The crucial aspect of the averaging by Canuto and Dubovikov is their equation (A5), which is used in the critical final averaging procedure to arrive at the results (6c)

equations (7). The relationship (A5) replaces the average of the correlation of two mesoscale variables with the product of the resolved gradients of the two variables. That is, we are expected to believe that we get the *the same contribution from the resolved field that we get from averaging the unresolved values over the mesoscale*! This is an outrageous statement, which cannot be true. It will be shown below that (A5) is similar to stating $0.01 = O(1)$. Since equation (A5) plays a crucial role in arriving at their overall results, the whole of this paper cannot be trusted and should be rejected.

Perhaps the most important result from Capet et al. (see both Fig. 6 of 'Mesoscale to Submesoscale Transition in the California Current System. Part I: Flow Structure, Eddy Flux, and Observational Tests', and Fig. 1 of 'Mesoscale to Submesoscale Transition in the California Current System. Part III: Energy Balance and Flux') is the shallow spectrum of tracers and kinetic energy in the near-surface variables. These shallow spectra have crucial energetic implications, as so elegantly discussed in those papers.

However, the shallow spectra also have implications for averaging over the mesoscale range of scales, as Canuto and Dubovikov attempt to do here. Fox-Kemper et al. (in press, Ocean Modelling, http://dx.doi.org/10.1016/j.ocemod.2010.09.002) do a similar averaging procedure keeping in mind the shallow spectra. Let us rewrite the equation (2b) here in terms of decomposing the power spectrum based on grid scale Δx and front width L_f. We consider the horizontal power spectrum of buoyancy, $B(k)$, as it is clearly addressed here in (6c), and in Capet et al. and in Fox-Kemper et al. Thus, the average of the density variance over all scales may be decomposed as

$$b = \overline{\overline{b}} + b'' + b' \quad (1)$$

$$\langle b^2 \rangle = \int_0^\infty B(k)dk \quad (2)$$

$$\langle b^2 \rangle = \int_0^{2\pi/\Delta x} B(k)dk + \int_{2\pi/\Delta x}^{2\pi/L_f} B(k)dk + \int_{2\pi/L_f}^{\infty} B(k)dk \quad (3)$$

Thus, we see immediately that

$$\langle \overline{\overline{b}}^2 \rangle = \int_0^{2\pi/\Delta x} B(k)dk \tag{4}$$

$$\langle b''^2 \rangle = \int_{2\pi/\Delta x}^{2\pi/L_f} B(k)dk \tag{5}$$

$$\langle b'^2 \rangle = \int_{2\pi/L_f}^{\infty} B(k)dk \tag{6}$$

Canuto and Dubovikov insist that the average of the gradients of their fields goes as deformation radius times the average of the field. *This is only true if the spectrum of the field is strongly peaked near the deformation radius*. It is readily apparent from the work of Capet et al. that this is not true. Instead, it is a better approximation to take $B(k) \propto k^{-2}$ over the range of scales present in the Capet simulations (Figure 6 of Capet et al., Part III, left panel, middle row), which here are the range from $k = 0$ to $k = 2\pi/L_f$. Assuming $B(k) = b_0 k^{-2}$ over this range, we find

$$\langle \overline{\overline{b}}^2 \rangle = \int_0^{2\pi/\Delta x} B(k)dk = b_0 \int_0^{2\pi/\Delta x} k^{-2}dk \tag{7}$$

$$\langle b''^2 \rangle = \int_{2\pi/\Delta x}^{2\pi/L_f} B(k)dk = b_0 \int_{2\pi/\Delta x}^{2\pi/L_f} k^{-2}dk \tag{8}$$

The variance of buoyancy gradient goes as $k^2 B(k)$, which is just

$$\langle |\nabla \overline{\overline{b}}|^2 \rangle = \int_0^{2\pi/\Delta x} B(k)dk = b_0 \int_0^{2\pi/\Delta x} dk \tag{9}$$

$$\langle |b''|^2 \rangle = \int_{2\pi/\Delta x}^{2\pi/L_f} B(k)dk = b_0 \int_{2\pi/\Delta x}^{2\pi/L_f} dk \tag{10}$$

We can therefore integrate these relations to find the area-averaged gradients of the buoyancy at different scales.

$$\langle |\nabla_H \overline{\overline{b}}|^2 \rangle = b_0 2\pi/\Delta x \tag{11}$$

$$\langle |\nabla_H b''|^2 \rangle = b_0 (2\pi/L_f - 2\pi/\Delta x) \tag{12}$$

Finally, we arrive at the assertion of the scaling of Canuto and Dubovikov's (A5), which is for $\tau = b$,

$$\overline{\overline{|\nabla b''|^2}} \approx |\nabla_H \overline{\overline{b}}|^2 \tag{13}$$

$$2\pi/\Delta x = (2\pi/L_f - 2\pi/\Delta x). \tag{14}$$

Which means that for Canuto and Dubovikov's averaging equations (A5) to hold for a shallow spectrum such as that both simulated and observed in the surface ocean, it must be the case that $2L_f \approx \Delta x$. That is, the size of the submesoscale fronts from which the submesoscale features form *cannot be appreciably smaller than the coarse-resolution general circulation model grid scale.* The grid scale of these models is roughly 100km and the scale of the fronts is O(1km), the crucial averaging equation (A5) of Canuto and Dubovikov is apparently in error comparable to stating $0.01 = O(1) - 0.01$.

Thus, the 'averaging' in this paper is not averaging at all, and Canuto and Dubovikov have not even remotely set out to do what is claimed in this paper. I therefore recommend rejection.

Interactive comment on Ocean Sci. Discuss., 7, 1289, 2010.