Particulate Matter in the Ocean: Decadal Comparisons of Repeat Sections

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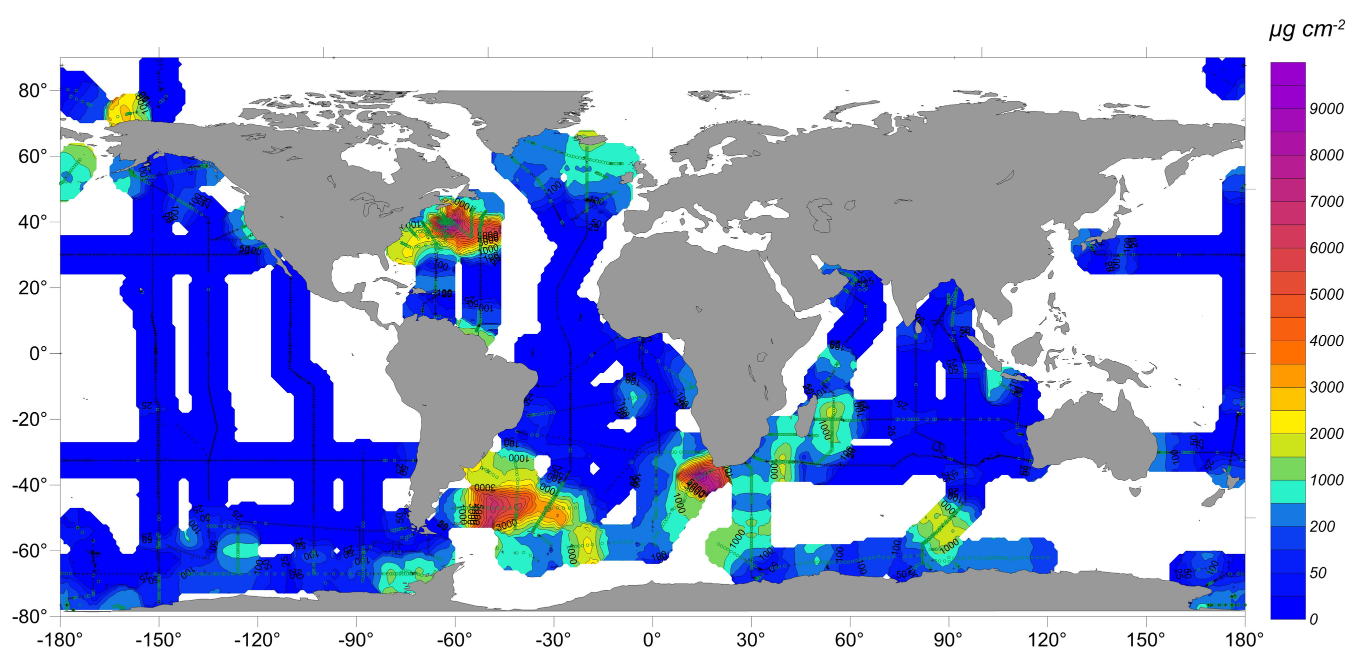

Figure 1. Excess particulate matter in the nepheloid layer ($\mu g\ cm^{-2}$). Transect locations (**black** & **green** lines) of beam attenuation data (Gardner *et al.*, 2018a).

PURPOSE:

Basin-wide sections of beam c_p (proxy for particulate matter concentration - PM) in ocean basins collected during numerous oceanographic programs over the last four decades (WOCE, SAVE, JGOFS, CLIVAR, GO-SHIP, *etc.*) record variable concentrations in euphotic surface waters, very low concentrations through most of the water column, and very low to very high concentrations near the seafloor (Figure 1).

Sections re-sampled at decadal intervals show that sub-surface particle distributions are very similar over these time spans: areas of high eddy kinetic energy (EKE: Figure 2) are more likely to have high bottom PM concentrations, whereas areas of low EKE (most of the ocean) are very likely to have low PM concentrations.

Quantifying the temporal and spatial distribution of particles in the ocean helps in identifying and understanding mechanisms affecting the sources and sinks of particles. We added O_2 contours to sections to track relationships between PM and oxygen concentration, which sometimes seem correlated and sometimes not. The general O_2 distribution in these sections is very similar, though decades apart in time.

Mapping the intensity of PM in benthic nepheloid layers (Figure 1) aids in understanding deep ocean sediment dynamics, linkage with upper ocean dynamics, and in assessing the potential for scavenging of adsorption-prone elements near the deep ocean seafloor, as investigated in the GEOTRACES program.

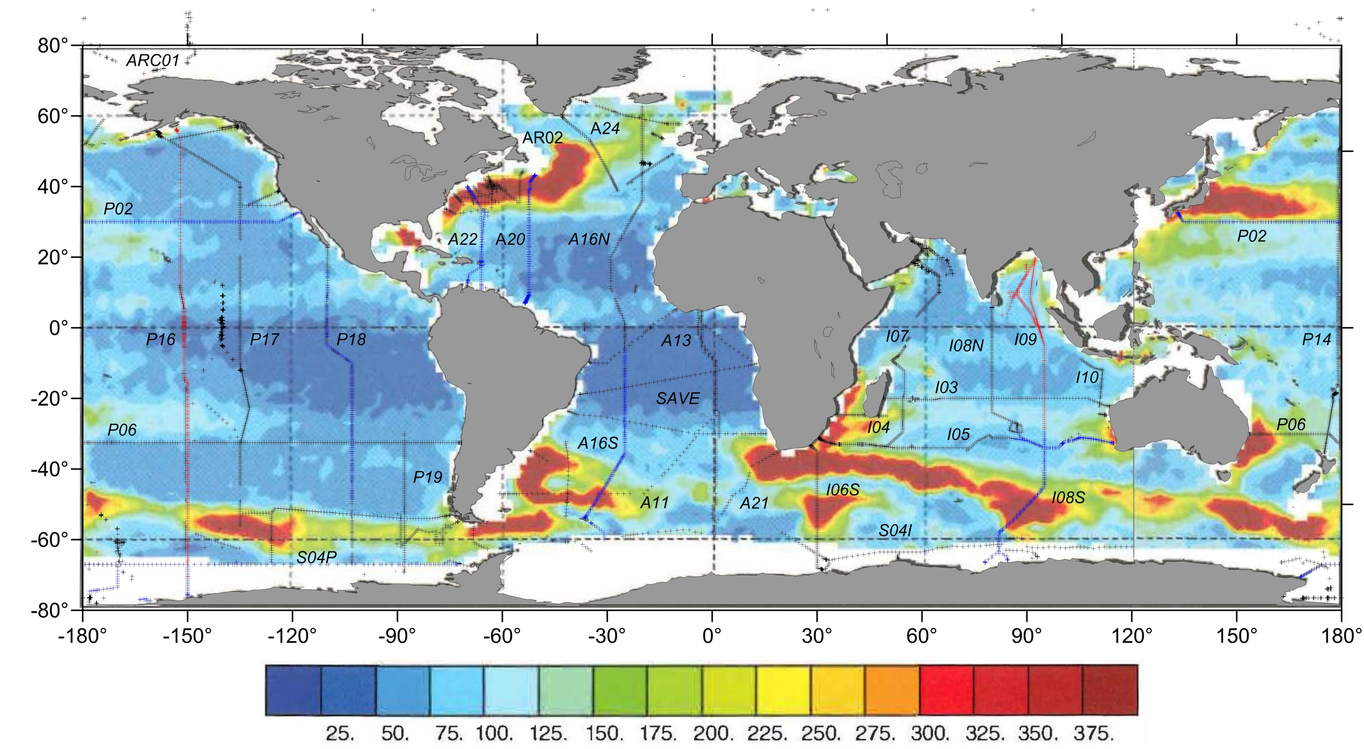

Figure 2. An estimate of the kinetic energy per unit mass, cm^2/s^2, in the ocean, derived from the altimetric variability and the geostrophic relationship (Wunsch, 2015) with c_p transects plotted. **Black** symbols indicate lines occupied once, **blue** occupied twice, and **red** occupied three times (Gardner *et al.*, 2018b).

Figures 3-5. Repeat sections of beam attenuation coefficient (c_p) in the Pacific and Indian Oceans (see Figures 1 & 2 and map inserts on each section for transect locations). A beam attenuation coefficient of 0.1 m^{-1} is approximately equivalent to PM of 100 $\mu g\ l^{-1}$, 0.2 m^{-1} ~200 $\mu g\ l^{-1}$, *etc.* Contours indicate the O_2 concentration ($\mu mol\ kg^{-1}$); vertical dotted lines are the station casts.

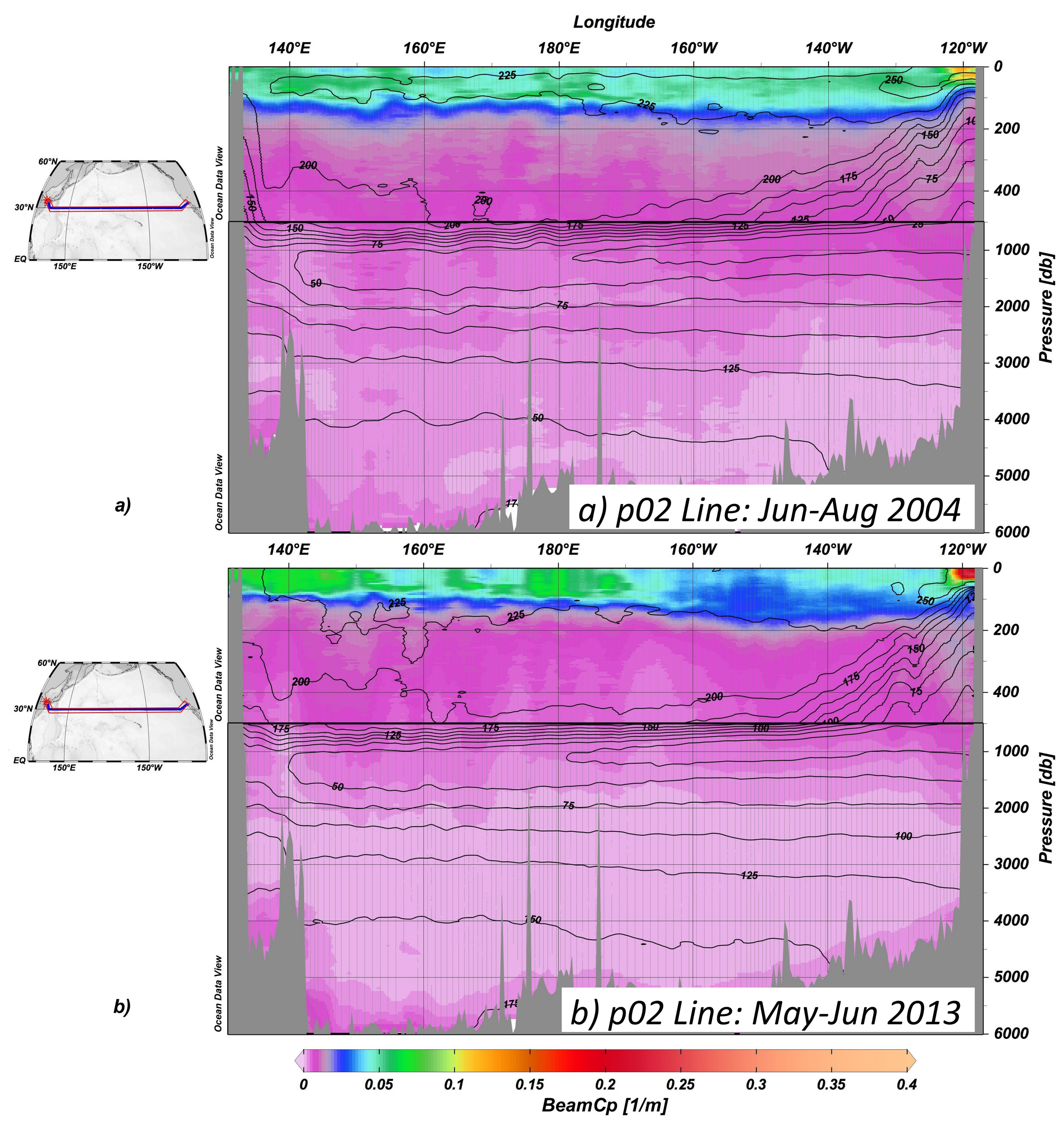

Figure 3. Most of the Pacific Ocean has very low c_p from 250 m to the seafloor (Figures 3, 4). An O_2 minimum stretches across the Pacific at about 1000 m along 30°N (This Figure).

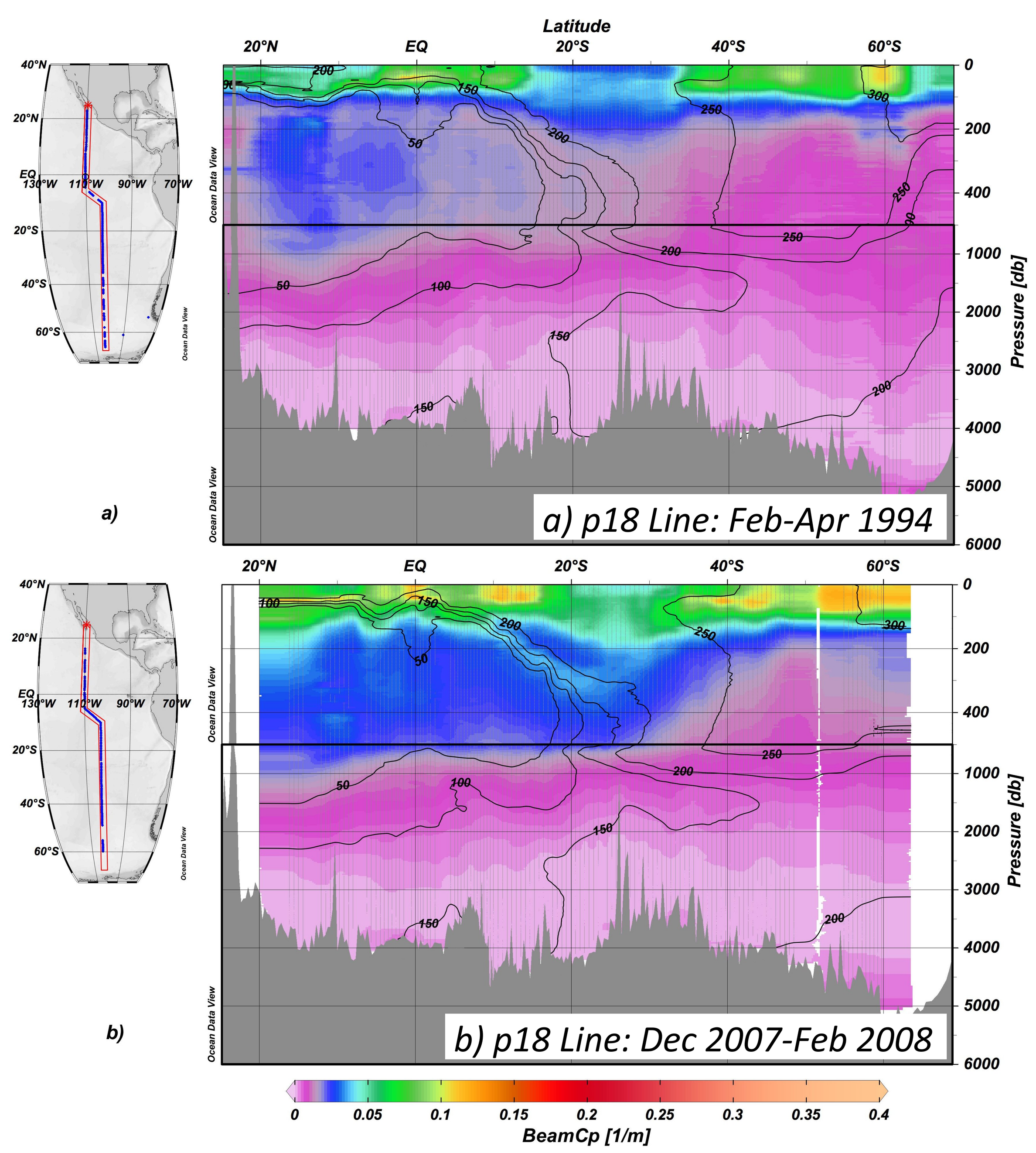

Figure 4. Line p18 at ~110°W shows that in the northern section between 100 to 1500 m a slight increase in c_p corresponds with values of O_2 less than 50 $\mu mol\ kg^{-1}$. Other studies indicate this may be due to an increase in bacteria in the intense O_2 minimum.

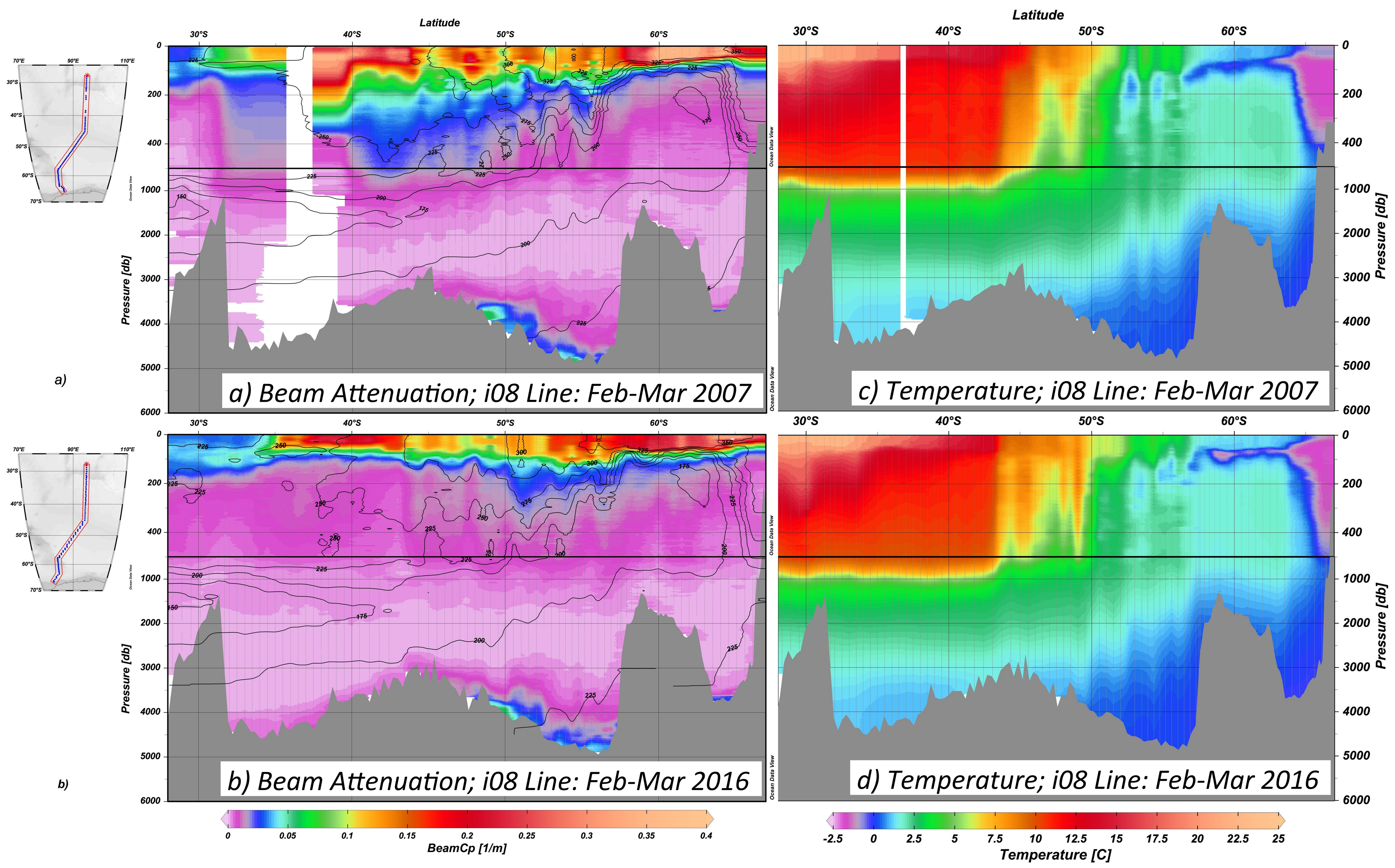

Figure 5. Benthic nepheloid layers best coincide with areas of high surface eddy kinetic energy (Figure 2), *e.g.* areas in the Antarctic Circumpolar Current. Surface energy can be propagated to the seafloor through topographic Rossby waves in areas with sloping seafloor or baroclinic eddies generated beneath strong non-linear eddies, creating bottom currents sufficient for resuspension of bottom sediments. Undulations in Temperature, c_p, and O_2 are associated with non-linear eddies.

References

1. Wunsch, C. (2015) - Modern Observational Physical Oceanography, Princeton University Press. Page 64. Fig. 3.32b.
2. Gardner WD, MJ Richardson, AV Mishonov (2018a), Global Assessment of Benthic Nepheloid Layers and Linkage with Upper Ocean Dynamics. *Earth and Planetary Science Letters*, 482, pp 126-134; https://doi.org/10.1016/j.epsl.2017.11.008.
3. Gardner, W. D., Mishonov, A. V., & Richardson, M. J. (2018b), Decadal comparisons of particulate matter in repeat transects in the Atlantic, Pacific, and Indian Ocean Basins. *Geophysical Research Letters*, 45. https://doi.org/ 10.1002/2017GL076571.
4. Transect plots created with Ocean Data View: Schlitzer, R., Ocean Data View, odv.awi.de (2017).

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