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Eddies and chlorophyll in the Southern Ocean

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The Southern Ocean is a region of intense eddy activity, yet the long-term mean influence of eddies on biological productivity and biogeochemistry is not well established. To this end, we examined the relationship between phytoplankton activity and mesoscale eddies on the basis of satellite data south of 30°S. Eddies were detected from sea level anomalies (Aviso, http://www.aviso.oceanobs.com/) using the Okubo-Weiss parameter and were then tracked over time with a correspondence-based approach. Chlorophyll-a (GlobColour Project, http://www.globcolour.info/) was taken as proxy for phytoplankton activity. The sea level anomalies (1/3°, 7 days) were linearly interpolated to match the resolution of the chlorophyll data (0.25°, 8 days). Based on data from 1997 to 2010, we identified and tracked over 120 000 eddies with slightly more eddies being anticyclonic than cyclonic. Nearly one third of the detected eddies existed one month or more. This gave us an excellent mean statistics despite frequent gaps in the chlorophyll data due to cloud cover. Average amplitudes and diameters of eddies in the Antarctic Circumpolar Current (ACC) are about 10 – 20 cm and 100 km, respectively. The largest amplitudes (> 50 cm) and diameters (> 200 km) occur in regions of high sea surface gradients in the ACC and north of the Subtropical Front in the western ocean basins. Long-lived eddies propagate distances of 500 km and more.

Our results reveal a distinct but spatially variable signal in chlorophyll related to eddies. Overall, eddies contribute 15 % to the total chlorophyll in most of the ACC and more than 30 % in the regions where eddies are largest and most intense. Cyclonic eddies show enhanced chlorophyll intensities (relative to the background chlorophyll) north of the Subtropical Front as well as in areas along and south of the Polar Front. In contrast, chlorophyll intensities of cyclonic eddies are reduced regionally between the Subtropical and the Polar Fronts. However, these imprints on chlorophyll by cyclonic eddies are largely offset by the anticyclonic eddies, which generally show a signal of approximately the same magnitude but of opposite sign. Thus, it is crucial to differentiate between cyclonic and anticyclonic eddies when examining the relations between eddies and chlorophyll in the Southern Ocean. Our hypothesis is that the spatially heterogeneous imprint of eddies on chlorophyll is caused by the different geneses and dynamics of cyclonic versus anticyclonic eddies in concert with a bottom-up limitation of phytoplankton by light and nutrients.

Our findings support the idea that eddies modulate biological productivity and hence carbon fluxes in the Southern Ocean through biophysical interactions.