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Interactive comment on "Imprint of Southern Ocean eddies on chlorophyll" *by* Ivy Frenger et al.

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General Appraisal

The paper presents the results of a truly impressive data analysis of the effects of mesoscale eddies on sea surface chlorophyll in the Southern Ocean, comprising an extensive and widely new look into the regional and seasonal variation of these effects. In respect of how those interesting results are set into scientific context, however, the paper has severe weaknesses. I think these weaknesses can be overcome by rewriting major parts of the manuscript, sections 1, 4 and 5 in particular.

Specific Comments

The mesoscale ocean dynamics govern the range from a few kilometres to a few hundreds of kilometres horizontally. The data used in the study by Frenger et al., collected by satellite remote sensing, provide a horizontal resolution of 1/3 of a degree for eddies (Aviso SLA) and 0.25° for the concentration of sea surface chlorophyll (ESA GlobColour Project product), i.e. approx. 37 km and 28 km in latitude, respectively. In consequence, only the larger fraction of mesoscale eddies is investigated. This needs, but is not yet, be made clear in the paper.

Eddies, or the mesoscale dynamics in general, affect phytoplankton hence the chlorophyll concentration in various ways, particularly by time-variable horizontal and vertical advection and associated transports of nutrients, and by vertical current shears that control stratification and subduction hence the light environment which phytoplankton cells experience. (In the Southern Ocean, where most macro-nutrients are abundant, it is likely the mesoscale upwelling of the primary production-limiting micro-nutrient iron that enhances biological production in the ACC with its meandering fronts; Hense, et al., Regional ecosystem dynamics in the ACC: Simulations with a three-dimensional ocean-plankton model , J. Mar. Systems, 2003.) Vertical velocities, and therefore possible upwelling of nutrients, but are known be most intense at the smallest part ($\leq$ 10 km) of the mesoscale range (Martin et al., Patchy productivity in the open ocean, Global Biogeochem. Cycles 2002; Lévy, Mesoscale variability of phytoplankton and of new production: Impact of the largeâĂŘscale nutrient distribution, J. Geophys. Res., 2003; Klein & Lapeyre, The oceanic vertical pump induced by mesoscale and submesoscale turbulence, Annu. Rev. Mar. Sci. 2009). The relevance of those small scales has been noted initially by Woods (Mesoscale upwelling and primary production, in Toward a theory on biological–physical interactions in the world ocean, ed. B. J. Rothschild, Dordrecht Kluwer,1988), who raised the hypothesis that key to understanding the plankton patchiness which was revealed with the advent of satellite chlorophyll images, lies in the dynamics of mesoscale jets, where dynamical constraints limit upwelling to horizontal dimensions of about ten kilometres. This hypothesis received first observational support in 1992 (Strass, Chlorophyll patchiness caused by mesoscale upwelling at fronts, Deep-Sea Res. I). These latter two publications, by the way, would close the glaring time gap of the literature review given in the Introduction (p.1, lines 20

– 22.) between the cited advent of satellite chlorophyll images (Gower et al. 1980) and Doney (2003).

The presumably most important horizontal scale for stimulating phytoplankton growth, as explained above, unfortunately is not resolved by the present study. Moreover, most of the above-mentioned studies have demonstrated that up- and downwelling predominately are driven by changes in time of the mesoscale flow field (related to the development of frontal meanders due to baroclinic instability, frontogenesis by eddy-eddy interaction etc.). For the ACC, Strass et al. (Mesoscale frontal dynamics: Shaping the environment of primary production in the Antarctic Circumpolar Current, Deep-Sea Research II, 2002) have shown with an in situ study that the acceleration/deceleration of a frontal jet by interaction with an eddy creates a pattern of up- and downwelling cells and of chlorophyll patches on a much smaller horizontal scale than that of the involved eddy. Frenger et al. in their present study, however, analysed only eddies that were tracked over at least three weeks, hence eddies which were not subject to much change in time. Both by the selection of eddies of larger size and of low temporal change, Frenger and co-authors likely introduce a bias towards eddies of rather limited impact on biological production and biogeochemical rates. Their conclusion that eddy-driven stirring and trapping dominate over biogeochemical effects therefore seems not robust but rather a result of the horizontal/time scale bias. This requires an honest and thorough discussion.

Throughout their ms Frenger and co-authors associate cyclonic eddies with thermocline lifting and anticyclonic eddies with thermocline deepening. Undisputable is that cyclones display a lifted thermocline and anticyclones a deepened thermocline. However, whether or not the thermocline moves up or down after eddies have been fully formed is in contestation. It may well be the reverse of the indicated way, i.e. that during eddy slow-down due to processes such as eddy-induced Ekman pumping, the thermocline in cyclones moves downward and in anticyclones upward (e.g. Gaube et al., 2014). I therefore recommend the authors use to a more careful wording, i.e.

lifted/deepened instead of lifting/deepening.

On p. 20, lines 30-31 the authors bring forward the argument that anticyclones cause an abatement of grazing pressure, without providing a reference. In general I would doubt that a reference for this argument exists, which could be considered representing the widely accepted and unquestioned state of knowledge regarding mesoscale variability of grazing. Therefore, I consider this argument pure speculation, and suggest remove it from the ms.

Technical Issues

Fig. 4 should be enlarged to full-page size to enhance its readability in the pdf-version of the paper, and the caption therefore be shifted to next page, if possible.

Caption Fig 6 associates autumn with the months January to May, what is certainly not correct. If the given months are valid, then the season should be termed high summer – autumn or so.

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