Reviewer Comment 2, V. Strass, and *author response*:

Major comments

General Appraisal

Comment a

1. 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.
2. *Thank you for the positive assessment regarding our analysis, and for providing comments and references to better set our paper into context.*
3. *We have included the additional references and modified sections 1, 4 and 5 according to the above comment and the detailed comments below.*

Specific Comments

Comment b

1. 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.
2. *We have included a sentence in the Method and Discussion section to clarify the constraints due to the resolution of the satellite data.*
3. *p6L10 "The resolution capacity of Aviso SLA allows to analyze the larger mesoscale eddies [Chelton et al., 2011]."*

Comment c

1. 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 large scale 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).

2. *Thank you for these points and the additional references. Our objective is not to discuss in our paper processes $\leq 10\,km$, that is submesoscale processes (which appear to be the focus of the points above/below). These are, even though connected to the mesoscale, a separate field of study, and we certainly do not wish to claim to resolve direct submesoscale effects in the data we use. Hence, we have included the suggested references and tried to make very clear throughout the text that we focus on the larger mesoscale as resolved by the satellite data we use for the study. Further, we have included in the Discussion section a paragraph on the potential effects of eddies on chlorophyll/biogeochemical rates which we do not consider in our analysis (see also Reviewer Comment 1 by Francesco d'Ovidio, and below)*

3. *p20L22: "Further, we may underestimate the overall effect of eddies on Chl also because of additional effects of eddies that are not considered in our analysis. Such effects include the impact of smaller mesoscale features, and of submesoscale processes near the edges of eddies [Woods, 1988, Strass, 1992, Martin et al., 2002, Lévy, 2003, Klein and Lapeyre, 2009, Siegel et al., 2011], e.g., due to eddy-jet interactions and associated horizontal shear-induced patches of up- and downwelling. Such features are*

included in our analysis only insofar they have rectified effects on the larger mesoscale Chl patterns resolved by the data we use. Another effect we do not consider is non-local stirring [D'Ovidio et al., 2015], the contribution of eddies to lateral dispersion outside the eddies' cores in interaction with the ambient flow. This effect, for instance, shapes iron plumes downstream of shelves along the ACC, thus preconditioning Chl blooms [Ardyna et al., 2017]. Therefore, we note that the overall effect of eddies on biogeochemical rates may be larger than suggested by our analysis of the mesoscale, local imprint of eddies on Chl.".

Comment d

1. 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 eddyeddy 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 eddydriven 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.

2. *See also response above. We agree that additional effects of the smaller mesoscale and of the submesoscale on shorter time scales are important for biogeochemical rates; even with our focus on the larger mesoscale, we were starting out with the hypothesis that these eddies affect biogeochemical rates. Yet, our conclusion is valid, that the Chl imprint we find of the scales that our data do resolve can be explained largely by advection. This conclusion does not negate that effects on biogeochemical rates may be at play, too. To try to accommodate your concern, and the main comment by Francesco d'Ovidio, that overall biogeochemical effects may be underestimated, we included a paragraph in the Discussion section (see response to comment above), and highlighted throughout the text that we focus on the larger mesoscale.*

3. *See previous comment/response.*

Comment e

1. 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.
2. *We much appreciate this comment.*
3. *We replaced "lifting/deepening" with "lifted/deepened" throughout the text.*

Comment f

1. 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.
2. *We would like to keep this hypothesis, yet, to make clear that it is a mere hypothesis/speculation, we rephrase the respective sentences mentioning grazing (see below).*
3. *p19L35: "Hypothetically, an alleviation of grazing pressure [...]", and p21L18: "and, more speculatively, with an abatement of grazing pressure caused by anticyclones via deepened mixed layers,".*

Technical Issues

Comment g

1. 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.

2. *We agree; yet, we do not see how the Biogeosciences LaTeX template (which does not allow to use additional packages) would allow us to do this; we will ask the editorial/production team at the publication stage to enlarge the figure.*

Comment h

1. 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.
2. *Thank you.*
3. *We have adjusted the caption of Fig 6 to "**a** high summer to autumn ACC waters R2 (SSH -60 to -40 cm, January to May) and **b** R3 northern ACC winter to early spring deep mixed layer waters (SSH -50 to -15 cm, July to September);"*

References

M. Ardyna, H. Claustre, J. B. Sallée, F. D'Ovidio, B. Gentili, G. van Dijken, F. D'Ortenzio, and K. R. Arrigo. Delineating environmental control of phytoplankton biomass and phenology in the Southern Ocean. *Geophys. Res. Lett.*, 44(10):5016–5024, 2017. ISSN 19448007. doi: 10.1002/2016GL072428.

D. B. Chelton, M. G. Schlax, and R. M. Samelson. Global observations of nonlinear mesoscale eddies. *Progress in Oceanography*, 91:167–216, oct 2011. ISSN 00796611. doi: 10.1016/j.pocean.2011.01.002.

F. D'Ovidio, A. Della Penna, T. W. Trull, F. Nencioli, M. I. Pujol, M. H. Rio, Y. H. Park, C. Cotté, M. Zhou, and S. Blain. The biogeochemical structuring role of horizontal stirring: Lagrangian perspectives on iron delivery downstream of the Kerguelen Plateau. *Biogeosciences*, 12(19):5567–5581, 2015. doi: 10.5194/bg-12-5567-2015.

P. Klein and G. Lapeyre. The oceanic vertical pump induced by mesoscale and submesoscale turbulence. *Annu. Rev. Mar. Sci.*, 1:351–375, 2009. doi: 10.1146/annurev.marine.010908.163704.

M. Lévy. Mesoscale variability of phytoplankton and of new production: Impact of the large-scale nutrient distribution. *J. Geophys. Res.*, 108(C11):3358, 2003. ISSN 0148-0227. doi: 10.1029/2002JC001577.

A. P. Martin, K. J. Richards, A. Bracco, and A. Provenzale. Patchy productivity in the open ocean. *Global Biogeochem. Cycles*, 16(2):1025, 2002. doi: 10.1029/2001GB001449.

D. A. Siegel, P. Peterson, D. J. McGillicuddy, S. Maritorena, and N. B. Nelson. Bio-optical footprints created by mesoscale eddies in the Sargasso Sea. *Geophysical Research Letters*, 38:L13608, 2011. ISSN 0094-8276. doi: 10.1029/2011GL047660.

V. H. Strass. Chlorophyll patchiness caused by mesoscale upwelling at fronts. *Deep Sea Res. Part A. Oceanogr. Res. Pap.*, 39(1):75–96, 1992. doi: 10.1016/0198-0149(92)90021-K.

J. Woods. Scale upwelling and primary production. In *Towar. a Theory Biol. Interact. World Ocean*, pages 7–38. Springer Netherlands, Dordrecht, 1988. doi: 10.1007/978-94-009-3023-0_2.