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Earth System Dynamics
Discussions

Interactive comment on "Influence of position and strength of westerlies and trades on Agulhas leakage and South Benguela Upwelling" *by* Nele Tim et al.

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Reviewer #1:

We thank the reviewer for the constructive report and recommendations to revise the manuscript. In the following, we list our responses to the comments and the changes that we would introduce in the manuscript.

Page 1 Rephrase to: Line 3: Agulhas leakage constitutes a fraction of warm and saline water transport from the Indian Ocean into the South Atlantic.

It would be changed as suggested

Line 4: "The leakage is stronger during intensified westerlies and probably also when the wind systems are shifted poleward." Probably? If you are not sure or there is no evidence based on that study for that I would leave it out.

It would be left out

Line 10: Give numbers here for the CO2 emission scenarios or the RCP ones you referring to.

RCPs would be added

Rephrase:Line 15: An increased contribution of Agulhas water to the upwelling system will feed water masses that will import more preformed nutrients and oxygen into the upwelling region.

It would be rephrased as suggegsted

Line 19: with larger scale implications –like what? Line 20: change to Southern Hemisphere Westerlies and Easterly Trade winds. Line 20: Here, we analyze several observational.....the last century and past two millennia. With the aim to understand what?

This is rather a question of writing style. We use the first paragraph of the introduction to prelude the analyses we did. As we analyze the winds here, the aim to understand the impact on upwelling and leakage is stated in the last paragraph of the introduction. Paragraph changes to: "The regional oceanographic phenomena around Southern Africa, the Agulhas Current, the Agulhas leakage, and the Benguela upwelling, are all three to a large extent influenced by one of the two wind regimes in this region, the Southern Hemisphere Westerlies and the Easterly Trade winds. Thus, here, we analyze several observational data sets and model simulations."

Page 2 Line 28: As the Peeters et al. 2004 record is based on qualitative reconstructions of Agulhas leakage rather than quantitative numbers I would suggest to rephrase that to: "During glacial periods leakage was strongly diminished, based on qualitative reconstructions of foraminiferal assemblage counts, whereas the transport of Indian

Ocean waters into the South Atlantic was enhanced during interglacial periods (Peeters et al., 2004).

It would be changed as suggested

Page 3 Line 1: Simon et al. 2013 and 2015 actually, noted that changes in temperature and salinity in the Agulhas leakage is at least partly the result of variability in the composition in the current itself and can be a poor indicator of the strength of the leakage. Hence please rephrase that part to actually refer to the citations in an appropriate way.

We would exclude this sentence when reformulating this paragraph. See the new wording in the answer to the following remark.

Line 2: I dislike the "gateway theory" of driving AL amount very much. The common assumption is that shifts of the Southern Hemisphere westerly wind belt, (in particular the position of the zero wind stress curl) would have led to the widening/narrowing of the gap between Africa and the STF, thereby controlling the amount of warm salty Indian Ocean waters leaking into the South Atlantic. However, this assumption has been questioned (De Boer et al., 2013; Durgadoo et al., 2013). These studies showed that the position of the STF is not related to the position/shifts in the wind belt i.e.,position of the zero wind stress curl and that Agulhas leakage increases with northward shifted westerlies a scenario originally proposed for a narrower gateway. It is therefore unclear whether shifts of the wind fields did in fact act to alter past rates of Agulhas leakage, which might imply that other factors, despite the movement of the STF, were equally important in determining leakage.

We would change the paragraph about the impact of the position of the westerlies according to the reviewers suggestion: "The impact of the position of the westerlies on the Agulhas leakage is still under debate. The studies of DeRuijter et al. (1982) and of Biastoch et al. (2009) found that a more northerly position hinders the westward flow of Agulhas water into the South Atlantic, whereas a more southerly position leads to a wider passage of throughflow between the south coast of South Africa and the

westerlies. However, recent studies found diverging results. De Boer et al. (2013) showed the there is no linkage between the position of the zero wind stress curl and of the subtropical front. The study by Durgadoo et al. (2013) found that an enhanced leakage tends to occur when westerlies are shifted equatorwards due to the redistribution of momentum input by the winds. Nevertheless, there is consensus on the impact of the westerlies on the Agulhas leakage and that the strength of westerlies is the key driver of the leakage: stronger westerlies lead to a stronger wind stress curl and an intensified transport from the Indian Ocean into the South Atlantic (Durgadoo et al., 2013 and Cheng et al., 2018)."

Page 7: Line 1-6: Here the work of Loveday, B. R., P. Penven, and C. J.C. Reason (2015), Southern Annular Mode and westerly-wind-driven changes inIndian-Atlantic exchange mechanisms, Geophys.Res.Lett., 42, 4912–4921,doi:10.1002/2015GL064256. should be cited and discussed in comparison.

We would add this reference and discuss it: "These results agree with the study of Loveday et al. (2015). They found that SAM modulates Indian Ocean westerlies and further detected the impact of this connection to the Agulhas leakage."

Page 9: Line 6: Peeters et al. 2004 cant be used as reference for the LIA comparison. More-over, ther are more studies in the area that cover the LIA interval and should be taken into account here when comparing to data. e.g. Hahn et al., 2017 Clim. Past, 13,649–665, 2017 https://doi.org/10.5194/cp-13-649-2017 Moreover, if westerlies shifted equatorward and or weakened during glacials remains debated and speculative until now.

We would modify this part as followed: "This is supported by the studies by Hahn et al. (2017), Stager et al. (2012), and Granger et al. (2018), who also found that the winds shifted equatorward during cooler and poleward during warmer periods. Nevertheless, the position of Southern Hemisphere westerlies during the LIA is still under debate and seems to depend on the region as studies of the African, the South American and the

Australian sector provide varying results (Chase and Meadows, 2007)."

Line 13: In the weaker emission scenario, by contrast, significant trends mark a northward shift of the westerlies and a weakening of trades and westerlies. So I wonder how the different RCP scenarios can provide such different results and hence how reliable they are then at all? If the models are struggling to reproduce the trends in the observational time period how can we believe any estimate for the RCP scenarios? Moreover, I dont understand the explanation given for the differences?Here more explanation would be appreciated with the regards to the ozone recovery mentioned.

We would modify and extend our explanation: "Although the simulations struggle to reproduce the observed trends, we provide here an explanation as to why the simulations with different scenarios of greenhouse emissions produce different trends of the wind systems. This explanation involves the compensation of diverging trends caused by ozone and by greenhouse gases. The strongest scenario rcp8.5 indicate a poleward shift and intensification of westerlies (and a poleward shift and weakening of the trades). In the weaker emission scenario (rcp2.6), by contrast, the simulation displays a northward shift of the westerlies and a weakening of trades and westerlies. As prescribed ozone concentrations are the same in all three scenarios, the amount of greenhouse gas emissions is likely the factor that causes the difference in the simulated trends of the wind systems. It has been previously found that the the ozone recovery causes a northward shift and a weakening of the tropospheric jet, and a lowering of the SAM (Southern Annular Mode) values Watson et al. (2012). This is likely the effect seen in the simulations with the weaker rcp2.6 scenario. Only with the stronger rcp8.5 scenario are the emissions strong enough to counteract the effects of ozone recovery The simulated trends under rcp4.5 forcing are not insignificant , which in our interpretation would indicate a balance of both driving factors, ozone recovery and greenhouse gas emissions. It has to be kept in mind that these results depend on the model ."

Page 11: Fig.6: That is interesting result. Hence looking at the Agulhas Current itself it seems like that more a northerly position of the trades is linked to positive SST anoma-

lies in the current itself but actually the opposite for the areas outside the main flow path. How is a northerly position of the trades related to warmer Agulhas SSTs in the model? That part is a bit confusing to start with in terms of which ocean areas around South Africa are correlating with what position of the trades?

We suppose that a northerly position of the trades reduces upwelling in the western part of the south coast and that the Agulhas Current is located closer to the coast. Hence, the positive correlation at the coast is linked to the more northerly position of the Agulhas Current and the warmer SSTs due to reduced upwelling. The negative correlation is where the current is located when trades are located more southerly. To indicate the selected regions in this study, we would add a figure early in the manuscript showing them.

Page 13 Line 9: Here an-other perspective should be give as Beal& Elipot 2016 showed based on observations that there is a broadening not strengthening of the Agulhas Current since the early1990s.

We would add and change this to: "Beal et al. (2016) confirms that intensified winds impact the Agulhas Current, though not by strengthening it but by broadening it. Thus, the coherent variability and trends in the two wind systems cause a modulation of both oceanic components, Agulhas Current and Agulhas leakage."

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