# Response to Anonymous Referee #2

*Original reviewer's comments are inserted in black, Author Replies (AR) are added in blue, and Changes made to the Manuscript (CM) are finally listed in grey, whereby page and line numbers refer to the fully revised version of the manuscript.*

This manuscript studies the Agulhas Leakage estimates and changes in its thermohaline properties after leaving the Agulhas Current and before entering the South Atlantic. The authors use two offline Lagrangian tools, Parcels and Ariane, based on the velocity field obtained from a 1/20 degree ocean sea ice model covering 1958-2014. They find a robust estimation between the two tools regarding the variability and trend of the leakage, although the mean (climatological) value could vary a lot. They also identified cooling and freshening occurs when the water moves from the Indian Ocean towards the Atlantic Ocean, and a density increase since the thermal effect dominates.
This work confirms the results from Parcels, which is recently developed, are overall consistent with those from the well-established tool Ariane. This encourages the future applications of Parcels as it is getting more and more widely accepted by the community. This works also compares and discusses different experimental designs in the leakage estimation, which is insightful. The presentation is very clear. I would recommend publication of the work only with a few minor suggestions.
AR: Thank you for your positive reply. Your specific comments below pointed us to some ambiguities that we think could be resolved. We want to point out that we do not fully agree with the summary above. It is not only the variability and trend of Agulhas leakage that agree well between the two Lagrangian tools, but also the mean (climatological) transport. The mean transport varies, however, with different designs of the Lagrangian experiment, but this is independent of the Lagrangian tool. We modified the relevant part in the section Discussion to state that more clearly.
CM: ll.386-389 All of these test cases show that changing certain parameters of the Lagrangian experiment can affect in particular the total transport of Agulhas leakage, even if the same Lagrangian tool is being used, and that designing such an experiment to estimate Agulhas leakage is not straight forward due to the turbulent regime.

- L52: The discussion of Lagrangian particles vs. Eulerian tracers is not clear to me. The authors first say both methods are 'widely used', then the authors say the tracking of Lagrangian particles is 'the most widely used'. This is confusing. I understand the authors want to say they are used to estimate different things. Please consider rewriting this part.

  AR: We deleted 'widely' when referring to both the Lagrangian and tracer based approaches. The Lagrangian method is certainly used the most as it the most flexible method. When using an additional passive tracer, a modification of parameters of the experiment would require a rerun of the ocean general circulation model which is more expensive than conducting an offline Lagrangian experiment.

  CM: ll.52-54 As a result, a Lagrangian approach or tracer based estimates in ocean models are used to analyse the variability, trends and characteristics of Agulhas leakage in more detail.
  ll.56-57 The tracking of particles with offline Lagrangian tools is the most widely used approach to estimate Agulhas leakage in ocean models due to its flexibility (e.g. Doglioli et al., 2006; Biastoch et al., 2008; van Sebille et al., 2009).

- L62: Somewhere in the Introduction, it will be nice to explicitly state that both Ariane and Parcels are offline tools instead of online. (Or maybe they can also be implemented into the GCM and run online?)

AR: We have now included that already in the beginning of the paragraph about Lagrangian tools (see changes to lines 56-57 above) as all the mentioned tools (Ariane, CMS and Parcels) are offline tools.

- L113: It is mentioned the hindcast simulation using JRA55-do covers 1958-2019. But here it says 1958-2014. Did I miss anything?

  AR: The JRA55-do forcing does cover the period 1958 to present (currently until mid 2020), but at the time of conducting the hindcast simulation in INALT20 only the period 1958-2018 was available. As particles are advected for 5 years, the last release year is 2014 and as we usually use the release year as the reference date, this results in a time series for Agulhas leakage from 1958 to 2014.

  CM: ll.93-94 Output from a hindcast simulation with the eddy-rich ocean-sea ice model configuration INALT20 (Schwarzkopf et al., 2019) from 1958 to 2018 was used to conduct offline Lagrangian experiments.
  ll.102-103 Here, atmospheric boundary conditions are given by the JRA55-do forcing data set covering the period from 1958 to the present (Tsujino et al., 2018).

- L136: What if a single simulation of 57-years is performed with the particles continuously released at the 32S section? What is the advantage of the current design compared to this one? Could a recirculated particle that could 'pollute' the source be the reason?

  AR: The current design ensures that all particles are advected for exactly the same time period (here 4 years). In addition, the fast transit time through the area and the low number of particles that do not reach any of the boundaries of the area within 4 years (ca. 2%), demonstrate that an advection for 4 years is long enough. A particle that is advected long enough could potentially become part of the Agulhas Current again and cross the release section at 32°S at a time when another particle is just being released due to the continuous release. This would artificially increase the transport at that section as 2 particles represent the same part of the transport and is against the idea of determining Agulhas leakage as a direct connection between the Indian and Atlantic Ocean through the Agulhas Current.

- Fig. 1: It will be nice to label Cape Basin on the map. Plus, please indicate what the red dots represent in the caption.

  AR: We added another panel to Fig. 4 in the manuscript (Fig. R1 in this document) with a map, where the Cape Basin is labelled. We also adjusted the caption of Figure 1.

  CM: In caption to Figure 1: Release positions of particles (shown as red dots) in experiment (b) A and (c) P with a shading of the number of particles per grid cell.

- L411: There are two 'for example's in this sentence. Please consider rewriting.

  AR: Thanks for pointing that out. We have deleted one 'for example'.

  CM: ll.420-422 Agulhas leakage could also be estimated with Parcels based on a variety of differently gridded products, e.g. reanalysis products, which do not have a non-divergent velocity field as required by Ariane.

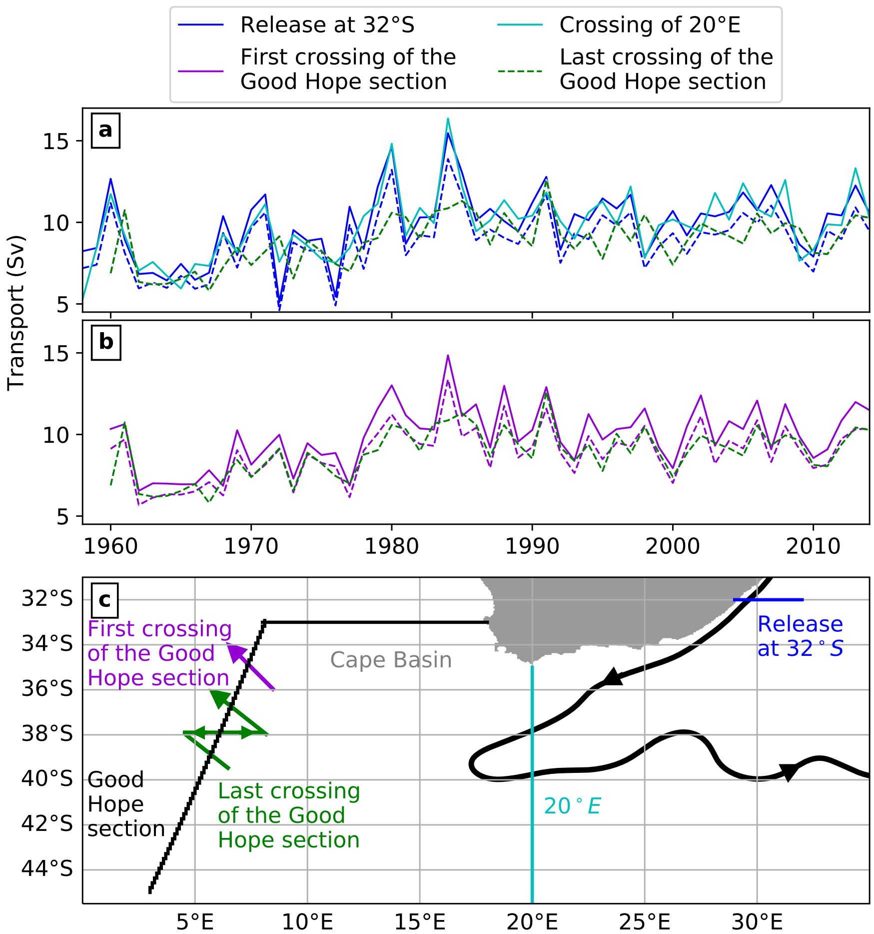


Figure R1: Comparison of the year of reference used to calculate a time series of the Agulhas leakage transport for experiment P: time series of Agulhas leakage transport referenced to the release year (blue in (a)), year of crossing 20°E (cyan in (a)), year of the first crossing of the Good Hope section (purple in (b)) and year of last crossing of the Good Hope section (green in (a) + (b)). Dashed lines show the combined transport of all particles that cross the Good Hope section an odd number of times, while for the solid lines this additional criterion was not applied. (c) Schematic path of the Agulhas Current via the Retroflection into the Agulhas Return Current (black arrow) and all the sections used for assigning the reference date in (a) and (b). The Cape Basin is located northwestwards of the Agulhas Retroflection and southeastwards of the Good Hope section.

# References


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