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Ocean Science
Discussions

Interactive comment on "Impact of mesoscale eddies on water mass and oxygen distribution in the eastern tropical South Pacific" *by* Rena Czeschel et al.

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Interactive comment on "Impact of mesoscale eddies on water mass and oxygen distribution in the eastern tropical South Pacific" by Rena Czeschel et al.

Anonymous Referee #1 Received and published: 5 February2018 Review of Manuscript: "Impact of mesoscale eddies on water mass and oxygen distribution in the eastern tropical South Pacific" by Rena Czeschel et al.

This paper used multiple-platform observations to investigate different types of

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mesoscale eddies in the eastern tropical South Pacific region. The transports and life-cycle evolution of the observed eddies is the main point of this paper, which provide with a lot of valuable information of the eddies within this region. The results of this paper is abundant and interesting, if the authors can put the observational results into a more consistent story, the significance of this paper will be improved substantially. Some further clarification and discussion are also needed. I recommend considering publication after major revision, and I will leave my questions in the Specific Comments.

Reply to reviewer #1 We would like to thank the reviewer for taking the time and for providing constructive and very specific comments, which helped to improve the manuscript considerably. The revised manuscript emphasizes the transport of eddies and the title has been changed to "Transport, properties and life-cycles of mesoscale eddies in the eastern tropical South Pacific". The "Discussion and conclusion" paragraph has been changed to "Discussion and outlook" and restructured. We have carefully addressed his/her comments. The point-by-point responses follow below (written in bold).

Note: During the review process we noted the failure of the temperature sensors in 70, 78 and 280 m in the Stratus mooring in November 2014, September 2014 and March 2015, respectively. For calculations of the annual mean as a background field only data were used that covered an entire year (10 April 2014 to 9 April 2015). Therefore we skipped these temperature data as well as the uncomplete salinity data in 85 m depth for the calculation of the annual mean, which lead to slight modifications. Therefore Fig. 6a,b and Fig. 9b has been refigured and calculations of the AHA and ASA (Table 1), the heat and salt transport across the Stratus mooring (Table 2) as well as heat and salt fluxes in the ETSP (chapter 4.3) have been corrected. We corrected the eddy track of ACE2 for the first weeks, which is shown in the movie (supplement) and Fig. 1. Consequently, the composite of the ACE2 of the surface signatures for SLA, SST anomaly and chlorophyll have slightly changed (Fig. 4c, g, k) as well as the properties of ACE2 in Fig. 5.

Specific Comments:

1. Page 2, Line 3-5: It is a little confusing to say the "isolation" and "mixing" of the water mass at the same time. If the mixing reaches maximum, the water mass is no longer strictly isolated. Maybe the reader can understand the meaning of authors comment after finishing the whole paper, as the presentation here within the abstract, the author could give a clarified presentation.

We rewrote the sentence to: "Furthermore, four profiling floats were trapped in the ACE2 during its westward propagation between the formation region and the open ocean, which allows conclusions on lateral mixing of water mass properties with time between the core of the eddy and the surrounding water. Strongest lateral mixing was found between the seasonal thermocline and the eddy core during the first half of the eddy lifetime."

2. Page 5, Line 14-17: A sketch of the mooring and the equipment/probes on it will help readers to imagine how the mooring operates.

We added a sketch of the mooring and the distribution of all instruments in the supplementary Fig. S1. Consequently we changed the consecutive numbering of the corresponding figures S1-S3 to S2-S4 in the figure caption as well as in the text.

Fig. S1. Distribution of the instruments attached to the Stratus mooring between 8 March 2014 to 25 April 2015.

3. Page 7, Line 5-9: The figure of the trajectory of the Argo floats should be given, which will directly demonstrate how the floats being trapped and moving with the eddy.

We have followed your suggestions. In order to improve the visualization we added the track of eddy ACE2 as well as the trajectories of the relevant floats into the movie (supplementary) to better follow the movements of the floats within the eddy instead of a new figure (showing the trajectories of the floats that are trapped in the eddy). The locations of the floats that cross the eddies are also marked in the composite of the

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eddies (Fig. 4). We hope that you agree with this approach.

4. Page 8, Line 1-6: The high-frequency observation of mesoscale eddies by mooring is quite valuable. With the altimeter data providing the eddies' location and radius, the mooring observations can be projected onto eddy center coordinate and reconstruct the three-dimensional structure of the mesoscale eddies (Similar to Fig.4), which may give a lot of useful information of the eddies.

We have tried to follow your idea of a three-dimensional plot. The figures below show the time series of the temperature anomalies vs depth at the position of the Stratus mooring (19°37'S, 84°57'W) and the Hovmoeller diagram (time-latitude) of sea surface temperature anomaly (coloured) and sea level anomaly (contoured) at the longitude position of the Stratus mooring for the a) MWE, b) ACE1, c) ACE2, and d) CE. We do not think that these plots would enhance the amount of information about the eddies significantly. Instead, we added a Hovmoeller-diagramm (time-latitude) of the SLA at the longitude position of the Stratus mooring (Fig. 3b, see below) showing the position of the individual eddies in relation to the mooring (white dashed line).

Figure 3. Time series for the deployment period 8 March 2014 to 25 April 2015 at the position of the Stratus mooring (19°37'S, 84°57'W) for (a) weekly delayed, high-pass filtered sea level anomaly (in cm; blue curve) and geopotential anomaly between 450 and 295 m depth in m2 s-2 (orange curve), (c) oxygen in μmol kg-1, (d) salinity and (e) the meridional velocity component in cm s-1, Hovmoeller diagram (time-latitude) at the longitude position of the Stratus mooring for (b) SLA in cm. The white curve in (e) is the mixed layer depth defined for the depth where the potential density anomaly is 0.125 kg m-3 larger than at the surface. The black dots on the vertical line at the left mark the depths of the used oxygen (c), conductivity (d) and velocity (e) sensors and the black contour lines are selected density contours. Black solid (dashed) lines show the date of the passages of the anticyclonic (cyclonic) eddies. 5. Page 12, Line 14-17: There is two types of transports can be done by eddies: stirring and trapping. The stirring transport happen when there is a background tracer gradient, with the swirling velocity

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of eddies, the down-gradient transport of tracer will emerge. The stirring transport does NOT need the eddy to move. On the other hand, when eddy traps a water mass within its core area, the tracer within this water mass will be transported. The net flux of this kind of trapped-transport happens when the eddy is moving and the trapped water mass having different properties contrasted with surrounding environment. The main focus of the authors is the second kind of transportation. This should be clarified. And with the measurements of the mooring, the first kind of stirring transport can also be evaluated quantitatively.

Thank you very much, you are absolutely right. We have added a few sentences in the manuscript to clarify that: “Horizontal eddy transport can be explained by two mechanisms: 1) by eddy stirring, which occurs at the periphery of the eddy (e.g. Gaube et al., 2015; Chelton et al., 2011) and 2) by eddy transport of water masses trapped in the eddy interior (Gaube 2013; 2015). We are focusing on the latter mechanism. “

6. Page 18, Line 1-5: From Fig.5c, significant variation of the nonlinear parameter U/c can be observed. At the same time, the nonlinear parameter U/c is also used by the authors to compute the vertical extent of the trapped fluid by the eddy. This means the volume of the trapped water by the eddy will also experience significant variation. But the trapped water mass is expected to be quite coherent and isolated, what will cause significant variation of its volume. The authors should give further clarification and discussion.

Yes, you are right and now we have discussed this in the text on p18: “Nonetheless, significant variations of the nonlinear parameter U/c determined at the surface might indicate changes of the volume of the eddies, which can be influenced by friction, stratification, fluctuations of the mean flow or the collapse with other eddies. Maps of SLA show a permanent change of the radius due to an irregular and varying shape and the merging with other eddies (supplement: Movie M1), which makes it sometimes difficult to track an eddy during its whole lifetime. Fluctuations are also produced by the coarse resolution of the satellite data ($\frac{1}{4}^{\circ}$ x $\frac{1}{4}^{\circ}$) and the merging algorithms used by AVISO.

However, the MWE and CE show stronger fluctuations of the nonlinear parameter than the ACE1/2, which probably mirrors the higher variability of the swirl velocity of both eddy types (Fig. 5b). Nonetheless, the nonlinear parameter U/c is always higher than 1 and therefore indicates a trapped volume despite strong fluctuations at the surface. The small variations of the eddy properties of the ACE2 (Fig. 5a-e) suggest a relatively stable structure."

7. Page 22, Line 6-8: The lateral mixing between eddy-core and surrounding water is related to the evolution of eddy, especially its decaying processes. Could the lateral mixing derived from the Argo floats be used to explain the variation of eddy amplitude observed by altimeter?

Thanks for the hint. For a better overview we marked the residence time of the four floats that were trapped in ACE2 in Fig. 5a and discussed the mixing with the observations from altimeter data (p23). "During this period the variability of the amplitude of the ACE2 is negligibly small, which might be due to the coarse resolution of the satellite data. The radius increases up to 50 km with a nearly consistent rotation velocity at the same time (Fig. 5a, b). During the second half of the lifetime the radius of the ACE2 slightly increases but the maximal rotation velocity and therefore the nonlinear parameter decreases until the decay of the ACE2."

Please also note the supplement to this comment:
https://www.ocean-sci-discuss.net/os-2018-5/os-2018-5-AC1-supplement.zip

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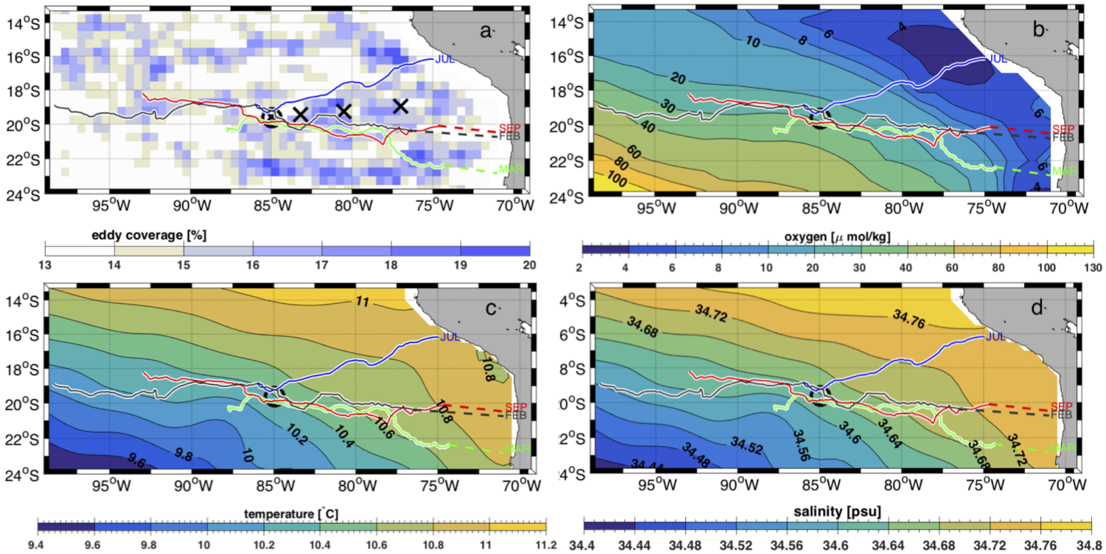

Fig. 1.

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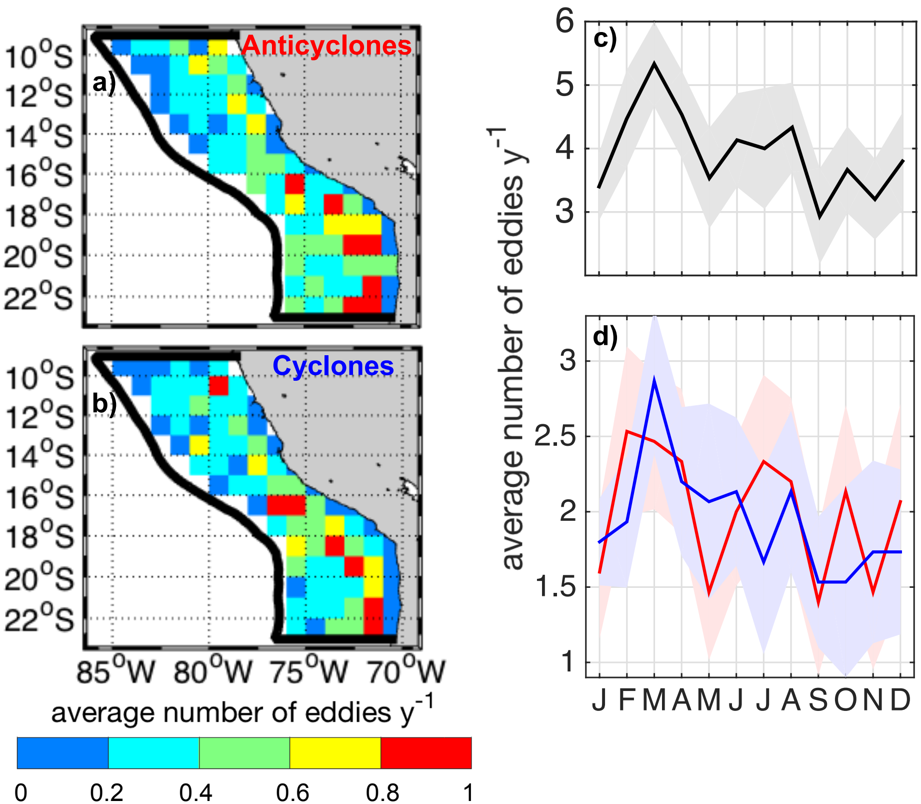

Fig. 2.

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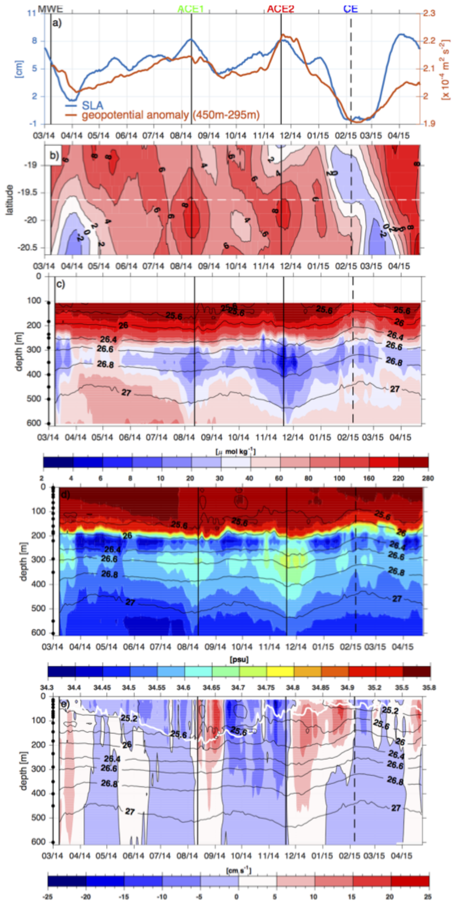

Fig. 3.

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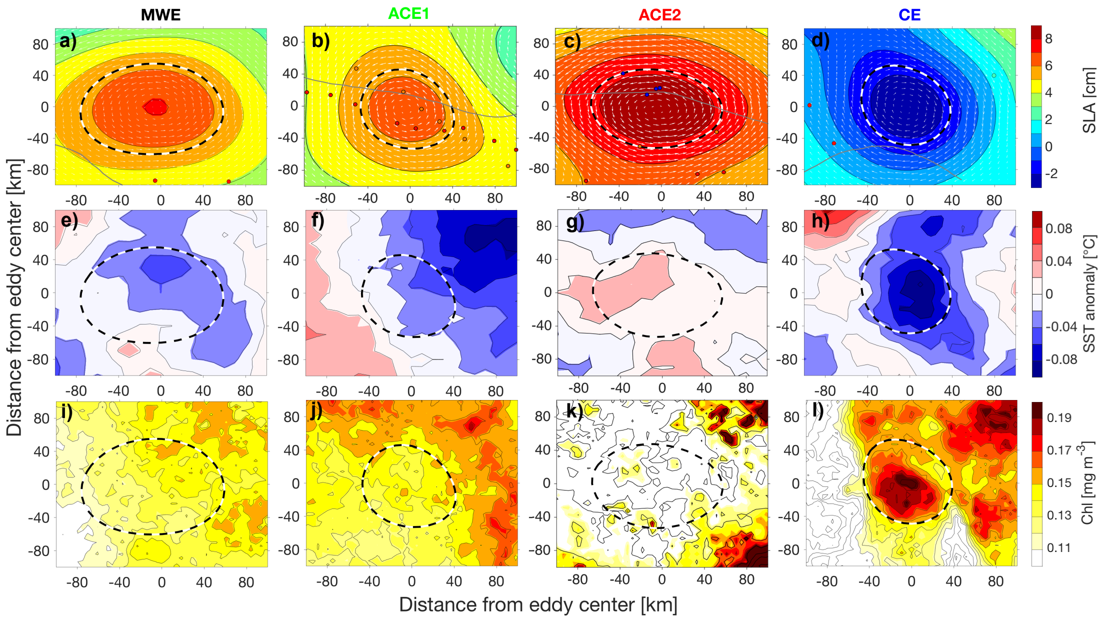
MWE
ACE1
ACE2
CE
a)
b)
c)
d)
e)
f)
g)
h)
i)
j)
k)
l)
Distance from eddy center [km]
Distance from eddy center [km]
SLA [cm]
SST anomaly [°C]
Chl [mg m^{-3}]
8
6
4
2
0
-2
0.08
0.04
0
-0.04
-0.08
0.19
0.17
0.15
0.13
0.11
80
40
0
-40
-80

Fig. 4.

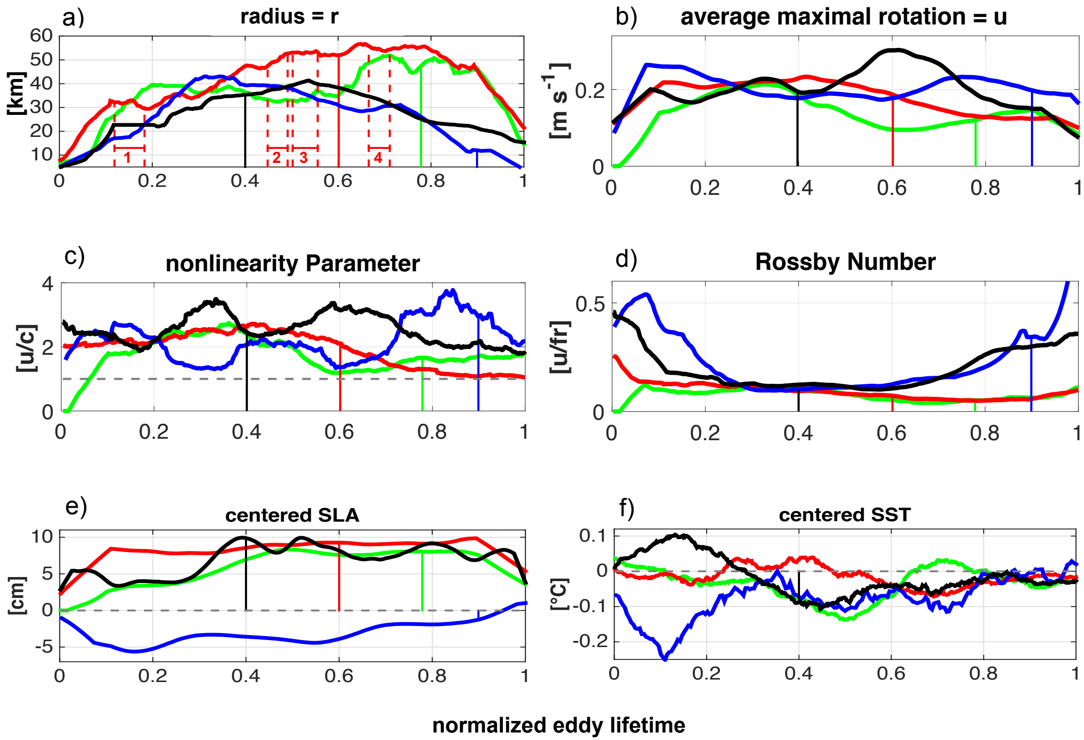

Fig. 5.

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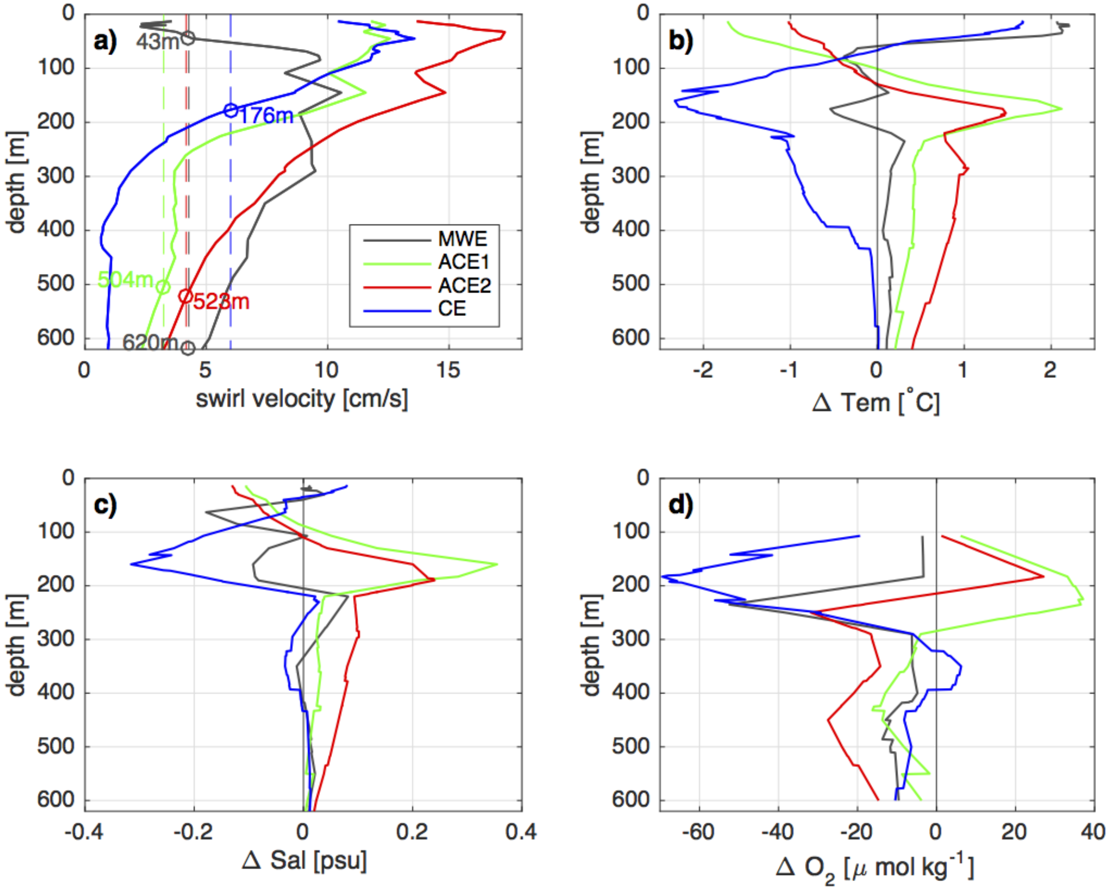

a)
43m
176m
504m
523m
620m
MWE
ACE1
ACE2
CE
depth [m]
swirl velocity [cm/s]
b)
Δ Tem [˚C]
c)
Δ Sal [psu]
d)
Δ O2 [μ mol kg-1]

Fig. 6.

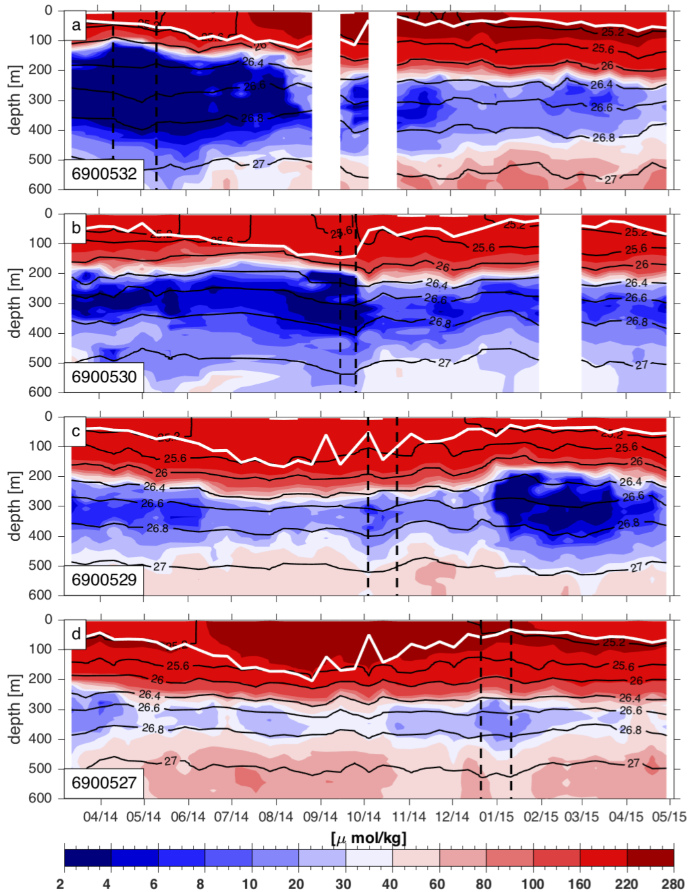

a
6900532
b
6900530
c
6900529
d
6900527
depth [m]
0
100
200
300
400
500
600
04/14 05/14 06/14 07/14 08/14 09/14 10/14 11/14 12/14 01/15 02/15 03/15 04/15 05/15
[μ mol/kg]
2 4 6 8 10 20 30 40 60 80 100 160 220 280

Fig. 7.

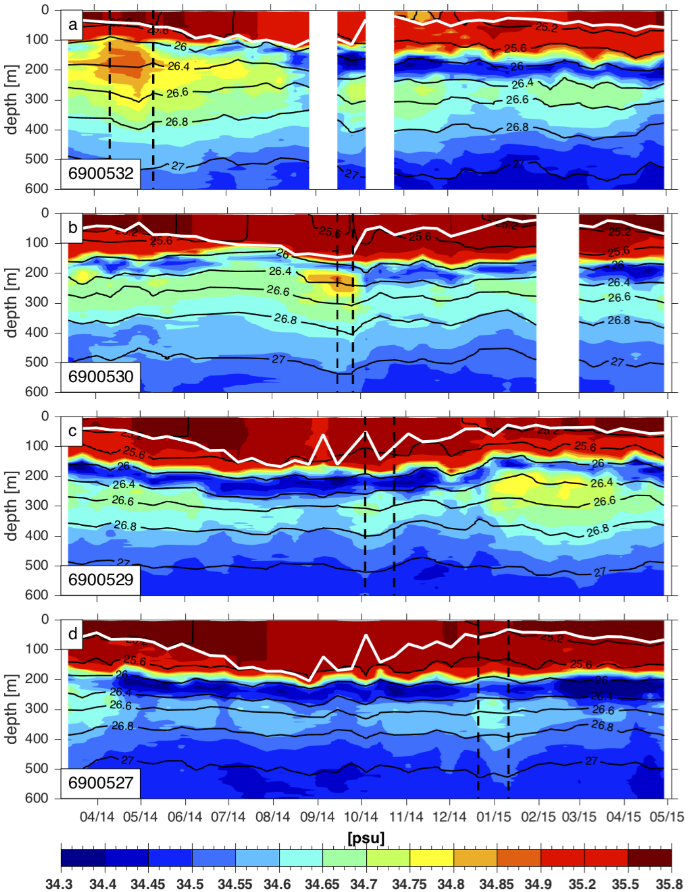
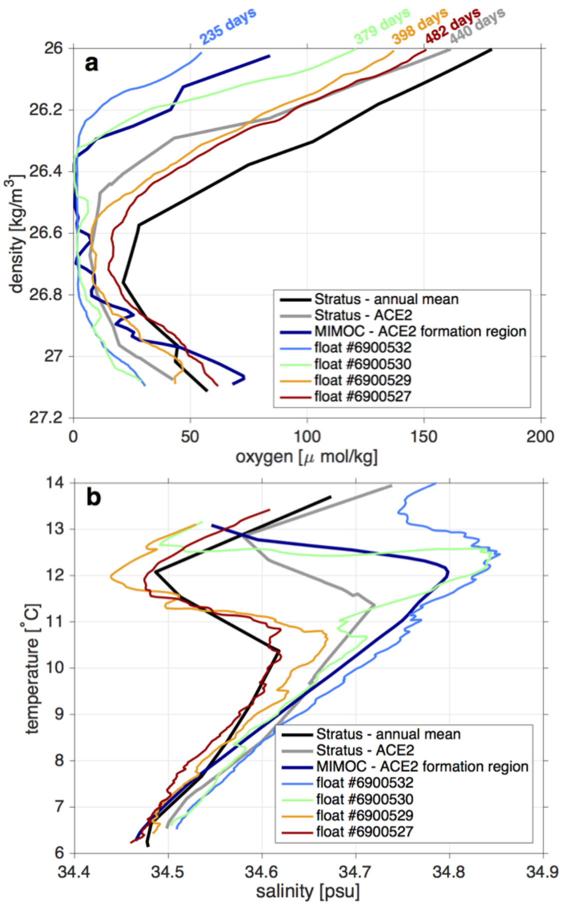

a
6900532
b
6900530
c
6900529
d
6900527
depth [m]
0
100
200
300
400
500
600
25.2
25.6
26
26.4
26.6
26.8
27
04/14 05/14 06/14 07/14 08/14 09/14 10/14 11/14 12/14 01/15 02/15 03/15 04/15 05/15
[psu]
34.3 34.4 34.45 34.5 34.55 34.6 34.65 34.7 34.75 34.8 34.85 34.9 35.2 35.5 35.8

Fig. 8.



235 days
379 days
398 days
482 days
440 days
a
26
26.2
26.4
26.6
26.8
27
27.2
density [kg/m^3]
0
50
100
150
200
oxygen [μ mol/kg]
Stratus - annual mean
Stratus - ACE2
MIMOC - ACE2 formation region
float #6900532
float #6900530
float #6900529
float #6900527
b
14
13
12
11
10
9
8
7
6
temperature [°C]
34.4
34.5
34.6
34.7
34.8
34.9
salinity [psu]
Stratus - annual mean
Stratus - ACE2
MIMOC - ACE2 formation region
float #6900532
float #6900530
float #6900529
float #6900527

Fig. 9.