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Biogeosciences Discussions

Interactive comment on "Evidence of eddy-related deep ocean current variability in the North-East Tropical Pacific Ocean induced by remote gap winds" *by* Kaveh Purkiani et al.

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We thank the reviewer for carefully reading our manuscript and helping us to clarify the presentation of our results a lot. All corrections, modifications and explanations are given in red color lines in the text of our manuscript as well.

Responses to Reviewer #1

L103: "July 2013 and April 2016": This period does not agree with the figure caption of figure 11b, which indicates to show data from April 2013 to May 2016. Please clarify.

Done. Our data presented in this study covers the period from April 2013 to May 2016.

Correction is added to the text.

L107: The mooring was deployed for three years between 2013 and 2016. Now you talk about four years ("60 min during the first year and 45 min during the following three years"). Please clarify.

The mooring was indeed deployed for three year the typo is corrected. "60 min during the first year and 45 min during the following two years".

L109: Please add the geographical location of the mooring.

Done, more additional information is added to the text: At a water depth of ca. 4100 m, three moorings were deployed 8 km apart at the vertices of an equilateral triangle with geographical coordinates of (11°51.11′N, 116°58.43′W), (11°48.30′N, 116°59.36′ W) and (11°53.19′N, 117°00.48′W).

L168: The swirl velocity is mentioned in chapter 3.2 as well as in chapter 3.5 "Translation speed and swirl velocity of eddies". Unfortunately, I could not find anything about the swirl velocity. I think it could be quite important concerning the lifetime of an eddy.

The average surface swirling velocities (Vθ) of the eddies increase outward and reaches values of around 20 cm/s and 10 cm/s at the edges of the eddies for ACEs and CEs respectively. The nonlinearity parameter of eddies, which is characterized by the ratio of swirl velocity to translation velocity (Vθ/VT), is calculated. Most of the eddies of from both types in this region indicate a significant degree of nonlinearity (Vθ/VT>1), implying that eddies can maintain a coherent structure, which may isolate the interior water mass without interaction with ambient water while propagating in the ocean. Similar to previous study (Stramma et., al 2014 and Czeschel et al., 2018) in the South Pacific Ocean, the activity of nonlinear long-lived eddies in this region may result in the large-scale anomalous water mass distribution in this region.

Figure 1: I would recommend to remove the EKE for the Atlantic Ocean in Figure 1 and . Figure 4 shows the zonal variability of meridionally averaged EKE and one might

think that the EKE of the Atlantic was taken into account.

Done! In the new figures the regions in the Atlantic Ocean are masked out.

Figure 4: According to Figure 2 the regions TT and PP are at about 95 âŮę E and 85 âŮę E, respectively. Why is it shown at âĹij98 âŮę E and âĹij92 âŮę E in Figure 4?

Figure 4 does not show the geographical location of TT and PP gap winds, but the zonal variation of laterally averaged EKE in the ocean with the local maximums driven by TT and PP gap winds. The caption of Figure 4 is corrected for more clarification as below. “The dashed lines show the EKE of the ocean circulation in the open ocean and two local maxima driven by TT and PP gap winds respectively“.

L226: Why don’t you choose the median eddy radius?

The eddy radius exhibits a skewed distribution due to long-lived mesoscale eddies. Using a median instead of a mean should therefore result in a more robust estimate of the center of the distribution than using the mean. We believe that using the median instead of mean would pull out the outliers in the tails of the histogram distribution. This outlier data are mainly the long-lived mesoscale eddies with the main focus of this study. Therefore, the mean is chosen for statistical analysis.

L235: There is no word about the swirl velocity, although it is even mentioned in the title. Please add information/estimates about the swirl velocity.

Additional information is added in section 3.5.

L267: It is not a surprising statement that the distance of eddies increases with their lifetime. Please rephrase or skip the sentence.

Done! It is removed.

Figure caption of Figure 7: The last sentence is misleading. Please rephrase.

Done! The lifetimes of detected eddies are divided to six classes with the length of

38 days for each class. Tracks of eddies are shown in colors corresponding to each lifetime class.

L275: I would recommend to calculate the annual mean for the period from July to June for each characteristic eddy parameter as El Nino/La Nina events show their peak during the turn of the year. Sometimes an El Nino year is followed by a La Nino year, which means that an annual mean from Jan-Dec would cancel the anomaly.

This idea has been earlier tested. Changing the averaging period did not help to improve the statistical correlation between ONI and eddy characteristic parameters. By taking the period from July to June for eddy characteristics, some times even less significant correlation was obtained.

L287: I don’t understand the last part of the sentence as the EKE at TT seems to be even more related to EL Nino events. Please clarify.

Some more discussion is added to this section. Please see lines 300-30

L323: I cannot see a tilting of the currents to a northward direction on 12 April, it seems to be rather on 22 of April in 406 m a.b. and on 25 April at 6m a.b..

It is corrected. We have earlier defined the tilting as a time in which zonal current velocity increases enough high to decline the southward current direction. However, we it more informative if the northward tilt was mentioned. The ocean currents tilt into northward direction at 22-April and 25-April at 406 m and 6 m above the seafloor respectively.

L327: At the end of March as well as at the beginning of April, there is also a strong deviation of the current velocities. The reverse of the deep current from a southward to a northward direction occurs with three weeks after the time of maximum SSH showing a strong time lag between the passage of the eddy and the response of the deep current.

The deep sea in this region is indeed a dynamic environment, characterized by daily

to seasonal variations in current properties. We agree that variations in the current velocity occur at the end of March and early April. However, during this period no significant variation in the current direction was observed. An analysis of sea-surface height anomalies indicates that the weak current variation signal cannot be related to the anomalies driven by the passage of a mesoscale eddy as no significant SSHA is observed in this period. We therefore summarize that as the current variation signal is only limited to the lower current meters at 6 mab and 206 mab, this must be due to interaction of deep sea current and bottom topography in this region, which could not develop at higher levels above the seafloor (e.g., 406 mab).

L393: Why do you calculate the correlation between the EKE at TT and SR from the annual cycle over 24 years and not from the time series for the whole period from 1993 to 2016?

This is modified based on the daily time series for the whole period. More explanation is given below.

L394: The lag of 224 is not clear to me. The peak in the vicinity of the TT region occurs in December. The maximum of the EKE in the SR occurs in April, which means a lag of 120 days. Please clarify.

Analyzing the lag correlation between EKE at the location of the gap winds with EKE at SR based on daily time series led to a reduced and correction of the time lag to 165 days with a maximum correlation of 83% between EKE at TT and SR. No significant correlation was again found between PP and SR. The time lag between EKE at the gap winds and EKE at SR is now consistent with the required time for a long-lived ACE with the average translation velocity of 16.9 cm/s (see table 1) to travel a distance of 2400 km from TT gap winds to the SR region.

L400: It is not clear to me, why monthly mean current velocities are used instead of the time series for the whole period of three years. Please explain.

First of all we shall mention again that the black line in the Fig 11b is a combination of three moorings. As we have focused on the large scale responses of SR hydrodynamic properties as well as mesoscale eddies to the gap winds, analyzing the small-scale temporal variation of deep-sea current properties is not in the scope of this study.

Besides, the use of monthly mean current velocities is more consistent with the presentation and derivation of EKE from long-term surface data at different locations as well as the long-term reanalysis products for the deep sea.

By providing our data as monthly averages, we hope to contribute to reducing the environmental impact of deep-sea mining by broadening the knowledge of temporal variability of ocean current properties in the deep sea environment.

L400: “four years from April 2013 to May 2016“: It should be three years. Please correct.

Done!

L408: “four years“. Should be three years.

Done!

Figure 11: Do you show northward velocity? In Figure 10 the current velocities show a southward current except for the passage of the ACE. Please clarify. Units are given in mm/s and in cm/s. Please, choose consistent units.

Figure 11b shows the monthly average of the ocean current speed (Vel = (U2+V2)0.5) . In this figure more emphasis is given to the fact that long-term current observation as well as reanalysis products are able to indicate seasonal anomalies even in the deep sea when mesoscale eddies cross this region. As it was mentioned earlier in the caption of this figure no change is made.

Units are changed to cm/s in the figure.

Technical corrections: L2: Better: “world ocean”

Done!

L10: typo: correct “that” into “than”

Done!

L32: typo: correct “kilimeters” into “kilometers”

Done!

L110: Usually, the figure number should be sorted by their order of appearance, which means that Figure 10 should be Figure 1.

Done!

L113: typo: correct “products” into “product”

Done!

Figure 1: The indication of a), b), c), d) is missing in the figures. It is not immediately clear which season is shown in which figure.

The original figure (please see attached Figure 1) had all the indications. This must been a technical issue. In the new figure the indications from a) to d) are better positioned and shown.

Caption of Figure 4: typo: delete one “period”

Done!.

L241: The translation speed should be uniformly given to one decimal place.

Done!. In the entire text the translation velocities are given to one decimal.

Table 1: Please add the information in the caption, that this table only includes statistics about ACEs.

Done!.

Figure 7: The location of eddy generation is difficult to recognize, especially the ones that are coloured in yellow and orange.

We have tried with other colors and markers, but they were covered anyways and it is difficult to recognize them as there are more eddies specially in the shorter lifetime classes. Therefore, we kept the figure as it was.

Figure 8: typo at the label of the y-axis: correct “ifetime” into “Lifetime”. Hyphens are missing at the label of the colorbar. Please add hyphens. Indication of a)-d) is missing in the figure caption. Please add a)-d).

Done! All suggestions have been followed. Similar to Fig 1, the indication of a) to d) was missing in the figure after compiling in the journal template. The original figure (please see attached figure 8) had all indications. The issue will be discussed with the technical support of the journal.

L323: typo: correct “North” into “north”.

Done!

L328: typo: correct “soutward” into “southward”.

Done!

Figure 9: 9a shows different y-axis scales.

Done! Scales in right axis are edited.

Figure caption of Figure 9: Please indicate that TT is black and PP is red in the figure caption.

The black and red dots in a) refer to EKE at TT and PP, and in b) to f) refer to eddy characteristics of ACEs and CEs respectively.

Figure 10: Figure 10f is very small, hard to see and does not give any new information that cannot be obtained from Fig. 10a-d. I would recommend to drop Fig. 10f.

Done! Fig. 10f is removed. The caption is edited accordingly.

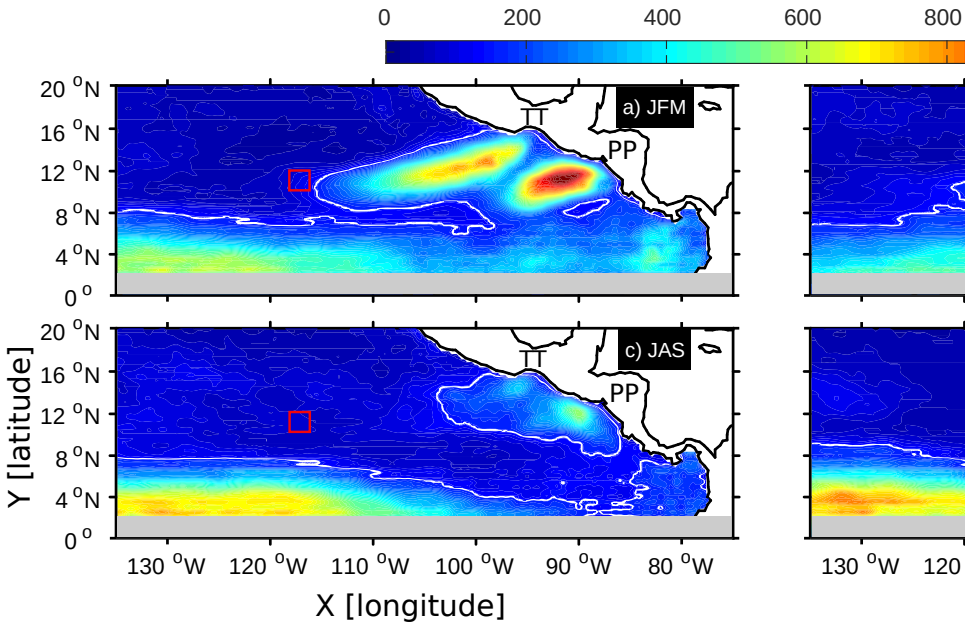
L431: typo: correct “describes” into “describe”

Done!

Figure 11: In Figure 9, the EKE in the TT (PP) gap wind regions is shown in black (red). In Figure 11 it is the opposite way round, which is confusing on first sight. Please plot the EKE of TT and PP in the same colour each.

Done! It is all corrected. The color of TT and PP follows the same as what is presented in Figure 9.

Interactive comment on Biogeosciences Discuss., https://doi.org/10.5194/bg-2020-77, 2020.



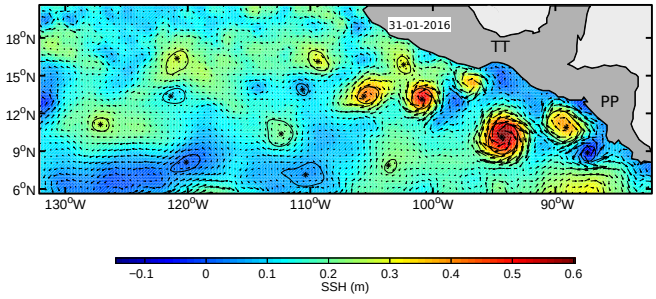

31-01-2016
TT
PP
18°N
15°N
12°N
9°N
6°N
130°W
120°W
110°W
100°W
90°W
−0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
SSH (m)

Fig. 2.

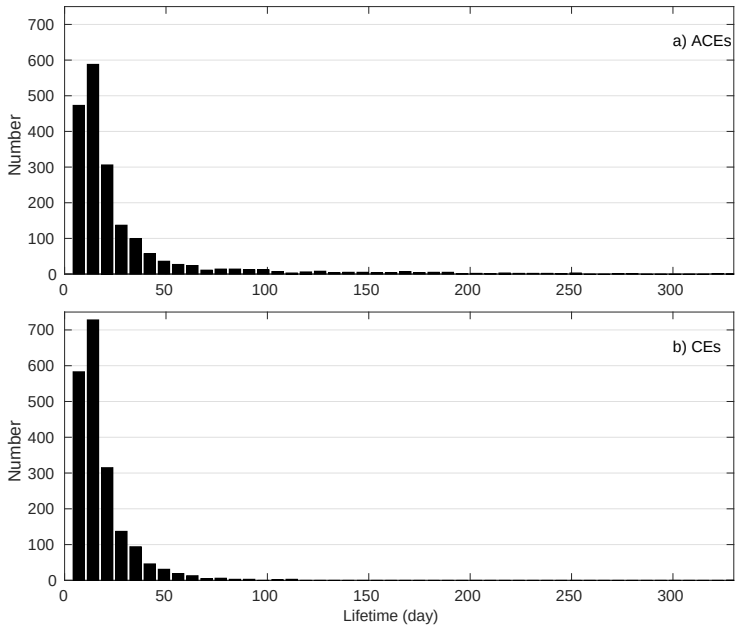

a) ACEs
b) CEs
Number
Number
0
100
200
300
400
500
600
700
0
50
100
150
200
250
300
Lifetime (day)

Fig. 3.

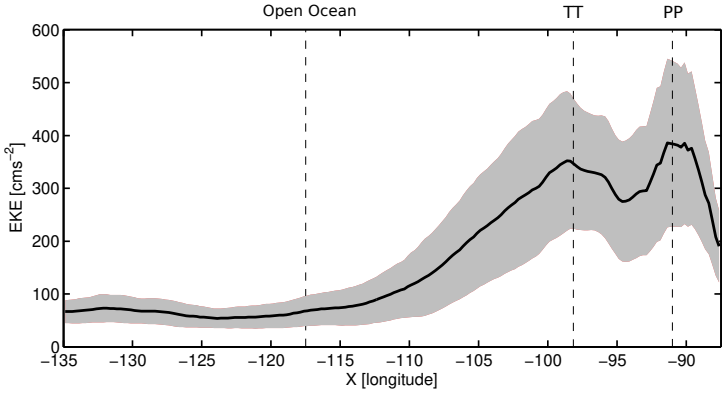

Open Ocean
TT
PP
600
500
400
300
200
100
0
EKE [cms^{-2}]
−135
−130
−125
−120
−115
−110
−105
−100
−95
−90
X [longitude]

Fig. 4.

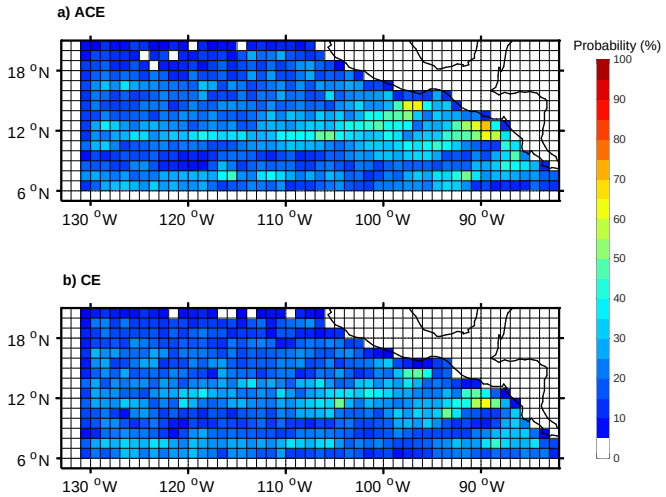

a) ACE
b) CE
18 °N
12 °N
6 °N
130 °W
120 °W
110 °W
100 °W
90 °W
Probability (%)
100
90
80
70
60
50
40
30
20
10
0

Fig. 5.

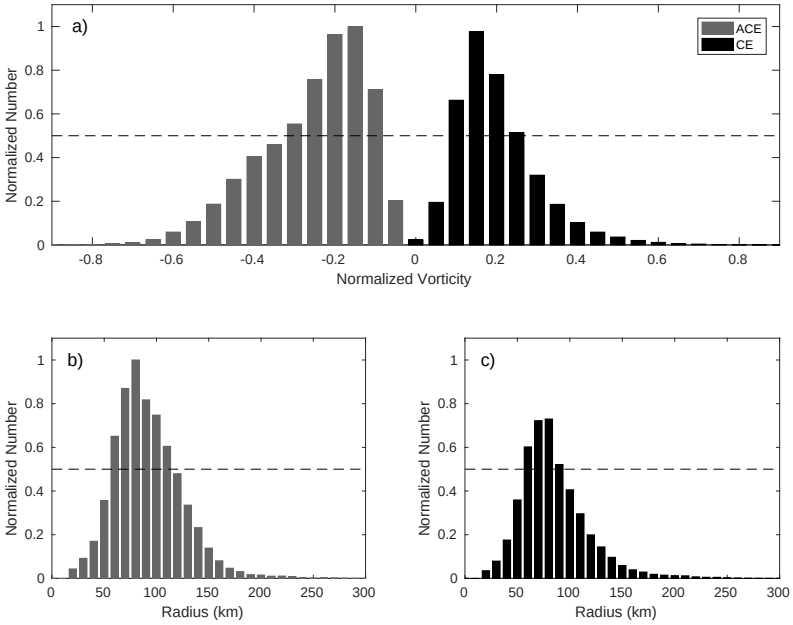

a)
ACE
CE
Normalized Number
Normalized Vorticity
b)
Radius (km)
c)
Radius (km)

Fig. 6.

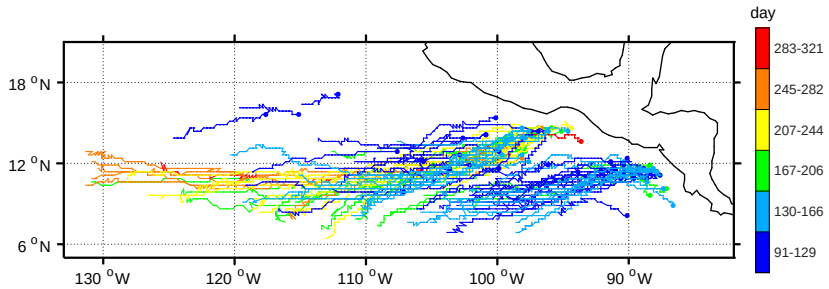

day
283-321
245-282
207-244
167-206
130-166
91-129
18 °N
12 °N
6 °N
130 °W
120 °W
110 °W
100 °W
90 °W

Fig. 7.

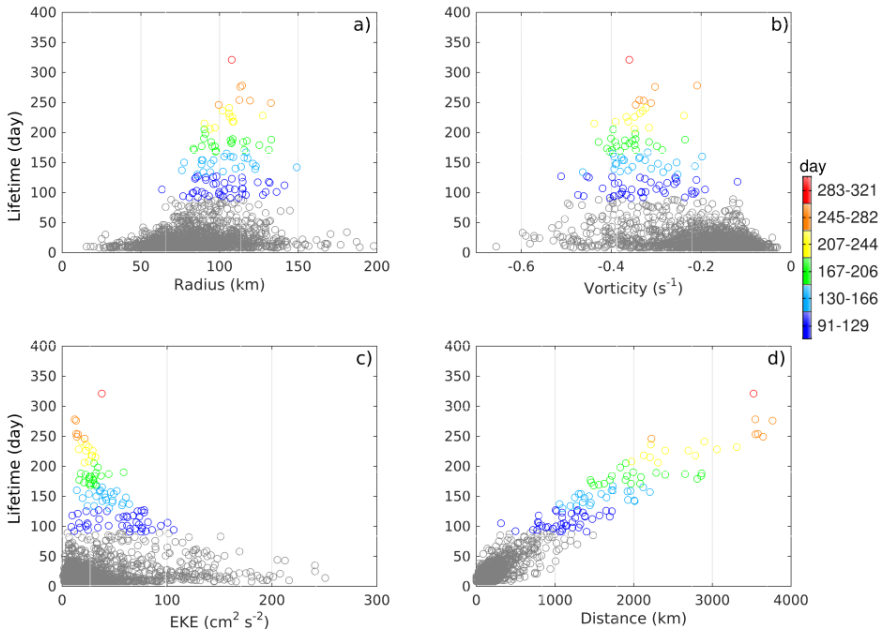

a)
b)
c)
d)
Lifetime (day)
Radius (km)
Vorticity (s-1)
EKE (cm2 s-2)
Distance (km)
day
283-321
245-282
207-244
167-206
130-166
91-129

Fig. 8.

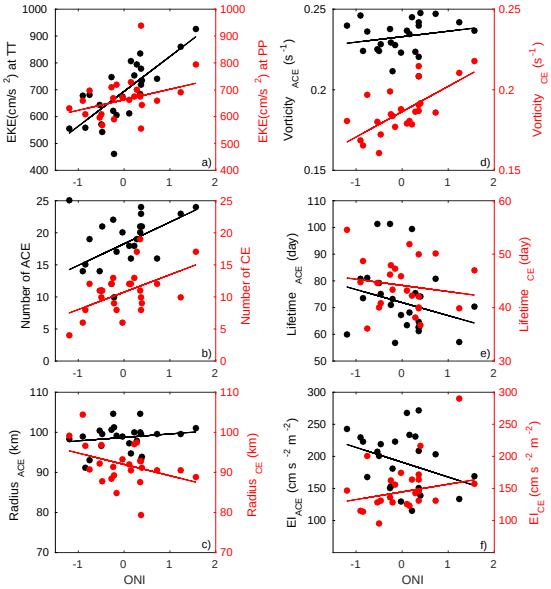

EKE(cm/s 2) at TT
EKE(cm/s 2) at PP
Vorticity ACE (s-1)
Vorticity CE (s-1)
Number of ACE
Number of CE
Lifetime ACE (day)
Lifetime CE (day)
Radius ACE (km)
Radius CE (km)
EI ACE (cm s-2 m-2)
EI CE (cm s-2 m-2)
ONI
ONI

Fig. 9.

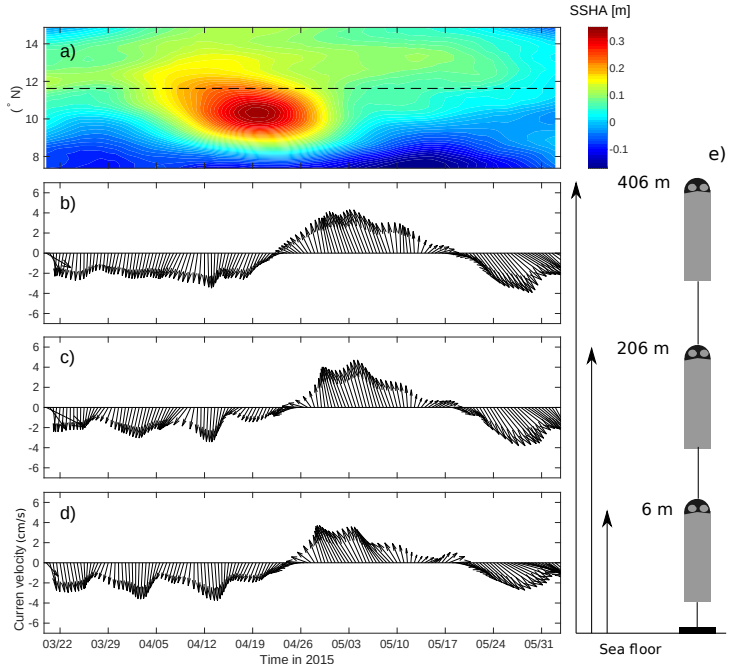

SSHA [m]
a)
b)
c)
d)
e)
406 m
206 m
6 m
Sea floor
Curren velocity (cm/s)
03/22
03/29
04/05
04/12
04/19
04/26
05/03
05/10
05/17
05/24
05/31
Time in 2015

Fig. 10.

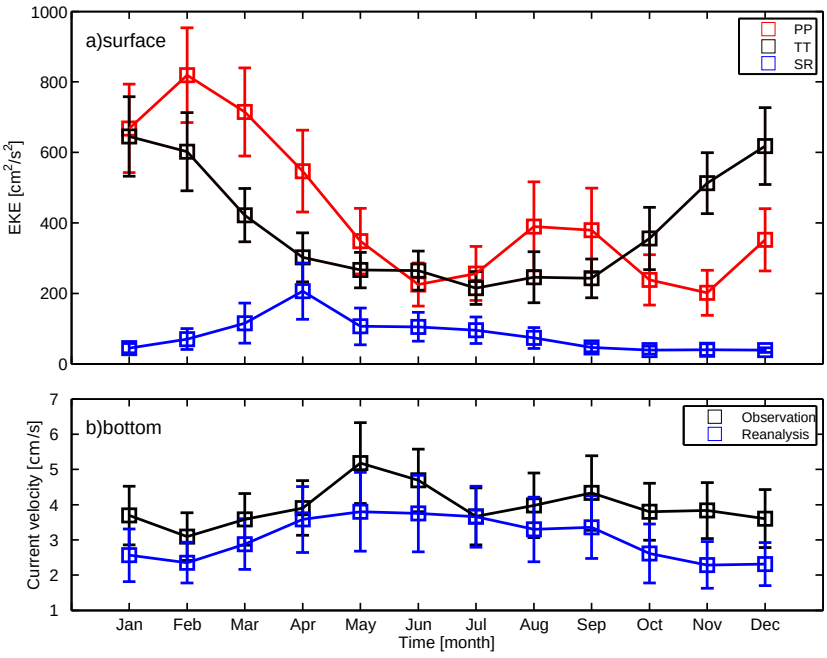

a)surface
PP
TT
SR
EKE [cm²/s²]
b)bottom
Observation
Reanalysis
Current velocity [cm/s]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time [month]

Fig. 11.