1st NPOCE Webinar on
Dynamics and variability of the Pacific Western Boundary Currents
March 22, 2022

Long-term measurements of the Mindanao Undercurrent

Jae Hak Lee

KIOST & GeoSystem Research

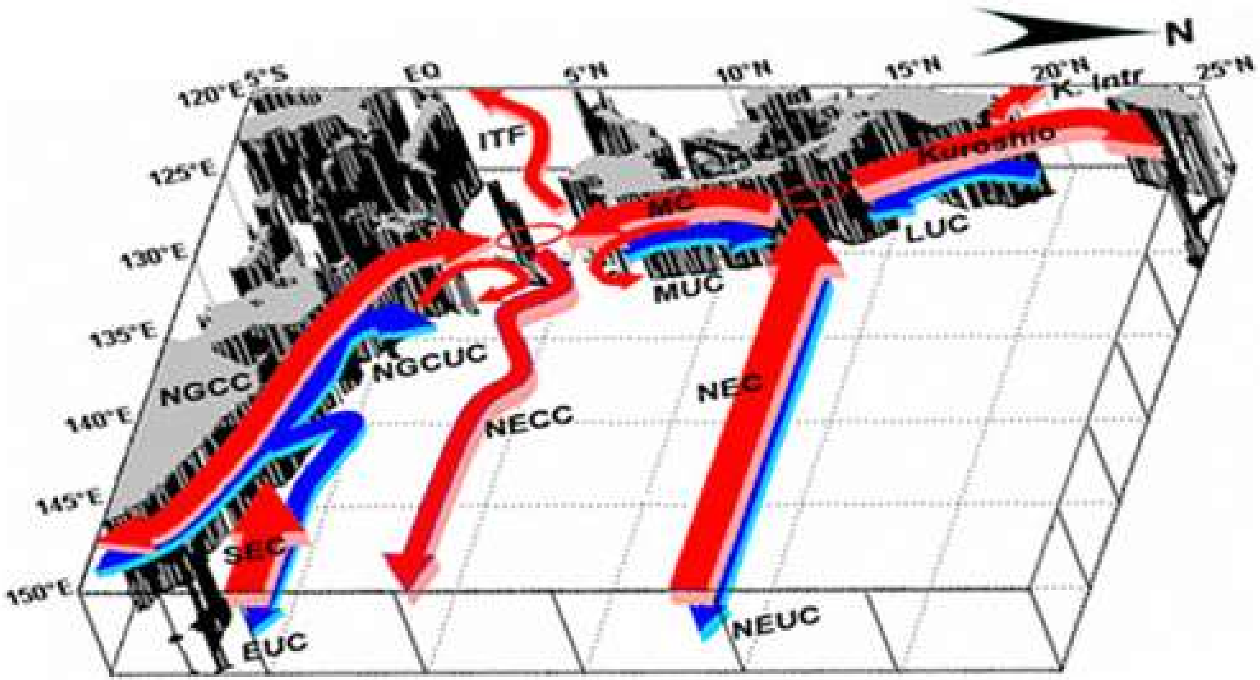
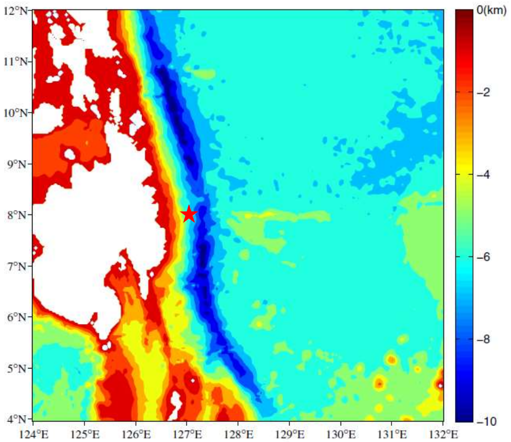


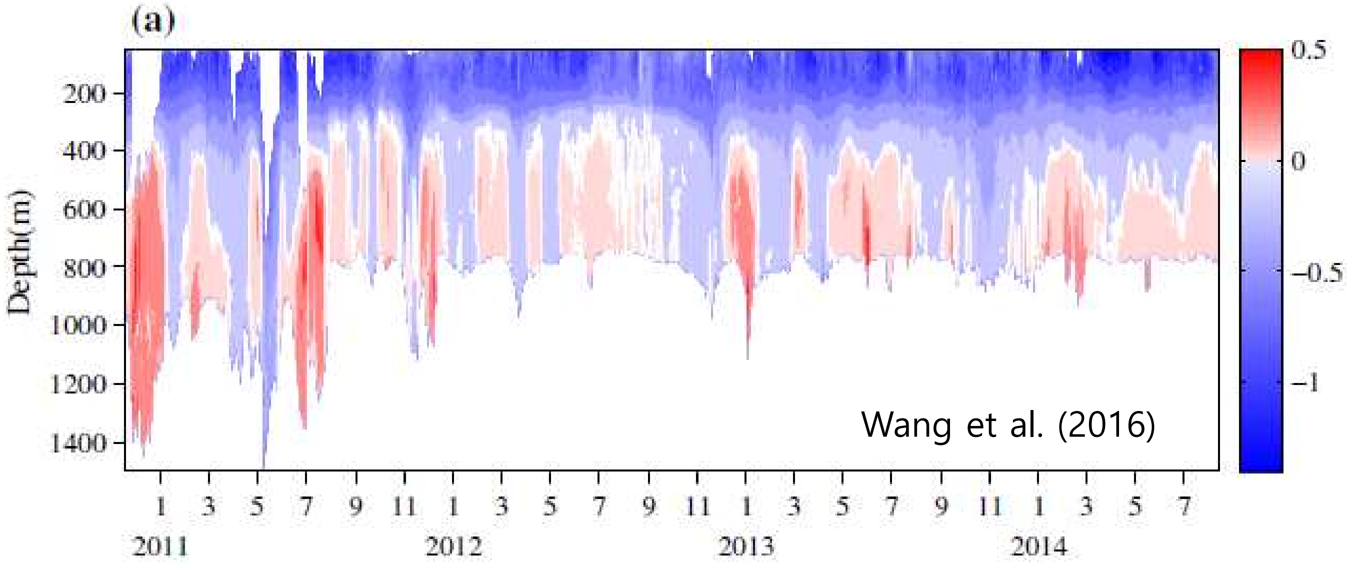
Figure 2: Sketch indicating surface and subsurface currents in the western Pacific.
(From NPOCE Science Plan, 2010)

NPOCE mooring observation

8°N, 127.05°E

Dec. 2010 – Aug. 2014





Qu et al. (2012), Wang et al. (2014), Zhang et al. (2014), Wang et al. (2015),

Wang Fan et al. (2016), Wang Fujun et al. (2016), Ren et al. (2018), …

Strong intraseasonal variability caused by the subthermocline eddies

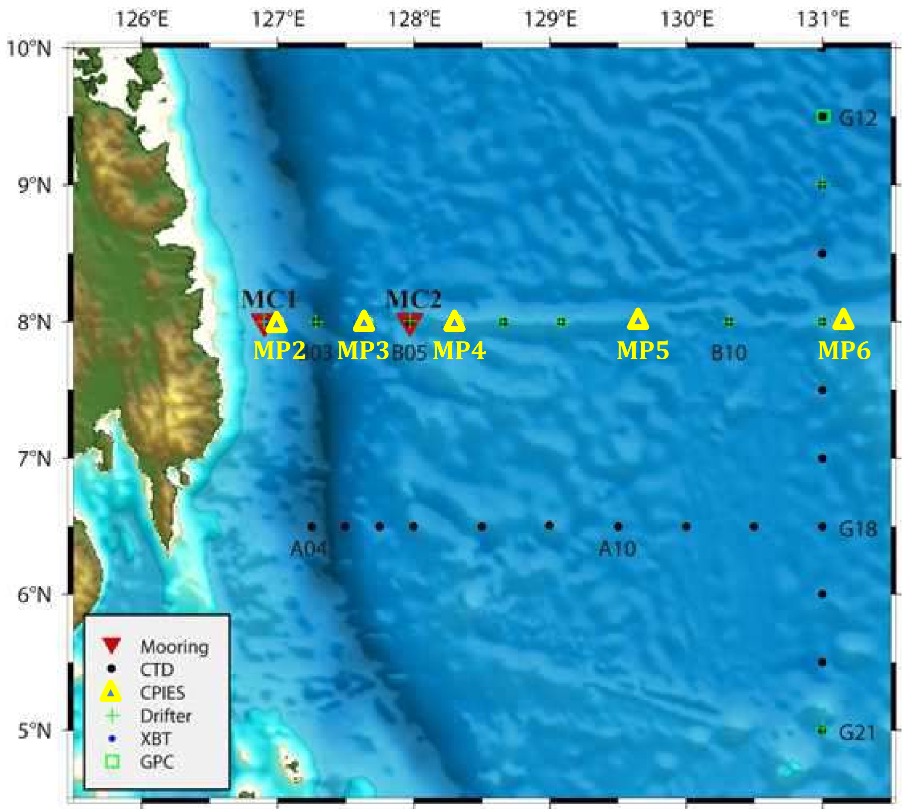
Mooring observation by KIOST & Inha Univ.

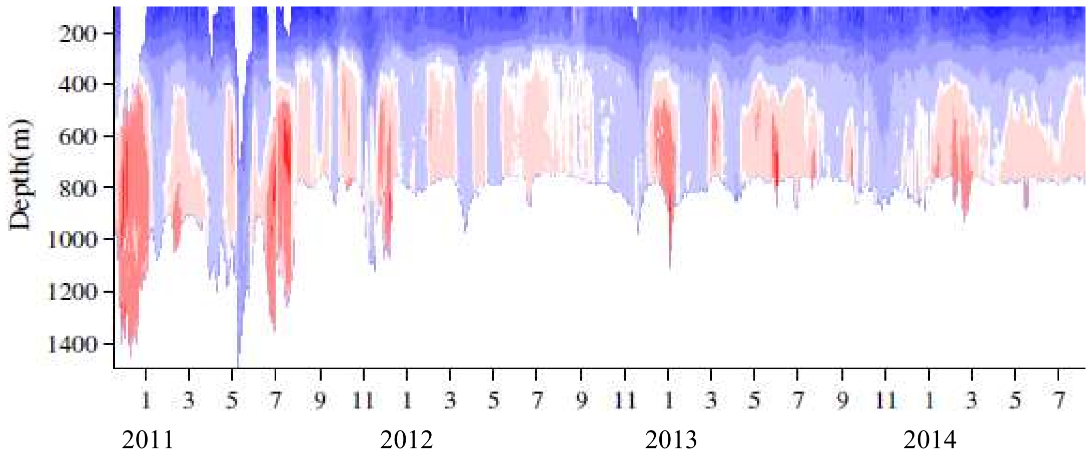
- 2 CM sites, 5 CPIES sites
- Data acquisition

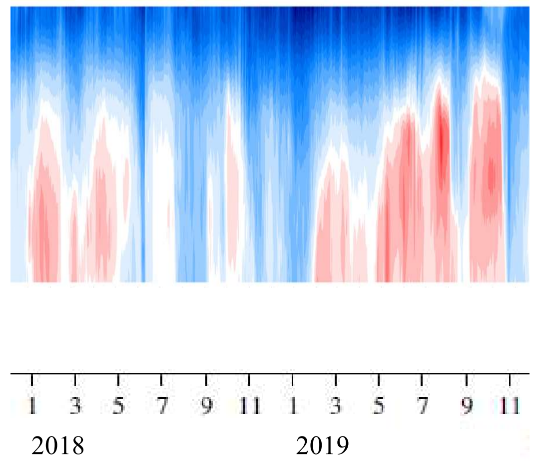
  MC1, MP2, MP3, MP4, MP6: Nov. 2017 – Dec. 2019

  MC2: Nov. 2017 – Nov. 2018

  MP5: no data

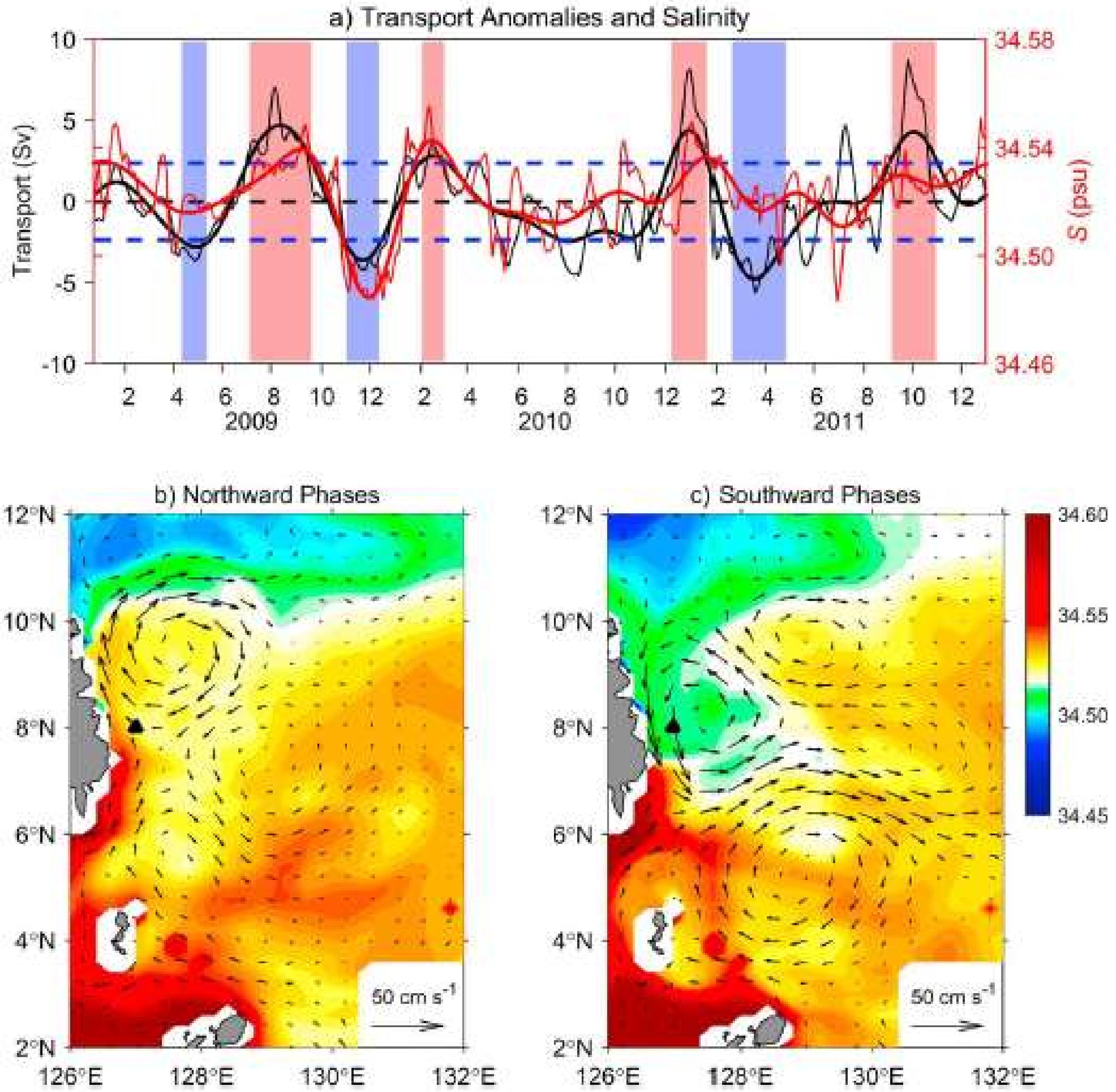






	NPOCE (Zhang et al. 2014, Wang et al., 2016)	GAIA/KIOST
Mooring location	8°N, 127.05°E	8°N, 126.9°E
Period	12/2010 – 8/2014	11/2017 – 12/2019
Vertical range Mean Maximum range	 600 ~ deeper than 1000 m 400 ~ deeper than 1000 m	 700 ~ deeper than 1000 m 400 ~ deeper than 1000 m
Max mean velocity Maximum velocity	< 10 cm/s < 50 cm/s	5.8 cm/s at ~900 m 72.5 cm/s at ~600 m (Lasted 3 weeks with > 40 cm/s)
Variability	Semiannual ~187 days Intraseasonal ~66 days	Intraseasonal 70-80 days

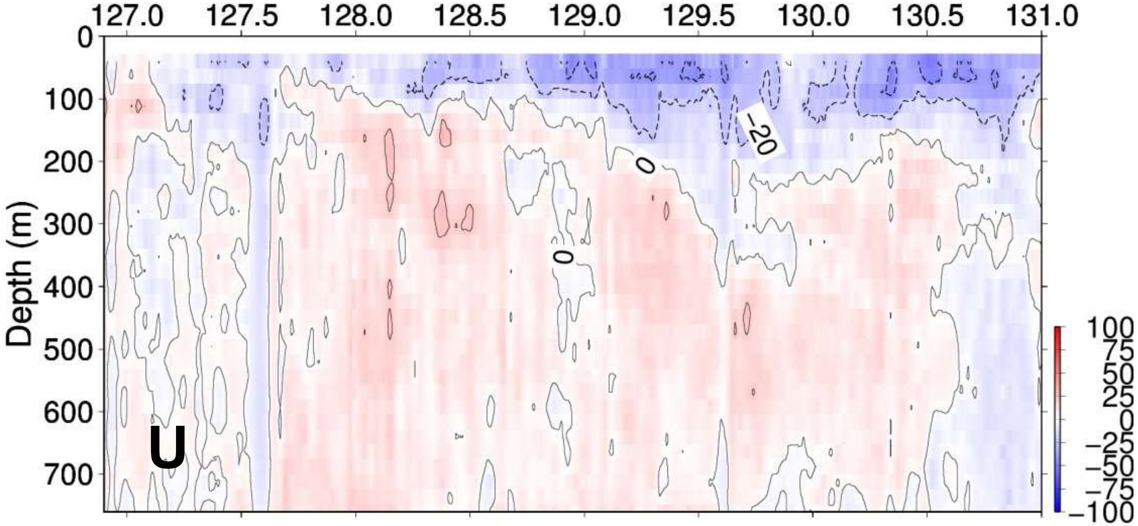
Q1: Does the MUC transport South Pacific Waters?

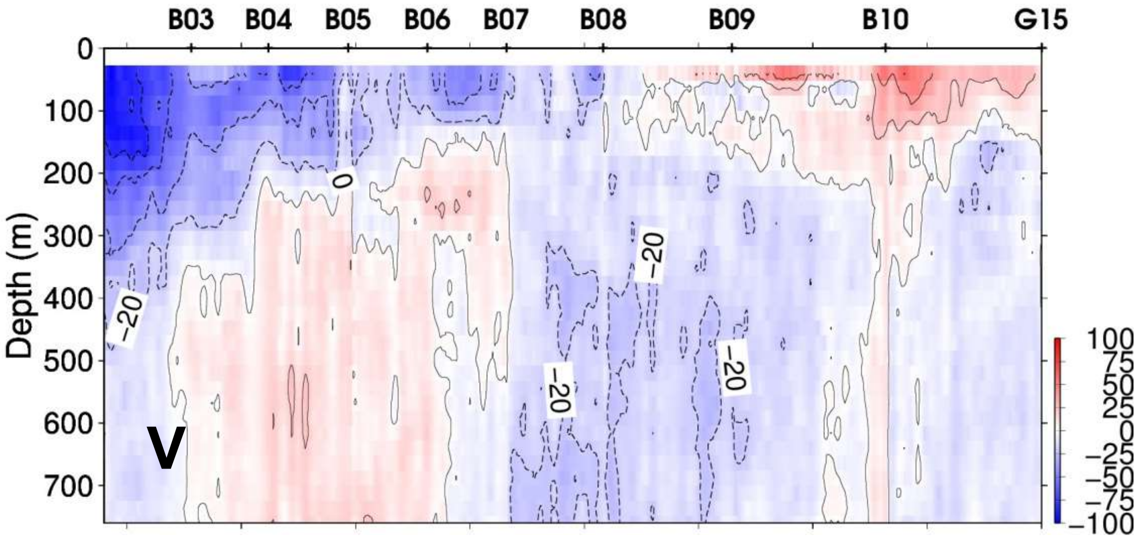


OFES output
126.6 - 127.2°E
26.8–27.1σ_θ

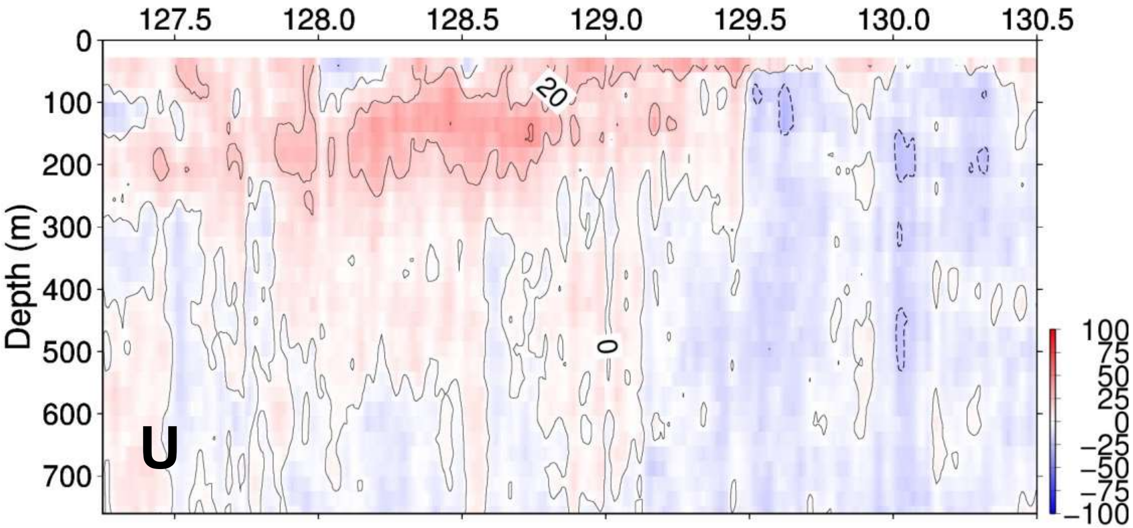
Wang et al. (2016)

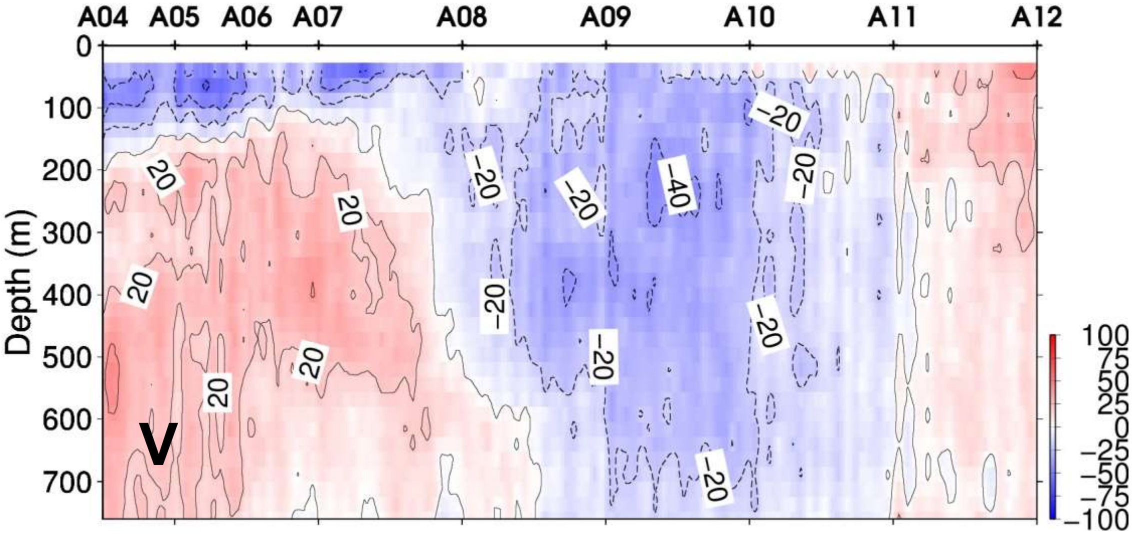
8°N, Nov. 2017, VADCP

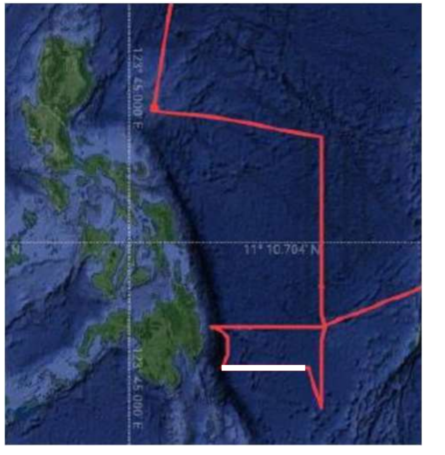




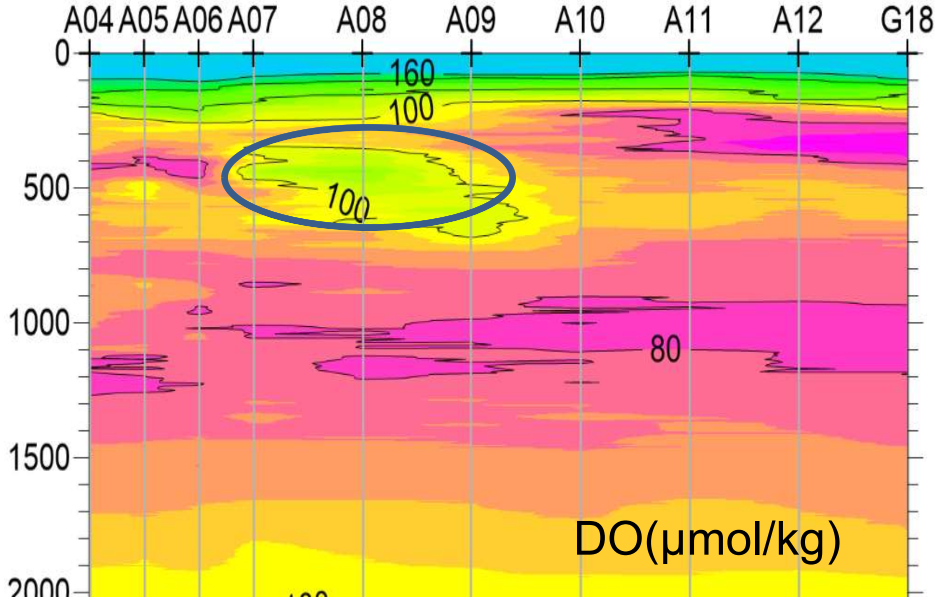
6.5°N, Nov. 2017, VADCP

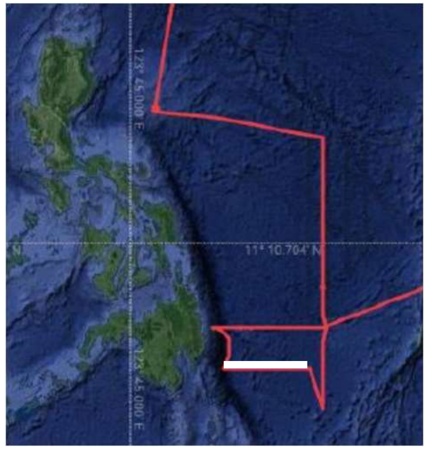


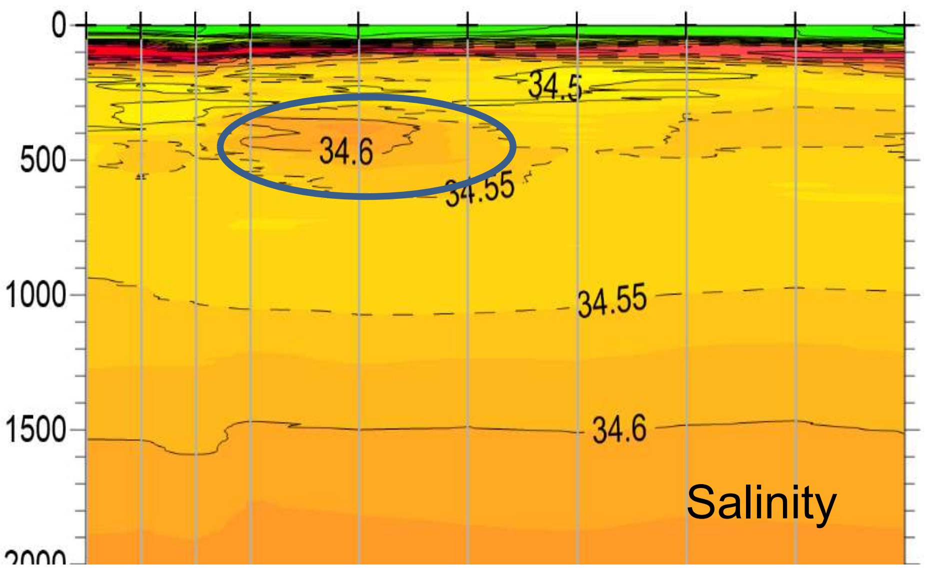


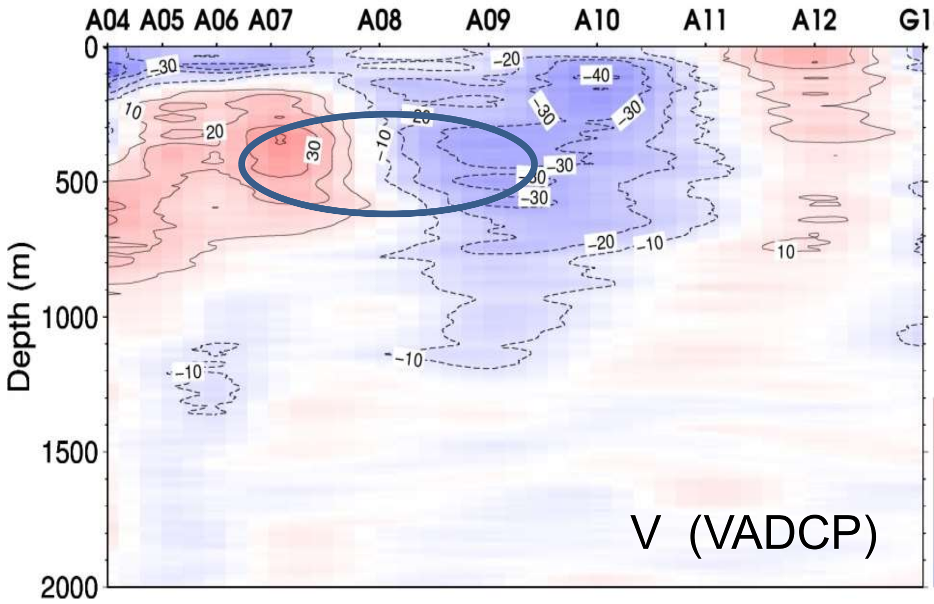


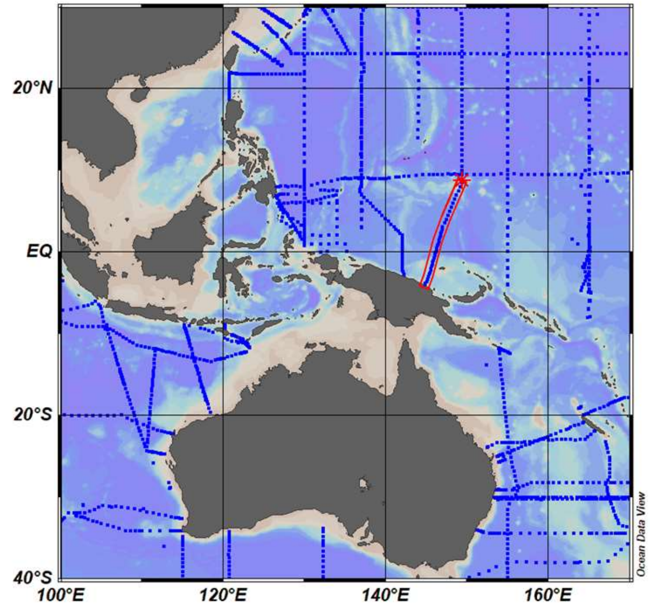
6.5°N

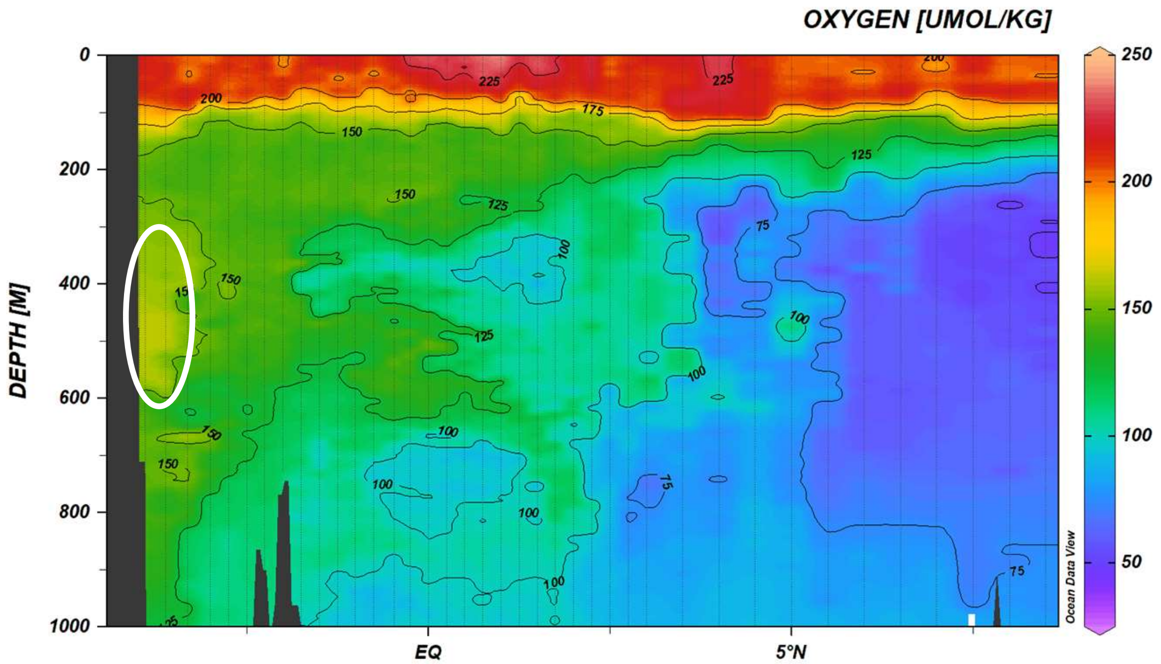

A04 A05 A06 A07 A08 A09 A10 A11 A12 G18
0
500
1000
1500
2000
160
100
100
80
DO(μmol/kg)

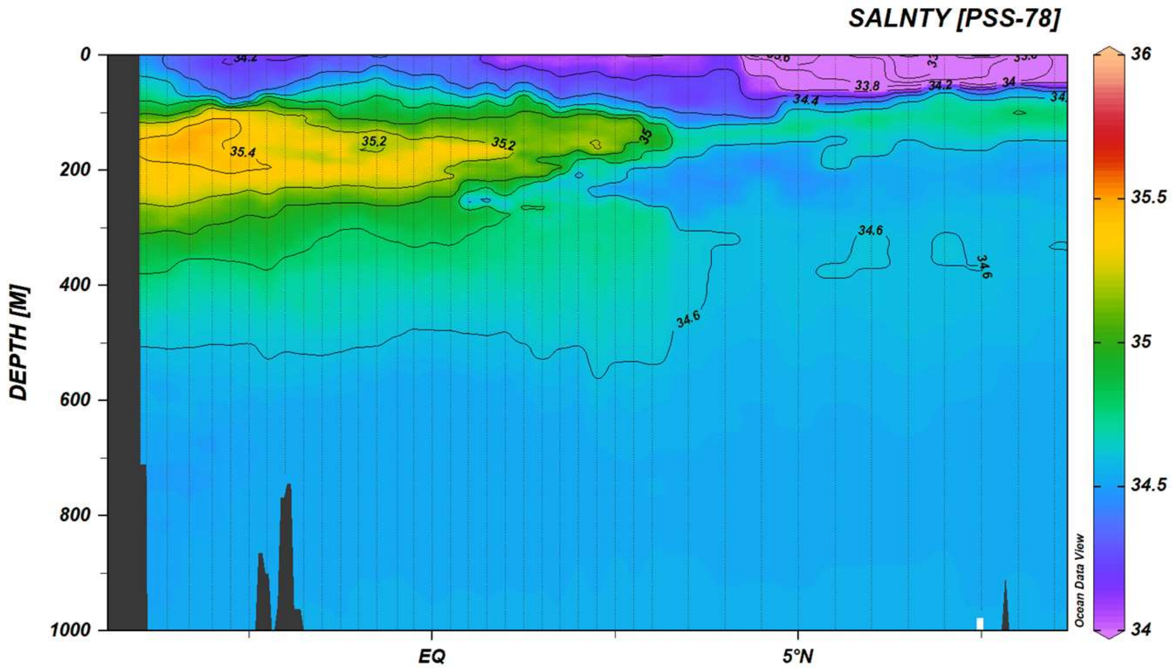


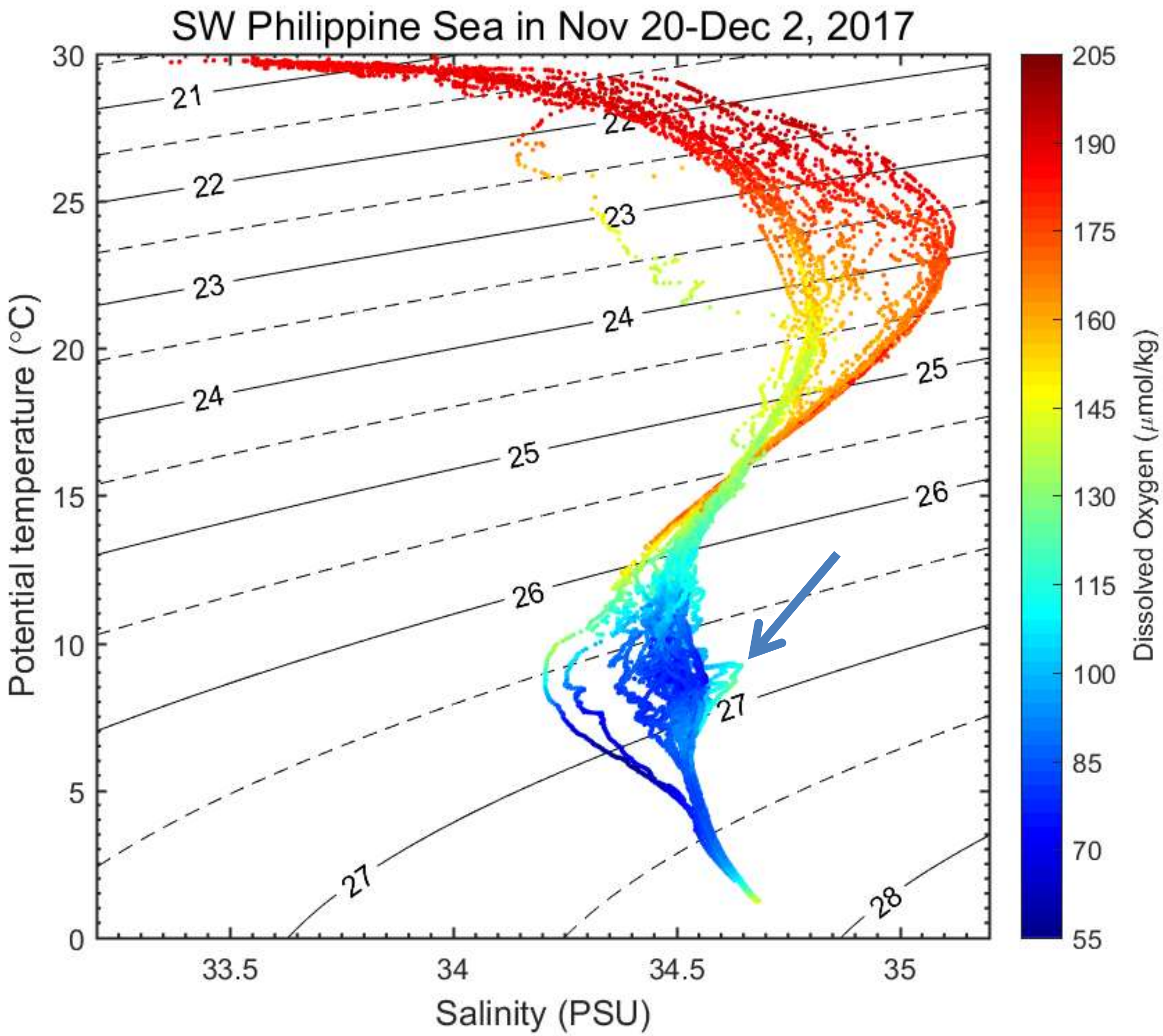

0
500
1000
1500
2000
34.5
34.6
34.55
34.55
34.6
Salinity


A04 A05 A06 A07 A08 A09 A10 A11 A12 G1
Depth (m)
0
500
1000
1500
2000
-30
-20
-40
10
20
30
-10
-30
-20
-10
10
V (VADCP)

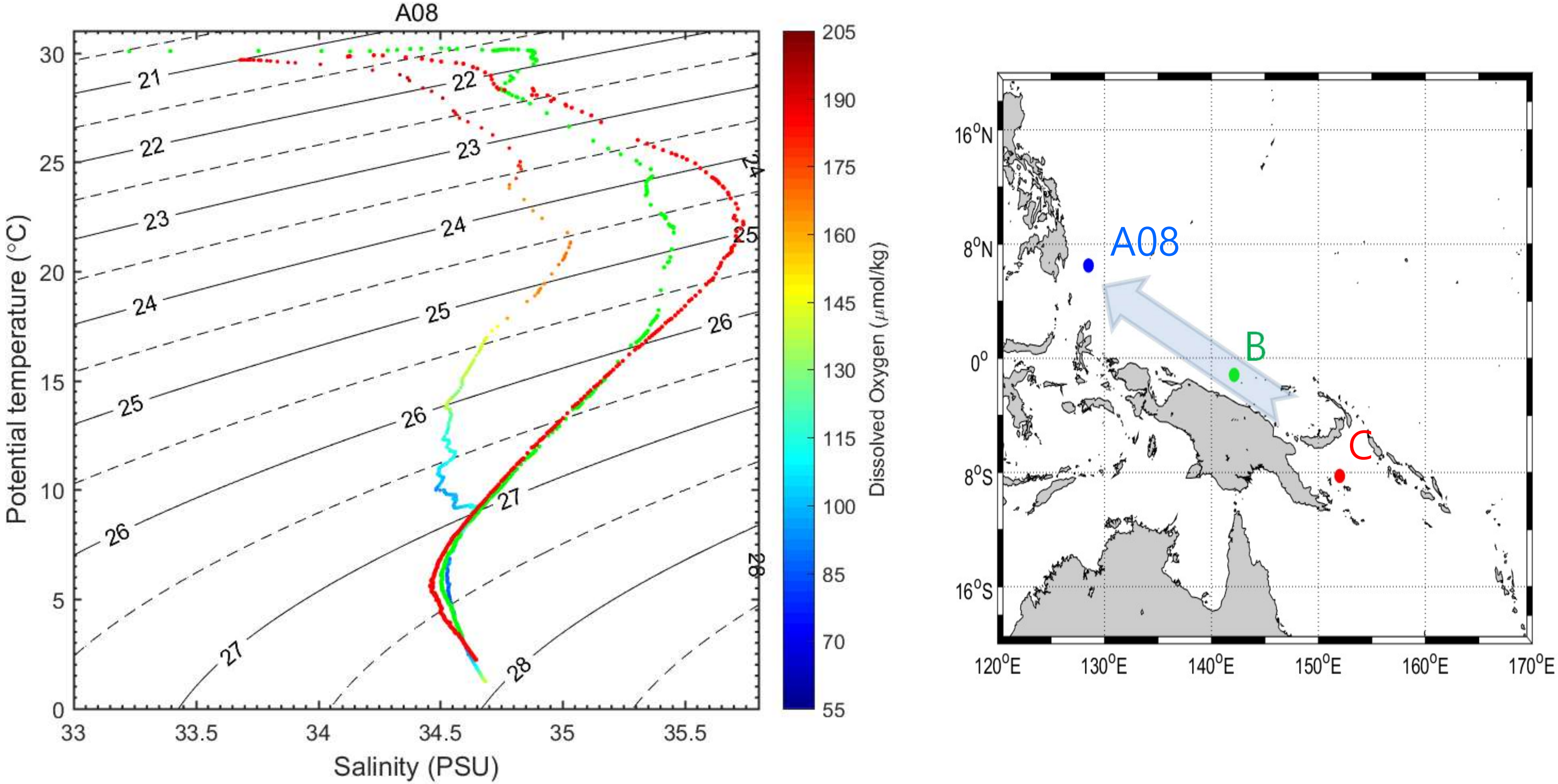

20°N
EQ
20°S
40°S
100°E
120°E
140°E
160°E
Ocean Data View


OXYGEN [UMOL/KG]
DEPTH [M]
0
200
400
600
800
1000
EQ
5°N
250
200
150
100
50
Ocean Data View


SALNTY [PSS-78]
DEPTH [M]
0
200
400
600
800
1000
EQ
5°N
36
35.5
35
34.5
34
Ocean Data View



SW Philippine Sea in Nov 20-Dec 2, 2017
Potential temperature (°C)
Salinity (PSU)
Dissolved Oxygen (μmol/kg)
30
25
20
15
10
5
0
33.5
34
34.5
35
205
190
175
160
145
130
115
100
85
70
55
21
22
23
24
25
26
27
28



A08
Potential temperature (°C)
Salinity (PSU)
Dissolved Oxygen (μmol/kg)
205
190
175
160
145
130
115
100
85
70
55
A08
B
C
16°N
8°N
0°
8°S
16°S
120°E
130°E
140°E
150°E
160°E
170°E

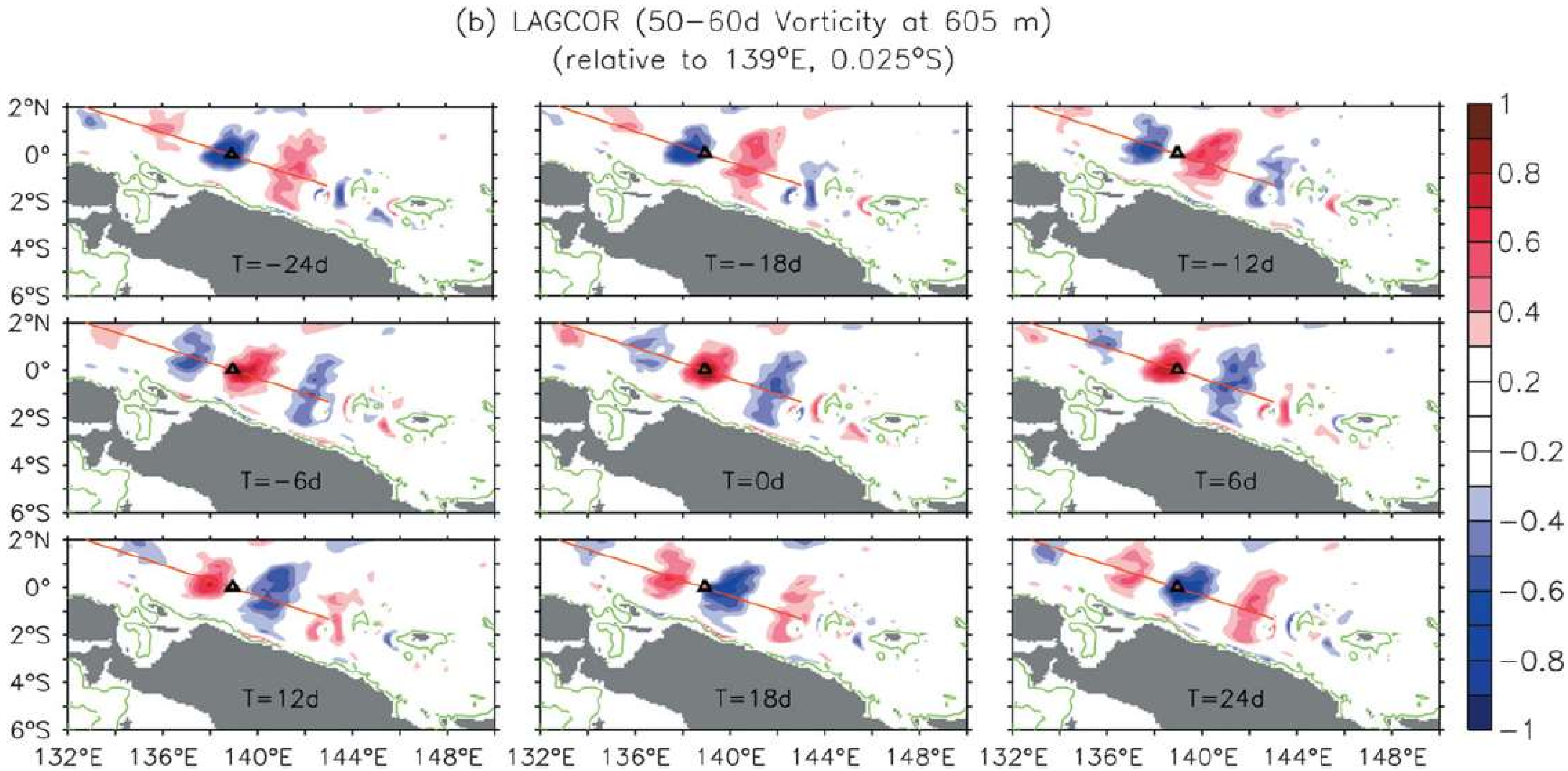


FIG. 9. Lag correlation maps of 50–60-day-bandpassed vorticity relative to the vorticity at (a) 0.675°S, 141°E and (b) 0.025°S, 139°E. Triangles, red lines, and green lines indicate the relative location, pathway of eddies, and 605-m isobath, respectively.

Chiang and Qu (2013)

Q1: Does the MUC transport South Pacific Waters?

Yes, both observation data and model outputs support it.

Q2: What cause the MUC variability?

Wang et al. (2014)

- The ISV of the subthermocline current was caused by the subthermocline eddies from three different pathways.
- The subthermocline eddies <u>propagating along 10N–11N</u> contributed more to the ISV of the subthermocline current east of Mindanao than did those eddies propagating <u>westward along 8N</u> or <u>northwestward from the New Guinea coast</u>.

Chiang et al. (2015)

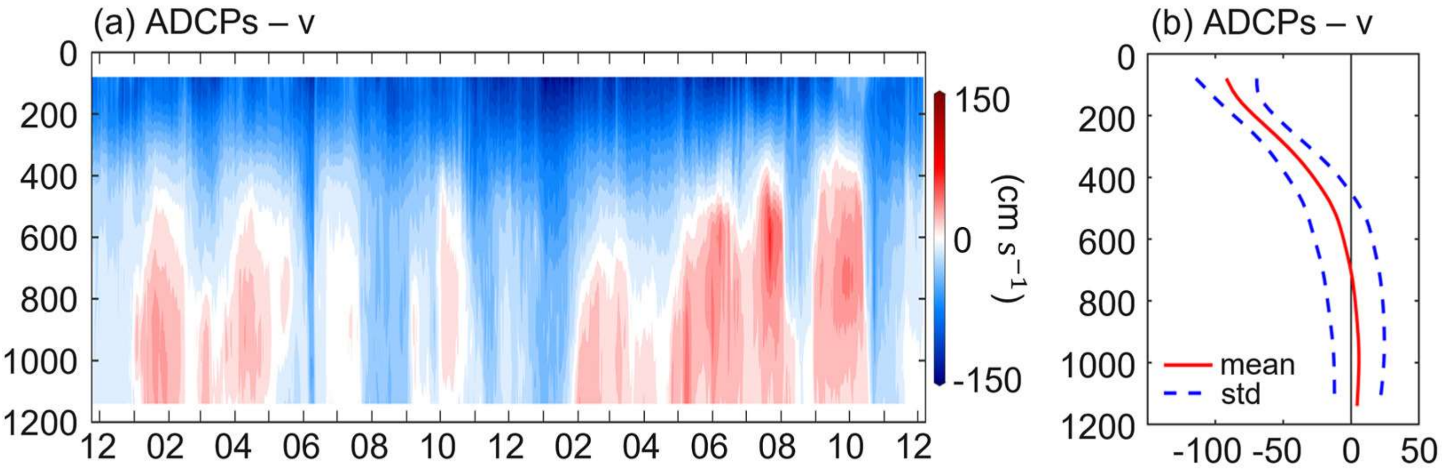
- There are at least two groups of subthermocline eddies near the Philippine coast: <u>one originates from the southeast</u>, and <u>the other from the east</u>
- The westward propagating ones play a more important role in modulating the subsurface circulation near the Philippine coast

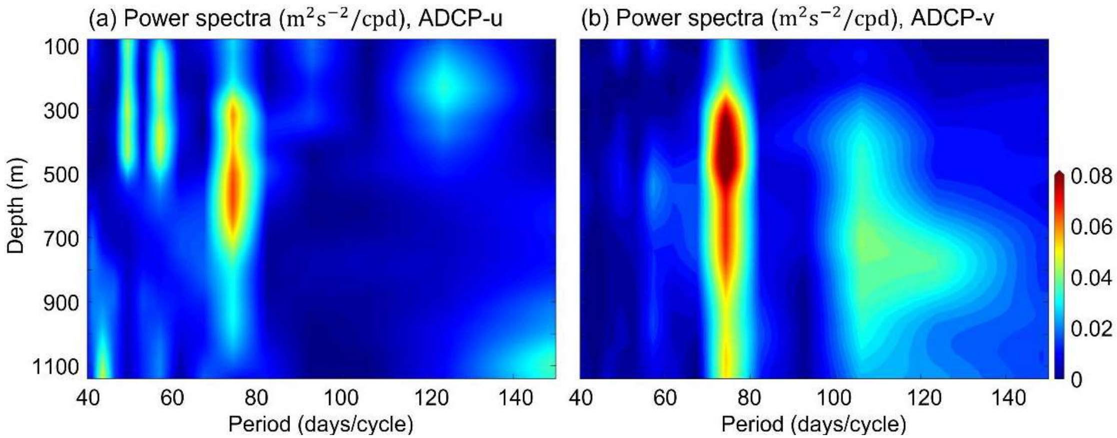
Effect of the sub-thermocline eddy on the MUC in 2019

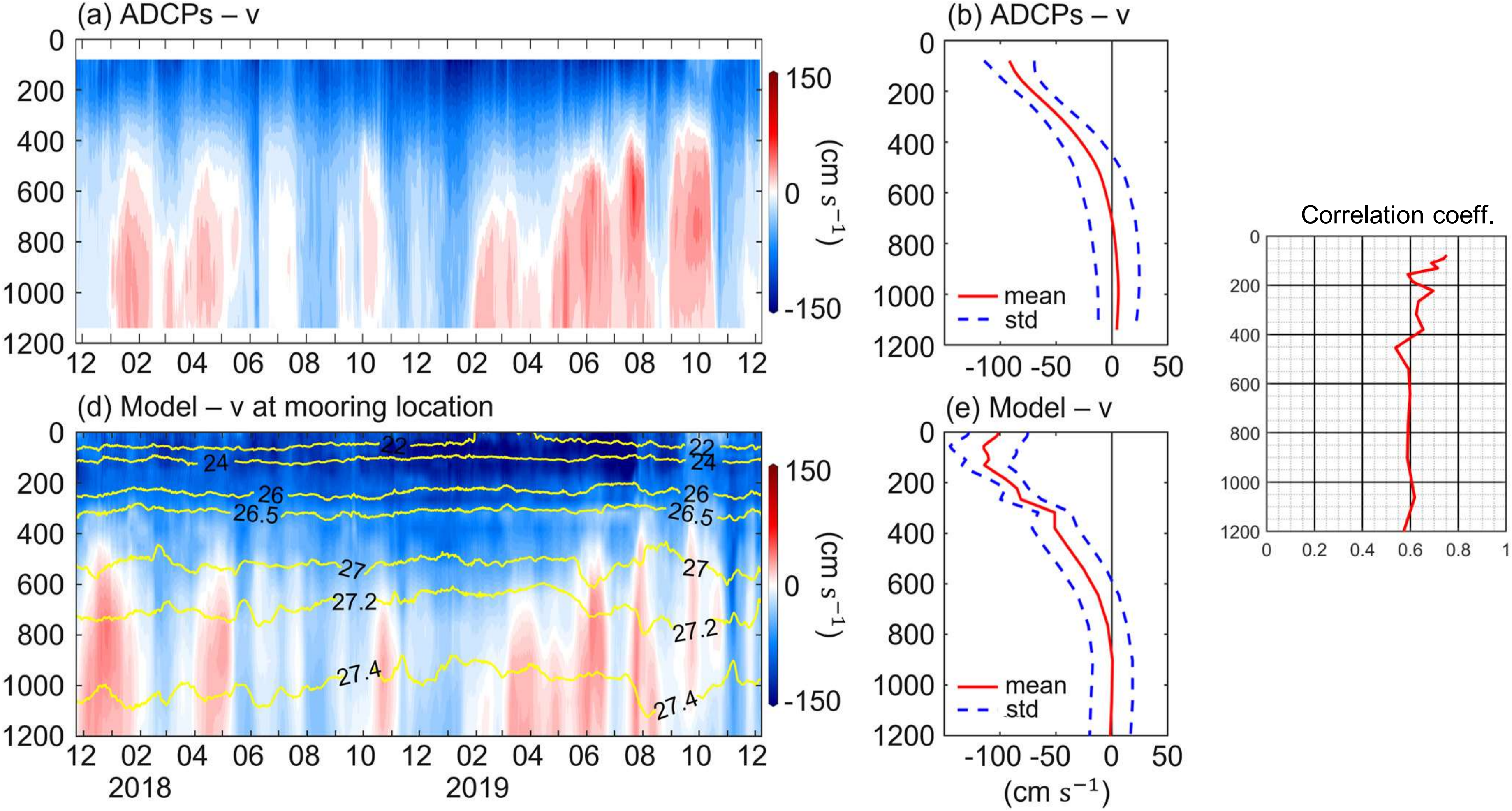
Fuad et al., JGR Oceans, 127(2), 2022

Data used

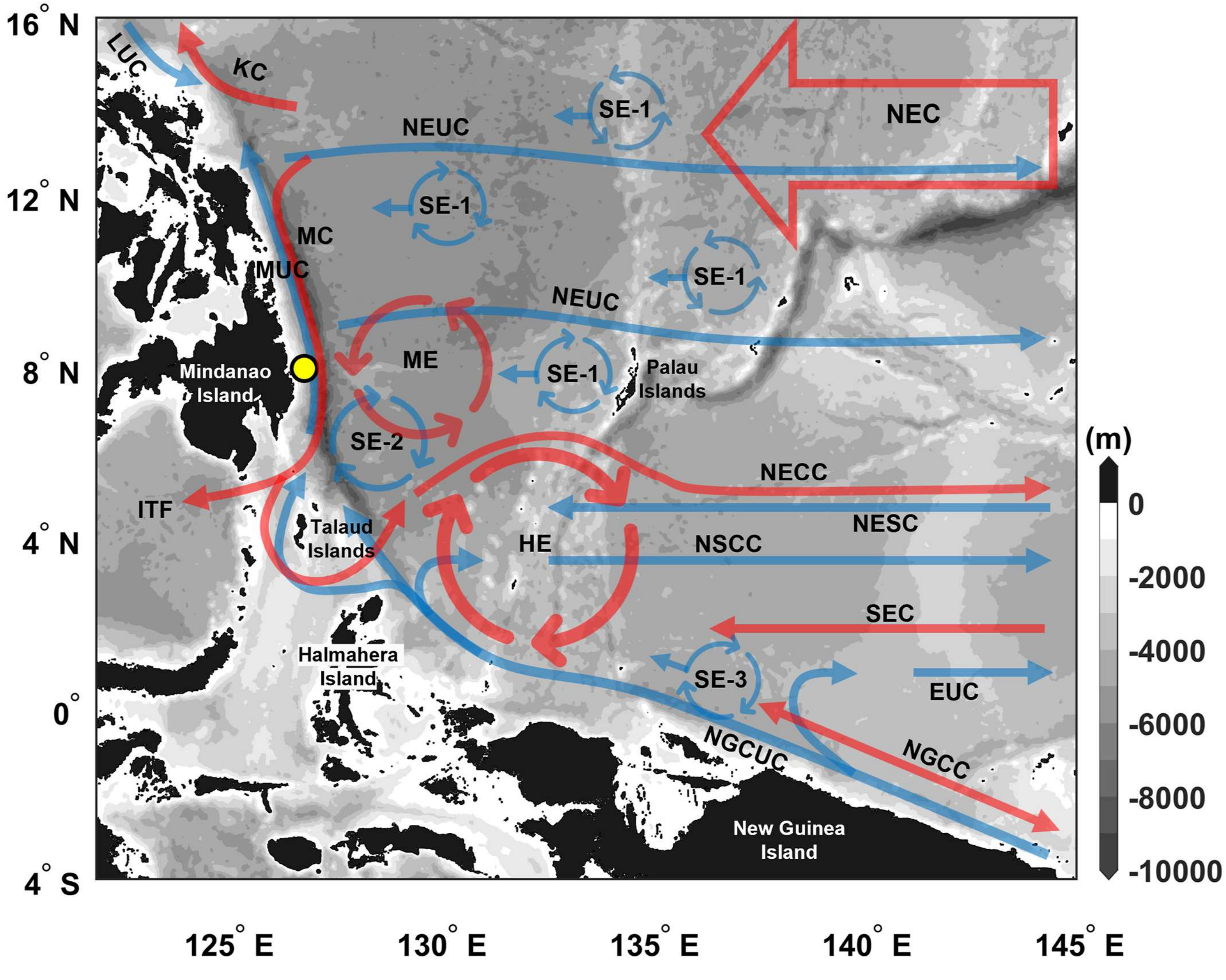
- Observation data
  MC1 (127E, 8N) : 2017/11 – 2019/12
- Model output
  GLOBAL ANALYSIS FORECAST PHY 001 024 / Mercator Ocean


(a) ADCPs – v
0
200
400
600
800
1000
1200
12
02
04
06
08
10
12
02
04
06
08
10
12
150
0
-150
(cm s^{-1})
(b) ADCPs – v
0
200
400
600
800
1000
1200
-100
-50
0
50
mean
std


(a) Power spectra (m^2s^{-2}/cpd), ADCP-u
(b) Power spectra (m^2s^{-2}/cpd), ADCP-v
Depth (m)
100
300
500
700
900
1100
40
60
80
100
120
140
Period (days/cycle)
0.08
0.06
0.04
0.02
0



(a) ADCPs – v
(b) ADCPs – v
Correlation coeff.
(d) Model – v at mooring location
(e) Model – v
(cm s−1)
mean
std
2018
2019



16° N
12° N
8° N
4° N
0°
4° S
125° E
130° E
135° E
140° E
145° E
LUC
KC
NEUC
SE-1
NEC
MC
MUC
NEUC
ME
Mindanao Island
Palau Islands
SE-2
ITF
Talaud Islands
HE
NECC
NESC
NSCC
SEC
Halmahera Island
SE-3
EUC
NGCUC
NGCC
New Guinea Island
(m)
0
-2000
-4000
-6000
-8000
-10000

Eddy identification methods

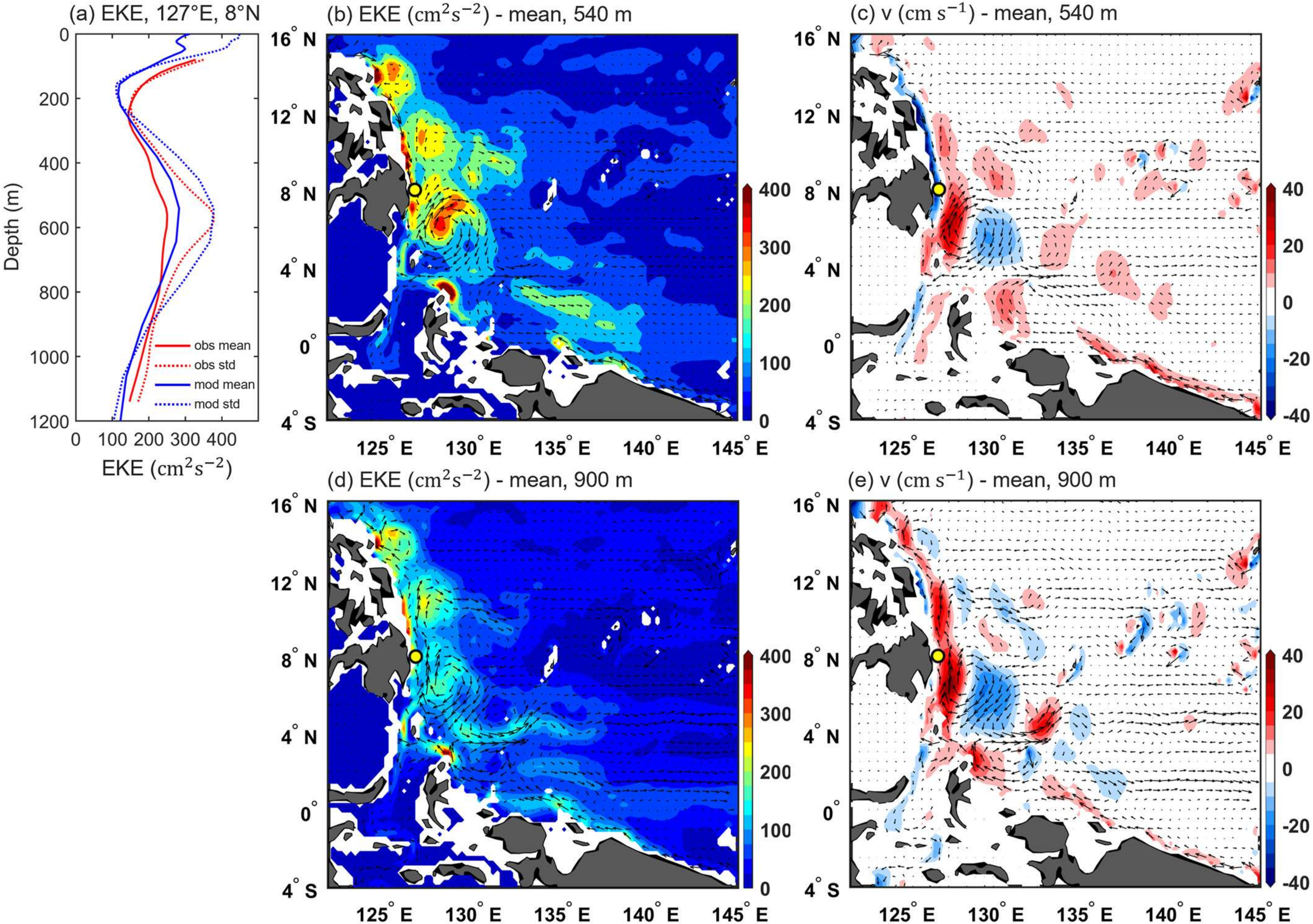
Eddy Kinetic Energy:

$$EKE = \frac{1}{2}(u'^2 + v'^2)$$

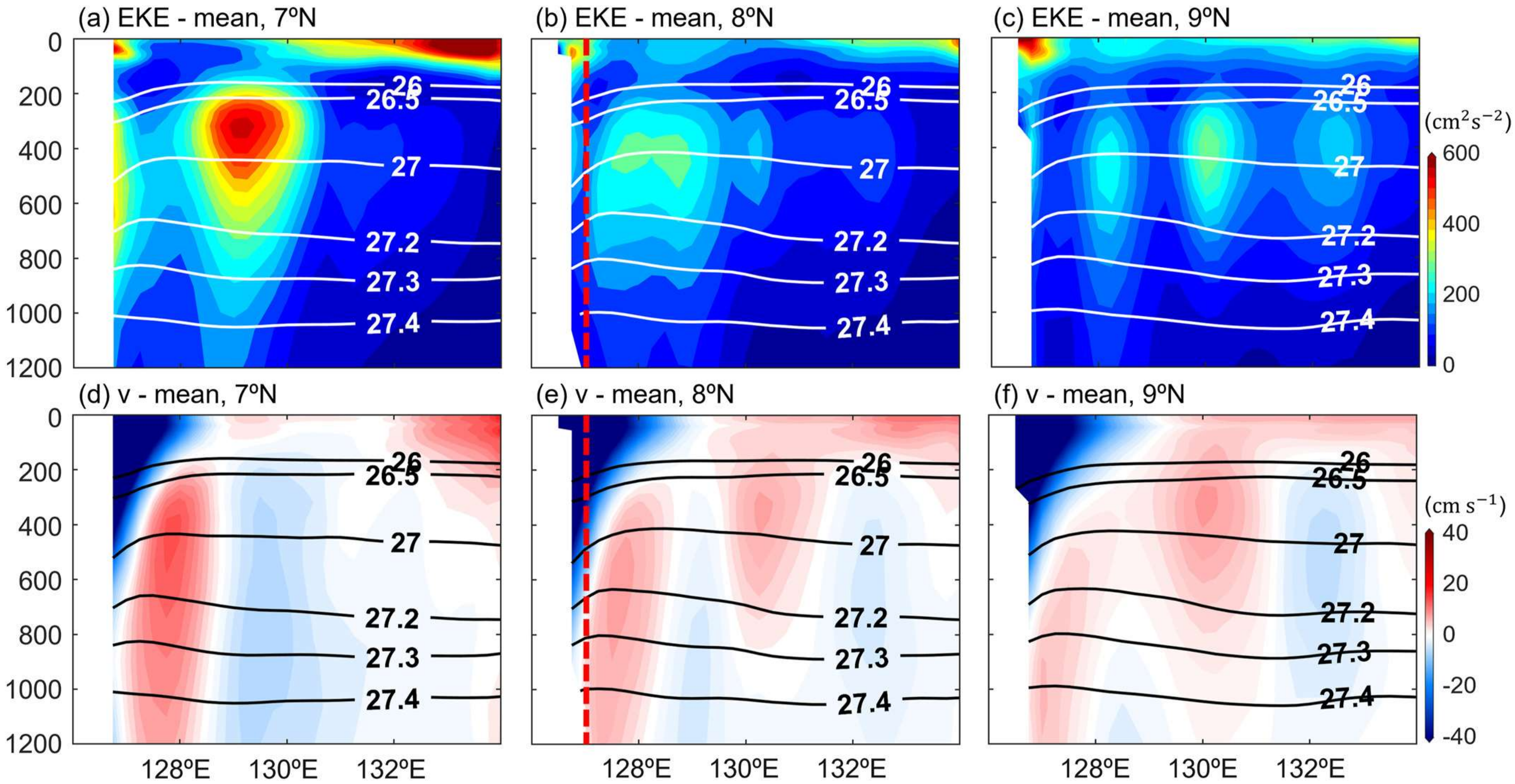
Okubo-Weiss parameter:

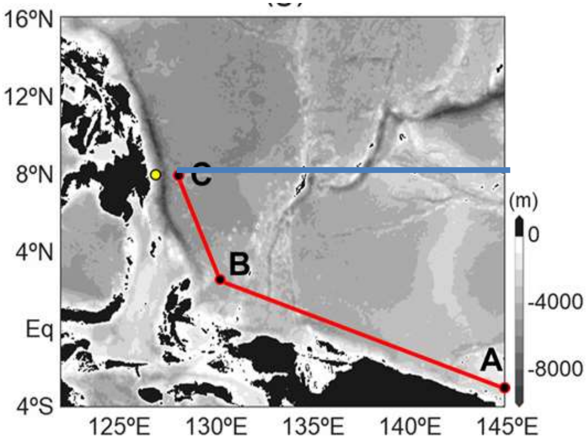
$$W = 4\left(\frac{\partial v}{\partial x}\frac{\partial u}{\partial y} - \frac{\partial u}{\partial x}^2\right)$$

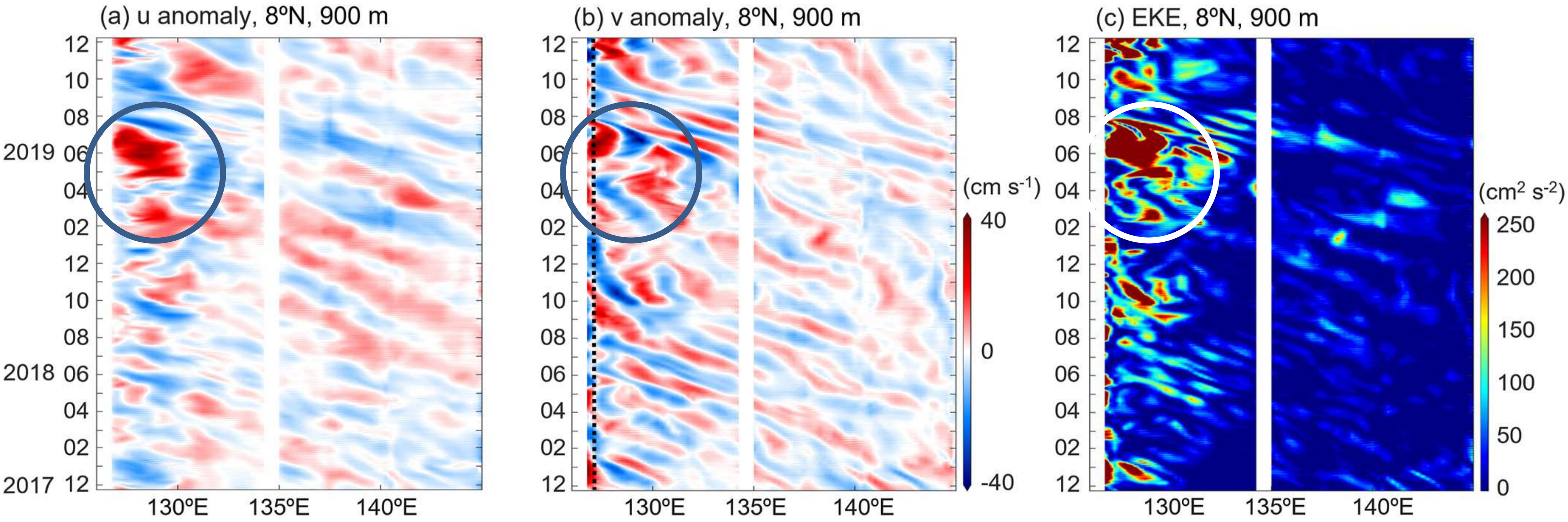
The EKE averaged over observation period (Nov 2017 – Dec 2019)



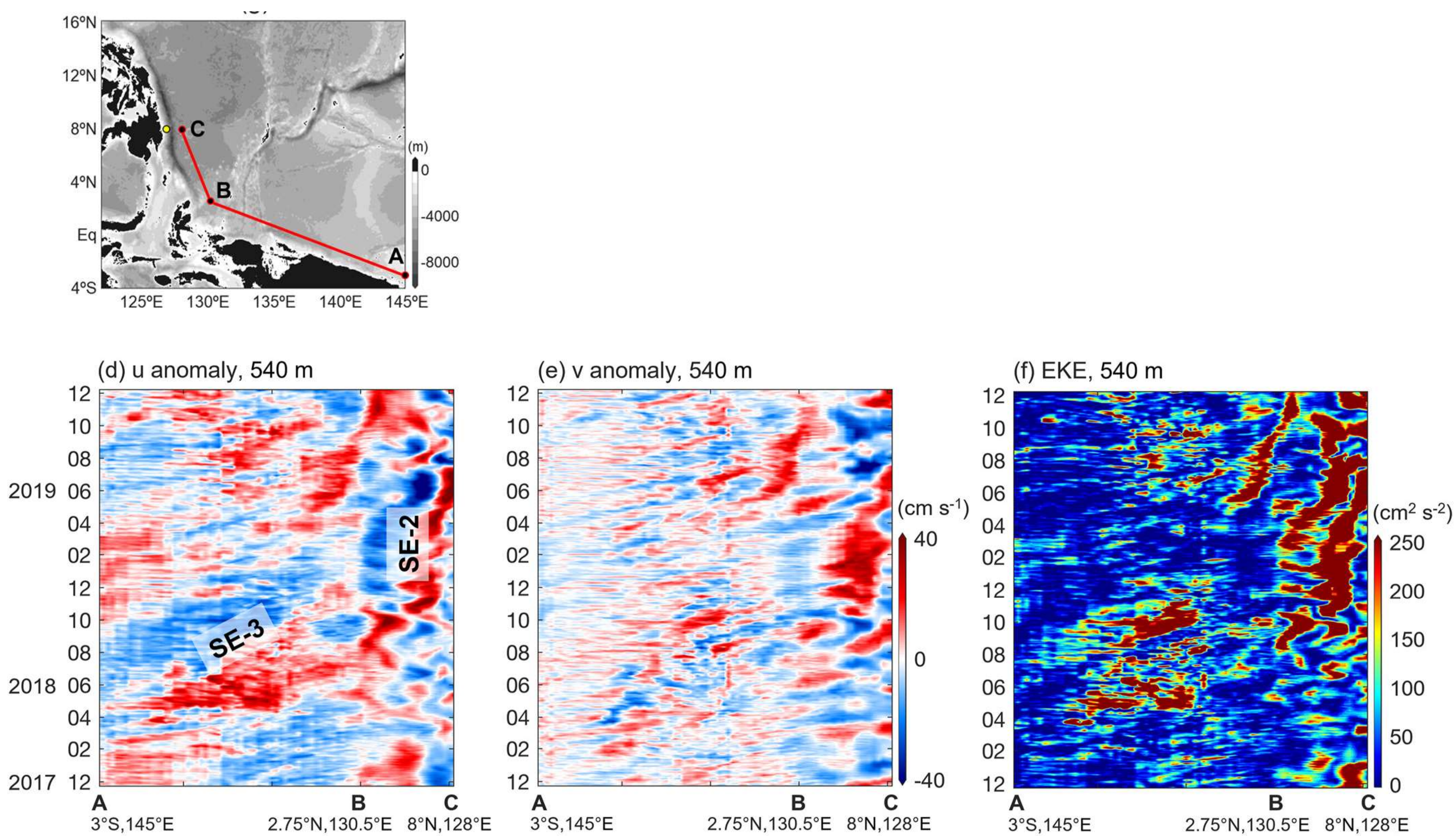
EKE and meridional velocity averaged over observation period (Nov. 2017 – Dec. 2019)





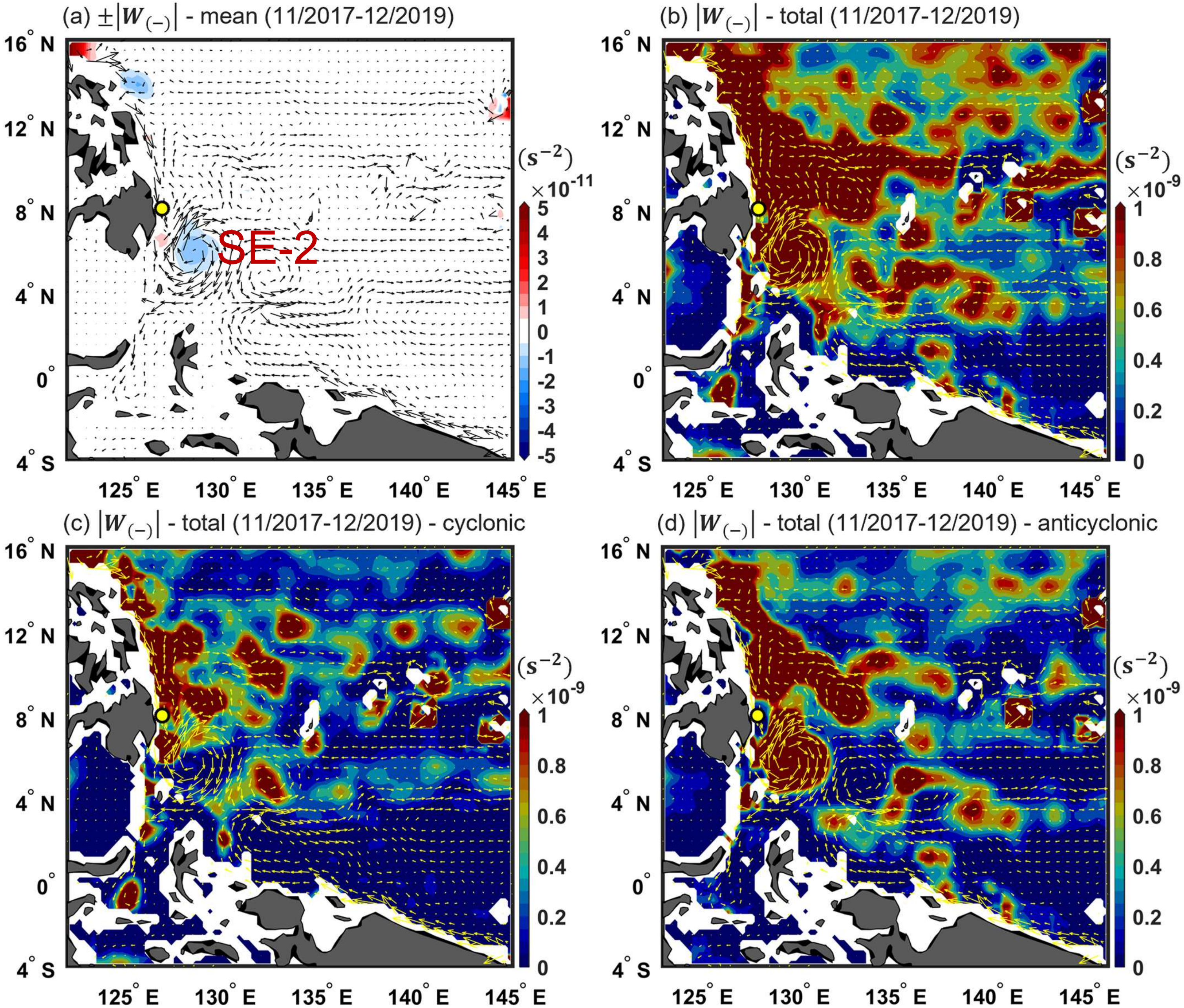


The EKE was very high in May–July 2019, indicating a strong eddy event distinct from the typical westward eddies(SEs-1).

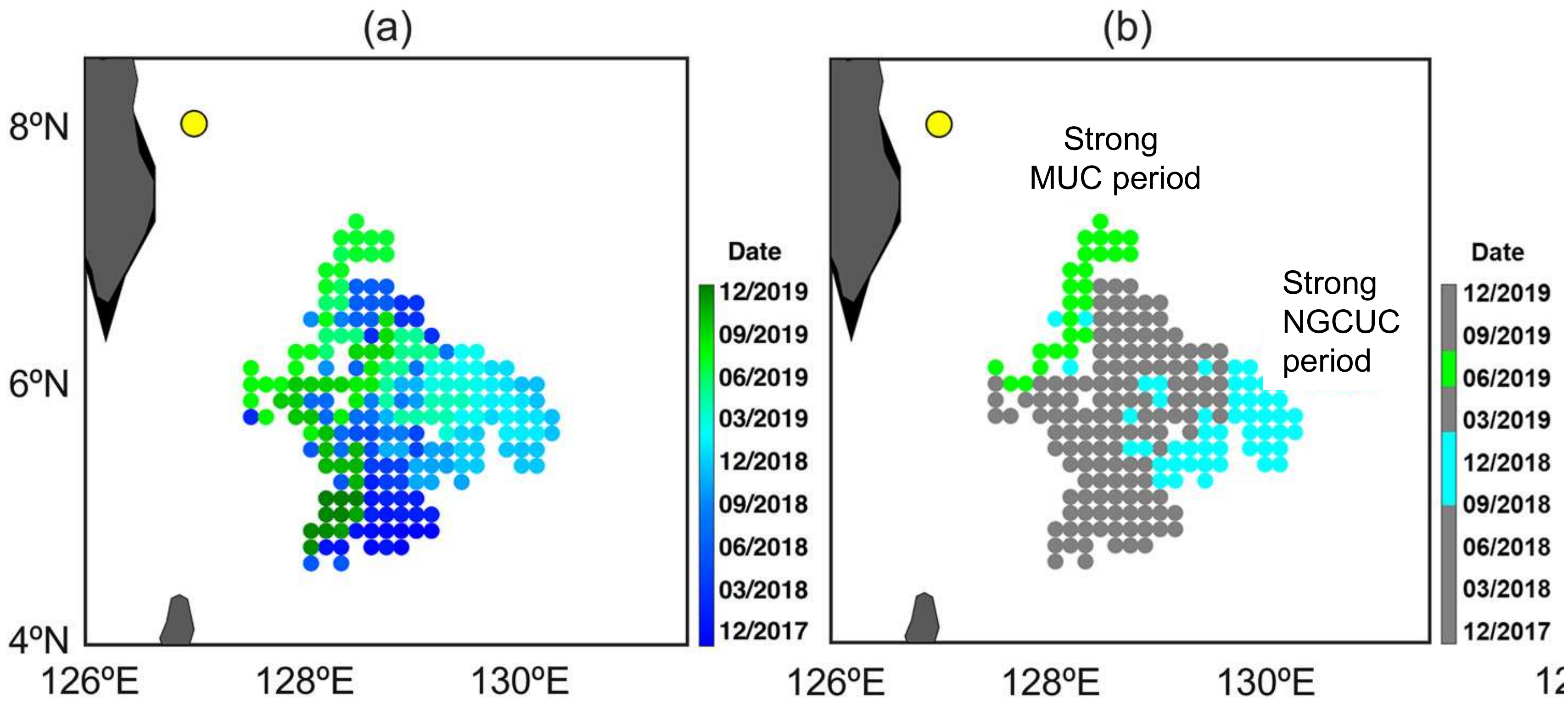


The SE-2 was not genuinely originated from the New Guinea coast. It could be considered as a quasi-stationary eddy rather than a propagating eddy,

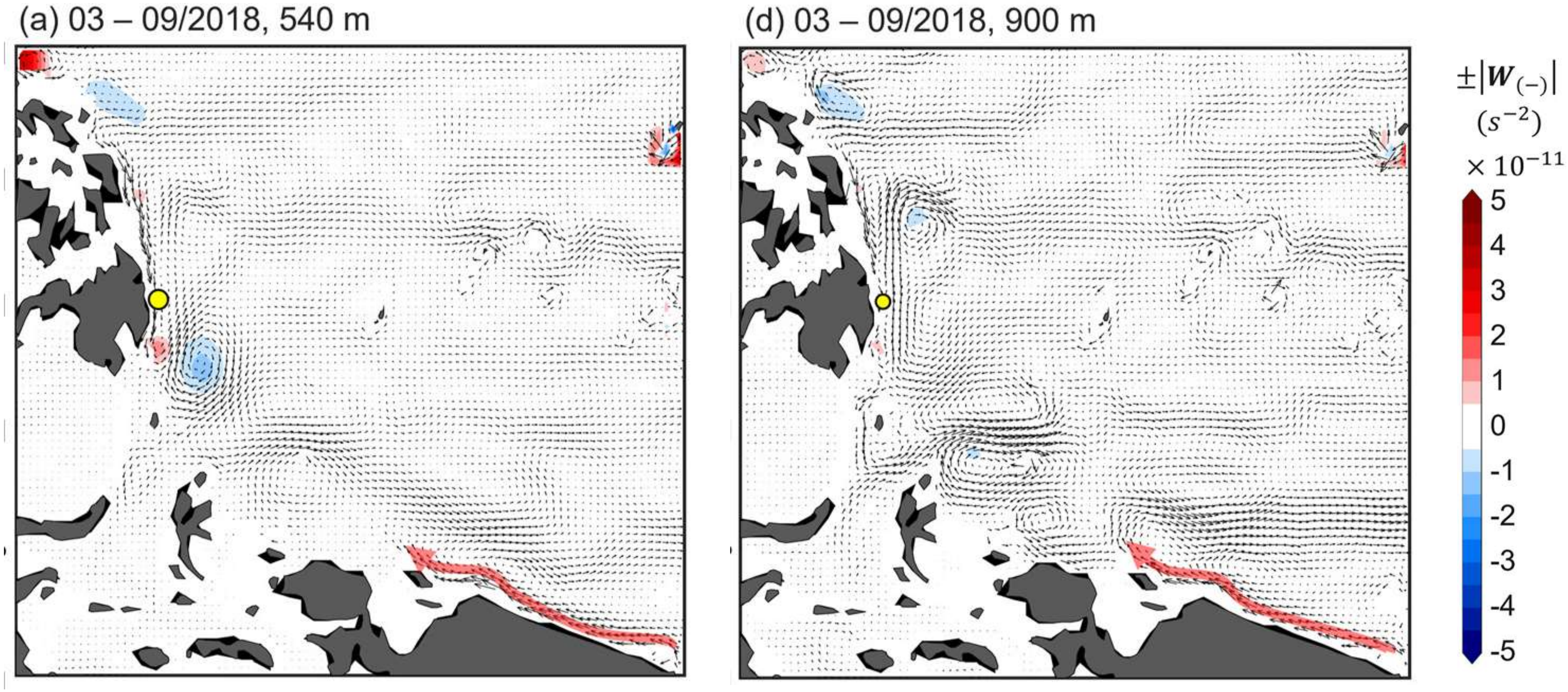
Horizontal distribution of cyclonic and anticyclonic eddies averaged from Nov. 2017 to Dec. 2019



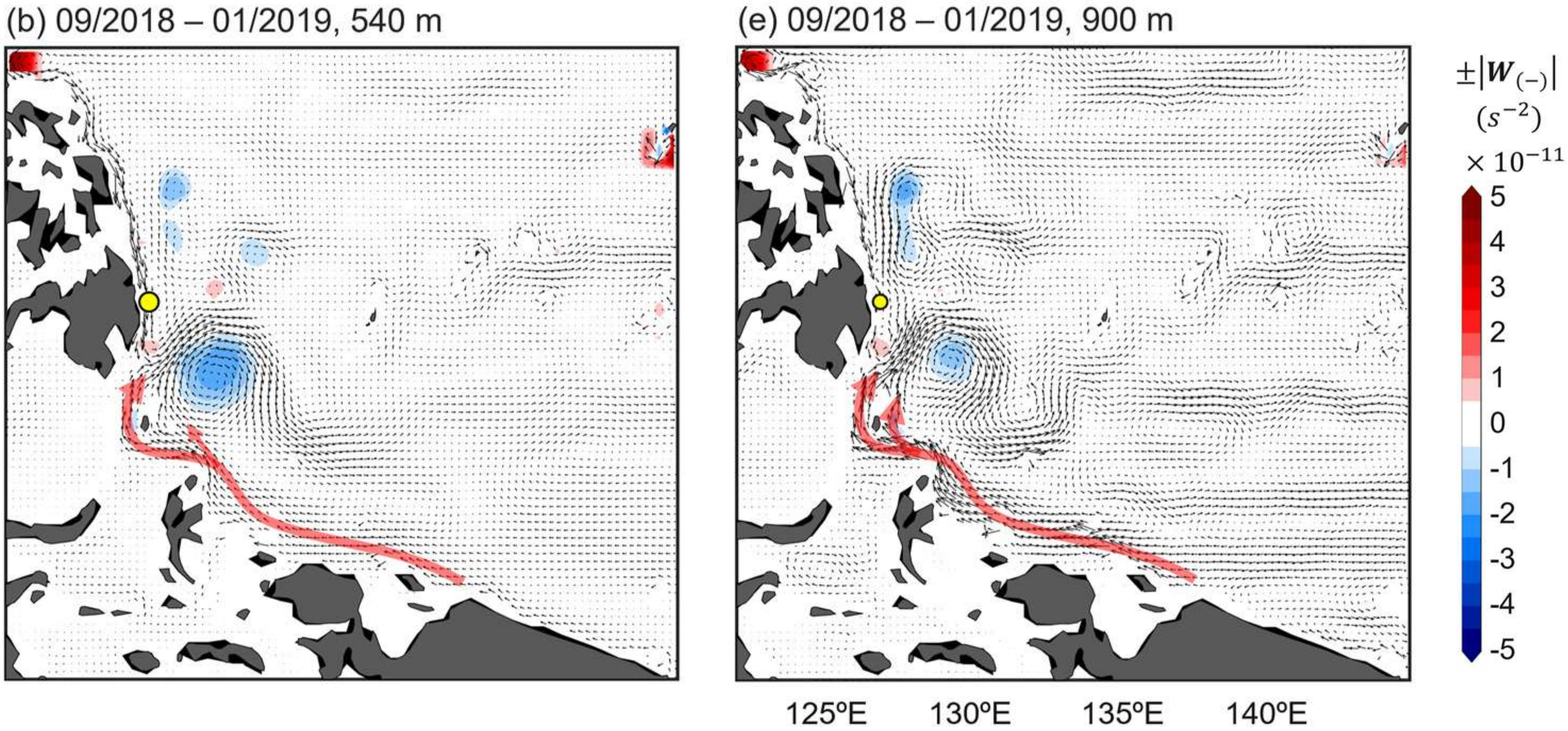
The anticyclonic SE-2 core moves erratically within 4–8°N, 127–130°E with the mean translation speed of about 11 cm/s.



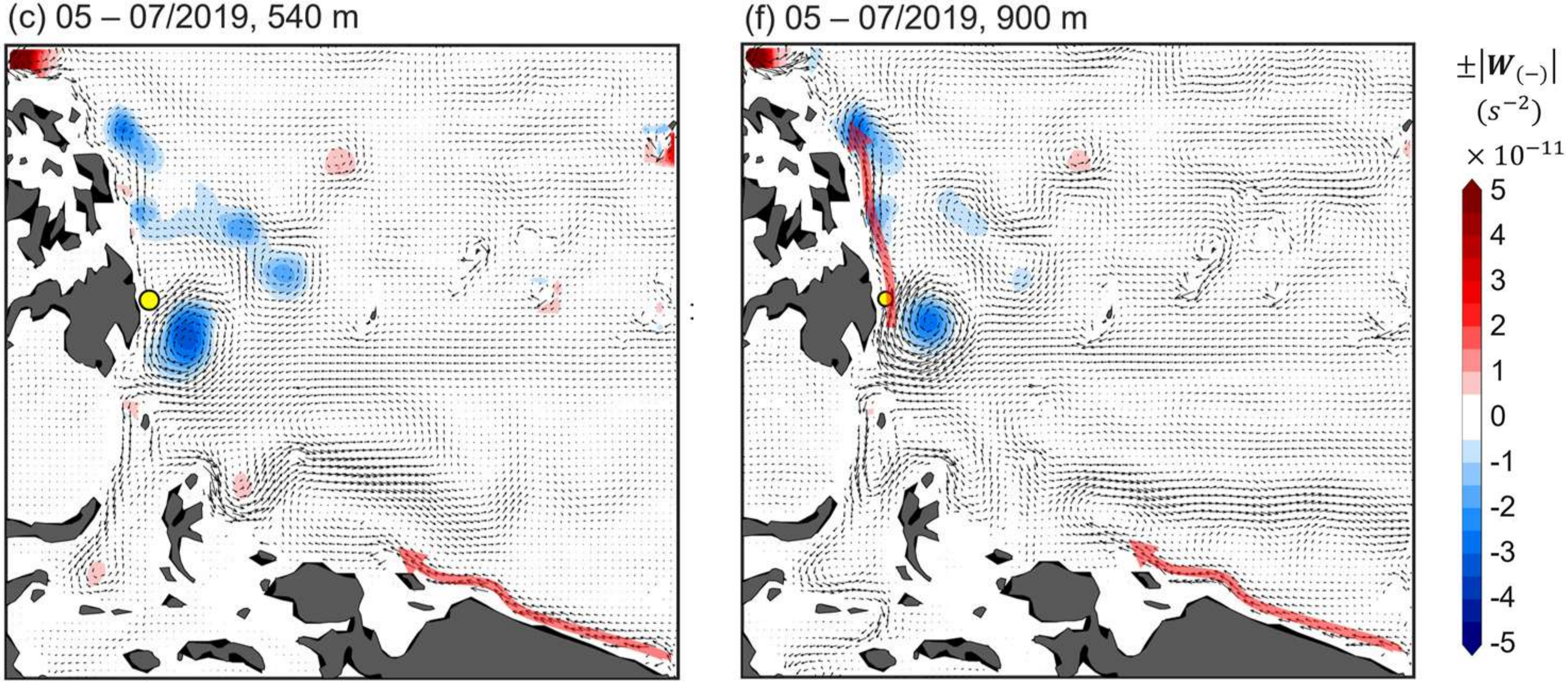
Moderate MUC & NGCUC period (March - September 2018)

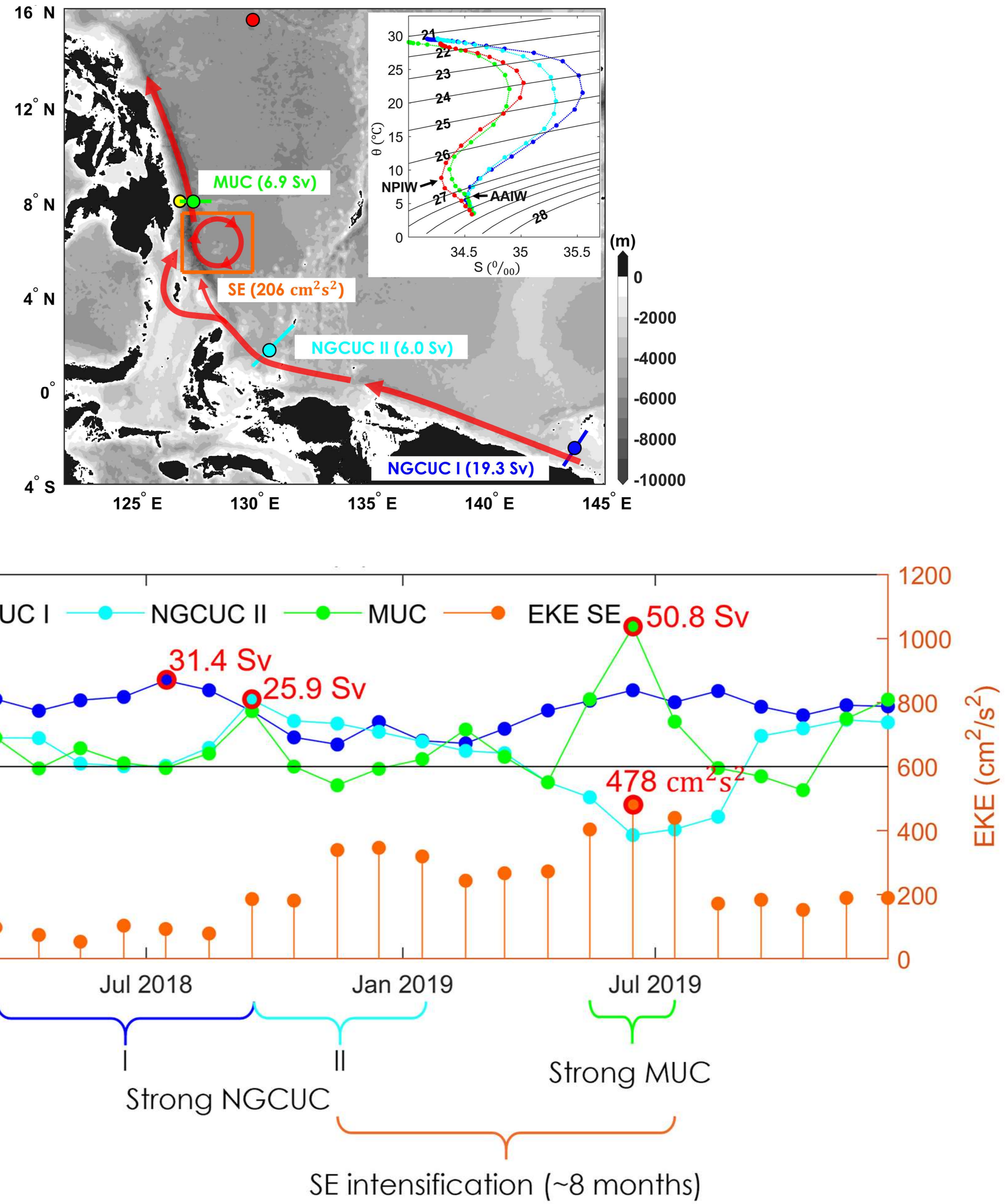


Strong NGCUC period (September 2018 – January 2019)



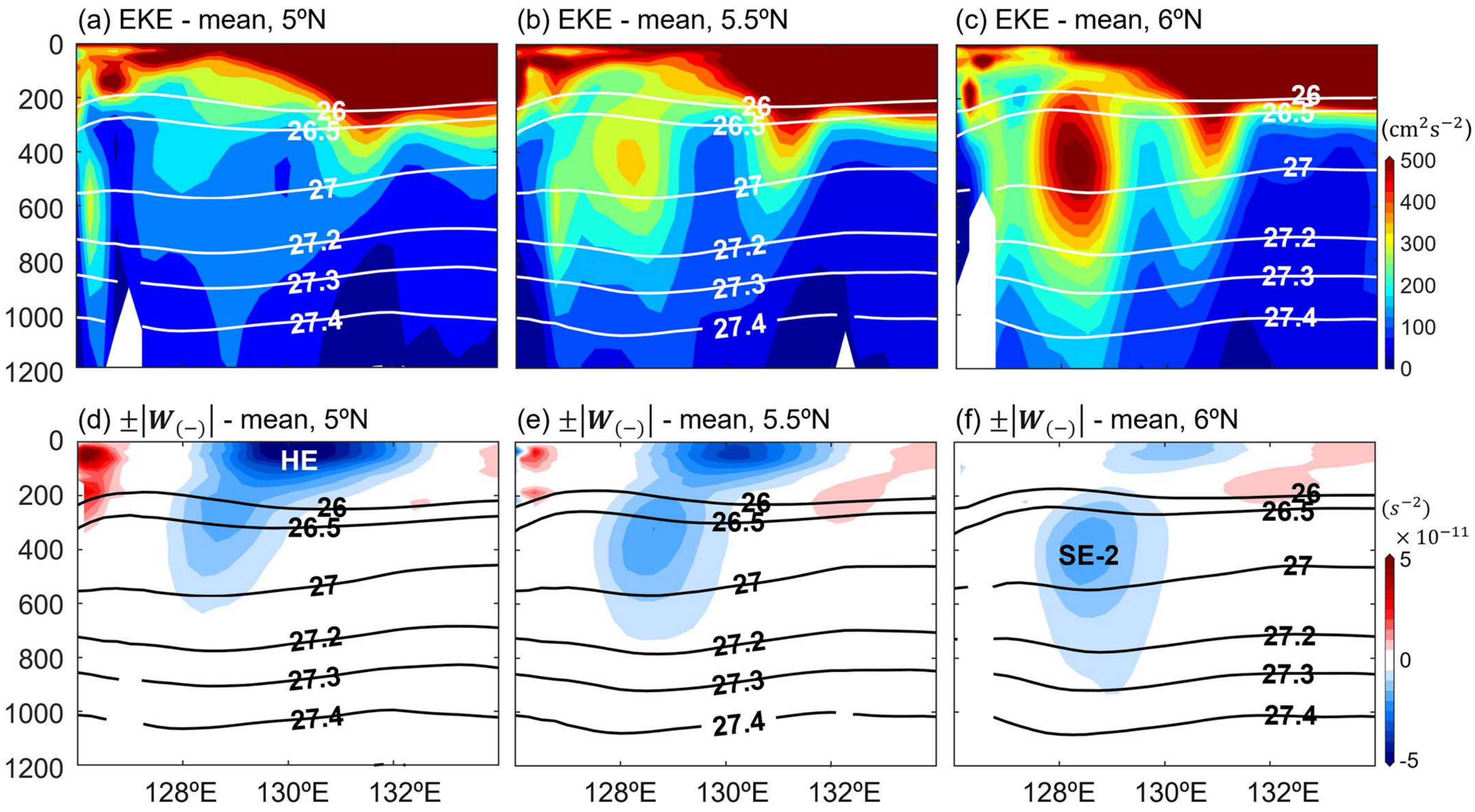
Strong MUC period (May – July 2019)





MUC (6.9 Sv)
SE (206 cm^{2}s^2)
NGCUC II (6.0 Sv)
NGCUC I (19.3 Sv)
NPIW
AAIW
θ (°C)
S (‰)
(m)
125° E
130° E
135° E
140° E
145° E
16° N
12° N
8° N
4° N
0°
4° S
NGCUC I
NGCUC II
MUC
EKE SE
31.4 Sv
25.9 Sv
50.8 Sv
478 cm^{2}s^2
transport (Sv)
EKE (cm^2/s^2)
Jan 2018
Jul 2018
Jan 2019
Jul 2019
I
II
Strong NGCUC
Strong MUC
SE intensification (~8 months)

Possible relation between the Halmahera eddy and SE-2



Summary

- The Mindanao Undercurrent(MUC) was observed as a quasi-permanent current with strong intraseasonal variability with a period of 70-80 days from a mooring observation (Nov 2017 - Dec 2019).
- Observation data and model outputs show the enhanced MUC in May-July 2019.
- The intensified subthermocline eddy southeast of Mindanao Island (SE-2) is found to cause the observed strong MUC event.
- The behavior of the SE-2 is related to changes in the strength of the New Guinea Coastal Undercurrent.

Q2: What cause the MUC variability?

- The subthermocline eddies propagating westward along 8N–11N contributed to the intraseasonal variability of the MUC.
- In 2019, the intensified subthermocline eddy southeast of Mindanao Island, which is considered as a quasi-stationary eddy rather than a propagating eddy, is found to cause the strong MUC.

Remark

- The result indicates that the SE-2 has an important role on the intermediate circulation system in the equatorial Pacific WBC.
- Li et al. (2021) reported a strong intrusion of the westward-flowing North Equatorial Subsurface Current (NESC) into the Makassar Strait crossing over the WBC system. The connection between the NESC and the ITF may conflict with that between the NGCUC and the SE-2. This indicates that the nonlinearity of the low latitude WBC system is very large.
- Note that subsurface currents in the western North Pacific (MUC, LUC, EUC, NESC, NGCUC etc.) appear at different depth ranges.

Thank you