PICES XIII Annual Meeting

A three-dimensional numerical study of the spirals and water exchange near the shelf front in the northern South China Sea in winter

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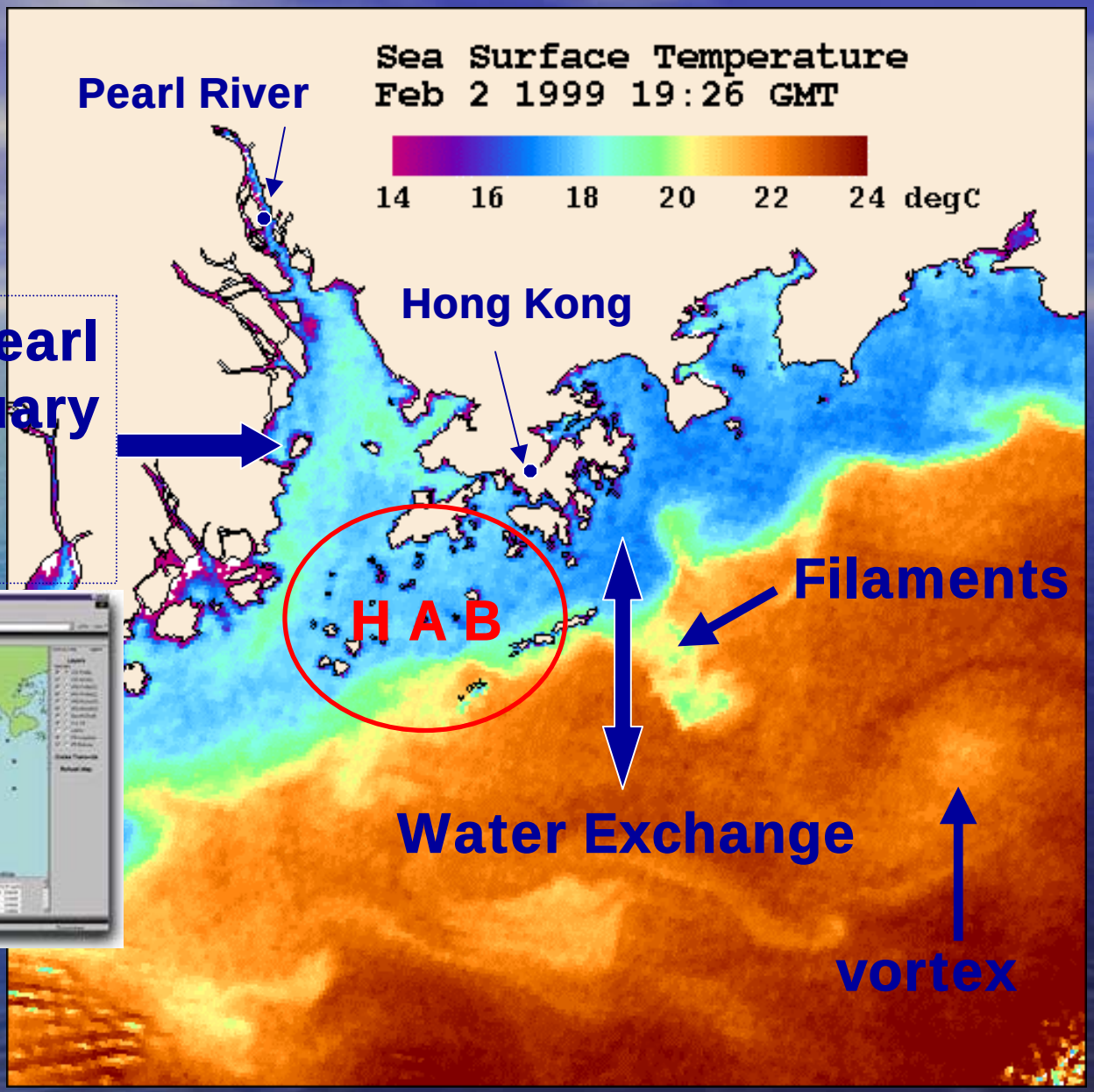
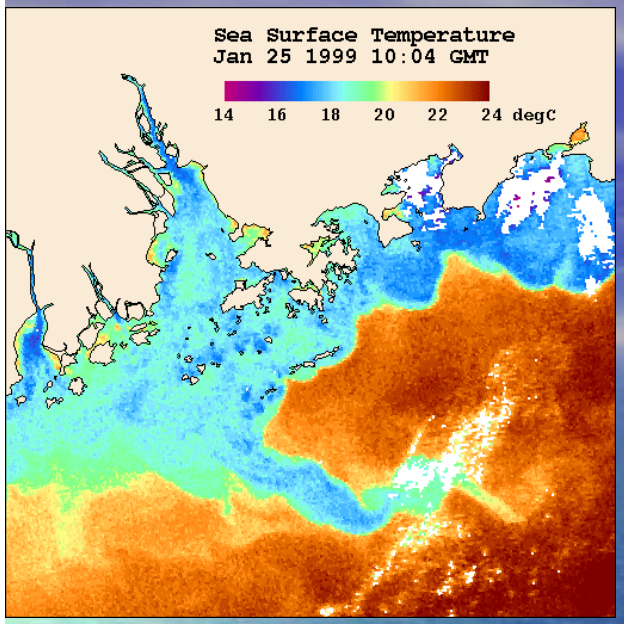


PREPP (Pearl River Estuary Pollution Project)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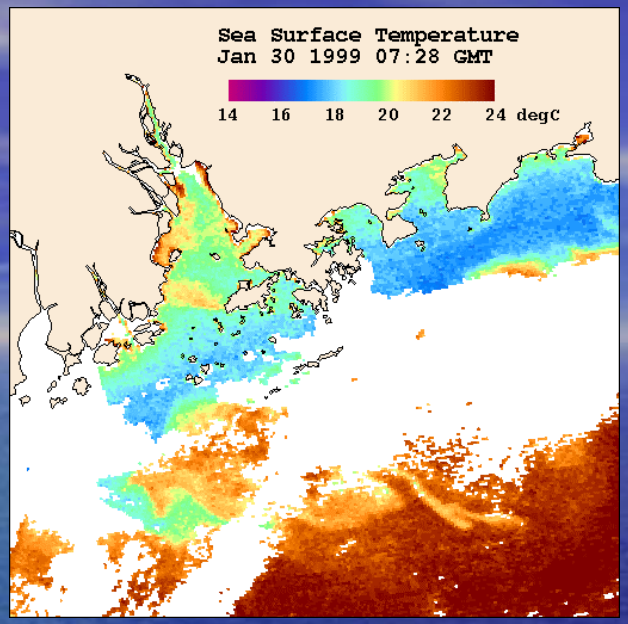
14 16 18 20 22 24 degC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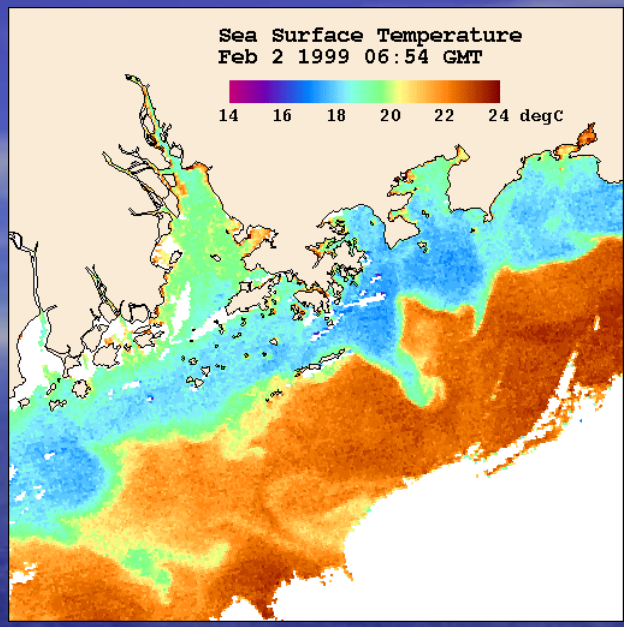
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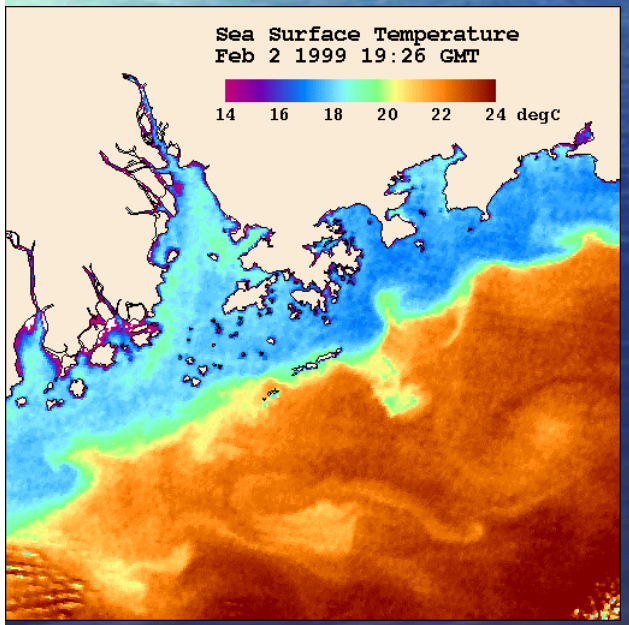
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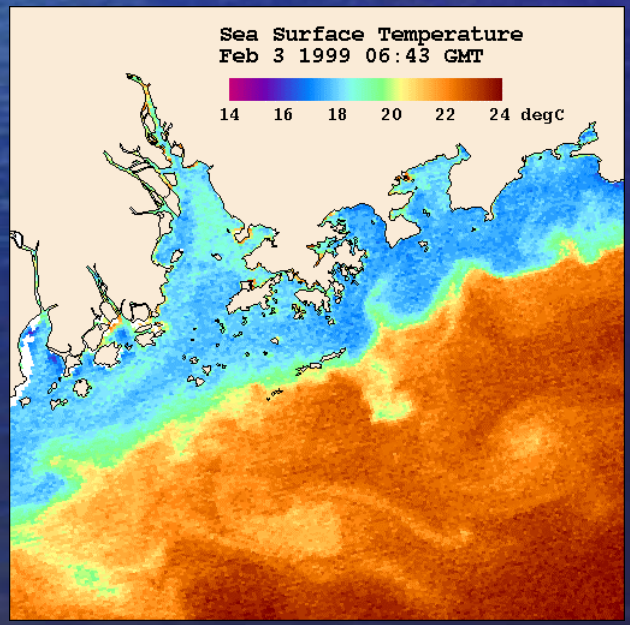
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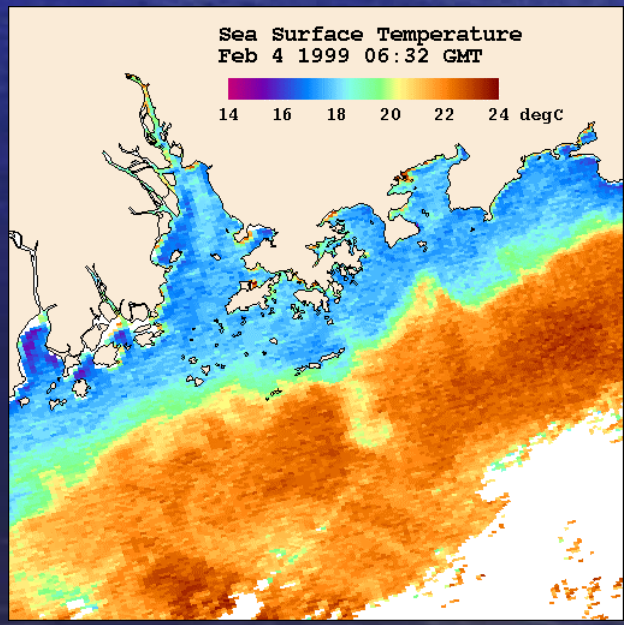
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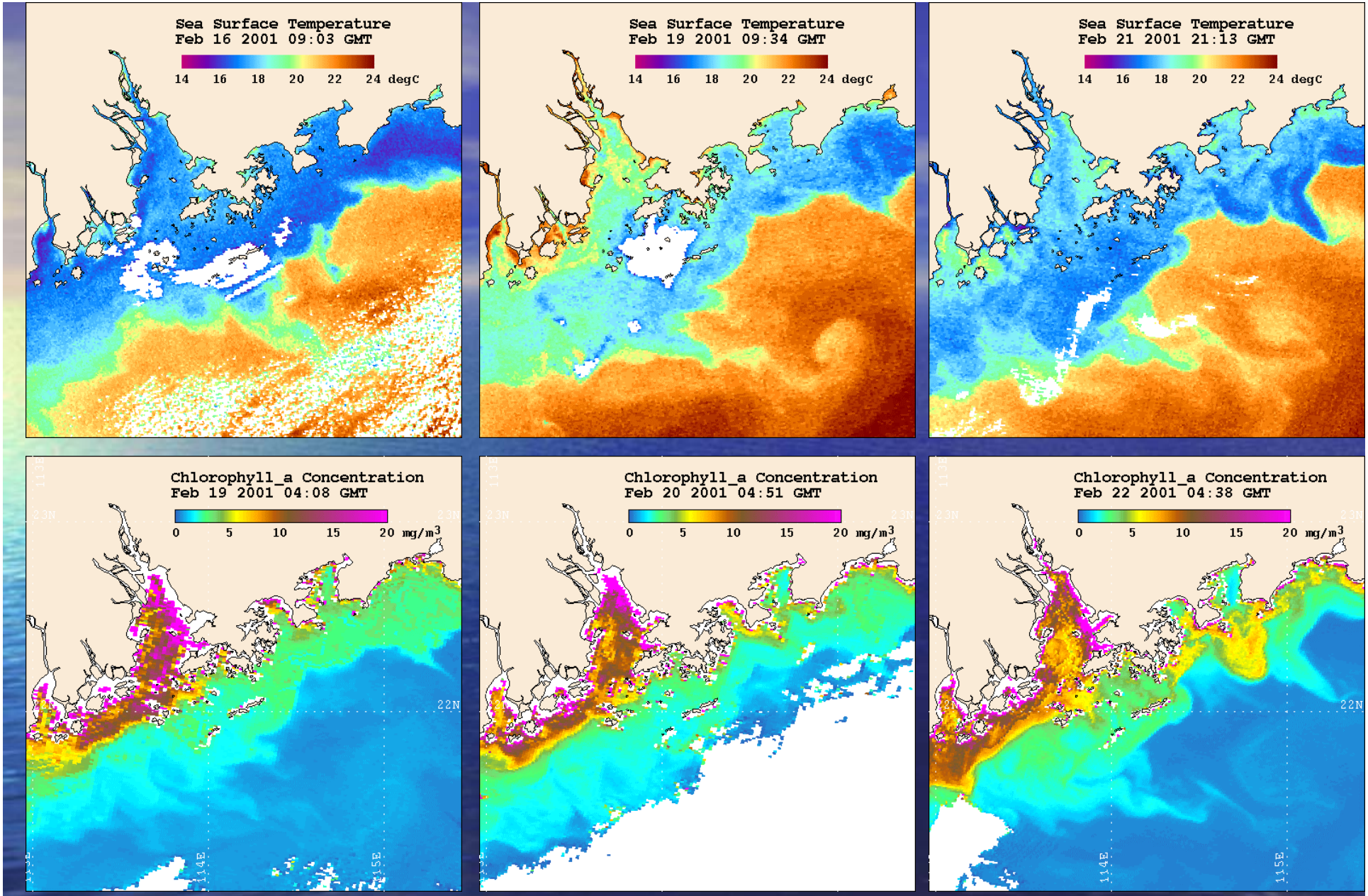


Development of the eddy and picture of the chlorophyll_a

What are the Scientific Questions

- What is the main mechanism of the cross-front water exchange?

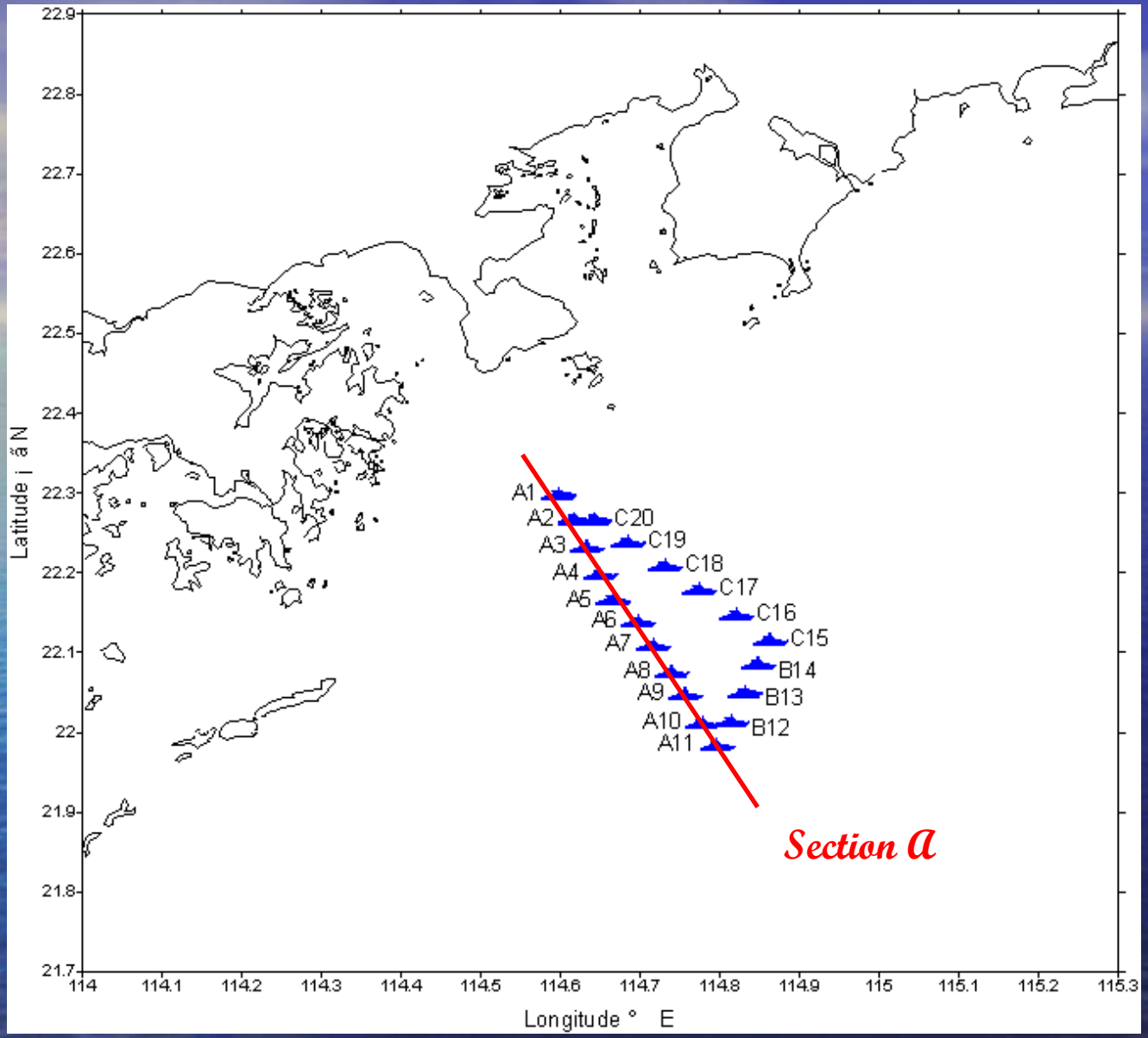
  Observation

- How the filaments and eddies generate?

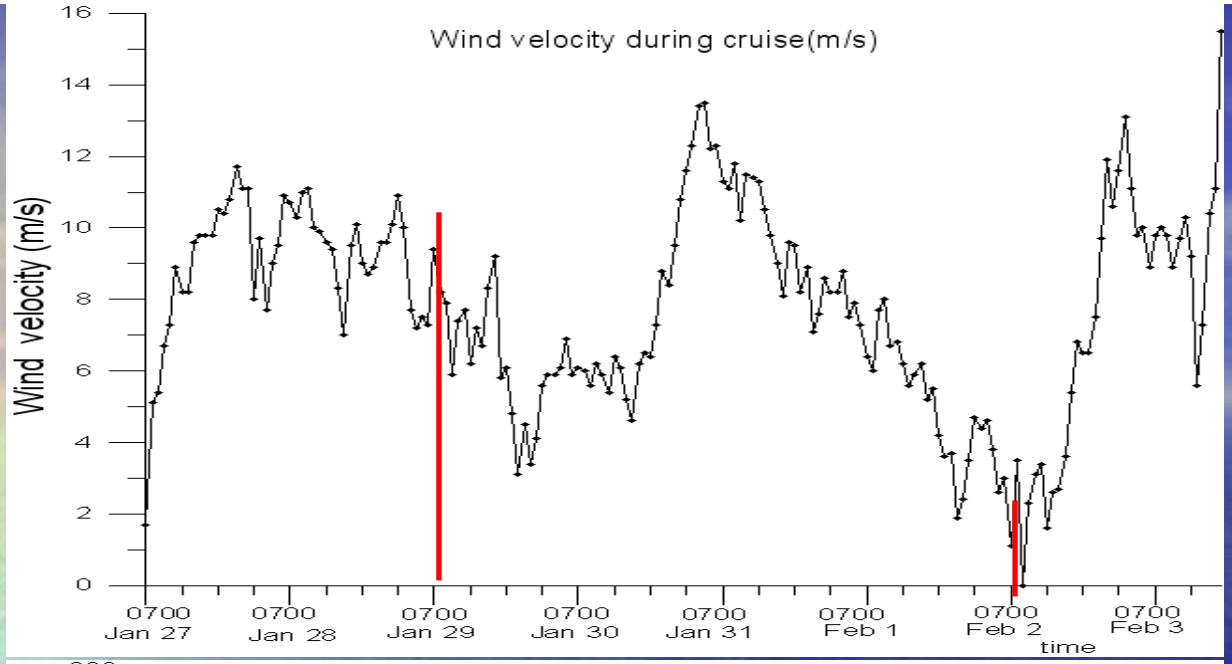
  Model

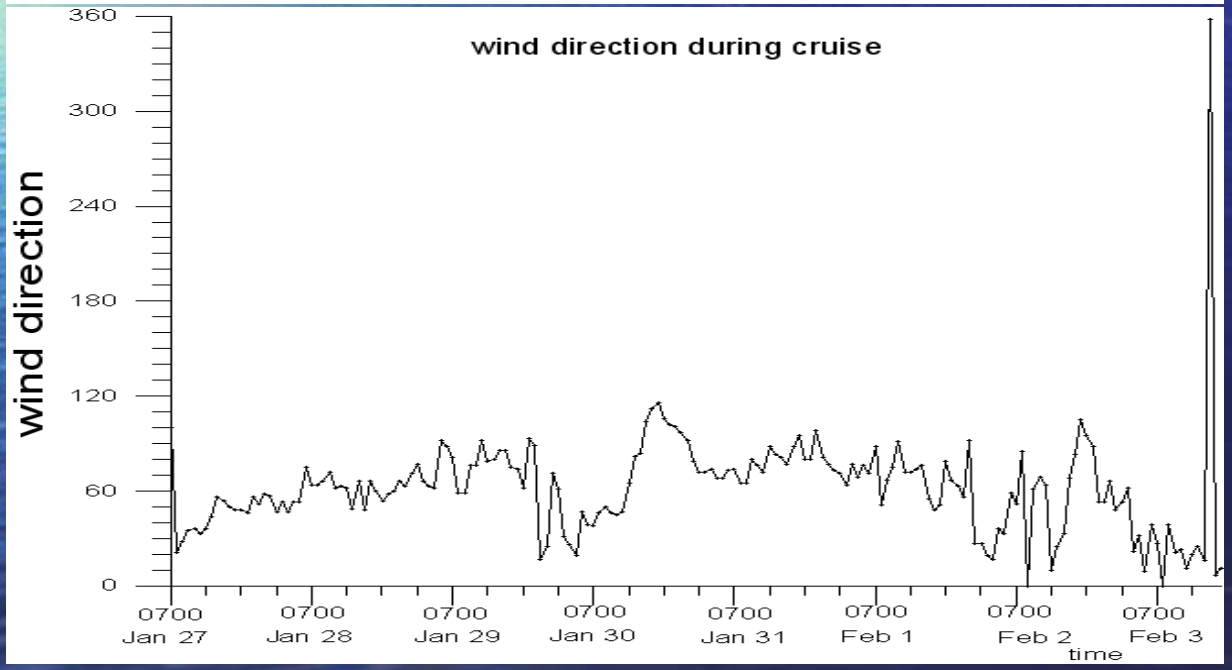
Observation

- During Jan 26 – Feb 6 in 2004, the cruise for the project ‘Spiral eddy front, circulation and water exchange in the northern shelf region of the South China Sea ’
- The temperature and salinity data could be got by Seabird 25 CTD
- A 1200k ADCP was put together with the CTD, and we can know the detail vertical velocity structure, and the shipborne ADCP data was also included.
- YSI in the sea surface to detect the SST and Chl-a. If the gradient of the SST or Chl-a is beyond some constant we fixed, a alarm machine would alarm, and we can know the exact position of the front.
- To know the pattern of surface velocity, CODAR was included in this cruise
- The wind sensor is about 10 m above the sea surface. The average wind velocity in the cruise is 7.8 m/s, average wind direction, 60° and average air temperature, 16.5℃.
- Chemical, optical and weather observation

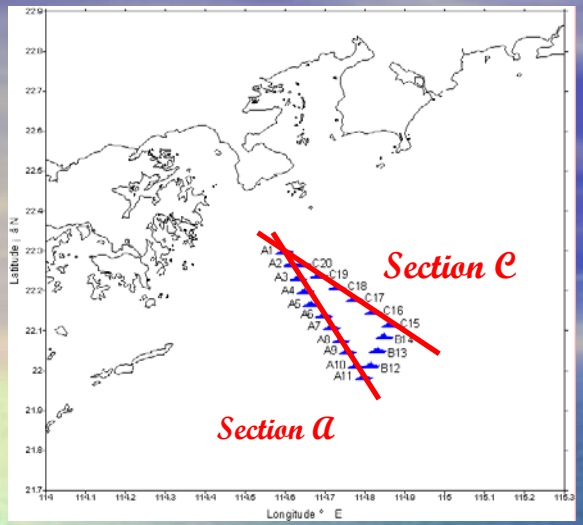


Location of the stations of the winter cruise in 2004



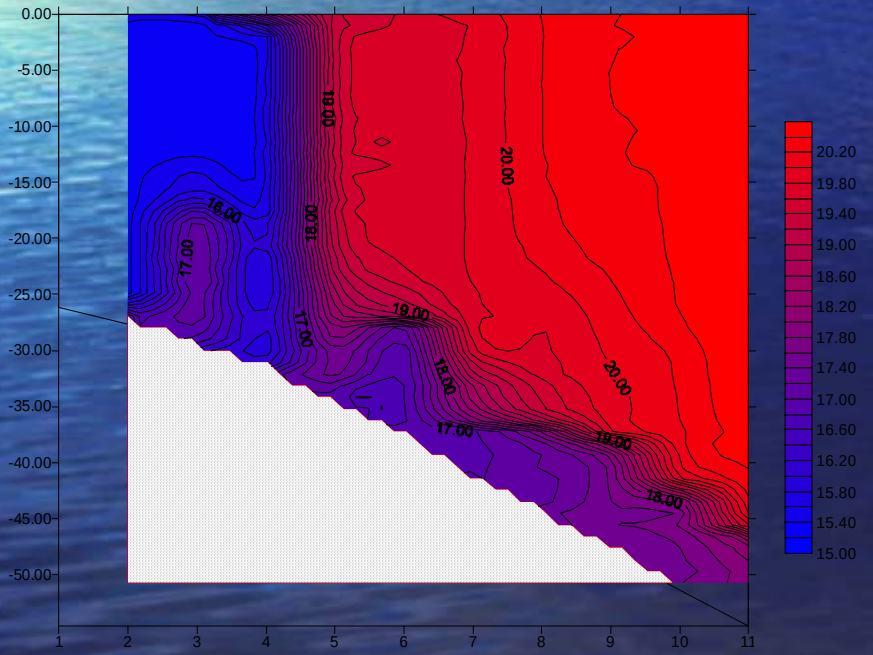


Wind velocity (up) and direction (down) during the cruise

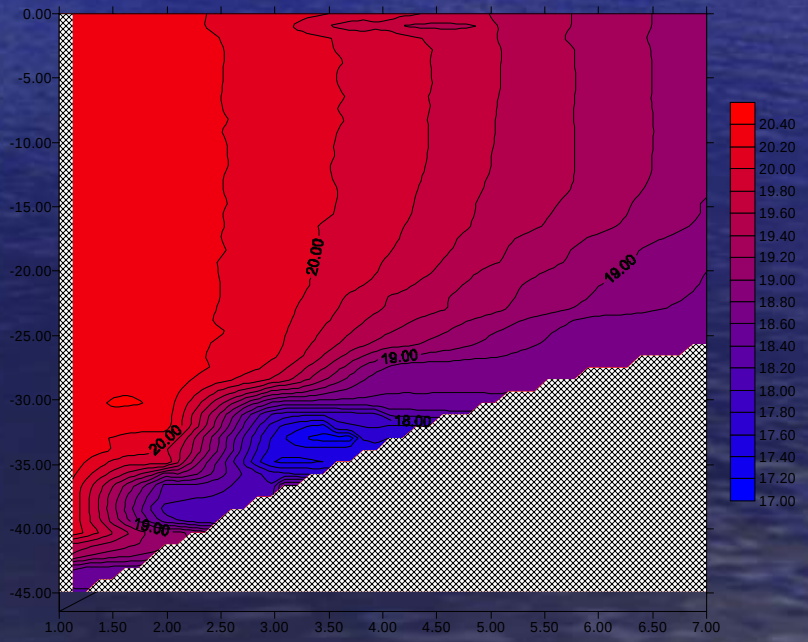


The survey of Section C is 10 hours later than that of Section A, so the velocity of the front is about 0.5m/s. It is faster than the tidal current, wind drive current, and the flux is larger than the Ekman transport. We guess that the strong mixing in the shelf make it seem like the front move so quickly.

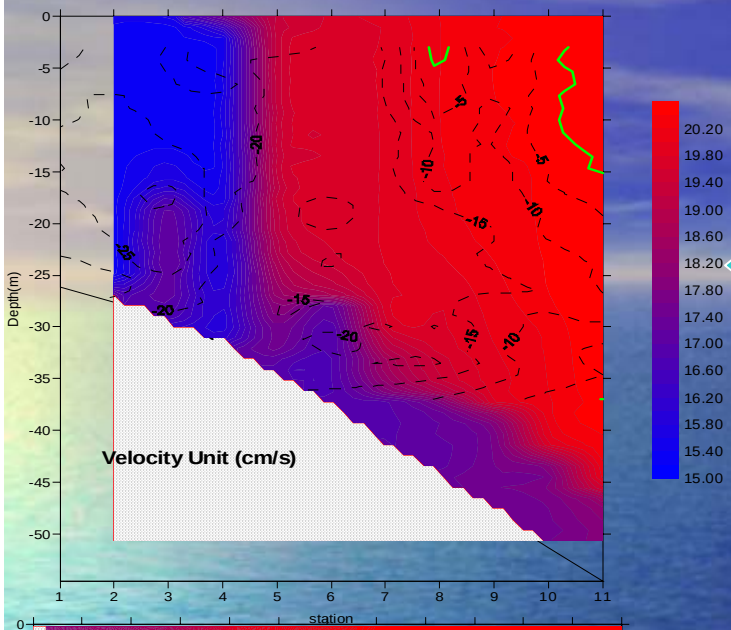
Section A



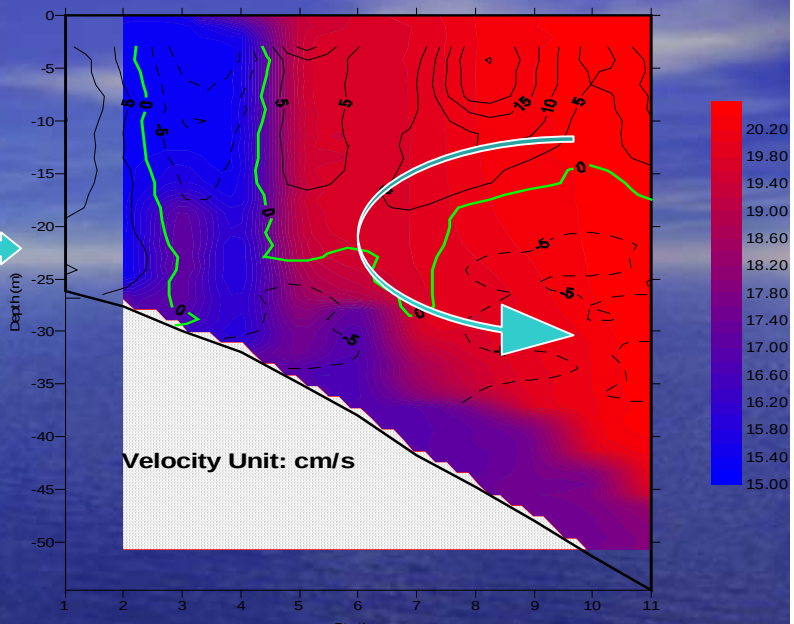
Section C



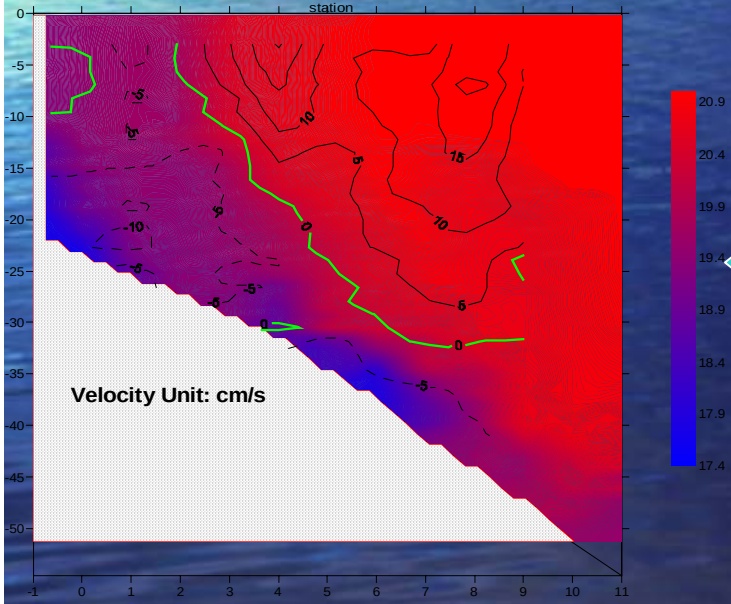
Along-front velocity, Solid line northeast, Dotted line southwest



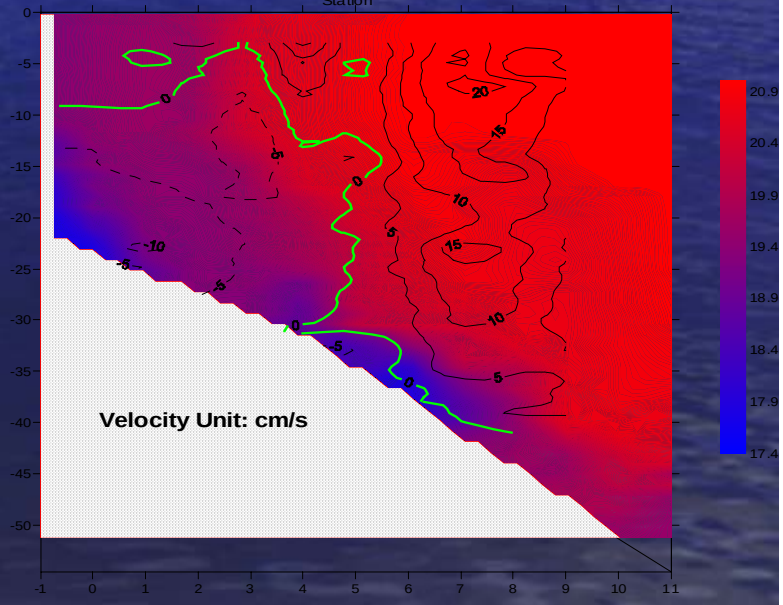
Cross-front velocity, Solid lines onshore,Dotted lines offshore

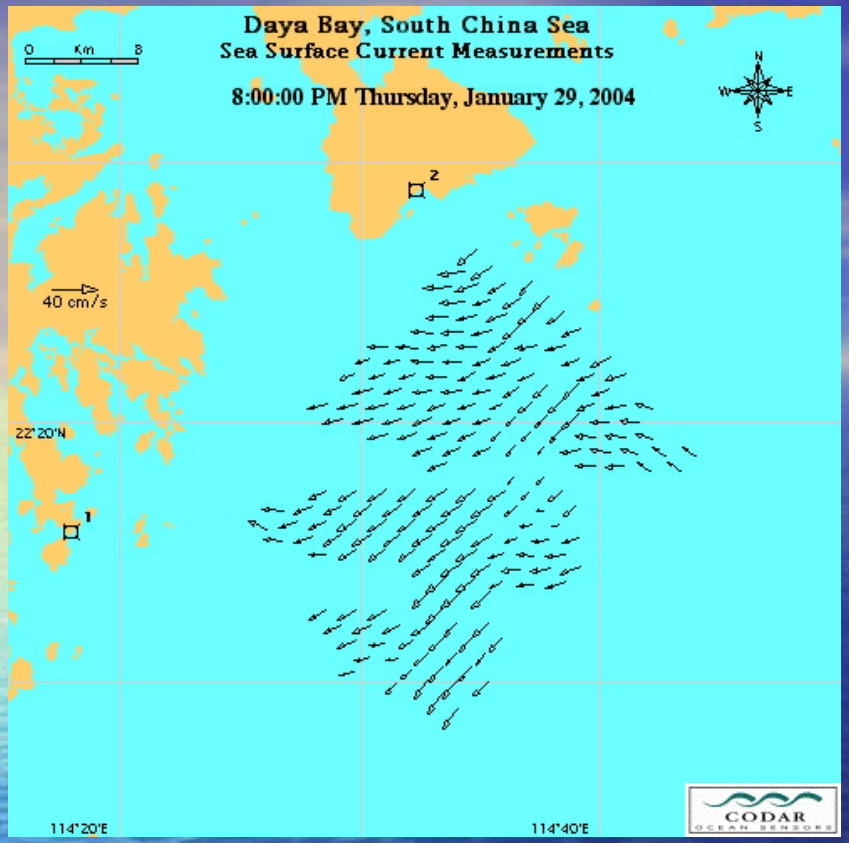


Jan 29, 2004 in strong wind

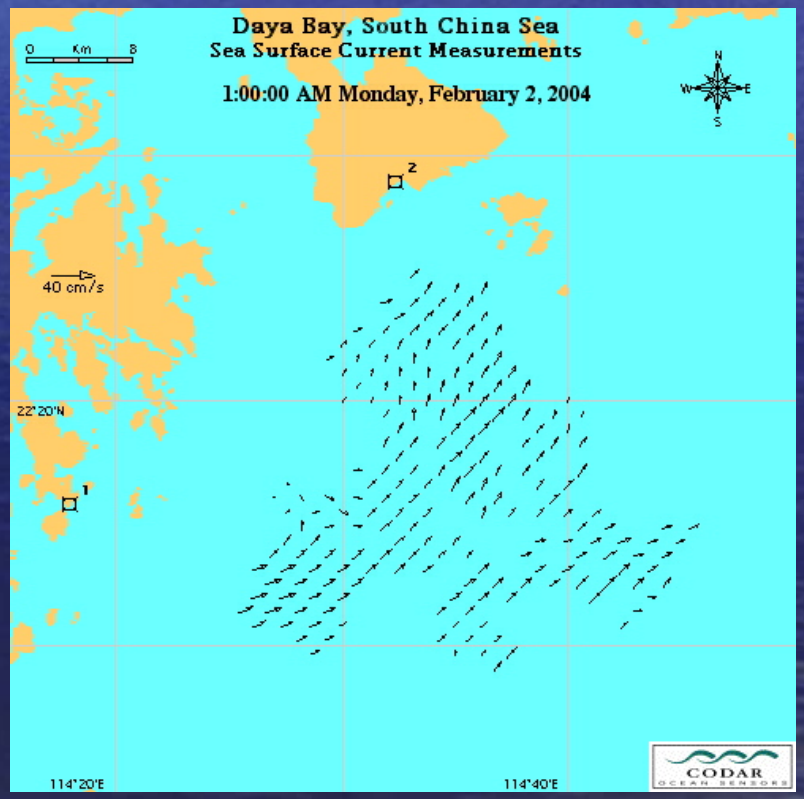


Feb 2, 2004 in normal wind



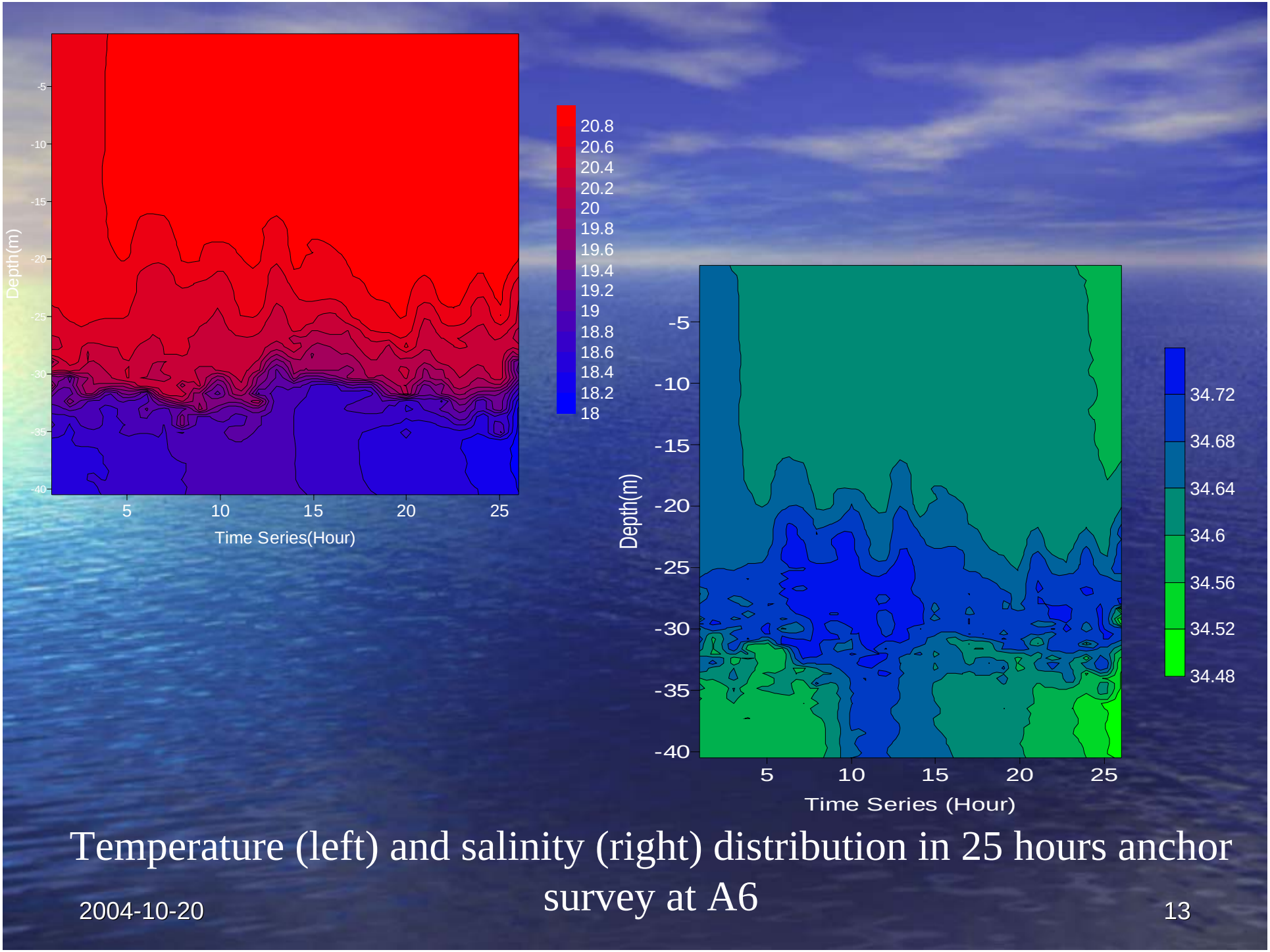


Strong surface current along the wind direction in the strong wind



Compensated flow generate in the normal wind

Surface velocity from CODAR data



Temperature (left) and salinity (right) distribution in 25 hours anchor survey at A6

Calculate the water exchange

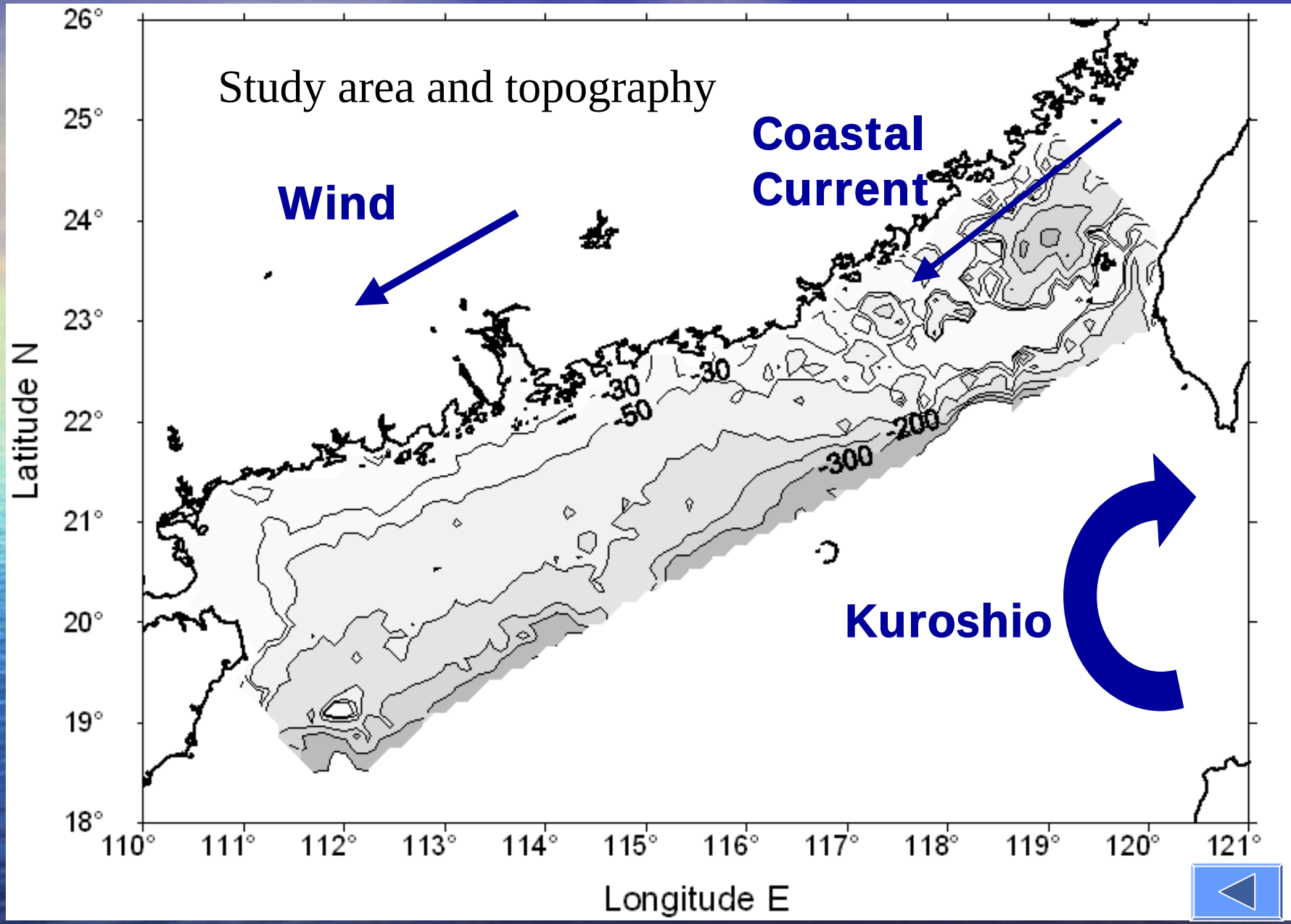
To calculate the water exchange between the both sides of the front, many people do a lot of good work (Pringle, 2000; chapman,1997). Here we only calculate the exchange from two mechanisms.

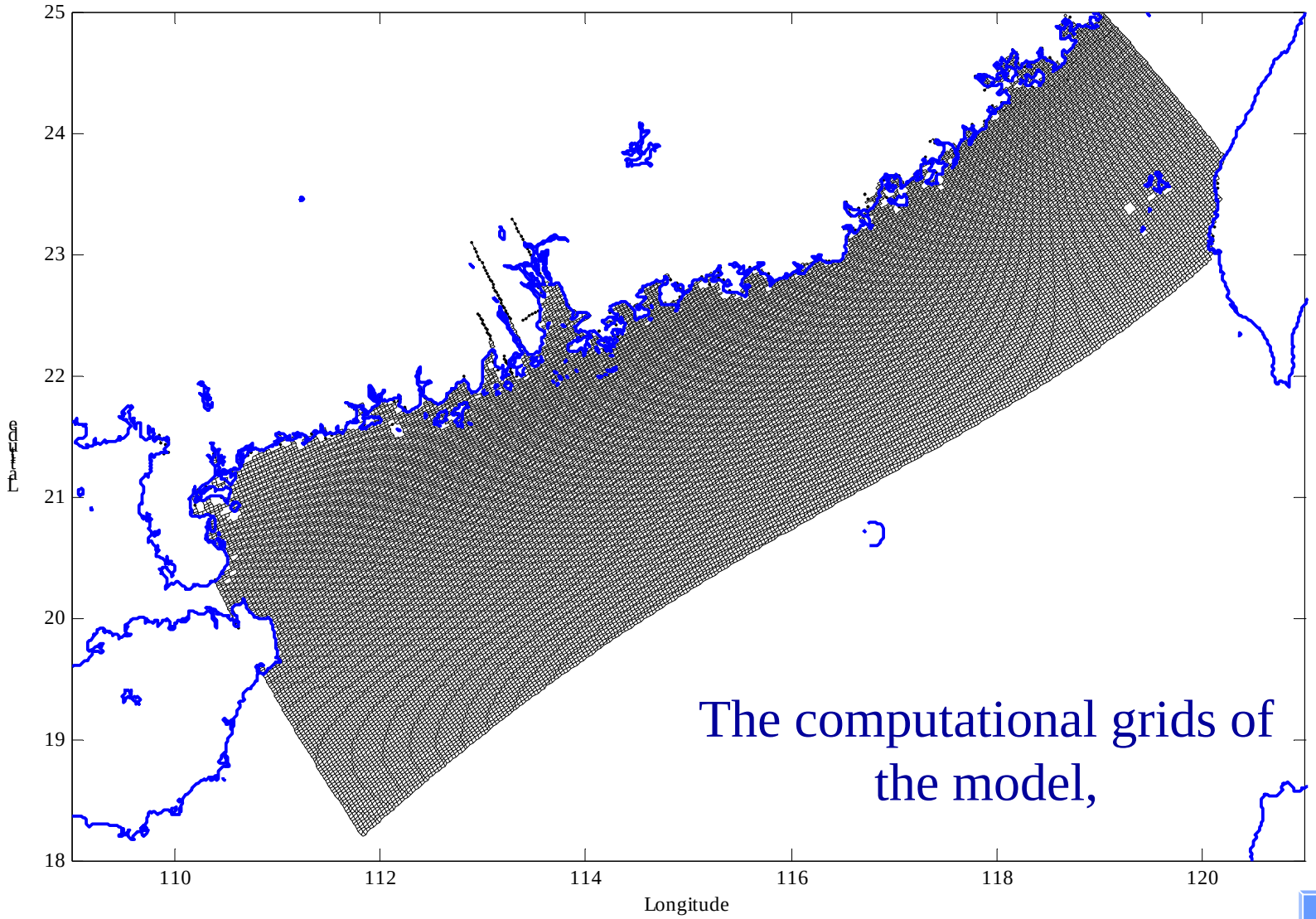
- 1. Transportation in the bottom layer. In the observation we can know the velocity of the bottom layer is about 5m/s and the thickness is 5m. If the length L is about 700km, the flux is about 17.5Sv. But it is related to the bottom friction and wind stress, the estimate is not exactly right.
- 2. The eddies generate with the frontal instability. The radius of the eddy can be known from the satellite pictures, here we use the relation $R=4L_R$, L_R is Rossby deformation radius.

  Here $L_R \approx 5$km, so the radius is 20km. If the period of the eddy cross the front is 10^4s , the flux is about $2.5S_v$.

Model Description

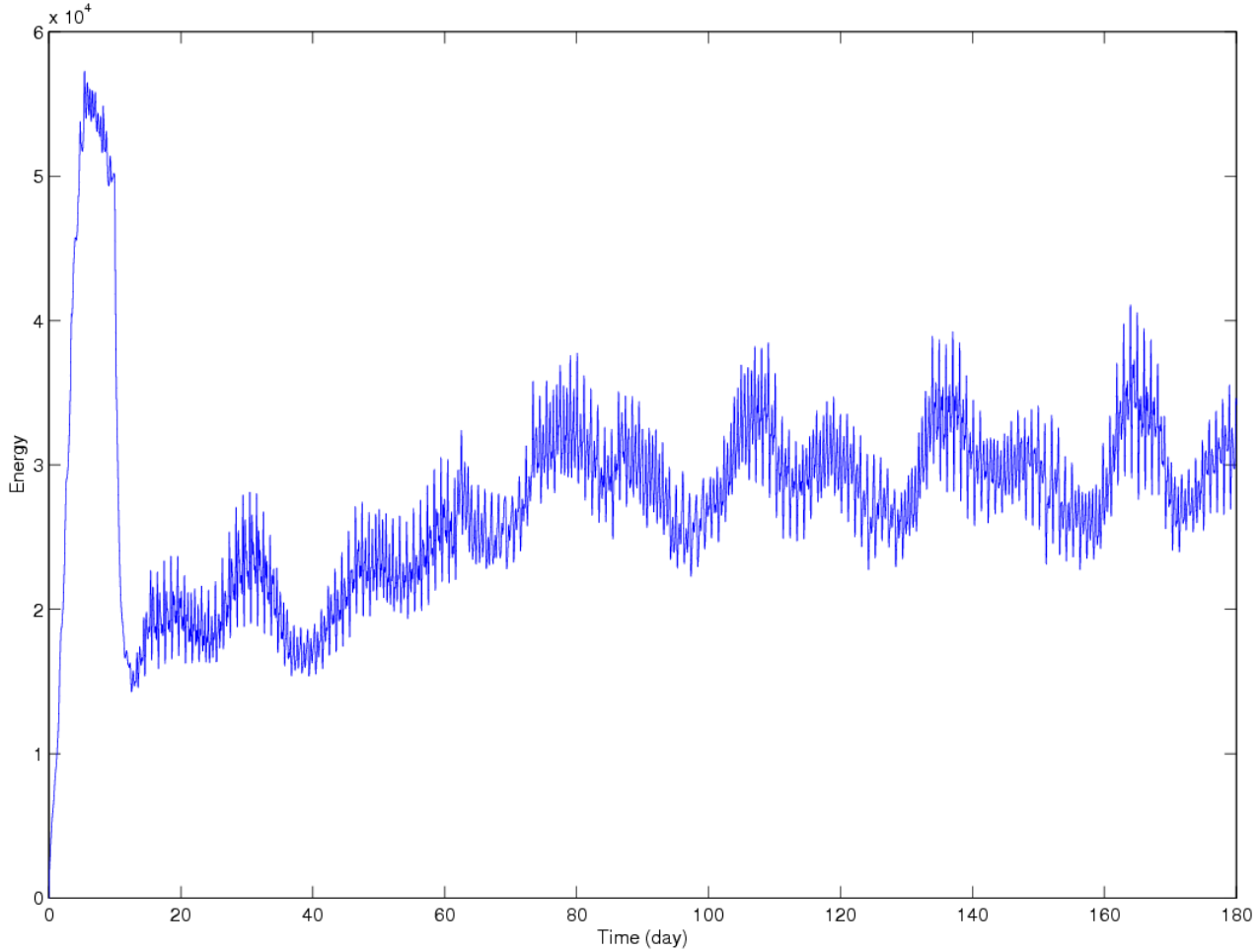
- Princeton Ocean Model
- The simulated area is between 18° N and 25° N, 110° E and 120° E
- the domain includes South Taiwan Strait, shelf of the Northern SCS, PRE, Dapeng Bay, Daya Bay and east area of Hainan island
- The orthogonal curvilinear coordinates is used, 301*181 in horizontal, 15 levels in vertical
- The resolution is from 1.6km near the PRE to 9.5km in the open SCS
- The time step of the external mode is 108 seconds, and which of the internal mode is 6 seconds.
- Run model for 180 days as the initial ground


Study area and topography
Wind
Coastal Current
Kuroshio
-30
-30
-50
-200
-300
26°
25°
24°
23°
22°
21°
20°
19°
18°
Latitude N
110°
111°
112°
113°
114°
115°
116°
117°
118°
119°
120°
121°
Longitude E



The computational grids of the model,

Spin-up Energy

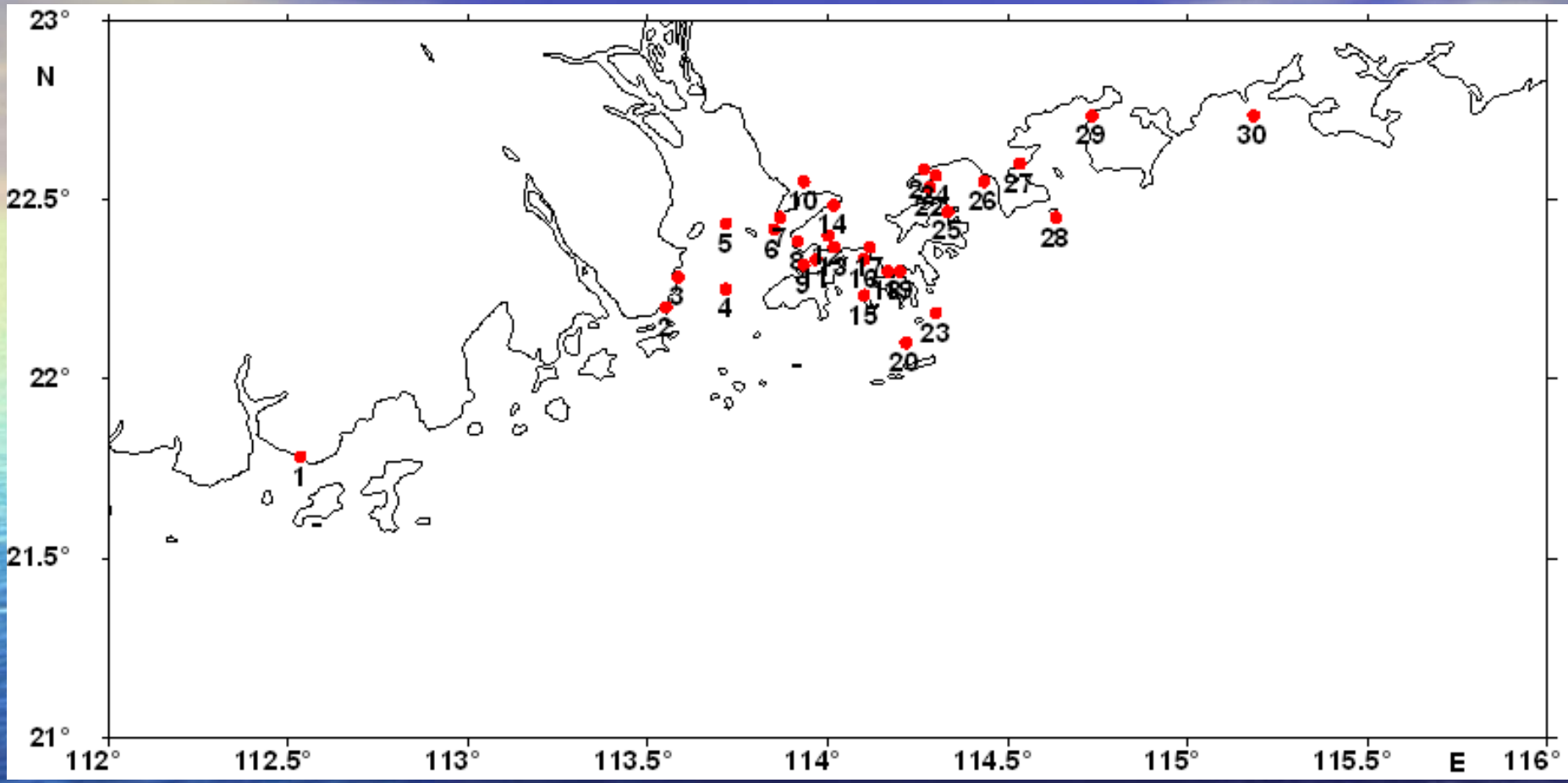


Open boundary and Surface boundary

- Four subtidal elevation, M2, K1, S2 O1, were added in the open boundary each time step
- In the first 180 days spin-up calculation, climatological force is used. The surface condition is monthly average wind of January, average wind velocity about 6.5 m/s, average wind direction about 70°.
- Wind force: After 180 days, to simulate the front closer to the observation, we use MM5 model output every 6 hours as the wind force, and also consider the observed wind in cruise.
- Heat flux: monthly average heat flux with experience formula

Validation

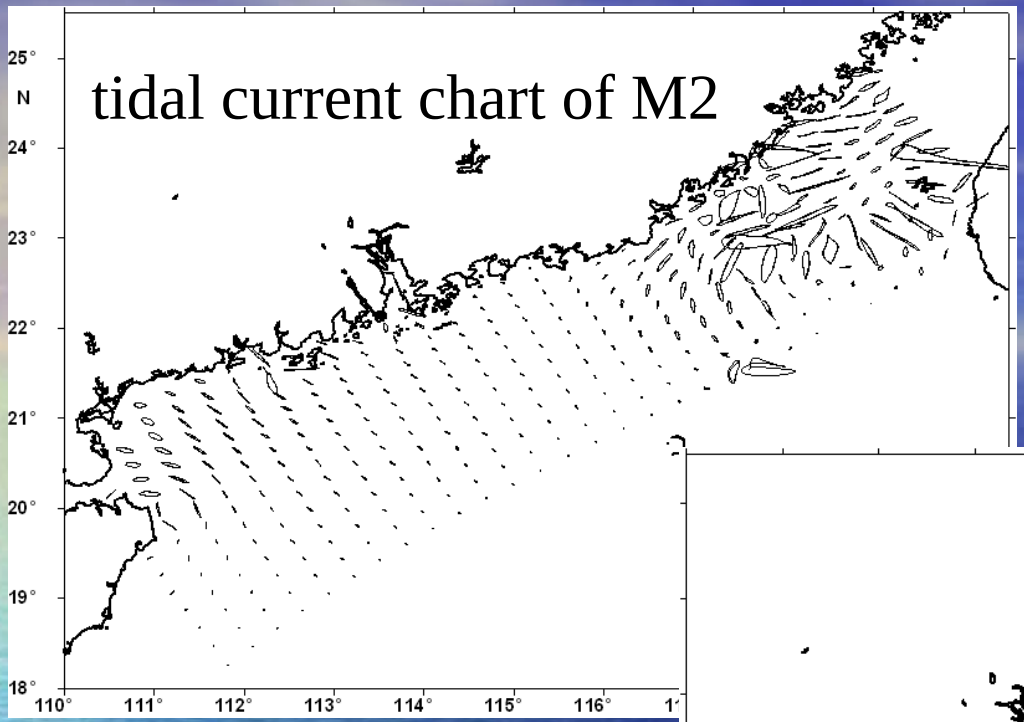
- *Tide*
- *Temperature and salinity*
- *Current*

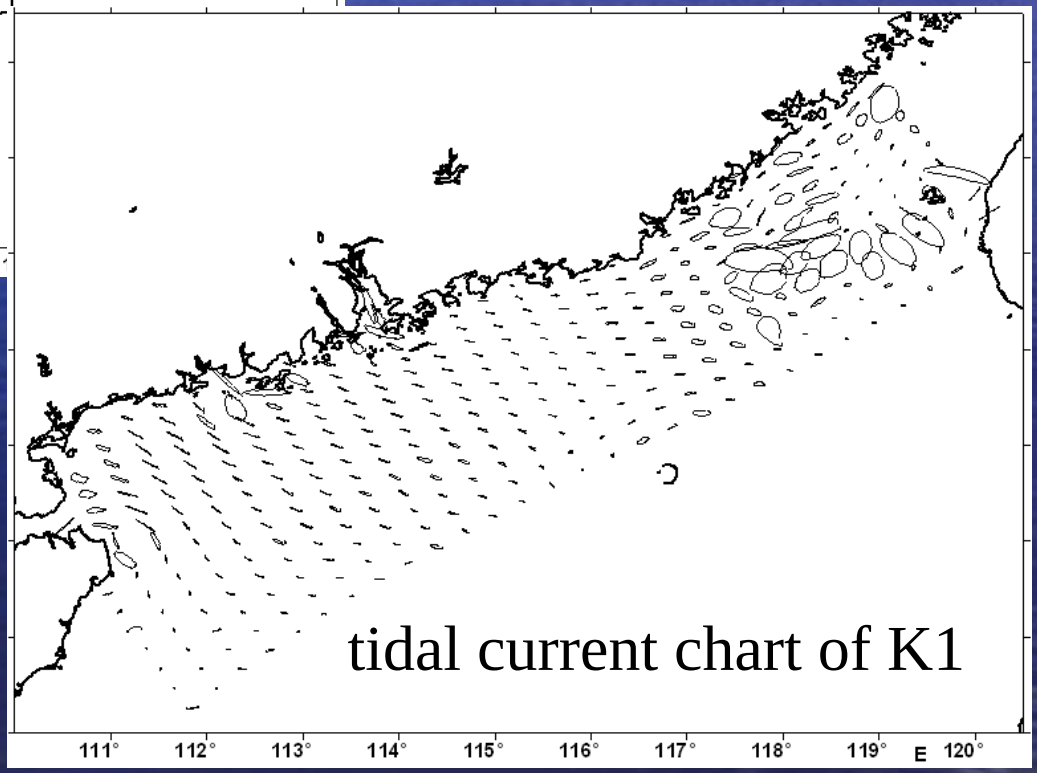


30 tidal observed stations

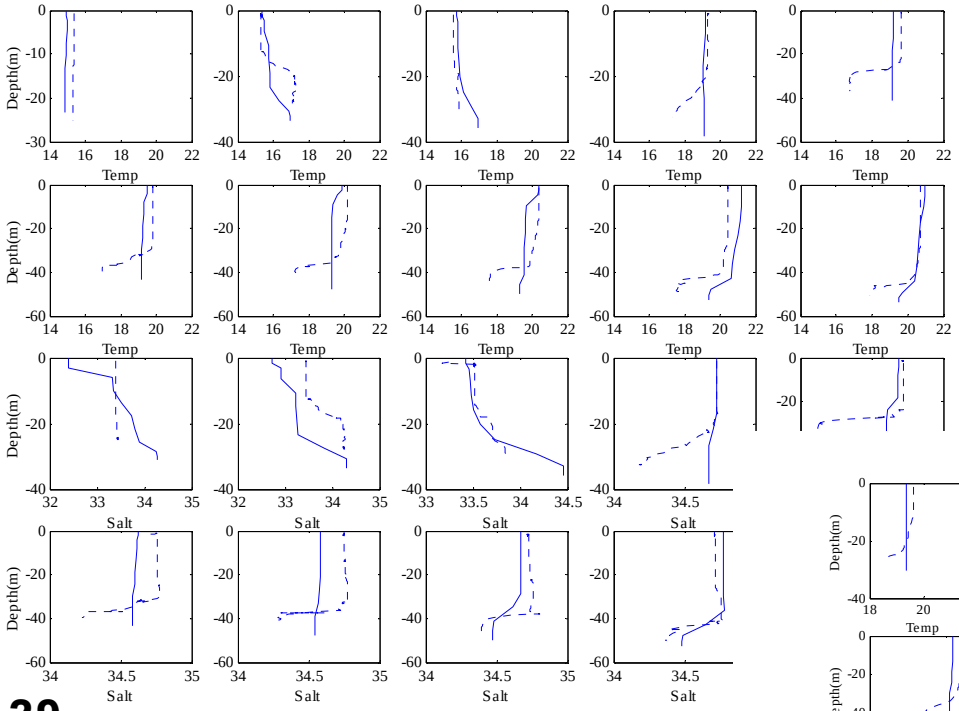
M2

stations	Amplitude (Observ)	Amplitude (Model)	DAMP	Phase (Observ)	Phase (Model)	DPHS
1. Xiachuan Dao	60	62.79	2.79	315	315	0
2. Macau	40.3	41.02	0.72	271	276	5
3. Zhuhai	30	37.17	7.17	275	271	-4
4. Shanbanzhou	47.7	45.67	-2.03	291	306	15
5. Dawanshan	45	46.88	1.88	287	292	5
6. Tai O	52.8	53.13	0.33	302	317	15
7. Chiwan	63.8	65.25	1.45	343	340	-3
8. Tap Shek Kok	41	42.97	1.97	272	273	1
9. Chek Lap Kok	49	50.15	1.15	309	301	-8
10. Wenwei Zhou	50	51.47	1.47	298	308	10
11. Tai Mo To	60.9	54.65	-6.25	298	317	18
12. Chi Ma Wan	49	49.84	0.84	292	300	8
13. Tai Lam Kok	36	42.43	6.43	264	272	8
14. Tsim Bei Tsiu	45	48.37	3.37	292	297	5
15. Yung Shue Wan	39	38.54	-0.46	267	266	-1
16. Tsing Yi	42	45.52	3.52	271	282	11
17. Tsuen Wan	61	57.05	-3.95	323	314	-9
18. Xianggang	38	44.99	6.99	270	278	8
19. HK Harbour	44	45.80	1.80	278	280	2
20. Wailingting	39	45.74	6.74	268	279	11
21. Dapengwan	33	37.67	4.67	268	261	-7
22. Yan Chau Tong	39	43.44	4.44	258	263	5
23. Waglan Island	39	41.77	2.77	256	261	5
24. Dagan	35.9	40.64	4.74	267	258	-9
25. Pak Sha O	34.7	40.64	5.94	229	258	30
26. Ping Chau	40	39.96	-0.04	268	258	-10
27. Dayawan	30	37.02	7.02	260	257	-3
28. Tuoning liedao	33.8	40.09	6.29	255	257	2
29. Tsang Chau	37	41.77	4.77	252	256	4
30. Honghai Wan	30	35.10	5.10	250	252	2

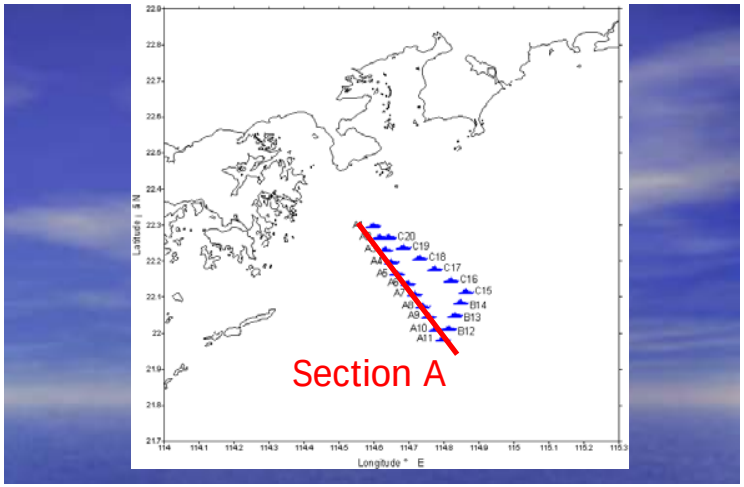

tidal current chart of M2
25°
N
24°
23°
22°
21°
20°
19°
18°
110°
111°
112°
113°
114°
115°
116°

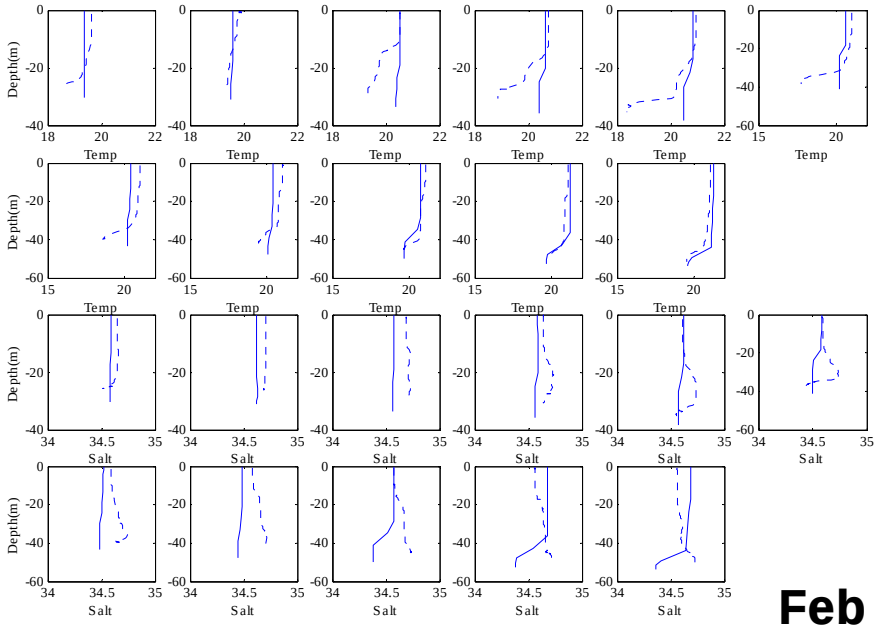

tidal current chart of K1
111°
112°
113°
114°
115°
116°
117°
118°
119°
E
120°

Temperature and Salinity



Jan 29





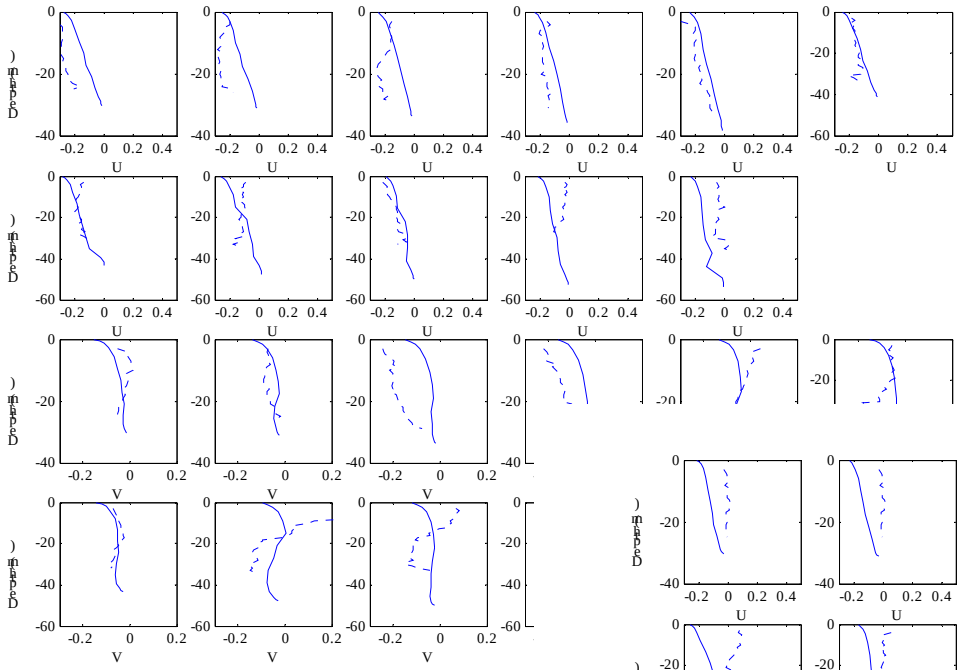
Feb 1

Comparison of the observed and simulated profile of temperature and salinity in the stations from A2 to A11. The relative errors are about 15% for temperature and 20% for salinity.

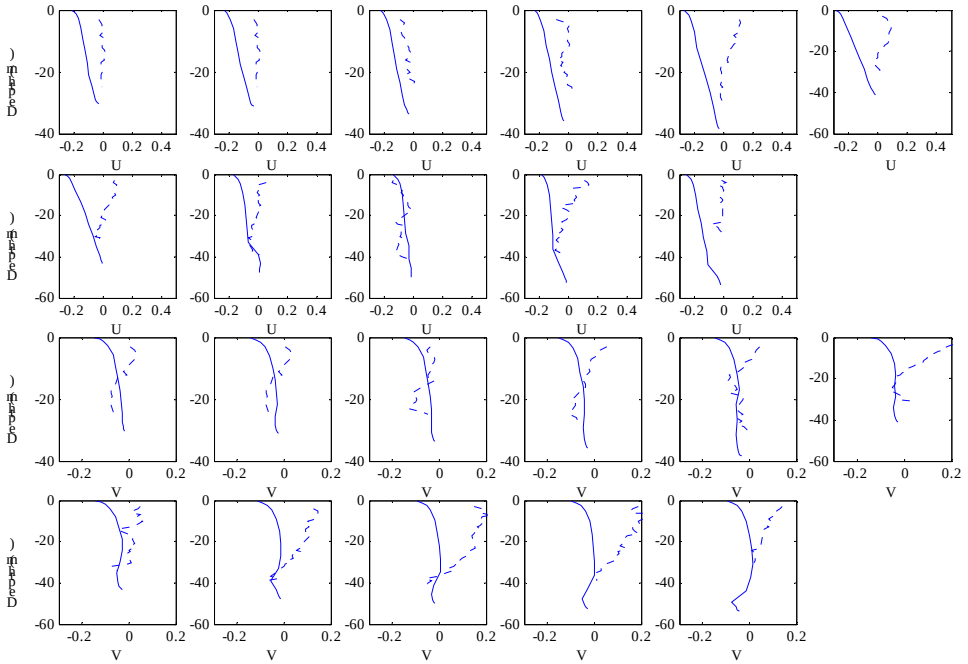
Current

- The current of this area can be concluded that it is combined of tide current, wind forced current, baroclinic current and geostrophic current. In the winter, the northeast wind is prevail, and the coastal current from northeast to southwest is also strong.

Velocity along the front

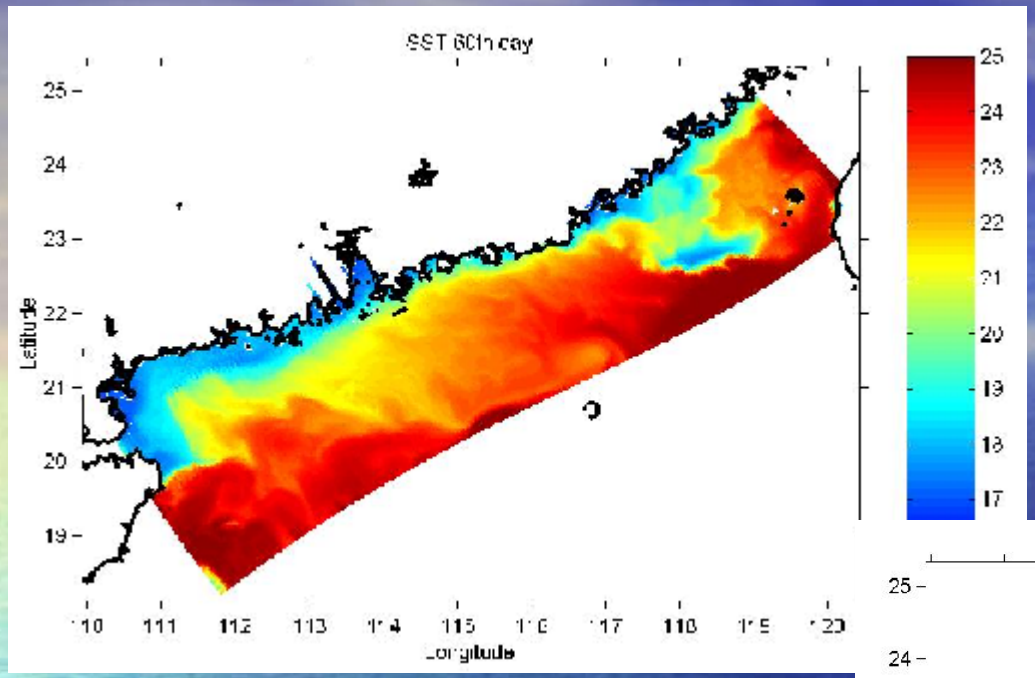


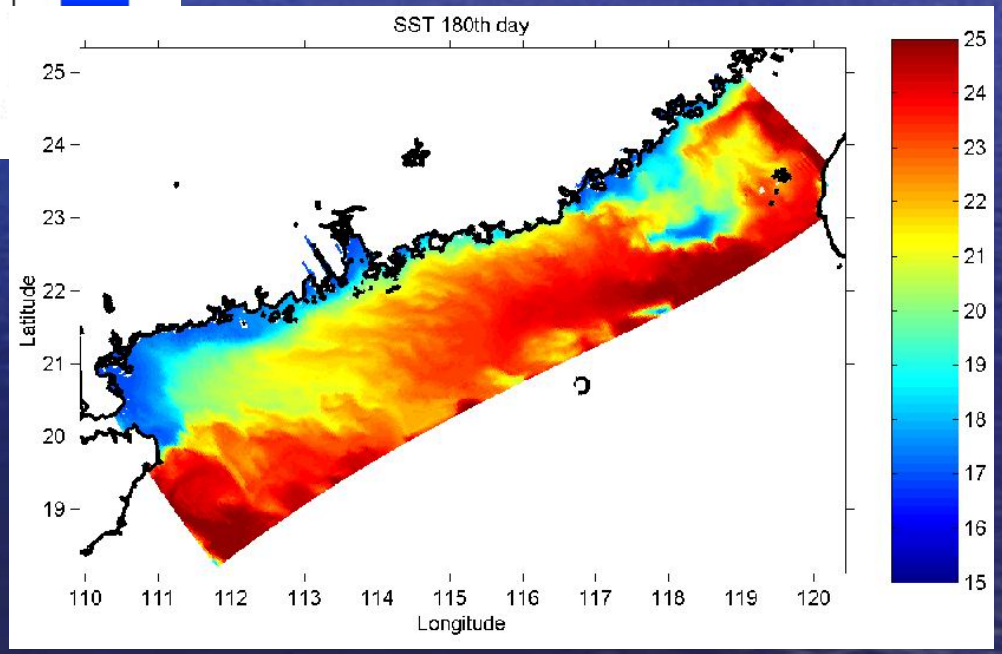
Velocity cross the front



Result

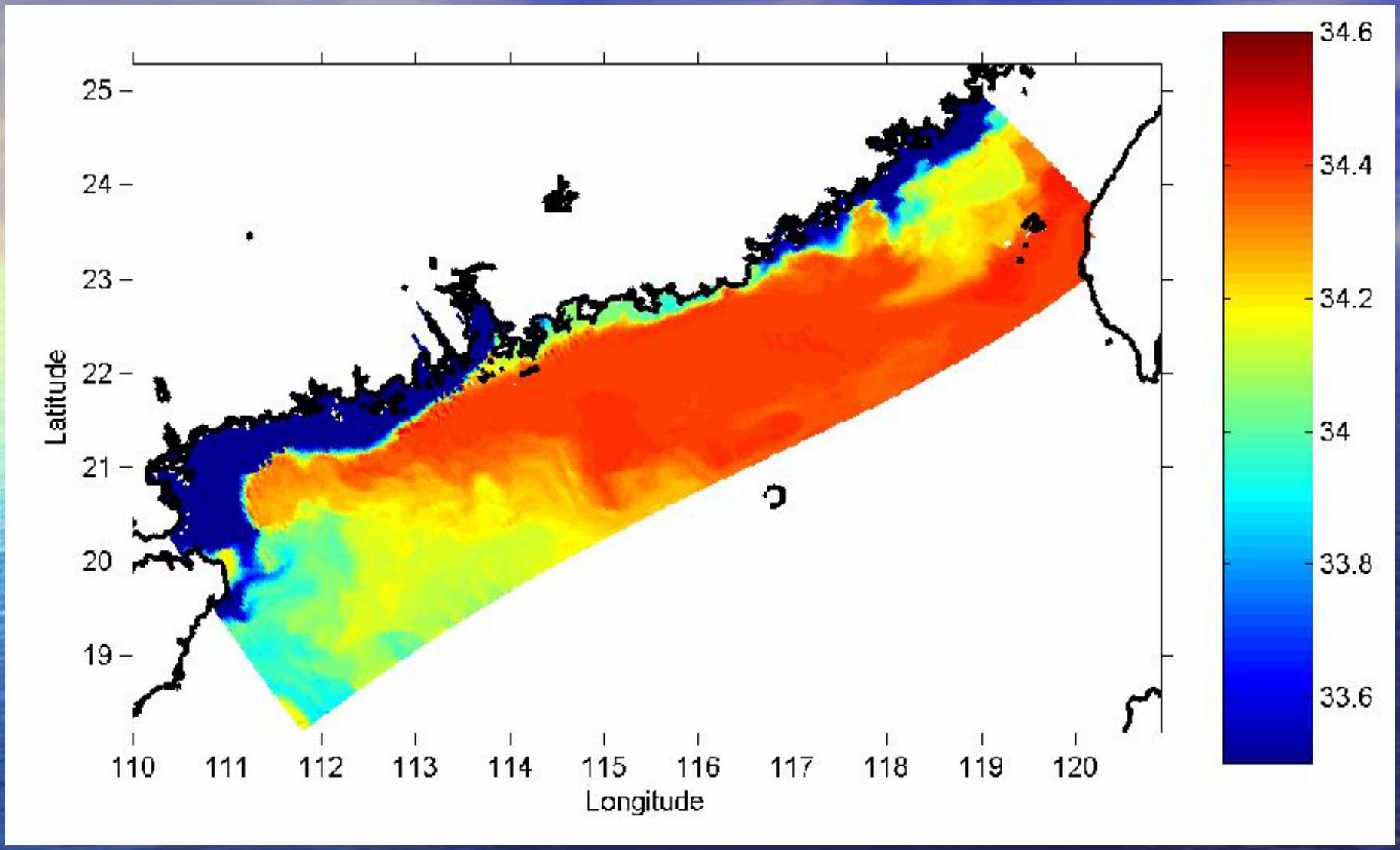
- 180days SST
- Salinity
- Current
- 2001 MM5 input



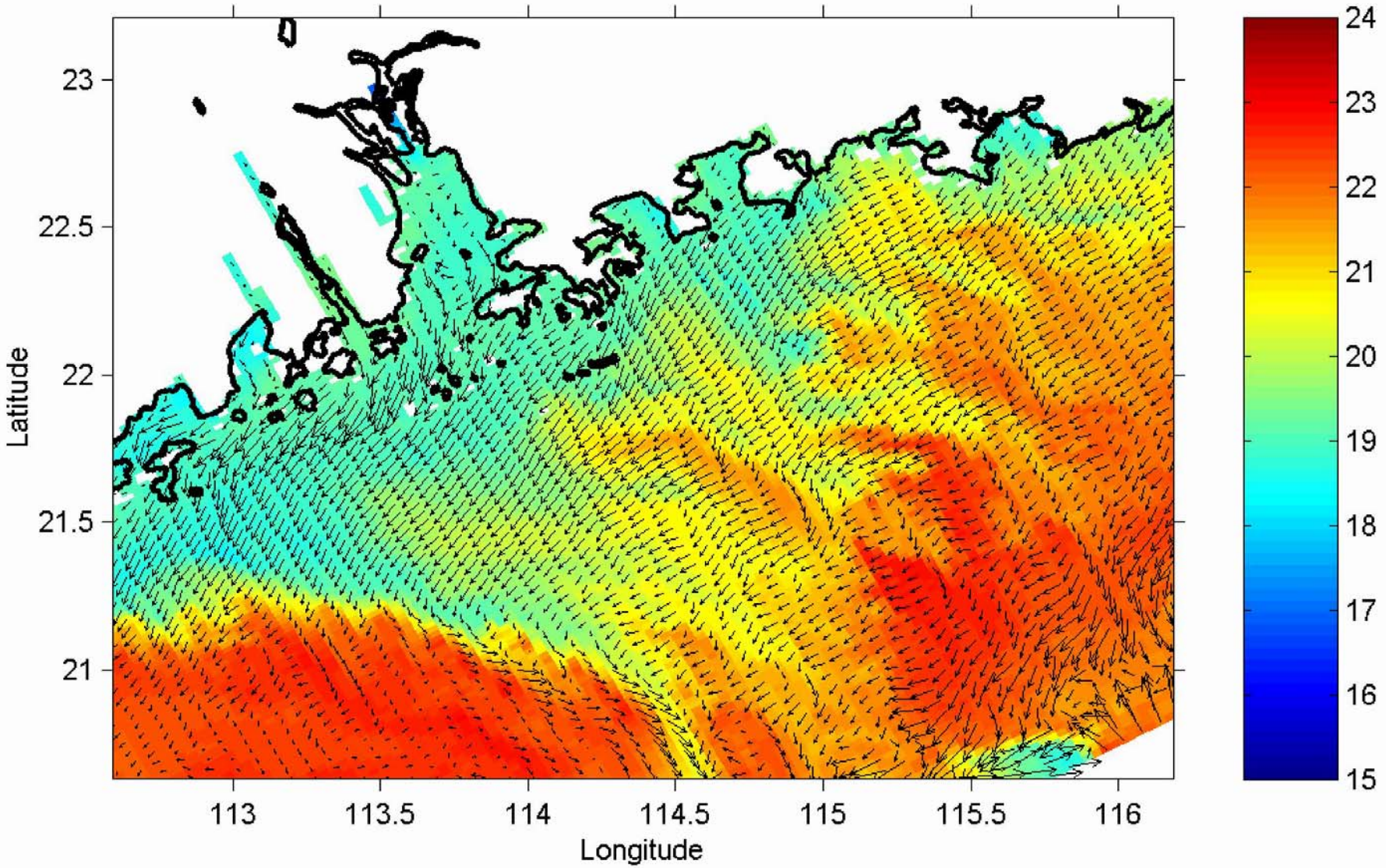


Filaments also generate in the monthly averaged wind

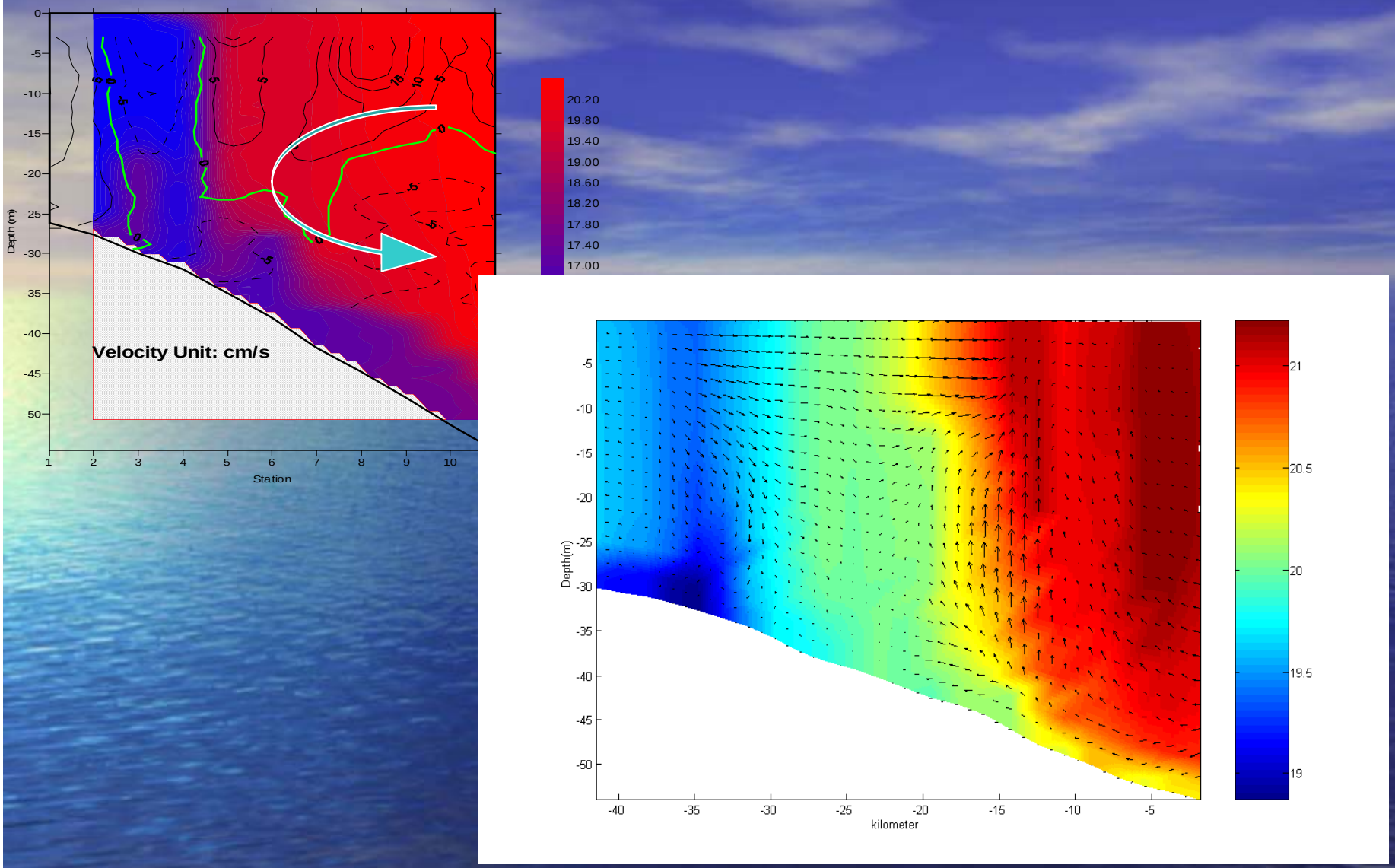
Temperature in monthly wind



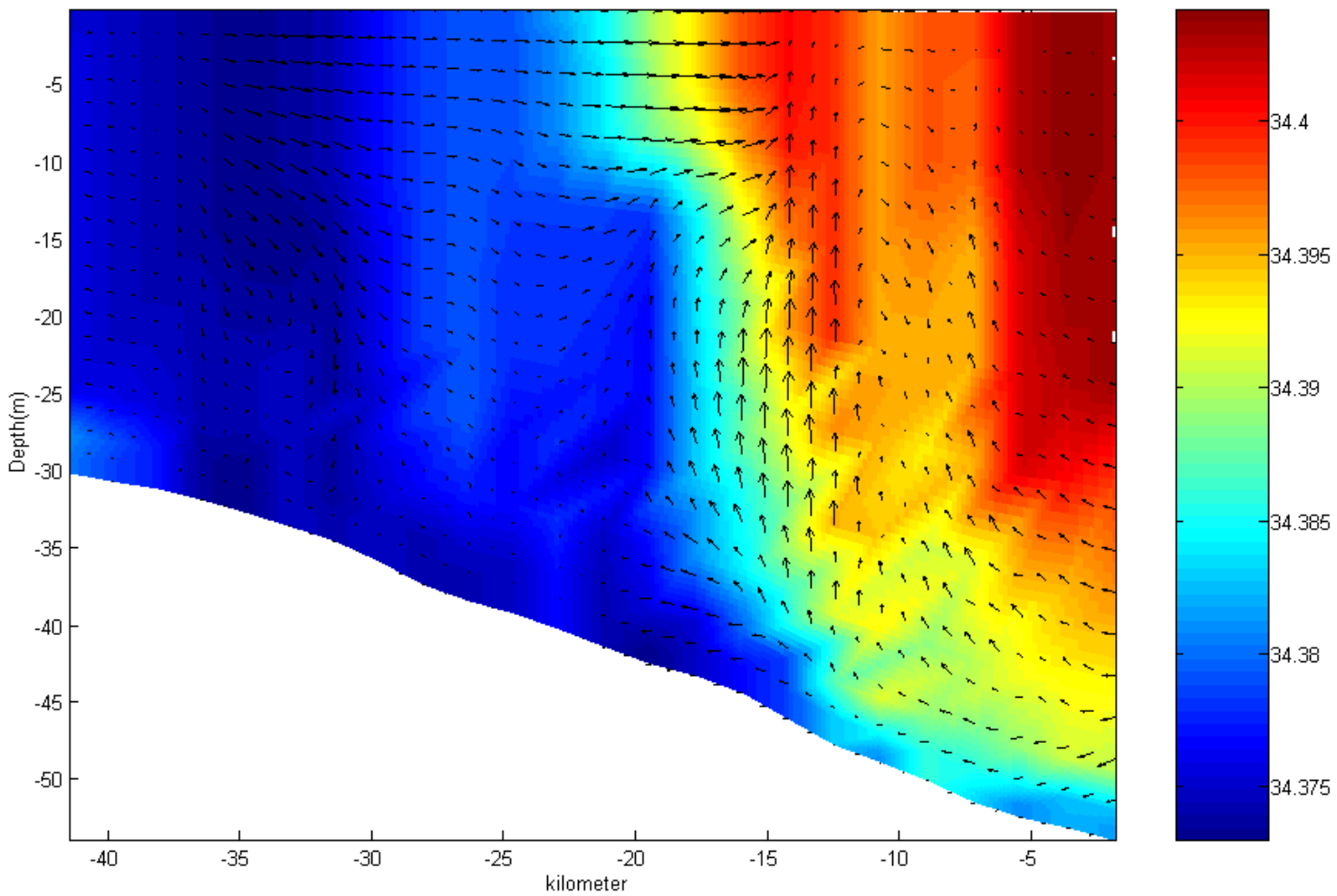
Salinity in monthly wind



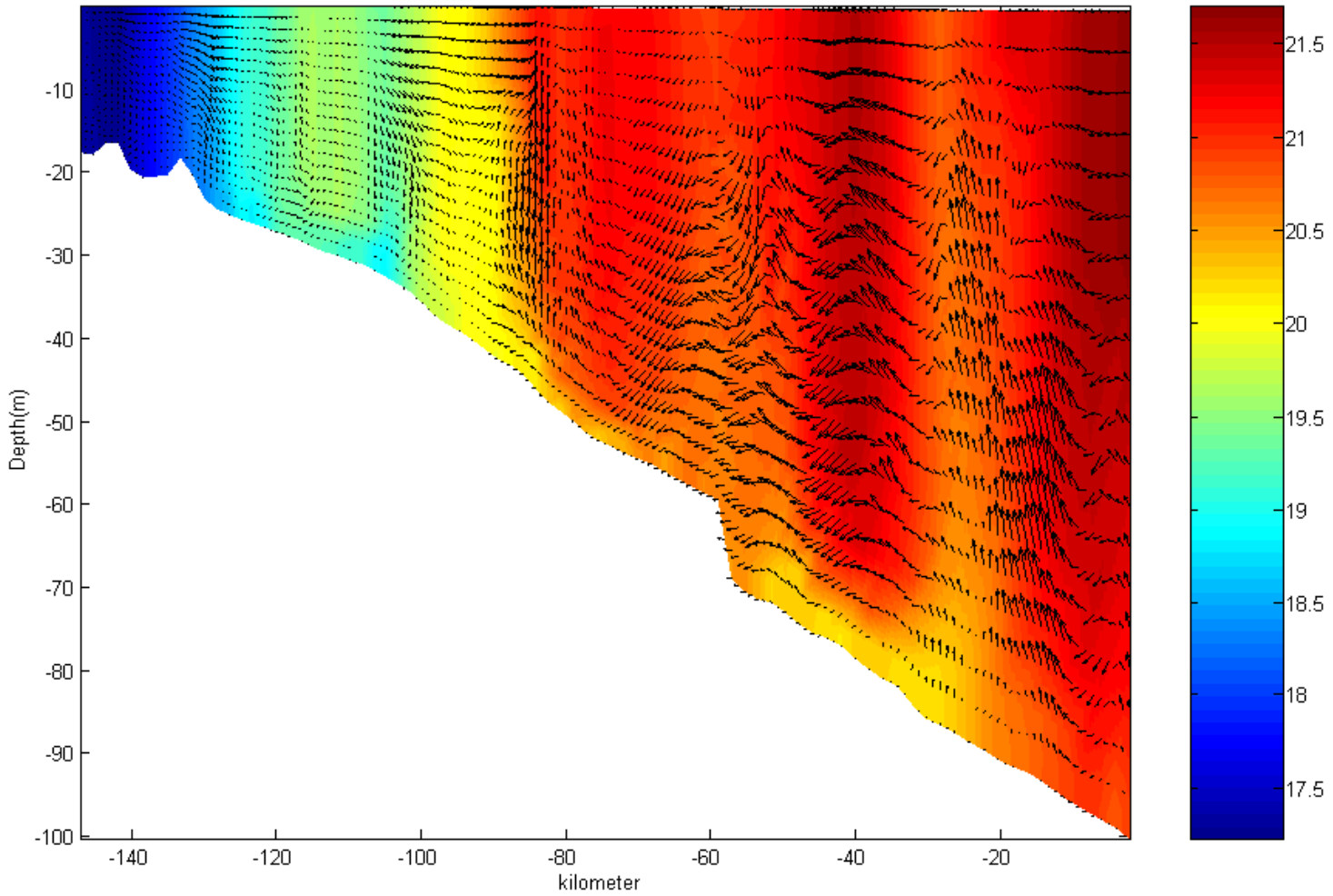
Surface velocity



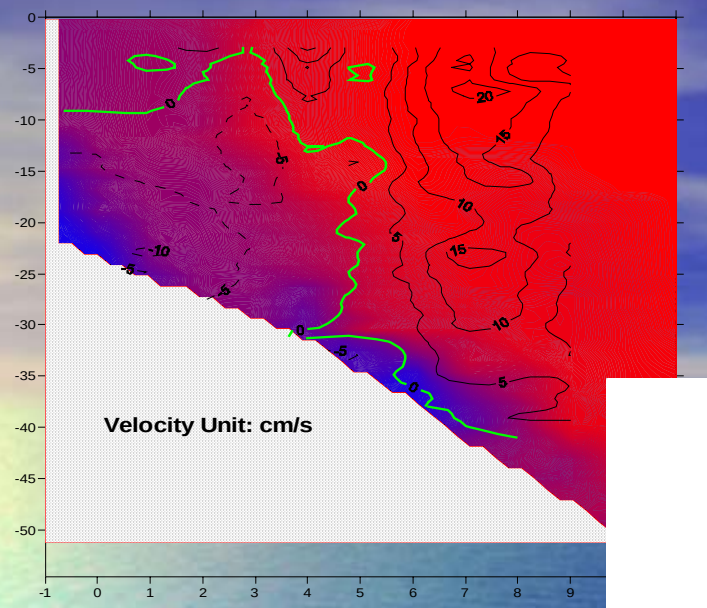
Temperature and velocity of Section A in the simulation in the Jan 29

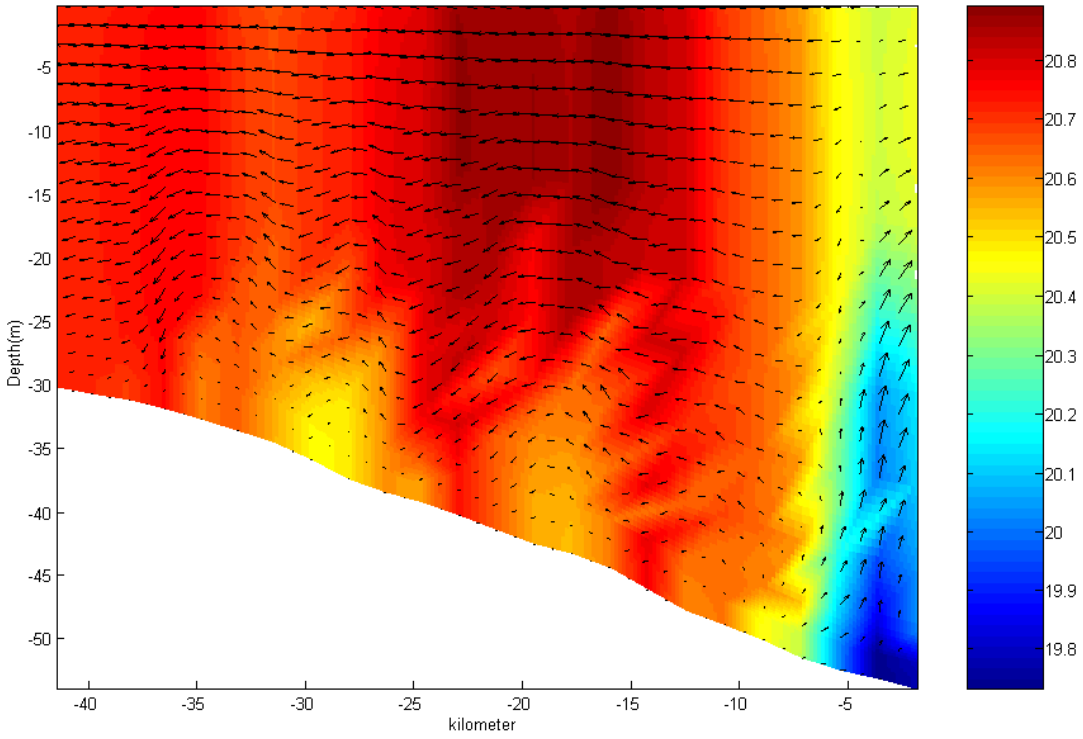


Salinity and velocity of Section A in the simulation in the Jan 29

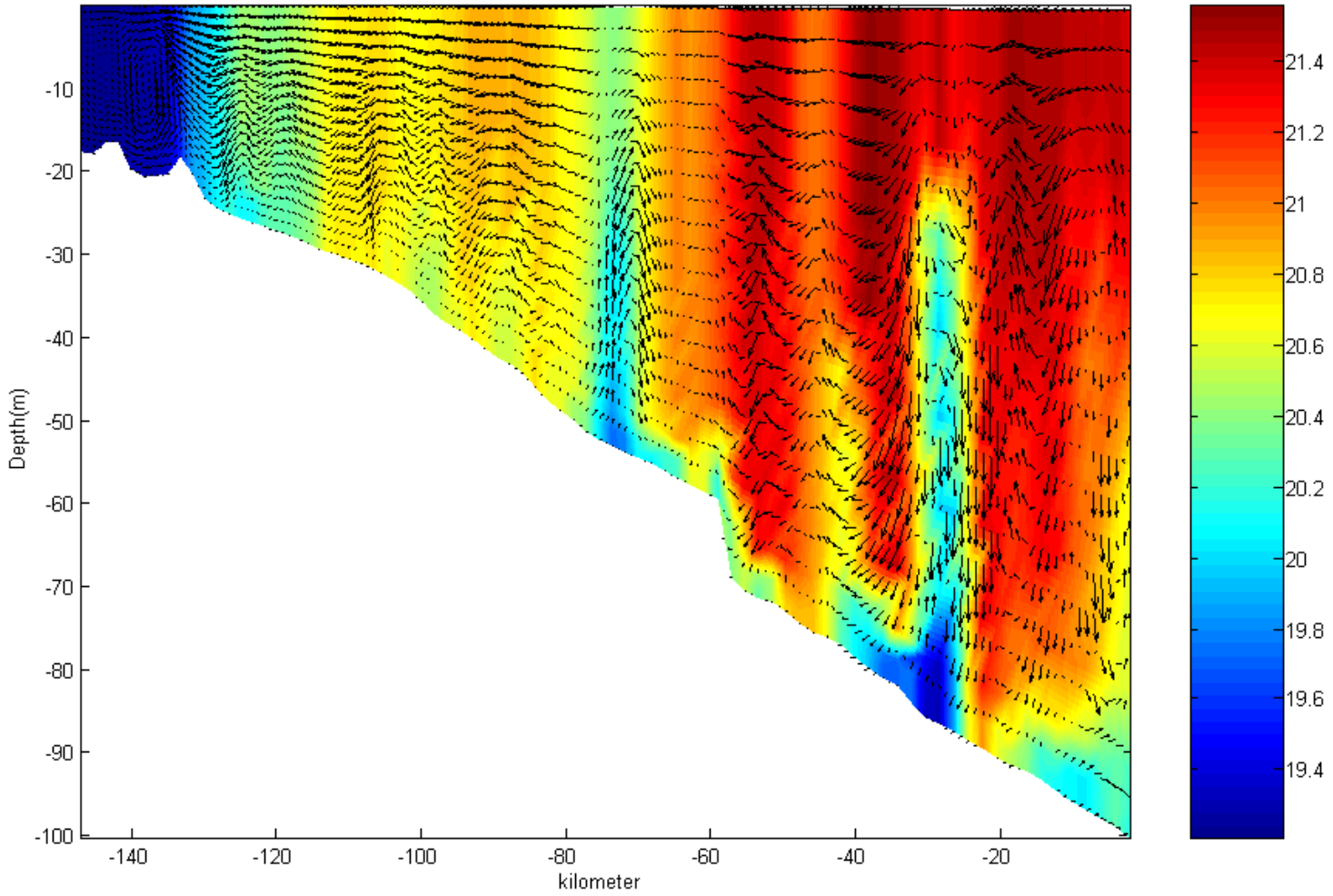


Temperature and velocity in the elongated section





Temperature and velocity of Section A in the simulation in the Feb 1



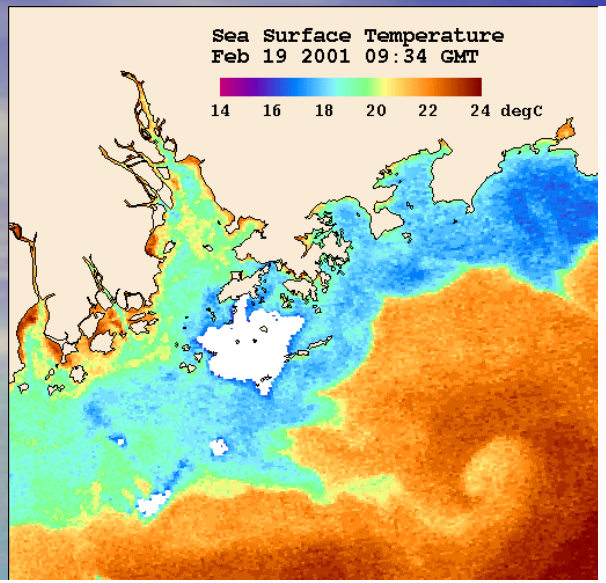
Temperature in Feb 2

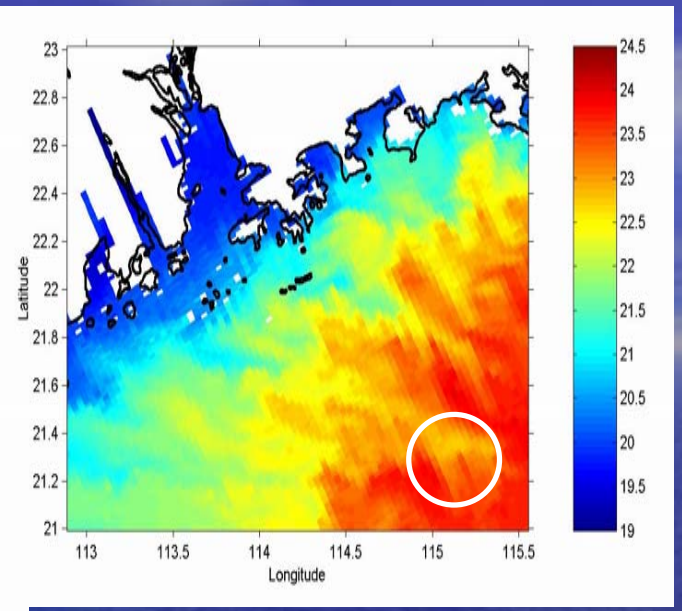
Summary of the model result

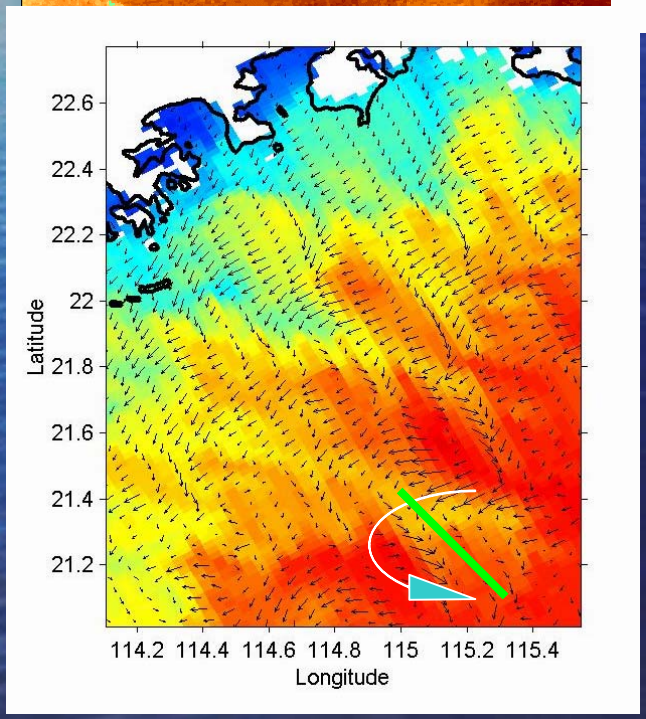
- The front is stronger in the observation, and the more filaments near the front generated in the simulation
- Cross-front circulation is similar to that in the observation
- Some filaments and eddies also found in the bottom layer

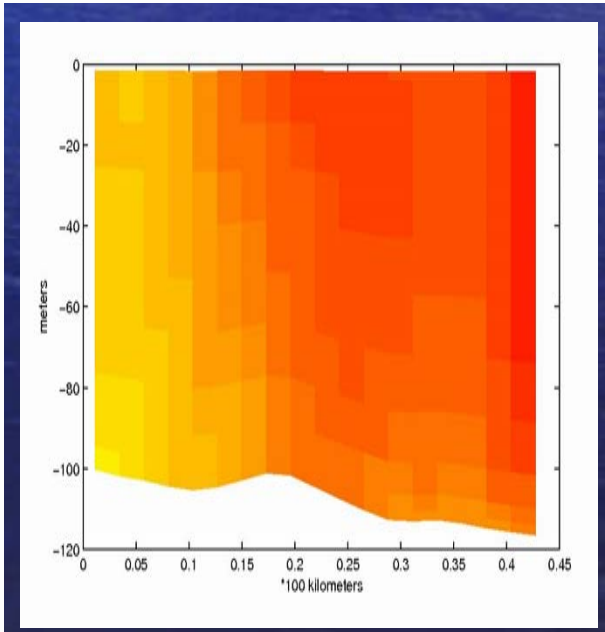
Eddy formation

- In imagery SST picture in Feb 29 2001, an eddy was found in the study area.
- In the simulation, with the MM5 wind force in 2001, the eddy generate in this condition
- The filaments are important in the first stage of the formation of the vortex. The generation of the filaments is mostly due to the inertial instability of the front.









Eddy formation in the MM5 wind force, 2001

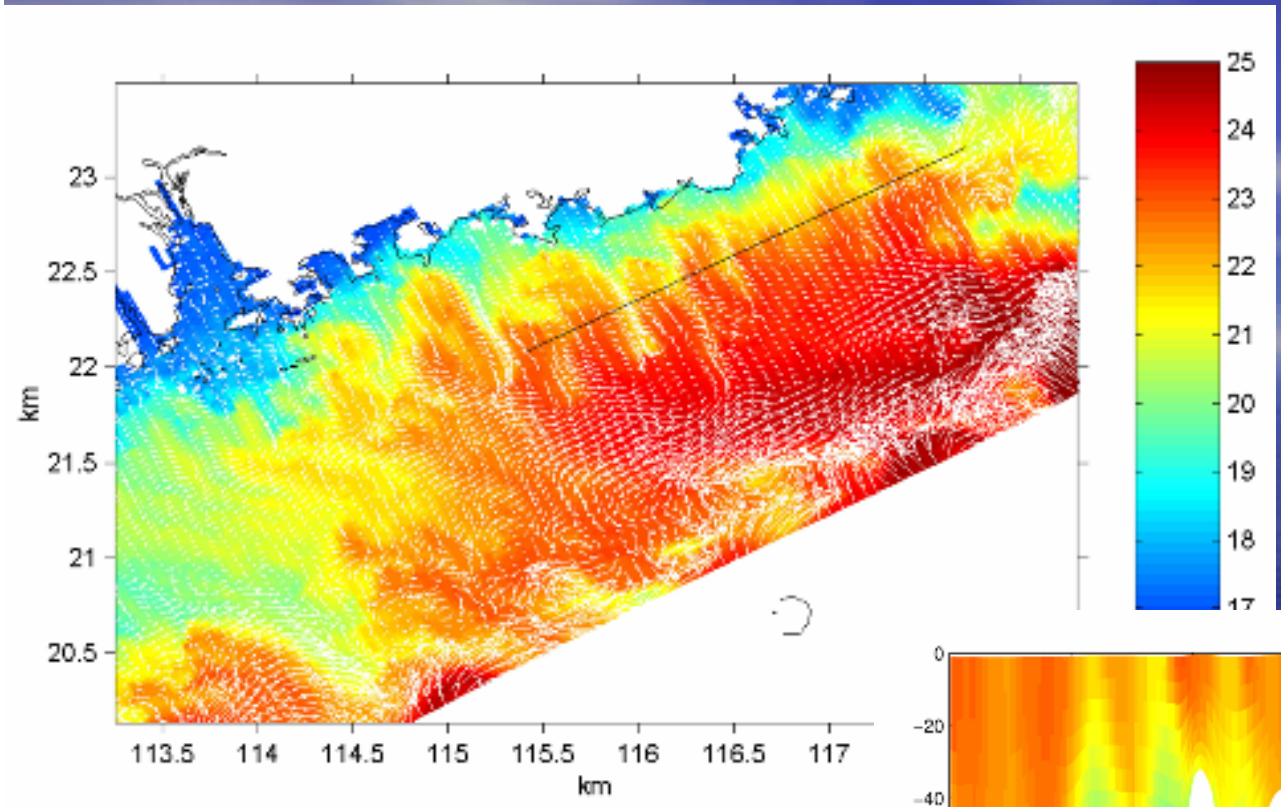
Sensitive experiments

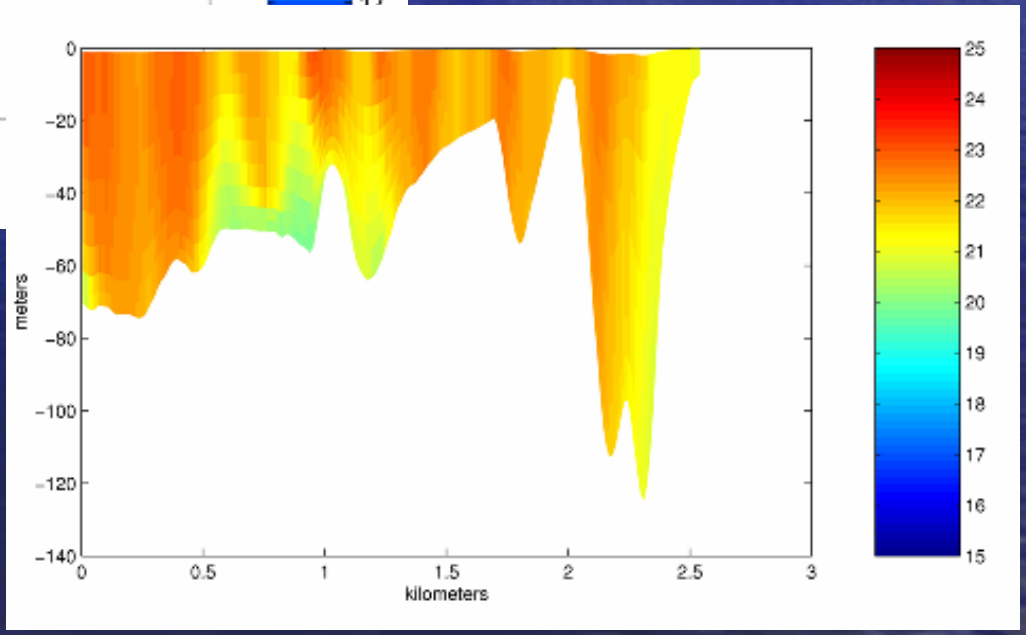
- No wind

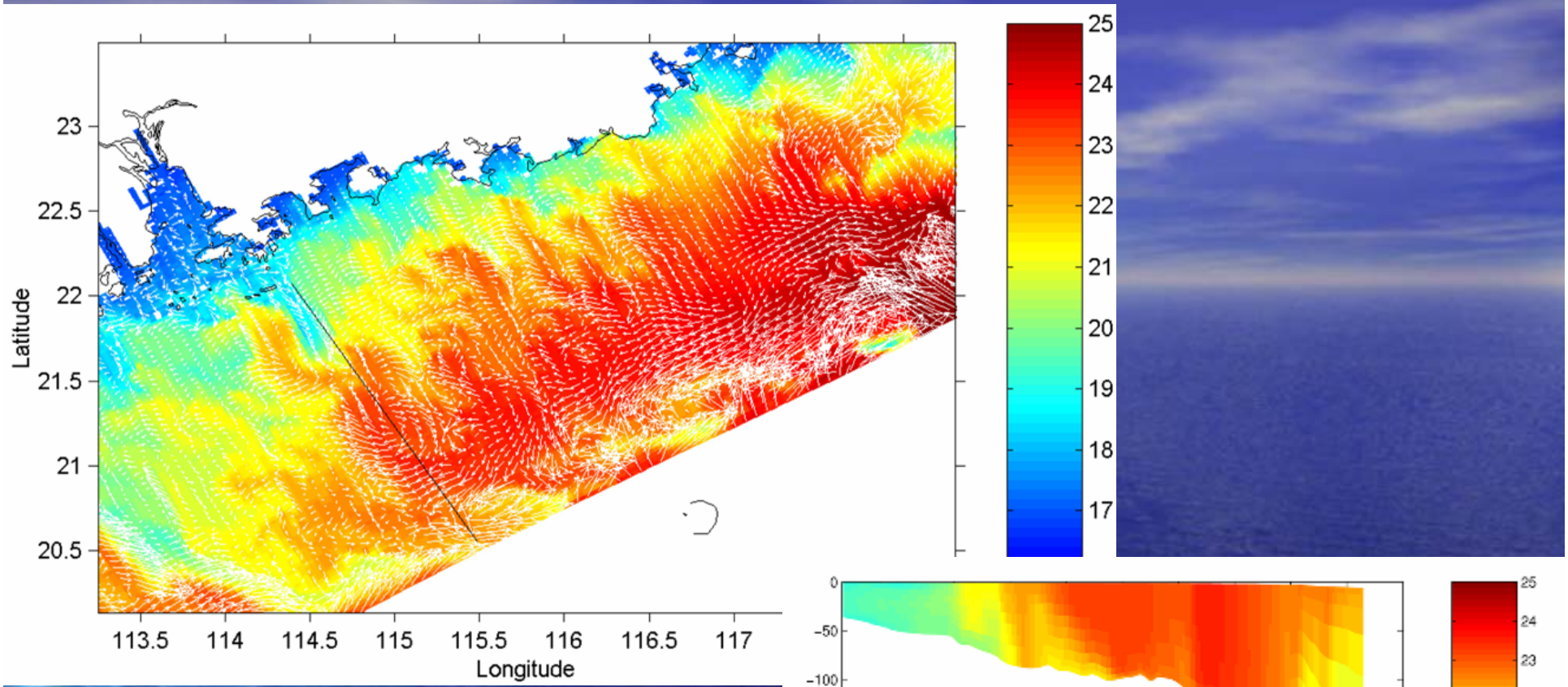
  the eddies will generate in 70 days, but most of them are the warm core rings; the filaments are wider in the bottom

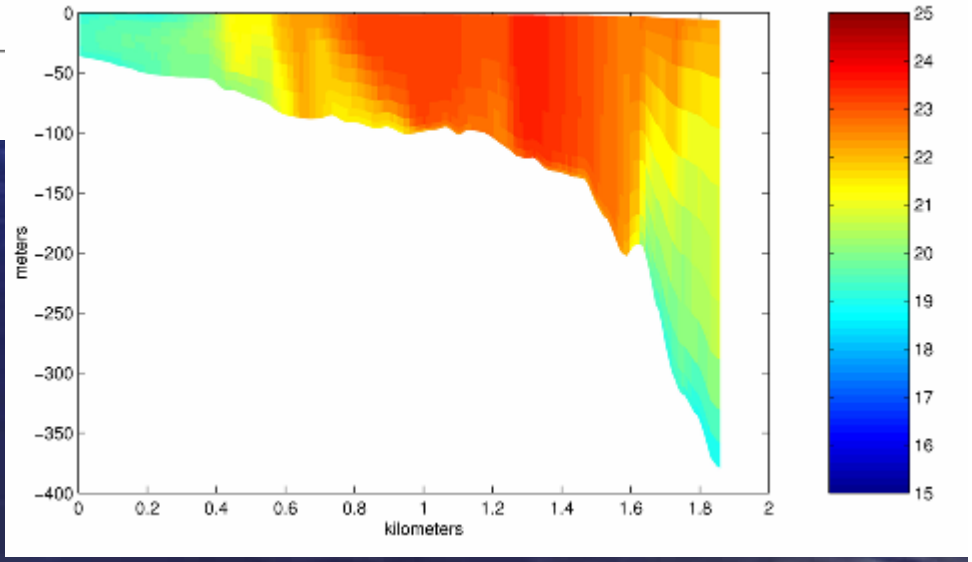
- Changeable wind

  No eddy was found in this experiment, we will find some other way to have the experiment


23
22.5
22
21.5
21
20.5
km
113.5
114
114.5
115
115.5
116
116.5
117
km
25
24
23
22
21
20
19
18


0
-20
-40
-60
-80
-100
-120
-140
meters
0
0.5
1
1.5
2
2.5
3
kilometers
25
24
23
22
21
20
19
18
17
16
15


Latitude
23
22.5
22
21.5
21
20.5
113.5
114
114.5
115
115.5
116
116.5
117
Longitude
25
24
23
22
21
20
19
18
17


meters
0
-50
-100
-150
-200
-250
-300
-350
-400
0
0.2
0.4
0.6
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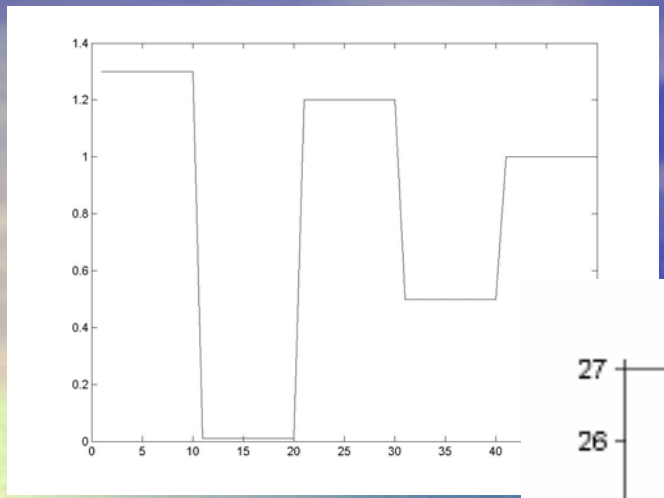
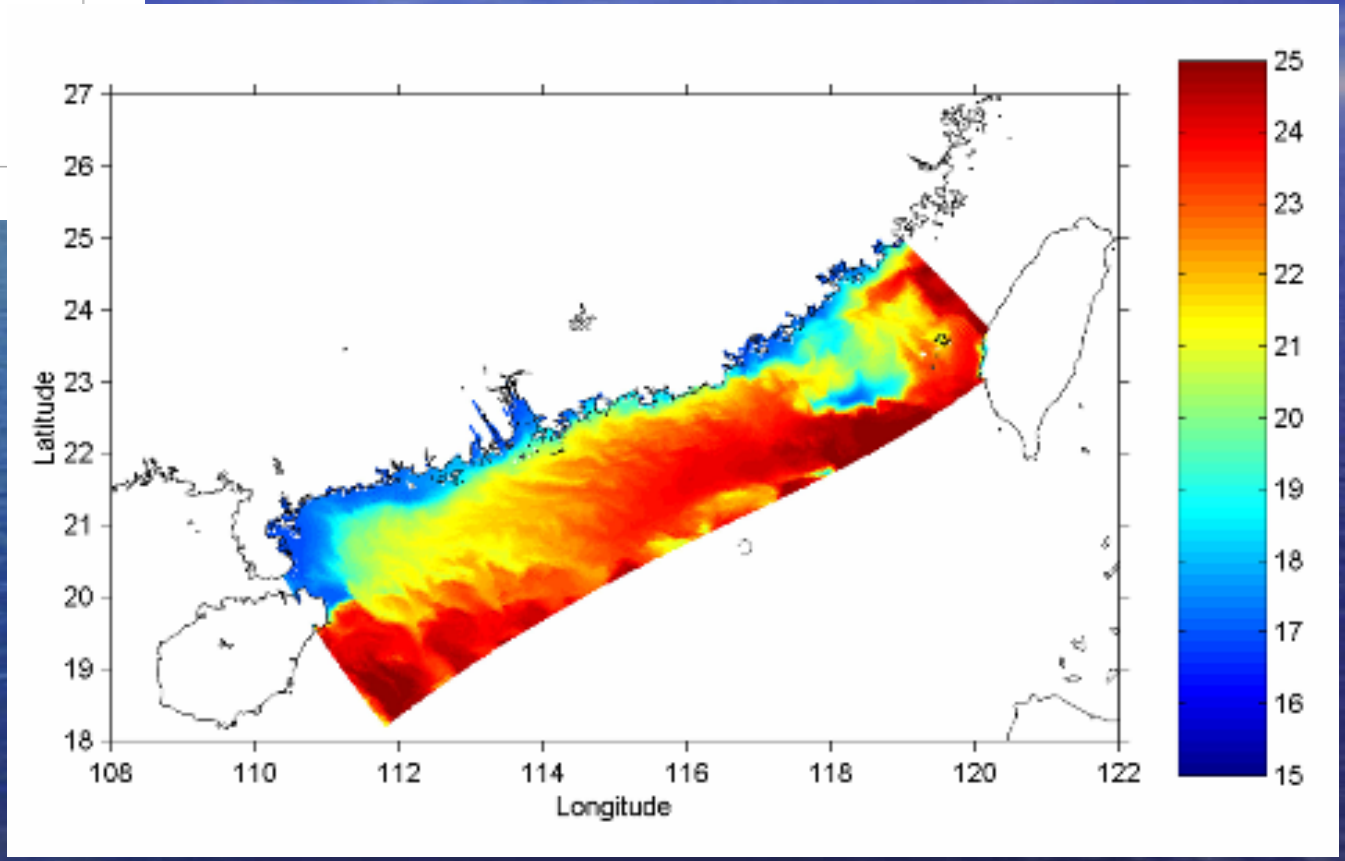
24
23
22
21
20
19
18
17
16
15





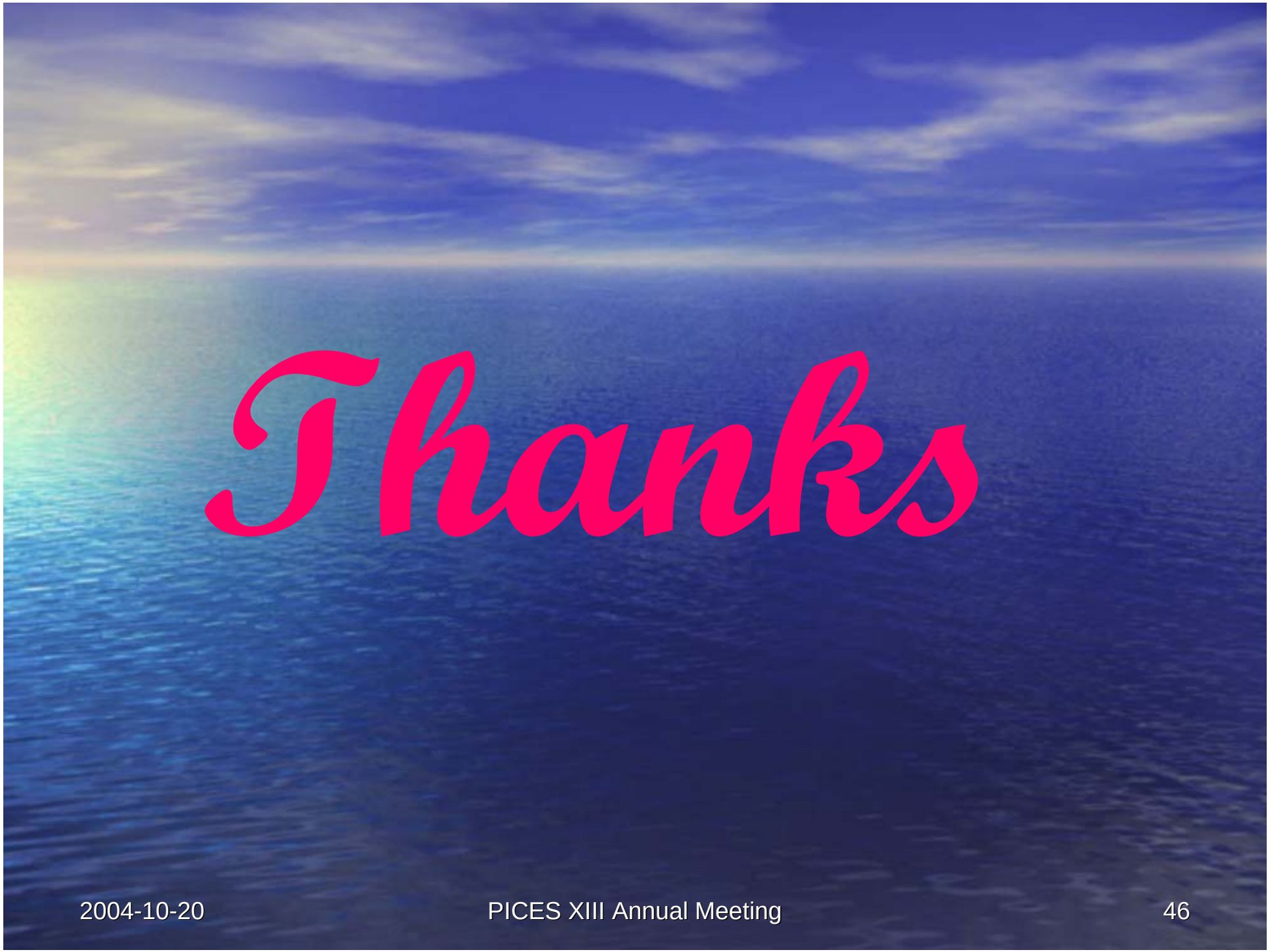
In the idealized variety wind no eddy was found

Conclusion and prospect

- The model successfully reproduce the front dynamics and the characters of the temperature, salinity, current.
- We concluded that the cross-front exchange is large under the up-layer(20m), especially in the strong wind. So the changeable wind in the winter maybe devote more to the offshore transportation.
- In the surface, the filaments often appear, and they are the main characters of the cross-front transport in this area. Although the vortex can carry more water offshore, the survey of it is very difficult and need us to do more to find the mechanisms.

Future work

- This work is the base of the future work in this area, the chemical, optic and biological work was also included in this project.
- The observation will continue in this area, more information can be got in the future


Thanks