国家海洋环境预报中心
NATIONAL MARINE ENVIRONMENTAL FORECASTING CENTER
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Preliminarily Study of MLD and SCML in the SCS using 3-D physical-biogeochemical model

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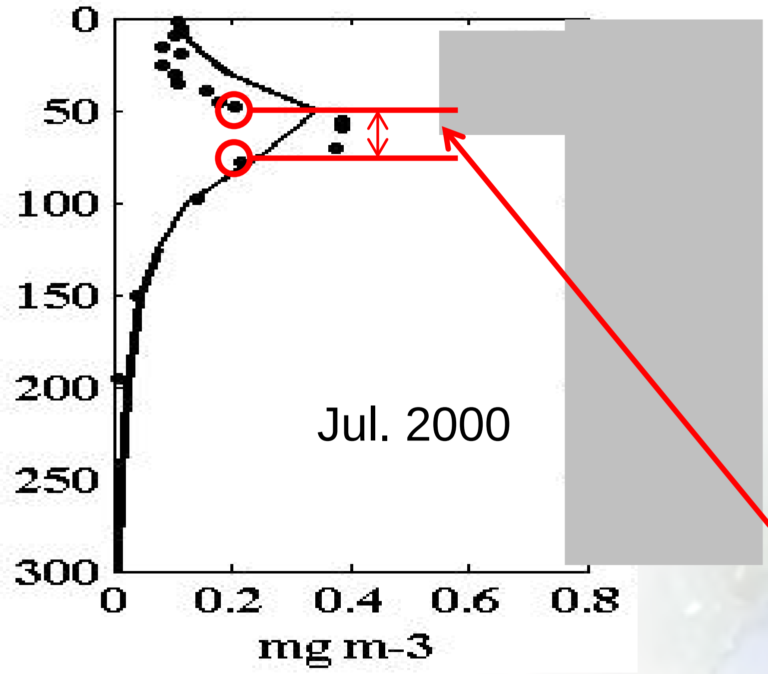
Outline

- Brief Introduction
- Model Configuration
- Model results and Discussion
- Conclusion

Brief Introduction

- **SCML**: Subsurface Chlorophyll Maximum Layer, including three characterization factors which are Depth, Strength and thickness.
- Beckmann and Hense (2007) defines these three characterization factors from the dynamic aspect.



Example: Chlorophyll-a at SEAST

Depth: the water depth of the maximum chlorophyll concentration occurring at, which is also the maximum biomass of zooplankton at. Hence, the factor of depth could provide information of fishery;

Strength: the maximum concentration of subsurface chlorophyll, or the vertical integration value at SCML. Beckmann and Hense (2007) thought it's more reasonable using the integration value to study the SCML.

Thickness: the range of SCML. Simplest definition: the range between the two positions located at the two sides of SCML with the same concentration value (or a constant percentage of SCM, like 50%)

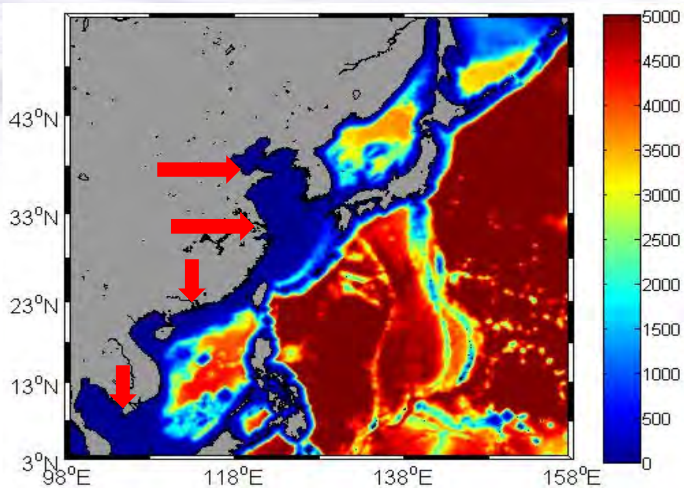
Position			Longitude and Latitude	Thickness (m)	Strength (mg/m3)	Depth (m)	Reference
Ocean	Tropic Sub-tropic	West Pacific	17-20˚S 165˚E	---	0.25-0.3	80-110	Radenac and Rodier, 1996
			6-10˚N 165˚E	---	0.15-0.25	80-120	
		The South China Sea	12-19.5˚N 111-118˚E	---	0.1-0.6	50-100	Chen et al., 1989
		ALOHA Station at east Pacific	22.75˚N 158˚W	56** 102**	0.21	90-130	Hense and Beckmann, 2008
		Sub-tropic region at northeast of Atlantic	20-35˚N 5-30˚S	59	0.31	80-110	Perez et al., 2006
			10-43˚E		19*		
	Temperate zone	The Sargasso Sea	30-35˚N 61˚W	---	0.25-0.3	100	Varela et al., 1992
		North pacific	45.17˚N 136.93˚W	60	0.12	55-65	Anderson, 1969
	Polar region	Southern Ocean	60-62.5˚S 54-62.5˚W	50	0.62	75	Holm-Hansen and Hewes, 2004
Coastal water		Eastern coastal water of Indian Ocean	21-30˚S 111-115˚E	---	0.4-0.9	85-110	Hanson et al., 2007
		Bay of Bengal	21-43˚N 88˚E	---	0.1-0.2	65-100	Murty et al., 2000
			11.5˚N 81-92˚E			50-100	
		The East China Sea	24.5-26.5˚N 120-123.5˚E	---	0.5-0.8	30-50	Gong et al., 2000
		South of Yellow Sea	32.7-37˚N 119-122.5˚E	---	>2	10-20	Fu et al., 2009
			122.5-124˚E		<0.5	30	
		English Sea	49˚N 6˚W	5	26	30	Sharples et al., 2001
		Gulf of Finland	59.7˚N 23.6˚E	5-6	1.6-2.5	30-35	Pefros-Alio et al., 1999
		The Great Wall Bay and is adjacent sea areas at Antarctic	62˚12’-62˚14’S 58˚56’-58˚58’W	---	4.1-7.8*	5-10	Li. 2004

---: lack of data; * integrate concentration value at SCML; **Euler Method(56m) and Lagrange Method (102m).

Gong 2012.

Model Configuration

Physical Model: ROMS



- **Model Grid**: Rectangle Orthogonality
- **Topography**: GEBCO 0.5’×0.5’

Establishment

Region：98°E ~ 158°E，3°N ~ 52°N；

Resolution: 1/12° ×1/12° ×22sigma levels;

Open Boundary：South, east and north

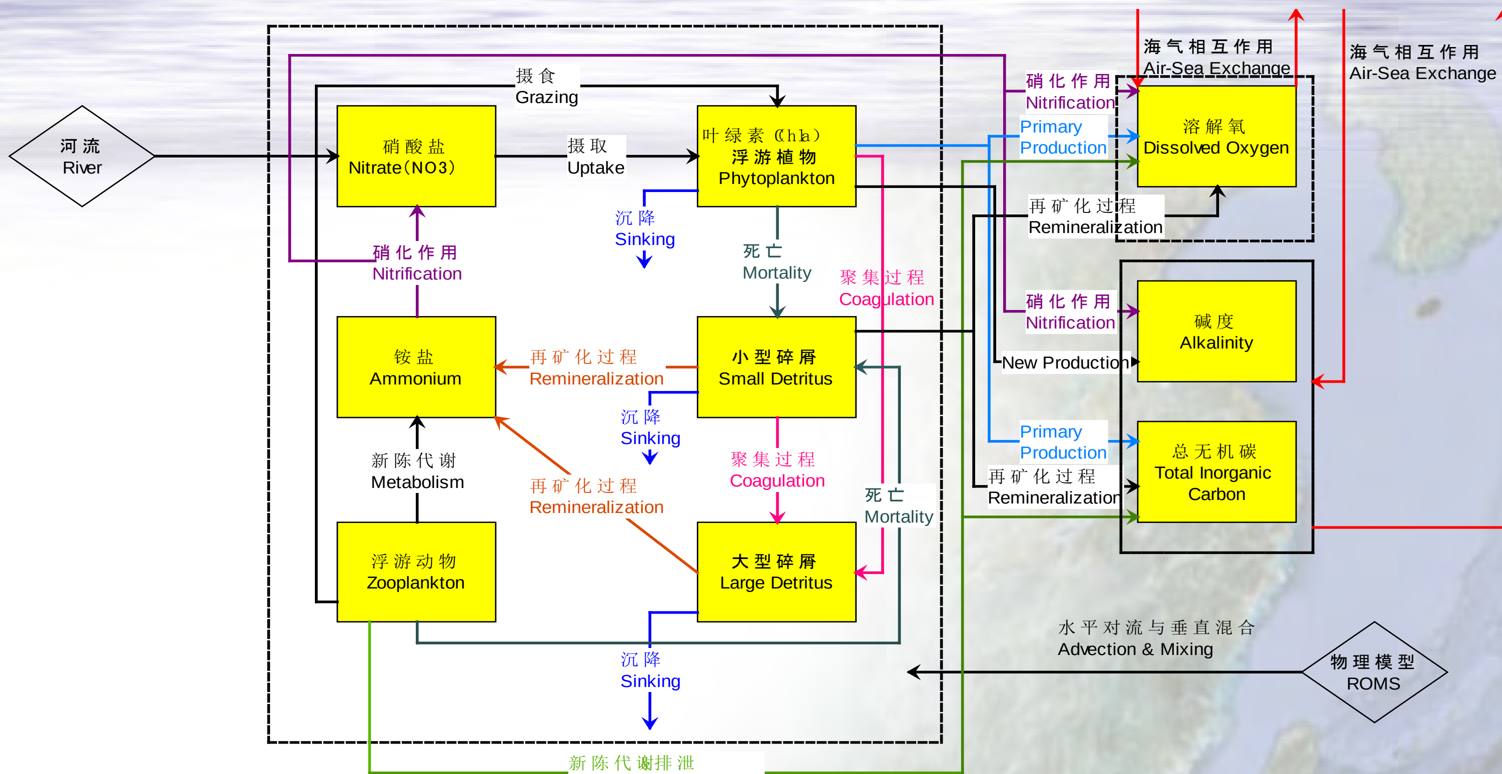
	Yellow River		Chang Jiang		Zhu Jiang		Mekong River	
	Temp	runoff	Temp	runoff	Temp	runoff	Temp	runoff
1	1.1	2700	6.8	9800	19	4150	26	7040
2	2.2	2000	5.4	11626	19	4050	26	4190
3	6.9	6000	7.3	18201	20	4100	27	3020
4	13.6	3300	11.7	16638	23	6650	29	2680
5	19.3	2600	17.9	19601	25	15750	30	3690
6	23.8	2200	23.1	30382	28	16850	29	10400
7	25.9	3500	25.1	42003	29	19250	29	17300
8	26.0	5200	27.0	47603	29	16900	28	26000
9	20.8	2100	25.2	40509	28	10900	29	31000
10	15.1	2800	22.1	25902	26	8400	29	29900
11	8.9	3800	17.0	15191	23	6250	28	20500
12	1.7	2000	11.3	11201	20	4900	27	12100

- Boundary Data
- Climatology Data

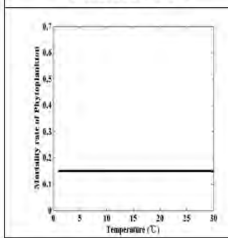
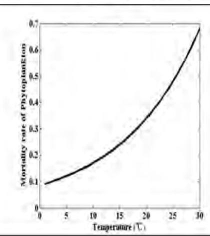
SODA（0.5º×0.5º×40）

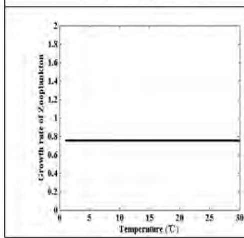
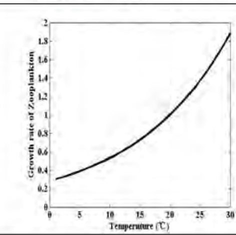
- Forcing Data: COADS and NCEP2 Reanalysis
- Initial Data: WOA09

Ecosystem Model Establishment



Model Optimization

Mortality rate of phytoplankton	
Old Model	Modified Model
Mp=Constant	Mp=Mor*exp（Kmor*T）
Constant=0.15	Mor=0.0585; KMor=0.0693
	

Growth rate of Zooplankton	
Old Model	Modified Model
Gmax=Constant	$Gmax=\mu_{20}*q_{10}^{(T-20)/10}$
Constant=0.75	$\mu_{20}=1$; $q_{10}=1.8840$
	

Initial Conditions for Ecosystem Model

Variable	Unit	Initiation and Boundary Filed
NO3	mmol N m^{-3}	WOA09 (1°×1°×24)
DO	mmol N m^{-3}	WOA09 (1°×1°×24)
TIC	mmol N m^{-3}	WOA09 (1°×1°×24)
TALK	mmol N m^{-3}	WOA09 (1°×1°×24)
Chlorophyll-a	mg m-3	SeaWiFS (9km)
Phytoplankton	mmol N m^{-3}	Calculated by Chlorophyll-a (rate: 0.5)
Zooplankton	mmol N m^{-3}	Calculated by Chlorophyll-a (rate: 0.5)
Large Detritus(N/C)	mmol N m^{-3}	Calculated by Phytoplankton (rate: 0.35) Gruber et al., 2006
Small Detritus(N/C)	mmol N m^{-3}	Calculated by Phytoplankton (rate: 0.35) Gruber et al., 2006
NH4	mmol N m^{-3}	Constant as 1

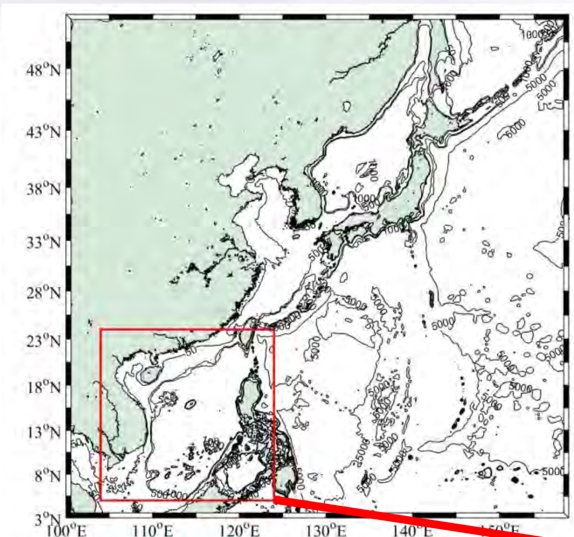
River Input

River Month	Yellow River		Yangtze River		Pearl River		Mei Gong River	
	NO3	NH4	NO3	NH4	NO3	NH4	NO3	NH4
1	22.5	48.2	40.7	10	41.4	0.7	40	0.5
2	25.0	45.8	39.2	12.9	42.9	1.4	40	1
3	30.0	4.2	40	11.4	43.6	1.5	40	1
4	30.0	2.1	42.1	6.4	50	1.6	50	1
5	50.12	0.75	40.7	4.3	58.6	1.52	50	1
6	24.5	3.1	42.9	4.32	57.1	1.4	50	1
7	25.5	2.1	40	6.4	59.3	0.7	50	0.5
8	16.56	8.9	36.4	5	55.7	0.86	50	0.5
9	19.5	0.8	35	7.1	50	1.2	40	1
10	25.0	3.5	37.9	3.6	44.3	1.1	40	1
11	25.3	37	39.2	3.6	44.3	1.2	40	1
12	24.8	15.2	42.1	6.4	42.1	1.2	40	1

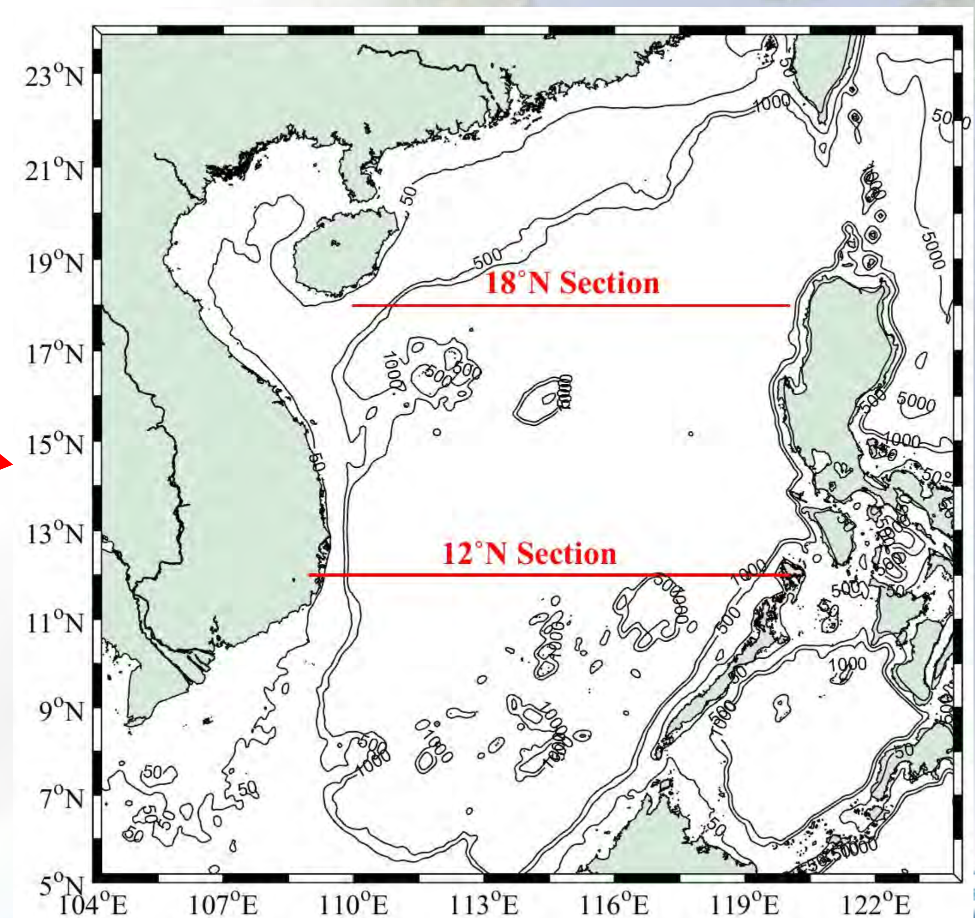
Zhang, 1996; Duan, 1999; Chen et al., 2010; Zhang et al, 2010

The South China Sea

Model Set up:
Upper Forcing: NCEP reanalysis data;
Simulation Time: 2001 to 2012;
Output of time resolution: 5 days

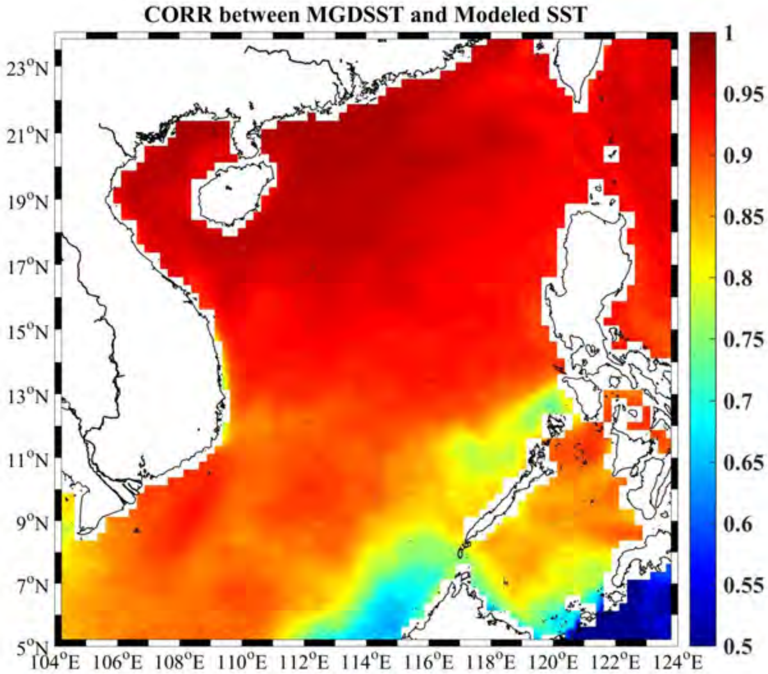


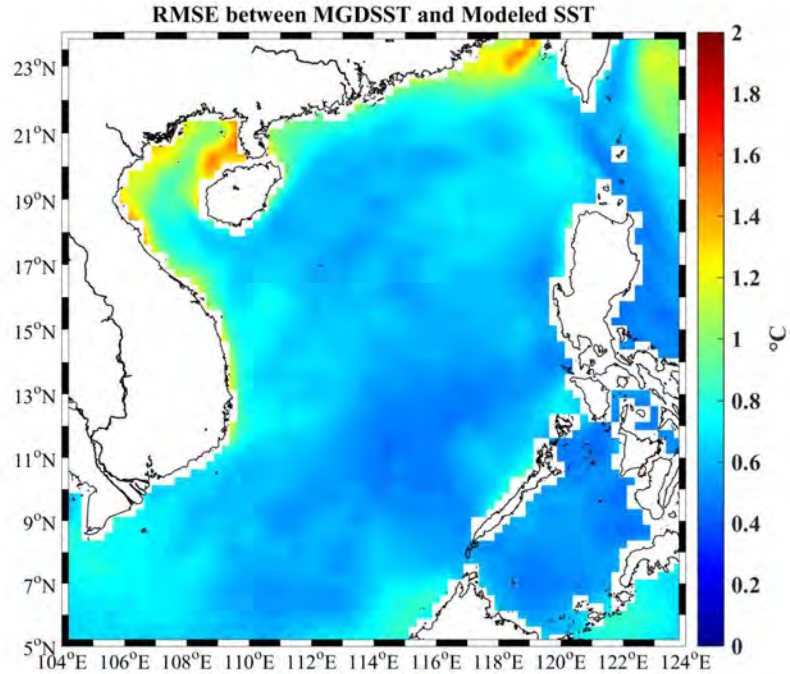
5-24° N; 104-120° E;



Model Validation

Modeled SST and MGDSST DATA



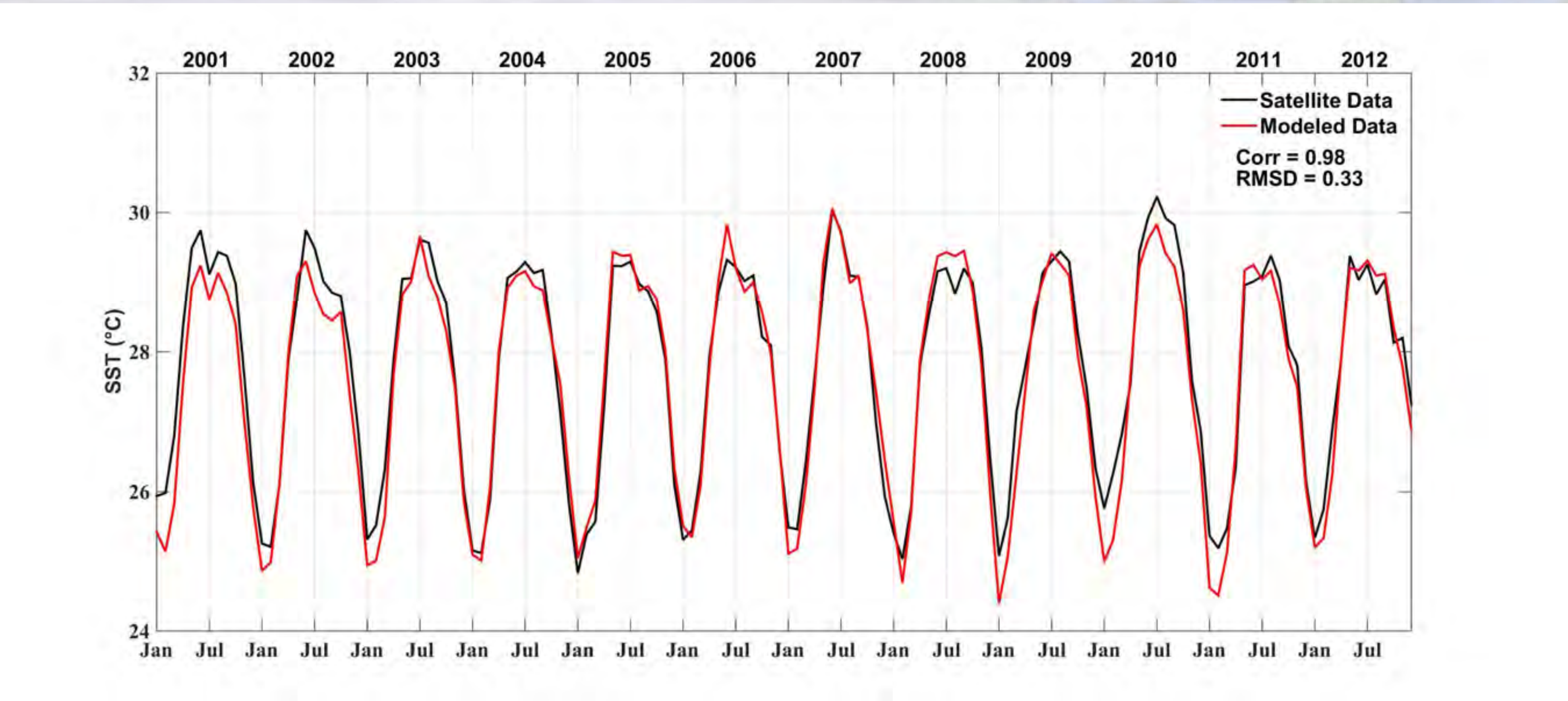


Correlation rate is higher than 0.9 in the north-center of SCS;

RMSE is quite lower in the center of SCS

Model Validation

Modeled SST and MGDSST DATA



Black Line: Satellite SST data from MGDSST;
Red Line: Modeled SST data.
The Correlation rate is 0.98, and RMSD is 0.33, which shows a good performance of physical progress under ROMS model.

Model Validation

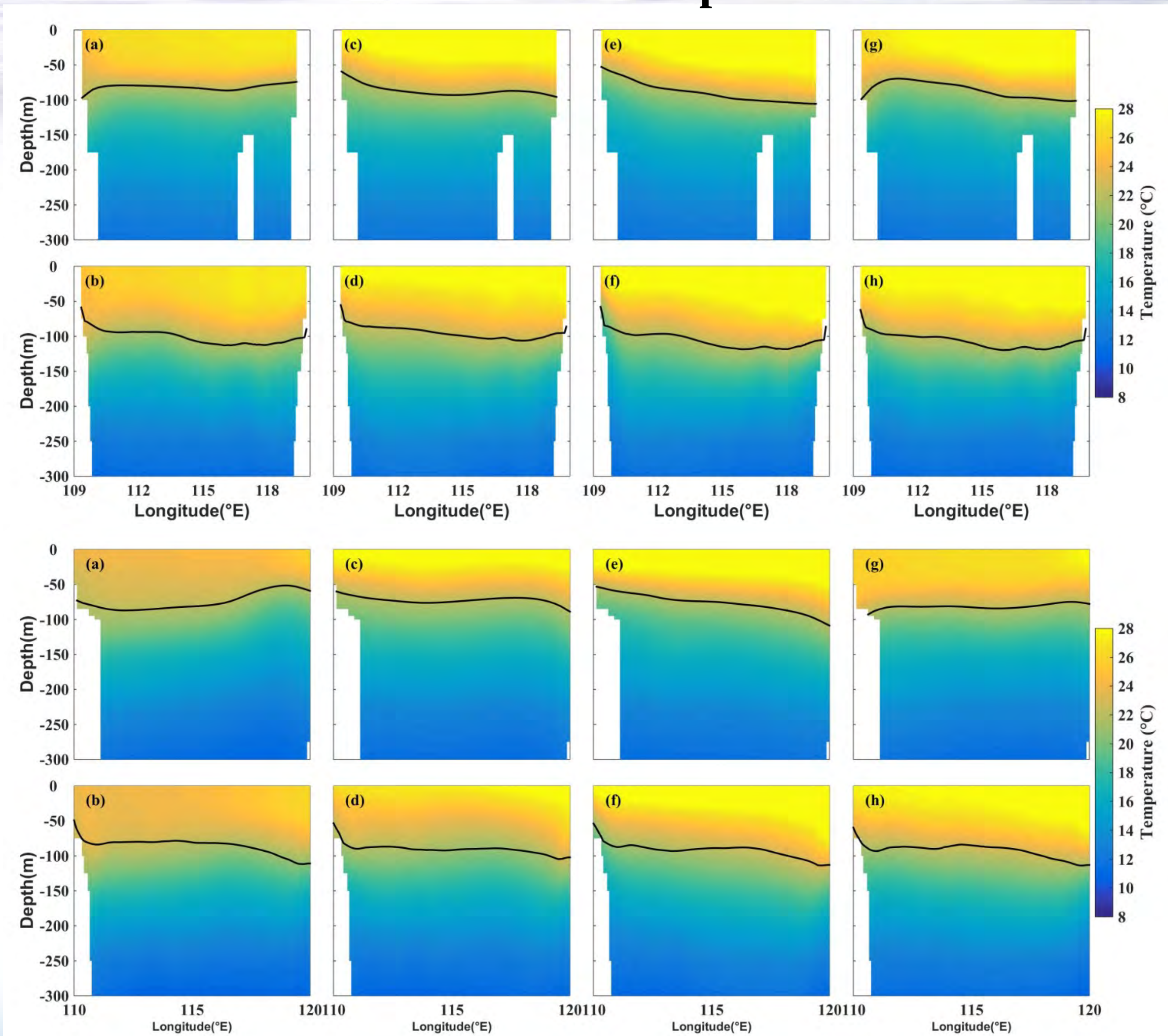
---Temperature

WOA13

ROMS

WOA13

ROMS

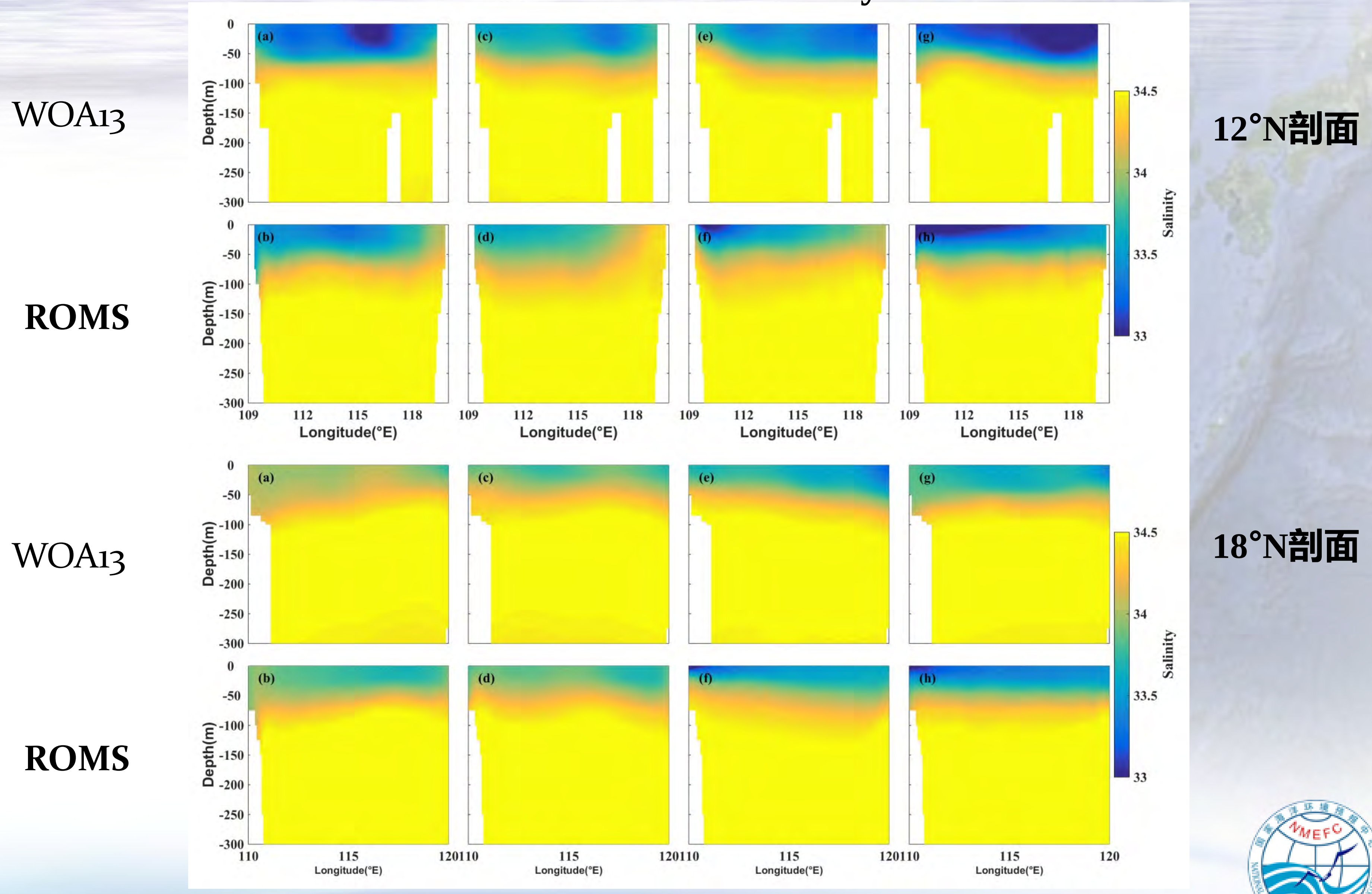


12°N剖面

18°N剖面

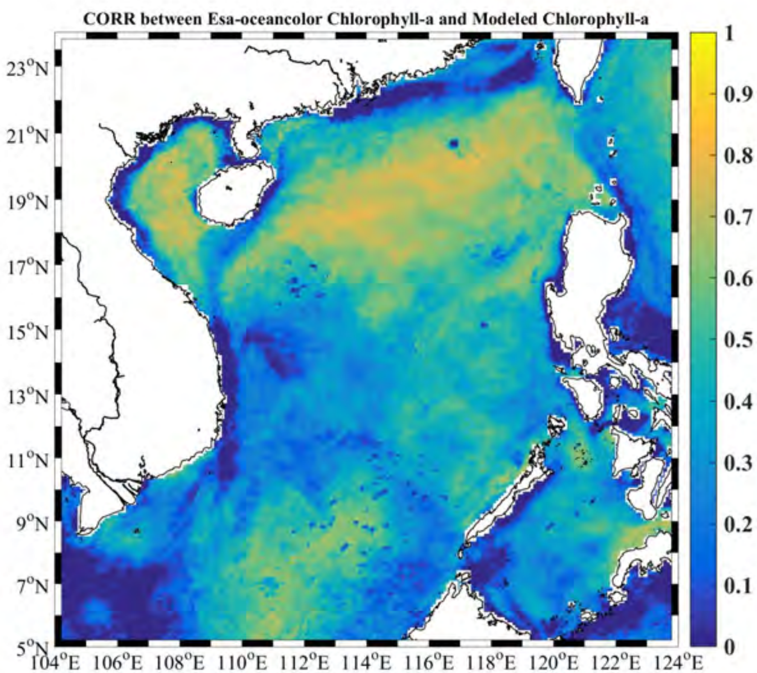
Model Validation

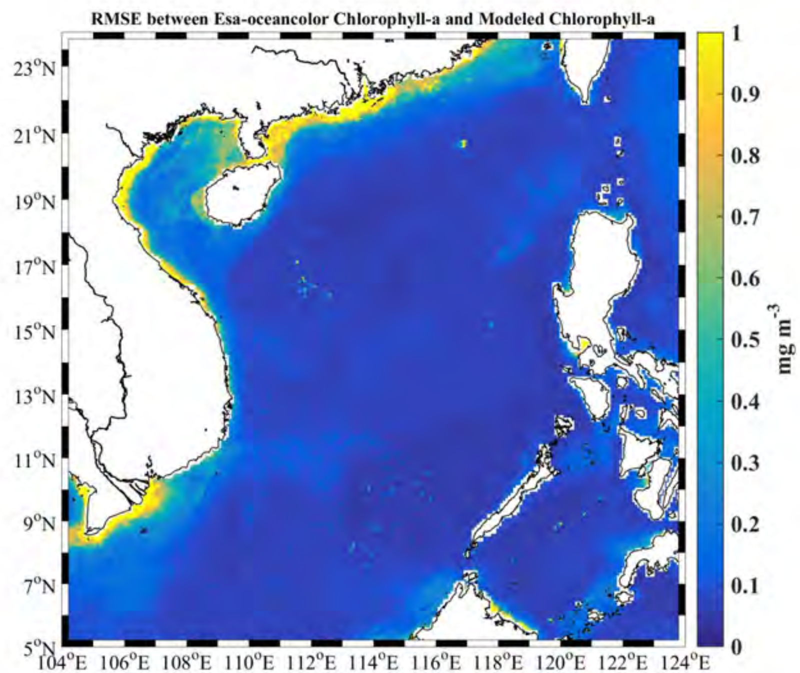
---Salinity



Model Validation

Model Chlorophyll-a and Esa-oceancoulour Chlorophyll-a Data





Correlation rate is higher than 0.9 in the north-center of SCS;
And about 0.7 in the south of SCS

RMSE is quite lower in the center of SCS

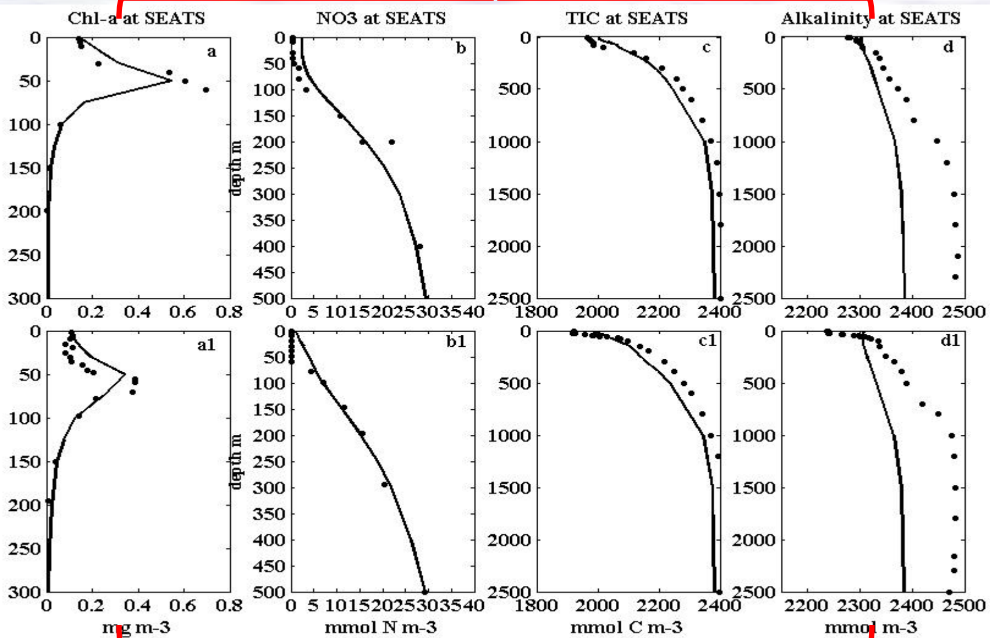
Model Validation

SEATS: 18° N、 116° E

Correlation

1

2000.1



2000.7

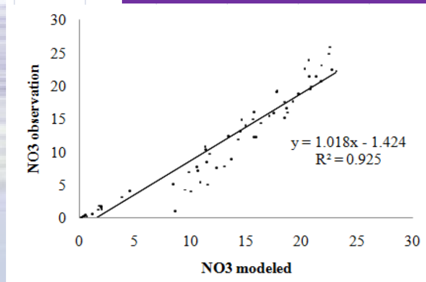
Black circle: Obs
Black line: Model

2

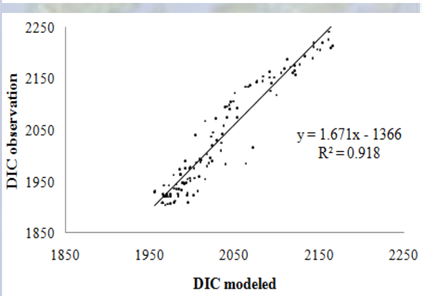
1998.9

2000.7

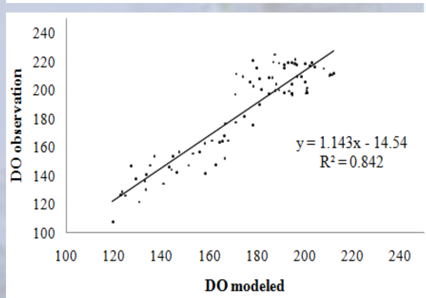
NO3



DIC

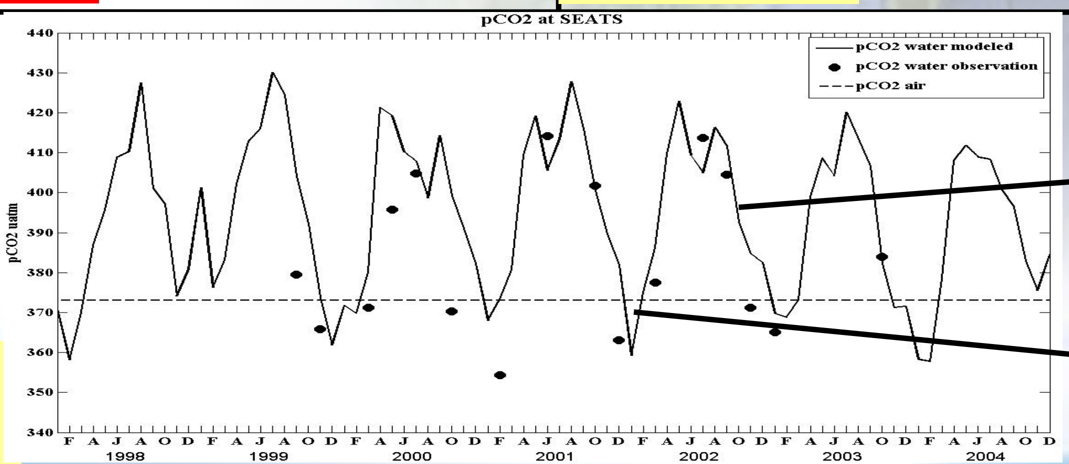


DO



X: Model
Y: Obs

3

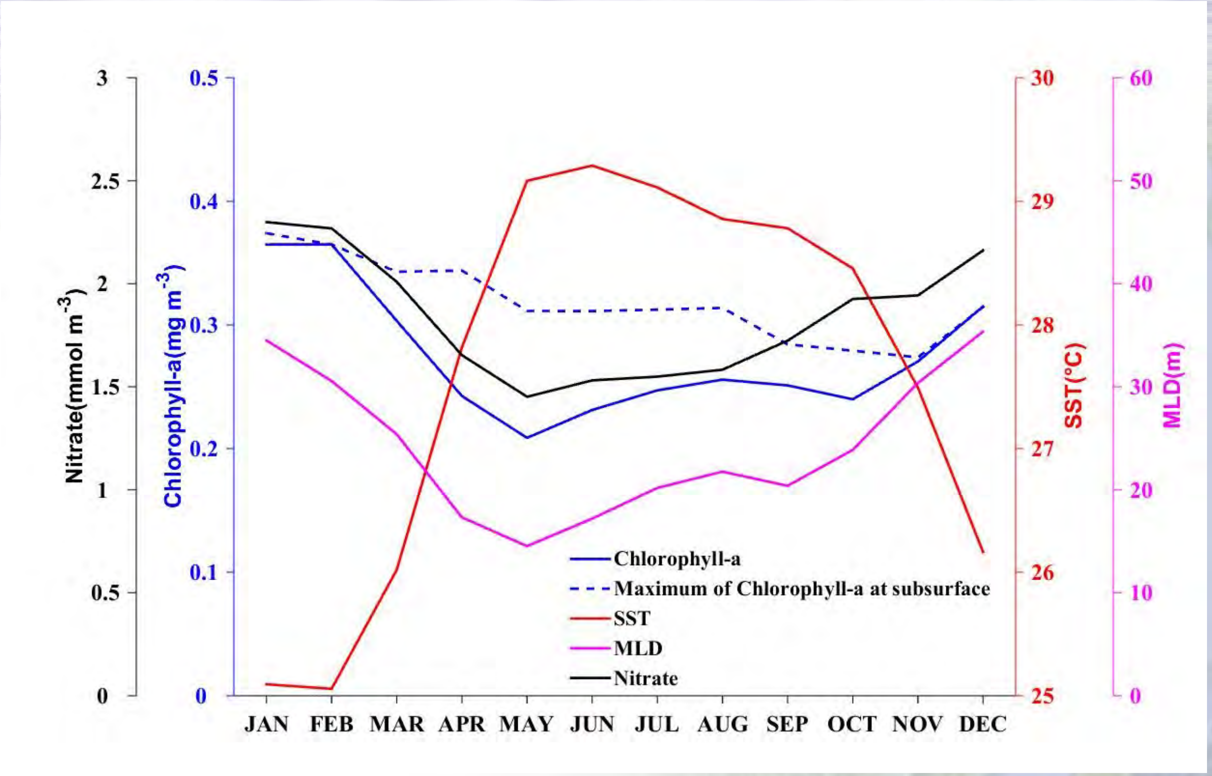


3-10月为源

11-2月为汇

Black circle: Obs from 1999-2003
Black line： model from 1998-2004
Black dotted line: air CO2 373μatm

Seasonal Variation of Modeled SST/Chl-a/SCMs/Nitrate/MLD



SST performs a complex changeable characteristic with a small amplitude from 25 to 29.2˚C

The surface chlorophyll-a over the entire SCS reveals a strong seasonal cycle, double-peak characteristic, with the highest concentration at winter and a following value at late summer.

The Nitrate concentration reaches the minimum value at spring due to the consumption by the phytoplankton at winter, and then has a supplement at the following months.

Seasonal and Spatial Variation of Modeled Chlorophyll-a

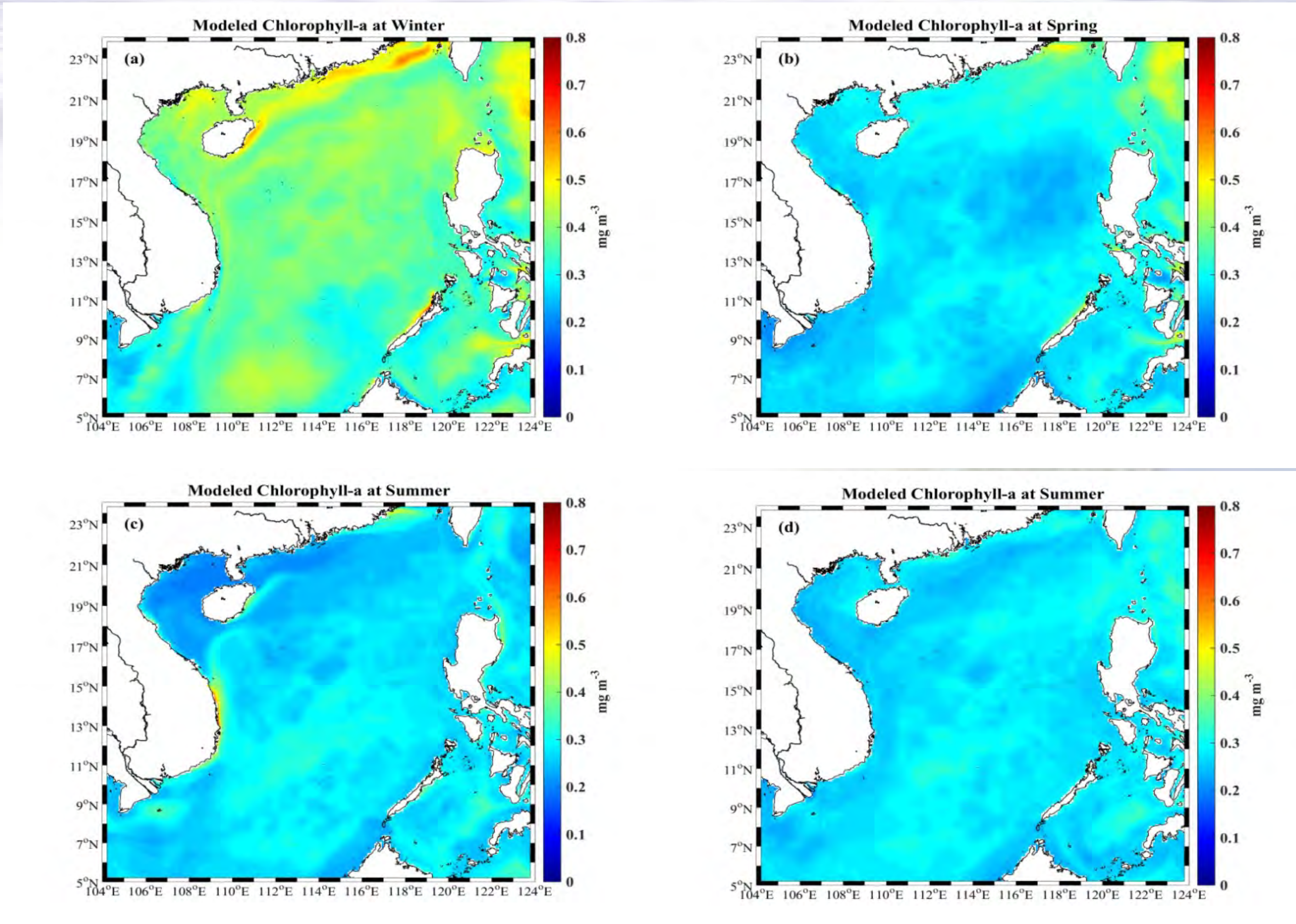


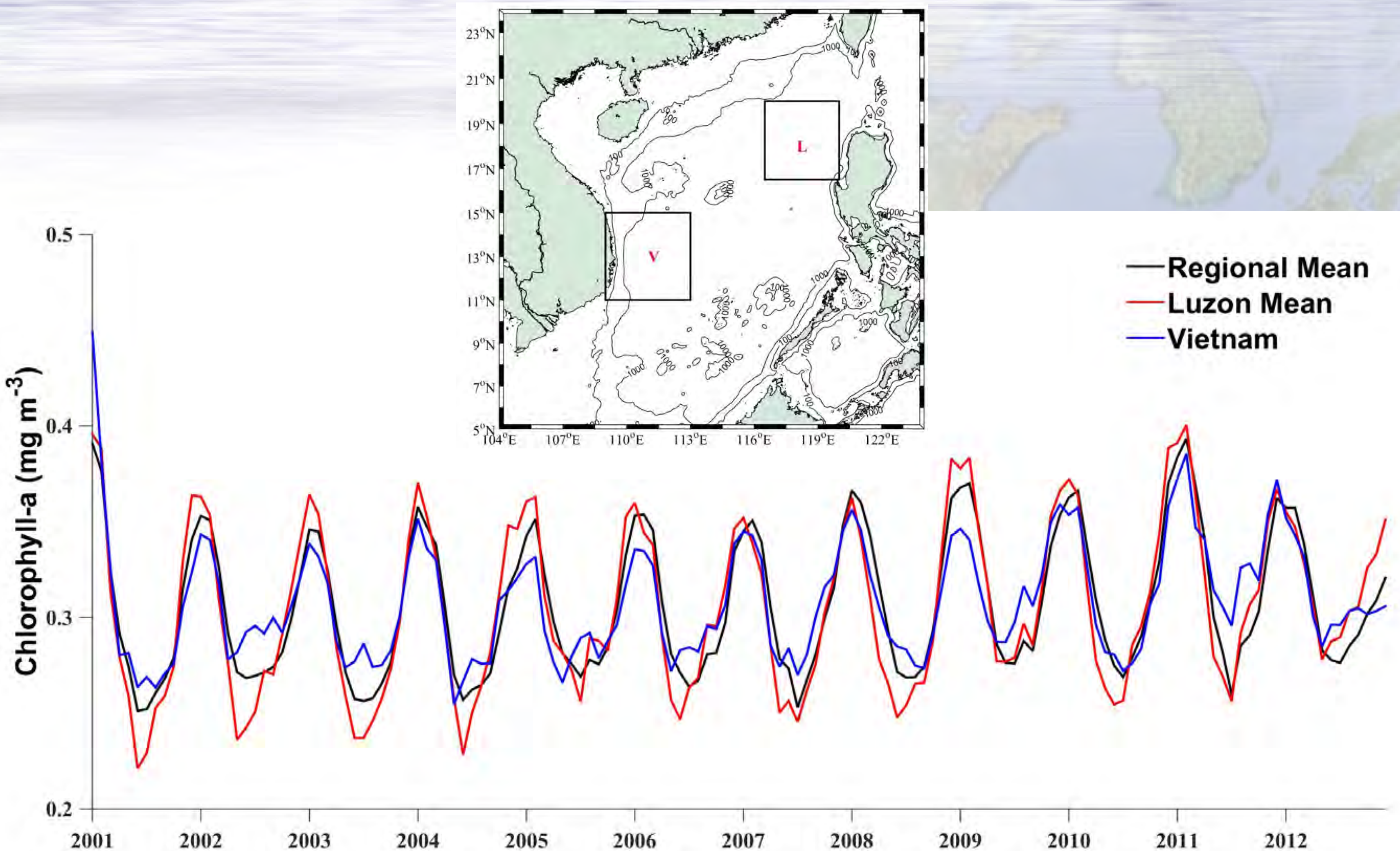
Fig.a : Chlorophyll-a distribution at winter, showing the maximum concentration value during all the year. Due to influence of upwelling under Northeast Monsoon, the chlorophyll-a concentration at west coastal line of Philippine and Palawan Island exists an obvious high value compared with the east coastal line of Vietnam.

Fig.b: Due to the nutrients absorbed by phytoplankton at winter, the chlorophyll concentration reaches the lowest value in the all year.

Fig.c: In the east of Vietnam, due the upwelling influence, there exists a high concentration of chlorophyll-a, about 0.5 mg m3. For all the region, the chlorophyll-a reaches at a secondary high value followed by winter.

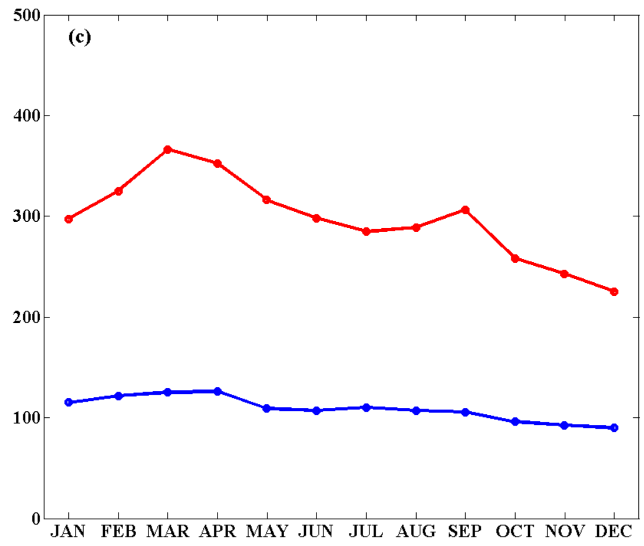
Fig. d, the concentration of chlorophyll-a is lower than that at summer, but higher than at spring.

Long-term Variation of Modeled Chlorophyll-a



Black line: the regional-mean concentration of Chlorophyll-a;
Red line: the Luzon-mean concentration of Chlorophyll-a, taking an dominant role at winter;
Blue line: the Vietnam-mean concentration of Chlorophyll-a, taking an dominant role at summer.

Seasonal Variation of Modeled Primary Production and New Production

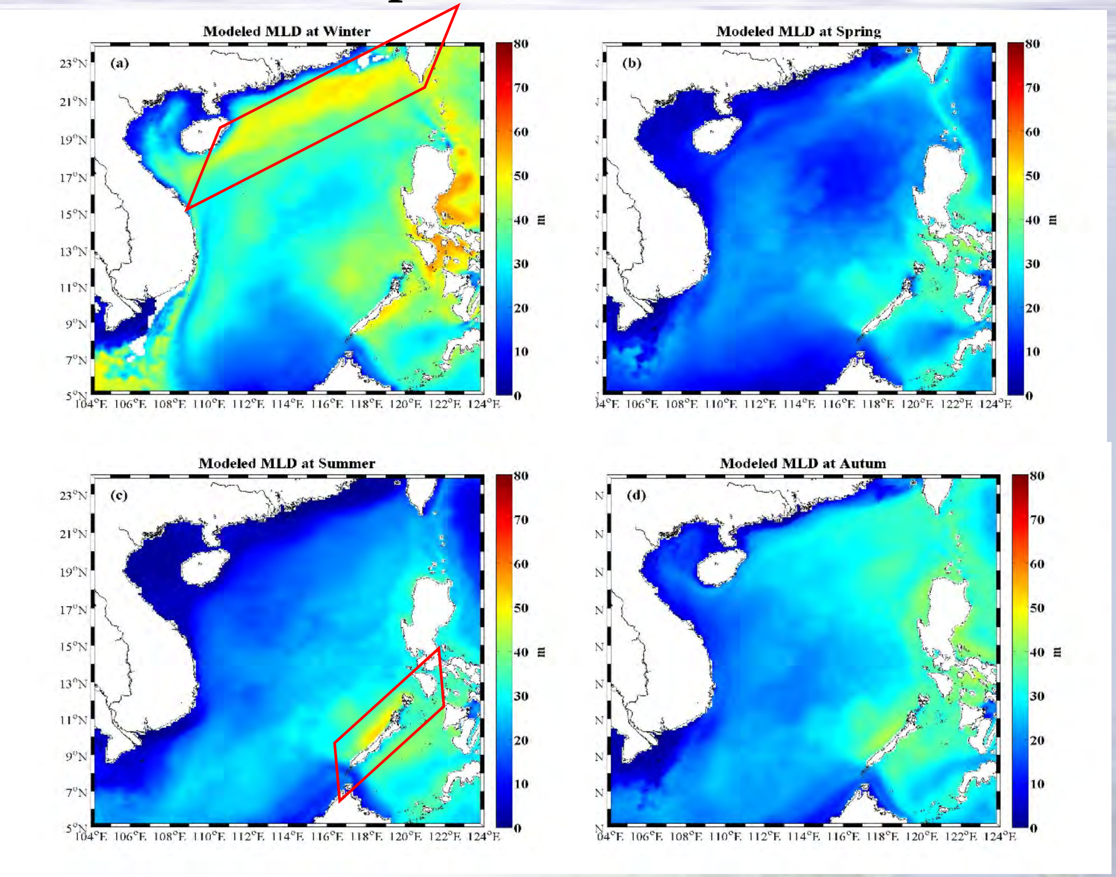


Red Line: Primary Production
Blue Line: New Production

Annual-mean results in SCS	
Primary Production (mgC/m^2/day)	293
New Production (mgC/m^2/day)	103
f-ratio (NP/PP)	0. 35

f-ratio in SCS is 0.35, similar with results 0.28±0.08(2001.3), 0.32±0.14(2002.10) in north of SCS from Chen (2005):

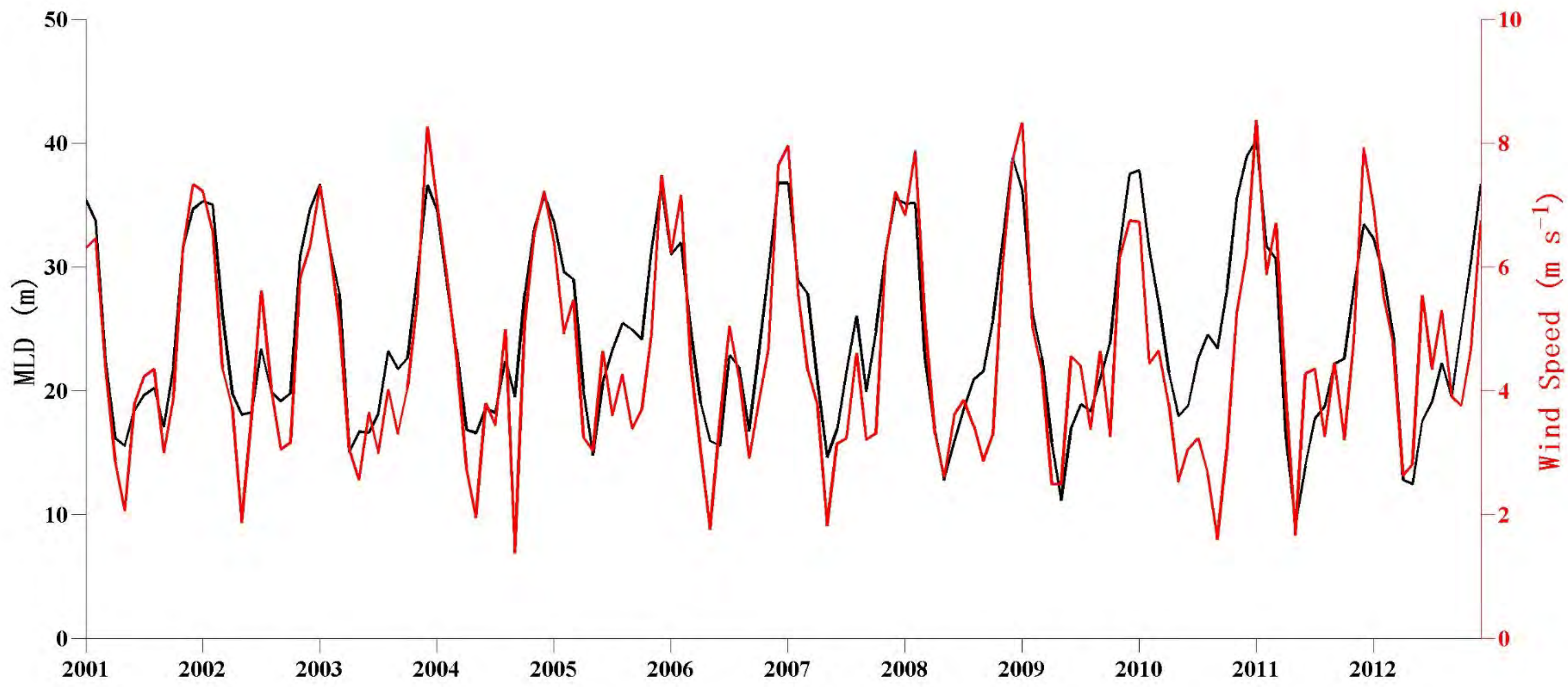
Seasonal and Spatial Variation of Modeled MLD



At winter, due to the influence of northeast monsoon, the maximum MLD is located at northwest region of the SCS, about 50m;
At spring, the MLD at SCS region is quite shallow due to the weak monsoon;
At summer, under the effect of southwest monsoon, the maximum MLD is located at the southeast of the SCS, reaches at 55m;
At autumn, due to the monsoon changing and becoming weaker, the MLD is being weaker, but still deeper than that at spring.

Hence, data analysis indicates that monsoon has an obvious impact on the temporal and spatial features of MLD in the SCS through an adjustment of the current field.

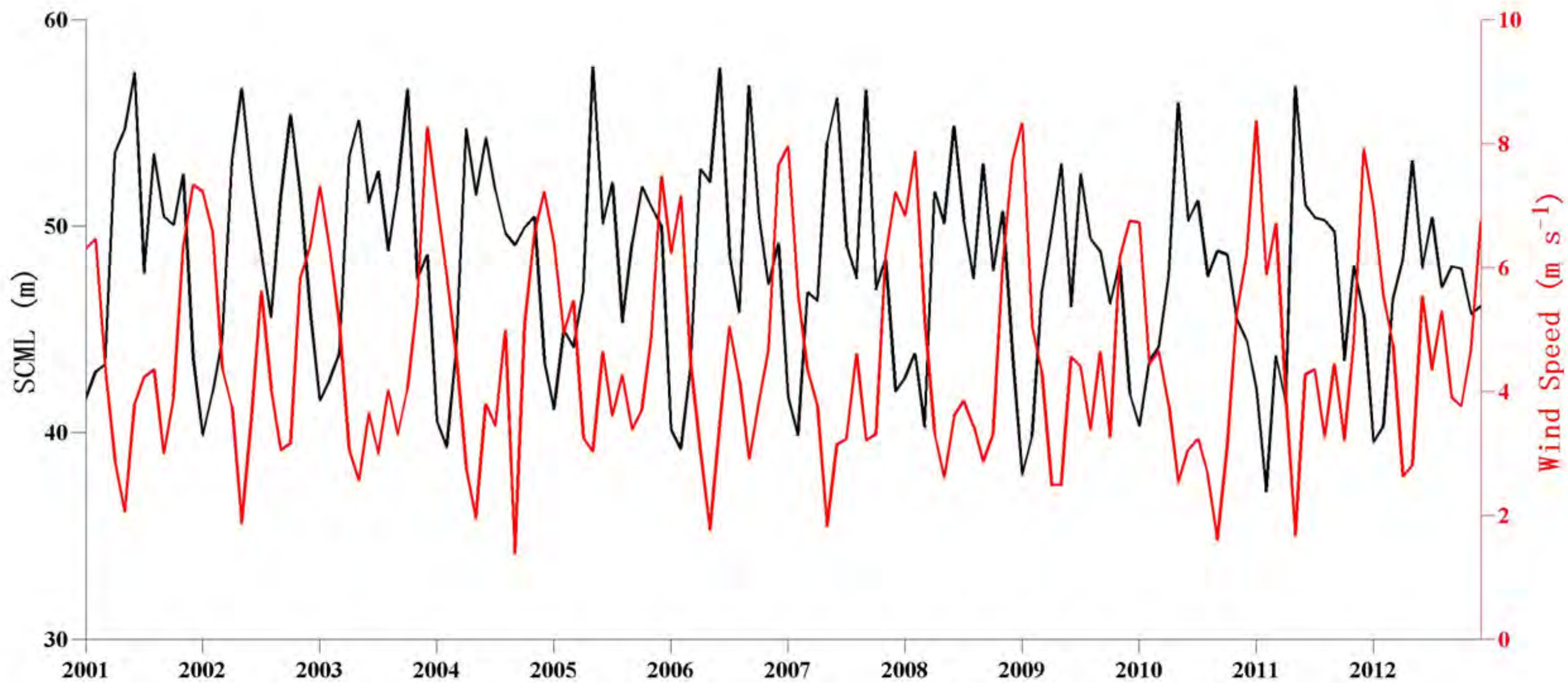
Seasonal Variation of Modeled MLD and Wind



The figure shows the long-term seasonal variation of MLD and wind speed. The black line is MLD, while the red line is wind speed.

The Correlation coefficient between MLD and Wind is 0.87, which shows a positive correlation. The stronger the wind speed, the deeper the MLD.

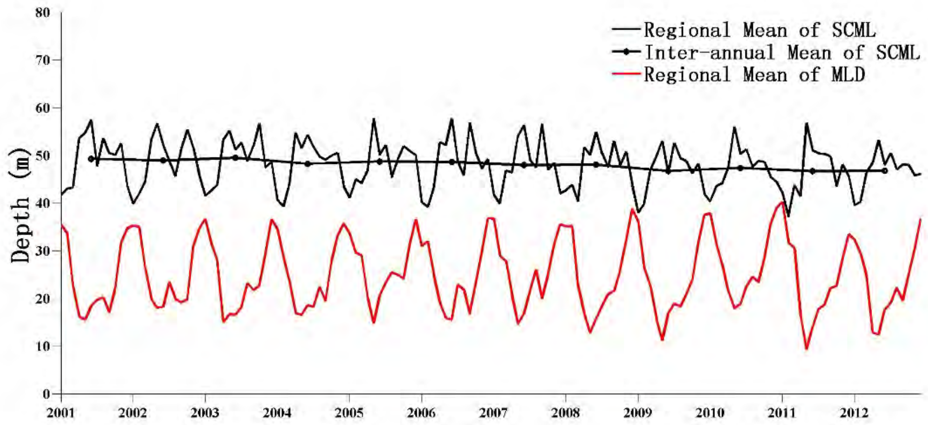
Seasonal and Spatial Variation of Modeled SCML and Wind Speed



The upper figure shows the long-term distribution of SCML and wind speed. The black line is SCM concentration, while the red line is wind speed.

The Correlation coefficient between SCM and Wind is -0.66, which shows a negative correlation. The stronger the wind speed, the weaker the SCML.

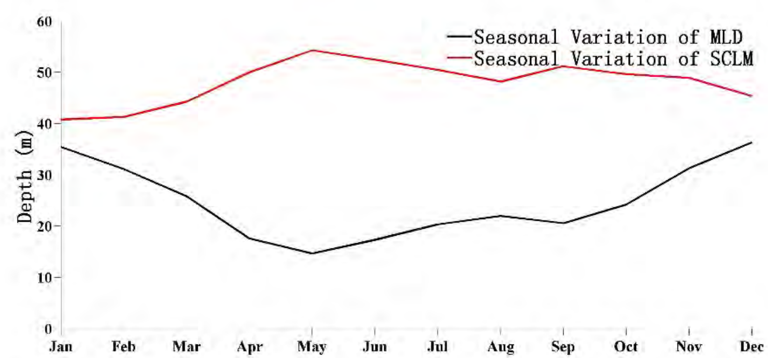
Long-term Variation of Modeled SCML



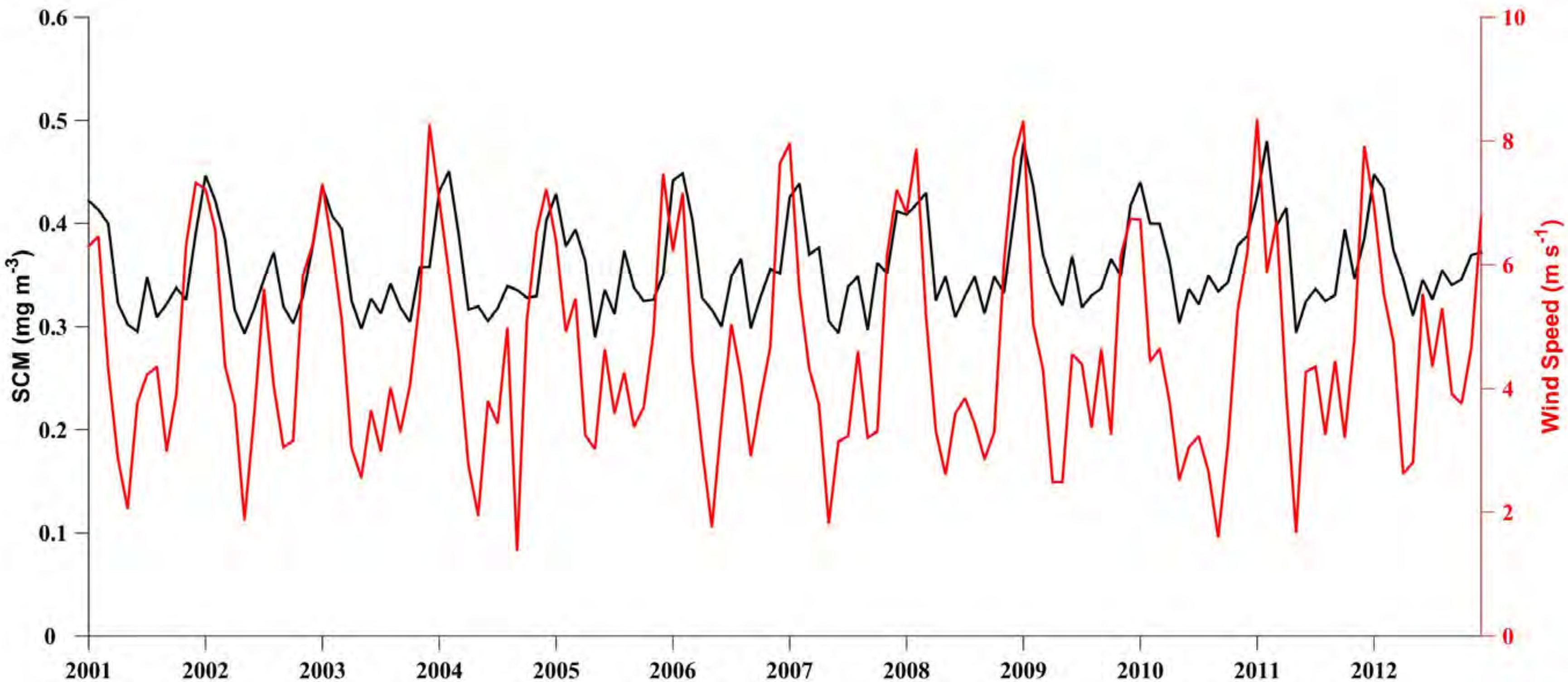
Black line: the regional-mean of SCML;
Circle Black line: inter-annual mean of MLD in the whole region;
Red line: the regional-mean of MLD;
The Correlation coefficient between SCML and MLD is -0.68, which shows a negative correlation.

Black line: the Seasonal Variation of MLD;
Red line: the Seasonal Variation of SCML;

Through the whole year, both of the MLD and SCML performs a double-peak distribution characteristic, one is at May, while the another is at Sep.



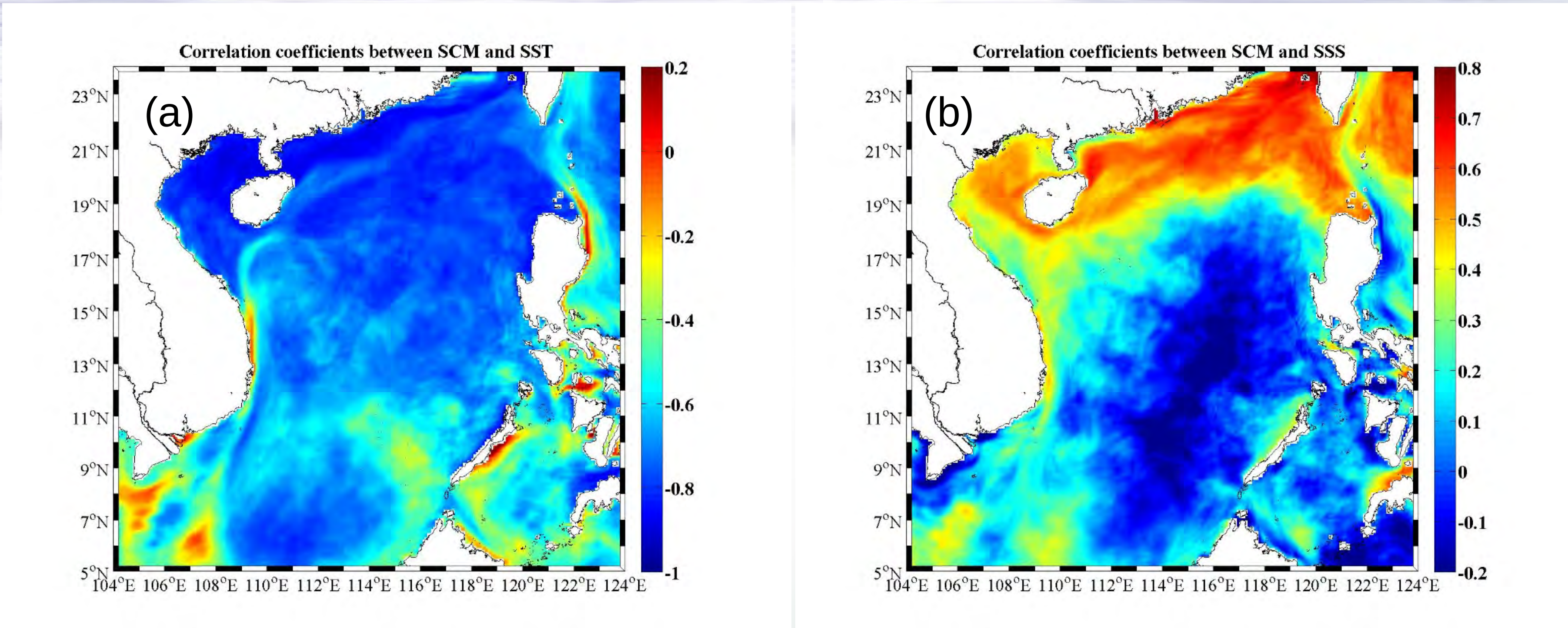
Seasonal and Spatial Variation of Modeled SCM and Wind Speed



The upper figure shows the long-term distribution of SCM and wind speed. The black line is SCM concentration, while the red line is wind speed.

The Correlation coefficient between SCM and Wind is 0.70, which shows a positive correlation. Stronger wind at winter results in stronger mixing and more nutrients supplied to subsurface, and further resulted in a higher chlorophyll concentration at subsurface.

Correlation between Modeled SCM and SSS, SST

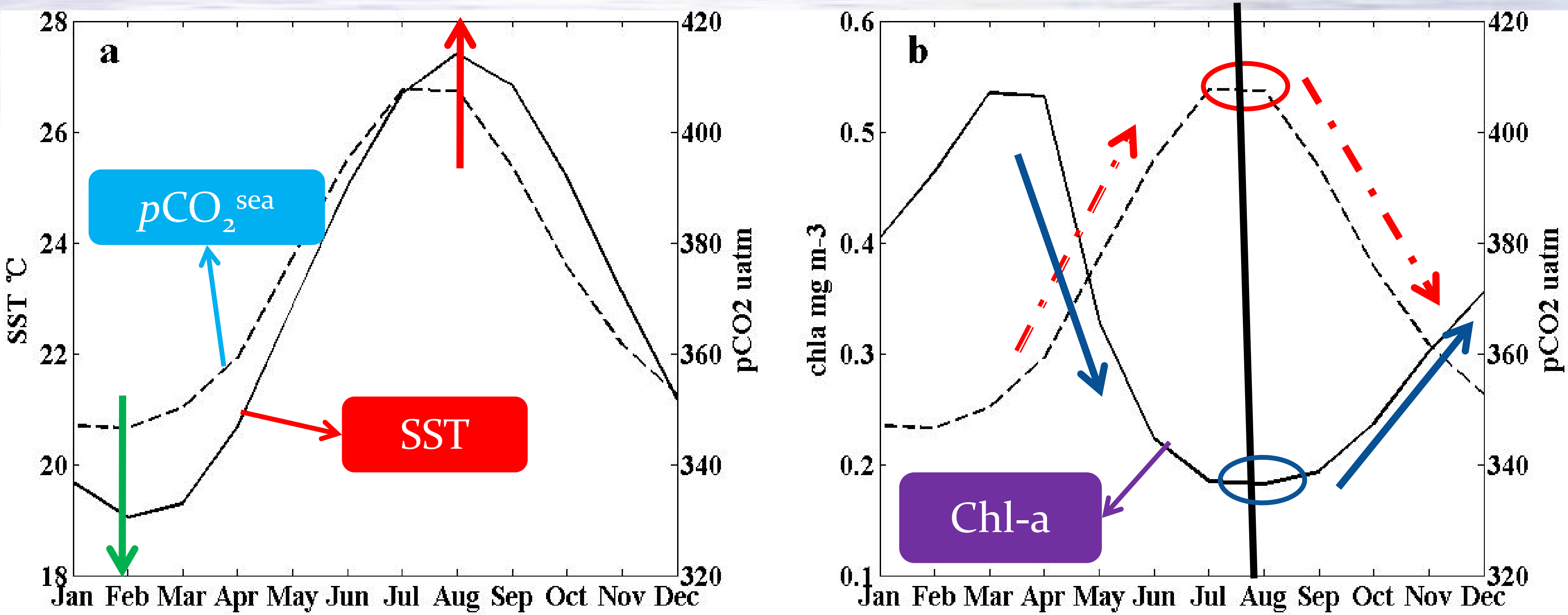


The upper figure shows correlation coefficients between SCM and SST (a) and SSS (b). As shown in figure (a), in the SCS region, SCM has a negative relationship with SST, a strongest correlation ratio is found at the northwest of the SCS, reaches at about -0.92, while weaker correlation occurred at the south region of the SCS.

However, a positive correlation between SCM and SSS is discovered. The results have good agreements with the results from Liao et al. (2018).

	temp	salt	Numbers
Correlation	-0.87	0.44	144

Factors of controlling pCO_2^{sea}

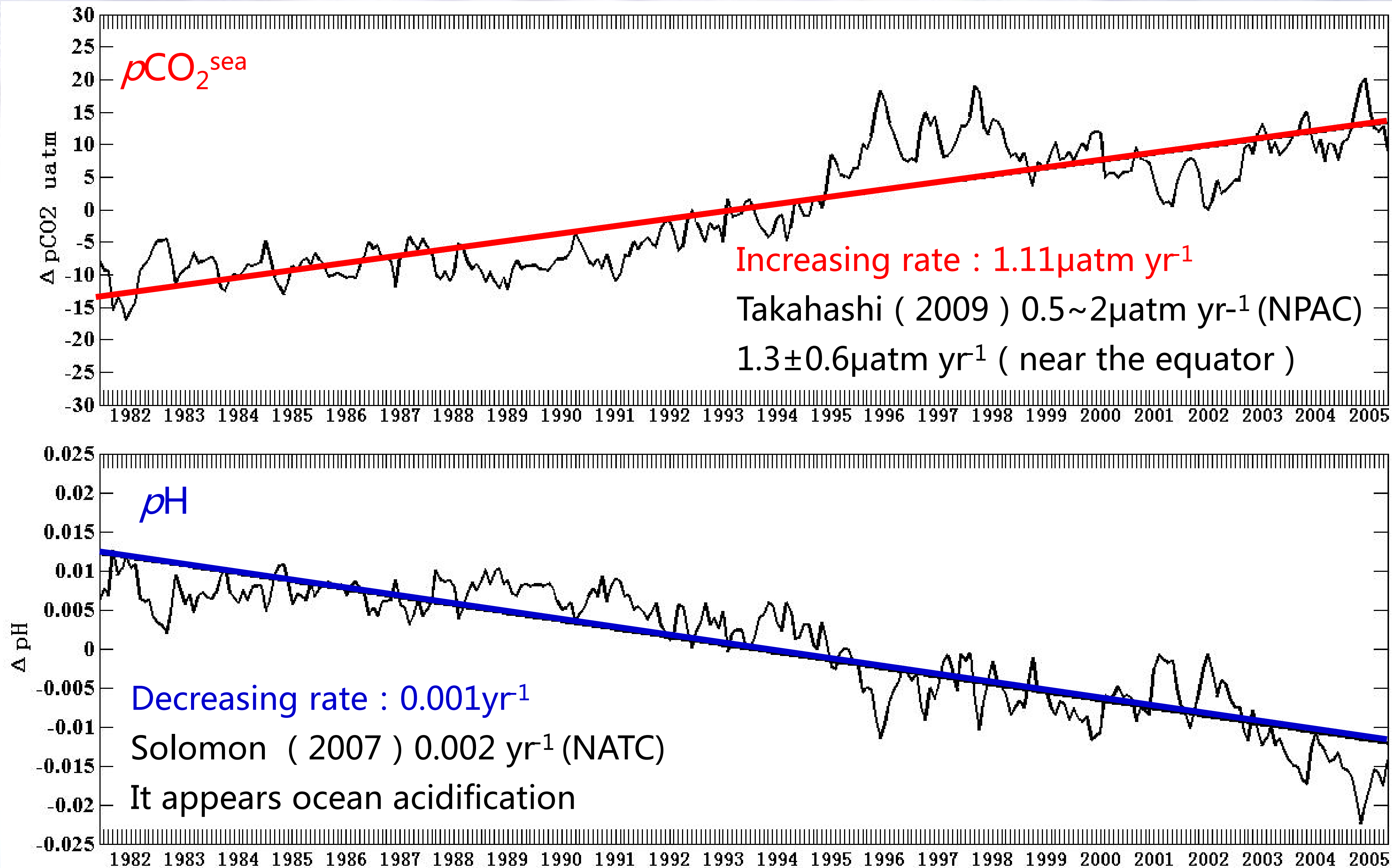


As we can see from the upper picture, the SST varies from 19 to 28, and pCO2 in seawater changes from 350 to 420 uatm. In figure a, the SST and pCO2 have a positive relation with each other, reaches the lowest value in February, and gets the highest value in August. While, the pCO2 has a negative relation with chlorophyll-a, which is shown in figure b. In August, the carbon reaches the highest value, while the chlorophyll has the lowest value.

	T/B ratio
SCS	1.22

According to Takahashi (2002), we found pCO2 in SCS is mainly controlled by SST, and secondly by biological activity.

Seasonal Variation of pCO2 and pH



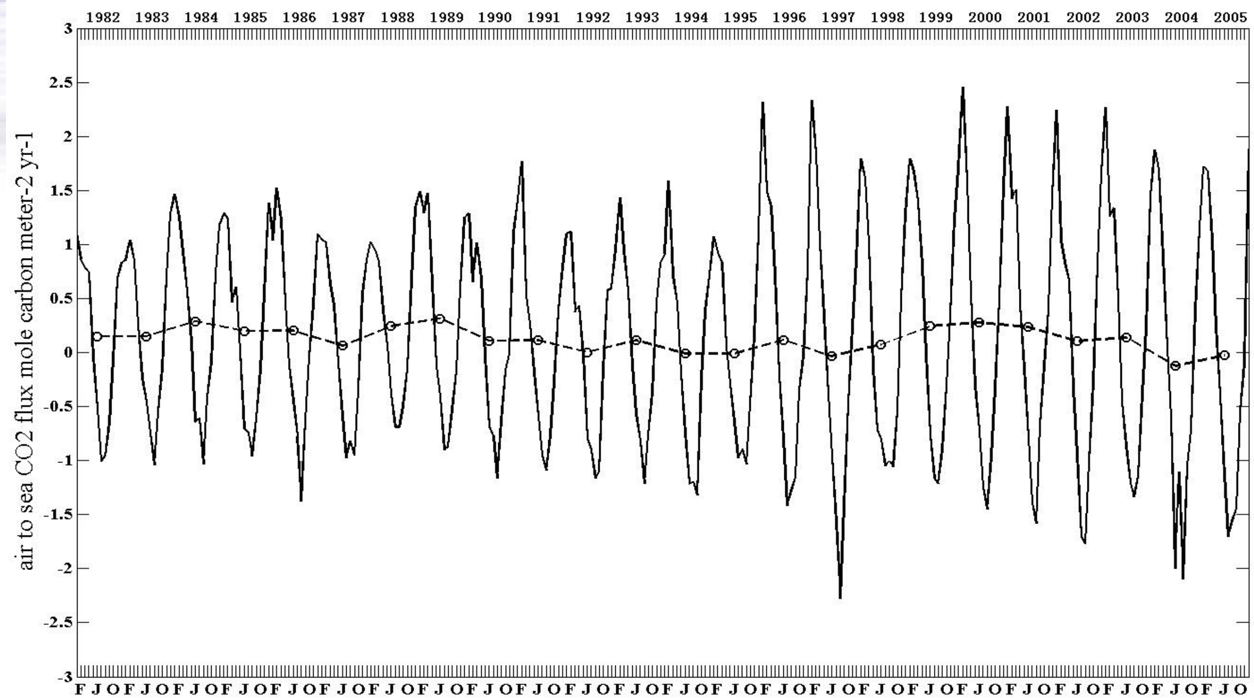
Seasonal and interannual characteristics of air-sea CO2 flux

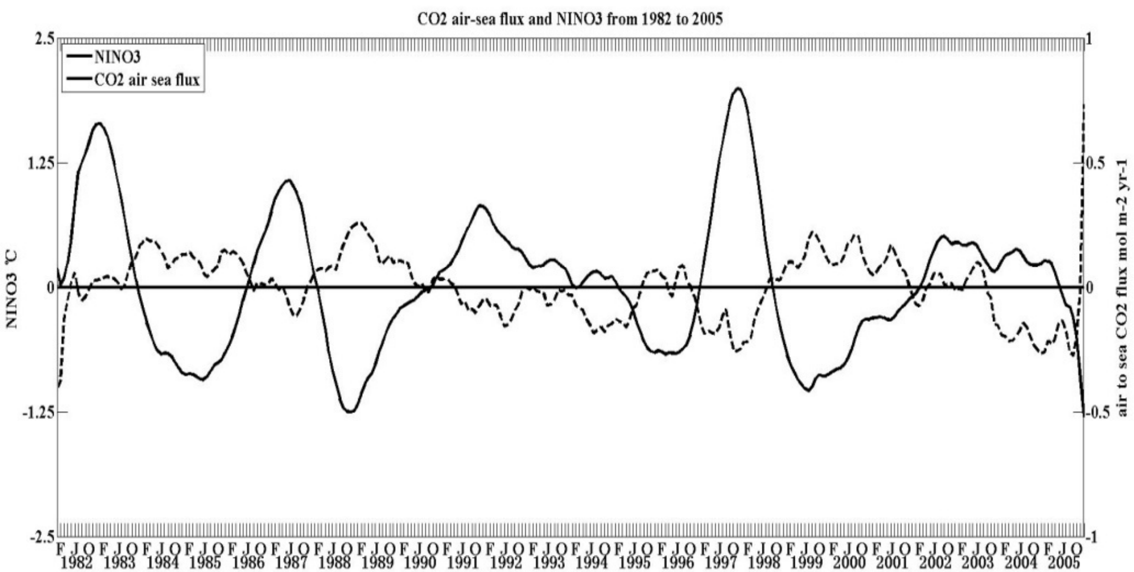
Solidline: Monthly mean value；
Circle: interannual mean Value;

Interannual value of Air-sea CO_2 flux varies from -0.13 to 0.31mol m^{-2} yr^{-1};

Mean value of 24 years: 0.12mol m^{-2} yr^{-1}

Hence, the NWP is a sink of CO2 to the atmosphere





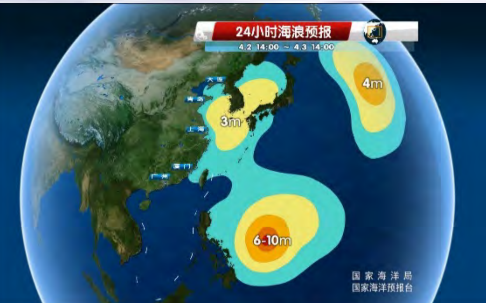
Solidline：NINO3 index
Dashes：air-sea CO2 flux

(1)Positive phase: air-sea CO2 flux performs a negative value, and reaches the lowest in 1997；

(2)Negative phase: air-sea CO2 flux performs a positive value;

Conclusion

- On the basis of a regional ocean modeling system (ROMS), a three dimensional physical-biogeochemical model with a resolution of 1/12˚×1/12˚ is established to investigate the physical variations and ecosystem response in the SCS from 2001 to 2012. The validation results show that the correlation coefficients for modeled SST and Chlorophyl-a are 0.98 and 0.51 and the RMSDs are 0.33 and 0.07 compared with the satellite data of MGDSST and ESA-oceancolor chlorophylly-a data, which means the coupled model has a capability to reproduce the observed seasonal variation features over the same period in the SCS.
- The surface chlorophyll-a over the entire SCS reveals a strong seasonal cycle, double-peak characteristic, with the highest concentration at winter and a following value at late summer.
- The variability of MLD was analyzed by the Empirical Orthogonal Function (EOF). The first mod shows that the variability is same in the whole area of SCS basically with a 42.8% proportion. The second mode shows that the variability is negative-positive dipole-type, and has a positive correlation with a rate of 0.58 when MEI leads 2 month. The third mode performs a positive-negative-positive distribution from south to north, and has a negative correlation with PDO index with a rate of -0.6.
- The MLD and SCML perform an opposite seasonal variation with a same double-peak feature (Spring and Autumn), and the correlation coefficient is -0.68 between each other. The 12 a mean value of SCML is about 48.04m, and MLD is 24.69m.
- The variability of SCML was analyzed by the EOF. The first mod shows that the variability is same in the whole area of SCS basically with a 63.6 % proportion. The largest variability of SCML is located at the west of Philippines, about 116˚E and 15˚N. The second mode shows that the variability is dipole-type, with a largest negative variability center at the west of Luzon strait, which probably resulted by the Kuroshio intrusion. The positive variability of SCML is at the south of 15 ˚N. The third mode has a strong positive variability center at the east-center of the SCS and the rest regions perform a negative variability.
- The 12 a mean value of subsurface chlorophyll-a maximum is about 0.39mg m^{-3}, and has a positive relation with the wind. The subsurface chlorophyll-a maximum value has a positive correlation with wind and SSS, correlation ratios are 0.70 and 0.44, has a negative correlation with SST, correlation ratio is -0.87.
- The ocean performs an obvious acidification phenomenon, and the air to sea CO2 flux has a good correlation with ENSO events.


24小时海浪预报
4m
3m
6-10m
国家海洋局
国家海洋预报台


海洋预报
1-1.8m
3-3.5m

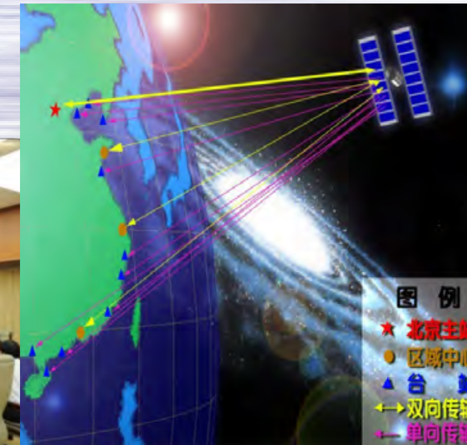


图 例
北京主站
区域中心
台 站
双向传输
单向传输


lenovo

Thanks!