Ecosystem models and forecasts for Chinese coastal seas

Reporter: Shan GAO

National Marine Environmental Forecasting Center

2024年3月

Marine Ecological Forecasting System

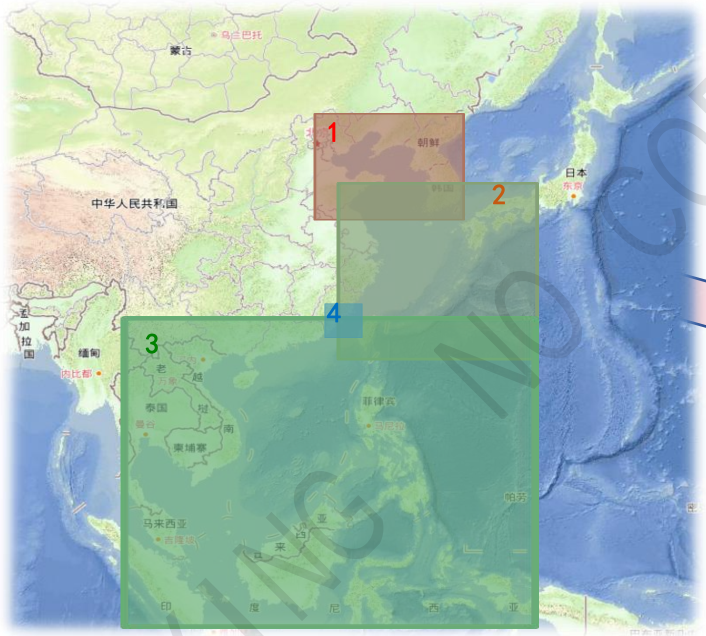
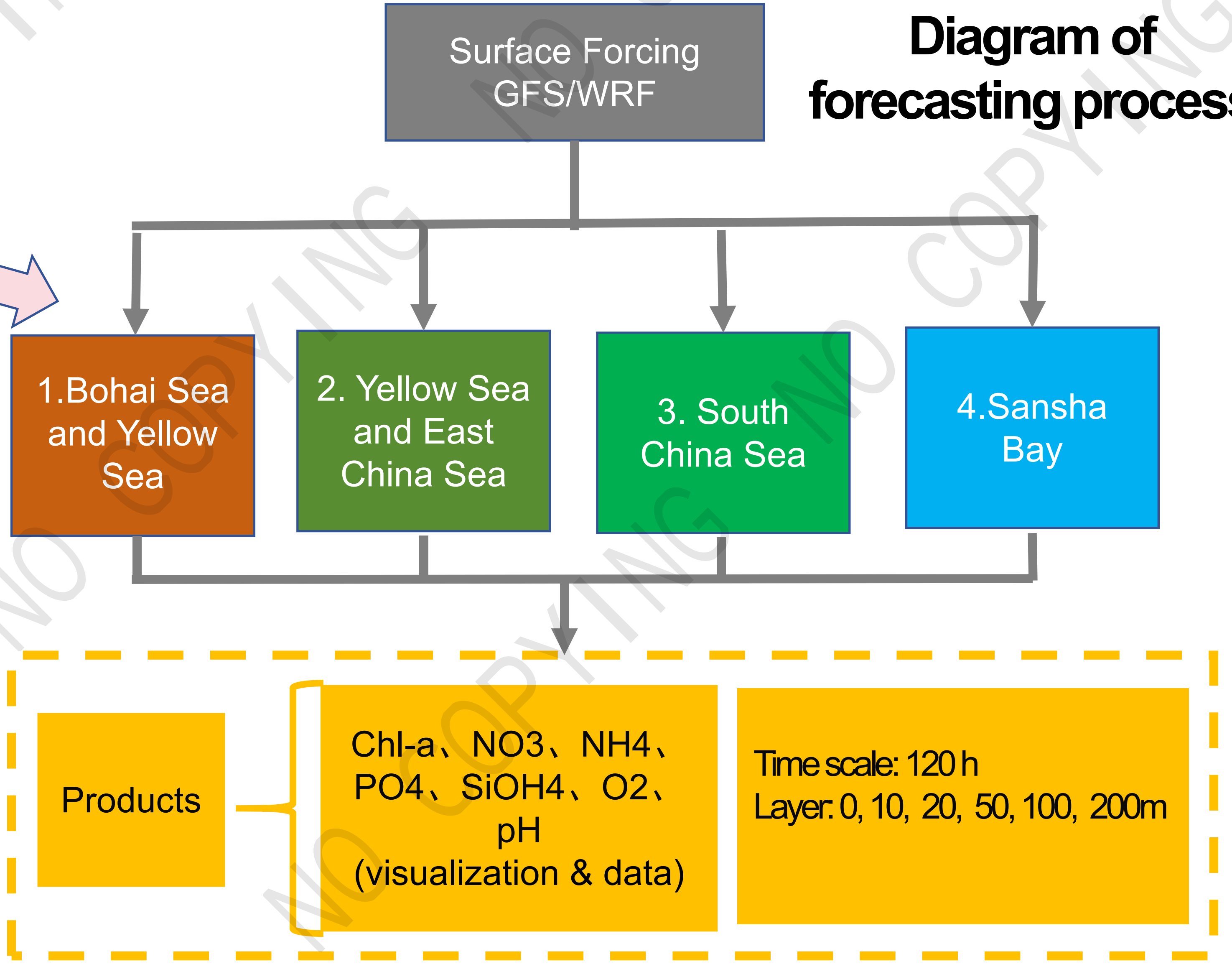
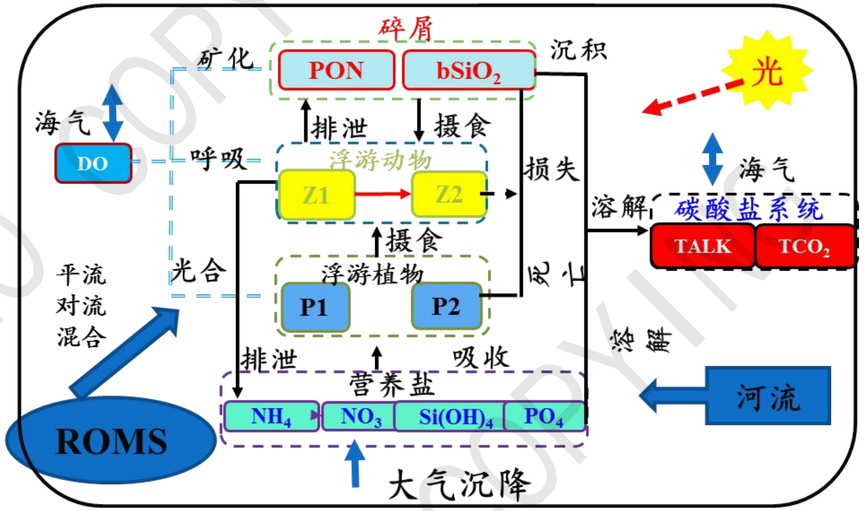
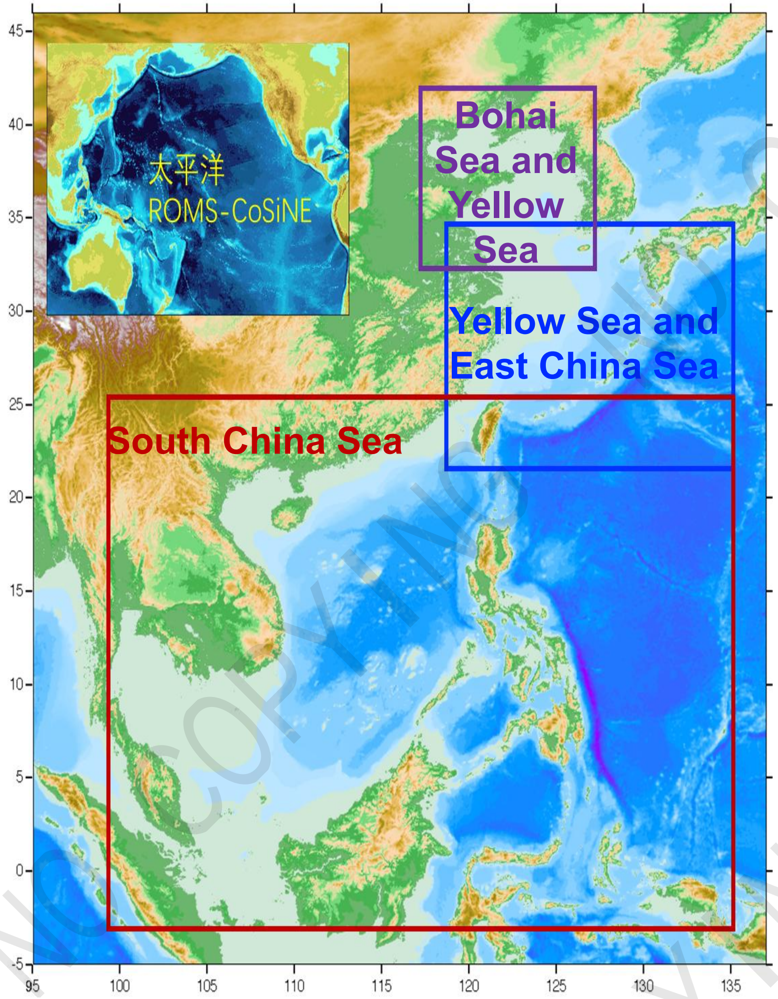


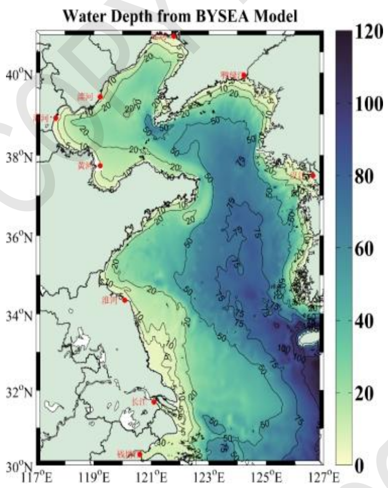
Diagram of forecasting process





System configuration





◆**Domain：**

✓29.85 - 41.18° N， 117.27-127.36° E

◆**Horizontal Resolution**

✓1 /24° *1/24° ， Grid number: 274×249

◆**Vertical Resolution**

✓30 Layers

◆**Initial Condition**

✓ WOA13

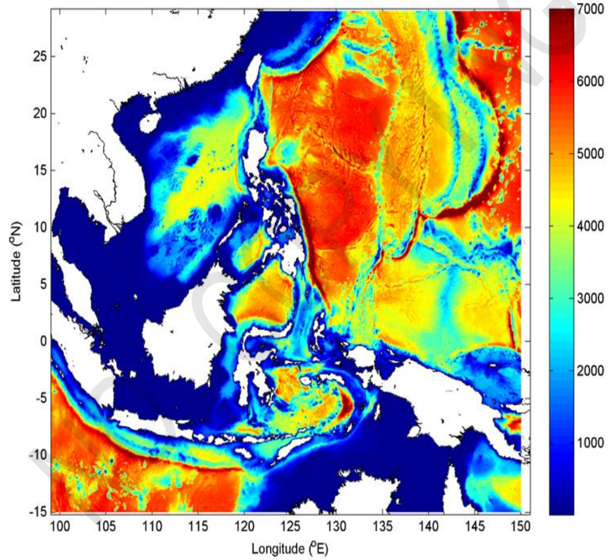
◆**Forcing:**

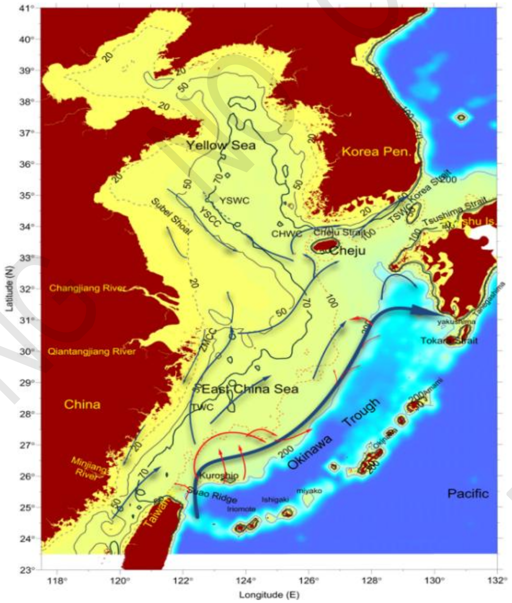
✓**Surface:** WRF/GFS

✓**Open Boundary:** SODA

✓**River:** Changjiang, Huanghe, Huaihe Qiangtangjiang,Yalvjiang, Haihe,Liaohe, Luanhe,Hanjiang

◆**Tide:** 8 major constituents (M2,S2,N2,K2,K1,O1,P1,Q1)





◆**Domain：**

✓23.5 - 41.0° N, 117.5 -132.0° E

◆**Horizontal Resolution**

✓1 /24° *1/24°

◆**Vertical Resolution**

✓30 Layers

◆**Initial Condition**

✓ WOA13

◆**Forcing:**

✓**Surface:** WRF/GFS

✓**Open Boundary:** SODA

✓**River:** Changjiang, Huanghe, Minjiang, Qiangtangjiang,Yalvjiang, Liaohe, Hanjiang

◆**Tide:** 6 major constituents (M2, S2, N2, K2, K1, O1)

◆**Domain：**

✓-15 - 29° N, 99 - 150° E

◆**Horizontal Resolution**

✓1 /24° *1/24°

◆**Vertical Resolution**

✓30 Layers

◆**Initial Condition**

✓ WOA13

◆**Forcing:**

✓**Surface:** WRF/GFS

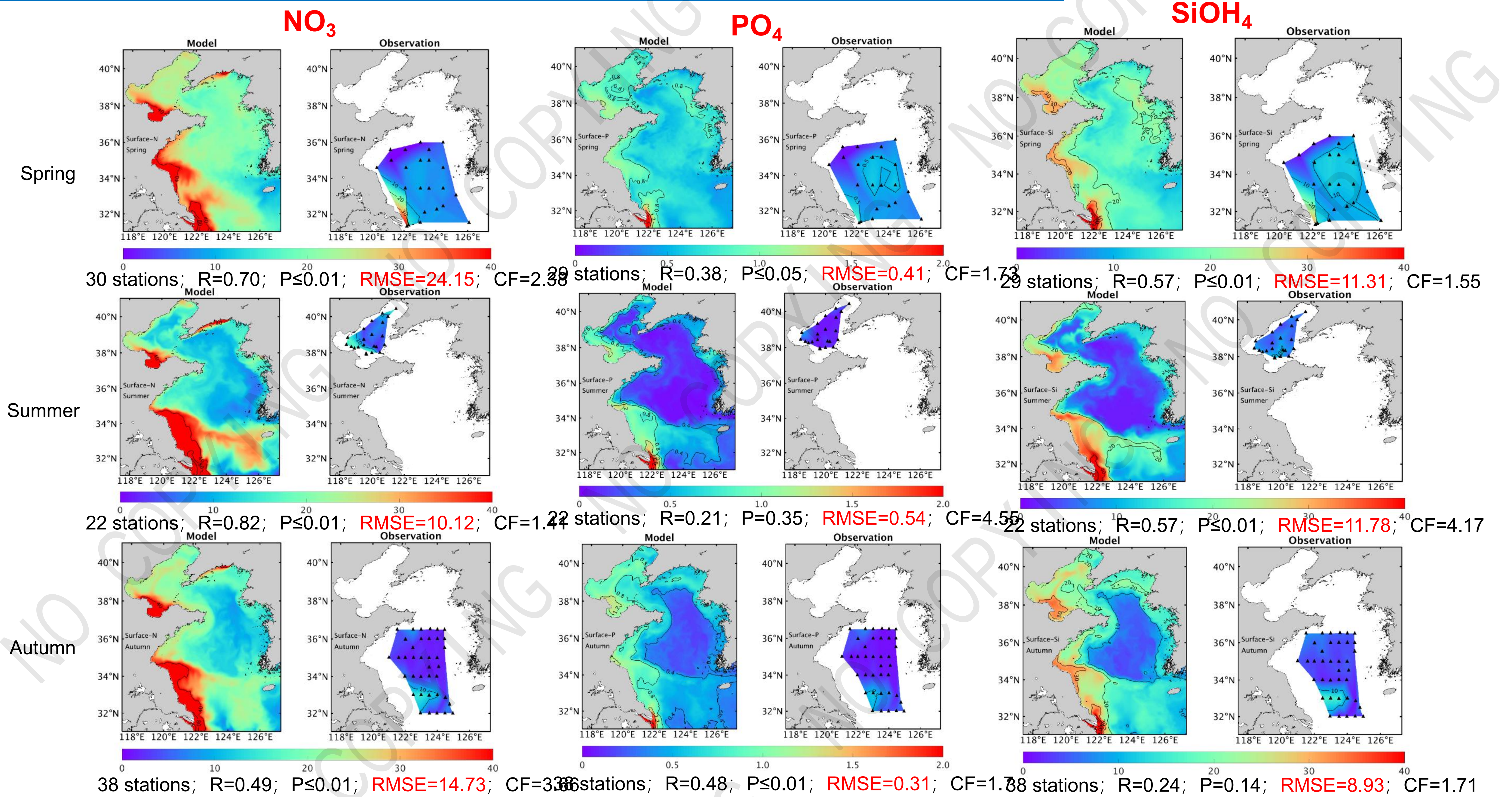
✓**Open Boundary:** SODA

✓**River:** 21 rivers

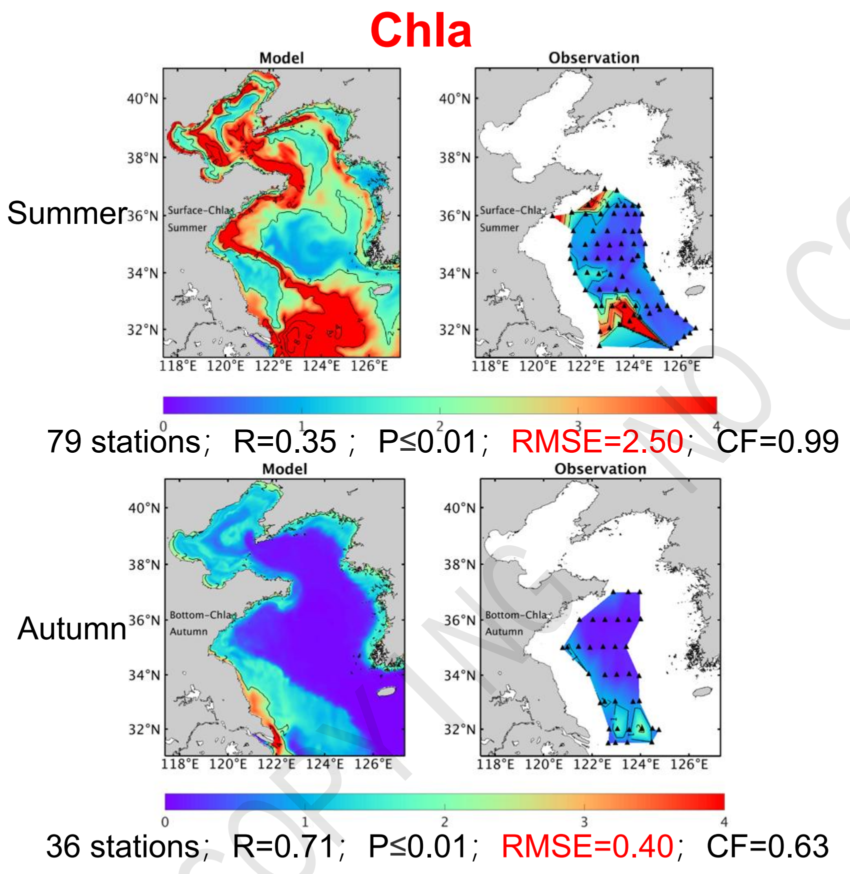
Zhujiang, Meigonghe, Honghe, Jiulongjiang,Huangganghe so on

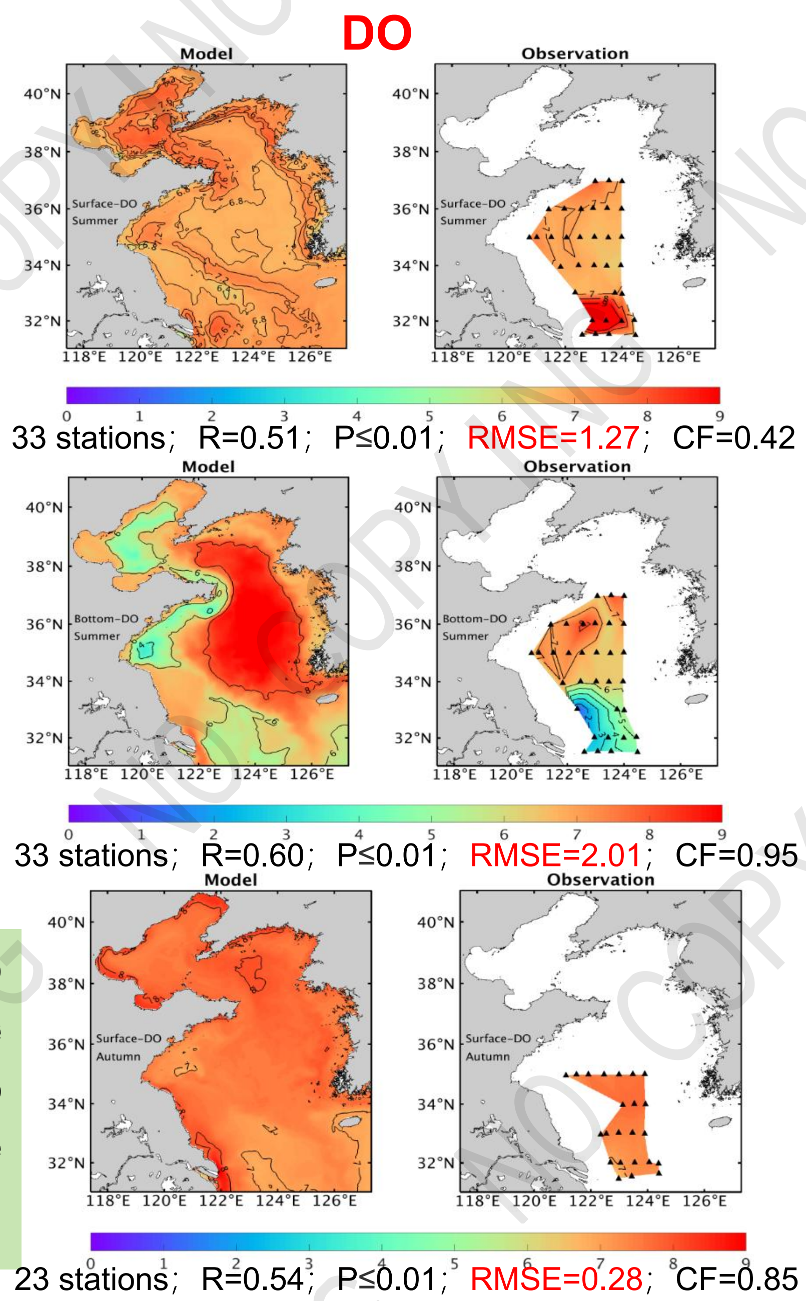
◆**Tide:** 8 major constituents (M2,S2,N2,K2,K1,O1,P1,Q1)

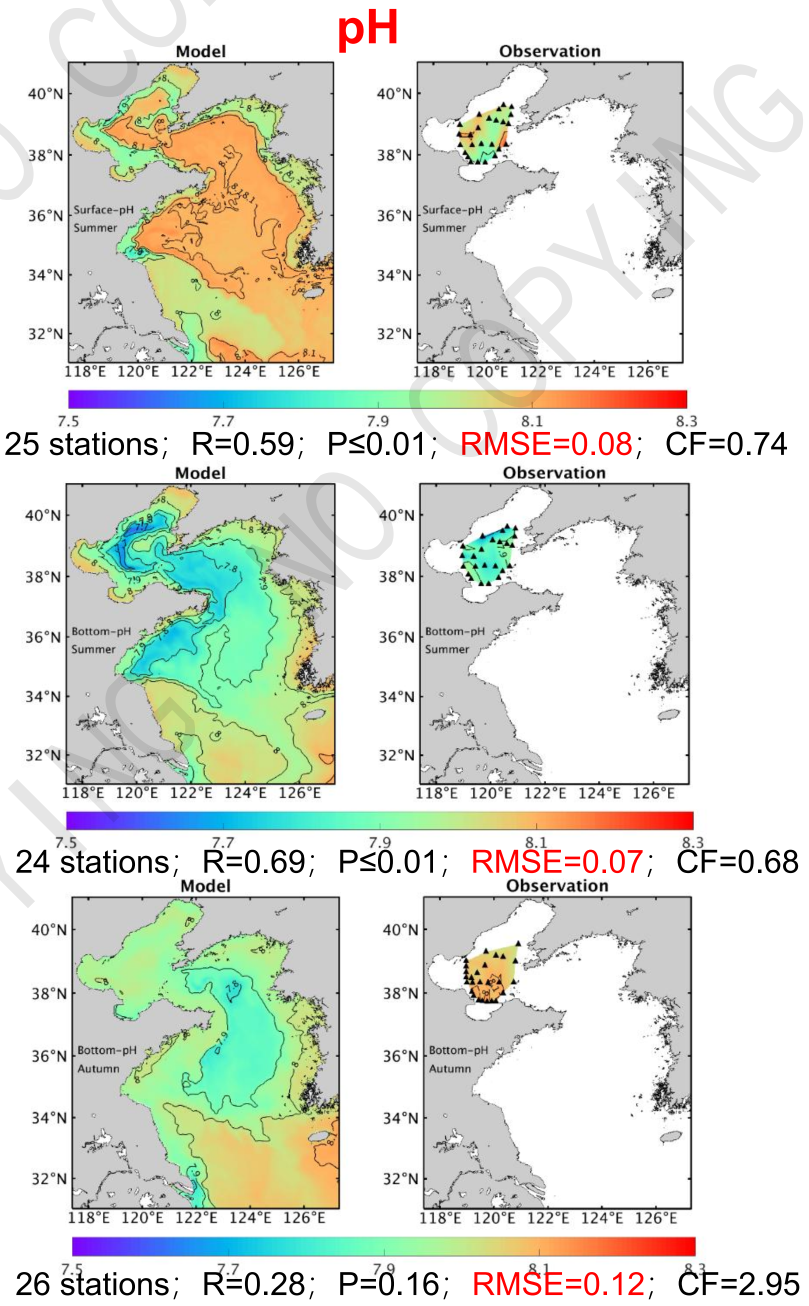
Model validation of bhsbio —— NO_3、PO_4、$SiOH_4$



Model validation of bhsbio —— Chla、DO、PH

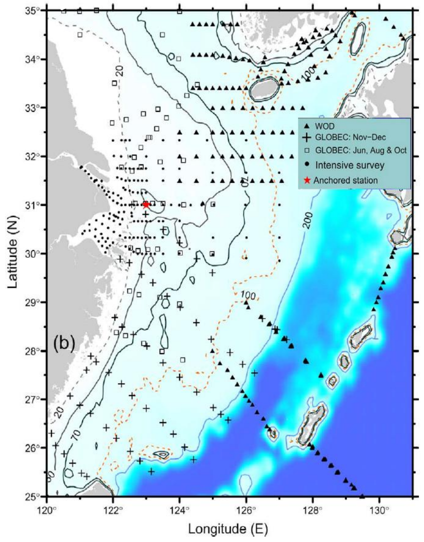


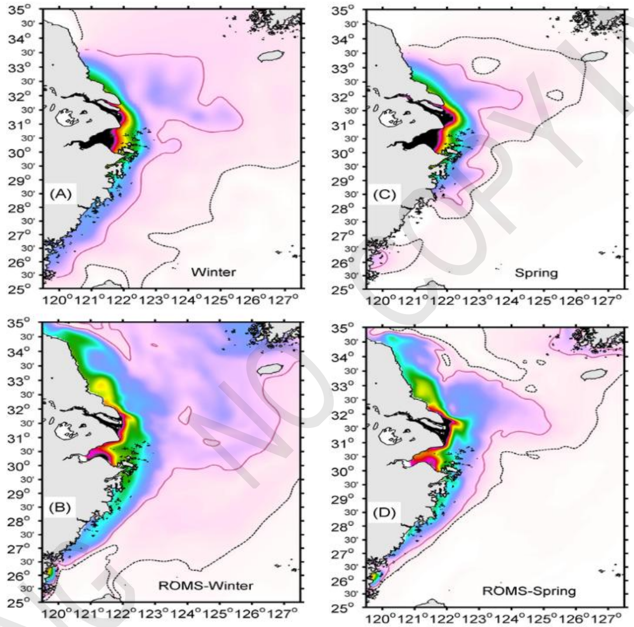


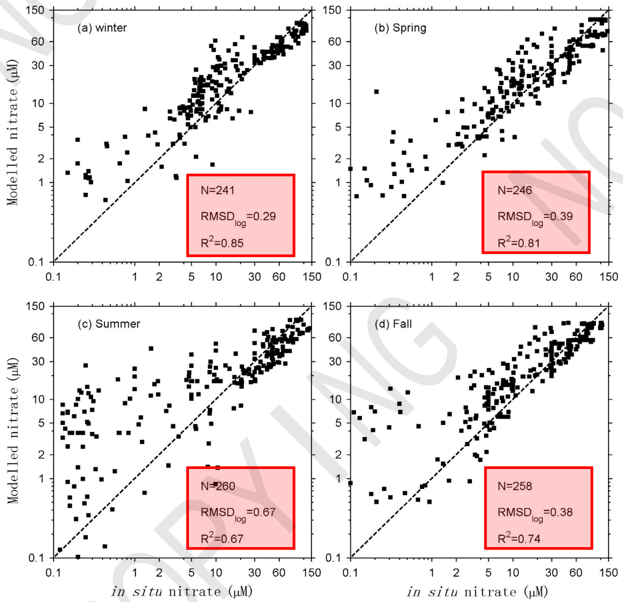


Overall, the simulated nutrients, chlorophyll, DO are agree well with the situ data. These comparisons show that the model is able to reproduce the biogeochemical dynamics in the Bohai Sea and Yellow Sea.

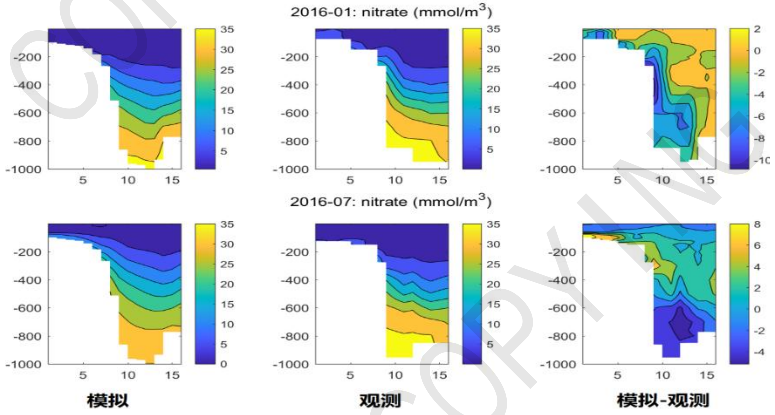
Model validation of ecsbio —— NO3、Chla

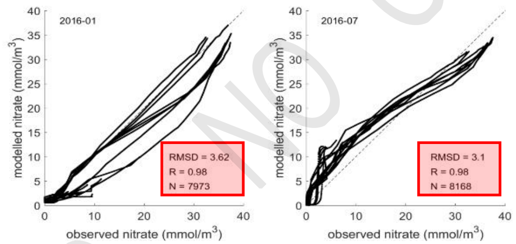




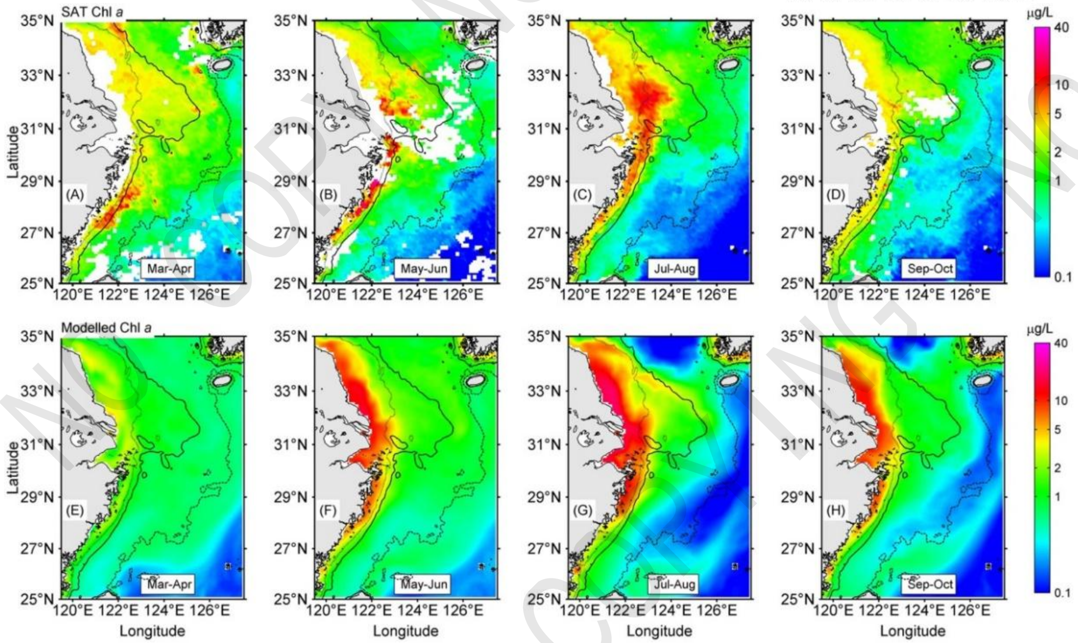


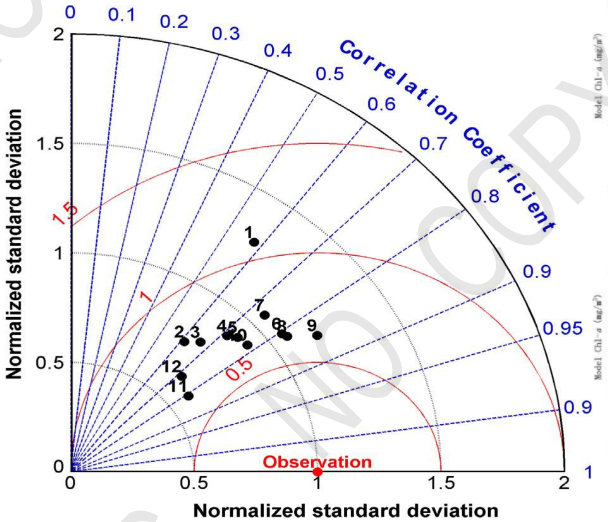
Simulated nitrate are compared with the observed data and agree well with correlation coefficients of **0.85, 0.81, 0.67, and 0.74**, respectively

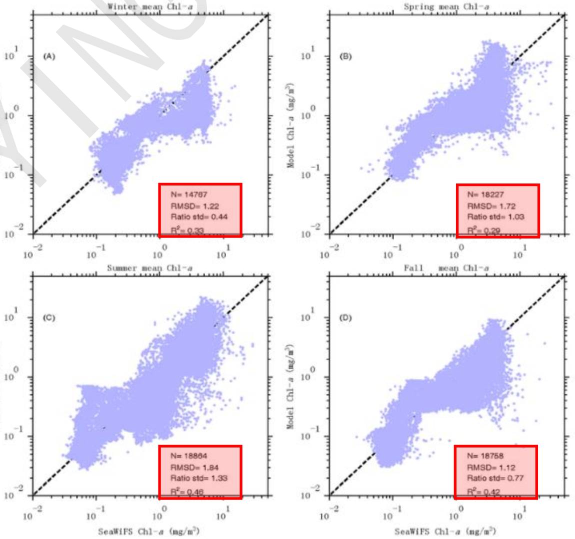




At the PN cross-section, the correlation coefficient between simulation and observation reaches over **0.97.**



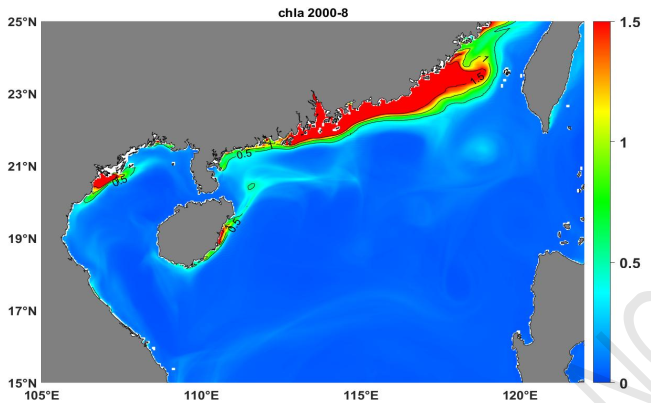




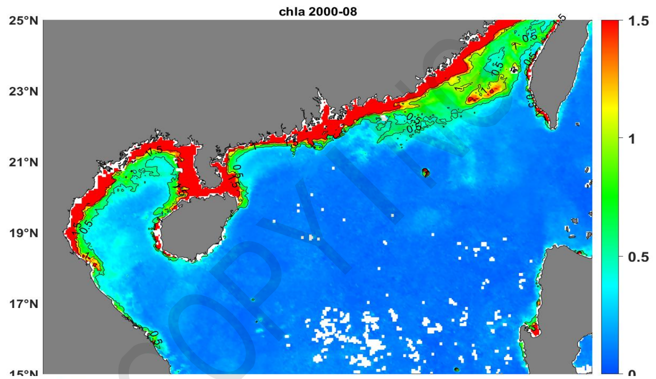
Simulated chlorophyll also show similar spatial and seasonal patterns with observations, and correlation coefficients are **0.62 and 0.83** in spring and autumn, respectively

Model validation of scsbio —— Chla

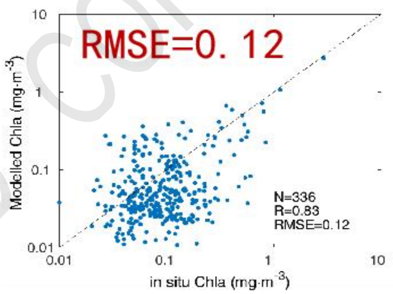
Model

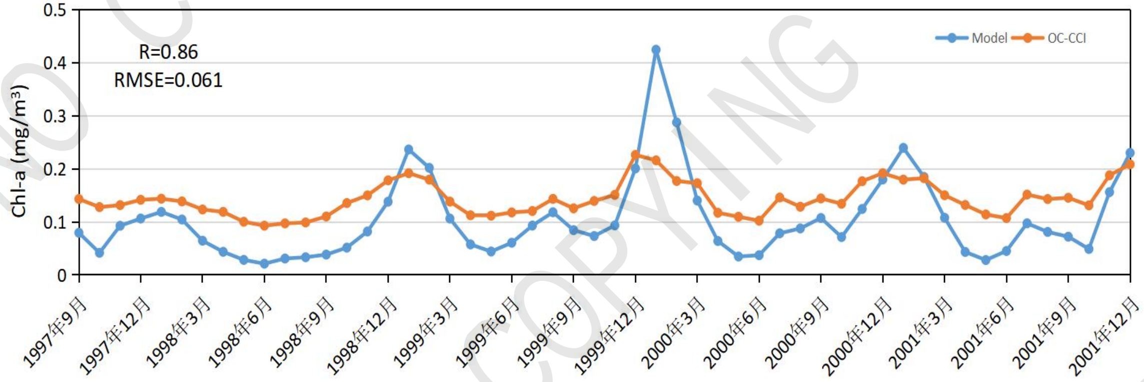


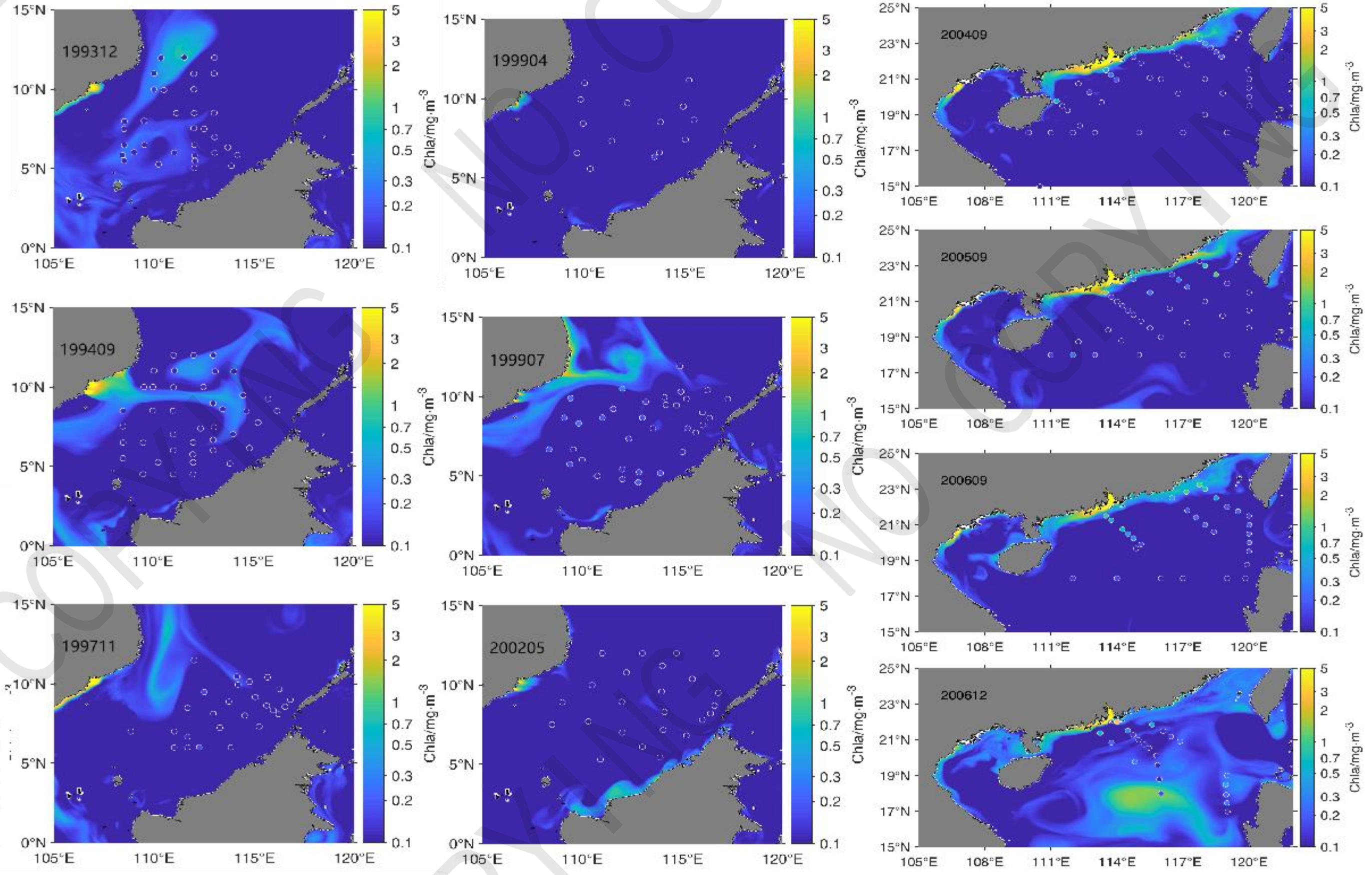
OC-CCI



Surface layer







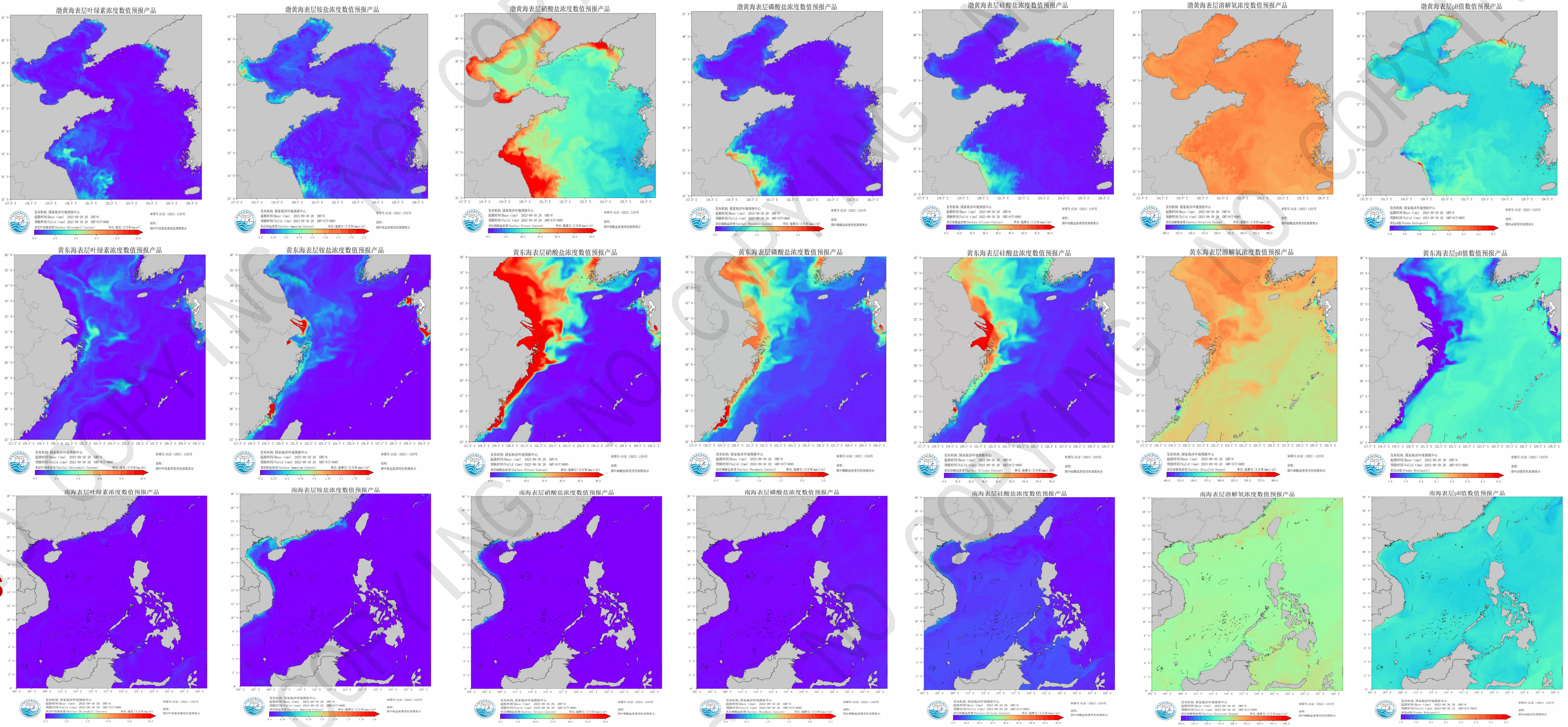
75m layer : RMSE = 0.17

150m layer : RMSE = 0.07

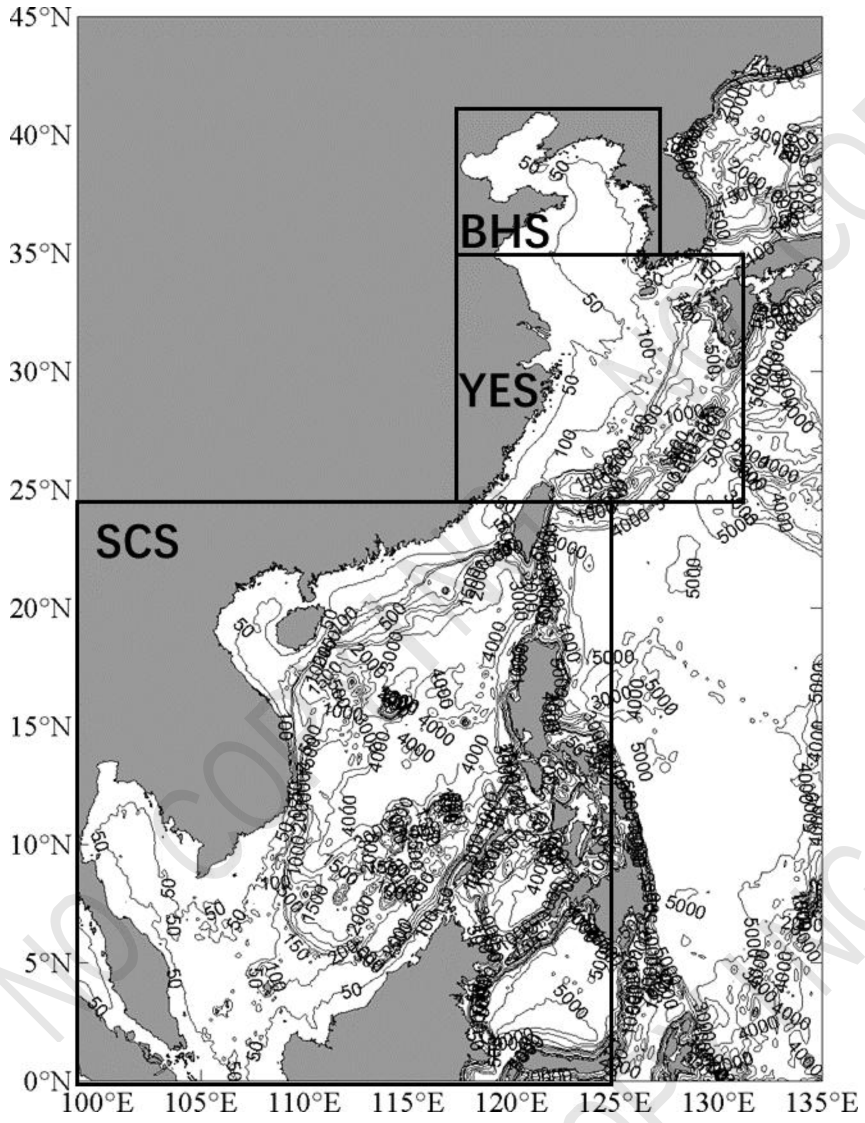
depth >200m: RMSE = 0.061

Ecological forecasting products

	Chlorophyll-a	NH4	NO3	PO4	SiOH4	DO	pH
BHS							
ECS							
SCS							



Verification and evaluation of forecasting results



(1) $\text{bias} = M_n - D_n$ M_n: forecasting results, D_n: Observation data

(2)
$$\text{rmse} = \sqrt{\frac{1}{N}\sum_{n=1}^{N}(M_n - D_n)^2}$$

(3) The percentage model bias

$$Pbias = \frac{\sum_{n=1}^{N}(D_n - M_n)}{\sum_{n=1}^{N} D_n} \times 100$$

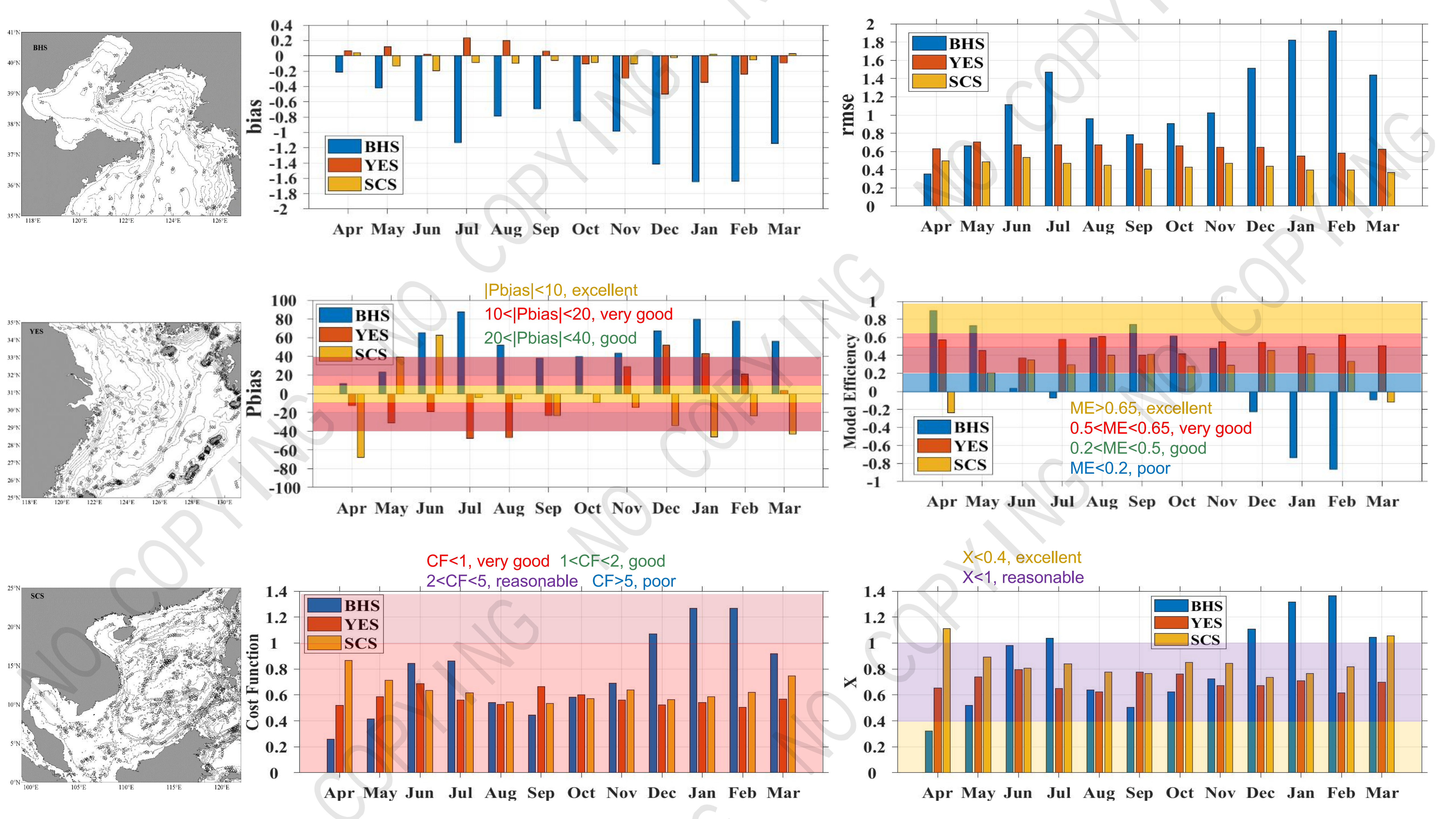
(4) The Nash Sutcliffe Model Efficiency

$$ME = 1 - \frac{\sum_{n=1}^{N}(D_n - M_n)^2}{\sum_{n=1}^{N}(D_n - \overline{D})^2}$$

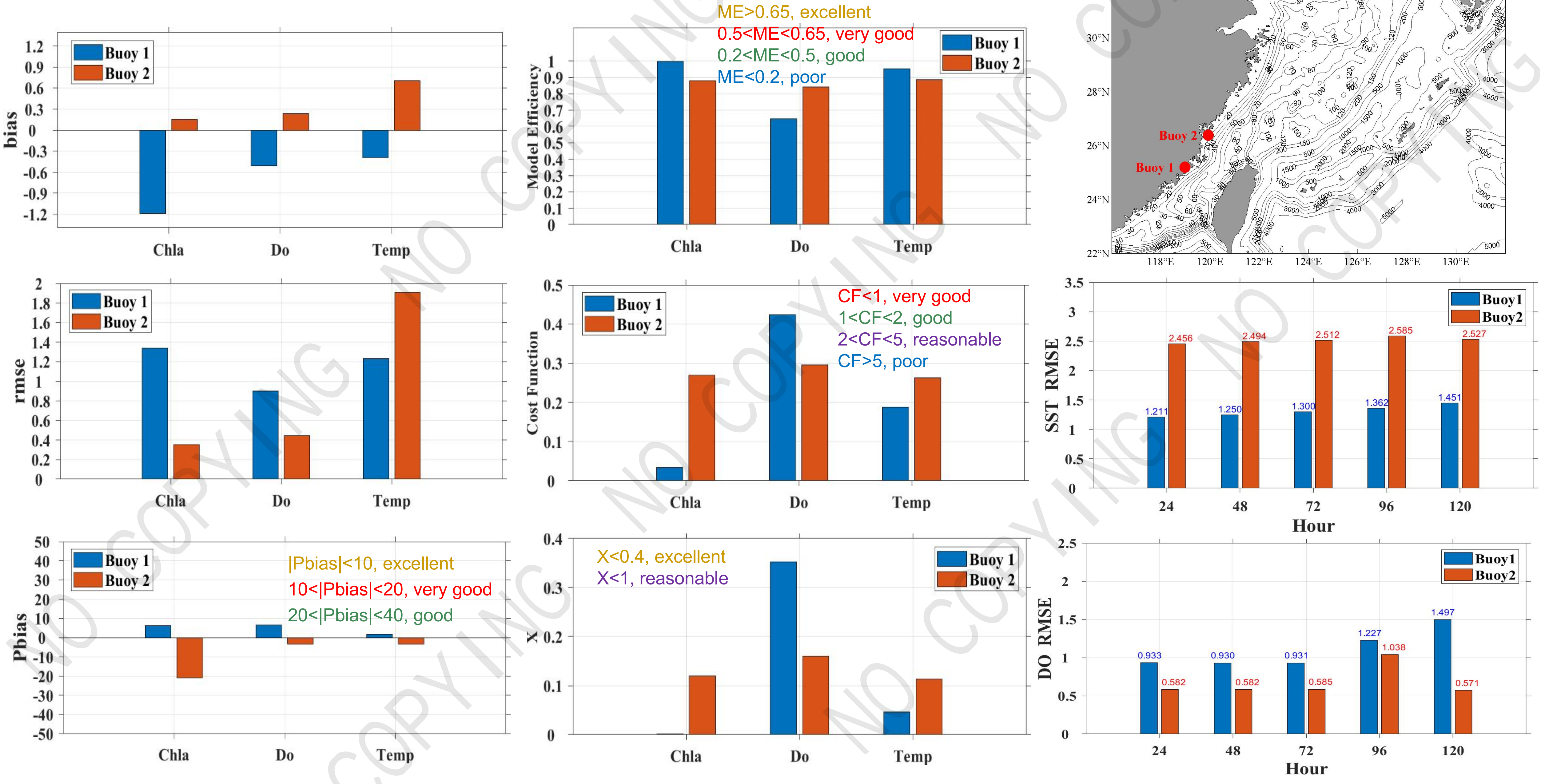
(5) The cost function

$$\text{CF} = \frac{1}{N}\sum_{n=1}^{N}\frac{|D_n - M_n|}{\sigma_D}$$

(6) χ function $\chi^2 = \frac{1}{N\sigma_D^2}\sum_{n=1}^{N}(D_n - M_n)^2$


BHS
YES
SCS
bias
rmse
Pbias
|Pbias|<10, excellent
10<|Pbias|<20, very good
20<|Pbias|<40, good
Model Efficiency
ME>0.65, excellent
0.5<ME<0.65, very good
0.2<ME<0.5, good
ME<0.2, poor
Cost Function
CF<1, very good 1<CF<2, good
2<CF<5, reasonable CF>5, poor
X
X<0.4, excellent
X<1, reasonable
Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar

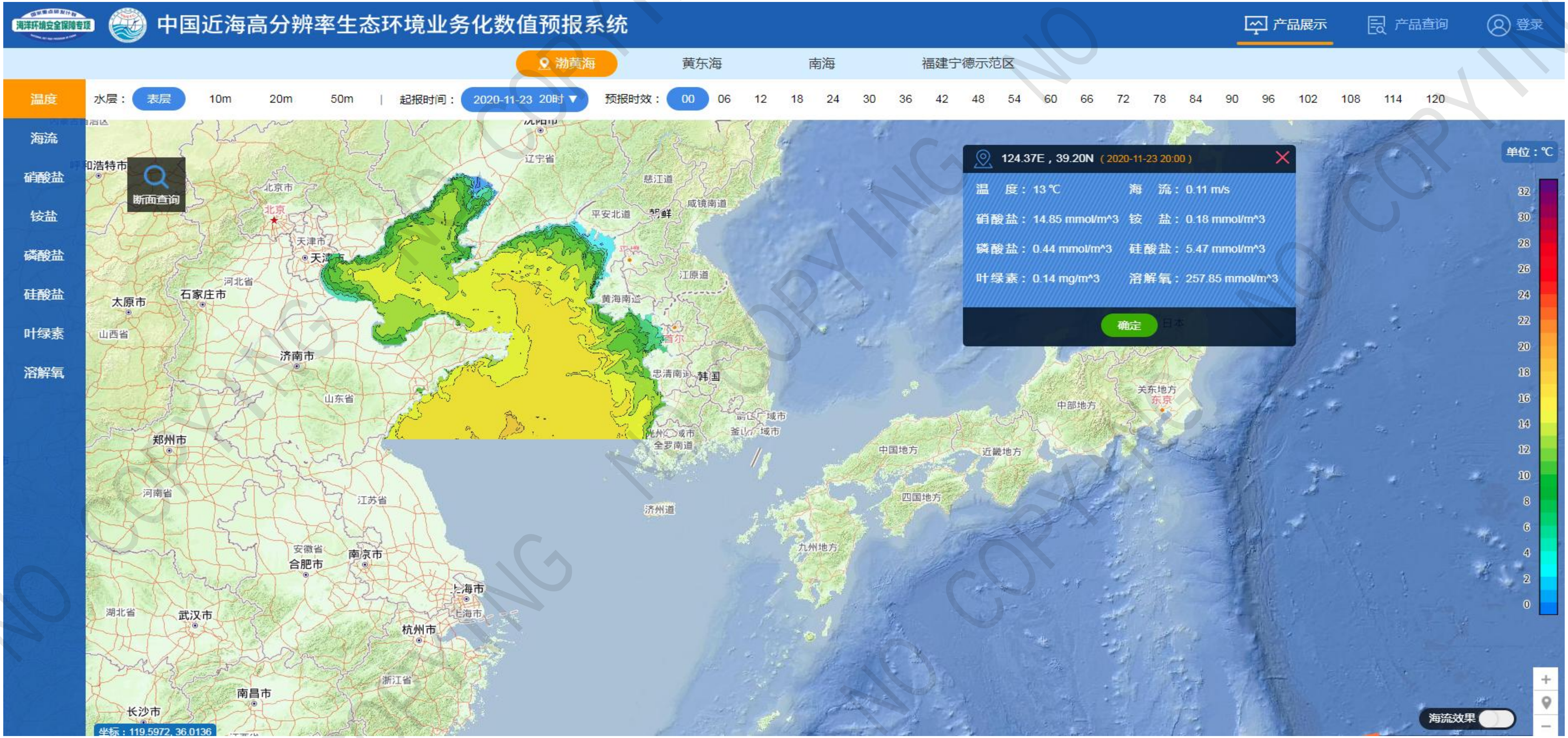
Verification and evaluation of forecasting results —— Chla、 DO、SST



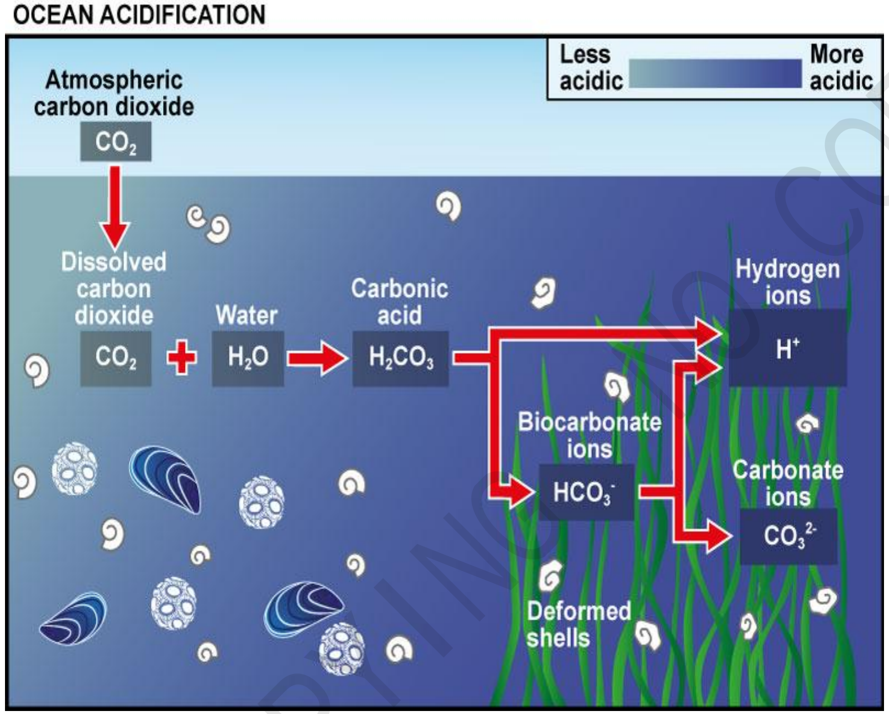
Platform display

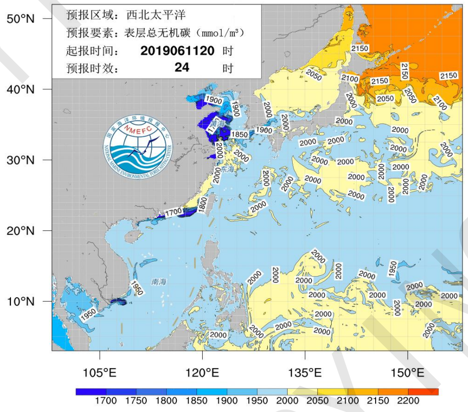
https://www.nmefc.cn/ybfw/styb/WestNorthPacific

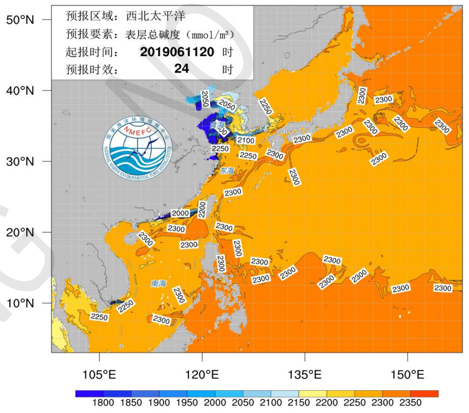
http://202.108.199.24:8080/BJ_SZYB_Web/default.htm

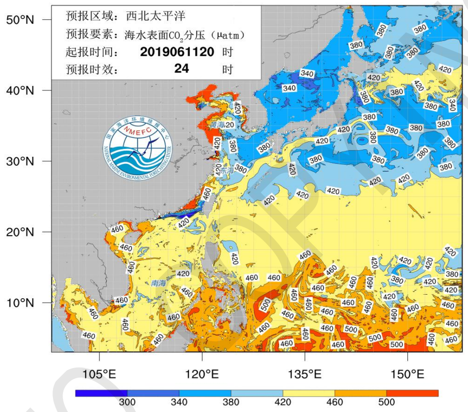


Application Case: Ocean Carbon Cycle









Using the temperature, salinity, TALK, TIC, PO4, and SiOH4 numerical forecast data from the high-resolution ecological environmental operational numerical prediction system, calculations and predictive forecasts for seawater acidity and alkalinity are conducted.The calculation of seawater pH utilizes the Newton method.

Hsws=αH/fH

αH represents the hydrogen ion activity, and **fH** represents the activity coefficient of hydrogen ion (H+). The specific calculation equation is as follows.:

αH=TA - CAlk - BAlk - OH - PAlk - SiAlk + Hfree + HSO4 + HF ;

fH = ln10.*(TC.*K1F.*H.*(H.*H + K1F.*K2F + 4.*H.*K2F)./Denom./Denom + BAlk.*H./(KBF + H) + OH + H)

TA represents the total alkalinity, TC represents the total inorganic carbon.
CAlk= TC.*K1.*(H + 2.*K2)./Denom; Denom= (H.*H + K1.*H + K1.*K2);
H=10.^(-pHx); BAlk= TB.*KB./(KB + H); OH= KW./H;
PAlk= TP.*PhosTop./PhosBot; SiAlk= TSi.*KSi./(KSi + H);
PhosTop = KP1.*KP2.*H + 2.*KP1.*KP2.*KP3 - H.*H.*H;
PhosBot = H.*H.*H + KP1.*H.*H + KP1.*KP2.*H + KP1.*KP2.*KP3;
Hfree= H./FREEtoTOT; FREEtoTOT = (1 + TS./KS);
HSO4= TS./(1 + KS./Hfree); HF= TF./(1 + KF./Hfree)。

KP1, KP2, KP3, KSi, KW, KB, KS, KF are coefficients related to temperature and salinity. TSi and TP represent the silicate and phosphate, respectively. K1 and K2 are the first and second dissociation constants of carbonic acid, specified as follows.

K1=10(A1-A2/Tk-log(Tk)*A3+Salt*(A4-Salt*A5)) ;

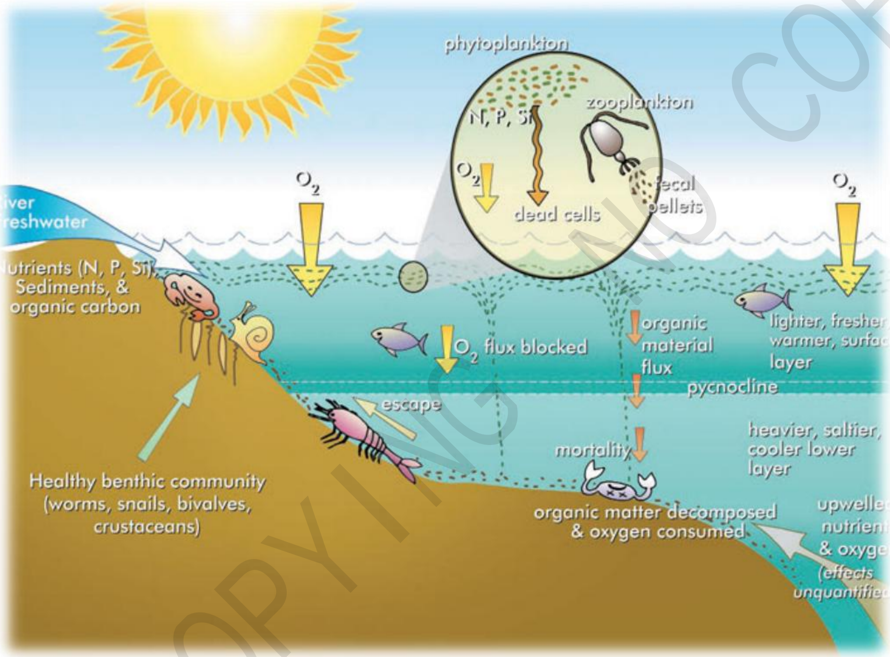
K2=10(B1-B2/Tk+Salt*(B3-Salt*B4))。

Tk represents temperature in Kelvin, Salt represents salinity, and the rest are parameter values.

Ji et al., 2017,Acta Oceanologica Sinica

Application Case: Hypoxia Zone

Marine hypoxia process:



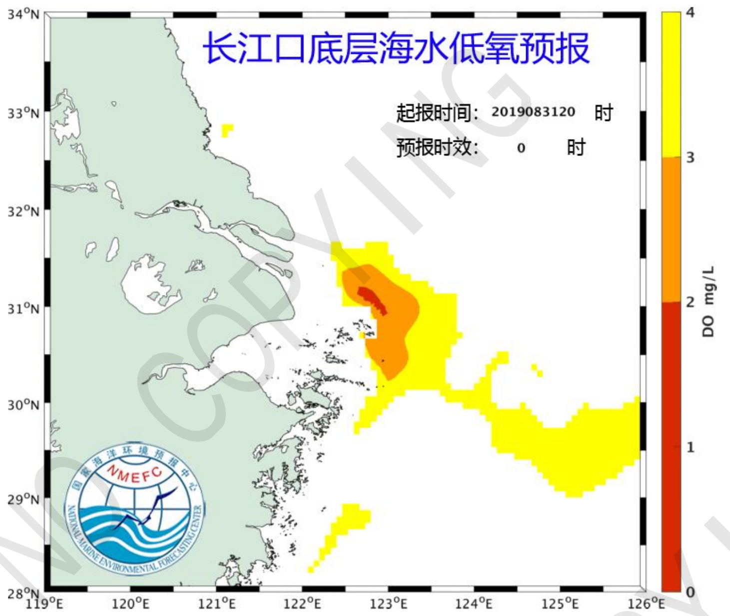
$$Ox_{\min} = \text{minimum}[Ox(i,j,1),...Ox(i,j,t)], t = 1,2,...,k$$

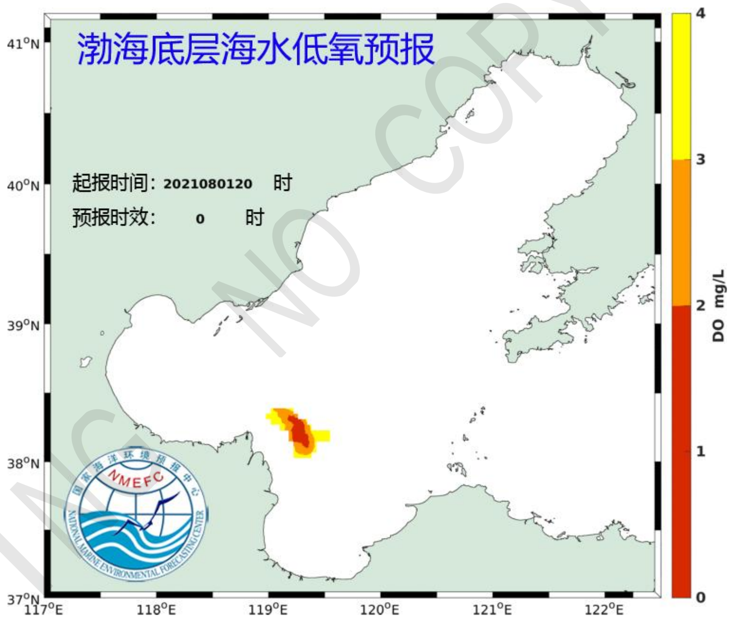
$$S = \sum_{i=1}^{M}\sum_{j=1}^{L} A(i,j) * mask(i,j)$$

$$mask(i,j) = \begin{cases} 1, if\ Ox_{\min} \le 3.0 \\ 0, if\ Ox_{\min} > 3.0 \end{cases}$$

Definition of hypoxia: When the concentration of dissolved oxygen in water is less than 3mg/L, it is considered to be hypoxia.

Hypoxia forecasting products





Hypoxia red alert (DO < 2mg/L)

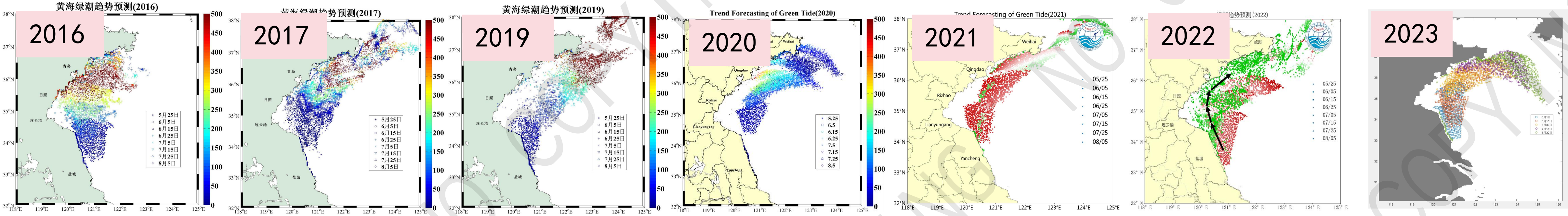
Hypoxia orange alert(2mg/L < DO < 3mg/L)

Hypoxia yellow alert (3mg/L < DO < 4mg/L)

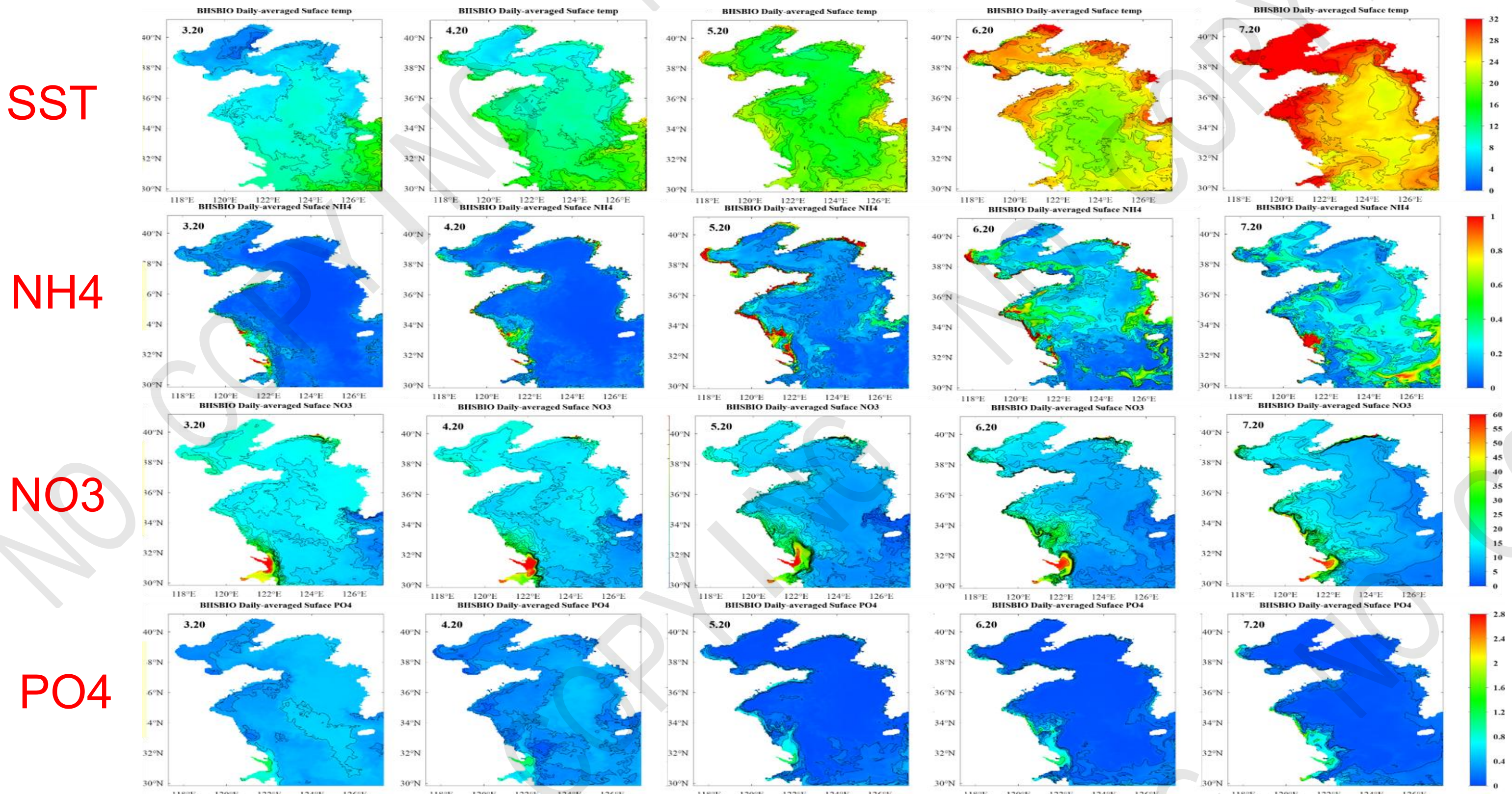
Zheng et al., 2016, Nat. Hazards Earth Syst. Sci.

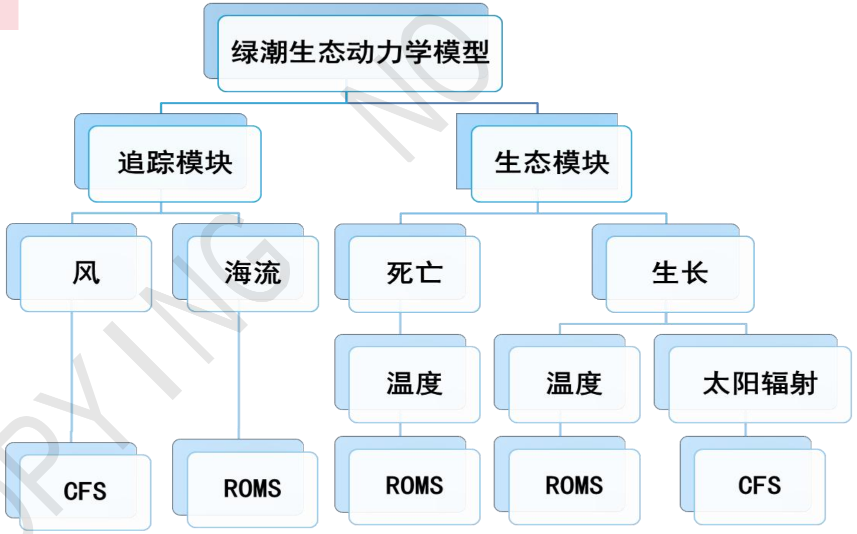
Zheng et al., 2021, Acta Oceanologica Sinica

Application Case:Entermorpha(green tide) in the Yellow Sea



Environmental Element Forecast for March to July 2023





$$\frac{dx}{dt} = R_1 \times v_{cx}(x,y,t) + R_2 \times v_{wx}(x,y,t) \times \cos(\theta - \beta)$$

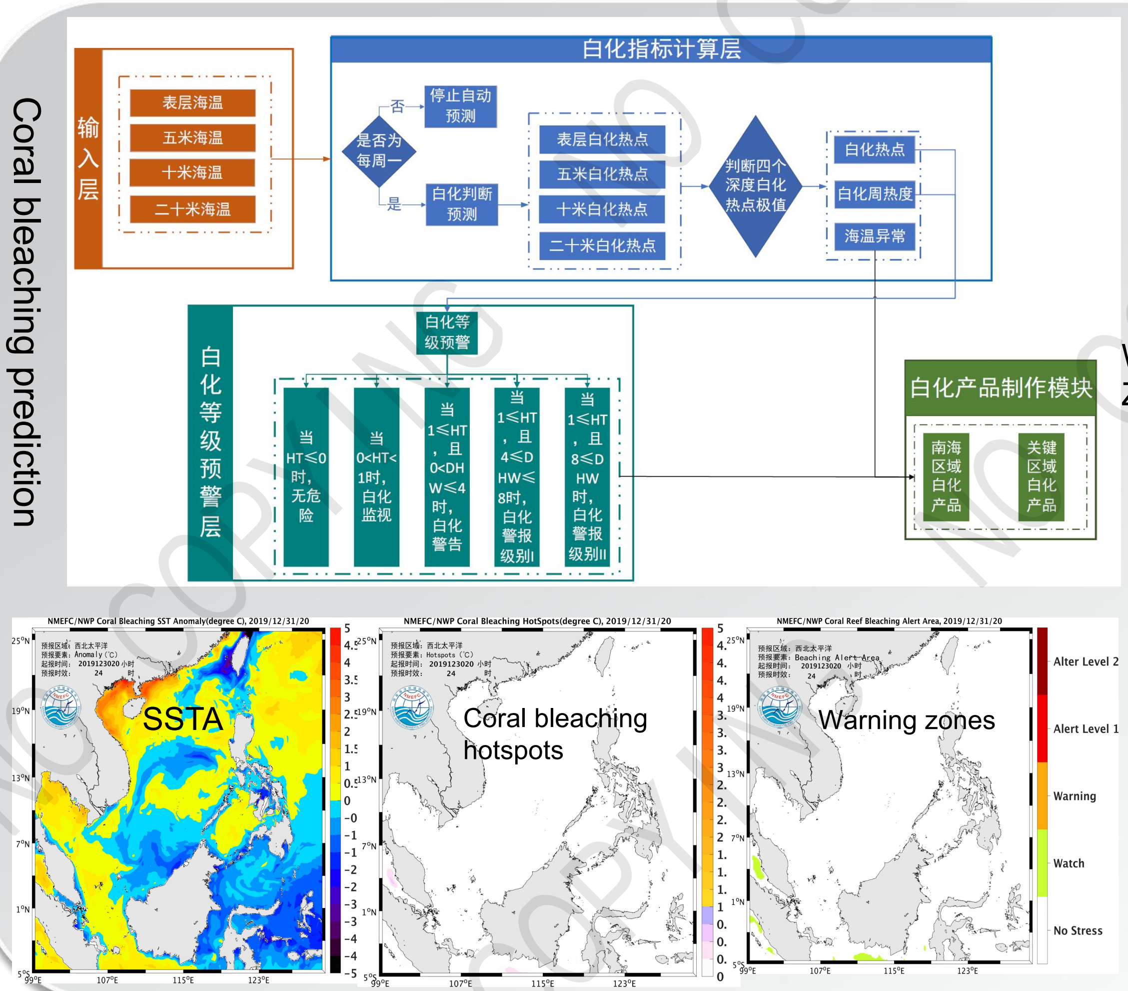
$$\frac{dy}{dt} = R_1 \times v_{cy}(x,y,t) + R_2 \times v_{wy}(x,y,t) \times \sin(\theta - \beta)$$

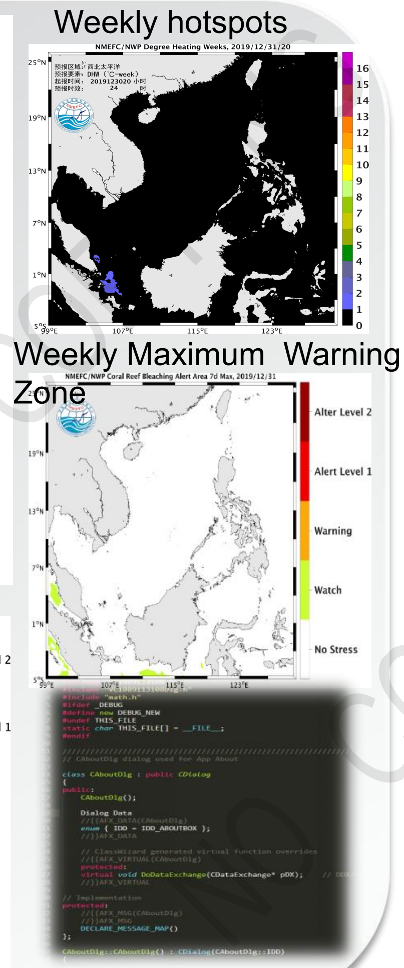
$$\frac{dBio}{dt} = G \times Bio - D \times Bio \qquad G = G_{max} \times f_G(T) \times f(I) \times f(N,P) \qquad D = D_{max} \times f_D(T)$$

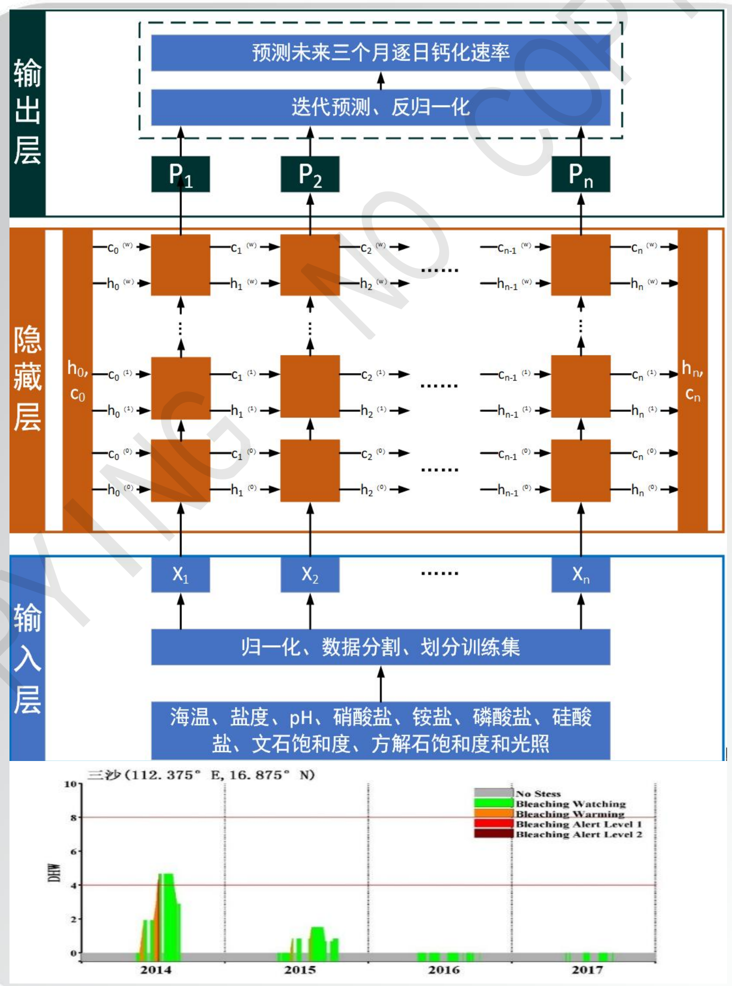
Application Case: Coral Bleaching and Calcification Rates

Based on LSTM deep learning, using ten key elements including sea temperature, salinity, seawater pH, aragonite saturation, and calcite saturation, predictions were conducted for coral bleaching hotspots and coral reef calcification rates.

Coral bleaching prediction







Calcification Rate Prediction

Thank you for watching!