DRAGONESS WP4- Ocean and coastal information products and services
Activity Report on

Assessment of current status on the ocean and coastal information products and services in China

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Contents

I. Introduction of the marine environment forecast products and service in China

➢ The administrative infrastructure of the marine environment forecasting systems

- **The State Ocean Administration of China (SOA)** is responsible for the marine environment forecasting.
- **China Meteorological Agency (CMA)** also has the marine forecast service.
- The national marine disaster forewarning system is organized by **all levels of the local governments** to monitor or observe marine disasters, and to issue disaster warning or the disaster prevention activities.

- **The SOA** is an administrative agency under the **Ministry of Land and Resources of People's Republic of China (P.R.C.)** in charge of the supervision and management of sea area and marine environmental protection, survey of national maritime rights and interests (according to laws and regulations.) It also brings out and organizes marine technological research.

Introduction of the marine environment forecast products and service in China

➢ China marine environment forecast system

China marine environment forecast system consists of:

- National Marine Environment Forecasting Center (NMEFC) (National Marine Environment Forecasting Station),
- Qingdao marine environment forecast stations,
- Shanghai marine environment forecast stations,
- Guangzhou marine environment forecast stations,
- Hainan Province marine forecasting station.

• **NMEFC** is the national marine forecasting center confirmed by IOC, WMO and IGOSS, and it undertakes marine environment forecast services of the **northwest Pacific Ocean and the China seas** assigned by the international organizations and the Chinese government.

• **Qingdao, Shanghai, Guangzhou marine environment forecast centers** are responsible for **Bohai Sea, Yellow Sea, East China Sea and the east part of South China Sea**.

• **Hainan Province marine forecast center** is responsible for the **west part of the South China Sea**.

•The **central ocean observing stations or the sea stations** are responsible for marine environment parameter forecasting service around the station areas.

Introduction of the marine environment forecast products and service in China

- **Data used for ocean information products**

  - The **data used for ocean information products** come from:
    - the international voluntary ships (GTS data)
    - the domestic ships
    - the coastal observation stations
    - buoys and the remote sensing.

  - All these data have been transferred by the global communication system (GTS), the post and telecommunication network, the ocean data transmission network, the satellite communication network and some special transmission networks.

Introduction of the marine environment forecast products and service in China

➢ Products and services

•The marine environment forecast products in China mainly include:

- •ocean waves
- •sea surface temperature
- •storm surge
- •sea ice
- •tide, tidal current
- •ship best route selection
- …

•The wave forecast is a short-term forecast item in China Seas and the northwest Pacific Ocean which is disseminated every day regularly over television and etc. The Sea surface temperature (SST) changes quite slowly and the SST forecasting products are provided in every ten days. The storm surge forecast mainly gives storm surge news, the warning and the urgent alarming; Sea ice forecast provides information or warning in a ten-day period or monthly regularly in winter.

II. Oceanic research and numerical modeling by different institutions in China

1. Tides and tidal currents

NMDIS (National Marine Data and Information Service) manages the tide data recorded from the tidal stations along Chinese coast and is in charge of the tidal prediction and tidal current analysis.

SOA maintains the Chinese sea level monitoring station networks.

Oceanic research and numerical modeling by different institutions in China
Tide and tidal current

Theoretical Progress in tidal prediction:

- Fang Guohong et al. (1981) and Wang Ji et al. (1981)proposed the **shallow water harbor tidal prediction method** respectively;

- Wang Ji (1986) published the **method of tide data harmonic analysis**.

- Fang Guohong (1987) introduced the new low-pass filtering in the tidal current data analysis.
- Xiu Richen (1987) proposed the permanent forecast method of tidal current field.
- Xu Yanguang (1989) proposed the harmonic analysis method for the tidal current data with non-uniform sampling.

- Chen Manchun et al. (2006) modified the methods proposed by Fang Guohong et al. (1981) and Wang Ji et al. (2001) respectively by **adding different harmonious terms**, and the results have been verified by in situ data. This method has been used by NMDIS to compile the harbor tide table in 2006.

Oceanic research and numerical modeling by different institutions in China
Tide and tidal current

Theoretical Progress in tidal prediction:

表 5 成山角港误差统计表

使用资料年份	预报年份	方法	极值预报误差比较							
			高潮时均方差/min	高潮高均方差/cm	低潮时均方差/min	低潮高均方差/cm	高潮时误差大于30 min的频率(%)	高潮高误差大于30 cm的频率(%)	低潮时误差大于30 min的频率(%)	低潮高误差大于30 cm的频率(%)
1990	1991	调和法	41.3	13.0	12.0	12.0	14	4	2	3
		方案Ⅰ	25.9	13.0	11.8	12.0	10	4	3	3
		方案Ⅱ	26.9	13.0	12.3	12.0	10	4	2	3
1990	1992	调和法	38.0	13.0	13.2	13.0	14	5	3	5
		方案Ⅰ	24.3	13.0	13.2	13.0	11	4	3	5
		方案Ⅱ	27.3	13.0	12.1	13.0	11	5	2	5
1990	1993	调和法	40.2	13.0	13.7	13.0	14	5	3	6
		方案Ⅰ	26.4	13.0	12.5	13.0	10	5	2	6
		方案Ⅱ	26.4	13.0	11.8	13.0	10	5	3	6
1990	1994	调和法	39.1	13.0	13.2	12.0	12	5	2	3
		方案Ⅰ	27.5	13.0	14.7	13.0	9	5	4	3
		方案Ⅱ	29.4	13.0	14.0	13.0	10	5	3	4
1990	1995	调和法	34.8	13.0	12.6	13.0	13	4	2	4
		方案Ⅰ	22.1	13.0	15.8	13.0	8	4	3	4
		方案Ⅱ	21.9	13.0	13.5	13.0	8	3	2	3
1990	1996	调和法	39.2	13.0	13.4	13.0	13	6	3	6
		方案Ⅰ	25.7	13.0	13.4	13.1	10	5	3	5
		方案Ⅱ	25.2	13.0	12.8	13.0	9	6	3	6
1990	1997	调和法	36.7	12.0	13.3	12.0	12	5	4	4
		方案Ⅰ	21.9	12.0	13.4	13.0	8	5	3	5
		方案Ⅱ	22.3	12.0	12.8	12.0	8	5	3	4
1990	1998	调和法	40.1	13.0	12.9	13.0	14	5	3	4
		方案Ⅰ	20.7	13.0	12.7	13.0	9	5	3	4

续表 5

使用资料年份	预报年份	方法	极值预报误差比较							
			高潮时均方差/min	高潮高均方差/cm	低潮时均方差/min	低潮高均方差/cm	高潮时误差大于30 min的频率(%)	高潮高误差大于30 cm的频率(%)	低潮时误差大于30 min的频率(%)	低潮高误差大于30 cm的频率(%)
		方案Ⅱ	24.1	13.0	12.3	13.0	8	4	2	4
1990	1999	调和法	43.6	13.0	12.3	13.0	15	5	2	5
		方案Ⅰ	22.2	13.0	13.7	13.0	7	5	2	5
		方案Ⅱ	25.2	13.0	11.6	13.0	8	5	1	5
1990	2000	调和法	40.1	13.0	13.5	12.0	13	5	3	5
		方案Ⅰ	25.4	12.0	13.0	13.0	9	4	2	5
		方案Ⅱ	26.3	12.0	12.3	13.0	8	5	2	5
1990	2001	调和法	40.1	12.0	16.3	12.0	14	4	5	5
		方案Ⅰ	29.0	12.0	18.4	12.0	11	5	5	5
		方案Ⅱ	30.6	12.0	16.8	12.0	11	4	4	4
1990	2002	调和法	43.3	13.0	16.4	13.0	16	6	4	6
		方案Ⅰ	31.6	13.0	16.7	13.0	12	6	5	5
		方案Ⅱ	33.2	13.0	16.0	13.0	13	6	4	6

Chen et. al. 2006

Oceanic research and numerical modeling by different institutions in China
Tide and tidal current

Modeling Progress in tidal current prediction:

- The tidal current numerical model was mainly **two-dimensional before 1986**.
- Yu Kezun (1986) proposed a 3-dimensional tidal current numerical model for the Bohai Sea.
- Tang Yuxiang (1986, 1987) studied the **interaction between tidal current and the tidal residual current**
- Feng Shizuo (1986, 1987, 1988) proposed a **weak nonlinearity theory** related to the tidal Lagrange residual flow and its transportation, and calculated the Lagrange residual flow field in Bohai Sea.
- Fang Guohong (1986) calculated the tidal current in China Seas.
- Zhao Baoren et al. (1994) **simulated the tidal current** in Bohai Sea, Yellow Sea and the East China Sea numerically.
- Zhou Huamin et al.(2005) calculated the tidal wave systems in Bohai Sea after considering the **different tidal constituent interaction and sea bottom frictional** influence, and the result showed a good agreement with in situ data.
- The North Sea forecasting center of State Oceanic Administration developed a three dimensional ocean current numerical model and the forecast service application system for the Bohai Sea tidal current forecasting (Zhang Yongmei et al.,2005).

Oceanic research and numerical modeling by different institutions in China
Tide and tidal current

Modeling Progress in tidal current prediction:

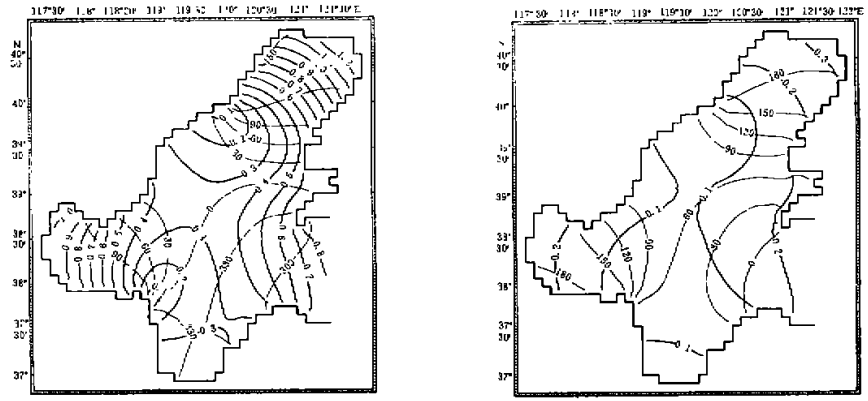

图3 渤海M_2分潮同潮图

图4 渤海S_2分潮同潮图

Dou et. al. 1993

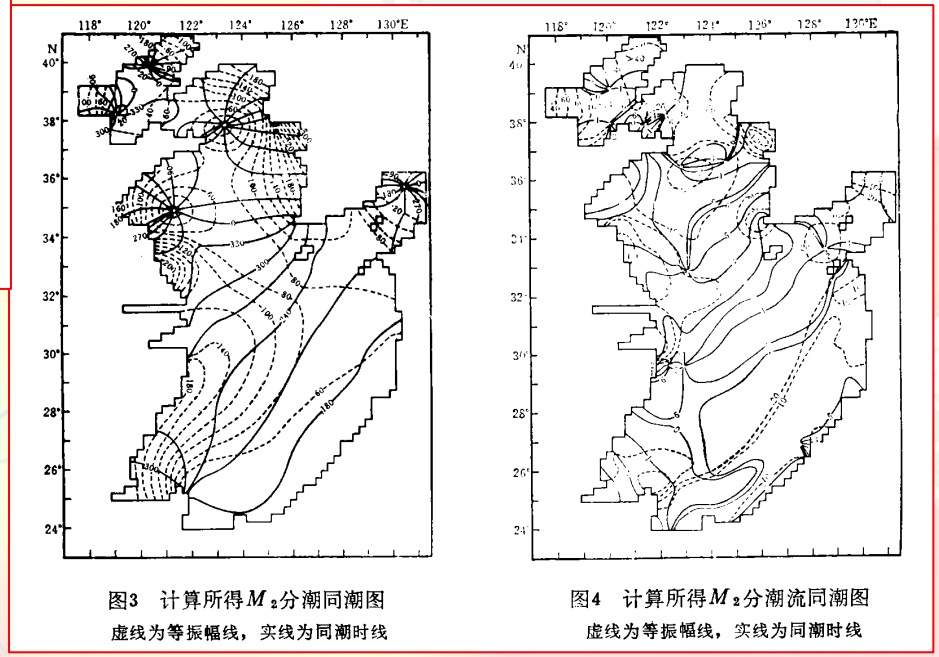

图3 计算所得M_2分潮同潮图
虚线为等振幅线，实线为同潮时线

图4 计算所得M_2分潮流同潮图
虚线为等振幅线，实线为同潮时线

Zhao et. al. 1994

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Oceanic research and numerical modeling by different institutions in China

Ocean Waves

2. Ocean waves

The ocean wave forecasting service was **started in the late-1980s** in China, and the forecasting services in **China seas and the northwest Pacific Ocean** have been broadcasted in television and broadcasting stations everyday.

The ocean wave forecasting service system has been established in **NMEFC**, which includes the ocean wave information acquisition system, the ocean wave analysis, the forecast technology supporting system and the wave forecast service system.

Until the late-1980s, the **wave frequency spectrum model and the significant wave theory** have been mainly used in ocean wave forecasting in China, which includes the ocean wave frequency spectrum proposed by Wen Shengchang et al. (1994), Sverdrup-Munk-Bretshneder (SMB) method based on **the significant wave theory and in situ observation database**, and the computational method by Wilson and Walden.

From the late 1980s, NMEFC started to run wave prediction model **MRI** from Japan (the first generation wave model), **BMO model** from British (the second generation model of ocean wave) and **WAM model** (the third generation wave model) respectively and carried out model inter-comparisons.

Oceanic research and numerical modeling by different institutions in China
Ocean Waves

The main progress in the ocean wave numerical model development

- Wen Shengchang et al. (1994,1999) from Ocean University of China (OUC) proposed a new **hybrid ocean wave numerical model** on the research basis of the ocean wave numerical model project carried out in the national 7th-5year and 8th-5year science and technology programs from 1985 to 1995.

  - This model was based on the energy equation of the **significant waves and the relationship of wind wave growth**. Therefore, this model was also named as Wave Energy Numerical Model (WEN model).

  - This model has been verified in many kinds of weather conditions for the ocean wave forecasting and hind-casting, and is now running in both national and local marine forecasting centers operationally.

Oceanic research and numerical modeling by different institutions in China
Ocean Waves

- Yuan Yeli et al (1992) in the First Institute of Oceanography of SOA developed a new third generation wave model called **LAGFD-WAM** which was based on the WAM model with modification of the source function in wave energy diffusion.
  - The empirical **energy diffusion function** in the WAM model was replaced by the theoretical equation proposed by Yuan Yeli. The modification improved the model result especially in high sea states.
  - The **wave-current interaction** was also considered in the model including uneven and un-steady current especially. This model has been widely used in ocean engineering and ocean environmental parameter computation in China.

- A global wave numerical model in spherical coordinates, **MASNUM**, was developed based on the LAGFD-WAM model by Yang Yongzeng et al. (2005) in order to evaluate the **wave-induced mixing** in the upper ocean and the impact of surface waves on ocean-atmosphere fluxes.

- Another ocean wave model, **YE-WAM**, was developed by Yin et al. (1996) in the institute of oceanography of CAS, with **wave breaking diffusion** due to depth effect in **shallow water** considered. This model gave good result especially for shallow waters.

Oceanic research and numerical modeling by different institutions in China
Ocean Waves

The main progress in the ocean wave numerical model development

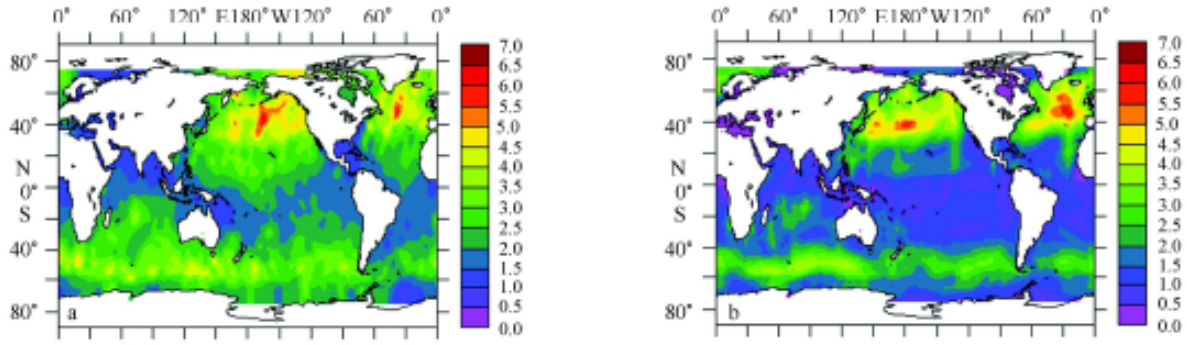


图 3　1 月月平均有效波高 T/ P 数据(a)与模拟数据(b)对比(单位:m)

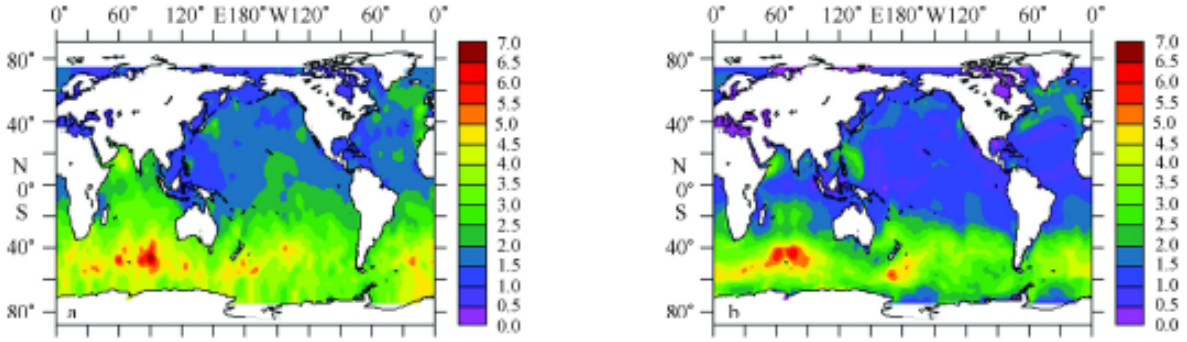


图 4　7 月月平均有效波高 T/ P 数据(a)与模拟数据(b)对比(单位:m)

Yang et al. (2005)

Oceanic research and numerical modeling by different institutions in China
Ocean Waves

The main progress in the ocean wave numerical model development

- For the **global ocean wave operational numerical forecasting**, China is still at the starting stage. Wen Bin et al. (2007), working at the hydrological and meteorological center of the general staff of PLA, has carried out the global ocean wave forecasting experiment based on the **WaveWatch III model** modified by improving the control equations, the program structure and the numerical and physical processing method after the wave-current interaction and wind wave physical mechanism are considered more reasonably. All these modifications improved the model performance and efficiency. One-month global ocean wave forecasting experiment showed that the correlation coefficient of the significant wave height between the model result and satellite altimeter data is greater than 0.9.

Oceanic research and numerical modeling by different institutions in China
Ocean Waves

The main progress in the ocean wave numerical model development

global ocean wave operational numerical forecasting

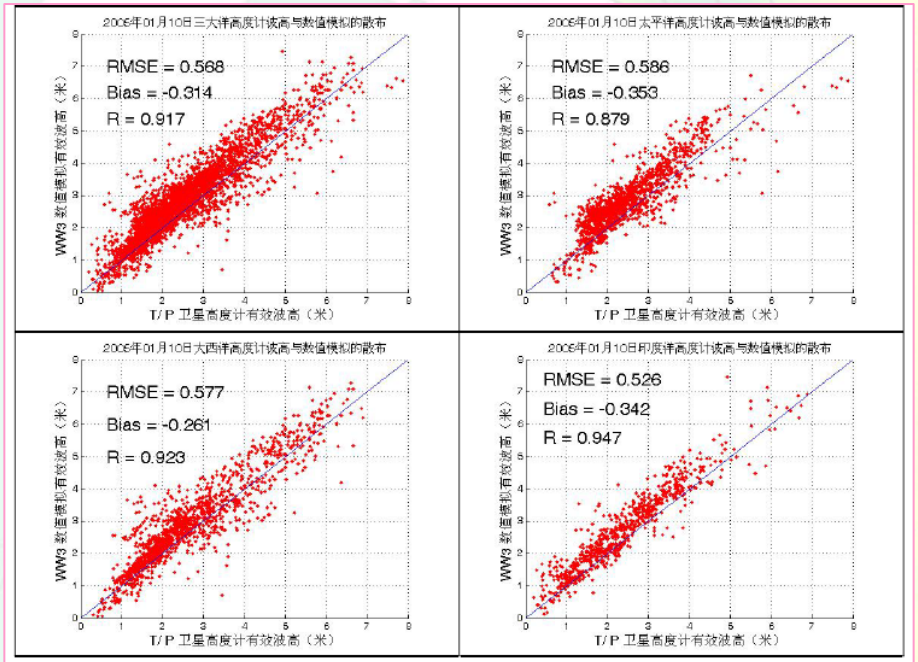
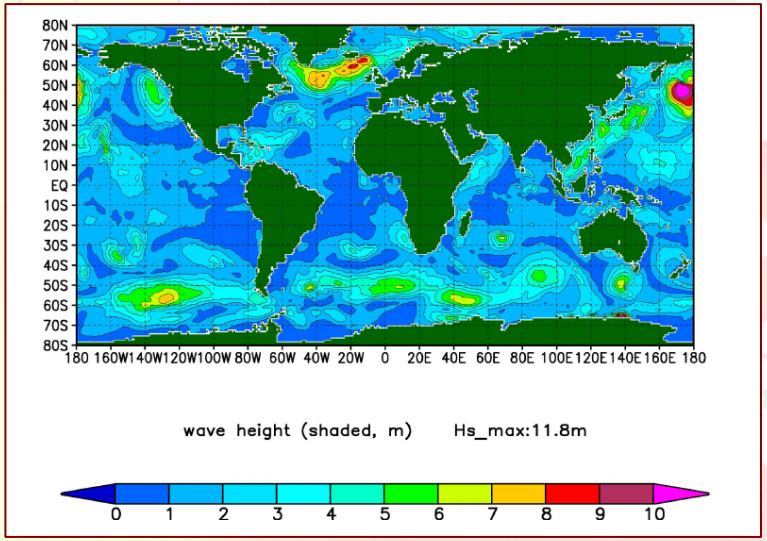


图 4.10　2005 年 01 月 10 日高度计有效波高和模式结果的比较



Wen et al. (2005)

Wen et al. (2007)

Oceanic research and numerical modeling by different institutions in China
Ocean Waves

The **main national projects** involved in the ocean wave research

- The main research of the ocean wave numerical forecasting was carried out in the national key projects entitled “Marine Environmental Numerical Forecasting” in the national 7th-5year science and technology program,

- “the catastrophe marine environment numerical forecasting and the key technology researches in the offshore environment” in the national 8 th -5year science and technology program and

- “the marine environment forecast and the disaster reduction technology research” in the national 10 th -5year science and technology program.

- Currently, we are carrying out the **national 11th -5year science and technology supporting program (2005-2010)** with the project entitled “the severe marine disaster early warning and the emergency technology research”. In this project, we are launching the research on the offshore severe marine disaster early warning technology (OUC), the key technology study of the Tsunami early warning, the marine climate variation, **the global wave forecasting technology**, and the marine disaster accident emergency and forecasting technology (NMEFC).

Oceanic research and numerical modeling by different institutions in China

3. 3-D marine environmental parameter profile simulation and forecasting

The sea surface temperature (SST) analysis and forecasting service can be divided into:

- the SST rapid report (in a near-real time),
- the SST average report (SST data analysis) and
- the SST forecast report (forecast model).

SST forecasting methods include:

- the empirical forecasting method,
- the mathematical-statistical method and
- the numerical forecasting method.

Oceanic research and numerical modeling by different institutions in China
3-D marine environmental parameter profile simulation and forecasting

Descriptions of SST forecasting

➢**The SST empirical forecasting** is based on SST's continuity, periodic, similarity and its relationship to other parameters.

➢**The mathematical-statistical forecasting method** is based on several mathematical-statistical forecasting equations established by Ocean University of China and NMEFC respectively, which includes period analysis (harmonic analysis, spectrum analysis, variance analysis and etc.), time series forecasting model, correlation forecasting (regression analysis or stepwise regression analysis model), and EOF (Empirical orthogonal function) analysis. The mathematical-statistic forecasting is simpler than the numerical forecasting method in computation, and it was the main SST forecasting method before the late-1980s.

➢**The SST numerical forecasting method** was mainly developed in the 1980s under the support of the national 7th-5year science and technology program with the project entitled "Marine environment numerical forecasting research" coordinated jointly by NMEFC and OUC. The model included the anomaly model and the mixed-layer model. Both the contribution of ocean current transportation to the thermal equilibrium and the detailed physical processes in the upper mixed layers were considered in the mixed-layer model.

Oceanic research and numerical modeling by different institutions in China
3-D marine environmental parameter profile simulation and forecasting

Forecasting Models

- The **three-dimensional ocean numerical model** for China Seas was developed by NMEFC in 2004 based on the **Bohai 3-dimensional ocean model** supported by the national 10th-5year science and technology program. The model covers 10-45N, 103-145E with a spatial resolution of 1/12ºx1/12º, and the sigma coordinate is used in the vertical direction with 21 layers. The initial field was provided by the WOD global dataset.

- At the same time, NMEFC developed a **3-dimensional ocean numerical model for Taiwan and its adjacent areas** with a resolution of (1/30ºx1/30º) and 21 layers in vertical direction (sigma coordination) on the basis of the Princeton ocean model (POM) model.

- In 2004, NMEFC, jointly with the Shanghai Typhoon Research Institute, started to develop **ocean-atmospheric coupling model based on the MM5v3 atmospheric model and the POM ocean model** and the in-situ data (buoy data, telemetry data and remote sensing data) was used to verify model outputs.

- Jointly with Ocean University of China, NMEFC carried out the **3-dimensional ocean assimilation research** and related experiments and in 2004 successfully established the **temperature vertical structural model and a three dimensional assimilation system**.

Oceanic research and numerical modeling by different institutions in China
3-D marine environmental parameter profile simulation and forecasting

Recent Progress in Theories and Models

- The SST simulation could be greatly improved after the effect of **ocean mixing** caused by waves in the ocean-atmosphere coupling process is considered.

- Qiao Fangli et al. (2004)(The first Institute of Oceanology, SOA) established **ocean wave-circulation theory and developed ocean wave-circulation coupling model** to improve the simulation and predictive ability of upper layer ocean. In this model, wave mixing process has been expressed as the form of ocean wave directional spectrum which could be computed directly. This result has been embedded into the POM model and a series of experiments show that simulation results in China seas or global ocean have been greatly improved in solving the problem of non-consistencies between the simulation and field observation in the upper ocean layers. The correlation coefficient between the simulation and field observations has been improved 30% compared with ordinary numerical simulations.

- Qiao Fangli et al.(2004) further analyzed the physical processes that affect the vertical mixing, and discussed the **effect of ocean waves and tidal current** movements on the temperature vertical structure. The simulated results show that the temperature vertical structure in Yellow Sea and East China Sea is consistent with in situ observation after both ocean wave mixing and tidal current mixing are considered in numerical models.

- The follow-on researches also showed that **ocean wave mixing and tidal current mixing** should be considered in 3-dimensional ocean simulation and both of these two mixing processes will improve the capability and accuracy of numerical forecasting model.

- Song Zhenya et al.(2007) analyzed the 50-year simulated SST average and also found that the **atmospheric-ocean waves-circulation coupling numerical model** could resolve the problems of the simulated SST and that the coupling model is more reasonable for SST simulation.

Oceanic research and numerical modeling by different institutions in China
3-D marine environmental parameter profile simulation and forecasting

Recent Progress in Theories and Models

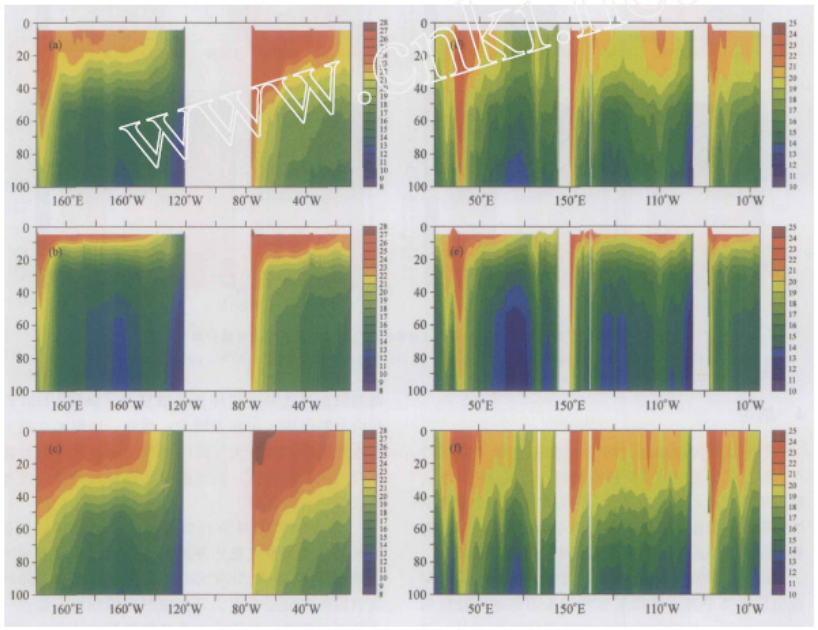


图 11 Levitus 资料断面温度分布与数值模拟结果的比较

(a) 7 月沿 35°N 海浪-环流耦合模式结果；(b) 7 月沿 35°N 非耦合模式结果；(c) 7 月沿 35°N Levitus 资料结果；
(d) 1 月沿 35°S 海浪-环流耦合模式结果；(e) 1 月沿 35°S 非耦合模式结果；(f) 1 月沿 35°S Levitus 资料结果

Yuan et al. (2006)

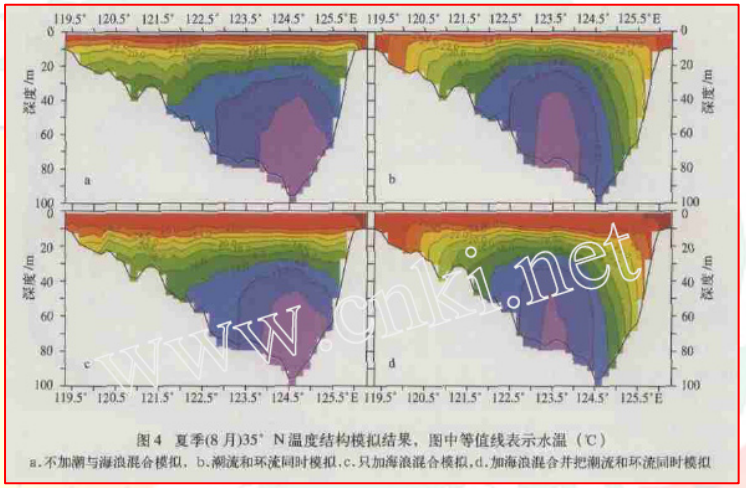


图 4 夏季(8 月)35° N 温度结构模拟结果，图中等值线表示水温 (℃)
a.不加潮与海浪混合模拟，b.潮流和环流同时模拟.c.只加海浪混合模拟,d.加海浪混合并把潮流和环流同时模拟

Hu et al. (2004)

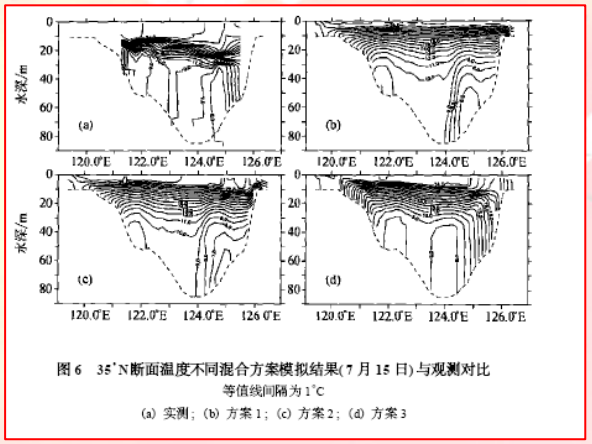


图 6 35°N断面温度不同混合方案模拟结果(7 月 15 日)与观测对比
等值线间隔为 1°C
(a) 实测；(b) 方案 1；(c) 方案 2；(d) 方案 3

Qiao et al. (2004)

Oceanic research and numerical modeling by different institutions in China
3-D marine environmental parameter profile simulation and forecasting

Assimilation methods in simulation

- In recent years, all kinds of assimilation methods have been used in ocean simulation and forecasting processes in China: Nudging, Filters, Variation methods……

Examples

- Zhu Jiang et al.(2007) established **a general ocean data assimilation system**, based on the three dimensional variation method, which can be used to **assimilate in situ temperature/salinity data and altimeter data**. The temperature and salinity fields will be modified after the altimeter data is assimilated in this assimilation system. This system might also **assimilate ARGO buoy data and other in situ data**. The assimilated results show that the monthly average error of temperature and salinity in the upper ocean above 420 m are 0.63℃ and 0.34 psu respectively. It seems that assimilation techniques could greatly improve ocean simulation and forecasting.

- Zhao Qian et al. (2005, OUC) used the **Nudging assimilation** method to simulate 3-D temperature field in Bohai Sea, Yellow Sea, East China Seas based on NASA high resolution satellite SST data. The rms error at 3 test station gives 1.307, 0.526, and 0.744 respectively while the rms error using heat-flux data to simulate SST gives 2.160, 0.979, and 1.330 respectively. Although only SST is assimilated in their study, 3 dimensional temperature fields will be affected at the same time.

Oceanic research and numerical modeling by different institutions in China
3-D marine environmental parameter profile simulation and forecasting

Assimilation methods in simulation

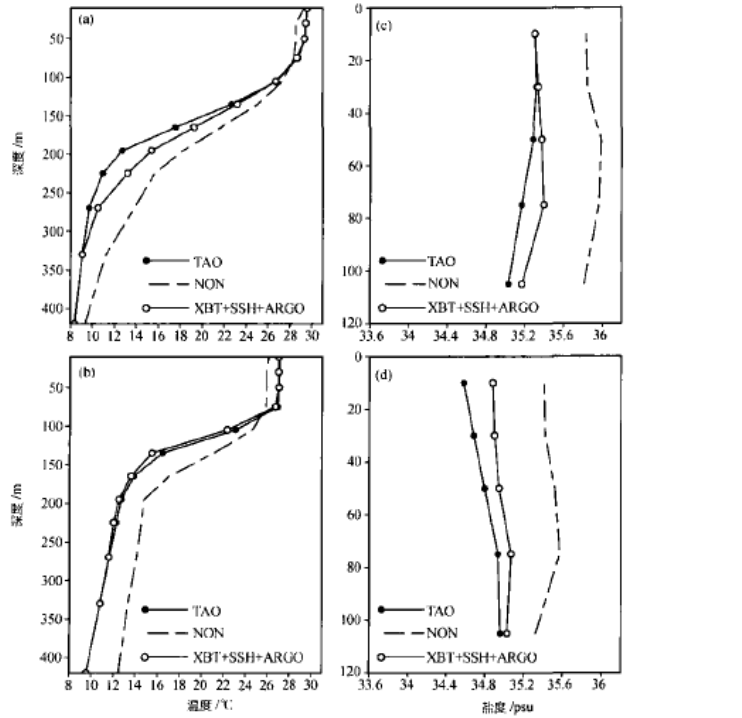


图 6 试验结果与独立的 TAO 资料的垂直温盐廓线

(a) 2001-07 的温度点(156°E, 5°N); (b) 2001-07 的温度点(140°W, 2°S); (c) 2001-11 的盐度点(95°W, 8°S); (d) 2001-11 的盐度点(95°W, 0°N)

Zhu et al. (2007)

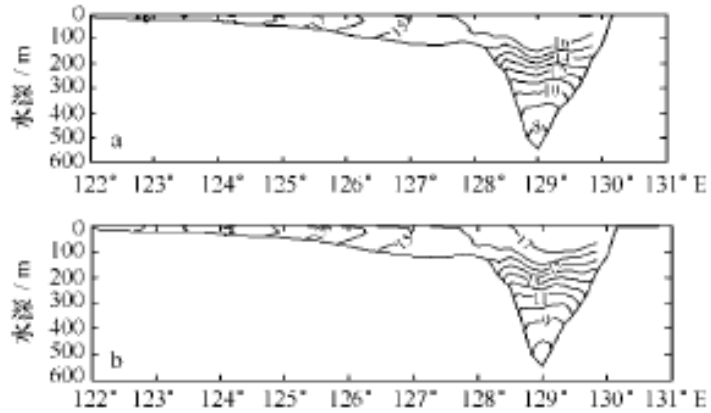


图 7 32°N断面温度的分布

a 气候平均值模拟结果, b 遥感资料同化结果

Zhao et al. (2007)

Oceanic research and numerical modeling by different institutions in China

4. Storm surge forecasting

Begin in 1980s

The National marine environment forecasting station developed a typhoon-related storm surge numerical forecasting model and applied the numerical model scheme to coastal areas. Furthermore, five mutually nesting numerical forecasting sub-models were developed, and the models could output the storm surge level and the maximum sea level at each grid in China Seas.

In the **national 7th-5year key science and technology program**, the typhoon storm surge forecasting had been carried out in China. **The Institute of Oceanology of CAS**, **South Institute of Oceanology of CAS**, **Xiamen Univ**., **Zhongshan University**, and **Ocean University of China** have been undertaking researches on the storm surge numerical forecasting in China seas.

2000-2005

The operational ocean environment forecasting and disaster reduction technology have been carried out in the national 10th-5year key science and technology program. This project had established **wind storm surge – ocean wave coupling model** with high resolution in tropical ocean, and also had built the **wind storm surge floodplain numerical model**. **The operational wind storm surge numerical forecasting service** was started in 2003 for the temperate zone.

Oceanic research and numerical modeling by different institutions in China
Storm surge forecasting

In recent years, China has made great progress in the coastal storm surge real-time monitoring and forecasting systems.

Surge Forecasting System in National Center of Ocean Technology in Tianjin

Project entitled "The research of coastal wind storm surge real-time monitoring and forecasting and application"

(1) development of the tide and wind speed / direction real-time monitoring facilities. This system can operate automatically.
(2) Establishment of the wireless data transmission network at ultra-short waveband.
(3) Establishment of the system for the monitoring data transmission and real-time service data updating. The whole system monitors the hydro-meteorological parameters along Tianjin coast in real time.
(4) development of the real-time monitoring software, the network operation software, the visualization software, the tidal analysis and forecasting software, the short-term storm surge analysis and forecasting software, and all kinds of graphs drawing software.
(5) This project had also established an information service system which can carry out data sampling, data processing, astronomical tide prediction and storm surge forecasting

Oceanic research and numerical modeling by different institutions in China
Storm surge forecasting

In recent years, China has made great progress in the coastal storm surge real-time monitoring and forecasting systems.

Surge Forecasting System in Shanghai Marine Environment Forecasting Station

Objectives: storm surge early-warning and forecasting

The system includes three sub-modules:

- the expert reasoning subsystem,
- the statistical empirical forecasting subsystem and
- the numerical modeling subsystem.

Performance: The average errors for high water level in 24hr and 48hr are 17cm and 23cm respectively, and the time difference for high water level is 9min which appears to be of the same accuracy as the international forecasting systems.

Oceanic research and numerical modeling by different institutions in China
Storm surge forecasting

In recent years, China has made great progress in the coastal storm surge real-time monitoring and forecasting systems.

Surge Forecasting System in NMEFC

NMEFC has developed a **high resolution typhoon storm surge numerical model with nesting techniques**. The main improvement lies in model horizontal resolution and the grid nesting techniques which avoid the boundary extraneous wave and enhance the model stability. The model has a **3.7km resolution** and was **running operationally** from 2003 and since then more than 11 typhoon surges had been simulated. The relative error is less than 30% at 70% of the observation stations. The storm surge numerical model plays an important role in typhoon disaster forecasting.

Oceanic research and numerical modeling by different institutions in China
Storm surge forecasting

Recent improvements

It should be noted that the ocean wave forecasting and storm surge forecasting are usually done separately. As a matter of fact, both ocean wave and storm surge are generated by wind, therefore, the wave and the surge may have interaction to each other.

Yin et al (2006) established a coastal high resolution (2'×2') two-way **coupled wave-tide-surge model** based on the third generation ocean wave model and tidal storm surge model, including three main physical mechanisms:

- The wind stress associated with ocean wave state,
- The bottom stress and
- The radiation stress related with wave-current interaction.

The comprehensive effects of three main physical mechanisms show positive net impact on seal level and increase it by as much as 25 cm. The results also show that the wave heights and sea levels simulated by the coupled wave-tide-surge model agree better with the measured values compared to uncoupled model results, particularly for peak storm conditions. **The coupled model seems to be able to provide more accurate forecast**.

Oceanic research and numerical modeling by different institutions in China
Storm surge forecasting

Recent improvements

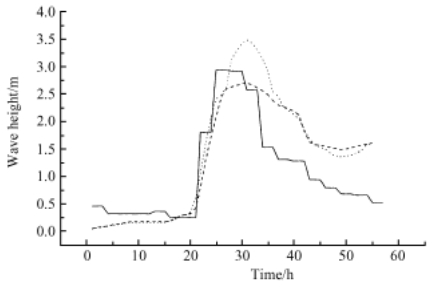


Fig. 2 Comparisons of simulated and measured wave heights for the 20UTC 22 April 1998-02UTC 25 April 1998 storms

Measured data—; uncoupled wave model---; coupled wave-tide-surge model(radiation stress mechanism)....

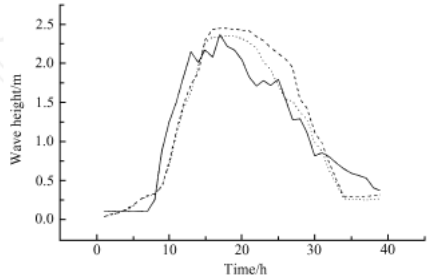


Fig. 3 As in Fig. 2, for the 00UTC 01 April 1999-14UTC 02 April 1999 storms

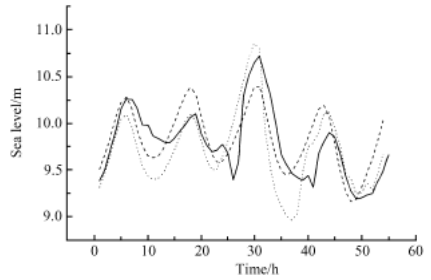


Fig. 4 Comparisons of simulated and measured sea level for the 20UTC 22 April 1998-02UTC 25 April 1998 storms

Measured data—; uncoupled tide-surge model---; coupled wave-tide-surge model(radiation stress mechanism)....

Yin et al (2006)

Oceanic research and numerical modeling by different institutions in China

5. Sea ice monitoring and forecasting

Institutions for Sea Ice Study

Several institutions in China are carrying out the research on the sea ice, such as

- NMEFC,
- National Satellite Ocean Application Service (NSOAS),
- National Marine Environment Monitoring Center (NMEMC) in Dalian,
- Tianjin Univ.,
- Dalian Univ. of Science and Technology and
- ……

➢NMEFC is in charge of **sea ice forecasting service**;
➢NMEMC owns the in situ sea ice observations and the **sea ice mechanics testing facilities**;
➢ Tianjin Univ. and Dalian Univ. of Science and Technology are carrying out some **studies mainly in the sea ice mechanics**; and
➢the Qinhuangdao central ocean station of the North Sea Branch of SOA owns the capability of the sea ice in situ **observation** and the **sea ice mechanics experiment facilities**.

Oceanic research and numerical modeling by different institutions in China
Sea ice monitoring and forecasting

Sea ice monitoring

Two main different kinds of methods

- aviation monitoring
- satellite monitoring

- The aviation monitoring is to use camera, the microwave radiometer, the side-looking radar, usually operated by the aviation group that belongs to the **North Sea Branch of SOA**.

- The satellite remote sensing monitoring is to mainly use the NOAA and the HY-1 satellite data to determine sea ice parameters such as sea ice scope, floating speed, ice category and etc.

Oceanic research and numerical modeling by different institutions in China
Sea ice monitoring and forecasting

Sea ice forecasting

The sea ice forecasting mainly includes

- the extra long-range forecasting,
- the ice growth,
- the ice ablation and
- the ice flow.

The sea ice extra long-range forecasting is mainly related to the solar activity, ENSO and its relation to the sea ice in Bohai Sea. The empirical equations for the sea ice growth and other ice parameters are mainly dependent on the sea ice generation/disappearance physical process, the moving process and the atmospheric and oceanic parameters. NMEFC has developed its own **sea ice forecasting numerical model**.

Oceanic research and numerical modeling by different institutions in China

Sea ice monitoring and forecasting

- Huang Ruiheng et al. (1991) established the satellite sea ice monitoring system for the Bohai Sea and Yellow Sea;
- Huang Ruiheng et al. (1993,1997) proposed the template matching and the sequence image computation to estimate sea ice movement;
- Liu Jianqiang et al. (1999) proposed to monitor the sea ice using Radarsat data;
- Jin Yaqiu and Huang Runheng (2001) carried out the sea ice observation in Bohai Sea using **SAR and DMSP** SSM/I data, and the microwave scattering coefficient and the polarized ratio had been used to recognize different sea ice;
- Han Suqin et al. (2005) used **MODIS data** to monitor sea ice in Bohai Sea;
- Luo Yawei et al. (2004) carried out sea ice monitoring and forecasting using **HY-1 satellite data**.

- The sea ice numerical forecasting research was started mainly from the project “marine environmental numerical forecasting research” of the national 7th-5year science and technology key program (1985-1990). Yang Shiying and Bai Shan (1991,1992) used the marine environment forecasting center developed **sea ice numerical forecasting model**, the satellite remote sensing data, and the observed data to predict the Bohai Sea winter sea ice in a quasi-operational way;
- Zhang Zhanhai et al. (1994) proposed a **Bohai Sea sea ice numerical forecasting and service system**;
- Liu Qin Zheng et al (1998) summarized China’s sea ice research;
- Wu Huiding and Li Hai (1999) proposed a sea ice dynamic-thermodynamic model for the sea ice prediction.
- Deng Bing et al (2003,2004) analyzed the Bohai Sea and Yellow Sea sea ice forecast result with a statistical method;
- Liu Qin Zheng et al (2003) analyzed the Bohai Sea sea ice properties and the numerical forecasting;
- Su Jie et. al (2003,2004,2005) published the series articles to study the sea ice-sea coupled model;
- Li Chunhua et al (2005) analyzed the Bohai Sea sea ice numerical forecasting in 2004-2005 to study the Nudging assimilation method;
- Liu Yu et al (2006) analyzed the 2005-2006 **sea ice numerical forecasting result with the PIC model**

Oceanic research and numerical modeling by different institutions in China
Sea ice monitoring and forecasting

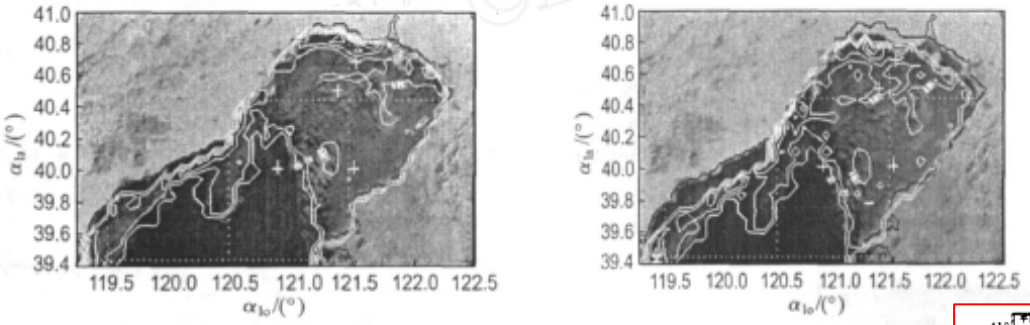


图 7 模拟的辽东湾 48 h 冰厚等值线图与卫星遥感图像对比

Fig. 7 Comparison of distributions of sea ice thickness between simulation and satellite

Wang et al. (2007)

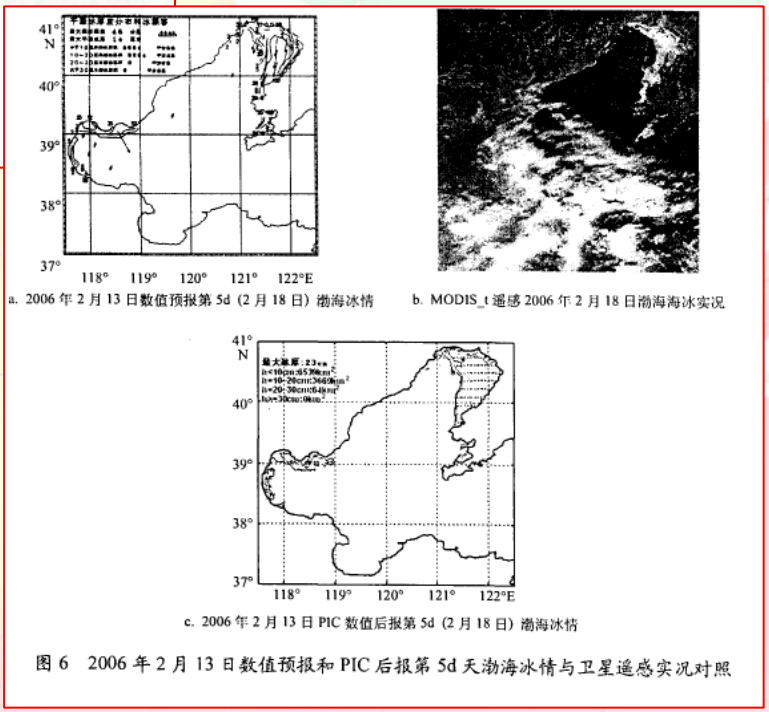


图 6 2006 年 2 月 13 日数值预报和 PIC 后报第 5d 天渤海冰情与卫星遥感实况对照

Liu et al. (2006)

Oceanic research and numerical modeling by different institutions in China

6. Red tide monitoring and forecasting

The red tide forecasting techniques may be divided into:

- the empirical analysis method,
- the probability statistical method and
- the eco-dynamic numerical model method based on the forecasting theory

The eco-dynamic numerical model is considered to be the most prospective method in red tide forecasting.

Oceanic research and numerical modeling by different institutions in China
Red tide monitoring and forecasting

The empirical analysis forecasting method is mainly based on the variations of the environment factors:
wind, rainfall, temperature, illumination and etc., the physical oceanography parameters (tide, ocean current, front, temperature and etc.), as well as the ecology factors (nutritive elements such as nitrogen, phosphorus, silicon and etc., red tide ecology characteristics like photoaxis, hastens and etc……)

The probability statistics forecasting model includes multi-variation regression statistical model and nonlinear model.

- **The multi-variation statistical method** is to analyze the variations of the environment factors during red tide processes, and to find the main environment factors of controlling the red tides to create certain discrimination equations for forecasting red tides.

- **The nonlinear method** includes neural network models and etc…

- **The data analysis method** includes principal component analysis, regression analysis, cluster analysis and etc.

The dynamical numerical model is mainly based on the mechanism of red tide occurrence, and the model simulates red tides' occurrence, development, withering processes by using the physical - chemistry - biology coupling eco-dynamic numerical model such as the nutrition dynamic model, the red tide ecological-dynamic models and etc.

Oceanic research and numerical modeling by different institutions in China
Red tide monitoring and forecasting

Many kinds of the **red tide empirical forecast methods** are proposed based on the different influencing factors of the red tide.

- Lin Zuxiang et al. (2002), from the South China Sea Branch of SOA, based on tidal variation.
- Zhao Dongzhi et al. (2004), from the National Marine Environmental Monitoring Center of SOA, based on the sea temperature information.

The red tide probability statistical method is widely used for time being.

- Deng Suqing et al (2004), from Zhejiang Univ.,
- Li Peishun et al. (2004), from the North China Sea Marine Forecasting Center of SOA, the forecasting accuracy in Yellow Sea and Bohai Sea is about 70%.

The nonlinear statistical forecasting method was proposed based on different neural networks in different institutions and universities such as

- Tianjin University (Wang Hongli et al. (2006)),
- Shanghai Jiaotong University (Yang Jianqiang et al (2003)) and etc.

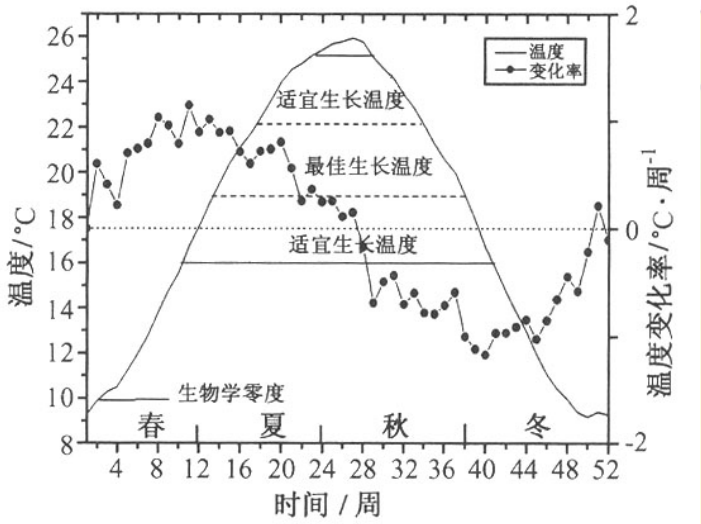


图 1　年内周均温度变化与赤潮环境温度关系

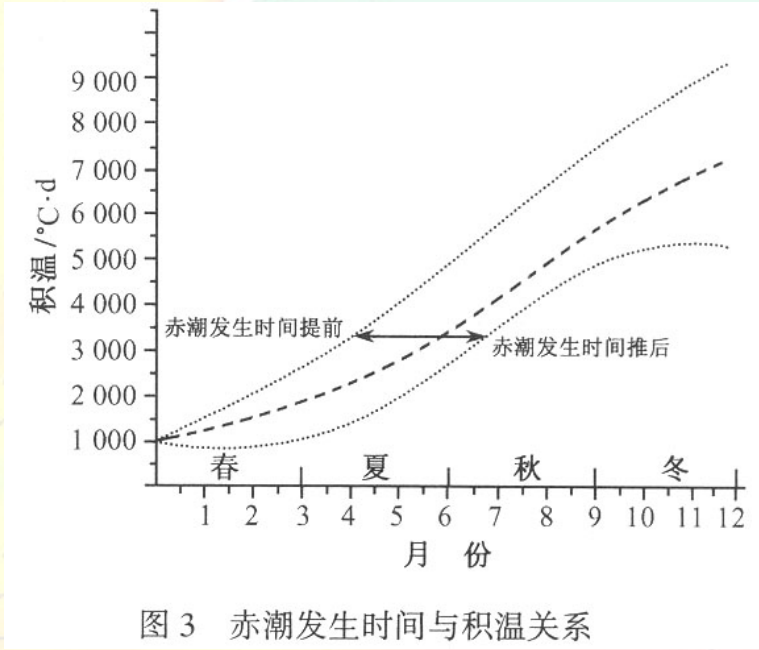


图 3　赤潮发生时间与积温关系

Zhao et al (2004)

Oceanic research and numerical modeling by different institutions in China
Red tide monitoring and forecasting

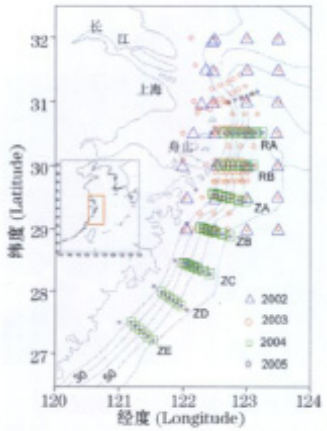


图 1 2002—2005 年各航次调查站位

Fig.1 Investigation area and stations set during the cruises from 2002 to 2005

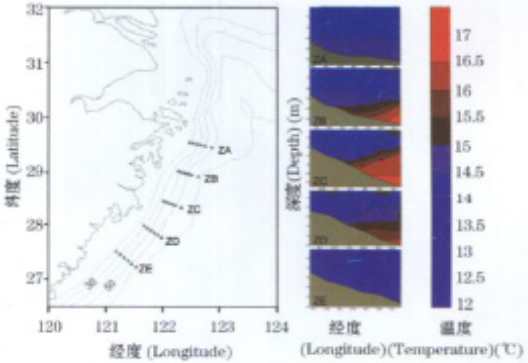


图 4 2004 年 4 月 4~6 日东海赤潮高发区暖水团的分布

Fig.4 The distribution of the warm water mass in red tide area in East China Sea during April 4–6, 2004

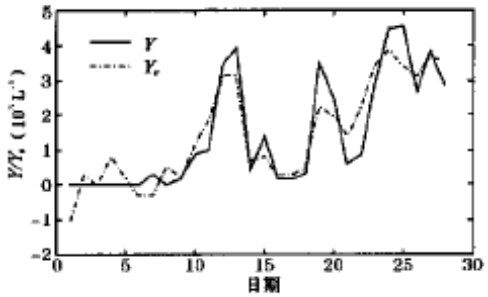


图 2 赤潮生物细胞浓度的实测值与计算值

Xie et al. (2004)

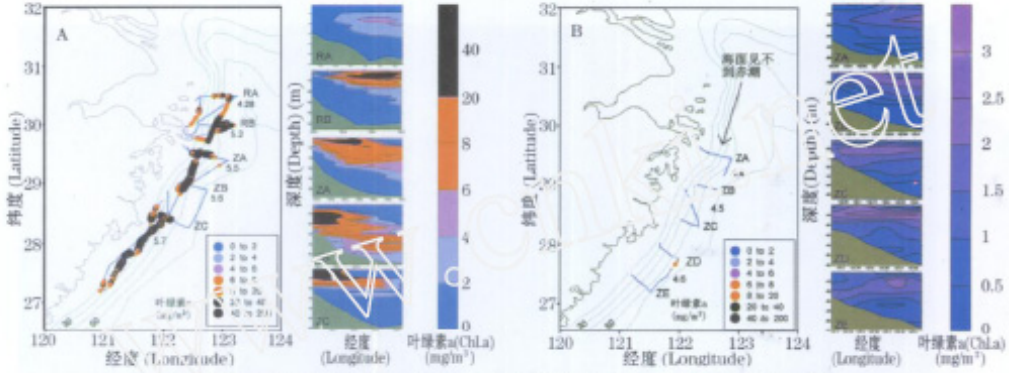


图 2 2004 年 5 月海上实测面积达到 1 万 km² 的特大规模原甲藻赤潮分布状况(A)及其于 4 月份在次表层的“孕育”过程(B)

Fig.2 Distribution of the large scale red tide caused by *Prorocentrum donghaiense* with the area around 10 000 km² in May, 2005 (A) and its developing process in April, 2005 at the subsurface layer

Zhou et al. (2006)

Oceanic research and numerical modeling by different institutions in China
Red tide monitoring and forecasting

The eco-dynamic red tide forecasting model is the **most promising method**.

- Wang Shousong et al (1997), from **Zhongshan University**, proposed the red tide nutrition dynamical model to study the red tide variation in Dapeng Bay;

- Xia Zongwan et al. (1997), from **South China Sea Branch of SOA**, proposed an ecological simulation model of red tides in Dapen Bay based on the coupling of water and ecological dynamics.

- Wang Hongli et al (2002), from **Tianjing University**, proposed a red tide eco-dynamical model in Bohai Sea;

- Qiao Fangli et al (2000), from the **first institute of oceanography of SOA**, proposed a red tide ecological dynamic model to study red tide in the Changjiang delta sea area and conducted the red tide ecological model parameter optimization.

Oceanic research and numerical modeling by different institutions in China
Red tide monitoring and forecasting

The red tide monitoring by satellite remote sensing

- Huang Weigen et al.(2004), **from the Second Institute of oceanography of SOA**, monitored the Zhejiang sea area red tides by using water color and SST variations and tracked the red tide process.

- Wang Qimao et al (2004), from the **National satellite ocean application service of SOA**, proposed to use the ratio of CCD channel 2 and channel 1 to monitor red tides in Bohai Sea and it showed the capability of the HY-1 data in red tide monitoring.

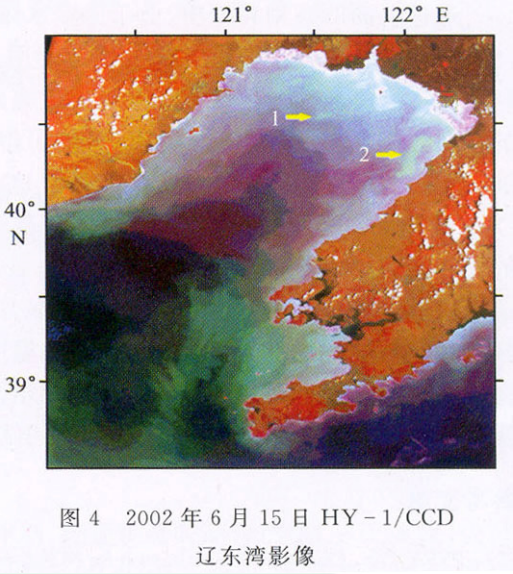


图 4 2002 年 6 月 15 日 HY－1/CCD 辽东湾影像

Wang et al. (2004)

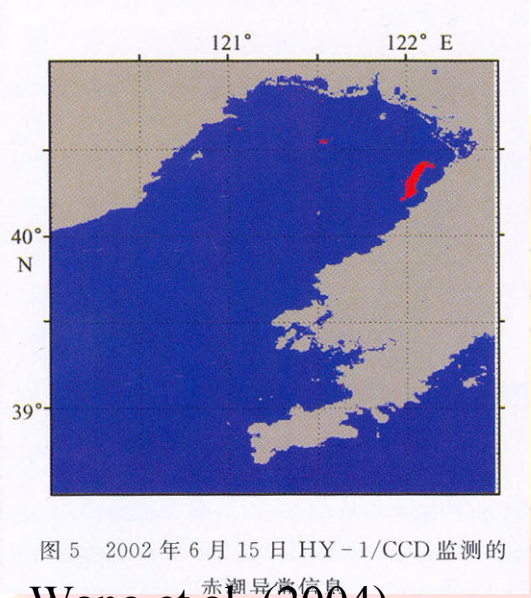


图 5 2002 年 6 月 15 日 HY－1/CCD 监测的赤潮异常信息

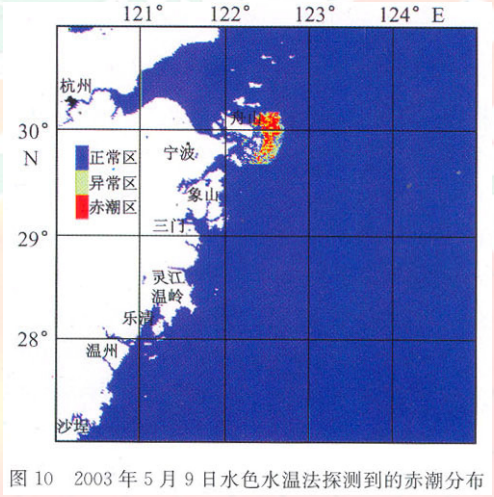


图 10 2003 年 5 月 9 日水色水温法探测到的赤潮分布

Huang et al (2004)

Oceanic research and numerical modeling by different institutions in China
Red tide monitoring and forecasting

Forecasting Capabilities

In 2004, NMEFC announced 30 forecasting reports for the red tides in China Seas, among which there are 15 reports in Yellow Sea and Bohai Sea, 13 reports in East China Sea and 5 reports in South China Sea. The correct rate is 31% for Yellow Sea and Bohai Sea and 41% for East China Sea.

In 2006, the red tide forecasting reports announced 35 red tide events in China Seas (12 in Yellow Sea and Bohai Sea, 13 in East China Sea and 10 in South China Sea).

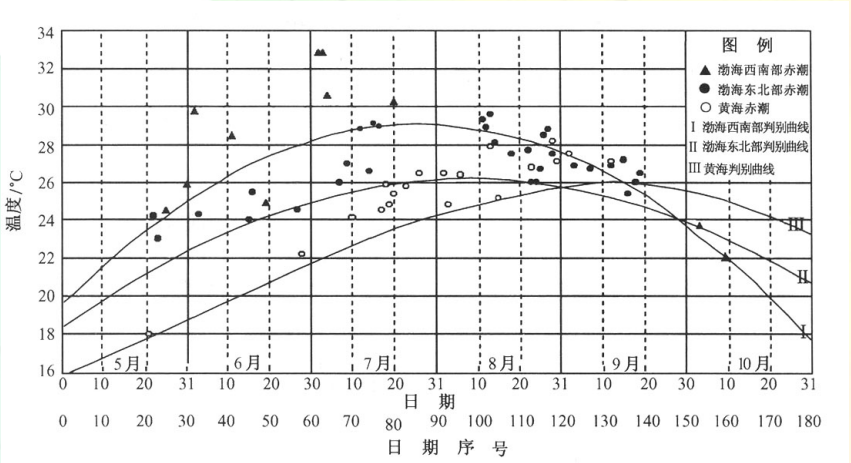


图 5 赤潮点聚及预报判别曲线图

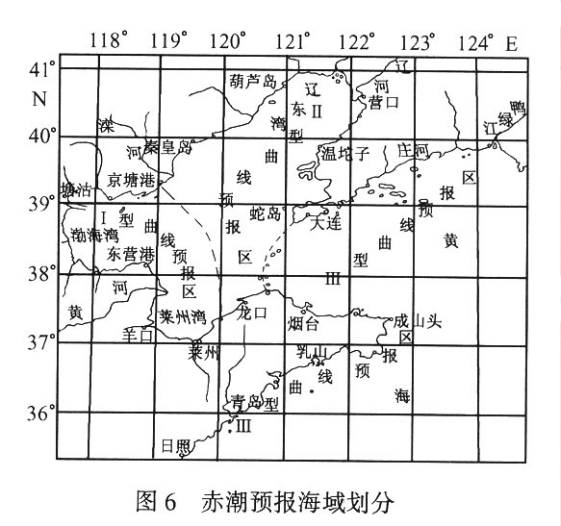


图 6 赤潮预报海域划分

Oceanic research and numerical modeling by different institutions in China
Red tide monitoring and forecasting

The research projects related to the red tide include:

- **"The ecology and mechanism of harmful red tide occurrence and its the forecast and prevention"** supported by China fundamental research project (973)(coordinated by Zhou Mingjiang, Institute of Oceanography of CAS, and Zhu Mingyuan, FIO/SOA)

- **"Harmful red tide forecast technique research"** supported by the national 10th-5year science and technology program (coordinated by Huang Weigen and Ding Dewen) and etc.

Summary

Brief introduction of the marine environment forecast products and service in China including

- **The administrative infrastructure of the marine environment forecasting systems**
- **Products and services**

and

Brief introduction of Oceanic research and numerical modeling by different institutions in China

- **Tides and tidal currents**
- **Ocean waves**
- **3-D marine environmental parameter profile simulation and forecasting**
- **Storm surge forecasting**
- **Sea ice monitoring and forecasting**
- **Red tide monitoring and forecasting**