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Study on environmental impact of pollutant dispersion from Yangtze River to Zhoushan sea area

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Abstract. The pollutants from the Yangtze River will diffuse along the coastal zones with the action of the current. However, whether they will reach Zhoushan city or not and the impact, diffusion path of the pollutants from the Yangtze River is not clear. At present, there are few studies on the large-scale diffusion of pollutants from the Yangtze River into the sea. In this study, the transport and diffusion of chemical oxygen demand (COD) from the Yangtze River to Zhoushan sea area were studied by numerical simulation. The results showed that the diffusion of pollutants from the Yangtze River could reach Zhoushan. Both Hangzhou Bay and Zhoushan Island were greatly affected, resulting in an increase of COD concentration of 0.5-0.8 mg/L in most of Zhoushan sea areas. Because of the low background concentration of COD in Zhoushan, the percentage of COD increment caused by pollution in the Yangtze Estuary was more than 50%.

1. Introduction

The Yangtze River is the largest river in China. With the continuous movement of pollutants from the Yangtze River into the sea, pollutants are transported along the coast, forming the main pollution zone along the East China Sea coast. Zhoushan City, Zhejiang Province, is a famous fishing ground in China. It is located in the underwater delta area of the Yangtze Estuary. It may be the sea area most directly affected by the pollution of the Yangtze River because of the accept of the inflow of the Yangtze River[1].

At present, most of the studies on pollutant transport in the Yangtze Estuary are focused on the diffusion of pollutants in small-scale outlets. Most studies showed that pollutants could indeed diffuse into the Hangzhou Bay. Xia X. J. used the two-dimensional hydrodynamic water quality model to simulate the influence of tributaries drainage along the Yangtze River on the water quality of Hangzhou Bay. The research showed that the influence mainly concentrated in the local offshore waters of Hangzhou Bay[2] .

Wu T. studied the water age and detention time of Hangzhou Bay[3]. Based on ROMS (Regional Ocean Model), a three-dimensional hydrodynamic model of Hangzhou Bay-Yangtze Estuary-East China Sea was established. It was found that the freshwater from the Yangtze River could enter Hangzhou Bay directly through the northern part of Hangzhou Bay, and the water body was obviously affected by the runoff of the Yangtze River. The detention time in flood season was 18 days, and in dry season was 12-32 days.

Wang B. D. et al. pointed out diluted freshwater and nutrient transport in the Yangtze River were influenced by various dynamic factors. A part of the water from the Yangtze River flowed southward

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outside the mouth and entered the coastal areas of Zhejiang Province, and its influence scope also included the vast areas such as Zhoushan Sea Area [4]. Liu Y. found that the Yangtze River, Qiantang River and other small rivers along the coast and pollution outlets had little impact on the Zhoushan sea area, and the contribution of the Yangtze River to the water quality was much greater than that of the Qiantang River [5].

There are few large-scale studies on pollutant diffusion from the Yangtze River to Zhoushan. In recent years, Zhoushan is short of fishery resources and its water quality has deteriorated. Whether the pollutants entering the Yangtze Estuary will affect Zhoushan, the extent of the impact on Zhoushan sea area and the route of pollutant diffusion are not clear at present. In order to find the environmental impact of pollutant dispersion from Yangtze River to Zhoushan sea area, the transport and diffusion of chemical oxygen demand (COD) from the Yangtze River into the sea and its impact on Zhoushan were studied.

2. Methodology

2.1. Model description

A two-dimensional hydro-dynamical and water quality model was used to simulate the hydrodynamics and water quality. The vertically averaged two-dimensional shallow water equations were used. The basic equations were as follows:

$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}=0 \qquad (1)$$

$$\frac{\partial hu}{\partial t}+\frac{\partial}{\partial x}\left(hu^2+\frac{1}{2}gh^2\right)+\frac{\partial}{\partial y}\left(huv\right)=-gh\left(\frac{\partial z_0}{\partial x}+\frac{u\sqrt{u^2+v^2}}{C_z^2 h}\right)+fhv+W_x$$
$$+\frac{\partial}{\partial x}\left(hT_{xx}\right)+\frac{\partial}{\partial y}\left(hT_{xy}\right) \qquad (2)$$

$$\frac{\partial hv}{\partial t}+\frac{\partial}{\partial y}\left(hv^2+\frac{1}{2}gh^2\right)+\frac{\partial}{\partial x}\left(huv\right)=-gh\left(\frac{\partial z_0}{\partial y}+\frac{v\sqrt{u^2+v^2}}{C_z^2 h}\right)-fhu+W_y$$
$$+\frac{\partial}{\partial x}\left(hT_{xy}\right)+\frac{\partial}{\partial y}\left(hT_{yy}\right) \qquad (3)$$

Where x and y are rectangular coordinates, u and v are vertical average velocity components in x and y direction, ξ is water level, d is still water depth, g is gravity acceleration, f is Coriolis force parameter, C_z is chezy coefficient, T_{xx}, T_{xy}, T_{yy} are eddy viscous force components of water flow in each directions, W_x and W_y are wind stress component in x and y direction, t is time.

The vertically averaged two-dimensional unbalanced sediment transport equation was adopted for suspended sediment transport, and its basic equation was as:

$$\frac{\partial hs}{\partial t}+\frac{\partial hus}{\partial x}+\frac{\partial hvs}{\partial y}=\frac{\partial}{\partial x}(D_x\frac{\partial s}{\partial x})+\frac{\partial}{\partial y}(D_y\frac{\partial s}{\partial y})-\alpha\omega\left(s-s_*\right) \qquad (4)$$

Where ω is settling velocity of sediment, S is vertical average sediment concentration, S_* is sediment carrying capacity of current, α is suspended sediment settlement probability, D_x and D_y are diffusion coefficient in x and y directions.

The transport mode of pollutants can be simulated according to the convection-diffusion equation of substances. The basic equation is as follows:

$$\frac{\partial(hC)}{\partial t}+\frac{\partial(huC)}{\partial x}+\frac{\partial(hvC)}{\partial y}=\frac{\partial}{\partial x}\left(D_x h\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial x}\left(D_y h\frac{\partial C}{\partial y}\right)-hk_p C \quad (5)$$

Where C is vertical average pollutant concentration, D_x and D_y are pollutant diffusion coefficients, and K_p is degradation coefficient of pollutants.

2.2. Initial and boundary conditions

In the computational domain, triangular meshes were used to deal with dynamic boundary problems by limiting water depth. The meshes were divided into dry, wet and semi-dry types. In hydrodynamic calculation, the outer sea water boundary without temporary observation station was obtained by using the global tidal model (TPXO7), and the coastal boundary of the model was slippable and non-accessible.

The model ranged from Xuliujing of Yangtze River, Fuchunjiang Hydropower Station of Qiantang River, Rudong, Jiangsu Province to the north, Xiangshan, Zhejiang Province to the south, and 280 km to Zhoushan Sea. The maximum space step was 10 km and the minimum was 200 m. When automatically dividing triangular element meshes, local refinement of key areas were implemented, such as Zhoushan Islands, to ensure the accuracy of simulation. The dynamic time step was used and controlled by the critical CFL number. In this study, the critical CFL number was 0.8 and the average time step was about 0.8s.

2.3. Calculation conditions

Xuliujing is the control section of the main stream of the Yangtze River into the sea, and the conventional section of the pollutant statistics of the Yangtze River into the sea. Therefore, in this study, the pollutants concentration from the Yangtze River into the sea was based on the Xuliujing section. The typical conventional pollution monitoring index COD_{Mn} was selected as the main pollutant.

Yan Q. et al. presented the monitoring concentration of COD_{Mn} in Xuliujing from 1997 to 2011 ranged from 1.4 mg/L to 3.9 mg/L [6]. According to Shanghai Marine Environment Bulletin 2016 [7], most of the chemical oxygen demand (COD) meets the first class of seawater quality standards (2mg/L). Therefore, the concentration of COD_{Mn} in Xuliujing was set 2.0 mg/L.

The effect of wind was taken into account in pollutant diffusion. The latest ERA5 data set from the European Mesoscale Meteorological Center (ECMWF) was used for wind data [8]. The data set had a very high spatial and temporal resolution: the temporal resolution was 1 h, and the spatial resolution was 30 km. In the model, ERA5 wind field was interpolated into the computational unit by bilinear interpolation.

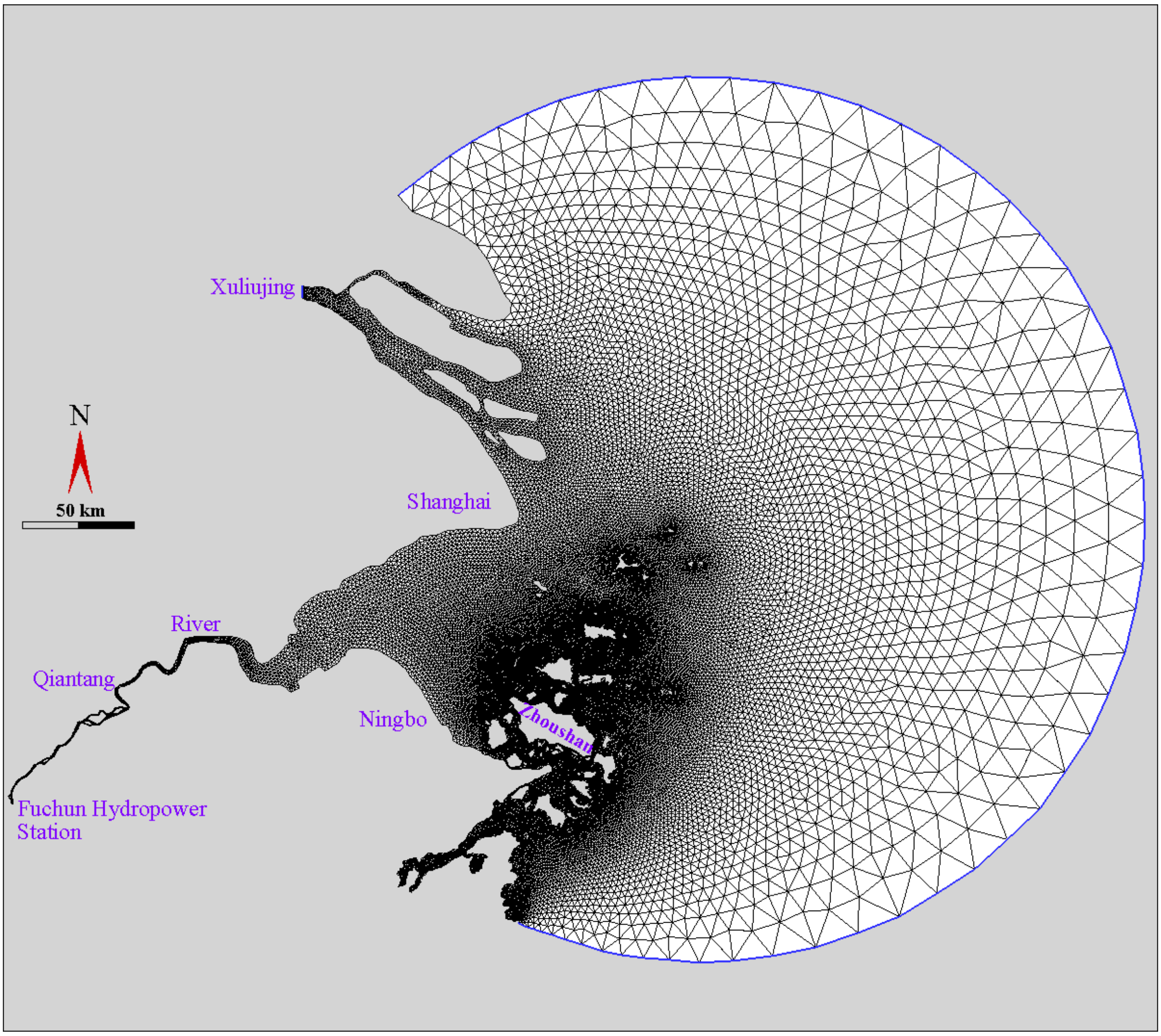

Figure 1. Computational mesh schematics.

3. Results and discussion

3.1. Model validation

The model was verified by the continuous tidal level, tidal current and sediment concentration of large, medium and small tides measured in summer of 2014, so as to ensure that the parameters of the model were reasonable. The calculated results of the model fit well with the observed ones, and the maximum error of the tide levels was 0.09m. The errors of velocity calculation at each point were less than 20%. The flow direction verification results showed that the calculated and measured currents were in good agreement. Sediment verification could reflect the peak and valley processes of sediment concentration changing with tide. The verification results showed that the selection of sediment parameters was reasonable.

3.2. COD background concentration in Zhoushan

The measured COD data were used as background concentration in Zhoushan. COD concentration showed obvious characteristics of high values near shore and low values offshore. The concentration inside Hangzhou Bay was high, and the maximum concentration could reach 1.6 mg/L. The water quality in the east of Shengsi and Qushan islands was the best and the pollution level was the lowest, below 0.8mg/L. The measured data conformed to the distribution trend of marine environmental pollution in Zhoushan City, and COD generally conformed to the first class of seawater quality standards (2mg/L).

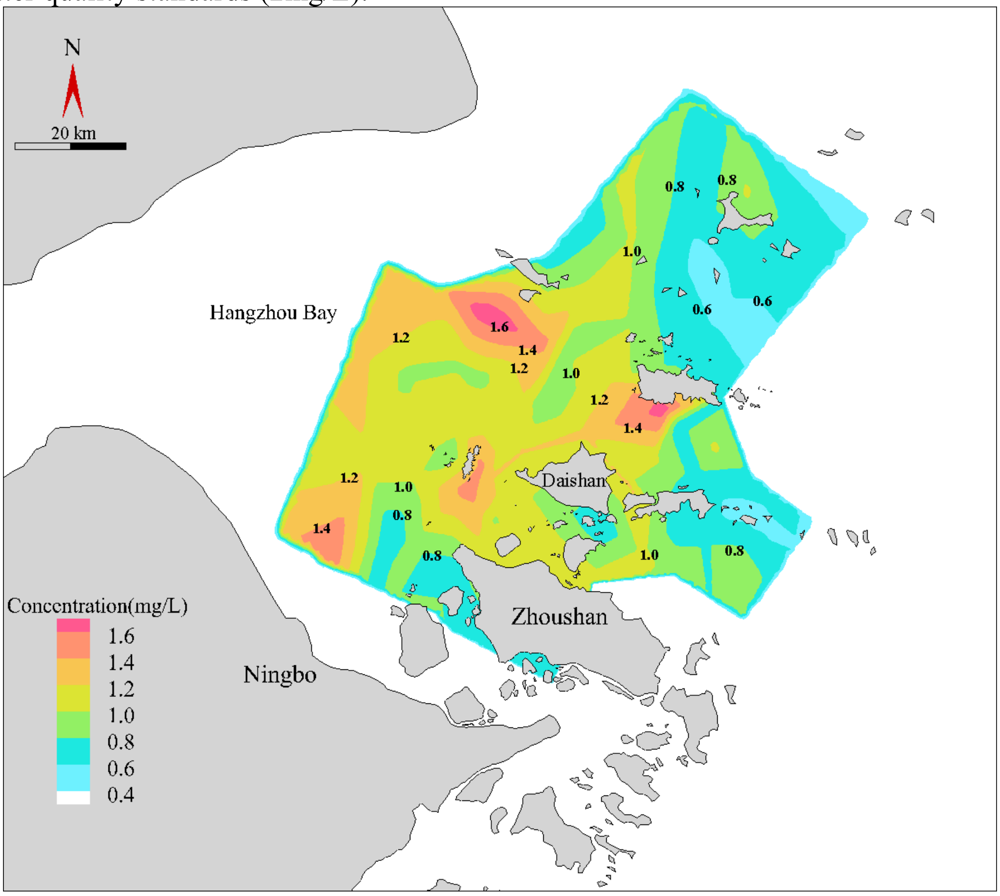

Figure 2. COD background concentration distribution in Zhoushan City.

3.3. COD increment of Zhoushan caused by pollutants from the Yangtze River

Through mathematical simulation, after the pollutant concentration reached a stable level, the pollutant increase in Zhoushan caused by COD pollutant concentration in Xuliujing section of the Yangtze Estuary was analyzed.

The contour line was in the longitudinal north-south direction and diffused from the nearshore to the distant sea area. Pollutant diffusion migrated to the inside of Hangzhou Bay, and the vertical diffusion distance was far from north to south. Both Hangzhou Bay and Zhoushan Island were greatly affected. The trend of pollutant diffusion was similar to that of pollution level distribution in Zhoushan.

Near Luchao Port in Shanghai, the increment of COD concentration was about 1 mg/L. The increment of COD concentration was between 0.5 and 0.8 mg/L in most of Zhoushan sea areas (Shengsi, Daiquyang, Zhoushan Island), and less than 0.5 mg/L in the south and east of Zhoushan Islands.

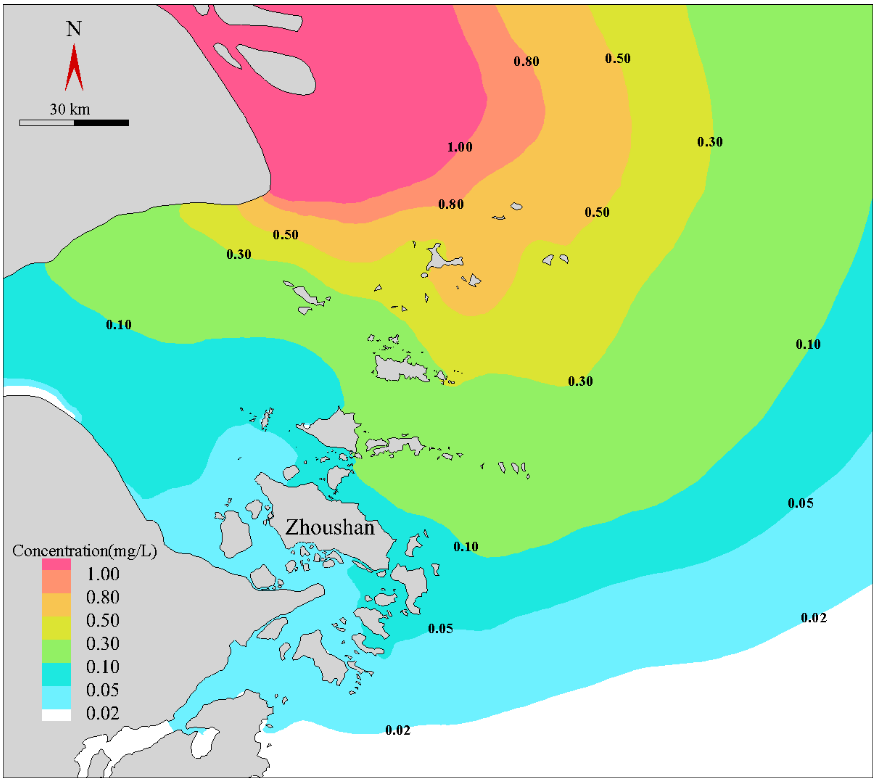

Figure 3. COD increase of Zhoushan caused by pollutants from Yangtze River.

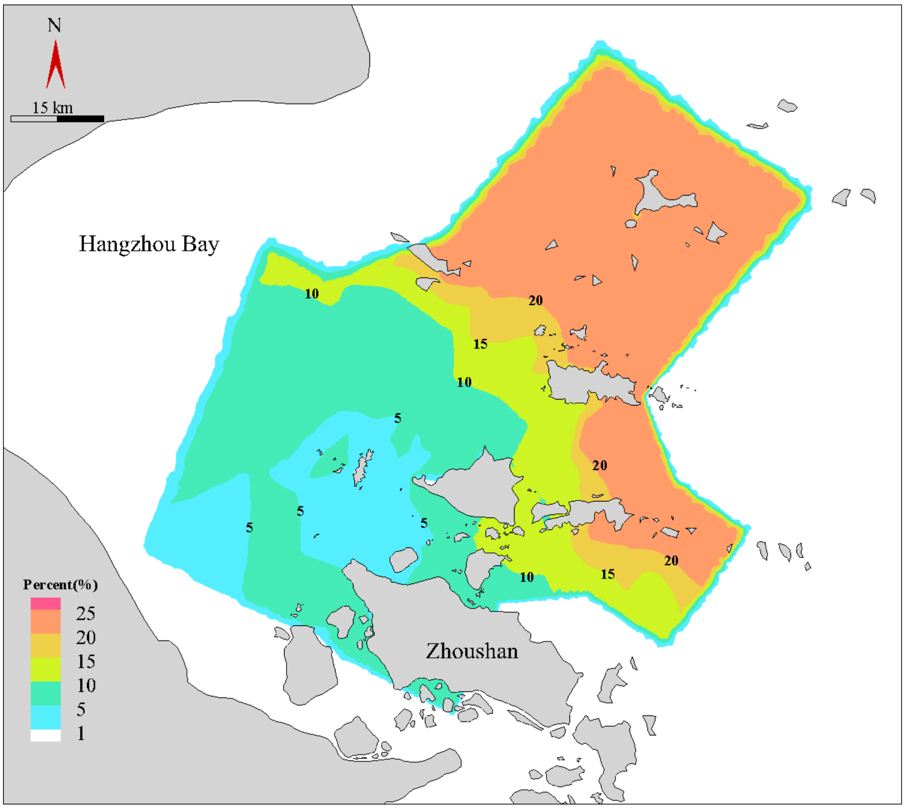

Figure 4. Influence of pollutants from the Yangtze River on COD of Zhoushan sea area.

3.4. The influence of the Yangtze River on Zhoushan sea area

The pollutants from the Yangtze Estuary had great influence on COD in Zhoushan sea area. Pollutant diffusion migrated to the inside of Hangzhou Bay, and the vertical diffusion distance was far to the south of Zhoushan. Because of the low background concentration of COD in Zhoushan, the percentage of COD increment caused by pollution from the Yangtze Estuary was more than 50%. The proportion of Dayangshan and Qushan islands could reach more than 70%.

4. Conclusions

In this study, the COD concentration in the Xuliujing section of the Yangtze River estuary was taken as the initial concentration to study the transport and diffusion of COD into Zhoushan sea area. A two-dimensional flow and water quality model developed independently by our institute was used to simulate the hydrodynamic and water quality. The results showed that the vertical diffusion distance of pollutants from the Yangtze River to the sea was far from the north to the south. Both Hangzhou Bay and Zhoushan Island were greatly affected, resulting in an increase of COD concentration of 0.5-0.8 mg/L in most of Zhoushan sea areas. The increment of COD concentration in the south and east of Zhoushan Islands was below 0.5 mg/L. Because of the low background concentration of COD in Zhoushan, the percentage of COD increment caused by pollution in the Yangtze Estuary was more than 50%.

Acknowledgments

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References

[1] Shi L. F., Lu L.F. (2011) A short note on the dispersion, mixing, stratification and circulation within the plume of the partially-mixed Changjiang River estuary, China, J. hydro-environ. Res., 5:111-126.
[2] Xia X.J., Xu J., Chen Y.Q., Li Q. (2017) Effect of drainage from branches along the Yangtze River in Shanghai on water quality in Hangzhou Bay, Yangtze Estuary. China w. trans., 38: 59-61.
[3] Wu T. (2016) Characteristics of water age and residence time in Hangzhou Bay. Ckni doctoral and master's thesis, Zhejiang University.
[4] Wang B. D. (1998) On the extension and nutrient transportation of the Changjiang River diluted water. J. ocean. huanghai& bohai seas., 16: 43-47.
[5] Liu Y. (2002) Effect of discharges from Yangtse River and Qiantang River on the water quality in Zhoushan Area. Ckni doctoral and master's thesis, Zhejiang University.
[6] Yan Q., Chen L. B., Guo W., Jiang H. T. (2013) Variation of Flow Rate and Water Quality of Changjiang River at Xuliujing Section in 1997-2011. J. Eco. Rural Environ., 29: 577-580.
[7] Shanghai Marine Environment Quality Bulletin 2016. (2017) http://www.shanghaiwater.gov.cn/.
[8] European Centre for Medium-Range Weather Forecasts. (2018) http://www.ecmwf.int/.