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Study on Ship Exhaust Diffusion in Yangshan Port based on Gaussian Plume Model

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Abstract

Due to the large number of vessels and frequent activities in the surrounding areas of the port, the spread of exhaust emissions from vessels will cause harm to the environment in the surrounding areas. However, the range of exhaust emission diffusion is uncertain, and its expansion range is affected by many factors such as wind speed and direction, which brings certain difficulties in tail gas control. In this paper, the improved gaussian plume model is used to calculate the concentration of ship exhaust gas after diffusion and the peak concentration of ship exhaust gas after diffusion within a certain range near yangshan port, and the visualization of the exhaust gas diffusion of several ships near yangshan port is realized in combination with MATLAB, so as to provide decision support for the tail gas control near yangshan port. The results show that the model is simple and effective in simulating the gas diffusion concentration and diffusion range of the ship's tail gas in the port environment. Under the influence of monsoon climate, sea wind direction and wind speed show seasonal changes. Yangshan port is located in the east China sea under the influence of the sub-thermal monsoon climate. Yangshan Port is located in the East China Sea and is affected by the subthermal monsoon climate. In the end, this paper considers the influence of the variation of the diffusion range of ship exhaust in Yangshan Port on the surrounding areas under the influence of the monsoon climate and ship position changes. The results show that the diffusion range of ship exhaust will change under the influence of the monsoon climate in different months.

Keywords

Ship’s exhaust gas; Matlab; Gaussian plume model; Yangshan port.

1. Introduction

Shipping is the most important mode of transportation in international trade, accounting for more than two-thirds of the total international trade volume. Most of my country's import and export goods are transported by sea, and the shipping industry is an important support for China's national economy, foreign trade and social development. However, while the shipping industry promotes international trade and stimulates economic development, it also has a negative impact on the atmospheric environment, especially causing serious pollution to port cities. Taking Hong Kong as an example, the air pollutants emitted by ships account for about one-third to half of the city's total. The number of deaths from heart and lung diseases and lung cancer caused by particulate matter emitted by ships has reached 60,000 worldwide every year[1]. The University of Southern California predicts that if measures are not taken to control the emissions of ships, by 2020, ship emissions will become the main factor of air pollution in Southern California [2].

At present, air pollution in our country is serious, which is harmful to people's health. Therefore, the control and treatment of air pollution have become particularly important. The diffusion process of

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gaseous pollutants in the atmosphere is complete and complex. The pollutants are transported, diffused, and diluted by wind, turbulence, etc., so that the pollutants leave the source and their concentration is reduced [3]. Understanding the distribution characteristics of atmospheric pollutants in the air and the law of diffusion and migration will provide a basis for pollution control and governance, and the evaluation of ambient air quality. The atmospheric diffusion model is an important tool for studying the atmospheric diffusion process and concentration changes[4]. Through unremitting practical research, domestic and foreign scholars have established atmospheric diffusion models that apply to different meteorological and topographical conditions from small and medium scales to global scales[3]. Many documents have classified and studied atmospheric diffusion models. Among all these models, the Lagrangian model and the Gaussian model may be the most commonly used. Both of these models can predict the concentration of pollutants from different sources and types of air pollutants in the downwind direction. The Lagrangian model can be applied not only under uniform and stable conditions on flat terrain, but also under unstable conditions on complex terrain, but it cannot be applied in real time due to its large amount of calculation. The Gaussian model has been widely used in atmospheric dispersion models due to its easy implementation and real-time response characteristics [5]. In terms of land-based pollution gas diffusion research, the Gaussian plume model has been widely used in many applications such as the emission research of large-scale industrial activities and the diffusion of volcanic ash released by volcanic eruptions [6]. Yu Qi et al. [7] studied the applicability of Gaussian plume model and smoke mass model in nuclear accident emergency. Gan Guangwei et al. [7] used the Gaussian plume model to study the impact of the large amount of acid gas evacuated through the torch in the refinery on the surrounding atmospheric environment, and put forward countermeasures and suggestions for the exhaust of the acid gas torch in the refinery. Li Yunyun [8] and Leng Haiqin [9] studied the application of Gaussian misty rain model in the leakage and diffusion of hazardous chemicals. Chen Kun et al. [10] applied Gaussian plume to the study of the diffusion of natural gas after leakage in mountainous areas, and obtained the diffusion of natural gas in different terrains. Zhang Bincai et al. [11] integrated the Gaussian plume model and GIS to visualize the diffusion process of air pollutants. In terms of ship exhaust gas diffusion at sea, Fu Jinyu et al. [12] applied the Gaussian plume model to the sea, and through the improvement of the Gaussian rain model, combined with MATLAB to simulate the emission of a single ship at sea. Fu Jinyu et al. [13] applied the Gaussian misty rain model to the diffusion of harmful gases at sea to simulate the diffusion of harmful gases after the collision of the Sanji ship. At present, most studies on the diffusion of gaseous pollutants are concentrated on land, but there is not much research on the diffusion of pollutant gases from ships at sea, and less consideration is given to the environmental impact of ship exhaust after diffusion.

The coastal areas of China are mostly affected by the monsoon climate, and the diffusion of pollutants is easily affected by wind speed, wind direction and other factors. Therefore, the diffusion range of ship exhaust will change with the seasons. This paper studies the diffusion mechanism of ship exhaust at sea, uses Gaussian plume model, and takes Yangshan Port as an example to simulate the diffusion range and concentration of ship exhaust near Yangshan Port, and considers the influence of monsoon climate and ship position changes in Yangshan The impact of ship exhaust diffusion in the port on the surrounding area provides decision support for the management of ship exhaust in Yangshan Port.

2. Problem description

The exhaust gas emitted by ships often contains polluting gases such as nitrogen oxides and sulfides, which cause environmental damage to the surrounding areas, especially in the port areas where ships are docked and pass through. With the improvement of people's living standards, people have higher and higher requirements for the air environment. How to use the air pollutant diffusion model to effectively predict the direction of the diffusion of ship exhaust, the concentration after diffusion, and

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consider the impact of the diffusion of pollutant gas on the port and surrounding areas, will help to provide help for the treatment of ship exhaust in the port.

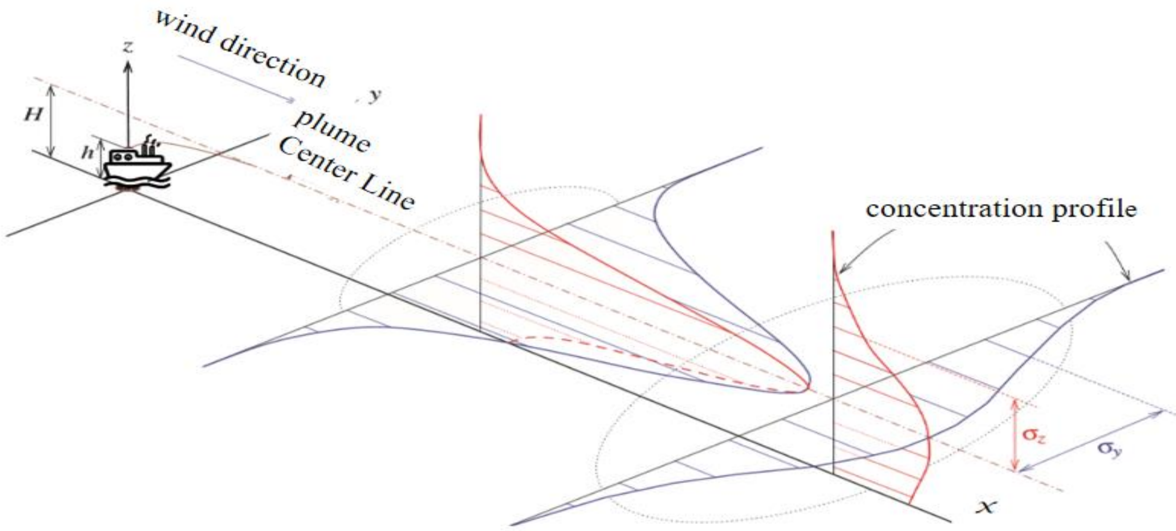

Figure 1. Schematic diagram of ship exhaust gas diffusion

2.1 Model Assumptions

The application of Gaussian plume diffusion model to the diffusion of marine ship exhaust requires related improved assumptions.

1: The ship chimney is regarded as a single emission point source, and the source strength Q is constant.

2: The ship exhaust is a neutral and stable substance, and no chemical reaction occurs with the air when the diffusion decays.

3: Diffusion is isotropic, and the vortex diffusion coefficient only depends on the leeward distance.

4: The wind speed is large enough that other directions except the diffusion in the X direction can be ignored.

5: Pollutants will not penetrate into the sea water.

6: Treat ships near Yangshan Port as fixed emission point sources

2.2 Method Selection

The Gaussian plume model is a standard method for studying the diffusion of atmospheric pollutants under the action of turbulence and advection. The biggest advantage of the Gaussian plume model is that it has a very fast response time, convenient calculation introduction, and low calculation cost of the model. Because the Gaussian model does not require high input conditions for meteorological data and has high accuracy in the simulation of point source air pollutant diffusion, it is widely used in the simulation of point source pollutant emissions. In the past few decades, the Gaussian dispersion model has become a unique and effective air quality management tool.

The Gaussian plume model is as follows:

$$C(x,y,z)=\frac{Q}{\pi\mu\sigma_y\sigma_z}\exp\left[-\frac{1}{2}\left(\frac{y^2}{{\sigma_y}^2}\right)\right]\times\left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]+\exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\}$$

The formula is an improved model of the mathematical model of Gaussian plume, where C is the concentration of ship tail gas in the air at any point in space (x, y, z) at a certain moment, and the unit is mg/m^3; Q is the emission source intensity, and the unit is mg/s; u is the average wind speed of the

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environment at the time of leakage, in m/s; H is the effective height of the emission source, in m; σx, σy, and σz are the horizontal vertical axis, horizontal horizontal axis and vertical upward diffusion parameters, respectively ; x, y, z are the downwind distance, the crosswind distance, and the vertical wind distance respectively, in m.

2.3 Model parameter setting

σy and σz are functions of the atmospheric conditions and the distance from the release source downwind. To determine σy and σz, firstly determine the atmospheric stability according to local wind speed, meteorological conditions (mainly sunshine intensity) and the Pasquill-Gifford model [14] as shown in Table 1. The atmospheric stability level is divided into 6 levels, and the atmospheric stability level increases from A to F. A is extremely unstable and F is moderately stable. Finally, the diffusion coefficient equation of the Pasquill-Gifford model is determined according to the atmospheric stability level and the diffusion coefficients σy and σz are calculated. Pasquill-Gifford model diffusion coefficient equation is shown in Table 2

Table 1.Atmospheric stability level of Pasquill-Gifford model

Sea surface wind speed/($m \cdot s^{-1}$)	Strong solar radiation during the day	moderate solar radiation during the day	weak solar radiation during the day	thin clouds covering the sky at night or cloud cover not less than 4/8	no cloud at night or cloud cover less than 4/8	dense and cloudy Day or night
0~2	A	A, B	B			D
2~3	A, B	B	C	E	F	D
3~5	B	B, C	C	D	E	D
5~6	C	C, D	D	D	D	D
≥6	C	D	D	D	D	D

Table 2.Diffusion coefficient equation of Pasquill-Gifford model

Atmospheric stability level	σy / m	σz / m
A	0.22X(1+0.0001X)-1/2	0.20X
B	0.16X(1+0.0001X)-1/2	0.12X
C	0.11X(1+0.0001X)-1/2	0.08X(1+0.0002X)-1/2
D	0.08X(1+0.0001X)-1/2	0.06X(1+0.0015X)-1/2
E	0.06X(1+0.0001X)-1/2	0.03X(1+0.0003X)-1
F	0.04X(1+0.0001X)-1/2	0.016X(1+0.0003X)-1

The X value in the diffusion coefficient equation in the table is the distance from the position where ship exhaust diffuses to the downwind direction to the emission source. According to the annual wind speed data measured by Shengsi Station, the annual average wind speed along the coast of Shengsi is 7m/s[15]. The intensity of solar radiation is actually the intensity of sunlight received on the ground, which varies greatly in different regions. of. Generally speaking, low latitude areas have a large direct sun angle, so the light intensity should be large. On the contrary, the high latitude areas have lower light intensity. Yangshan is located in the middle latitude area. The solar radiation intensity during the day is medium. Based on this, we can determine Yangshan The atmospheric stability of is D level. According to Table 2, when the atmospheric stability is D, the diffusion coefficient σy is $0.08X(1+0.0001X)^{-1/2}$, and σz is $0.06X(1+0.0015X)^{-1/2}$.

3. Example simulation

3.1 Related parameters

The relevant parameters required by the model mainly include the wind speed and direction of the Yangshan sea area, the exhaust emission rate of ships near Yangshan (kg/s), the climb height of the ship after exhaust emission, and the predicted effective height. As shown in Table 3 and Table 4.

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Table 3. Setting of exhaust gas diffusion parameters of a single ship

Parameters	Wind speed	Wind direction	Ship tail gas emission rate (kg/s)	Ship tail gas climb height (m)	Predicted height (m)
Data	7	April-August southeast wind Northwest wind from November to March	1	15	0 (on the sea)

Data

Parameters	Wind speed	Wind direction	Ship tail gas emission rate (kg/s)	Ship tail gas climb height (m)	Predicted height (m)
Data	7	April-August southeast wind Northwest wind from November to March	1 0.6 0.8 1.2	13 10 11 15	0 (on the sea)

3.2 Exhaust gas diffusion diagram of a single ship

Set the wind direction to the X-axis direction, set the relevant parameters as shown in Table 1, and use MATLAB programming to obtain the diffusion diagram of ship exhaust after discharge as shown in Figure 2.

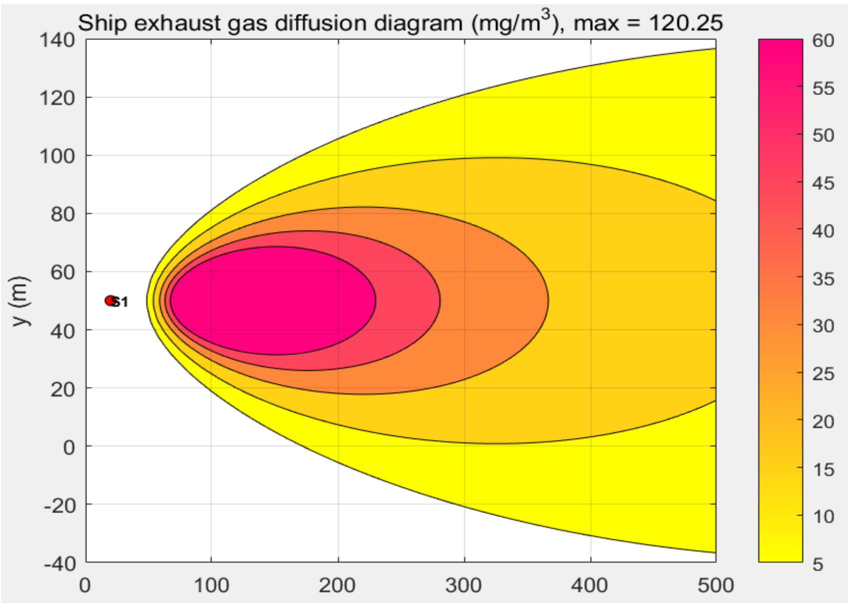

Figure 2. Single vessel exhaust diffusion diagram

The point 's1' in Figure 1 is the name of the ship, and the location of 's1' is the location of the ship. From the figure, it can be seen that the pollution concentration of the polluted area is divided into five parts. The darker the color area represents the pollution in this part of the area The higher the substance concentration value, the maximum value of the exhaust gas concentration obtained by calculation is 120.25mg/m^3, which is located in the red area in the figure. The range of the simulated ship exhaust gas diffusion in the figure is in the area of 180×500m.3.3 Exhaust gas diffusion diagram of multiple ships

3.3 Exhaust gas diffusion diagram of multiple ships

Figure 3 is the diffusion diagram of exhaust gas from four ships. The pollutant concentration value at a certain point in the figure is affected by the combined effect of the four ship emission sources's1','s2','s3', and's4'. The parameter settings are shown in Table 2. The area after the ship exhaust has diffused is divided into five parts, among which the highest pollutant concentration is 197.6mg/m^3, and the simulated range is within a 350×2000m area.

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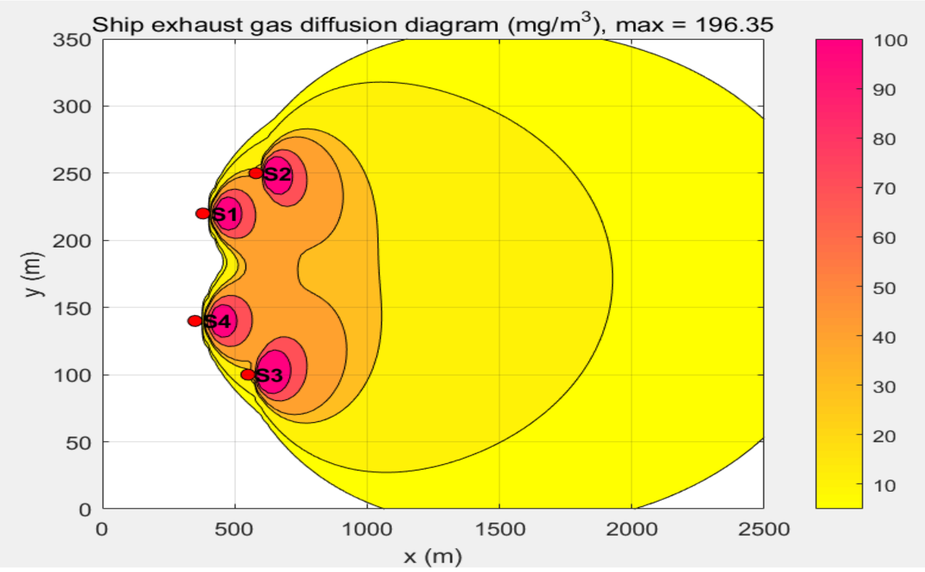

Figure 3. Exhaust gas diffusion diagram of four ships

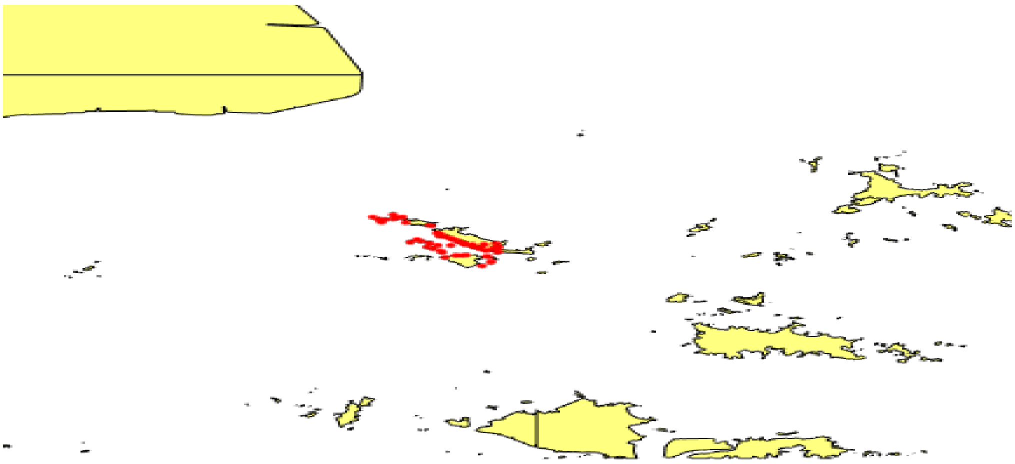

Figure 4. Ship location map near Yangshan Port at some time

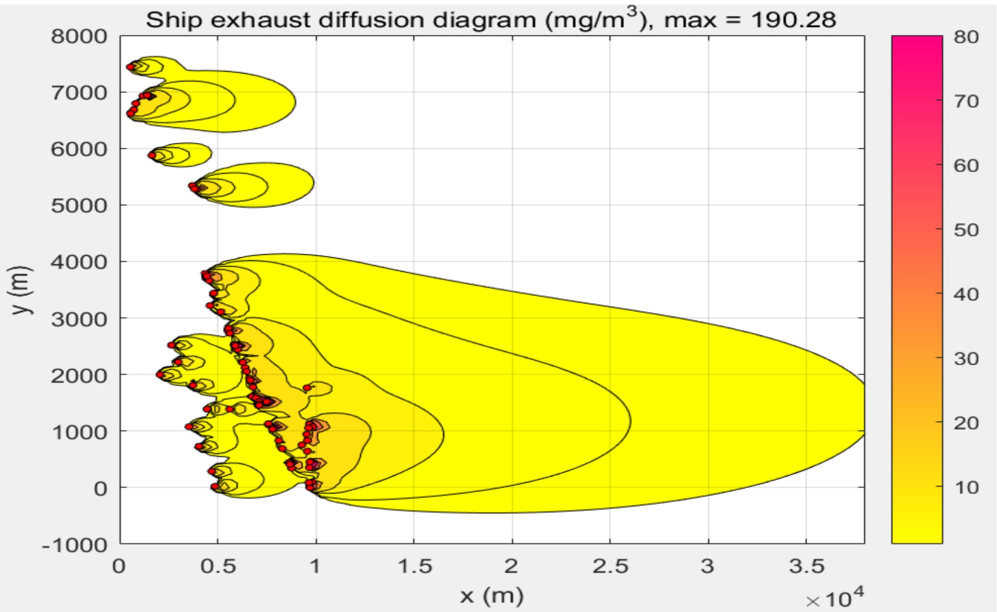

Figure 5. Exhaust gas diffusion diagram of multiple ships

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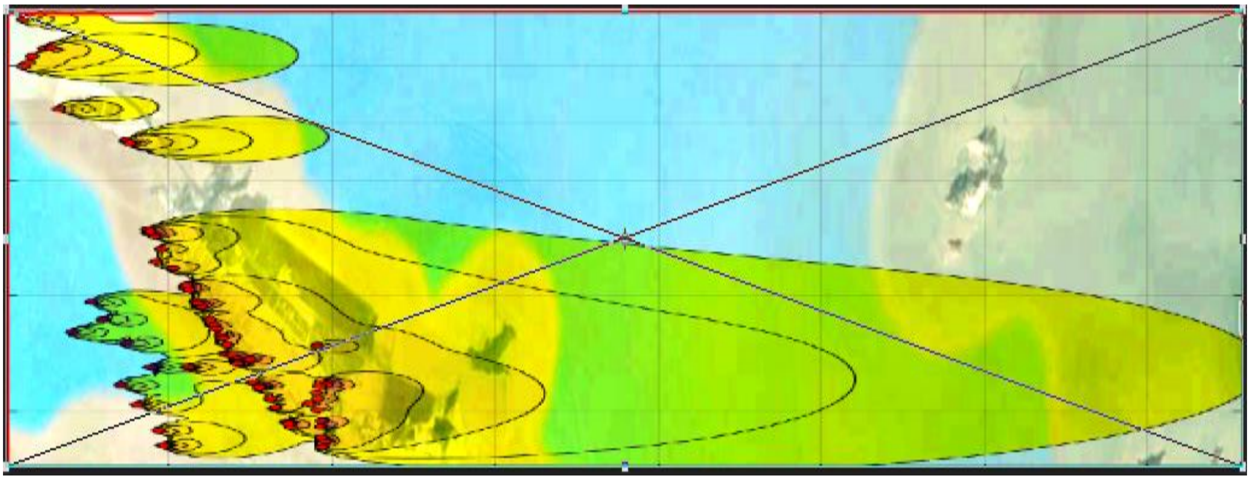

Figure 6. Dispersion map of ship exhaust near Yangshan Port

Figure 4 is an intercepted map of the ship's location near Yangshan Port at a certain time. The location coordinates of the ship at a certain time in Yangshan Port are input into the map. Figure 5 is the ship exhaust generated based on the location coordinates of Yangshan Port and nearby ships at a certain time Diffusion diagram. Figure 6 is a map of ship exhaust diffusion generated by combining with the map of Yangshan Port. The red dots in the figure are ships berthed at Yangshan Port or passing near Yangshan Port. In the simulation, the highest concentration of ship exhaust after diffusion is 223.47mg/m^3. It can be seen from the figure that the scope of ship exhaust diffusion is large, and the farthest diffusion distance is 33km, so it will have a certain impact on the environment of nearby areas.

4. Analysis of factors affecting the diffusion of ship exhaust

4.1 The influence of monsoon climate on the diffusion of ship exhaust

The diffusion of exhaust gas from ships near Yangshan Port will be affected by the monsoon climate, which in turn will cause certain damage to the atmospheric environment in the surrounding area. China is a major monsoon region in the world, and all regions are affected by the monsoon climate [16]. Yangshan Island belongs to Shengsi County and is located in the northern sea area of Zhejiang China. Affected by the monsoon climate, northerly and northwesterly winds prevail from November to March of the following year, and southerly and southeasterly winds prevail from April to August in the northern sea area of Zhejiang. The highest monthly wind direction and frequency in Shengsi are shown in Table 5 [17].

Table 5. The most wind direction and frequency in each month in ShengSi

Venue	Project	January	February	March	Apri	May	June	July	August
Shengsi,Zhe jiang Provice, China	Wind direction frequen-cy	Northwest wind 27	Northwest wind 21	North wind 14	Southeast wind 14	Southeast wind 16	South-east wind 16	South wind 25	Southeast wind 19
	Project	September	October	November	December				
	Wind direction frequen-cy	Northeast wind 19	northeast wind 20	Northw-est wind 20	northwest wind 27				

According to this, from April to August each year, the southeast wind prevails in Yangshan Port, and the northwest is the main direction for the diffusion of ship exhaust. The area closest to Yangshan Port in the northwest is the Shanghai Lingang area. The distance between the two places is More than 30 kilometers. According to MATLAB simulation of ship exhaust gas from ships near Yangshan Port, the diffusion range of its pollutant gas is about 30 kilometers. Based on this, it is inferred that ship

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exhaust gas with a concentration of 1-2mg/m^3 diffuses to the southeast coastal area of Lingang. Figure 7. Therefore, it will have a certain impact on the environment of the coastal area of the port.

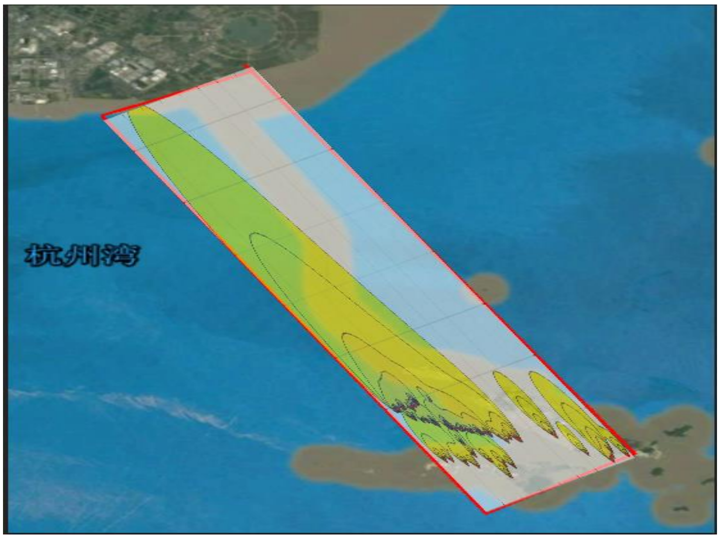

Figure 7.Dispersion range of ship exhaust in Yangshan Port from April to August

Affected by the winter monsoon generated by the Mongolia-Siberian High from November to March of the following year, northwest wind prevails in the Yangshan Port area, and the diffuse direction of ship exhaust in the Yangshan Port area is the southeast direction. The islands near Yangshan in the southeast direction are mainly oceanic Shandao and Qushan. Dayangshan is 3.6 kilometers away from Yangshan Port. From the simulation results of the Gaussian Misty Rain model, the concentration of ship exhaust in Yangshan Port after spreading to Dayangshan is about 10-30mg/m^3. Therefore, the diffusion of Xiaoyangshan ship's exhaust gas will affect Dayangshan. The environment has a great impact. Qushan is about 30 kilometers away from Yangshan Port, and ship exhaust with a concentration of about 1-2mg/m^3 will diffuse into the area. Therefore, this area will also be affected by the diffusion of Yangshan Port's ship exhaust, as shown in Figure 8.

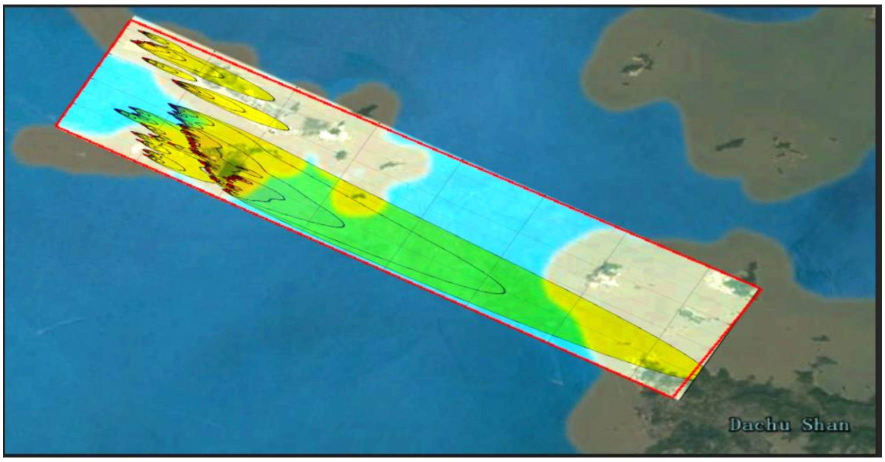

Figure 8. Dispersion range of ship exhaust in Yangshan Port from November to March of the following year

4.2 The influence of the distribution of ships on the diffusion of ship exhaust

Since most of the time the ship is on the way, even if the ship is docked at the dock or port operation, the position of some ships near the port will change. Like the entering and leaving of the port, the

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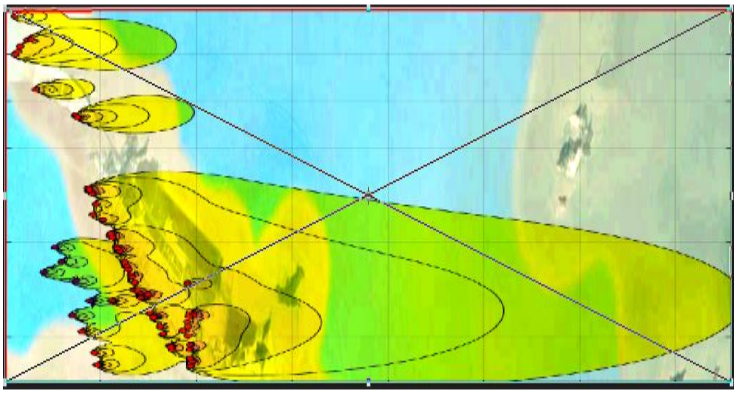
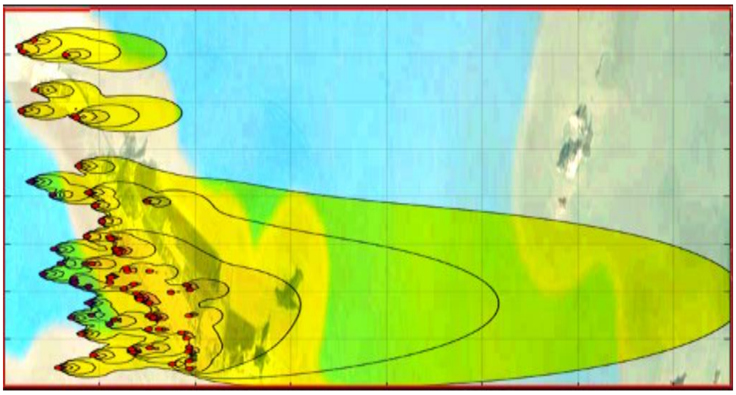
change of the position of the ship is the change of the position of the emission source. The scope of air pollution diffusion is related to the location of the emission source, so the change of ship position will have a certain impact on the emission of ship exhaust. This paper intercepts ship location information near Xiayangshan Port at different times (Note: Set the same number of ships and the same ship emission rate and other parameters), and use MATLAB to simulate the impact on ship exhaust diffusion under different emission source distributions. As shown below.



a



b

Figures a and b are the ship exhaust diffusion diagrams at different times in Yangshan Port. The peak point concentrations of the ship exhaust diffusion concentration in Figures a and b are 223.47mg/m^3 and 222.23mg/m^3 respectively. The change of position changes the peak point concentration of ship exhaust gas diffusion concentration. In addition, it can be seen from the figure that although the total diffusion range has not changed greatly, the concentration line of high concentration value has changed, indicating that the closer the area to the Yangshan Port is, the more vulnerable the ship's exhaust gas diffusion changes caused by the movement of the ship. Impact. It can be seen from the map that Dayangshan is closer to Yangshan Port and is more susceptible to changes in ship exhaust gas diffusion.

5. Conclusion

In this paper, the Gaussian plume model is used to simulate the diffusion of ship exhaust. First, MATLAB is used as a tool to simulate single-point and multi-point ship exhaust diffusion maps. Then, Yangshan Port is taken as an example to study the range and concentration of ship exhaust after the diffusion of Yangshan Port and nearby ships, to generate the exhaust gas diffusion map of Yangshan Port. Considering that ship exhaust is susceptible to the influence of monsoon climate during the diffusion process, it analyzes the changes in the direction of ship exhaust diffusion and the possible impact on surrounding areas under the influence of different seasonal monsoon climates, and provides some references for the management of ship exhaust in Yangshan Port. In this paper, the Gaussian misty rain model is used to simulate the dispersion of ship exhaust gas, and the loss caused by the

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dispersion of ship exhaust gas dissolving in seawater and the influence of ship speed on the dispersion of ship exhaust gas during traveling are not considered. Therefore, further improvement is needed.

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Reconstruction and Optimization of Cross-border Logistics Network Based on Dry Ports Driven by Trade and Policy of "One Belt One Road".

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