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Large Eddy Simulation Study of Urban Heat Island Effect and Urban Air Pollution Diffusion

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Abstract: With the improvement of urbanization, the temperature of the city also changes, and the urban heat island is most closely related to the temperature change. The surface temperature in the center is higher than that in the suburbs, causing the atmosphere to rise and form a low-pressure vortex, which is not conducive to the discharge of pollutants and waste heat from exhaust gas, and will cause harm to the physical and mental health of residents over time. The purpose of this paper is the effect and urban air pollution diffusion. In the experiment, the large eddy is used to simulate the diffusion of two typical urban pollution sources. The diffusion of fixed sources and their impact on ground are affected by the atmosphere. During the day, when there is a movement in it, the pollutants from fixed sources are easier to reach the ground.

1. Introduction

With the rapid improvement of urbanization in China, there have been problems such as the continuous increase of urban land use, the increase of human interference to the environment, and the increase in the density of urban buildings, which have changed the influence of urban thermal and dynamic effects, thus bringing about a series of urban environmental problems. The resulting heat island effect has caused a series of problems to the urban environment that cannot be ignored. At the same time, high-quality environment and healthy air have gradually become a scarce resource, and the improvement of air quality has become a governance requirement at the national strategic level [1].

With the process of urbanization, the scale of cities is increasing, and problems such as urban heat island effect and air pollution have become more important and prominent. Creating a comfortable environment and high-quality air is not only the needs of people's lives, but also the needs of the continuous improvement of science and technology.According to Budhiraja B. Thermal

responses in improved environments are measured in terms of urban surface heat island intensity compared to natural environments. The winter urban heat island effect in Delhi was assessed using regional climate and surface urban heat island indicators. Statistical analyses were performed to determine their relationship and to identify areas of heat stress in the Delhi metropolitan area. His research is the first to use regional climate zones to analyse Delhi's seasonal urban heat island. A pronounced solar heat island effect can be seen in all seasons. The urban heat island has a maximum temperature of 3.5℃ at night, and is between "low-level" and "low-level" in summer and winter. The "urban-rural" trend makes the surface heat island intensity the highest at night [2]. In this work, Ihadua I cerates systems related to mesoscale, mesoscale and regional systems. Issues discussed include the island in downtown and the urban density of the São Paulo region in the region, involving microphysical, energy combined with sea breezes and cold fronts during the evolution of the universe. To this end, it Four components were used: identifying hydrometeors using fuzzy reflections, calculating rainfall diameter, and estimating the size of using polarization measured by X-ray weather. It shows that density in downtown influence precipitation, water and snow mass formation, and storm depth and duration. It is also worth noting that the asymmetric formation of thunderstorms is caused by strong motion in downtown São Paulo, which is caused. It is also worth noting that this phenomenon in the city depends on the mixing state to generate powerful pools of rain and cold water. These processes within the troposphere that persist in downtown São Paulo should be considered in convective parameterization schemes and associated cold pool simulations [3].Numerical simulation is more and more widely used in meteorological environment research.

This paper elucidates an overview, an overview of urban pollution diffusion, barriers to energy stress and environmental degradation, and the practical implications of this research. In the experiment, the ARPS model was used in the large eddy simulation, taking M city as the research object, to study the influence on the urban pollution diffusion.

2. Large Eddy Simulation of Urban Heat Island Effect and Urban Air Pollution Diffusion

2.1. Overview of Urban Heat Island Effect

The concept of "urban heat island" describes the phenomenon that the atmospheric and surface temperature of an urban area is higher than that of its surrounding suburbs. The emergence of the urban heat island effect will increase the consumption of water and energy, and the urban heat island effect can also lead to heat island circulation, which is not conducive to the diffusion of pollutants in urban areas [4]. In addition, the urban heat island effect is also related to various urban meteorological problems such as "urban dry island and wet island", "urban cloud" and "urban rain island" [5]. It is of great significance to study the island effect and deeply analyze its causes for improving the urban living environment.

The factors that affect the heat island effect can be attributed to the following two categories: the thermophysical properties of the urban underlying surface and the heat generated by human activities, and some meteorological and geographical conditions will also affect the urban heat island phenomenon [6]. The discussion of the various influencing factors of the heat island effect has attracted extensive attention. The urban heat island effect brings many hazards. On the one hand, high temperature will directly endanger people's health. Medical research shows that the ambient temperature is closely related to the physiological activities of the human body. On the other hand, the heat island effect will adversely affect the ecological environment [7]. The local high temperature in the urban area will lead to the local circulation of air between the urban area and the suburbs, which is not conducive to the diffusion of pollutants. The high temperature will also

strengthen the photochemical reaction. In addition, the urban heat island effect will also lead to increased electricity consumption in summer. In addition, urban heat island is conducive to the formation of precipitation in water-deficient cities, which can reduce the fuel consumption of urban residents for heating in winter, and can reduce the number of frost days in cities, so that spring comes early and autumn goes late, which is conducive to greening. Prolong the growth period. The phenomenon of urban heat island is closely related to people's life, and it is characteristics of urban heat island to improve the living environment of urban residents [8-9].

2.2. Overview of Urban Pollution Diffusion

Air pollution has always been a research hotspot in the field of environmental economics. Especially in recent years, people's awareness of environmental protection has become higher and higher. Topics such as "smog" and "climate warming" have received extensive attention from the whole society. There are more and more studies [10-11]. In recent years, with the aggravation of air pollution, the air pollution problem has been paid attention to by all aspects. In most cases, the pollutants discharged into the atmosphere are always transported, diluted, and removed. It is precisely because of the transport and dilution of the atmosphere that the concentration of pollutants is gradually reduced until they are completely removed [12]. The existence of urban heat island can affect the temperature field, wind field and planetary boundary layer, and then affect the diffusion process of urban pollutants. In this paper, fixed source is selected as the simulation research target. At present, the research methods for fixed sources mainly include field observation, wind tunnel test research and numerical simulation [13].

2.3. Energy Shortage and Environmental Degradation Hinder

Construction and sustainable improvement of urban ecological civilization economy, the scale of cities continues to expand, and the original vegetation, waters and bare surfaces are gradually replaced by impervious surfaces such as cement, asphalt, and metals [14]. The heat island effect brought about by this process has become a major factor in energy consumption and environmental degradation in urban areas. Energy is the material basis of human activities. As an important area of energy consumption, there is an obvious positive correlation between energy consumption and urban thermal environment. In the case of extreme high temperature weather in summer, as the temperature continues to rise, the demand for cooling energy consumption continues to increase, which has caused huge pressure and challenges to the urban power supply system. The high temperature and extreme weather in summer have repeatedly caused the power supply load in major cities across the country to be too high, and the substations are fully loaded, and the crisis of "electricity shortage" is serious [15-16]. In addition, with the continuous increase of energy consumption. Issues such as energy shortage and environmental degradation brought about by the heat island effect have become a bottleneck affecting the construction of urban ecological civilization and sustainable improvement. The growth of energy demand produces a large amount of waste heat emissions, which aggravates the urban thermal environment, and the poor urban thermal environment in turn requires more energy to improve, further aggravating the scarcity of energy, and ultimately leading to a vicious circle of urban energy shortage and environmental degradation..

2.4. Practical Significance

This paper proposes a built environment optimization and regulation to cut the urban heat island

effect, and provides decision support for land space planning, optimization and management[17-18]. The control and guiding role of planning can put the mitigation of the urban heat island effect in the position of taking precautionary measures and prevent problems before they occur, and solve the urban thermal environment problem at the source. Improvement in the direction of "people-oriented". With the intensification of the urban heat island effect, more and more planning work has begun to try to optimize the urban built environment through planning methods to alleviate the urban heat island effect, laying a foundation for the planning practice of improving the urban thermal environment [19].

3. Investigation and Research on Large Eddy Simulation of Urban Heat Island Effect and Urban Air Pollution Diffusion

3.1. Large Eddy Simulation

The ARPS model is a non-static system established by the Center for Storm Prediction and Analysis at the University of Oklahoma. It is designed for the prediction of convective storms and mesoscale weather systems. The numerical prediction system adopts a three-dimensional non-static compressible model in the terrain following coordinate system. In order to minimize the simplification of the original governing equations. In addition, the ARPS model also includes a large number of parameterized models of physical processes.

3.2. Research Content

This paper takes M city as the research object to study the influence on urban pollution diffusion. The large eddy method is used to simulate the diffusion of two typical urban pollution sources. It provides a useful reference for alleviating the urban heat island effect.

3.3. Initial Field

In this paper, constant static steady-state atmospheric initial field variables are used, and the initial field of each state variable is only a function of height. where θ_0 is the potential temperature at z=0 and p_0 is the standard atmospheric pressure. The expression is:

$$\bar{\theta} = \theta_0 \, exp\left(\frac{N^2 z}{g}\right) \tag{1}$$

$$\bar{p} = p_0 \, \pi^{-1/k} \tag{2}$$

4. Analysis and Research of Large Eddy Simulation of Urban Heat Island Effect and Urban Air Pollution Diffusion

4.1. Urban Heat Island Effect

The urban heat island effect is the phenomenon that the improvement of urbanization causes the temperature in the city to be higher than that in the outer suburbs. This phenomenon is mainly

caused by the change in the properties of the urban underlying surface and the emission of anthropogenic heat. Numerical simulation is used to analyze the impact on the urban heat island. It is hoped that the causes and laws of island can be obtained and provide useful information for alleviating the urban heat island effect. refer to.

The heat island intensity is defined as the difference between the temperature in the upper urban area and the average temperature of the farmland on the first grid on the ground. The average urban is the average of intensities on the grid points whose surface coverage type is urban, and the maximum heat island intensity is the urban heat island intensity. The simulation results of average maximum heat island intensity are shown in Table 1 and Figure 1:

Table 1. Urban heat island intensity data simulation

Time/h	Max UHII	Mean UHII
10	3.16	2.89
15	2.54	2.04
20	2.08	1.98
25	5.95	2.60
30	6.71	2.85
35	7.65	2.76

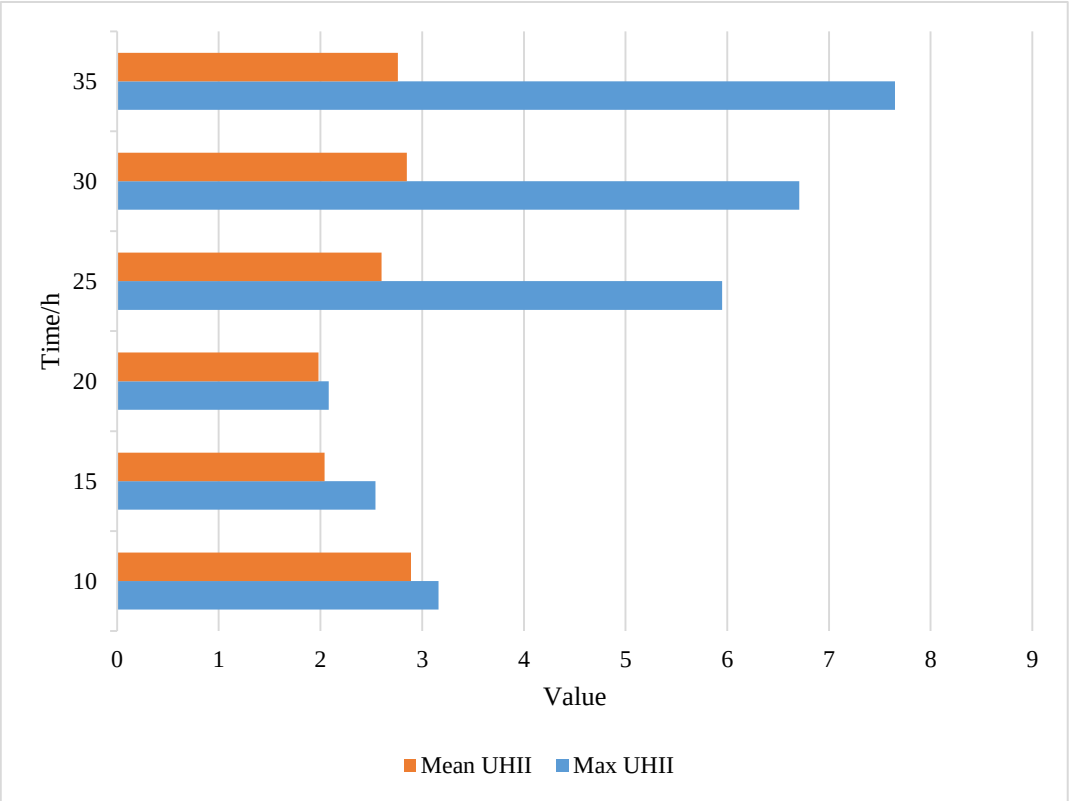

Figure 1. Average and maximum heat island intensity

The average heat island intensity can reflect the overall intensity can also eliminate random effects at individual points. According to it, the mean heat island intensity has two peaks in the

morning and early morning, followed by a trough. The maximum heat is 7℃.

4.2. Impact of Urban Heat Island on Urban Pollution Diffusion

Pollutants in cities, will effect the lives of residents, and the diffusion process of pollutants is closely related to the existence of urban heat islands. Calculation results and analysis Since the concentration of pollutants near the ground is most closely related to people's lives, two variables in the diffusion process of fixed sources are mainly investigated. One is the maximum landing concentration, that is, the maximum concentration on the first-layer grid on the ground in the downwind direction. value; the other is the maximum landing distance, that is, the horizontal distance between the location where the maximum landing concentration occurs and the location of the point source. The daily variation of the maximum landing concentration of the chimney exhaust of the A power plant and the B power plant is shown in Table 2 and Figure 2:

Table 2. Data table of the maximum landing concentration of the power plant

Time/h	PS max	
	A	B
10	0.75	0.84
15	1.56	1.69
20	0.65	0.79
25	1.87	1.94
30	0.14	0.07
35	0.34	0.10

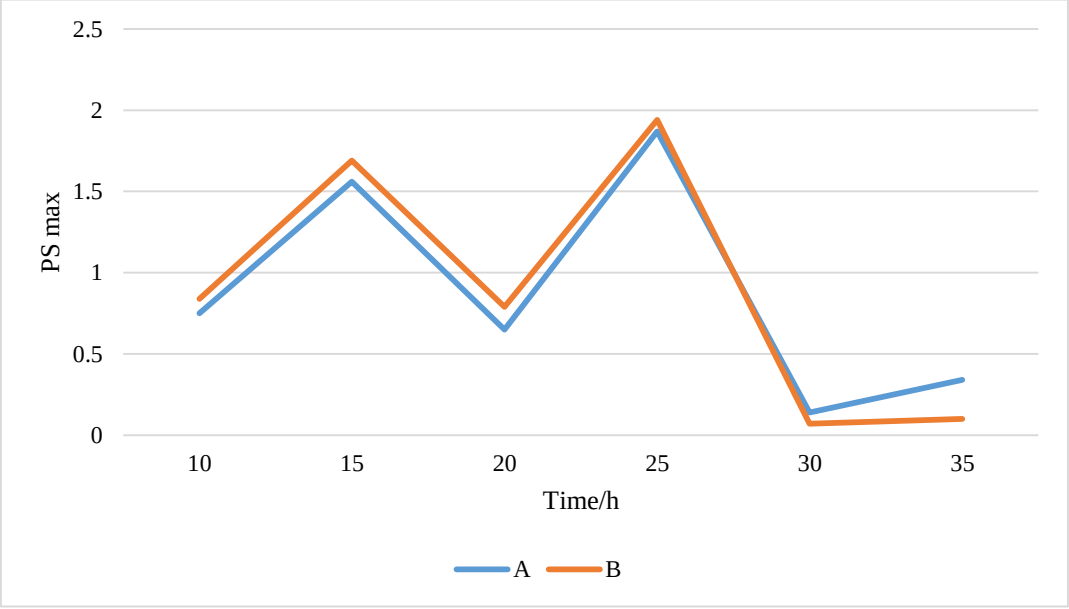

Figure 2. Daily variation of maximum landing concentration of chimney exhaust from Plant A and Plant B

Under the unstable stratification during the day, the convection movement of the lower atmosphere is vigorous, the maximum landing concentration of pollutants is large, and the maximum landing distance is relatively short. Under the stable stratification at night, the atmospheric air field is stable, the vertical convection becomes weaker, and it is more difficult for high-altitude pollutants to reach the ground, the maximum landing concentration is significantly reduced, and the maximum landing distance is significantly increased. The daily variation of the maximum landing distance of the exhaust gas from the two power plants is shown in Table 3 and Figure 3:

Table 3. Maximum landing distance data table of the power Plant

Time/h	A	B	
10	12.8	11.4	
15	8.9	7.8	
20	23.5	15.7	
25	39.4	24.6	
30	40.1	45.1	
35	37.5	43.2	

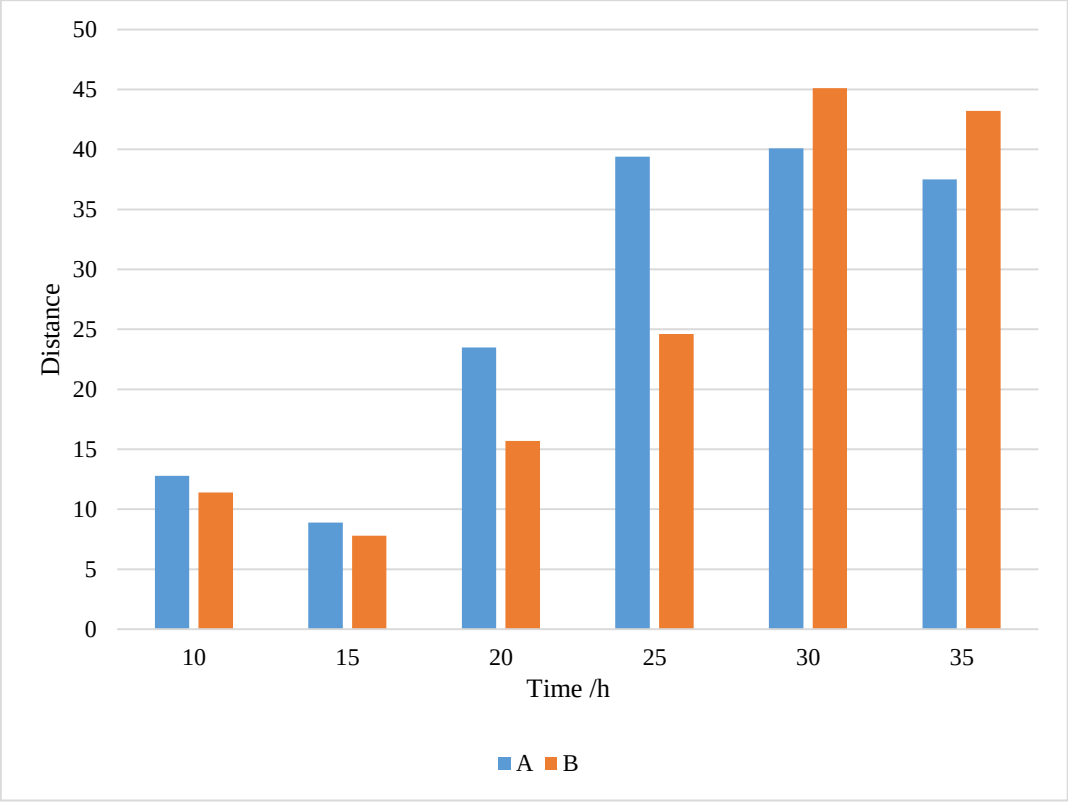

Figure 3. Diurnal variation chart of the maximum landing distance of the maximum exhaust gas from the two power plants

The large eddy numerical simulation method is used to simulate the diffusion of two typical urban pollution sources. The diffusion of fixed sources and their impact effects the atmosphere.

5. Conclusion

In recent years, the continuous warming of the global climate and the frequent occurrence of extreme abnormal weather have seriously threatened the human living environment and public health, especially the urban thermal environment problem represented by the heat island effect has become increasingly prominent. In this paper, the method of large eddy simulation and the mesoscale meteorological simulation system ARPS are used to simulate the typical urban pollutant diffusion in the M city area. The main factors affecting the urban heat island effect are numerically studied, and the diffusion process of urban pollutants and its influence by the heat island effect are simulated and analyzed.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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