Studying the influence of aerosol types on solar radiation prediction

Mingjie WANG[1], Ling YANG[1], Jinye ZHANG[1]*, and Ruibei LIU[2]

[1]College of science, Hubei University of Technology, 430068 Wuhan, China
[2]College of Software Engineering, Hubei RADIO&TV University, 430073Wuhan, China

Abstract. The influence of aerosol types on Solar radiation prediction was studied in this paper. According to Chinese population density, China administration districts were divided into areas with urban aerosol type and rural aerosol type based on Arcgis. The Solar radiation all over China was simulated by the Mesoscale numerical Weather Prediction Model (WRF). The forecasting was compared with the data of "Clouds and the Earth's Radiant Energy System" released by NASA. The results showed that there was a big improvement when the different aerosol types in different areas were taken into consideration.

1 Introduction

Solar power generation is one of the renewable energy industries which are strongly supported by the Chinese government[1].Compared with the traditional power generation, the output of solar power is determined by the intensity of solar radiation. Solar radiation is directly affected by the position of the sun and various meteorological factors, which will cause discontinuity and uncertainty of the power output and have a great impact on the safety of grid connection. Therefore, it is very important to forecast the solar radiation accurately in the next few days. The safety and stability of the grid connection of the photovoltaic power are emphasized in the "National Medium and Long-term Science and Technology Development Plan Outline (2006-2020)" [2].

Many researchers have conducted extensive research for the short-term forecast of solar radiation [3-5].The research results show that the mesoscale numerical model has good forecasting under clear air conditions[6][7].

Aerosol is one of the important components in the atmosphere, and its physical and chemical properties of absorption and scattering affect the amount of solar radiation. Some scholars have studied the influence of aerosols on solar radiation. The results show that the increase of aerosols caused by pollution and other changes has a significant impact on the surface solar radiation flux in China[8][9].

In this article, ArcGIS software is used to analyze the population density of all the cities in China and find a suitable threshold of population density. The cities are divided into two types with rural aerosols and urban aerosols. Then the solar radiation predicted by the mesoscale model WRF under different aerosol mechanisms is chosen for the cities, which improves the accuracy of solar radiation prediction.

2 Selection of population density threshold

The data of population density are from "Main Data Bulletin of the National 1% Population Sample Survey in 2015" released by the National Bureau of Statistics and the corrected total land area of China issued by the National Bureau of Surveying and Mapping. Urban population density $\overline{X_1}$ is

$$\overline{X}_1 = \frac{N \times \alpha_1}{S \times \beta_1} \tag{1}$$

and rural population density $\overline{X_2}$ is

$$\overline{X}_2 = \frac{N \times \alpha_2}{S \times \beta_2} \tag{2}$$

In the formulas, N is the total population, α_1 is the proportion of the population living in cities, α_2 is the proportion of the population living in the countryside, S is the land area of China, β_1 is the proportion of China's urban areas, and β_2 is the proportion of China's rural areas.

Taking the average of urban population density and rural population density as the population density threshold, the results showed that the prediction had higher accuracy. The threshold is calculated by formula (3):

* Zhang Jinye: zhangjinye@hbut.edu.cn

$$\overline{X} = \frac{1}{2}\left[\frac{N \times \alpha_1}{S \times \beta_1} + \frac{N \times \alpha_2}{S \times \beta_2}\right] \quad (3)$$

From the calculation, the population density threshold is 109.63 persons/km². and the Chinese regional administrative divisions are classified and marked as urban type and rural type according the threshold. The result of the division is shown in Figure 1.

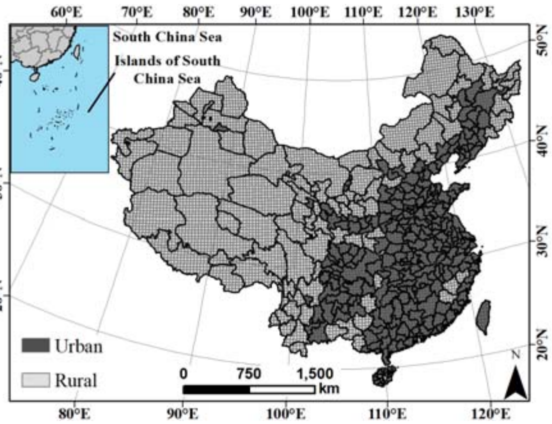


Fig. 1. The classification of urban and rural aerosol types in China

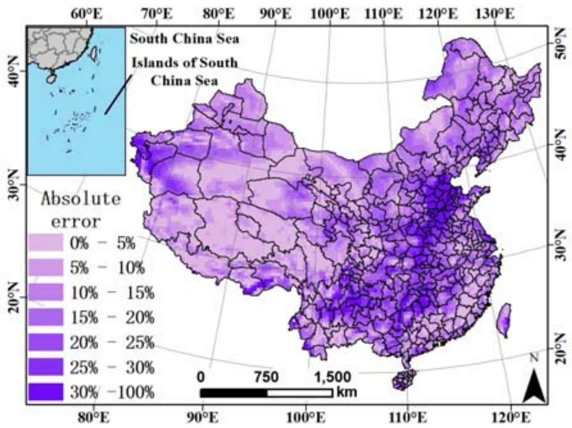
3 Error analysis

We use the average absolute error to evaluate the forecast accuracy:

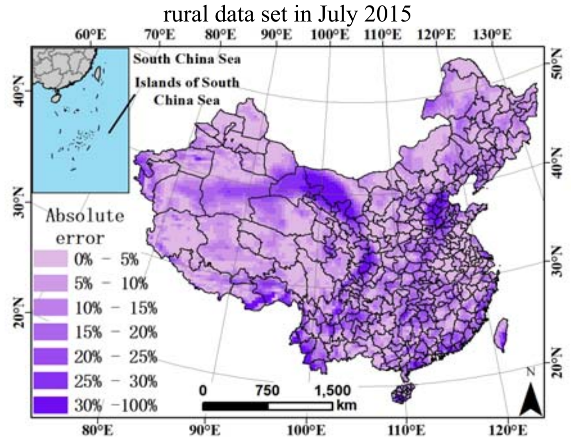
$$E_{MAP} = \frac{\frac{1}{N}\sum_{i=1}^{N}|P_f^i - P_o^i|}{\frac{1}{N}\sum_{i=1}^{N}P_o^i} \times 100\% \quad (4)$$

In the formula， N is the length of time series, i is the i^{th} day; P_f^i is the forecast value on the i^{th} day， P_o^i is the observed value on the i^{th} day.

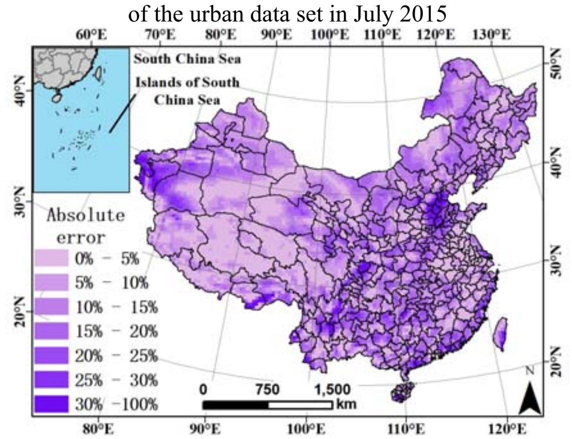
K1 is used to represent the absolute error of solar radiation forecast with rural aerosol type relative to that from CERES, and K2 is the absolute error of the solar radiation forecast with urban aerosol type relative to the CERES value， and K3 is the absolute error of the selected solar radiation forecast according to the regional administrative divisions relative to the CERES value. They are shown in Figure 2 and Figure 3.



(a)The spatial distribution of absolute percentage error of the rural data set in July 2015



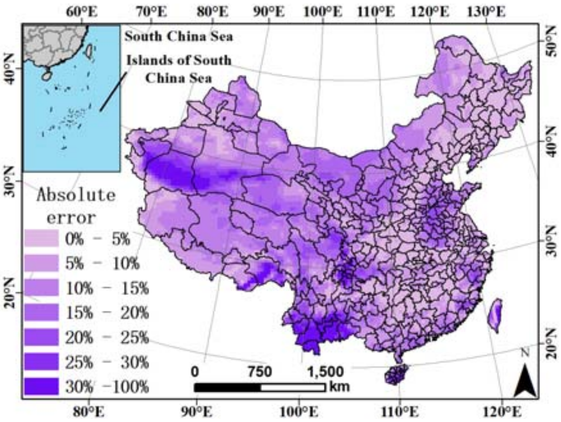
（b）The spatial distribution of the absolute percentage error of the urban data set in July 2015



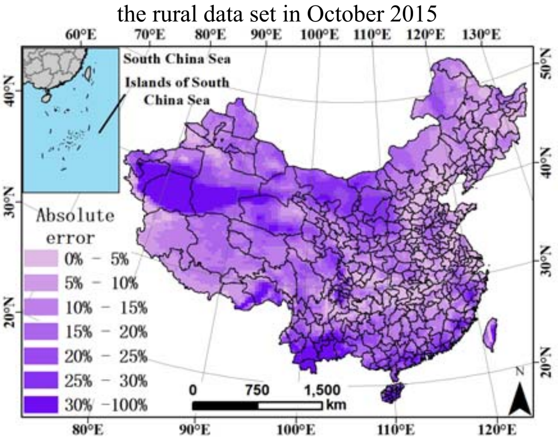
（c）The spatial distribution of the absolute percentage error of the mixed data set in July 2015

Fig. 2. Spatial distribution of absolute percentage error of rural data set, urban data set, and mixed data set in July 2015

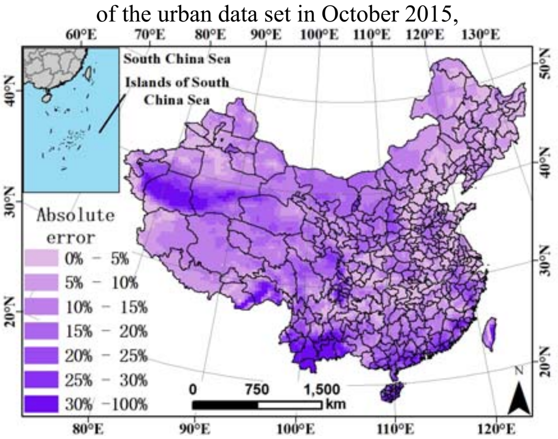
From Figure 2 (a) and (b), we can see that the low absolute errors of K1 are distributed in the northeast of China and the Qinghai-Tibet Plateau. The high absolute errors are distributed in Southeast China and the Kunlun Mountains, and the high errors are above 15%. The high absolute errors of K2 are concentrated in the Beijing-Tianjin-Hebei urban agglomeration, the Qilian-Hengduan mountain range and some coastal cities. The high errors are above 25%. As shown in Figure 2 (c), the error of the selected solar radiation forecast K3 is much lower than K1 and K2. Only the Beijing-Tianjin-Hebei urban agglomeration, the Hengduan Mountains and the western Kunlun Mountains have a little higher error.



(a)The spatial distribution of the absolute percentage error of the rural data set in October 2015



（b）The spatial distribution of the absolute percentage error of the urban data set in October 2015,



（c）The spatial distribution of the absolute percentage error of the mixed data set in October 2015

Fig. 3. The spatial distribution of the absolute percentage error of the rural data set, urban data set, and mixed data set in October 2015

From Figure 3 (a) and (b), it can be seen that in October 2015, the absolute error K1 is high in southern Yunnan, Taiwan Province and the Kunlun Mountains, and the errors in these areas are all above 20%. K2 has high value in the Tarim Basin, Kunlun Mountains, the eastern of Inner Mongolia, Hainan Province and some coastal cities, and the errors in these areas are all above 25%. From Figure 3 (c), it can be seen that the absolute errors in these areas are falling from more than 25% to about 15%.

4 Conclusions

In this paper, Chinese cities are classified into two types with urban aerosols and rural aerosols by setting the threshold of population density. The solar irradiance forecasting based on WRF in different aerosol type is chosen for the classified regions. We find that the errors are much lower than that only with rural aerosol type or only with urban aerosol type especially in the areas such as the Qinghai-Tibet Plateau, coastal cities, and central and eastern cities. There is a great improvement in the Qilian Mountains in July and the error is reduced by 16%. The largest improvement in October happens in coastal cities and the error is reduced by 9%. So the comprehensive consideration of the type of aerosol can effectively improve the accuracy of radiation forecasting.

Acknowledgments

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