Research on the Spatial-Temporal Distribution Pattern of the Network Attention of Fog and Haze in China

Lingyan Weng¹ and Xugao Han²

¹ Jingling College, Nanjing University, No.8 Xuefu Road, Pukou district, Nanjing, China.
² School of Humanities and Political Education, Nanjing University of Chinese Medicine, 138 Xianlin Road, Qixia district, Nanjing, China.
Email: hanxugao@163.com

Abstract. Understanding the spatial-temporal distribution pattern of fog and haze is the base to deal with them by adjusting measures to local conditions. Taking 31 provinces in China mainland as the research areas, this paper collected data from Baidu index on the network attention of fog and haze in relevant areas from 2011 to 2016, and conducted an analysis of their spatial-temporal distribution pattern by using autocorrelation analysis. The results show that the network attention of fog and haze has an overall spatial distribution pattern of “higher in the eastern and central, lower in the western China”. There are regional differences in different provinces in terms of network attention. Network attention of fog and haze indicates an obvious geographical agglomeration phenomenon, which is a gradual enlargement of the agglomeration area of higher value with a slight shrinking of those lower value agglomeration areas.

1. Introduction
In early 2013, along with persistent strong smog weather appeared in many cities in China's eastern coastal areas, fog and haze was widely concerned by the whole society. In recent years, the domestic research on fog and haze mainly focus on the causes of smog [1-2], the weather characteristics of smog process [3-4], the social effect of smog weather and its treatment [5-8]. Researches on the network attention of fog and haze and its spatial-temporal distribution characteristics remained fewer. With the rise of the concept of "Internet+", the Internet, with the advantages of convenient and efficient exchange of information, has gradually been applied to geographical research and so enriched traditional methods in geography [9-10]. What followed is that web-based tools such as web forums and search engines are widely used in the analysis of regional differences in geography. According to the 2013 CNNZ Research Report released by CNZZ Data Centre, netizens using Baidu search engine accounted for 84.5% of all internet users. Baidu index can not only reflects accurately and timely people's attention and the degree of their concern of an object, but also be used effectively to obtain data and applied to scientific research as an important tool for studying regional differences. Chinese scholars such as Xiong Lifang [11], Li Shan [12], He Xiaoyan [13] and others had applied Baidu index to research on the characteristics of inter-regional urban networks, tourism and other topics. Following them by using Baidu index, this paper collected data on network attention of fog and haze in 31 provinces and cities, and analysed the annual variation characteristics of network attention, discrete degree of network attention and its hot spots and the cold spots in 31 different provinces for the sake of controlling the smog weather and improving environmental quality by adjusting measures to local conditions.
2. Materials and Methods

2.1. Materials
By exploring the Baidu data (http://index.baidu.com/) of network attention paying to fog and haze to conduct a spatial analysis, this paper collected Baidu index of network attention of fog and haze day by day from January 1, 2011 to December 31, 2016 and accumulated the network attention of fog and haze in different years in 31 provinces in China mainland. Proceeding on the basic data of network attention and using the current administrative divisions map in China that forms the vector diagram as the base map, this paper analysed the spatial-temporal distribution pattern of network attention of fog and haze in the mentioned years by using ArcGIS10.2 software, and took 2013, 2014, 2015 and 2016 as the representative years to conduct a spatial agglomeration effect analysis of network attention payed for fog and haze.

2.2. Spatial Autocorrelation Analysis Method
Spatial autocorrelation analysis is a method used to determine the correlation and the degree of correlation of a variable in spatial position, which has two representative ways in global and local level. Global spatial autocorrelation measures the general distribution of a variable in the whole space, and decides if there is agglomeration characteristic or not. By using ArcGIS10.2, Global Moran’s $I$ shows the overall spatial pattern of network attention of fog and haze in China. The calculation formula is as below:

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij} \left( x_j - \bar{x} \right) \left( x_j - \bar{x} \right)}{\sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij} \sum_{i=1}^{n} \left( x_j - \bar{x} \right)^2}$$

(1)

Where $I$ refers to global Moran index, $n$ refers to amounts of the study area, $\omega_{ij}$ refers to the weight of spatial unit $i$ and $j$, $x_j - \bar{x}$ and $x_j - \bar{x}$ refers to the deviation of the average value and observed value in space $i$ and $j$ respectively. $I > 0$ indicates positive correlation in space where observed object is of the characteristic of agglomeration; $I < 0$ indicates negative correlation in space where observed object is of discrete characteristic; $I = 0$ indicates no spatial correlation where observed object is randomly distributed in space.

While to test the significance of Moran’s $I$, take the Z-score and 95% of P value as a confidence interval to make a two-sided check. When $Z > 1.96$ or $Z < -1.96$, $P > 0.05$, there is no rejection to null hypothesis as the observed variable is randomly distributed in space; when $Z > 1.96$ or $Z < -1.96$, $P < 0.05$, there is rejection to null hypothesis as the observed variable is distributed in agglomeration or discretely.

Local spatial autocorrelation is used to identify the specific geographical distribution of certain agglomeration area. This paper uses Getis-Ord $Gi^*$ to measure the local spatial autocorrelation of network attention of fog and haze in China and decides if there is agglomeration area of higher or lower value. The calculation formula is as below:

$$G_{i}^{*} = \frac{\sum_{j=1}^{n} \omega_{ij} x_j - \bar{x} \sum_{j=1}^{n} \omega_{ij}}{S \left( n \sum_{j=1}^{n} \omega_{ij}^2 - \left( \sum_{j=1}^{n} \omega_{ij} \right)^2 \right)^{1/2} (n-1)^{-1}}$$

(2)

$$\bar{x} = \frac{\sum_{j=1}^{n} x_j}{n}$$

(3)
\[ S = \left( \frac{\sum_{j=1}^{n} x_j^2}{n - \overline{x}^2} \right)^{1/2} \]  

(4)

Higher value of \( G_i^* \) indicates higher value agglomeration in adjoining areas, that is the hot-spot area; lower value of \( G_i^* \) indicates lower agglomeration in adjoining area, that is cold-spot area; a value of \( G_i^* \) tending to 0 indicates no agglomeration phenomenon [14].

3. Results and Discussions

3.1. The Spatial-Temporal Distribution Pattern of Network Attention of fog and Haze in China

By dividing annual network attention of fog and haze in every single province by the sum of network attention in all provinces of the same year, this paper got the fog and haze network attention index (FHNAI), and gained the spatial-temporal distribution pattern of network attention of fog and haze in China by classifying them into three categories. (Figure 1).

Figure 1. Spatial-temporal pattern of network attention of fog and haze in China (2013-2016).

In the year of 2013, only the FHNAI of Beijing, Jiangsu, Zhejiang, Guangdong and Henan 5 provinces overtopped 5 (category I). 16 provinces, including Heilongjiang, Jilin, Liaoning, Hebei, Shandong, Shanxi, Shaanxi, Anhui, Shanghai, Sichuan, Hubei, Hunan, Jiangxi, Fujian, Guangxi and Hainan fell in category II with an FHNAI of (2, 5]. All the other 10 provinces in China saw their FHNAI fall in (0, 2] (category III). Overall, the year of 2013 saw a spatial distribution pattern of
network attention of fog and haze that was characteristic of “higher in eastern and central, lower in western China”(Figure 1). The distribution pattern of network attention of fog and haze was consistent with the distribution of fog and haze pollution in China.

In the year of 2014, Henan province returned from category I to II, Chongqing and Yunnan climbed to category II from III with no changes in the overall spatial distribution pattern. In the year of 2015, Shandong province turned into category I, Yunnan and Guangxi fell to category III. While the areas covered by category II moved generally towards the north, but the overall spatial distribution pattern of “higher in eastern and central, lower in western China” remained unchanged. In comparison to 2014 and 2015, 2016 saw a larger change that was a 10 percent increase of the provinces in category I, as Hebei, Henan and Sichuan province climbed into category I, while Jiangsu and Zhejiang province dropped out. Jilin province reduced from category II to III. It is worth noting that, during the entire period of research, there was no significant promotion of Inner Mongolia, Ningxia, Gansu, Qinghai, Xinjiang and Tibet, which were all in the category III of the FHNAI (Figure 1).

3.2. The Spatial Agglomeration Effect of Network Attention of Fog And Haze in China

3.2.1. Global spatial autocorrelation analysis. By using ArcGIS10.2, this paper obtained a global spatial autocorrelation index I and its significance level (Z-score and P value) of network attention of fog and haze from 2011 to 2016, and conducted a comparison analysis through three spatial weight methods (Table 1).

The global autocorrelation index I of network attention of fog and haze reached by three spatial weight methods were all positive values during the period of research and had passed the 5% significance test. Results showed that Chinese network attention of fog and haze had spatial positive correlation characteristics, which were similar regions of the same network attention of fog and haze had the distribution characteristic of spatial agglomeration. At the same time, an analysis of the average of global spatial autocorrelation index I reached through three weight methods showed that a decreasing order of the level of spatial positive correlation of network attention of fog and haze was that method I >method III>method II. Among these three methods , annual spatial autocorrelation index I values from 0.07 to 0.4, and tended to grow gradually in general, which indicated that the distribution pattern of similar regional higher spatial agglomeration or lower spatial agglomeration was strengthened steadily (Table 1).

**Table 1.** Global spatial autocorrelation index and its significance level of network attention of fog and haze in China.

| Years | Method I<sup>a</sup> | Method II<sup>b</sup> | Method III<sup>c</sup> |
|-------|----------------|----------------|-------------------|
|       | I   | Z               | P    | I   | Z     | P    | I    | Z   | P    |
| 2011  | 0.193 | 2.612            | 0.009 | 0.163 | 2.484  | 0.010 | 0.079 | 2.986 | 0.003 |
| 2012  | 0.191 | 2.638            | 0.008 | 0.171 | 2.640  | 0.008 | 0.089 | 3.319 | 0.009 |
| 2015  | 0.201 | 2.752            | 0.006 | 0.175 | 2.675  | 0.007 | 0.092 | 3.405 | 0.007 |
| 2014  | 0.192 | 2.649            | 0.008 | 0.183 | 2.788  | 0.005 | 0.093 | 3.445 | 0.006 |
| 2016  | 0.326 | 3.948            | 0.001 | 0.301 | 4.032  | 0.001 | 0.164 | 5.038 | 0.001 |
| Averages | 0.394 | 4.661            | 0.001 | 0.347 | 4.543  | 0.001 | 0.198 | 5.878 | 0.001 |

<sup>a</sup> Method I indicates through Inverse Distance method.
<sup>b</sup> Method II through Fixed Distance method.
<sup>c</sup> Method III through Zone of Indifference method.

3.2.2. Local spatial autocorrelation analysis. In order to more effectively analyse the agglomeration characteristics of network attention in China, this article took network attention in the year of 2013, 2014, 2015 and 2016 as four representative samples. By using the method III in calculating the global spatial autocorrelation index and ArcGIS10.2 software to obtain the local spatial autocorrelation index Gi*, and in particular by using the natural break method to classify local spatial autocorrelation index...
of each year into four types, this paper produced an evolution map of the hot spots of network attention in China as shown in figure 2 below.

Seeing from the overall spatial structure, the general pattern of the spatial distribution of network attention of fog and haze in China remained stable. Hot spots of network attention of fog and haze were mainly located in 14 provinces of Beijing, Tianjin, Liaoning, Jilin, Shandong, Henan, Anhui, Jiangsu, Shanghai, Shanxi, Hubei, Inner Mongolia and Shaanxi. Cold spots were mainly located in 3 provinces of Qinghai, Xinjiang, and Tibet. The amounts of province fallen in these two agglomeration types were relatively stable in different period of time (Figure 2).

Figure 2. The hot spot map of network attention of fog and haze in China (2013-2016).

Seeing from the variation of 6 types of local spatial autocorrelation index, regions covered in different types were of certain changed with overall pattern remained stable. From 2013 to 2016 with the exception of 2014, there were 9 provinces in the extremely significant hot spots, 29.03% of all the provinces in China. The rate of relatively significant hot spots experienced a process of increase followed by a decrease, which was increased from 6.45% in 2013 to 16.13% in 2014 and reduced to 12.90% in 2016. While the weight of normal significant hot spots tended to decrease from 6.45% in 2013 to 3.23% in 2016. In the year of 2013 and 2015, Qinghai and Tibet were in the normal significant cold spots with Xinjiang joined this group in 2014 but dropped out in 2016. Generally speaking, cold spots took little weight in the whole map, in which 8 provinces remained unchanged during these four years in terms of the agglomeration characteristics, that was 25.91% of all provinces in China.

Seeing from the variation of agglomeration characteristics in different province, 9 provinces of Beijing, Tianjin, Liaoning, Hebei, Shandong, Henan, Jiangsu, Anhui and Shanghai were in the extremely significant hot spots in 2013. During these 4 years, Anhui province experienced a variation...
pattern of “out-in-out” of the extremely significant hot spot area group, of which Shanghai dropped out and reduced to relatively significant hot spots in 2016 when Shanxi and Inner Mongolia joined in. Shaanxi were in the random distribution areas in 2013 and climbed into relatively significant hot spots in 2016 indicating that network attention of fog and haze moved towards the north-western part of China during this period of time.

4. Conclusions
During the period of research, the network attention of fog and haze is generally presented characteristic of the spatial distribution pattern of “higher in the eastern and central, lower in the western China”. There are increase in some eastern and central provinces and decrease in other provinces in terms of network attention, of which Inner Mongolia, Ningxia, Gansu, Qinghai, Xinjiang and Tibet experienced a relatively slow growth.

Network attention of fog and haze in China has the characteristic of global dependency and positive spatial correlation, which is enhanced gradually. As the overall spatial distribution pattern remained stable, local characteristic of differentiation appears a gradual enlargement of the agglomeration area of higher value and a slight shrinking of those lower value agglomeration areas.

5. Acknowledgments
This work is supported by the National Natural Science Fun (Grant No. 41701609).

6. References
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