Regional atmospheric visibility characteristics and its effect on radiation in China

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Abstract. Spatial and temporal characteristics of atmospheric visibility in China were investigated by using monitored meteorological data. The results show that the atmospheric lowest visibility (<10km) occurrence frequency in China can be observed in the east of Sichuan, Chongqing, and the east of Guizhou. The visibility in most regions of China exhibits a decreasing trend from 1980 to 2010. It is also found that fog is the major weather phenomenon affecting visibility in China. The second is precipitation except the Northwest and Inner Mongolia, where sand and dust is the major weather phenomenon affecting visibility. Our results also identify the total radiation under the condition of low visibility is less than that under the condition of normal, meanwhile, the atmospheric scattered radiation increase. Net radiation in the condition of low visibility is less than that in the normal condition in most cases over China.

1. Introduction
Atmospheric visibility is an indicator to reflect the degree of atmospheric transparency. So it is an obvious qualitative indicator of air quality. Atmospheric visibility in the daytime is defined as the distance at which an average observer can just barely distinguish a black object silhouetted against the horizontal skyline. In an uncontaminated atmosphere, visibility normally ranges from 145 to 225 km [1]. Atmospheric visibility has only not attracted the attention of the public, but also provides a useful way for investigating variations in the atmosphere [2]. Atmospheric visibility is well received by the impact of meteorological factors. Visibility increases with temperature and wind speed, while declines with relative humidity and atmospheric pressure [3, 4]. Visibility is also affected by human activities. Many studies have researched long term visibility trends and the impacts of dominant air pollutants [5-8]. Important studies have been undertaken to examine visibility characteristics at regional, continental, and global scales [9-11].

This study aims at better understanding the climatic characteristics of atmospheric visibility and its impact. So we conducted research on atmospheric visibility in China by regional division. In view of the different regions, regional characteristics and influences of atmospheric visibility were analyzed.

2. Material and methods
Data at 593 observation stations (excluding those mountainous stations) across China were collected. They include atmospheric horizontal visibility (4 times per day), wind speed (4 times per day), and
daily average relative humidity from January 1980 to December 2010, as well as observed radiation data at 122 observation stations among 593 from January 1980 to December 2000.

The trend of annual average visibility in different regions was analyzed. Further efforts have been also made to explore temporal distribution and duration of low visibility occurrence frequencies in different regions. Finally, the influence of low visibility to radiation has been examined.

3. Results and discussion

3.1. Spatial distribution of atmospheric low visibility occurrence frequency

The spatial distribution of atmospheric low visibility (<10km) occurrence frequency (occurrence times/total observation times) in China averaged over 1980 through 2010 is shown in Figure 1. The highest atmospheric low visibility (<10km) occurrence frequency can be observed in the east of Sichuan, Chongqing, and the east of Guizhou where there were at least 0.5% on an annual basis in winter (Figure 1d). Those areas filled by green color in Figure 1a and Figure 1c, namely in spring and autumn, including Jiangxi, Hunan, Hubei, Fujian, and Guangdong provinces also observed relatively high occurrence frequency with annual fog days greater than 0.2%. The average annual fog days in the rest of China were less than 0.2%. In terms of nationwide, the visibility is best in summer.

![Spatial distribution of atmospheric low visibility occurrence frequency](image)

**Figure 1.** The spatial distribution of atmospheric low visibility (<10km) occurrence frequency in China from 1980 to 2010. (a) Spring (b) Summer (c) Autumn (d) Winter

3.2. Trend of atmospheric visibility

The variation of 10-years average visibility is presented in Figure 2. According to the administrative division, China is divided into nine regions. As shown, the visibility variation in total 30 years exhibit a decreasing trend in most areas of China, including Northwest, Central China, North China, East China, Northeast, and South China (according to the administrative division of China). But in Tibet, Inner Mongolia, and Southwest, the visibility first increased and then decreased subsequently. In particular, a strong decreasing trend can be observed in all regions in China.
3.3. The proportion of weather phenomena affecting visibility

The main weather phenomena, affecting atmospheric visibility, include precipitation, dust weather, fog and haze. In order to understand the major weather phenomenon affecting atmospheric visibility in different regions of China, we analyze the major weather phenomenon under the condition of low visibility. The result is shown in Table 1. From the Table 1, we can get that fog is major weather phenomenon affecting visibility in China. The second is precipitation except the Northwest and Inner Mongolia, where sand and dust is the major weather phenomenon affecting visibility.

| Region          | Precipitation | Sand and dust | Fog | Haze |
|-----------------|---------------|---------------|-----|------|
| Northeast       | 25            | 3             | 67  | 3    |
| North China     | 20            | 2             | 71  | 2    |
| Northwest       | 26            | 36            | 32  | 0    |
| Central China   | 31            | 0             | 61  | 2    |
| East China      | 27            | 0             | 63  | 3    |
| South China     | 29            | 0             | 55  | 10   |
| Southwest       | 33            | 2             | 55  | 2    |
| Inner Mongolia  | 14            | 40            | 40  | 0    |
| Tibet           | 37            | 24            | 25  | 0    |

3.4. Duration of atmospheric low visibility

Figure 3 shows that the duration of atmospheric low visibility in 9 regions of China. The proportion which low visibility lasted one day is the highest in vast majority areas of China. Secondly, the proportion which low visibility lasted two days is the higher. Meanwhile, the proportion of sustained two days in North China and East China is the highest than that in the other regions. Overall, the duration of atmospheric low visibility is not very long, more than 70% lasted for one day. But East China is an exception, this shows that the duration of low visibility in East China is longer compared to other regions.
3.5. The influence of atmospheric visibility to radiation

Atmospheric visibility is an indicator to reflect the degree of atmospheric transparency. The atmospheric aerosols have an important impact on the solar radiation. In order to understand the low visibility on the influence of solar radiation, we compared and analyzed the variation of total radiation, scattered radiation, and net radiation under the condition of low visibility and normal.

3.5.1. Total radiation. The variation of total radiation under the conditions of low visibility and normal is shown in Table 2. Total radiation in the condition of low visibility is less than that in the normal condition in four seasons over China. If the reduction amount to counting, the largest of the three regions are Northwest, Southwest, and Tibet. The reduced maximum value of radiation appeared in different seasons for different regions. The reason could be the weather phenomena influencing the regional visibility is different. Overall, the effect of low visibility is to reduce the total radiation.

| Region       | Winter |      | Spring |      | Summer |      | Autumn |      |
|--------------|--------|------|--------|------|--------|------|--------|------|
|              | Low visibility | Normal | Low visibility | Normal | Low visibility | Normal | Low visibility | Normal |
| Northeast    | 808    | 894  | 1884   | 2065 | 2343   | 2565 | 1171   | 1339 |
| North China  | 889    | 1079 | 2043   | 2221 | 2370   | 2576 | 1272   | 1471 |
| Northwest    | 870    | 1089 | 2017   | 2340 | 2487   | 2719 | 1329   | 1553 |
| East China   | 1106   | 1322 | 2113   | 2309 | 2380   | 2545 | 1480   | 1653 |
| Central China| 1033   | 1157 | 2122   | 2169 | 2345   | 2461 | 1457   | 1554 |
| South China  | 1411   | 1570 | 2125   | 2285 | 2235   | 2396 | 1697   | 1863 |
| Southwest    | 1253   | 1724 | 1985   | 2272 | 2421   | 2733 | 1791   | 1867 |
| Tibet        | 946    | 1434 | 1941   | 2364 | 2024   | 2827 | 1202   | 1778 |
| Inner Mongolia| 719   | 1003 | 1982   | 2235 | 2489   | 2772 | 1051   | 1461 |

3.5.2. Scattered radiation. The variation of scattered radiation under the conditions of low visibility and normal is shown in Table 3. Scattered radiation in the condition of low visibility is more than that in the normal condition in four seasons over China. If the increase amount to counting, the largest regions is Northwest. The reduced maximum value of radiation appeared in spring and summer of Northeast. Overall, the effect of low visibility is to increase the scattered radiation.

3.5.3. Net radiation. The variation of net radiation under the conditions of low visibility and normal is shown in Table 4. Net radiation in the condition of low visibility is less than that in the normal condition in most cases over China. The influence of visibility on the net radiation is more complex. When visibility is low, the total radiation is less than that under the condition of normal, meanwhile, the atmospheric counter radiation and scattered radiation increase. But seen from the Table 4, net radiation under the condition of low visibility is less than that under the condition of normal. In Tibet and North China, the net radiation under the condition of low visibility is more than that under the condition of normal.

![Figure 3. Duration of atmospheric low visibility in 9 regions of China](image-url)
Acknowledgements
The work was supported by the project of Tianjin Meteorological Bureau (201727ybxml9).

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