CORRELATIVE ANALYSIS ON RELATIONSHIP BETWEEN CHANGES OF SURFACE SOLAR RADIATION AND THE HAZE POLLUTION (ATMOSPHERIC TURBIDITY INDEX) IN BEIJING FROM 1961 TO 2011*

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ABSTRACT

Increased aerosol or haze was the reason to radiation reduces, but there is no evidence. This research was aim to quantitatively analyze the contribution of air pollution to Surface Solar Radiation (SSR) reducing in Beijing. Because there had no long time series of the ground observation aerosol data, in order to reflect the atmospheric pollution and aerosol levels, we developed an Atmospheric Turbidity Index (ATI) whose the monthly/ annual variation was significantly correlated with aerosol optical depth (AOD), and ATI could well reflects the change air pollution. The ATI and SSR had significant negative correlation relationship. The changes of Beijing SSR presented a clear downward trend. From the inter-annual variability, the SSR was on the sharply decline trend from 1960 to about 1990, and a increase slowly trend after 1990s, as negative correlation relationship with SSR the trend AOD was going in the opposite direction.

Keywords: Surface Solar Radiation, Atmospheric turbidity Index, Atmospheric pollution, Haze pollution.

1. Introduction

In past half a century, many scholars analyzed and discuss various regional and global terrestrial Surface Solar Radiation （SSR）observation data, influence factors, which carried on the ground radiation data (Wild *et al*., 2005; IPCC 2007; Ding *et al*., 2014; Qi *et al*., 2014). The results showed that, the SSR less about 10% from 1960 to 1990, it is called Global "dark", from the end of the 80's up to now, the SSR has started a trend of increase in many parts, it was called Global "brighten"(Wild *et al*., 2005). Wang *et al*. (2010) studied scholars began to pay attention to the relationship between radiation change and China atmospheric haze or aerosol. Qi *et al*. (2015) study showed that haze pollution aerosol air pollution is the main factor which affecting reduces of SSR in the eastern region. The main reason was the increasing of total suspended particles in the atmosphere. But these studied thought increased aerosol or haze was the reason to radiation reduce, however, there is no evidence.

Because there is no long time series of the ground observation aerosol data, direct radiation and scattering radiation are used to get the atmospheric turbidity factor, and according to the atmospheric turbidity factor reflecting the atmospheric pollution and aerosol levels. The haze weather in Beijing is serious in recent years, whether the haze weather could reduce the SSR need further evidence. In this study, the annual variation of SSR in the Beijing during the period 1961–2011 is investigated based on the available surface solar radiation data. We focused on the correlation between SSR and air pollution, in order to quantitative analysis contributes to air pollution in the SSR changing.

2. Data and methods

2.1. Data

The SSR data used in this paper are collected from Beijing sites in China covering the entire period 1961—2011, and have direct and diffuse radiation measurements. In addition to SSR data, conventional meteorological data are obtained from the above Beijing sites with precipitation, sunshine percentage, sunshine duration, temperature, total cloud cover, and low cloud cover. The aerosol optical depth (AOT) data over Beijing are from the MODIS Land Standard Products MOD08_M3 by NASA during the period 2001-2012.

2.2. Methods

2.2.1. The atmospheric turbidity Index (ATI)

The study calculated atmospheric turbidity factor using meteorological observation data, due to the short time series data of aerosol. The atmospheric turbidity reflected to the change of aerosol (Qi *et al*., 2015). We developed the methods to measure the atmospheric turbidity factor (ATI) based on Direct Solar Radiation (DSR) and Diffuse Radiation (DR). ATF was formulated as:

$$ATI = \frac{DSR}{DR} \tag{1}$$

The atmospheric turbidity mainly depends on the content of atmospheric aerosol under the same solar altitude in the sunny day. The ATI value is very small when the atmosphere is clean, and the atmospheric turbidity serious, ATI values greater. There is a certain relationship between atmospheric turbidity and the surface solar radiation (SSR).

$$SSR = DSR + DR \tag{2}$$

By comparing the formula (1), (2) found

$$\frac{SSR}{ATI} = DR + \frac{DR^2}{DSR}$$

$\frac{SSR}{ATI}$ and DR are quadratic equation, so the SSR and ATI are two non independent variables. The SSR and ATI were tested by the MODIS Land Standard Products MOD08_M3.

2.2.2. Trend analysis, significance Test

Annual time-series of the indices were calculated for each station. Trends in the annual indices were calculated using linear trend estimated for each station, using all available years from 1961 to 2011. Statistical significance of the trends is evaluated at the 5% level of significance against the null hypothesis (Wei, 2007).

3. Results and discussion

3.1. The AOD and ATI relationship analysis

The variation patterns of the monthly ATI and AOD over Beijing from 2000 to 2011 are shown in Figure 1.

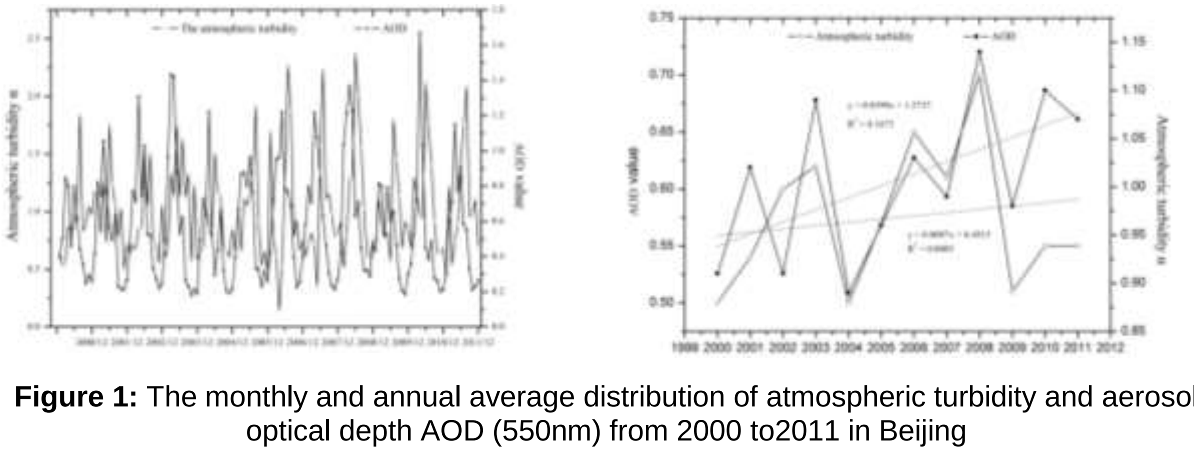

Figure 1: The monthly and annual average distribution of atmospheric turbidity and aerosol optical depth AOD (550nm) from 2000 to2011 in Beijing

The change trend of the ATI and AOD are roughly the same. The ATI and AOD values are lower in autumn and winter. From the change of the average annual analysis, the highest value of ATI and AOD were appeared in 2008, the lowest value appeared in 2004. The monthly/ annual ATI and AOD were significantly correlated, and the correlation coefficient was 0.285/0.541 by significant test at 0.01/0.05 level. So the atmospheric turbidity can better reflect the atmospheric conditions.

3.2. Relations between the SSR and metrological elements

The meteorological factors affecting the SSR changed a lot, the existing studied have shown that (Chen *et al*., 2005; Che *et al*., 2006; Zhang *et al*., 2004; Elminir *et al*., 2006), the aerosol factor of human activity is the main influence factor. Shao *et al*. (2009) found that the SSR decreased with the increase of PM10 concentration in North China.

The correlation coefficient between precipitation, low cloud cover, total cloud cover, sunshine percentage, atmospheric turbidity and the SSR were showed in Table 1. From 1961 to 2011, a negative correlation relationship between the SSR and low cloud cover, turbidity in partial and simple correlation, and the simple correlation coefficient through the 0.01 significance level test. There was no significant correlation between the SSR and precipitation, sunshine percentage, total cloud cover. The ATI and SSR had significant negative correlation relationship.

Table 1: The correlation and partial correlation coefficients SSR and climatic factors

	Precipitation	Sunshine percentage	low cloud cover	total cloud cover	atmospheric turbidity
partial correlation coefficient	0.341	-0.155	-0.441	0.514	-0.422**
simple correlation	-0.131	0.793**	-0.577**	-0.133	-0.530**

**Values significant at 0.01probability level

3.3. The ATI and the SSR relationship

The Aerosols are important factors that result in the change of SSR. Because there is no long time series of the ground observation aerosol data, direct radiation and scattering radiation are used to get the ATI, and according to the ATI reflecting the atmospheric pollution and aerosol levels. Zhang *et al*. (1997) had studied the relationship between solar radiation and air pollution change in cities change and found that the ATI could well reflect the atmosphere pollutants and its change trend. The atmospheric turbidity was increased, an average of 0.036/10a, the increase of atmospheric turbidity on behalf of the content of the aerosol, and the content of aerosol made the SSR decreased, consistent with the change of the SSR(Figure 2). Look from partial correlation and simple correlation, the atmospheric turbidity and SSR had significant negative correlation relationship (table 2). It showed that many factors of the SSR reduced, atmosphere turbidity index in the Beijing area was the main factor of the SSR reduction.

Figure 2: The distributions of SSR and ATI from1961 to2011 in Beijing

4. Conclusions

The study analyzed the annual variability of SSR in Beijing during the 1961-2011 periods, and the correlation between SSR and atmospheric pollution. The variation of the SSR and AOD are very small, and showed a slight decreasing trend over Beijing, and the SSR and AOD were significantly correlated. The change trend of the ATI and AOD are roughly the same. The monthly/ annual ATI and AOD were significantly correlated, so the atmospheric turbidity can better reflect the atmospheric conditions. The changes of Beijing SSR were analyzed which could be seen that the average of the Beijing, presented the downward trend; the Beijing inter-annual SSR different ranged for each year decline, showing a decreasing trend. From the inter-annual variability, the SSR was on the decline before 1990s, and then slowly began to increase. All the factors that influence the change of SSR, the atmosphere turbidity index in the Beijing area was the main factor of the SSR reduced.

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