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Short communication

Do aerosols impact ground observation of total cloud cover over the North China Plain?

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ABSTRACT

Ground observation of the total cloud cover (TCC) showed a significant downward trend during the past half century over the North China Plain (NCP). The objective of this paper is to examine whether aerosols have impacted the surface observations of TCC by human observers. TCC observations by the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Aqua (TCC_{sat}) were firstly compared with ground observations (TCC_{grd}) at 201 synoptic stations over the NCP. Results showed that both data sets were in good agreement. The correlation coefficient between TCC_{grd} and TCC_{sat} ranged from 0.80 in winter to 0.90 in summer. The relationship between TCC_{sat}–TCC_{grd} and visibility was then analyzed, which showed no significant correlation. Finally, long-term trends of TCC_{grd} and visibility were not correlated. These results indicated that aerosols likely did not impact the long-term trend of TCC_{grd} over the NCP.

1. Introduction

About 60% of the world is coved by cloud and cloud is an important factor for weather prediction and climate change. Due to the profound influence of clouds on both the water balance and global radiation budget, even small variations can alter the climate response. However, there are still large uncertainties in cloud observations including amounts, types, heights and thicknesses (Stephens, 2005).

The up–down observation by satellite provides an overall view of the cloud coverage continuously and extensively. It is critically influenced by the number of spectral bands and sensor's spatial resolution (Kotarba, 2009). About 2–3 decades of satellite cloud cover data have been accumulated from ISCCP (International Satellite Cloud Climatology Project) (Rossow and Schiffer, 1999). The ISCCP data has played an important role in many applications; however, its use in global multi-decadal studies is still being debated. Evan et al. (2007) pointed out that the long-term global trends in cloudiness from the ISCCP record were influenced by artifacts associated with satellite viewing geometry. Ground-based observation can back to 1950 or earlier and the data are widely used for study of long-term variation of cloudiness. Analysis of ground observation of total cloud cover (TCC) showed an increasing tendency of TCC over northern Indian Ocean (Norris, 2001), North America and Europe (Warren et al., 2007; Sanchez-Lorenzo et al., 2012). In contrast, a decreasing trend was found in South America, Eurasia and Africa (Warren et al., 2007). In China, TCC decreased until the middle of 1990s and then leveled off or turned signs at much of synoptic stations (Xia, 2010; Zong et al., 2012). Ground-based cloud observation relies on the eye sight and experience of observer as well as the contrast between reference and ambient environment. It was speculated that an increase of aerosol loading in the atmosphere obscured the ground-based observation of very thin and middle-level clouds, resulting in an underestimation of total apparent cloud cover and thereby a decreasing trend of TCC (Warren et al., 2007). Therefore, detection of the potential effects of these factors on ground-based observation of cloud is urgently required for better understanding of long-term variation and trend of cloudiness (Xia, 2010). It is also very important for deep understanding of related climate changes, for example, global dimming and brightening, global warming and global water cycling (Wild, 2009; Wang and Dickinson, 2013; Xia, 2013).

As a result of rapid economic development and population growth in China, aerosol optical depth was observed to increase from 0.38 in 1960 to 0.47 in 1990 (Qiu and Yang, 2000; Luo et al., 2001). More specific, aerosol optical depth at 550 nm (AOD) in Beijing, a mega-city in the NCP varied from about 0.28 in 1980 to about 0.68 in 2005, implying a significant increase in aerosol loading during the past 25 years (Xia et al., 2007). If the obscuring effect of aerosol does exist, it will undoubtedly contribute to the variation and trend of TCC in China. Changes seen in cloud types associated with the Indian monsoon were consistent with

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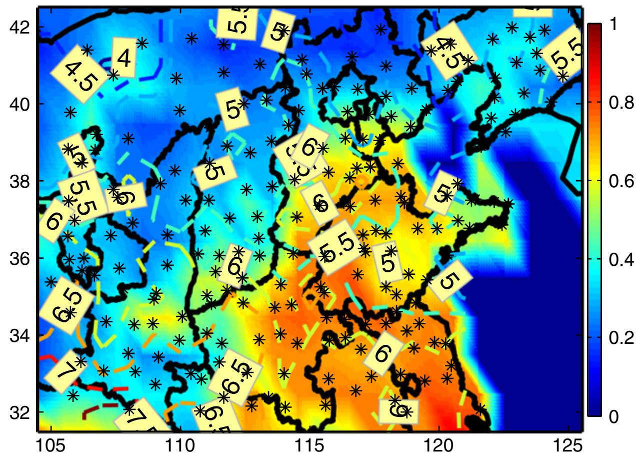

Fig. 1. Spatial distribution of annual mean aerosol optical depth at 550 nm by the Aqua MODIS and total cloud cover over the North China Plain. The locations of synoptic stations are represented by stars.

this hypothesis suggesting that increased pollution (black carbon) may be affecting monsoonal precipitation, causing drought in northern India (Eastman and Warren, 2013). It was expected that aerosol obscuring effect in regions with higher aerosol loading would be larger than that in the mildly polluted regions if there were similar increasing trends of aerosol loading in both regions and if aerosols did influence human observations of TCC. However, analysis of TCC during the period 1954–2009 in China showed that TCC in regions with lower AOD showed comparable or even larger decreasing trends than that in regions with higher AOD, which was obviously not consistent with the hypothesis of aerosol obscuring effect in China (Xia, 2012). The hypothesis that aerosols impacted observations of cloud cover by human observer was further tested in this paper. This objective is achieved by a detailed analysis of the difference between TCCs by satellite observations (TCC_{sat}) and surface observers (TCC_{grd}) ($\Delta TCC = TCC_{sat} - TCC_{grd}$). The rationale behind this analysis is that if TCC_{grd} was influenced by the aerosol obscuring effect, one would expect that ΔTCC should increase as aerosol loading increases. This is because TCC_{grd} would decrease as aerosol loading increases, contrarily, TCC_{sat} would likely increase due to probably misclassification of aerosols to cloud. The paper is organized as follows. A brief description of data and methods is given in Section 2. Major results are presented in Section 3. Summary and conclusions are provided in Section 4.

2. Data

2.1. Ground-based total cloud cover and visibility

The total cloud cover and visibility are observed at 1-h intervals or 3-h intervals at national climate and basic weather stations, respectively (Xia, 2012). Total cloud cover is the fraction of sky obscured by clouds. It varies between 0 and 10 with unit of one-tenth. Days with cloud cover of zero represents a clear day and ten represents an overcast day, respectively. In this paper, TCC_{grd} and visibility (km) at 201 synoptic stations over the North China Plain (NCP: 32°N–42°N, 105°E–125°E) observed at 14:00 LST were used because the observations were close to the overpass time of the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Aqua.

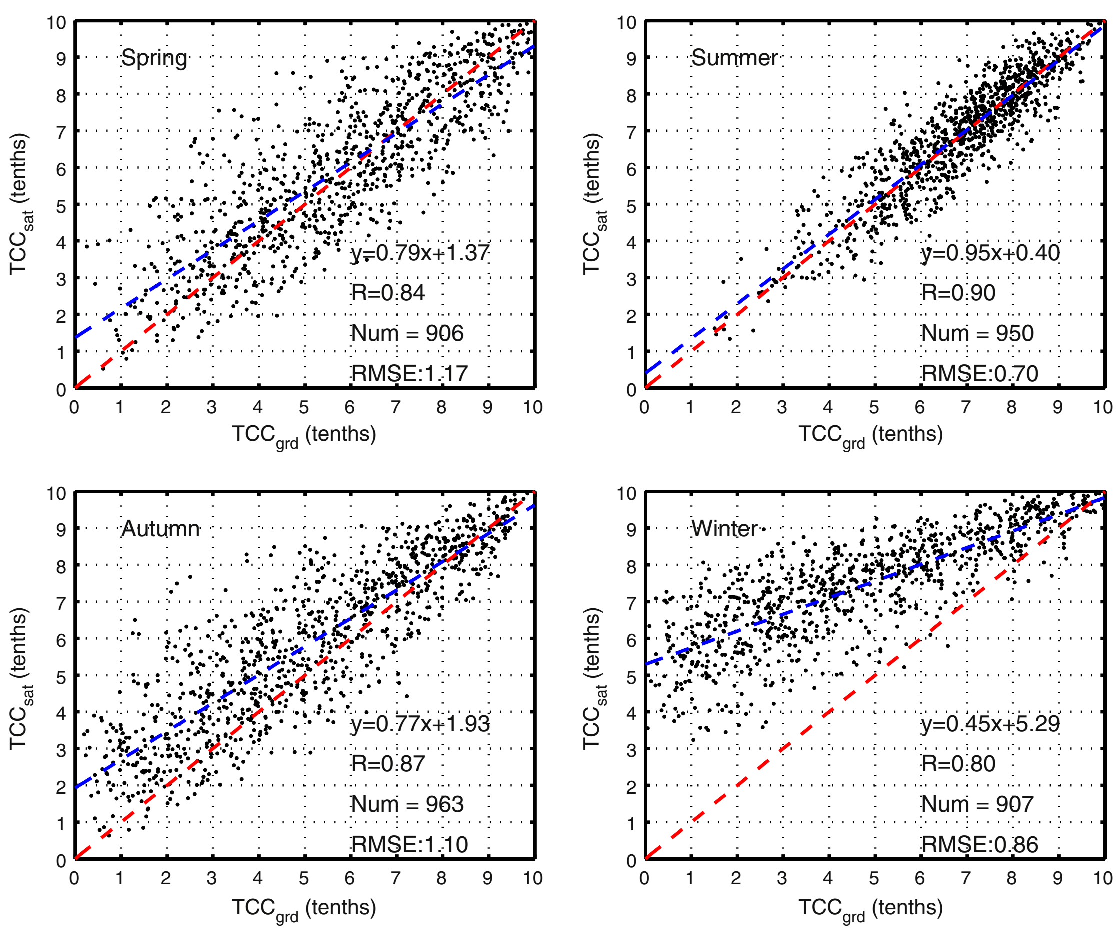

Fig. 2. The scatter plot of total cloud cover measured by human observers (TCC_{grd}) and the Aqua aboard MODIS (TCC_{sat}) in four seasons over the North China Plain.