Science of the Total Environment 633 (2018) 452–462

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Temporal and spatial variations in sand and dust storm events in East Asia from 2007 to 2016: Relationships with surface conditions and climate change

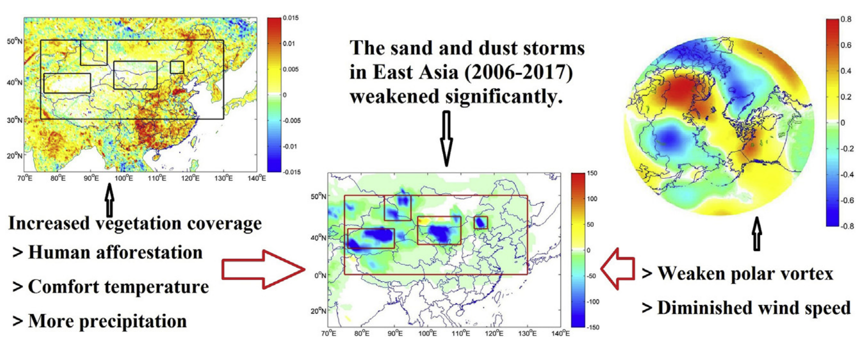
Linchang An [a,b,c], Huizheng Che [a,*], Min Xue [a], Tianhang Zhang [c], Hong Wang [a], Yaqiang Wang [a], Chunhong Zhou [a], Hujia Zhao [a], Ke Gui [a,b], Yu Zheng [a,d], Tianze Sun [a,b], Yuanxin Liang [a,b], Enwei Sun [d], Hengde Zhang [c], Xiaoye Zhang [a]

[a] Key Laboratory of Atmospheric Chemistry of CMA, Institute of Atmospheric Composition, Chinese Academy of Meteorological Sciences, Beijing 100081, China
[b] College of Earth Science, University of Chinese Academy of Sciences, Beijing 100081, China
[c] National Meteorological Center, CMA, Beijing 100081, China
[d] Nanjing University of Information Science & Technology, Nanjing 210044, China

HIGHLIGHTS

- Sand and dust storms in East Asia (2006–2017) weakened significantly.
- Increasing vegetation cover in the dust source area control the soil degradation.
- Polar vortex indirectly affects sand and dust storms by reducing the wind speed.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 5 January 2018
Received in revised form 6 March 2018
Accepted 7 March 2018
Available online xxxx

Editor: Jianmin Chen

Keywords:
Sand and dust storms
Surface conditions
NDVI
Climate change

ABSTRACT

We analyzed the frequency and intensity of sand and dust storms (SDSs) in East Asia from 2007 to 2016 using observational data from ground stations, numerical modeling, and vegetation indices obtained from both satellite and reanalysis data. The relationships of SDSs with surface conditions and the synoptic circulation pattern were also analyzed. The statistical analyses demonstrated that the number and intensity of SDS events recorded in spring during 2007 to 2016 showed a decreasing trend. The total number of spring SDSs decreased from at least ten events per year before 2011 to less than ten events per year after 2011. The overall average annual variation of the surface dust concentration in the main dust source regions decreased 33.24 μg/m^3 (−1.75%) annually. The variation in the temperatures near and below the ground surface and the amount of precipitation and soil moisture all favored an improvement in vegetation coverage, which reduced the intensity and frequency of SDSs. The strong winds accompanying the influx of cold air from high latitudes showed a decreasing trend, leading to a decrease in the number of SDSs and playing a key role in the decadal decrease of SDSs. The decrease in the intensity of the polar vortex during study period was closely related to the decrease in the intensity and frequency of SDSs.

© 2018 Elsevier B.V. All rights reserved.

* Corresponding author.
E-mail address: chehz@cma.gov.cn (H. Che).

https://doi.org/10.1016/j.scitotenv.2018.03.068
0048-9697/© 2018 Elsevier B.V. All rights reserved.

1. Introduction

Sand and dust storms (SDSs) are natural events that can have disastrous effects on both the environment and human activities (Sun et al., 2001; Zhou and Wang, 2002; Tam et al., 2012). SDS events in East Asia mainly occur in the spring and may cause a decrease in visibility to <10 km, or even occasionally to <0.1 km. The concentrations of particles with diameters <10 μm increase significantly, which affects the air quality and can cause respiratory symptoms in humans (Zhang et al., 1998; Kim et al., 2001; Seinfeld et al., 2004; Che et al., 2006; Meng and Lu, 2007). The sand and dust particles influence weather systems and the climate by changing the radiation balance, both directly by absorbing and scattering radiation and indirectly by affecting the cloud cover when they act as cloud condensation nuclei (Tegen, 2003; Gong et al., 2006; Che et al., 2013; Bi et al., 2014; Huang et al., 2014; Che et al., 2015). In addition, Essential micronutrients are carried to the oceans by these sand and dust particles, providing nutrients via processes such as particle floating, adsorption and co-precipitation (Yuan and Zhang, 2006; Wang et al., 2009; Martínez-Garcia et al., 2011; Tan et al., 2012; Tan et al., 2013; Fan et al., 2017).

There have been many studies of the distribution and frequency of SDSs in East Asia in recent years. Ground observation records, satellite data, and dust model results are used to analyze the distribution and frequency of SDSs in East Asia (Zhang et al., 2003a; Mikami et al., 2005; Xu et al., 2011; Li et al., 2012; Chen et al., 2017a). In particular, an integrated SDSs forecasting system–CUACE/Dust (Chinese Unified Atmospheric Chemistry Environment for Dust) has been developed and successfully used in the SDSs forecasts in East Asia (Gong and Zhang, 2008). The main source areas for dust in East Asia are the deserts and semiarid regions of Mongolia and northern China (Wang et al., 2006; Wang et al., 2008a), from where ~800 Tg of sand and dust particles are injected into the atmosphere annually. About 30% of these particles are redeposited in the desert regions and about 70% left the source areas and are transported to North China, the Korean Peninsula, Japan, and the northern Pacific Ocean, with some particles even reaching America and France (Zhang et al., 1997; Chun et al., 2001; Zhang et al., 2003b; Grousset et al., 2003; Mukai et al., 2004; Che et al., 2005; Yuan and Zhang, 2006; Gong et al., 2007; Zhang et al., 2008). There are two main reasons for the variation in the distribution and frequency of SDSs in East Asia directly: (1) changes in the surface conditions of the source areas and (2) variations in the wind in the near-surface layer (Zhang et al., 2005; Yu et al., 2009). Both of these reasons are closely related to climate change. Precipitation, soil moisture, low air temperature, surface soil conditions as well as human activities are the important factors that determine the vegetation coverage and then influence SDSs events indirectly (Natsagdorj et al., 2003;Liu et al., 2004; Lee and Sohn, 2011; Wang et al., 2018). Furthermore, the distribution and frequency of SDSs are strongly related to the near-surface wind which is supposed to be linked with large-scale atmospheric circulations such as polar vortex, cold air activity, surface pressure field, and so on (Littmann, 1991; Qian et al., 2002; Zhao et al., 2004; Yang et al., 2007).

Although many studies have been conducted, there is still a lack of high-quality dust data with excellent temporal and spatial resolution. The ground observation data lack long-term continuous dust concentration records, and the spatial resolution of the observation station also restricts studies. The satellite observation data and mode simulation results have good temporal and spatial resolution, and there are large quantities of algorithm researches (Qu et al., 2006; Chen et al., 2017a, 2017b), the accuracy of data still needs to be improved. Most previous studies tend to focus only on the ground condition, or studies only on the climate facts. It still needs comprehension to analyze the factors related to SDSs. Although considerable research has been devoted to study the increase of SDSs events, few attention has been paid to the reasons why SDSs weakened significantly in recent years.

Therefore, this paper intends to make a comprehensive study of the reduction of the distribution and frequency of SDSs in East Asia in recent years, by using both ground observation data and dust model results in order to get better spatial and temporal resolution and accuracy. We carried out a detailed analysis of the distribution and frequency of SDSs in East Asia from 2007 to 2016. The relationship between the variation in climatic factors (such as temperature, air pressure, wind, polar vortex, and so on) and the occurrence of SDSs were compared to determine the main controls on the interannual variation in SDSs. This research may provide scientific support for the prevention and mitigation of SDSs in East Asia.

2. Materials and methods

2.1. Observational data from ground stations

The China Meteorological Administration (CMA) grades the weather phenomenon of SDSs into five levels: floating dust; blowing dust; SDSs; severe SDSs; and super-severe SDSs. The near-surface wind speed and the horizontal visibility are used to characterize this weather phenomenon when winds blow dust or sand up from the ground (Table 1).

Based on records from 673 standard ground stations in China (Fig. 1), we recorded three grades of sand and dust event: Blowing Sand or Dust (BSD); SDS; and severe SDS. BSD is recorded when at least five adjacent standard ground stations record blowing dust or a more severe sand and dust phenomena at the same observation time during a sand and dust event. An SDS event is recorded when at least three adjacent standard stations record an SDS or a more severe sand and dust phenomena at the same observation time in a sand and dust event. A severe SDS process is recorded when at least three adjacent standard stations record a severe SDS or a more severe sand and dust phenomena at the same observation time in a sand and dust event. If a sand and dust event meets two or three of these conditions, the most severe grade will be recorded (CMA, 2006). BSD is named and recorded as weaker than an SDS event as a result of the low visibility. Therefore we described three grades of sand and dust event as SDSs.

2.2. Surface dust concentration of CUACE/Dust model

The Chinese Unified Atmospheric Chemistry Environment for Dust (CUACE/Dust) is an operational mesoscale numerical model to forecast SDSs in East Asia. The model includes a comprehensive dust aerosol module with emission, dry/wet deposition, and other dynamic atmospheric processes. CUACE/Dust combines observational data from the CMA ground dust monitoring network and retrieves dust information from Chinese geostationary satellites in a data assimilation system (Gong and Zhang, 2008; Wang et al., 2008b). A threat score system evaluated the performance of CUACE/Dust against all available observations in 2006 and gave an average threat score in spring of 0.31 for 24 h forecasts, 0.23 for 48 h forecasts, and 0.21 for 72 h forecasts (Zhou et al., 2008). CUACE/Dust operations began in 2007 and we assessed the model using the surface dust concentration product over 119 SDS events occurring during 2007 and 2016. The results showed that the

Table 1
Wind speed and visibility in sand and dust weather phenomena.

	Floating dust	Blowing dust	SDS	Severe SDS	Super-severe SDS
Wind speed (m/s)	≤3.0	>3.0	>3.0	>3.0	>3.0
Visibility (km)	<10	1–10	0.5–1	0.050–0.5	<0.050

Download English Version:

https://daneshyari.com/en/article/8860047

Download Persian Version:

https://daneshyari.com/article/8860047

Daneshyari.com