ARTICLE IN PRESS

Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research xxx (2017) xxx–xxx

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

www.elsevier.com/locate/asr

Detection of aerosol pollution sources during sandstorms in Northwestern China using remote sensed and model simulated data

Mikalai Filonchyk, Haowen Yan *, Shuwen Yang, Xiaomin Lu

Department of GIS, Faculty of Geomatics, Lanzhou Jiaotong University, Lanzhou 730070, China

Received 9 June 2017; received in revised form 26 November 2017; accepted 27 November 2017

Abstract

The present paper has used a comprehensive approach to study atmosphere pollution sources including the study of vertical distribution characteristics, the epicenters of occurrence and transport of atmospheric aerosol in North-West China under intensive dust storm registered in all cities of the region in April 2014. To achieve this goal, the remote sensing data using Moderate Resolution Imaging Spectroradiometer satellite (MODIS) as well as model-simulated data, were used, which facilitate tracking the sources, routes, and spatial extent of dust storms. The results of the study have shown strong territory pollution with aerosol during sandstorm. According to ground-based air quality monitoring stations data, concentrations of PM_{10} and $PM_{2.5}$ exceeded 400 μg/m^3 and 150 μg/m^3, respectively, the ratio $PM_{2.5}/PM_{10}$ being within the range of 0.123–0.661. According to MODIS/Terra Collection 6 Level-2 aerosol products data and the Deep Blue algorithm data, the aerosol optical depth (AOD) at 550 nm in the pollution epicenter was within 0.75–1. The vertical distribution of aerosols indicates that the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) 532 nm total attenuates backscatter coefficient ranges from 0.01 to 0.0001 $km^{-1} \times sr^{-1}$ with the distribution of the main types of aerosols in the troposphere of the region within 0–12.5 km, where the most severe aerosol contamination is observed in the lower troposphere (at 3–6 km). According to satellite sounding and model-simulated data, the sources of pollution are the deserted regions of Northern and Northwestern China.

Keywords: Northwestern China; Air pollution; Aerosol; Dust storm; Aerosol source

1. Introduction

Every year, the wind erosion cause the formation of huge amounts of mineral particles of dust and aerosol in the deserts of East Asia which are then released to the atmosphere. Because of large-scale wind transport, a significant contribution into air pollution with particulate matters, along with local sources, can be caused by remote sources of aerosols. Location and parameters of aerosol pollution sources often remain unknown. This relates in particular to natural aerosol sources, as well to those located outside China (Rogge et al., 1993; Tegen et al., 2002; Shen, 2007; Engling et al., 2011; Viana, 2014).

Aerosol, or particulate matter, are liquid and hard airborne particulates, usually classified by grade, are distributed between $PM_{2.5}$ (particulate matter < 2.5 μm) and PM_{10} (particulate matter < 10 μm). They are also one of the most important factors, determining environmental situation in the region affecting climate, air quality, human health, and that of all life forms. It is known that areas of intensive aerosol pollution are associated with increased risks of respiratory diseases, cardiovascular diseases, and allergic diseases (Boman et al., 2006; Pope and Dockery, 2006; Shiraiwa et al., 2012; Mimura et al., 2014), with

* Corresponding author.
E-mail addresses: filonchyk.mikalai@gmail.com (M. Filonchyk), haowen2010@gmail.com (H. Yan).

https://doi.org/10.1016/j.asr.2017.11.037
0273-1177/

Please cite this article in press as: Filonchyk, M., et al. Detection of aerosol pollution sources during sandstorms in Northwestern China using remote sensed and model simulated data. Adv. Space Res. (2017), https://doi.org/10.1016/j.asr.2017.11.037

smaller particles causing more harm to human health (Janssen et al., 2011).

Determining the location of the regions with aerosol sources and assessing their capacity are important issues for monitoring the condition of the environment (Poirot and Wishinski, 1986). Using the aerosol concentration data and relevant meteorological information it is possible to solve the inverse problem and to determine the sources power distribution (Park et al., 2004; Maso et al., 2007; Wang, 2010) provided that correlation between the source and caused concentration is known. The important source of atmospheric aerosols is dust formed by wind erosion able to change the temperature conditions of the atmosphere and affect the structure of atmospheric dynamics (Huang et al., 2007; Sun, 2012), and, therefore, influence the change of climate. In addition, the study of vertical distribution of aerosols indicates the importance of sand and dust during transport to dissemination and absorption of solar radiation in the atmosphere (Twomey, 1972; Lacis and Hansen, 1974; Tegen, 2003; Slingo et al., 2006; Zhu et al., 2007).

The North-West China with the area of more than 3 million km^2 and the population of more than 95 million people, lies within arid and semiarid climatic area featuring one of the largest Asian desert zones. The largest deserts are the Taklamakan and Gobi deserts. Sandstorms originating here may penetrate more than thousand kilometers into Asian Continent (Huang et al., 2008). This is not just Chinese territory but also the territories of neighbor countries. Numerous studies were dedicated to aerosol sources and their tendencies during sandstorms, many of them being focused just on one or several specific locations, thus indicating that the matters are of local character. For example, according to the Xu et al. (2013) and Wang et al. (2014) data, the airborne pollution source in Qinghai Province is Tibetan Plateau region. The research of Chu et al. (2008) shows that Lanzhou City in Gansu Province is affected by high volume of airborne pollutions from Junggar and Tarim Basin. According to the Quan et al. (2001) and Qian et al. (2002) data, the desert regions of North and North-West China are the main sources of high sandstorms. As per soil and dust samples analysis, the main sources of dust formation are the Gobi and Taklamakan deserts (Derbyshire et al., 1998; Sun et al., 2001; Chen et al., 2003). Many previous researches of dust source identifications were mainly based on addressing specific issues using single instrument. According to the CALIPSO satellite data, vertical dust distributions were analyzed (Huang et al., 2008; Chen et al., 2010); sandstorms were also studied using MODIS satellite (Xu et al., 2011; Liu and Liu, 2015). Yet, the lack of multiple studies of dust storms determined the performance of the present research.

The main contribution of this study is determination of geographic regions – sources of aerosol pollution through the combination of satellite data and field observations performed in North-West China, which were obtained from remote sensing data and atmospheric modeling data using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT), the Cloud-Aerosol Lidar and the Infrared Pathfinder Satellite Observations (CALIPSO), and the Ozone Monitoring Instrument (OMI), the aerosol pollution predicting method by the Navy Aerosol Analysis and Prediction System (NAAPS), as well as the satellite data by Moderate Resolution Imaging Spectroradiometer (MODIS) (to determine the aerosol pollution level). The remote sensing data comprise information on aerosols in the entire atmospheric layer and, in particular, in the lower troposphere where large-scale transport of particulate matters mainly occurs. They are much less exposed to local aerosol sources than ground-based measurements. Therefore, in the scope of restoring a large-scale spatial distribution of particulate matter sources, remote measurement data are of an objective advantage as comparison to ground-based measurements. Thus, according to remote aerosol monitoring data, the main purpose of this study is search for the main geographical areas where solid aerosol parts are formed.

2. Materials and methods

2.1. Study areas

The Northwestern China ($^1/_3$ of the territory of China) includes Shaanxi, Gansu, Qinghai Province, Ningxia Hui, and Xinjiang Uygur Autonomous Region (Fig. 1) with the total population exceeding 95 million (Table 1). In terms of the surface structure, the eastern part of the region belongs to the Loess Plateau, the western part belongs to the Qinghai-Tibet Plateau. Northwards to Qinghai-Tibet Plateau is Tarim Basin with the Taklamakan Desert in the middle. Eastwards, there are high plateaus covered with steppes, semi-deserts, and deserts. Inner Mongolia lies on the Mongolian Plateau with an average altitude of 1000 m. The main part of the plateau is occupied by the Ala Shan and Gobi Desert. South to the Mongolian Plateau there are the Ordos Plateau and the Loess Plateau rich in loess and river sediments, are very fertile and exposed to erosion, resulting in intense breaking up with ravines and river valleys.

2.2. Data and processing

2.2.1. MODIS satellite data

The purpose of the MODIS system is data collection for calibrated global interactive Earth models as a single system. In the future, the models should predict global changes with an accuracy sufficient to make reasonable decisions aimed at environmental protection. The MODIS data with respect to the entire Earth's surface come from Terra and Aqua satellites every 1–2 days covering 36 spectral zones (ranging 0.405–14.385 μm) with a resolution of 250–1000 m and a survey bandwidth of about 2330 km providing modeling on a global and regional scale.

Please cite this article in press as: Filonchyk, M., et al. Detection of aerosol pollution sources during sandstorms in Northwestern China using remote sensed and model simulated data. Adv. Space Res. (2017), https://doi.org/10.1016/j.asr.2017.11.037