JOURNAL OF ENVIRONMENTAL SCIENCES XX (2016) XXX–XXX

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/jes

JES JOURNAL OF ENVIRONMENTAL SCIENCES

www.jesc.ac.cn

Case study of dust event sources from the Gobi and Taklamakan deserts: An investigation of the horizontal evolution and topographical effect using numerical modeling and remote sensing

Jin Fan[1,3], Xiaoying Yue[2], Qinghua Sun[3], Shigong Wang[1,4,*]

1. College of Atmospheric Sciences, Lanzhou University, Lanzhou 730000, Gansu, China. E-mail: fan.538@osu.edu
2. College of Geography and Environmental Science, Northwest Normal University, Lanzhou 730070, Gansu, China
3. Division of Environmental Health Sciences, College of Public Health, The Ohio State University, Columbus, OH 43210, USA
4. College of Atmospheric Sciences, Chengdu University of Information Technology, Chengdu 610103, Sichuan, China

ARTICLE INFO

Article history:
Received 2 February 2016
Revised 8 May 2016
Accepted 16 May 2016
Available online xxxx

Keywords:
East Asia dust
WRF
MODIS
Tarim Basin
Topographical effect

ABSTRACT

A severe dust event occurred from April 23 to April 27, 2014, in East Asia. A state-of-the-art online atmospheric chemistry model, WRF/Chem, was combined with a dust model, GOCART, to better understand the entire process of this event. The natural color images and aerosol optical depth (AOD) over the dust source region are derived from datasets of moderate resolution imaging spectroradiometer (MODIS) loaded on a NASA Aqua satellite to trace the dust variation and to verify the model results. Several meteorological conditions, such as pressure, temperature, wind vectors and relative humidity, are used to analyze meteorological dynamic. The results suggest that the dust emission occurred only on April 23 and 24, although this event lasted for 5 days. The Gobi Desert was the main source for this event, and the Taklamakan Desert played no important role. This study also suggested that the landform of the source region could remarkably interfere with a dust event. The Tarim Basin has a topographical effect as a "dust reservoir" and can store unsettled dust, which can be released again as a second source, making a dust event longer and heavier.

Introduction

Dust events have drawn a great deal scientific attention in arid and semi-arid areas of East Asia over the last four decades. Many studies have revealed that mineral dust aerosols have a potent impact on human health, Earth's energy budget and atmospheric chemistry. High particulate matter concentrations during dust events induce lung disease as well as cardiovascular inflammation (Sun et al., 2005). Dust aerosol interrupts the radiative balance of Earth's atmospheric system directly and indirectly. The particles are brightly colored and tend to scatter solar radiation in multiple directions, thereby reducing the radiation that reaches the ground (Mahowald et al., 2014; Wang et al., 2013). Additionally, dust aerosol can act in the atmosphere to condense clouds or ice nuclei (Ackerman et al., 2004; Sassen et al., 2003), thereby forcing an indirect effect on radiative energy budgets. Moreover, dust aerosol can provide surfaces for some photochemical reactions (Ramazan et al., 2004; Cwiertny et al., 2008).

* Corresponding author. E-mail: wangsg@lzu.edu.cn (Shigong Wang).

http://dx.doi.org/10.1016/j.jes.2016.05.046
1001-0742/© 2016 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V.

The Gobi and Taklamakan Deserts are two main dust sources over East Asia (Fig. 1a, b). The total area of these deserts is approximately 1,632,000 km^2 and accounts for 13.8% of the entire East Asian region. Because precipitation is rare and both strong gusts and high surface air temperature exist, the annual dust production has been estimated to be as much as half of the global total (Zhang et al., 1997), which ranges from 500 to 6000 Tg/yr (Huneeus et al., 2011; Prospero et al., 2010). The enormous source region and attributes of the local climate indicate that East Asian dust is not confined at its emission area but could have various influences over the entire northern hemisphere (Uno et al., 2009; Cottle et al., 2013). Furthermore, the annual frequency of East Asian sandstorms oscillates over a 10-year period (Yang et al., 2013). Statistical analyses indicate that two-thirds of the sandstorms in the northern hemisphere can be observed in the springtime, and the summer has the lowest frequency of sandstorms (Hsu et al., 2013; Wang et al., 2013).

Although the above studies reveal important chemico-physical properties of East Asian dust and represent our knowledge about it, the effects of the unique landforms around source regions for a dust event seem to have been neglected. To study these effects, we applied the Weather Research and Forecasting Chemistry (WRF/Chem) model combined with the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model (Peters-Lidard et al., 2015) to provide preliminary results regarding dust's horizontal evolution and the topographical effect of the surrounding landform. In addition, a dataset using moderate resolution imaging spectroradiometer (MODIS) was also considered to assess the model simulation. The model's reality and reliability have been demonstrated by previous WRF/Chem-GOCART simulations in different global regions (Tie et al., 2007; Chapman et al., 2009; Zhang et al., 2010; Grell et al., 2011), indicating that this model system can profile aerosol properties, meteorology and atmospheric chemistry.

1. Model system and remote sensing

1.1. Model description

The Weather Research and Forecasting Model (WRF) is a mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting. The system contains an Advanced Research WRF (ARW) dynamical solver, which was primarily developed at NCAR (National Center for Atmospheric Research). The ARW solver uses a Runge–Kutta 2nd or 3rd order time integration scheme to solve non-hydrostatic equations on horizontal Arakawa-C (Arakawa and Lamb, 1977) grids and vertical mass-based terrain-following coordinates. The model gives the user a choice of 2nd to 6th order advection schemes for spatial discretization (Skamarock and Klemp, 2008). WRF with ARW is a fully compressible and Euler non-hydrostatic model. The model comprises a series of microphysical processes, parameterization schemes and dynamical options from simple to sophisticated. For the physics in this case, cloud-resolving

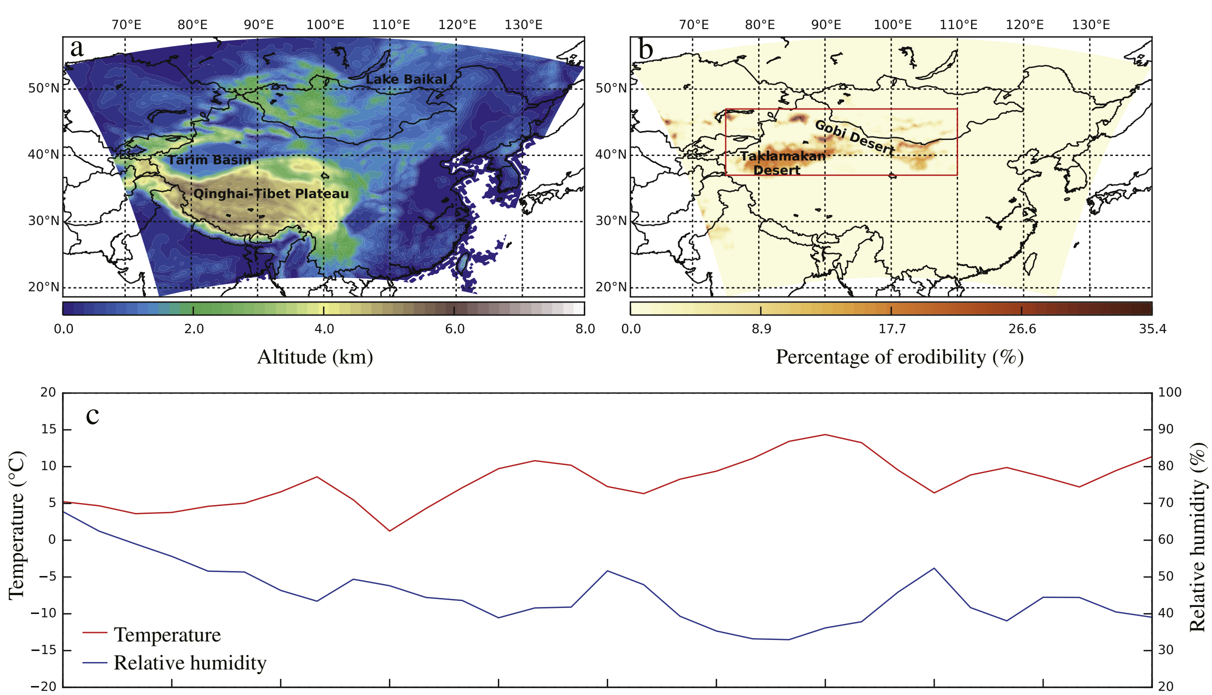

Fig. 1 – The WRF/Chem-GOCART model domain shown according to the (a) topography and (b) percentage of soil erodibility. The red box shows the source region, and the (c) surface temperature and relative humidity from NCEP-FNL are averaged in the box with daily resolution. (a, b) Also show the location of the Tarim Basin, the Qinghai-Tibetan Plateau, Lake Baikal, the Taklamakan Desert and the Gobi Desert. WRF/Chem: Weather Research and Forecasting Chemistry; GOCART: Goddard Chemistry Aerosol Radiation and Transport; FNL: Final Analysis; NCEP: National Centers for Environmental Prediction.

Please cite this article as: Fan, J., et al., Case study of dust event sources from the Gobi and Taklamakan deserts: An investigation of the horizontal evolution and topographical..., J. Environ. Sci. (2016), http://dx.doi.org/10.1016/j.jes.2016.05.046