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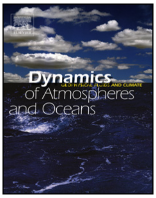

A global satellite view of the seasonal distribution of mineral dust and its correlation with atmospheric circulation

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ABSTRACT

Aerosols make a considerable contribution to the climate system through their radiative and cloud condensation nuclei effects, which underlines the need for understanding the origin of aerosols and their transport pathways. Seasonal distribution of mineral dust around the globe and its correlation with atmospheric circulation is investigated using satellite data, and meteorological data from ECMWF. The most important sources of dust are located in North Africa, the Middle East and Southwest Asia with an observed summer maximum, and East Asia with a spring peak. Maximum dust activity over North Africa and the Middle East in summer is attributed to dry convection associated with the summertime low-pressure system, while unstable weather and dry conditions are responsible for the spring peak in dust emission in East Asia. Intercontinental transport of mineral dust by atmospheric circulation has been observed, including trans-Atlantic transport of North African dust, trans-Pacific transport of Asian dust, and transport of dust from the Middle East across the Indian Ocean. The extent of African dust over the Atlantic Ocean and its latitudinal variation with season is related to the large-scale atmospheric circulation, including seasonal changes in the position of the intertropical convergence zone (ITCZ) and variation of wind patterns. North African aerosols extend over longer distances across the North Atlantic in summer because of greater dust emission, an intensified easterly low level jet (LLJ) and strengthening of the Azores-Bermuda

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anticyclonic circulation. Transport of East Asian aerosol is facilitated by the existence of a LLJ that extends from East Asia to the west coast of North America.

1. Introduction

Dust aerosols, the tiny soil particles in the atmosphere from both natural and anthropogenic sources, modify the radiation budget of the Earth-atmosphere system directly by scattering and absorbing solar and infrared radiation (McCormick and Ludwig, 1967; Miller and Tegen, 1998), semi-directly through changes in atmospheric temperature structure and the evaporation rate of cloud droplets (Hansen et al., 1997; Ackerman et al., 2000; Koren et al., 2004), and indirectly through impact on optical properties of clouds (Gunn and Phillips, 1957; Liou and Ou, 1989) and suppression (Ferek et al., 2000; Rosenfeld, 2000) or invigoration (Andreae et al., 2004) of precipitation formation. Additionally, dust aerosols degrade air quality (Prospero, 1999) and adversely affect human health (Pope et al., 2002). Dust is also a source of iron which is a nutrient for phytoplankton (Fung et al., 2000). Therefore, dust particles can affect marine biogeochemical processes, thereby contributing to the oceanic uptake of carbon (Jickells et al., 2005). Their contribution to the climate system and atmospheric environment is therefore of considerable significance, underlining the essential need for investigation into the origin of dust aerosols and their temporal variation, as well as their transport pathways in the atmosphere.

Mineral dust from wind erosion of dry soils is among the most abundant atmospheric aerosol components in terms of aerosol dry mass (Textor et al., 2006; Chen et al., 2007) and contributes more than half of the total global aerosol burden (Textor et al., 2006), with an estimated global annual burden of 17.4–35.9 Tg (trillion grams; Ginoux et al., 2001; Tegen et al., 2002; Luo et al., 2003; Zender et al., 2003) and a global annual emission of 1950–2400 Tg (Ginoux et al., 2004). Remote sensing analyses have shown that major sources of mineral dust are located in arid regions, including deserts, semi-arid deserts (with sparsely vegetated ground) and dry lake beds, where annual rainfall is extremely low (Goudie and Middelton, 2006), and substantial amounts of alluvial sediment have been accumulated (Prospero et al., 2002; Ginoux et al., 2012). In addition to these natural sources, human induced disturbance of the land surface and climate variability, have created anthropogenic sources of mineral dust (Prospero et al., 2002; Tegen et al., 1921) that have contributed to an increase in the wind-blown dust concentration within the atmosphere.

Despite their short atmospheric lifetime of 1–2 weeks, mineral dust aerosols regularly travel long distances of an intercontinental scale (Swap et al., 1992; Chin et al., 2007) and are occasionally transported a full circuit around the globe (Uno et al., 2009). Previous studies have used ground-based measurements, satellite data and model analysis to identify major sources of mineral dust aerosols and their transport pathways. Using the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) over the East Asian region, Huang et al. (2008) demonstrated that dust events are more frequent over Taklimakan, while less frequent and more intense over the Gobi desert. Their results also indicated that dust aerosols from these sources can reach to an altitude of 9 km where they are subject to long-range transport over eastern China and across the Pacific Ocean by the upper tropospheric westerly jets. Analysis of the first full year of the CALIOP dataset by Liu et al. (2008) revealed the spring peak of dust activity over Tibetan Plateau, with dust plumes reaching to the height of 11–12 km.

The influence of dust aerosols on the climate system and cloud properties has also been extensively studied. For example, a decrease of surface incoming shortwave radiation and atmospheric heating by dust layers was noted by several numerical analyses (e.g. Huang et al., 2009; Mallet et al., 2009) and from satellite observations (e.g. Kaufman et al., 2001). The net direct radiative forcing by dust at the top of the atmosphere (TOA) is controversial and both negative and positive radiative forcing was identified (Claquin et al., 1998; Liao and Seinfeld, 1998), although general agreement is that it is negative over the ocean where shortwave backscattering dominates, while positive above high surface albedos (such as deserts) and clouds where shortwave and/or longwave absorption dominates (e.g. see Claquin et al.,