Temporal analysis of Sand and Dust Storms (SDS) between the years 2003 and 2017 in the Central Asia

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Abstract. Mineral dust particles play a vital role in climate and the Earth's energy budget and can have impact on weather systems. It has both direct (dust-radiation effect) and indirect (dust-microphysical effect) impacts on the energy budget effect. The most important sources of dust aerosols are located in the Northern Hemisphere, primarily over the Sahara in North Africa, the Middle East, Central and South Asia respectively and Central Asia is under the influence of mineral dust. The objective of this study to carry out intensity and frequency analysis of sand and dust storm in Central Asia for the period 2003-2017 and compare the results with global values as well as the values of the Middle East region. The AOD and AE parameters can be used to differentiate between coarse and fine particles of aerosols. To investigate average annual and monthly AOD (aerosol optical depth) and AE (angstrom exponent) for the period 2003-2017, AOD and AE data of MODIS Aqua is obtained from Giovanni website. In summary, for the last years (2013-2017), annual mean AOD is comparably lower than the other periods while the values are the highest between 2008 and 2012 for both Central Asia and Middle East. The results point out that there is no increasing trend in AOD values for the recent years and annual Central Asia AOD values show a similar trend with the Middle East AOD values.

1 Introduction

Mineral dust aerosols, the tiny soil particles suspended in the atmosphere, have a key role in the atmospheric radiation budget and hydrological cycle through their radiative and cloud condensation nucleus effects. Mineral dust aerosols are blown into the atmosphere mainly from arid and semi-arid regions where annual rainfall is extremely low and substantial amounts of alluvial sediment have been accumulated over long periods. They are subject to long-range transport of an intercontinental scale, including North African dust plumes over the Atlantic Ocean, summer dust plumes from the Arabian Peninsula over the Arabian Sea and Indian Ocean and spring dust plumes from East Asia over the Pacific Ocean. Mineral dust aerosols influence the climate system and cloud microphysics in multiple ways [1].

Approximately 1,000 Tg to 2,000 Tg (1-2 billion tons) of dust is emitted to the atmosphere from the deserts every year [2]. The most important sources of dust aerosols are located in the Northern Hemisphere, primarily over the Sahara and Sahel in North Africa, the Middle East, Central and South Asia respectively [1]. The annual amount of dust released from the Sahara into the atmosphere is about the half of dust released from all sources on Earth, while the dust released from the Sahara and Middle East regions is about 70% of global annual dust emissions. The annual amount of dust emitted from Arabian Peninsula (Middle East) to the atmosphere was estimated to 221 million tons [3].

2 Material and methodology

2.1 Aerosol optical depth

Aerosol Optical Depth (AOD) provides important information about the concentration, size distribution, and variability of aerosols (desert dust, sea salt, haze, and smoke particles) in the atmosphere. It is a dimensionless number related to the amount of aerosol distributed within the vertical column of atmosphere over the observation location. AOD provides a quantitative measure of the extinction of solar radiation due to aerosol scattering and absorption [4]. Heavy dust regions are defined by AOD higher than 0.3. Around deserts, AOD values are above 1.0 and usually below 3.0 [4].

Giovanni website provides a simple way to visualize, analyze, and access Earth science remote sensing data, particularly from satellites, without having to download the data. It includes data for aerosols, atmospheric chemistry, atmospheric temperature and moisture, and rainfall. It was developed by the Goddard Earth Sciences

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Data and Information Services Center (GES DISC).

2.2 Angstrom exponent

The Angstrom exponent (AE) is an exponent that expresses the spectral dependence of aerosol optical thickness (τ) with the wavelength of incident light (λ). It provides additional information on the particle size, aerosol phase function and the relative magnitude of aerosol radiances at different wavelengths. AE (computed from τ measurements on two different wavelengths) can be used to find τ on another wavelength using the relation below:

$$\tau_\lambda = \tau_{\lambda_o} \left(\frac{\lambda}{\lambda_o}\right)^{-\alpha}$$

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The Angstrom Exponent is a useful quantity to evaluate the particle size of atmospheric aerosols or clouds, and the wavelength dependence of the aerosol/cloud optical properties. It is inversely related to the average size of the particles in the aerosol: the smaller the particle size, the larger the Angstrom Exponent is. Therefore, low AE values indicate strong presence of coarse aerosols relating to the dust events [5].

2.3 Study area and period

For the analysis between the years 2003 and 2017, domain covering Central Asia (extending from 34° to 48° North and 47° to 70° East) is selected. Middle East Region is examined for further analysis and comparison. To investigate average annual and monthly AOD and AE for the period 2003-2017, MODIS Aqua data is obtained from Giovanni website (http://disc.sci.gsfc.nasa.gov/giovanni).

3 Results

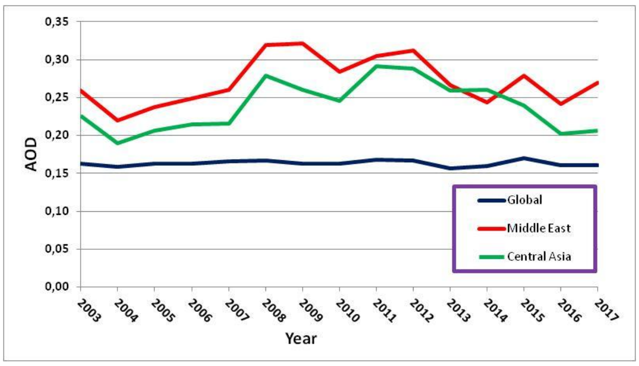

Fig. 1. Average Annual AOD for Middle East and Central Asia regions with Global AOD values.

In general, the AOD and AE parameters can be used to differentiate between coarse and fine particles of aerosols. Low AE and high AOD point out dust storms.

Average annual and monthly AOD and AE graphs are plotted for three regions (global, Middle East and Central Asia) to investigate the trends (Figure 1, Figure 2 and 3).

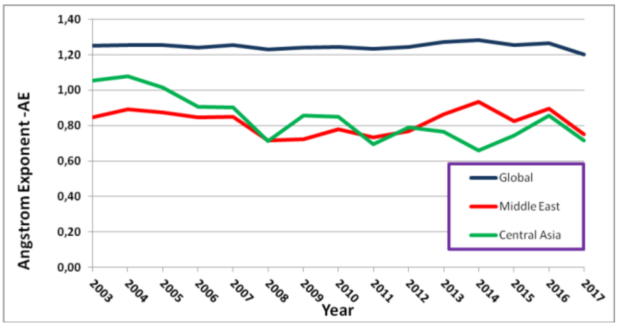

Fig. 2. Average Annual AE for Middle East and Central Asia regions with Global AOD values.

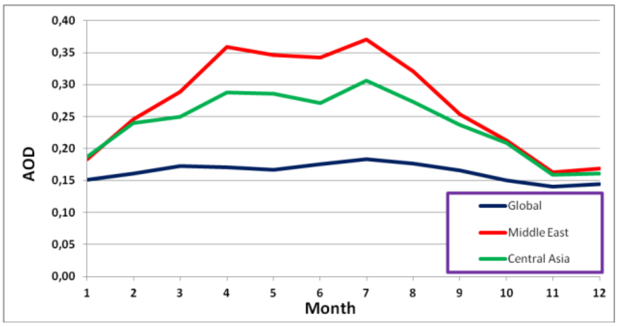

Fig. 3. Average Monthly AOD for Middle East and Central Asia regions with Global AOD values.

Annual AOD values of the Central Asia almost follow the values of Middle East Region. For the last years (2013-2017), annual mean AOD is comparably lower than the other periods while the values are the highest between 2008 and 2012 for both Central Asia and Middle East. The results point out that there is no increasing trend in AOD values for the recent years (Figure 1). Increase in annual AOD values is accompanied by a decrease in AE values (coarse particles) (Figure 2).

Seasonal variation of AOD in the Central Asia is similar to averaged AOD values of the Middle East which has a maximum in July (Figure 3).

References

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