Analysis of vertical distribution patterns of dust storms in association with atmospheric circulation patterns and topography in western Iran

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Extanded Abstract

Introduction

The west and southwest areas of Iran are characterized by high-levels of dust events mainly due to their location in the vicinity of vast deserts. Western Iran is located in the vicinity of some important dust sources: the Tigris and Euphrates basin in Iraq as well as Syria in the west and the Arabian Peninsula in the south. These sources are among the most active in the dust belt, especially in the recent years.

Overall, sand and dust storms are the most important atmospheric phenomena in arid and semi-arid regions. They have been recognized as the regions with a wide range of environmental and climate impacts including distractive effects upon air quality and human health, agricultural activities, land use and soil formation. They are also recognized as the factor of desertification. Dust particles are important components of the earth's climate system as they affect the balance of solar radiation by scattering and absorption. These feedbacks have a direct link with the intensity and height of the column of dust in the troposphere. The aim of current study is to understand the vertical distribution patterns of Middle Eastern Dust Storms (MEDS) associated with atmospheric circulation patterns and topography in cold period of the year (November-May) in west Iran.

Material and methods

The horizontal and vertical distribution of dust aerosols was simulated with chemistry/aerosol module of Weather Research Forecast system (WRF-CHEM). The WRF–Chem was configured

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with the Goddard global ozone chemistry aerosol radiation and transport (GOCART) dust emission scheme to calculate the influx of dust into the atmosphere. The effect of the Zagros Mountains on vertical and horizontal distribution of dust emission was also examined by WRF model in an area between 16º–44ºN and 33º–65ºE with a 30 km horizontal grid spacing. The FNL re-analysis data set were used to provide the initial and lateral boundary conditions in a control run and in a simulation run by removing the Zagros Mountains.

The atmospheric circulation pattern was investigated to explain the mechanisms of dust emission in the Middle East and its vertical emission over this region. The hourly visibility and dust dataset of 34 synoptic stations in the western part of Iran were obtained from the Iran Meteorological Organization (in 2004-2013 period) to extract dust events in the study area. The NCEP/NCAR 6-hourly reanalysis dataset with 2.5°×2.5° horizontal resolution was used for this period.

Results and discussion

The atmospheric circulation patterns lead to generation of dust events in the Arabian region in two categories of frontal and non-frontal patterns. In the frontal events of MEDS that occur in the cold period of the year, dust is created under the influence of emigrate systems of westerly winds setting in the Middle East region. Formation of a divergence system in mid-level of troposphere (500 hPa) leads to formation of a surface convergence center as well as frontogenesis, air uplift and atmospheric instability condition in the source areas of MEDS. In addition the Polar Jetstream position as one of the enhancing factors of instabilities and air uplift in the region has a key function in vertical distribution of MEDS. Generally, MEDS events occurred due to the frontal pattern are similar to the precipitation systems except the lack of humidity in case of dust generation in arid lands of the Middle East. Frontal patterns are divided into two patterns including Trough and Blocking. These two patterns are the dominant patterns of dust generation in November to May in this region in cold period. In frontal pattern, the vertical distribution of column dust is divided into two categories: in first pattern the maximum height of dust is above 7 km and in second pattern the maximum height is below 4 km. These patterns are related to the position and strength of Polar Jetstream, the strength of mid-levels vorticity, and upward motions of air flow. In the first vertical distribution pattern, there is upward motion to the 9 km of the troposphere as in second pattern the upward motion is 5 km of the troposphere.

In non-frontal pattern neither frontogenesis happens nor there is a polar front Jetstream which causes instabilities in the Middle East dust storm sources. Dust generation is due to the regional circulation system in the lower level of troposphere. In this pattern, the concentration of dust load is less than frontal MEDS and the maximum height of column dust is below 3.5 km.
The results of the analysis about the impact of topography on vertical and horizontal distribution of MEDS reveal that the Zagros Mountains have a limited effect on the vertical and horizontal distribution of MEDS. However, in the absence of the Zagros Mountains and the main factor which control the vertical and horizontal distribution pf dust storm is the strength of atmospheric systems.

Conclusion

Two main patterns of cold period of MEDS are frontal and non-frontal patterns. The vertical

distribution of column dust in mentioned patterns are different. In frontal pattern the height of dust is varied from 4 to 7 km in the troposphere. The position and strength of Polar Jetstream, the strength of mid-levels vorticity, upward motions of air flow and divergence of moisture flux in MEDS sources are the most important factors which determine the strength and height of dust storm in the Middle East in the cold period. In non-frontal pattern the concentration of dust in the troposphere is below 3.5 km. the result of this study reveals that the important strength of atmospheric systems is more than topography barrier in vertical and horizontal transport of MEDS in west Iran.

Keywords: atmospheric circulation patterns, column dust height, frontogenesis, Zagros Mountains.