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Assessment of Dust Variability Over Iraq During 2003-2012 Using SCIAMACHY Absorbing Aerosol Index

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Abstract:

Dust storms are the most significant weather phenomena affecting Iraq and greatly degrading ecosystem and human health. There has been an increase in the frequency of dust storms occurrence in Iraq and bordering countries of Iran, Kuwait, and Saudi Arabia. The aim of this research was to assist the variability of dust storms over Iraq using remotely sensed data. Monthly means of Absorbing Aerosols Index (AI), satellite images, rain and wind were respectively acquired from TEMIS, MODIS, and MERRA-2 websites for a period of 10 years (2003-2012). Results of comparisons between MODIS images and AI maps for a dust event showed that AI provides a good indication of the initiation, development and transportation of dust particles. Analysis of 10 years data indicated that the majority of dust events over Iraq are caused by the northwesterly wind (shamal wind) and the highest values of AI occur during the summer months. Southern cities of Basra and Nasiriyah are the most affected cities by dust storms while the central cities of Baghdad and Anah are less affected. Dust activities over Mosul and Rutba are relatively lower than those in the other four cities. This may be attributed to relatively slower winds and much less sources of dust particles around the two cities. Results also showed that rainfall plays an affecting rule in the occurrence of dust storms. It was found that when rain increases in certain year AI tend to decrease in the flowing year.

Introduction

Dust and sand storms normally happen in arid and semi-arid regions and could cause damages to the ecosystem and human health (Goudie, 2009). Also, dust particles re an important component of the earth's climate system and modify climate through their direct radiative effects of scattering and absorption (Tegen et al., 1996), through indirect radiative effects via their influence on clouds microphysics (Rosenfeld et al., 1997), and by their role in processes of atmospheric chemistry (Schwartz et al., 1995). Dust storms are usually caused by strong and turbulent wind blowing over desert and areas of dry fine soils. They could lift large quantities of dust particles into the air and transport them hundreds or thousands of kilometers away (Zoljoodi et al., 2013).

Monitoring of dust storm constituents by ground-based instrumentation is very limited in spastically and temporally therefore satellite measurements are considered an important tool in observing the transport of dust storms over long distance from their sources and the severity and concentration of dust over particular location. Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY), developed at Koninklijk Nederlands Meteorologisch Instituut, provided global data on the transport of smoke and dust plumes over long distances for the period 2002-2012. SCIAMACHY measured backscattered radiance in near Ultra-Violet (UV) region of the spectrum and from these measurements, the SCIAMACHY ozone retrieval algorithm computes an absorbing Aerosol Index (AI), which is a qualitative measure of the presence of UV absorbing aerosols such as mineral dust and smoke (Tilstra et al., 2012).

Dust storms are of major concern in arid and semiarid countries. In Iraq and surrounded countries there has been an increasing trend in the occurrence of dust storms in recent years due to shortage of rainfall which causes drought and desertification. Since last decade an extensive research works have been conducted by research workers. Kutiel and Furman (2003) analyzed reduction in visibility to determine the properties of dust storms in the Middle East countries. Anderson (2004) carried out an analysis for forecasting in Qatar. Khalid (2009) located sources of dust storms in Iraq byb employing absorbing aerosols index. Maghrabi (2011) showed that dust storms can affect meteorological parameters. Khoshhal et al., (2012) indicated that the temporal and spatial characteristics of dust storms can play an important rule their initiation and transport. Al-Dabbas et al., (2012) determined dust load in Iraq studied using dust events during two years. Al-Jumaily and Ibrahim (2013) used absorbing aerosols index and synoptic weather maps to investigate the formation of dust storms in Iraq. They concluded that dust storms in Iraq are initiated from source regions near the borders with Syria as well as from the desert areas inside Iraq.. Nabavi et al., (2016) employed TOMS-OMI Aerosol Index data to identify long-term changes in the horizontal distribution of dust storms in West Asia from 1980 to 2016. Broomandi et al., (2017) Identified the sources of dust storms in the City of Ahvaz in Iran by using HYSPLIT model and the mean monthly maps of AI.

Materials and Methods

Study area:

Iraq lies between 29°5- to 37°15- N latitudes and 38°45- to 48° 45-E longitude. Iraq is a country in Western Asia spanning most of the northwestern end of the Zagros mountain range, the eastern part of the Syrian Desert and the northern part of the Arabian Desert. Most source regions in Iraq are located in the lower valleys between Tigris and Euphrates rivers. There is also large source area of dust in the border region between Iraq. Dust storms in Iraq are usually occurring during spring and summer months but can happen any time of the year. Most dust storms are driven by Shamal wind, a northwesterly wind blowing over Iraq and it is usually strong during the day and decreasing at night. Shamal wind blows mostly during summer but sometimes in winter. Figure 1 shows the six locations that has been chosen for this study. These locations represent the northern, central, and southern parts of Iraq.

Data Sources:

Monthly means of AI data for the period of 10 years (2003-2012) were acquired from Tropospheric Emission Monitoring Internet Service (TEMIS) website (http://www.temis.nl). Satellite images were acquired from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Terra satellite operated by NASA. Data for rainfall and wind were obtained from The Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) Web service (Gelaro et al. 2017)

Results and Discussion

To illustrate the behavior of AI during dust events, a severe dust storm was chosen. The storm was initiated and developed by shamal wind and lasted for three days (3-5 July 2009). Figure 2 shows the satellite images captured by MODIS and corresponding AI maps. It seen that AI is a good indicator of the presence and movement of dust particles. On July 3rd the storm was thick and located on the northwestern part of Iraq. AI map indicate a high values of AI on that location. On the next day, the dust spread east and southeast and AI values became lower indicating that the storm was weakening. On third day the storm has covered almost the entire country and completely blocking the ground from view. The AI map indicates high values in the regions close to the border with Iran. These results suggest that AI provide a useful information about the dust storms. Figure 3 gives the 10 years (2002-2012) monthly means of AI over Iraq. It is obvious that most dust activities occur during the months of April to September and the pattern of these activities is directed from northwestern part of the country towards southeastern part. This is usually a result of shamal wind. Figure 4 shows the variations of monthly means of AI over the 10 years period for six selected cities.in Iraq. For all cities, AI values are higher in summer and lower during winter and an obvious trend of increasing AI with years is seen. Mosul and Rutba have relatively lower values of AI than other four cities. This may be explained by the fact that Mosul city is characterized by relatively low wind and Rutba is located further to the west were no major source of dust exist in that region. The 10 years monthly means of AI for the six cities are illustrated in Figure 5. It is clear that Basra and Nasiriyah are characterized by higher values of AI followed by

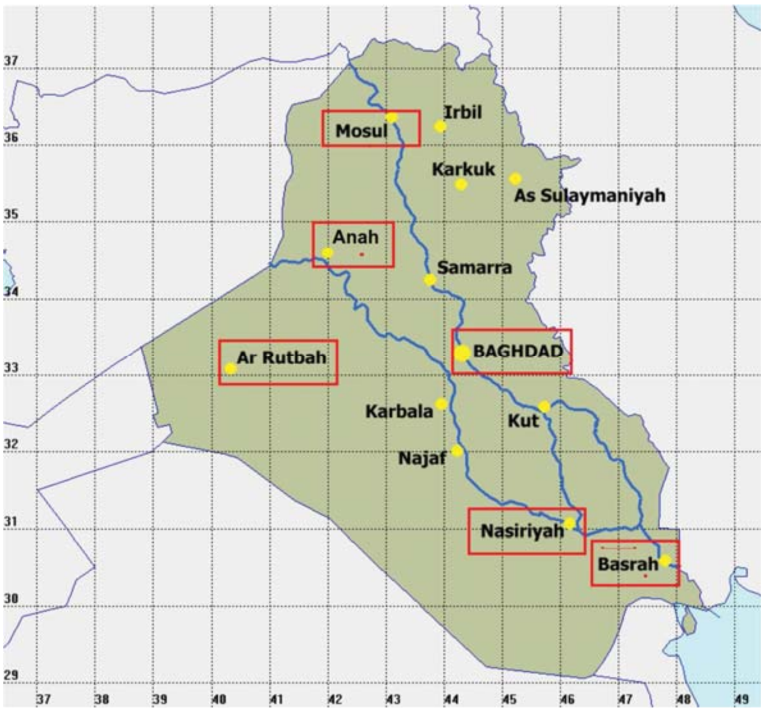
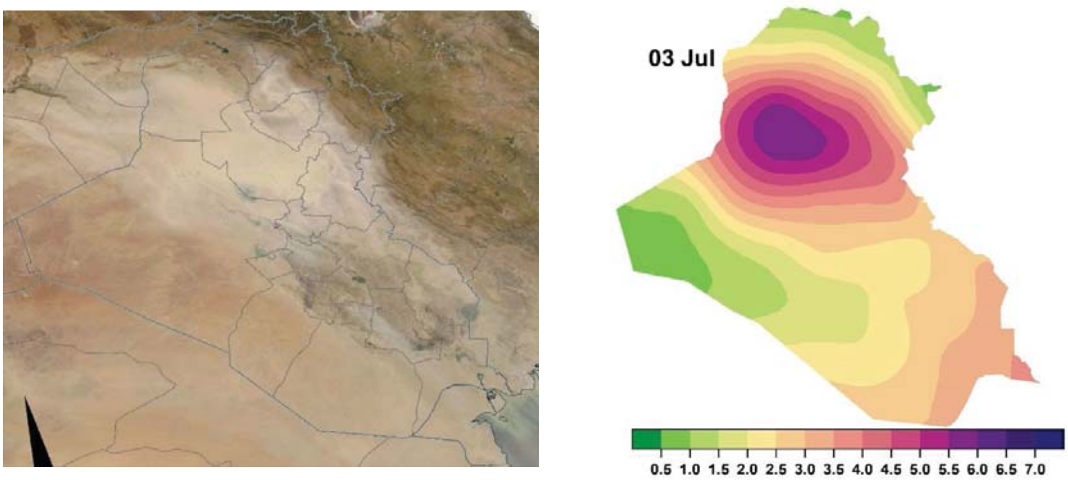


Figure 1: Iraq map showing selected cities.



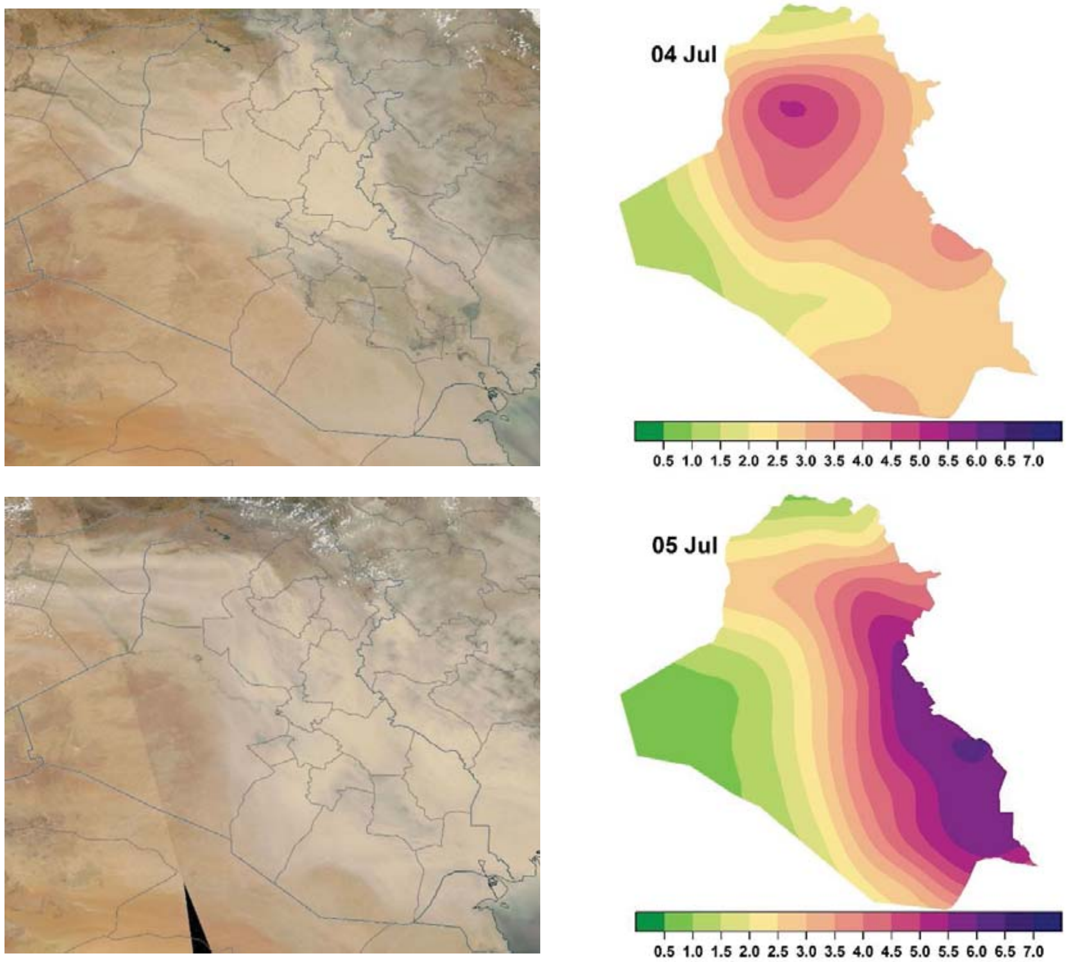
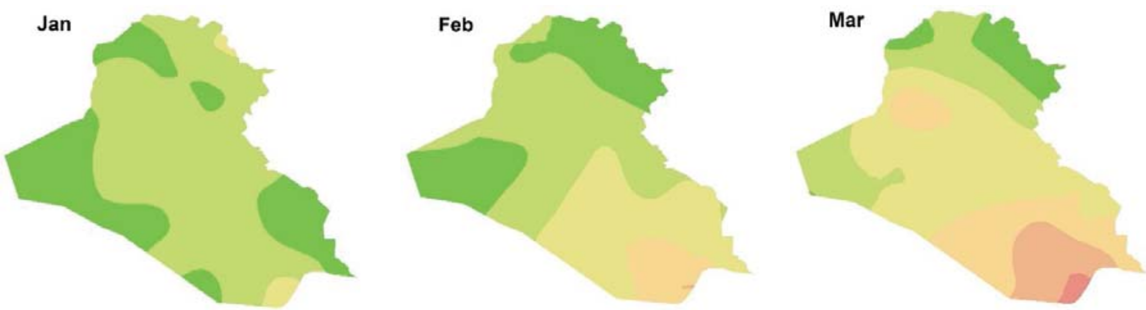


Figure 2: Modis images and aerosols index maps for 3-5 July 2009 dust storm over Iraq.



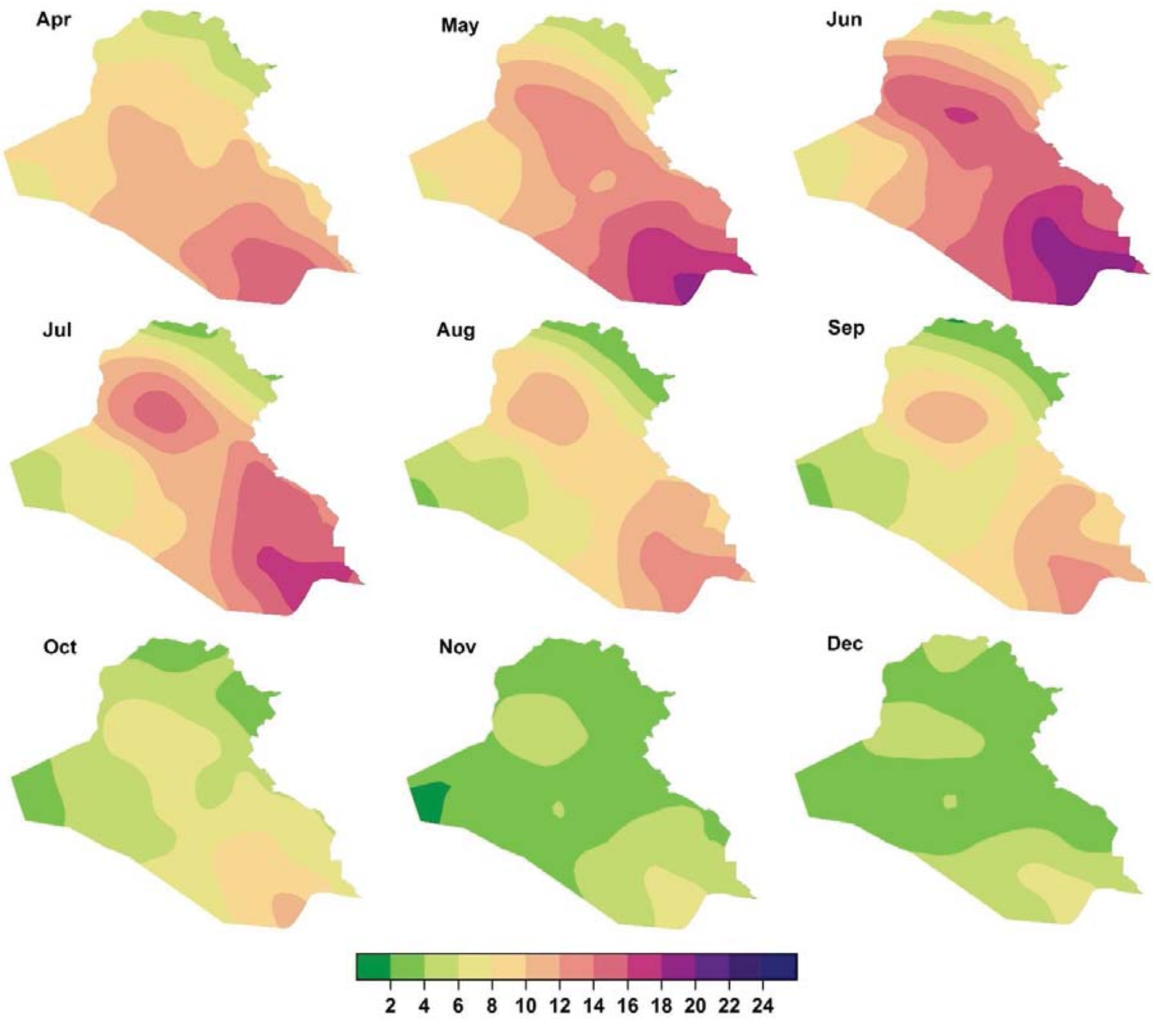


Figure 3: Monthly means of AI over Iraq for 10 years period (2003-2012).

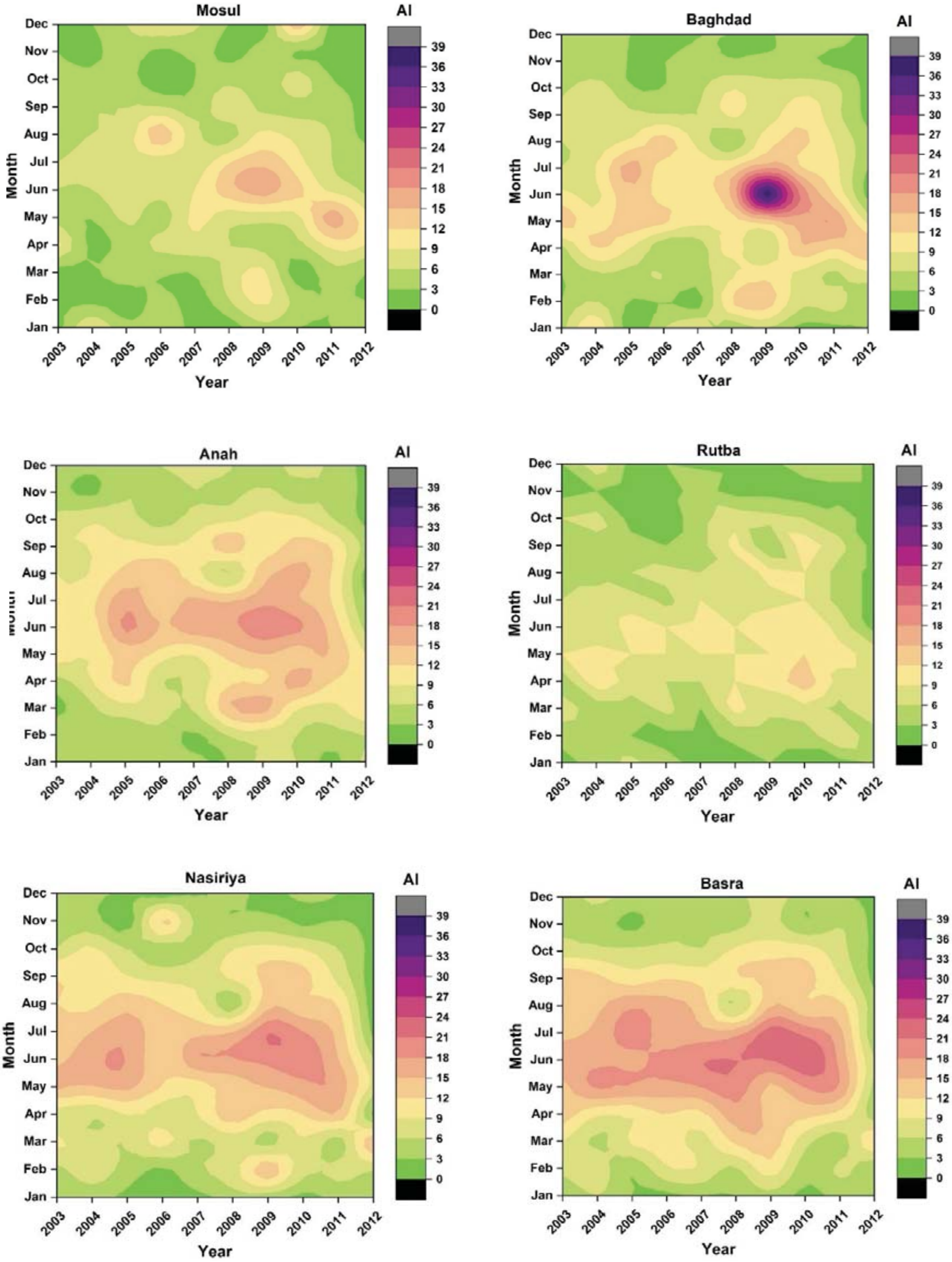


Figure 4: Variations of monthly AI over 10 years period for selected cities in Iraq.

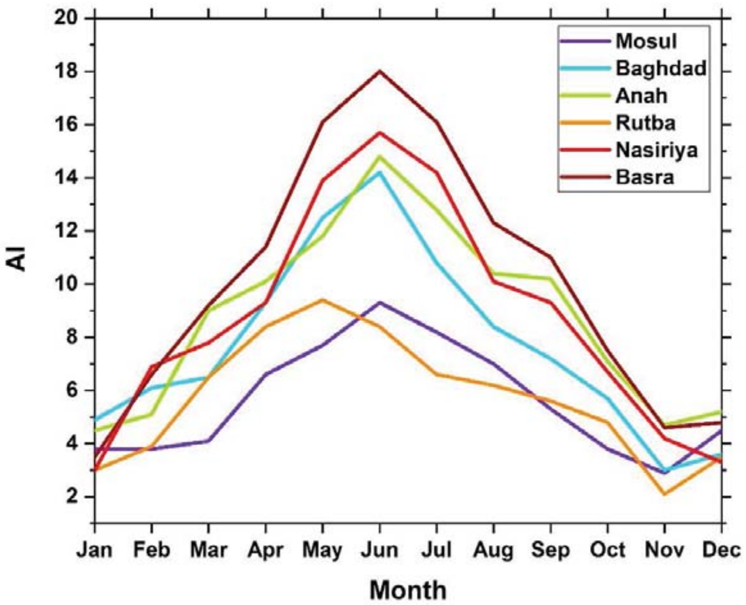


Figure 5: Monthly means of AI for 10 years period (2003-2012).

Baghdad and Anah while Mosul and Rutba have the lowest AI values. The maximum AI occur during the months of June and July and lowest values of AI occur in the months of December and January. It is believed that wind and sources of dust are the main two factors determining dust activities at a particular location. Figure 6 shows the wind rose plots for the six cities. The plots indicate that the wind is almost northwesterly in Anah, Baghdad, Nasiriyah, and Basra while in Mosul and Rutba significant contribution to the wind may come from directions other than northwest. Figures 7 and 8 gives the variations of the monthly means of wind speed and wind direction over the 10 years period. It is clear that the wind patterns can slightly vary from one to another but no obvious trend of increasing/decreasing is obvious. The general pattern is that wind is high in summer and low in winter. The results also show that the windiest cities among the six are Nasiriya, Anah, and Basra. An important factor on dust activities is rainfall. It is known that shortage of rainfall in any place leads to drought, desertification, and consequently intense dust activities. Figure 9 shows a comparison between annual rainfall and annual mean of AI. It can be seen that when an increase in rainfall in a given year a decrease in AI occur in the next year. This obvious for all cities except the city of Basra where in some years the rainfall-AI relation does not hold, this may be attribute to the contribution of smoke and other pollutant to the AI in Basra. This needs further investigation.

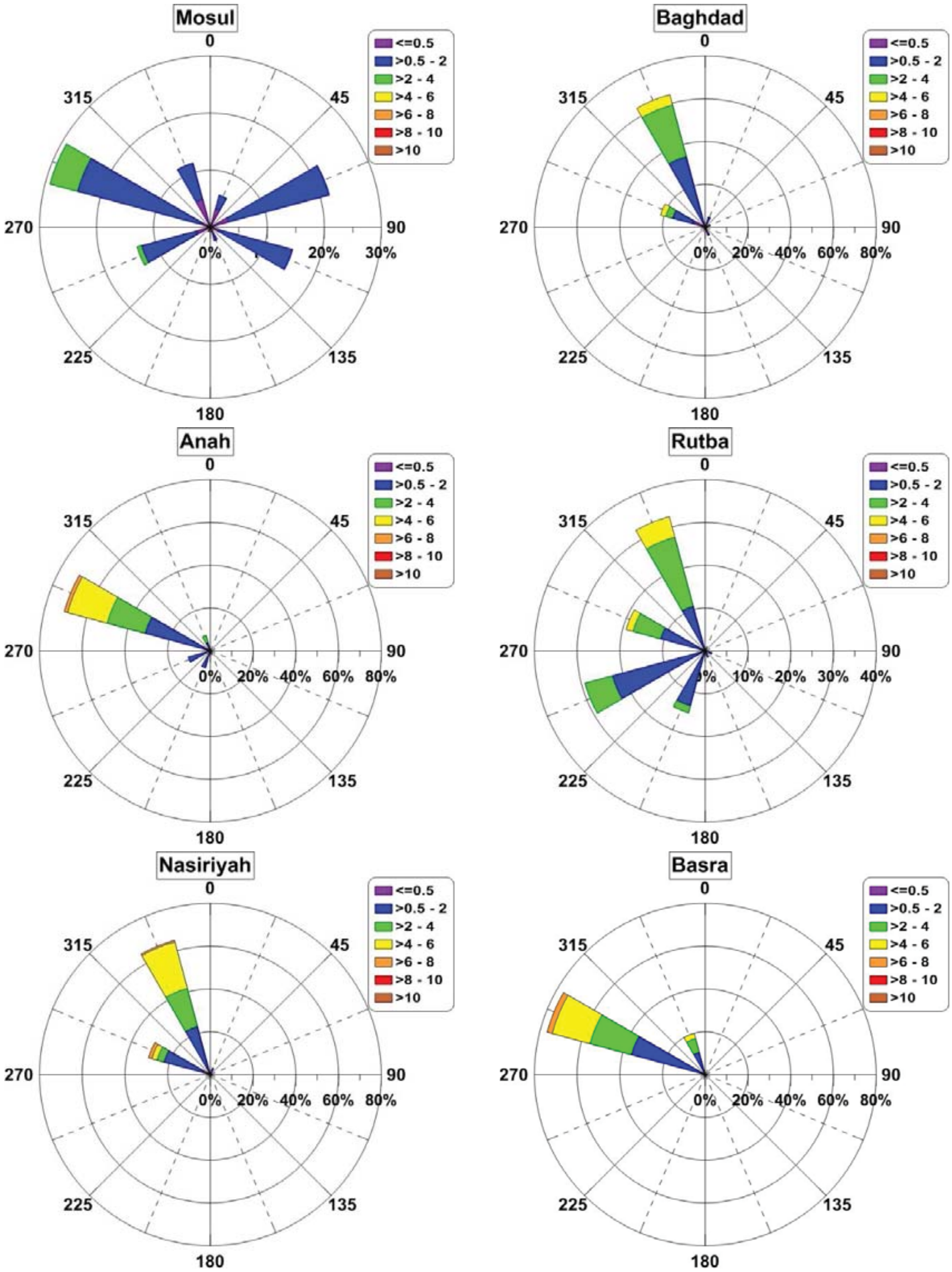


Figure 6: Wind rose plots for the selected cities.

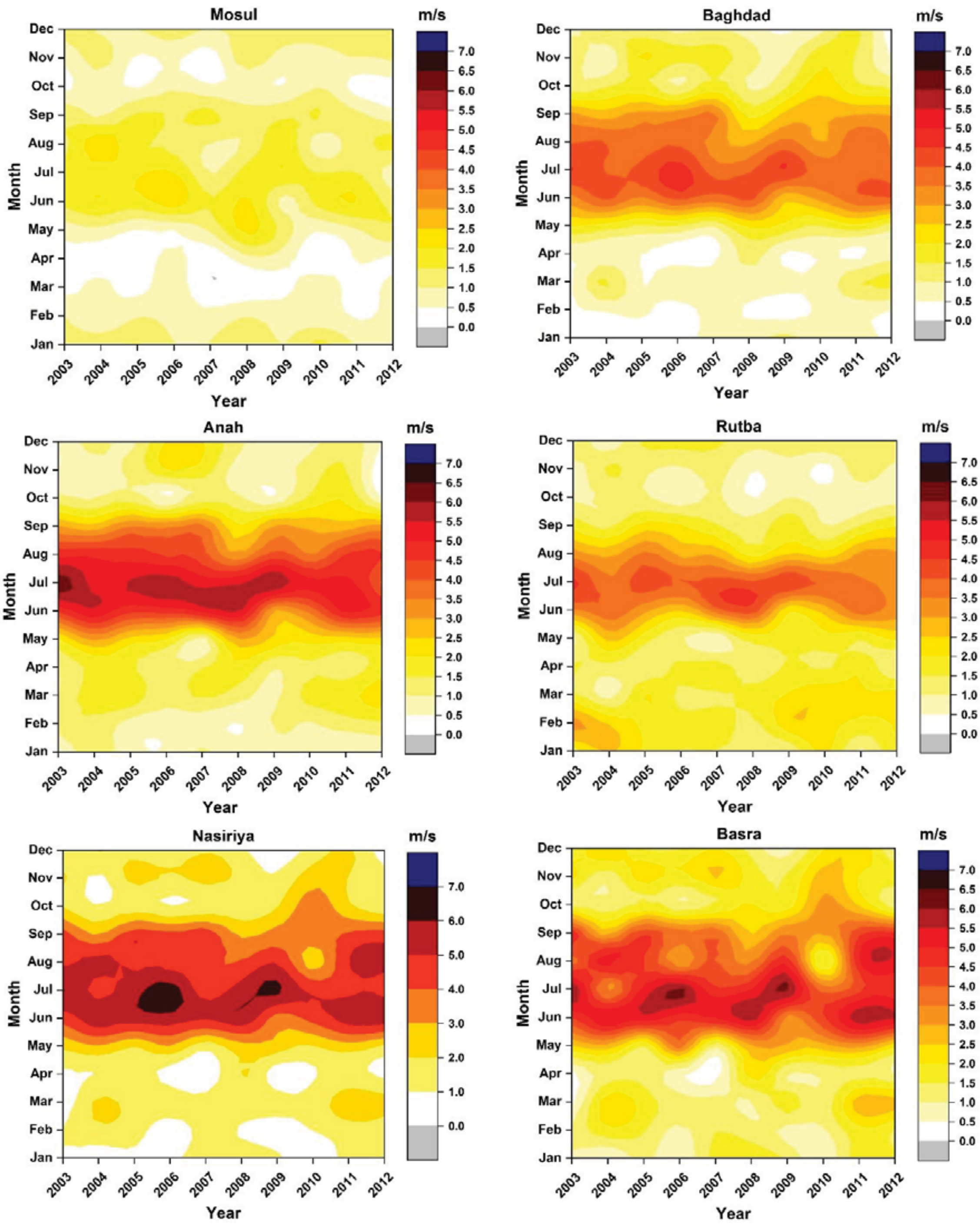


Figure 7: Variations of monthly wind speed for the selected cities.

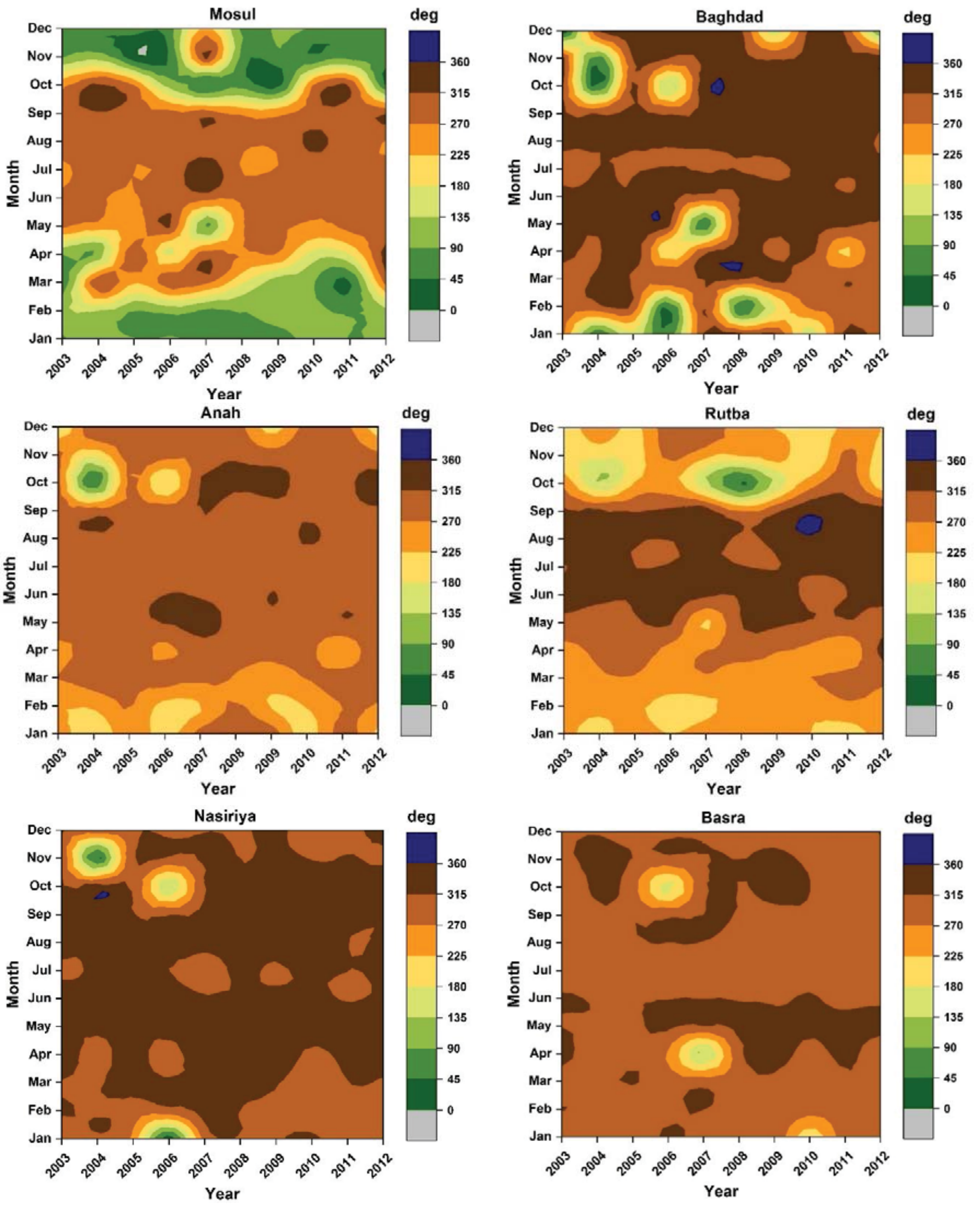


Figure 8: Variations of monthly wind direction for the selected cities.

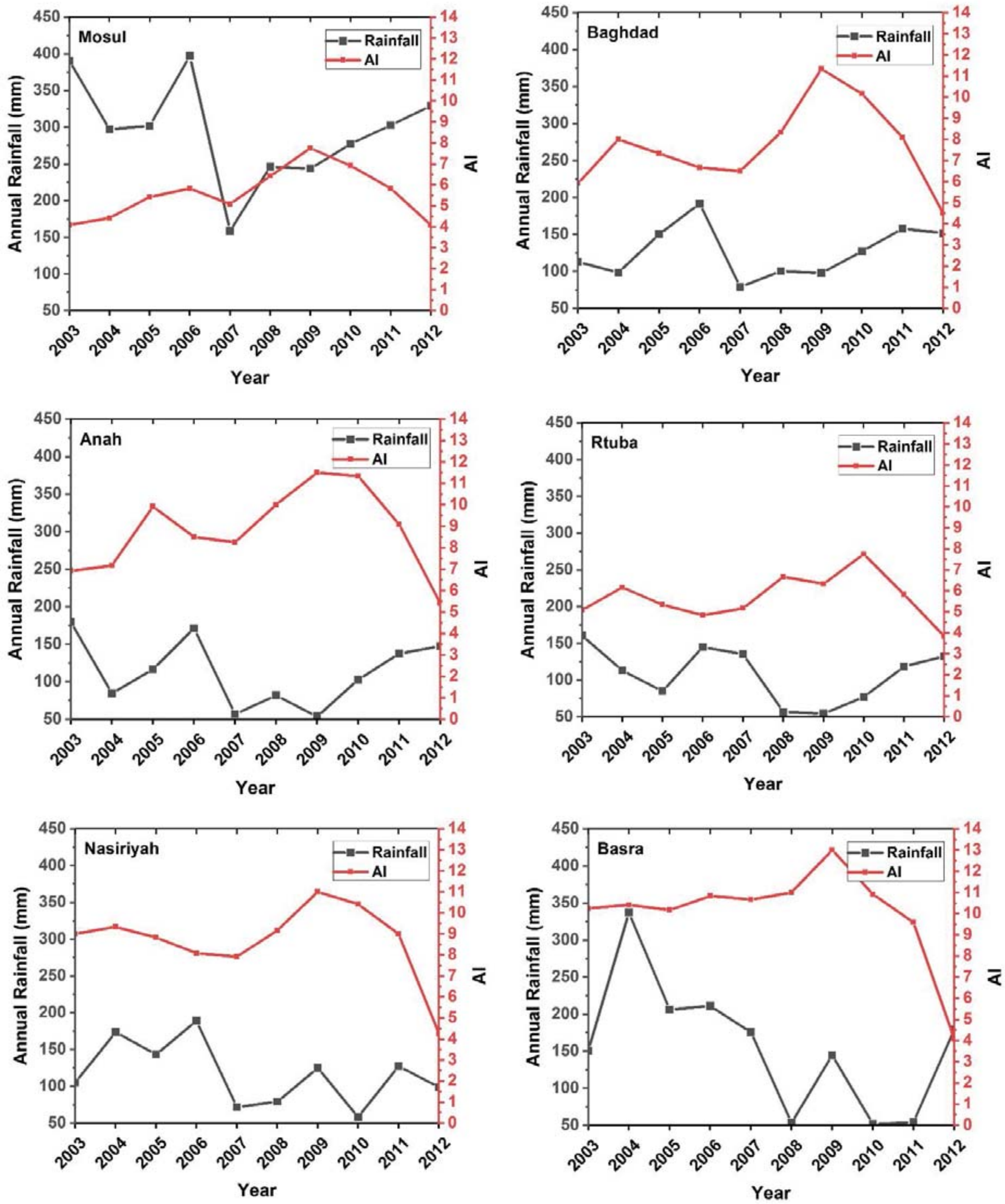


Figure 9: Annual mean of AI and annual total rainfall (mm) for the selected cities.

Conclusions

This work aimed at evaluating dust variability over Iraq using SCIAMACHY Absorbing Aerosol Index over Iraq (AI). Data were acquired from TEMIS , MODIS, and MERRA-2 websites for the period 2003-2012. From results of analysis, it was concluded AI is a good indicator of the initiation, development, and transportation of dust storms. Most dust activities occur during the summer months and dust storms are mainly caused by shamal wind. Results of AI for six selected cities in Iraq suggested that Basra and Nasiriyah and most affected by dust storms followed by Baghdad and Anah. The cities of Mosul and Rutba are less affected by dust because no major source of dust particles are located close to them and there are significant contribution to the wind from directions other than northwest direction. Also Mosul is characterized by slow winds. Analysis of annual rainfall and AI indicated that when rain increases in a given year AI tend to decrease on the following year.

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