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Effect of Climate Change on Spring Massive Sand/Dust Storms in Iraq

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ABSTRACT

Sand and Dust storms are considered a major natural disaster that cause many damages to society and environment in Iraq and surrounded deserted regions. Two spring sand/dust storms on May in two different years were synoptically analyzed. These sand/dust storms were compared in terms of dust surface concentration from NMMB/BSC-Dust model, sea level pressure, surface wind vector, satellite vegetation index and stations rainfall. The findings of this sand/dust storms comparison indicate that Iraq in spring may be affected by two types of wind one dust storm initiated by Shamal which have long occurred in this region and caused frequent dust storms in spring and second by Al-Khamsian. Dust storm in 2012 is massive than sand/dust storm in 2018 where the highest dust surface concentration is reached to (7700 μg/m3) in 22 May 2012 and about (3100 μg/m3) in 11 May 2018. Increase in vegetation cover over Iraq in 2018 was about 23% more than in 2012. Rainfall level in season (2017-2018) was higher than in rainfall season (2011-2012) in Iraqi dust sources regions. Low-pressure gradient, less strong wind, rise in rainfall level and enhancement in vegetation cover are contributed to decrease the storm concentration of 2018 roughly by half.

KEYWORDS: Dust Storm, Dust Surface Concentration, NMMB/BSC-Dust, Surface conditions.

الخلاصة

تعتبر العواصف الرملية والترابية كارثة طبيعية كبرى تسبب أضرارا كثيرة للمجتمع والبيئة في العراق والمناطق المتصحرة المجاورة. تم تحليل عواصف رملية / غبار الربيع في شهر مايو في عامين مختلفين. تمت مقارنة هذه العواصف الرملية/الترابية من حيث تركيز سطح الغبار من الموديل NMMB / BSC-Dust، الضغط عند مستوى سطح البحر ، متجه الرياح السطحية، ومؤشر الغطاء النباتي الاقمار الصناعية ومحطات هطول الأمطار. تشير نتائج هذه المقارنة بين العواصف الرملية والترابية إلى أن العراق في الربيع قد يتأثر بنوعين من الرياح, العاصفة الترابية التي تبدا برياح الشمال والتي حدثت منذ كثيرا في هذه المنطقة وتسببت في عواصف ترابية متكررة في فصل الربيع والثانية من قبل رياح الخماسين. عاصفة الغبار في عام **2012** اكثف من عاصفة الرمل / الغبار في **2018** حيث تم وصلت إلى أعلى تركيز الغبار السطحي (**7700** ميكروغرام/م^3) في **22** مايو **2012** وحوالي (**3100** ميكروغرام/م^3) في **11** مايو **2018**. زيادة الغطاء النباتي فوق العراق في عام **2018** أكثر بنحو **23** ٪ مما كان عليه في عام **2012**. كان مستوى هطول الأمطار في الموسم (**2018-2017**) أعلى من موسم الأمطار (**2011-2012**) في مناطق مصادر الغبار في العراق. ساهم التدرج المنخفض للضغط ، والرياح الأقل قوة**0**، وارتفاع مستوى هطول الأمطار وتحسين الغطاء النباتي في تقليل تركيز العاصفة لعام **2018** تقريبًا إلى النصف.

INTRODUCTION

Sand and dust storms are one among the foremost important phenomena has serious impact on health and economy and consider a serious problem in West Asia, where their intensity, extent and frequency are changed with time and need to well study (Cuevas, 2013; Shepherd *et al.*, 2016; Sissakian, Al-Ansari, & Knutsson, 2013). Iraq is one of the most influenced nations in the Middle East respect to the events of sand and dust storms (Albarakat & Lakshmi, 2019; Sissakian *et al.*, 2013). The most essential sources of sand and dust in the Middle East are Mesopotamia, mainly the vicinity between the Tigris and Euphrates rivers and the central plateaus of Saudi Arabia, in addition to large and wide variety of small sources in most of the region (Hamidi, Kavianpour, & Shao, 2013). Lack of rainfall, building of dams, and the change direction of river flow for irrigation have significantly decreased the river water. This is the fundamental cause of the drying of lakes and wetlands (such as the Mesopotamian marshes) where the area became less especially from 1982 to the present. This system has led in recent decades to a sharp increase in the frequency and intensity of dust storms in this region (Albarakat, Lakshmi, & Tucker, 2018; Terradellas, Basart, & Cuevas, 2016). Another factor causing a dust storm is strong surface winds, which are lift fine dust particles into the air and strong turbulence, or convection spreads this dust to an outsized area, and carry this dust over long distances by powerful winds (Shao, 2008).

The needs for monitoring and forecasting dust events, for assessing and mitigating their negative impacts, approved by WMO by launch the Sand and Dust Storm System - Warning Advisory and Assessment System (SDS-WAS) with the task of enhancing countries ability to give estimates, perceptions, data and information to users appropriate and high quality through a global partnership of research and operational networks (UNEP, 2016). Non-hydrostatic Multi scale Model B grid (NMMB) is designed and developed at the Barcelona Supercomputing Center (BSC) in collaboration with NOAA/National Centers for Environmental Prediction (NCEP), NASA Goddard Institute for Space Studies and the International Research Institute for Climate and Society (IRI) (Pérez, 2011). The dust model is embedded into NMMB model to be NMMB/BSC-Dust (Zavisa Janjic, 2011) to give short medium-range dust forecasts for both regional and global domains and provides a good description of the horizontal distribution and temporal variability of the dust (Pérez, 2011).

The vegetation cover plays an important role in stabilizing the topsoil, thereby suppressing particle stimulation and dust emissions (Kim et al., 2017). The satellite-derived Normalized Difference Vegetation Index (NDVI) is an indicator of the vegetation cover and is an important factor in analyzing and characterizing dust sources and distinguishing dust emissions. NDVI is the most used indicator because of its simplicity, availability and apparent benefit in a variety of ecosystems (Hamel, Garel, Festa-Bianchet, Gaillard, & Côté, 2009; Pettorelli et al., 2011). NDVI extract from solar reflective data relates to the state of vegetation and the production of plant biomass on ground surfaces (Silleos, Alexandridis, Gitas, & Perakis, 2006). MODerate resolution Imaging Spectroradiometer (MODIS) is an imaging instrument that carried by means of each Aqua and Terra satellites of NASA. The MODIS NDVI was extracted from the reflectance information; red (0.62–0.67 µm) and near-infrared (0.841–0.876 µm) (Chen, Fedosejevs, Tiscareno-Lopez, & Arnold, 2006). Several studies have investigated NDVI in the previous decade in ecology (Pettorelli et al., 2011; Tomasz Borowik, 2013). The NDVI processed as the proportion of the red and NIR reflectance information, as appeared in equation NDVI=(NIR-Red)/(NIR+Red) where NIR and Red are the measure of near infrared and red light, individually, reflected by a surface and estimated by satellite sensors (Jackson & Huete, 1991).

The analysis in this research deal with an important liturgical phenomenon that has not been addressed in previous studies in Iraq is the severe dust storms that are the most powerful dust storm over Iraq in the past decade. These dust storms appear on the form a massive wall of mobile dust that suddenly blows and accompanies it many risks, both on public health and on the extent of the vision and the impact on it transportation. Therefore, we found that it is important to study this serious phenomenon and identify the causes of their occurrence.

MATERIALS AND METHODOLOGY

This study cover comparison of two massive sand/dust storms passed on Iraq in term of synoptic weather conditions; dust surface concentration, vegetation cover and rainfall, so many of data sources are used. Analysis is used in this study includes three steps: First, synoptic analysis of surface conditions like surface winds (m/s) and sea level pressure (mb) for severe dusty days 22 May 2012 and 11 May 2018 is employed. Variety of weather maps can produce by using Plymouth State Weather Center[1] server for real-time data saved based on their own choices of different options, such as, region, parameter and time of observations. The center was provided by NOAA and NASA with reliable source of real time weather data and additional processing power and data storage capacity. The plotted surface data maps for two dust storms cases are extracted from the center. Second, analysis of dust surface concentrations (DSC) for two different dust storms occurred on spring. Dust prediction models provide 72 hours (at 3-hourly basis) of DSC forecast

[1] Website: http://vortex.plymouth.edu/myo/sfc/pltmap-a.html

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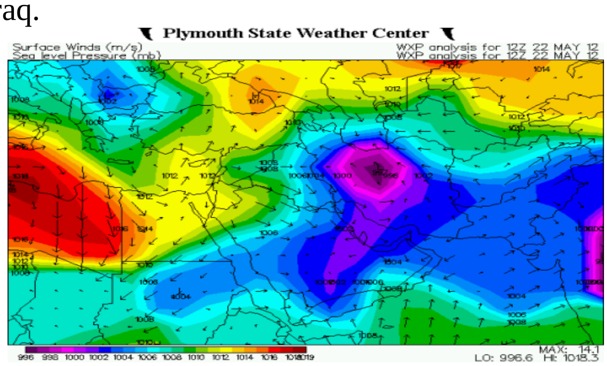
covering the Northern Africa-Middle East-Europe (NA-ME-E) region. The data of DSC each 3 hours on days 22-23 May 2012 and 11-12 May 2018 at Iraqi provinces extracted from results of NMMB/BSC-Dust model runs, https://sds-was.aemet.es. Third, analysis of vegetation cover data over Iraq is achieved based on MODIS sensor board on Terra satellite, which is extracted from https://giovanni.gsfc.nasa.gov during spring month (May) in 2012 and 2018 when dust storms are occurred. Spatial distribution of NDVI represented by GIS map based on 0.05° data averaged for spring month during the dust storm occurred using ArcGIS software. Fourth, the ground-based observations of rainfall data for Iraqi stations were obtained from Iraqi Meteorological Organization and Seismology (IMOS) to evaluate the impact of their changes on dust storms concentrations

RESULTS AND DISCUSSION

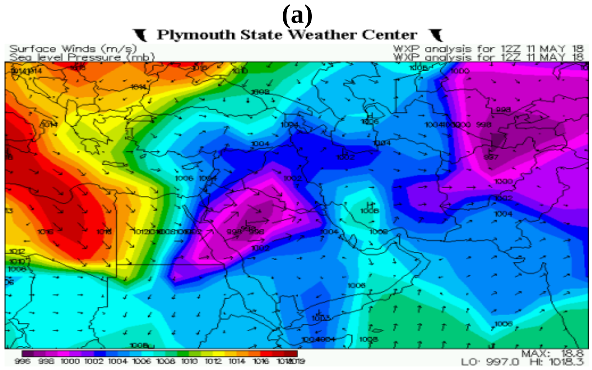
Synoptic analysis of surface conditions

Case study 1: At 12Z on 22 May 2012, Fig 1a shows low-pressure system with enclosed circulations centered on Iran associated to the Monsoon with a ridge over the Mediterranean associated to the sub-tropical high stretching easterly. Iraq is under the influence of strong pressure gradient led to produce northwesterly wind (Shamal) often strong during the day, blowing over northwestern Iraq southward to Kuwait and Arabian Gulf states with value reached about (13.38 m/s) especially in west and south of Iraq which rise dust from dust sources that exist in northwestern and western portions of Iraq.

Case study 2: In Fig 1b a severe red sand/dust storm was struck al-Muthanna province in southern Iraq on Friday 11 May 2018 due to the presence of low-pressure system of the Khamasin extension. The low Khamasin came from North Africa specifically the desert of Libya through Egypt and Levant passing through southern Iraq and the provinces of Muthanna, Dhi Qar, Basra and parts of the province of Miysan pointing out this storm considered a dry storm. The enclosed circulations of low pressure centered on north of Arabian Saudi at 12 Z with value about (996 mb) and highest wind reached value to about (14.20 m/s) located at the center of low pressure and about (9.26 m/s) at the western region of Iraq. These high winds lift the dust from its sources in both northern Saudi Arabia and western Desert of Iraq creating a "red" dust storm swept through Al-Muthanna province in southern Iraq.



(a)

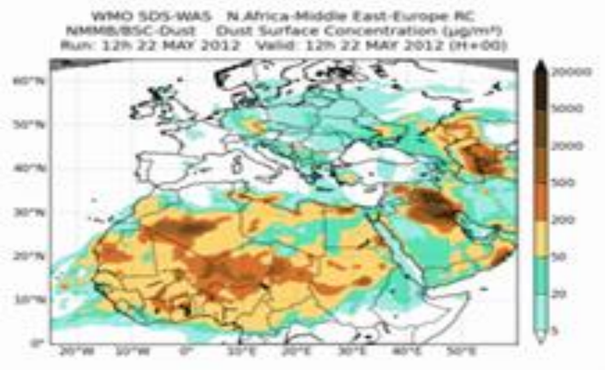


(b)

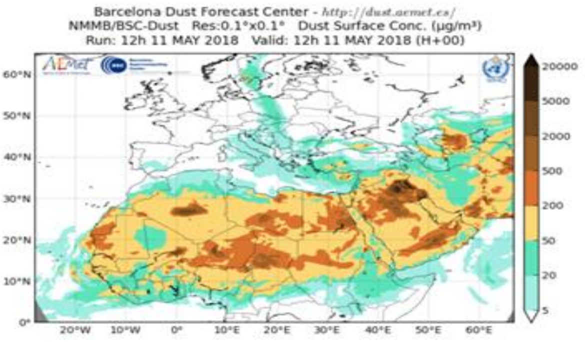
Figure 1 Surface winds (m/s) and sea level pressure (mb) in dusty days at 12:00 UTC on 22 May 2012, (b) 11 May 2018.

Dust surface concentration analysis

Dust surface concentrations (DSC) dataset of the NA-ME-E was investigated as a reliable alternative of the ground based instruments. Spring Dust storms occurred due to rising dust from neighboring countries and Iraq where hot spot sources of dust is existed. In this study, the mean values of concentrations for two different dust storms occurred on spring extracted from results of NMMB/BSC-Dust model. It is clear from Fig 2(a) on 22 May 2012 a thick dust storm invaded most of Iraq and affected many areas of the country in north, middle and south. Dust extended from Syria and northern Iraq southward to Kuwait and the fine sediments of the Tigris and Euphrates riverbeds and impermanent rivers in the Syria-Iraq region is contributed to this storm. This thick dust storm that pervaded Iraq and Kuwait led to force the closure of the Baghdad airport and suspended operations in two ports in Kuwait. The highest DSC value is reached to (7700 μg/m^3). Fig 2(b) illustrate a dust storm has hit Iraq on Friday, May 11, 2018 which is shrouded the western, and southern parts of Iraq and the highest DSC value is reached to (3100 µg/m^3). This storm will not be followed by rain like every time except for some anomalies in a number of areas, but very lightly, as it is a dry storm.



(a)



(b)

Figure 2. Dust surface concentration (µg/m^3) on dusty days at 12:00 UTC (a) 22 May 2012, (b) 11 May 2018.

Dust surface concentration analysis in Iraq

Hourly comparison of DSC and an in-depth analysis of two cases, namely 22-23 May 2012 and 11-12 May 2018, have been explained below. Temporal variations of max dust concentrations in 16 Iraqi cities that are more affected by these dust storms are shown in Fig 3. The data of DSC at Iraqi cities are extracted from NMMB/BSC-Dust model runs for each three hours. In general, it is clear that peaks of DSC on storm 2012 in all selected sites is high than on storm 2018 except at Al-Salaymaniyah city is low due to raining weather which is suppressed the dust storm. The highest dust concentration was over the western parts of Iraq than others parts due to the strong wind, Al-Jazeera desert and western desert, so the cities: Dhi-Qar, Al-Muthanna, Basra and Salahaddin witness highest values about 7700 µg/m^3 at 12 Z, 7300 µg/m^3at 9 Z, 6800 µg/m^3 at 9Z, 6000 µg/m^3 at 6Z respectively. In storm 2018 the concentrations have been reduced at all stations and the storm does not last for a long time like the 2012 storm for number of reasons. One of the most important reasons is gusting from the sandy desert areas and the frequent rain, that led to the flourish vegetation cover and therefore the soil became more stable even in areas of sand/dust sources. The highest DSC was reached in Iraqi cities: Diyala, Al-Najaf, Al-Anbar, Waist and Misan with value about 3100 µg/m^3 at 9 Z, 3000 µg/m^3at 9 Z, 2400 µg/m^3 at 12 Z, 1900 µg/m^3 at 6Z respectively.

Vegetation cover analysis

The MODIS-Terra NDVI for May for years 2012 and 2018 are used in region of Iraq to generate vegetation pattern map and show the change of vegetation cover after seven years. Spatial distribution of vegetation cover is quite different in Iraqi cities from north to south and hot spots sources of dust as shown in Fig 4. The range value of NDVI value over Iraq is high in May 2018 (0.03-0.67) than on May 2012 (-0.03-0.63). The maximum NDVI appears at the north and east of Iraq with high altitude due to non-interference of the human/domestic animal activities where the forest and no dust storms occur. The minimum of NDVI is detected at Al-Jazeera in northwest of Iraq and the north of Al-Anbar province and western, southern parts of Iraq where open land of barren areas and sand dunes. Maximum value of NDVI in regions of hot spot sources which faced highest dust concentrations illustrated in Table 1 for two study cases. Its notes that the values of vegetation index at almost study dust sources in 16 Iraqi cities are high in May 2018 than in May 2012. This is one of the reasons for the decline in dust concentrations especially in that dust sources regions in year 2018. In general, an obvious rise in NDVI at some province (district) is found, especially at Al-Sulaymaniyah (Chamchamal), Diyala (Baladrose), Wasit (Kut) and Baghdad (Al-Tajee). NDVI values of these regions were>0.25 where shrub and grassland and pastures may be attributed to increasing in rainfall levels. NDVI is close in both years and slightly higher in 2018 in the western and southern regions with values<0.18 where barren areas of rock and sand dune. The highest present increase in NDVI is reached to nearly double that it was especially at Kirkuk (Hawija), Dhi Qar (Nasiriyah), Salahaddin (Samarra) and Al-Sulaymaniyah (Chamchamal). The mean increase of vegetation index over Iraq after seven years from 2012 is 23% caused to reduce the concentration of dust storm 2018 by half.

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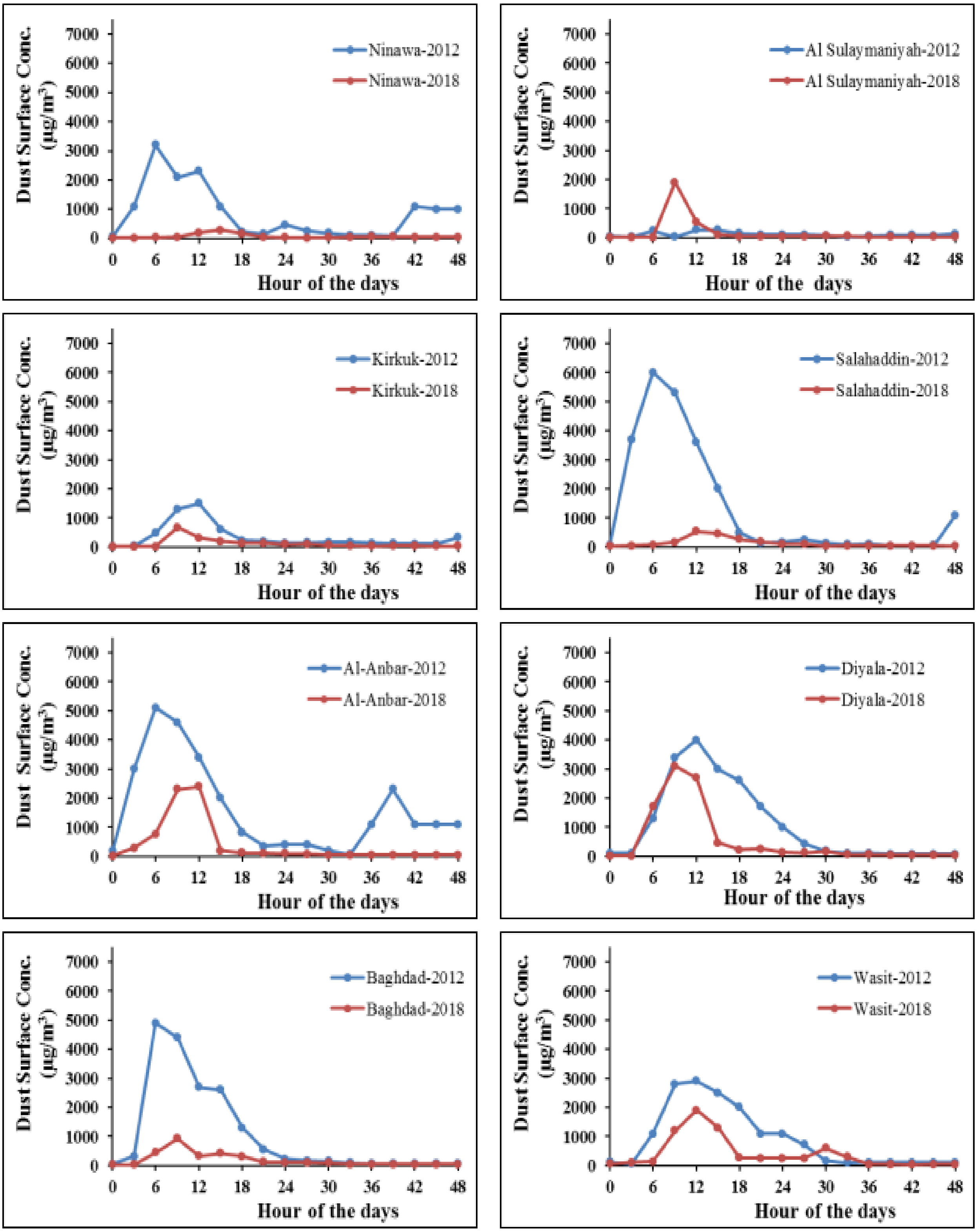

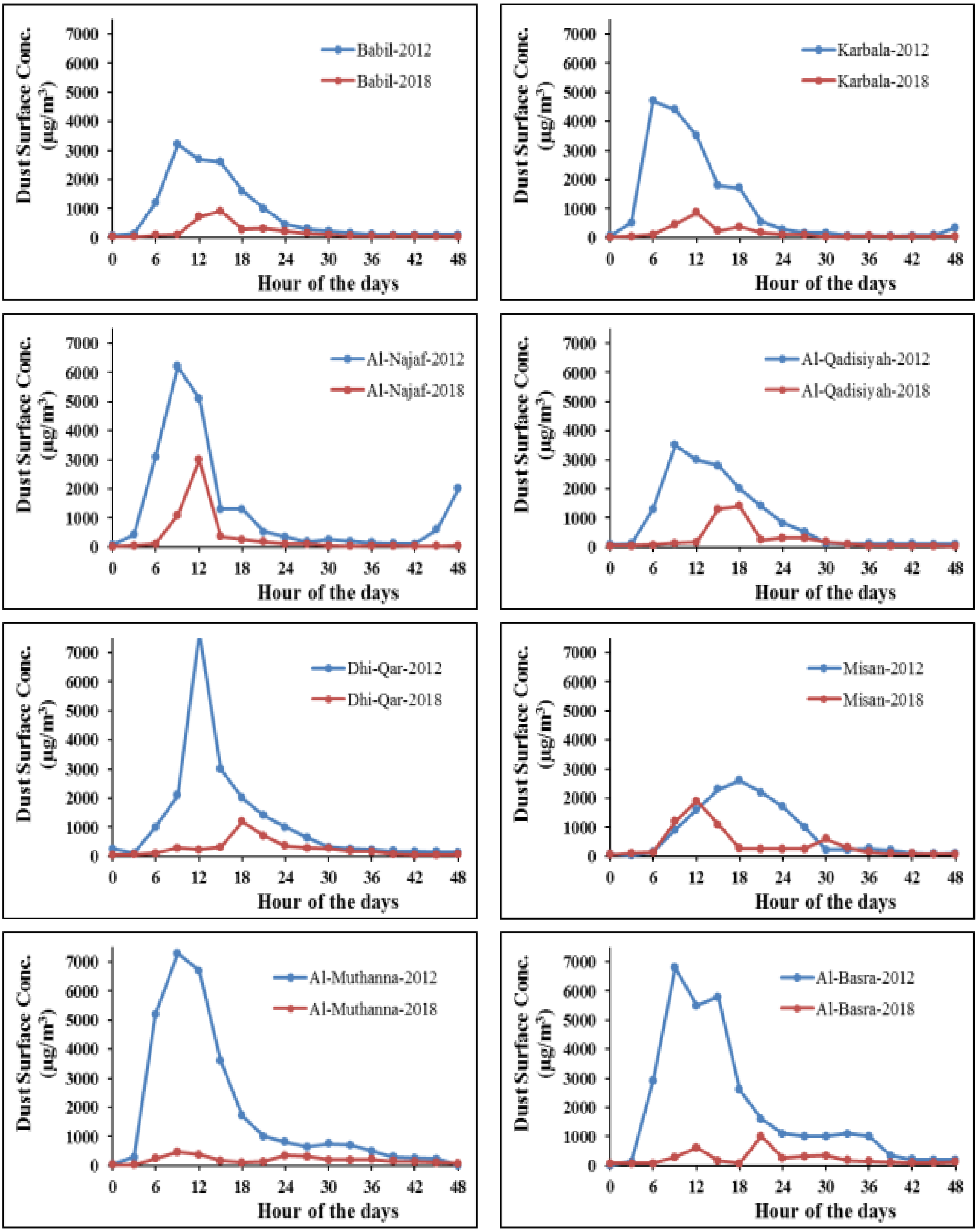

Figure 3. Comparison max dust surface concentration on days 22-23 May 2012 and 11-12 May 2018 at Iraqi provinces

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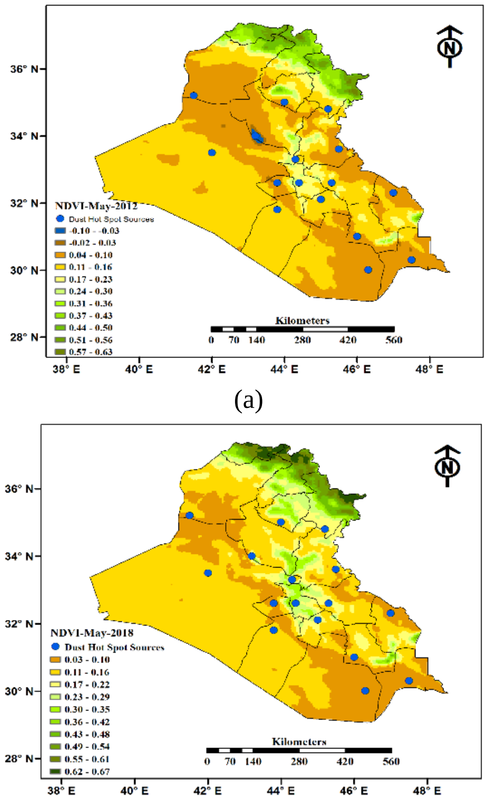

(a)

(b)

Figure 4. Spatial distribution of NDVI on (a) May 2012 (b) May 2018 with hot spot dust sources (blue color points) in Iraq.

Table 1. Max NDVI at sand/dust sources in study cases.

Province/District	Lat.	Long.	Max NDVI May-2012	Max NDVI May-2018	Increase%
Ninawa/ Al-Baag	35.0	41.5	0.090	0.107	18.9
Al-Sulaymaniyah/ Chamchamal	35.0	45.6	0.257	0.367	42.8
Kirkuk/ Hawija	35.0	44.0	0.096	0.149	55.2
Salahaddin/ Samarra	34.0	43.0	0.090	0.129	43.3
Al-Aanbar/ Rutba	33.5	42.0	0.131	0.135	3.1
Diyala/ Baladrose	33.6	45.5	0.341	0.441	29.3
Baghdad/ Al-Tajee	33.3	44.3	0.251	0.341	35.9
Wasit/ Kut	32.6	45.3	0.289	0.377	30.4
Babil/ Al-Hala	32.6	44.3	0.162	0.175	8.0
Karbala/ Aeen Tamer	32.6	43.6	0.088	0.102	15.9
Al-Najaf/ Najaf	31.8	43.8	0.120	0.121	0.8
Al-Qadisiyah/ Diwania	32.3	45.0	0.182	0.183	0.5
Dhi Qar/ Nasiriyah	31.0	46.0	0.078	0.118	51.3
Misan/ Ali-Alkarbee	32.3	47.0	0.071	0.079	11.3
Al-Muthana/ Al-Salman	30.0	46.3	0.068	0.092	35.3
Al-Basrah/ Al-Zabeer	30.3	47.5	0.076	0.084	10.5

Rainy seasons analysis in Iraq

Figure 5 shows the comparison of cumulative rainfall during rainy seasons (September 2011 - May 2012) for the first study case and (September 2017 - May 2018) for the second study case in 12 Iraqi stations where measurements are available. These data acquired from the IMOS weather stations. In general rainfall levels is high in rainy season (2017-2018) than in other case (2011-2012). This increase in rainfall was observed in the northern regions than in the central and southern regions of Iraq. This is one of the reasons for the decline in dust storms numbers and a decrease in dust concentrations in Iraq particularly in selected dust sources.

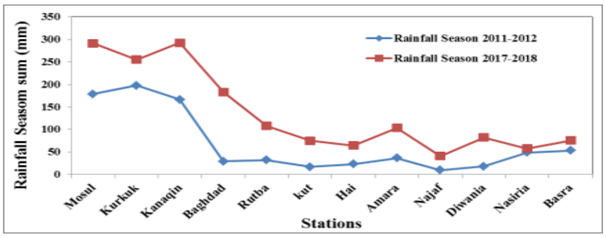

Figure 5. Cumulative rainfall in twelve IMOS stations during rainy seasons 2011-2012 and 2017-2018.

CONCLUSIONS

The present study focuses on the two massive dust/sand storms that have occurred in Middle East on May over the period of 2012–2018. This study was carried out using various datasets including synoptic data; meteorological elements, vegetation index, reanalysis data and numerical results of NMMB/BSC-Dust model for a better identify areas most affected by dust storms.

Analysis of surface weather maps indicated that Iraq in spring might be affected by two types of wind one dust storm initiated by Shamal, which have long occurred in this region and caused frequent dust storms in spring and second by Al-Khamsian. The stronger northwestern winds over Iraq during the dust-storm days were related to increase in pressure gradient. High wind speed in western part of Iraq is one of the reasons for increase the intensity of storms. Other factors may have contributed to a severity and lifetime of dust storms are lack of rainfall and shrinking of green spaces. Vegetation cover overall of Iraq in May 2018 is more abundant than in May 2012 where the mean increase of vegetation index over Iraq after seven years from 2012 is 23% caused to reduce the concentration of dust storm 2018 by half. Levels of rainfall during rainy season 2017-2018 is high than at rainy season 2011-2012 may have caused reduction in dust storm concentrations in May 2018 at the regions affected by storms so dust storm in 2012 is massive than storm in 2018.

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