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Increase in dust storm related PM_{10} concentrations: A time series analysis of 2001–2015☆

Helena Krasnov [a,*], Itzhak Katra [a], Michael Friger [b]

[a] Department of Geography and Environmental Development, Ben-Gurion University of the Negev, Beer-Sheva, 84105, Israel
[b] Department of Public Health, Faculty of Health Sciences, Ben-Gurion University of the Negev, Beer-Sheva, 84105, Israel

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ABSTRACT

Over the last decades, changes in dust storms characteristics have been observed in different parts of the world. The changing frequency of dust storms in the southeastern Mediterranean has led to growing concern regarding atmospheric PM_{10} levels. A classic time series additive model was used in order to describe and evaluate the changes in PM_{10} concentrations during dust storm days in different cities in Israel, which is located at the margins of the global dust belt. The analysis revealed variations in the number of dust events and PM_{10} concentrations during 2001–2015. A significant increase in PM_{10} concentrations was identified since 2009 in the arid city of Beer Sheva, southern Israel. Average PM_{10} concentrations during dust days before 2009 were 406, 312, and 364 μg m^{-3} (median 337, 269,302) for Beer Sheva, Rehovot (central Israel) and Modi'in (eastern Israel), respectively. After 2009 the average concentrations in these cities during dust storms were 536, 466, and 428 μg m^{-3} (median 382, 335, 338), respectively. Regression analysis revealed associations between PM_{10} variations and seasonality, wind speed, as well as relative humidity. The trends and periodicity are stronger in the southern part of Israel, where higher PM_{10} concentrations are found. Since 2009 dust events became more extreme with much higher daily and hourly levels. The findings demonstrate that in the arid area variations of dust storms can be quantified easier through PM_{10} levels over a relatively short time scale of several years.

1. Introduction

Desert dust storms have played an increasingly pronounced physical and chemical role in the global system (Shao et al., 2011). One of the environmental consequences of atmospheric dust is the significance for climate through a range of possible influences and mechanisms. It is also possible that dust may affect climate through its influence on marine primary productivity (Jickells et al., 1998), and may also affect air temperatures through the absorption and scattering of solar radiation (Li et al., 1996; Moulin et al., 1997; Alpert et al., 1998). Numerous studies have shown high concentrations of ambient particulate matter (PM) during dust events in different parts of the world (Rodrıguez et al., 2001; Krasnov et al., 2014). Mineral dust also strongly affects public health in arid environments with frequent dust storms (Vodonos et al., 2014; Yitshak-Sade et al., 2015). Studies have shown that particulate matter with an aerodynamic diameter of less than 10 μm (PM_{10}) significantly increases pollution levels above the standard values of air quality during dust storm events (Mitsakou et al., 2008; Querol et al., 2009; Krasnov et al., 2014).

Due to the placement of Israel in the global dust belt, dust events are a common phenomenon. Dust events have shown to increase daily PM_{10} levels in the center of Israel (Tel Aviv) to as high as 2100 μg m^{-3} (Ganor et al., 2009; Kalderon-Asael et al., 2009). In the desert Negev region (southern Israel) hourly PM_{10} concentrations can reach levels above 5000 μg m^{-3} (Krasnov et al., 2014). The suggested increasing frequency of dust storms in the southeastern Mediterranean (Ganor et al., 2010) over the past few decades has led to growing concern regarding PM_{10} levels. Changes in the amounts of dust and associated dust storm were shown to occur in several regions (Zhu et al., 1997; Zhang et al., 2003; Fiol et al., 2005; Mahowald et al., 2007). Goudie and Middleton, (2001) claim an increase in dust storm frequency concurrent with drought periods in the Sahel, and cite others who claim an increase in dust storms occurrence since the 1950s. A study based on 63 years of dust data

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* Corresponding author.
E-mail addresses: krasnovh@post.bgu.ac.il (H. Krasnov), katra@bgu.ac.il (I. Katra), friger@bgu.ac.il (M. Friger).

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in Iceland showed that the highest frequency of dust events was found during the 2000s in south and north-east Iceland (Dagsson-Waldhauserova et al., 2014).

These studies however, did not refer to the atmospheric concentration during these dust events. The aim of the present study was to examine changes in PM concentrations associated with dust events over the last 15 years (2001–2015) in different parts of Israel. Israel is located, between 29° and 33° north of the equator, which is characterized as a subtropical region, between the temperate zone and the tropical zone. The unique setting creates a situation where the northern and coastal regions of Israel show Mediterranean climate (characterized by hot and dry summers and cool rainy winters). Whereas the southern and eastern areas are characterized by an arid climate. This remote area is between the major dust sources and should be better identified on the world dust map. Results from the arid city of Beer Sheva (southern Israel) were compared to Rehovot (central Israel) and Modi'in (eastern Israel) in order to evaluate spatial changes on a small scale (Fig 1).

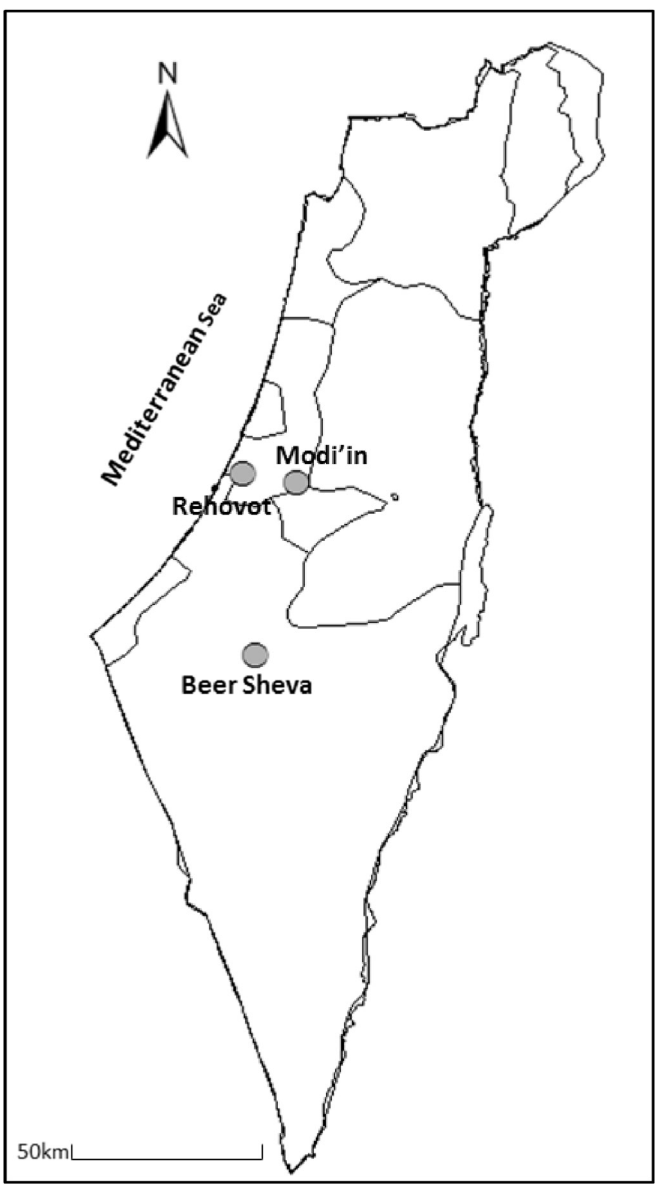

Fig. 1. Map of the study area (Israel). The study is based on three cities in Israel- Beer Sheva (southern Israel); Rehovot (central Israel) and Modi'in (eastern Israel).

2. Materials and methods

2.1. Study area

The study is based on three cities in Israel- Beer Sheva (southern Israel); Rehovot (central Israel) and Modi'in (eastern Israel). The city of Beer-Sheva (31.2498° N, 34.7997° E), population of 196,300, is located in the Negev desert, southern Israel. The area is characterized by hot, dry summers dominated by daily land and sea breeze circulation and wet, cool winters with considerable cyclonic activity. The semi-arid northern Negev desert has an average annual rainfall of about 100 mm, most of which falls from December to March. The region's average annual temperature is 19.8 °C, with large differences between winter and summer and between day and night. Atmospheric humidity varies between 5% and 93%. Rehovot (31.8980° N, 34.8081° E) is a city in the center district (population 199,999) of Israel, about 20 km south of Tel Aviv. Rehovot's climate is classified as warm and temperate. The winter months are rainy while the summer months are dry. The average annual temperature is 20 °C with average relative humidity of 65%. The rainfall average is 537 mm. Modi'in (31.9077° N, 35.0076° E) is located about 35 km southeast of Tel Aviv and 30 km west of Jerusalem (population 90,000). During the summer season there is intense solar radiation, and relatively high temperature and relative humidity, although lower than the coastal strip (Rehovot). During the winter, the temperatures are relatively low especially at night. The annual rainfall is 400–650 mm.

Dust events in Israel are dominated by a specific synoptic system prevailing during each season (Alpert et al., 1990; Kahana et al., 2002; Alpert and Ziv, 1989; Ganor et al., 2010). In the winter, cold low-pressure systems penetrate Israel— with the Cyprus Low being the dominant system (Alpert et al., 1990). The Red Sea Trough is the most common system in the autumn (Kahana et al., 2002), whereas highs and warm low-pressure system – Sharav Low – is specific to spring (Alpert and Ziv, 1989). The summer period is considered as a dust-free season (Ganor et al., 2010) due to the influence of the quasi-stationary Persian Trough system (Alpert et al., 1990). Israel has two origins for the aeolian material. The primarily is in North Africa (about 60%–80%) and some minor contribution from the deserts in the east and south-east of Israel. The main synoptic system contributing dust is the Cyprus low that enters Israel from the south-west.

2.2. Environmental data

Data for Beer Sheva, Rehovot and Modi'in were obtained from the monitoring stations of the Ministry of Environmental Protection (http://www.sviva.gov.il) within the framework of the National Air Monitoring System. The monitors are located on top of school buildings in the middle of each city. The data were recorded every 5 min by a dichotomous ambient particulate monitor (Thermo Scientific 1405DF; Thermo Fisher Scientific Inc.) that provides a continuous direct mass measurement of particle mass utilizing two tapered element oscillating microbalances. The database consists of sequential time series of daily records including: daily and hourly atmospheric PM_{10} concentrations ($\mu g\ m^{-3}$), wind speed ($m\ s^{-2}$), air temperature (C°), relative humidity (%) and rain (mm). The monitoring station are all placed in a relatively "clean" areas far from industry and other possible anthropogenic dust sources.

Each day was classified as either a dust day or a non-dust day. A dust day was defined as PM_{10} daily average above 200 $\mu g\ m^{-3}$ for the purpose of this study; followed by Krasnov et al. (2014) and Vodonos et al. (2014). The records were collected over 14 years between January 2001 and December 2014 (in total: 5115 daily records). Descriptive statistics of the different parameters is