Impact of Saharan dust on precipitation chemistry in Croatia

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Abstract

The aim of this research was to examine Saharan dust transport over the Mediterranean towards Croatia. We analyzed several episodes of mud rain events during the period 2001-2005 on two mountainous, background sites. The mud rain events related to Saharan dust outbreaks were identified using Earth Probe/Total Ozone Mapping Spectrometer (TOMS) aerosol index (AI) data and backwards trajectories. The mud rains were characterized by higher calcium concentrations and pH values. In addition, we investigated the contribution of mud rains to the annual total calcium deposition.

Keywords: aerosol index, TOMS, trajectories, calcium, pH

1 Introduction

The Sahara is the world's largest source of aeolian desert dust (Middleton and Goudie 2001). The dust can be entrained over large areas in dust storms, transported over thousands of kilometers and then deposited downwind. Saharan dust aerosols have a major influence on soil characteristics, oceanic productivity, and air chemistry. Atmospheric dust loadings may have considerable climatic significance through a variety of possible influences and mechanisms. Thus, Saharan dust is the subject of considerable scientific interest (e.g. Middleton and Goudie, 2001).

Saharan dust can be removed from the atmosphere by dry or wet deposition. The latter is also known as the mud rain, and such events we examined in this work. Mud rains are frequent over southern Europe and they have been reported since ancient times (Middleton and Goudie 2001). Nevertheless, few investigations have dealt with this phenomenon in Croatia. The most comprehensive one is the work of Lisac (1973), where meteorological, chemical and mineralogical aspects of one mud rain event were analyzed.

In this work we tried to determine the frequency of mud rain events over Croatia during the period 2001-2005 and their influence on precipitation chemistry. In order to detect mud rain events we used TOMS aerosol index, backwards trajectories and precipitation chemistry analysis.

2 Data and methods

2.1 Sampling sites

We analyzed episodes of mud rains over Croatia for two mountainous, background sites (Fig. 1). The sites are parts of Co operative Programme

for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) network. The Site 1 (1594 m) is situated in a protected area (the National Park Northern Velebit). The nearest pollution sources are in the industrial town of Rijeka, about 60 km northwestward. The site has a maritime precipitation regime with more precipitation during the cold part of year. The Site 2 (988 m) is situated in the Nature Park Medvednica and about 10 km far from the city of Zagreb. The precipitation at Site 2 exhibits a continental regime, with higher amounts during the warm part of year.

2.2 Precipitation data

In this work we used the data from the daily bulk precipitation samples collected during the period 2001-2005 at Site 1 (676 samples) and 2 (555 samples). The samples were collected in open polyethylene buckets in accordance with the precipitation measurement protocol, from 07:00 to 07:00 CET. All samples were analyzed in the chemical laboratory of the Meteorological and Hydrological Service of Croatia, according to the EMEP manual. Analysis details are given in Špoler Čanić et al. (2009).

2.3 Aerosol index

The TOMS aerosol index (AI) is a measure of how much the wavelength dependence of backscattered UV radiation from an atmosphere containing aerosols differs from that of a pure molecular atmosphere. Therefore, AI represents an ideal tool for monitoring intensity and pathway of desert dust on daily basis (Herman et al., 1997). The daily maps and data of AI from the Earth Probe/TOMS were downloaded from: http://toms.gsfc.nasa.gov. The resolution of the AI data over globe is 1.25° in longitude and 1.00° in latitude.

2.4 Backwards trajectories

Origins of air parcels that arrived at the two receptor points (Sites 1 and 2) have been identified using the two-dimensional backwards trajectories downloaded from http://www.emep.int. Backwards trajectories are calculated by tracking an air parcel every two hours for 96 hours backwards in time, four times per day (at 00, 06, 18 and 21 h UTC). The trajectory calculation was based on the wind fields at 925 hPa of PARLAM-PS model at 50 x 50 km^2.

2.5 Mud rain event detection

Mud rain events associated with Saharan dust intrusions over Croatia were identified on the basis of TOMS AI maps. When the points closest to the sampling sites simultaneously had AI>0.7 the daily maps of AI and

backwards trajectories were investigated for the possible Saharan source. Precipitation chemistry analysis was carried out next, with particular regard, to the calcium concentration and pH value of the samples since only these two parameters are consistently affected by Saharan dust in rain water (Löye-Pilot et al. 1986).

3 Results and discussions

Mud rains occurred in 22 dust outbreaks during the period 2001-2005. The majority of them (17) were between April and July. In all cases both, calcium concentration was higher then annual volume weighted average (VWA) and pH was greater than 5.

In order to find out if mud rains significantly affect calcium concentration in precipitation, here we focus only on the dust outbreaks that reach

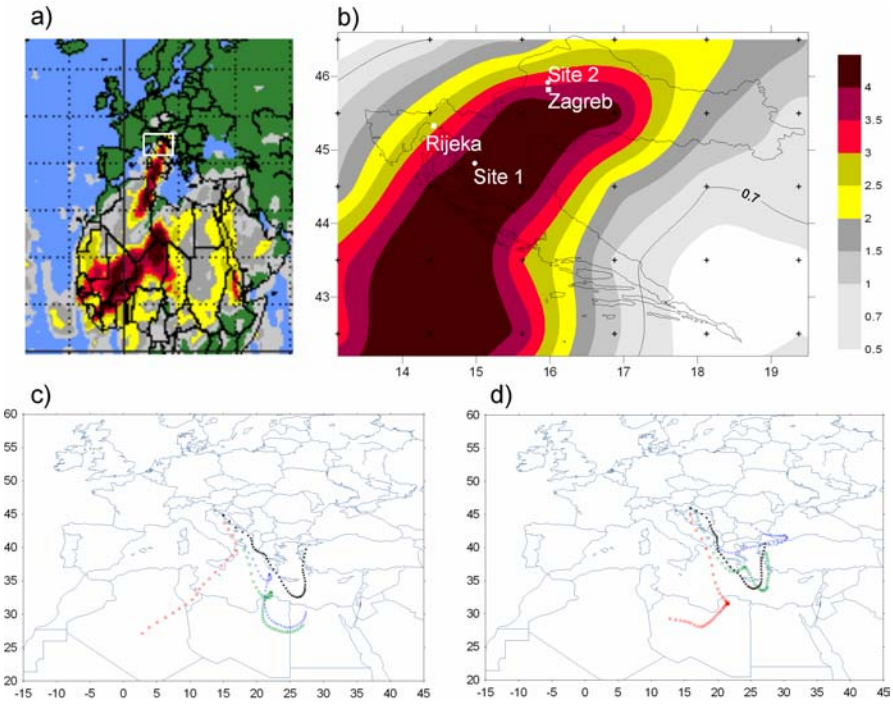

Fig. 1 a) TOMS map of AI for 12 April 2002. Strong Saharan plume over Mediterranean towards Croatia is indicated by a white square. b) Distribution of AI over Croatia. Small black crosses represent horizontal resolution of AI data. c) and d) backwards trajectories for Site 1 and 2, respectively. Trajectories are calculated four times per day at: 00 (black), 06 (blue), 12 (green), and 18 h (red) UTC.

both sampling sites. Namely, the trend analysis of the calcium concentration VWA at Croatian sampling sites had shown significant increase after 1995, which was addressed to the post-war recovery (Špoler Čanić et al. 2009). However, some researchers have shown that dust storm occurrence increased. Thus, the observed increase of calcium in precipitation could also be due to more frequent mud rains. Nevertheless, when days with mud rains were excluded from the calculation of the calcium concentration VWA in precipitation, the obtained concentrations still exhibited pronounced increasing trend. This further corroborates the major role of the post-war recovery in the increase of calcium concentration in precipitation over Croatia.

Considering entire investigated period, the most intensive episode with highest AI occurred in April 2002. Fig. 1 shows Saharan dust transport over Mediterranean towards Croatia on 12 April 2002. The backwards trajectories (Fig. 1 c and d) for Site 1 and 2 also point to Saharan area as a source region

Compared to Site 2, the mud rains at Site 1 were more frequent, and they were accompanied with higher calcium concentrations and pH values. These can be attributed to the different geographical positions.

4 Acknowledgments

Our work was supported by the Ministry of Science, Education and Sport (grants No. 004-1193086-3036, No. 037-1193086-2771 and No. 119-1193086-1323) and EMEP4HR project number 175183/S30 provided by the Research Council of Norway. We thank the NASA/GSFC/TOMS group for the use of aerosol index data.

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