AN EPISODE OF SAHARAN DUST OVER CROATIA

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INTRODUCTION

In recent years the role of the desert dust in the global system has become increasingly apparent (Goudie 2009 and the reference therein). The world's largest source of desert dust is the Sahara with about half of the total global dust emission. The dust can be transported over thousands of kilometres and is deposited downwind by wet (i.e. mud rain) and dry processes. Mud rains are frequent over southern Europe and they have been reported since ancient times. In spite of that only few investigations have dealt with this phenomenon in Croatia (e.g. Lisac 1973).

In this work we analysed one mud rain episode, with the highest TOMS (Total Ozone Mapping Spectrometer) aerosol index over Croatia during the period 2001-2005. This episode was connected with strong Saharan dust outbreak which occurred over Mediterranean Sea from 8th to 14th April 2002. The synoptic situation over Croatia was analysed for the episode, as well as AI images, backwards trajectories and precipitation chemistry.

DATA AND METHODS

We analysed the precipitation chemistry data from 14 monitoring sites in Croatia (Fig. 1). Sites 12 and 14 are mountainous, background sites and they are parts of Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) network. In daily bulk precipitation samples were determined: pH values, electrical conductivity and concentrations of main ions (i.e. SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Ca^{2+}, Mg^{2+}, Na^+ and K^+). Further analysis details can be found in Špoler Čanić et al. (2009).

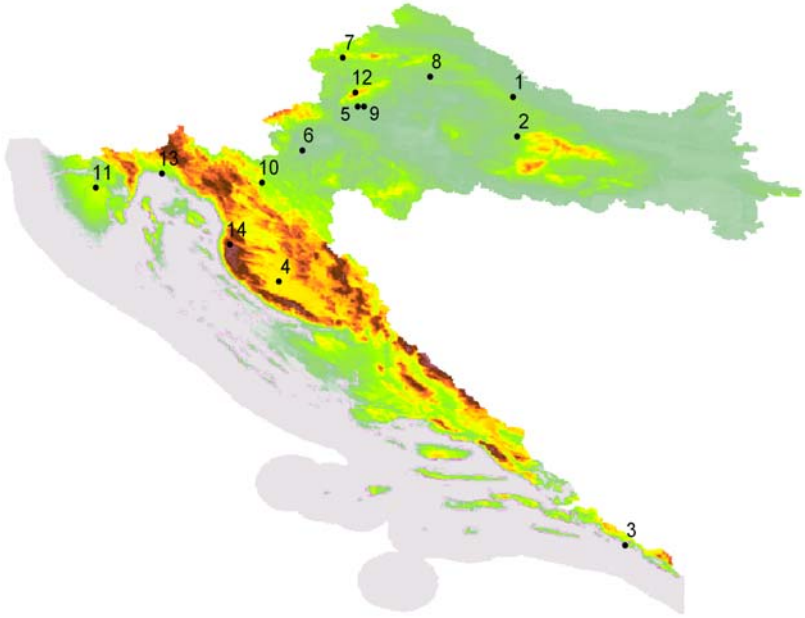

Figure 1. Sampling sites

Aerosol index

The analysed mud rain episode was identified using TOMS aerosol index (AI). The AI is defined as 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. Herman et al. (1997) have shown that AI is a useful tool for monitoring intensity and pathway of desert dust on daily basis. In this work the daily maps and data of AI from TOMS Earth Probe were used (http://toms.gsfc.nasa.gov).

Backwards trajectories

Backwards trajectories are useful tools for tracing source regions of air pollution and determining transport patterns at receptor sites in general. Source regions of air parcels that arrived at the two receptor points (site 12 and 14) on April 2002 have been identified using the two dimensional backwards trajectories (www.emep.int). EMEP 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, 12 and 18 h UTC).

SYNOPTIC SITUATION

From 7th till 9th of April there was a small cyclone over Croatia, with circulation of moist and unstable air along the vertical. It was rainy in plains and valleys and snowy in mountainous areas. Over the Adriatic Sea severe gusts of jugo were recorded first and, as the cyclone was moving, severe gusts of bura later. The next day (10th of April) was less rainy due to the influence of branch of the anticyclone over northern Europe. However, a new large cyclone, originated from the western Mediterranean, approached from the south-western Mediterranean (Fig. 2). The high altitude wind was southwest. Due to this synoptic situation it was mainly cloudy from 11th till 15th of April, with severe jugo in some places. Frontal passages brought heavy rain and thunderstorms, especially in the night from 12th to 13th of April. The greatest amount of precipitation fell over northern Adriatic Sea and mountainous areas.

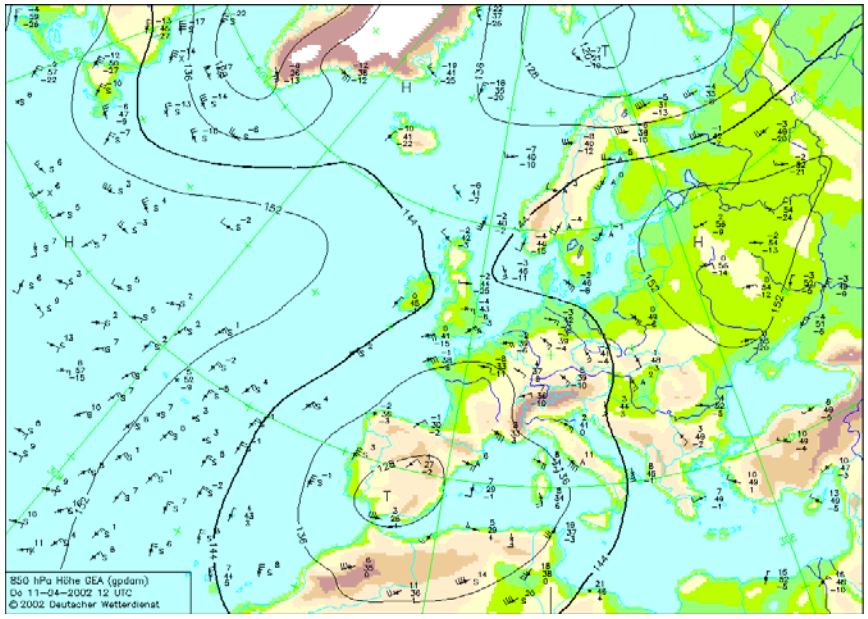

Figure 2. The synoptic situation at 850 hPa over Europe on 11th April 2002 at 1200 UTC (from the Europäische Wetterbericht, 2002)

RESULTS AND DISCUSSION

The AI was highest at 12th April 2002 (Fig. 3) and Fig. 4 shows Saharan dust transport over Mediterranean towards Croatia on that day. The TOMS data provide AI values higher then 4 during the main streamline of the outbreak over Croatia. For the same day AI values were between 1.2– 2.2 over the south-eastern coast of Italy (Blanco et al. 2003). The backwards trajectories (Fig. 5 a and b) for Site 12 and 14 also indicated Sahara Desert as a source region.

The Table 1 shows the ions concentrations and pH values at measurement sites over Croatia with precipitation on 12th April 2002. Comparing to annual volume weighted averages (VWA) for 2002 ions concentrations were highest at Site 14, the highest Croatian measurement site. Ion concentration of SO_4^{2+} was almost 15 times higher and concentration of Ca^{2+} was almost 12 times higher then VWA at Site 14. The only exception was NH_4^+ which was highest at Site 5. Ions concentrations were the lowest at Site 13 which was the site with highest amount of precipitation. The exceptions were Ca^{2+} and K^+, which were lowest at Site 3 and Site 12 respectively. Site 3 was in area with very low AI (Fig. 4). The pH was elevated (pH > 5.0) at all sites. The highest pH change was at Site 5 and the lowest at Site 10. According Löye-Pilot et al. (1986) only calcium concentration and pH value are consistently affected by Saharan dust in rain water.

Correlation analysis is useful technique to characterize relations among the ions present in precipitation. The Table 2 shows correlation between ions from all measurement sites at 12th April 2002. The highest correlation coefficient was between Na^+, Cl^- and Mg^{2+} which imply strong sea salt component in rain composition of this event. The ions: SO_4^{2-}, Mg^{2+} and K^+ are also highly correlated, as well as SO_4^{2+} and NO_3^- and NO_3^- and Ca^{2+}.

Table 1 Precipitation amount, ratio of concentrations of base ions at 12th April 2002 and VWA for 2002 at the monitoring sites.

ID	Site	mm	SO_4^{2-}	NO_3^-	NH_4^+	Na^+	Mg^{2+}	Ca^{2+}	Cl^-	K^+	pH
1	Bilogora	9.7	5.75	0.88	1.17	6.22	2.86	10.50	5.18	2.19	1.39
2	Daruvar	7.4	3.52	0.68	0.32	3.35	1.44	6.63	4.27	1.17	1.26
3	Dubrovnik	10.8	5.49	1.02	0.90	3.90	1.77	3.94	3.94	1.44	1.28
4	Gospić	14.8	7.13	1.16	-	5.06	1.75	4.37	4.23	1.98	1.47
5	Grič	20.6	4.11	0.98	1.28	5.97	1.91	6.71	4.94	2.26	1.69
6	Karlovac	17.6	6.48	1.11	0.55	8.51	3.03	9.42	6.84	2.59	1.51
7	Krapina	22.0	5.24	0.78	1.10	7.07	1.35	7.02	5.45	2.52	1.50
8	Krizevci	9.8	3.53	0.83	1.04	5.58	1.78	4.09	2.62	0.75	1.28
9	Maksimir	14.0	4.15	1.04	0.69	3.49	1.51	4.82	3.01	1.02	1.28
10	Ogulin	21.0	7.32	0.99	0.25	5.86	2.57	7.64	5.44	2.25	1.05
11	Pazin	12.2	4.17	1.10	0.74	3.55	2.56	5.06	3.32	2.73	1.67
12	Puntijarka	33.3	3.35	0.78	0.22	1.37	1.86	4.66	3.15	0.56	1.66
13	Rijeka	59.6	1.61	0.64	0.41	1.23	1.17	4.59	1.15	1.65	1.66
14	Zavižan	11.9	14.70	1.79	0.49	9.25	4.78	11.89	9.14	7.19	1.54

Dash represents no analysis for samples.

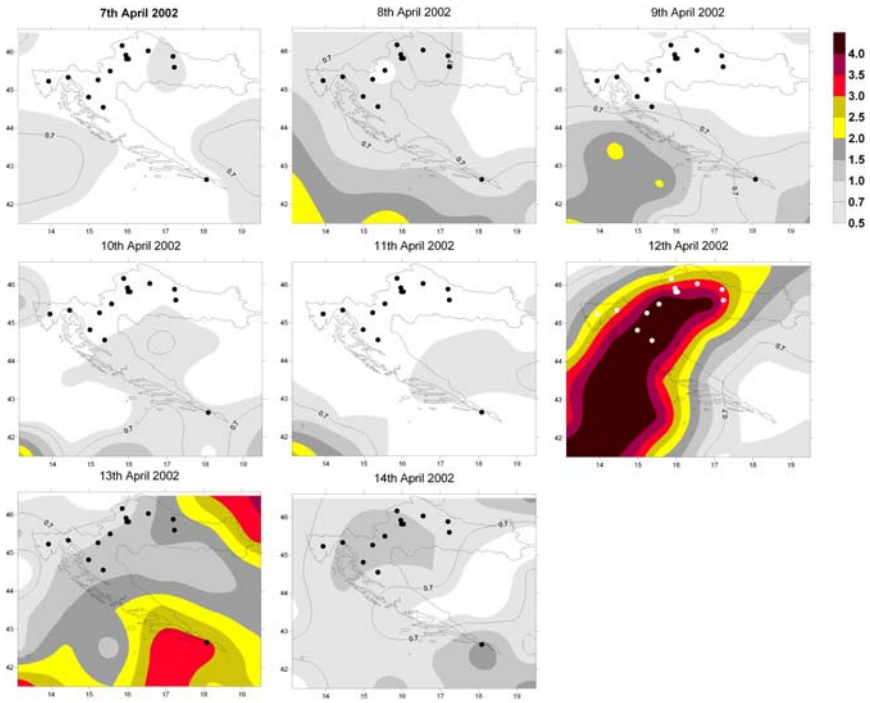

Figure 3. Evolution of AI over Croatia during Saharan dust outbreak which occurred over Mediterranean Sea from 8th to 14th April 2002. The threshold value AI =0.7 (Prospero et al. 2002) is emphasised.

CONCLUSIONS

Mud rain episode in April 2002 was the episode with highest AI over Croatia during the period 2001-2005. The spatial changes of precipitation chemistry were influenced by topography and distance from the Sahara as well as with the "AI plume" shape. The pH was elevated at all sites. Further, all ions at all sites had greater concentrations comparing to VWA for analysed episode and the highest ratio was mainly for Ca^{2+}.

Acknowledgments

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Table 2 Correlation coefficients among ions concentrations from all measurement sites at 12th April 2002

	H^+	SO_4^{2+}	NO_3^+	NH_4^+	Na^+	Mg^{2+}	Ca^{2+}	Cl^-	K^+
H^+	1,00	0,19	0,11	-0,21	0,05	0,02	0,19	0,05	0,00
SO_4^{2-}		1,00	**0,81**	0,17	0,61	**0,78**	0,59	0,59	**0,87**
NO_3^-			1,00	0,17	0,20	0,43	**0,70**	0,18	0,68
NH_4^+				1,00	0,04	0,14	0,54	0,03	0,57
Na^+					1,00	**0,95**	0,15	**1,00**	0,60
Mg^{2+}						1,00	0,10	**0,95**	**0,77**
Ca^{2+}							1,00	0,17	0,67
Cl^-								1,00	0,58
K^+									1,00

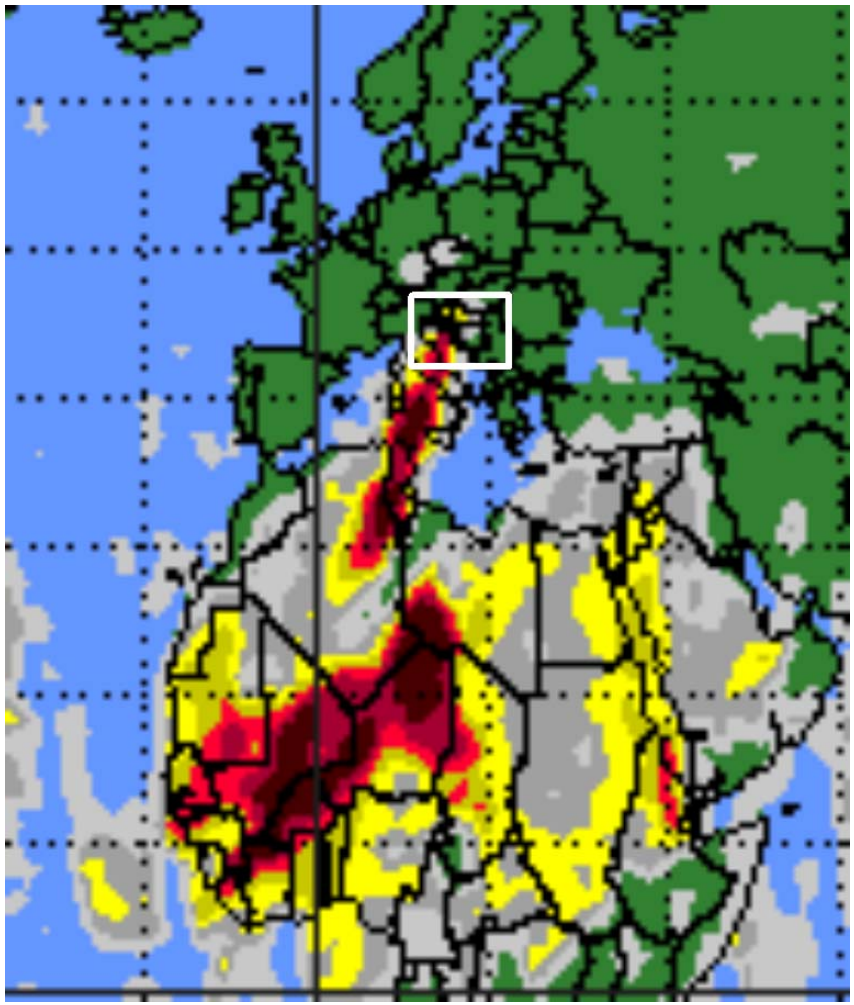

Figure 4. TOMS map of AI for 12th April 2002. A white square indicates strong Saharan plume over Mediterranean towards Croatia.

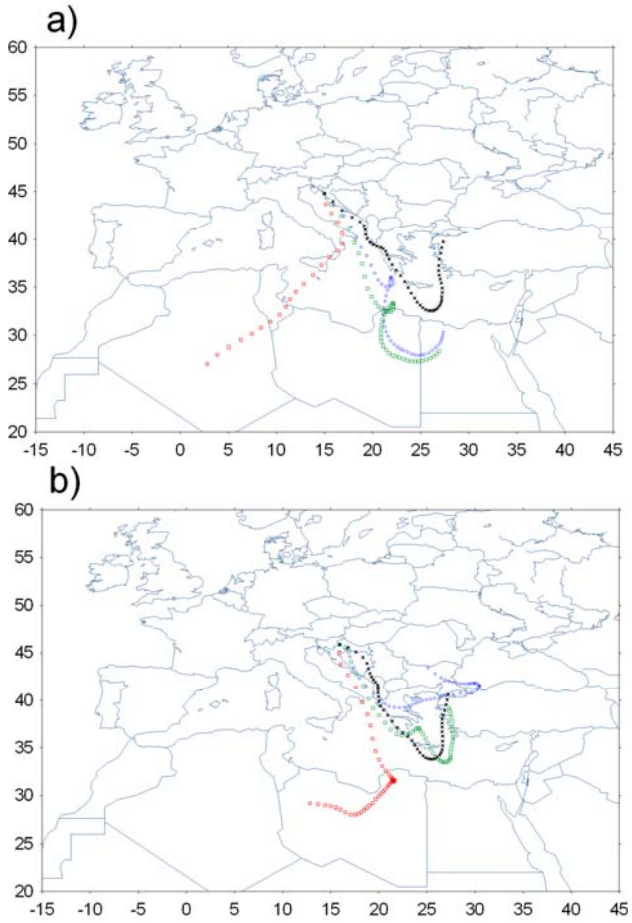

Figure 5 Backwards trajectories for Site 14 (a) and 12 (b), respectively for 12th April 2002. Trajectories are calculated four times per day at: 00 (black), 06 (blue), 12 (green), and 18 h (red) UTC.

Future events

ACCENT/GLOREAM2009 WORKSHOP ON TROPOSPHERIC CHEMICAL TRANSPORT MODELLING, BRESCIA, ITALY, 26 - 27 NOVEMBER 2009

ACCENT/GLOREAM2009 Workshop on tropospheric chemical transport modelling, taking place in Brescia, Italy. The workshop will start on Thursday, 26 November 2009at 9.00 a.m. and will end on Friday, 27 November 2009 at 4.00p.m.

The aim of ACCENT/GLOREAM is to investigate the processes and phenomena which determine the chemical composition of the troposphere by means ofadvanced and integrated modelling, both on regional (over Europe) and global scale.

Please have a look at the website (http://automatica.ing.unibs.it/gloream/index.html) for more information on the workshop venue, call for abstracts, workshop registration, accommodation and contact information.

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