Dust Transport to the Eastern Mediterranean and Their Impact on Climate

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1. Introduction

Atmospheric particles and mainly the mineral dust particles play a crucial role in the earth's radiation balance and climate through direct and indirect effects. By scattering and absorbing incoming solar and outgoing infrared radiation, dust particles can alter the Earth's radiative balance. The net effect can be heating or cooling depending on a number of variables, especially the concentration, composition and physical properties of dust. Indirect feedbacks between dust and climate are also possible as a result of the dust's chemical reactivity and involvement in the biogeochemical cycles of other substances with links to climate.

Annually, 300 to 700 million tons of dust originated from Saharan Deserts are transported over short to long distances to the Atlantic, Mediterranean Sea, southern Europe as reported and discussed in many publications (e.g. Carlson and Prospero, 1971; Moulin et al., 1998; Goudine and Middleton, 2001). It has been estimated that yearly amount of Saharan dust leaving North Africa in a northeasterly direction towards eastern Mediterranean is some 100 million tons (Ganor and Foner, 1996). By the year 2100, it is anticipated 10% increase from its current level (IPCC, 2001).

This large quantity of dust transport must have a significant impact on climatic processes especially in the Mediterranean region. Here, we will summarize the results of our past studies related with episodic dust transport to eastern Mediterranean, and the knowledge gained with respect to the processes responsible for dust transport and deposition. And we will review the key components of dust-climate cycle, identifying critical uncertainties and priorities for future research.

2. Dust transport to the eastern Mediterranean

The episodic character of dust transport on the eastern Mediterranean site has been studied by Güllü et al., (2005). It has been found that dust is transported in pulses and most of the dust pulses occurred during April to November with the most intense cases occurring during April, May and October which is consistent with other studies on the same region. During the years 1992, 1993 and 1998, a total of 46 dust episodes covering 157 days out of 789 days were identified. Time series plots of Al for the study period and corresponding dust episodes are depicted in Figure 1. Important source regions for dust observed in the eastern Mediterranean accumulate in three general areas; (1) in western parts of North Africa covering Morocco and Algeria where big sand dunes of Erg Iguidi, Grand Erg Oriental, (2) in Libyan deserts and (3) Arabian deserts.

Anomalous high sulphate levels during summer in the atmosphere over the Eastern Mediterranean sea have been reported (Güllü et al., 1998; Ganor et al., 2000; Luria et al., 1996). The usual explanation for this phenomenon has been long-range transport of sulphates emanating from industrial areas of eastern and central Europe. However, another possible source of the anomaly is marine biogenic production of sulphate from the oxidation of dimethylsulphide. Aerosols were sampled in southern coastline of Turkey, in the northeastern Mediterranean Sea and analyzed to determine SO4 and Al during and after dust episodes. The selected two cases given below

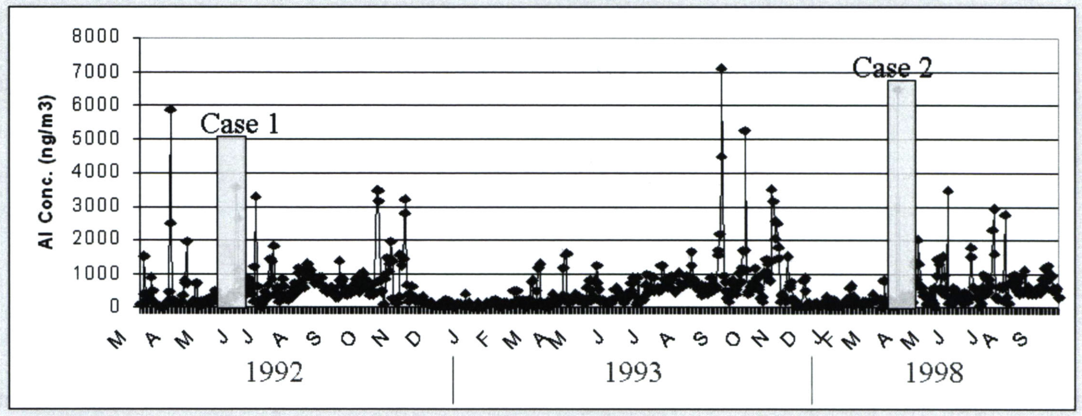

Figure 1. Temporal variation of Al concentration at Antalya in 1992, 1993 and 1998.

are examples of dust transport and its subsequent sulphate release.

3. Effects of mineral dust on climate

The *Cemiliana* theory put forward by Saydam (1996) suggests that the wet deposition of reduced iron from desert dusts to surface waters of the Mediterranean, during the day, has the potential to induce phytoplankton blooms. And, increasing of biogenic activity leads an increase in atmospheric biogenic sulphate concentration via DMS-MSA-SO4 chain oxidation.

During desert dust transport, dust particles incorporated into the clouds. In cloud droplets, the iron present in the dust is photochemically reduced to Fe(II). At daytime Fe(II) concentration reaches its maximum level in clouds, and its subsequent precipitation supplies dissolves Fe(II) to the sea surface. Fe(II) is a limiting micronutrient for planktonic algae in open oceans where other major nutrients are abundant. It has been shown that addition of dissolved Fe(II) to the surface of the ocean resulted in an enormous increase in phytoplankton growth (e.g. Martin, 1988). And also, *Emiliana huxleyi* blooms have been observed several times in the Mediterranean and even in enclosed basins like the Black Sea, and have been linked with prior wet dust deposition events (Saydam and Yılmaz, 1998; Saydam and Polat, 1999). Based on this, it has been suggested that deposition of desert dust in rainwater with readily formed Fe(II) to the sea surface enhance the marine productivity and this leads an increase in atmospheric sulphate concentration later than 8 to 10 days. Increased level of atmospheric sulphate enhances cloud formation and leads to an increase of the earth albedo. Thus, the probability of the right combination of dust with cloud under intense solar radiation and its subsequent precipitation to the sea surface may be one of the rate determining factors in regulation of the climate.

4. Case Studies

The two cases of Saharan dust transport into the eastern Mediterranean in June 1992 and March 1998 were examined in terms of transport patterns and their subsequent sulfate release to the atmosphere. As shown in Figure 2, the computed air mass trajectories arriving at Antalya on 12 and 13 June indicated Saharan origin, and from the TOMS aerosol index the during the same period, it can be seen that, the whole Saharan region is loaded with significant amounts of desert dust. The PM10 sample was taken during this event, reflected in the abnormal Al concentration (3298 ng m^{-3}) value which is almost factor of 15 times higher than background Al concentrations measured in the same region. It has been known that on

14 of June, there was rain all over the Turkey. As shown in figure, the measured SO4 concentrations in the aerosol samples increased significantly 8 days later than the episode.

For the 26 of March 1998 case, there is a good correspondence between satellite observations, TOMS Aerosol Index and trajectory calculations ending at Antalya (Figure 3) which all indicates dust transport from the Saharan region. This episode lasts only one day, and is the most intensive episode throughout the study period. As shown in Figure 3, on the following day of episode, precipitation was observed in the southwestern part of Black Sea where high amount of dust deposited on Black Sea. After 9 days, high amount of SO4 were observed on the aerosol sample taken from the same site.

5. Conclusions and recommendations for future works

The results show that there is a definite, biogenic generation of sulphate from the Mediterranean Sea and that this contributes to the sulphate content of the aerosol over eastern Mediterranean especially during the spring and autumn season. However, the biogenic sulphate contribution to the total atmospheric sulphate release is still unknown. Bu we believe that, especially during dust transport season, the magnitude of biogenic sulphate release will be high enough to change Earth's radiative balance in the Mediterranean basin.

Climate forcing by particulates is currently recognized as one of the greatest uncertainties in global climate models (Haywood and Boucher, 2000; IPCC, 2001). As the eastern Mediterranean basin is under the influence of massive dust transport, we recommend the following items for future studies to reduce the uncertainties in GCM and also in LCM's.

- ❖ Episodic transport of dust, its mineralogy and chemical composition should be incorporated into the models
- ❖ Source regions of dust should be incorporated into the models
- ❖ The level of detail with respect to heterogeneous reactions on solid surfaces into the atmospheric chemistry models should be increase

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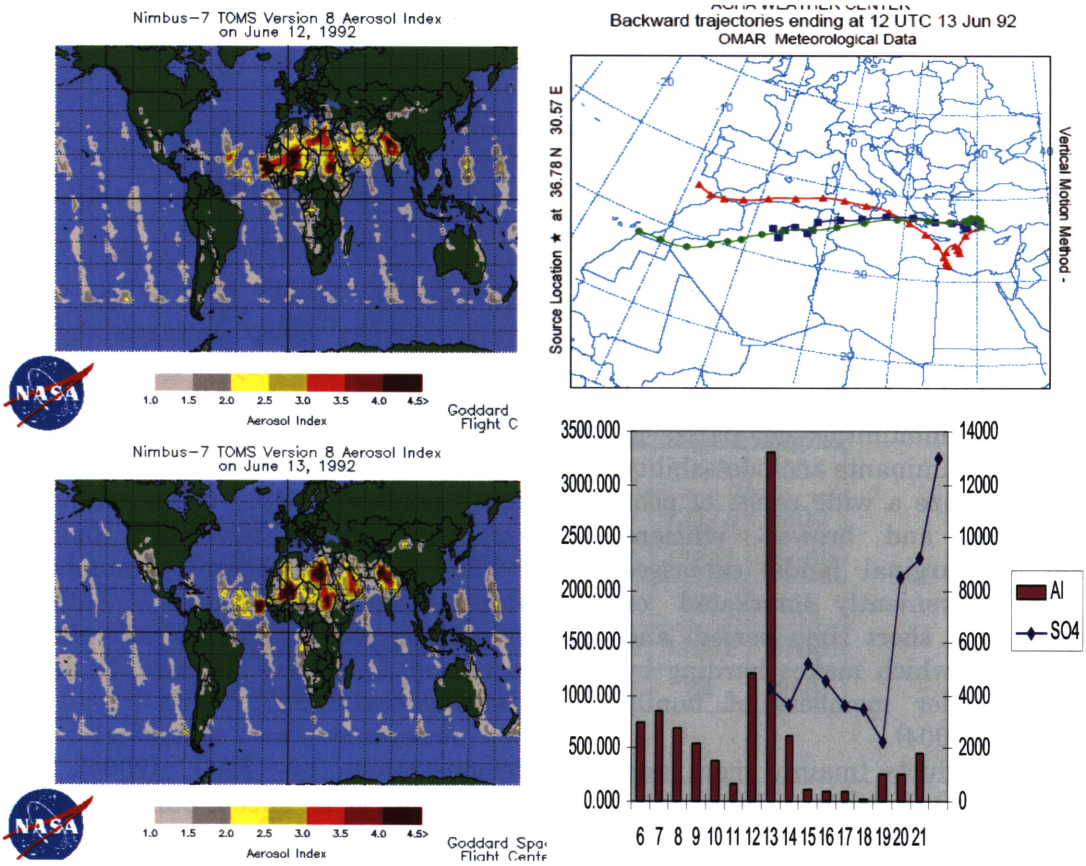

Figure 2. The TOMS Aerosol Index, bactrajectory and Al and SO4 concentration variation for the episode observed during 12-13 June 1992.

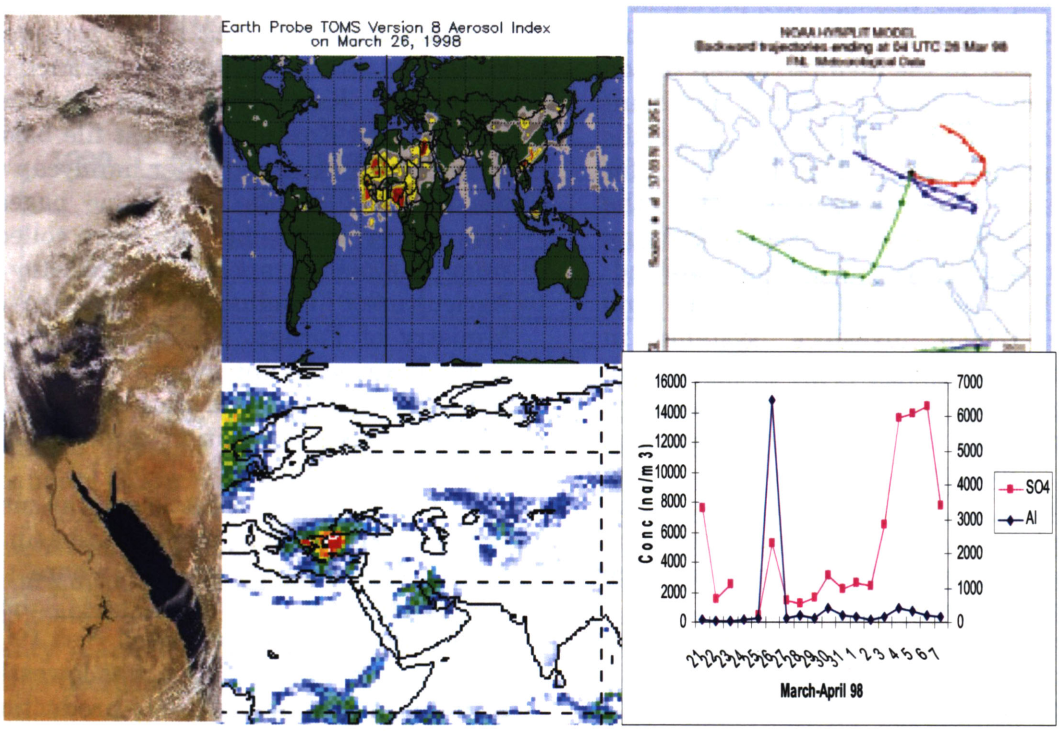

Figure 3. The SeaWIFS picture, TOMS Aerosol Index, bactrajectory and Al and SO4 concentration variation for the episode observed during 26 March 1998.