

Airborne pollen, spores, and dust across the East Mediterranean Sea

Yoav Waisel · Eli Ganor · Valentina Epshtein ·
Amnon Stupp · Amram Eshel

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Abstract Airborne pollen and spores, as well as airflow directions, were continuously monitored during a cruise across the East Mediterranean from Tel Aviv, Israel, to Istanbul, Turkey. In spite of the fact that a high-altitude dust cloud moved, at that, time from North Africa, across the East Mediterranean, only a few dust particles were monitored on the boat. The numbers of counted airborne pollen along the cruise path were rather small. This is, in part, because the trip was taken after the main flowering season in the East Mediterranean region. Nevertheless, airborne pollen grains were still found, either as a result of remnant pollen releases by late-flowering plants or because of secondary lift-up of previously settled pollen. The presented pollen counts are average pollen counts /m³ air /6 h. The counts ranged between ~5 pollen/m³ of air in mid-sea (July 16th–July 17th) or ~6 pollen/m³ of air on the Israeli coast (July 16–July 17th), and 30 pollen/m³ of air near the coasts of Turkey and of the Greek Islands (July 18th–July 19th) and some 18 taxa of pollen were identified, most of them at the family level. Some 30 taxa of different spores were recorded. The

numbers of airborne spores were relatively low in mid-sea (300–750 spores/m³ air), but were high near the coasts of Turkey (1,200–2,400 spores/m³ air) and of Israel (340–1,695 spores/m³ air).

Keywords Pollen · Spores · Dust particles · Mediterranean Sea · Wind flow trajectories

1 Introduction

The question of the long-distance transport of pollen and spores has occupied aerobiologists for a long time. Such information is of crucial importance for allergy sufferers who have to know where the sources of the allergenic pollen that cause them so much suffering. The measurement of pollen and spore dispersal across inland landscapes is usually hampered by the difficulty in precisely locating a single source, i.e., one tree, that the records of its pollen distribution will not be misled by the proximity of other pollen-releasing plants of the same species. Only in some cases was this possible because of the changes in plant cover across the study area (Kynan et al. 1991; Waisel et al. 2004). On the sea shore, it should be an easier task because the pollen sources of the transporting sea winds are plants from across the sea.

Thus, identification of the airborne pollen and of the spores would give us a clue as to their sources; the pollen of desert plants would indicate that the source

Y. Waisel (✉) · V. Epshtein · A. Eshel
Department of Plant Sciences, Tel Aviv University,
Tel Aviv 69978, Israel
e-mail: waisel@post.tau.ac.il

E. Ganor · A. Stupp
Department of Geophysics, Tel Aviv University,
Tel Aviv, Israel

is Africa or the Arabian Peninsula, whereas the pollen of North Mediterranean plant species would point to a European origin.

Records of airborne pollen and spores monitored in Israel near the coast of the Mediterranean Sea have yielded, from time to time, pollen grains (e.g., *Alnus* or *Betula*) that are not typical of the local flora. A similar observation was reported several years ago from Amman, Jordan, where pollen grains were recorded which did not belong to the local flora (Al-Eisavi and Dajani 1988). The obvious assumption was that such pollen grains originated in Turkey, in the Balkan, or in the deserts of North Africa, and were then transported to Israel across the Mediterranean.

In order to test such assumptions, we have joined the team of the R/V “Mediterranean Explorer” on a research cruise from Tel Aviv, Israel, to Istanbul, Turkey.

2 Materials and methods

During five days of the summer of 2005 (July 15th–19th), we monitored the airborne pollen and spores over the East Mediterranean Sea. The sampling of pollen and spores was continuously carried out (day and night) along the cruising path from Tel Aviv (Herzlia marina), Israel, to Istanbul, Turkey (Fig. 1). Back trajectories of the air mass flow patterns at some of the sampling points along the cruising path were computed using the NOAA hybrid single particle Lagrangian integrated trajectory (HYSPLIT) software.

Pollen and spores were continuously monitored using a Burkard volumetric pollen and spores trap, based on the Hirst method (Hirst 1952). The instrument was mounted on top of the captain’s cabin of the boat (some 3 m above the water level). Suction of the instrument was set at a rate of 10 liter/min. The tapes were then divided into 6-h fragments, stained, and analyzed.

The 6-h period was selected because of the extremely low yield of pollen and spores and because of the high variability of the counts when shorter periods were considered. Concomitantly, airborne pollen and spores were monitored for two days (July 15th and July 16th) in Tel Aviv, near the beach, using a “Rotorod” Model 87 sampler. Nevertheless, differences in pollen counts that are obtained by “Rotorod” and “Burkard” pollen and spore traps,

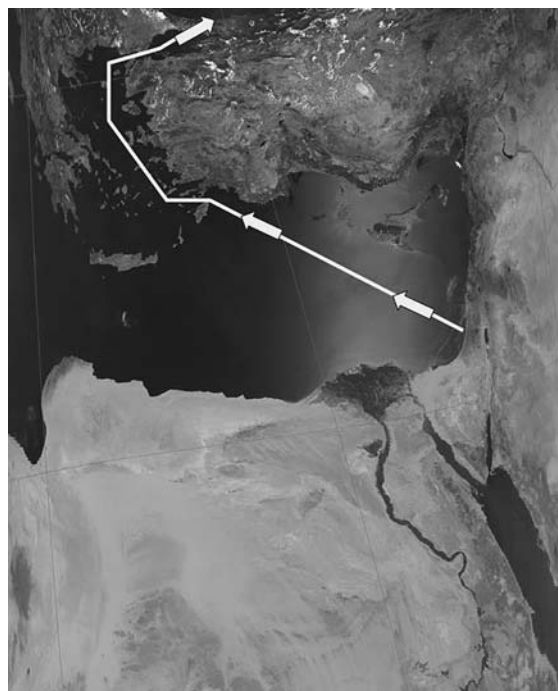


Fig. 1 Satellite image of the Eastern Mediterranean (July 18th, 2005), with the marked cruising path of the “Mediterranean Explorer” from Israel to Turkey

or by other different instruments, were shown to be of little significance, at least at the low pollen count ranges (Frenz et al. 1997; Frenz 1999; Belmonte et al. 2000).

3 The synoptic situation

On July 15th, 2005, a weak cold front passed over the coasts of Israel and Lebanon. During the remaining days of the cruise, the climatic conditions were unwavering summer conditions, typical of the East Mediterranean. The surface winds were recorded, and those at higher altitudes were obtained from the meteorological service of Israel. Wind directions during the journey varied from a NW–W direction along the shores of Israel and Cyprus, and a N–NW direction along the shores of southern Turkey. At an altitude of 3,000 m above sea level, the winds were invariably from the NW to the SE direction. Throughout the monitoring period, there were no abnormal phenomena insofar as to the horizontal visibility, the humidity, or the temperature. The paths of the back trajectories of the wind flow (Fig. 2) were

recorded every 6 h for 48 h at altitudes of 50, 500, and 3,000 m. This was done for various hours and points along the sailing path. A satellite picture of the Eastern Mediterranean (Fig. 1) shows a dust trail extending from the deserts of Egypt, via Cyprus, to Turkey that was carried by the high-altitude southerly wind flow during the trip.

This dust trail was not reported by the meteorological services of Egypt, Israel, Lebanon, or Syria. The Tel Aviv University (TAU) dust model (2007) shows that most of the dust on that date was at an altitude of some 3 km (Fig. 3). Therefore, only a little dust was collected on the monitoring tapes of our Burkard sampler on board the “Mediterranean Explorer” and in the Tel Aviv air pollution monitoring station.

The monitoring of airborne pollen was done on the coast near Tel Aviv and that of suspended dust particles (PM₁₀) was undertaken continuously by the office of Environmental Quality in Tel Aviv, located at Tel Aviv University on the roof of the Yad-Avner building.

4 Results and discussion

4.1 Wind flow trajectories

On July 15th at 10 UTC, wind flow at the altitude of 3,000 m was from the direction of the Egypt (Fig. 2a). The sources of dust at 3,000 m probably originated in the Beni Suef and the Beni Mazan

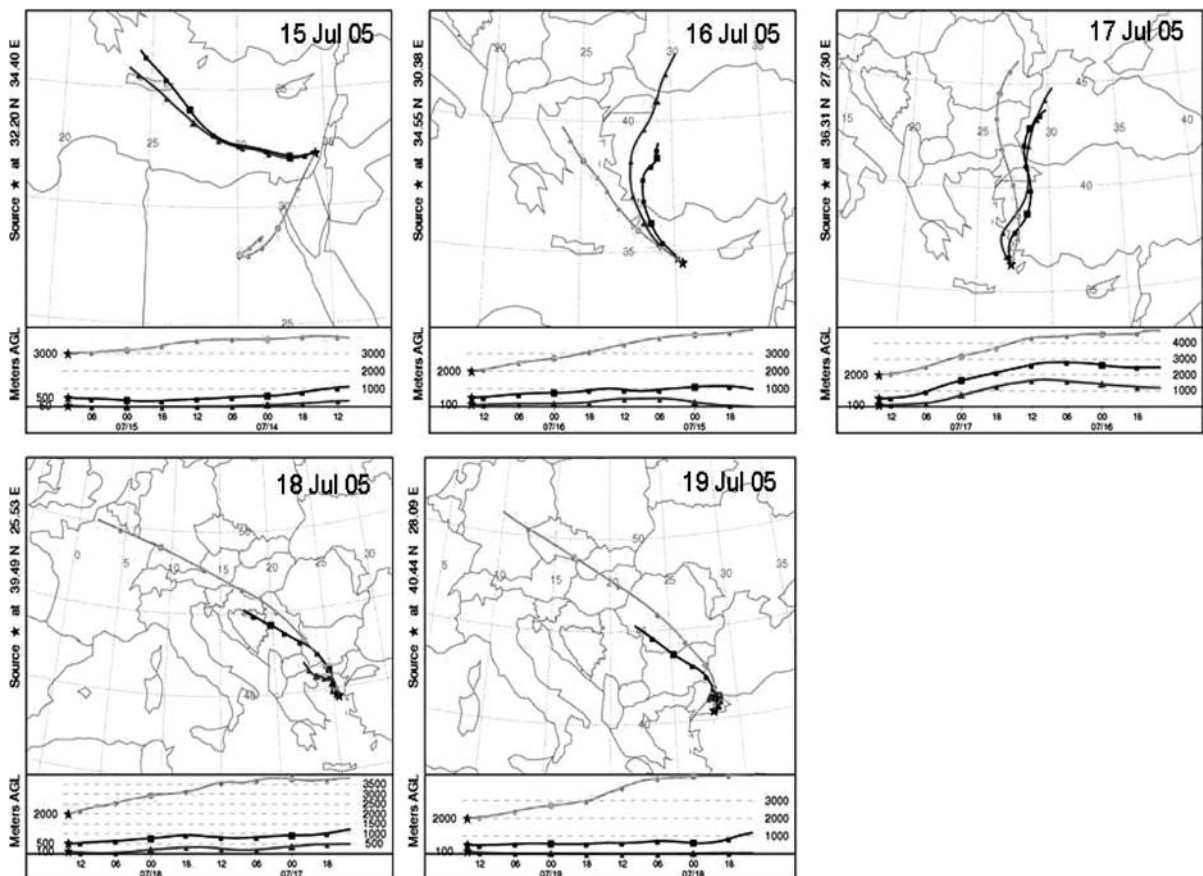


Fig. 2a–e The wind flow back trajectories at altitudes of 50, 500, and 3,000 m above sea level for different points along the described cruise path. **a** Backward trajectories at the reference point Lat. 32:20 and Lon. 34:40, on July 15th, 2005. **b** Backward trajectories at the reference point Lat. 34:55 and

Lon. 30:38, on July 16th, 2005. **c** Backward trajectories at the reference point Lat. 36:31 and Lon. 27:30, on July 17th, 2005. **d** Backward trajectories at the reference point Lat. 39:46 and Lon. 24:46, on July 18th, 2005. **e** Backward trajectories at the reference point Lat. 41:00 and Lon. 28:50, on July 19th, 2005

regions in Egypt. At lower altitudes, the air mass moved from the direction of Crete.

Wind flow on July 16th at 14 UTC and at altitudes of 50 and 500 m was north–northwesterly, from the direction of central Turkey and the Black Sea (Fig. 2b). At an altitude of 3,000 m, the wind direction was northwesterly over the Aegean Sea and Greece.

On July 17th at 10 UTC (Fig. 2c), the wind flow west of Rhodes was northerly at all altitudes; at altitudes of 50 and 500 m, the wind blew from the direction of the Black Sea, while at 3,000 m, it blew from the direction of Bulgaria and Romania.

Wind flow on July 18th at 10 UTC (Fig. 2d) was north–northwesterly at all altitudes; it blew from the direction of Northern Greece and Yugoslavia. The origin of the air masses at an altitude of 50 m was the Aegean Islands and the mainland of Greece, whereas at higher altitudes, the air masses moved from the direction of the Balkan and from as far as Germany.

Air flow on July 19th at 14 UTC (Fig. 2e) at an altitude of 50 m was rather calm, with local variations in wind direction. However, at altitudes of 500 and 3,000 m, the wind blew from the northwest from Central Europe over Turkey and Bulgaria.

During the days of the current study (July 15th–19th), a dust cloud that apparently originated in North Africa was monitored (see Fig. 1) to be moving eastwards, in the general patterns of air movements typical for the region (see LaFontaine et al. 1990; Ganor et al. 1998). The mean airborne dust concentrations recorded in Tel Aviv for 3-h spans were far less than 180 mg/m^3 , except on July 19th, when concentrations of 180 mg/m^3 were recorded. These readings reveal that the desert dust particles did not descend to sea level from the high-altitude plume, but, rather, remained at high altitudes. Such a phenomenon was described recently by Israelevich et al. (2002, 2003).

The altitude of the dust cloud over Tel Aviv during July 16th–18th at 12 UTC, as modeled by the TAU dust model, is shown in Fig. 3. As can be seen, on July 16th, the dust layers were at the heights of 1,000–4,000 m above sea level, with maximal concentrations recorded at an altitude of 3,000 m. Later on, as it moved eastwards, on July 17th and 18th, the dust cloud dropped to lower altitudes.

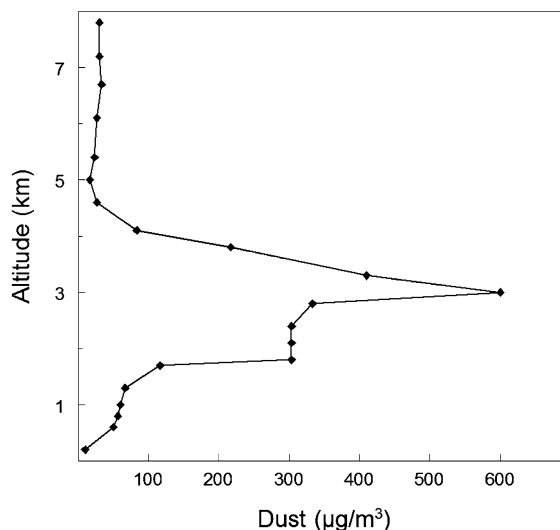


Fig. 3 Tel Aviv University (TAU) dust model for the distribution of dust concentrations at different altitudes. Plotted for July 16th, 2005

4.2 Pollen and spore counts and species diversity

The numbers of counted airborne pollen along the cruise path were rather small. This is apparently because the trip was taken during July, i.e., after the main flowering season in the East Mediterranean region. Nevertheless, some airborne pollen were still found, either as a result of remnant pollen releases by late flowering plants or because of secondary lift-up of previously settled pollen (see Waisel et al. 1997a, b).

The pollen counts ranged between 30 pollen/m^3 of air near the coasts of Turkey and the Greek Islands (July 18th–19th) and less than 5 pollen/m^3 of air at mid-sea (July 16th–17th).

In spite of the fact that the trip was taken long after the end of the flowering season, pollen of some 18 taxa were identified, mostly at the family level (Table 1). This reflects the same order of magnitude for the values that were reported by Comotis and Mandrioli (1996) during their trip across the Adriatic Sea. Nevertheless, because the Adriatic is located between two heavily vegetated coasts, the atmosphere above it seems to be richer in pollen. It is interesting to note that, in both cases, the pollen of the Urticaceae comprised a good part of the airborne flora, followed by the pollen of the Poaceae.

As mentioned before, the trip was done beyond the main flowering season and the number of recorded

Table 1 Average daily airborne pollen concentrations (number /m³ air)

	On board the Mediterranean Explorer					Tel Aviv	
	July 15th	July 16th	July 17th	July 18th	July 19th	July 15th	July 16th
Apiaceae				0.3			
Arecaceae	1.0		0.8		1.0	2.0	0.4
<i>Artemisia</i>			0.3				
Asteraceae					0.4		
Brassicaceae					0.4		
Chenopodiaceae + Amaranthaceae	2.0				0.9		0.4
Cupressaceae	0.3		0.6		0.3	0.4	
Ephedraceae			0.6				
Moraceae			0.3		1.6		
Myrtaceae	2.0			0.3		0.8	1.6
<i>Parietaria</i>	0.9	0.9		8.4	15.3	0.4	0.4
Pinaceae			0.6	0.9			
<i>Plantago</i>	0.2		0.3	0.3	4.5	0.2	
Poaceae	0.2			1.5	4.0	0.2	1.2
Polygonaceae	0.7						
Rubiaceae				0.3	0.8		
<i>Typha</i>	2.1	0.9			2.1	1.6	0.4
Others	0.6		0.8	0.6	0.9	1.2	
Total pollen	10.0	1.8	4.3	12.6	32.2	6.4	4.0

pollen was very small. At mid-sea, only the pollen of *Parietaria*, *Typha*, and Arecaceae were in noticeable concentrations. It is interesting to note the appearance of pollen of the Cupressaceae and of *Pinus*, although their pollination season in the East Mediterranean ended 3–4 months before the measurements were taken. Closer to the coasts, the pollen of Arecaceae, Chenopodiaceae, Moraceae, Myrtaceae, *Plantago*, and Poaceae were monitored. The appearance of high concentrations of *Parietaria* can be expected, since not only its main flowering season is in mid-summer, but also because the airborne pollen grains of the Urticaceae are known for their long-distance transportation (see Cabezudo et al. 1997). Most of the pollen that were monitored during July 18th–19th, when the boat was close to the coasts, have apparently originated in Turkey, in the Aegean Islands, or even in more distant regions of the Balkan. Only the pollen of the Arecaceae (which is possibly date palm pollen) and Chenopodiaceae might have traversed all the way from North Africa. Nevertheless, it is more likely that even such pollen have originated on nearby coasts.

The numbers of airborne spores were rather low in mid-sea (300–750 spores/m³, air) but were high near

the coasts of either Turkey (1,200–2,400 spores/m³ air) or of Israel (340–1,695 spores/m³ air). Some 30 taxa of different spores were recorded (Table 2). Identification was based on morphological features and, therefore, several of them were left unidentified. The recorded number of spores in the East Mediterranean was almost 40× smaller than the number of recorded spores over the Adriatic (see Comotis and Mandrioli (1996). It is hard to reach conclusions as to the differences of the airborne flora on both seas because the monitoring was not performed simultaneously. Nevertheless, it is important to note that, in both cases, *Cladosporium* was the main contaminant, followed by *Alternaria*.

The recorded concentrations of spores varied much less during the cruise from Tel Aviv to Rhodes, i.e., when monitoring was done on the open seas, at distances of >100 km from the nearest coast. Presumably, these are fungal spores that were produced on the Aegean islands, or on the Turkish mainland and were carried away by the wind along the shown trajectories. The high concentrations of spores that were monitored when the boat was on the open sea demonstrate their easy transportation over long

Table 2 Average daily airborne spore concentrations (number /m³ air)

	On board the Mediterranean Explorer					Tel Aviv	
	July 15th	July 16th	July 17th	July 18th	July 19th	July 15th	July 16th
Agrocybe		1.6		0.3		0.4	
Albugo			3.0		1.3		
Arthrinium	4.0	0.9	9.6	3.2	21.6	3.6	1.6
Ascospore	2.0	23.2	17.6	21.6	70.4		3.6
Alternaria	15.3	43.2	37.6	70.8	236.8	22.4	34.4
Aspergillus	28.0			1.6	13.5	2.4	93.6
Botrytis			2.4	10.8	8.5	0.8	
Cladosporium	263.2	1,174.4	630.4	1,128.0	1,904.0	1,168.0	1,496.0
Chaetomium	1.0		0.3		1.6	1.2	0.8
Coprinus	4.0	17.6	10.4	24.0	24.8	9.6	
Diatrypaceae			2.1	3.3	6.4		
Drechslera		0.9	1.6	1.5	1.8		
Epicoccum		0.8	1.2	3.0	24.0	1.2	1.2
Ganoderma	4.0	1.8	0.8	3.0	24.8	28.8	24.8
Leptosphaerulina							
Myxomycetes			0.3	0.6	0.4		1.2
Nigrospora			0.3	0.6	1.6	0.4	
Oidium	0.3	3.6	2.1	1.5	1.6	0.4	0.4
Periconia				0.3	0.8		
Peronospora			0.3	0.8	3.6		
Pithomyces				0.9			
Pleospora		0.9	0.9	0.6	0.9		
Polythrincium				0.8	1.6		
Rust	1.0	3.6	2.1	2.7	10.8	0.8	0.8
Sphacelotheca		0.9			0.8		0.4
Spegazzinia			0.3	0.3			
Stemphylium	1.0	3.6	1.5	1.5	8.1		0.8
Sporomiella			0.8				
Torula	0.6		0.3	2.1	4.8	1.2	0.8
Ustilago	20.0	20.0	78.9	0.3	11.2	1.6	3.6
Others	9.6	23.4	10.5	26.4	51.2	16	11.6
Total spores	354.0	320.4	795.3	1,261.0	875.7	1,262.0	1,695.0

distances and their possible contribution to dispersal of allergy, as well as of plant pathogenicity.

5 General conclusions

Only a small number of pollen grains, but a large number of spores, originating probably in Greece and Turkey, seem to cross the Mediterranean and reach the Coastal Plain of Israel. However, it was important

to notice that several genera of fungi that belong to plant pathogenic taxa are carried across the sea. Such fungi may cause the spread of diseases from southern Europe to the East Mediterranean countries.

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