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On the degradation of air quality due to SO_2 and PM_{10} in the Eordea Basin, Greece

A. TRIANTAFYLLOU, Kozani, P. KASSOMENOS and G. KALLOS, Athens

Summary. In this study an attempt is made to analyse meteorological and air quality observations obtained in the Eordea Basin, Northern Greece, during the period 1991–1993. During this period 118 episode-days being characterised by increased SO_2 and/or PM_{10} concentrations were identified. The increased SO_2 and PM_{10} concentrations are mainly due to the power plants operating in the area. These air quality characteristics were interpreted in relation with the local, synoptic, and mesoscale meteorological conditions. The results indicated that the episode-days in this area can be grouped in relation to their synoptic circulation characteristics in five categories. It was found that relatively high concentrations of SO_2 and high concentrations of PM_{10} usually are accumulated under moderate to strong northerly winds.

Keywords: air quality, elevated stacks, synoptic classification, air pollution episodes, mountainous basin.

Über die Verschlechterung der Luftqualität aufgrund von SO_2 und PM_{10} im Eordea Becken, Griechenland

Zusammenfassung. In dieser Studie wird der Versuch gemacht, die meteorologischen und lufthygienischen Messungen aus dem Eordea Becken in Nordgriechenland aus dem Zeitraum 1991–1993 zu analysieren. In dieser Zeit waren 118 Tage durch erhöhte SO_2 und/oder PM_{10} Konzentrationen gekennzeichnet. Die erhöhten Konzentrationen sind hauptsächlich auf die in dieser Gegend betriebenen Kraftwerke zurückzuführen. Die genannten lufthygienischen Kenngrößen wurden bezüglich der örtlichen synoptischen und mesoskaligen Wetterverhältnisse untersucht. Die Ergebnisse zeigten, daß die belasteten Tage in dieser Gegend aufgrund ihrer Beziehung zu den synoptischen Zirkulationsmustern in fünf Kategorien eingeteilt werden konnten. Es stellte sich heraus, daß relativ hohe SO_2 Konzentrationen und hohe PM_{10} Konzentrationen typischerweise bei mäßigen bis starken Nordwinden auftraten.

1. Introduction

During the last three decades the Eordea Basin, Northern Greece, suffers from major air quality problems, mainly caused by four power plants with eleven stacks burning lignite, general industrial activity and lignite mining. Emissions for both dust and SO_2 from the power stations are estimated of the order of 10^8 kg/year for each one of the pollutants. For SO_2 this number means that almost 20 % of the total emissions in Greece were produced by the four power plants in the Eordea Basin (BERGE et al. 1995). On the other hand, the central heating in the residential areas (combination of lignite and oil) during the cold months of the year appears to be another source of air pollutants (especially of SO_2) in this region, however, there are no reliable emission data from this type of source. Moreover, the variability of the physiographic characteristics and the terrain complexity of the Eordea Basin may lead to the formation of local atmospheric circulations of various types, which subsequently affect pollutant transport and dispersion (ARRITT and PIELKE 1984, PHYSICK 1988).

During the past two decades, due to complains of the habitants, the air quality in the Eordea Basin has been the subject of some investigations mainly by groups employed by the Greek Public Power Corporation (GPPC), which has the control of the power plants. These studies dealed with either sporadic measurements of various air pollutants for reduced time periods or environmental impact assessment of the various power plants (existing and scheduled) (LALAS et al. 1987, ZEREFOS et al. 1991). Recently TRIANTAFYLLOU (1994) studied in a more systematic way the behaviour of the plumes emitted by the power plants in relation to the meteorological conditions occurring in the Eordea Basin.

The objective of this study is to identify the synoptic conditions, which lead to various types of dispersion conditions in the examined area and consequently to enhanced concentrations of air pollutants. All the available data has been analysed for a period of two years while typical cases characterised as episode-days are analytically discussed.

2. Description of the Eordea area — The main air pollution sources

The broad, and relatively flat-bottomed Eordea Basin is located in the northwestern mountainous region of Greece. The main axis of the Basin is oriented along the SE-NW direction (about 50 km long) while its width ranges from approximately 10 to 25 km. The Basin presents a slight slope to the NW of the order of 2 : 1000, its height above the mean sea level (MSL) ranges from 550 to 700 m while it is (about

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5. Discussion

The method described above provides a basis for solving the questions posed in the introduction. For example, it renders possible to locate the optimum additional spots for observations to achieve the covering of all the territory with information at a given level.

The coverage with information on temperature and precipitation provided by the Estonian network of synoptic observations is poorest in the south-eastern part of the Pärnu district, in the Lahemaa National Park area and in the northern part of the Saaremaa island. The coverage of the territory with information would become more uniform if for each of these areas an additional data source is added. For example, for precipitation, the data of meteorological posts (lower-order stations) could be used. If the coverage level needed is lower than the existing level, some of the observation spots can be omitted.

As for sunshine duration, the maps of coverage with information look like columns (Fig. 9). To create a more uniform picture, additional measurements at Viljandi are needed as well as in the Lahemaa National Park area and in the Väinamere area covering the western coastal zone and eastern side of two major islands Saaremaa and Hiiumaa.

All these evaluations have been based on information theory where the step width of classification exerts a certain influence. In the examples presented in this work, the unit of each element was adopted as the respective class width. In general, the response to this problem depends on our needs: which variations considered to be informative for us and which not. In one case the precision of temperature 0.5 °C is needed, for other purposes the accuracy of 5 °C may be sufficient. But in every case the results must be presented with reference to the step width, because every change in classification changes more or less the level of coverage with information too.

This investigation into coverage with information was made on the assumption that in interpolating the TCI levels around the station in each spot only the nearest adjacent station is taken into account The problem can be solved in a more general way, too, by taking into account more than one adjacent source of information. This approach involves some methodical problems connected with the choice of an optimum number of adjacent information sources and integrating the information from different meteorological stations. Underlying the solution of these problems can be the method developed in this work.

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Dr. J. Kadaja
Estonian Meteorological and
Hydrological Institute
Teaduse 2
EE3400 Saku
Estonia

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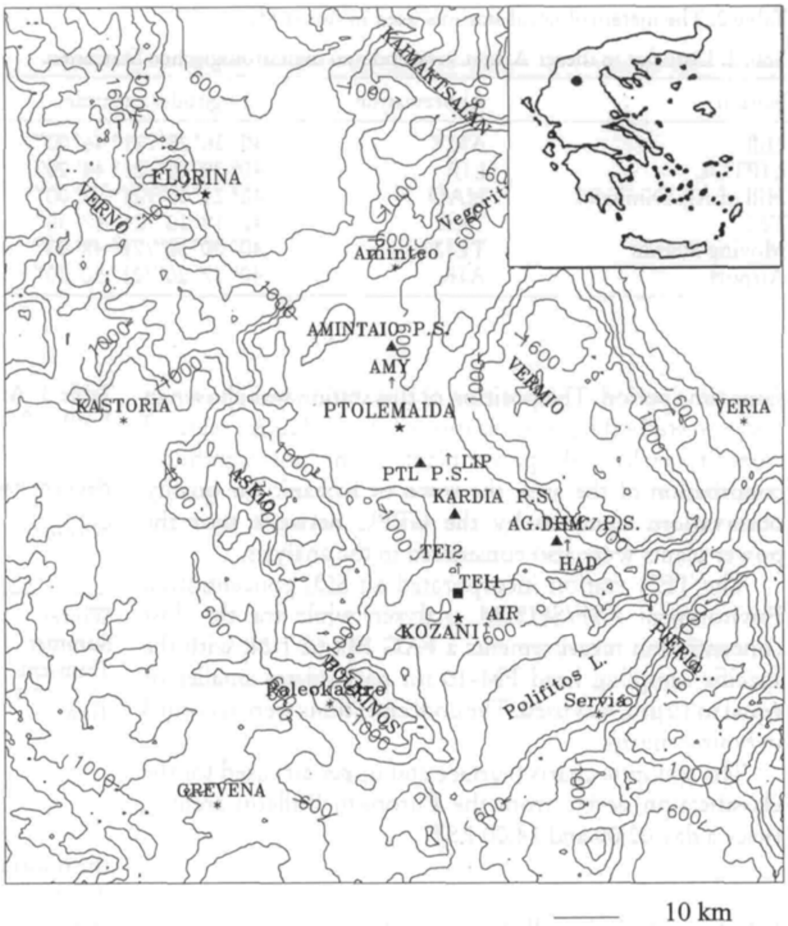


Fig. 1. Geographical map of the Eordea Basin. Contours are every 200 m. Arrows and square indicate the location of meteorological and air quality stations, respectively, while triangles and stars indicate the location of the power plants and cities, respectively. In the upper corner the additional map indicates the position of the Eordea Basin in Greece.

Abb. 1. Karte des Eordea Beckens, Höhenlinienabstand 200 m. Pfeile und Quadrate bezeichnen die Lage von meteorologischen und lufthygienischen Stationen. Dreiecke und Sterne bezeichnen die Lage von Kraftwerken und Städten. Die eingeblendete Karte in der oberen Ecke zeigt die Position des Eordea Beckens in Griechenland.

90 km) far from it. The main mountains, mainly covered by forests, surrounding the Basin are Kaimaktsalan (2524 m), Vermion (2050 m), and Pieria (2911 m) to the east, Vernon (2128 m), Askio (2111 m), and Bourinos (1866 m) to the west (Fig. 1).

There are openings to the northwest and south connecting the Basin with the other parts of the Greek mainland. Another opening, located to the south, joints the Basin with the valley of Aliakmon. In the southern part of the Basin an artificial lake (Polifitos) is located, 25 km long and 3 km wide. In this area more than 150 000 people live and work, mainly in the towns of Kozani and Prolemais.

Within the Basin there are four power plants producing more than 2/3 of the electrical energy of Greece and a number of other light industries. Thus the main sources of air pollution in the Eordea Basin are associated with the industrial activity, the open coalmines, and the central heating in the towns during winter. The air pollutants released are mainly particulates, SO_2, NO_x, and traces of heavy metals. The relative percentages of SO_2 and PM_{10}[1] emitted by the power plants in the area are presented in Table 1.

[1] It is believed that only particles with a diameter <10 μm are likely to be responsible for most of the adverse health effects due to their ability to reach the lower regions of the human respiratory tract.

Table 1. The emitted pollutant percentage from the power stations in the Eordea Basin.

Tab. 1. Prozentuale Schadstoffemissionen von den Kraftwerken im Eordea Becken.

Power Station	Abbreviation	Emission PM_{10}	percentage (%) SO_2
Amynteo	AMINTAIO P.S.	2.0	55.6
Ptolemais	PTL P.S.	20.6	12.1
Kardia	KARDIA P.S.	55.6	17.8
Ag. Dimitrios	AG. DHM. P.S.	21.6	12.4

3. Analysis of the meteorological and air quality observations

Data and instrumentation

The meteorological data used in this study were obtained by a surface network of six anemometric stations being operated from June 1991 to May 1993, belonging either to GPPC or to Technological Education Institute of Kozani (TEI1). The station locations are shown in Fig. 1 while Table 2 displays the station coordinates and altitude.

The air quality data used in this study (SO_2 and PM_{10}) were mainly obtained at the TEI1 station (see Fig. 1) for the

Table 2. The meteorological stations used in this study.

Tab. 2. Liste der in dieser Arbeit verwendeten meteorologischen Stationen.

Station	Abbreviation	Longitude/Latitude	Altitude (m) ASL
Hill	AMY	40° 36′ 25″/21° 46′ 00″	745
LIPTOL	LIP	40° 29′ 00″/21° 44′ 20″	650
Hill of Ag. Dimitrios	HAD	40° 23′ 30″/21° 57′ 00″	725
TEI	TEI1	40° 19′ 10″/21° 47′ 30″	730
Moving Station	TEI2	40° 20′ 30″/21° 48′ 00″	670
Airport	AIR	40° 17′ 20″/21° 50′ 20″	625

same time period. The position of this station was chosen in a way to study the transportation of the pollutants released from the stacks of the power plants to the most significant conurbation of the area, the town of Kozani. Air quality observations obtained by the GPPC network near the power plants were also considered in the analysis.

The TEI1 station incorporated an SO_2 concentration Environment ASF/SH20M analyser, while for the dust concentration measurements a FAG FH 62 I-N, with the specific sampling head PM-10 for particulates smaller or equal to 10 µm, was used. The concentrations were recorded in hourly means.

The synoptic charts (surface and upper air) used for the classification derive from the European Bulletin archive, twice a day 02.00 and 14.00 LST.

Selection of an air pollution episode

Based on the air quality data from the main monitoring station (TEI1) and taking into account the data from the monitoring network of the GPPC, days with enhanced concentrations (episode days) were identified.

A SO_2 event was defined as a case during which the daily mean concentration of SO_2 was greater than or equal to 30 µg/m^3 with duration of at least two consecutive days.

A PM_{10} event was defined as a case during which the daily mean concentration of PM_{10} was greater than or equal to 80 µg/m^3 which lasted for at least two consecutive days. This value is typical for large concentrations at the above-referred station.

According to the above criteria, 118 episode-days were identified during the 1991–1993 period. These days were classified by season (Table 3). During winter (November to February) 42 and 34 days with enhanced SO_2 and PM_{10} concentrations were observed respectively. During summer (June to September) the respective days were 25 for SO_2 and 44 for PM_{10}. Only a small number of episode-days (about 15 %) was identified during the transient months (March, April, May, October).

Table 3. Analysis of occurrence of air pollution episodes in the Eordea Basin for different seasons.

Tab. 3. Tage mit erhöhten Schadstoffbelastungen im Eordea Becken, nach Jahreszeiten aufgeschlüsselt.

Season	Episode-days			Total
	SO_2	SO_2 and PM_{10}	PM_{10}	
Winter	20	22	12	54
Summer	1	24	20	45
Transient	7	5	7	19
Total	28	51	39	118

Surface wind observations

In order to study daily surface wind conditions for the examined period, wind roses were constructed considering the 6 surface stations data at different periods of the day. Fig. 2a shows the wind roses constructed at various surface stations in Eordea Basin at 02:00 and 14:00 LT for the period 1991–1993.

During the night, the prevailing winds blow from north or northwest with medium (5–7 m/s) to strong intensities (more than 7 m/s). There is a gradual weakening of northerly winds from the northern (AMY Station) to the southern part of the Basin. This is probably due to the synoptic scale or valley winds (the middle slope of the Basin runs from south to north, except for the location of the AIR station in which the slope is opposite; so northerly winds are intensified). The weak SSE winds observed at the LIP and HAD stations are associated with local phenomena such as the downslope winds from nearby mountains. The same applies to the weak northeasterly winds monitored by the AIR station. It is worth noting that calms (winds with wind speed less or equal to 1 m/s) were reported quite often (from 10 to 70 % of the days) except for the AIR station where calm conditions appear in only 5 % of the days.

During the noon the winds in the Eordea Basin showed a different behaviour. In the northern part of the Basin the northerly winds reinforced, which can be attributed to the channelling of the synoptic wind as in the night time case. This effect becomes quite obvious in the middle of the Basin along the NW-SE axis (LIP and HAG stations). A significant portion of southerly winds (weak or very weak 1–5 m/s) is possibly caused by the local thermal circulations in the Aliakmon valley (i.e. upslope flows or lake breeze). This effect is more apparent during the warm and transient months of the year.

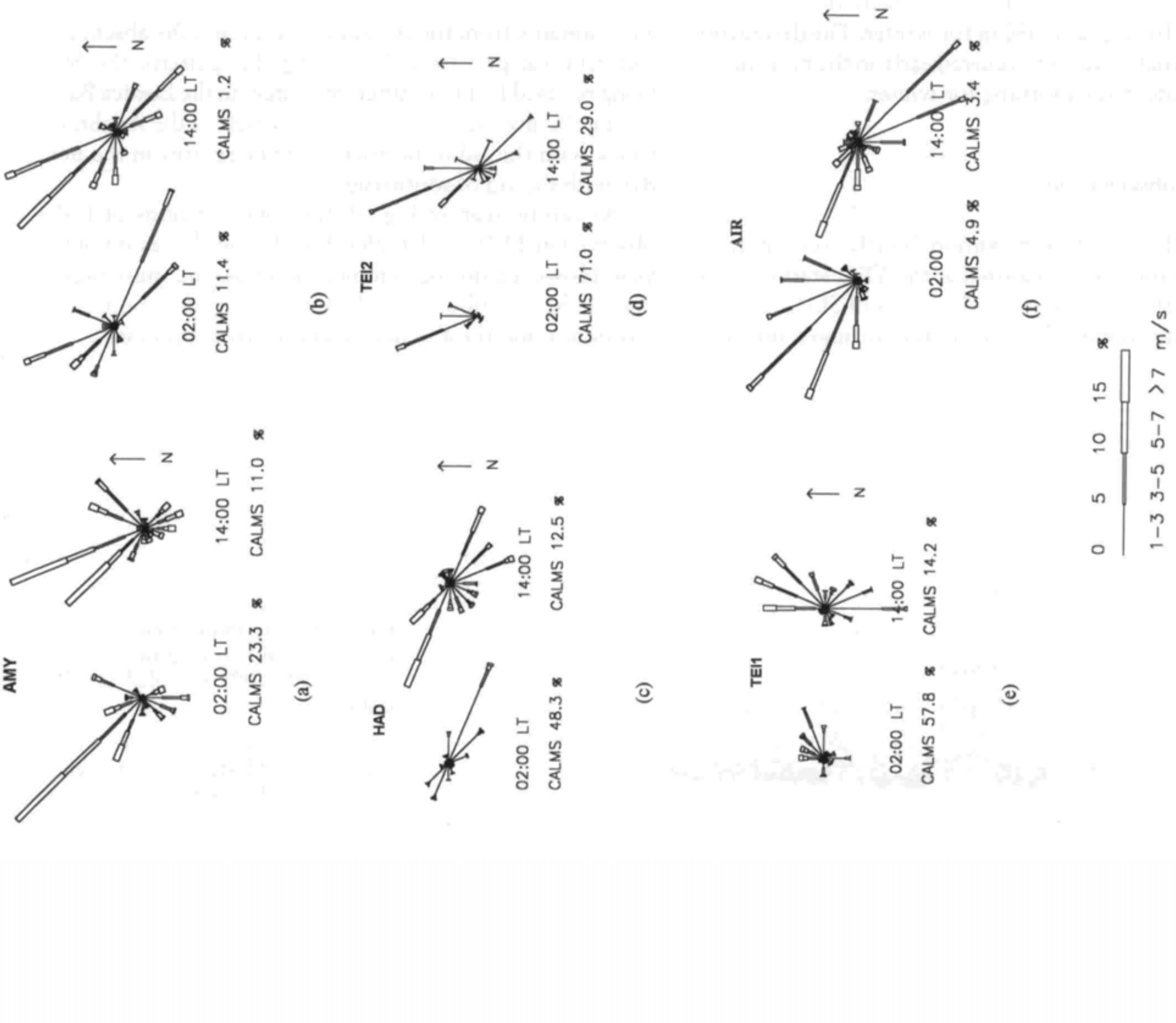


Fig. 2a. Wind roses constructed for the surface observations at 02.00 and 14.00 LT for the period 1991–1993. For each wind rose the abbreviated station name as well as the frequency of the calms are given.

Abb. 2a. Bodenwindrosen für 02.00 Uhr und 14.00 Uhr lokale Zeit (LT) für den Zeitraum 1991–1993. Für jede Windrose sind der abgekürzte Stationsname und die Häufigkeit von Windstillen angegeben.

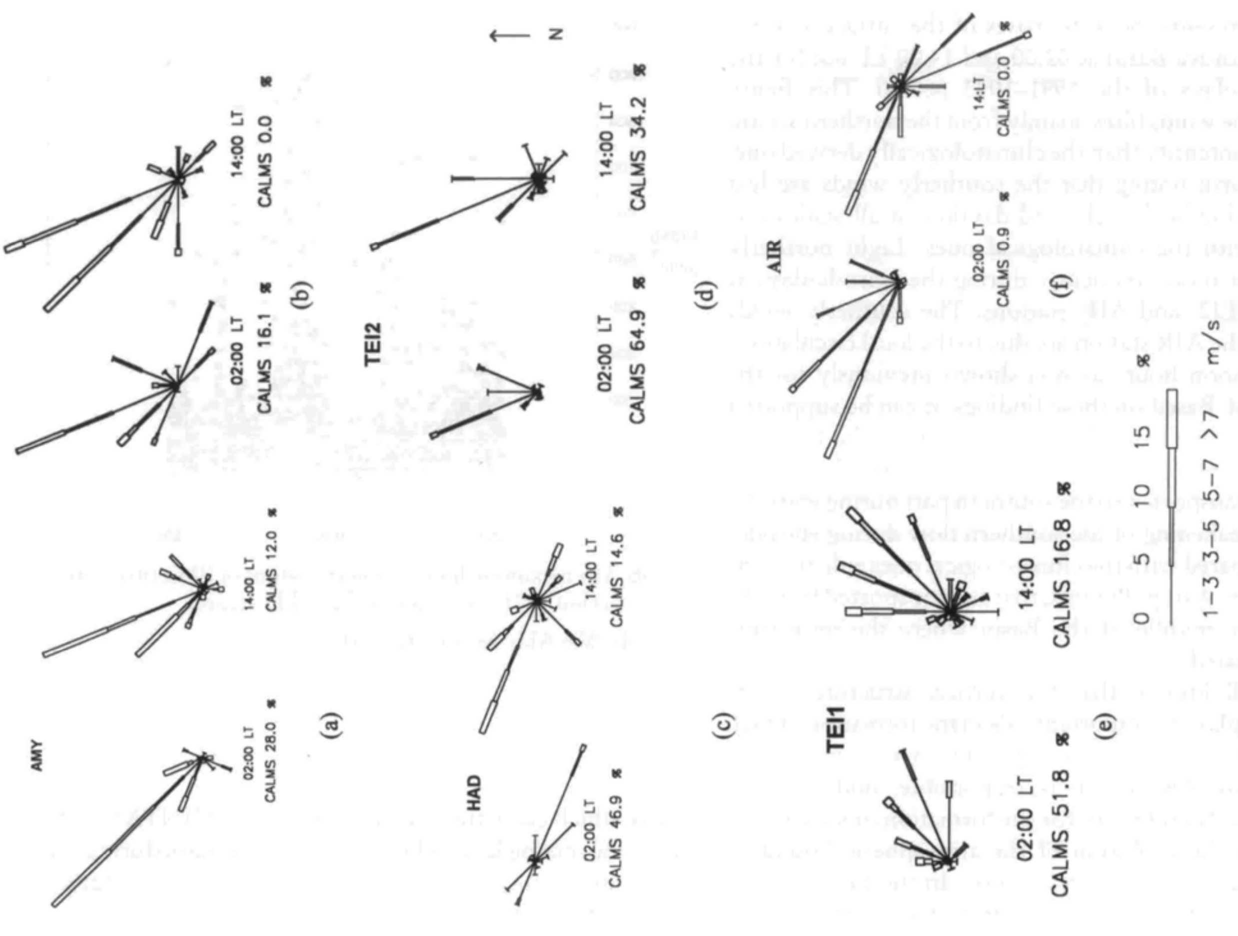


Fig. 2b. As for Fig. 2 but for the air pollution episode days for the period 1991–1993.

Abb. 2b. Wie Abb. 2a, aber für luftschadstoffbelastete Tage aus dem Zeitraum 1991–1993.

Fig. 2b presents the wind roses of the surface stations within the Eordea Basin at 02.00 and 14.00 LT but for the 118 episode-days of the 1991–1993 period. This figure shows that the winds blow mainly from the northern sector, with greater intensity than the climatologically derived one. It is also worth noting that the southerly winds are less frequent during both night and daytime at all stations as compared with the climatological ones. Light northerly winds appear more frequently during the episode-days at the TEI1, TEI2, and AIR stations. The southerly winds observed at the AIR station are due to the local circulations during the noon hours as was shown previously for the whole period. Based on these findings, it can be supported that air pollutants from the northern part of the Basin (in which the most significant power plants are located) are frequently transported to the southern part during episode-days. The weakening of the southern flow during episode-days as compared with the climatological ones enhances the accumulation of air pollutants, that are transported from the north, in the middle of the Basin where the measuring station is located.

It is well known that the vertical structure of the atmosphere plays an important role in the formation of high air pollutant concentrations, especially over complex terrain. The complex terrain is responsible, under certain meteorological conditions, for the formation of local flows, which affect the evolution of the atmospheric boundary layer (KAO et al. 1975, BANTA 1984). In the Eordea Basin area a number of detailed observations were performed by TRIANTAFYLLOU et al. 1995, who found that the inversion depth in the basin ranges from 150 to 250 m for summer and autumn and from 250 to 650 m for winter. The destruction of the nocturnal inversion occurred early in the morning for summer or late in the morning for winter.

Air quality observations

Fig. 3a and 3b present the maximum hourly concentrations of both SO_2 and PM_{10} measured at the TEI1 station. It can be seen that the maximum hourly values of SO_2 are higher during winter, obviously due to the stronger northerly winds which carry the released SO_2 from AMINTAIO P.S. inside the mixing layer which formed in the basin during the day hours (TRIANTAFYLLOU et al. 1995). This is in agreement with Fig. 3a.

Some of the high values of SO_2 measured during the summer season might be attributed to the recirculation of air pollutants from the Aliakmon valley and the absence of wet removal processes. Following this pattern, the SO_2 being released from the different sources in the Eordea Basin during the preceding night is transported to the Aliakmon valley with the aid of northerlies while returns in the next day with the aid of southerlies.

As can be seen in Fig. 3b the concentrations of PM_{10} observed in TEI1 reach high values during all seasons of the year. However, during summer the values are quite higher due to the contribution of lignite mining operation, open coalmines, and the absence of wet removal processes.

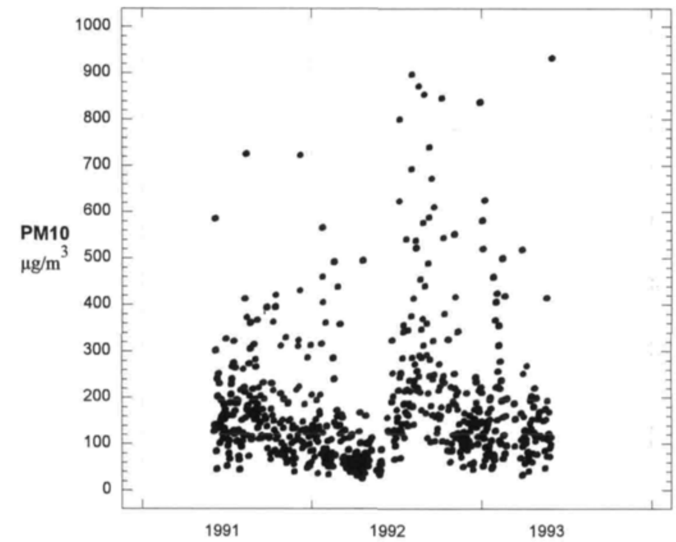


Fig. 3b. The maximum hourly concentrations of PM_{10} (in μg/m³), for the period 1991–1993 recorded at TEI1 station.

Abb. 3b. Wie Abb. 3a, aber für PM_{10}.

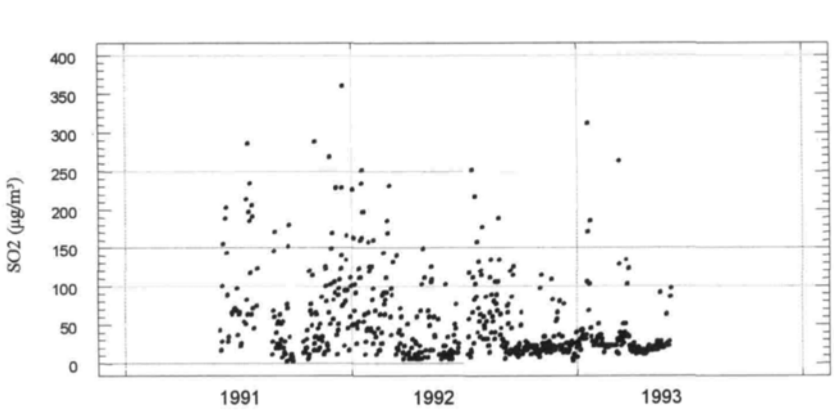


Fig. 3a. The maximum hourly concentrations of SO_2 (in μg/m³), for the period 1991–1993 recorded at TEI1 station.

Abb. 3a. Die höchsten beobachteten stündlichen SO_2-Konzentrationen in μg/m³ an der Station TEI1 im Zeitraum 1991–1993.

4. Synoptic classification of the days with increased air pollutant concentrations and analysis of typical cases

In order to classify the episode days, surface and upper air synoptic charts were analysed. The clustering criteria used for the classification were those described in KALLOS et al. 1993: the position of the synoptic systems with respect to the examined area, the atmospheric conditions at 850 and 700 hPa, the existence of warm advection in the lower troposphere, and the surface pressure gradient. This classification resulted in the following five synoptic condition categories:

I. An anticyclone covers the Balkan Peninsula as the extension of the anticyclonic circulation over Europe. This synoptic pattern occurs during the cold period of the year and leads to episodes of both SO_2 and PM_{10}.

II. The high-pressure system located over the Balkan Peninsula and the Central Mediterranean combines with the thermal low located over the Anatolian Plateau. When the latter extends towards the west the pressure gradient over the Aegean intensifies while the pressure field over the Balkans mainland weakens. This category occurs during the warm period of the year and leads to episodes of the PM_{10} type.

III. An anticyclone covers the whole Southern Europe, especially the area of Central and Eastern Mediterranean. Over the Central Mediterranean a ridge progresses toward east, which in some cases is associated with a trough over the Western Mediterranean and the Iberian Peninsula. This synoptic pattern is usually associated with warm advection in the lower troposphere over Greece. This phenomenon occurs during all seasons and leads to episodes of both SO_2 and PM_{10} during winter and of PM_{10} during summer.

IV. After the passage of a cold front or a relatively shallow low over Greece, which is moving to the east or southeast, a weak synoptic northerly or northwesterly circulation is established. Clear sky conditions support the formation of surface temperature inversions within the Basin. During these days, relatively high SO_2 and PM_{10} concentrations can occur. This synoptic pattern also includes the case in which an edge of a cold front is passing over Northern Greece during the warm period of the year.

V. A cold front moves southwards over Northern Greece. During these days SO_2 and PM_{10} episodes are quite common during the cold and warm period of the year, respectively.

It should be noted that there is a small number of episodes (~10 %) which cannot be classified in the abovementioned categories and which is characterised as 'unclassified'.

The distribution of episode-days for each season and the synoptic category is shown in Table 4.

Table 4. Occurrence of air pollution episodes in the Eordea Basin for different seasons and synoptic categories for the period of 1991–1993.

Tab. 4. Tage mit erhöhten Schadstoffbelastungen im Eordea Becken, nach Jahreszeiten und nach synoptischen Kategorien aufgeschlüsselt.

Synoptic category	Winter	Summer	Transient	Total
I	19		2	21
II		9		9
III	21	15	9	45
IV	2	15	5	22
V	4	4	1	9
Unclassified	8	2	2	12
Total	54	45	19	118

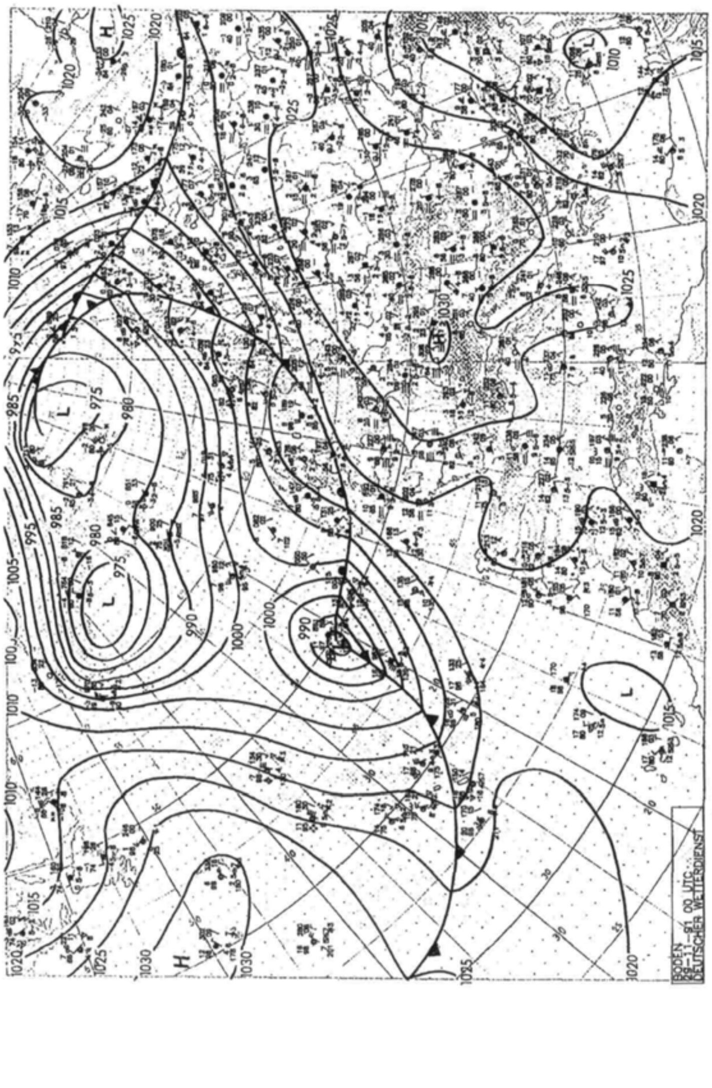
It can be seen that most of the episode-days appear with the synoptic category III (45 days, about 40 %), while the categories IV and I appear in about 20 days each. It is worth noting that only a small number of the episode-days occurred during the transient months of the year. Almost half of them occurred under the synoptic category III. This can be attributed to the frequent rainfall during this period of the year. It is worth noting that several episodes were associated with warm advection in the lower troposphere. The poorest air quality conditions occurred under the synoptic category III for both PM_{10} and SO_2, while during the synoptic category II the recorded concentrations were the lowest observed. Characteristic cases, representative for each synoptic category, are discussed below.

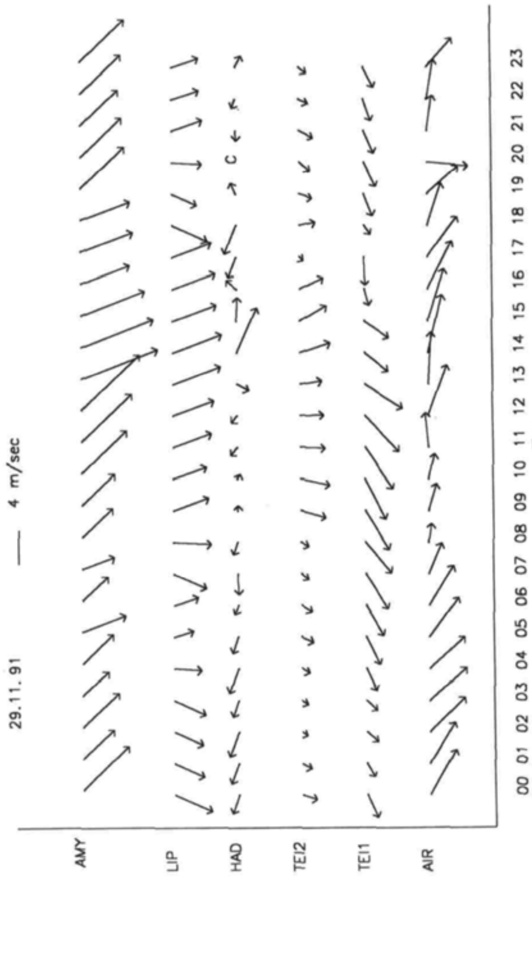
Typical case for synoptic category I

Two of the days classified in this synoptic category are the 29th and 30th of November 1991. During these days, a high pressure system established over the Balkan Peninsula assisted by the gradual displacement of the anticyclonic circulation from Central to Southeastern Europe (Fig. 4a).

Under these synoptic conditions a rather strong wind regime was established in the area while relatively lower surface temperatures were reported in the Eordea Basin. These low temperatures are mainly due to transport of cold air masses as a result of the extension of the Siberian High westward over the Balkans. The surface winds measured in the Eordea Basin are shown in Fig. 4b. It can be seen that the surface winds at the northern part of the Eordea Basin blow from the northwestern sector (AMY station) with moderate or high intensity. These winds weaken at the centre of the Basin and turn to southerly directions (HAD station).

In the area of TEI1 the winds are northeasterly strengthening during noon hours. It is clear that the wind flow regime in this area is significantly affected by the topography. In the southern part of the Basin the winds were strong blowing from the northern sector during the night while





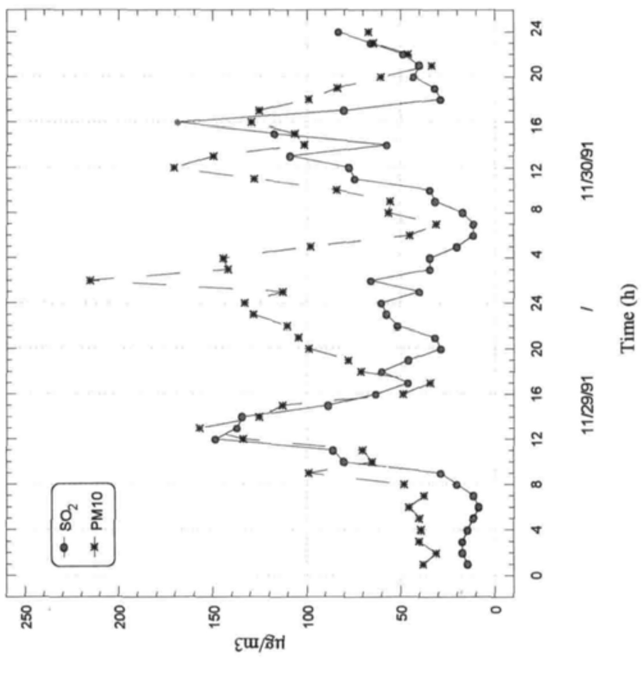


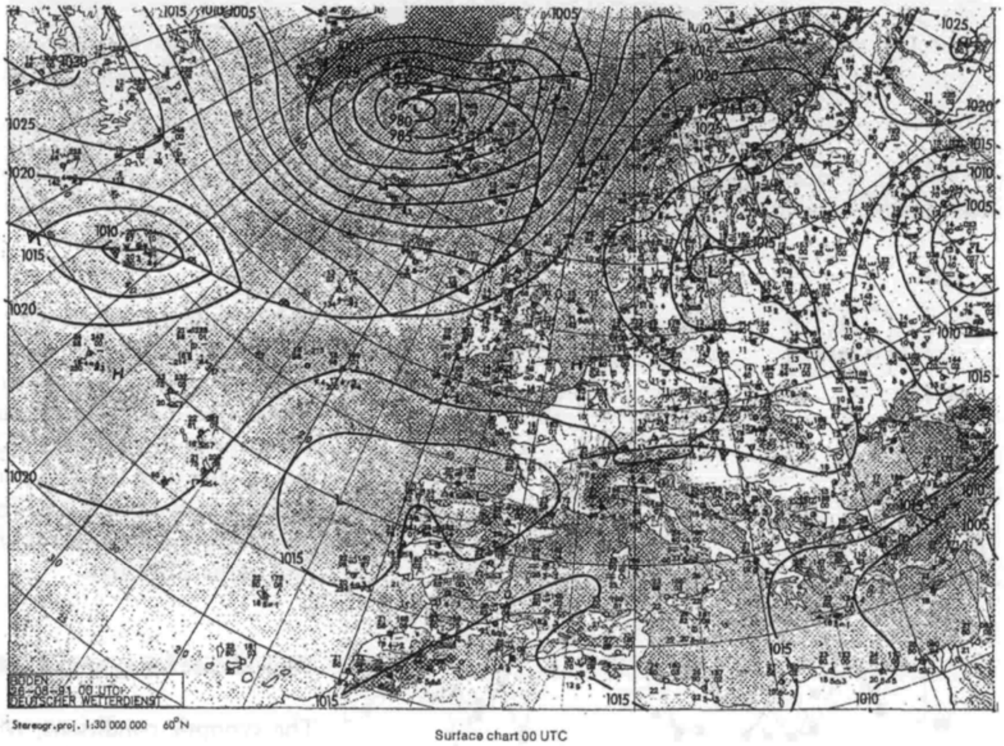
Fig. 4. The surface (a) synoptic systems at 02.00 LT, (b) winds, for 29 November, 1991, and (c) hourly concentrations of SO_2 and PM_{10} for 29 and 30 November, 1991 (synoptic category I).

Abb. 4. a) Bodenanalyse für den 29. 11. 91, 02.00 Uhr LT, b) Wind am 29. 11. 91, c) stündliche Konzentration von SO_2 und PM_{10} am 29. und 30. 11. 91 (synoptische Kategorie I).

during the next day their direction shifted to the western sector following the slope flows being developed in this area during these hours.

The hourly concentrations of SO_2 and PM_{10} measured in the TEI1 station for 29th and 30th of November 1991 are shown in Fig. 4c. The concentrations of PM_{10} presented two peaks, around noon and midnight respectively. The peak during noon hours might be due to the contribution of various sources with small stacks located near the measuring sites, the greater wind velocities observed and fumigation associated with the inversion break up (ZOUMAKIS et al. 1992). The wind velocities permitted a better diffusion of the released pollutants and consequently its transportation to the ground. The midnight peak on the other hand, however, might be caused by the plume impingement from the same shorter stacks near the measuring sites.

It is worth noting that SO_2 concentrations showed their maximum values during noon hours. This is probably associated with the transportation of SO_2 by the strong northerly winds, released from AMINTAIO P.S. during these hours. It has been already mentioned that this power plant releases the greater amounts of SO_2 in the Eordea Basin, while during these hours the temperature inversion over the area is destroyed.



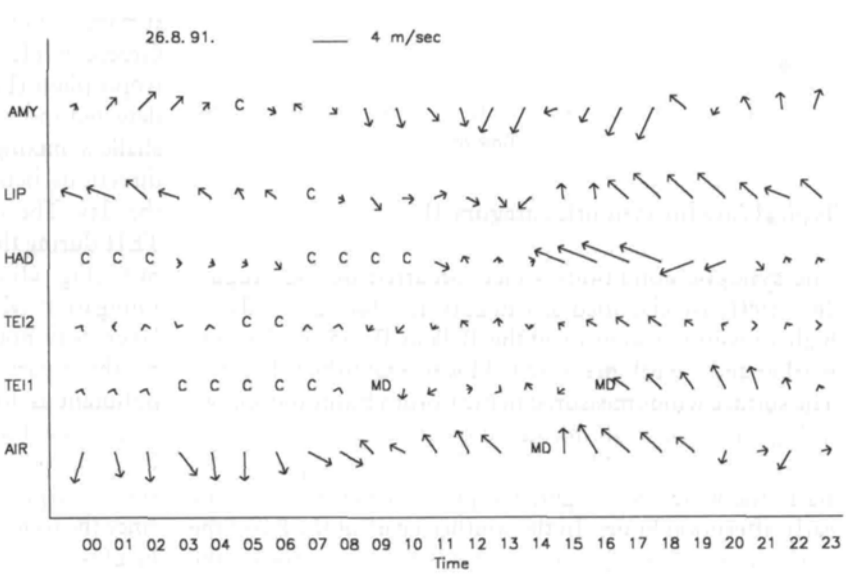


Fig. 5. The surface (a) synoptic systems at 02.00 LT, (b) winds, for 26 August 1991 (synoptic category II).

Abb. 5. a) Bodenanalyse für den 26. 08. 91, 02.00 Uhr LT, b) Wind am 26. 08. 91 (synoptische Kategorie II).

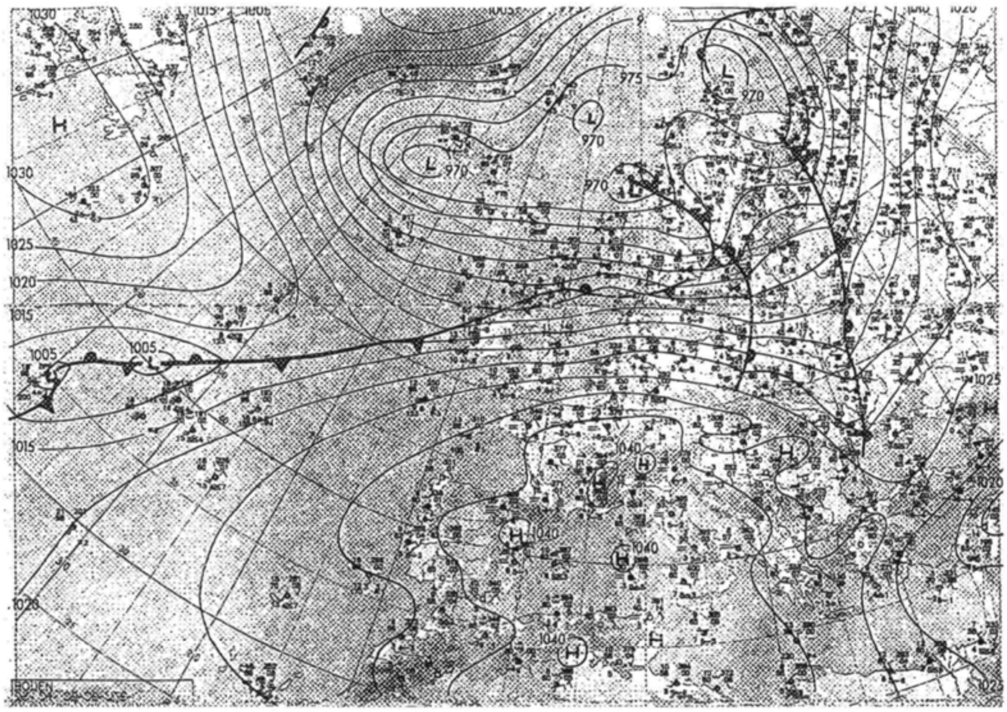
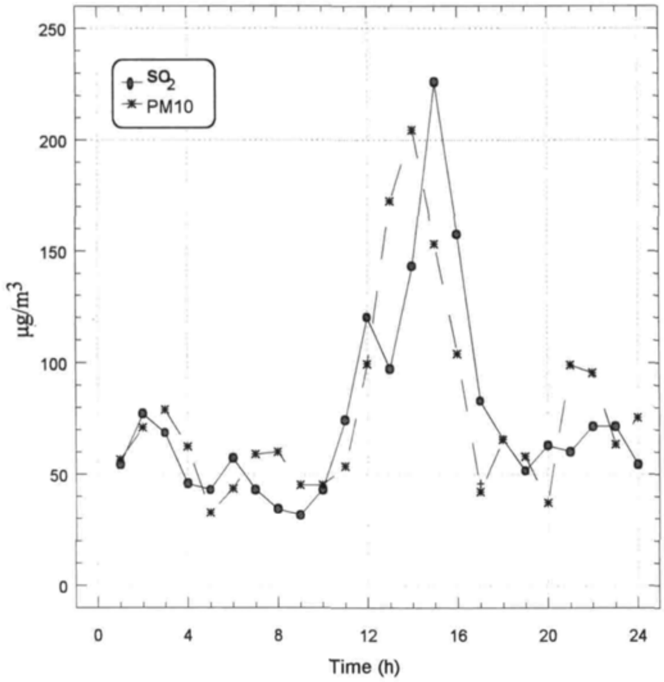


Fig. 6. The surface (a) synoptic systems at 02.00 LT, (b) hourly concentrations of SO_2 and PM_{10}, for 3 January, 1992 (synoptic category III).

Abb. 6. a) Bodenanalyse für den 03. 01. 92, 02.00 Uhr LT, b) stündliche Konzentrationen von SO_2 und PM_{10} am 03. 01. 92 (synoptische Kategorie III).



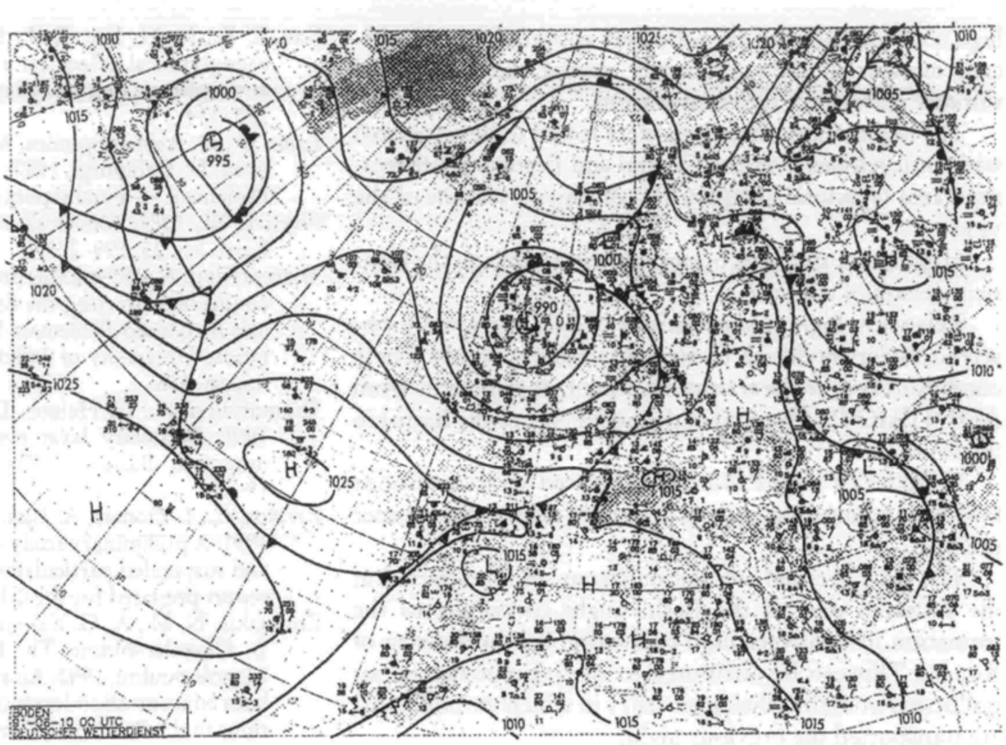
Typical case for synoptic category II

The synoptic conditions which occurred during August 26th, 1991, are classified as category II. During this day, a high pressure system over the Balkan Peninsula became weaker and a weak pressure field was established (Fig. 5a). The surface winds measured in the Eordea Basin and shown in Fig. 5b were weak during all day, even in the northern part of the Basin (AMY station). In the central part of the Basin the winds were light, except for HAD station in the early afternoon hours. In the southern part of the Basin the winds were blowing from northern directions during the night, while during the day they shifted to the southern sector (4–5 m/s).

The concentrations of air pollutants recorded in TEI1 during this day reached a maximum value during noon hours for both PM_{10} and SO_2. The observed peak of SO_2 was smaller than the PM_{10} one, due to the weak flow field established over the Basin. This weak flow did not allow the transportation of SO_2 from its main source (AMINTAIO P.S.) to the TEI1 area.

Typical case for synpotic category III

The synoptic conditions, which occurred during January 3rd, 1992, are classified as category III. During this day, a surface anticyclone covered Southern Europe including Greece while a strong ridge was detected in the lower troposphere (Fig. 6a). A rather strong thermal advection was detected and was responsible for the establishing of a rather shallow mixing layer. The winds blow from northeastern directions, being weak or very weak in the Basin, almost all the day. The concentration of air pollutants recorded in TEI1 during the day peak at noon hours for both PM_{10} and SO_2 (Fig. 6b), mainly during to the inversion break up fumigation (ZOUMAKIS et al. 1992). This shallow mixing layer does not allow the transportation of SO_2 from the northern part of the Basin, where the main source of this pollutant is locataed. This is because the effective stack height was higher than the mixing layer all the time. For PM_{10} significant concentrations were measured in TEI1 station, especially during the night and the next morning, since the sources were other stacks with lower effective stack heights.



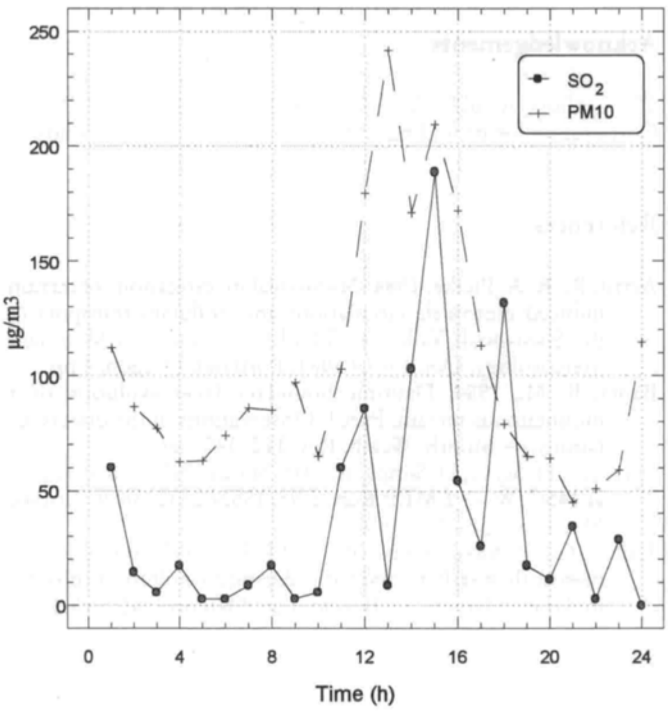


Fig. 7. The surface (a) synoptic systems at 02.00 LT, and (b) hourly concentrations of SO_2 and PM_{10}, for 10 June, 1991 (synoptic category IV).

Abb. 7. a) Bodenanalyse für den 10. 06. 91, 02.00 Uhr LT, b) stündliche Konzentrationen von SO_2 und PM_{10} am 10. 06. 91 (synoptische Kategorie IV).

Typical case for synoptic category IV

Two of the days classified to this synoptic category were the 10th and 11th of June 1991. According to Fig. 7a, a front passed over Greece moving eastwards. In the lower troposphere the winds were weak from northerly directions while a weak ridge appeared over Western Greece. The winds over the northern and central part of the Basin were mainly northerly during the time period from 08.00 to 19.00 LT. Calms are reported during the night and next day, except for the AIR station, where local circulations were detected during the noon hours of the next day. The concentrations of air pollutants recorded in TEI1 during the 10th of June (Fig. 7b) become as high as 250 µg/m^3 at noon hours (12.00–17.00 LT). This seems to be associated with the fumigation mechanism combined with intense thermal vertical movements during this period, due to the transportation of air pollutants from the northern part of the Basin. On the contrary, during the rest of the day concentrations were less than 100 µg/m^3. The SO_2 concentrations recorded in the same station appear more or less the same pattern.

Typical case for synoptic category V

Typical days attributed to synoptic category V were those of 18th to 20th January, 1992. A cold front was passing over Northern Greece moving southwards, while over Western and Central Europe an anticyclone was established. In the Basin the winds are northerly being very strong during all the day hours. This flow pattern favours the transportation of air pollutants from the sources located in the northern part of the Basin.

5. Conclusions

In this study, the prevailing synoptic weather conditions, associated with relatively high concentrations of SO_2 and PM_{10} in the Eordea Basin during the period 1991–1993, have been analysed. The mesoscale circulations, which resulted as a combination of the synoptic weather patterns and the local flows induced by physiographic characteristics, have also been analysed for each synoptic category. The relatively high concentrations of air pollutants appeared for a significant number of days, especially during the winter and summer seasons for different reasons.

The highest concentrations were found to be associated with anticyclones over the Central and Eastern Mediterranean area (synoptic category III) during all seasons of the year.

High concentrations occur very rarely during the transient season of the year.

Relatively high concentrations of SO_2 are usually observed under moderate to strong northerly winds. These conditions favour the transportation of air pollutants from AMINTAIO P.S. (located at the north part of the Basin) to the south.

Episodes of high PM_{10} are associated with conditions favouring fumigation and occur mainly during the summer months.

The local thermal circulation (from south) detected at the southern part of the Basin might contribute to the formation of relatively high concentrations in the area of Kozani. This can be attributed to the recirculation of air pollutants from the Aliakmon valley in which the pollutants are transported the previous night.

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A. TRIANTAFYLLOU
(Author responsible for further communications)
Technological Education
Institute of Kozani
Mining Engineering Department
Environmental Physics
Laboratory
GR-50100 Kozani, Greece
e-mail: atria@kozani.teikoz.gr

Dr. P. A. KASSOMENOS
G. KALLOS
University of Athens
Department of Applied Physics
Laboratory of Meteorology
Panepistimioupolis
Building PHYS-V
GR-15784 Athens, Greece
e-mail: pkassom@dap.uoa.gr

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