Environmental Modeling & Assessment
https://doi.org/10.1007/s10666-020-09699-6

Air Quality Levels in the Vicinity of Three Major Greek Airports

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Received: 28 April 2019 / Accepted: 31 January 2020

Abstract

Aviation is a basic necessity of our world, but its contribution to air pollution is considered significant. In this paper, the contribution of air traffic to air pollution levels in the area of the three larger airports of Greece is examined through the use of EDMS (Emission and Dispersion Modeling System), a regulatory model proposed by the US EPA (United States Environmental Protection Agency). To ensure a better understanding of air traffic contribution to air quality levels, the hourly aircraft movements along with the corresponding meteorological data for a whole year, 2009, were taken into account. During this year, air traffic peaked both in Greece as a total and in each of the three airports of this work. Airport emissions calculated by EDMS are found to be in good agreement with emissions monitored at Athens International Airport as well as with emission results and published data for International Zurich Airport. Concentration results have shown that PM_{10} and SO_2 concentrations are well below the limit values, whereas NO_2 concentrations exceeding limit value are expected in small areas under specific circumstances, when heavy air traffic coincides with meteorological conditions favoring air pollutant accumulation. Finally, the comparison of computational results with monitoring air quality data shows a good agreement, if other sources of air pollution are excluded.

Keywords Greek airports · Emissions · Air pollution levels · EDMS · Computational approach · Exceedances

1 Introduction

Aviation is a key element of the modern lifestyle, but its contribution to air pollution is significant. Air pollution poses a major threat to public health, as it is considered to be the biggest environmental risk to health on a global scale [1], while atmospheric pollutants can harm ecosystems and other aspects of the natural environment [2].

Alarming levels of air pollution appear mainly in China, India, and some parts of Africa [3], while concentrations of air pollutants at Europe keep reducing over time with PM_{10} and $PM_{2.5}$ still exceeding limit values, according to Directive 2008/50/EC [4].

In Greece, carbon monoxide levels are very low, but nitrogen and sulfur oxides sometimes exceed limit values (Directive 2008/50/EC) at local scale, mainly at small areas of western Attica and in the area of Kozani and Ptolemais, where the lignite center of Western Macedonia of the Public Power Corporation is located. Particulate matter concentrations exceed limit values in extended areas of southern and western Greece, as a result of both pollution transport from sources outside the country and local anthropogenic and physical sources, e.g., emissions due to fuel and biomass burning and natural emissions from unvegetated soil and from the sea [5]. As for urban environments, at the level of the three major cities of Greece, namely Athens, Piraeus, and Thessaloniki, where more than half of the country's population lives, air quality has been improving over the years since the 1980s [6]. In the areas of Thessaloniki and Heraklion airports, there are no air quality monitoring stations. On the contrary, in the greater area of Athens airport, Mesogia, an air quality

Highlights

- EDMS was applied to estimate air pollution levels in the area of 3 large airports.
- Emissions, especially for NO_x, are in good agreement with previous results.
- A NO_x emission rate of 4 to 5 kg per aircraft movement has been calculated.
- CO, PM_{10}, and SO_2 concentrations were found well under limit values.
- Higher concentrations of NO_2 were found, but only under specific circumstances.
- In the nearby residential areas, local sources dominate in air pollution levels.
- Model results are generally in good agreement with monitoring data, if effects from other sources are excluded.

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monitoring network operates. Nitrogen dioxide, the main air pollutant related to airport activities, has generally shown significant decreases; nevertheless, during the last decade, concentrations started to increase again [7].

Aviation emissions of air pollutants occur during the overall course of a flight, i.e., both during take-off or landing and cruise. Although overall aircraft cruise emissions are about 4 times larger than emissions near the ground, contributing thus significantly to total GHG emissions, in local scale, i.e., in the vicinity of airports, take-off and landing emissions are more condensed and direct [8]. This is the reason of focusing the interest of this work on air pollution levels close to airport areas.

The main sources of air pollutant emissions at airports are aircraft movements, which are to some extent standardized by means of the "landing-take-off cycle" or LTO [9]. Ground sources, such as auxiliary power units, ground service equipment, and brake/tire residues from aircraft, also contribute significantly to airport emissions. The dispersion of emitted pollutants in the ambient air around the airport affects environmental compartments, such as ecosystems, but the potential impact which draws the greater attention is the risk to public health. A recent review article [10] shows that this impact depends on multiple parameters, including the particularities of air traffic daily variation, aircraft mix, and ground activities, as well as local particularities such as the orography and meteorology of the area. Several modern studies focus on the pollutants considered as the most dangerous for human health, namely fine particles, including black carbon particles [11], and dangerous gases such as formaldehyde and tropospheric ozone. Concentrations of the main air pollutants from aviation, i.e., CO, NO_2, PM_{10}, and SO_2, are found to be distinctly higher than the background at short distances, but at more distant residential areas, levels tend to fall close to background. Because of this, it is difficult to derive quantitative conclusions on the effect of airport air pollutant emissions on public health. In the proximity of aerodromes, the concentration of tropospheric ozone is decreasing due to primary pollutants emitted which photochemically react with ozone and lead to O_3 depletion; however, at larger distances, the contribution of airport activities to the formation of O_3 is important and leads to increased ozone levels [10].

In this work, the emissions and concentrations of the main air pollutants around the three major airports of Greece, located near the cities of Athens, Thessaloniki, and Heraklion, are described and assessed through detailed computational approach. All three airports have been analyzed in the past, in regard to their environmental impacts, mainly in the framework of the European Directive for Environmental Impacts Assessment, while Athens airport had caused scientific debate regarding its impact on air quality right from the start [12]. The main objective of this work is to assess air quality in the area of each of the three above airports using a focused and realistic approach, similarly in scope to many other works for airports across Europe and the USA [11, 13–15].

2 Methods

There are two general categories of methods for studying air pollution: those that are based on measurements and the ones that rely on computational approaches.

Measurement-based methods rely on performing field measurements of concentrations, using either fixed or mobile equipment. Starting in the early 1980s, several European cities have installed networks of air quality monitoring stations [6, 16–18] while some large airports also use such stations to monitor air pollution in their area [19–23]. Measurement-based methods excel in accuracy but lack spatial coverage, and they need additional work (i.e., the use of specific pollutants as indicators of emission sources) to point out the links between measured concentrations and emissions, which usually occur from various sources, e.g., road traffic, heating, and industry.

Computational methods rely on a variety of simulation systems that calculate and interconnect the emissions from each source with the final concentration occurred. Those methods became popular in recent years due to the abundance of computational power and, at the same time, the necessity for large-scale air quality assessments. Computational methods contain uncertainties related to internal assumptions and simplifications of the models used, as well as to lack of details in input data. Despite these uncertainties, the use of computational methods is clearly encouraged by modern European and national legislation.

This work contains the results of computational simulation of air pollutant emissions and concentrations in the vicinity of the three largest Greek airports, using one of the most acknowledged relevant systems. This system is EDMS, the regulatory model proposed by the US EPA for compliance checking of existing or planned airports with air quality limits. EDMS is a modeling system combining emissions and dispersion calculations to assess air quality in the area around airports [24]. The model generates an air pollutant emission inventory, related to all sources in and around the area of an airport, and simulates air pollutant dispersion in order to assess air pollutant levels in the greater area of the airport under examination. Emission calculation is carried out by simulating the airport's activity, based on aircraft data, airport's layout, and scheduling data. Meteorology data, used in dispersion calculations, are produced by the AERMET, the meteorological data preprocessor of AERMOD, based on weather data from the airport's location. Dispersion calculations are performed through the application of the AERMOD model, coupled with AERMAP. AERMOD is a steady-state US EPA–recommended dispersion model, developed for short- to mid-range (up to 50 km) calculations of concentrations. In the stable boundary layer, dispersion follows a Gaussian distribution in both horizontal and vertical axes, whereas in the convective boundary layer, dispersion is Gaussian in the horizontal direction, and bi-Gaussian in the vertical direction. AERMAP is the terrain preprocessor of AERMOD, locating emission sources and concentration receptors on the 3D surface of the study area. The architecture of EDMS, shown in Fig. 1, is typical of modern-day multi-tiered approaches, consisting of several modular components.

Although EDMS has been replaced by the Aviation Environmental Design Tool (AEDT) as of May 2015, the latter has retained the same approach and methodology of EDMS, adding modern user-interface elements including GIS interaction, and mainly integrating air quality with noise assessment [25].

EDMS has been used in Europe and the USA to either assess air pollution levels related to large- or middle-sized airports' activity [14, 15] or compare monitoring and computational results [13]. The added value of our approach is the implementation of the EDMS at the three larger Greek airports in the most realistic way, i.e., using real hourly meteorological data, a real mix of aircraft and real-time distributions of aircraft movements. To ensure a sufficient margin of safety into the results of the calculations, the aircraft movements of 2009 were used as input data; during this year, the number of aircraft movements was the largest ever recorded, both in Greece as a total and in each of the three airports of this work. Meteorological data were derived for 2009 from the meteorological stations of the three airports. More specifically, the input data imported into the model included the number and daily time schedule of the aircraft movements (LTOs) for each airport, as per the operational profiles of the examined airports, which were provided by the Hellenic Civil Aviation Authority. The meteorological data used, namely wind speed and direction, temperature, and cloud cover from the meteorological station installed in each airport, were provided by the Athens International Airport S.A. for the airport of Athens or by the Hellenic National Meteorological Service for the airports of Thessaloniki and Heraklion. Upper air data were acquired by the international radiosonde database [26].

Emissions were determined on an hourly basis for the whole year, for all aircraft operations in the airports examined (flight modes and ground operation), as well as for the ground support equipment and auxiliary power units. The emission factors used by EDMS 5.1.3 originate from the "Base of Aircraft Data," an acknowledged aircraft performance model [27]. Concentrations were calculated on a 500 × 500 m grid, on an hourly basis and for the time periods that limit values refer to. The number of aircraft movements peaks during summer in Greece, due to tourism, so our concentrations' analysis focused on July and August of 2009, although some model runs were performed for the rest of the months and resulted in much lower concentration levels.

3 Results and Discussion

3.1 Emissions

The results of emissions' calculation for the three largest Greek airports, namely "Athens Eleftherios Venizelos

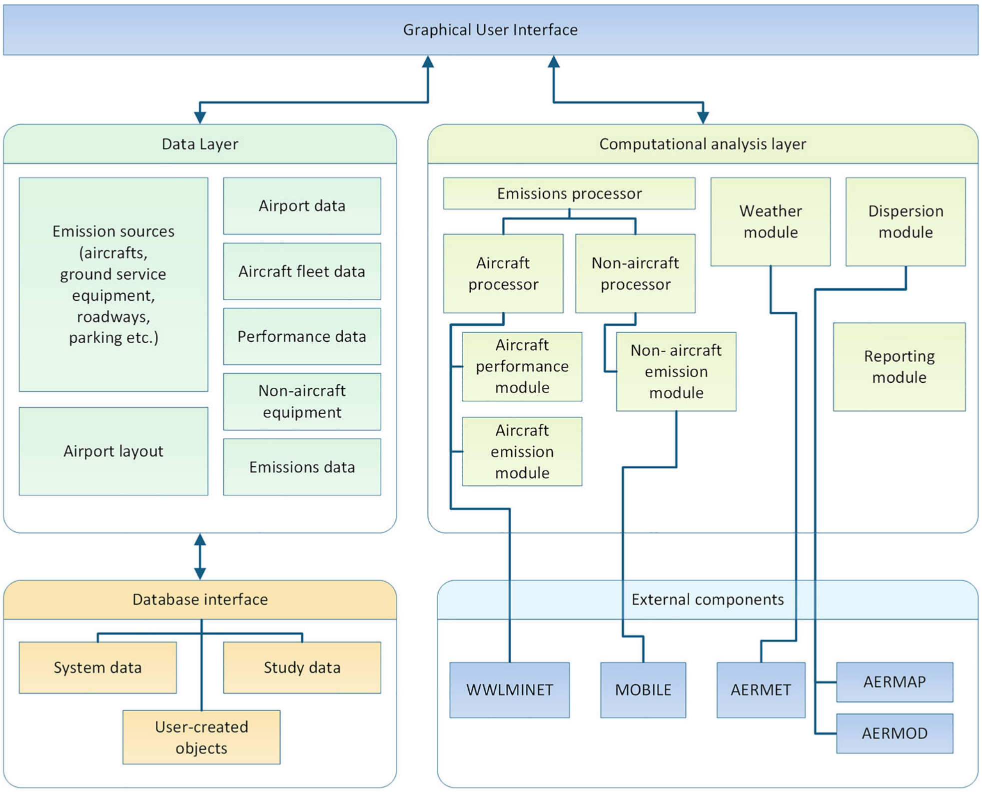


Fig. 1 Graphical representation of EDMS architecture

International Airport" (ATH), "Thessaloniki Macedonia International Airport" (SKG), and "Heraklion Nikos Kazantzakis International Airport" (HER), are shown in the following Table 1 for each major pollutant (including non-methane volatile organic compounds or NMVOC and total hydrocarbons or THC). Results are apportioned among sources, namely aircraft (i.e., emissions related to aircraft movements using their main engines), auxiliary power units (APU—the small turbine at the tail end of an aircraft that provides energy on the ground), and Ground Service Equipment (GSE—a variety of support equipment to service aircraft operations while on the ground).

It is to be noted that, although HER and SKG served similar numbers of flights (around 50,000 LTOs), there are significant differences in the emissions, mainly due to the different aircraft mix and particularly due to the portion of propeller aircraft. These types of aircraft (turboprop) are known for lower emissions [28, 29] and their annual flight number has been accounted for in each airport's flight mix. Namely, SKG served 14.7% propeller aircraft while HER served 8.6% of this type of aircraft. It is to be noted that the emissions of the largest airport (ATH), which served four times the movements of each of the other two, are far more than four times larger, indicating the lack of general simple linearities in emissions' relation with annual flight numbers. The only pollutant that displays a rough linear relation with flight number is NO_x, which is by far the main pollutant related to airport operations. For the above three airports, the rate of NO_x emissions, in kg per LTO, is at the same range, specifically 4.75 (ATH), 3.80 (SKG), and 5.13 (HER).

The above emissions calculated by EDMS are found to be in good agreement with the monitoring data of the actual operation of ATH [30] since the differences are 6.6% for CO, − 3.1% for NO_x, and 6.1% for THC. This is a strong indication of the credibility of the emissions predicted by EDMS when the model is fed with detailed operational data of an airport.

Another way of quantifying the NO_x emissions rate is the emission index (EI), defined as mass of NO_x per mass of fuel. Over the past three decades, NO_x EIs have declined steadily, nearly 20% down compared with the 1980s' levels [31]. At airports where fuel burn data is available, it would be worth comparing our metric (NO_x emissions per LTO movement) with EIs. Unfortunately, none of the three airports considered in this work collects fuel burn data, so such comparison cannot be carried out at present time, but it may be achievable in the future, since operational and environmental monitoring at airports is getting more demanding, mainly due to the requirements for reducing carbon footprint.

The comparison—in terms of emitted pollutants per LTO—between this study emission results and published data for International Zurich Airport (ZRH) acquired by different methods [32, 33] indicates a good agreement for NO_x but quite a few differences for CO and HC, as shown in Fig. 2.

The differences in the emissions per LTO of the above charts are attributed to variations between methods and assumptions integrated in each model, as well as to differences between airports and flight mixes (see, for example, the close agreement of various methods for ATH and for ZRH, contrasted with the difference between these two airports).

The good agreement of various methods on NO_x under different circumstances allows the suggestion of a rule of thumb for the rough estimation of average emissions per LTO as follows: "At airports where jets are a majority, an average emission of NO_x between 4 and 5 kg per aircraft movement is expected."

3.2 Concentrations

While emissions have been calculated in NO_x and SO_x terms, concentrations must be converted to NO_2 and SO_2 to ensure comparability with the respective limit values. To convert

Table 1 Emission results for ATH, SKG, and HER airports, per source for each major pollutant

Emissions (tn/year)								
		CO	NMVOC	THC	NO_x	SO_x	PM_{10}	$PM_{2.5}$
ATH	Aircraft	651.817	112.908	97.651	852.728	72.337	4.918	4.918
(LTOs 210,147)	APU	25.189	1.778	1.538	35.047	4.106	3.363	3.363
	GSE	994.723	32.766	0.000	110.143	3.370	3.575	3.433
	Total	1671.729	147.452	99.189	997.918	79.813	11.856	11.714
SKG	Aircraft	68.840	12.337	10.670	159.145	11.865	1.092	1.092
(LTOs 50,238)	APU	7.016	0.501	0.433	7.116	0.892	0.832	0.832
	GSE	239.128	7.740	0.000	24.839	0.767	0.744	0.713
	Total	314.984	20.578	11.103	191.100	13.524	2.668	2.637
HER	Aircraft	69.727	15.590	13.484	192.867	13.439	1.297	1.297
(LTOs 44,842)	APU	11.811	0.817	0.707	7.842	1.097	1.193	1.193
	GSE	278.394	9.040	0.000	29.207	0.900	0.893	0.857
	Total	359.932	25.447	14.191	229.916	15.436	3.383	3.347

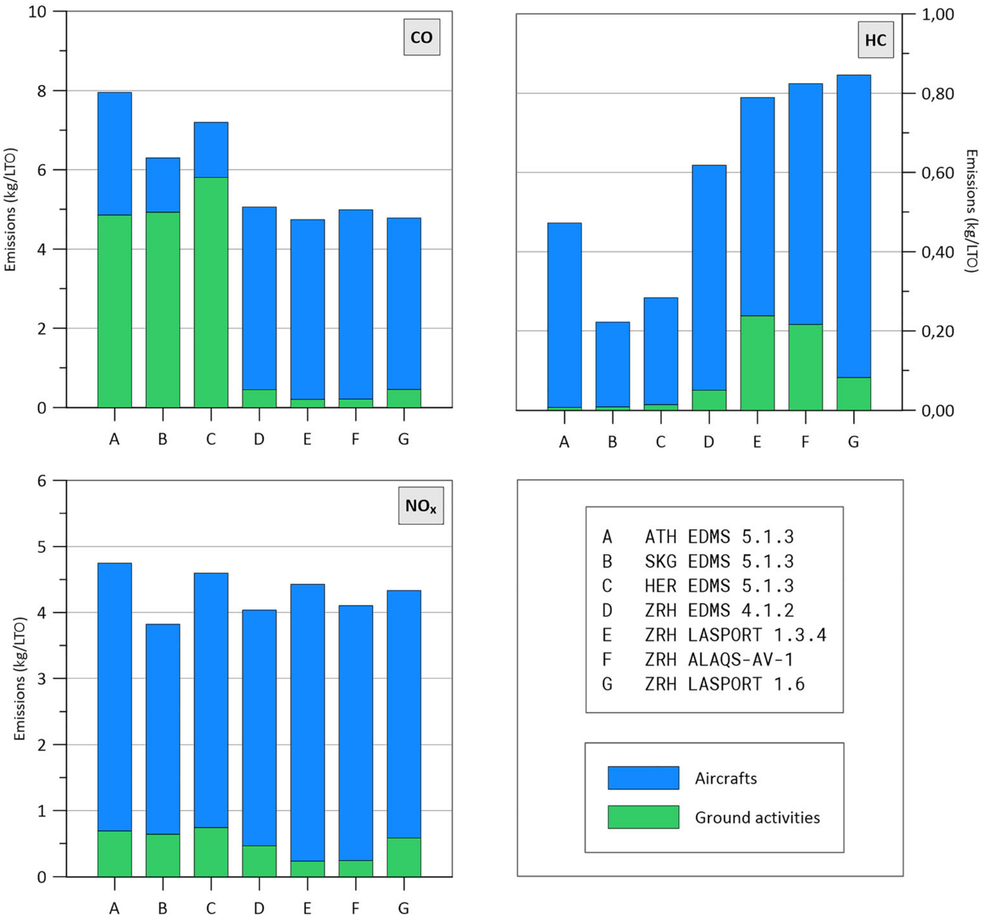


Fig. 2 Comparison of emission results calculated with different methods

NO_x to NO_2 levels, the empirically derived value of 0.80 for hourly NO_2/NO_x ratio and a value of 0.75 for the annual ratio were chosen [34, 35], instead of more complicated approaches, such as the ozone-limited method, which leads in generally lower NO_2 values. For SO_x, it was considered that the total quantity of emitted oxides is quickly converted in SO_2.

Limit values in Greece (Table 2) are ratified by national legislation and fully adopt Directive 2008/50/EC.

As expected, concentration results have been found to vary from minimum values, during periods with no significant air pollution, to maximum values during periods when the flight frequency and the atmospheric mixing conditions led to high concentrations.

The highest concentrations for Athens International Airport appear on July 19th, at 6 a.m., when wind was blowing from the south-east (145°) with a very low speed (0.9 m/s). The concentration contours for this particular air pollution event are shown in Fig. 3.

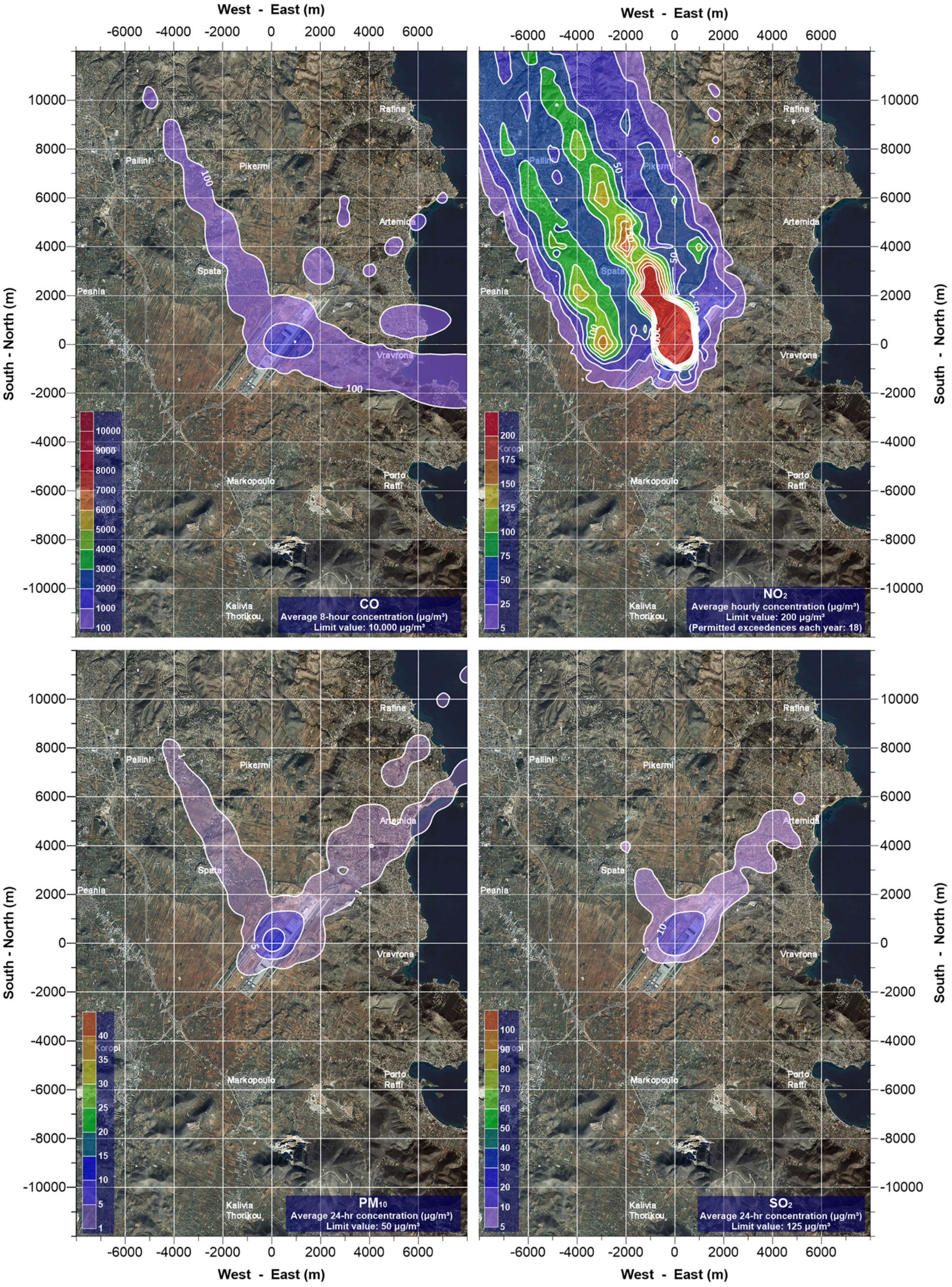
Following the same steps, the highest concentrations of NO_2 for SKG appear on July 31st, at 9 p.m., under low speed (1.54 m/s) eastern (80°) wind. The contours of NO_2 levels are shown in Fig. 4, while CO, PM_{10}, and SO_x levels are omitted from graphing because they were found to be very low, sometimes not exceeding 1% of the limit value, even during this maximum concentration event.

At the Heraklion airport, the highest NO_2 levels, shown in Fig. 5, were found on July 6th, at 9 p.m., under southeastern wind (110°) with low speed (1.54 m/s). Again, CO, PM_{10}, and SO_x levels were found to be extremely low.

Table 2 Limit values of air pollutant levels according to national and European legislation (Directive 2008/50/EC)

Pollutant	Limit concentration ($\mu g/m^3$)	Averaging period	Permitted exceedances each year
CO	10.000	Maximum daily 8 h mean	–
NO_2	200	1 h	18
PM_{10}	50	24 h	35
	40	1 year	–
SO_2	350	1 h	24
	125	24 h	3
	40	1 year	–

Fig. 3 Highest concentration of the year around Athens International Airport



3.3 Estimated Exceedances

In all three airport cases, NO_2 was the only pollutant with its maximum concentrations approaching or sometimes exceeding limit values, while all other pollutants were found in concentrations many times lower than the corresponding limit values. In the areas of SKG and ATH, the NO_2 hourly limit value (200 μg/m^3) is exceeded several times, mainly in July and August. However, these exceedances occur in small areas downwind of the airports. In the area of HER, NO_2 levels are quite lower and exceedances of limit values are scarce.

3.4 Frequency of High Concentration Events

As the analysis of air pollution in the area the three airports has been focused on the most adverse situations, i.e., those with the higher concentrations, there is a point in finding out how often these situations are expected to occur. To this aim, the maximum NO_2 concentrations, for all 1488 h of July and August (the busiest months in Greek airports), have been collected and classified as shown in the histograms of Fig. 6.

The above histograms indicate that the relative frequency of very high levels (exceeding or close to limit values) is quite

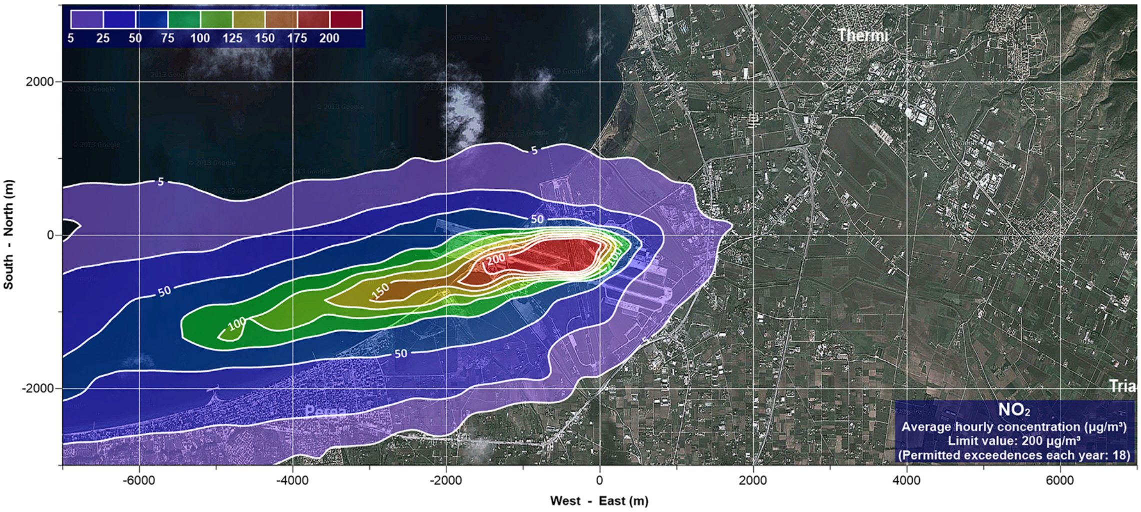


Fig. 4 Highest NO_2 concentration of the year around Thessaloniki International Airport

low, despite the intense use of the airports and the consequent intense emissions. Levels from 0 to 150 μg/m^3 cumulatively hold around 80% of the processed hours. This finding is in line with a work that calculated typical concentration of NO_2 around Athens International Airport [36].

An aspect that may draw attention is that higher NO_2 levels are considerably more frequent in Thessaloniki than those in Athens, despite the higher emissions at the latter airport. This is attributed to the difference in dispersion conditions: in SKG, the higher frequency of low wind speeds (below 2 m/s) delays the dispersion of emitted pollutants and leads to higher concentrations despite the lower emissions, while the frequently occurring winds with speeds above 3 m/s in ATH favor the dispersion of emitted pollutants in such a way that concentrations remain well below SKG's respective NO_2 levels. This explanation, i.e., the dominance of dispersion conditions over the emission rates in defining the final concentration levels, is confirmed by the case of Heraklion. There, similar emission rates as in SKG, lead to considerably lower concentrations because of the higher frequency of medium (3–6 m/s) and high (above 6 m/s) wind speeds.

3.5 Computational Results Vs. Monitoring Measurements

Model results were compared to measurements in the area of the Athens International Airport as it was the only airport with systematic monitoring results. The airport's corporation operates an air quality monitoring network (AQMN) in Mesogia region with five stations as shown in Fig. 7.

The stations of AQMN measure local concentrations, originating both from the airport and other sources, e.g., road traffic or urban pollution originated by metropolitan agglomerations. For example, Spata station is situated in close proximity to a high traffic road, the periphery road of Spata located at the limit of the urban area, while Markopoulo station is installed almost in the center of the city. Thus, measurements from AQMN do not exclusively reflect the influence of the airport, as in other works [37–39]. Nevertheless, a comparison between these two data sets can still give some interesting findings especially in case of limit exceedances.

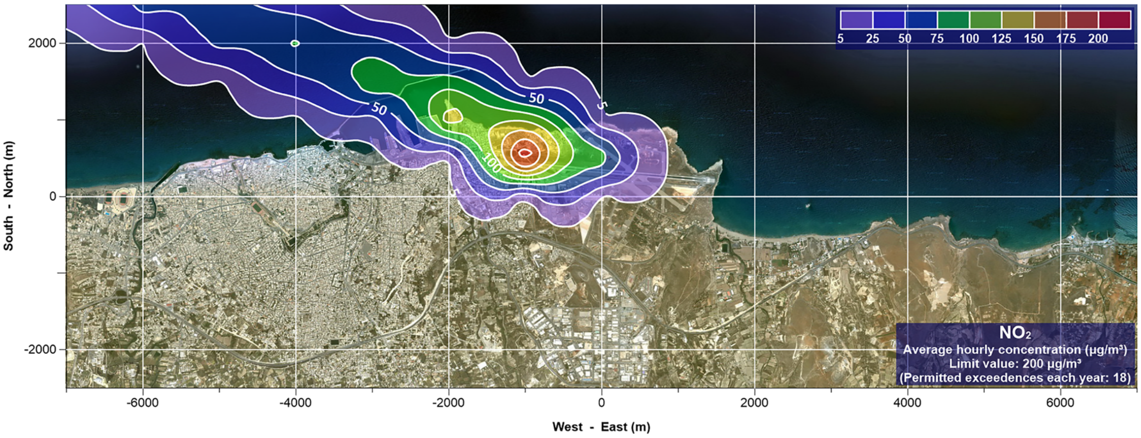


Fig. 5 Highest NO_2 concentration of the year around Heraklion International Airport

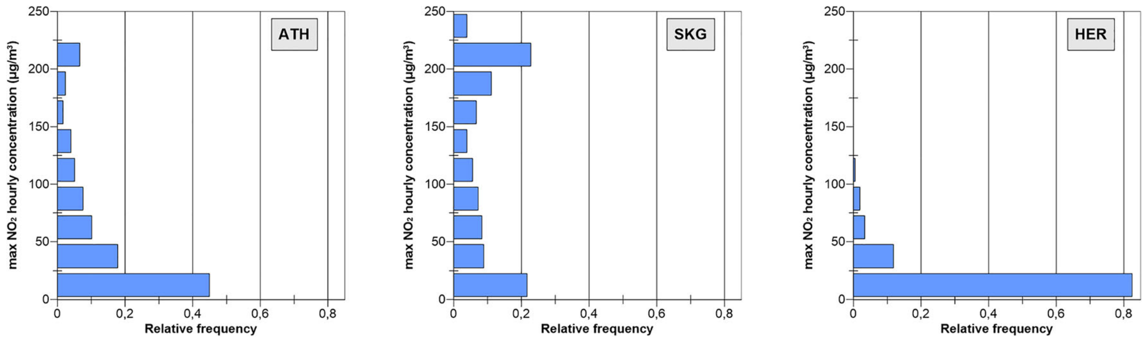


Fig. 6 Relative frequency of maximum NO_2 levels during July and August around the three larger Greek airports

Initially, four of the five stations have been selected to compare computational results with measurements of the AQMN, excluding the one located at the longer distance (AQMN Glyka Nera). EDMS was applied to calculate the concentrations of the main air pollutants for the whole year at the area of the four stations.

Generally, as airport activities are mostly associated with nitrogen oxide emissions, the calculated air quality levels of all pollutants except NO_2 are insignificant and they are not further discussed. The same was observed for the respective measured concentrations with the exception of PM_{10}. More explicitly, regarding CO levels, measurements as well as calculations at all four stations are very low and they are considered negligible. A similar finding is derived for SO_x levels. Measured concentrations, which are quite low too, e.g., 5–9 $\mu g/m^3$ for the Spata station, are mainly connected to other local or distant anthropogenic sources. The corresponding estimated SO_x levels due to airport operation are of the order 1–2 $\mu g/m^3$. For PM_{10} concentrations, measured values range from 20 to 50 $\mu g/m^3$, while the results of EDMS are very low due to the low corresponding emissions. This difference confirms that particulate matter in East Attica, which mainly originates from road traffic, residential and commercial activities, and natural sources [40–42], cannot be related to the operation of Athens International Airport and it will not be further examined. Therefore, in the analysis to follow, nitrogen dioxide is taken into account as this pollutant is mostly associated with the airport operation whereas it is also strongly connected to road traffic and residential heating emissions. Finally, no measurable influence due to the airport emissions was detected for the stations of Koropi, Markopoulo, and Pallini (Fig. 7), most probably due to their relatively longer

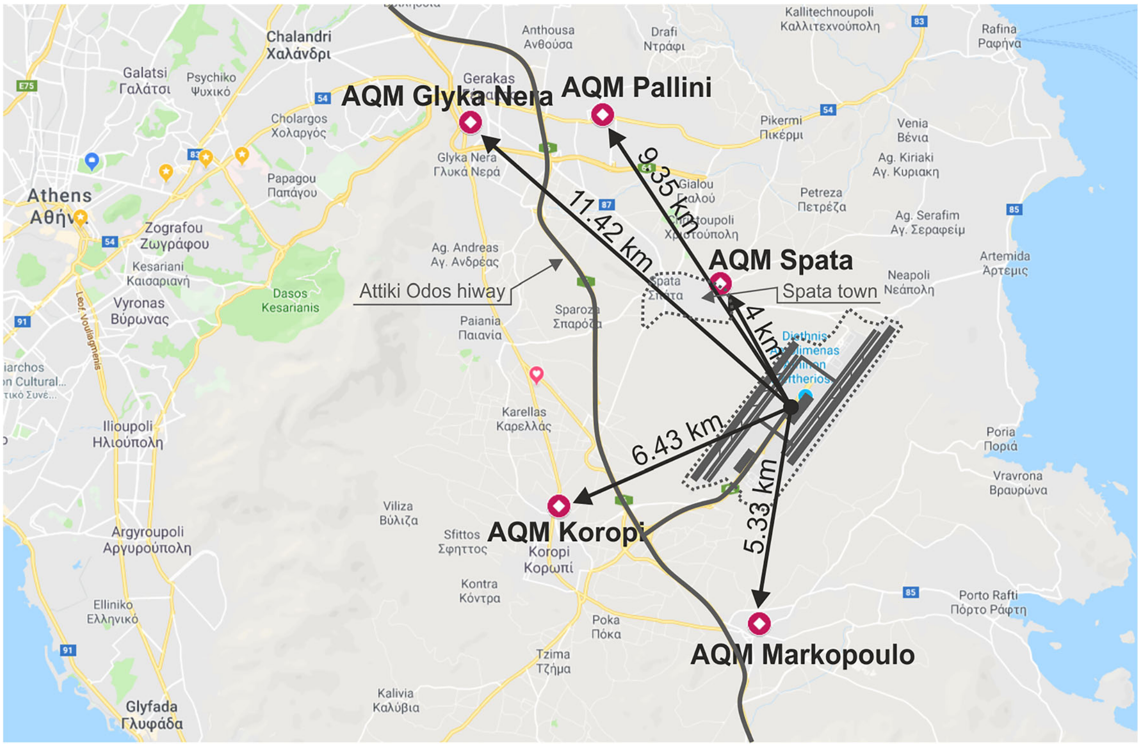


Fig. 7 The stations of AQMN

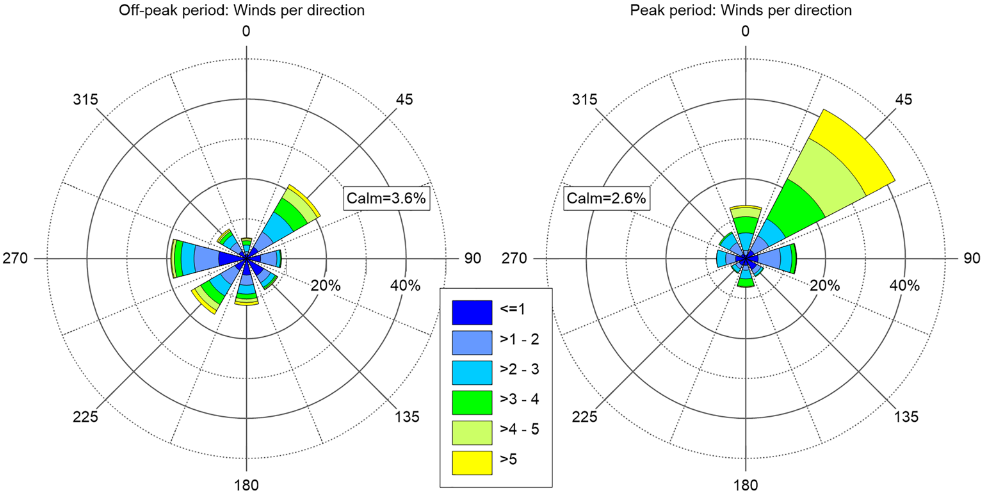


Fig. 8 Wind rose diagram for the area of Spata (peak and off-peak periods)

distance from the airport. Except from the distance, the above finding is further confirmed by the wind rose (Fig. 8) showing low frequencies of wind directions favoring air masses transfer from the airport towards these areas. Only the station of Koropi would be expected to be influenced due to the prevailing northeastern winds; still, in this case, apparently the distance from the airport predominates. As a result, the station of Spata is the only one taken into account in the analysis to follow.

3.5.1 Off-Peak Period

For the off-peak period of the year (January to June and September to December), mean hourly measured and calculated NO_2 concentrations for all wind sectors are presented in the rose diagram of Fig. 9. As shown in the rose diagram, the higher mean measured hourly concentrations occur for western winds suggesting that air masses rich in air pollutants from the Greater Athens Area and probably also from Attiki Odos, the highway crossing Attica from east to west, contribute significantly to NO_2 levels at the area of Spata. At the east and north of the area of Spata, no emission sources are located and hence, it is considered that mean NO_2 levels for northern and eastern winds are mainly associated with local sources and they represent the area background for the off-peak period (11–13 μg/m^3). Finally, winds originating from south-east and south transfer air masses from the area of the airport and hence, in this case, the corresponding measured NO_2 levels should be associated with air traffic. By subtracting the background concentration, occurring for northern and eastern winds, from the mean hourly concentrations occurring with southern and southeastern winds, it is concluded that the airport contribution in the Spata area is of the order 15 μg/m^3. This finding is in agreement with the respective calculated mean hourly NO_2 concentrations for the south and south east wind sectors.

The above results verify that, in the absence of other pollution sources, the model simulates realistically NO_2 levels associated with the airport operation.

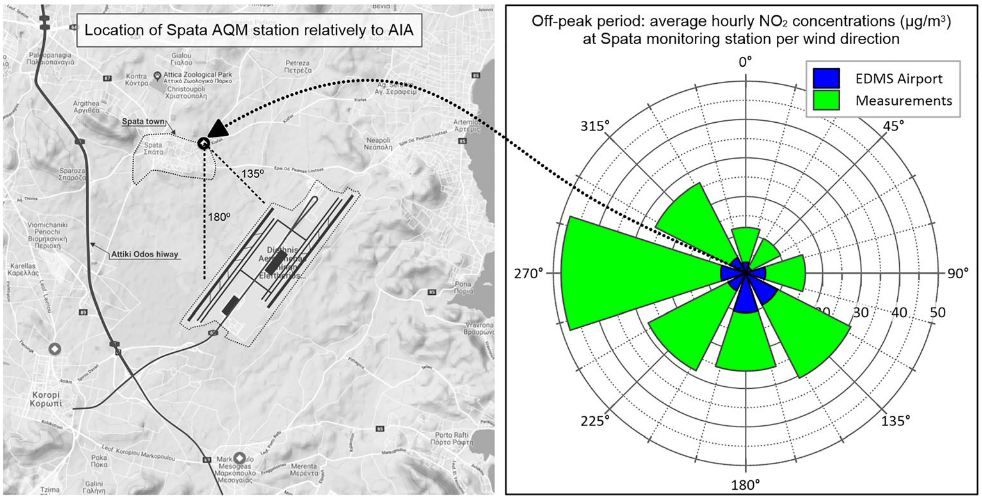


Fig. 9 Rose diagram of the measured and calculated NO_2 concentrations in Spata (off-peak period)

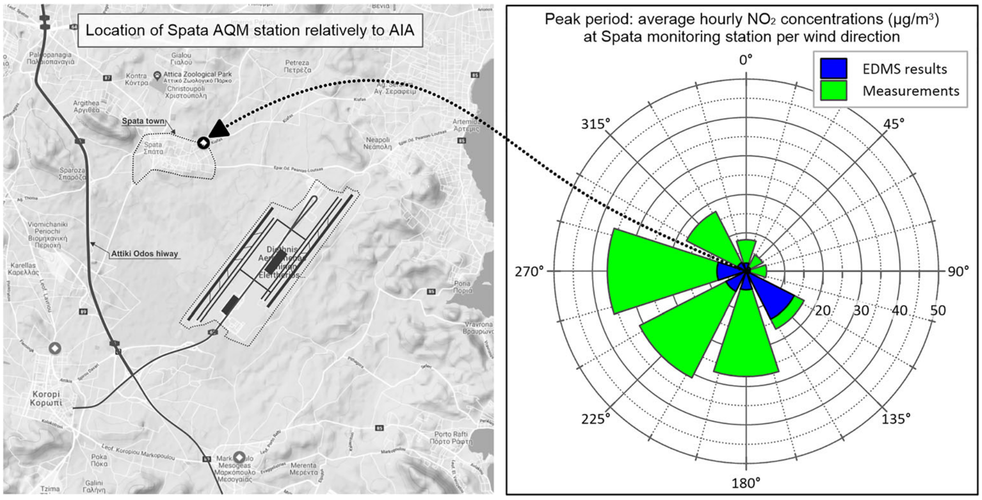


Fig. 10 Rose diagram of the measured and calculated NO_2 concentrations in Spata (peak period)

3.5.2 Peak Period

The analysis below focusses on the two busiest months, July and August. A rose diagram for this period of the year was constructed (Fig. 10) for the measured and calculated average hourly NO_2 concentrations for each wind direction. Similarly to the off-peak period, the rose diagram shows that the measured average hourly NO_2 levels for southern and southeastern winds, which are associated with the airport operation, range from 17 to 28 $\mu g/m^3$. Taking into account that the background NO_2 levels, those measured for northern and eastern winds, are of the order 5–8 $\mu g/m^3$, it can be concluded that the contribution of the airport to the average hourly NO_2 levels in Spata is of the order 10–20 $\mu g/m^3$. This finding is partly verified by EDMS calculations as shown in the wind rose diagram for southeastern winds, whereas for southern winds, calculated NO_2 levels are well below the corresponding measurements.

4 Conclusions

In this work, a thorough assessment of air pollution related to air traffic, in the vicinity of the three larger airports of Greece (Athens, Thessaloniki, and Heraklion), was carried out. Scientifically approved and validated models and real-life input data that allowed for the computational determination of air pollutants' emissions and concentrations in the vicinity of the airports for realistic scenarios were used. This approach, which is applied for the first time to the particular airports, is different from the usual "worst theoretically expected scenario" (that usually appears in environmental impact studies) and has produced realistic results that quantifies the contribution of each airport to local air pollution levels. These results can be used in decision-making procedures for improving air quality in the affected area of each airport and are also useful in clarifying the extent at which each airport influences local air quality. It must be reminded that the main purpose of this work is focused on assessing air quality in the area of each of the three examined airports, using a detailed and realistic approach, similar to many other works for airports across Europe and the USA. Emission/dispersion models like EDMS, which in most cases do not account for photochemistry effects, are suitable for this type of local assessments, due to the small timescale, height, and range of the impacts. These local range assessments are useful because each airport affects local air quality levels in a different way. For example, as we described above, SKG and HER serve similar number of flights each year but cause significantly different air pollutant concentrations and, hence, the mitigation measures must be adjusted to each particular case. The local level of decision-making is different from the nationwide or global policy making for aviation, the latter being supported by works that refer to large/global-scale phenomena [43–46].

The EDMS model that has been used to compute air pollutants' emissions and concentrations is recommended by the US EPA and is widely used for airports. The real meteorological records for 2009 and the detailed air traffic data and corresponding aircraft types for this year, during which air traffic in Greece reached its peak, were used as input to EDMS. Results were acquired for the whole year, but the analysis focused on the two busiest months, July and August, when the most intense emissions occurred.

Of course, the model used in the framework of this study is not a 3-D photochemical dispersion model. However, in terms of air pollutant emissions, it is comprehensive and accurate based on detailed statistical data and measurements. In terms of air pollution levels, as shown from the discussion in Section 3.5, it provides a realistic approach of the airports' impact in the surrounding areas and it can be used operationally, in contrast to the time demanding and CPU-consuming 3-D photochemical dispersion models which can provide useful and detailed knowledge in the framework of a research study and not on a regular basis.

Emission results show consistency for all three airports in this work and with results of previous works, taking into account the different aircraft mix and the simplifications of various modeling approaches. In particular, for NO_x which is the main airport pollutant, there is a rough linear relation between emissions and annual flight number, starting from 3.80 kg/LTO for SKG, 4.75 kg/LTO for ATH, and 5.13 kg/LTO for HER.

Concentration results have shown the expected variation, ranging from zero, when air traffic was low, to relatively high concentrations during periods with high traffic and meteorological conditions favoring air pollution accumulation. PM_{10} and SO_x concentrations are well below the limit values, and the only pollutant that may exceed existing limits is NO_2. Concentrations exceeding NO_2 limit value are expected only in small areas and under specific circumstances, when heavy air traffic coincides with meteorological conditions favorable for high pollution levels. However, such conditions are not often expected and, according to the model results, occur a few times, much less than 18, which is the maximum number of exceedances allowed according to the EU air quality standards. It has to be stressed that these high values appear mainly close to the airports and do not seem to affect residential areas.

Finally, the comparison of model results to air quality measurements in the Athens airport shows clearly that local source emissions mostly influence measured concentrations, which is in agreement to the model findings that air pollution from airports is limited in the very close to the airport area and does not affect larger areas.

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