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Particulate matter pollution from aviation-related activity at a small airport of the Aegean Sea Insular Region

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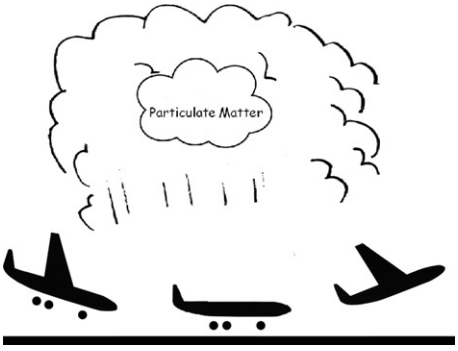
HIGHLIGHTS

- Aviation activity accounted for up to a 10-fold increase TSP mass concentration.
- Elemental analysis showed that aircraft emissions are the dominant source of PM.
- Particle number concentrations increased by 2 orders of magnitude during take-offs.
- Mean particle size dropped from 70 to 20 nm during due to aircraft activity.

GRAPHICAL ABSTRACT



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ABSTRACT

The unprecedented growth in aviation during the last years has resulted in a notable increase of local air pollution related to airports. The impacts of aviation on air quality can be extremely high particularly around airports serving remote insular regions with pristine atmospheric environments. Here we report measurements that show how the atmospheric aerosol is affected by the activity at a small airport in a remote region. More specifically, we provide measurements performed at the airport of Mytilene, Greece, a regional yet international airport that serves the entire island of Lesvos; the third largest island of the country. The measurements show that the activity during landing, taxiing and take-off of the aircrafts accounted for up to a 10-fold increase in particulate matter (PM) mass concentration in the vicinity of the airport. The number concentration of particles having diameters from 10 to 500 nm also increased from ca. 4×10^2 to 8×10^5 particles cm^{-3}, while the mean particle diameter decreased to 20 nm when aircrafts were present at the airport. Elemental analysis on particle samples collected simultaneously at the airport and at a remote site 3 km away, showed that the former were significantly influenced by combustion sources, and specifically from the engines of the aircrafts. Our results show that despite their small size, local airports serving remote insular regions should be considered as important air pollution hotspots, raising concerns for the exposure of the people working and leaving in their vicinities to hazardous pollutants.

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1. Introduction

Insular areas around the globe tend to be attractive destinations, partly due to their clean atmospheric and maritime environment. Airports that are located on islands get quite busy during the warm seasons due to the growing numbers of arriving and departing travellers. Air traffic, together with supporting ground services, during the periods of high activity, can therefore become important pollution sources. As a result, they can impact air quality and entail a health hazard to workers, nearby residents and travellers (Pedersen et al., 1999).

In view of the potential health effects related to aviation, a number of studies have looked into the combustion emissions from aircraft engines (e.g. Knighton et al., 2007; Onasch et al., 2009; Beyersdorf et al., 2012; Williams et al., 2012). The consensus of these studies is that the major pollutant when aircraft engines are running in idle and very low thrust (i.e. when the planes are parked or they taxi to/from the runway) is unburned fuel, whereas at higher engine speeds carbonaceous particulate matter (PM) consisting of elemental and organic carbon are more dominant. Mazaheri et al. (2011) more specifically showed that the ground emissions from an airplane depend on the operating modes during landing and take-off (LTO) and ground running procedures (GRP), which are primarily defined by the power required from the engines of the aircraft: 4% thrust in idle, 7% thrust during taxiing, 30% thrust in the approach, 65% thrust in cruising, 85% thrust during climb out, and 100% thrust during take-off. Overall, Anderson et al. (2006) estimated that aromatic species accounted for >50% of the total aircraft emissions, while Knighton et al. (2007) and Cross et al. (2013) found that 10–20% of the total hydrocarbon emissions were volatile organic compounds.

Most of the studies investigating air pollution emissions from grounded aircraft published thus far focus on airports that serve major cities. Yu et al. (2004), for instance, estimated that aircraft emissions nearly double sulphur dioxide (SO_2) concentrations near Hong Kong International Airport. Carslaw et al. (2006) found that concentrations of nitrogen oxides (NO_x) are increased by up to 15% at areas around the London Heathrow Airport due to the emissions from the airplanes and the ground activities. More recently, Dodson et al. (2009) showed that aircraft activity contributed ca. 25% of the total black carbon (BC) at sites in the proximity of a small regional airport near Warwick, Rhode Island, whereas Hudda and Fruin (2016) and later Shirmohammadi et al. (2017) reported a minimum 2-fold increase in particle number (PN) concentrations in a large area around the Los Angeles International Airport.

In contrast to the large airports, studies focusing on mid-sized or small regional airports are surprisingly scarce (cf. Kesgin, 2006; Lu and Morrell, 2006; Klapmeyer and Marr, 2012; Hsu et al., 2014), despite the fact that they are visited by hundreds of thousands of people annually. What is more, real-time measurements of particle size distributions and chemical composition associated with aircraft emissions in airports are very limited. As a result, we are still lacking important information for understanding how the properties of PM from grounded aircraft emissions, as well as the contribution of the local meteorological conditions, affect regional air quality.

Here we evaluate the contribution of the emissions from aircrafts and ground services at the small-scale international airport of Mytilene, Greece, to local air quality. More specifically, we report measurements of the PM mass concentration, as well as the size distributions and chemical composition of particles observed in and at the vicinity (ca. 3 km away) of the airport. The sampling was conducted from 22 July to 11 August 2014 when the touristic period, and thus aircraft activity, was at its peak.

2. Experimental

2.1. Location

Fig. 1 shows a map and an aerial photograph of our study area with the locations of the sampling stations marked on it. The airport of Mytilene (39°02′57″N, 26°36′23″E, 8 m above sea level) is located ca. 8 km south of the city. Its runway is 2.4-km long and is adjoined by a taxiway where aircrafts stay only for a short period of time (30 to 60 min). Depending on their schedule, some of the aircrafts are also being refuelled during their short stay at the airport; a process in the GRPs that is a major contributor to overall emissions related to the aviation activities (Amato et al., 2010; Hsu et al., 2013; Schlenker and Walker, 2016).

In 2014, the airport of Mytilene served >5.5 thousand flights and 460 thousand passengers according to the Hellenic Civil Aviation Authority (HCAA, 2015). On average 10 domestic regular flights were served daily during the cold period (November to April), while the number increased to ca. 15 flights/day during the warm period (May to October), with many international charter flights being added to the workload. More than 45% of the annual flights and 55% of the annual number of passengers were served between June and September (cf. Table S1 in the supplement).

2.2. Instrumentation

The monitoring station where all instruments were deployed was within the premises of the airport, ca. 300 m away from the aircraft parking area and ca. 50 m from the runway. For reasons of comparison, samples of the PM were also collected at a remote station (39°01′09″N, 26°36′35″E, 150 m above sea level) on a hill ca. 3 km away from the airport (cf. Fig. 1a).

Meteorological conditions including wind speed, wind direction, temperature and relative humidity were acquired from the meteorological station of the airport throughout the entire sampling period. The concentration of particles having diameters larger than 2.5 nm was measured by an ultrafine Condensation Particle Counter (uCPC; TSI Model 3775) with a 3-min time resolution. A Scanning Mobility Particle Sizer (SMPS; TSI Model 3034) was used to measure the size distribution of airborne particles having diameters between 10 and ca. 500 nm, also with a 3-min time resolution. Total Suspended Particle (TSP) samplers operated at 28 lpm were used at the main and at the remote station to collect samples on pre-treated filters (Whatman QM-A quartz; 47 mm in diameter; Part No. 1851-047). The filters were placed in a single-stage, stainless-steel holder and were changed every 8 h. Before and after sampling, the filters were weighted to determine the mass concentration of the suspended PM (Triantafyllou et al., 2016a). After gravimetric analysis, the filter samples were analyzed for trace metals using a high-resolution energy dispersive X-Ray fluorescence spectrometer (PANanalytical Model Epsilon 5; Emmanouil et al., 2016; Margui et al., 2012). Ambient air was delivered to the instruments through a 5-m long conductive silicone tube having an internal diameter of 8 mm. The inlet of this tube was at 1.7 m above ground (breathing height). All the instruments employed in this work are listed in Table S2 in the supplement.

3. Results and discussion

3.1. Meteorological conditions

The winds during the sampling period were typical of the Mediterranean summer. As shown in Fig. 2, the prevailing winds had a N to NW direction (45% frequency) with wind speeds ranging up to 8.2 m/s, which are characteristic of the Etesian wind patterns observed in the region during the summer period (Kotroni et al., 2001; Poupkou et al., 2011; Tyrlis and Lelieveld, 2013; Tombrou et al., 2015; Triantafyllou et al., 2016b). From those cases, 19% exhibited light wind speeds between 1 and 3 m/s, 33% exhibited gentle wind speeds between 3 and 5 m/s, and 44% exhibited moderate wind speeds between 5 and 7 m/s. Calm conditions (i.e. average wind speed <1 m/s) were observed ca. 22% of the entire sampling period. The average ambient temperature and relative humidity were 29 ± 3 °C and 55 ± 12%, respectively.