

Effect of anthropogenic sources on total particles and Cloud Condensation Nuclei levels in the Eastern Mediterranean

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Abstract

The absorption and scattering of radiation by atmospheric aerosol particles, especially those originating from anthropogenic activities, is a key component of anthropogenic climate change. Aerosol particles also act as cloud condensation nuclei (CCN) “indirectly” forcing climate through the modification of cloud properties and precipitation efficiency. The activation of particles to form CCN depend highly on particle size and chemical composition and differs upon location and proximity to sources. Particle number size distributions, aerosol chemical composition and CCN measurements were performed at two sites in the Eastern Mediterranean, namely a remote background site at Finokalia, Crete and an urban background location downtown Athens, Greece. The aim of the study is to characterize the levels and distribution of total aerosol particles (CN) and CCN in the different environments and analyse the role of anthropogenic sources in the measured levels.

Keywords: Cloud Condensation Nuclei, Urban, Remote Background, Anthropogenic Sources

1. Introduction

Aerosol particles are both primarily emitted in the atmosphere from natural and anthropogenic sources and also secondarily formed by processes that include the partitioning of semi-volatile components between the gas and the aerosol phase, such as condensation and nucleation (Hofman et al., 2016). It is clear that depending on the environment and the proximity to sources, particles may exhibit significant differences in their number size distribution as well as their chemical composition, which directly impacts on their ability to act as CCN and ultimately as cloud droplets.

2. Methodology

Measurements of cloud condensation nuclei concentrations at 5 different levels of supersaturation (0.2, 0.38, 0.52, 0.66, 0.73 and 1.00%) were conducted using a Droplet Measurement Technologies (DMT) constant flow streamwise thermal-gradient CCN counter (CFSTGC; Roberts and Nenes, 2005) at both locations for a yearlong period with the aim to perform a “closure” study between measured and estimated CCN levels. Köhler theory is subsequently used using particle number

size distributions and chemical composition in order to estimate CCN levels during specific events when no direct CCN measurements exist. At Thissio, a TSI Scanning Mobility Particle Sizer (SMPS, 3034) was used to measure the size distribution of particles with diameters from 10.4 to 470 nm (scanned range), with a 5 min time resolution. The measured number size distributions by the SMPS, were inverted using the Aerosol Instrument Manager software (AIM, TSI version 6.0), including the correction for multiply charged particles. The Finokalia station operates a TROPOS type custom-built SMPS (Wiedensohler et al., 2012) for measuring the size distribution of aerosol particles with diameters from 9 to 848 nm, every 5 min, as well. Bulk aerosol chemical composition of PM₁₀ at Finokalia was measured in parallel with the size distributions using daily 24-h quartz fiber filters (PALL Tissuquartz, 2500 QAT 47 mm). Samples were examined for water-soluble ions after extraction with nanopure water. At Thissio, mass and chemical composition of non-refractory submicron aerosol particles were provided by an Aerodyne Research Inc. Aerosol Chemical Speciation Monitor (ACSM; Ng et al., 2011), with a 30 min time resolution.

3. Results and Discussion

3.1. CCN Measurements

CCN levels measured at the two locations indicate that CCN concentrations in Athens during winter are almost 5-fold higher than the respective ones at Finokalia, and this is attributed to the additional anthropogenic sources in a large urban center such as Athens. Additionally in Athens, CCN particles increase significantly with increasing supersaturation, which shows that in the urban environment there is a much larger amount of small particles which activate at higher supersaturation levels. These particles may originate from combustion sources such as traffic or biomass burning, from which emissions are enhanced during wintertime. These particles may be less hygroscopic than larger, more CCN-active particles and require higher level of supersaturation in order to activate and grow to CCN-relevant sizes.

3.2 Impact of anthropogenic sources

From the measured particle number size distributions, particle number concentrations for Aitken mode (25–100 nm) and accumulation mode (>100 nm) are calculated for both sites. At Finokalia, Aitken and accumulation mode particles were of 386 ± 305 and $1,506 \pm 1,107 \text{ cm}^{-3}$ while at Thissio the concentrations are remarkably higher and the respective values were of $1,435 \pm 412$ and $5,517 \pm 1,893 \text{ cm}^{-3}$. Figure 1 depicts the mean diurnal variability of nucleation-mode ($\leq 25 \text{ nm}$) particles at both measurement sites. A clear seasonal trend is observed at both sites, with a burst of particles taking place around noon, consistent with NPF events, with corresponding peaks being observed earlier during spring and summer, accordingly to the solar irradiance cycle. Higher concentrations are observed during winter at both sites with concentrations at Athens being once more almost 5-fold higher. As expected, in Athens the particles in nucleation mode shows a dominant profile peaking during the morning between 7:00 and 9:00 LT, which is consistent with the morning rush hour. Also, during winter at Athens there is

a peak between 18:00 and 20:00 LT, which could be attributed to local combustion sources, emitting ultrafine mode particles in the urban atmosphere.

4. Conclusions

Total particle (CN) and CCN concentrations were monitored at two different environments in the Eastern Mediterranean, a remote background site in Crete and an urban location in downtown Athens in order to investigate the contribution of anthropogenic sources. It occurs that aerosol particle levels are significantly higher at the urban location, both for CN and for CCN. Levels are even higher during wintertime, when additional anthropogenic emissions dominate the urban atmosphere, contributing a large number of ultrafine particles ($\leq 100 \text{ nm}$) from sources such as central heating and biomass burning systems for heating purposes. These sources may contribute to an almost 5-fold increase in particle concentrations compared to the background conditions.

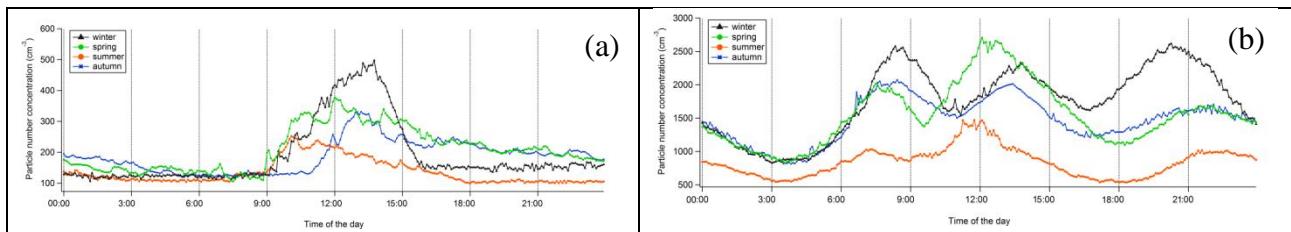


Figure 1. Average diurnal variation of nucleation mode ($\leq 25 \text{ nm}$) particle number concentration at **(a)** Finokalia, and **(b)** Thissio, over the period August 2015–August 2016.

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