The effect of Boundary Layer Meteorology in GHGs concentrations –The case study over 3 European cities using an aerial platform

Maggos T.[1,*], Flocas H.[2], Soulos T.[3], Lenarcic M.[4], Panagopoulos P.[1], Gotti A.[5], Karakitsios S.[5] ,Sarigiannis D.[5]

1 Environmental Research Laboratory, INRASTES, NCSR "Demokritos", Athens, Greece

2Department of Physics, Section of Environmental Physics –Meteorology, University of Athens, Greece

3Artemis S.A Lefkipos Technological Park, Athens, Greece

4 AEROVIZIJA d.o.o, Ulica Ivane Kobil SI-1000 Lubljana, Slovenia

5 Environmental Engineering Laboratory, Department of Chemical Engineering, Aristotle University of Thessaloniki, Greece

*corresponding author: e-mail: tmaggos@ipta.demokritos.gr

Abstract

In the frame of an EC Horizon 2020 project named "ICARUS" (Integrated Climate forcing and Air pollution reduction in Urban Systems), a newly constructed N.A.S.A Awarded light aircraft equipped with high-tech scientific instrumentation was used to perform an aerial mapping over Athens, Thessaloniki and Ljubljana greater Area. The main goal of the current study was to evaluate the effect of atmospheric boundary layer (ABL) on Green House Gases (GHGs) concentrations over three different areas of the cities. Detailed meteorological information were provided by aircraft instrumentation, radiosonde data as well as regional modelling results available from the Atmospheric Modelling group of University of Athens. The estimation of the mixing height of the ABL was based on the synoptic scale atmospheric circulation and the prevailing background wind. It was generally found that the mixing height variation following the prevailing meteorological conditions results in different concentration profiles in the lower troposphere over the examined regions.

Keywords: GHG, boundary layer meteorology, mixing height

1. Introduction

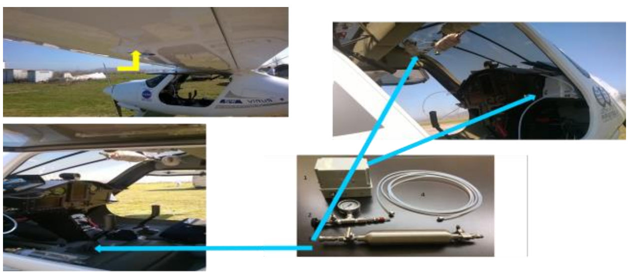
Several studies regarding the air quality in European cities have been conducted but nearly all of them consist of surface monitoring [Kocak et.al 2012, Saraga et.al 2015]. Due to limits of facilities and budget very little aircraft-based studies have been performed in order to monitor and study vertical and spatial variation of air pollution and GHGs [Geng et.al 2009, Tombrou et.al. 2015]. The advantages of in-situ aircraft measurements can provide information for the horizontal and vertical distributions of air pollutants and gases in a large spatial area and for the gradients between cities and rural regions. These measurements are necessary in order to better understand the characterizations of air pollutants and GHGs not only in the cities but also in their surrounding areas.

With the view to investigate the spatial and temporal variability of GHGs in the lower troposphere over and inside the BL, aircraft-based GHGs measurements were conducted for the first time over 3 South European cities during both summer and winter period in 2017.

The objective of this study is to investigate the role of the atmospheric boundary layer on the GHGs airborne concentration under different meteorological conditions over the examined regions in winter and summer.

2. Methodology

The design of the aerial survey campaign includes, in each one of the three cities, the performance of 5 flights (inside and over the mixing height layer; approximately 1500 and 4000 ft, respectively) under three different weather conditions that were selected as the most critical in terms of pollution for each site (e.g. for Athens: sea breeze, north winds and calm focused on biomass burning periods).



Picture 1. LMA sampling configuration

The winter and summer period aerial campaigns took place during February– March 2017 and April-September 2017 respectively. The estimation of the mixing height of the ABL was based on the synoptic scale atmospheric circulation and the prevailing background wind.

The Light Man Aircraft (LMA) named Pipistrel which is designed as an aerial platform of sensing environmental data, was operated above the three selected ICARUS cities providing selected GHGs (CO_2, CH_4, N_2O, SF_6), at different height. NCSRD equipped the LMA with the appropriate sampling instrumentation while sampling performed through inlets located under the wing. Stainless steel canisters were filled with pressurized air using a special design pump in terms of shape and dimensions as well as its capability to pressurize sampled air up to 2 bars (Picture 1). Samples were analysed using a specially designed greenhouse gas analyser (THERMO G.A.S GC/FID/ECD) installed at NCSRD for high-precision concentration measurements.

In winter, the aerial campaign took place over Athens and Thessaloniki. In **Athens**, two flights were performed over the three selected monitoring locations (urban, suburban, regional). The sea breeze development was the main characteristic of 22/2/17 while the Northerly wind regime was prevalent on 25/2/17. Six samples of GHGs were collected above the mixing layer and another six samples within the mixing layer. In **Thessaloniki,** two winter flights were performed over the three selected monitoring locations (urban, suburban, regional). Northerly winds prevailed on 2/3/17 while the sea breeze developed on 21/3/1. Six samples of GHGs were collected above the mixing layer and another six within the mixing layer

In **summer** the aerial campaign took place over Athens, Thessaloniki and Ljubljana. **In Athens**, three flights were performed over the three selected (urban, suburban, regional) monitoring locations. The sea breeze developed on the 22/5/17 while Northerly wind prevailed on 15/6/17 and 21/6/17. Nine samples of GHGs were collected above the mixing layerand another nine within the mixing layer. In **Thessaloniki**, three summer flights were performed over the three selected different (urban, suburban, regional) monitoring locations. Northerly winds predominated on the 13/5/17 while the sea breeze developed on 9/6/17 and 4/7/2017. Nine samples of GHGs were collected above the mixing layer and another nine within the mixing layer. In **Ljubljana**, two summer flights were performed over the two selected different (urban, regional) monitoring locations. Southerly winds prevailed on the 25/9/2017 and 26/9/2017. Six samples of GHGs were collected above the mixing layer

3. Results and Discussion

Key results in terms of concentration levels of GHGs and VOCs above and within the atmospheric mixing layer are presented on **Table 1** and **Figure 1**. Concentration values within the mixing layer showed slightly higher values for all GHGs. No significant differences are observed between suburban and traffic site. Due to the large extent of sampling area covered by the aircraft we can consider suburban and traffic site as an "over the city" site. Slight differences between rural and "over the cities" concentrations were observed though without a specific trend; slightly higher concentrations were observed during the winter campaigns over all cities.

It was found that the northerly wind in winter forms higher mixing layer, of about 1000 m in winter contributing to the ventilation of the lower troposphere. On the contrary, under southerly wind the mixing height is lower (of 500-600 m) and favours the accumulation of GHCs. The sea breeze, despite the low mixing height allowed the ventilation of the coastal areas while increased concentrations are observed above the ABL.

Table 1. GHGs mean values for both periods over the different sampling sites

Athens	N2O (ppb)		SF6 (ppt)		CH4 (ppm)		CO2 (ppm)	
	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer
Rural	312.3	340.9	11.1	11.3	1.82	1.81	379.5	388.5
Suburban	318.7	332.3	11.4	11.1	1.85	1.84	387.9	385.3
Traffic	319.0	329.1	11.4	11.5	1.83	1.85	386.9	388.0

Thessaloniki	N2O (ppb)		SF6 (ppt)		CH4 (ppm)		CO2 (ppm)	
	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer
Rural	316.8	316.9	10.7	11.2	1.85	1.89	392.5	395.0
Suburban	321.7	316.7	10.9	11.4	1.88	1.88	393.5	397.2
Traffic	317.4	330.1	10.5	11.6	1.86	1.90	392.9	392.7

Ljubljana	N2O (ppb)		SF6 (ppt)		CH4 (ppm)		CO2 (ppm)	
	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer	Over Mix Layer	In Mix Layer
Rural	337	342	10.1	10.5	1.97	2.02	402	406
urban	339	344	10.6	10.5	1.99	2.04	398	416

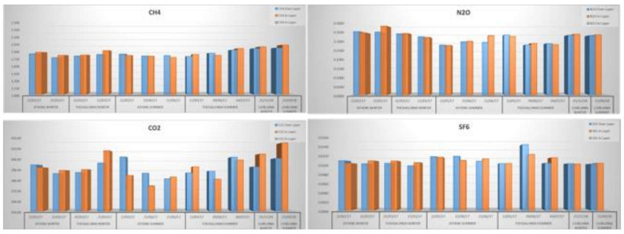


Figure 1. GHGs temporal and height variation over all cities

References

Geng F., Zhang Q., Tie X.,…. And Zhao C. (2009), Aircraft measurements of O3, NOx, CO, VOCs and SO2 in the Yangtze River Delta region (1989), *Atmospheric Environment*, **43**, 584-593.

Kocak M., Theodosi C., Zampas P.,… and Kallos G. (2012). Influence of mineral dust transport on the chemical composition and physical properties of the Eastern Mediterranean aerosol, *Atmospheric Environment* **57**, 266-277.

Saraga D., Makrogkika S., Karavoltsos S…..and Maggos Th. (2015), A Pilot Investigation of PM Indoor/Outdoor Mass Concentration and Chemical Analysis during a Period of Extensive Fireplace U2485-2495 se in Athens, *Aerosol and Air Quality Research*, **15**, 41-48.

Tombrou M., Bossioli E., … and Szabo-Takacs B. (2015), Physical and chemical processes of air masses in the Aegean Sea during Etesians: Aegean-GAME airborne campaign, *Science of the Total Environment,* **506-507,** 201-216.