Project Number 282910

ÉCLAIRE

Effects of Climate Change on Air Pollution Impacts and Response Strategies for European Ecosystems

Seventh Framework Programme

Theme: Environment

D1.5 – Integrated dataset of canopy scale flux and in-canopy gradient measurements at a forest site

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Organisation name of lead contractor for this deliverable : **NERC**

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	☐
PP	Restricted to other programme participants (including the Commission Services)	☑
RE	Restricted to a group specified by the consortium (including the Commission Services)	☐
CO	Confidential, only for members of the consortium (including the Commission Services)	☐

1. Executive Summary

This delivery encompasses the generation of additional campaign-based measurements at the 9-site ECLAIRE flux network, depending on the capability and instrument availability at the individual sites.

Objectives:
To provide a comprehensive integrated dataset of above-canopy fluxes, in-canopy gradients and landscape scale measurements to:

- Quantify exchange processes with semi-natural vegetation in one of the most polluted areas in Europe, the Po Valley.
- Study chemical processing within and above a forest canopy, with emphasis of NO-NO_2-O_3, NH_3-HNO_3-NH_4NO_3 and VOC-O_3 interactions.
- Provide a spatial pattern of pollutant concentration (NH_3, NO_2, O_3, HNO_3) across the Po Valley for spatial assessment and ground truthing of satellite retrievals.

2. Activities:

The study of interactions between chemistry and surface/atmosphere exchange requires the collocation of a larger set of equipment than can be achieved by a single institute. For this purpose an integrated intensive measurement campaign was performed at the Bosco della Fontana, Mantova province, Lombardy, Po Valley, Italy. This formed a key activity of WP1 in the first project year. A total of ten institutes from six countries took part in the campaign. To host this large campaign, UNICATT established a major new 42 m tall measurement walk-up tower with a 100 A mains power supply, in a remnant natural mixed oak-hornbeam forest (*Querco-Carpinetum boreoitalicum*) at the LTER site and nature reserve of Bosco Fontana. Flux measurements were installed on the tower (with most instrumentation placed in two cabins at the base of the tower) and at two nearby in-canopy locations (in-canopy eddy covariance tower & soil chamber flux system). Aerosol concentrations were also measured in a turret of the hunting castle of Bosco Fontana and a ceilometers atmospheric profiling system was operated in the car park of the park office. In addition, weekly passive diffusion samplers for NH_3, NO_2, O_3 and HNO_3 were maintained at various sites around the forest and across the Po Valley. This spatial activity also linked the BF measurements of ÉCLAIRE to concurrent measurements of chemical composition operated by the FP7 project PEGASOS, with supersites at San Pietro Capofiume, in Bologna and at the Monte Cimone observatory, and also serve as ground-truthing of the ÉCLAIRE Earth observation products. The PEGASOS Zeppelin was operated during the period 11-Jun to 9-July out of Ozzano airport near Bologna and visited Bosco Fontana on 3-July.

The measurements attracted additional contributions, partly provided in kind and partly supported marginally by the ÉCLAIRE unallocated budget: Dr Silvana Munzi (Univ. of Lisbon) sampled lichens at the locations of the diffusion sampler network. UGOT, in collaboration with IVL and technically supported by NERC, performed additional aerosol number flux measurements using EEPS, in a pioneering study. The Univ. d'Aquila had agreed to make canopy-scale flux measurements of NO_2 using LIF, but had to pull out at short notice due to concerns relating to the seismic activity in the region at the time. Table 1 summarises the measurements that were performed at Bosco Fontana.

Table 1. Summary of the measurements performed during the ECLAIRE Integrated Po Valley Campaign.

Entity	Instrument	Location	Institute
Aerosol			
Size distributions 5 nm – 20 mm	DMPS / APS	Turret	UHEL / NERC
Size segregated aerosol flux 6-300 nm	EEPS / UHSAS	Tower	UGOTH / NERC
Submicron non-fractory chemistry & fluxes	HR-ToF-AMS	Tower	NERC
Total water soluble inorganic aerosol gradients	GRAEGOR	Tower	NERC / ECN

Black carbon $PM_{2.5}$	Ethalometer	Turret	NERC
Gases			
Reactive inorganic gas gradients (NH_3/HNO_3/SO_2/HCl)	GRAEGOR	Tower	NERC / ECN
VOC concentrations and fluxes	PTRMS / PTR-ToF-MS	Tower	NERC / ULancaster / UHEL / Juelich
In-canopy VOC gradients	PTRMS	Tower	NERC / ULancaster
Leaf-level VOC & CO_2 exchange	Li-COR cuvette	Canopy clearing	CNR / UNICATT
O_3 flux gradients	Chemiluminescence	Tower / in-canopy tower	UNICATT / NERC / INRA(G) / CNR
O_3/NO/NO_2/CO_2/CH_4 concentrations	Gas analysers	Tower	NERC
Soil flux NO/NO_2/O_3/N_2O/CH_4/CO_2	Chambers	Forest floor	KIT
CO_2 / H_2O flux	Li-COR	Tower	UNICATT
NO canopy flux	Ecophysics	Tower	INRA(G)
Diffusion tube network NH_3/NO_2/HNO_3/O_3	Diff tubes	various	NERC / INRA(R) / DHMZ
Satellite retrieval of column NH_3, O_3, CO, HNO_3	IASI	MetOp satellite	UBL
Meteorology			
Turbulence at 5 heights	Sonic anemometer	Tower / in-canopy tower	NERC / UNICATT / INRA(G)
T & RH gradients in & above canopy	RH/T probes	Tower / in-canopy tower	INRA(G) / NERC
Turbulence profile	ceilometer	Park office car park	KIT
Vegetation sampling			
Lichen survey across diffusion tube network		various	Uni. Lisbon

3. Results:

The deliverable is the data themselves, not a full report about the data. Here we outline a few highlights from the database:

a) High quality fluxes of biogenic VOCs are emerging from the analysis of the PTRMS (NERC/Univ. Lancaster) and, as a novelty, of the PTR-ToF-MS (UHel/Juelich). Isoprene emissions were very high (Fig. 1) and agreed well between both instruments. The leaf-level VOC emission measurements clarified that isoprene emissions were dominated by the oaks (*Quercus spp*.), while monoterpene emissions were dominated by limonene from hornbeam (*Carpinus betulus*) and hazel (*Corylus avellana*). The PTR-ToF-MS approach allows a much larger number of compounds to be measured (Figure 2), providing an overall picture of the total VOC flux with this canopy. This is one of the first times that such measurement has been realised.

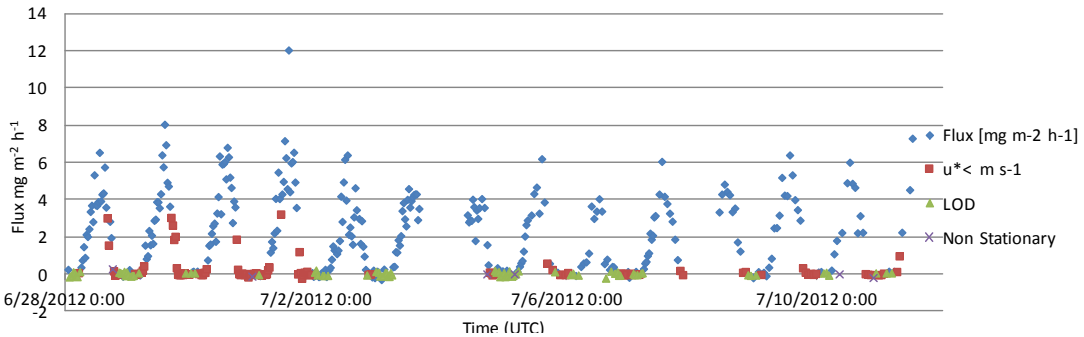

Figure 1. Example time-series of isoprene emission fluxes above Bosco Fontana measured by PTRMS in collaboration between NERC and Univ. Lancaster and with PEGASOS.

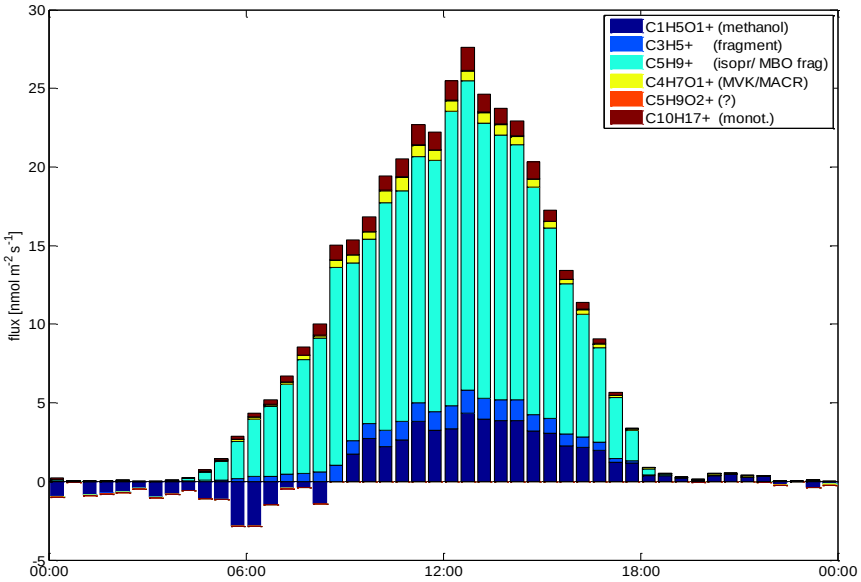

Figure 2. Summary of the total VOC flux resolved by the PTR-ToF-MS, covering more than 40 compounds.

b) Concentrations of inorganic nitrogen compounds in aerosol (NO_3^-, NH_4^+) and gas-phase (NH_3, HNO_3) were very high, also compared with the PEGASOS supersite at San Pietro Capofiume. Flux measurements indicate that the forest is an efficient sink for all these compounds. Flux measurements by Aerosol Mass Spectrometer and GRAEGOR wet chemistry gradient (NERC, ECN) demonstrate that deposition rates of nitrate (Figure 3a) greatly exceeded the efficiency of the physical deposition processes and indicate that much of the NH_4NO_3 evaporates during deposition, increasing its effective removal rate by the forest. And this effect contributes to the decrease in NO_3^- concentration in the morning. The high aerosol deposition rates are also reflected in the size-segregated particle number flux measurements (Figure 3b) by NERC and UGOT.

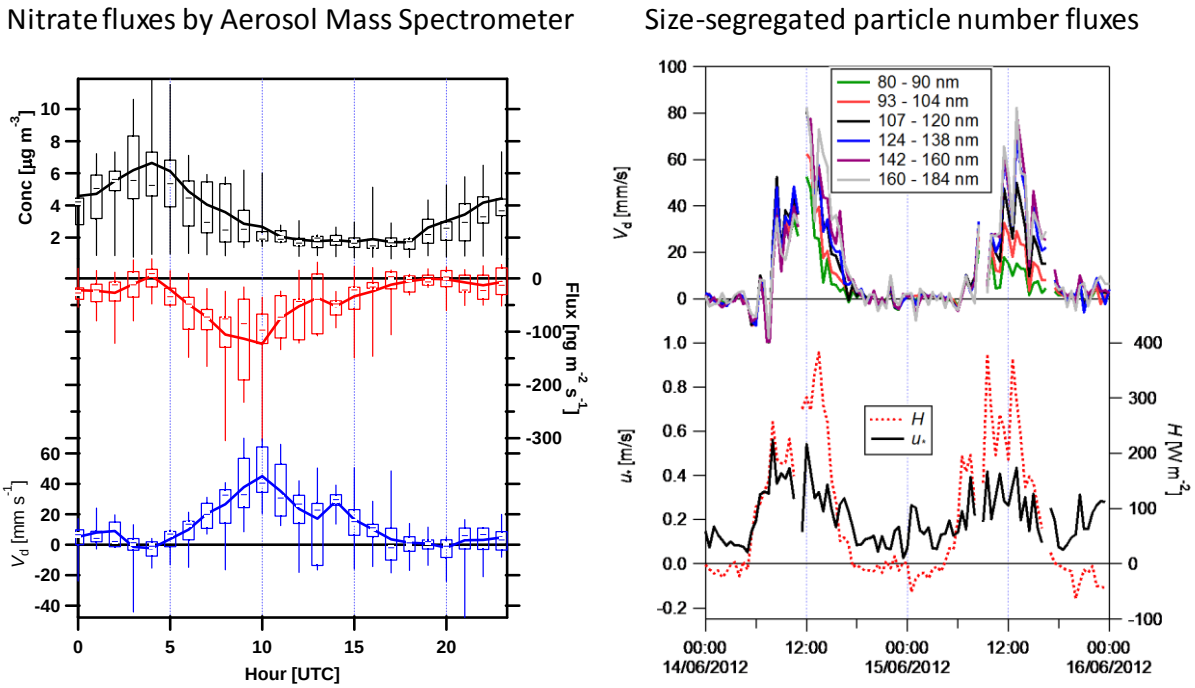

Figure 3. (a) Average diurnal cycles of the concentrations, flux and deposition velocity of aerosol nitrate as measured by the Aerosol Mass Spectrometer flux system operated by NERC. (b) Example time-series of the size segregated deposition velocity derived from particle number fluxes with an optical particle spectrometer (NERC, UGOT), in relation to heat flux (H) and friction velocity (u_*).

c) Mean NO soil emissions at Bosco Fontana site measured by KIT were with 130.2 µg NO m^{-2} h^{-1} extremely high and at the higher end of values found for forest ecosystems (Figure 4). Rewetting of the soil resulted in an extreme increase in NO emissions from around 100 before the rain up to 800 µg N m^{-2} h^{-1} after the rain event. NO_2 deposition to the forest soil was on average 86.5 µg N m^{-2} h^{-1} for the entire observation period. In consequence, the soil of Bosco Fontana forest site functioned as a net source for NOx of about 40 µg N m^{-2} h^{-1}. It must be highlighted, that due to high NO concentrations in ambient air in 15 cm height (mean value: 15.2 ppbv) and taking photo chemical reaction triade between NO, NO_2 and O_3 into account, low ozone mixing ratios of O_3 in ambient air could be detected (mean value: 17.9 ppbv). The laboratory measurements of BOKU (Task 2.1) using soil cores from this site indicate that most of this emission originates from the leaf litter. Above-canopy flux measurements of NO by INRA showed net deposition throughout the campaign, including after the rain. Thus, the NO emitted from the soil is fully converted to NO_2 in the canopy air space. A model will be used to quantify the fractions of the NO_2 taken up by the over-storey and released to the atmosphere, respectively.

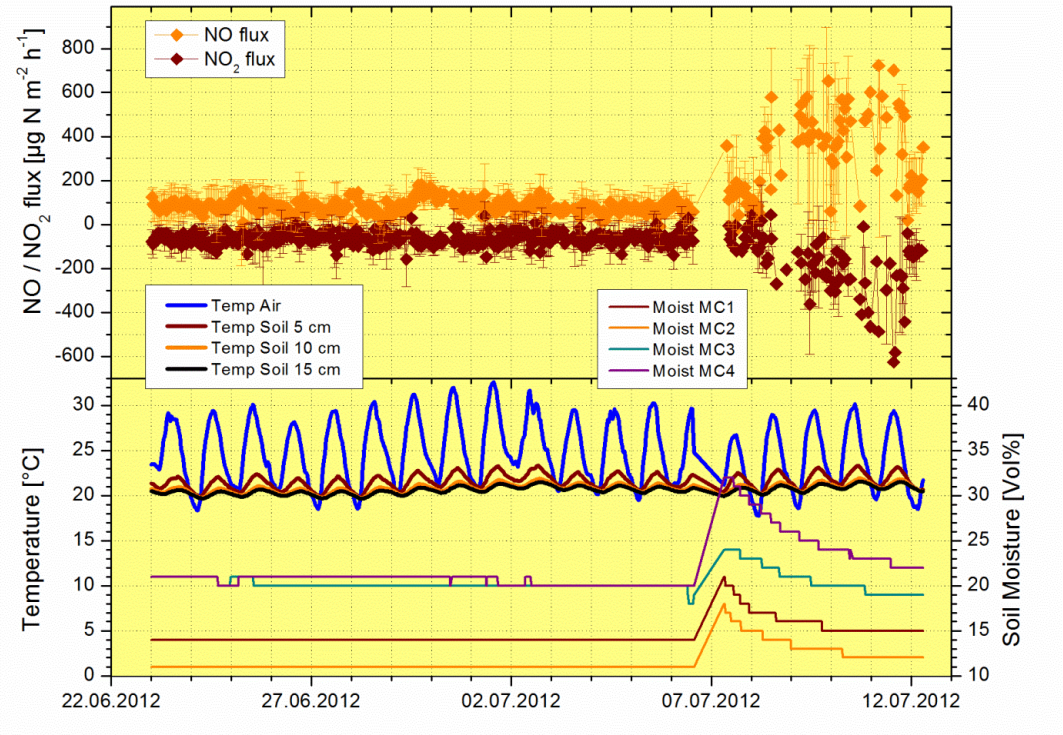

Figure 4. Dynamics of NO and NO_2 flux (± SD) at the soil-atmosphere interface, air and soil temperature across soil profile and volumetric soil water content (0-8 cm) for the period June 22nd to July 12th 2013 at Bosco Fontana Forest site. The increase in the fluxes is related to a precipitation event on 7-July.

d) Comparison of the time-series of column integrated tropospheric concentration of NH_3 derived from the IASI satellite by ULB shows good qualitative agreement in the temporal structure for most of the time, but also some differences (Figure 5), which still remains to be explained fully. The satellite retrievals (also of the other chemical compounds such as CO and O_3) corroborate the findings that Bosco Fontana is situated in a much more polluted area than the PEGASOS supersites at San Pietro Capofiume, Bologna and Monte Cimone. It is now planned to apply high spatial resolution modelling to help link the column measurements of the satellite to the ground-based measurements of diffusion network.

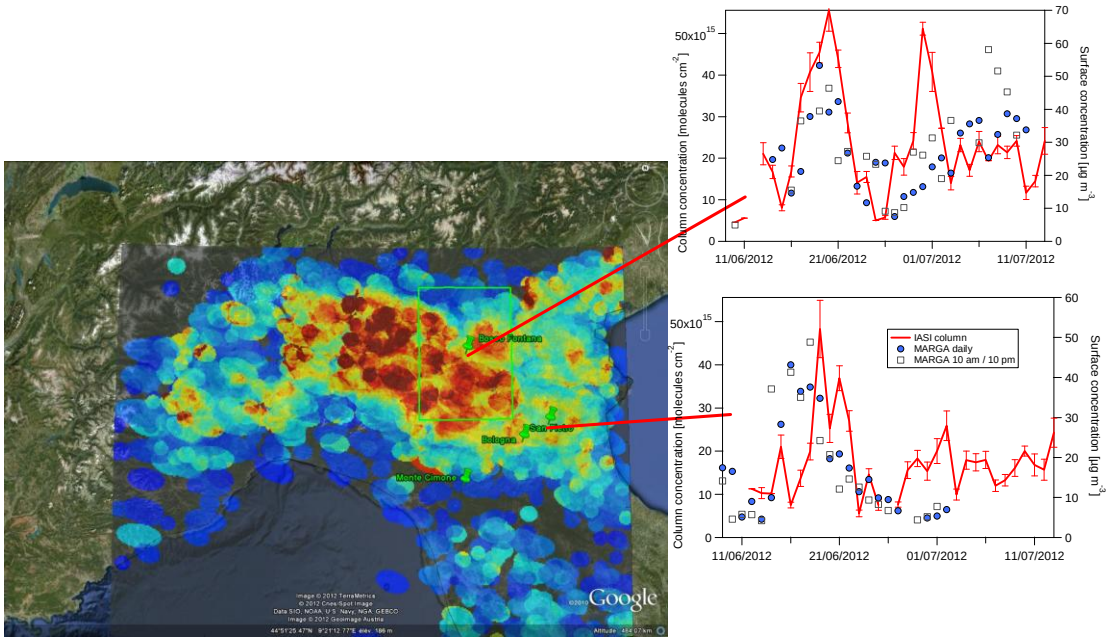

Figure 5. Composite image of the NH_3 column concentration field derived from IASI by ULB for the measurement campaign. Also shown are the daily time-series averaged over the area (green box) centred around Bosco Fontana and San Pietro Capofiume (red lines), compared with ground-observations by MARGA/GRAEGOR (operated by NERC/ECN), comparing full-day averages (blue symbols) and measurements that coincide with the 10:30 am satellite pass over (empty symbols).

4. Milestones achieved:

The associated milestone MS 5 has been partially achieved in that some of the data have been submitted to the database.

5. Deviations and reasons:

Additional financial resources had to be made available from the unallocated budget to support the establishment of the measurement site (tower, cabin and power supply) as this turned out to be much more costly than originally envisaged.

It is unfortunate that an NO_2 eddy-covariance flux measurement could not be realised because the external collaborator (Univ. l'Aquila) dropped out of the campaign at short notice, being put off by the seismic activity in the area at the time.

6. Publications:

Presentations:

1. **Misure alla torre micrometeorologica della RNO del BOSCO della FONTANA in Marmirolo (MN).**
   Written presentation at the Local meeting of the first ECLAIRE results at Bosco Fontana, Forest Police, 28 December 2012, Marmirolo (I)
2. **Ozone fluxes to different vegetated surfaces and first results of ozone flux partition at a mature forest ecosystem in the Po Valley, Bosco Fontana**.
   Oral presentation, COST Action ABBA Meeting, Paris, 25th-27th February 2013.

3. **Ozone removal by a peri-urban mixed oak-hornbeam forest.**
   Accepted abstract at the XVI° European Forum on Urban Forestry to be held in Milan 2013 in May 2013.

Media dissemination

1. [***Newspaper article***] "Clima, vertice di esperti in Cattolica", Giornale di Brescia, 24/10/2011,
2. [***Newspaper article***] "La lotta all'inquinamento atmosferico inizia da quello che mettiamo nel piatto", Corriere della Sera - Brescia, 25/10/2011,
3. [***Newspaper article***] "I cicli climatici secondo l'esperto", Giornale di Brescia, 26/10/2011,
4. [***Newspaper article***] "Progetto ECLAIRE, oggi gli ultimi appuntamenti", BresciaOggi, 27/10/2011,
5. [***Newspaper article***] "Sarà la tecnologia a battere lo smog", Corriere della Sera-Brescia, 27/10/2011,
6. [***Newspaper article***] "L'aria di Bosco Fontana sotto la lente", Gazzetta di Mantova, 11/5/2012, http://gazzettadimantova.gelocal.it/cronaca/2012/05/11/news/l-aria-di-bosco-fontana-sotto-la-lente-1.4495702
7. [***Newspaper article***] "Una torre di quaranta metri misura i polmoni di Bosco Fontana", Roberto Bo, Gazzetta di Mantova, 12/6/2012, http://gazzettadimantova.gelocal.it/cronaca/2012/06/12/news/una-torre-di-40-metri-misura-i-polmoni-di-bosco-fontana-1.5254573
8. [***Webarticle***] "Eclaire, vedetta dell'ecosistema", A. Olivari, CattolicaNews, 28/6/2012, http://www.cattolicanews.it/studi-e-ricerche-eclaire-vedetta-dell-ecosistema
9. [***WebTV video***] "La torre di Éclaire misura lo smog", 4/7/2012, Video Interview on Youcatt.it, http://www.youcatt.it/2012/07/04/la-torre-di-eclaire-misura-lo-smog/
10. [***Newspaper article***] "Bosco Fontana polmone malato", Elena Caracciolo, Gazzetta di Mantova, 12/7/2012, http://gazzettadimantova.gelocal.it/cronaca/2012/07/12/news/bosco-fontana-polmone-malato-1.5398945

In addition, several papers are being prepared from the dataset in preparation to meet Deliverable 1.6 (4 publications on integrated campaign).

7. Meetings:

The measurements were prepared during the first two ECLAIRE annual meetings (kick-off in Brescia, 24-27 Oct 2011 and 2nd annual meeting in Edinburgh, 15-18 Oct 2012). Results were reviewed, data exchanged and papers prepared during the 3rd annual meeting in Zagreb, 22-24 Oct 2013 and a Component 1 meeting at NERC / CEH Edinburgh 26-28 May 2014.

8. List of Documents/Annexes:

N/A