One year of ozone flux measurements and O₃, NOx and CO₂ profiles at the micrometeorological flux tower of Bosco Fontana (Mantua, Italy)

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Aims

• Study the ozone dynamic at a mature plane forest in a highly ozone polluted area in the Po Valley (Italy)

• Assess the **ozone deposition pathways** and the actual **ozone taken up by trees**

• Evaluate the **ecosystem services** related to the ozone removal

• Gathering data for **models** development (e.g. DO3SE) to be employed for the simulation of the ozone deposition in future climatic scenarios
Why ozone?

• We considered OZONE as a “model” pollutant.  

  because

• Ozone is dangerous for plants (which are even more sensitive to this pollutant than animals)

• Ozone is the most important air pollutant during the vegetative growing period (PM is most relevant “only” in winter)

• Ozone is usually very high in the Po valley
Bosco Fontana

Mantua city

Typical

Oak – Hornbeam

Planitital Mesophilus Mixed forest

with

Corylus avellana, Cornus mas, Crataeugus laevigata, Sambucus nigra, Ruscus aculeatus

> 230 ha

In an area with very intense agricultural and industrial activity

Relict of the original Po Valley forests, just at the outskirts of the Mantua city
Bosco Fontana
Micrometeorological Tower
Micrometerological tower

- 40 m tall
- Equipped for Eddy Covariance measurements and profiles
Eddy covariance

- Ultrasonic anemometer
- Fast hygrometer (H$_2$O)
- Fast IRGA (CO$_2$ + H$_2$O)
- Fast ozone analyzer
Bosco della Fontana, Mantova, Italy
Results

- **INTENSIVE** Joint field campaign: 10th June 2012 - 12th July 2012
- **LONG TERM** measurements: 15th July 2012 - 31st December 2013
An example of measurements (intensive campaign)

O₃ fluxes

Top tower (42 m)
1-Year of ozone fluxes (daily average of fluxes)
Diurnal variation of ozone fluxes

Vegetative period
Ozone fluxes and concentrations

Dormant period
Ozone fluxes and concentrations

Even in winter, when there are no leaves
But where does the ozone go?

Quantify the pathways.
Usually it is done by modelling . . . .

But direct measurements are needed for validation.
Flux partition

Ozone fluxes have been partitioned “at least” into

a **stomatal** and

a **non-stomatal** part

by means of an energy budget method based on the
**derivation of the bulk stomatal conductance** from
**water fluxes** by the inversion of the well known
**Penman-Monteith equation** for evaporation.
\[ F_{\text{meas}} = F_{\text{stom}} + F_{\text{NonStom}} + \Delta S \]

\[ F_{\text{deposited}} = F_{\text{stom}} + F_{\text{NonStom}} \]
The storage flux ....

Below canopy O3 FLUX (mV m/s)

Deposition velocity (cm/s)
Conductances corrected for storage: the real drivers of deposition

2013 July-August

Conductances (m/s)

hours (GMT+1)

G stom
G residual
G nonStom

Conductances corrected for storage: the real drivers of deposition
The Ozone fluxes corrected for storage

2012

2013

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Concentration profiles may help in understanding the fate of the ozone below the canopy.
O₃ and NO concentration profiles, long-term campaign (summer 2013)

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...and NO2 concentration profiles, long-term campaign
Trace Gas Exchange at Soil-Atmosphere Interface

Graph showing NO and NO₂ flux over time from 22.06.2012 to 02.07.2012.
The net ozone removal
an ecosystem service…

On annual basis the **non-stomatal deposition** accounts for **83%** of the total ozone deposition.
... but this service has a biological cost

i.e. what are the **negative effects of ozone on plants**?

→ What is the *phytoxical dose* taken up by plants?

→ what is the possible **reduction of annual biomass production**?
The loss of growth can be hardly visible in a mature stand, since for example the loss of biomass increments can interest the roots

But

\( \text{CO}_2 \) measurements can help in identifying this cost
The net CO₂ budget is not negative nor zero...

Possible reasons:

• Interannual climatic variability (needs for multiannual measurements…)

• Stimulated decomposition activity due to the dead wood management policy adopted 20 years ago.

• Response to abiotic or biotic stressors (e.g. to ozone, ….)

Carbon balance on 12 months = + 192 g/m²

Our ecosystem resulted a carbon emitter instead of a carbon sink…
There are some evidences that the ozone taken up by stomata depletes the carbon assimilation …
Conclusions

1. The studied forest is a net **sink for tropospheric ozone**

2. The **ozone removal ecosystem service** amounted around 75 Kg ha\(^{-1}\) yr\(^{-1}\)

3. The quantity of the ozone **absorbed by leaves** during the vegetative period ranged between **30% and 55% of the total ozone deposition**.

4. The phytotoxic cost of this ecosystem service is a **reduction of carbon uptake** and a **missing annual growth** between 15% and 30% was estimated.

5. This study highlights the **importance of making direct measurements of ozone fluxes on forests and perform them as long as possible**

6. **Bosco Fontana** is a novel facility: everybody is welcome (30 KW available)
Thanks for your attention
The non-stomatal component ....

Is due to ozone disruption on the non transpiring surfaces and on chemical scavenging...

But not all the ozone is really removed: part of it is TEMPORARILY stored into the trunk space (STORAGE)

And it undergoes to a cyclic diurnal uptake and release...

Like a slow single mouthfuls and digestion...
An example of CO$_2$ flux measurements

CO$_2$ fluxes

Net respiration

Net photosynthesis
Fluxes corrected by the storage

2013 April-July

Diagram showing ozone fluxes (nmol m\(^{-2}\) s\(^{-1}\)) over hours (GMT+1) from April to July 2013. The graph includes fluxes corrected by the storage, with lines representing different components:
- Storage
- Fstom
- Fresid
- FnonStom
- Ftot
- Fdeposited

Ozone Fluxes (nmol m\(^{-2}\) s\(^{-1}\))
Concentration profiles, intensive campaign

O₃, ppb

NO, ppb

NO₂, ppb

CET +1 (legal time)
Median Flux profiles, June - July 2012

O$_3$ flux, nmol m$^{-2}$ s$^{-1}$

[Diagram showing ozone flux profiles with color-coded contour lines and a scale for flux values ranging from -26 to 2 nmol m$^{-2}$ s$^{-1}$]
Median Flux profiles, June - July 2012

![Graph showing ozone fluxes from different sources over a 24-hour period in GMT+1, with COFA top (42 m), ROFI (32), NOAA (24), and COFA2 (16) as distinct lines.](image)
Ozone Fluxes

Fast Ozone Sensors

CEH ROFI
(Rapid Ozone Flux Instrument)

UNICATT COFA
(Chemiluminescence Ozone Fast Analyser)

CRA-RPS
NOAA Fast-ozone Sensor
Gradient Data

- 5 heated gas inlets
  - Ozone
  - NO/NO$_2$
  - CO$_2$/H$_2$O
  - Continuously purged, sampled sequentially

- Aspirated thermocouples (Type-E)
- RH&T Probes (in radiation shields)
Met Data

- WXT – rainfall, windspeed & direction, temperature, relative humidity
- Rainfall – tipping bucket
- Net radiation, direct & diffuse PAR
- Aspirated thermocouples (Type-E)
- Leaf Wetness clips
- Soil Heat Flux
- Soil water content (TDRs) +
- 5 sonic anemometers
- Ceiliometer