One year of ozone flux measurements and O_3, NOx and CO_2 profiles at the micrometeorological flux tower of Bosco Fontana (Mantua, Italy)

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éclaire
Effects of climate change on air pollution impacts and response strategies for European ecosystems

15th Task Force on Measurement and Modelling Meeting

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

> 230 ha

In an area with
very intense agricultural
and industrial activity

Typical

Oak – Hornbeam

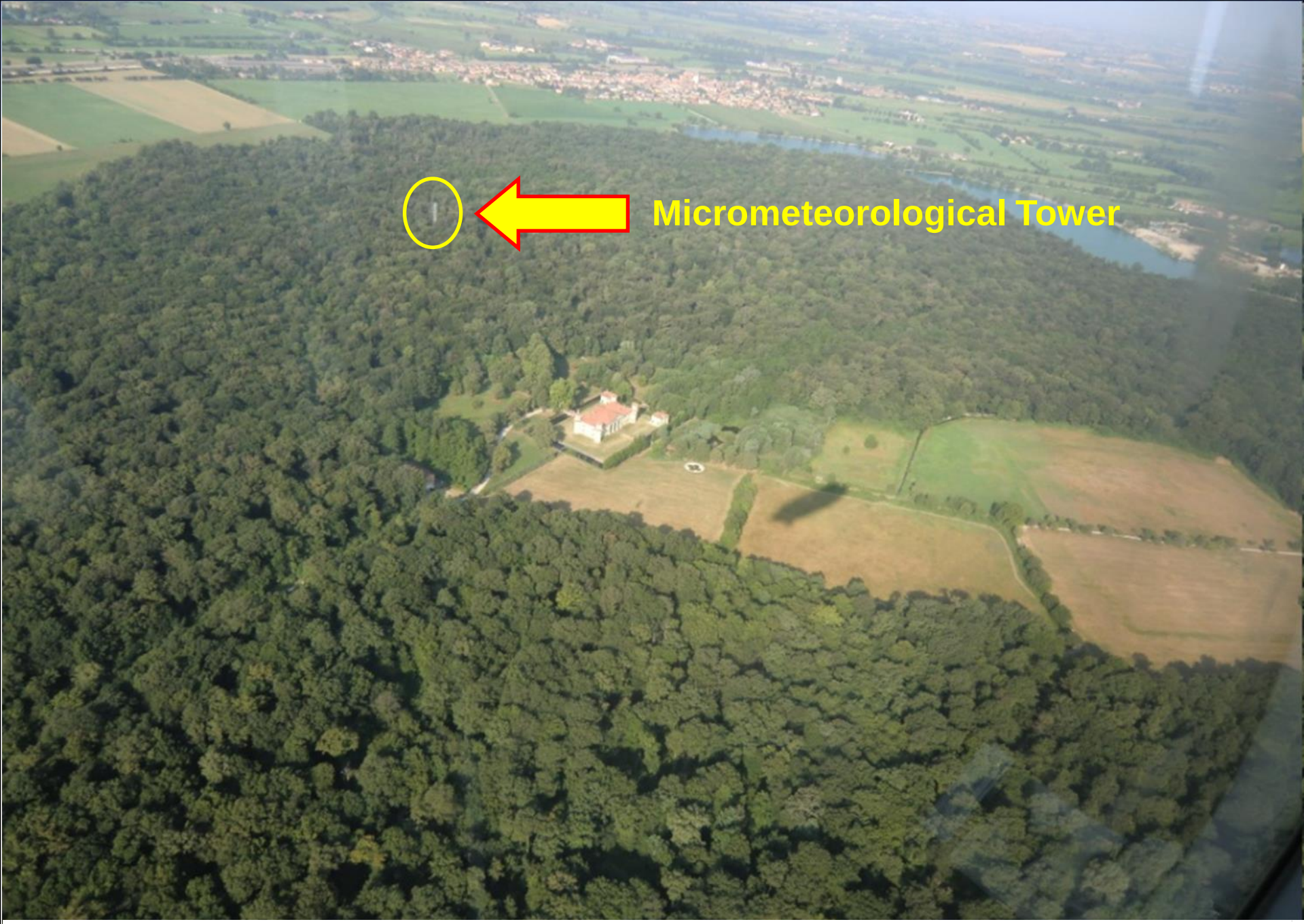
Planitial Mesophilus Mixed forest

with

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

Relict of the original Po Valley forests, just at the outskirts of the Mantua city

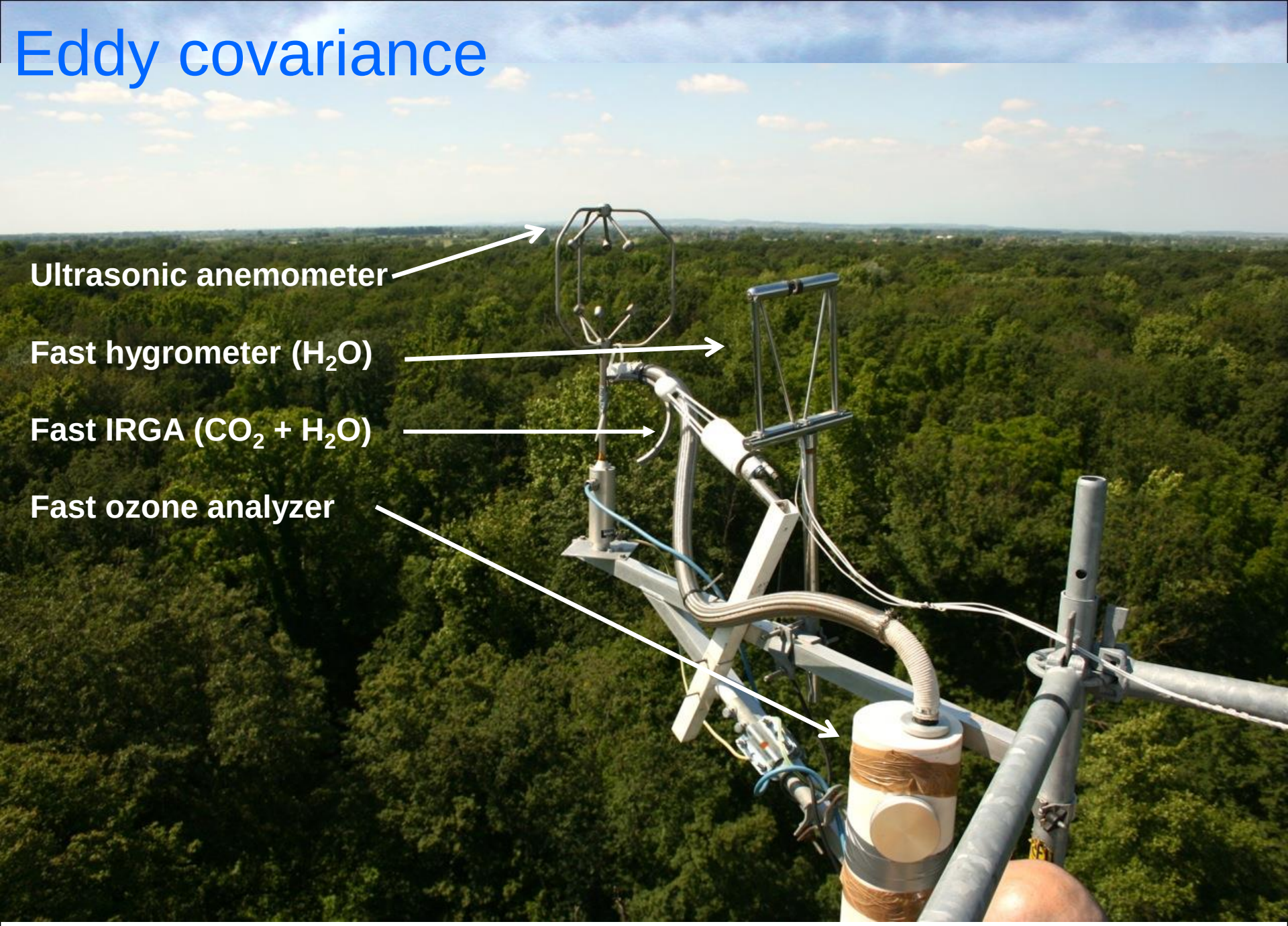

Bosco Fontana


Micrometeorological Tower

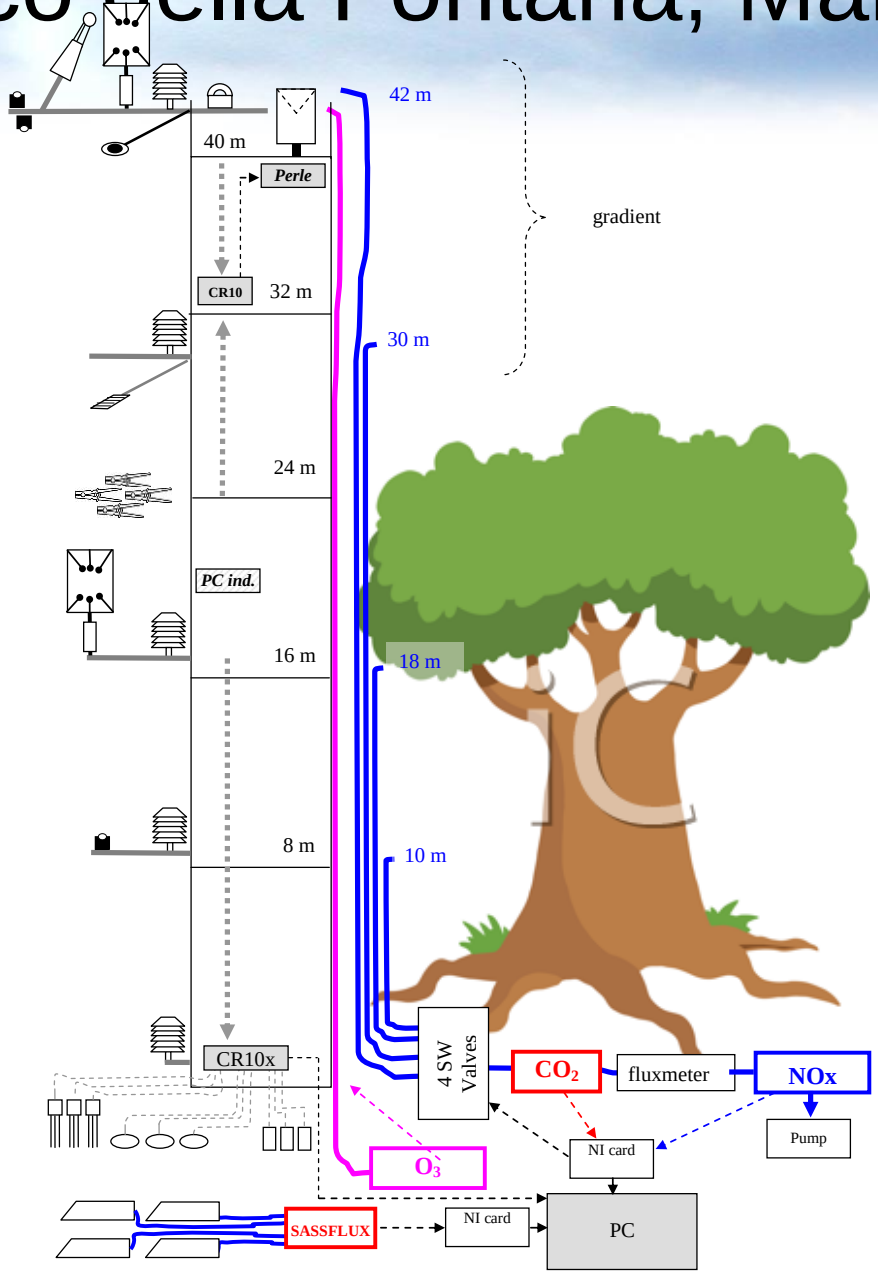
Micrometerological tower

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

Eddy covariance



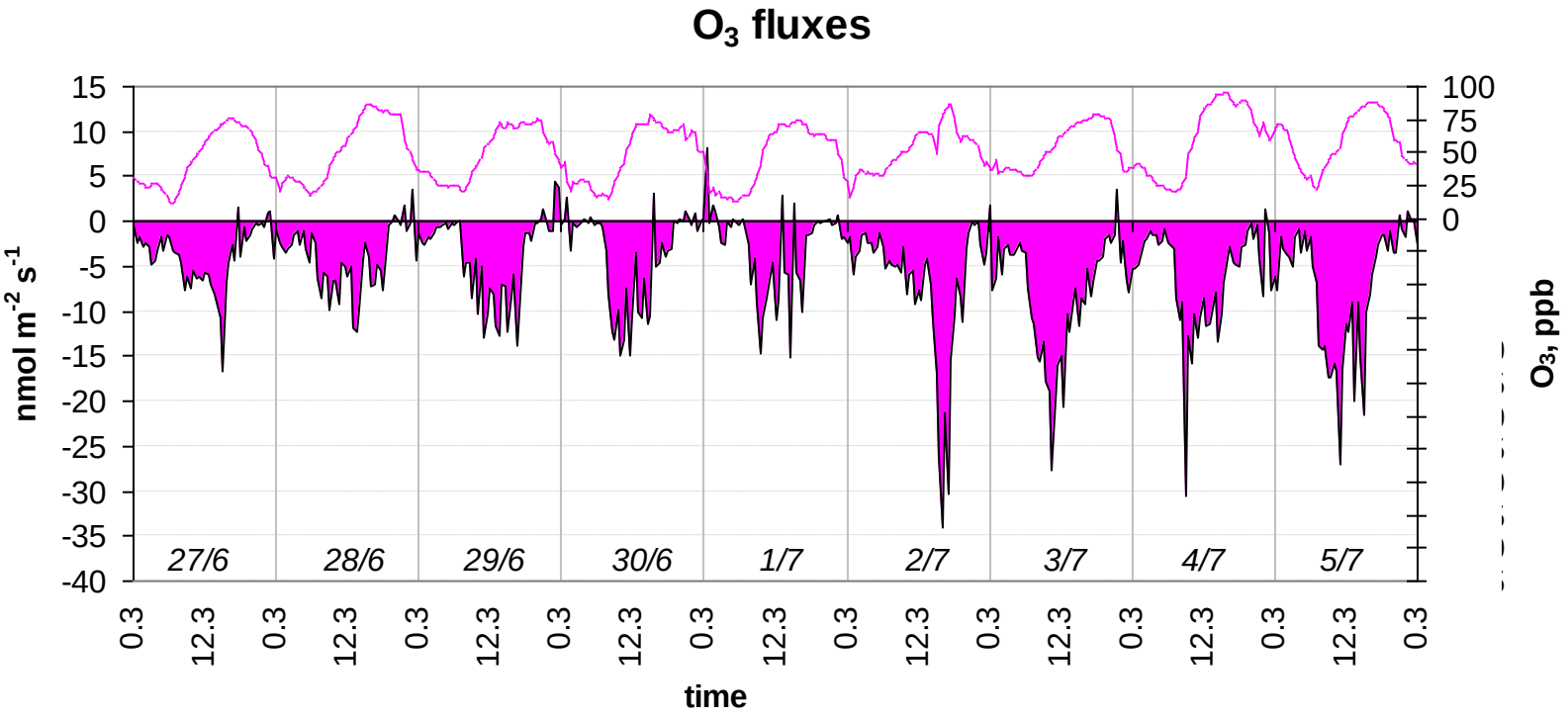
Bosco della Fontana, Mantova, Italy



Results

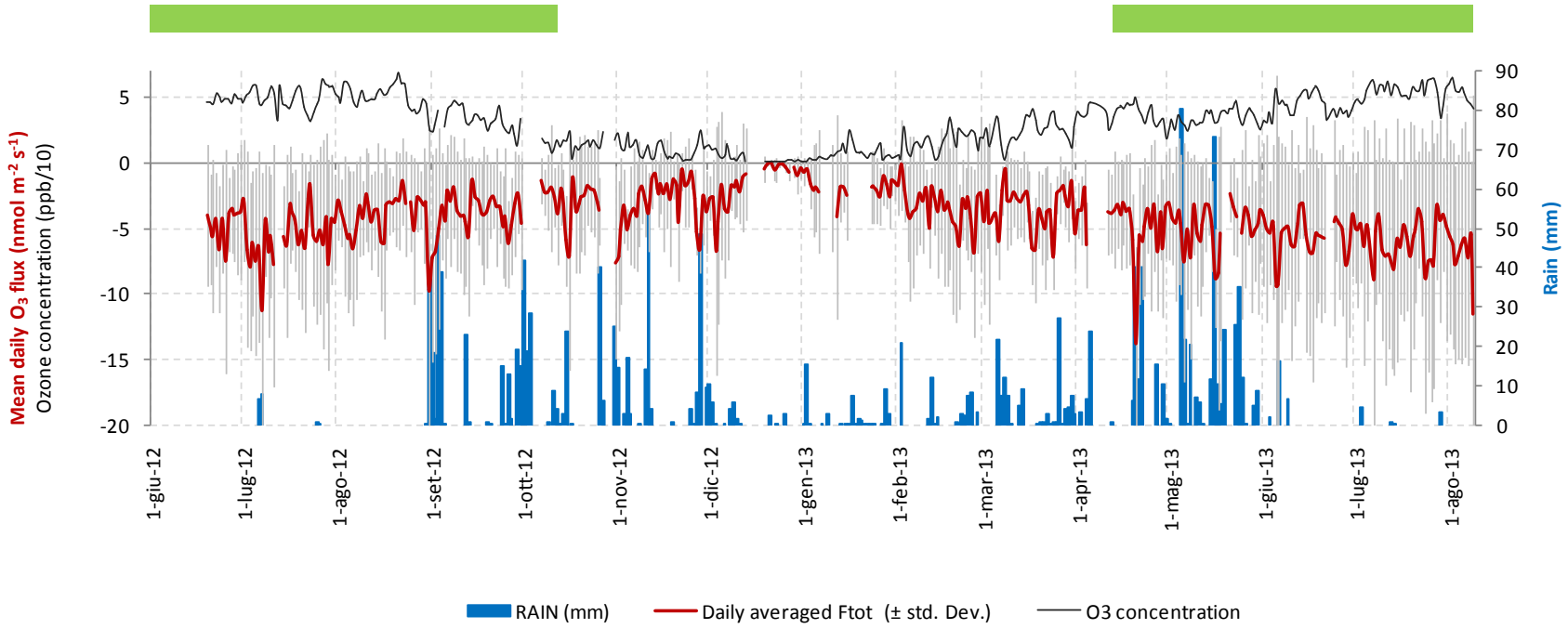
- **INTENSIVE** Joint field campaign: 10th June 2012 - 12th July 2012
- **LONG TERM** measurements: 15th July 2012 - 31st December 2013

An example of measurements (intensive campaign)



Top tower (42 m)

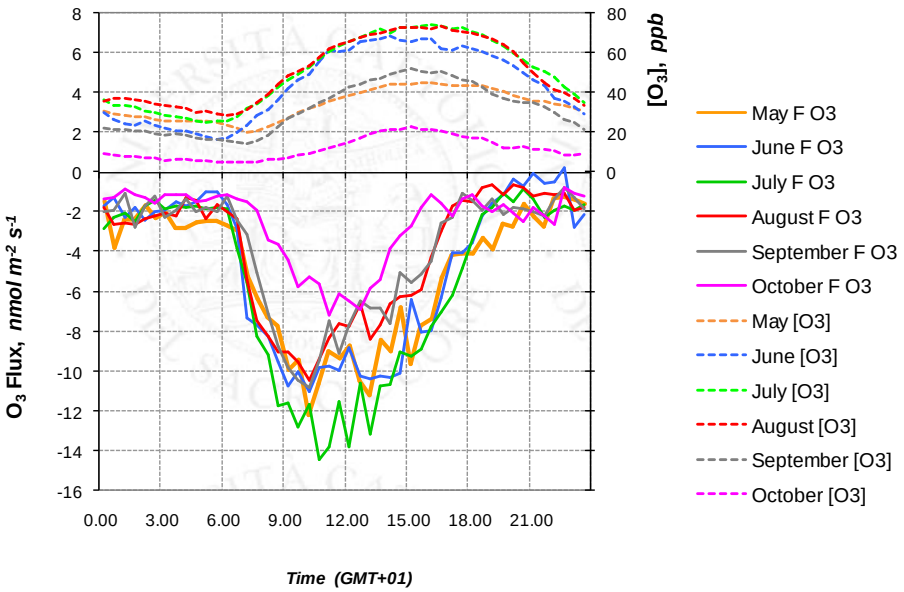
1-Year of ozone fluxes (daily average of fluxes)



Diurnal variation of ozone fluxes

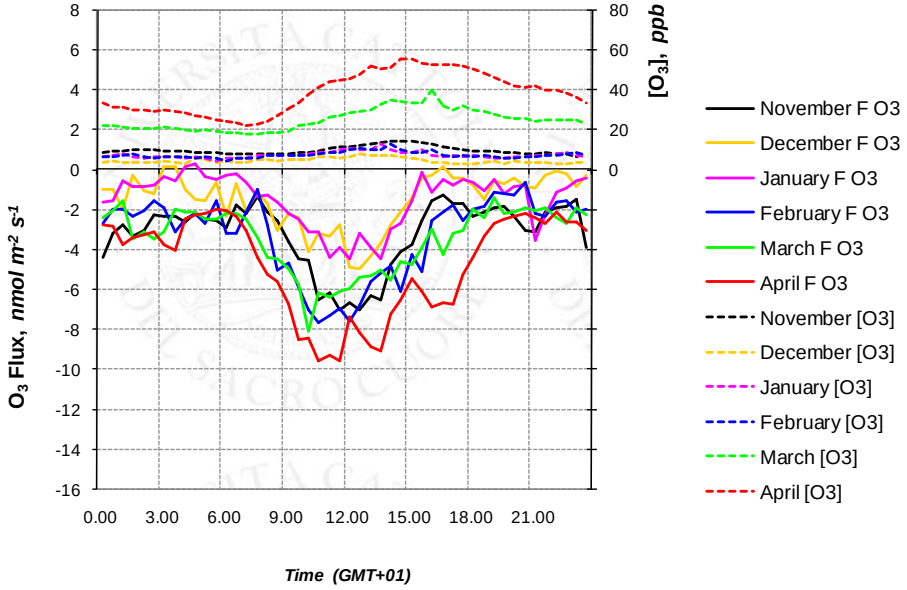
Vegetative period

Ozone fluxes and concentrations



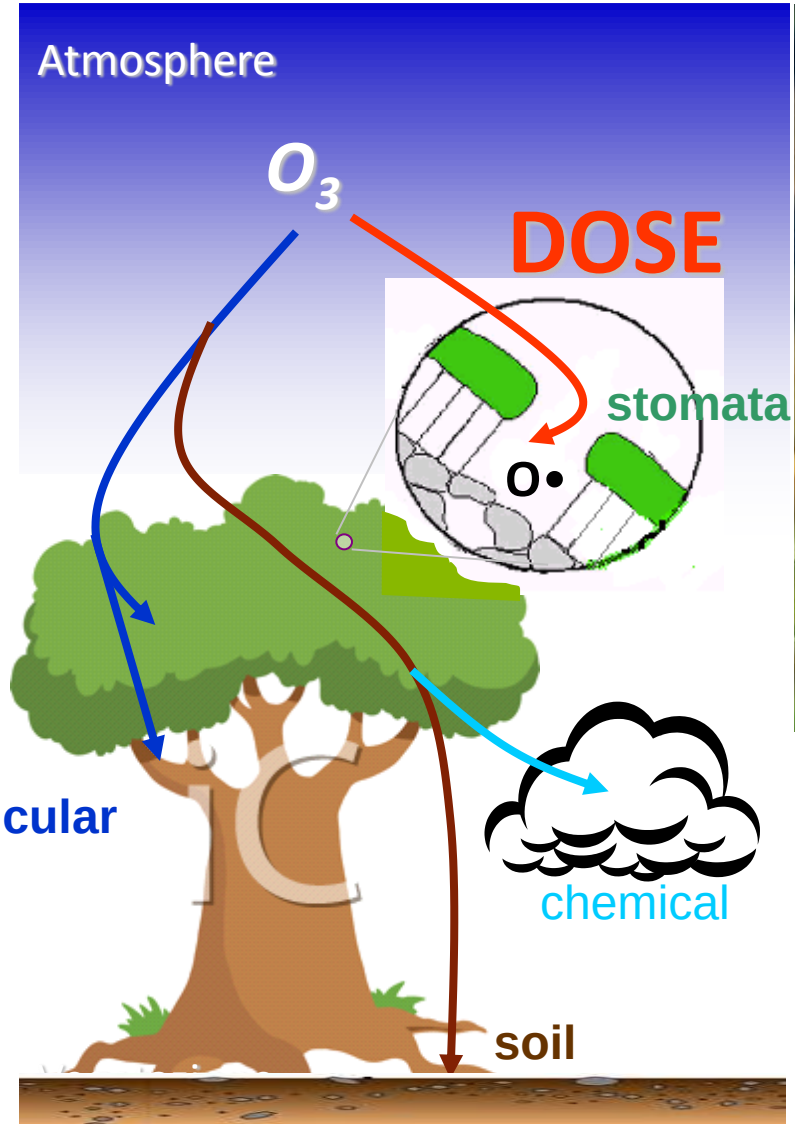
Dormant period

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

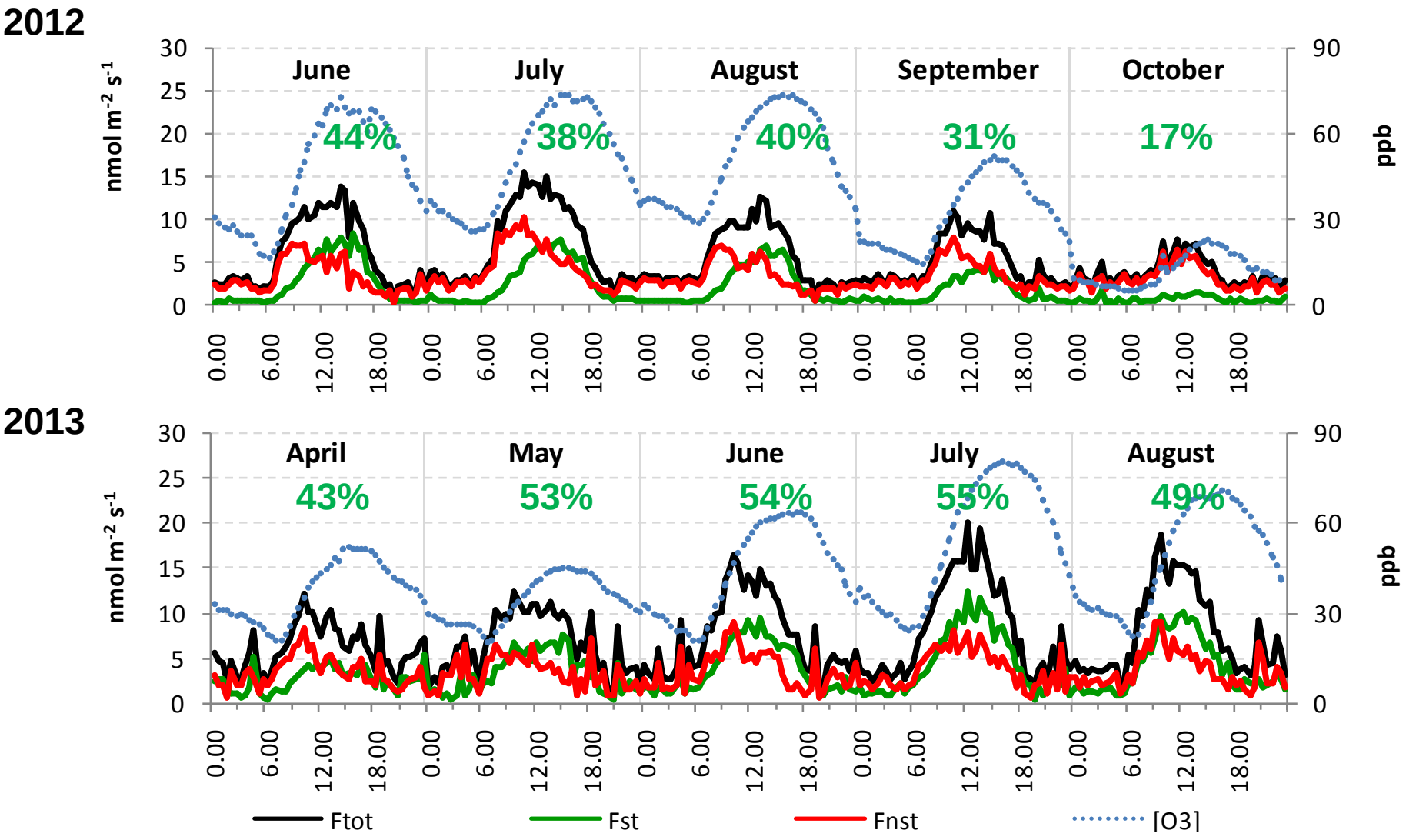
Flux partition

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.

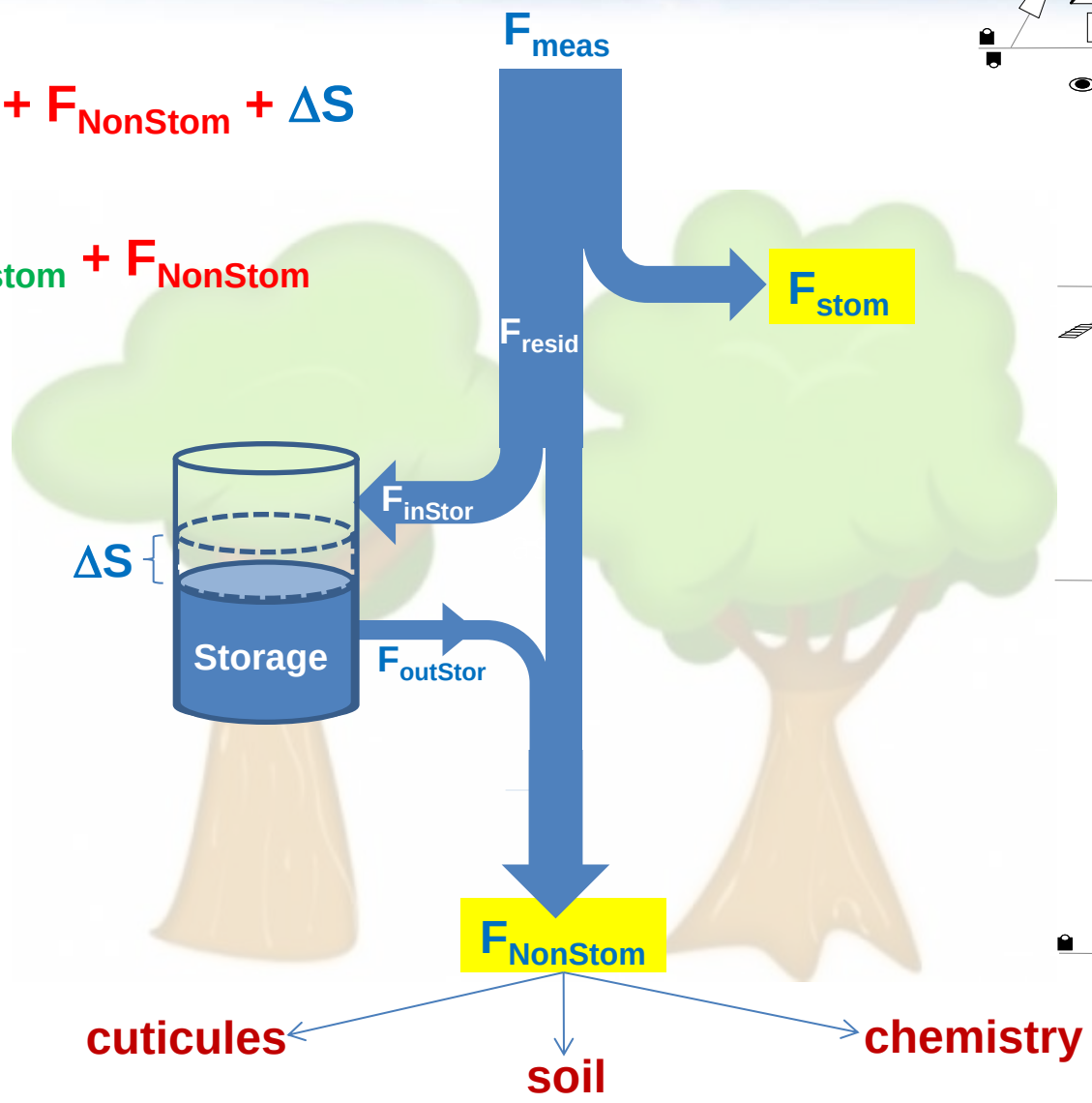
Flux partition results

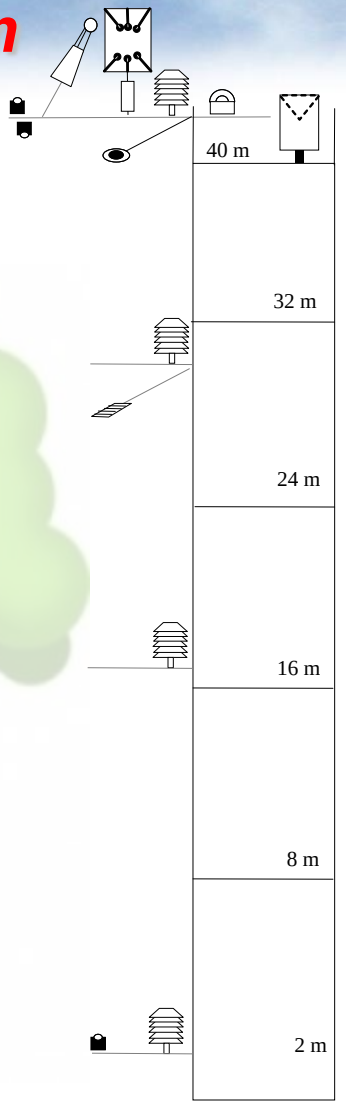


Storage & $F_{NonStom}$

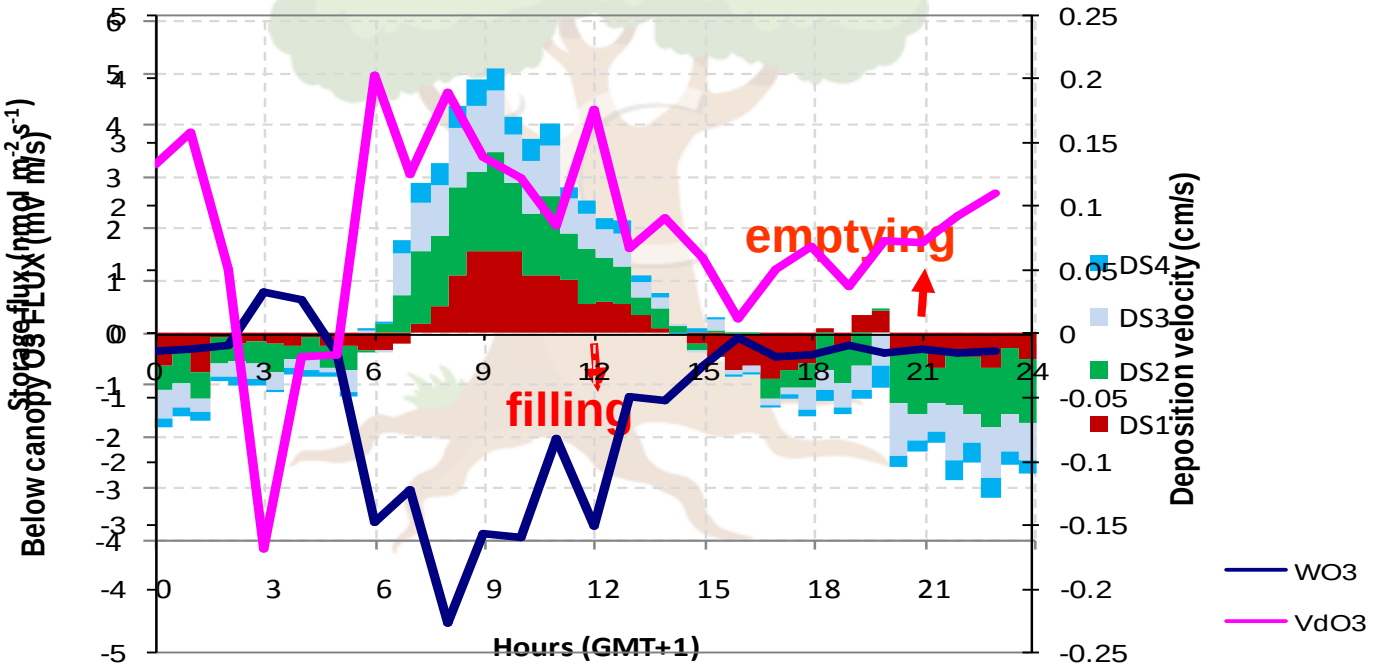
$F_{meas} = F_{stom} + F_{NonStom} + \Delta S$

$F_{deposited} = F_{stom} + F_{NonStom}$

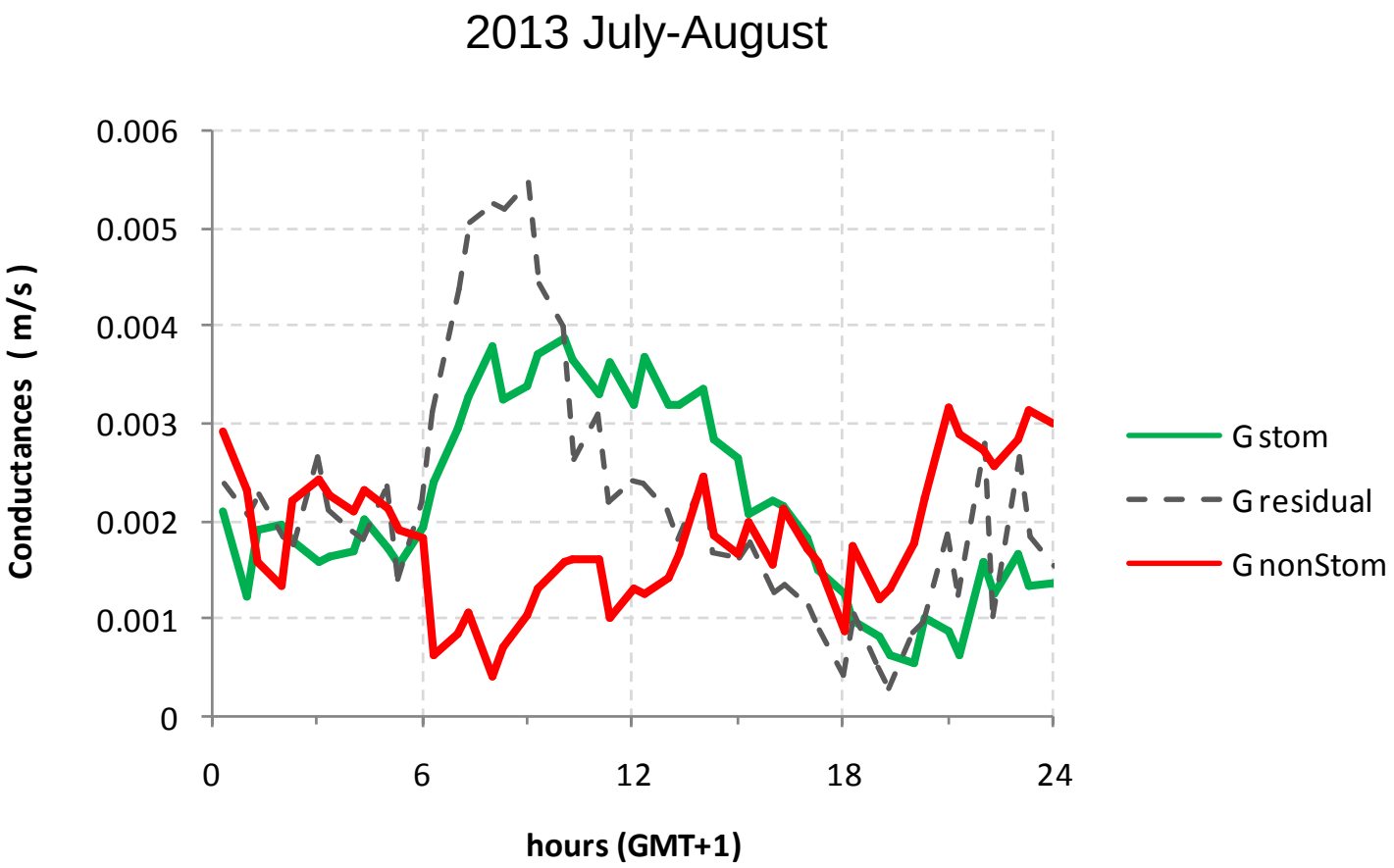




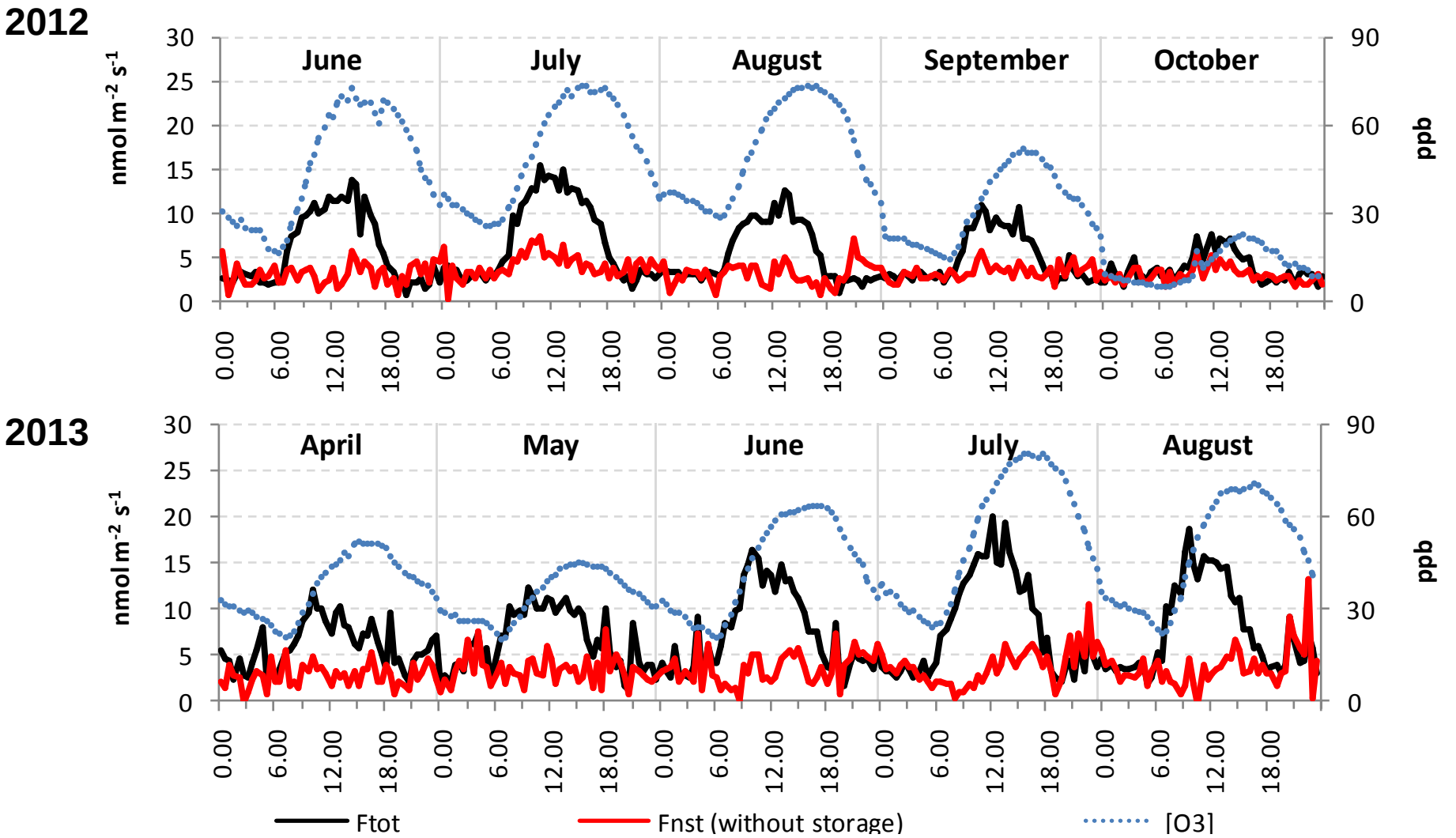
The storage flux ….



Conductances corrected for storage: the real drivers of deposition

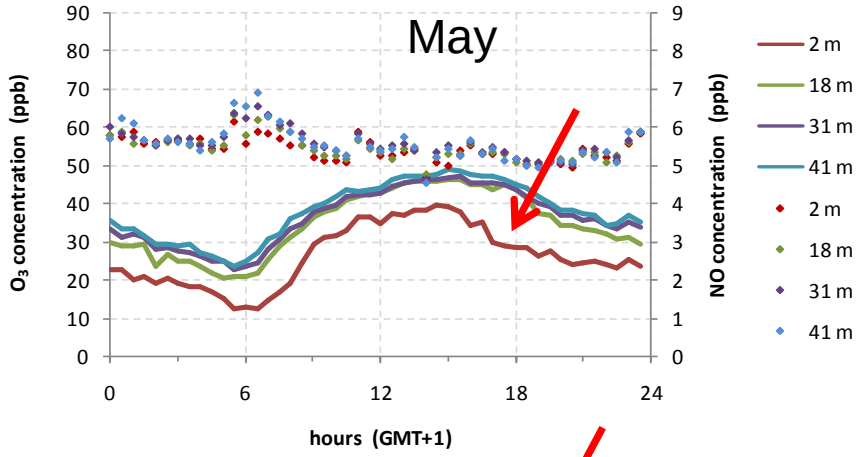


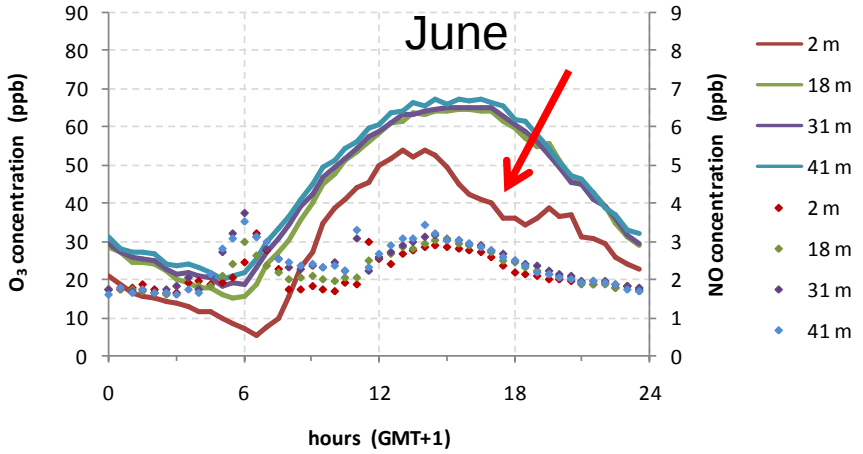
The Ozone fluxes corrected for storage

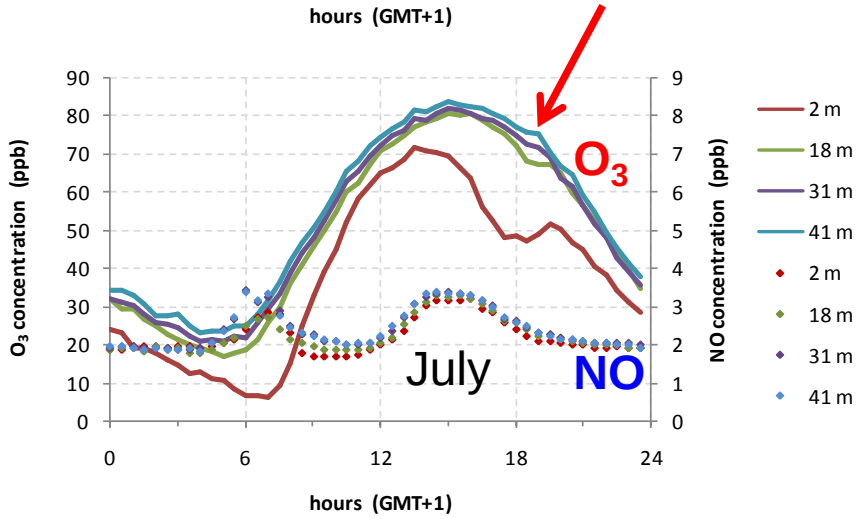


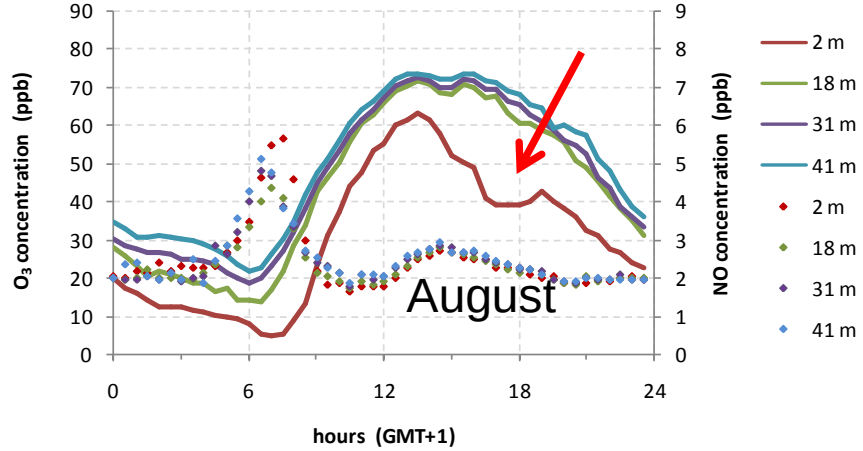

Concentration profiles may help in understanding
the fate of the ozone
below the canopy

O_3 and NO concentration profiles, long-term campaign **(summer 2013)**

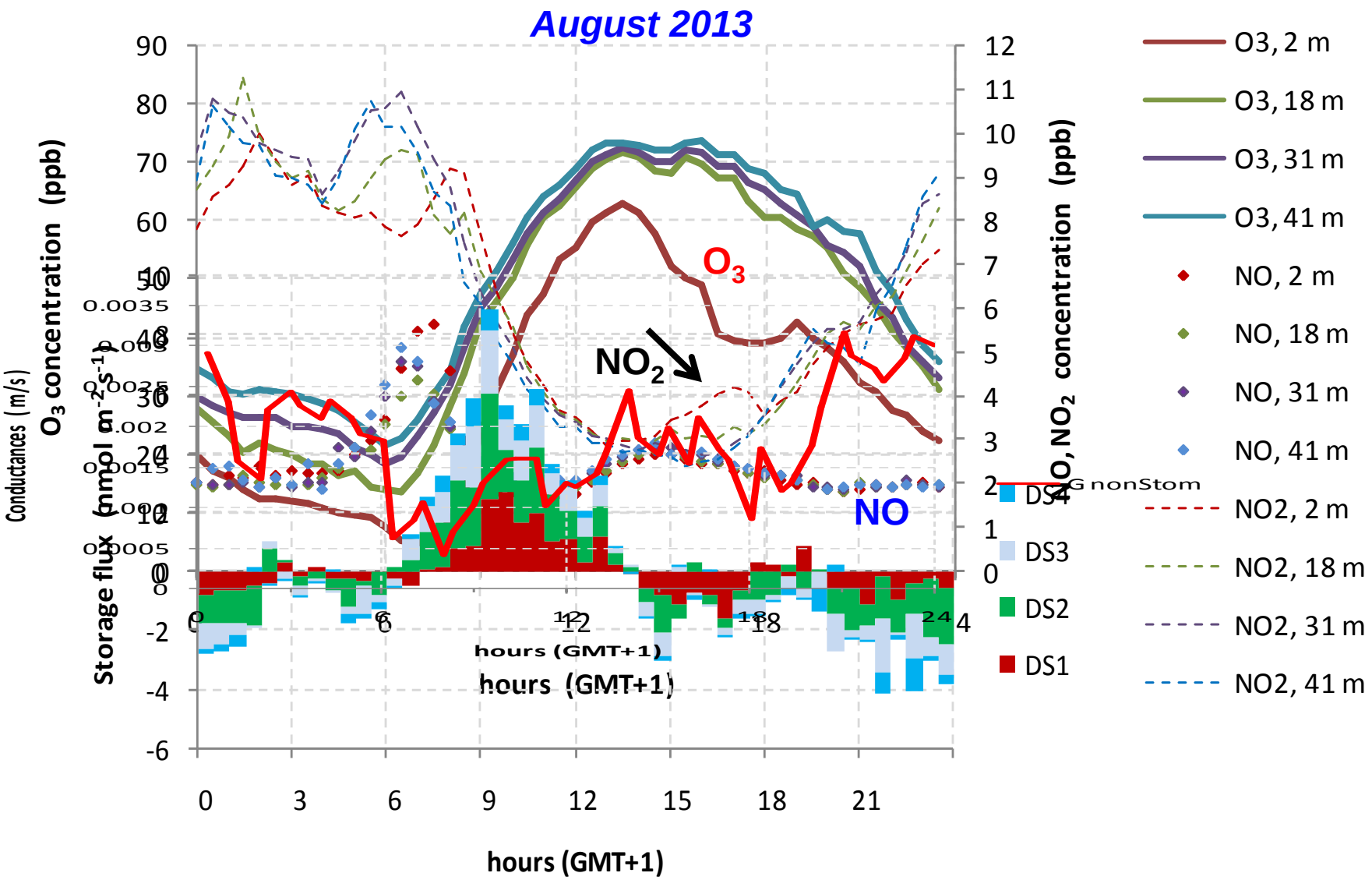




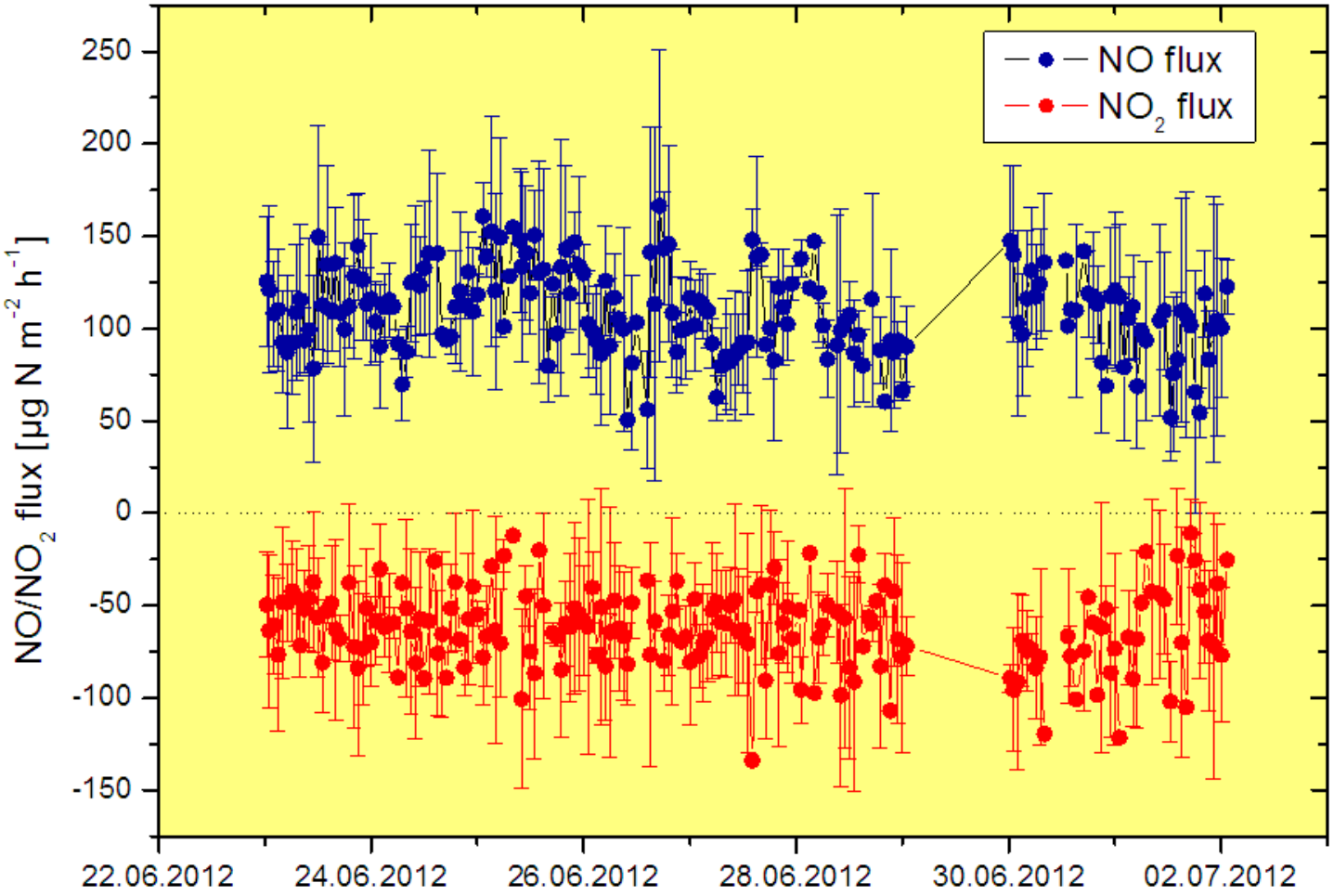




…and NO_2 concentration profiles, long-term campaign



Trace Gas Exchange at Soil-Atmosphere Interface



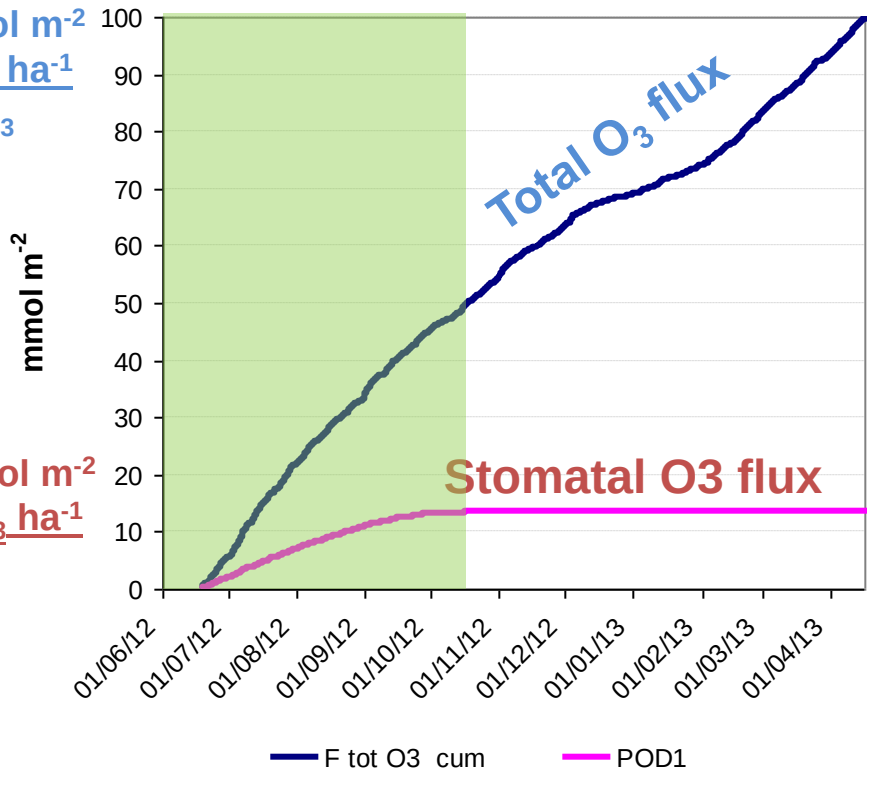
Institute of Meteorology and Climate Research (IMK) – Atmospheric Environmental Research (IFU)
Garmisch-Partenkirchen, Germany

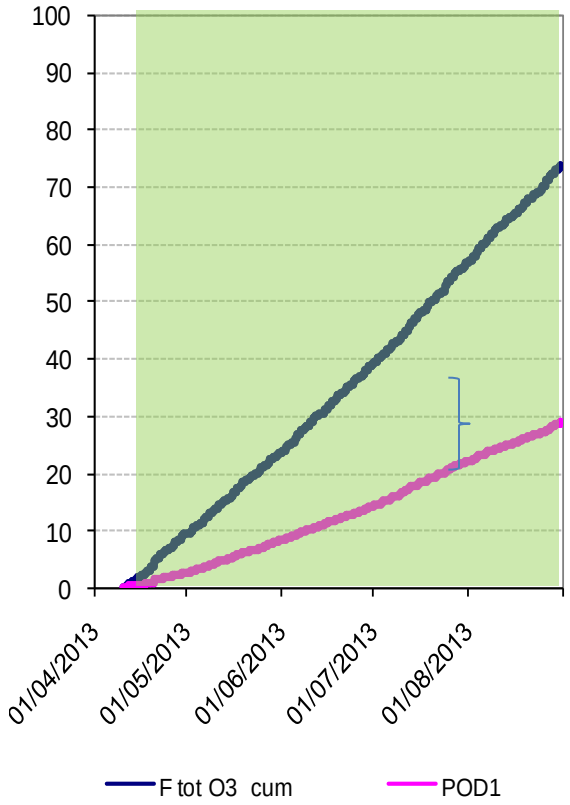
The net ozone removal

an ecosystem service…

105 mmol m^{-2}
50 kg O_3 ha^{-1}
11.76 t O_3

13.5 mmol m^{-2}
6.5 kg O_3 ha^{-1}
1.52 t O_3





74 mmol m^{-2}
35 kg O_3 ha^{-1}
8.13 t O_3

29 mmol m^{-2}
14 kg O_3 ha^{-1}
3.16 t O_3

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**?

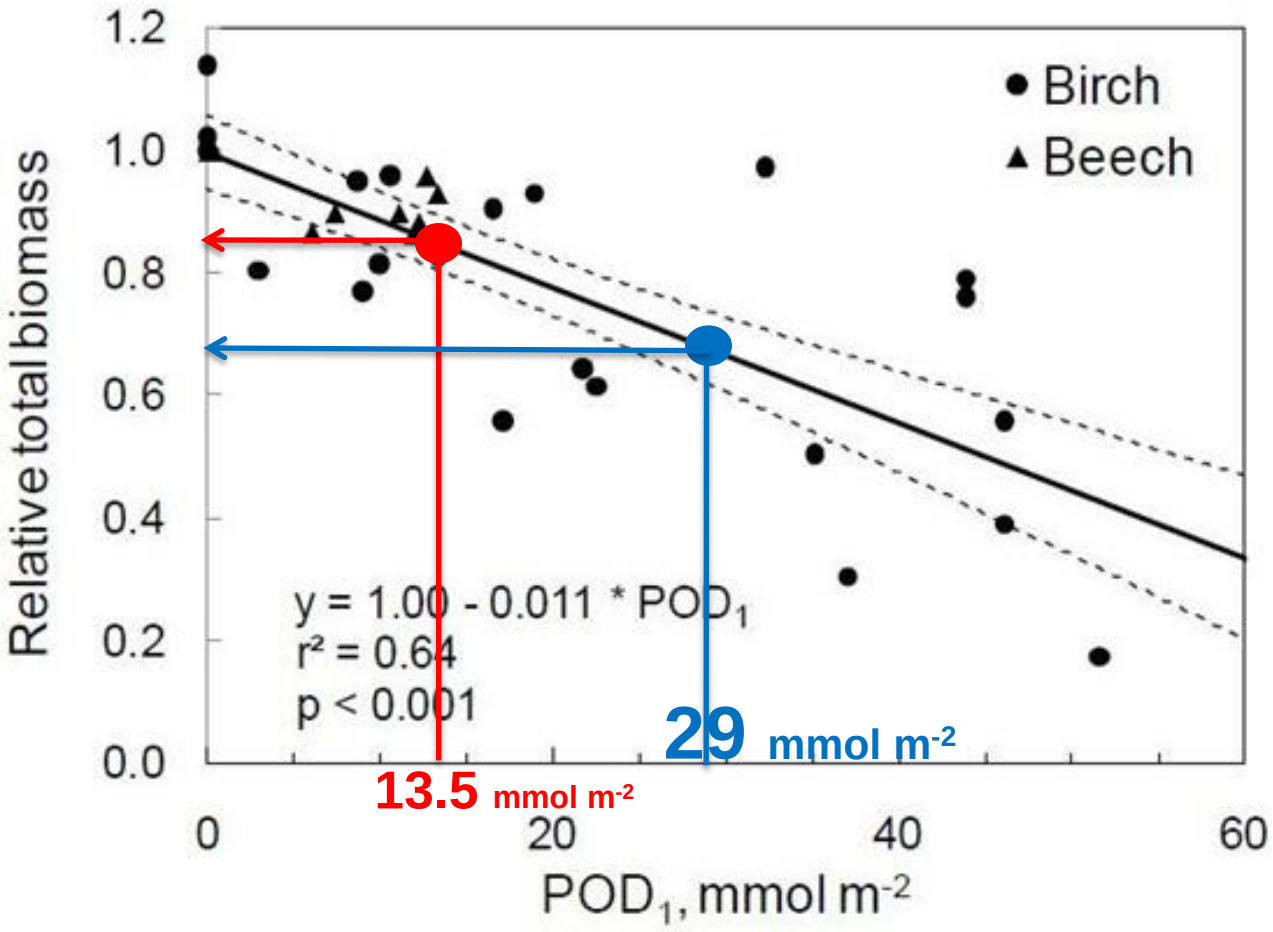
→ What is the ***phytoxical dose*** taken up by plants?

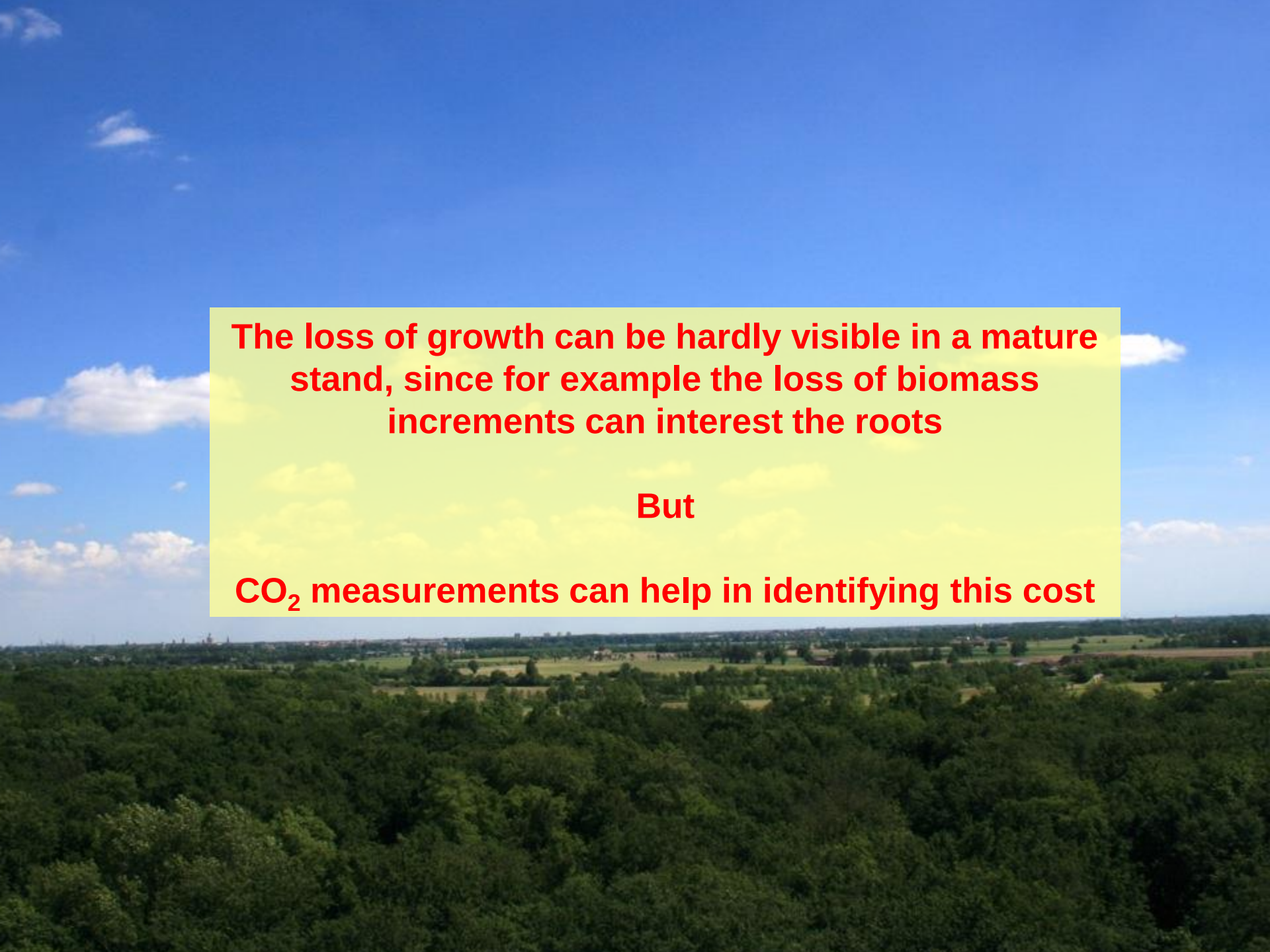
→ what is the possible **reduction of annual biomass** production?

… an estimate of the missing growth

- 15%

- 30%





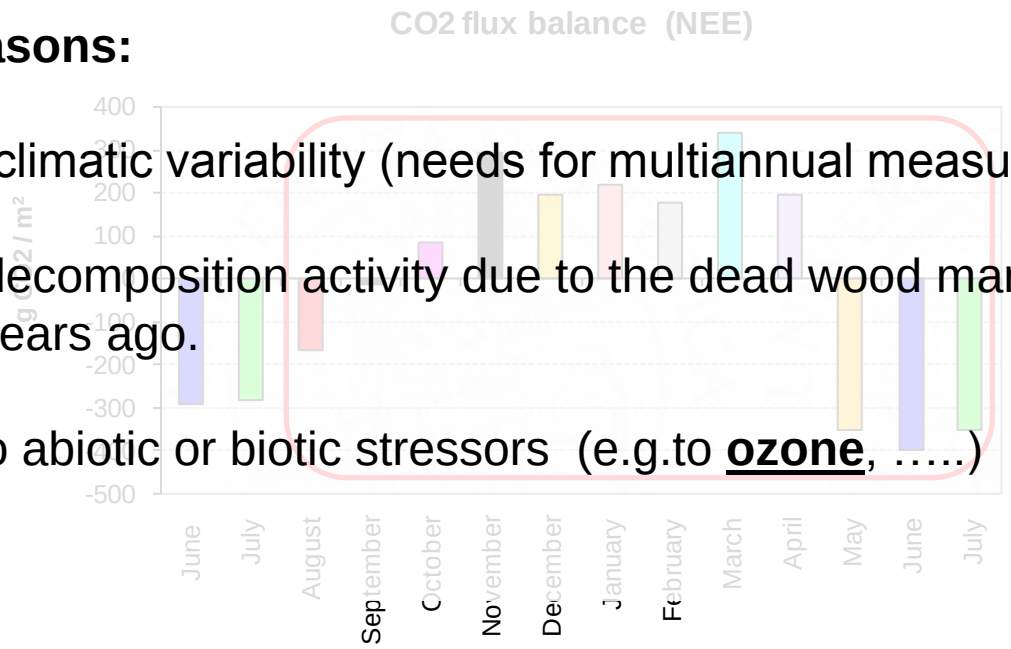
The loss of growth can be hardly visible in a mature stand, since for example the loss of biomass increments can interest the roots

But

CO_2 measurements can help in identifying this cost

The net CO_2 budget is not negative nor zero…

Possible reasons:

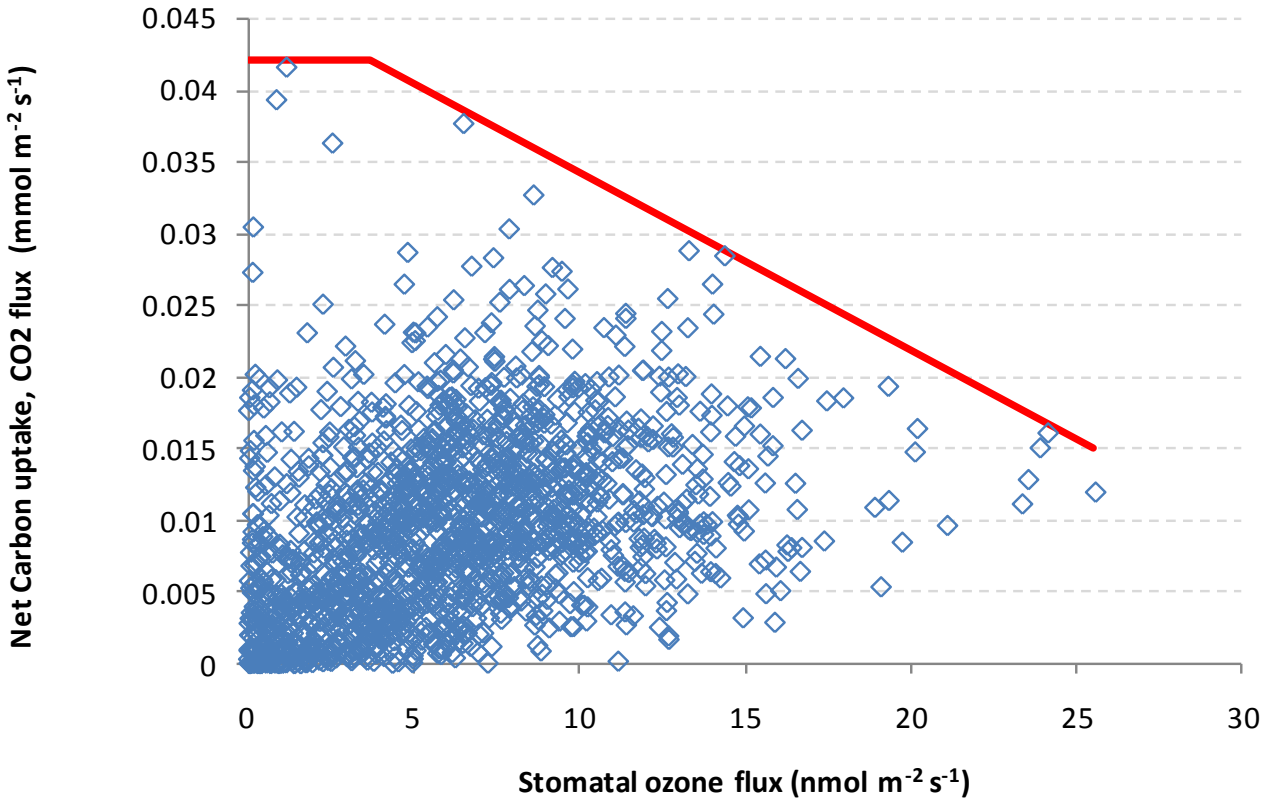


- Interannual climatic variability (needs for multiannual measurements…)
- Stimulated decomposition activity due to the dead wood management policy adopted 20 years ago.
- Response to abiotic or biotic stressors (e.g.to **ozone**, …..)

Carbon balance on 12 months = **+ 192 g/m2**

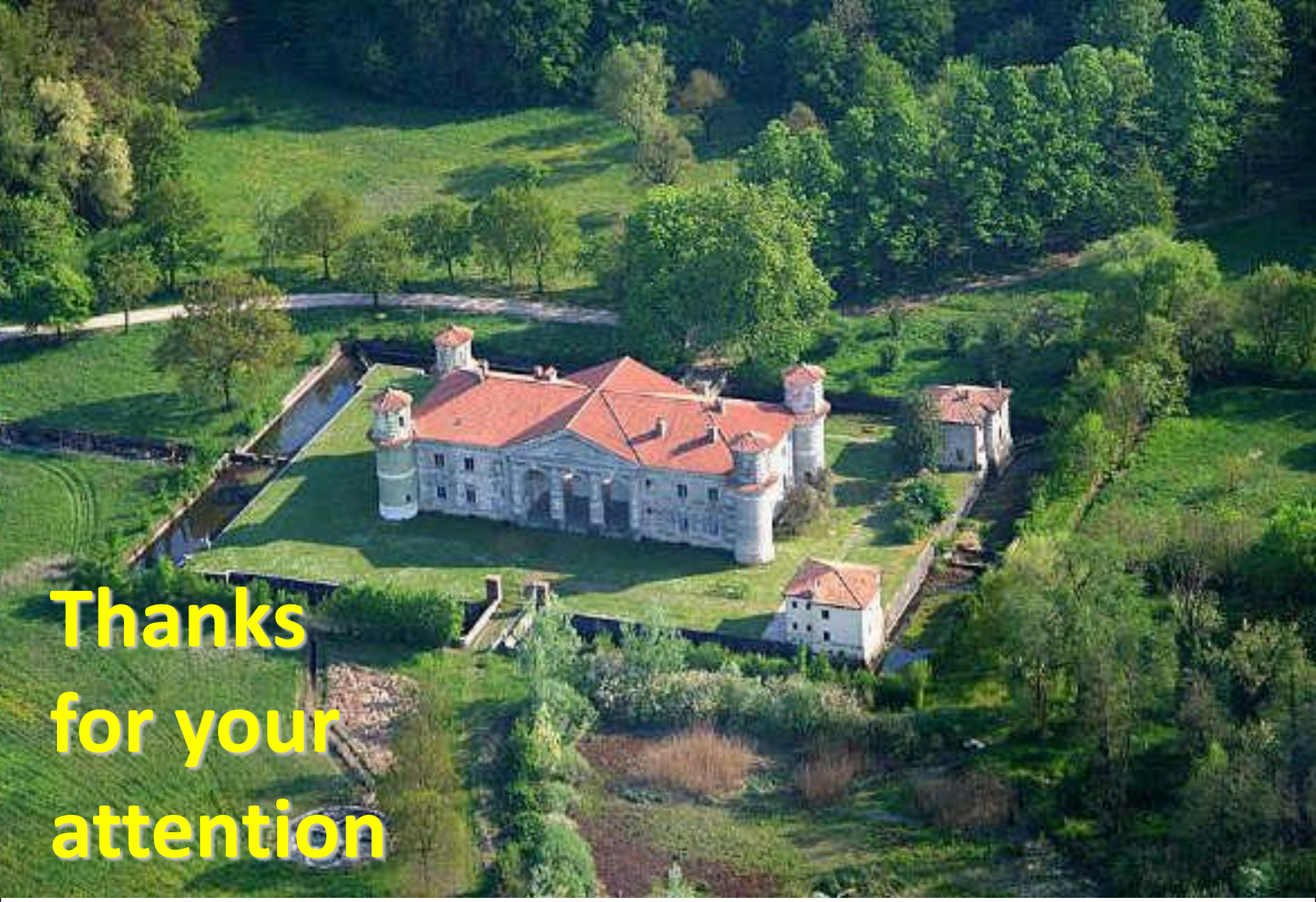
Our ecosystem resulted a carbon emitter instead of a carbon sink…

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 phytotoxical 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

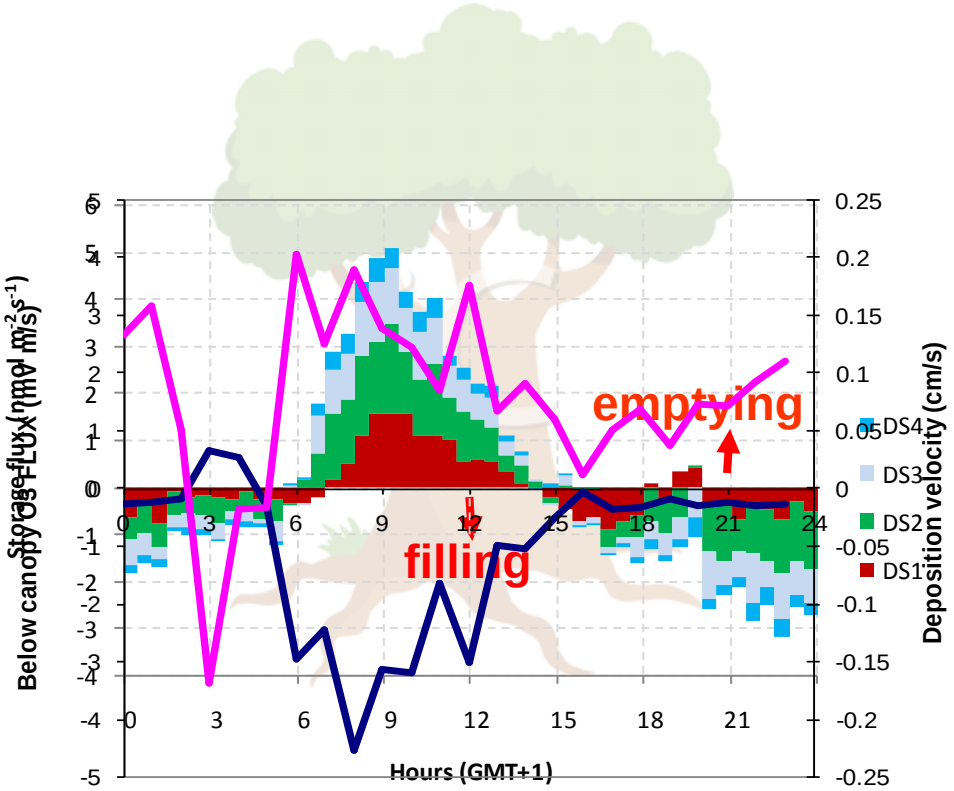
The non-stomatal component ….

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

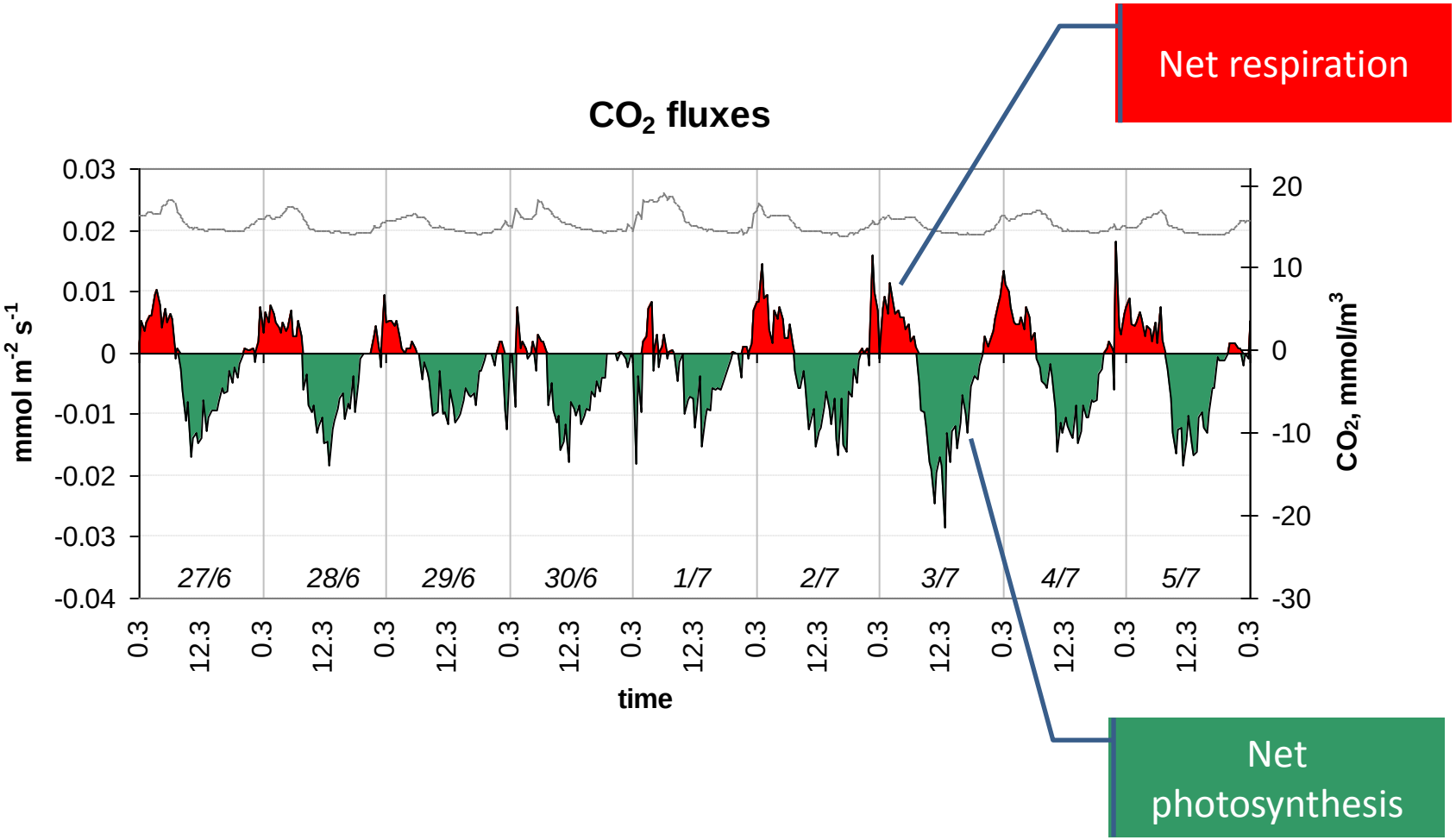
But not all the ozone is really removed: part of it is TEMPORARILY stored into the trunk space (**STORAGE**)

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

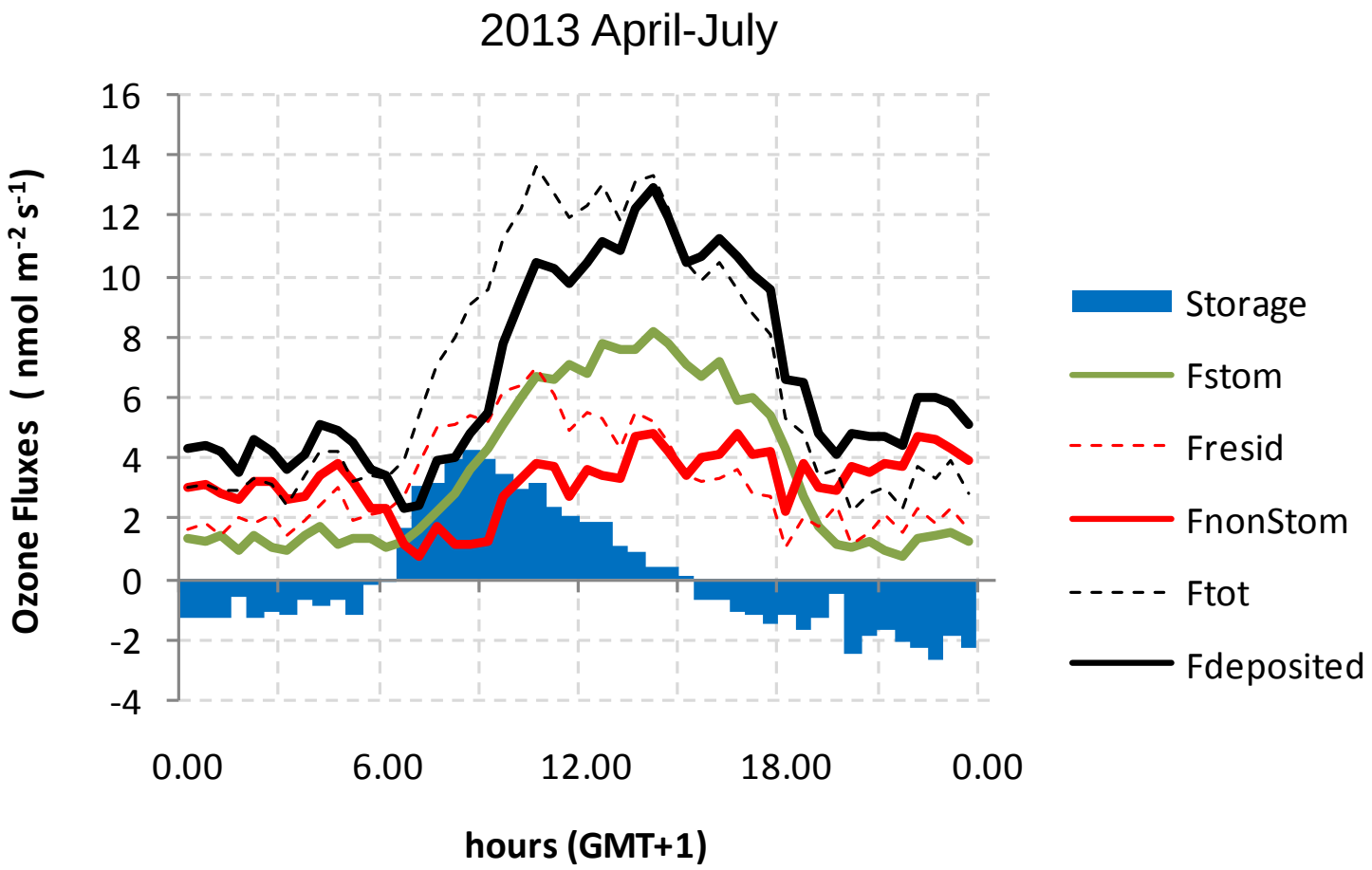
Like a slow single mouthfuls and digestion…



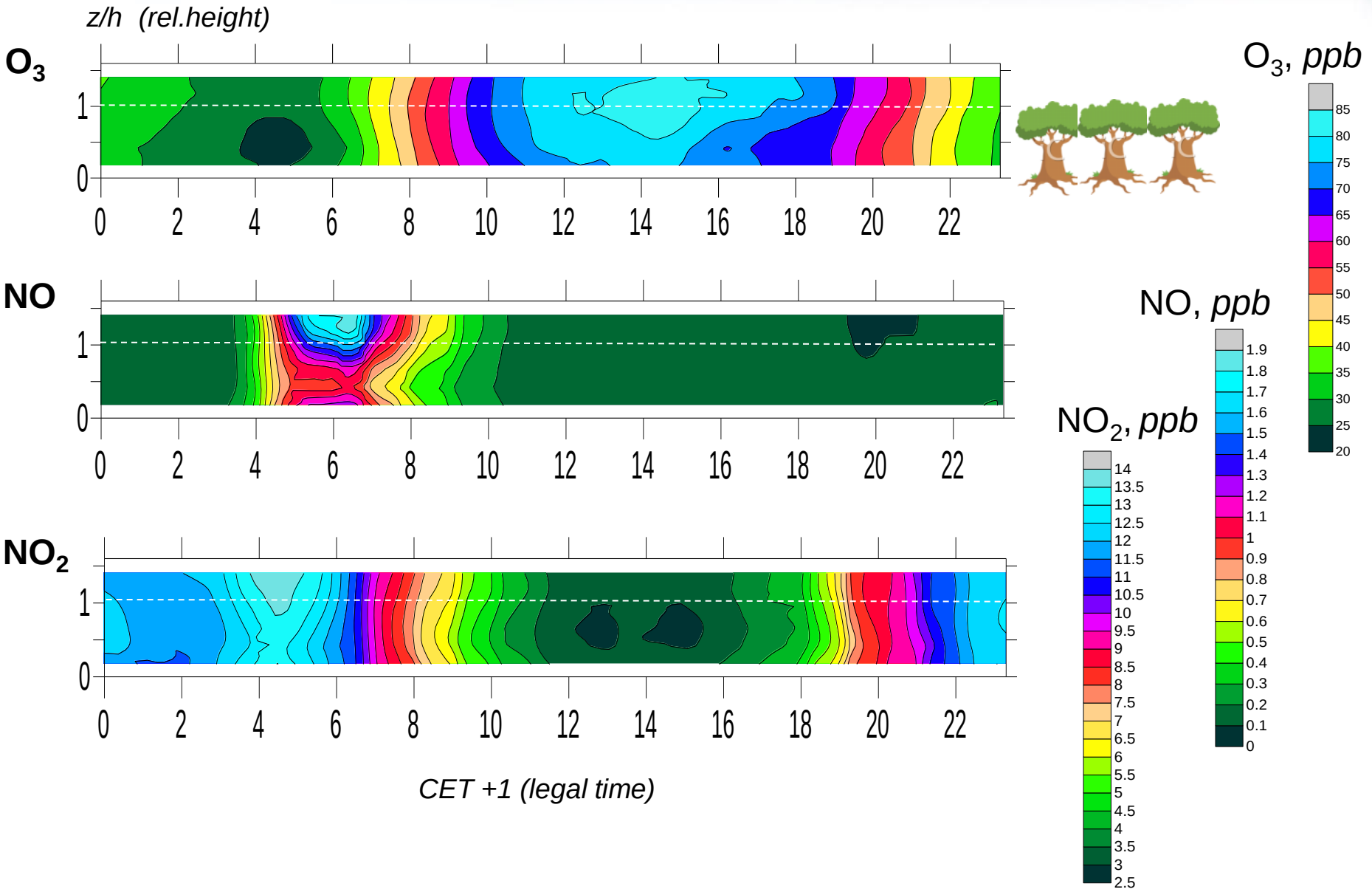
An examples of CO_2 flux measurements



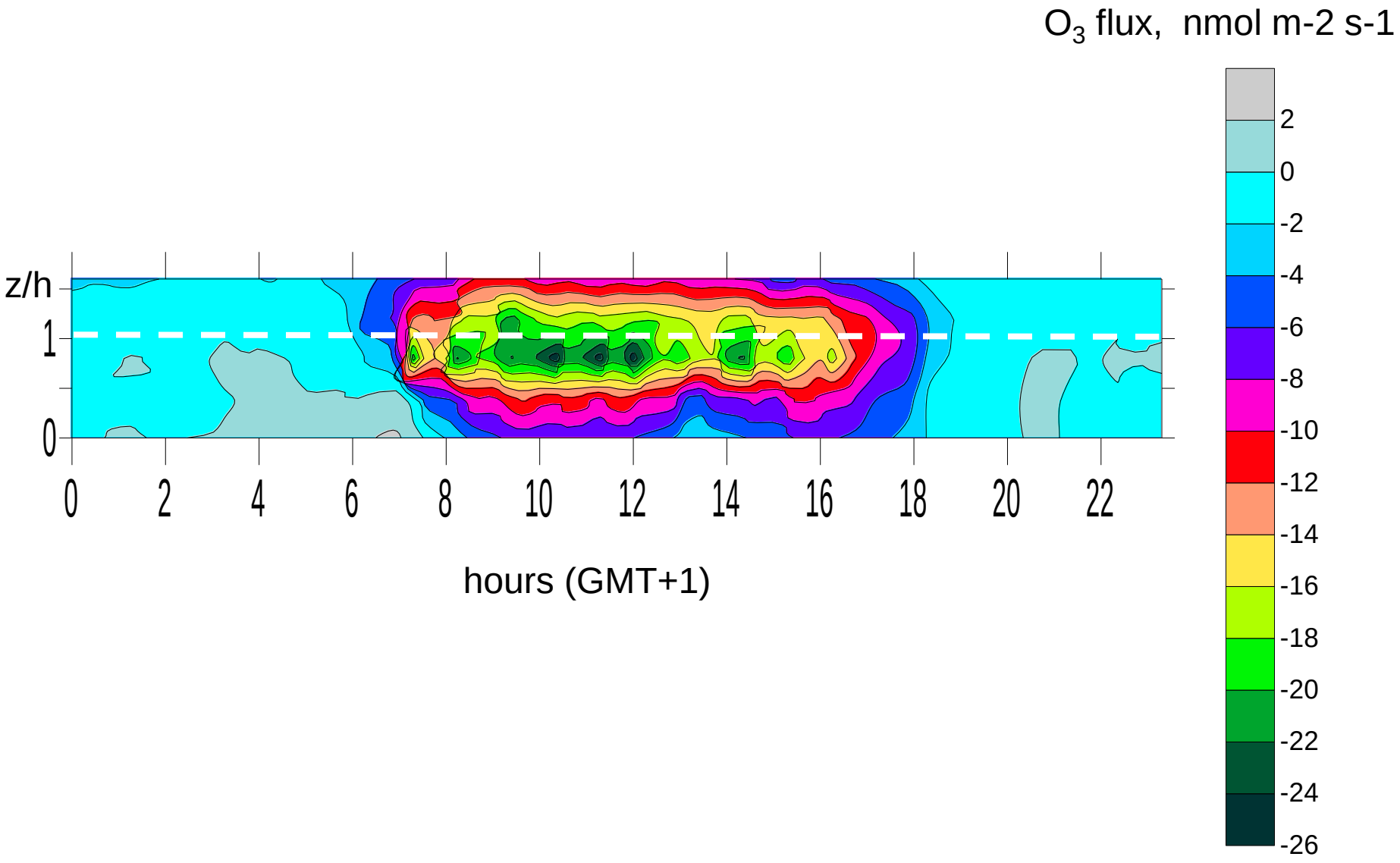
Fluxes corrected by the storage



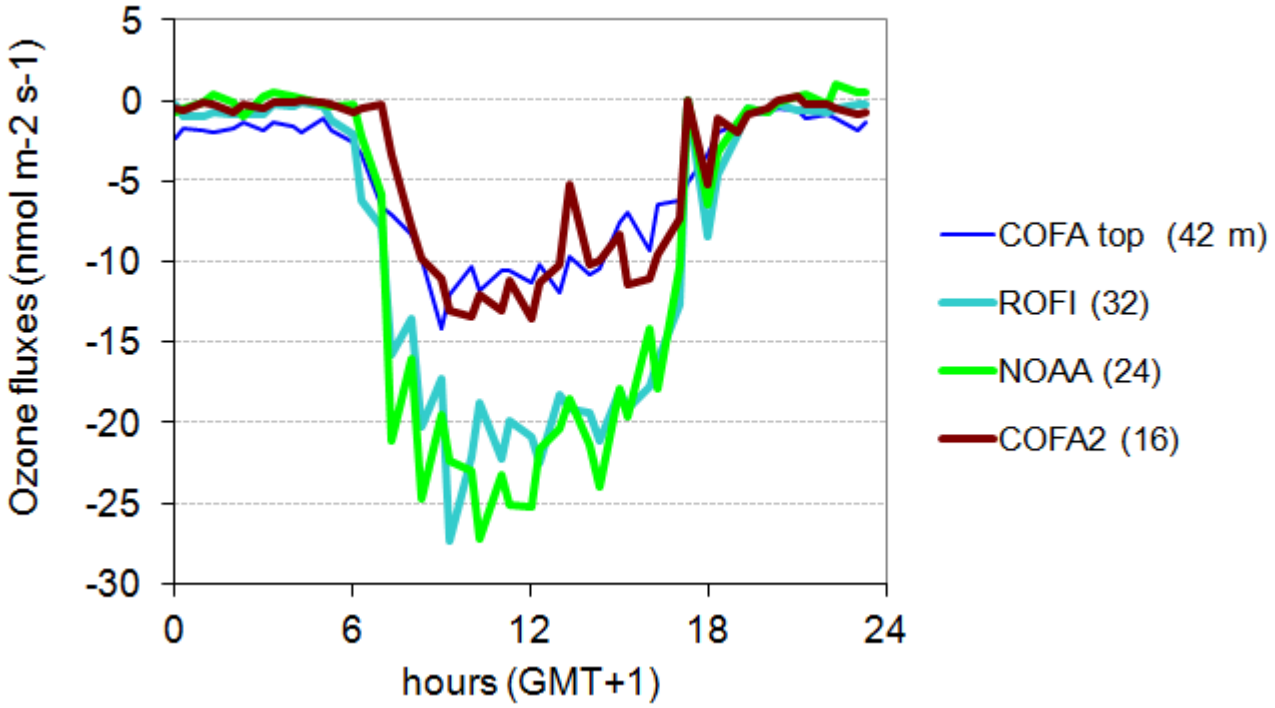
Concentration profiles, intensive campaign



Median Flux profiles, June - July 2012



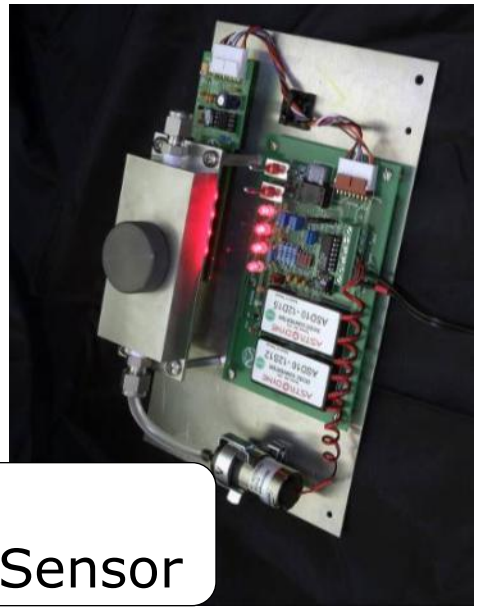
Median Flux profiles, June - July 2012



Ozone Fluxes

Fast Ozone Sensors

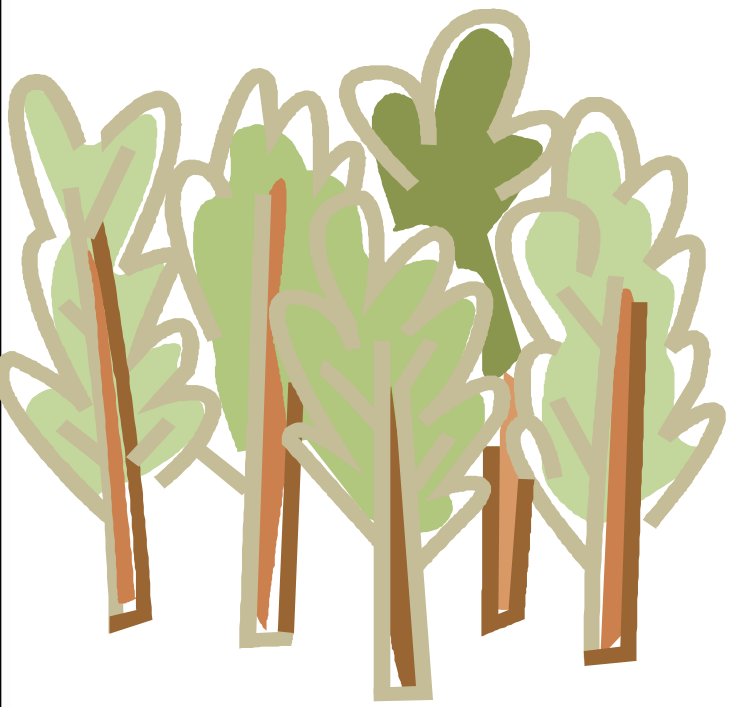
CEH ROFI
(Rapid Ozone Flux Instrument)



CRA-RPS
NOAA Fast-ozone Sensor

UNICATT COFA
(Chemiluminescence
Ozone Fast Analyser)

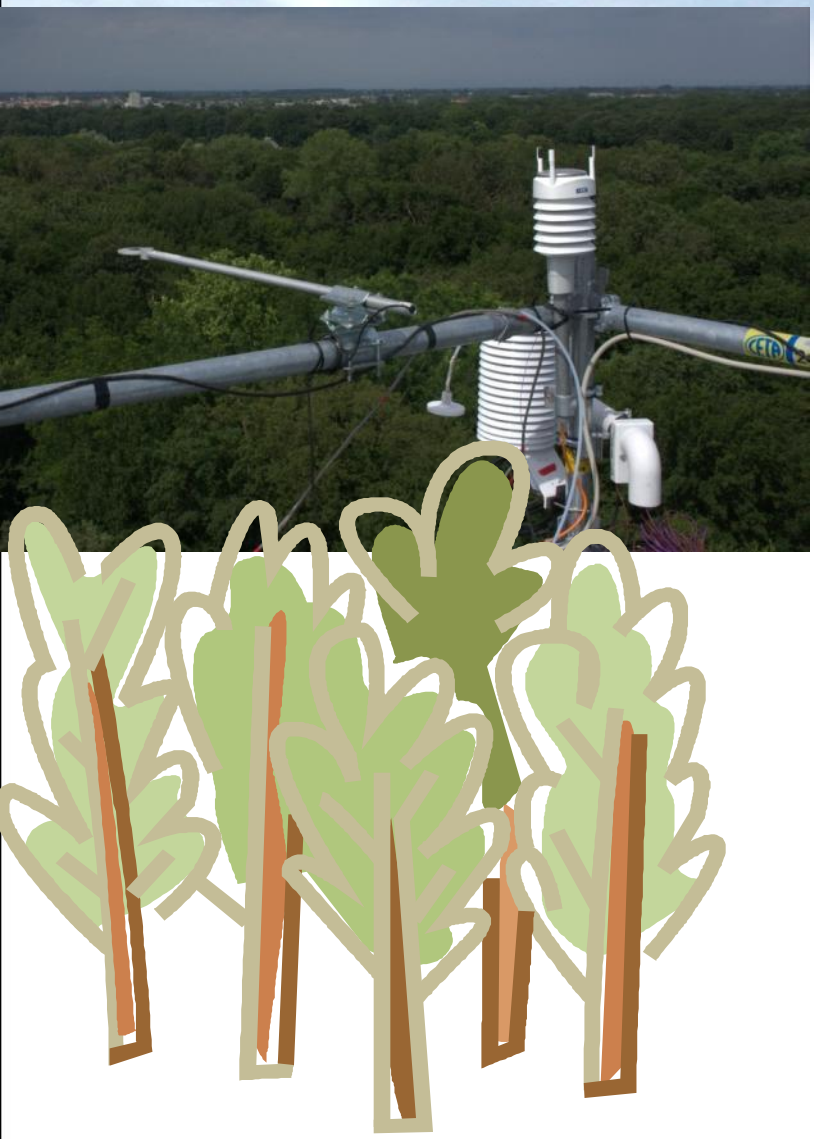
Gradient Data



- 5 heated gas inlets
  - Ozone
  - NO/NO_2
  - CO_2/H_2O
  - Continuously purged, sampled sequentially
- Aspirated thermocouples (Type-E)
- RH&T Probes (in radiation shields)

M Coyle, CEH 2012

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

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