evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

BVOC emissions and tropospheric ozone removal from crop and forest species

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Tato akce se koná v rámci projektu:
Vybudování vědeckého týmu environmentální metabolomiky a ekofyziologie a jeho zapojení do mezinárodních sítí (ENVIMET; r.č. **CZ.1.07/2.3.00/20.0246**) realizovaného v rámci Operačního programu Vzdělávání pro konkurenceschopnost.

Outline:

PART 1

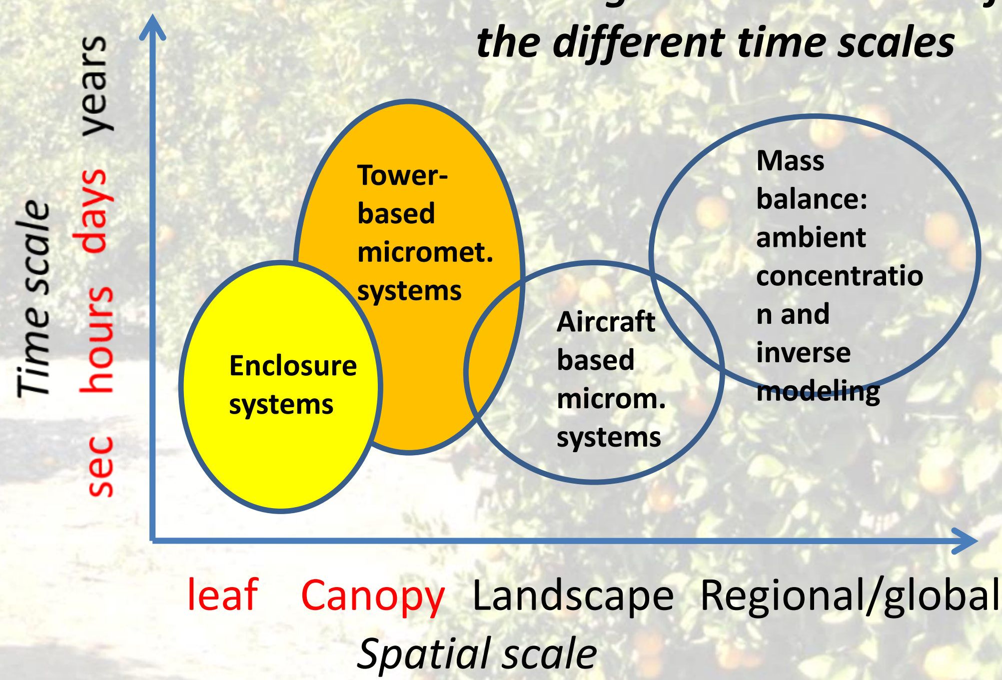
Why study troposheric ozone?

What are Biogenic Volatile Organic Compounds (BVOC)?

We cover two of these important levels of investigation over three of the different time scales

PART 2

Experimental measurements: from leaves to ecosystem



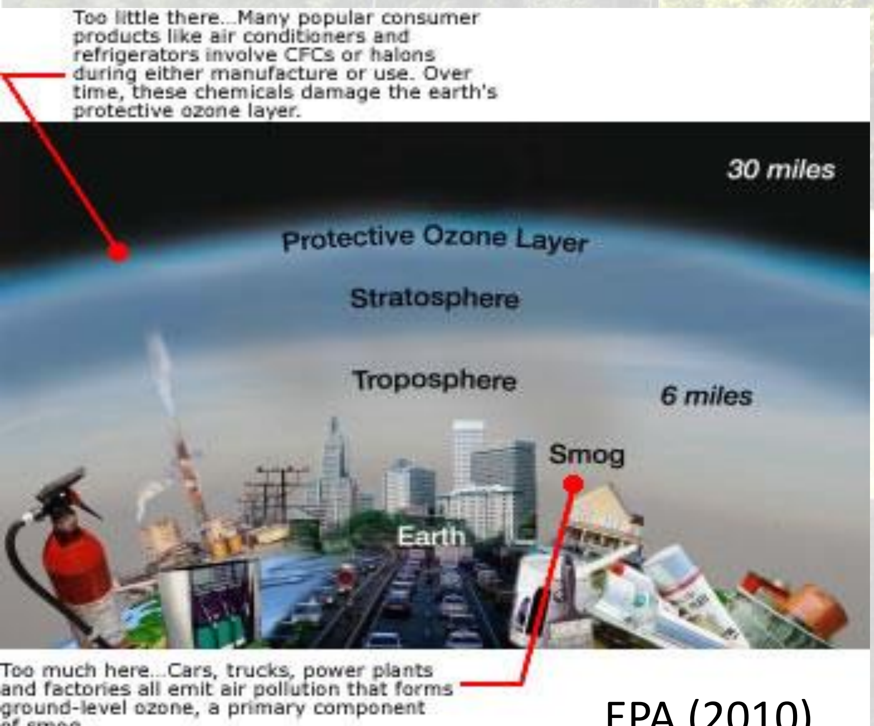
Ozone in low troposphere: an increasing threat for plants

Ozone in the stratosphere is GOOD!

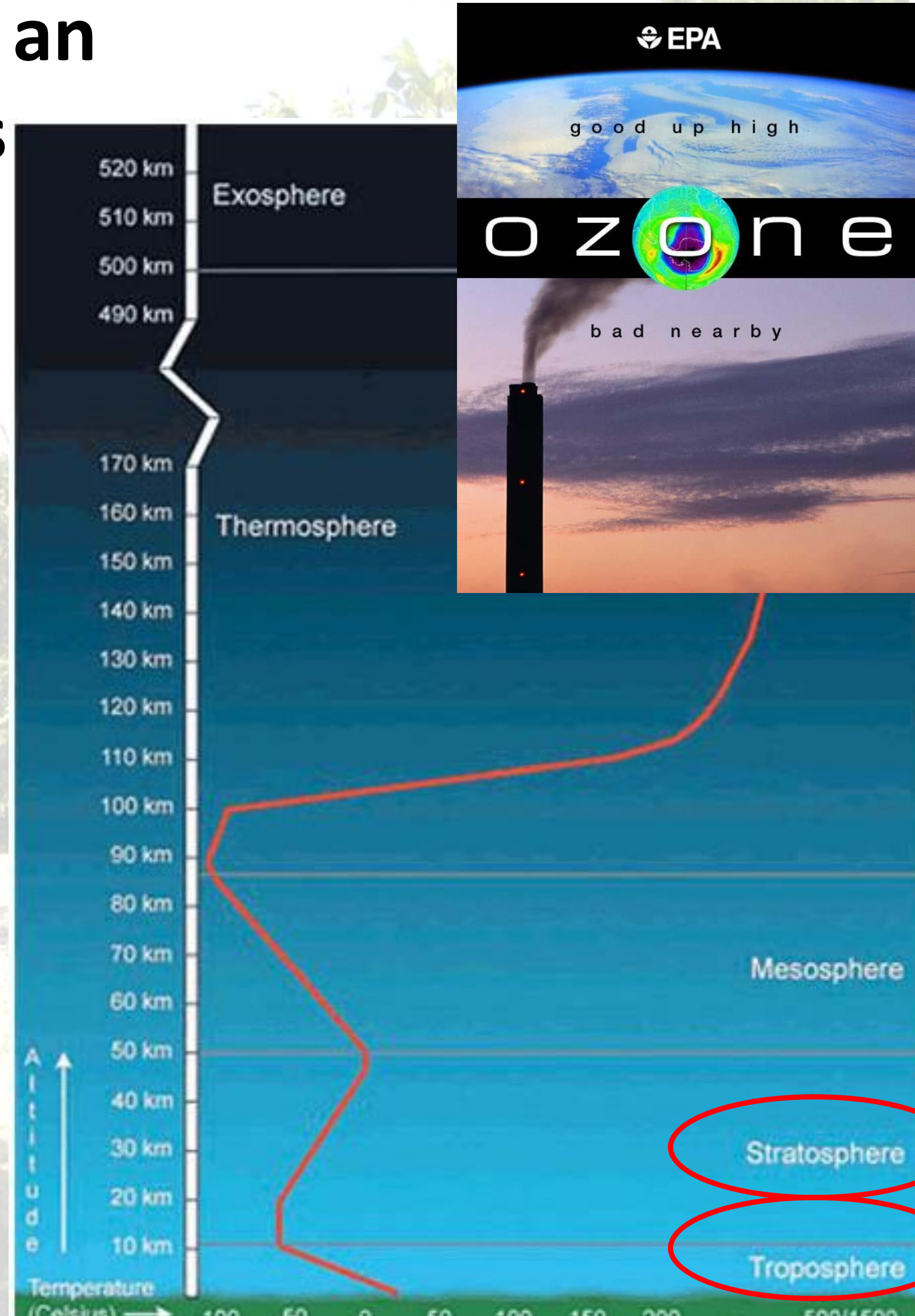
protects life on Earth from the sun's harmful ultraviolet (UV) rays

Ozone in the troposphere is BAD!

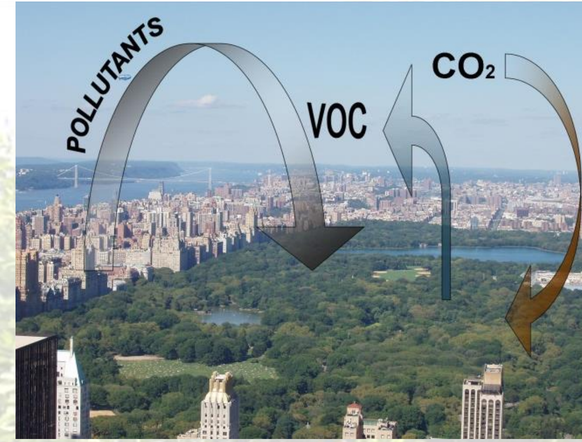
Damages humans and plants, greenhouse gas



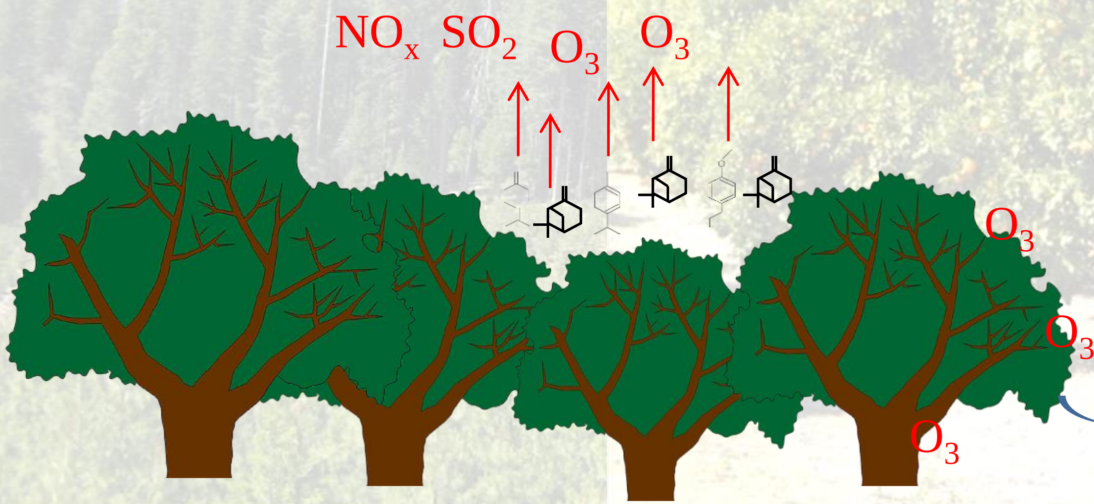
EPA (2010)

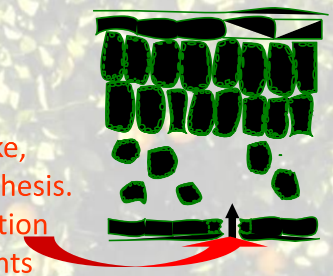


Relevance of plants for CO_2 and atmospheric pollutant removal



1. **Stomatal sink.** Stomatal opening regulate carbon uptake and largely contribute to pollutant removal in the atmosphere





CO2 uptake, photosynthesis. Detoxification of pollutants

2. **Surface deposition on cuticles and soil.** Adsorption processes

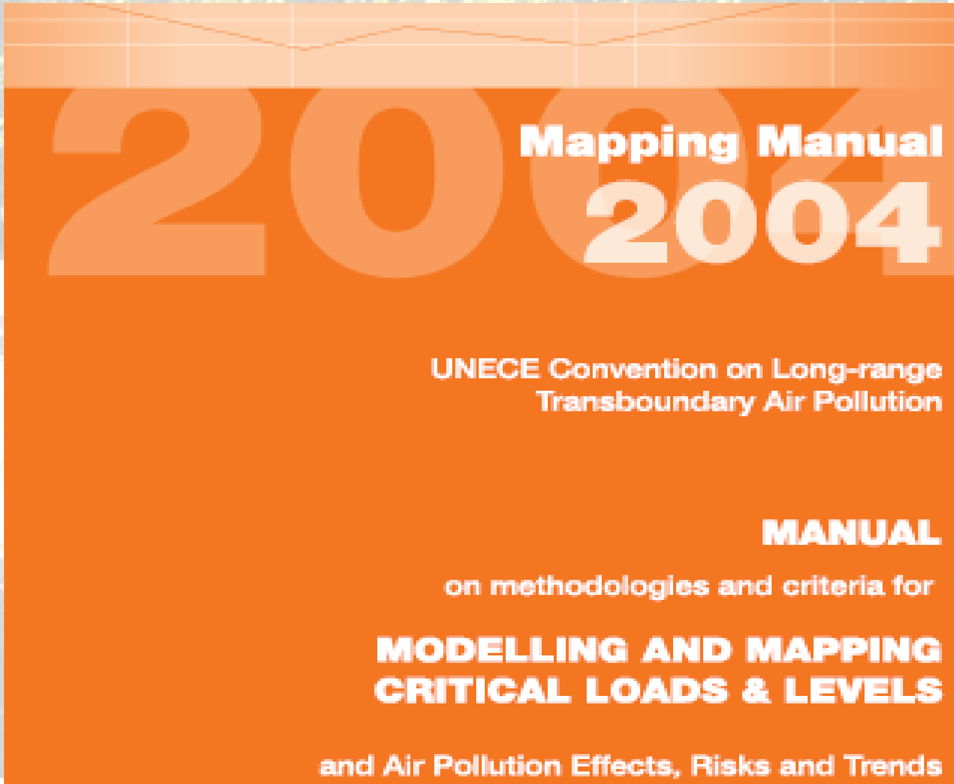
3. **Chemistry in the gas phase.** Reactions between BVOC and ozone

"Non-stomatal uptake"

Regulations to assess ozone risk to plants:

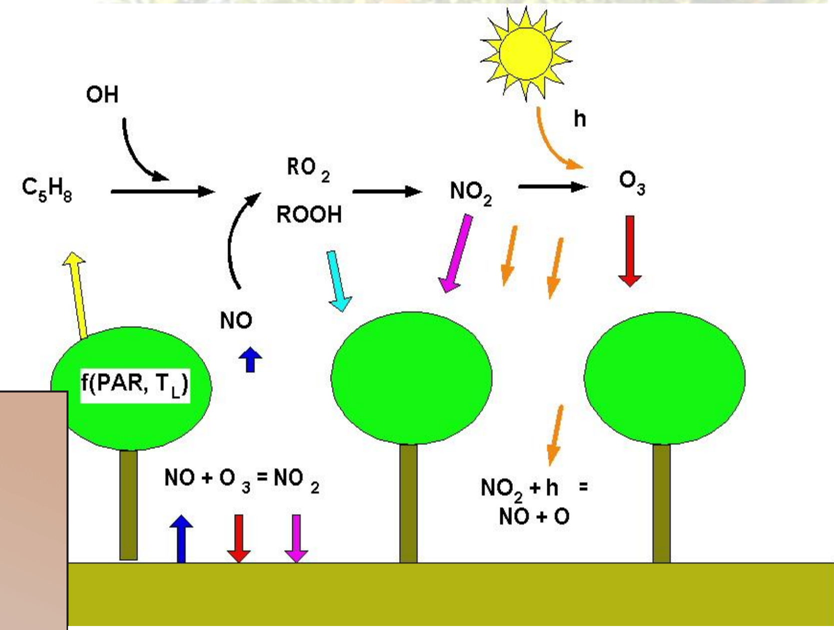
The present regulation in US and EU to assess critical ozone levels, is mostly based on estimates of an accumulated exposure over a threshold concentration (eg AOT40, SUM0)

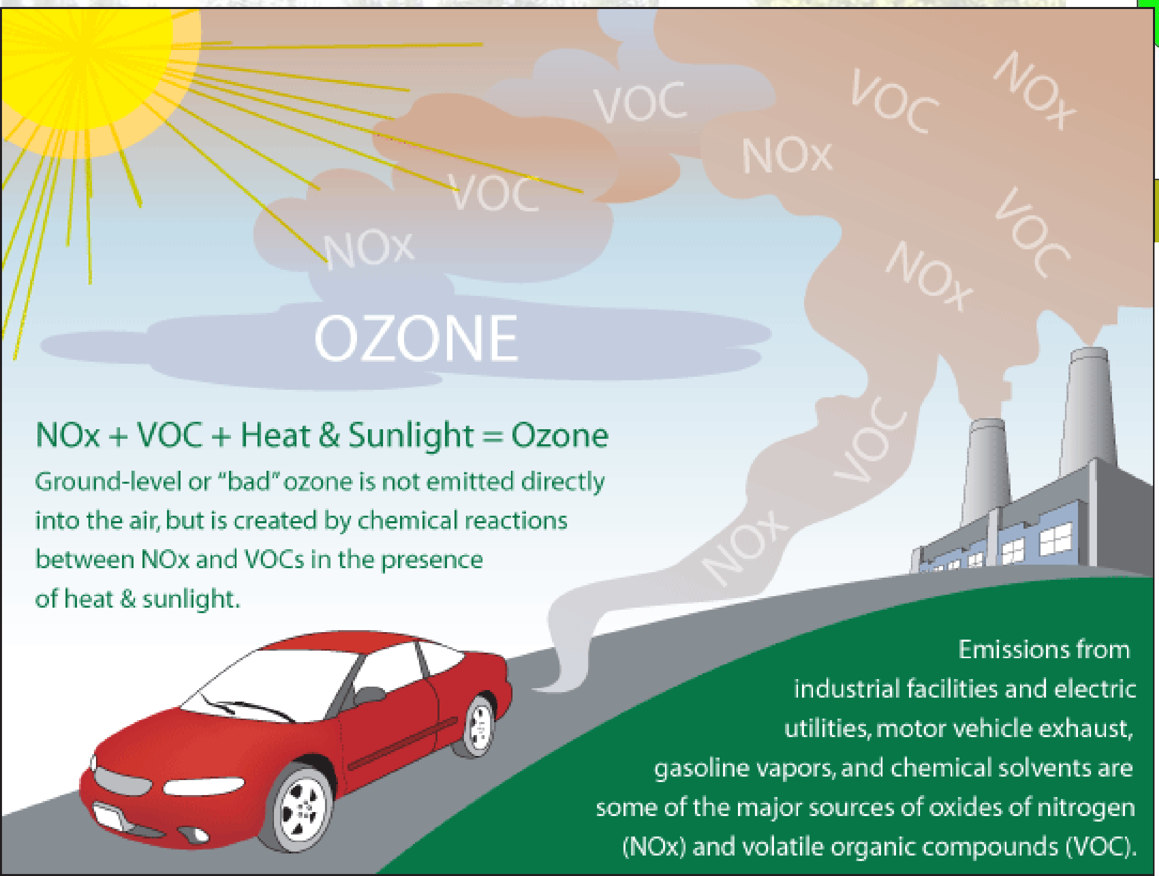
Scientific consensus is that flux estimates are more accurate because they include analysis of plant physiology and different environmental parameters that control the uptake of ozone (not just the exposure)

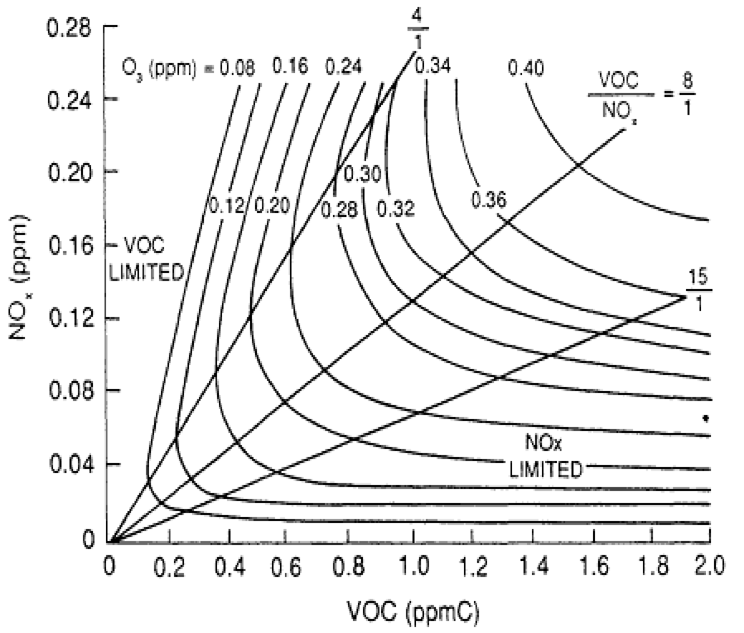


Ozone formation in the troposphere

O_3 formation is caused by photolytic reactions in wich NO_2 VOC and OH radicals take part







What are plant volatiles ?

Volatile organic compounds (VOC)

Biogenic (BVOC)

“Living plants”

Litter

Vegetation burning

Phytoplancton

Soil microorganisms

Anthropogenic (AVOC)

Small scale combustion

Mobile sources

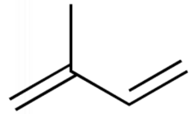
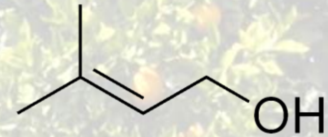
Solvent use

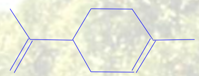
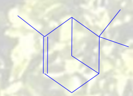
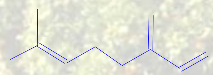
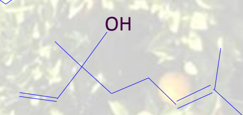
Fossil fuel production and distribution

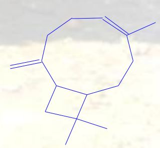
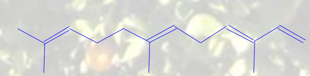
Chemical industry

Fossil fuel combustion

Types of Biogenic VOC

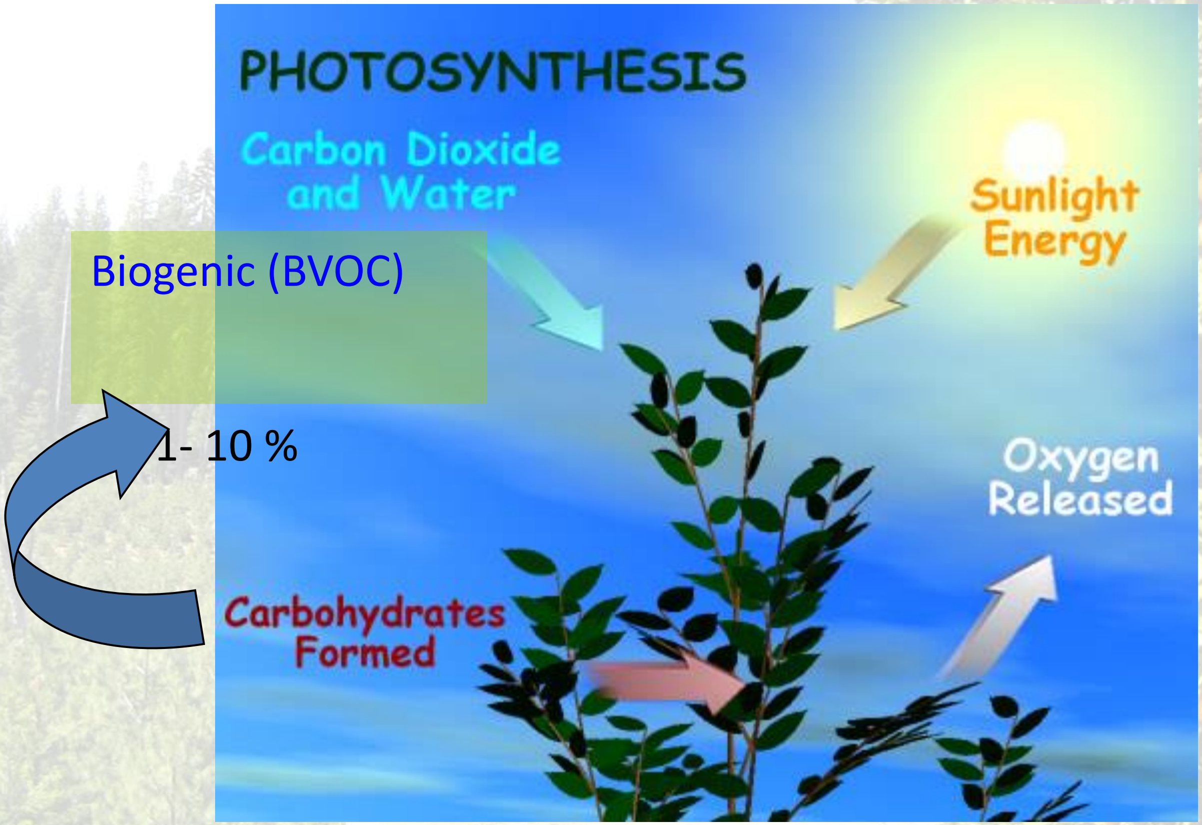
- Hemiterpenoids → C_5, only a few produced naturally
  - Isoprene
    (C_5H_8, alkene)
    
  - Methylbutenol
    ($C_5H_{10}O$, alcohol)
    

- Monoterpenoids → C_{10}, thousands of different structures
  - Limonene
    
  - α- pinene
    (alkene)
    
  - myrcene
    (alkene)
    
  - linalool
    (alcohols)
    

- Sesquiterpenoids → C_{15}, most varied class of terpenoids
  - ß-caryophyllene
    
  - farnesene
    

- **Isoprene (C_5H_8)**
- **Monoterpenes ($C_{10}H_{16}$)**
- **Oxygenated VOC**
- **Sesquiterpenes ($C_{15}H_{24}$)**

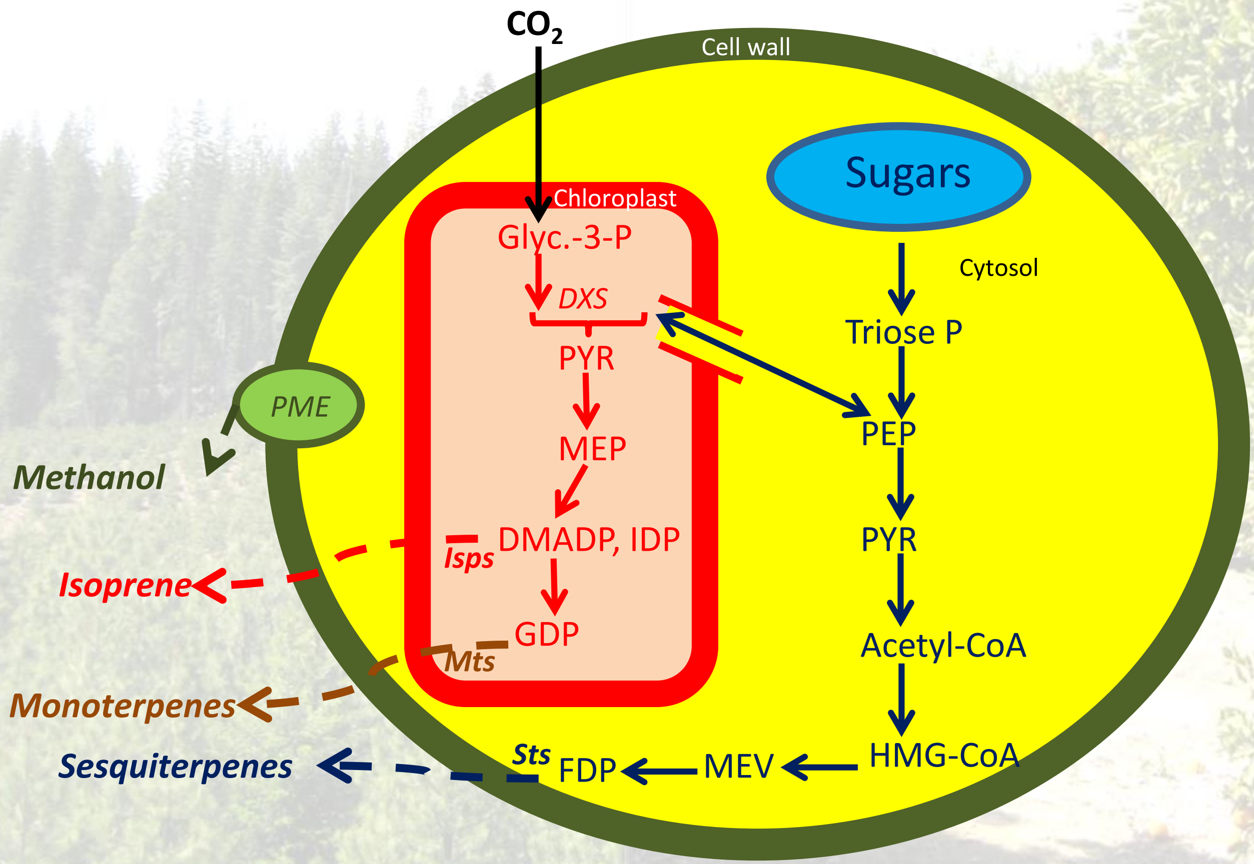
The emission of BVOC from plants



Plants recycle some Carbon fixed with Photosynthesis to form BVOC!

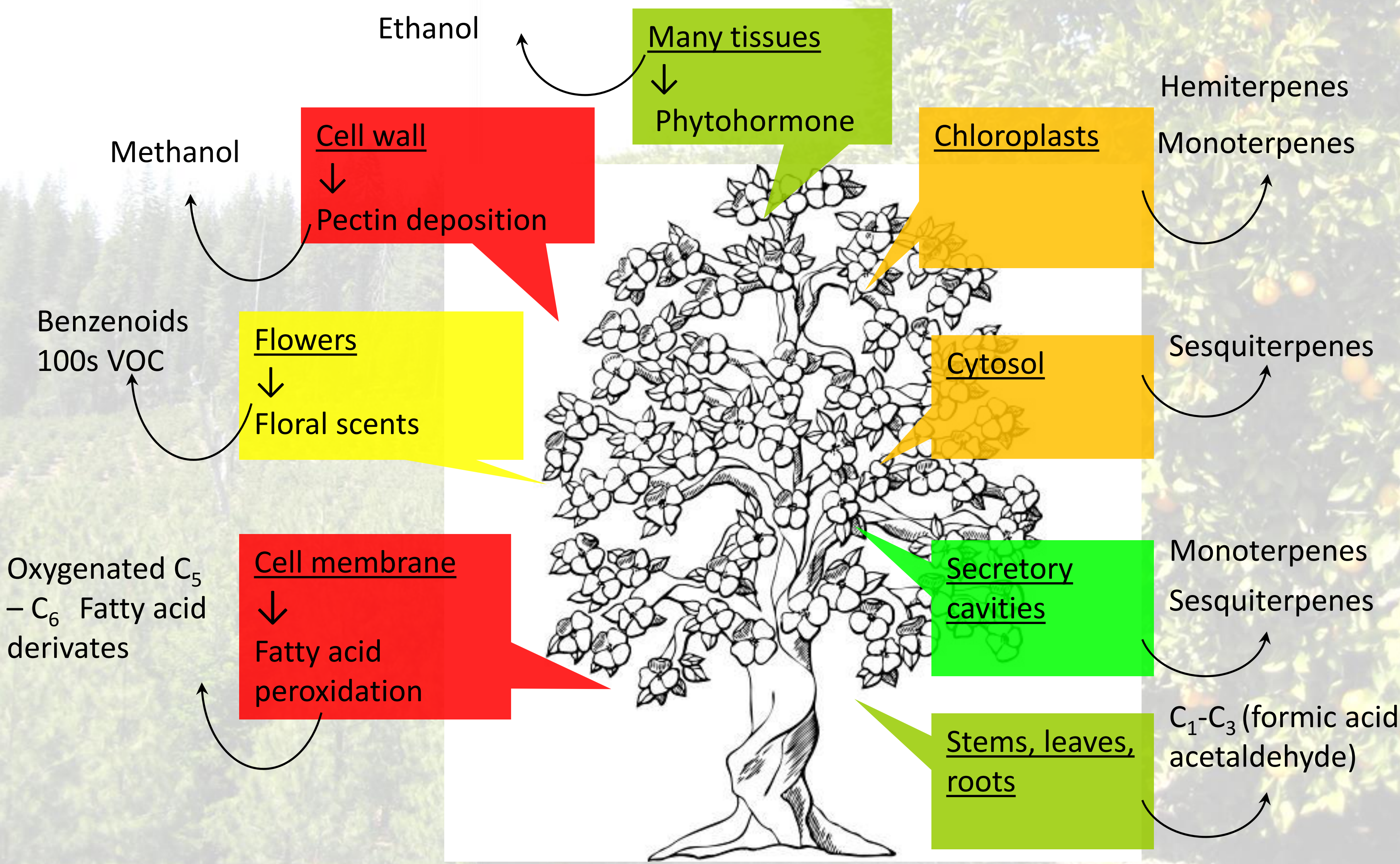
The emission of BVOC from plants

Cytosol and Choloroplasts are the main site of production of isoprenoids



Isoprene (choroplastic origin) is more depending on photosynthetic pathway, while monoterpenes depend more on temperature-driven catabolism of sugars in the cytosol

Source of volatiles in the plant



Why BVOC are emitted?

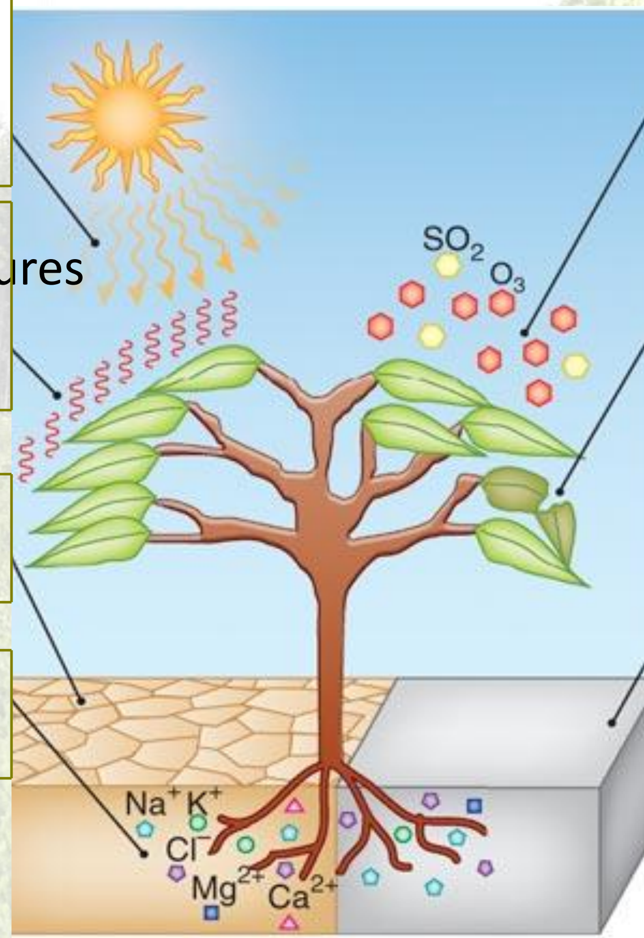
- Protection of the plant against:

High light

High temperatures

Water deficit

Soil salinity



Air pollution

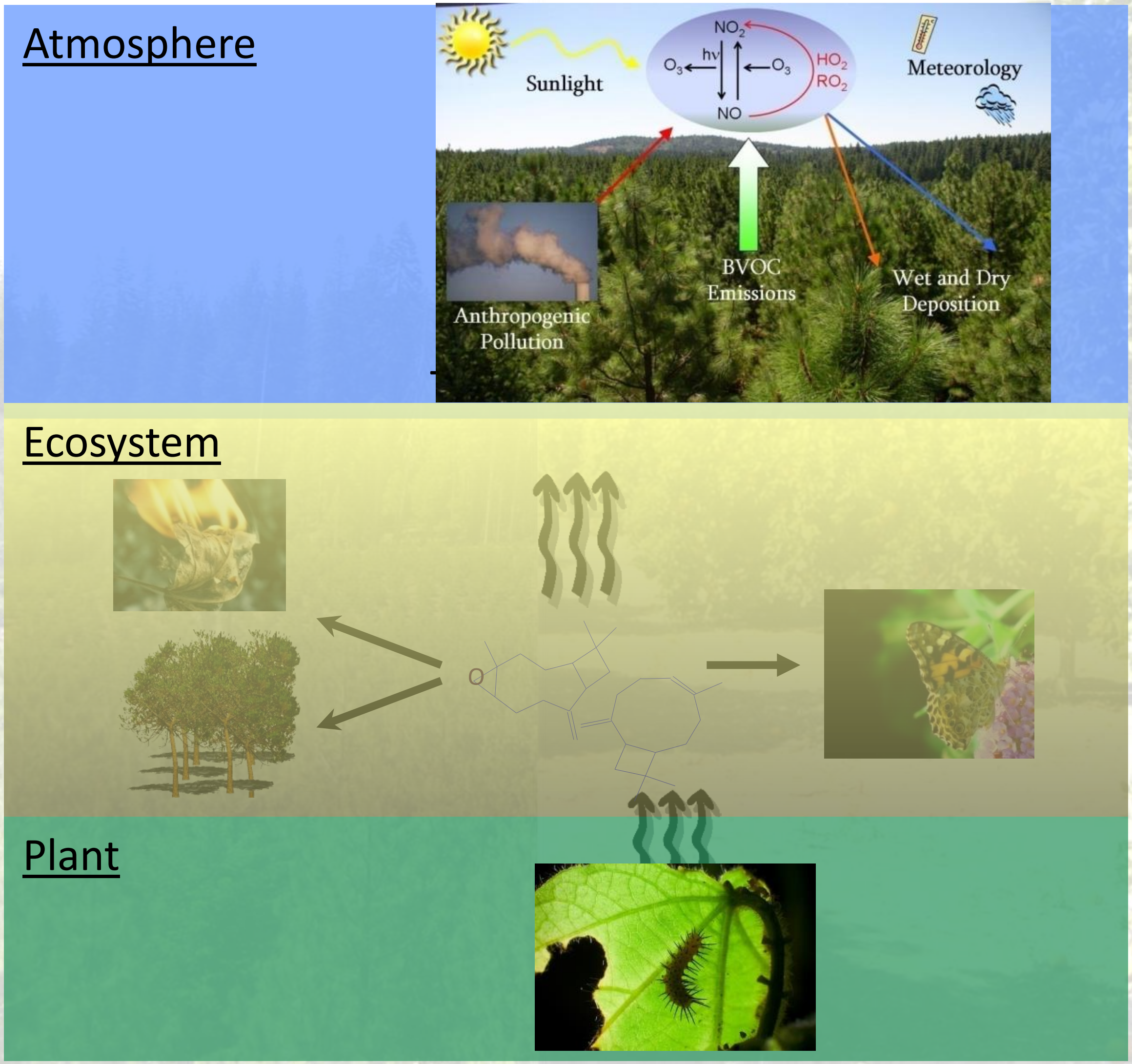
Biotic stress:
Mechanical damage due to herbivores

Pathogens infection

Cold stress

Vickers et al. (2009)
Nature Chemical Biology

Plants interact with the ecosystem using BVOC



- Key component in the biosphere-atmosphere interactions.

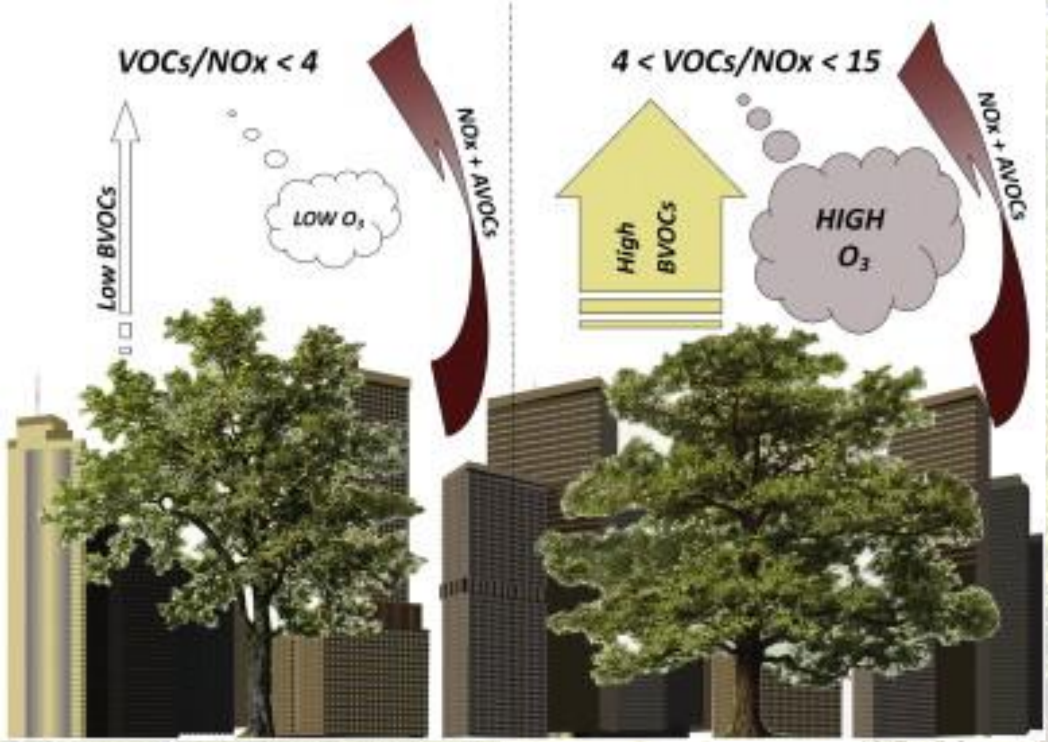
Sunlight

VOC + NOx ⟶ Ozone

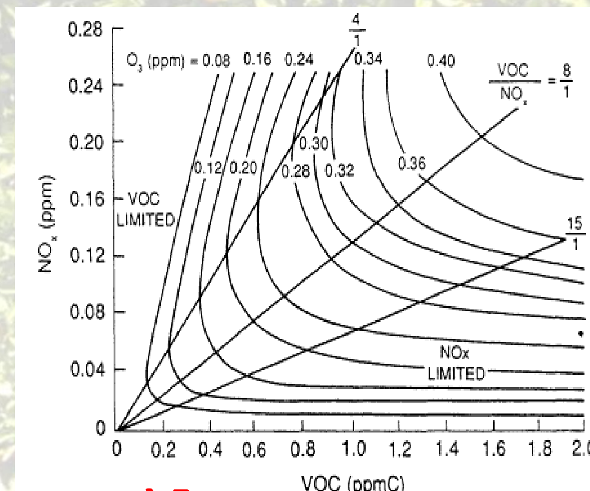
- Affect other plants and organism
- Favour the ecosystem perturbation
- Play an additional or alternative role in plant defences

BVOC & Ecosystem changes

The ozone-forming potential from certain VOC species has to be considered



Ozone is photochemically produced when VOC and NOx are abundant and around a ratio of 8!



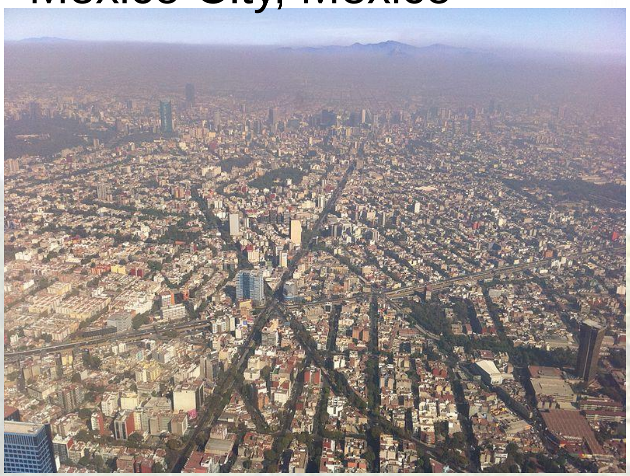
$$OFP_{species} = B[(E_{iso}R_{iso}) + (E_{mono}R_{mono})]$$

where B is the biomass factor [(g leaf dry weight m^{-2} ground area)], E_{iso} and E_{mono} are species-specific mass emission rates [(µg VOC) g^{-1} leaf dry weight day^{-1}] for isoprene and monoterpenes respectively, R_{iso} and R_{mono} are reactivity factors [g O_3 g^{-1} VOC].

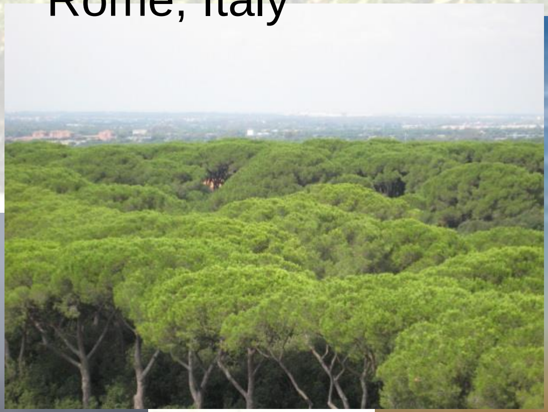
Dust and aerosol primarily emitted from combustion sources and formed by photochemical activity

San Francisco, California, USA

Mexico City, Mexico



Rome, Italy



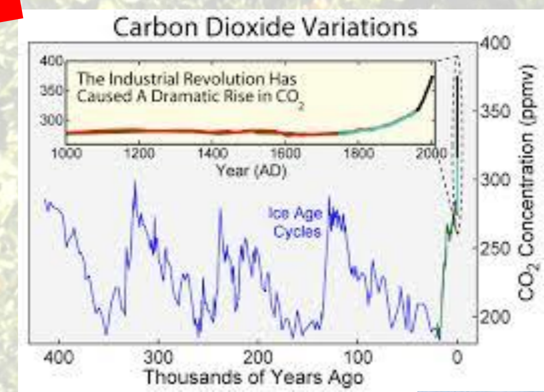
Sao Paolo, Brazil

Beijing, China

VOC emission in changing ecosystems

Pollution

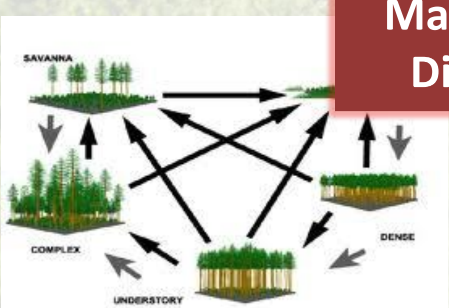
Biotic stress



VOC emission

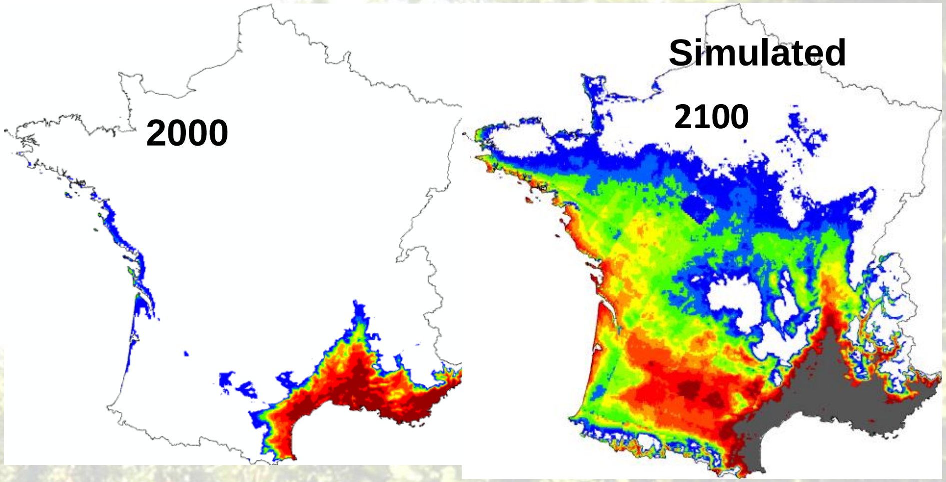
Climate Change

Ecosystem Management & Disturbances



Climate change & Species composition

Climatic areas for holm oak
(Quercus ilex)



Projection in 2100 is based on the ARPEGE model (Meteo-France) using a scenario with an increased mean temperature of 2.5 C.

(*Badeau et al., 2007*)

In southern and central Europe the most sensitive forest types are tree species which are at the southernmost limit of their distribution range. Thermophilous trees particularly Mediterranean **evergreen oaks** favored at the expense of conifers & beech

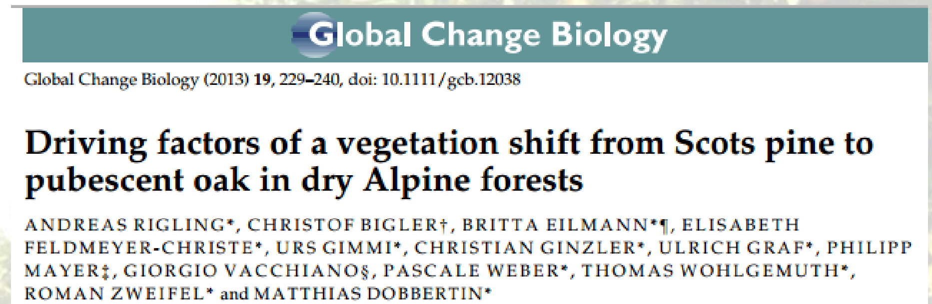
ELSEVIER
Environmental and Experimental Botany
journal homepage: www.elsevier.com/locate/envexpbot

The challenge of Mediterranean sclerophyllous vegetation under climate change: From acclimation to adaptation

Filippo Bussotti, Francesco Ferrini, Martina Pollastrini, Alessio Fini*
University of Florence, Department of Agri-Food Production and Environmental Sciences (DISPAA), Piazzale delle Cascine 18, 50144 Firenze, Italy

Climate change affects plant composition and VOC emission

Contraction of *P. sylvestris* at the lower limit of its range in Switzerland is in favor of a greater expansion of the deciduous xero-tolerant oak species *Quercus pubescens*

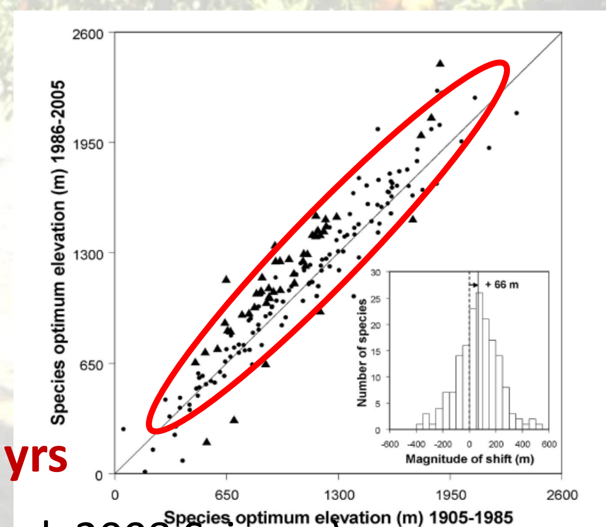

Global Change Biology

Global Change Biology (2013) **19**, 229–240, doi: 10.1111/gcb.12038

Driving factors of a vegetation shift from Scots pine to pubescent oak in dry Alpine forests

ANDREAS RIGLING*, CHRISTOF BIGLER†, BRITTA EILMANN*¶, ELISABETH FELDMEYER-CHRISTE*, URS GIMMI*, CHRISTIAN GINZLER*, ULRICH GRAF*, PHILIPP MAYER‡, GIORGIO VACCHIANO§, PASCALE WEBER*, THOMAS WOHLGEMUTH*, ROMAN ZWEIFEL* and MATTHIAS DOBBERTIN*

Comparing the **altitudinal distribution** of 171 forest plant species between 1905 and 1985 and 1986 and 2005 along the entire elevation range (0 to 2600 meters above sea level) in west Europe



30 m/10 yrs

(Lenoir et al, 2008 Science)

Species composition change in favour of high VOC emitter?

The greater terpene emission capacity may confer protection against multiple stresses and may partly account for the success of the **invasive species**, and may make invasive species more competitive in response to new global change-driven combined stresses

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2010) **19**, 863–874

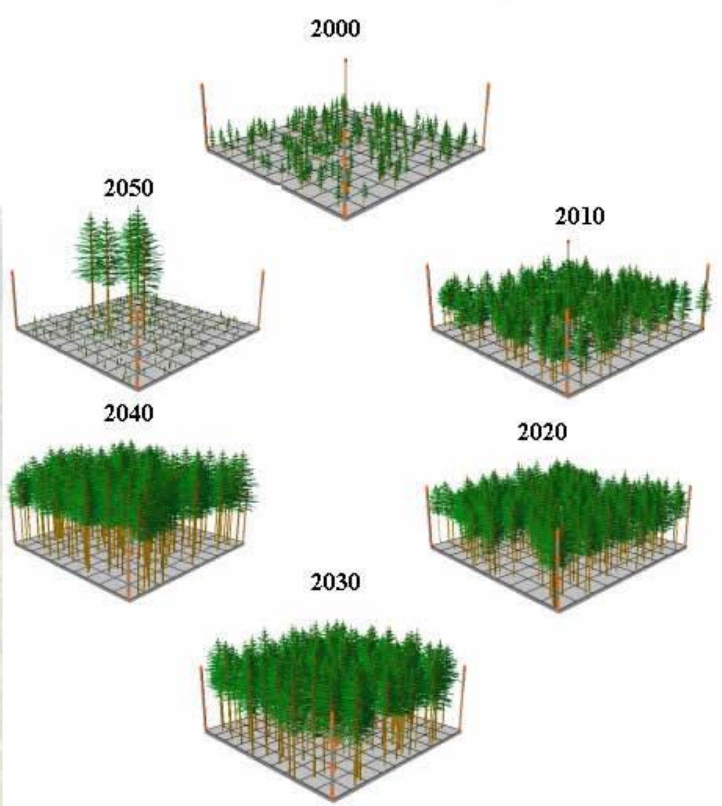
RESEARCH PAPER

Measurement of volatile terpene emissions in 70 dominant vascular plant species in Hawaii: aliens emit more than natives

Joan Llusià[1]*, Josep Peñuelas[1], Jordi Sardans[1], Susan M. Owen[2] and Ülo Niinemets[3]

Ecosystem management & VOC emission

Abandonment of forest management favours senescent trees with low natural regeneration and loss of biodiversity



Old trees are less vulnerable to drought stress. Long rotation periods in water limited ecosystems is postulated


Agricultural and Forest Meteorology 192–193 (2014) 18–26

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

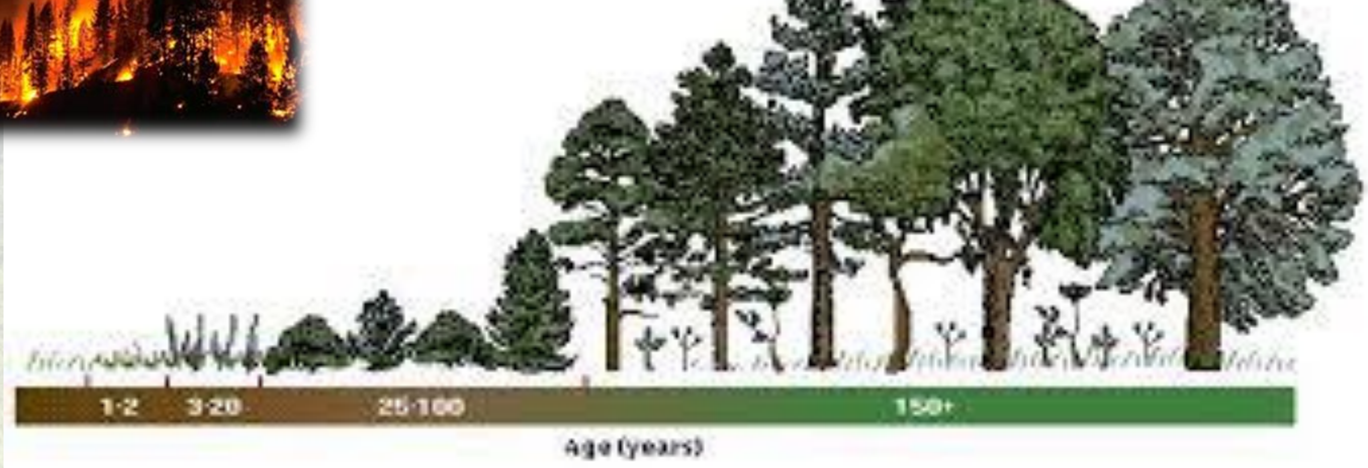
journal homepage: www.elsevier.com/locate/agrformet

Competition and tree age modulated last century pine growth responses to high frequency of dry years in a water limited forest ecosystem

Jaime Madrigal-González*, Miguel A. Zavala

Disturbances, ecological successions and structural changes

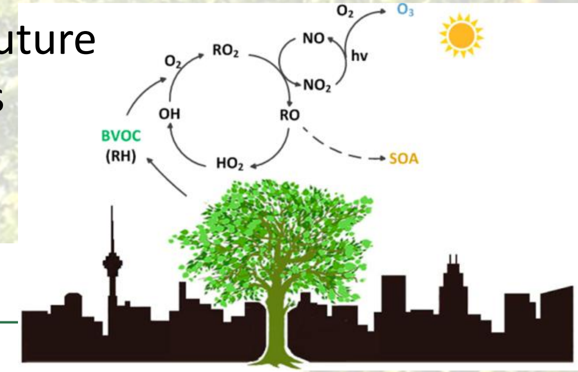
Not all ecosystems reach their climax due to frequent disturbances…



Successional dynamics affect species composition and structural changes of the canopy

Changing ecosystems in urban areas

Urban management plays an important role in determining future urban BVOC emissions in response to environmental changes

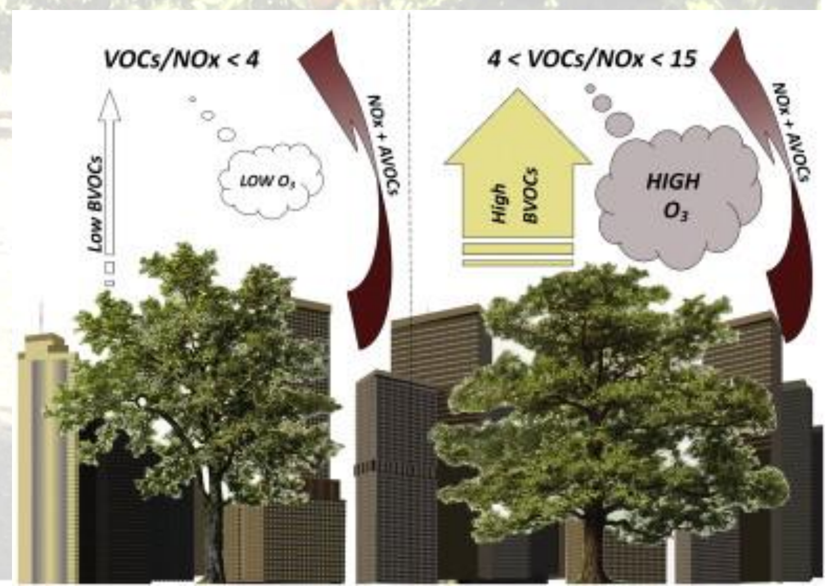


Environmental Science & Technology 2014

Role of Management Strategies and Environmental Factors in Determining the Emissions of Biogenic Volatile Organic Compounds from Urban Greenspaces

Yuan Ren,† Ying Ge,† Baojing Gu,‡ Yong Min,§ Akira Tani,∥ and Jie Chang*,†

A high ecosystem service value (e.g., lowest BVOC/leaf mass ratio) could be achieved through positive coping in confronting environmental changes and adopting proactive urban management strategies on a local scale, and optimizing the species composition of existing and newly planted trees



Stressed ecosystems & emission changes

VOC emissions change in response to oxidative stress: the ecosystem may turn from source to sink

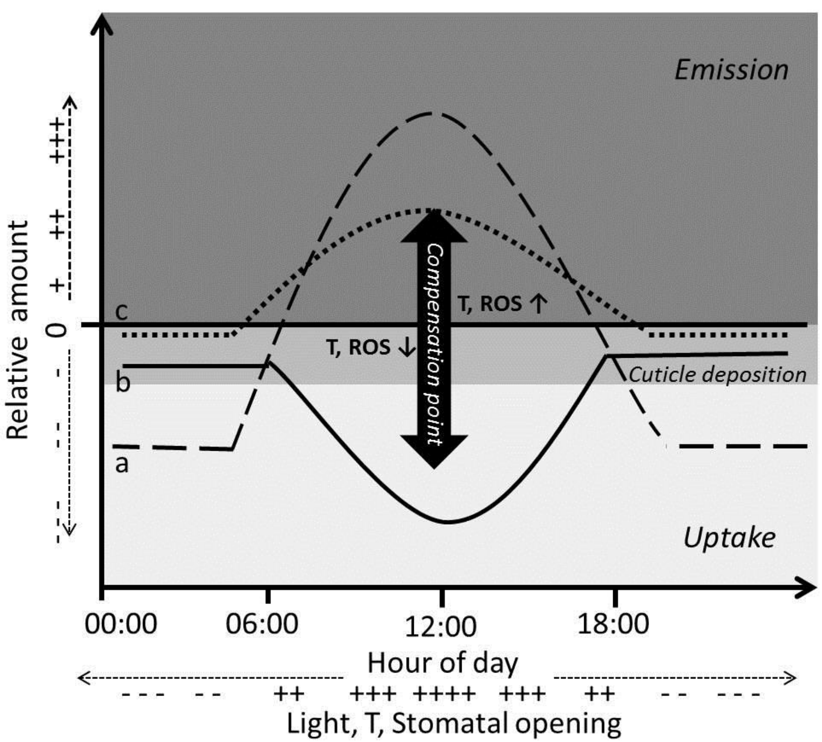
Plant, Cell & Environment

Plant, Cell and Environment (2014) doi: 10.1111/pce.12322

Invited Review

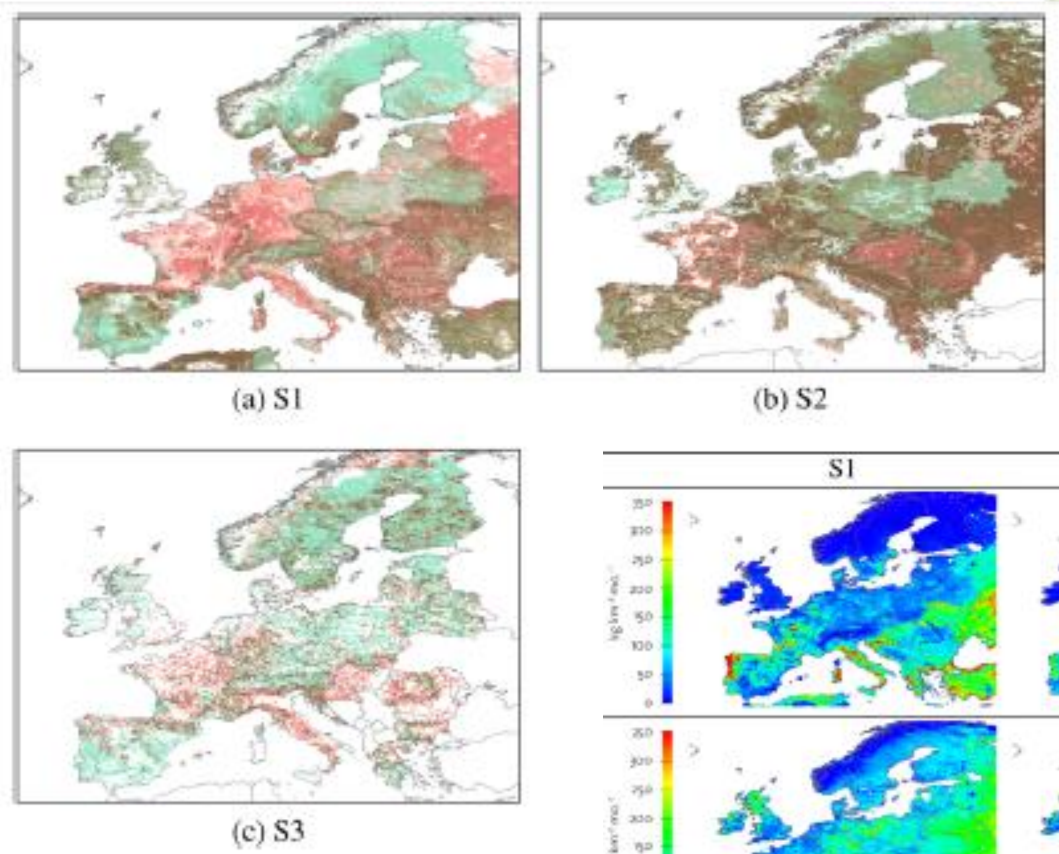
Bidirectional exchange of biogenic volatiles with vegetation: emission sources, reactions, breakdown and deposition

Ülo Niinemets[1,2], Silvano Fares[3], Peter Harley[1] & Kolby J. Jardine[4]



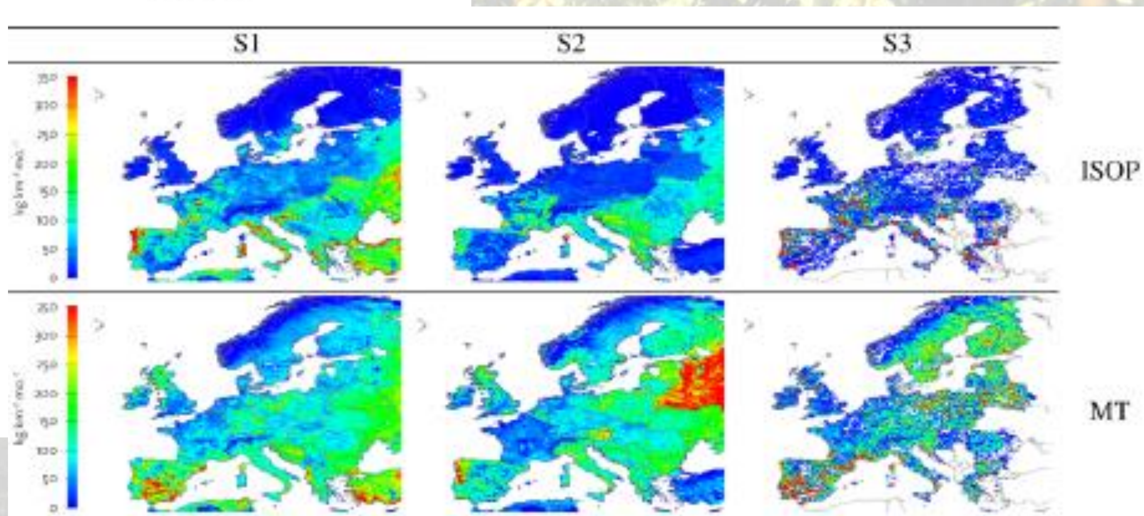
Can emission models properly take into account ecosystem changes? Are current vegetation inventories adequate?

Emissions based on three different vegetation inventories diverge due to a potential miss-attribution of broad-leaved trees and reduced tree-cover



(a) S1 (b) S2 (c) S3

Oberbolz et al. ACP 2013



Divergent Emission factors produce emission uncertainties

The uncertainties in emission estimates lead to uncertainties (2 to 10%) in life-time prediction of ozone, CO, CH4

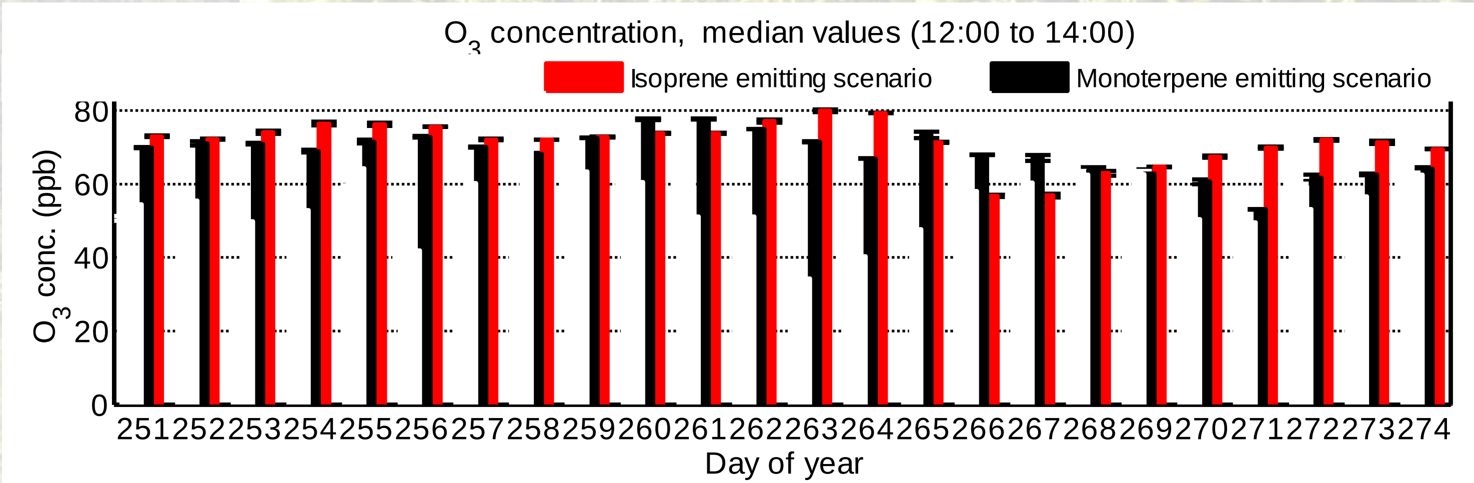
Atmos. Chem. Phys., 13, 2857–2891, 2013
www.atmos-chem-phys.net/13/2857/2013/
doi:10.5194/acp-13-2857-2013

Atmospheric Chemistry and Physics
Open Access

Quantifying the uncertainty in simulating global tropospheric composition due to the variability in global emission estimates of Biogenic Volatile Organic Compounds

J. E. Williams[1], P. F. J. van Velthoven[1], and C. A. M. Brenninkmeijer[2]

A global model (MEGAN coupled with CLM) run with realistic BEF from prevailing MT emitting species predicted lower concentrations of tropospheric ozone compared with an isoprene emitting scenario



Environmental Science & Technology 2013
pubs.a

Observations of Diurnal to Weekly Variations of Monoterpene-Dominated Fluxes of Volatile Organic Compounds from Mediterranean Forests: Implications for Regional Modeling

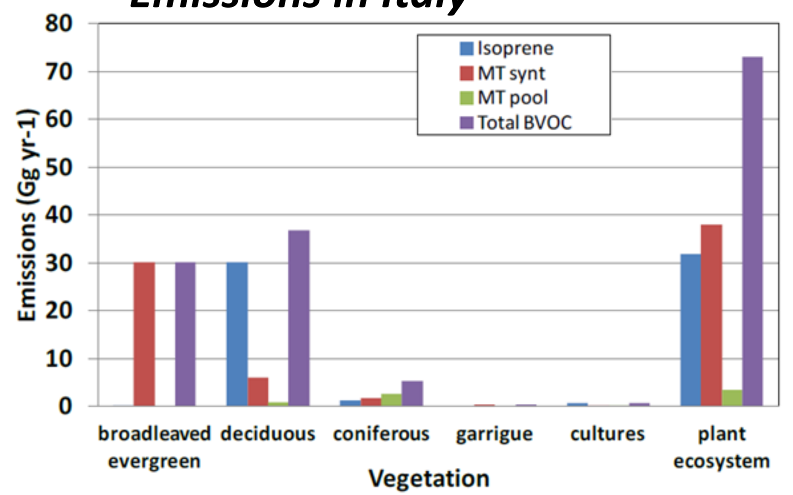
Silvano Fares,[†,*] Ralf Schnitzhofer,[‡] Xiaoyan Jiang,[§] Alex Guenther,[§] Armin Hansel,[‡,∥] and Francesco Loreto[⊥]

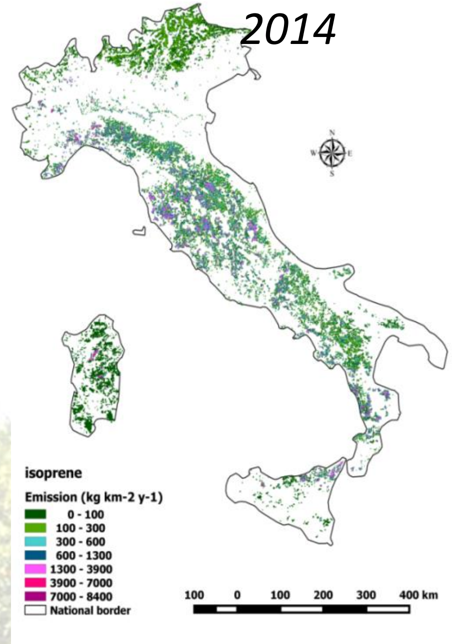
Kemper, Fares and Ciccioli, Atm. Env. 2014

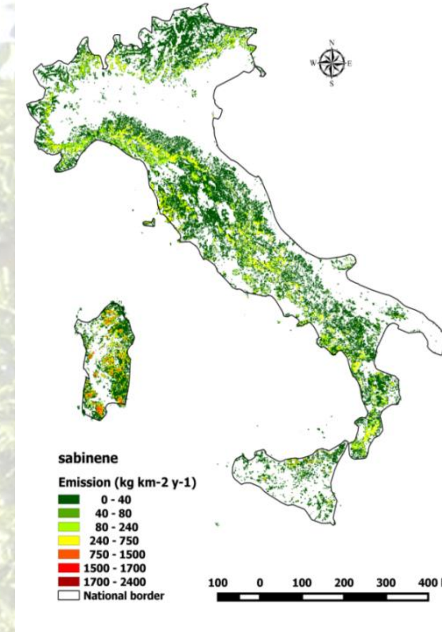
Integration of vegetation maps & national forest inventories: Emission Factor attribution for a realistic estimate

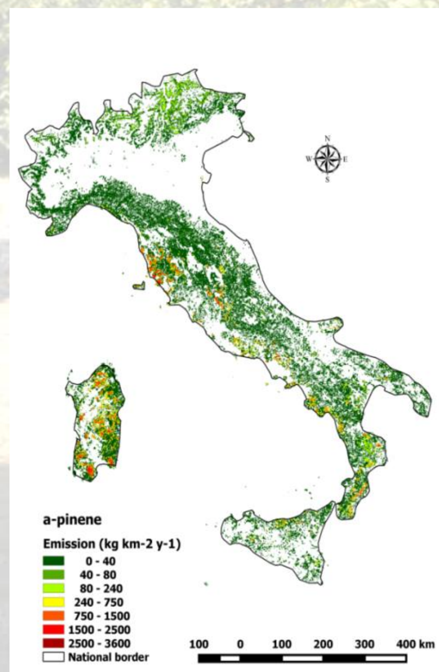
Do we have enough information on BEF? Is it still worth measuring BEF at leaf/ecosystem scale?

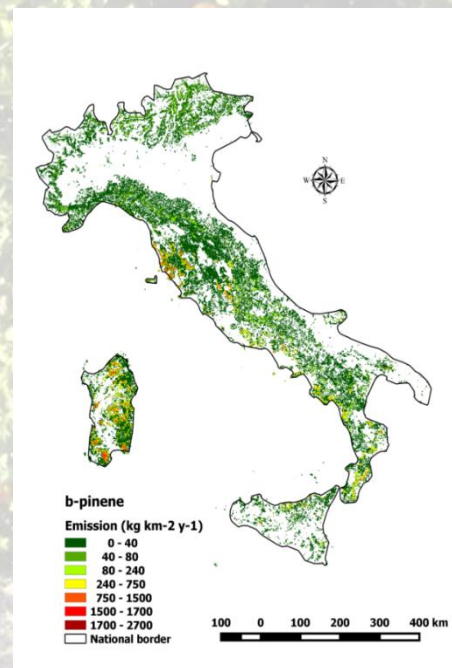
Emissions in Italy





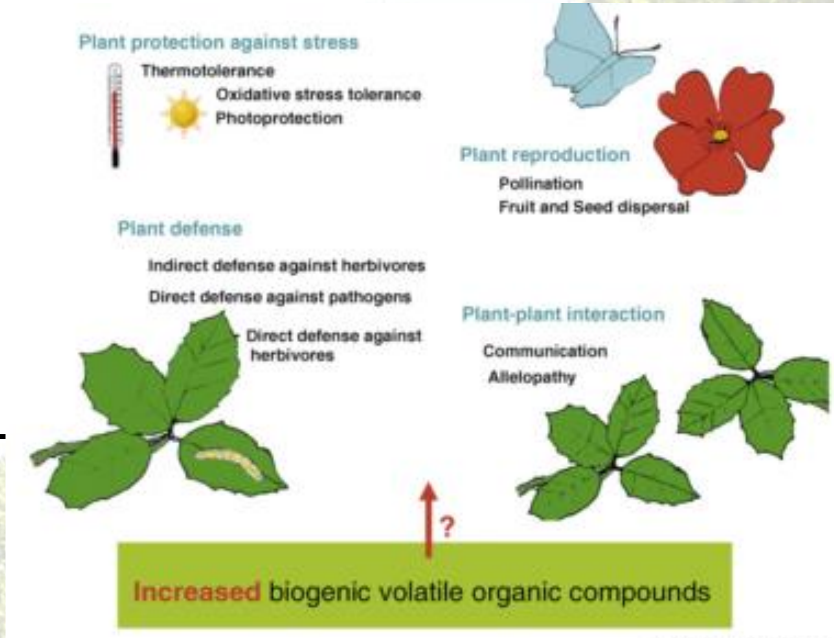






Climate change & biotic stress: overlapping signalling & VOC emission

Copolovici et al. 2014 J. Env. Exp. Bot.: Larvae feeding induced emissions of stress marker compounds **(*E*)-β-ocimene** and homoterpene **DMNT and methyl salicylate** from *Alnus glutinosa*. The emissions were more strongly elicited in **drought-stressed** plants.

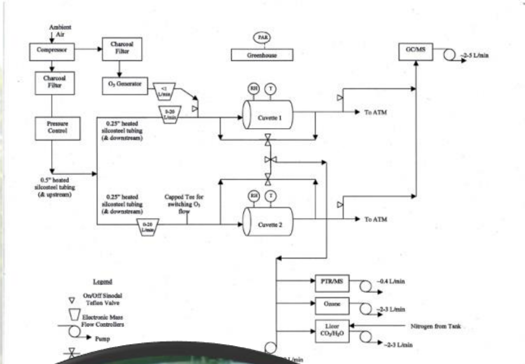


Penuelas and Staudt 2010

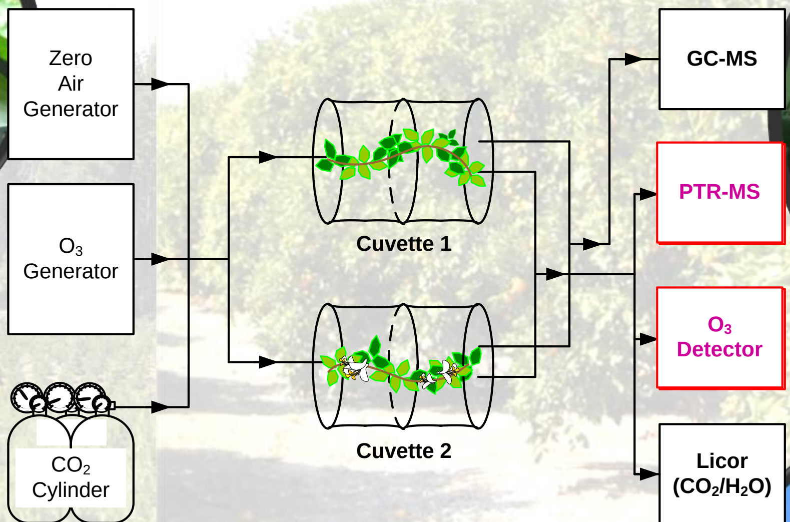
Winter et al. PCE 2012: overlapping signalling and responses to abiotic and biotic stress factor demonstrated by stronger expression of **herbivore-induced volatiles by high levels of heavy metals**

Part 2: Laboratory studies help understanding the net balance between ozone formation by BVOC and sequestration, and the antioxidant role of BVOC

Methods: enclosures



In a greenhouse or in a lab, where is possible to control environmental parameters, leaf/branch enclosures allow measuring gas exchange according to the Fick`s law:



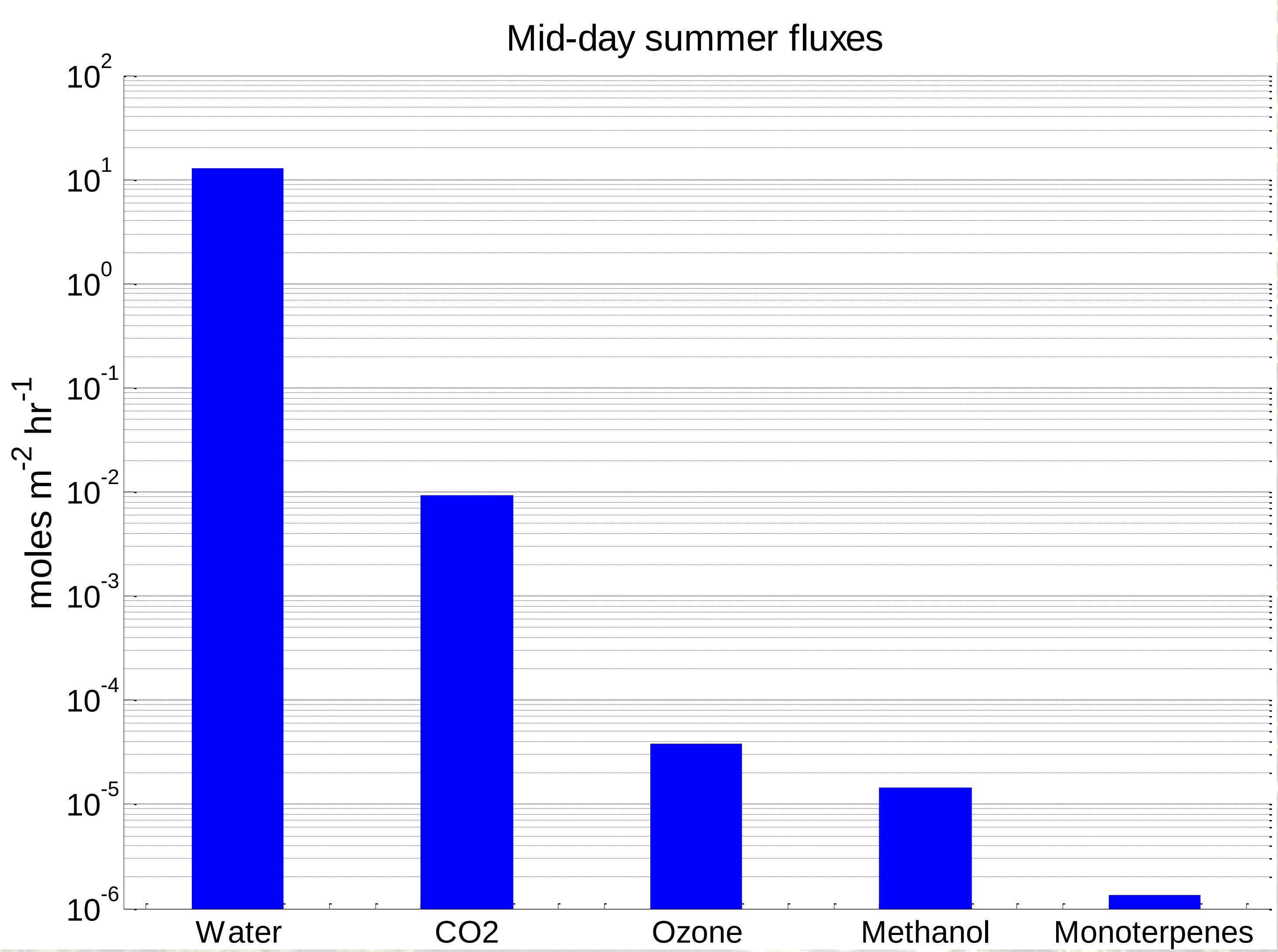
Flux

$$\Phi_x = F \cdot \frac{[X]_{in} - [X]_{out}}{A^L}$$

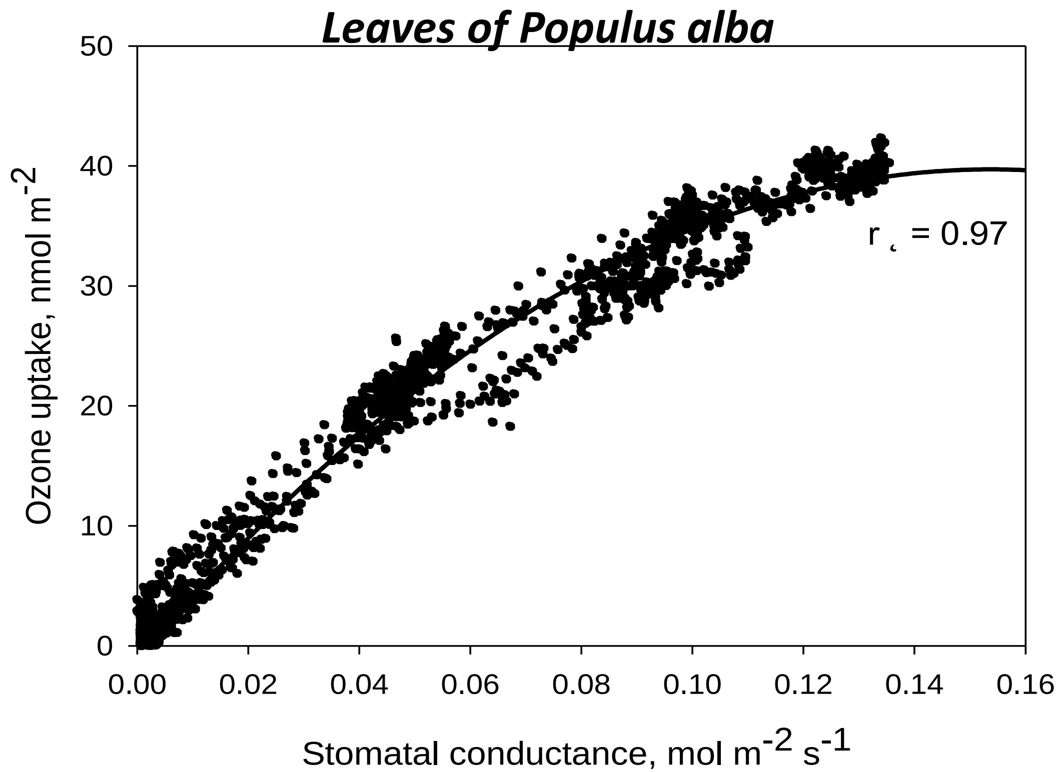
F=air Flux A^L=Leaf Area

X = Concentration of CO_2, Water, ozone, BVOC

Flux intercomparisons

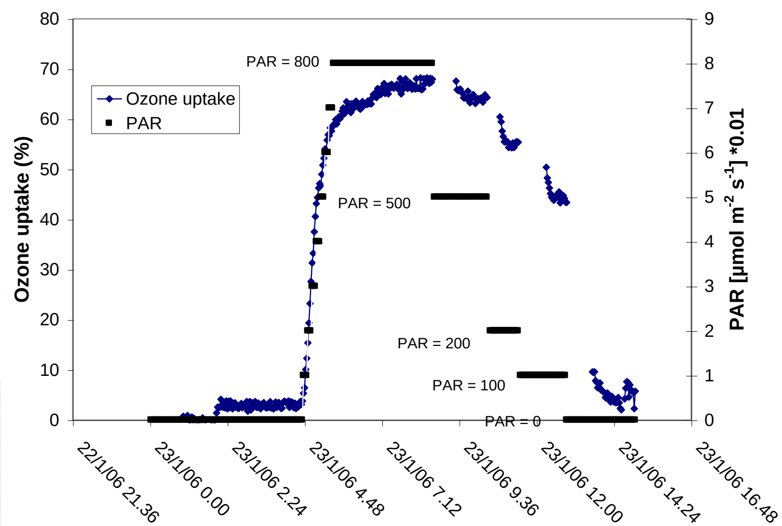


Results: ozone uptake from plants



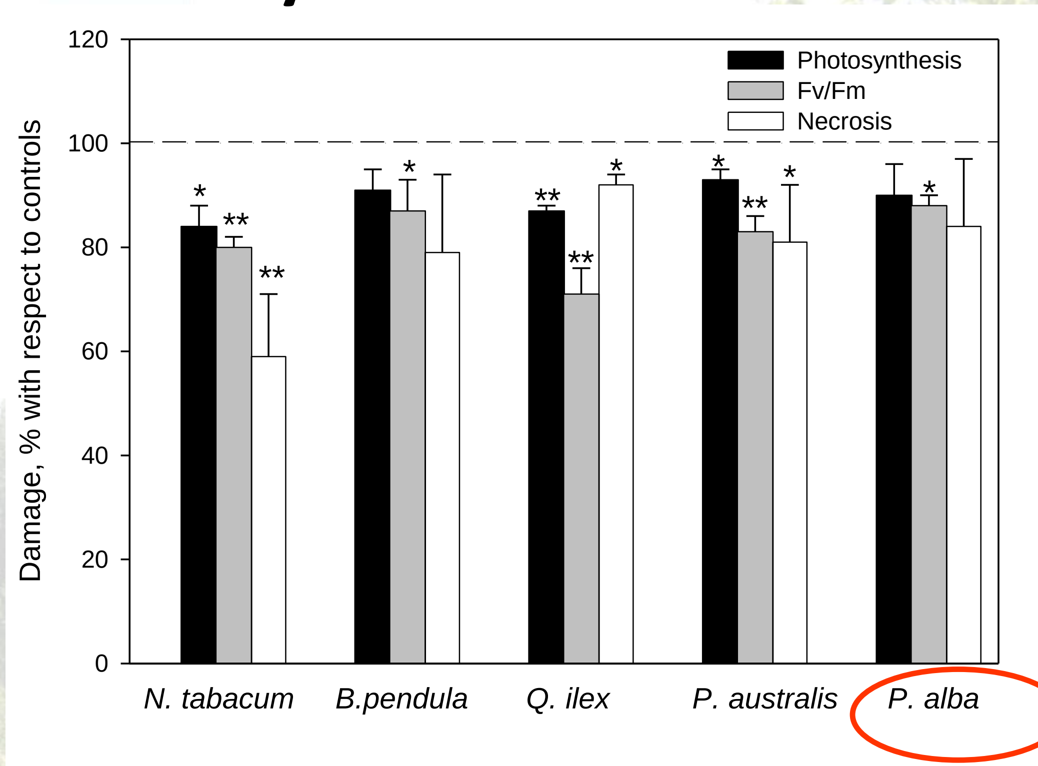
Ozone uptake is proportional to stomatal aperture, therefore related to the physiology of plants

Loreto and Fares, Plant Physiology 2007



Isoprenoids = antioxydants

100 = % ozone damage normalized vs plants which do no emit isoprenoids



Loreto and Fares, Plant Physiology, 2007

Isoprene production was inhibited

Leaf which naturally produces isoprene

Where does the reaction between ozone and BVOC take place?

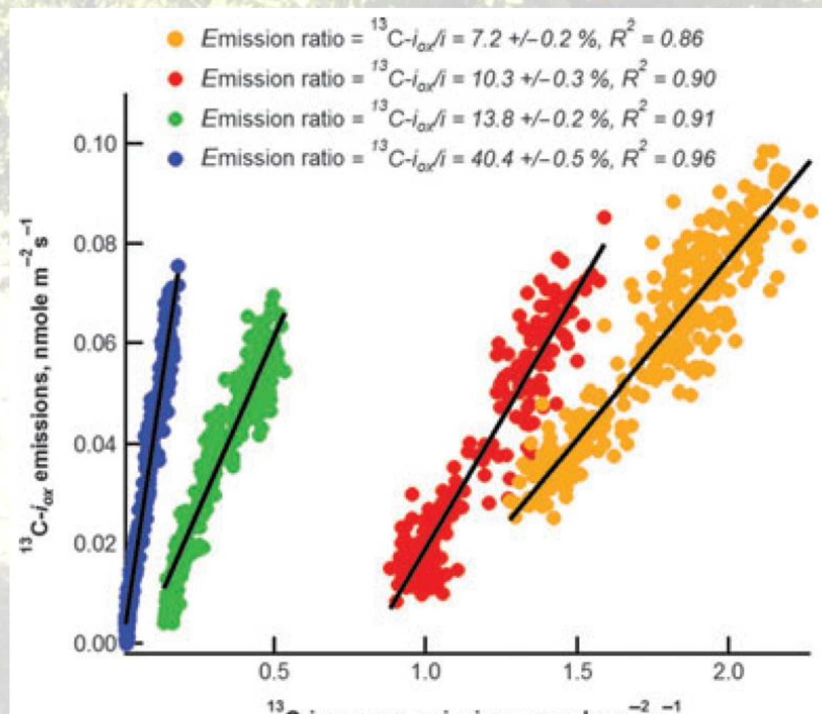
C-Labeling experiments suggest that isoprene reacts with ROS in leaves, and emission of its reaction products is directly proportional to heat stress

Global Change Biology

Global Change Biology (2012) 18, 973–984, doi: 10.1111/j.1365-2486.2011.02610.x

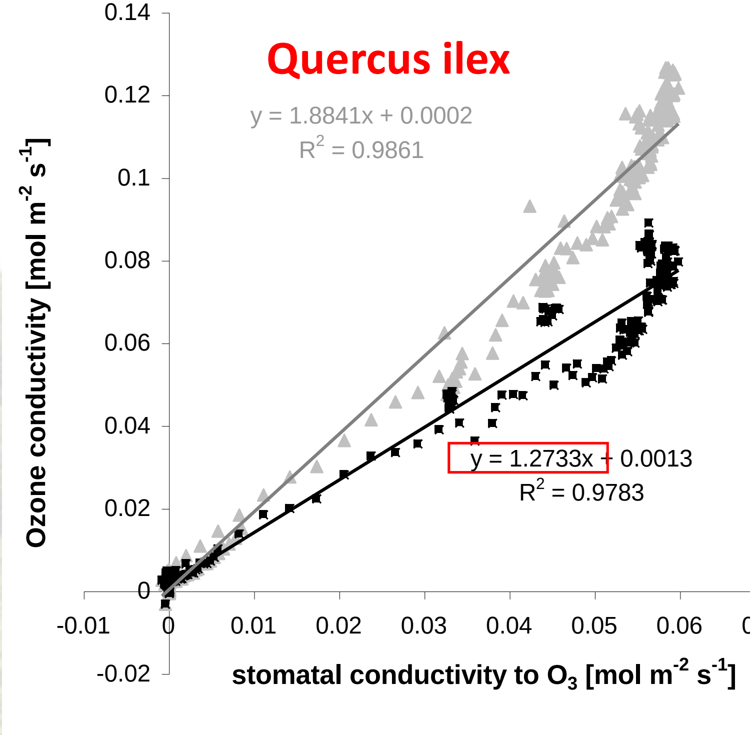
Within-plant isoprene oxidation confirmed by direct emissions of oxidation products methyl vinyl ketone and methacrolein

KOLBY J. JARDINE*, RUSSELL K. MONSON†, LEIF ABRELL‡§, SCOTT R. SALESKA¶, ALMUT ARNETH**††, ANGELA JARDINE*, FRANÇOISE YOKO ISHIDA‡‡, ANA MARIA YANEZ SERRANO‡‡, PAULO ARTAXO§§, THOMAS KARL¶¶, SILVANO FARES***, ALLEN GOLDSTEIN†††, FRANCESCO LORETO‡‡‡ and TRAVIS HUXMAN*¶

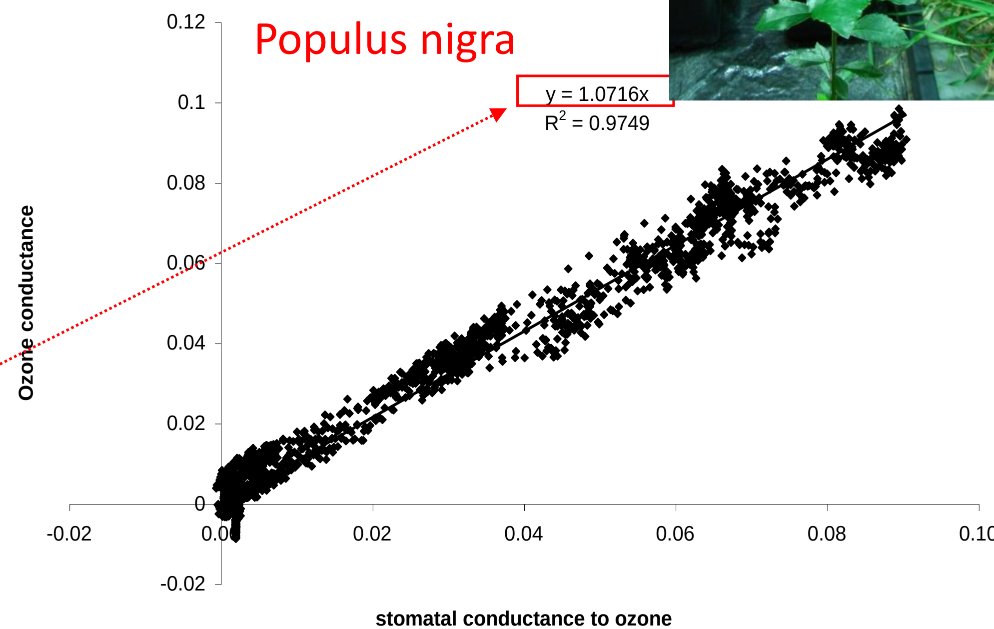


Which role of BVOC?

Holm oak is a strong monoterpene emitter = = major role of BVOC in removing ozone!

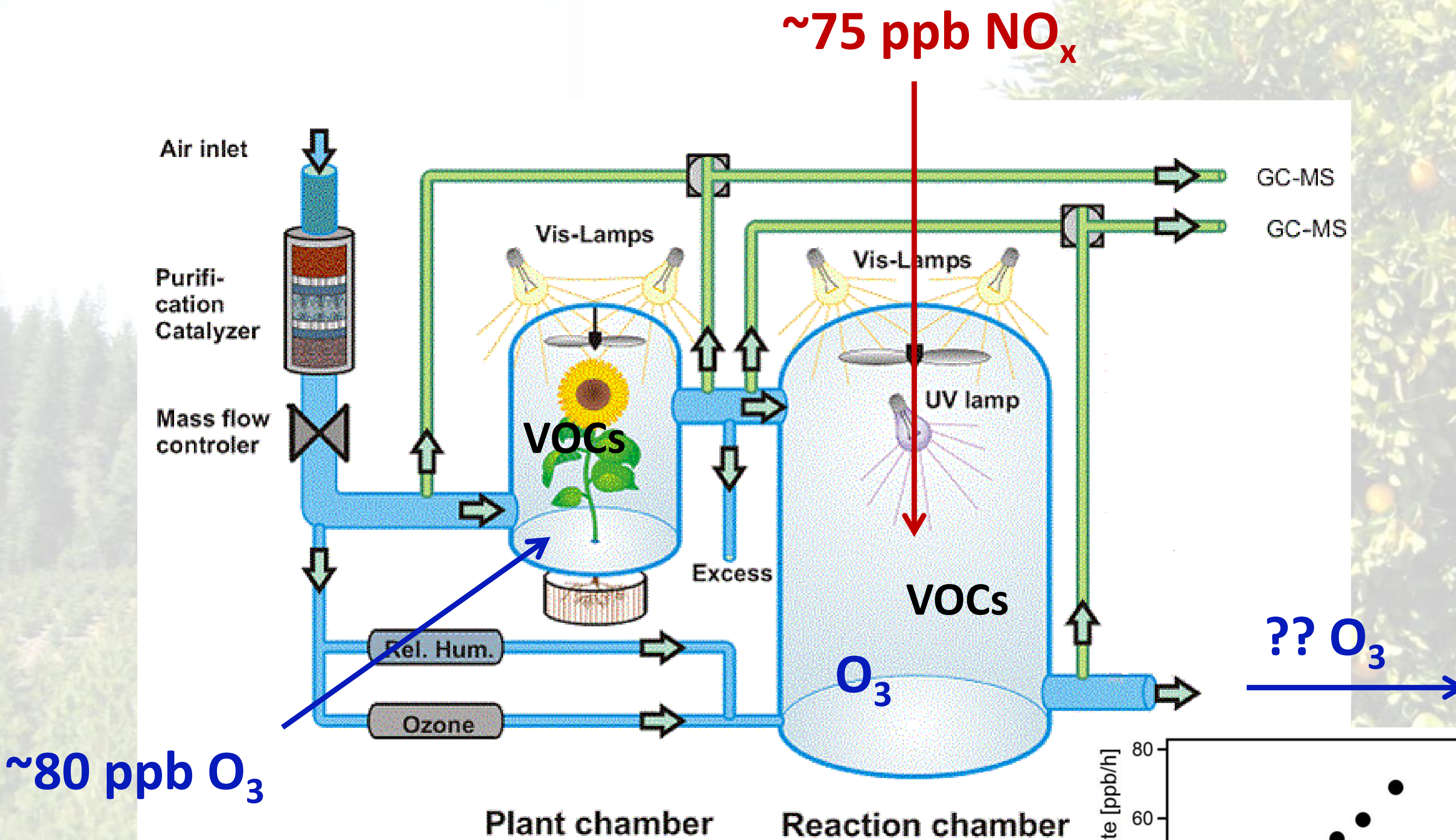


Fares et al. Plant Biol. 2008



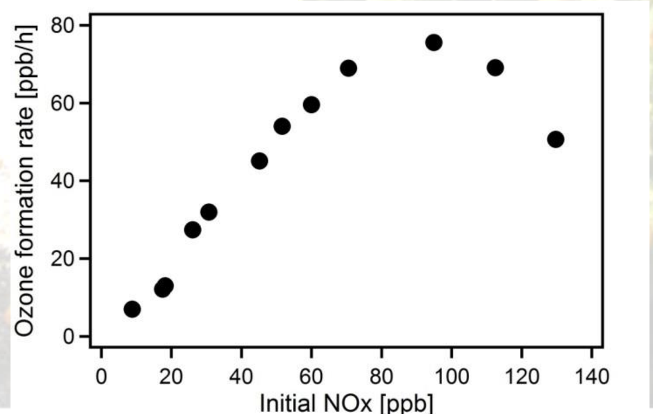
Populus emits isoprene, less reactive with ozone than monoterpenes, therefore no relevant contribution of isoprene to ozone removal was observed

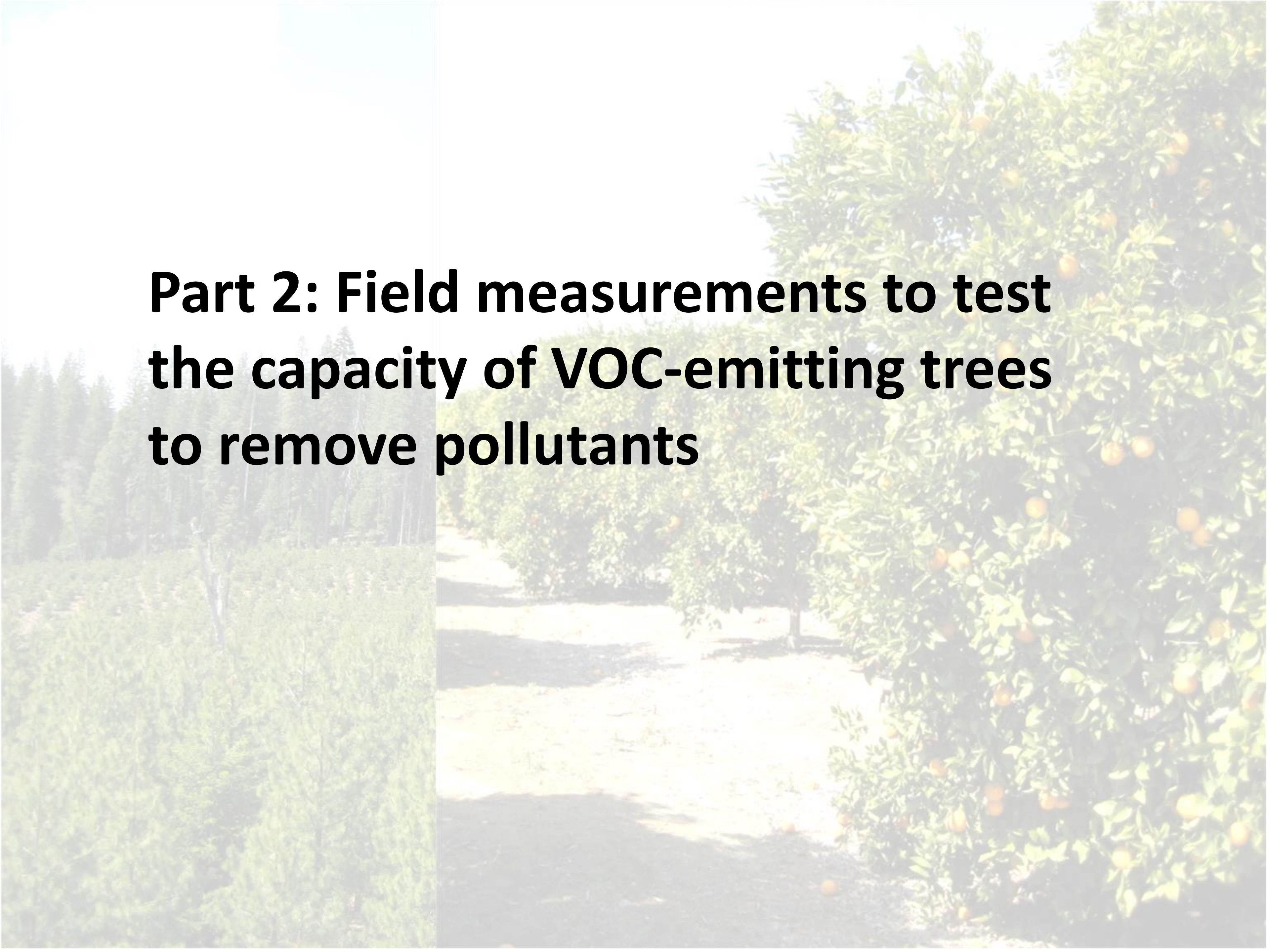
Laboratory experiments at Forschungszentrum-Juelich: testing O3 formation of α-pinene under NOx limited conditions



RT= 3-4 min

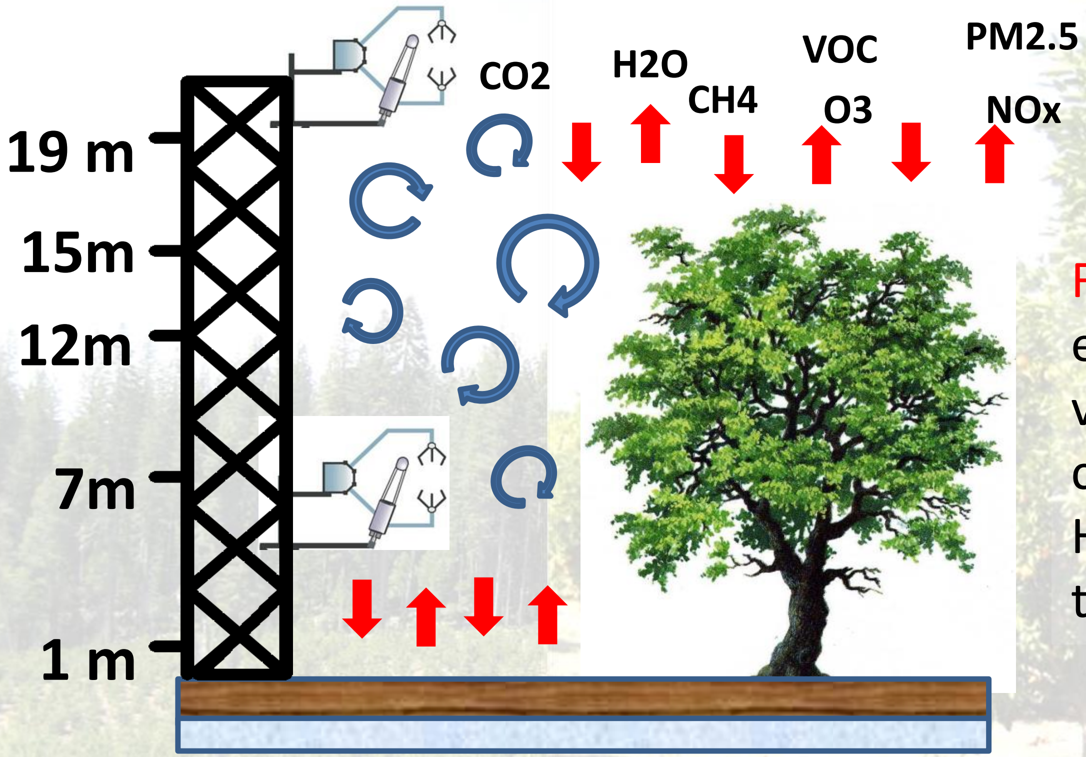
RT= ~ 50 min





Part 2: Field measurements to test the capacity of VOC-emitting trees to remove pollutants

A canopy-scale approach: Eddy Covariance flux measurements



Fluxes are measured from the eddy covariance (EC) between vertical wind speed and gas concentration (ozone, VOC, CO_2, H_2O), with observations 10 times per second

$$\boxed{\Phi_x = \overline{w' X'}}$$

CO2 flux: Subtracting modelled ecosistem respiration to the Net Ecosystem Exchange (NEE) , Gross Primary Productivity (GPP) is calculated

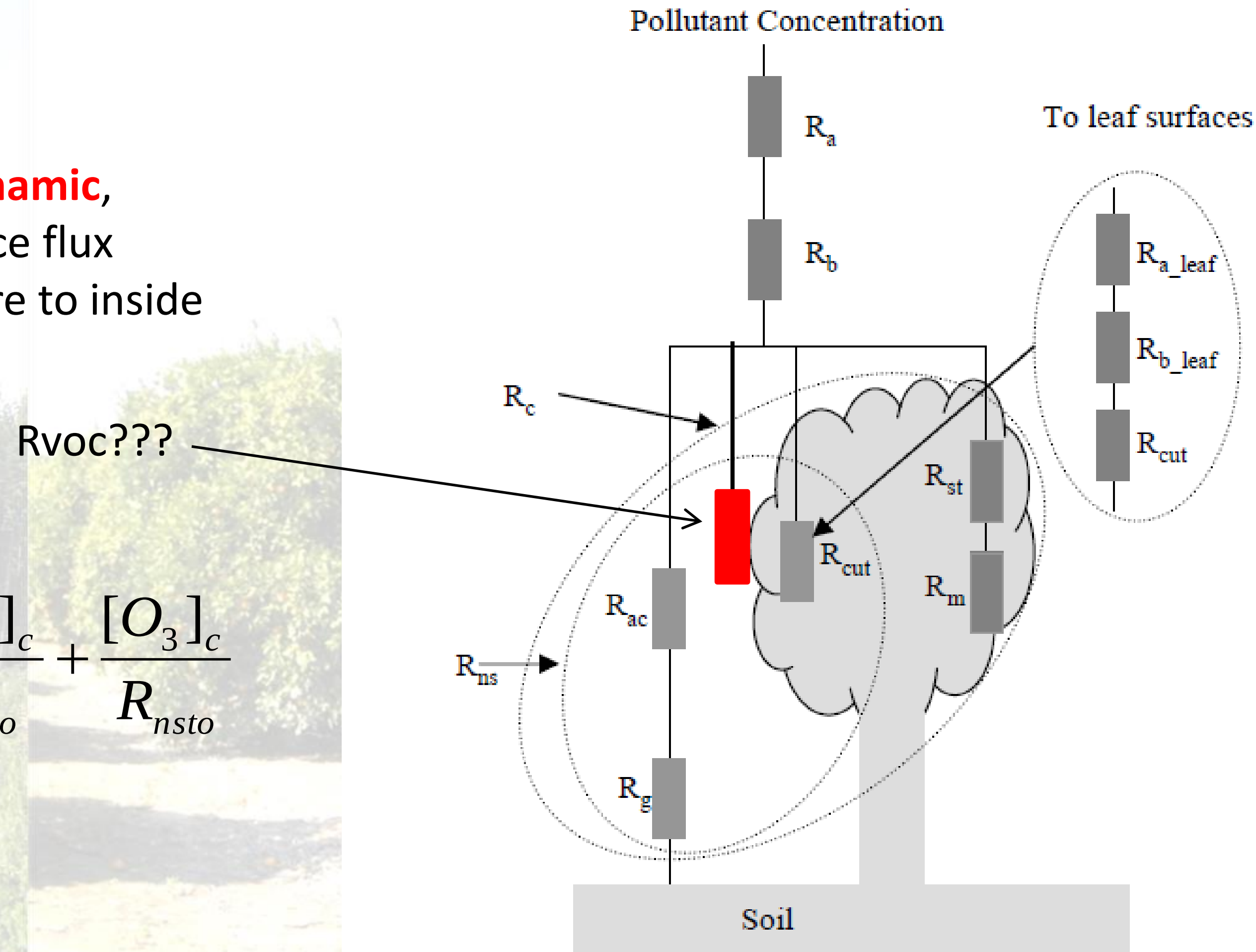
Water flux: Stomatal conductance is calculated from measured transpiration by inversion of Monteith equation, therefore an estimate of stomatal ozone fluxes is possible

Ozone fluxes: sum of stomatal and non stomatal components

How is ozone deposition partitioned between various sinks?

BIG LEAF MODEL:

A series of resistances (**aerodynamic**, **boundary layer, stomata**) reduce flux magnitude from the atmosphere to inside the leaves, obeying Ohm`s law.



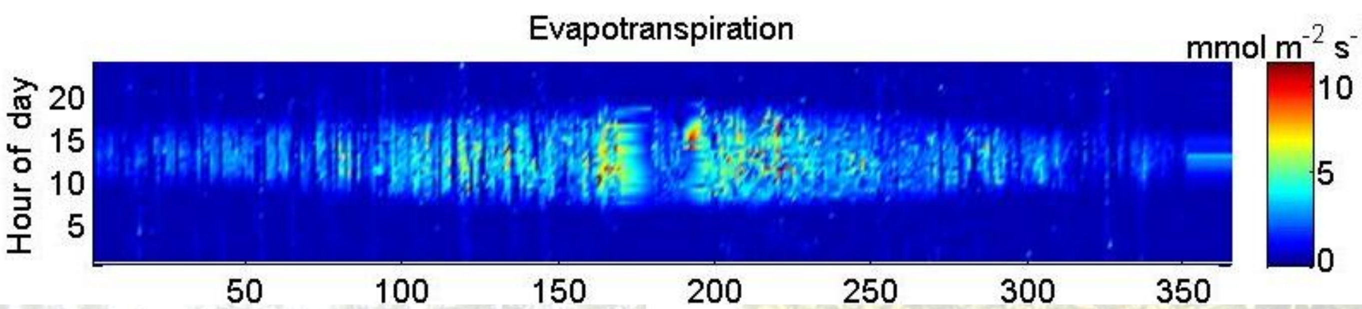
$$F_{O3} = F_{O3sto} + F_{O3nsto} = \frac{[O_3]_c}{R_{sto}} + \frac{[O_3]_c}{R_{nsto}}$$

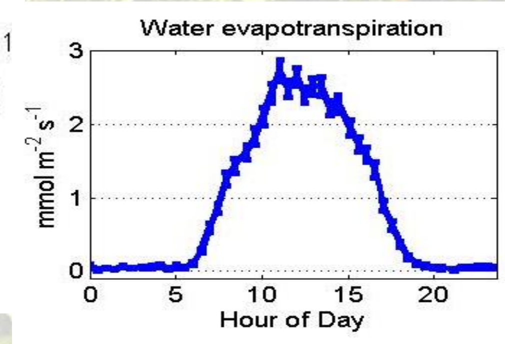
Monteith equation to calculate Stomatal Resistance, when latent heat is measured

$$\lambda E = \frac{\rho c_p \left[e_s(T_0) - e(z_m)\right]}{\gamma(R_a + R_b + R_{sto})}$$

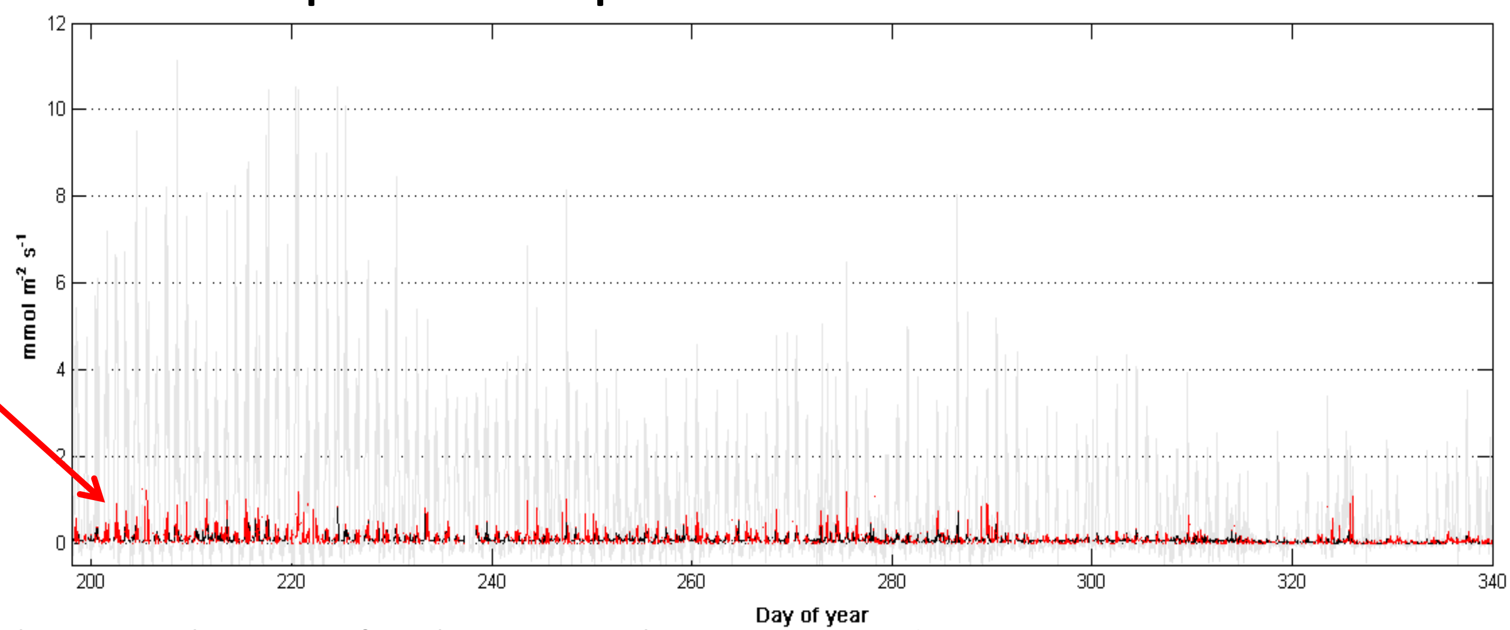
Partitioning ozone fluxes among its various sinks: stomata

Eddy Covariance above canopy





Transpiration vs evaporation



Eddy Covariance below the canopy

Up to 20% is the contribution of soil to ET in the non-rainy days

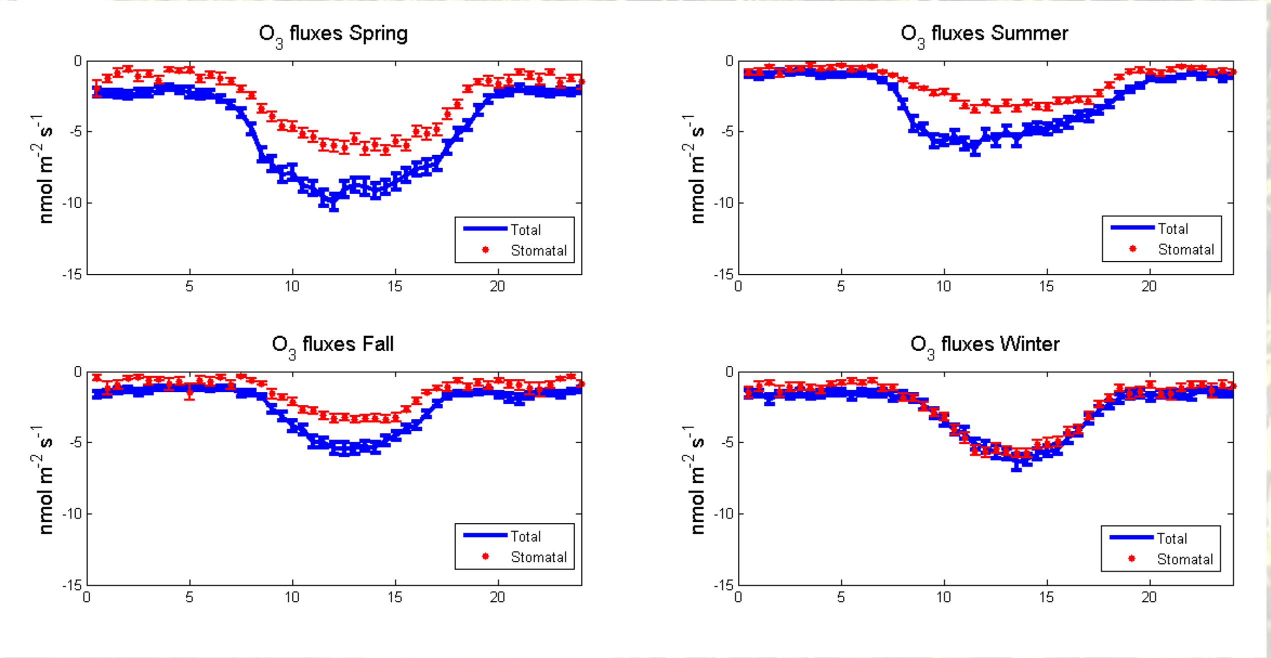
Partitioning ozone fluxes among its various sinks: stomata

Monteith equation to calculate stomatal conductance

After subtracting the evaporative component

$$\lambda E = \frac{\rho c_p \left[e_s(T_0) - e(z_m)\right]}{\gamma(R_a + R_b + R_{sto})}$$

$$O_3 Flux_{stomatal} = \frac{[O_3]_{sto}}{R_{sto}}$$



Most of ozone removed by forest is in the canopy region, a portion up to 70% is removed by stomata!

Eddy covariance data to parameterize Ball-Berry equation

FOR A SINGLE LEAF

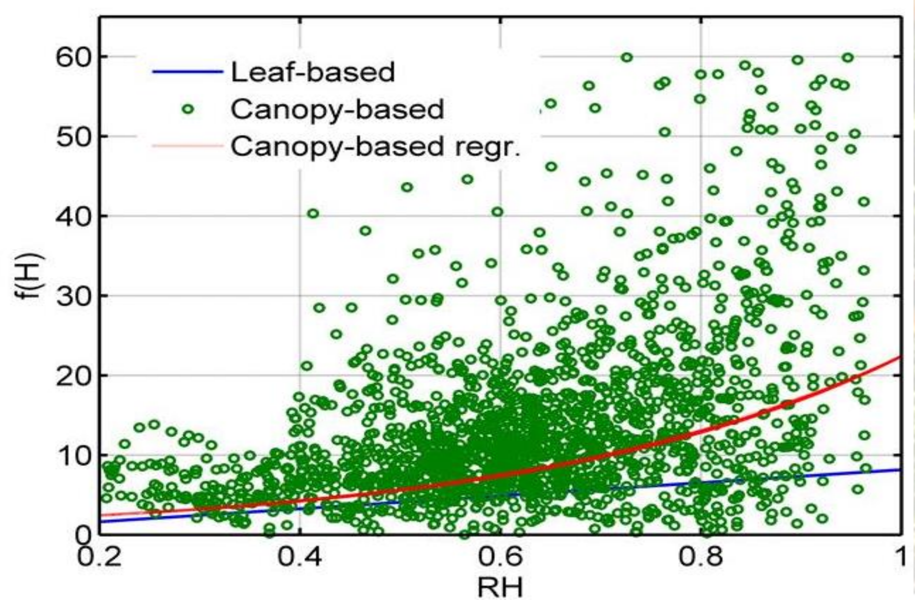
$$G_{sto} = \frac{m * A * RH}{Ca} + G_0$$

FOR A CANOPY

The relationship between RH and Gsto is not linear, modification of m (=f(H)) calculation produces the best agreement with observed Gsto

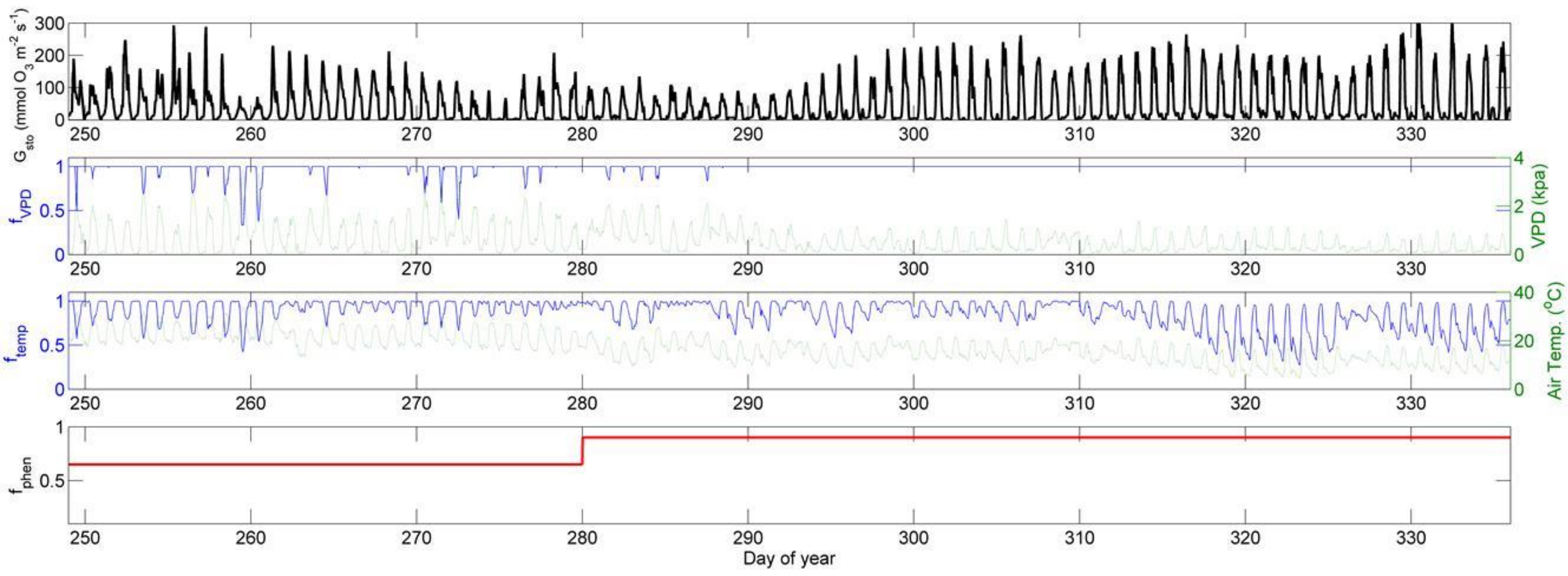
$$f(H) = \frac{Ca * F_{LE}}{v * \delta * L * \rho_a * (q_{sat(T_a)} - q_a) * A} - \frac{Ca * G_0}{A}$$

$$G_{sto} = \frac{a * b\exp(RH) * A}{Ca} + G_0$$



Modelled stomatal conductance: the DO3SE approach

$$G_{sto_{DOSE}} = g_{\max} * f_{phenol} * f_{light} * \max\{ f_{\min}, (f_{temp} * f_{VPD} * f_{SWP})\}$$



Calculation of non-stomatal ozone fluxes by BVOC

Calculation steps:

1) Characterization of the reacting BVOC species :

Fluxes of VOC species can be measured with GC-MS exposing branches in enclosures to ozone-free air under standard environmental conditions, thus obtaining Basal Emission Factors

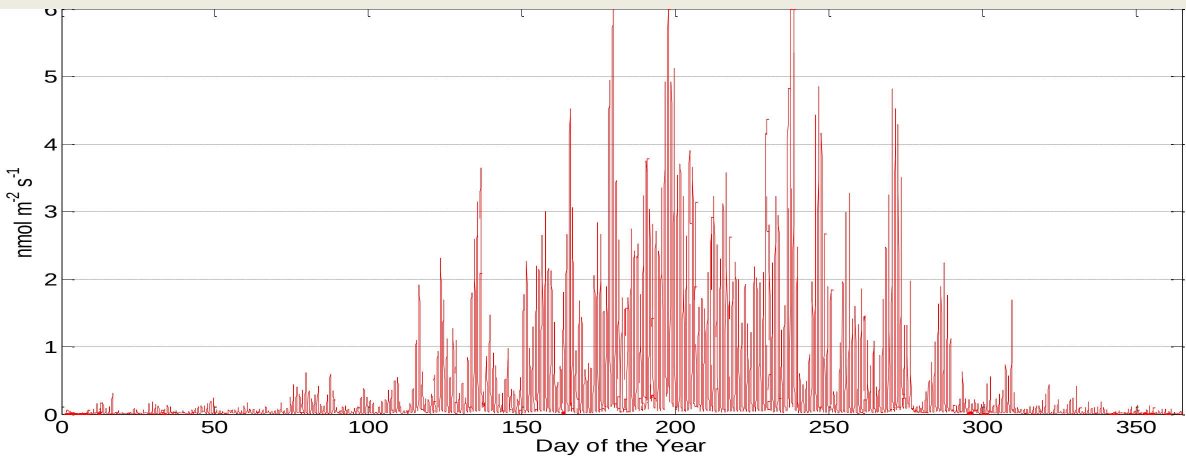
2) Fluxes are then modelled using the algorithms proposed by Tingey et al. (1993) and Guenther et al. (1995) in which BVOC emission are function of light and temperature:

$$E_{L+T} = BEF\left[\frac{\alpha C_L PAR}{\sqrt{1+\alpha^2 PAR^2}}\right] * \left[\frac{\exp\left(\frac{C_{T1}(T-T_S)}{RT_S T}\right)}{0.961+\exp\left(\frac{C_{T2}(T-T_M)}{RT_S T}\right)}\right]$$

$$E_T = BEF\exp\left[\beta(T-T_s)\right]$$

3) Reactivity with ozone: we can assumed 1 mol (O_3) reacting with 1 mol (BVOC), considering past experiments using smog chambers

Ozone chemical flux from reaction with BVOC



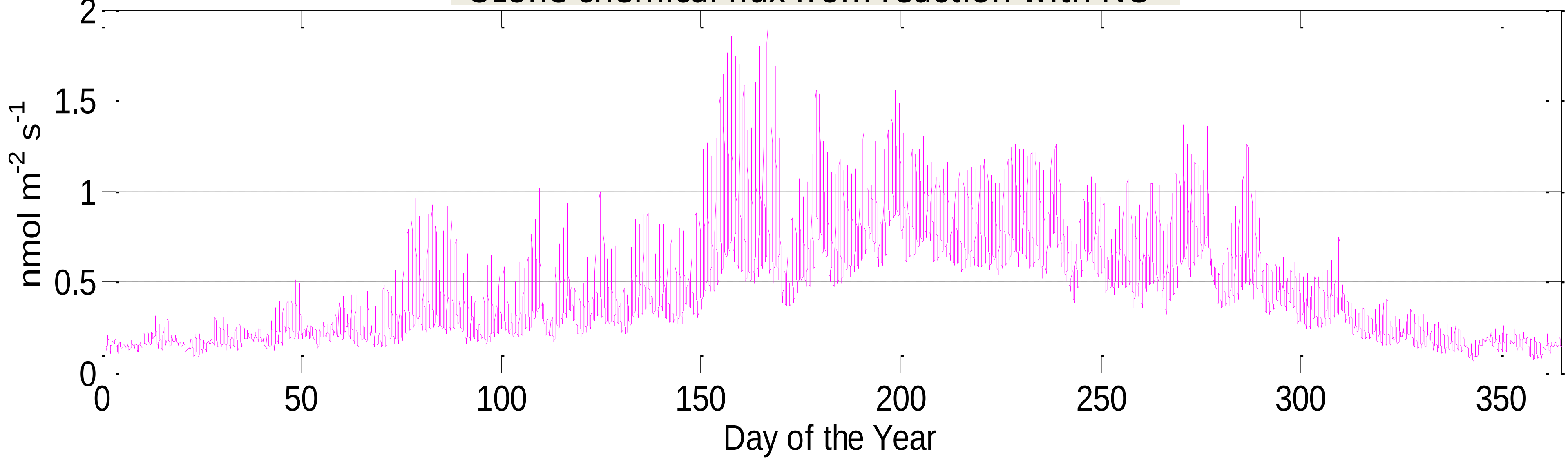
Non-stomatal ozone fluxes: NO

Definition of a BEF for NO according to Firestone et al. (1986) and Steinkamp et al. (2010):

$$F_{NO(0^o<T\leq 10^oC)} = 0.28 \cdot T_{soil} \cdot BEF; \qquad F_{NO(10^o<T\leq 30^oC)} = e^{0.103 T_{soil}} \cdot BEF; \qquad F_{NO(T>30^oC)} = 21.97 \cdot T_{soil} \cdot BEF$$

NO flux from soil was modeled for all year and we assumed 1 mol (NO) reacting with 0.8 mol (O_3), accounting for the *uv*-driven O_3 formation due to the conversion of some NO molecules in NO_2 (Dillon et al. 2002).

Ozone chemical flux from reaction with NO



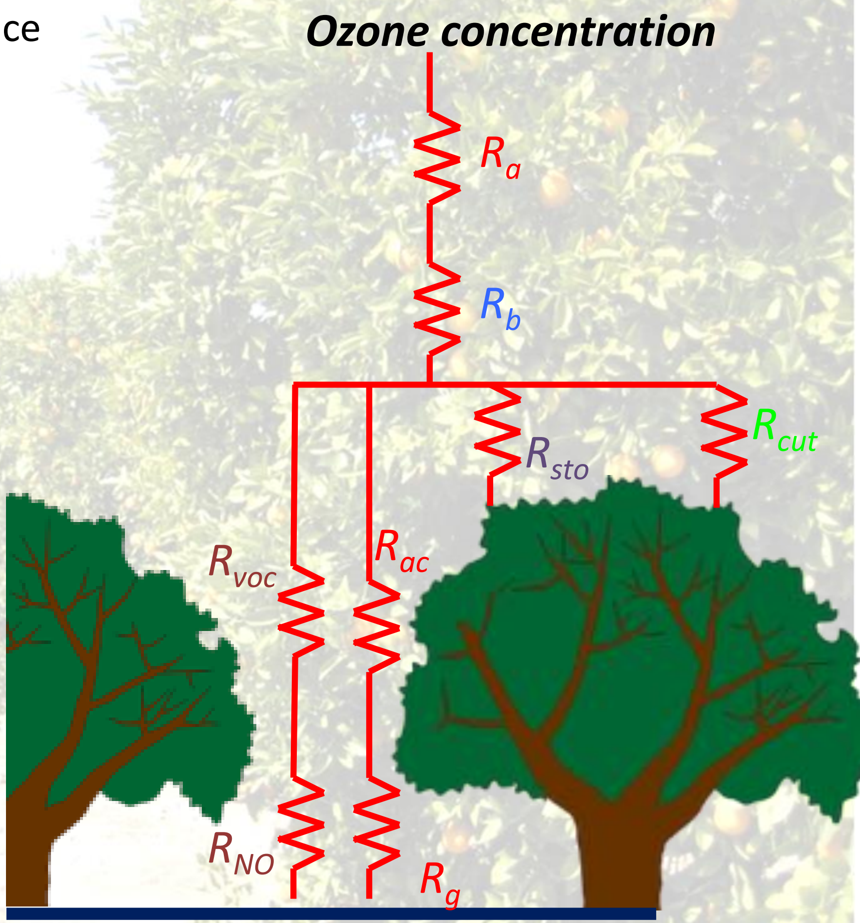
Other non-stomatal ozone fluxes

Cuticular resistance as function of humidity and turbulence (Zhang et al. 2002; Erisman et al. 1994)

$$Rcut(dry) = \frac{Rcut(dry)_0}{e^{0.03 \cdot RH} \cdot LAI^{1/4} \cdot u_*} \qquad Rcut(wet) = \frac{Rcut(wet)_0}{LAI^{1/2} \cdot u_*}$$

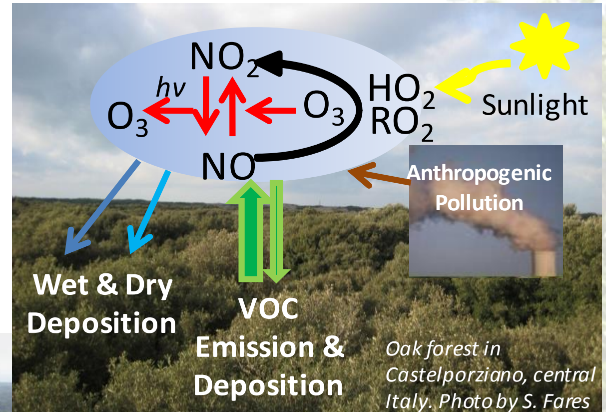
Below-canopy resistances as the sum of in-canopy aerodynamic resistance and ground resistance as function of LAI, tree height, turbulence and soil water content, all parameters measured on site (Zhang et al. 2002, Bassin et al. 2004)

$$Rac = \frac{14 \cdot LAI \cdot zc}{u_*} \qquad Rg = 200 \cdot 300 \cdot \frac{SWC}{SWC_{fc}}$$



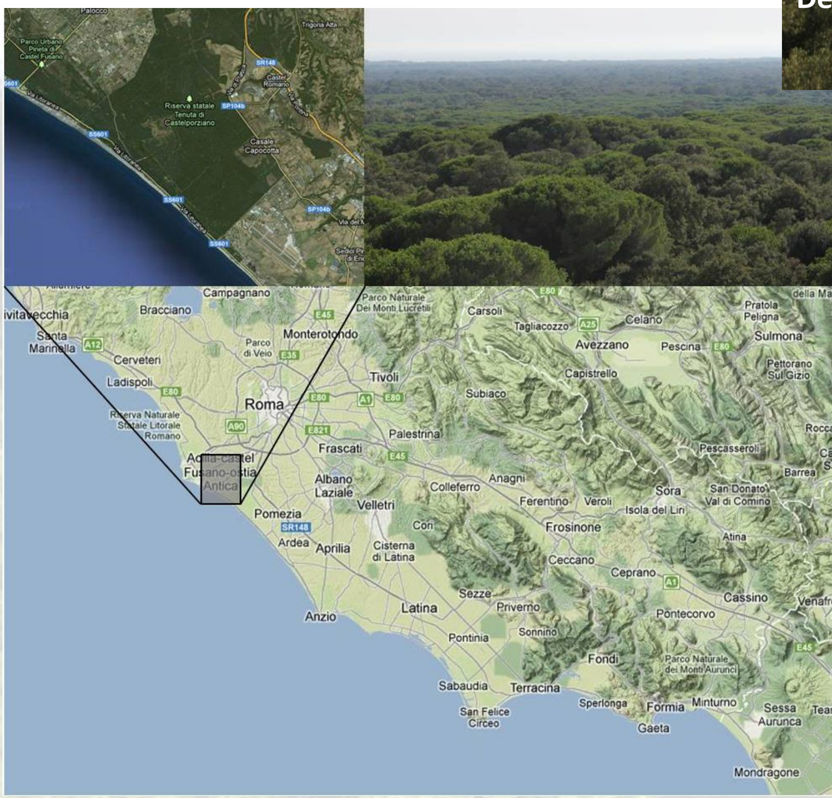
Evidences from field experiments: the Holm oak urban forest in Castelporziano

Above the canopies of Mediterranean oaks and pines a complex photochemistry takes place with concurrent phenomena of ozone formation and ozone deposition



Oak forest in Castelporziano, central Italy. Photo by S. Fares

~ 6000 ha, 25 km from Rome downtown



Biogeosciences, 6, 1043–1058, 2009
www.biogeosciences.net/6/1043/2009/

Biogeosciences

The ACCENT-VOCBAS field campaign on biosphere-atmosphere interactions in a Mediterranean ecosystem of Castelporziano (Rome): site characteristics, climatic and meteorological conditions, and eco-physiology of vegetation

S. Fares[1,2], S. Mereu[3], G. Scarascia Mugnozza[1], M. Vitale[3], F. Manes[3], M. Frattoni[4], P. Ciccioli[4], G. Gerosa[5], and F. Loreto[1]

Atmospheric Environment 67 (2013) 242–251

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

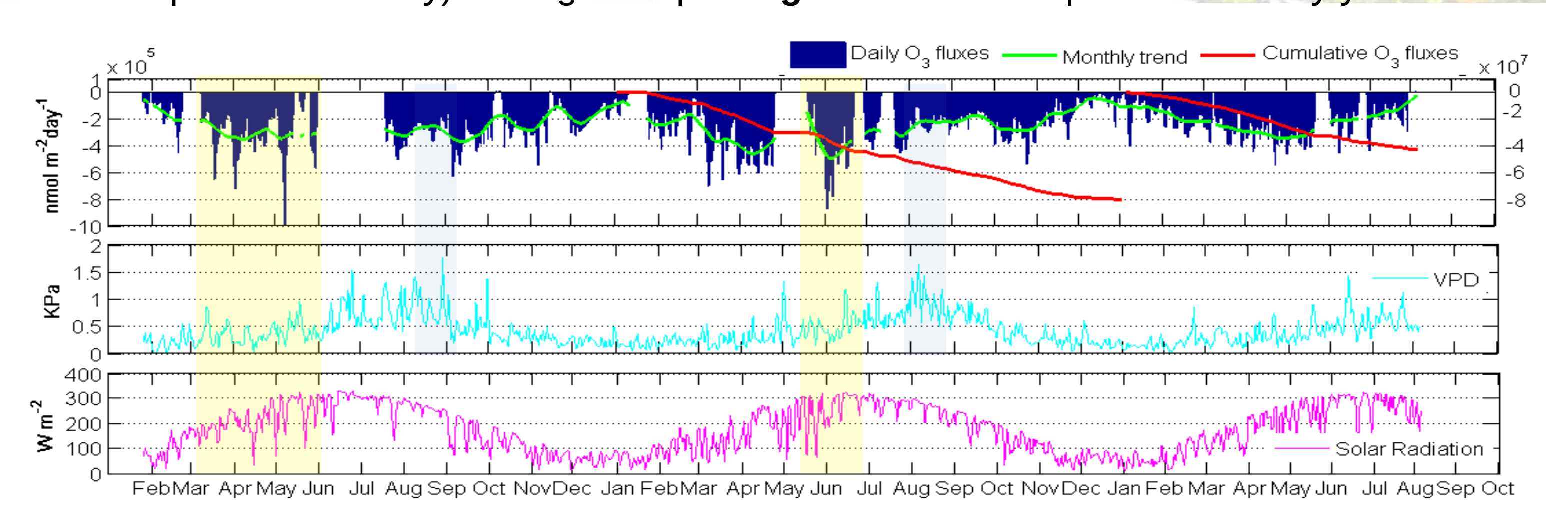
ELSEVIER

Testing of models of stomatal ozone fluxes with field measurements in a mixed Mediterranean forest

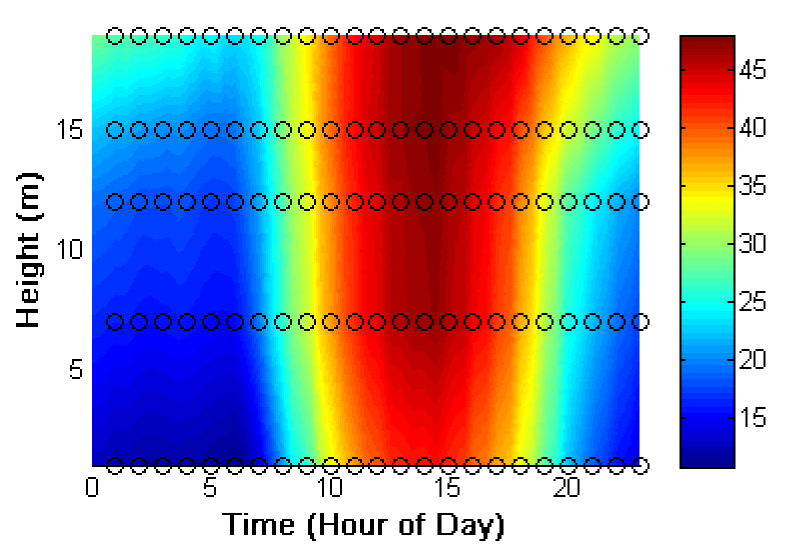
S. Fares[a,*], G. Matteucci[b,c], G. Scarascia Mugnozza[a], A. Morani[b], C. Calfapietra[b,f], E. Salvatori[d], L. Fusaro[d], F. Manes[d], F. Loreto[e]

Ozone fluxes in the Holm Oak forest

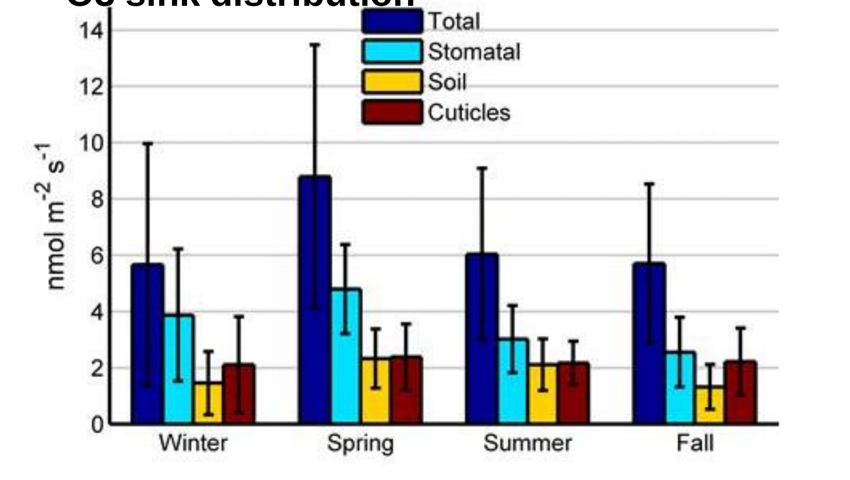
Ozone fluxes are higher during warm days, when non-stomatal sinks (e.g. gas-phase chemistry) are higher. Up to **8 g O3 m-2** are sequestrated every year!



Atmospheric O3 concentration gradient from the oil to above the canopy

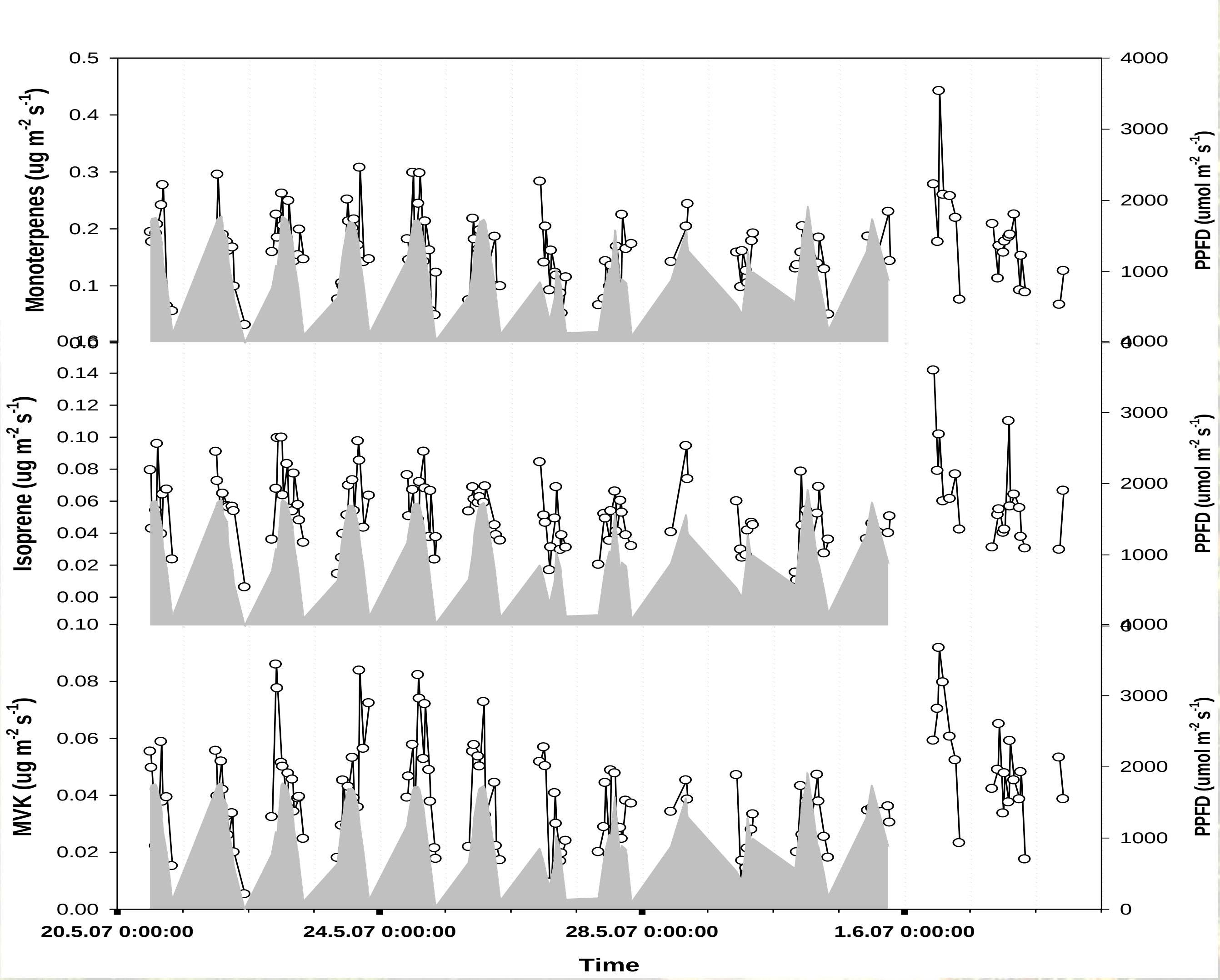


O3 sink distribution



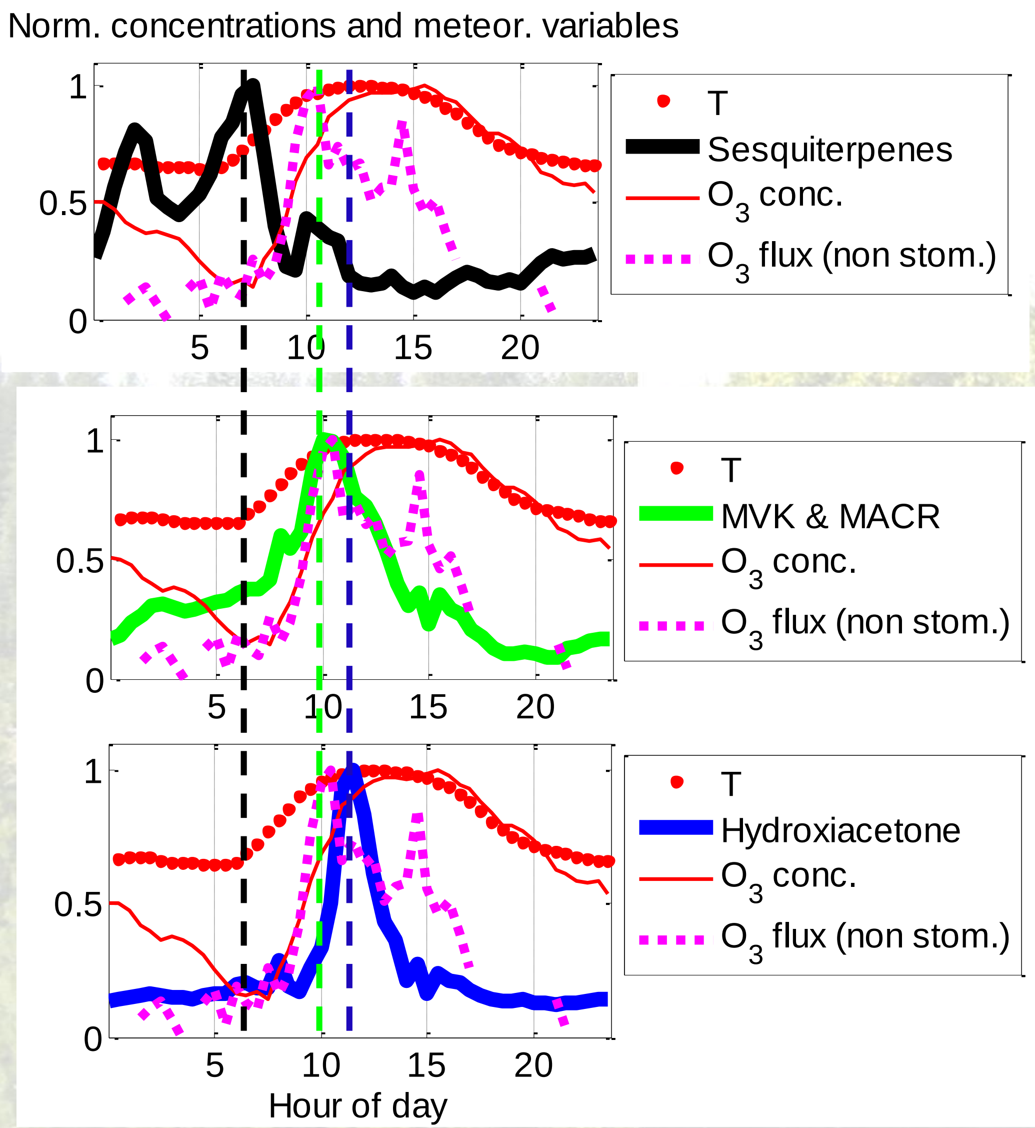
Fares et al. Atm. Env. 2013; Fares et al. Agr. For. Met. 2014; Savi et al. 2014

Clear diurnal fluxes of isoprene, monoterpenes and of Methyil Vinyl Chetone (MVK), one of the main oxidation products of isoprene



Davison et al. Biogeos. 2009; Fares et al. Biogeos. 2009

Evidences of non-stomatal ozone fluxes: VOC concentrations



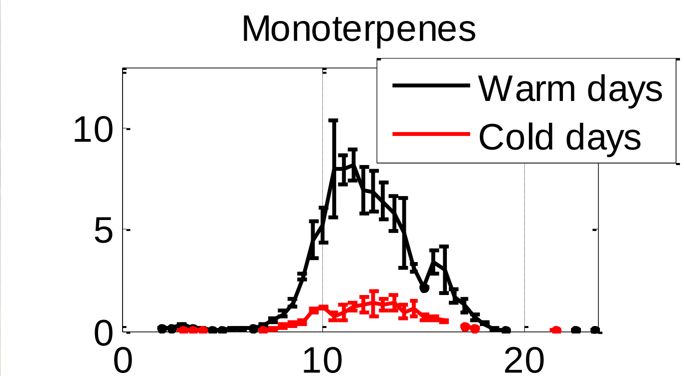
Sesquiterpenes react with ozone in few seconds, therefore they disappear fast during the day when atmospheric ozone builds up

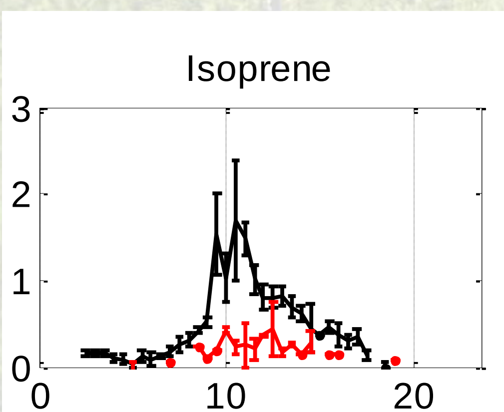
Non-stomatal ozone fluxes peak in coincidence with the highest concentration of Methyl-vynil-ketone + Metacrolein, two oxidation products from reaction between ozone and isoprene

SQT>>Isoprene>>Acetone

The field campaign in 2014

Preliminary data show how Holm Oak is a predominant Monoterpene emitter



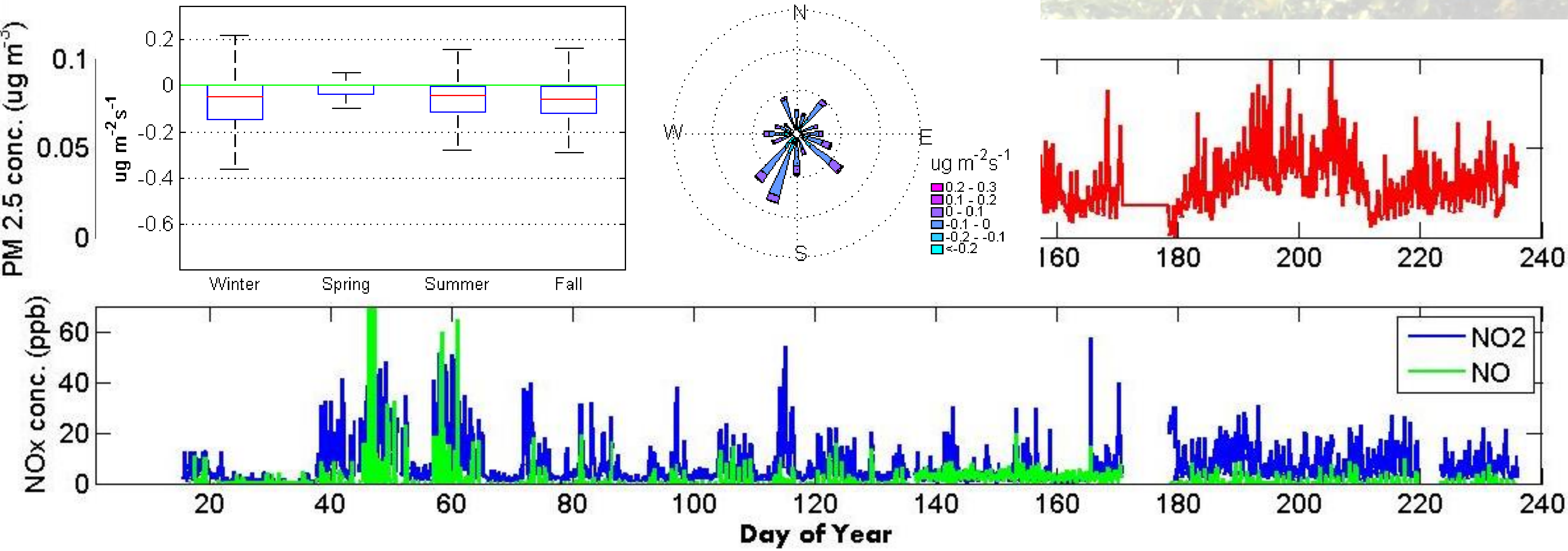


Deployment of PTRMS to the field site

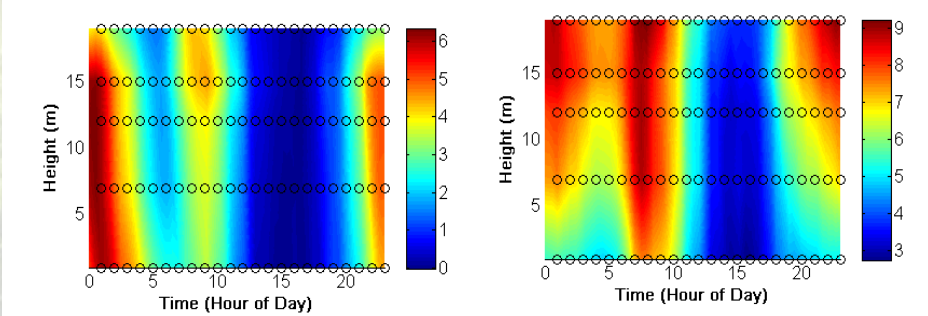
Fluxes peak during the day because primary emitted BVOC depend on light and temperature

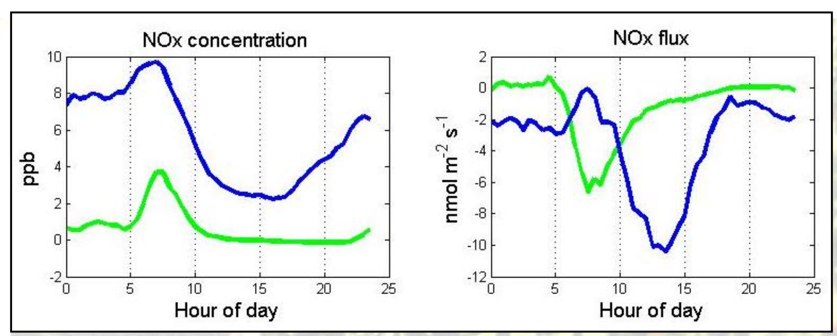
Not only O3 & BVOC: urban Oaks of Castelporziano can remove PM and NOx from the atmosphere!

PM SEASONAL FLUXES **PM FLUXES AND WIND DIRECTION**

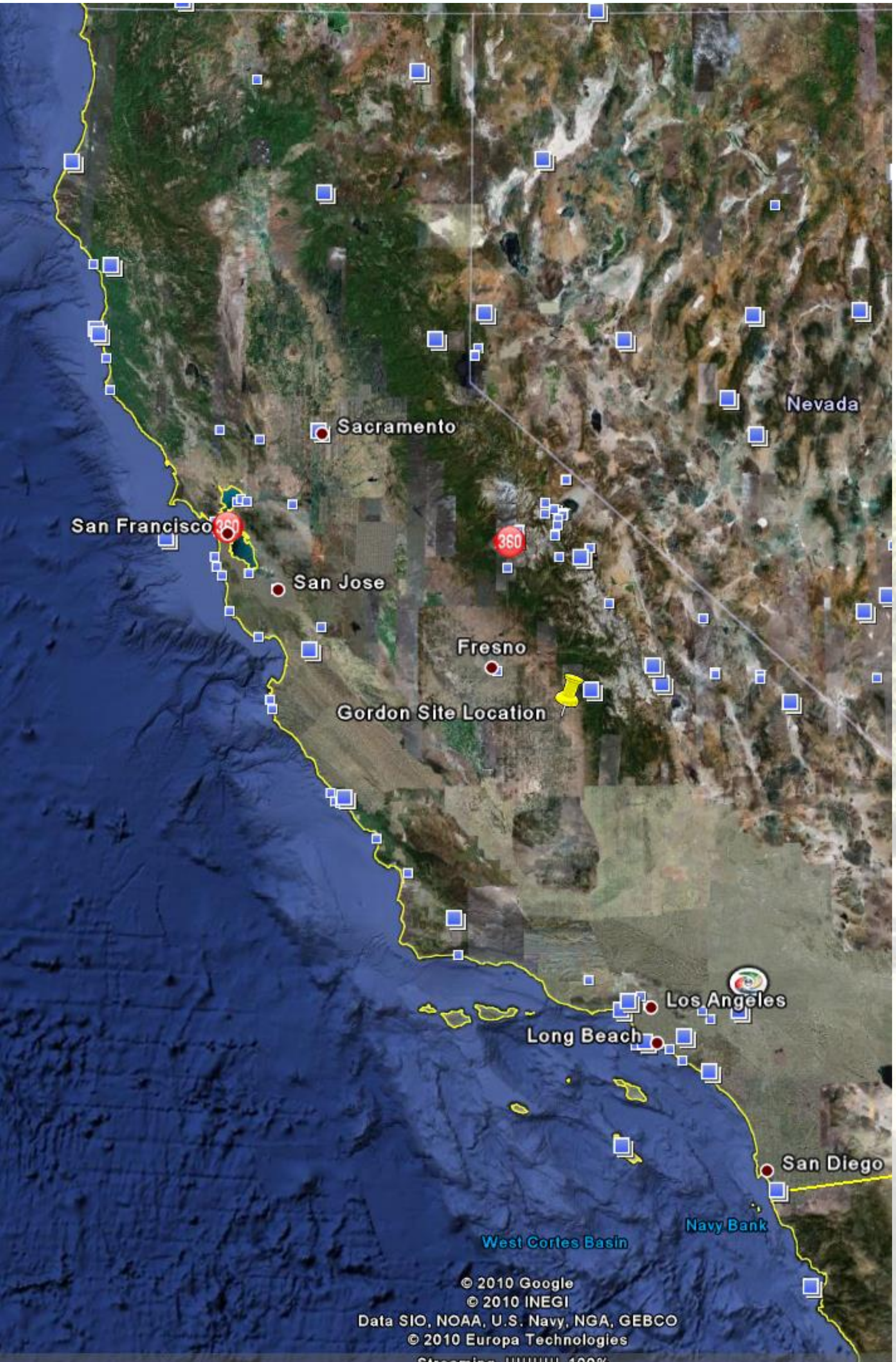


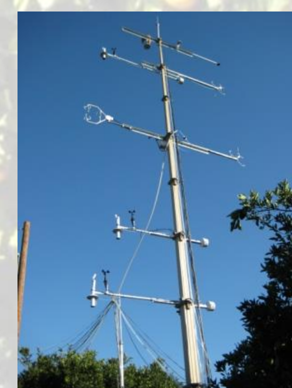
NO **NO_2**





field measurements
in Exeter(Central valley, CA)



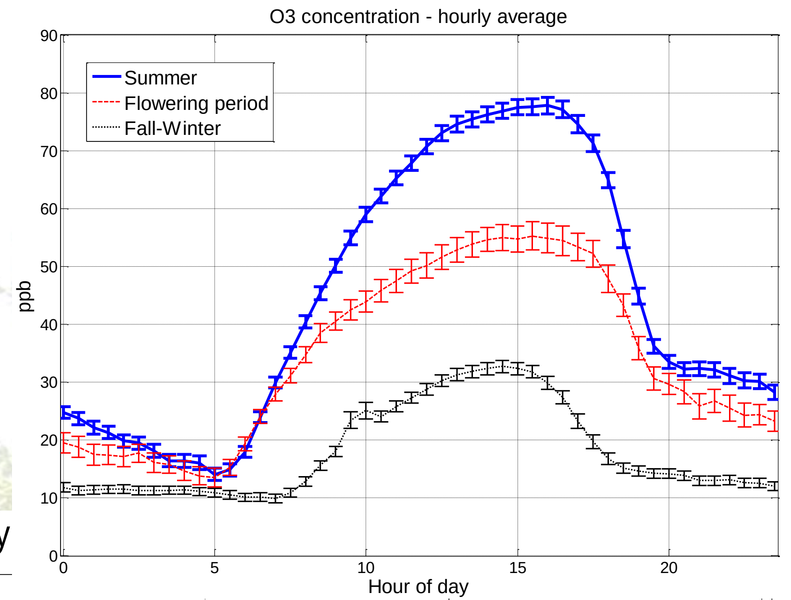


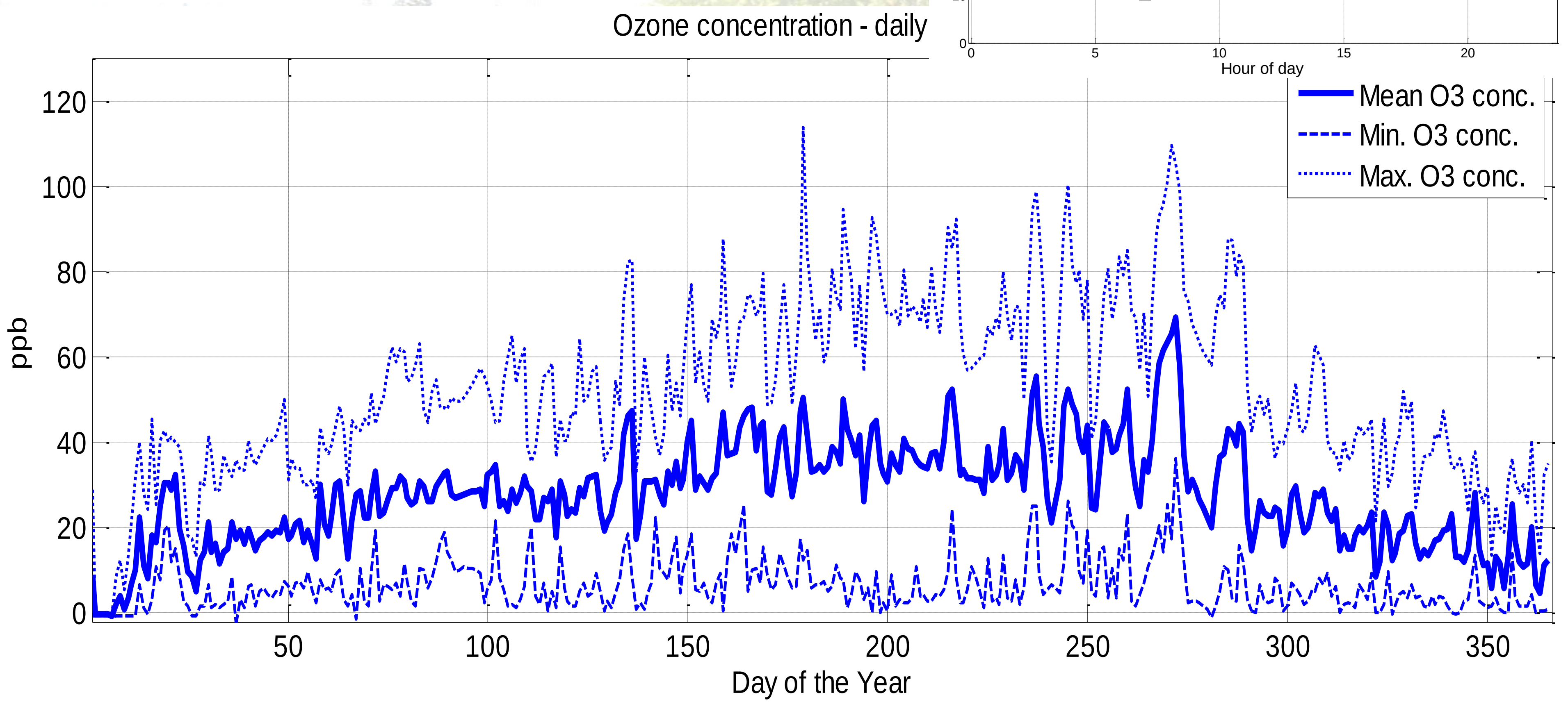
Views of Research Site

Tower

Seatainer housing instruments

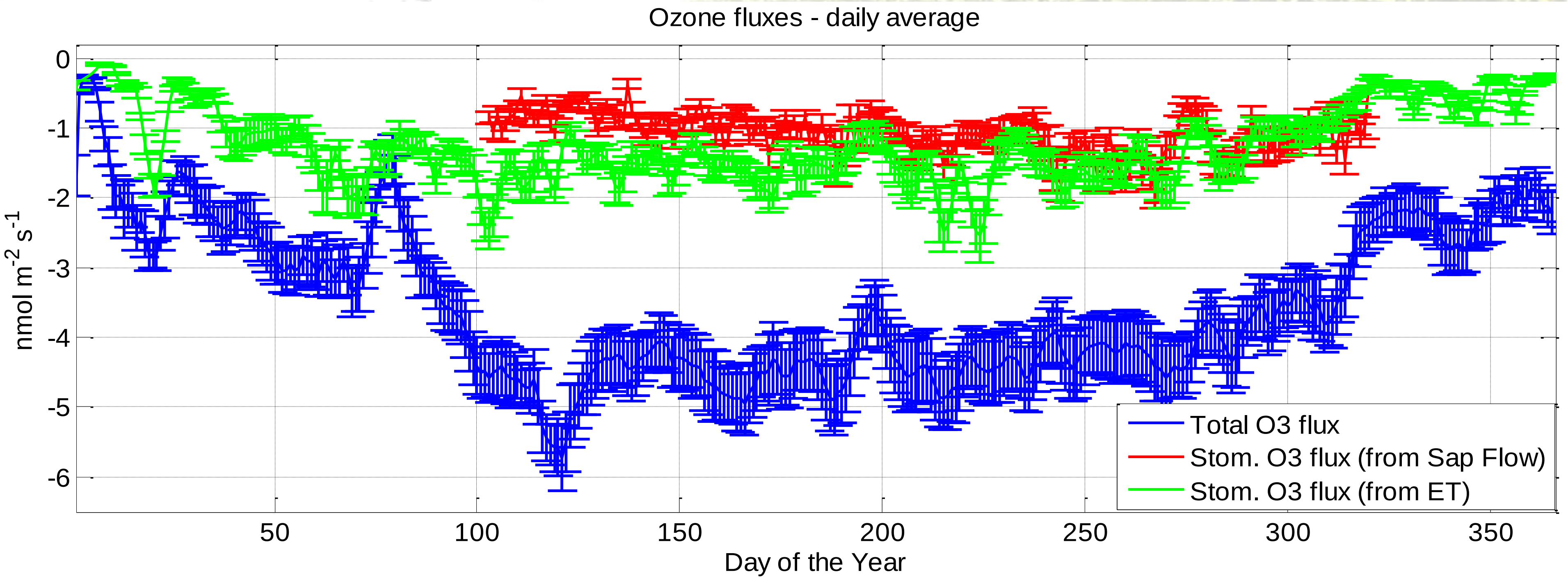
Summer levels of ozone largely exceed phytotoxic thresholds of 40 ppb





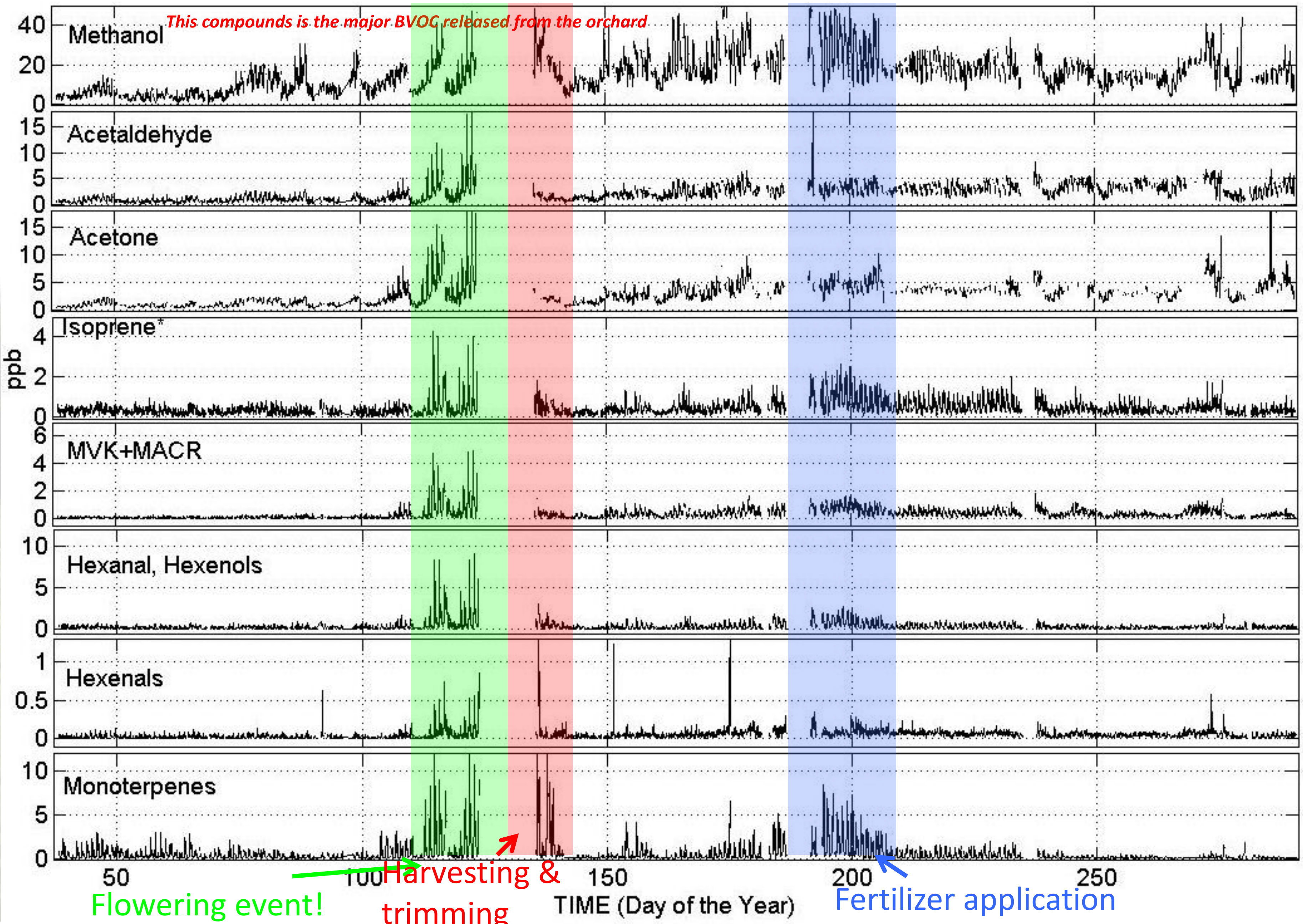
Stomatal ozone flux is a minor fraction of total ozone flux

Fares et al. Env. Poll. 2012

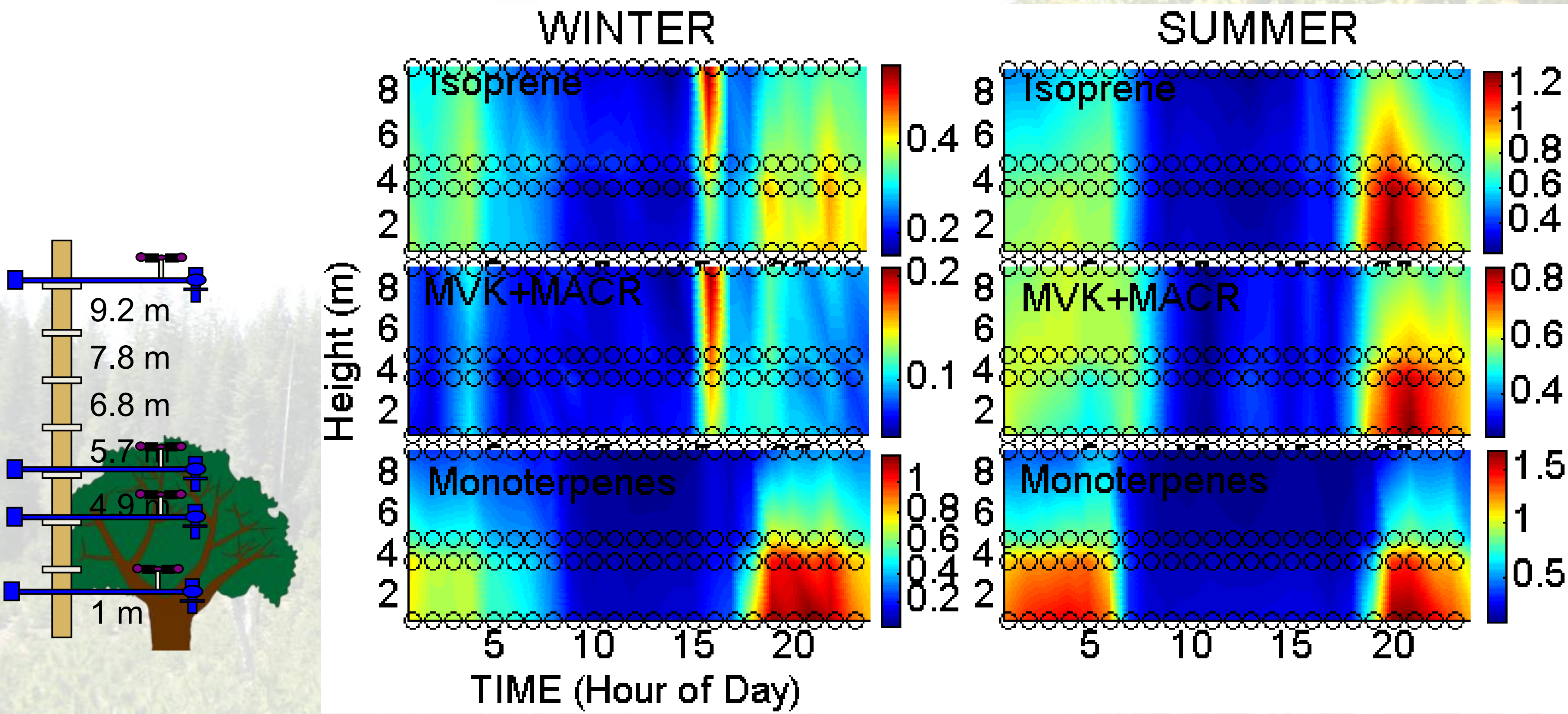


BVOC concentration in the Orchard:

Fares et al. ACP 2012



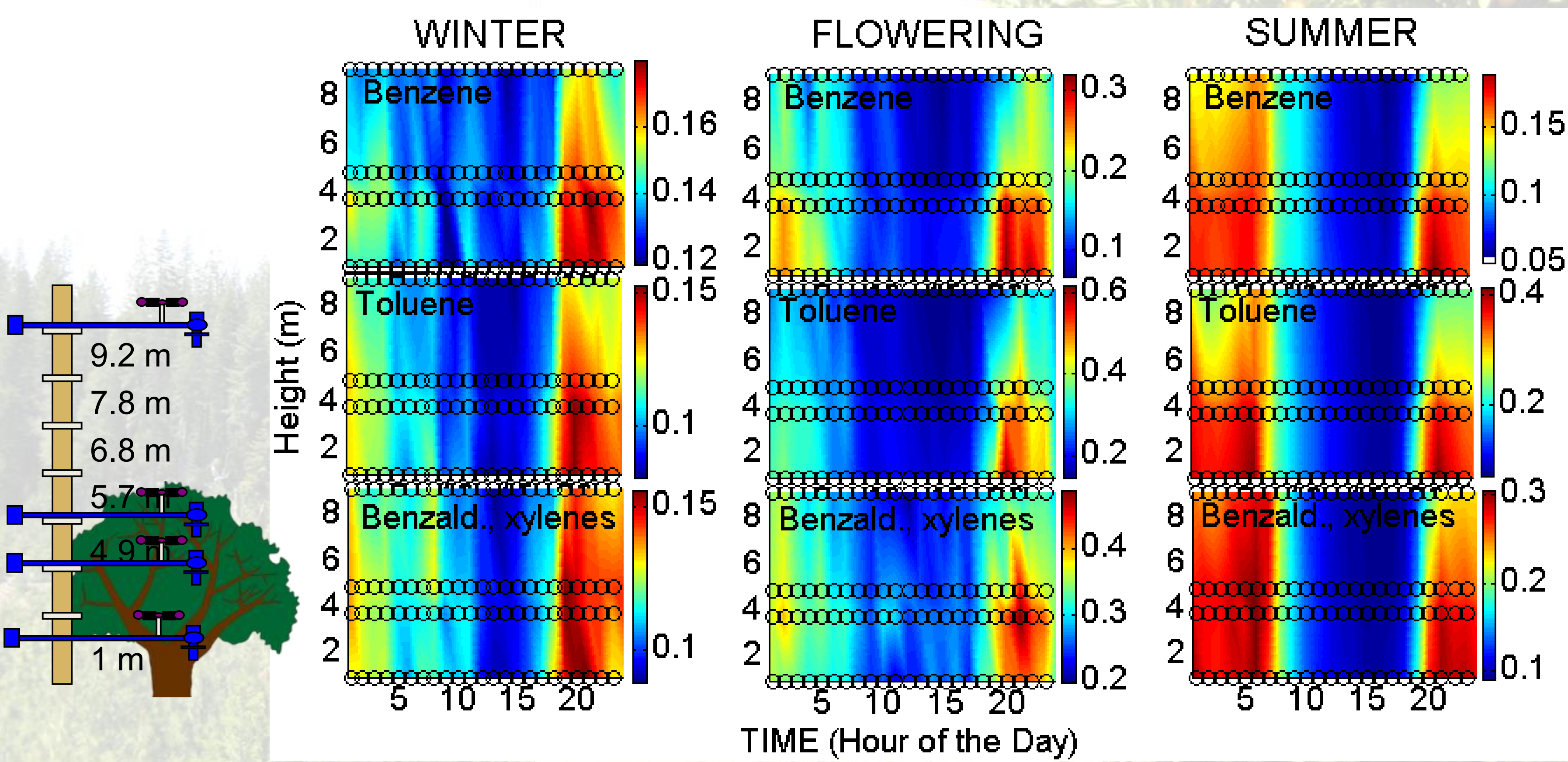
Isoprenoids are emitted during all year



Monoterpenes and isoprene are emitted from the plants as a function of light and temperature, but still air in the evenings causes them to accumulate to higher concentrations (highest near the ground).

Fares et al. ACP 2012

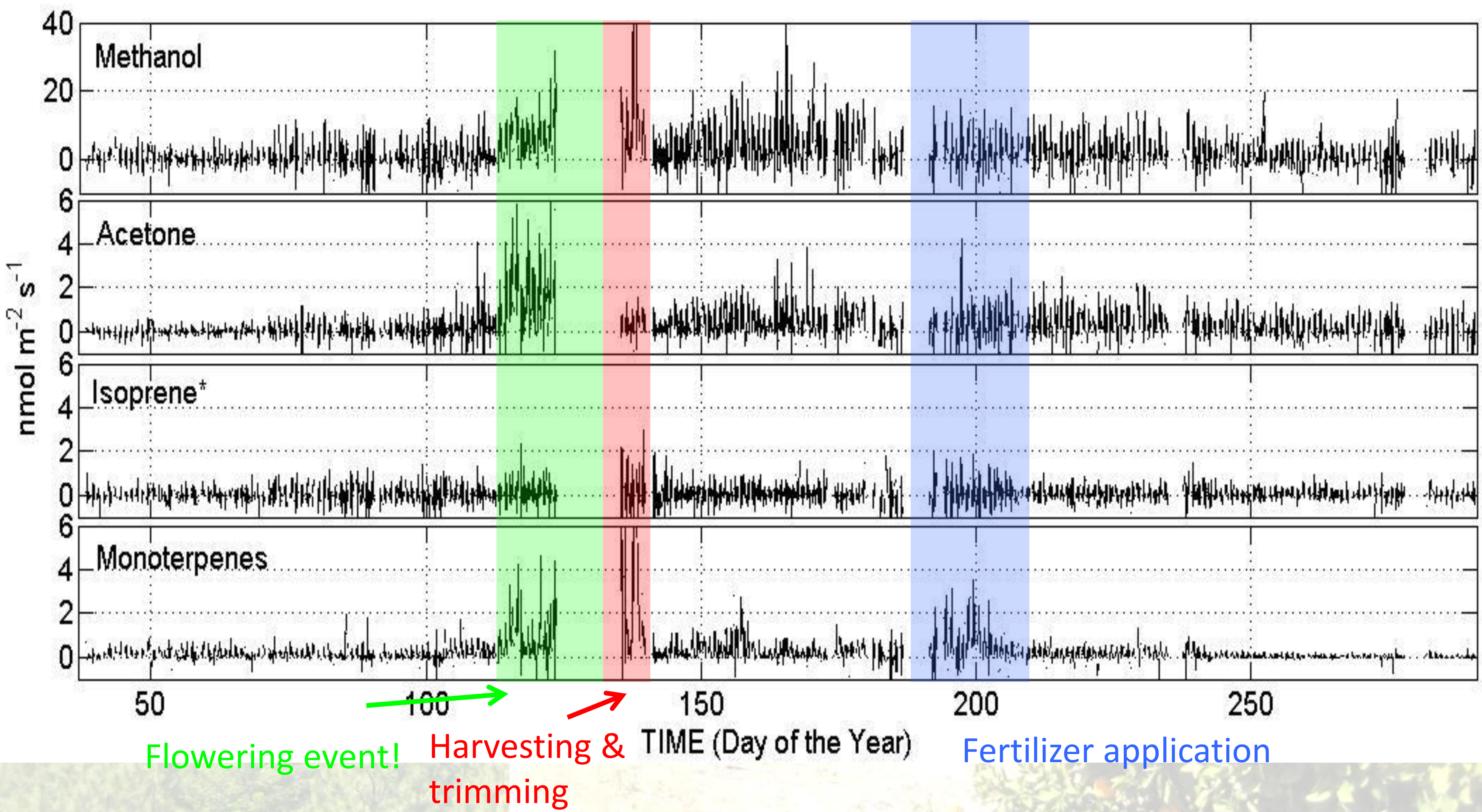
During all year, the orchard is a source of benzenoid compounds



Benzenoids are in floral scents, but are emitted all the year even if we don`t smell them!

Fares et al.
ACP 2012

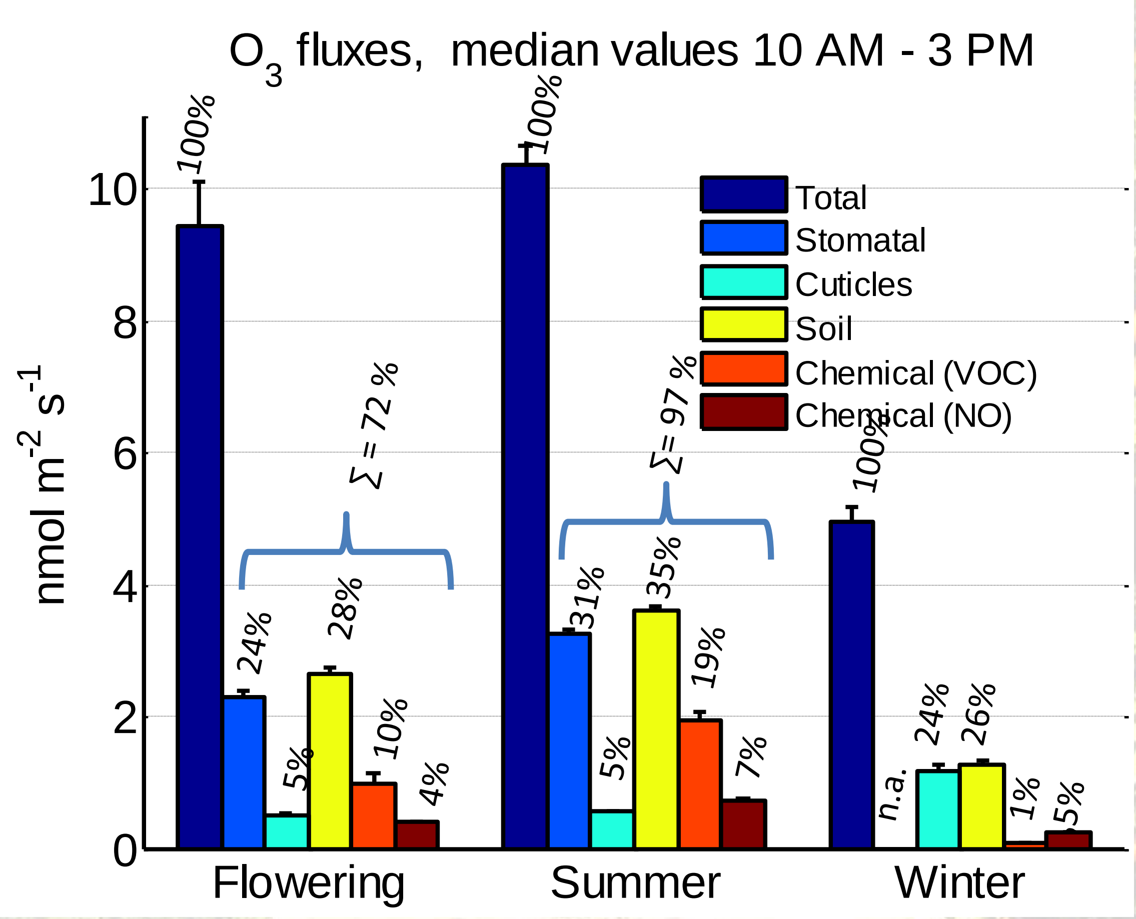
BVOC fluxes



Large fluxes during the flowering period…

Fares et al. ACP 2012

Stomatal and non-stomatal fluxes: final balance



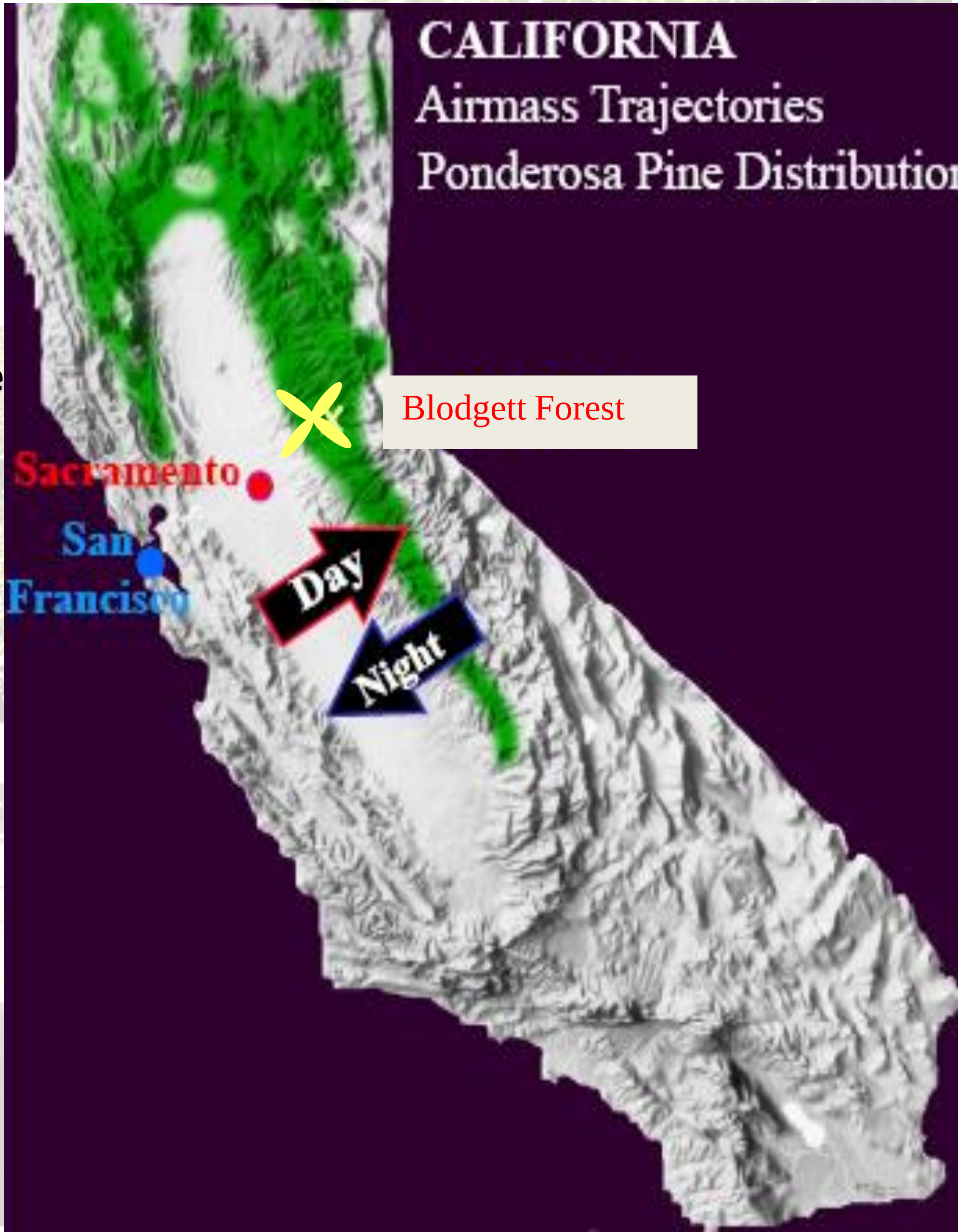
We believe that the model **underestimates Fvoc** during **flowering**, because not fully accounting for the burst of BVOCs coming from flowers.

Fares et al. Env. Poll. 2012

Long term field measurements in Blodget Forest

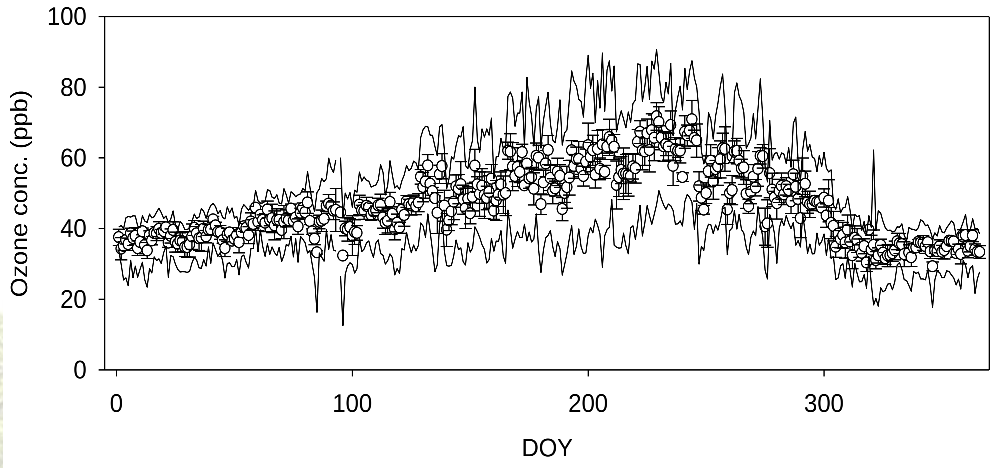
Since 1999, Eddy covariance and gradient measurements of ozone, CO2, have been performed

Through a multiyear analysis (2001-2006), we observed different sinks of ozone uptake, elucidating their dependence on plant physiology and environmental conditions

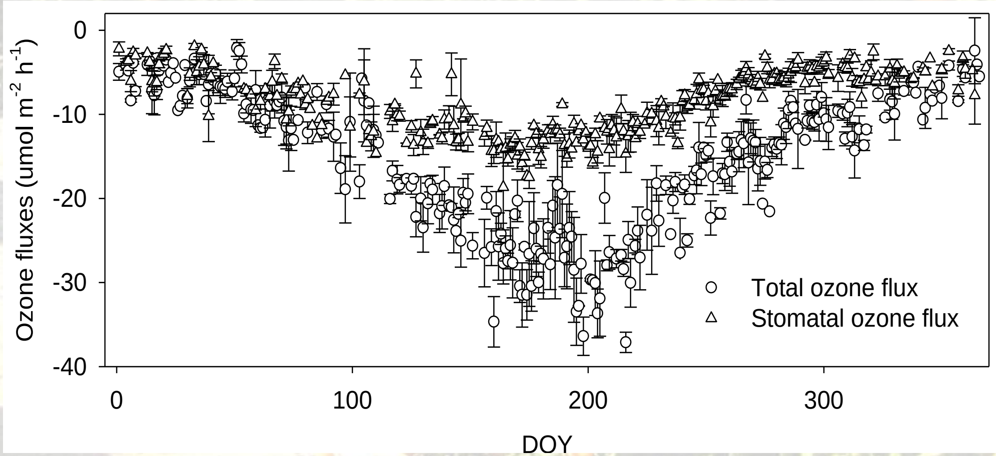


Daily ozone concentration & fluxes

The daily ozone concentrations showed maximum diurnal peaks above 90 ppb!

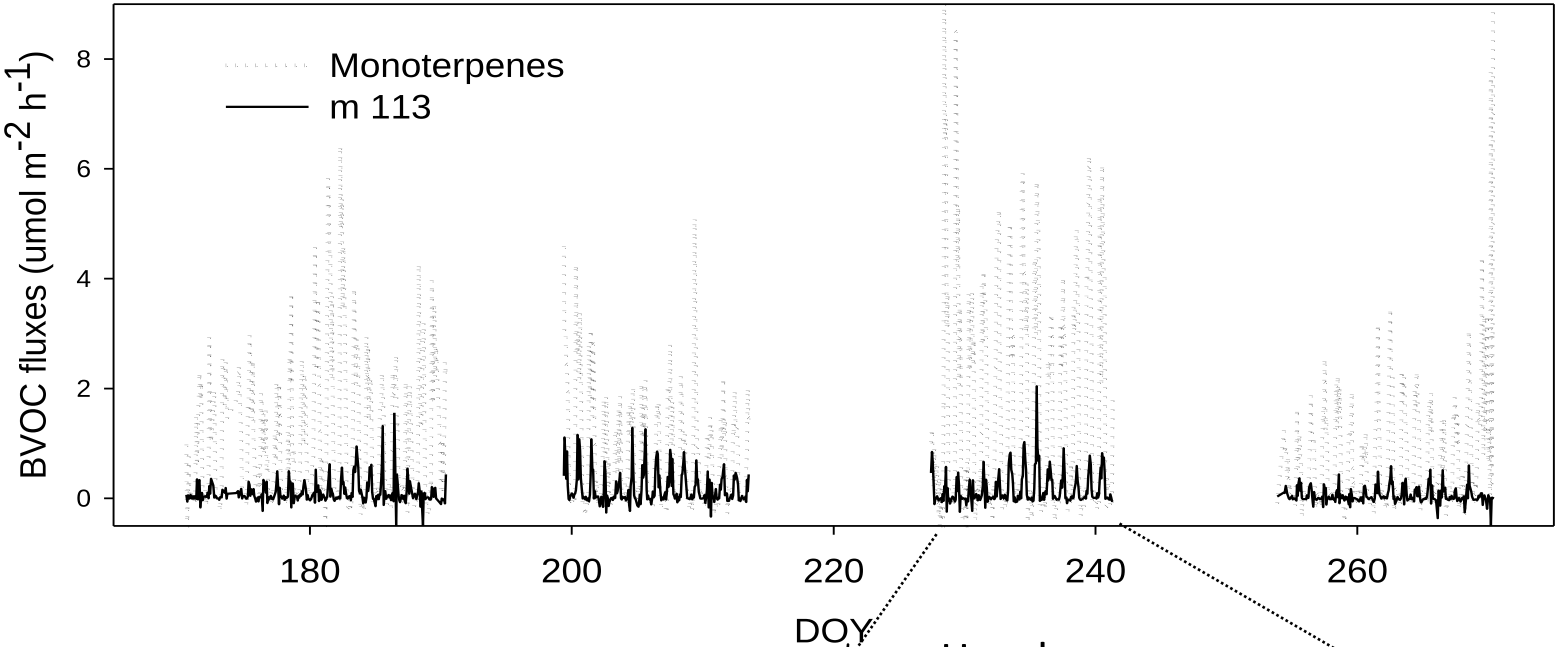


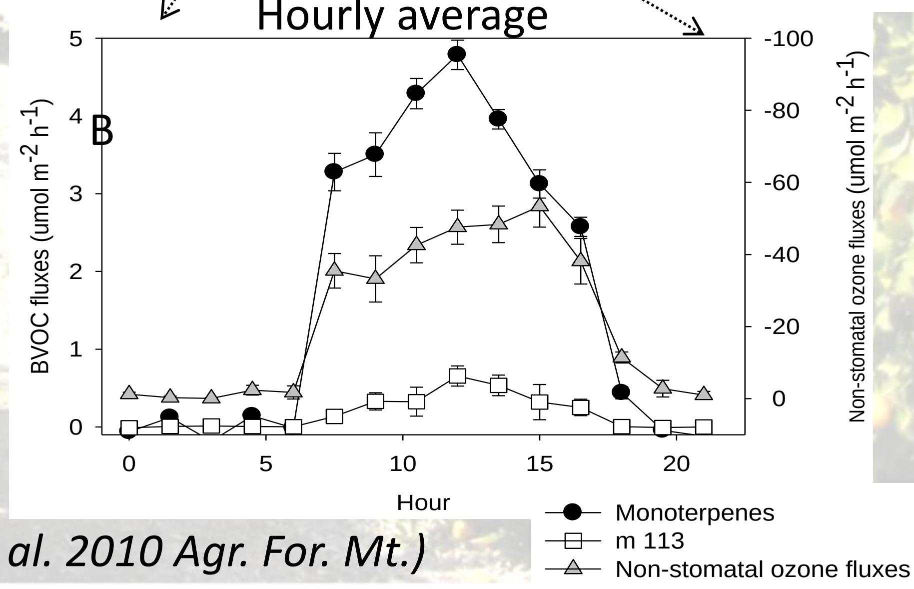
Stomata represented a significant sink of ozone for this ecosystem, but not the major sink, similarly to Citrus site!



Fares et al. Agr. For. Met. 2010

Evidence of non-stomatal ozone removal at Blodgett:



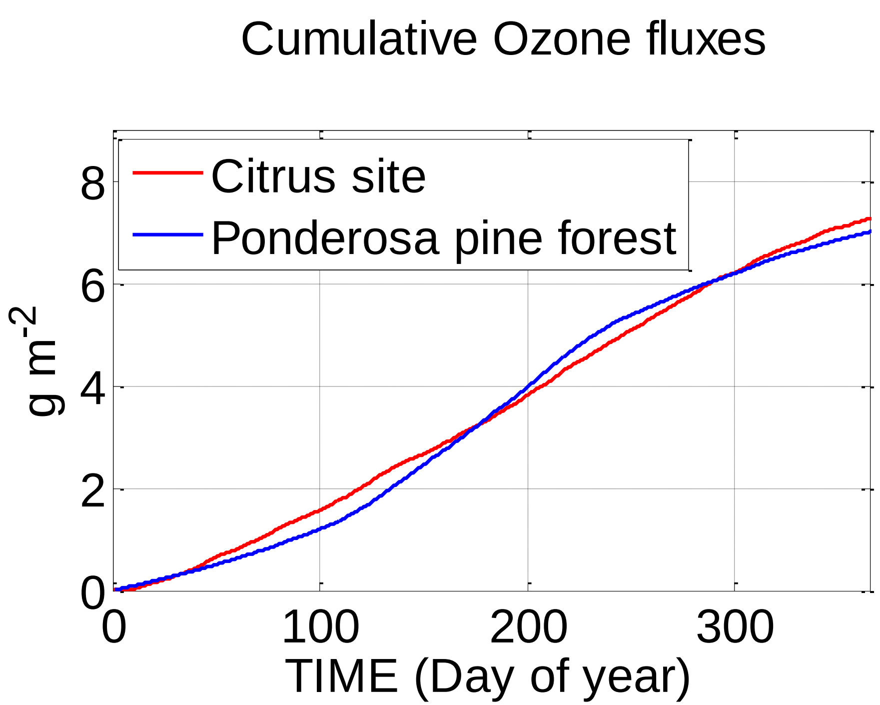


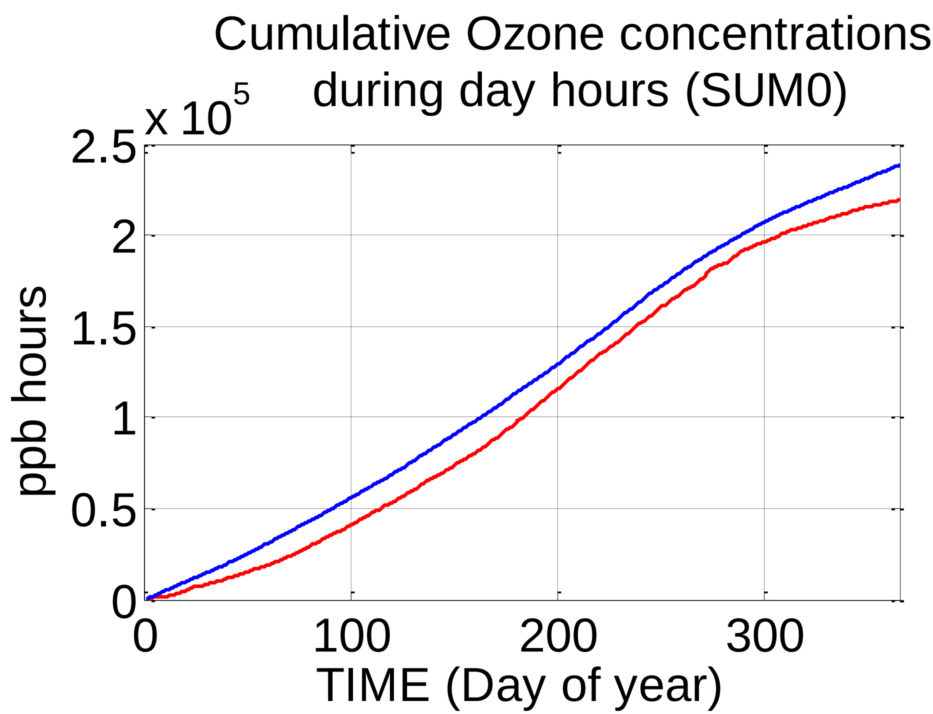
Non-stomatal ozone fluxes peak during the day in coincidence with monoterpene fluxes and the fluxes of the oxidation products of monoterpenes (m113)!

We calculated that up to 40 % of ozone uptake is due to BVOC!

(Fares et al. 2010 Agr. For. Mt.)

How much ozone is removed every year?



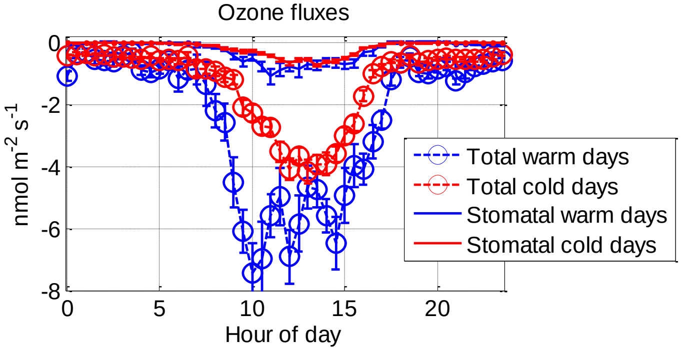


About 7 grams of ozone are removed per square meter of orchard, comparable to a ponderosa pine plantation located in the Sierra Nevada Mountains.

The Citrus orchard and Pine plantation have approximately the same efficiency for ozone removal, since cumulated ozone concentration is similar at these sites.

Conclusion form field studies (I): Non-stomatal O3 removal as a proxy of in-canopy BVOC reactivity

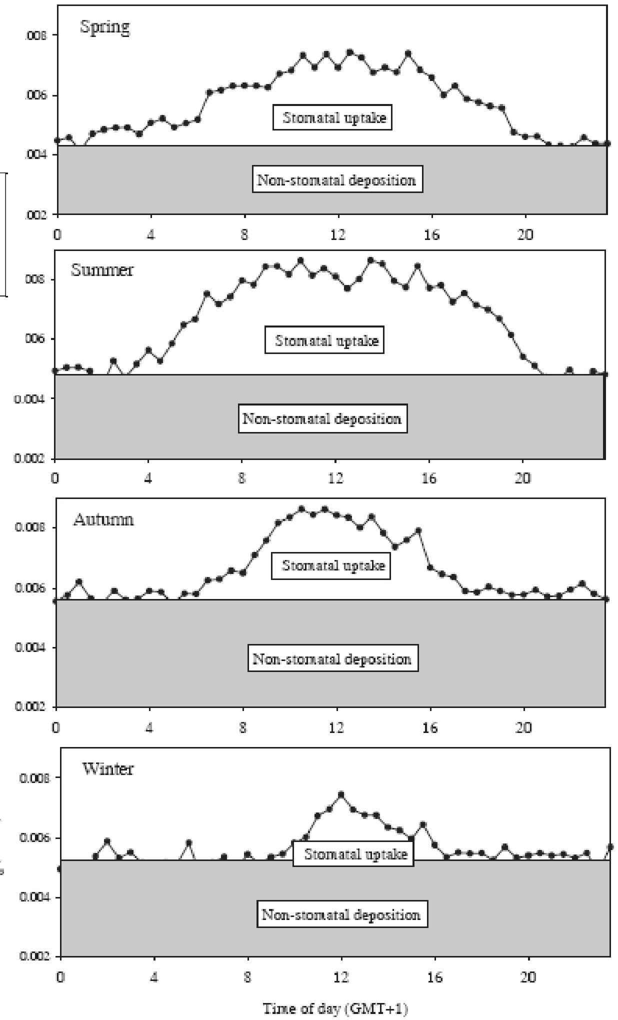
Holm Oak



Fares et al. 2014

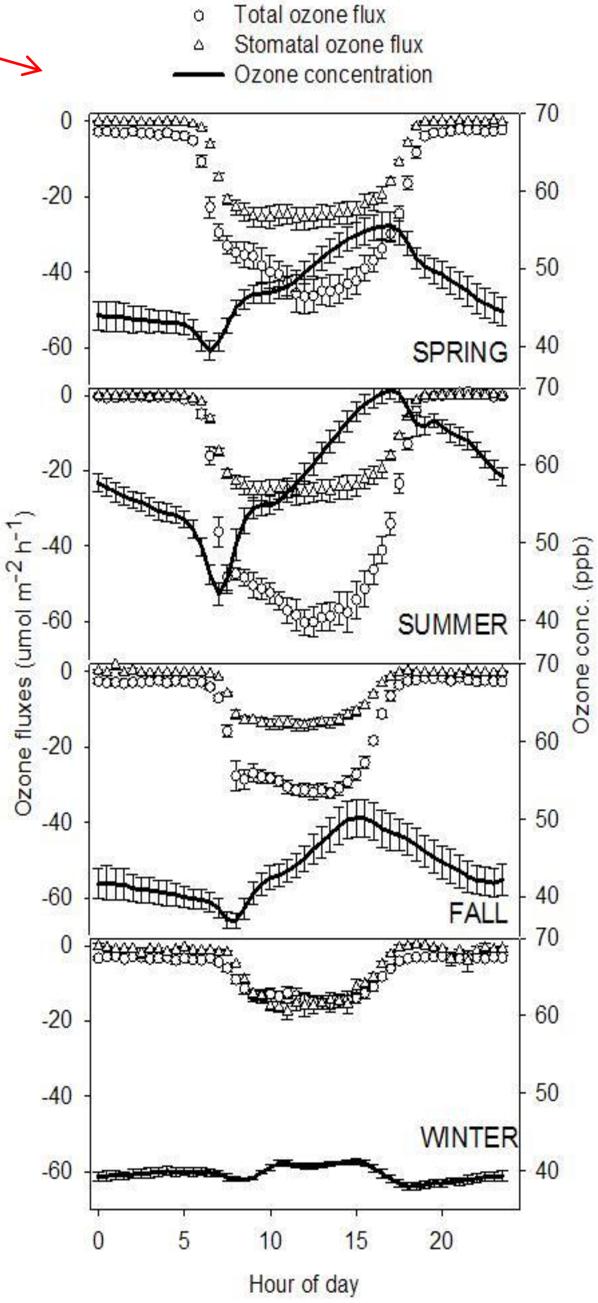
Norway spruce

Mikkelsen et al. 2005

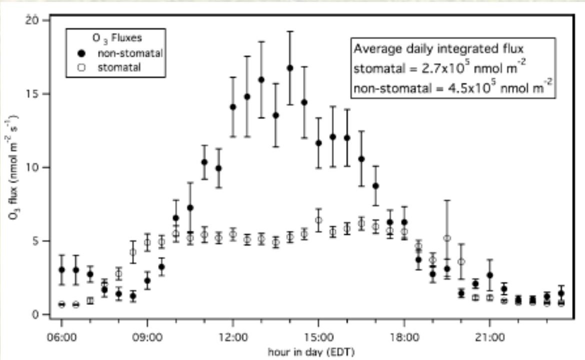


Ponderosa pine

Fares et al. 2010



Mixed hardwood forest



Hoog et al. 2007

Conclusion form field studies (II): Ozone impact on GPP

- Reduction in carbon assimilation was more related to stomatal ozone flux than to ozone concentration.
- The negative effects of ozone occurred within a day of exposure/uptake

O3 concentration

Stomatal O3 flux

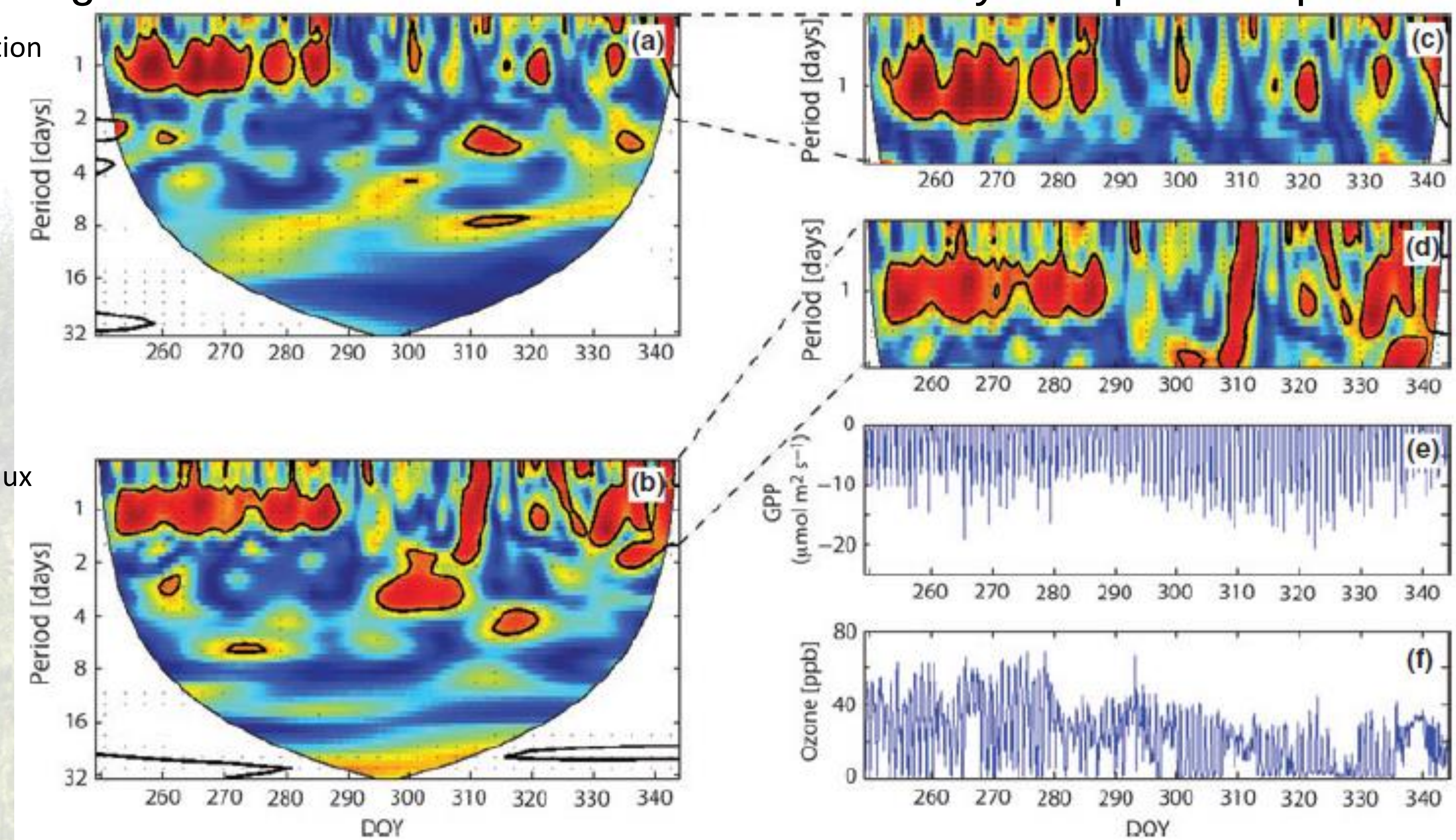


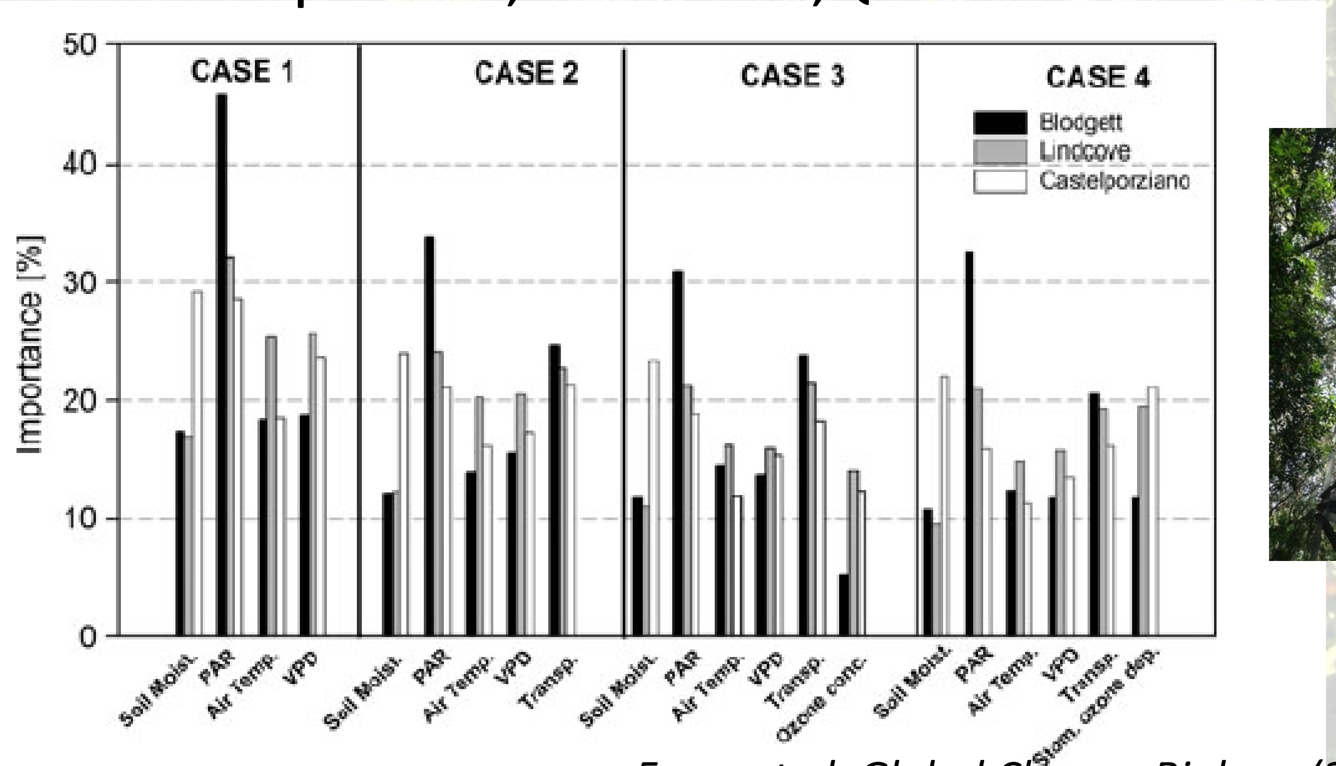
Fig. 3 Wavelet coherence analysis to look the temporal correlations between the residuals of gross primary productivity (GPP) and ozone concentration (a, c) or stomatal ozone deposition (b, d) for the Castelporziano site. The colors for power values are from blue (low temporal correlations with GPP) to red (high temporal correlations with GPP). The thick black line in a and b indicates the cone of influence that delimits the region not influenced by edge effects. Days of the year (DOY), days after September 1st of year 2011.

Fares et al (2013) GCB

Conclusion form field studies (II): Ozone impact on GPP

- Long-term continuous eddy-covariance measurements (>9 years at 30 min resolution) at three Mediterranean-type sites showed that Up to 12–19% of the carbon assimilation reduction is explained by higher stomatal ozone flux!

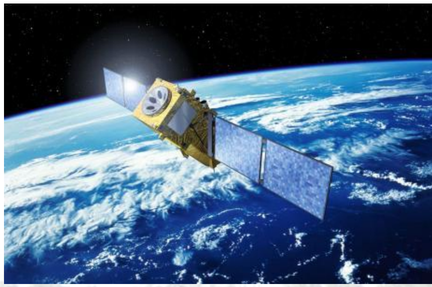
Random Forest Analysis of the effects on GPP at three Mediterranean-type ecosystems: **Pinus ponderosa, Citrus sinensis, Quercus ilex**



Fares et al. Global Change Biology (2013)

Semi-empirical models for the assessment of ecosystem services provided by urban trees

Remote sensing and modeling



Measurements on site

Literature

Leaf temperature and radiative transfers

↓

Photosynthetic flux density of a leaf

↓

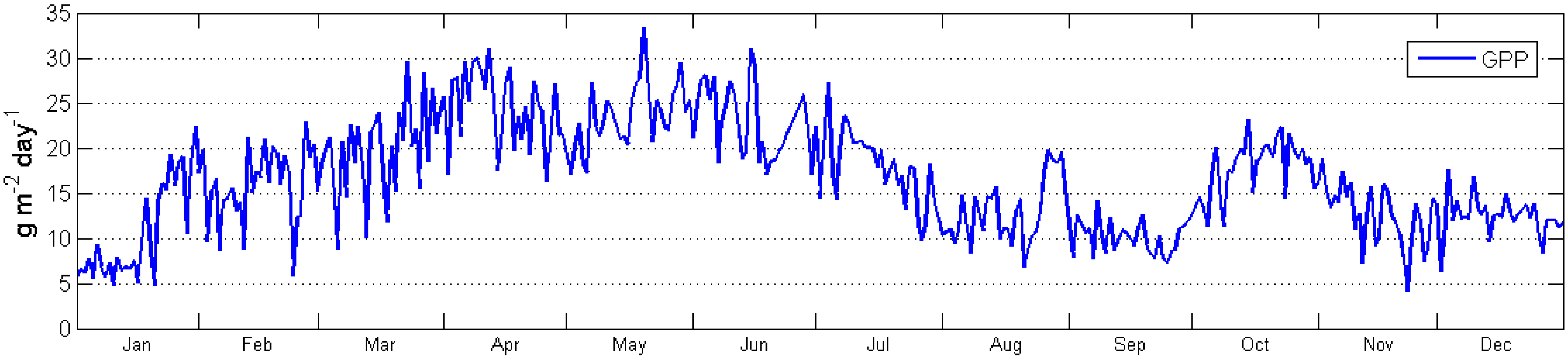
Stomatal conductance

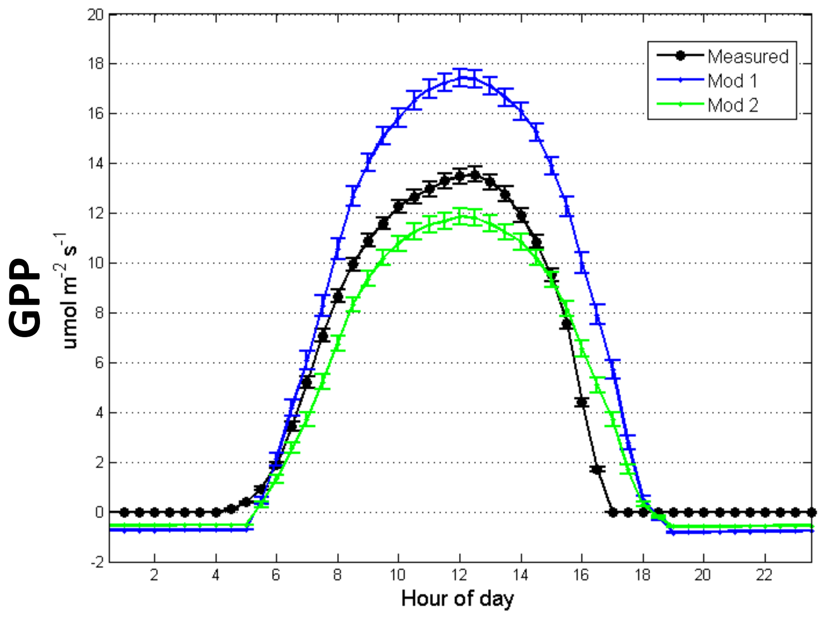
↓

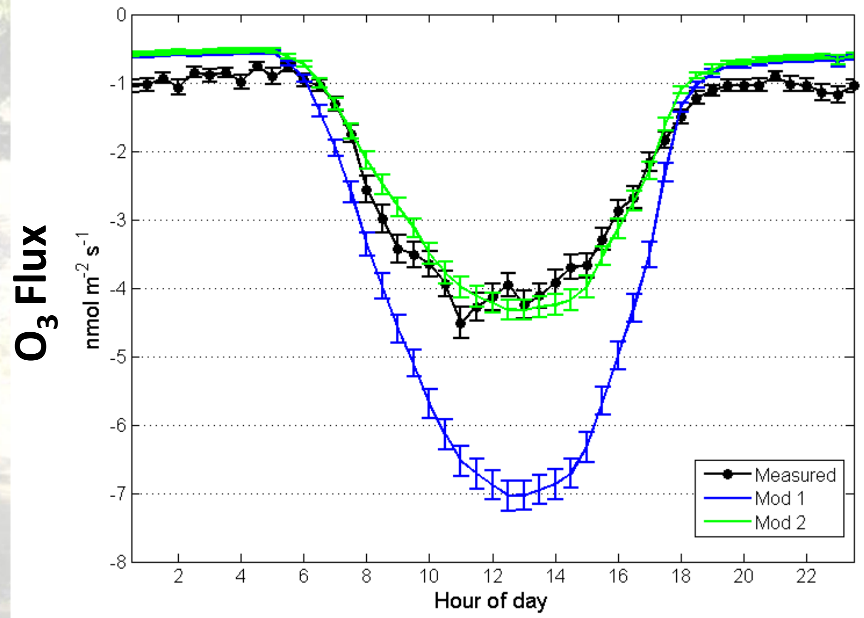
Air pollutants deposition, BVOC and carbon fluxes

Bibliography: Goudriaan and van Laar, 1994; Stavrakou et al., 2008; Farquhar et al., 1980; Baldocchi, 1994; Harley et al., 1992; Ball et al., 1987.

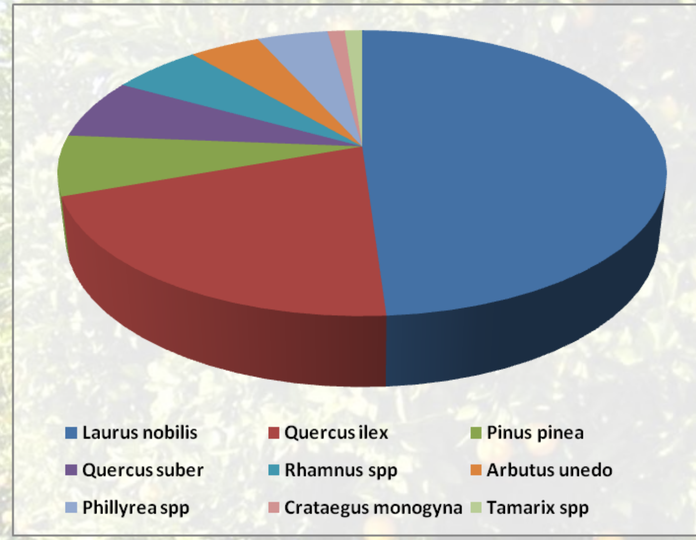
Model validation (in progress)

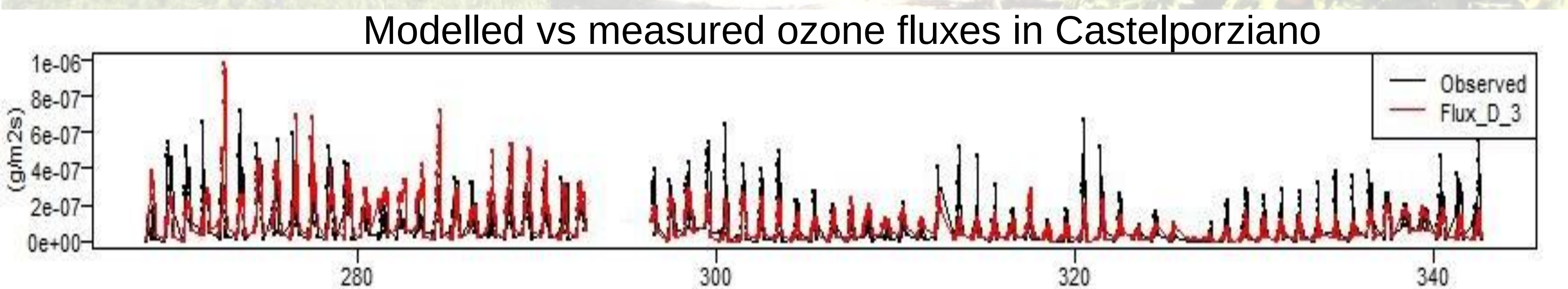






Field measurements are used to validate modelled data





DAY OF YEAR

UFORE model, Morani et al. 2014

Conclusions

- Comparing **VOC emissions** and **O_3 uptake** is important for studying the role of plants for tropospheric O_3 balance.

- Future scenarios of climate change may affect species composition and BVOC emission.

- The O_3 forming potential of VOCs highly depends on **NO_x** concentration. As long as air is polluted, strong emitters tend to be **a source of ozone**. It is worth paying attention to consider the species with high emission rates as sources of ozone in urban or suburban area.

- Modelling is the way to assimilate experimental results and provide urban planners a valuable tool to select the most suitable tree species which maximize ecosystem services. However, extensive parameterization is still needed!

Thank You!

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CRA CONSIGLIO PER LA RICERCA E LA SPERIMENTAZIONE IN AGRICOLTURA

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Tato akce se koná v rámci projektu:
Vybudování vědeckého týmu environmentální metabolomiky a ekofyziologie a jeho zapojení do mezinárodních sítí (ENVIMET; r.č. **CZ.1.07/2.3.00/20.0246**) realizovaného v rámci Operačního programu Vzdělávání pro konkurenceschopnost.