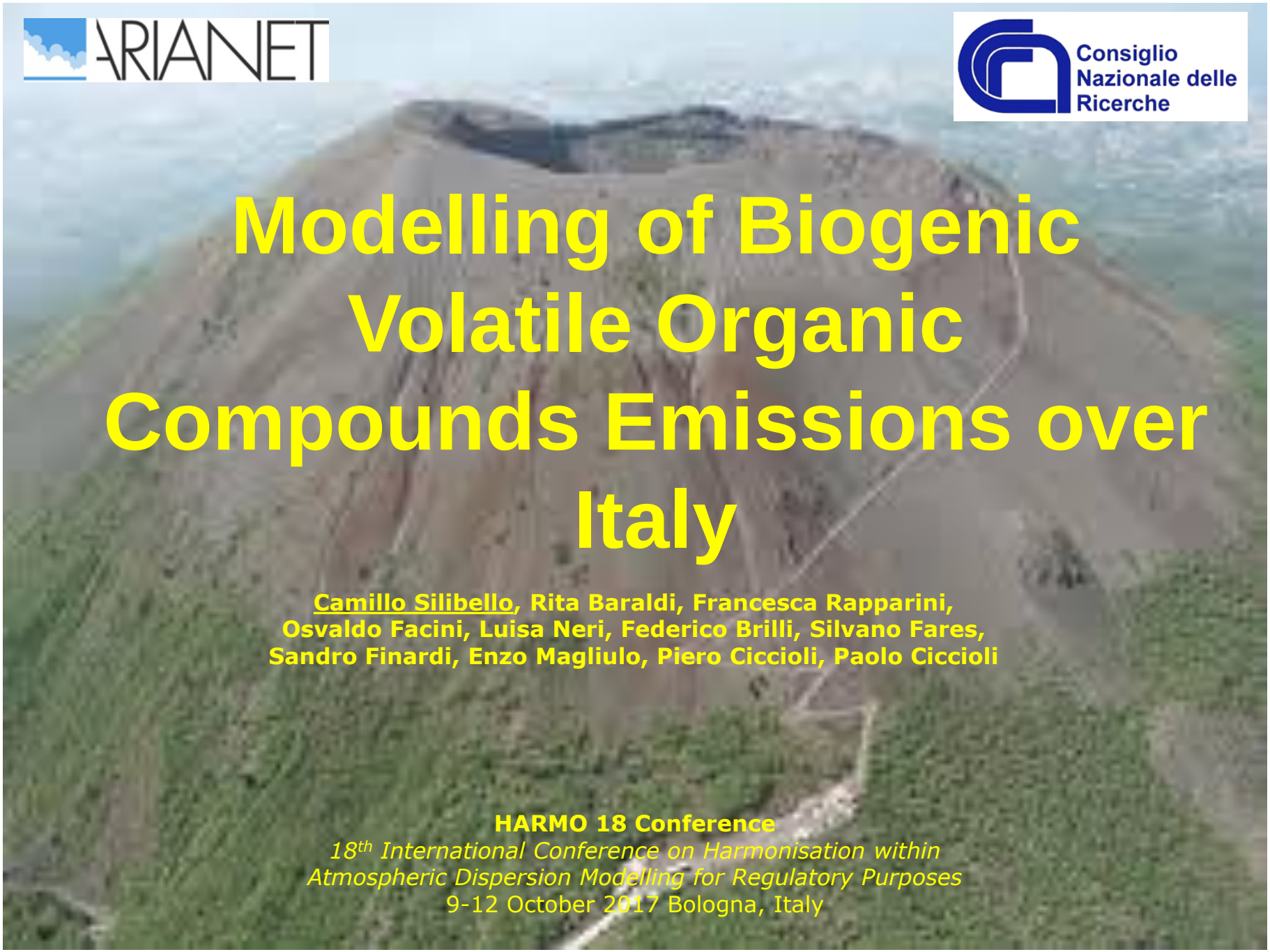


Modelling of Biogenic Volatile Organic Compounds Emissions over Italy

Camillo Silibello, Rita Baraldi, Francesca Rapparini, Osvaldo Facini, Luisa Neri, Federico Brilli, Silvano Fares, Sandro Finardi, Enzo Magliulo, Piero Ciccioli, Paolo Ciccioli

HARMO 18 Conference
18th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
9-12 October 2017 Bologna, Italy

Why ?

1. Develop a Plant-Specific emission model (***BIOVOC***) based on an **accurate recognition of plants over the Italian territory;**

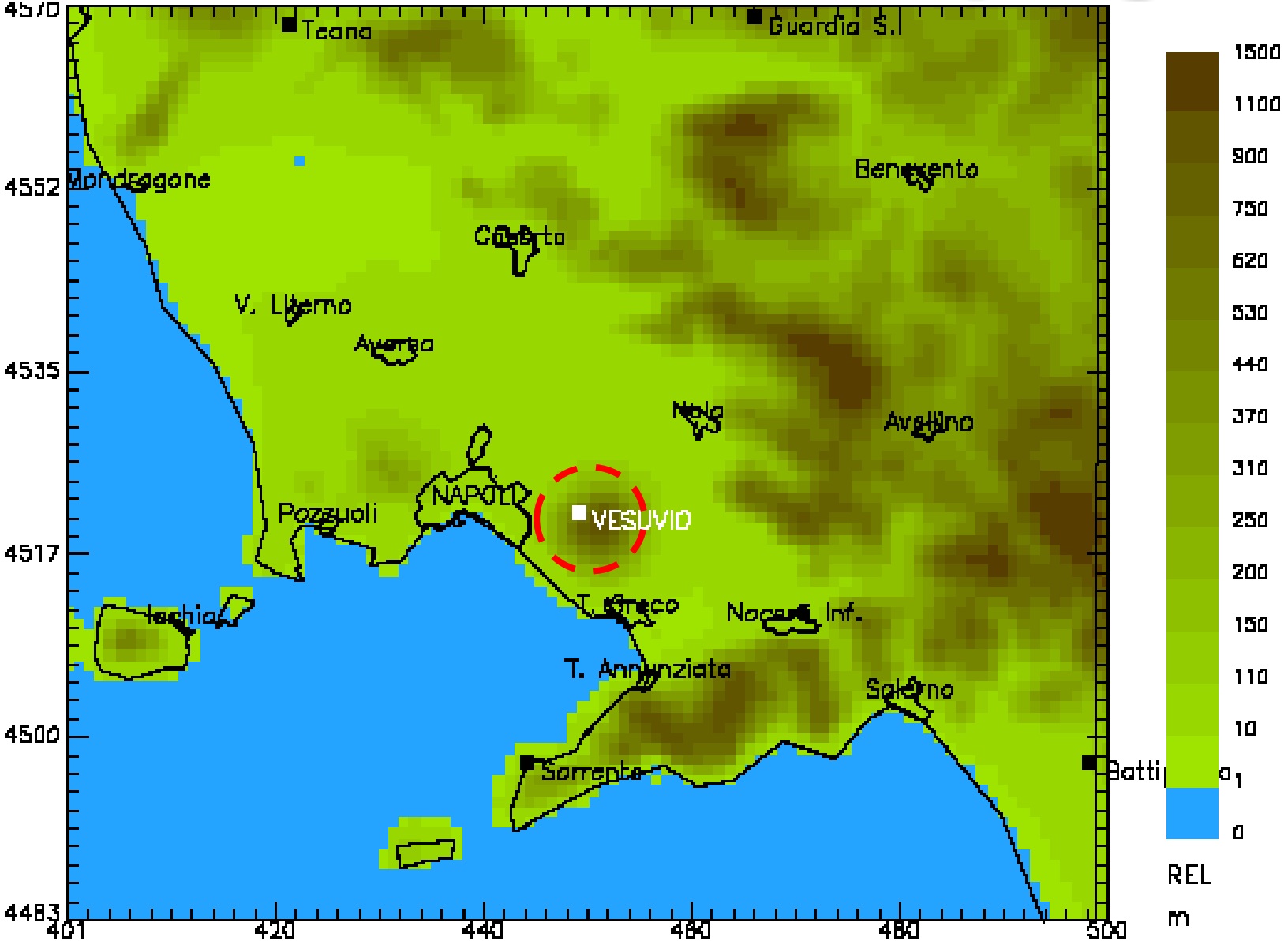
2. Compare BVOCs emissions estimated by BIOVOC model with MEGAN model ones;

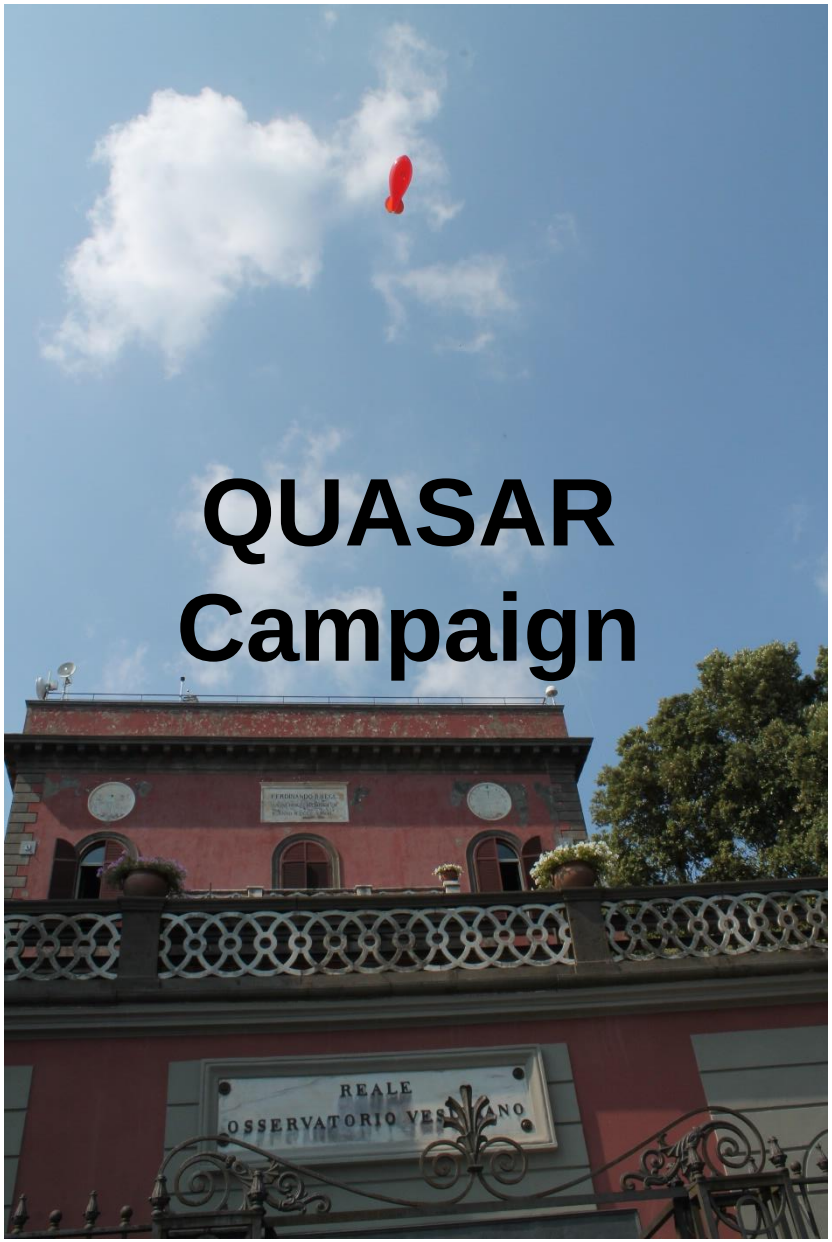
3. Compare CTM (with BIOVOC/MEGAN) BVOCs predicted concentrations with **measurements** collected during the QuASAR (**Qu**alità dell'**A**ria **S**tudi **A**mbientali e **R**icerca) experimental field campaign (July 14-16, 2015).

More info on AriaSaNa project at: http://www.ariasana.org/

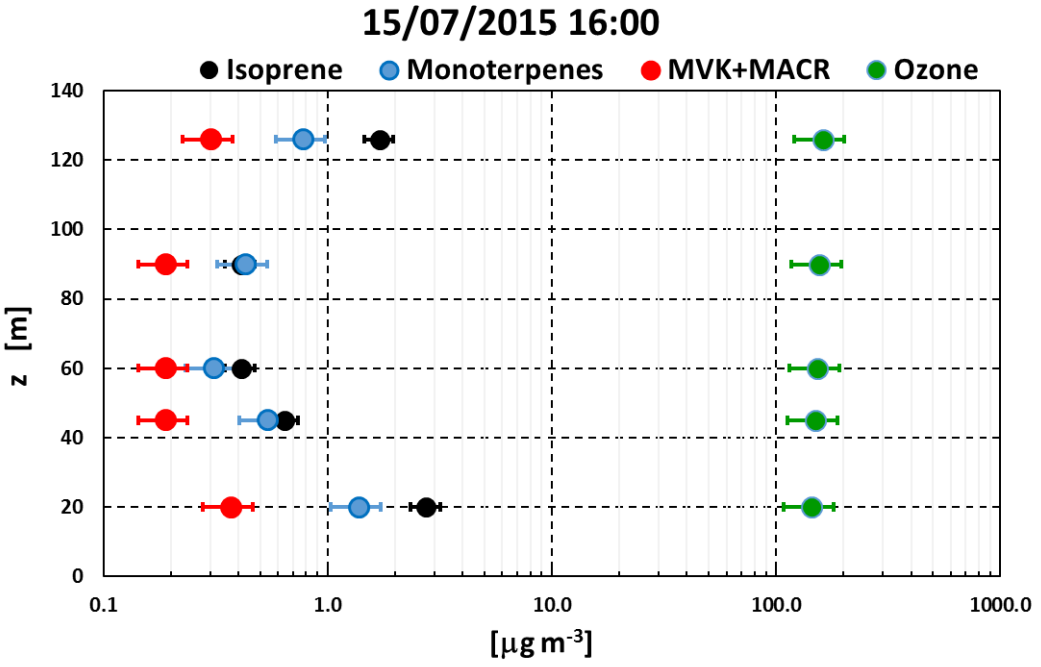
Where QuASAR Campaign ?

Where QuASAR Campaign ?





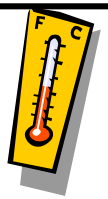
A **tethered balloon,** filled with 9 m^3 of helium, was used to lift the inlet of a Teflon sampling line connected to a Proton Transfer Reaction - Mass Spectrometer (**PTR-MS**) measuring different **BVOC compounds** to altitudes **up to 100 m** above the Vesuvius Observatory (614 m a.s.l.). **Three measurements per day** were performed during the campaign (July 14-16, 2015).



Plant-Specific emission model

Based on: Pacheco *et al.*, 2015: A highly spatially resolved GIS-based model to assess the isoprenoid emissions from key Italian ecosystems. *Atm. Environ.*, 96, 50-60

- **Tree species/Vegetation types**
- **Basal Emission Factors** (BEF, µg g (DW)$^{-1}$ h^{-1}): express the capacity of plants to emit isoprenoids under so called “basal conditions” (T= 30°C and PAR=1000 µmol m^{-2} s^{-1}).

Environmental Correction factors	 LIGHT	 TEMP	 SEASON (γ_S) – **Foliar biomass (LAI)** – **phenology enzymes activity photosynthesis**	 CANOPY (γ_C) **Leaves emissive characteristics under direct sunlight or shaded**	 LITTER (γ_L) **emissions from dead biomass accumulated on the soil**
 Synthesis (E_{L+T}) ISOP,OVOC, MTS	☑	☑	☑	☑	
 Pool (E_T) MTP,SQT		☑	☑	☑	☑

Emission rates

The real emission rate (E_{real}) [µg m^{-2} h^{-1}] is expressed by following eq.:

SEASON LITTER

$$E_{real} = E_{max} \cdot \gamma_S \cdot \gamma_c \cdot (1 + \gamma_L) \cdot D_B$$

CANOPY

foliar biomass density

Synthesis emission
E_{L+T}
ISOP,OVOC, MTS

$$E_{L+T,max} = BEF_{max} C_L C_T$$

Pool emission
E_T
MTP,SQT

$$E_{T,max} = BEF_{max} \exp\left[-\beta(T - T_S)\right]$$

C_L and C_T are activity factors accounting for light and temperature, β an empirical coefficient equal to 0.09 °K^{-1}, T is the leaf temperature (°K) and T_S is the leaf temperature at standard conditions (=303.15 °K).

Basal Emission Factors

Tree species

Nr.	Specie	Foliar biomass density	$E°_{max}$ Isoprene	$E°_{max}$ MTS (T+L)	E°max MTP (T)	$E°_{max}$ SQT (T)	$E°_{max}$ OVOC METHANOL 80%) (L+T)	Leaf seas. type	Seas. Type Karl et al.
1	Acer campestre	270	0	1.5	0	0.001	10	0	dec
2	Acer monspessulanum	270	0	2	0	0.001	10	0	dec
3	Acer platanoides	270	0.1	1.5	0	0.001	10	0	dec
4	Acer sp.	270	0	2	0	0.001	10	0	dec
5	Ailanthus Altissima	270	0	0	0	0	0	0	dec
6	Alnus cordata	270	0	0	0.72	0.001	2	0	dec
7	Alnus glutinosa	270	0	1.5	0	0.001	10	0	dec
8	Alnus incana	270	0	1.5	0	0.001	10	0	dec
9	Arbutus unedo	300	0.1	0	0.2	0.001	2	0	dec
10	Betula pendula	230	0	0	1.5	0.15	2	0	dec
11	Betula pubescens	230	0	2	0.2	0.2	2	0	dec
12	Carpinus betulus	300	0	0.5	0	0.001	10	0	dec
13	Carpinus orientalis	300	0	0	0	0.001	10	0	dec

• • •

Vegetation types

86	Transitional Woodland-Shrub	400	5	5	5	0.01	2	0	eve
87	Sparsely Vegetated Areas	140	0.5	0.5	0.5	0.001	2	2	eve
88	Inland Marshes	200	10	1	1	0.001	2	2	eve
89	Peatbogs	330	10	1	1	0.001	2	2	eve
90	Salt-Marshes	200	10	1	1	0.001	2	2	eve
91	Broad-Leaved Forest	360	15	5	0.5	0.001	2	2	dec
92	Coniferous Forest	950	3	2.5	2.5	0.001	2	3	eve
93	Mixed Forest	660	10	2	2	0.001	2	2	mix

Broadleaf forests (CLC level IV)

3.1.1.1

Forest areas covered by evergreen oaks and evergreen broadleaf species

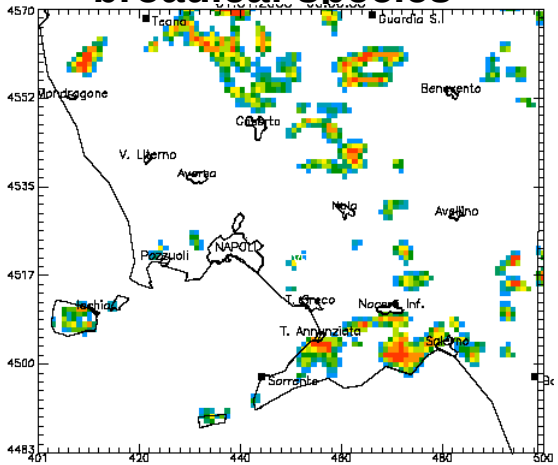
Quercus:
Ilex (33%)
Suber (33%)
Coccifera (34%)

3.1.1.2

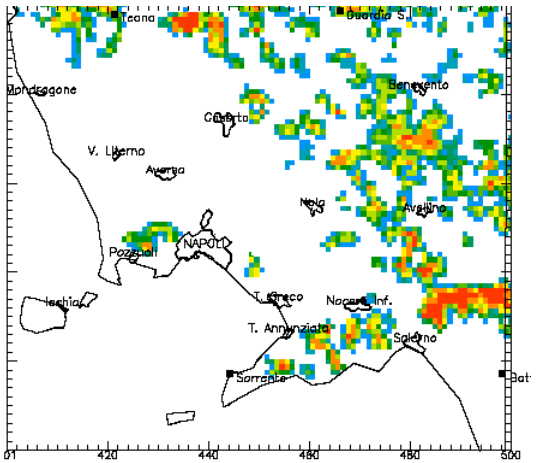
Forest covered by deciduous oaks

Quercus:
Cerris (40%)
Pubescens (40%)
Petraea (8%)
Frainetto (8%)
Robur (4%

Evergreen oaks and broadleaf species



Deciduous oaks



Tree species associated to each CLC subclasses (lev. IV) according to Italian regional forestry departments data

3.1.1.3

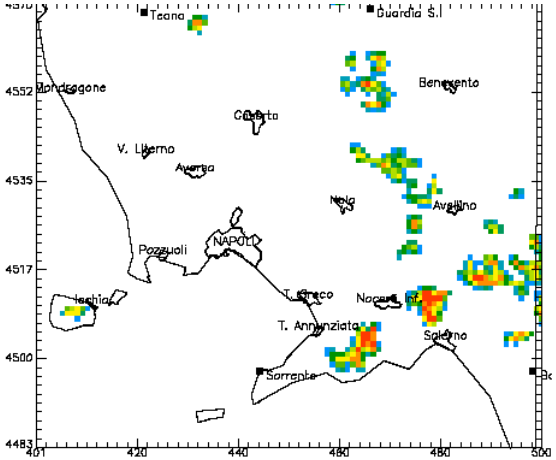
Mixed forest areas covered by autochthonous broadleaf species

Fraxinus excelsior 50%
Carpinus betulus 50%

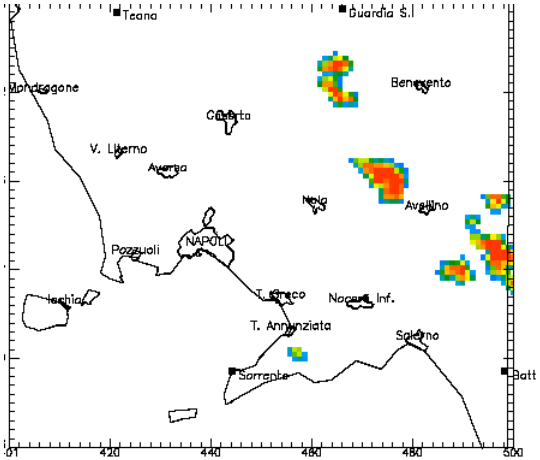
3.1.1.5

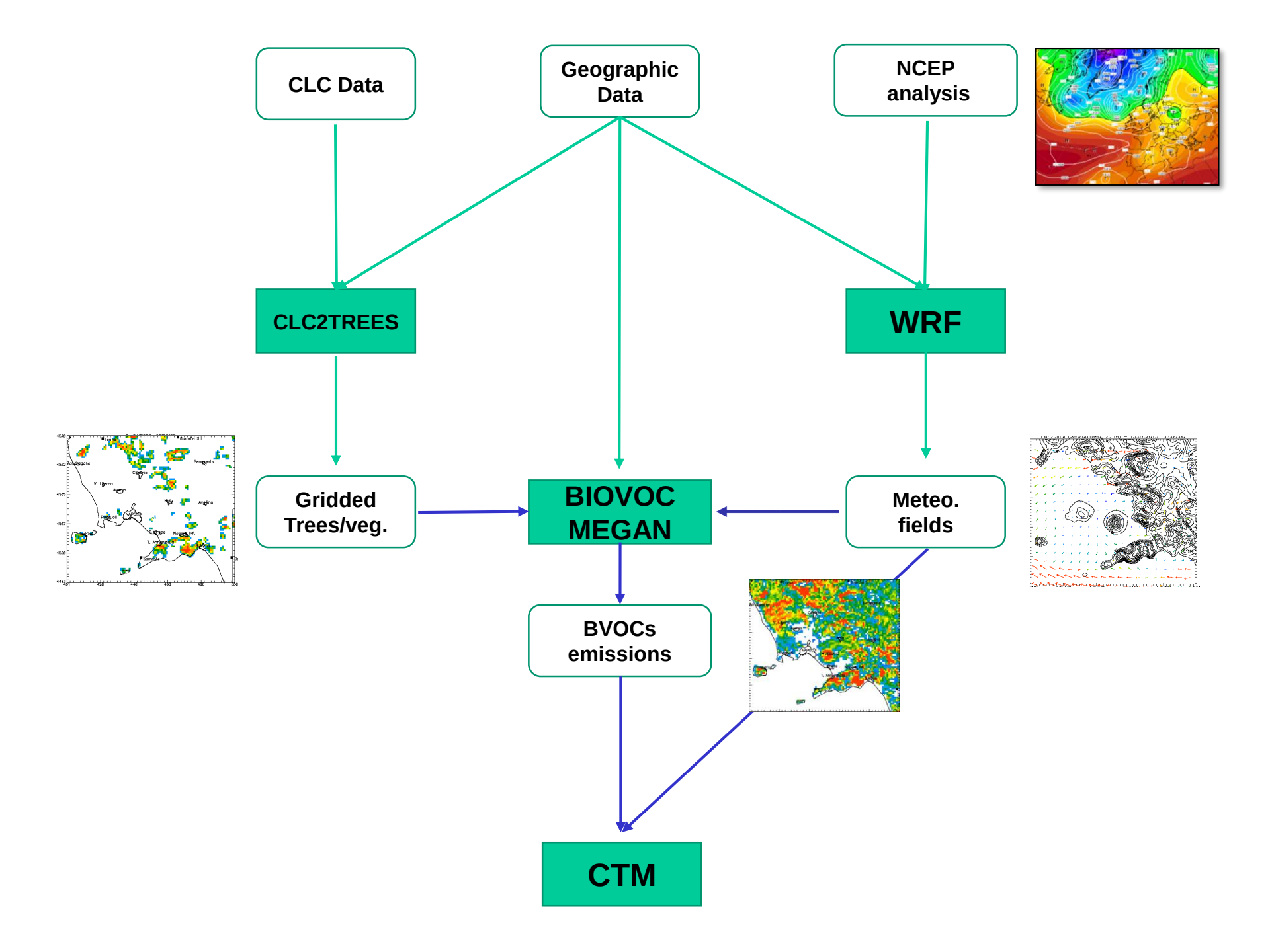
Forest areas covered by Fagus sylvatica (100%)

Mixed forest areas (autochthonous species)



Fagus sylvatica




CLC Data
Geographic Data
NCEP analysis
CLC2TREES
WRF
Gridded Trees/veg.
BIOVOC MEGAN
Meteo. fields
BVOCs emissions
CTM

BVOC emissions (July, 14-17 2015)

- Plant-Specific emission model (**BIOVOC**);

- **MEGAN v.04** model based on 4 Plant Functional types:
  1. Broadleaf trees;
  2. Needle leaf trees;
  3. Shrublands;
  4. Herbaceous.

Emissions from ISOP concentration Measurements and WRF PBL height (Mixed Boundary Layer Method)

$$ISOP_{emission} = ISOP_{concentration} \cdot \frac{PBL_{height}}{lifetime}$$

Using WRF PBL height and typical lifetime

ISOP + OH → …

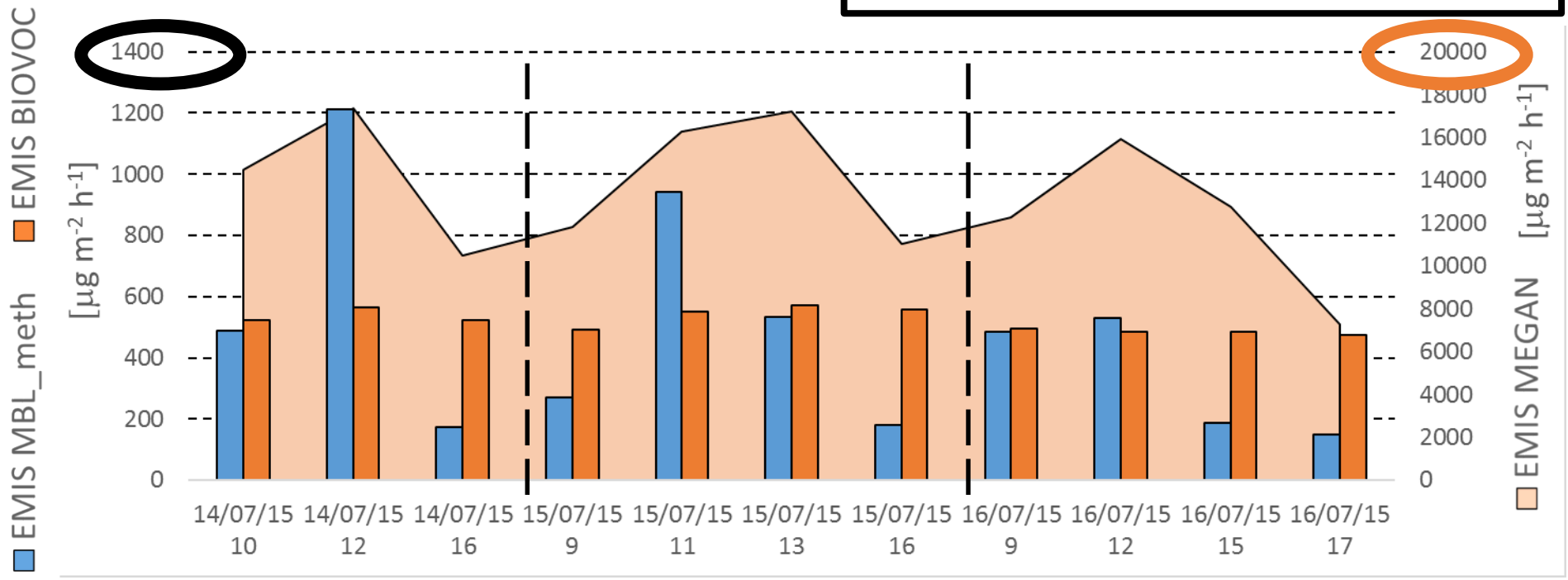
$$\frac{d[ISOP]}{dt} = -k[OH][ISOP]$$

k = 9.9 10^{-11} (at 298 °K)

[OH] = 1.5 10^{6} molec cm^{-3}

Typical lifetime of ISOP:

τ_{ISOP} = 1 / (k [OH]) = 1.9 hr



Emissions from TRP concentration measurements and WRF PBL height (Mixed Boundary Layer Method)

$$TRP_{emission} = TRP_{concentration} \cdot \frac{PBL_{height}}{TRP_{lifetime}}$$

Using WRF PBL height and typical lifetime

TRP + OH → …

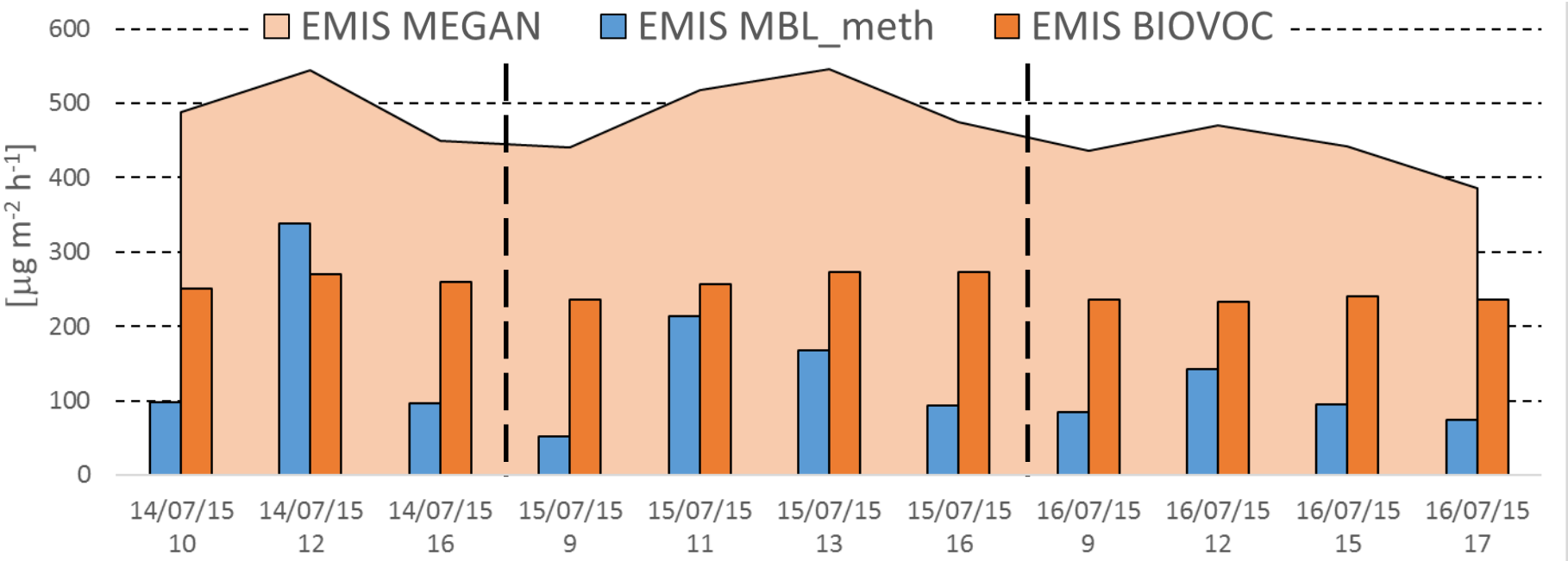
$$\frac{d[TRP]}{dt} = -k[OH][TRP]$$

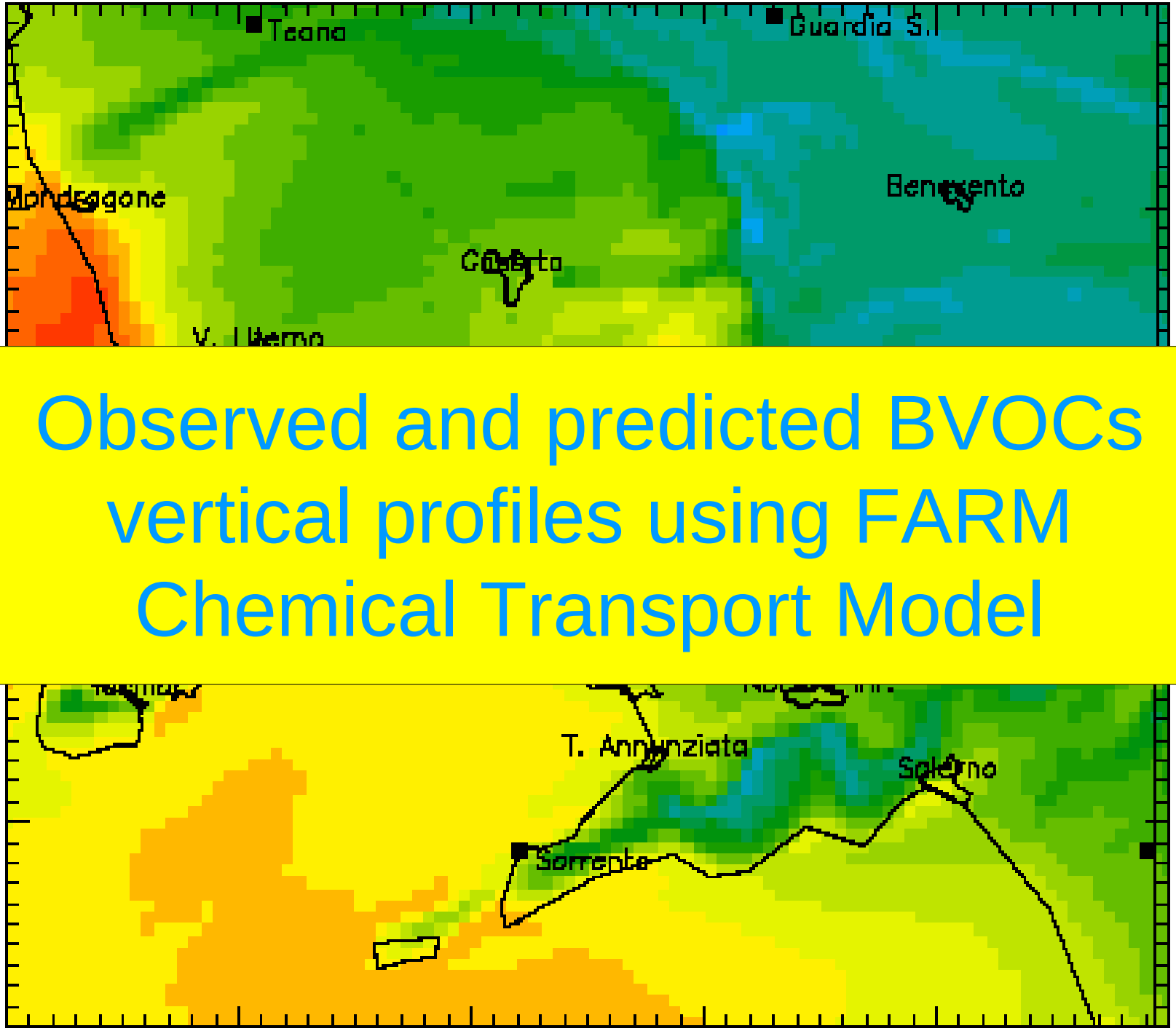
k =8.2 10^{-11} cm^3 $molec^{-1}$ s^{-1} (at 298 °K)

[OH] =1. 5 10^6 molec cm^{-3}

Typical lifetime of TRP:

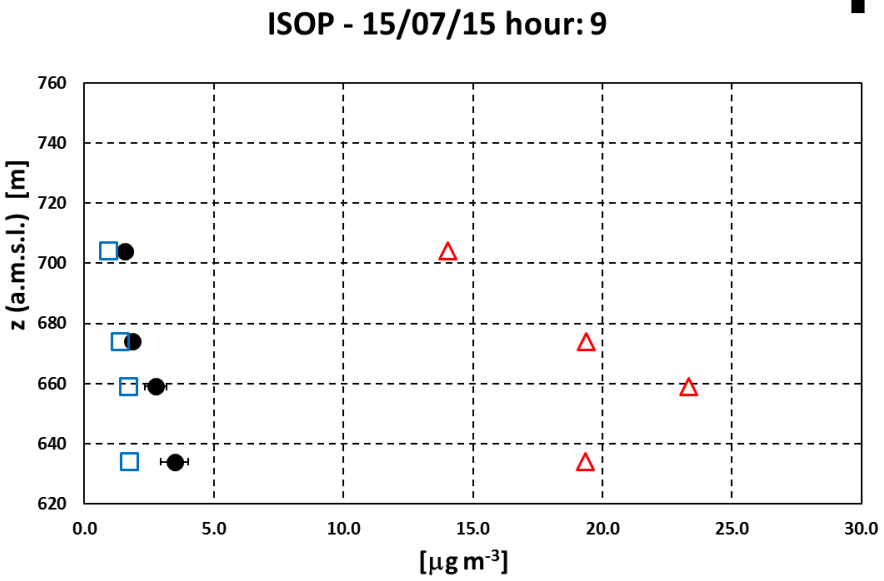
τ_{TRP1} = 1 / (k [OH]) = 2.3 hr

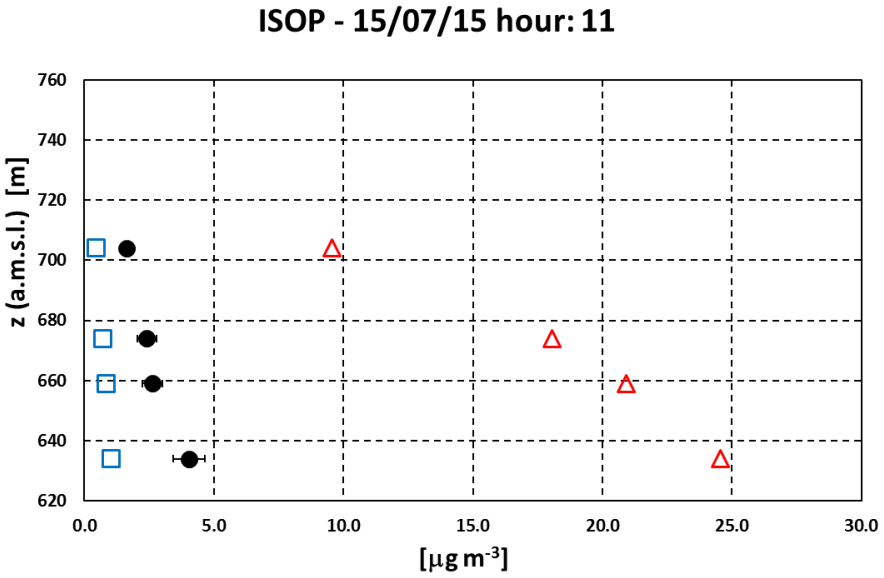


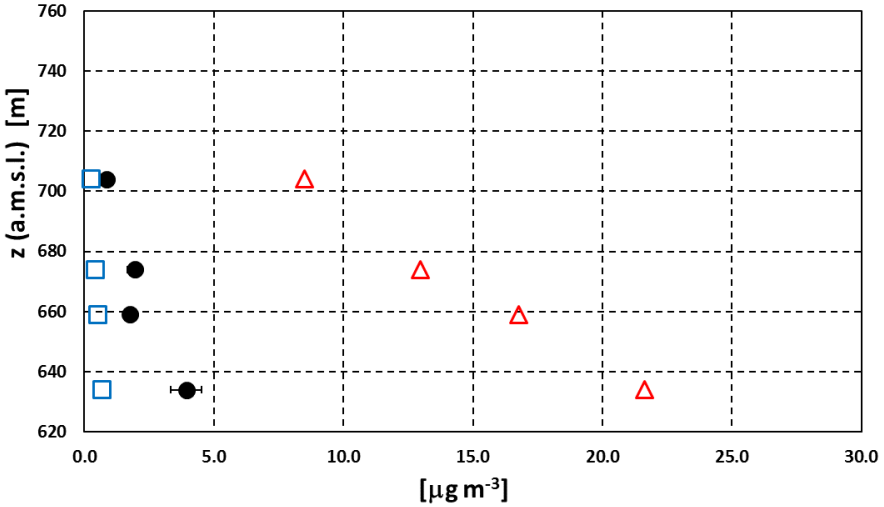


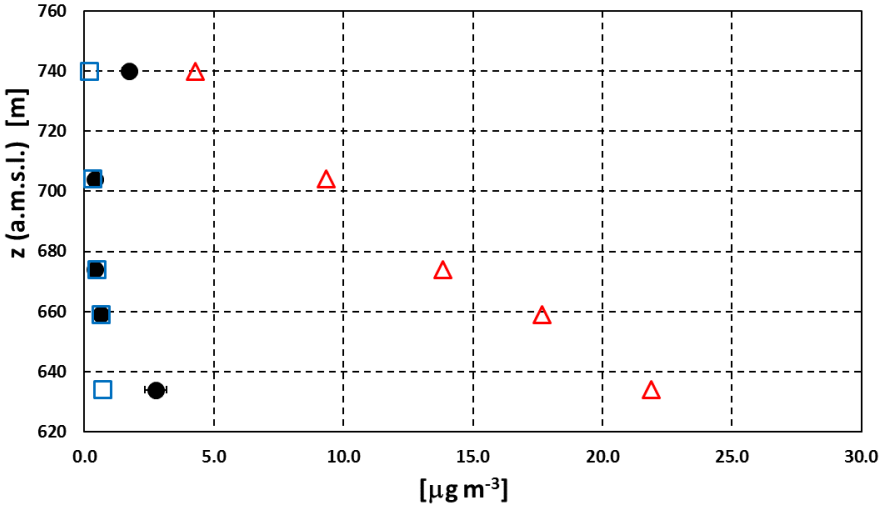
Observed and predicted BVOCs vertical profiles using FARM Chemical Transport Model

Isoprene





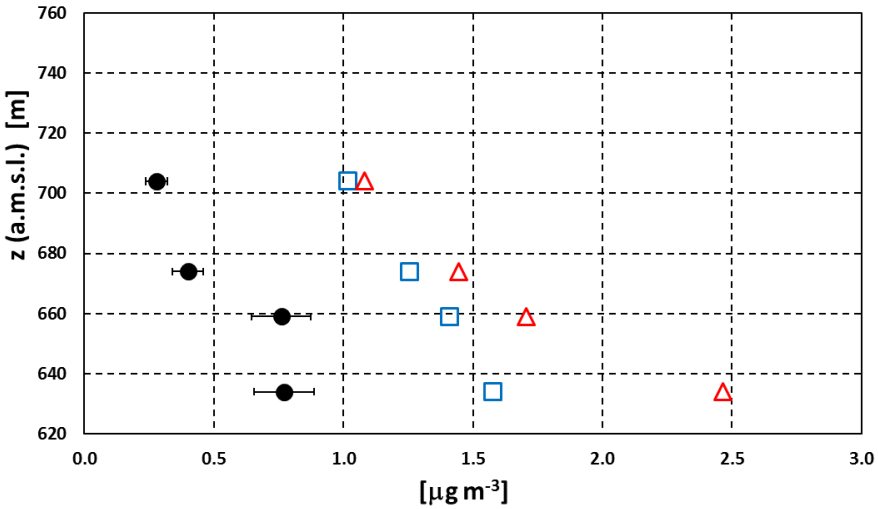




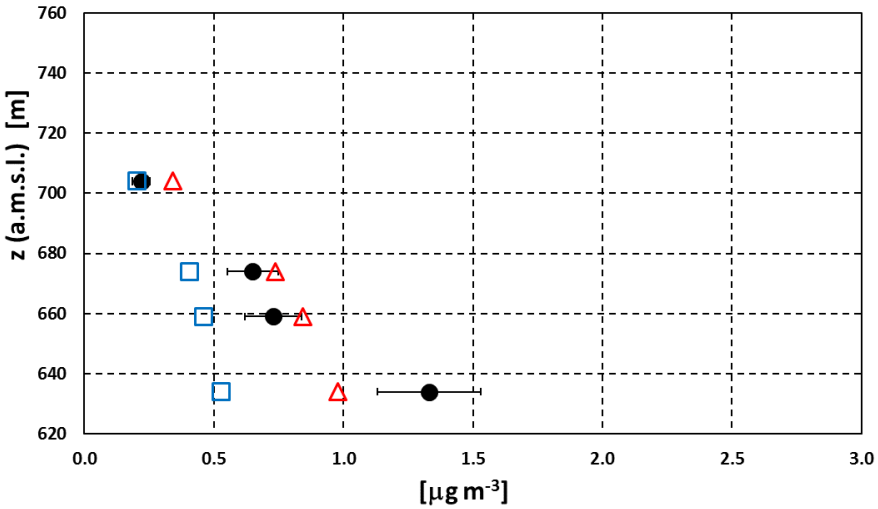
● PTRMS □ BIOVOC △ MEGAN

Monoterpenes

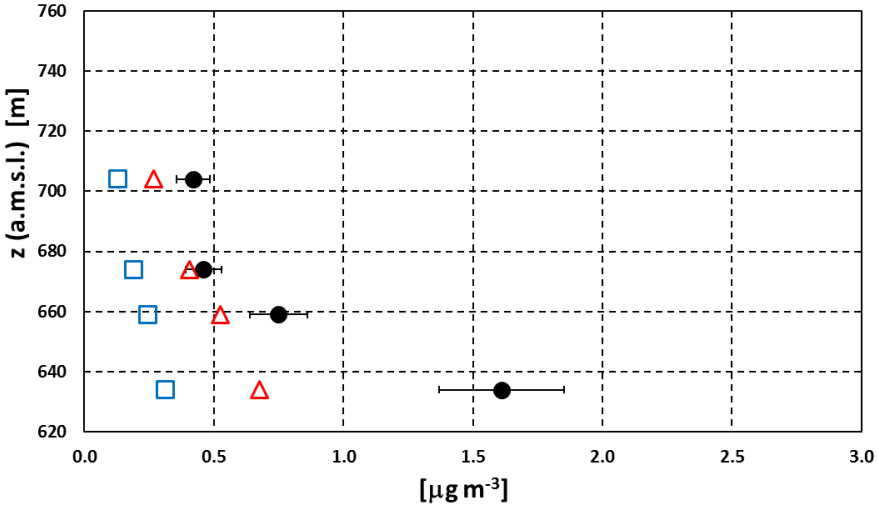
TRP1 - 15/07/15 hour: 9



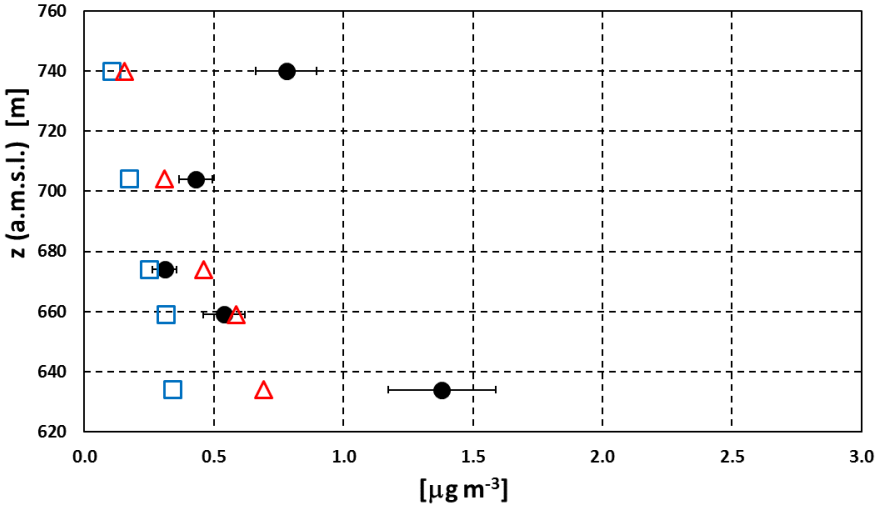
TRP1 - 15/07/15 hour: 11



TRP1 - 15/07/15 hour: 13

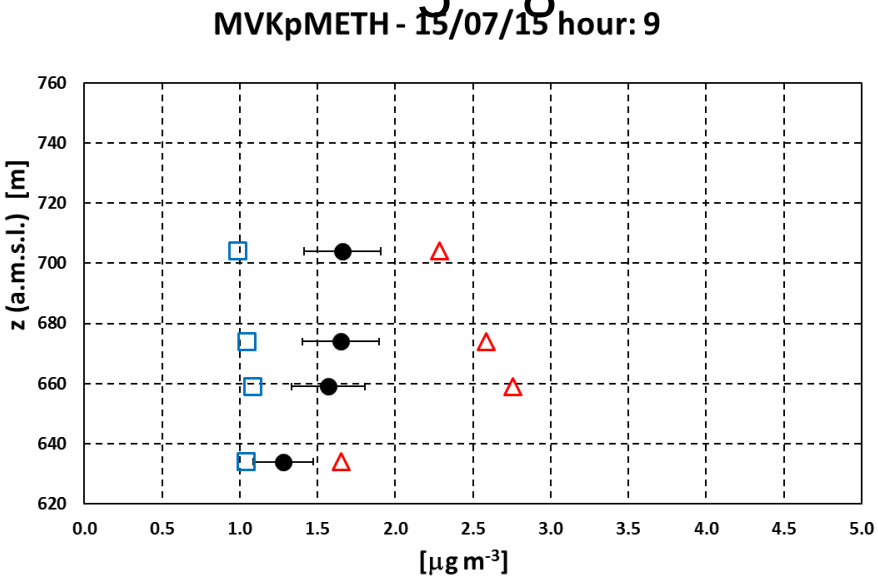


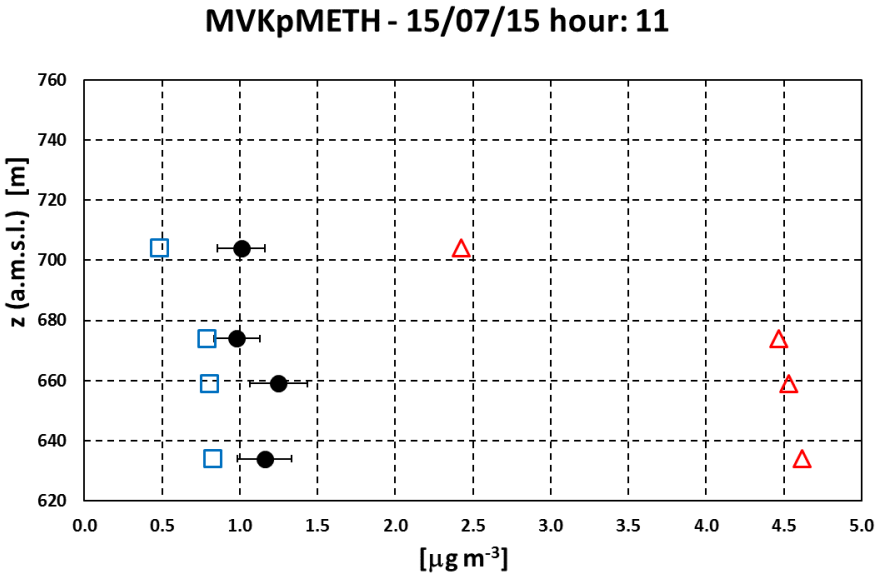
TRP1 - 15/07/15 hour: 16

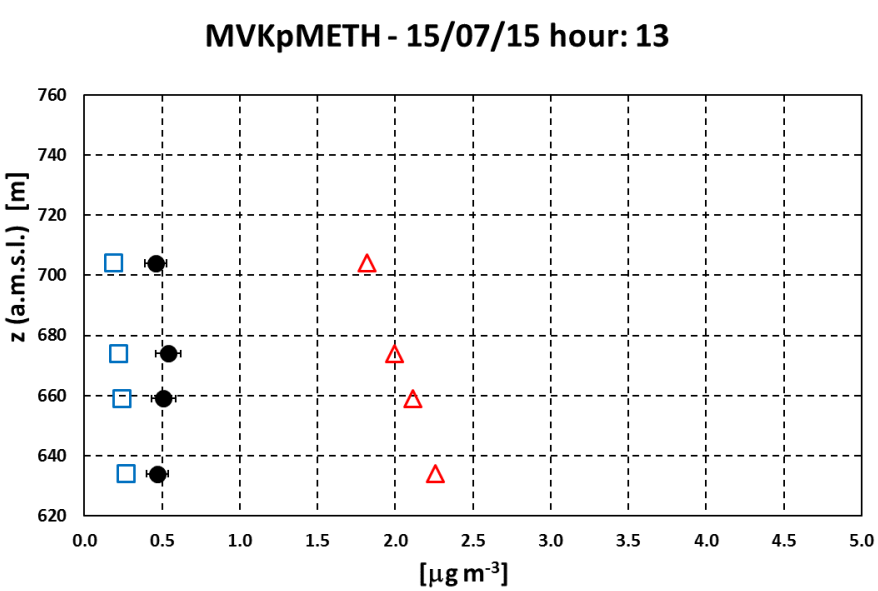


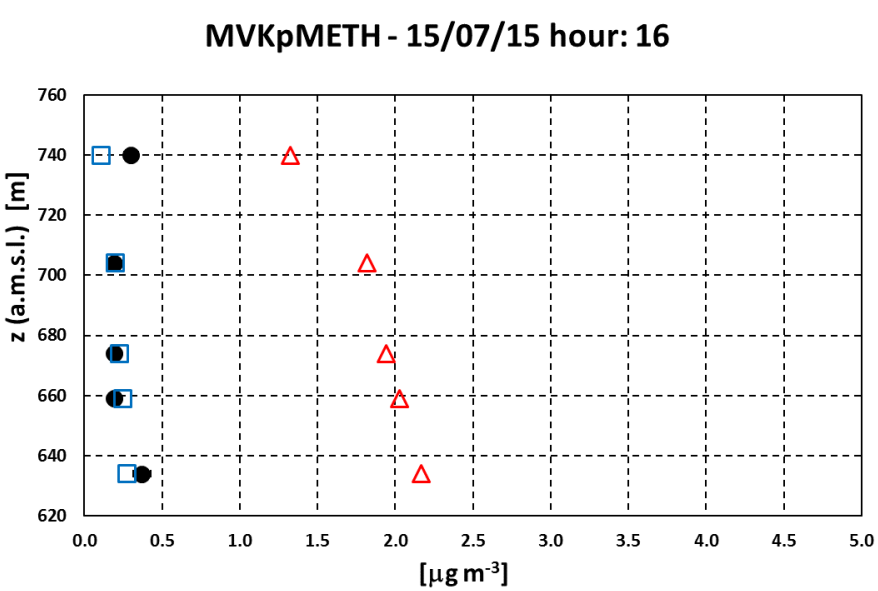
● PTRMS □ BIOVOC △ MEGAN

C_5H_8+OH→MVK + MACR



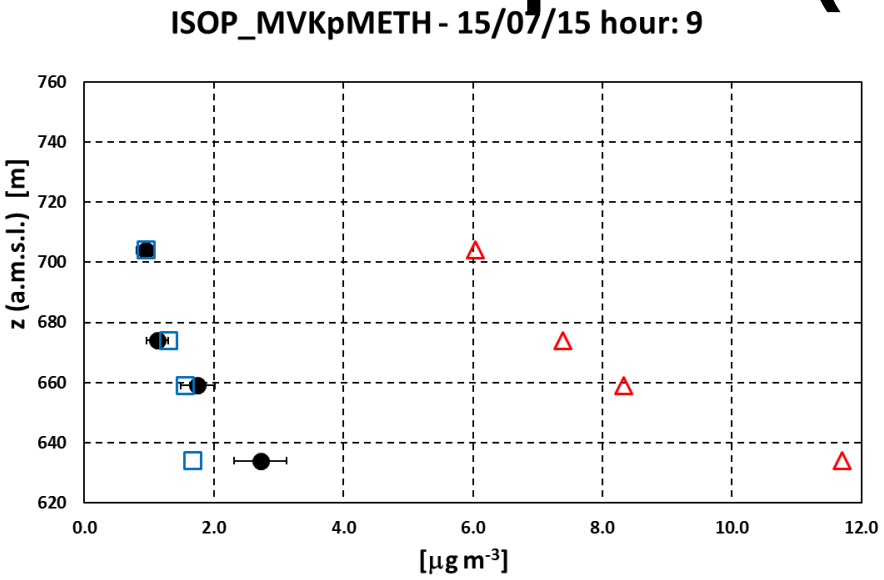


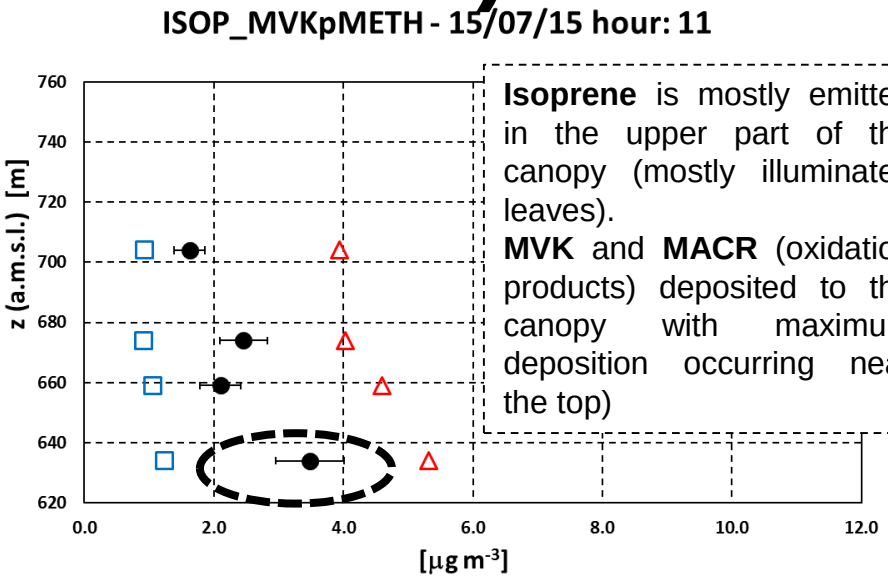




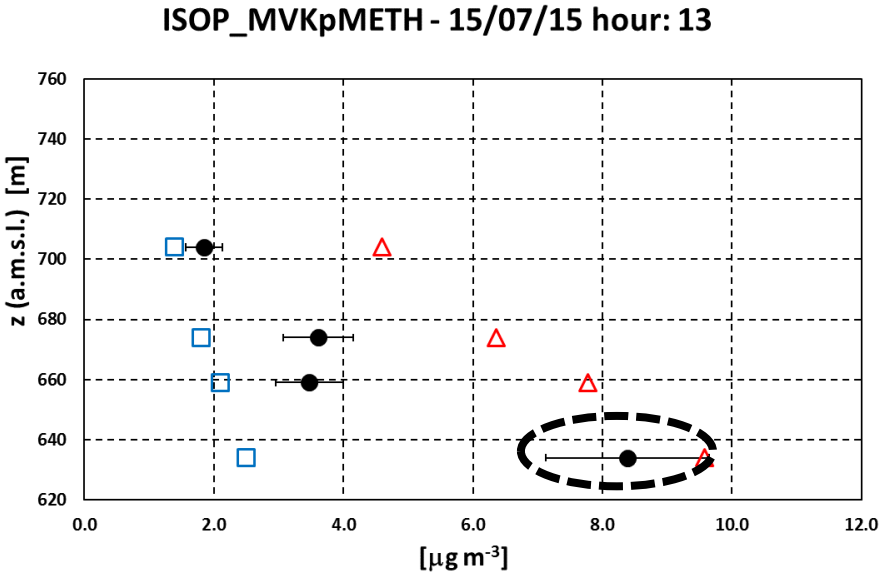
● PTRMS □ BIOVOC △ MEGAN

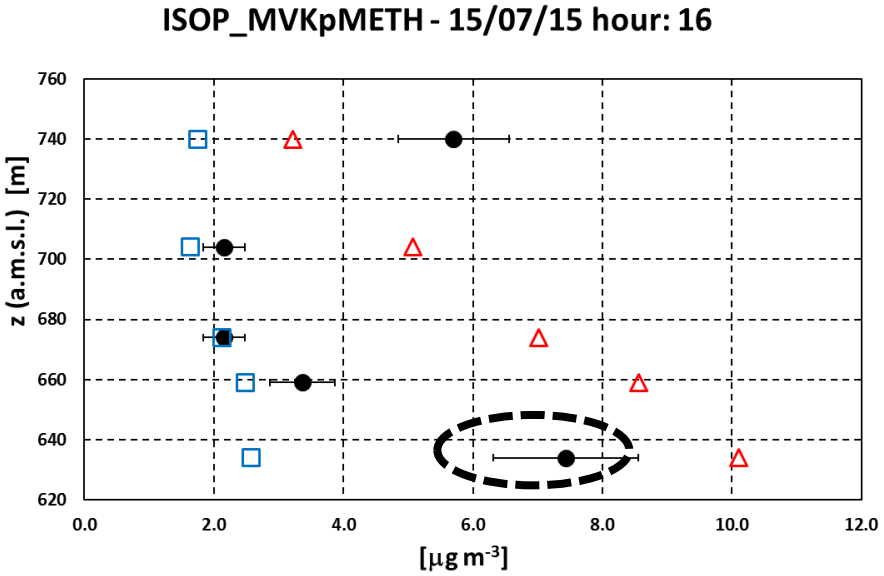
Isoprene/(MVK+MACR)





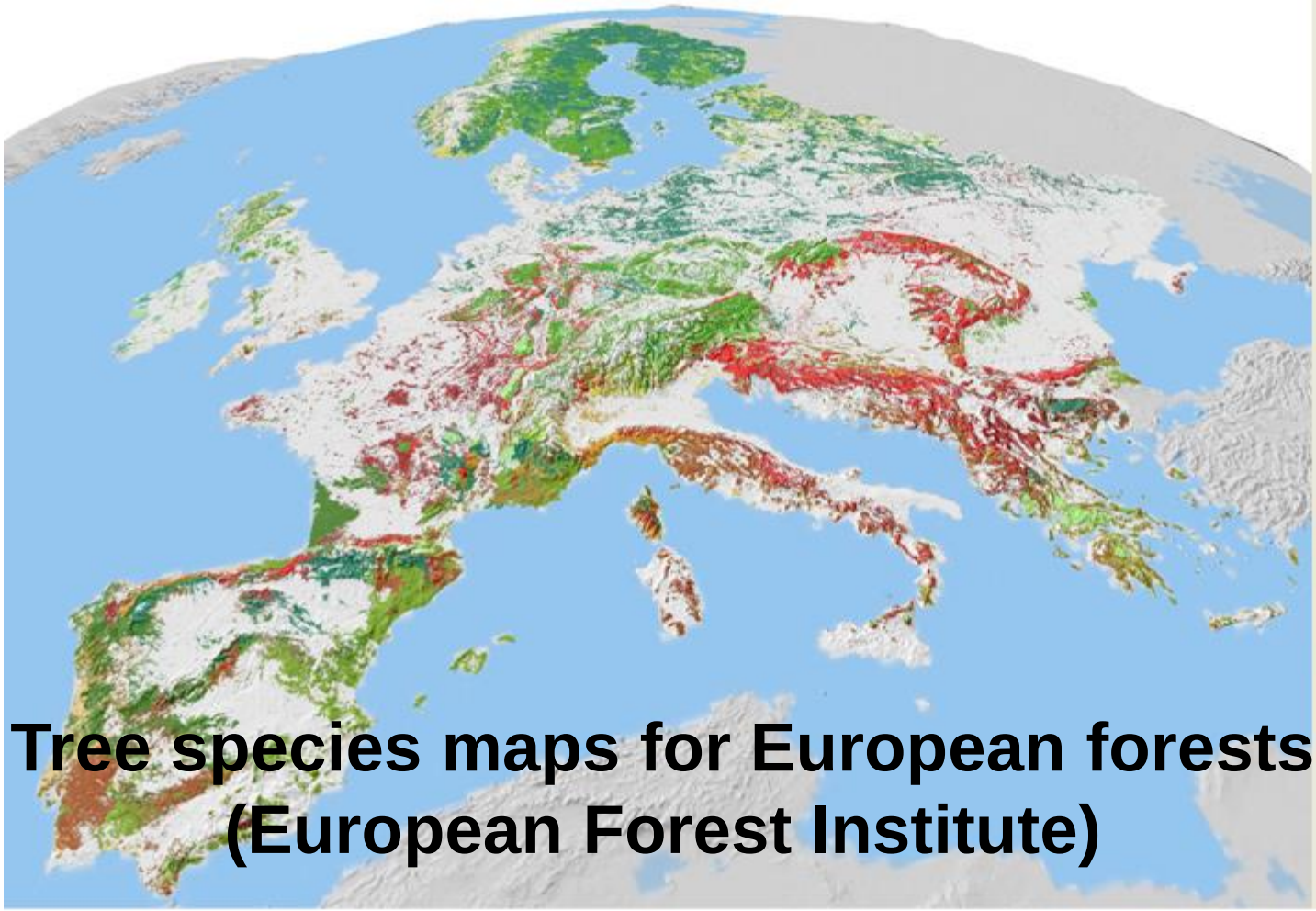
Isoprene is mostly emitted in the upper part of the canopy (mostly illuminated leaves).
MVK and **MACR** (oxidation products) deposited to the canopy with maximum deposition occurring near the top)





● PTRMS □ BIOVOC △ MEGAN

If I will use a different trees distribution map?

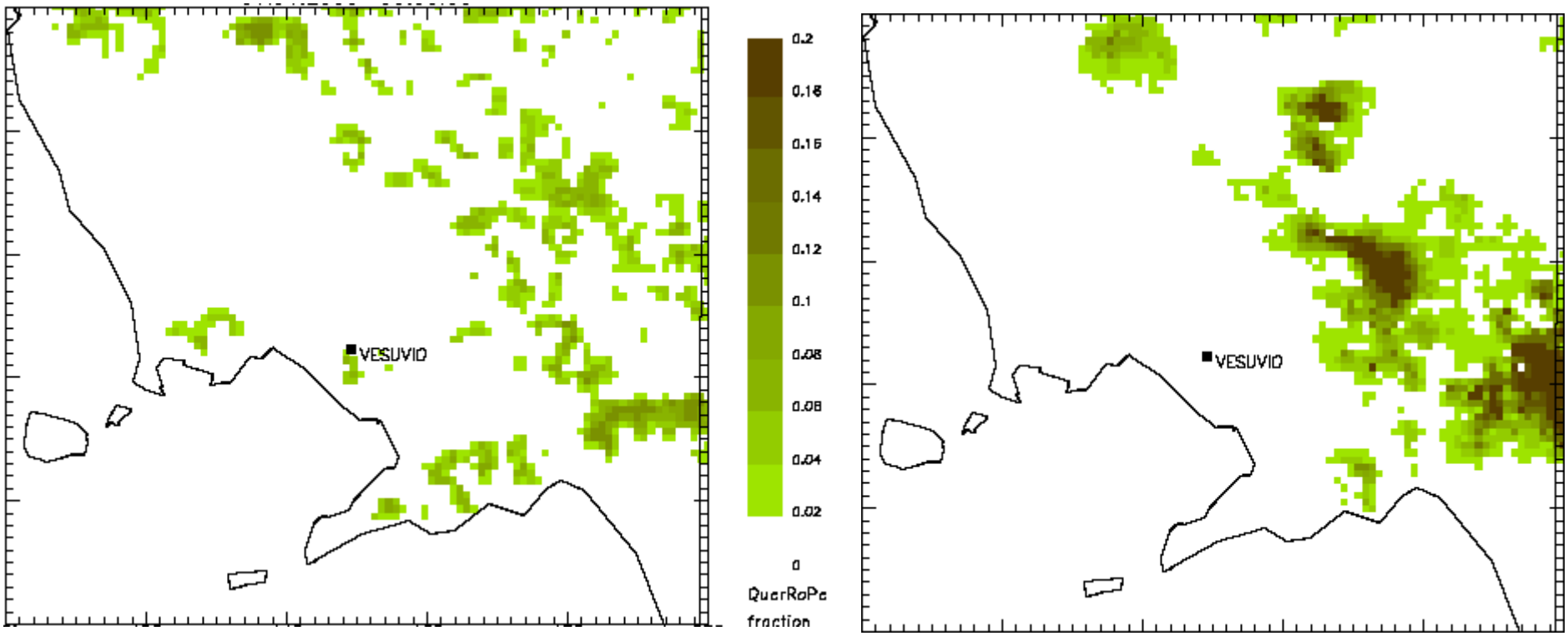


Tree species maps for European forests (European Forest Institute)

Quercus Petraea and Quercus Robur

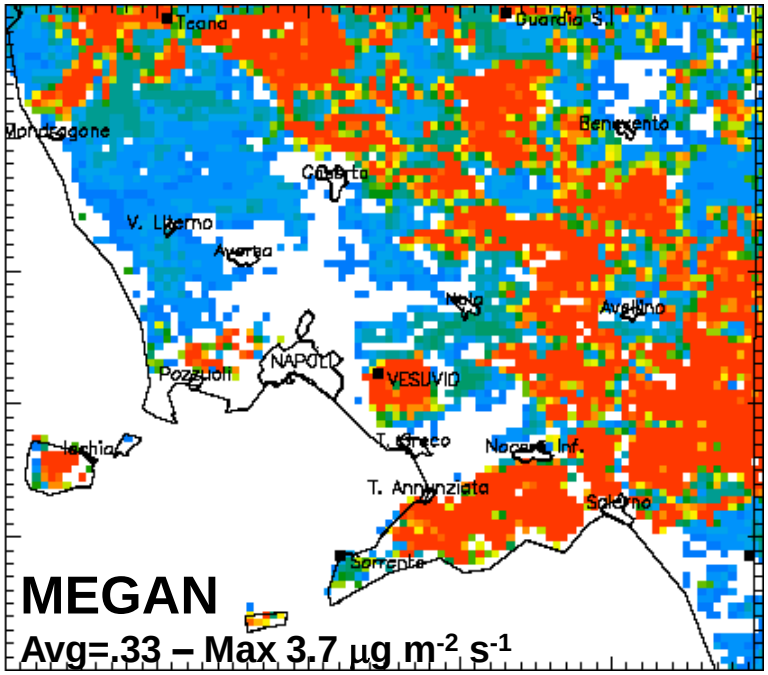
CLC lev IV elab.

EFI



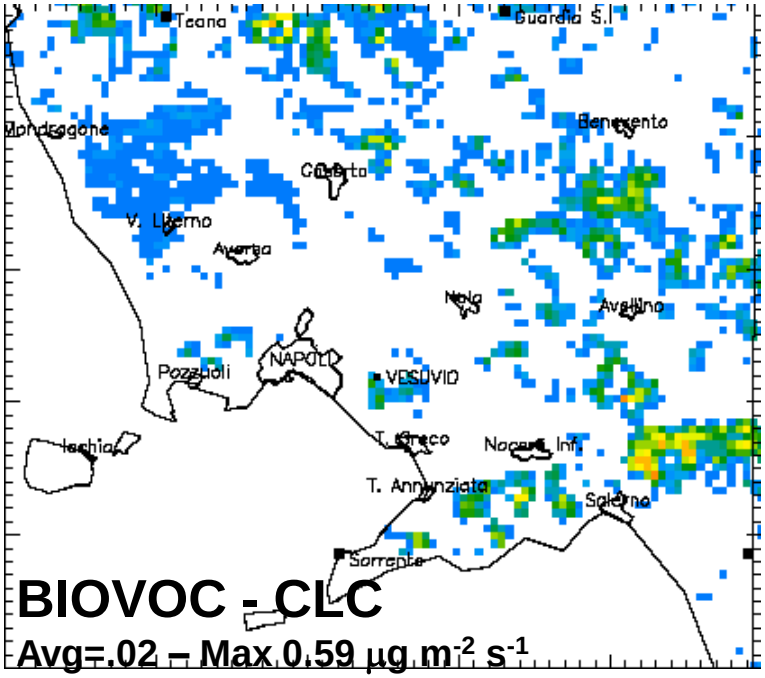
Fraction covered by Quercus Petraea and Quercus Robur from the elaboration of CLC database (left) and from the "Tree species maps for European forests" (right).

Isoprene emission rates [μg m^{-2} s^{-1}]



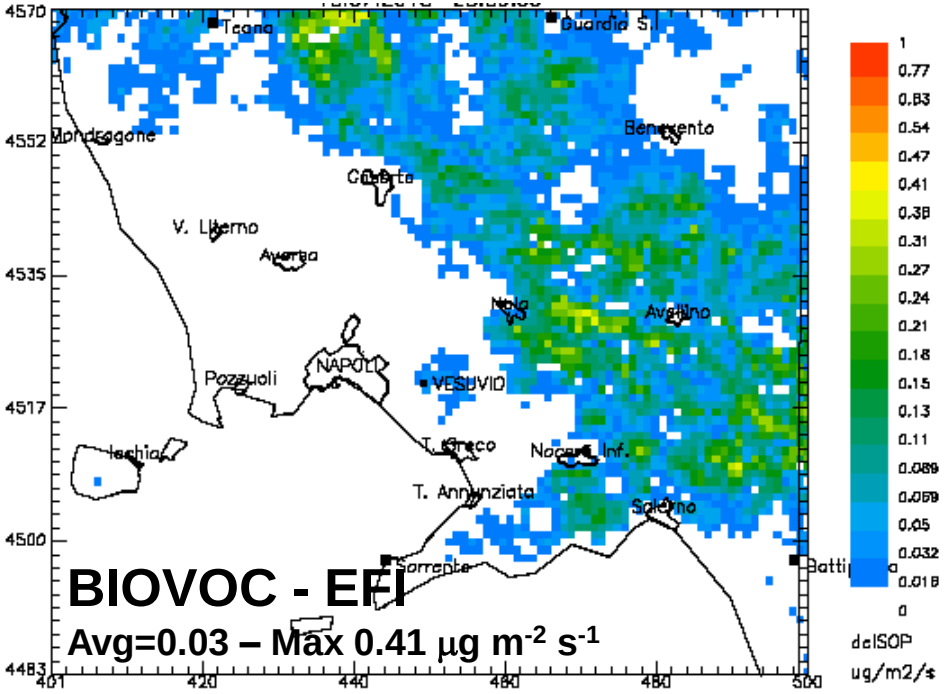
MEGAN

Avg=.33 – Max 3.7 μg m^{-2} s^{-1}



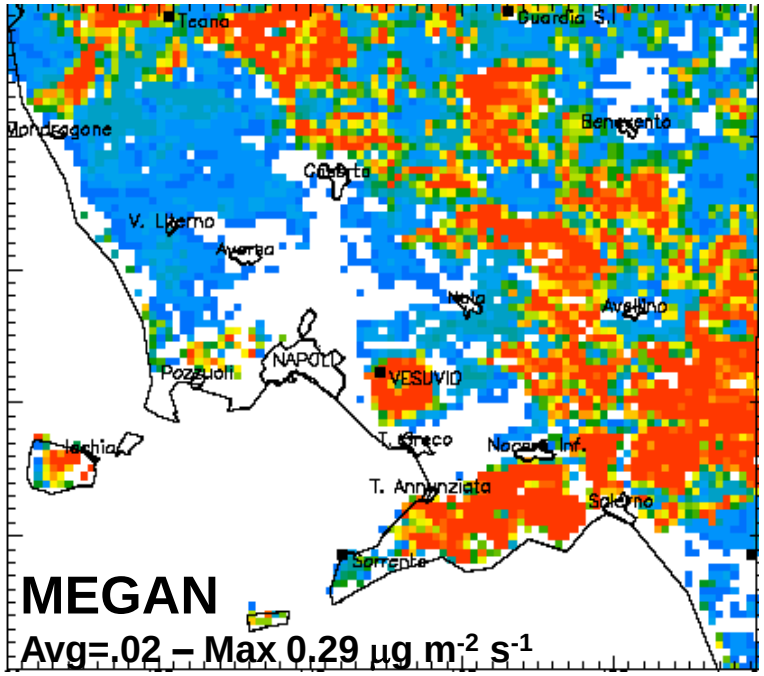
BIOVOC - CLC

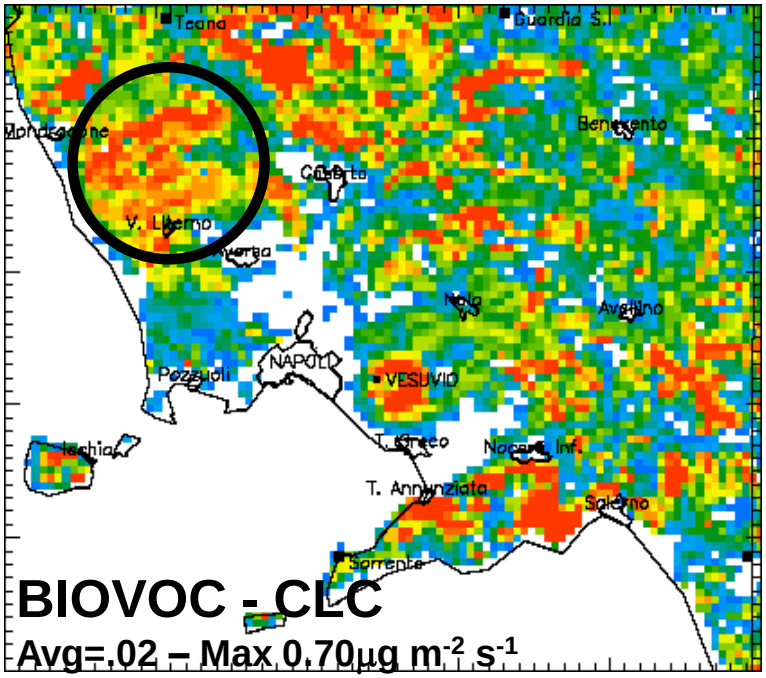
Avg=.02 – Max 0.59 μg m^{-2} s^{-1}



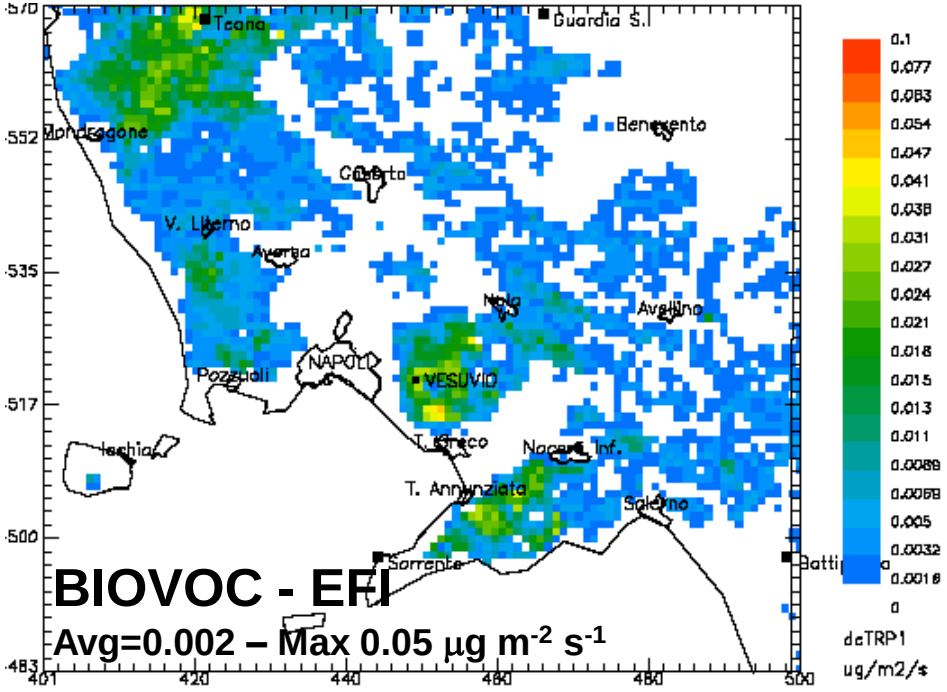
BIOVOC - EFI

Avg=0.03 – Max 0.41 μg m^{-2} s^{-1}

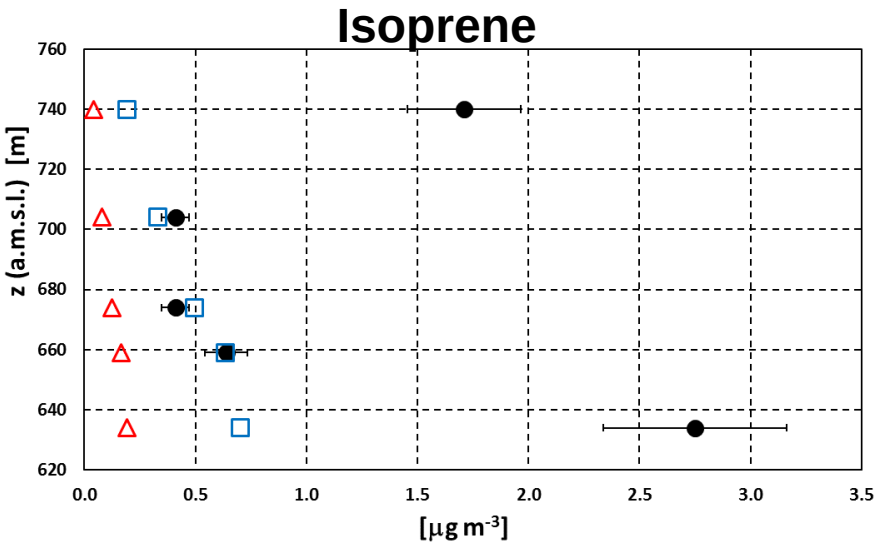


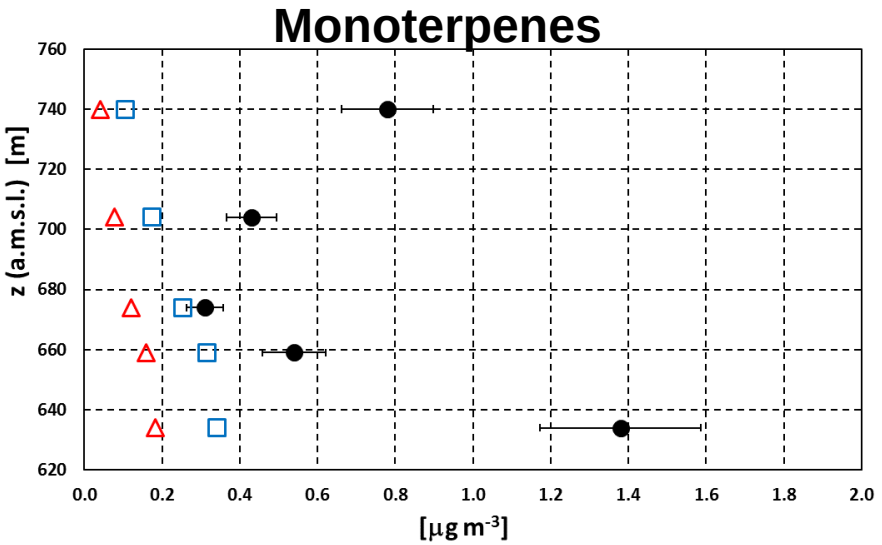


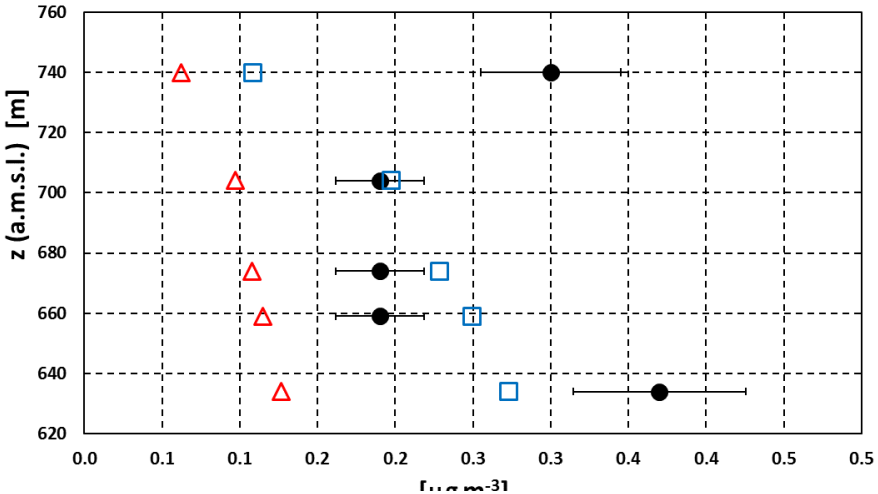
Mono-terpenes emission rates [µg m^{-2} s^{-1}]

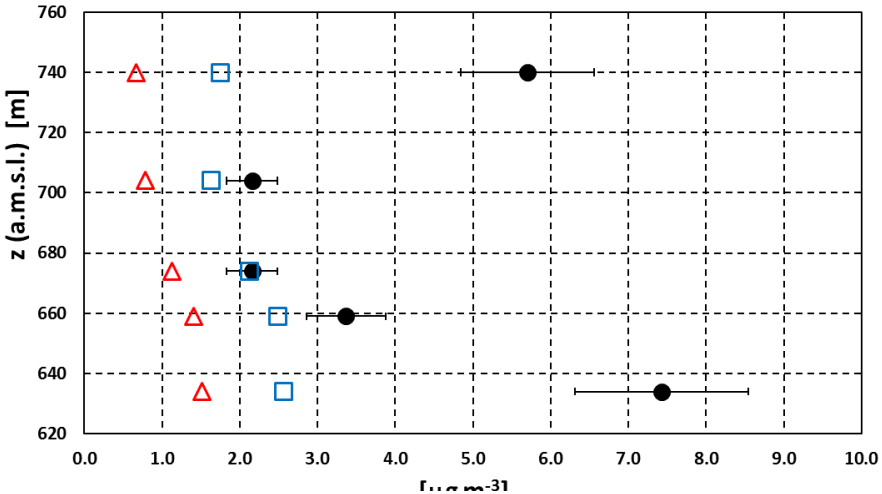


15/7/2016 hour: 16





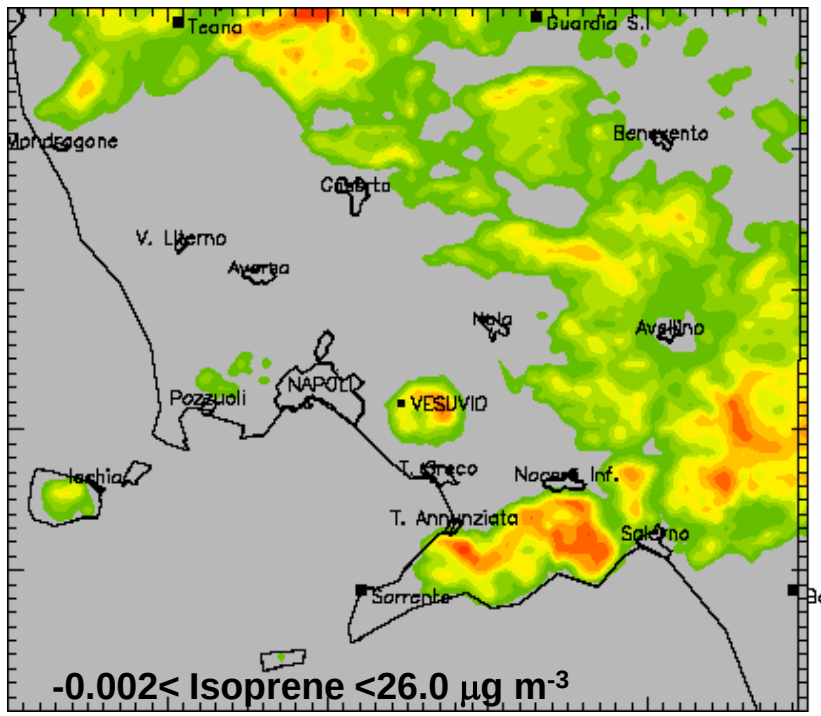


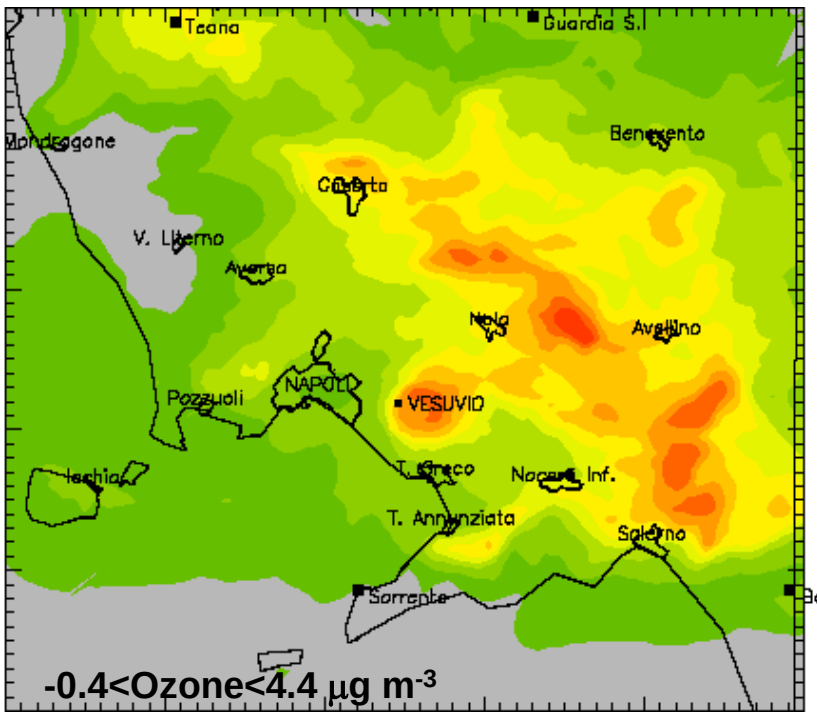


● PTRMS ◻ BIOVOC △ BIOVOC_EFI

What we can expect from BIOVOC with respect to MEGAN?

MEGAN minus BIOVOC (CLC) runs


Teano
Guardia S.I
Benevento
Caserta
V. Liberno
Avella
Nola
Avellino
Pozzuoli
NAPOLI
VESUVIO
Ischia
T. Greco
Nocera Inf.
T. Annunziata
Salerno
Sorrento
-0.002< Isoprene <26.0 μg m-3
c_ISOP
μg/m3


Teano
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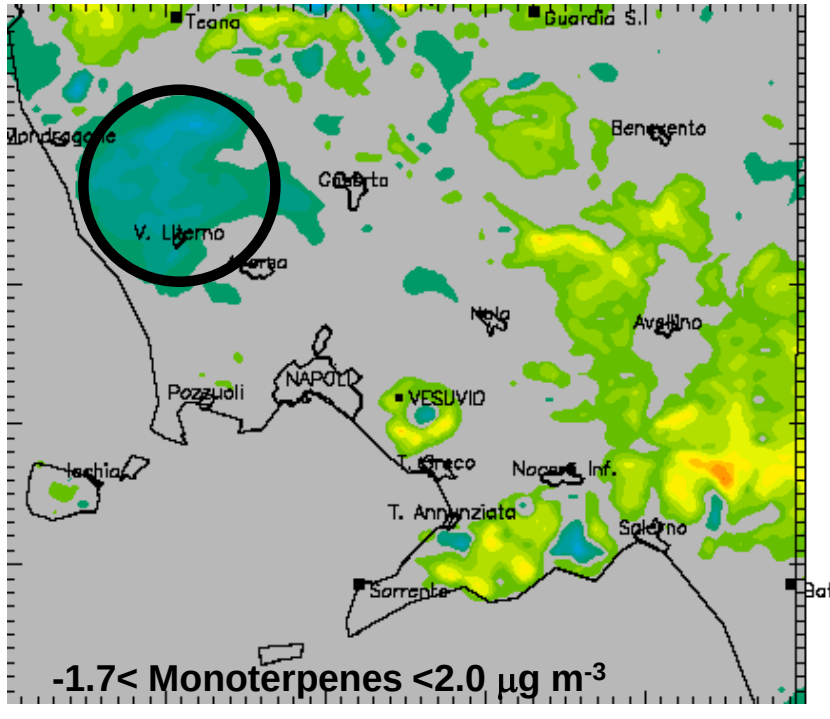
Avella
Nola
Avellino
Pozzuoli
NAPOLI
VESUVIO
Ischia
T. Greco
Nocera Inf.
T. Annunziata
Salerno
Sorrento
-0.4<Ozone<4.4 μg m-3
c_O3
μg/m3


Teano
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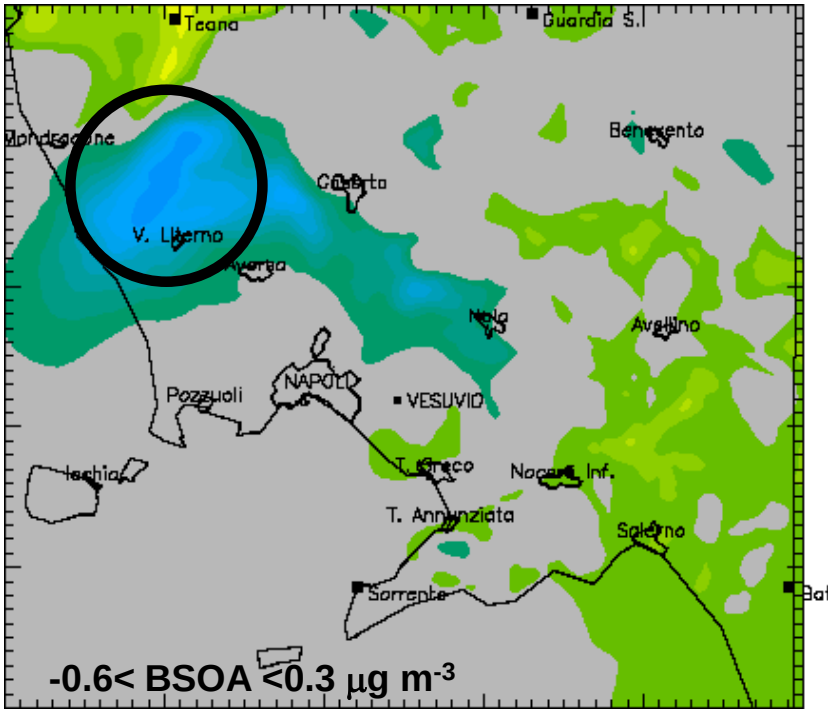
V. Liberno
Avella
Nola
Avellino
Pozzuoli
NAPOLI
VESUVIO
Ischia
T. Greco
Nocera Inf.
T. Annunziata
Salerno
Sorrento
-1.7< Monoterpenes <2.0 μg m-3
c_TRP1
μg/m3


Teano
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Caserta
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Avella
Nola
Avellino
Pozzuoli
NAPOLI
VESUVIO
Ischia
T. Greco
Nocera Inf.
T. Annunziata
Salerno
Sorrento
-0.6< BSOA <0.3 μg m-3
c_ABIO
μg/m3

Insights from these first tests

- Significant differences in isoprene emissions between MEGAN and BIOVOC modules
- Better performance of BIOVOC module fed with Corine Land Cover data (particularly for Isoprene)
- Higher estimated Isoprene and O_3 levels using MEGAN
- Higher estimated Monoterpenes levels using BIOVOC in some areas leading to higher BSOA concentrations

After June 2017 forest fire ...

Thank you for your attention !