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# Ground-level ozone and its potential effect on Mediterranean forests

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1. INTRODUCTION
2. MATERIALS AND METHODES
3. RESULTS
4. CONCLUSION

# 1. INTRODUCTION

* Ground-level ozone
* Secondary air pollutant
* Formed in photochemical reaction caused by precursor compounds such as methane ($CH_4$), nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs) under high temperatures and sunlight

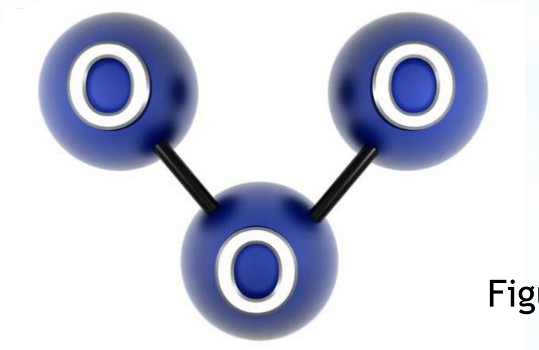


Figure 1. Ozone molecule

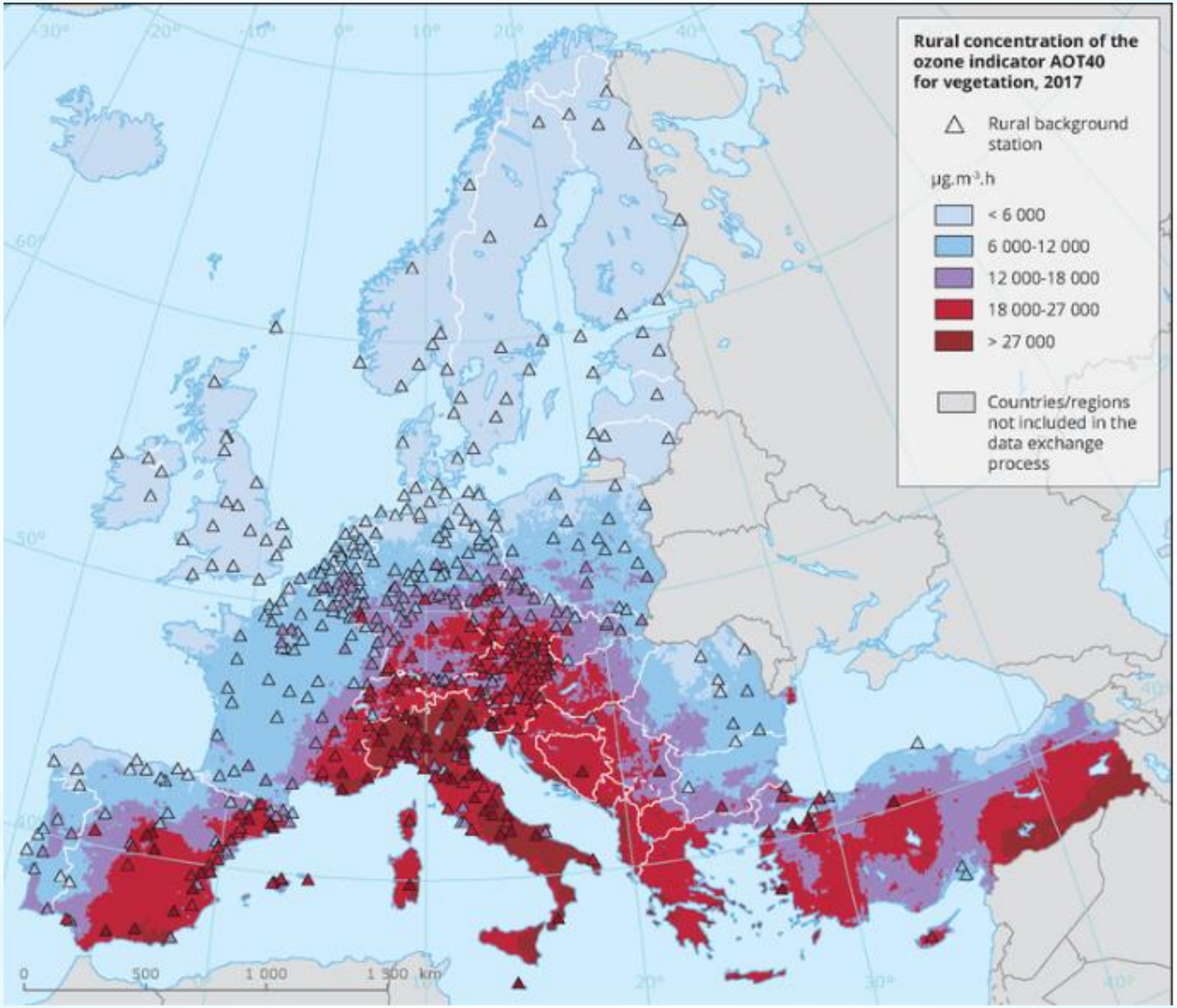
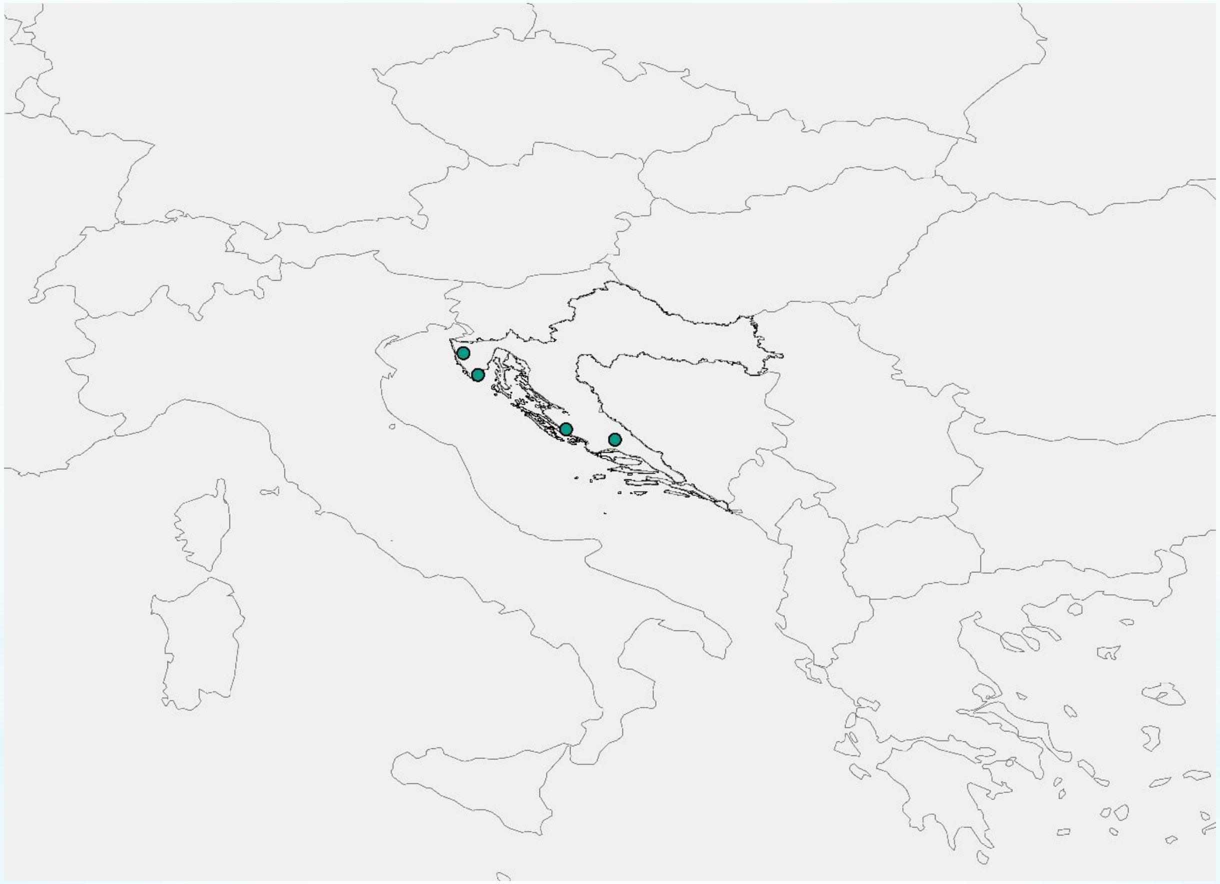



Figure 2. Rural concentration of the ozone indicator AOT40 for vegetation, 2017
(European Environmental Agency)

European Environment Agency

# And in Croatia?



# 2. MATERIALS AND METHODES

* PLOT DESCRIPTION
* MEASUREMENTS
  * Passive ozone
  * Active ozone
* STATISTICS
  * AOT40 and PODY
  * Life project and MOTTLES approach
  * Random Forest Analysis

# 2. MATERIALS AND METHODES

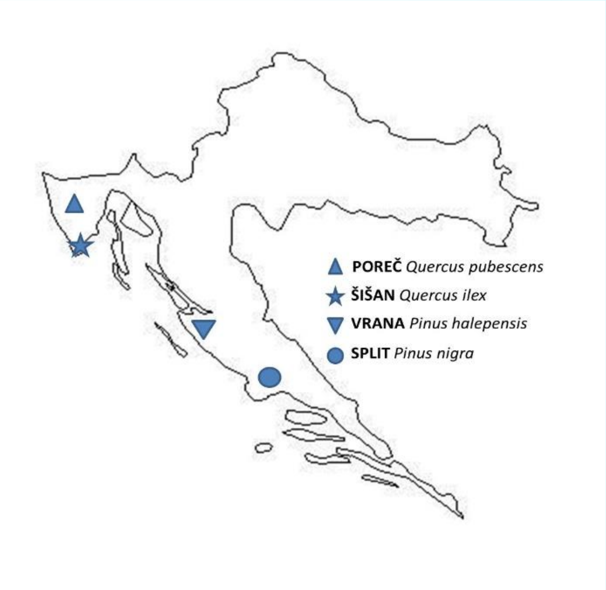



Figure 3. Plots location

Table 1. Plots characteristics

| Code | PORE | SISA | VRAN | SPLI |
|---|---|---|---|---|
| Forest type | Thermophilous deciduous forest | Broadleaved evergreen forest | Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions | Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions |
| Main species | Pubescent oak | Holm oak | Aleppo pine | Black pine |
| Region | Istria | Istria | Dalmatia | Dalmatia |
| Latitude | 45°14'59.2" N | 44°51'41.2" N | 43°53'23" N | 43°41'59" N |
| Longitude | 13°43'52.9" E | 13°59'24.4" E | 15°33'47" E | 16°26'34" E |
| Elevation (m) | 264 | 3 | 20 | 550 |
| Soil type | Terra rossa | Terra rossa | Calcocambisol | Calcocambisol |
| Biogeographical Zone | Mediterranean | Mediterranean | Mediterranean | Mediterranean |

# Passive ozone

* Measurements: Ogawa samplers
* Frequency: every two weeks
* Location: on open field
* Ozone concentration is calculated from nitrates

* Data from passive ozone were computed using the Loibl equation to convert the bi-weekly ozone data in hourly data

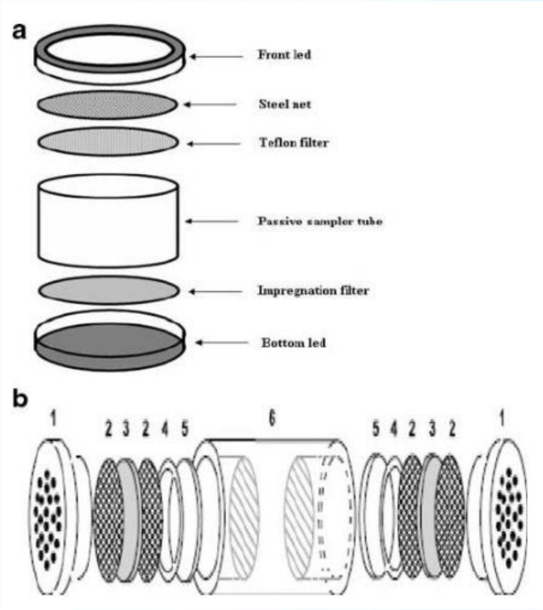



Figure 4. Ogawa sampler
(from: Salem et al., 2009)

# Active ozone

- Active samplers
- Hourly data were downloaded for 4 sites by ERA5-land database

Figure 5. Measuring sation of ozone of Croatian Meteorological and Hydrological Service

# AOT40

- „AOT40 is the sum of the differences between the hourly mean $O_3$ concentration (in ppb) and a threshold value of 40 ppb $O_3$ when the concentration exceeds 40 ppb during daylight hours, accumulated over a **stated time period**"

ICP Vegetation, 2017

# AOT40

Directive 2008/50/EC

* $$\mathbf{AOT40}_{dir} = \int_{t=1May}^{31\,July} \max\big(([O_3] - 40, 0)\big).\,dt \quad (1)$$

[O3] – ozone concentration
dt – time step (1 h)

ICP Vegetation

* $$\mathbf{AOT40}_{ICP} = \int_{t=SGS}^{EGS} \max\big(([O_3] - 40, 0)\big).\,dt \quad (2)$$

[O3] – ozone concentration
dt – time step (1 h)
SGS – start of the growing season
EGS – end of the growing season

# LIFE project and MOTTLES approach

* „The LIFE programme is the EU's funding instrument for the environment and climate action. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental and climate policy and legislation by co-financing projects with European added value"
* „MOTTLES is founded by the programme LIFE 2015 under the sub-programme Environment and Resource efficiency project application. MOTTLES proposes and demonstrates an integrated approach for deriving scientifically-based thresholds and proper critical levels for forest protection against O3 in a changing climate"

# AOT40 and MOTTLES

MOTTLES EQUATION:

* $$\mathbf{AOT40}_{pheno} = \int_{t=aSGS}^{aEGS} \mathbf{max}\left(([O_3] - \mathbf{40}, \mathbf{0})\right). dt \quad (\mathbf{3})$$

[O3] – ozone concentration
dt – time step (1 h)
aSGS – actual start of the growing season
aEGS – actual end of the growing season

# AOT40 and MOTTLES

* Model parameters were used from Mottles project for the species
* For *Quercus pubesces* we needed start and end of growing season (leaves onset and falling leaves)

* For soil water capacity (SWC) according with soil type we used

terra rosa - SWCmax - 0.476; SWCmin- 0.084;

calcocambisol - SWCmax - 0.439; SWCmin - 0.066

# PODY

* DO3SE (Deposition of $O_3$ for Stomatal Exchange) model is used to determine the PODY (Phytotoxic $O_3$ Dose above a threshold flux of Y)
* PODY - the accumulated stomatal $O_3$ uptake during a specified time period
* Treshold Y: 0, 1 and 3 mmol $m^{-2}$
* POD0, POD1 and POD3

# PODY

* EQUATION

$$g_{sto} = g_{max} \times [f_{phen} \times f_{light} \times \max\{f_{min}\,(f_{temp} \times f_{VPD} \times f_{SWC})\} \quad (4)$$

$$PODY = \int_{i=1}^{n} [((g_{sto} \times [O_3]) - Y), 0].\, dt \qquad (5)$$

$g_{sto}$ - hourly stomatal conductance of $O_3$ (mmol $O_3$ $m^{-2}$ )
$g_{max}$ - specific maximum stomatal conductance of a plant species to $O_3$ (mmol $O_3$ $m^{-2}$ PLA $s^{-1}$)
$f_{phen}$ – species phenology
$f_{light}$ - photosynthetically flux density at the leaf surface (PPFD, μmol photons $m^{-2}$ $s^{-1}$)
$f_{temp}$ - surface air temperature (T, $^{\circ}$C)
$f_{VPD}$ - vapor pressure deficit (VPD, kPa) estimated through the surface air humidity
$f_{SWC}$ – soil water content (SWC, $m^3$ $m^{-3}$).
$f_{min}$ - minimum $g_{sto}$ expressed as a fraction of gmax
*this functions are limiting factors expressed in relative terms in values from 0 to 1 to a proportion of gmax

(ICP Vegetation, 2017)

# Random Forest Analysis

* Machine learning technique
* It is a statistical tool consisted of large number of data from individual trees combined
* The predictor with the highest importance is assigned with value of 1
* The importance of other predictors is expressed in terms of the relative magnitudes of the average values of the predictor statistics, relative to the most important
* We used RFA to determine the most important predictor among the other predictors

# Random Forest Analysis - parameters

## Our data

* Growth
* $O_3$ passive concentrations
* DEPOSITION in the forest (THR) and on the open field (BOF)

pH, Cond, $Ca^{2+}$ , $Mg^{2+}$ , $Na^{+}$ , $K^{+}$ , $NH_4^{+}$ , $SO_4^{2-}$ , $NO_3^{-}$ , $Cl^{-}$ , T.Alk.

* SOIL

pH ($H_2O$; $CaCl_2$), P i $P_2O_5$, K, N, Humus, C, C/N, $CaCO_3$, soil texture (sand, slit, clay)

* FOLIAR

N, P, K, S, C, Ca, Mg, Fe, Mn, Zn, Cu

## Downloaded data

* CLIMATIC

2 meter temperature (2t);

2 meter dewpoint temperature (2d);

10 metre U wind component (10u);

10 metre V wind component (10v);

instantaneous surface sensible heat flux (f);

relative humidity (r);

total precipitation (tp);

volumetric soil water layer (swvl) 1, 2, 3 and 4

$O_3$ measured – AOT40

$O_3$ calculated – POD0; POD1; POD2; AOT40dir; AOT40icp; AOT40pheno

# 3. RESULTS

* Comparison of passaive and active ozone
* AOT40dir, AOT40icp, AOT40pheno
* POD0, POD1, POD3
* RFA

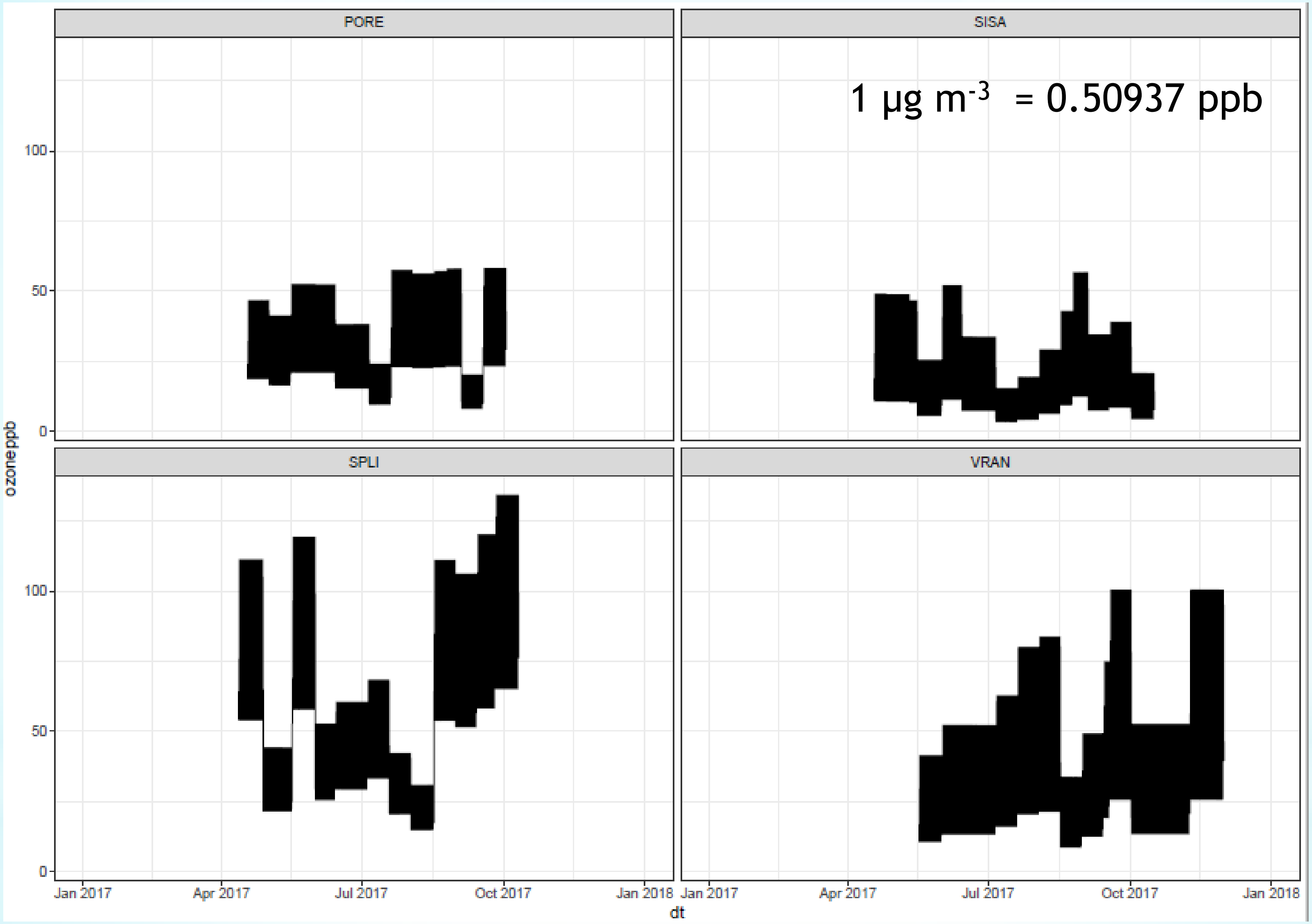



Figure 6. Passive ozone in 2017

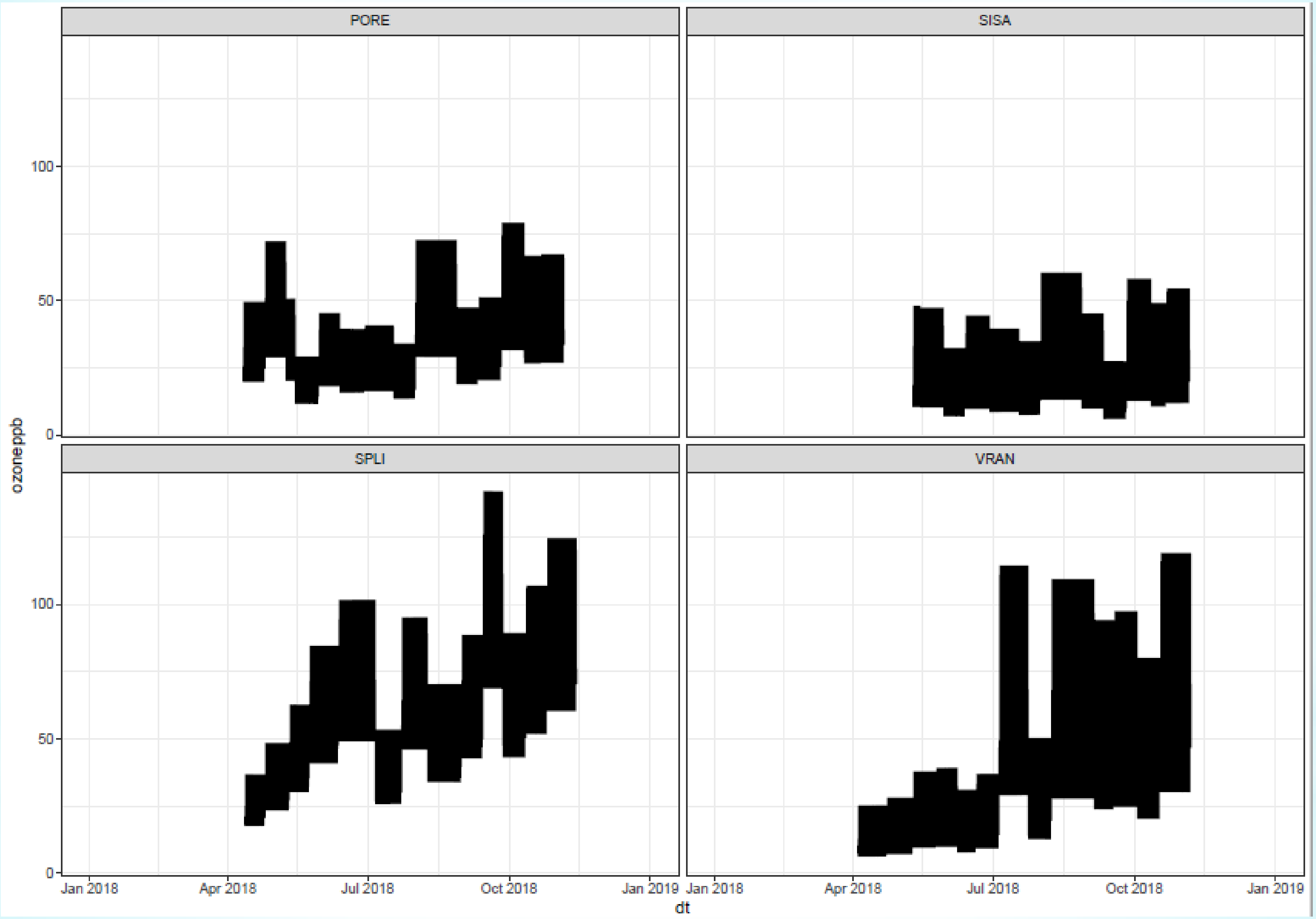



Figure 7. Passive ozone in 2018

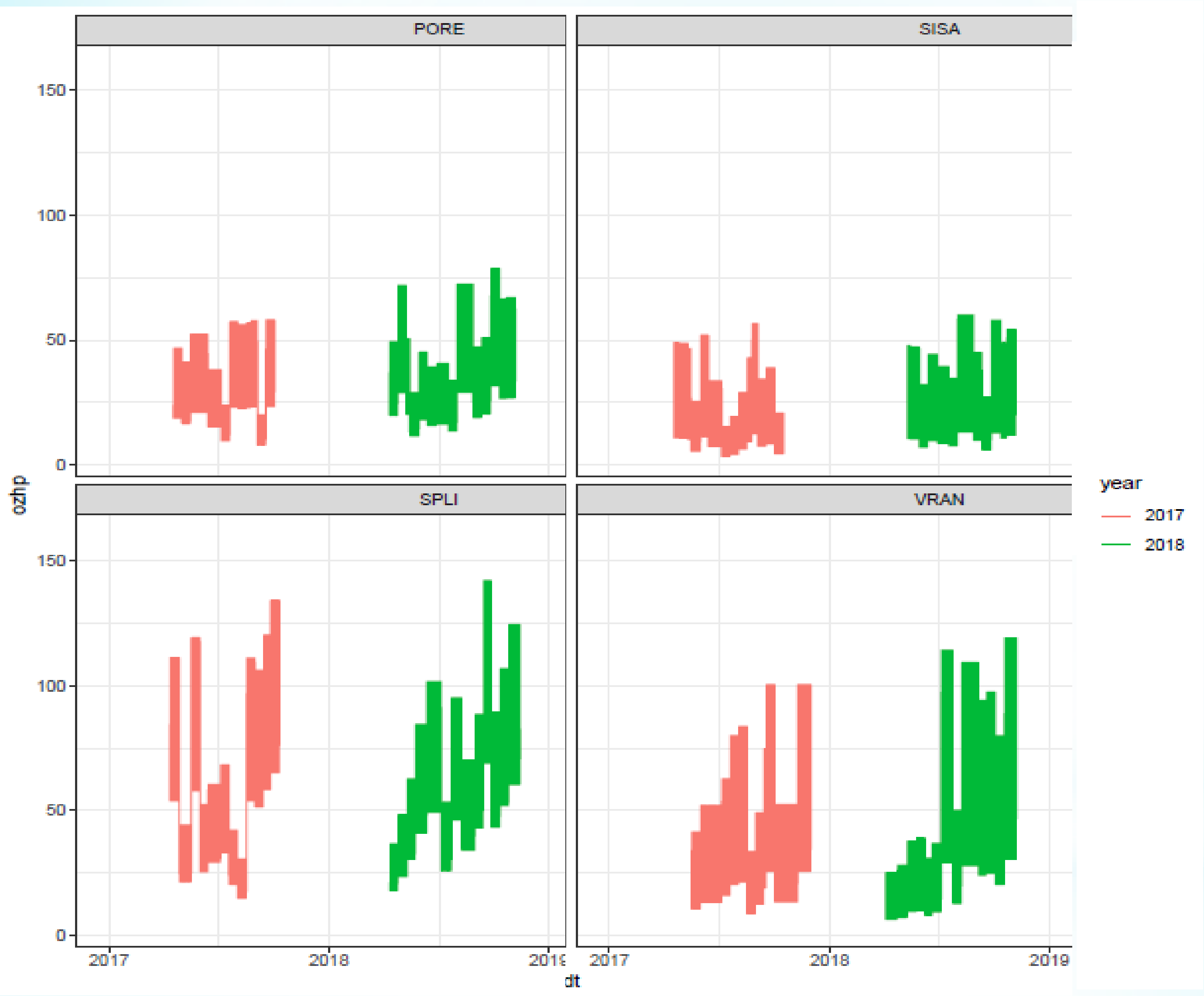



Figure 8. Passive ozone in ppb.h for 2017 and 2018

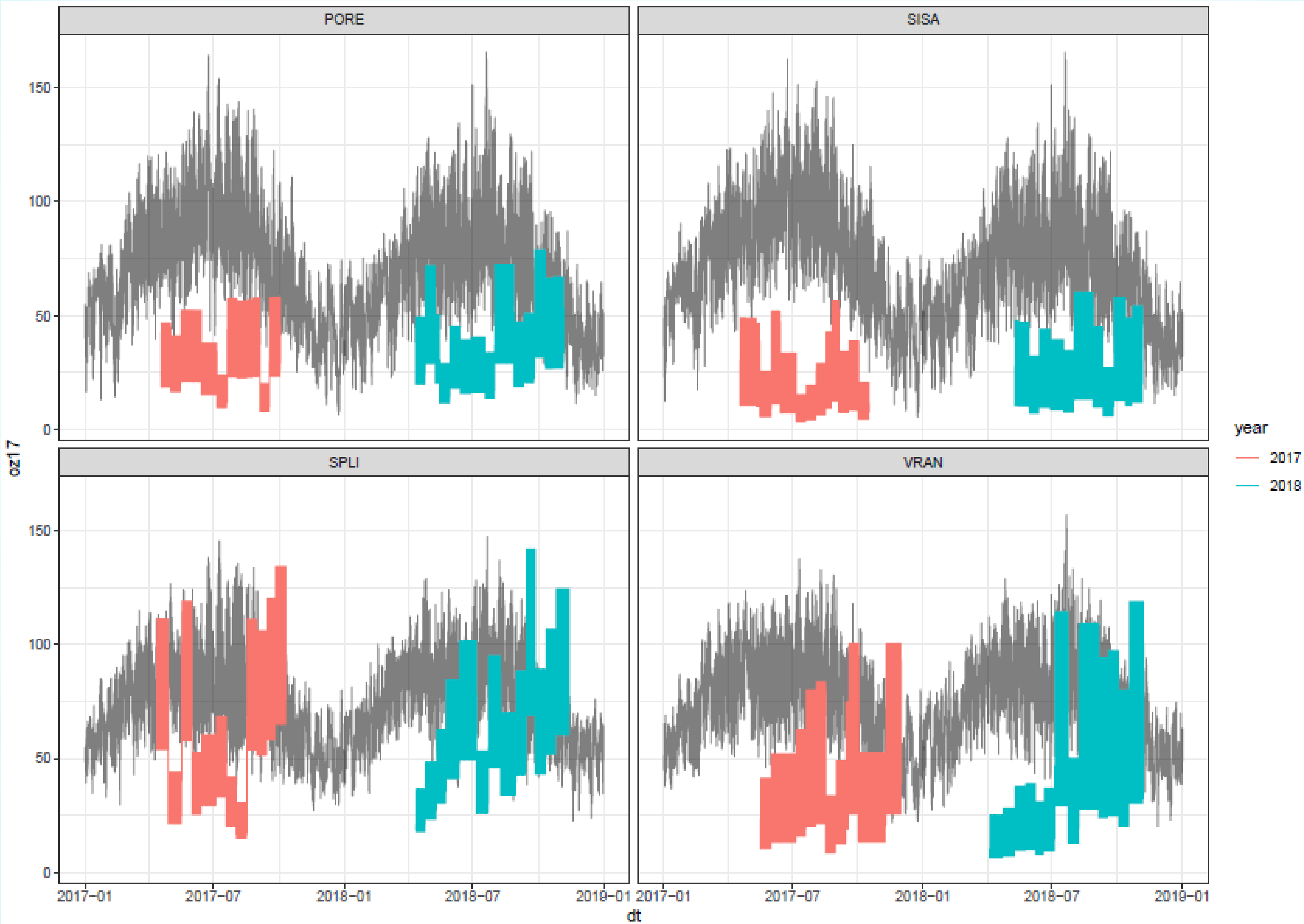



Figure 9. Passive vs. Modeled ozone in ppb.h for 2017 and 2018

Table 2. Results from passive O3 for POD0, POD1, POD3, AOT40dir, AOT40icp and AOT40pheno

| PASSIVE | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Plot** | **Year** | **POD0** | **POD1** | **POD3** | **AOT40dir** | **AOT40icp** | **AOT40pheno** |
| | | | mmol m-2 | | | ppb h | |
| PORE | 2017 | 11.53 | 4.73 | 0.47 | 7870.19 | 7068.57 | 7221.03 |
| SISA | 2017 | 3.33 | 0.09 | 0.00 | 2486.57 | 2379.27 | 2379.27 |
| SPLI | 2017 | 32.64 | 24.24 | 14.80 | 57359.01 | 57895.57 | 57895.57 |
| VRAN | 2017 | 6.81 | 2.45 | 0.29 | 20170.01 | 25297.37 | 25297.37 |
| | | | | | | | |
| PORE | 2018 | 16.32 | 7.58 | 0.93 | 13112.74 | 11543.69 | 16590.08 |
| SISA | 2018 | 3.30 | 0.12 | 0.00 | 4479.54 | 5829.34 | 5829.34 |
| SPLI | 2018 | 31.88 | 21.81 | 9.06 | 55880.15 | 68677.81 | 68677.81 |
| VRAN | 2018 | 9.23 | 3.20 | 0.39 | 39692.13 | 45760.95 | 45760.95 |

Table 3. Results from active O3 for POD0, POD1, POD3, AOT40dir, AOT40icp and AOT40pheno

| | | ACTIVE | | | | | |
|---|---|---|---|---|---|---|---|
| **Plot** | **Year** | **POD0** | **POD1** | **POD3** | **AOT40dir** | **AOT40icp** | **AOT40pheno** |
| | | | mmol m-2 | | | ppb h | |
| PORE | 2017 | 37.98 | 28.05 | 12.39 | 134380.56 | 135426.21 | 139676.49 |
| SISA | 2017 | 18.72 | 6.03 | 0.07 | 140155.35 | 181734.96 | 181734.96 |
| SPLI | 2017 | 74.70 | 59.16 | 34.40 | 120382.30 | 166724.94 | 166724.94 |
| VRAN | 2017 | 24.45 | 13.19 | 2.39 | 123544.66 | 167754.94 | 167754.94 |
| PORE | 2018 | 37.12 | 27.23 | 12.20 | 115571.88 | 114182.72 | 120216.05 |
| SISA | 2018 | 15.34 | 3.73 | 0.00 | 115571.88 | 142021.47 | 142021.47 |
| SPLI | 2018 | 69.68 | 54.14 | 29.68 | 119089.75 | 163507.35 | 163507.35 |
| VRAN | 2018 | 27.17 | 14.90 | 3.34 | 123177.15 | 163827.55 | 163827.55 |

# RFA

* Among all parameters ozone, especially PODY, were the parameters with the highest influence on forest ecosystems and its growth

# 4. CONCLUSION

* From passive measurements higher concentrations were in Dalmatia
* From active measurements concentrations were higher in Istria
* AOT40 showed similar values for all three equations
* Vlaues of AOT40 from passive samplers were lower than from active samplerss
* PODY values were higher using active samplers
* PODY is more suitable for ozone assessment because it is more biologically and climatologically meaningful than AOT40
* RFA predicted that PODY has the biggest influence on forest growth

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# *THANK YOU FOR YOUR ATTENTION!

Figure 10. Passive samplers on SISA plot