Sources of uncertainty in large-scale assessment of ozone impacts on forest growth

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Impacts of ozone on tree functions and forest growth

As a strong oxidant, ozone has a negative impact on many cellular and molecular processes

Tree biomass is consequently reduced, with a lower magnitude for evergreen species

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Ferretti et al. 2018
Wittig et al. 2009

For adult trees, growth is mainly sink-driven

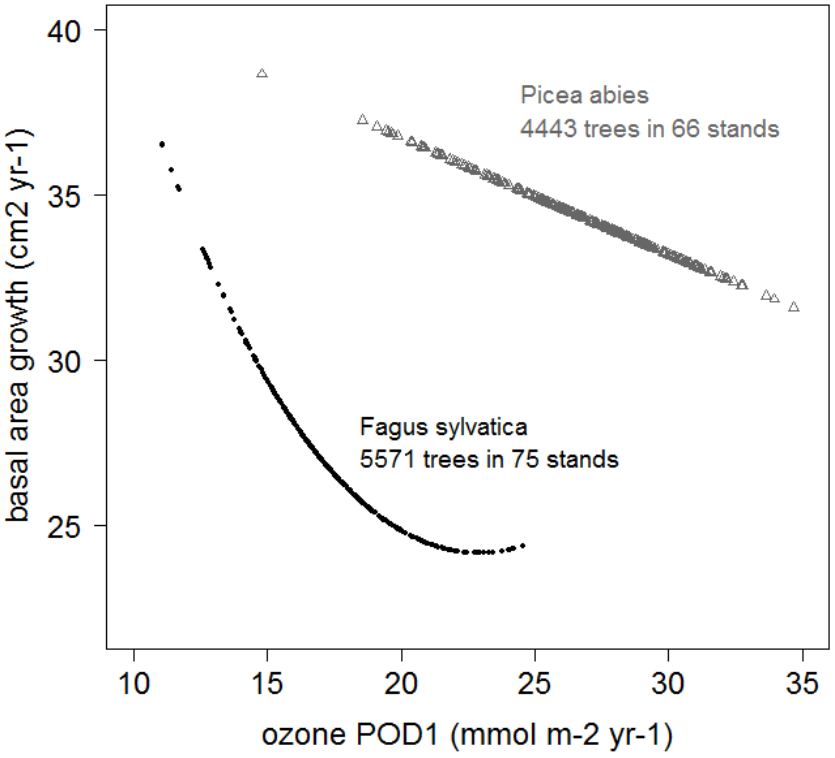
Körner 2015

Other environmental factors may have a stronger impact

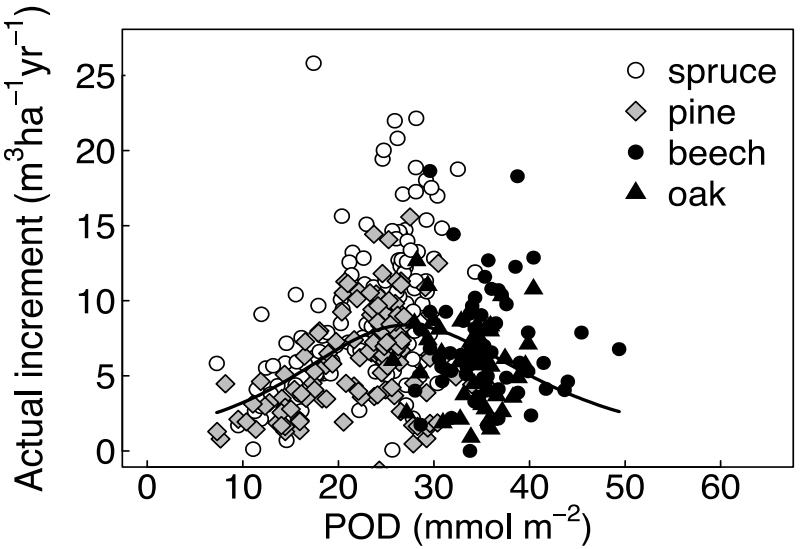
Acclimation and compensatory processes

See Cailleret et al. 2018 J. Ecol.

Contradicting inventory-based ozone-growth relationships



Braun et al. 2017
(Swiss cantonal plots)



Etzold et al. in rev.
(ICPF-Level II)

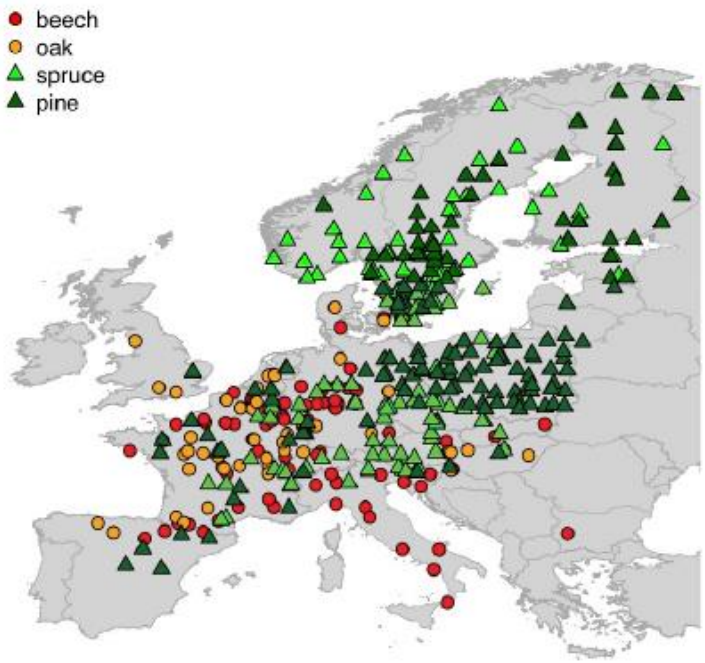
Potential reasons for these differences

- Different **diversity and representativity of the studied populations** (e.g. length of the gradient covered in terms of site characteristics and atmospheric conditions; DBH/age structure)
- Different **data sources**: e.g., measured vs modelled O_3 data
- Different **O3 metric** (mean O_3, AOT40, or POD1)
- **Statistical approach** (other BAI predictors, linear vs. non-linear model)

To derive robust O_3-growth relationships at European scale, we need a comprehensive study that considers for all these 'uncertainty sources'

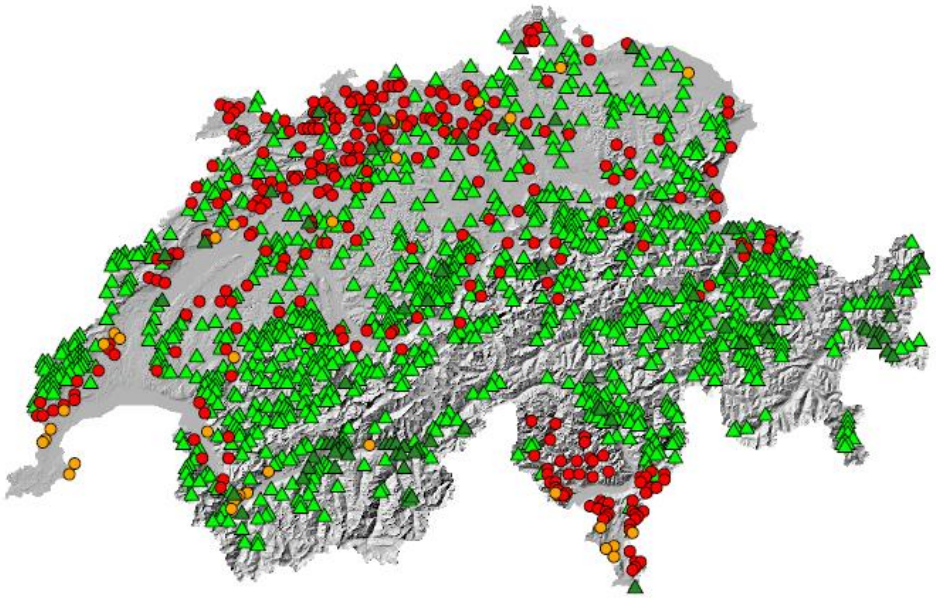
Data sources

ICP Forests Level II



Etzold S.

Swiss NFI

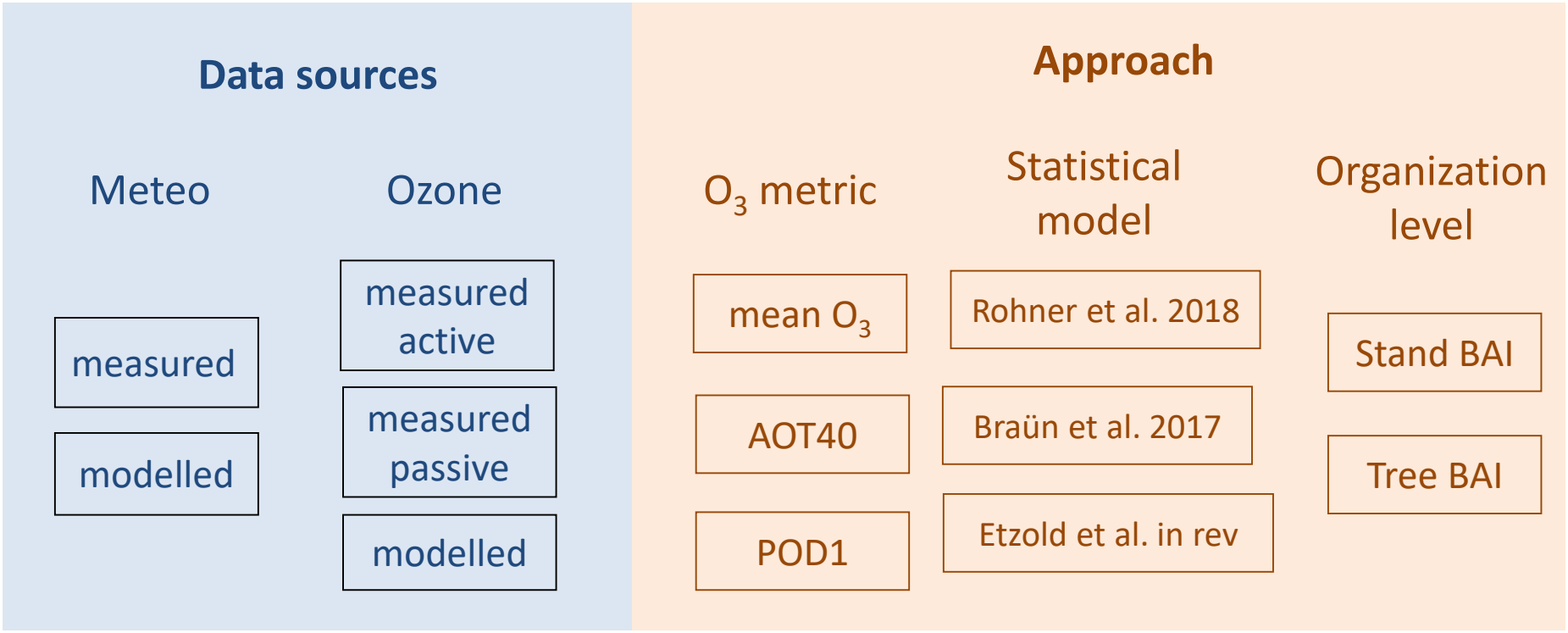


Mina M.

	# sites	period
ICP Forests	>200	2000-2015
Swiss NFI	>1’300	1983-2015

Overall approach

Test as many data sources and approaches as possible !

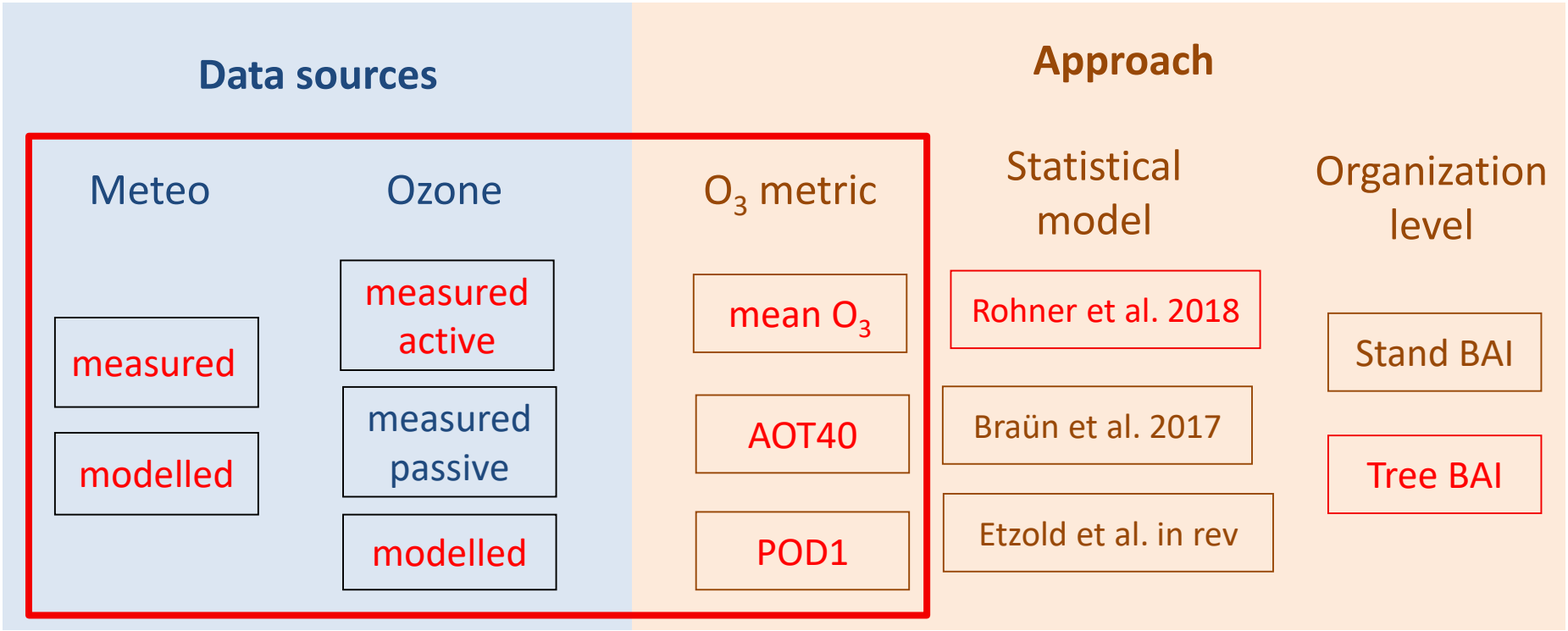


Any consistency in the ozone-growth relationships ?

Quantify the different uncertainty sources

Overall approach

Here, we focus on the source of atmospheric data and on the O_3 metric



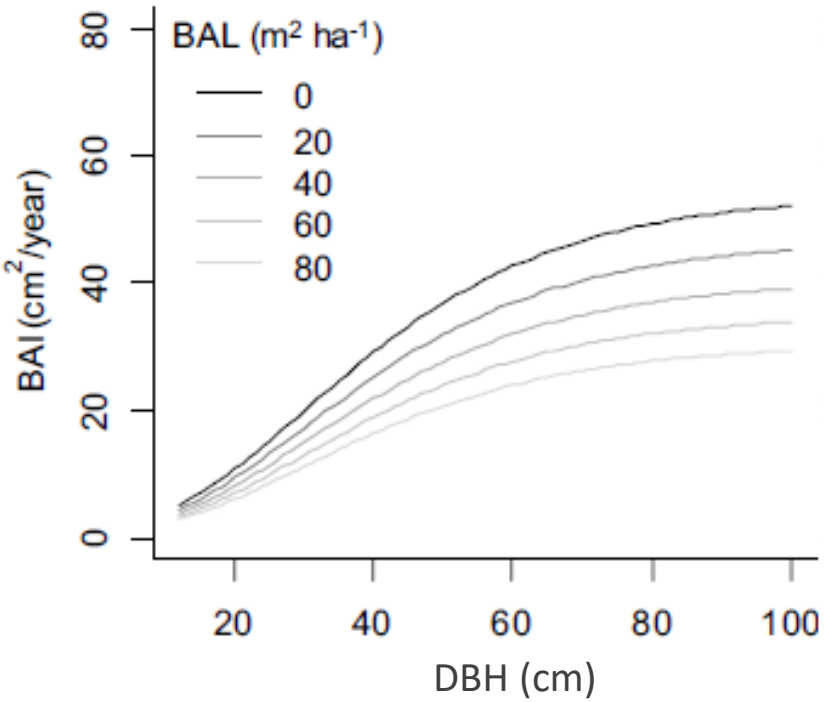
Using ICP-Forests Level-II plots and EMEP [0.1 deg] data

Overall approach

Non-linear mixed-effect model simulating individual tree growth

BAI ~ exp(b1 * (1 - exp(b2 * DBH))) * exp(b3)

b3 ~ site + climate + stand + Ndep + O3metric + (1|plotID)



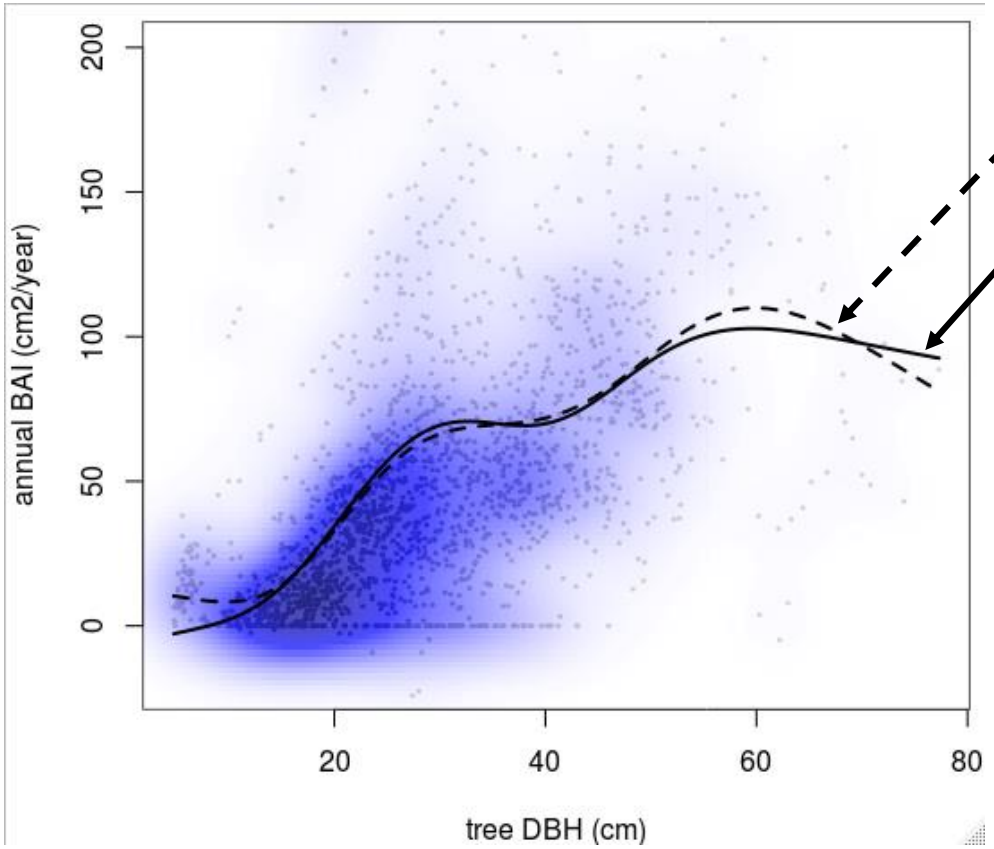
Rohner et al. 2018 EJFR; Mina et al. 2018 J. Ecol. Telk and Hilt 1991; Thürig et al. 2005 FEM

Increasing competition intensity (Basal Area of Larger trees) induces a decrease in tree BAI.

Results: performance of the modeling approach

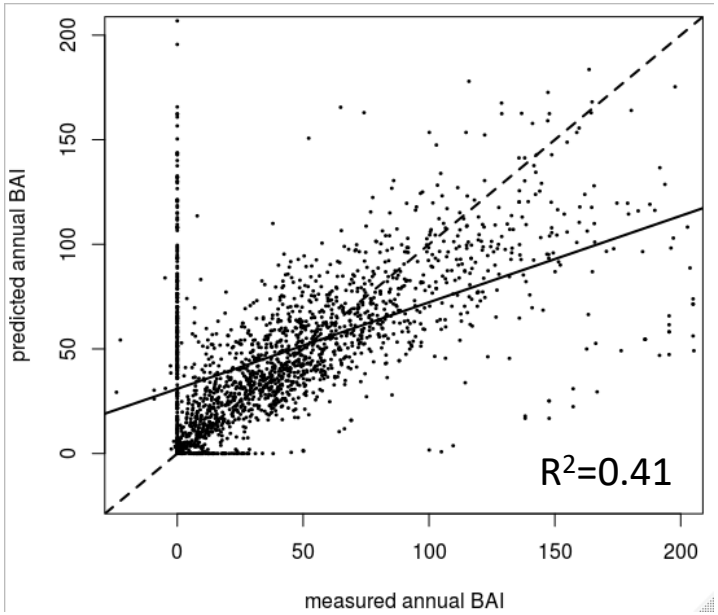
Ex: on Quercus sp.: 28 plots; 1160 trees; >2000 BAI values

Accuracy of the best model: BAI ~ (DBH, BAL, $T_{Apr-Aug}$, pH, mean $[O_3]$)



Spline fitted on the raw data

Spline fitted on the predictions of the growth model

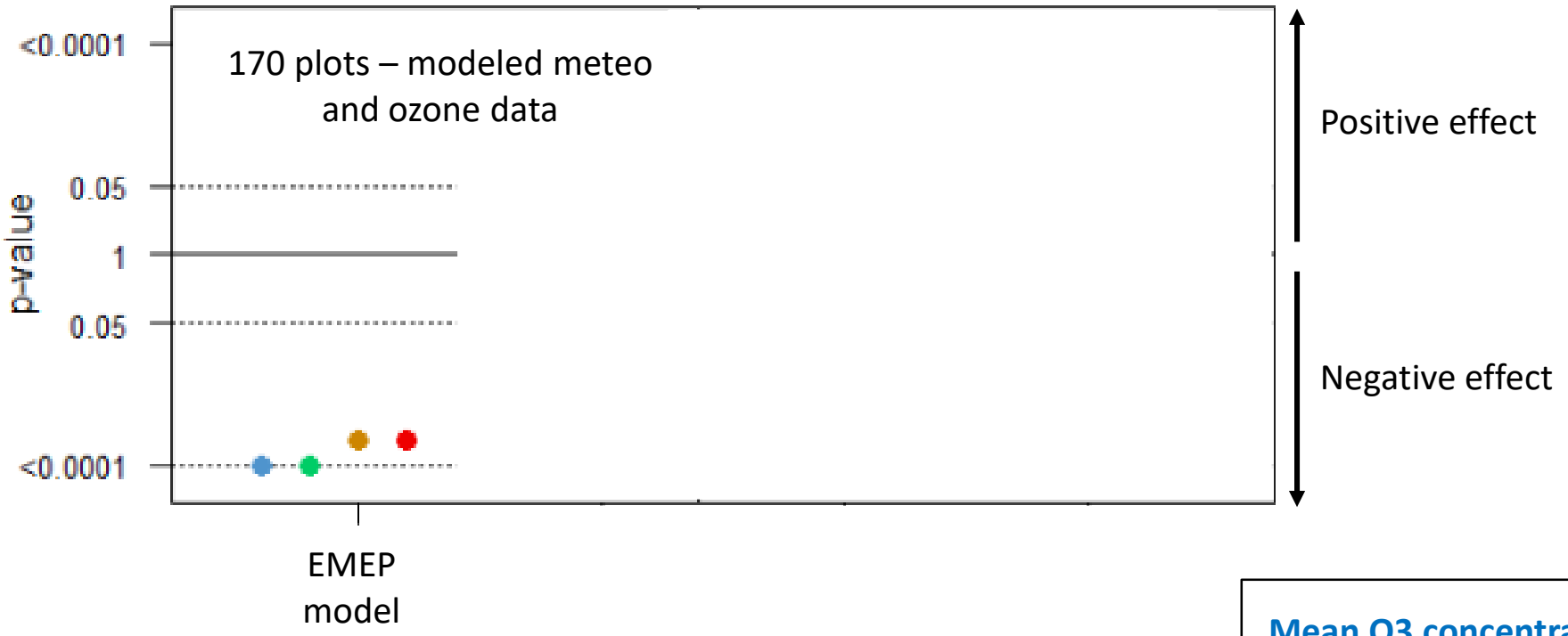


Results for the main European tree species

	Fagus sylvatica	Quercus sp.	Pinus sylvestris	Picea abies
BAL	-0.27	-0.42		-0.49
DDOM	-0.17	-0.06	0.13	
grWB	0.41	0.30	1.76	-0.98
grT	0.32	0.24	2.78	-1.04
meanT	0.10	-0.34	0.60	0.47
Ndep	0.03	-0.30	1.44	0.13
Mean [O3]	**-0.21**	**-0.17**	**0.12**	**-0.32**

Results: uncertainty in ozone-growth relationships

Due to the source of data input and to the ozone metric used
ex: with *Fagus sylvatica*



The negative effect of O_3 on tree BAI is highly significant whatever the metric used

Mean O3 concentration

AOT40

POD0

POD1

Results: uncertainty in ozone-growth relationships

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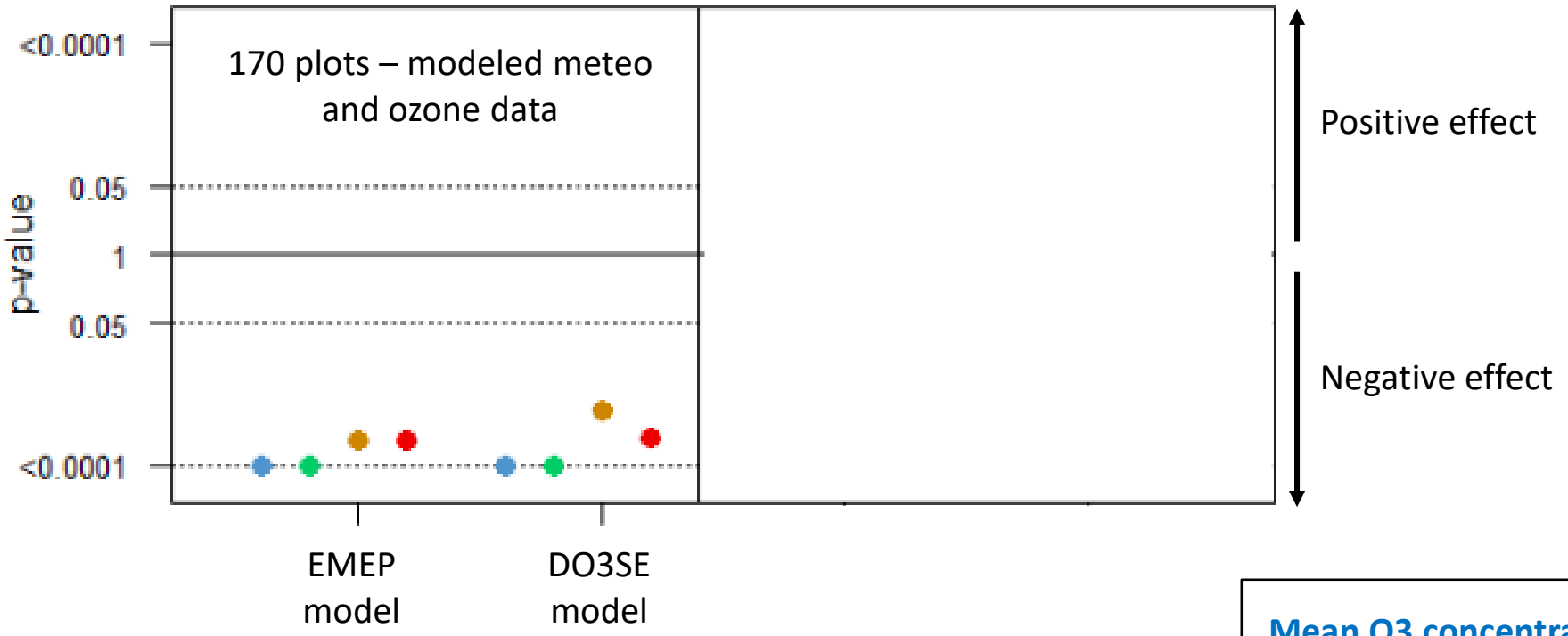


The negative effect of O_3 on tree BAI is highly significant whatever the ozone uptake model used

Mean O3 concentration

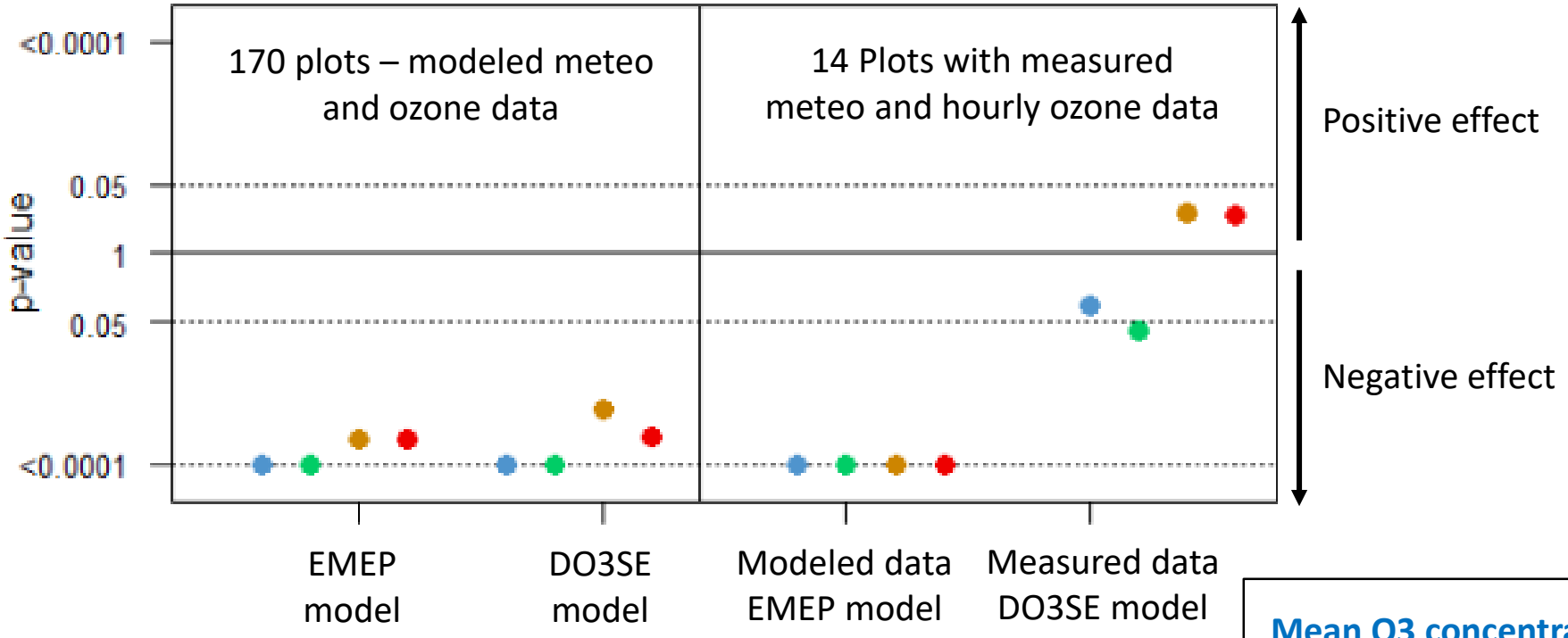
AOT40

POD0

POD1

Results: uncertainty in ozone-growth relationships

Due to the source of data input and to the ozone metric used
ex: with *Fagus sylvatica*



The negative effect of O_3 on tree BAI is not significant anymore with the measured data

Discussion - perspectives

For *Fagus sylvatica*, ozone-growth relationships seem not stable:

- Even at a 0.1°grid, EMEP data do not capture stand-scale O_3 patterns
- When the number of plots is low, the relationship depends on the source of the meteo and ozone data, and on the choice of the O_3 metric

More sources of uncertainty have to be considered:

- Statistical model/approach used
- Tree vs. stand level BAI
- Parameterisation of ozone uptake models (e.g., POD estimates are highly sensitive to the phenological function within DO3SE)

If there is no best approach, we will test all of them and analyze distributions of p-values

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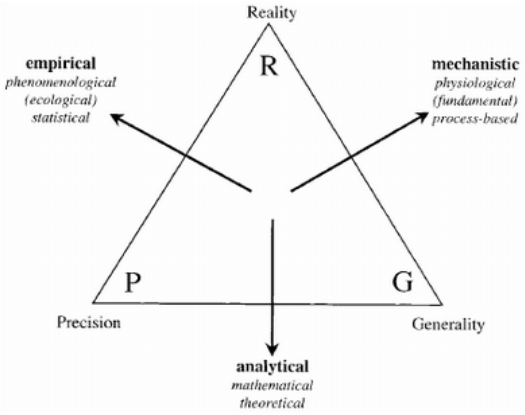
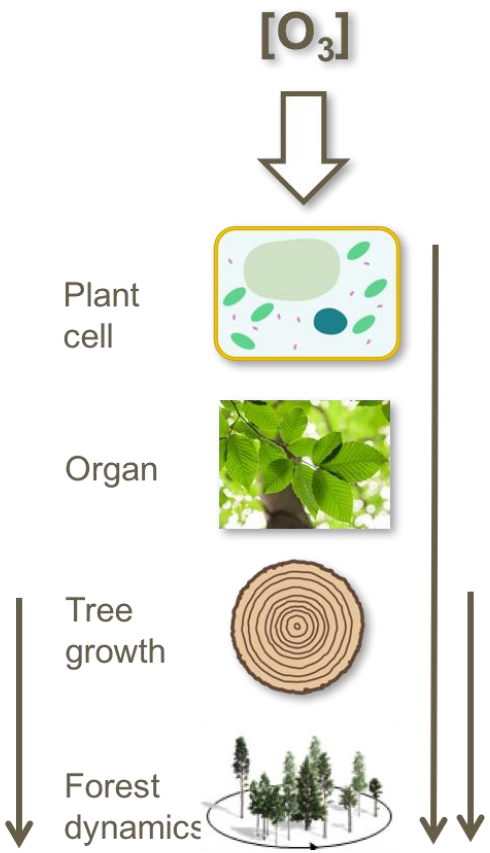
Project framework



Levins' model classification (1966)



O_3 deposition and uptake model: **DO_3SE**

Physiological model **CASTANEA** 2

ICP Forests Swiss NFI 1

Forest gap model **ForClim** 3

Empirical analysis ⟷ Process-based modeling tools