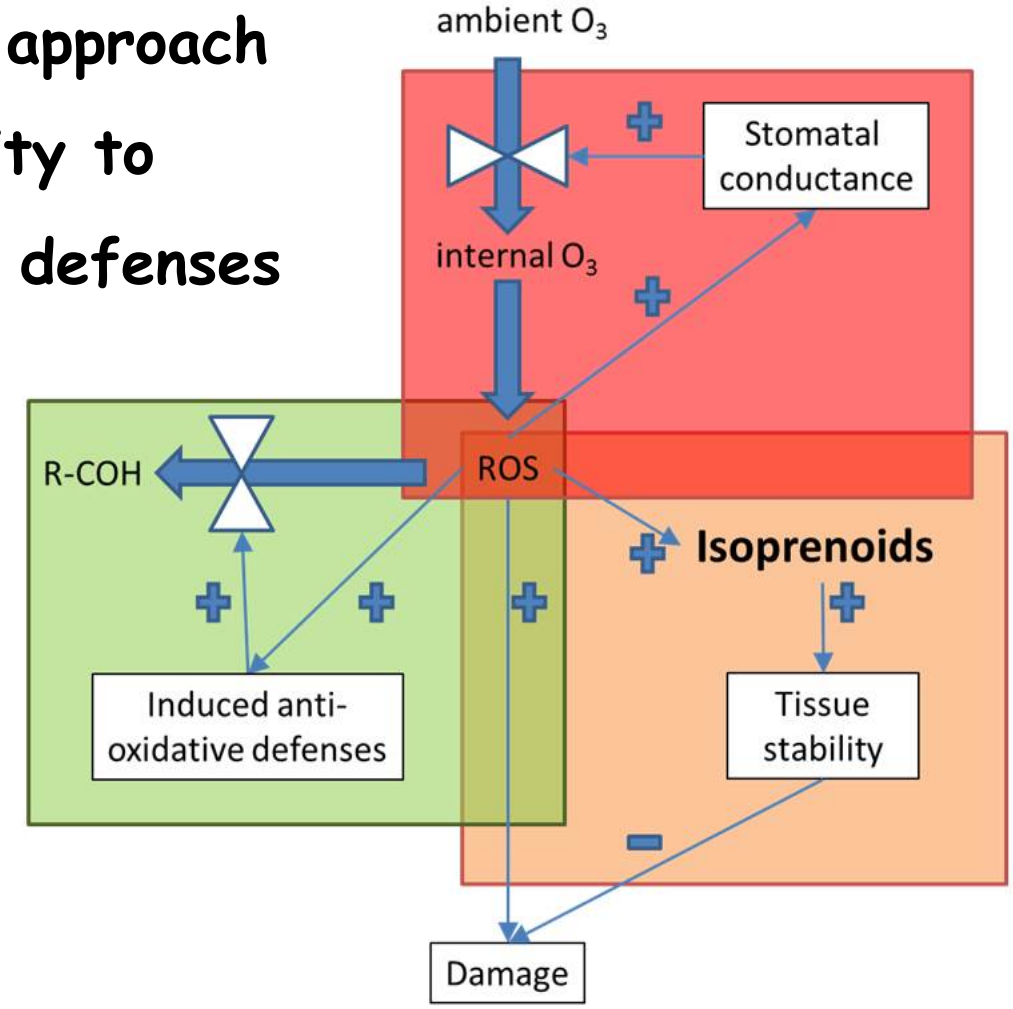
Karlsruher Institut für Technologie

A mechanistic modelling approach to link ozone susceptibility to constitutive and induced defenses



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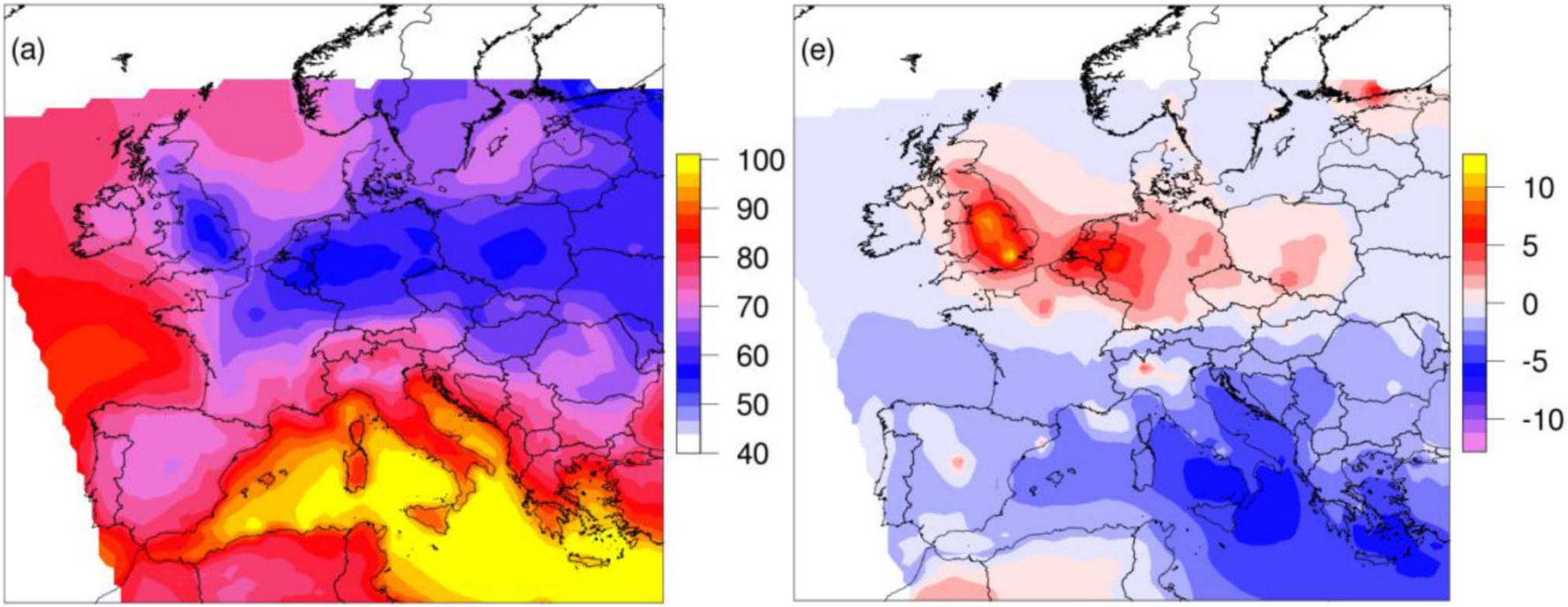
Ozone is ubiquitous



Annual mean O3 concentrations (µg m−3) 1998-2007 (left) and changes projected to 2030 (right) based on GEA (Global Energy Assessment) emission scenario (Colette et al. 2012).

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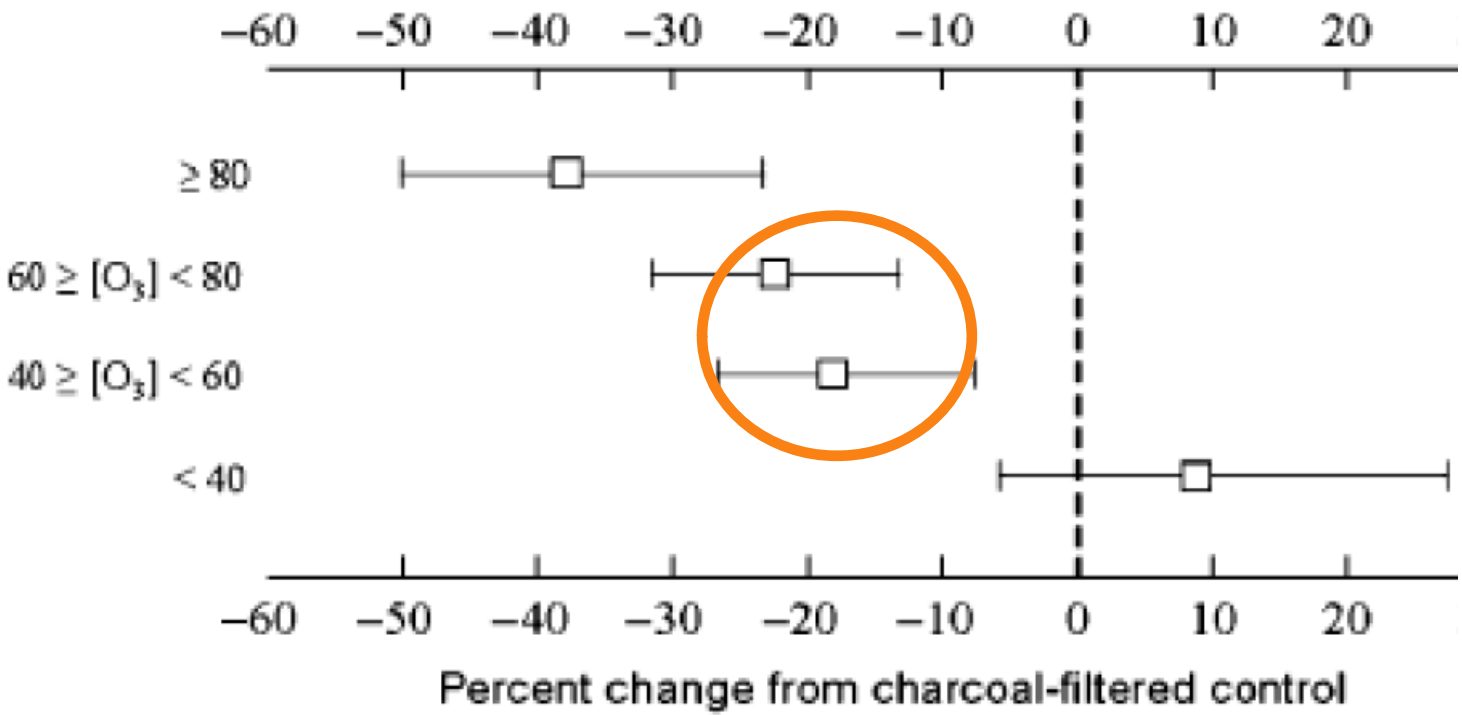
Ozone damage is ubiquitous



Effect on biomass production due to O3 (µg m−3) (Wittig et al. 2009).

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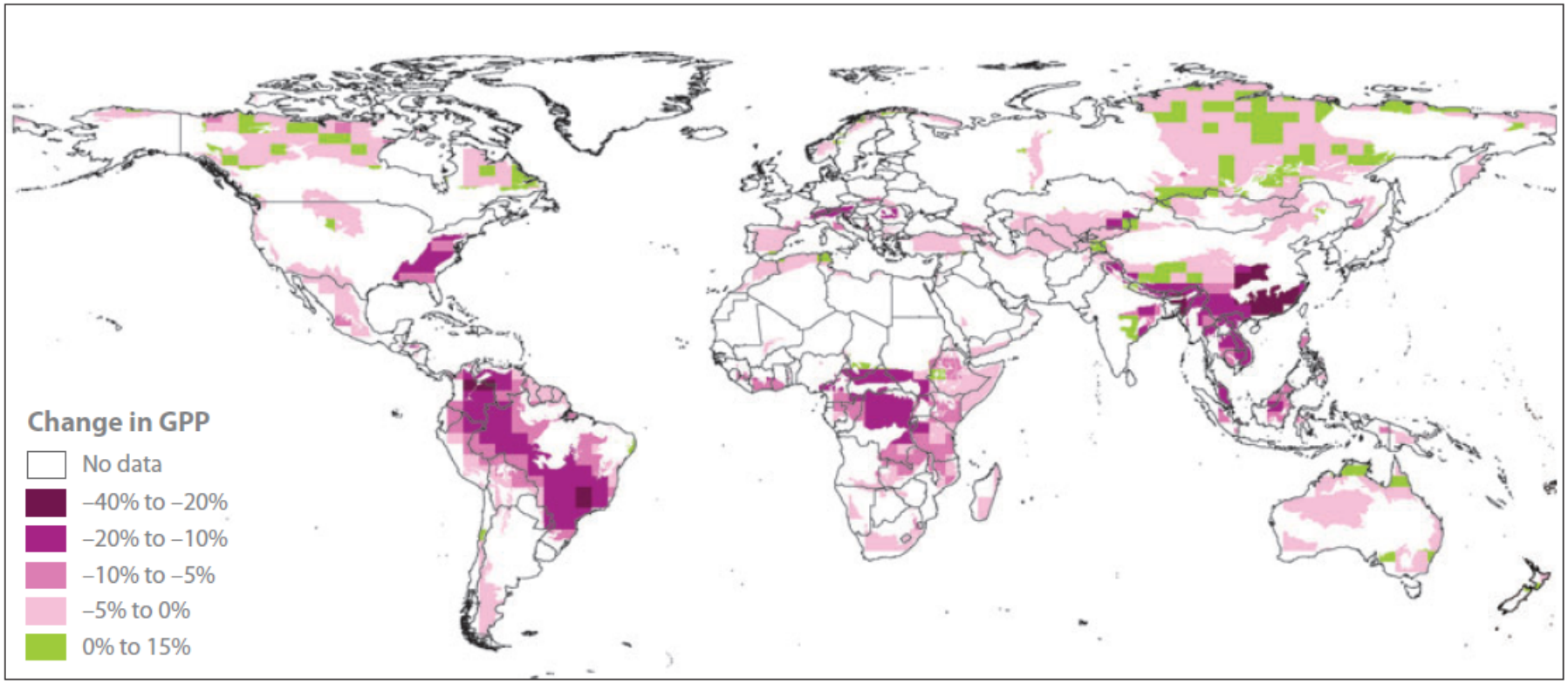
Ozone damage will be ubiquitous



Projected percentage change in GPP due to O3 change (for 2100, Ainsworth et al. 2012).

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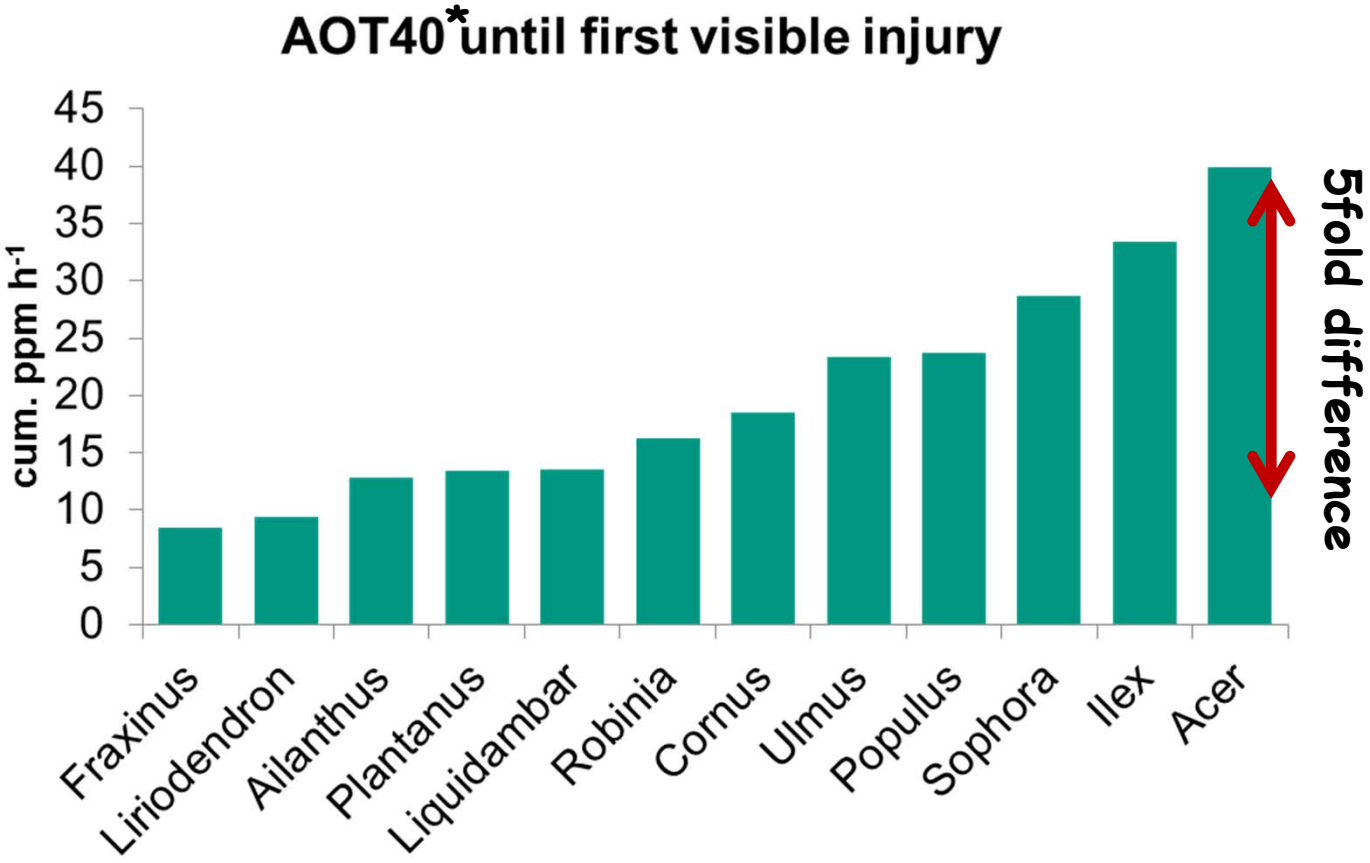
Ozone damage depends on sensitivity



Differences in sensitivity (Feng & Li 2017).

***sum of hourly O3 concentrations exceeding 40 nmol mol-1**

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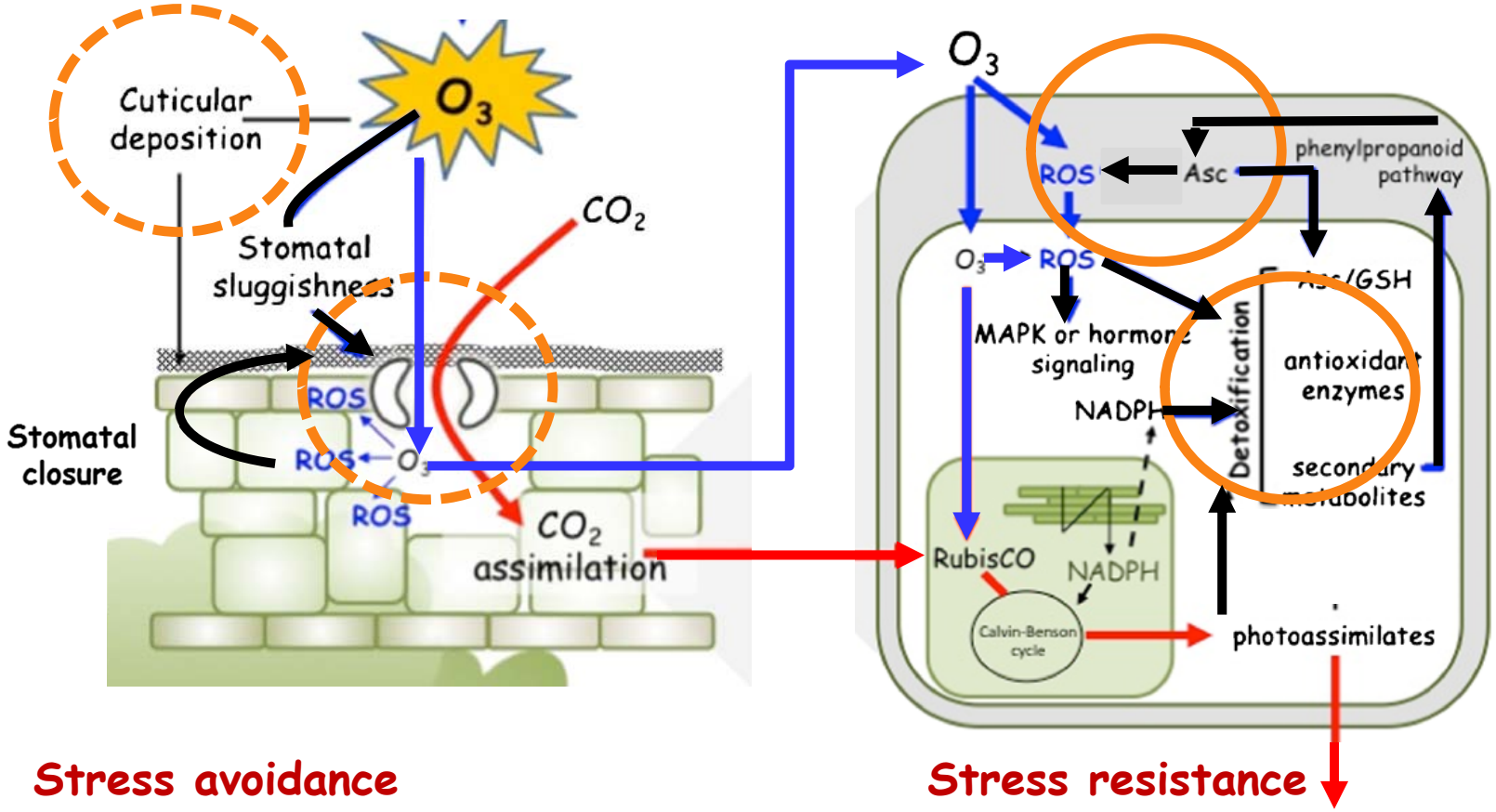
Ozone sensitivity depends on…



Stress avoidance **Stress resistance**

Short-term, small-scale responses: surface properties, stomata responses, constitutive defenses, induced defenses (modified after Jolivet et al. 2016).

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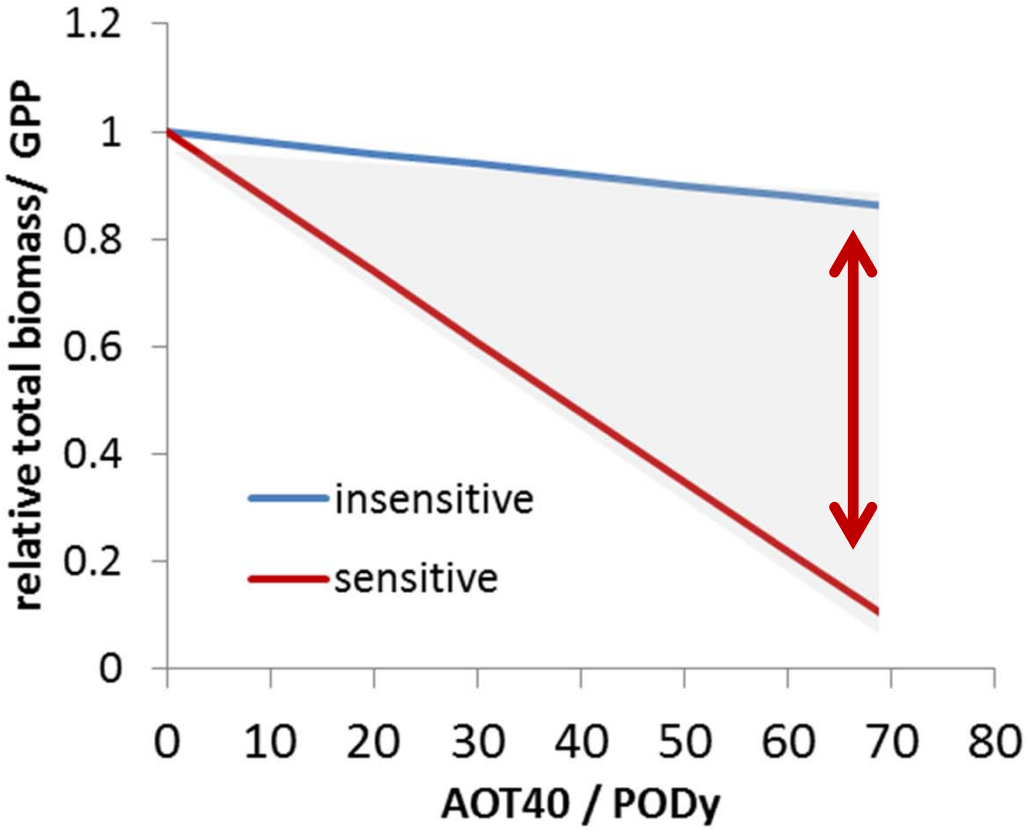
Ozone impact models 1



Linear model to reduce gross primary production (GPP) or biomass to either concentration (AOT) or uptake (PODy) of ozone (Reich 1987)

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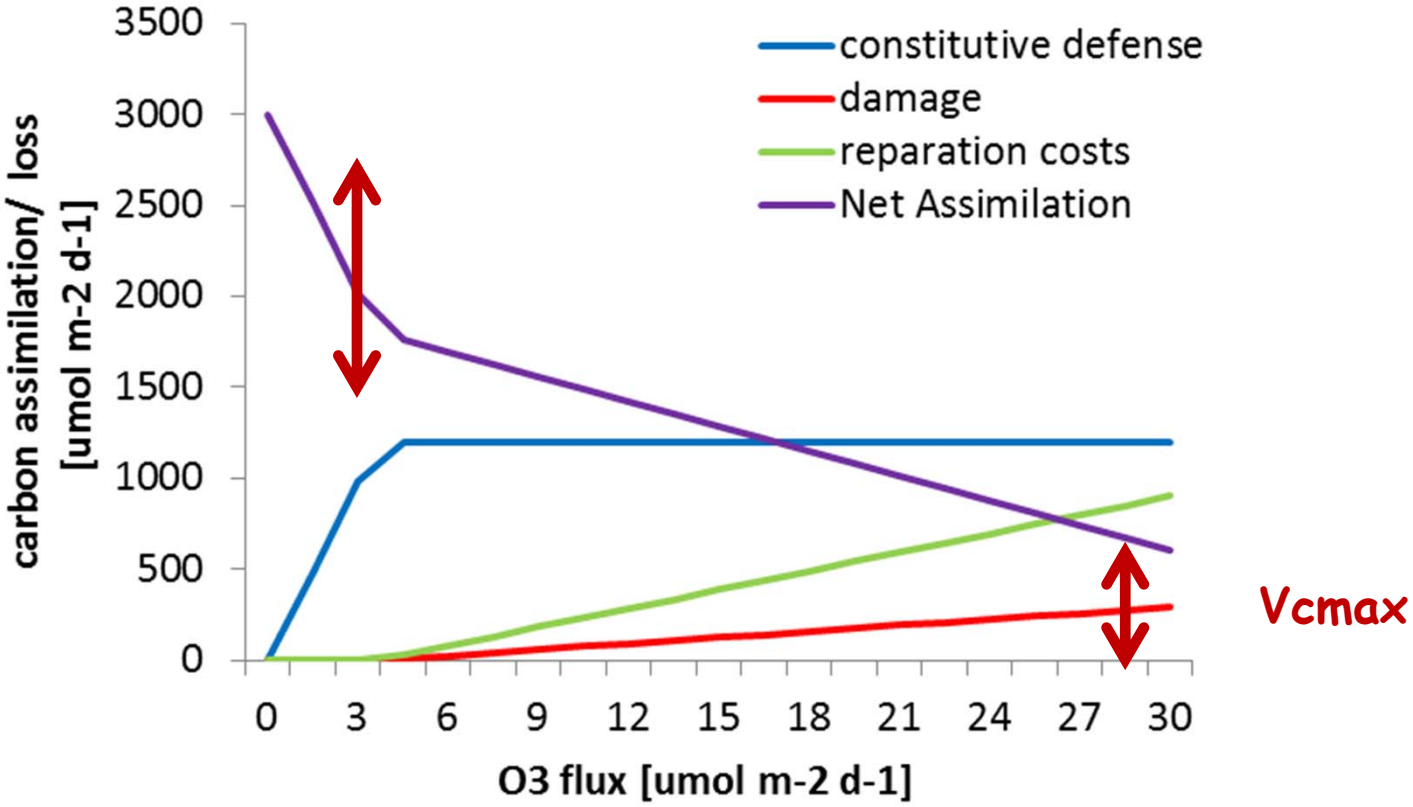
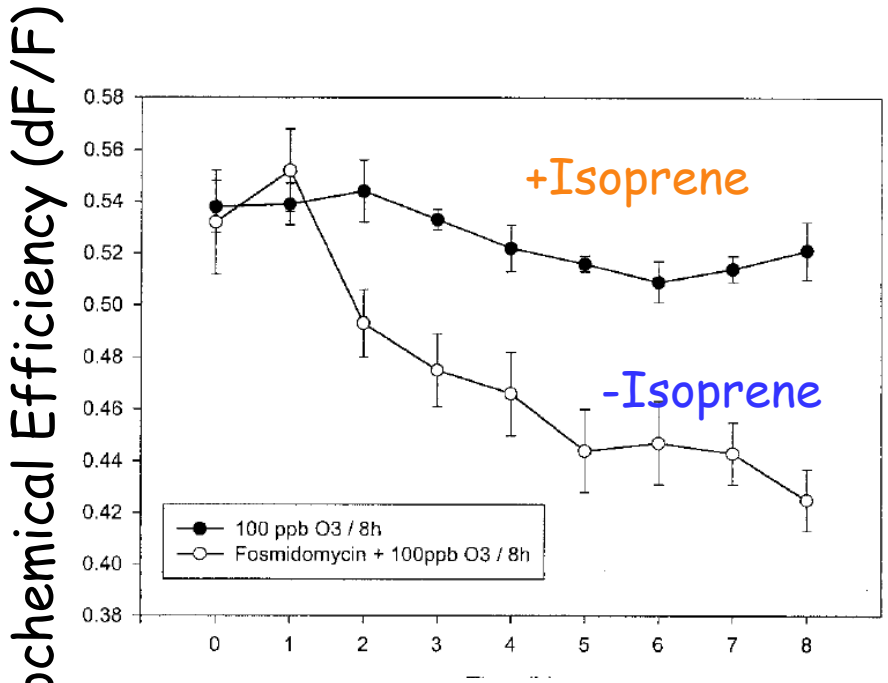
Ozone impact models 2

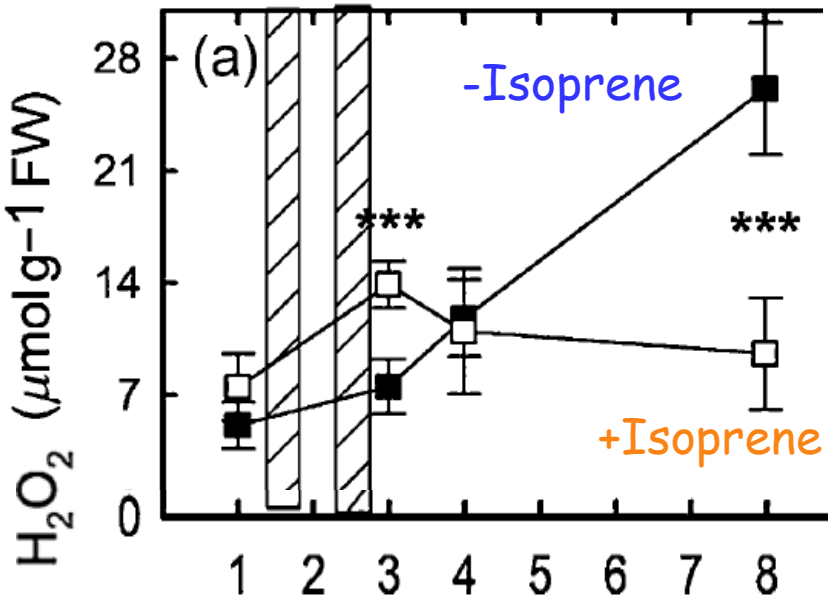


Composite model reducing gross primary production (GPP) based on defense, damage, and reparation cost (Deckmyn et al. 2007)

→ 1) No connection to BVOCs , → 2) No induced defense

The BVOC connection



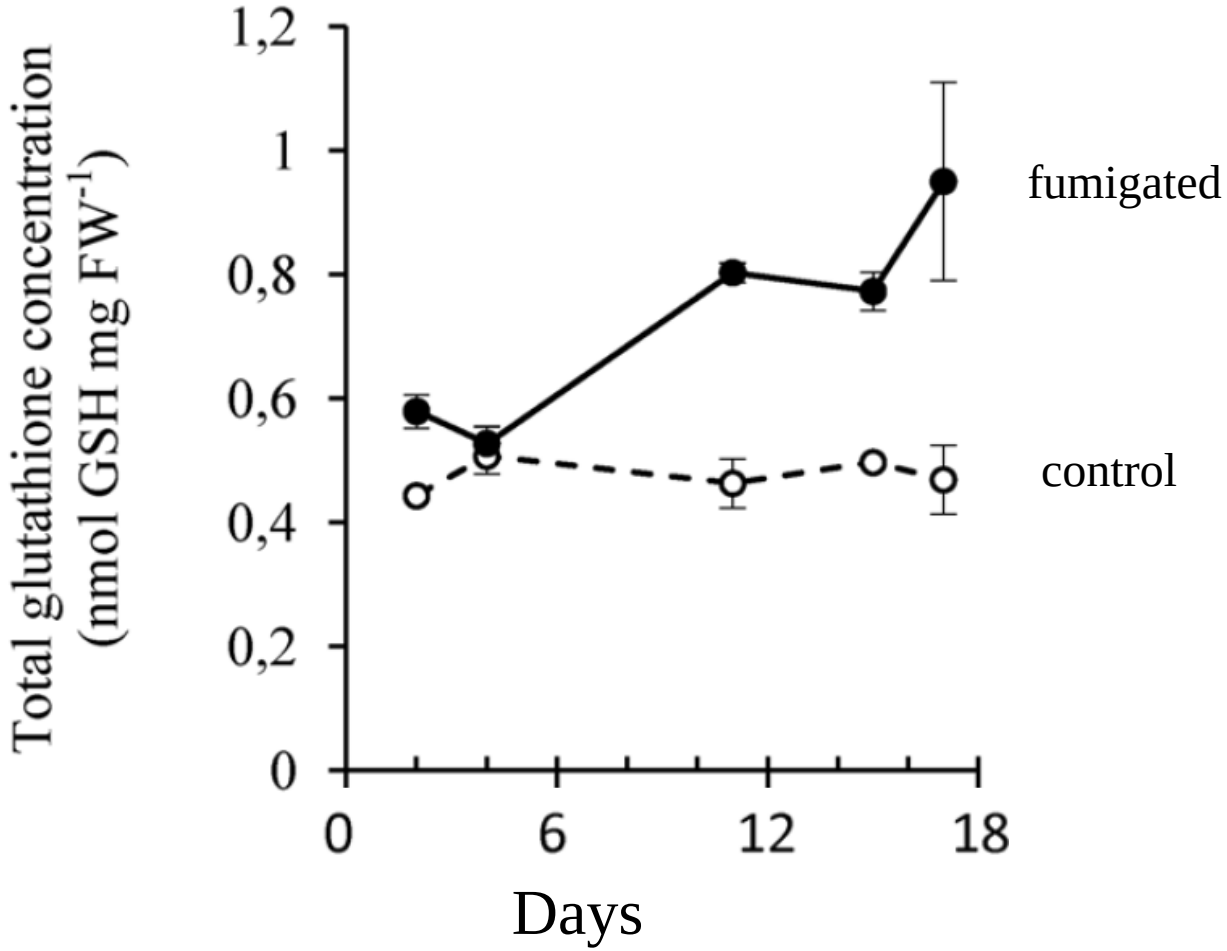


Membrane stabilization (Phragmites) (Loreto & Velikova 2001)

Direct anti-oxidation (Tobacco) (Vickers et al. 2009, PCE)

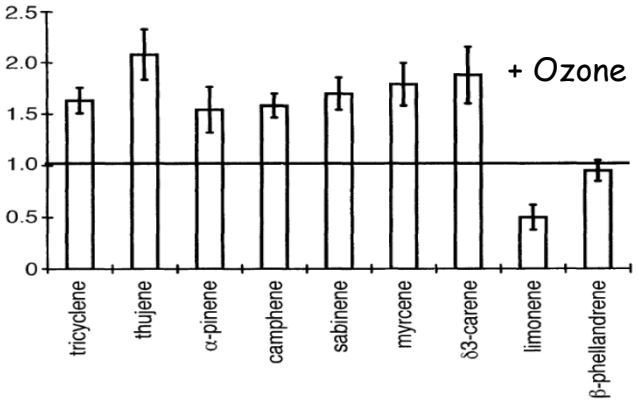
1) Protection due to biogenic volatile organic compounds (BVOCs)

The defense induction

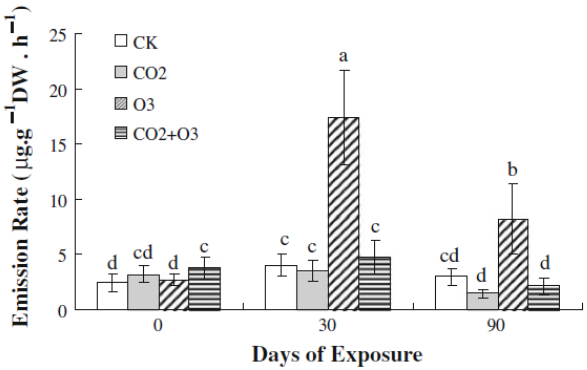


2) Induced defense (Poplar, Dumont et al. 2014))

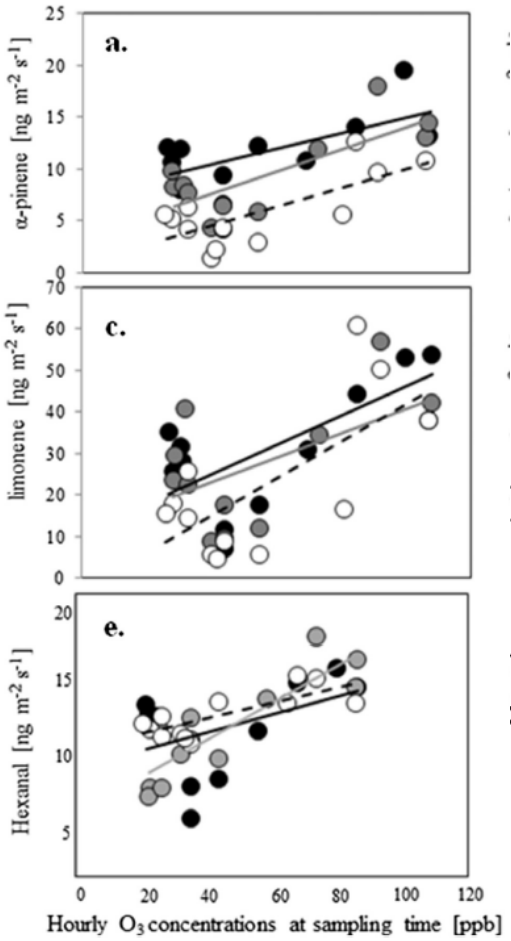
The BVOC induction



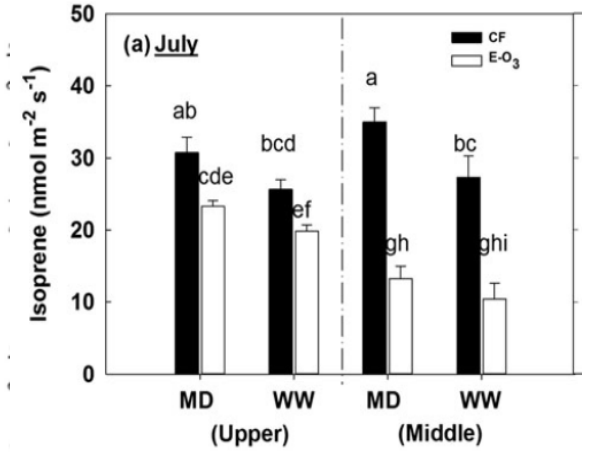
(Scots pine, Heiden et al. 1999)



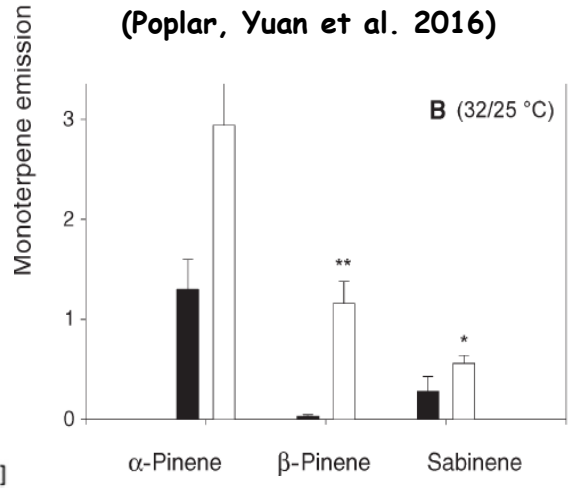
(Chinese pine, Xu et al. 2012)



(Birch, Carriero et al. 2016)



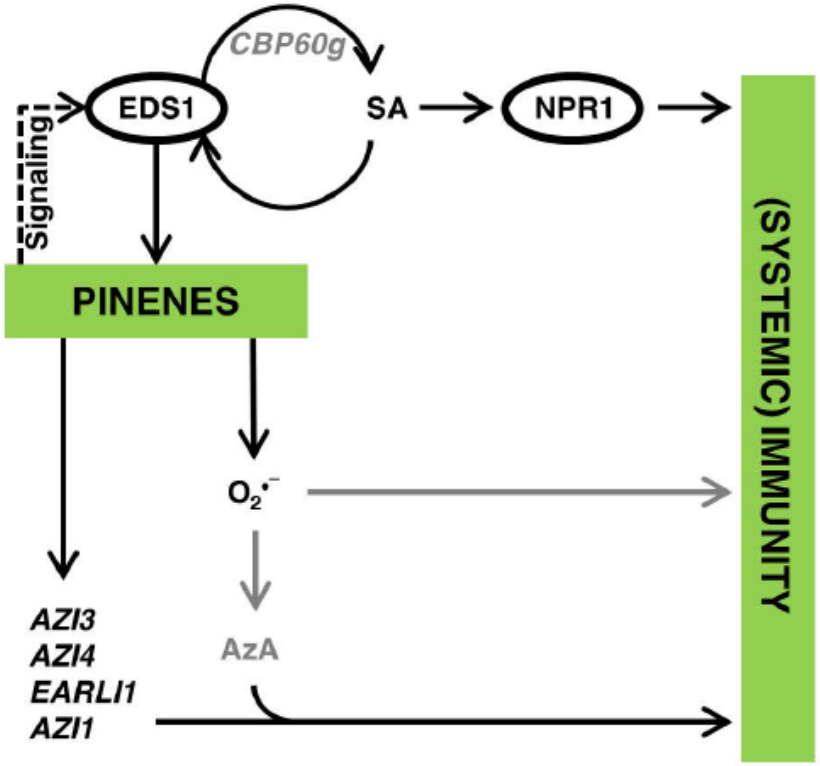
(Poplar, Yuan et al. 2016)



(Holm oak, Loreto et al. 2004)

Ozone induced biogenic volatile organic compounds (terpenoids, LOX)

BVOC and Defense induction connected



Indirect anti-oxidation by activation of the defense system (Riedlmeier et al. 2017)

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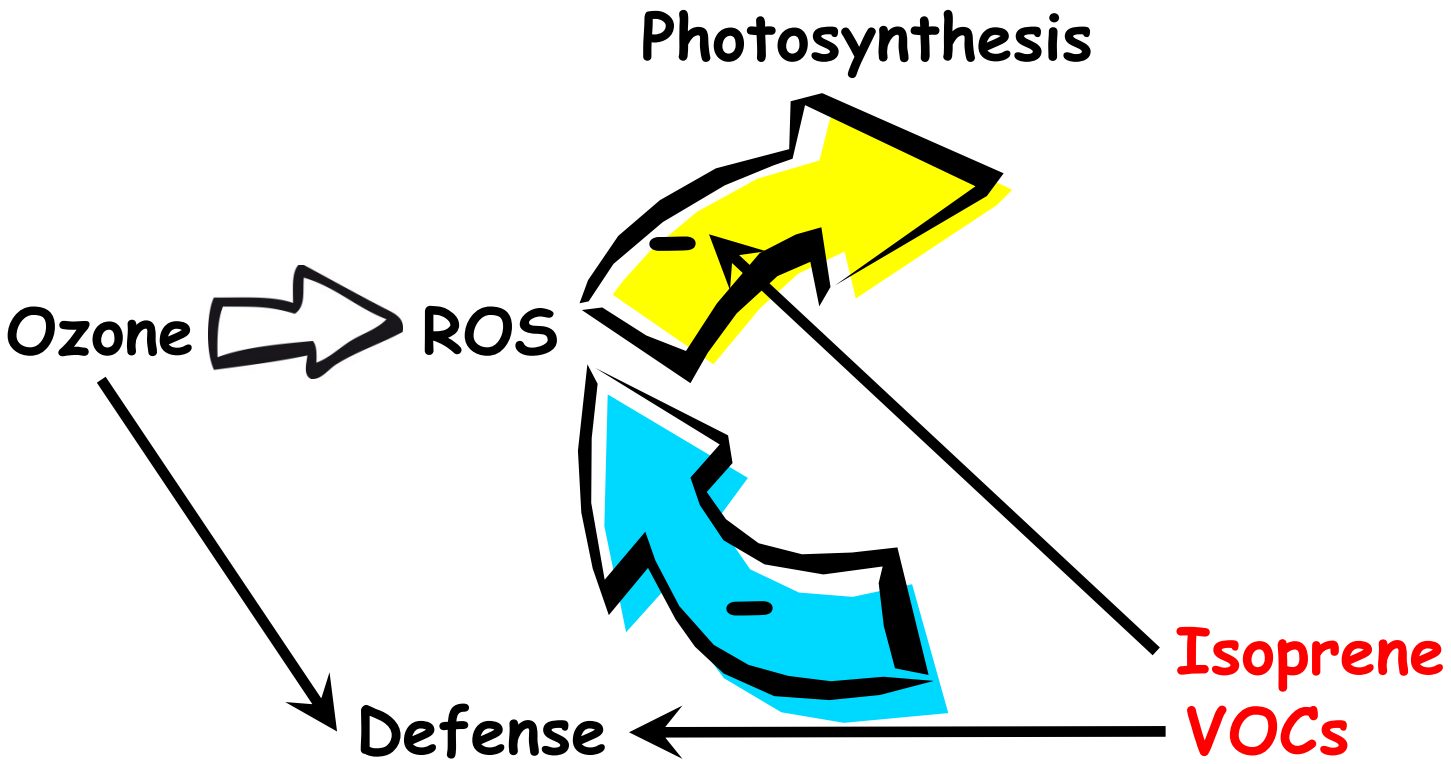
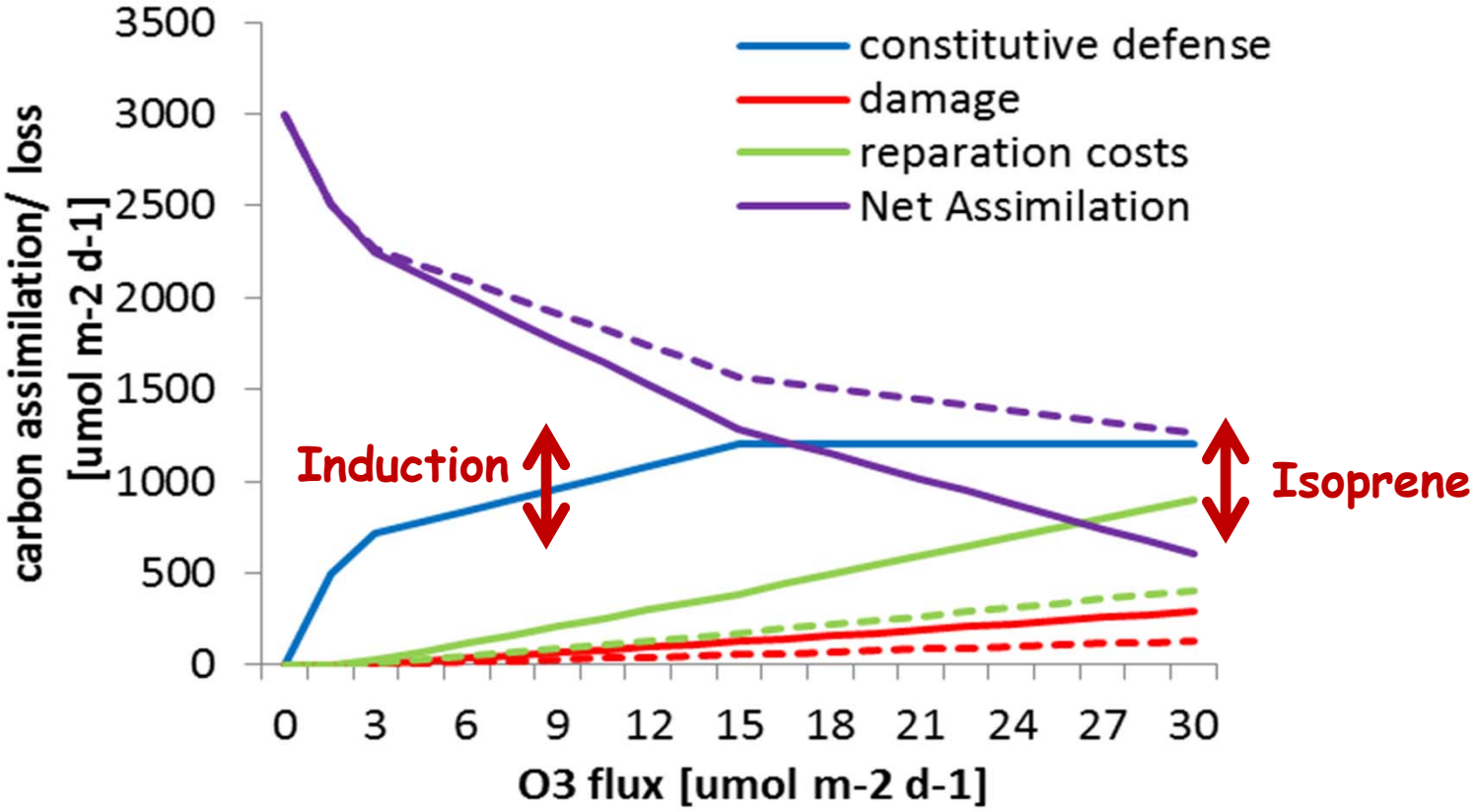
A new approach



A new approach



New modelling approach (suggested in Tiwari et al. 2016)

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A new approach

Photosynthesis

$$Eiso = J\ [a + b(J\text{-}Jv)]\ \min\{1;\ C_i/\Gamma^*\}\ f(T)$$

J-Jv

+

Isoprene
VOCs

Linked Photosynthesis – Emission model
(Morfopoulos et al. 2014, Grote et al. 2014)

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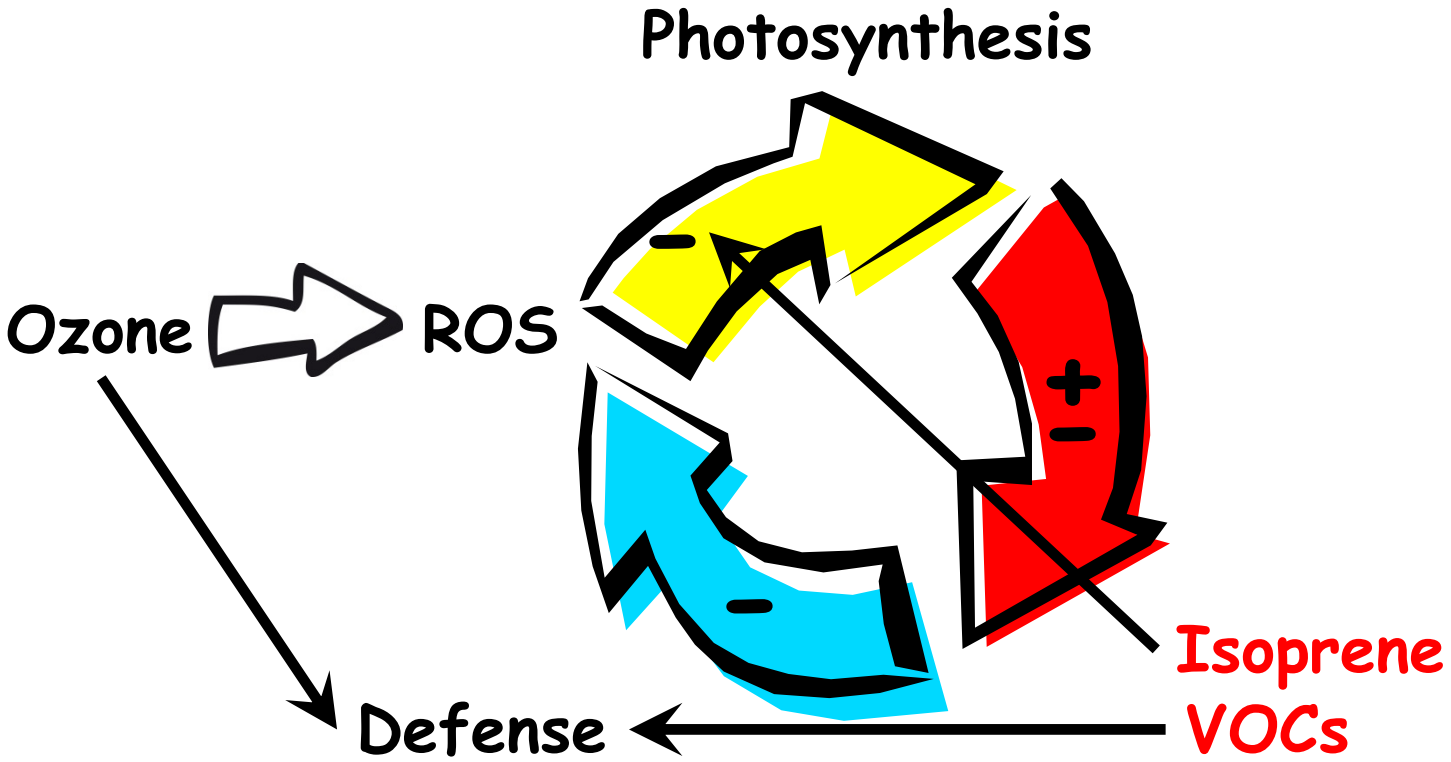

New modelling approach (suggested in Tiwari et al. 2016)

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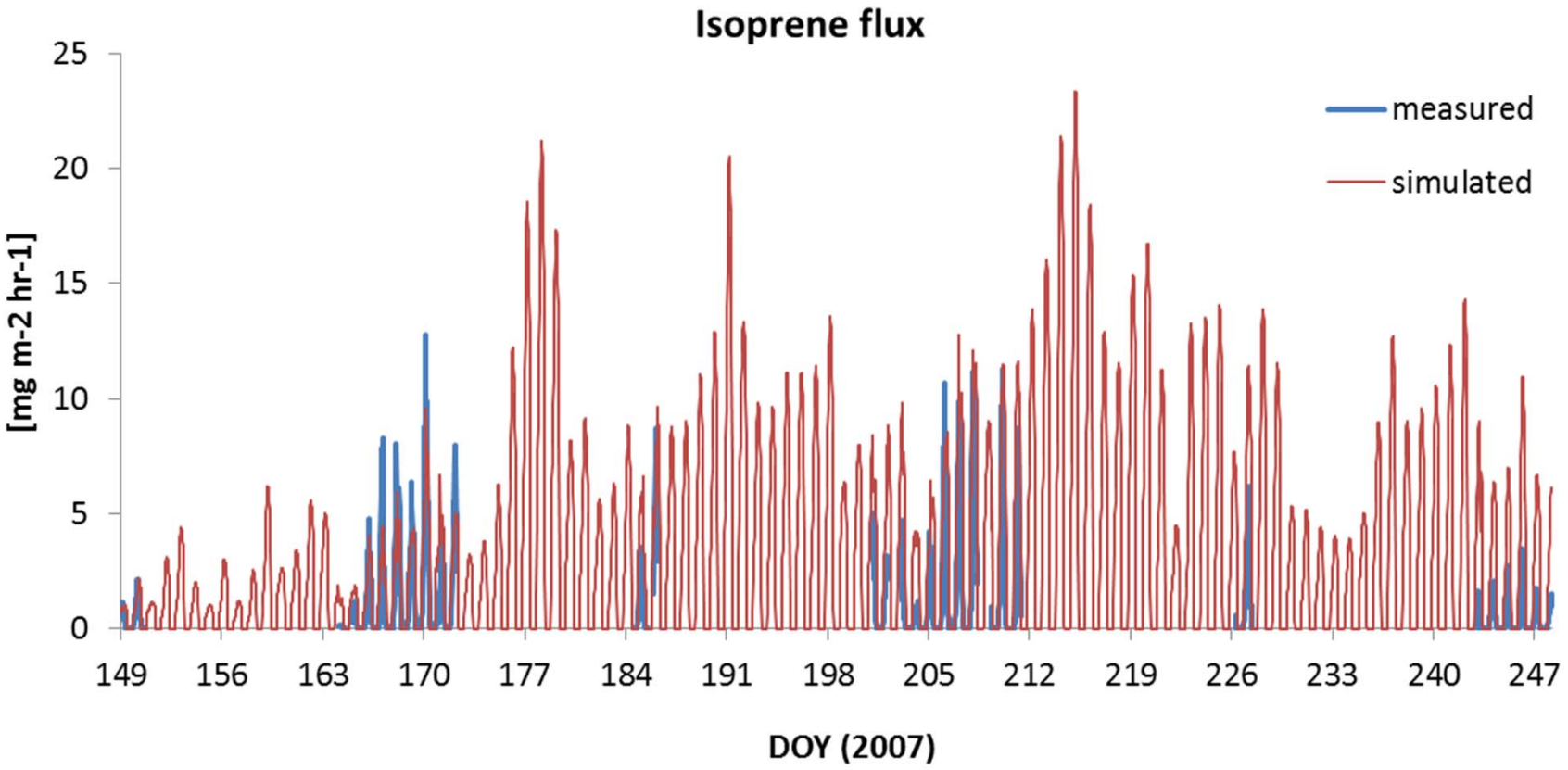
Testing the new approach



Example: Harvard Forest Emission modelling

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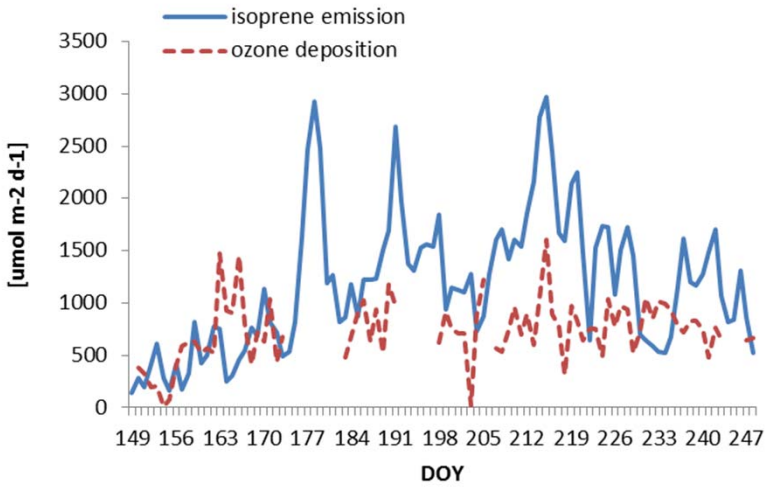
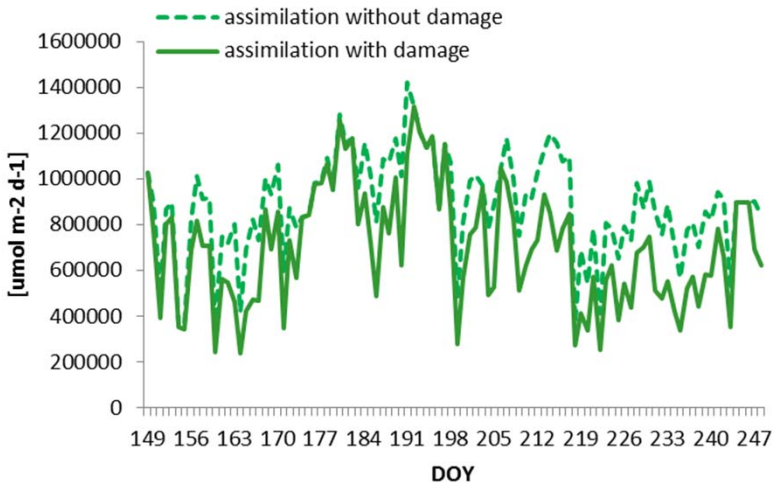
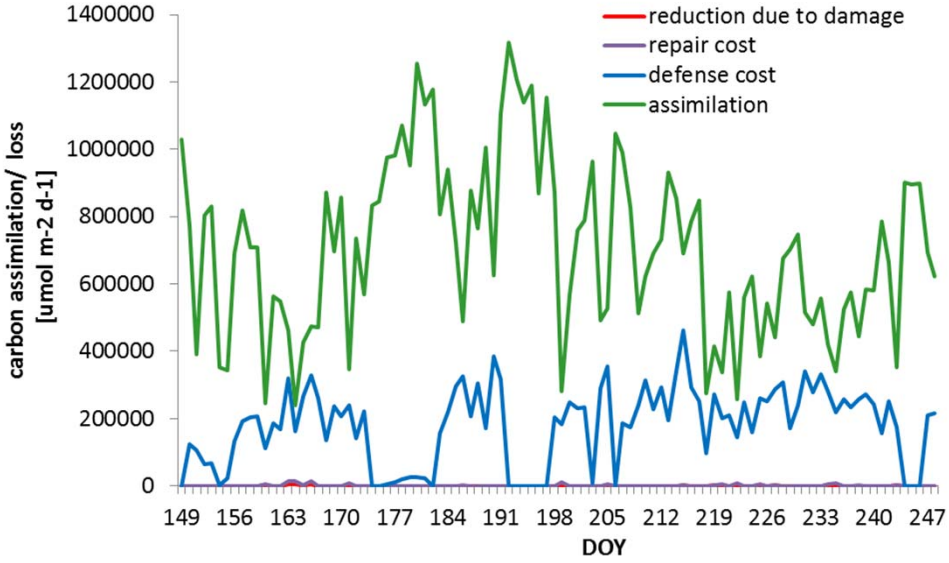
Testing the new approach







Estimated damage: 20%

Example: Harvard Forest Damage modelling

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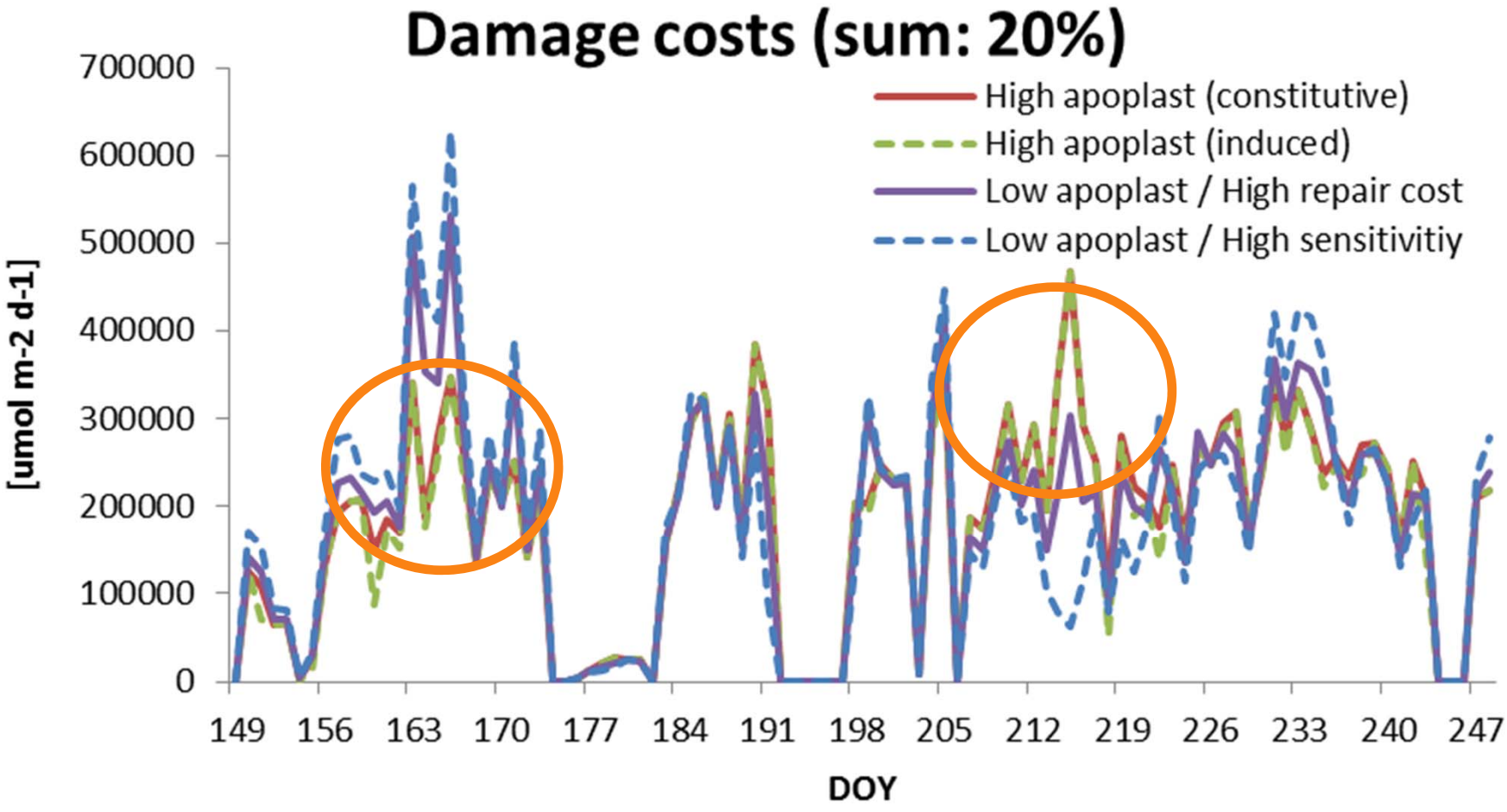

Example: Harvard Forest Sensitivity

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Take home

- There is a deficit in modelling defense reactions: No induction, No connection to BVOCs!

➢ Plant responses to ozone cannot be realistically estimated if boundary conditions change.

➢ New modelling approaches are needed – and are being developed.

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Take home

"To the philosopher, the physician, the meteorologist, and the chemist, there is perhaps no subject more attractive than that of ozone"

Fox 1873

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