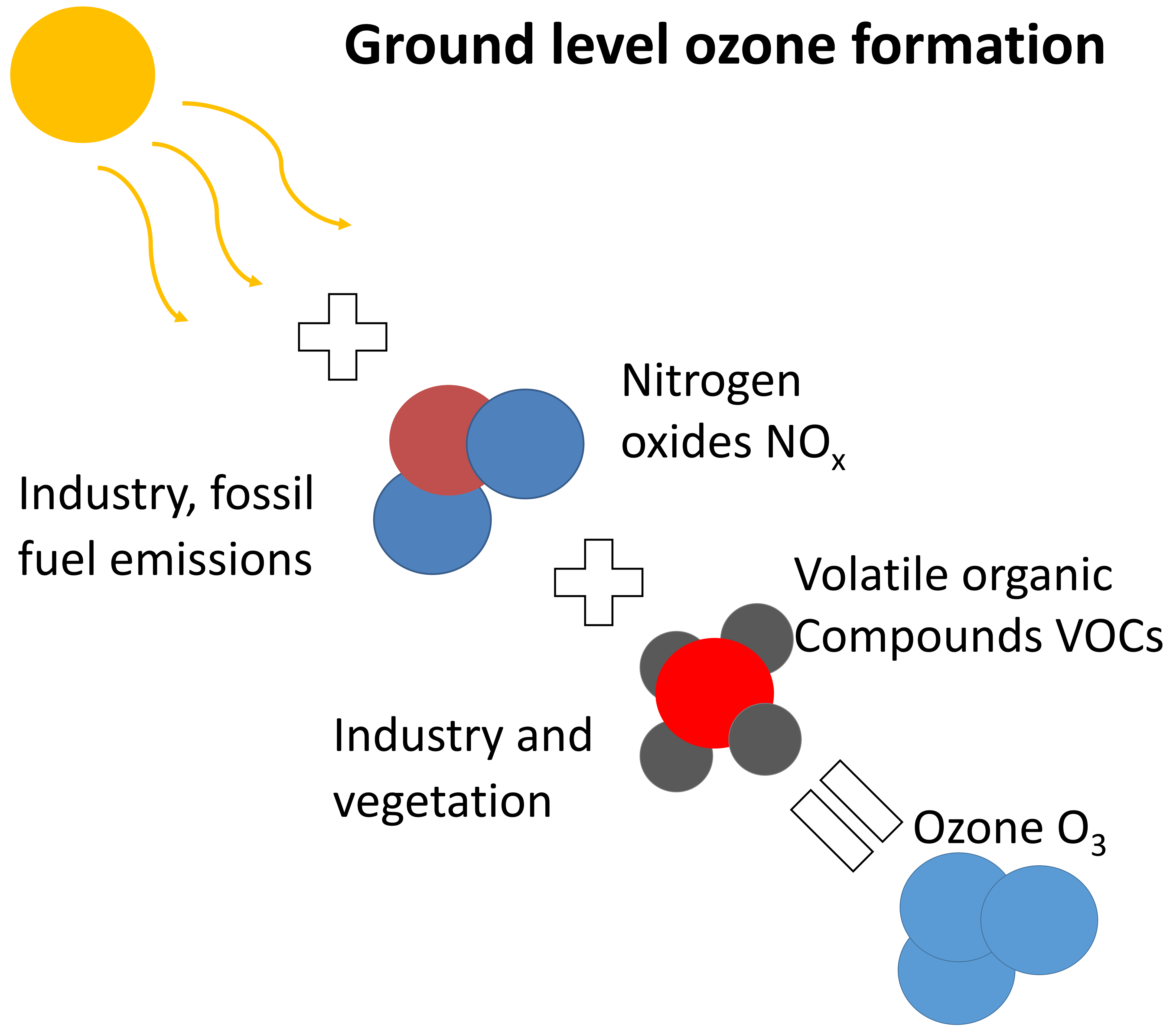
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL
enquiries@ceh.ac.uk
www.ceh.ac.uk

European carbon sink strength reduced by plant ozone damage: from pre-industrial to future

Rebecca Oliver[1], Lina Mercado[1,2], Stephen Sitch[2]
[1]Centre for Ecology and Hydrology, UK
[2]University of Exeter, UK

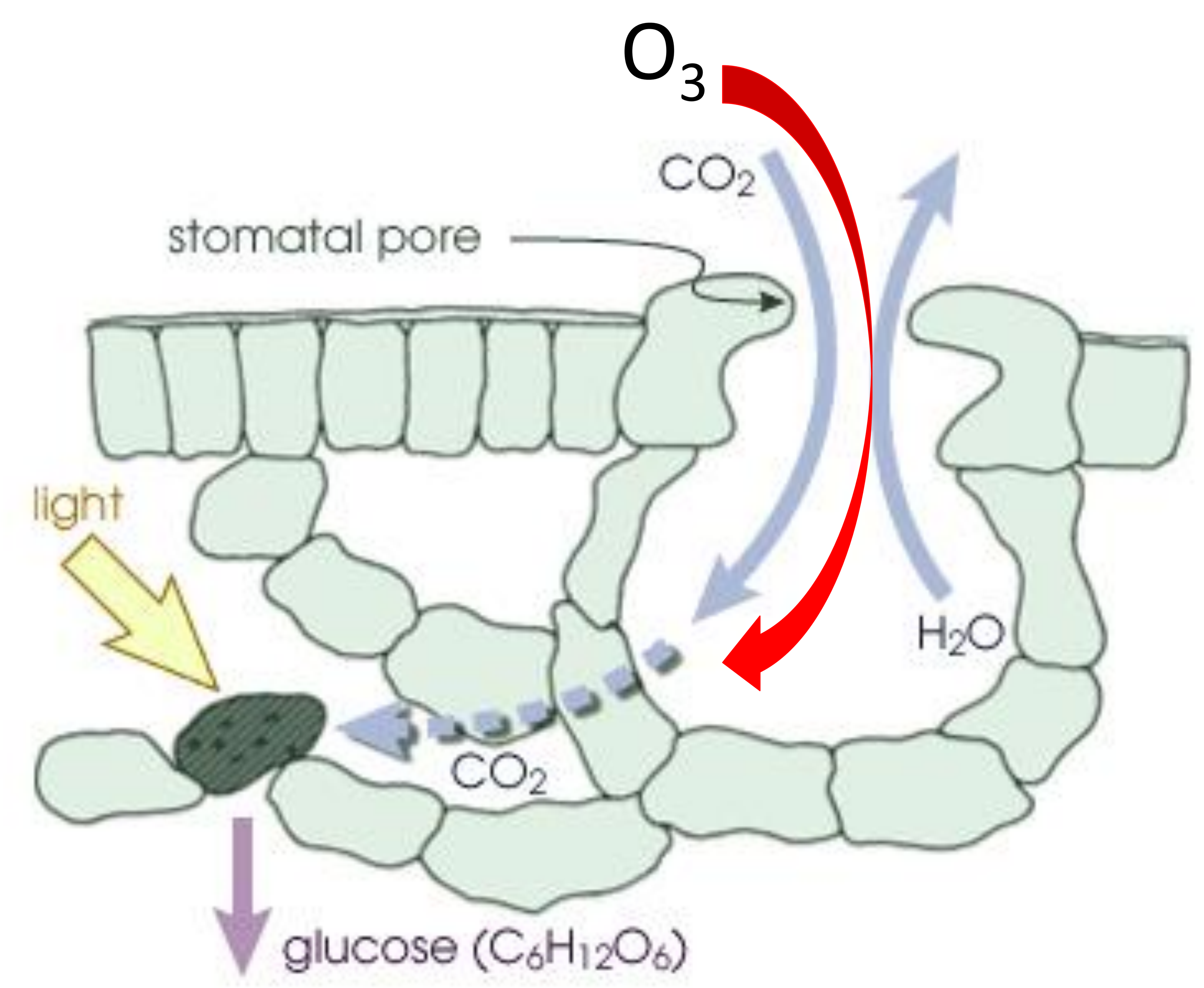
NERC SCIENCE OF THE ENVIRONMENT

Introduction

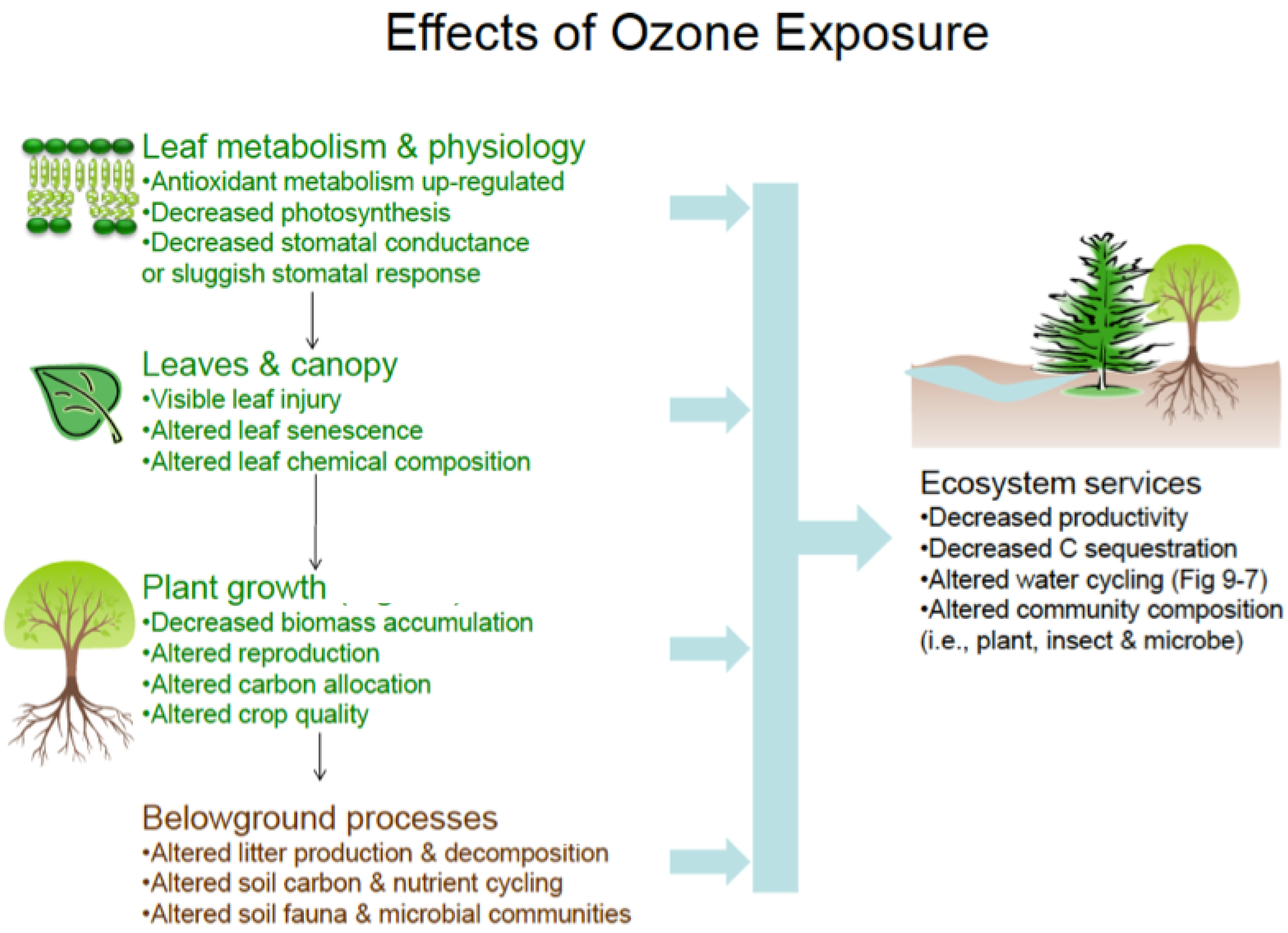


- Tropospheric ozone is a globally abundant and increasing air pollutant
- Secondary air pollutant formed by photochemical reactions with other air pollutants
- Rising background concentrations due to hemispheric transport
- A global problem

Introduction



www.nasa.gov.uk



Methods: Re-calibration of JULES for ozone damage

- Ozone damage in JULES modelled using flux-gradient approach of Sitch *et al*., (2007)

- Using observed dose-response relationships derived from latest field data (CLRTAP Mapping Manual (2011), Karlsson *et al*., (2007))

- Two Parameters:
    - *i)* F_{o3crit} – critical threshold
    - *ii)* *a* – fractional reduction of photosynthesis

  Both are plant functional type (PFT) specific

- 5 PFTs in JULES (broadleaf tree, needle-leaf tree, C_3 grass, C_4 grass, shrub)

- High and low plant ozone sensitivity

Methods: Stomatal conductance model

- Alternative stomatal conductance (*gs*) parameterization

$$g_s = 1.6RT_l \frac{A_{net}\beta}{c_a - c_i}$$

From:

$$c_i = (c_a - c_*)f0\left(1 - \frac{dq}{dqcrit}\right) + c_*$$

Simplified version of the Leuning (1995) empirical model

To:

$$c_i = c_a\left(\frac{g_1}{g_1 + \sqrt{dq}}\right)$$

Belinda Medlyn *et al.*, (2011) optimal stomatal model

Advantages of Medlyn *gs* model:

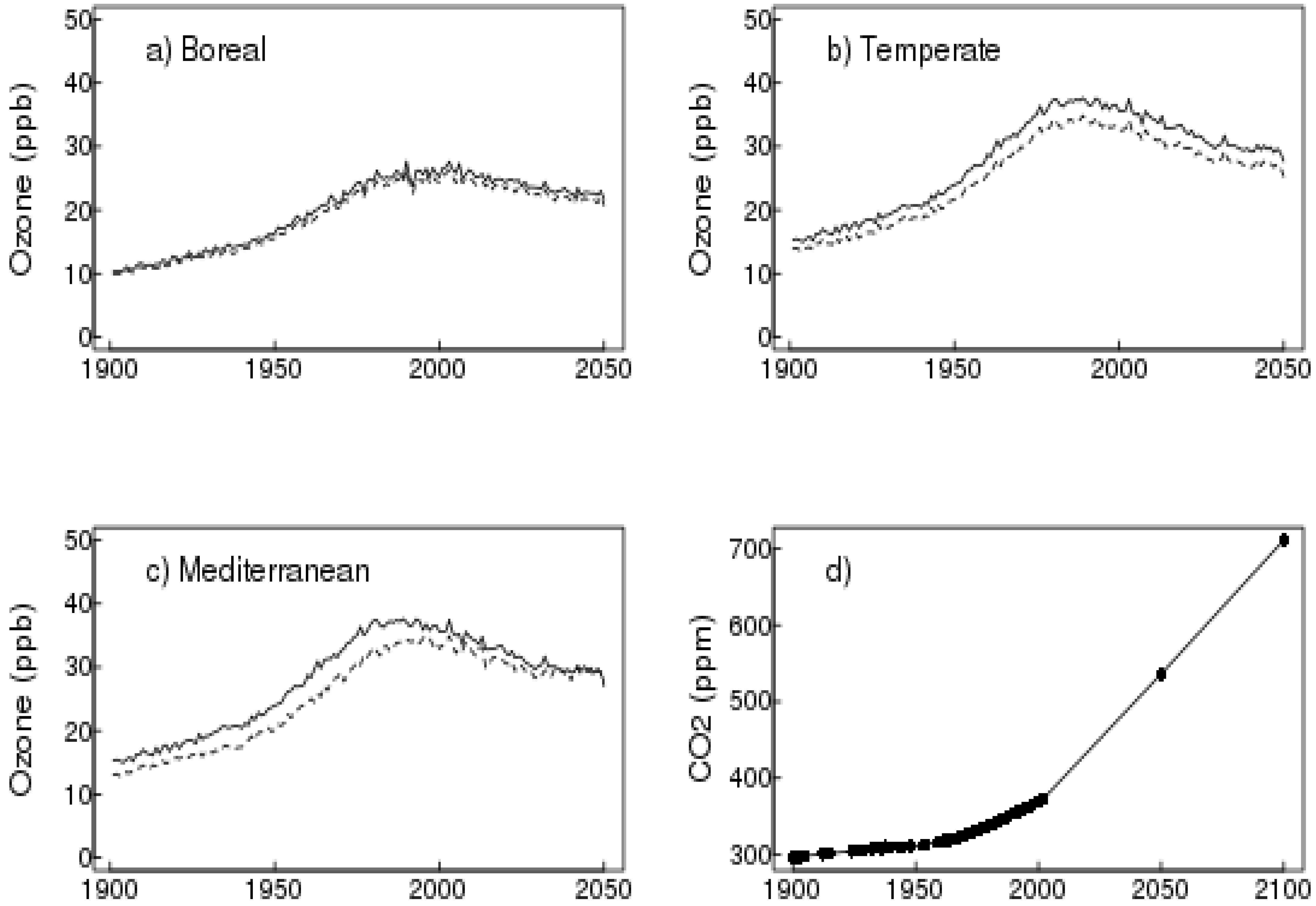
i) More realistic *gs* response to VPD
ii) Single parameter
iii) Easier to parameterise (Lin *et al.*, 2015)

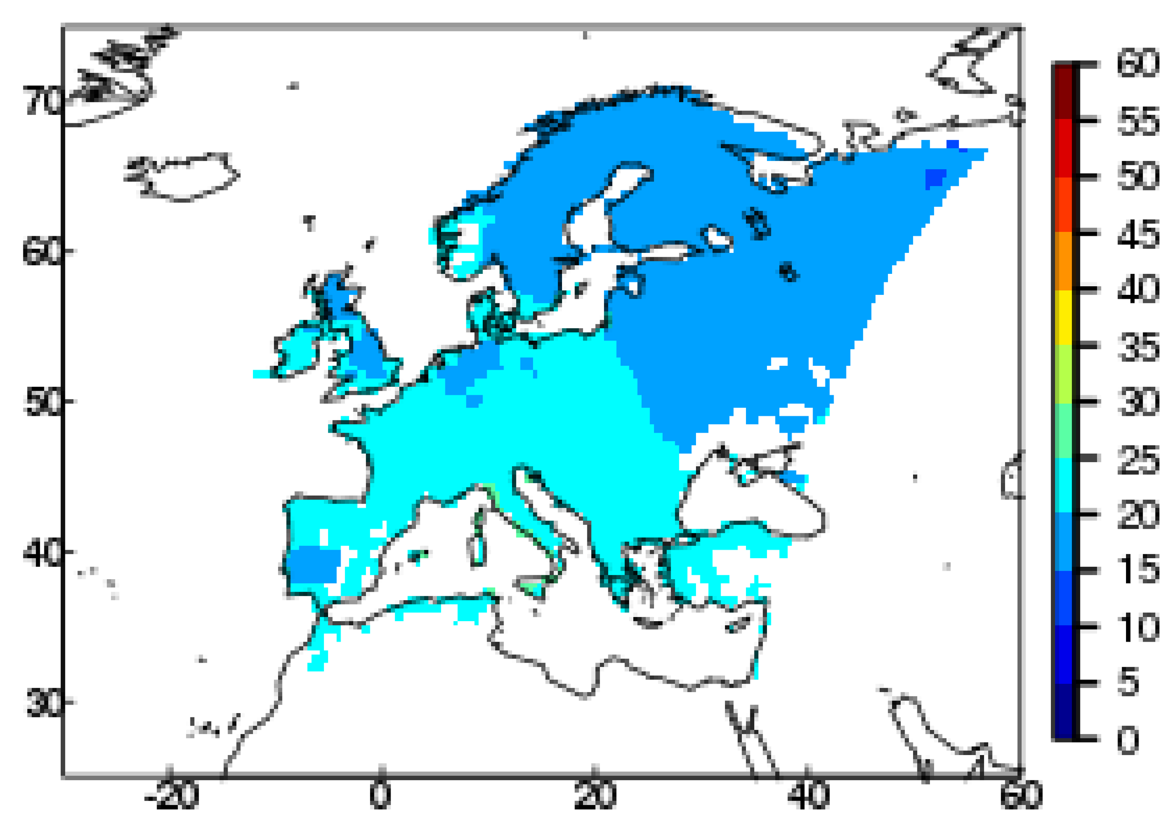
Methods: Model experiment

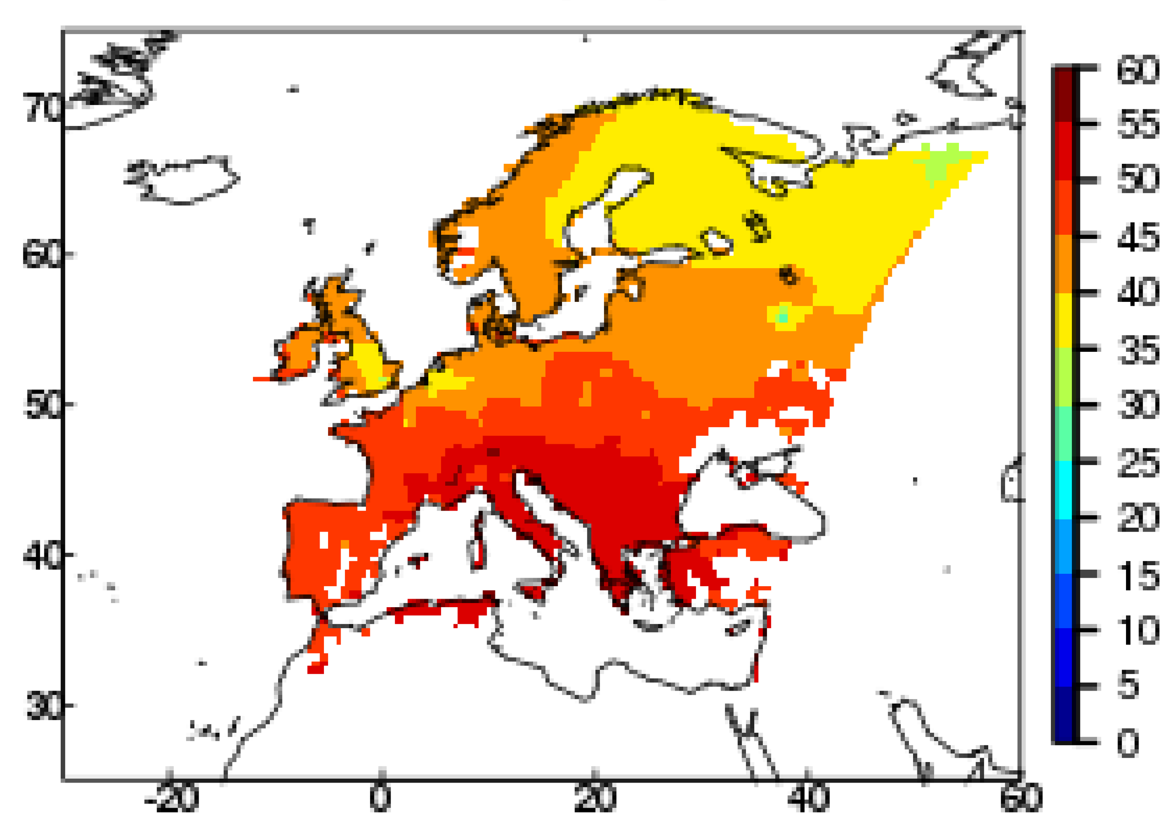
- Factorial suite of model experiments to investigate the temporal and spatial evolution of ozone impacts on European vegetation from **1901** to **2050**:

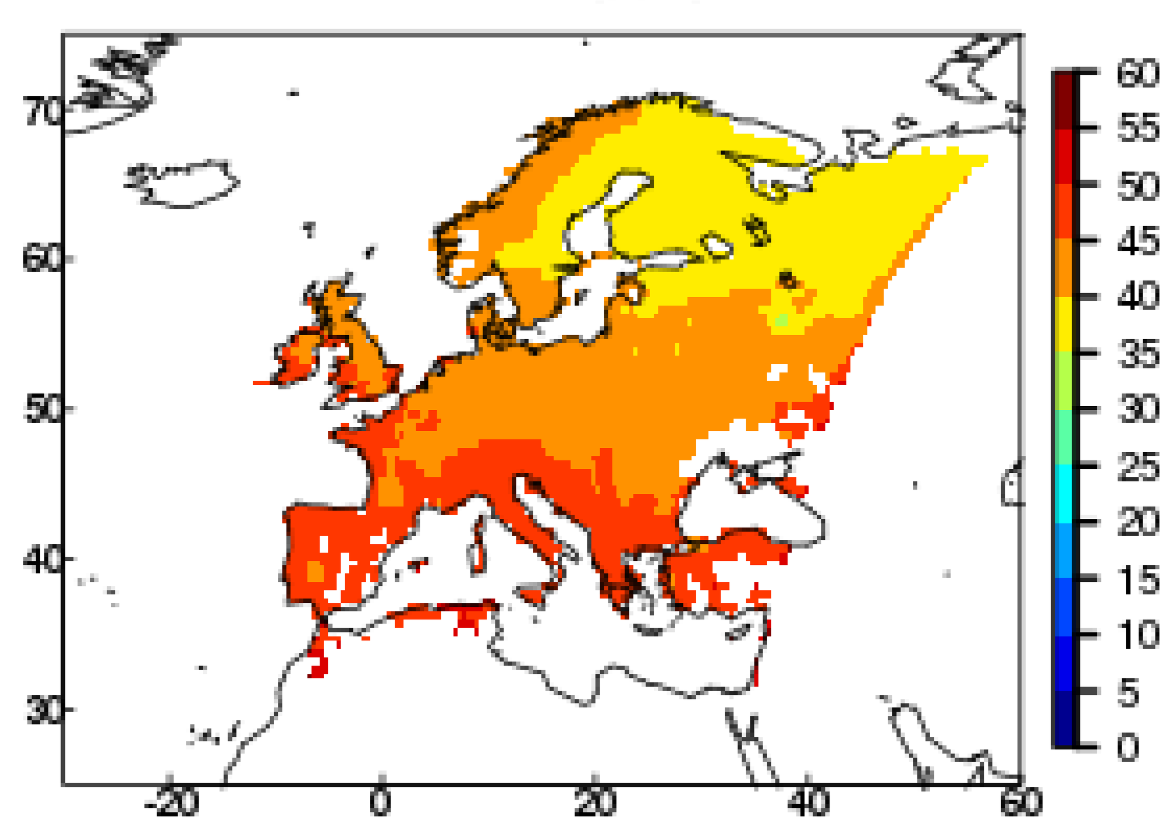
O3 : Fixed CO_2, varying O_3
CO2 : Varying CO_2, fixed O_3
CO2 + O3 : Varying CO_2, varying O_3

Ozone forcing: regional annual average (EMEP)



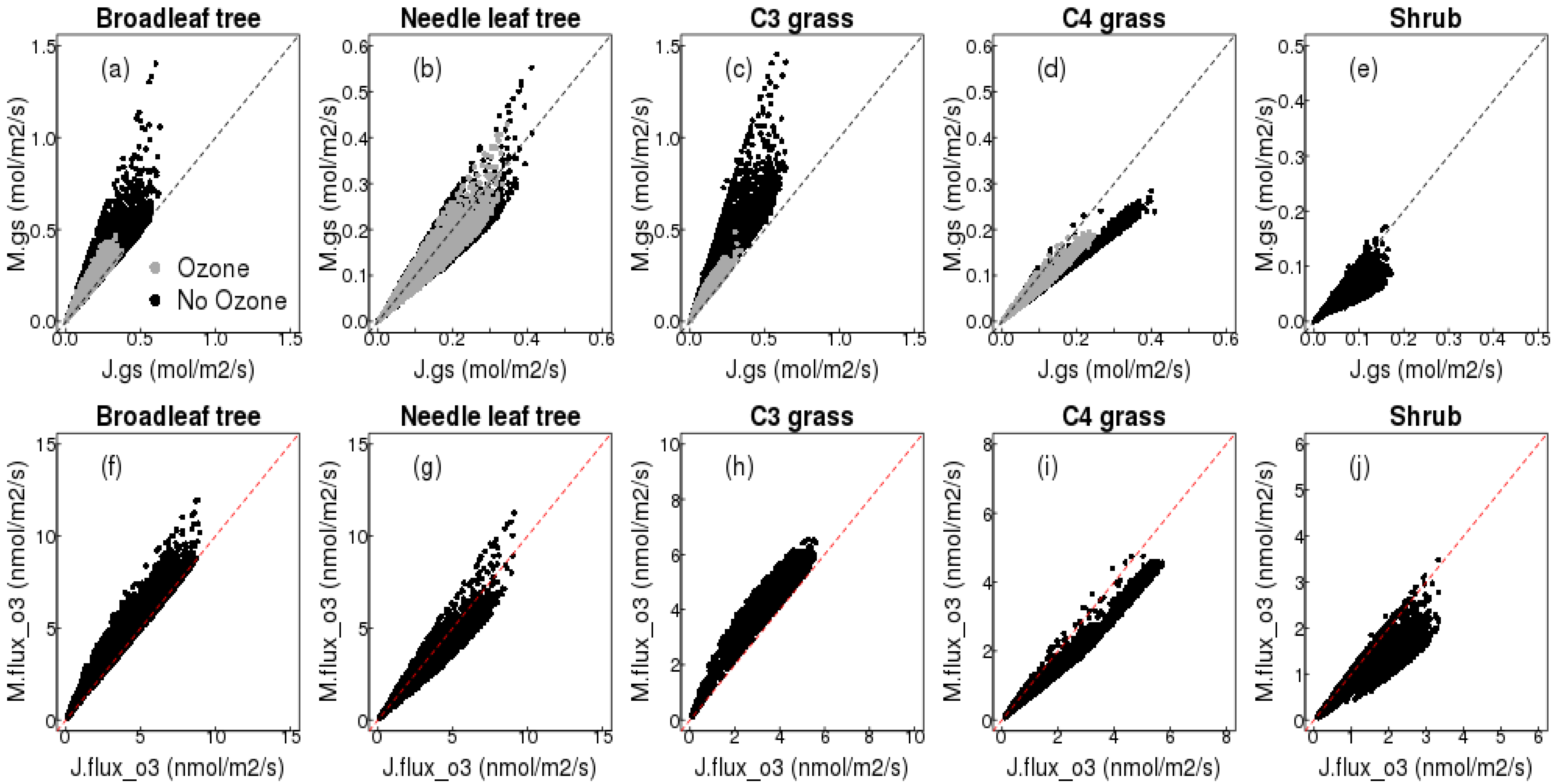






Results: Impact of *gs* model formulation

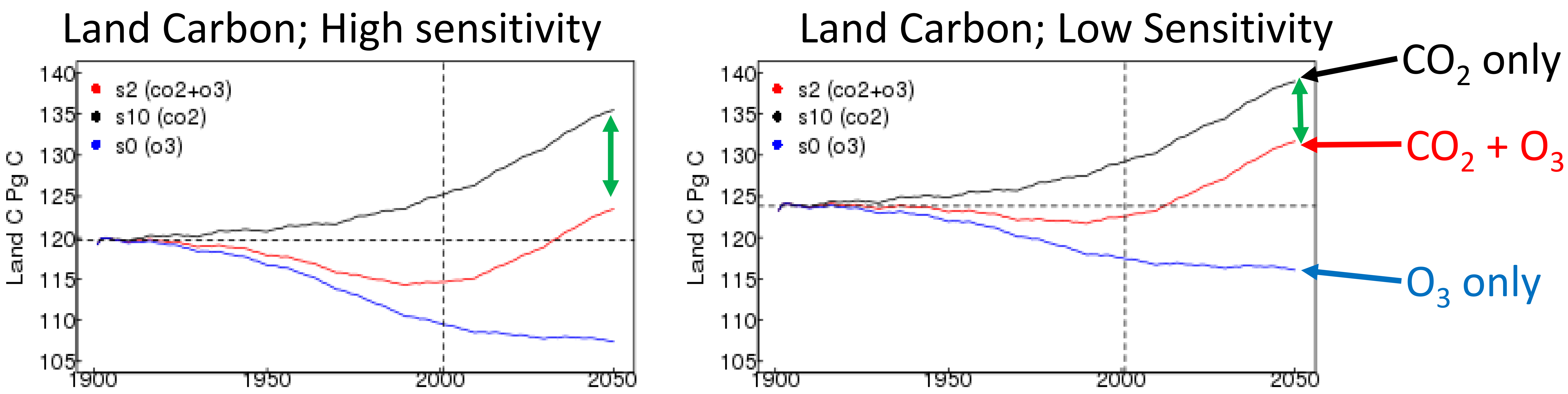
- Medlyn less conservative water use strategy BT and C3 grass
- Medlyn more conservative water use strategy NT, C4 grass and shrub



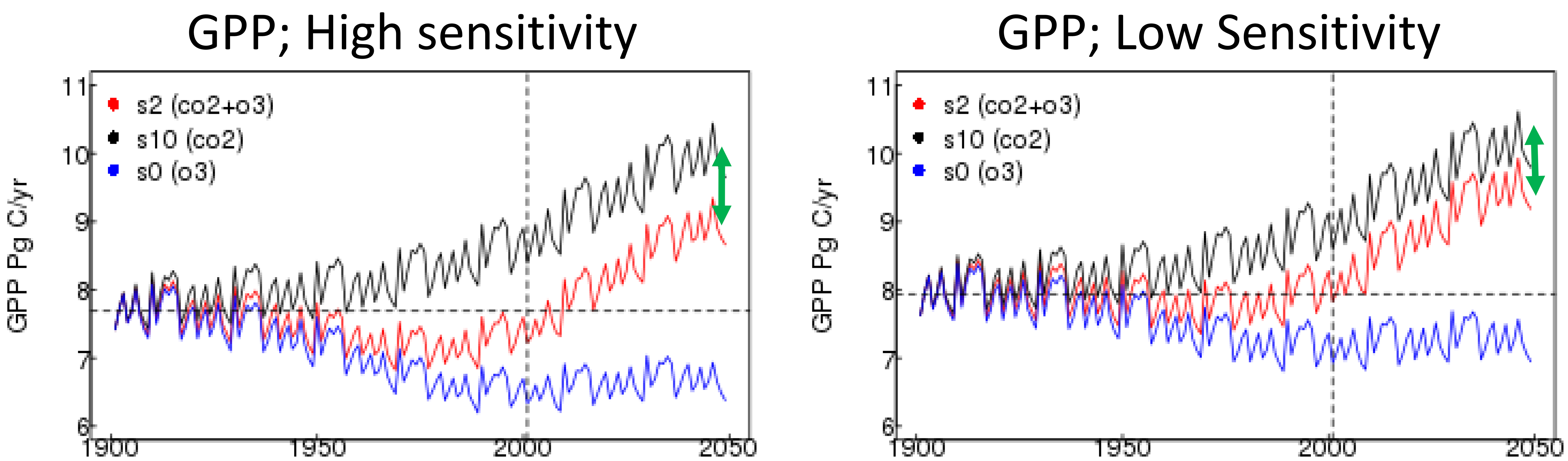
Results: 1901 to 2050

Potential gains in terrestrial carbon sequestration from CO_2 fertilisation partially offset by concurrent rises in tropospheric ozone

Land carbon storage:
-6 to -10 %

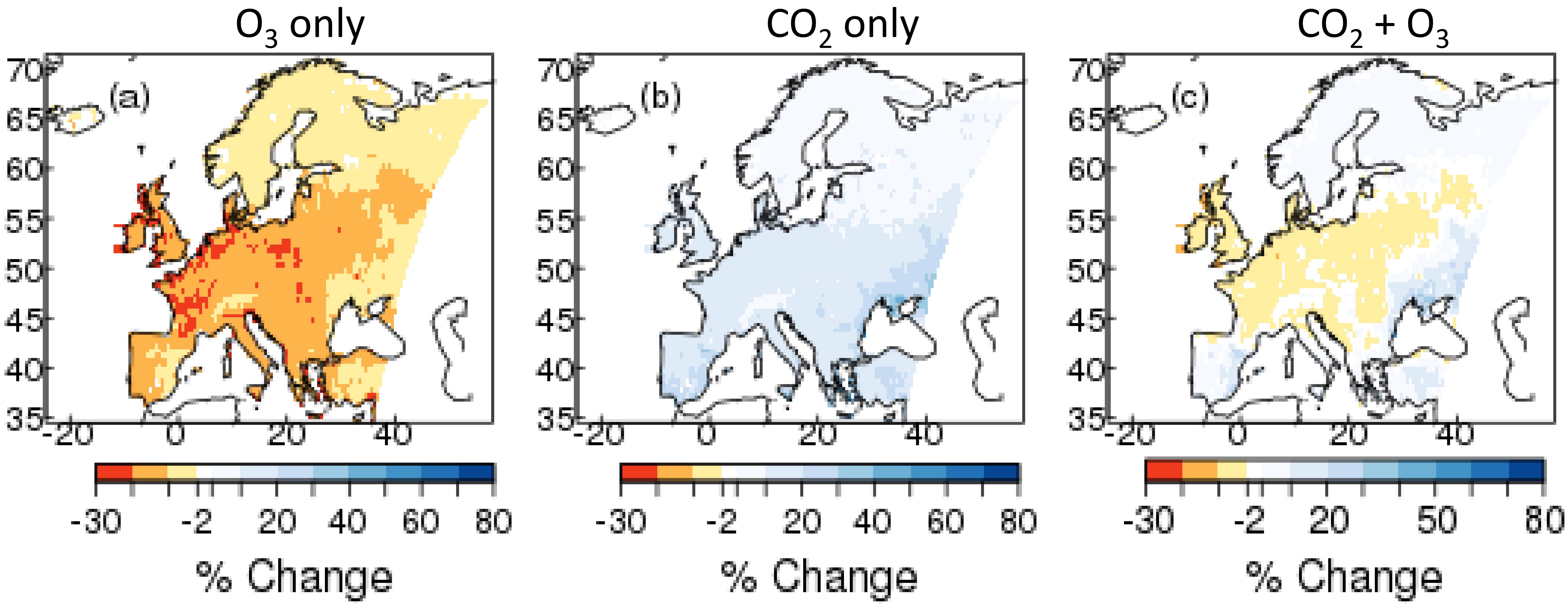


GPP :
-8 to -13 %



Results: 1901 to 2050

Land Carbon Storage: High Plant O_3 Sensitivity



Larger impacts for temperate Europe compared to boreal and Mediterranean regions

In many areas of temperate Europe, carbon stocks remain significantly reduced by 2050

Summary

- O_3 significantly compromises the European land carbon sink into the future
- Modelled terrestrial carbon dynamics sensitive to tropospheric O_3 and its interaction with atmospheric CO_2
- Effects of O_3 on plant physiology add to uncertainty of future trends in the land carbon sink, and climate-carbon feedbacks
- O_3 damage is a missing component of carbon cycle assessments, needs greater consideration in Earth system models

References

- Sitch S, Cox PM, Collins WJ, Huntingford C (2007) Indirect radiative forcing of climate change through ozone effects on the land-carbon sink. *Nature,* **448**, 791-794.

- Clrtap (2011) Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends: Chapter III Mapping Critical Levels for Vegetation. **www.icpmapping.org**.

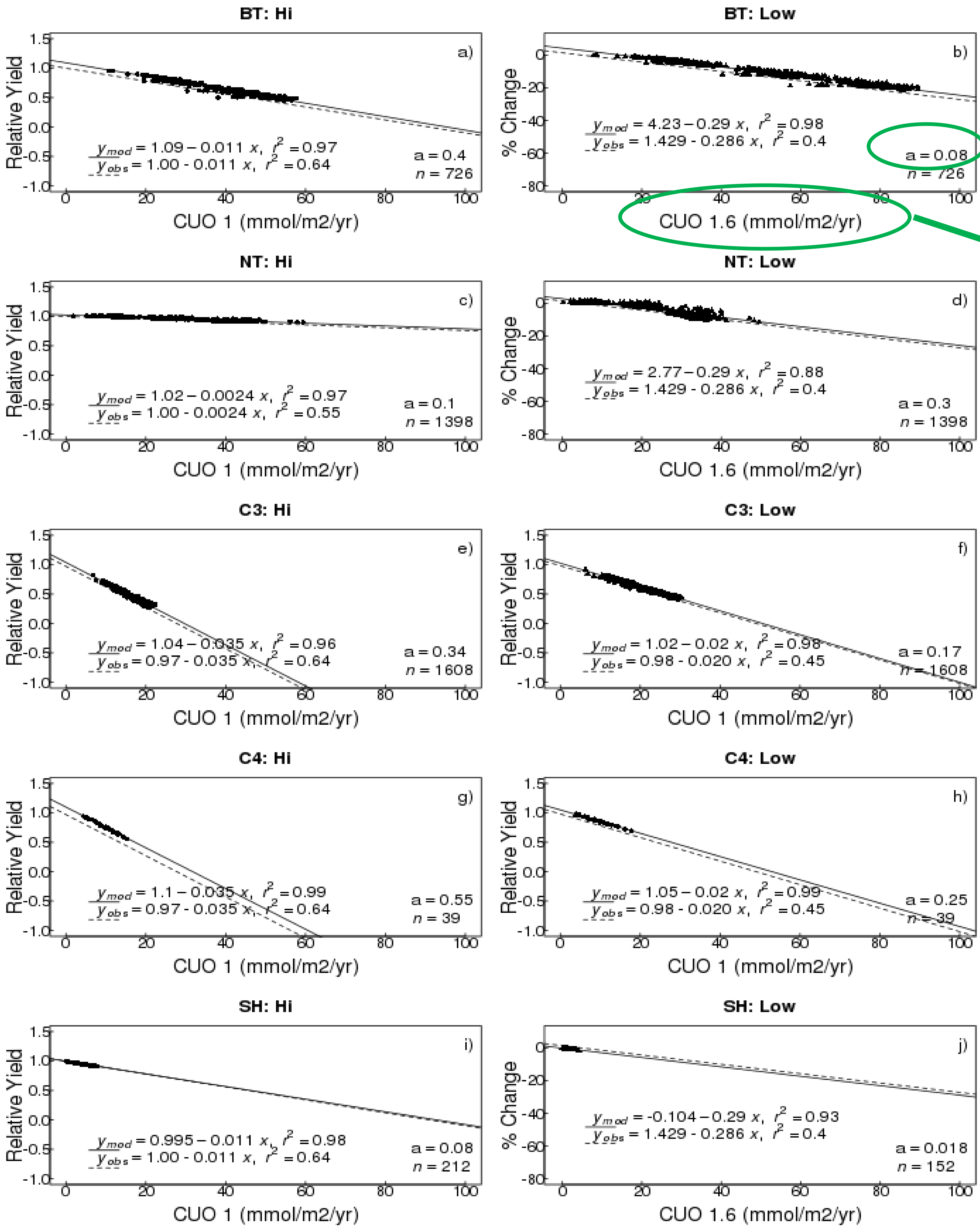
- Karlsson PE, Braun S, Broadmeadow M *et al.* (2007) Risk assessments for forest trees: The performance of the ozone flux versus the AOT concepts. *Environmental Pollution,* **146**, 608-616.

- Leuning R (1995) A critical appraisal of a combined stomatal-photosynthesis model for C3 plants. *Plant, Cell & Environment,* **18**, 339-355.

- Medlyn BE, Duursma RA, Eamus D *et al.* (2011) Reconciling the optimal and empirical approaches to modelling stomatal conductance. *Global Change Biology,* **17**, 2134-2144.

- Lin Y-S, Medlyn BE, Duursma RA *et al.* (2015) Optimal stomatal behaviour around the world. *Nature Climate Change,* **5**, 459-464.

Methods: Re-calibration of JULES for ozone damage



a – fractional reduction of photosynthesis

Fo3crit – critical threshold above which damage occurs