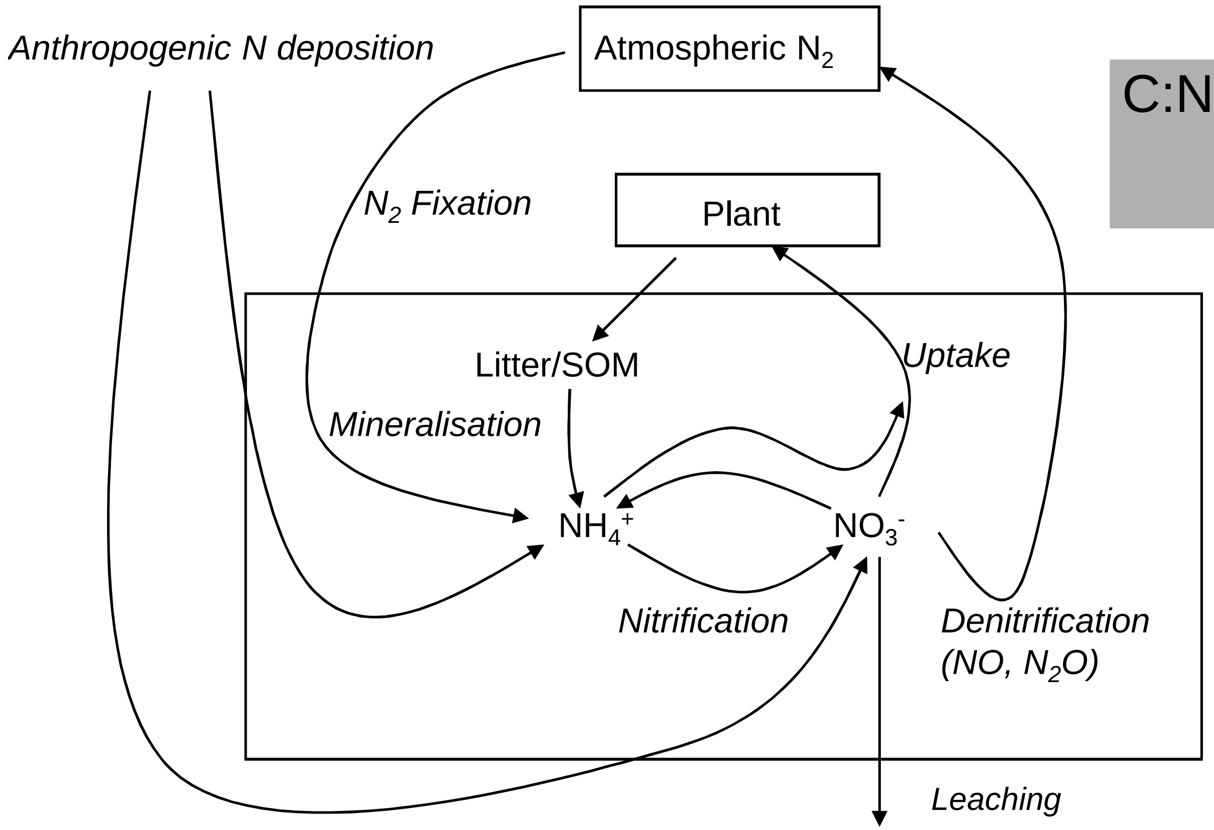
JULES- Plant Physiology

Stephen Sitch, Josh Fisher, Federica Pacifico, Lina Mercado, Richard Ellis, Doug Clark, David Galbraith, Chris Huntingford, Chris Jones, Sandy Harrison, Peter Cox, Olivier Boucher, Nicolas Bellouin, Patricia Cadule, Pierre Friedlingstein et al.

UNIVERSITY OF LEEDS
UNIVERSITY OF EXETER
UNIVERSITY OF OXFORD
Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL
University of BRISTOL
Met Office

Terrestrial Nitrogen Cycle



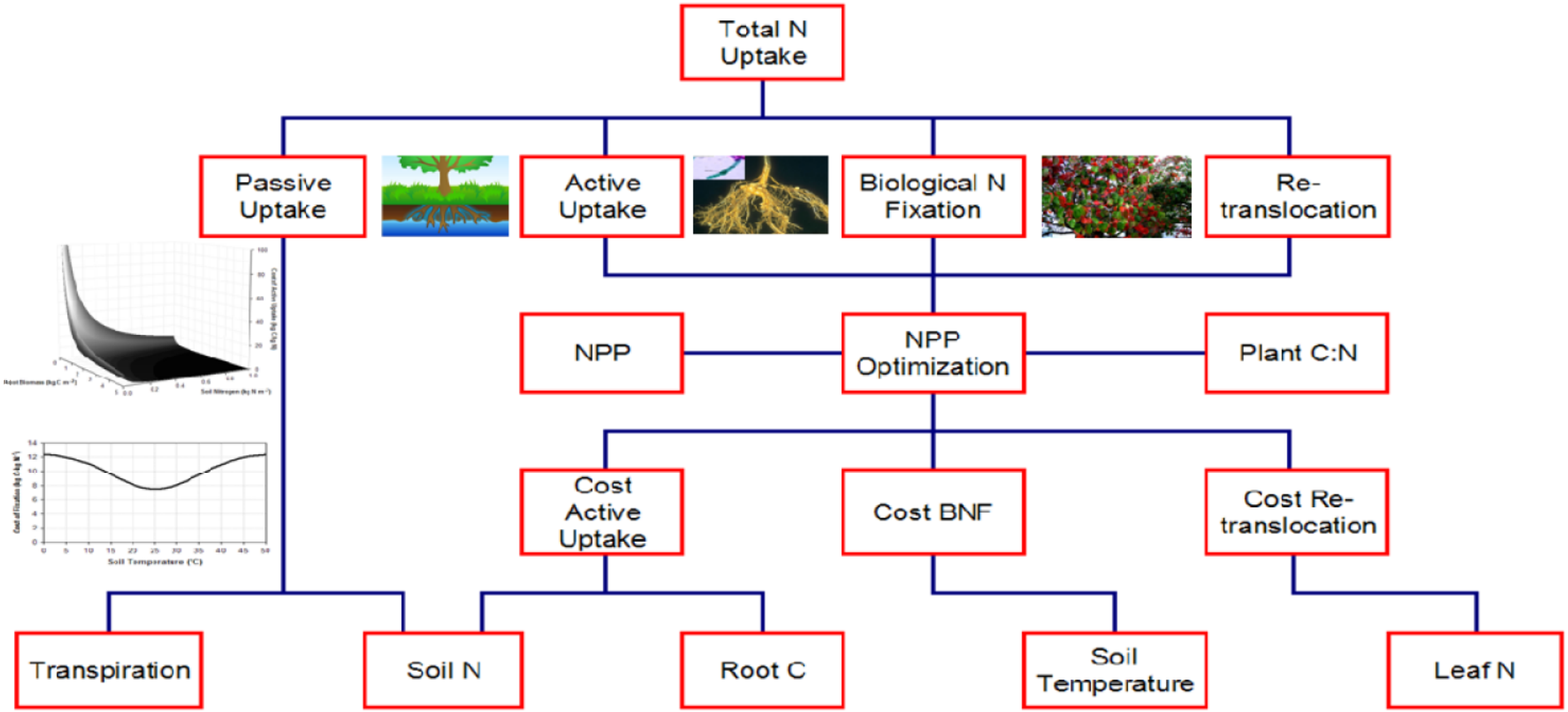
C:N Wood (150-500)

Leaves (30)

C:N Soils (15)

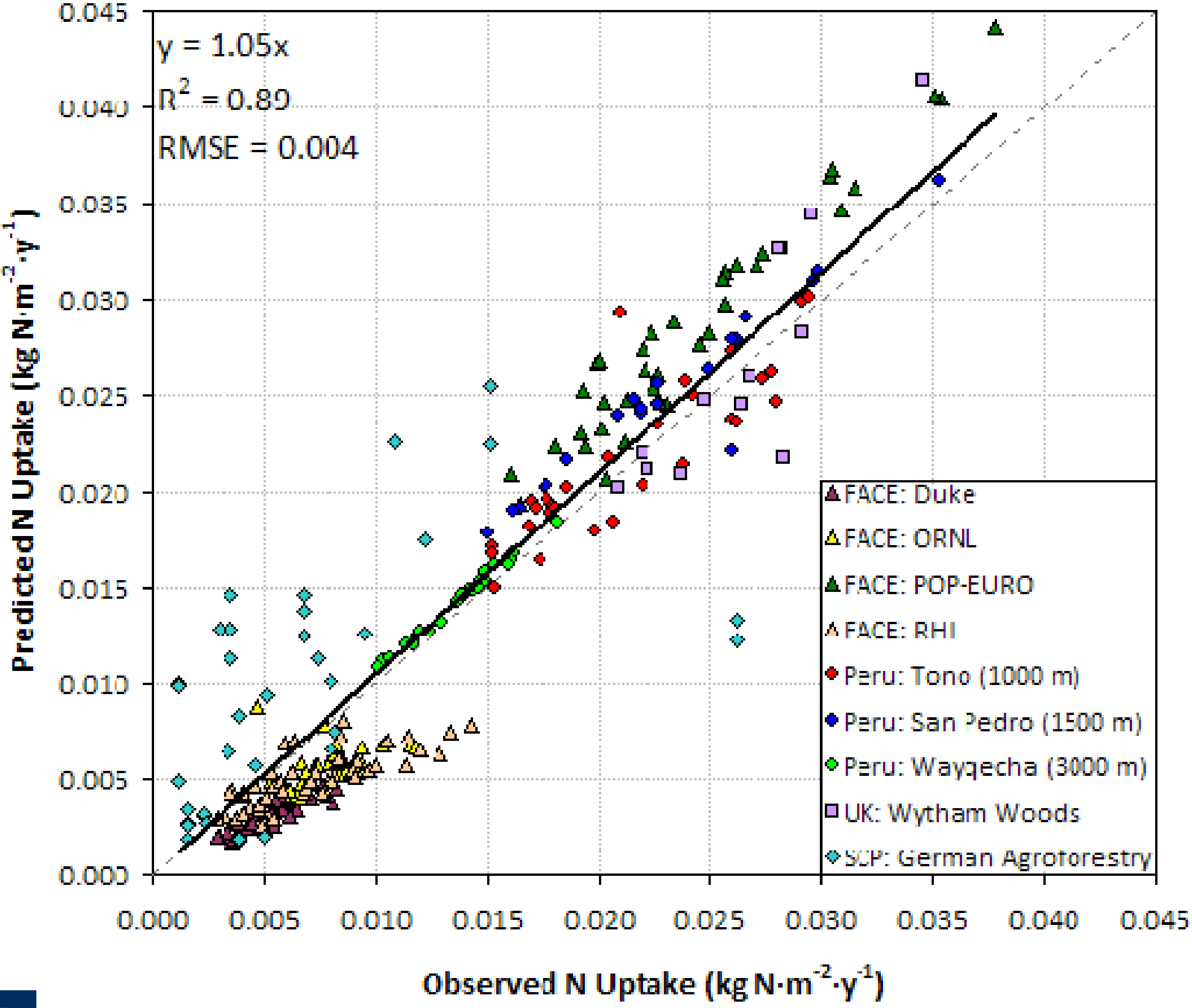
Competition between Microbes and Plants for Mineral N:
For C-sequestration want N in the plants

Fixation & Uptake of Nitrogen (FUN)



Fisher et al., GBC submitted

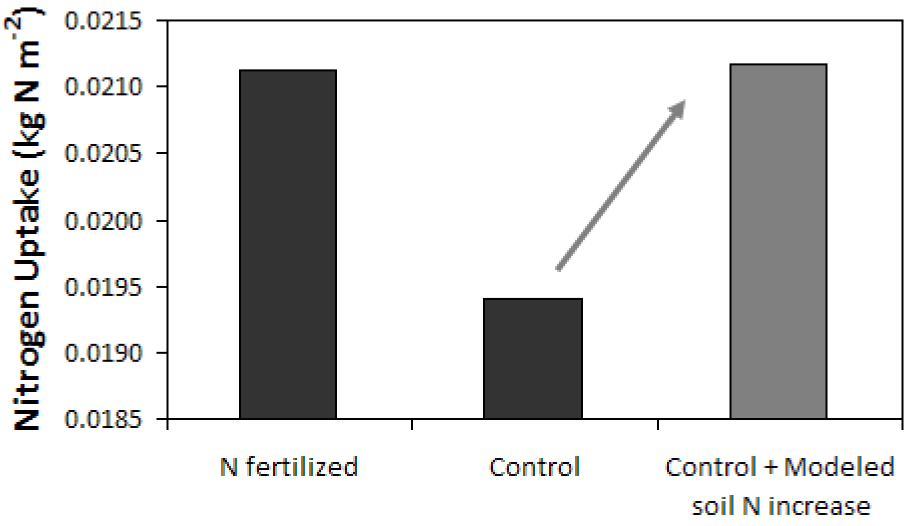
Fixation & Uptake of Nitrogen (FUN)

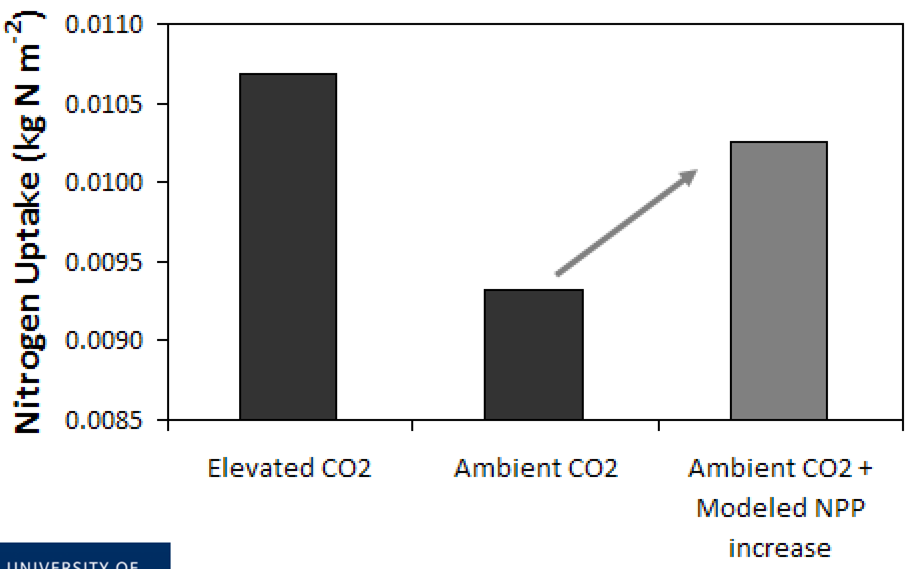


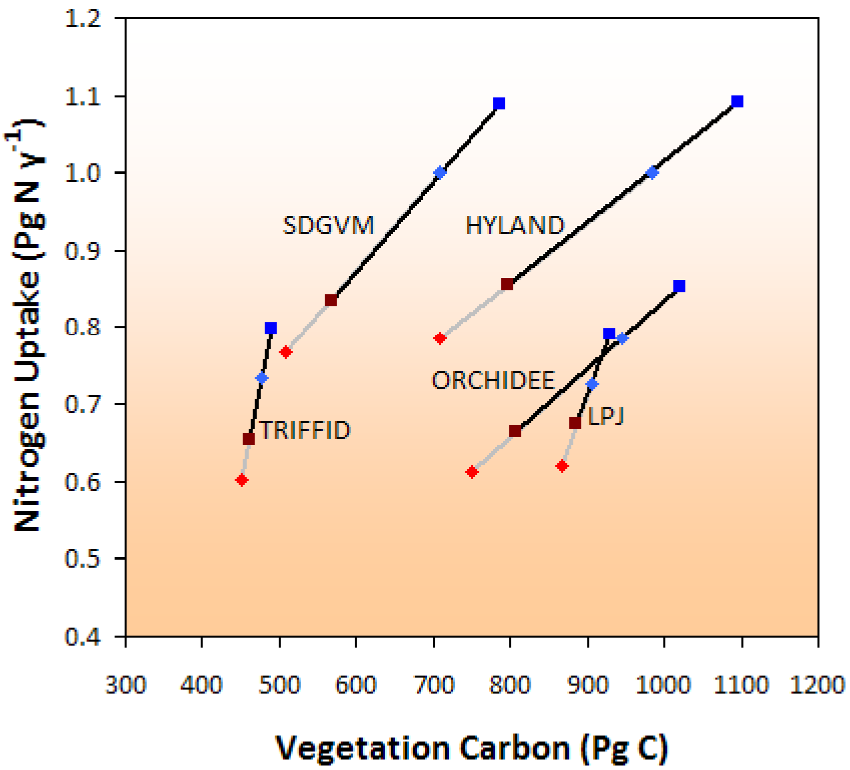
UNIVERSITY OF OXFORD

Fisher et al., GBC submitted

Fixation & Uptake of Nitrogen (FUN)



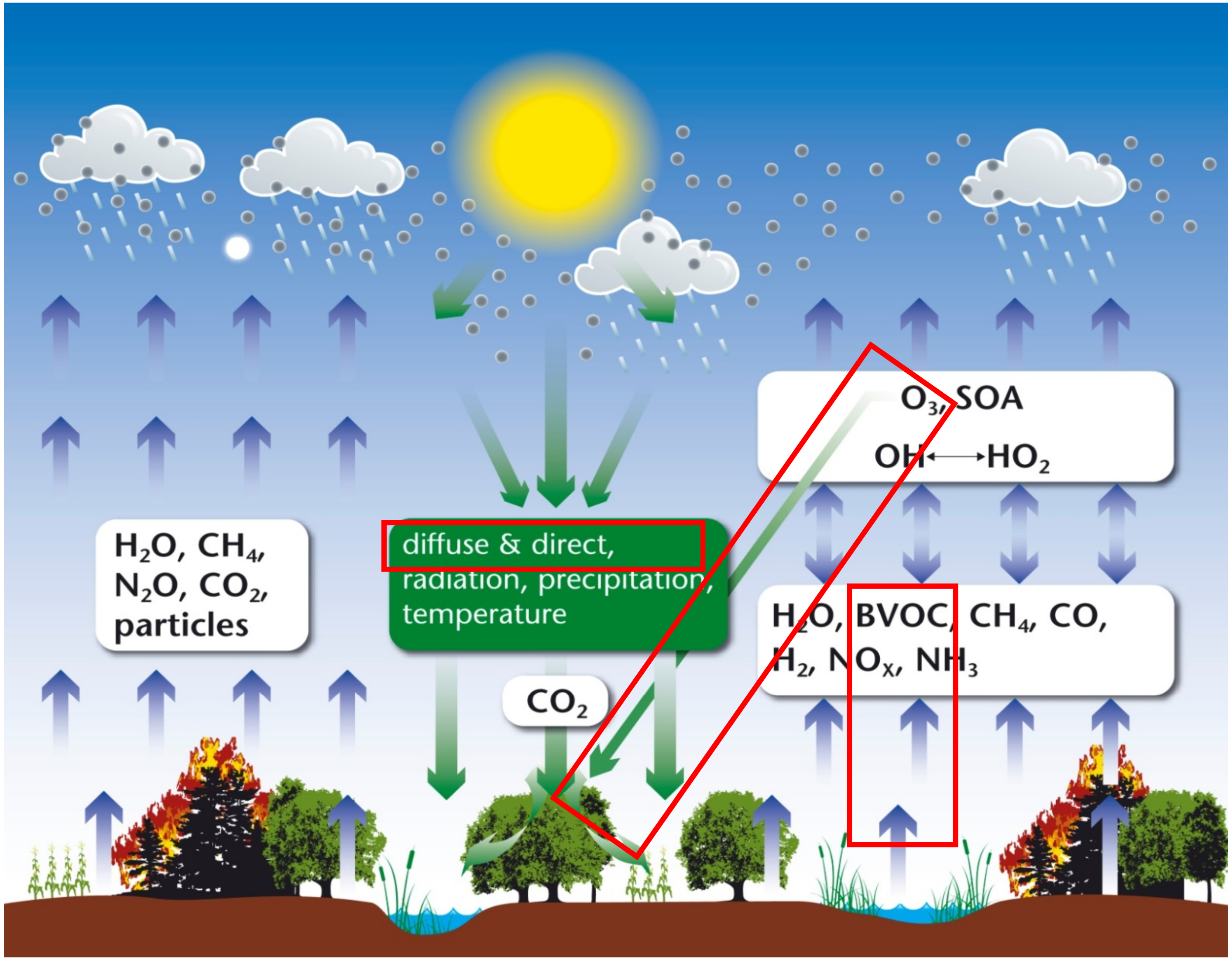




UNIVERSITY OF OXFORD

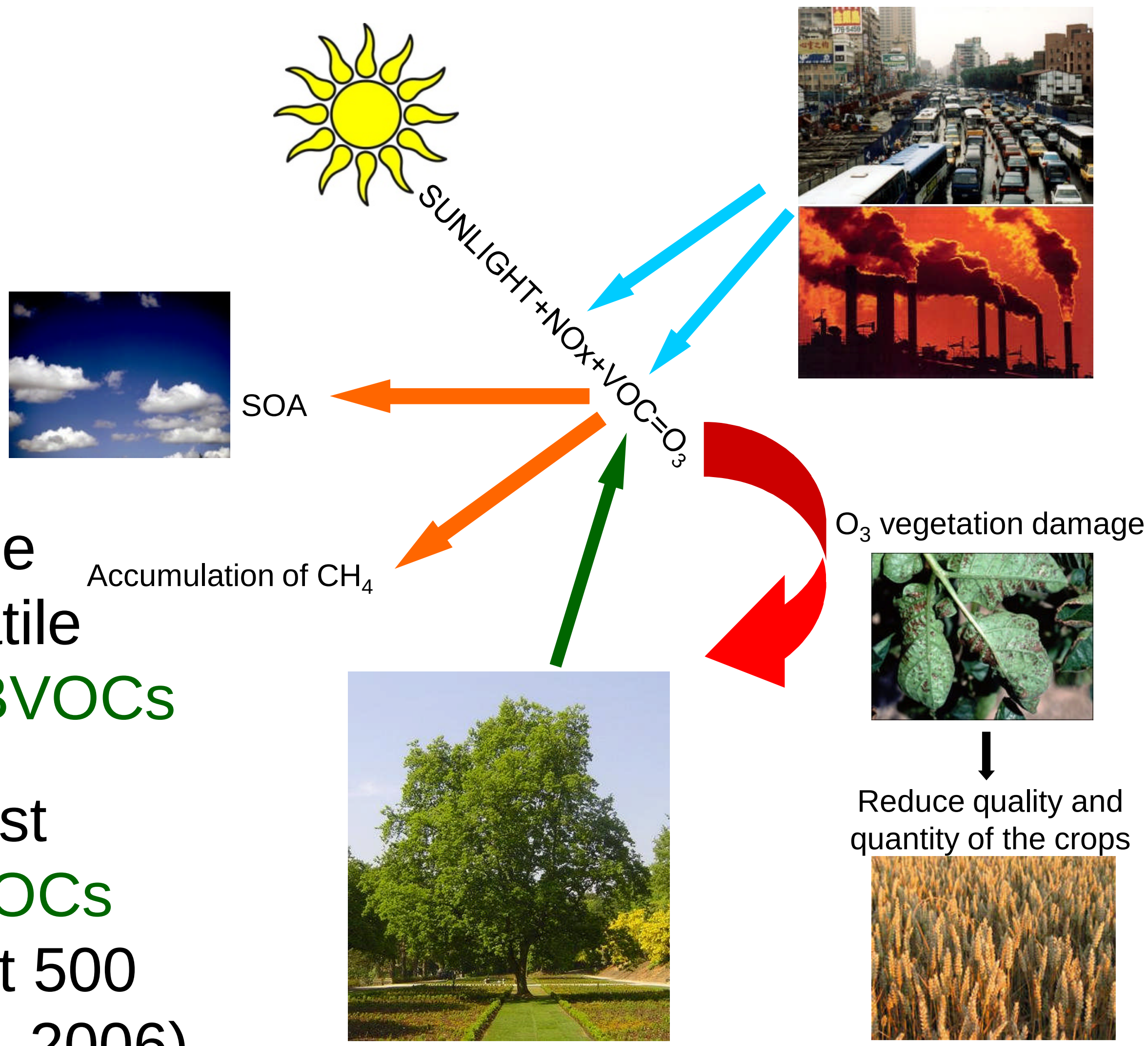
Fisher et al., GBC submitted

Modelling Land Trace-Gas Exchange



Arneth, Sitch, Bondeau et al., GCB submitted

Biogenic Isoprene Emission for Air Quality & Climate



Vegetation emits a wide range of Biogenic Volatile Organic Compounds BVOCs

Isoprene has the largest emission flux of all BVOCs with estimates of about 500 TgC/y (Guenther et al., 2006)

Pacifico, Harrison, Jones et al., in prep

Modelling Biogenic Isoprene Emissions

Process-based model for isoprene emission [Arneth et al., 2007]

Assumes that all isoprene emitted from the leaves has been synthesized in chloroplasts via the DXP pathway and that a certain proportion of electrons absorbed by leaves is going to isoprene synthesis.

$$I = \varepsilon_S \frac{(A + R_d)}{7} f_T \cdot f_{CO_2}$$

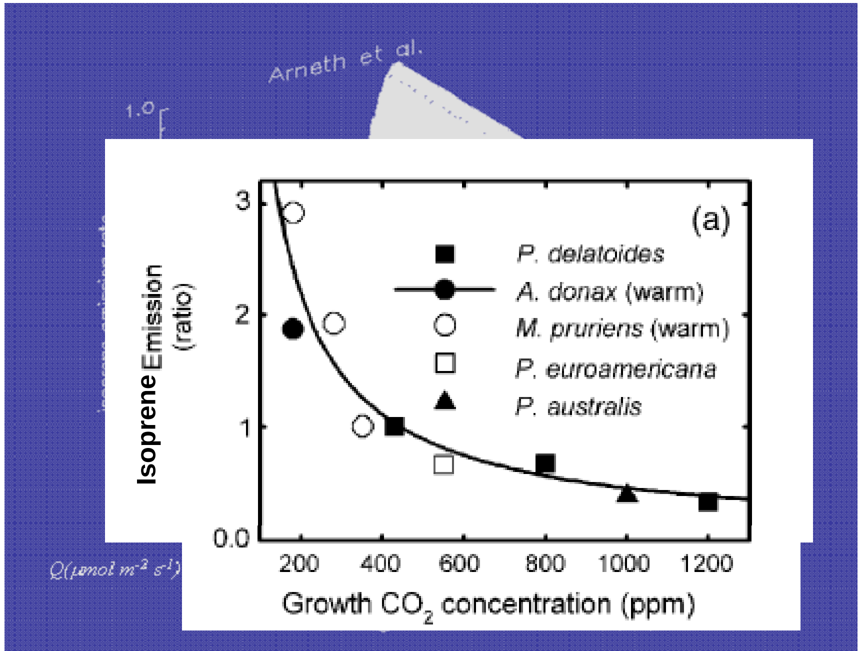


Figure 6 *Possell et al., 2005*

I	**isoprene emission (mgC/m^2/h)**
A	**net photo**synthesis rate (mol/m^2/h)
R_d	respiration rate (mol/m^2/h)

$\varepsilon_S = \frac{7 \cdot I_S}{A_S + R_{dS}}$ electron fraction used for isoprene production (PFT dependent) (mgC/mol)

$f_T = \exp(a_T(T - T_S))$ temperature factor, a_T is an empirical parameter equal to 0.1

$f_{CO2} = \frac{CO_{2S}}{CO_2}$ atmospheric CO_2 concentration factor

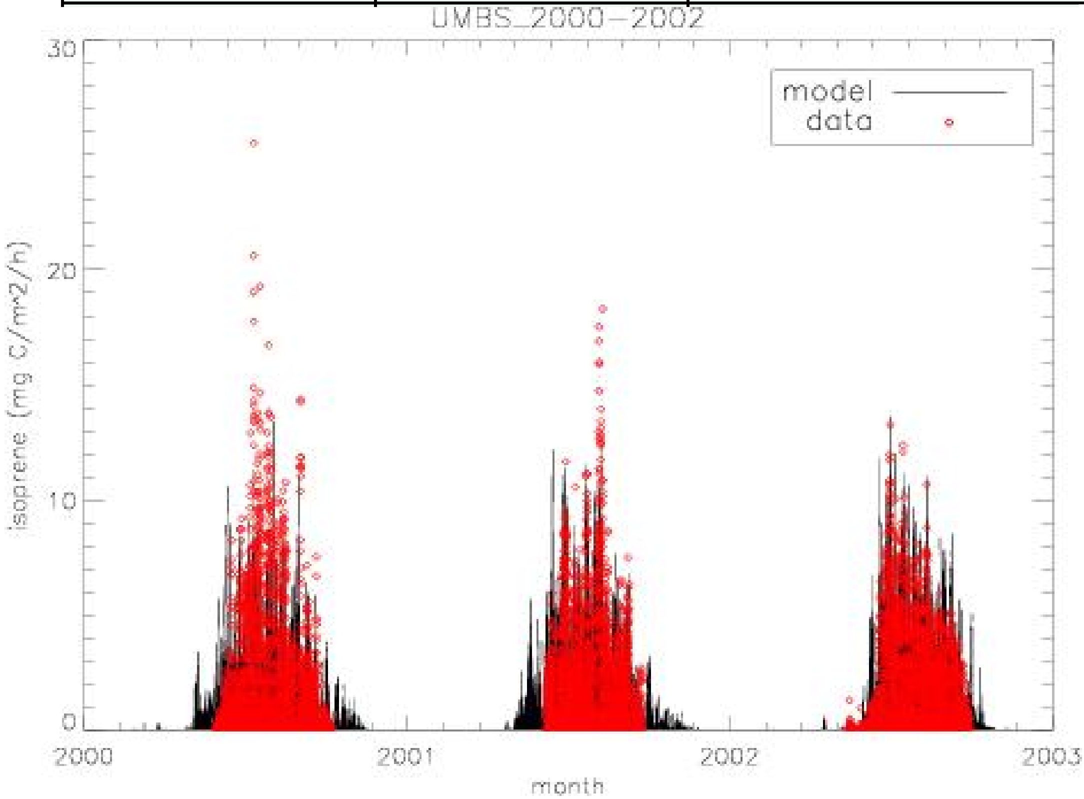
--$_S$ indicates standard conditions, T=30°C and PPFD=1000μmol/m^2/s

Useful for future projections, as it's mechanistic

Pacifico, Harrison, Jones et al., in prep

Modelling Evaluation of Isoprene Emissions

Site	Record period	Tree species PFT	Measurement technique	Reference
University of Michigan (UMBS) 45°30' N; 84°42' W	May 2000-Oct 2002 (~5 months every year)	*Populus grandidentata, P. tremuloides, Fagus grandifolia, Betula papyrifera, Acer rubrum, A. saccharum, Qiercus rubra,* **Deciduous broadleaf forest**	eddy covariance fast isoprene sensor	*Pressley et al., 2005*

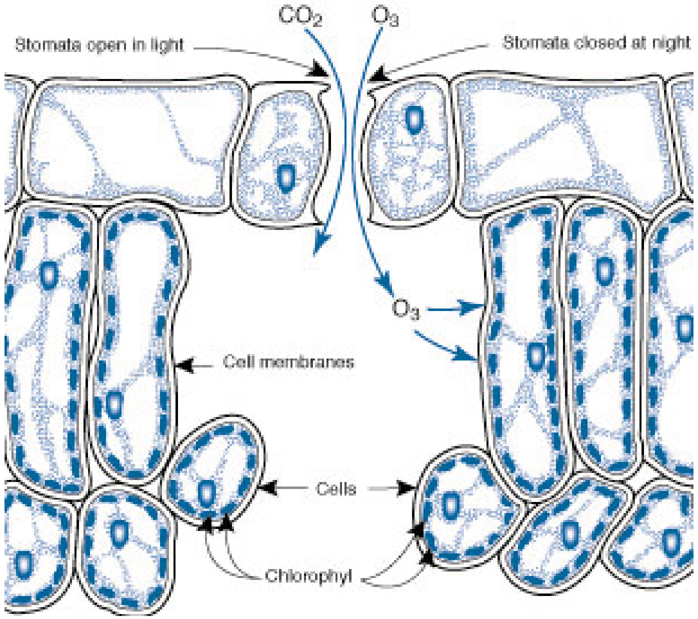


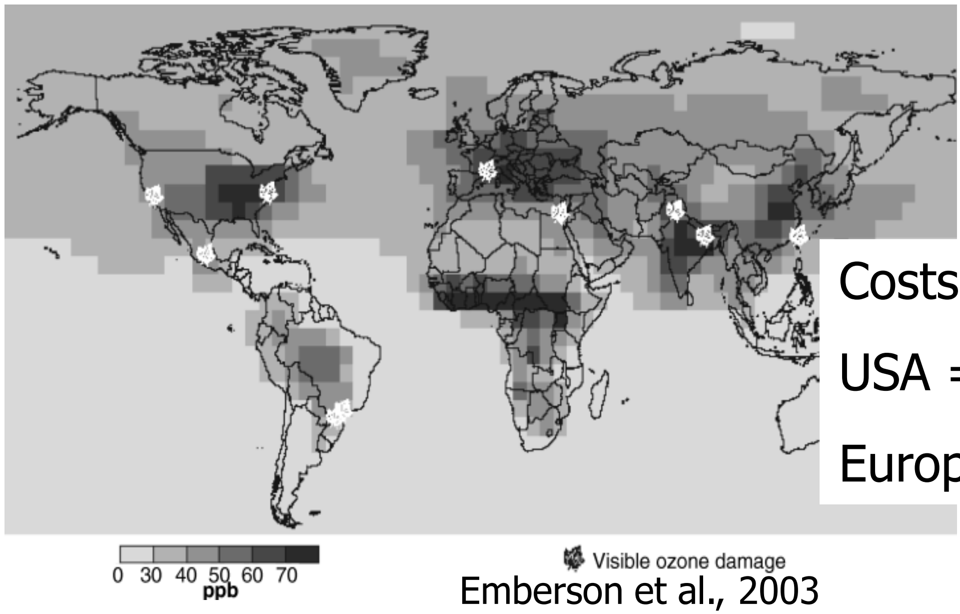
JULES phenology has been modified to delay leaf onset and speed up fall

A time-lag of two/three weeks between the onset of photosynthesis and that of isoprene emission has been observed in various experiments (Monson et al., 1994; Fuentes et al., 1999)

Pacifico, Harrison, Jones et al., in prep

Plant Ozone Injury





Emberson et al., 2003

Costs associated with reduction in crop yields:

USA = US$2-4 billion (Murphy et al. 1999)

Europe = 4 billion EU (Holland et al. 2002)

Plant – Ozone - Water Interactions

Hydrological Cycle

TOTAL RUNOFF LOW, x10^12 m3/yr 29.3787

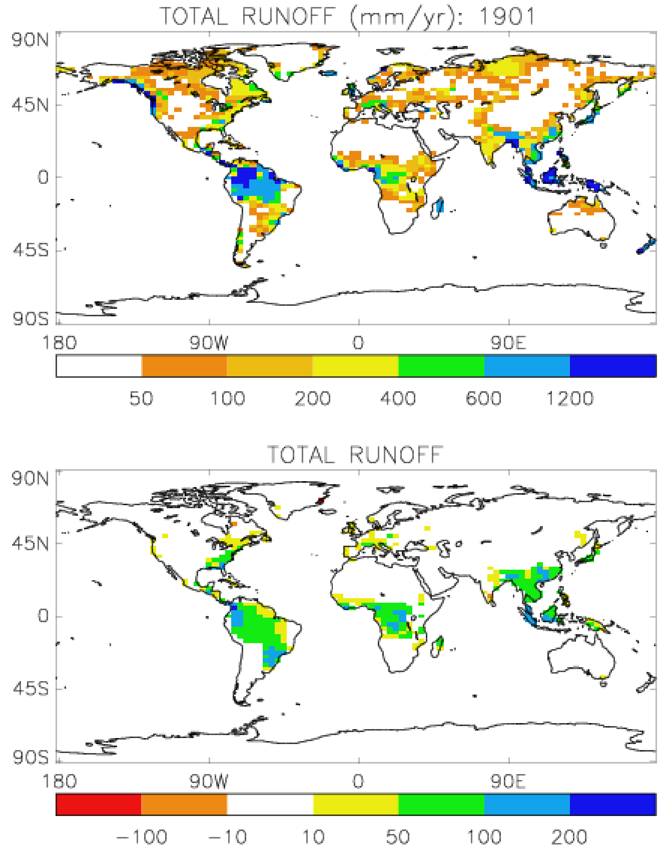
TOTAL RUNOFF HIGH, x10^12 m3/yr 30.0169

% Change (1901-1995) in RUNOFF

HIGH	
X(CO2)	2.2
X(O3)	5.6
X(O3CO2)	7.5
LOW	
X(CO2)	2.6
X(O3)	2.7
X(O3CO2)	5.0

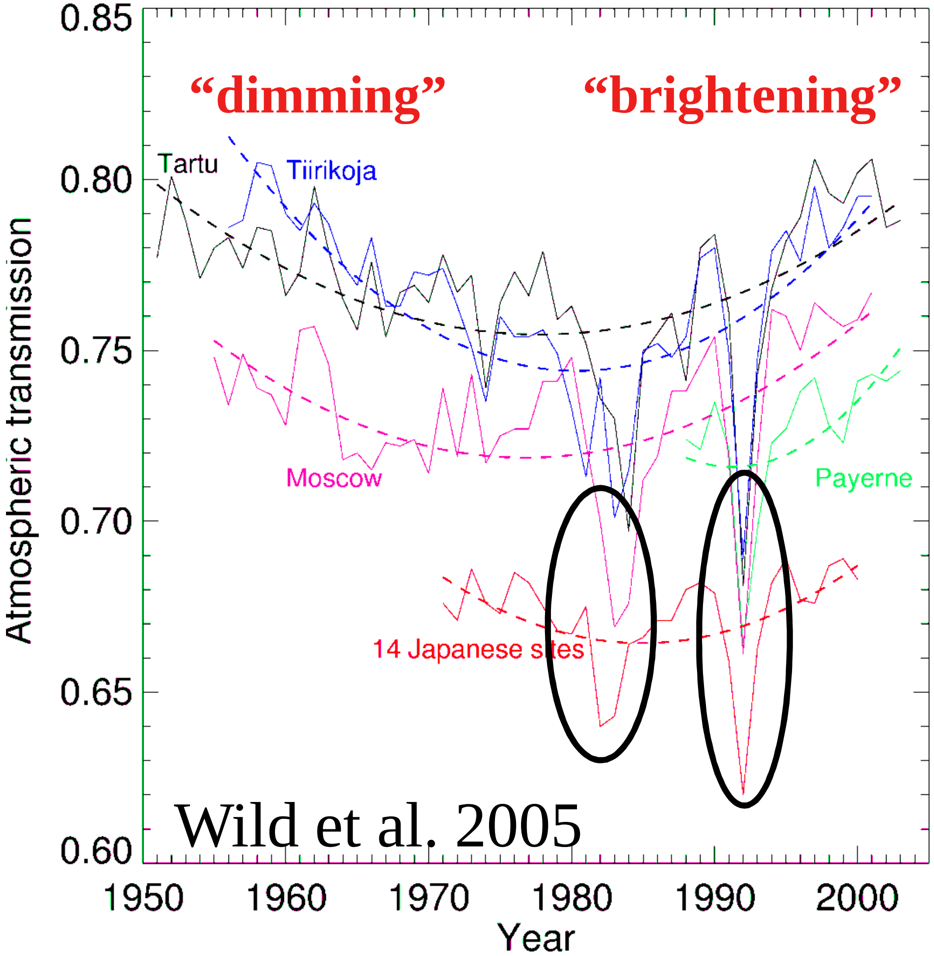
% change (1901-1995) in GS

HIGH	
X(CO2)	-4.3
X(O3)	-7.3
X(O3CO2)	-10.4
LOW	
X(CO2)	-4.6
X(O3)	-4.6
X(O3CO2)	-8.4



- From a recent meta-analysis by Wittig, Ainsworth & Long, 2007:
- % change in Gs ambient o3 vs charcoal filtered (zero o3) = -13%
- % change in Gs elevated o3 vs charcoal filtered (zero o3) = -10%
- % change in Gs ambient o3 vs elevated o3 = -6%

Global Dimming & Brightening



Decrease in surface radiation (1950-1980)

Stanhill and Cohen 2001, Liepert 2002, Wild et al 2005

Subsequent increase radiation (1980-2000) **Wild et al 2005, 2007**

Linked to changes in cloudiness & anthropogenic aerosol emissions

Volcanic eruptions
El Chichón 1982 and Pinatubo 1991

Mercado et al., Nature, 2009

Counteracting effects of changes in Radiation on Plant Photosynthesis

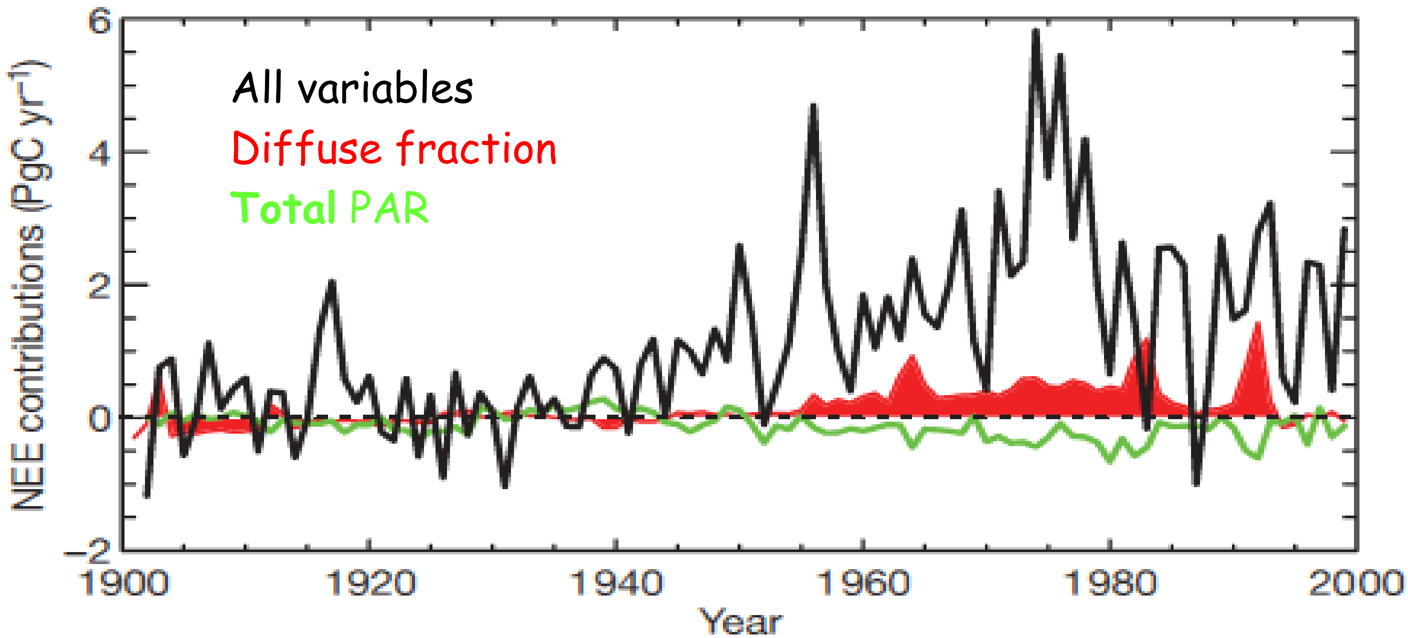
Increase (scattering) aerosols/clouds

Decrease radiation surface → Decrease photosynthesis

Increase diffuse fraction → Enhancement of photosynthesis

Mercado et al., Nature, 2009

Contributions to Global Land Sink



<u>During 1960-2000 (dimming & brightening periods)</u>

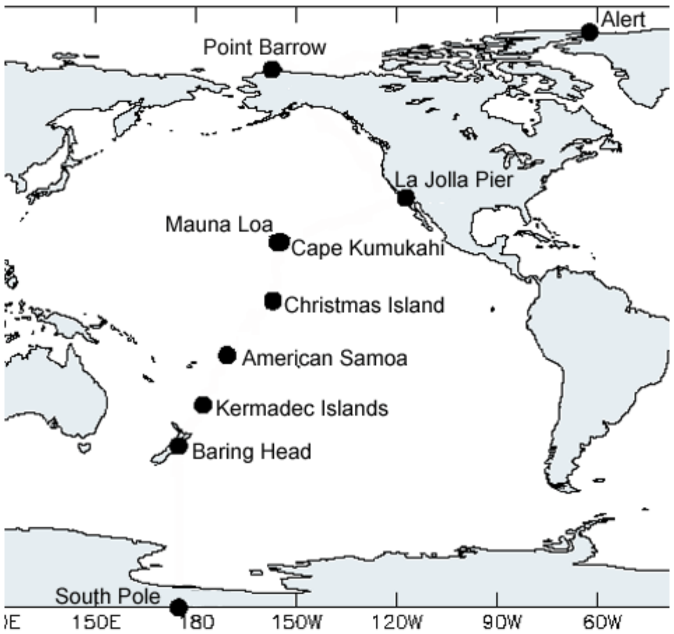
Diffuse radiation fertilization effect	+23.7%
Reductions in total PAR	-14.4%
Net balance	+9.3%

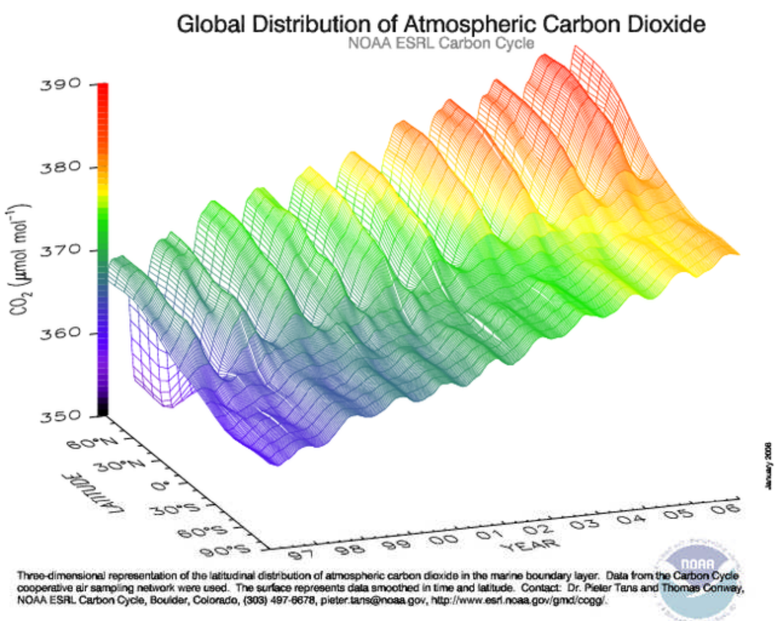
Diffuse radiation fertilization overwhelms "global dimming"

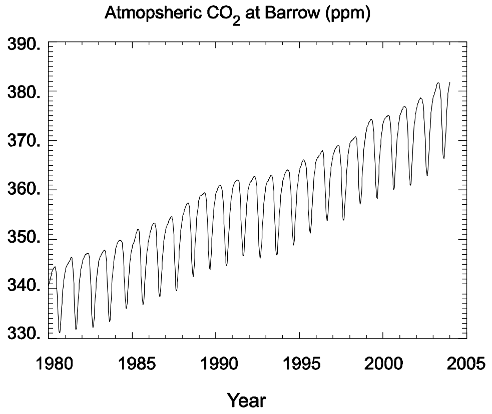
Steeper GHG emission cuts required to stabilize climate if anthropogenic aerosols decline as expected

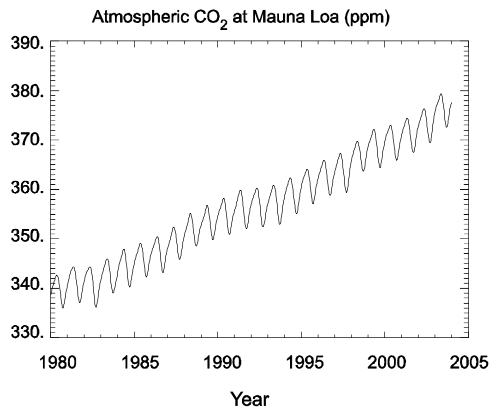
Mercado et al., Nature, 2009

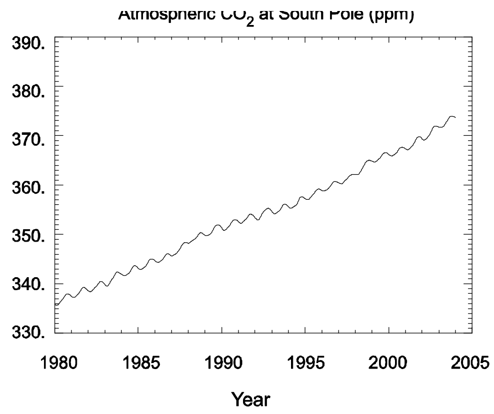
Seasonal cycle at different Monitoring stations





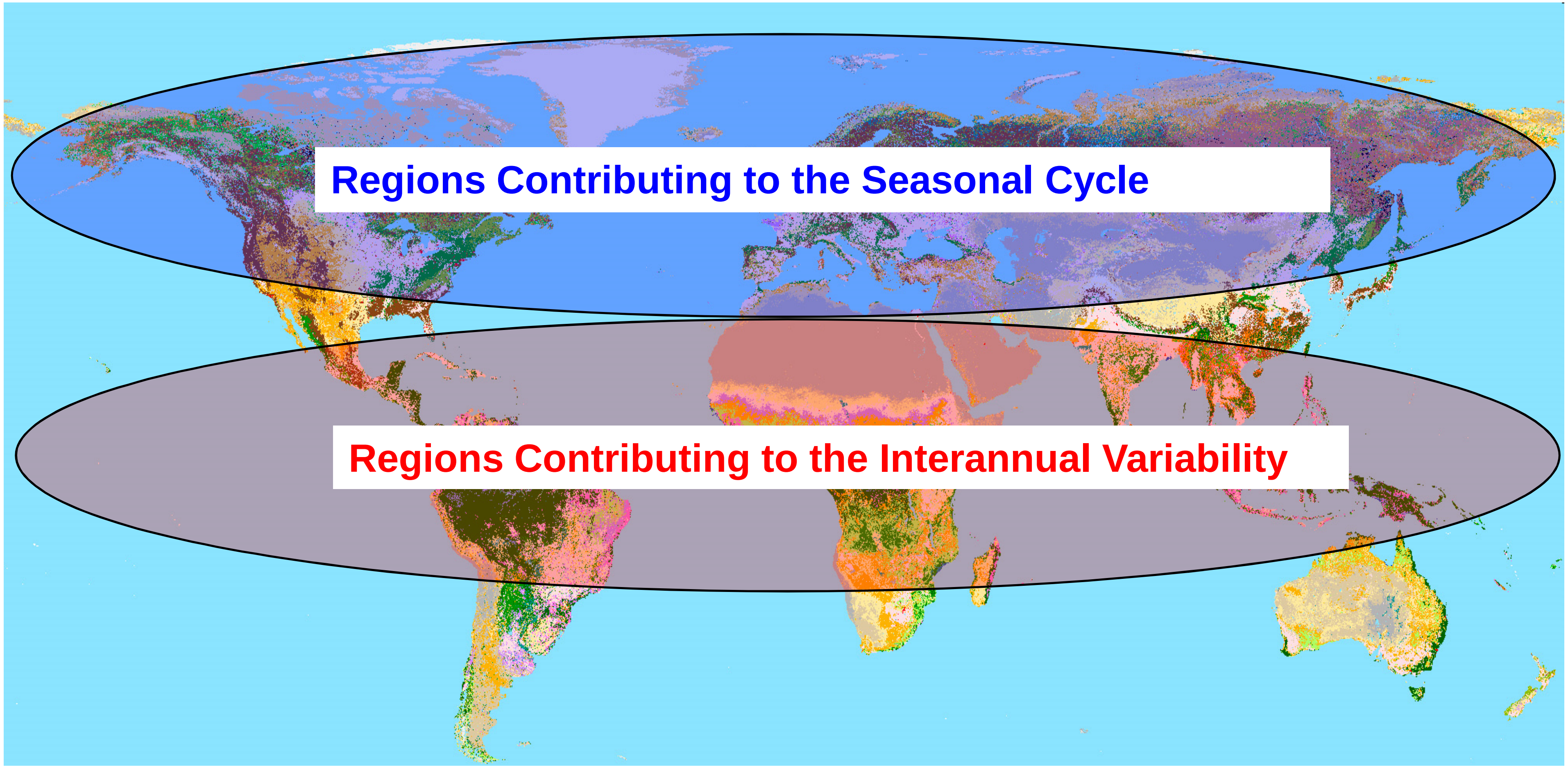






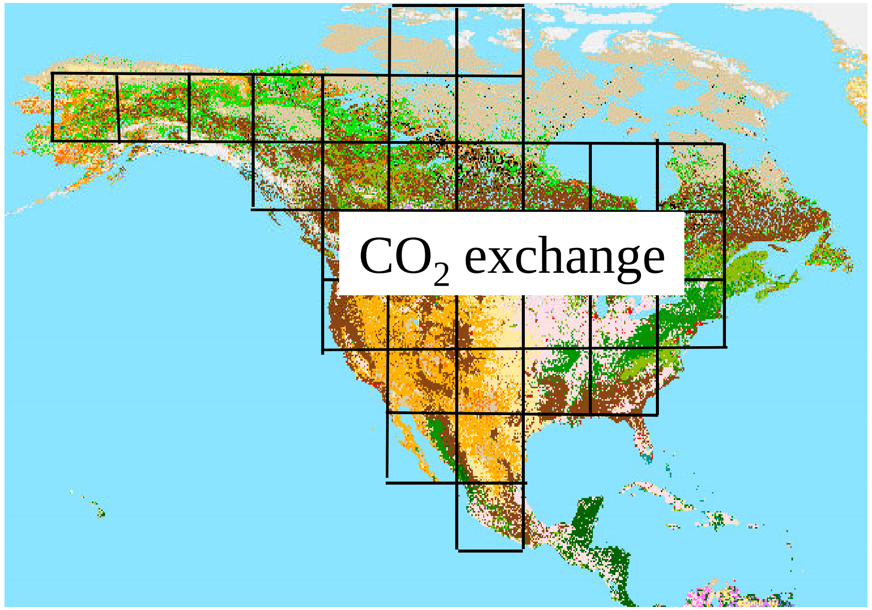
Cadule et al., GBC submitted

Regional Strategy to Evaluate models



Cadule et al., GBC submitted

CO_2 Transport Modelling



Wind →

Atm.CO_2

← f^{-1} (Wind)

Forward

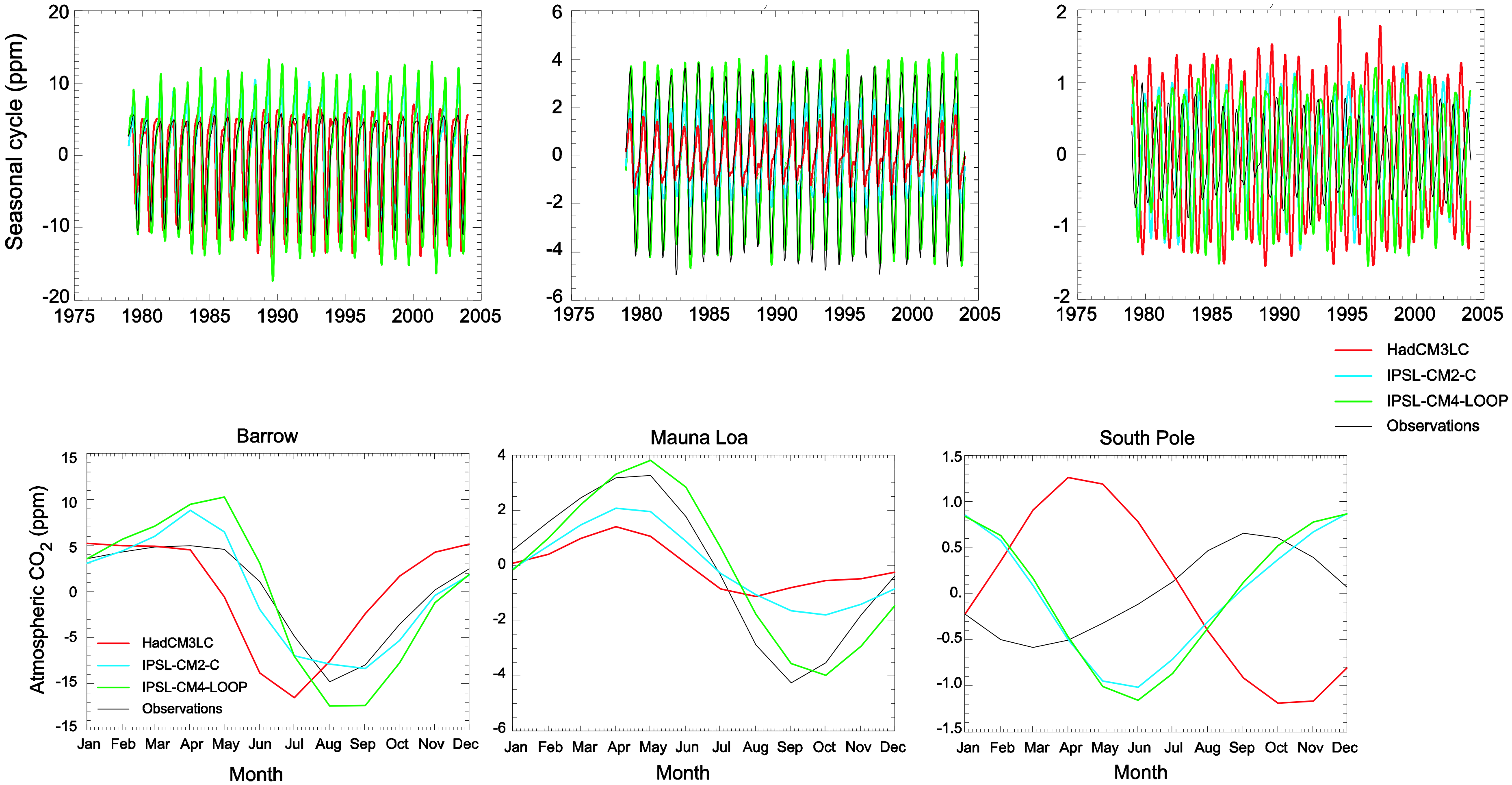
Inverse

Institut Pierre Simon Laplace

Cadule et al., GBC submitted

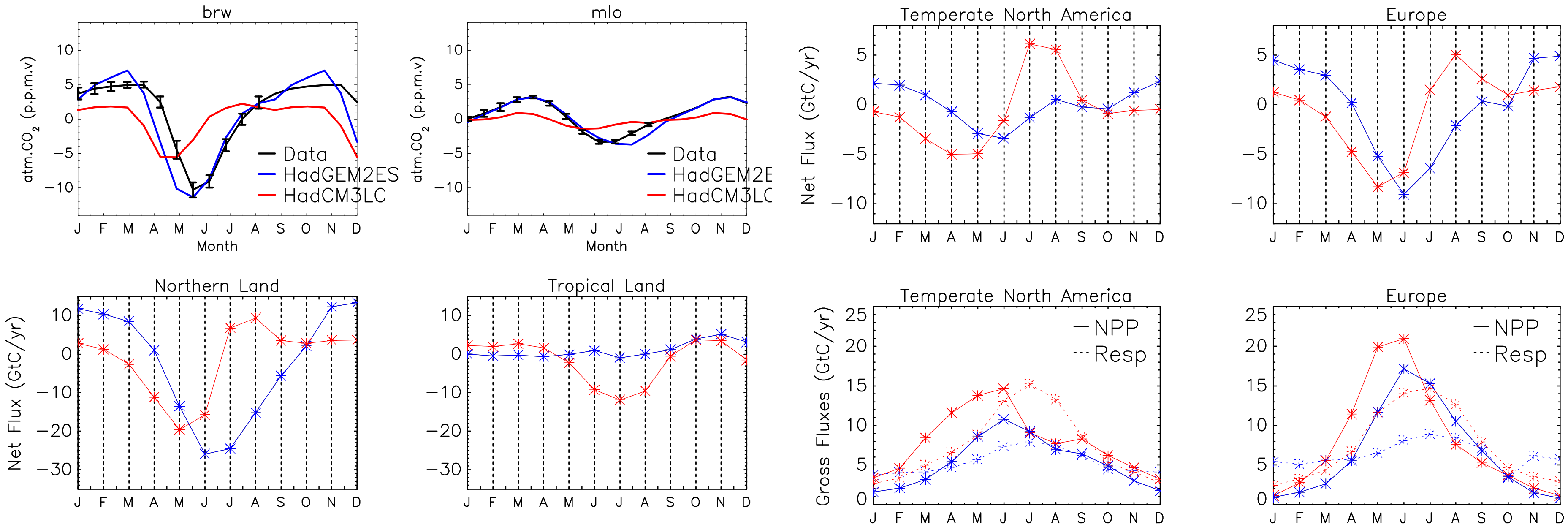
Met Office

Seasonal Cycle



Cadule et al., GBC submitted

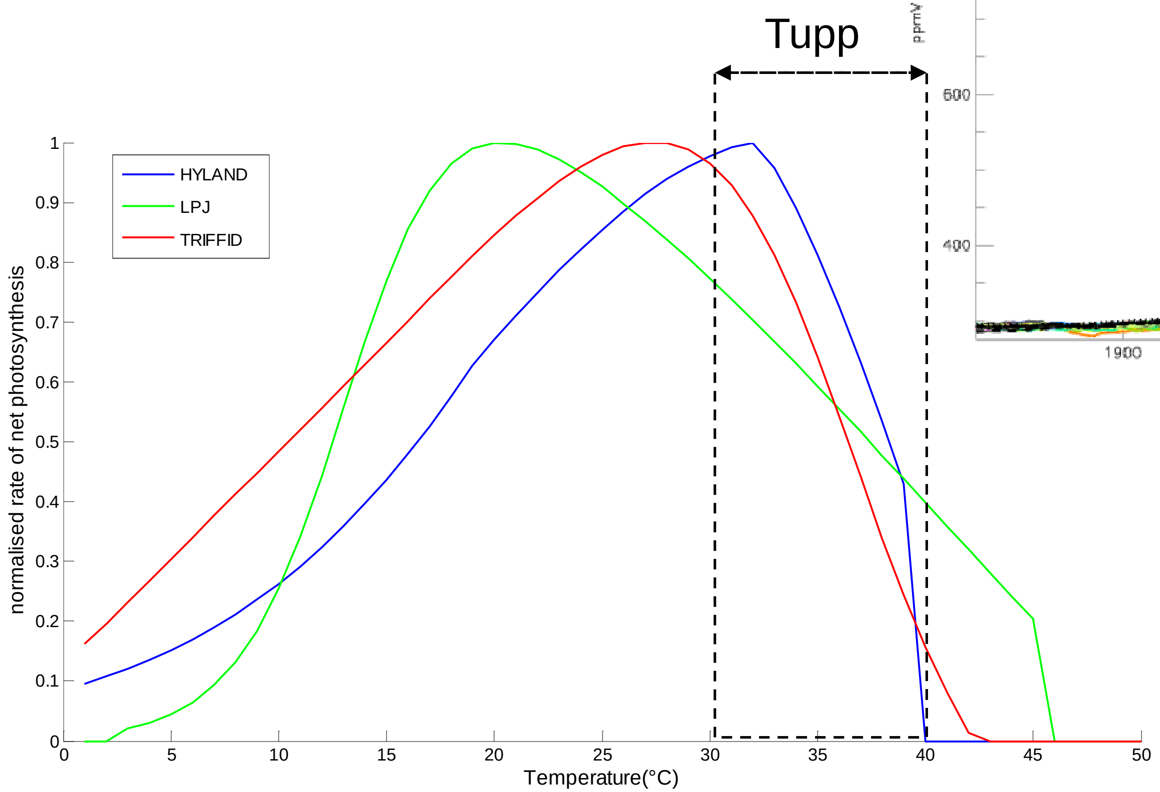
Improved SC (HadGEM2)

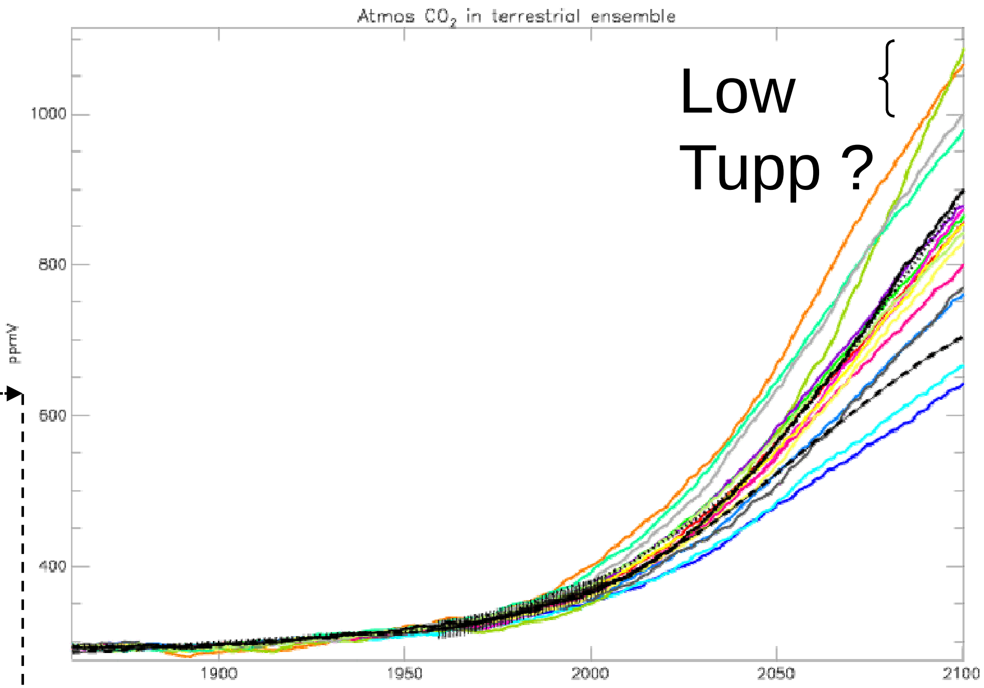


Transferring Parameterizations from HadGEM2 to JULES v2
(In progress - R. Ellis, D. Clark, CEH, Wallingford)

Institut Pierre Simon Laplace
Sciences de l'environnement
Met Office

Ecophysiology at high temperatures





Booth et al., submitted

Courtesy D. Galbraith

Summary

✓Implementing into JULES state-of-the-art representations of:

Plant Nitrogen Cycle (FUN) (J. Fisher et al.,)

(N-Deposition; Future C sinks; Climate Stabilization & Mitigation)

✓ Progress in mechanistically modelling non-CO_2 trace gas exchanges:

Isoprene, (F. Pacifico et al.,) (Biofuels)

Plant O_3 – water relations (Food Security)

✓ Implementation of diffuse/direct radiation into JULES

(L. Mercado et al.,) (Food Security, Geoengineering)

✓ Global Calibration of JULES (R. Ellis, D. Clark et al.,)

✓ Identified Ecophysiology at high temperatures (J. Lloyd et al.) (Tipping points)

Extras