Air pollution effects in a changing climate

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Outline

- Scope
- Sulphur
- Oxidized nitrogen
- Reduced Nitrogen. ($NH_{3,}$ NH_4)
- VOC
- Ozone
- Land use

Scope (climate, ecological response)

Climate, (IPCC 4th Assessment 2007)

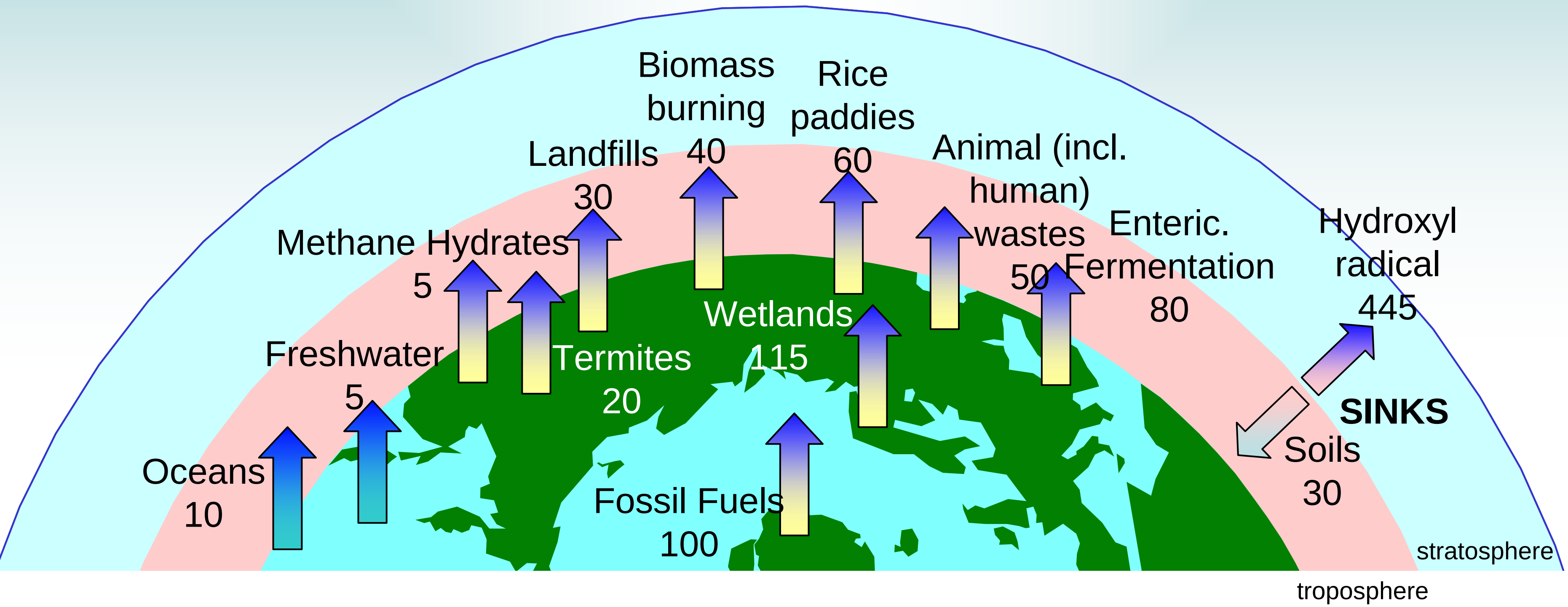
- 11 of the 12 years (1995-2006) rank among the 12 warmest years in the instrumental record, since 1850.
- For the next two decades, a warming of about 0.2 ^{o}C per decade is projected..(for a range of SRES)
- Diurnal temperature range has declined
- Mid latitude westerly winds have strengthened
- Increased precipitation in N Europe, and a decrease in the Mediterranean
- Increased frequency of heavy precipitation over land
- Decreased area of seasonally frozen land

Scope (Ecological response)

- Biological response to temperature (Q_{10} =~2)
- For many processes a clear optimum temperature exists
- Thus the direction of response is determined by the starting point, and responses to temperature may be –ve.
- Most ecological responses are conditional eg water status, redox (for soils),

GLOBAL METHANE BUDGET (Mt)

Annual Source	515 Mt
Annual Sink	475 Mt
Net Input to Troposphere	30 - 50 Mt



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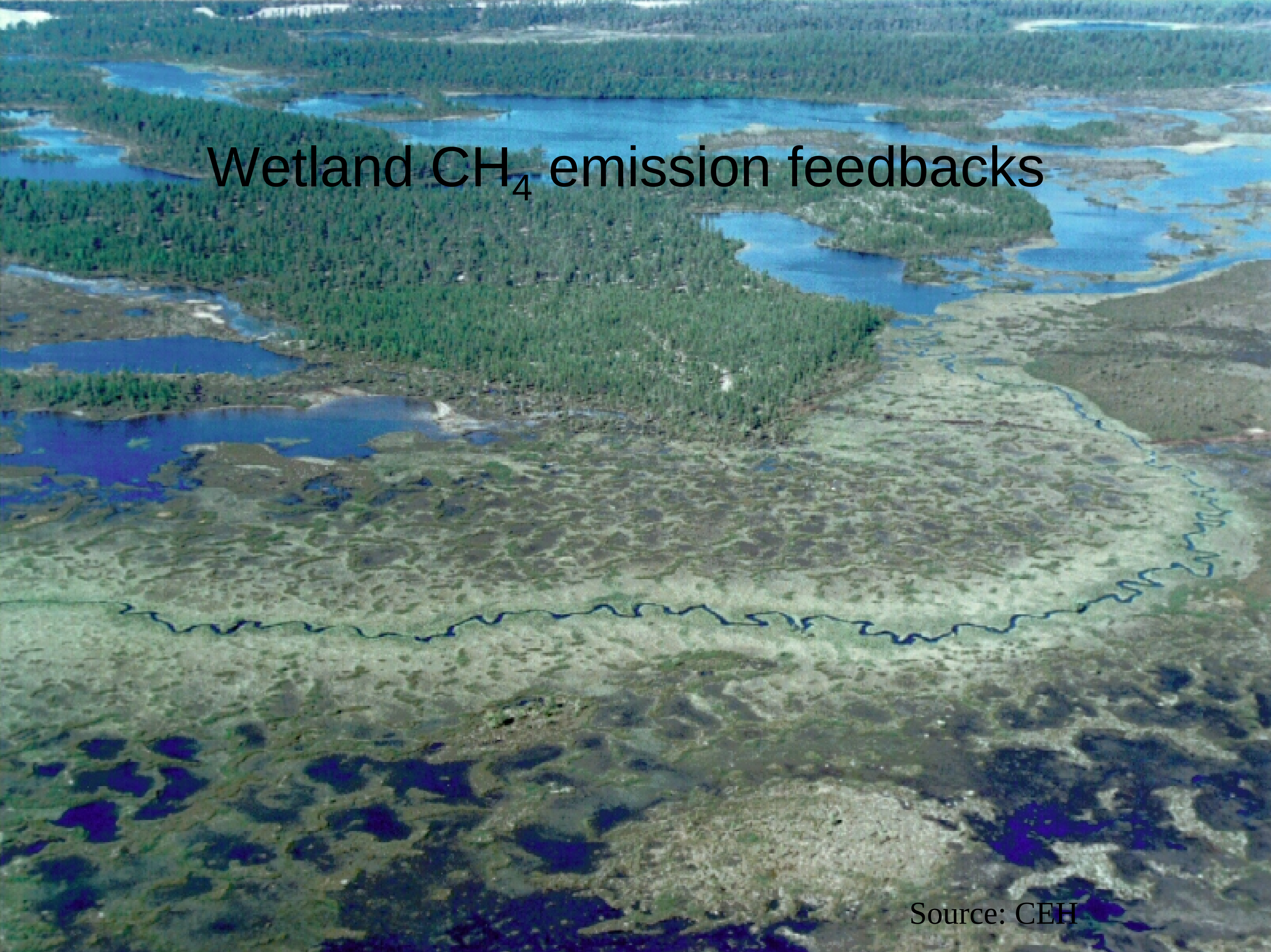
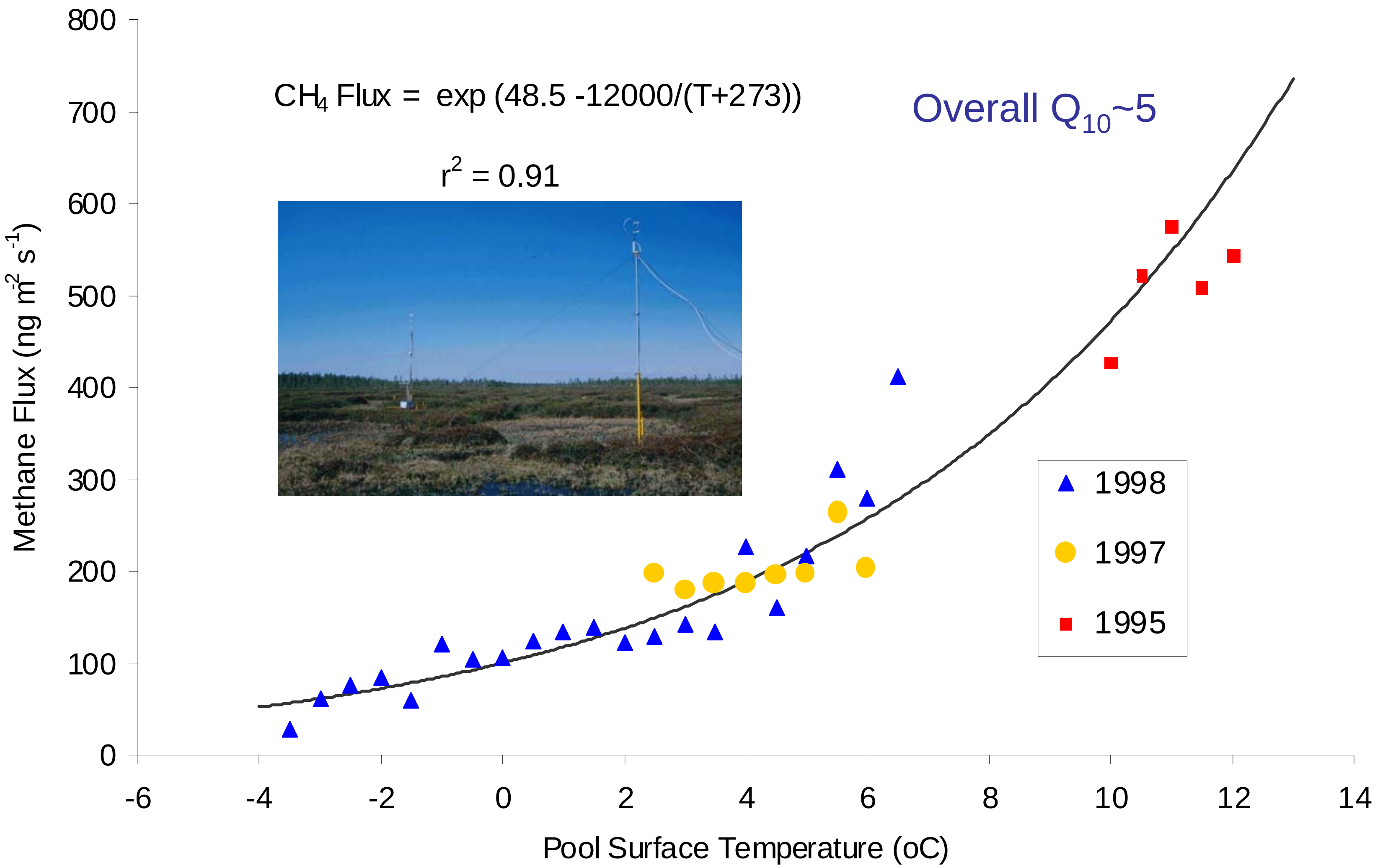
Wetland CH_4 emission feedbacks



Source: CEH



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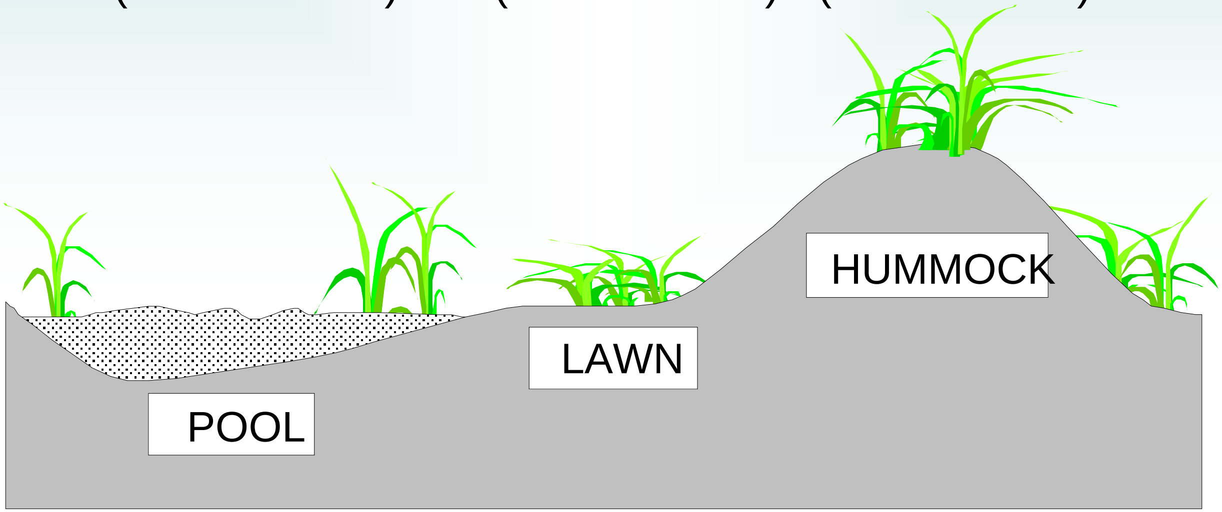
Conditional responses, the anaerobic methane production requires waterlogged soil

Atmosphere-surface Exchange of CH_4 Over Pealands

Mean Flux (15^{o}C) μ mol m^{-2} h^{-1}

+111.2 (std. dev. 32.3)	+103.2 (std. dev. 38.1)	-8.5 (std. dev. 9.3)



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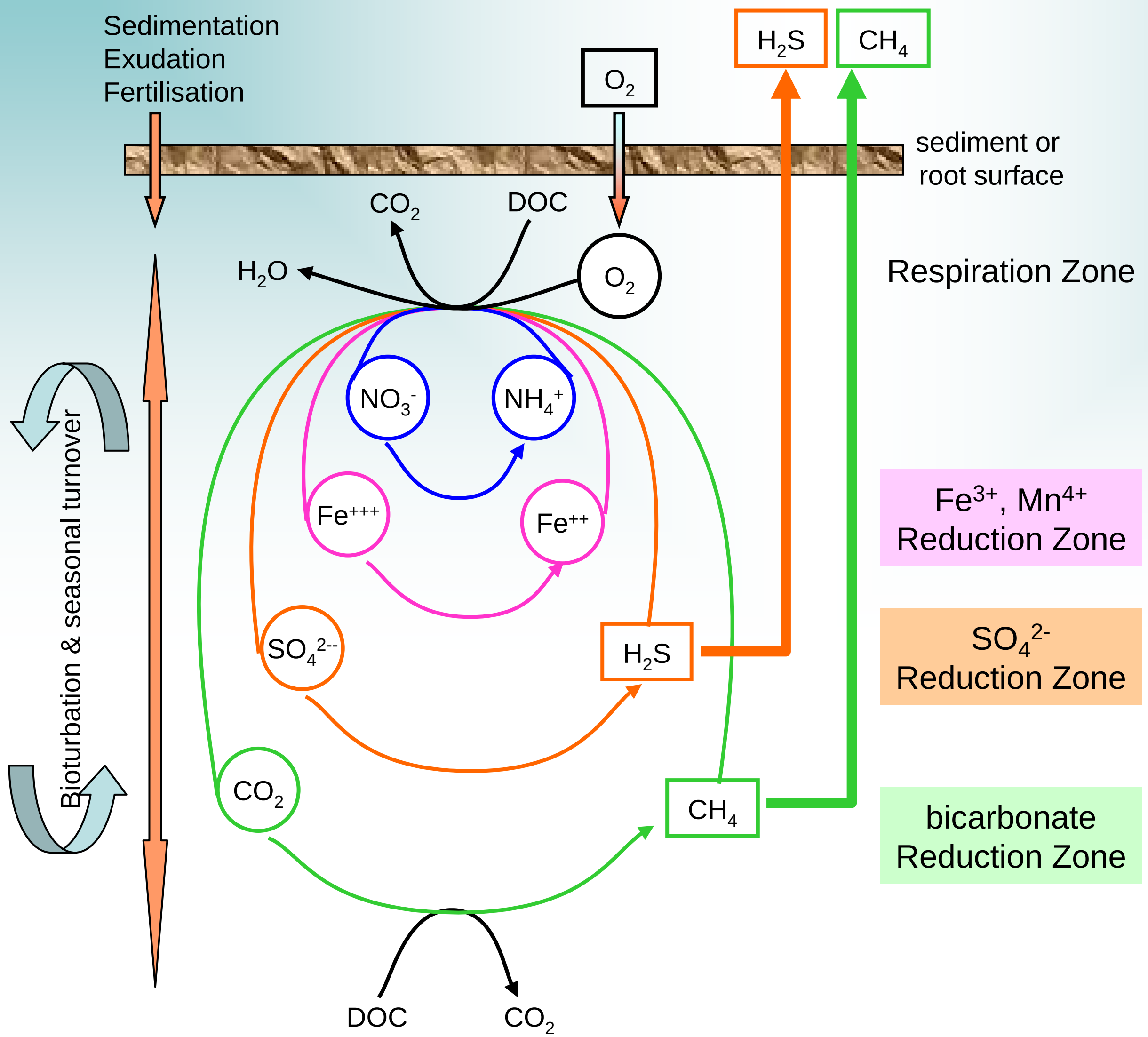
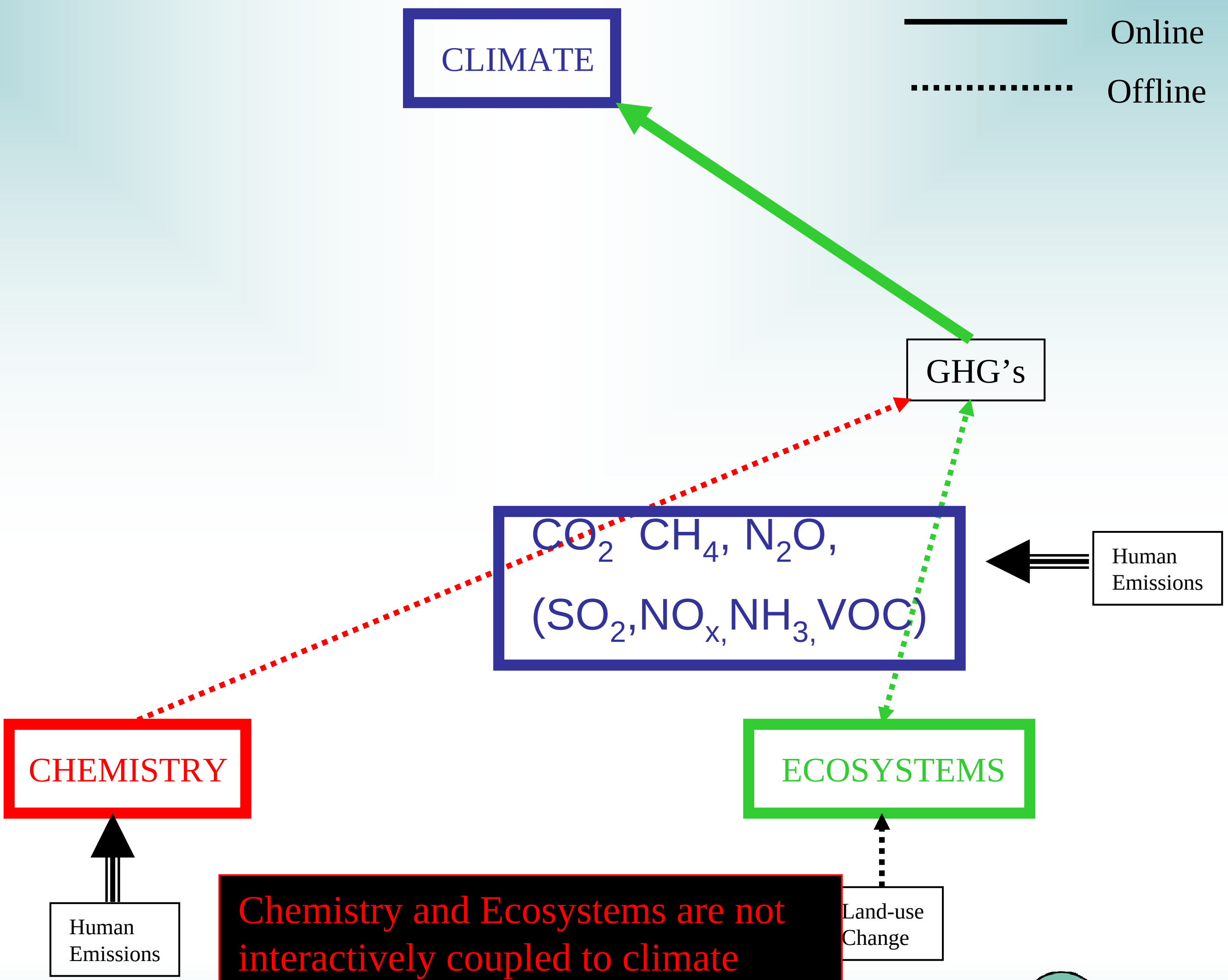


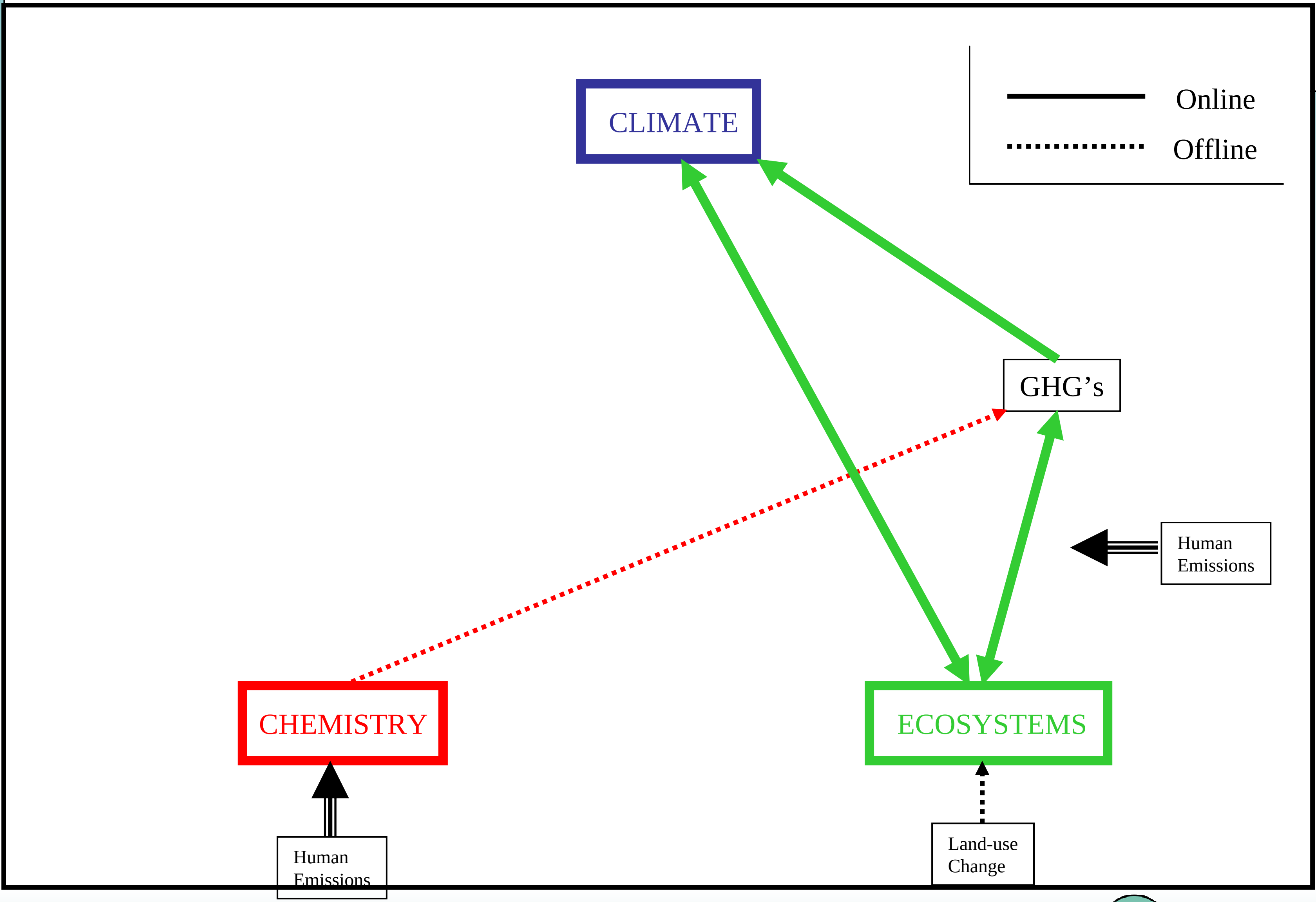
Sedimentation
Exudation
Fertilisation
O_2
H_2S
CH_4
sediment or
root surface
CO_2
DOC
H_2O
O_2
Respiration Zone
Bioturbation & seasonal turnover
NO_3^-
NH_4^+
Fe^{+++}
Fe^{++}
Fe^{3+}, Mn^{4+}
Reduction Zone
SO_4^{2--}
H_2S
SO_4^{2-}
Reduction Zone
CO_2
CH_4
bicarbonate
Reduction Zone
DOC
CO_2

Standard GHG-only GCM Climate Projections



Chemistry and Ecosystems are not interactively coupled to climate

Climate-Carbon Cycle Coupling



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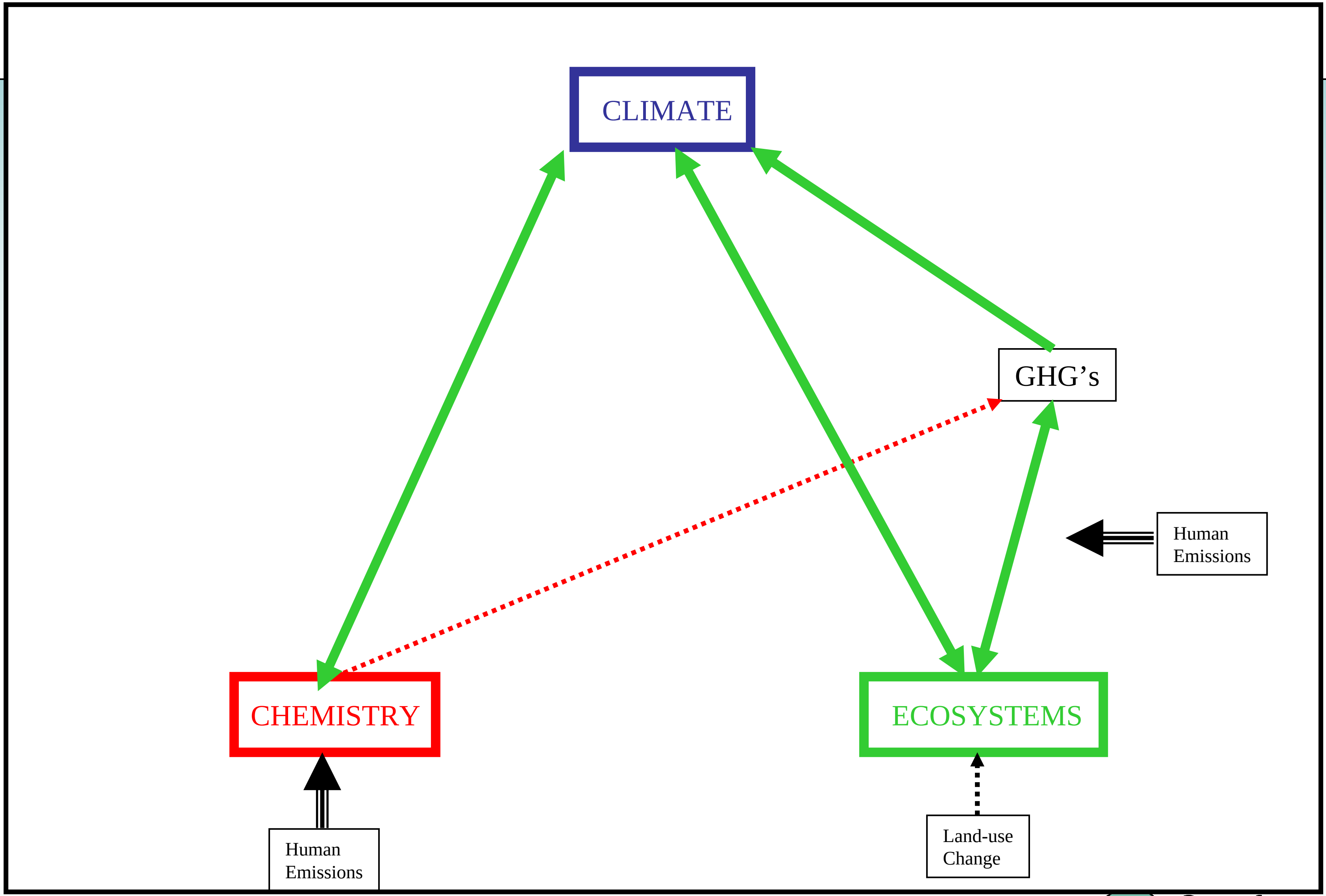
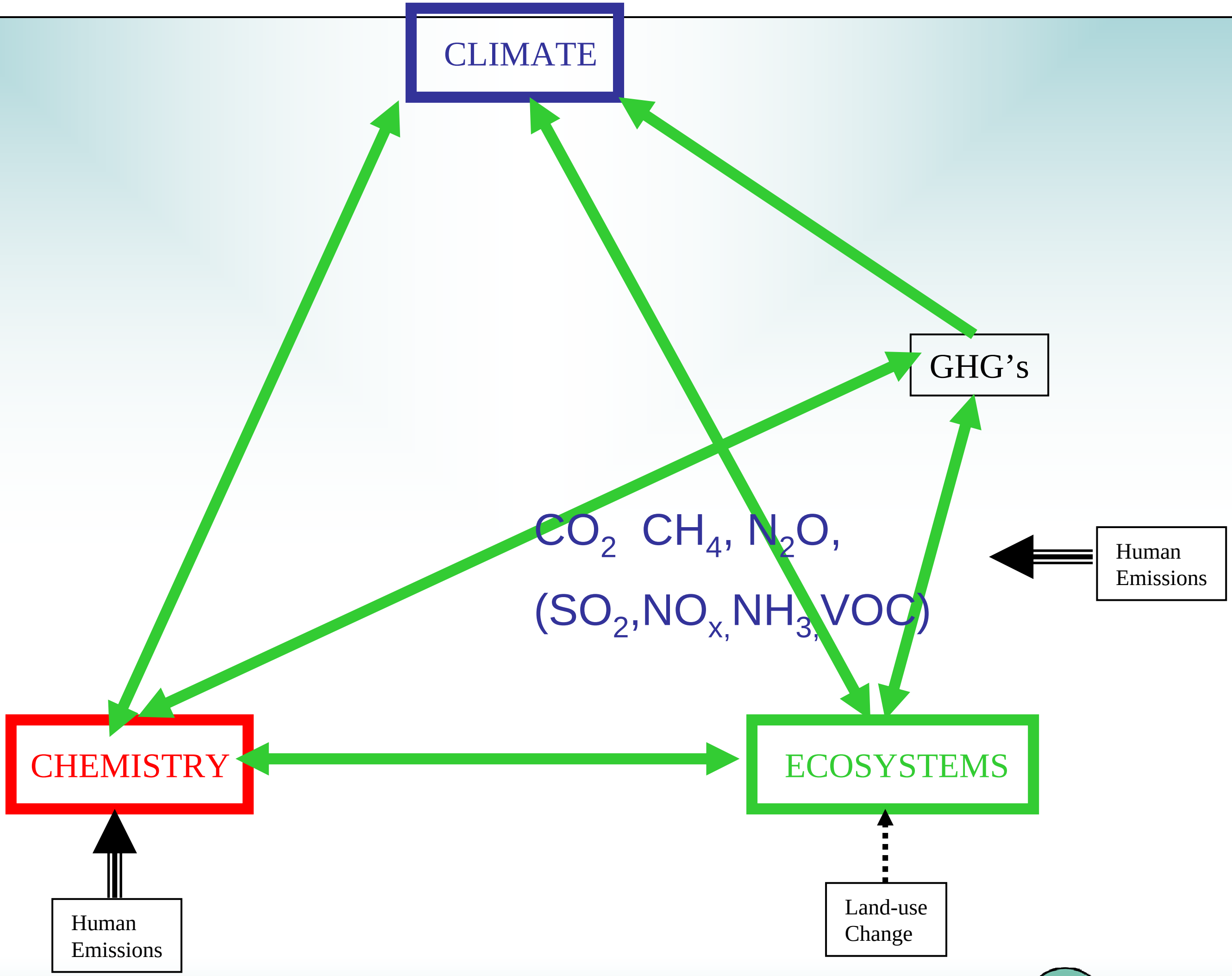


Climate-Biogeochemical Cycle Coupling

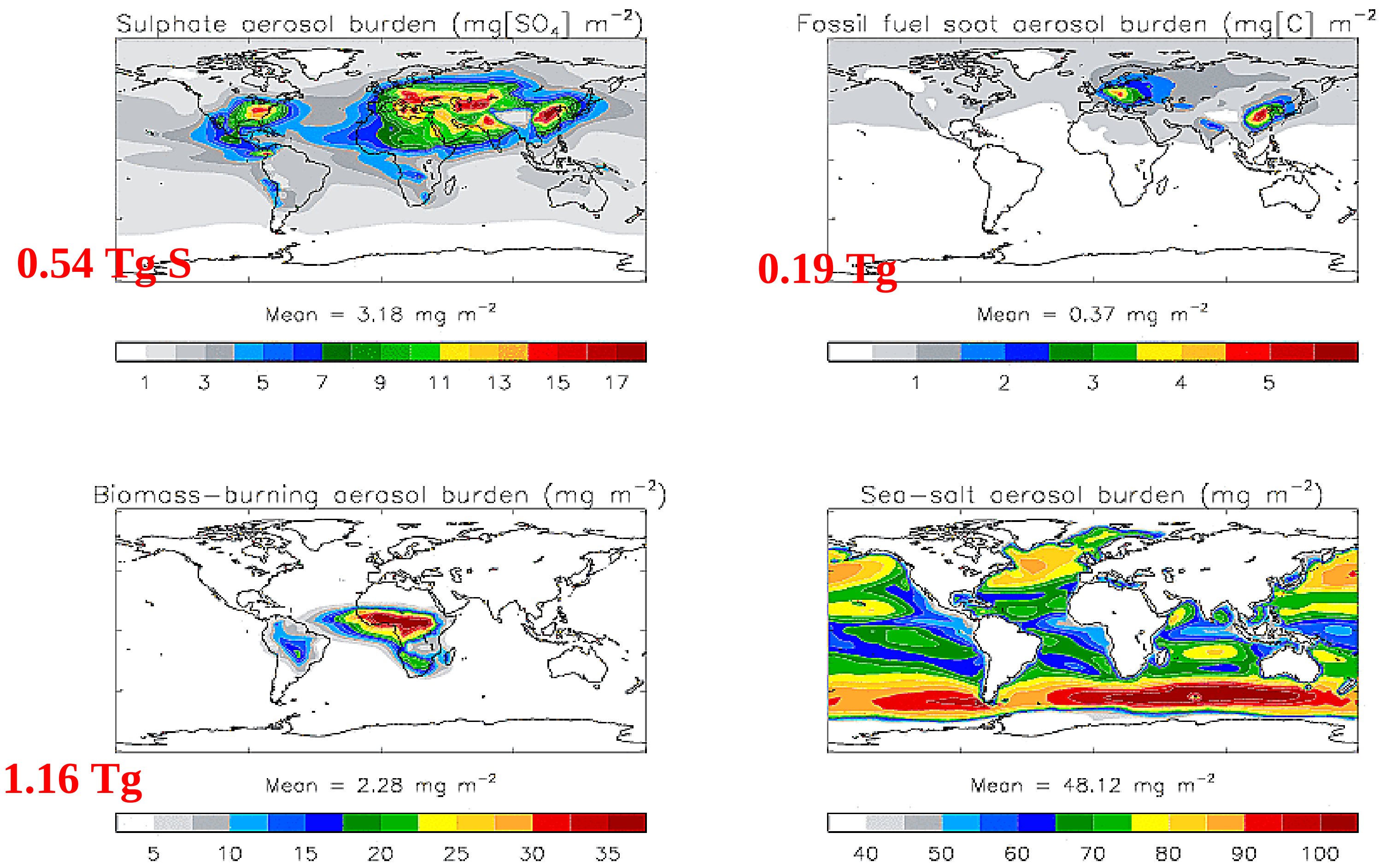


Global climate models do not yet include the major biogeochemical cycles

- Carbon
- Nitrogen
- Sulphur

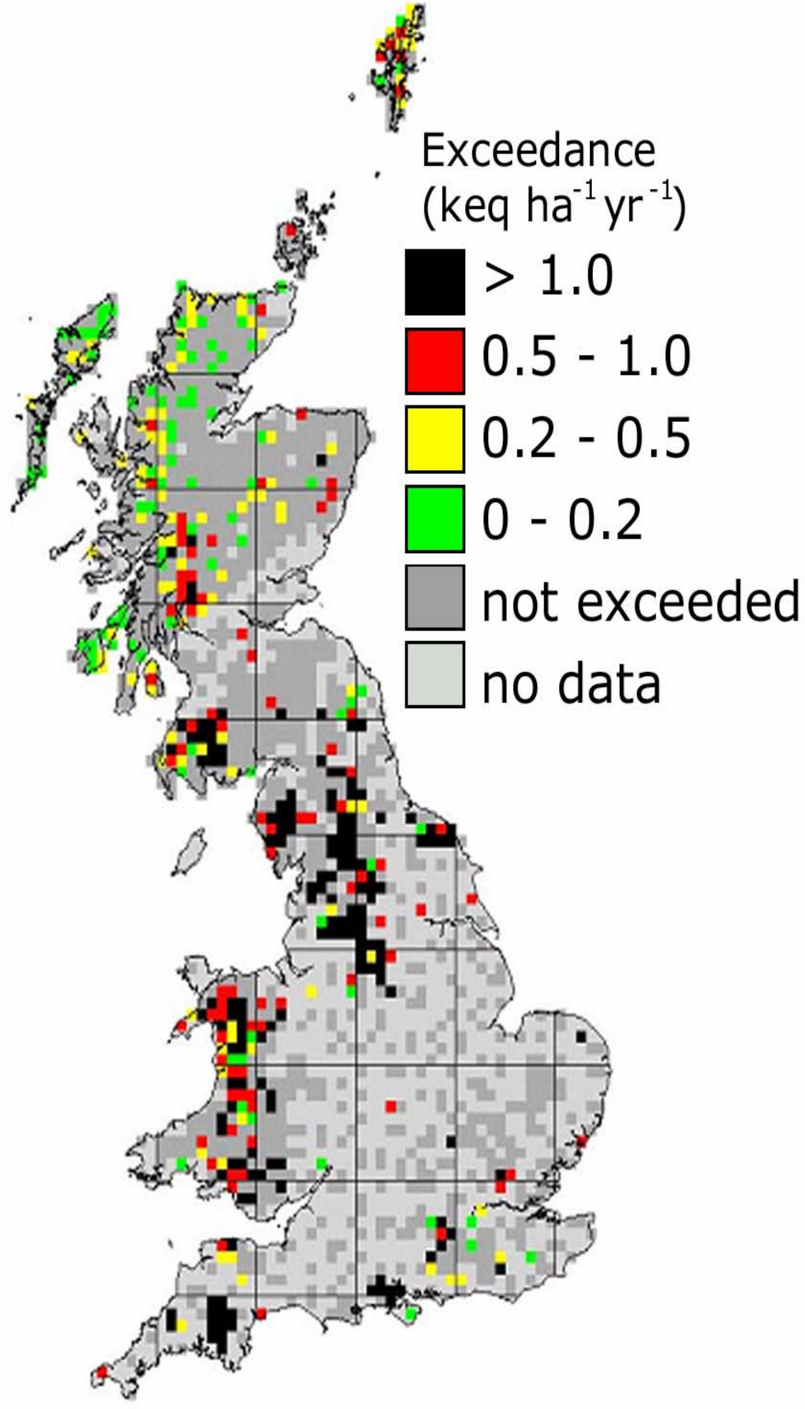
Sulphur

Aerosol Species Modelling in HadGEM (SULPHUR)



5 aerosol species (including mineral dust)

Exceedance of the critical load for freshwater acidity.



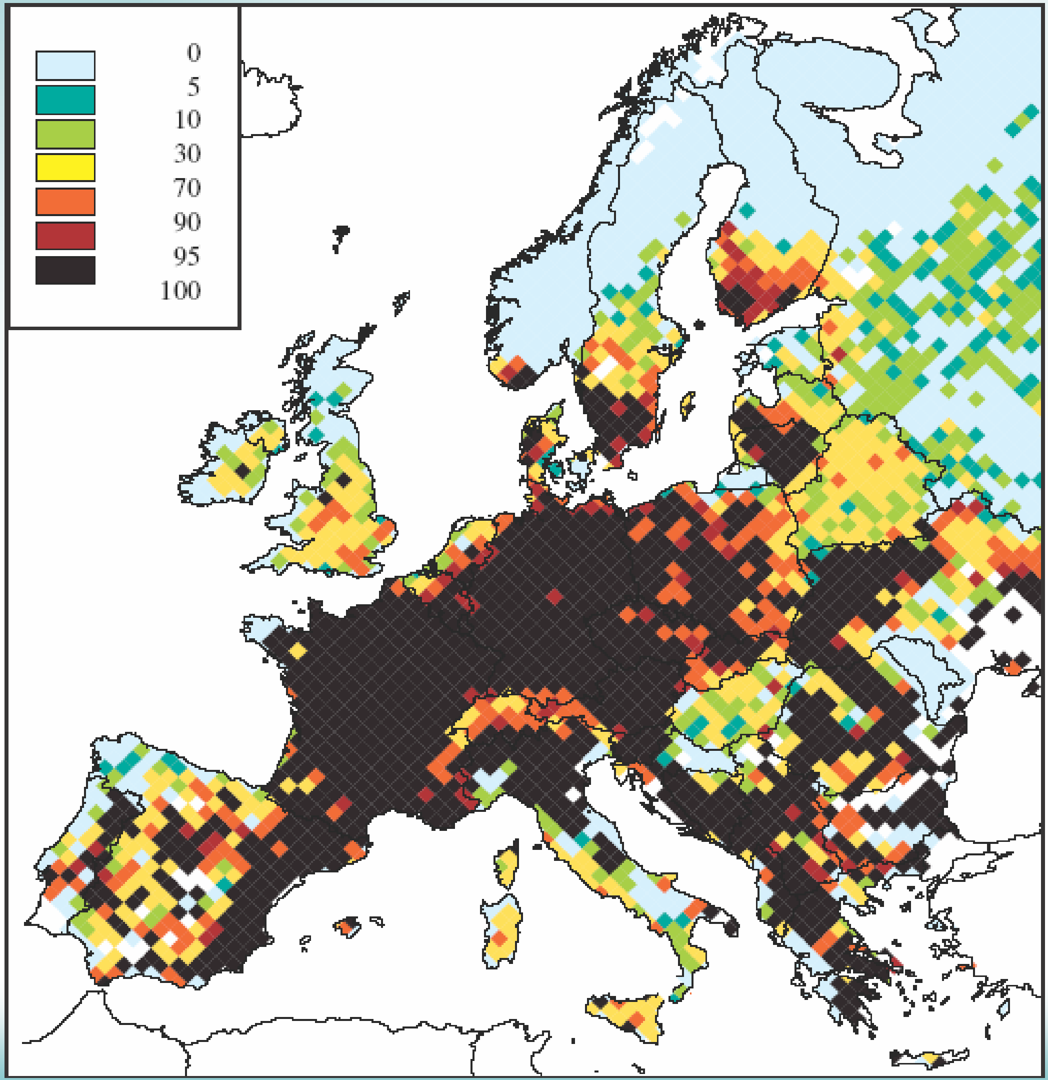
Sulphur

- Sulphur emissions have declined throughout Europe by >80% since peak emissions.
- Ambient SO_2 concentrations are generally <2 ppb and do not represent a threat to ecosystems or human health
- Sulphur still contributes to acid deposition, but is no longer the main contributor
- No major climate sensitive features have been identified for effects of sulphur deposition

Nitrogen

- Large exceedances of CL remain in Europe
- Effects on ecosystems clear at regional scales
- The different forms of Nitrogen appear to have differential effects (NH_x, NO_y)
- There are important interactions between the N and C cycles
- Strong interactions between N effects and climate are likely

Predicted effects of Nitrogen deposition in Europe



% of ecosystems area with grid average N deposition > eutrophication critical loads (for 2000)

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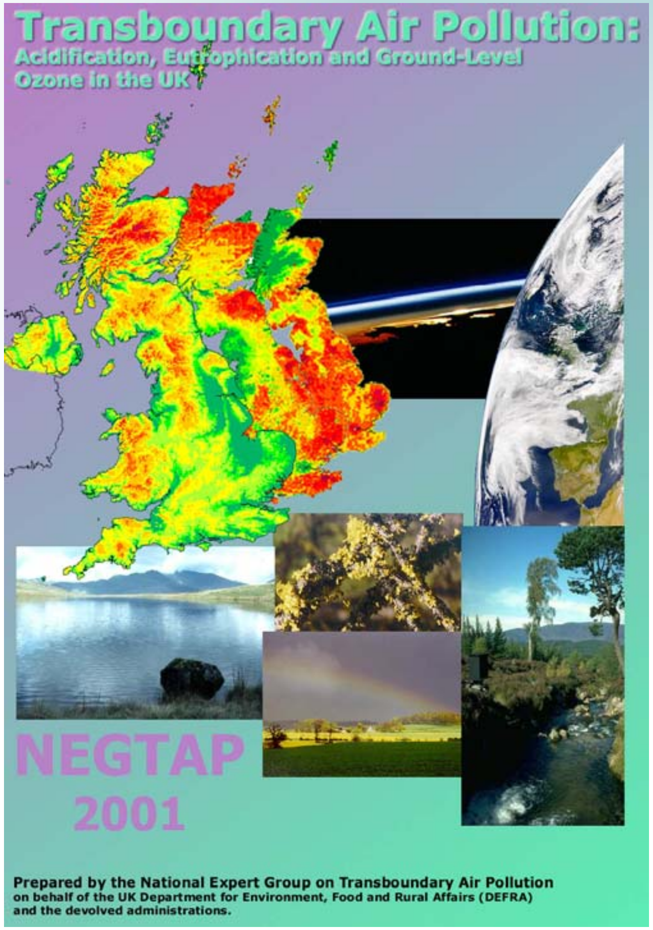
Detecting the Signal of Nitrogen Deposition in Semi-Natural Vegetation

- 400 1 km x1 km survey plots throughout the UK
- Species composition and cover 1978, 1980, 2000
- N deposition (Reduced and Oxidized) 5 km
- Clear signal linking loss of biodiversity to N deposition.



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Detecting the influence of N dep and climate at country

Predictors of **proportion of upland plots occupied** by any one mesophyte in each 1km CS square in 1998

	Partial tests		Direction of correlation	Unconditional tests		Direction of correlation
	Chi sqr	p		Chisqr	p	
Mean min jan	2.83	0.09		0.73	0.4	
Total Nitrogen	4.08	< 0.05	+	51.82	<0.001	+
NHx	0.15	0.69		46.42	<0.001	+
NOy	5.5	< 0.05	+	39.87	<0.001	+
Change in sheep numbers	0.6	0.43		17.73	<0.001	+
Total sheep 2000	0.14	0.71		12	<0.001	+
Growing season change	1.35	0.25		14.09	<0.001	-
Average temperature	4.8	< 0.05	+	42.86	<0.001	+
Amount of intensive Broad Habitat in square	0.71	0.39		5.13	<0.05	+

- Best unique predictors of presence in each square are temperature and N deposition

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Effects of NH_x deposition on plant diversity

- 61 out of 146 species tested in upland vegetation showed significant correlations between abundance in plots averaged over all three survey years, and modeled NHx deposition in 1996

- 23 of these were more likely to be present at higher deposition (positive indicators)
- 38 were negative indicators

- 19 of the negative indicators and 6 of the positive indicators can be considered to carry the strongest, unique signal of NHx deposition impacts (excludes amalgamated taxa in CS data)

- They showed significant relationships with NHx even after covarying out the unique or shared signal attributable to grazing and climate change

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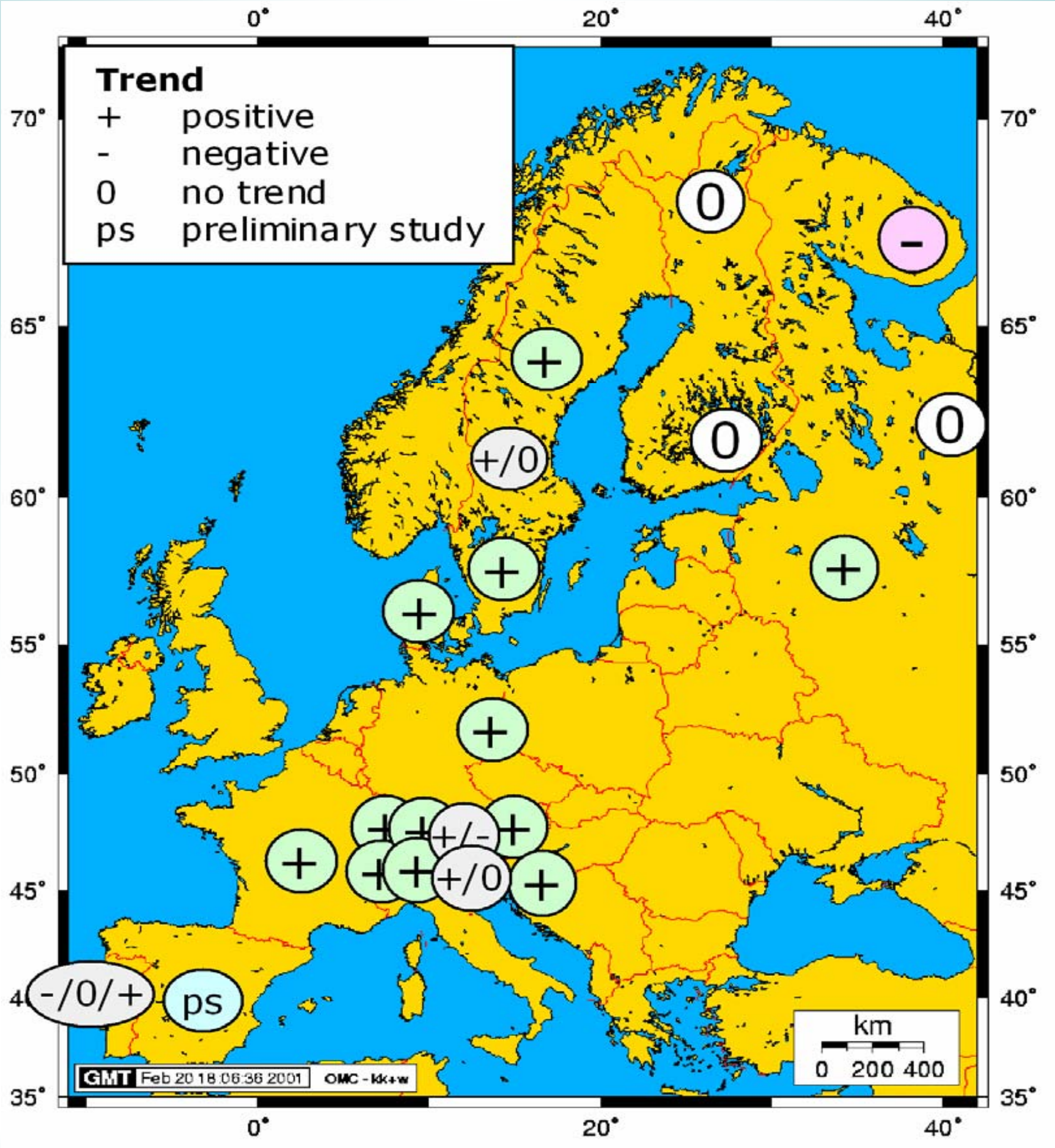
Nitrogen deposition and the carbon cycle



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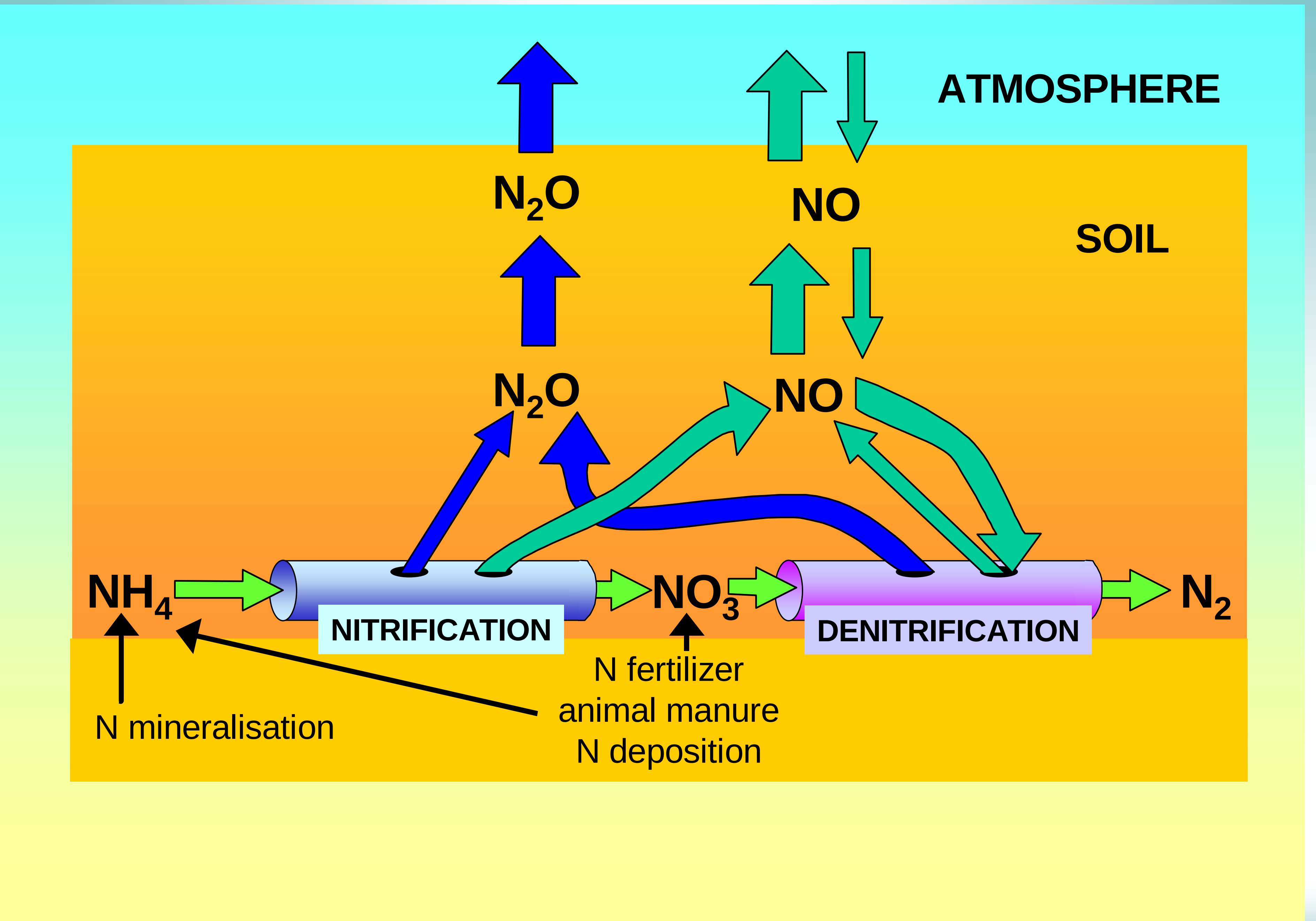
ATMOSPHERE
SOIL
N_2O
NO
N_2O
NO
NH_4
NO_3
N_2
NITRIFICATION
DENITRIFICATION
N mineralisation
N fertilizer
animal manure
N deposition
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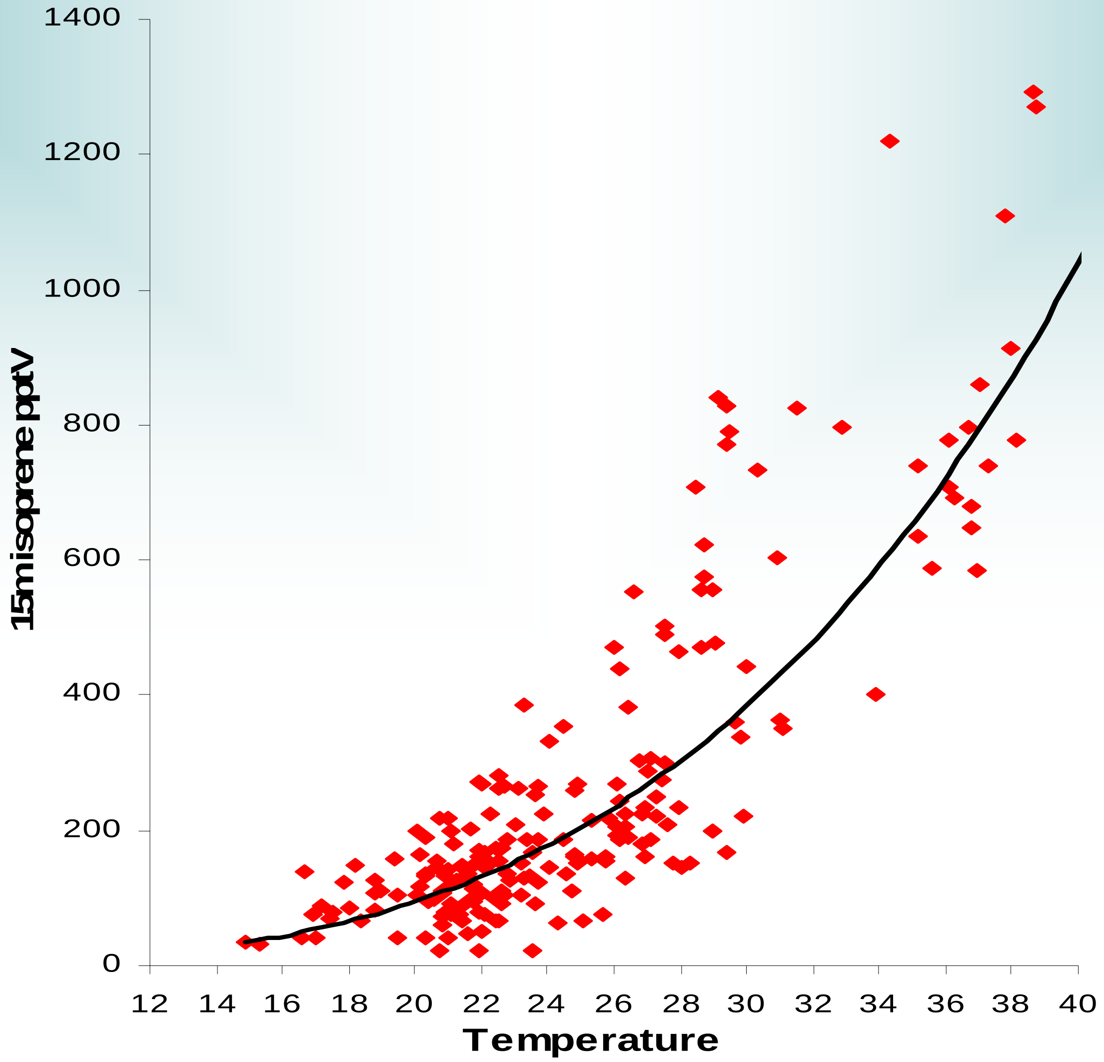
Biogenic VOC emissions

Isoprene emission and air temperature



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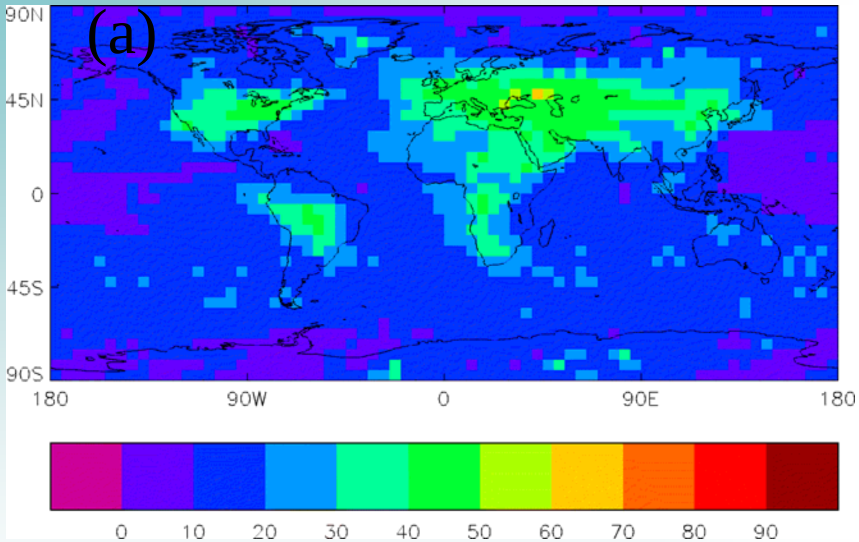
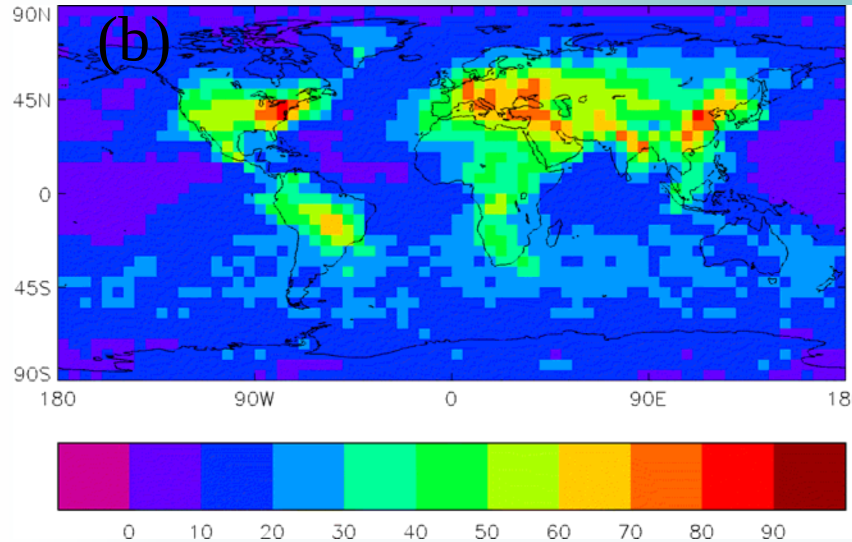
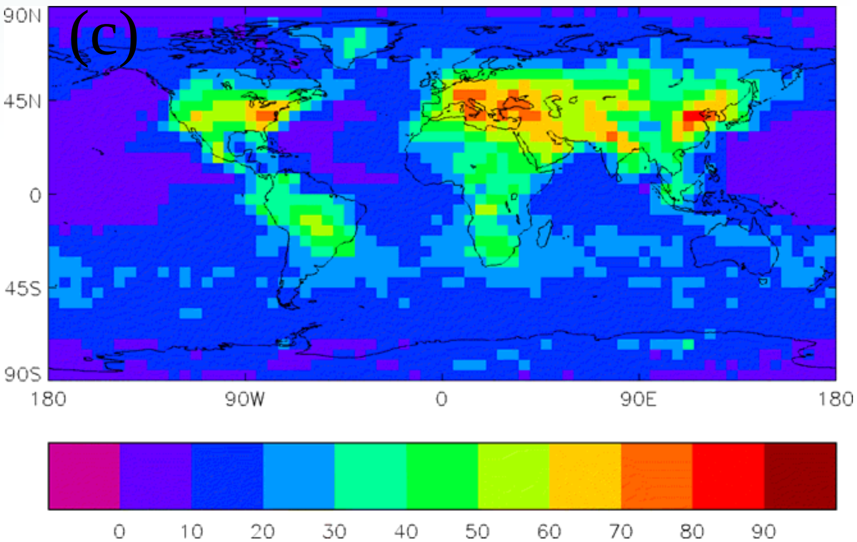
Surface July ozone concentrations in parts per billion







(a) 1990 emissions and vegetation
(b) 2090 emissions, 1990 vegetation
(c) 2090 emissions and vegetation

Sanderson et al., 2003

Climate change leads to increased isoprene emissions and therefore increased ozone, but vegetation change (especially Amazon dieback) suppresses this increase.

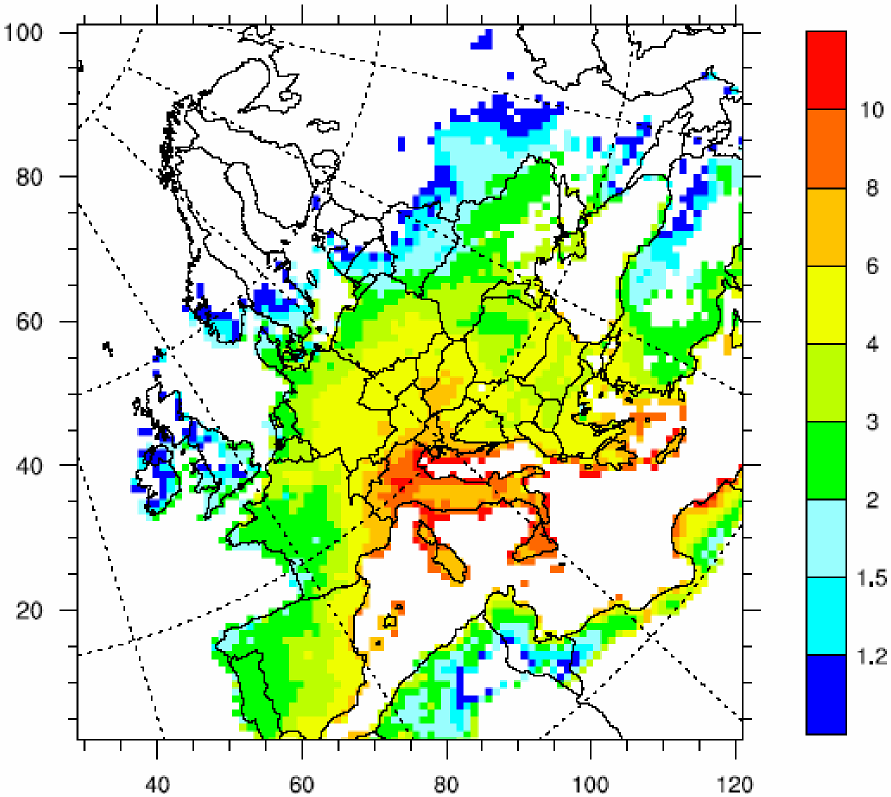
Land Use change

- Vegetation affects the biophysical characteristics of the land-surface (e.g. albedo, roughness length, Bowen ratio).
- Climate influences the distribution, type and structure of vegetation.
- There are potentially strong feedbacks between vegetation dynamics and climate.
- **Most strategies to address CO_2 emission reduction will influence land use**

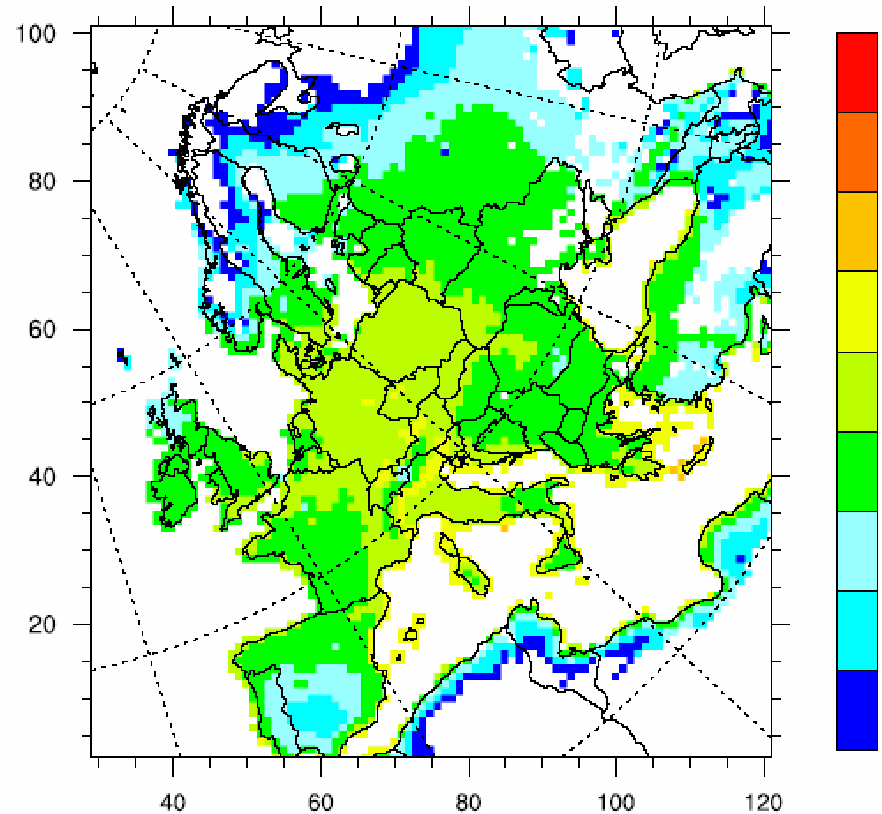
Ozone effects and Climate

- Substantial work to date projects an increase in mean surface ozone concentration in the northern mid-latitudes though the 21st century.
- The full extent of feedbacks has not been investigated, but these may increase OR decrease the concentrations.
- Effects of modest increases in ozone above current values appear to be significant.

How do flux and concentration based risk assessments compare? - Forest trees



(e) $R_{CL}(\mathrm{AOT40}_f)$



(e) $R_{CL}(AF_{st}1.6)$ - Forests

R_{CL} values are normalised values of each critical level to allow the use of the same scale for comparability.

Simpson *et al* 2006 (in press), A comparison of two different approaches for mapping potential ozone damage to vegetation. A model study

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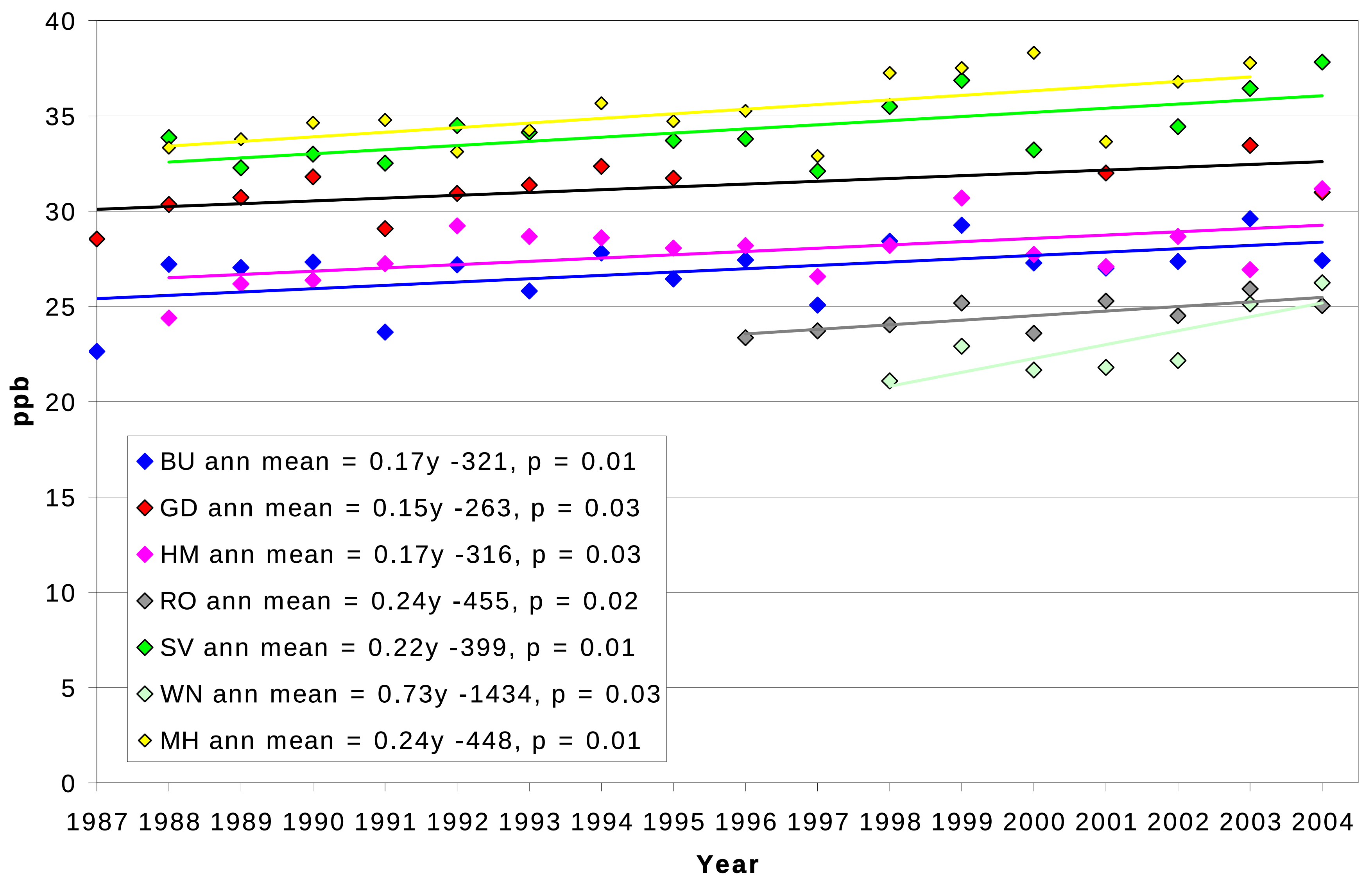
Statistically significant trends



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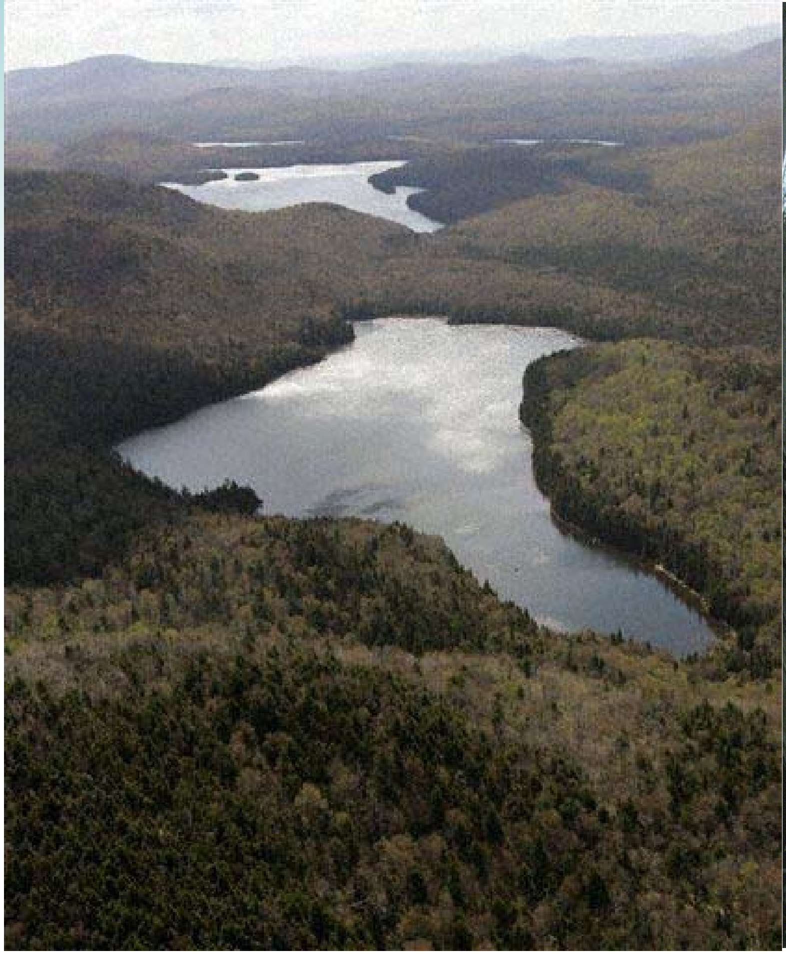
Data from http://www.airquality.co.uk and Mace Head from Peter Simmonds, Bristol University

Ozone feedback

- Ozone effects will become chronic throughout the Northern Hemisphere in cropland and semi-natural vegetation
- Crop breeding programmes could moderate yield effects for crops
- The largest effects may be in reducing the Carbon sink of semi-natural vegetation, especially forests

Acidified lakes and forest soils



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Focus for climate air pollution effects interactions

- Nitrogen deposition effects on ecosystems, the carbon cycle and GHG emissions
- Ozone effects on crops, semi-natural vegetation and the global carbon cycle.
- Land use interactions with climate and biogeochemical cycles (VOC, water use, energy crops)

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