Air pollution impacts on forest ecosystems in a changing climate

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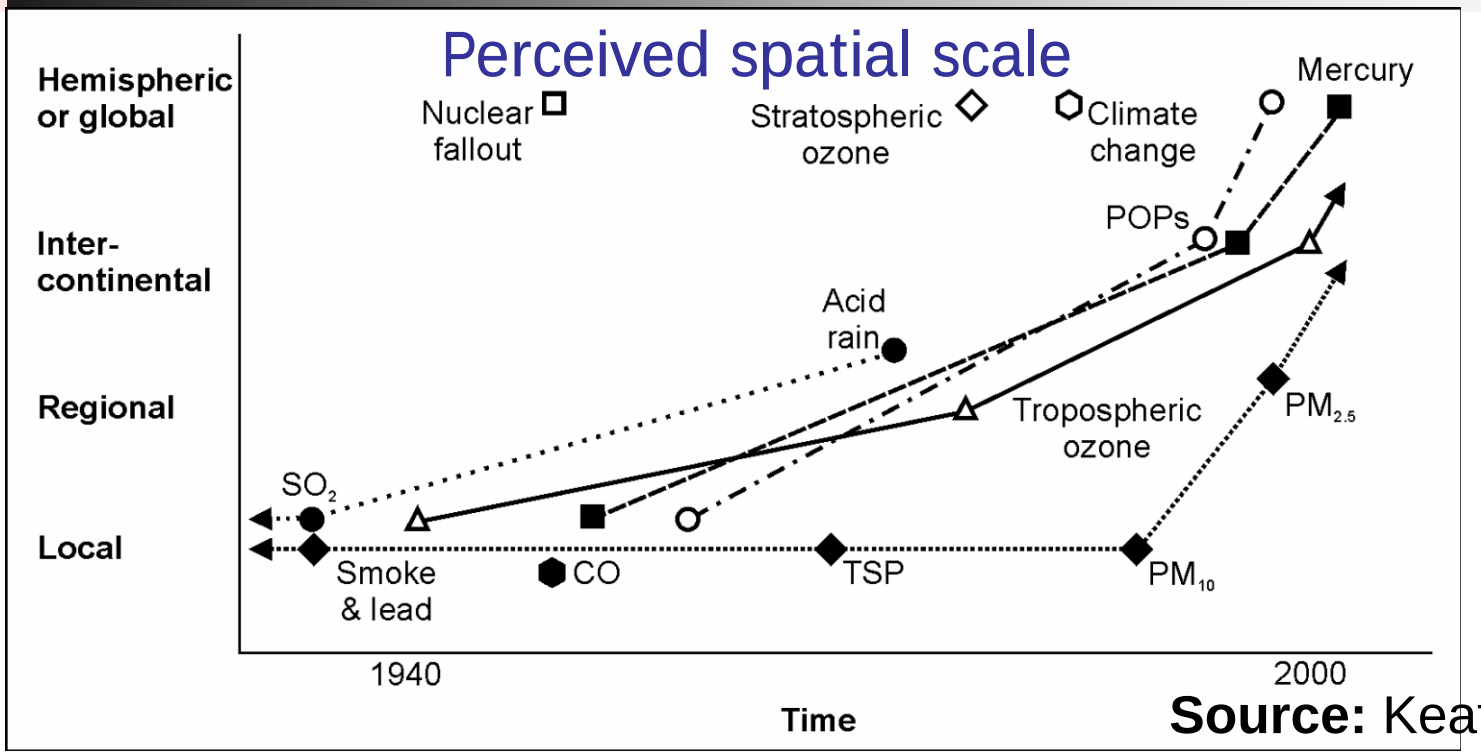
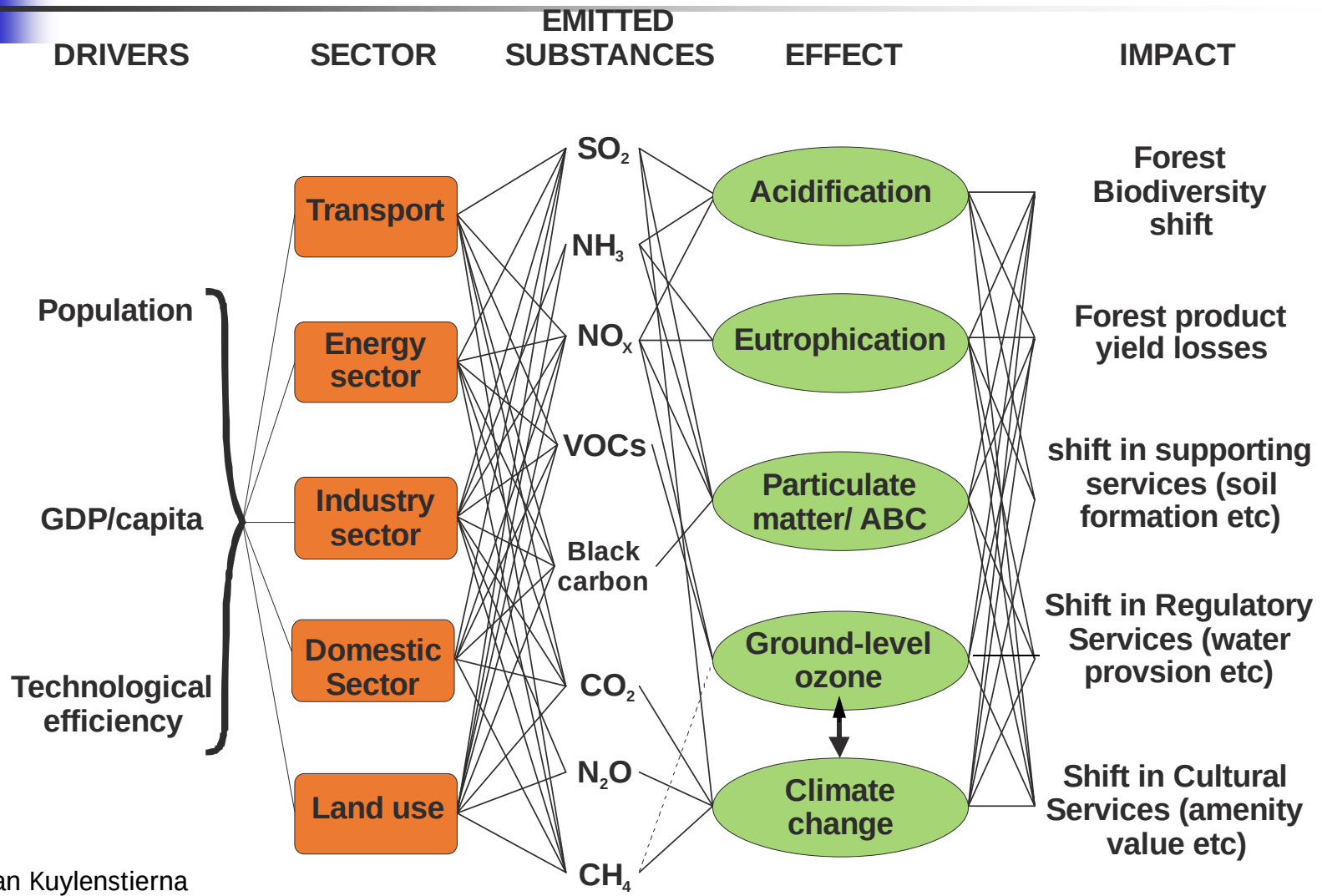


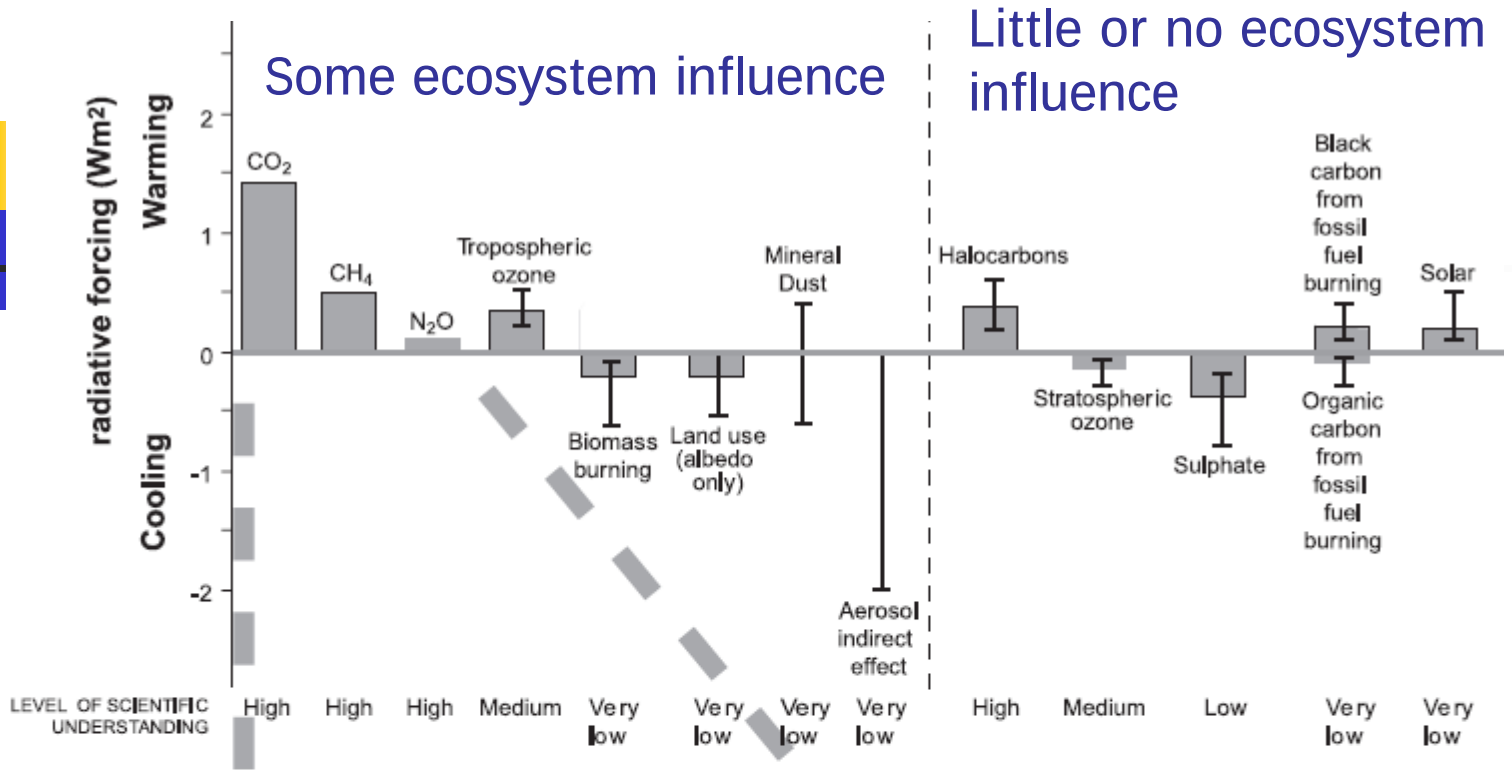
Source: Keating *et al.*, 2004

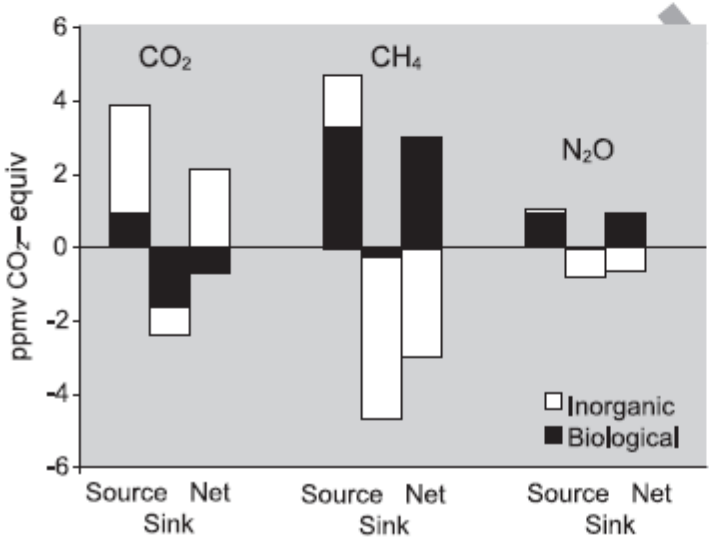
Air pollution is the main driver of the ongoing climate change



By Johan Kuylenstierna

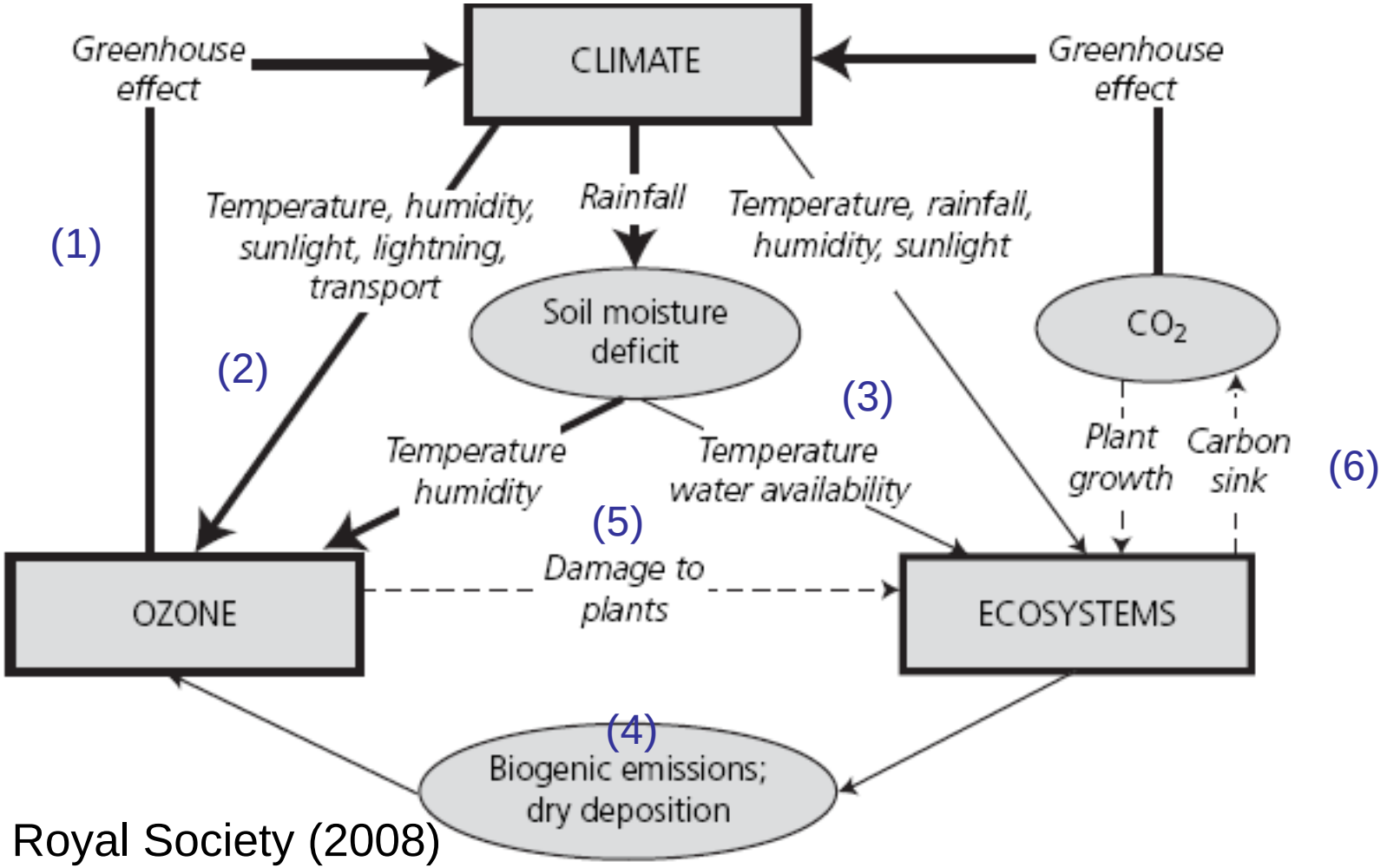
Global annual mean radiative forcing





Source: IPCC 2001

Interactions
Climate – Ozone - Ecosystems



Source: Royal Society (2008)

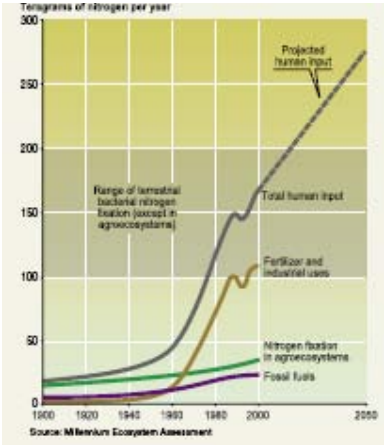
Interactions
Climate - Nitrogen - Ecosystems

Nitrogen form	Climate driver	Impact on climate
N2O	Emission higher in wetter soils	▪Positive radiative forcing
NH3		▪Aerosols/particulate formation
NOx	Warming increases emissions	▪Tropospheric O3 formation ▪Tropospheric oxidising capacity ▪Acid rain formation ▪Fertilization of plants (deposition)

Source: Millennium Assessment (2005)

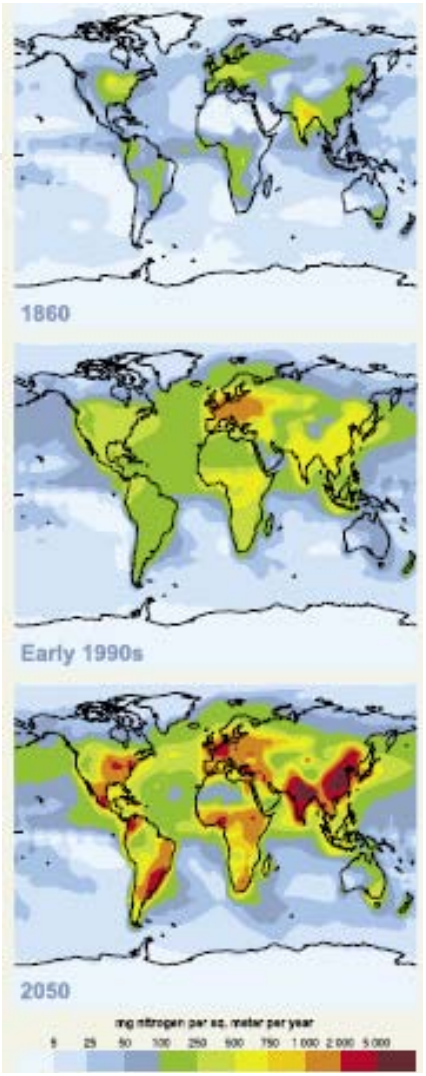
Nitrogen: effects on forest growth

Global trend in the creation of reactive Nitrogen (Nr) on Earth by human activities



+1-1.5% forest growth per 1 kg N deposition, or 30-70 kg C / kg N

Estimated total Nr deposition from the atmosphere

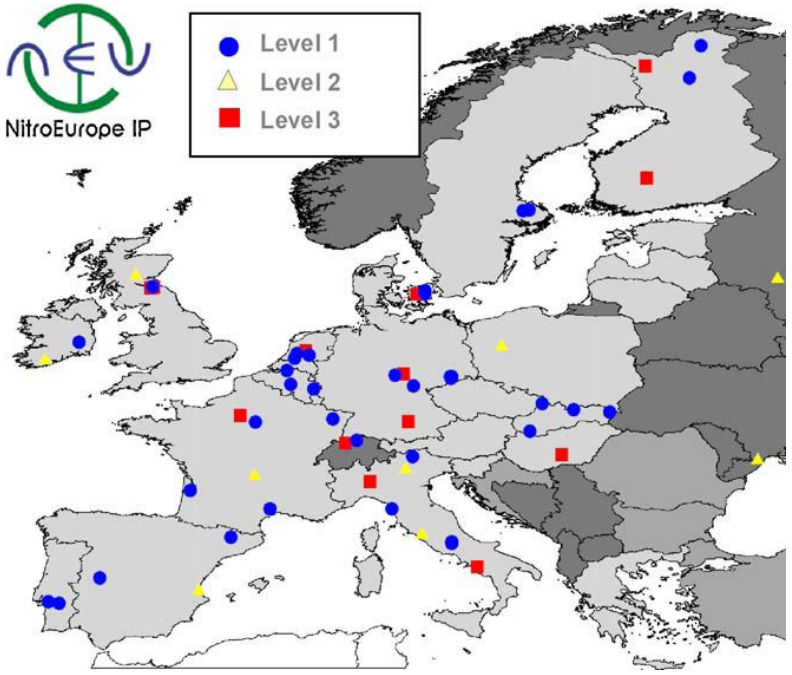


Source: Millennium Assessment (2005)

De Vries et al 2008, 2009

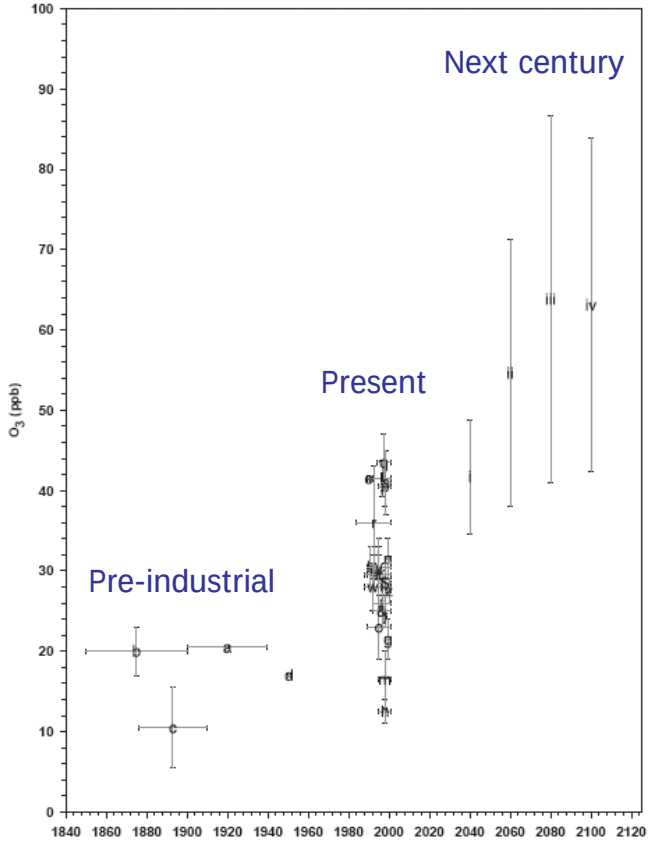
Nitrogen: effects of forests

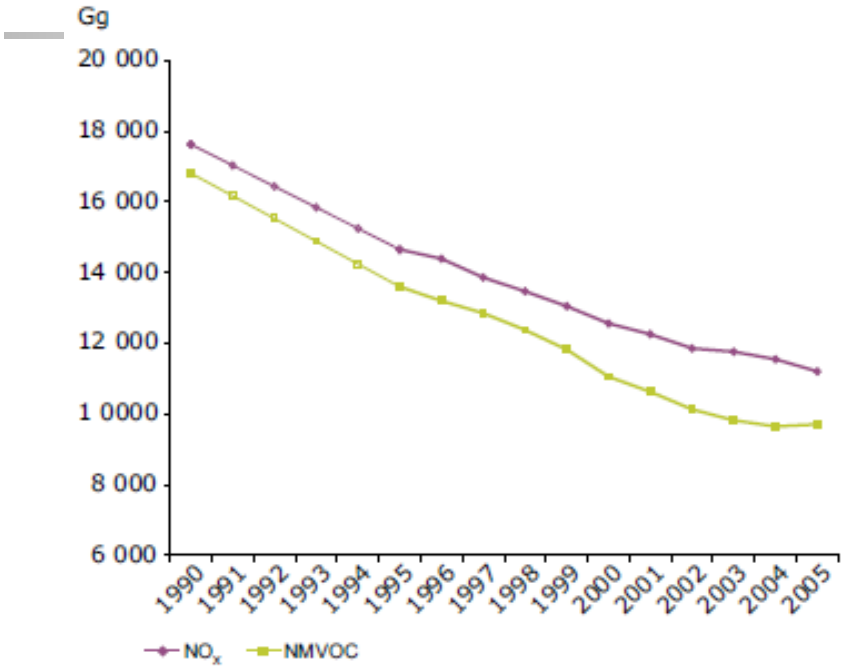
- Grasslands are the largest source of N2O
- Forests are the largest source of NO and sink of CH4
- N deposition rates affect NO and N2O fluxes in nonagricultural ecosystems
- The NO and N2O emission ratio is influenced by soil type and precipitation



Source: Skyba et al 2009

Ozone pollution
An increasing problem





<u>Ozone concentrations</u>

Northern Hemisphere

Since 1874 to 2000: +100%

Present annual rate: +0.5-2%

(Paoletti 2007)

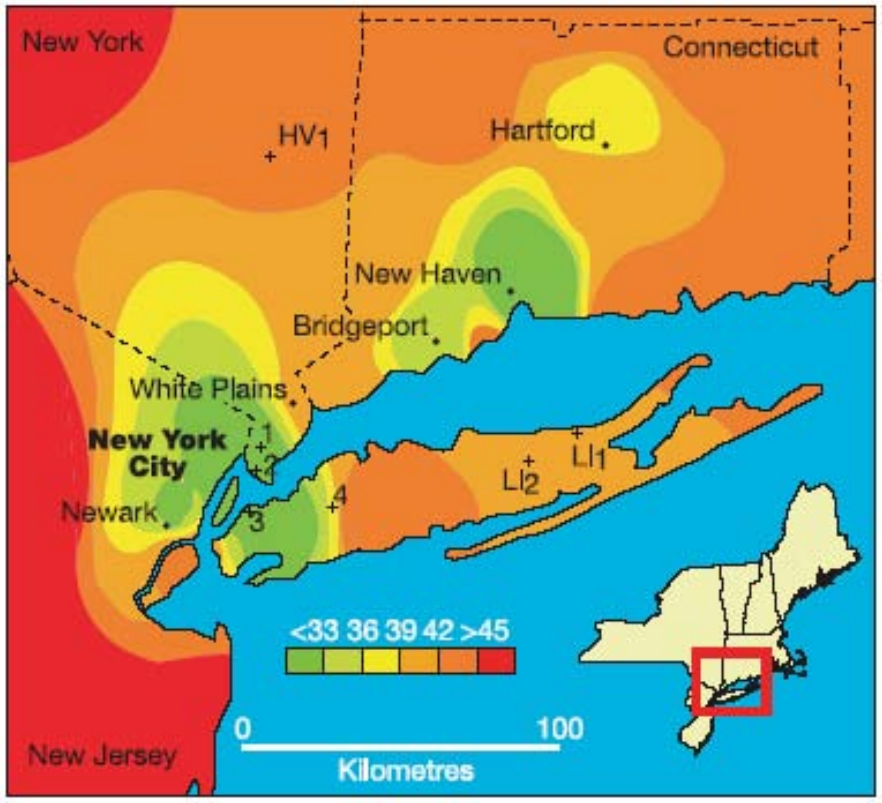
<u>Emission of ozone precursors</u>

Europe (32 countries)

Since 1990 to 2005 : -36% -42%

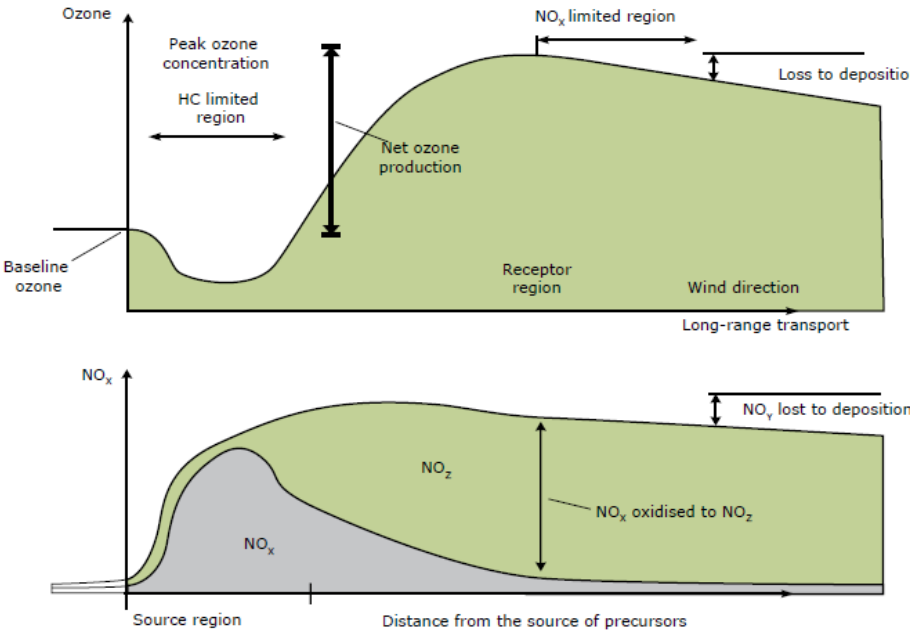
(EMEP 2008)

Ozone pollution is more elevated at remote sites than in the cities



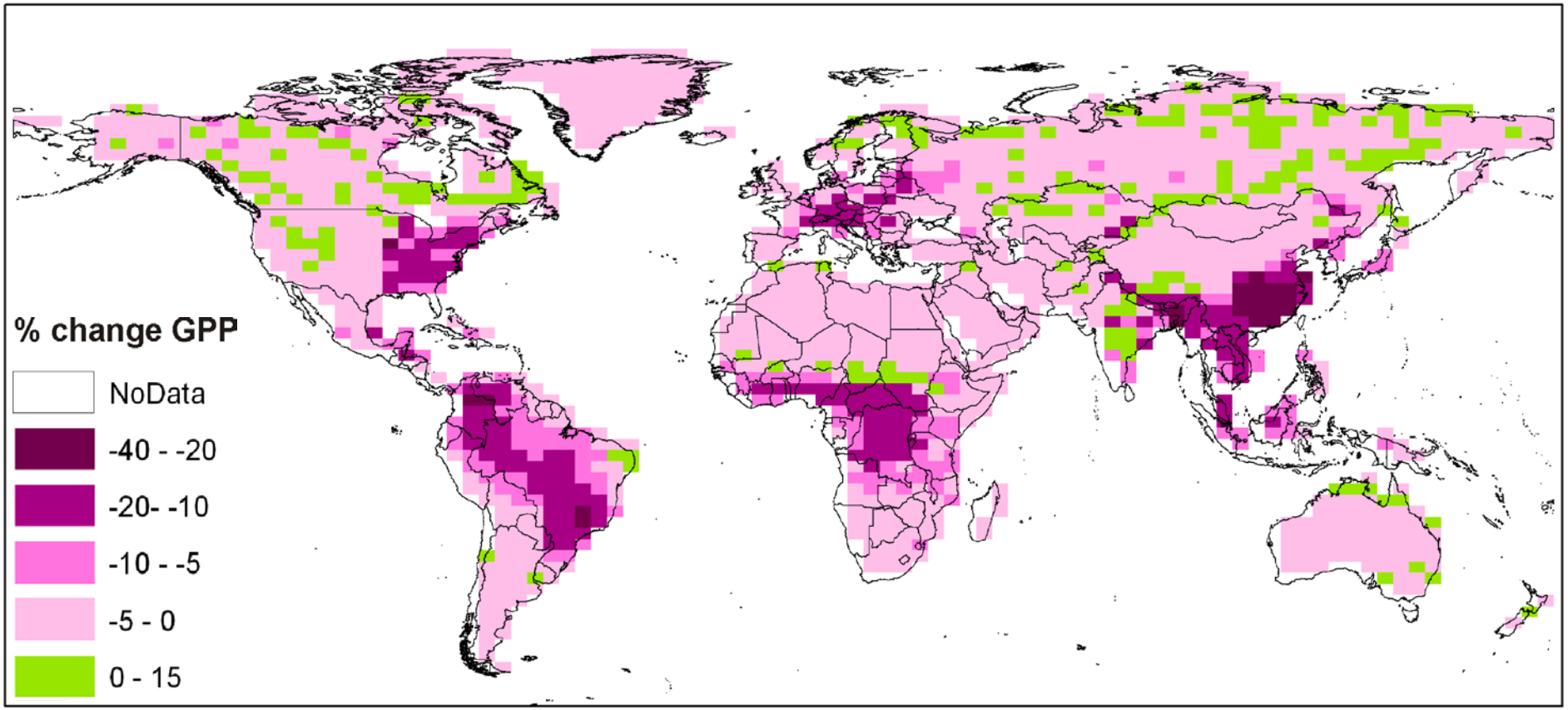
Source: Gregg et al. 2003

Non-lineary of ozone formation



Source: Solberg et al. 2004

Carbon sequestration (1)



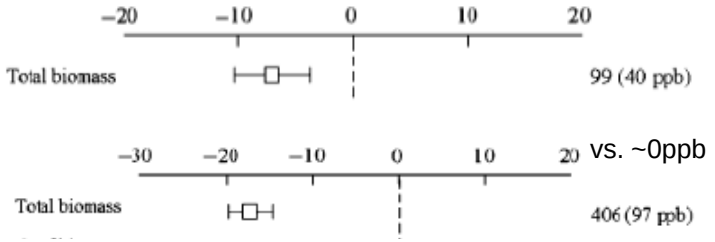
Source: Sitch et al. (2007)

GPP reductions due to ozone
Modelled for the period 1901 and 2100

Carbon sequestration (2)

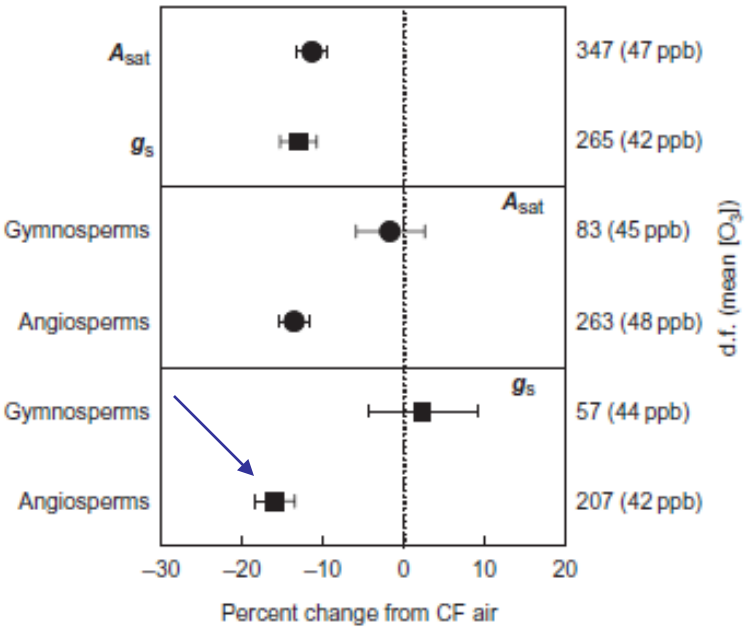
- Meta-analysis: -7% today (40ppb) vs. pre-industrial (~0ppb) and -10% in 2100 (97ppb) vs. today
- A 1% reduction in C sink strength per year has been experimentally suggested (Beech, Kranzberg Forst)
- O_3 exposure may suppress the gains in C sequestration due to increased atmospheric CO_2 (Aspen Face CO_2+O_3).
- Poplar: -21% FACE (50ppb) vs. –22% meta-analysis (60ppb)

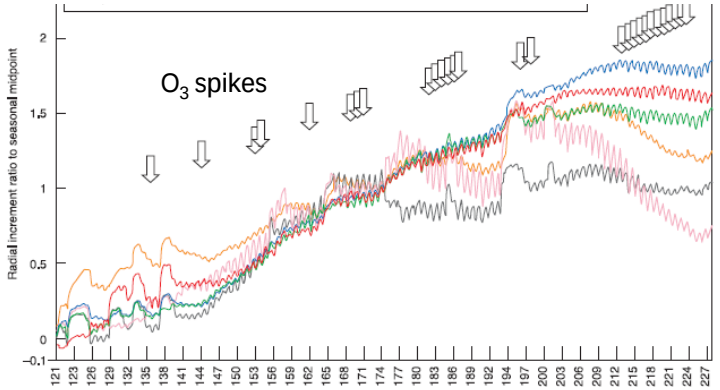
Sources: Matyssek et al. 2007, Karnosky et al. 2005, Wittig et al. 2009

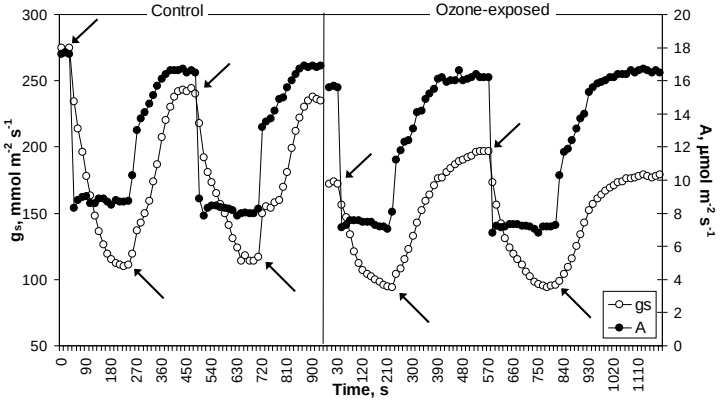


Water balance

- Ozone reduces long-term stomatal conductance, but...
- Ozone peaks amplify water losses from mature trees
- Altered hydrological balance at the landscape level
- Increased tree predisposition to drought







Sources: Wittig et al. 2007, McLaughlin et al. 2007, Paoletti & Grulke 2010

Wildfire

Ozone exposure

- Increased leaf and branch loss: increasing litter layer
- Accumulation of phenols: increased recalcitrance of litter
- Decreased root/shoot ratio because of decreased root mass
- Reduced ability to control leaf water loss
- Increased pest attacks

Nitrogen deposition

- Increased leaf and branch production: increasing forest fuel
- [Increased litter decomposition]
- Decreased root/shoot ratio because of increased shoot mass
- Increased pest attacks

Source: Grulke et al 2009

What can we do?

- More knowledge of synergistic interactions under realistic conditions
  - Manipulative experiments in the field
  - New long-term forest monitoring approaches (COST Action FP0903 => Supersites)
- Development of improved risk assessment models (flux-based ozone models, dynamic models of critical loads)
- Adaptive forest management
  - to reduce individual tree level drought stress e.g. larger gaps with sparse pole-sized trees left, drought tolerant ecotypes/species, ...

Conclusions

- Air pollution and climate change are posing new threats to our forests and changing their ability to face classic stressors
- IUFRO priority !