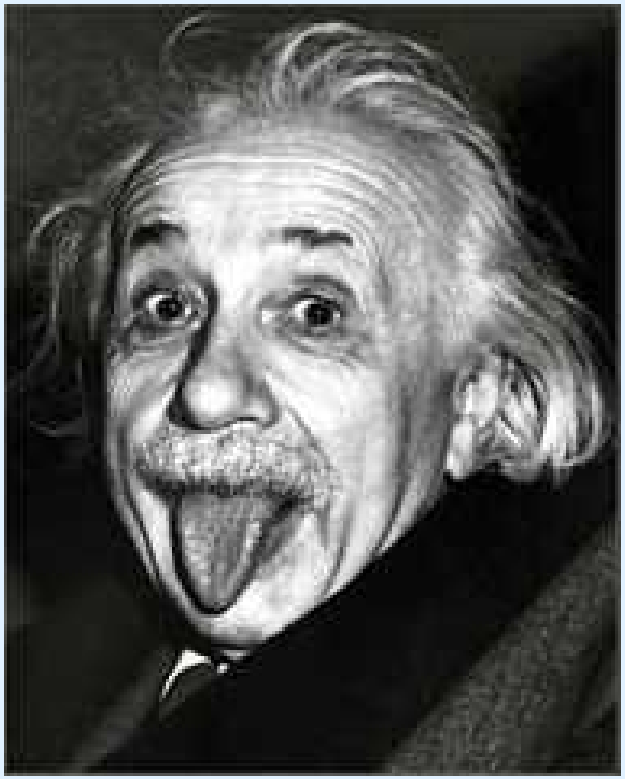
Highly Contrasting Effects of Different Climate Forcing Agents on Terrestrial Ecosystem Services

Peter Cox

Chris Huntingford, Lina Mercado, Stephen Sitch, Nicolas Bellouin, Olivier Boucher, Nicola Gedney

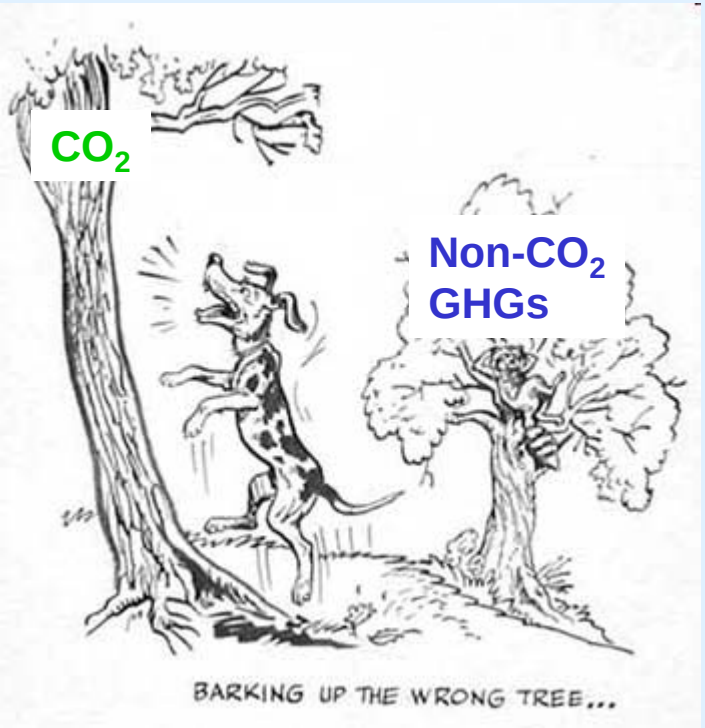
BEWARE :

Deliberately Provocative !!



Climate Mitigation:
are we barking up the wrong tree ?

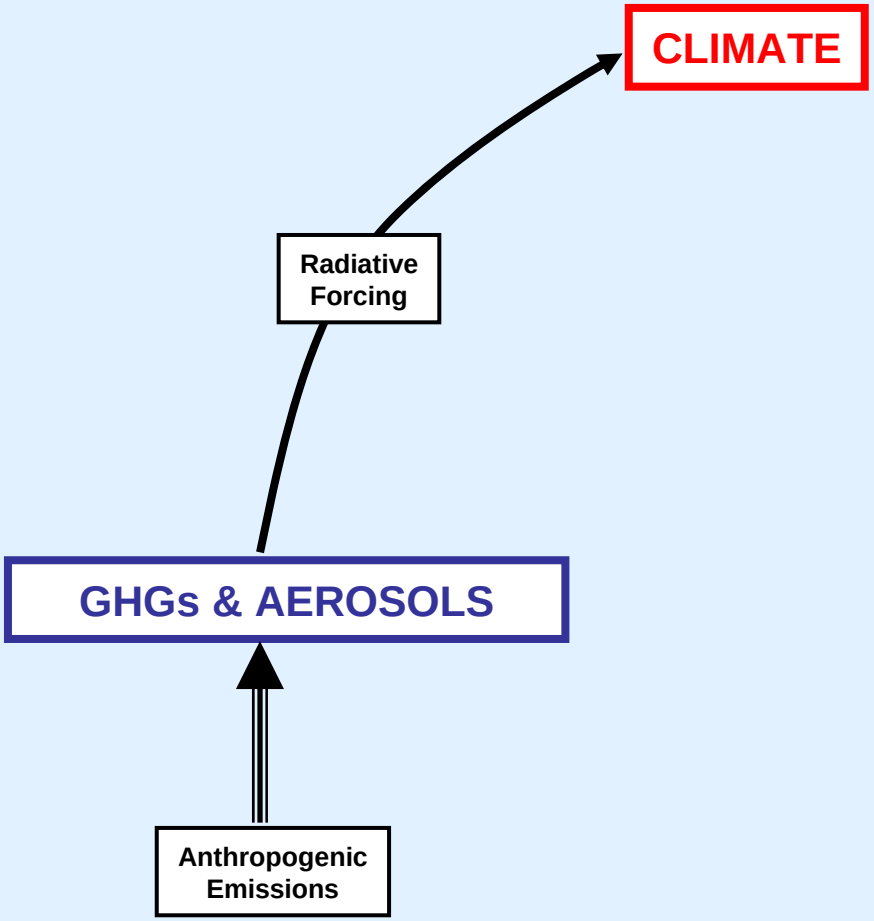
Peter Cox



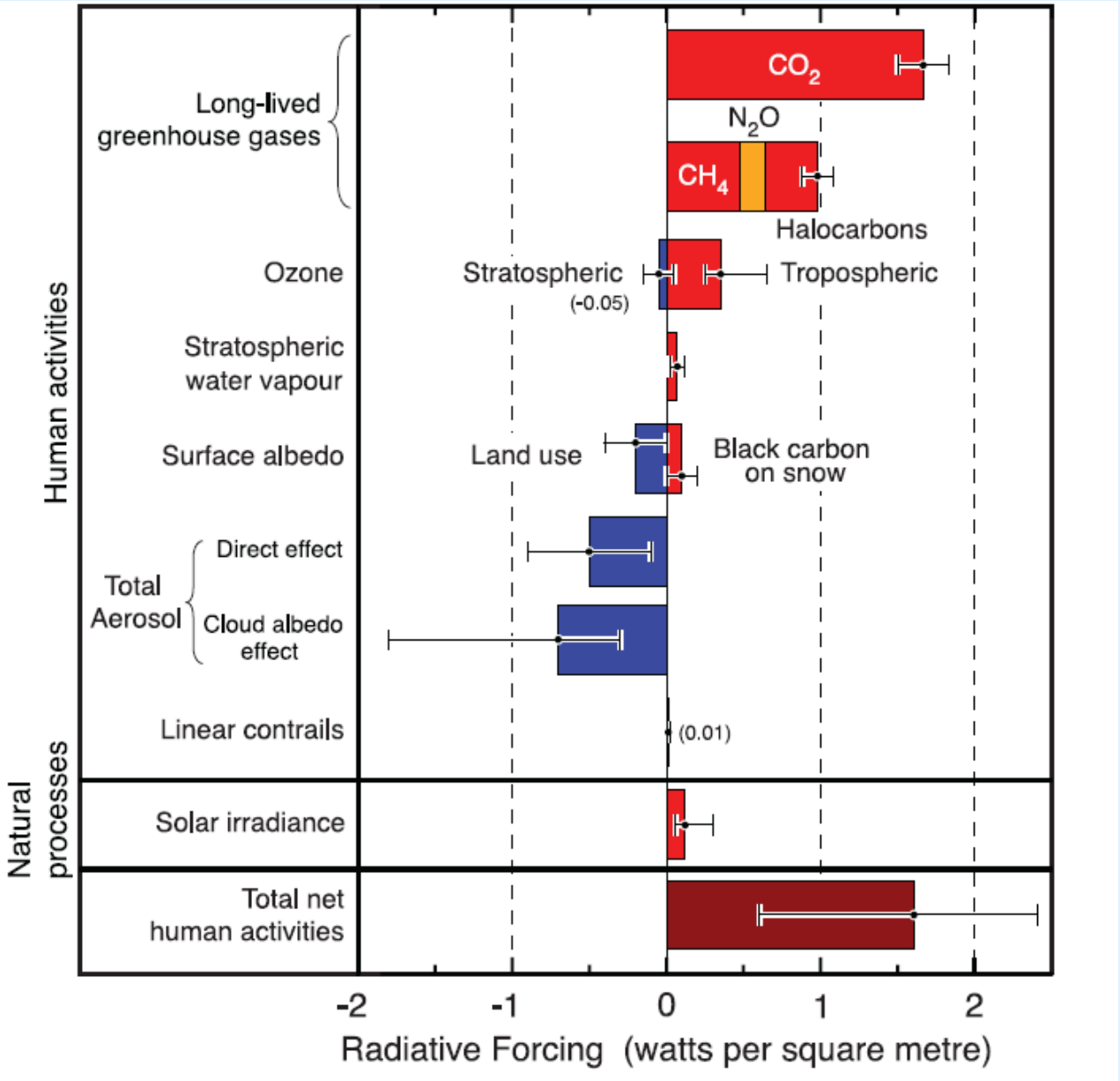
Rationale

- The impacts of different atmospheric pollutants are typically compared in terms of Radiative Forcing or Global Warming Potential

Direct Climate Forcing by GHGs and Aerosols



Radiative Forcing of Climate 1750-2005



Is this a useful Metric for Impacts ?

IPCC 2007

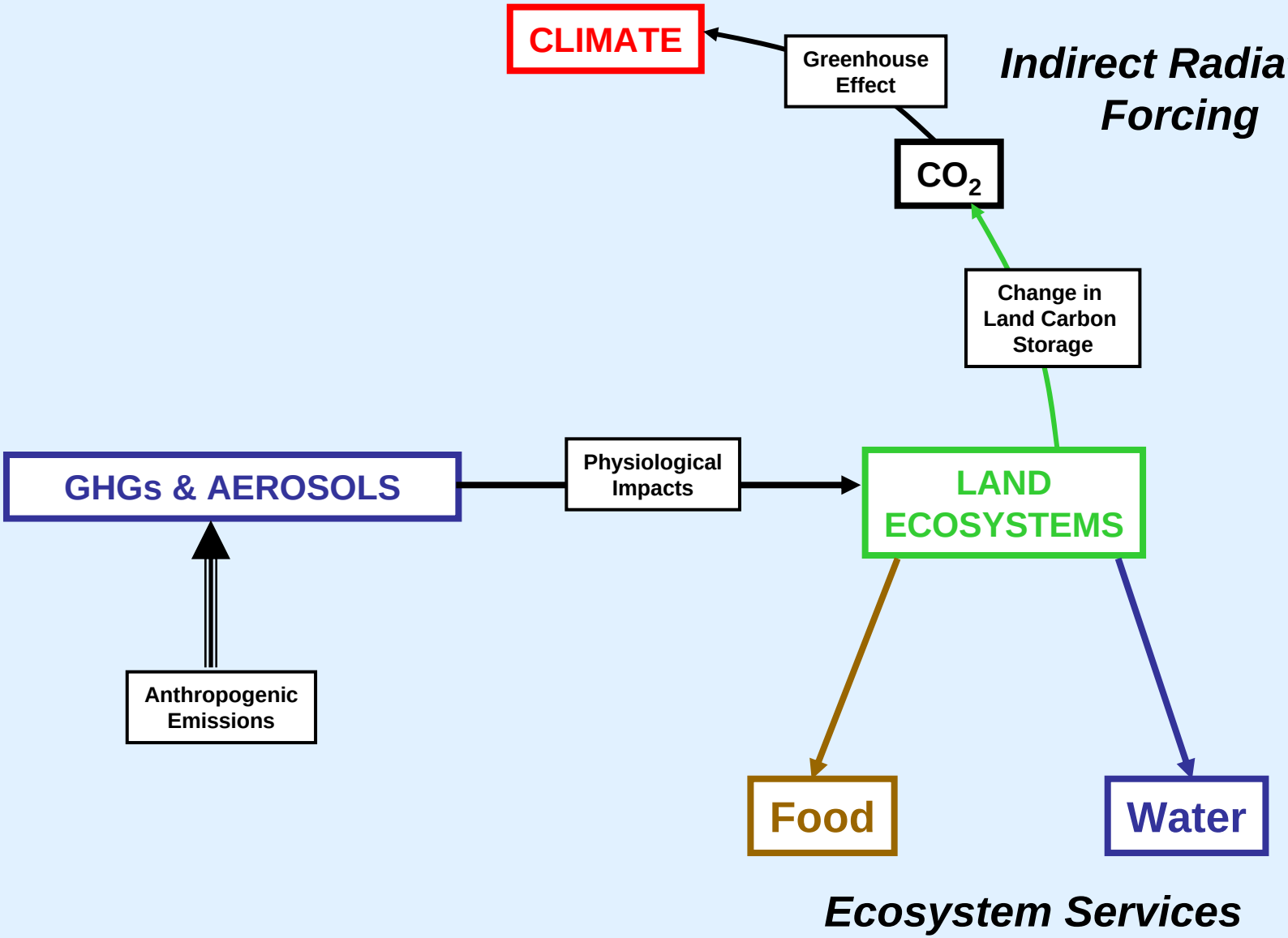
Rationale

- The impacts of different atmospheric pollutants are typically compared in terms of Radiative Forcing or Global Warming Potential

- But Ecosystems and Ecosystem Services are affected *directly* by many atmospheric pollutants, as well as *indirectly* via the impact of these pollutants on climate change.

- How do the *Physiological Impacts* of different pollutants vary ?

Physiological Effects on Ecosystem Services and Indirect Climate Forcing



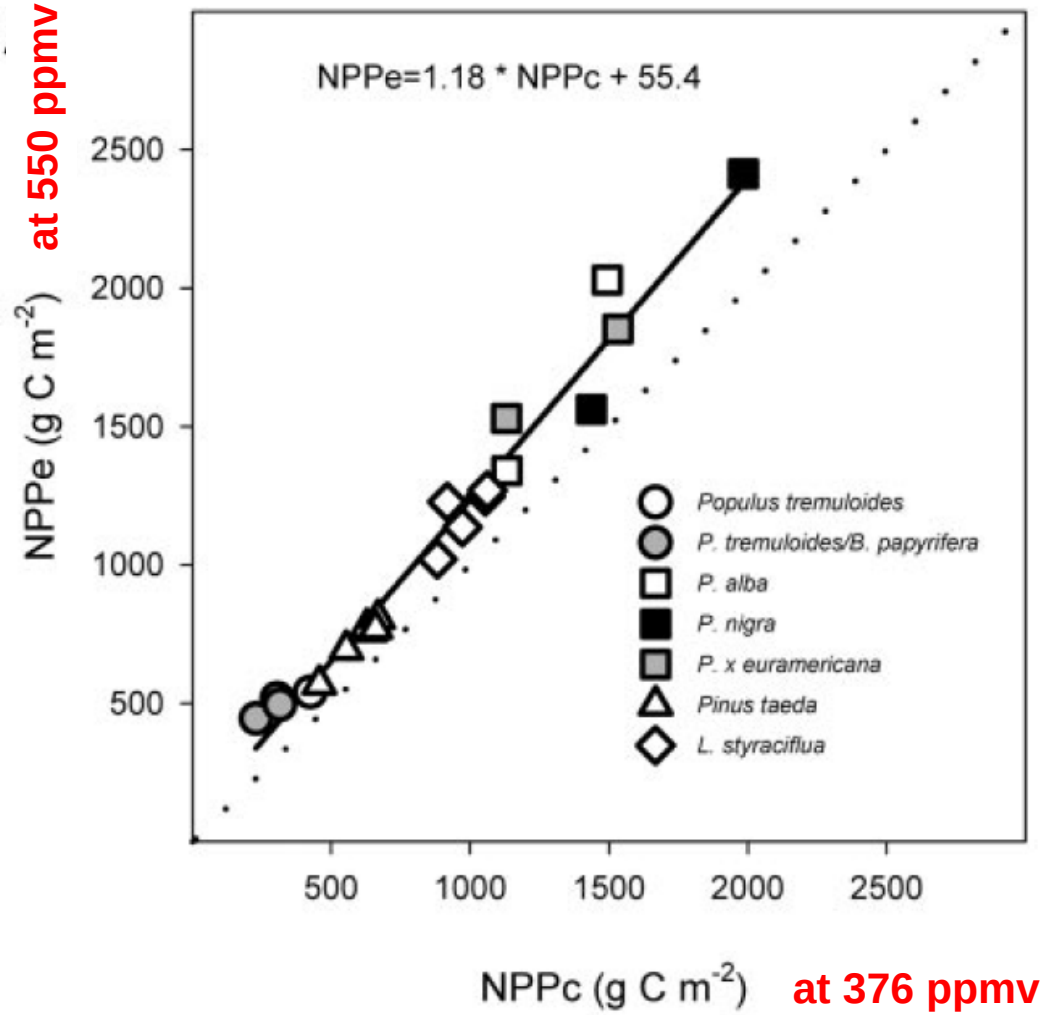
Physiological Effects of Atmospheric Pollutants

- **CO_2 Fertilization Effects - increasing CO_2 may lead to:**

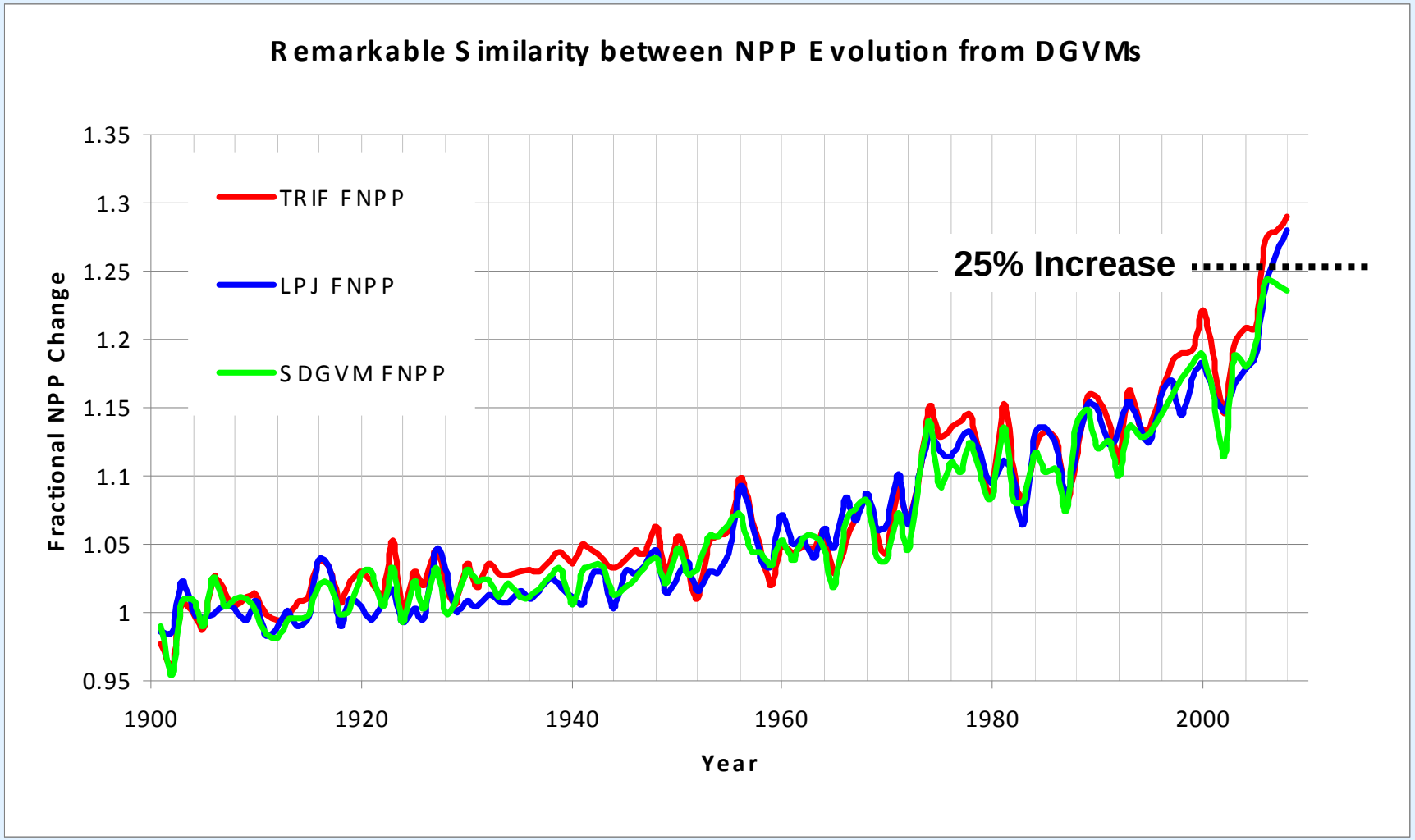
  Enhancement of Net Primary Productivity/growth (depends on nutrients)

CO_2 Fertilization of NPP (FACE Experiments)

Norby et al. 2005



Dynamic Global Vegetation Models agree on NPP increase in 20th Century !



Outstanding issue : how will nutrient availability limit CO_2 fertilization ??

Physiological Effects of Atmospheric Pollutants

- **CO_2 Fertilization Effects - increasing CO_2 may lead to:**
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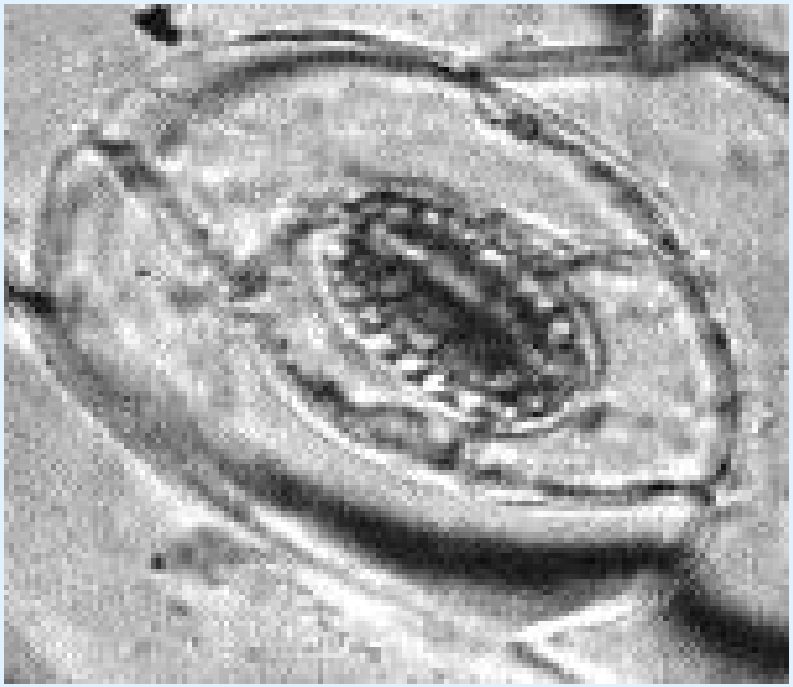
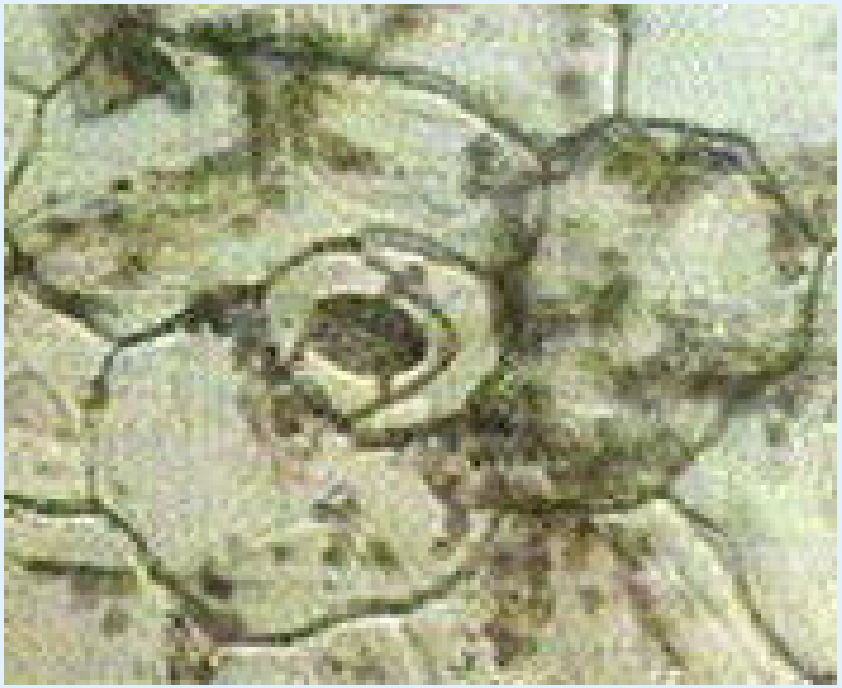
  - CO_2 induced Stomatal Closure (leading to higher Runoff?)

Stomata : Linking Water and CO_2





Stomata are pores on plant leaves (typical dimension 10-100 x 10^{-6} m), which open and close in response to environmental stimuli, allowing carbon dioxide in (to be fixed during photosynthesis) and water vapour out (forming the transpiration flux).

Source: Mike Morgan (www.micscape.simplenet.com/mag/arcticles/stomata.html)

Physiological Effects of Atmospheric Pollutants

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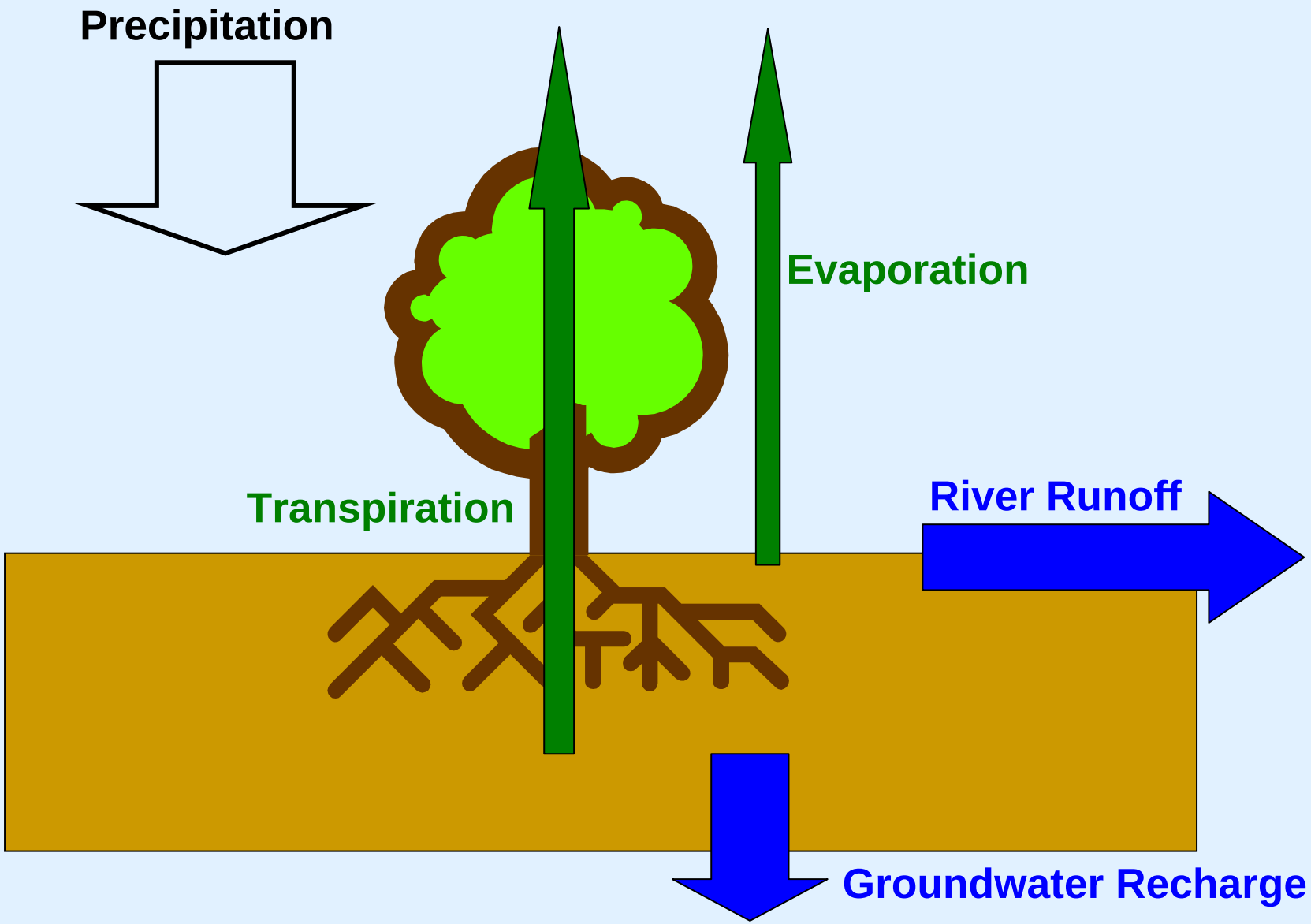
  - Increase in Water Use Efficiency

Partitioning of Water on Land



Green and Blue Water

- Water balance:

Precipitation ~ Evapotranspiration + Runoff

- Water availability:

Precipitation ~ Green Water + Blue Water

Controlled largely by Climate

Controlled largely by Ecosystems

“Available” to Humans

Physiological Effects of Atmospheric Pollutants

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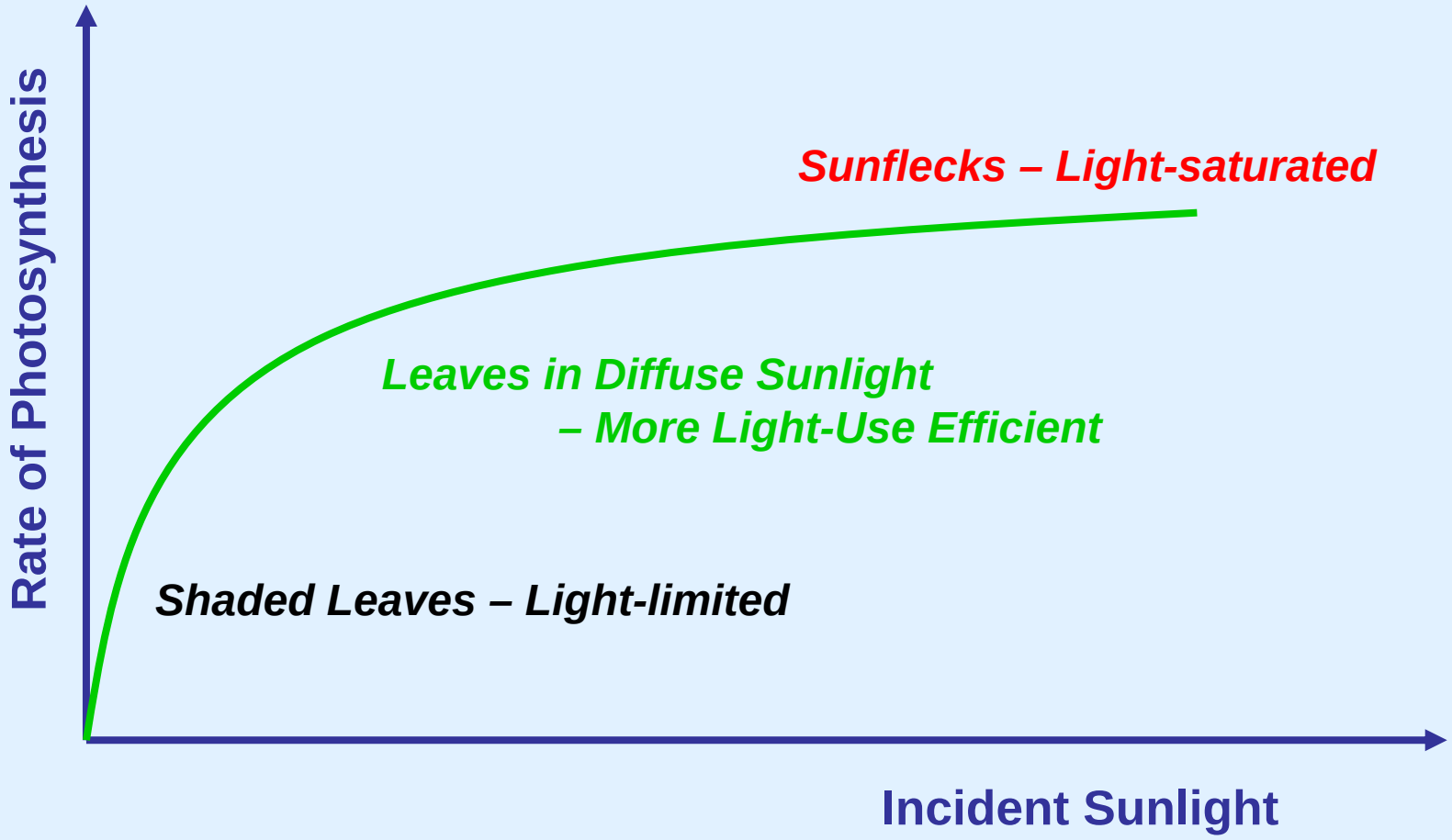
- **Diffuse Radiation Fertilization - increasing aerosols or cloud cover:**
  - Reduces sunlight reaching the surface ('global dimming') reducing NPP
  - Increases 'diffuse fraction' of sunlight increasing NPP ('diffuse radiation fert.')
  - *Overall plants like it hazy…..*

Diffuse Radiation Fertilization



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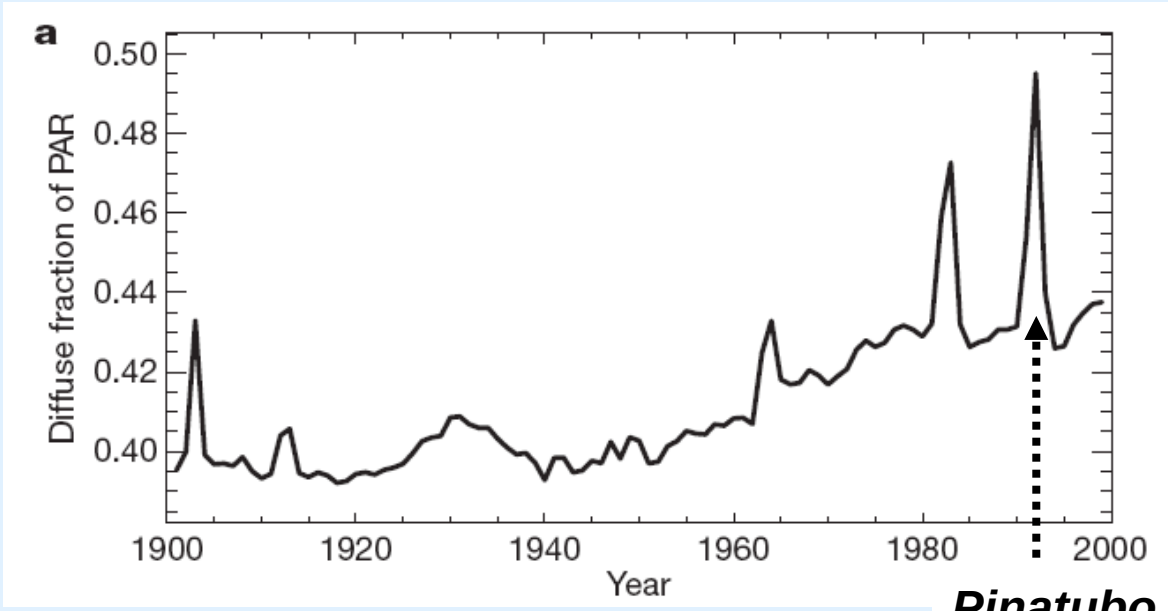
LETTERS

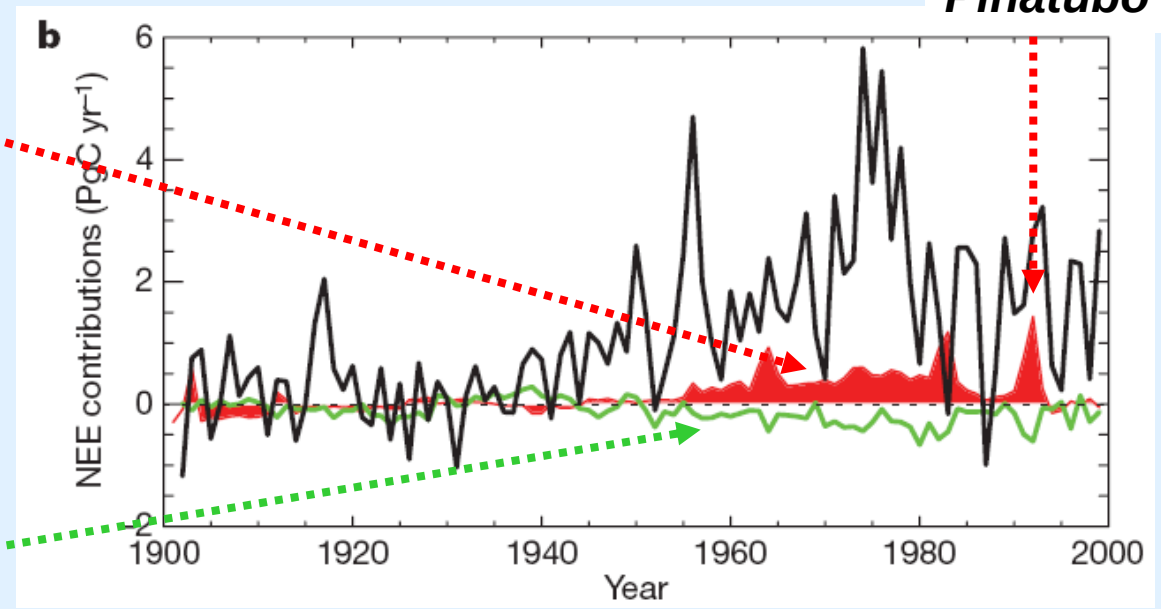
Impact of changes in diffuse radiation on the global land carbon sink

Lina M. Mercado[1], Nicolas Bellouin[2], Stephen Sitch[2], Olivier Boucher[2], Chris Huntingford[1], Martin Wild[3] & Peter M. Cox[4]

Mercado et al., 2009

Impact of Diffuse PAR on the 20th Century Land Carbon Sink





25% enhancement of 1960-1999 land carbon sink by variations in diffuse radiation

Partial offset by reductions in Total PAR

Physiological Effects of Atmospheric Pollutants

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  - Reduces sunlight reaching the surface ('global dimming') reducing NPP
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  - *Overall plants like it hazy…..*

- **O_3 Damage to plants – increases in ground-level ozone lead to:**
  - Reduced NPP
  - Reduced stomatal conductance (increasing runoff)
  - Damage to photosynthetic machinery

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LETTERS

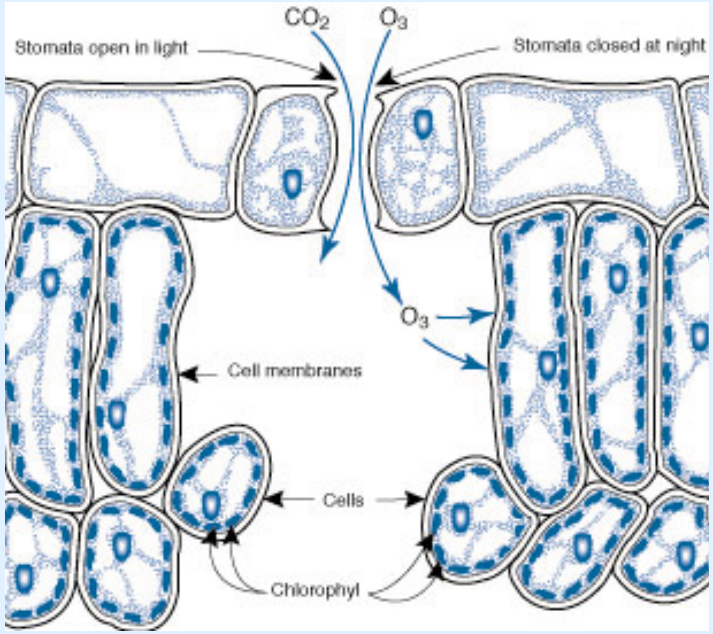
Indirect radiative forcing of climate change through ozone effects on the land-carbon sink

S. Sitch[1], P. M. Cox[3], W. J. Collins[4] & C. Huntingford[2]

Sitch et al., 2007

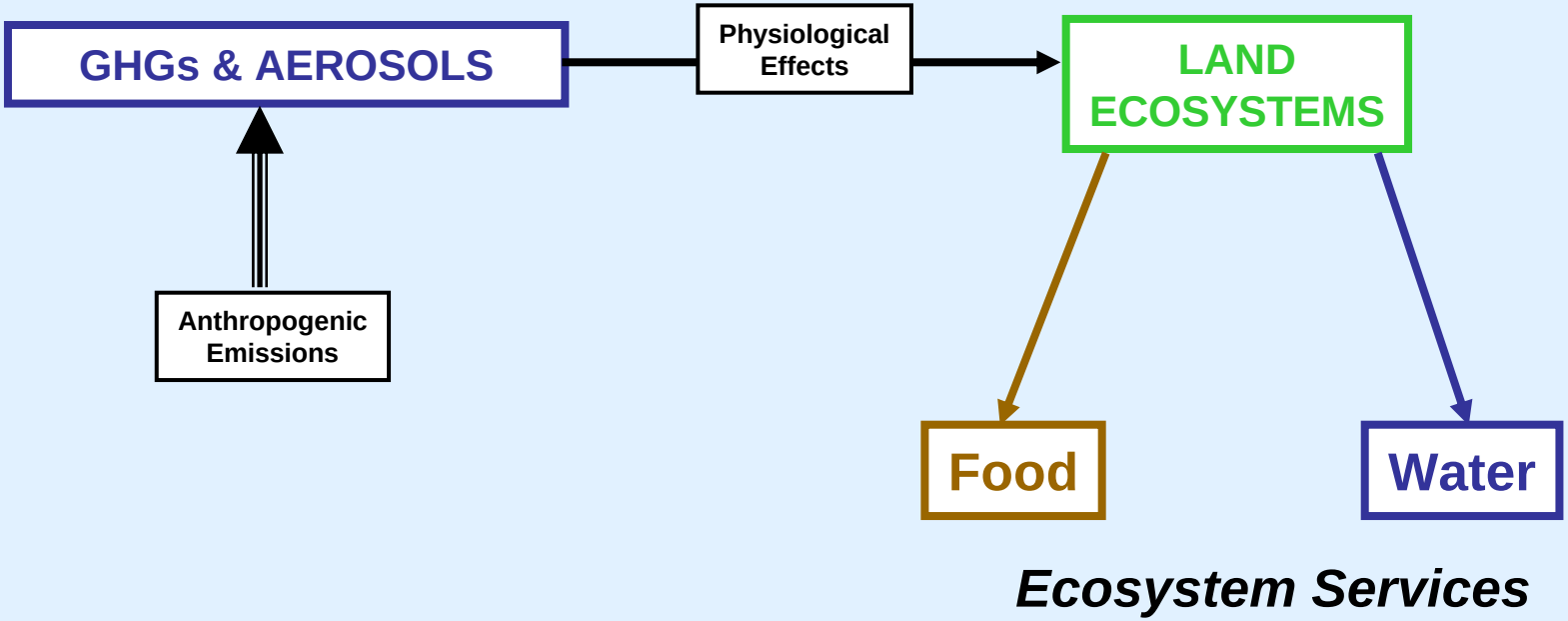
Effects of Ozone Exposure on Plants

- O_3 reduces plant production
  - causes cellular damage inside leaves
  - reduced photosynthetic rates
  - Increased C-allocate to detoxify and repair leaves

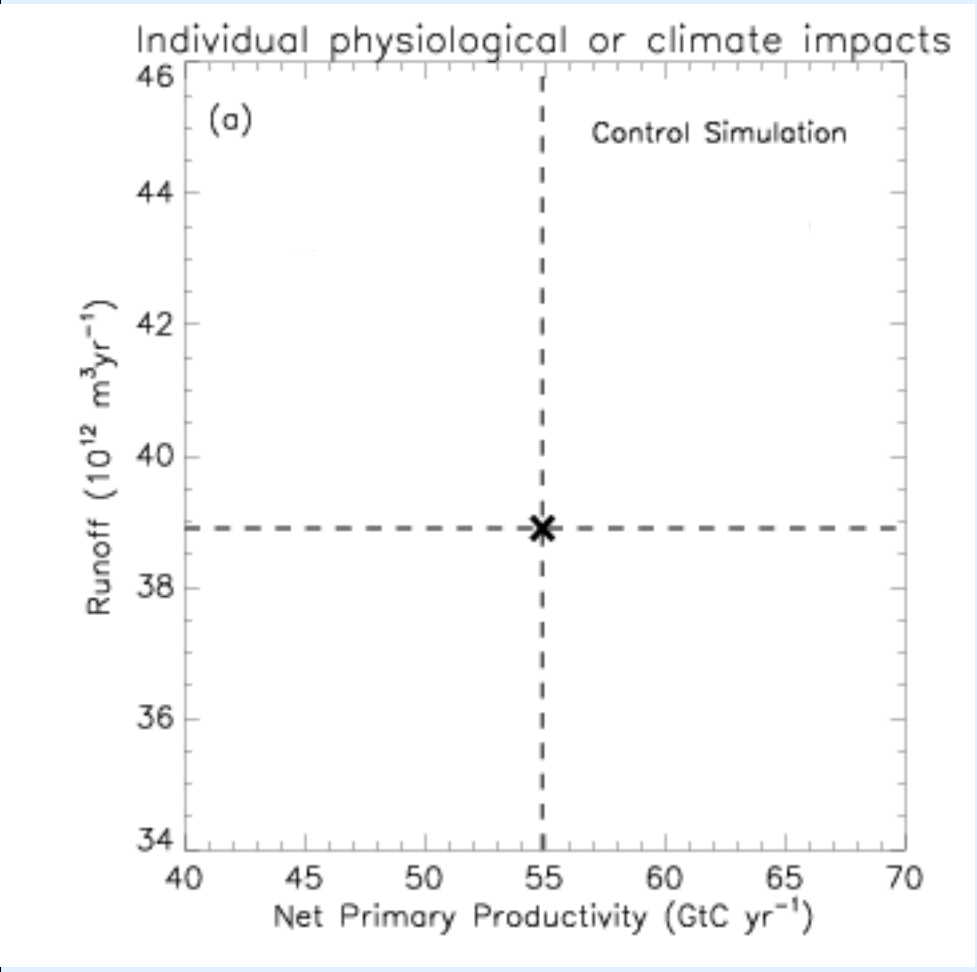


- O_3 reduces stomatal conductance
  - lowers internal leaf [CO_2] reducing rates of photosynthesis
  - reduces O_3 uptake.

Physiological Effects on Ecosystem Services



Contrasting Impacts on NPP and Runoff



Contrasting Climate & Physiological Impacts on NPP

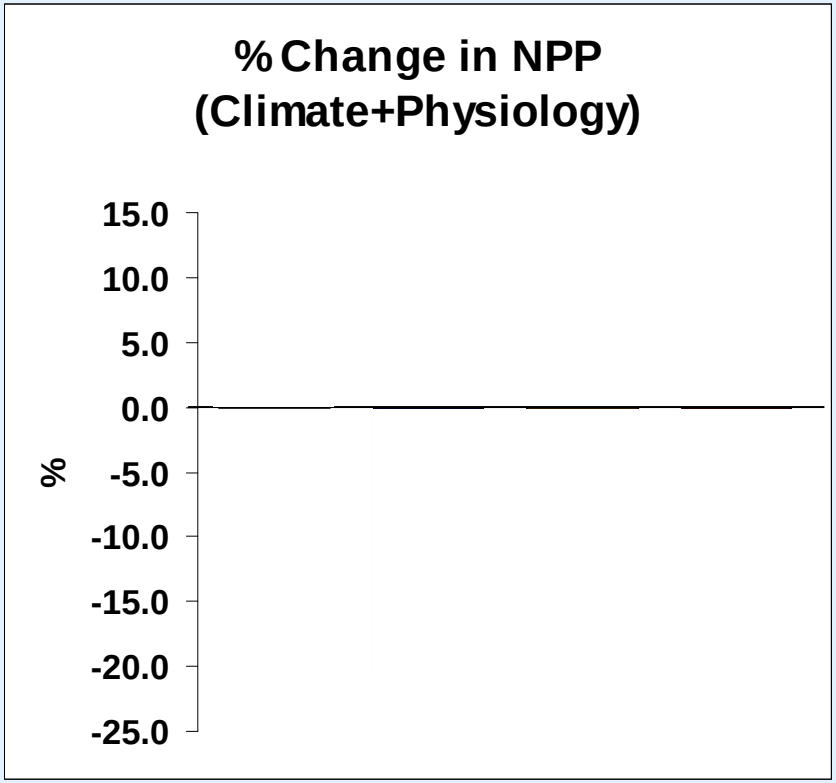
CO_2 Physiology Only

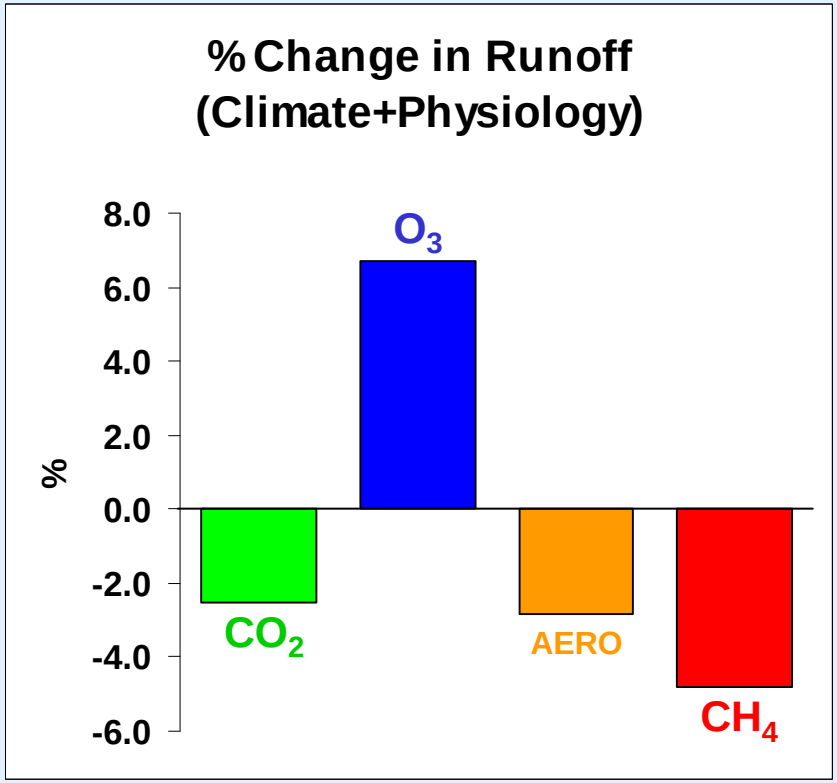
Climate Change Only

O_3 Physiology Only

-Aerosol Physiology Only

Impacts on Food and Water of +1 W m^{-2}

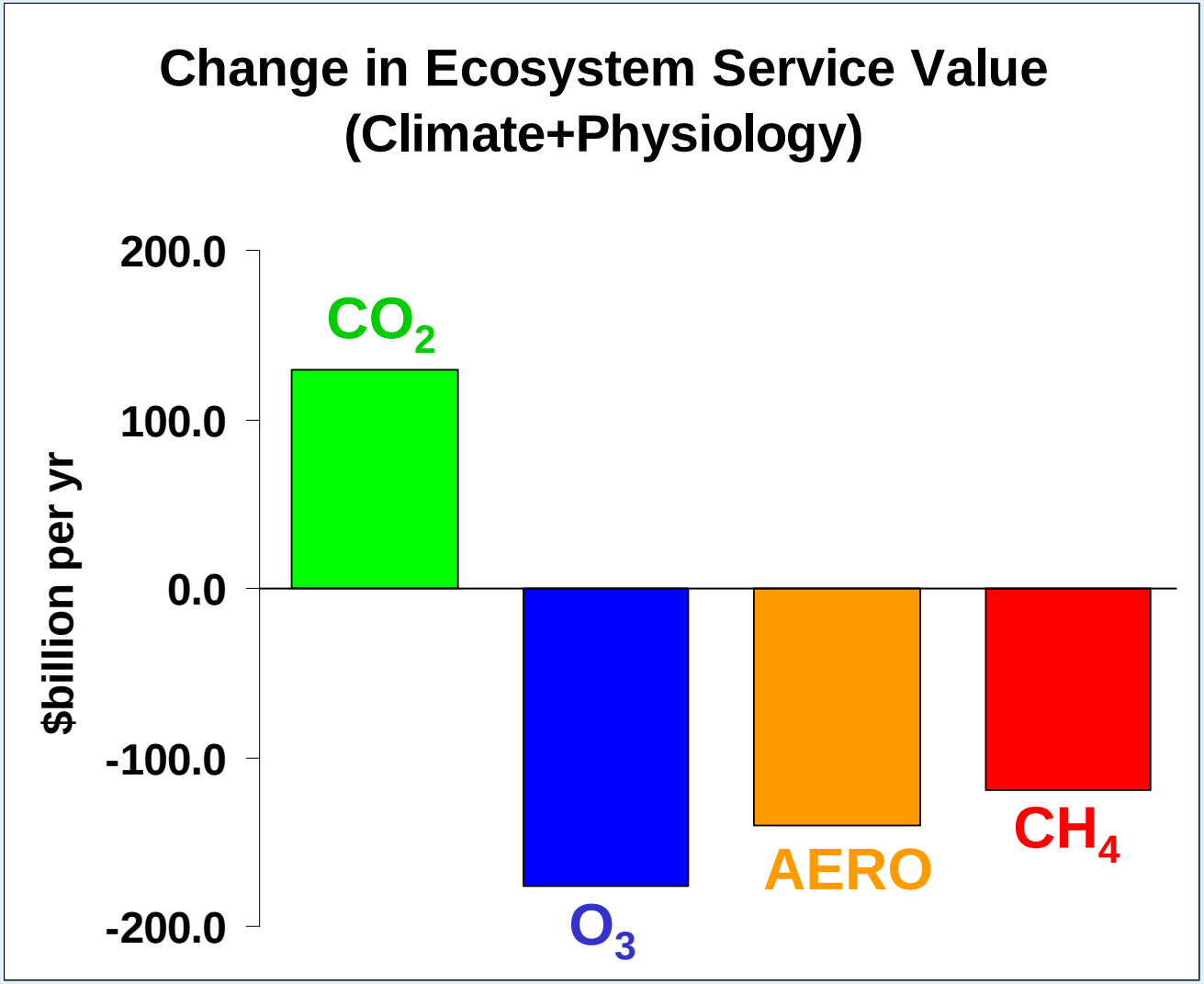




BEWARE :

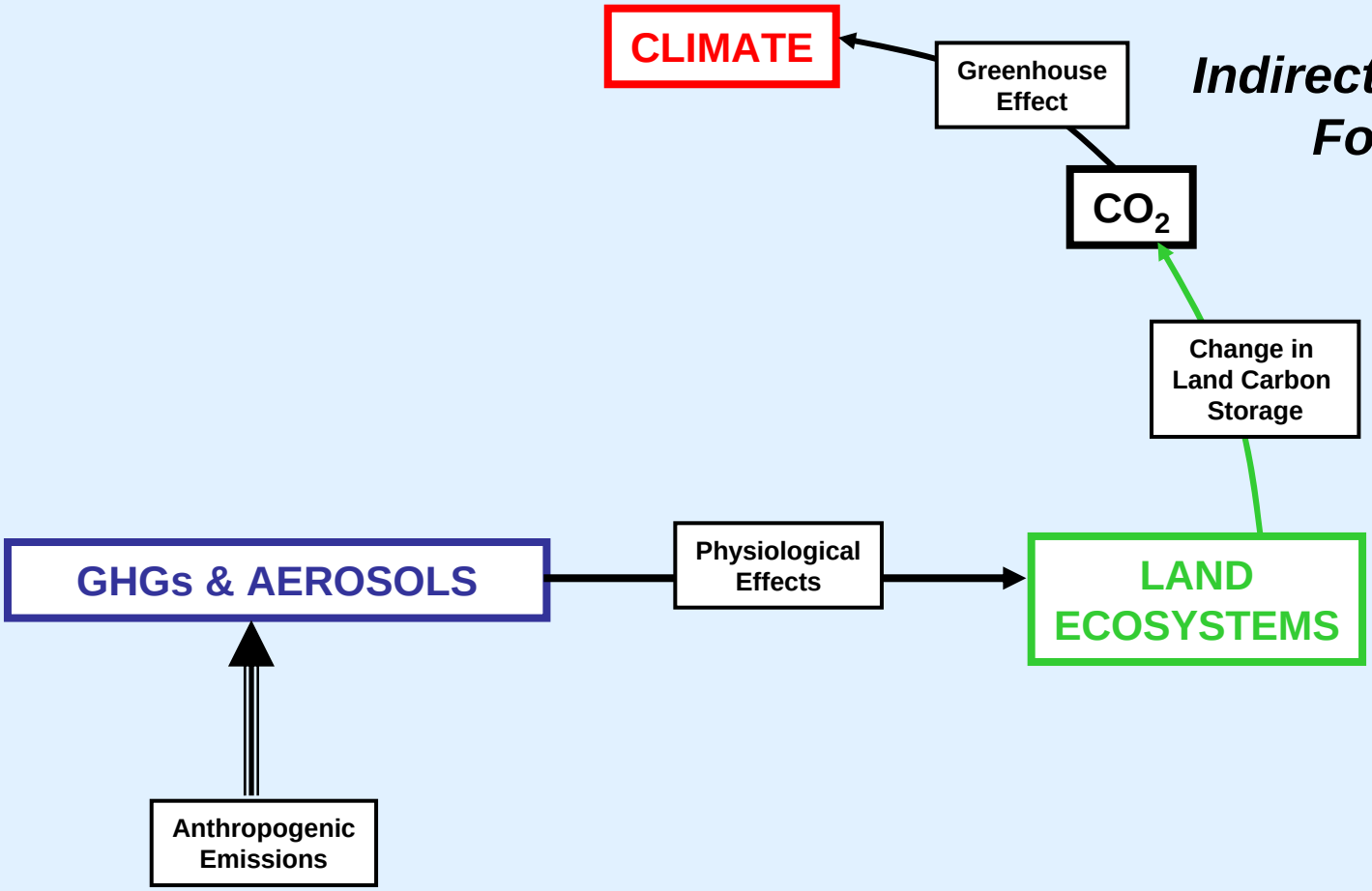
Brave Extrapolation !!

Change in Ecosystem Service Value



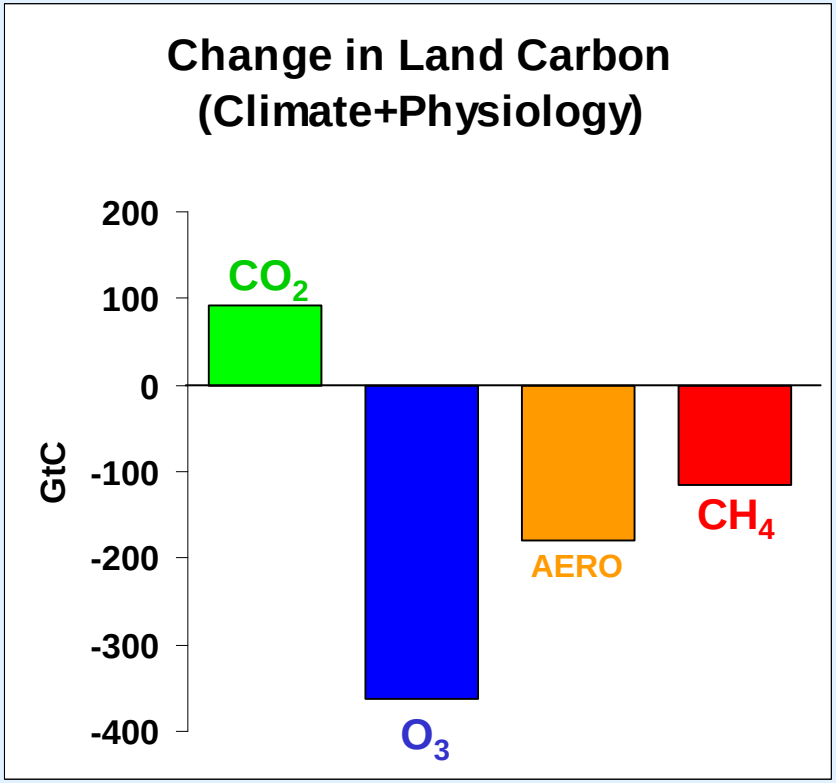
Based on valuations from Costanza et al. (1997);
Food & Fibre ~ $1.40 tr/yr, Fresh-water ~$1.70 tr/yr

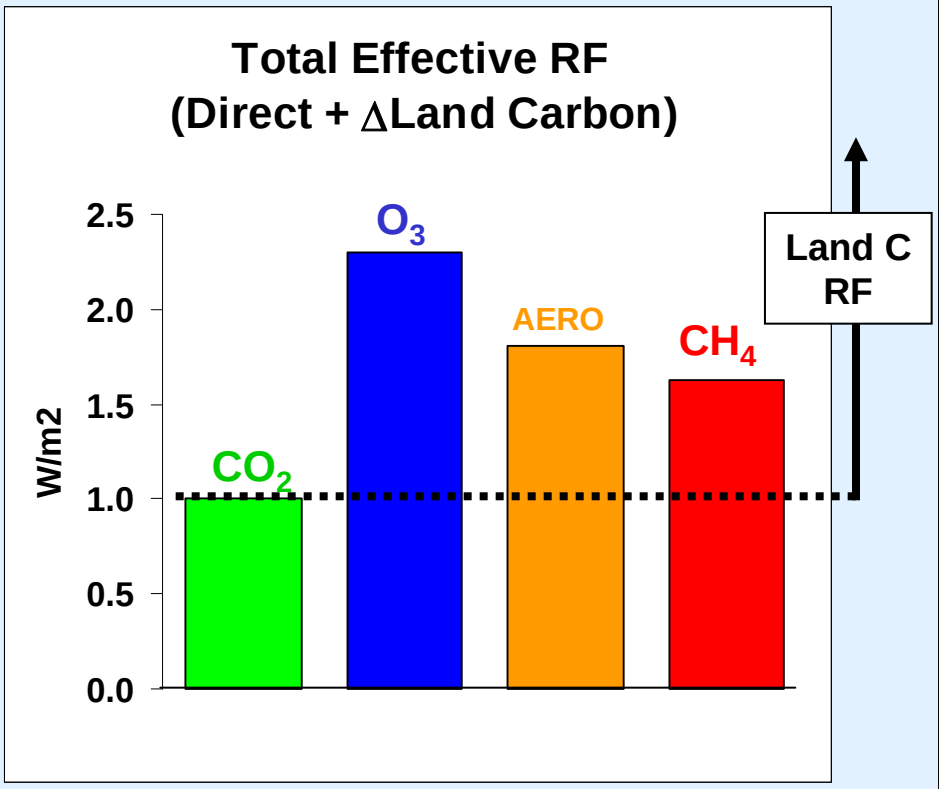
Indirect Climate Forcing



Indirect Radiative Forcing

Impact on Land Carbon Storage of +1 W m^{-2} and Total Effective Radiative Forcing





Land Carbon Radiative Forcing is extra radiative forcing due to released land carbon relative to CO_2
(assuming an Airborne Fraction of 0.5)

Conclusions

- Land Ecosystems and Land Ecosystem Services are affected *physiologically* by many atmospheric pollutants, as well as via the impact of these pollutants on climate change.
- The *Physiological Impacts* of different atmospheric pollutants on land ecosystem services vary radically, and are often larger than the impacts of climate change alone.
- Current global models suggest that CO_2 fertilization will increase land carbon storage, whereas climate change alone will tend to reduce it. Reductions in aerosols or increases in ground-level O_3 would have even more negative impacts on land carbon storage.
- These *Physiological Impacts* imply an Indirect forcing of climate change through changes in land carbon storage.
- We estimate that the total climate impact of a 1 Wm^{-2} Direct Radiative Forcing due to O_3 is equivalent to a 2.3 Wm^{-2} of CO_2. The equivalent figures for Aerosol reduction and CH_4 increase are 1.8 and 1.6 Wm^{-2} respectively.

→ Research Agenda to 2030

Research Agenda 2030

- Climate Mitigation strategies need to take account of the very different physiological impacts of different atmospheric pollutants on ecosystem services.
- Scientifically this requires reducing uncertainties in the *Physiological Impacts*, especially:

  CO_2 fertilization effects on the land (and nutrient limitations)

  Ocean acidification

- Current understanding of the *Physiological Impacts* on Land Ecosystems, suggests that mitigation strategies focussing on non-CO_2 GHGs should be a higher priority

Fiddling While Rome Burns…..?

Contrasting Impacts on Runoff