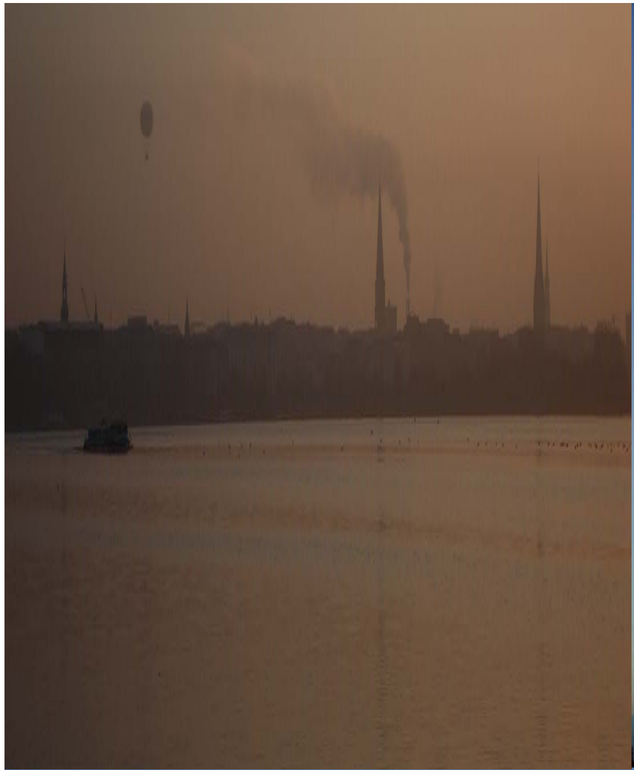

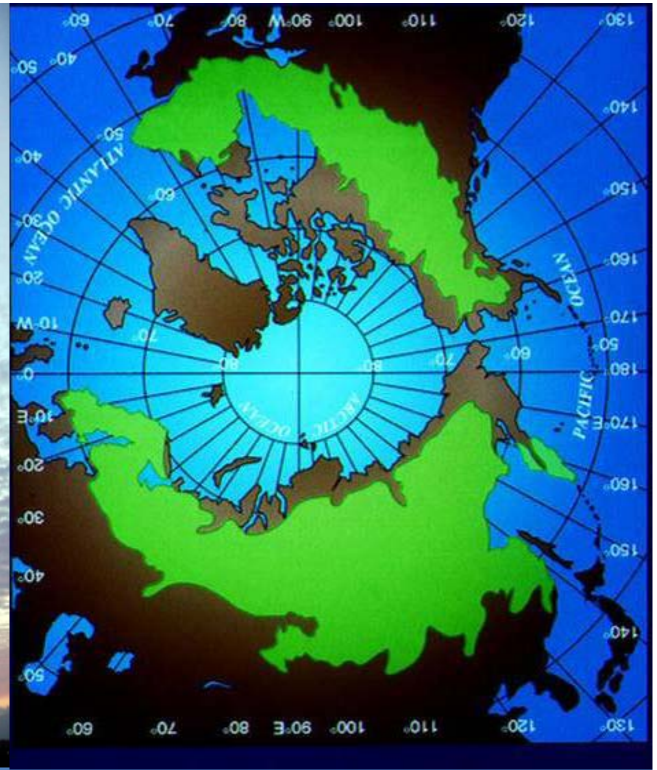

Ch 6 Attributing causes of regional climate change

Jonas Bhend, Hans-Christen Hansson and Marie José Gaillard

September 2012

Attributing causes of regional climate change

Regional evidence of global warming

Jonas Bhend | Postdoc CSIRO Marine and Atmospheric Research

September 2012

CLIMATE ADAPTATION FLAGSHIP

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Overview of subchapter 6.2

- Regional evidence of global warming
  - Processes causing global warming (mainly increasing GHG concentrations)
  - Sources of information for chapter 6.2 (formal detection and attribution, consistency)
- Changes in key variables
  - Attributable changes in temperature, circulation and the hydrological cycle
  - No attribution for changes in other variables (e.g. snow cover, runoff, properties of the Baltic Sea)
- Event-attribution – proximate vs. ultimate causes
  - Cold winter of 2009/10 in Europe, Russian heat wave of 2010
- No attribution of changes in impacts (many confounding factors)
  - Strategies to attribute changes in impacts

A quick word on terminology / sources of information

Climate change: Deterministic response to changes in external forcing

Internal variability: Random fluctuations independent of external forcing

Detection: "The observed climate change is unlikely due to internal variability alone" = detection of (some) external forcing

Attribution: Mix of plausible external forcing mechanisms that best explain the detected change.

i) Consistency: simulated response to forcing is consistent with observed change

Used in BACCII

: no other plausible forcing (or combination) is able to explain the observed change

Causes of regional temperature change

- First formal detection and attribution studies for temperature and temperature extremes in northern Europe
  - Warming in summer has been detected (Jones et al. 2008, Stott et al. 2010)
  - Change in temperature extremes detected (Zwiers et al. 2010)

- The regional studies are in line with a number of studies detecting and attributing various aspects of warming in Europe and globally.

- Discrepancies between observed and simulated circulation changes may affect robustness of detection (mainly in winter)
→ detection of human influence on warming in summer is robust

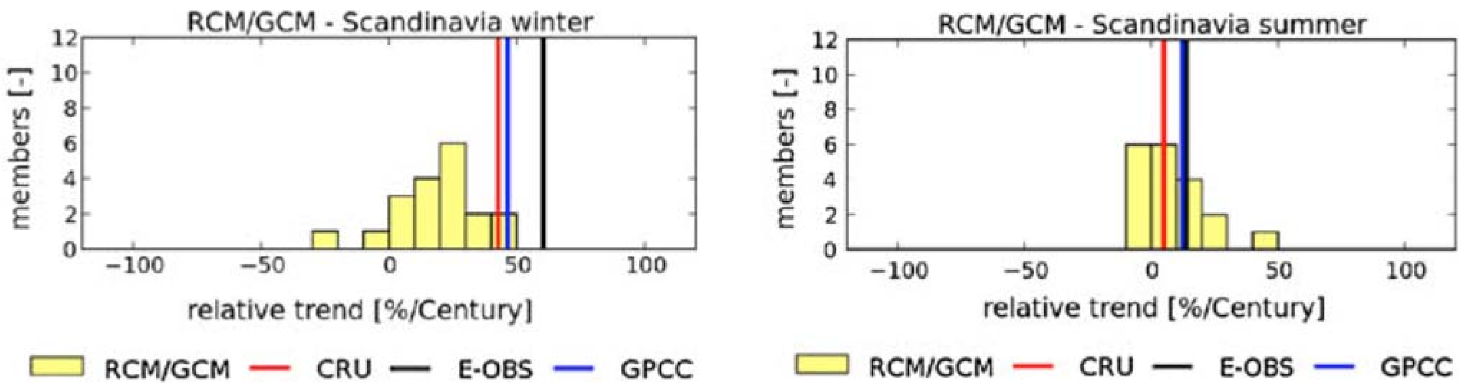
Causes of circulation changes

- Successful attribution of SLP trends globally, but not for northern mid- and high latitudes (Gillett and Stott, 2009)
  - Sign of change consistent, but tendency for models to underestimate observed changes

- Detection of changes in storminess in winter (Wang et al. 2009), but inconsistency across studies:
  - Recent increase not outstanding in light of historic changes (Matulla et al. 2008, Bärring and Fortuniak 2009)
  - Long-term increase in storminess in reanalysis (20CRv2, Donat et al. 2011)

Causes of changes in the hydrological cycle

- First formal detection and attribution studies for global precipitation and extremes, and Arctic precipitation
- No regional detection and attribution studies
- Observed regional rainfall change in winter underestimated in simulations



Observed relative precipitation trends in winter (DJF, left) and summer (JJA, right) from 1961 to 2000 (vertical lines) along with the distribution of simulated precipitation trends in an ensemble of 19 regional climate model simulations (yellow bars, reproduced from van Haren et al. 2012).

Summary

- Accumulation of evidence of a detectable human influence (mainly GHG) on regional warming.
- Gaps in understanding of regional circulation changes and changes in hydrological cycle
- Lack of studies on attribution of changes in other variables (e.g. snow cover, runoff, sea ice)
- Attribution has to be revisited as understanding of non-GHG forcings is fragmentary (see aerosols and land-use changes)

Ch 6 Attributing causes of regional climate change

6.3 Aerosols

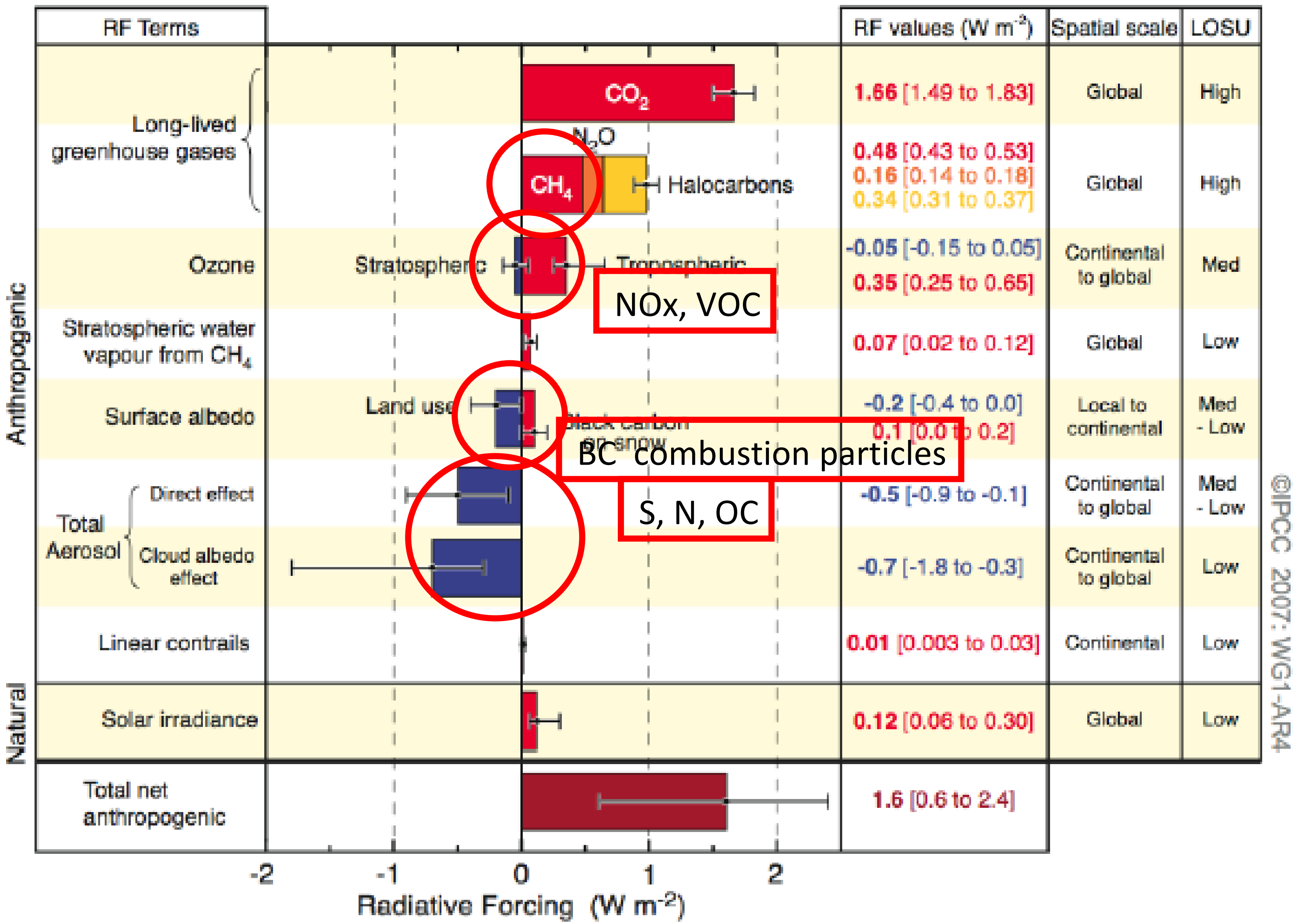
Hans-Christen Hansson and Jonas Bhend

September 2012

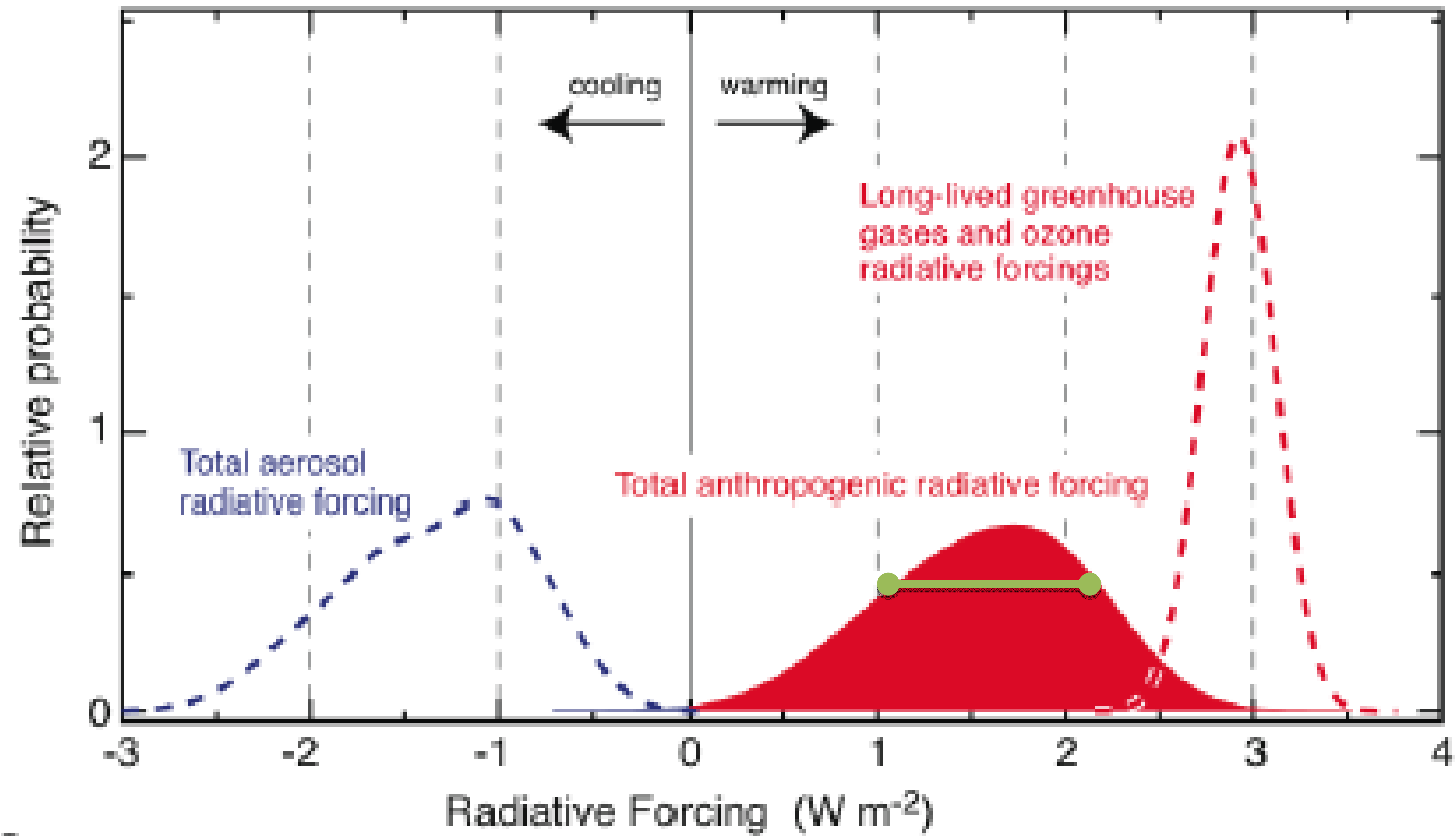
6.3 Aerosols

- Basics about aerosols and climate:
  - Atmospheric aerosol sources, particle size distribution, formation, aerosol-cloud interaction
  - Direct and indirect aerosol climate effects, total aerosol climate effect vs climate sensitivity
- Global climate and air quality:
  - Key air quality components
  - Possible mitigations strategies and effects
- Regional climate and natural/anthropogenic aerosols:
  - Observed and possible climate effects
  - Expected future climate change due to aerosols

Radiative Forcing Components

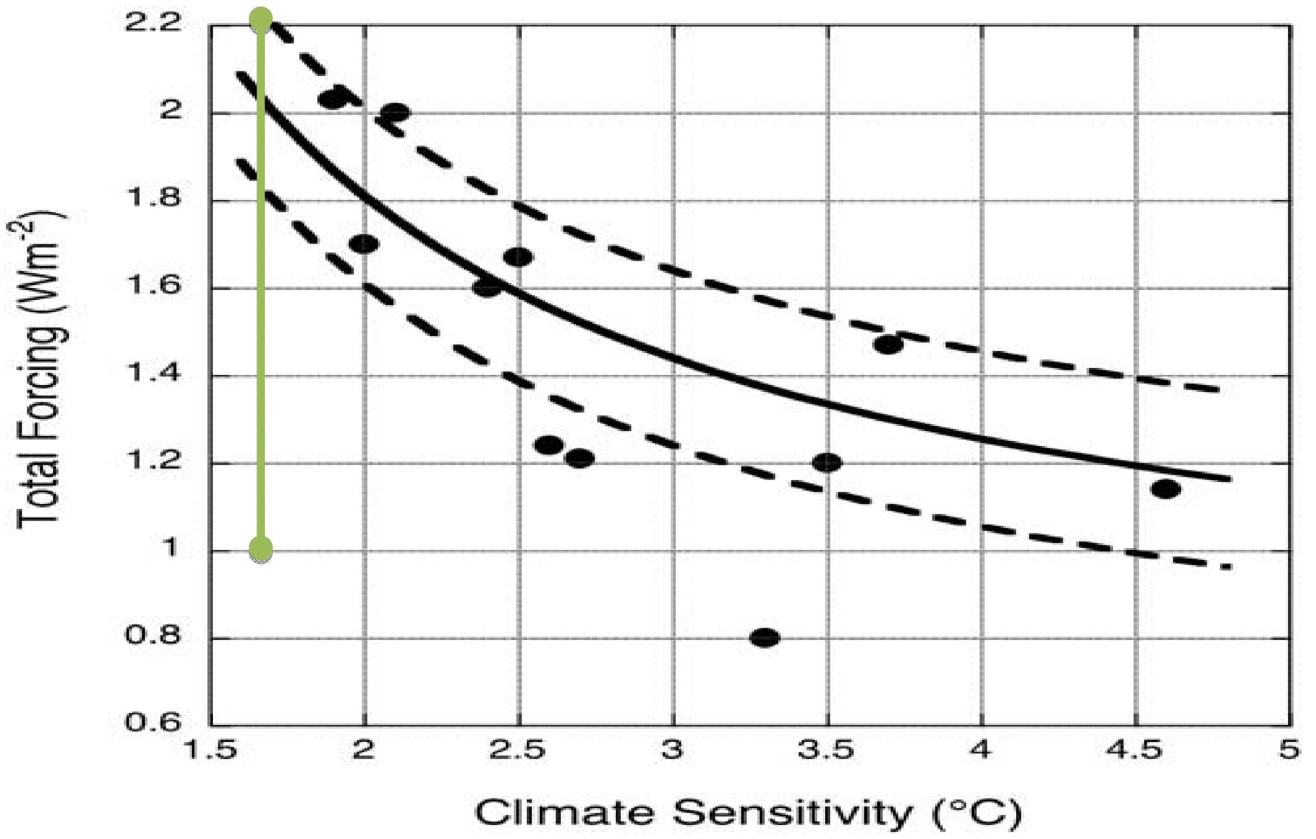


Greenhouse gases + particles =



IPCC, chapt. 2, 2007

The total aerosol effect and climate sensitivity



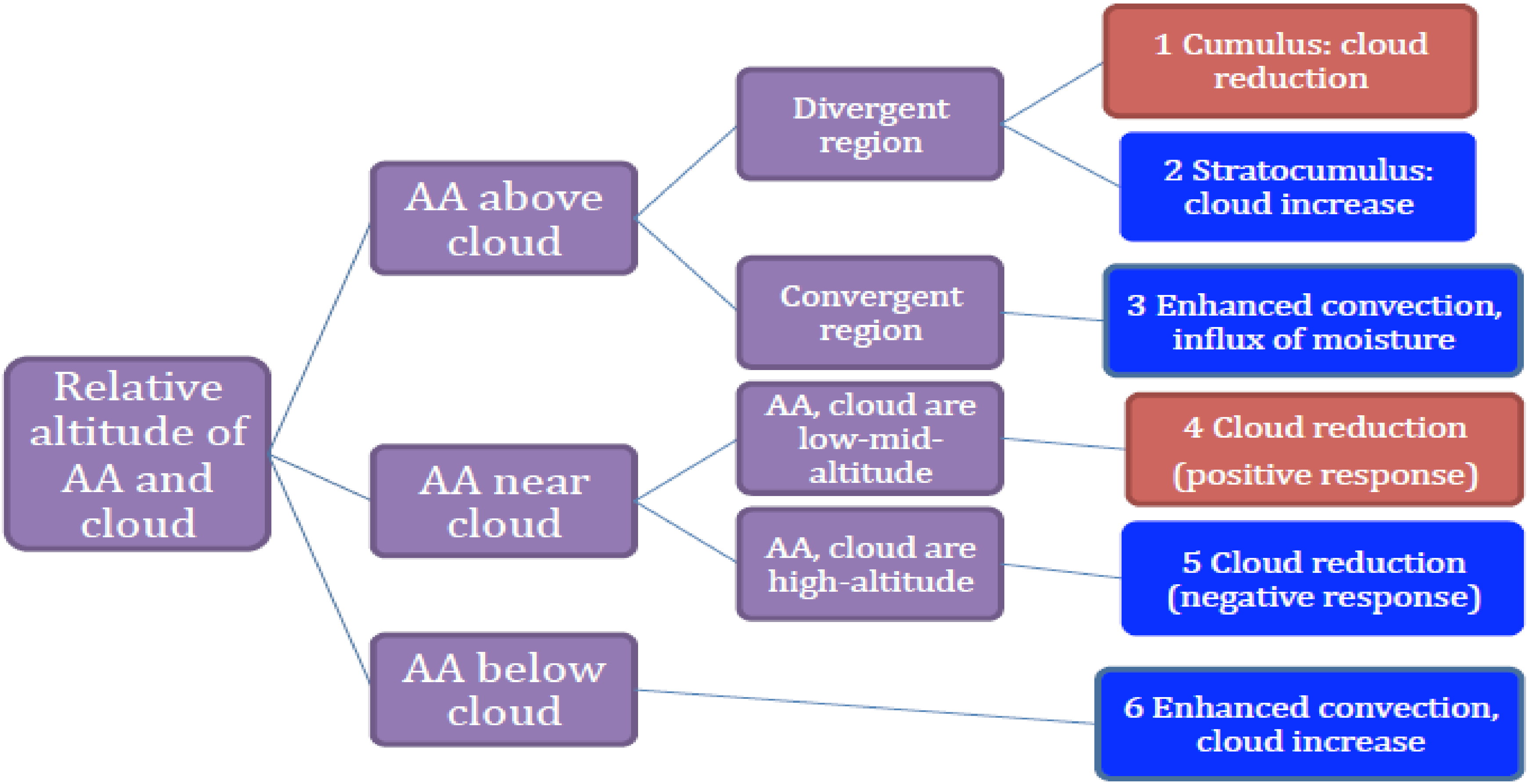
Kiehl, 2007

Indirect aerosol climate effects

Lohmann and Feichter, 2005 and Lohmann et al., 2010

Effects	Cloud type	Description	Forcing Wm^{-2}
First indirect aerosol effect (Twomey effect)	All clouds	The more numerous smaller cloud particles reflect more solar radiation	- 0.9 +/- 0.4
Second indirect aerosol effect (Albrecht affect)	All clouds	Smaller cloud particles decrease precipitation efficiency, prolonging cloud lifetime	Uncertain
Semi-direct effect	All clouds	Absorption of solar radiation by BC may cause evaporation of cloud particles	Uncertain
Glaciation indirect effect	Mixed ice and liquid clouds	More ice nuclei increase the precipitation efficiency	Uncertain
Thermodynamic effect	Mixed ice and liquid clouds	Smaller cloud droplets delay the onset of freezing	Uncertain
Riming indirect effect	Mixed ice and liquid clouds	Smaller cloud droplets decrease the riming efficiency	Uncertain
Total anthropogenic aerosol effect	All cloud types	Includes the above mentioned indirect effects plus the direct aerosol effect	0 to -1.8

BC semidirect effect on clouds



Koch and Del Genio, ACP, 2010

Anthropogenic sulfur emissions in Europe

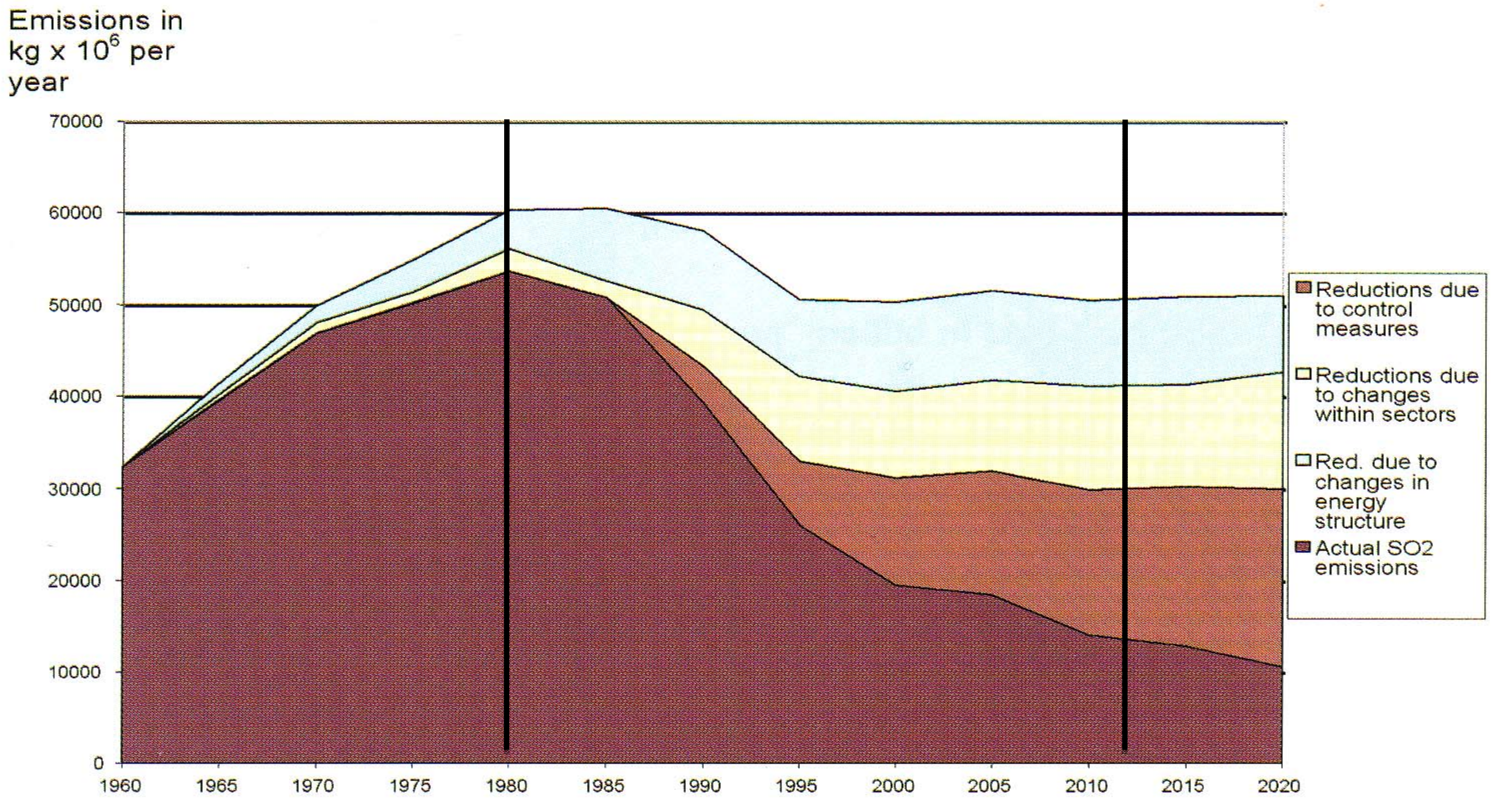
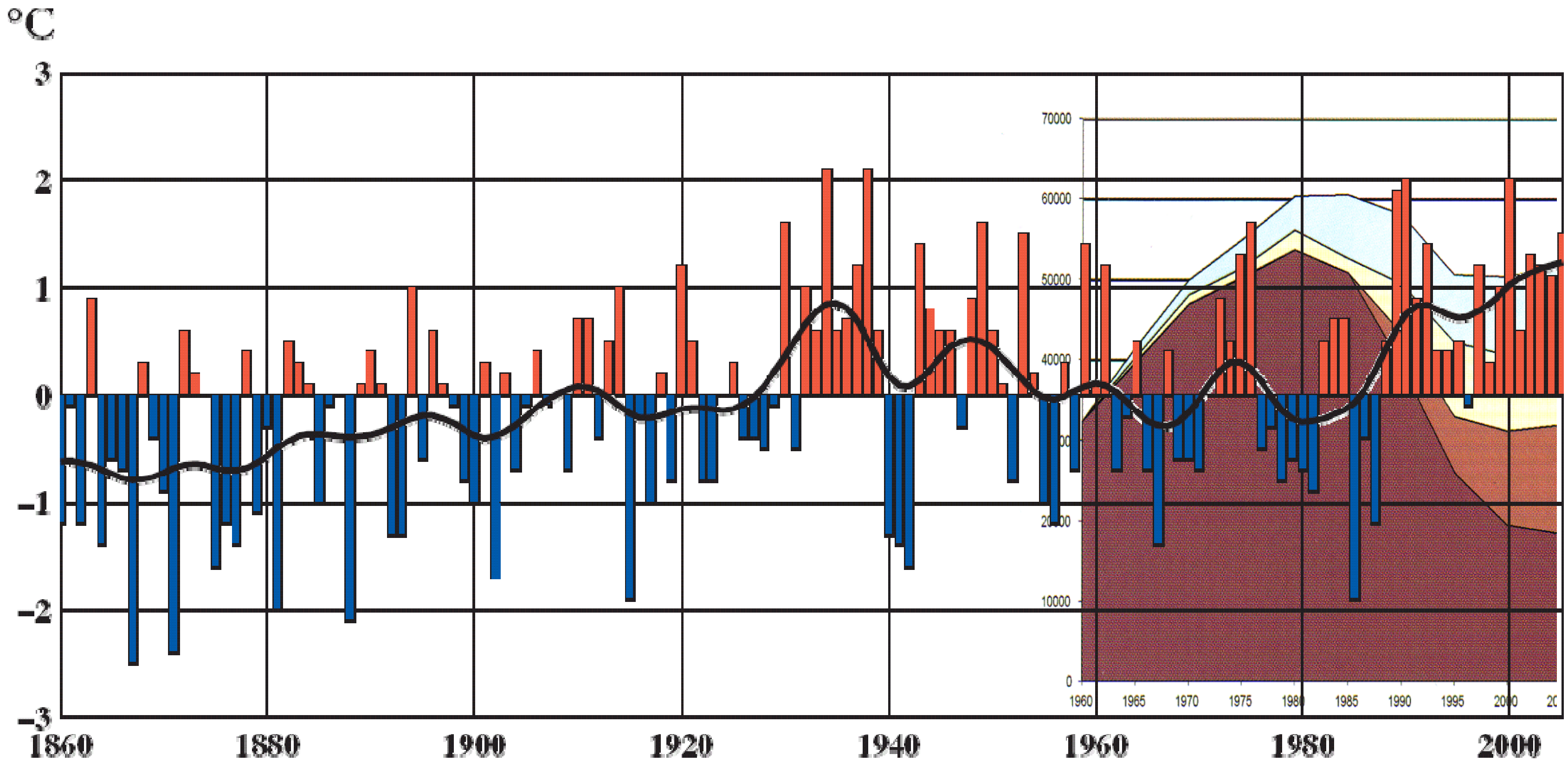


Figure 6.1. The prevention of SO2 emissions in Europe 1960-2020: actual levels compared to hypothetical levels taking into account energy consumption growth

Source: IIASA

Have this reduction affected temperatures over Scandinavia? If so, to what extent?

Is this a coincidence, or actual relationship???



Regional studies

- 76% of the simulated multidecadal variance in detrended 1860–2005 North Atlantic sea surface temperatures depend on aerosols (HadGEM2-ES, Booth et al., 2012)
- A dimming period up till about the mid-1980s followed by a brightening which was fairly well described by the model as expected by the varying aerosol emissions (Zubler et al., 2011),
- the interaction between the regional climate and the air pollutants finding that a perturbation of the temperature in the range -1.5 – +1.5°C due to aerosols and ozone. No spatial correlation between forcing and temperatures (RegCM3/CAMx , Huszar et al., 2012)
- However regional models have difficulties with boundary conditions
- Important including major forcing processes and feedbacks!

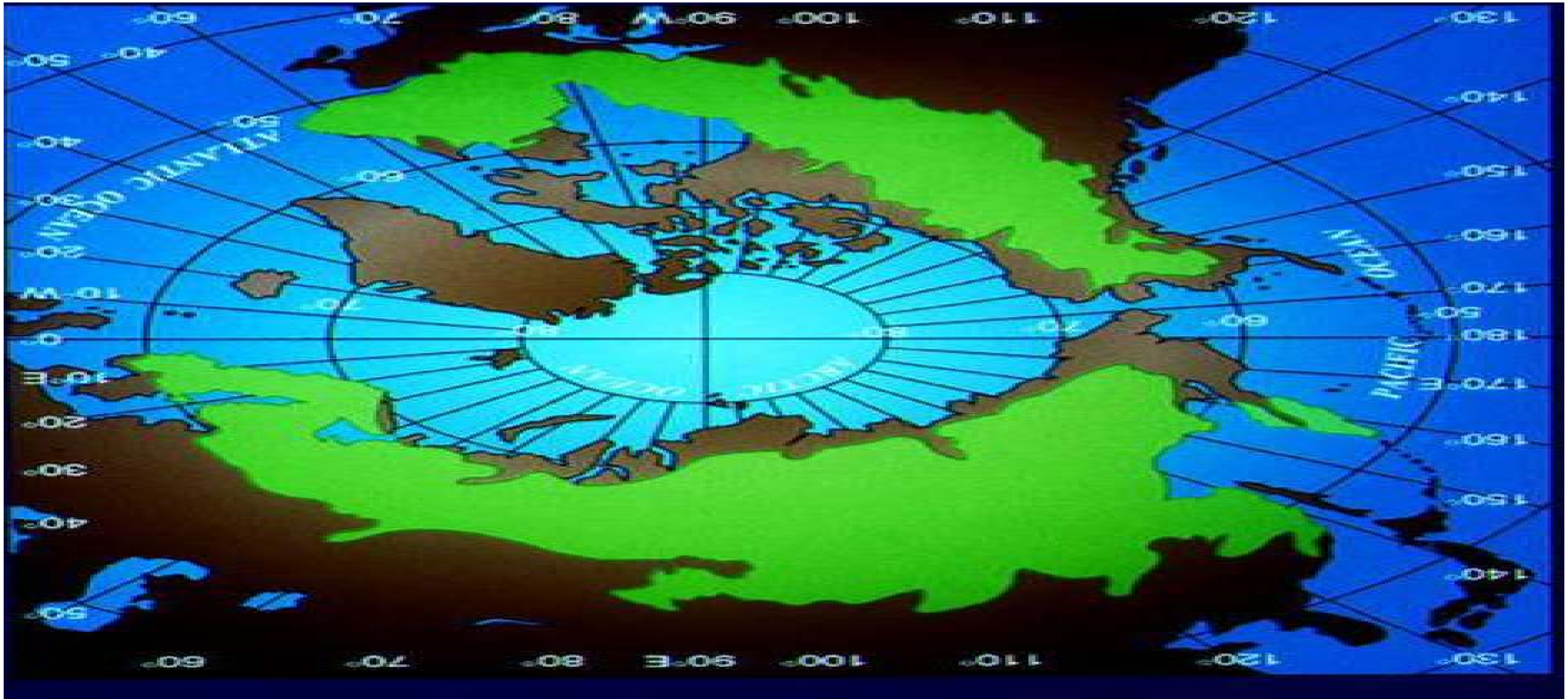
Summary 6.3

→ First evidence of regional aerosol climate effects on circulation and regional climate forcing in the European region.

→ The major uncertainty in the climate predictions on regional and global scale is due to uncertainties in describing the anthropogenic aerosols influence on climate forcing.

→ In regions with high emissions of anthropogenic aerosols will be affected considerably more than the global average

→ The Aerosol-Cloud- Climate interaction is not well understood and is the main reason for the uncertainty in the climate projections



Ch 6 Attributing causes of regional climate change

6.4 Land cover and resource management

Marie José Gaillard, Thomas Kleinen, Patrick Samuelsson, Johan Berg, Anne Birgitta Nielsen, Camilla Sandström, Jed Kaplan, Anne Wramneby

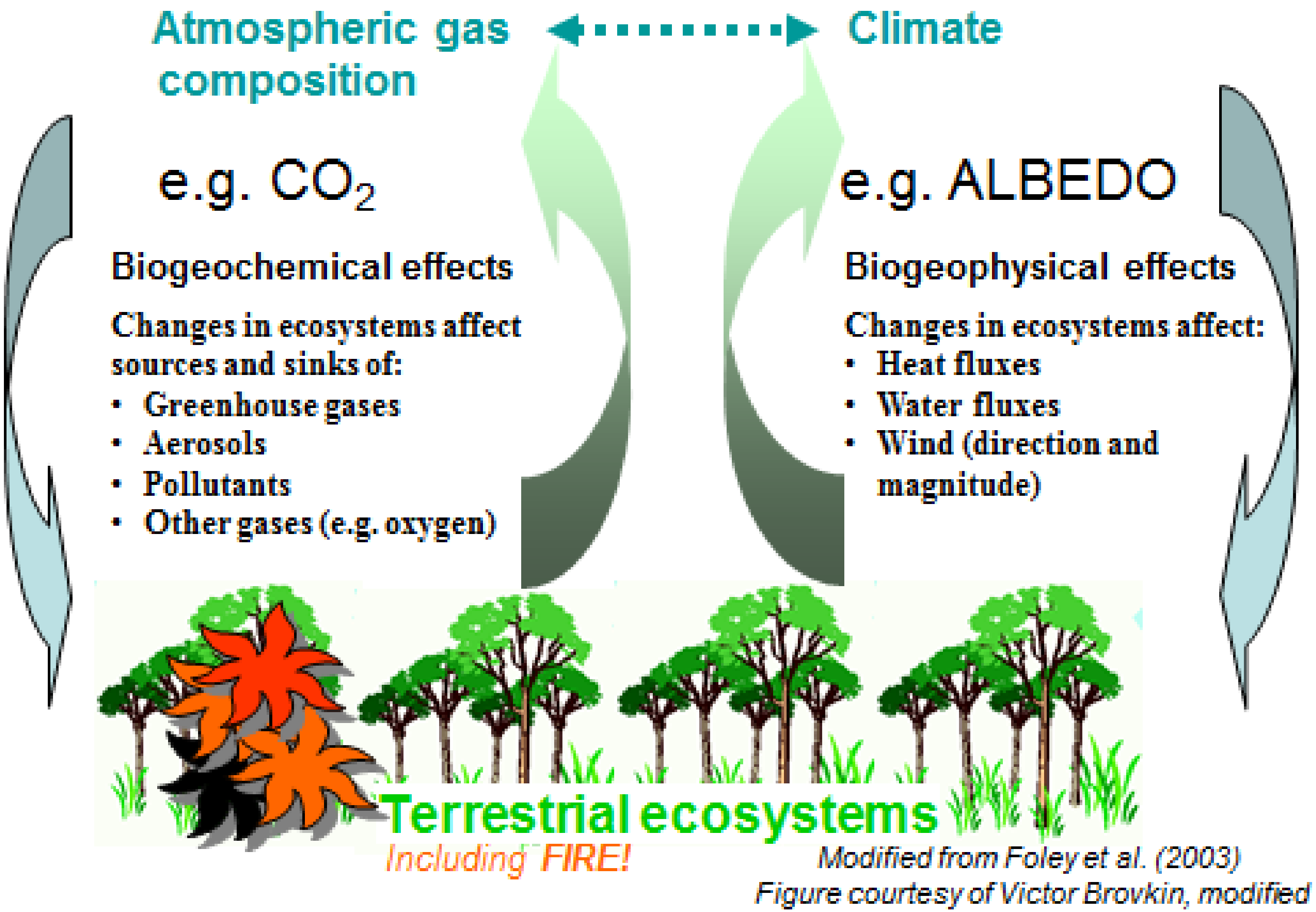
September 2012

6.4 Land cover and resourse management

- Land cover-climate feedbacks
  - Biogeophysical feedbacks
  - Biogeochemical feedbacks
  - Effects of land cover changes
- Long term land cover changes and past climate
  - Methods for reconstruction of past natural and anthropogenic land cover
  - Major past land-uses in the Baltic Sea catchment area
    - Land-use and land-cover shange since the Neolithic (6000 BP)
      - Neolithic to Iron Age (6000-1000 BP)
      - Middle Ages
      - Modern times
  - Studies of the effect of anthropogenic land-cover change on climate in the past
- Potential future trends in land-cover and associated effect of climate
  - Future land-cover change due to anthropogenic climate change and possible feedbacks
  - Resource management and future land-cover change scenarios: possible effect on future climate

6.4 Land cover and resourse management

- Vegetation/land-cover is part of the climate system



vegetation/land cover – climate feedbacks

- Biogeophysical effects are related to the exchange of energy and moisture between the atmosphere and the land surface. There are two possible contrasting biogeophysical effects of a vegetation change (climate or human-induced) **from e.g. grass- to forest-dominated land surface**:
  - a **warming effect** due to the lower albedo of forests compared to that of low herb vegetation (high albedo), and
  - a **cooling effect** due to higher evapotranspiration associated with forest expansion.
- Biogeochemical effects are mainly photosynthesis-mediated and result in terrestrial carbon **sinks** and **sources**. For example, in cold regions, **warming** leads to vegetation growth, **increasing photosynthesis and carbon uptake (sink)**, which then leads to **a cooling**.

Questions

1. Is human-induced vegetation/land-cover change (i.e. land-use change) a climate forcing?
2. Can the recent climate warming be partly attributed to historical land-use changes, i.e. anthropogenic land-cover change?
3. If so, how much did it contribute to the climate change compared to changes in CO2 concentrations in the atmosphere?
4. Did land-use change in the Baltic region contribute to the observed regional warming since 1850?

Answers

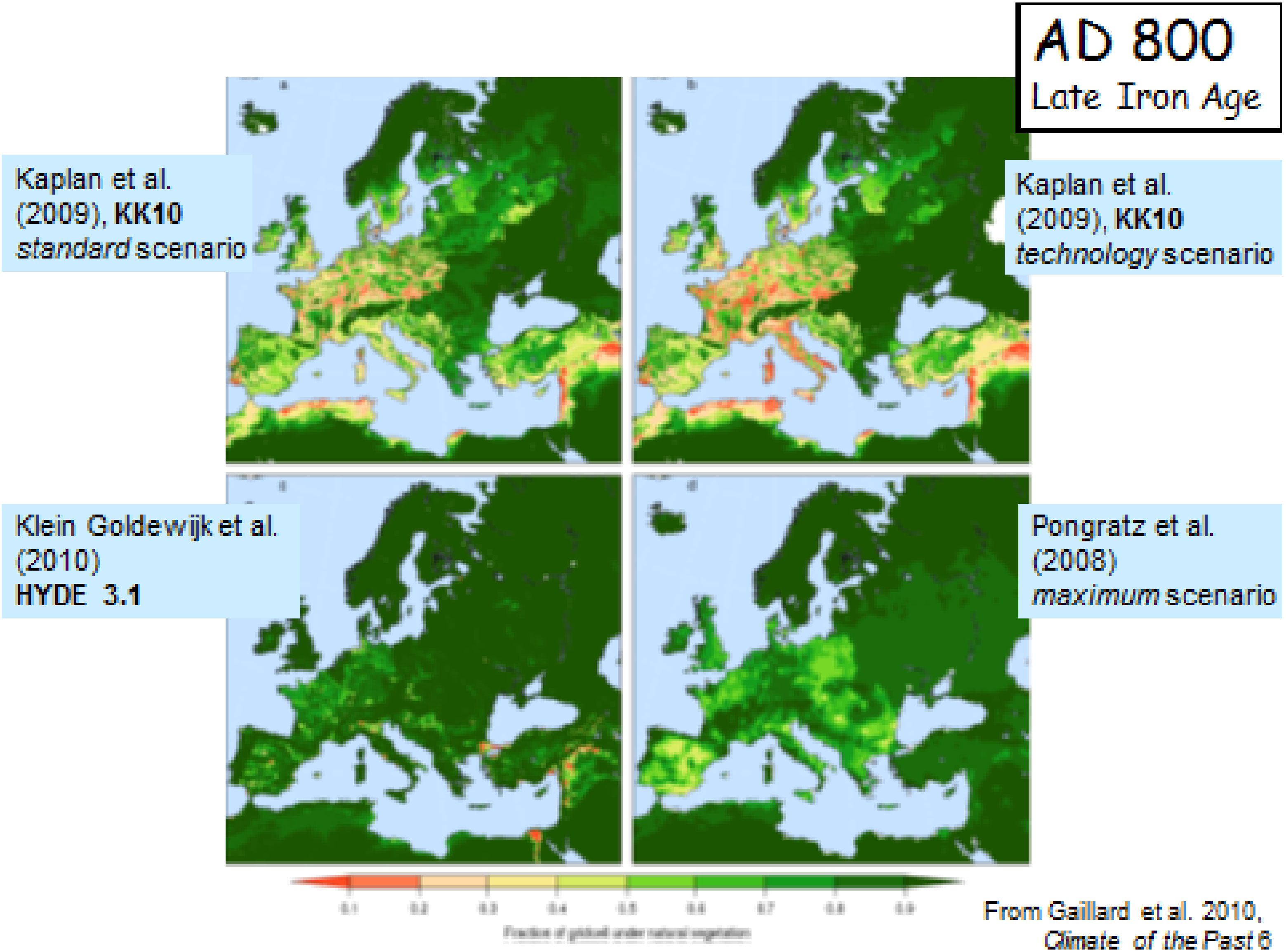
1. Substantial land-use change,may have significant effects on climate by amplifying or mitigating climate change, at global and continental scales (e.g. Betts, 2010).

2. and 3. Globally, **biogeophysical effects** from anthropogenic land-cover change (ALCC) (i.e. **deforestation)** during the last millennium were found to have **a slight cooling** influence on mean temperature (−0.03 K in the 20th century), while **biogeochemical effects** led to **a strong warming** (0.16–0.18 K, Pongratz et al. 2010). The climate response to **historical deforestation**, both globally and in most regions, was dominated by a warming due to the release of CO_2.

   However, the reconstruction of historical ALCC used by Pongratz et al. differs substantially from other model- and empirical reconstructions (pollen-inferred)

4. Very little is known on the effects of historical land-use changes on the regional climate of the Baltic region

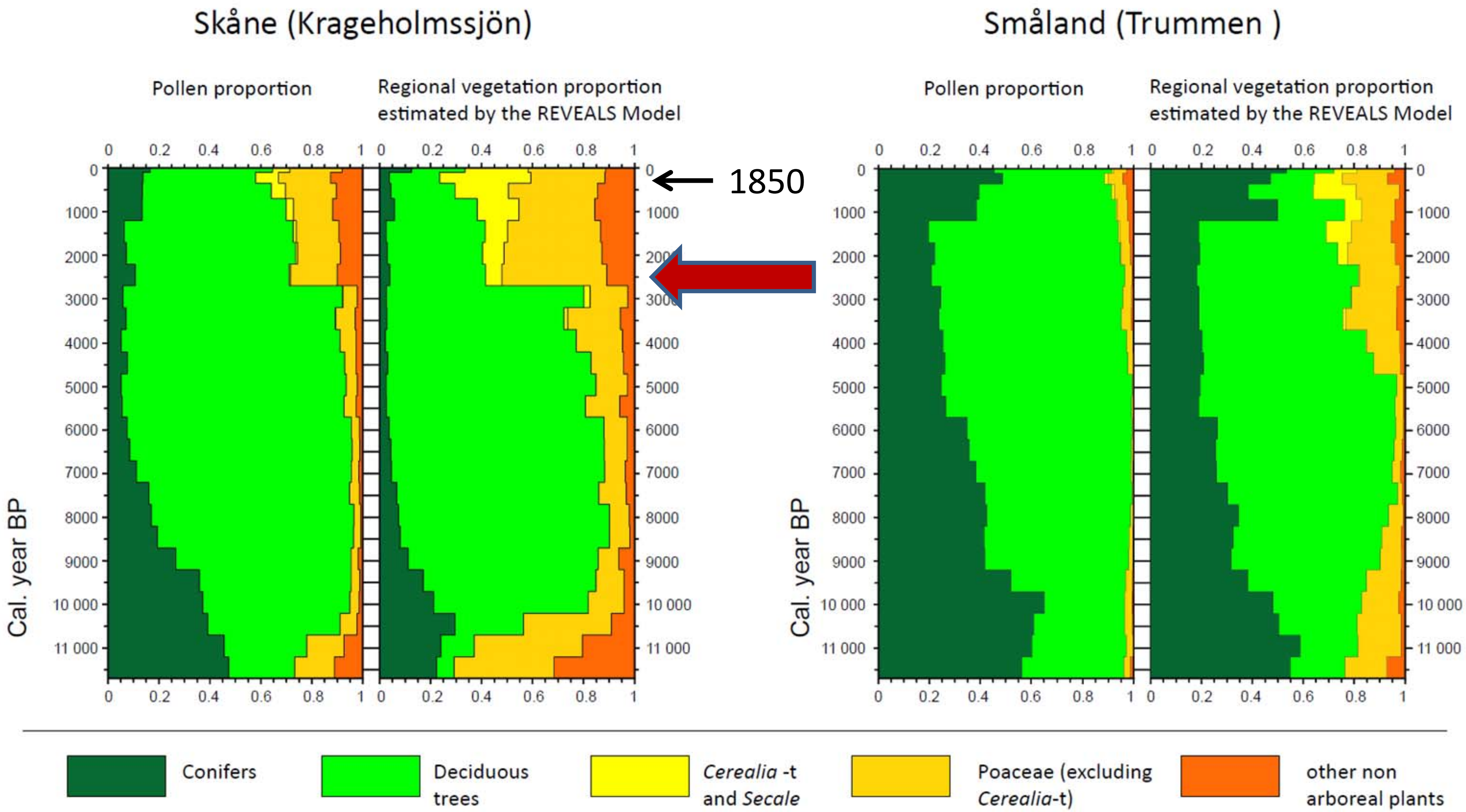
Differences between model-predicted historical land-cover



From Gaillard et al. 2010, *Climate of the Past* 6

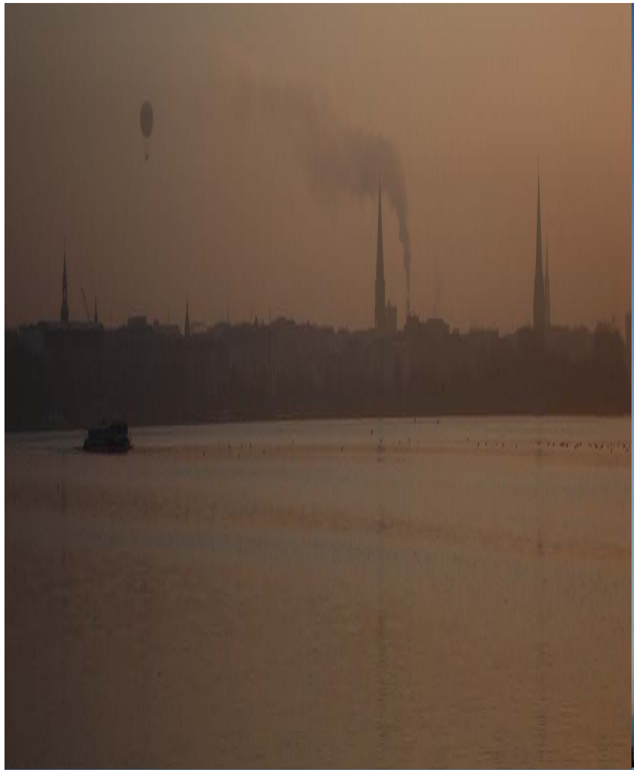
Pollen-inferred land-cover reconstruction

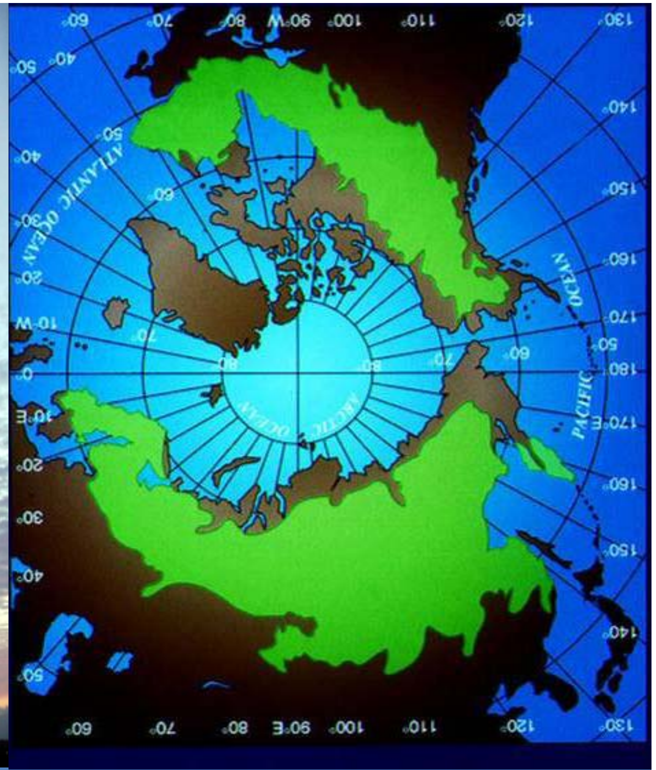
The largest deforestation occured ca. 3000 years ago in many parts of Europe.



Conclusions

- It is essential to include land-use change in studies of climate change
- Descriptions of historical anthropogenic land-cover change need to be evaluated and improved
- There are no published studies specifically designed to study the effects of historical land-use changes on climate in the Baltic region
- The net result of the biogeochemical and biogeophysical effects of a land-use change (deforestation or reforestation) is not known
- The effects of historical anthropogenic land-cover change on climate (from global to regional scales) are not well known (badly quantified)
- The Swedish LANDCLIM project (coordinator MJ Gaillard) currently studies past land cover-climate interactions at the regional spatial scale in NW Europe; results will be published in the course of 2013





Ch 6 Attributing causes of regional climate change

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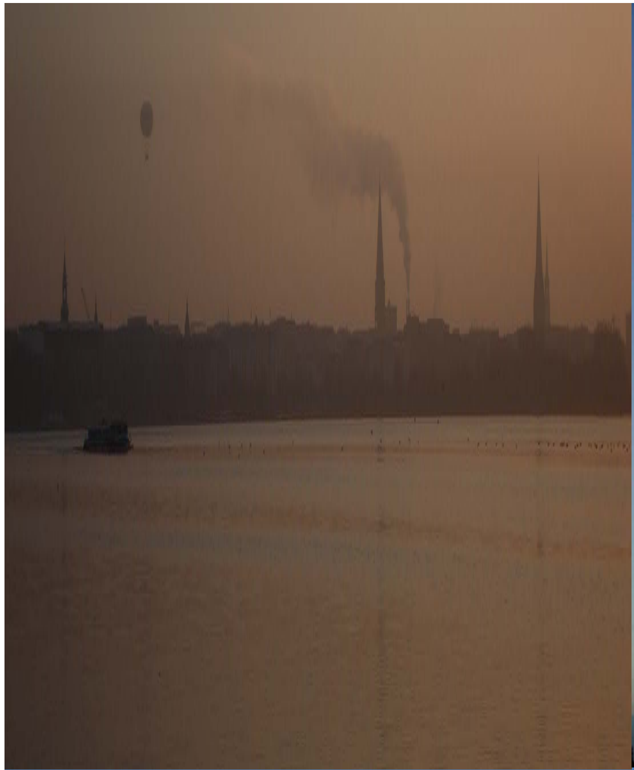
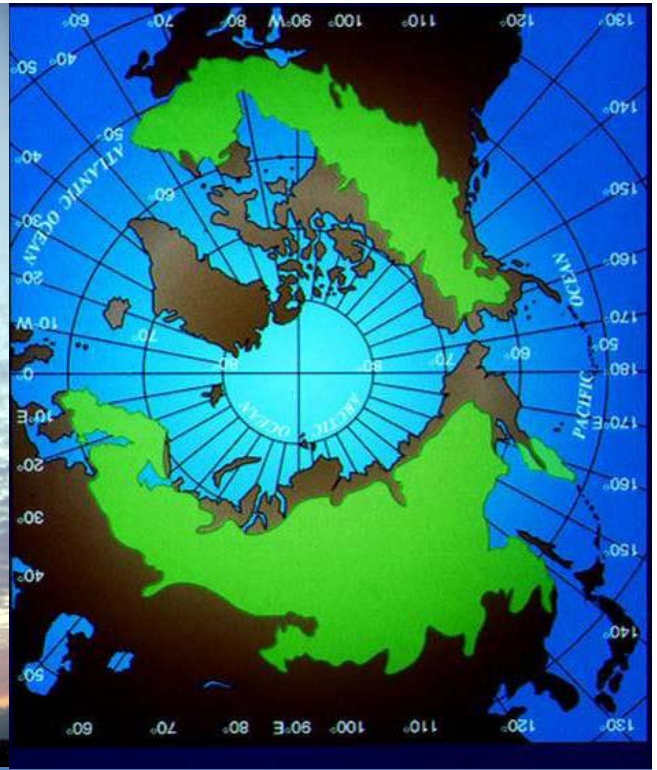
Summary

- Accumulation of evidence of a detectable human influence (mainly GHG) on regional warming.
- First evidences of regional climate effects of regionally emitted anthropogenic aerosols. However large gaps in understanding and models of regionally important climate forcing processes.
- A synthesis of model studies on land-atmosphere interactions demonstrates vegetation/land-cover changes do influence regional climate. All vegetation feedbacks and forcing are still not known, neither at the global nor at the regional scale
- Attribution has to be revisited as understanding of non-GHG forcings is fragmentary (see aerosols and land-use changes)
- Detection is still very difficult. Earth System Models are emerging, but methodologies for evaluation have to be further developed to ensure high reliability.





Thank you

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