

What do we know about the human impact on aerosol cloud-mediated climate processes in the Baltic Region?

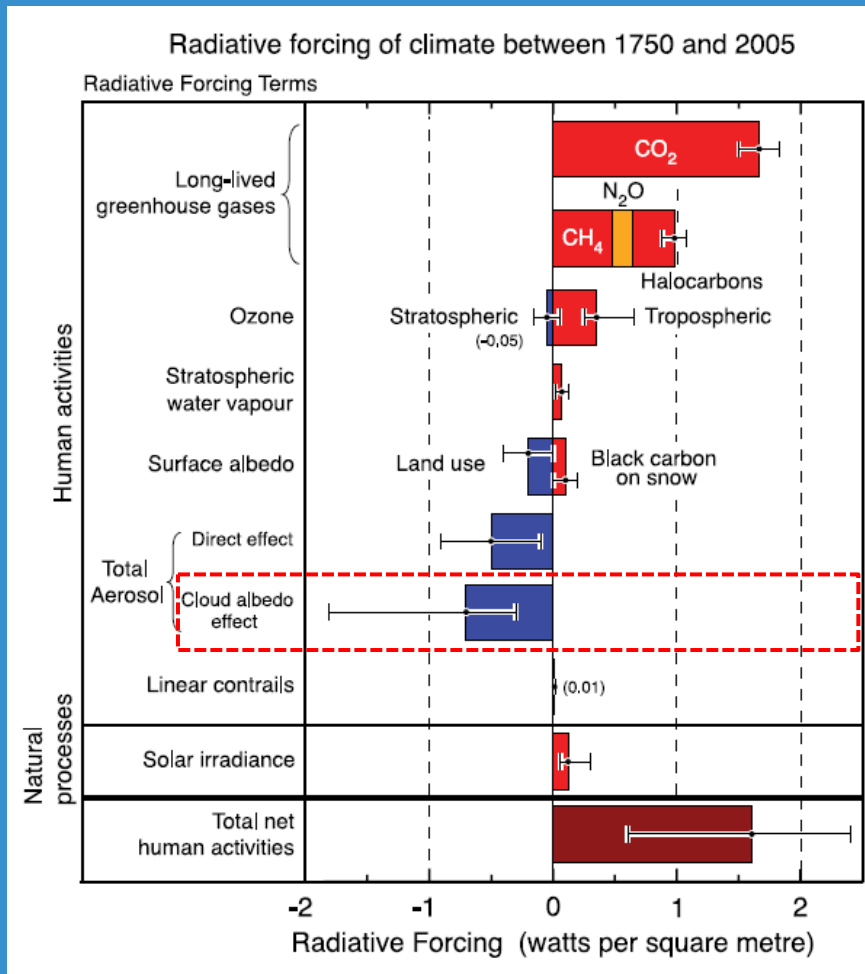
Olaf Krüger

Content

The Global Perspective
The Energy budget
The Cloud Scale
Current Discussion
Air Pollution and Cloud Albedo
Significant Observations
Phytoplankton and Clouds
Desideratum

The Global Perspective

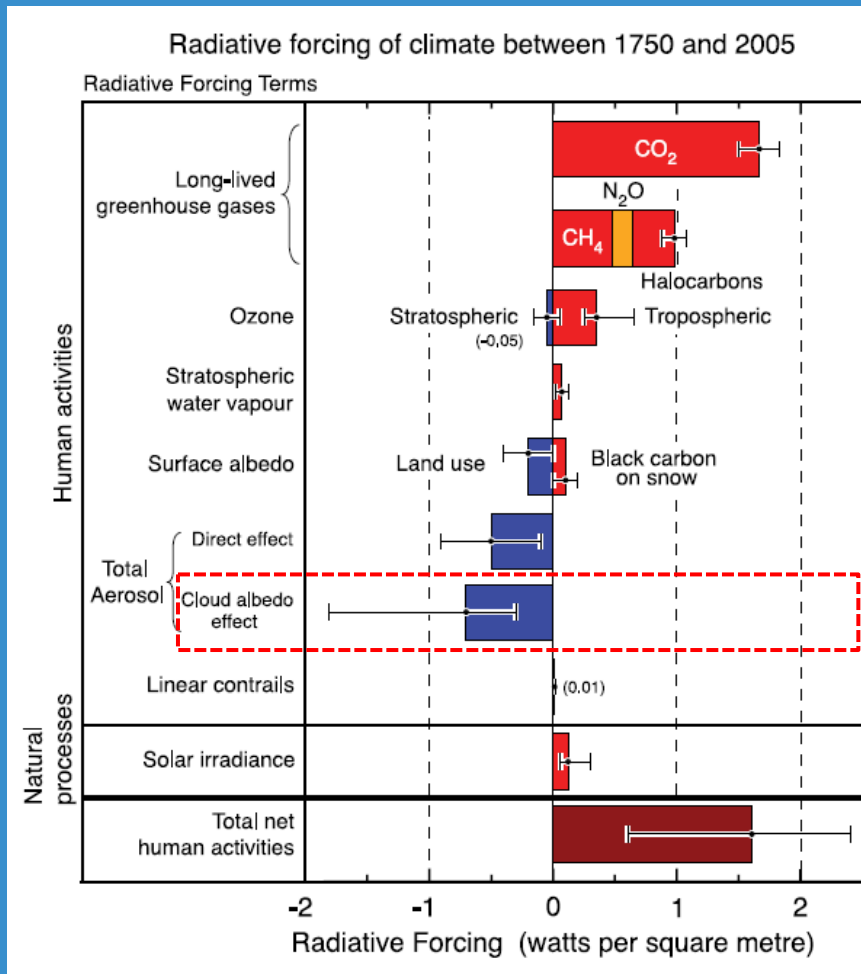
IPCC 2007



Anthropogenic Aerosols counteract the global warming.

The Global Perspective

IPCC 2007

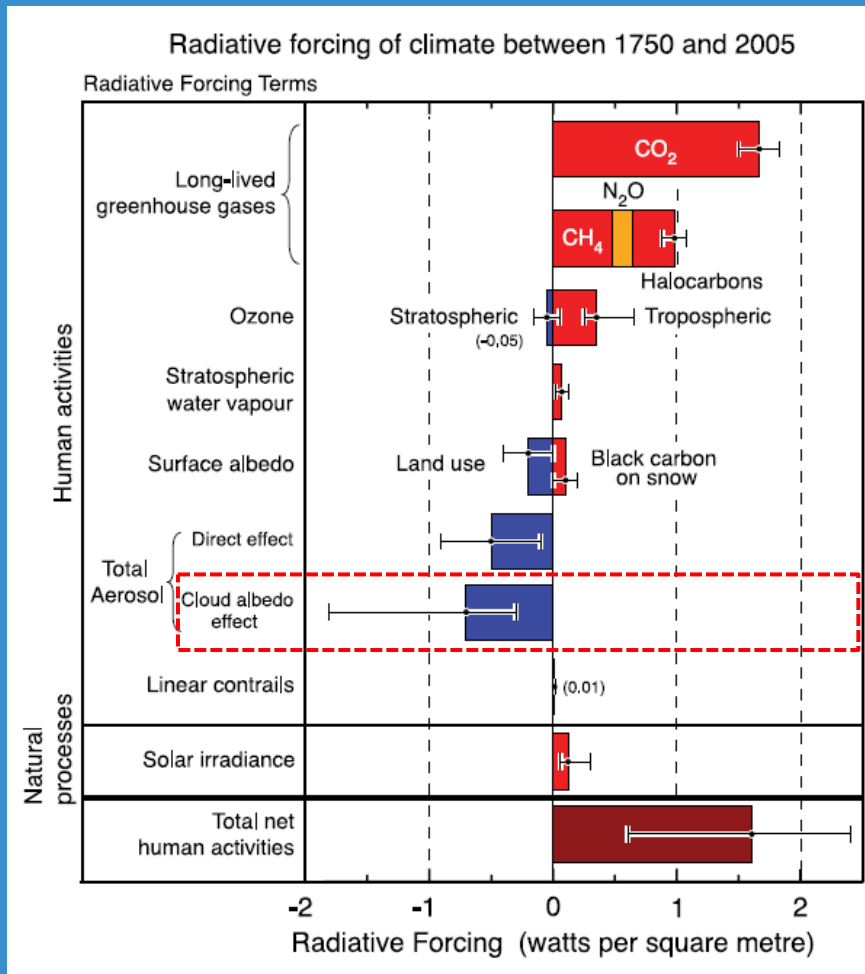


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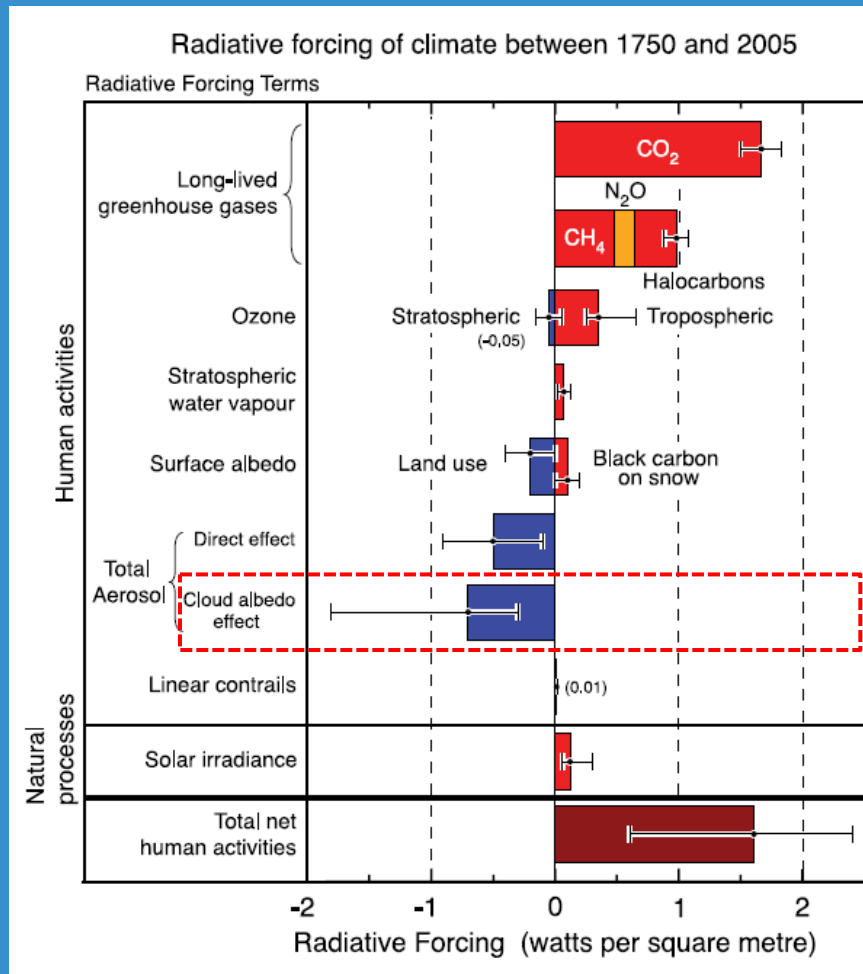
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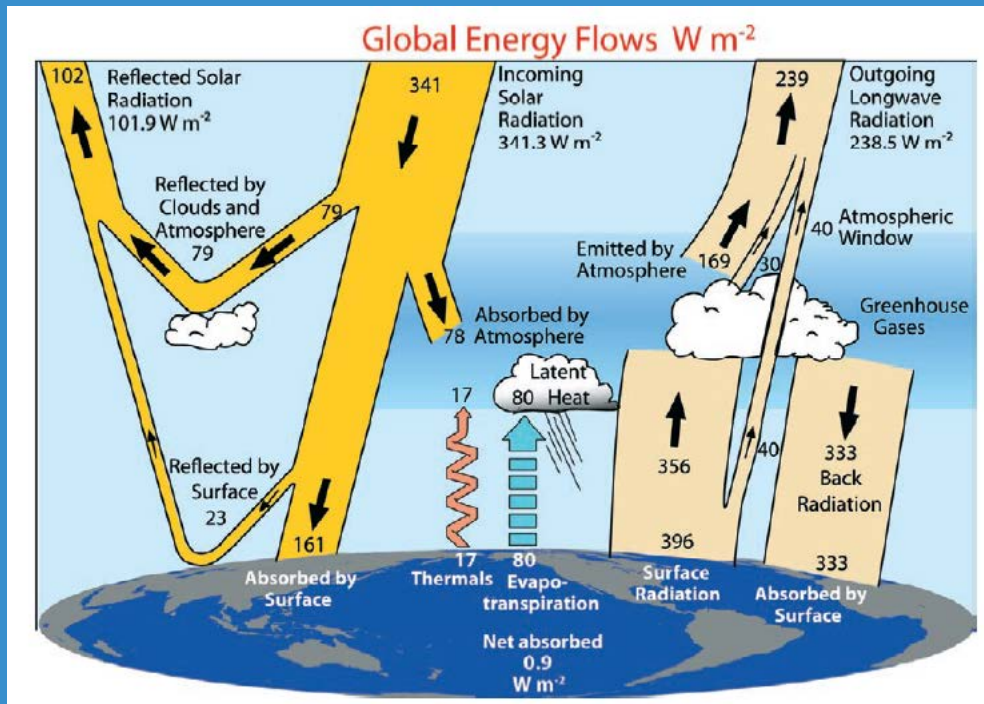
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Furthermore, on the regional scale and the cloud scale the radiative forcing can be positive.

The Energy Budget

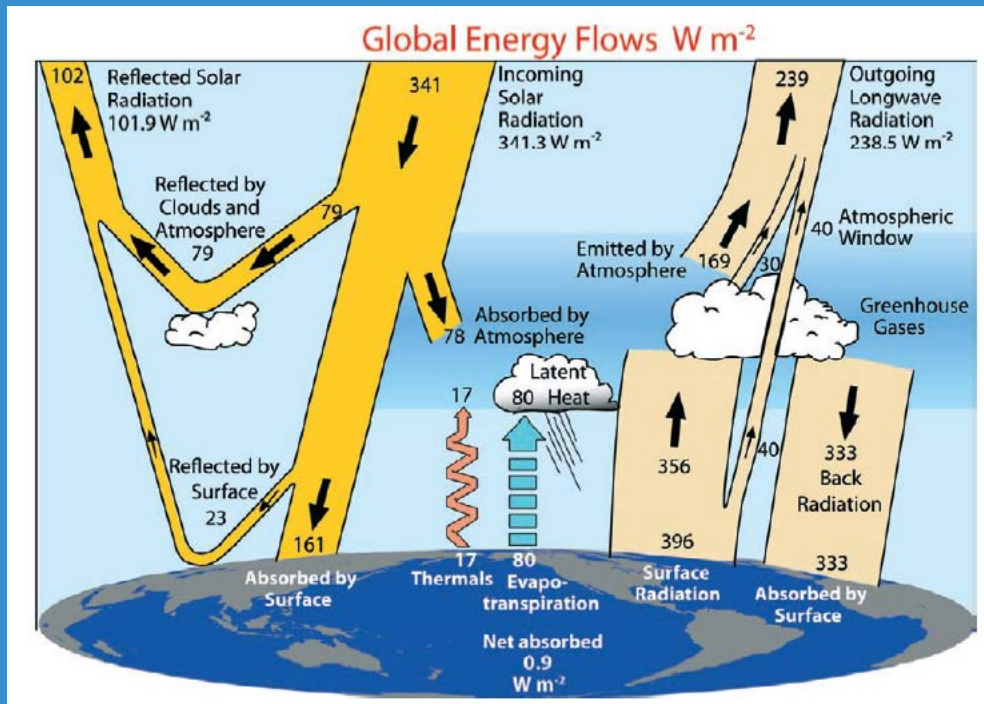
Trenberth et al. 2009

Increase or reduction of local planetary albedo (albedo, cloudiness).



The Energy Budget

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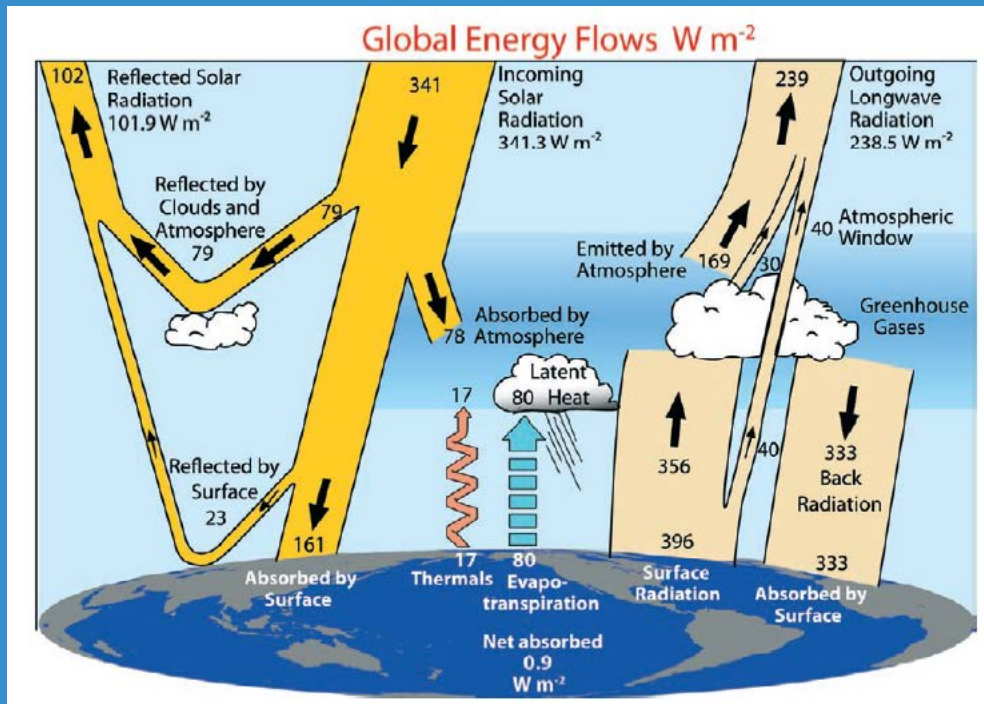


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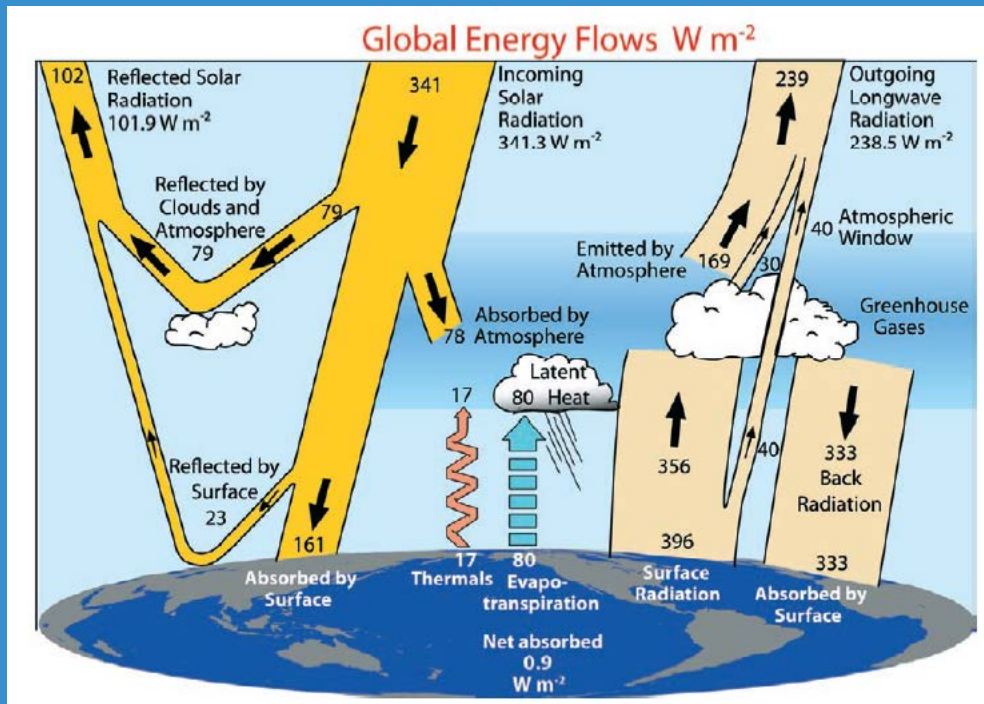
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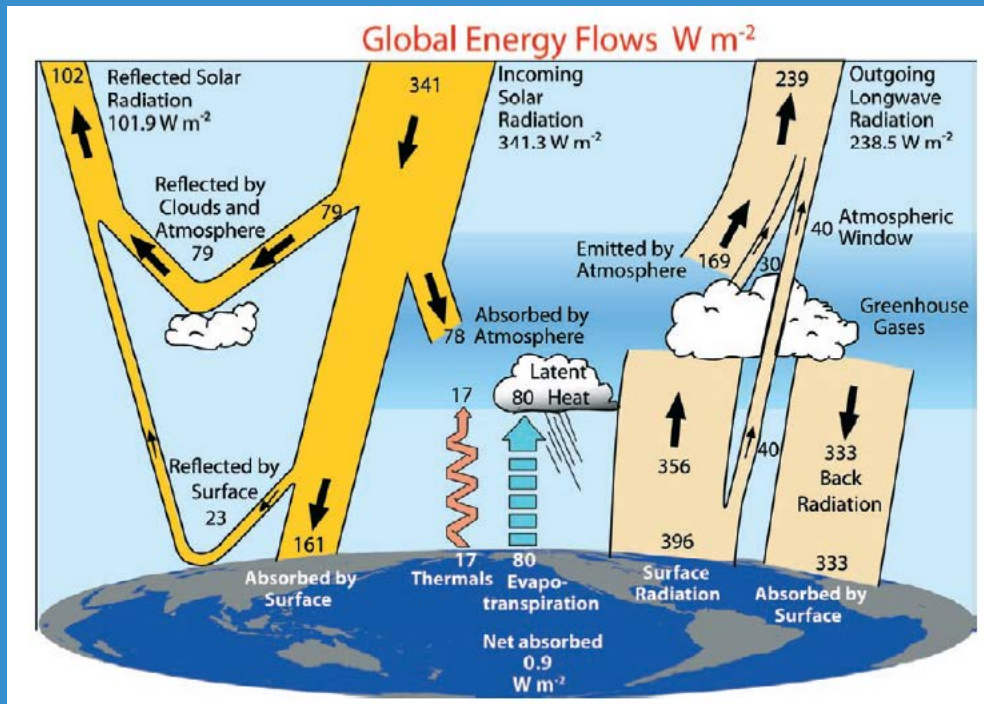
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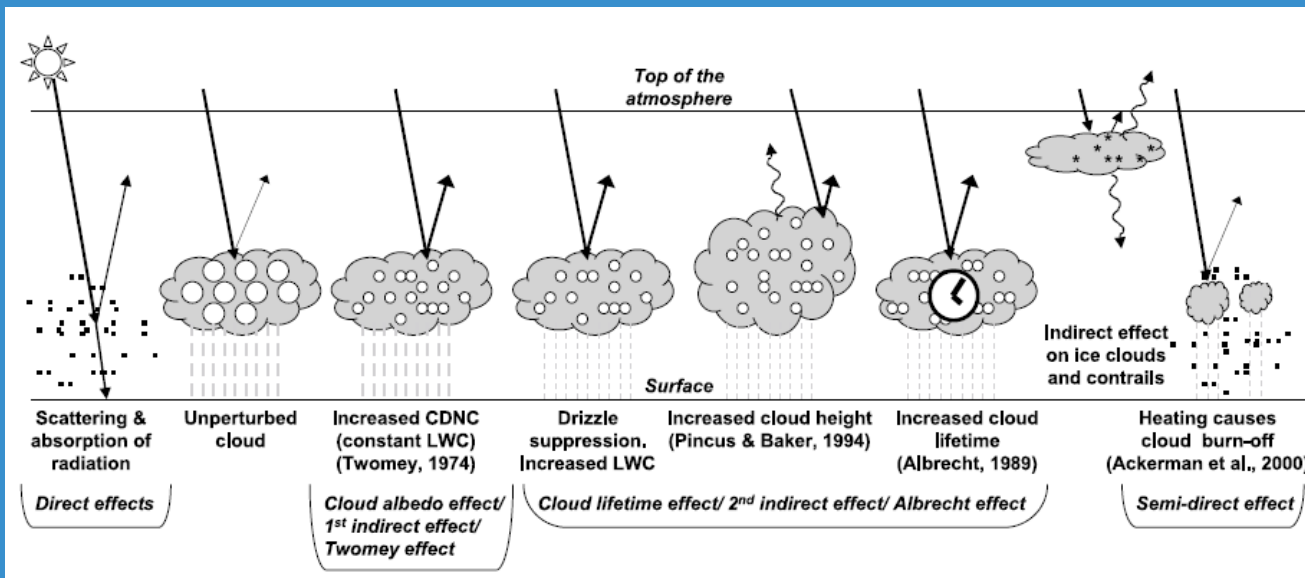
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Change in temperature gradient (reduction in difference NET down, land $-15.6 W m^{-2}$, ocean $+6.9 W m^{-2}$).

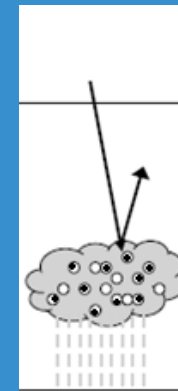
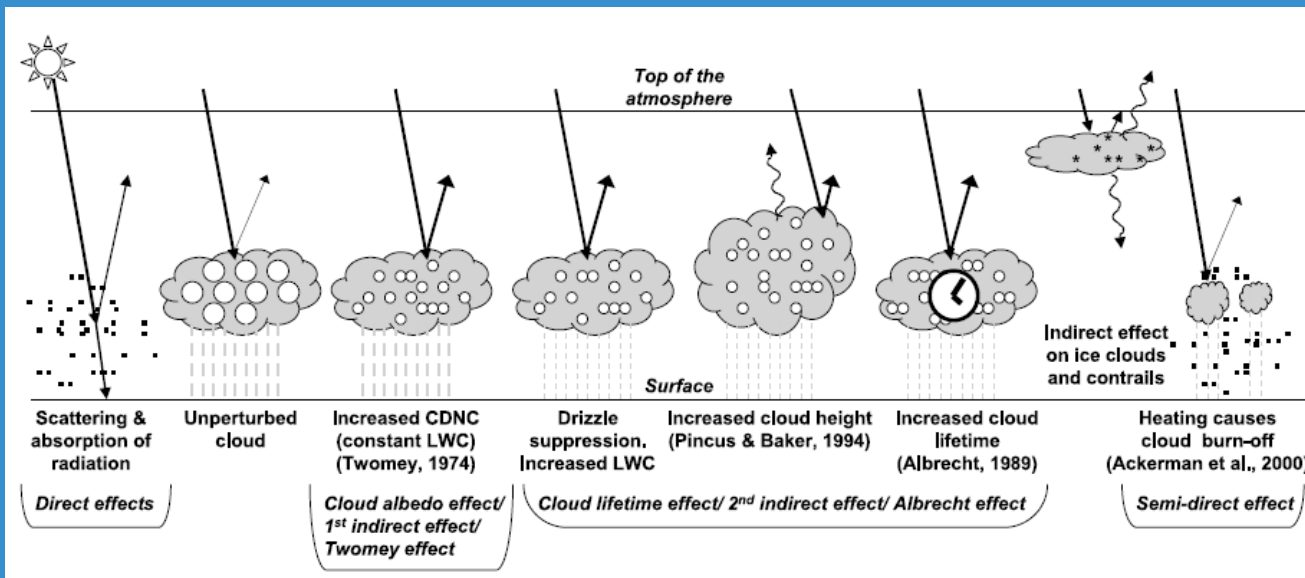
The Cloud Scale

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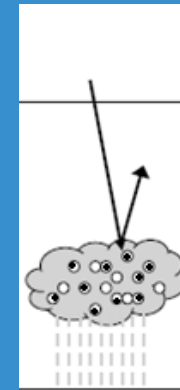
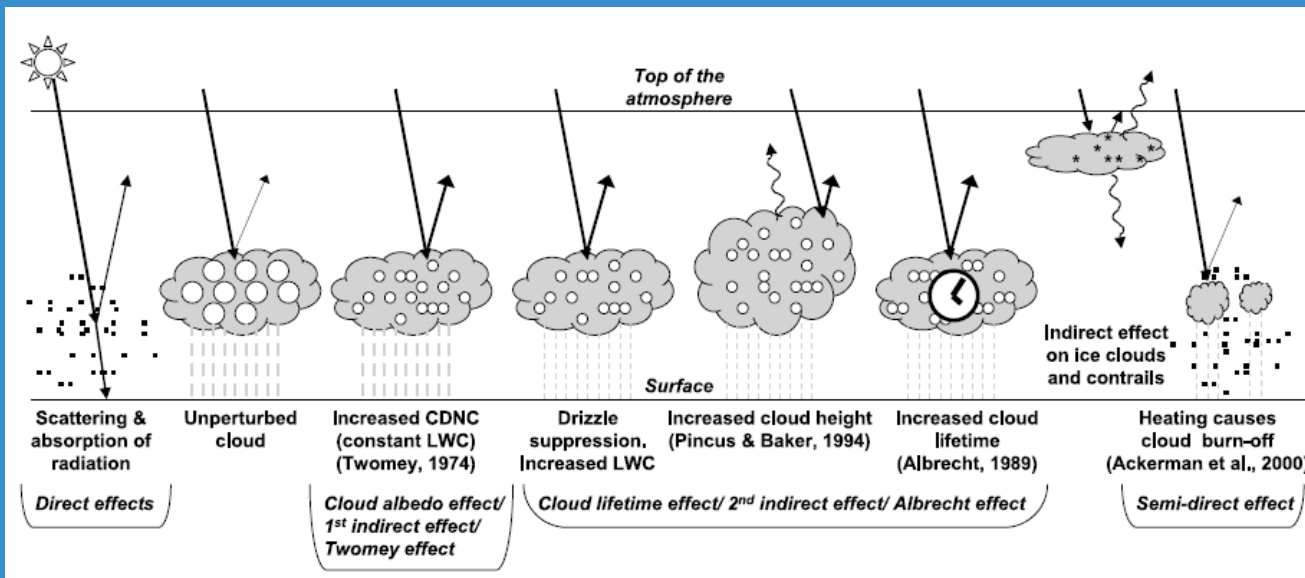
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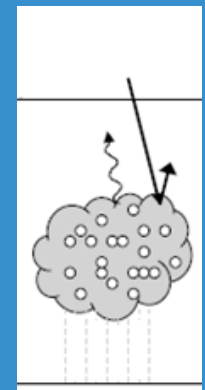
Graßl,
1978
Albedo
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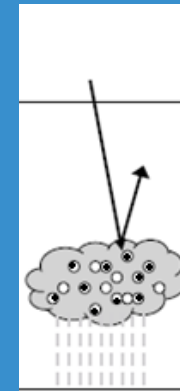
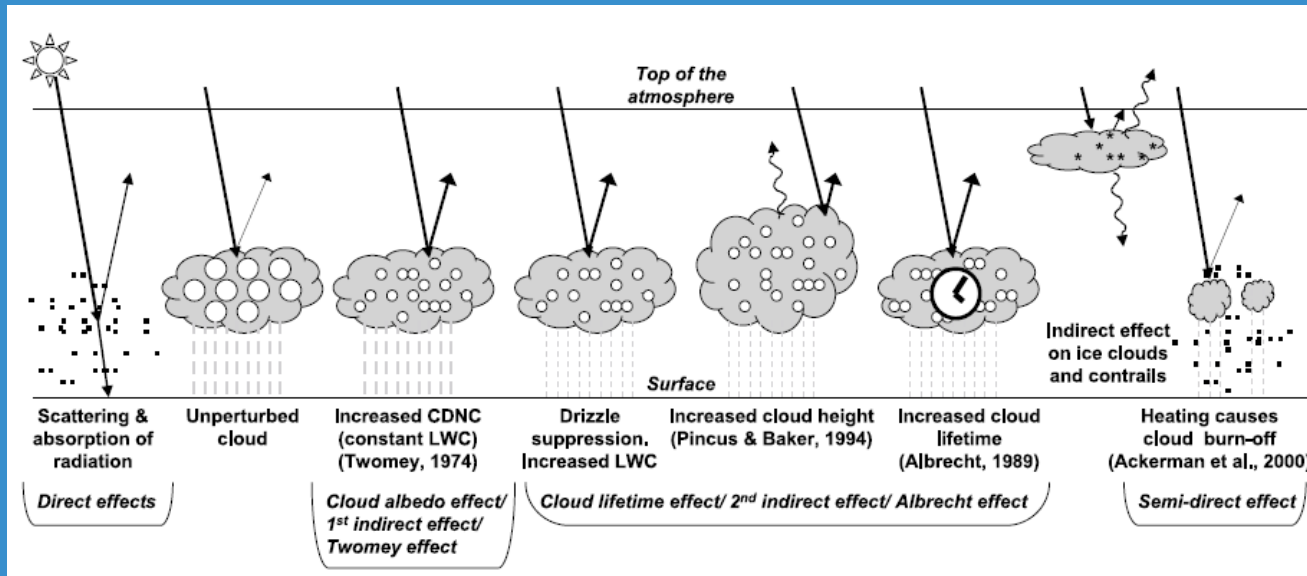
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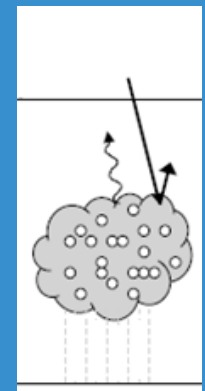
Krüger and Graßl, 2011
Precipitation reduction

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Current Discussion

Otto et al. 2013

The rate of global mean warming has been lower over the past decade than previously. It has been argued that this observation might require a **downward revision of estimates of equilibrium climate sensitivity**.

The estimates of effective radiative forcing by aerosols in particular vary strongly between model based studies and satellite data.

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Stevens and Bony, 2013

Questions: How do **marine boundary-layer clouds** depend on their environment? Or how do atmospheric circulations couple to moist convection through **surface and radiative fluxes**?

The first question ends up being key to explaining the intermodel spread in climate sensitivity, the second to the pattern of the regional response to warming.

Current Discussion

Bond et al. 2013

However, global **atmospheric absorption attributable to black carbon** is too low in many models and should be increased by a factor of almost 3.

The best estimate of industrial-era climate forcing of black carbon through all forcing mechanisms, including clouds and cryosphere forcing, is $+1.1 \text{ W m}^{-2}$ with 90% uncertainty bounds of $+0.17$ to $+2.1 \text{ W m}^{-2}$.

The uncertainties in net climate forcing from black-carbon-rich sources are substantial, largely due to lack of knowledge about cloud interactions with both black carbon and co-emitted organic carbon.

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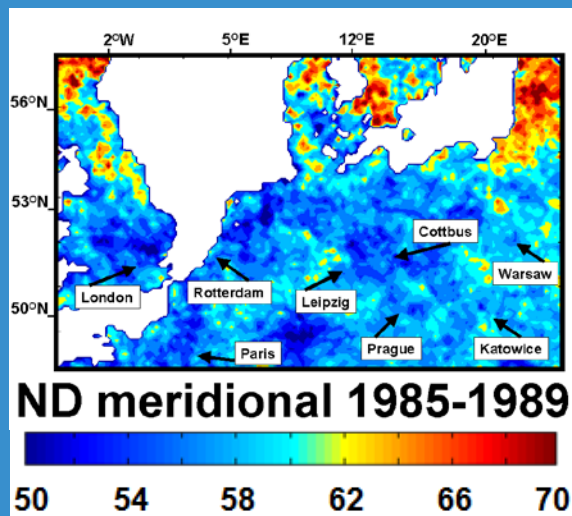
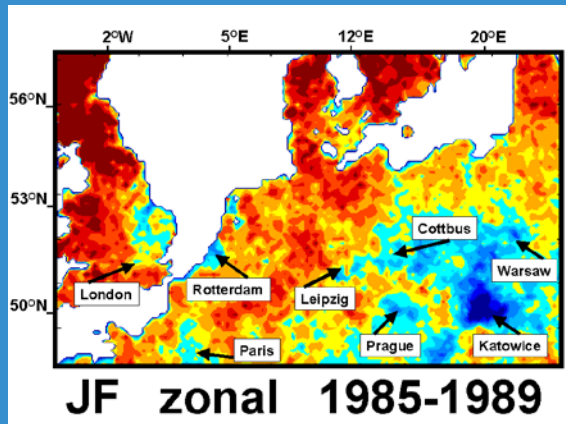
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Andreae and Ramanathan 2013

Because BC is concentrated near ist sources, it intruduces **spatial gradients in solar heating** of the surface. The net effect e.g. is a weakened monsoon circulation and a reduction of evaporation, reducing the amount of water available for rainfall.

Better observational constraints are needed at all scales, from aerosol microphysics to global satellite studies of cloud properties.

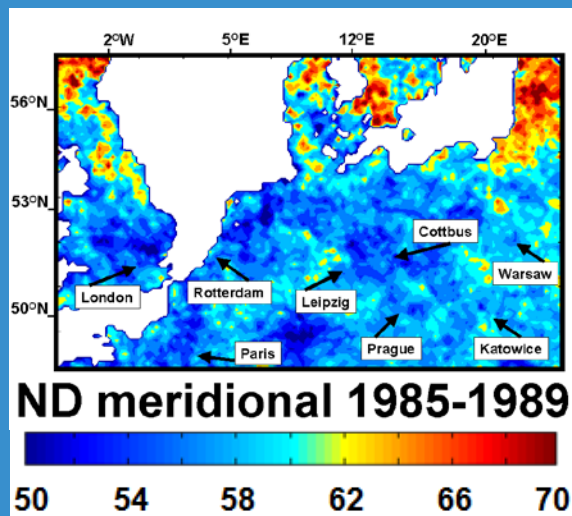
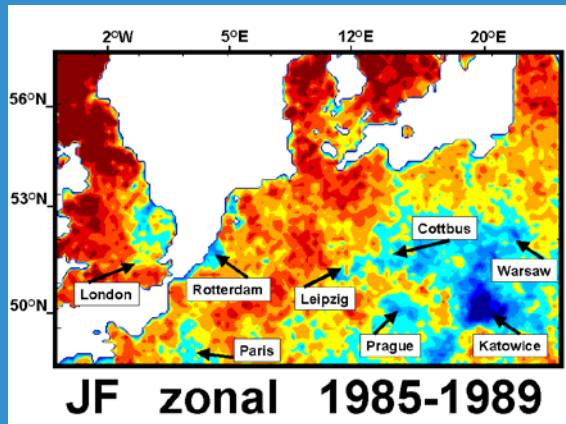
Air Pollution and Cloud Albedo



Cloud Reflectance [%]

The late 80s mean cloud reflectance in Central Europe reduced to late 90s by about 2% (in strongly polluted regions 5%).

Air Pollution and Cloud Albedo

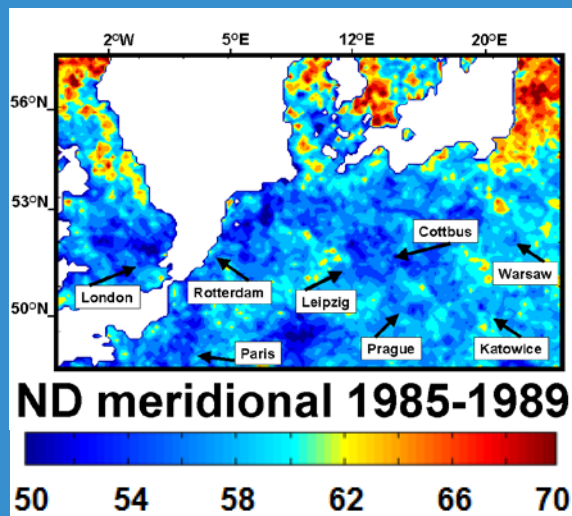
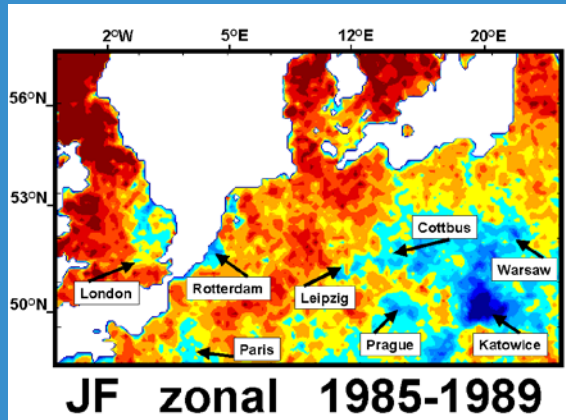


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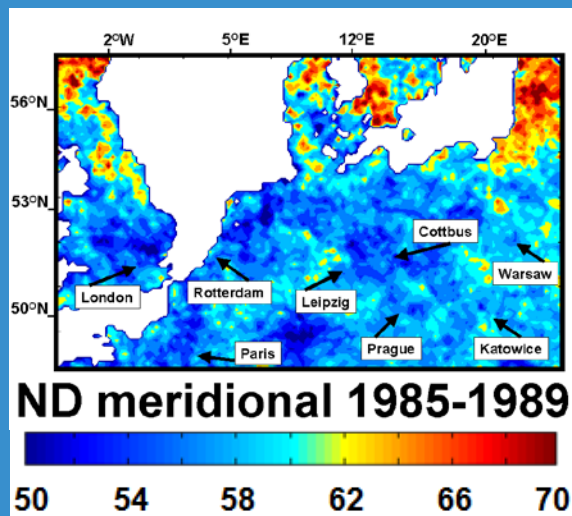
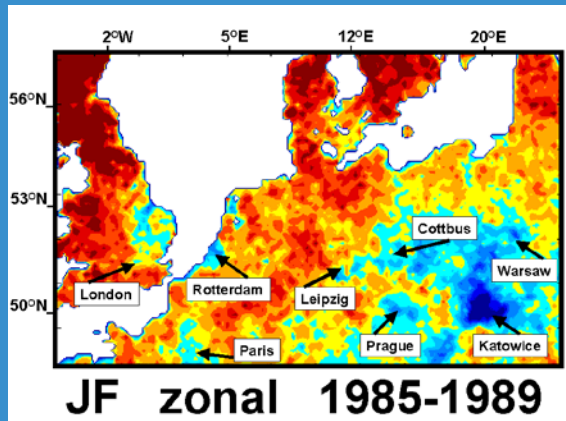
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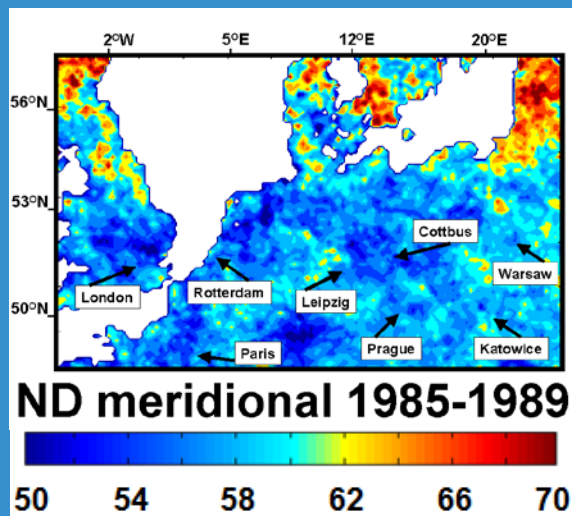
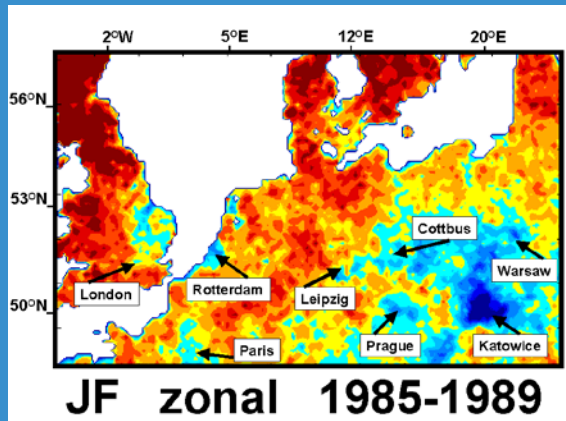
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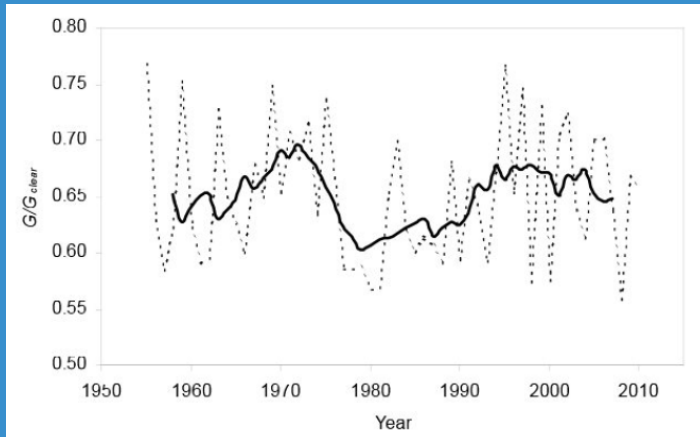
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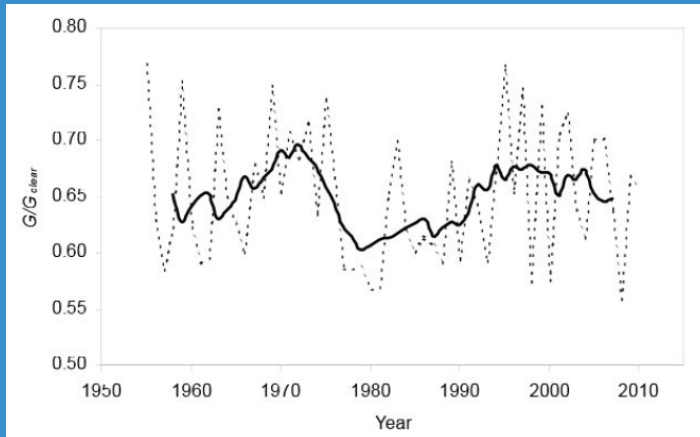
If climate change leads to a change in the frequency of circulation types then it will change the magnitude of aerosol effects on climate in the Baltic Region.

Further Significant Observations



Time series of global irradiance in Estonia show a conspicuous low relation G/G_{clear} during the summers of late 1970s and the 1980s.

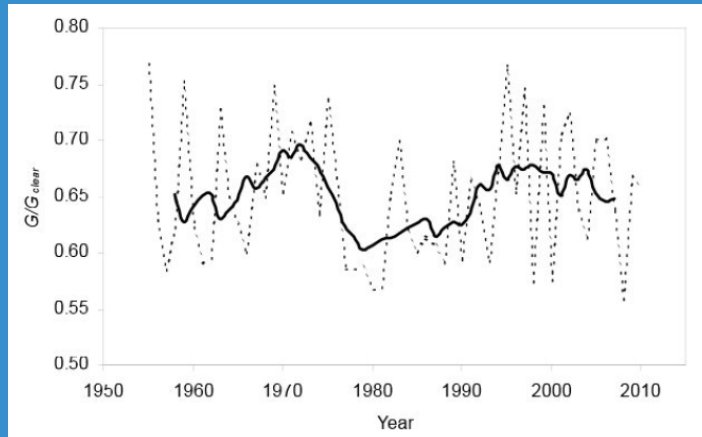
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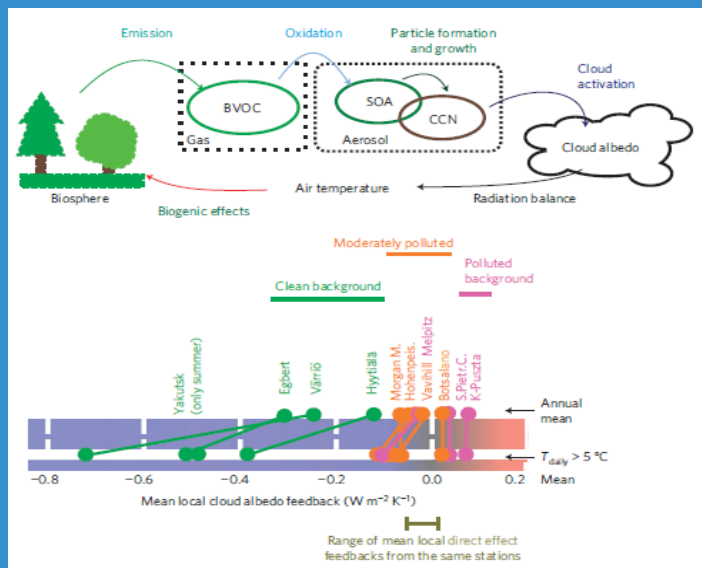
Cloud properties could have changed due to anthropogenic aerosols.

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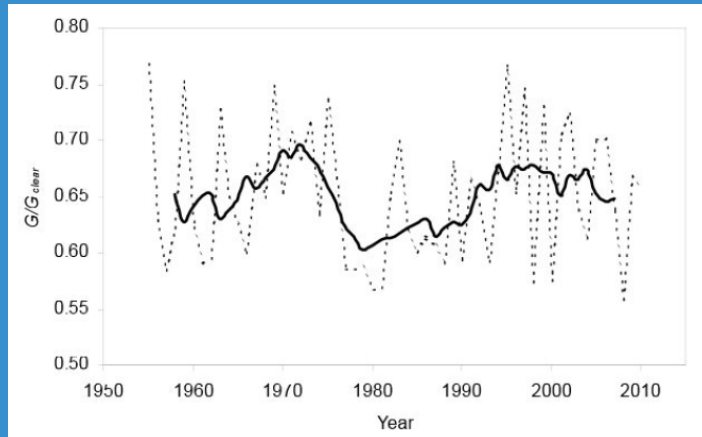
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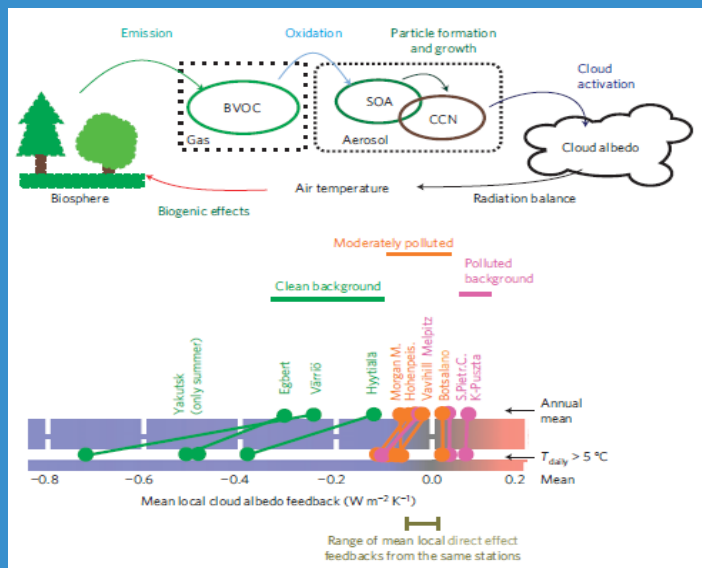
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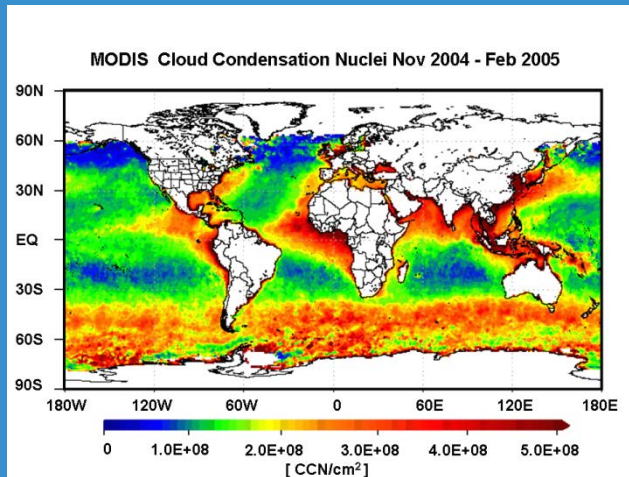
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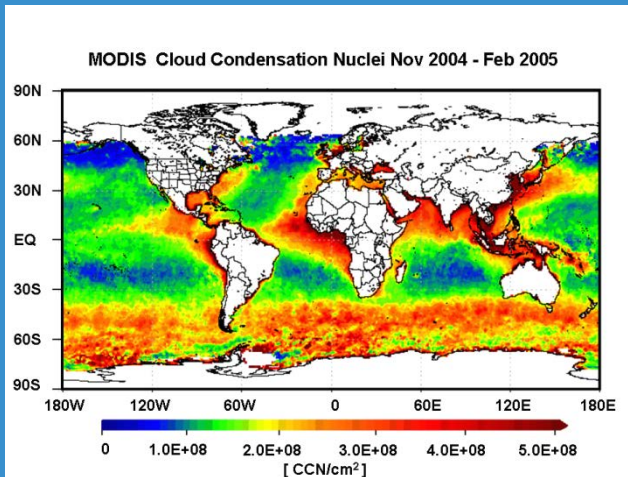
The negative feedbacks were strongest at the most northern and remote sites.

Cloud Condensation Nuclei



The Baltic Region is a region with CCN number of 10^8 - 10^9 per cm^3 .

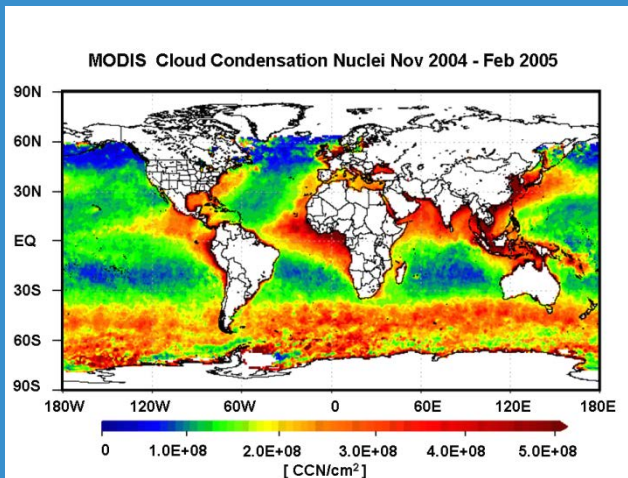
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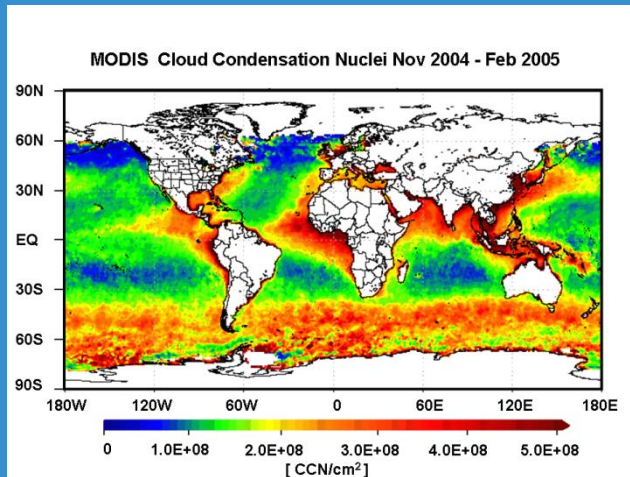


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The aerosol number concentrations are of similar magnitude as along the coasts of West Afrika, India and China.

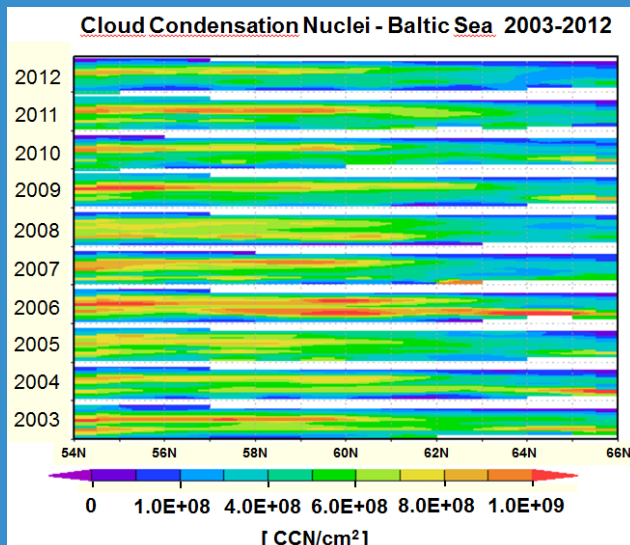
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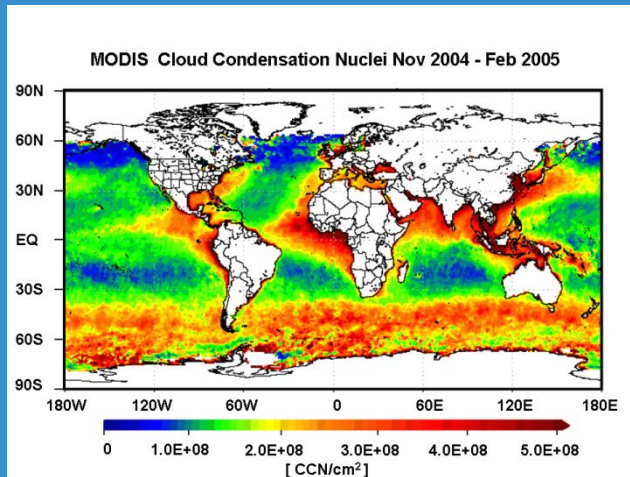
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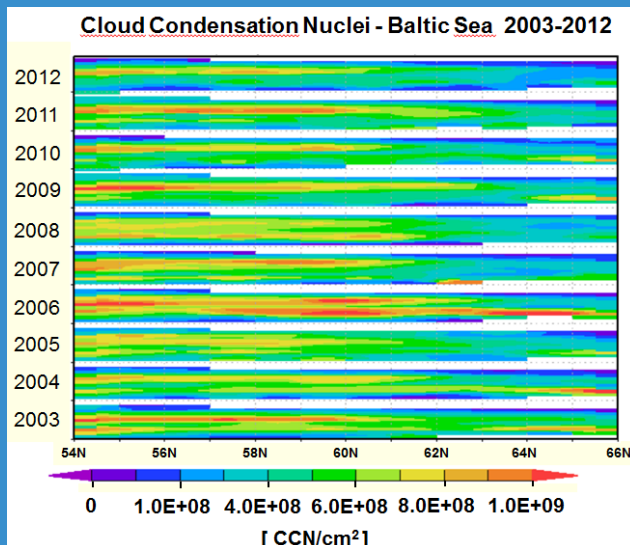


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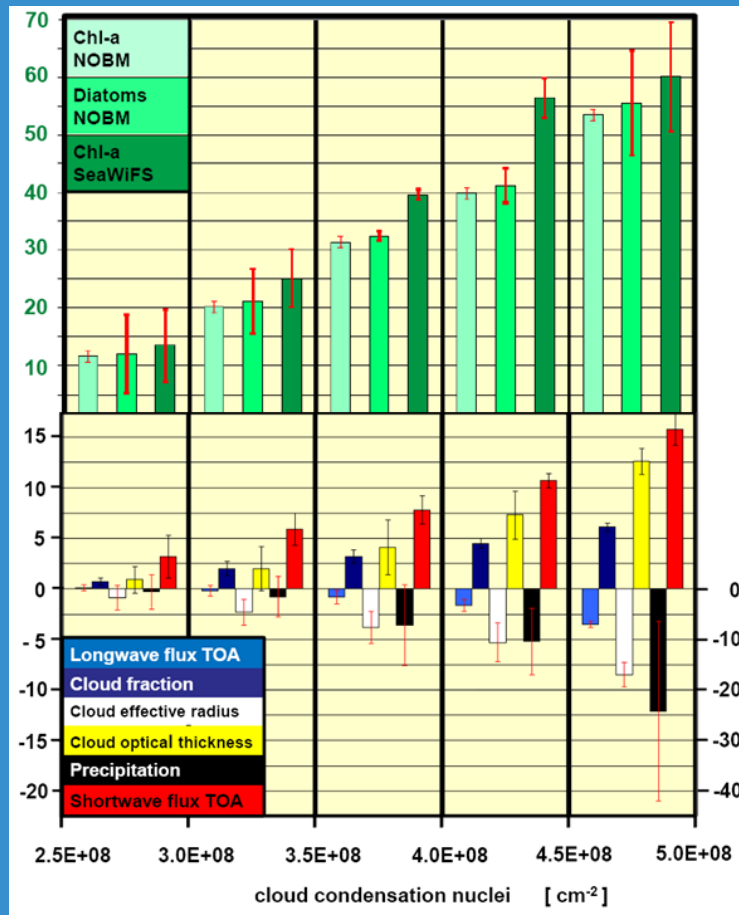
High CCN numbers are also observed in the stormtrack of the Southern Ocean. The area is an interesting testbed for analysis of the natural aerosol cloud-mediated processes.



Phytoplankton and Clouds

Chl-*a*
change [%]

Clouds
Radiation
change [%]

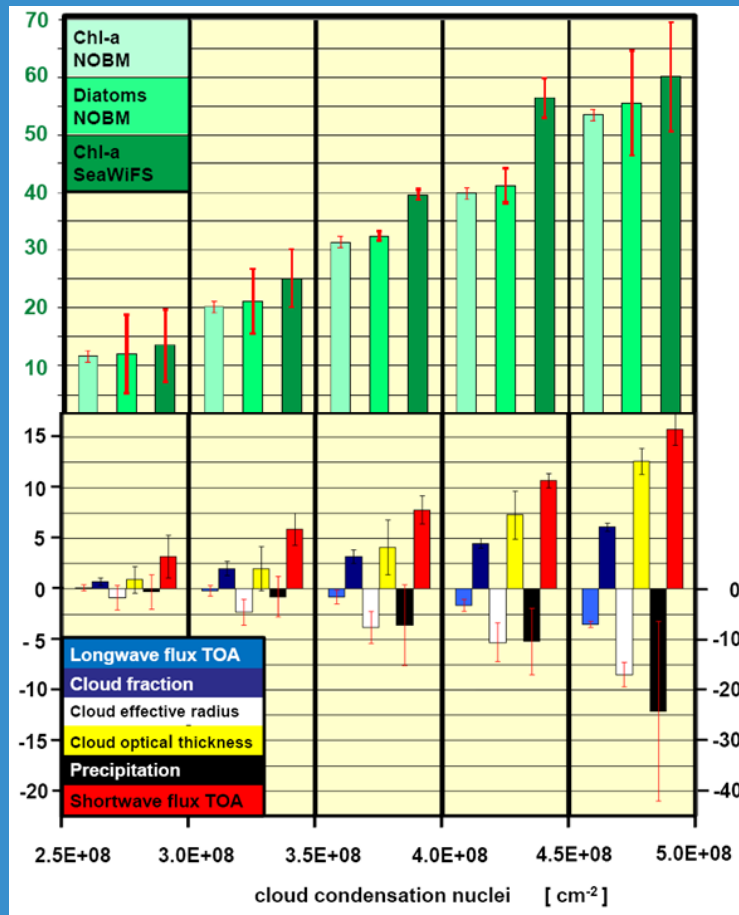


Aerosol cloud-mediated climate processes are observed over the Southern Ocean from 45°S to 65°S, especially in regions with plankton blooms, indicated by high chlorophyll-*a* concentration in seawater.

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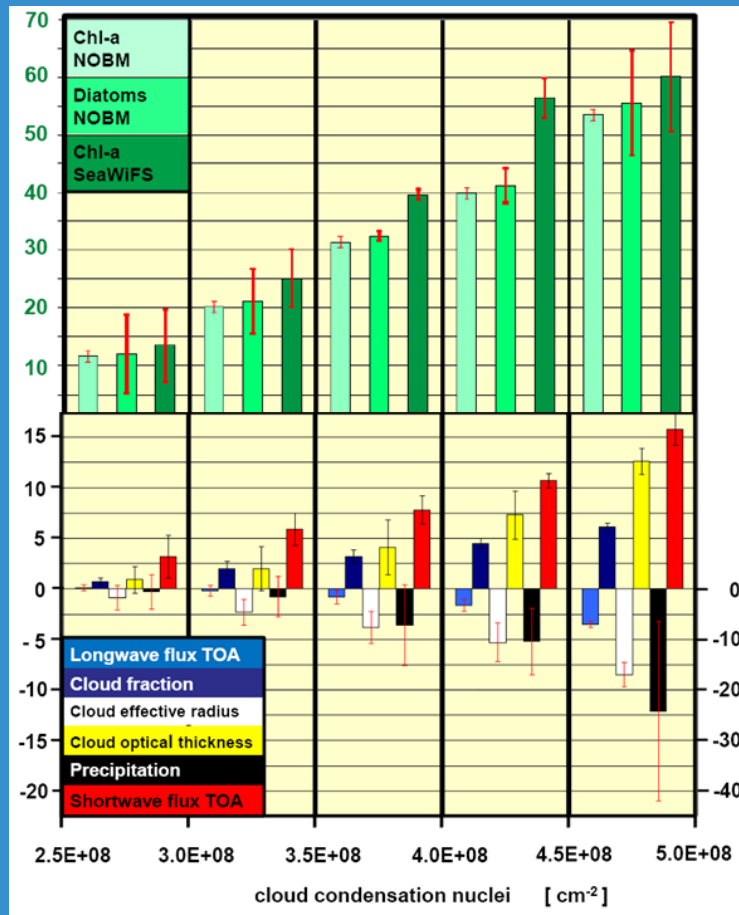
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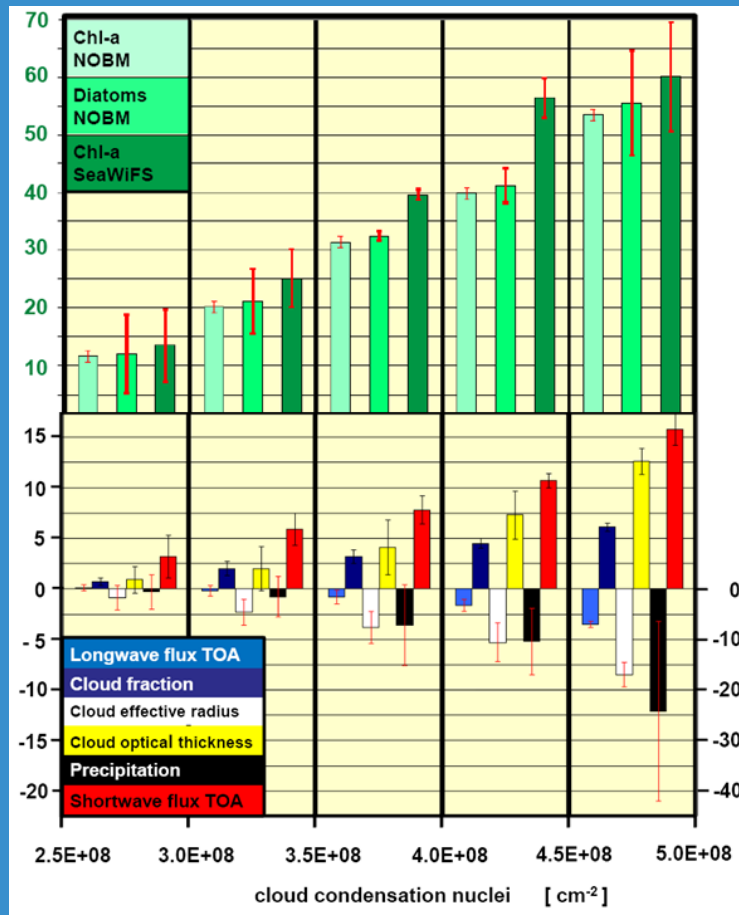
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The upward short-wave radiative flux at the top of the atmosphere increases.

Precipitation amount decreases.

Desideratum

We need to investigate the influence of changing emissions (e.g. sulphur, black carbon and BVOCs) on regional climate

Modelling activities constrained by observations need to be focussed on aerosol cloud-mediated climate processes in the Baltic Region.

This ideally should include:

- Treatment of biogenic and carbonaceous aerosols.
- Change of biogenic emissions in a changing climate including dimethyl sulphide (DMS).
- Effects of spatial gradients in solar heating (dependent on circulation types).
- Effects of higher CCN numbers and absorption on cloud albedo and precipitation.

Thank you for your attention.