Max-Planck-Institut für Meteorologie
Max Planck Institute for Meteorology

WHY

Aerosol-cloud interactions are a crucial climate forcing
Observations at global scale needed: Satellite data
Goal: Better model predictions of future climate change

Aerosol - Cloud Interactions

Clues from **satellite data** in support of **climate modeling**

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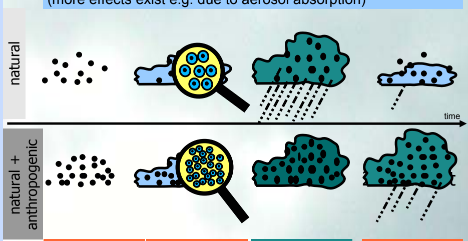
What are aerosol-cloud interactions?

Radiative effects by anthropogenic aerosols
(more effects exist e.g. due to aerosol absorption)

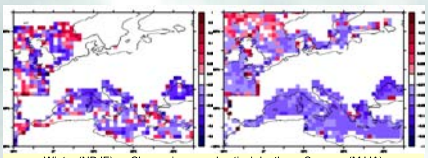


Direct	1st indirect	cloud albdeo	2nd indirect
↑ aerosol number ↑ scattering/absorption ↑ planetary albedo	↑ condensation nuclei ↑ droplet number ↓ droplet size ↑ cloud albedo	COD = 3/2 LWP / CDR COD = cloud optical depth LWP = liquid water path CDR = cloud droplet radius	↓ droplet size ↓ rain formation rate ↑ cloud water ↑ cloud lifetime ↑ (mean) cloud albedo

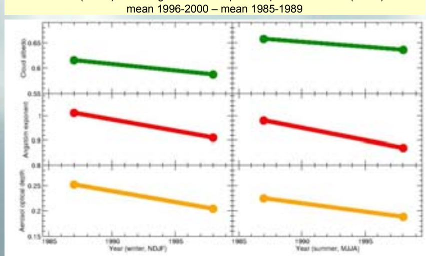
Observable effects of aerosols on clouds
↑ increasing aerosol burden
↓ decreases cloud droplet size
↑ increases cloud albedo

Emission reduction in Europe: A test region

In the late 20th century, pollution by secondary aerosol (sulfur dioxide and nitrogen compounds) has been reduced over Europe
→ Aerosol effects decreased



Winter (NDJF) Change in aerosol optical depth Summer (MJJA)
mean 1996-2000 – mean 1985-1989



Aerosol optical depth is a measure for aerosol concentration

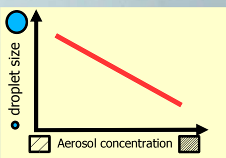
Angstöm exponent is a measure for aerosol particle size
- large Angström exponent refers to small particles
- small particles are typically anthropogenic

All data derived from **AVHRR satellite measurements**

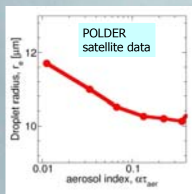
Mean values
- for northern hemisphere winter (NDJF) and summer (MJJA)
- for two periods, 1985-1990 and 1996-2000
- for Europe (5-29E / 49N-58N)
Aerosol quantities over sea only

Satellite analysis at **global scale**

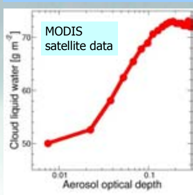
First indirect effect: Aerosols change cloud droplet size

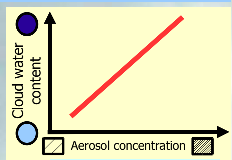


Schematical view of the first aerosol indirect effect



Second indirect effect: Aerosols change cloud water content

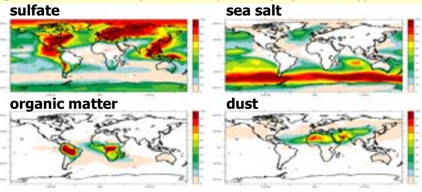


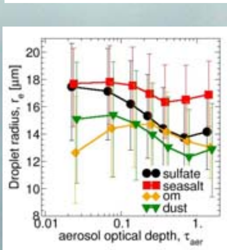


Schematical view of the second aerosol indirect effect

Combination satellite data-model: **Which aerosol type** is dominant?

Model calculations:
Regions with dominant (> 50% of optical depth) aerosol types



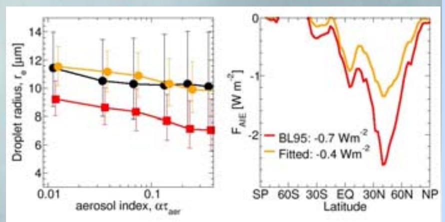


Combination :
- aerosol characterization from **model**
- aerosol optical depth and cloud droplet size from **MODIS** data

Potential error sources:

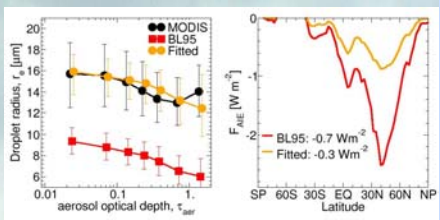
- the region where organic matter (OM) dominates may be too small in the model
- the relationship for dust may be biased when MODIS mistakes large dust particles for small cloud droplets

Estimating the **radiative forcing** by combining model and satellite data



black: relationship from POLDER satellite data
red: relationship for the model's standard formulation
orange: relationship with model is fitted to POLDER

Zonal annual mean radiative forcing by the aerosol indirect effect from the model:
red: with the standard formulation
orange: fitted to POLDER data



black: relationship from MODIS satellite data
red: relationship for the model's standard formulation
orange: relationship with model is fitted to MODIS

Zonal annual mean radiative forcing by the aerosol indirect effect from the model:
red: with the standard formulation
orange: fitted to MODIS data

POLDER and MODIS satellite data:
- two different satellite-based instruments
- data for eight months (POLDER) and one year (MODIS) are taken
- model estimations for the same periods

The numbers give the global annual mean radiative forcing by the 1st indirect effect. Although measurement-based relationships are different, the result is similar:
-0.3 to -0.4 W m⁻²

Conclusions

Europe: A test region **1.**

Satellite data show for the late 20th century over Europe:
- reduction in aerosol concentration
- increase in aerosol particle size (less anthropogenic aerosol)
- decrease in cloud albedo (decrease of aerosol indirect effect)

The **indirect effect** from satellite data **2.**

Satellite data confirm at a global scale:
- the postulated decrease in cloud droplet size with increasing aerosol concentration
- the postulated increase in cloud water content with increasing aerosol concentration

Aerosol type **3.**

A combination of satellite data and model results shows
- the indirect effect of sulfate is most important
- organic carbon and sea salt seem to play a minor role

Radiative forcing **4.**

Constraining the model to simulate the satellite-derived relationship between cloud droplet size and aerosol concentration yields a **radiative forcing of -0.3 to -0.4 W m⁻²**

NEXT

new satellite data:
- *new data from POLDER for 2003 will be analyzed*
- *a longer dataset for MODIS (2000 - 2004) will be used*
- *along with MODIS, data for the radiative fluxes exist from the same satellite platform – a purely observation-based estimate of the radiative forcing seems possible*
- *future LIDAR and RADAR in space will provide vertical information*

models improvements:
- *different models with prescribed parameterizations for aerosol-cloud interactions will be intercompared within the international AEROCOM project*
- *the link between aerosols and clouds will be improved in the model*

better climate simulations:
- *long-term climate simulations are underway for the next IPCC assessment report*
- *period of the integration: 1850 to present-day with realistic aerosol concentrations / emissions; and present-day to 2100 for different energy consumption scenarios*
- *model configurations include the improvements shown here*
- *more realistic assessment of aerosol indirect effects is possible for past and future climate*

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