COMBINE

Studies of the Aerosol Indirect Effect in CAM-Oslo.

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Outline

- Introduction
- Prognostic treatment of cloud droplet number concentration in CAM-Oslo
- Resulting distributions of r_{eff}, CDNC and the aerosol indirect effect (AIE).
- Importance of microphysical sinks of CDNC.
- The competition effect among CCN.
- Conclusion and future work.

Introduction:

- The scheme for calculation of AIE presented here is based on the framework developed by Jon Egill Kristjansson for NCAR CCM3. *(JGR: Kristjansson, 2002)*
- The framework has since then been implemented in NCAR CAM2 and developed further.
- Improvements include:

  - Introduction of a continuity equation for CDNC.

  - A more sophisticated treatment of CCN activation.

Continuity equation for CDNC:

$$\frac{dN_l}{dt} = A_{N_l} + Nucl - \frac{N_l}{q_l}(AC + Coll + Accr) - E - Self$$

N_l=Cloud droplet number (#/cm^3).

A_{Nl}= Transport (convection & turbulence).

q_l= Mixing ratio for cloud water (liquid phase).

AC = Loss of cloud water due to autconversion of cloud droplets.

Coll = Loss of cloud water due to collection of cloud droplets by rain.

Accr = Loss of cloud water due to collection of cloud droplets by snow.

E = Evaporation of cloud droplets.

Self = Self-collection of cloud droplets (i.e. coalescence of cloud droplets which is not resulting in precipitation).

Activation of CCN to form cloud droplets:

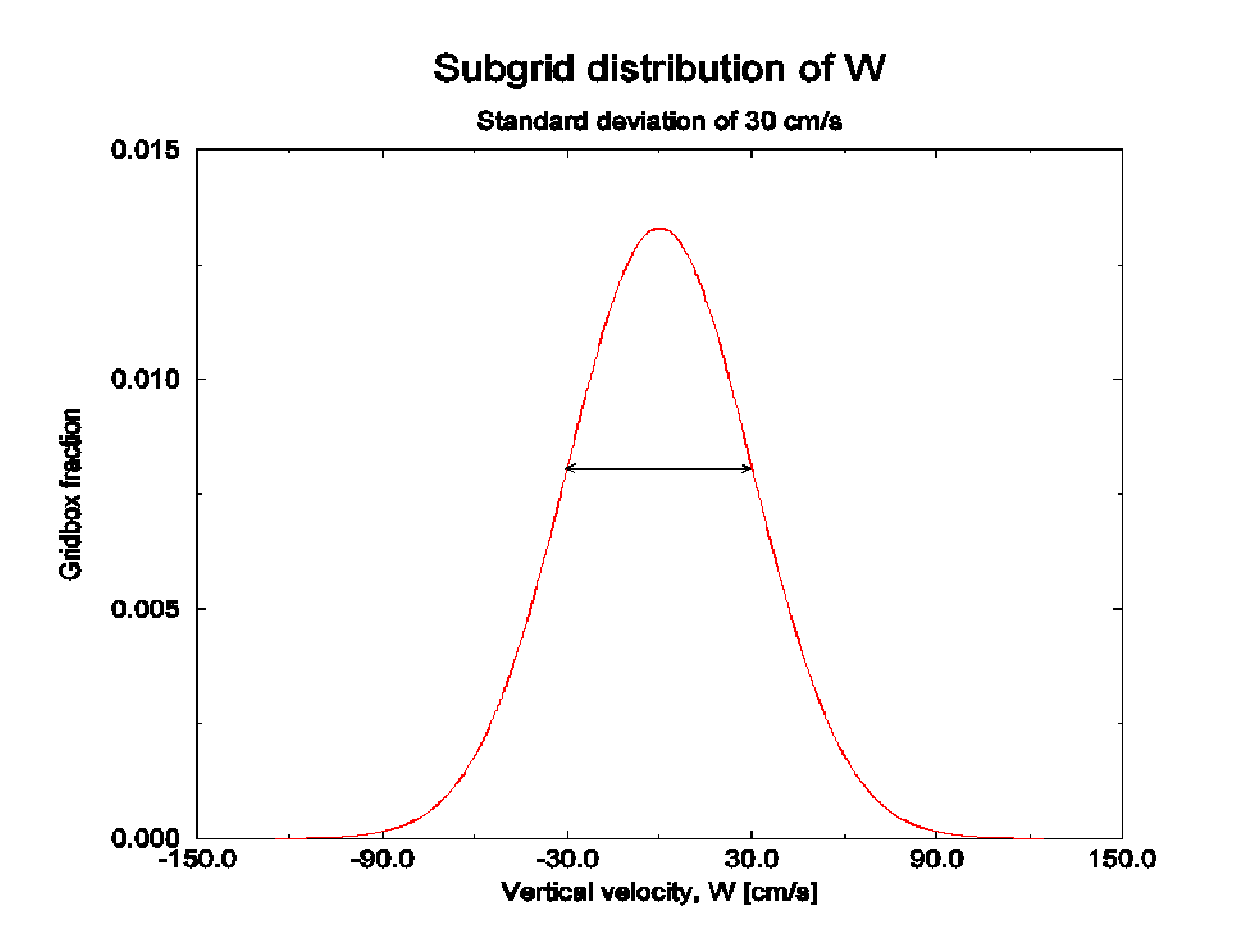
- Aerosol-concentrations based on AEROCOM B emissions, a life-cycle scheme developed by Ø.Seland and T. Iversen and aerosol size distributions based on work by A. Kirkevåg.
- Activation-term in continuity equation based upon scheme developed by *Abdul-Razzak et al., JGR 2000.*
- The scheme calculates supersaturations, S, based on a sub-grid parameterization of vertical velocity. Crucial for the calculation of S is also a so called **"competition-effect",** where each CCN competes with all present CCN for the available water vapor. Many CCN→lower supersaturation.
- Number of activated CDNC are calculated based on Köhler-theory.

Subgrid distribution of vertical velocity:

$\sigma_w \propto K/\Delta Z$,

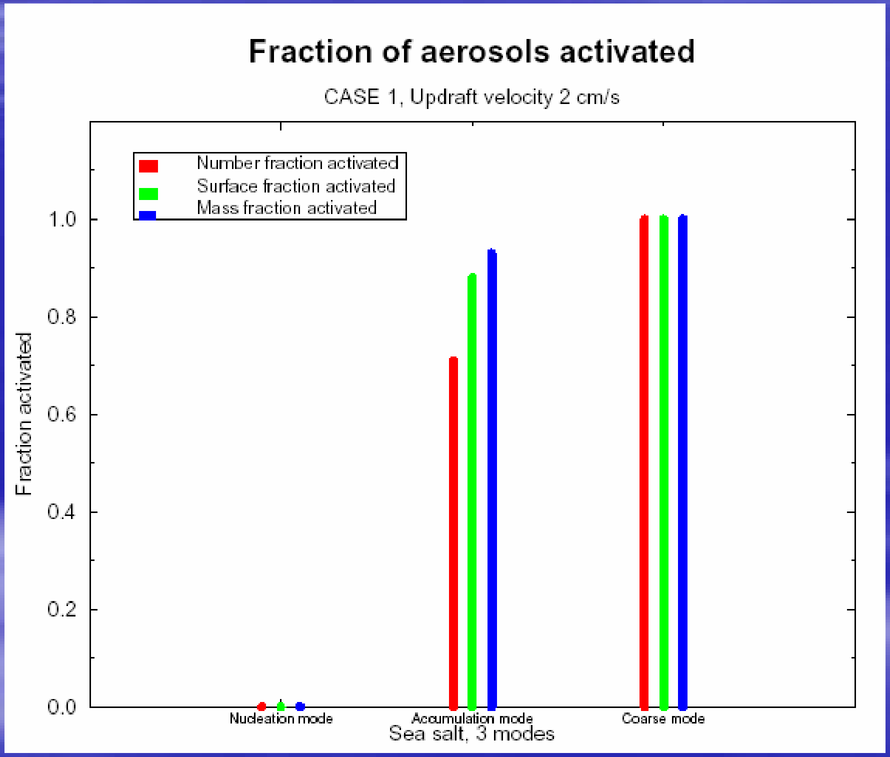
Where K is diffusivity coefficient and ΔZ the thickness of the model-layer.

Due to coarse vertical resolution in GCMs it is necessary with a lower bound for σ_w.

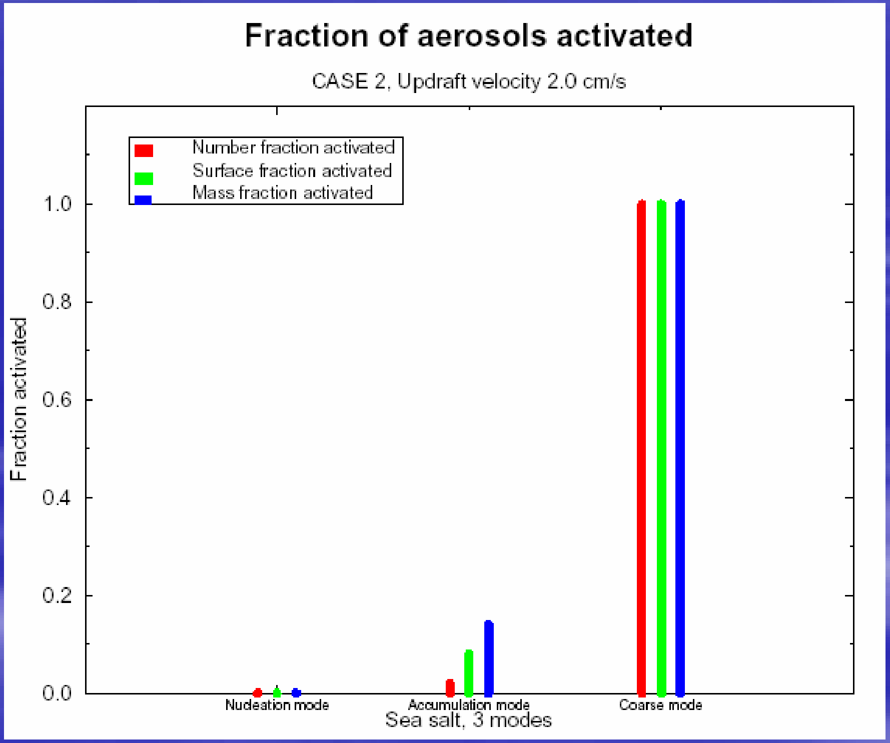


Droplet Nucleation (Ghan scheme):

Few large particles



Many large particles



Sources & sinks for cloud droplets per time-step (20 min):

NUCLE
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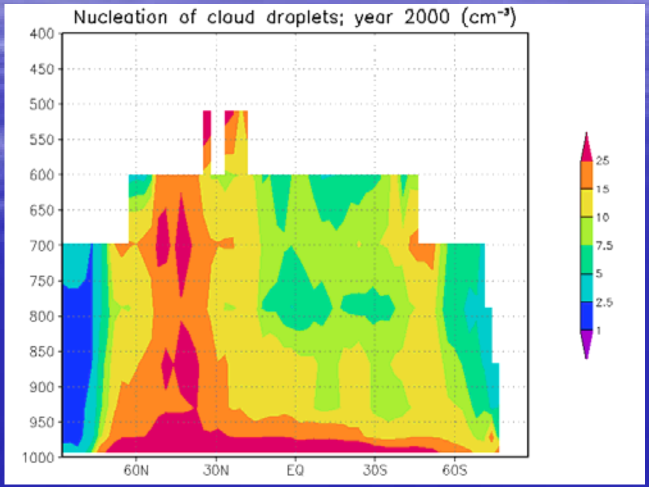

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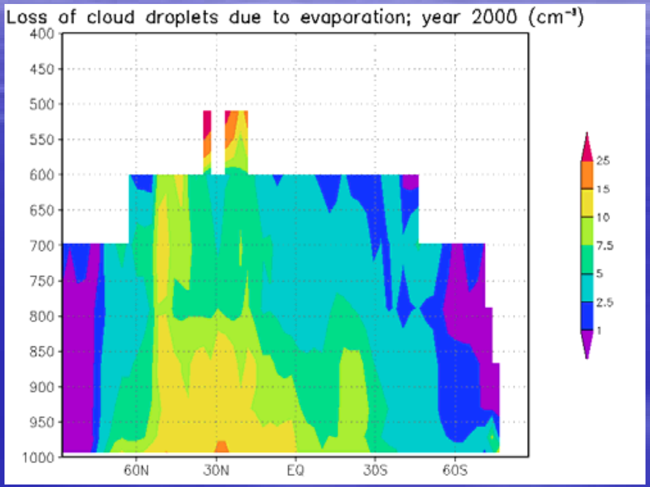

PRECIPI
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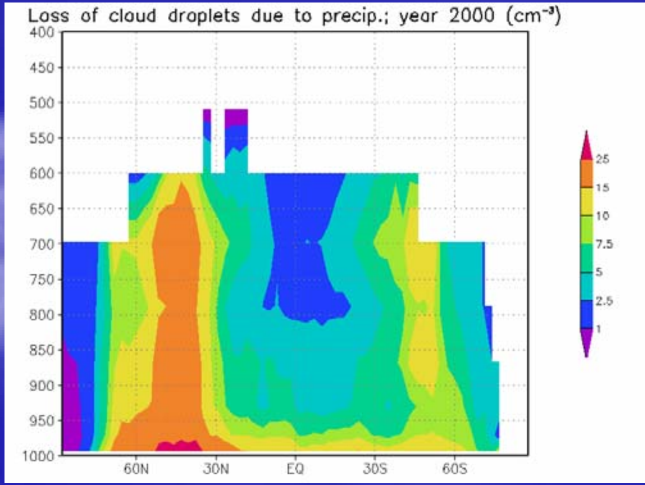

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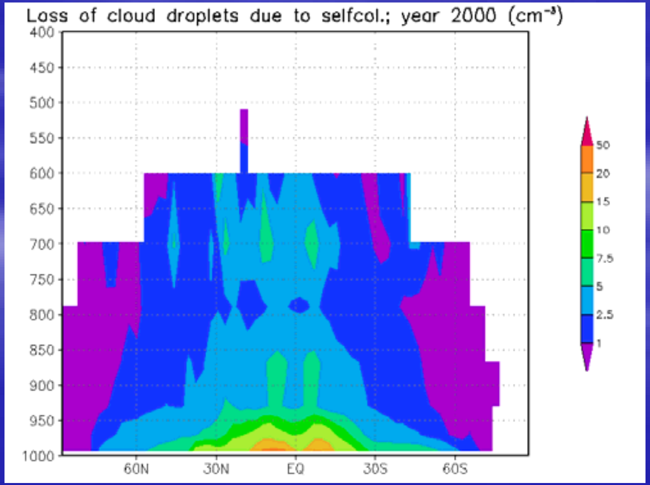
LECTION



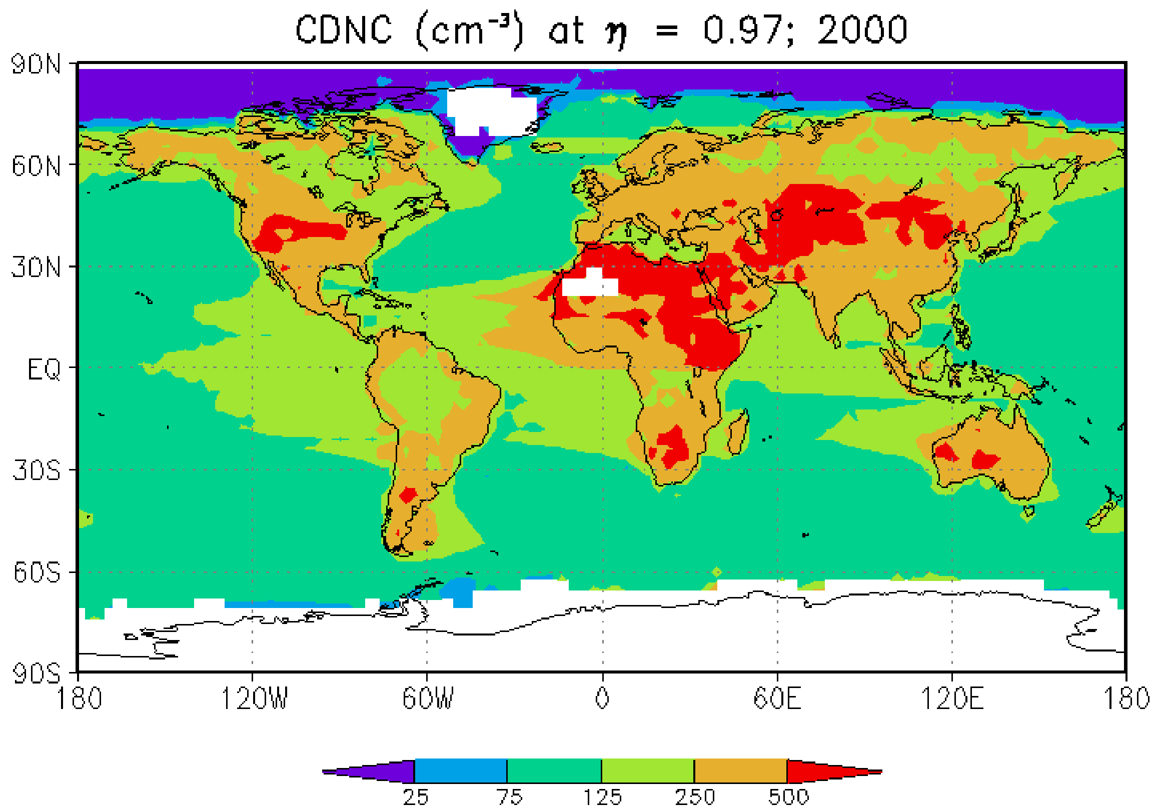
Model-development, step-by-step:

- Step1: Original scheme for calculations of AIE in CCM3. Diagnostic CDNC. IPCC aerosol emissions.
- Step 2: Same scheme in CAM2.0.1. IPCC aerosol emissions.
- Step 3: Continuity equation with simple nucleation term. IPCC aerosol emissions.
- Step 4: Continuity equation with more sophisticated nucleation term, no competition-effect. AEROCOM B aerosol emissions.
- Step 5: Continuity equation with sophisticated nucleation term, competition effect included. AEROCOM B aerosol emissions.

Comparison of r_e, LWP og ΔSWCF:

	Step1	Step2	Step3	Step4	Step5
r_e (μm)	10.31	10.29	12.50	12.14	10.96
Δr_e (μm)	-0.58	-0.51	-0.53	-0.35	-0.10
LWP (g/m^2)	41.2	65.4	51.8	60.92	63.50
ΔLWP (g/m^2)	1.93	1.46	0.79	0.76	0.26
ΔSWF (W/m^2)	-1.83	-0.91	-0.58	-0.40	-0.13

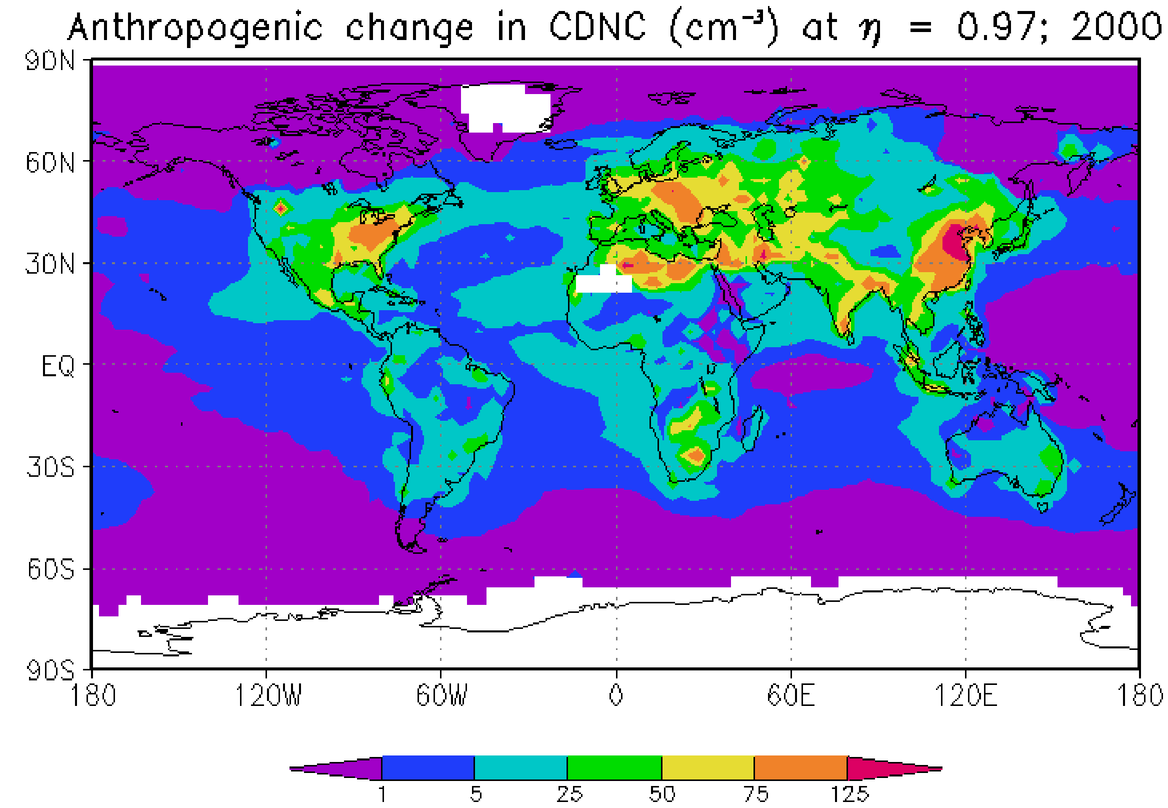
Step 5: Cloud droplet number concentration (CDNC)



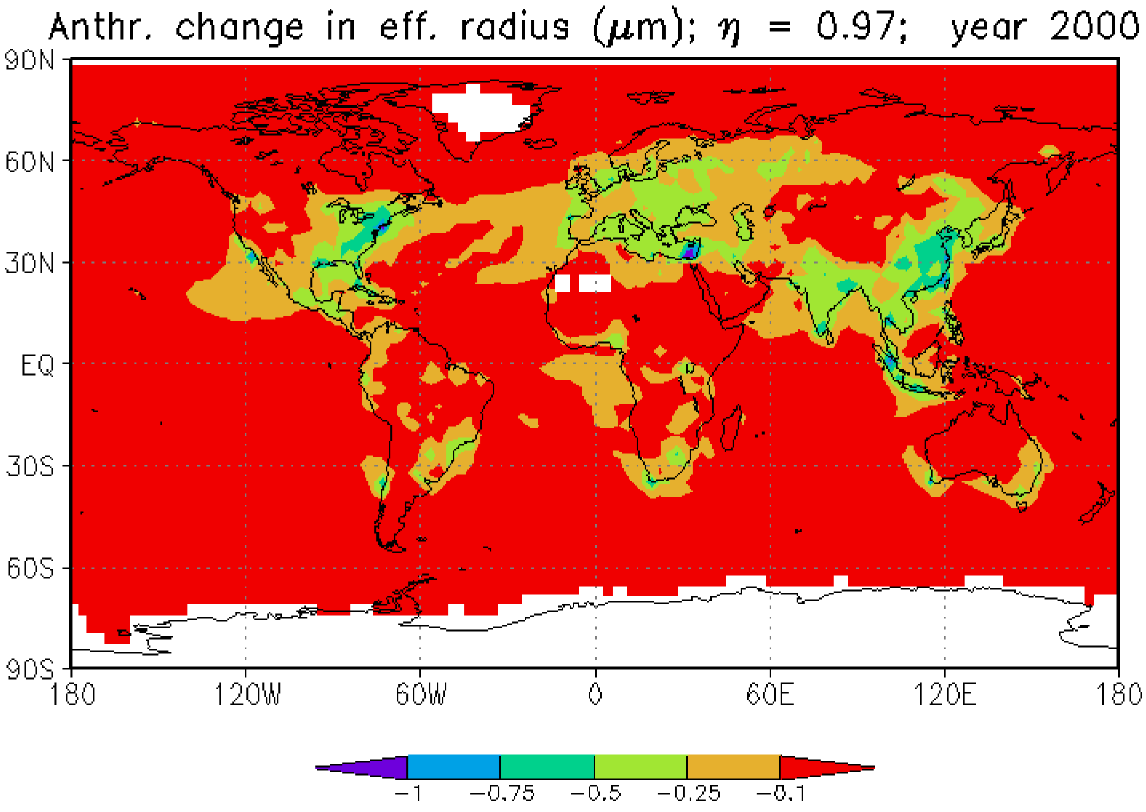
Step 5: Anthropogenic contribution to CDNC.

Global average increase of cloud droplets due to anthropogenic aerosols:

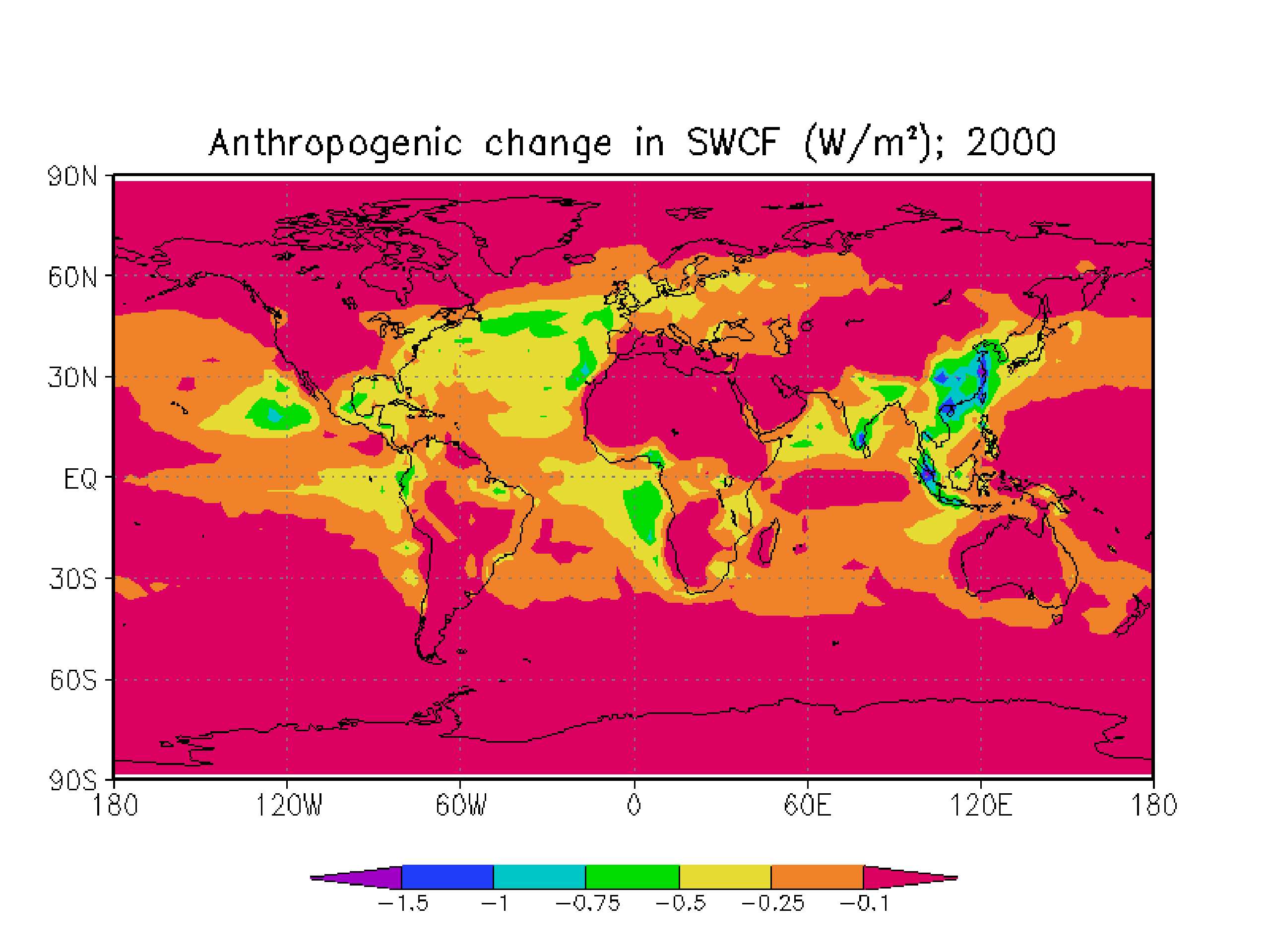
~ 5 %.



Step 5: Change in effective radius due to anthropogenic aerosols.



Step 5: Aerosol Indirect Effect (AIE)



Conclusion:

- The AIE is significantly reduced going from NCAR CCM3 to NCAR CAM2.0. The transition from random to max/random cloud overlap assumed to be important here.
- The introduction of a continuity equation with microphysical sinks for CDNC reduces the AIE further.
- Accounting for the competition effect among aerosols leads to lower supersaturation in a polluted cloud compared to a clean cloud.

→Small AIE

Future work:

- Extend and improve our aerosol scheme, e.g. let aerosols affect cloud cover as well as cloud optical/geometrical thickness.
- Compare model results with MODIS-data (Cooperation with G. Myhre, F. Stordal and researchers at NILU)
- Develop parameterization for aerosol-icecloud interaction (with U. Lohmann).

Thank you for the attention!

Cloud droplet number and albedo

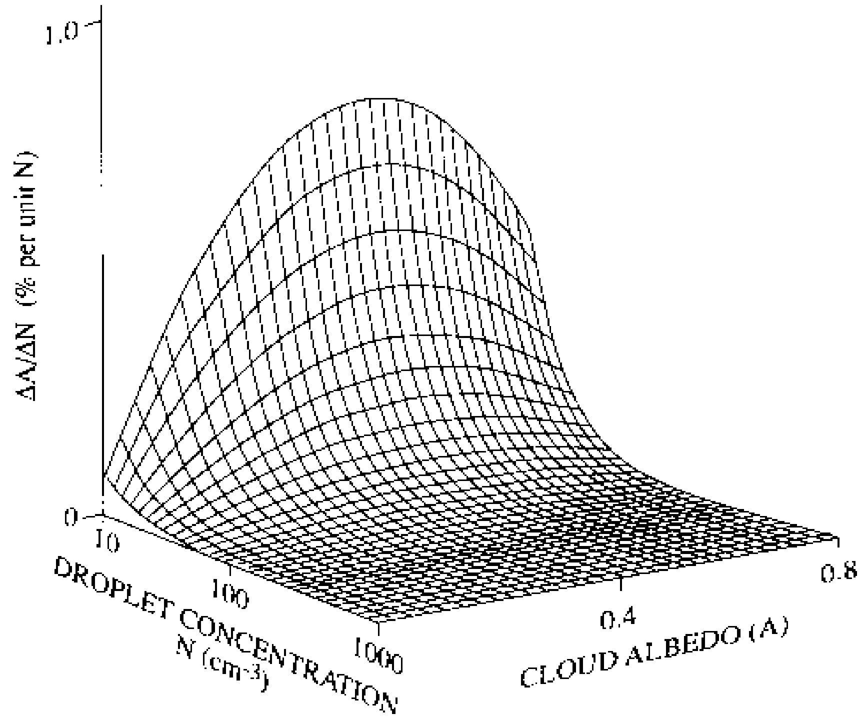


Figure 6 The change in the albedo of a cloud per unit change in the droplet concentration ($\Delta A/\Delta N$) as a function of the cloud albedo (A) and the droplet concentration (N), for a cloud with a constant liquid-water content. (Adapted from Twomey, 1991.)

Hobbs, 1993: Academic Press