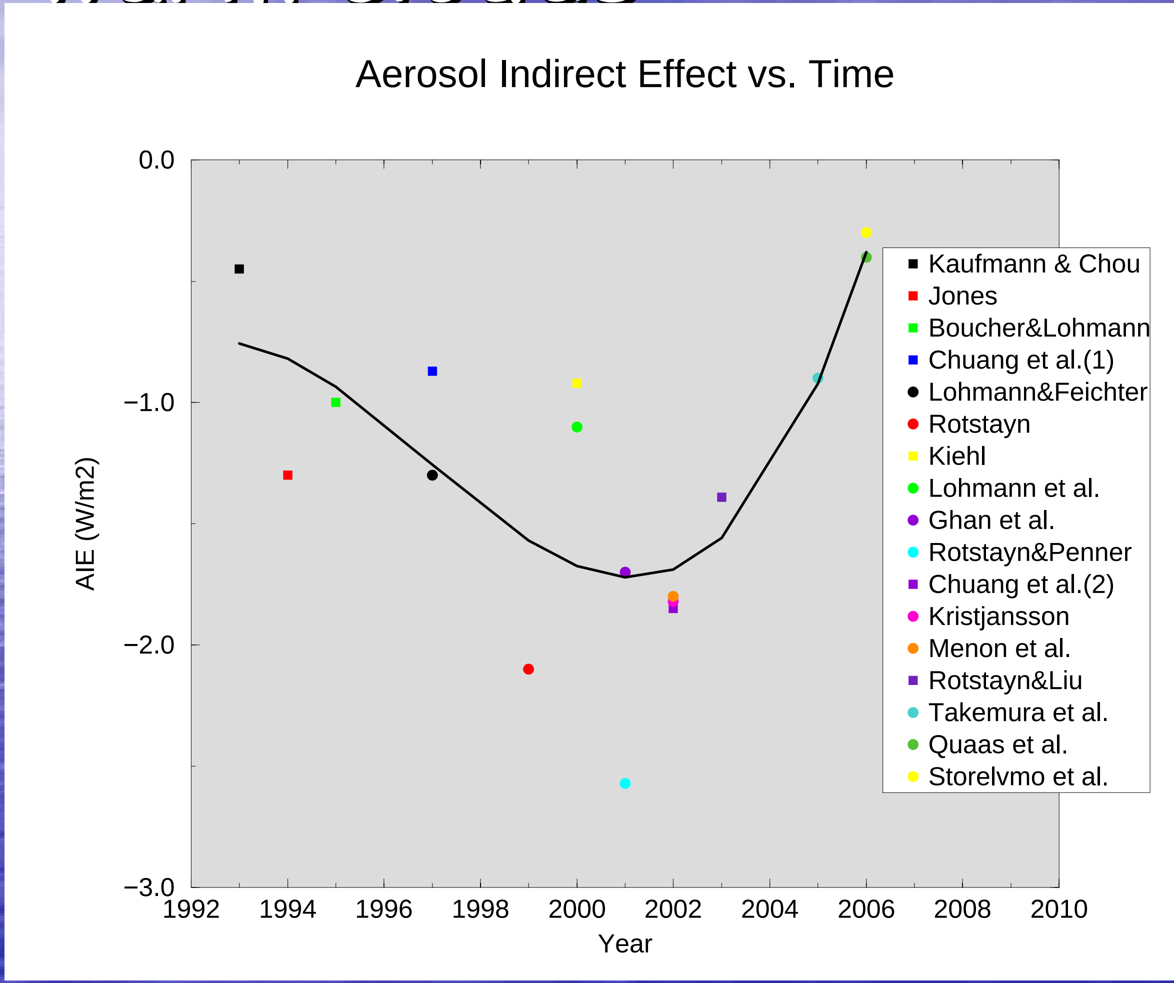
Modeling aerosol influence on warm and mixed-phase clouds in CAM-Oslo.

T. Storelvmo, J. E. Kristjánsson, T. Iversen, A. Kirkevåg, Ø. Seland, University of Oslo
U. Lohmann, ETH-Zürich

Aerosol Indirect Effect, warm clouds



Model estimates of the aerosol indirect effect on warm clouds.

■ represent 1st indirect effect (Twomey effect) only

● represent 1st and 2nd indirect effect (lifetime effect).

Modeling aerosol effects on warm clouds, CAM-Oslo

- CAM-Oslo is an extended version of the NCAR CAM2 GCM with horizontal resolution of 2.8º x 2.8º and 26 vertical layers.
- Extensions for calculation of aerosol indirect effects are based on a framework consisting of 5 modules:

  1. The aerosol life-cycle module, predicting aerosol mass concentrations from AEROCOM B emissions *(Iversen & Seland, JGR 2002).*
  2. The aerosol size distribution module, predicting aerosol number concentrations and sizes *(Kirkevåg & Iversen, JGR 2002).*
  3. The cloud droplet activation module, based on Abdul-Razzak and Ghan (JGR, 2000)
  4. Microphysical source and sink module
  5. Module for calculations of cloud droplet number concentration, based on the results from module 3 and 4.

Continuity equation for cloud droplet number concentration, N_l:

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

A = transport

Nucl = CCN activation to form cloud droplets (including “competition effect”)

AC = autoconversion

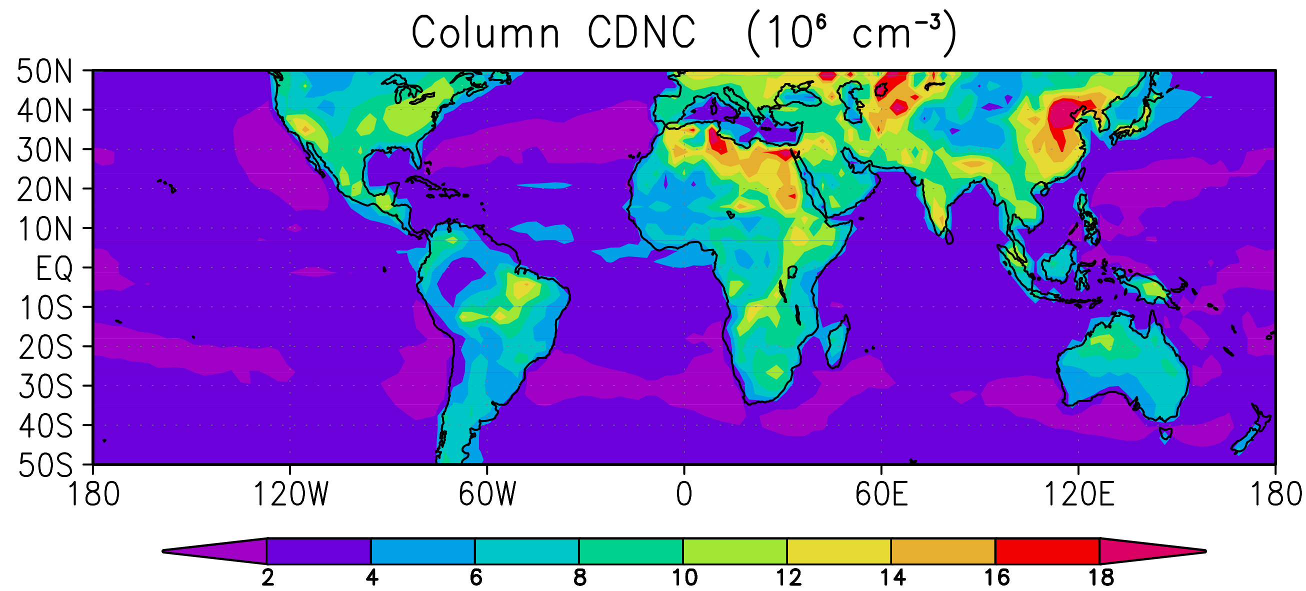
Coll = Collection of cloud droplets by rain

Accr = accretion (snow collecting cloud droplets)

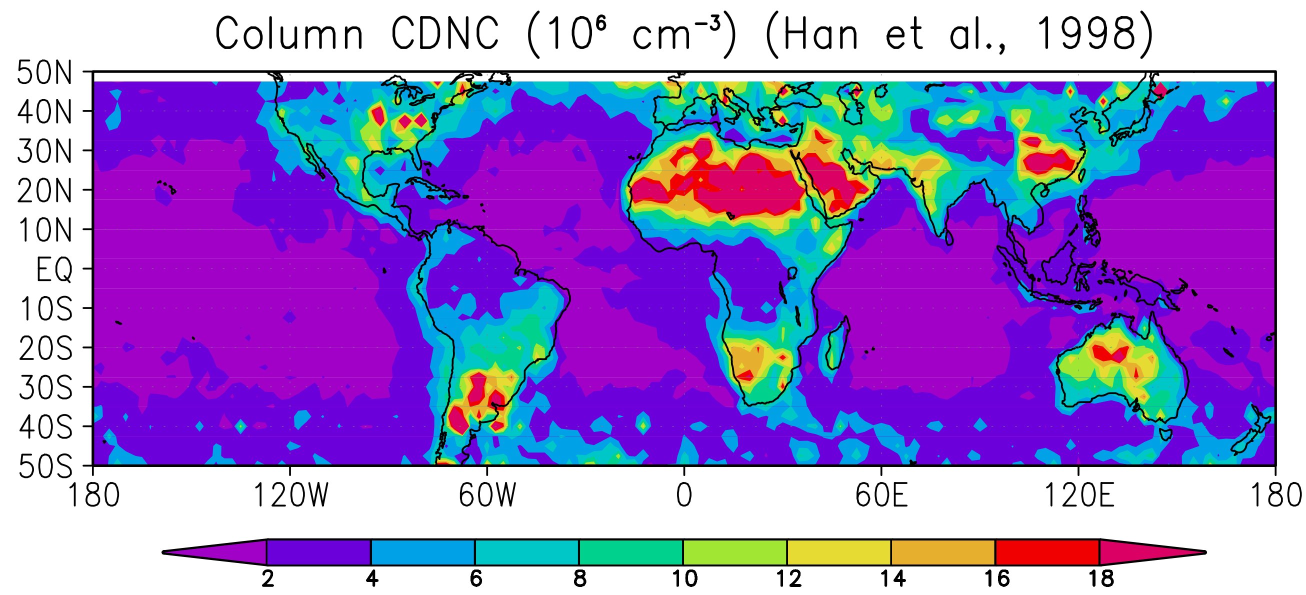
E = evaporation

Selfcollection = droplets collide, stick together, but do not fall out of cloud

Cloud droplet number conc.

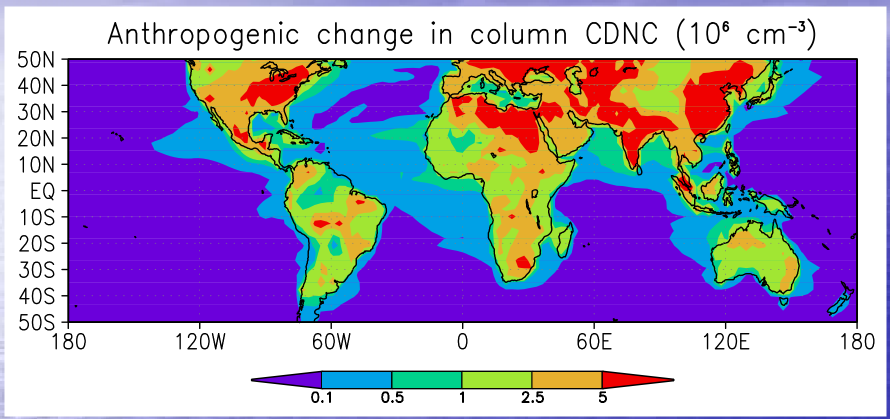


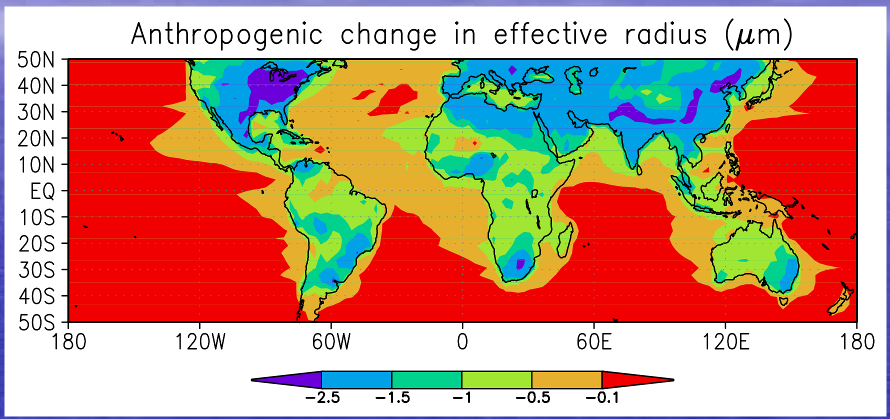
CAM-Oslo vertically intergrated cloud droplet number conc. for $T_c > 0^oC$

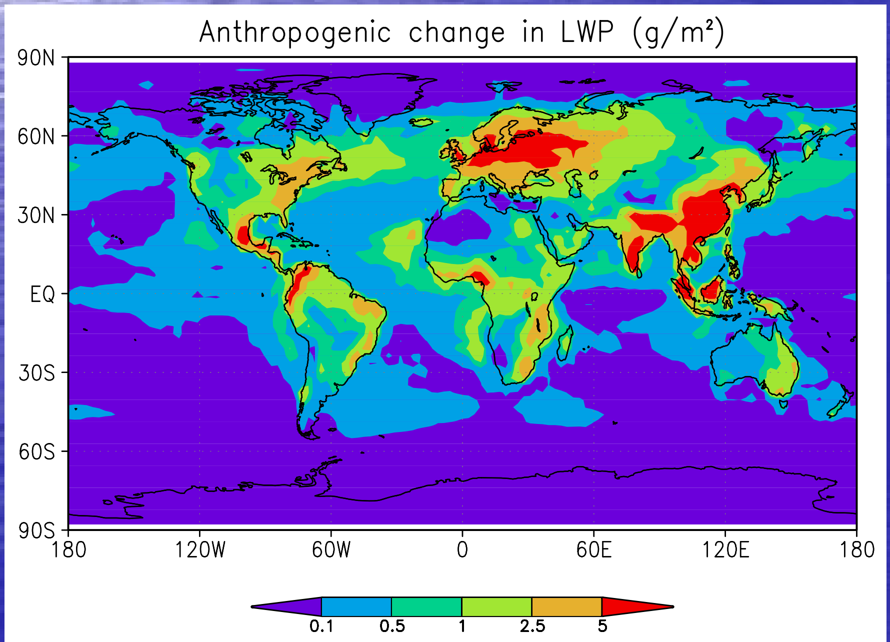


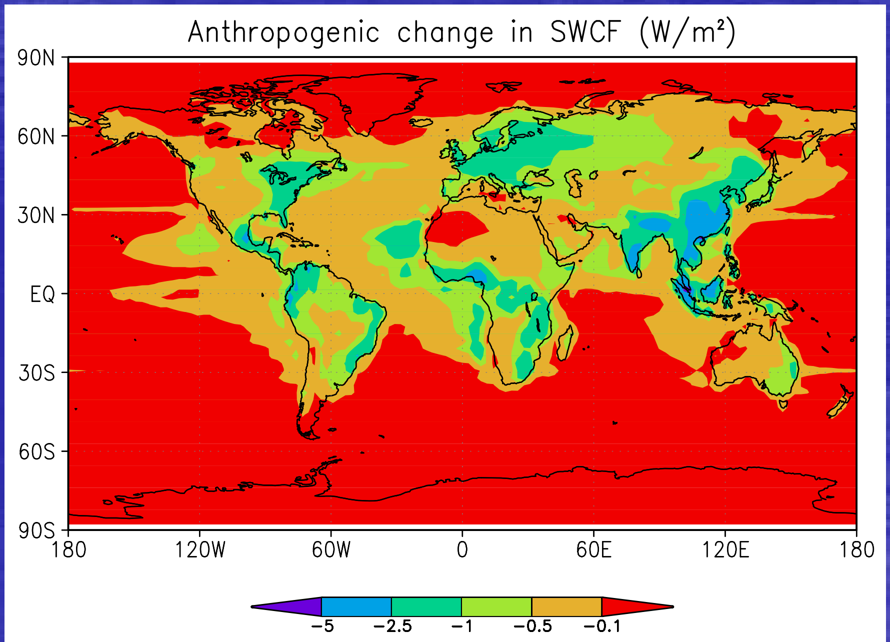
vertically intergrated cloud droplet number conc. as observed from satellite for $T_c > 0^oC$

Anthropogenic changes in CDNC, reff, LWP and SWCF (Control run)





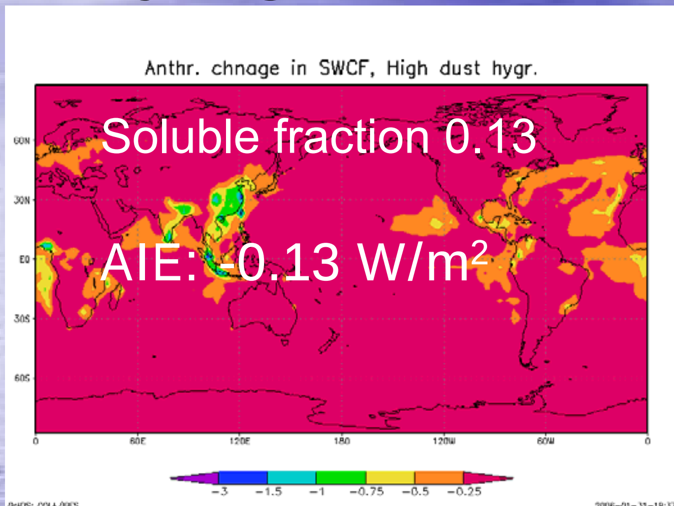


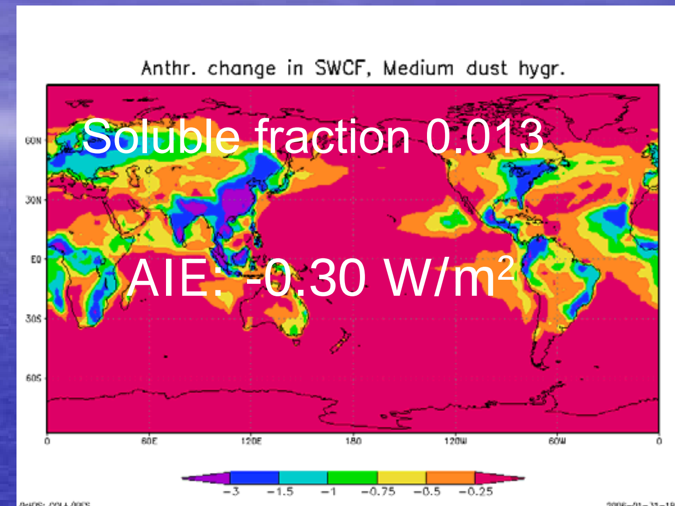


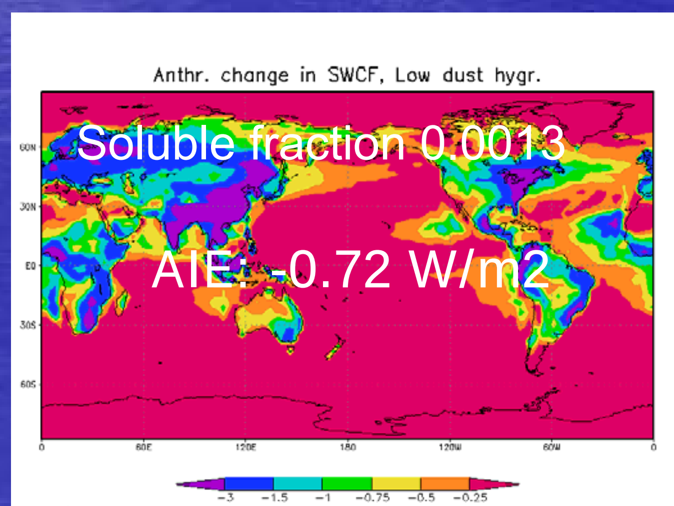
Sensitivity Studies

	CTL	Min_hyg +	Min_hyg-	R_{crit} 7.5	S_fixed
Δr_e (μm)	-0.40	-0.10	-0.73	-0.39	-0.59
ΔLWP (g/m^2)	0.68	0.26	1.32	0.60	1.54
ΔSWF (W/m^2)	-0.30	-0.13	-0.72	-0.28	-0.48

Varying soluble fraction for mineral dust:







Conclusions, warm cloud AIE

- CAM-Oslo with new treatment of aerosol influence on clouds gives a very small aerosol indirect effect (-0.13 W/m^2 to -0.71 W/m^2).
- Reasons for the small AIE are mainly the inclusion of microphysical sinks for cloud droplets and an aerosol activation scheme accounting for the competition effect
- The AIE is very sensitive to variations in the soluble fraction of dust aerosols.

Aerosol effects on mixed-phase clouds in CAM-Oslo

- We account for contact and immersion freezing of dust and BC aerosols, following the parameterization of Lohmann and Diehl (JAS, 2006).
- Freezing efficiencies specific to each aerosol species is used to obtain the Ice Nuclei (IN) concentration. Prognostic ice crystal number concentrations are then calculated.
- Model runs with preindustrial and present-day aerosol concentrations are carried out for 3 cases:

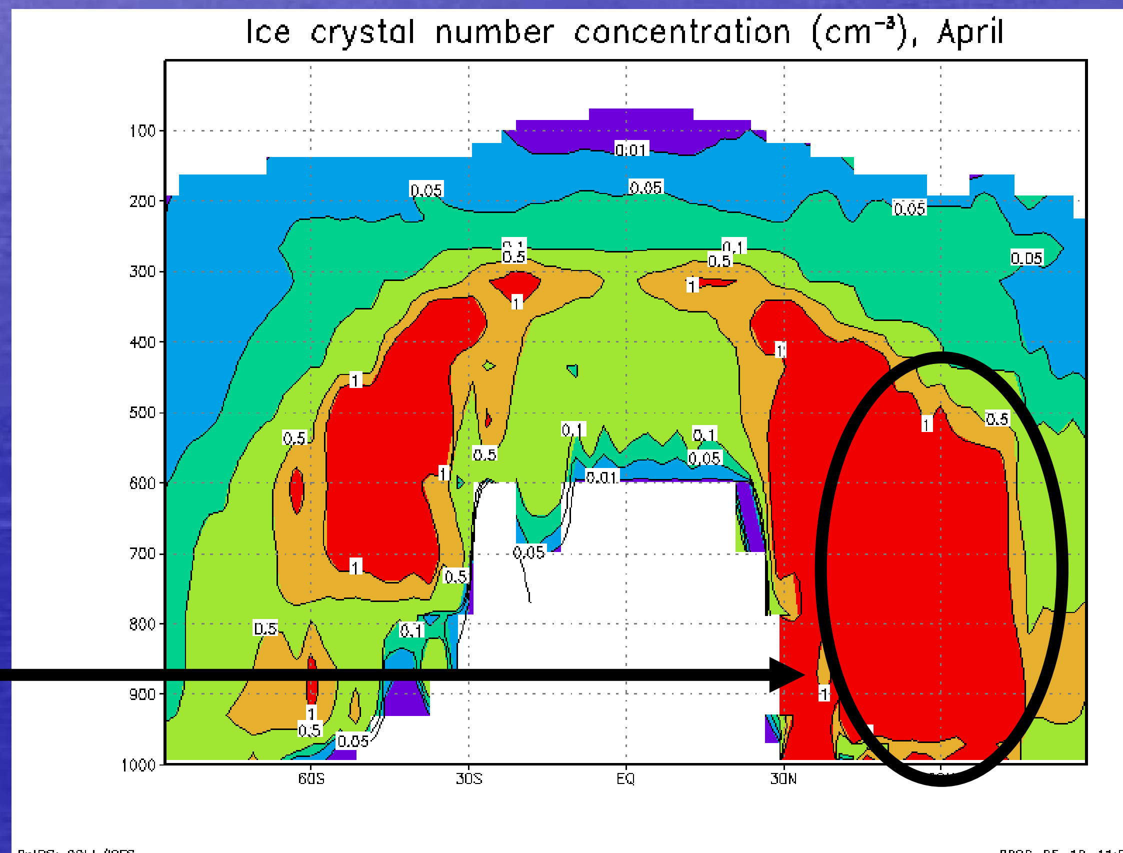
1. Control: Aerosol effects on liquid clouds only (Storelvmo et al., JGR 2006).
2. Dust_hghfrz: dust aerosols w/ high freezing efficiency assumed.
3. Dust_lowfrz: dust aerosols w/ low freezing efficiency assumed.

Ice crystal number conc., CAM-Oslo

$$\frac{dN_i}{dt} = A_{N_i} + Secp - selfc_i - (AC + Accr) + frz_{imm} + frz_{cont} + frz_{\mathrm{hom}} - mlt - subl$$

Korolev et al. (Q.J.R. Meteor. Soc., 2003):

Ice crystal number concentrations from 2 to 5 cm^{-3} were found in 5 field campaigns in Acrtic regions (42°N - 76°N).



Anthropogenic changes in cloud parameters

Simulation	Control	Dust_hghfrz	Dust_lowhfrz
Δ Cldfrac(%)	~ 0	-0.07	-0.54
Δ r_e (μm)	-0.73	-0.57	-0.66
Δ LWP (g/m^2)	1.32	-0.66	-0.48
Δ IWP (g/m^2)	~ 0	0.19	0.23
ΔF_{SW} (W/m^2)	-0.72	-0.10	0.41
ΔF_{LW} (W/m^2)	0.01	-0.05	-0.03
ΔF_{NET} (W/m^2)	-0.71	-0.15	0.38

Conclusions, Mixed-phase cloud AIE

- In CAM-Oslo, the glaciation indirect effect seems to represent a warming, the magnitude being determined by the number concentration and freezing efficiency of the background (dust) aerosols
- What about the ability of biological particles (bacteria, pollen etc.) to act as IN?

THANKYOU FOR THE ATTENTION!