VI-ACI
WP M3 Climate Modeling

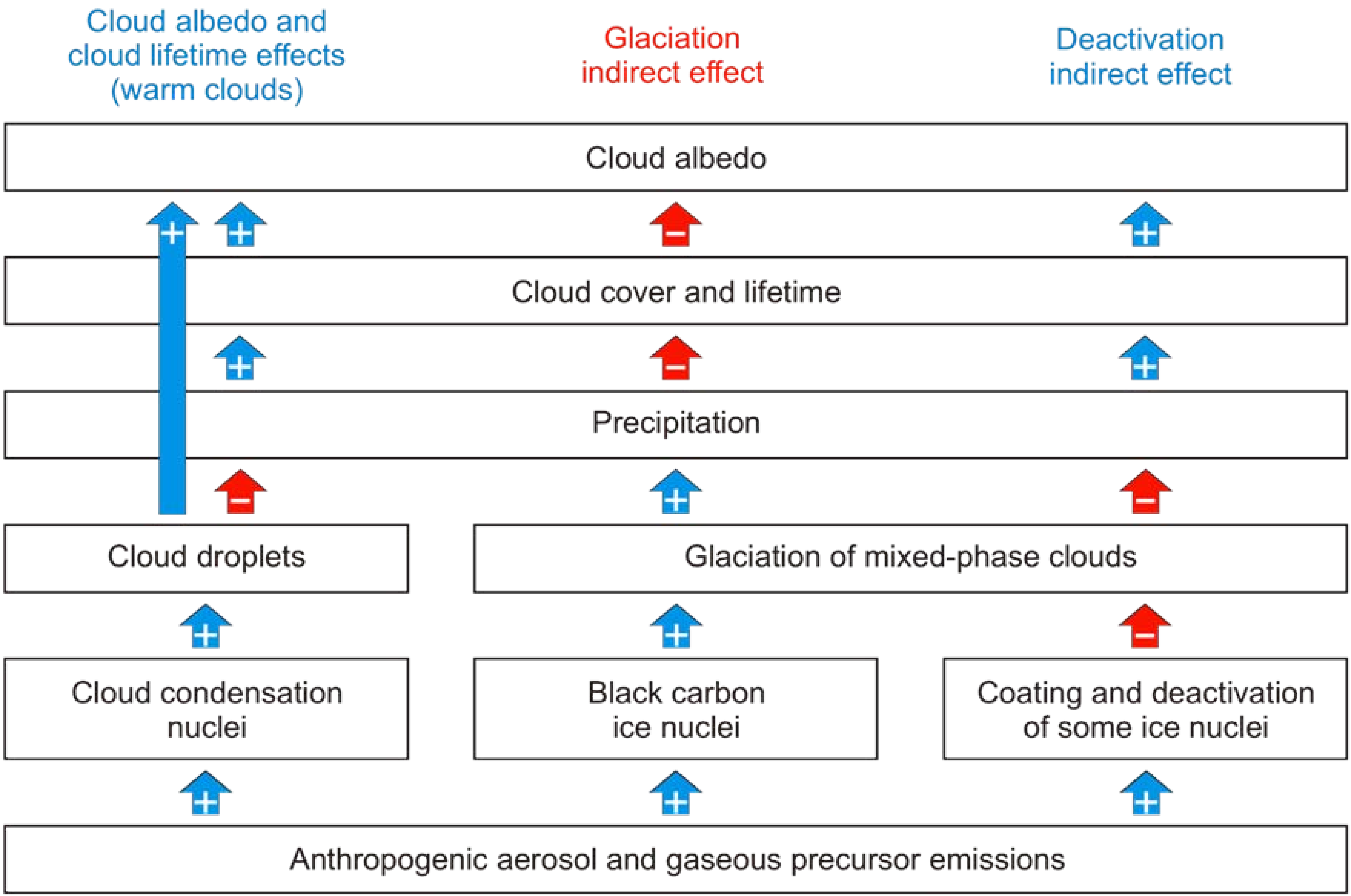
Karlsruhe, 27.4.2009

Milestones

3A (DLR): achieved (see last year's report)
3B (DLR): achieved (see last year's report)
3C (ETH): achieved
Using ECHAM5-HAM, a coupled atmospheric-aerosol model, the effect of varying the mineral composition of dust aerosols acting as ice nuclei (IN) was studied (Hoose et al., 2008). It was found that IN can be quasi-deactivated due to coating by anthropogenic soluble material. This contrasts an earlier study by Lohmann (2002) that found an increase in IN and thus increased glaciation resulting from anthropogenic black carbon aerosols.

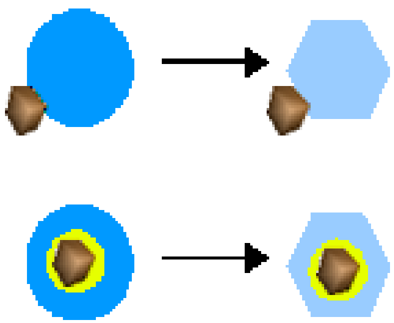
M3C

- Further work on the different aerosol effects on mixed-phase clouds is in progress
- We introduced thermophoretic contact freezing and evaluated the importance of the glaciation vs. the deactivation effect
- No results shown here as the new simulations are just being evaluated

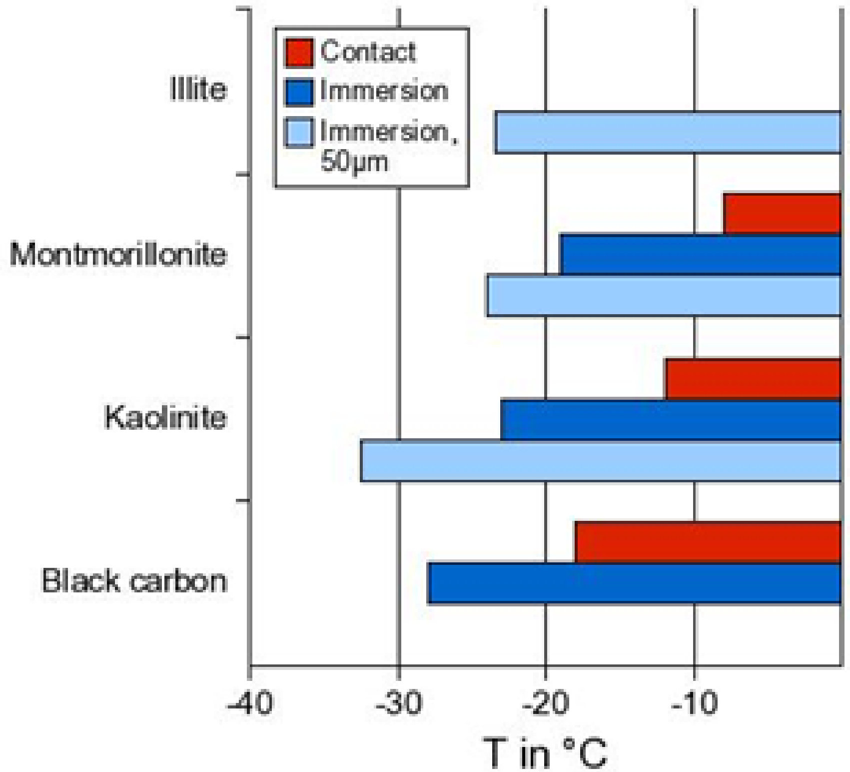


Cloud albedo and cloud lifetime effects (warm clouds)
Glaciation indirect effect
Deactivation indirect effect
Cloud albedo
Cloud cover and lifetime
Precipitation
Cloud droplets
Glaciation of mixed-phase clouds
Cloud condensation nuclei
Black carbon ice nuclei
Coating and deactivation of some ice nuclei
Anthropogenic aerosol and gaseous precursor emissions

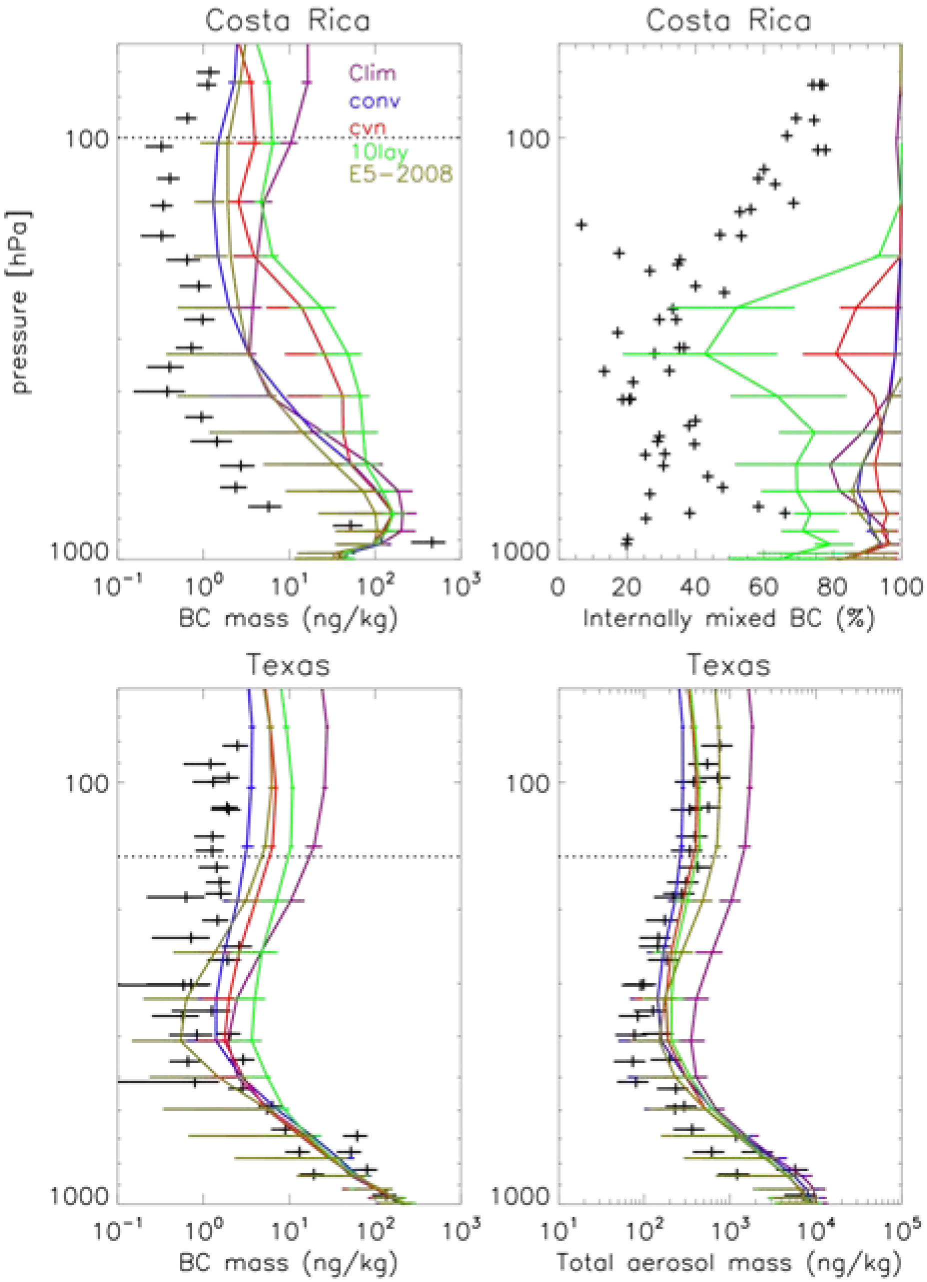
- -38 °C<T<0 °C: ice nucleus is required for freezing
- In ECHAM5-HAM: contact and immersion freezing, dust and black carbon



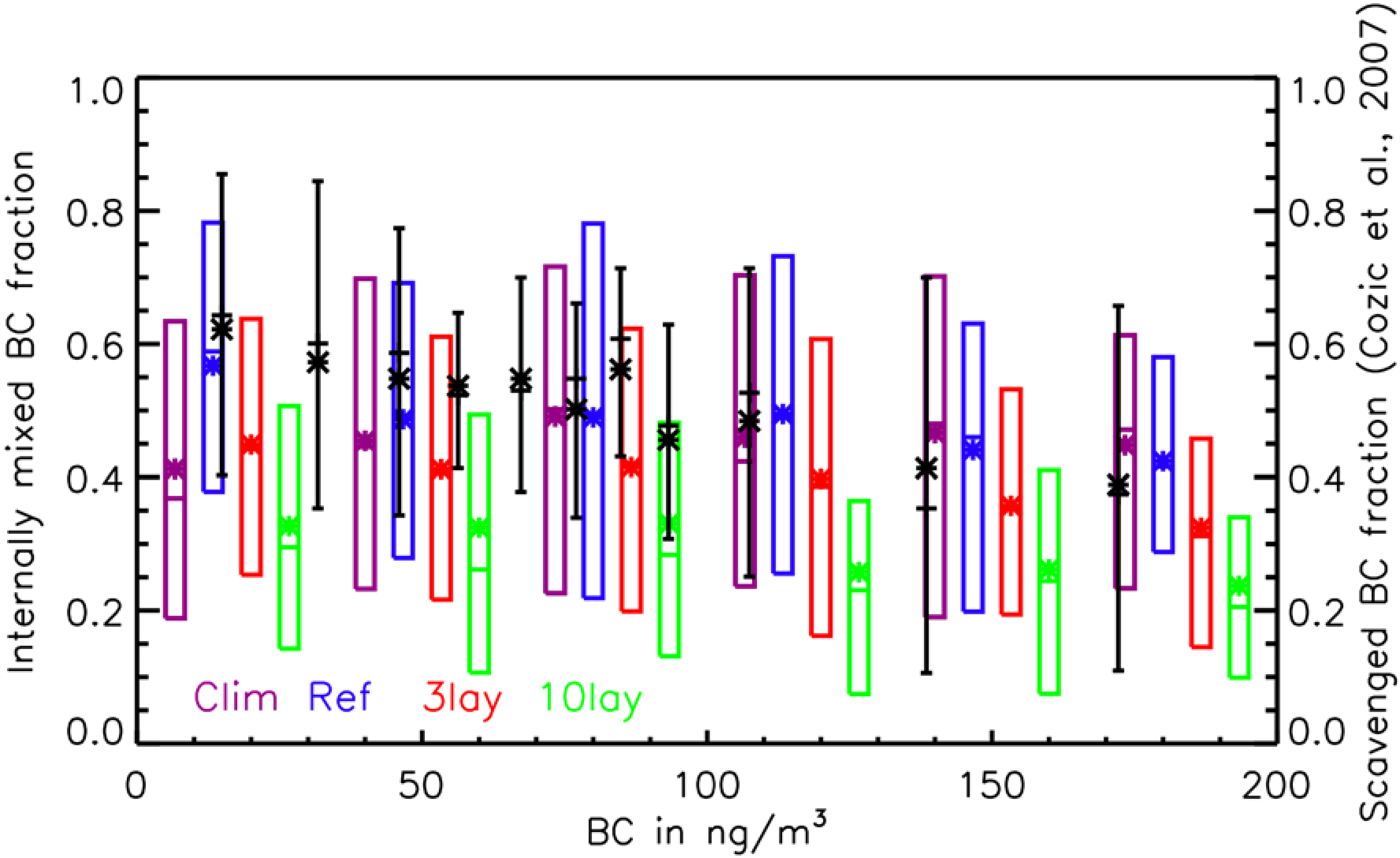
- coated material: only immersion freezing
- IN efficiencies depend on material and drop volume



Median freezing temperatures for different IN from lab experiments. Drop radii 250-350 µm. Adapted from *Diehl et al. (2006)* and *Hoffer (1961)*.



Costa Rica
Clim
conv
cvn
10lay
E5−2008
pressure [hPa]
100
1000
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
BC mass (ng/kg)
Costa Rica
0
20
40
60
80
100
Internally mixed BC (%)
Texas
BC mass (ng/kg)
Texas
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
Total aerosol mass (ng/kg)


Internally mixed BC fraction
Scavenged BC fraction (Cozic et al., 2007)
BC in ng/m3
Clim
Ref
3lay
10lay
0.0
0.2
0.4
0.6
0.8
1.0
0
50
100
150
200

Milestones

3D (DLR): in progress

- Parameterization for ice supersaturation based on homogeneous freezing and contrail cirrus implemented in ECHAM4
- Observations of ice supersaturation difficult to use for constraining model simulations since different observations vary widely (Burkhardt et al., 2008)
- Contrail cirrus just as natural cirrus coverage depends mainly on ice supersaturation and on the water vapor available for condensation (Burkhardt and Kärcher, 2009)

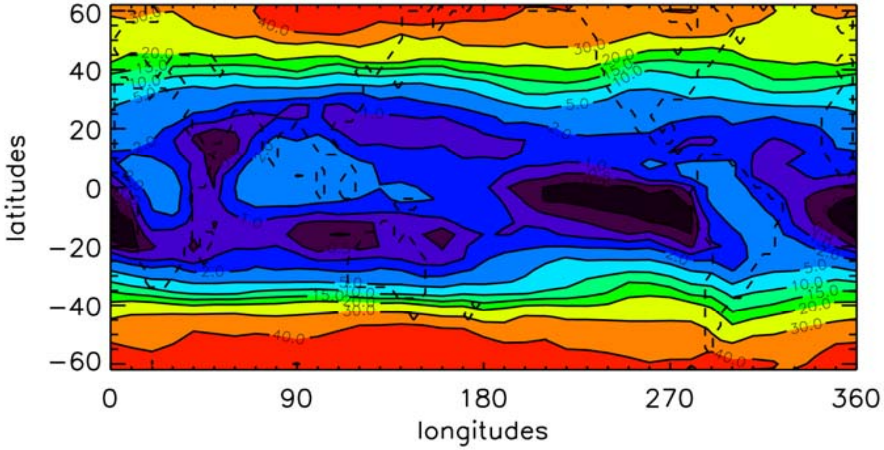
3D (DLR) future:

- Interactions between contrail cirrus and the humidity field and natural cirrus coverage
- The effect of the preprocessing of aircraft soot in short lived contrails

M3D

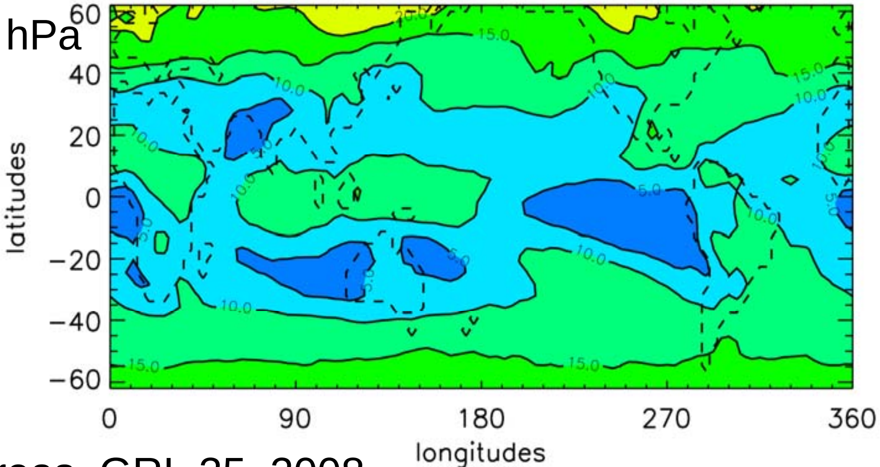
Validation of geographical patterns of ice supersaturation

AIRS supersaturation frequency (%)



ECHAM4 paramet. supersaturation

300 hPa



Burkhardt U. et al, 2008: Contrail cirrus supporting areas, GRL 35, 2008.

Absolute values of AIRS ice supersaturation estimates not reliable - therefore only patterns of ice supersaturation can be used for validation

Low latitude pattern of ice supersaturation frequency well represented by ECHAM4

M3D

frequency of tropospheric supersaturation

	Midlatitudes				Tropics			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
ECHAM4, 230 hPa	0.19	0.21	0.18	0.19	0.13	0.14	0.11	0.14
ECHAM4, 275 hPa	0.18	0.18	0.17	0.17	0.11	0.12	0.10	0.12
MOZAIC, 230 hPa	0.27	0.19	0.18	0.24	0.13	0.10	0.10	0.10
MOZAIC corrected	0.26	0.18	0.17	0.23	0.10	0.08	0.08	0.08
AIRS, 250–300 hPa	0.22	0.31	0.22	0.17	0.02	0.02	0.02	0.02

[a]Midlatitudes: 30N–60N/95W–35E and tropics: 30N–30S/80W–105E.

Burkhardt U. et al, 2008: Contrail cirrus supporting areas, GRL 35, 2008.

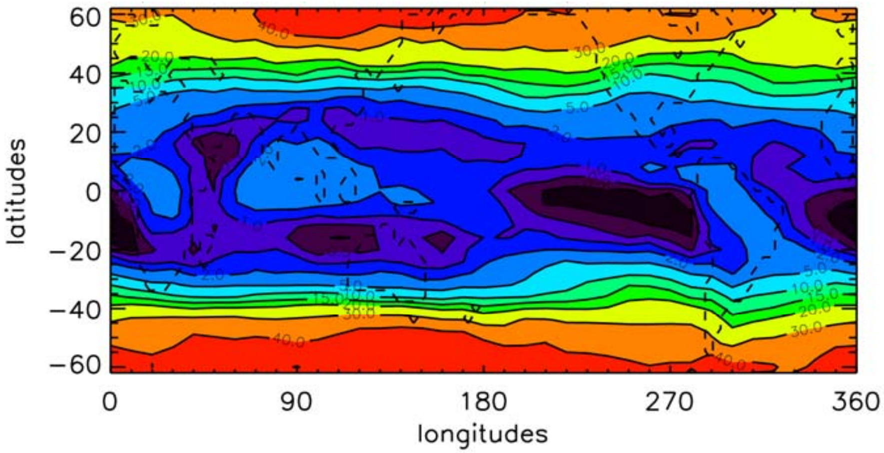
AIRS and MOZAIC estimates of frequency of ice supersaturation are fairly different

Difficult to constrain model estimates with observational data as long as different estimates differ so strongly

M3D

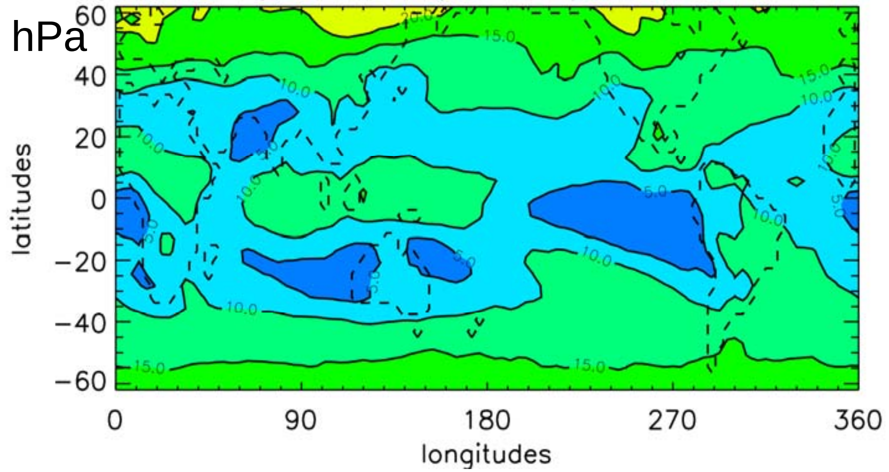
Validation of geographical patterns of ice supersaturation

AIRS supersaturation frequency (%)



ECHAM4 paramet. supersaturation

300 hPa



frequency of tropospheric supersaturation

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Measurements too uncertain for constraining ice supersaturation properly

Aerosol loading and aerosol IN properties needed in order to estimate the importance of heterogeneous freezing in UT

Burkhardt U. et al, 2008: Contrail cirrus supporting areas, GRL 35, 2008.

Milestones

3E (DLR): in progress:

- ECHAM4 with multimodal microphysical ice scheme applied to assess impact of heterogeneous IN on cirrus properties.
- Statistically significant reductions in modelled ice crystal number (Ni) caused by IN particularly in tropical upper troposphere.
- At midlatitudes, natural variability of Ni large compared to perturbation → statistically significant effect not yet quantified.
- But significant reduction in frequency of homogeneous nucleation shown.

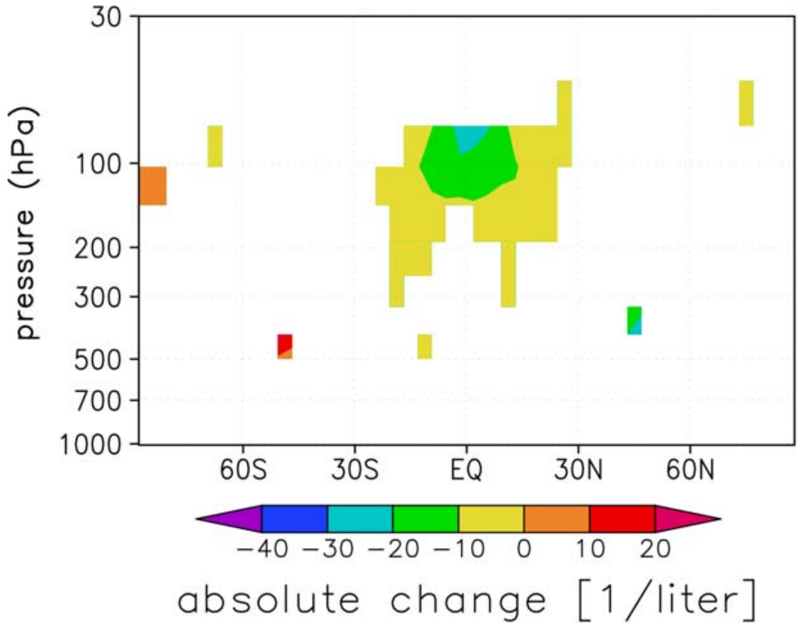
3E (DLR) future:

- Possible solution to quantify midlatitude effect: Method under development which is based on marking clouds susceptible for microphysical changes caused by IN.

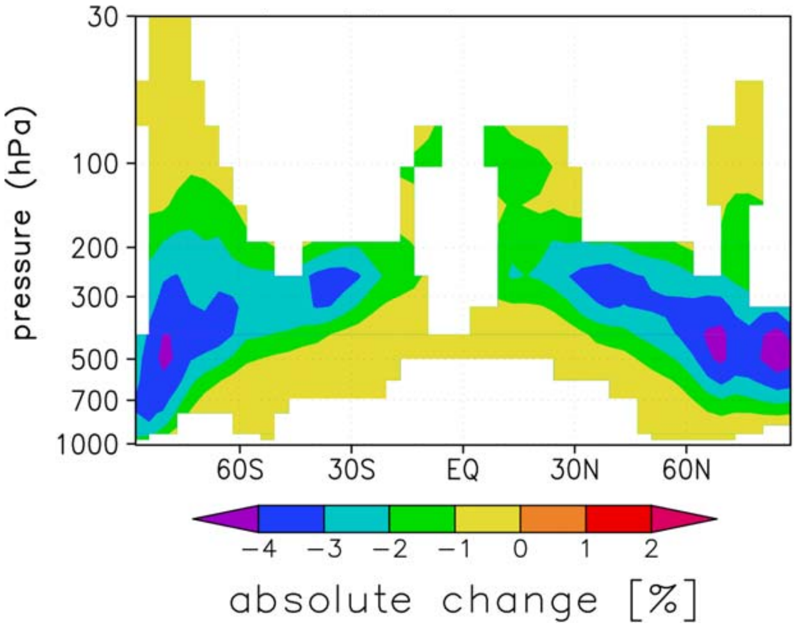
M3E

ECHAM4: Global impact of heterogeneous IN (BC+dust) on ice clouds

Δ N(ice), cloudy+clear sky mean



Δ frequency of ice from homogeneous freezing



Annual mean zonal averages (10 model years)

Significance level: 90% (t-test)

J. Hendricks et al.

Heterogeneous freezing significantly reduces N(ice) in tropical UT and frequency of ice formed by homogeneous nucleation at midlatitudes!

Δ N(ice) at midlatitues ?

WP M3(DLR) - future work

- Microphysical properties of natural cirrus depending on aerosol loading (indirect effect); aviation soot effect on natural cirrus.
- Interactions between contrail cirrus and humidity and natural cirrus
- Effect of preprocessed aerosols on cloud properties

Needed: ice nucleation properties of UT particles including preprocessed particles