

Microphysical sensitivities of wintertime precipitation

Axel Seifert

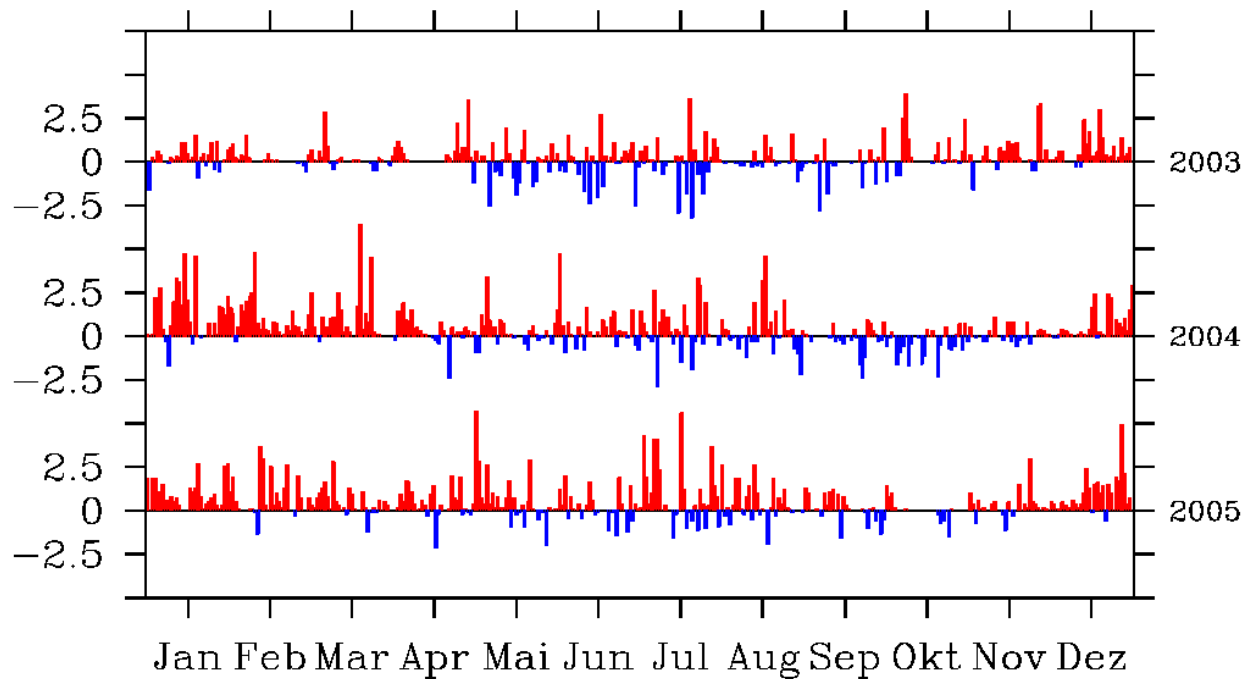
DWD, FE 13

Overview

- Verification of LM precipitation and cloud properties
- How can cloud microphysics help to remove the problems?
- Changes in microphysical parameterizations
- A sensitivity study: 7 March 2005
- Conclusions and outlook

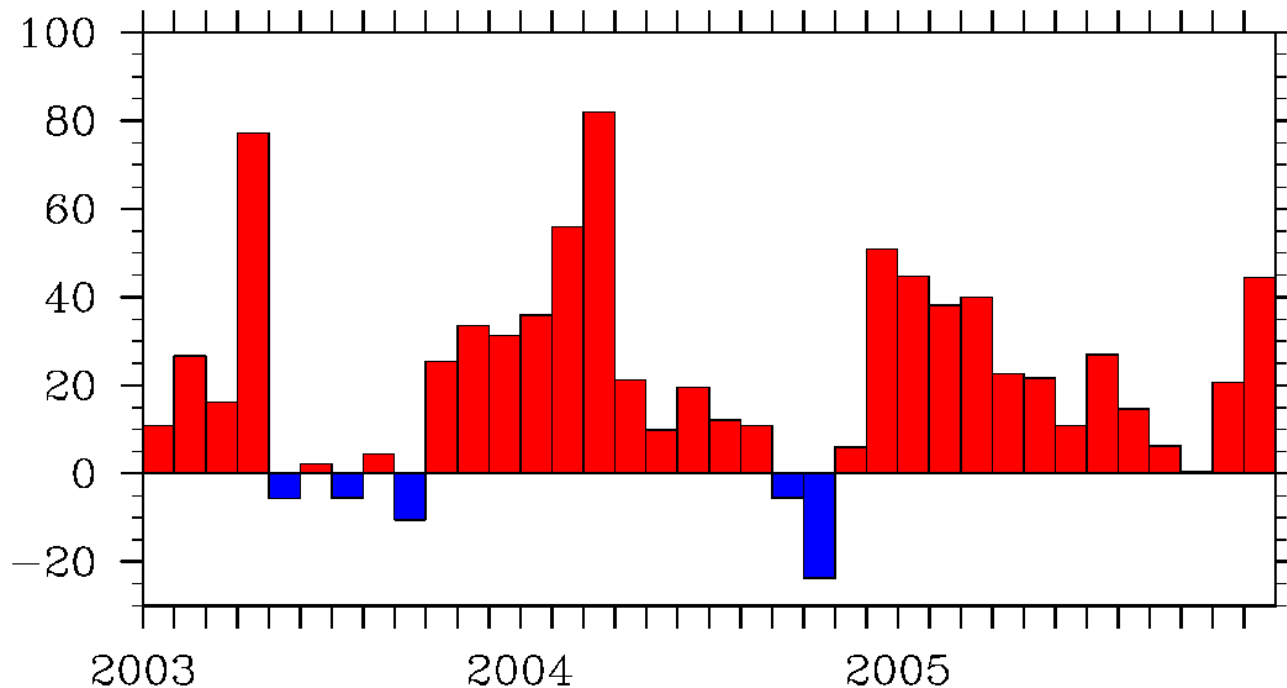
Long term verification of mean precipitation over Germany:

daily precipitation bias in mm



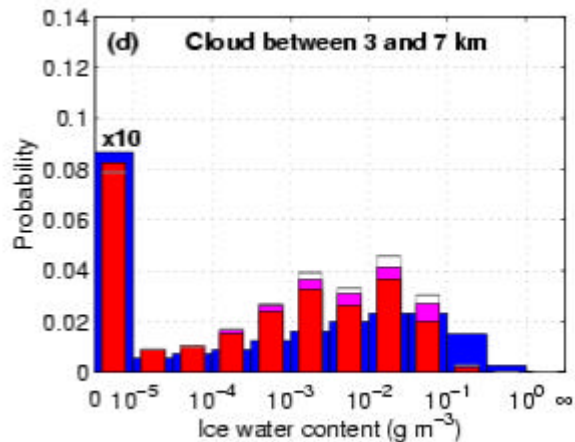
Long term verification of mean precipitation over Germany:

monthly precipitation bias in %

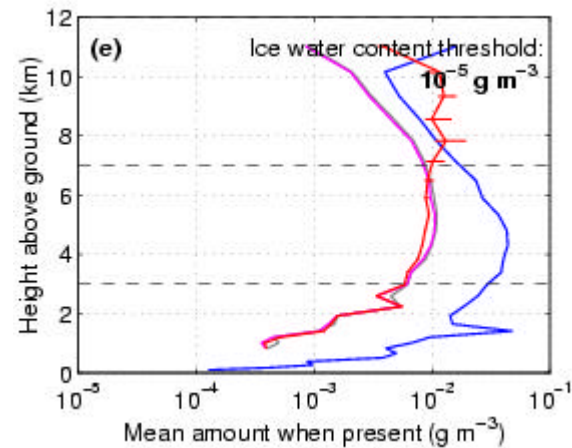


CLOUDNET verification of ice water content at Chilbolton:

PDF of ice content



Vertical profile of IWC



IWC underestimated, $\text{IWC} > 0.1 \text{ g/m}^3$ observed but hardly simulated

Problems:

- Conditional sampling, since the cloud radar cannot measure in rain
- For LM snow was not included, but only cloud ice

Is there a problem with LM ice microphysics? Facts and excuses

- Systematic overestimation of surface precip compared to measurements. But during winter the measurements might have a positive bias. During summer the model bias might be due to problems in the convection scheme.
- CLOUDNET verification shows a underestimation of IWC at Chilbolton, Palaiseau and Cabauw. But no snow was included in model output and, in addition, Lindenberg data does not show a strong underestimation of IWC.

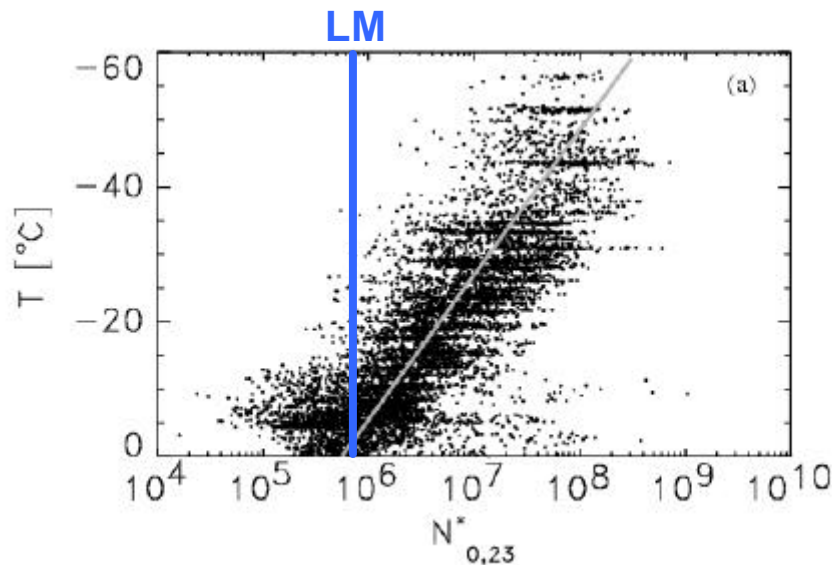
How can cloud microphysics remove the bias?

- Smaller ice particles/snowflakes would fall out slower, and maybe sublimate/evaporate in subsaturated regions, resulting in higher IWC aloft and reduced precipitation at the ground.

Observational evidence that snowflakes are smaller than assumed in LM:

Aircraft measurements of snow size distribution (Field et. al 2005)

Intercept parameter of size distribution



At lower temperature snowflakes are smaller, resulting in $N_{0,s} = N_{0,s}(T)$.

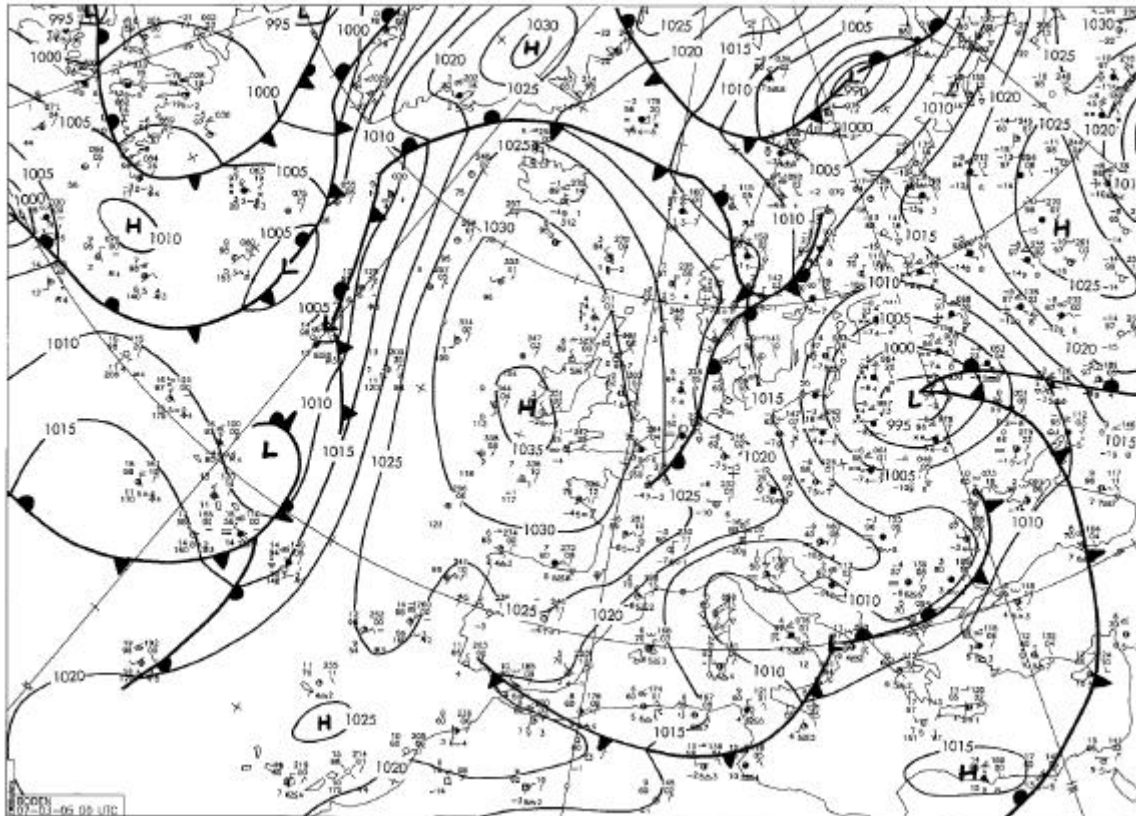
The value of $N_{0,s}$ assumed in LM is typical for ~ 0 °C

Changes to LM microphysics for this sensitivity study:

- Following Field et al. (2005), $N_{0,s}$ is parameterized as a function of temperature T and the snow mixing ratio q_s using a scaling approach.
- A threshold value for ice autoconversion (production of snow) of $qi0 = 0.1 \text{ g/kg}$ is applied.
- Mass-size-relation for snow is changed from $m = 0.038 D^2$ to $m = 0.069 D^2$ and fall speed is reduced using $v = 12 D^{1/2}$.
- Collision efficiency of snow collecting cloud ice is reduced from $e_{is} = 0.5$ to $e_{is} = 0.1$
- Depositional growth of ice and snow now includes the pressure and temperature dependency in H_i and D_v
- SB2001 autoconversion scheme is used with a constant cloud droplet concentration $N_c = 500 \text{ cm}^{-3}$

A sensitivity study: 7 March 2005

Surface analysis 07.03.2005 00 UTC

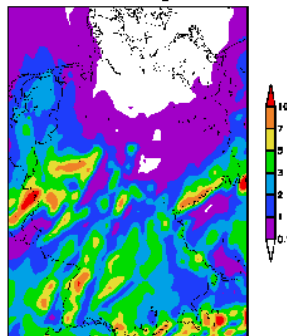


Sensitivity of accumulated surface precipitation 00 UTC + 24 h:

CONTROL

a) TOT PREC

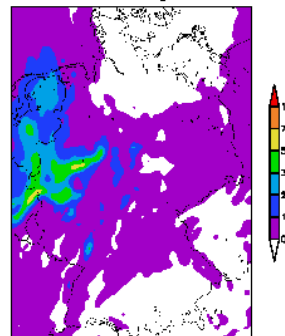
max=20.3901, avg=1.88903



totprec / acc. precipitation in mm

b) RAIN PREC

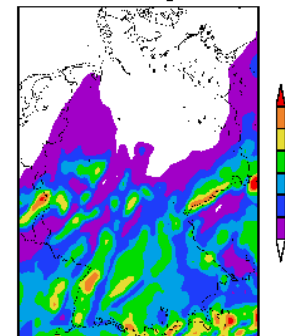
max=6.03467, avg=0.447513



rainprec / acc. precipitation in mm

b) SNOW PREC

max=19.374, avg=1.40985



snowprec / acc. precipitation in mm

EXPERIMENT

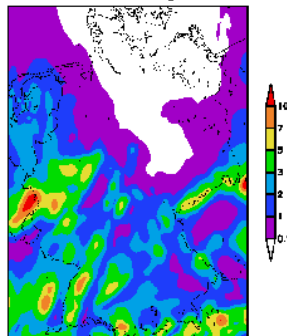
Mean precip reduced
by ~15 %

Maximum precip reduced
from 20 mm to 13 mm

Some drizzle removed

a) TOT PREC

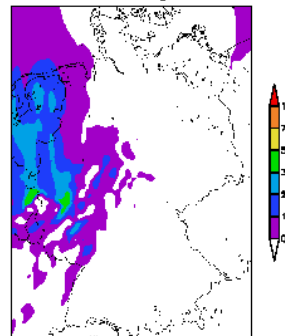
max=13.0708, avg=1.6097



totprec / acc. precipitation in mm

b) RAIN PREC

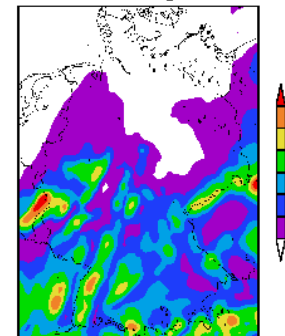
max=4.76489, avg=0.262194



rainprec / acc. precipitation in mm

b) SNOW PREC

max=12.916, avg=1.32882



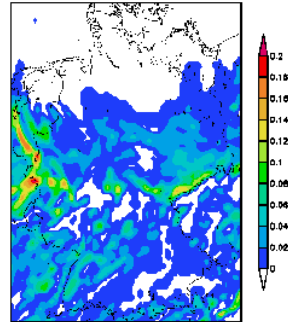
snowprec / acc. precipitation in mm

Sensitivity of column integrated water content (00 UTC + 24 h):

CONTROL

a) TQC

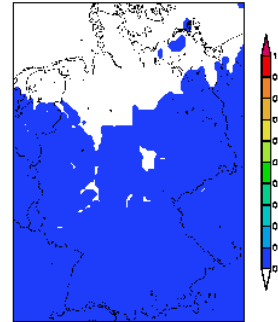
max=0.207821, avg=0.0154772



TQC / total water content [kg/m²]

b) TQI

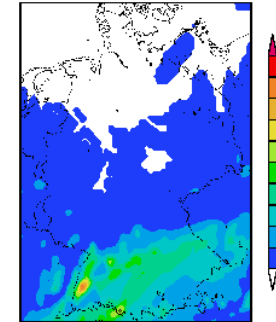
max=0.0288849, avg=0.00371234



TQI / total water content [kg/m²]

b) TQS

max=0.843521, avg=0.0629739



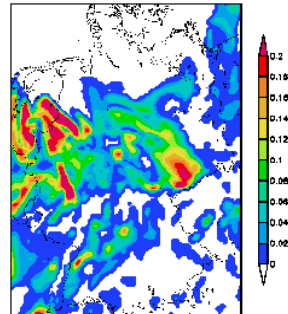
TQS / total water content [kg/m²]

EXPERIMENT

Ice and liquid water content is considerably increased. Most dramatic for cloud ice.

a) TQC

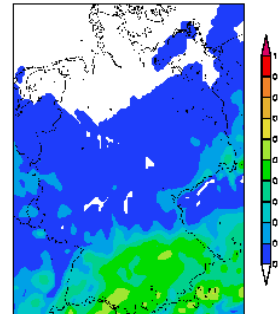
max=0.342896, avg=0.0250477



TQC / total water content [kg/m²]

b) TQI

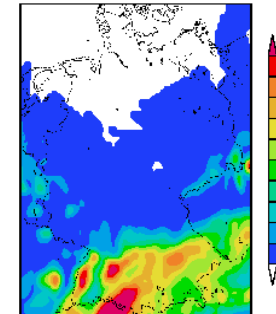
max=0.603058, avg=0.10426



TQI / total water content [kg/m²]

b) TQS

max=1.53369, avg=0.146646



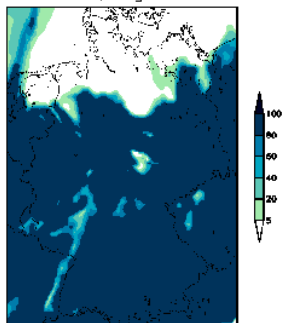
TQS / total water content [kg/m²]

Sensitivity of column integrated water content (00 UTC + 24 h):

CONTROL

a) CLCL

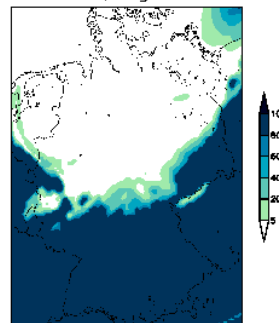
max=100, avg=72.1828



clcl - cloud cover in %

b) CLCM

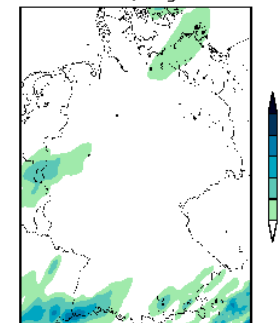
max=100, avg=48.2106



clcm - cloud cover in %

b) CLCH

max=83.0547, avg=3.48279



clch - cloud cover in %

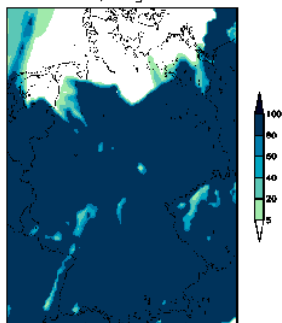
EXPERIMENT

Only high level cloud cover is increased in this case.

Low and mid level clouds are optically thick in both runs.

a) CLCL

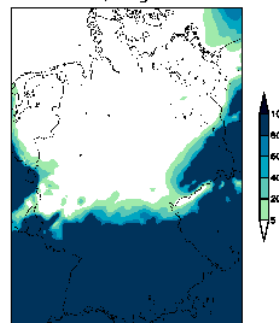
max=100, avg=76.6764



clcl - cloud cover in %

b) CLCM

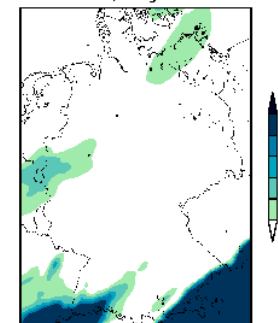
max=100, avg=43.3778



clcm - cloud cover in %

b) CLCH

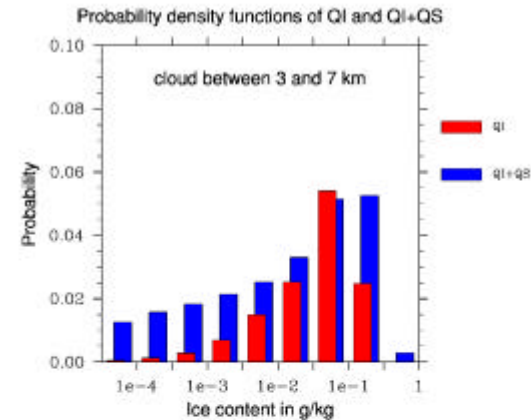
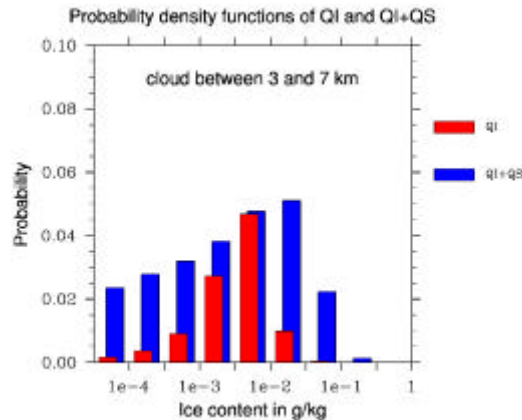
max=100, avg=10.6968



clch - cloud cover in %

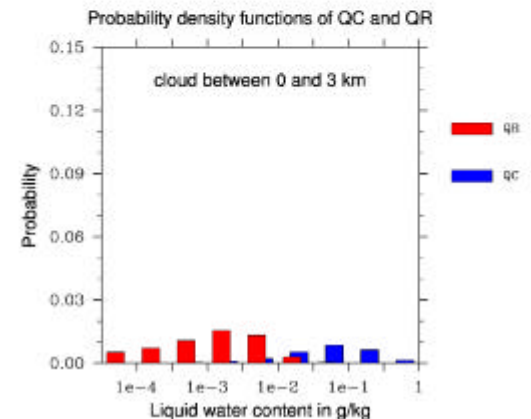
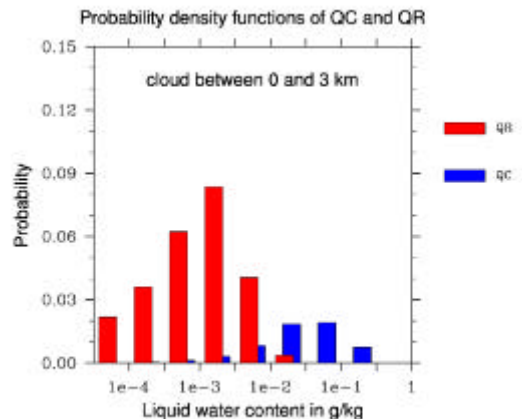
PDFs of control run and modified microphysics experiment

CONTROL



EXPERIMENT

PDF of ice content is shifted to higher mixing ratios



Less rain/drizzle, cloud water shifted to higher mixing ratios

Conclusions and outlook

- LM seems to have a positive bias in wintertime precipitation
- Changing the grid-scale microphysics could remove some of the problems, but would increase the IWC by a factor of 10.
- The long-term effects of optically thicker clouds on radiation and surface temperature have to be investigated.
An LM-Q experiment for Dec 2005 is planned.
- A reliable verification of CWC and IWC would be necessary, but seems to be almost impossible.
- Results need prognostic precipitation
(and cannot be easily transferred to GME)
- The modified microphysics could be applied in an ensemble system

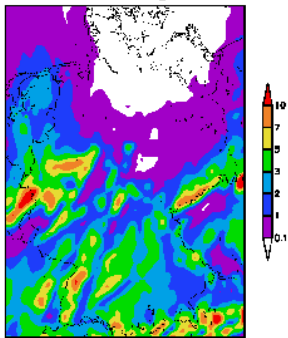
The End

Sensitivity to ice autoconversion threshold:

CONTROL

a) TOT PREC

max=20.3901, avg=1.88903

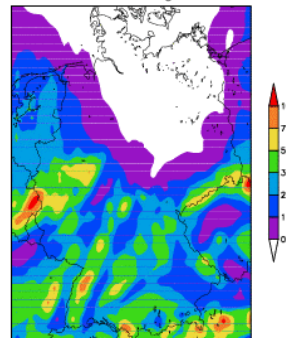


totprec / acc. precipitation in mm

$qi0 = 0.00$ g/kg

a) TOT_PREC

max=12.1348, avg=1.80966

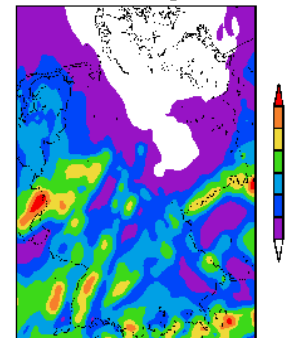


totprec / acc. precipitation in mm

$qi0 = 0.05$ g/kg

a) TOT PREC

max=13.4741, avg=1.70986

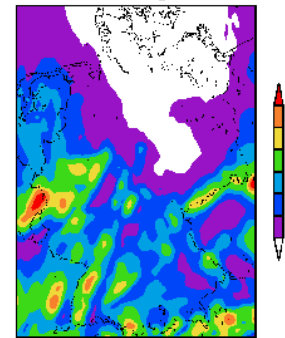


totprec / acc. precipitation in mm

$qi0 = 0.10$ g/kg

a) TOT PREC

max=13.04, avg=1.61044



totprec / acc. precipitation in mm

