

# GCSS - Microphysics

Ulrike Lohmann

ETH Zurich  
Institute for Atmospheric  
and Climate Science

Frascati,  
12.10.2006

Acknowledgements:  
Corinna Hoose



## Microphysics - what has been done so far?

- ▶ Explicit cloud microphysics in parcel models, LES and CRMs (sometimes with aerosols)

## Microphysics - what has been done so far?

- ▶ Explicit cloud microphysics in parcel models, LES and CRMs (sometimes with aerosols)
- ▶ In regional models: mainly bulk microphysics - single or double moment schemes (sometimes with aerosols)

## Microphysics - what has been done so far?

- ▶ Explicit cloud microphysics in parcel models, LES and CRMs (sometimes with aerosols)
- ▶ In regional models: mainly bulk microphysics - single or double moment schemes (sometimes with aerosols)
- ▶ In NWP models: bulk microphysics (mainly single moment), no aerosols

## Microphysics - what has been done so far?

- ▶ Explicit cloud microphysics in parcel models, LES and CRMs (sometimes with aerosols)
- ▶ In regional models: mainly bulk microphysics - single or double moment schemes (sometimes with aerosols)
- ▶ In NWP models: bulk microphysics (mainly single moment), no aerosols
- ▶ In climate models: mainly bulk microphysics (mainly single moment) together with bulk treatment of aerosols

## Microphysics - within GCSS

- ▶ PBL: Emphasis is on dynamics (e.g., turbulence schemes, cloud top entrainment) rather than on microphysics. However some GCSS cases (Dycoms, Rico) are used to test different microphysics scheme

## Microphysics - within GCSS

- ▶ PBL: Emphasis is on dynamics (e.g., turbulence schemes, cloud top entrainment) rather than on microphysics. However some GCSS cases (Dycoms, Rico) are used to test different microphysics scheme
- ▶ Polar: Different cloud variables are going to be compared in MPACE. Freezing parameterizations are evaluated starting from prescribed aerosol number and size distributions

## Microphysics - within GCSS

- ▶ PBL: Emphasis is on dynamics (e.g., turbulence schemes, cloud top entrainment) rather than on microphysics. However some GCSS cases (Dycoms, Rico) are used to test different microphysics scheme
- ▶ Polar: Different cloud variables are going to be compared in MPACE. Freezing parameterizations are evaluated starting from prescribed aerosol number and size distributions
- ▶ Extratropical clouds: Role of evaporation of precipitation

## Microphysics - within GCSS

- ▶ PBL: Emphasis is on dynamics (e.g., turbulence schemes, cloud top entrainment) rather than on microphysics. However some GCSS cases (Dycoms, Rico) are used to test different microphysics scheme
- ▶ Polar: Different cloud variables are going to be compared in MPACE. Freezing parameterizations are evaluated starting from prescribed aerosol number and size distributions
- ▶ Extratropical clouds: Role of evaporation of precipitation
- ▶ Cirrus: Competition homogeneous vs. heterogeneous freezing starting from prescribed aerosol concentrations starting in parcel models

# What is missing?

- ▶ PBL: Bulk microphysics schemes maybe evaluated but not individual processes

## What is missing?

- ▶ PBL: Bulk microphysics schemes maybe evaluated but not individual processes
- ▶ PBL: Joint influence of aerosols and dynamics

## What is missing?

- ▶ PBL: Bulk microphysics schemes maybe evaluated but not individual processes
- ▶ PBL: Joint influence of aerosols and dynamics
- ▶ Polar: Bergeron-Findeisen process

## What is missing?

- ▶ PBL: Bulk microphysics schemes maybe evaluated but not individual processes
- ▶ PBL: Joint influence of aerosols and dynamics
- ▶ Polar: Bergeron-Findeisen process
- ▶ Cirrus: Feedback of freezing on available aerosols and consequences for the next cloud cycles

## What is missing - in general?

- ▶ 2-way aerosol-cloud interactions: Evaporated cloud droplets leave behind larger aerosol particles → easier activation the next time

## What is missing - in general?

- ▶ 2-way aerosol-cloud interactions: Evaporated cloud droplets leave behind larger aerosol particles → easier activation the next time
- ▶ Both dynamics and aerosols control PBL clouds

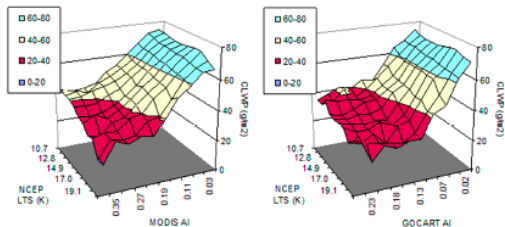
## What is missing - in general?

- ▶ 2-way aerosol-cloud interactions: Evaporated cloud droplets leave behind larger aerosol particles → easier activation the next time
- ▶ Both dynamics and aerosols control PBL clouds
- ▶ Pre-activation of ice nuclei allows a freezing onset at higher temperatures in the next ice nucleation event

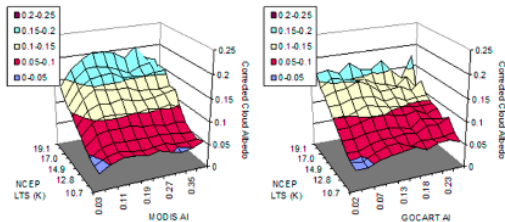
## What is missing - in general?

- ▶ 2-way aerosol-cloud interactions: Evaporated cloud droplets leave behind larger aerosol particles → easier activation the next time
- ▶ Both dynamics and aerosols control PBL clouds
- ▶ Pre-activation of ice nuclei allows a freezing onset at higher temperatures in the next ice nucleation event
- ▶ Evaluation of relevant processes, e.g.: ice multiplication, Bergeron-Findeisen process, relative humidity in mixed-phase clouds

# Static stability vs. aerosols [Matsui et al., JGR, 2006]

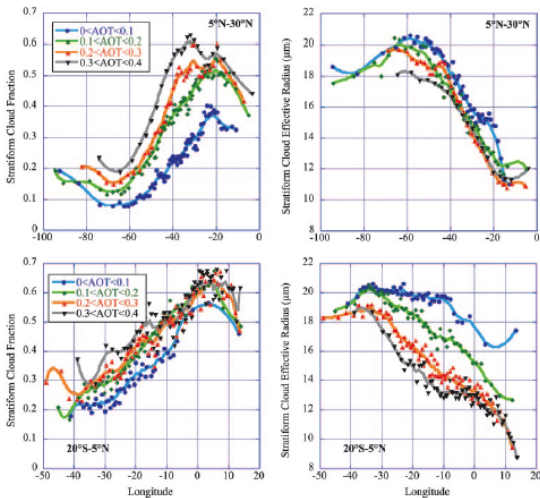


b. Cloud liquid water path



c. Corrected cloud albedo (cloud amount)

# Dynamics vs. aerosols



**Figure:** Kaufman et al., PNAS [2005]

# Dynamics vs. aerosols

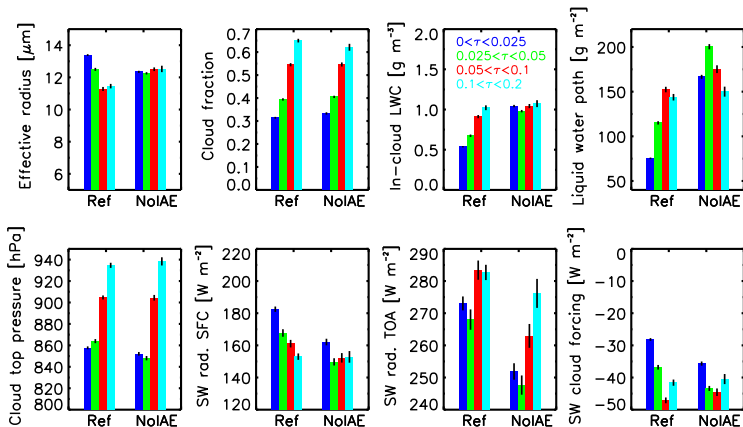
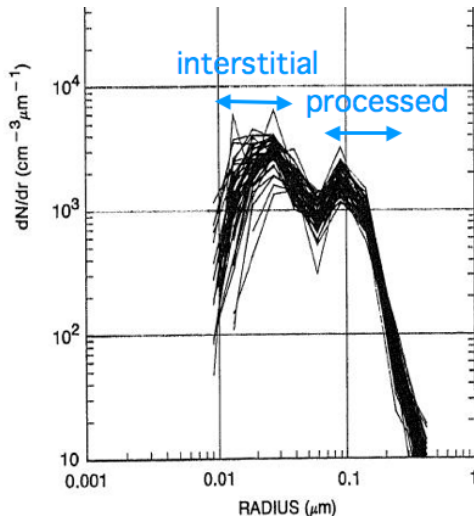


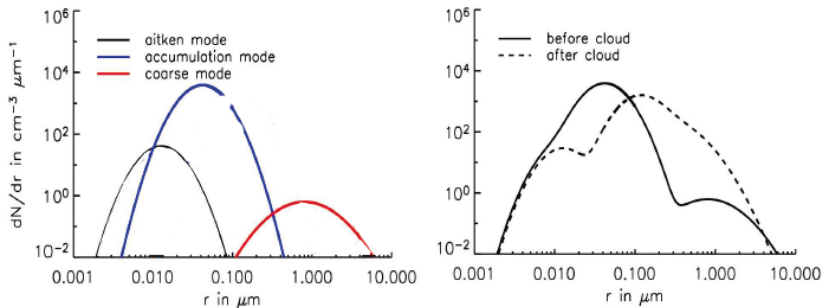
Figure: Lohmann et al., GRL [2006]

# Aerosol processing



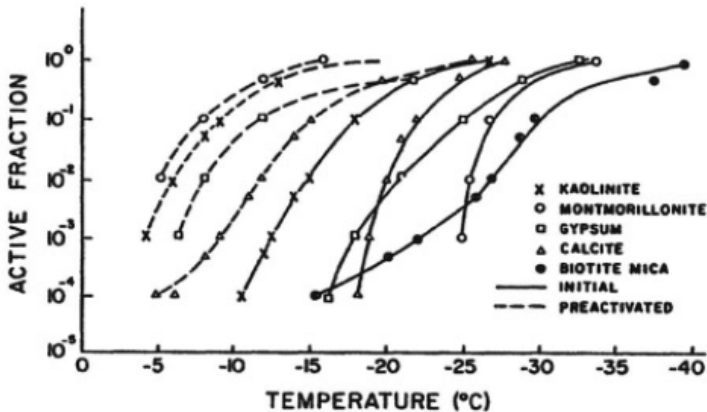
**Figure:** Hoppel minimum [Hoppel, 1990]

# Simulated marine aerosol size distribution



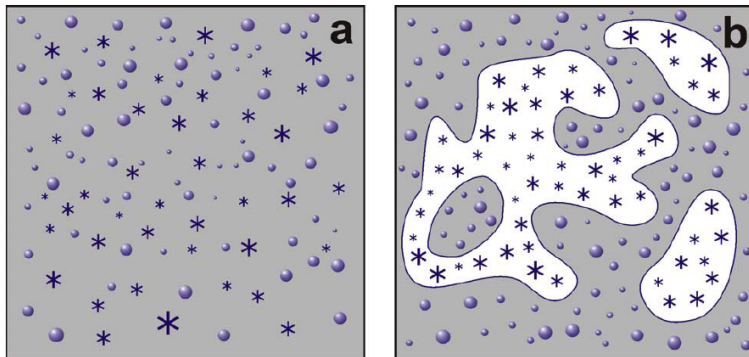
**Figure:** Courtesy: Corinna Hoose

# Freezing onset temperature with/without pre-activation



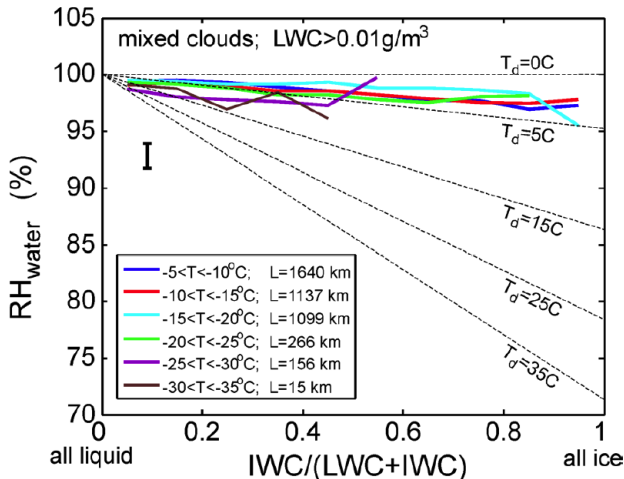
**Figure:** Pruppacher and Klett [1997]

# How well mixed are mixed-phase clouds?



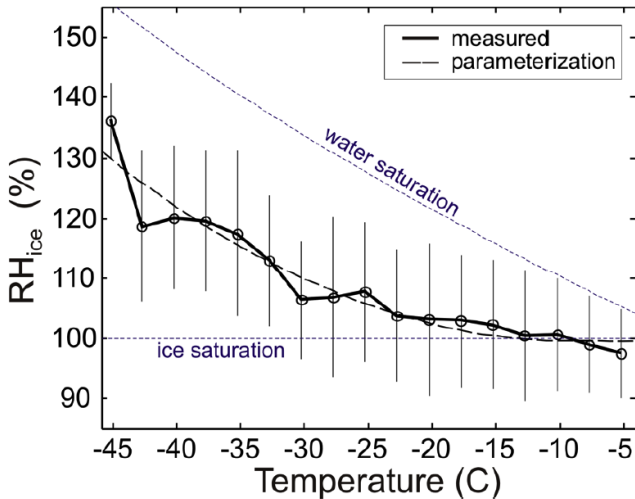
**Figure:** Korolev and Isaac, JAS, 2006, in press

## Relative humidity in mixed-phase clouds



**Figure:**  $RH = (1-f)RH_w + f RH_i$  with  $f = \frac{IWC}{TWC}$  does not seem justified [Korolev and Isaac, JAS, 2006]

## Relative humidity in ice clouds



**Figure:** Korolev and Isaac, JAS, 2006, in press

## Summary

- ▶ Aerosols as well as dynamics need to be considered when studying PBL clouds

## Summary

- ▶ Aerosols as well as dynamics need to be considered when studying PBL clouds
- ▶ Aerosols serve as an input for cloud microphysics, but their time evolution cannot be ignored for subsequent cloud cycles

## Summary

- ▶ Aerosols as well as dynamics need to be considered when studying PBL clouds
- ▶ Aerosols serve as an input for cloud microphysics, but their time evolution cannot be ignored for subsequent cloud cycles
- ▶ RH in mixed-phase and ice clouds is not well understood

## Summary

- ▶ Aerosols as well as dynamics need to be considered when studying PBL clouds
- ▶ Aerosols serve as an input for cloud microphysics, but their time evolution cannot be ignored for subsequent cloud cycles
- ▶ RH in mixed-phase and ice clouds is not well understood
- ▶ Aerosol activation in mixed-phase and ice clouds is still an open issue