Laboratory studies of the ice nucleating ability of pollen and model simulations of the effects of biological aerosol particles on cloud microphysics

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Primary biological aerosol particles

- **ubiquitous component**
- **contribution to total atmospheric aerosol:**

urban/rural air:	**25% on average**
remote marine air:	**10 to 20%**

(*Matthias-Maser and Jaenicke, 1995; Gruber et al., 1998*)

but other references: 1 to 10%

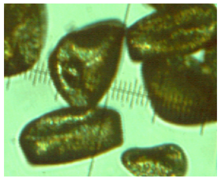
Ice nucleating efficiency of biological aerosol particles

(freezing activating temperatures from literature)

*	**bacteria**	**-2°C**
*	**lichen**	**-2°C**
*	**fungi**	**-3°C**
*	**marine plankton**	**-4°C**
*	**leaf litter**	**-4°C**
*	**pollen**	**-5°C to -15°C**

higher freezing temperatures than other ice nuclei like mineral dust or soot

Ice nucleating efficiency of pollen

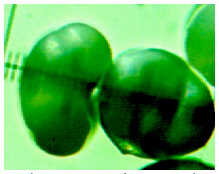

quercus rubra

pollen in the atmosphere

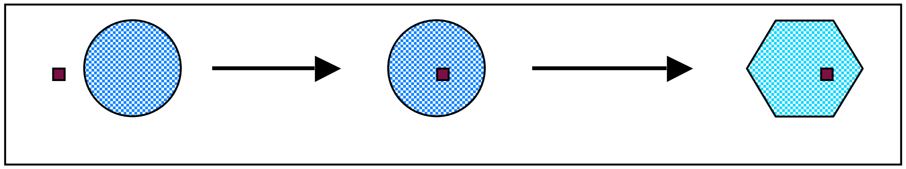
- radii from 5 to 50 µm
- lifted in high altitudes, long residence times (low sink velocities)
- concentrations temporarily comparable to those of ice nuclei

(*Gregory, 1978; Linskens and Jorge, 1986*)

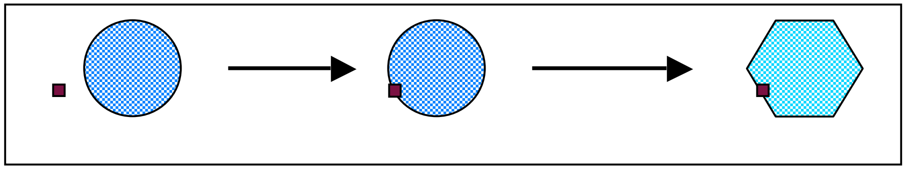
laboratory experimental techniques: Mainz vertical wind tunnel

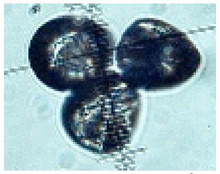

pinus sylvestris

- ➢ single drops freely floated at their terminal velocity
- ➢ super-cooled drops at temperatures down to -30°C
- ➢ immersion freezing



- ➢ contact freezing

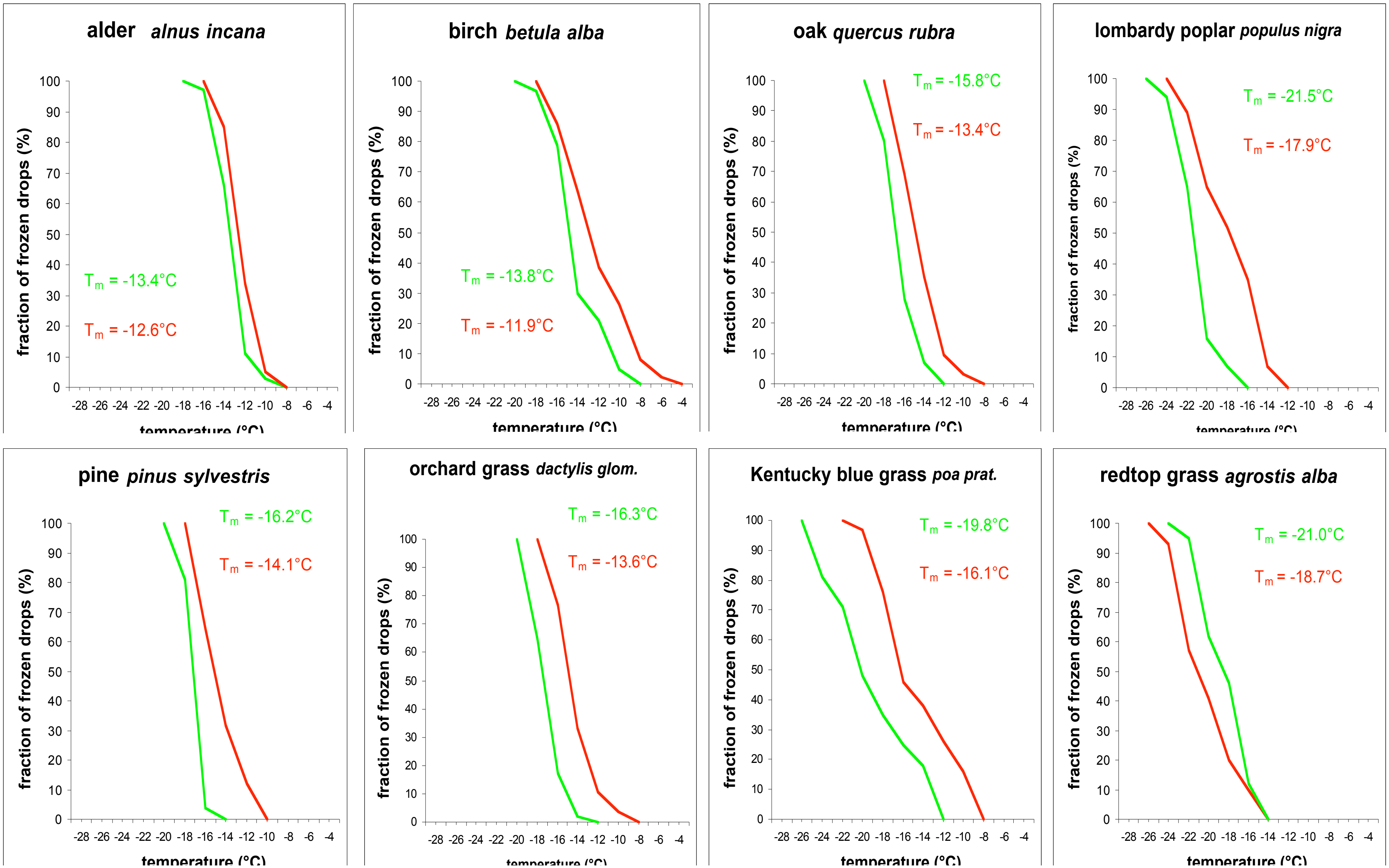



poa pratensis

pollen types: deciduous trees (*alder, birch, oak, Lombardy poplar*)
conifer (*pine*)
grass (*orchard, Kentucky blue, redtop*)

Results: Ice nucleating efficiency of pollen

contact freezing versus immersion freezing



Results: Ice nucleating efficiency of pollen

* not restricted to single pollen types
* contact freezing more efficiently than immersion freezing
* freezing activating temperatures: -5 to -15°C
* median freezing temperatures: -12 to -21°C

order of freezing efficiency:	releasing times:
alder	February to March
birch	April
oak	April to May
pine	May to June
orchard grass	June to July
Kentucky blue grass	May to July
Lombardy poplar	March to April
redtop grass	June to August

possible explanation for freezing ability of pollen:
biological freezing tolerance to protect the interior of the cells

(Diehl et al., 2002, Atm. Res., 61; v. Blohn et al., 2005, Atm. Res., 78)

Cloud model simulations: Convective mixed-phase cloud

- **adiabatic air parcel model with entrainment**
- **variable soluble and insoluble fractions of the particles**
- **sectional 2-dimensional description of the cloud microphysics**
- **warm microphysics**

* **cold microphysics**
  - **drop freezing in immersion and contact modes**
  - **growth of ice particles by deposition of water vapor**
  - **collision between super-cooled drops and ice particles**

(Simmel and Wurzler, 2006, Atm. Res., 80; Diehl et al., 2006, JGR, 111)

Immersion freezing

Contact freezing

freezing equations:

considering different ice nucleating efficiencies ***(Diehl et al., 2006, JGR, 111)***

$$-\frac{dN_f}{dt} = N_u\, a\, B_{h,i}\, V_d \exp(-aT)\frac{dT}{dt}$$

$$N_f = -N_0\left(a_{h,c}T + b_{h,c}\right)$$

constants $B_{h,i}$, $a_{h,c}$, $b_{h,c}$ derived from laboratory experiments:

(Hoffer, 1961; Pitter and Pruppacher, 1973; Levin and Yankofski, 1983; Diehl and Mitra, 1998; Gorbunov et al., 2001; Diehl et al., 2001, 2002)

biological particles (bacteria, leaf litter, pollen)

mineral particles (montmorillonite, kaolinite)

soot particles (large and small)

freezing point depression
Koop et al. (2000)

collision kernel
Kerkweg et al. (2003)

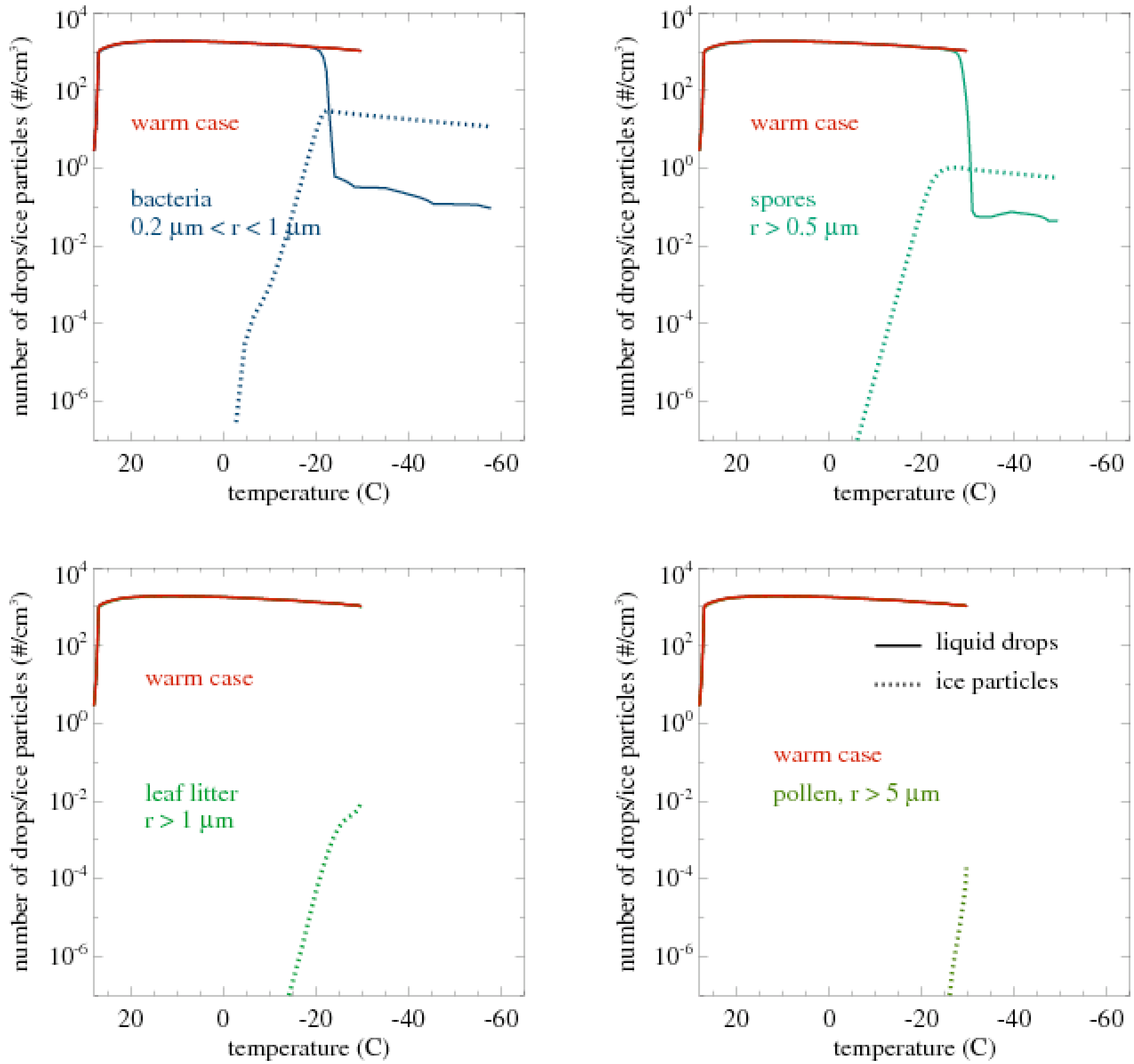
Present initialization and scenarios for sensitivity studies

- convective temperature and dew point profiles
- aerosol particle size distribution with a soluble fraction _ = 0.5
- temperature difference parcel – environment: 1 K
- defined fractions of the aerosol particles allowed as ice nuclei
- limited sizes of the ice nuclei

Scenarios:

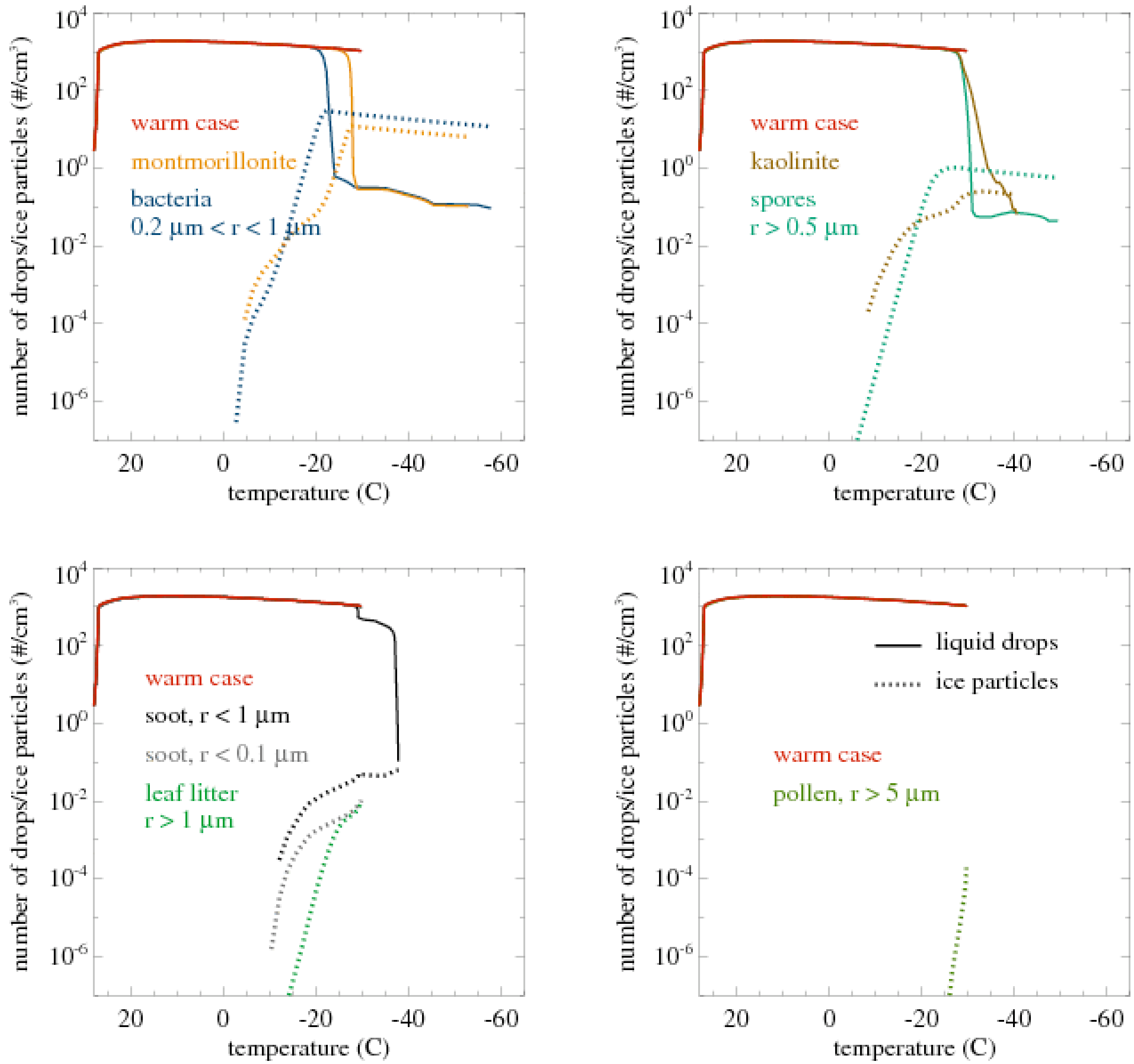
1	bacteria	1%	$0.2\ \mu m \leq r \leq 1\ \mu m$
2	spores	1%	$r \geq 0.5\ \mu m$
3	leaf litter	1%	$r \geq 1\ \mu m$
4	pollen	1%	$r \geq 5\ \mu m$
5	montmorillonite	20%	all sizes
6	kaolinite	20%	all sizes
7	soot	10%	$r \leq 0.1\ \mu m$
8	soot	10%	$r \leq 1\ \mu m$

Results: Effect of ice formation on drop and ice particle numbers



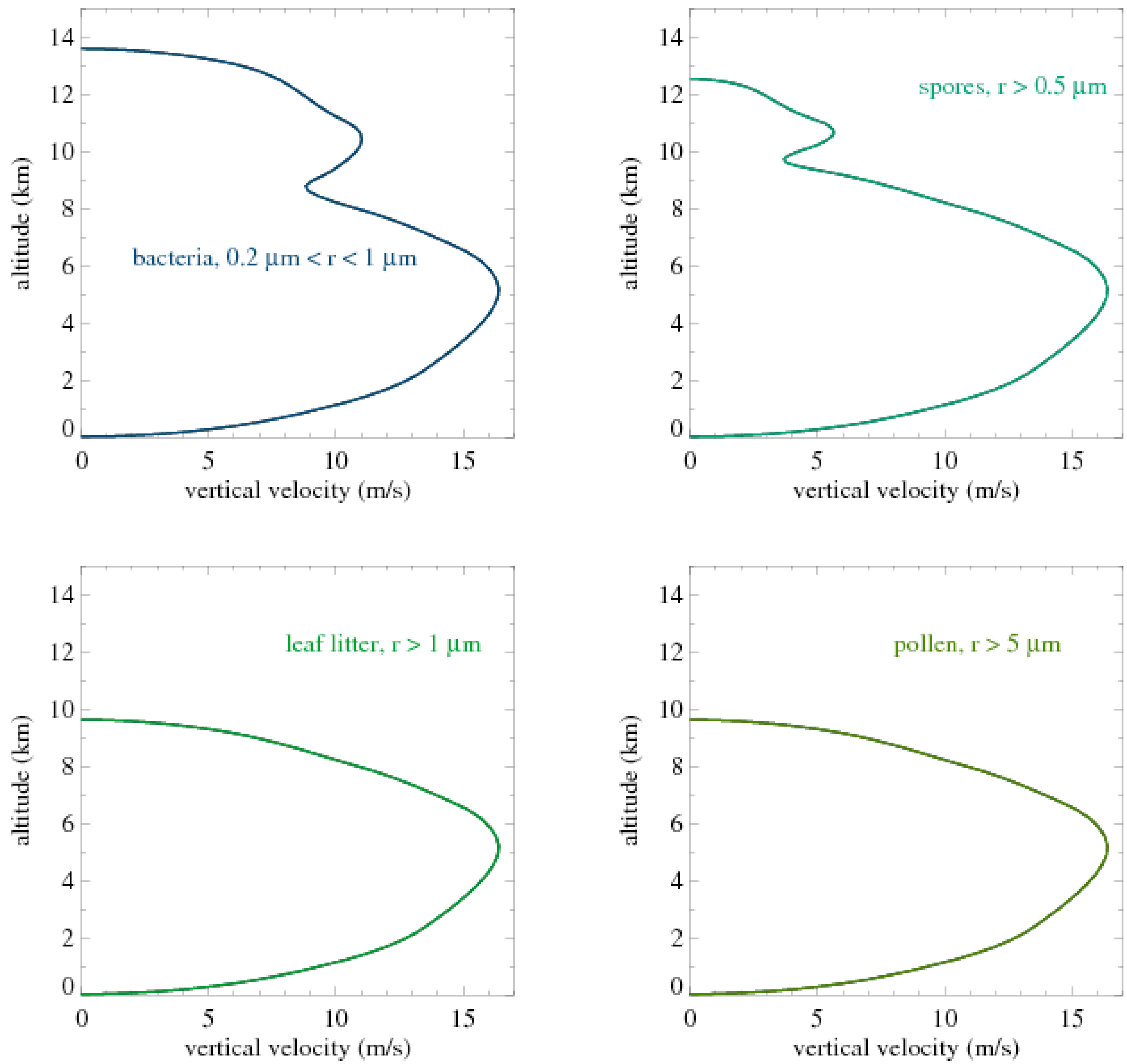
liquid and frozen drop numbers in cm^{-3} as functions of temperature

Results: Effect of ice formation on drop and ice particle numbers



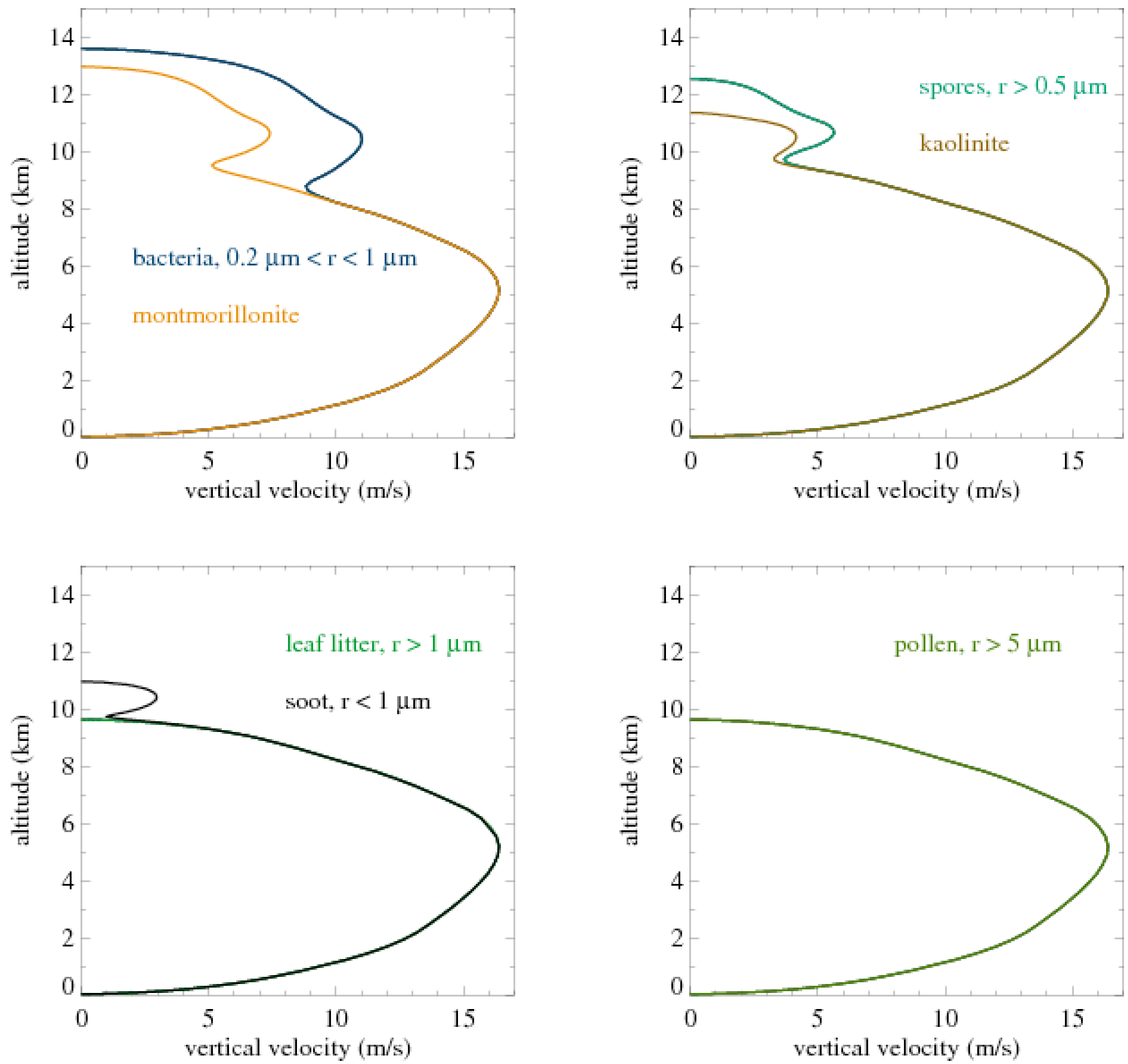
liquid and frozen drop numbers in cm^{-3} as functions of temperature

Results: Effect of ice formation on vertical cloud dynamics



altitude in km as functions of vertical velocity

Results: Effect of ice formation on vertical cloud dynamics



altitude in km as function of vertical velocity

Conclusions

Laboratory experiments:

* **ice nucleating efficiencies of pollen at relatively warm temperatures**
* **reasons for ice nucleating ability of biological particles might have a biological background (ensure the survival)**

Model simulations:

* **fractions of biological particles were much lower than dust or soot particles**

  <u>but:</u> effects on ice particle numbers, ice water content, and the vertical clouds dynamics were in the same order of magnitude

* **importance of biological particles for cloud microphysics**

  _ should not be neglected against mineral and soot particles

Future:

* **airborne measurements of biological aerosol particles to estimate their effects; e.g., pollen may temporarily be present in the atmosphere in huge amounts**
* **model simulations with measured biological particle distributions**