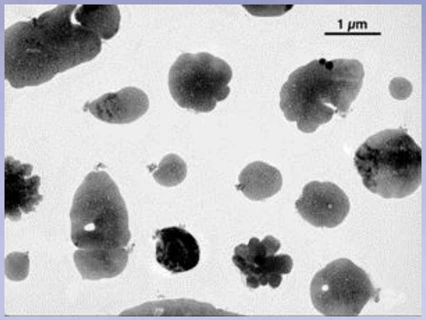
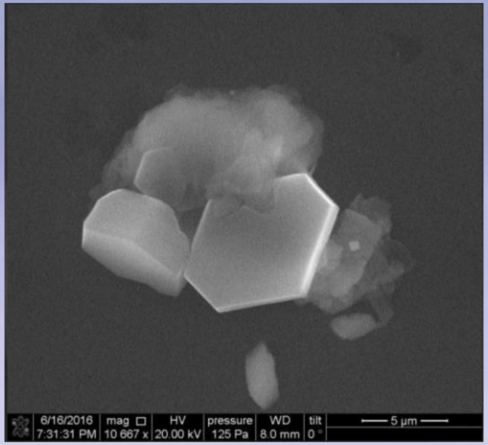
Bin microphysical schemes: new possibility to study the cloud physics

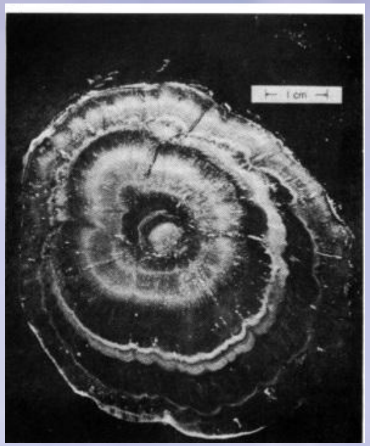
István Geresdi
University of Pécs, Faculty of Sciences

Characteristics of the cloud microphysics:

The size range of particles is: 10^{-5} mm – 10 mm



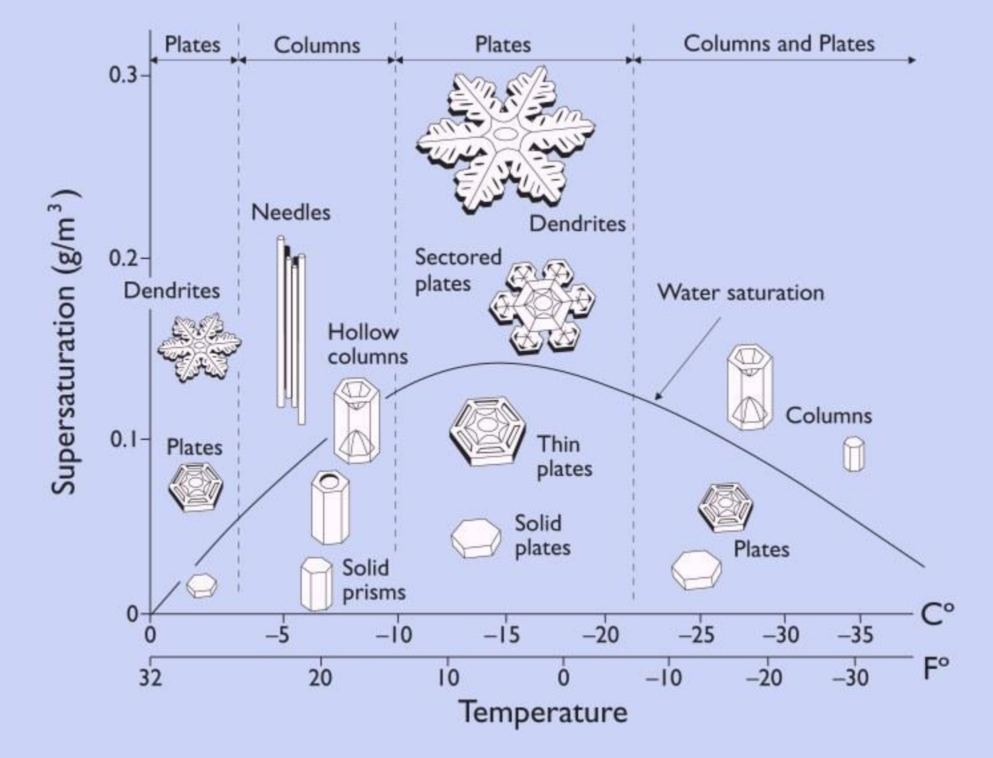




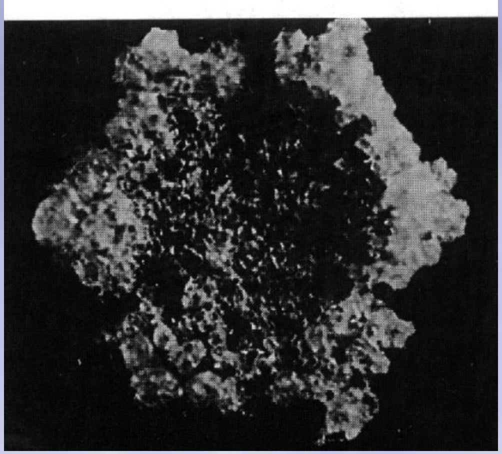
Interaction with cloud-scale dynamics of 100 m – 1 km

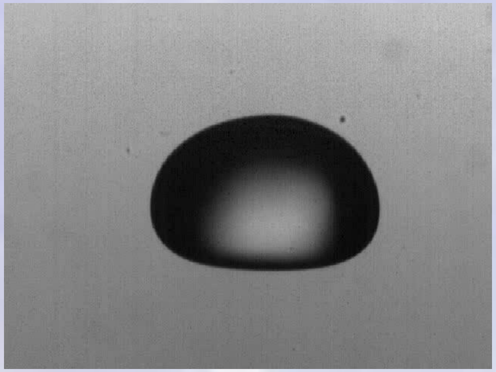
Characteristics of the cloud microphysics:

Extreme variability of the shape of ice particles:



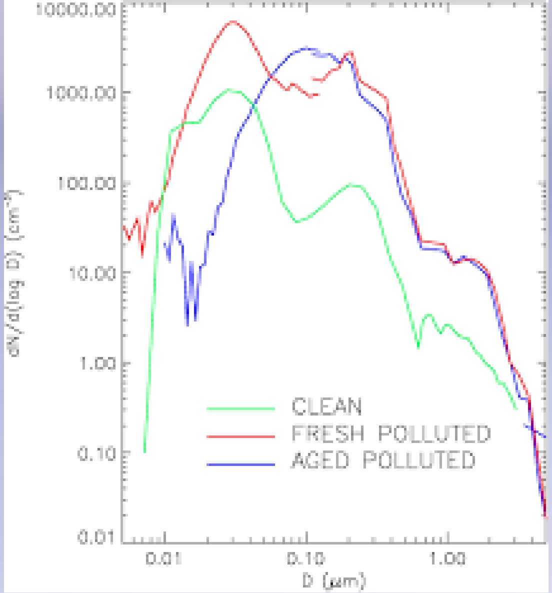
Rimed ice crystal

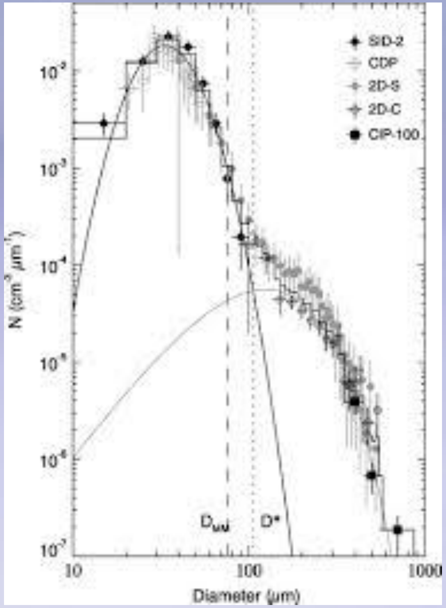




Characteristics of the cloud microphysics:

Size dependent concentration of the different types of hydrometeors





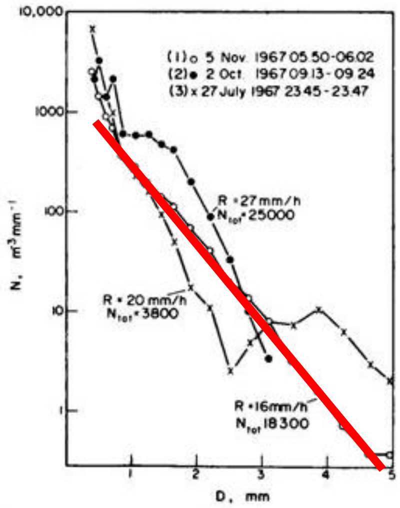


FIG. 10.1. Examples of measured drop-size distributions in rain. Indicated for each curve are the duration of the observation, the total number of drops counted, and the average rainfall rate. Distributions 1 and 2 were recorded during nearly constant rain; distribution 3 was recorded during a thunderstorm. (From Joss *et al.*, 1968.)

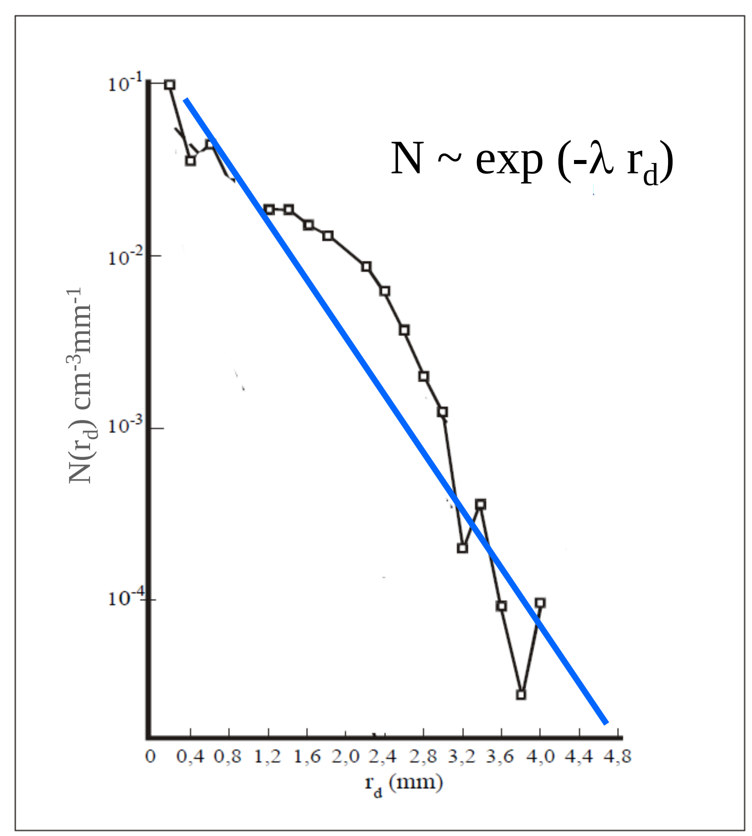
Observations

Characteristics of the cloud microphysics:

The shape and the size impact:

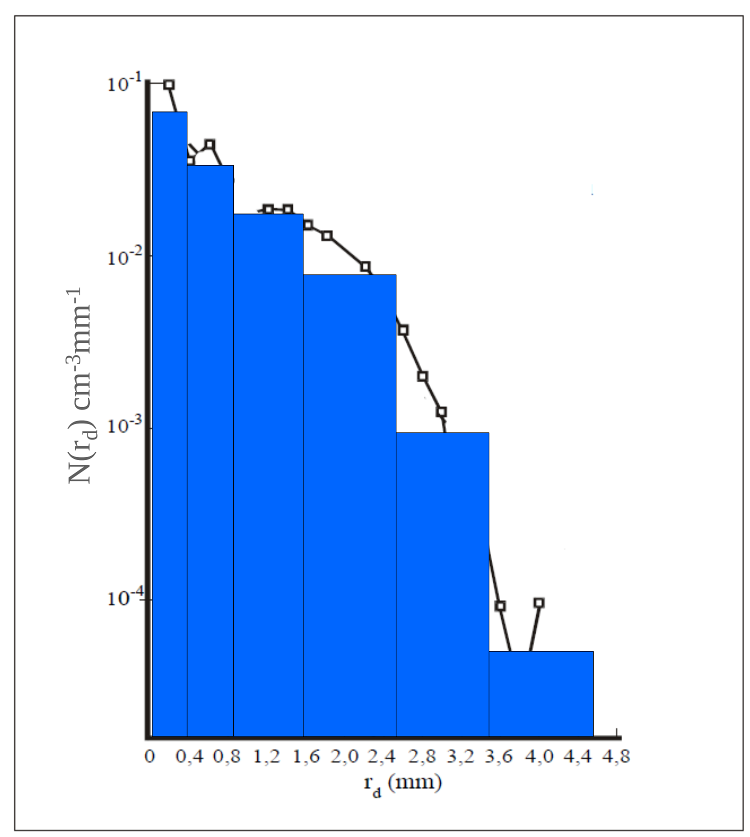
- (i) terminal velocity;
- (ii) diffusional growth rate;
- (iii) frequency of collisions;

Bulk microphysics



$N \sim \exp(-\lambda r_d)$

Bin microphysics



Advantages versus disadvantages of the bin microphysics

There is no any arbitrary assumption about the size distributions

Accurate simulation of precipitation formation and microphysics - cloud interaction.

The number of variables is about 50 times larger than in the bulk schemes

Rather complex computer code

Equations describes the collision - coalescence of the water drops:

Bulk scheme:

$$P = K\cdot(q_{cw} - a)$$

$$P = \frac{\rho^2 q_{cw}^2}{C_1 + \frac{C_2 N_{cw}}{\nu \rho q_{cw}}}$$

Bin scheme:

$$\frac{dN_k(t)}{dt} = \sum_{i=1}^{k-1} \int_{x_i}^{x_{i+1}} n_i(y,t)dy \int_{x_k}^{x_{k+1}-y} K_{k,i}(x,y)n_k(x,t)dx +$$

$$\frac{1}{2}\int_{x_{k-1}}^{x_k} n_{k-1}(y,t)dy \int_{x_{k-1}}^{x_k} K_{k-1,k-1}(x,y)n_{k-1}(x,t)dx + \sum_{i=1}^{k-2} \int_{x_i}^{x_{i+1}} n_i(y,t)dy \int_{x_k-y}^{x_k} K_{k-1,i}(x,y)n_{k-1}(x,t)dx$$

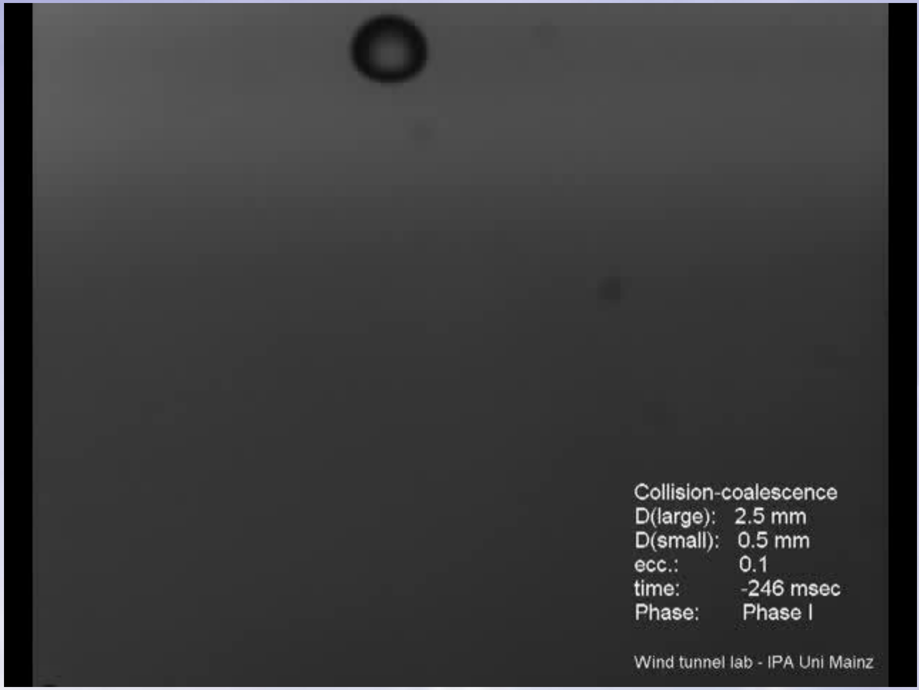
$$-\sum_{i=1}^{I} \int_{x_i}^{x_{i+1}} n_i(y,t)dy \int_{x_k}^{x_{k+1}} K_{i,k}(x,y)n_k(x,t)dx$$

$$\frac{dM_k(t)}{dt} = \sum_{i=1}^{k-1} \int_{x_i}^{x_{i+1}} n_i(y,t)dy \int_{x_k}^{x_{k+1}-y} (x+y)K_{k,i}(x,y)n_k(x,t)dx +$$

$$\frac{1}{2}\int_{x_{k-1}}^{x_k} n_{k-1}(y,t)dy \int_{x_{k-1}}^{x_k} (x+y)K_{k-1,k-1}(x,y)n_{k-1}(x,t)dx +$$

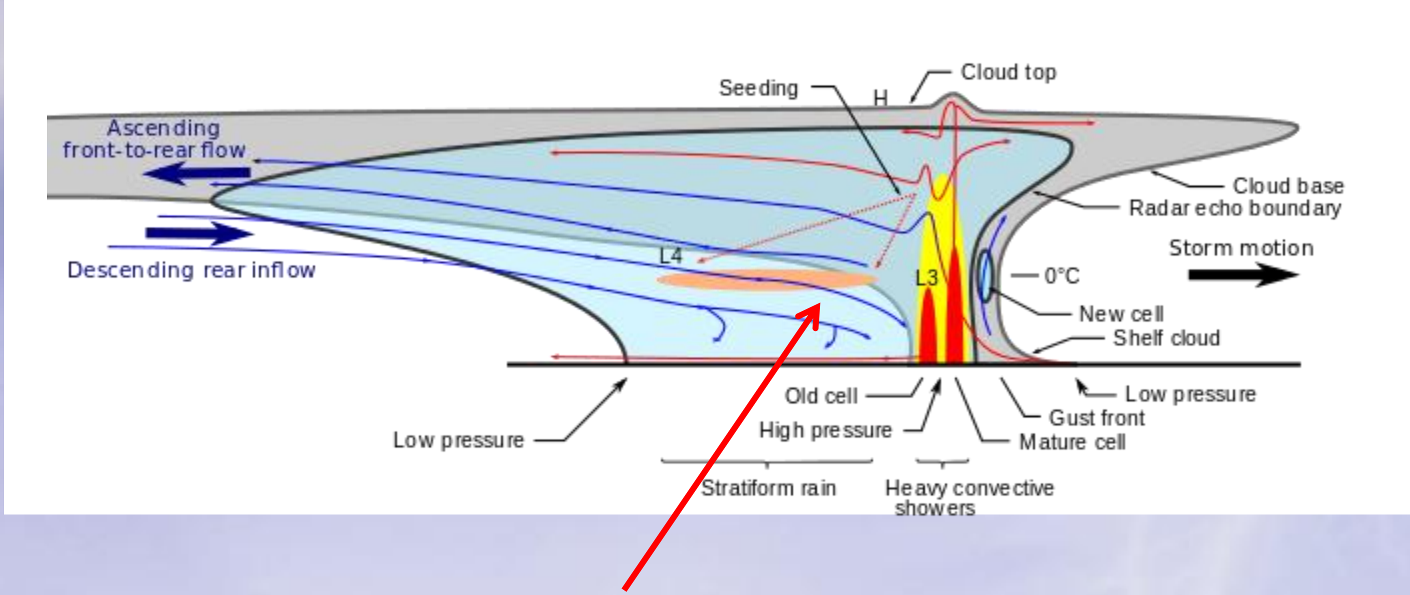
$$\sum_{i=1}^{k-2} \int_{x_i}^{x_{i+1}} n_i(y,t)dy \int_{x_k-y}^{x_k} (x+y)K_{k-1,i}(x,y)n_{k-1}(x,t)dx -$$

$$\sum_{i=1}^{I} \int_{x_i}^{x_{i+1}} n_i(y,t)dy \int_{x_k}^{x_{k+1}} xK_{i,k}(x,y)n_k(x,t)dx$$



The bin scheme as a research tool

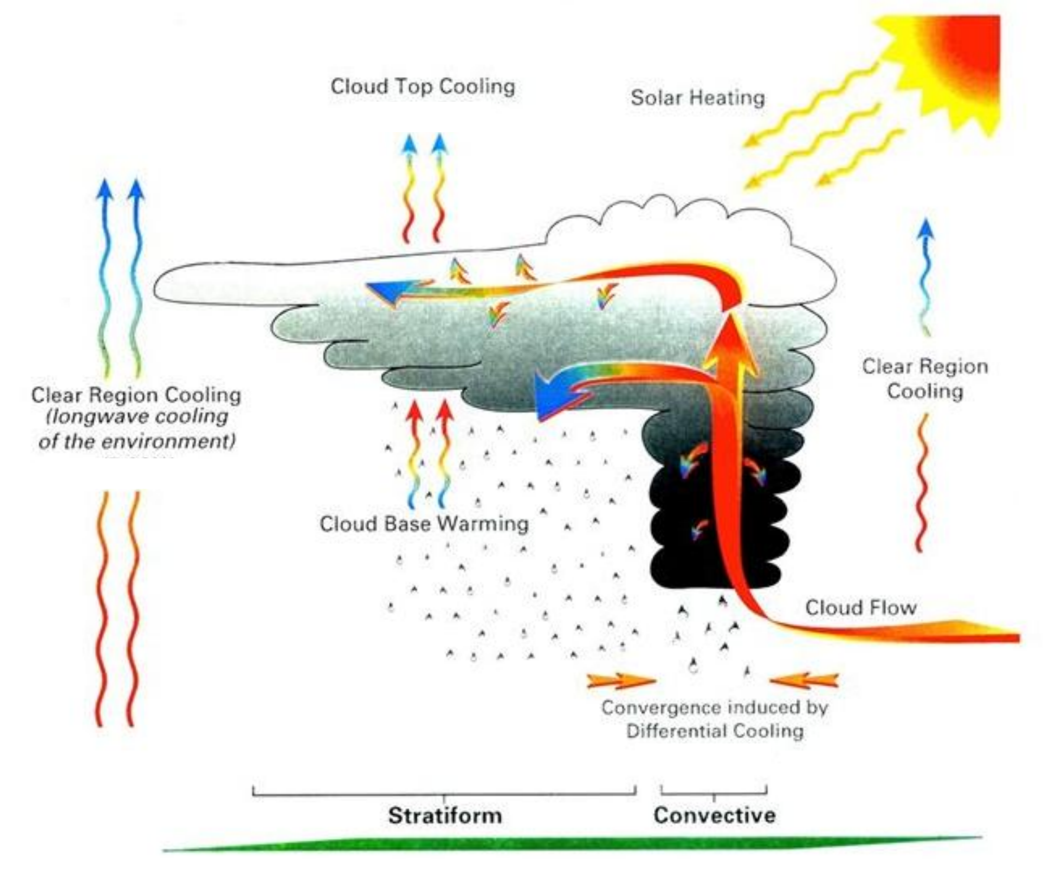
(i) Evolution and propagation of the squall lines*



melting and evaporation (melting starts at + 2°C)

*The results have been published in the Month. Weath. Rev. in 2017.
See also presentation by N. Sarkadi in the next session: Mikrofizikai folyamatok zivatarokban, zivatarláncokban

(ii) Cloud – radiation interaction*



The propagation of radiation (both short wave and longwave) is impacted by the size distributions

↓

More reliable results by bin scheme

The results were published in Atmos. Res. in 2015.

See also presentation by E. Lábó in the next session: A hosszúhullámú sugárzás stratocumulus felhőben történő terjedésének numerikus modellezése

(iii) Evaluation of the efficiency of weather modification

Small effect with large noise

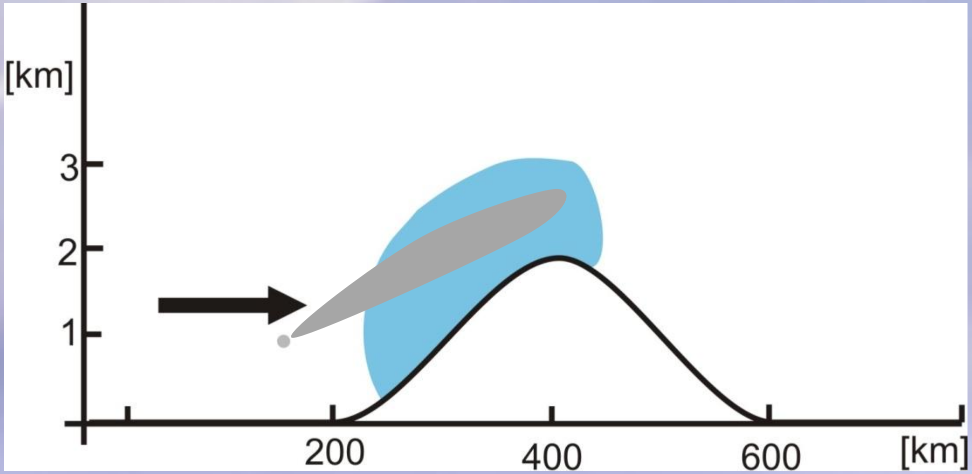
↓

Non conclusive result by statistical analysis

↓

Numerical experiments with a „solid” model

Results of numerical experiments[*]



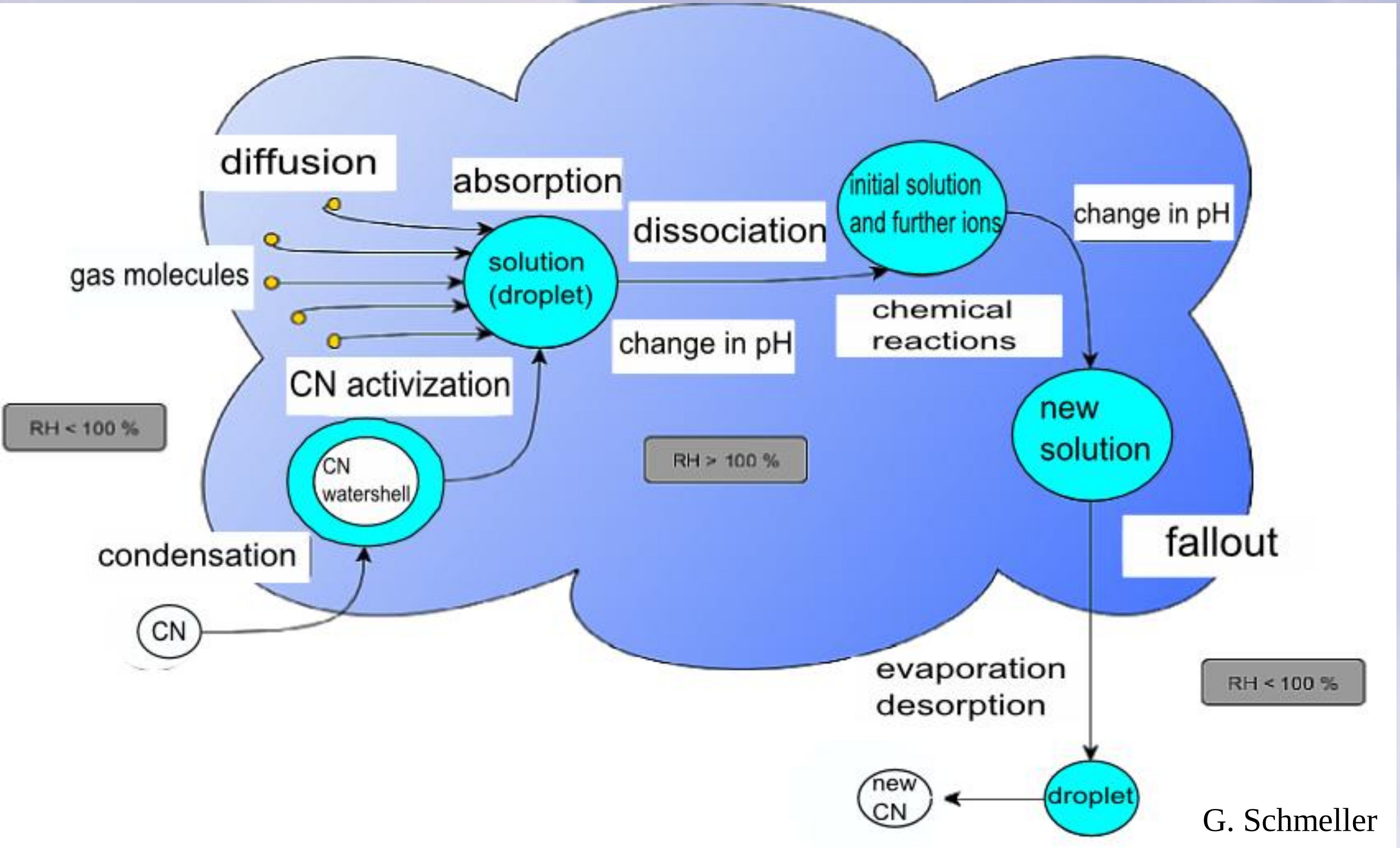
Efficiency depends on the cloud top temperature

More precipitation on the windward side, reduced precipitation on the leeward side

The amount of the accumulated precipitation can be reduced in the case of convective clouds.

[*] The results have been published in J. Appl. Met and Clim. in 2017

(iv) Numerical simulation of aerosol processing in clouds



G. Schmeller

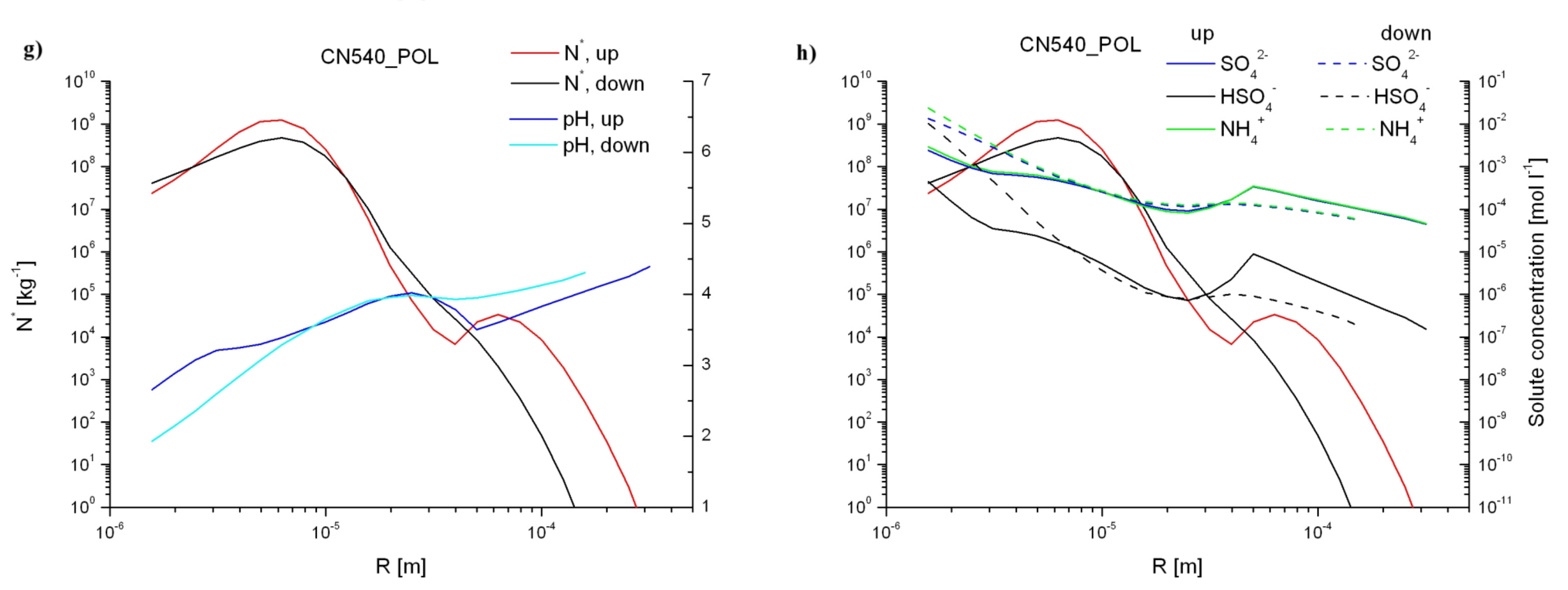
Simulation of cloud physics (warm cloud) +

- absorption/desorption of gases by water drops
- chemical reactions occur in water drops

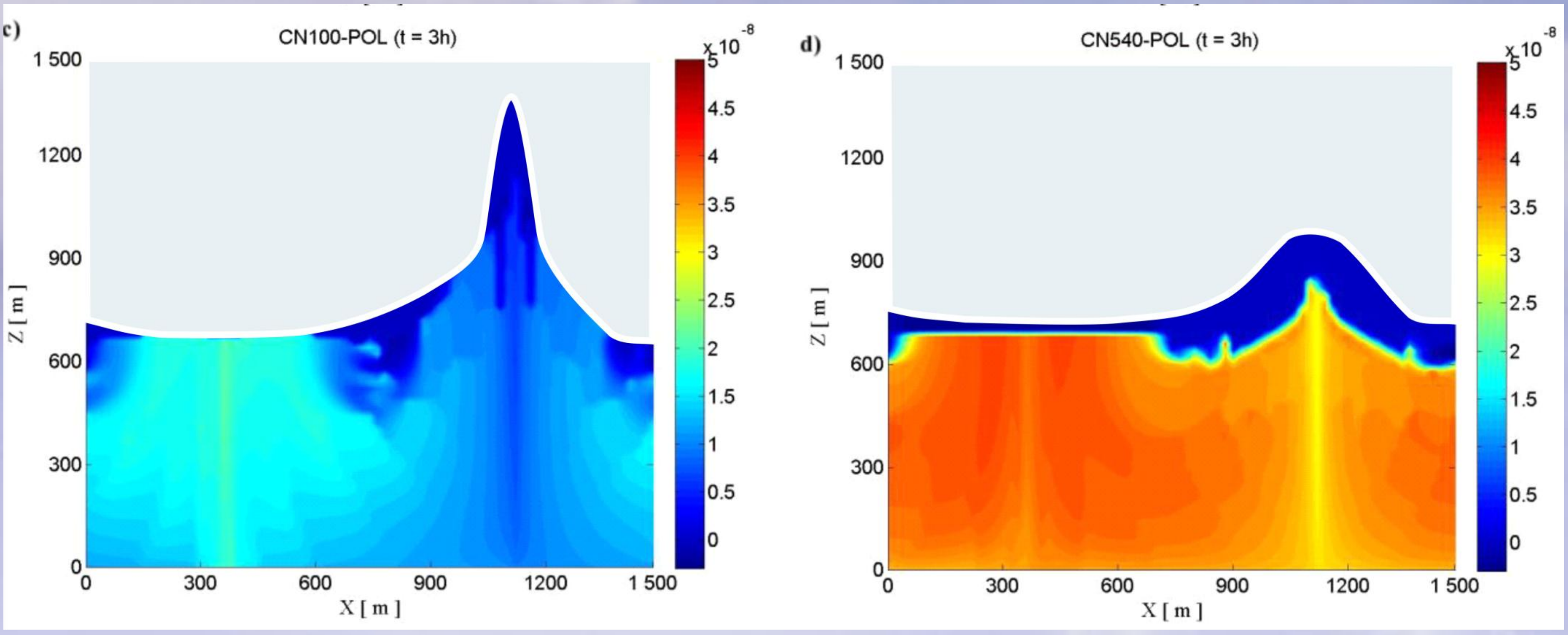
Results

The concentration of the compounds depends on size of the drops

Example for polluted airmass



Significant amount of sulfate is produced by cloud chemistry



The aqueous chemistry impacts the aerosol size distribution.

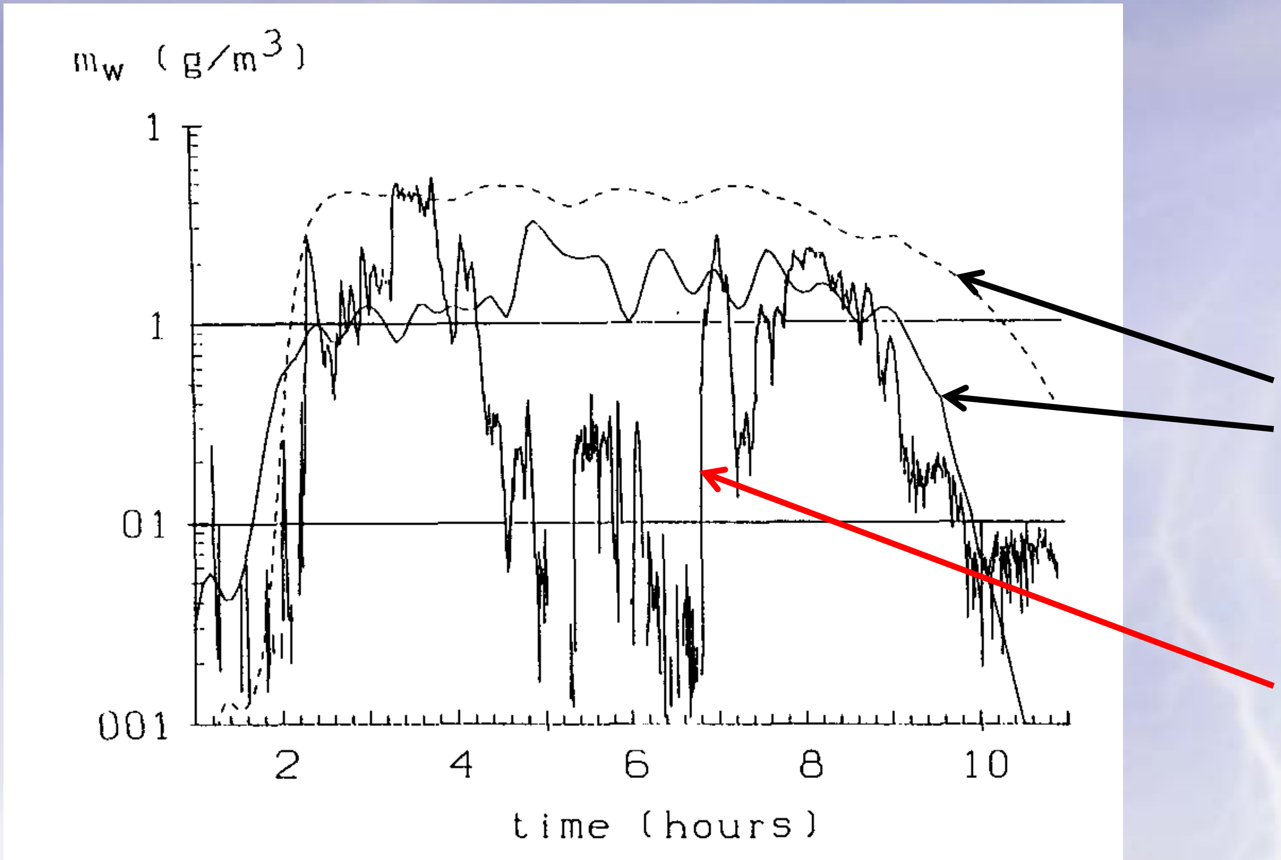
Alteration of the surface precipitation?

(v) Other ongoing research projects

Physics and chemistry of the fog

Problem to solve:

Fast temporal and spatial fluctuation of the water drop mixing ratio:



simulated

observed

(v) Other ongoing research projects (cont.)

Precipitation enhancement in semiarid regions

Problem to solve:

Numerical simulation of hygroscopic seeding.

Can the injection of giant aerosol particles promote the formation precipitation formation?

Thank you for your attention !