Cloud processing of aerosol particles: consequences for precipitation?

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The model DESCAM (DEtailed SCAvenging Model)

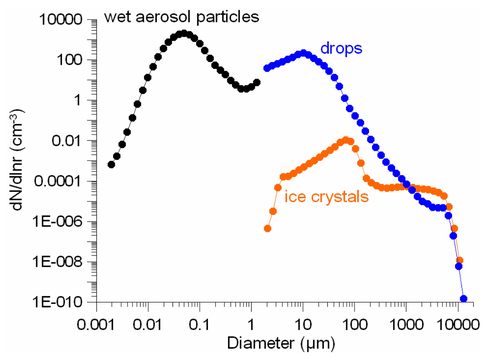
Flossmann and Wobrock (2010)

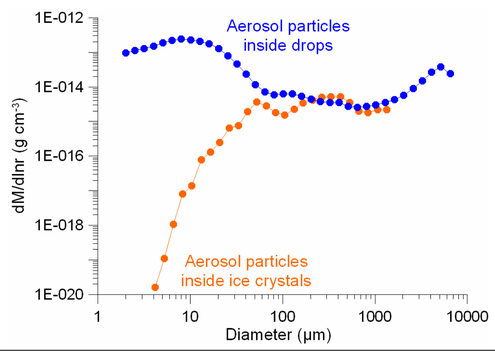
***3 + 2 density distribution functions*:**

f_d : drop number
f_i : ice crystal number
f_{AP} : wet aerosol particle number
$g_{AP,d}$: aerosol mass inside drops
$g_{AP,i}$: aerosol mass inside ice crystals

Coupled to 3-D meso-scale dynamic Model (Clark and Hall, 1991)

- *Warm microphysical processes* : aerosol particle growth and activation, droplet de-activation, growth of drops by condensation and collision-coalescence
- *Cold microphysical processes* : homogeneous and heterogeneous nucleation, growth by vapor deposition, riming and melting.



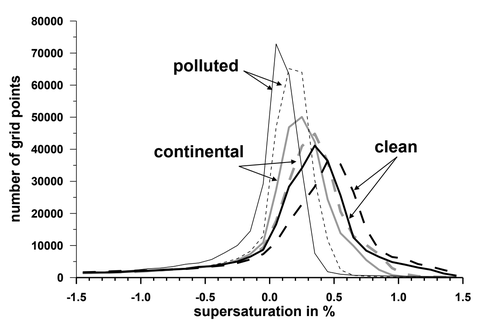


Motivation:

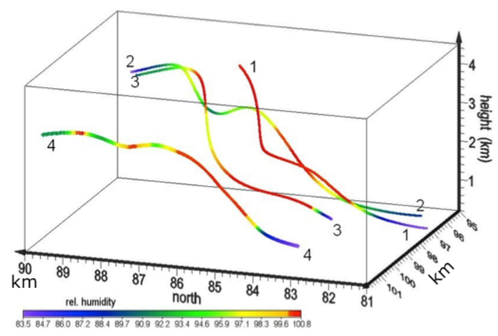
Are clouds able to modify the ambient aerosol particle spectrum so that the number concentration is reduced and the size and chemical composition of the particles is changed? Can they do it in such a way that the cloud forming on these particles will finally be able to precipitate and remove the water and pollution from the atmosphere?

1

Already in Flossmann and Wobrock, 2010b we have shown that inside clouds a strong mixing is present and cloud elements probably experience several consecutive super- and subsaturation periods. The strong turbulence results in the fact that inside cloud (LWC > 0.1 gm^{-3}) about 20% of the area is subsaturated. Each subsequent cloud cycle seems to enlarge the particles and broaden the particle spectrum:



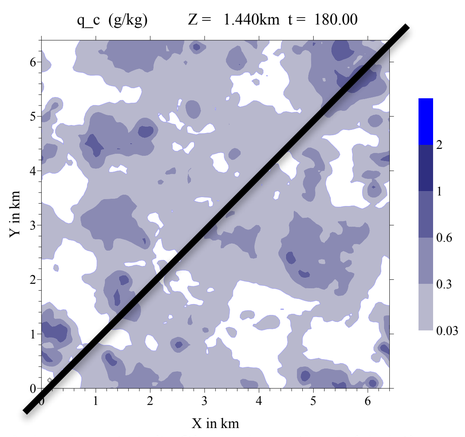
Role of aerosol concentration and composition for supersaturation in the cloud field (solid line pertains to complete soluble particles; dashed curve to particles with 0.01% solubility)

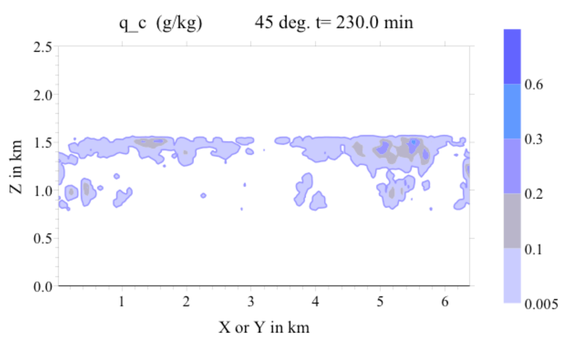


Humidity evolution along selected cloud parcel trajectories; red: supersaturated; blue: outside cloud; green: still in cloud

2

"Sandbox"-type scenario (6km*6km*2.5km) :
simulate the processes in **a marine stratocumulus cloud** as observed during the VOCALS-Rex campaign in 2008 over the **remote subtropical southeast Pacific** (Wood et al, 2011).
Below: a horizontal cross section at 1.4 km altitude at 3h and a vertical cross section along the indicated black line at almost 4h. Cloud cover stays around 55% during this time in the evolving stratocumulus field and the cloud fields have 20 to 60 drops/cm^3





A horizontal (left) and vertical (right) cross-section through the simulated cloud water in g/kg at 3h and almost 4h.

3

After 230 min, a second number density distribution function for **processed aerosol particles** was added in the model that allows separating the "pristine" particles from particles that went through several cloud cycles of successive condensation/evaporation periods. We note that **after 40 simulated minutes** of cloud lifetime (between 230 and 270 min in this simulation) locally **up to 20%** of the aerosol particle number concentration has already been in a previous cloud cycle. The processed particles spread over the entire boundary layer and do not stay confined to the cloud region (compare Fig. for q_c).

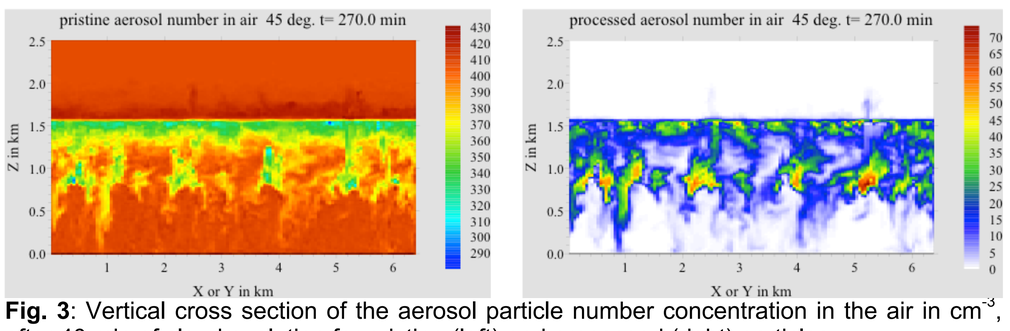
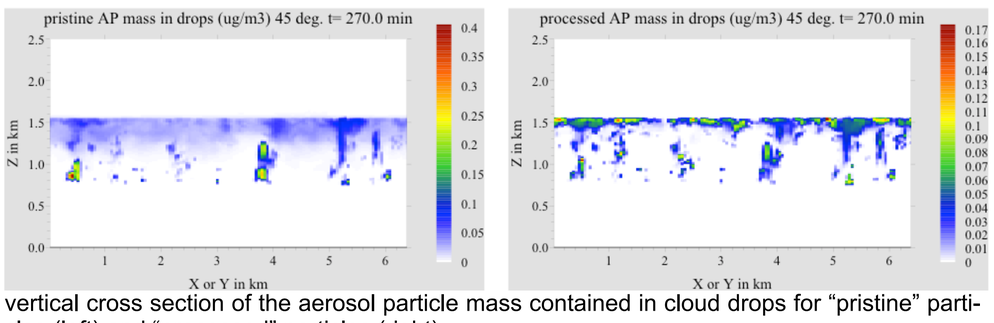


Fig. 3: Vertical cross section of the aerosol particle number concentration in the air in cm^{-3}, after 40 min of cloud evolution for pristine (left) and processed (right) particles.

4



vertical cross section of the aerosol particle mass contained in cloud drops for "pristine" particles (left) and "processed" particles (right).

All the pristine and the processed particles can nucleate drops when again entering super-saturated conditions. The Fig. shows that **about 30% of the drops formed on processed particles** that had already formed drops during previous cloud passages but that had been evaporated in sub-saturated regions.
For this rather shallow stratocumulus the cloud residence times of the drops were quite short and an observed broadening of the particle spectrum was quite small.
More studies also for larger cloud systems and longer times need to be performed to confirm the importance of cloud cycling of ambient aerosol particles.

References:

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