Arctic low-level boundary layer clouds: In-situ measurements and simulations of mono- and bimodal supercooled droplet size distributions at the cloud top layer

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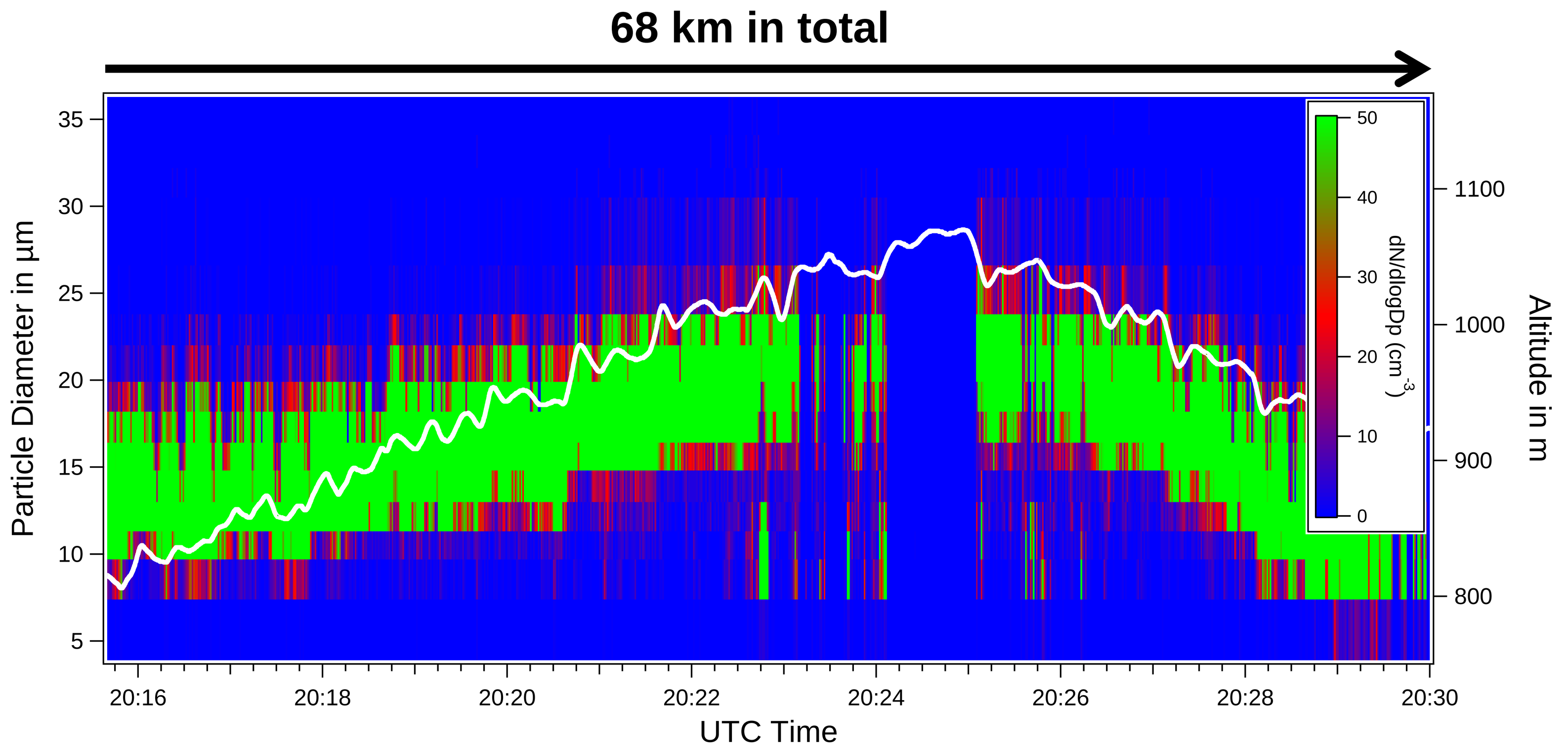
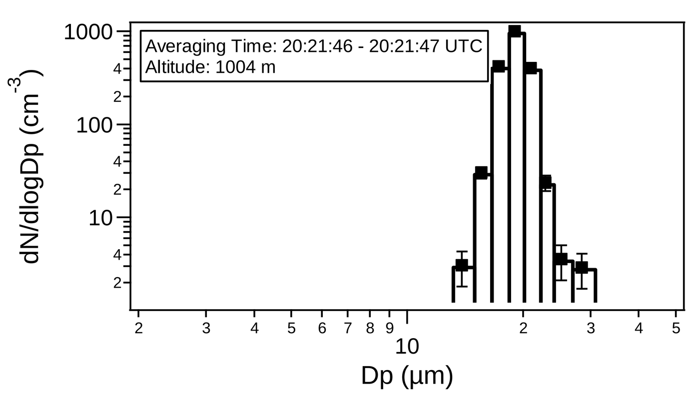
1. The VERtical Distribution of Ice in Arctic Clouds field campaign (VERDI)

- Joint research activity of seven German institutes to study Arctic boundary layer-, mixed-phase clouds.
- Performed in April/May 2012 above the Beaufort Sea out of Inuvik, NWT, Canada.
- Four cloud particle spectrometers with partially overlapping detection size ranges were operated side by side.
- Solar as well as broadband thermal-infrared radiation sensors, an optical particle counter, LiDAR and meteorological instruments were part of the instrumentation.

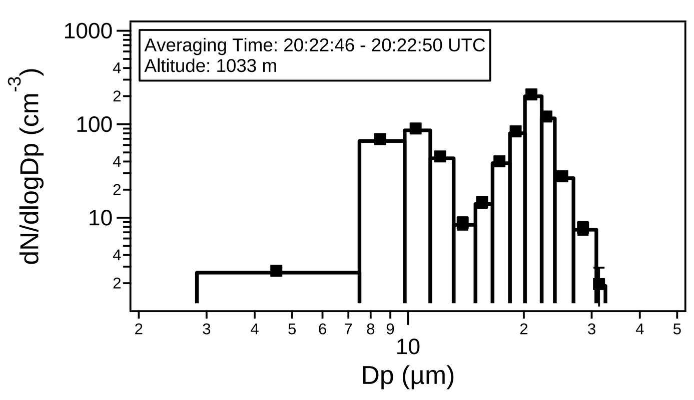
Measurement Platform: POLAR 5 (Basler BT-67 modification of a DC-3)

2. Droplet features inside and in the transition zone of mostly liquid arctic boundary layer clouds





In-Cloud



Transition zone
(Upper cloud layer)

Monomodal size distribution

Bimodal size distribution

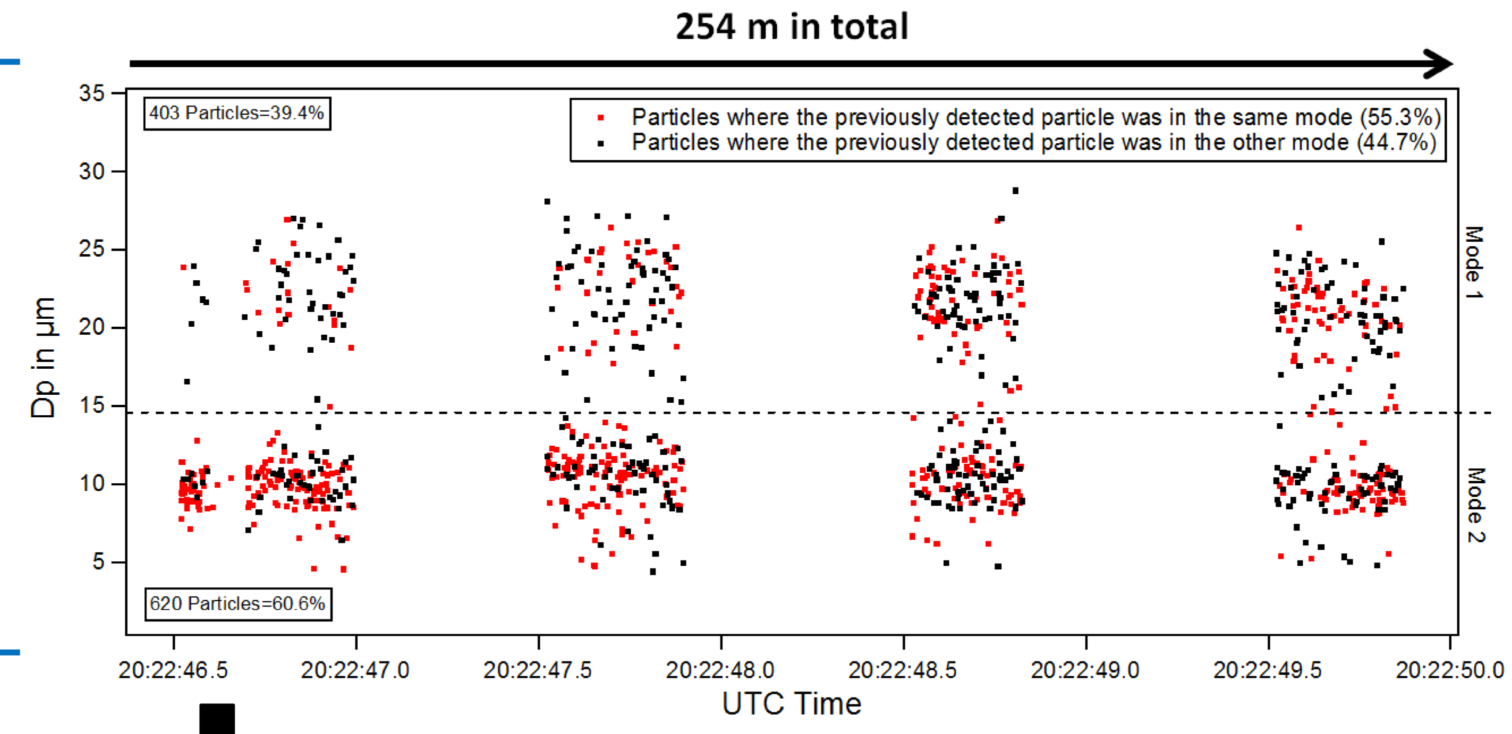
Question: What is the development process of the second mode?

a) Activation/condensation of newly entrained CCN

or

b) Evaporation processes

3. Spatial distribution of the droplets from the bimodal size distribution: Are the two modes from two different flight segments?



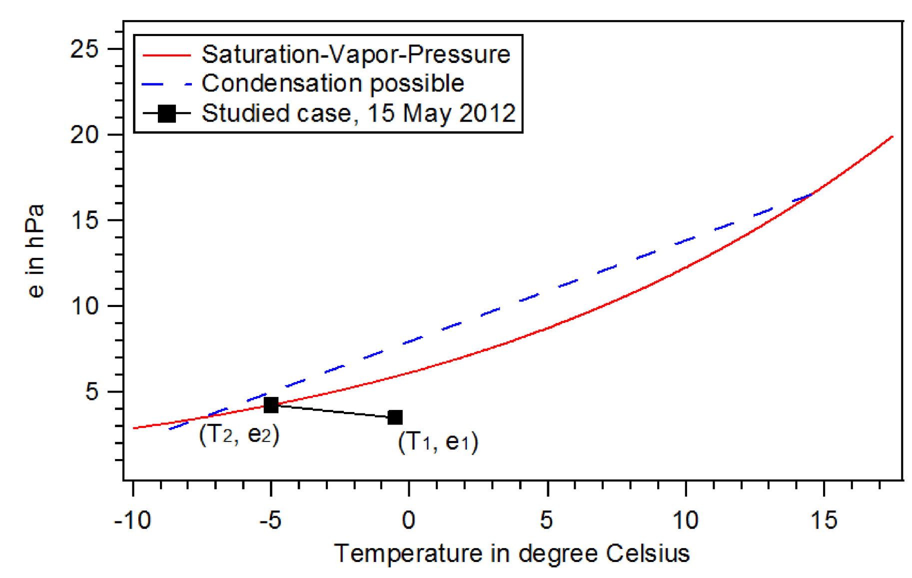
Particle-by-Particle data recorded by a Cloud Droplet Probe (CDP).

Droplets are well mixed in both modes! The distance between two detected particles is rougly 10 cm.

Both modes are from one flight segment and thus well mixed on a decimeter scale

4. Theoretical considerations and modeling

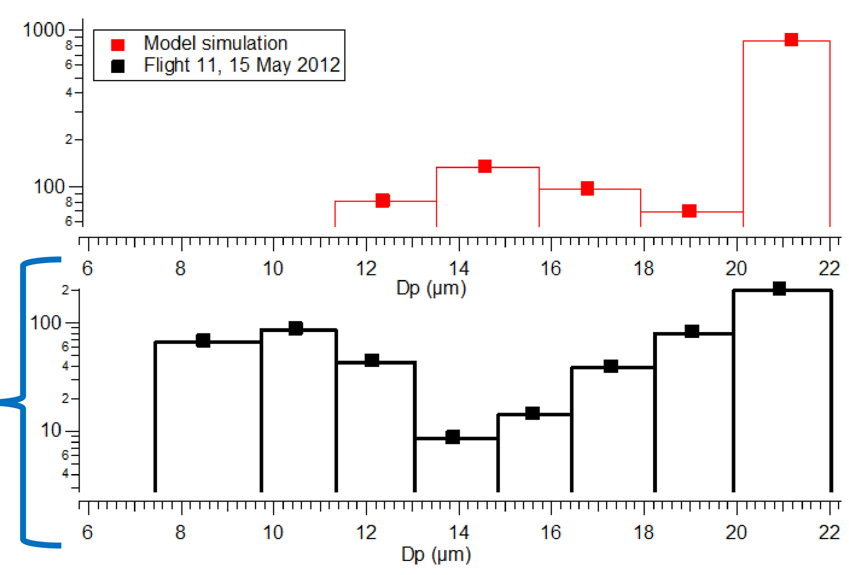
a) Isobaric mixing can lead to the supersaturation neccessary for condensation if the saturation-vapor-pressure curve is sufficiently nonlinear over the temperature range relevant to the mixing. However, in the studied case, the saturation-vapor-pressure line is almost linear in the range covered by the measurements.

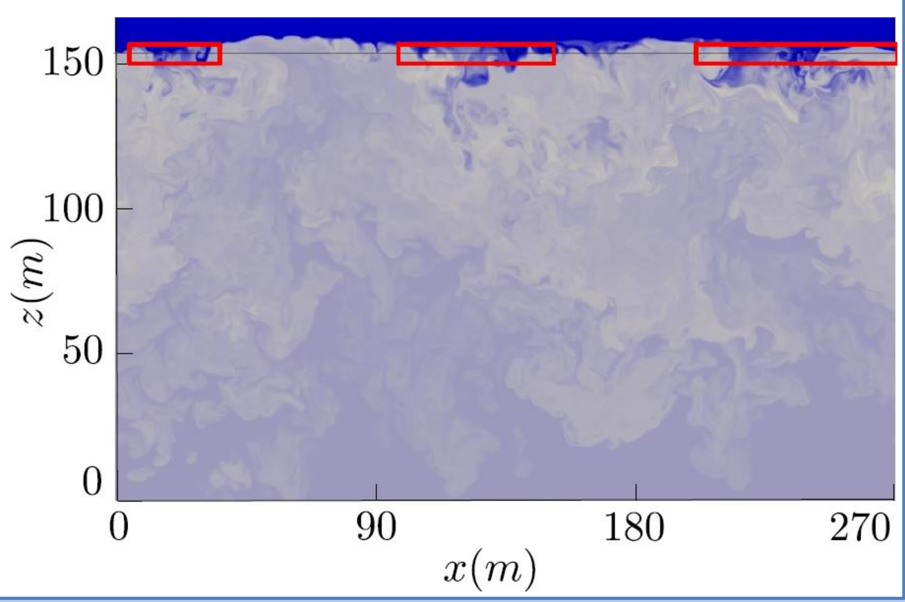


Condensation of new droplets is very unlikely.

b) The evaporation processes in the observed cloud transition zone were examined in more detail by using a model simulation study. Included effects: Evaporative and radiative cooling.

Simulation and measurement show similiar bimodal features!





5. Conclusions

Inside the transition zone of the observed boundary layer clouds we detected bimodal SDs where the second (smaller) size mode seems to be a result from eddy driven in-mixing of drier air with subsequent evaporation. To analyze this phenomenon in a higher resolution, a holographic instrument capable of detecting particles in a sample volume of a few cm³ in a single snapshot (Spuler and Fugal, 2011) can be used. This will allow even smaller mixing scales of both size modes to be investigated. Also new imaging remote sensing techniques as presented by Bierwirth et al. (2013) will help to identify the horizontal variability of this type of cloud and help to quantify eddy driven mixing processes.

Reference: Klingebiel, M., Lozar, A., Molleker, S., Weigel, R., Roth, A., Schmidt, L., Meyer J., Ehrlich, A., Neuber, R., Wendisch, M., Borrmann, S., 2014: Arctic low-level boundary layer clouds: In-situ measurements and simulations of mono- and bimodal supercooled droplet size distributions at the cloud top layer, Atmos. Chem. Phys. Discuss., **10**, 14599-14635.

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