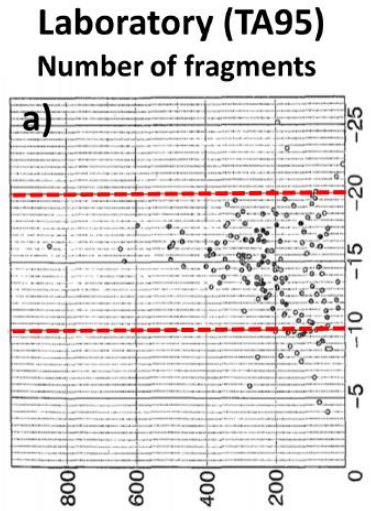
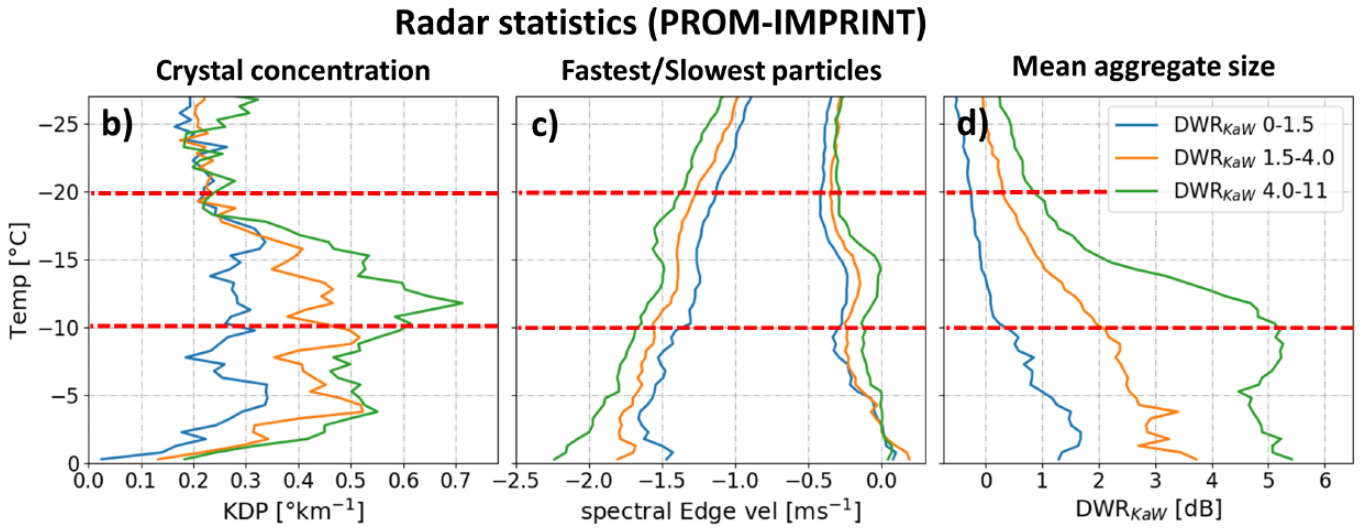
FRAGILE- EXPLORING THE ROLE OF FRAGMENTATION OF ICE PARTICLES BY LAB STUDY OF ICE-ICE COLLISIONS

Discrepancy in INP and ICNC

Collision fragmentation



Takahashi et.al 1995



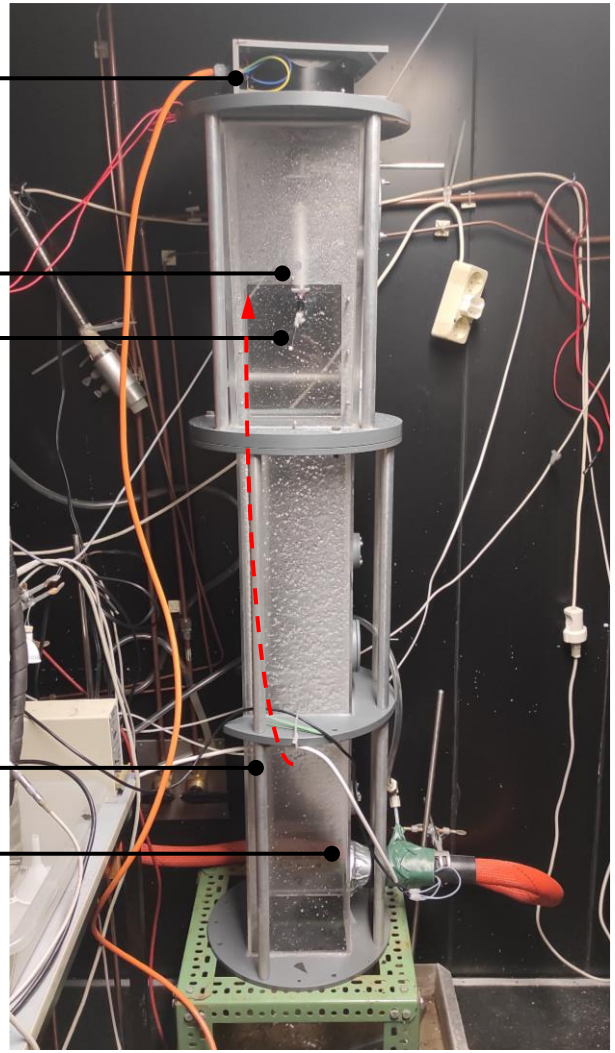
Von Terzi et.al 2022

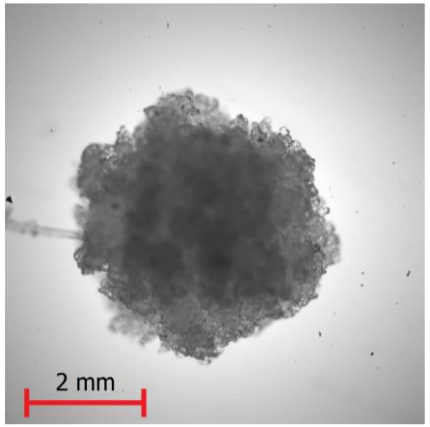
Sudha Yadav, Lilly Metten, Pierre Grzegorczyk, Alexander Theis, Subir K. Mitra, Miklós Szakáll
JGU, Mainz

PROJECT OBJECTIVES

- Collision induced fragmentation in the M-CR (Mainz cold room)
- Temperature dependence of the number of fragments
- Fragmentation without collision in M-WT

Graupel Generation Setup (GEORG)





Graupel generated at -15°C

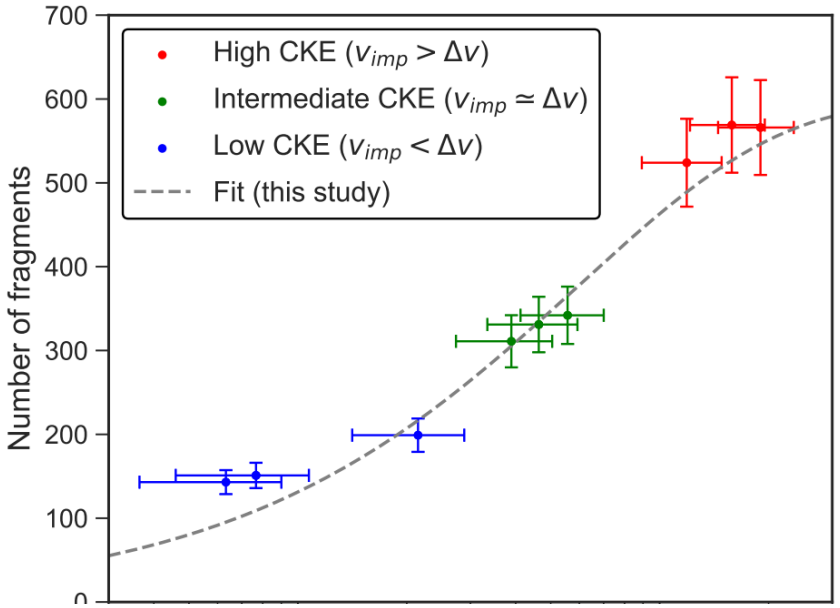
PROGRESS SINCE LAST MEETING

- Publication: *Grzegorczyk, P., Yadav, S., Zanger, F., Theis, A., Mitra, S. K., Borrmann, S., and Szakáll, M.: Fragmentation of ice particles: laboratory experiments on graupel–graupel and graupel–snowflake collisions, Atmos. Chem. Phys., 23, 13505–13521, https://doi.org/10.5194/acp-23-13505-2023*
- Laminarization of the supercooled droplet flux inside GEORG – lower LWC (0.4 g/m^3) so better repeatability in graupel's size (2-4mm) and density (0.2-0.6 g/m^3)
- Making the experimental collision setup more robust
- Characterization of liquid water content at graupel's location
- Graupel size and density characterization at -15 °C and -7°C
- Collisions between ice particles with different densities to study the effect of density on particle fragility.

COLLISIONS

Collision pair	Temperature (°C)	Falling particle diameter (mm)	Falling particle density ($g \cdot cm^{-3}$)	Fixed particle diameter (mm)	Fixed particle density ($g \cdot cm^{-3}$)
Gr-gr	-15	2.45	0.458	2.45	0.558
Gr-ice sphere	-15	5	0.9	2.45	0.558
Ice-ice sphere	-15 & -5	7	0.9	5	0.9
Ice-ice sphere	-15 & -5	5	0.9	5	0.9
Multiple collision gr-ice sphere	-7	5	0.9	2.45	0.558

Multiple collisions, ice on graupel – No more fragments after 4 collisions



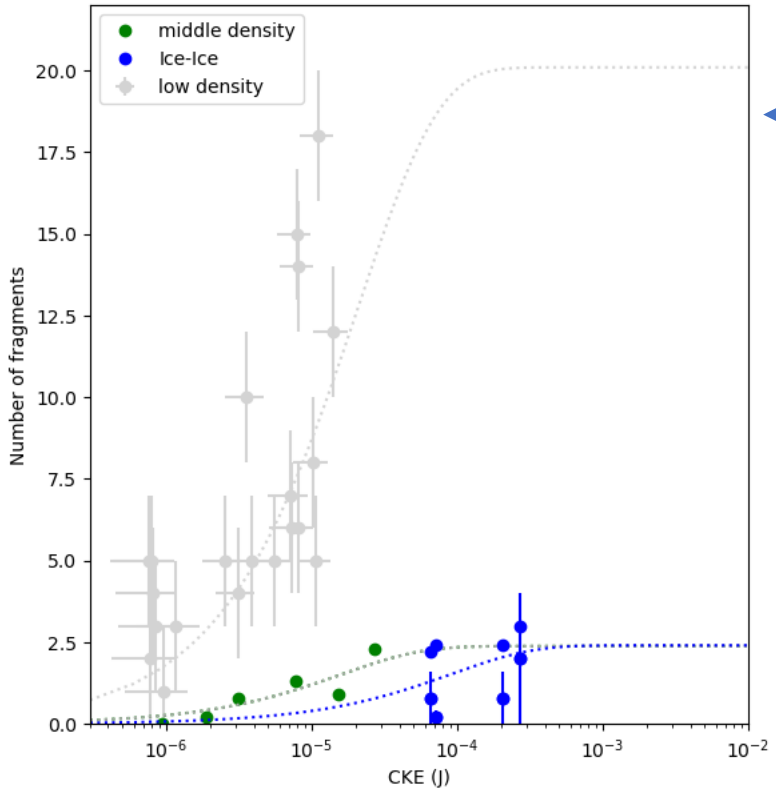
Graupel-graupel with dendrites

$$N = \alpha A(M)\left(1 - \exp\left(-\left[\frac{CK_0}{\alpha A(M)}\right]^{\gamma}\right)\right)$$

Philips et.al 2017

A(M) - number deof breakable asperities
C - asperity-fragility coefficient
Ko – collision kinetic energy
α - equivalent spherical area of the smaller particle
γ – shape parameter

Grzegorczyk et al. 2023

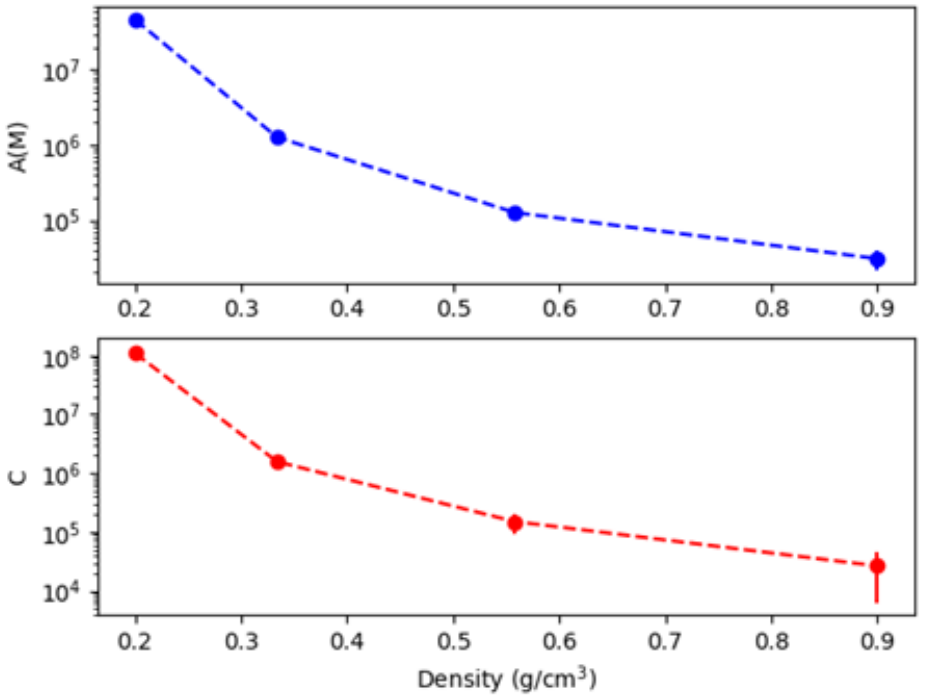


Bare Graupel-graupel collisions

Grey: -15 °C, Graupel -0.2(g/m³), 0.334 (g/m³)

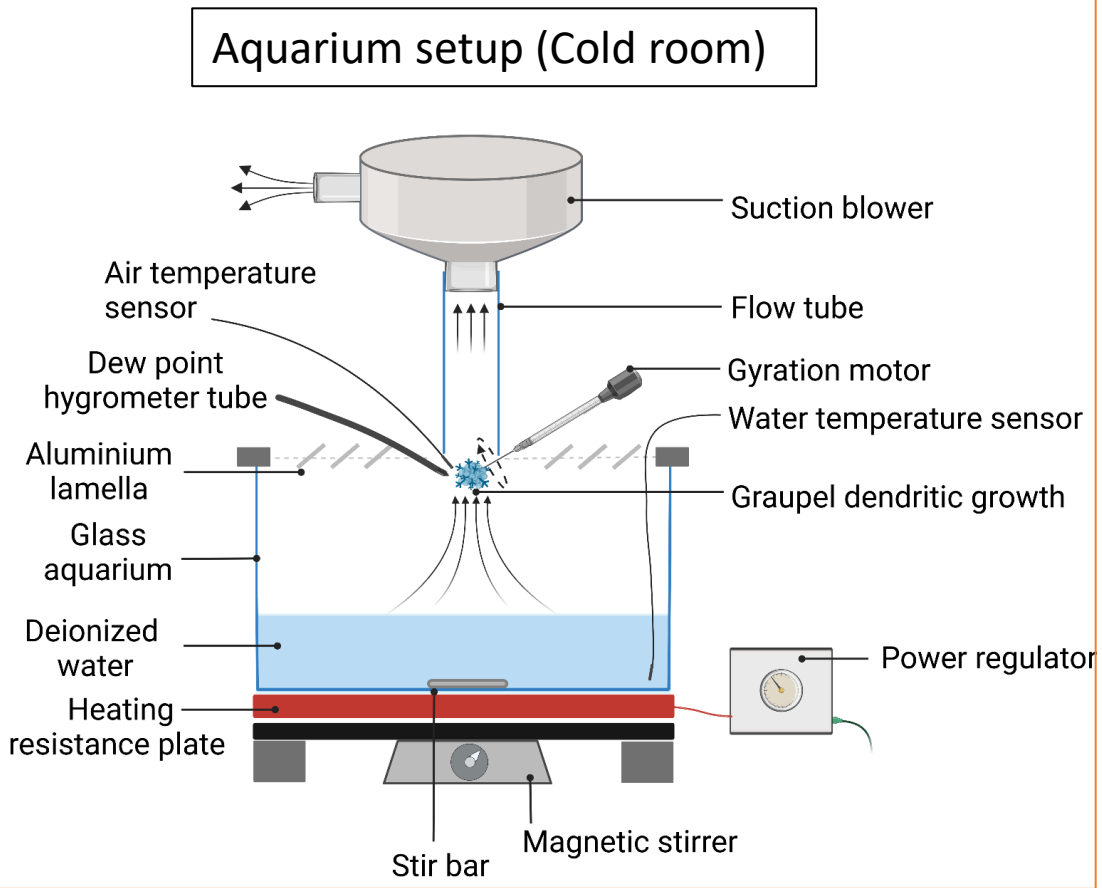
Green: -7 °C, Graupel - 0.558(g/m³)

Blue: -15 °C & -5 °C ,Ice sphere - 0.9(g/m³)

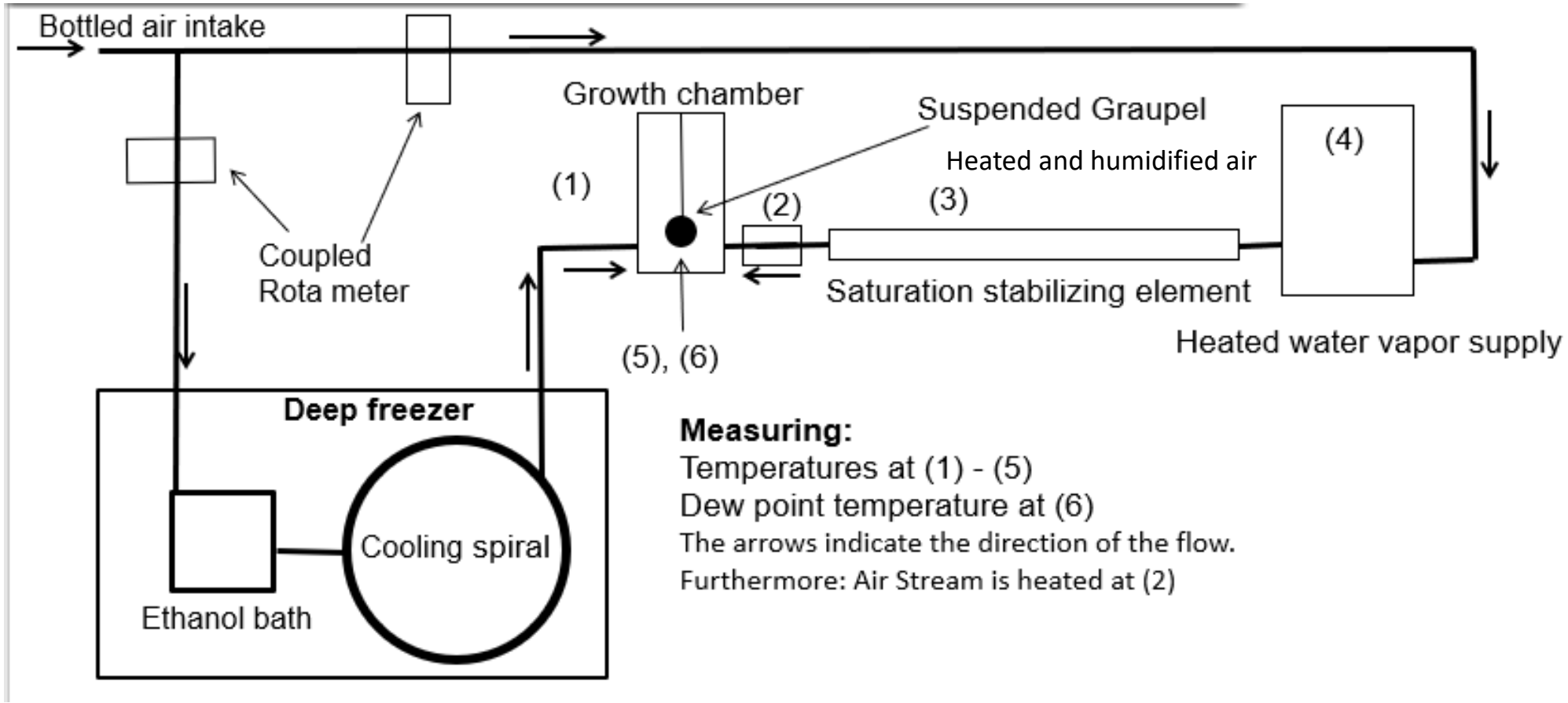


MIXING CHAMBER

- Supersaturation was too high
- Mixing chamber required for controlled supersaturation
- Adiabatic and Isobaric mixture of cold dry and warm moist air

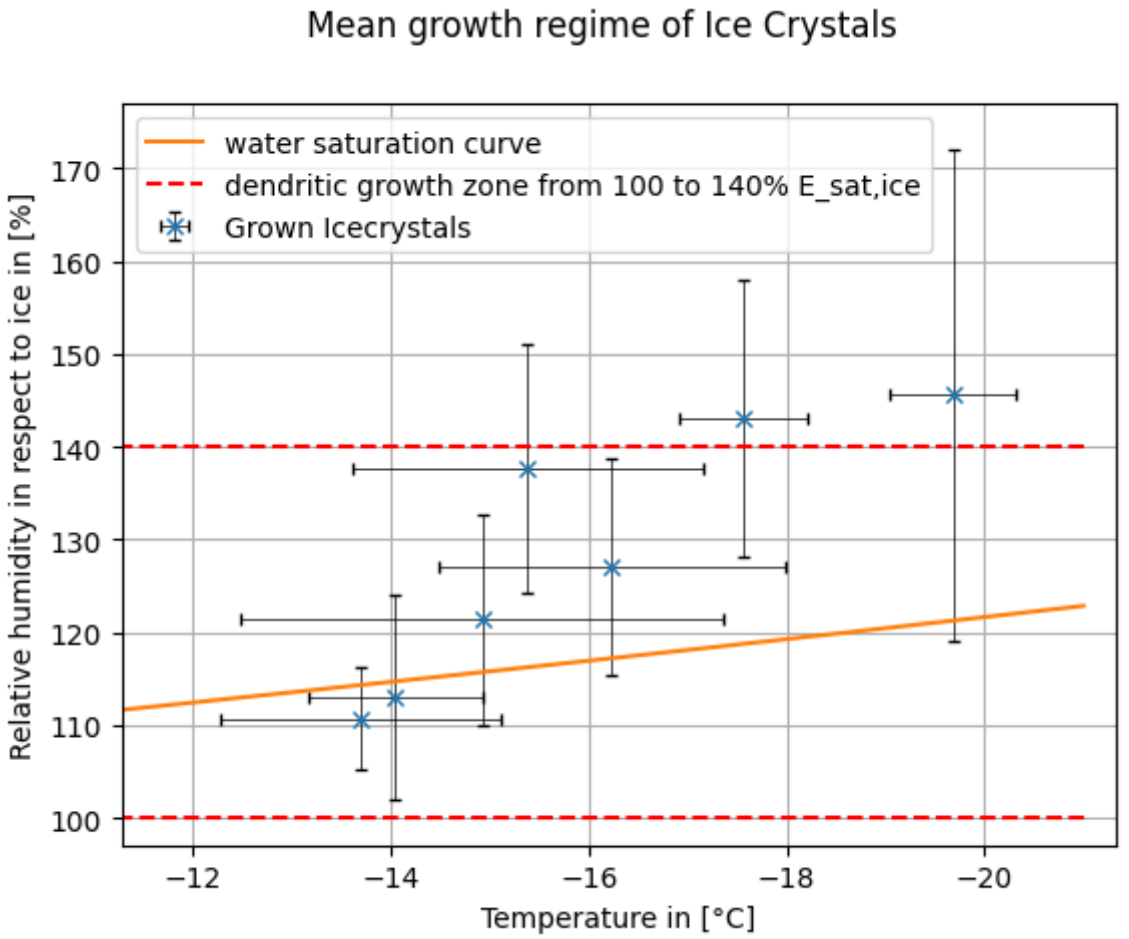


MIXING CHAMBER



MIXING CHAMBER

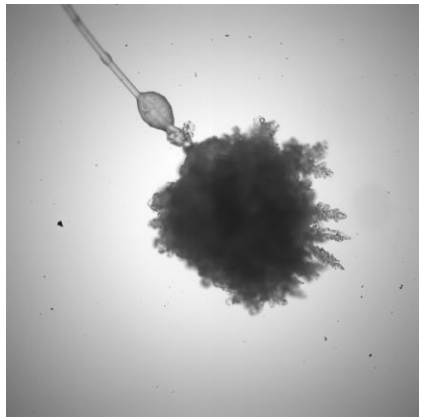
- Shown points: Means of temperature and saturation logs (in respect to ice) in the growth chamber
- Errors: standard deviation of said data logs
- Errors big because of long growth times (~20 minutes)



MIXING CHAMBER

- Growth regime:
- T = (-14.9 ± 2.4) °C
- Sat(ice) = (121.3 ± 11.3) %
- Dendrite crystal, experiment #2

- T = (-17.5 ± 0.6) °C
- Sat(ice) = (143.0 ± 14.9) %
- Sector plates and dendrite on graupel, experiment #5

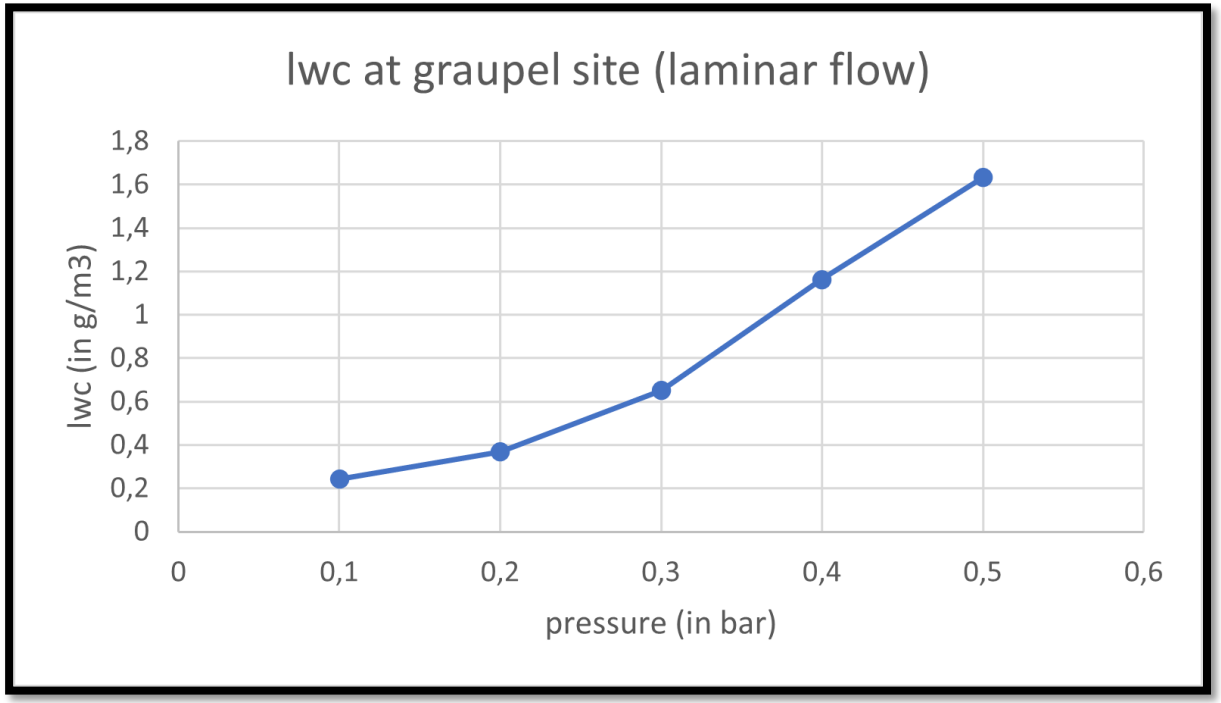


SUMMARY AND OUTLOOK

- Number of fragments increases with the CKE.
- Collisions between lowest density ice particles, did not produce more than 20 fragments but still a bit more than other SIP (droplet freezing - Keinert et al., 2020). This was consistent across a range of kinetic energy (10^{-7} to $2x10^{-5}$ J).
- Collision between lower density particles, being more fragile, produced a greater number of fragments than higher density ice particles.
- Generating different crystal habits in mixing chamber
- Temperature dependence of number of fragments during collision

	T (°C)	LWC (gm^{-3})	Growth time (min)	Diameter (mm)	Density ($g\ cm^{-3}$)
Turbulent	-10	3.46	3	2.43	0.49
	-10	3.50	7	4.47	0.78
	-15	2.32	3	2.24	0.33
	-15	2.20	6	3.51	0.51
	-20	0.71	7	2.05	0.25
Laminar	-15	0.41	10	2.95	0.26
	-15	0.41	15	3.65	0.29
	-7	0.37	5	1.63	0.5
	-7	0.37	10	2.45	0.46

LIQUID WATER CONTENT



Pressure (in bar)	Avg LWC (g/m3)	Std LWC (g/m3)
0.1	0.241	0.035
0.2	0.368	0.028
0.3	0.652	0.053
0.4	1.163	0.096
0.5	1.631	0.063

GRAUPEL SIZE & DENSITY CHARACTERIZATION

Temperature (°C)	Average LWC (gm−3)	Growth time (mins)	Number of graupels sampled	Avg Diameter (mm)	Avg Density without epoxy (gcm−3)	Avg Density with epoxy (gcm−3)
-7 ± 1.5	0.368	5	12	1.626 ± 0.185	0.499 ± 0.021	0.843 ± 0.135
-7 ± 1.5	0.368	10	15	2.450 ± 0.287	0.458 ± 0.023	0.558 ± 0.0470
-15 ± 1.5	1.631	3	10	2.432 ± 0.213	-	0.287 ± 0.056
-15 ± 1.5	1.631	9	10	3.862 ± 0.538	-	0.467 ± 0.057

MIXING CHAMBER

- Latest improvement: 7 ice rods instead of only 1, each half in length
- Saturation with single rod was not stable enough over time
- Increase in effective surface area for vapor deposition inside tubes by a factor of 4.43
- Increases flow rates to reduce growth time
- In the coming days: Insulation of the setup from temperature oscillation of the cold chamber, growth chamber regime is dependent on this