

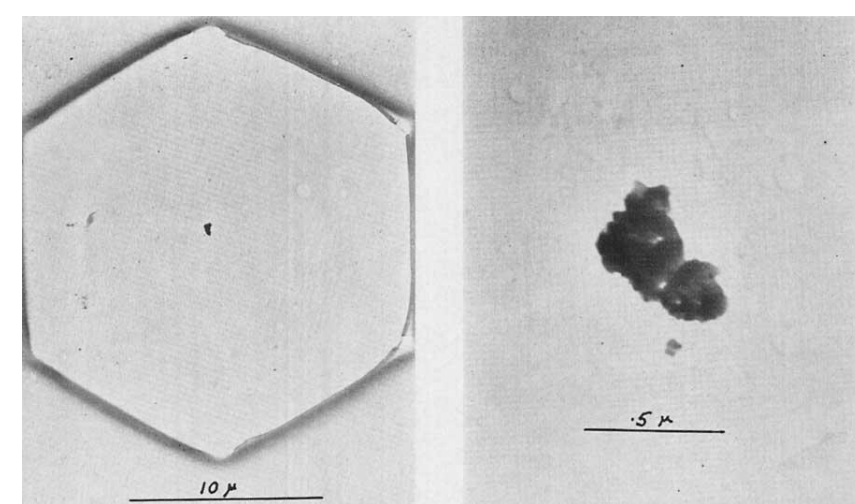
A hidden treasure: ice nucleating particles preserved inside Formvar replicas of ice crystals can be identified using scanning electron microscopy

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Motivation & Background

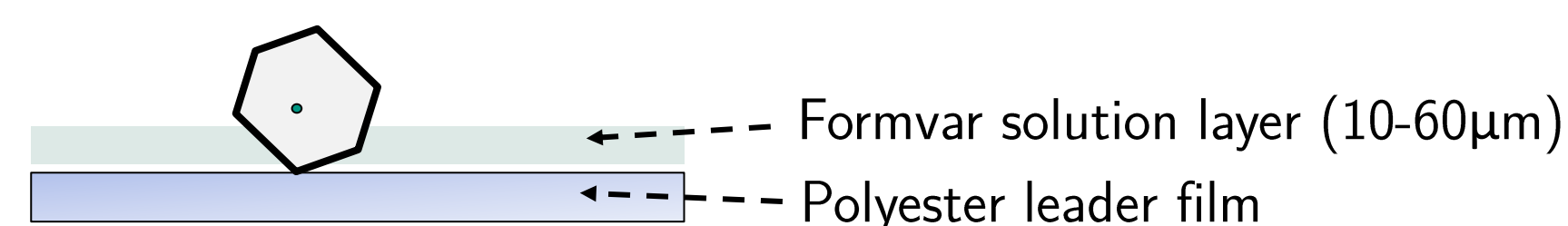
- Identifying the specific ice nucleating particles (INPs) inside individual atmospheric ice crystals remains difficult, in contrast to the established bulk INP characterization methods (on- and offline)
- Early work (e.g. Rucklidge 1965) identified clay INPs in ice crystal replicas via electron diffraction, but recognized elemental microanalysis as the "missing link" for definitive identification
- Our Approach: Reviving this "hidden treasure" concept by applying modern Environmental SEM (ESEM) and energy dispersive X-ray (EDX) spectroscopy to locate and identify INPs and background aerosols preserved inside the replicas



Ice crystal replica with unidentifiable central nucleus (Rucklidge, 1965).

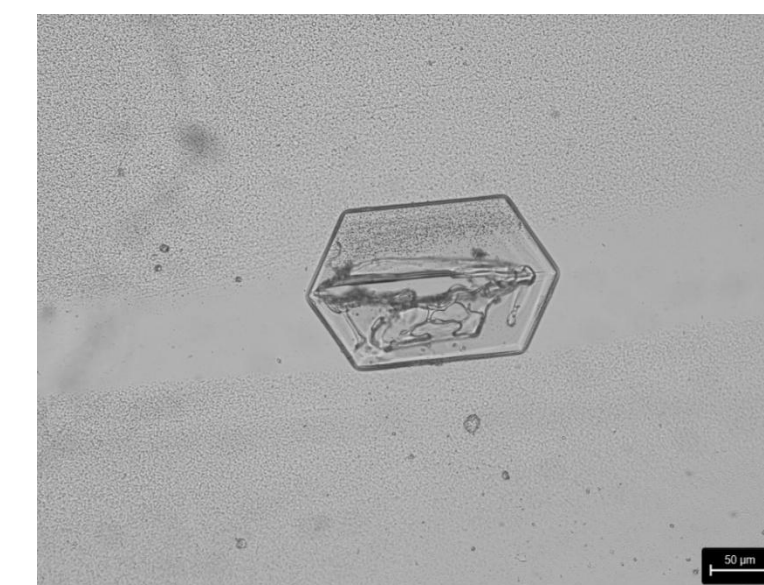
Formvar Replication Technique

- Introduced by Vincent Schaefer (1941) to preserve ice crystal morphology
- Crystals are captured in dissolved polyvinyl formal resin (Formvar); solvent evaporation leaves a permanent replica of captured ice crystals, allowing size and crystal habit analysis
- Residual Ice Nucleating Particles (INPs) can remain trapped within the replicas
- Captured on moving polyester photographic leader film in balloon-borne probes or probes installed in controlled laboratory environments (e.g. AIDA chamber)



Characterization & Analysis

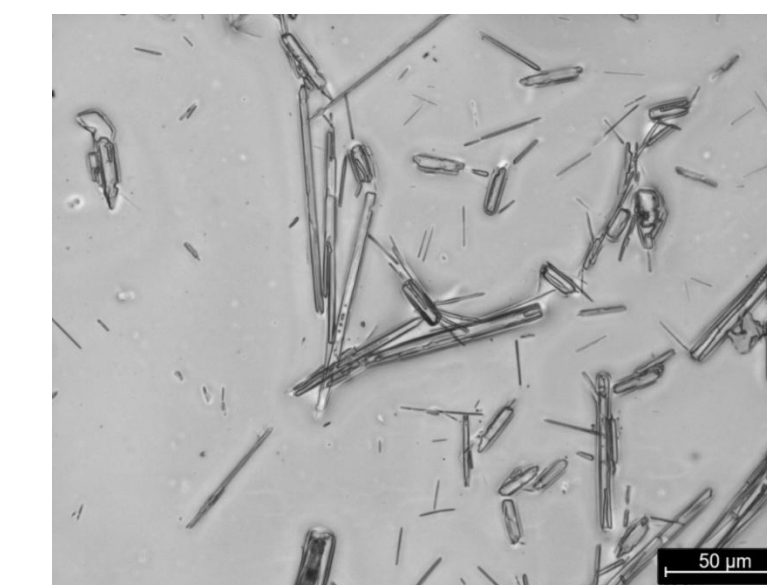
Optical Microscopy



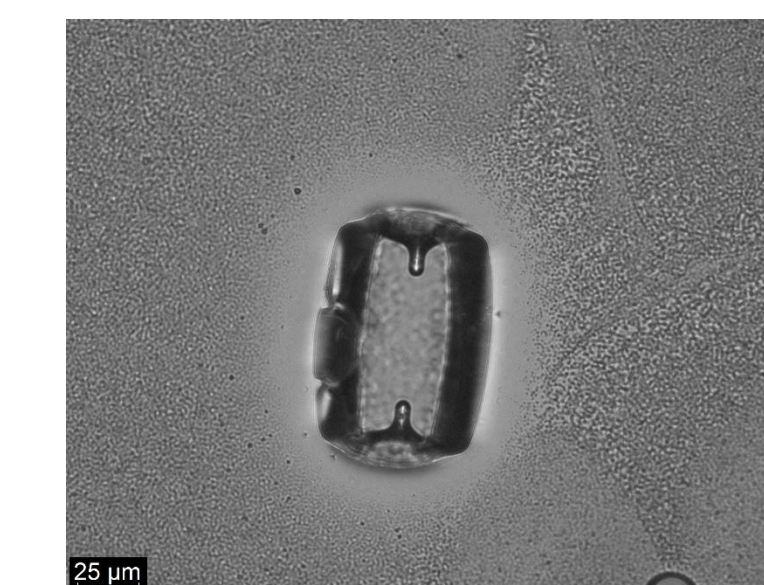
Replica of a plate ice crystal from a balloon-borne replicator ascent near Lindenberg, Germany (Oct 7, 2016) by TROPOS team. Collected within fully glaciated clouds at 8 km to 10 km altitude at temperatures below -30 °C.



Bullet rosette replica. Sampled during the TROPOS replicator campaign (Oct 7, 2016).

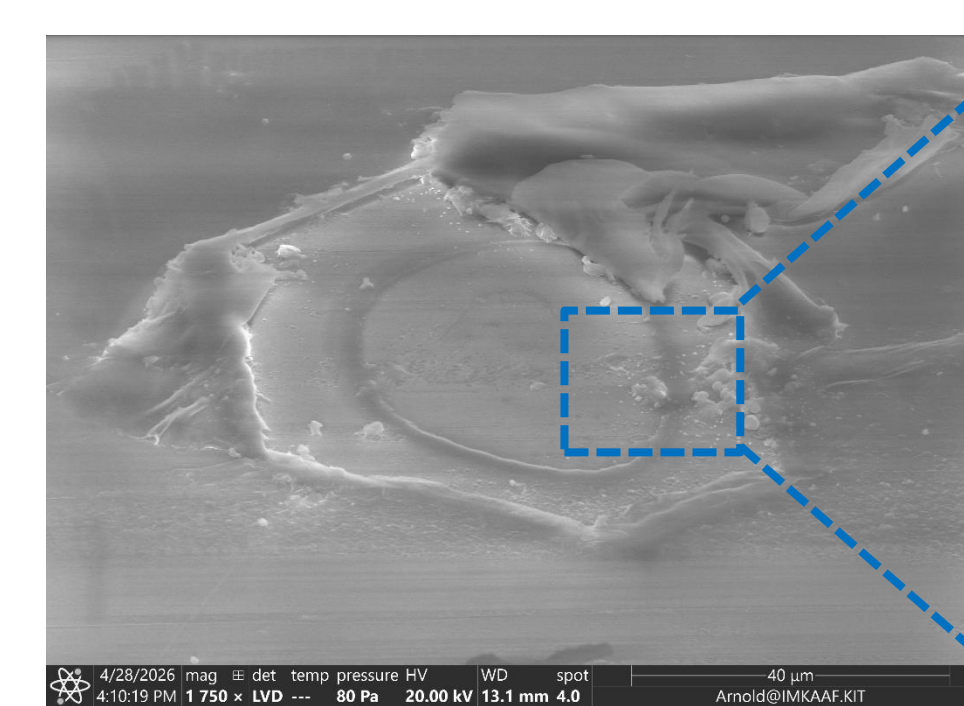


Sheath and needle replicas. Ice formed in the AIDA cloud chamber during the RICE01 campaign (Nov 29, 2012). Ice crystals were formed at -39°C using Arizona Test Dust (ATD) as INPs.

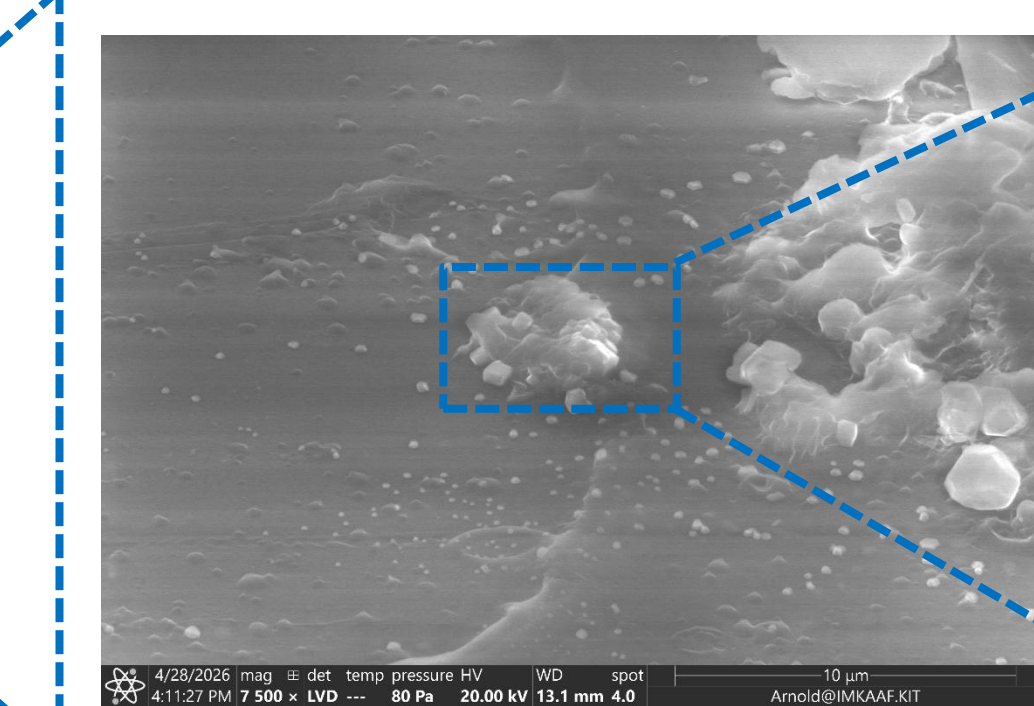


Hollow column replica. Collected at research station UFS Schneefernerhaus (Zugspitze), Germany (April 14, 2026) at -2 °C.

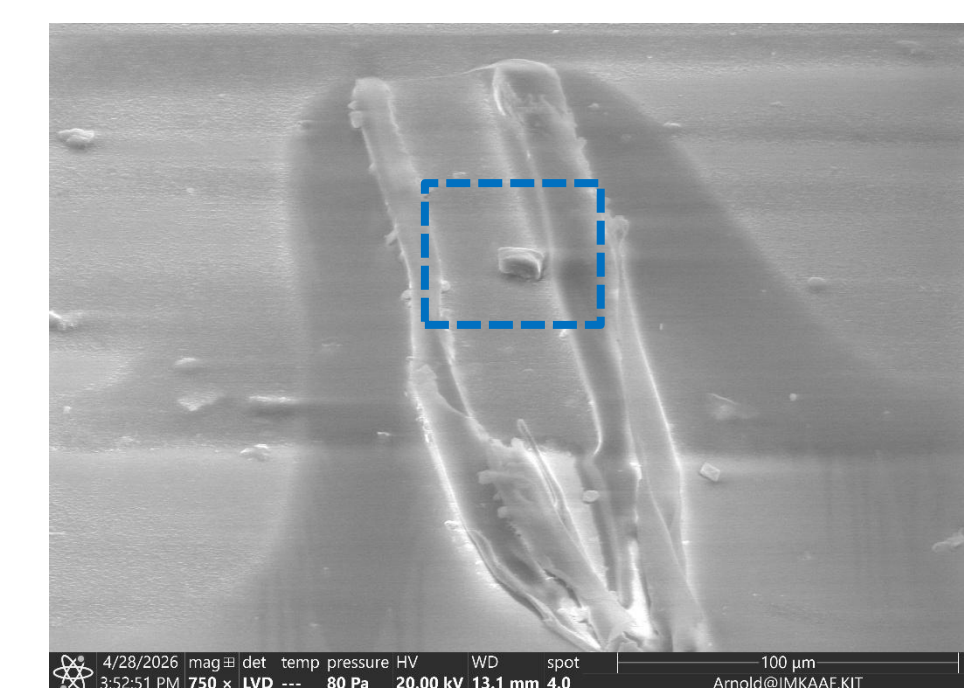
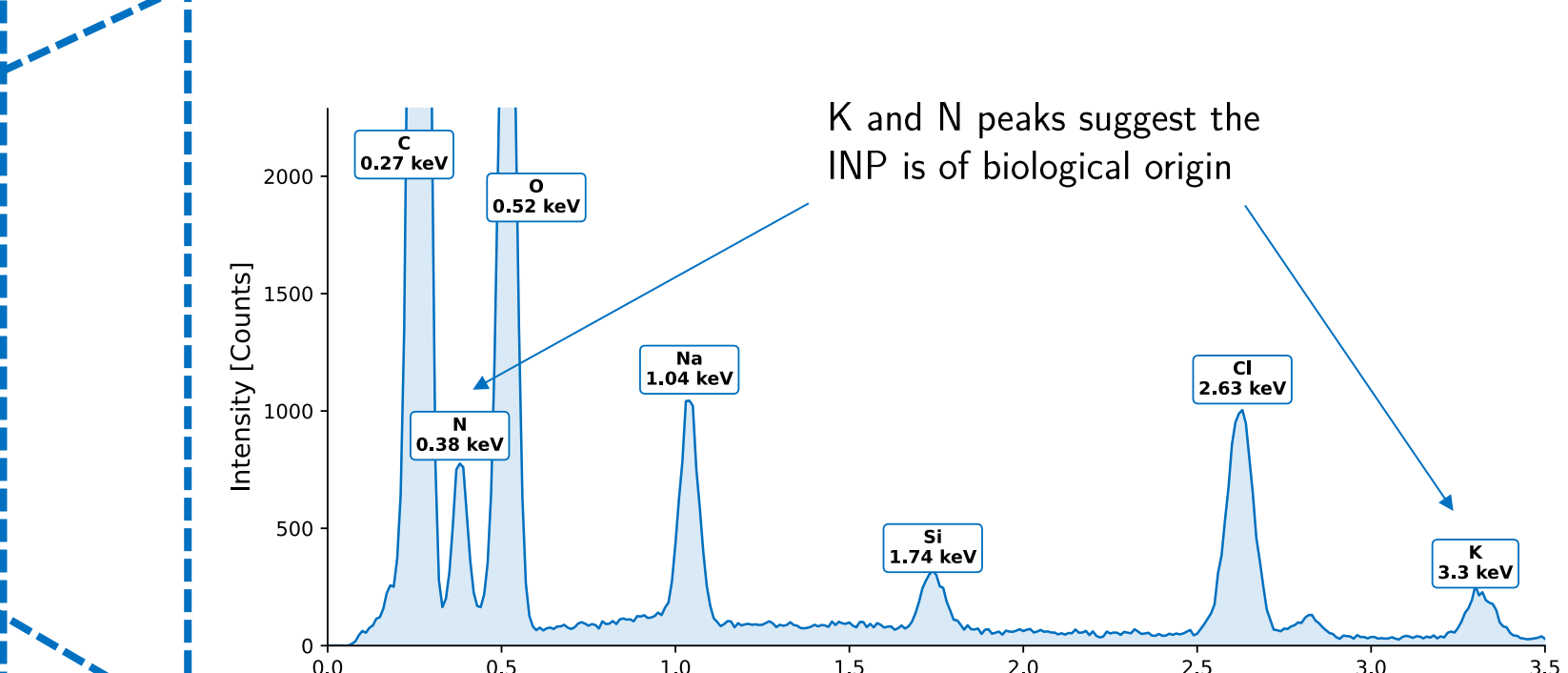
ESEM & EDX Spectroscopy



Replica of a plate crystal sampled during the TROPOS replicator campaign (Oct 7, 2016).



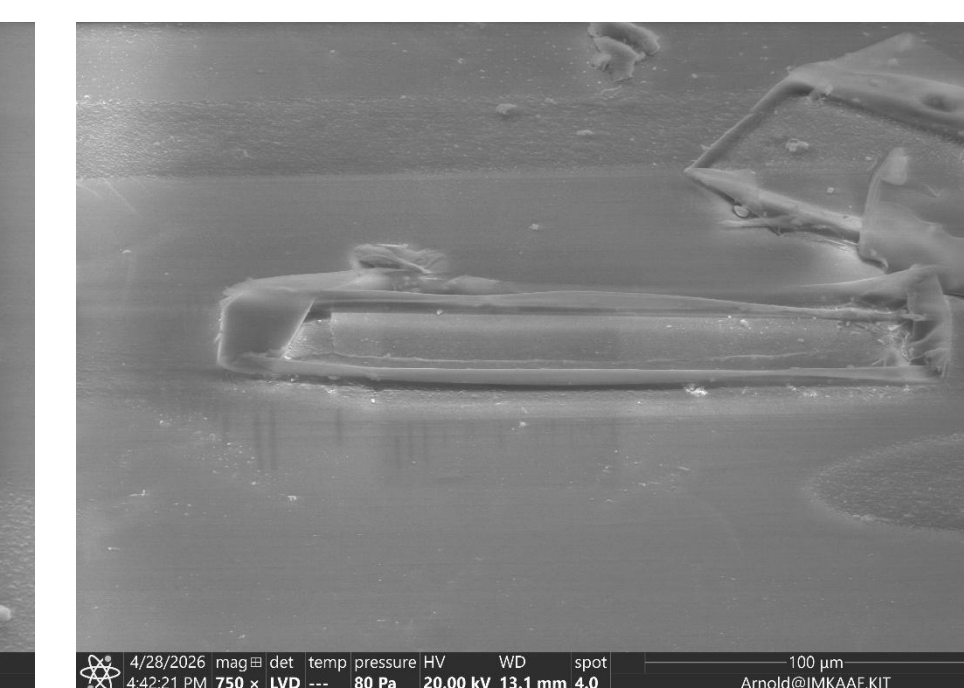
Replica of a "bullet" ice crystal with a quartz particle found within the replica. Sampled Oct 7, 2016 (TROPOS).



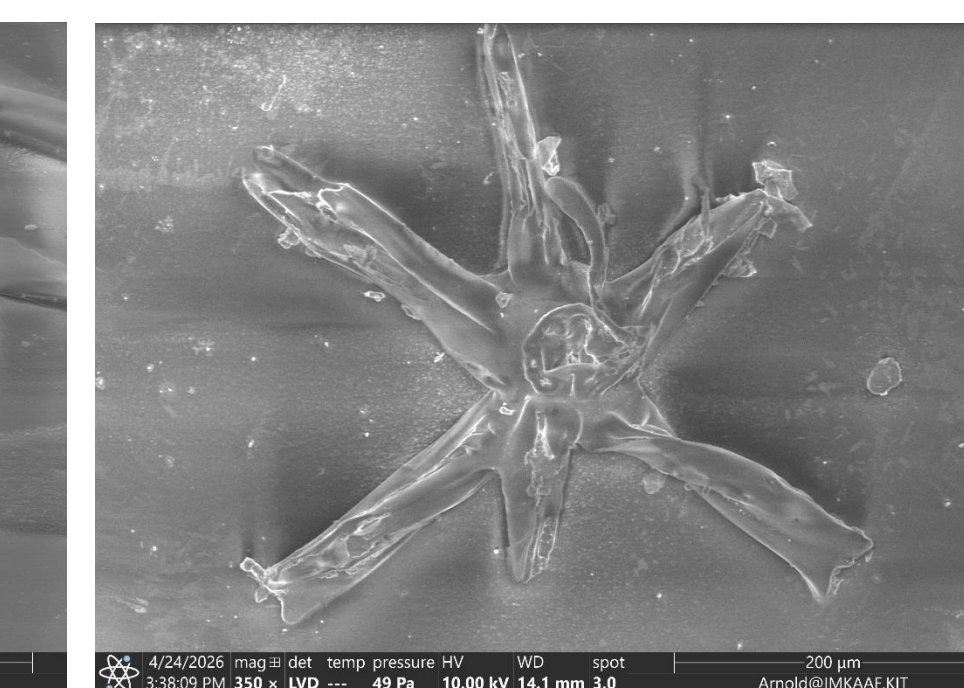
Replica of a "bullet" ice crystal with a quartz particle found within the replica. Sampled Oct 7, 2016 (TROPOS).



Replica of a plate ice crystal. The particle found within the replica shows K and N peaks similar to the EDX-spectrum shown above.

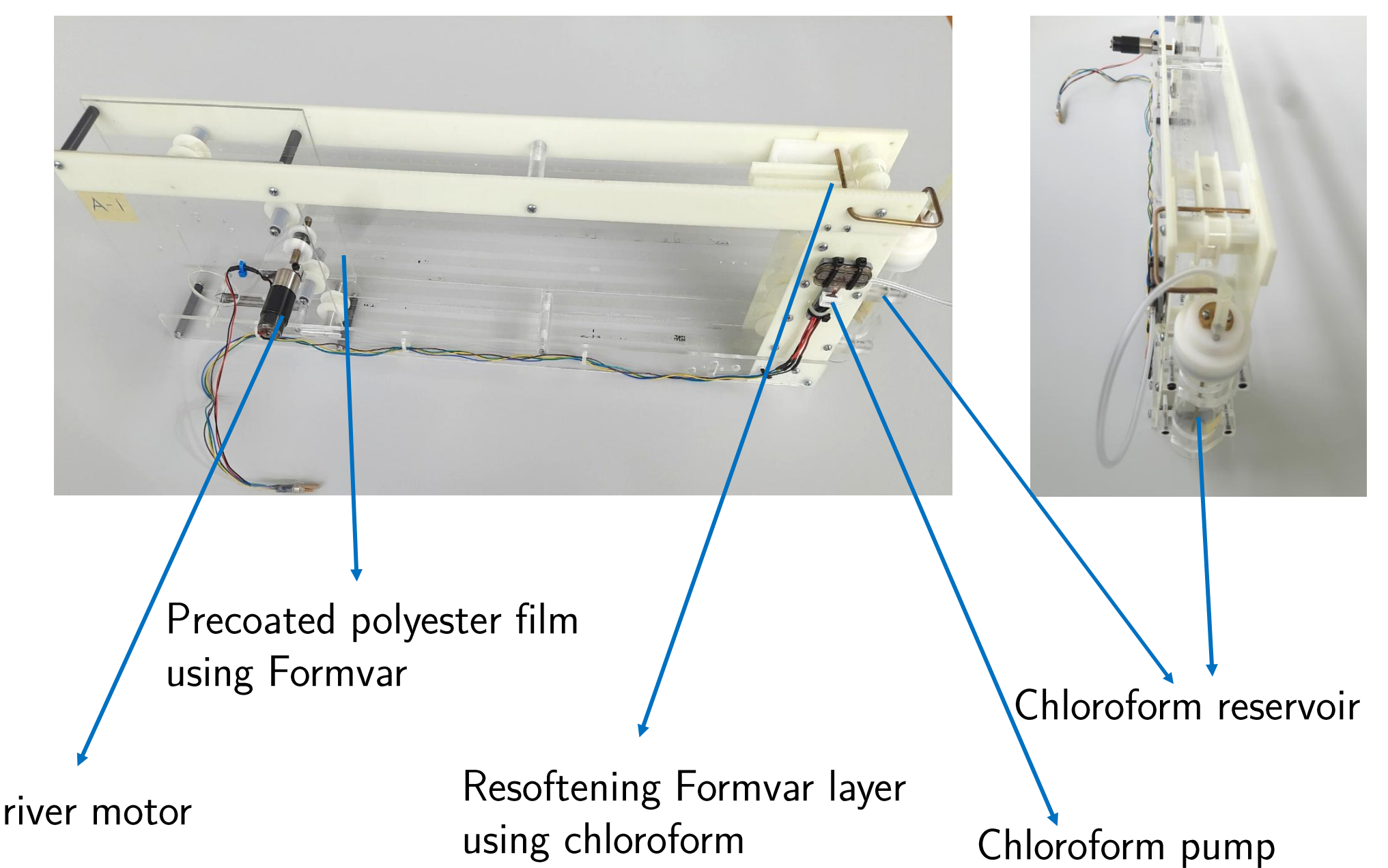


Replica of a column. No particles could be identified inside the replica.



Replica of a bullet rosette. Overlying Formvar film prevents particle identification in the central core.

Experimental Setup



Outlook

- Airborne measurements of ice crystal habits and glaciogenic AgI-seeding particles in mixed-phase clouds (with CloudLab, ETH Zürich)
- Comparison of INP-containing ice crystals with background aerosol and total ice crystal concentrations visible on the Formvar film
- Intercomparison of aerosol particles collected on Nuclepore® filters and those captured inside ice crystals on the Formvar film (simultaneous sampling)

References

- Schaefer, V. J.: A method for making snowflake replicas. *Science*, 93 (1941) pp. 239-240.
- Kumai, M.: Electron-microscope study of snow-crystal nuclei. *J. Atmos. Sci.*, 8 (1951) pp. 151-156.
- Koenig, L. R.: The chemical identification of silver-iodide ice nuclei: a laboratory and preliminary field study. *J. Atmos. Sci.*, 17 (1960) pp. 426-434.
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- Rucklidge, J.: The Examination by Electron Microscope of Ice Crystal Nuclei from Cloud Chamber Experiments. *J. Atmos. Sci.*, 22 (1965), pp. 301-308.