NTNU

Norwegian University of
Science and Technology

Microstructure of sea spray ice
Results from MICROSPRAY

Annual meeting 2022

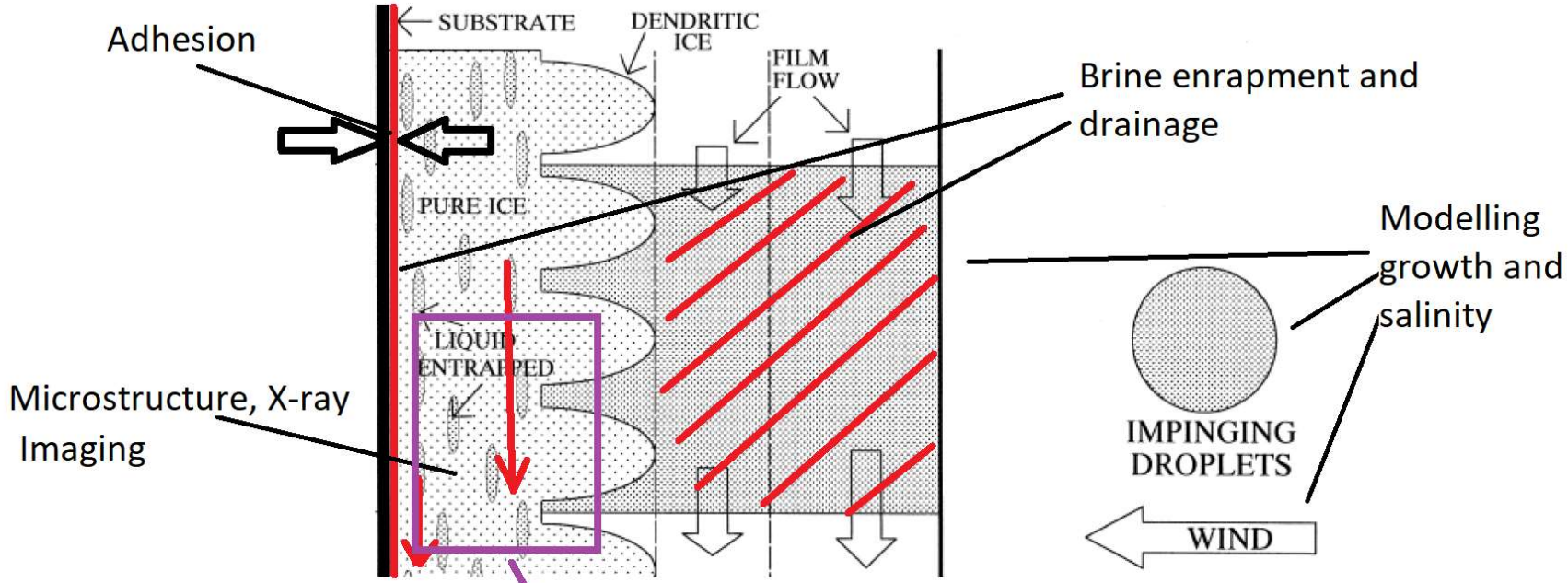
Trondheim, Scandic Lerkendal, 22.09.2022

Sönke Maus

Overview

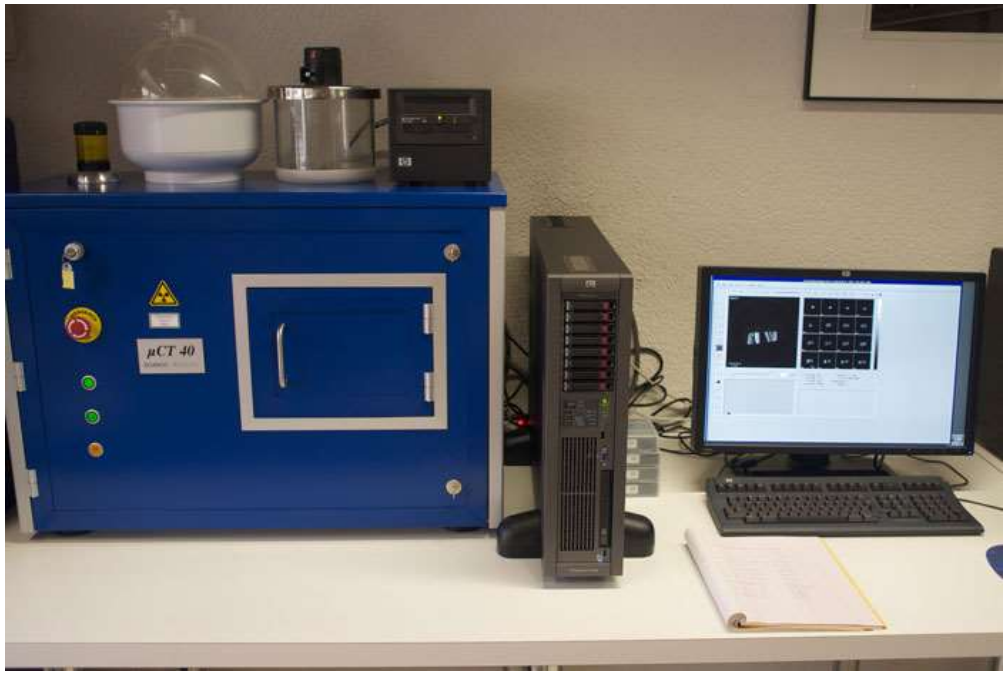
- Methods and objectives in MICROSPRAY
- X-ray computed microtomography (μ-CT)
- Learning from μ-CT of other saline ice types:
  1. Sea ice
  2. Frost salt scaling of concrete
- μ-CT imaging of saline spray ice (ice tank)
- Some field samples
- Challenges
- Modelling concepts and ideas

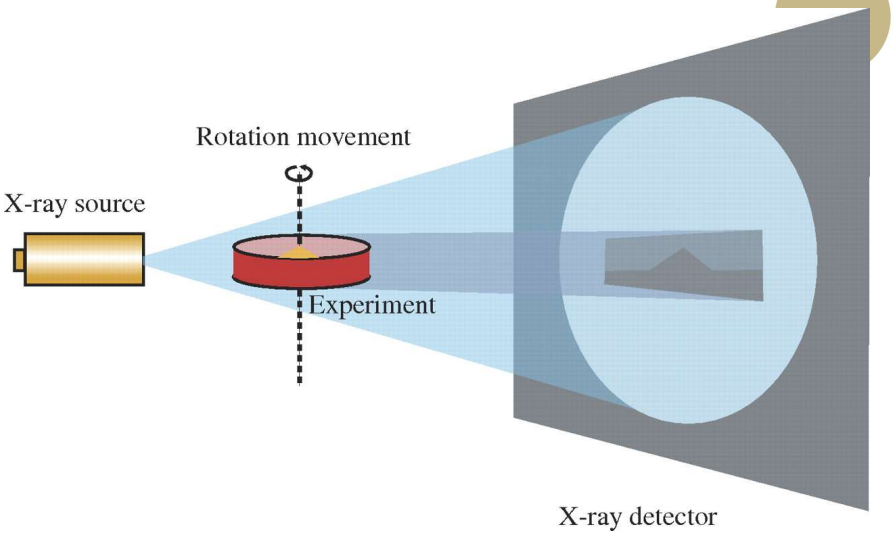
Methods applied/successful



XRT imaging
some lab + field ice
(4 cm, 25 micron resolution)

X-ray Computed Micro-Tomography

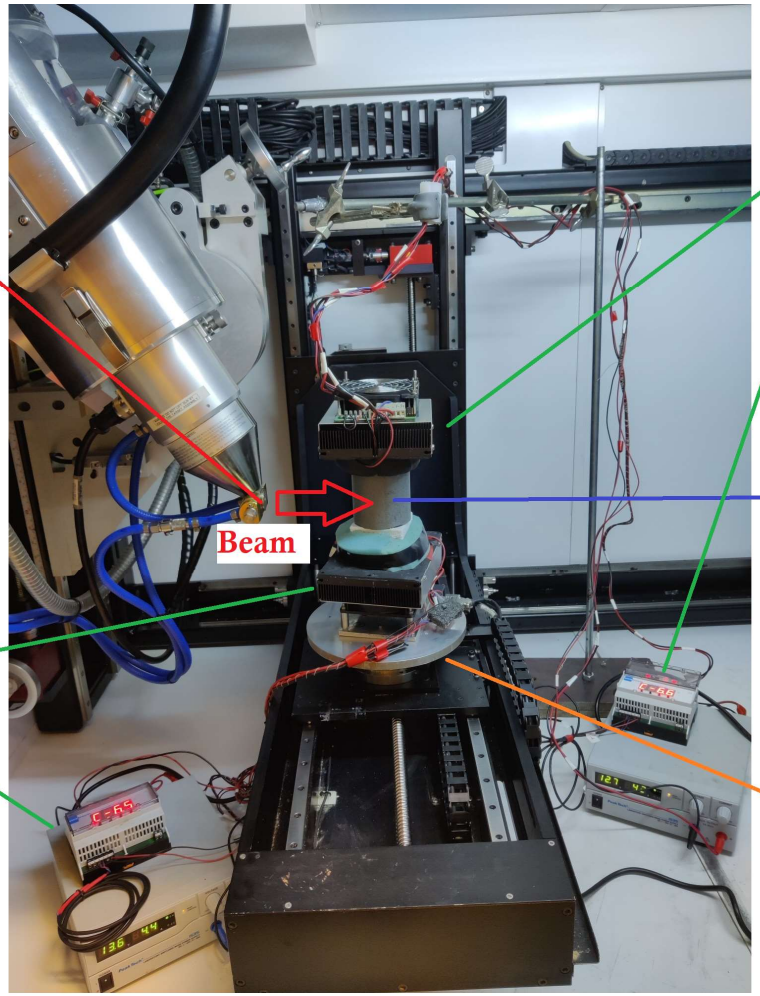




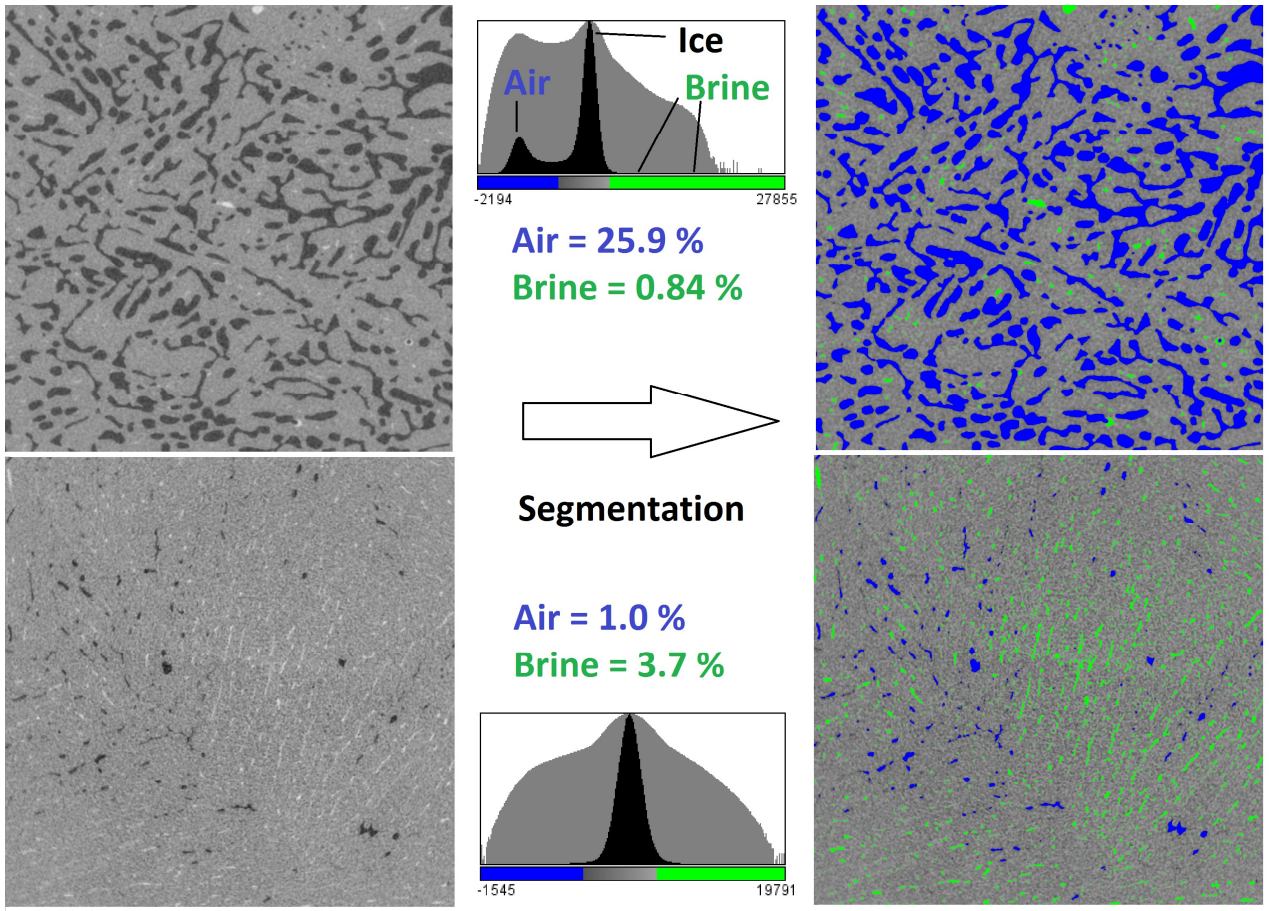
(From Kervyn et al., 2000, Geosphere)

This work: µCT40 from Scanco Medical in cold room

Setup at NTNU Physics (Nikon CT)

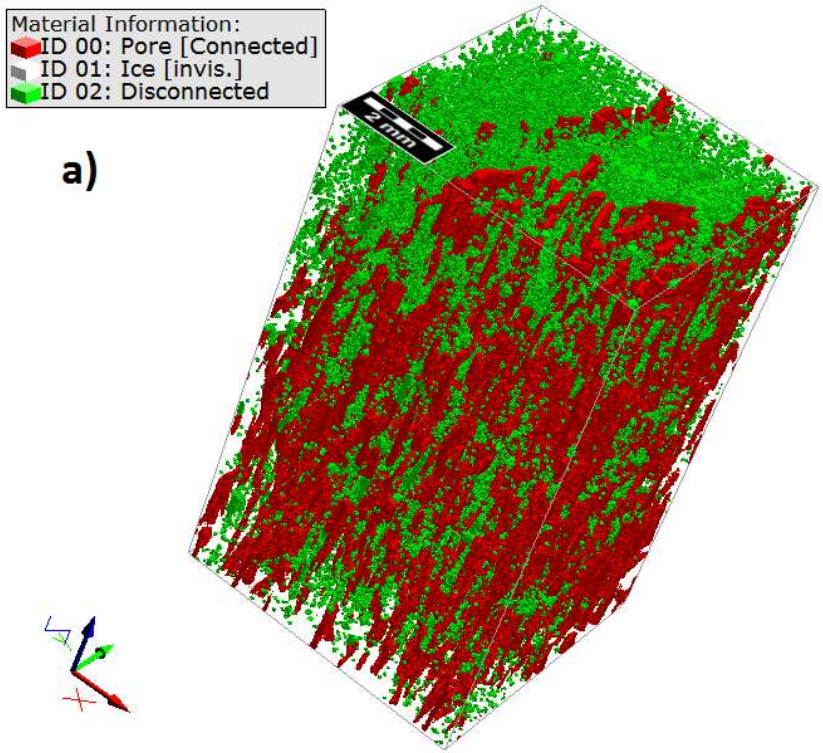


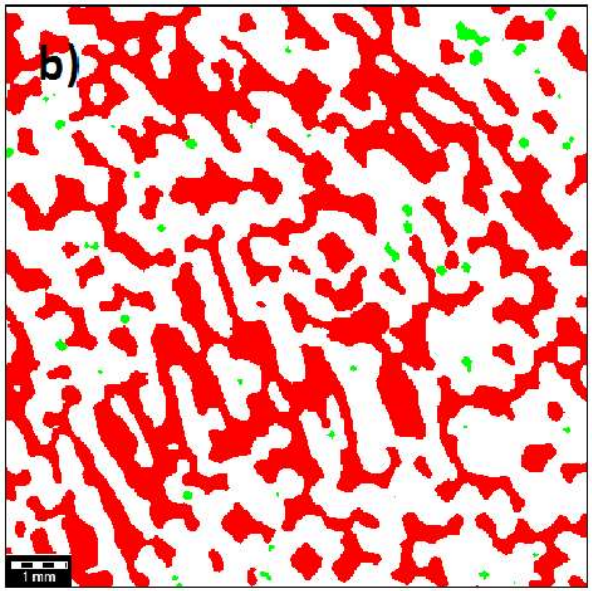
Sea ice: Ice-air-brine segmentation

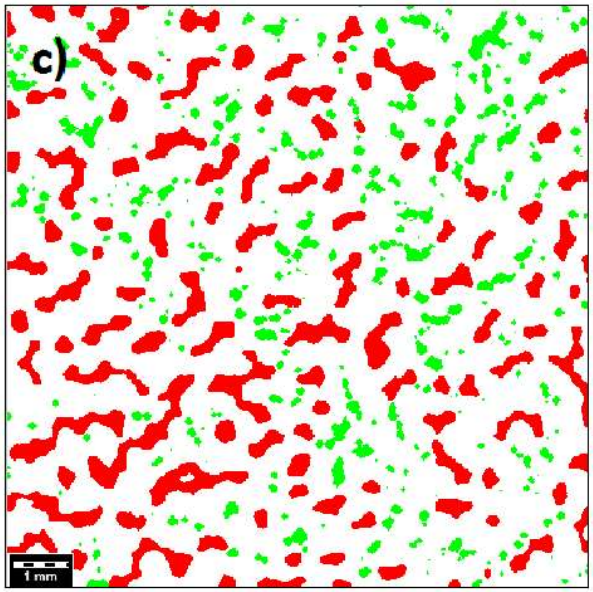


From Maus et al., The Cryosphere, 15, 4047-4072, 2021

Example: Sea ice pore connectivity

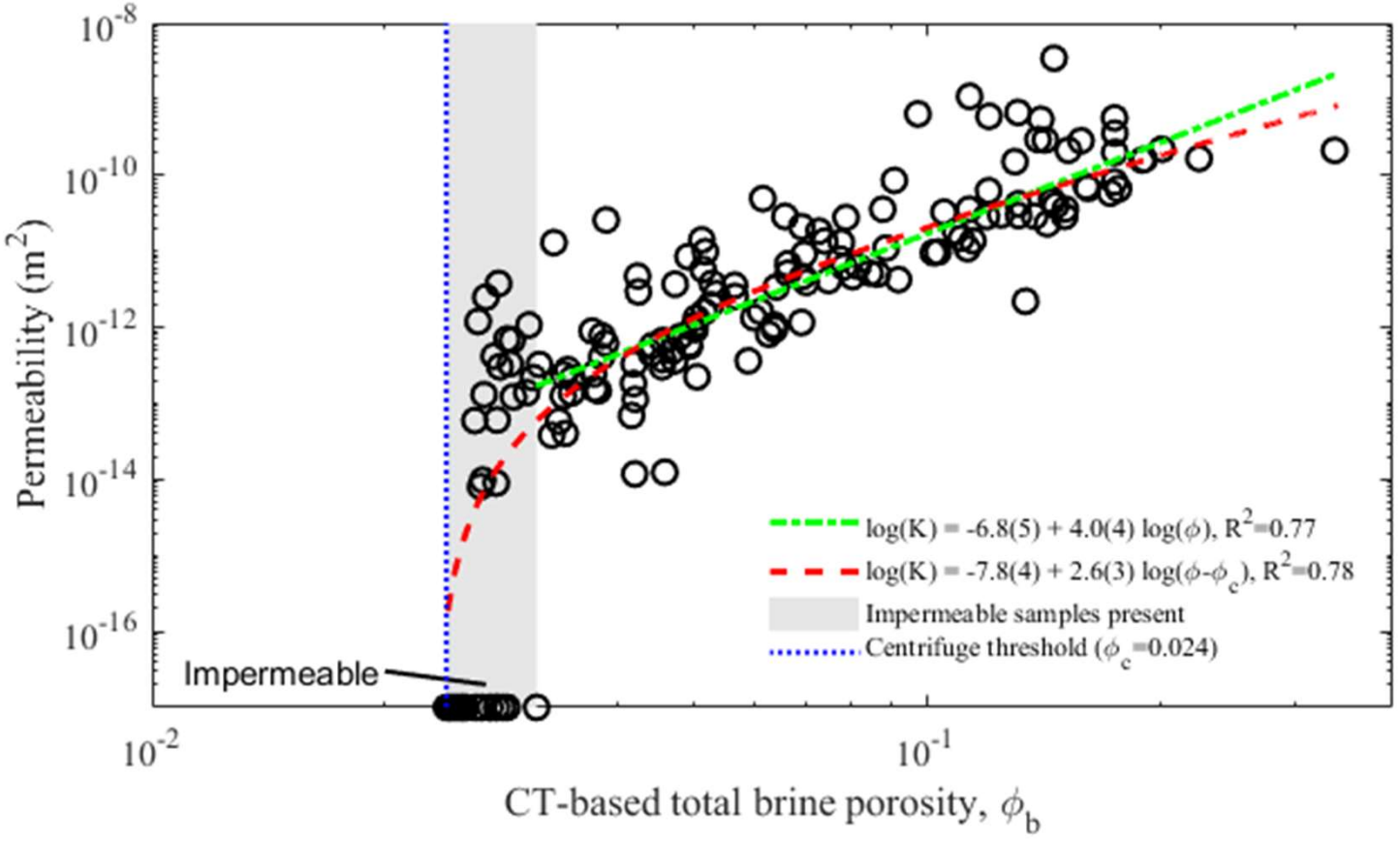






From Maus et al., The Cryosphere, 15, 4047-4072, 2021

Sea ice permeability- porosity threshold

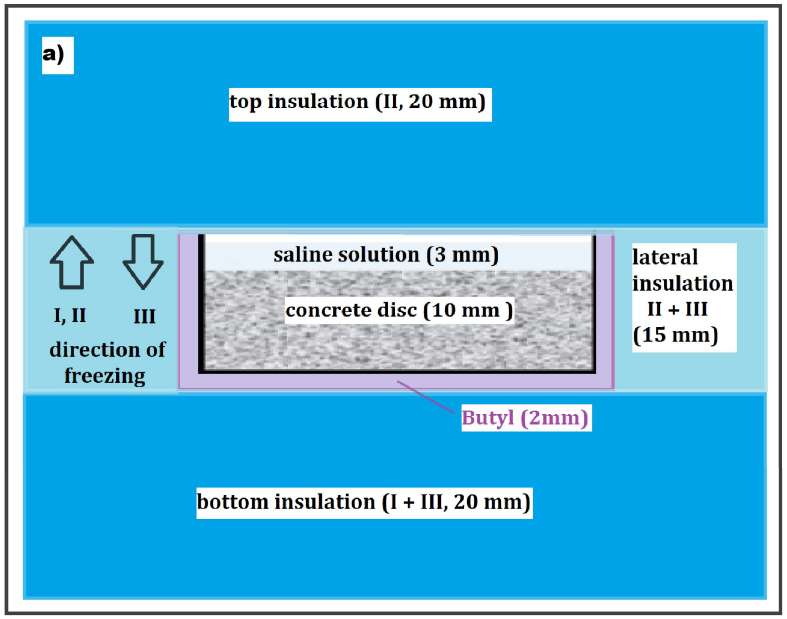


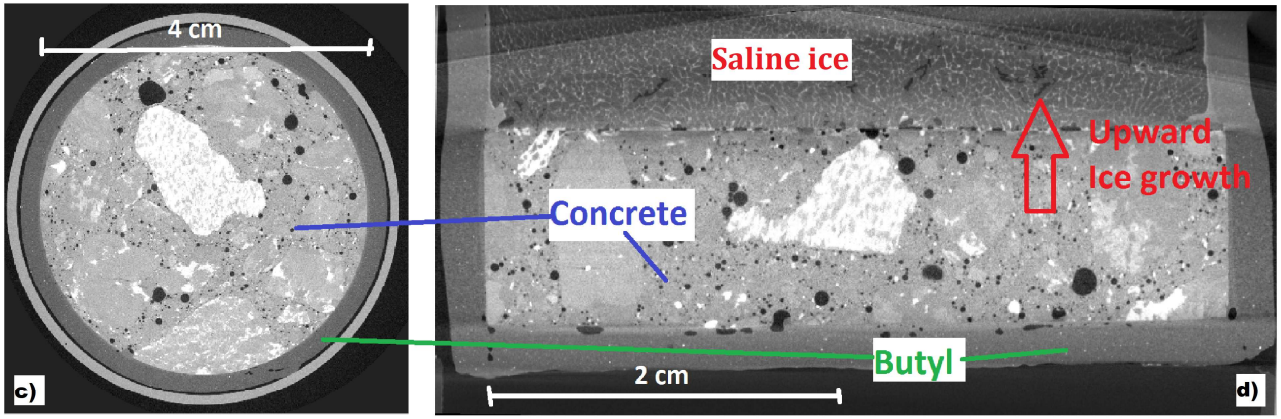
Young sea ice is impermeable at 2-3 % brine porosity

Other studies, ice types, directions: 5-4 % brine porosity

(From Maus et al., The Cryosphere, 15, 4047-4072, 2021)

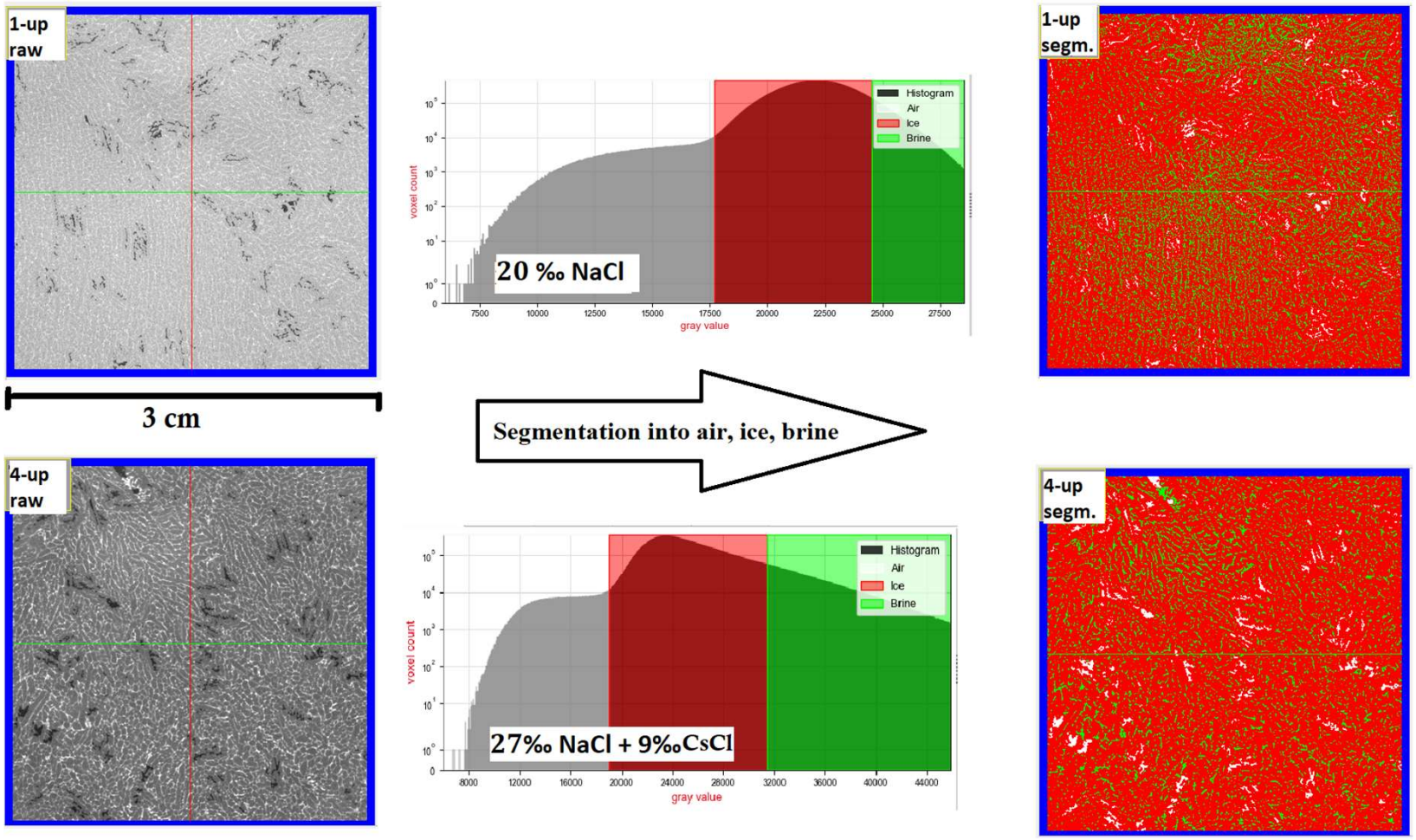
Second example
Frost salt scaling of concrete





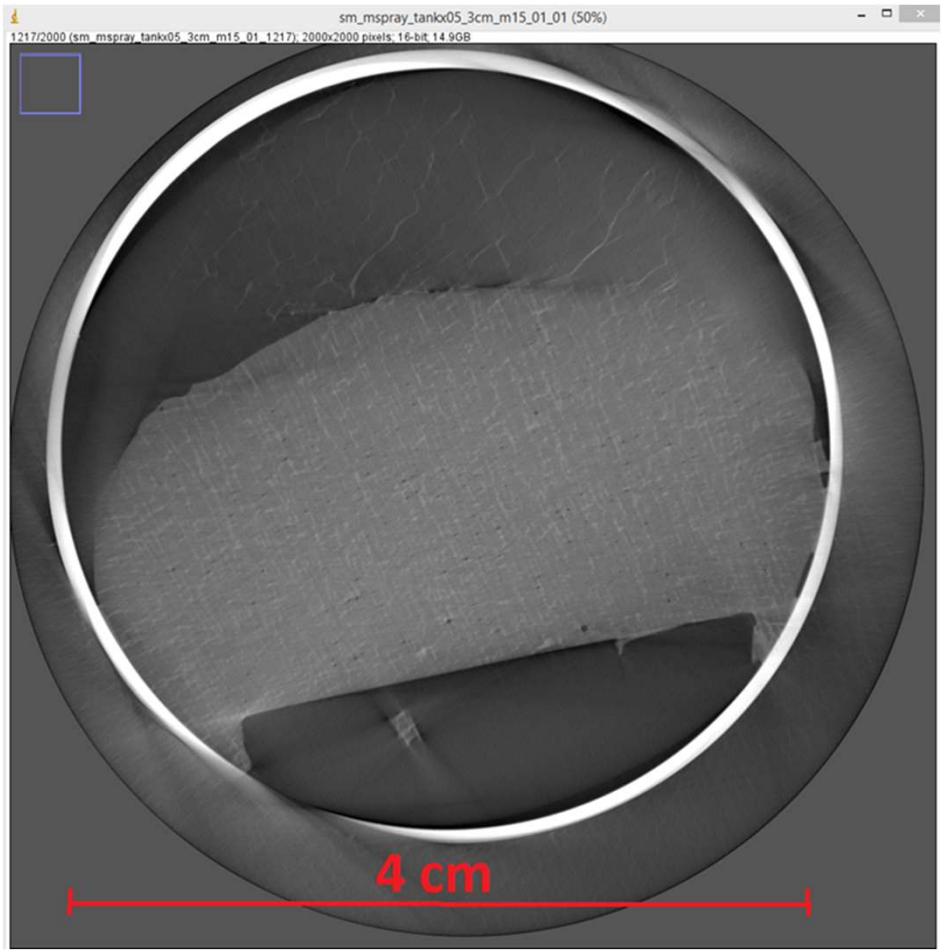
From Maus et al., X-ray micro-tomographic imaging and modelling of saline ice properties in concrete frost salt scaling experiments, Maz 2022, in review at Cold Regions Science and Technology

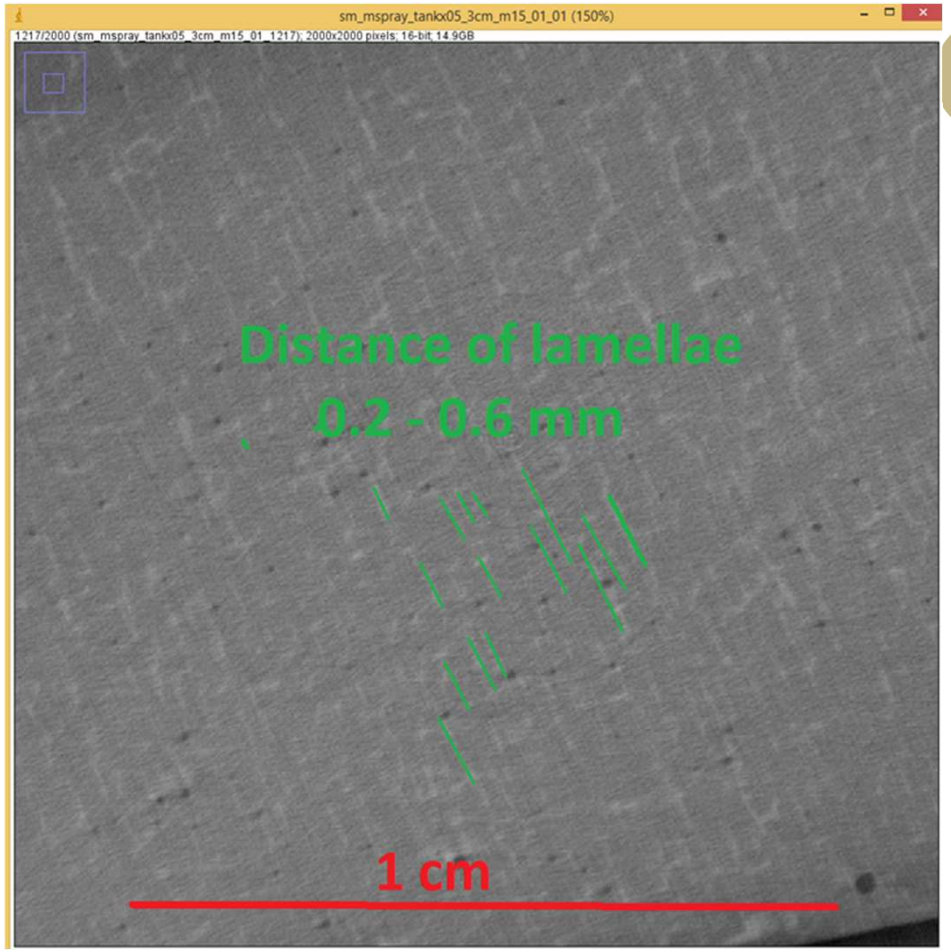
Frost salt scaling of concrete



(from Maus et al., May 2022, in review at Cold Reg. Sci. Technol.)

Saline spray ice, NTNU ice tank





Spray ice versus sea ice

- Saline ice (sea ice, saline ice on concrete, sea spray ice) freezes with a lamella-like structure
- Lamellae in sea spray ice have a smaller spacing than in sea ice

  (~ factor 2-3, minimum 0.2 mm compared to 0.4 mm)
- Difficult to detect with laboratory-based CT imaging settings (5 cm field of view, 25 µm pixel/voxel size)
- → Synchrotron-based imaging

Larger samples, ice tank



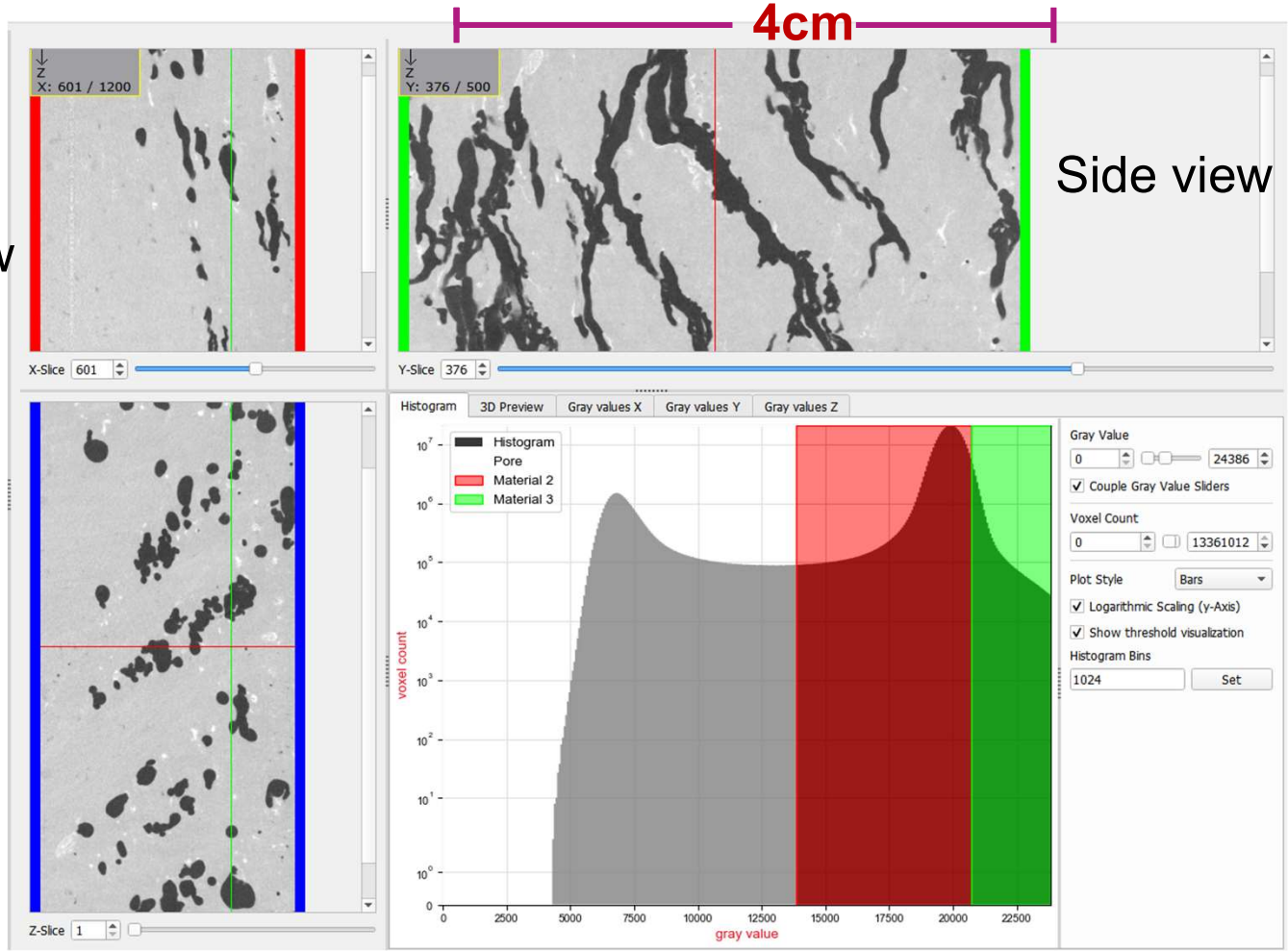
Tests with plates of different area:
3 x 3, 6 x 6, 9 x 9, 12 x 12 cm²

From 6 x 6 cm²:
- Brine drainage channels
- Outflow stalactites

Larger samples (9 cm), ice tank

Side view

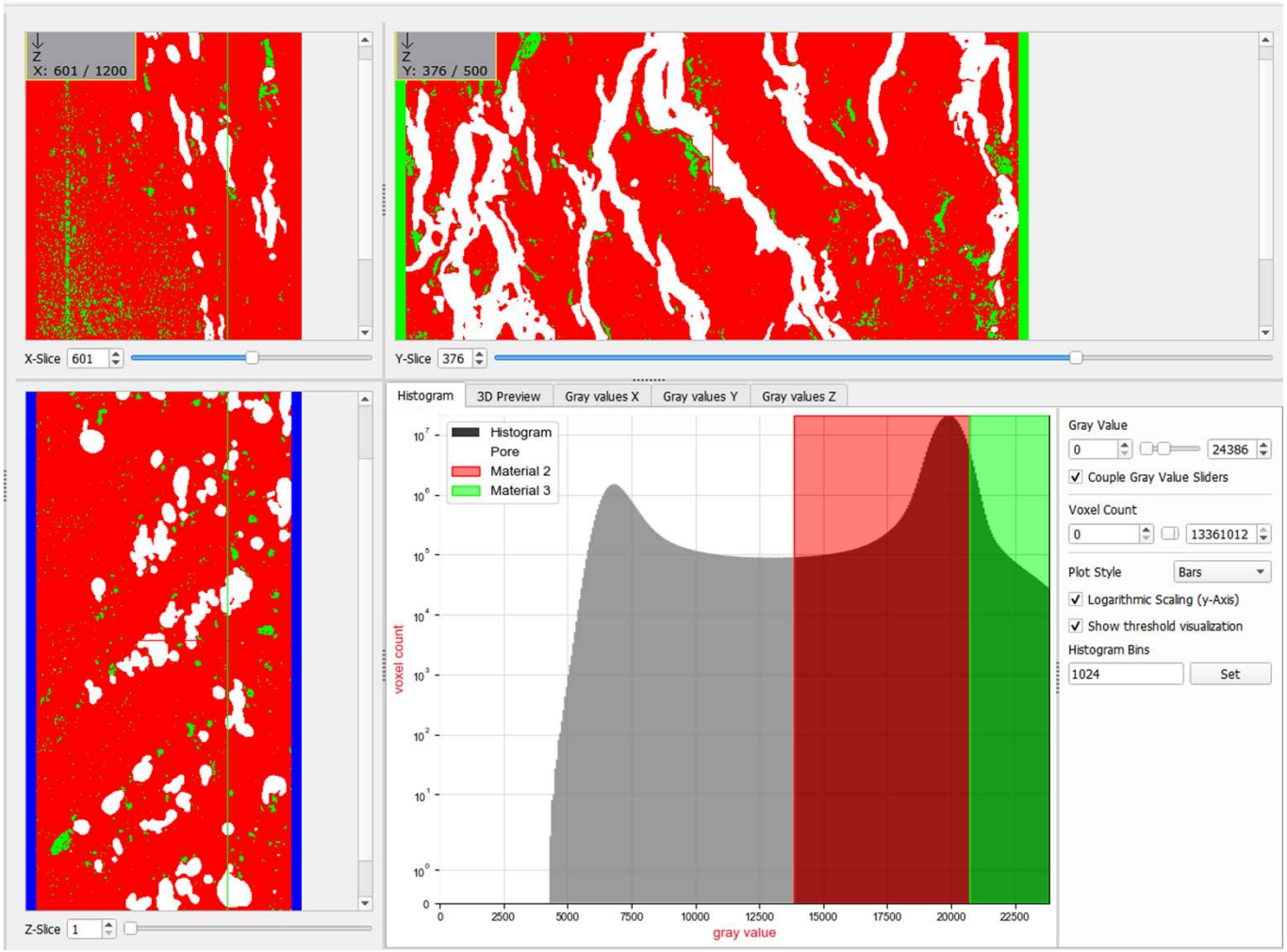
Top view



Drainage channels

- cm spacing
- larger at interface (ice-alumina)
- need some time to form

Spray ice segmented

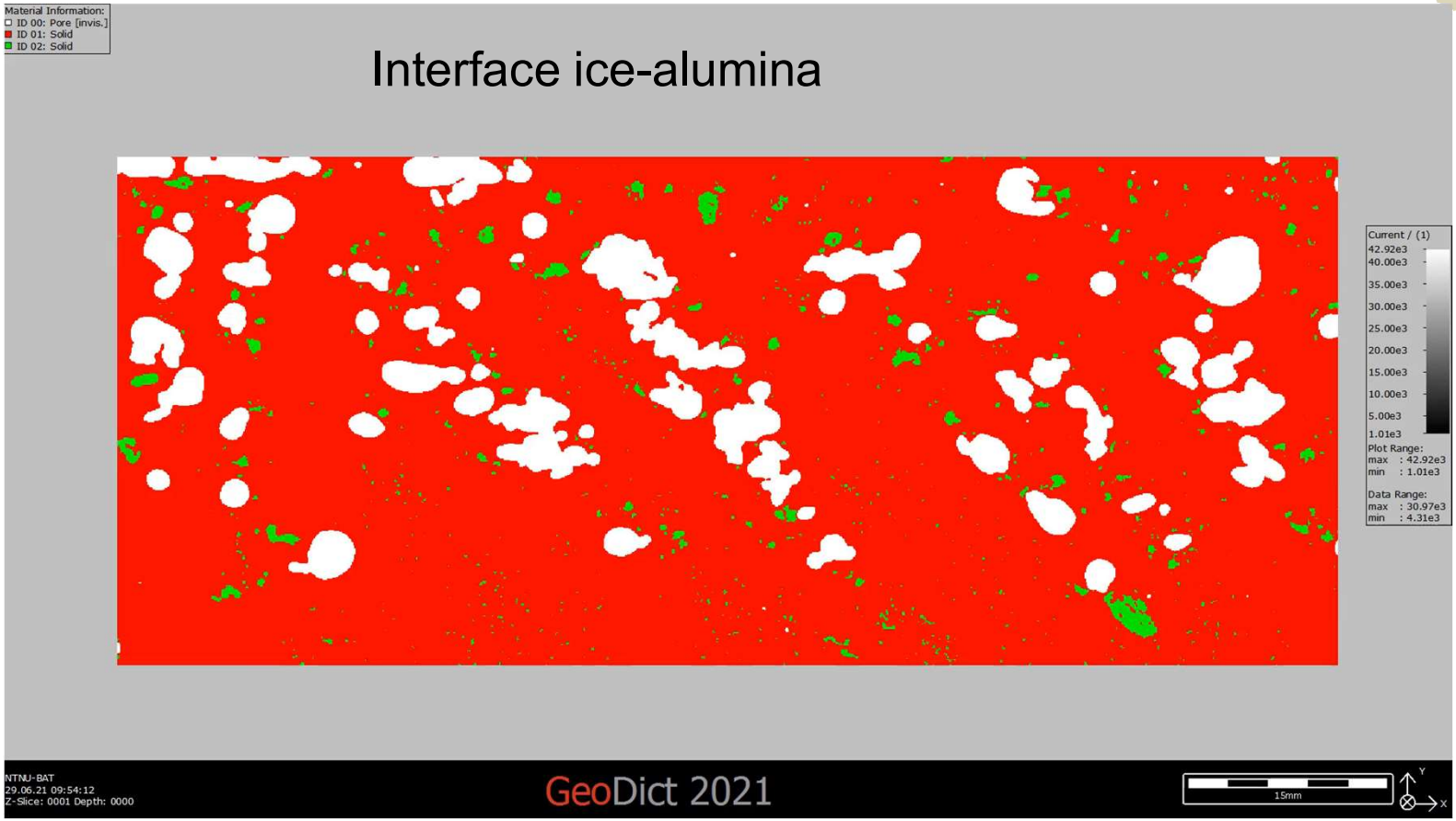


Drainage channels

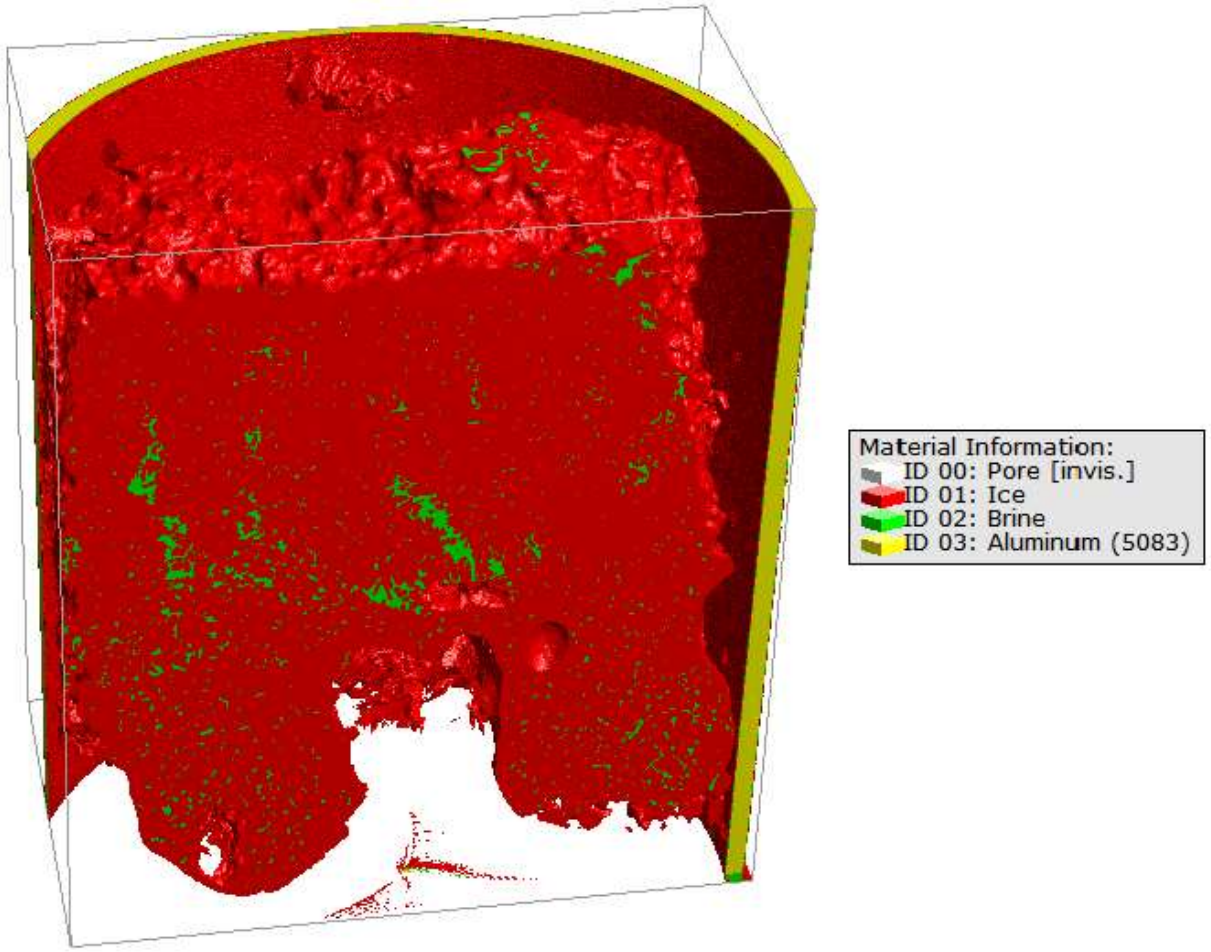
- cm spacing
- larger at interface (ice-alumina)
- need some time to form

View from top (in channel direction)

Growth direction



3D view from side



Svalbard samples, March 2021

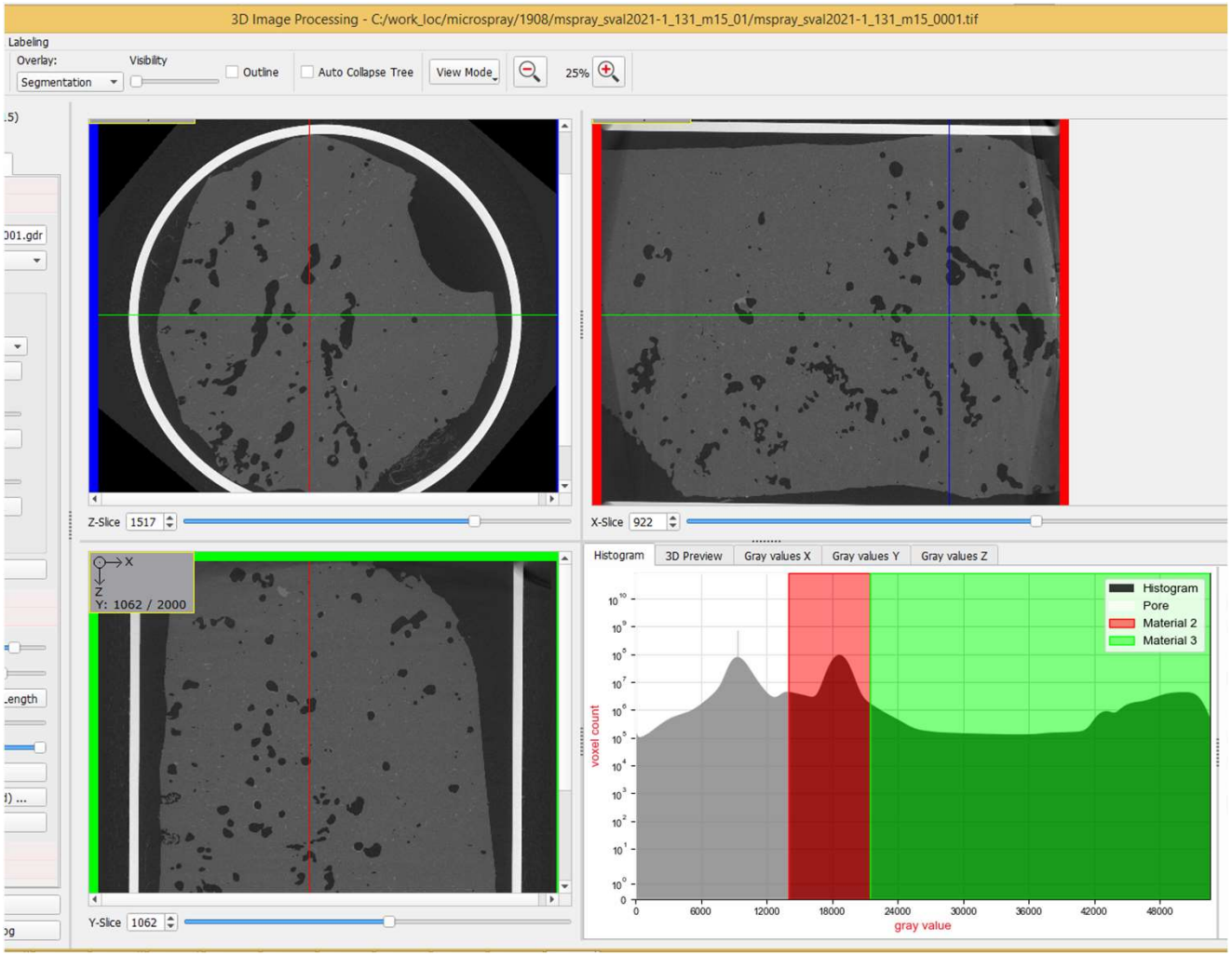




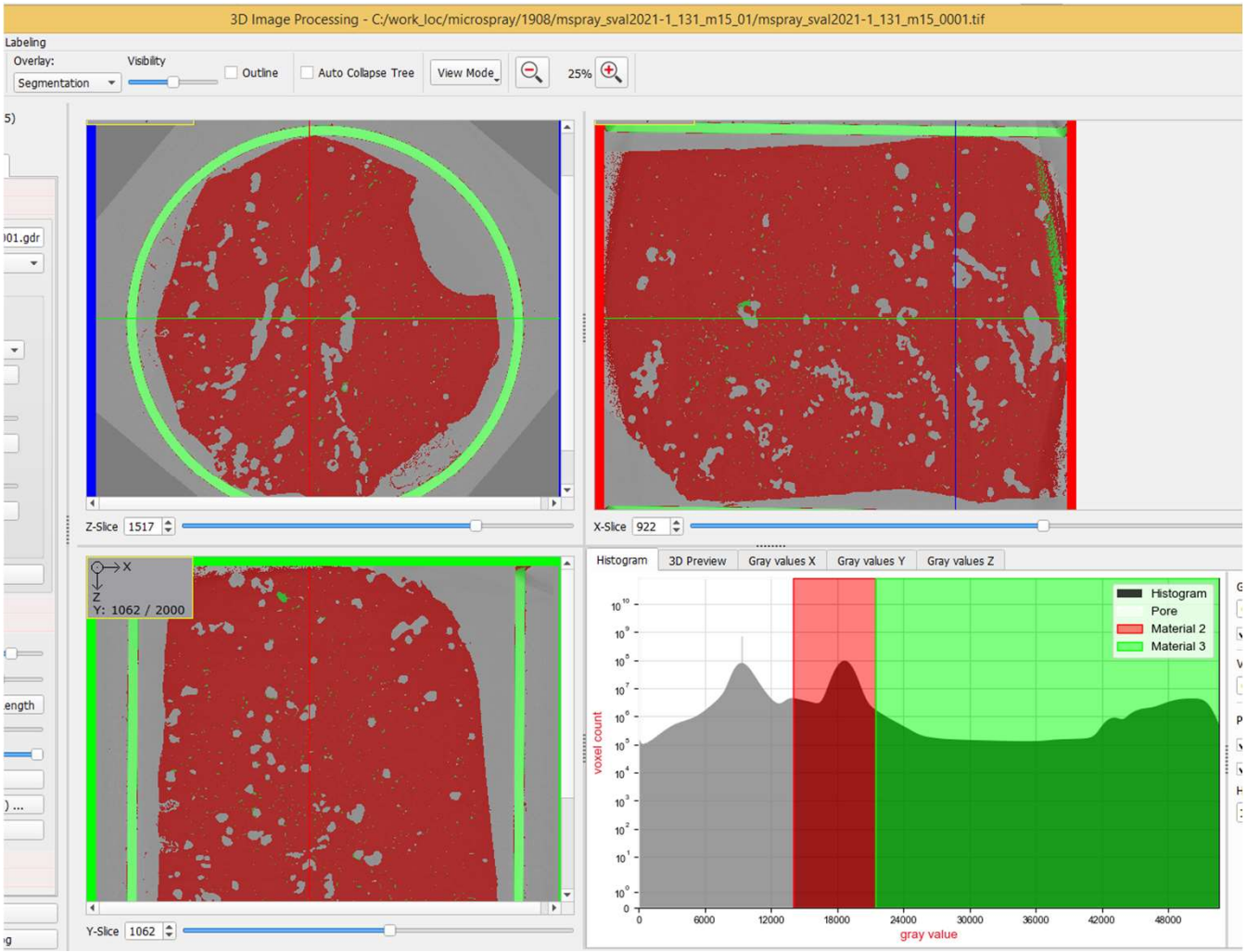


Thanks to
Juha Sipila Sørensen

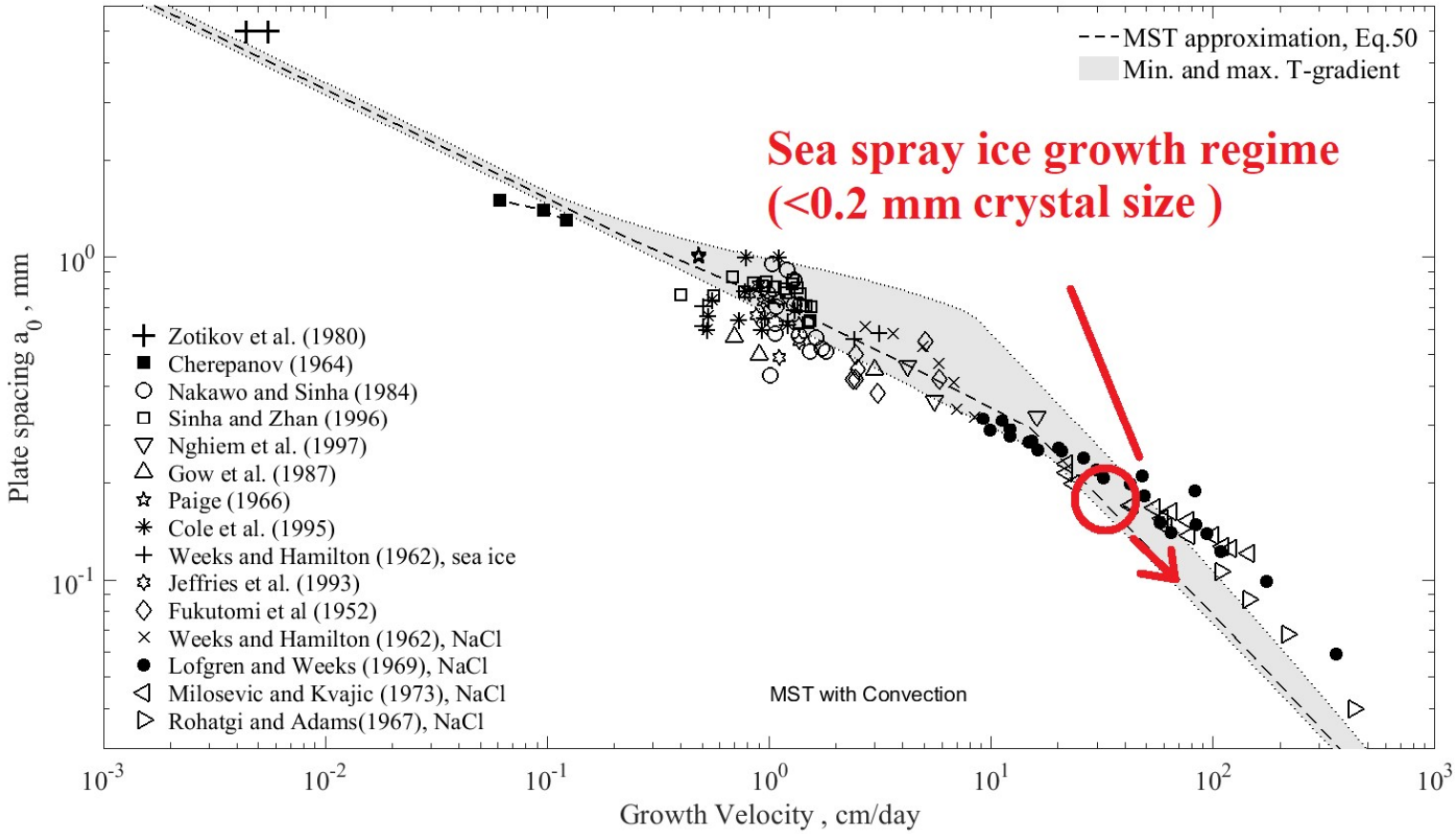
Svalbard samples



Svalbard samples segmented



Model basis: lamellae spacing



Morphological Stability
after Maus (2020)

Challenges

1. High resolution imaging of all pores
2. Crystal growth modeling (lamellae spacing, connectivity)
3. How do drainage channels form?
4. Brine at the interface (observation and modelling)
5. How does all this effect the bulk salinity

→ Higher resolution, smaller FOV

→ Synchrotron-based imaging

→ CFD simulation of pore network flow