Experimental and numerical study of heat and mass transport in snow in case of strong temperature gradient conditions

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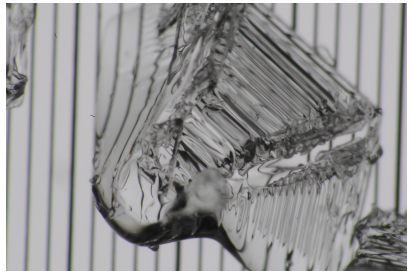
I – Motivations

Strong temperature gradient experiment

- Heat and mass transport
- Microstructure evolution
  - results in the form of vertical profiles



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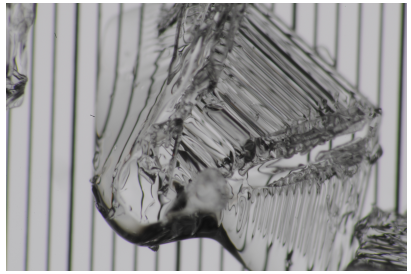
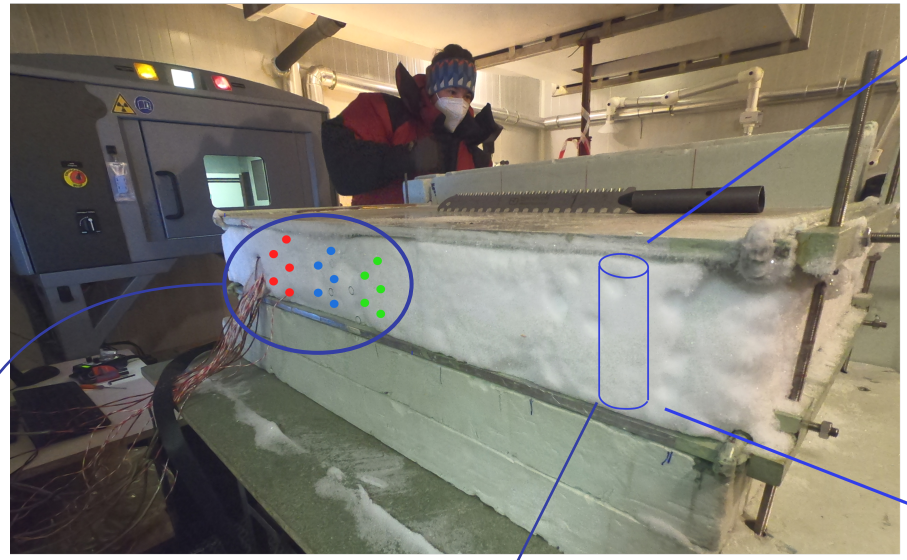
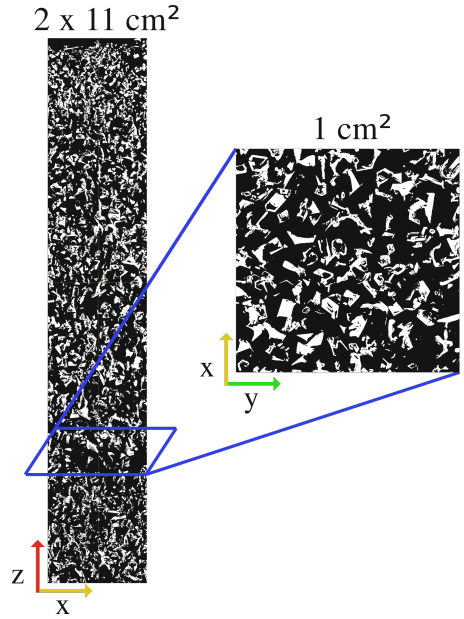


Evaluation with the macro-scale model of Calonne et al., 2015 which describes:

- diffusion of heat and water vapor
- source terms from phase changes

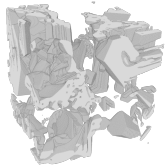
II - Design and measurements



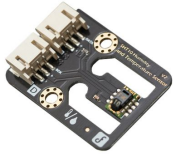


- Snow height: 14 cm
- ∇T ≈ 100 K/m with
  Ttop = -17°C
  Tbot = -2°C
- Duration = 3 weeks

Snow profiles tomographies (20 µm) at regular time steps



15 humidity and temperature sensors



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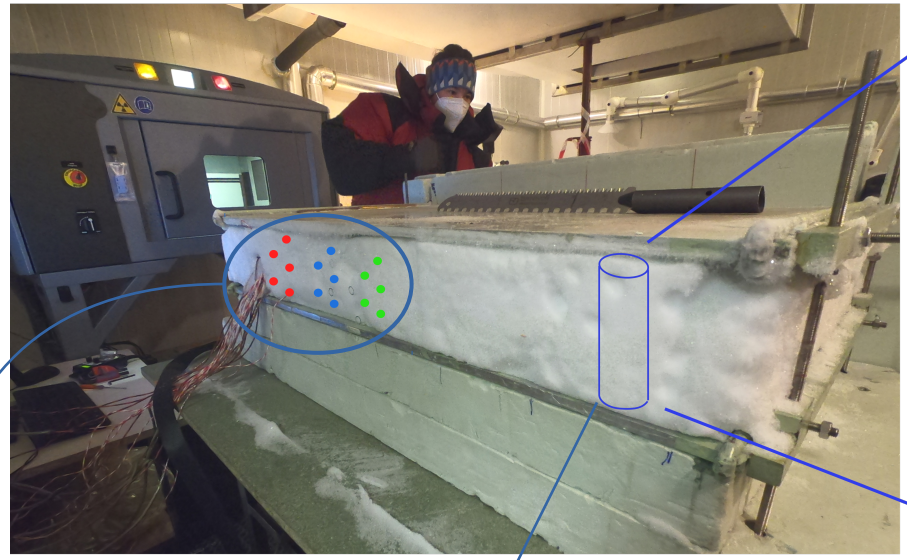

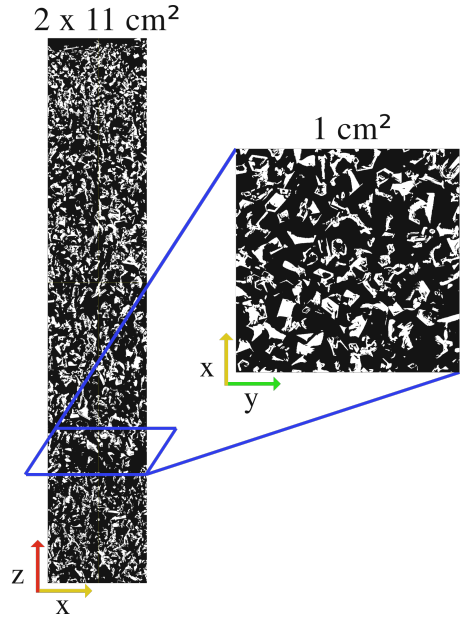

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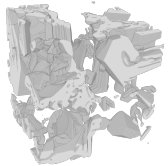

- Evolution of the microstructural properties (density, SSA, grain size)
- Evolution of the temperature and humidity conditions

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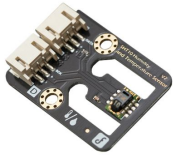
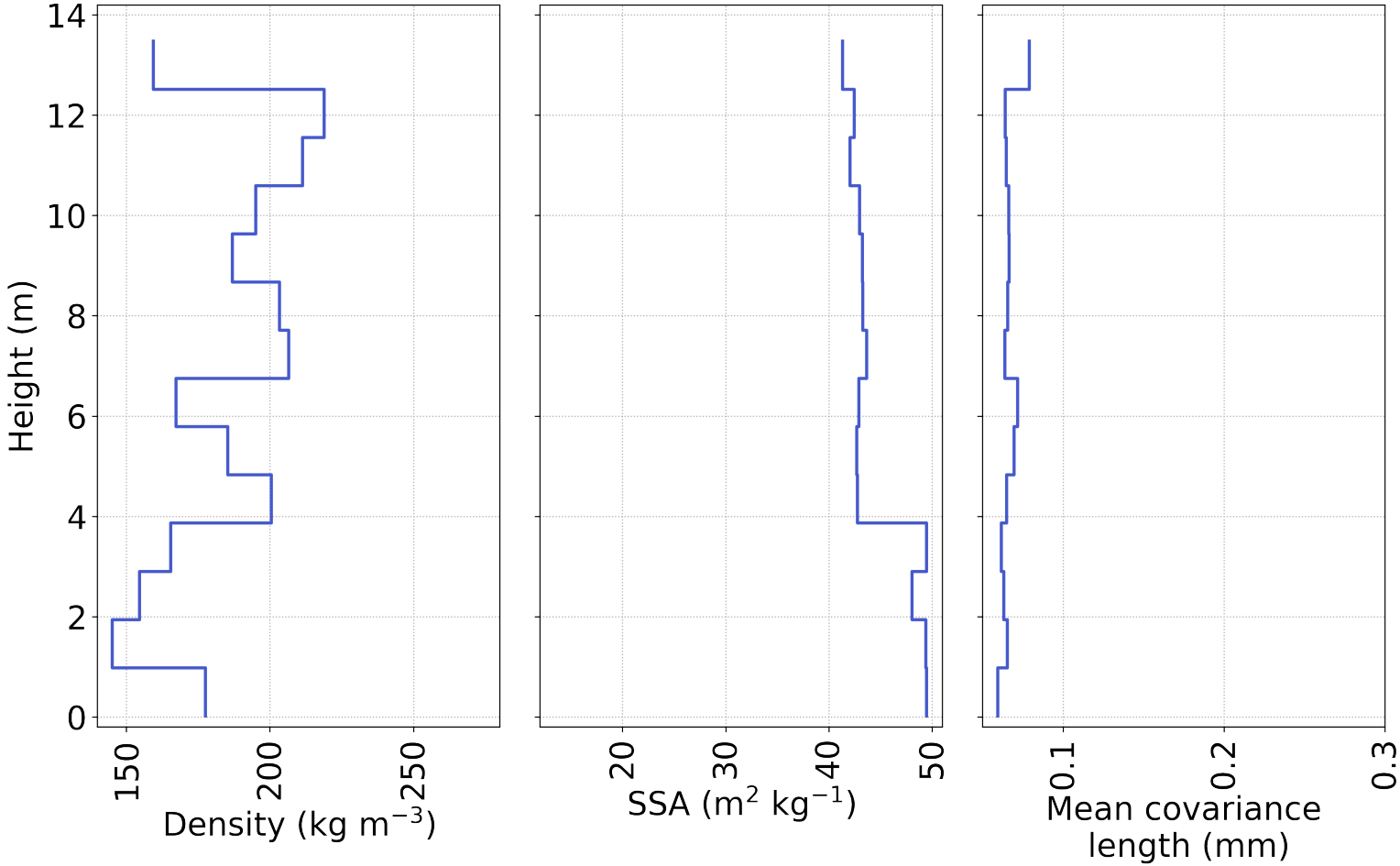
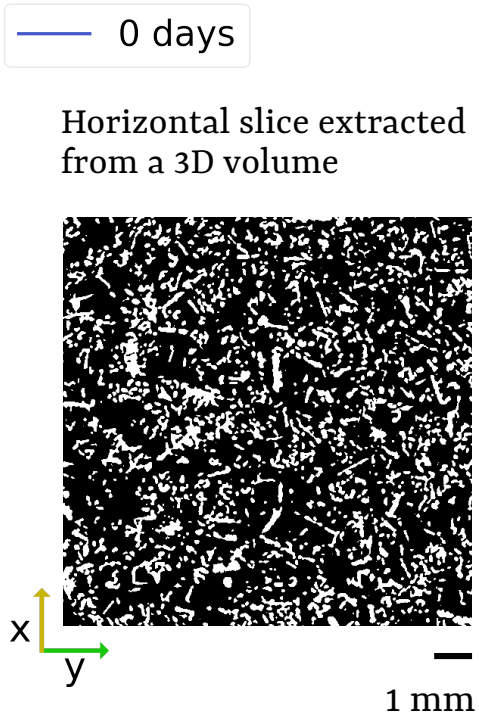


III – Microstructural properties from 3D images analysis





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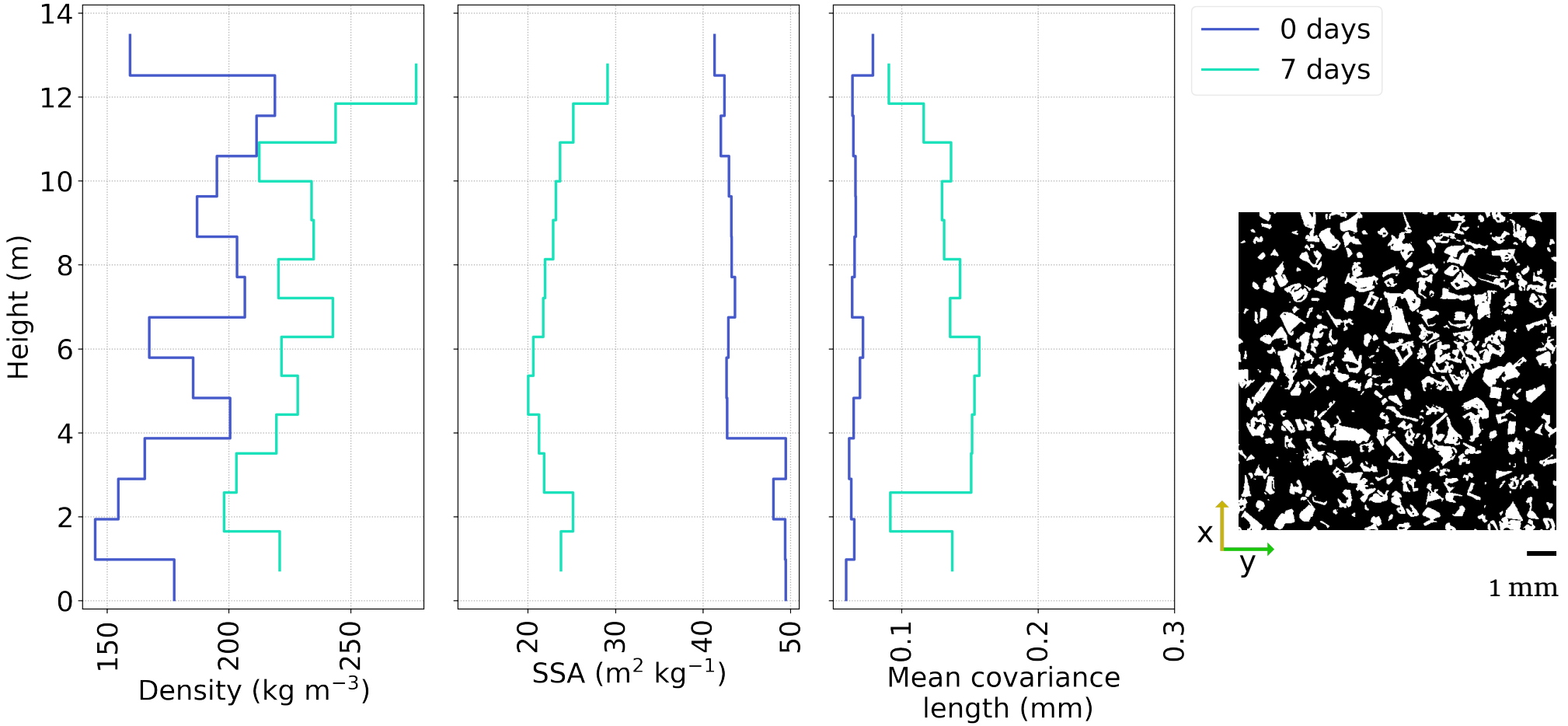

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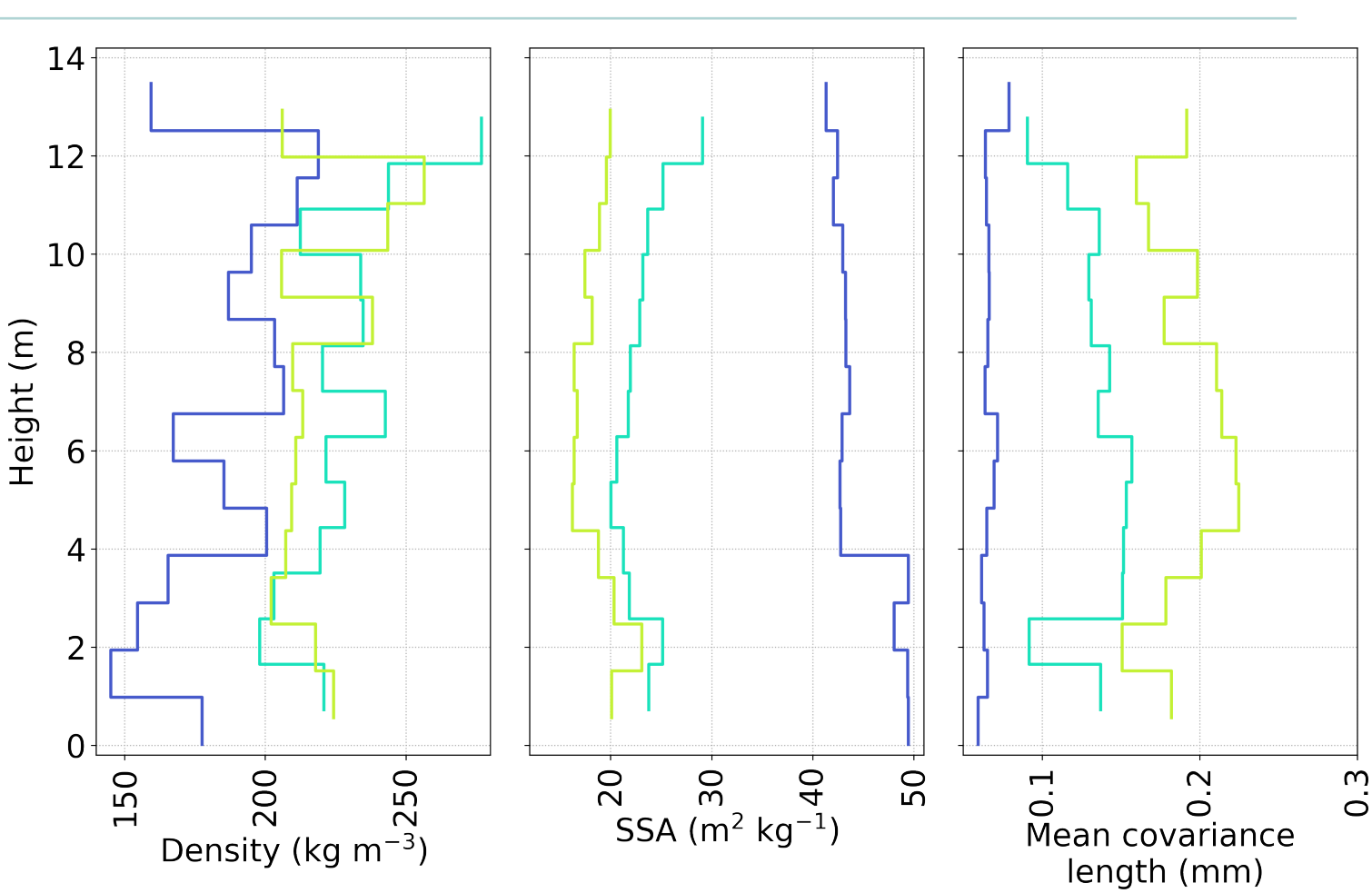

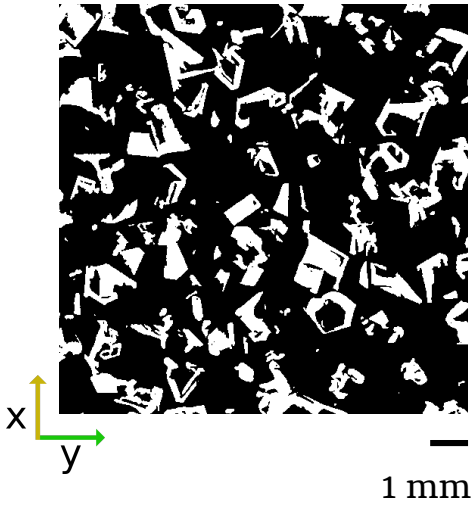

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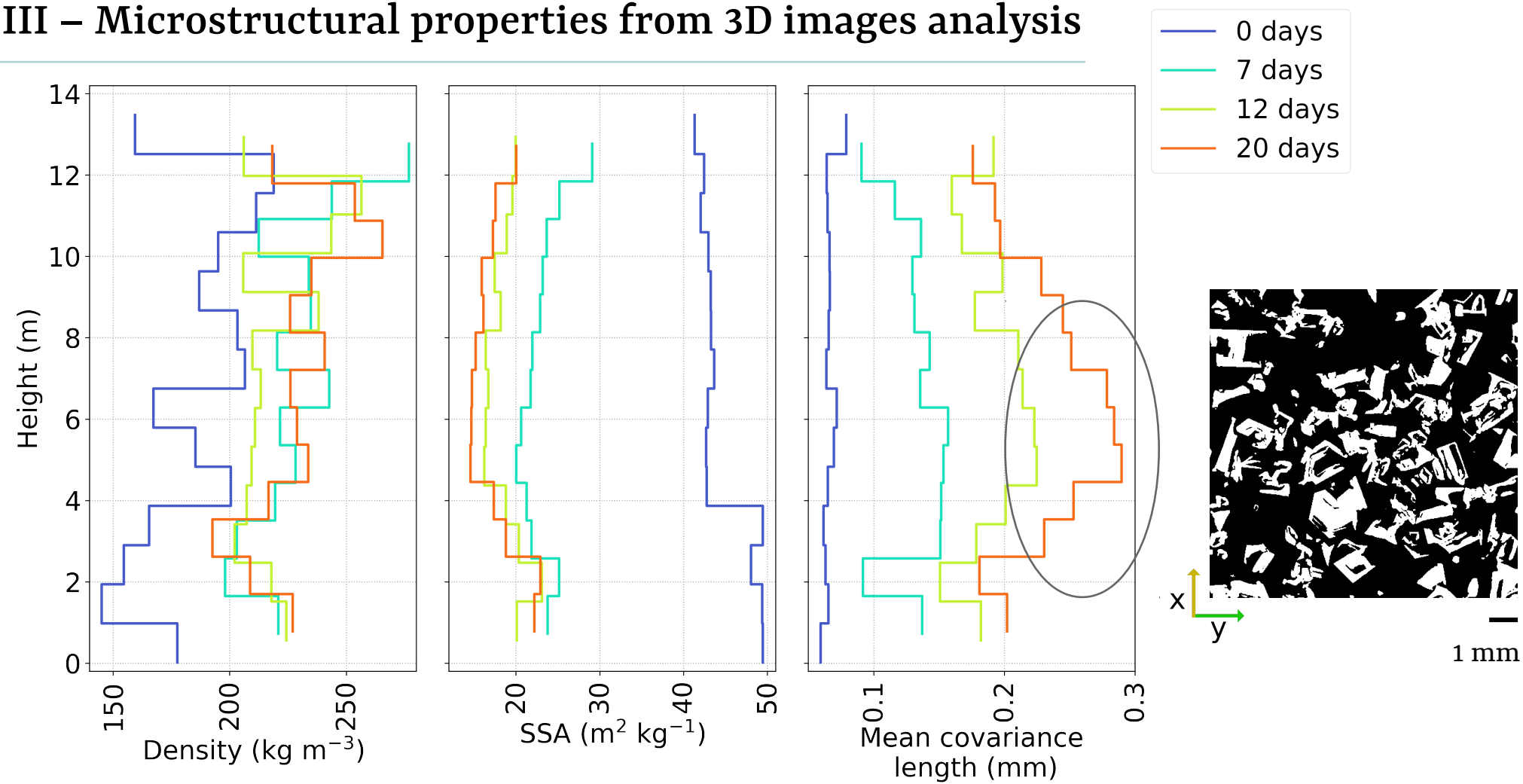

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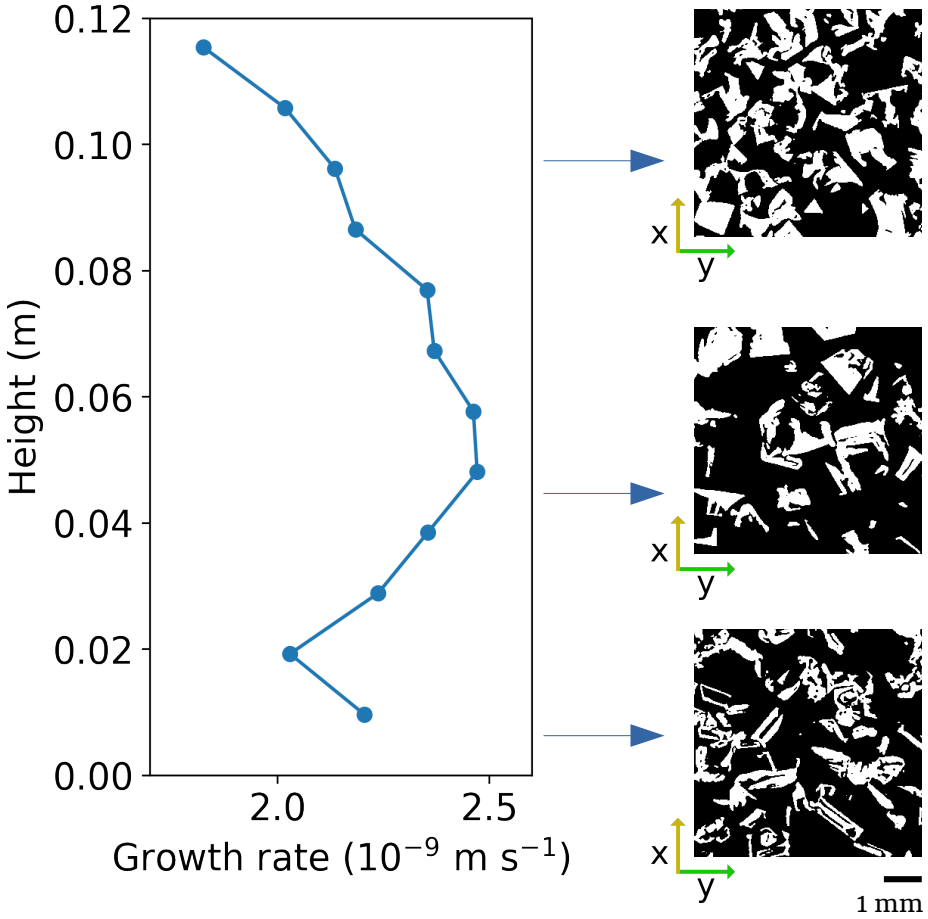

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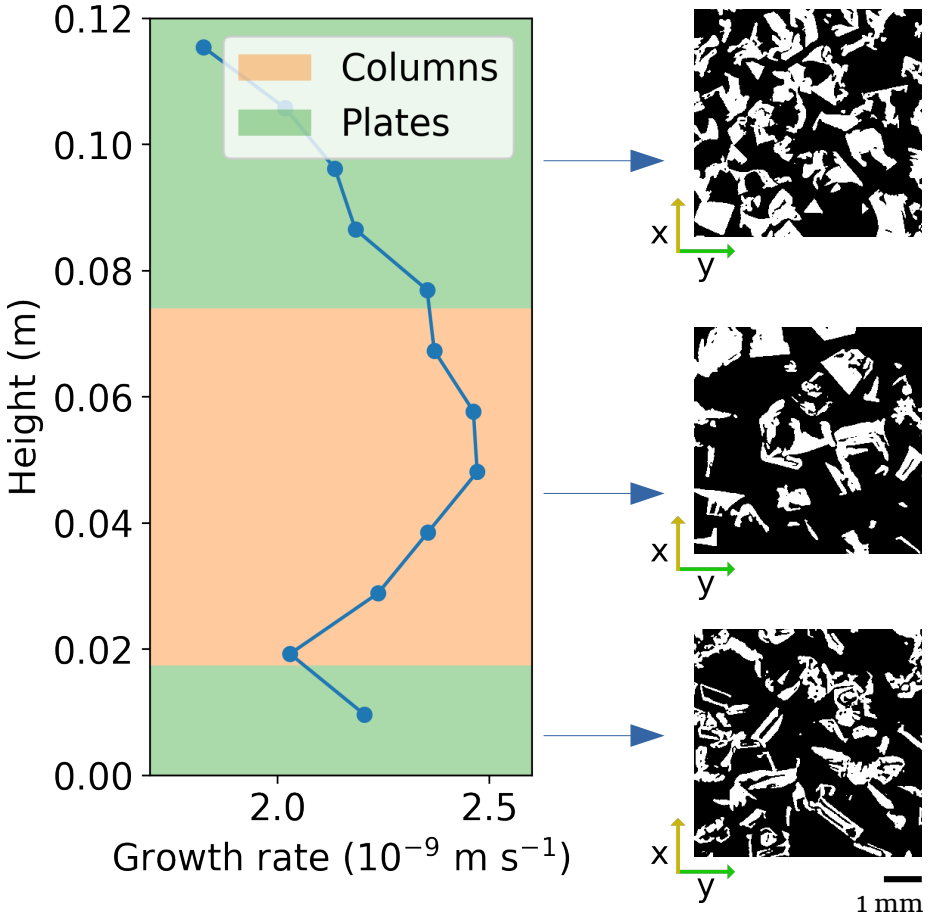
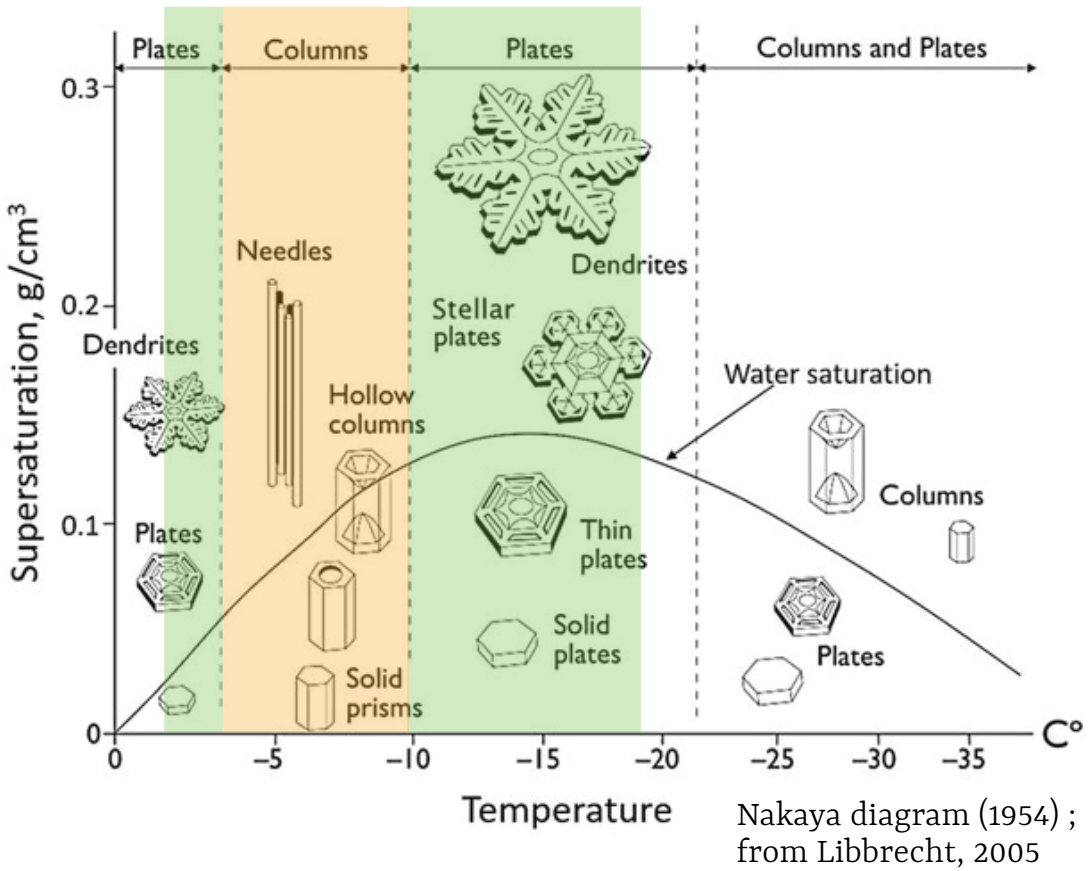
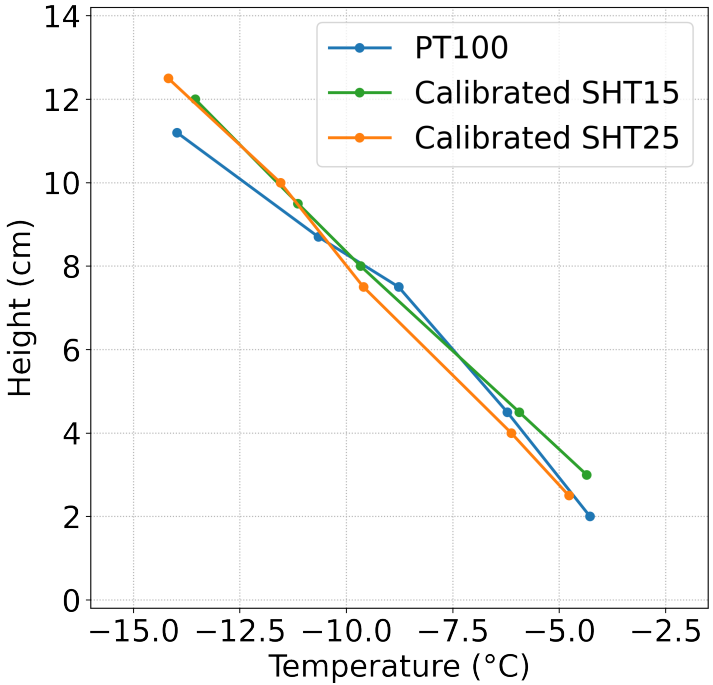


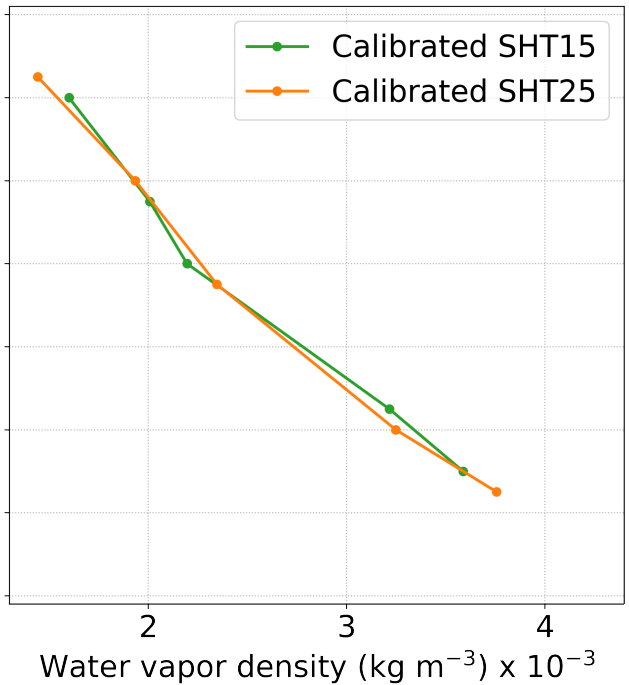


Nakaya diagram (1954) ; from Libbrecht, 2005

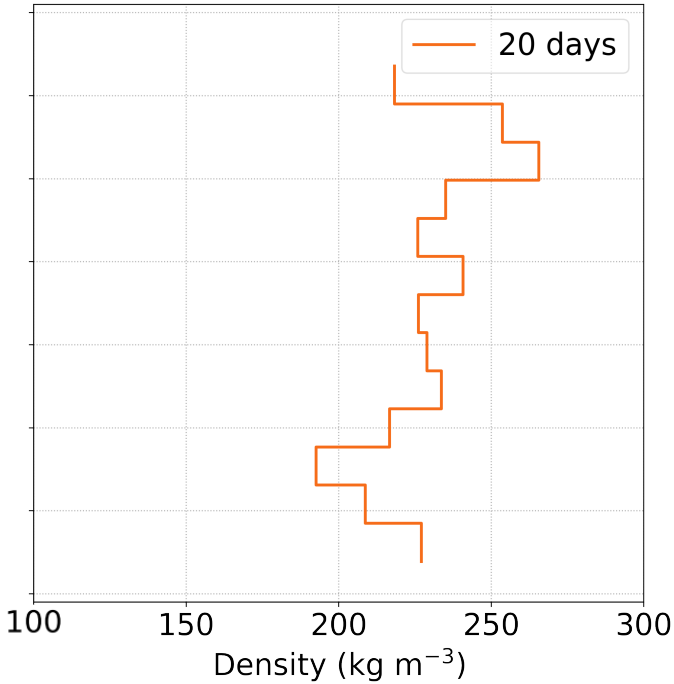
IV – First comparison to the model of Calonne et al., 2015



Temperature sensors



Humidity sensors



Tomographic profile

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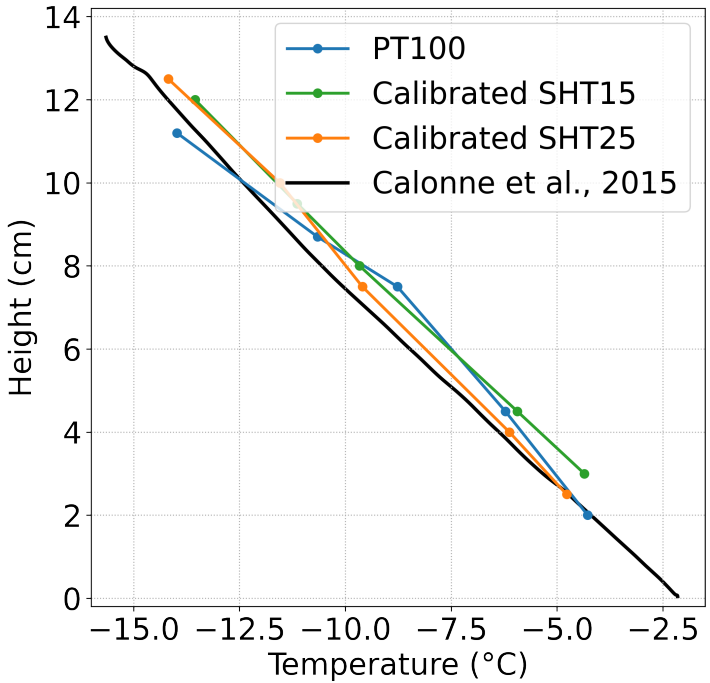

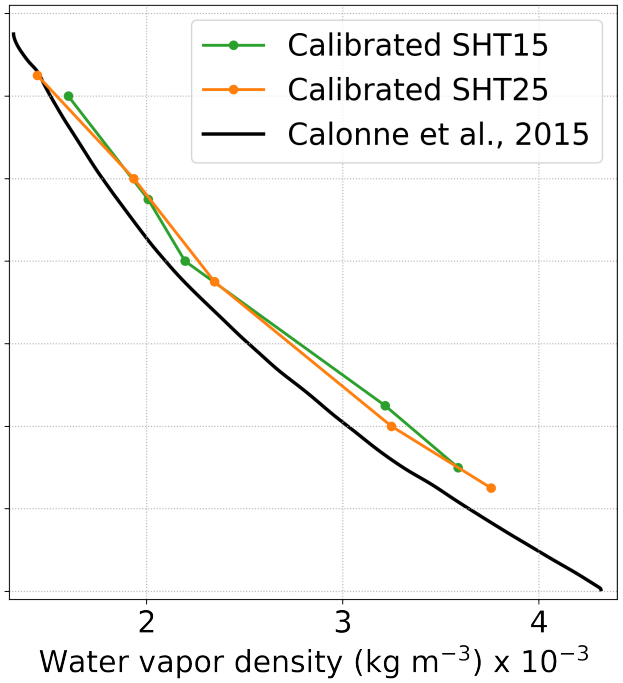

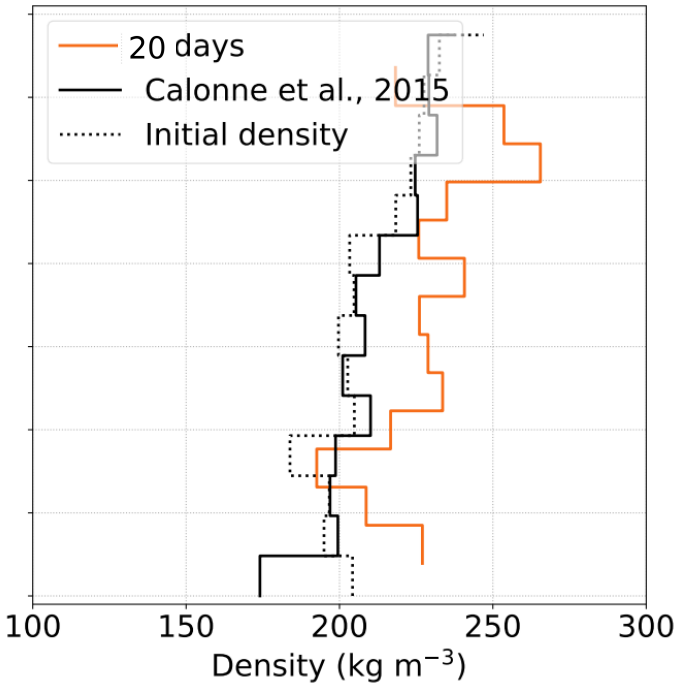

Parameters: Effective properties from measurements
Condensation coefficient $\alpha = 10^{-5}$
Initial experimental density profile

V – Outlook and references

Strong temperature gradient experiment

Model comparison:

- Rather good agreement between the experimental and simulation results.
- The density drop still needs to be investigated (new experiment in February 2022).

References :

- Calonne, N., C. Geindreau, and F. Flin, 2015. Macroscopic modeling of heat and water vapor transfer with phase change in dry snow based on an upscaling method: Influence of air convection. Journal of Geophysical Research: Earth Surface.
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- Nakaya, U., 1954. Snow Crystals. Natural and Artificial, Harvard University Press, 510 pp.

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Microstructure:

The difference between basal and prismatic regimes seems to have a significant impact on microstructure evolution.

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