



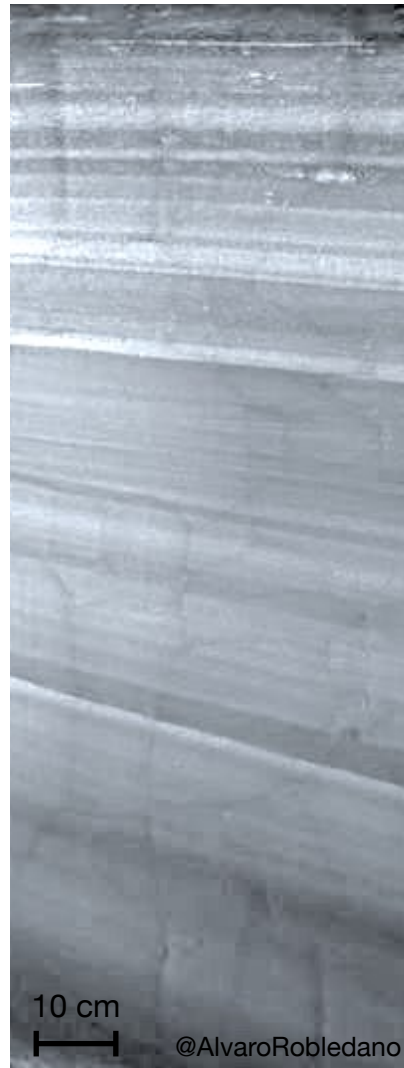
Multi-scale tomography of the seasonal evolution of the snow microstructure



Pascal Hagenmuller, Neige Calonne, Marie Dumont, Julien Brondex, François Tuzet, and Jacques Rouille

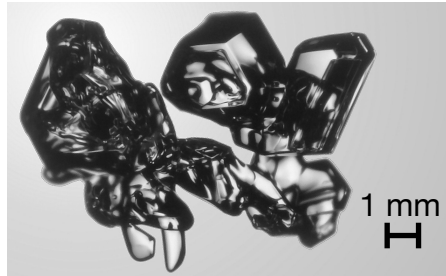
Univ. Grenoble Alpes, Université de Toulouse, Météo-France, CNRS, CNRM, Centre d'Études de la Neige, Grenoble, France







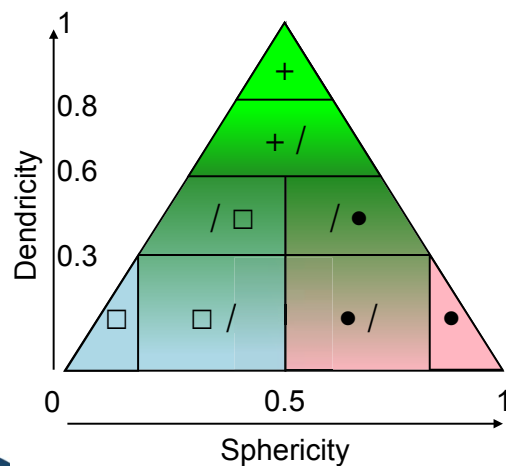
Crystal card



Crystal card



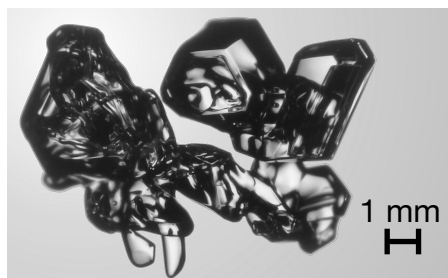
Current snowpack models
(Crocus / SNOWPACK)



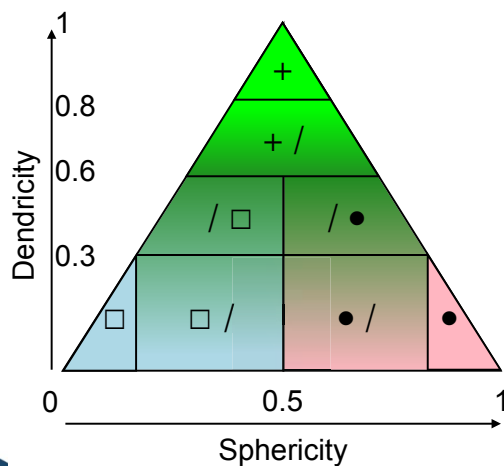
Vionnet et al., 2021



Crystal card



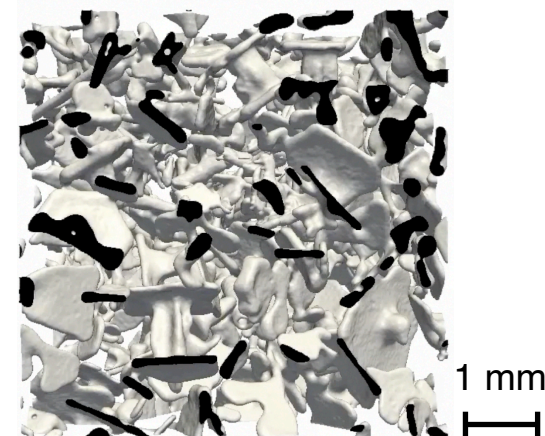
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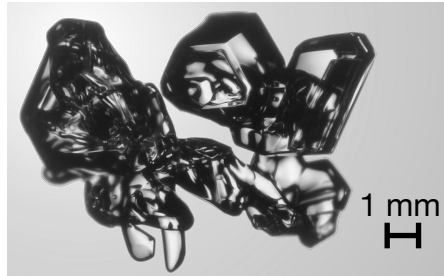
Vionnet et al., 2021



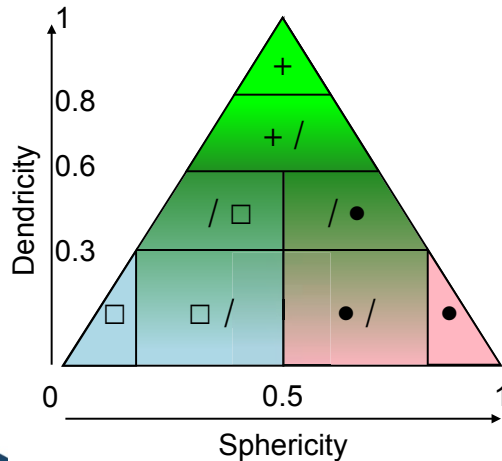
Tomography



Crystal card



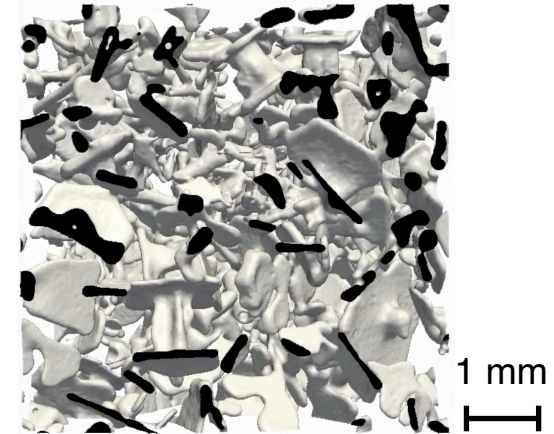
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Vionnet et al., 2021



Tomography



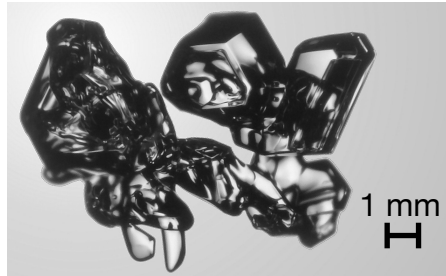
Future snowpack models
(IVORI)

$$C(r) \approx \phi(1 - \phi) - \frac{\rho_{ice}SSA}{4}r$$

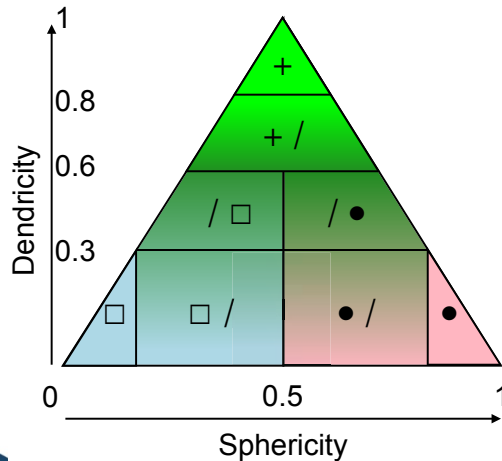
$$+ \frac{\rho_{ice}SSA}{4}\phi(1 - \phi)\left(\frac{\bar{H}^2}{8} - \frac{\bar{K}}{24}\right)r^3$$

Debye et al., 1957

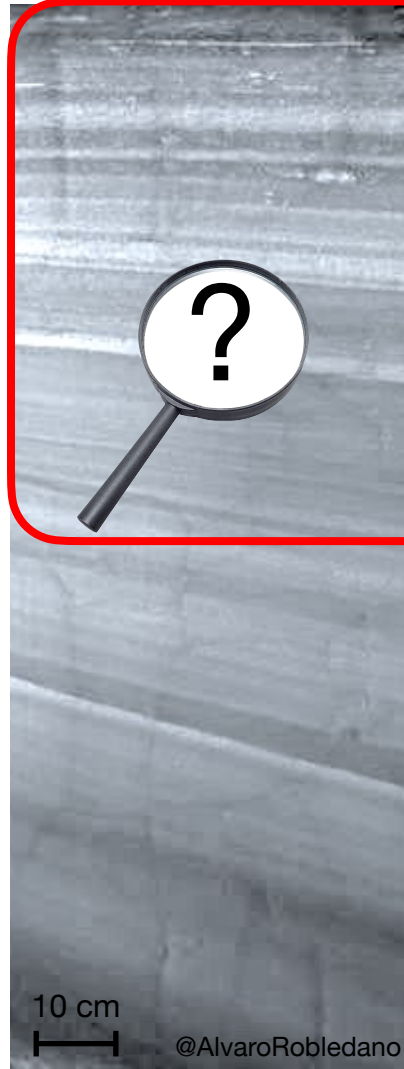
Crystal card



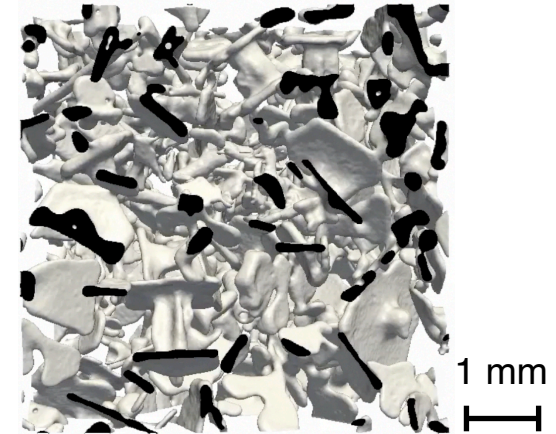
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Tomography



Future snowpack models
(IVORI)

$$C(r) \approx \phi(1 - \phi) - \frac{\rho_{ice}SSA}{4}r + \frac{\rho_{ice}SSA}{4}\phi(1 - \phi)\left(\frac{\bar{H}^2}{8} - \frac{\bar{K}}{24}\right)r^3$$

Debye et al., 1957



Col de Porte, 1325 m, French Alps



Hanging 600 kg (or 250 k€ ...)

Col de Porte, 1325 m, French Alps



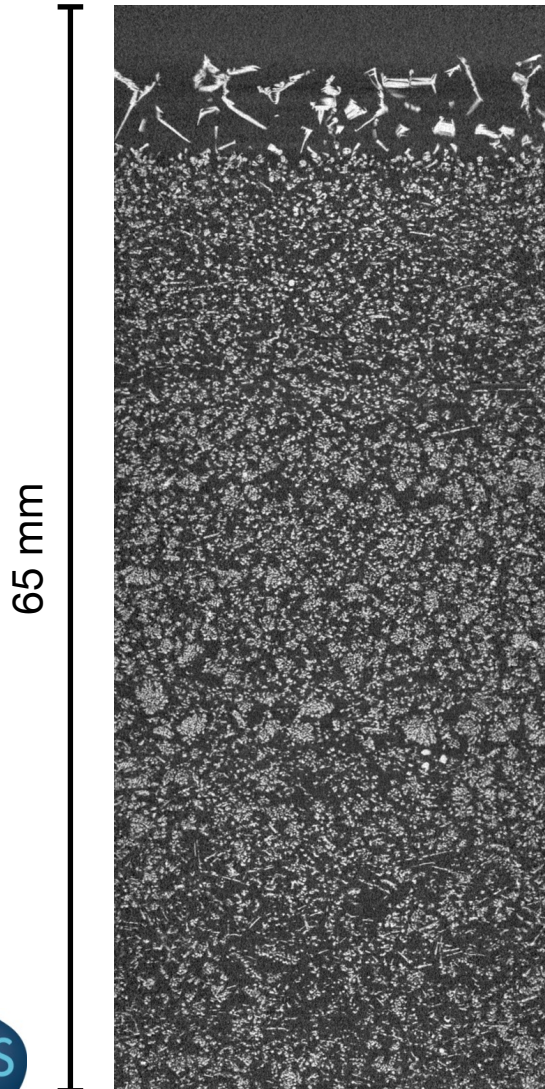
Col de Porte, 1325 m, French Alps



Col de Porte, 1325 m, French Alps

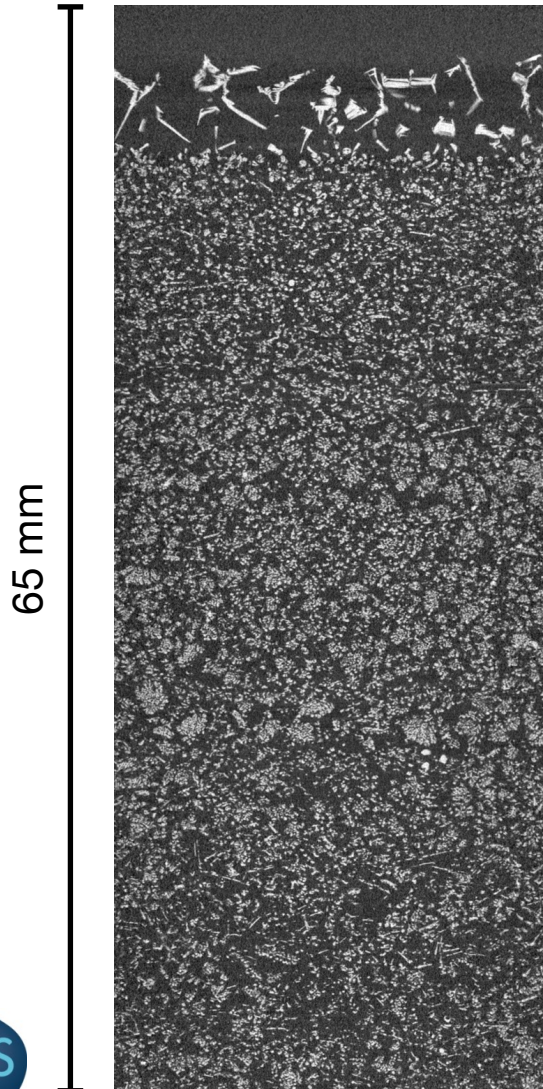
Fast: 42 μm , 2 min / cm

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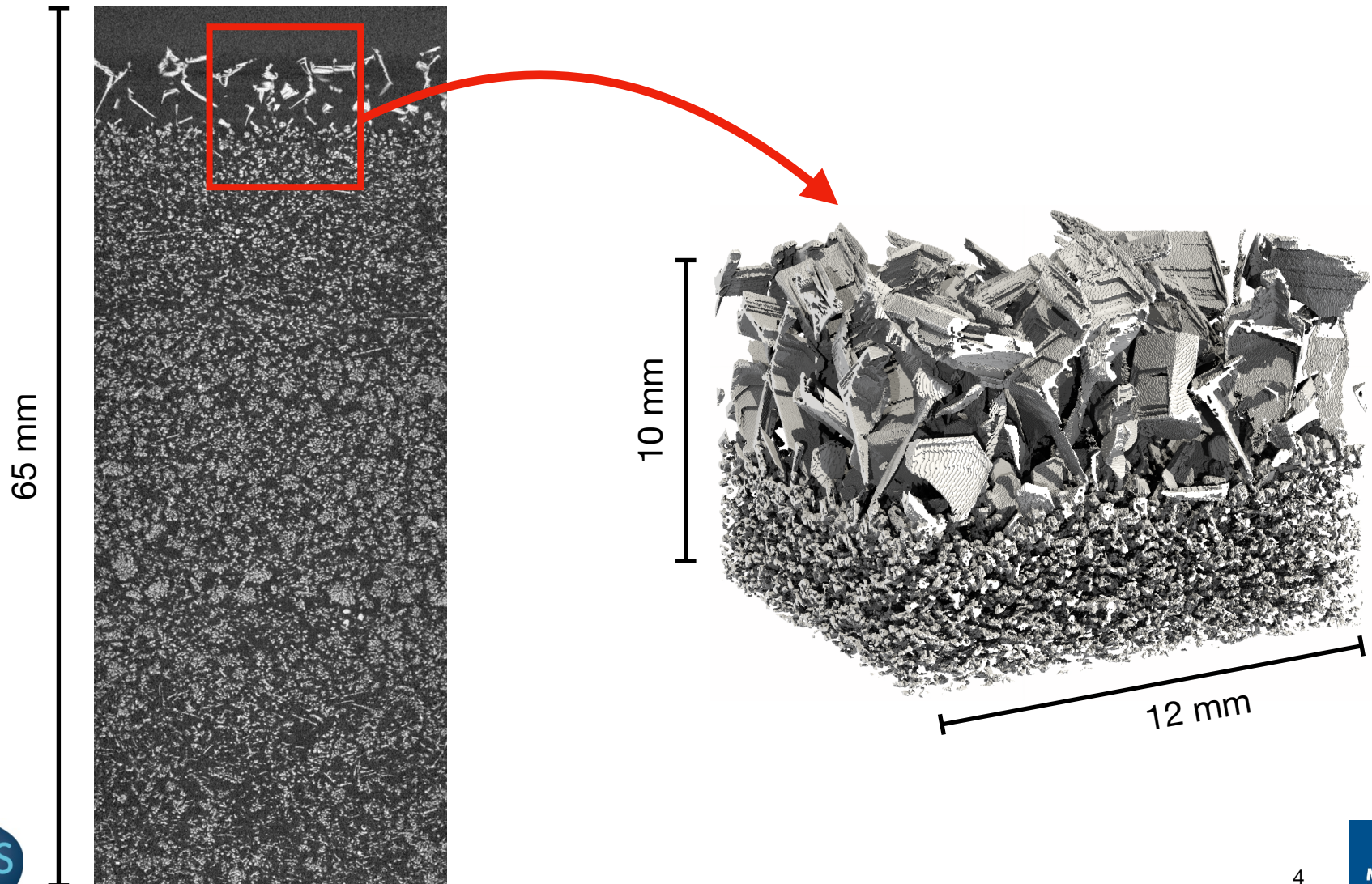
Fast: 42 μm , 2 min / cm

Zoomed: 10 μm , 60 min / cm



Fast: 42 μm , 2 min / cm

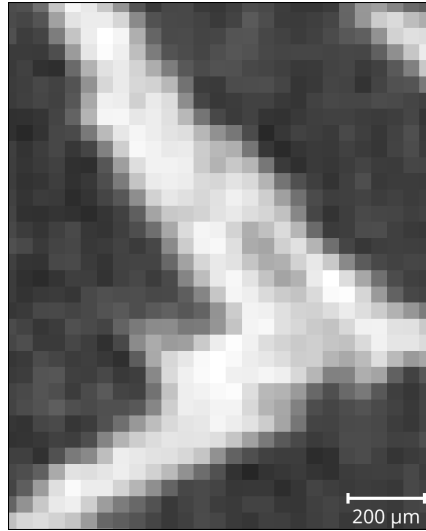
Zoomed: 10 μm , 60 min / cm



10 μm resolution



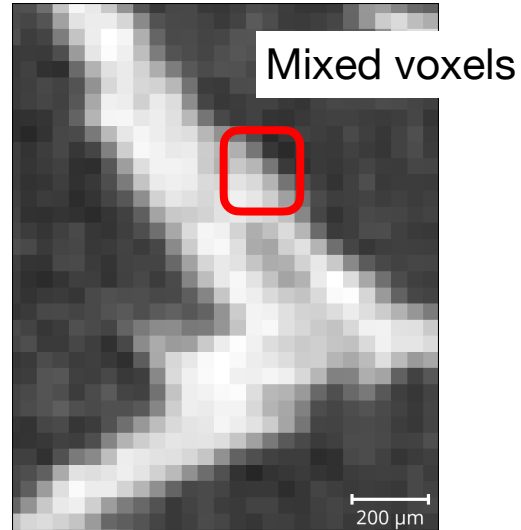
42 μm resolution



10 μm resolution



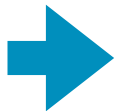
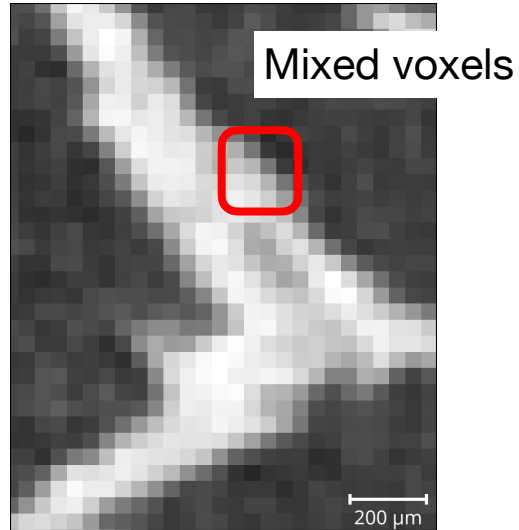
42 μm resolution



10 μm resolution

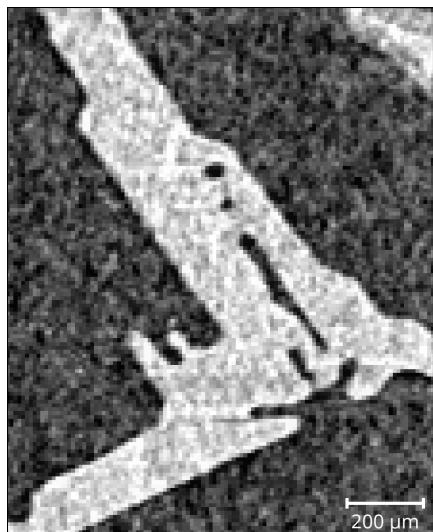


42 μm resolution

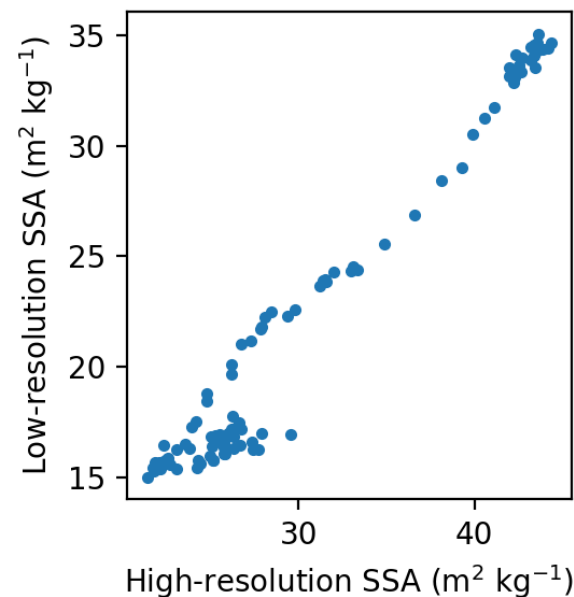
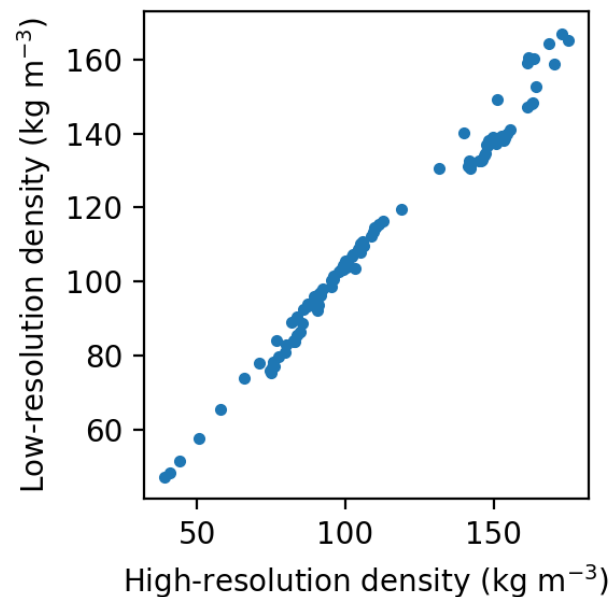
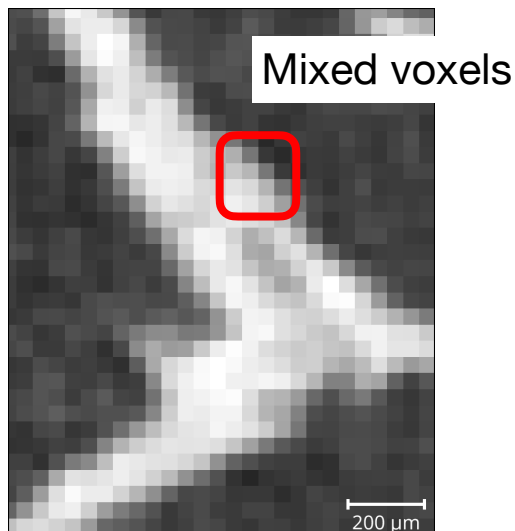


- Binary segmentation loses information.
- Dedicated statistical models

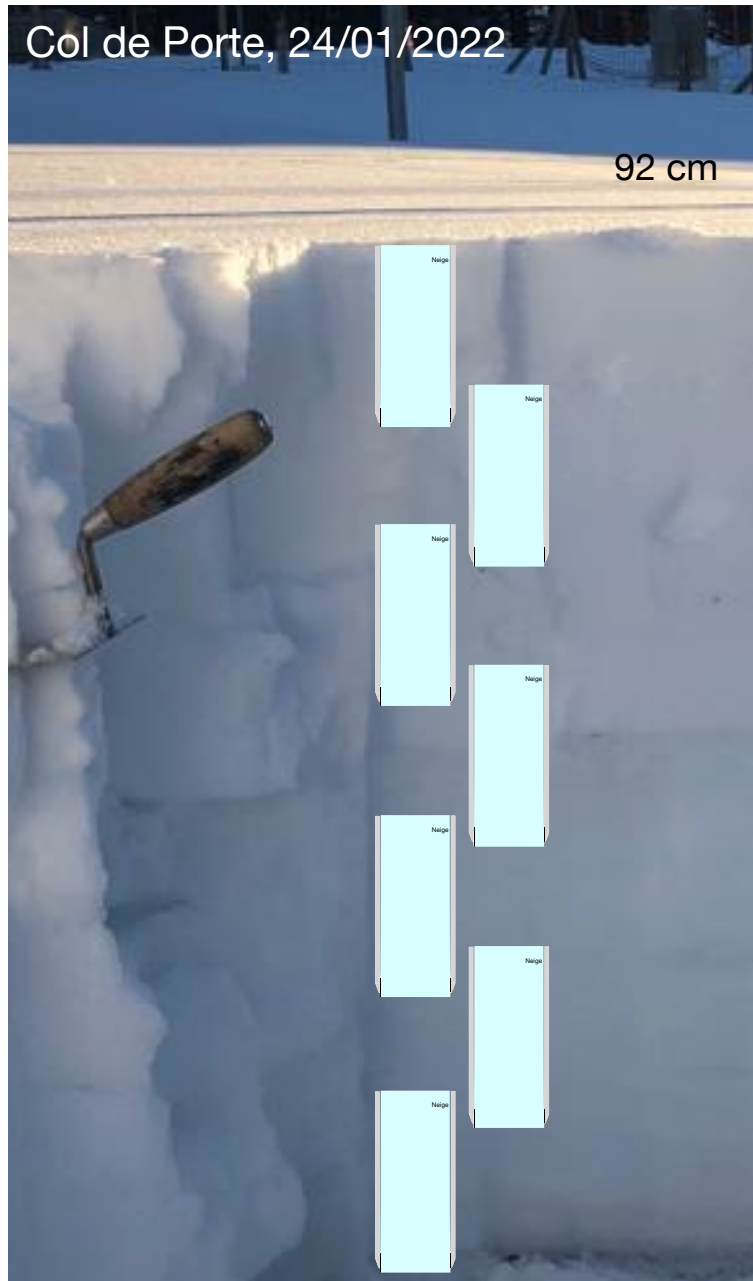
10 μm resolution



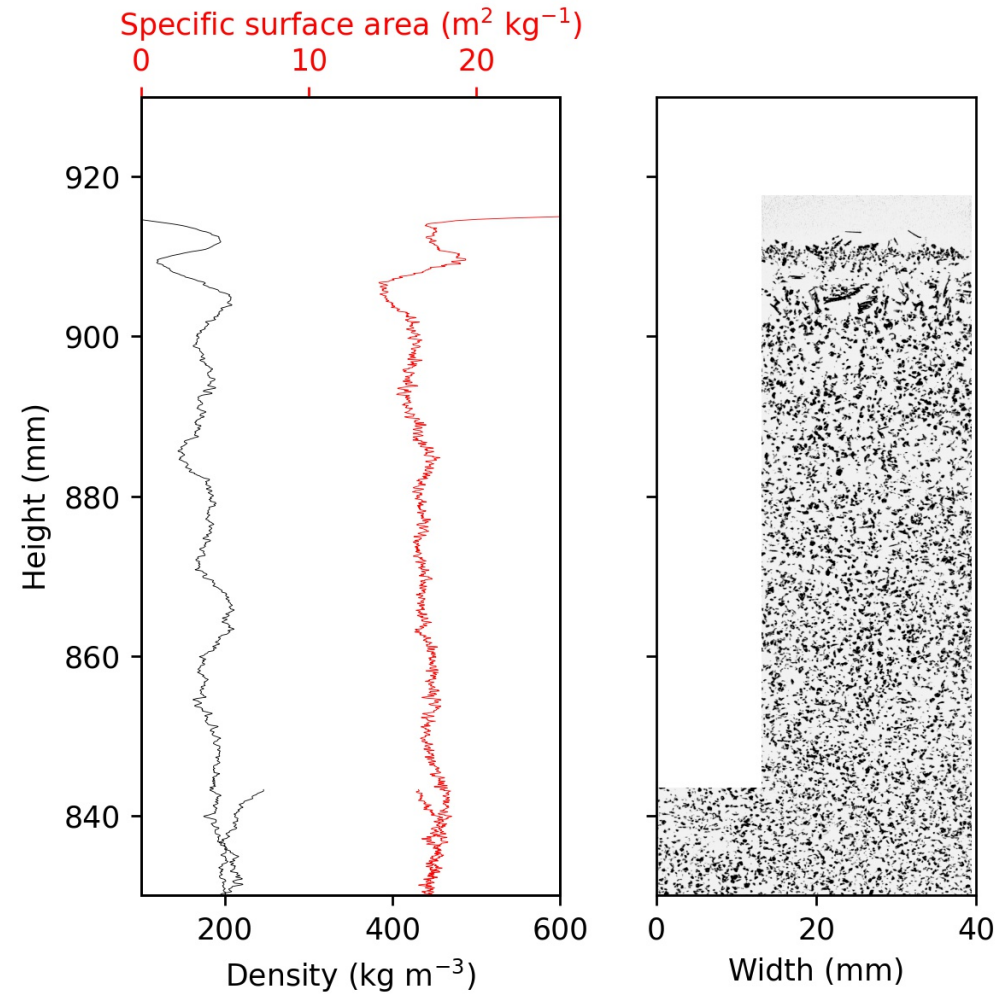
42 μm resolution

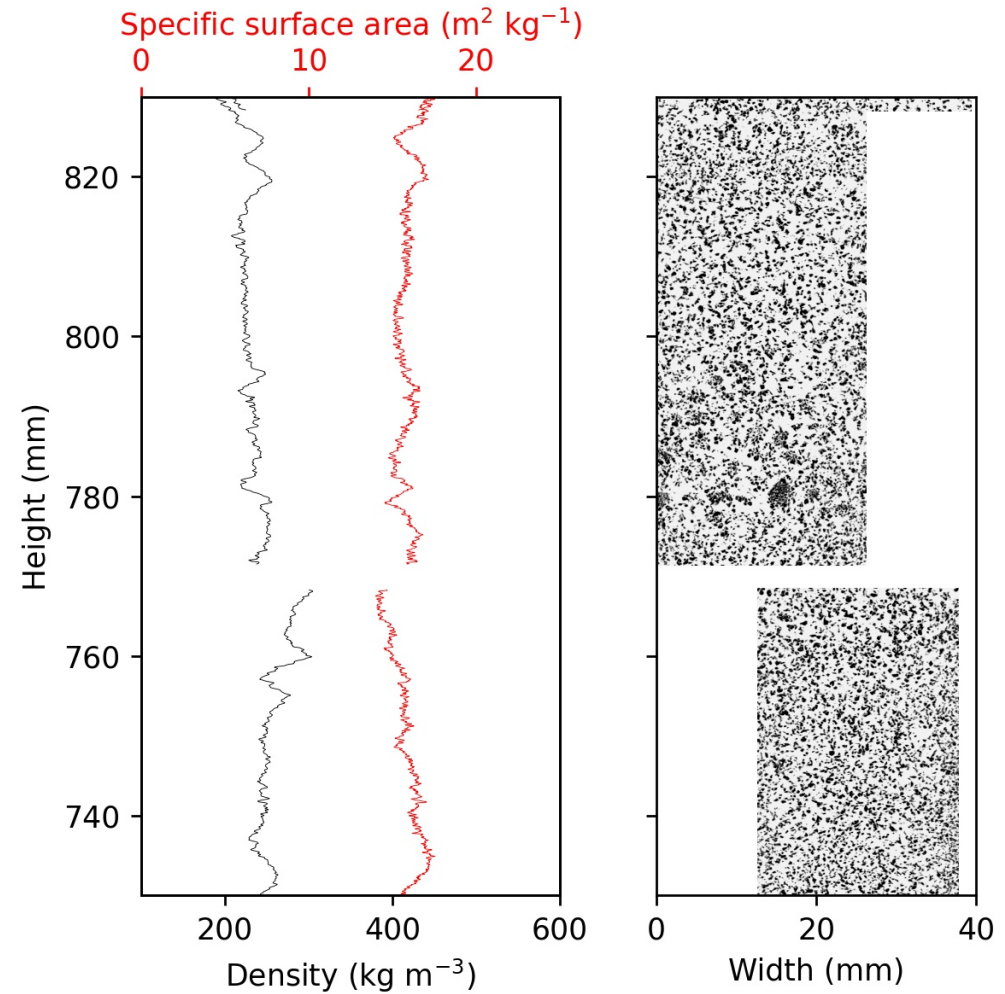


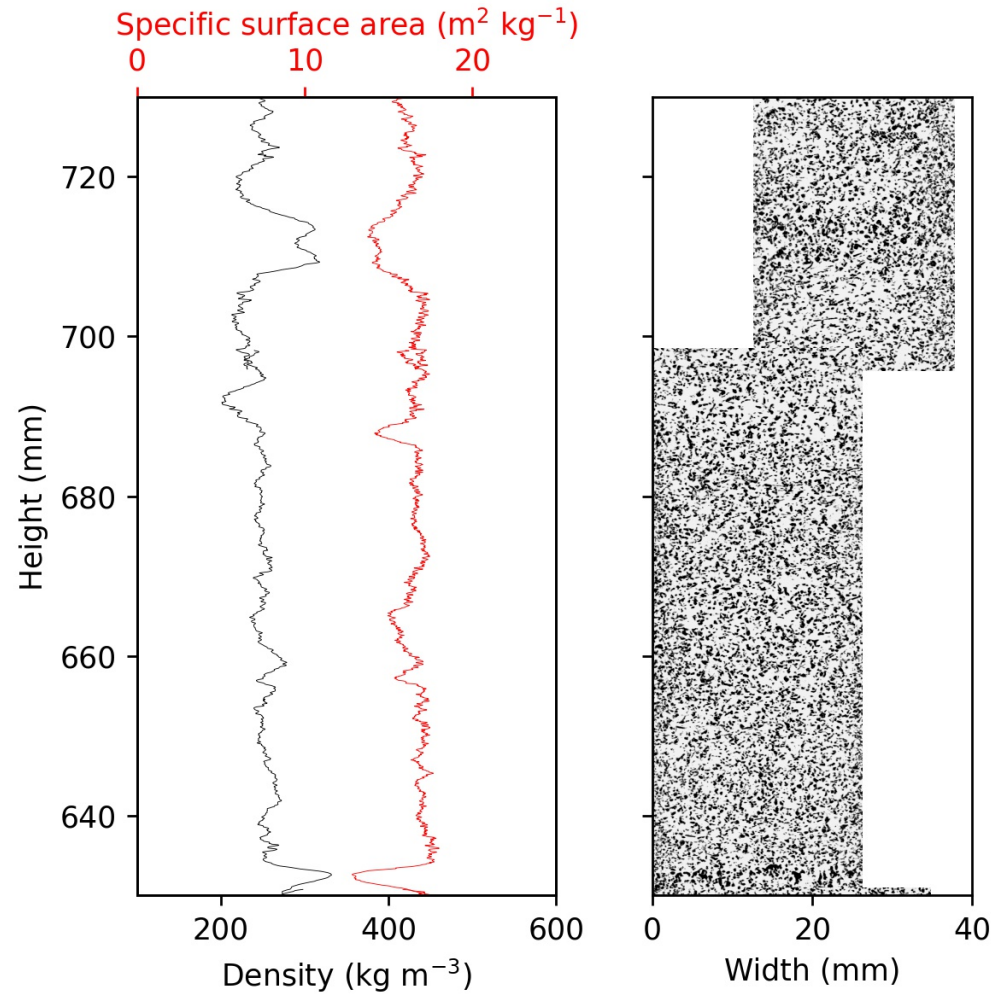
- ➔
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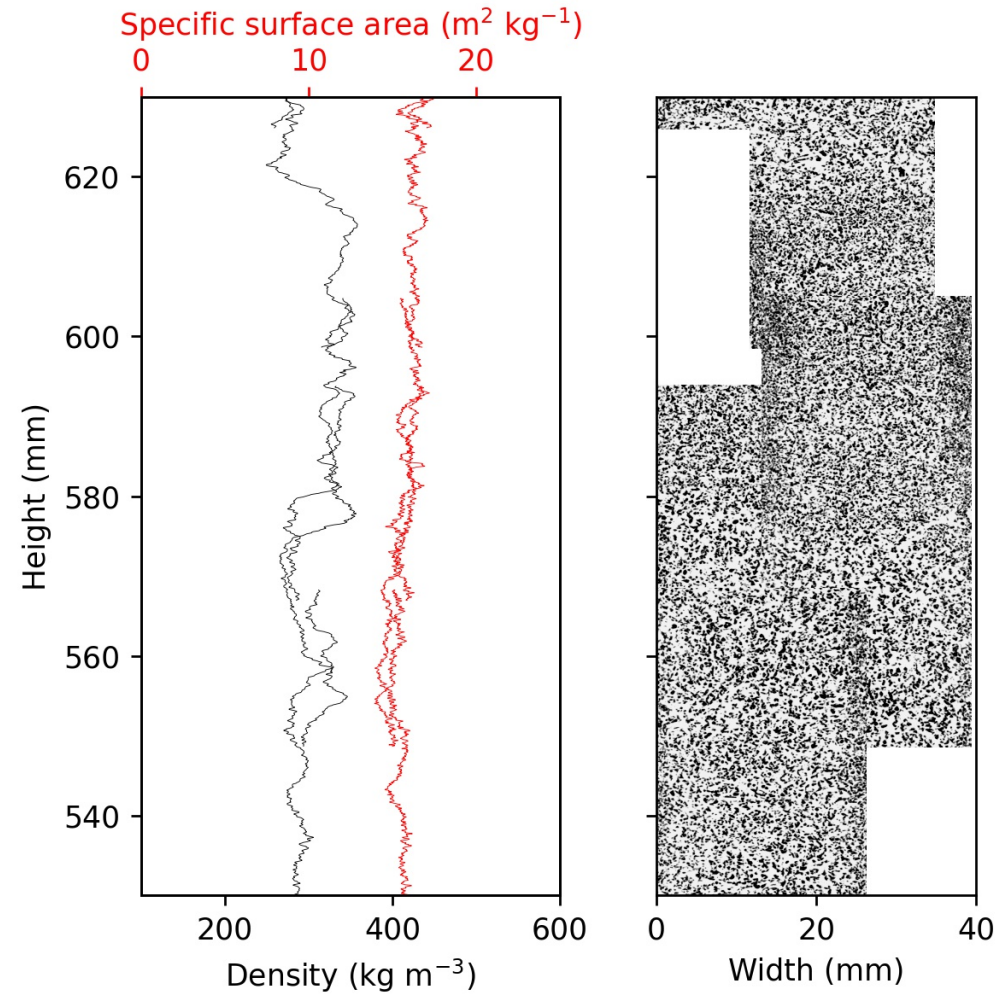


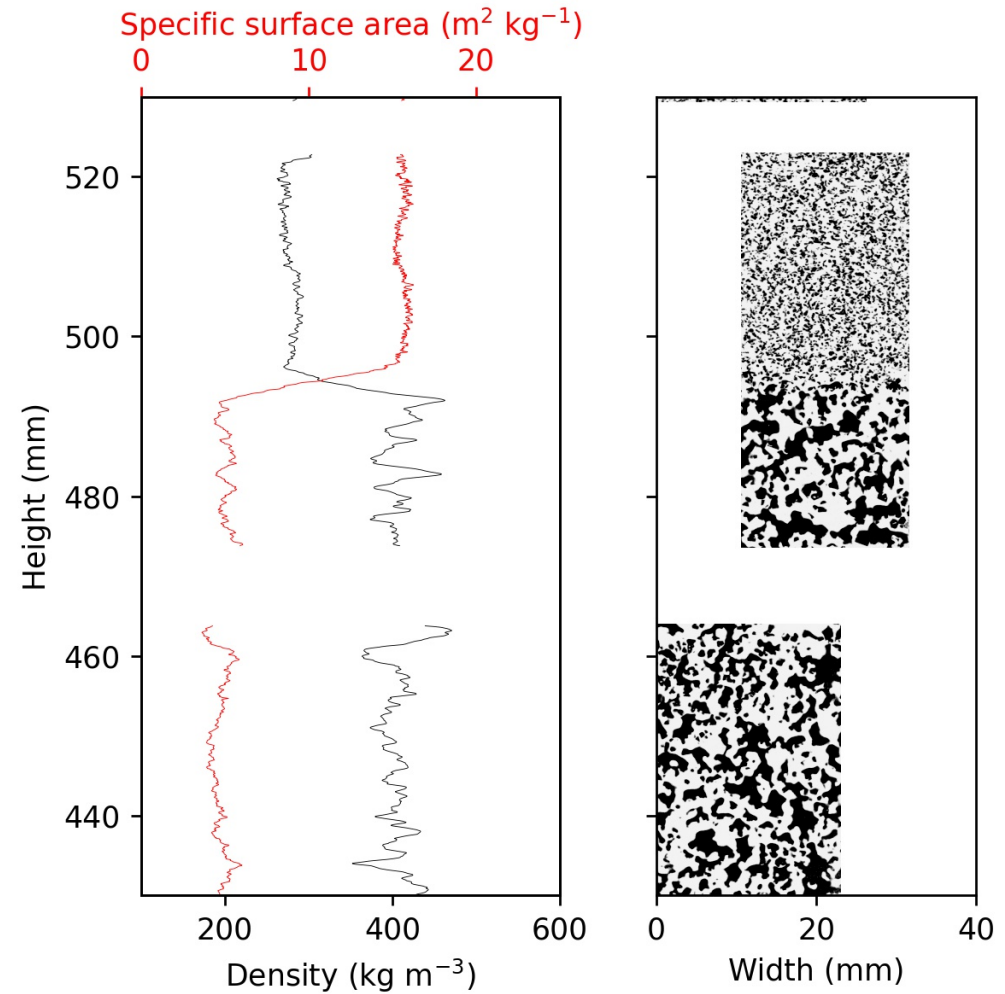


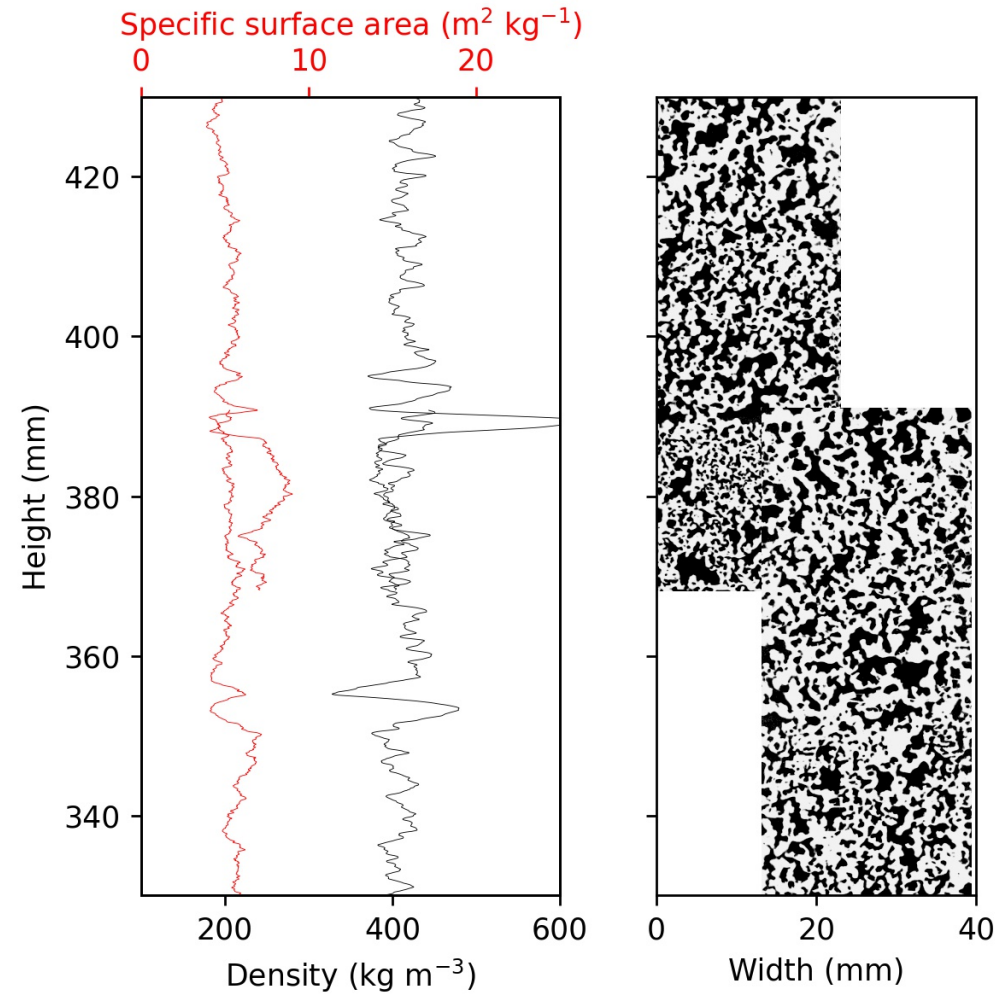


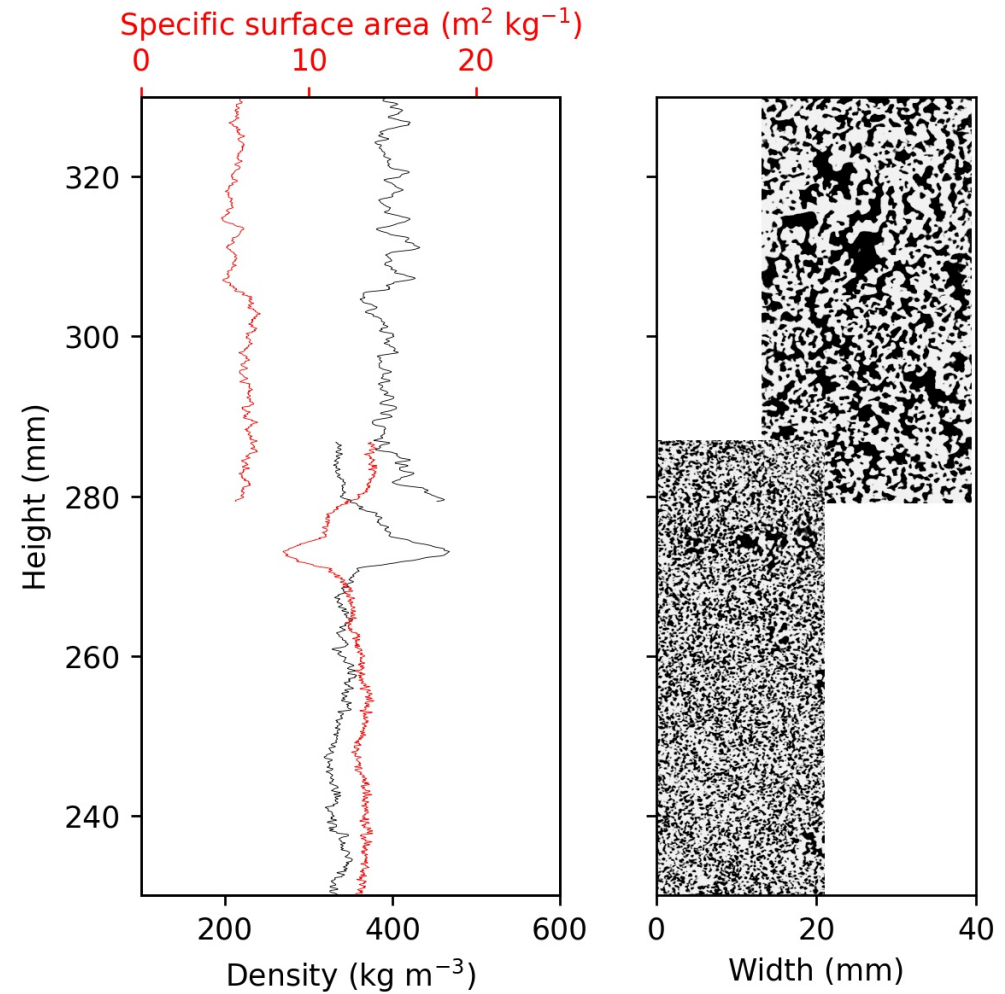


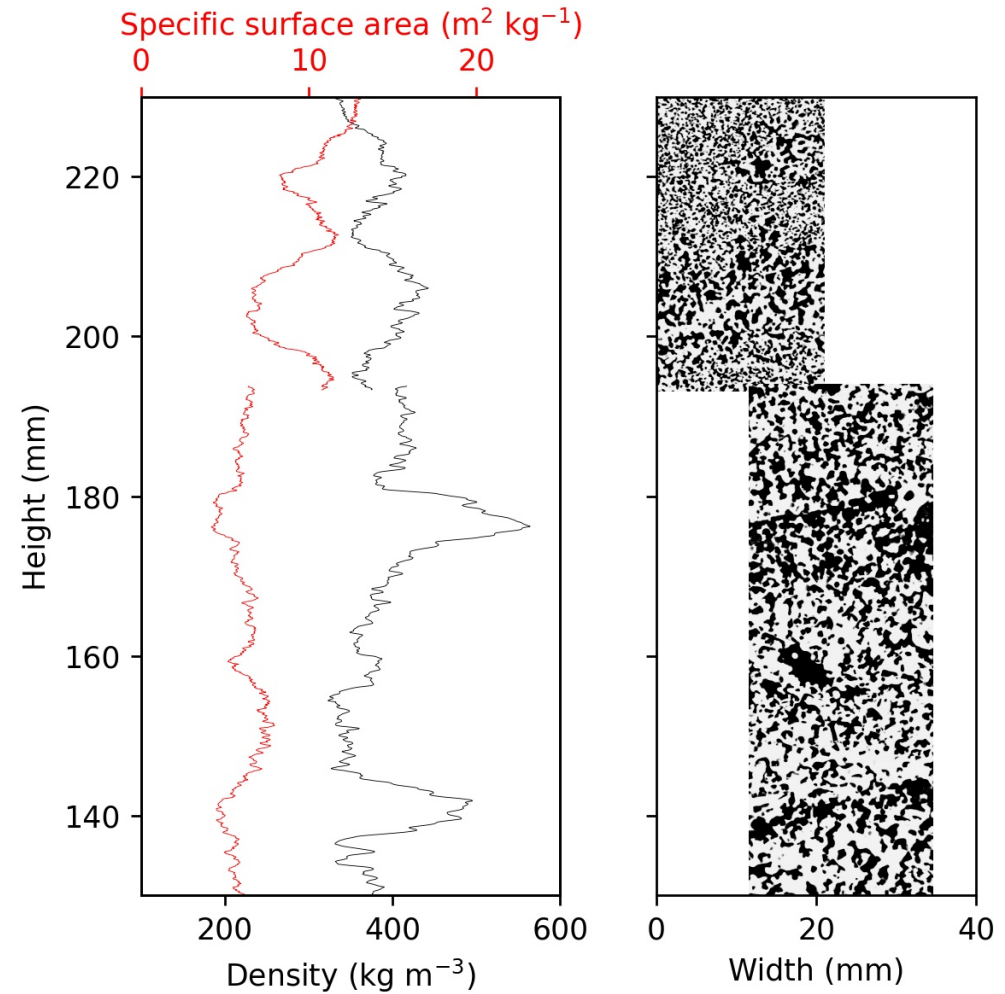


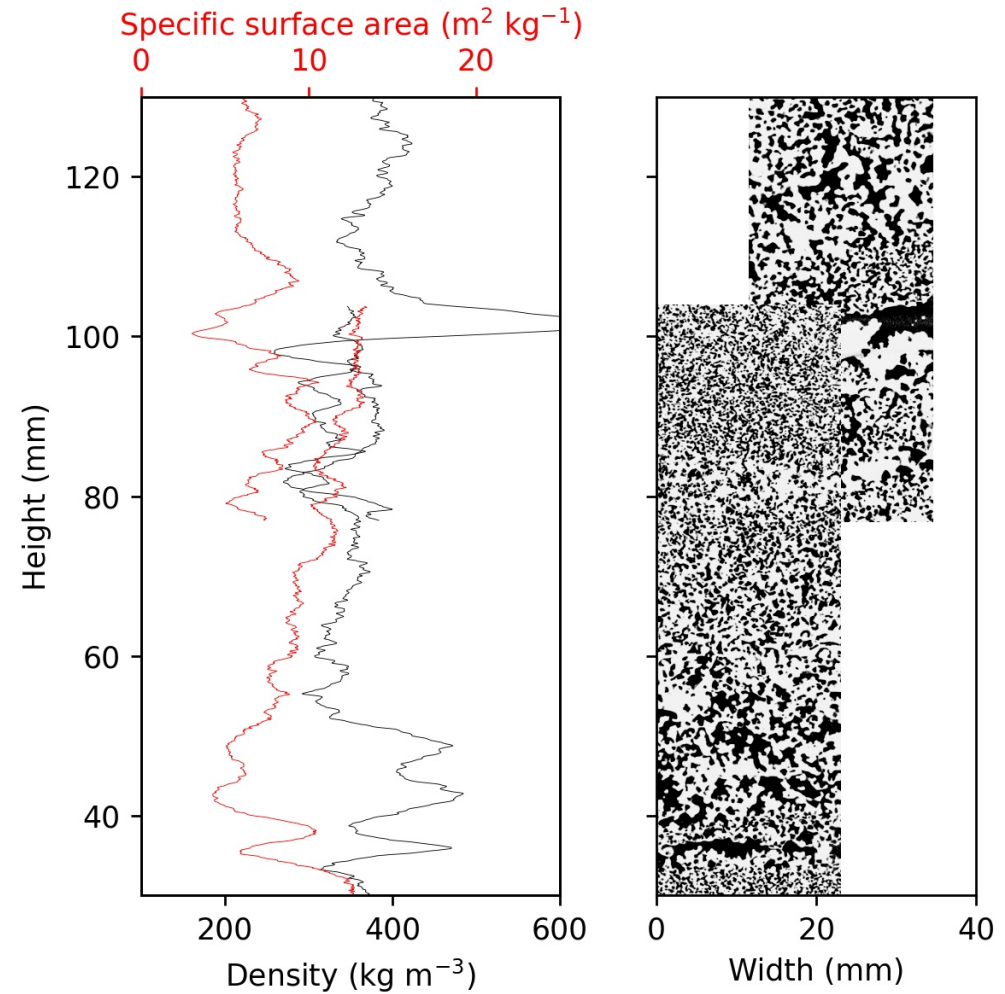


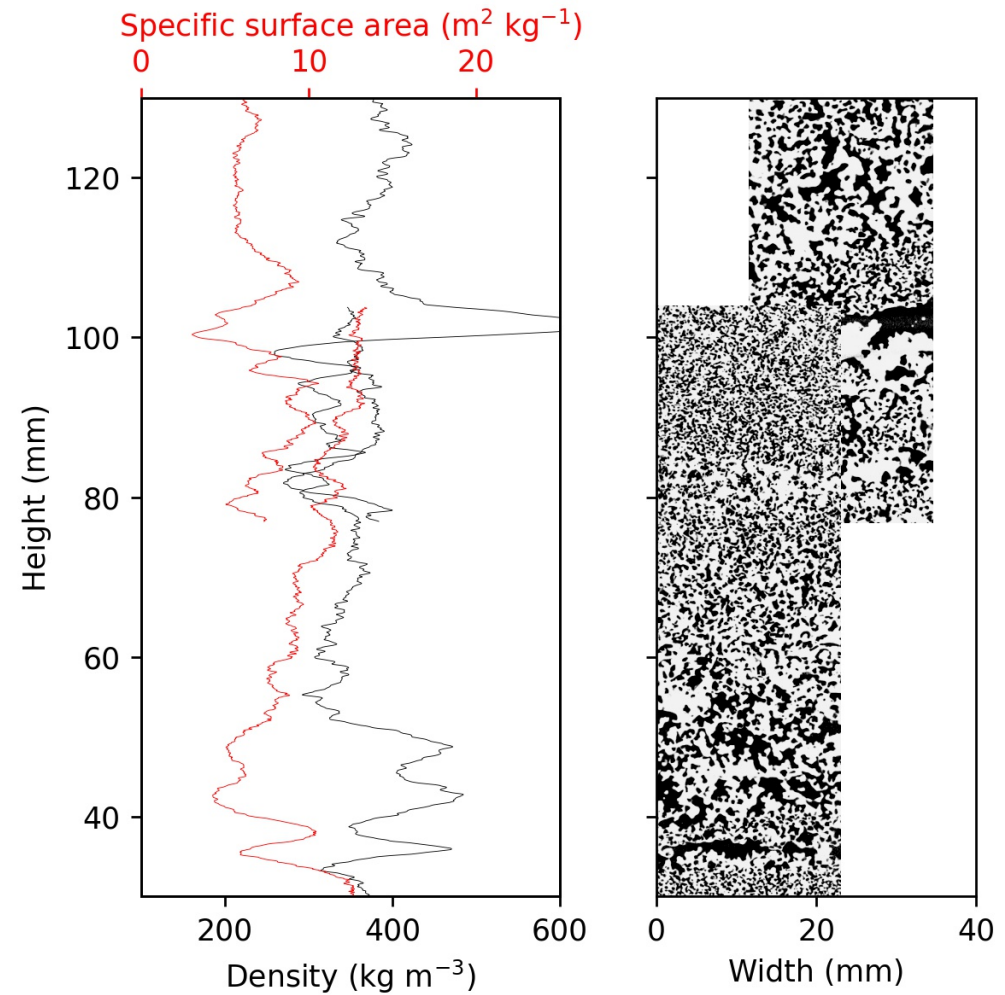












Concluding words

- Tomography in the field = game-changer in snow science
- Quantitative analysis of low-resolution images to be continued

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Col de Porte

Winter 2021-2022 : protocol

Winter 2022-2023 : seasonal

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**Canadian high arctic
station research**
Winter 2023-2024
Arctic snow



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Dome Concordia
end of project (?)
Snow, firn, porous ice

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pascal.hagenmuller@meteo.fr

 @docmepra