COMSOL® Simulation of the Liquid Water Content in Snow Using Dielectric Heating

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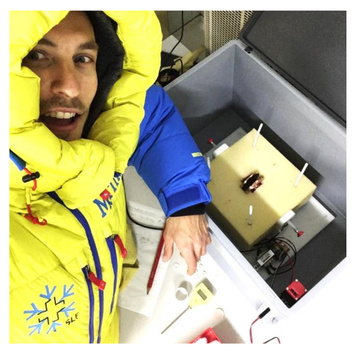

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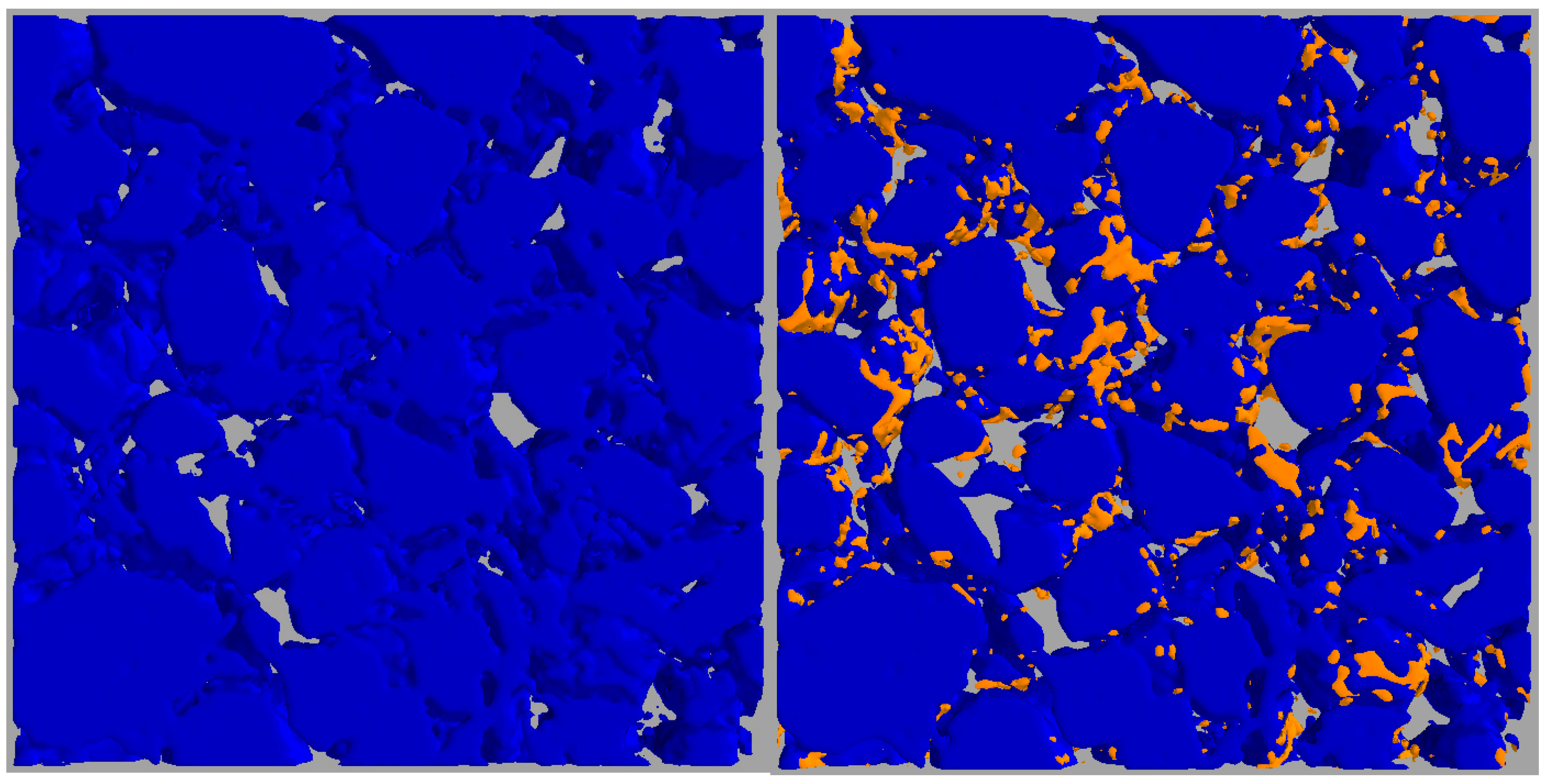

Figure 1. μ-CT scan (3.6 x 3.6 x 0.36 mm) of a dry (left) and a wet (right) snow sample: ice (blue), water (orange) and air (voids).

MOTIVATION:

- Liquid water influences the electromagnetic properties of snow. [1]
- Creating a defined liquid water content is necessary for the experimental investigation of wet snow.

COMPUTATIONAL METHODS:

Design of a new device using COMSOL®

Dielectric heat source (ec):

$$\vec{\nabla}\cdot\left(\varepsilon_0\varepsilon\cdot\vec{E}\right)=\sigma$$
$$\vec{E}=-\vec{\nabla}V$$
$$\dot{Q}_{diel}=\omega E^2\varepsilon_0\varepsilon''_{snow}Sd$$

Heat transfer (ht):

$$\left(\rho c_p\right)\frac{\partial T}{\partial t}=\vec{\nabla}\cdot\left(\lambda\cdot\vec{\nabla}T\right)+\dot{Q}_{diel}$$

- coupled multiphysics simulation with snow as phase changing material
- axially symmetric 2D problem
- frequency-transient time dependent study
- simulation input: electric current
- simulation output: temperature and liquid water content

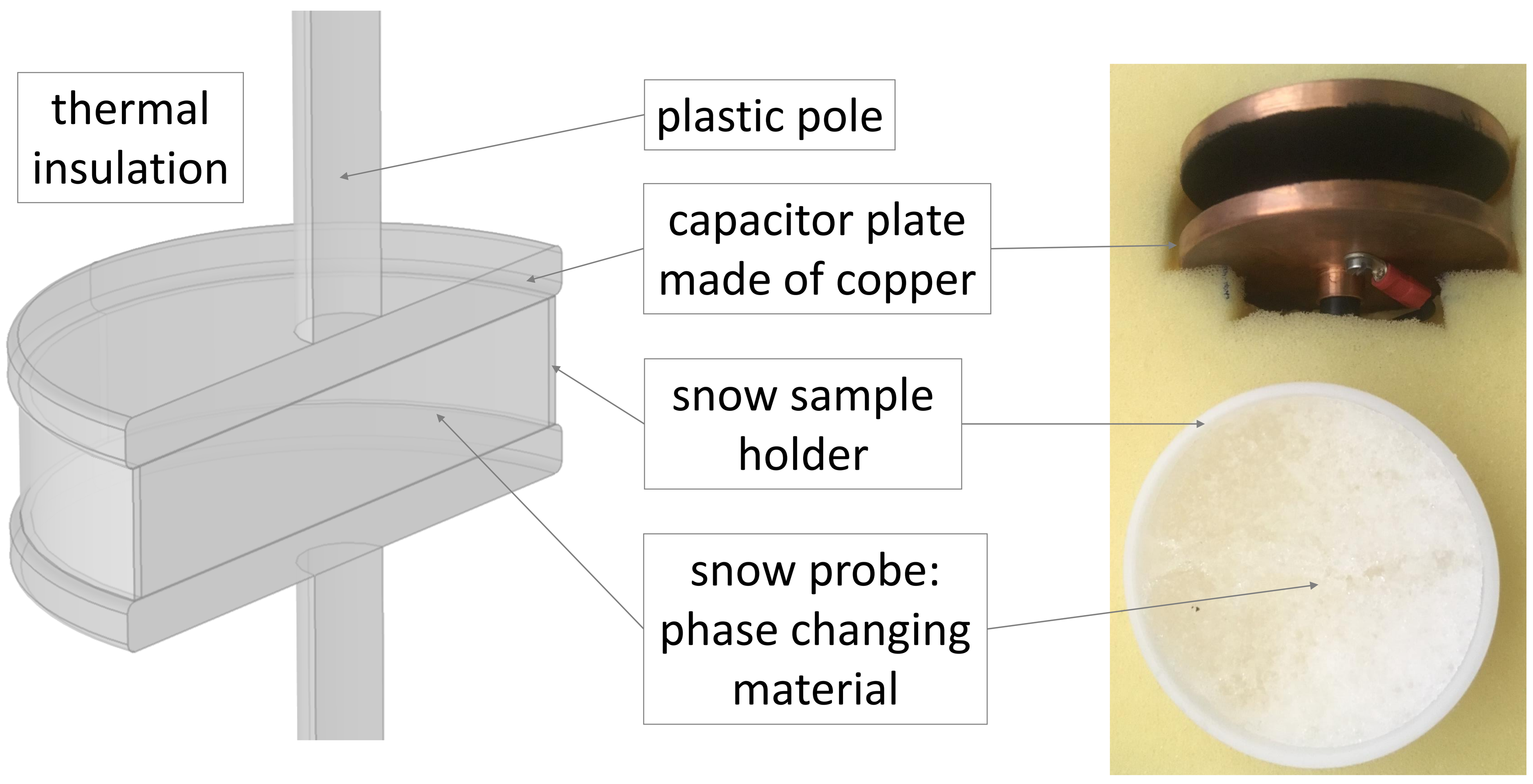

Figure 2. Simulation setup in COMSOL® and manufactured sample holder.

COMPUTATIONAL RESULTS:

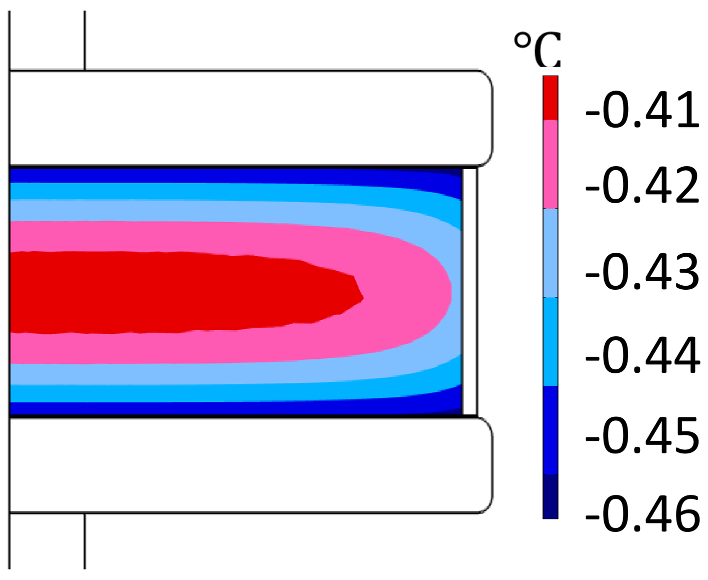

Figure 3. Small temperature gradient inside dielectric medium during dry snow heating.

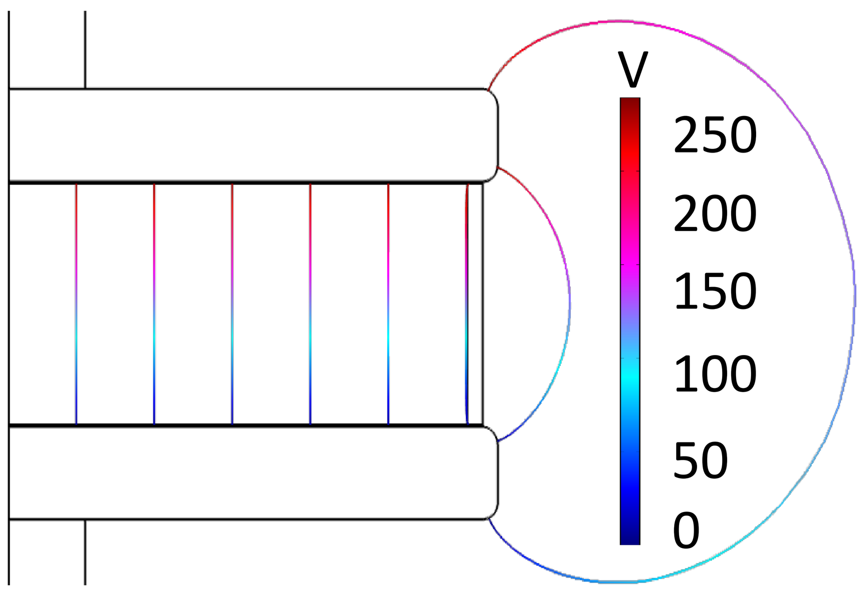

Figure 4. Linear electric field distribution during simulation between capacitor plates produce homogeneous dielectric heat source.

EXPERIMENTAL RESULTS:

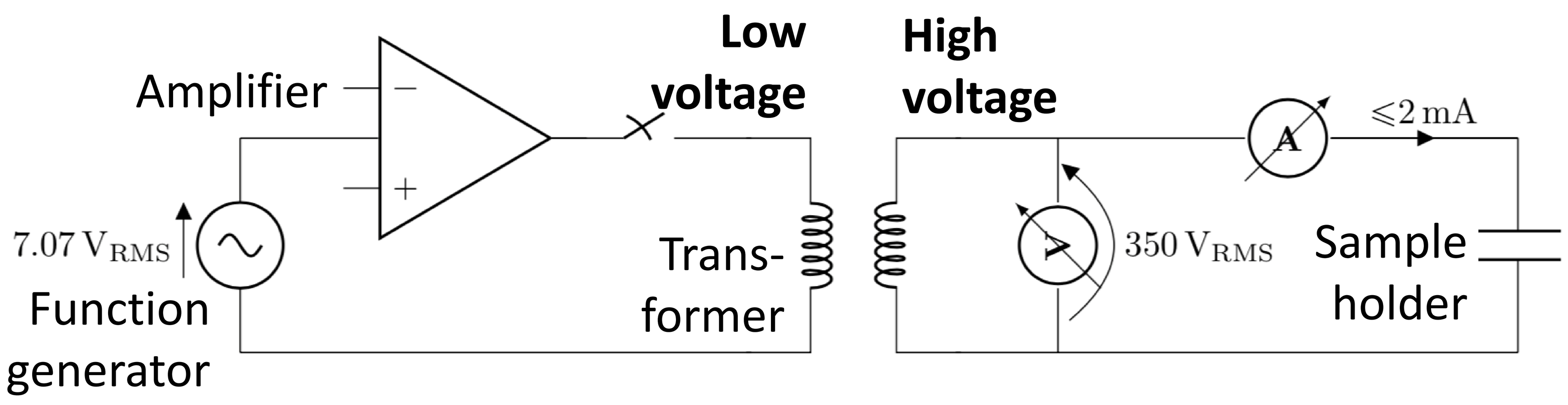

Figure 5. Electrical schematic of the experimental setup. Operating frequency: 18 kHz

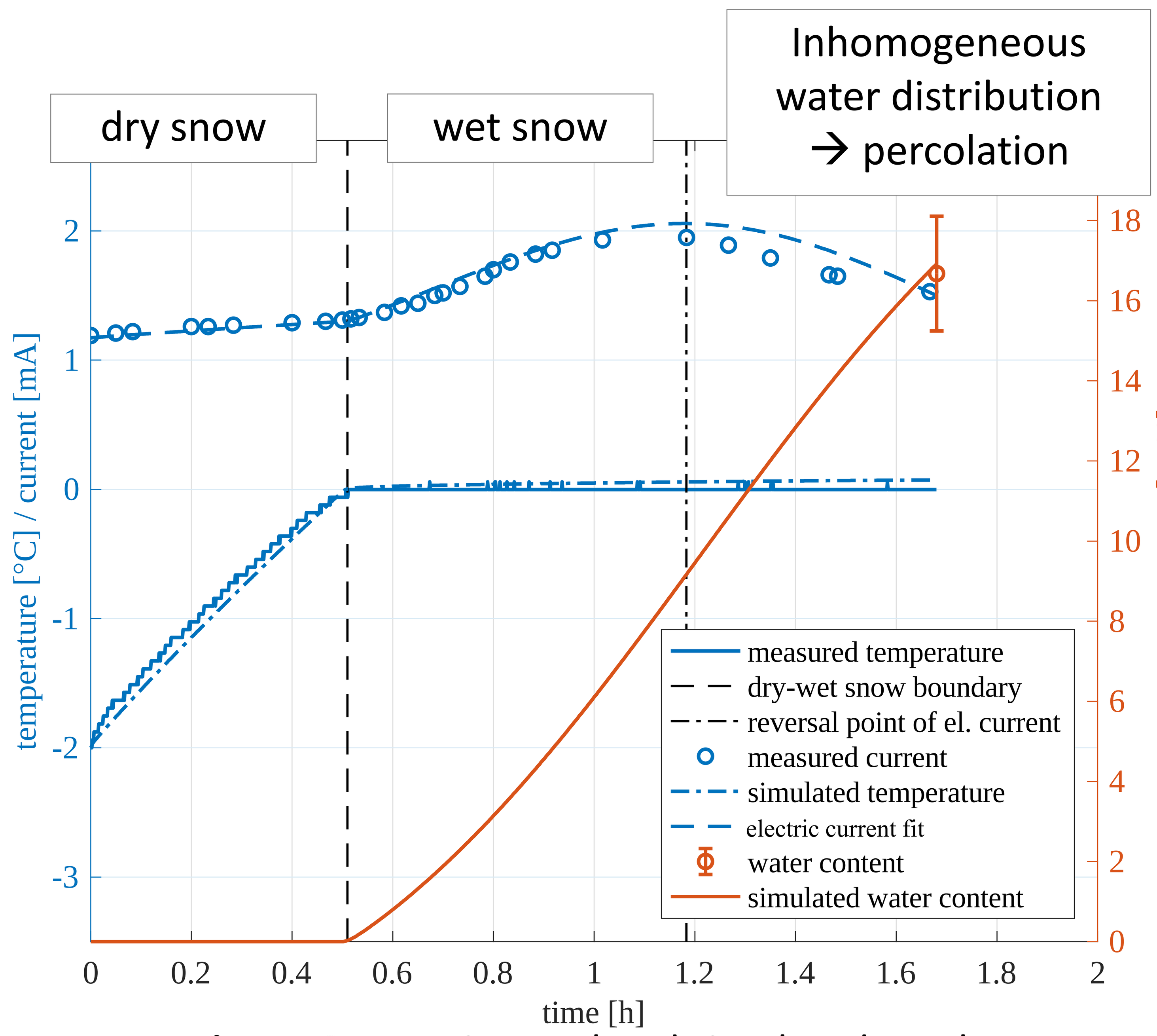

Figure 6. Experimental and simulated results

CONCLUSIONS:

- Simulations with COMSOL® are successfully used to design a new device, leading to insights on water content during the experiment.
- Based on the measured electric current, the simulation predicted the liquid water content within 1 wt%.
- The development of water content in the snow sample can be predicted.

REFERENCES:

[1] Mellor, Journal of Glaciology, Volume 57, pp. 15-66, (1977)