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Water content assessment in glacier ice and beneath it using Nuclear Magnetic Ressonance (NMR). Hansbreen glacier, Hornsund (SW Spitzbergen)

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Polythermal glaciers are widely spread on sub-polar regions and middle latitude mountains, their motion is mainly rouled by the englacial water content and subglacial drainage regime. In that sense water content assessments in ice is a major issue. For that ground-penetrating radar (GPR) has become the standard method since now, but scarce are the examples using Surface Nuclear Magnetic Resonance. It must be know that SNMR are the only geophysical procedure that detects from the surface the presence of water in the subsurface. The way forward that technique runs is doing a gradual increase of the magnetic pulse moment in order to investigate the subsurface deeper and deeper (Magnetic Resonance Sounding, MRS). The local Earth magnetic field leads in how should be the excitation frequency pulse moment in resonance with the water molecules (the Larmor frequency). When the electromagnetic pulse is removed the absorbed energy is released and can be detected, in essence a new electromagnetic field is obtained at the same frequency from the water hydrogen protons. A signal is obtained that decays exponentially with time (T*2), both related with the amount of water in ice (maximum signal amplitude) and its freedom degree within the ice (decay time). MRS data show different signals amplitudes according to the excitation loop dimensions. In a very high electrical resistive context (>2 Mega Ohms meter for glacier ice) the surveyed depth is directly related to the loop area. For small loops (30 m square loop) amplitudes around 50 nV are common as well as some decay time (T*2) above 300 ms. Enlarging the loop size (60 m square loop) it is possible to observe a decrease of the signal amplitude (E0 < 20 nV) but also the decay time (100 ms >= T*2 >40 ms). Increasing loop sizes (90 and 120 m square loops), a slight increase in amplitude, close to 30 nV, is observed with very high time decays (T*2 >500 ms) at the glacier bottom. In essence the water content detected using SNMR range between 0,12 % and 0,70 % while available GPR data from the same location range between 4% and 2%. The conclusion is that both geophysical methods don't converge, probably because some water content on ice has too short relaxation times being undetectable with conventional MRS devices, but in other hand it means that the low T*2 time decays data from large MRS loops elucidates that in the temperate-ice layer of a polythermal glacier water flows by seepage through veins and microfractures at a very low rate toward the glacier bottom, and a large amount of free water is close to the cold/temperate transition surface. In the cold-ice layer large T*2 time decays are common because water flows through fissures or karstic like conduits. In summary, combining the MRS and GPR techniques gives to the glaciologists a powerful toolkit to elucidate water flow-paths on glaciers, supercooled meltwater content and subglacial drainage or groundwater in aquifers.

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