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Sea spray freezing measurements with MRI and portable NMR

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Seawater spray and precipitation are two main sources of icing and ice accumulation in cold ocean regions, presenting a major challenge for shipping and operating maritime equipment [1].
There is a limited number of analytical techniques to study seawater spray ice formation. MRI is known for its non-invasive capabilities in measurements of a solid ice [2,3]. In this work, we investigated the potential of MRI as an analytical measurement technique for studies of the seawater spray ice.
The signal detected with MRI/NMR comes from pockets of brine in the forming ice, and the unfrozen water, with the 1H NMR signal from the brine decreasing as the temperature drops and the brine freezes further. 3D MRI showed different freezing patterns and temperature gradients depending on the initial freezing temperature and the surface geometry. T1-T2 maps indicated strong changes in relaxation parameters as the freezing progresses, indicating changing environment for the brine in the growing ice [4]. In a separate freezing series using Na NMR, the amount of sodium in the brine remained almost unchanged until the brine reached the eutectic temperature, and the sodium precipitation accelerated.
These measurements were done on an MRI scanner, with the freezing setup designed to fit a 4 cm i.d. RF probe inside a 2.4 T superconducting magnet. To explore a possibility of using NMR for freezing studies in a more open environment, we also used a portable, unilateral NMR device to characterize sea spray freezing on a cold surface. The device consisted of a flat 3-magnet array [5] with the sensitive volume (approx.2 mm x 15 x 15 mm) at 1 cm away from the magnet surface. 1D-resolved 1H NMR measurements provided information on the brine concentration, T2 and diffusion at a range of temperatures.
The results provide information on the changing environment in brine in freezing sea sprays, with a potential for NMR studies both in the lab and in the field.

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