DEVELOPMENT OF A COMPACT MRI SYSTEM IN A COLD ROOM FOR VISUALIZING MICROSTRUCTURES OF SNOW AND ICE: International Snow Science Workshop 2008

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ABSTRACT: We have developed a compact MRI (Magnetic Resonance Imaging) system for visualizing the three-dimensional microstructure of snow and ice by using a high-field-strength (1.04 T) permanent magnet in a cold room (-5 °C). In general, an MRI system uses a superconducting magnet; however, it cannot be used in a cold room because it is considerably large and requires a low-temperature cryogen (liquid nitro and liquid helium). The proposed MRI system consists of a portable MRI console and an extremely compact permanent magnet. A portable MRI console is set up at room temperature beside the cold room. A three-dimensional driven equilibrium spin-echo sequence and dual scan was used for the three-dimensional high-resolution imaging (image matrix = 256^3; voxel size = ((123 μm)^3; total imaging time = 2–16 h; and number of excitations = 1–8). Because the MRI signal from the ice is very weak in the MRI system, the air gaps in the snow and ice are filled with dodecane ($C_{12}H_{26}$), and the filler is imaged. This compact MRI system is a powerful tool to visualize the microstructure of snow and ice in a cold room.

KEYWORDS: compact MRI; microstructure; cold room.

1. INTRODUCTION

Ozeki *et al.* (2003) were the pioneers in visualizing the three-dimensional micro structures of Snowpack using a Magnetic Resonance Imaging (MRI). They used an MRI system that combined a superconducting magnet (4.75 T) and a specimen-cooling system, controlled by regulating the volume of cold airflow. However, it was a challenge to control the temperatures of snow and ice samples. Therefore, we have developed a compact MRI system by comprising a high- field- strength (1.04 T) permanent magnet in a cold room (- 5 °C). The proposed MRI system comprises a portable MRI console and an extremely compact permanent magnet. The portable MRI console is installed at room temperature outside the cold room.

However, it is observed that the image quality deteriorates because the magnetic field intensity of the permanent magnet is lower than that of a superconducting magnet. Therefore, we used a three-dimensional driven equilibrium spin-echo (3D-DESE) sequence and a dual scan for three-dimensional high-resolution imaging.

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2. METHODS

<u>2.1 Compact MRI System for visualizing the Three-dimensional Microstructures of Snow and Ice</u>

This system comprise a permanent magnet, a gradient coil set, and an RF probe installed in a cold room having a temperature of - 5 °C. Fig. 1 shows an overview of the permanent magnet in a cold room; characteristics are as follows: field strength = 1.04 T, gap width = 60 mm, homogeneity = 15.3 ppm over a 30 mm at 25 °C, dimensions = 45 cm (W) × 38cm (D) × 58cm (H), and weight = 300 kg. The RF coil is a ten-turn solenoid with a diameter of 30 mm.

We cut out of the snow specimen by the size of 10 cm × 2.4cm. Then we filled the air gap of the snow with dodecane ($C_{12}H_{26}$) by using a suction pump. An NMR signal was obtained for dodecane.

<u>2.2 Pulse Sequence for Snow and Ice</u>

A 3D-DESE sequence (repetition time (TR)/echo time (TE) = 200 ms/ 8 ms, image matrix = 256^3; voxel size = (120 μm)^3; total imaging time = 16 h) was used for three-dimensional high-resolution imaging (Fig. 2). A dual scan is a method implemented for acquiring a signal twice in high and low gain and synthesizing the signals.

Fig. 1. Permanent magnet in a cold room (- 5 °C).

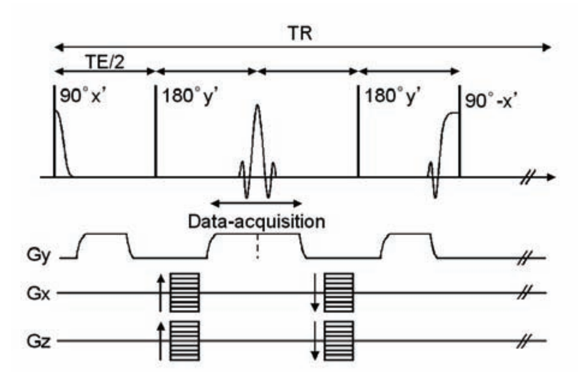

Fig. 2. 3D-DESE imaging sequence. The SE time (8 ms) was minimized to optimize the SNR of the NMR signal.

3.RESULTS

Fig. 3 shows two-dimensional central slices selected from a three-dimensional image data set of a depth hoar sample acquired using the 3D-DESE sequence. The bright regions indicate the presence of snow.

The sample was obtained from Hokkaido, Japan. A vertically connected structure is observed in Fig. 3–a. The flat square-shaped structure, representing the depth hoar, is observed in Fig. 3-b. Therefore, the three-dimensional data set is considered to have sufficient spatial resolution.

4.CONCLUSIONS

A compact MRI system was developed to visualizing the microstructure of snow and ice. An image with a high spatial resolution (pixel size = $(120\ \mu m)^3$) was visualized using this MRI system. We expect to further enhance this resolution (pixel size = $(100\ \mu m)^3$) by using an improved RF coil.

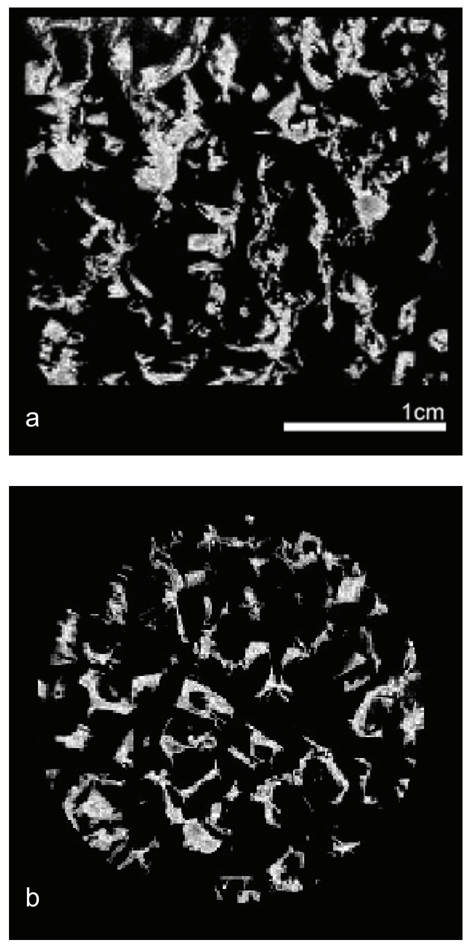

Fig. 3 Cross-sectional images of the depth hoar sample acquired using the 3D-DESE sequence and dual scan. TR = 200 ms, TE = 8 ms, image matrix size = 256 × 256, pixel size = $(120\ \mu m)^2$. a: Vertical cross section. b: Horizontal cross section.

5. REFERENCE

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