Methane Bubbles – What They Can Tell Us About the Impacts of Global Temperature Changes

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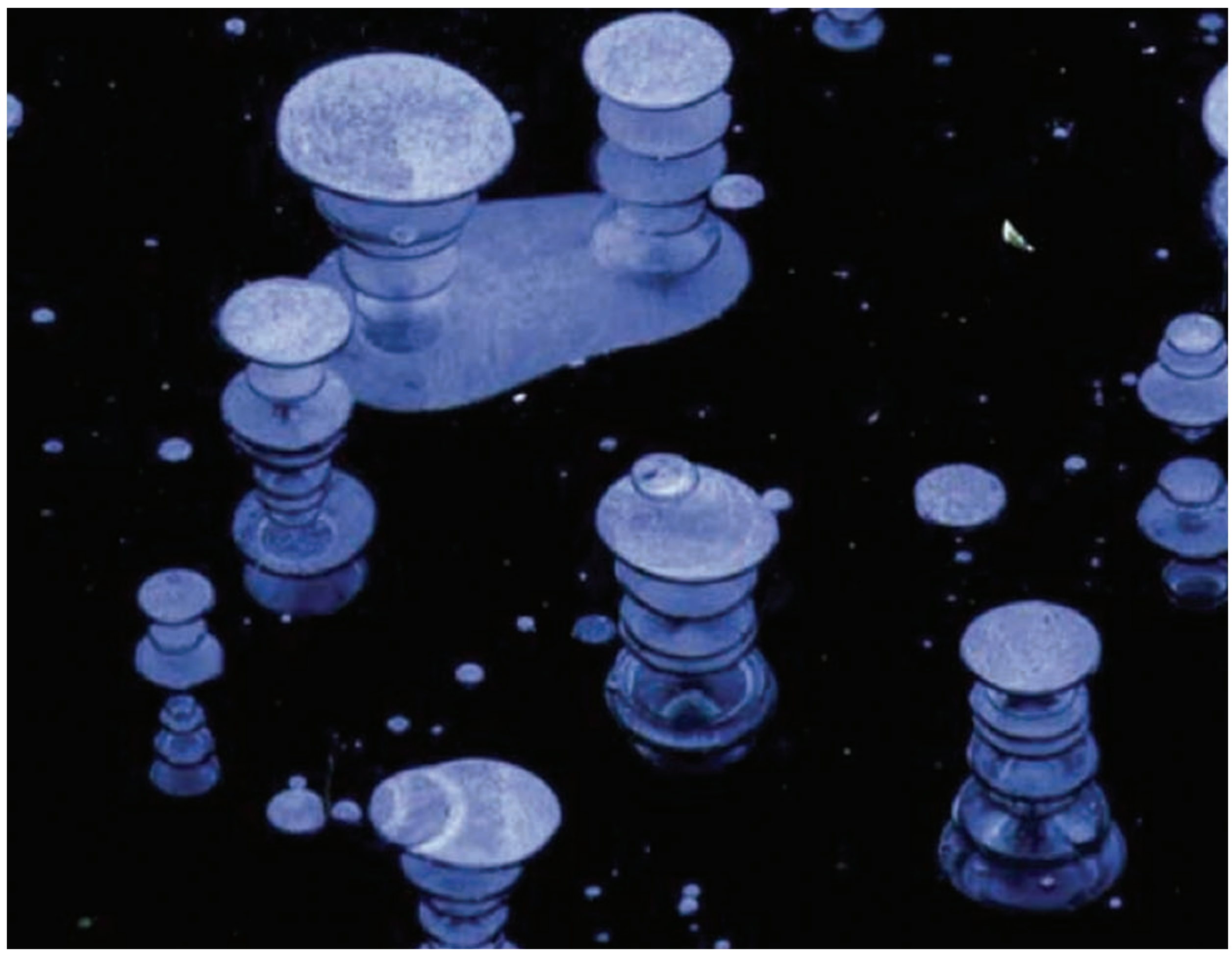
The arctic regions are expected to suffer the brunt of any temperature increases associated with global warming. A major change concomitant with warming is the release of carbon in the form of methane through the thawing of permafrost.

The thawing of permafrost (soil that is at or below the freezing point of water), threatens to release carbon into the atmosphere in the form of vast amounts of methane, a greenhouse gas some 23 times more potent in terms of warming than CO_2. The primary natural source of methane (CH_4) is microbial decay of organic matter under oxygen-free conditions in wetlands. As permafrost melts, it forms lakes which account for the majority of permafrost-derived methane emitted to the atmosphere via ebullition (bubbling). Previous studies appear to have grossly under-estimated the true rate of methane emission because random-sampling techniques can miss the ebullition sources, which occur in hotspots with little background emission. Permafrost degradation has already been linked to changes in vegetation composition, ecosystem functioning and the damaging impacts of permafrost degradation-induced subsidence on civil infrastructure.

Because there are significant uncertainties about the amounts of atmospheric methane, better measurements of this gas are needed to improve the accuracy of climate change estimates. A new research project aims to address these issues by pioneering a novel technique for measuring methane ice bubbles trapped within lake ice. As ice forms in autumn, bubbles released from lake sediments are trapped, resulting in stacks of ice bubbles separated by thin films of ice. With seed-corn funding provided through the Centre for Earth Observation Instrumentation (CEOI), the University of Cranfield has been investigating this.



(Photo by Michael Runtz)

Characterising Bubbles With Radar

Whilst methane gas is invisible to radar, its presence as bubbles in ice affects the strength of the radar return from the ice. The work has sought to qualitatively understand the relatonship between bubble presence and the backscatter from Synthetic Aperture Radar (SAR), in order to derive the volume of the bubbles, and hence the methane flux. This is based on laboratory measurements of simulated ice-bubble mixtures made from artificial materials.

If satellite-based SAR can provide quantitative measurements of the presence of methane bubbles, it will provide a much needed observation technique for constructing regional and pan-arctic estimates of current and future methane fluxes. Many recent pan-arctic studies show that permafrost extent is shrinking and that the upper portion of soil that thaws each summer is increasing. Some projections of permafrost melt forecast the current 10.5 million km^2 extent of near-surface permafrost will shrink to as little as 1.0 million km^2 by 2100.

An indoor measurement facility has been created at Cranfield University within the Department of Informatics and Systems Engineering, in order to simulate the radar properties of ice containing methane bubbles. Dry sand is used in place of ice, as it has a very similar response to a radar wave. Voids simulating gas bubbles are created using expanded polystyrene within the sand. The work will provide an understanding of how the signal returns are dependent upon the size, shape and density of the bubbles, and also on the radar frequency and the angle the bubbles are viewed from. A new in-house imaging technique known as Tomographic Profiling provides vertical slices of the radar returns through the ice volume, allowing separation of the ice and bubble signals. The work has provided important new insights into the physical interaction between a radar wave and the bubbles.

Monitoring Methane From Space

The main aim of this CEOI project is to establish optimum techniques for bubble identification and characterisation, with consideration to existing and future space SAR platforms. As methane bubbles can range in size from centimetres to metres in diameter, a combination of imagery from multiple satellites working in different parts of the frequency spectrum may offer the best prospect for providing the required measurements. Knowledge of methane emissions is important in its own right, but also provides essential information on the degradation of permafrost, snow cover and freeze-thaw processes, and therefore is likely a strong indicator of climate change. Provision of a space-based, remote sensing measurement scheme for methane flux release across the Arctic will be of immense benefit to climate modellers and those interested in land/atmosphere interactions and exchange, helping to reduce the current vast uncertainties in future methane release.