Laboratory Characterisation of the Radar Signature of Methane Bubbles in Lake Ice

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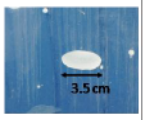
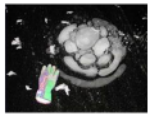
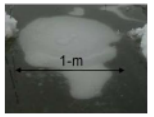
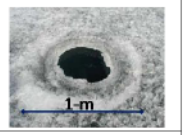
MOTIVATION

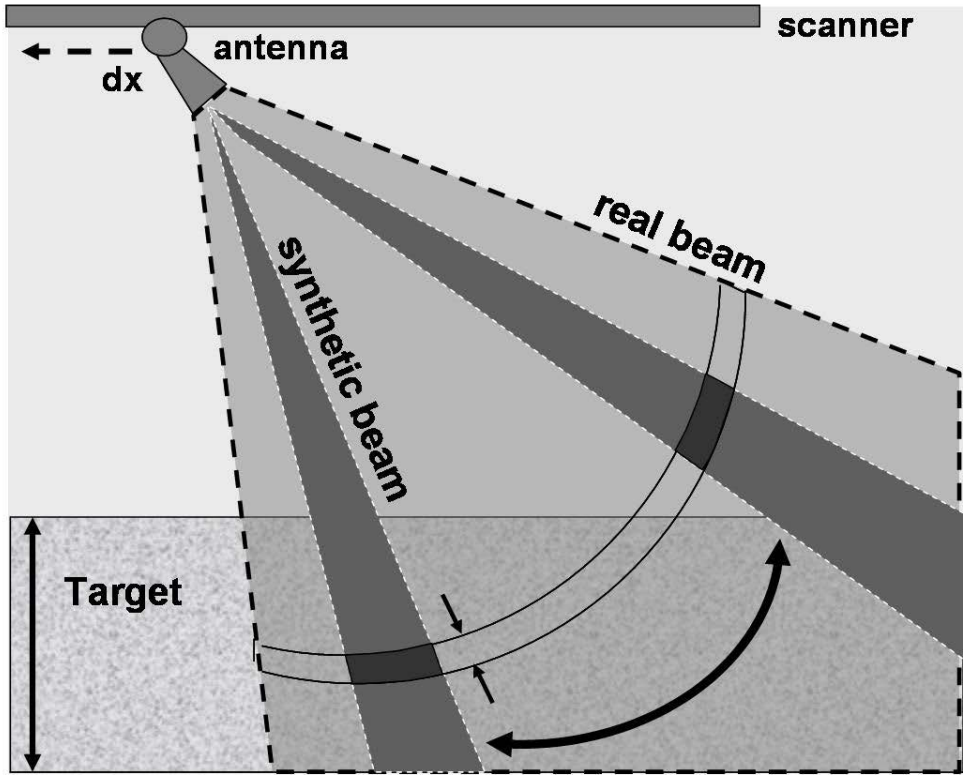
- Release of methane from thawing permafrost regions threatens to put vast amounts of this potent greenhouse gas into the atmosphere.
- One method of estimating the methane flux is by the observation of methane ice bubbles trapped within lake ice utilising SAR satellite imagery for pan-arctic monitoring
- Using laboratory simulations of ice bubbles, provided the opportunity to quantitatively analyse their radar signature in a carefully controlled, repeatable environment.

Report on physical configuration of methane (CH_4) ebullition bubbles in lake ice, provided to inform laboratory radar reflectivity measurements from simulated bubbles.

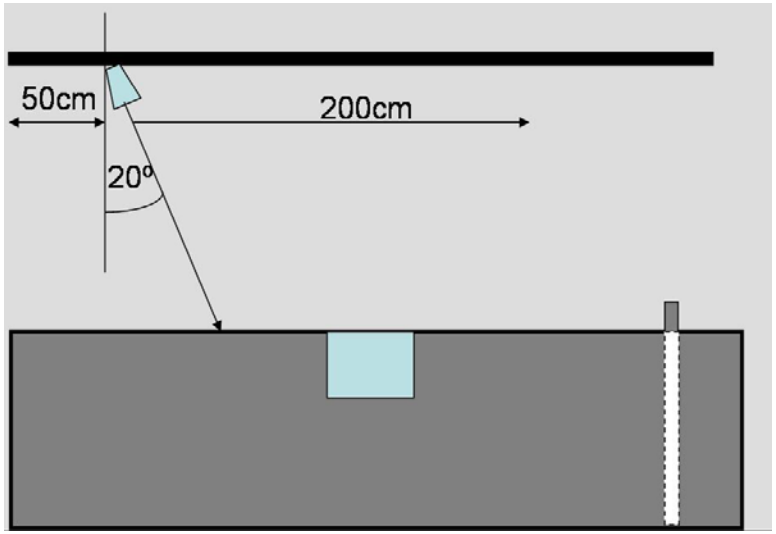
by Melanie Engram and Katey Walter Anthony

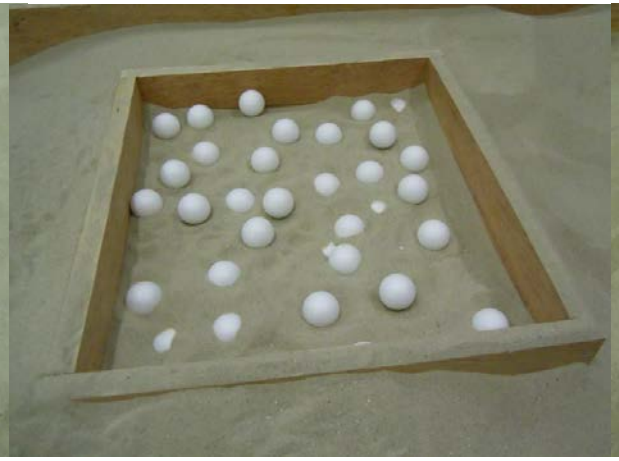
Water and Environmental Research Center (WERC)
Institute of Northern Engineering (INE)
University of Alaska Fairbanks (UAF)

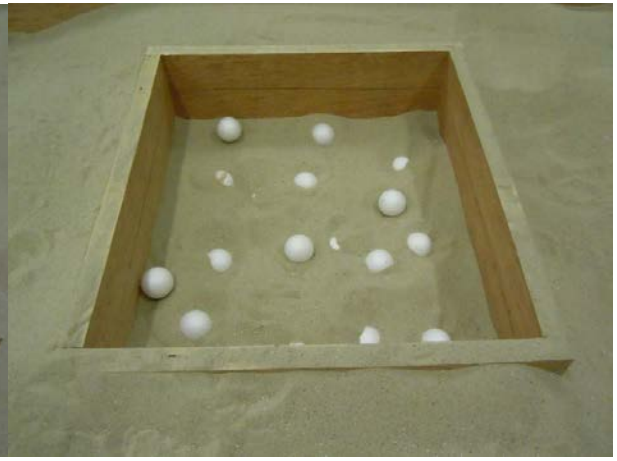
Bubble Category	N	A	B	C	Hotspot
Photo					
Priority for Laboratory Investigation	5th priority	2nd Priority	1st Priority	3rd Priority	4th Priority
Ebullition ($ml\ gas\ seep^{-1}\ d^{-1}$)	Negligible flux	Weak flux 22 , +/- 7 n=11 (mean,+/- SE)	Medium flux 351 , +/- 112 n=8 (mean,+/- SE)	Strong flux 1,525 , +/- 243 n=7 (mean,+/- SE)	Greatest flux 4,781 , +/- 578 n=10 (mean,+/- SE)
Description	Bubble(s) visible in one single layer, not multiple layers.	Isolated bubbles in multiple layers <50% merged	Merged bubbles (>50%) in multiple layers	Closed-ice surface. All bubbles merged horizontally with multiple layers or tiers.	Open hole in ice most of year, sometimes covered by thin snow or ice crust that is easily broken with fist or foot.
Size	Variable size	<50 cm diameter	Usually > 30cm diameter	Usually >40 cm diameter	Usually >40 cm diameter


scanner
antenna
dx
real beam
synthetic beam
Target

MEASUREMENTS

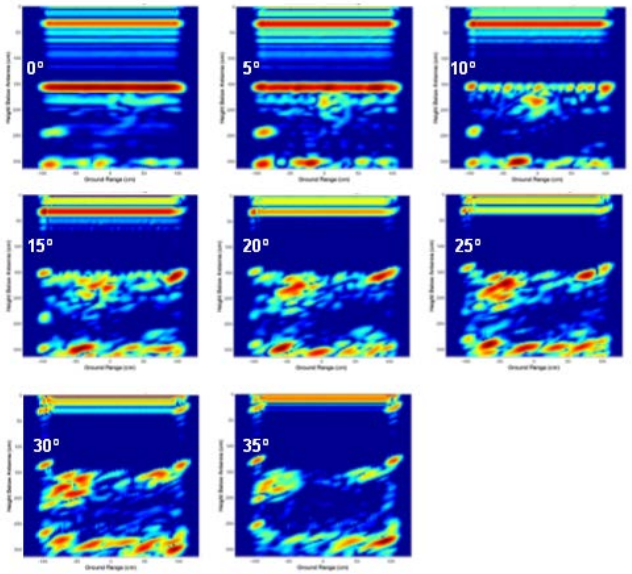




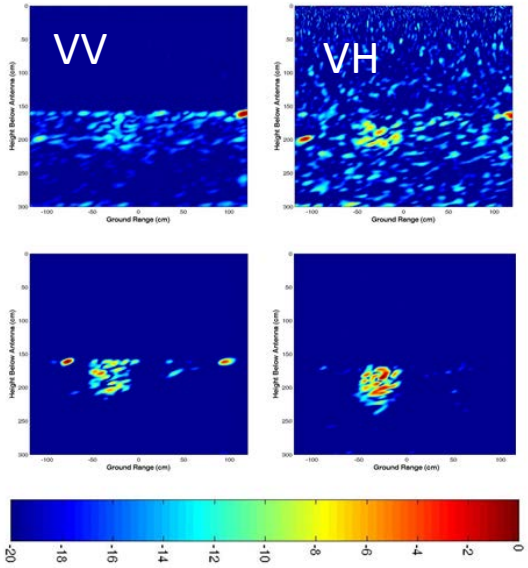


RESULTS

Effect of imaging geometry on C-Band results

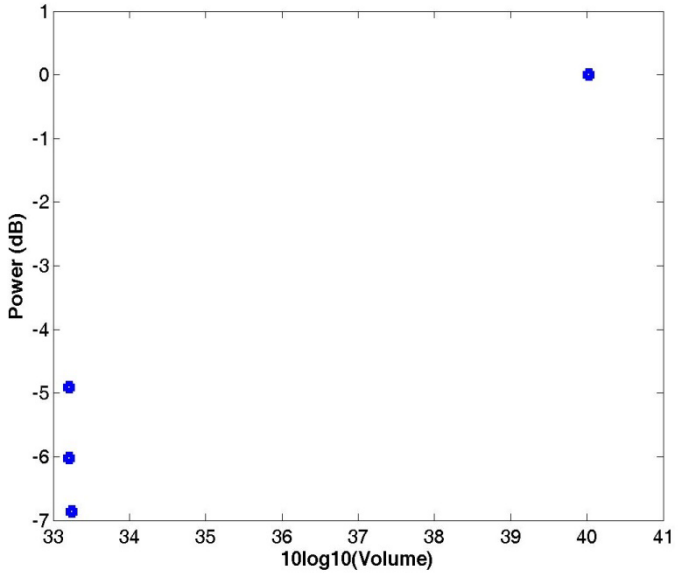


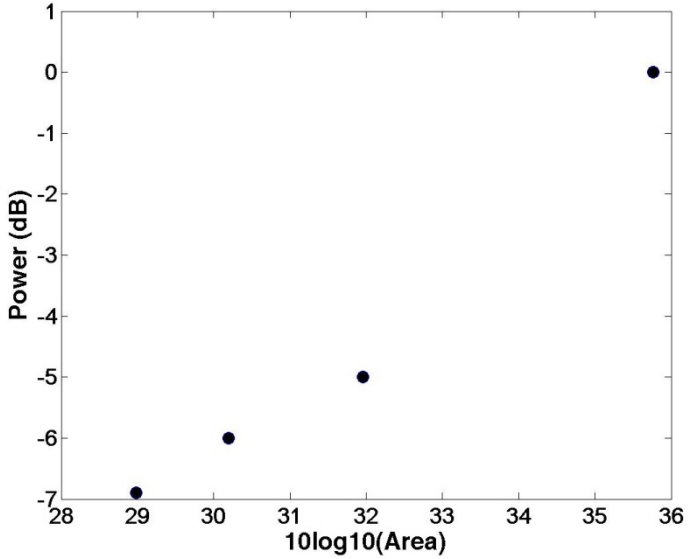
Ku-band backscatter for increasing 3-15% volume occupied by bubbles



Target-to-clutter ratio

Freq.	VV (dB)	VH (dB)
C	13.2	19.0
X	17.5	23.2
Ku	16.2	23.0

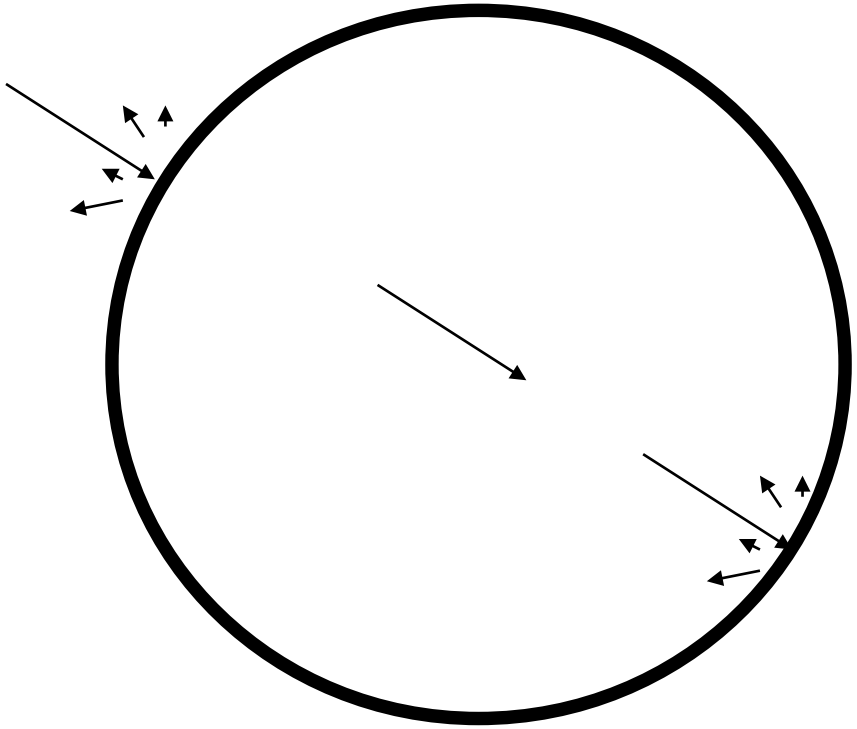




EXPLANATION

$\text{Area} \propto r^2$

$\text{Volume} \propto r^3$



Target-to-Clutter ratios for different satellites

Bubble area (0.5m x 0.5m)

Resolution	C_v / T_v	T / C (dB)	Extant Satellite	Pol.
1m x 1m	4	17.1	TerraSAR-X: Spotlight (Hi-res.)	Single
2m x 2m	16	11.1	TerraSAR-X: Spotlight	Single
3m x 3m	36	7.5 3.4	TerraSAR-X: Ultra Fine Radarsat-2: Ultra Fine	Single
8m x 8m	64	-1.0	TerraSAR-X: Fine Radarsat-2: Fine	Dual