

Fire and Ice: Measuring Antarctica's Frozen Sea

Dr. Cindy Furse, Dr. Ken Golden
David Lubbers, Dr. Joyce Lin Christian Sampson



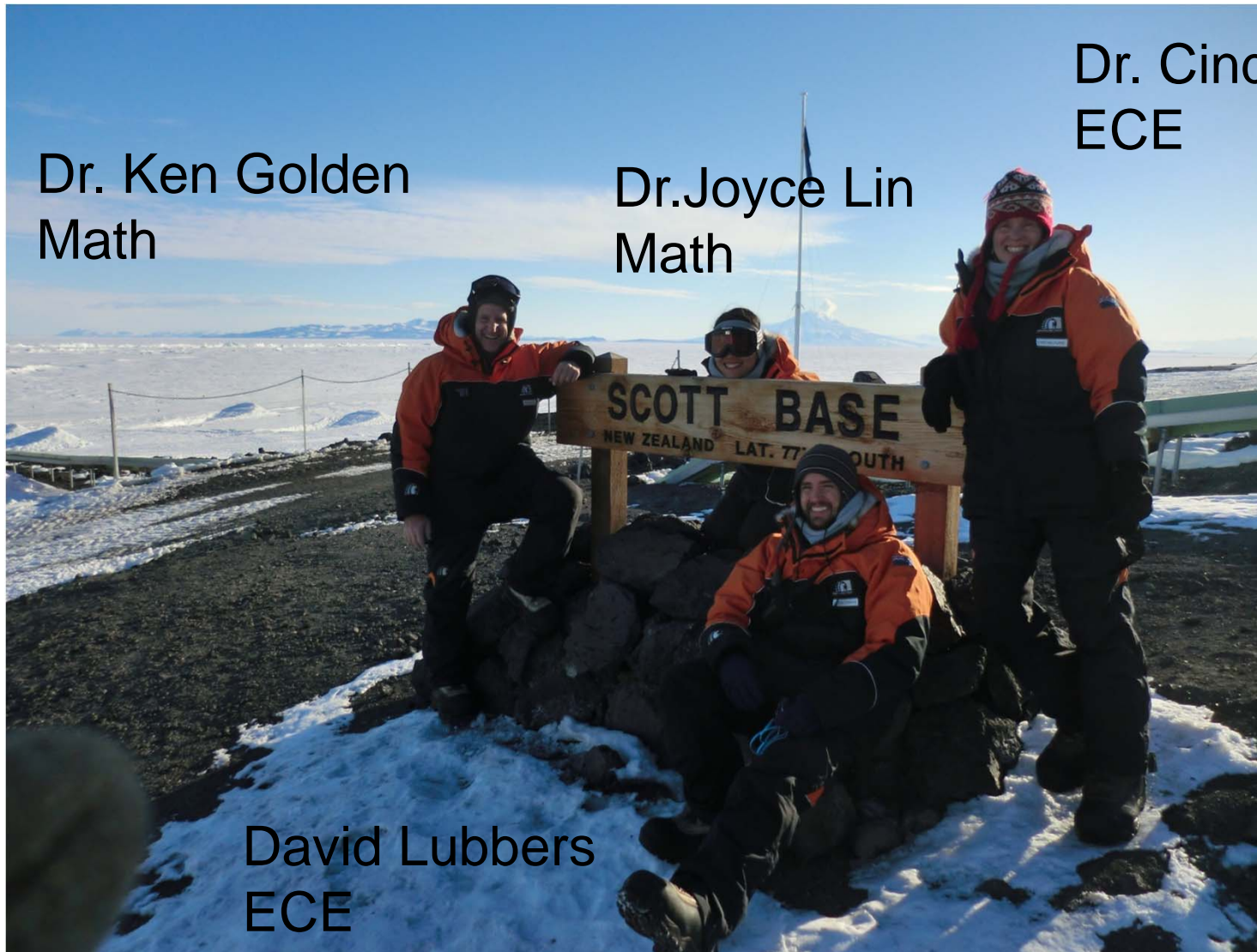


Antarctic Math & Engineering Expedition

Dr. Ken Golden
Math

Dr. Joyce Lin
Math

Dr. Cindy Furse
ECE



David Lubbers
ECE



International Research Collaboration



Photo: Ken Golden

Our expedition was a key activity in a 4 year interdisciplinary, international project:

U. of Utah - Math: Ken Golden PI

Elena Cherkaev, Jingyi Zhu

ECE: Cindy Furse

U. Alaska Fairbanks – Geophys. Inst.: Hajo Eicken

Victoria U., NZ – Chem. and Phys. Sciences: Malcolm Ingham

} Co-PI's



UTAH MATH: Joyce Lin, NSF Postdoc, Grad students Adam Gully, Christian Sampson, Senior Kyle Steffen

UTAH ECE: Seniors David Lubbers, Erik Gamez, Jake Hansen

UAF: Grad student Marc Mueller-Stoffels

VUW: Grad students Keleigh Jones, Sean Buchanan

National Science Foundation Collaborations in Mathematical Geosciences

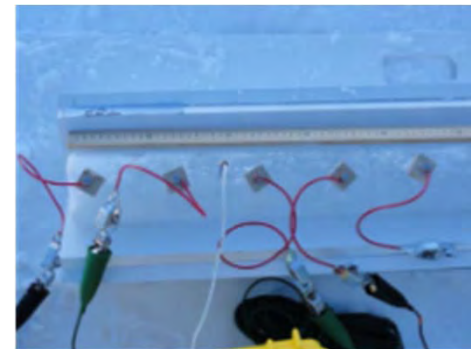
***Develop electromagnetic methods
to monitor sea ice processes which
are critical to understanding climate
and
improving global climate models.***





Team Members

- *Jake Hansen*
 - *Intro, Background, Key Properties*
 - *Procedures/Methods*
- *Erik Gamez*
 - *DC Measurements and Results*
- *David Lubbers*
 - *Anisotropic Measurements*
 - *AC Measurements and Results*





Why Study Sea Ice?

- *Winter: 7-10% of the Earth's surface*
- *Cycle of formation and degradation impactful*
- *Boundary: sunscreen and blanket*
- *Albedo: ratio of reflected sunlight to incident sunlight*
- *Climate and ocean life*
- *Most sensitive regions on Earth*





Sea Ice and Climate Change

- *Sea ice as the boundary layer between the ocean and atmosphere*
- *Nearly 40% loss*



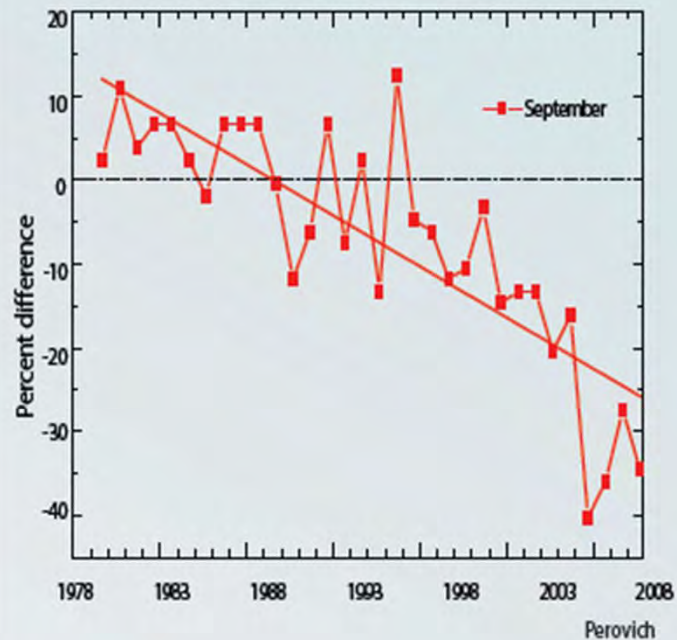
From: Don Perovich



Arctic meltdown

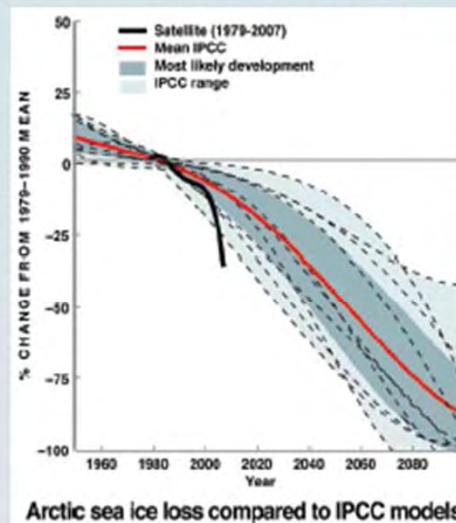
Summer Arctic sea ice pack is declining, and thicker, multiyear ice is being replaced by thinner first year ice.

Change in summer Arctic sea ice extent

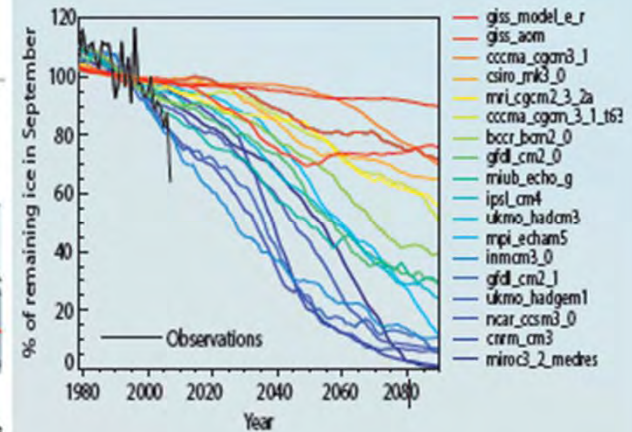


IPCC (Intergovernmental Panel on Climate Change) projections

global climate models underestimate observed decline in summer Arctic sea ice extent



September 2007



March 2009

Boé, Hall, Qu 2009



Properties of Sea Ice

- *Sea ice: simply frozen ocean water*
- *Sea ice is heterogeneous*
- *Composite: pure ice with inclusions of liquid brine, air pockets, and solid salts*
- *Most influential variable: Temperature*



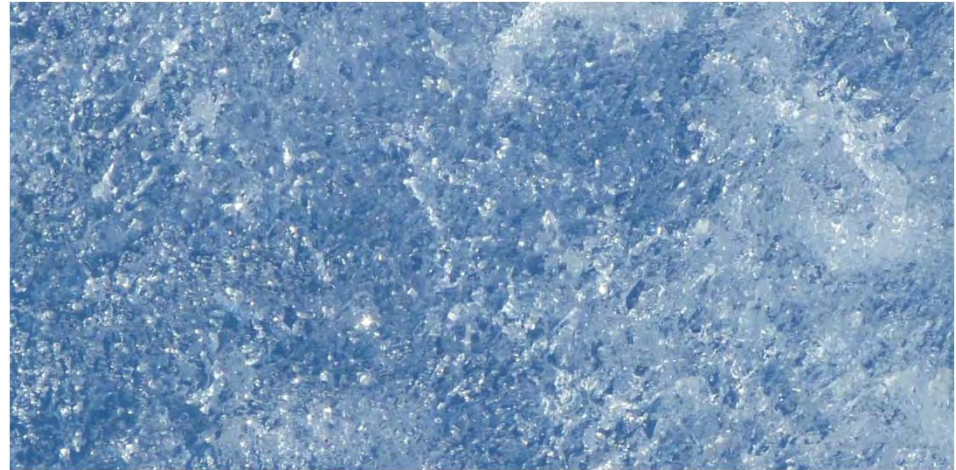
Courtesy of Dr. Ken Golden



Sea Ice and Climate Change



Vertical slice



Horizontal slice

Brine channels in the ice allow transport of sea water, forming snow ice and affecting heat exchange and melt pond evolution.



Why Study Sea Ice?



T. Naib, "Glacier And Ice Cap Melting Could Make Sea-Level Rise Worse Than Expected," [Online]. Available: <http://www.blog.thesietch.org/2007/08/17/glacier-and-ice-cap-melting-could-make-sea-level-rise-worse-than-expected/>. [Accessed 24 Sep 2012].





Why Study Sea Ice?

Global Temperature



Resistivity of Sea Ice





Why Study Sea Ice?

Global Temperature

How?

Resistivity of Sea Ice





Amount of Sea Ice

Dwindling Arctic Sea Ice



Source: NASA, 2009*

EPA, " Arctic Sea Ice," *Climate Change Indicators in the United States*, pp. 1-2, August 31, 2012. http://www.epa.gov/climatechange/pdfs/print_sea-ice.pdf. [Accessed October 7, 2012]





Sea Ice and Climate Change

- *Sea ice as the boundary layer between the ocean and atmosphere*
- *Nearly 40% loss*



From: Don Perovich





Why Study Sea Ice?

Global Temperature



Amount of Sea Ice





Melt Ponds



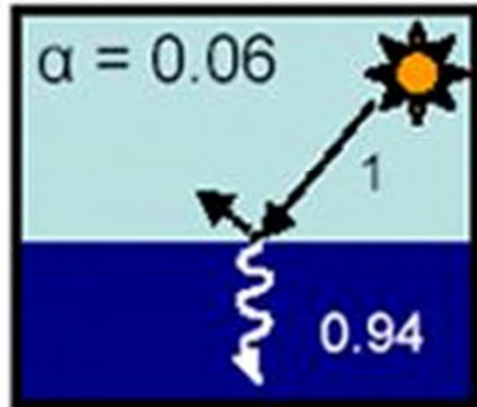
NASA, "Ponds on the Ocean," [Online]. Available: http://earthobservatory.nasa.gov/IOTD/view.php?id=51335,_ICESCAPE.jpg.



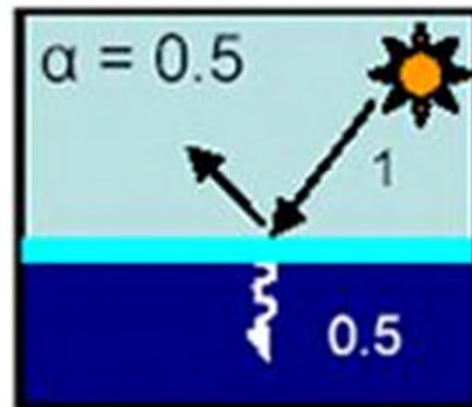


Melt Ponds/ Albedo

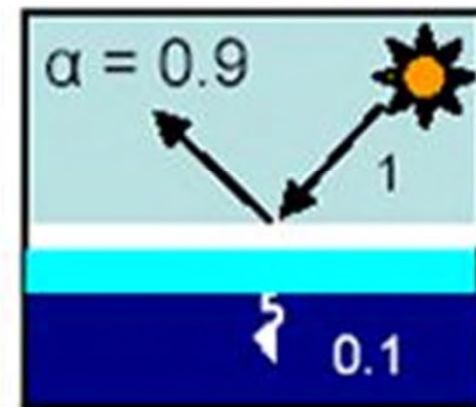
I. Open ocean



II. Bare ice



III. Ice with snow



National Snow and Ice Data Center (NSIDC). "Thermodynamics: Albedo," *All about Sea Ice*.
<http://nsidc.org/cryosphere/seaice/processes/albedo.html> [Accessed October 7, 2012]





Why Study Sea Ice?

Global Temperature



Amount of Sea Ice

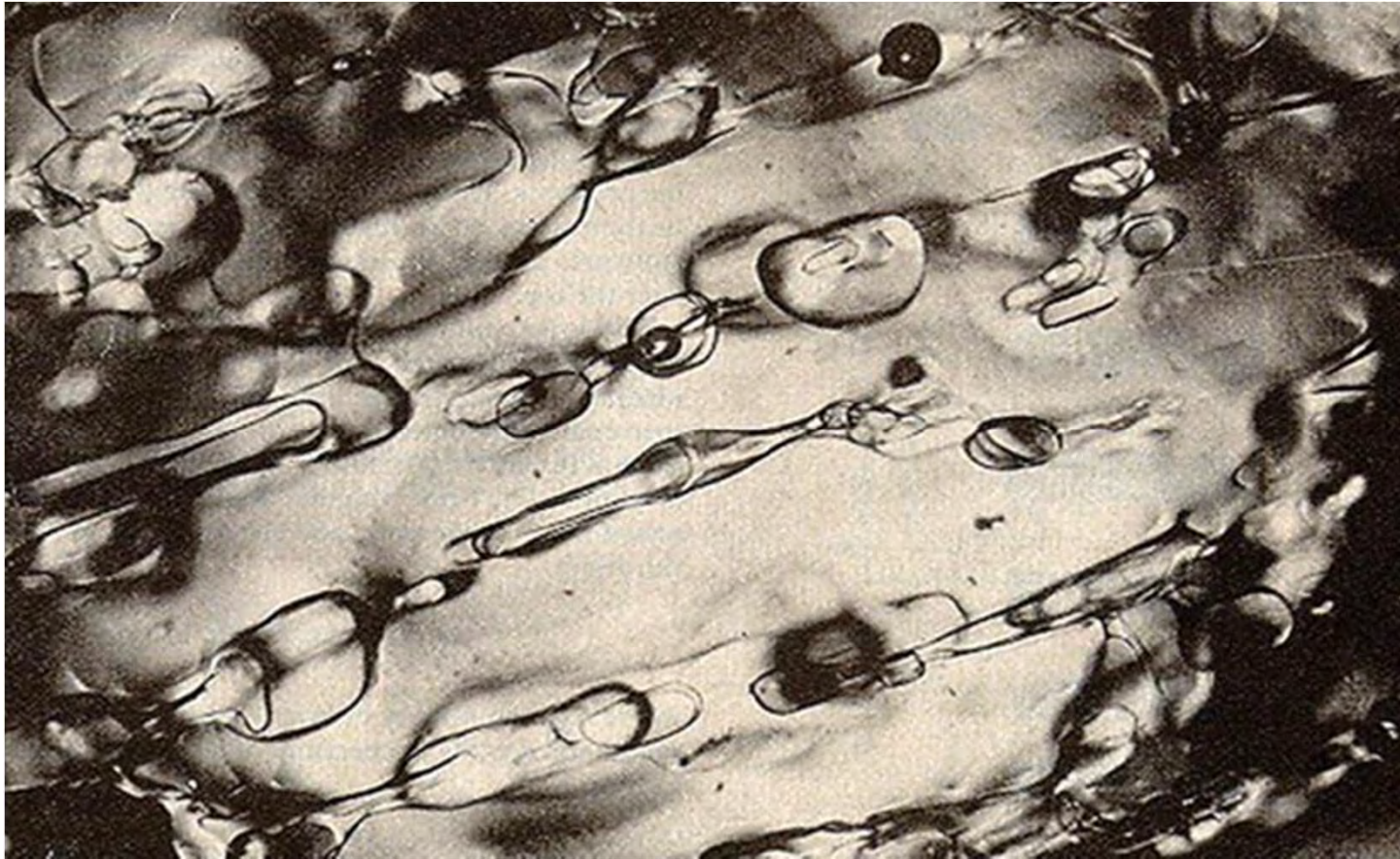


Melt Ponds





Brine Channels/Percolation



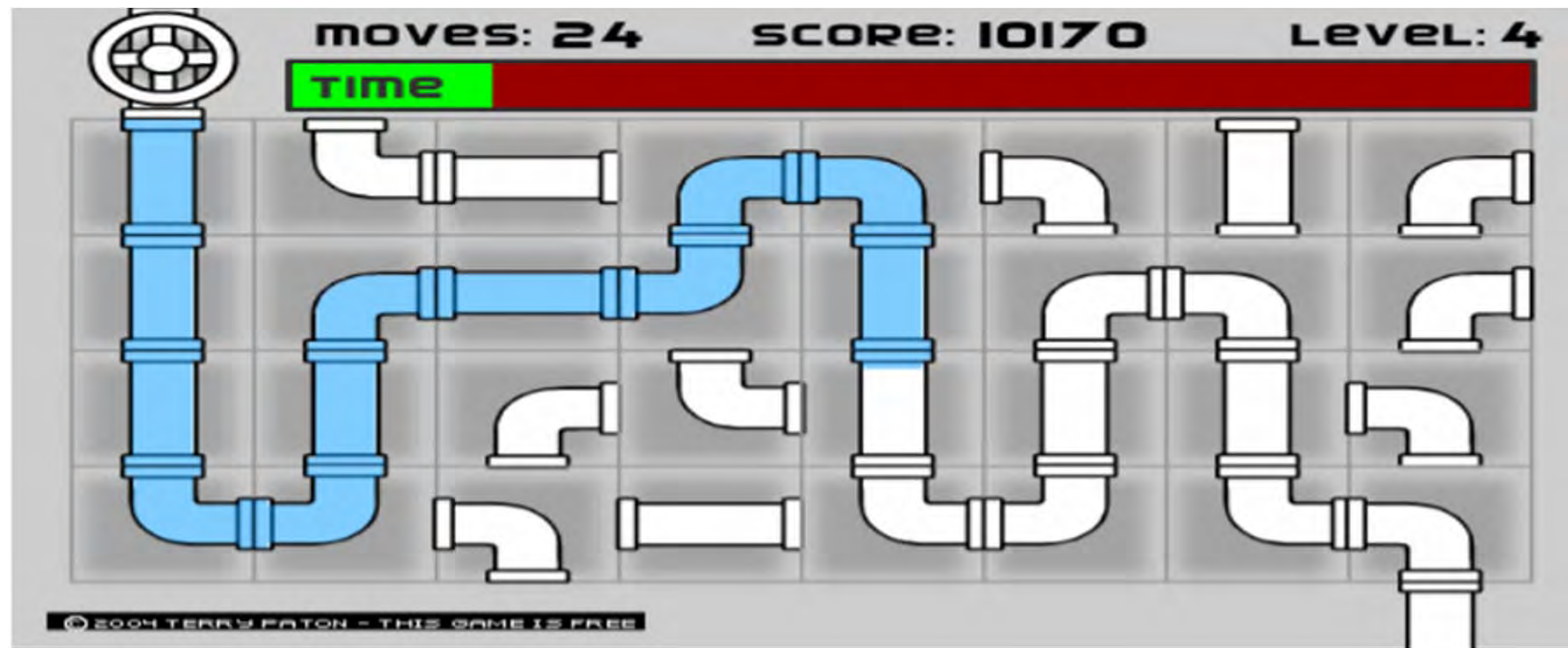
C Bitz, K. M. Golden, M Holland, E Hunke. "Sea Ice in the Global Climate System." 2009.
http://mathaware.org/mam/09/essays/Golden_etal_Sea_Ice.pdf





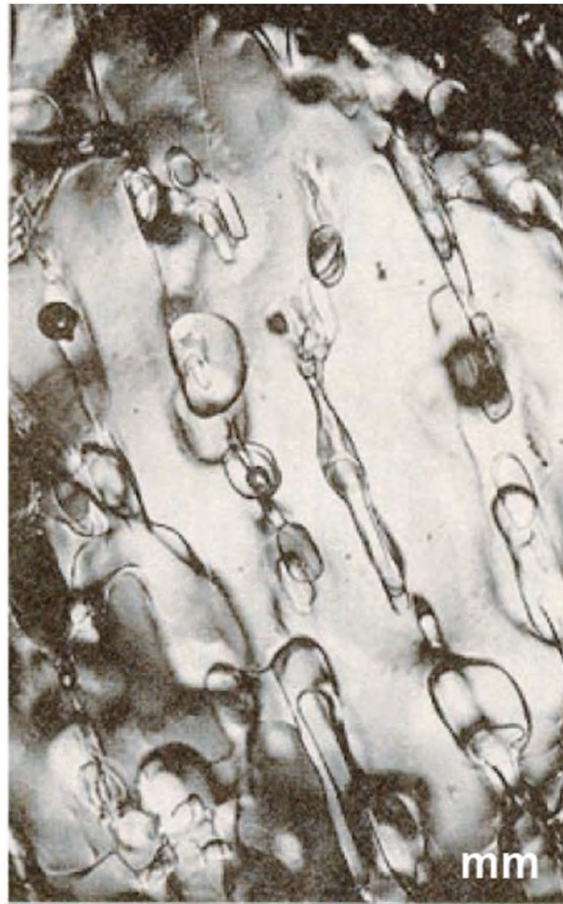
Properties of Brine

- *Brine: Salt water*
- *Host extensive algae and bacterial communities*
- *Facilitates the flow of salt water through sea ice*
- *Mediates the growth and decay of seasonal ice*





Prime Inclusions



Courtesy of Dr. Ken Golden



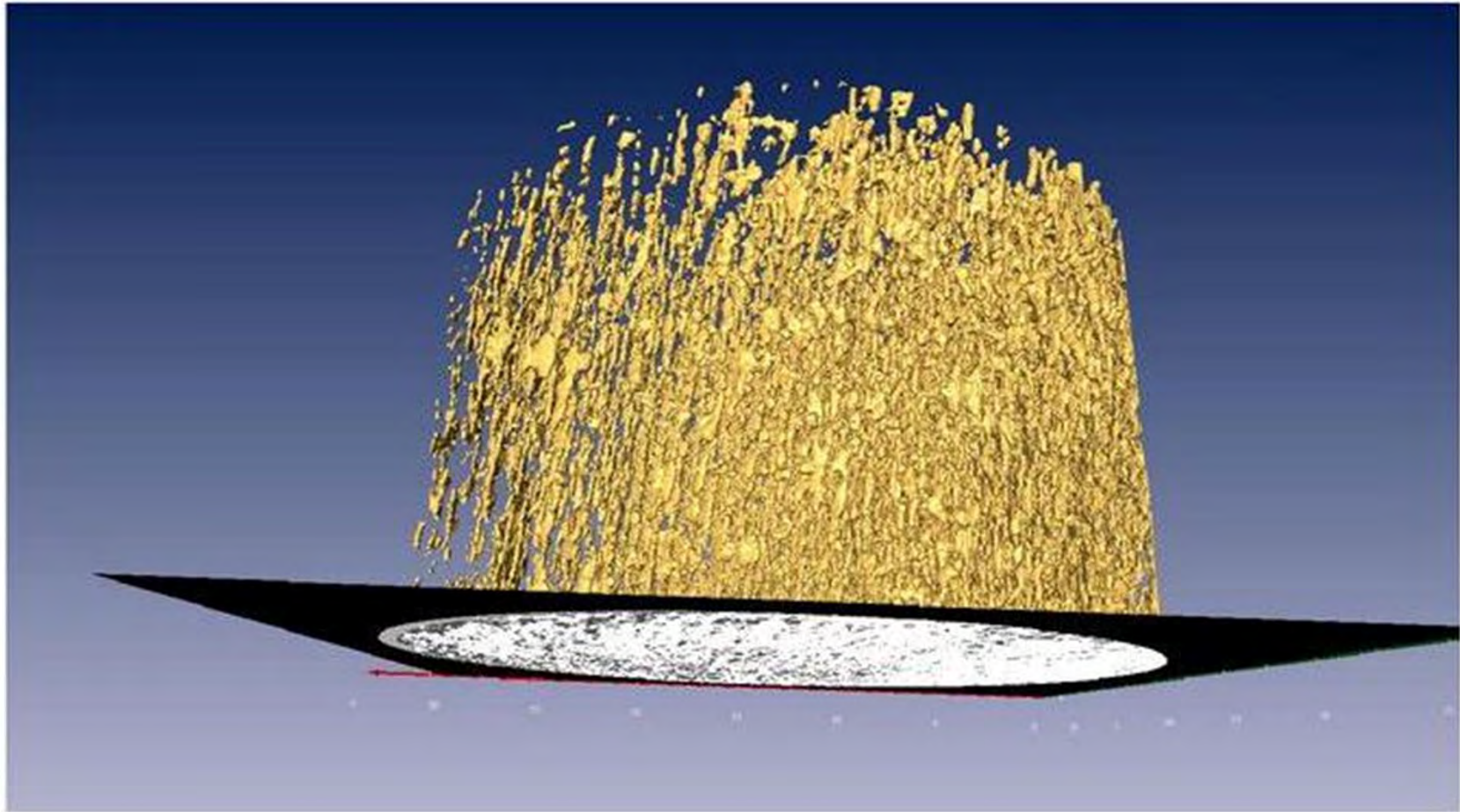
Fluid Transport Occurs



From Previous Work: Dr. KM Golden



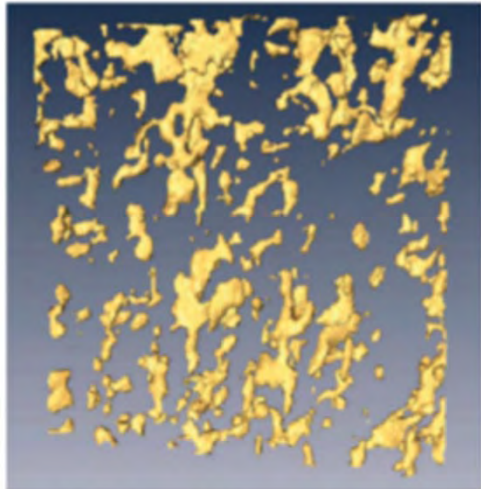
Electrical Transport



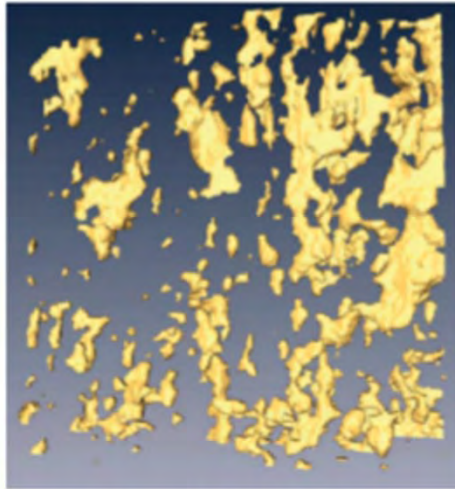
From Previous Work: Dr. KM Golden, Dr. Hajo Eicken



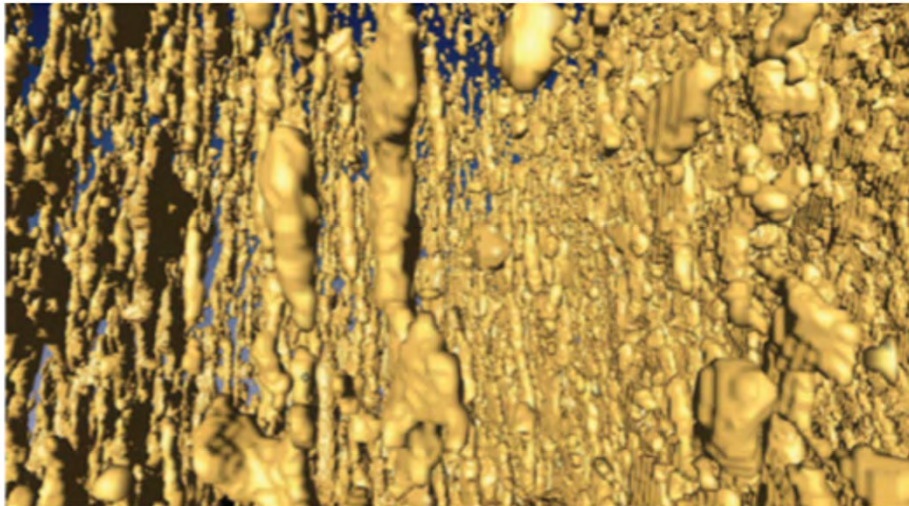
Rule Of Fives (cont.)



(a) $T = -15^{\circ}\text{C}$, $\phi = 0.033$



(b) $T = -6^{\circ}\text{C}$, $\phi = 0.075$



(c) $T = -4^{\circ}\text{C}$, $\phi = 0.11$

$$T = -5^{\circ}\text{C}$$

$$\Phi = .05$$

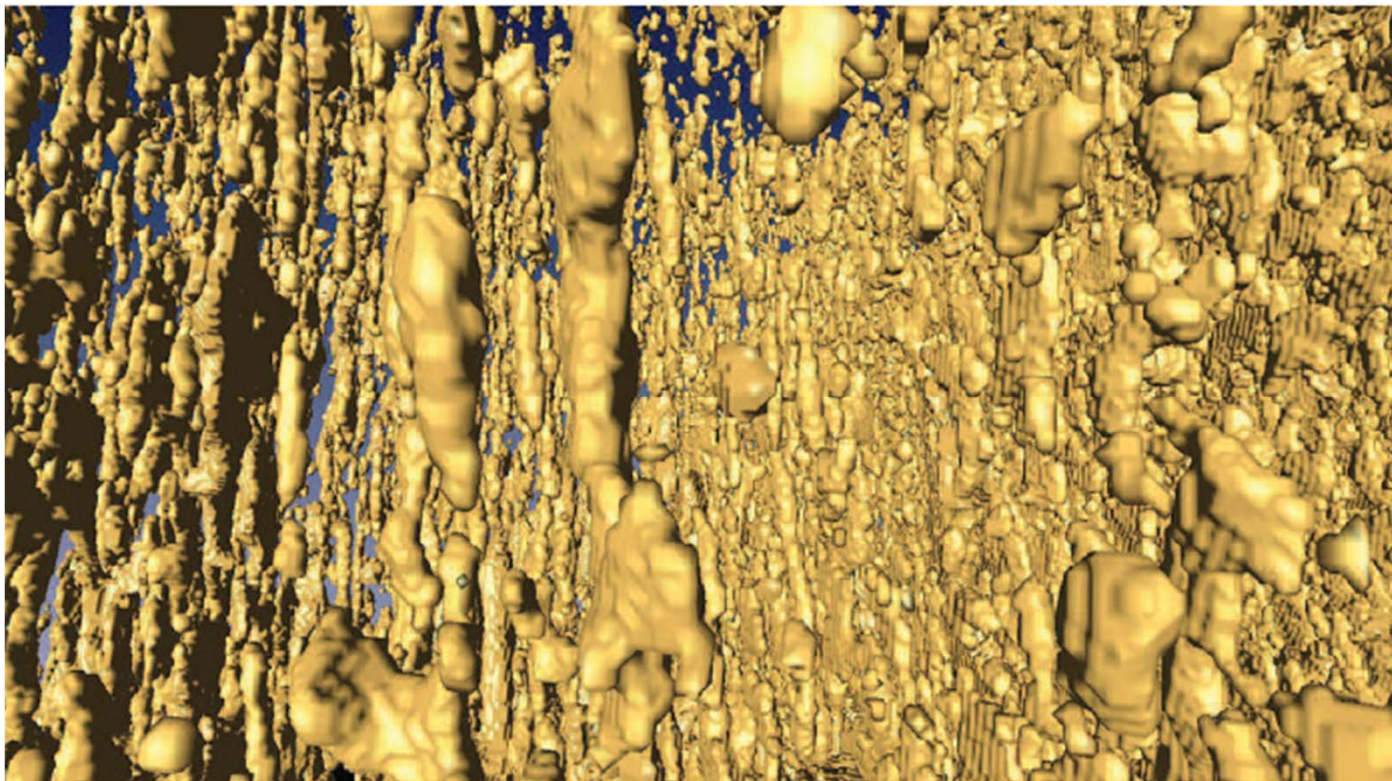
$$S = 5 \text{ ppt}$$

[2]C. Sampson, K.M. Golden, A. Gully, A.P. Worby, Surface impedance tomography for Antarctic sea ice, Deep Sea Research Part II: Topical Studies in Oceanography, In Press, Corrected Proof, Available online 15 December 2010



Anisotropy

- *The property of being directionally dependent*
- *Modeling is very difficult due to the anisotropic nature of sea ice*





Why Study Sea Ice?

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Amount of Sea Ice



Melt Ponds

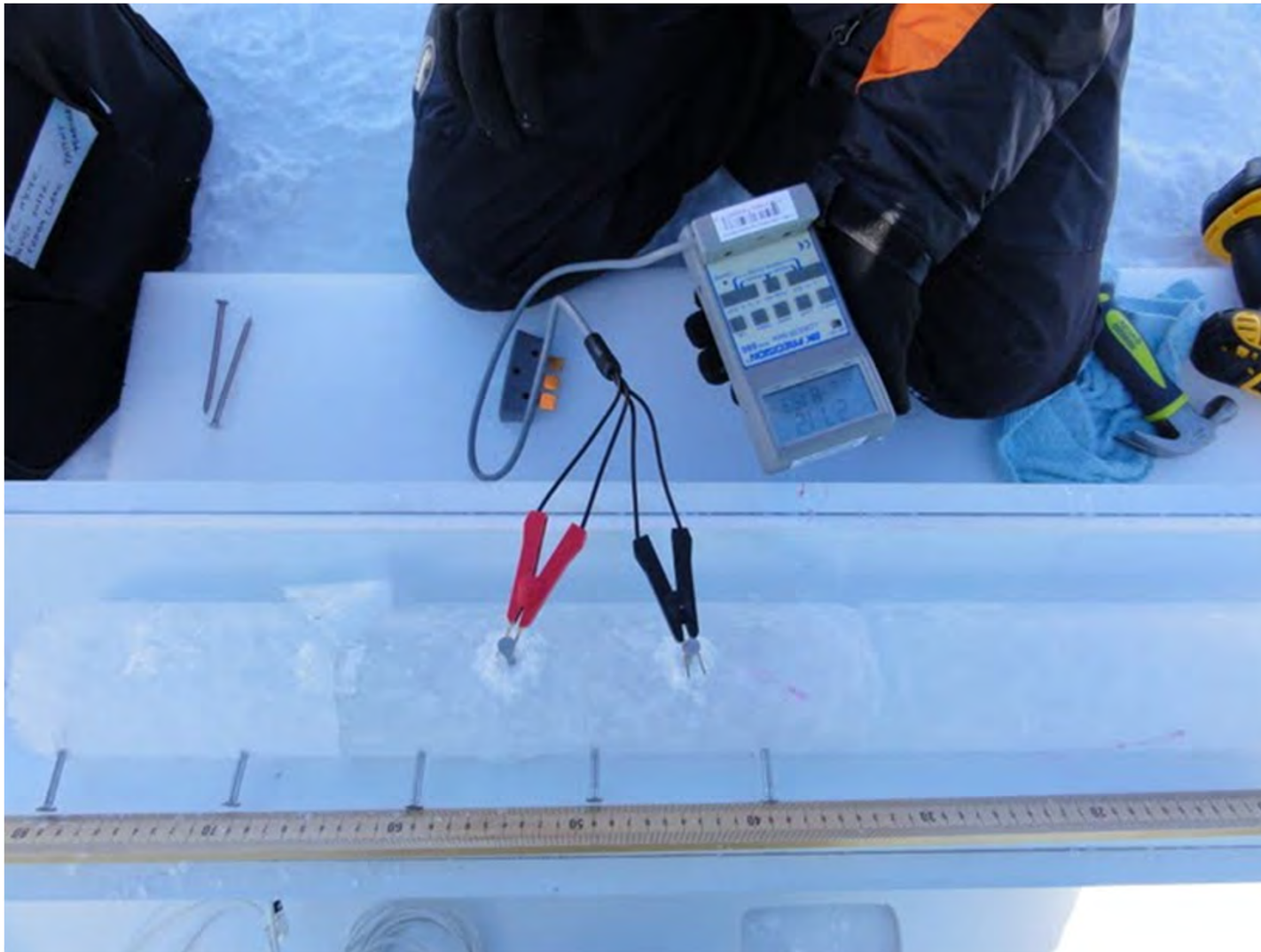


Percolation Rate





Resistivity of Sea Ice





Why Study Sea Ice?

Global Temperature



Amount of Sea Ice



Melt Ponds



Percolation Rate



Resistivity of Sea Ice





Sea Ice Cores (2.5 meters deep)





Sea Ice and Climate Change

- *Columnar ice*



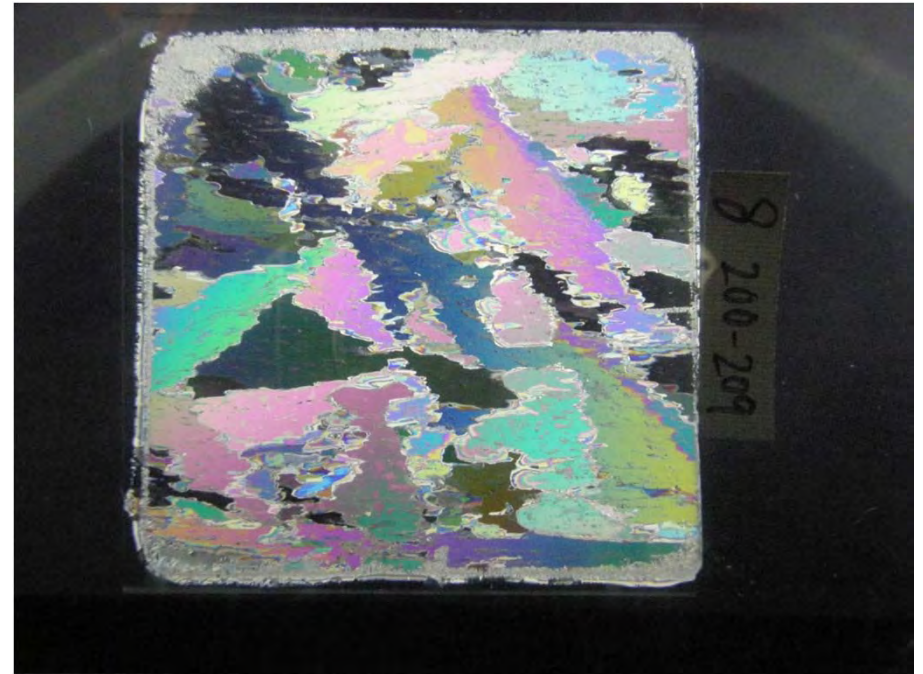
Courtesy of Dr. Pat Langhorne





Sea Ice and Climate Change

- *Platelet ice – deep*



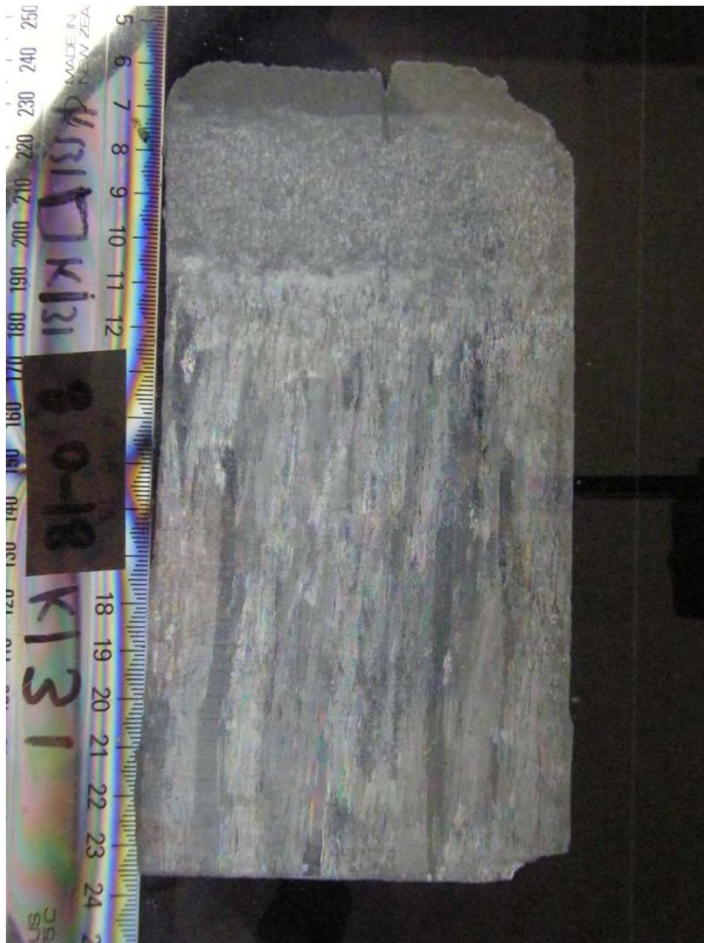
Courtesy of Dr. Pat Langhorne





Sea Ice and Climate Change

- *Columnar ice*



Courtesy of Dr. Pat Langhorne



Developing a Method





Sea Ice Cores (2.5 meters deep)



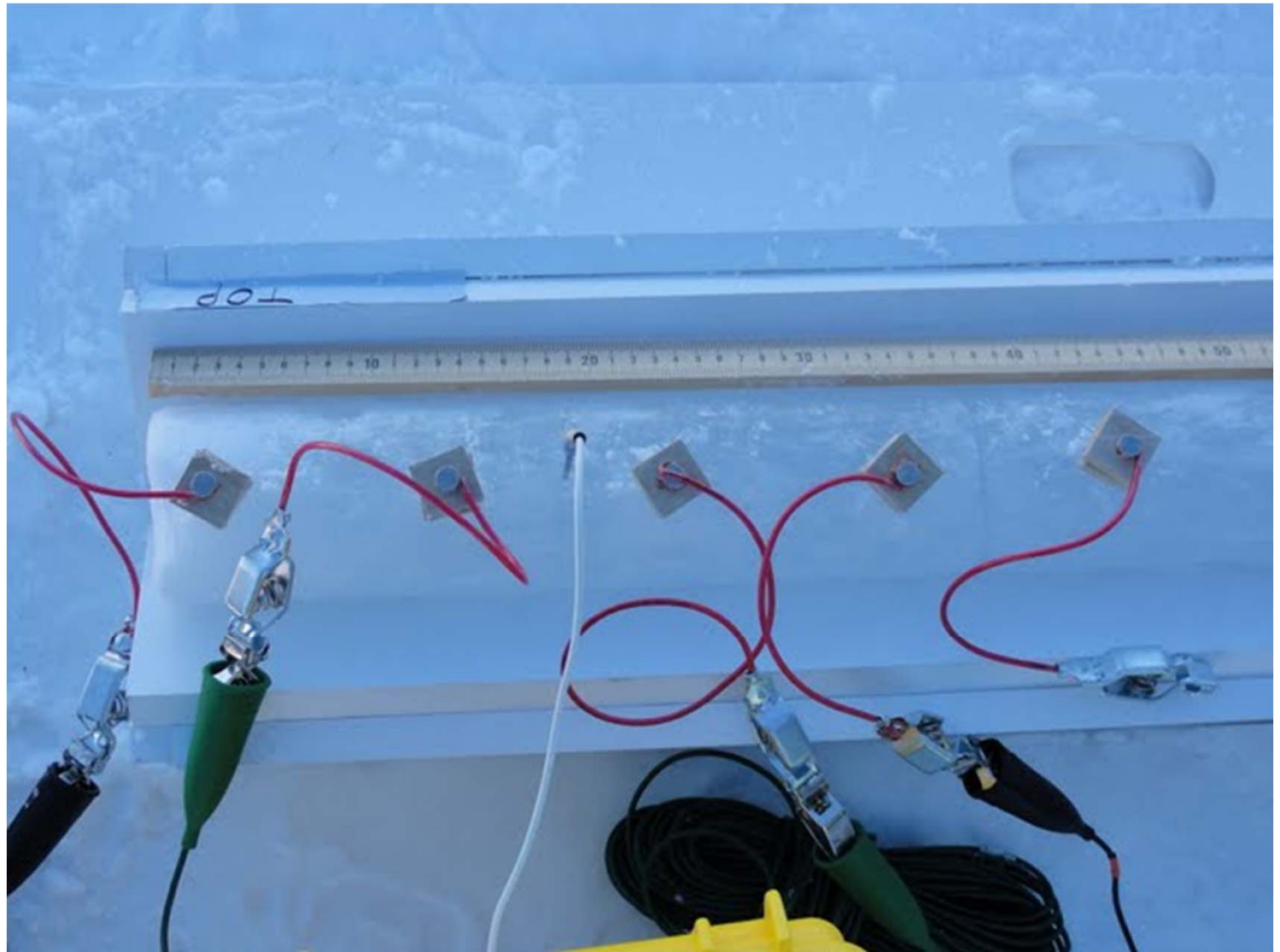


Crooked Cores



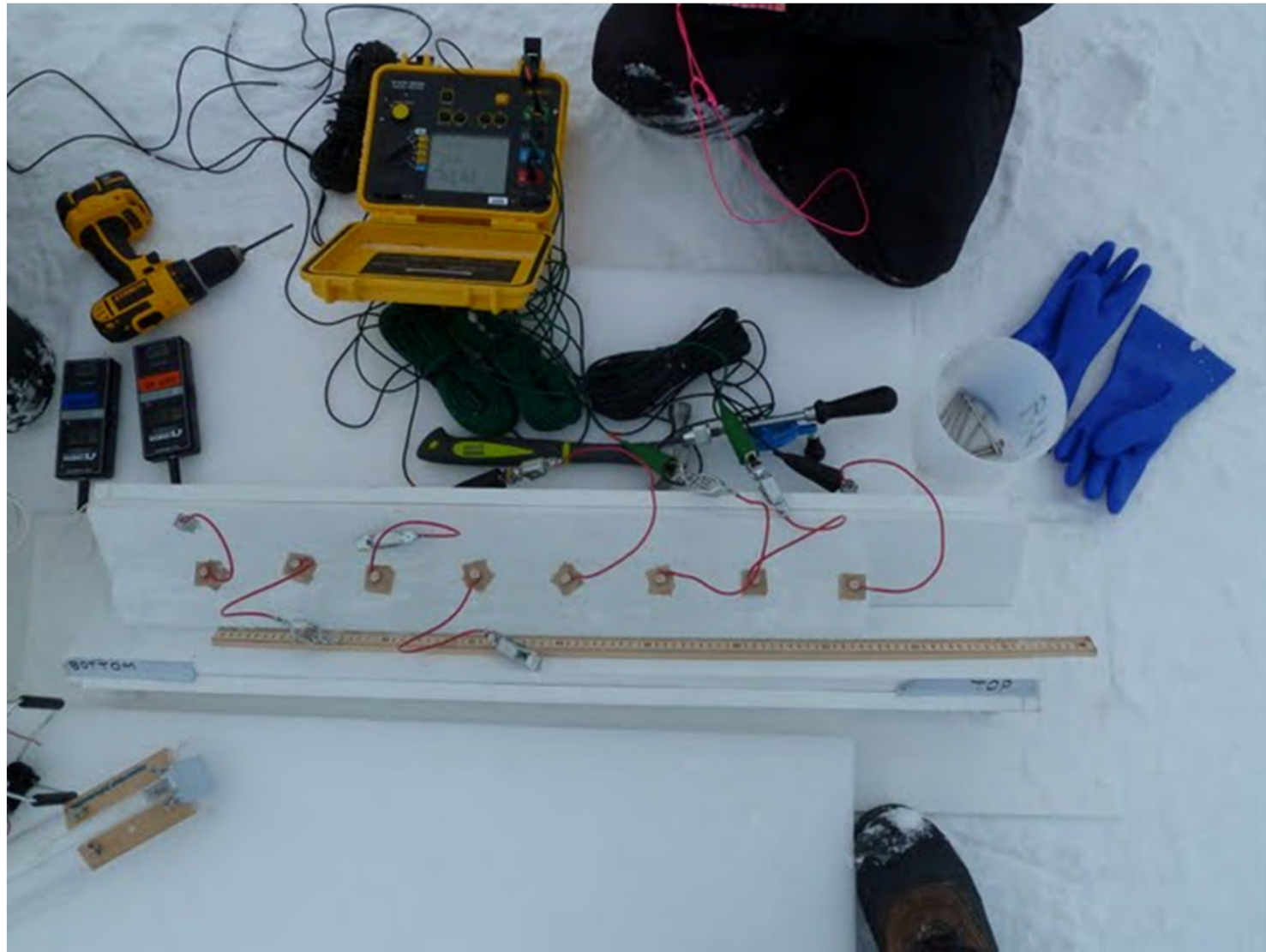


Measuring Resistance



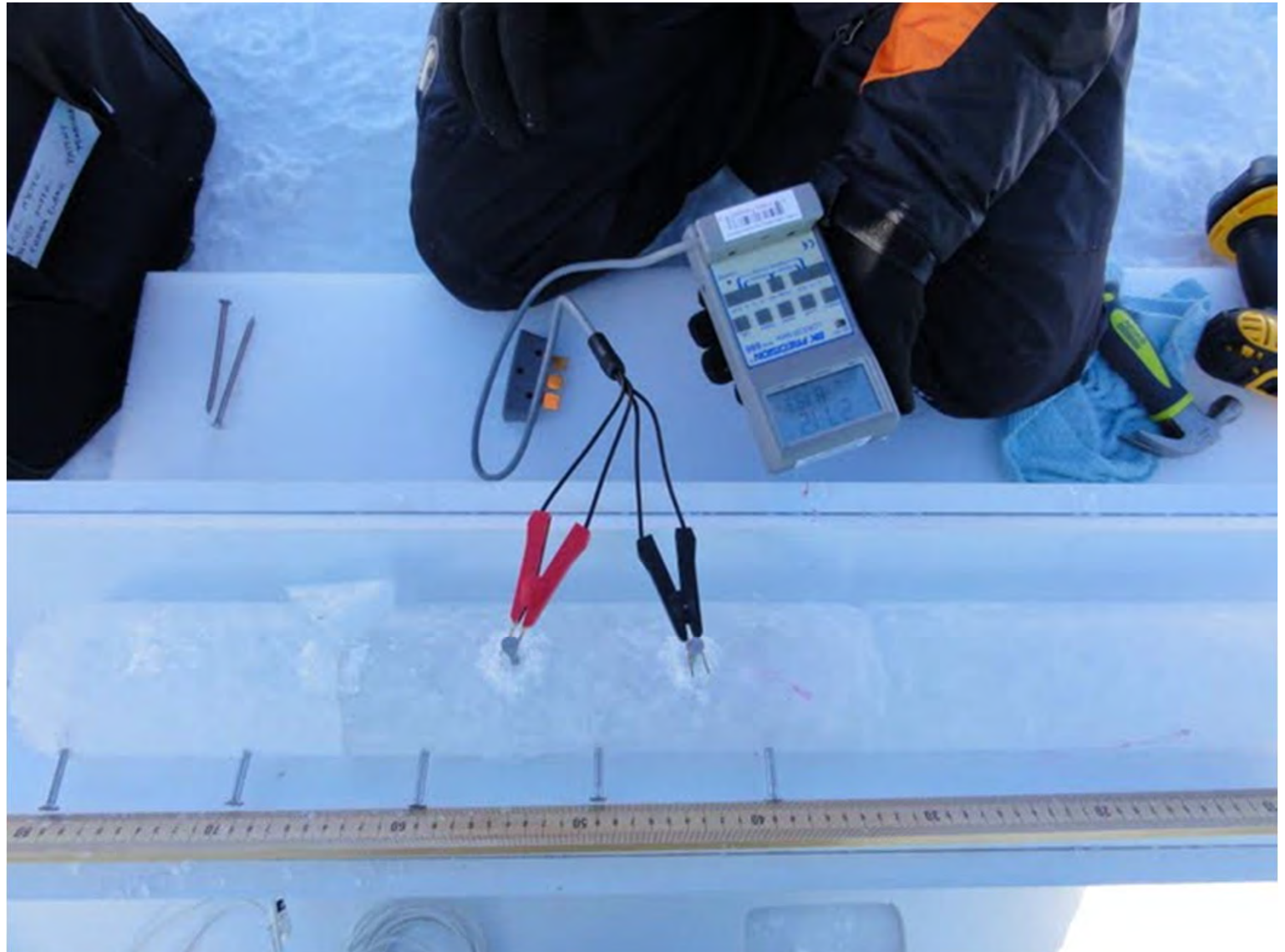


Vert. Resistance





Vert. Resistance





Things Go Wrong

- ***Corrosion***
- ***The sun is an enemy***
- ***Real ice is not the same as homegrown***



Horiz. Resistance (Fail)





Horiz. Resistance (Fail)



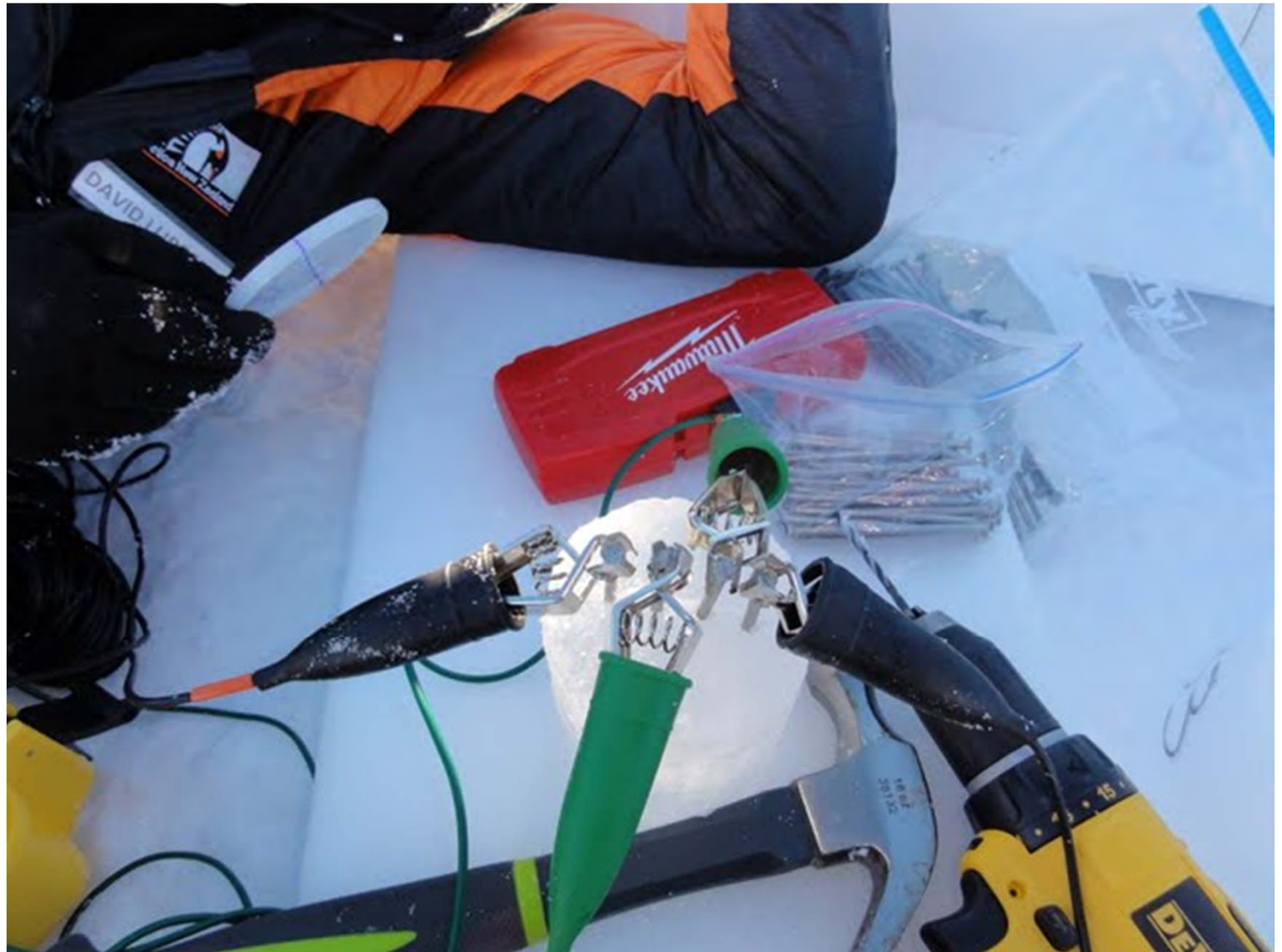


Horiz. Resistance (Fail)





Horiz. Resistance (Less Fail)





Vert. Capacitance (Fail)





Horiz. Capacitance (Less Fail)





Vert. Capacitance Success!



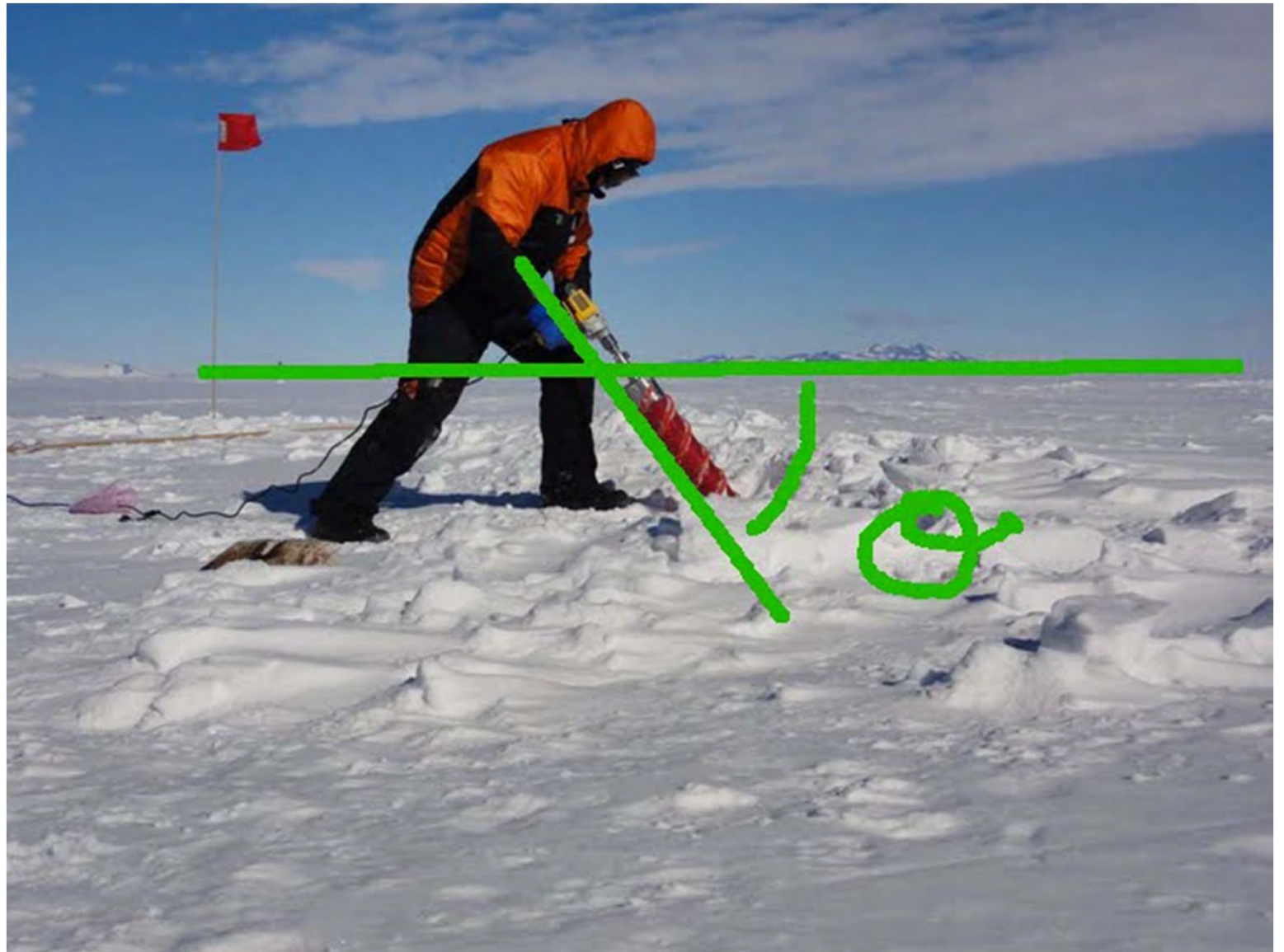


Crooked Coring: A Good Idea



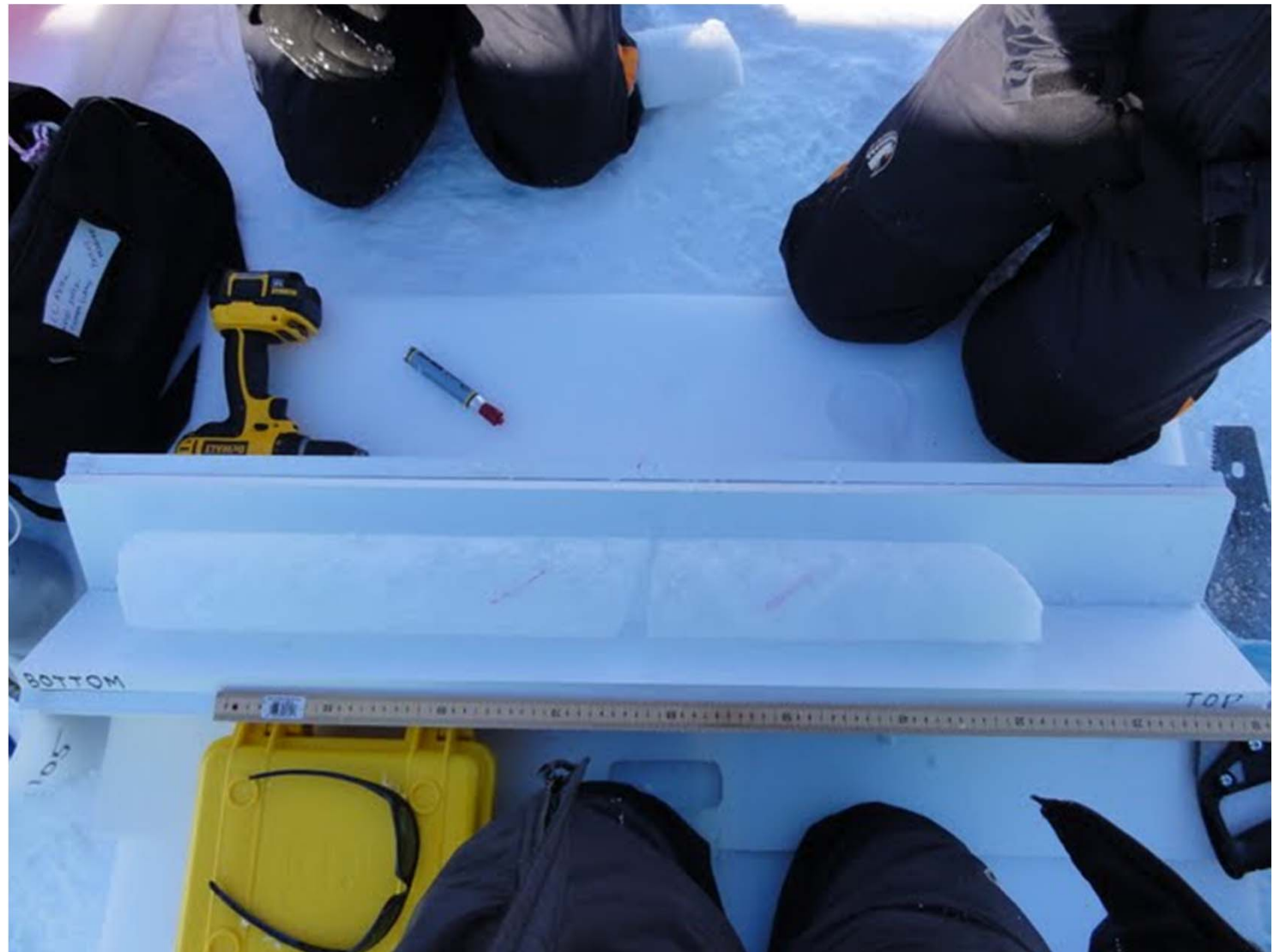


Crooked Coring: A Good Idea





Crooked Cores





Proving Anisotropy





The Lesson

- ***Things go wrong!***
 - ***When it goes wrong, fix it***
 - ***When your fix didn't work, fix it again***
 - ***Perservere***

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