Charting ice-ocean interactions within subglacial channels of an Antarctic ice shelf

Storm Petrel ready for deployment in Terra Nova Bay (2017)

A. L. Forrest, W. S. Lee, P. Dutrieux, D. Guihen, D. Haulsee, N. Kemp, C. Bongionvanni

alforrest@ucdavis.edu

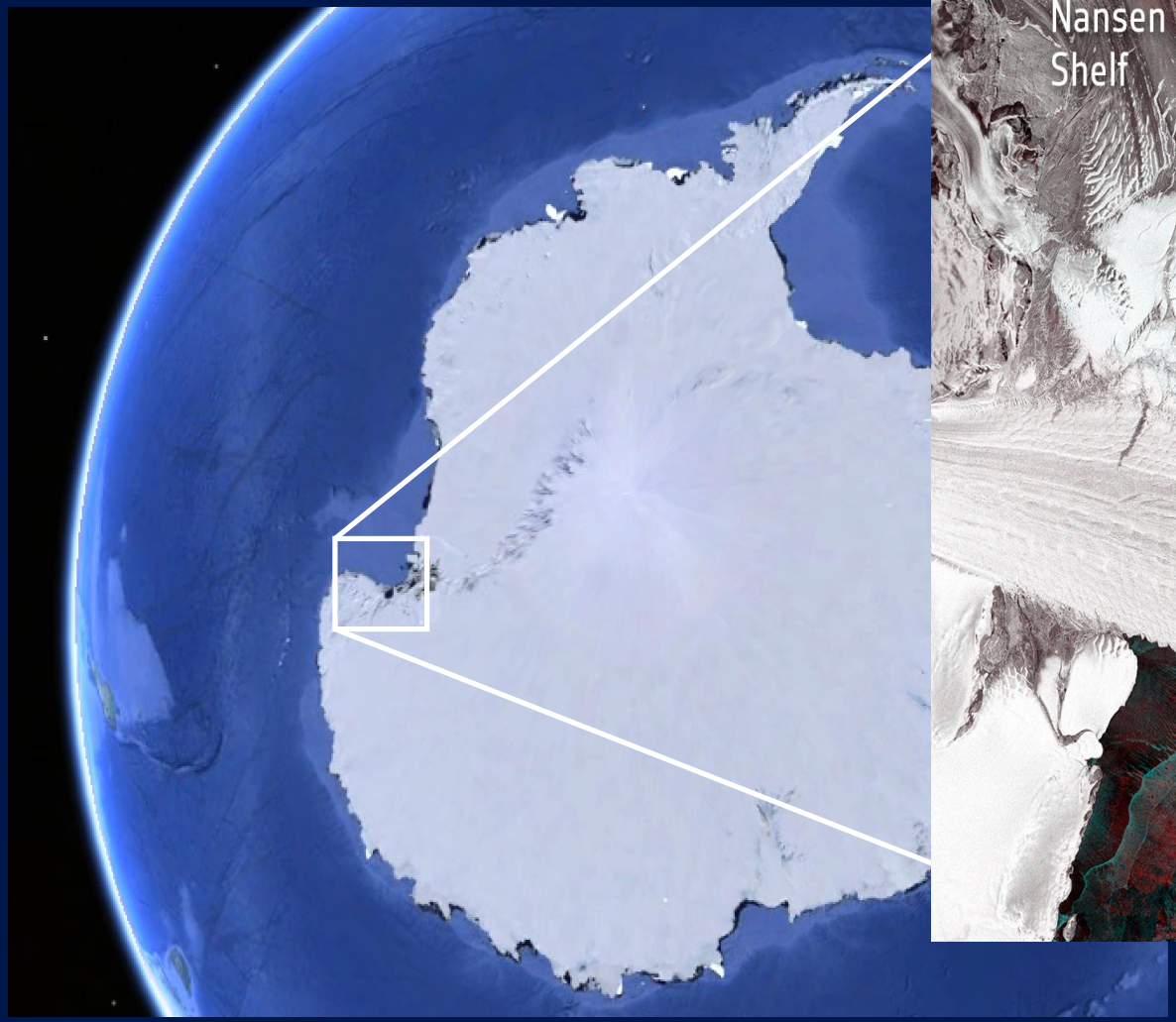
June 15, 2017

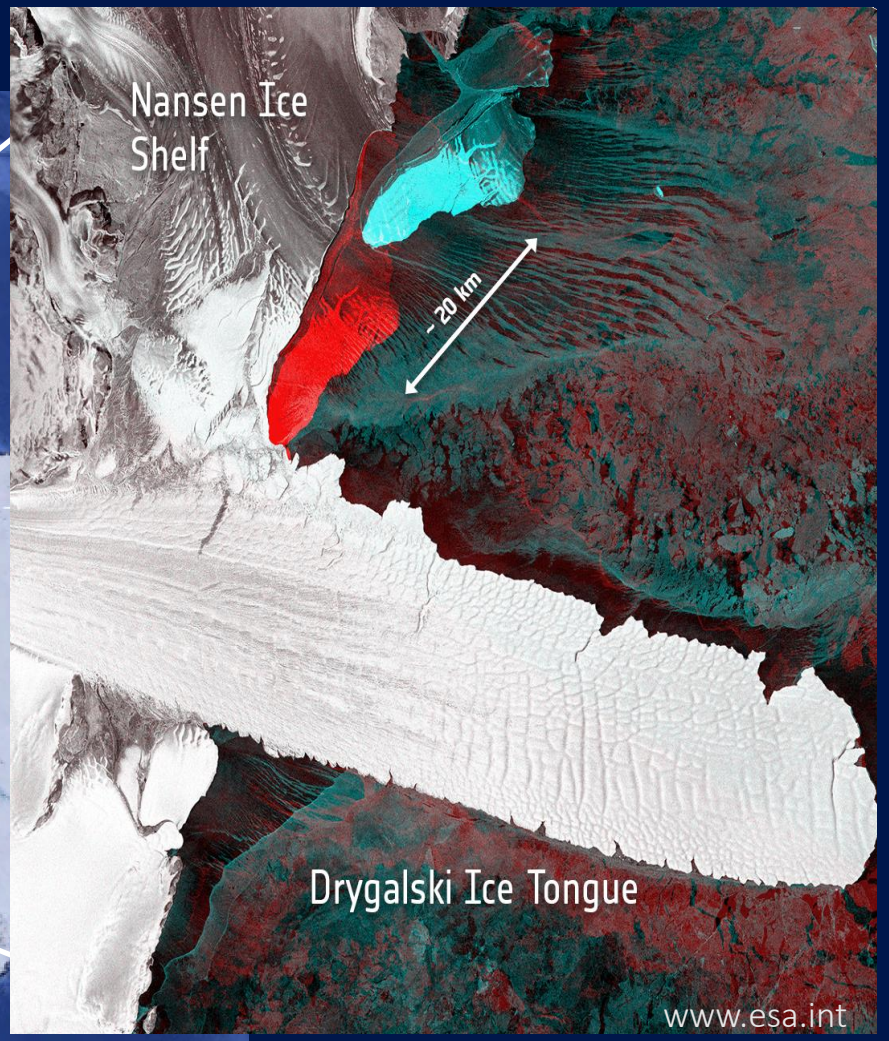
A changing cryosphere in a warming climate

- Polar regions are at the forefront of change
- Need to understand baseline conditions for predictions for tomorrow

Baffin Sea, Canadian High Arctic (2011)

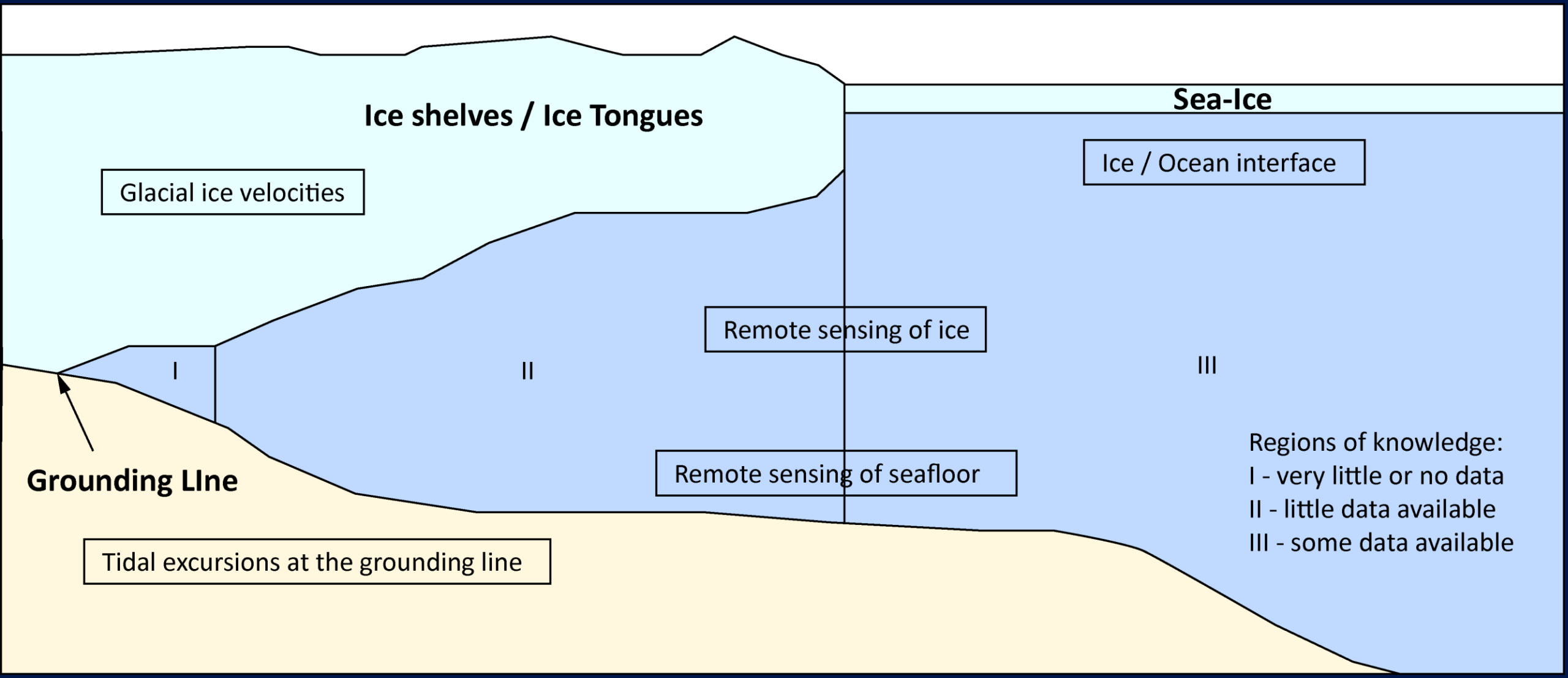
Ice shelf collapse





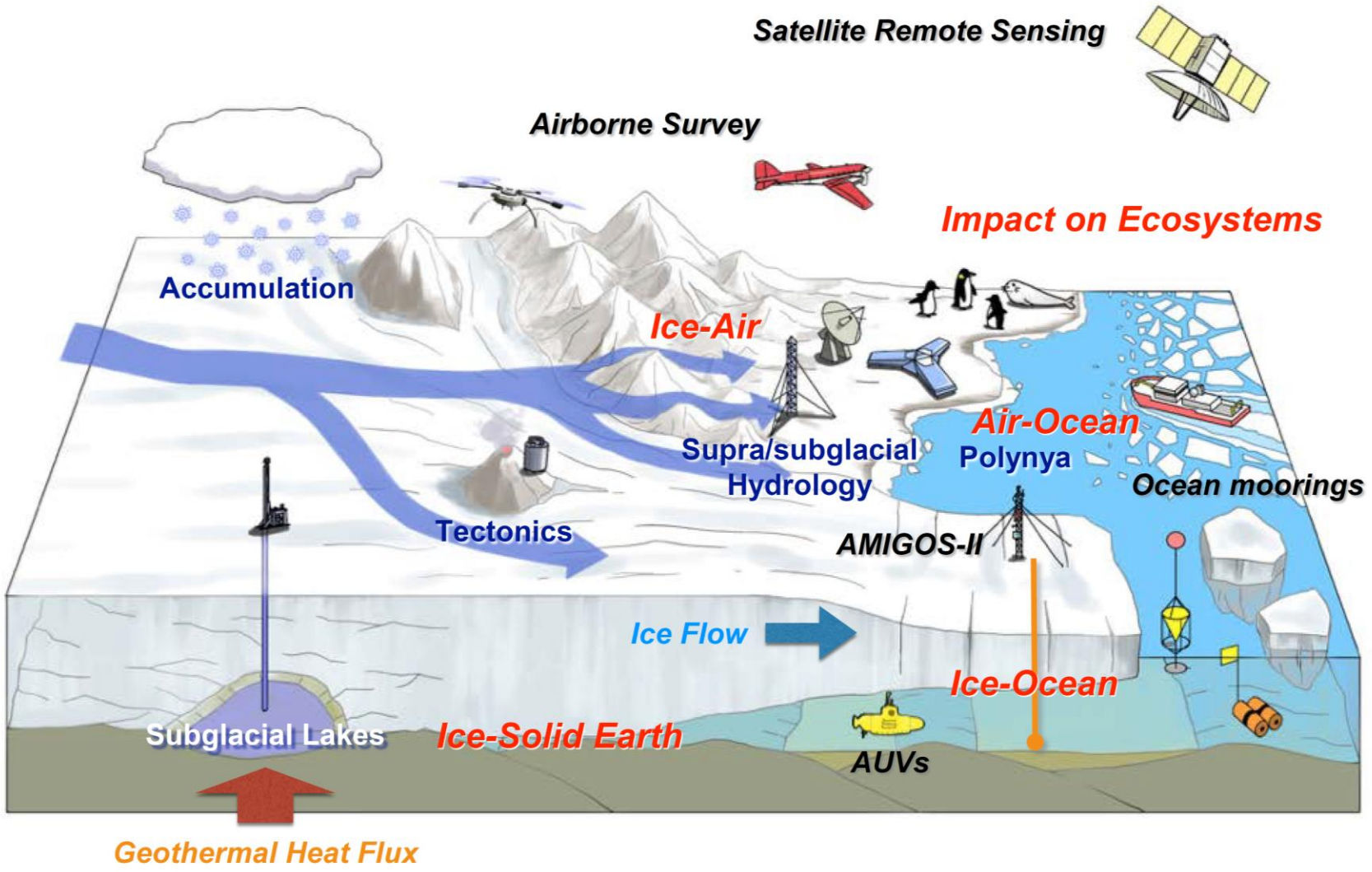
- Larsen C is poised to collapse but a large portion of Nansen Ice Shelf collapsed last year
- Work on Pine Island Glacier indicates that subglacial channels are a vital clue
- Subglacial channels, and supercooled water evolution, is the focus of this work

Underpinning science with engineering



LIONESS

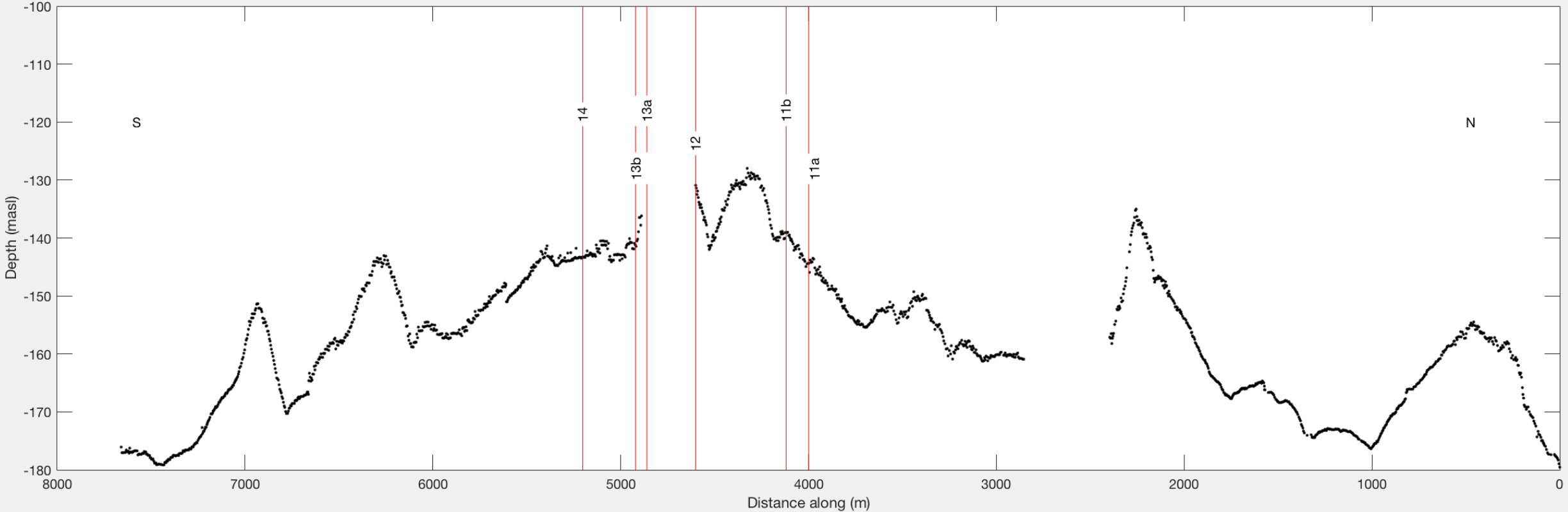
(Land-Ice/Ocean Network Exploration with Semiautonomous Systems)



KOPRI

UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING

Nansen ice shelf



Under ice tongues – Frozen access

Erebus Glacial Tongue Ice Camp, Antarctica (2010)

UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING

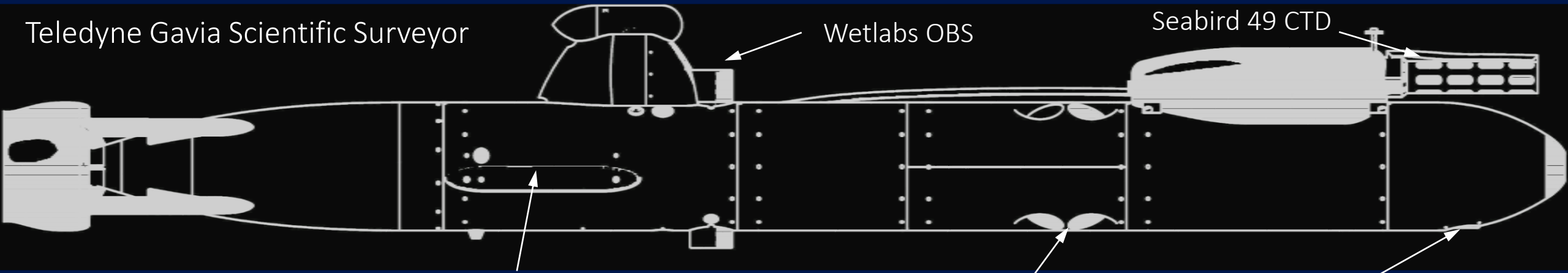
Working from icebreakers

RV Araon in front of the Nansen Ice Shelf (2017)

Autonomous Underwater Vehicles (AUVs)

Common instruments for AUVs enable measurements of:

- Physical properties (e.g. Seabird CTD)
- Optical backscatter (OBS) (i.e. chlorophyll, turbidity and CDOM)
- Acoustic backscatter and bathymetry (e.g. Sidescan, Multibeam)
- Imagery across a range of spectra (e.g. RGB cameras)



Gliders

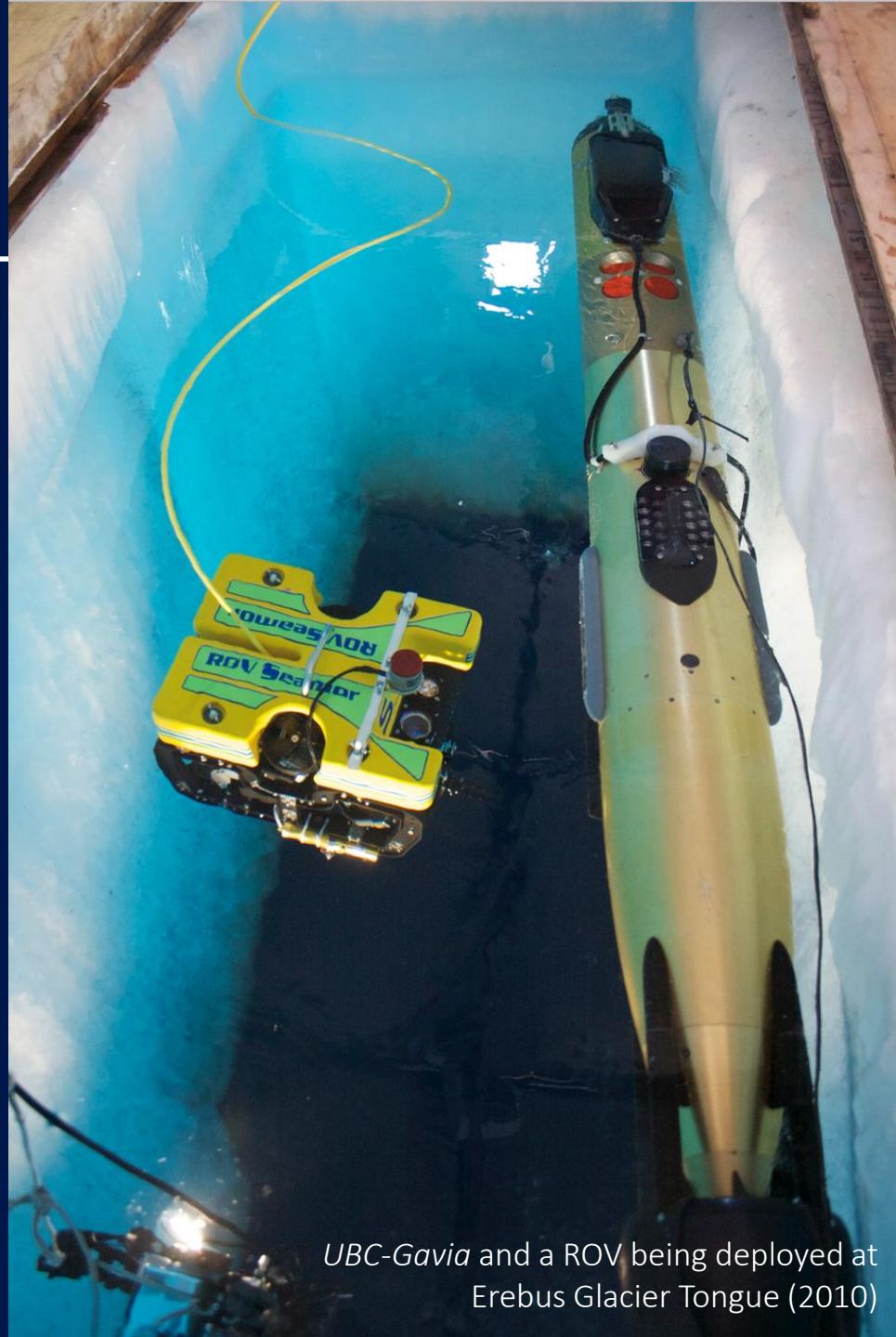
- Same sensors as AUVs focused on mid water column
- Designed to do yo-yos through the water
- AUVs maintain constant depth or altitude

Recovery of *Storm Petrel*, Terra Nova Bay, Ross Dependency (2017)

UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING

Remotely Operated Vehicles

- Tethered vehicles provide real time control of the vehicle and power
- These vehicles are used mainly for imagery and intervention work
- Used as an emergency back up for AUV recovery
- Many of the same instruments as the AUV

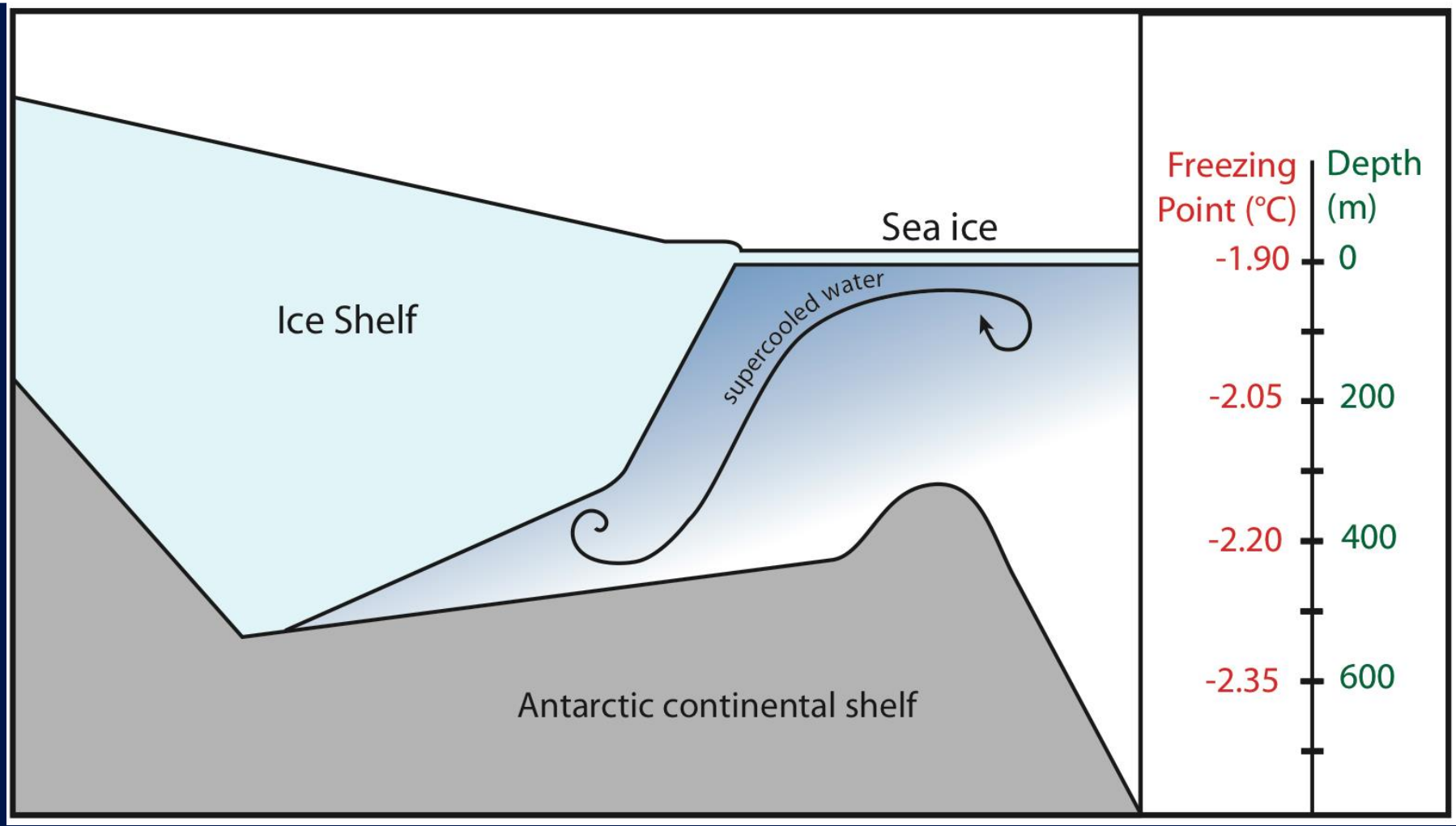


UBC-Gavia and a ROV being deployed at Erebus Glacier Tongue (2010)

UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING

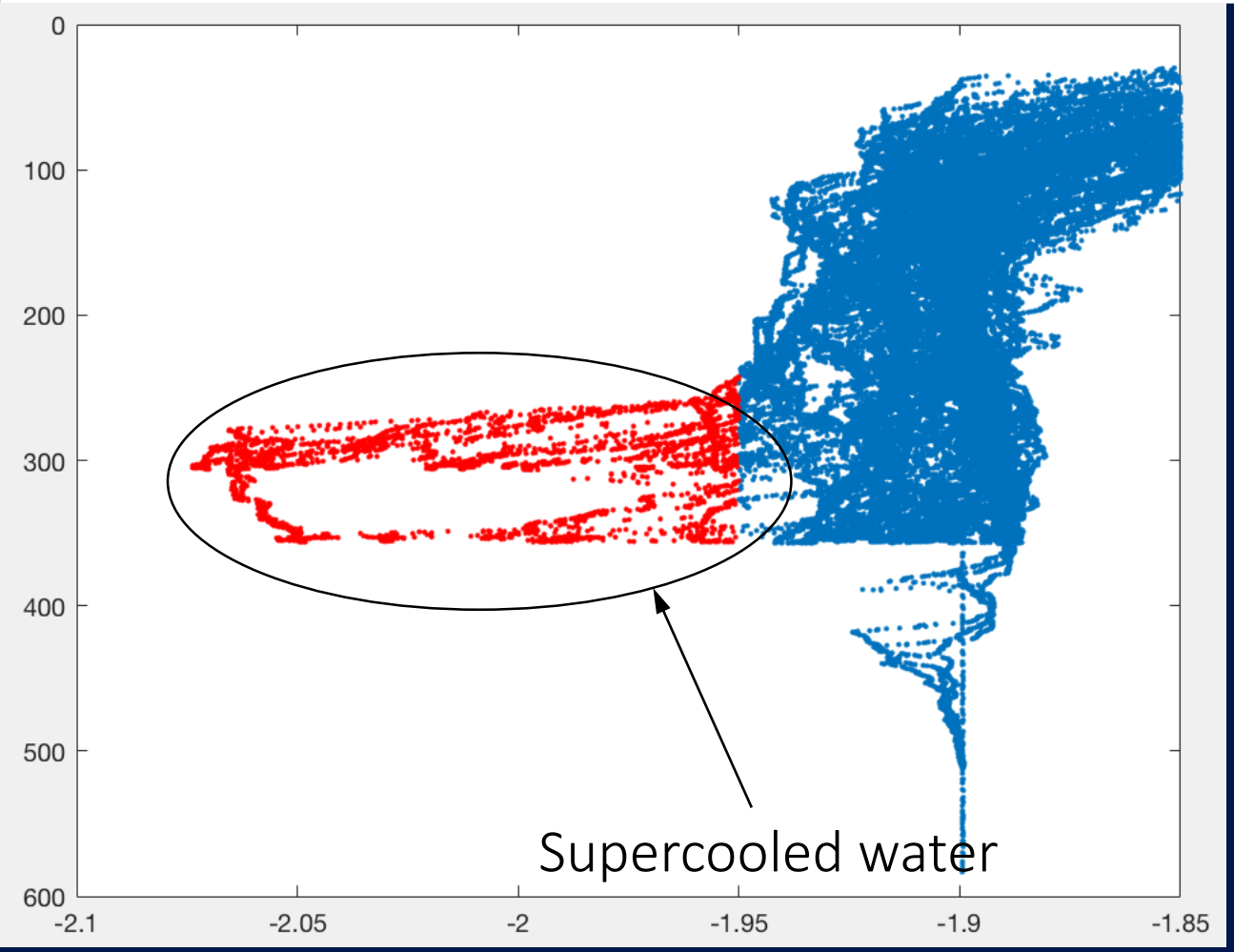
Aim 1: Identify fate of supercooled water

- Aim to identify supercooled water sources
- Supercooled water is when the pressure depresses the water below the in situ freezing temperature
- Critical mechanism for the formation of sea ice



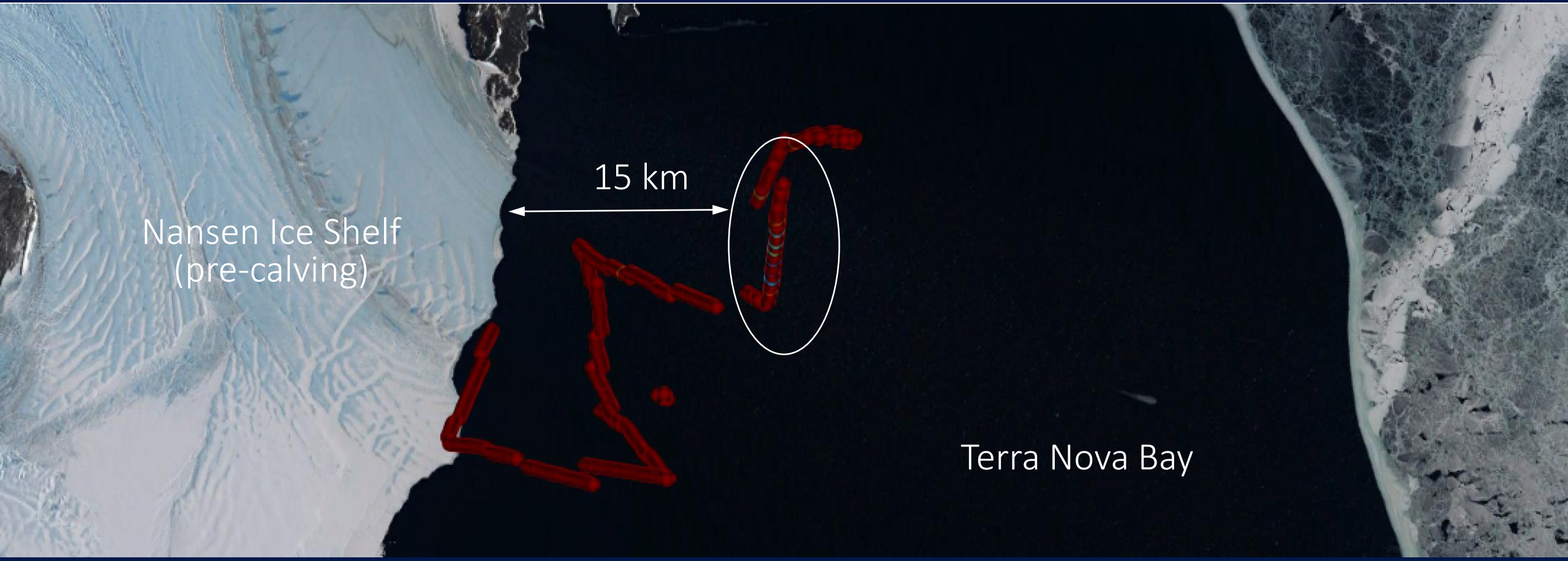
www.wikipedia.org

Glider temperature profiles



- Original experimental design to do repeated transects 5km, 2.5km and 1km parallel to ice front
- Initial dives were to 100 m but then increased to 350 m and finally to 500 m
- Clear evidence of supercooled water in region *although not in location initially thought*

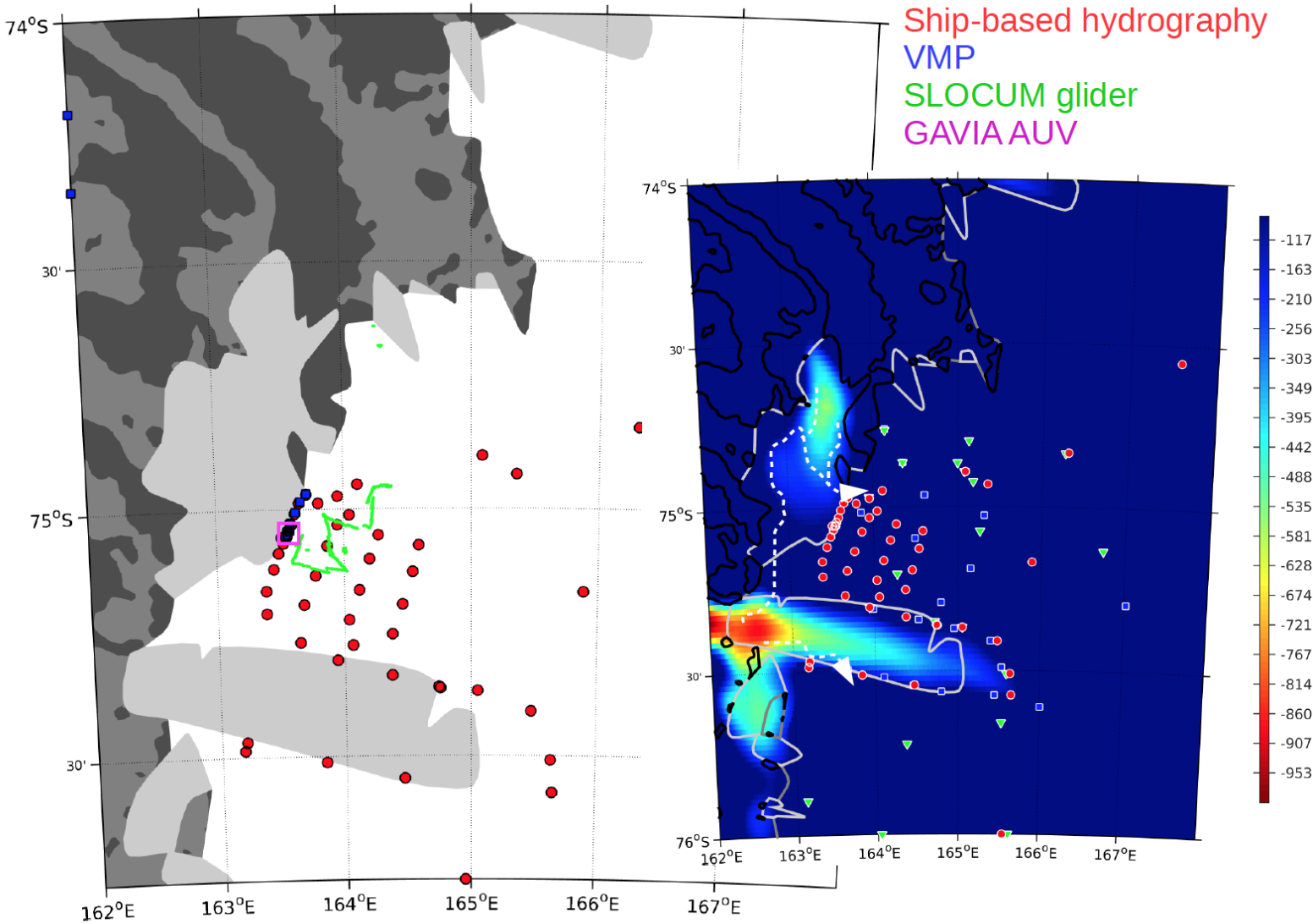
Location of supercooled water



UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING

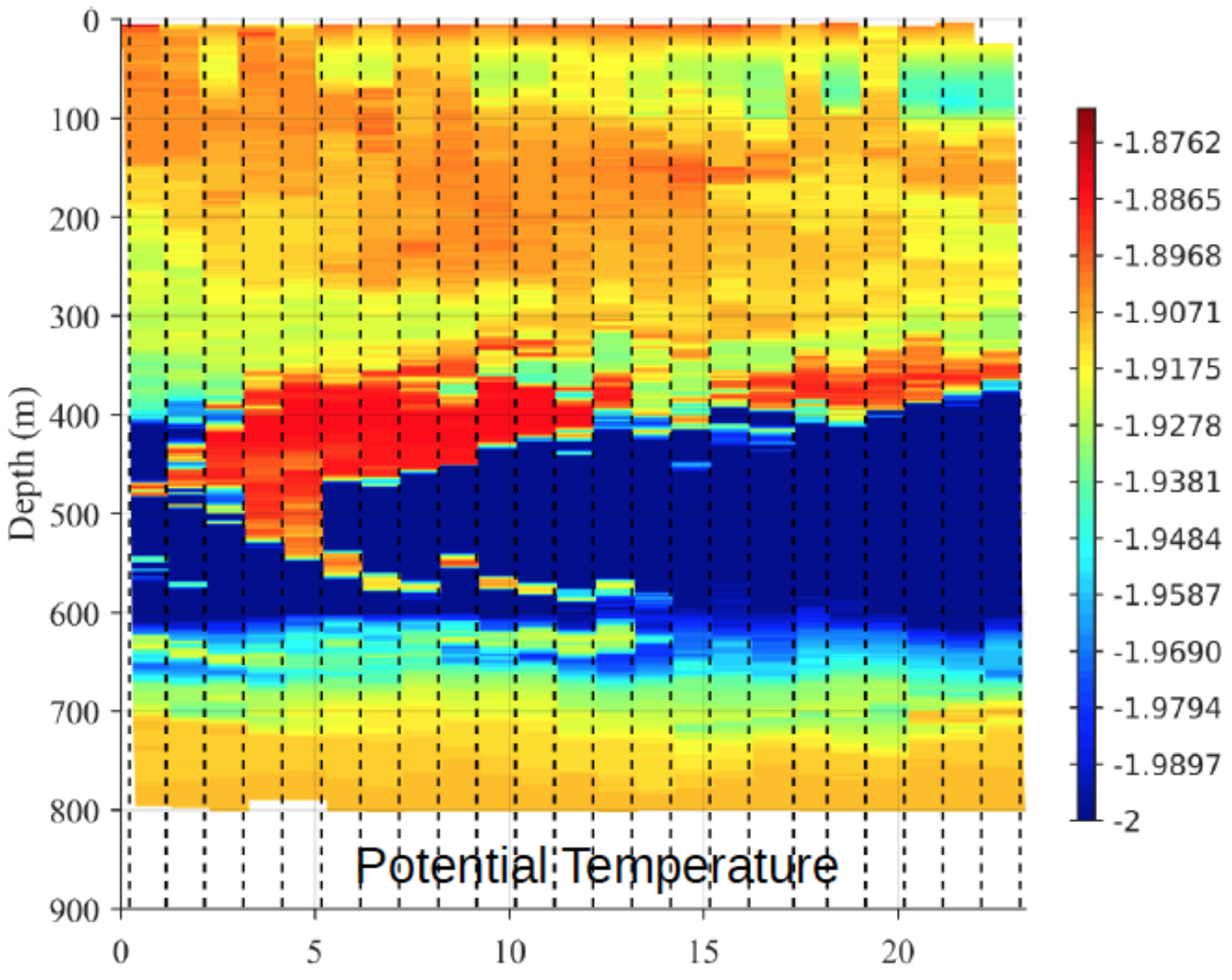
Larger scale circulation patterns

- Although focused on ice shelf calving fronts, regional drivers potential drive plume
- Tidal / inertial modulation of meltwater outflow
- Outflow being driven under Nansen than out into Terra Nova Bay at depth



UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING

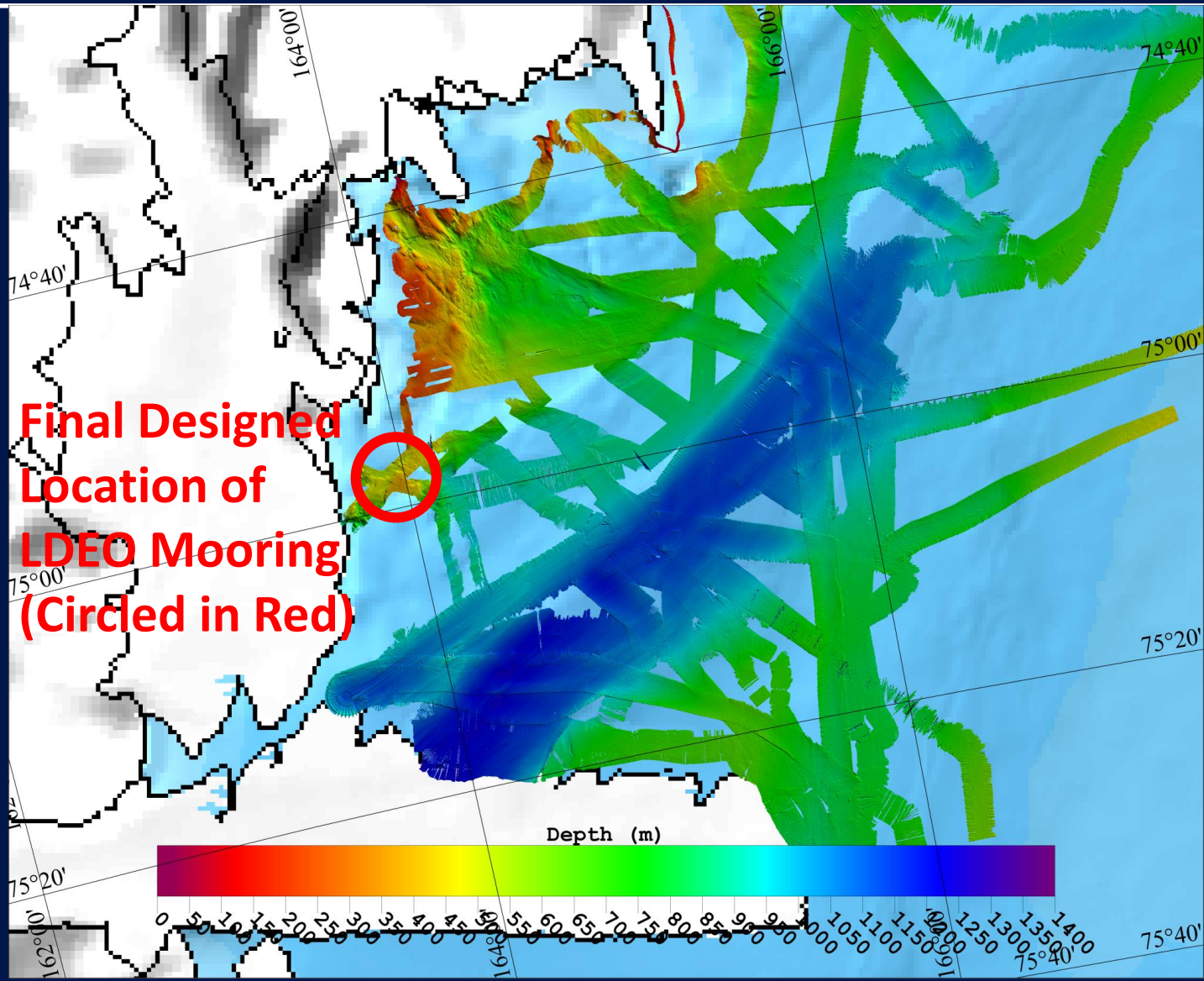
Plume formation



- Supercooled water emerges at a depth of 400-600 m
- Gale force winds (common as outflow winds off the ice shelf) could result in upwelling of this plume
- Possible effects for sea-ice formation

Bathymetry effects

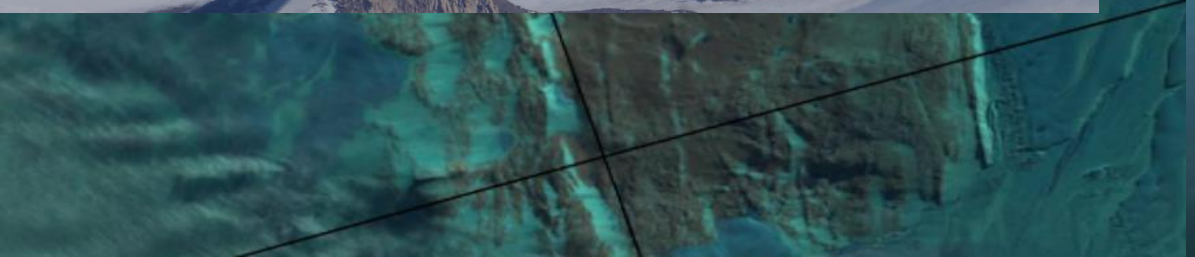
- The region where this supercooled water was present is immediately downstream of a seamount 350 m deep
- Flow is potentially being pushed up and over this seamount
- This may be a critical feature for sea-ice formation in the region



UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING

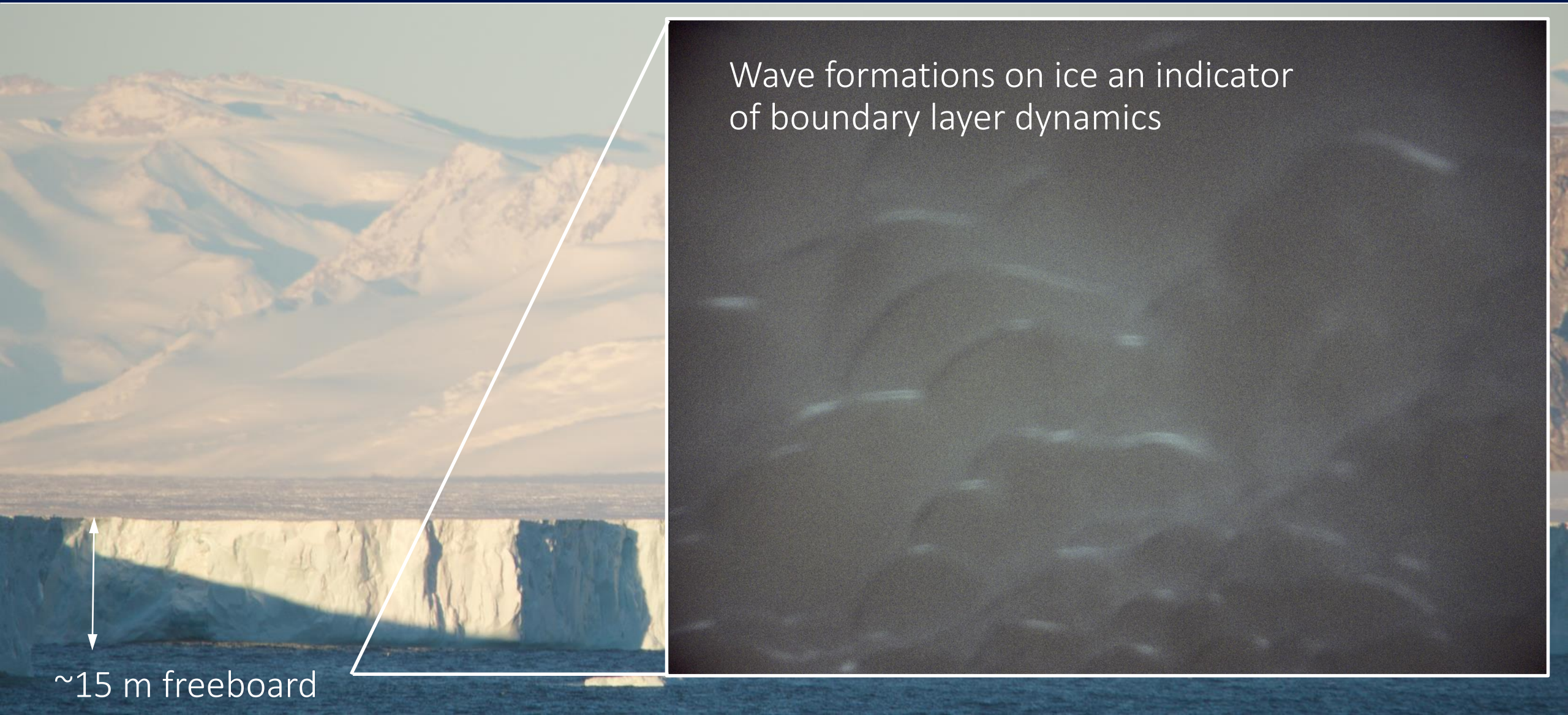
Aim 2: Multiple scales of measurement

Helicopter Operations (University of Texas – Austin)



AUV Operations (Gavia AUV)

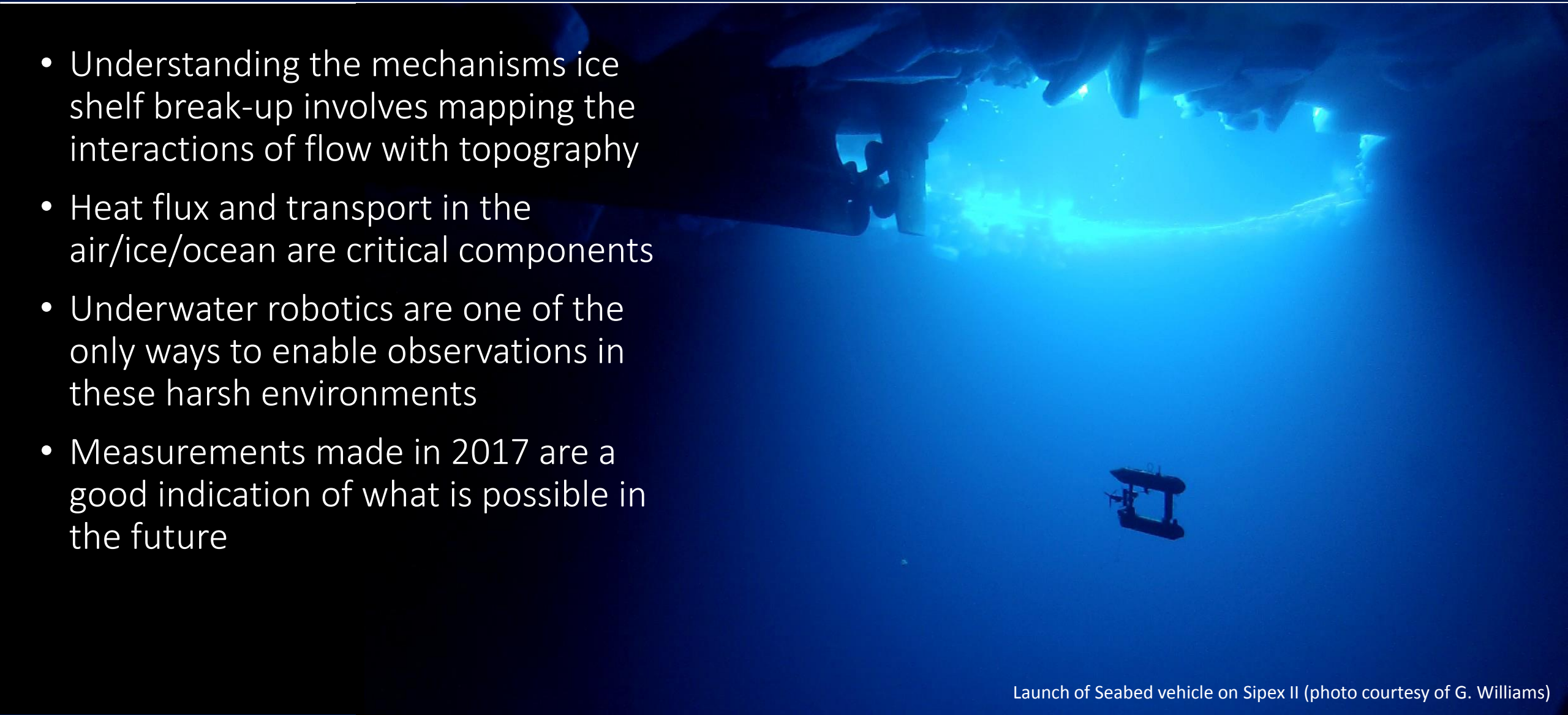
Scales of flow



Wave formations on ice an indicator of boundary layer dynamics

Conclusions

- Understanding the mechanisms ice shelf break-up involves mapping the interactions of flow with topography
- Heat flux and transport in the air/ice/ocean are critical components
- Underwater robotics are one of the only ways to enable observations in these harsh environments
- Measurements made in 2017 are a good indication of what is possible in the future

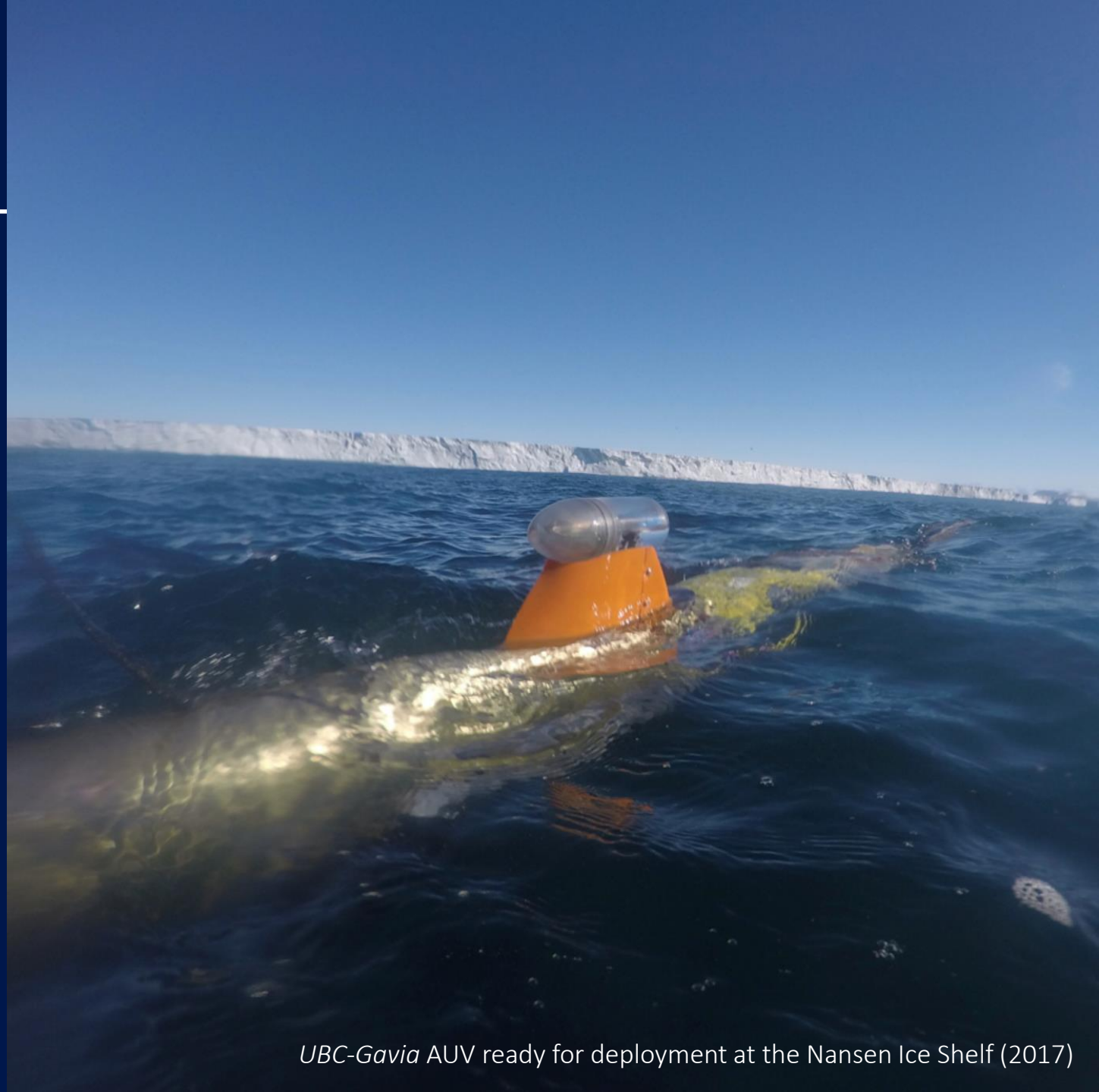


Launch of Seabed vehicle on Sipex II (photo courtesy of G. Williams)

Future work

- Nansen Ice Shelf is relatively small compared to other systems like the Thwaites, Totten, Ronne-Filchner or Ross ice shelves
- Future work will be on applying lessons learned in LIONESS on integrated observation systems on these larger systems
- Coupling our understanding of ice and ocean processes is essential for predicting ice shelf fate

UCDAVIS
CIVIL AND ENVIRONMENTAL ENGINEERING



UBC-Gavia AUV ready for deployment at the Nansen Ice Shelf (2017)

Acknowledgements

Questions?