AUVs as a research tool

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Marine science needs to do MUCH BETTER when it comes to observing the ocean in order to address basic scientific questions. 80-85% of the ocean is still unexplored, i.e. 56% of the Earth is still unknown to humans.

We need to do MUCH BETTER when it comes to monitoring the marine environment – e.g. bench-marking, watching, exploring which areas are protect-worthy

E.g. G7 science ministers backed a series of recommendations with the aim of significantly enhancing ocean observation (http://www8.cao.go.jp/cstp/english/others/20160517communique_2.pdf)

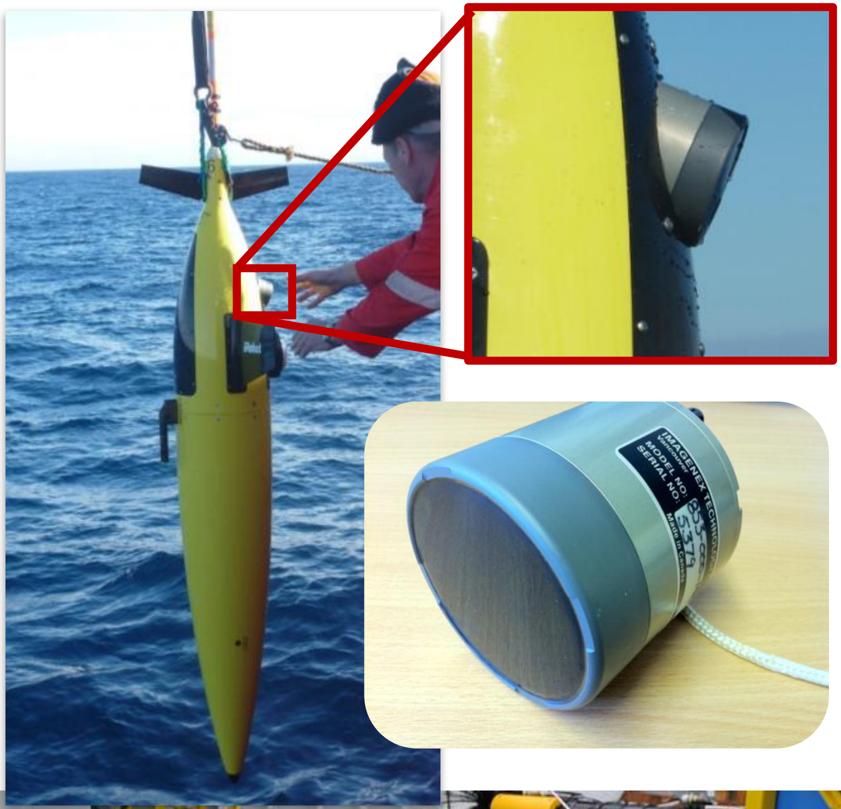
Many many science policy documents acknowleding the need for MUCH improved methods that will allow us to collect substantially more data.

Satellite data coverage: Daily, covers entire globe, goes on for decades
We need similar for interior ocean and coastal seas

The number of these is not likely to increase significantly in the foreseeable future, if ever.

The number of these is rising rapidly, and is set to continue…

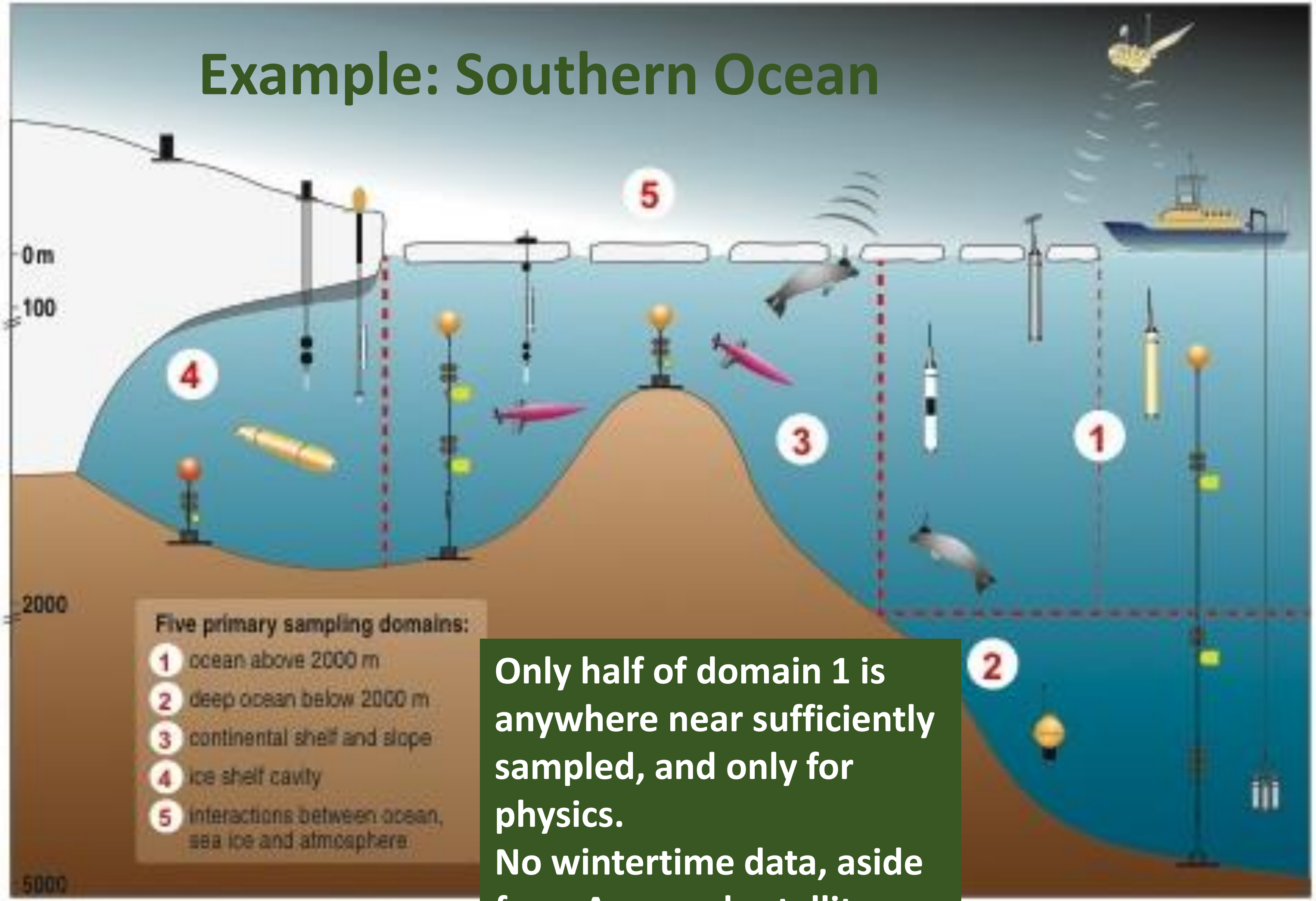
Marine science needs to move away from the dependence on large research vessels



Autonomous vehicles give greater spatial coverage than ships, plus control concerning where the data is collected.

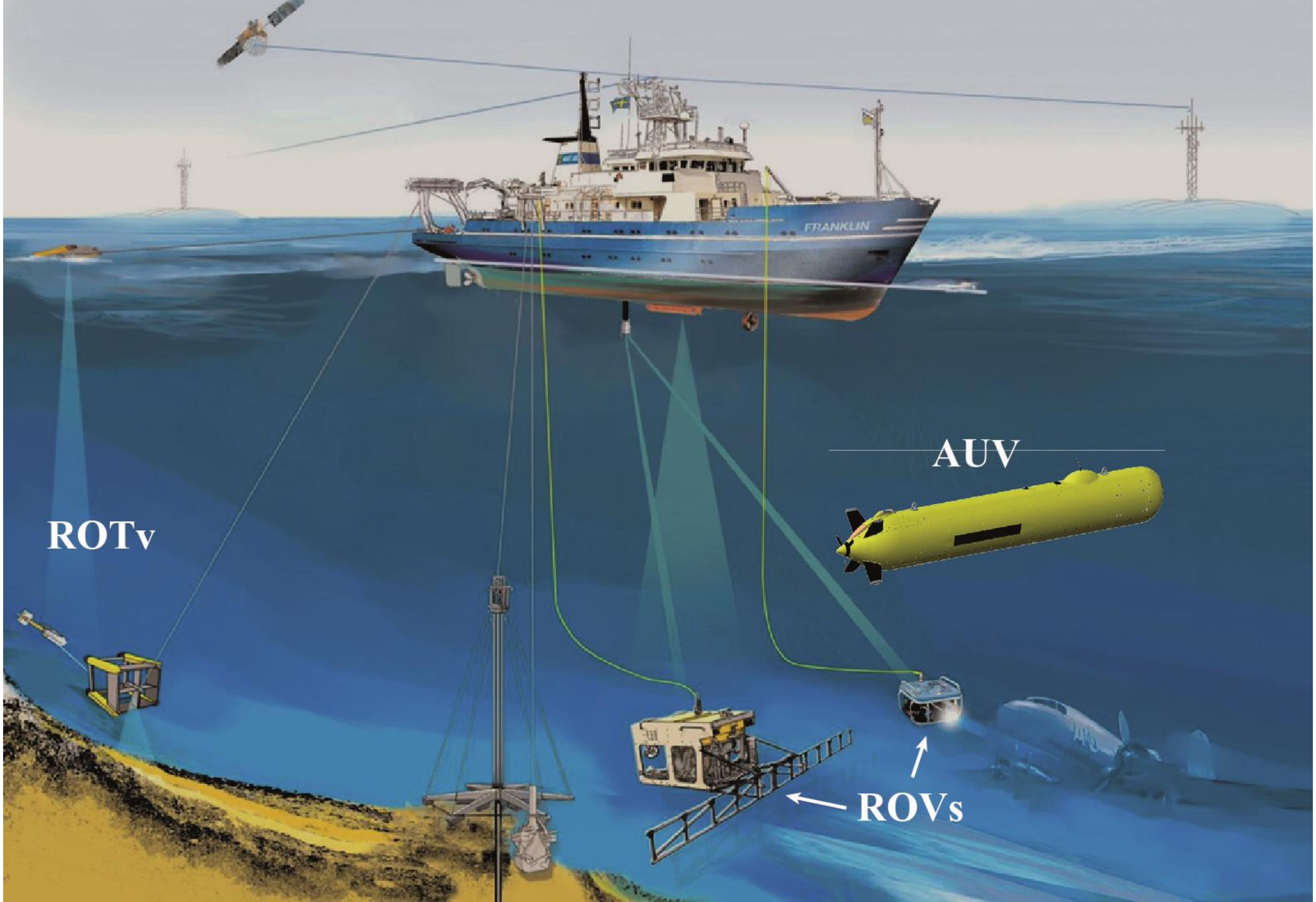
Can carry any number of exotic sensors.

Example: Southern Ocean



Only half of domain 1 is anywhere near sufficiently sampled, and only for physics.
No wintertime data, aside from Argo and satellites.
Long time series virtually non existent

Future for marine science:



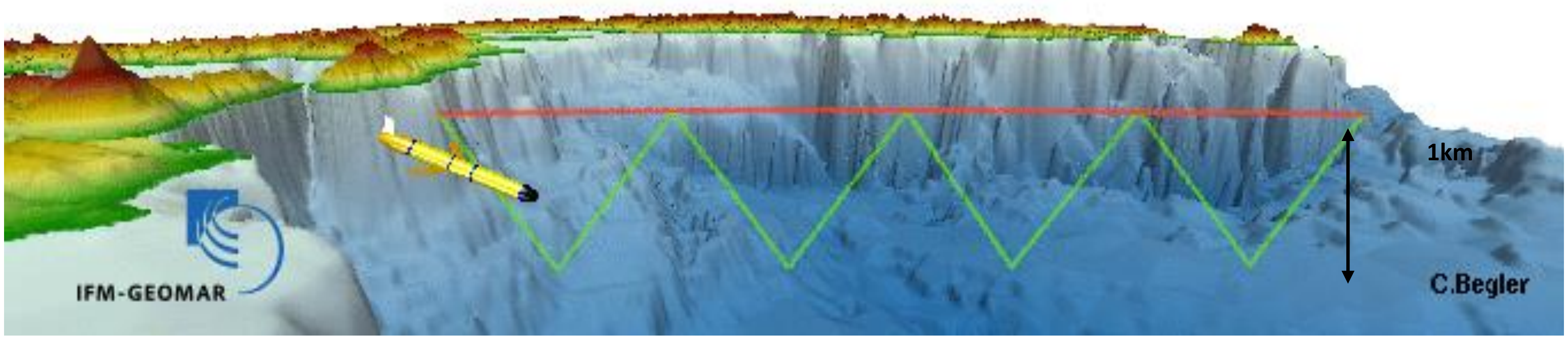
FRANKLIN
AUV
ROTv
ROVs

Gliders

How do gliders work & why utilise them?

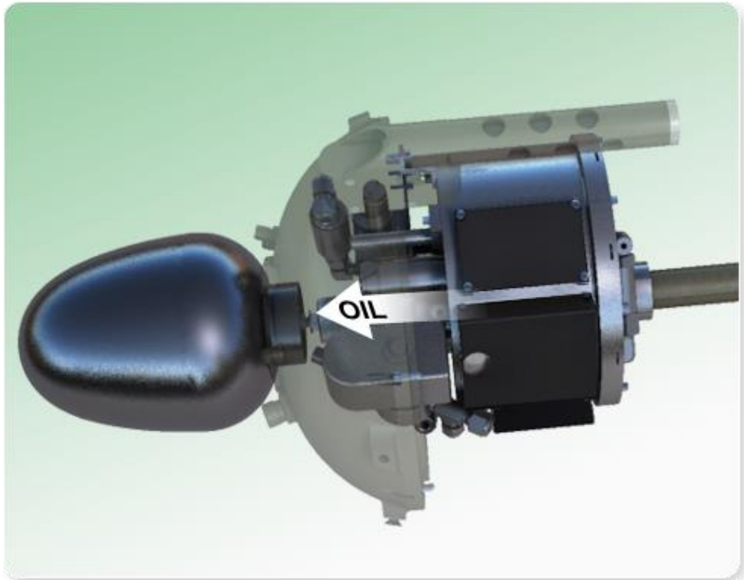
(or woman)

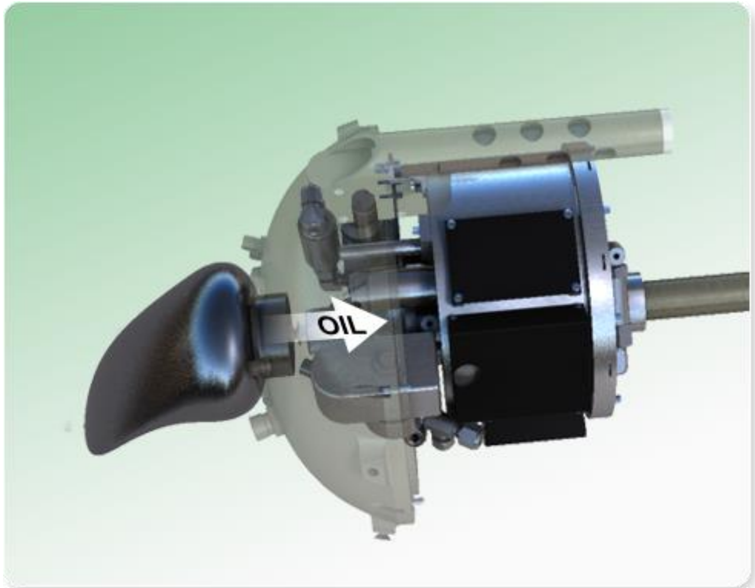
U = 25 km/day
2-5 km between dives
Autonomy = 2-10 months



overcoming the very low frequency "snapshot" sampling from ships

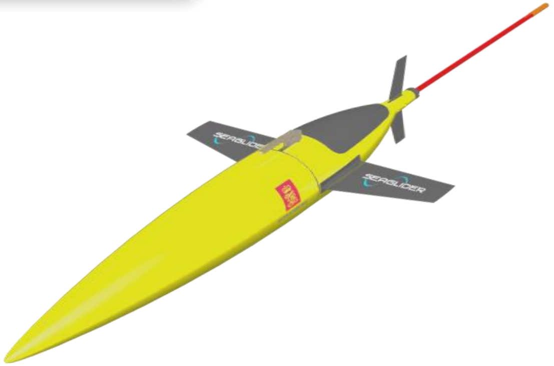
Variable Buoyancy Device





Main Purpose

- Maintain Specified Total Vehicle Displacement
- Vary Size of Bladder

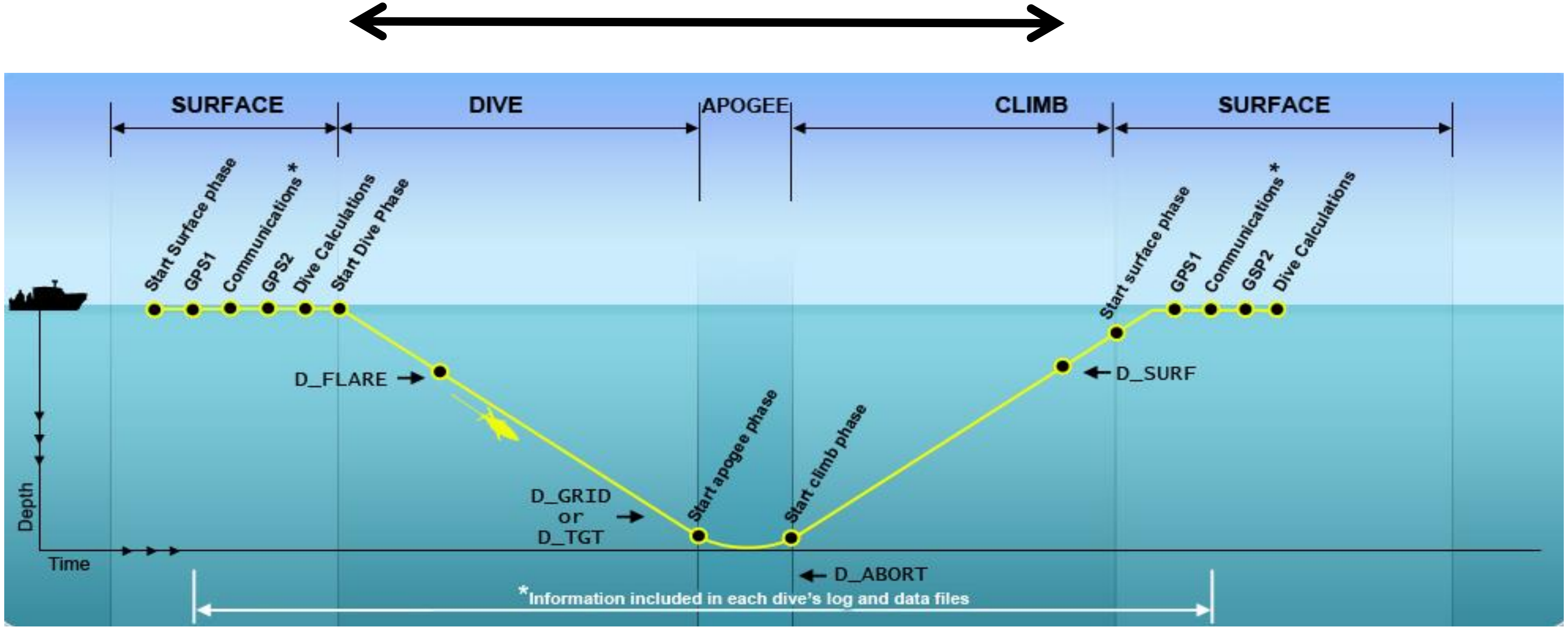


Gliders are ideal to measure the submesoscale

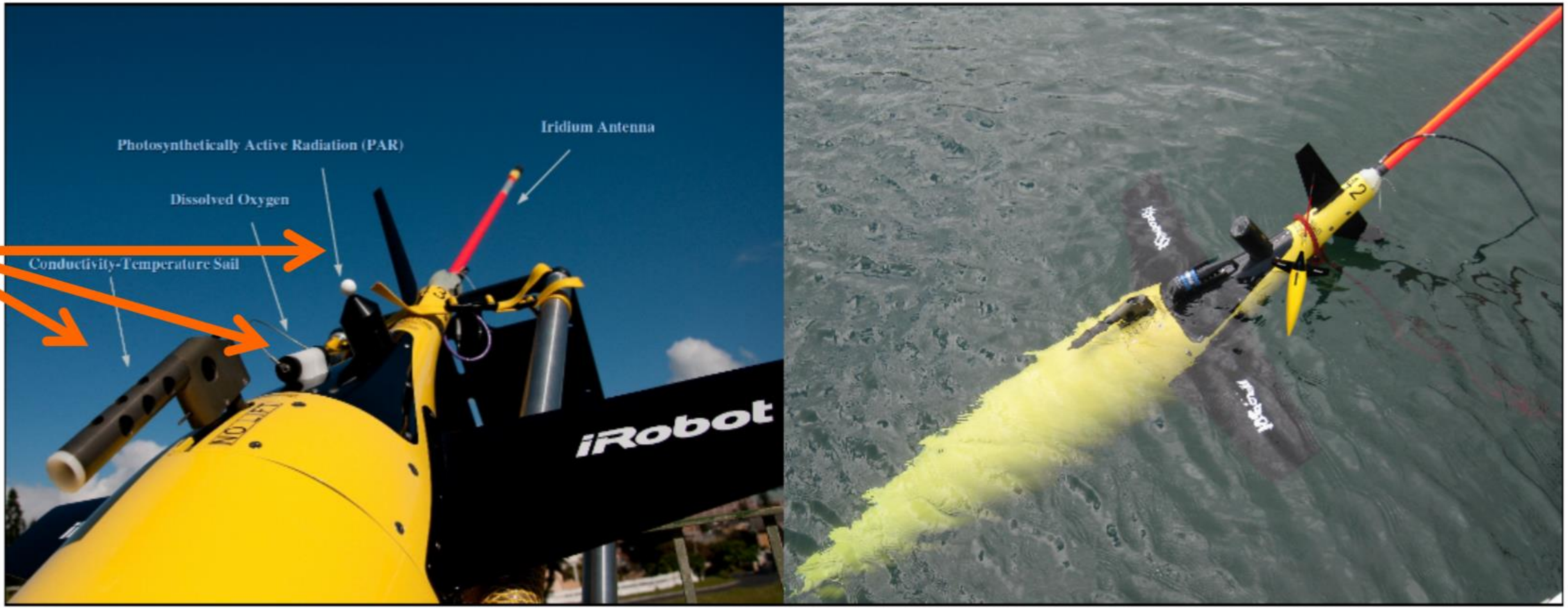
But shallower and/or faster dives use more battery

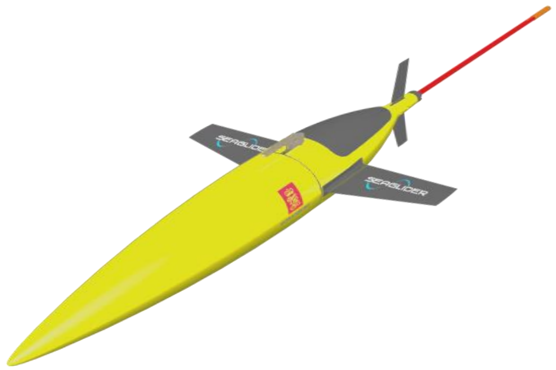
~ 4 km for dives to 1000 m depth

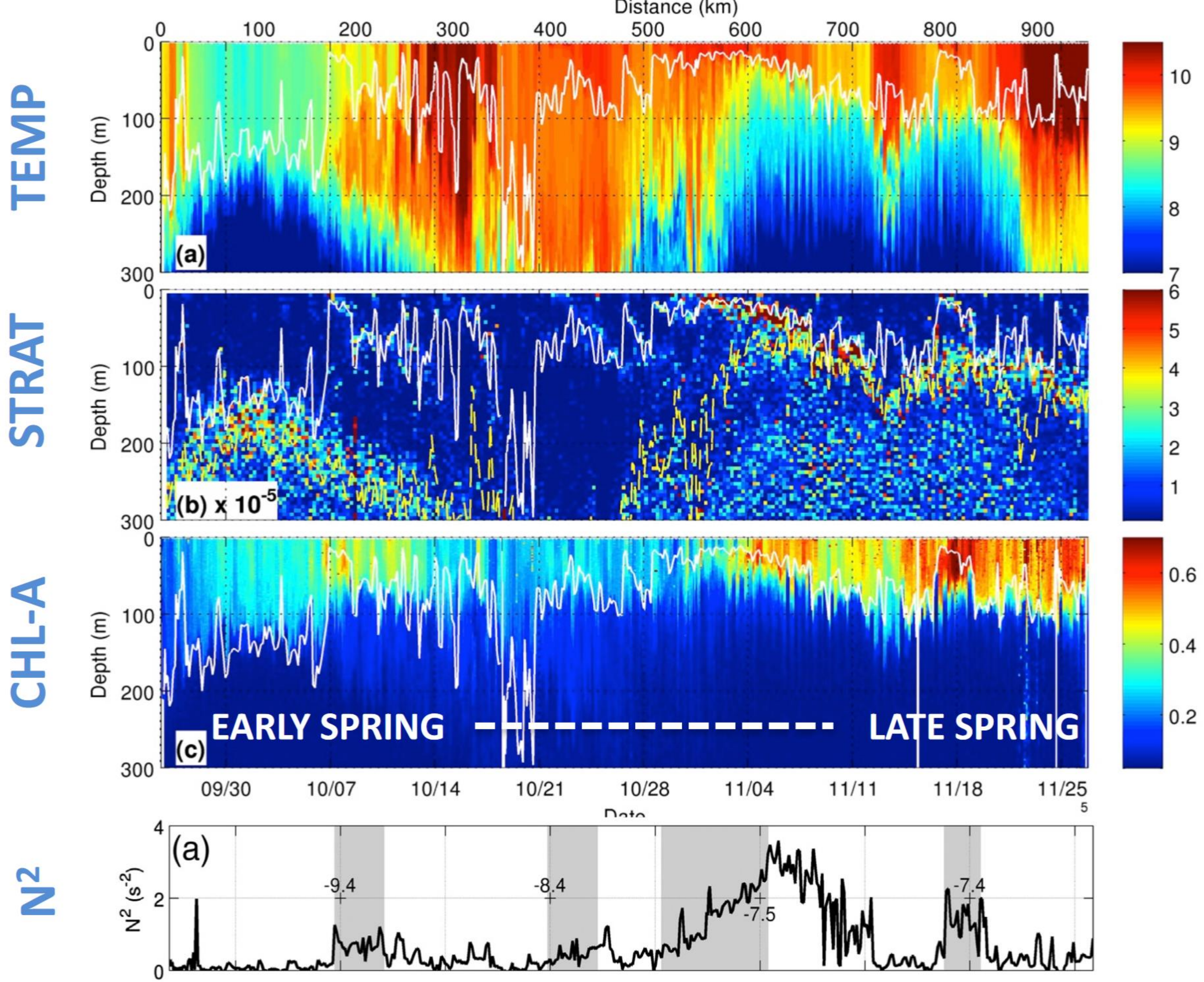
~ 0.4 km for dives to 100 m depth



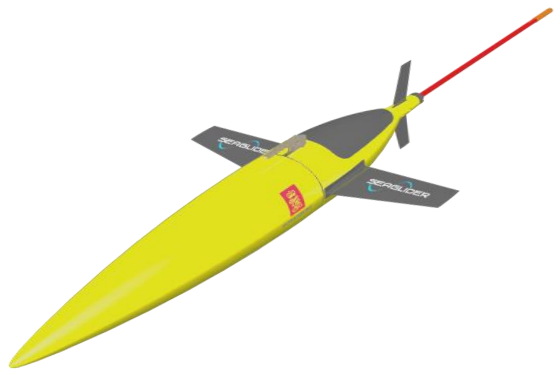
Physical
&
Biological
Sensors







Swart et al., 2015



Gliders are good tools that can expand those measurements that previously were only conducted by ship-borne CTDs and towed instruments. By using several gliders the problem with non-synoptic measurements can be overcome. A glider can be out several months and can be serviced by ship when convenient.

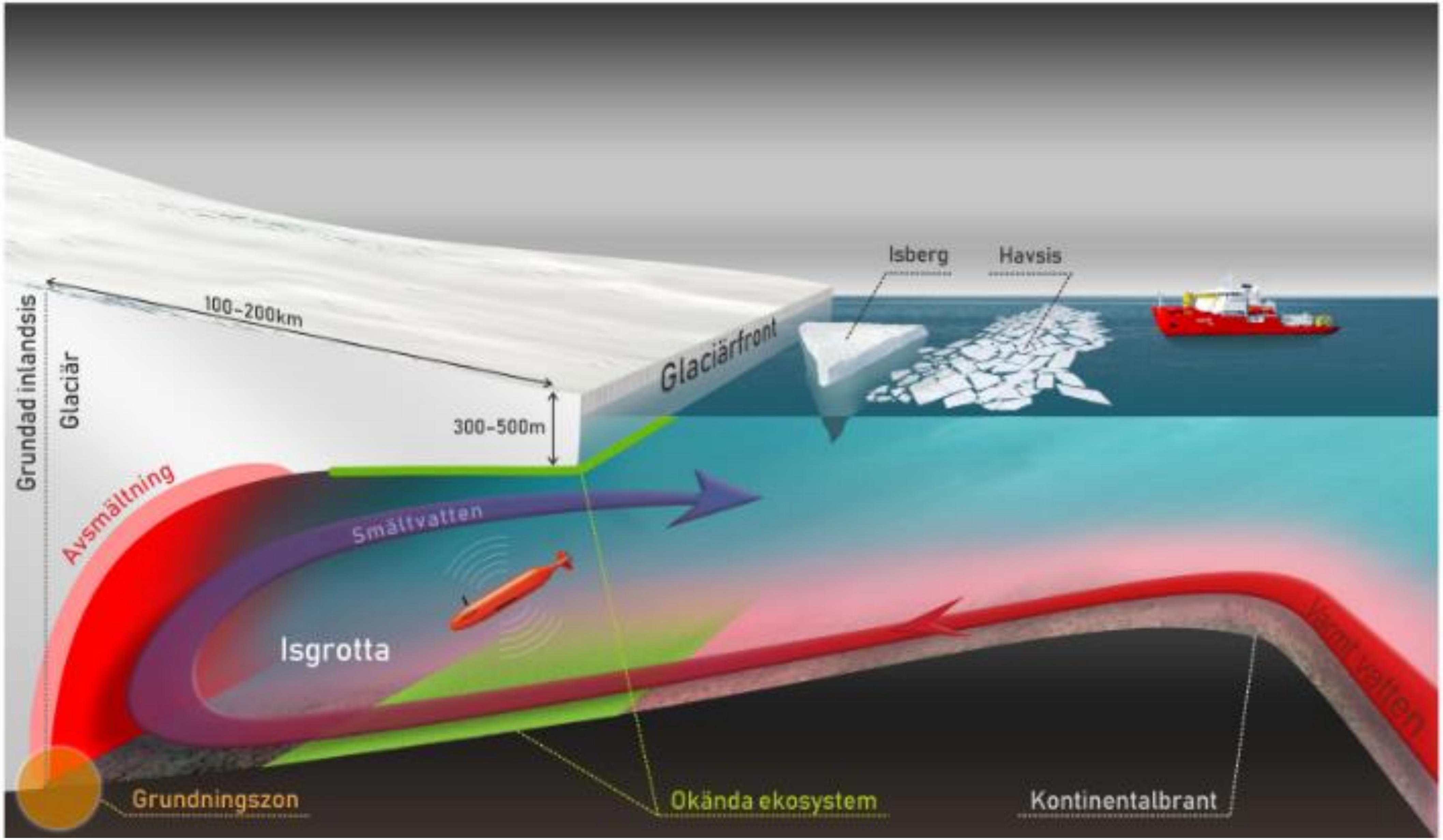
However, gliders can not survey (not good platform for acousti survey instrumentation), they are slow and they can not navigate under water.

More advanced AUVs needed for tasks where surveying is needed and/or correct navigation.

There are vast regions where we have almost no measurements at all, e.g., areas under ice shelves...

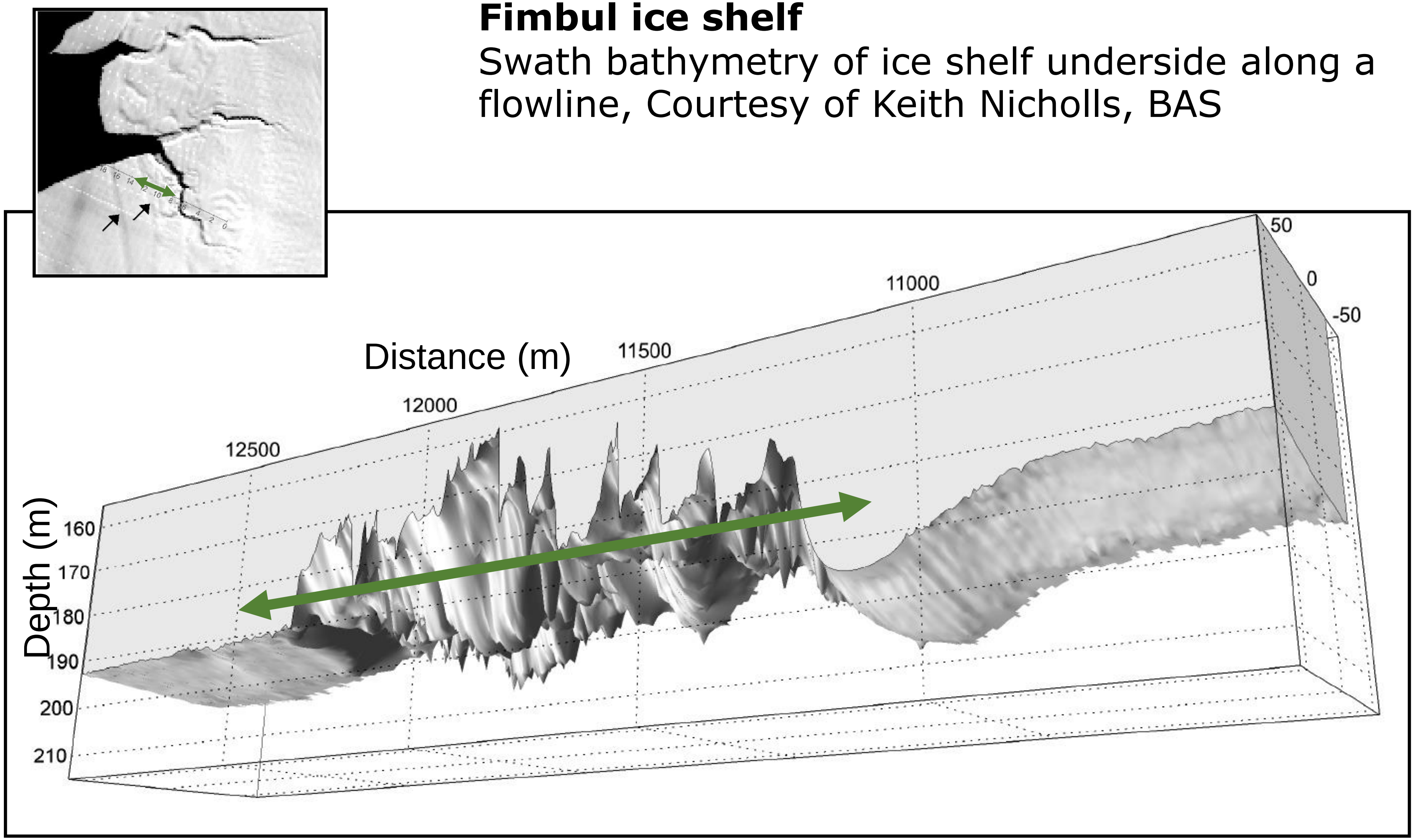
Foto credit: Peter Sheehan

AUVs can be used to explore under ice shelves



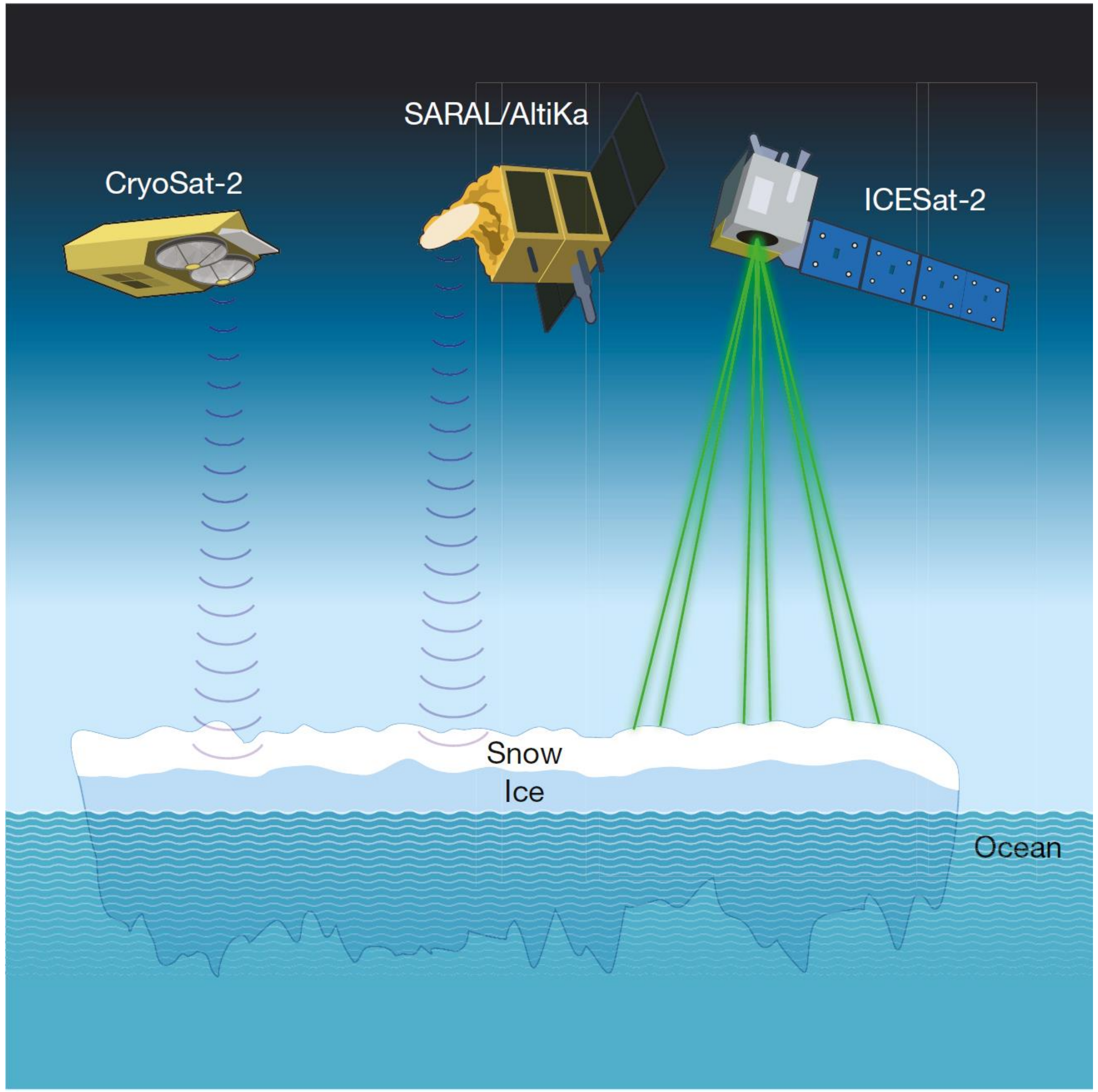
Fimbul ice shelf

Swath bathymetry of ice shelf underside along a flowline, Courtesy of Keith Nicholls, BAS

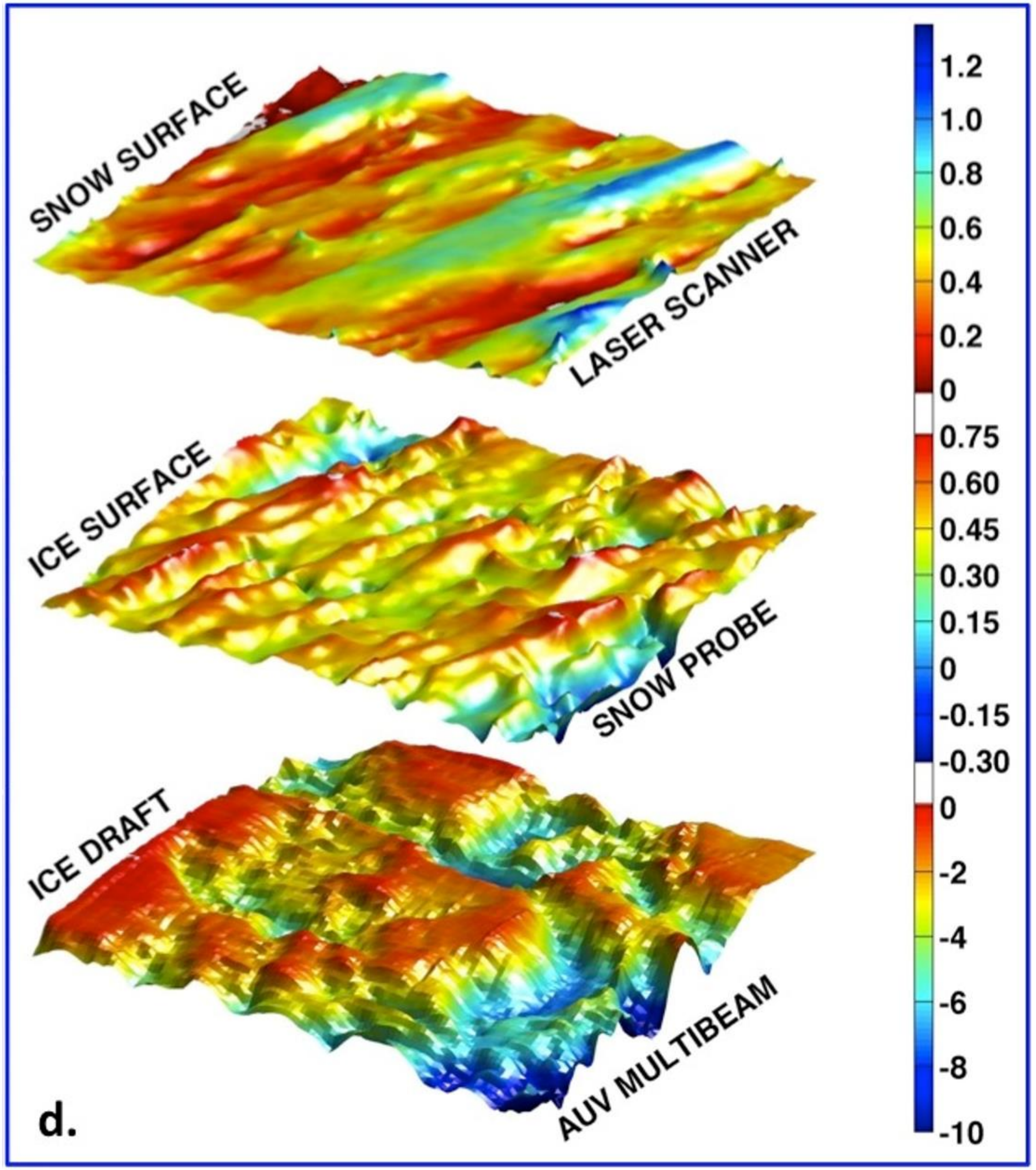



Or under sea ice
Foto credit: Peter Sheehan

Satellites provide global coverage of sea ice measurements…



But e.g., sea ice thickness is underestimated based on satellite data only



Williams et al, N. Geosc, 2014

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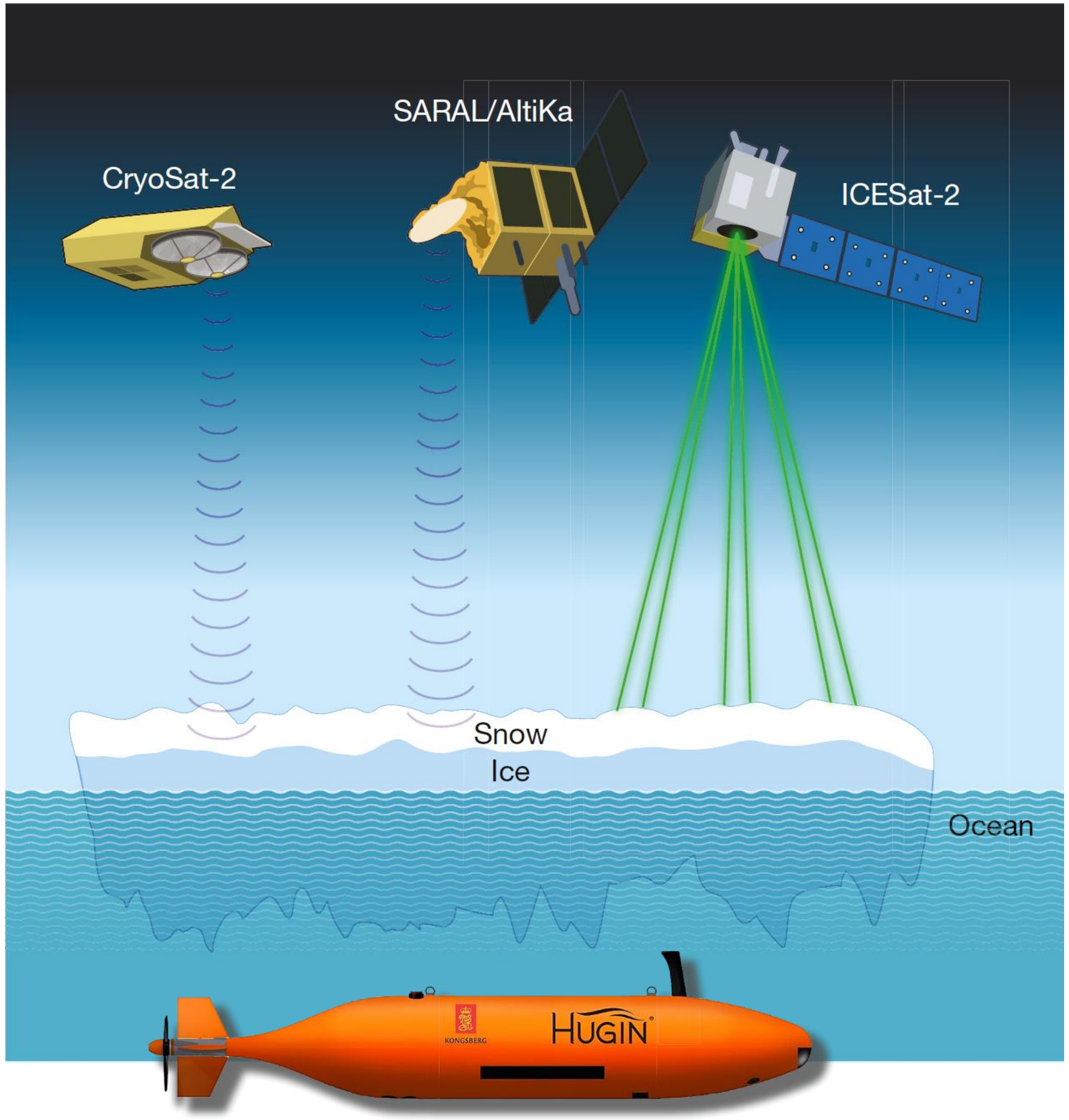

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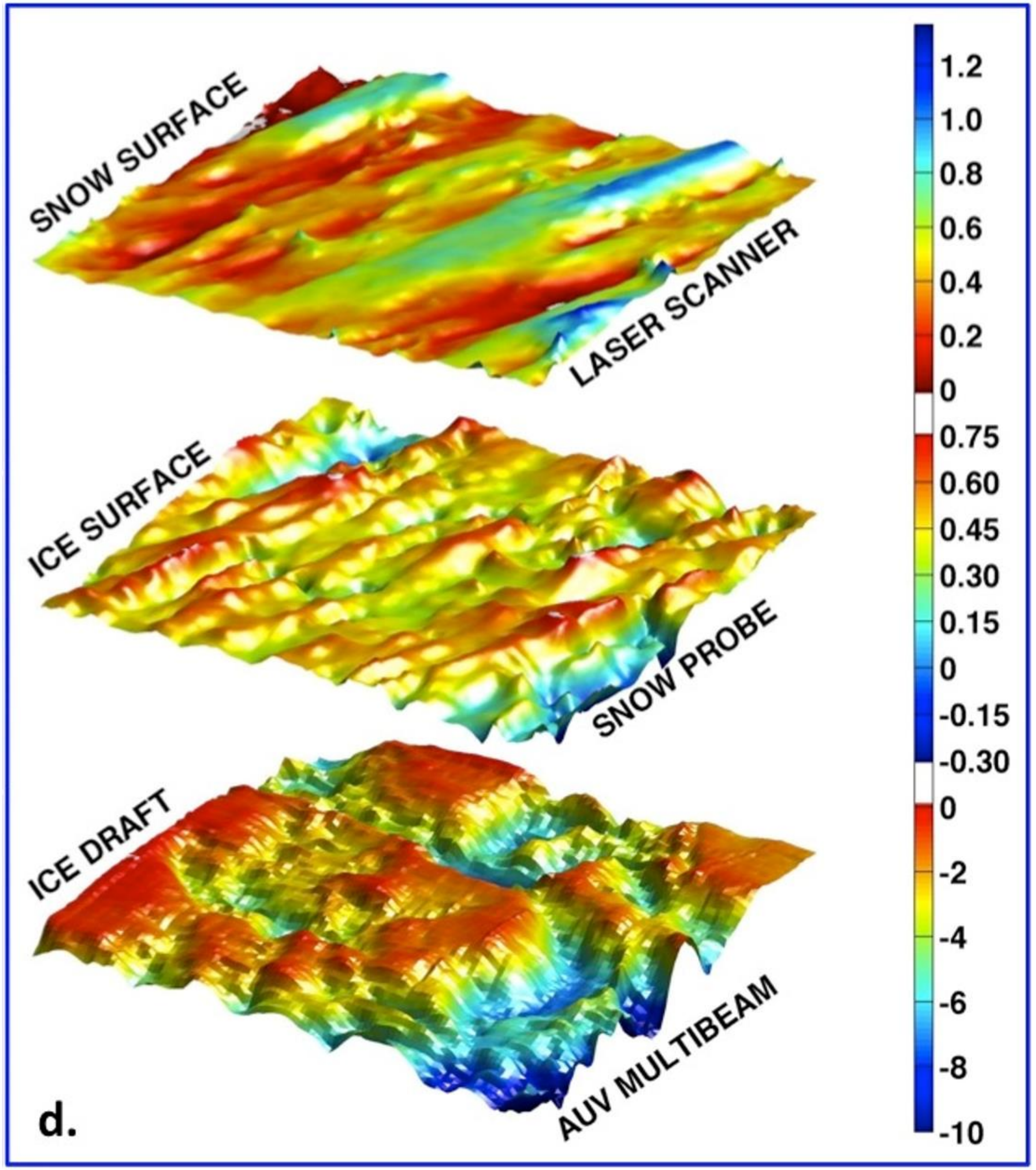
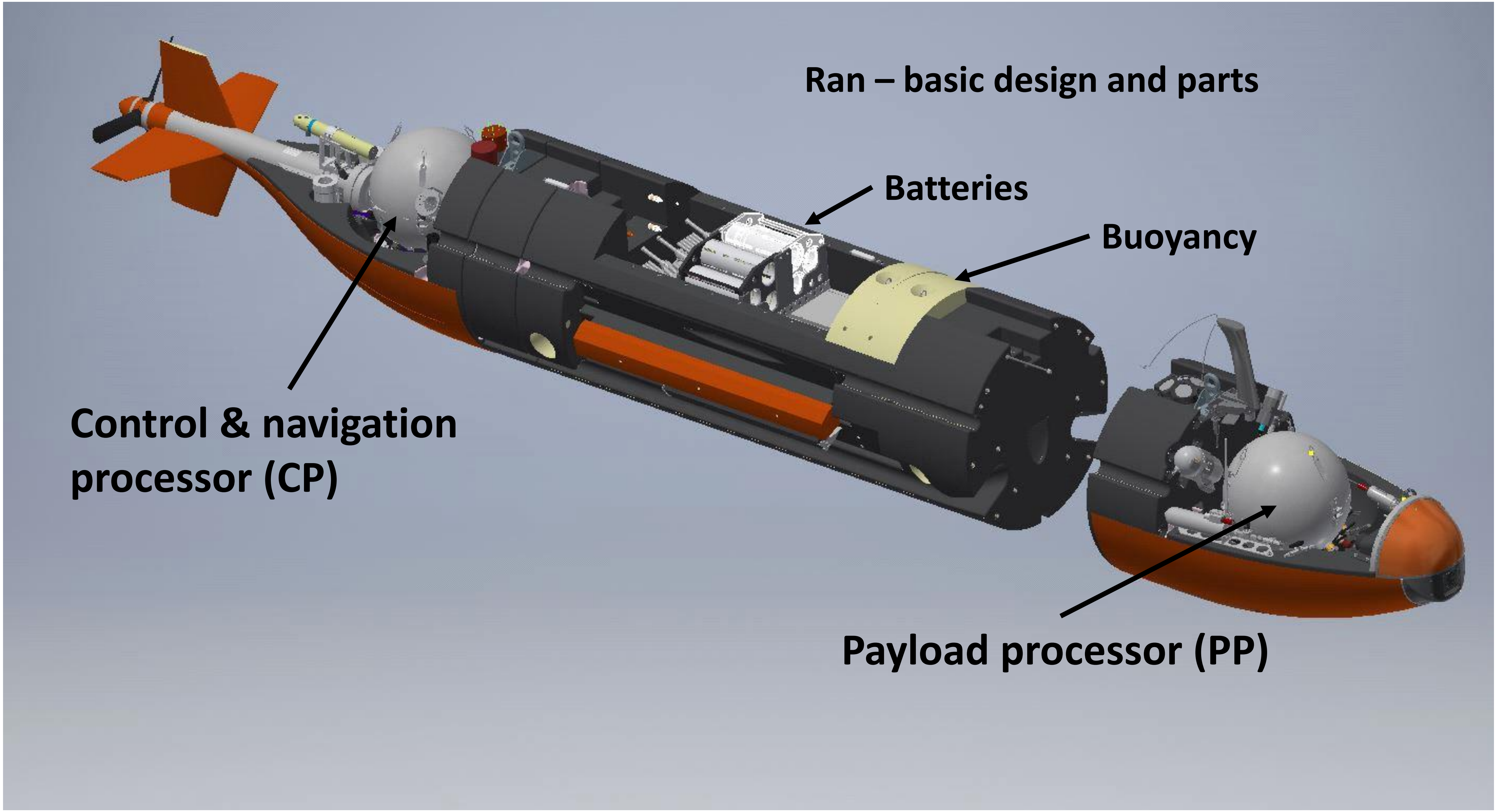


Williams et al, N. Geosc, 2014

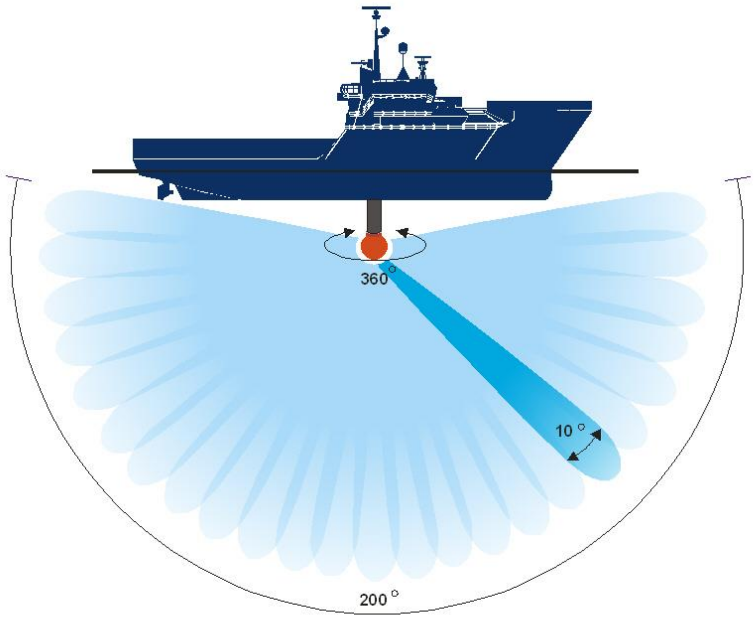
Ran – basic properties

Kongsberg Hugin 3000 AUV

Dimensions	Depth rating and range	Power supply	Endurance
Length: approx. 7.5 m Diameter: 875 mm Weight: 1850 kg	3000 m 300 km	4 (max 6) rechargeable and swappable Lithium Polymer batteries	36 hours


Ran – basic design and parts
Batteries
Buoyancy
Control & navigation processor (CP)
Payload processor (PP)

Ran – communication



Underwater

- USBL (HiPAP Transponder)
- cNODE Command Link
- Data Link

Surface

- WiFi
- Iridium
- UHF radio link

Ran – navigation

Modes of operation	Estimated navigation error	
	Real-Time	Post-Processed
Autonomous: no updates, straight line	0.09% of DT (CEP50)	<= 0.08% of DT (CEP50)
Autonomous: GPS fix every 1-2 hour	2-10 m	1-4 m
Autonomous: NavP UTP ranging	5 m	2 m
Supervised: HiPAP USBl updates	0.5-6 m (depending on depth and GPS accuracy	0.5-4 m

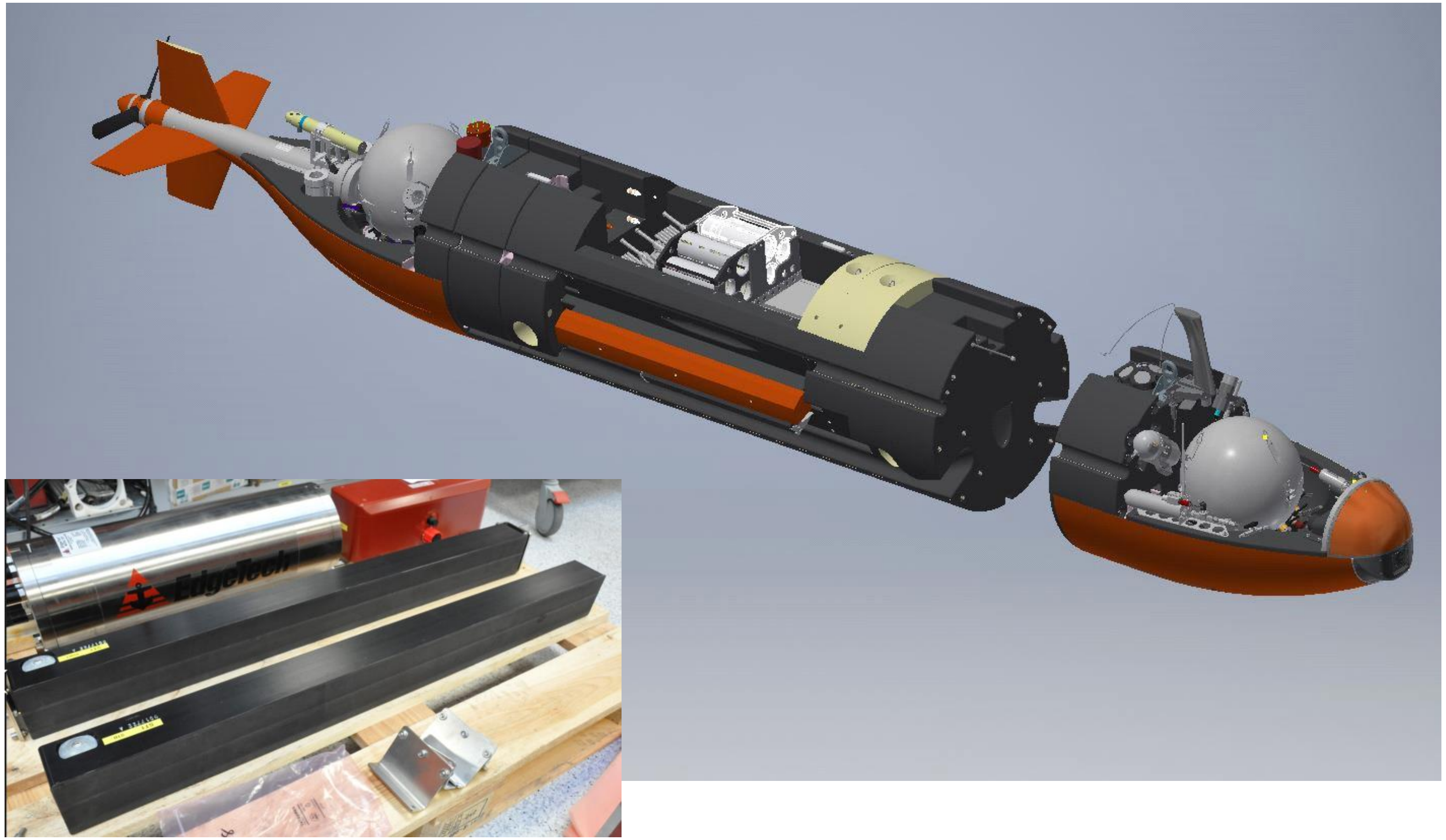
- **IMU (Honeywell Hg9900)**
- **GPS Receiver (AUV: Novatel)**
- **Compass (Leica DMC)**

- **Forward Looking Sonar/Anti-Collision System**
  Imagenex sonar and KM algorithms for improved contour following and obstacle avoidance

- **Altimeters**
  Kongsberg Mesotech 200/675 kHz forward and down looking

- **Doppler Velocity Log (DVL)**
  Nortek 500 kHz

Ran – acoustic sensors



- **Sub-bottom profiler**
  EdgeTech DW-216,
  configurable chirp pulses

- **Sidescan sonar**
  EdgeTech dual frequency,
  75 kHz and 410 kHz

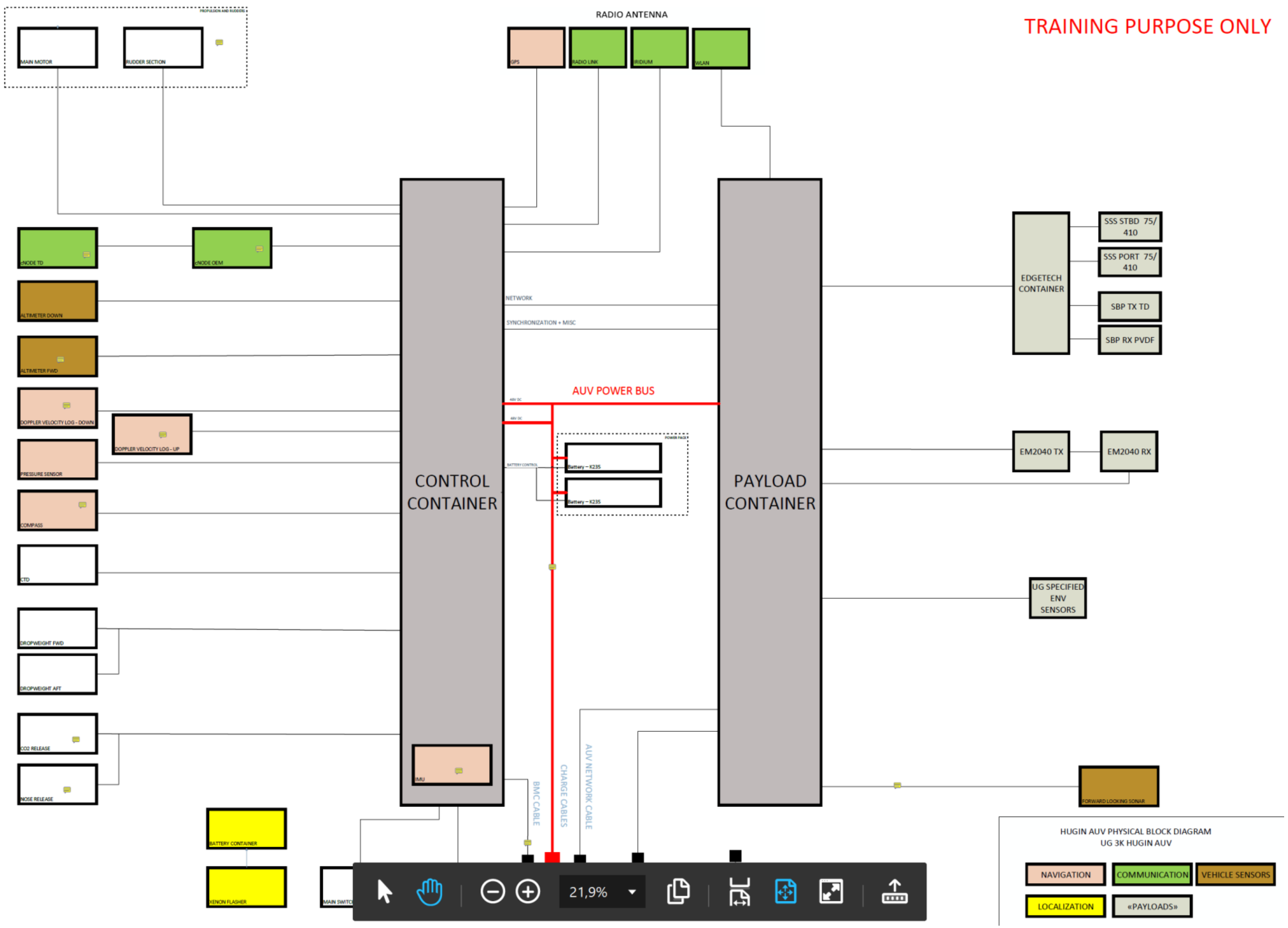
- **Multibeam Echosounder**
  Kongsberg EM2040, 200-400 kHz,
  0.7º × 0.7º beam width,
  swath coverage sector up to 140º

Ran – other sensors

- Upward looking DVL / ADCP
- Contros HydroC CO_2
- Sea-Bird/Wet-Labs ECO Triplet (FLBBCD)
- Sea-Bird/Satlantic Deep SUNA (max 2000 meter)
- 2x Sea-Bird combination SBE-19plusV2 and SBE-43
- Fluidion water sampling system

There is a general payload area where sensors and instruments can be placed
(60 cm long, 87 cm diameter), 6 RS232 connectors plus ethernet / LAN connection

UG_HUGIN_BLOCK_DIAGRAM.PDF



Eurofleets+ availability of shiptime and infrastructure:

https://www.eurofleets.eu/access/sea-call-oceans/

Deadline Sept 27th

Ran missions under and near Thwaites Glacier, Antarctica, 2019

SMaRC (Swedish Maritime and Robotics Center)
Swedens contribution to ITGC

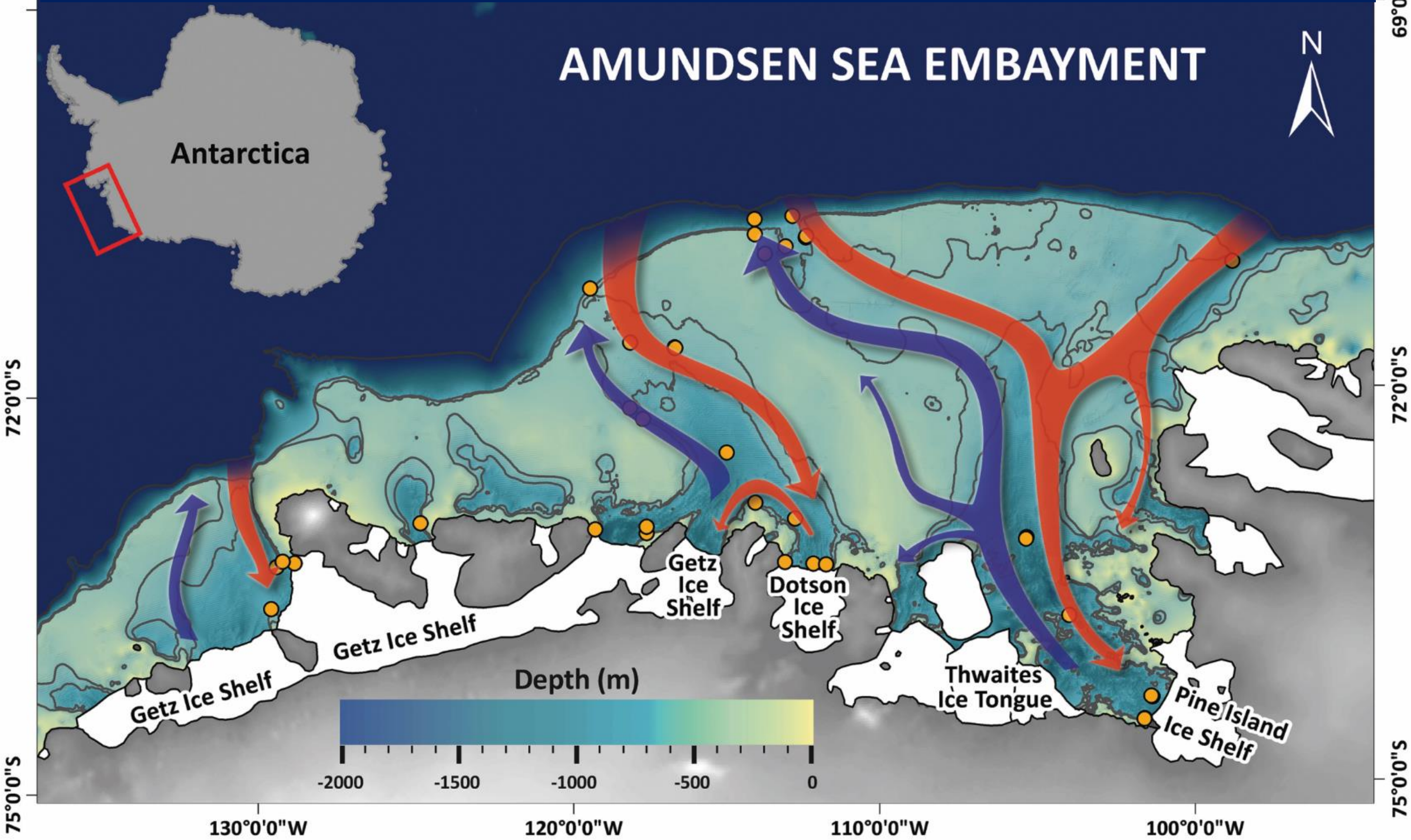
Wallenberg foundation

Anna Wåhlin
University of Gothenburg (Sweden)

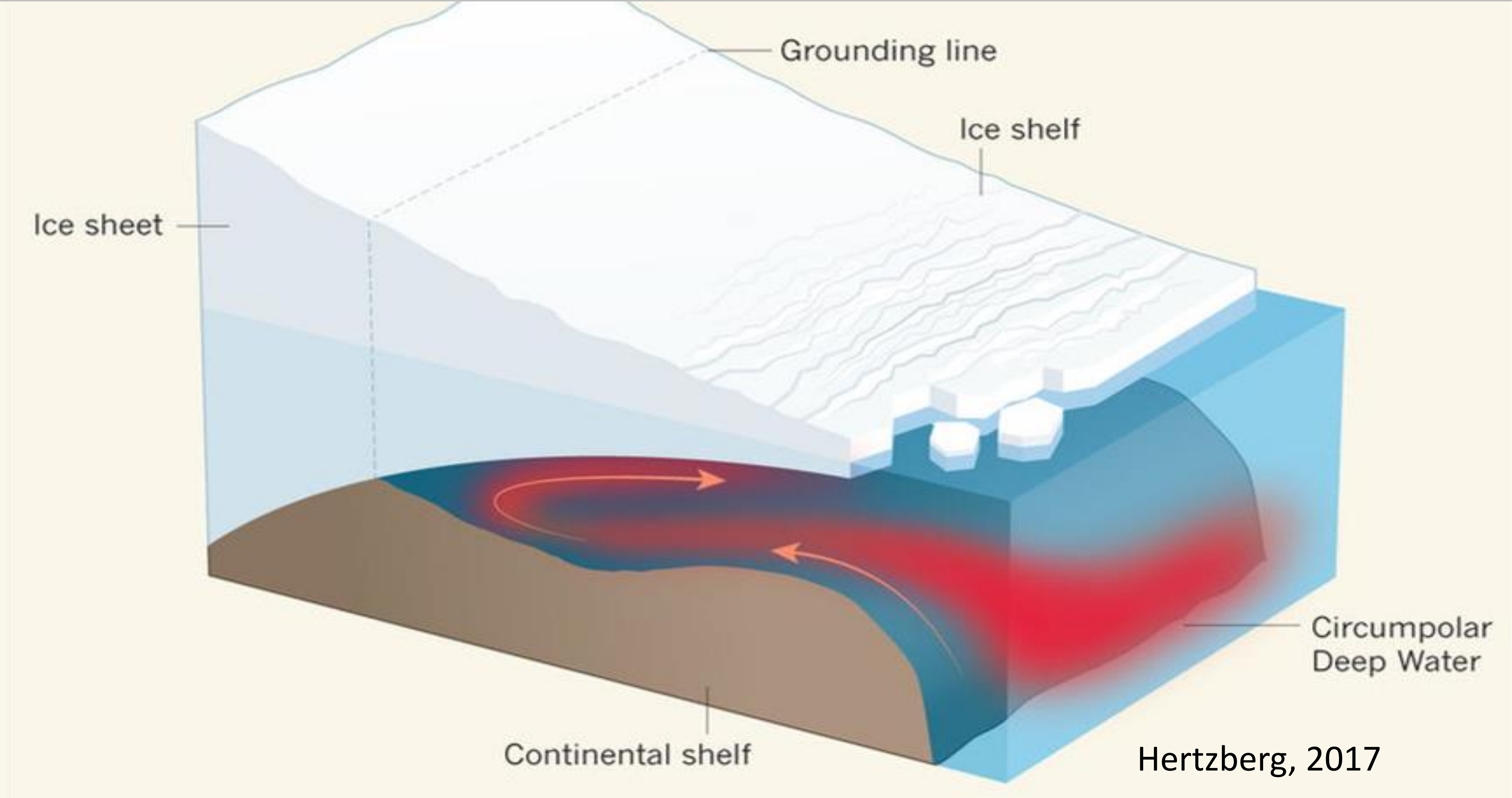
Jonas Andersson
Johan Rolandsson
Filip Stedt

Aleksandra Mazur
Salar Karam

Warm water flows southwards in deep troughs on the continental shelf



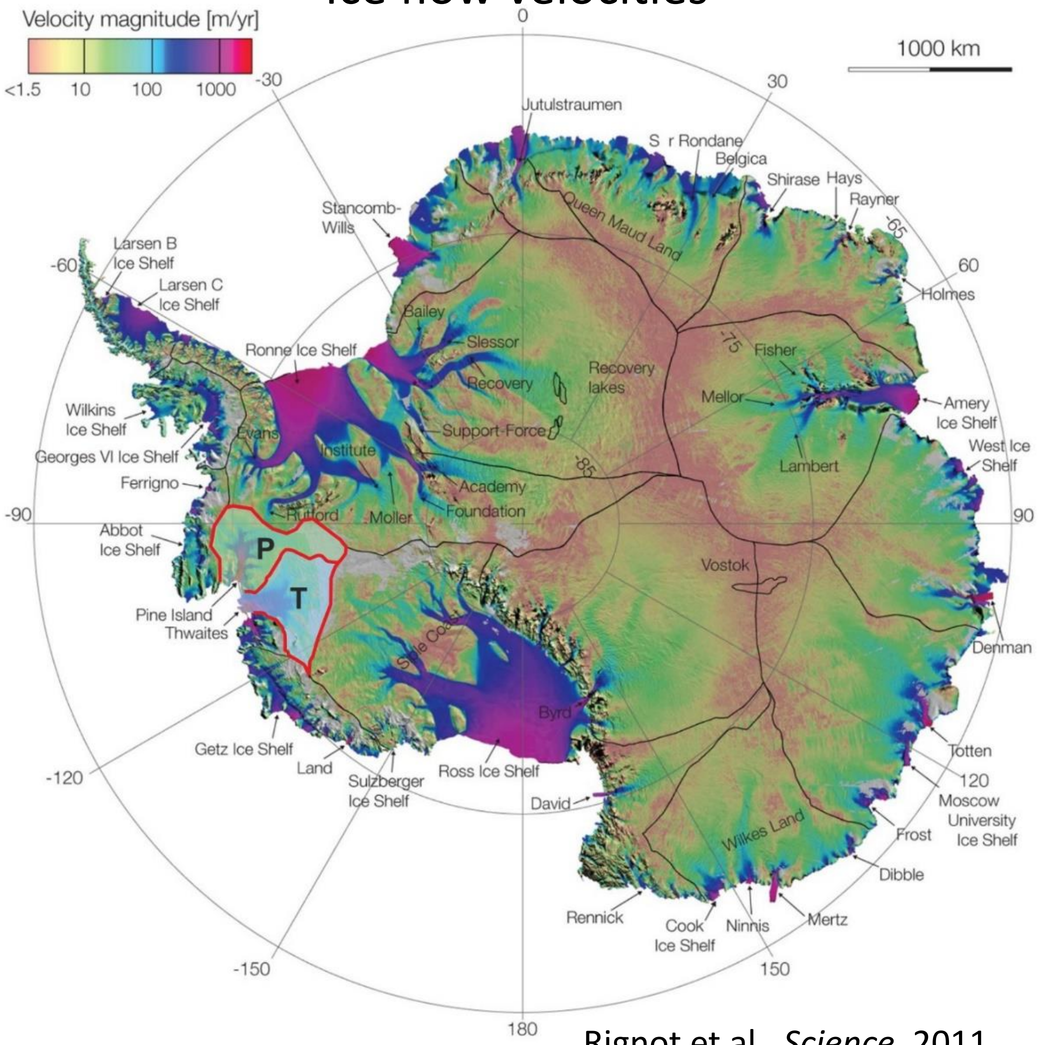
If warm water floods the continental shelf, it can access glacier ice and melt it from below. This leads to an acceleration of the glaciers out into the ocean. Especially pronounced in the Amundsen Sea



Hertzberg, 2017

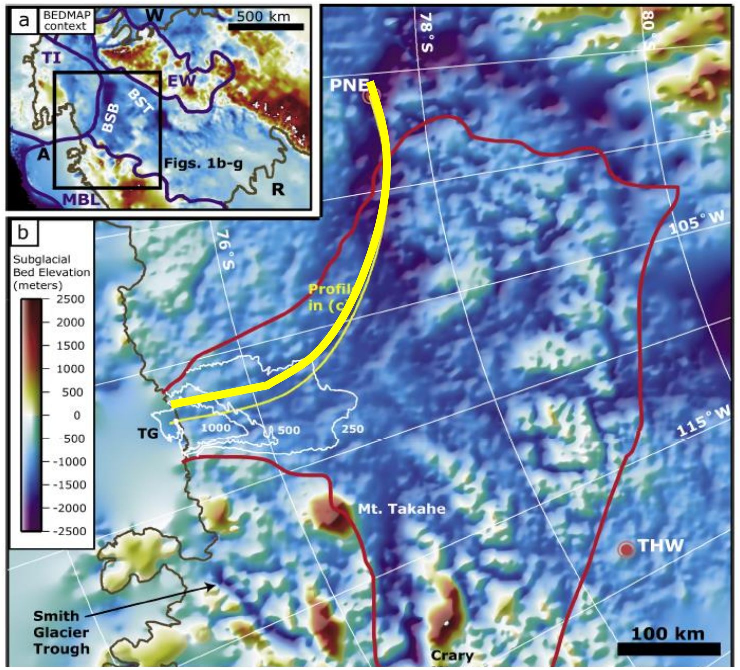
Why Thwaites – the 'soft underbelly' of WAIS

Ice flow velocities

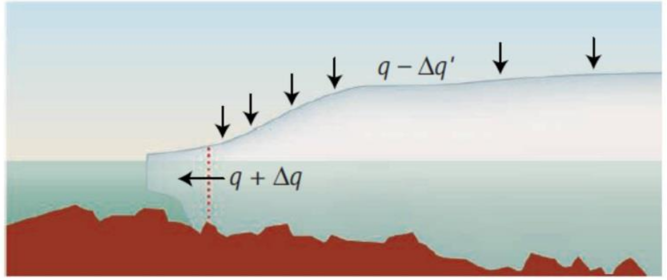


Rignot et al., *Science*, 2011

Bed topography



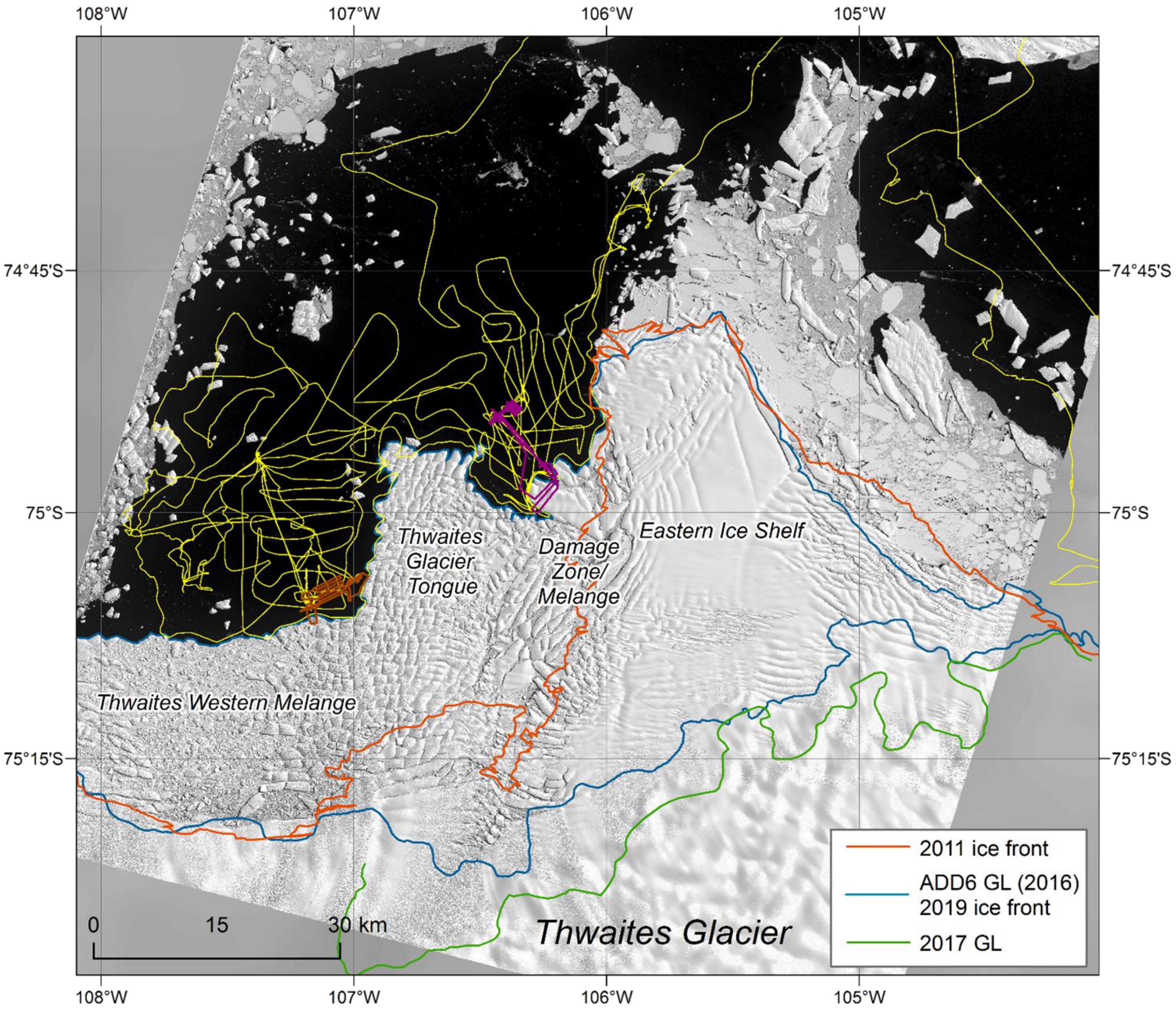
Holt et al., *GRL*, 2006



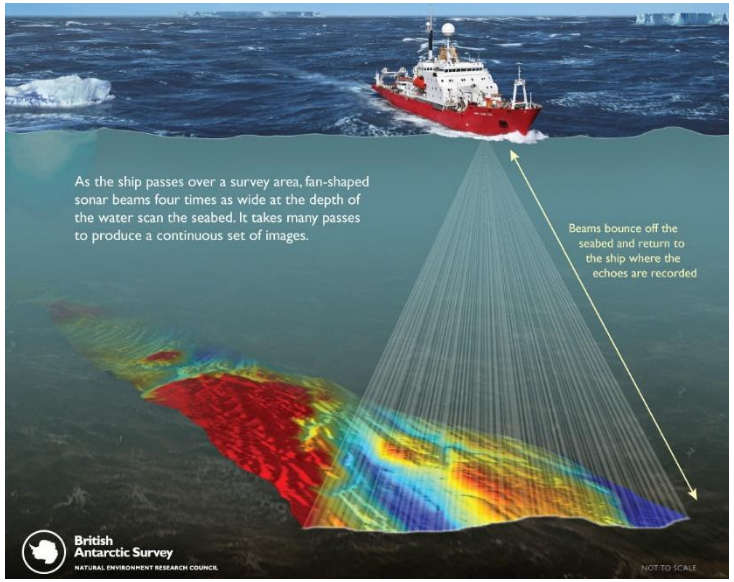
Vaughan & Arthern, *Science*, 2007
based on Weertman, 1974 and Schoof, 2007

Ship track NBP19-02

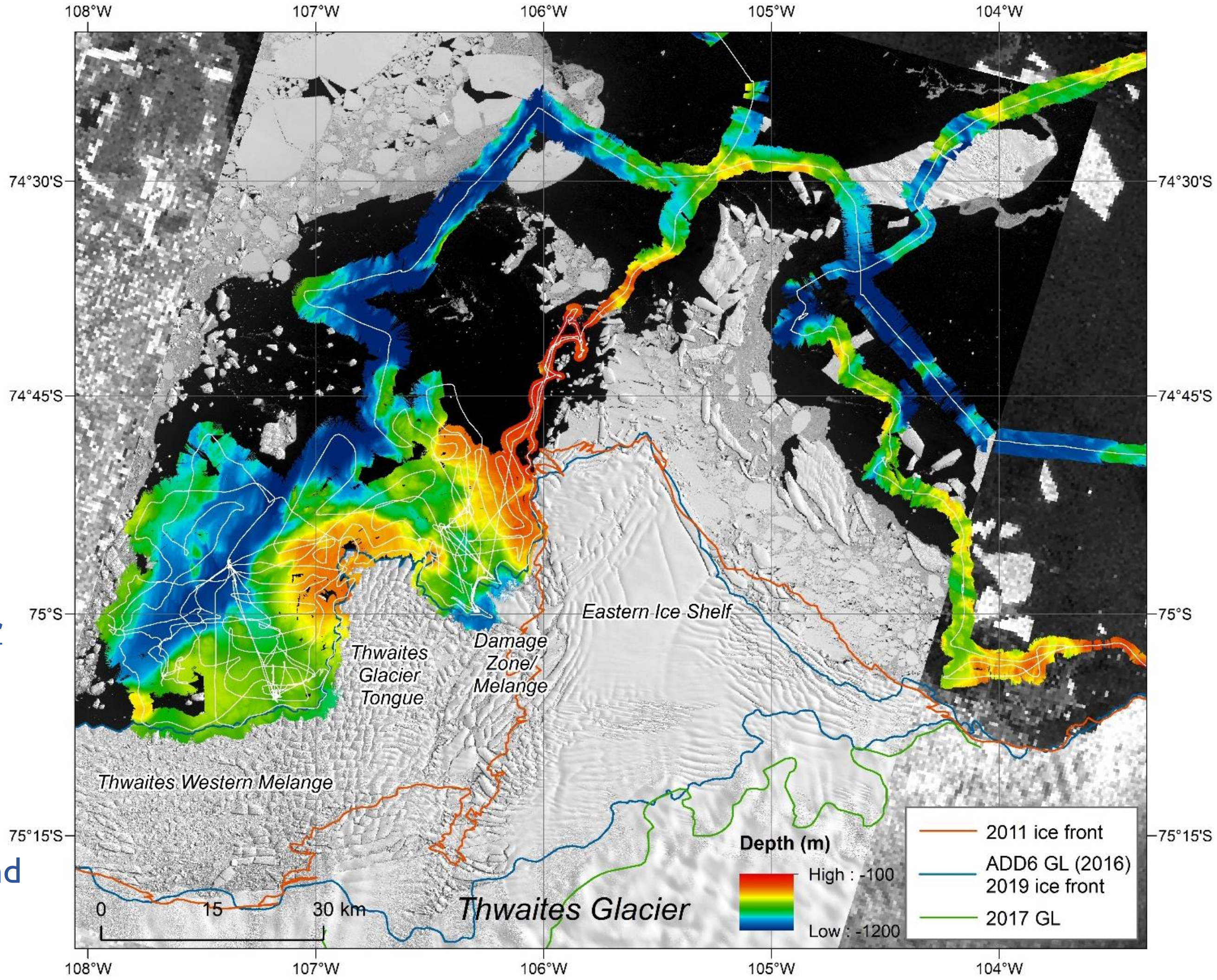
Hydrographic survey
Gliders
Seal tagging



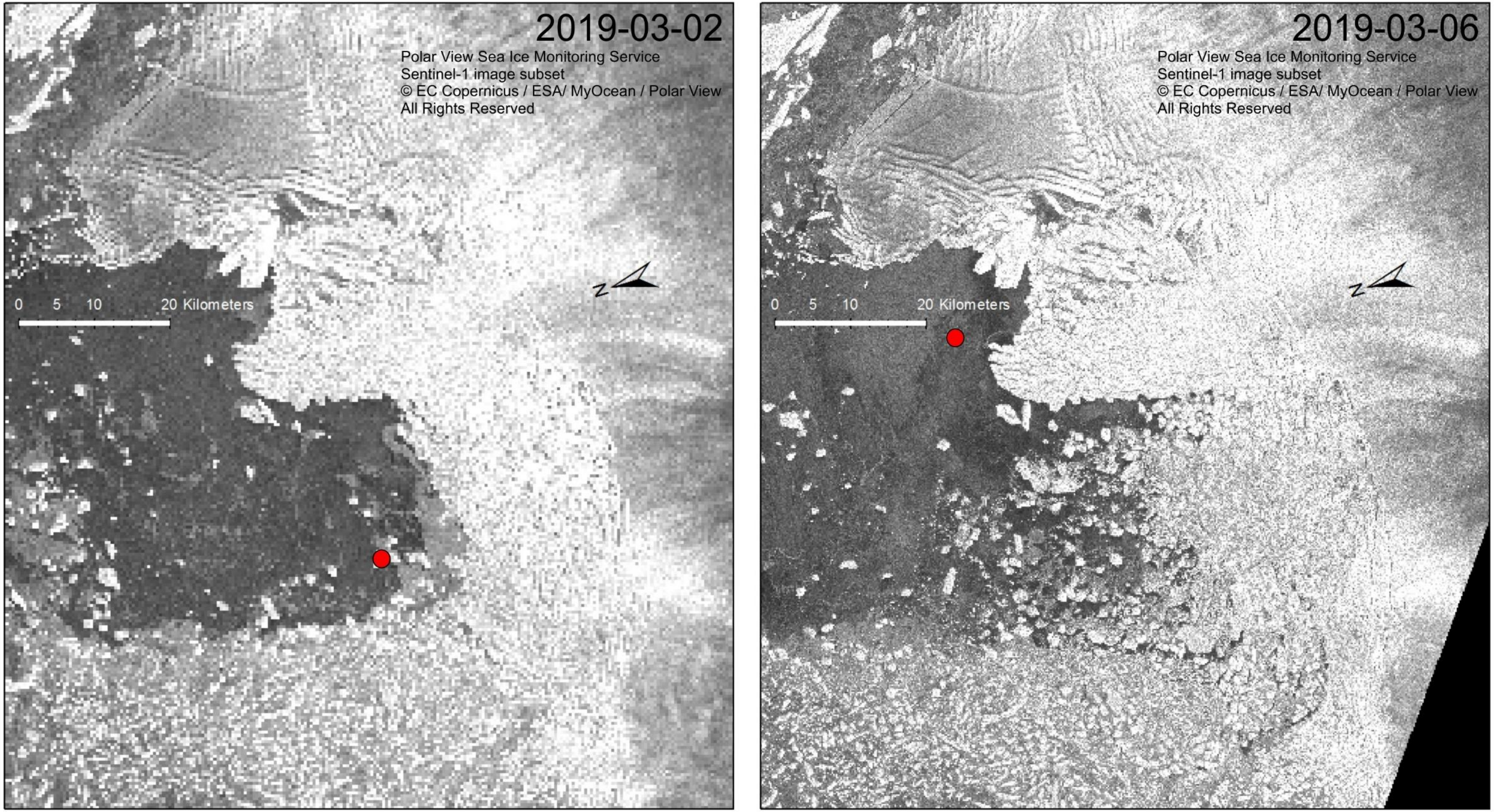
Shipboard geophysical data

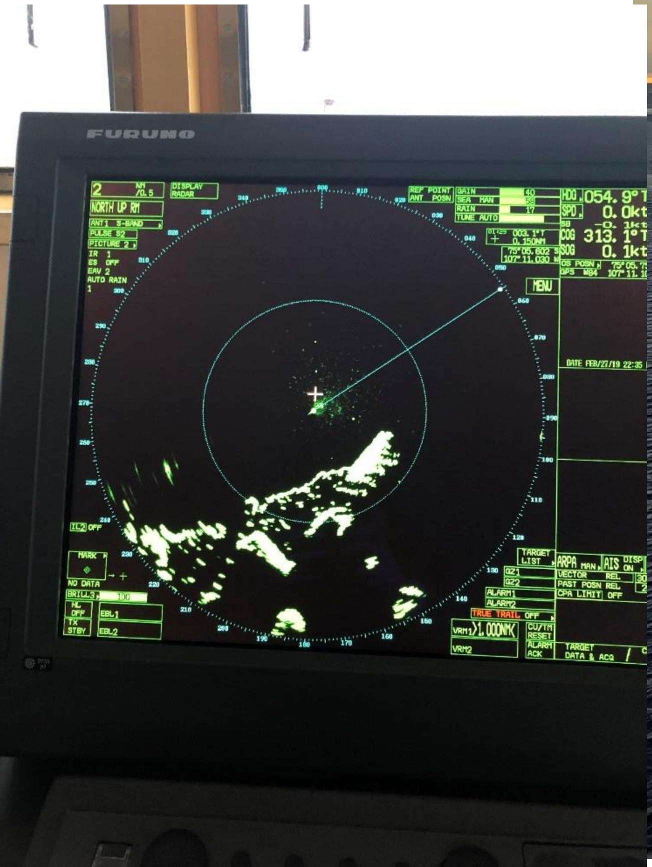


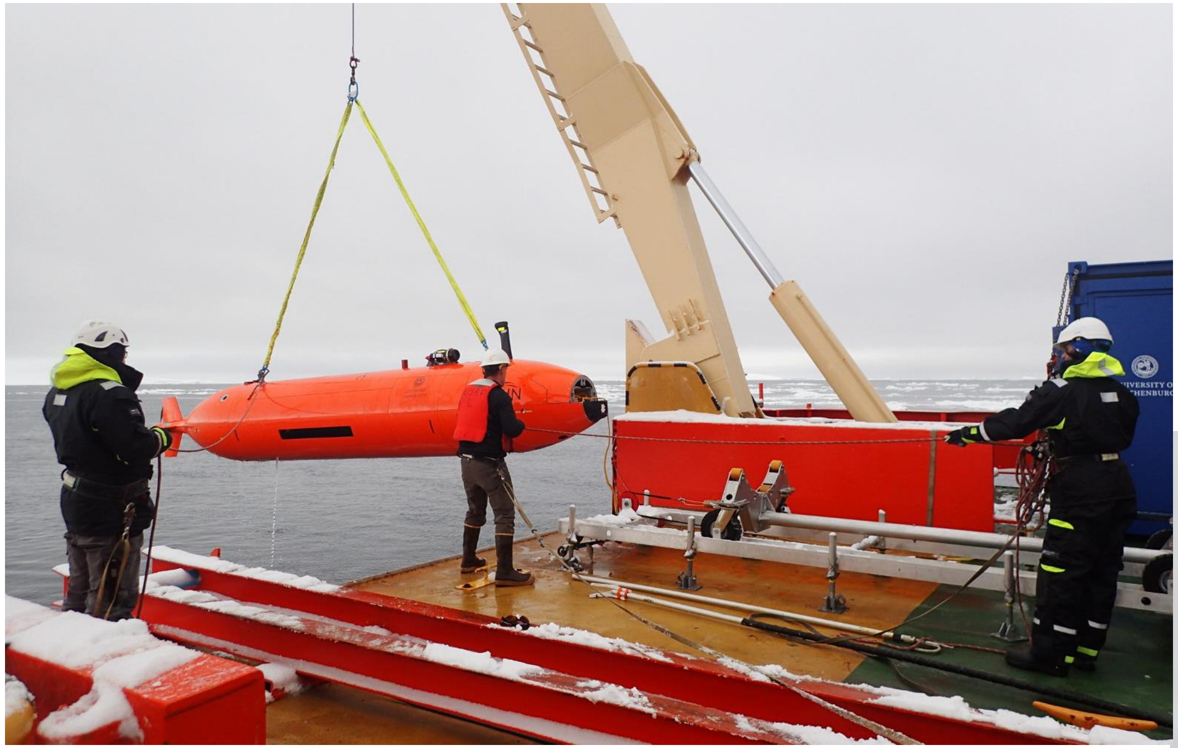
- <u>12 kHz EM122 multibeam echo sounder</u> on RVIB *Nathaniel B. Palmer*
- 1900 line-km (3250 km^2) of new bathymetry data in front of Thwaites
- Mapping revealed deep channels (>1000 m) and shallow areas that may have acted as former pinning points for TG



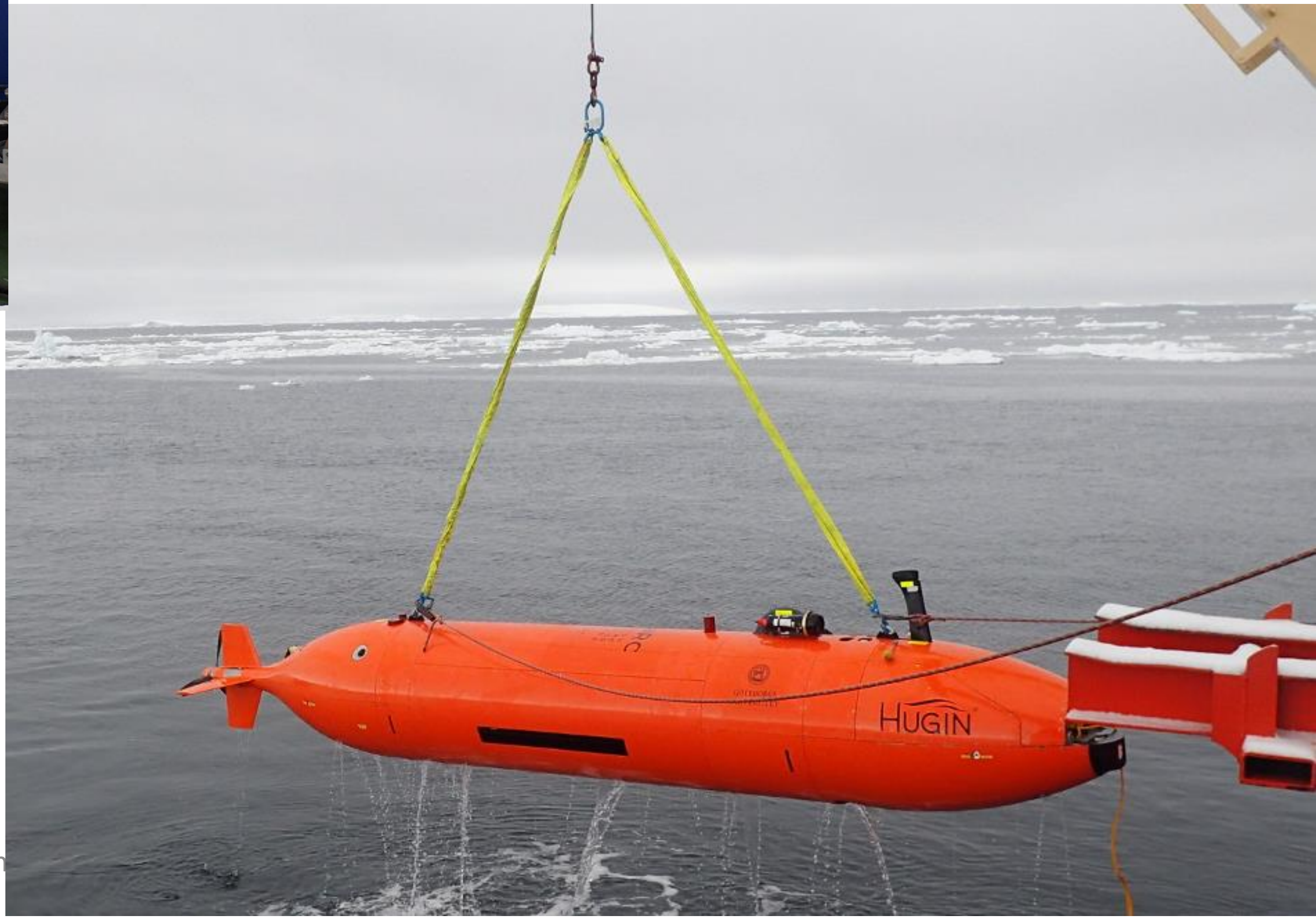
Rapidly changing conditions – were exceptionally lucky to get in (first ship here)




FURUNO
NORTH UP RM
DISPLAY RADAR
ANT1 S-BAND
PULSE S2
PICTURE 2
REF POINT ANT POSN
GAIN 40
RAIN 17
TUNE AUTO
HDG 054.9°T
SPD 0.0kt
COG 313.1°T
SOG 0.1kt
MENU
DATE FEB/27/19 22:35



LAR
Weather dependent




LAR

Sweden's contribution to ITGC: Ran

- 2 missions under Thwaitess
- 3 km under the ice shelf
- fine-scale (1.5. m) multibeam bathymetry, very high-resolution sidescan and sub-bottom profiler data.
- Sea-bed processes and ice-bed interactions that hold clues to Thwaites Glacier behaviour and change. Collaboration with THOR (US-UK geologists)

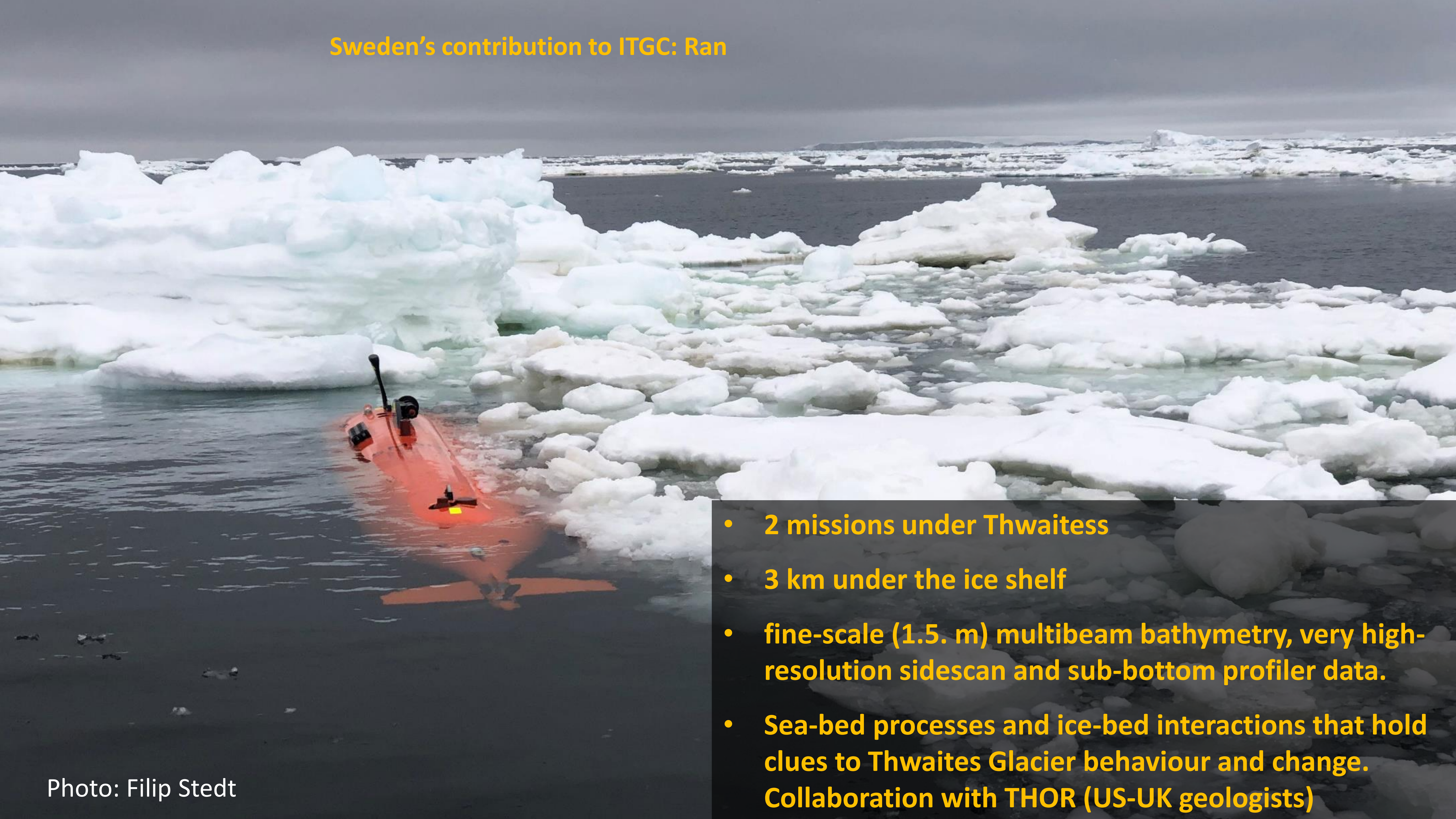
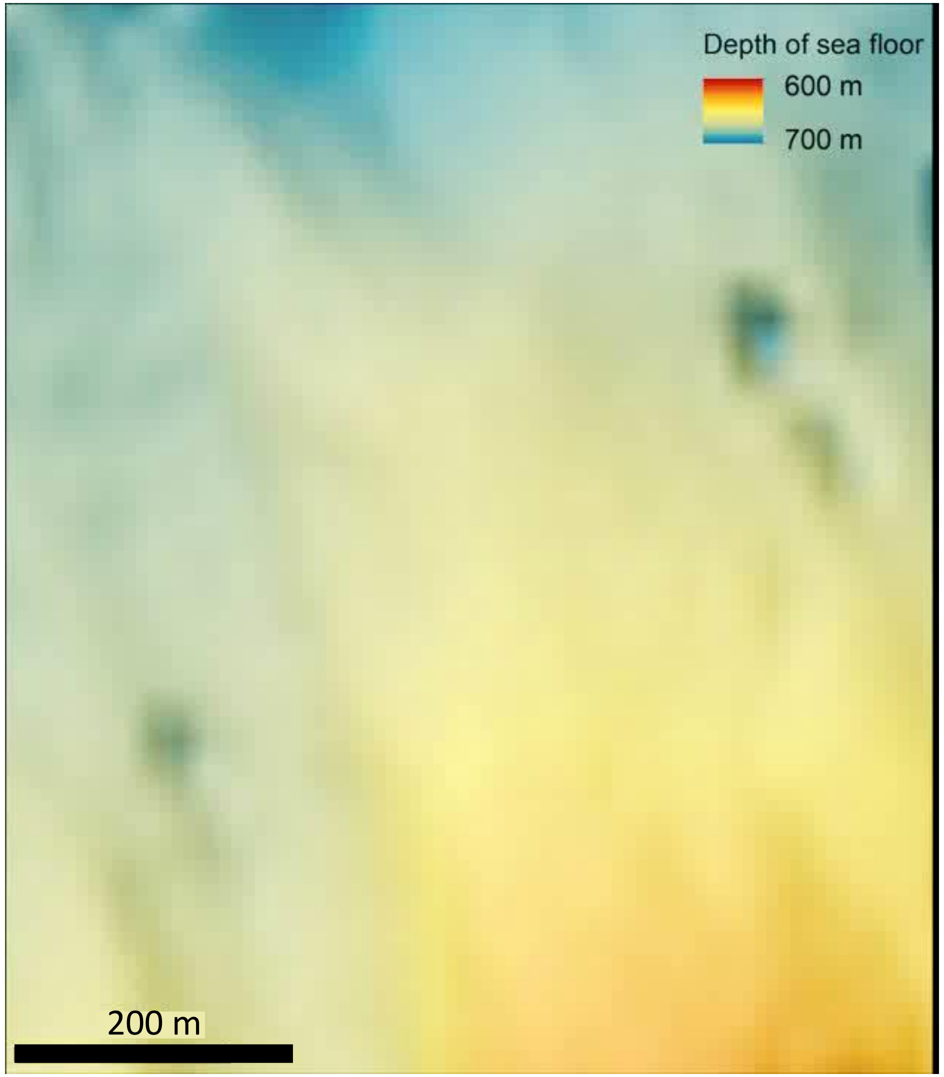


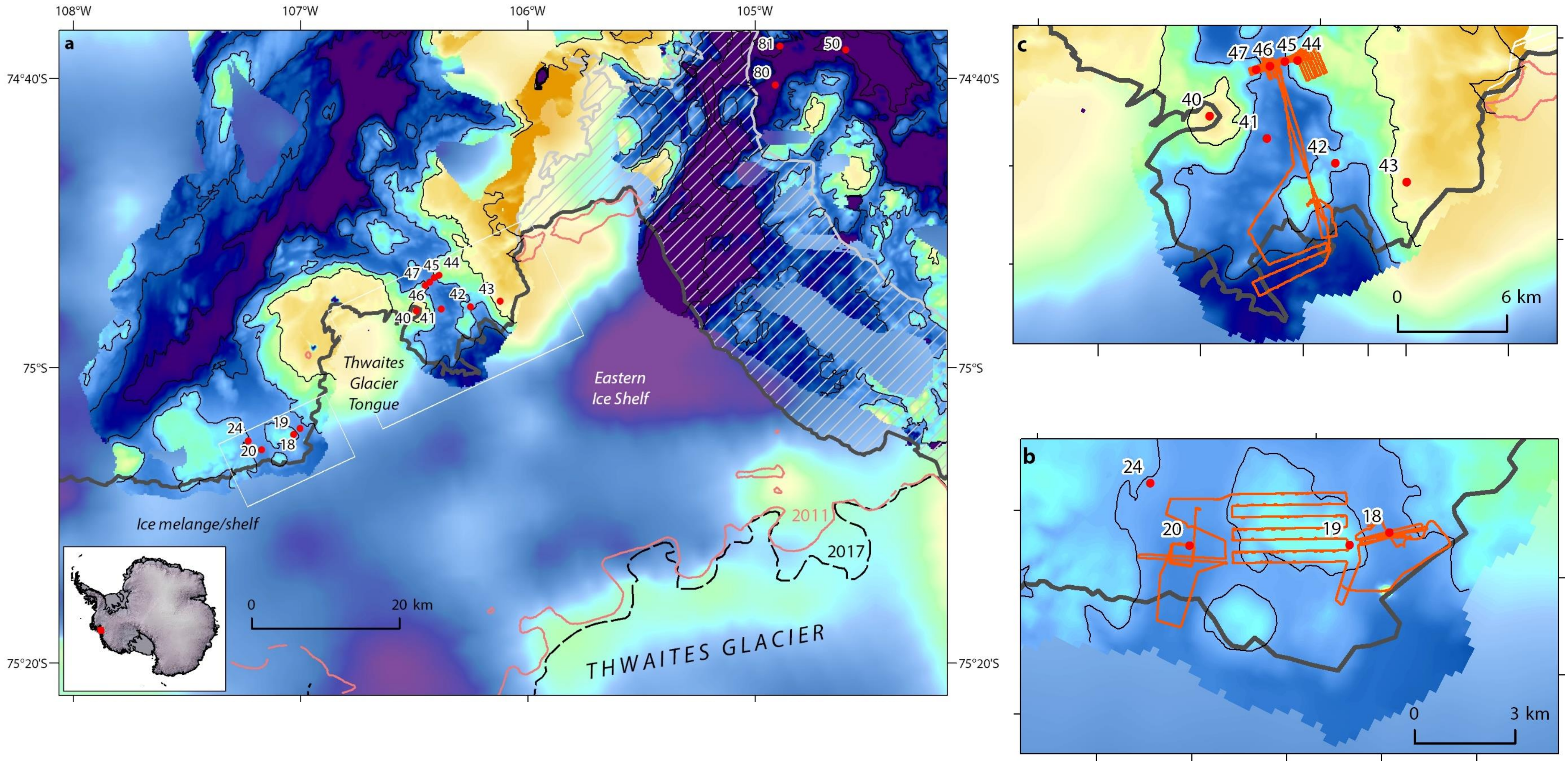
Photo: Filip Stedt

Comparison between shipboard and new AUV bathymetry

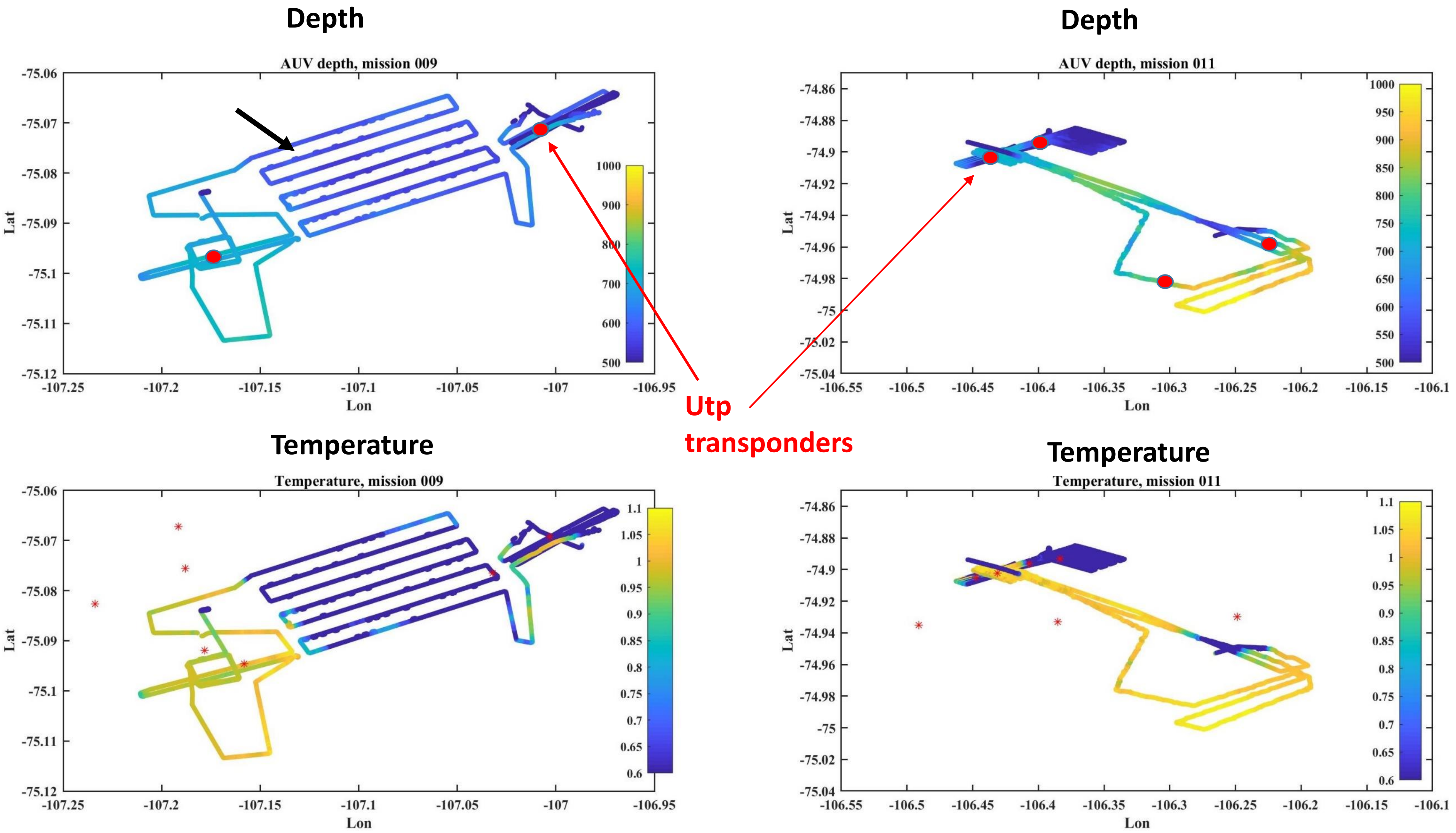
Orders of magnitude increase in resolution, transforming our ability to image recently deglaciated landscapes in Antarctica



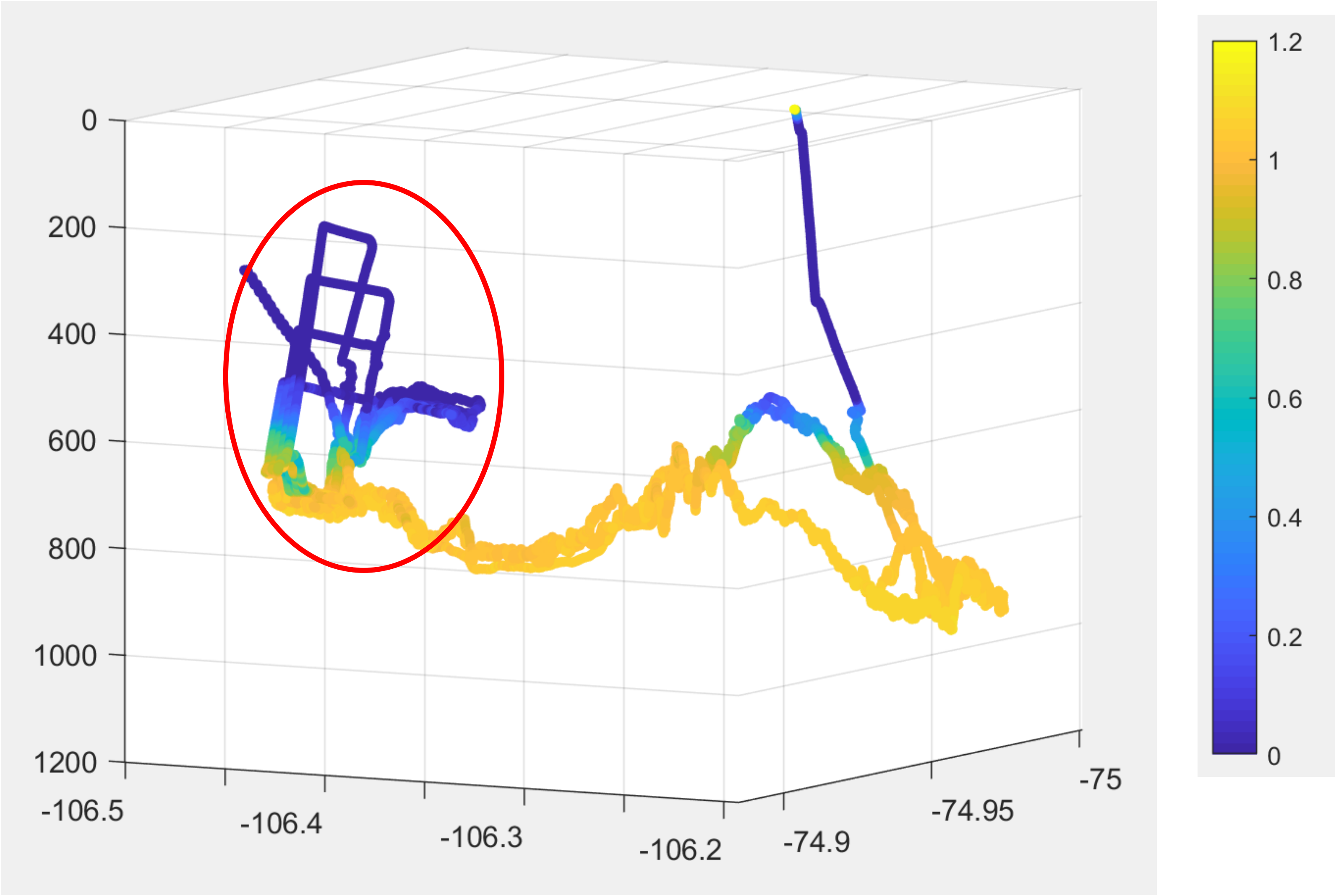
AUV missions under Thwaites

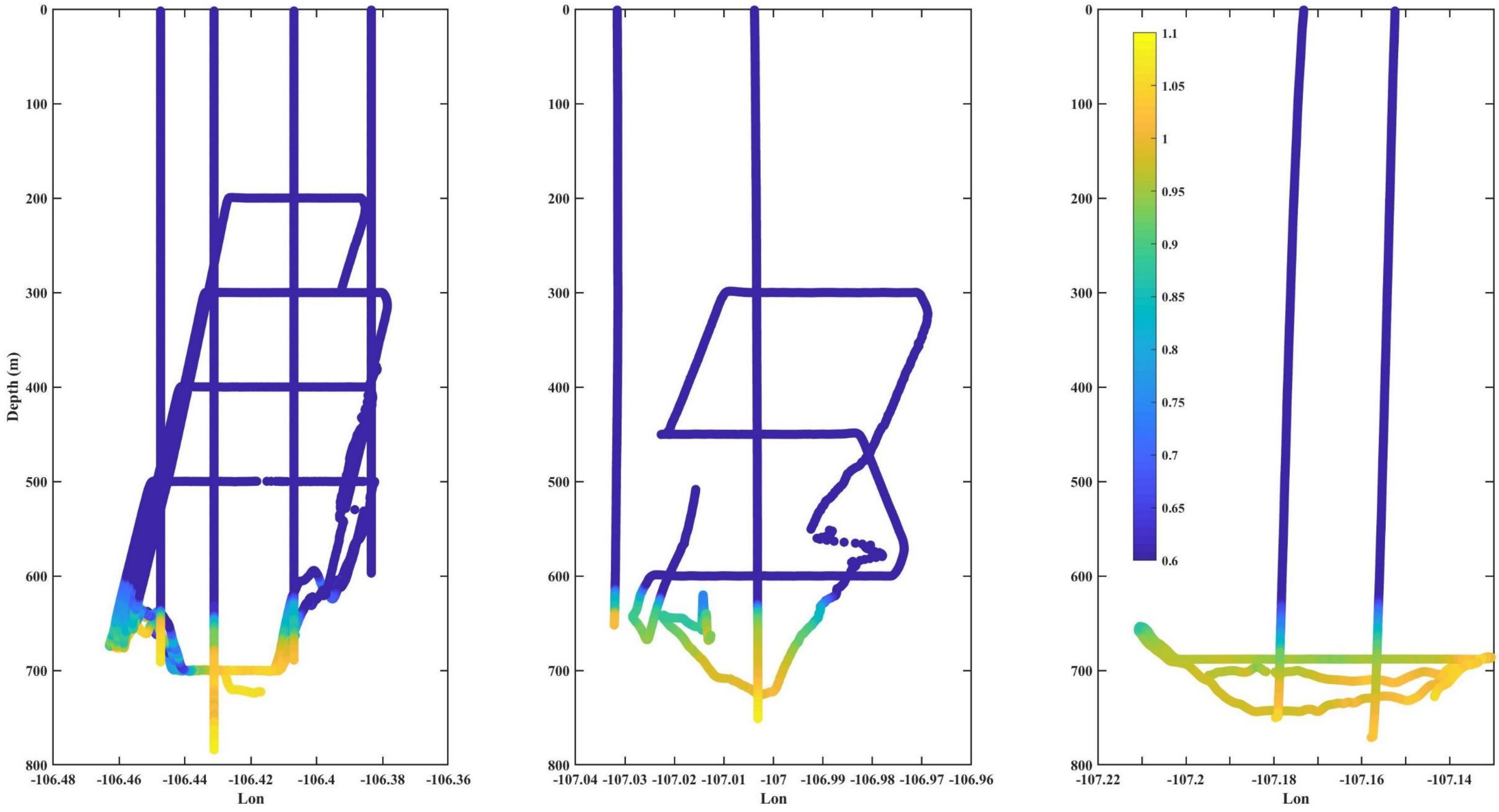


Track lines color coded by…

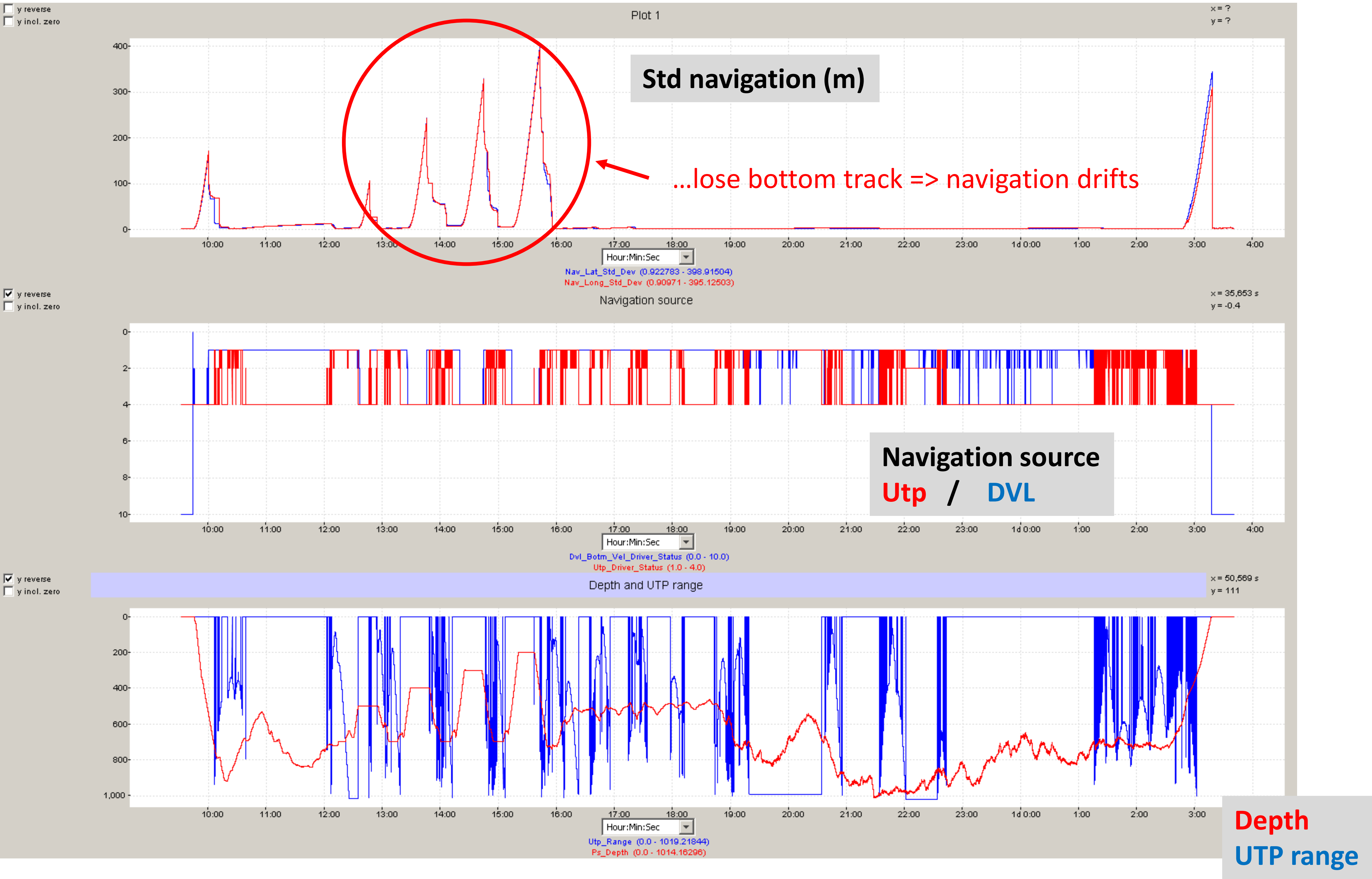


Mission 011, color coded by temperature:

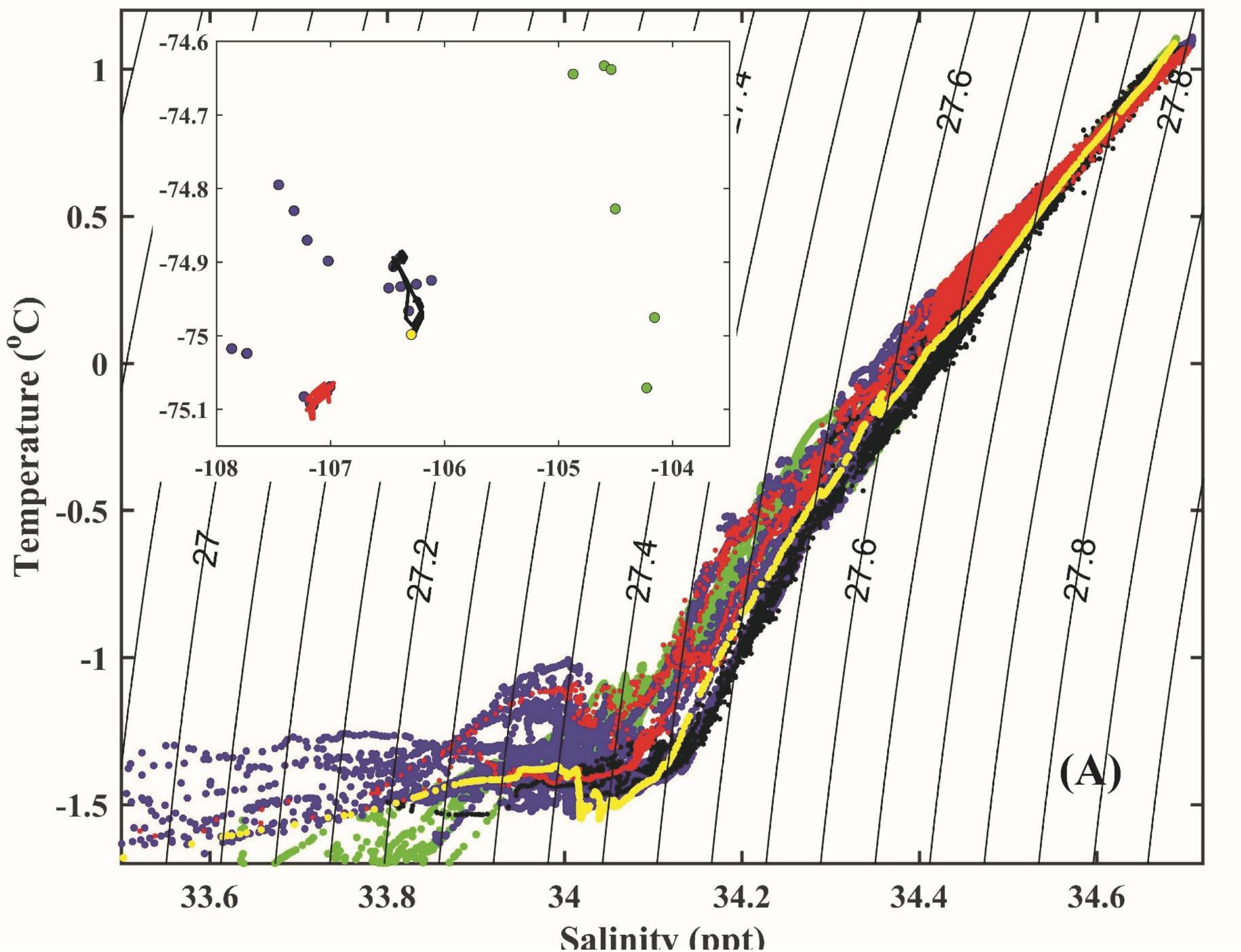




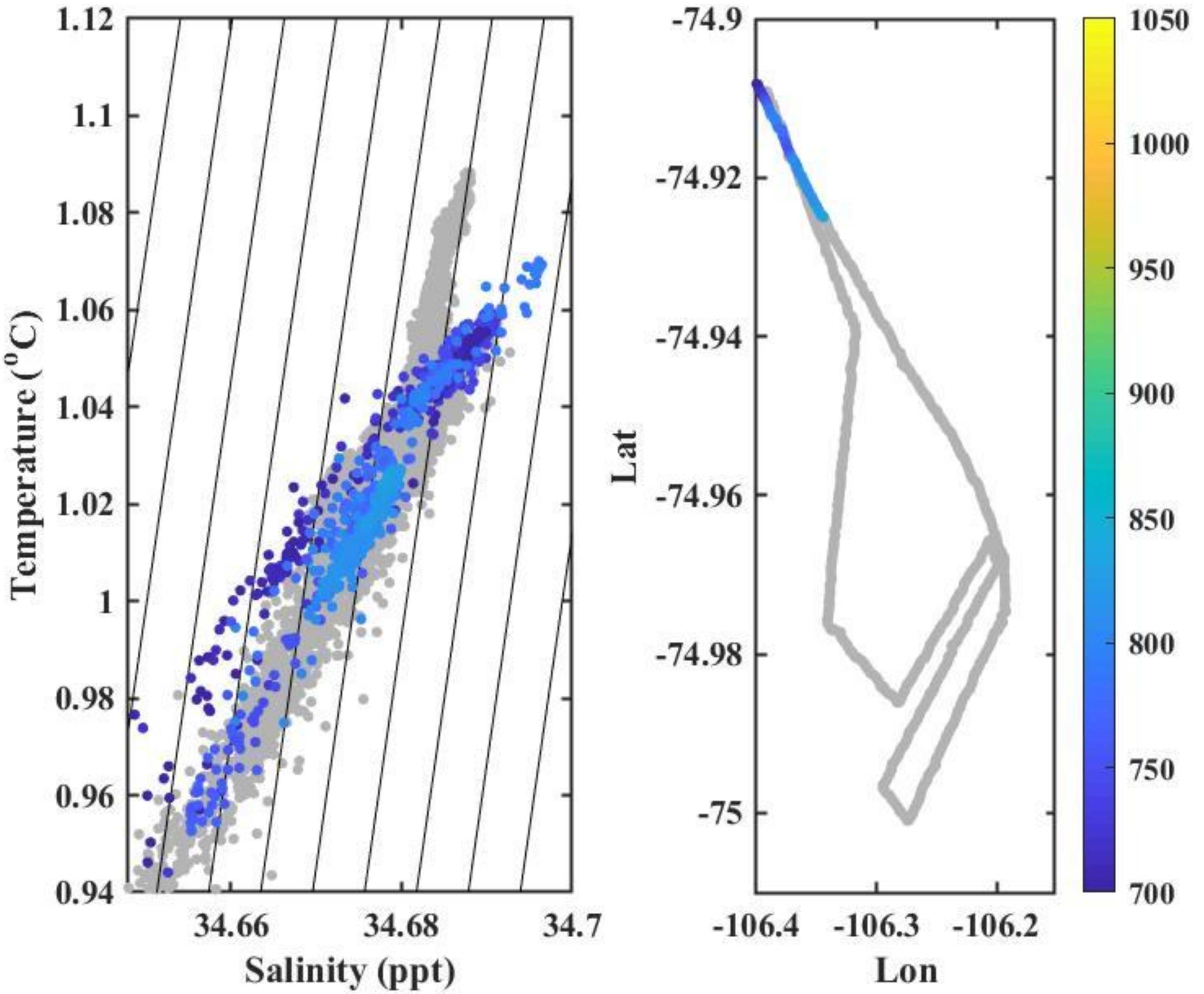
Depth (m)
0
100
200
300
400
500
600
700
800
-106.48
-106.46
-106.44
-106.42
-106.4
-106.38
-106.36
Lon
-107.04
-107.03
-107.02
-107.01
-107
-106.99
-106.98
-106.97
-106.96
-107.22
-107.2
-107.18
-107.16
-107.14
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6


Plot 1
Std navigation (m)
...lose bottom track => navigation drifts
Nav_Lat_Std_Dev (0.922783 - 398.91504)
Nav_Long_Std_Dev (0.90971 - 395.12503)
Navigation source
Navigation source
Utp / DVL
Dvl_Botm_Vel_Driver_Status (0.0 - 10.0)
Utp_Driver_Status (1.0 - 4.0)
Depth and UTP range
Utp_Range (0.0 - 1019.21844)
Ps_Depth (0.0 - 1014.16296)
Depth
UTP range

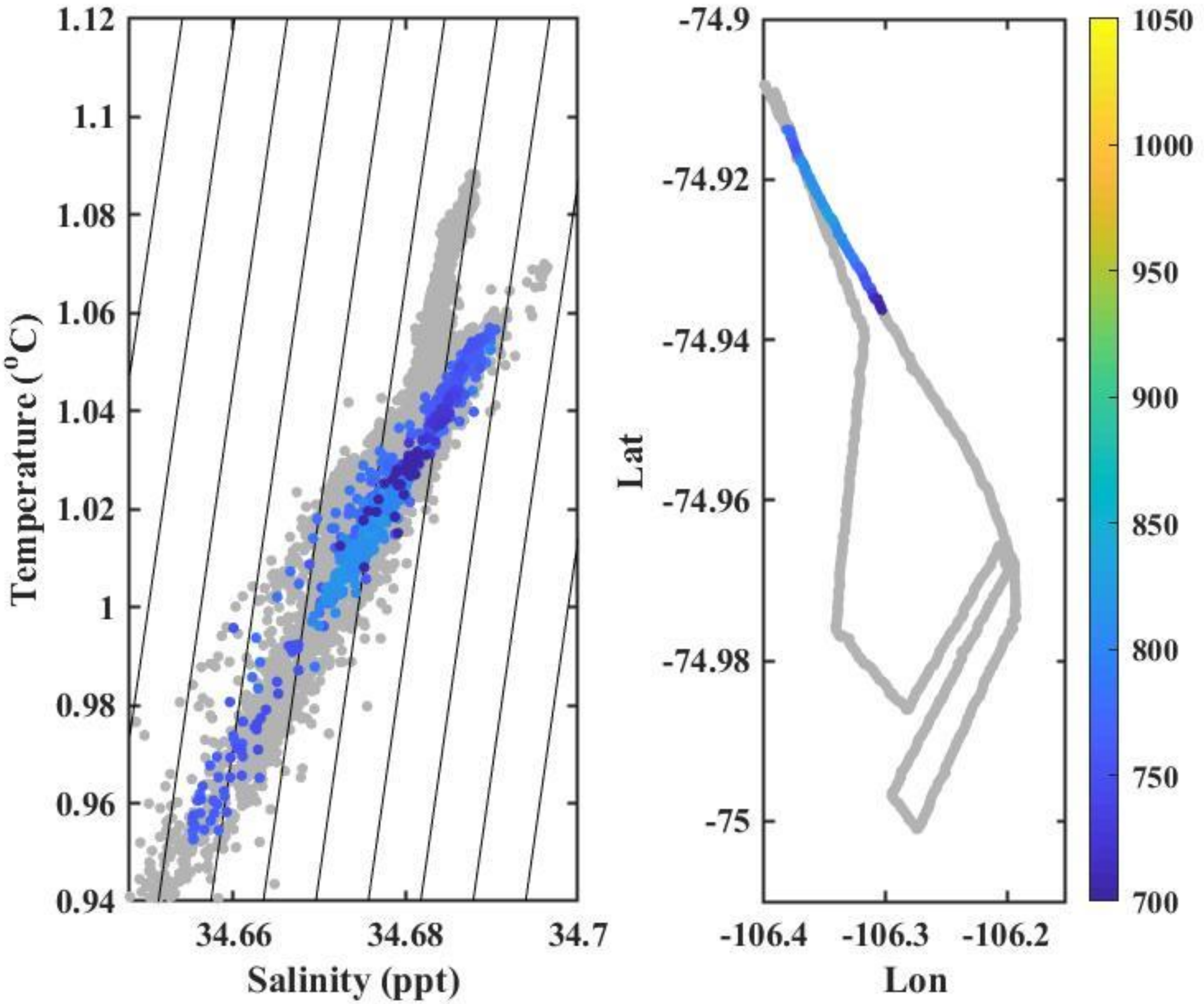
Temperature-salinity plot of under ice missions:



Temperature-salinity, zoomed scale:



Temperature-salinity, zoomed scale:



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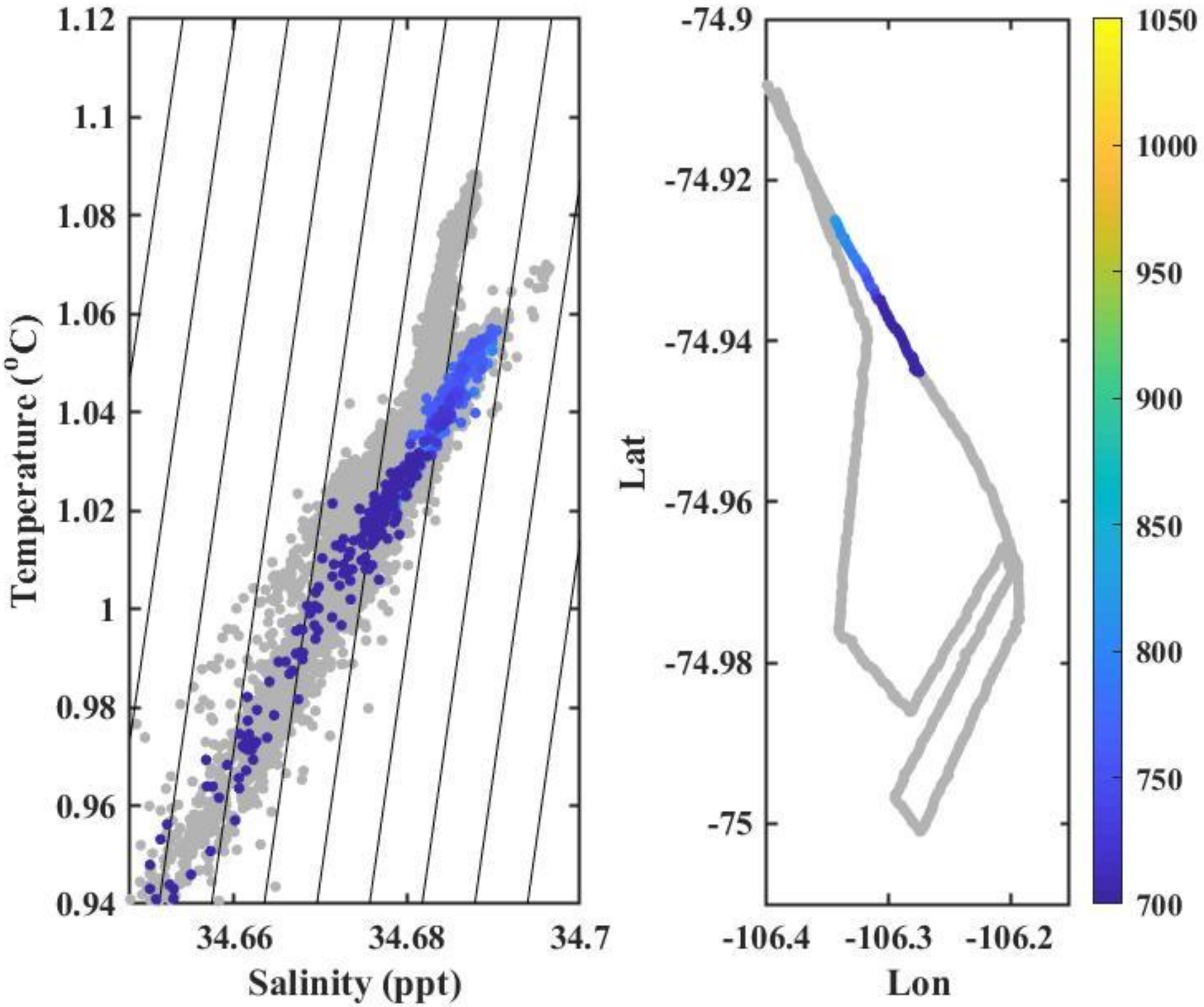
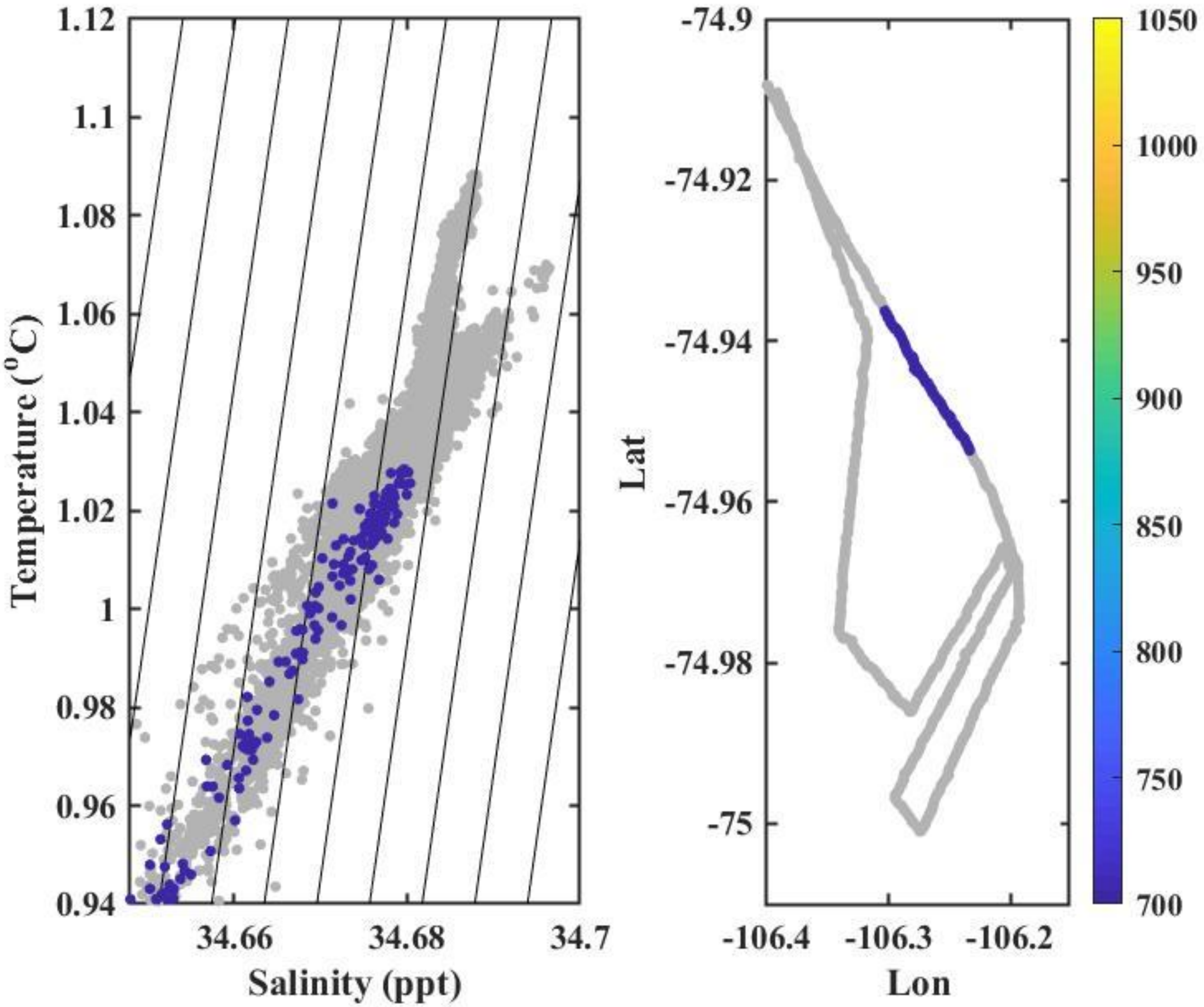


Temperature-salinity, zoomed scale:



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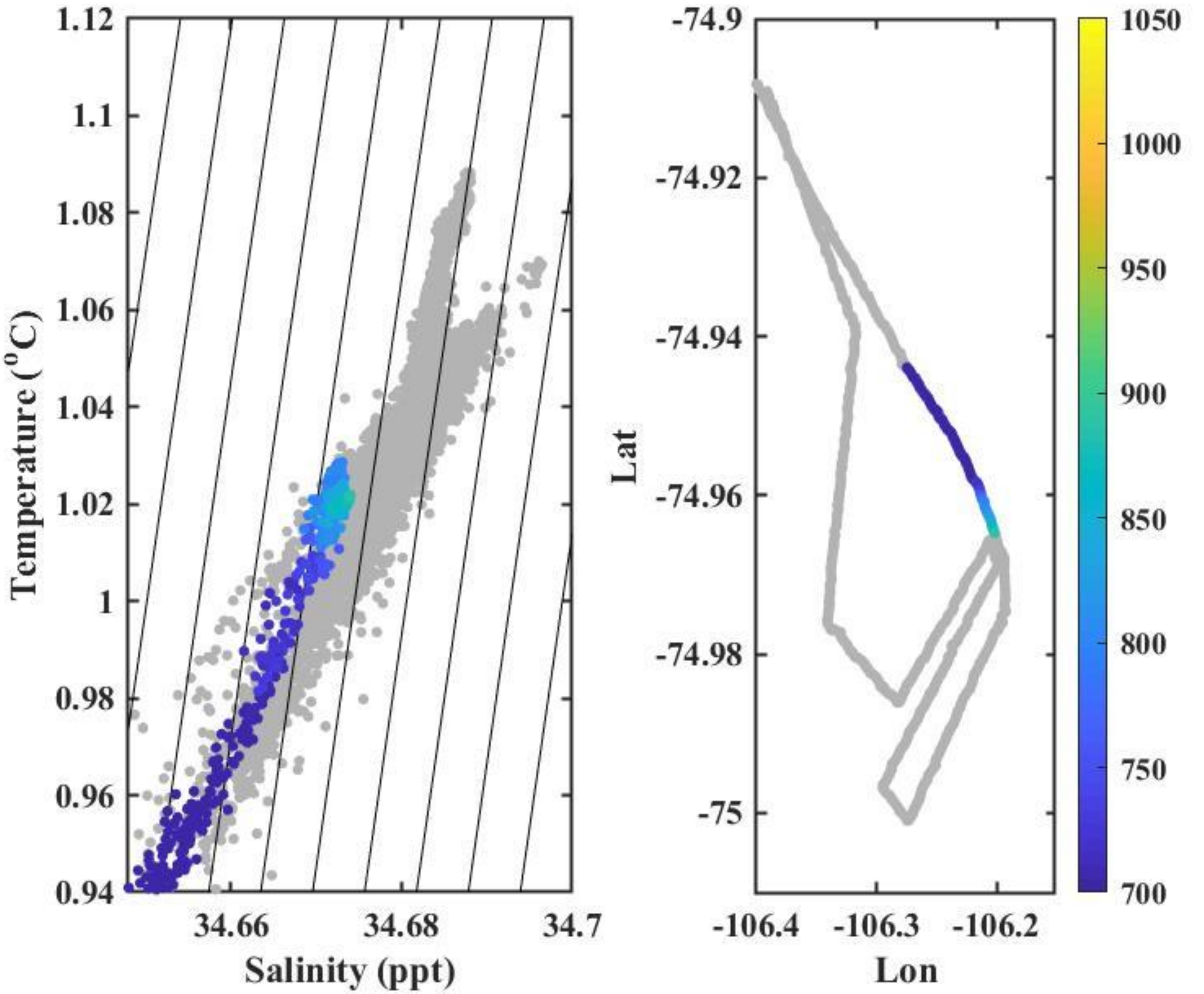

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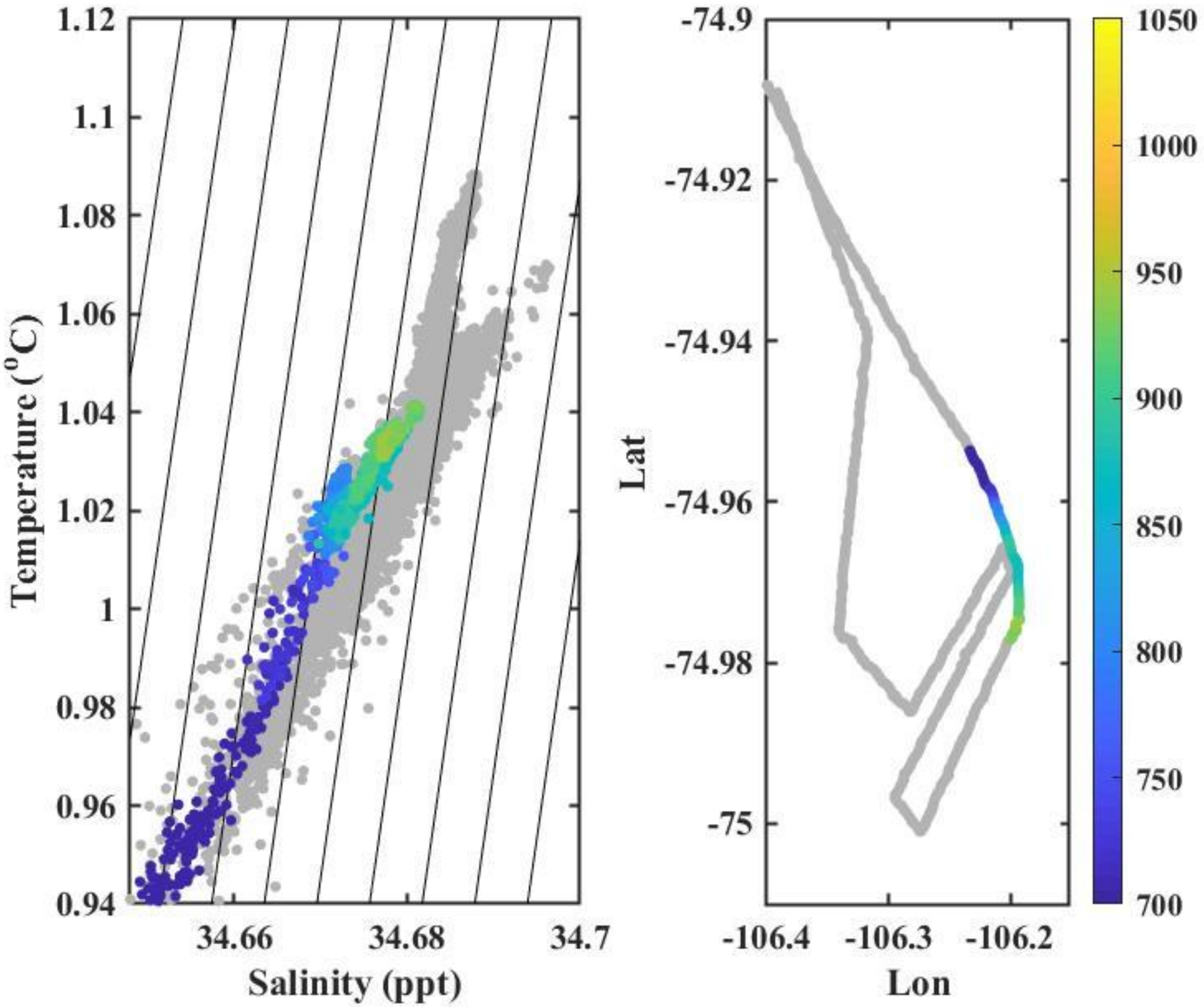
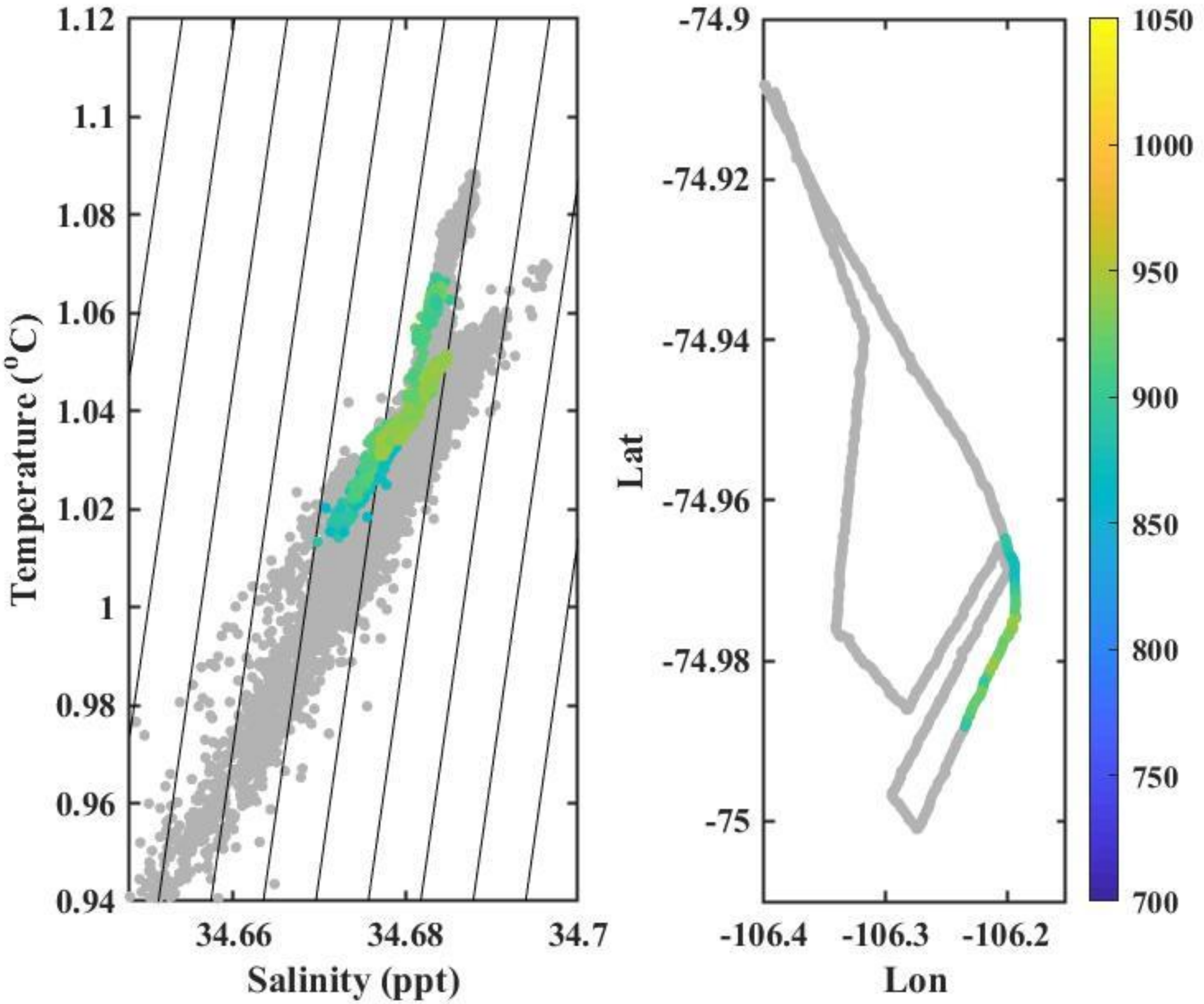


Temperature-salinity, zoomed scale:



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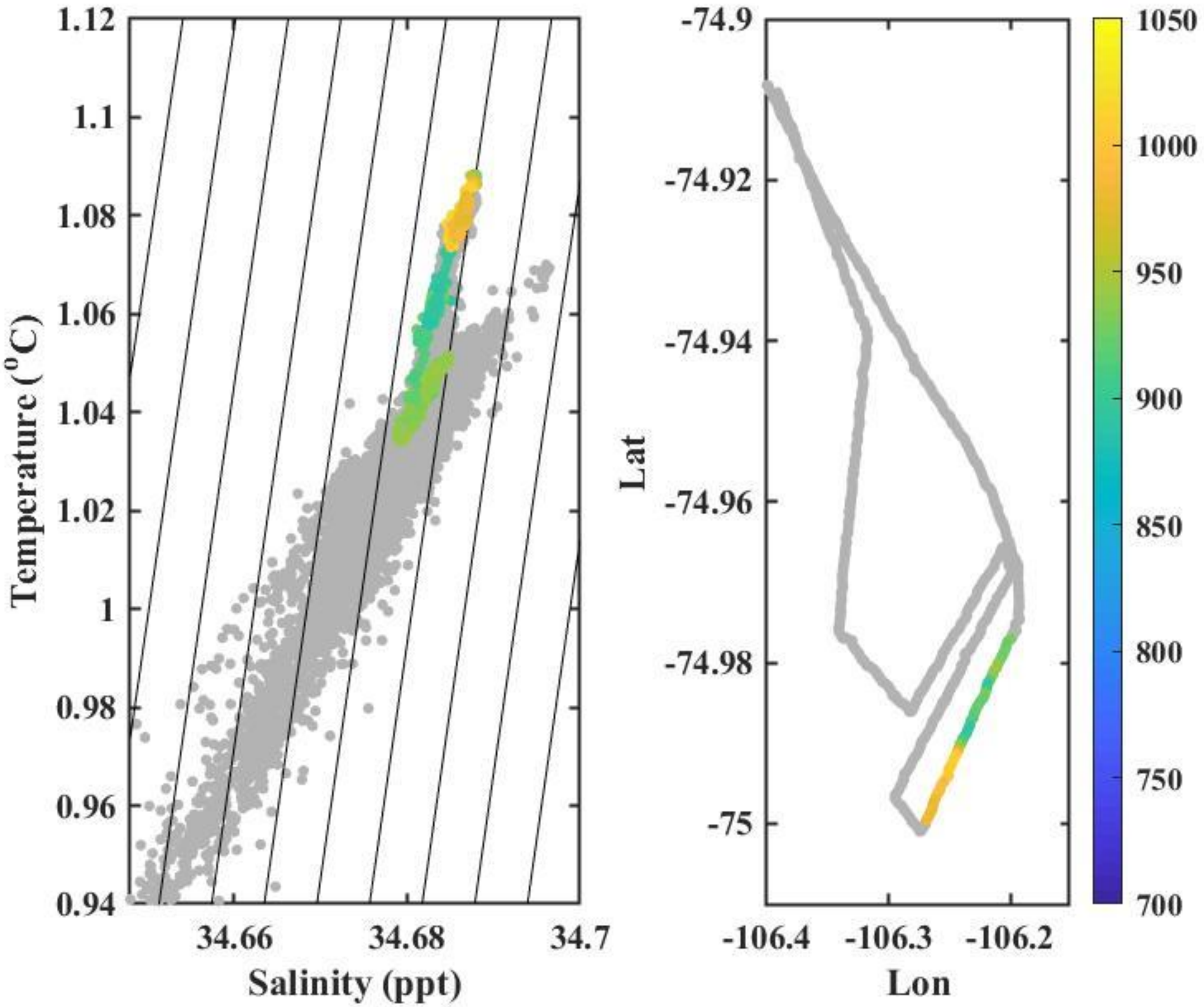

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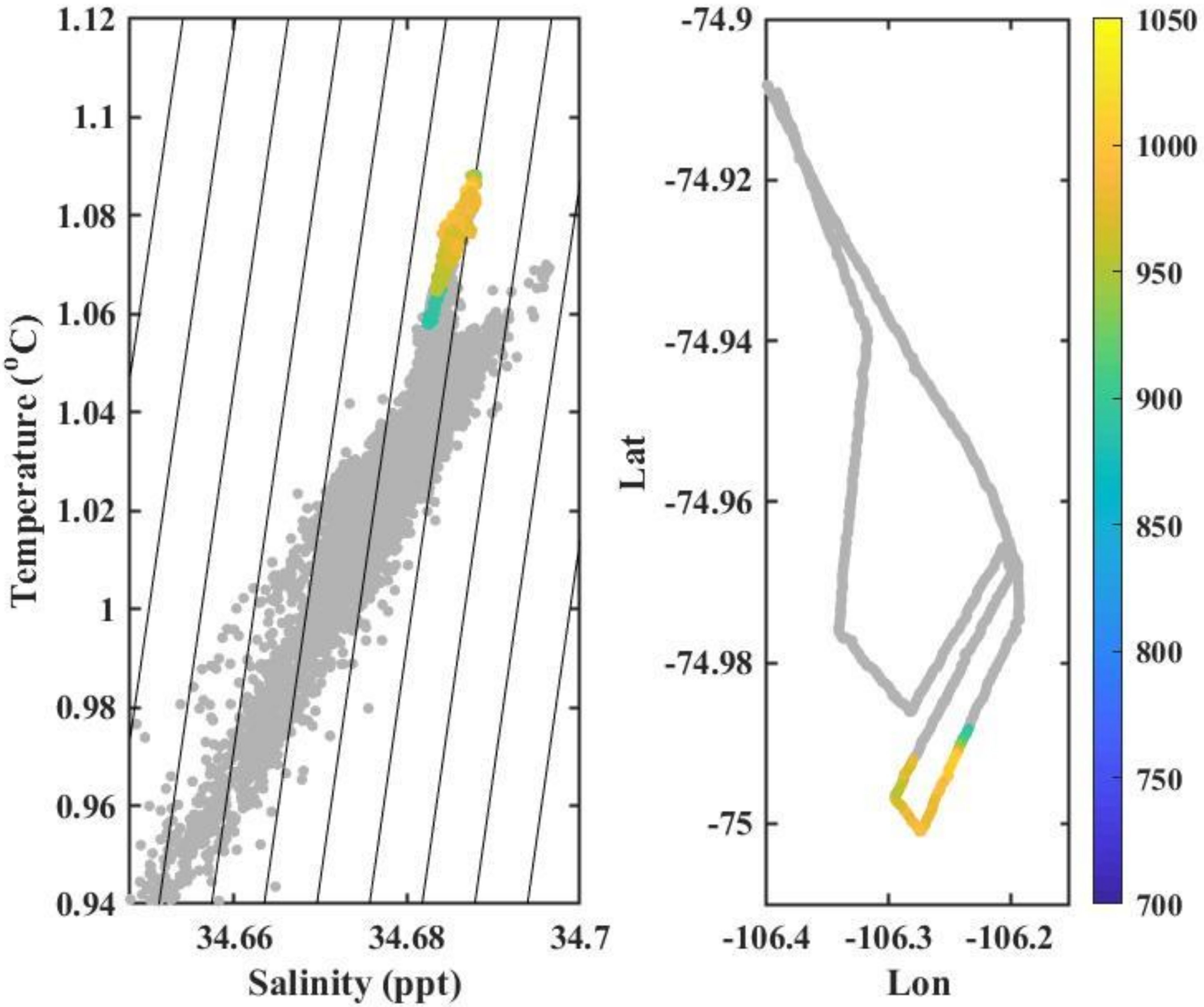
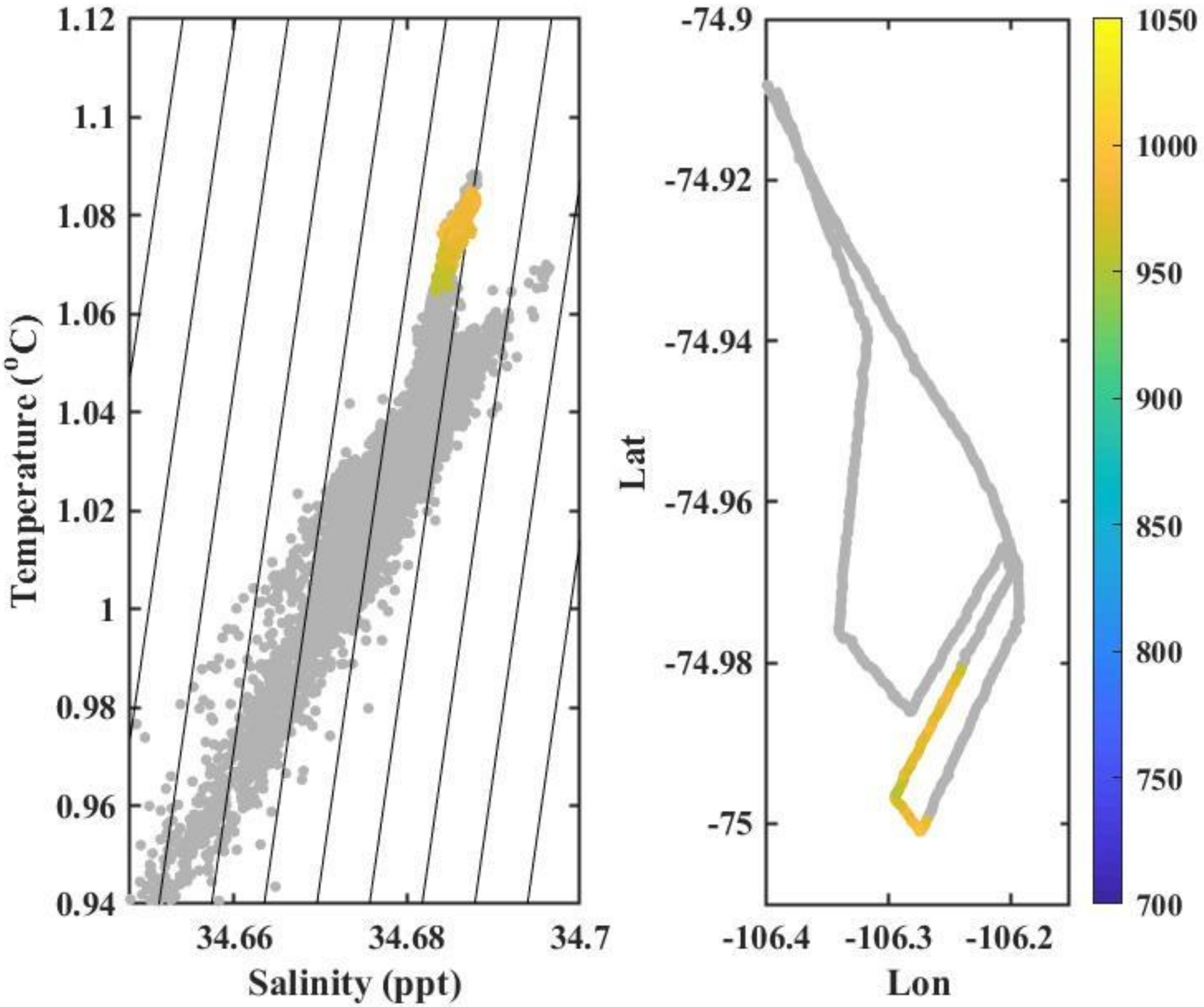
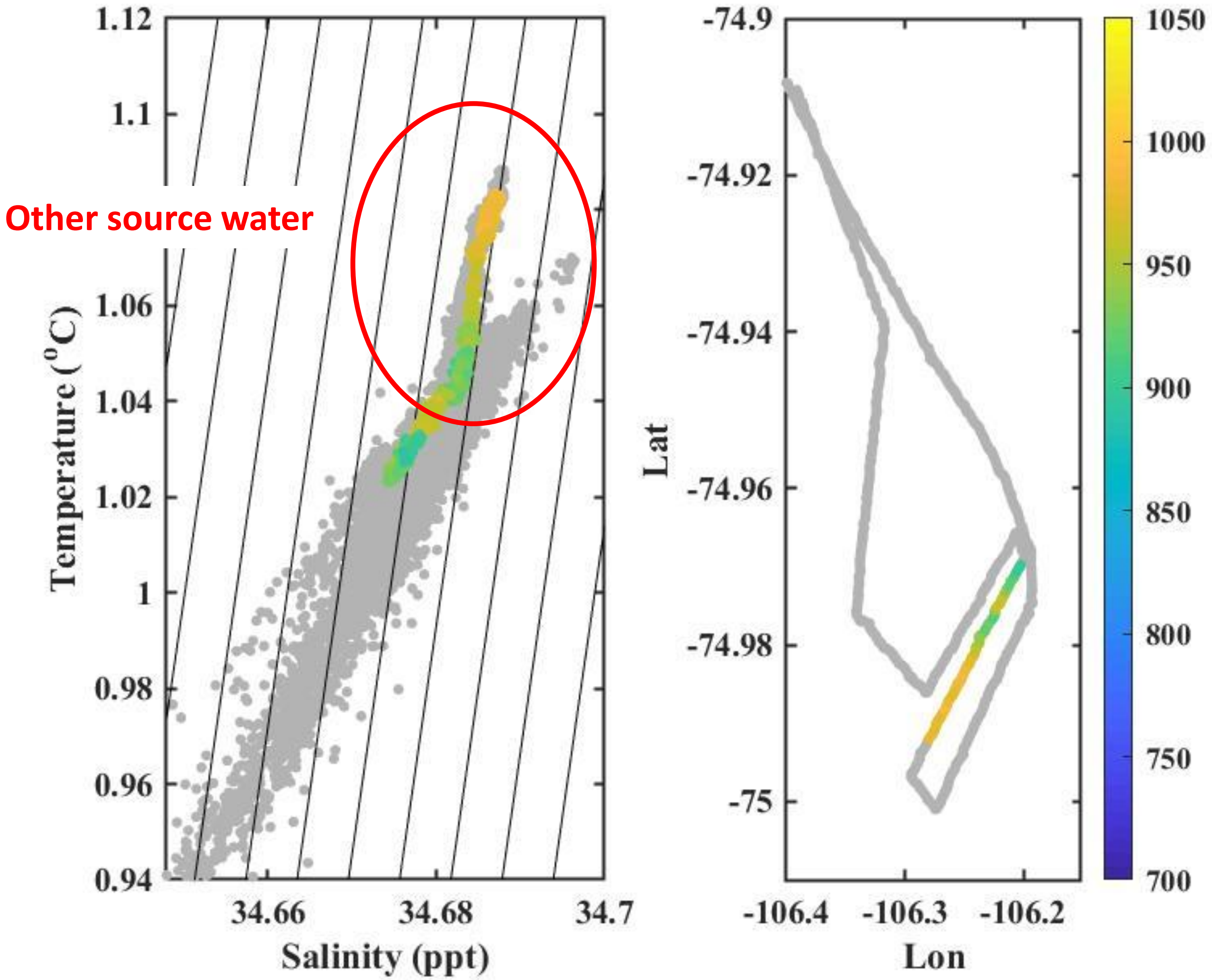


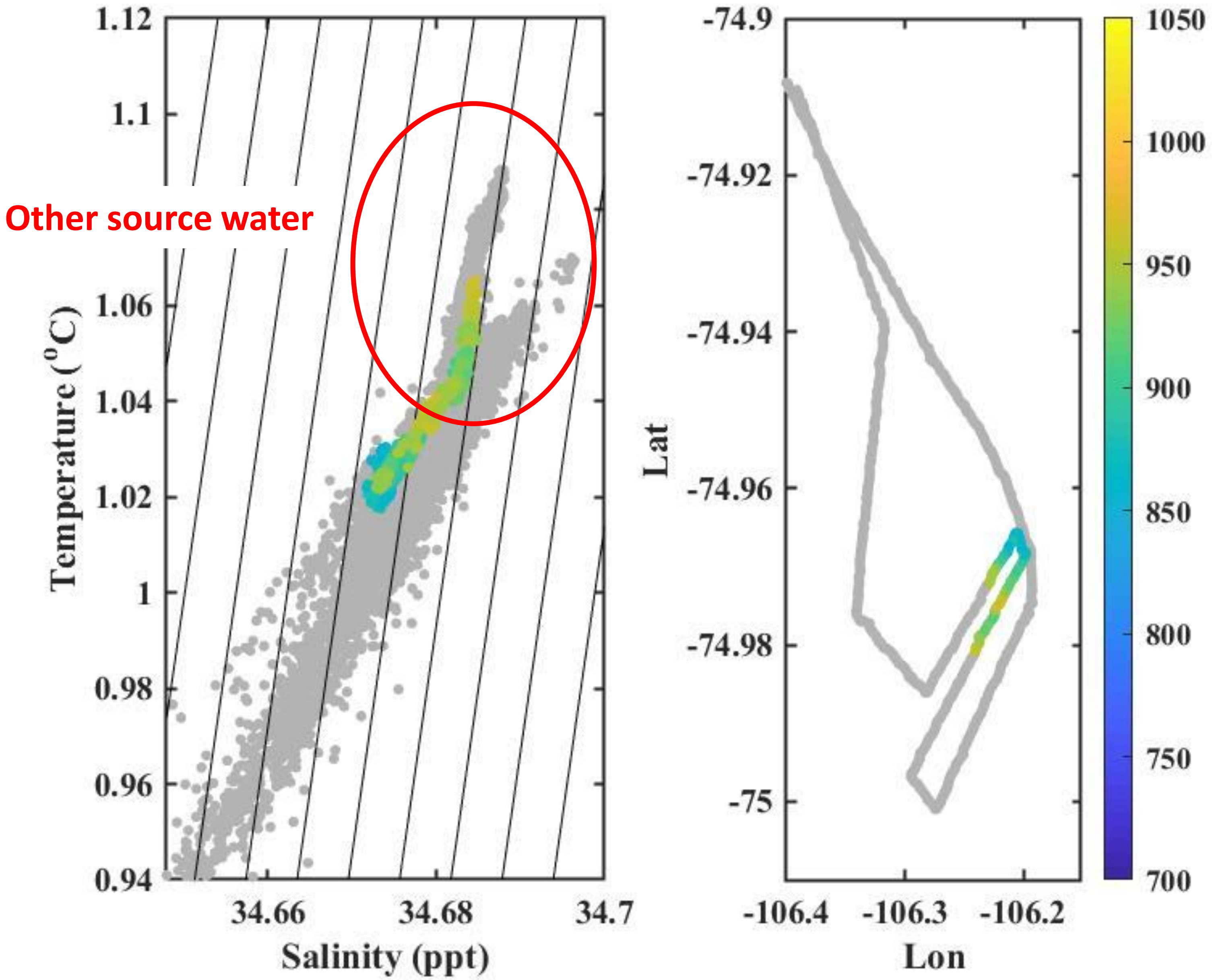
Temperature-salinity, zoomed scale:



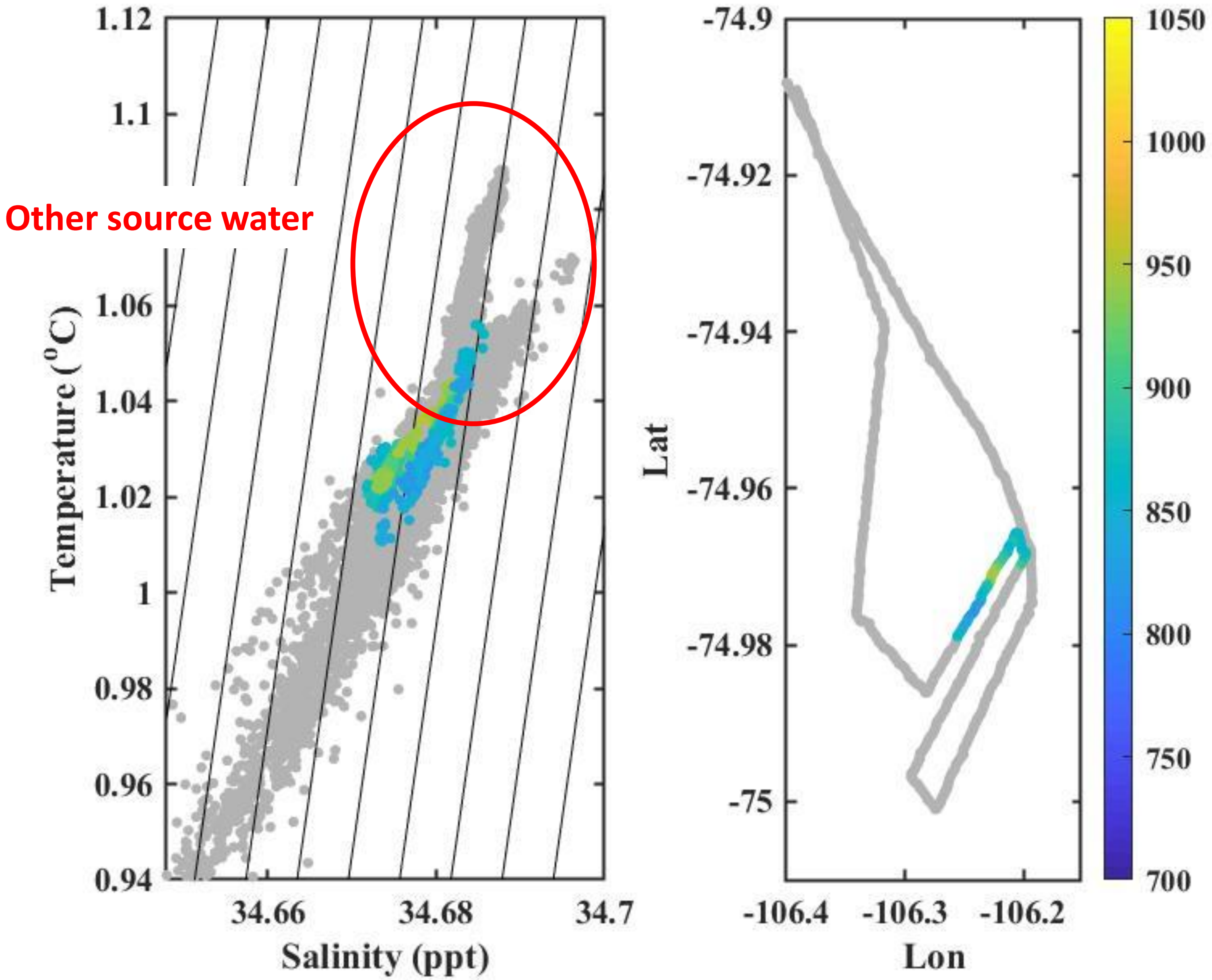
Temperature-salinity, zoomed scale:



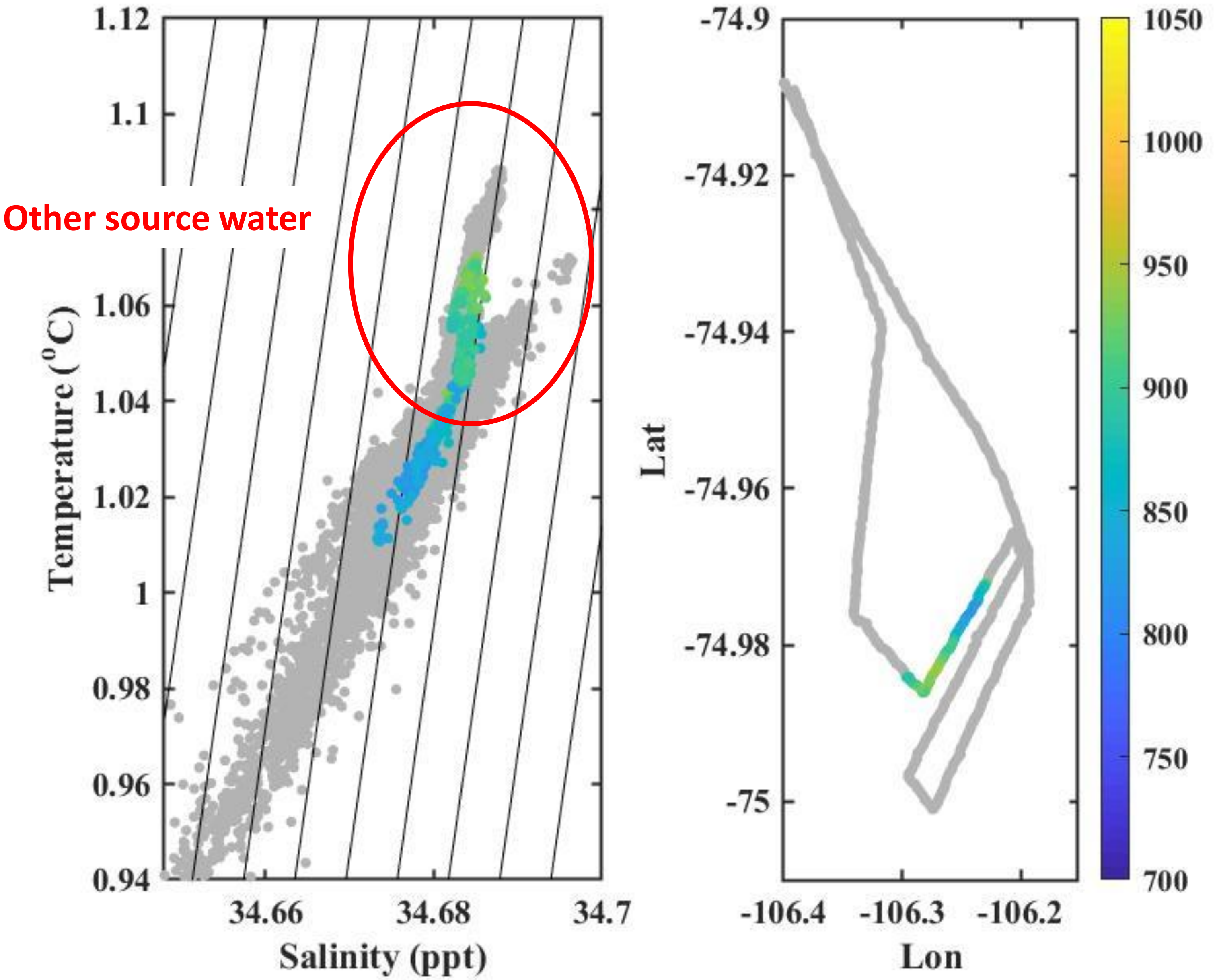
Temperature-salinity, zoomed scale:



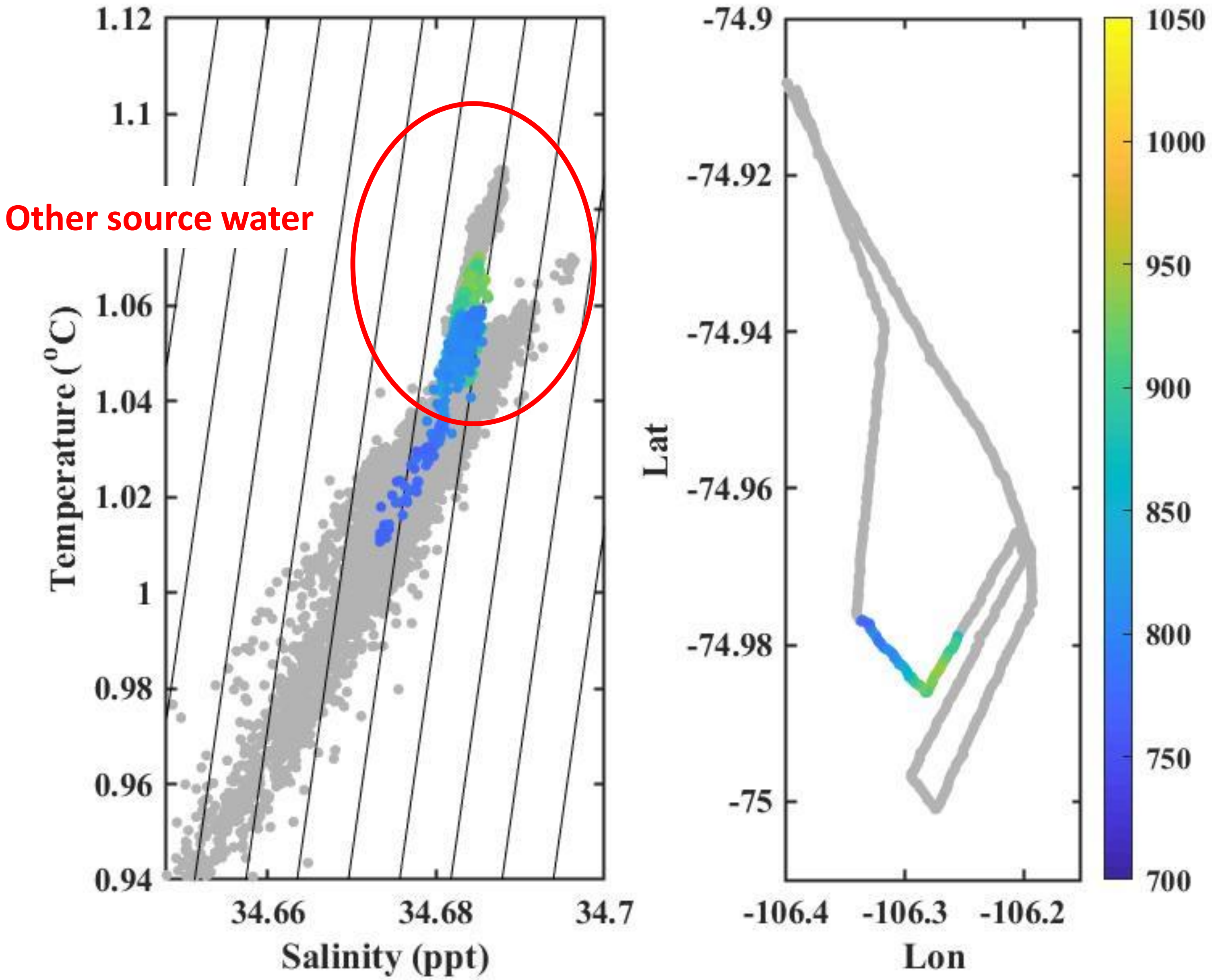
Temperature-salinity, zoomed scale:



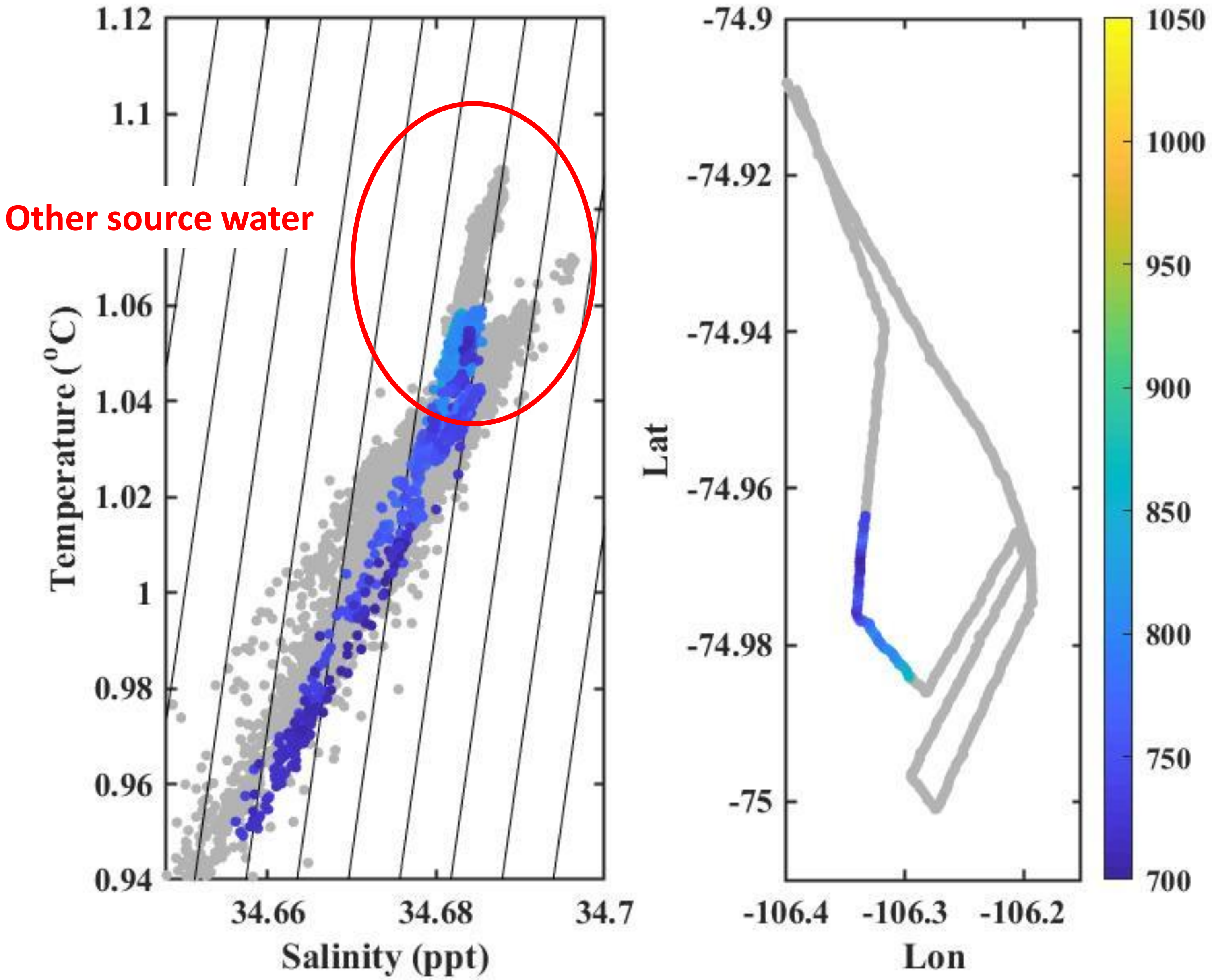
Temperature-salinity, zoomed scale:



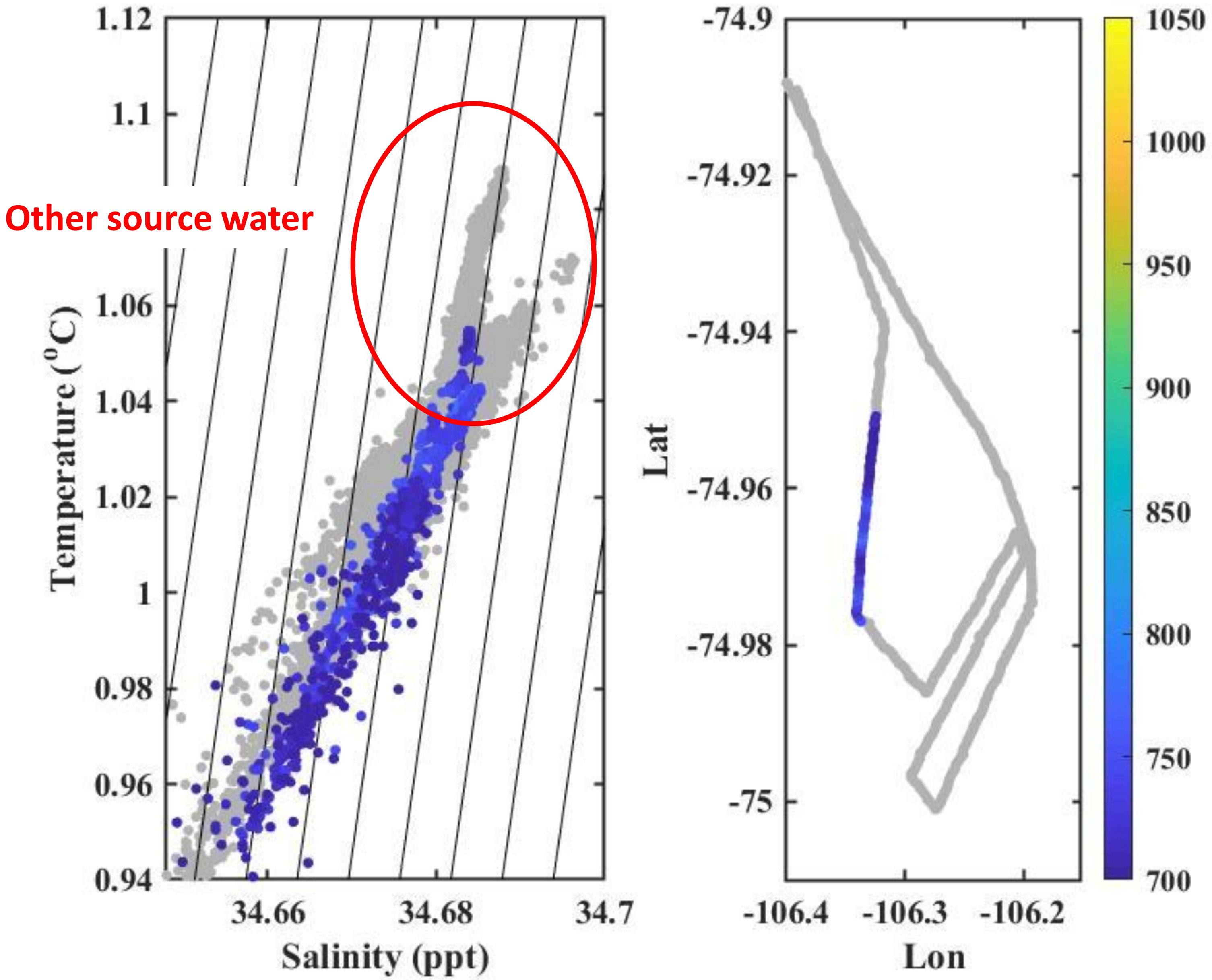
Temperature-salinity, zoomed scale:



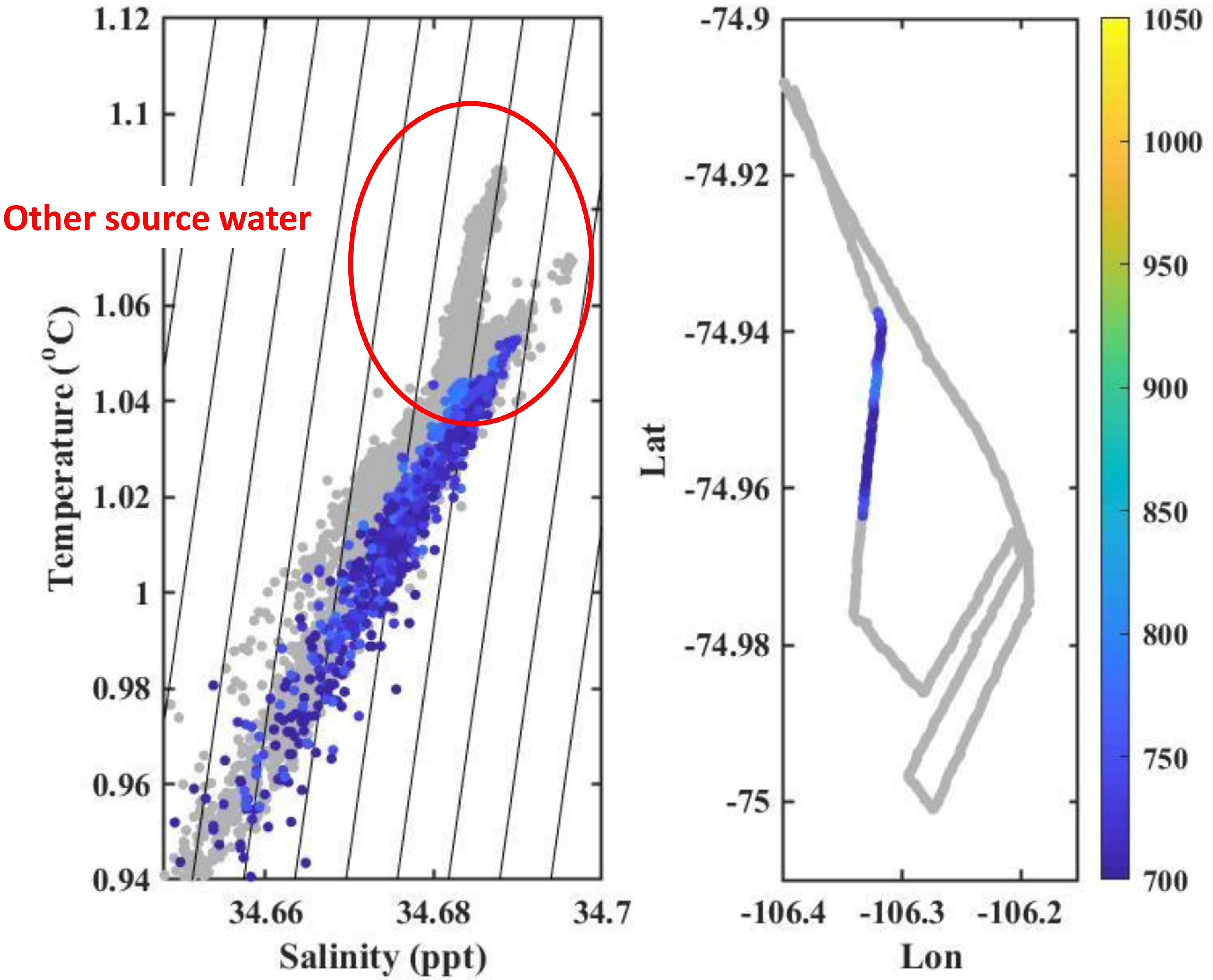
Temperature-salinity, zoomed scale:



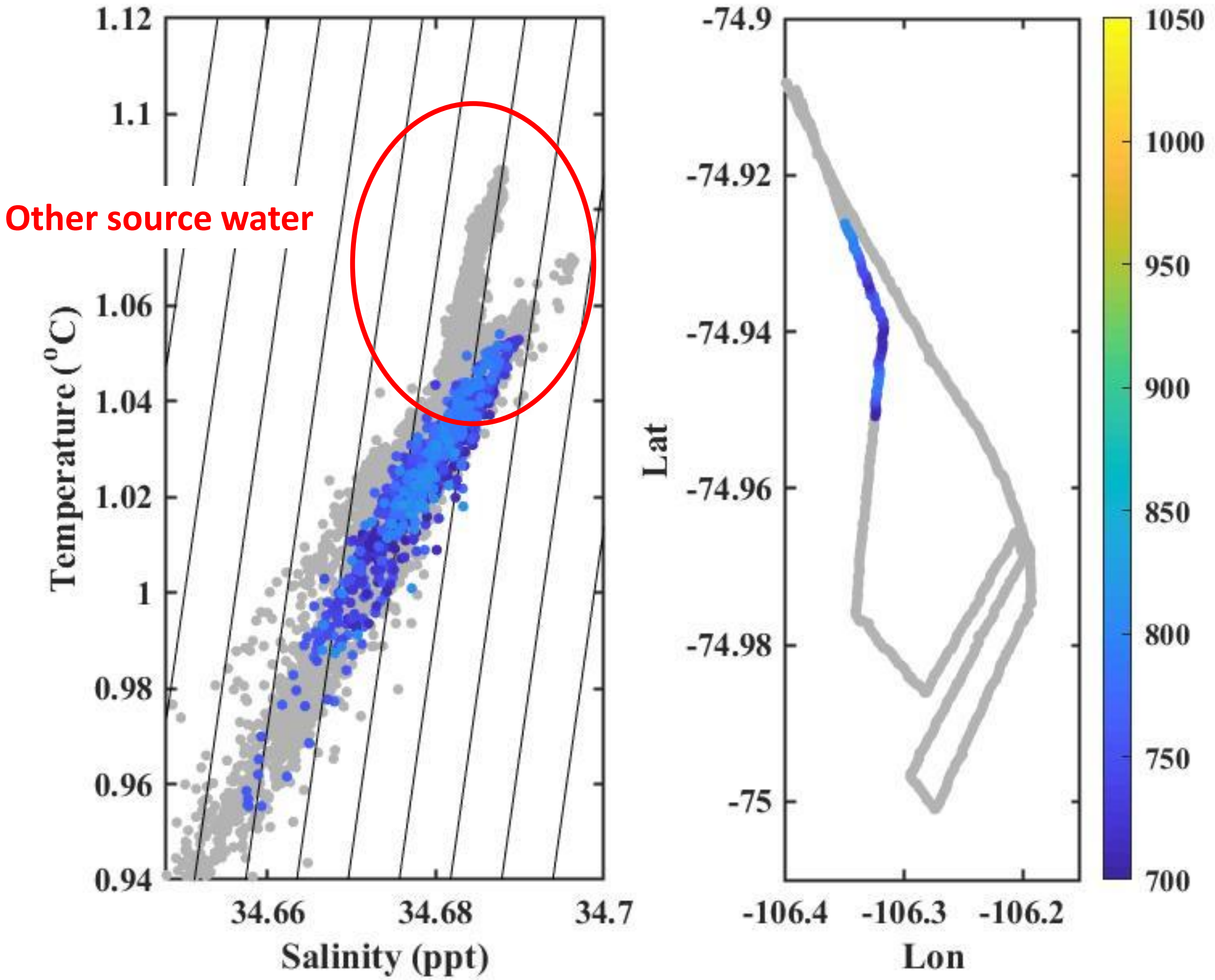
Temperature-salinity, zoomed scale:



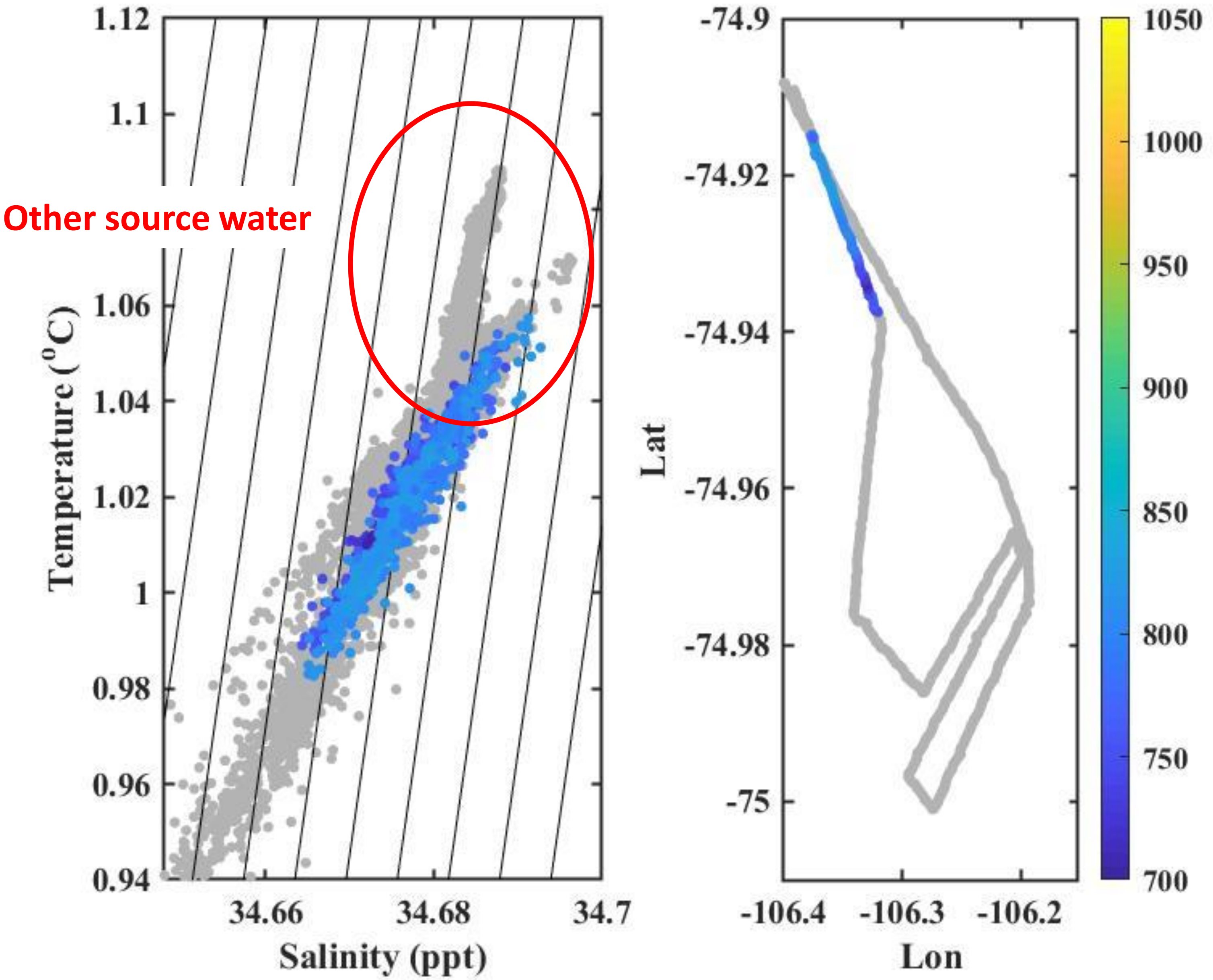
Temperature-salinity, zoomed scale:



Temperature-salinity, zoomed scale:



Temperature-salinity, zoomed scale:



Lessons learned:

- Loiter at depth and bring up to surface using commands
- Navigation when mid water is tricky, even using cNodes (range 1000 m but if long times without DVL can easily miss the cNode)
- Recovery is risky, weather sensitive and requires many hands – try to find alternative (less weather sensitive) solution with LARS
- Good bathymetry is best way to lower risk
- Good accuracy in sensor suite paid off

Is the investment of bringing a large AUV on long expedition worth it? Yes if going places where unique data can be obtained, e.g.:

  - Under ice shelves
  - Under sea ice
  - Fine-scale bathymetry

AUV measurements that are supplementary to ’ordinary’ ship measurements, better to go for smaller AUVs (e.g. gliders, small class AUVs e.g. Stenius tomorrow) – less infrastructure & staff needed. When not necessary with accuracy and data quality of larger AUVs


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Photo credit: Johan Rolandsson

Arriving at Thwaites Glacier

Photo credit: Linda Welzenbach


Thank you!