NEREID UNDER ICE (NUI): PROGRAM OVERVIEW FIRST FIELD RESULTS

2014-12-14

DeSSC

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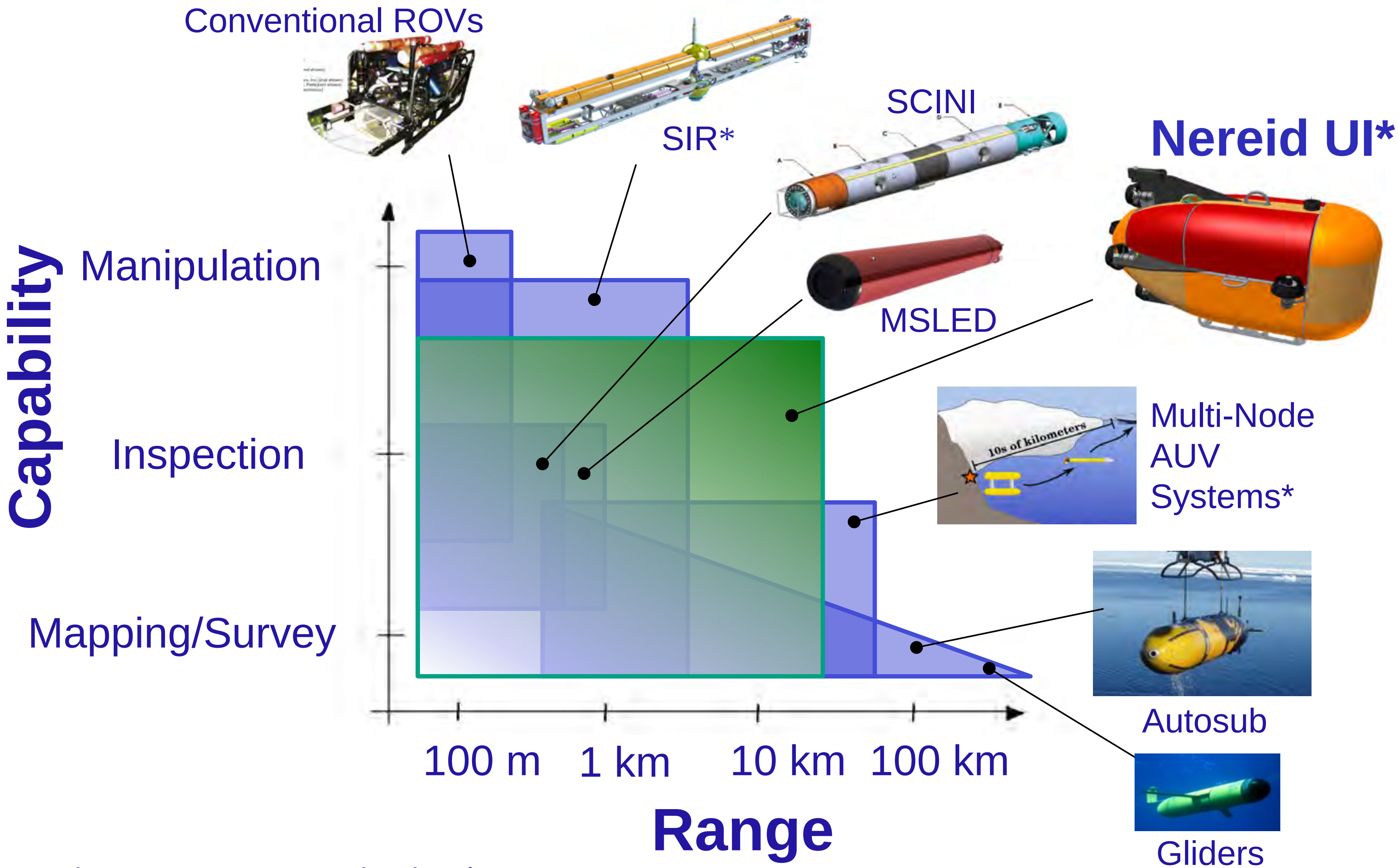
Project Timeline

- 2011-Sept. NSF MRI funding received, $2M NSF/$1M WHOI cost-share
- 2013-Sept. Core system dock-trials
- 2014-May: Full system dock-trials (WHOI); software/sensing tank-trials for under-ice navigation with proxy ice (JHU)
- 2014-June: Full system trials, extended fiber deployment, Tromsø Harbor
- 2014-July: First under-ice field trials, PS86-3 ice-breaker *Polarstern* (AWI)
- Final Report in preparation.

Nerid Under Ice (UI)

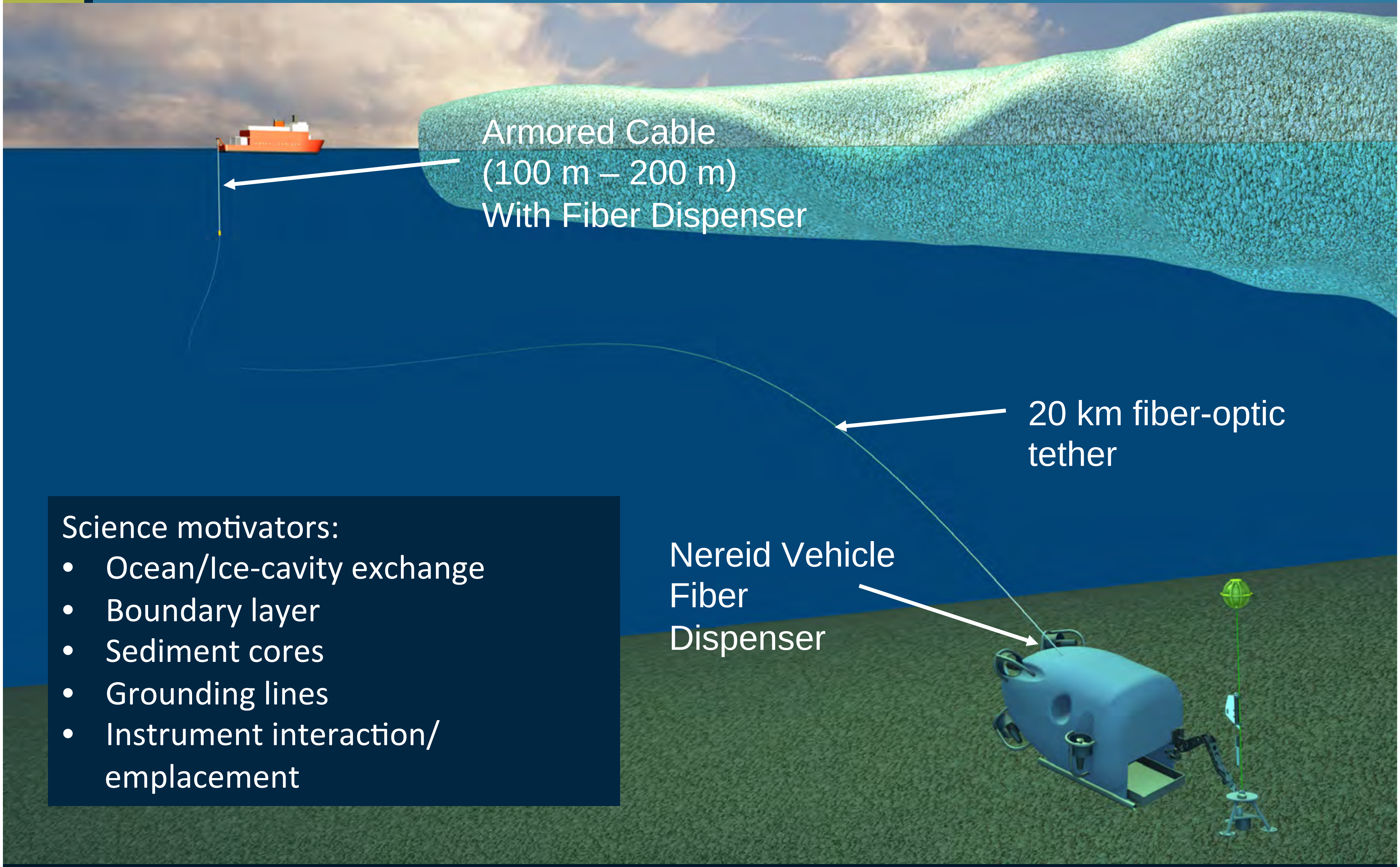


*These systems are under development

Telepresence: Enabled Capabilities

- Proactive Exploration:
  - HD video and real-time visualization of mapping, survey and other scientific data products
  - Respond to features of interest by altering sensing modality and trajectory as directed by science party
- Access:
  - Glacial ice tongues and shelves, sea ice, ice-covered sea floors
  - Distance from ice-breaker influenced water column
  - Proximity to ice/water interface, including ability to land on ice underside
- Intervention:
  - Future manipulation, sample retrieval, and instrument emplacement capability
- Autonomy development platform

NUI Glacial Ice Concept of Operations

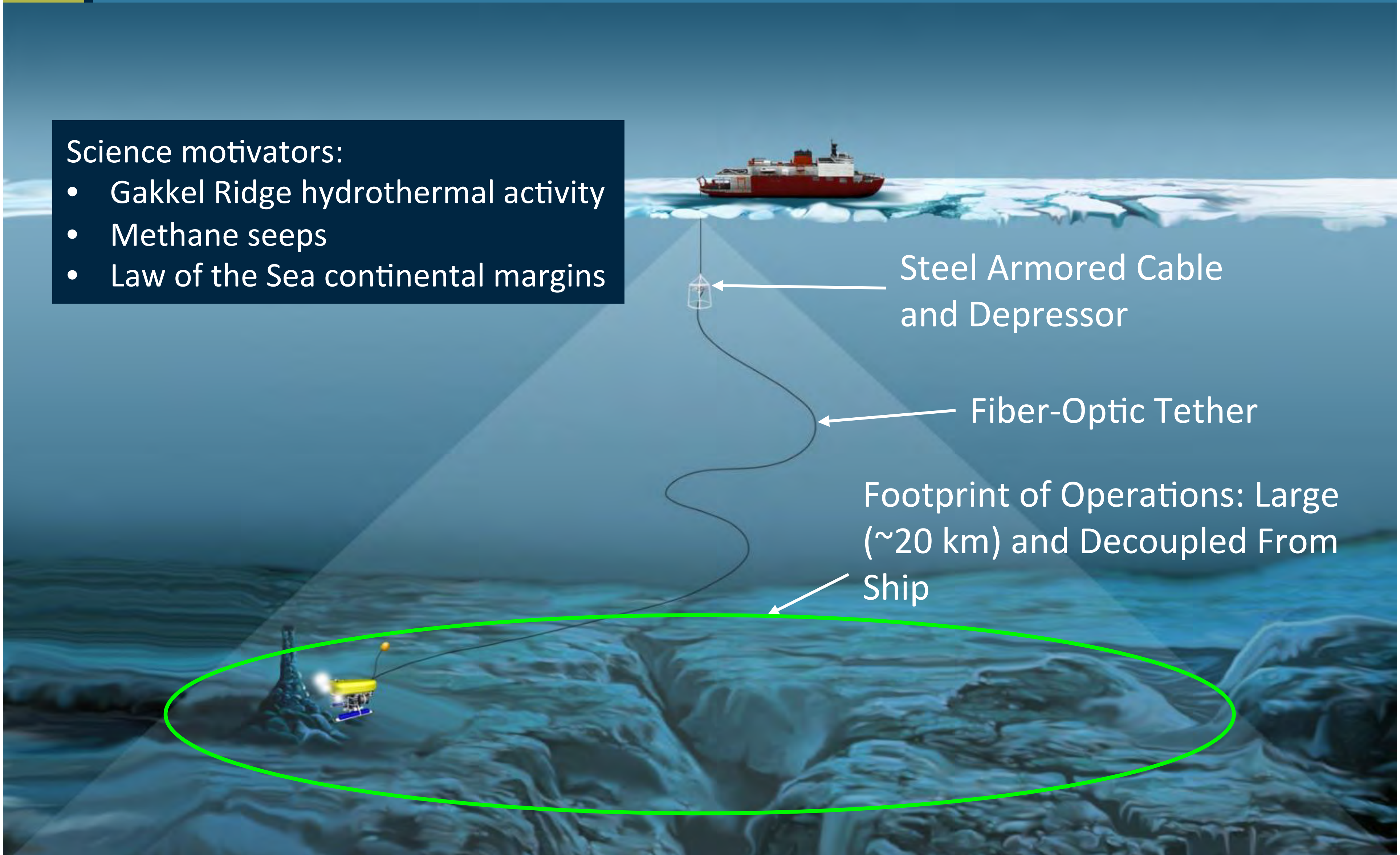


Science motivators:

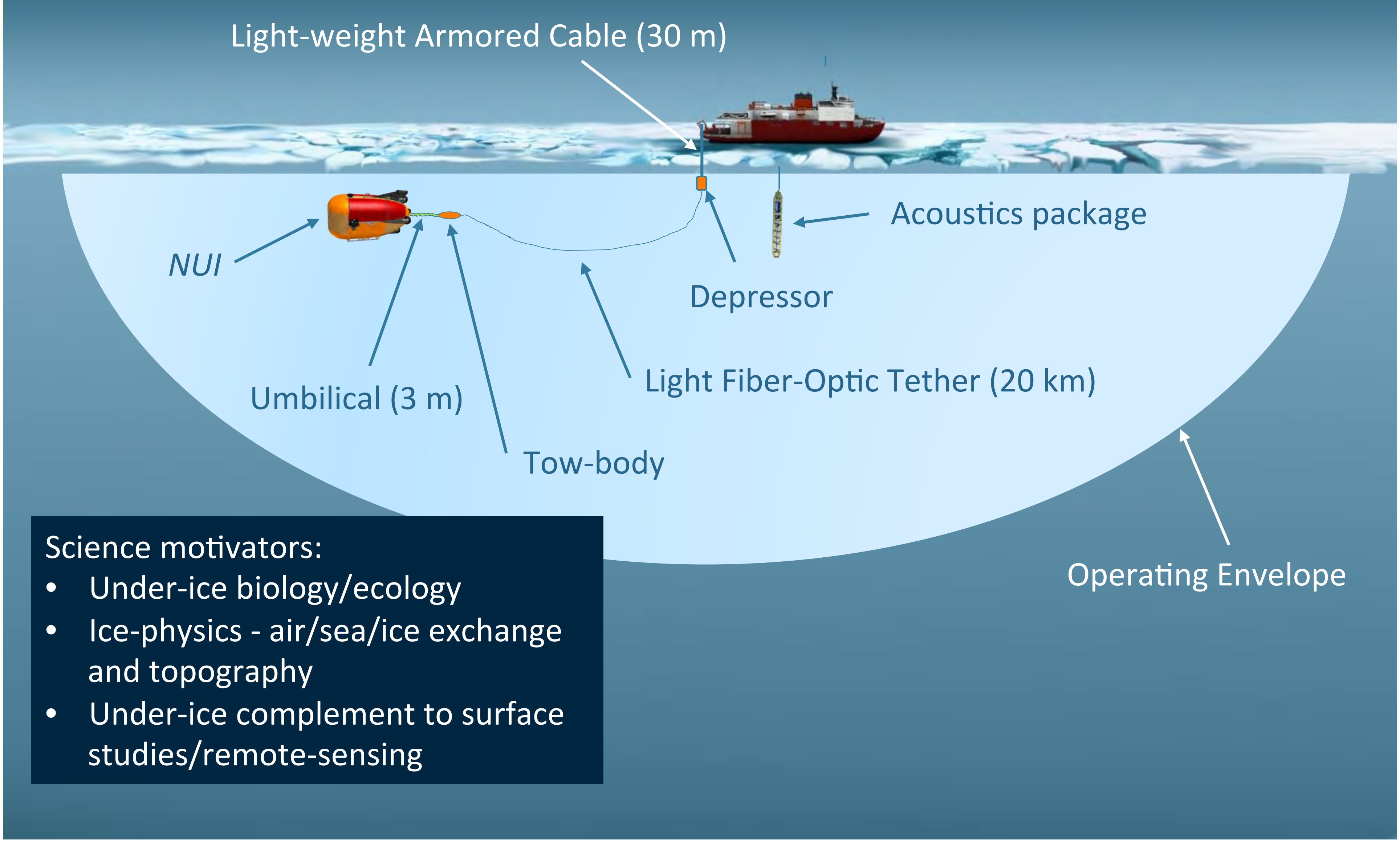
- Ocean/Ice-cavity exchange
- Boundary layer
- Sediment cores
- Grounding lines
- Instrument interaction/ emplacement

NUI Ice-Covered Sea Floor Concept of Operations

Science motivators:
- Gakkel Ridge hydrothermal activity
- Methane seeps
- Law of the Sea continental margins



NUI Sea Ice Concept of Operations



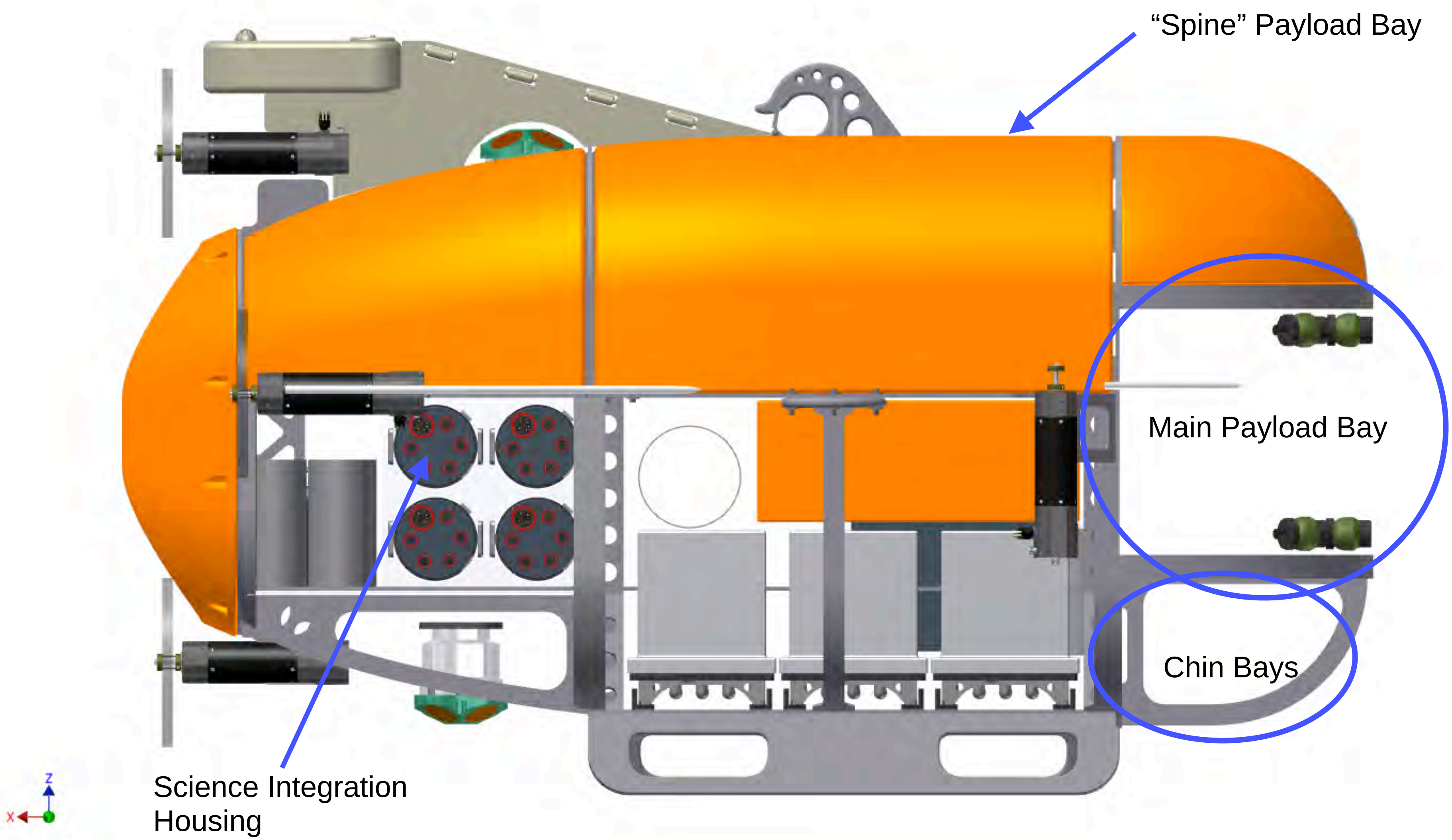
Science motivators:
- Under-ice biology/ecology
- Ice-physics - air/sea/ice exchange and topography
- Under-ice complement to surface studies/remote-sensing

NUI Specifications

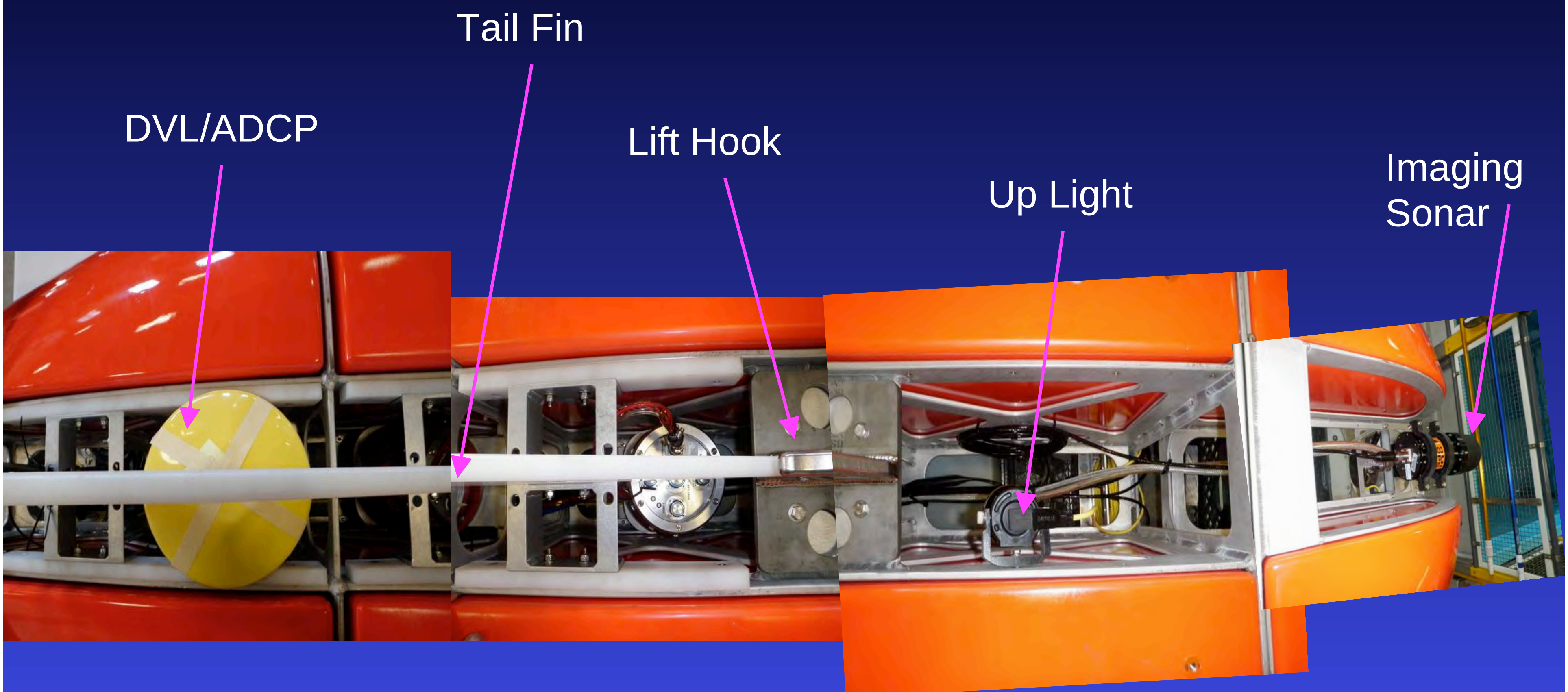
Performance	Range	40 km @ 1 m/s
	Displacement	1,800 kg
	Depth Rating	2,000 m
	Battery	18 kWhr Li-Ion
	Manipulator	6-DOF Electro-Hydraulic (planned future addition)
	Sample Payload	20 kg
Navigation	Inertial	IXSEA PHINS INS
	Acoustic	300 kHz up/down ADCP/DVL; 3.5 kHz and 10 kHz acoustic ranging; BlueView Imaging sonar for obstacle avoidance
	Pressure/Depth	Paroscientifc pressure sensor
Telemetry	Tether	20 km fiber-optic Gb Ethernet expendable tether
	Acoustic	LF (3 kHz) 20-300 bps acoustic telemetry to/from ship HF (10-30 kHz) acoustic telemetry to seafloor instruments
	RF	900 mHz RF modem for data telem on surface
Imaging	Optical	Real-time HD on internal pan-and-tilt (Kongsberg OE14-522 Hyperdome); 3 SD (DSPL nanocam); 1 upward-looking 1360x1024 color digital still camera*.
	Acoustic	Blueview P900 imaging sonar, 40 m range, fwd. looking. Imagenix Delta-T, upward looking for ice topography.
Chem/Bio Sensors	Chemical	Seabird SBE FastCAT-49, Seabird SBE25+ CTD*
	Biological	WetLabs ECO-FLNTURTD, SUNA nitrate sensor*, FRRF* (fluorometer, PAR sensor, pressure sensor), Eco-Triplet fluorometer*
	Optical	RAMSES Radiance ARC* and Irradiance ACC*
Auxiliary Payload		Support for 100 kg wet weight, 10 auxiliary sensors, 500 Whr Energy, 1000 W.

Table 1: ***Nereid-UI*** **specifications and sensors - * indicates sensors added for for 2014 Polar Operations.**

Sensor Payload/Placement



Spine Payload Bay (Docktrials)



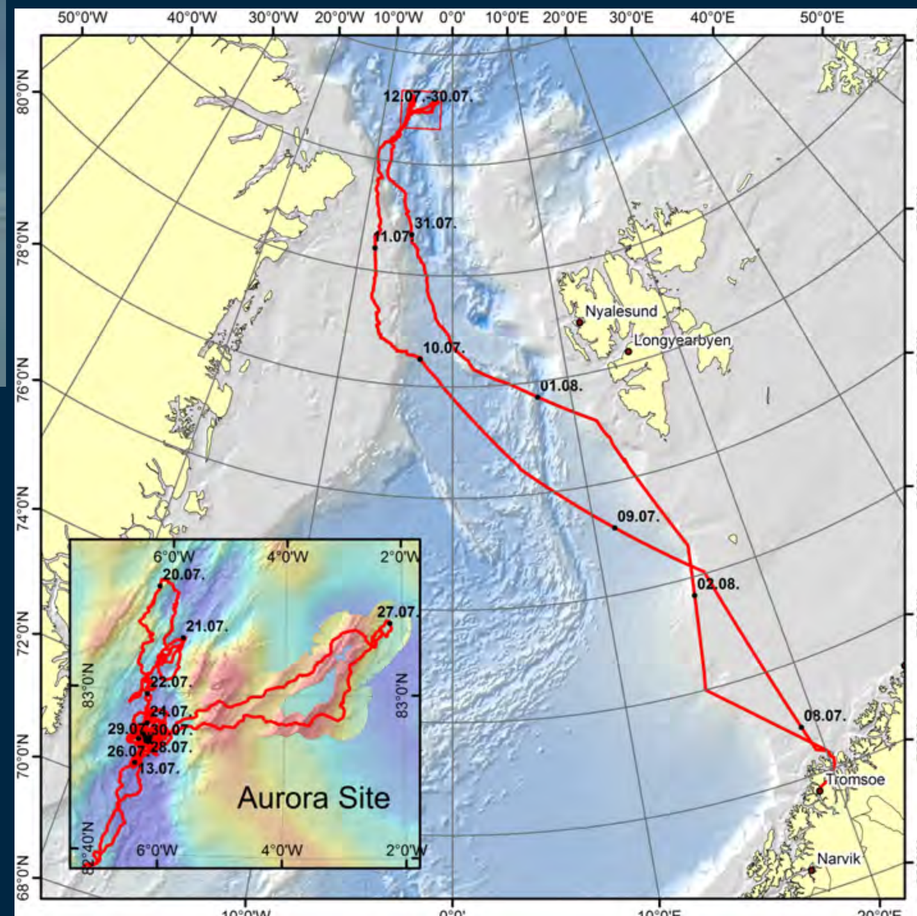
Aft section devoted to acoustics, recovery aids

Fwd section/Forehead intended for upward-looking sensors

PS86-3 Engineering Objectives

- Establish overall usability:
  - Viability of light fiber under ice
  - Launch and recovery systems
  - cold-weather protocols
  - Adequacy of pilot/operator situational awareness
  - Demonstrate ability to operate as an “inverted” ROV
  - Test contingency recovery plans
- Demonstrate significant excursion from ship
- Demonstrate piloted, semi-autonomous and autonomous “come-home” behaviors
- Demonstrate under-ice navigation in both georeferenced and ice-relative coordinate frames

NUI Summer 2014 Deployments at 83 N 6 W
F/V *Polarstern* PS86-3

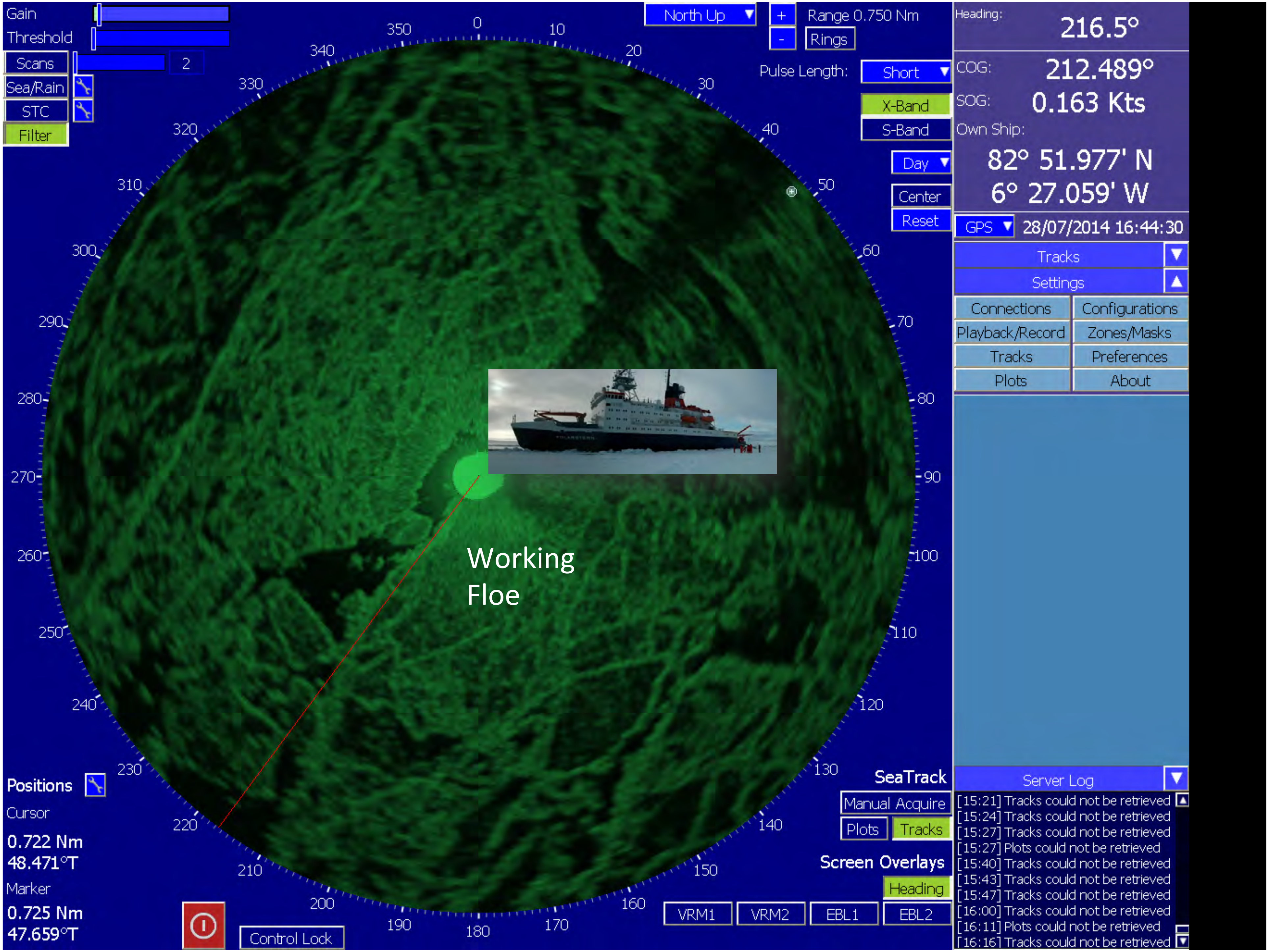


PS86-3 Engineering Team

Dive Statistics

Station	Date	Launch Time (UTC)	Recovery Time (UTC)	Dive Duration
PS86/0053-1	7/21/2014	11:44	16:52	5:08
PS86/0060-1	7/23/2014	11:03	16:08	5:05
PS86/0070-1	7/26/2014	6:43	11:44	5:01
PS86/0080-1	7/28/2014	12:29	17:49	5:20

- Four to six dives anticipated
- Attempted five, four resulted in successful separation
- Dives nui003, nui004
  - science-focused
  - ~4 km under-ice

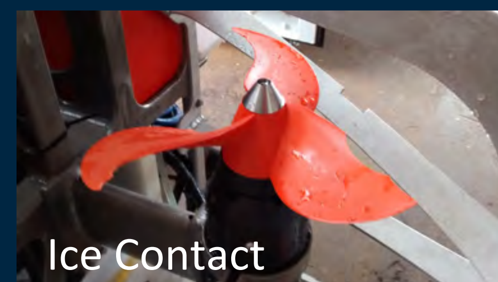


Gain
Threshold
Scans
2
Sea/Rain
STC
Filter
North Up
+
-
Range 0.750 Nm
Rings
Pulse Length:
Short
X-Band
S-Band
Day
Center
Reset
Heading:
216.5°
COG:
212.489°
SOG:
0.163 Kts
Own Ship:
82° 51.977' N
6° 27.059' W
GPS
28/07/2014 16:44:30
Tracks
Settings
Connections
Configurations
Playback/Record
Zones/Masks
Tracks
Preferences
Plots
About
Server Log
[15:21] Tracks could not be retrieved
[15:24] Tracks could not be retrieved
[15:27] Tracks could not be retrieved
[15:27] Plots could not be retrieved
[15:40] Tracks could not be retrieved
[15:43] Tracks could not be retrieved
[15:47] Tracks could not be retrieved
[16:00] Tracks could not be retrieved
[16:11] Plots could not be retrieved
[16:16] Tracks could not be retrieved
Working Floe
Positions
Cursor
0.722 Nm
48.471°T
Marker
0.725 Nm
47.659°T
Control Lock
SeaTrack
Manual Acquire
Plots
Tracks
Screen Overlays
Heading
VRM1
VRM2
EBL1
EBL2

Polar Challenges and Solutions

Temperature

Vibration



Ice Contact

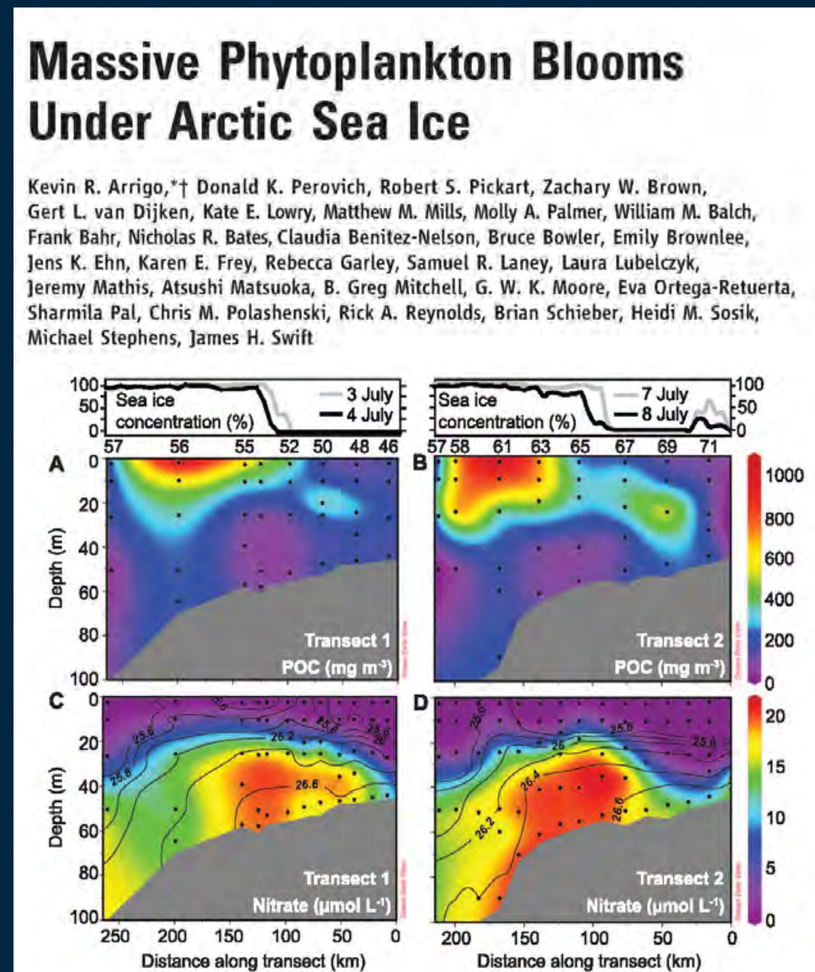
Logistics

PS86-3 Science Objectives

- Bio-available light and nutrients, and associated biological activity away from *Polarstern*
- Ice algae aggregates
- Ice physics, light-transmission and topography.
- Vertical profiles, transects at constant depth and constant "headroom"

Export of Algal Biomass from the Melting Arctic Sea Ice

Antje Boetius,[1,2,3]*† Sebastian Albrecht,[4]† Karel Bakker,[5]† Christina Bienhold,[1,2]† Janine Felden,[3]† Mar Fernández-Méndez,[1,2]† Stefan Hendricks,[1]† Christian Katlein,[1]† Catherine Lalande,[1]† Thomas Krumpen,[1]† Marcel Nicolaus,[1]† Ilka Peeken,[1,3]† Benjamin Rabe,[1]† Antonina Rogacheva,[6]† Elena Rybakova,[6]† Raquel Somavilla,[1]† Frank Wenzhöfer,[1]† RV Polarstern ARK27-3-Shipboard Science Party†



Massive Phytoplankton Blooms Under Arctic Sea Ice

Kevin R. Arrigo,*† Donald K. Perovich, Robert S. Pickart, Zachary W. Brown, Gert L. van Dijken, Kate E. Lowry, Matthew M. Mills, Molly A. Palmer, William M. Balch, Frank Bahr, Nicholas R. Bates, Claudia Benitez-Nelson, Bruce Bowler, Emily Brownlee, Jens K. Ehn, Karen E. Frey, Rebecca Garley, Samuel R. Laney, Laura Lubelczyk, Jeremy Mathis, Atsushi Matsuoka, B. Greg Mitchell, G. W. K. Moore, Eva Ortega-Retuerta, Sharmila Pal, Chris M. Polashenski, Rick A. Reynolds, Brian Schieber, Heidi M. Sosik, Michael Stephens, James H. Swift

Sensor Suite

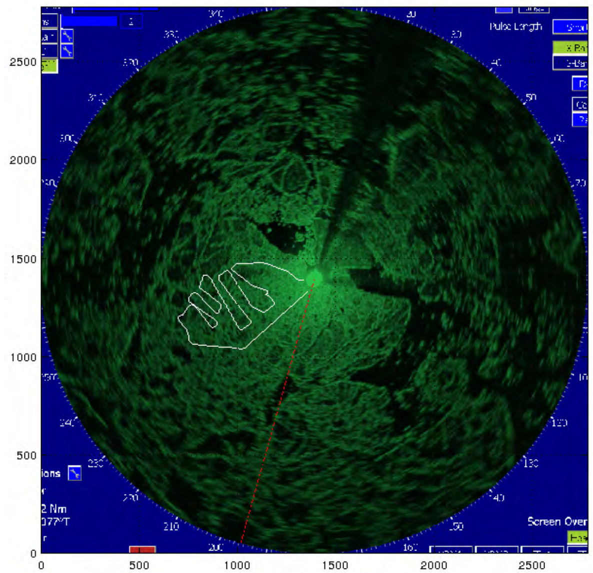
Not Shown:

- 2 CTDs
- Still Camera
- PAR

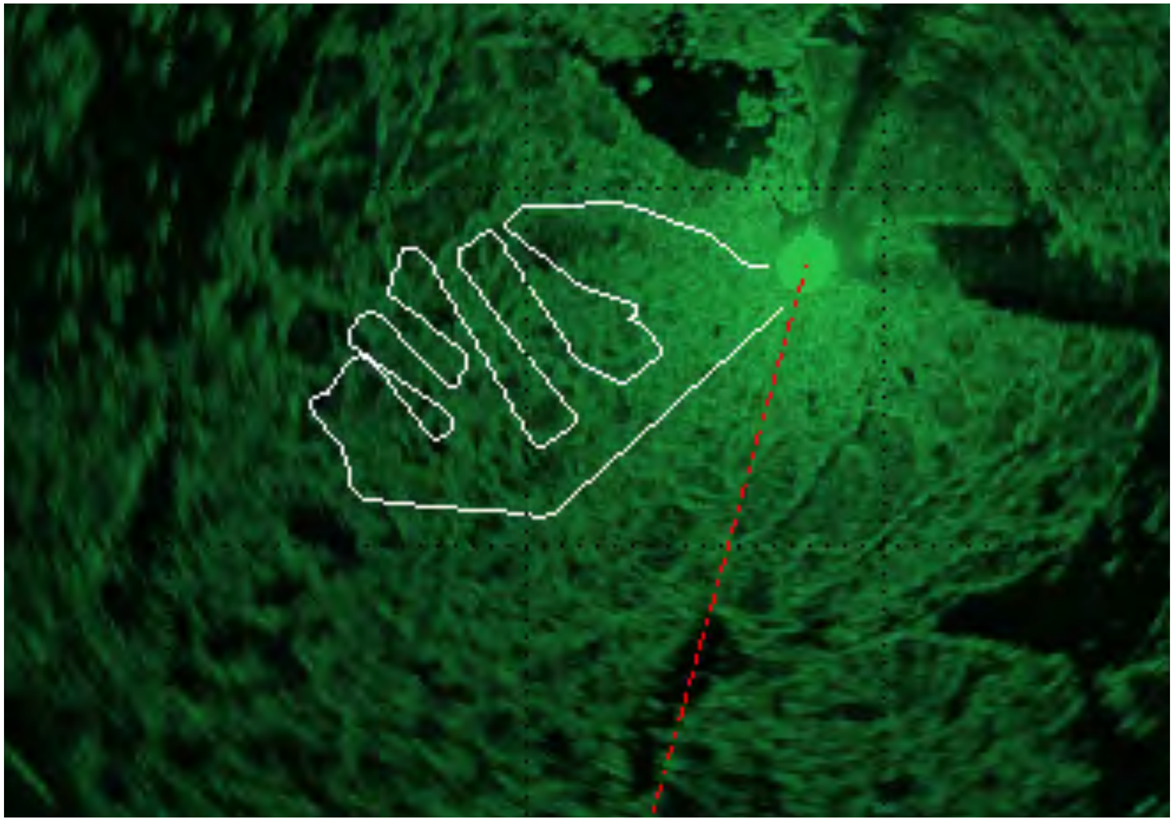
Dive Statistics: Science Systems

System/Sensor	Dive 1 7/18/14	Dive 2 7/21/14	Dive 3 7/23/14	Dive 4 7/26/14
Imagenix Upward Multibeam – under-ice topography	0%	0%	100%	100%
High-Def. Forward Camera	100%	100%	100%	100%
Upward Digital Still Camera	0%	0%	100%	100%
RAMSES Radiance ARC	0%	50%	100%	100%
RAMSES Irradiance ACC	0%	50%	100%	100%
Seabird SBE49 CTD	100%	100%	100%	100%
Seabird SBE25+ CTD	100%	100%	100%	100%
SUNA nitrate sensor	100%	100%	100%	100%
FRRF: fluorometer, PAR sensor, pressure sensor	0%	0%	100%	100%
Eco-Triplet fluorometer	100%	100%	100%	100%

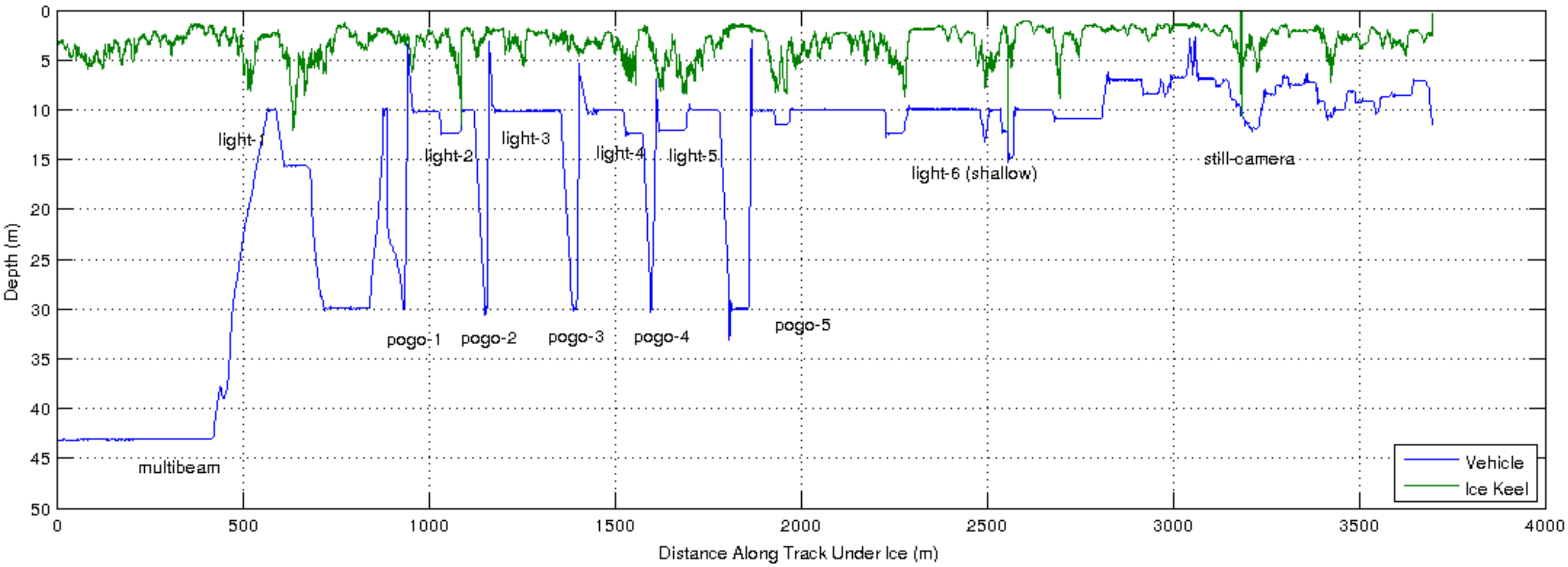
nui003



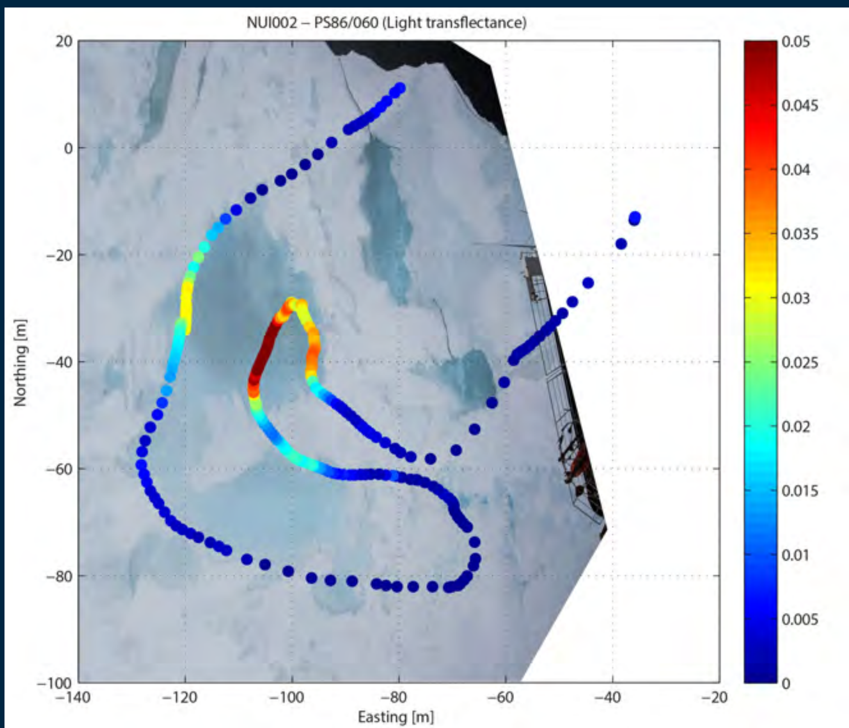
Ship's Ice Radar

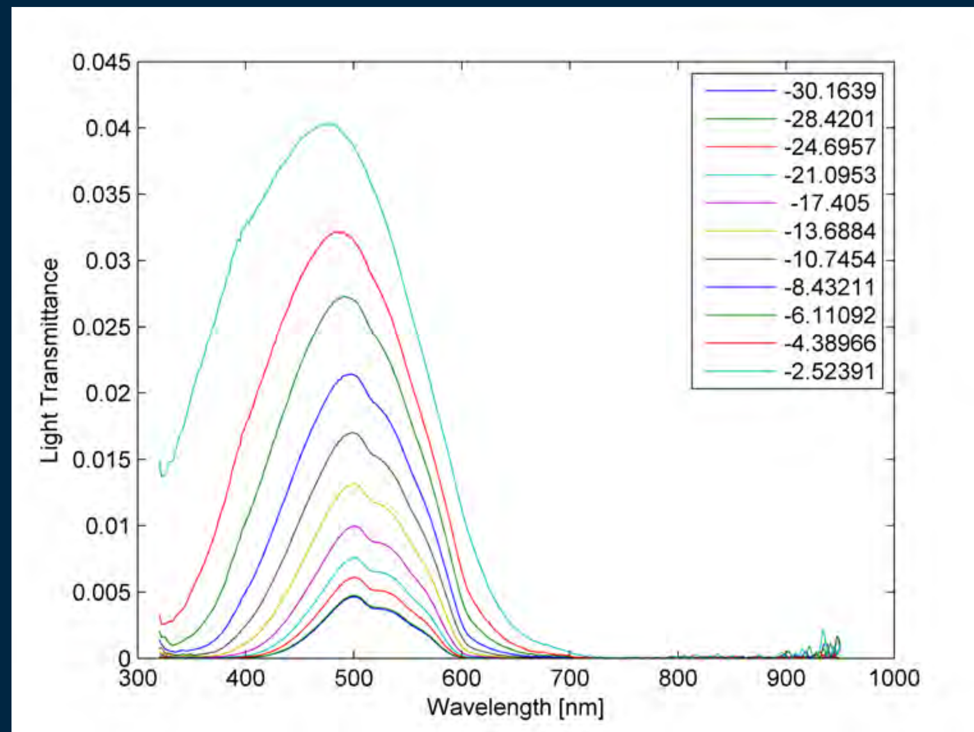


nui003


Depth (m)
Distance Along Track Under Ice (m)
0
5
10
15
20
25
30
35
40
45
50
0
500
1000
1500
2000
2500
3000
3500
4000
multibeam
light-1
light-2
light-3
light-4
light-5
light-6 (shallow)
still-camera
pogo-1
pogo-2
pogo-3
pogo-4
pogo-5
Vehicle
Ice Keel

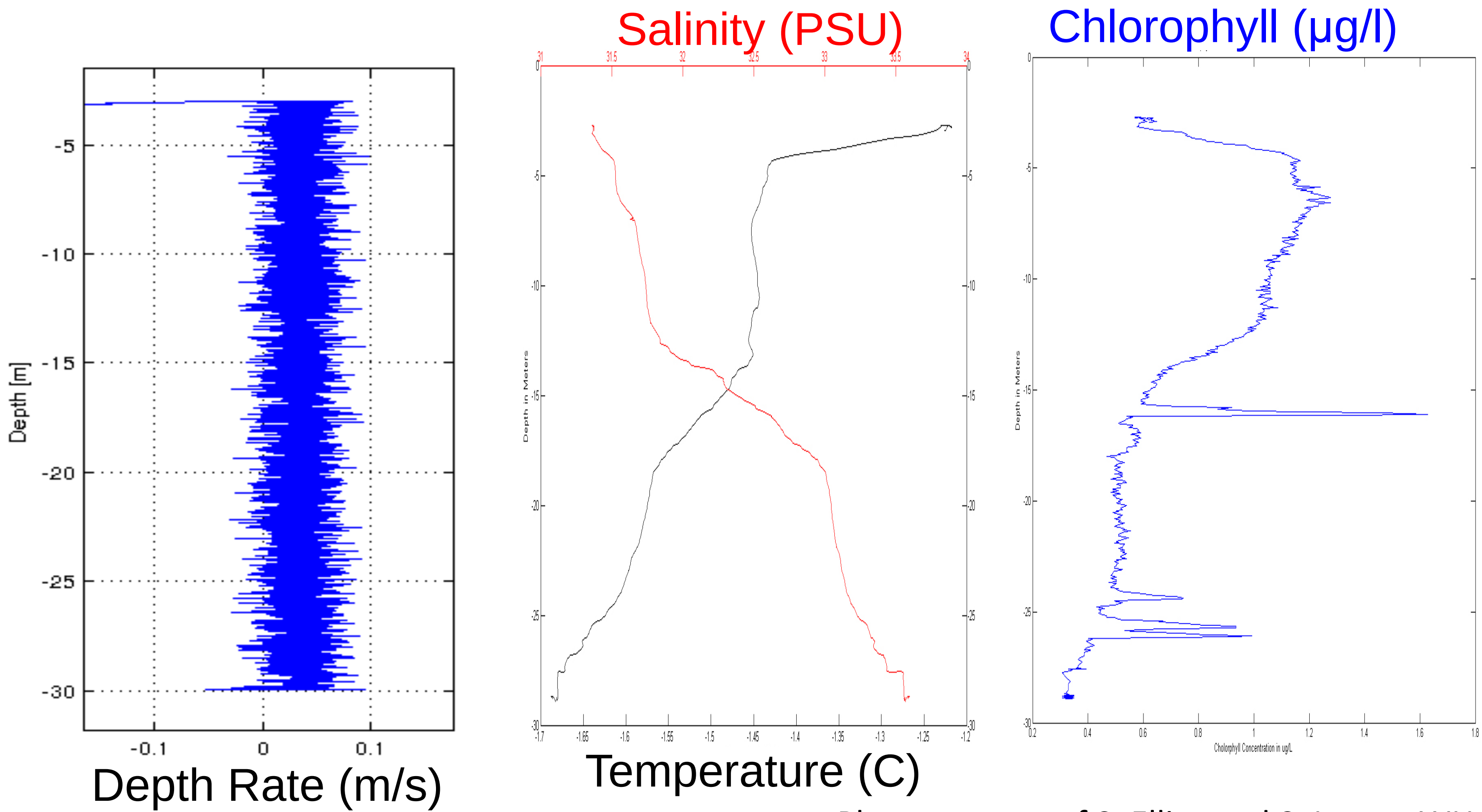
Upper Ocean Optics under Varying Ice Cover





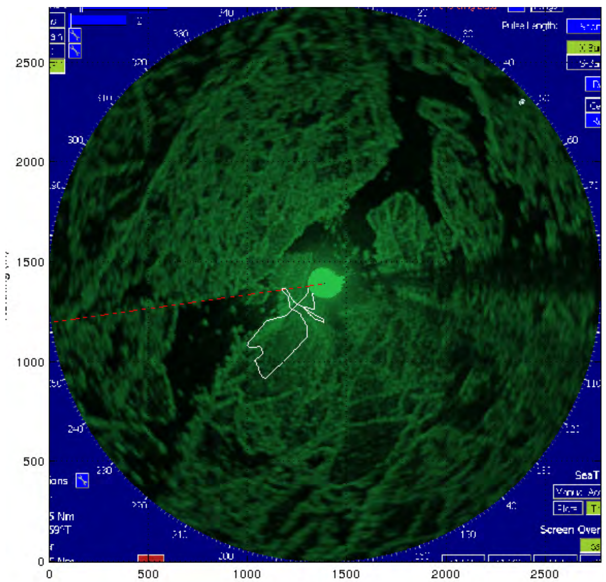
Images courtesy of C. Katlein, AWI

Co-Registered Upper Ocean Physics & Biogeochemistry



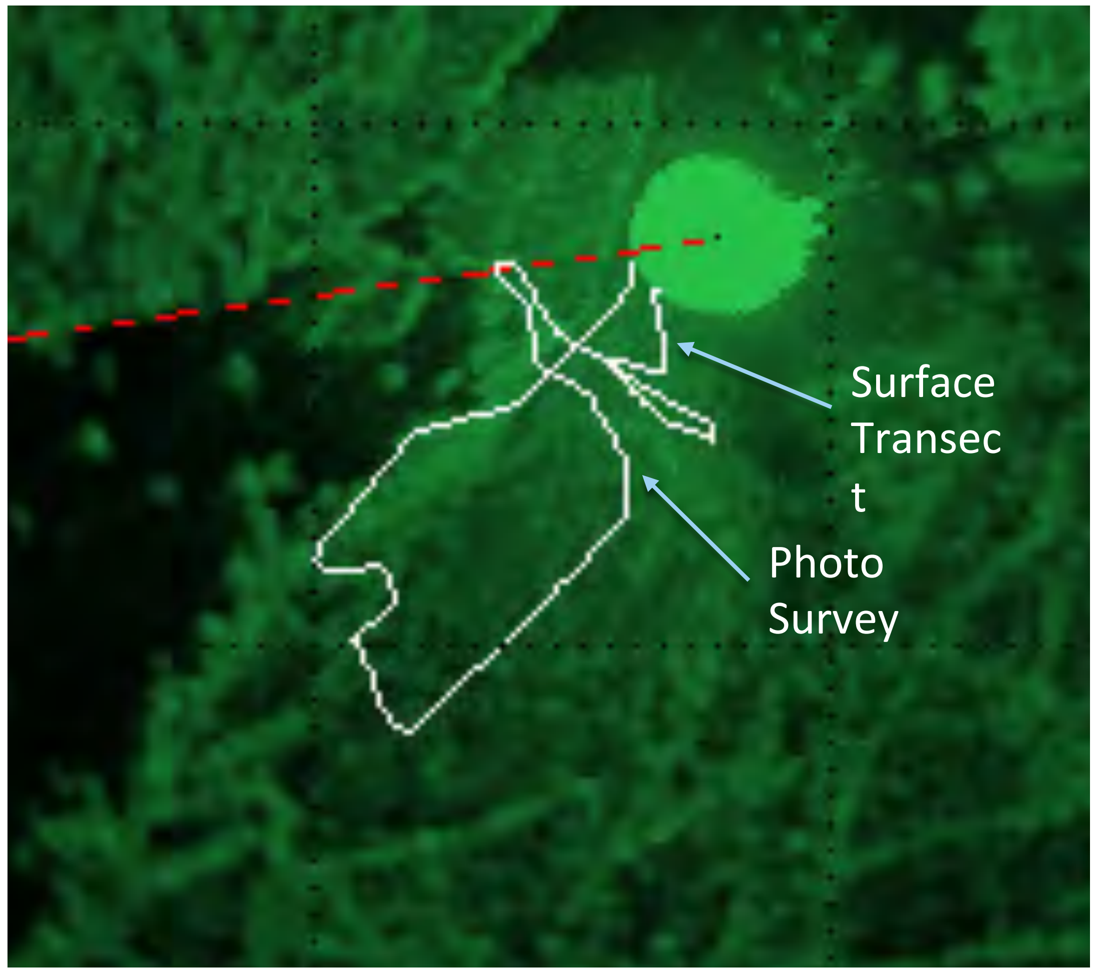
Plots courtesy of S. Elliot and S. Laney, WHOI

nui004

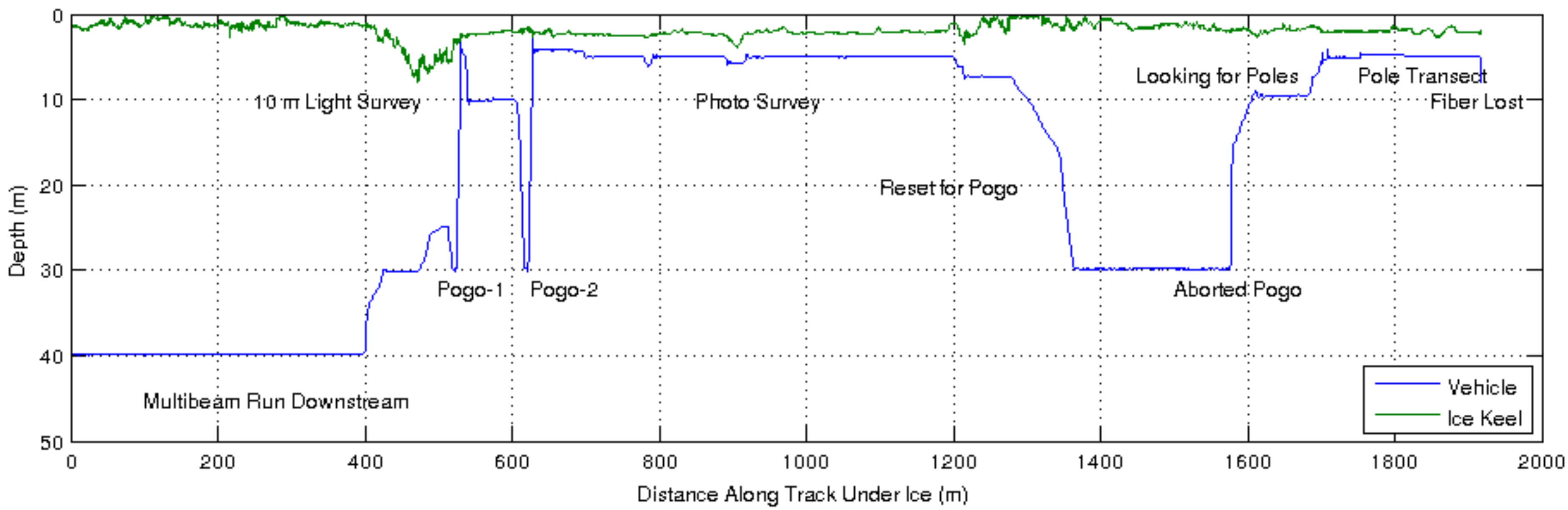


Telepresence Critical:

- Dynamic – 3 deg/hr; unstable pool
- Target selection for photo survey
- Locate surface transect



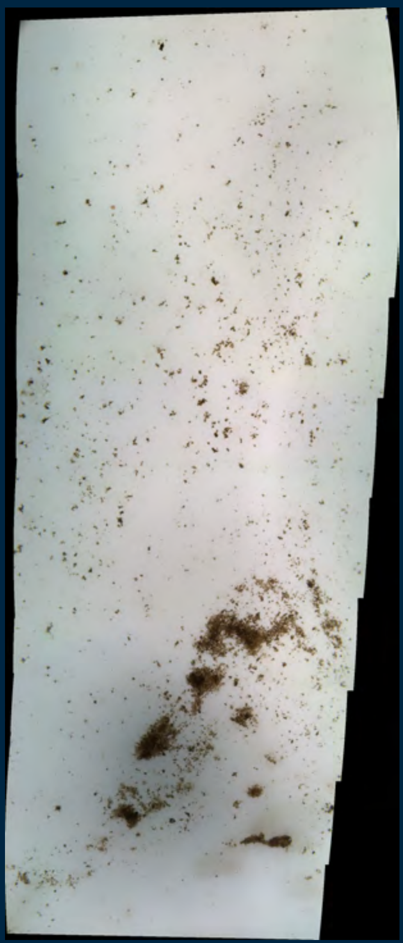
nui004



0
10
20
30
40
50
Depth (m)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance Along Track Under Ice (m)
10 m Light Survey
Photo Survey
Looking for Poles
Pole Transect
Fiber Lost
Reset for Pogo
Pogo-1
Pogo-2
Aborted Pogo
Multibeam Run Downstream
Vehicle
Ice Keel


Ice Algae Aggregates

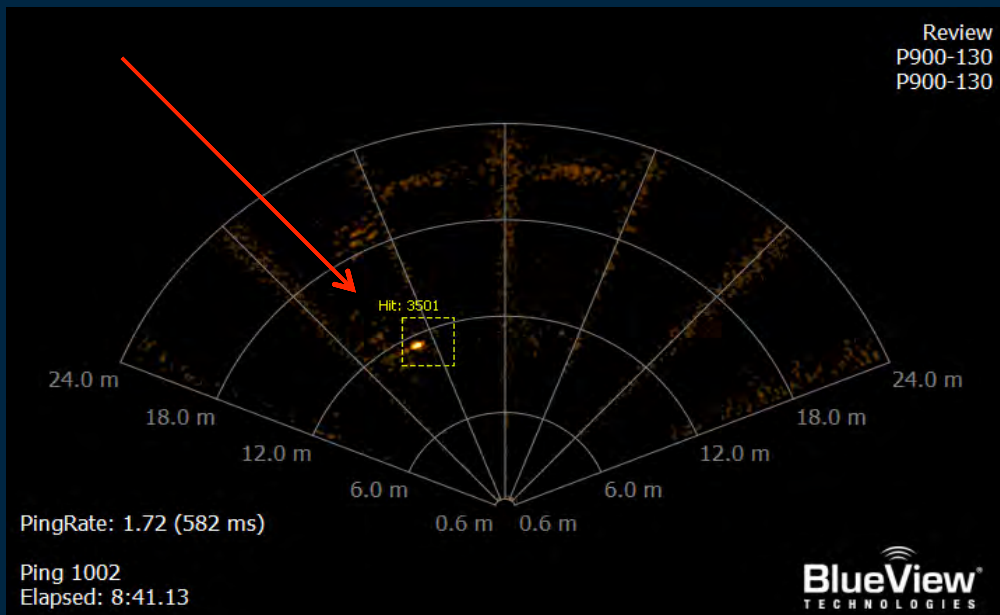
Photo Survey Mosaics



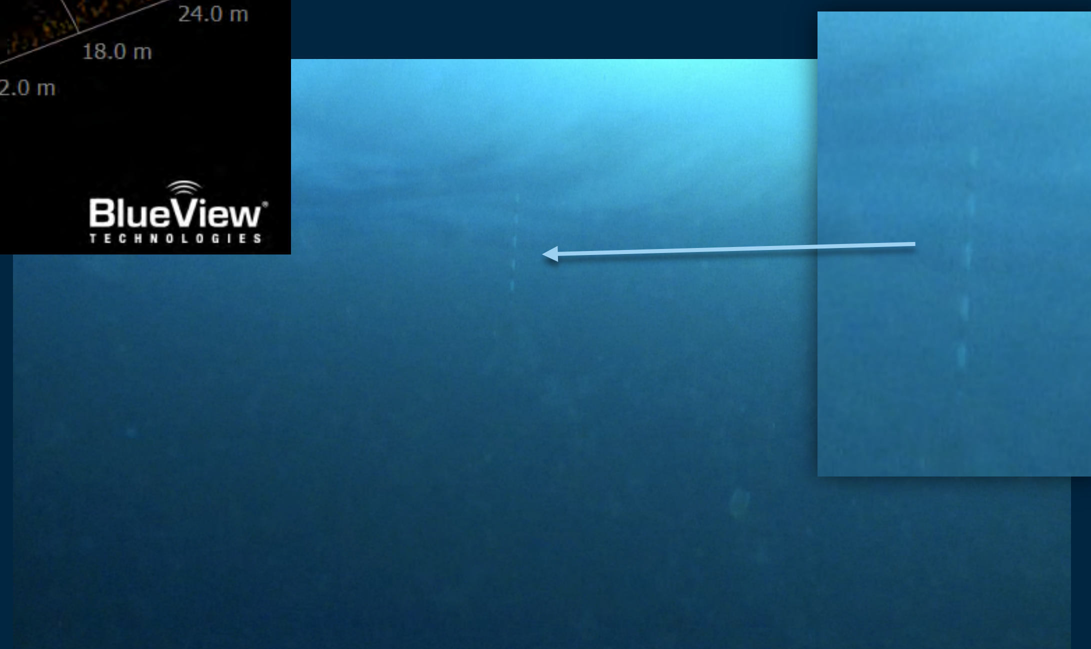
- Choose location
- Natural light
- Algal coverage estimation
- Co-registered with bio-optical measurements

Co-registration with Surface Transect

Co-Registration with Surface Transect



- Low visibility (< 10m)
- Need to find GPS-positioned through-ice poles for ir/radiance co-registered measurements transects



- Blueview P900 finds poles much farther than visual approach
- 5 cm relative positional accuracy attained.

PS86-3 Outcomes

- AGU Abstracts submitted:
  - C.R. German et al. (2014).
    First scientific dives of the *Nereid Under Ice* hybrid ROV in the Arctic Ocean.
    EOS Trans AGU (abstr*) In Press*.
  - L.L. Whitcomb et al. (2014).
    Preliminary Polar Sea Trials of *Nereid-UI*: A Remotely Operated Underwater Vehicle for Oceanographic Access Under Ice. EOS Trans AGU (abstr) *In Press*.
- ICRA paper submitted:
  - Christopher McFarland et al. Toward Ice-Relative Navigation of Underwater Robotic Vehicles Under Moving Sea-Ice: Experimental Evaluation in the Arctic Sea. IEEE ICRA 2015. *Submitted*.
- ECC presentation (AWI):
  - Katlein, C. et al. (2014) Investigating changes in the climate- and ecosystem of Arctic sea ice using remotely operated vehicles , ECC 2014, Bremen, Germany

Acknowledgements

- Vehicle development
  - NSF's Office of Polar Programs ANT-1126311, Peter Milne
  - James Family Foundation
  - George Fredrick Jewett Foundation East
  - WHOI
- Field Trials
  - NOAA OER
  - ONR
  - NSF OCE
  - Antje Boetius, AWI, and PS86 Scientific Research Team
  - Instruments/Equipment: H. Singh, T. Maksym, A. Plueddemann, *Deep Sea Challenger*, *Nereus*