HELMHOLTZ | GEMEINSCHAFT

ROBEX Allianz

HGF-Alliance ROBEX
Robotic Exploration of Extreme Environments

Technical advances to explore OCEANS – concepts and case studies from ROBEX

Frank Wenzhöfer[1], Sascha Flögel[2], Stefan Sommer[2],

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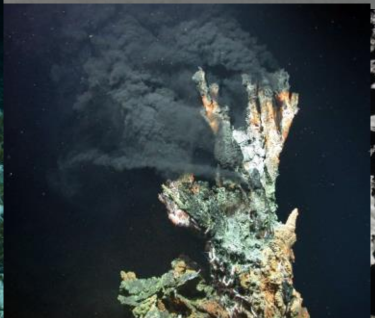
2 GEOMAR Helmholtz-Center for Ocean Research

AWI GEOMAR ROBEX

Helmholtz-Alliance ROBEX

The Helmholtz Alliance „Robotic Exploration of Extreme Environments – ROBEX“ brings together **160 experts** of space and deep-sea research. From **16 institutes** involved in space and marine research, the project partners are jointly developing technologies for the exploration of highly inaccessible terrain, such as the **deep sea and Polar Regions**, as well as the **Moon** and other planets.



Extreme environments

Moon

- -130°C to + 160°C
- Vacuum
- Light
- Solar radiation

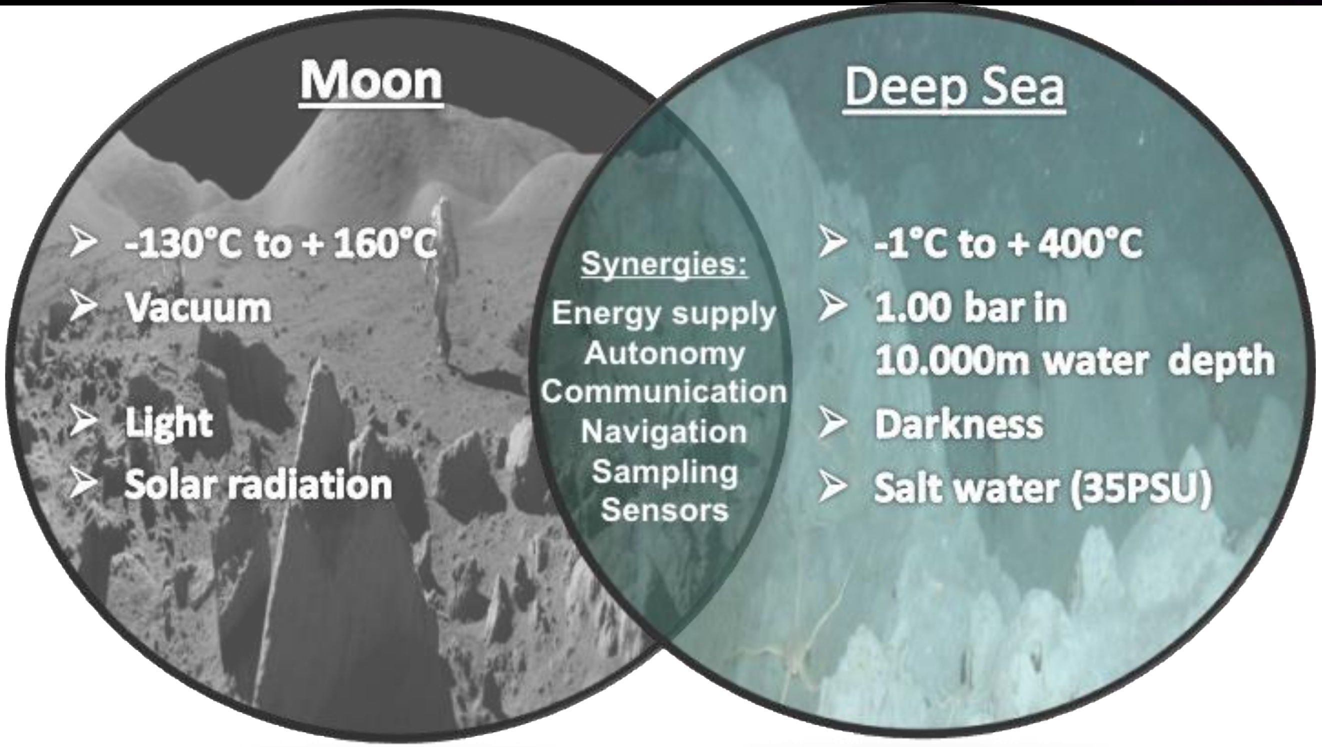
Synergies:

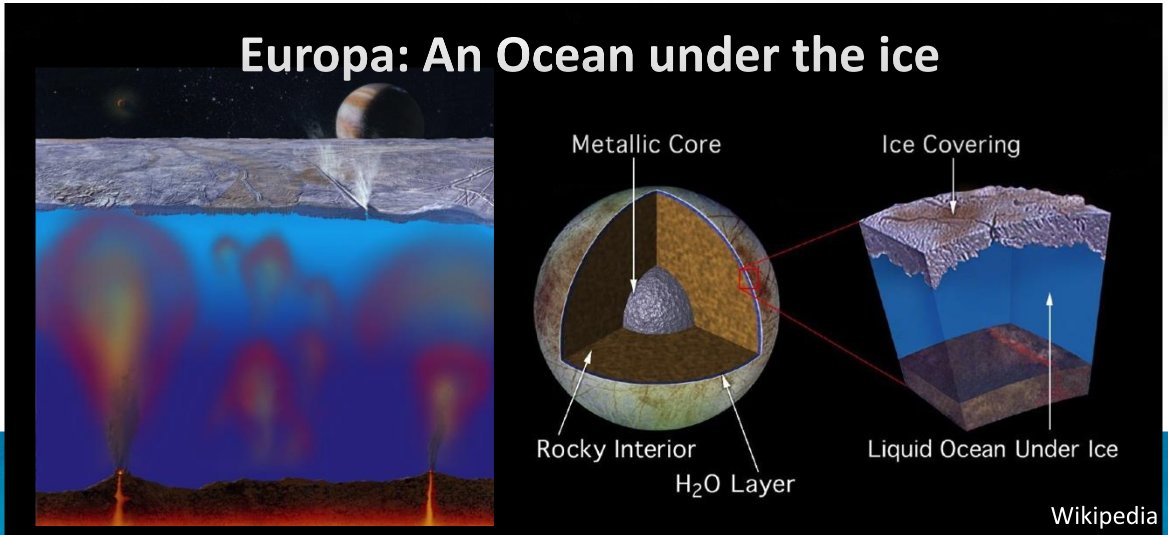
Energy supply
Autonomy
Communication
Navigation
Sampling
Sensors

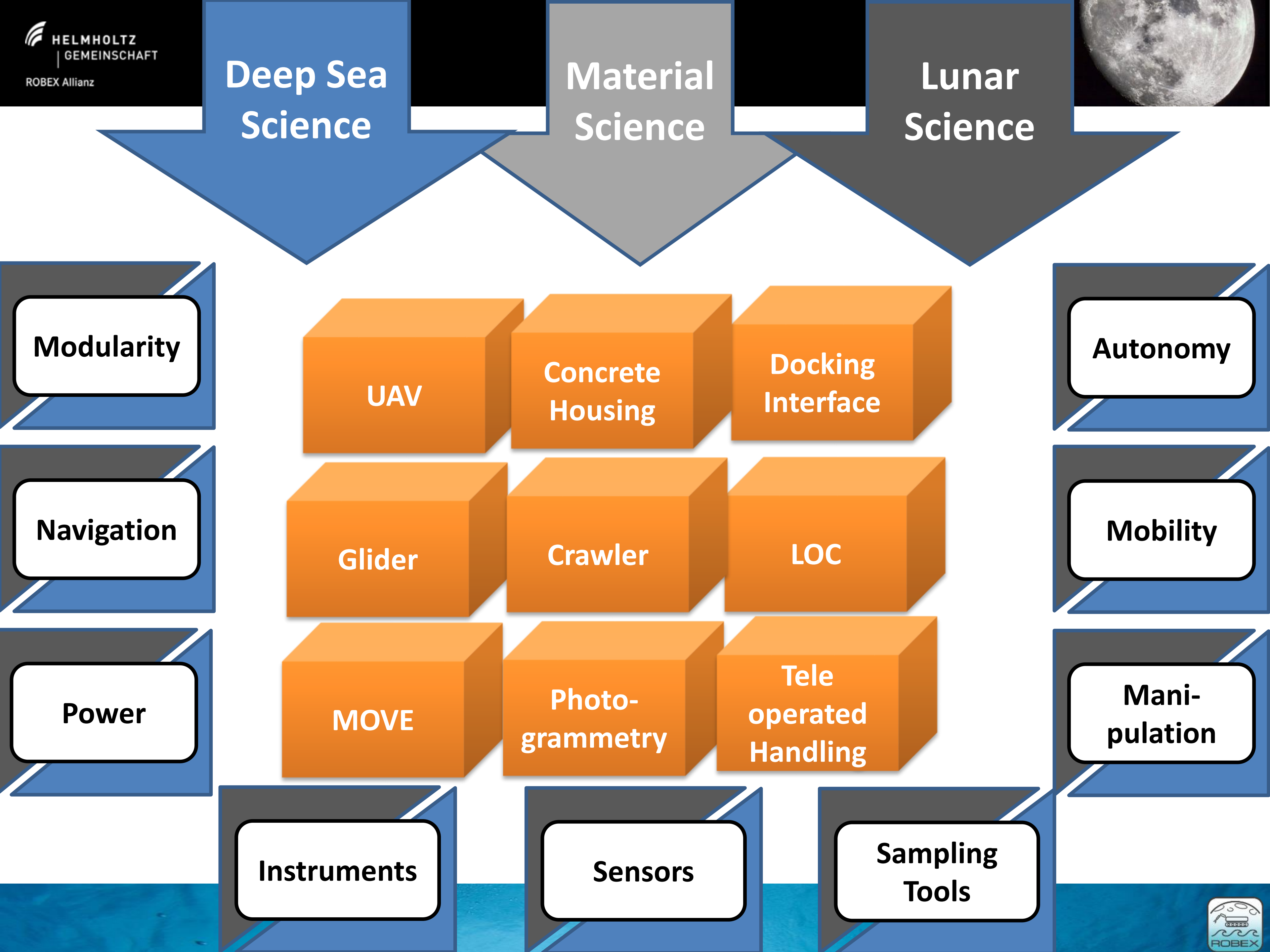
Deep Sea

- -1°C to + 400°C
- 1.00 bar in 10.000m water depth
- Darkness
- Salt water (35PSU)

Extreme environments






HELMHOLTZ
GEMEINSCHAFT
ROBEX Allianz
Deep Sea Science
Material Science
Lunar Science
Modularity
Navigation
Power
UAV
Concrete Housing
Docking Interface
Glider
Crawler
LOC
MOVE
Photo-grammetry
Tele operated Handling
Autonomy
Mobility
Mani-pulation
Instruments
Sensors
Sampling Tools
ROBEX

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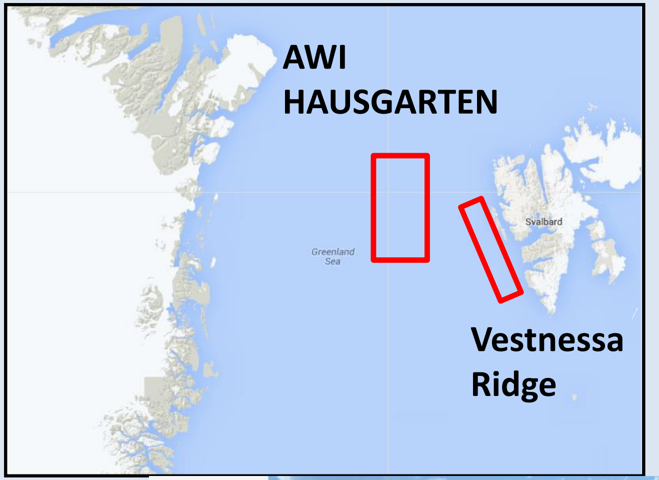
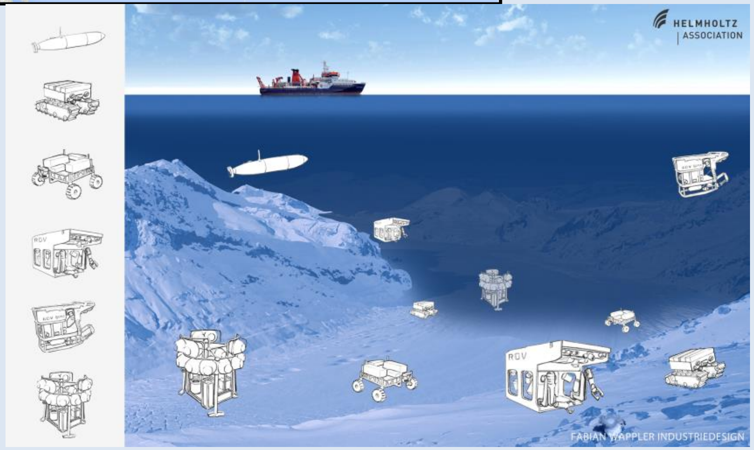
Demonstration Missions

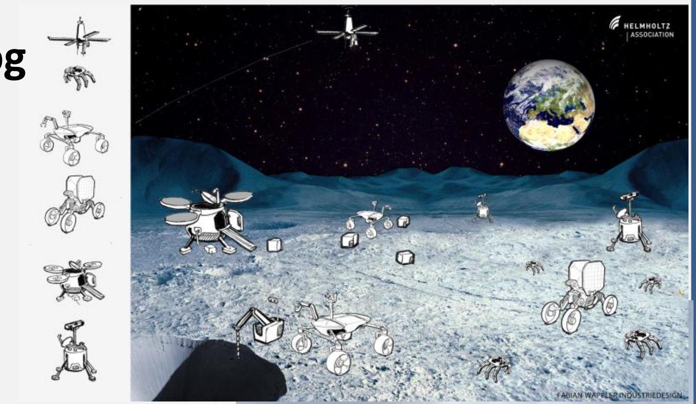
Deep Sea

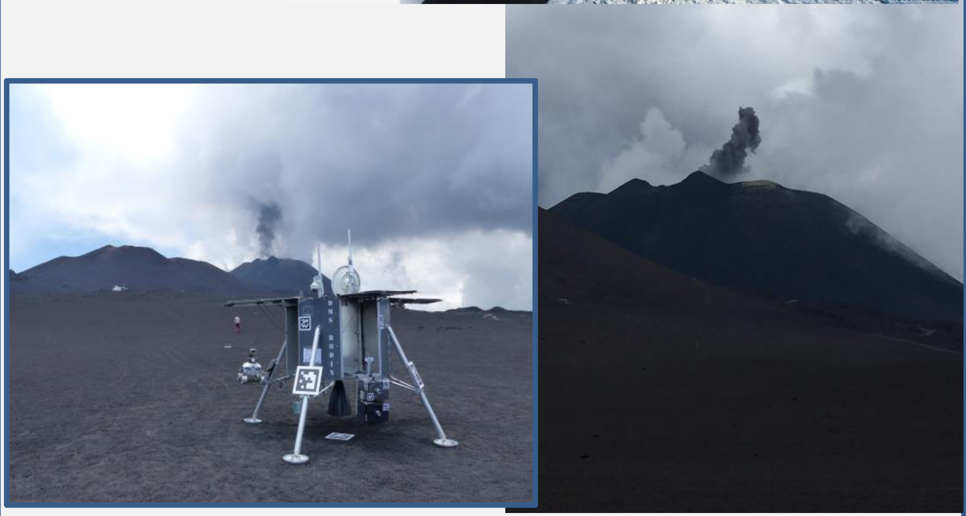




On Research Vessel Polarstern PS108
22.8.-9.9.2017

Moon-Analog





On Mount Etna 12.6.-7.7.2017

Deep-Sea Demo-Mission

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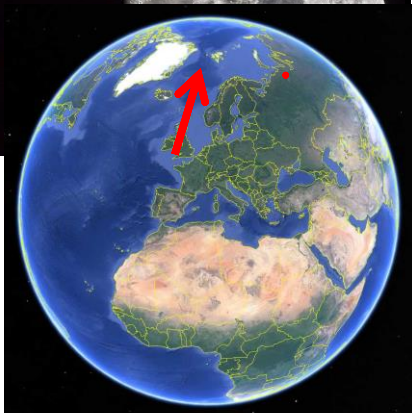


RV Polarstern PS 108

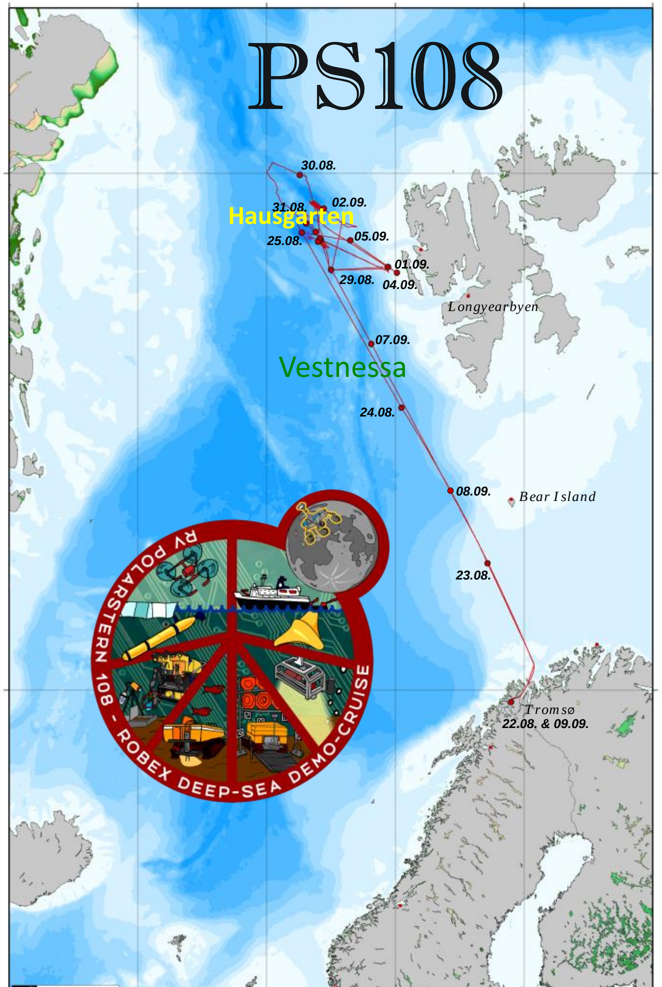
Duration: 19 days

22. August – 9. September 2017

Tromsø – Tromsø

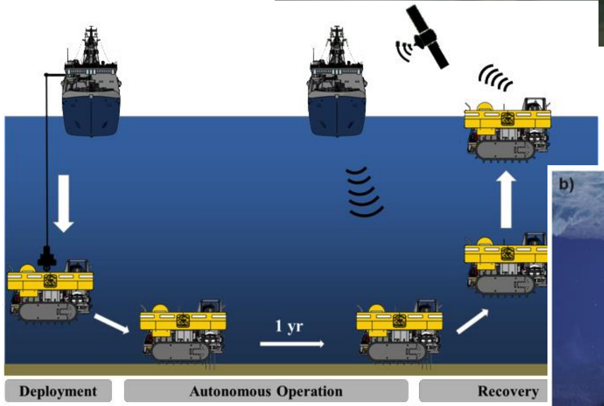
ROV Kiel6000

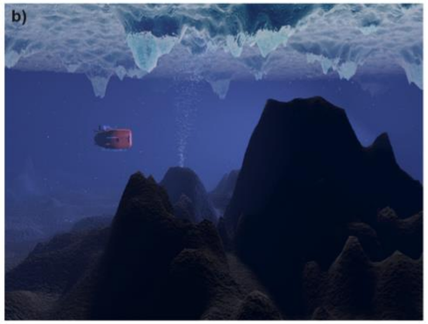
Number of Participants: 51



Deep-Sea Demonstration Mission Aims

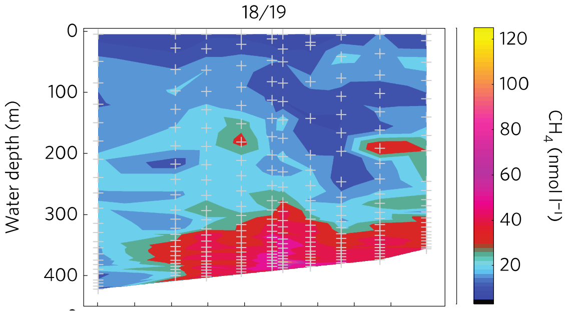
- Demonstrating the functionality of new and innovative robotic and sensor systems



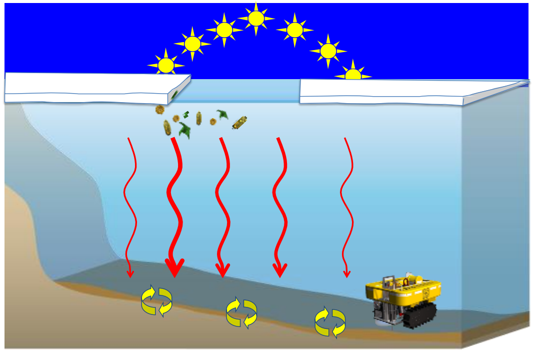


- Evaluating their operation for different mission scenarios

- Scientific challenges



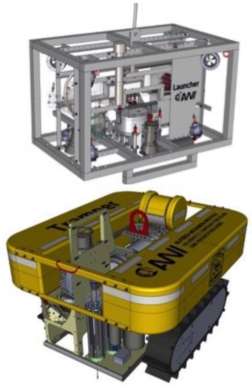
CH_4 distribution at seep sites off Spitzbergen
Steinle et al. Nature Geosciences 2015



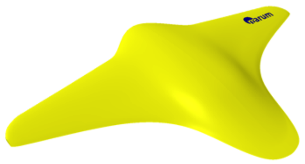
Platforms & Sensor Systems

Mansio-Viator

Tramper



Glider

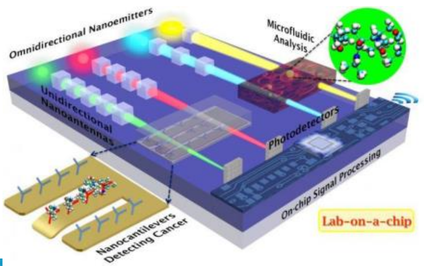


UAV's

O_2-Microprofiler

Underwater-MassSpec

Lab-On-Chip (LOC)



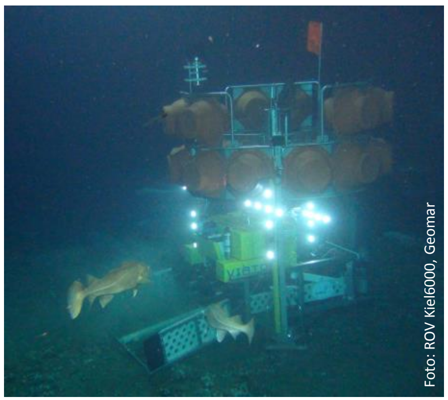
nanowerk.com

Camera systems

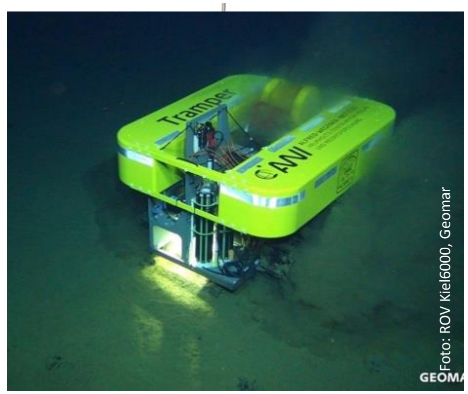
3D Laser-SmartCam

Platforms & Sensor Systems

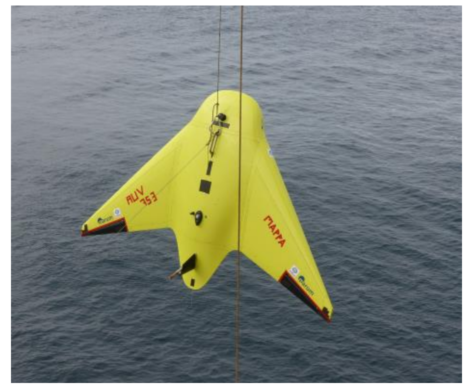
Mansio-Viator



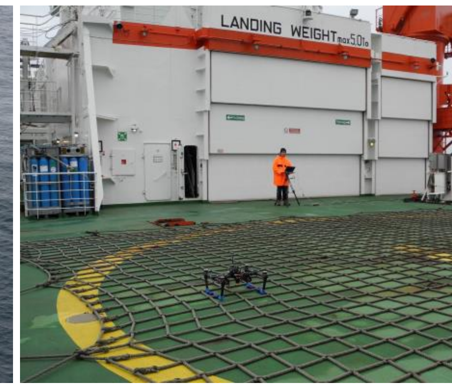
Tramper



Glider

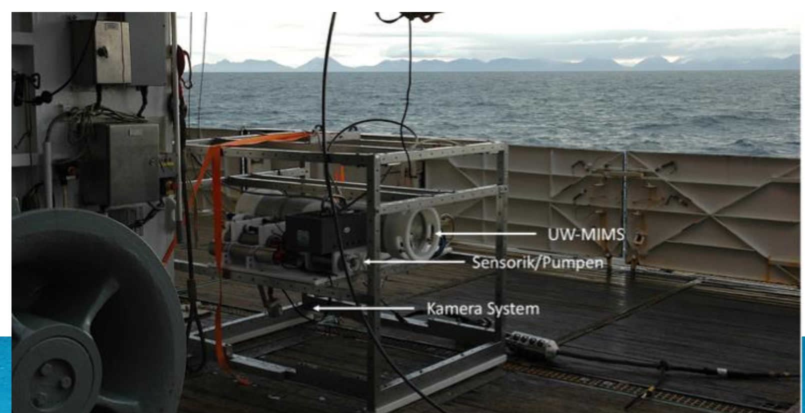


UAV's



O_2-Microprofiler

Underwater-MassSpec

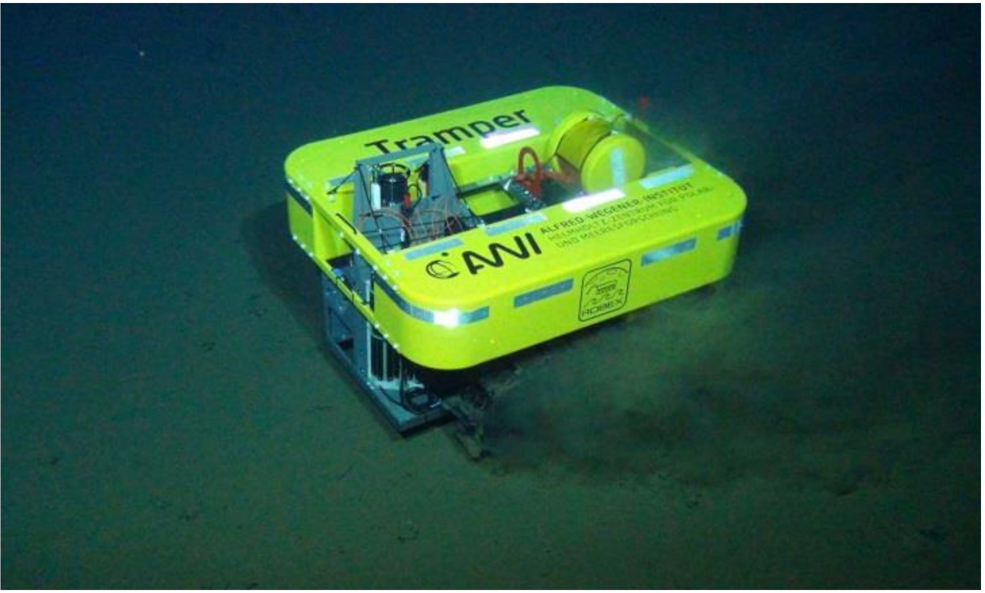


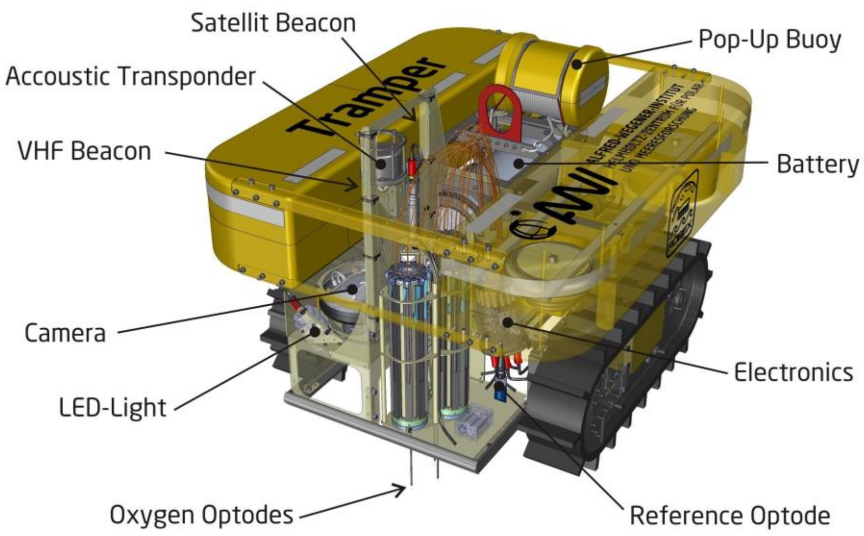
Camera systems

TRAMPER – TRAnsecting Marine Profiler for Ecological Research

ROBEX Allianz

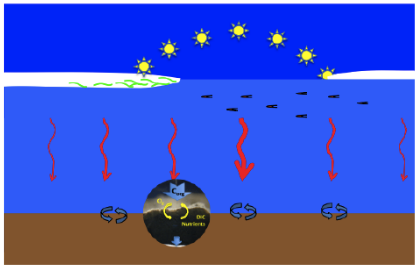
An autonomous crawler for long-term biogeochemical (benthic O_2 flux) studies in remote deep sea ecosystems





TRAMPER – TRAnsecting Marine Profiler for Ecological Research

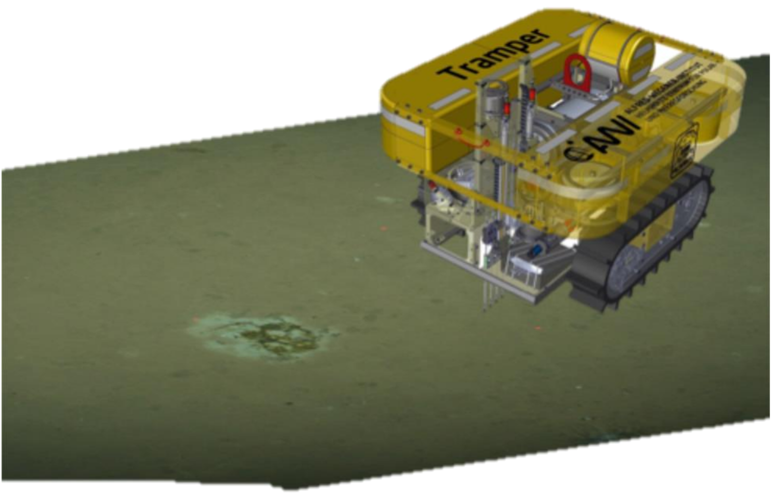
ROBEX Allianz



Mission scenario

Quantification of carbon export in ice-covered regions and its implications on Arctic deep-sea sediments

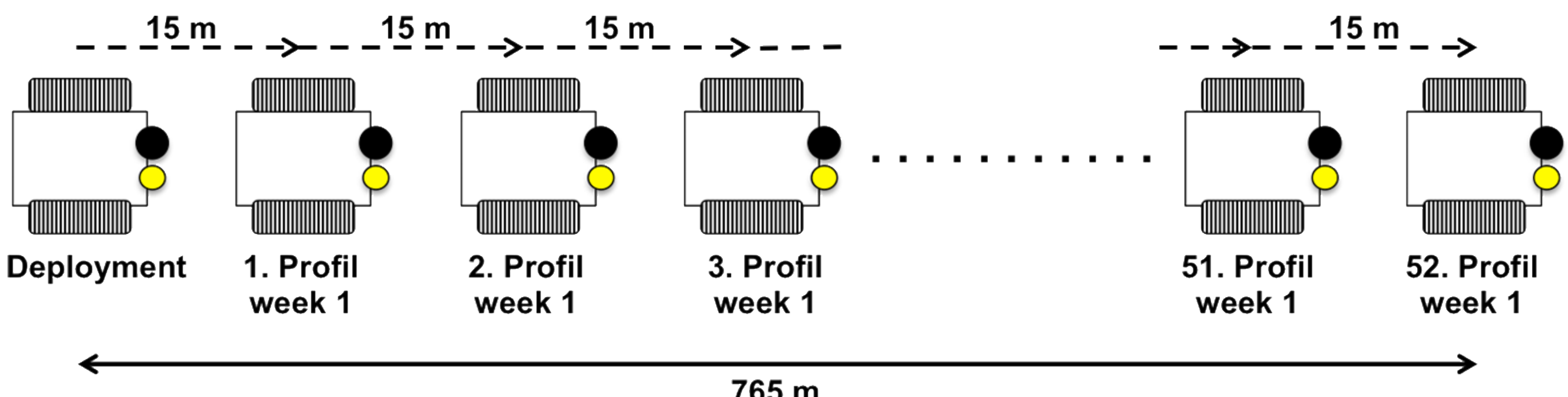
Measure microbial activity



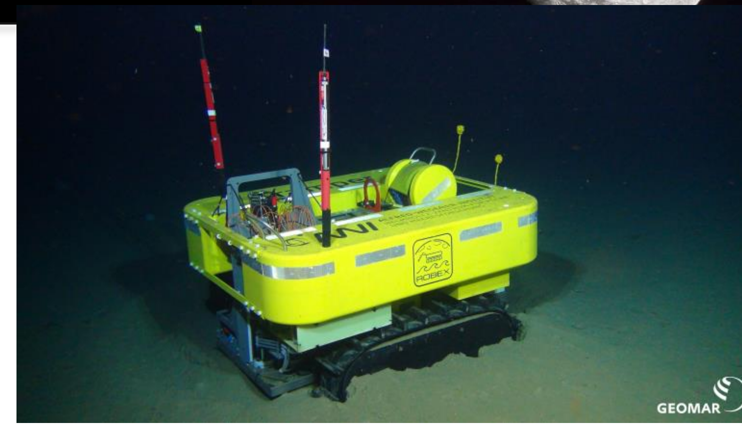
Payload:

- Cameras
- O_2 multi-microprofiler

1-year deployment



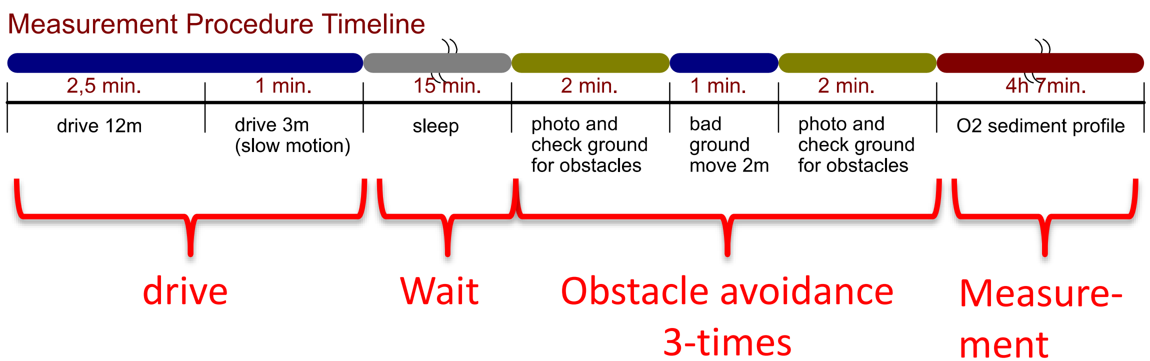
Tramper



Deployment
11.7.2016 (RV Polarstern PS99.2)
AWI LTER HAUSGARTEN HG IV
79°03,59'N 04°11,90'E 2478m wd

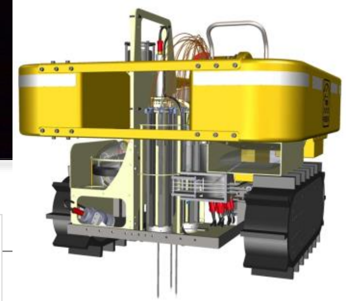
Recovery
27.8.2017 (RV Polarstern PS108)
AWI LTER HAUSGARTEN HG IV
79°03,56'N 04°12,89'E 2478m wd

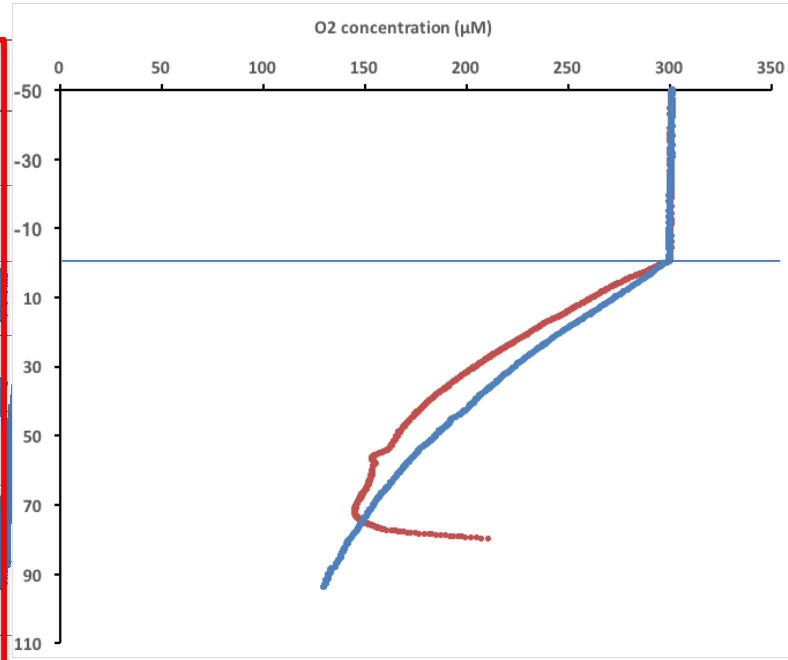
Timeline for 1-cycle

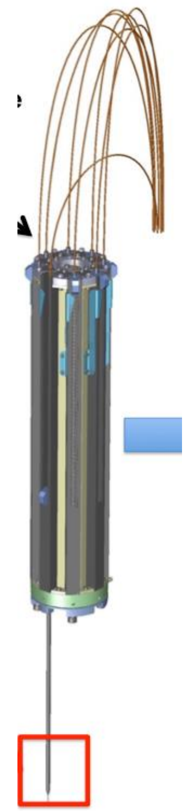


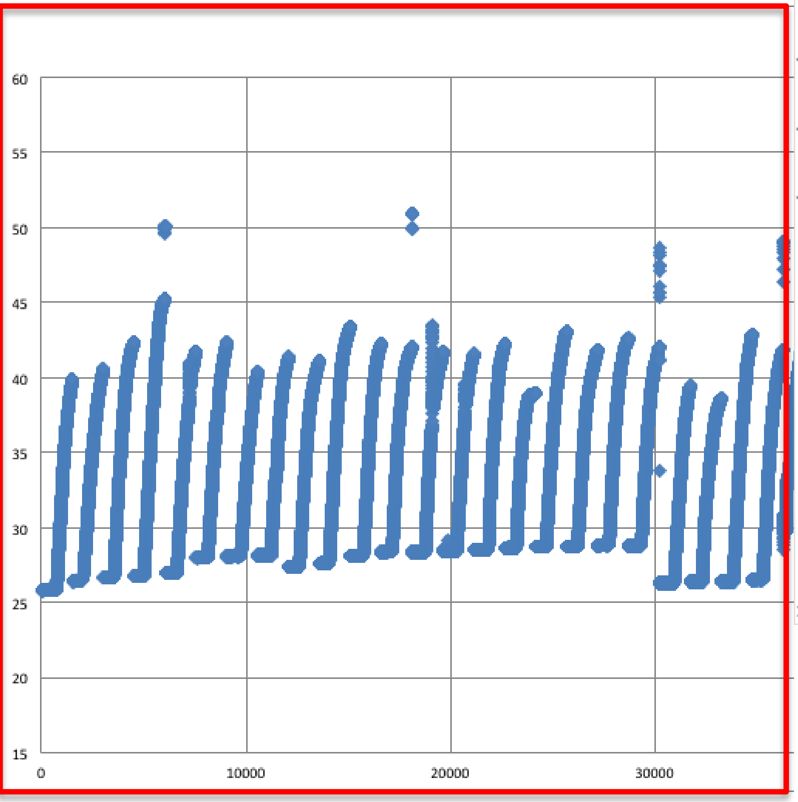
Duration: 59 weeks + 6 days
Distance: 345m + 35 circles (525m)
Measurements: total: 59 cycles -> 24 cycles useful (72 profiles)

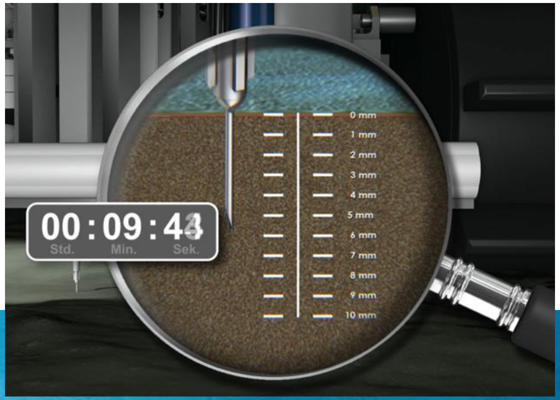
Tramper





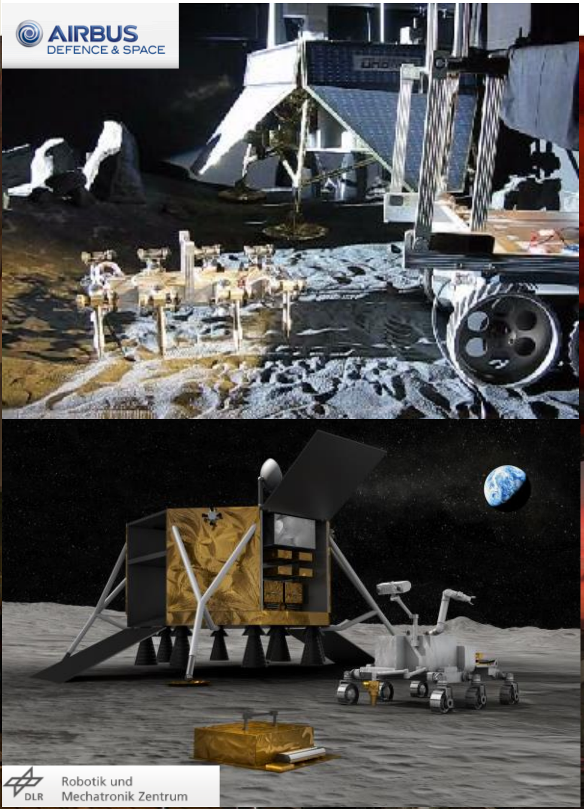


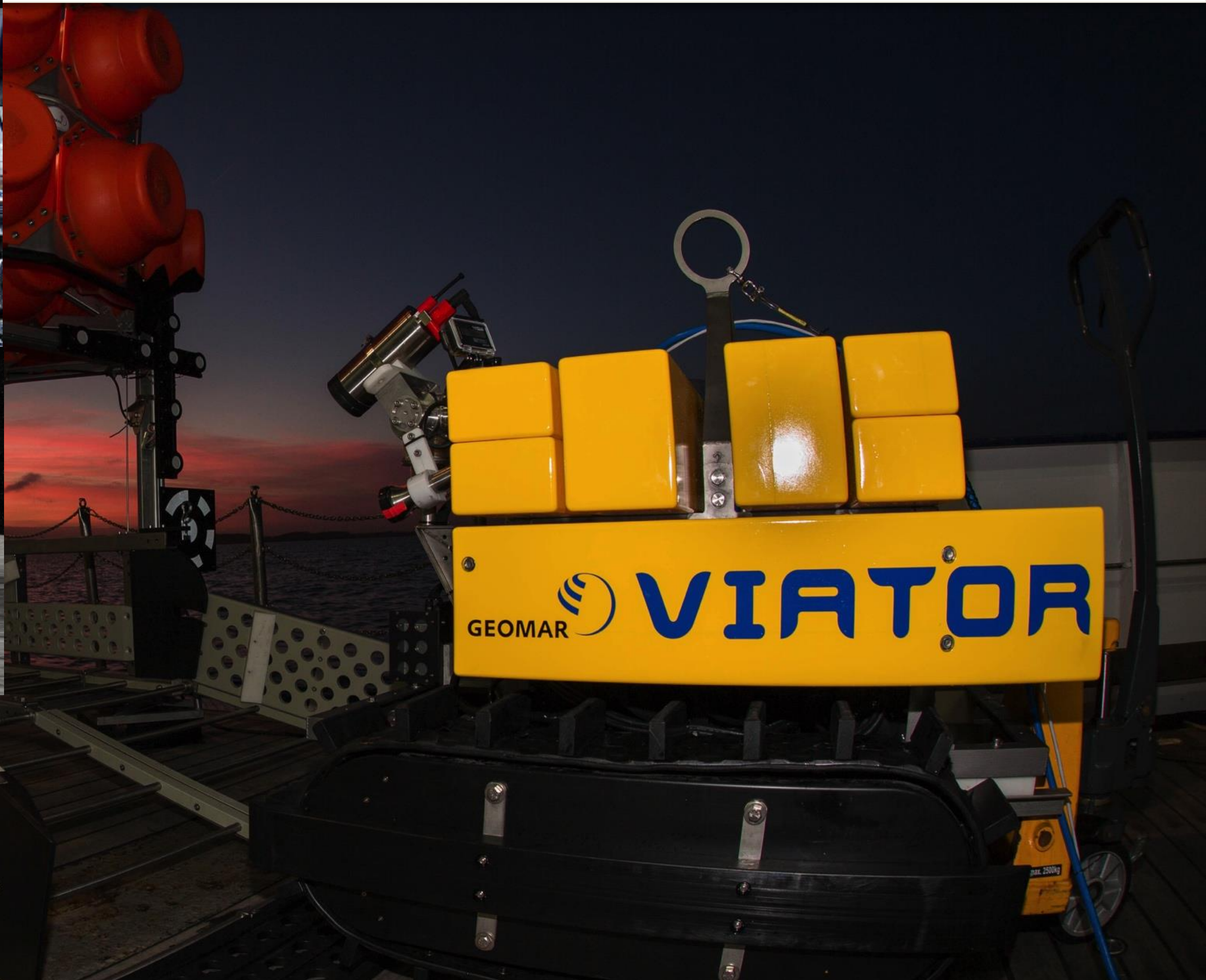




- 59 profiling cycles
- In-between sensor calibration

MANSIO-VIATOR





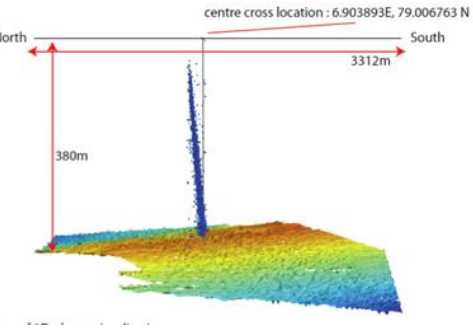
- **Autonomous deep-sea crawler and lander system (physical – and biogeochemical measurements & sea-floor mapping)**

Technical information and scientific payload

- Camera and laser scanner for mapping and navigation
- LED marker-based system for docking (near-field navigation)
- USBL system for far-field navigation
- Obstacle avoidance system
- Energy supply: 12 kW LiPo, inductive recharge

- pH, O_2, conductivity, temperature, pressure, turbidity, chlorophyll a, currents, …
- CH_4 sensor
- …

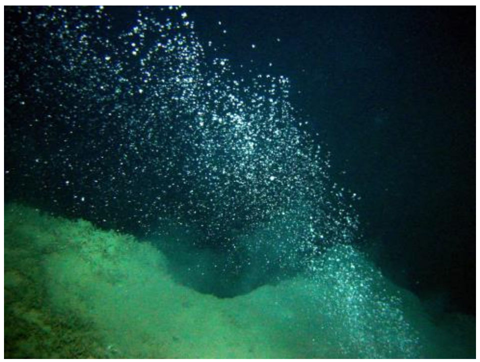
MANSIO – VIATOR



Mission scenario

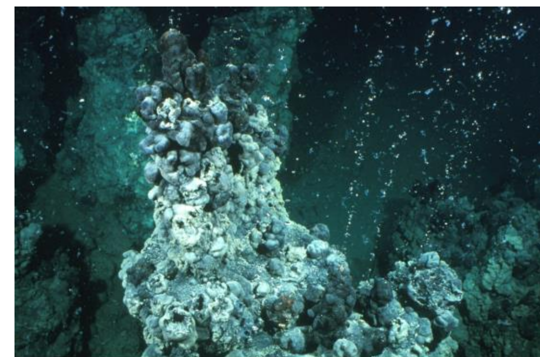
Detection and quantifying escaping free gas

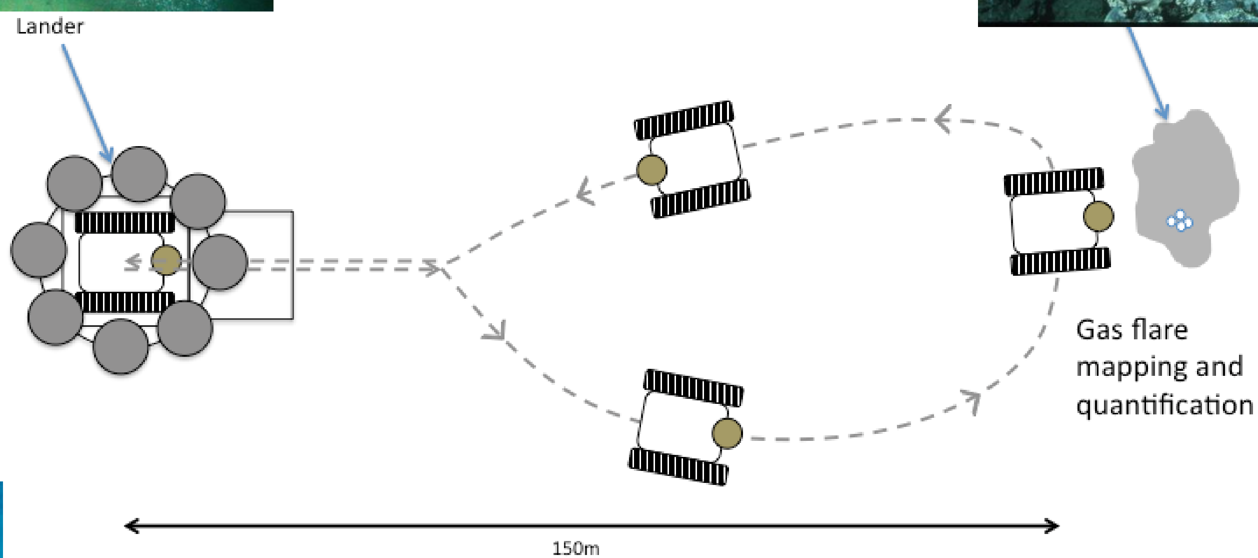
Detection of life



Payload:

- ADCP, CTD, O2, pH, Turbidity, Chlorophyll a, CH4





3D mapping - Laser Aided Photogrammetry

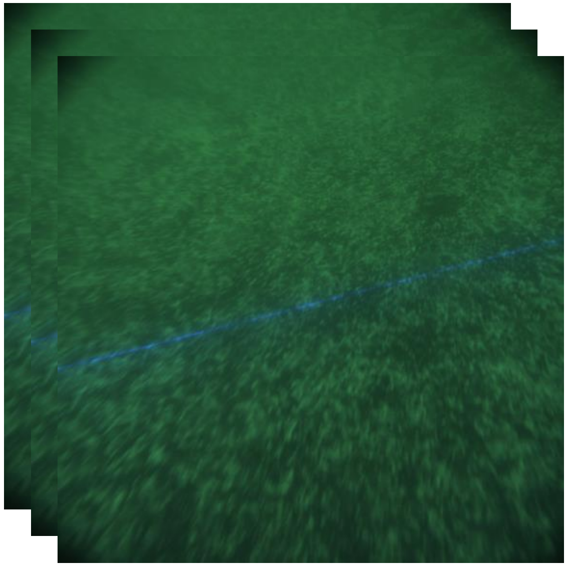
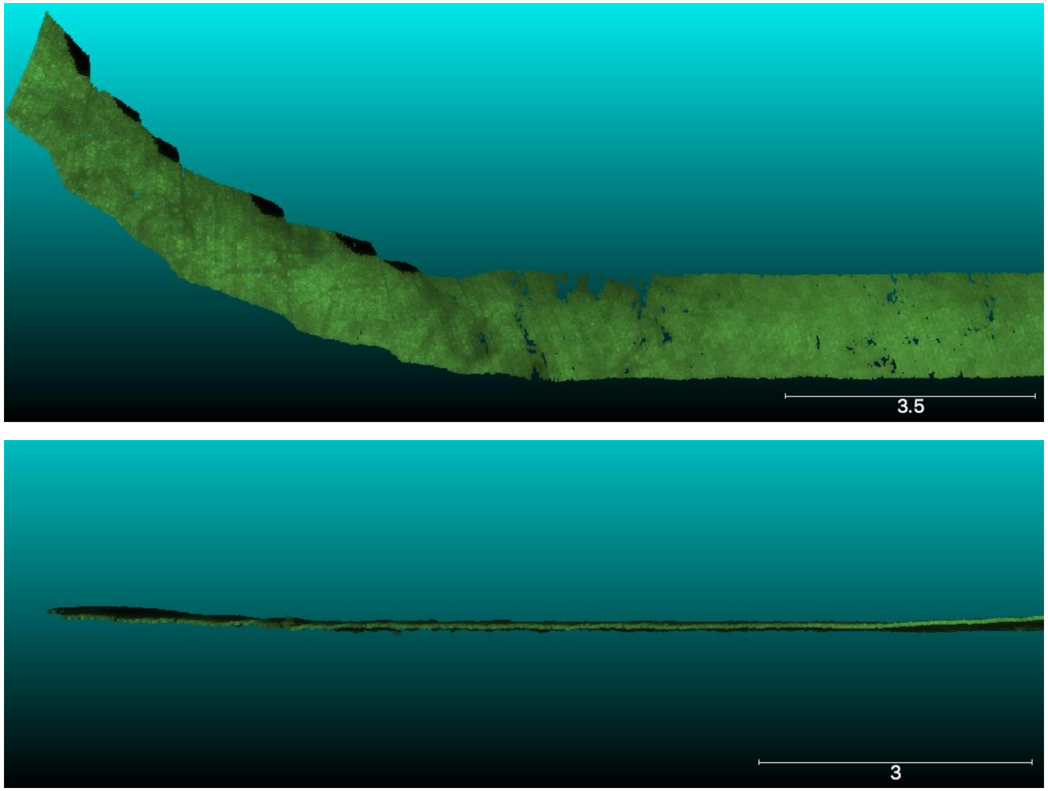


Image sequence



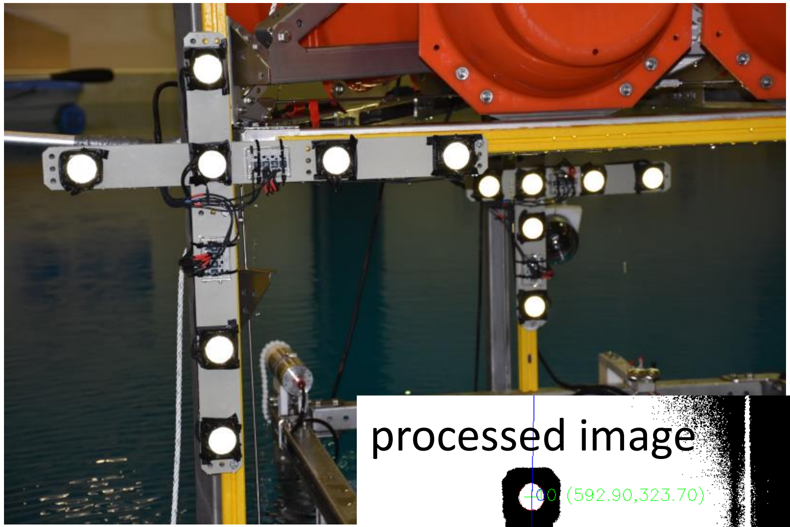
Reconstructed path segment 10 m using laser aided photogrammetry

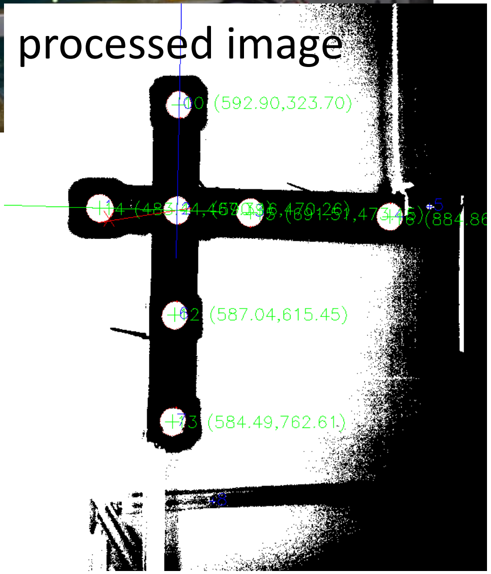
Sensor Head

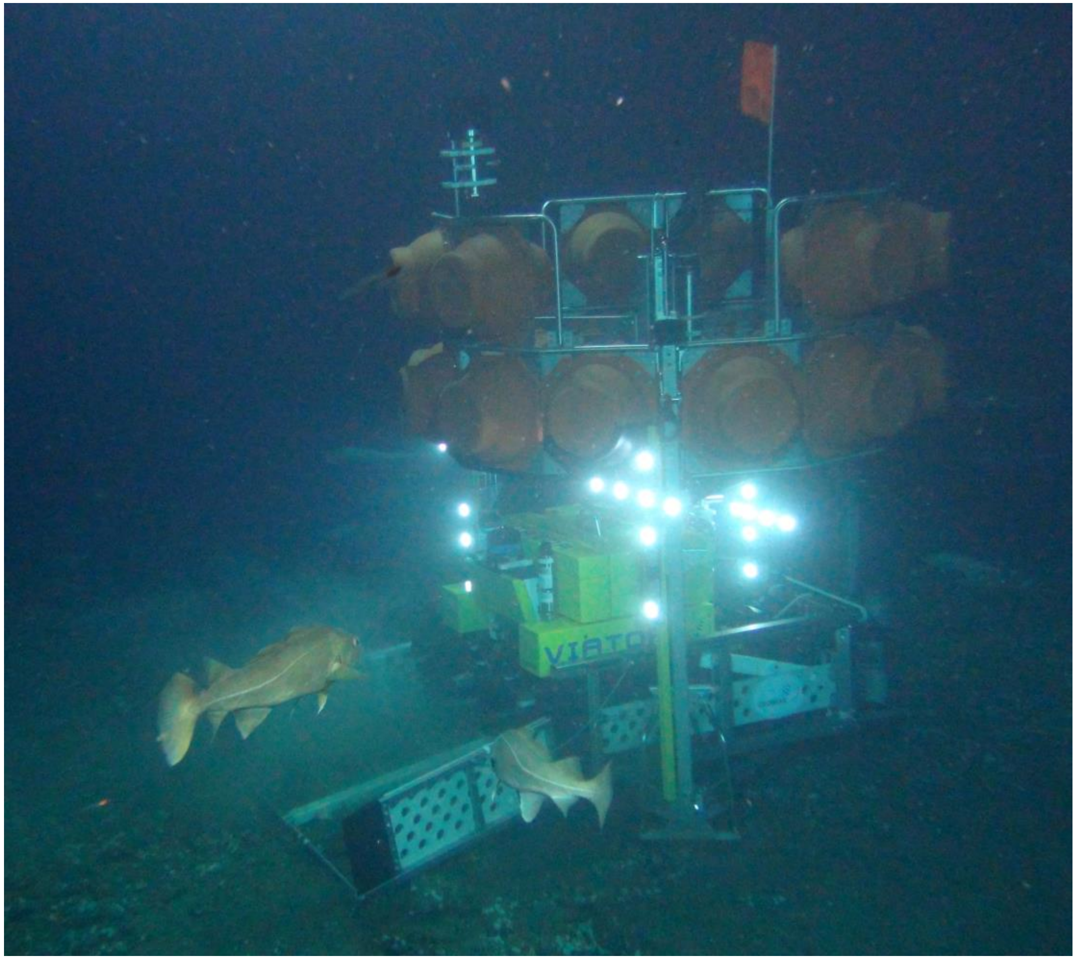
- PTU
- Camera
- Line Laser

MANSIO-VIATOR naviagation/docking

- … active LED markers work up to a distance of 10 m
- … 7 LEDs per marker -> pose estimation



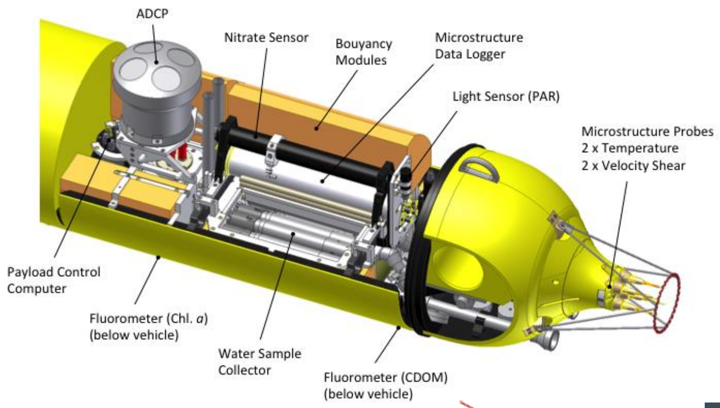


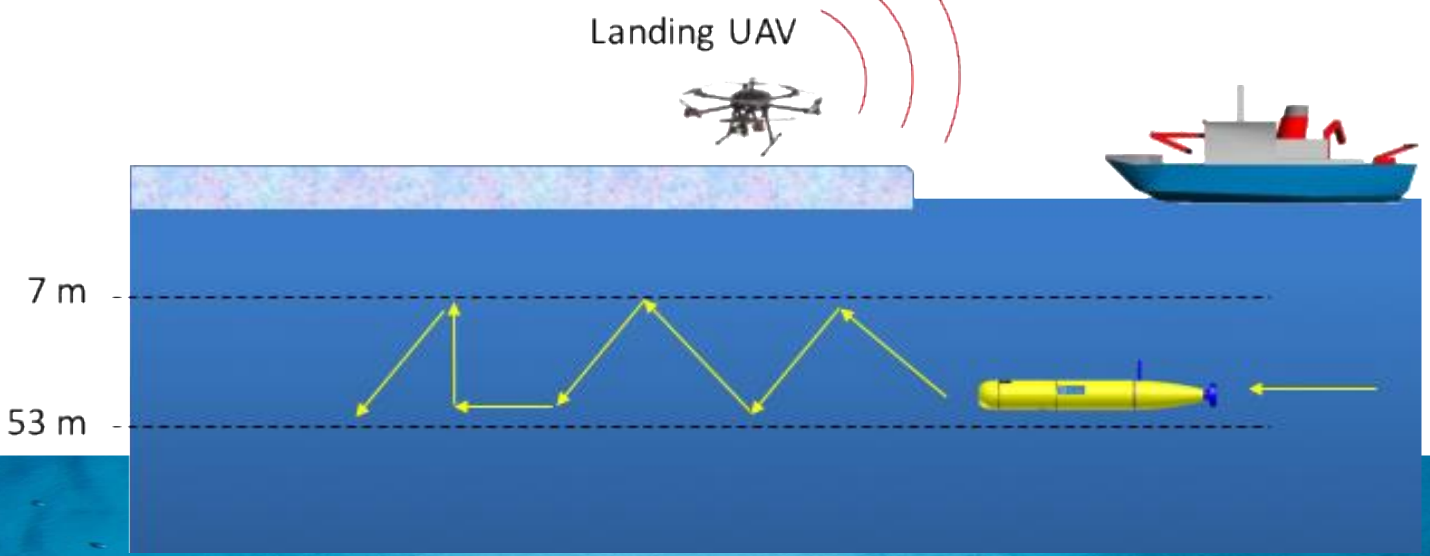


AUV mission under sea ice

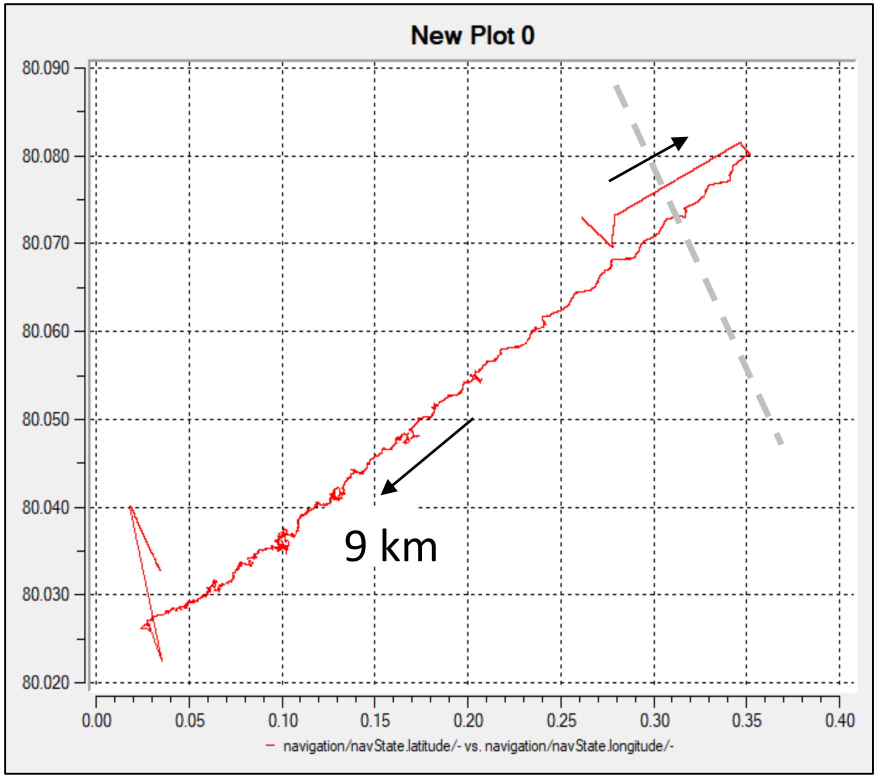
Quantification of biological and physicochemical properties under sea ice

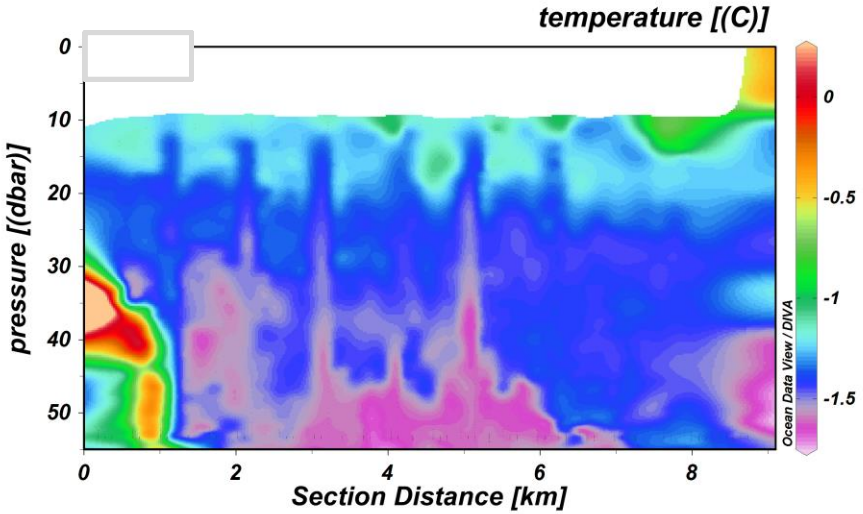
Detection of life

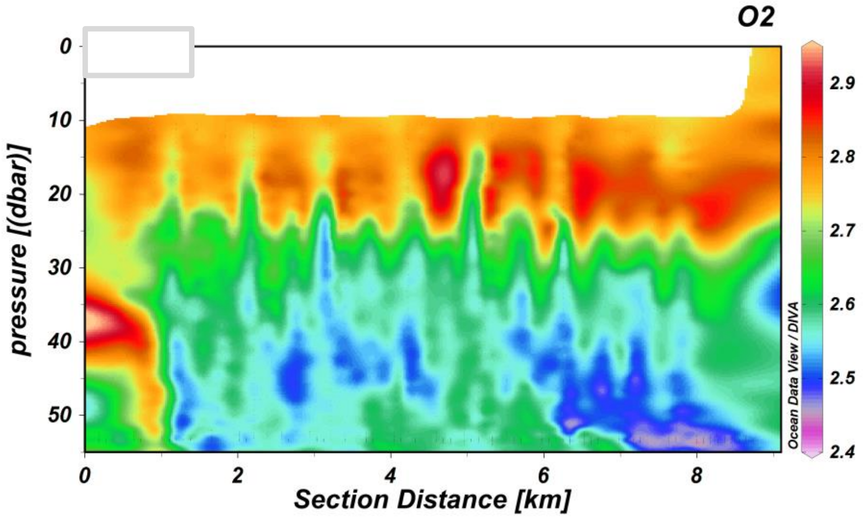




AUV mission under sea ice

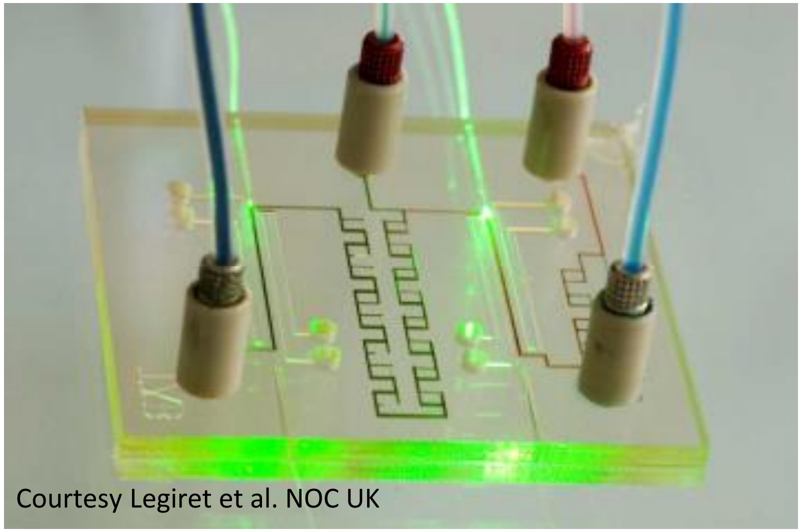




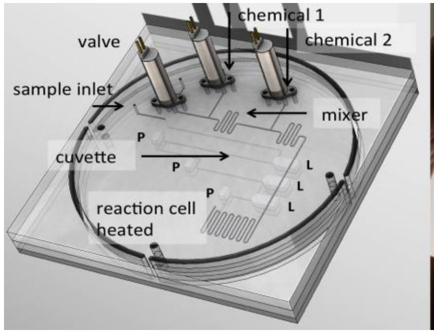


Lab on a Chip

Vision: Miniaturisation – in situ „Lab-on-a-chip“ (microfluidics)



Courtesy Legiret et al. NOC UK

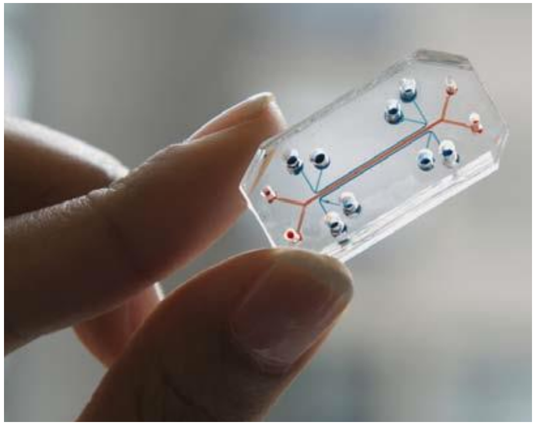


Sensors Analytics

*Nutrients (**NO_3^-, NO_2^-, Fe**), pCO_2, DIC, pH organics, etc.*

Experiments

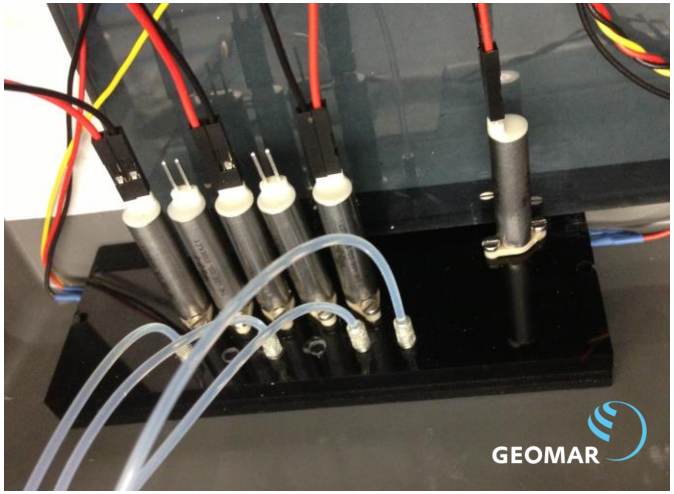
Lung tissue Chip (Whyss Institute)



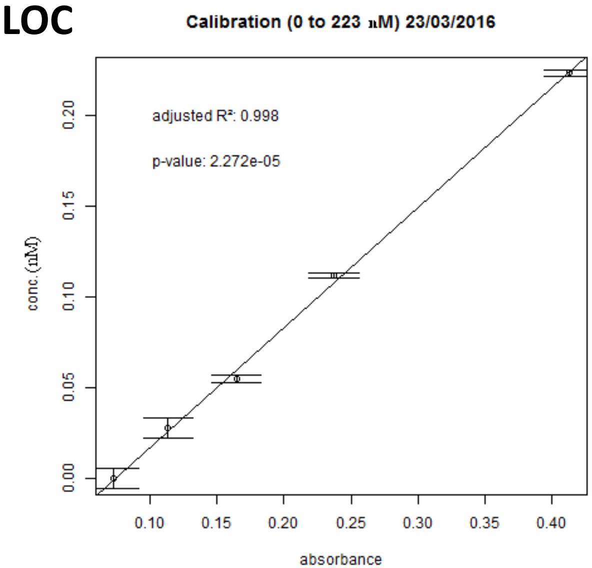
Advantages

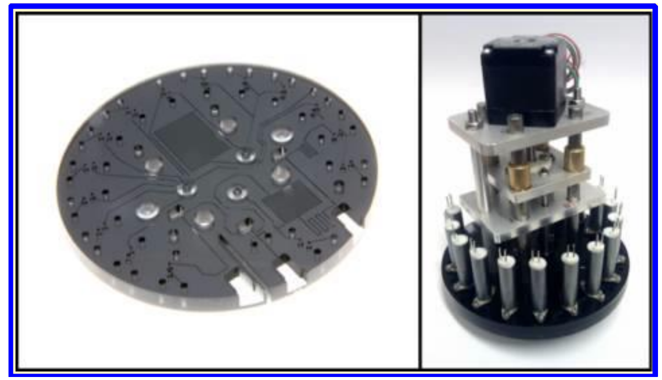
Low weight, size, energy demand, fast analysis time, calibrated

UW LOC measurements of nutrients



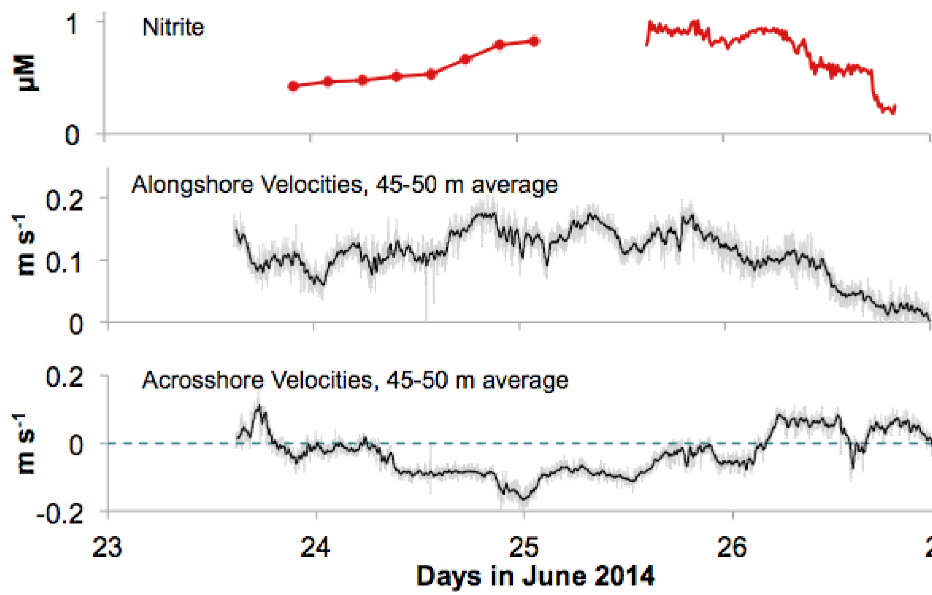
Fe-LOC





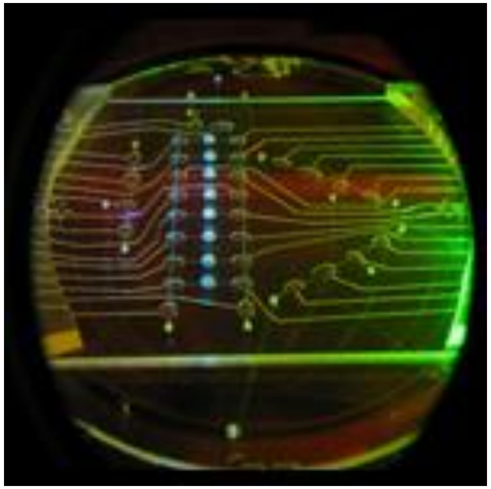
NO_2^-/NO_3^-LOC

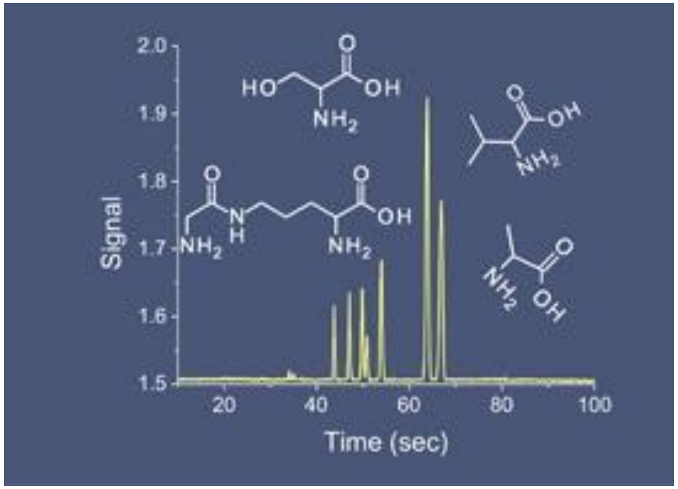
Yücel et al. 2015
coop. with NOCS



Space applications of LOC Technology

Astrobiology / ISS (LOCAD-PTS: Gram +/- Bacteria, Fungi), search for life





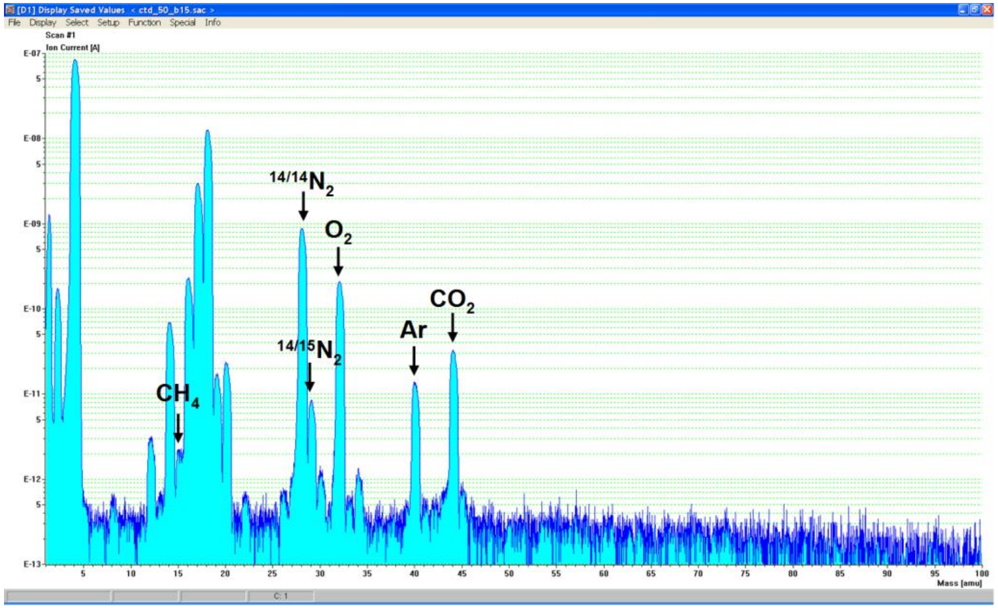
on-chip capillary electrophoresis, Skelley et al. 2005

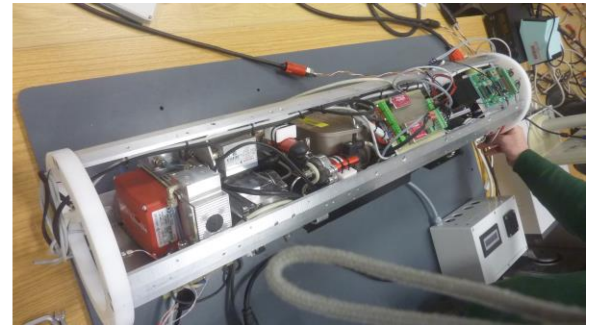
esa exomars

NASA

Ocean science (emerging but still in it´s infancies, potential might be vast but needs to be explored)

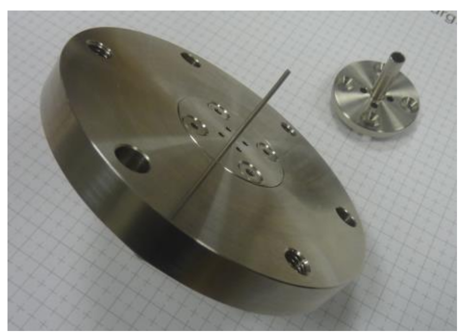
UW-MIMS technology – Quarupole mass filter

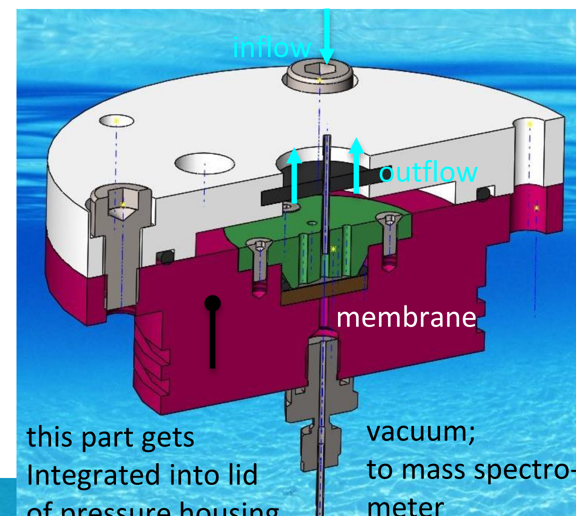




Membrane (Teflon/Silicone on permeable metal carrier)

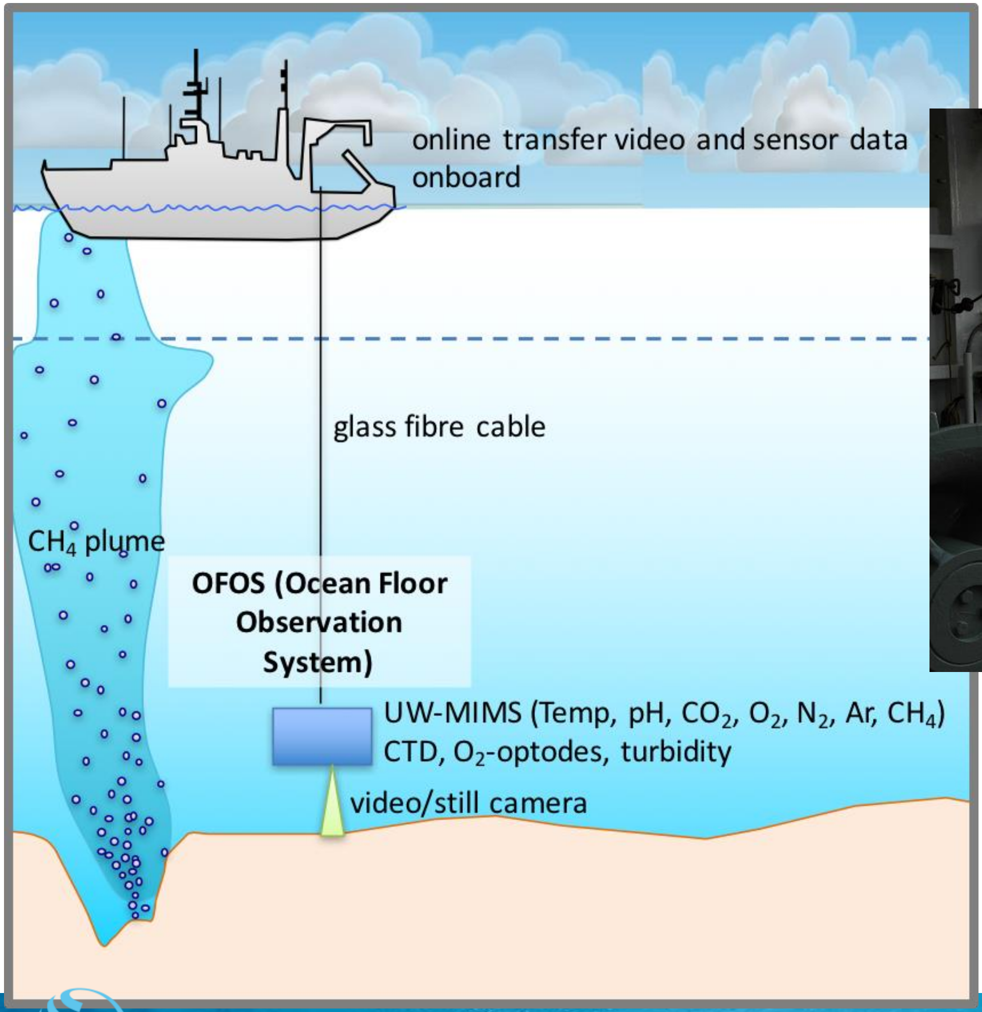
Membrane inlet

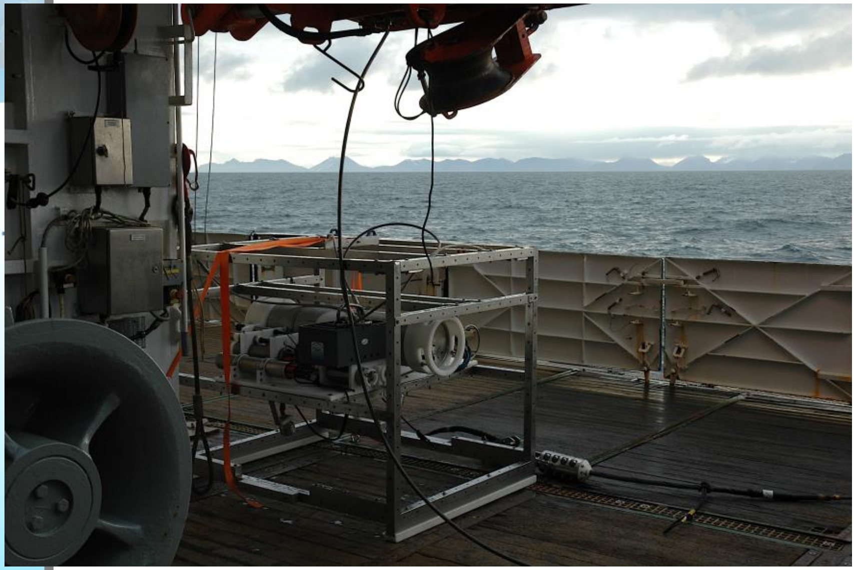




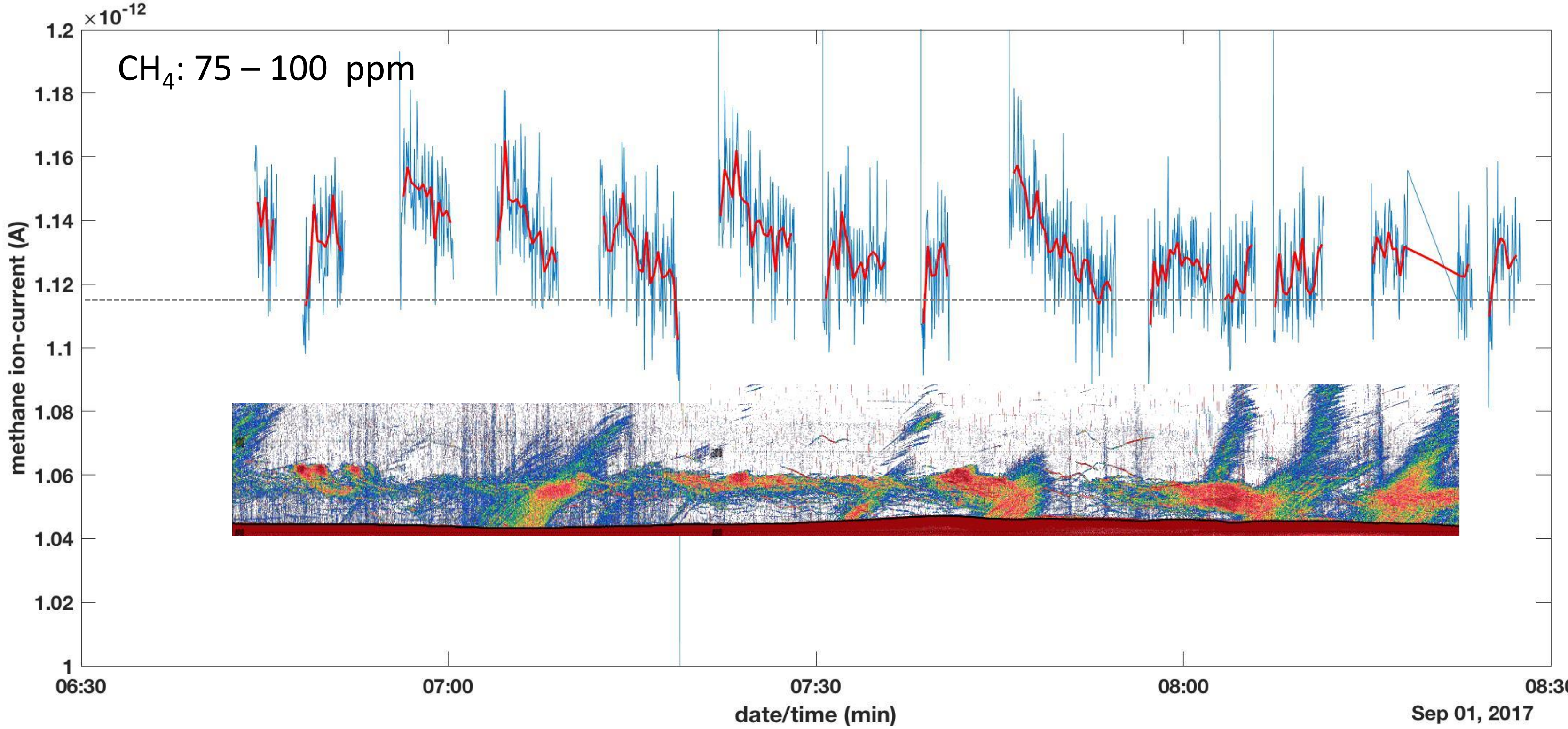
UW-MIMS technology – Quarupole mass filter

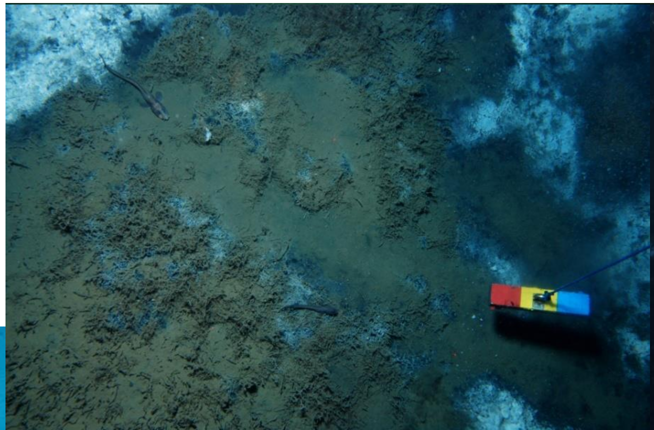
UW-MIMS technology for simultaneous measurement of volatiles - First tests at methane seeps off Spitsbergen Polarstern Cruise PS108





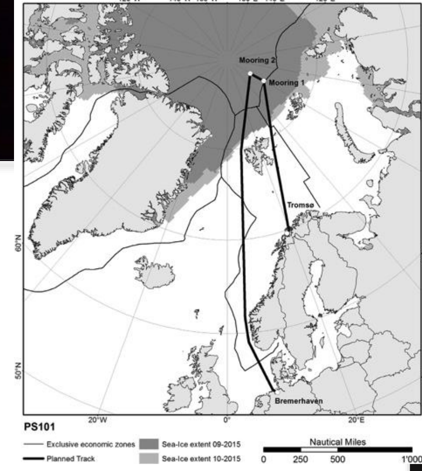
Methane seepage off Spitsbergen – hydroacoustic, chemical, and visual sensing

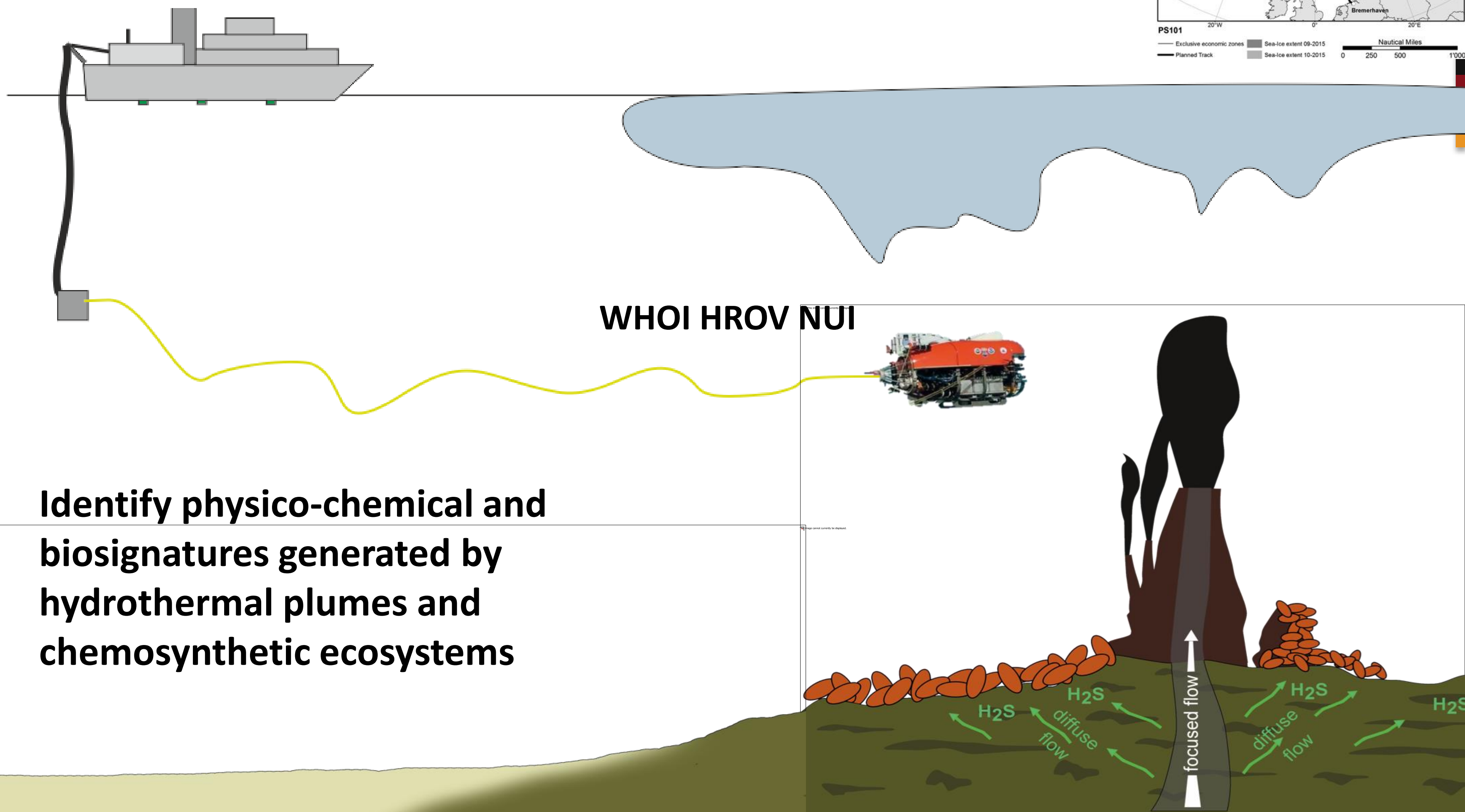




PS 101 2016 (Karasik Seamount – Hydrothermal vents)

PI: Chris German (WHOI), Antje Boetius (AWI)



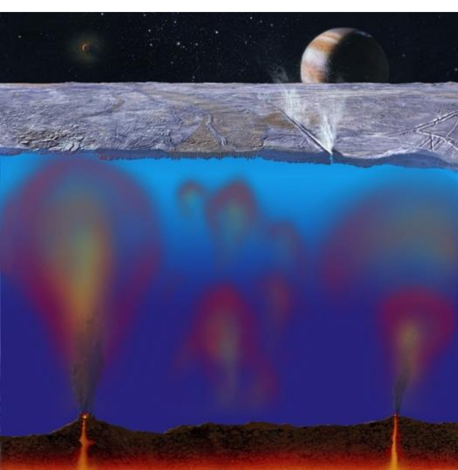


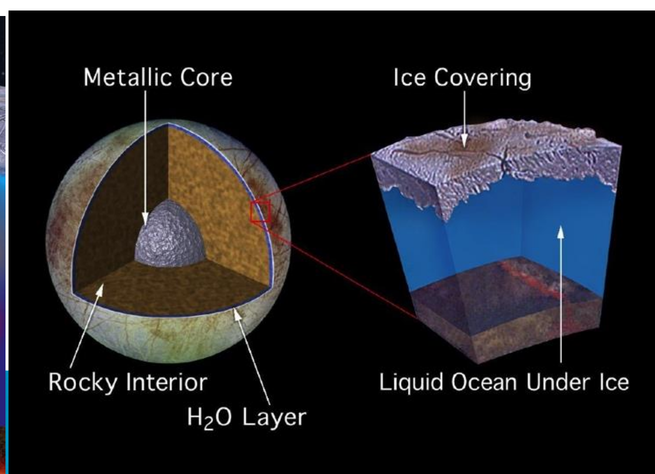
Identify physico-chemical and biosignatures generated by hydrothermal plumes and chemosynthetic ecosystems

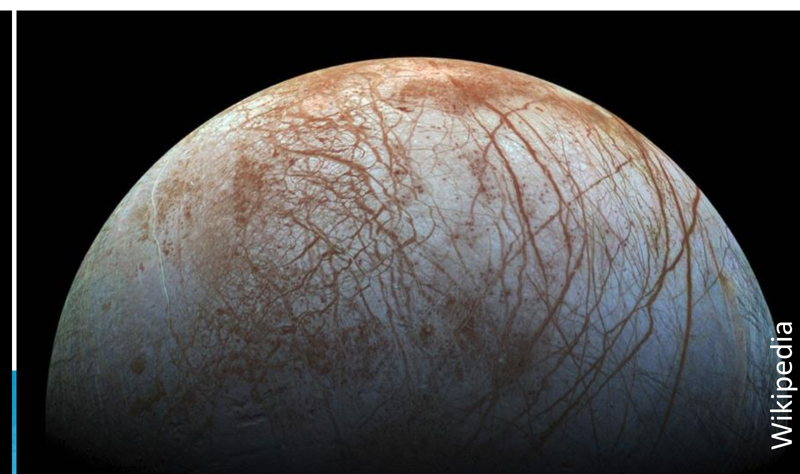
PS 101 2016 (Karasik Seamount – Hydrothermal vents)

Investigate the fate of biosignatures as they are released upward in hydrothermal plumes into the water column and/or the overlying ice-cover (NASA funded project; WHOI)

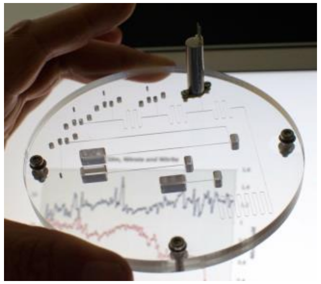
Europa: An Ocean under the ice



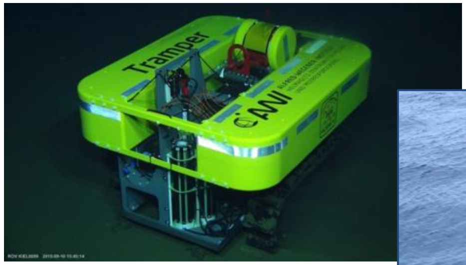




Summery/Conclusions

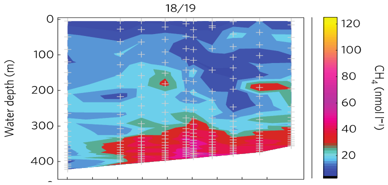


- **New robotic and sensor systems for ocean exploration**



- **Autonomous carrier platforms**

- **Concepts for mission scenarios for habitat detection and mapping**



CH_4 distribution at seep sites off Spitzbergen
Steinle et al. Nature Geosciences 2015