Scoot Swedish Centre for Ocean Observing Technology

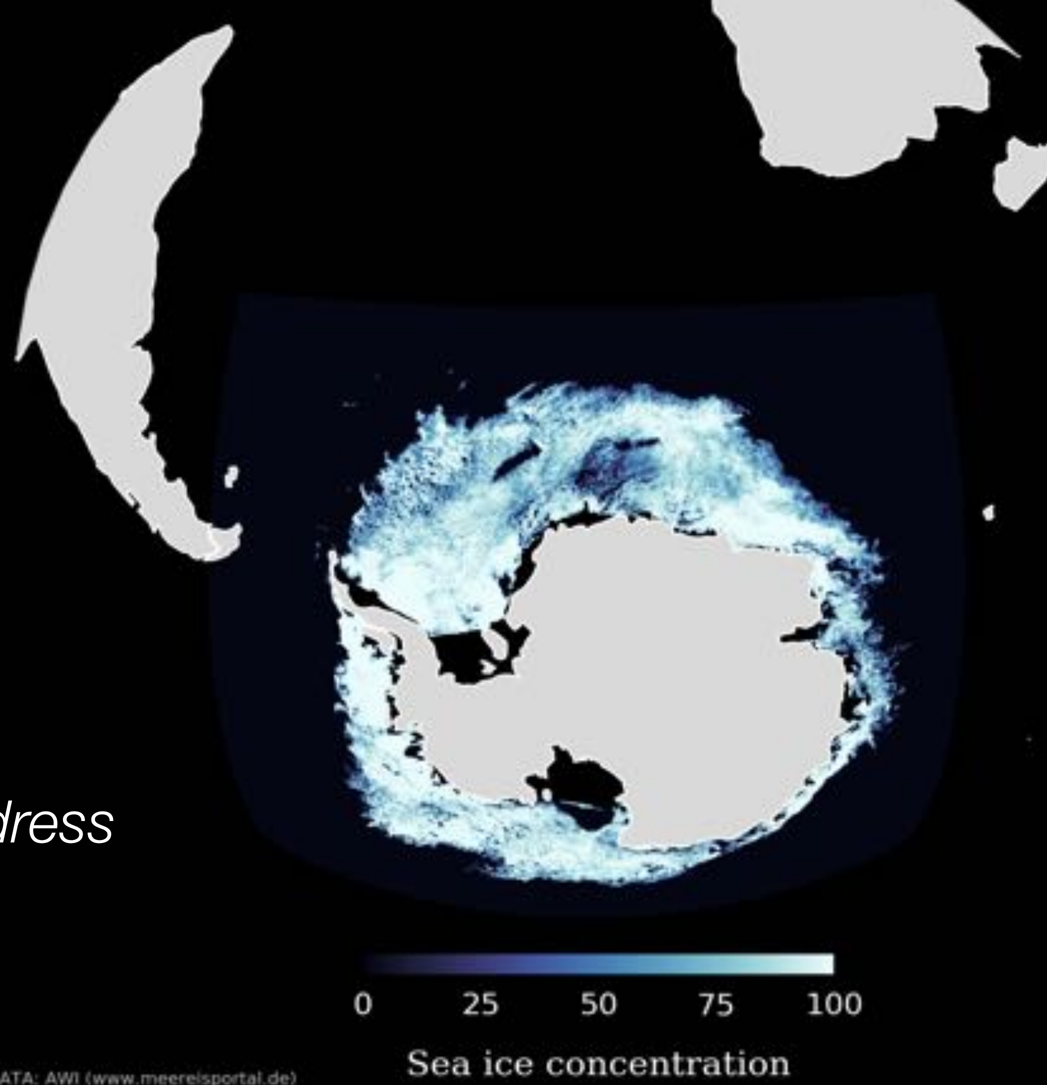
SCOOT enables ocean research and innovation

UNIVERSITY OF GOTHENBURG

MMT

SMHI

EUROPEAN UNION
European Regional Development Fund

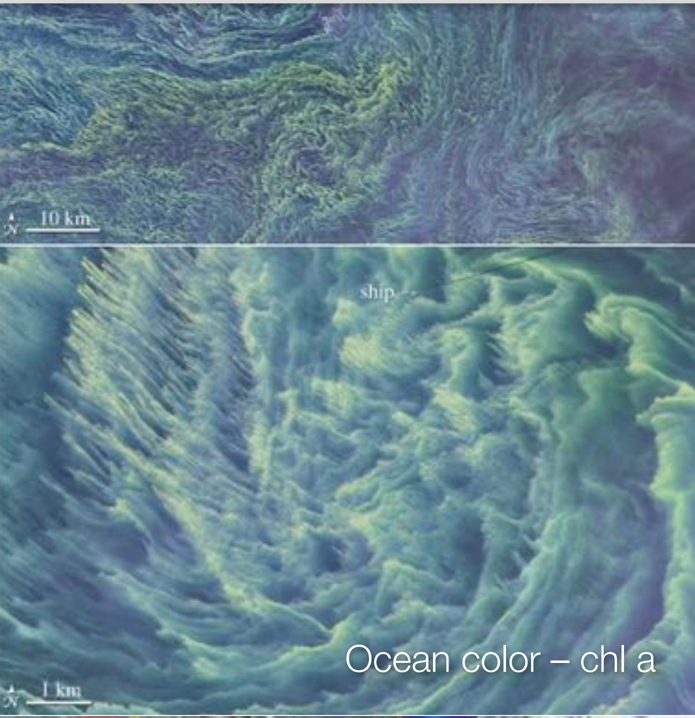


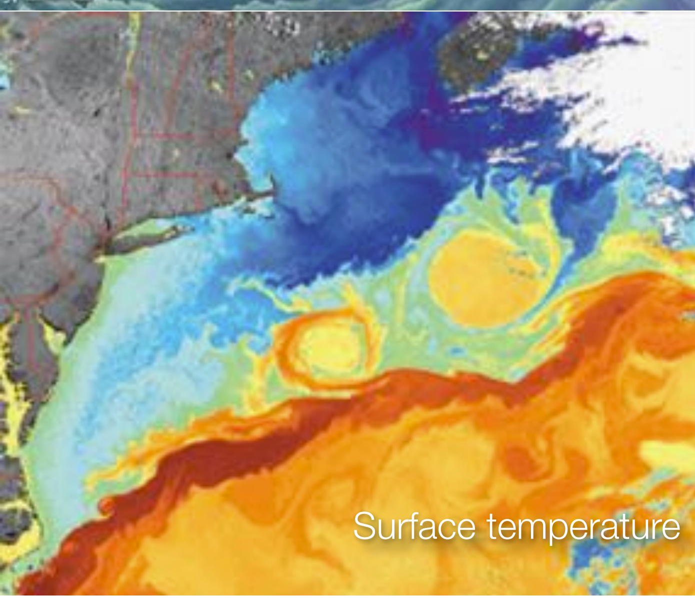
Observing new scales to address a global challenge

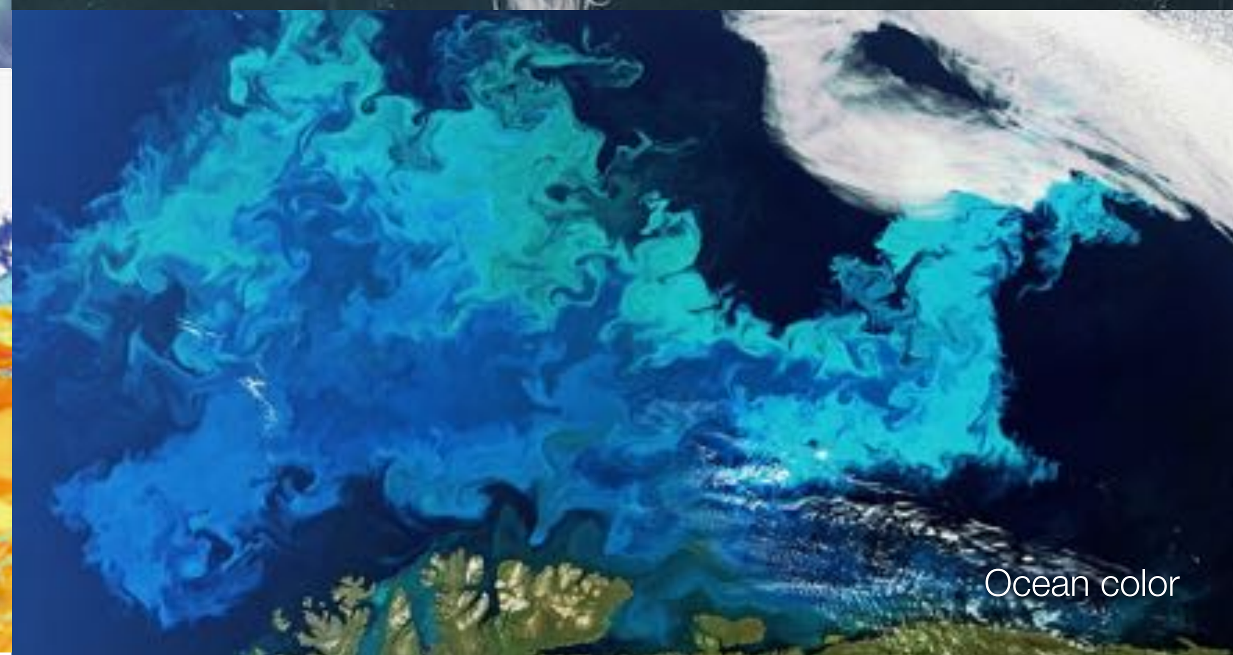
UNIVERSITY OF GOTHENBURG

Sebastiaan Swart

Ocean weather





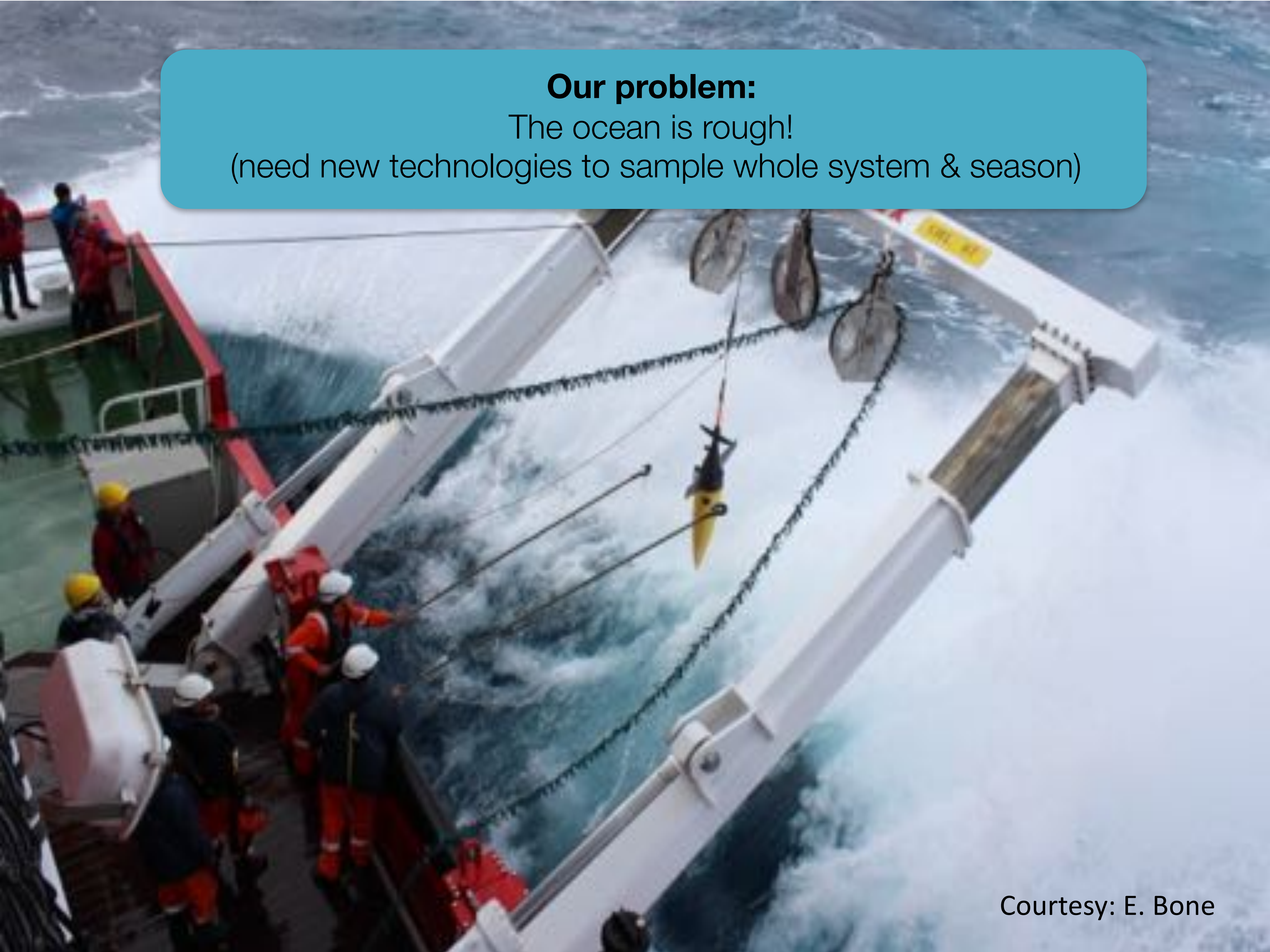



Our problem: The ocean is massive & often remote!

Our problem:

The ocean is rough!

(need new technologies to sample whole system & season)

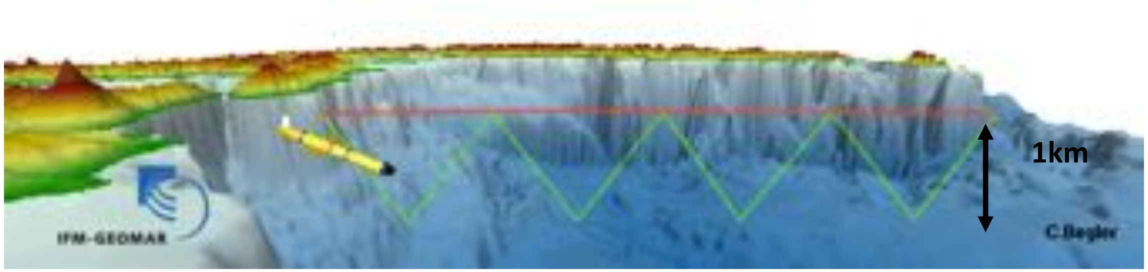


Courtesy: E. Bone

Research Approach 2019-2022

Why robotics?

U = 25 km/day
2 km between dives
Autonomy = 6-13 months



overcoming the very low frequency "snapshot" sampling from ships

Physical
&
Biological
Sensors

The Southern Ocean ‘blind spot’

Collecting high-resolution, seasonal observations of the upper ocean in the MIZ

WALLENBERG ACADEMY FELLOWS

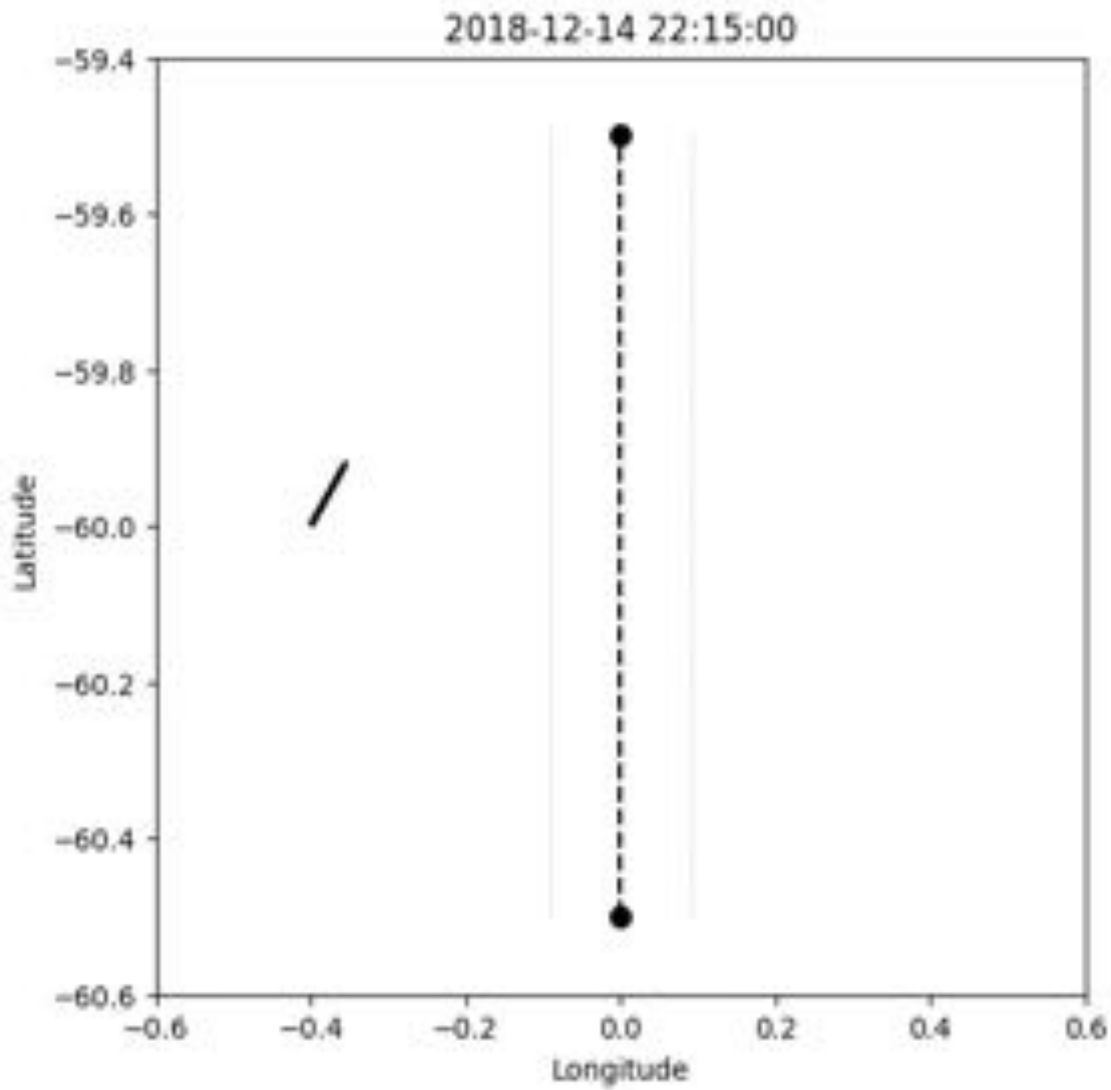
UNIVERSITY OF GOTHENBURG


ROAM
MIZ
OBSERVE • RESEARCH • EXPLORE


Sailbuoy movements

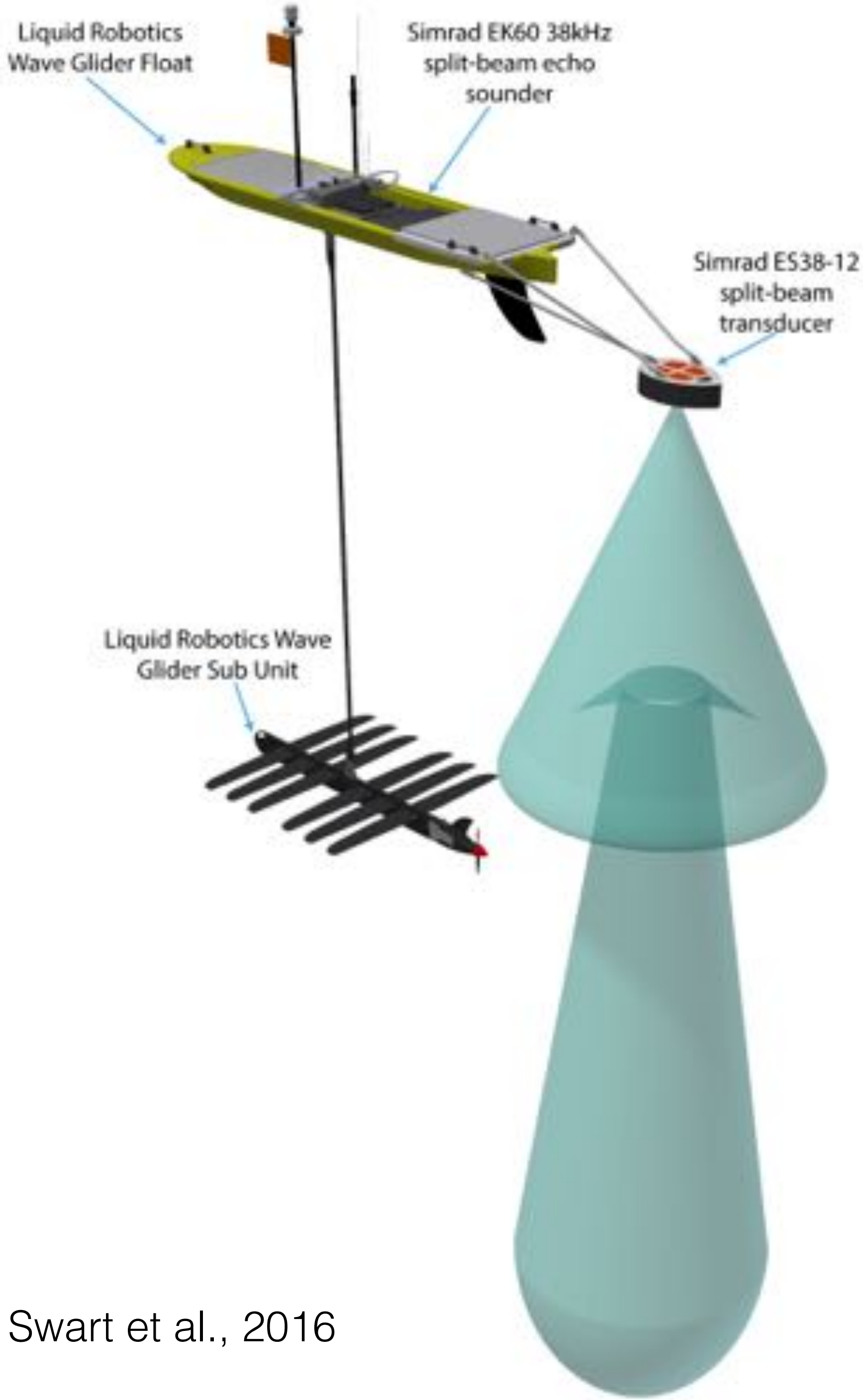
Colour is wind intensity (grey = weak, red = strong), arrow shows wind direction

Thick black line is intended line, thin grey lines are corridor width (5km)



Courtesy: F. Fourie

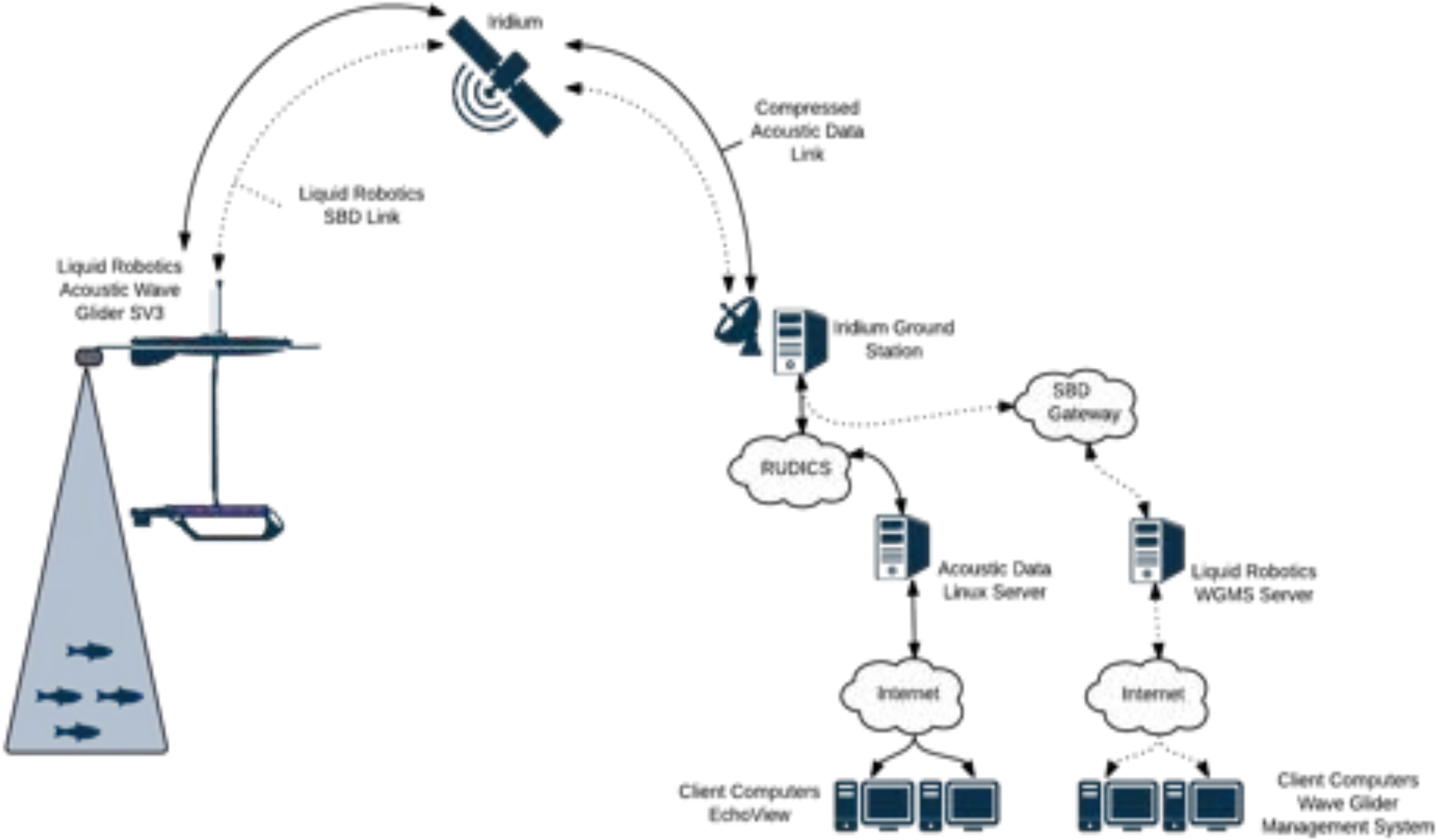
Spring – Summer MLD progression… a reminder of scales



Swart et al., 2016

Fisheries Acoustics Wave Glider

Carbon + Met Wave Glider

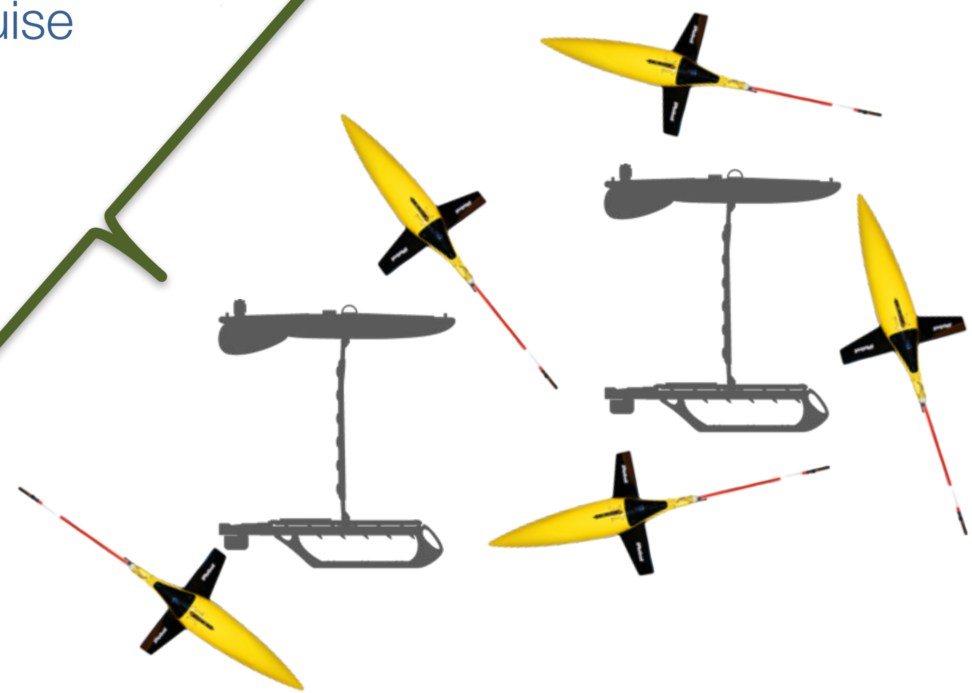


Fisheries Acoustics Wave Glider

Swart et al., 2016

What is the cost to data ratio…?

Standard 4 week research cruise
± $ 1.5 M)
Excl. personal, salaries,
expendables



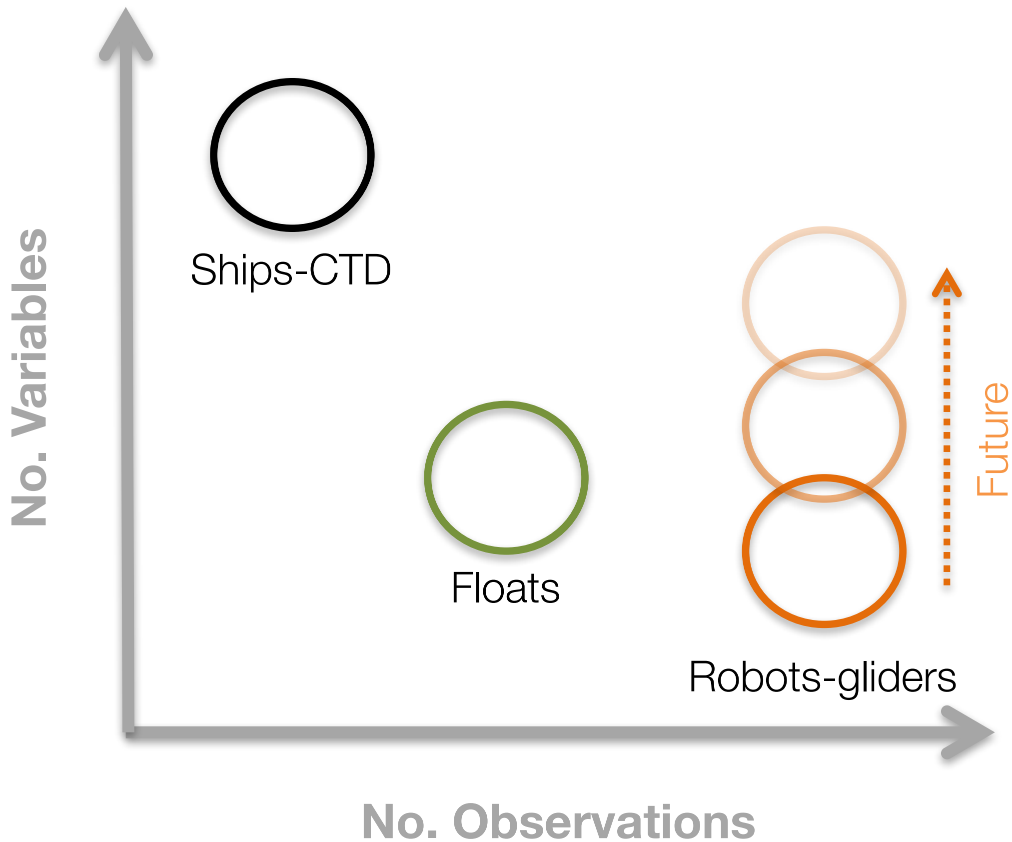
Sampling continuously, at high
frequency, with limited personal

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…

Observational marine science needs to move away from the dependence on large research vessels…

Ever growing measurement to variable ratio



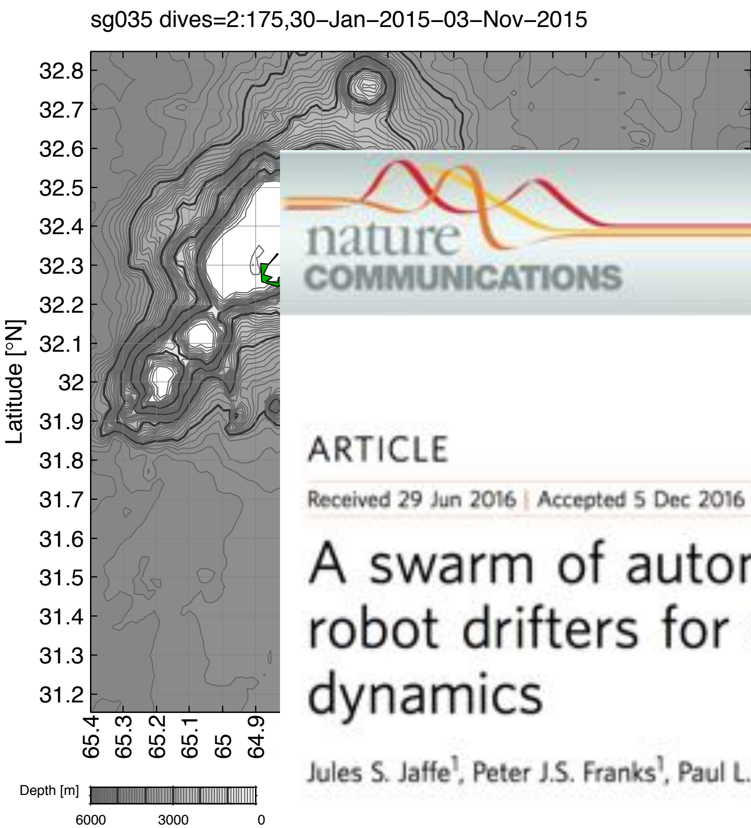
Ever increasing payloads

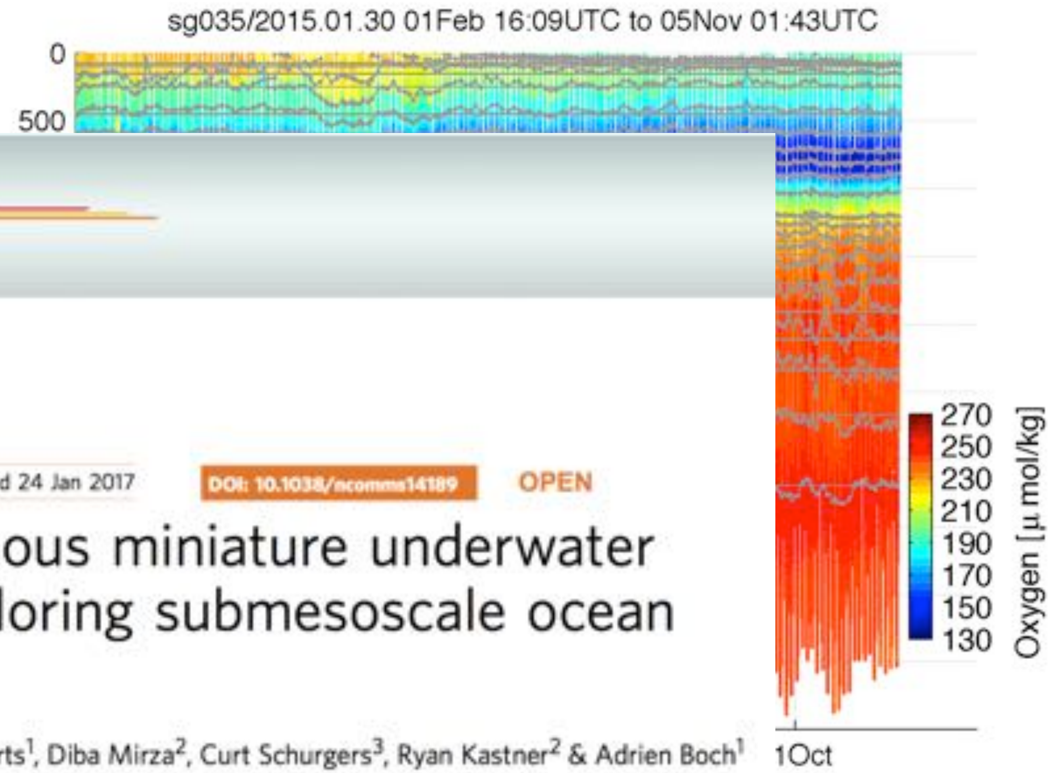
- CTD – free flow or pumped
- Dissolved oxygen – Clarke Electrode or Optode
- Fluorescence –chlorophyll, CDOM
- Fast repetition rate fluorometer – phytoplankton physiology
- Optical backscatter – particles, POC
- Beam transmission – particles, POC
- Nitrate
- Velocity – depth average, ADCP
- Turbulence – temperature and shear microstructure
- Passive acoustics – marine mammals, ambient noise, rain rate, wind
- Radiometers – PAR, spectral
- Zooplankton – cameras, acoustics
- Acoustic modem – communications, data relay
- Altimeter
- Echosounder
- Acoustic navigation
- pH
- CO_2

What does a climate scientist dream about…?

- ❑ Miniaturization
- ❑ Affordability
- ❑ Masses of robots
- ❑ Robustness
- ❑ Endurance
- ❑ (Reproducibility of measurements)
- ❑ (State of the art)

New developments & the future





nature COMMUNICATIONS

ARTICLE

Received 29 Jun 2016 | Accepted 5 Dec 2016 | Published 24 Jan 2017 DOI: 10.1038/ncomms14189 OPEN

A swarm of autonomous miniature underwater robot drifters for exploring submesoscale ocean dynamics

Jules S. Jaffe[1], Peter J.S. Franks[1], Paul L.D. Roberts[1], Diba Mirza[2], Curt Schurgers[3], Ryan Kastner[2] & Adrien Boch[1]

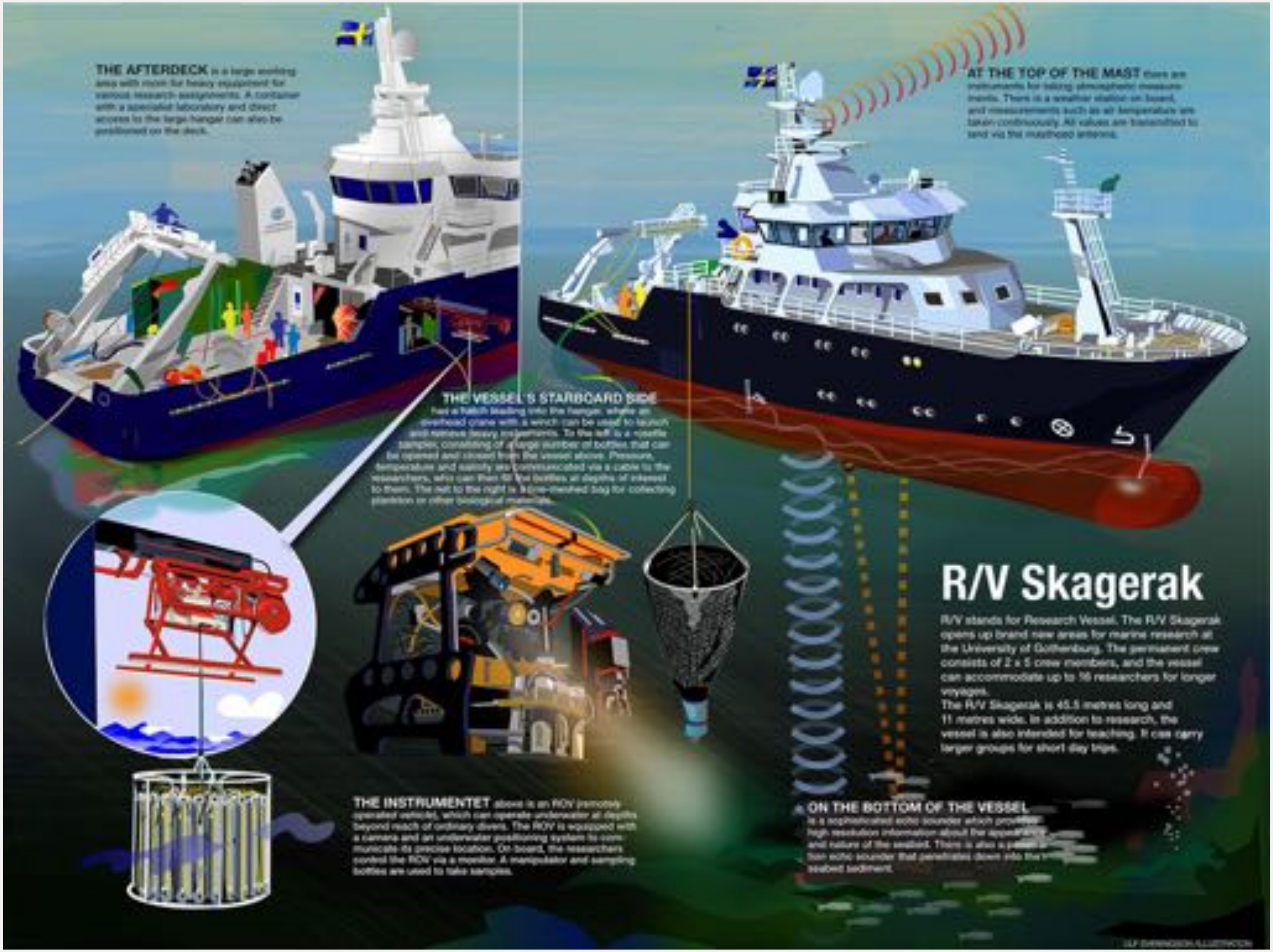
n, UW

Measuring the ever-changing 3-dimensional (3D) motions of the ocean requires simultaneous sampling at multiple locations. In particular, sampling the complex, nonlinear dynamics associated with submesoscales (<1-10 km) requires new technologies and approaches. Here we introduce the Mini-Autonomous Underwater Explorer (M-AUE), deployed as a swarm of 16 independent vehicles whose 3D trajectories are measured near-continuously, underwater. As the vehicles drift with the ambient flow or execute preprogrammed vertical behaviours, the simultaneous measurements at multiple, known locations resolve the details of the flow within the swarm. We describe the design,

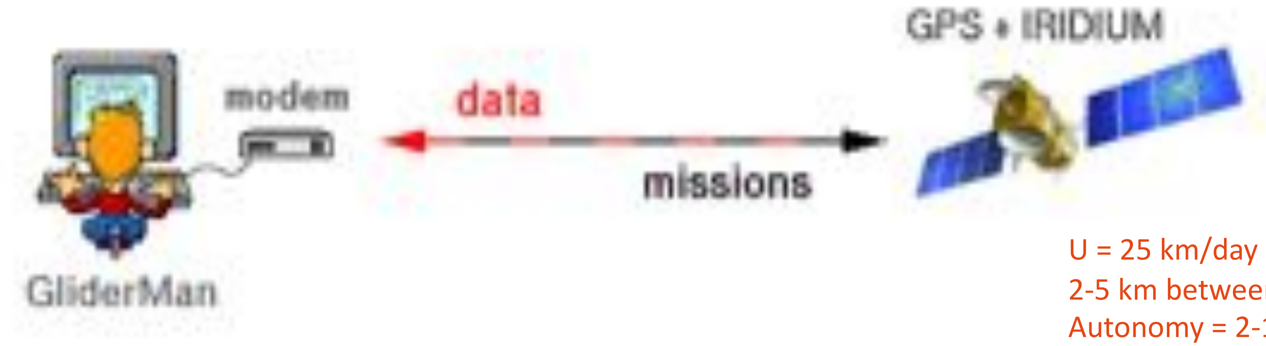
The future?

More info: www.sebswart.com

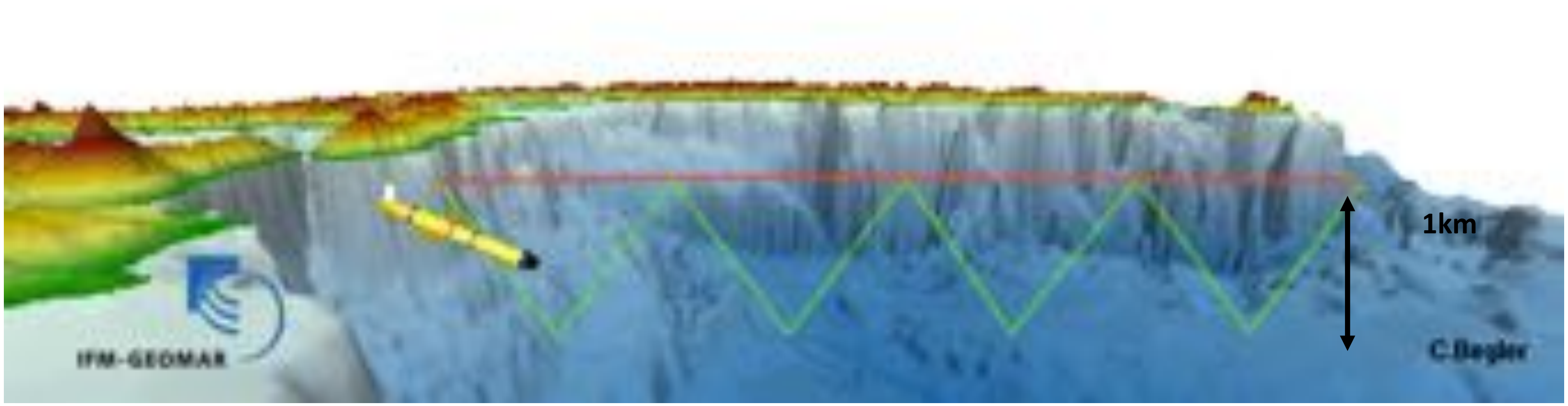

Marine Infrastructure at the University of Gothenburg
Tjärnö Marine Laboratory, Strömstad
Kristineberg Marine Research Station, Fiskebäckskil
Old R/V Skagerak, to be replaced during 2019
New R/V Skagerak, to be delivered in 2019
Ocean Observing platforms
Autonomous Underwater Vehicle
Autonomous benthic lander
Remotely Operated Vehicles
Seaglider
Autonomous Surface Vessel (ASV)


THE AFTERDECK
AT THE TOP OF THE MAST
THE VESSEL'S STARBOARD SIDE
R/V Skagerak
R/V stands for Research Vessel. The R/V Skagerak opens up brand new areas for marine research at the University of Gothenburg. The permanent crew consists of 2 x 5 crew members, and the vessel can accommodate up to 16 researchers for longer voyages.
The R/V Skagerak is 45.5 metres long and 11 metres wide. In addition to research, the vessel is also intended for teaching. It can carry larger groups for short day trips.
THE INSTRUMENTET
ON THE BOTTOM OF THE VESSEL

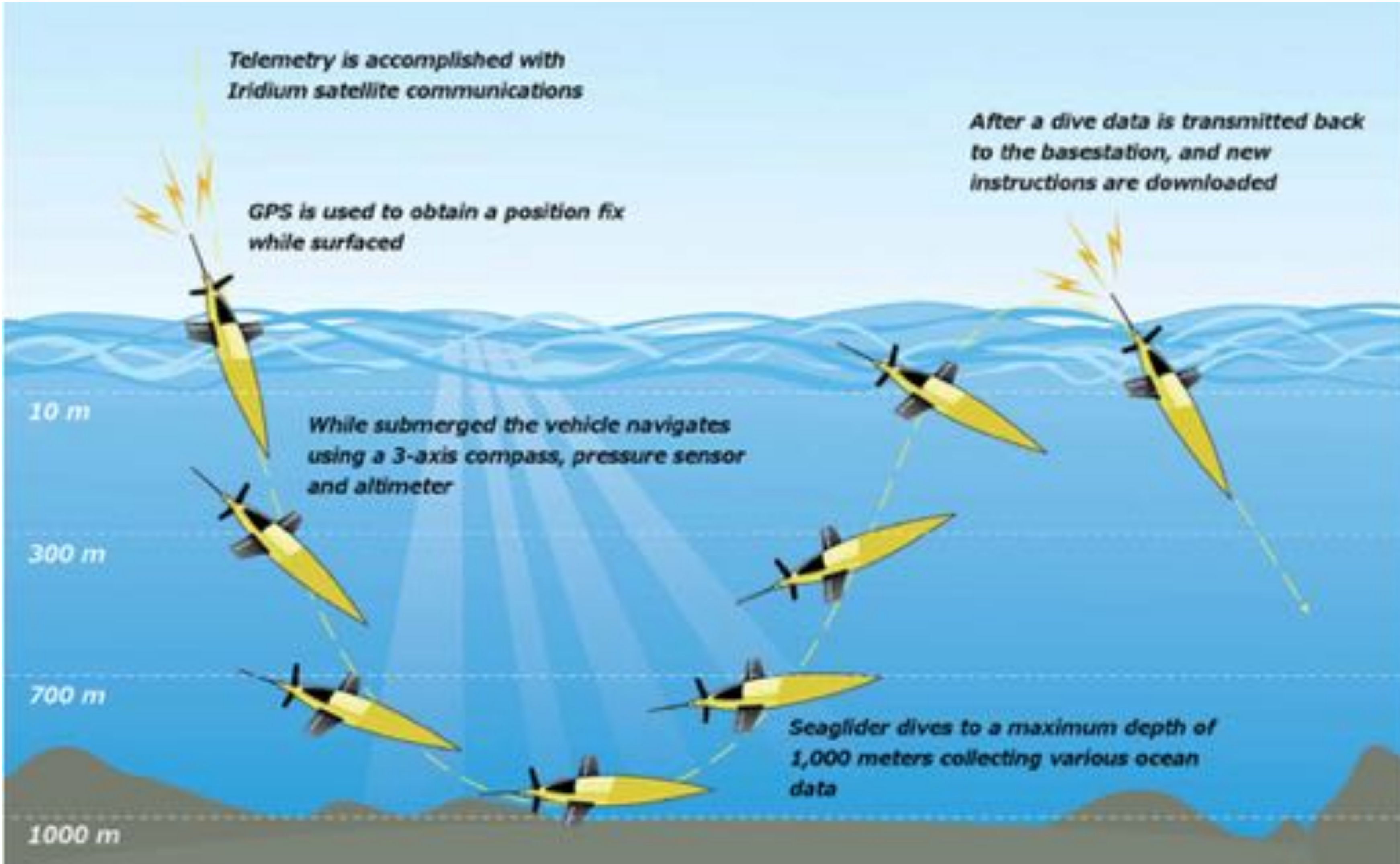
How do gliders work & why utilise them?

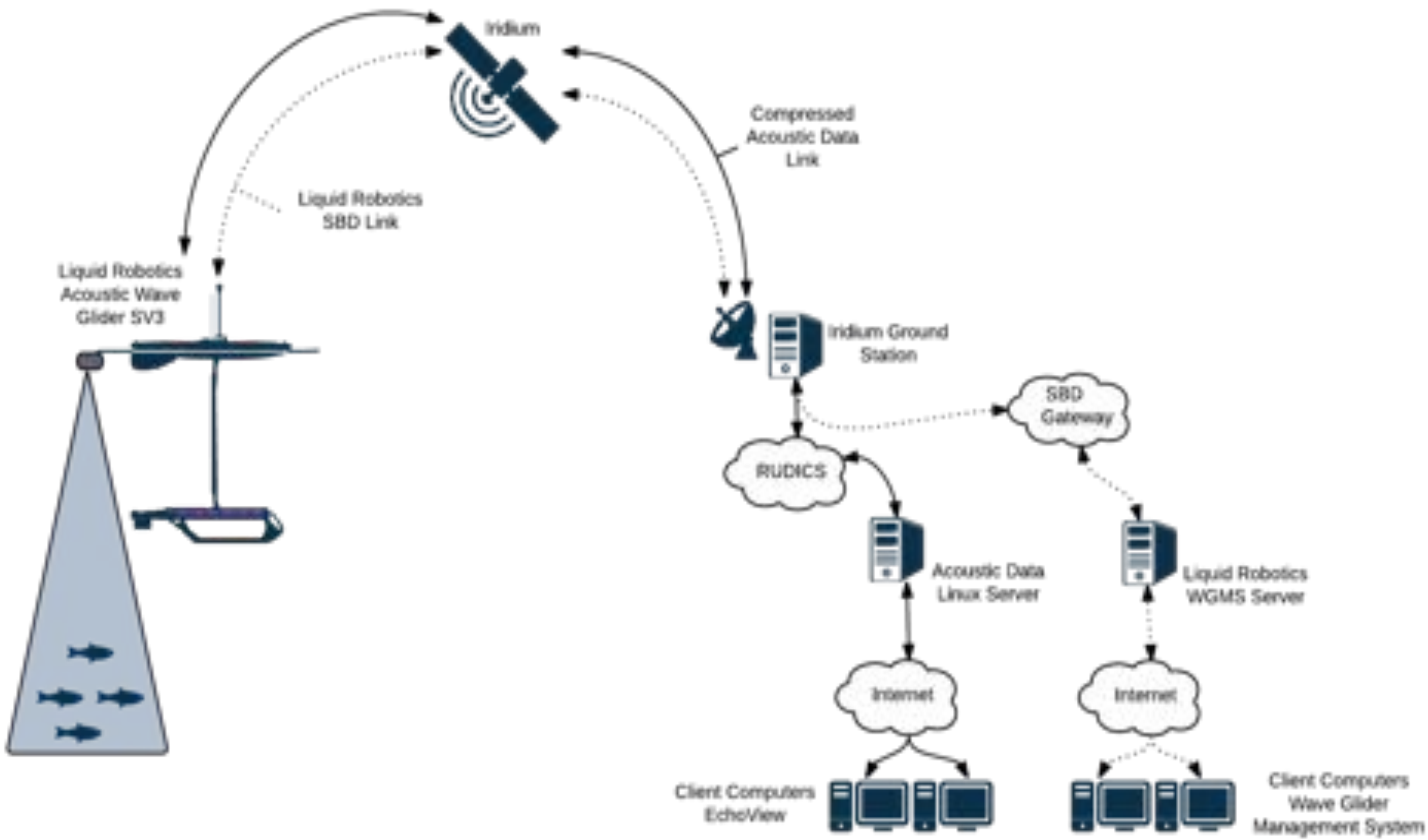


U = 25 km/day
2-5 km between dives
Autonomy = 2-10 months



overcoming the very low frequency “snapshot” sampling from ships


Telemetry is accomplished with
Iridium satellite communications
After a dive data is transmitted back
to the basestation, and new
instructions are downloaded
GPS is used to obtain a position fix
while surfaced
10 m
While submerged the vehicle navigates
using a 3-axis compass, pressure sensor
and altimeter
300 m
700 m
Seaglider dives to a maximum depth of
1,000 meters collecting various ocean
data
1000 m



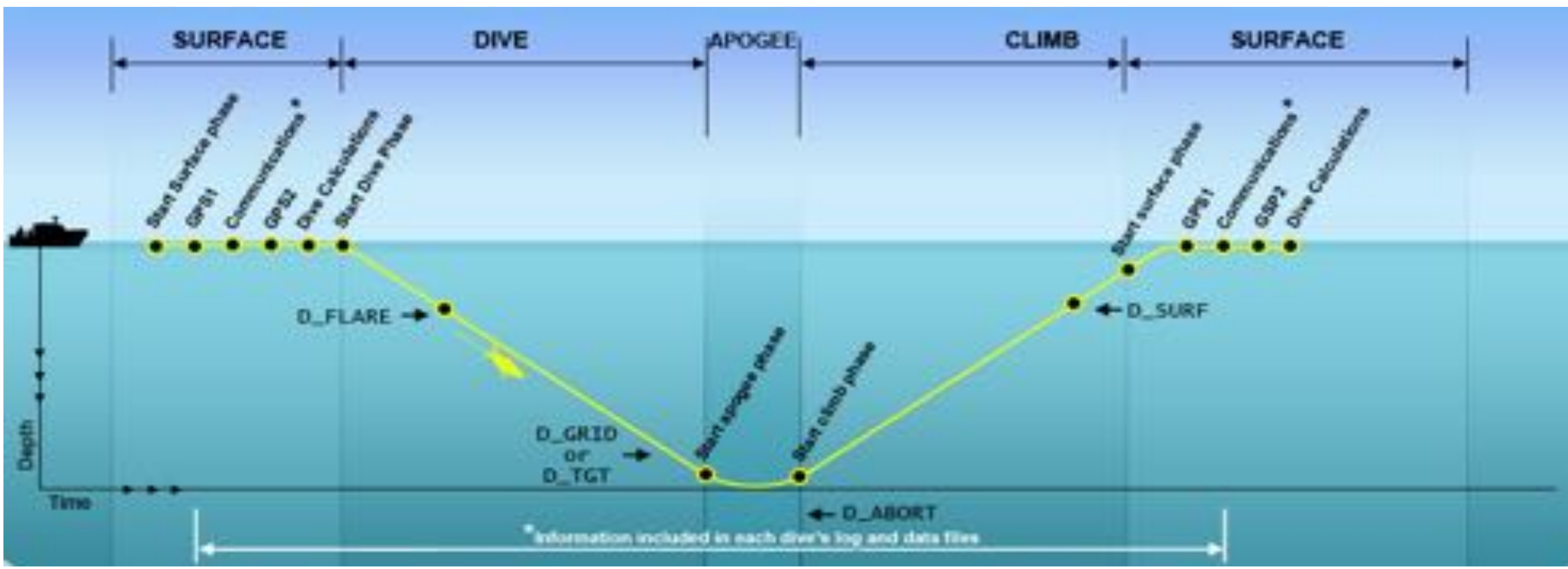
Swart et al., 2016

Gliders are ideal to measure the submesoscale

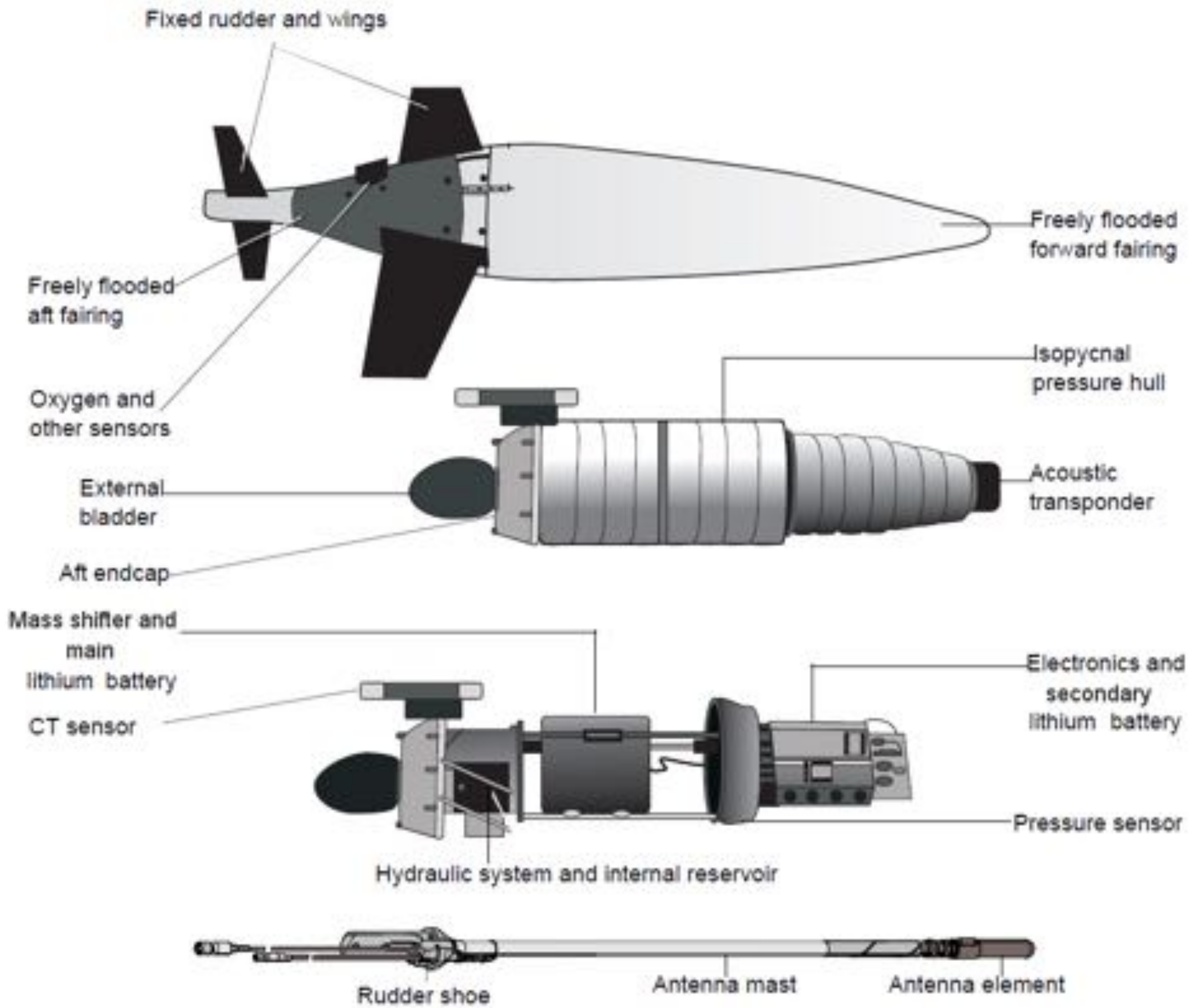
But shallower and/or faster dives use more battery

~ 4 km for dives to 1000 m depth

~ 0.4 km for dives to 100 m depth

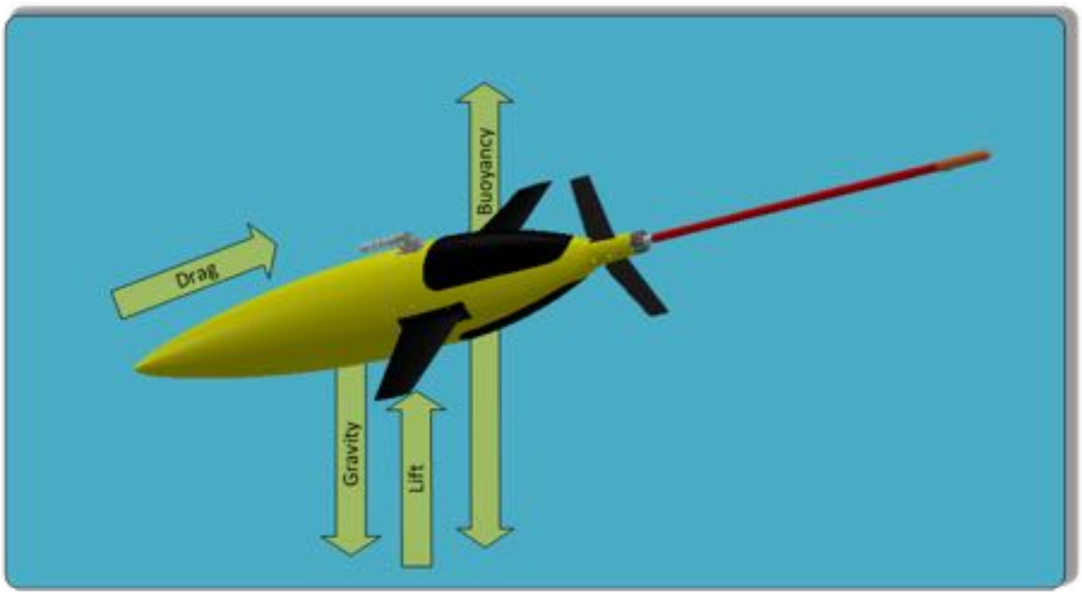


SEAGLIDER



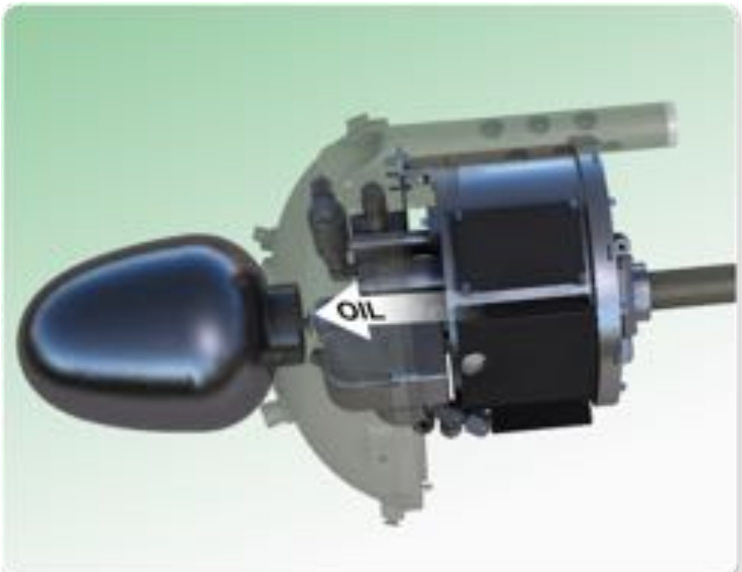
2m length, 1m wingspan, 52 kg, ~10 month endurance, 1km depth

Forces Affecting Glider Movement



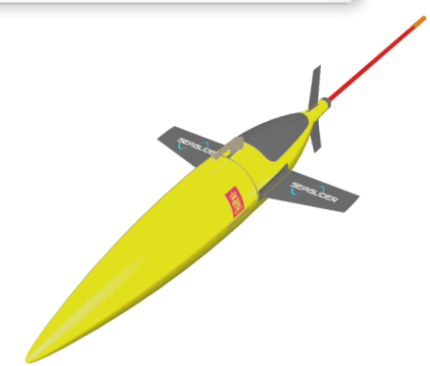
- **Static Forces**
  - Gravity
  - Buoyancy
- **Dynamic Forces**
  - Lift
  - Drag
- **Environmental Forces**
  - Stratification
  - Currents

Variable Buoyancy Device



Main Purpose

- Maintain Specified Total Vehicle Displacement
- Vary Size of Bladder



Glider Navigation Modes

- Ways to Navigate the Glider:
  - Waypoint Navigation - with or without current correction
  - Fixed Heading – with or without current correction

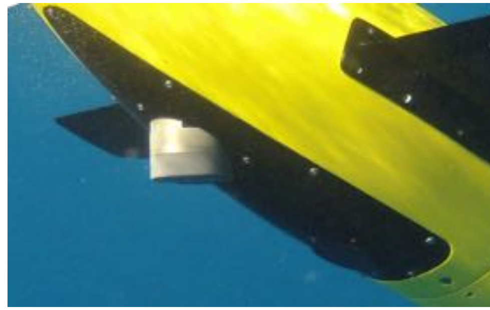
- Can Cover ~20 km Per Day Through Water in Normal Flight

Typical Sensors

- **CTD**
  - CT Sail (free flow)
  - GPCTD (pumped)
- **Dissolved Oxygen**
  - Aanderaa optode
  - Sea-Bird Electronics
  - KM Contros optode
  - JFE Rinko ARO-FT
- **Backscatter and Fluorescence**
  - WET Labs Eco Pucks
  - Turner Designs
  - Seabird SeaOWL
- **PAR**
  - Biospherical Instruments

Additional Sensors

- **Echo Sounder**
  - Imagenex ES 853
- **ADCP**
  - Nortek AD2CP
- **Microstructure Turbulence**
  - Rockland MicroPod
- **Passive Acoustics**
  - Kongsberg PAM
  - Ocean Sonics icListen
- **pCO2**
  - Aanderaa pCO2 optode
- **Fish Tag Detector**
  - Vemco VMT-35






MicroRider —Turbulence Payload Module

Turbulence sensors
- Shear Probes (2x)
- Fast Thermistors (1x)
- Micro Conductivity (1x option)

Supporting sensors
- Pressure
- Tilt
- Vibration 2x
- Gyro-sensors (option)

Data Recording
- Up to 64 GB memory

Supply (by platform)
- 9 — 18 VDC, ~1W
- Trigger signal (data on/off)

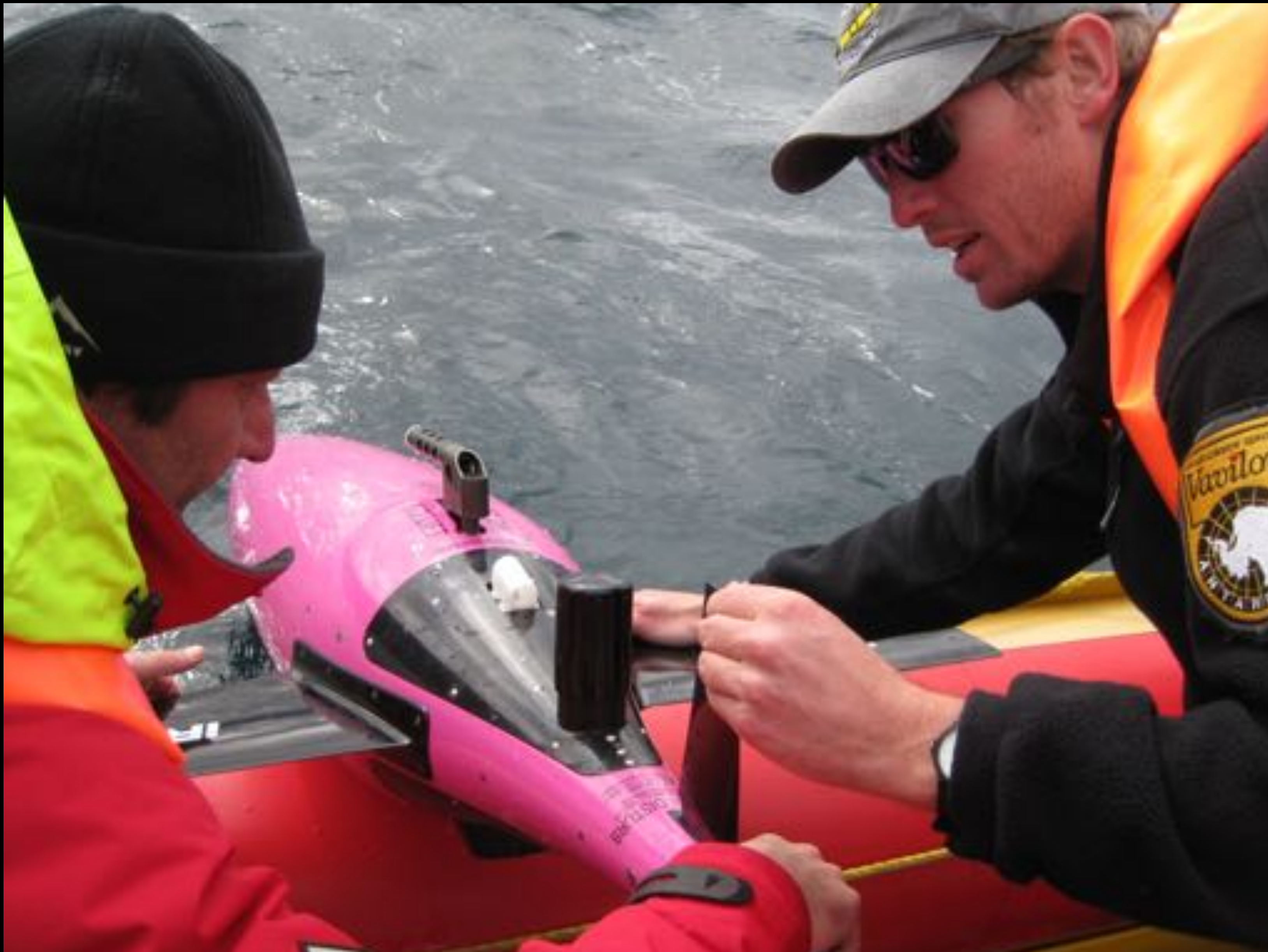
Inputs (options)
- 0 – 5 V analog
- Frequency input (e.g. SBE3)

Outputs
- USB data read-out
- RS-232 for “snippet” data

Ocean Microstructure Glider

- Several user groups worldwide
  - WHOI
  - Oregon State University
  - Tokyo University
  - GEOMAR
  - National Oceanography Centre UK
  - Uni Bergen
  - CSIR / U. Cape Town

- Also available on Seaglider and SeaExplorer



- IOP
- http://iop.apl.washington.edu/seaglider/dives.php?glider=662&mission=SCALE_Jul19
- http://www.roammiz.com