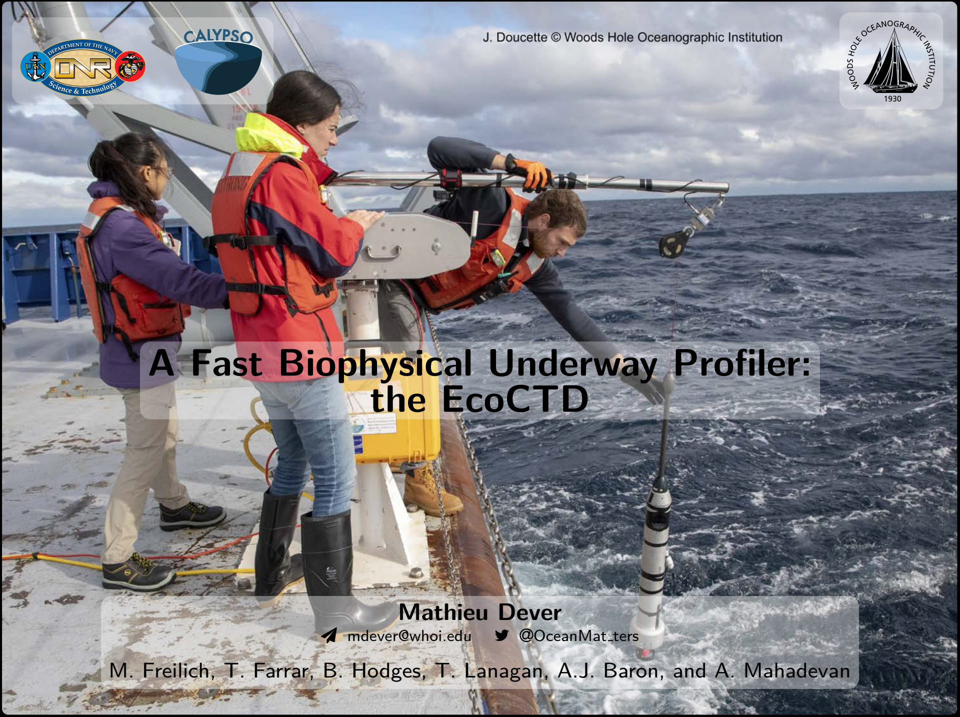
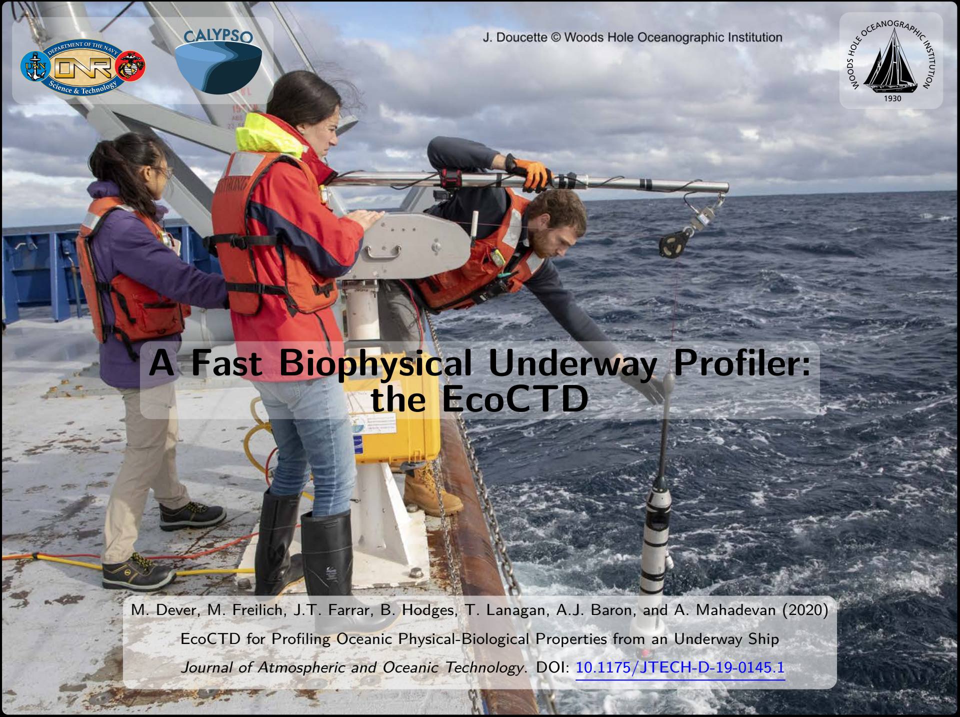


A Fast Biophysical Underway Profiler: the EcoCTD

Mathieu Dever

mdever@whoi.edu @OceanMat_ters

M. Freilich, T. Farrar, B. Hodges, T. Lanagan, A.J. Baron, and A. Mahadevan



A Fast Biophysical Underway Profiler: the EcoCTD

M. Dever, M. Freilich, J.T. Farrar, B. Hodges, T. Lanagan, A.J. Baron, and A. Mahadevan (2020)

EcoCTD for Profiling Oceanic Physical-Biological Properties from an Underway Ship

Journal of Atmospheric and Oceanic Technology. DOI: 10.1175/JTECH-D-19-0145.1

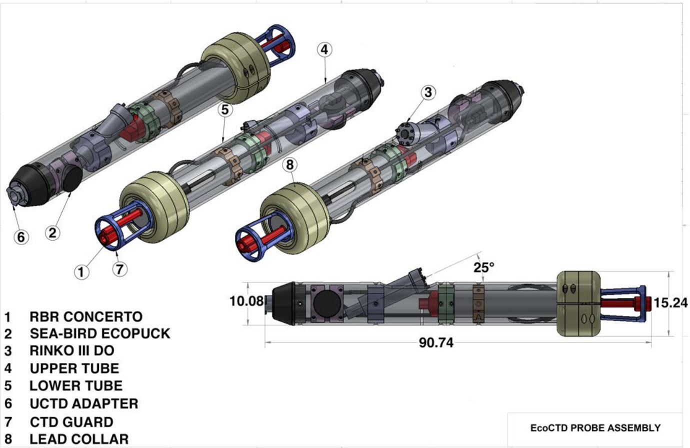
What is the EcoCTD?

RBR concerto^3 CTD

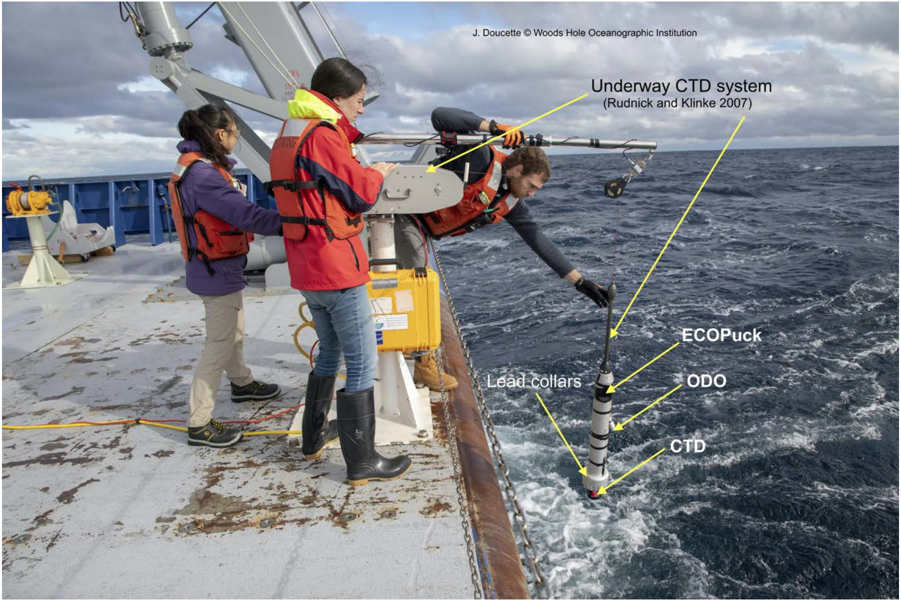
RBR T.ODO|fast

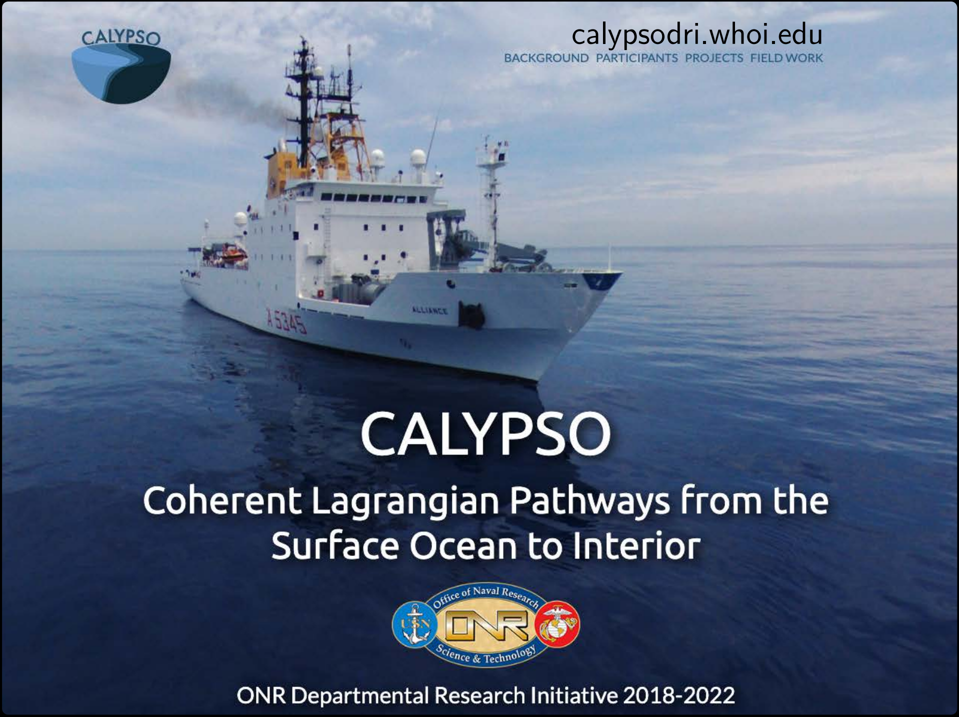
JFE RINKO III

WetLabs ECOPUCK



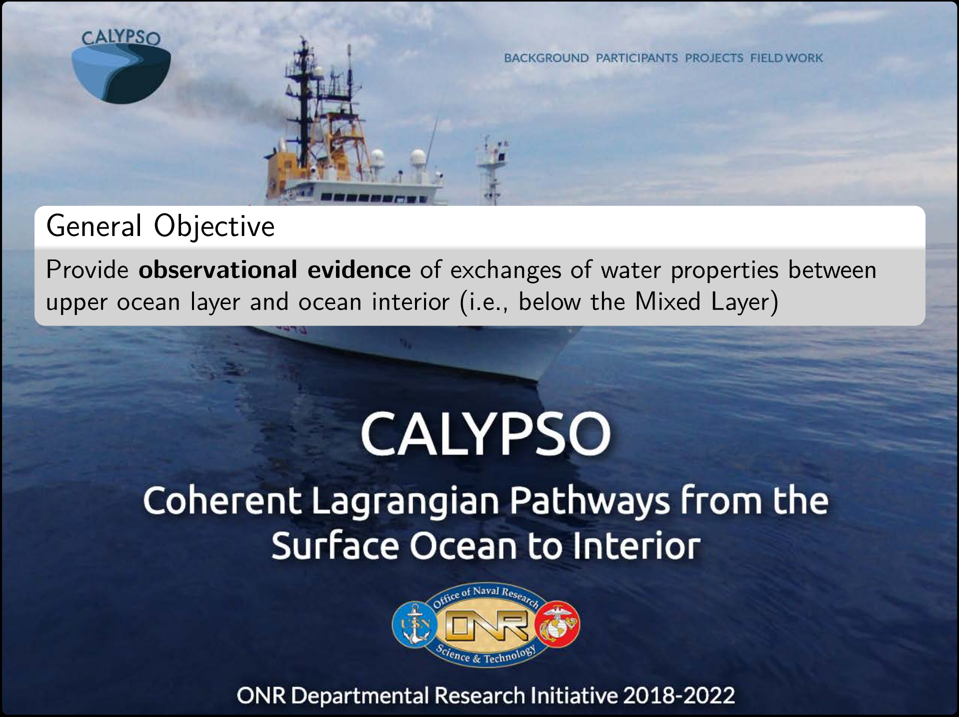
What is the EcoCTD?

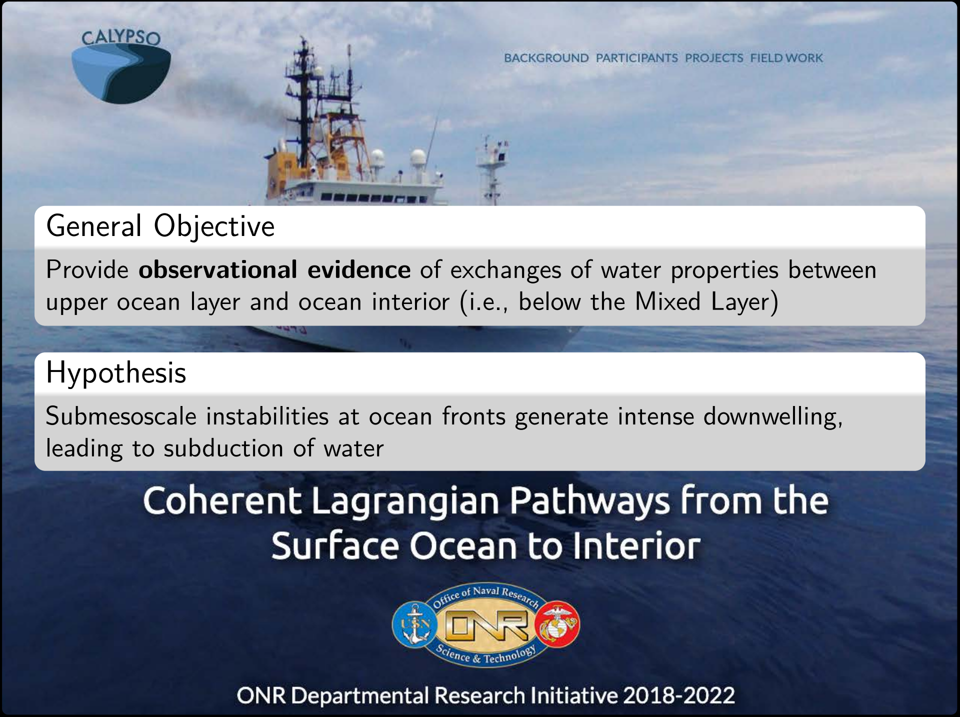



CALYPSO
calypsodri.whoi.edu
BACKGROUND PARTICIPANTS PROJECTS FIELD WORK
A 5345
ALLIANCE
CALYPSO
Coherent Lagrangian Pathways from the Surface Ocean to Interior
Office of Naval Research
ONR
Science & Technology
USN
ONR Departmental Research Initiative 2018-2022

General Objective

Provide **observational evidence** of exchanges of water properties between upper ocean layer and ocean interior (i.e., below the Mixed Layer)





General Objective

Provide **observational evidence** of exchanges of water properties between upper ocean layer and ocean interior (i.e., below the Mixed Layer)

Hypothesis

Submesoscale instabilities at ocean fronts generate intense downwelling, leading to subduction of water

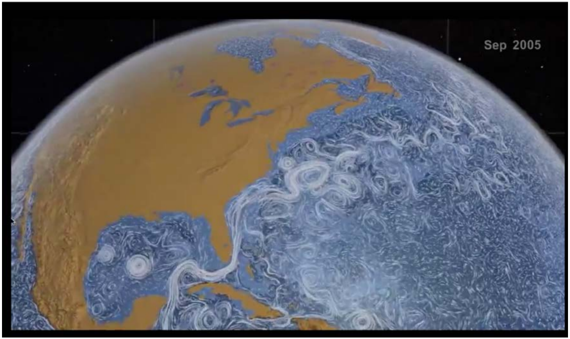
Submesoscale motions: Dynamical definition

Mesoscale motions

$t \sim$ days to months
$L \sim$ 10 to 1,000 km
$\Downarrow$

Very weak vertical velocities

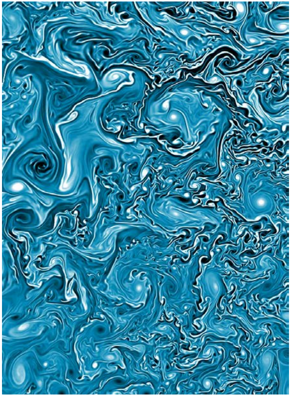
$W \sim$ O(1) m/day



Submesoscale motions: Dynamical definition

Mesoscale motions

$t \sim$ days to months
$L \sim$ 10 to 1,000 km
$\Downarrow$
Very weak vertical velocities
$W \sim O(1)$ m/day



https://ocean-next.github.io

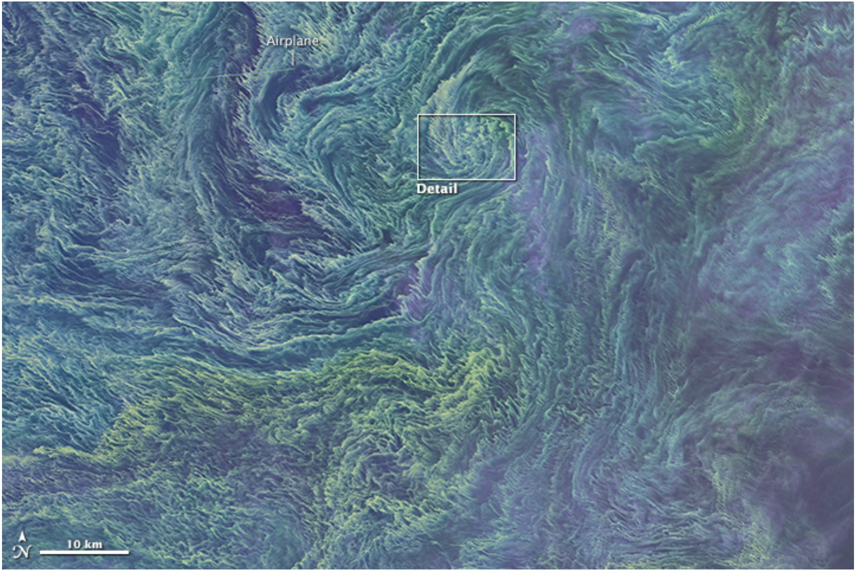
Turbulent motions

$t \sim$ seconds to minutes
$L \sim$ mm to cm
$\Downarrow$
Isotropic velocities
$W \sim U \sim V$

Submesoscale motions: Dynamical definition

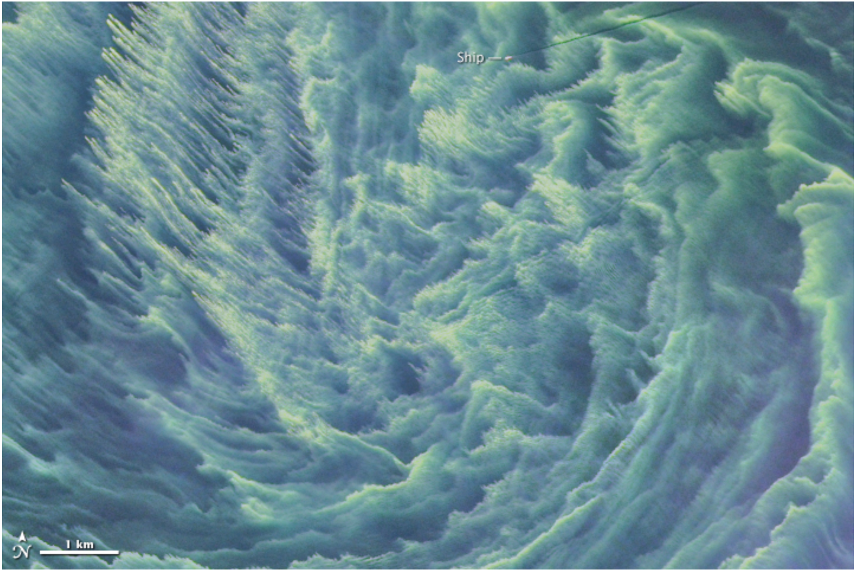
Mesoscale motions	Sumesoscale motions	Turbulent motions
$t \sim$ days to months $L \sim$ 10 to 1,000 km $\Downarrow$	$t \sim$ hours to days $L \sim$ 0.1 to 10 km $\Downarrow$	$t \sim$ seconds to minutes $L \sim$ mm to cm $\Downarrow$
Very weak vertical velocities	*Larg(er) vertical velocities*	*Isotropic velocities*
$W \sim$ O(1) m/day	$W \sim$ O(100) m/day	$W \sim$ U $\sim$ V

Submesoscale motions: Dynamical definition



nasa.gov

Submesoscale motions: Dynamical definition



nasa.gov

Submesoscale motions: spatio-temporal scales

- Spatio-temporal scales
  - L $\sim$ (0.1 – 10 km)
  - h $\sim$ (1 – 100 m)
  - t $\sim$ (hours – days)

- Awkward observational scales

  $+$ too small and too fast for satellites
  $+$ too big and too fast for ships' CTD

- Transitional regime between quasi-geostrophic mesoscales and turbulent scales

At submeso-scales, biological and physical have similar timescales
$\Rightarrow$ biological properties can be used as semi-conservative tracers.

Observational needs for Submesoscale motions

So we wanted something that :

1. can profile the upper 500 m of the ocean

Observational needs for Submesoscale motions

So we wanted something that :

1. can profile the upper 500 m of the ocean
2. can profile at a sub-kilometer lateral resolution

Observational needs for Submesoscale motions

So we wanted something that :

1. can profile the upper 500 m of the ocean
2. can profile at a sub-kilometer lateral resolution
3. has little impact on other science operations
   - 3a. can be used underway,
   - 3b. is versatile; easy to deploy and recover

Observational needs for Submesoscale motions

So we wanted something that :

1. can profile the upper 500 m of the ocean
2. can profile at a sub-kilometer lateral resolution
3. has little impact on other science operations
   - 3a can be used underway,
   - 3b is versatile; easy to deploy and recover
4. is relatively inexpensive

Observational needs for Submesoscale motions

So we wanted something that :

1. can profile the upper 500 m of the ocean
2. can profile at a sub-kilometer lateral resolution
3. has little impact on other science operations
   - 3a. can be used underway,
   - 3b. is versatile; easy to deploy and recover
4. is relatively inexpensive
5. can sample bio-optical properties (oxygen, chlorophyll fluorescence, backscatter)

Platform (Mfg)	Depth range	max. fall rate	Time intervals (300 m profiles)	Resolution at 8 knots	Instrument weight in air	Bio-optical sensors	Real-time data	Estimated Price
Triaxus (MacArtney)	0-350 m	< 1 m/s	600 seconds	2.4 km	120-160 kg	yes	yes	~ 1,000 k$
SeaSoar (Chelsea)	0-500 m	< 1 m/s	600 seconds	2.4 km	~150 kg	yes	yes	N/A
ScanFish (EIVA)	0-400* m	< 2 m/s	300 seconds	1.2 km	~75 kg	yes	yes	> 100 k$
fastCTD (Valeport)	0-600** m	unknown	unknown	unknown	2.5 kg	fluorometer only	X	N/A
UCTD (Teledyne)	0-1000** m	5 m/s	650 seconds	2.8 km	~5.5 kg	X	X	6.6 k$
EcoCTD	0-500** m	4 m/s	450 seconds	1.8 km	13 kg	yes	X	37 k$

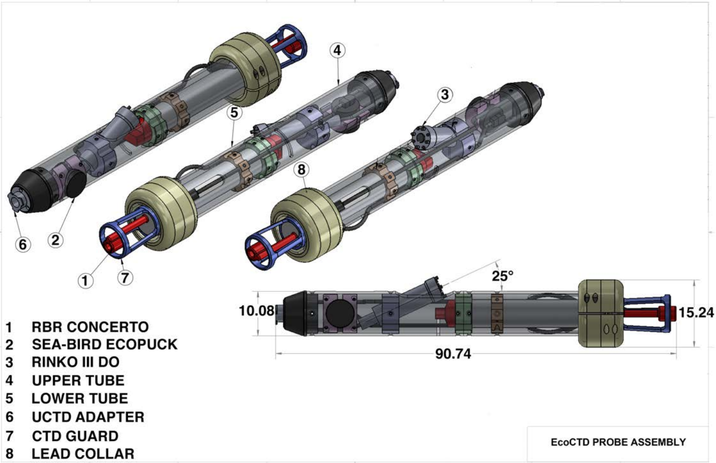
* Range only possible under winch control
** downward profiling only

RBR concerto^3 CTD Logger + battery (8AA)

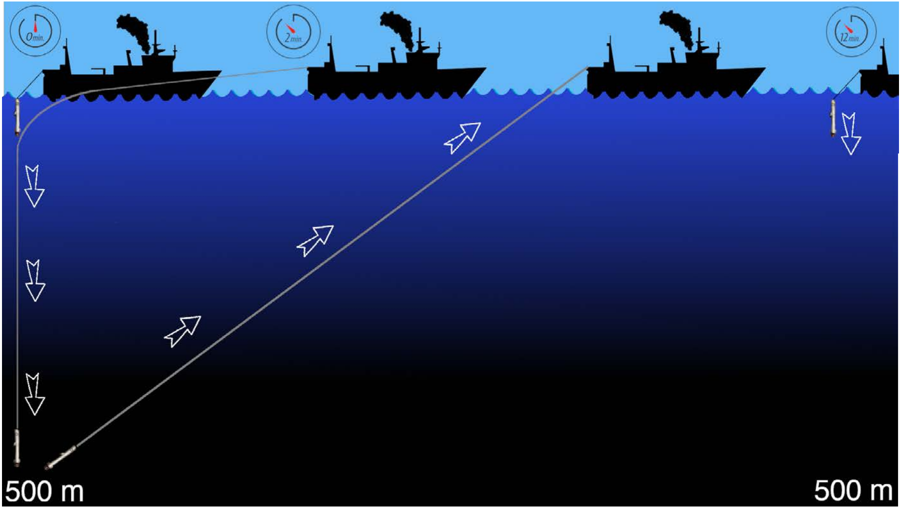
RBR ODO—fast ($\tau \sim$1s, 1Hz)

JFE RINKO ($\tau \sim$1s, 8Hz)

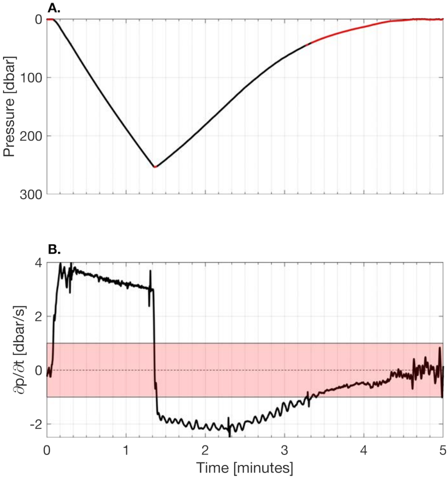
WetLabs ECOPUCK



Modus Operandi

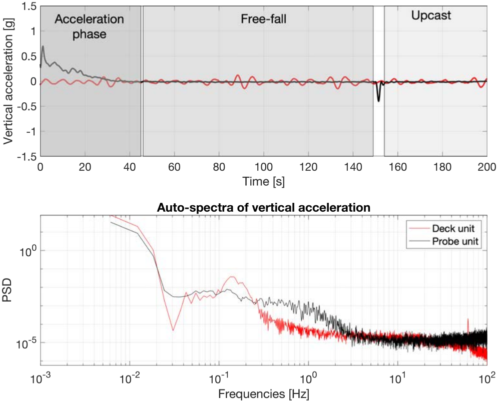


Example profile



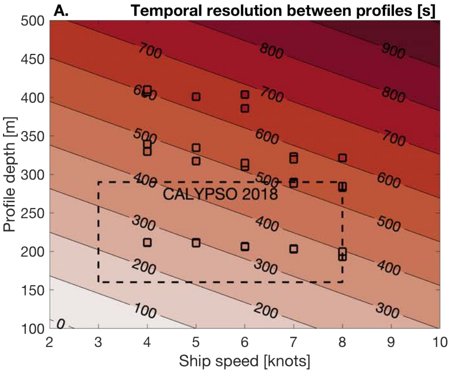
- Fall rate between 3 and 4 m/s
- Slow decrease of fall rate with depth (line drag)
- Ship heaving clearly visible on upcast, is it there on downcast?

Sampling characteristics



- Two IMUs were mounted onto
  (1) The ship's deck,
  (2) The EcoCTD probe
- Profile collected on a day with 3-5 m waves
- Peak in auto-spectra for the ship motion (8-10 s period)
- No peaks in auto-spectra for the Probe unit
- No significant cross-covariance found in the data $\Rightarrow$ Probe is free-falling!

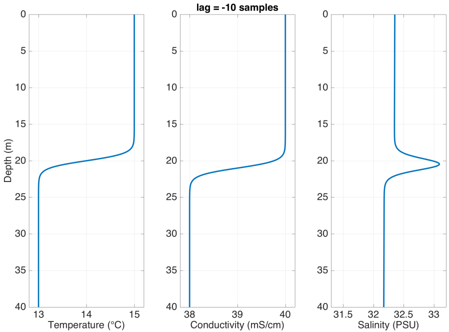
Sampling characteristics



- Quick profile turn-over (no line-spooling required for free-fall)
- High lateral resolution
- Can be used at higher speeds, although winch might heat up after a while...

Data processing

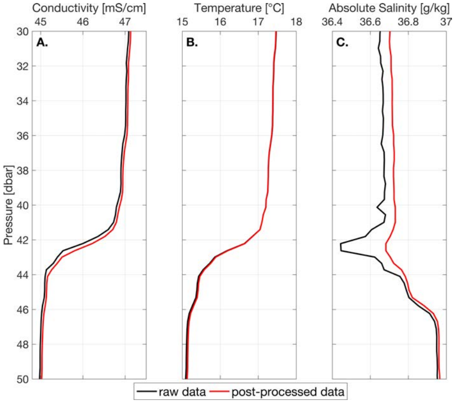
There are important data processing steps to be considered: Sensor alignment to correct for dynamic behavior based on existing literature (Barth 1996, Ullman and Hebert 2014, Halverson et al. 2017).



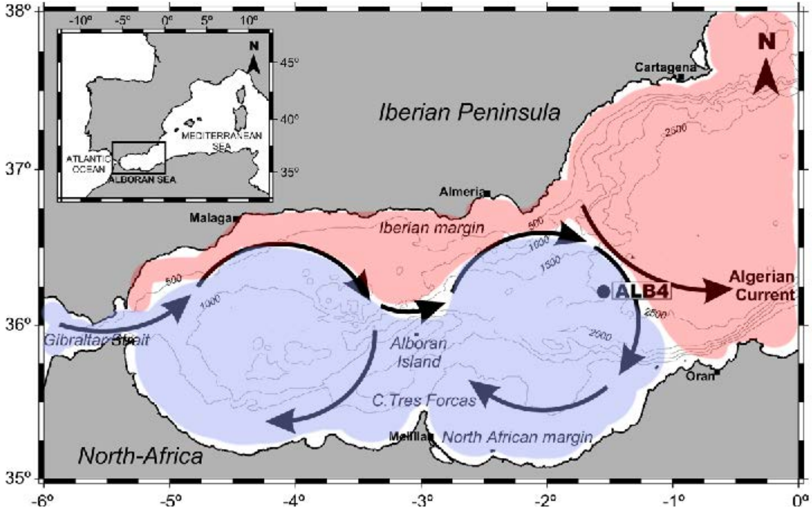
Animation by Rui Zhang

Data processing

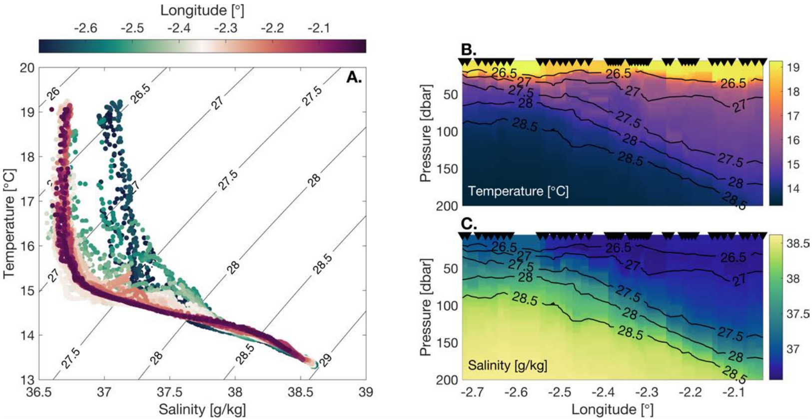
There are important data processing steps to be considered: Sensor alignment to correct for dynamic behavior based on existing literature (Barth 1996, Ullman and Hebert 2014, Halverson et al. 2017).



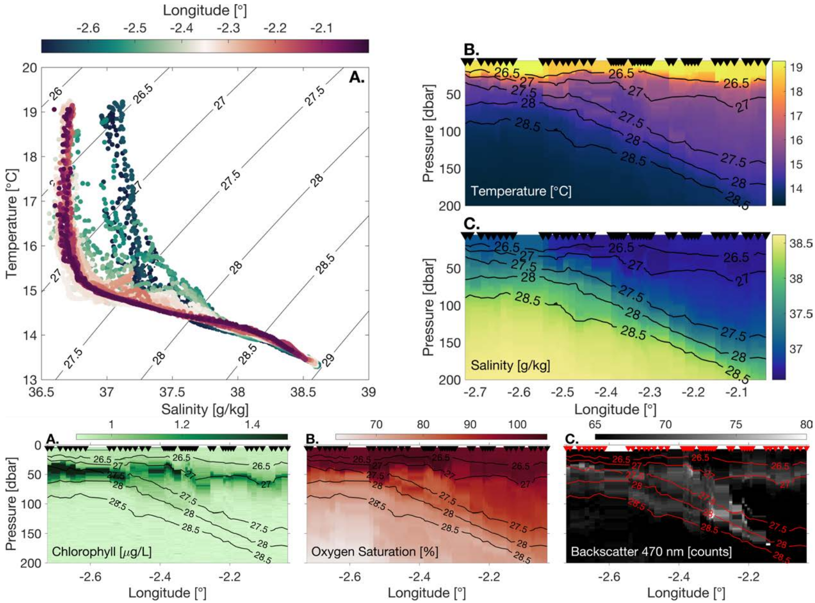
Field Data - the CALYPSO field site



Field Data - Section data



Field Data - Section data



Summary and ongoing work

1. EcoCTD collects concurrent bio-physical observations at high resolution
    - 1a. Sub-kilometer resolution at slow ship-speed
    - 1b. Optical channels can be customized (e.g., rhodamine, backscatter, fluorescence, etc.)

Summary and ongoing work

1. EcoCTD collects concurrent bio-physical observations at high resolution
2. Probe design provides high-quality data while the ship is underway
    - 2a. Need to apply important dynamic corrections

Summary and ongoing work

1. EcoCTD collects concurrent bio-physical observations at high resolution
2. Probe design provides high-quality data while the ship is underway
3. The modular and light-weight design makes it easy to deploy and recover
   - 3a) Fall-rate (i.e., vertical resolution) can be adjusted with lead-collars
   - 3b) Sensors can be added/removed as needed
   - 3c) Instruments can also be used in other applications

Summary and ongoing work

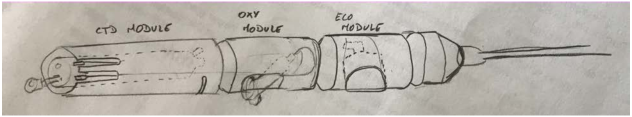
① EcoCTD collects concurrent bio-physical observations at high resolution

② Probe design provides high-quality data while the ship is underway

③ The modular and light-weight design makes it easy to deploy and recover

Future developmentsw

④ Improved design for enhanced modulability

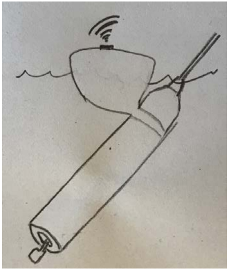


Summary and ongoing work

1. EcoCTD collects concurrent bio-physical observations at high resolution
2. Probe design provides high-quality data while the ship is underway
3. The modular and light-weight design makes it easy to deploy and recover

Future developmentsw

4. Improved design for enhanced modulability
5. Emergency Recovery System (ERS)




Thank You