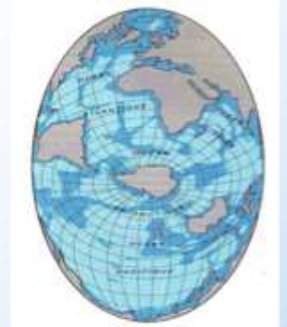
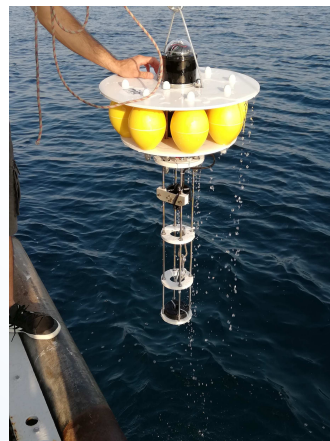


In situ measurement of Oceanic Vertical Velocities

Virtual, 26/09/2022

*Stéphanie Barrillon, Anne Petrenko, Jean-Luc Fuda, Caroline Comby, Andrea
Doglioli, Roxane Tzortzis (MIO, OPLC)*
and FUMSECK-vv consortium (MIO, LOCEAN, Canada, LOPS, SHOM, IRPHE)



Oceanic Vertical Velocities

Why ?

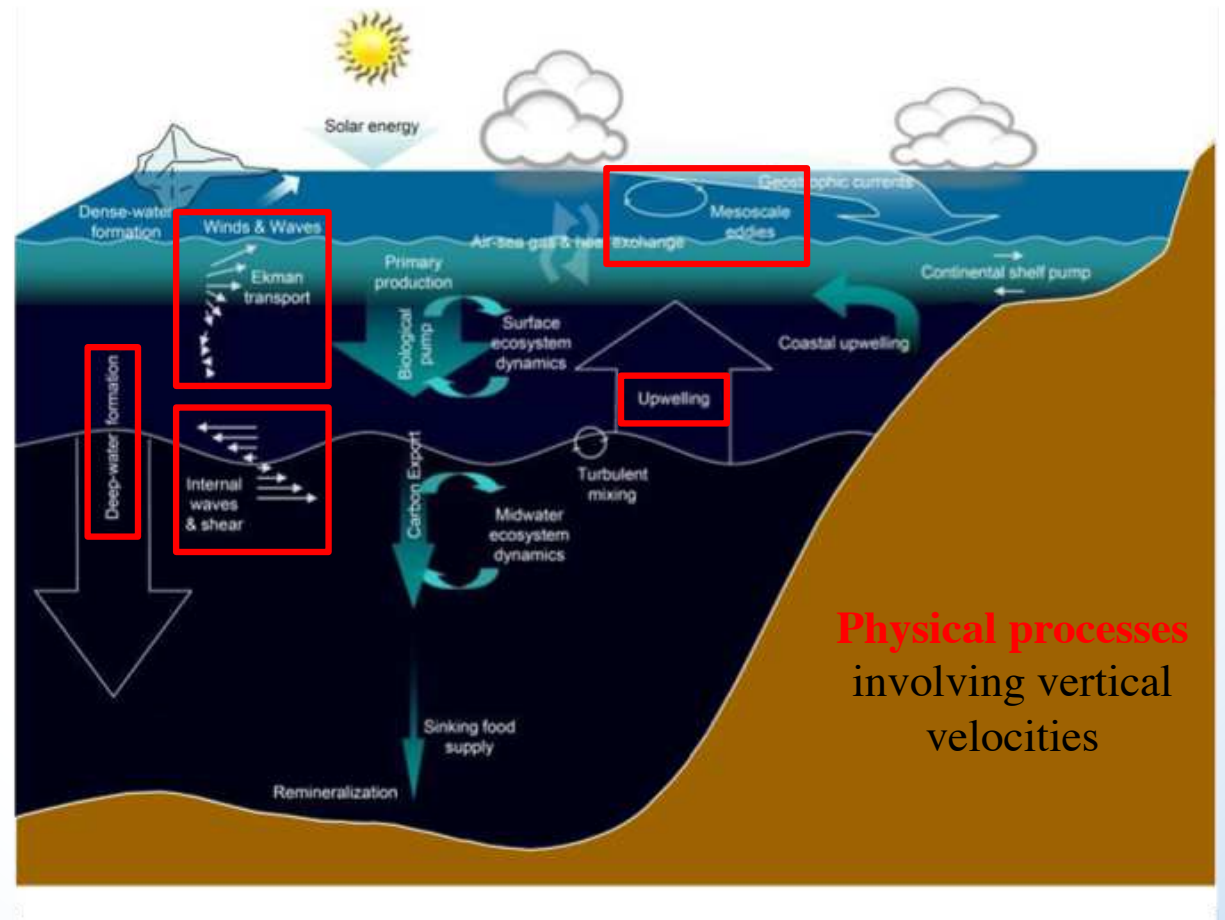
Many oceanic processes:
physical and
biogeochemical

Key for fine
understanding of

- **ocean dynamics** (meso and submeso scales)
- **vertical exchanges** (carbon sequestration, nutrients to surface)

In situ measurement
lacking : **challenge**

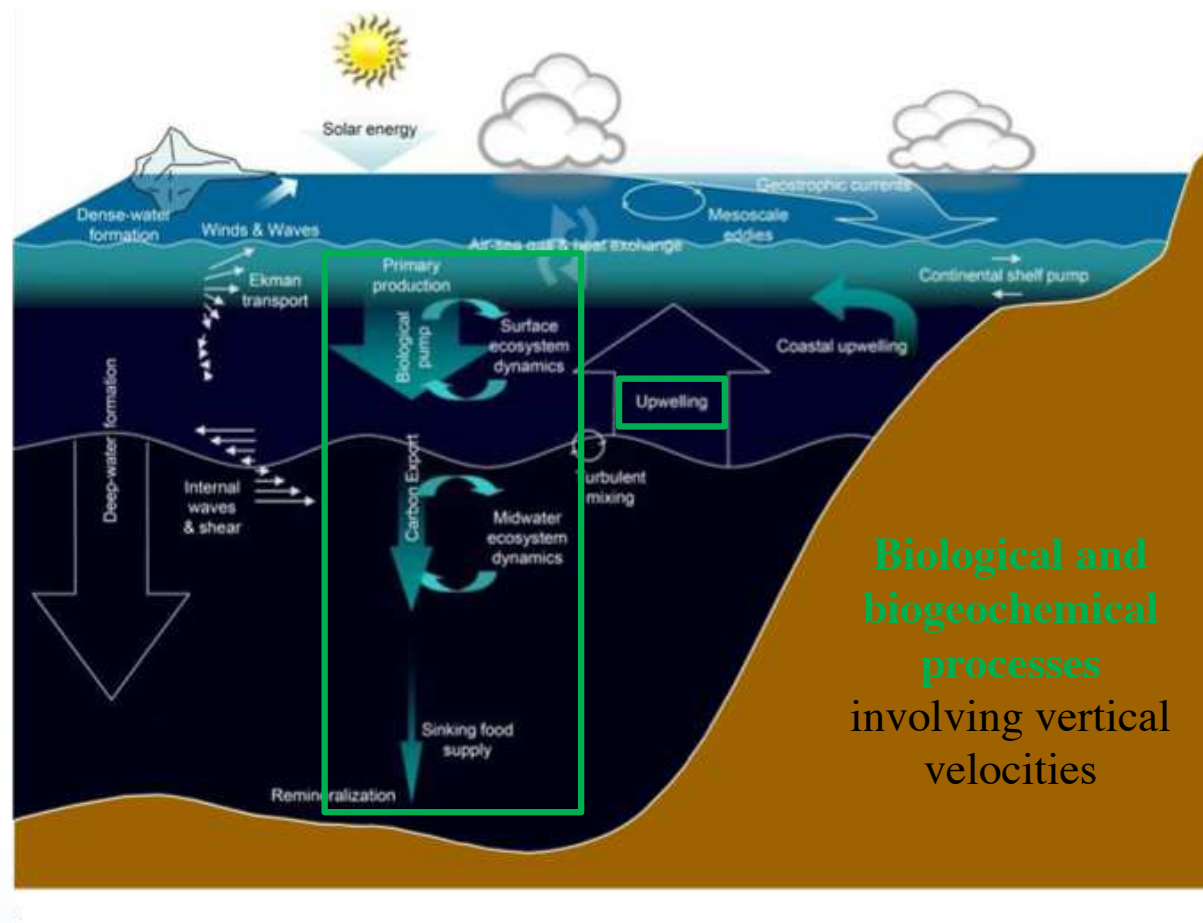
- very low intensities
- ephemeral nature



Oceanic Vertical Velocities

⚓ Why ?

- Many oceanic processes: **physical** and **biogeochemical**
- Key** for fine understanding of
 - ocean dynamics** (meso and submeso scales)
 - vertical exchanges** (carbon sequestration, nutrients to surface)
- In situ measurement lacking : **challenge**
 - very low intensities
 - ephemeral nature



Context: FUMSECK-vv

⚓ Vertical velocities and fine scale ocean dynamics

- 💬 3 years 2021-2023, LEFE-IMAGO
- 💬 **Key words** : fine scales, vertical velocities, *in situ* instrumentation, satellite observations, FUMSECK, BioSWOT, SWOT
- 💬 **Cruises**: FUMSECK 2019, VVPTEST (2020, 2021, 2022), PROTEVS-MED (2018, 2020, 2022), FIGURE (2022), BioSWOT-MED (2023)
- 💬 « **Lab** » tests: MIO wind tunnel 2021, COMEX pool 2021

⚓ Links with other projects

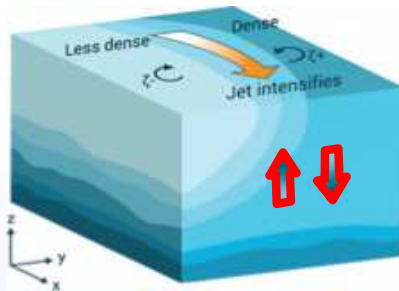
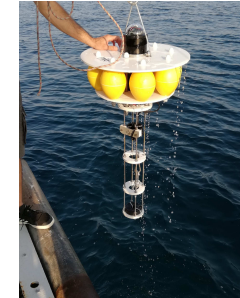
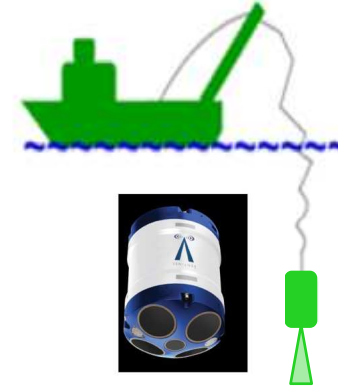
- 💬 BioSWOT-AdAC (F. d'Oviodio, A. Doglioli, G. Grégori, CNES, ongoing)
- 💬 GEPETO (F. Auclair, LEFE, ongoing)
- 💬 COGNAC20 (A. Ponte, LEFE, ongoing)
- 💬 SeaLAB (P. Le Gal, AMIDEX, starting)
- 💬 HOPE-vv (A. Petrenko, AMIDEX, submitted)
- 💬 RETROMIC (G. Grégori, EC2CO, resubmissio)

FUMSECK-vv objectives

Vertical velocities and fine scale ocean dynamics

⚓ *In situ* direct measurement of ocean vertical velocities

- 💬 How ? Best technology ?
- 💬 Which precision ?



⚓ Fine scale dynamics

- 💬 *in situ* detection
- 💬 Understand mechanisms

<https://www.mercator-ocean.fr/en/portfolio/medsub-2/>

⚓ Coupling with biogeochemistry

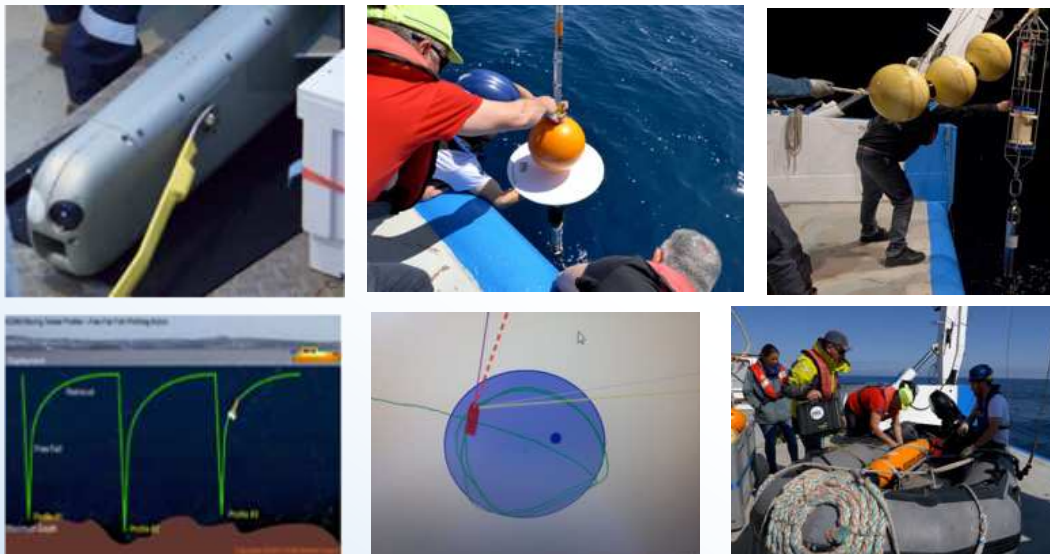
- 💬 Carbon pump
- 💬 Nutrients ascent
- 💬 Biodiversity, planktonic populations

→ Strategy

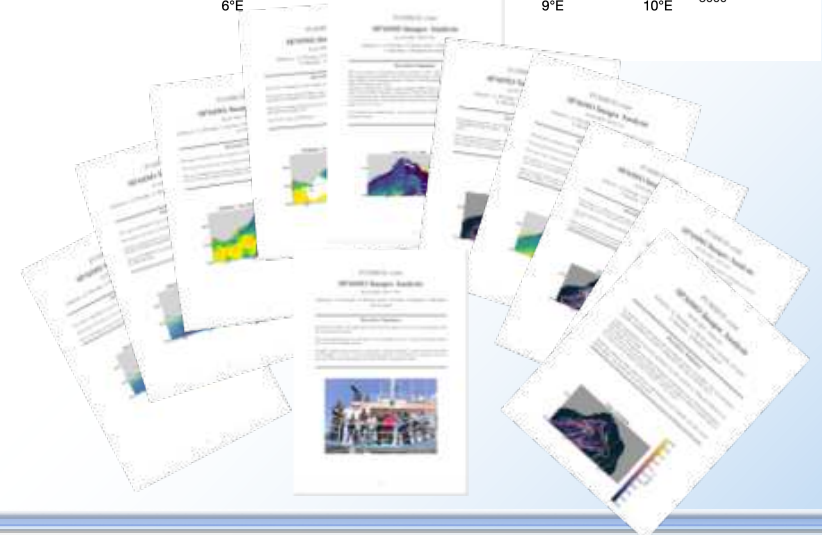
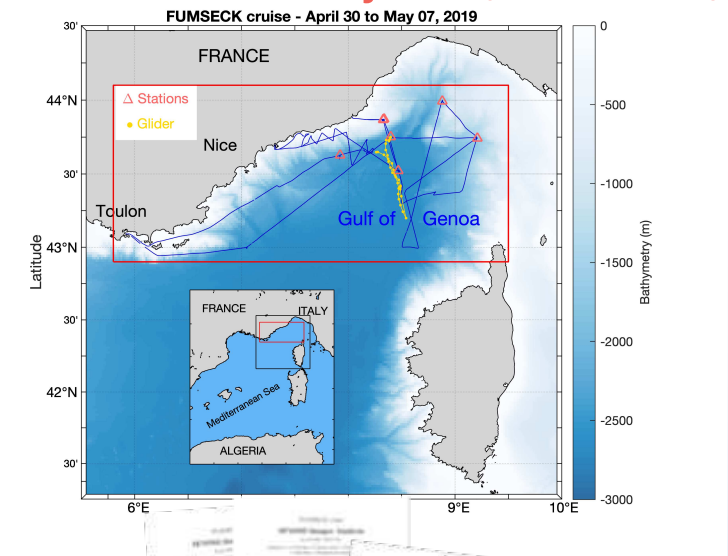
- 💬 Instrumental development
- 💬 *In situ* deployment
- 💬 Detailed analysis

⚓ **FUMSECK** (*Facilities for Updating the Mediterranean Submesoscale - Ecosystem Coupling Knowledge*), 30 avr - 07 mai 2019, Ligurian Sea. R/V Téthys II (S. Barrillon)

- 🗨️ SWOT preparation. Phys/bio coupling
- 🗨️ Innovant methods for fine scales : **vertical velocities**



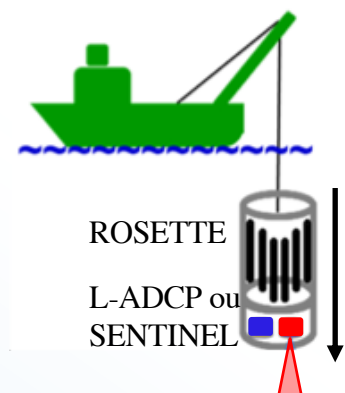
- 🗨️ Lagrangian strategy with SPASSO



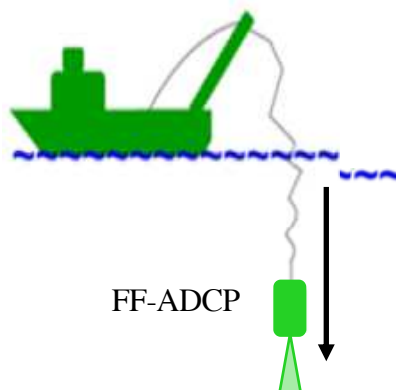
Vertical Velocities measurement

⚓ Direct *in situ* (ADCP)

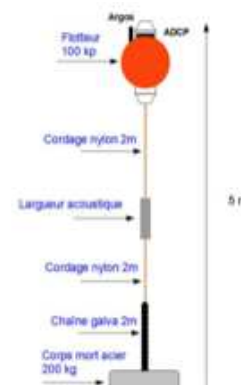
💬 CTD package



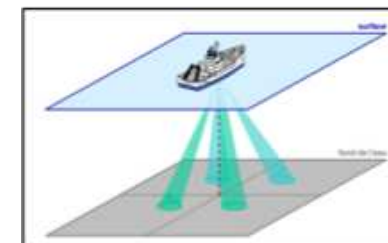
💬 Free-Fall



💬 Mooring



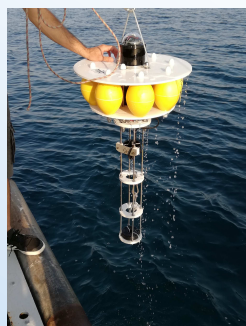
💬 Vessel-mounted



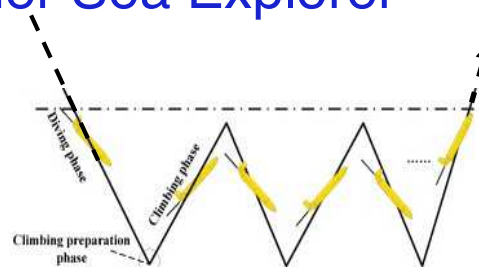
⚓ Direct *in situ* with flight model

💬 VVP

(Vertical Velocity Profiler)



💬 Glider Sea Explorer



⚓ Indirect :

💬 w equation

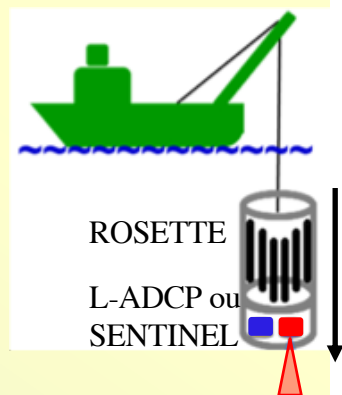
- + *in situ* density/ currents
- + satellite

⚓ + Modelisation (hydrostatic)

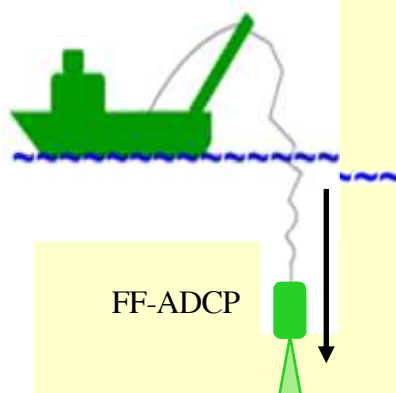
Vertical Velocities measurement

⚓ Direct *in situ* (ADCP)

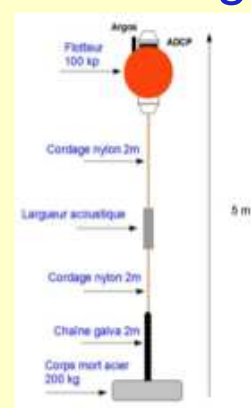
💬 CTD package



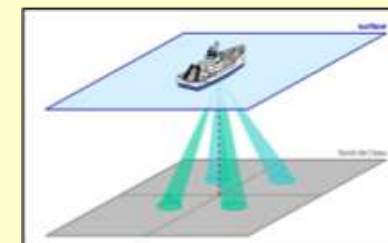
💬 Free-Fall



💬 Mooring



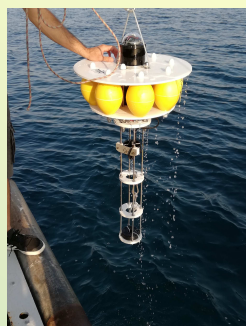
💬 Vessel-mounted



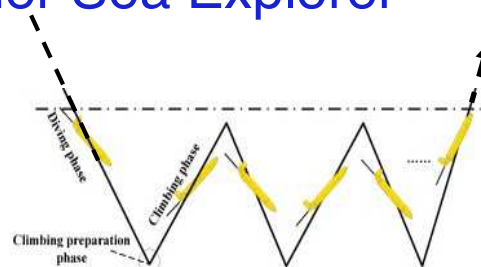
⚓ Direct *in situ* with flight model

💬 VVP

(Vertical Velocity Profiler)



💬 Glider Sea Explorer

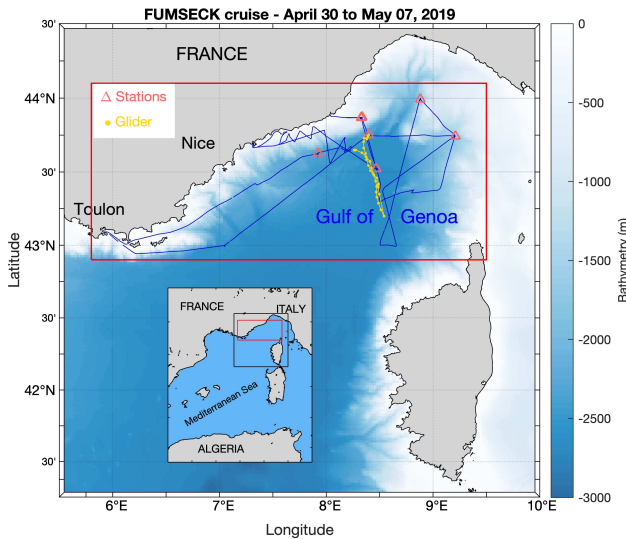


⚓ Indirect :

💬 w equation

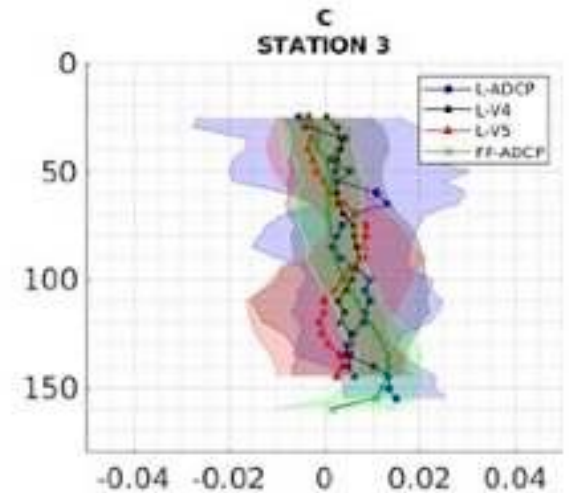
- + *in situ* density/ currents
- + satellite

⚓ + Modelisation (hydrostatic)



Comby *et al.* (2022)

- FUMSECK cruise, Med
- 6 stations
- 4 methods
 - Lowered-ADCP
 - Lowered-Sentinel
 - 4 beams + 5th vert.
 - FreeFall-ADCP



Results

Downcasts data 0 – 150 m

$\mu \sim \text{mm/s}$

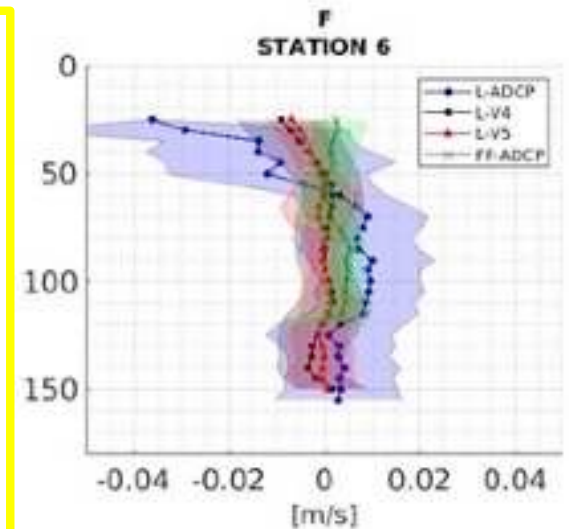
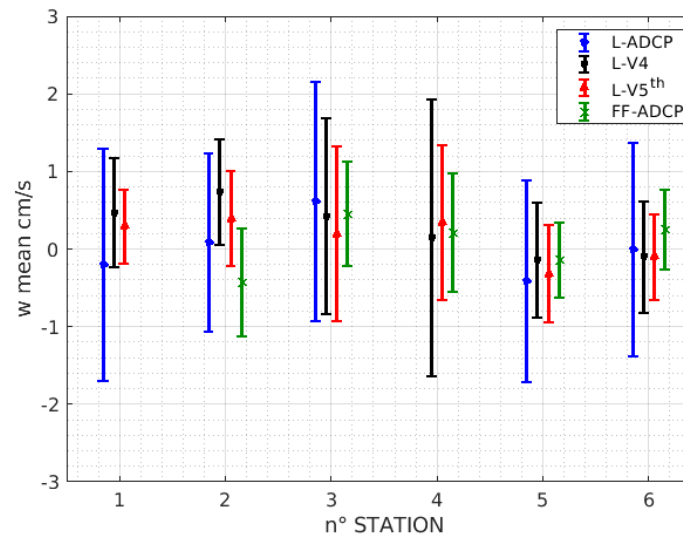
0.02	0.26	0.14	0.6	cm/s
------	------	------	-----	------

$\sigma \sim \text{cm/s}$

1.3	1.0	0.7	0.6	cm/s
-----	-----	-----	-----	------

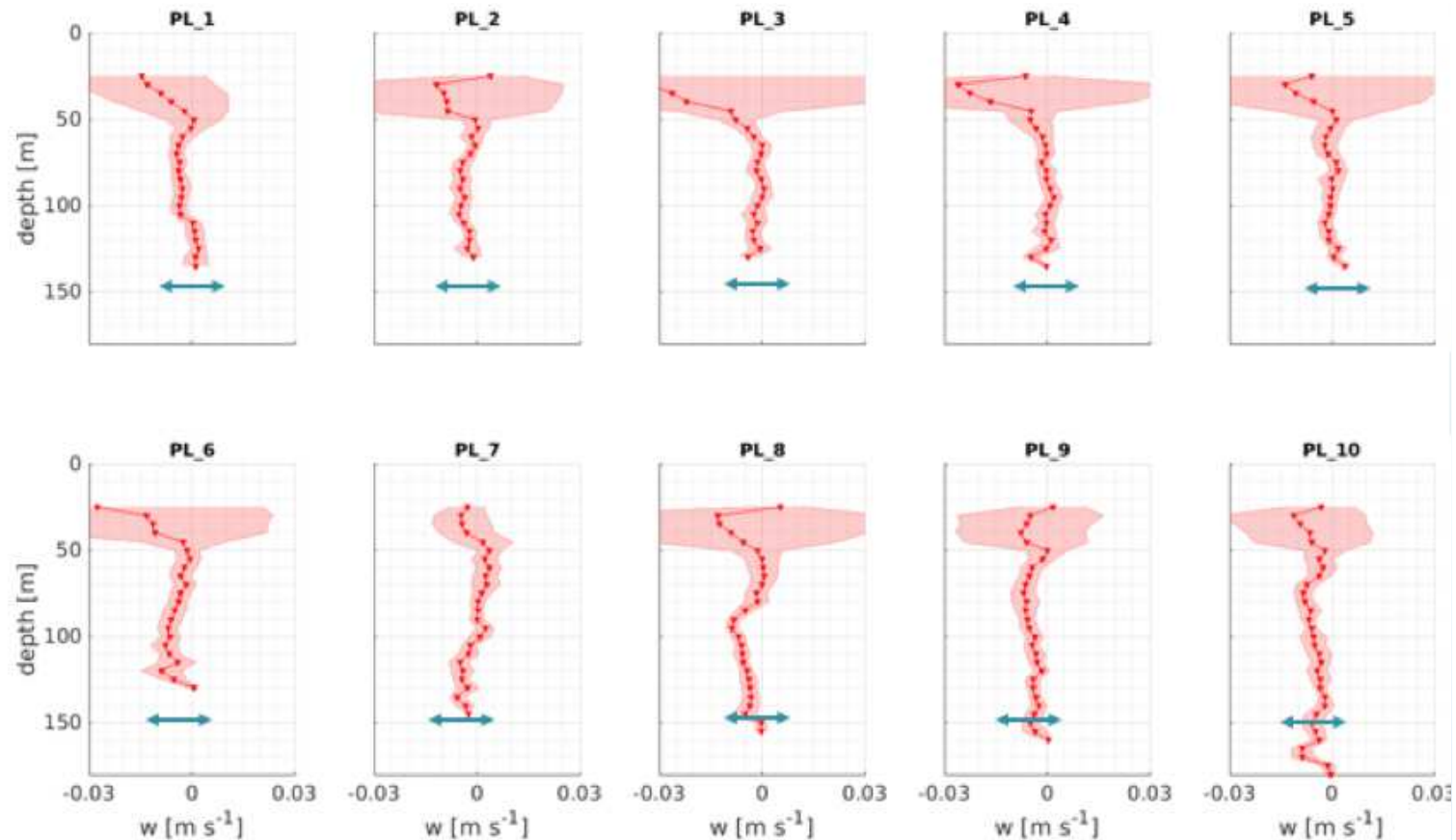
L-ADCP > L-V4 > L-V5 > FF-ADCP

➔ best FF-Sentinel



FreeFall-ADCP with Sentinel

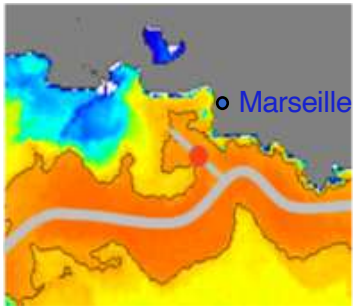
⚓ VVPTest 2022 (Med)



$$\sigma \approx 3 \text{ mm/s}$$

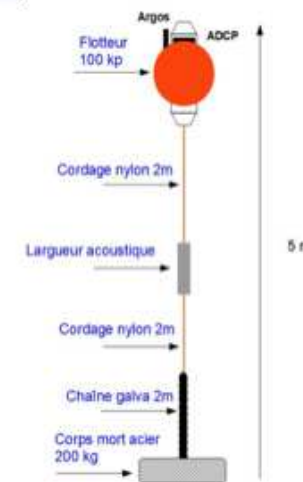
Caroline Comby

ADCP in mooring (JULIO)

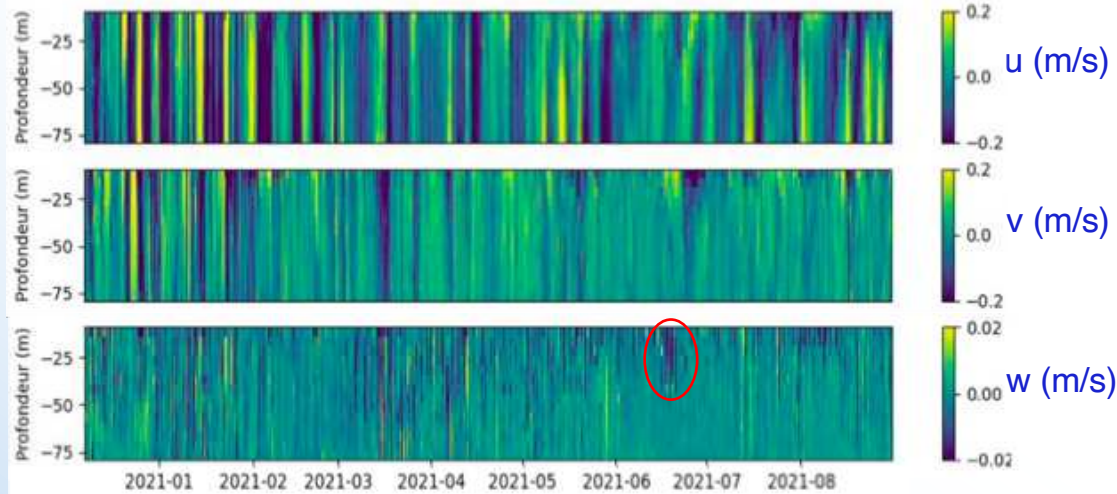


⚓ JULIO mooring

- 🗣 @100m
- 🗣 ADCP (300 kHz) + CTD
- 🗣 30 min resolution



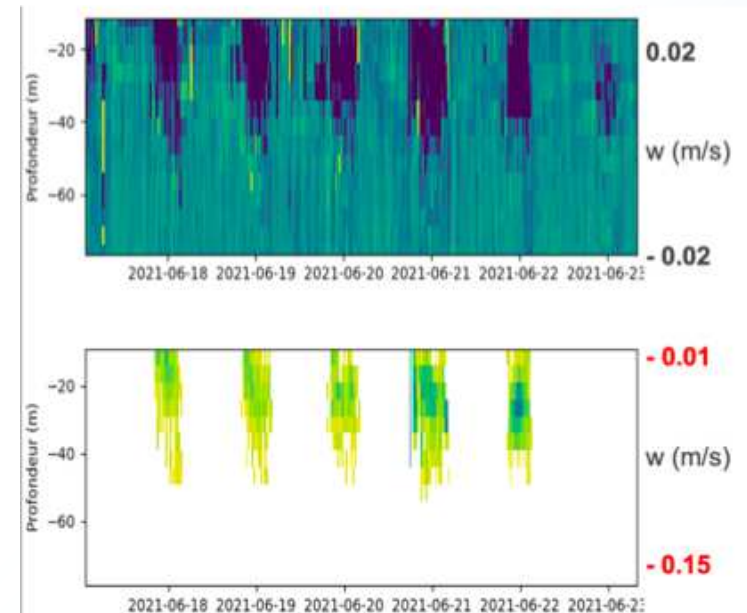
(dec. 2020 – aug. 2021)



→ nychthemeral migration

Anne Petrenko, <https://people.mio.osupytheas.fr/~petrenko/julio.htm>

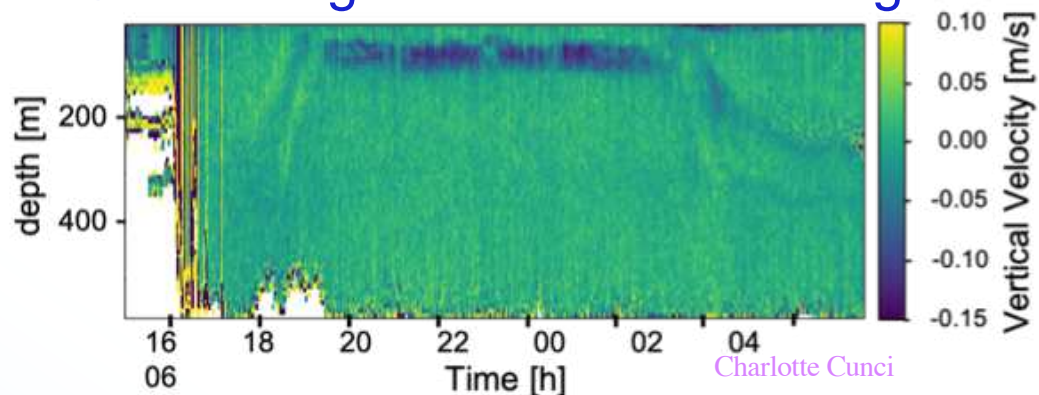
17-23 June 2021



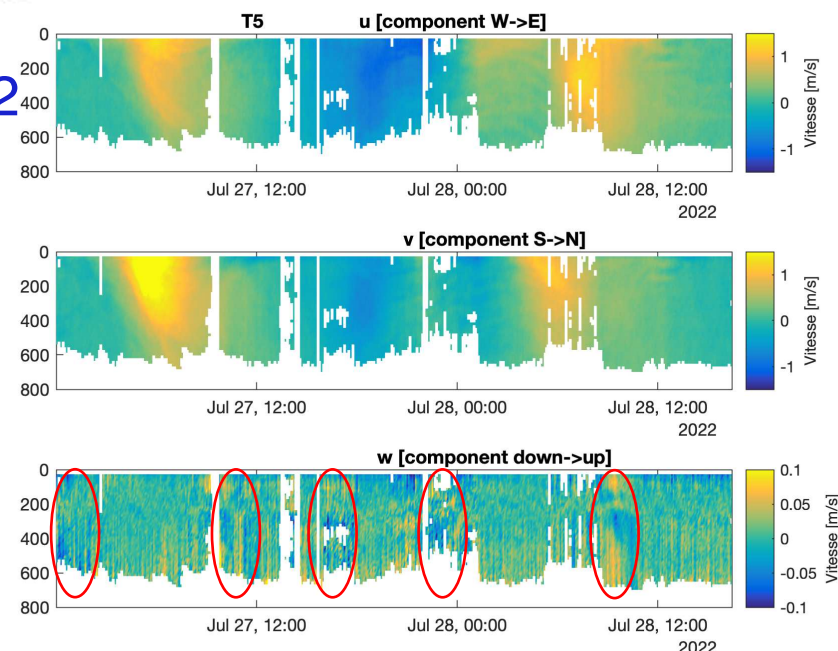
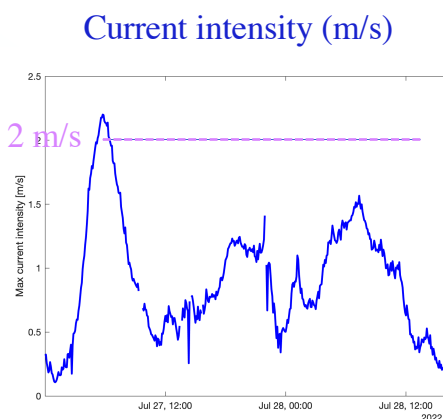
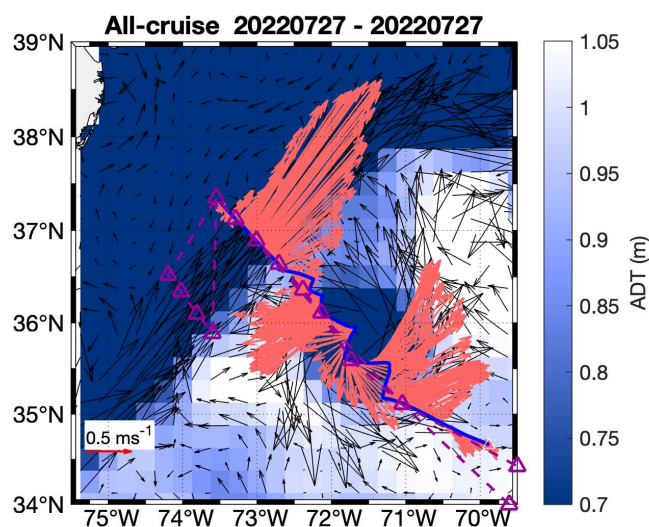
Vessel-Mounted ADCP

⚓ Simple removal of ship vertical movement

💬 FUMSECK: negative anomalies at night → krill nychthemeral migration



💬 FIGURE (M. Benavides) Gulf Stream 2022



Vertical velocities features on the fronts

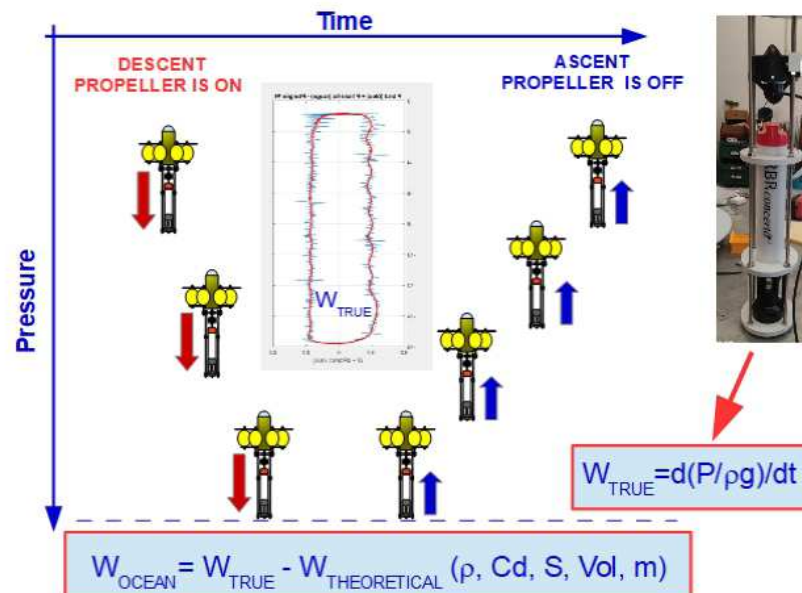
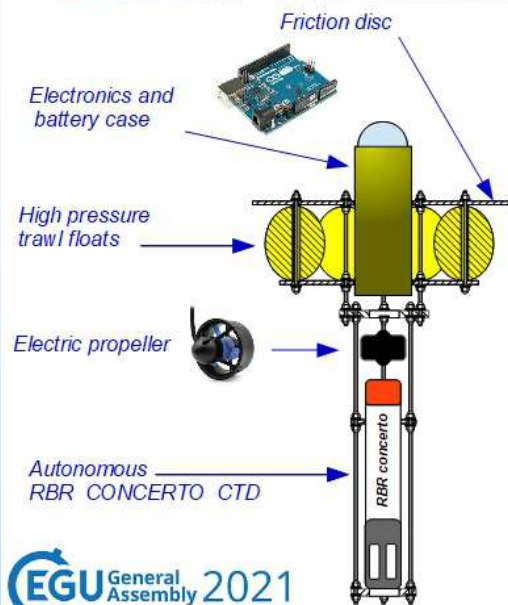
Vertical Velocity Profiler (VVP)

⚓ VVP (Fuda *et al.*, EGU 2021): autonomous profiler, MIO development

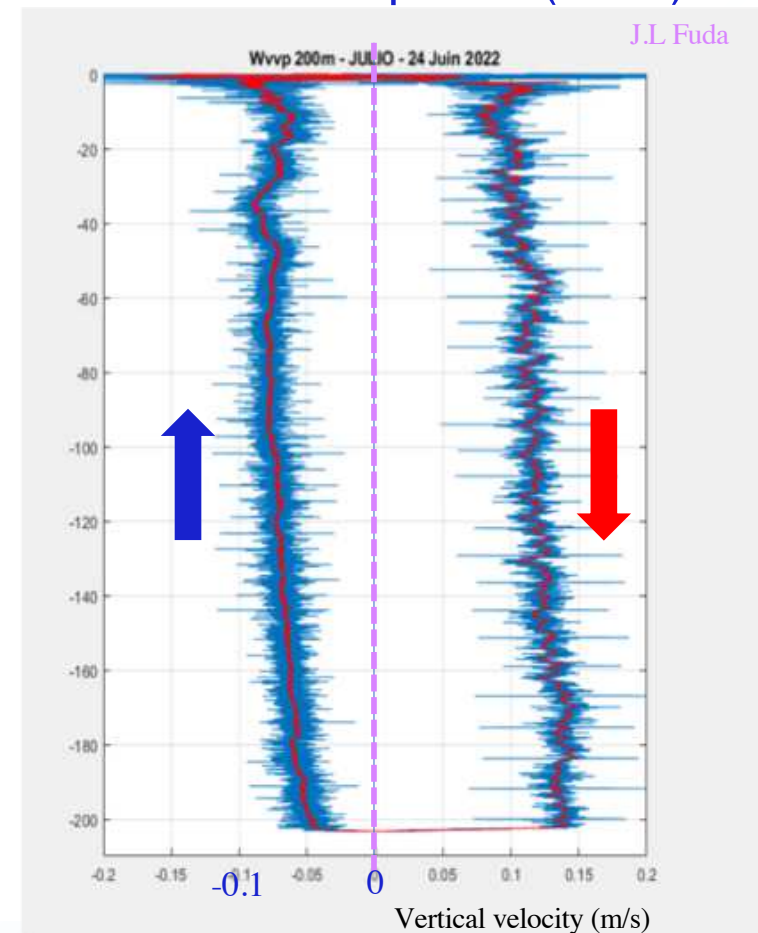
A new approach for measuring ocean vertical velocities



Fuda, J.-L.^{*1}, Barrillon, S.¹, Doglioli, A.², Petrenko, A.², Gregori, G.¹, Tzortzis, R.², Comby, C.², Thyssen, M.¹, Lafont, M.², Bhairy, N.¹, Malengros, D.¹, Guillemain, D.¹, and Grenz, C.¹



First 200 m profile (2022)



Vertical Velocity Profiler (VVP)

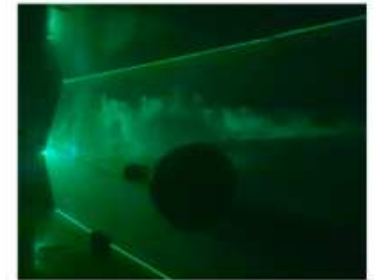
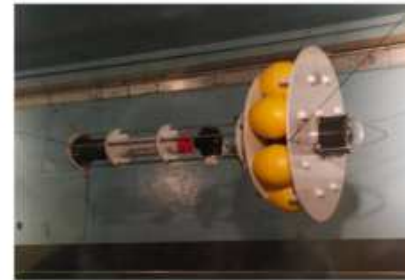
⚓ VVP development ⚓ Dynamic characterisation (wake)

💬 3 prototypes

💬 Numerous tests

- at sea
- wind tunnel
- COMEX pool

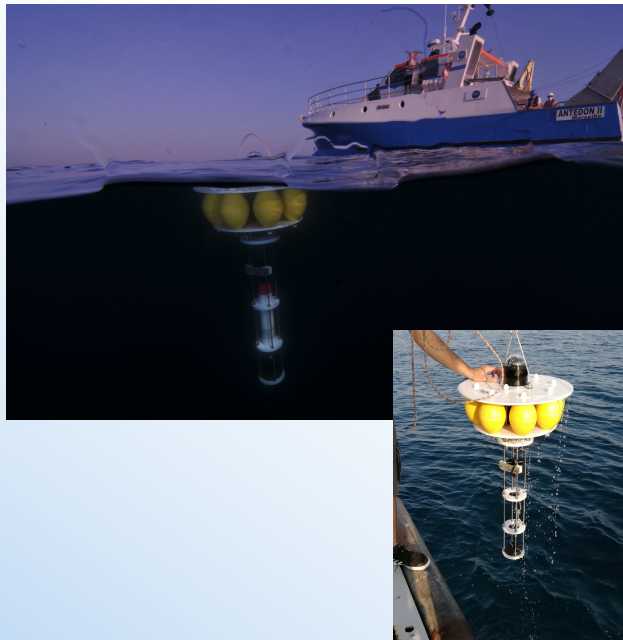
Grande soufflerie de Luminy (30/04/21)



Rade de Marseille (17/02/21, 20/04/21, 23/04/21, 24/08/21)

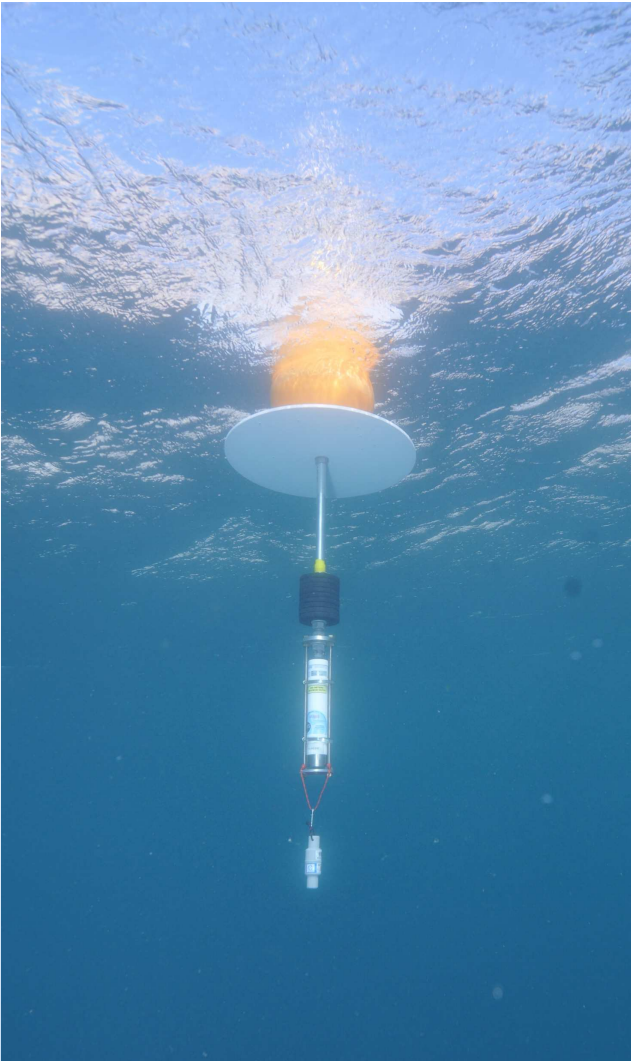


Fosse d'essais de la COMEX à Marseille (02/06/21, 03/06/21, 21/09/21)

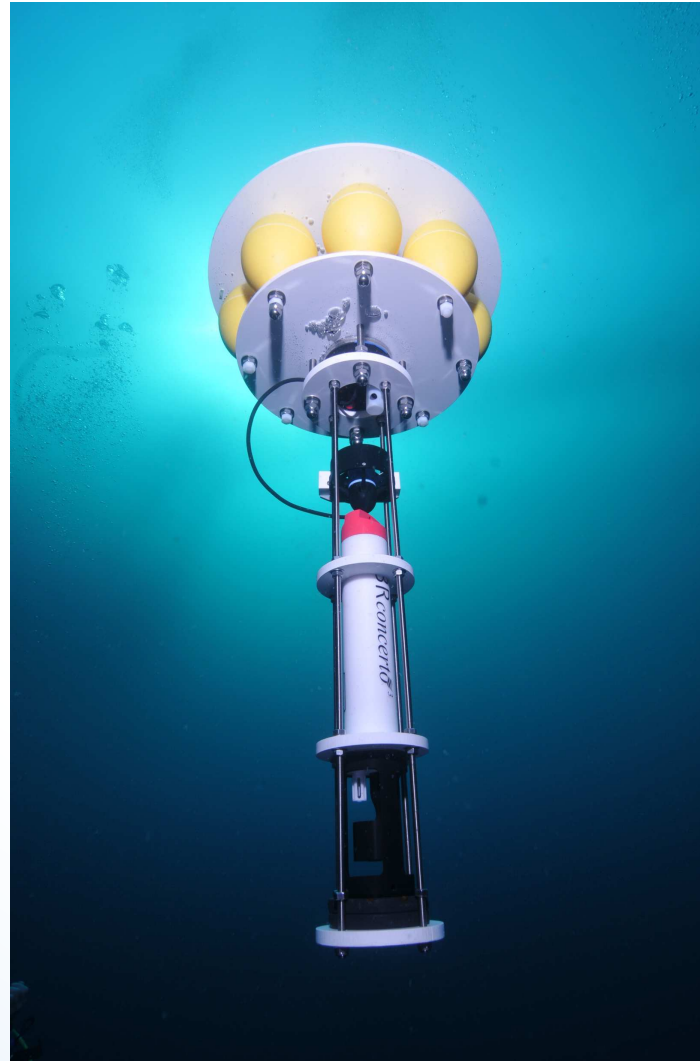


Vertical Velocity Profiler (VVP)

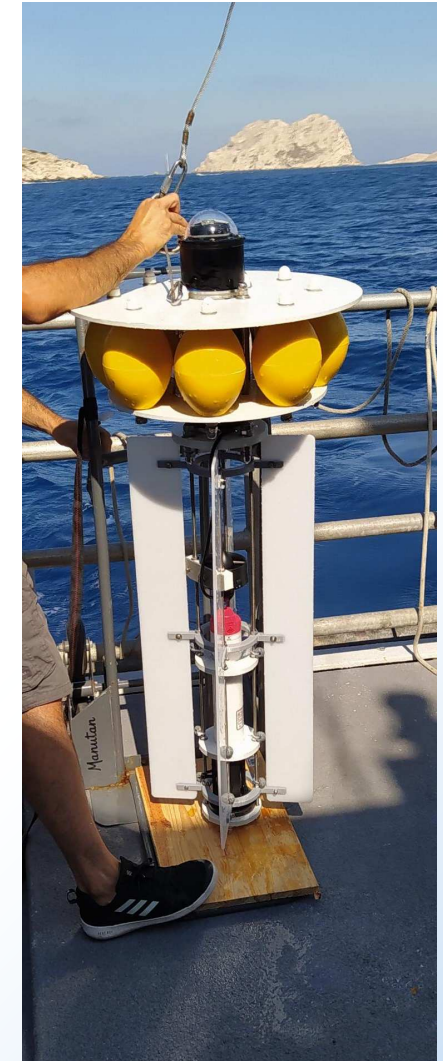
2019



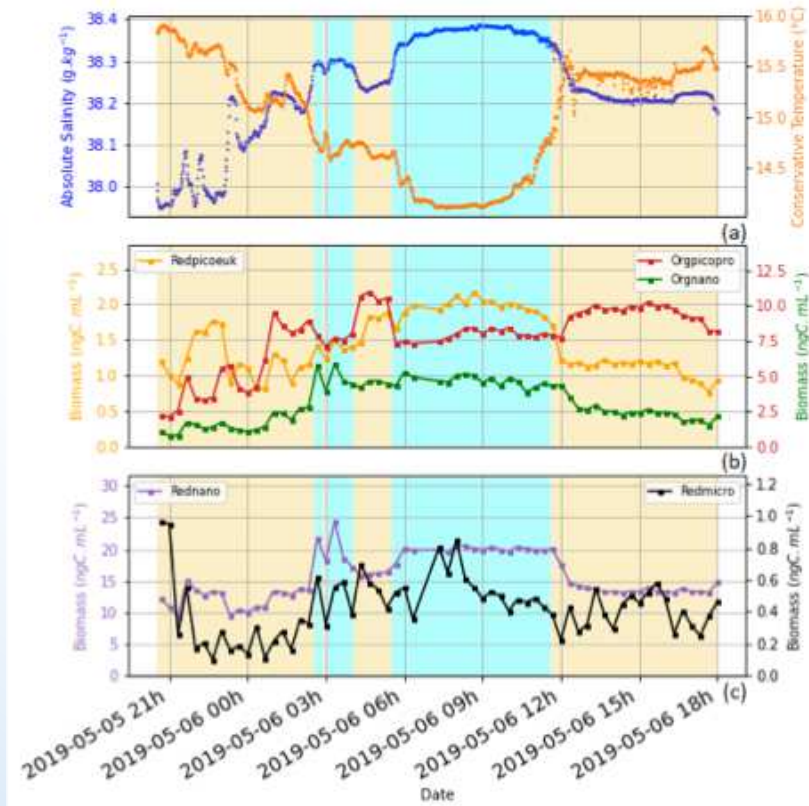
2021



2022

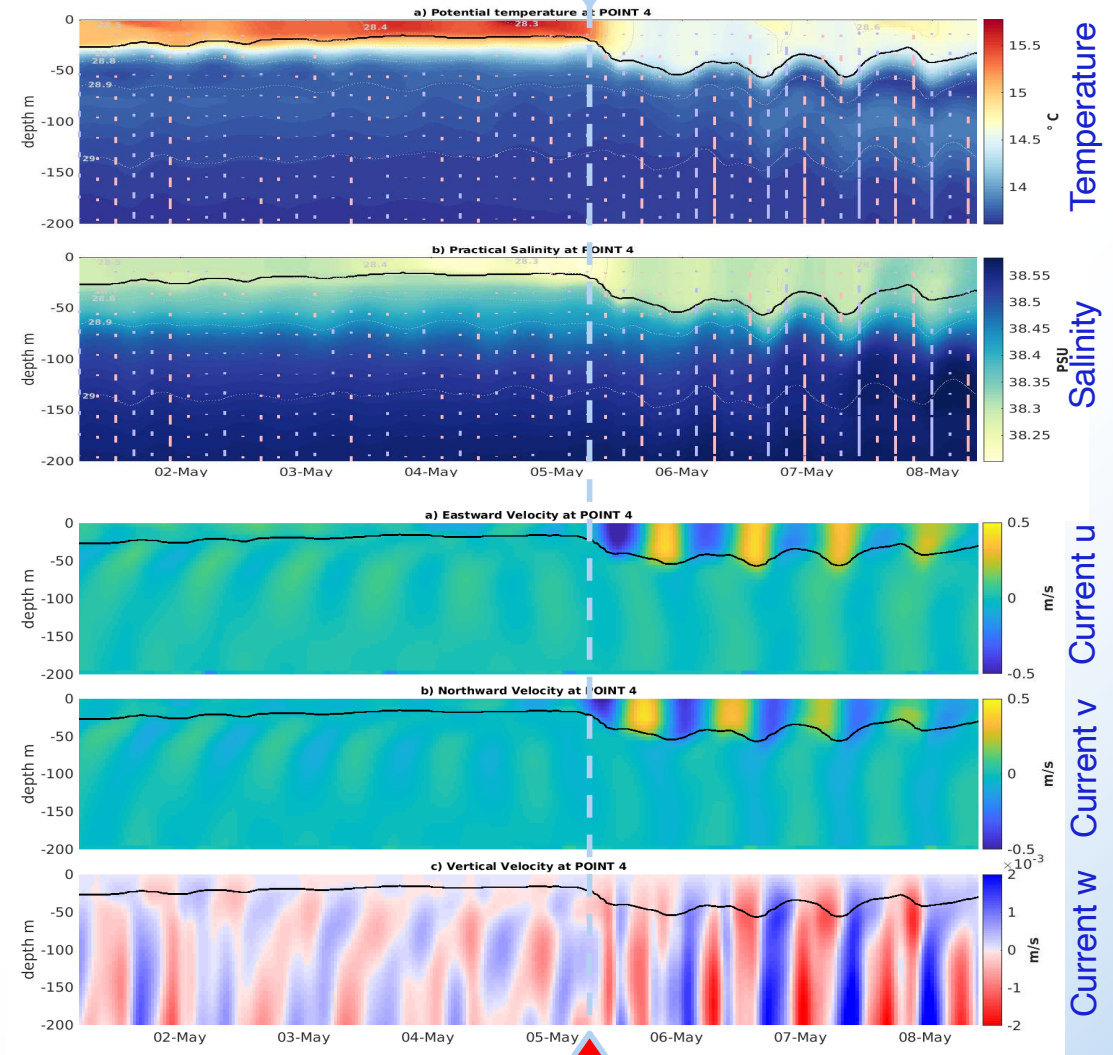


⚓ Storm influence (FUMSECK)



- 🗣️ Influence on phytoplankton
- 🗣️ Deeper mixing layer
- 🗣️ Current intensification (horizontal and vertical)

Caroline Comby



Temperature

Salinity

Current u

Current v

Current w

Perspectives

- ⚓ Develop, Deploy, Analyse, Interpret
- ⚓ Deeper understanding of vertical velocities → **Sealab** (AMIDEX, P. Le Gal, founded)
 - 💬 Back and forth between Lab and Sea experimental work
- ⚓ *In situ* deployment, exploitation and analysis of VVP and FF-Sentinel → **BioSWOT** cruise 2023 (A. Doglioli, G. Grégori)
 - 💬 Fine scales and their interaction with biology
- ⚓ Role of vertical velocities in carbon pump → **HOPE-vv** (AMIDEX, A. Petrenko, submitted)
 - 💬 VVP with ADCP
- ⚓ *In situ* measurement of vertical velocities → **ANR** project to submit (S. Barrillon)
 - 💬 Dedicated cruise, VVP flotilla, inter-comparison

Conclusion Vertical Velocities

- ⚓ Important for understanding the ocean and its evolution towards global change
- ⚓ Challenging in situ measurement
- ⚓ New methodologies and instruments developed

