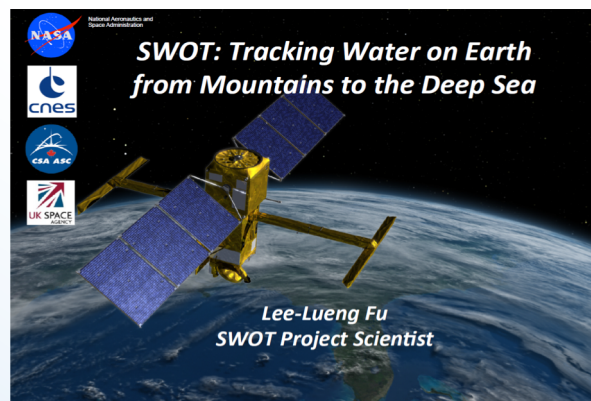


SWOT preparation Mediterranean cruises

11/09/2018, LOCEAN, Paris

*Stéphanie Barrillon (MIO), Andrea Doglioli, Gerald Gregori, Anne Petrenko,
Louise Rousselet, Jean-Luc Fuda, Francesco d'Ovidio*



SWOT and fine scales



SWOT offers unprecedented possibilities in the fine scale domain

- Fine scales : 1 – 10km / 1 – 10 days
- Dynamics = key factor in regulating biogeochemical and ecological processes
 - Important role in the biological Carbon pump transfer
 - Large influence on biodiversity, community structure, trophic chain
- Predominately investigated by numerical modelling → need of *in situ* measurements
- High resolution altimetry → direct and unprecedented access to fine scales



Demonstration and preparation cruises – NW Med.

- OSCAHR: November 2015. Ligurian sea
- PROTEUS – PREBIOSWOT: Spring 2018. South of Balears

} *Outline*

OSCAHR - Observing Submesoscale Coupling At High Resolution

P. Marrec

Thermosalinometer SST, SSS and Fluorescence

Surface

1 minute

100 to 200 m
horizontal
resolution



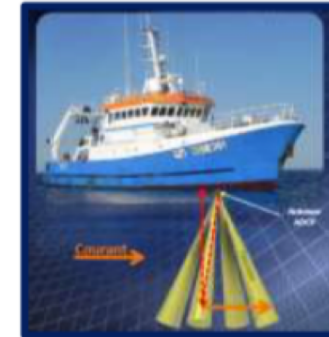
In situ Observations



Nov 3-6, 2015

Hull-mounted ADCP

150 kHz – 8m vertical resolution

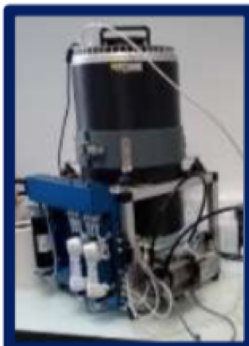


Phytoplankton Automated flow cytometry

Surface

20 minutes

3.7 to 2.4 km
horizontal
resolution



High-resolution pumping system (PASTIS)

During stations

0.1 to 1 m
Vertical resolution

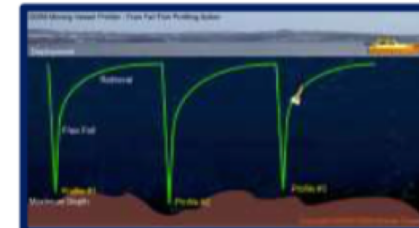
Discrete sampling



Continuous vertical CTD profiles (MVP)

≈ 2km horizontal resolution

≈ 1 m vertical resolution

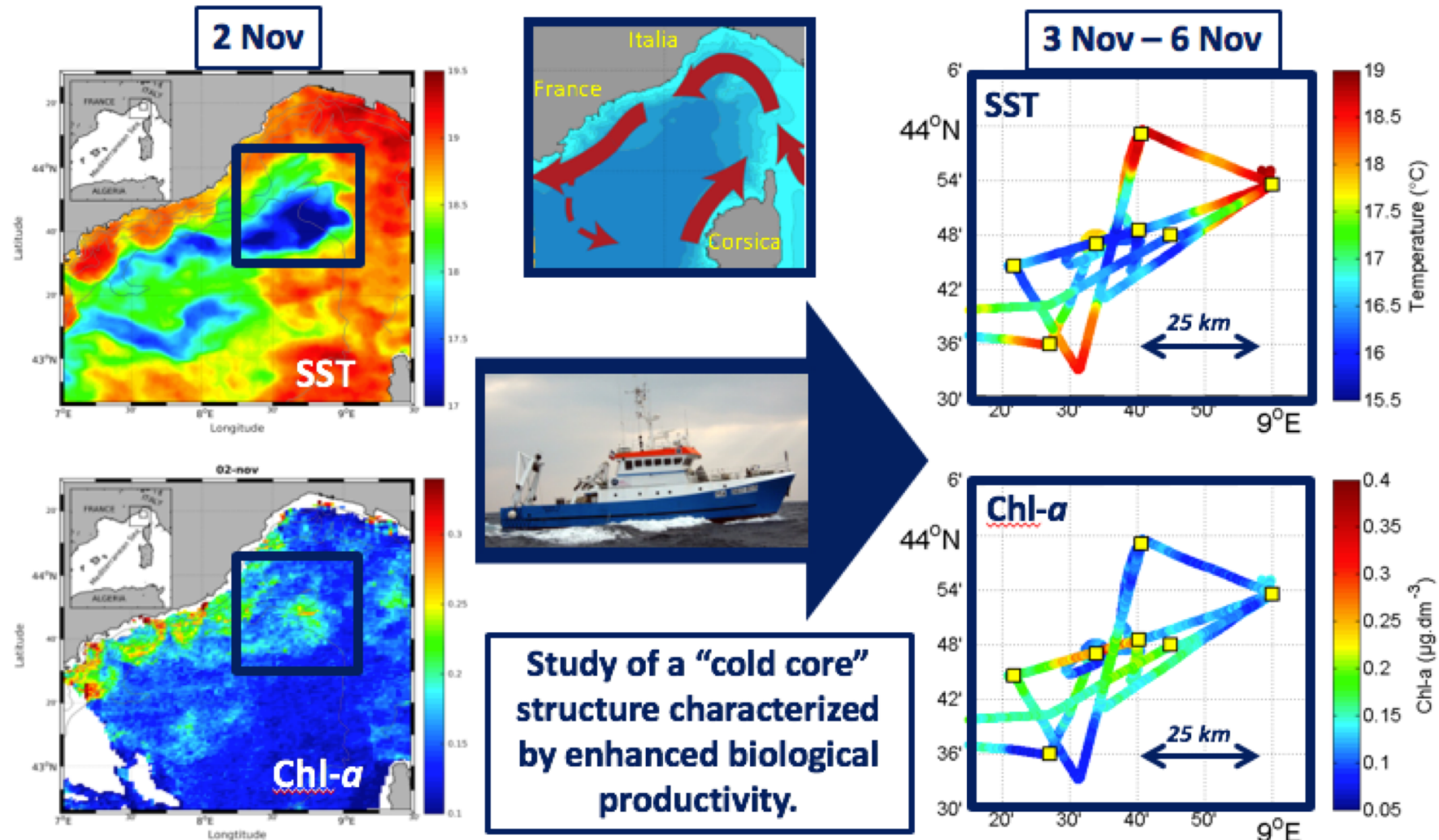


P.I. Andrea Doglioli & G rald Gr gori

OSCAHR - Strategy

Adaptative Lagrangian sampling strategy : near-real time analysis of satellite and numerical modeling data

(SPASSO software, d'Ovidio 2010, Nencioli et al. 2011)

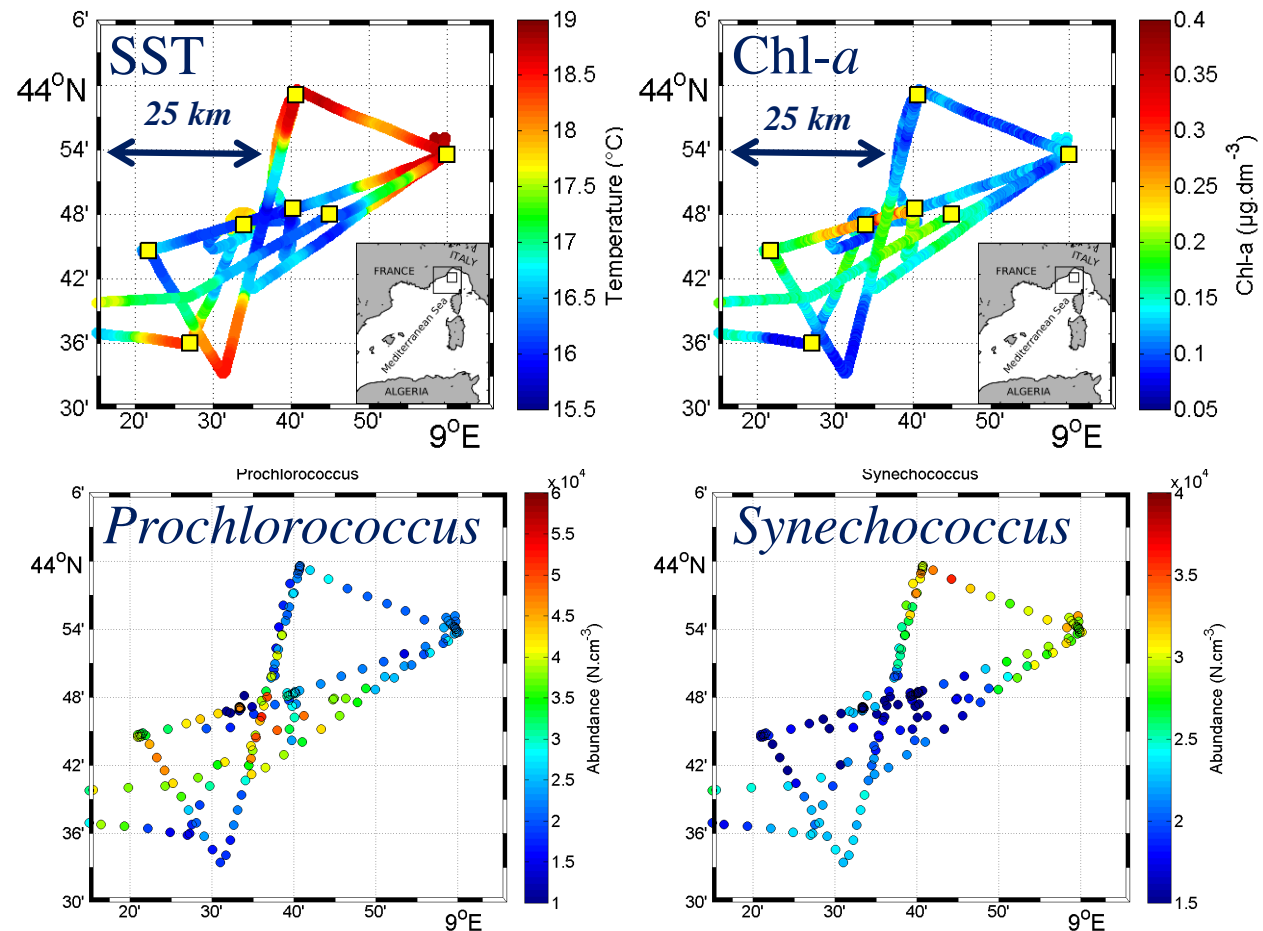


OSCAHR - Physics / Biology coupling



Surface distributions

- Phytoplankton population dominated by *Prochlorococcus* & *Synechococcus* ($15000 - 50000 \text{ cell.cm}^{-3}$)
- Cold core and highest Chl-a region:
 - *Proc.* (+*Pico. Nano*)
 - *Syn.*
- Warm boundary/lowest Chl-a region:
 - *Proc.* (+*Pico. Nano*)
 - *Syn.*

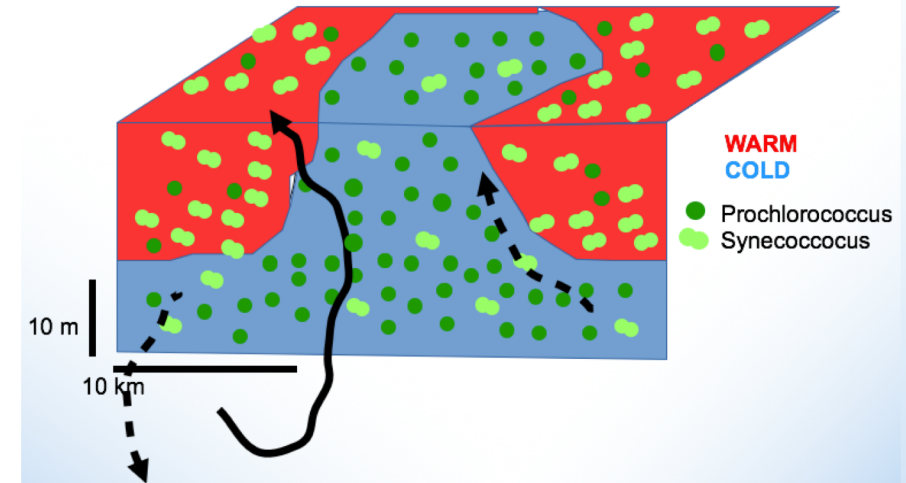
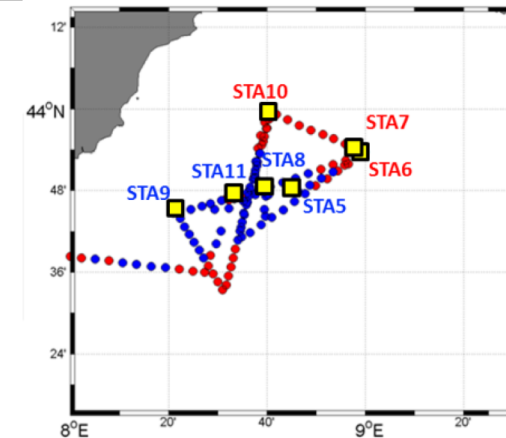
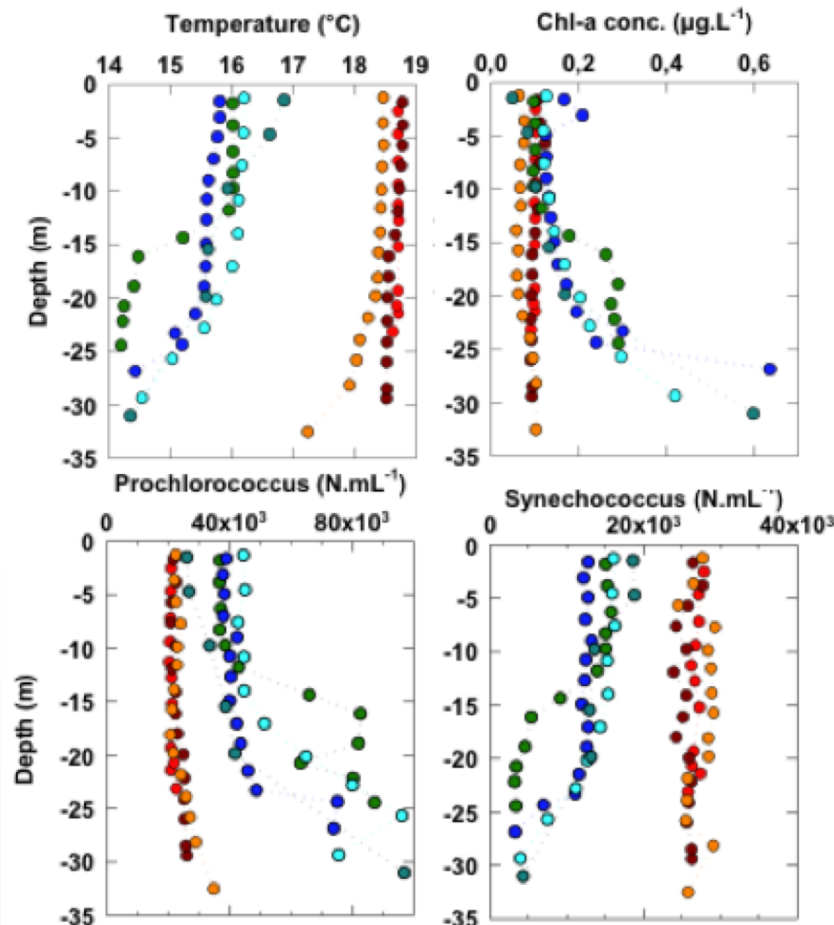


Marrec, P., et al. (2018). Coupling physics and biogeochemistry thanks to high resolution observations of the phytoplankton community structure in the North-Western Mediterranean Sea. *Biogeosciences*, 15, 1579-1606.

OSCAHR - Vertical measurements



Vertical profiles 0 - 35m



Subsurface rich *Proc.* & poor *Syn.* waters upwelled to the surface in the cold core of the submesoscale structure & enhanced biological productivity

OSCAHR - Vertical motions and effects on biology

L. Rousselet



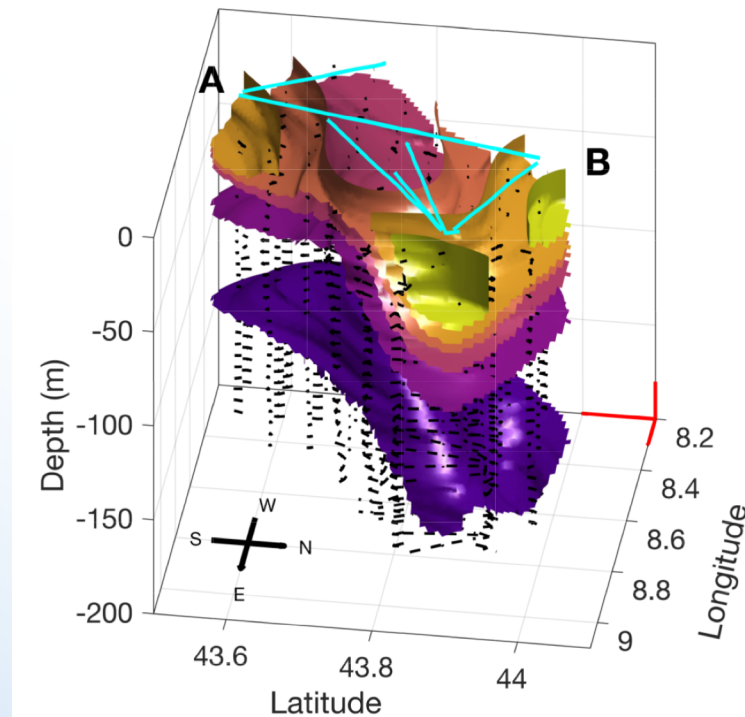
MVP and ADCP data

→ reconstruction of 3-D
fields : density and velocity
(horizontal components)

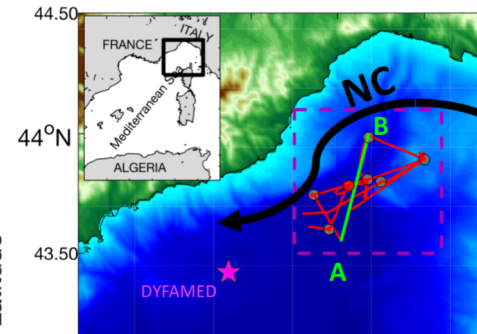
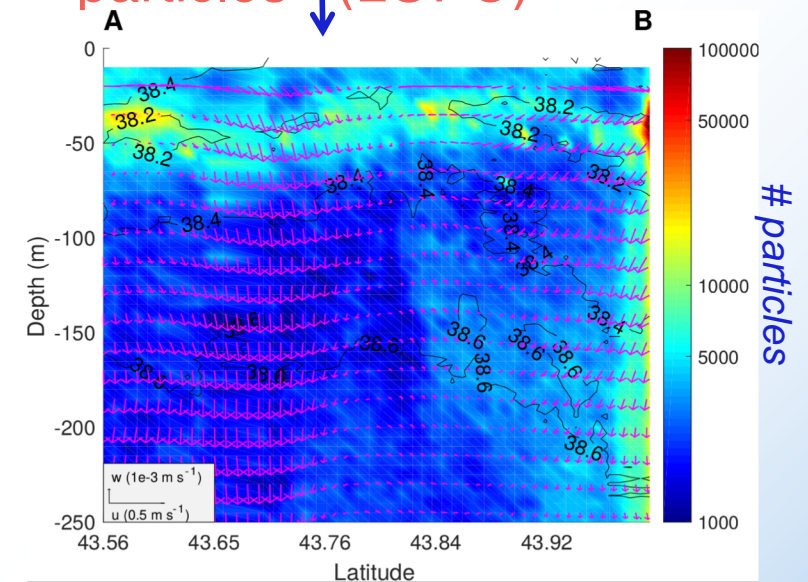
ω -equation



Vertical
component of
the velocity field

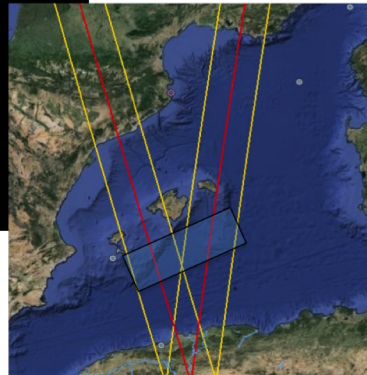
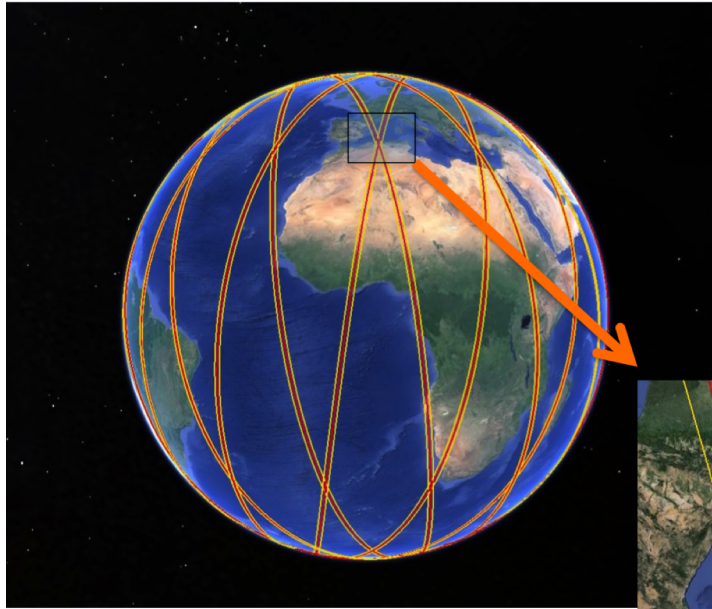


Validation with independent
measurement of number
of particles (LOPC)



Rousselet et al. (submitted to JGR), Vertical motions in a fine-scale cyclonic structure observed in the Ligurian Sea and their effects on a biogeochemical tracer.

PROTEUS - PREBIOSWOT



⚓ Objectives

- New *in situ* multiplatform measurements in the framework of SWOT
- Evaluate the interest of the Western Med. SWOT crossover
- A synergy among three programs



Cruise

- April 27 – May 14, 2018. South of Balears
 - BBP (Seasor, Cytometry, ADCP) (F. Dumas & P. Garreau)
 - Garcia del Cid (CTD grid) (A. Pascual)
 - Drifting buoys + 2 gliders + 1 plane

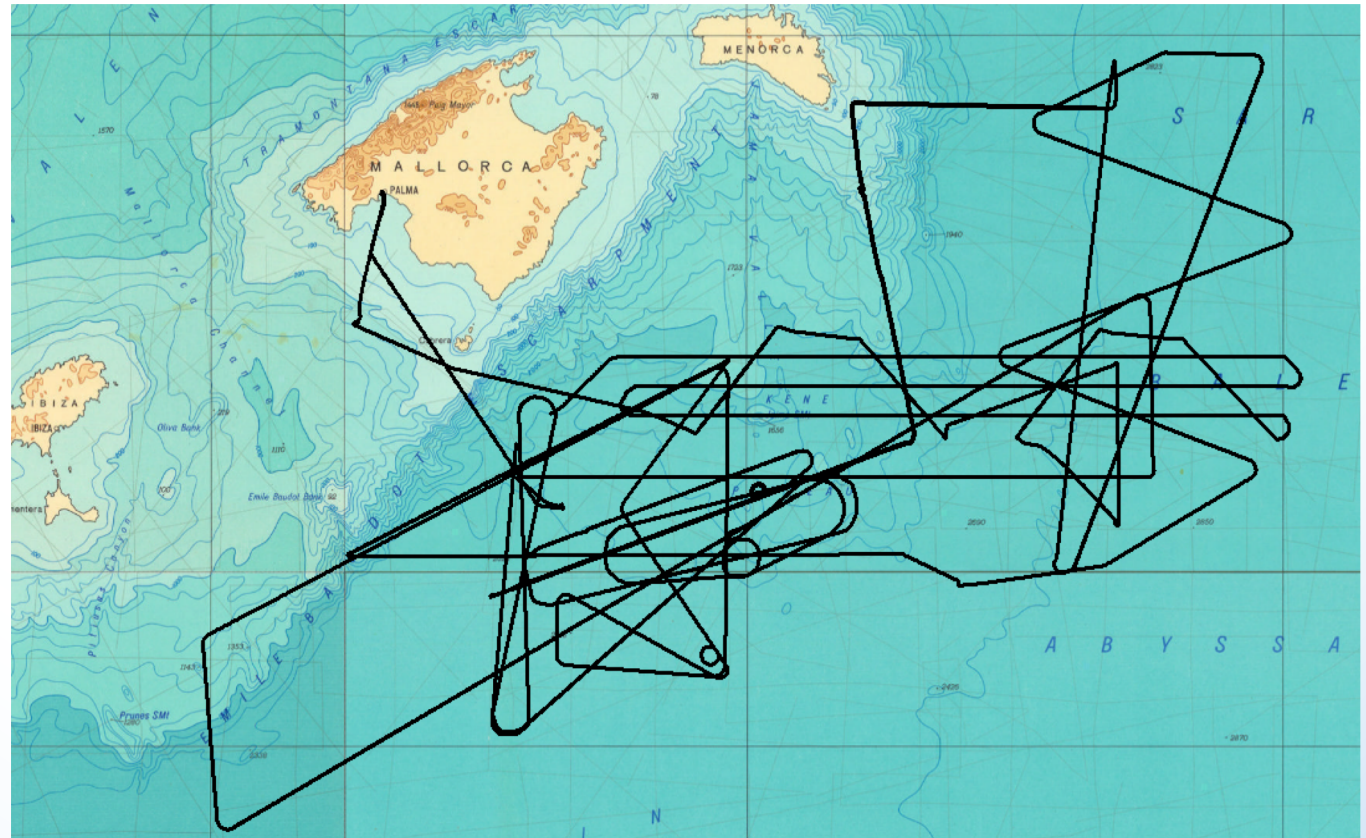
PROTEUS - PREBIOSWOT

BBP cruise



Numbers :

- ~4000 nautical miles
- 2 Seasons (~ 300 hours)
- ~ 150 CTD
- On-board data analysis
- Counted particles: 16 millions

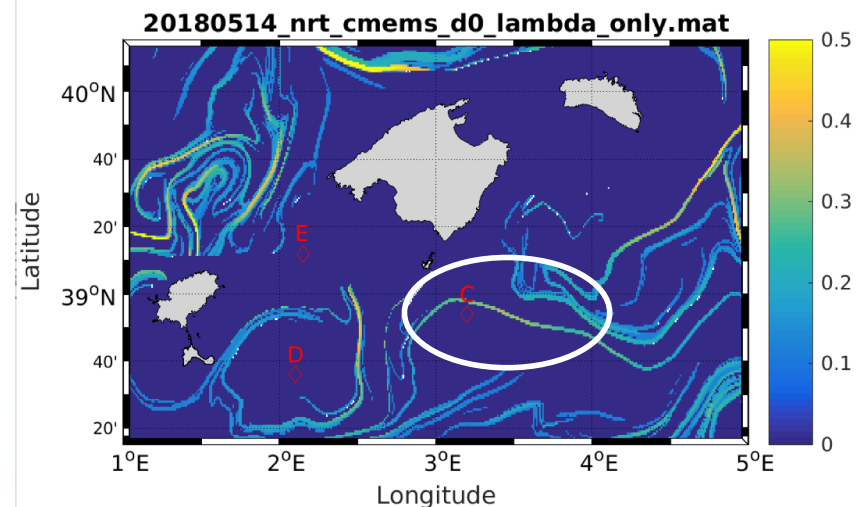
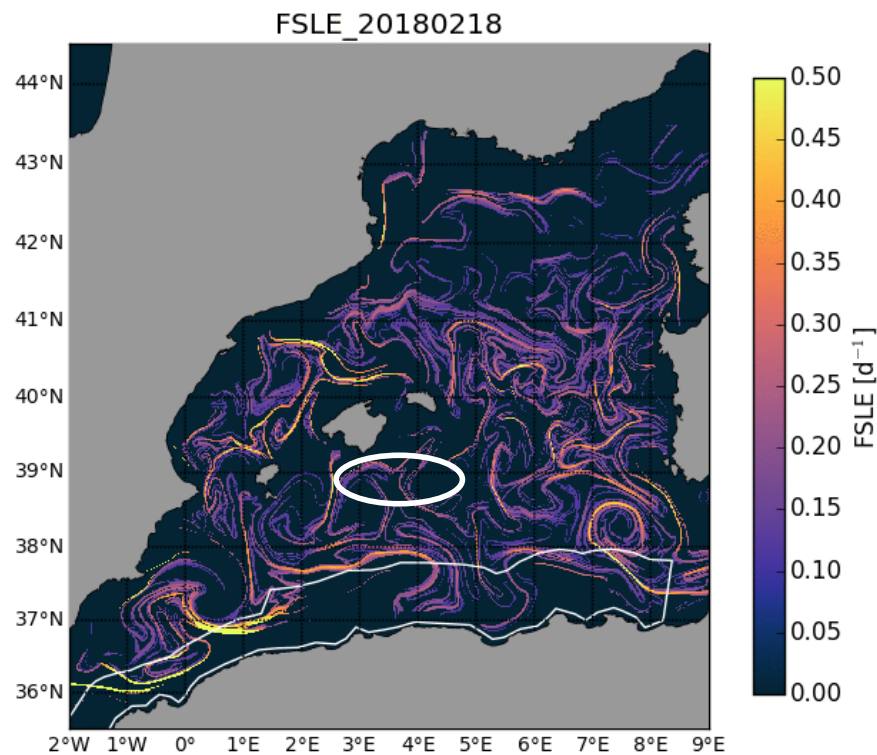


Satellite and Lagrangian analysis



Look for separations between 2 distinct water masses using SPASSO

- From altimetry, SST and Chl-a observations
- Daily bulletin during the cruise



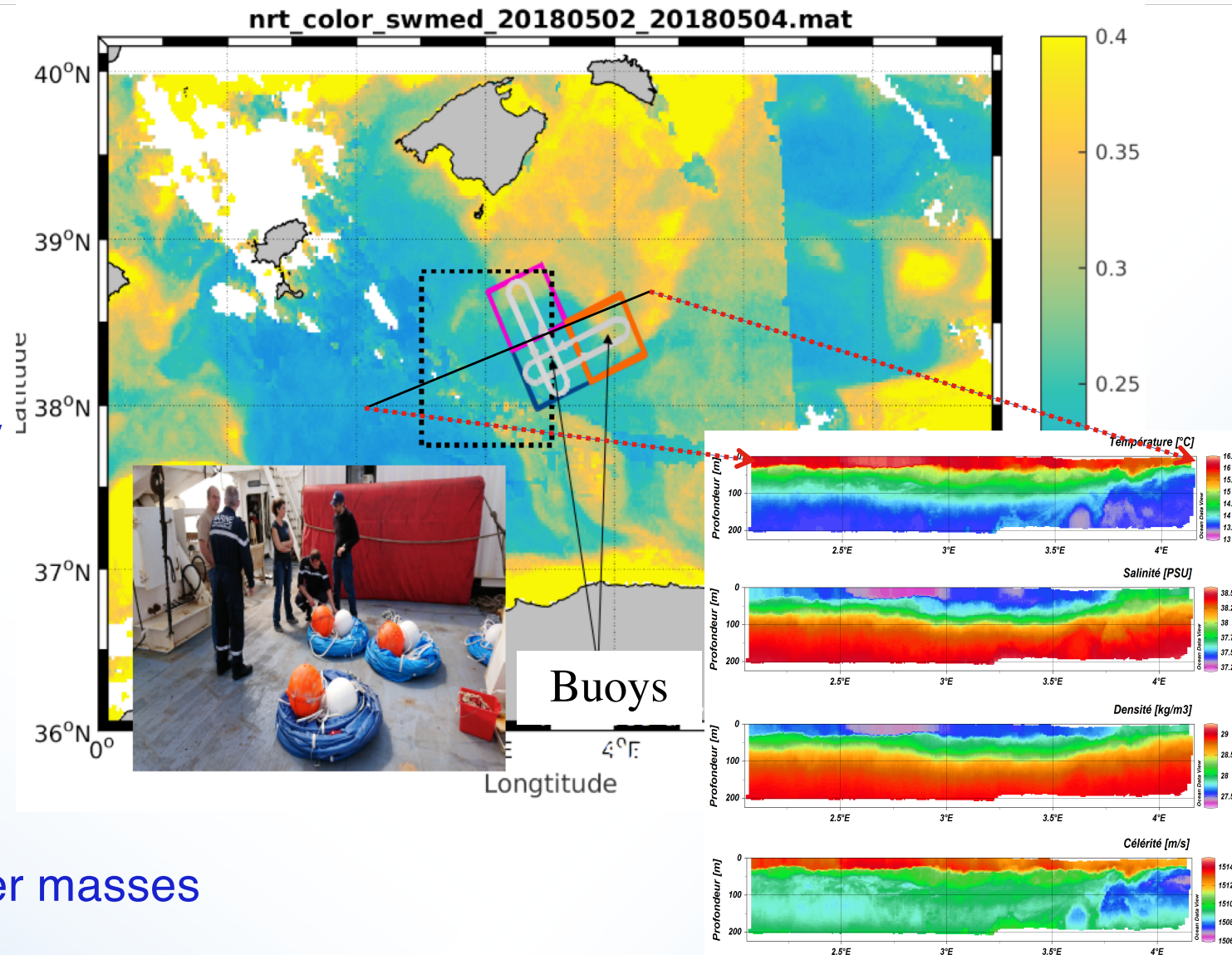
On-board analysis



2 water masses sampled

- Contiguous and well-contrasted
- Physical and biological survey
- Sampling strategy around 4 drifting buoys

→ 2 distinct water masses

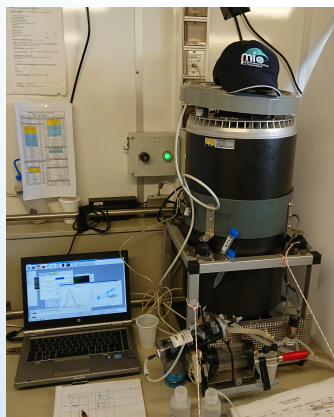


On-board analysis

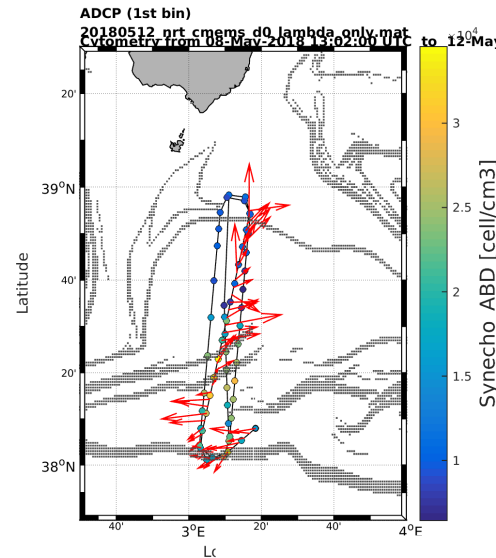


Survey of 2 water masses

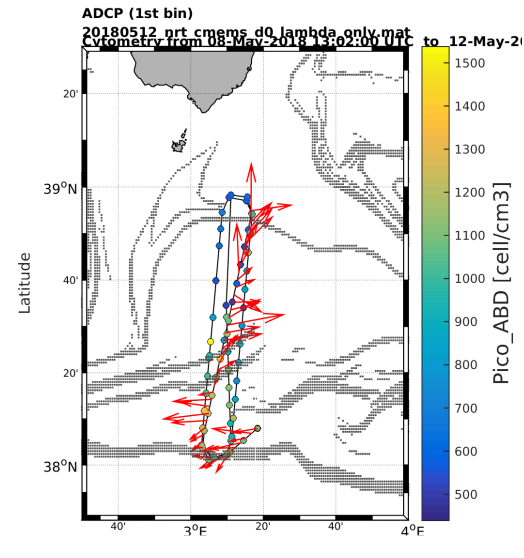
- : current (ADCP)
- : FSLE
- : abundance for a functional group



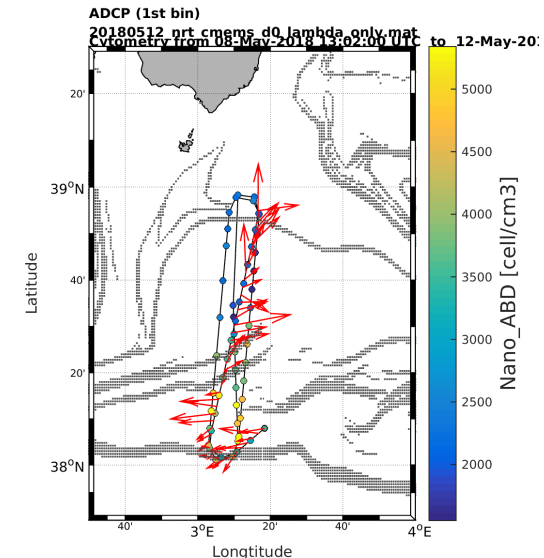
Synecho



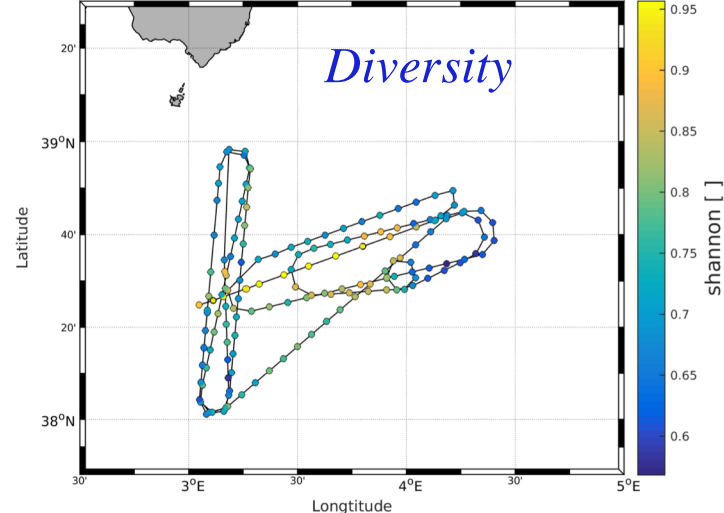
Pico



Nano



Cytometry from 08-May-2018 13:02:00 UTC to 12-May-2018 14:02:00 UTC



→ nice biodiversity contrast, higher diversity along the front

Conclusions & Perspectives



OSCAHR & PROTEUS-PREBIOSWOT

- Innovative **adaptive strategy** with **multidisciplinary** approach shows that **fine-scale physical structures** drive the **biogeochemical variability** and spatial **distribution of the phytoplankton functional groups**.
 - Gained **experience**
 - **Promising** results
 - → **deeper understanding** of the physical and biogeochemical processes at the fine scales

- Continue preparation with the Fumseck cruise in 2019



SWOT 2022 and the associated cruises

- 2D → 3D (increase horizontal and vertical resolution, access vertical velocities) → 4D (temporal evolution)
- ...

Backup

OSCAHR

Observing Submesoscale Coupling At High Resolution



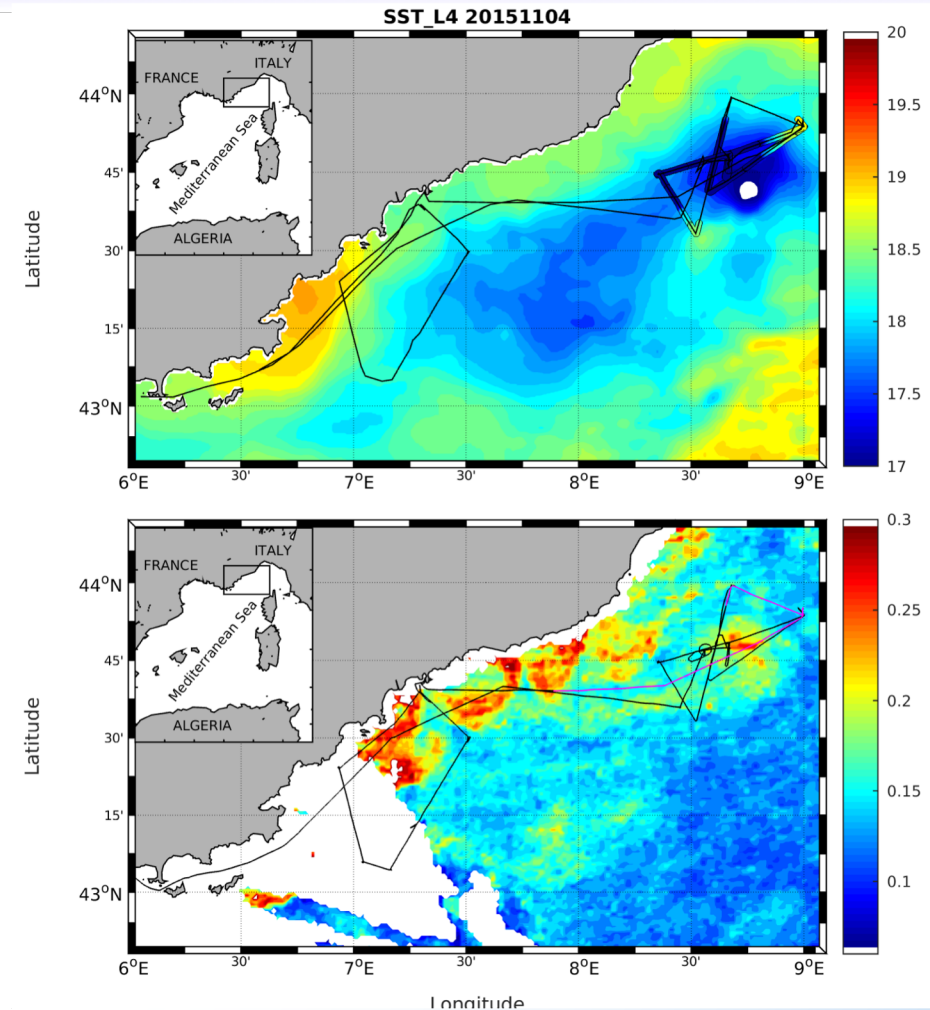
OSCAHR

Mapping the planktonic community across submesoscale physical features

Goals :

- *methodological development and validation of remote sensing measurements (altimetry, sst, ocean color, reconstitution of planktonic assemblages)*
- *in situ confirmation of the structuring effect of submesoscale on the first trophic levels and the associated biogenic elements*

Cruise : 29 Oct - 6 Nov 2015 in NW Med



A.M. Doglioli, G. Grégori, M. Thyssen, T. Wagener, P. Marrec, G. Rougier, N. Bhairy, J. Fenouil, A.deVerneil, L.Rousselet, F.Cyr, A.A. Petrenko, J.-M. André, F. d'Ovidio, A. Pietri, F. Nencioli, L. Jullion, C. Pinazo, C. Yohia and P. Marsalaix

Materials and Methods

Surface Horizontal Mapping

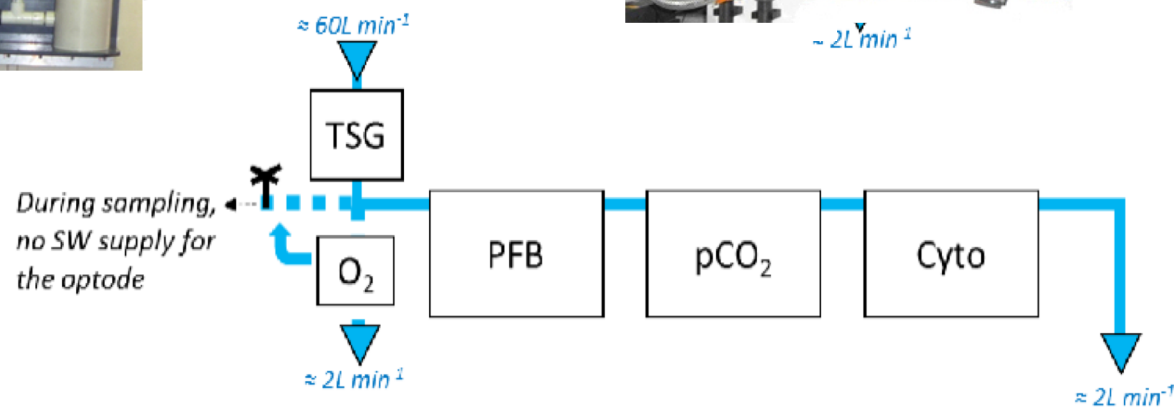
TSG
ThermoSalinoGraph



Fluorimeter



Onboard surface
water intake



Thermosalinograph

Fluorimeter

Automated flow cytometer Cytosense

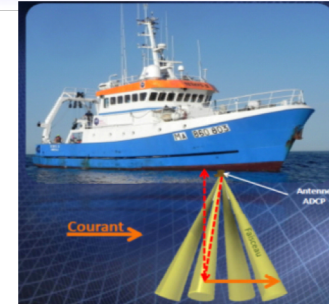
high-throughput sampling
(20' → 3.7 to 2.4 km)

Materials and Methods

Horizontal & Vertical Mapping

Hull-mounted ADCP

150 Khz (vertical resolution 8 m)

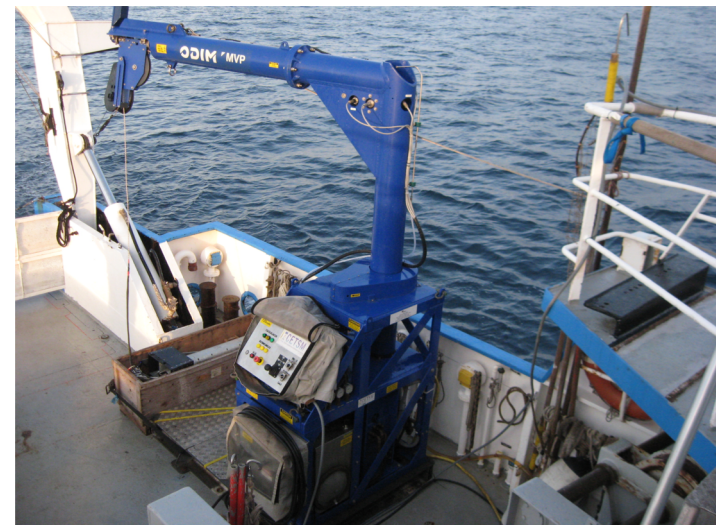


MVP Moving Vessel Profiler

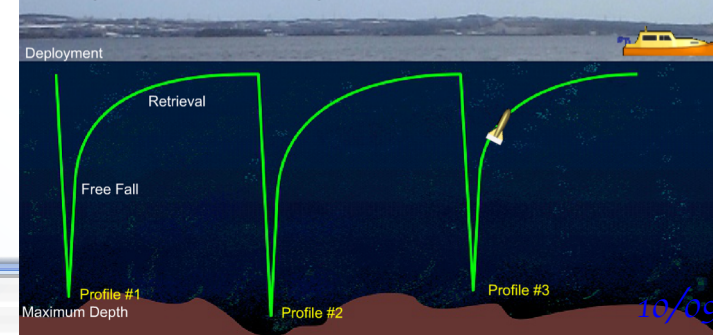
Multi-Sensor Free-Fall Fish:

CTD, fluorescence and LOPC
Laser Optical Particle Counter

~2 km horizontal resolution
~1 m vertical resolution



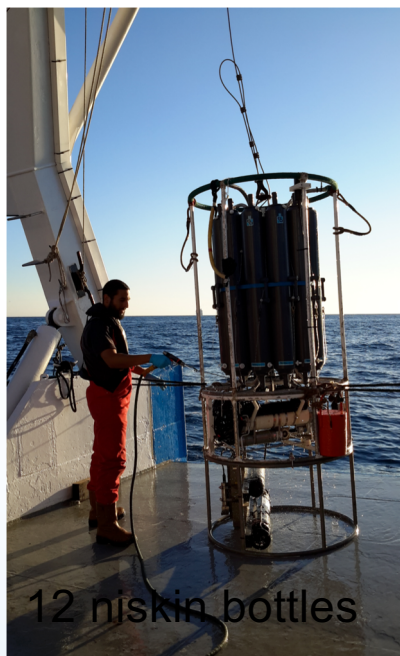
ODIM Moving Vessel Profiler - Free Fall Fish Profiling Action



Materials and Methods

High resolution vertical sampling

CTD carousel



ECOVSF3

Three-angle, Three-wavelength
Volume Scattering Function Meter

CTD SBE32

LOPC and LISST

Laser Optical Particle Counter

Laser In situ scatterometer and
transmissiometer

PASTIS

Pumping Advanced System To Investigate Seawater

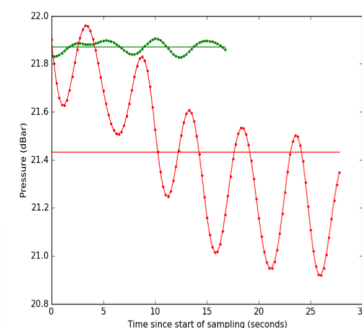


- bellows pump
- 30m PE tube
- CTD SBE19+



*Discrete
Sampling*

*vertical
precision
0.1 to 1 m*



Post-Cruise
Lab Analysis:
Nutrients and Cytometer FACScalibur

Materials and Methods

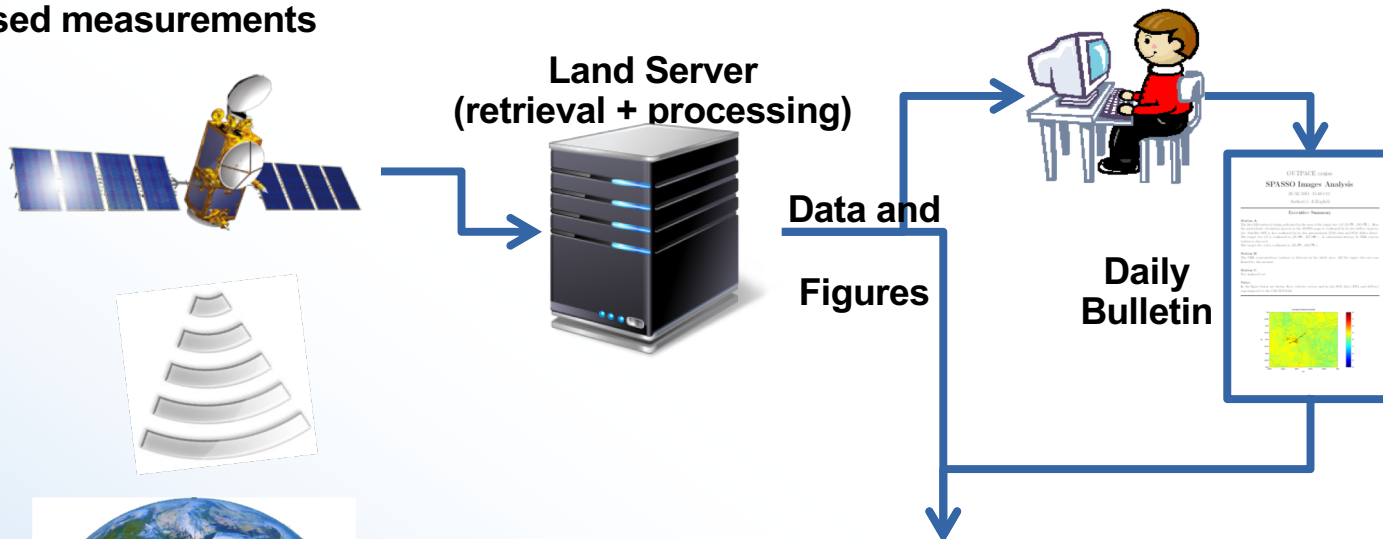
Adaptive Lagrangian sampling strategy

(Target the structures)

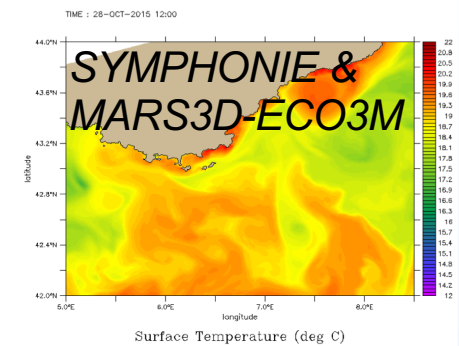
SPASSO

Software Package for Adaptive Sampling Strategy for Ocean campaigns
[d'Ovidio 2010, Nencioli et al 2011]

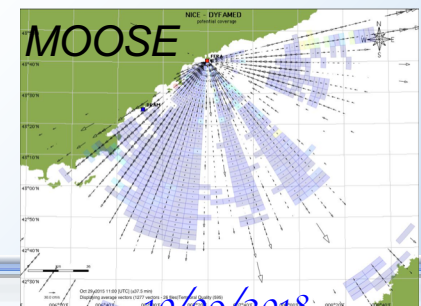
sensed measurements



+ Numerical Modeling Forecast



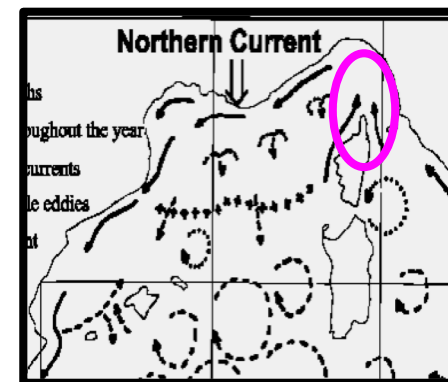
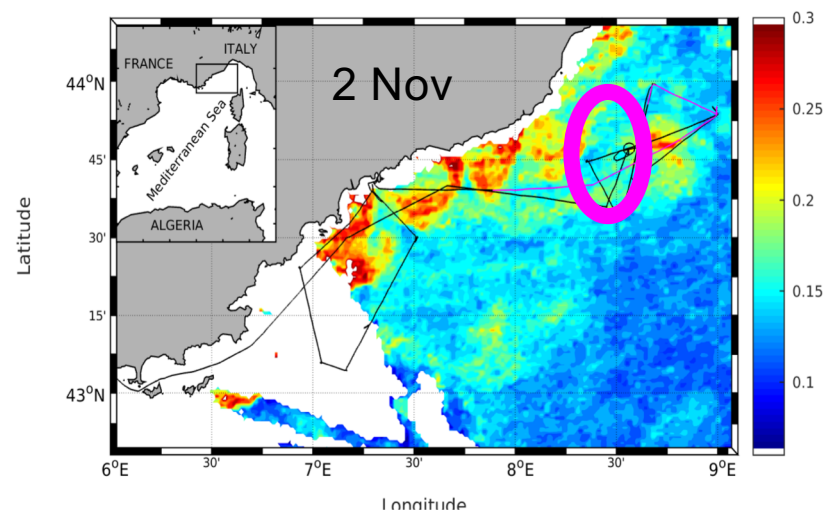
+ HF radar



Materials and Methods

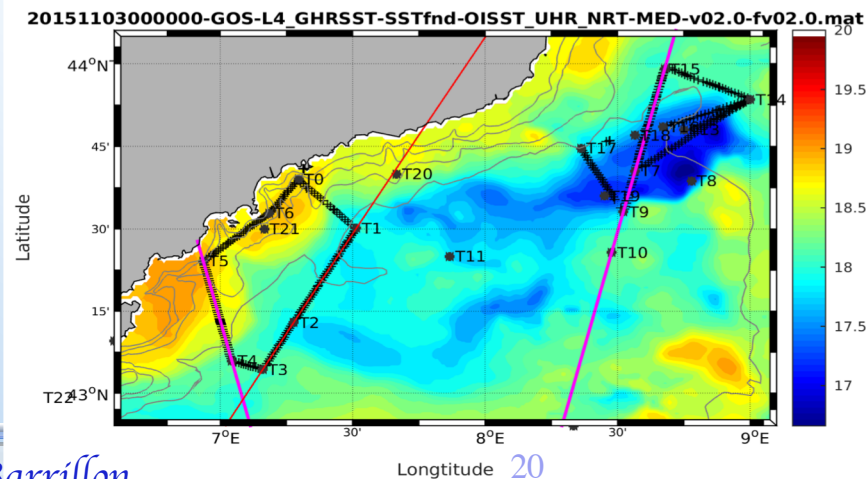
Adaptive Lagrangian sampling strategy

(Target the structures and follow them!)

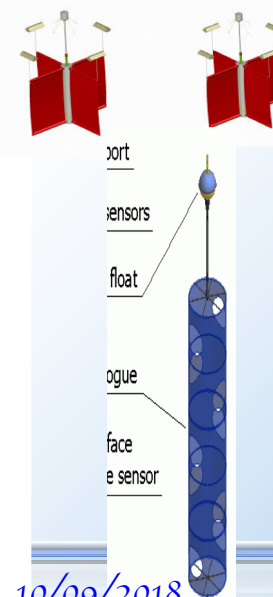
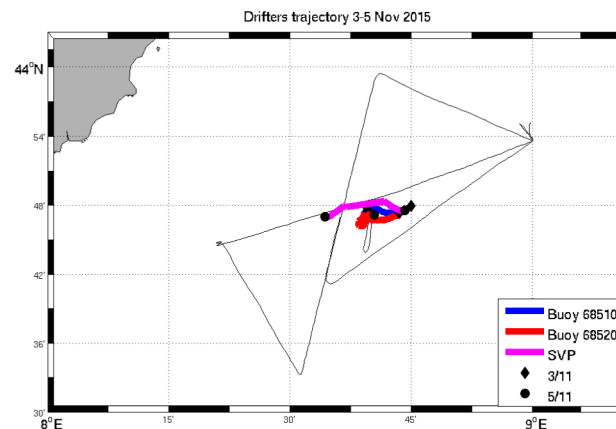


Millot 1998

Satellite tracks
Sara/AltiKa & Jason2

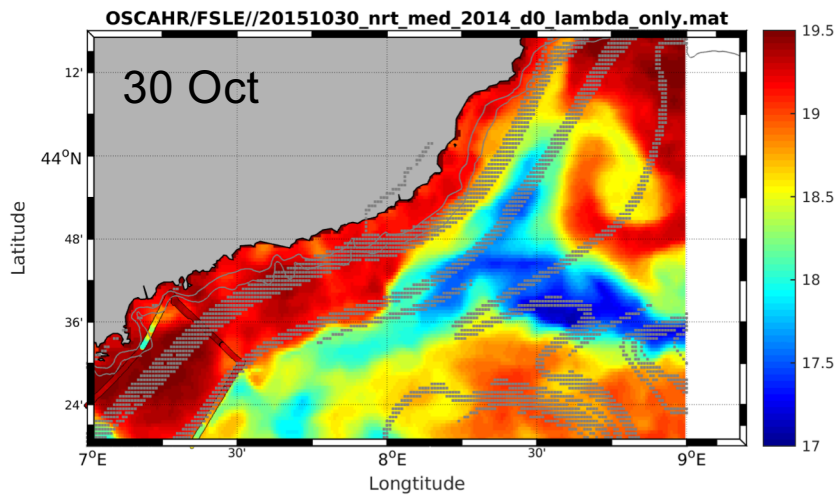


Lagrangian drifters
2 code and 1 SVP

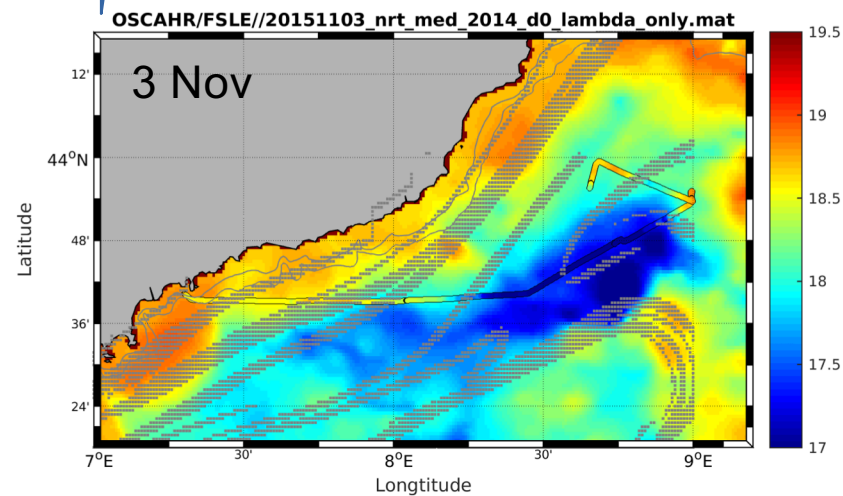


Results

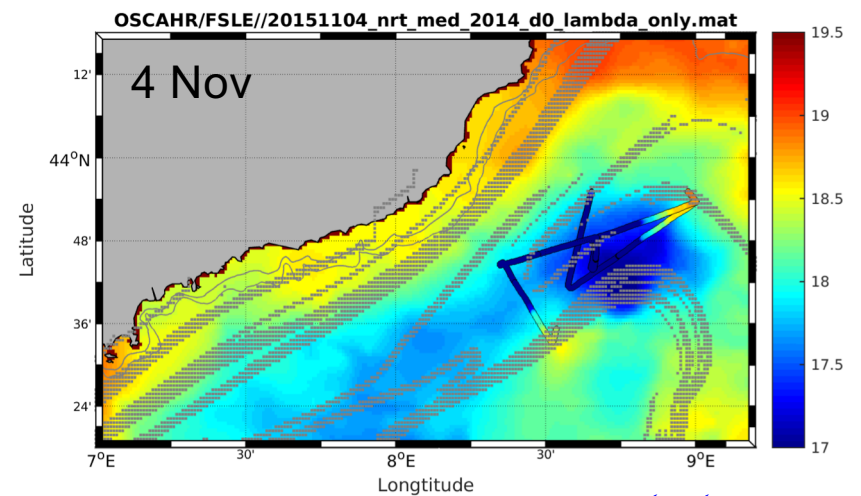
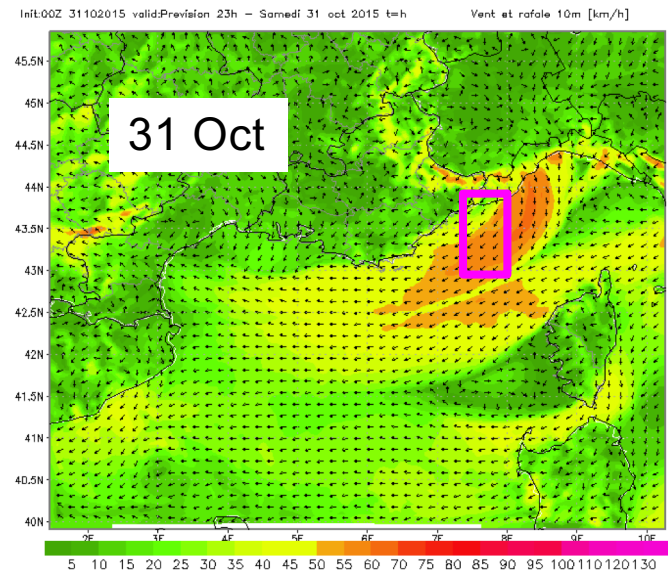
FSLE + SST + SST_tsg



General cooling + structure intensification



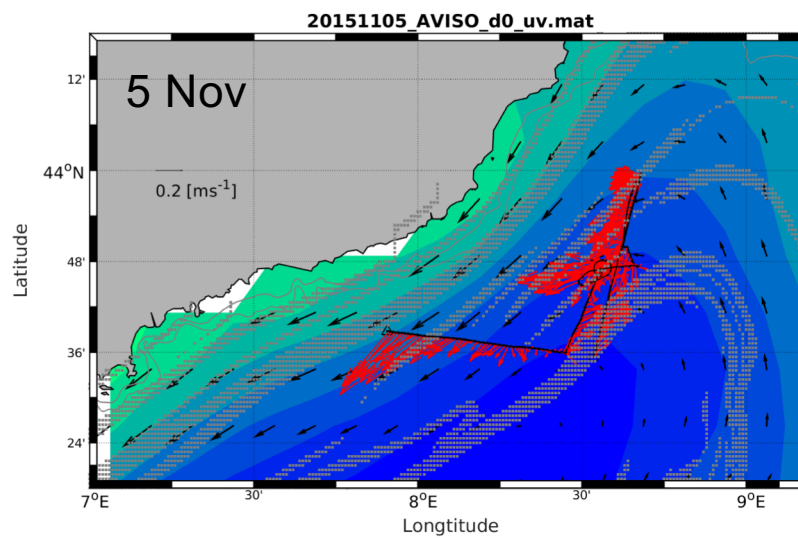
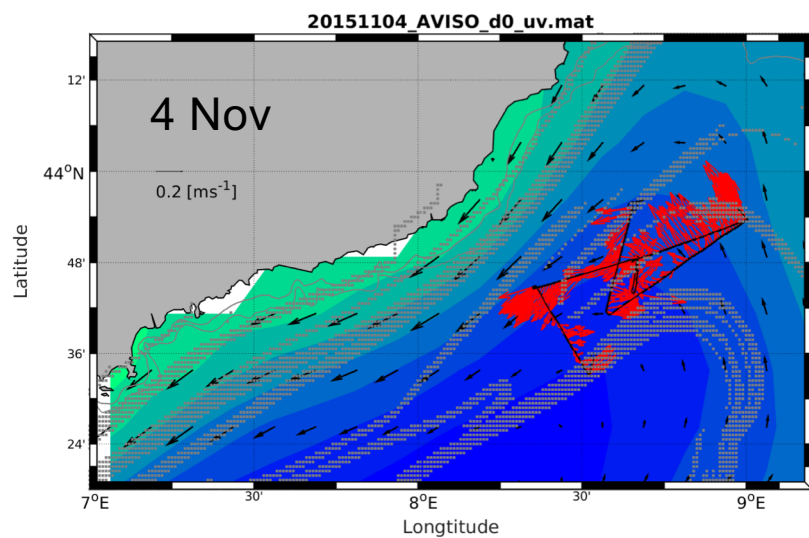
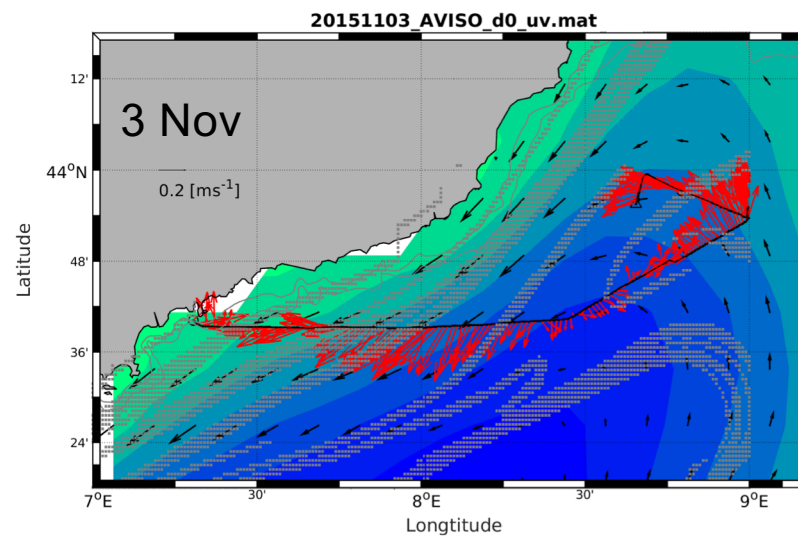
Strong NE Wind



Results

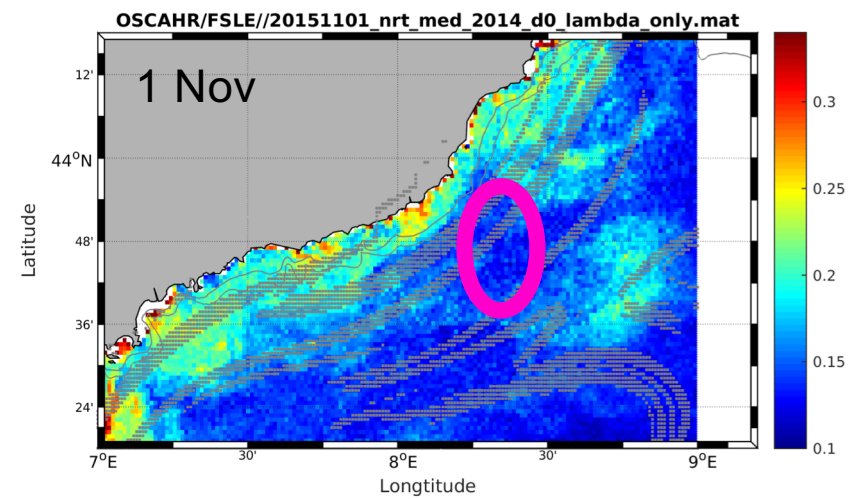
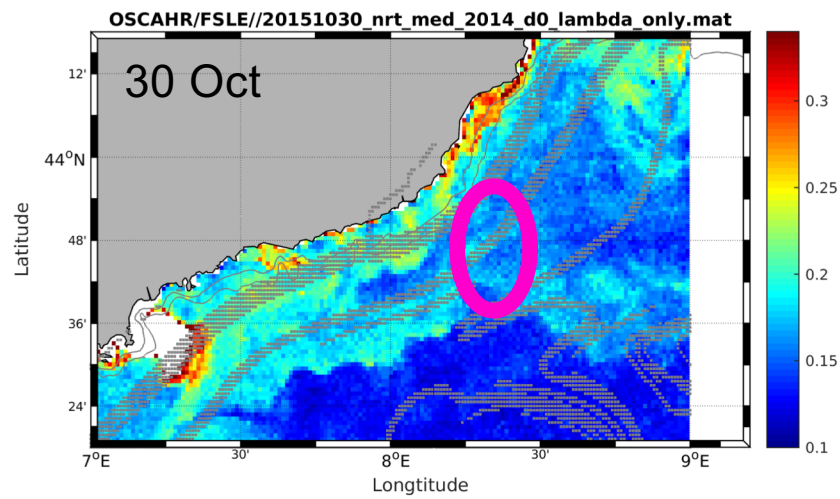
FSLE
+
SLA and AVISO current
+
ADCP (-27 m depth)

Cyclonic circulation

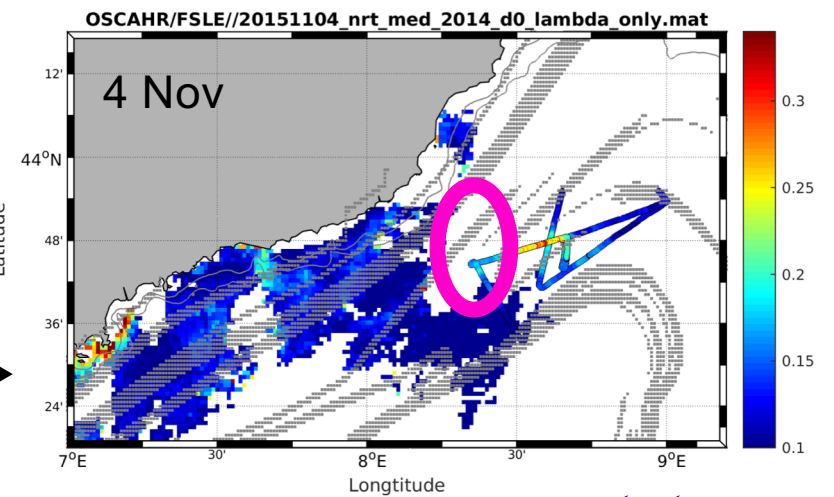
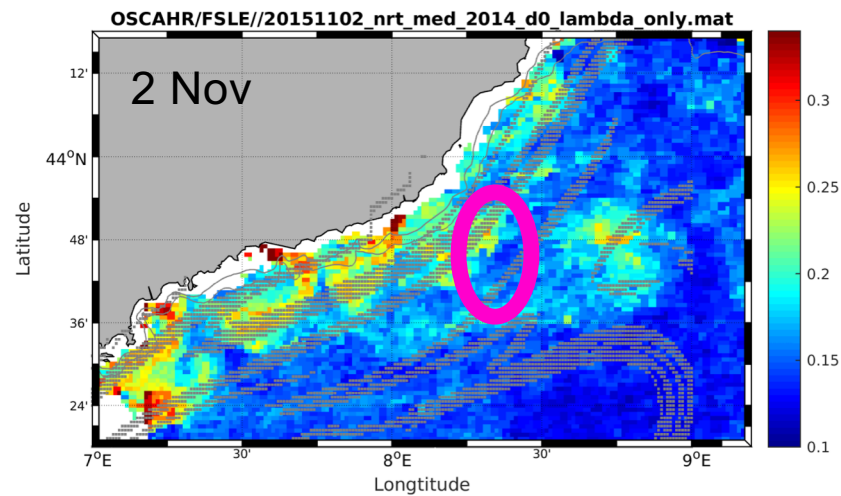


Results

FSLE + CHL



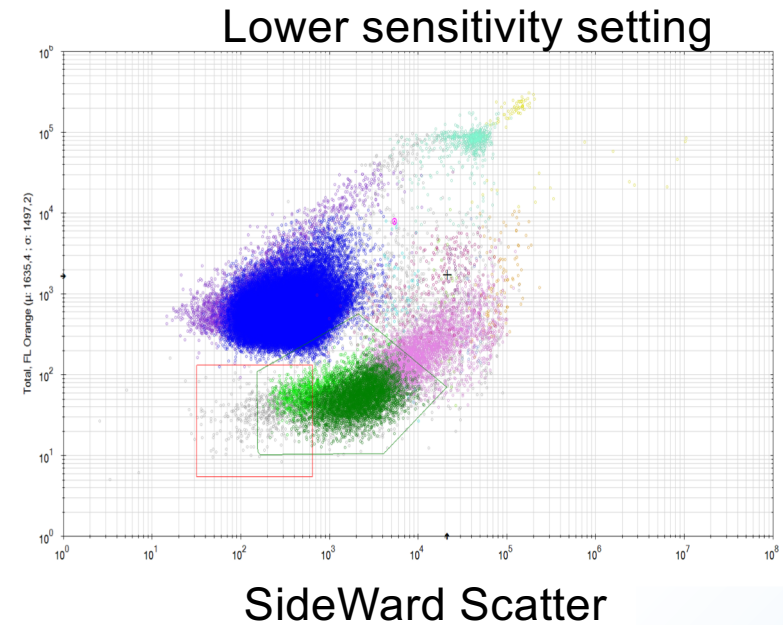
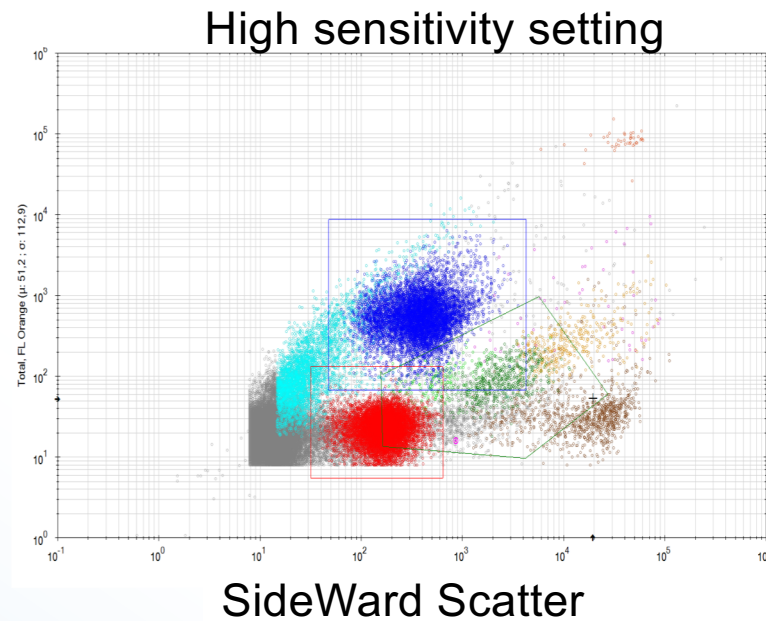
+ CHLtsg



Results

Phytoplankton assemblages

Single cell approach – sensitivity tests



9 functional groups identified:

Prochlorococcus

Synechococcus

Picoplancton & Picoplancton High FLR

Cryptophytes

Nanoplancton 1 & Nanoplancton 2

Microplancton & Microplancton High FLO

SPASSO



SPASSO (*Software Package for an Adaptive Satellite-based Sampling for Ocean campaigns*)

- Package with an automatic script to download and treat satellite data
 - Ran by crontab on satellite machine
 - Output as files and figures
 - **Figures plotting in Python**
- Multicampaign
- Figures accessible online
 - PREBIOSWOT all :
http://www.mio.univ-amu.fr/SPASSO/PREBIOSWOT/Figures_web/
 - PREBIOSWOT figures of the day:
http://www.mio.univ-amu.fr/SPASSO/PREBIOSWOT/Figures_web_oftheday/
- Daily bulletin during the cruise accessible online (.tex and .pdf)
 - PREBIOSWOT:
http://www.mio.univ-amu.fr/SPASSO/PREBIOSWOT/Bulletin_web/

Products

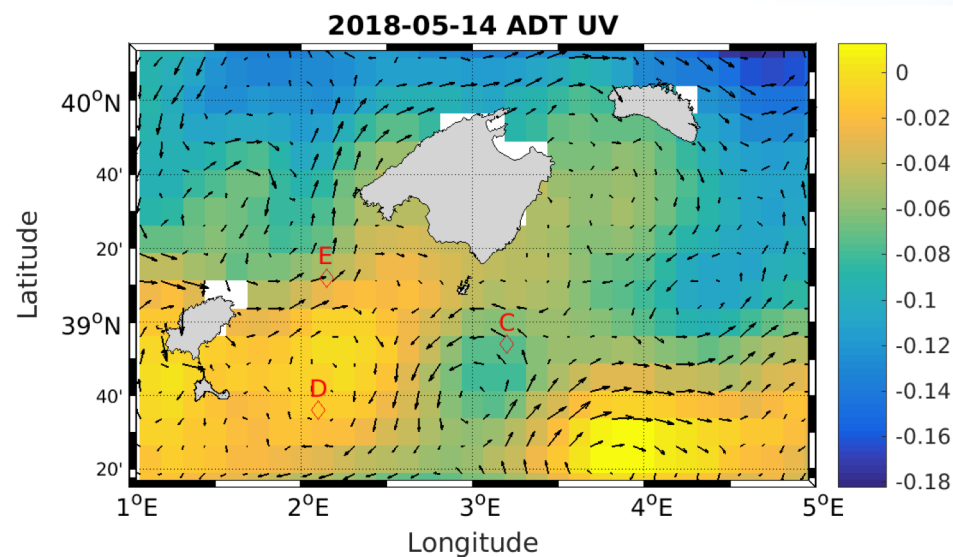
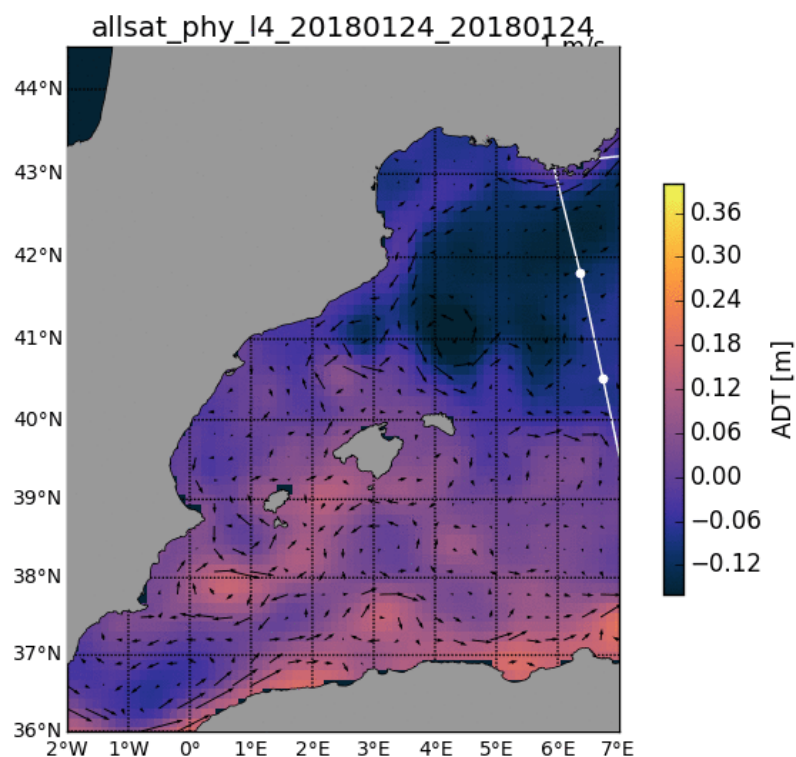


AVISO



SSH

- ftp://ftp.sltac.cls.fr/Core/SEALEVEL_MED_PHY_L4_NRT_OBSERVATIONS_008_050/dataset-duacs-nrt-medsea-merged-allsat-phy-l4-v3/
- $0.125 \times 0.125^\circ$ ($1/8^\circ$) - 0 day delay



Products

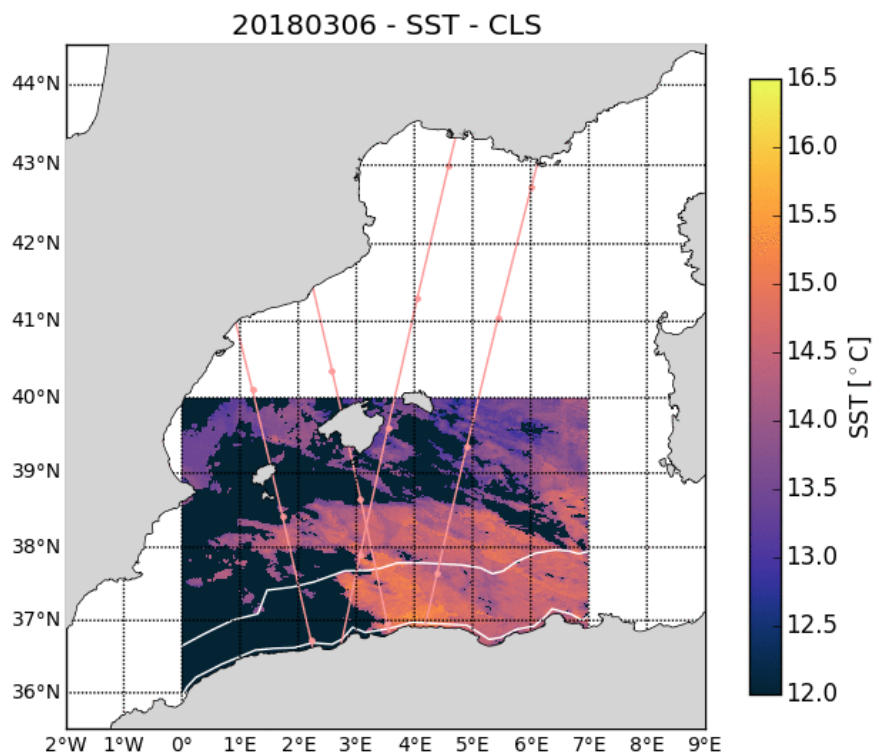


CLS (AVISO+)



SST

- <ftp://ftp.aviso.altimetry.fr/experimental/regional-southwestmediterranean/near-real-time/temperature/>
- $0.02 \times 0.02^\circ$ ($1/50^\circ$) - 1 day delay (naming convention is 2days delay)



Products

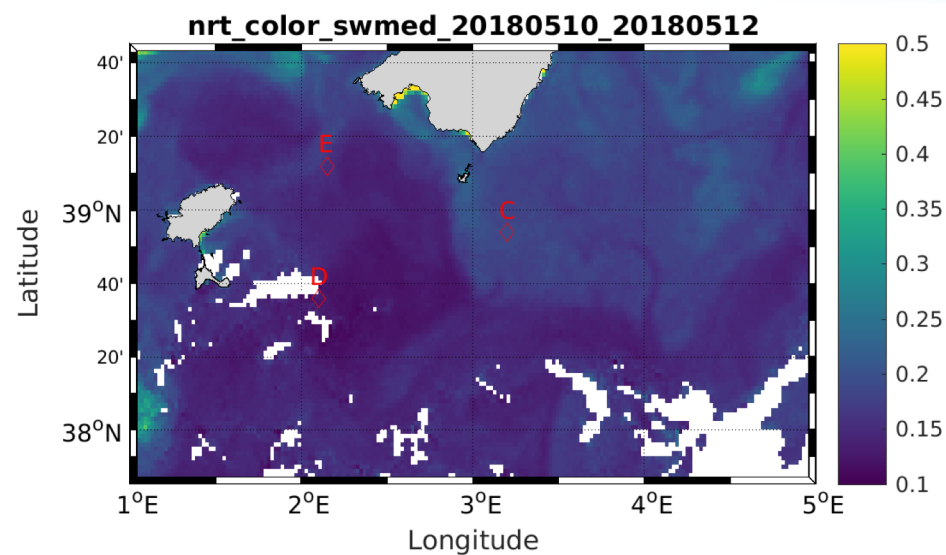
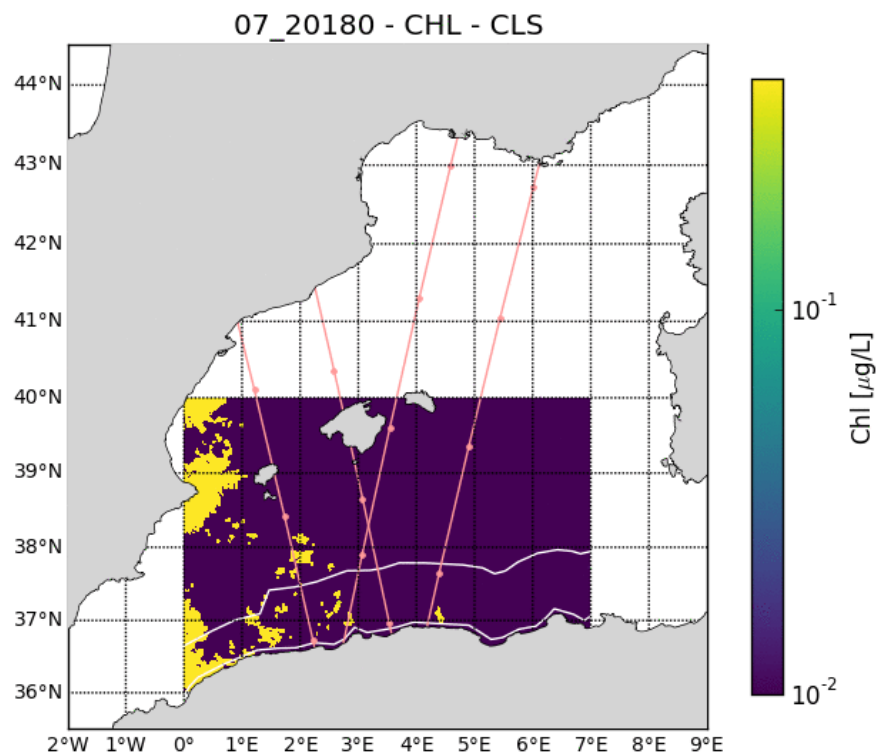


CLS (AVISO+)



CHL

- <ftp://ftp.aviso.altimetry.fr/experimental/regional-southwestmediterranean/near-real-time/color/>
- $0.02 \times 0.02^\circ$ ($1/50^\circ$) - 1 day delay (naming convention is 2days delay)



Products

MYOCEAN - CMEMS

CHL

- ftp://cmems-oc.isac.cnr.it/Core/OCEANCOLOUR_GLO_CHL_L3_NRT_OBSERVATIONS_009_032/dataset-oc-glo-chl-multi-l3-gsm_4km_daily-rt-v02/ 4km
x 4km 1day delay
- ftp://cmems-oc.isac.cnr.it/Core/OCEANCOLOUR_MED_CHL_L3_NRT_OBSERVATIONS_009_040/dataset-oc-med-chl-multi-l3-chl_1km_daily-rt-v02/ 1km
x 1km 1day delay

SST

- ftp://cmems.isac.cnr.it/Core/SST_MED_SST_L4_NRT_OBSERVATIONS_010_004/SST_MED_SST_L4_NRT_OBSERVATIONS_010_004_c_V2 0.01
x 0.01° 0 day delay
- ftp://cmems.isac.cnr.it/Core/SST_MED_SST_L3S_NRT_OBSERVATIONS_010_012/SST_MED_SST_L3S_NRT_OBSERVATIONS_010_012_b
0.063 x 0.063° 0 day delay

Products



JPL_OurOcean



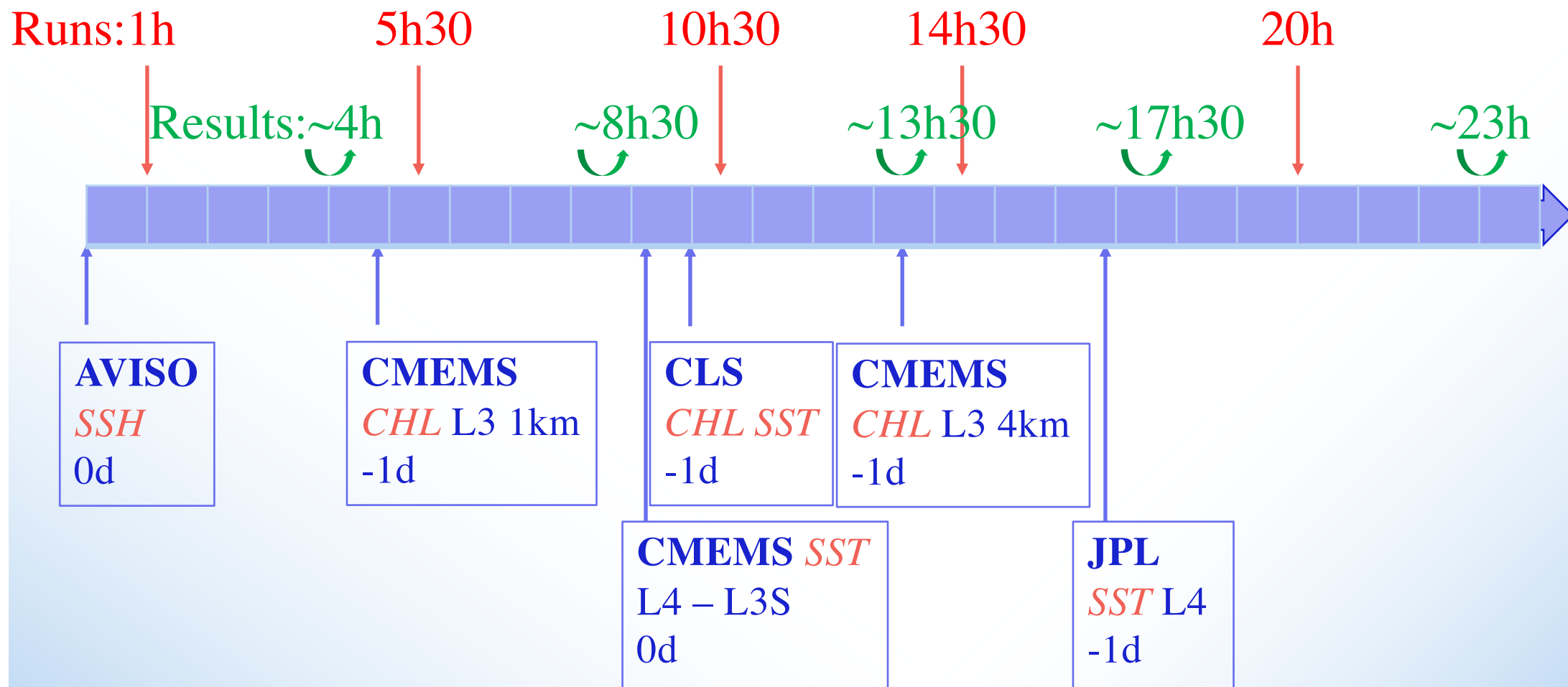
SST

- ftp://podaac-ftp.jpl.nasa.gov/OceanTemperature/ghrsst/data/L4/GLOB/JPL_OUROCEAN/G1SST/
- 0.01 x 0.01 °
- 1 day delay

Launches



Timescale



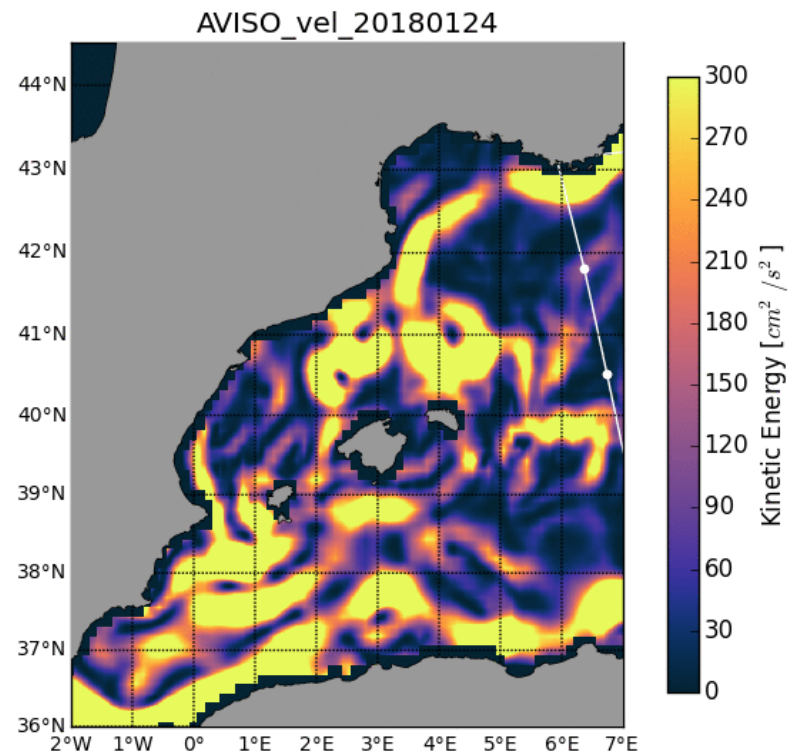
Analysed products



Kinetic Energy



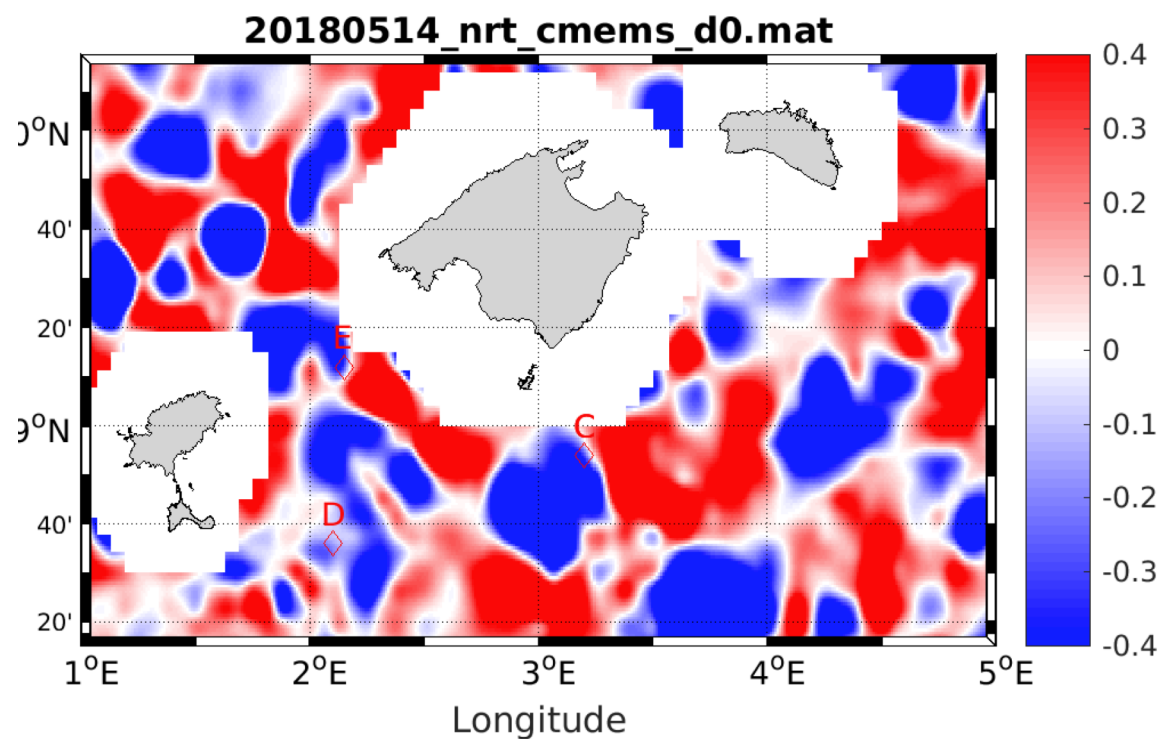
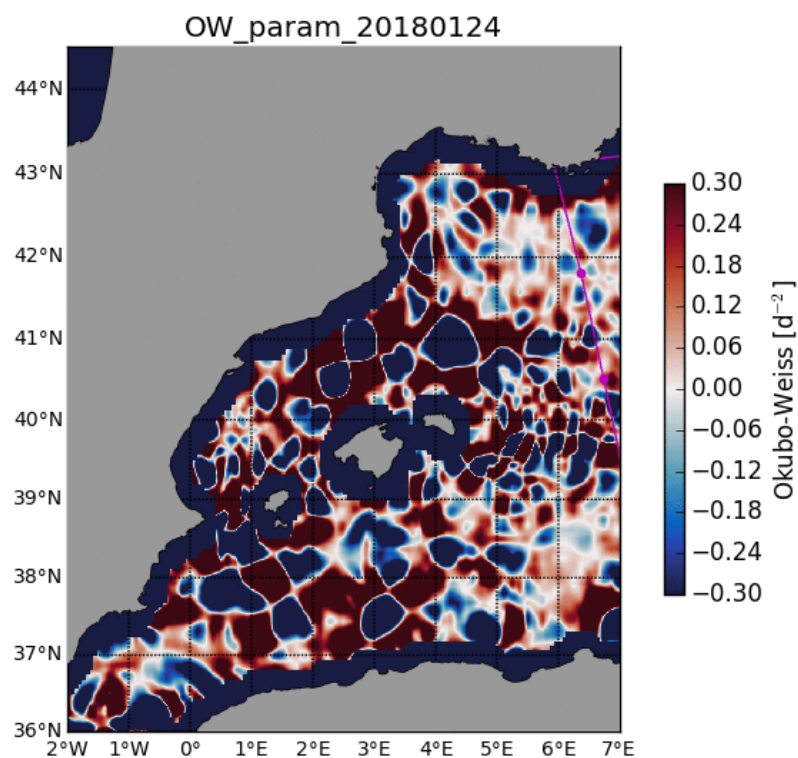
u^2+v^2 from AVISO



Lagrangian analysis

⚓ OW (Okubo-Weiss) parameter

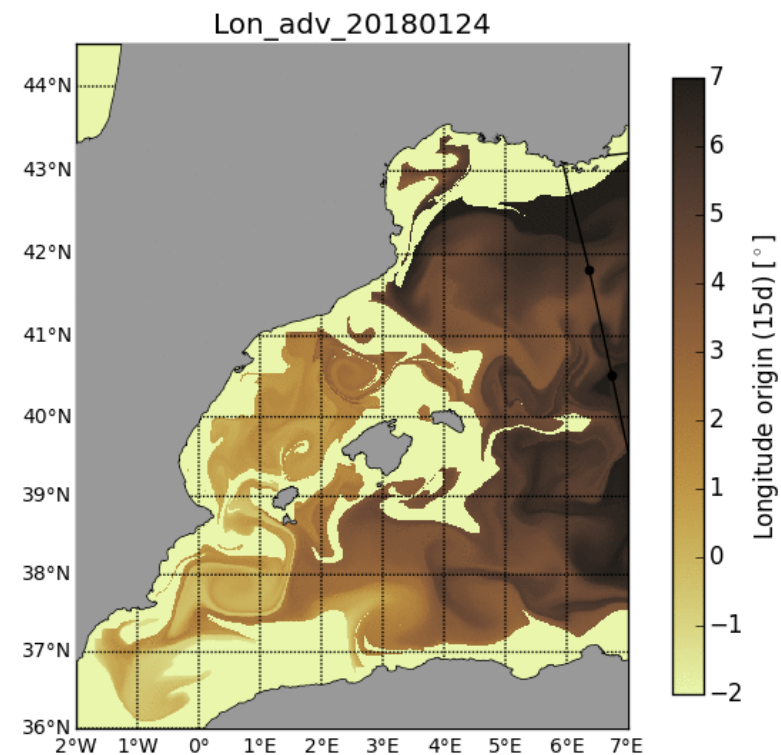
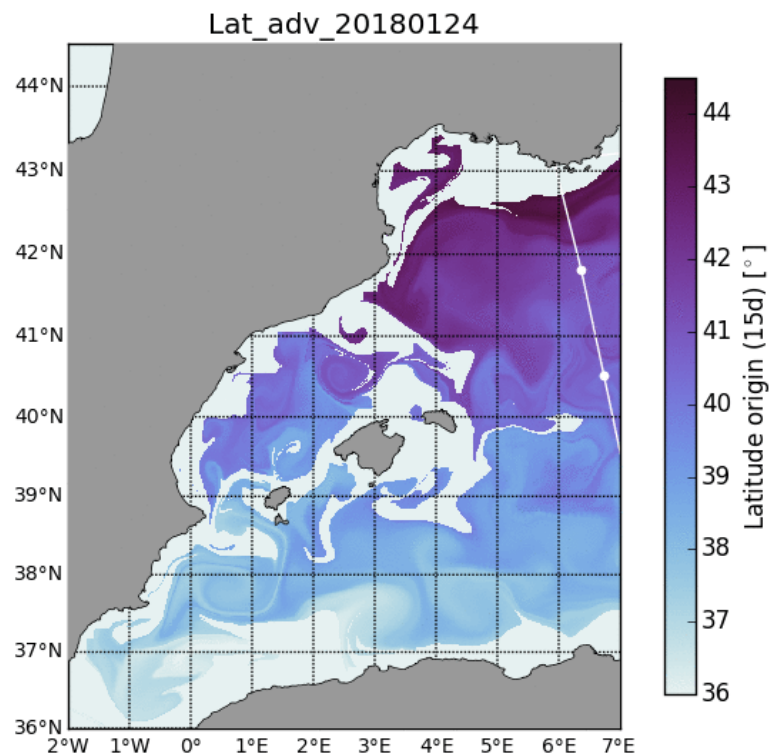
💬 15 days



Lagrangian analysis

⚓ Latitude and Longitude advection

💬 15 days



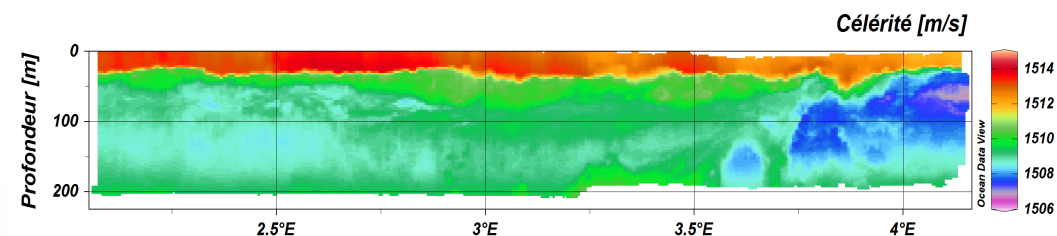
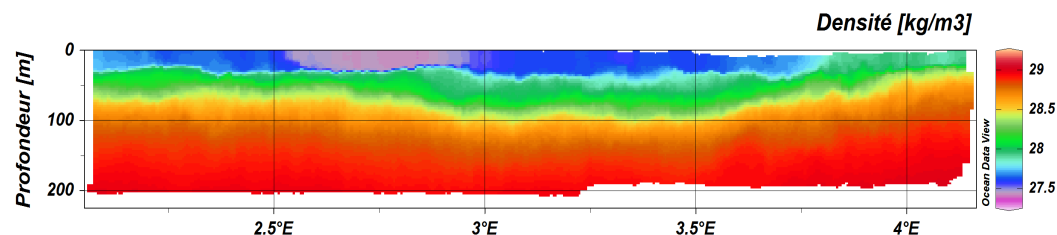
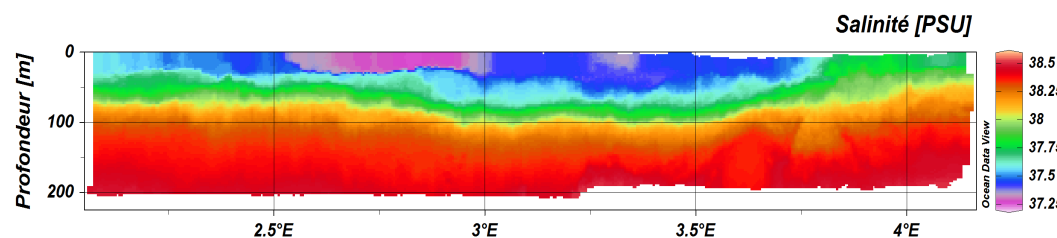
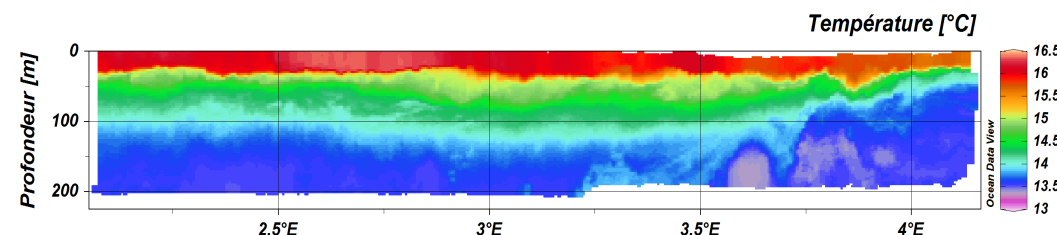
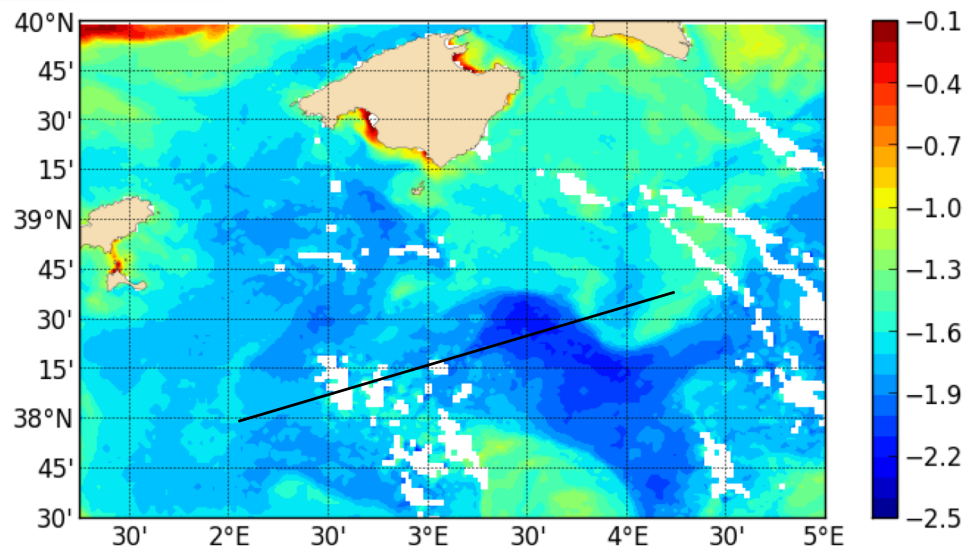
Analyse en ligne (on board)



Recherche d'une zone frontale

- 2 distinct water masses
- 2 different planktonic populations

log(chl) 20180501



A. Doglioli, G. Gregori

SWOT meeting

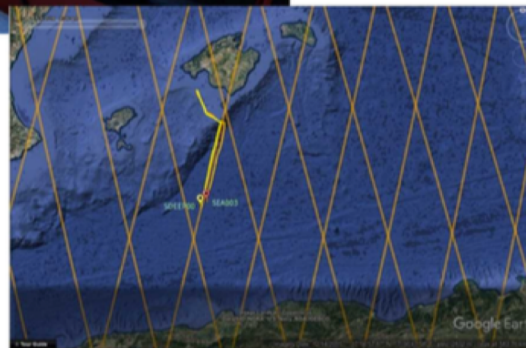
Pre-BIOSWOT: South-Baleares glider SeaExplorer (SEA003) mission



- Glider SeaExplorer (MIO, Marseille) equipped with 1 GPCTD, 1 Wetlabs triplet puck (Chla, CDOM, BB₇₀₀,) & 2 two-optical pathways MiniFluos (MFL-UV1 & MFL-UV2).



- SEA003 (FR) & SDEEPP00 (Spain) gliders deployed in parallel.



- Gliders and Sentinel 3 tracks

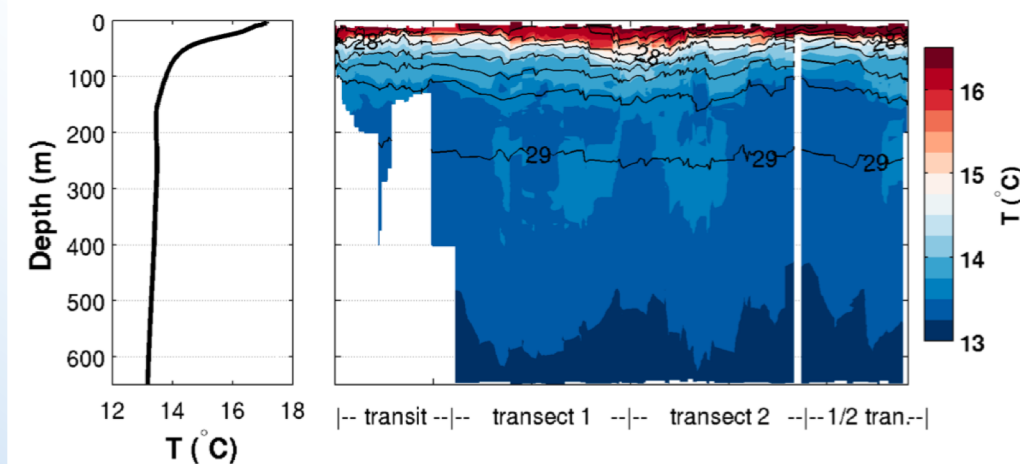
- Sea003 tracks : Transit - Transect 1 (N-S), Transect 2 (S-N), Transect 3 (½ transect N-S)



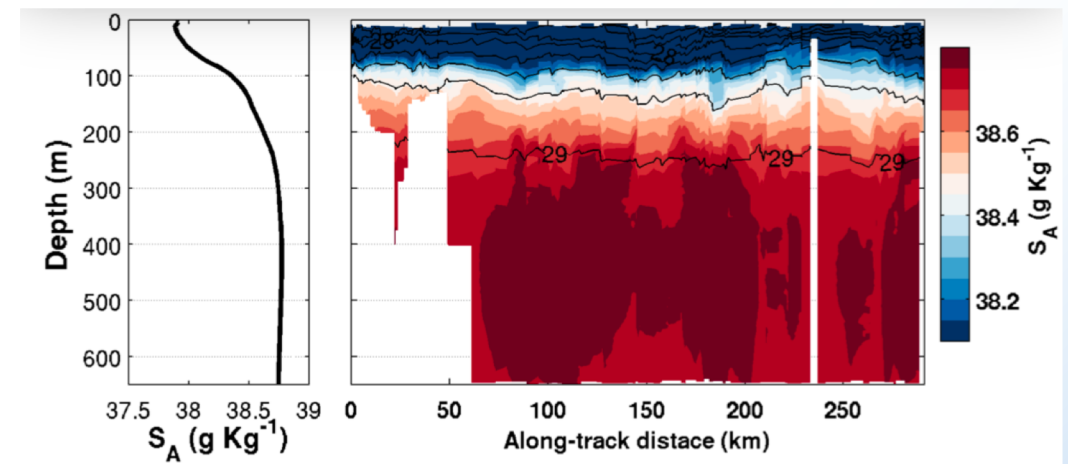
First look

- Tous les capteurs ont bien fonctionné pendant tout le déploiement
- Signal concentré en surface
- Distributions 5 fluos

Température



Salinité

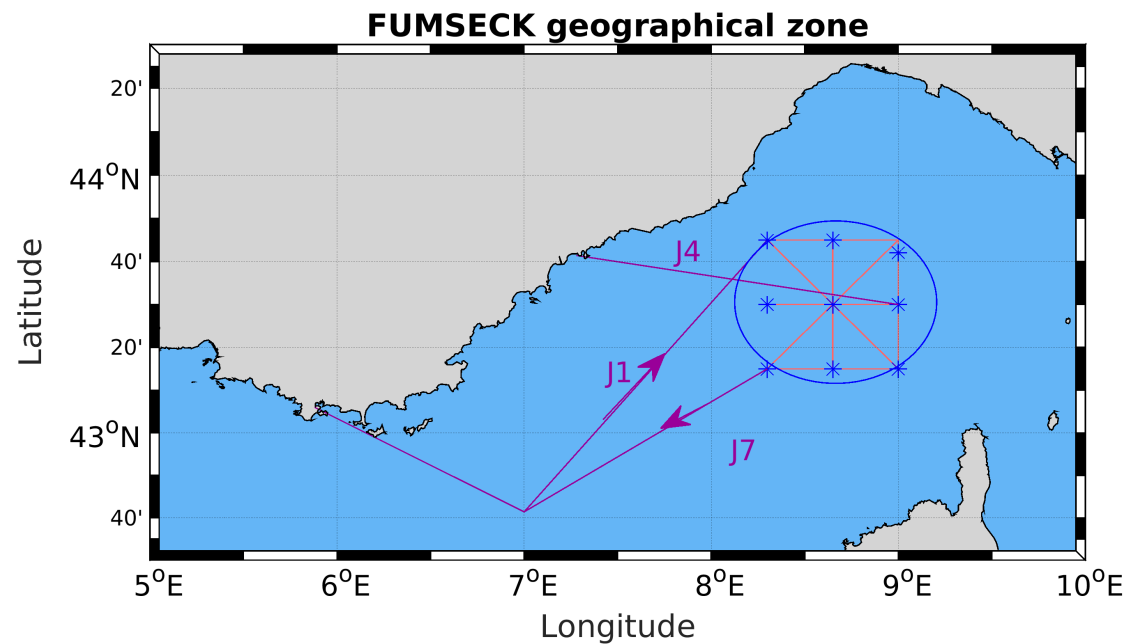


PREBIOSWOT 2018 :
un succès, beaucoup de données à analyser !



⚓ FUMSECK : *Facilities for Updating the Mediterranean Submesocale - Ecosystem Coupling Knowledge*

- 💬 Demande technologique pour mai 2019
- 💬 1 semaine dans golfe de Gênes sur le Téthys



⚓ Étude comportement poissons multi-capteurs tractés (petit et gros)

💬 Comportement rotatif du gros poisson - descente et remontée

💬 Connectiques

- instrument - câble tracteur
- plateforme - sondeur de profondeur sur le bateau
- plateforme - PC utilisé pour traiter les données

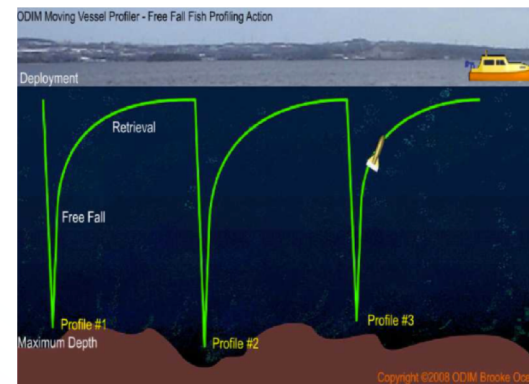
💬 Tests d'acquisition de données sur toute la chaîne.



Figure 2: Morocco 2012



Figure 1: Outpace 2015

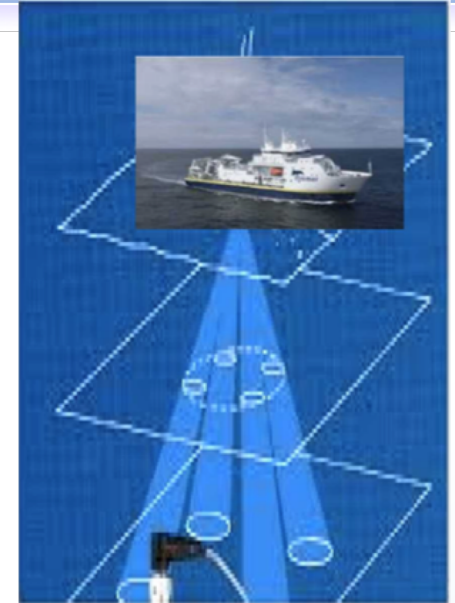


Vitesses verticales

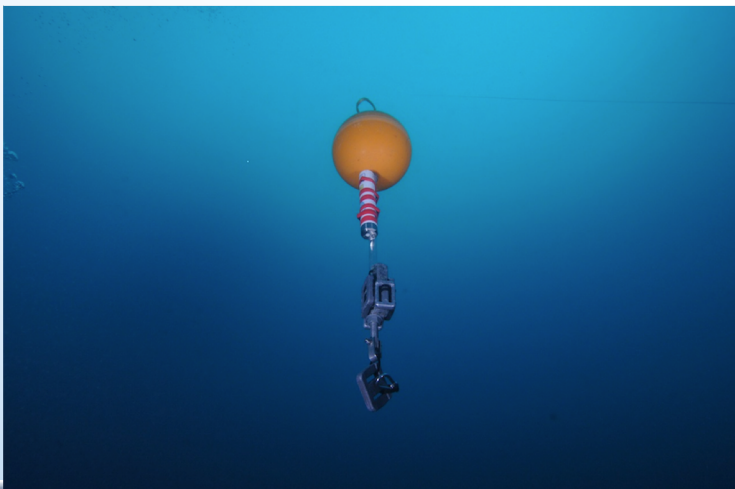


Vitesses verticales par ADCP

- Traitement CASCADE optimisation par minimisation vitesse verticale
- Pas de minimisation par SAVED
- → nouveau traitement possible ?
- Comparaison avec dérivées des mesures du MVP grâce à l'équation oméga.



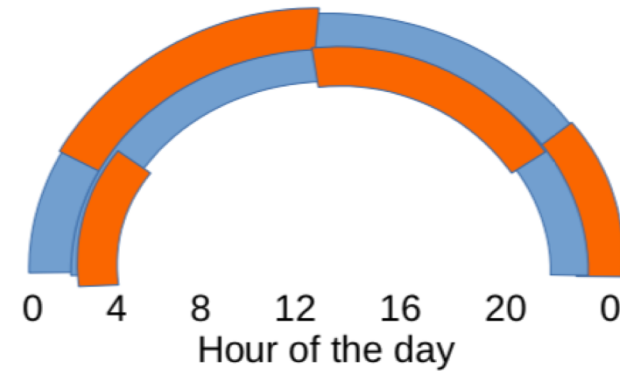
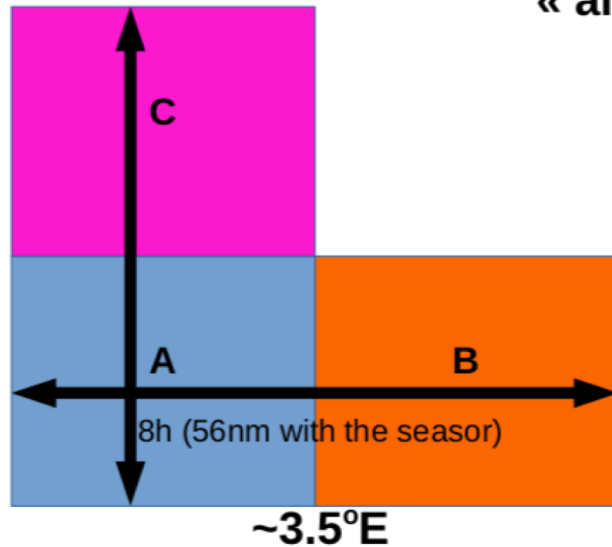
Mesures VVP ("Vertical Velocity Profiler") - Jean-Luc



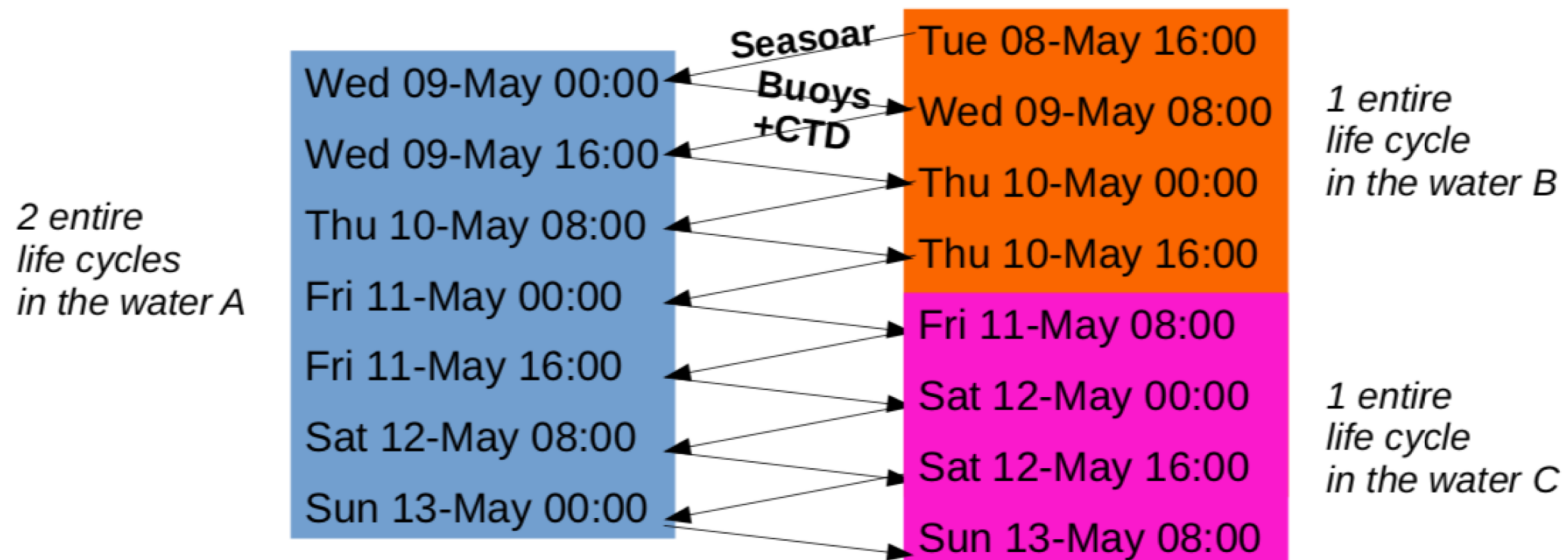
- Idée : Capteur pression + bouée, descente chute libre
- En cours de développement. Résultats encourageants (Jean-Luc + Robin)
- + mesures avec glider ?

« Aller-retour » strategy

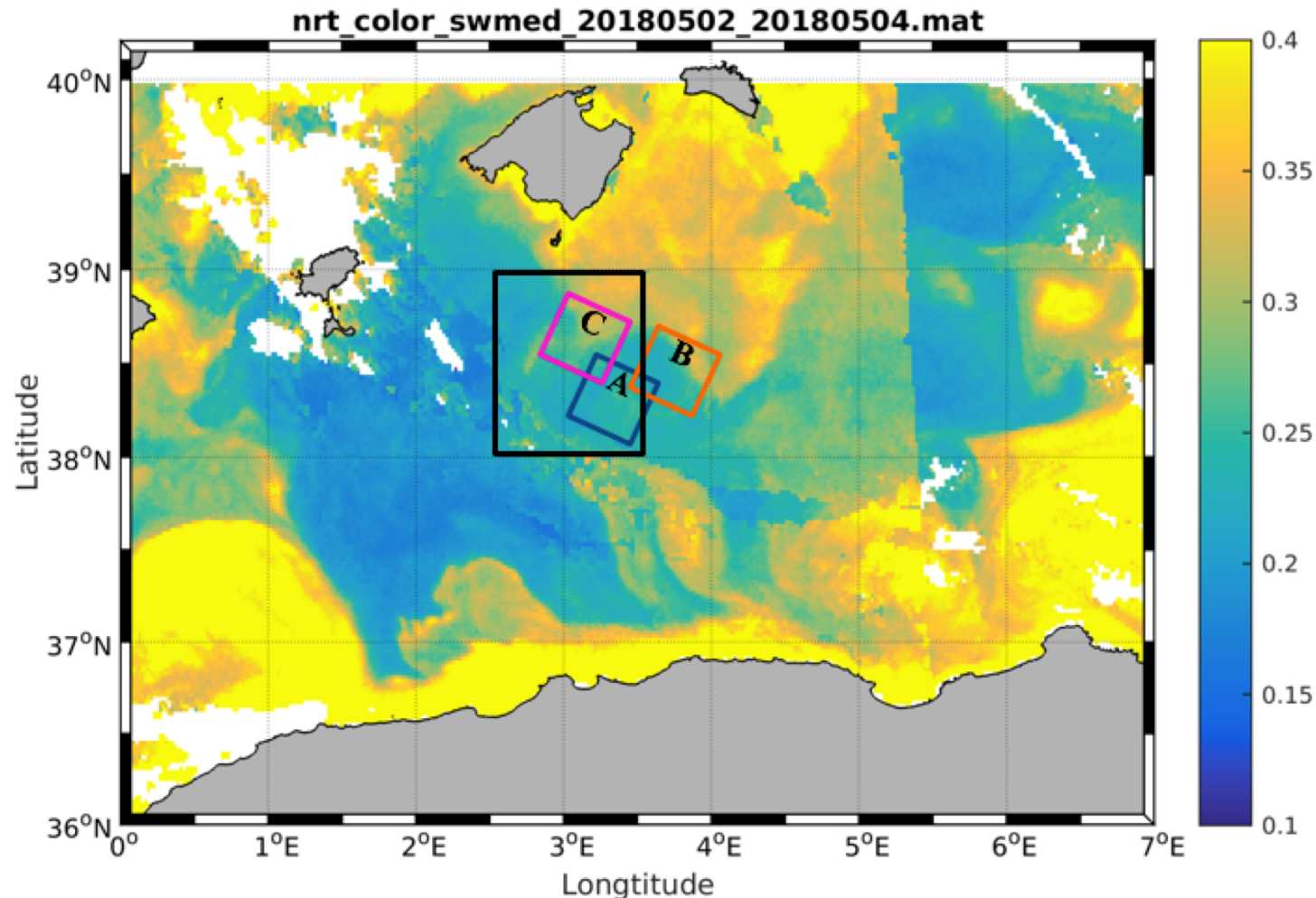
« aller-retour » strategy



In 2 days it is possible to cover the entire life cycle



« Aller-retour » strategy



The colored squares show the planned route of the BB sampling with the « aller-retour » strategy described in the previous slide

The black square shows the Garcia del Cid sampling area