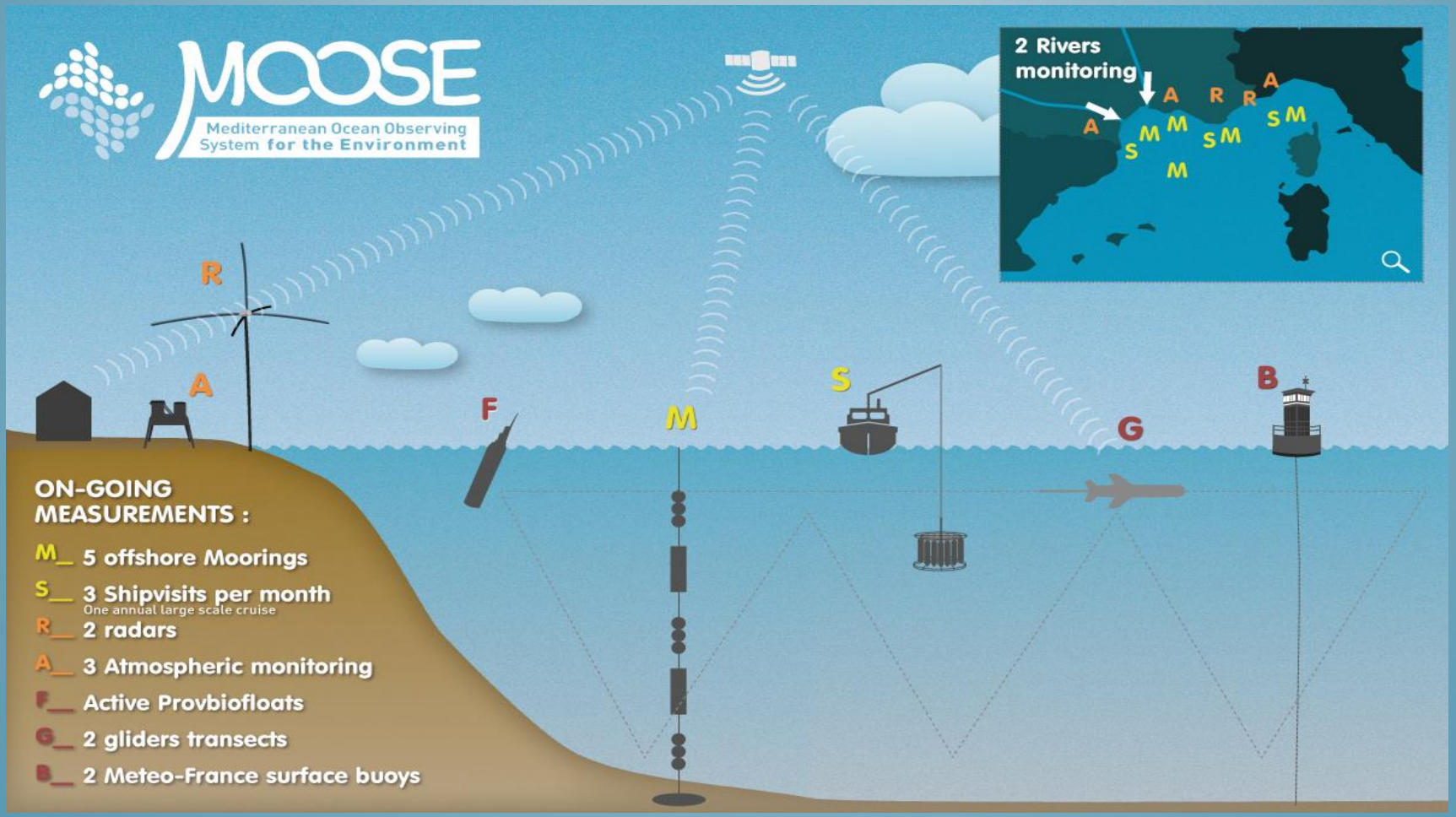
Mediterranean Ocean Observing System for the Environment

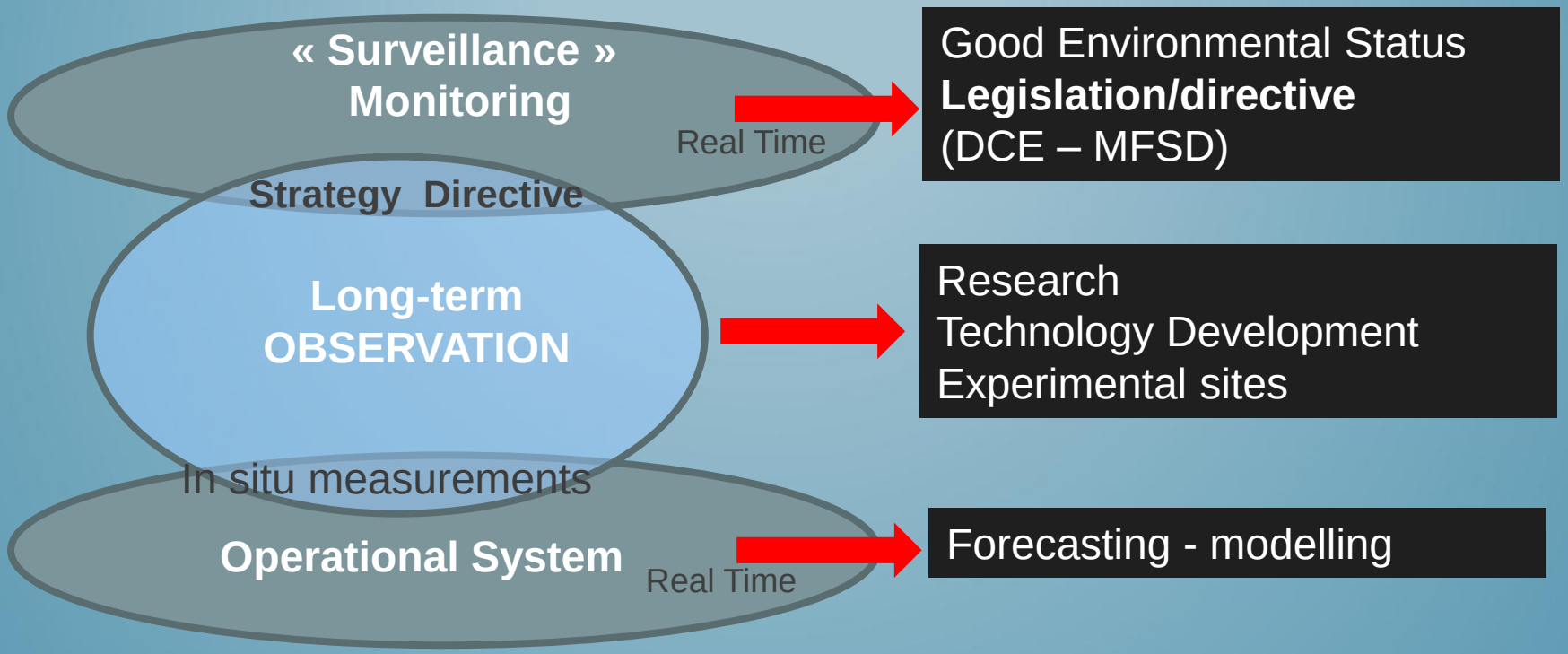
TAKING THE PULSE OF THE NW MEDITERRANEAN SEA



Patrick Raimbault: Mediterranean Institute of Oceanography (Marseille)
Laurent Coppola – Pierre Testor and MOOSE-Team

Long-term Environmental data

Why collect environmental data over long-time periods ?



Long-time programme (>10 years)
Data management= Heritage/**Patrimoine**

The MOOSE Network: motivation

The mediterranean Sea

The MOOSE Network: motivation

Hot spot for biodiversity

Anthropogenic impact

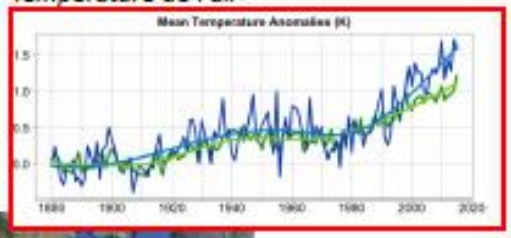
Climate Change

Sur-pêche

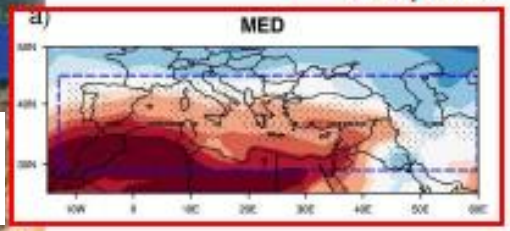
Urbanisation

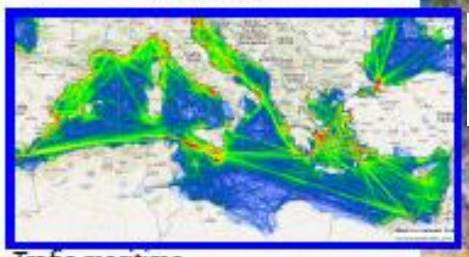
Littoralisation

Température de l'air



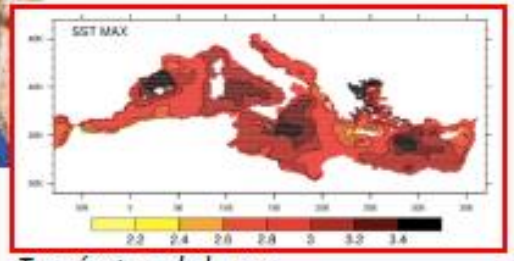
Précipitation



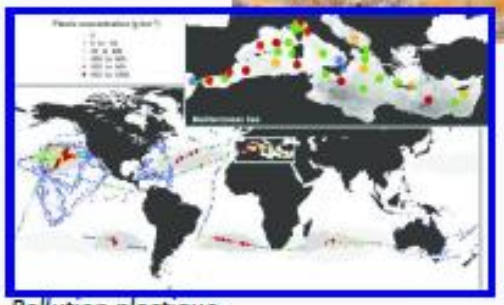


Trafic maritime

Strong anthropogenic pressure with geographical and seasonal imbalances



Température de la mer

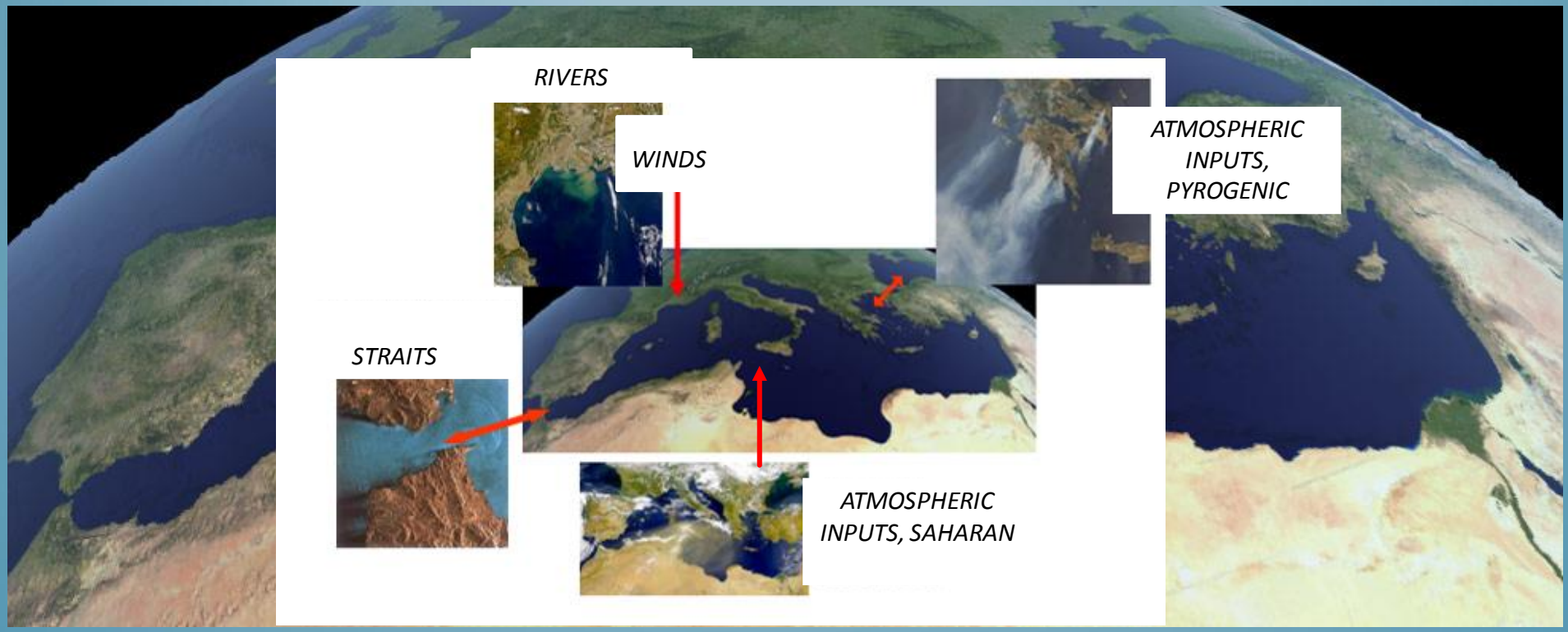


Pollution plastique

Circulation thermohaline

Le réseau MOOSE: motivation

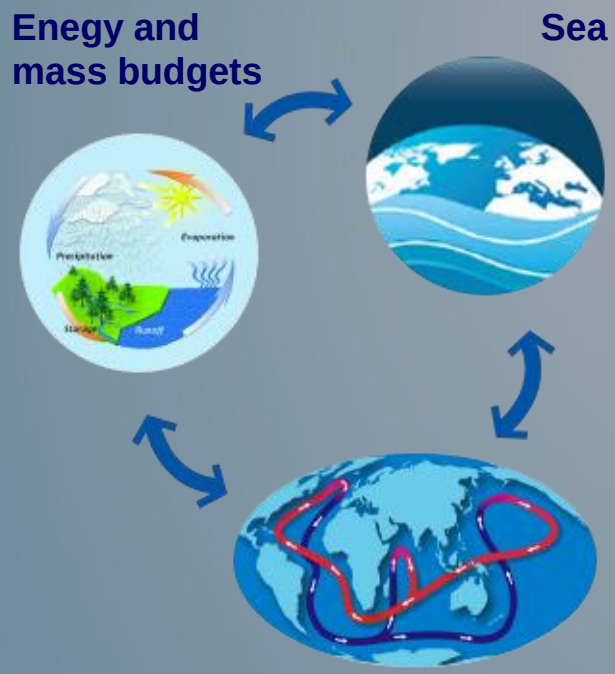
The Mediterranean Sea:
a unique coupled system (ocean/atmosphere/continent)

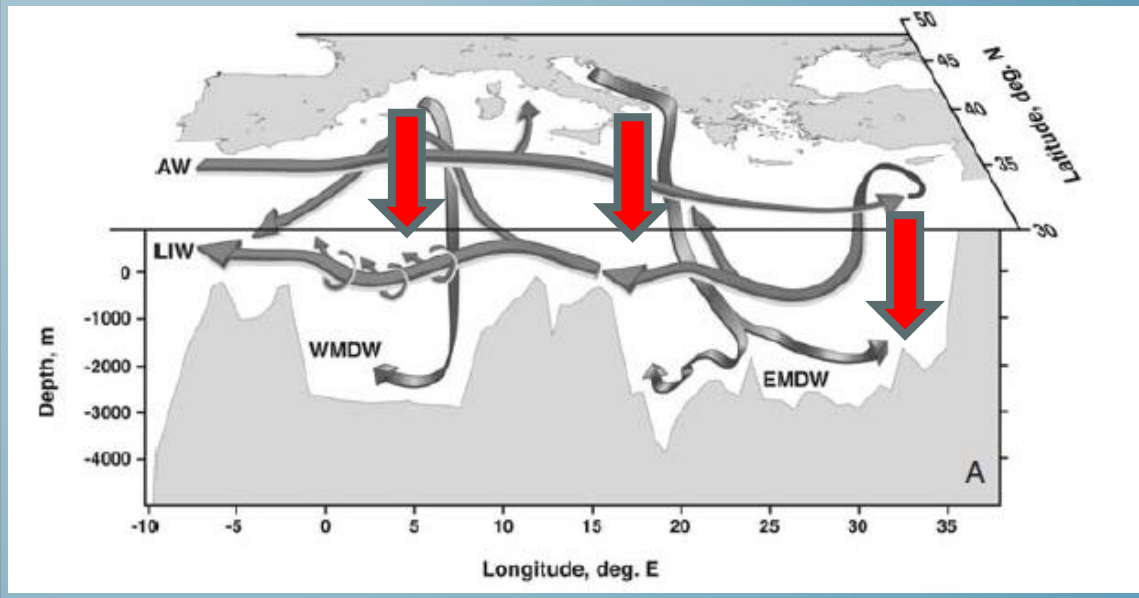


Rapid and significant evolution is suspected in response to climate change and human activity

The MOOSE Network: motivation

Conséquences dues aux variations climatiques





The Mediterranean Sea :

- **« hot spot » for climate change**
- **Oceanic model**

MOOSE OBJECTIVES

Historical data are precious and useful but not enough detailed

Understanding human impact on the marine environment needs accurate and integrated data from long-term observation.

In fact, the ocean is critically under-sampled both in space and time.

The MOOSE Strategy

Detecting changes implies monitoring

Monitoring is a real scientific activity that requires an adapted strategy sustainable in operational fashion

- **PERMANENCY OF SAMPLING**
- **KEY SITES**
- **SIMPLICITY OF LOGISTICS – INSTRUMENTATION**
- **STABLE ANALYTICAL PROCEDURES**

The real challenge for MOOSE was to use and integrate classical and new technologies to systematically monitor and resolve the variability at different spatial and temporal scales: regional - sub-basin -seasonal - interannual.

Selected key control sections and sites for routine monitoring by MOOSE has been conducted in the framework of Mistrals program.

LONG-TERM OBSERVATION

The MOOSE strategy

- *consider the whole continuum* ***continent-coastal zone- open ocean*** *in relation with the* ***atmosphere***
- *consider the* ***Mediterranean Sea*** *with a focus for the French community on* ***the north western basin (the region that we know better and where a large variety of ecoregions and forcing are present: Northern curent, dense water formation, spring phytoplnktonic blooms…***

Rivers

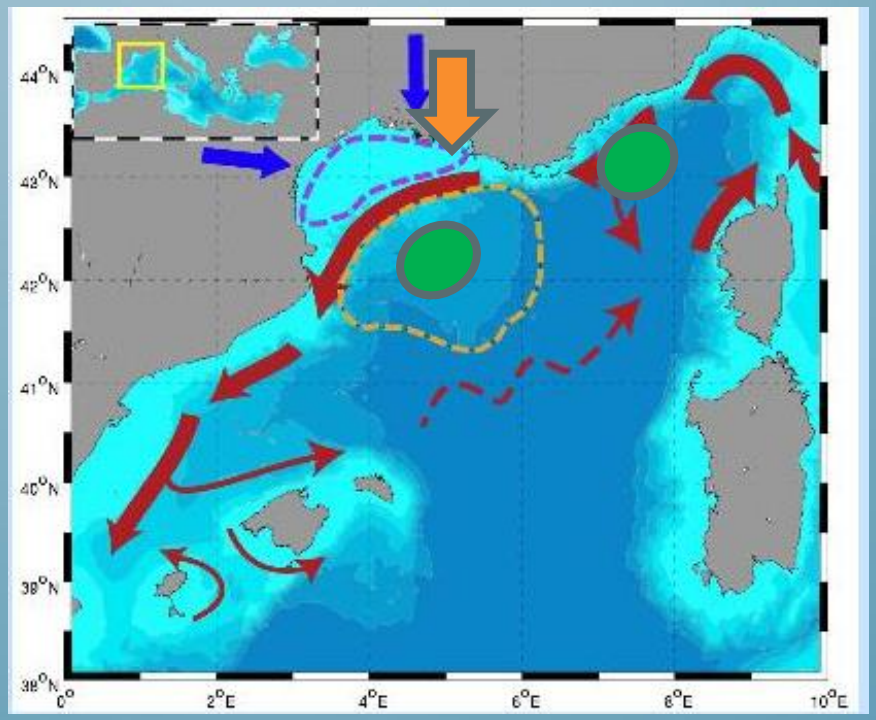
Prevailing Winds

Surface circulation

Dense shelf water

Deep convection

Phytoplankton boom



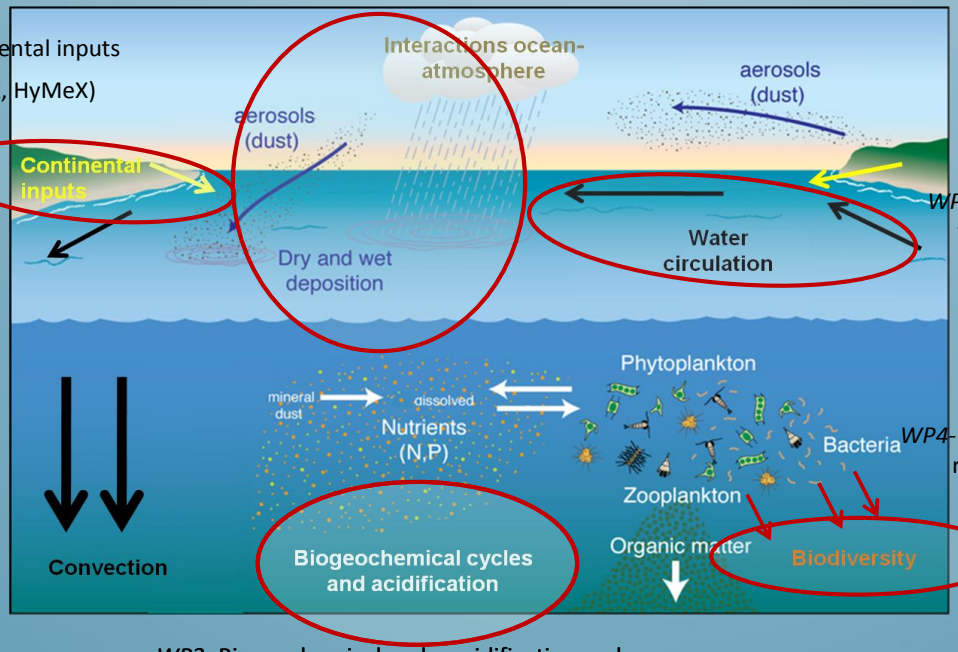
The MOOSE concept

- Focused on both scientific inquiry and societal issues
- Expanded to include physical, biogeochemical, and biological data
- Operated in collaborative fashion based on set principles and best practices
- Building on existing structures as much as possible
- Balancing research and innovation with the need for stability
- Providing maximum benefit to all users from each observation

Strong synergy between 3 MISTRALS projects HYMEX MERMEX and CHARMEX

WP5- Air-sea interactions (MERMeX, CHARMeX, HyMeX)

WP2- Continental inputs (MERMeX, HyMeX)

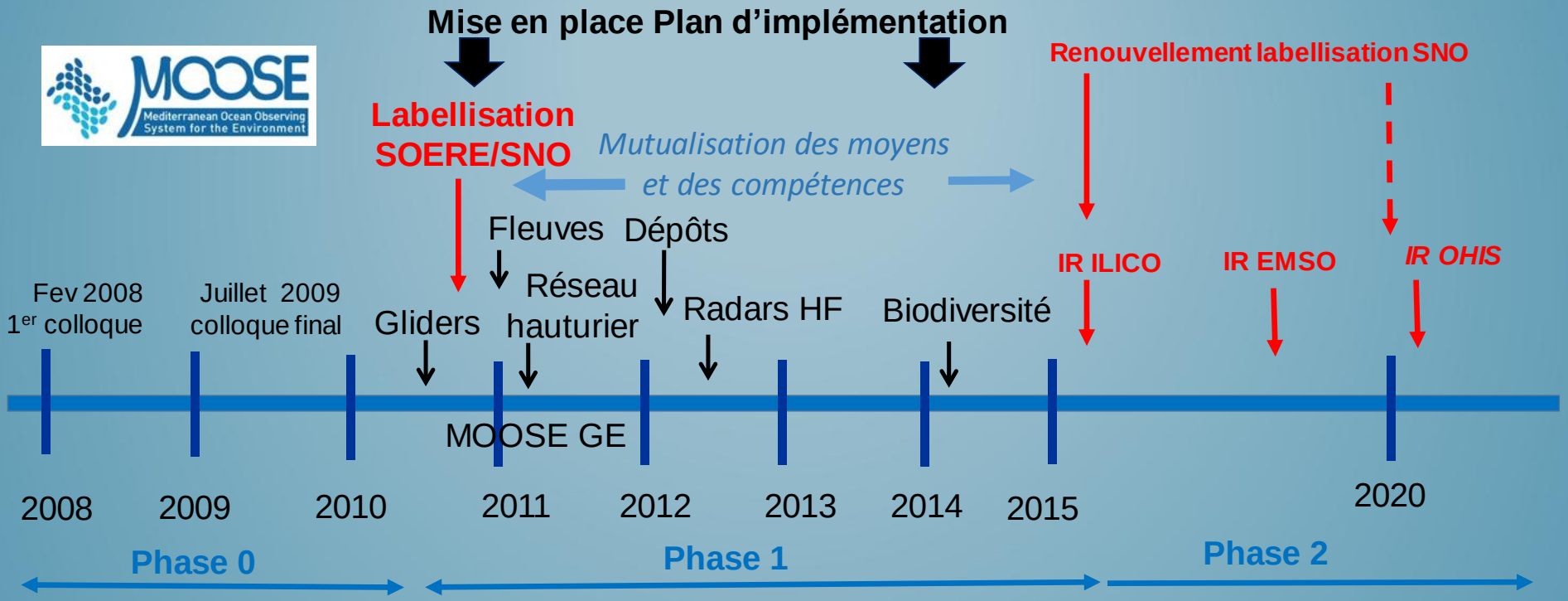


WP1- Mesoscale circulation of the North Gyre (HYMEX)

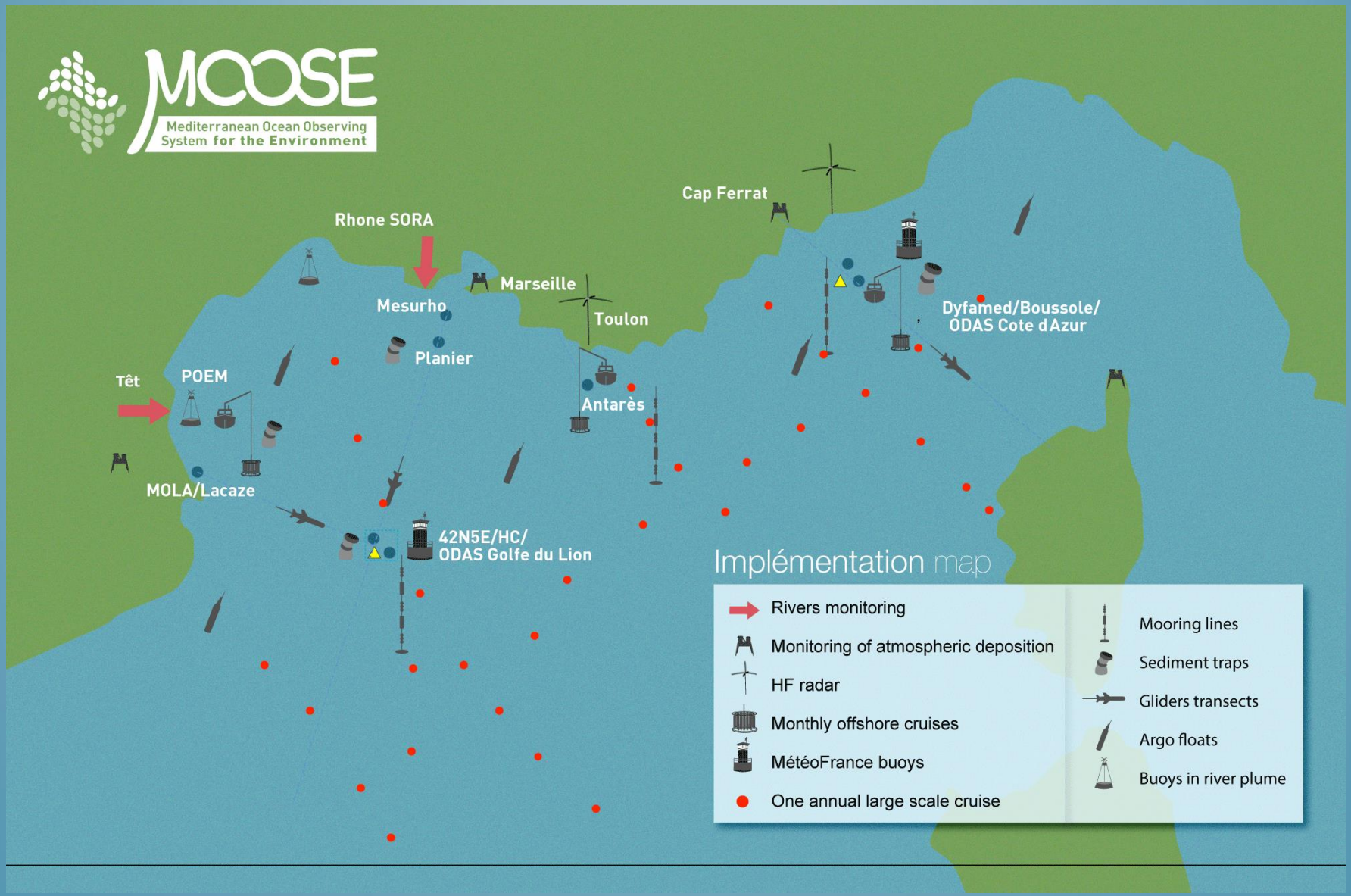
WP4- Biodiversity and biological ressources (MERMeX)

WP3- Biogeochemical cycle, acidification and contaminants (MERMeX)

MOOSE-Network: History



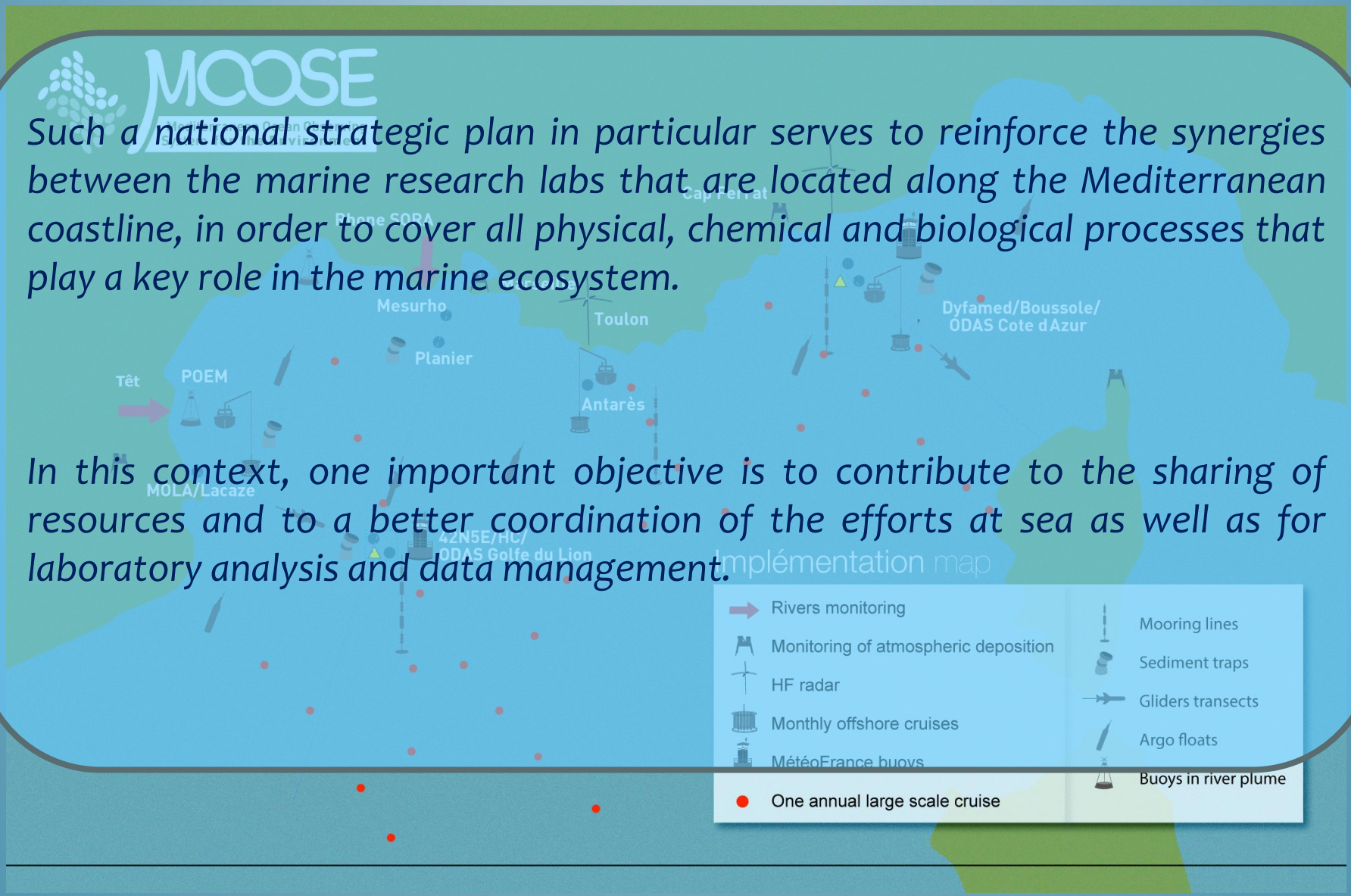
The MOOSE network: 2010-2024



The MOOSE network: 2010-2024

Such a national strategic plan in particular serves to reinforce the synergies between the marine research labs that are located along the Mediterranean coastline, in order to cover all physical, chemical and biological processes that play a key role in the marine ecosystem.

In this context, one important objective is to contribute to the sharing of resources and to a better coordination of the efforts at sea as well as for laboratory analysis and data management.



MOOSE DATA

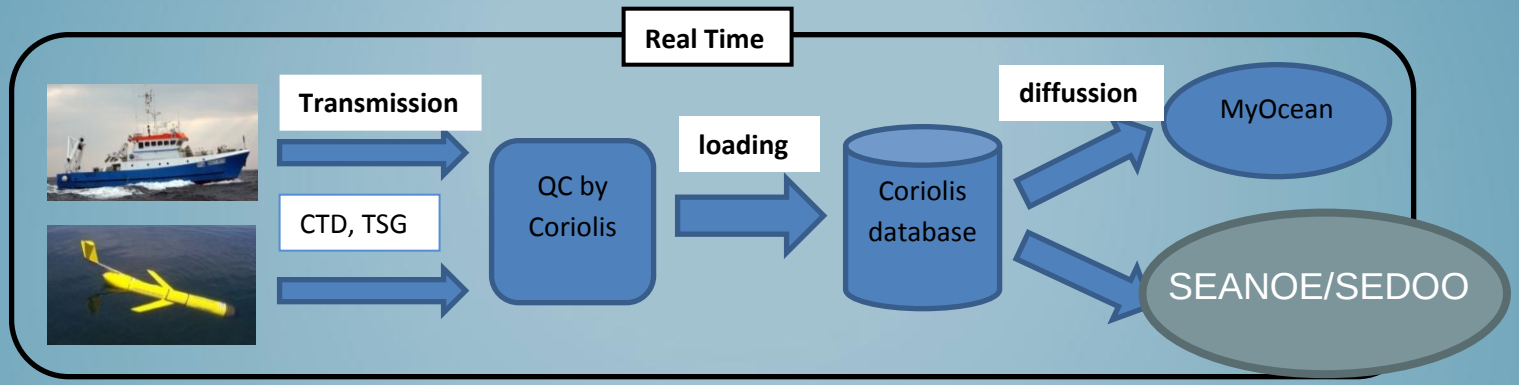
According to GOOS: Essential Oceanographic Variables (EOV)
« relevance, feasibility, cost effectiveness »

VARIABLES	R/V	MOORINGS	GLIDERS	RADARS	RIVERS	ATMOSPHERE
Meteorology	■	■				■
Temperature	■	■	■			
Salinity	■	■	■			
Curents	■	■	■	■		
Particles & zooplankton	■	■				
Oxygen	■	■	■			
DIC (AT-CT)	■					
nutrients	■				■	■
Carbon, Nitrogen		■			■	■
SPM					■	
Trace metals					■	■
TChla	■		■			
Pigments	■					
Bacteria	■					
Zooplankton	■					

+ Additional parameters: DOC, genomics …

Data management

Real time data: An easy email data sending process have been decided to collect CTD from ships

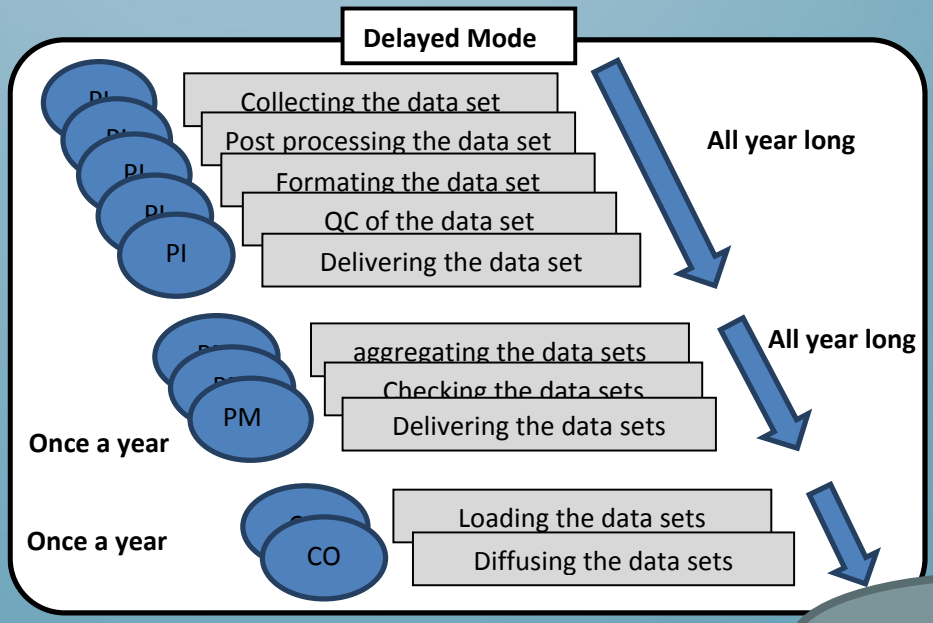


http://www.ifremer.fr/co-dataSelection/?theme=moose

Delayed data

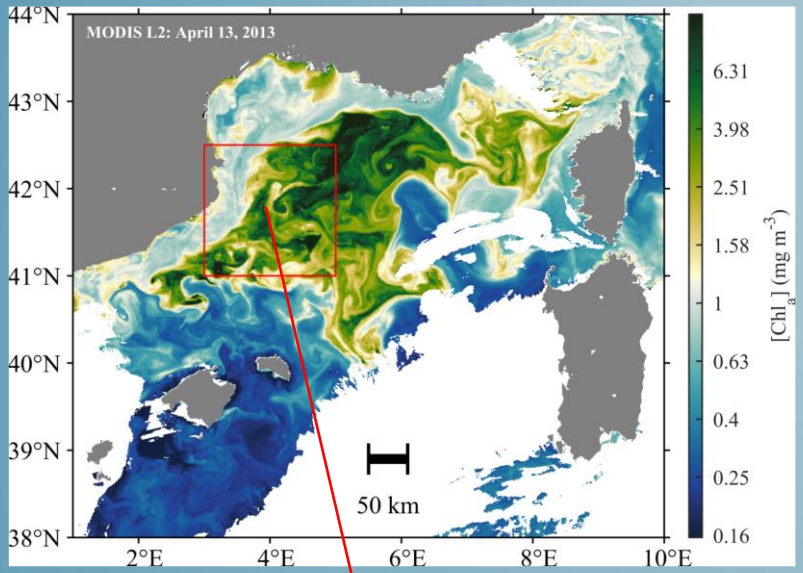
There are collected, controlled and analyzed by the PI.

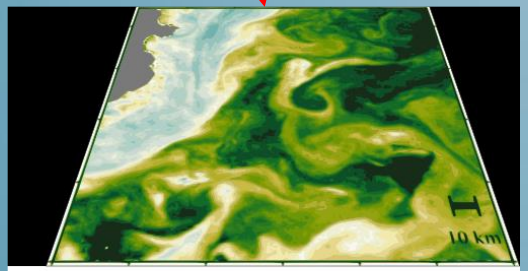
Once a year Moose head office delivers the global data set.

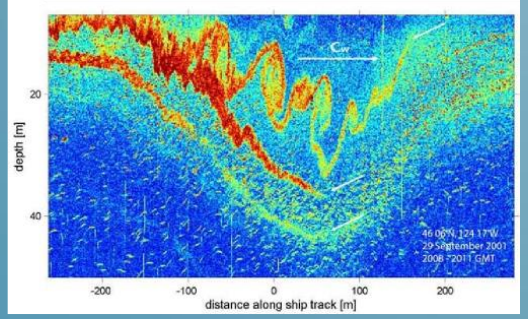


http://mistrals.sedoo.fr/MOOSE/

An *in-situ* observing system, capable of capturing most of all the scales of variability







Large scale circulation
(100-1000 km & 10-105 days)

Meso-scale gyres
(10-50 km & 1-10 days)

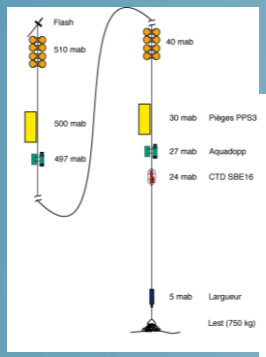
Fronts, filaments, sub mesoscale edies
sous-mésoechelle
O(1-10 km & 0.1-1 days)

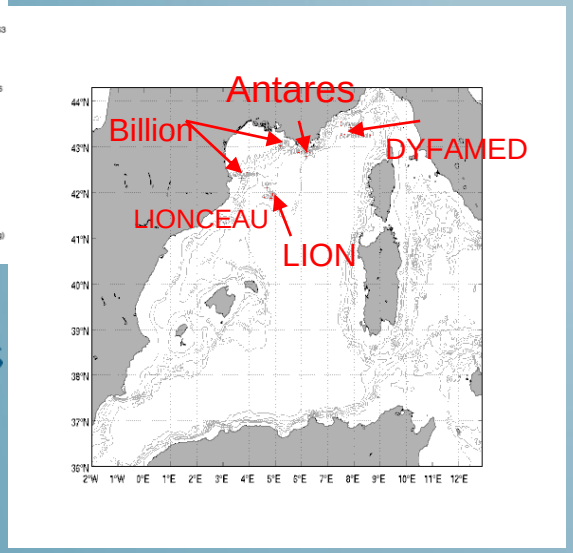
Micro-scale (diffudion, energy dsspation)
(0.01-100m & 1s - 103s)

Impacts on biocheogemical fluxes (T,S,O2,CO2)
Important but no well understood !

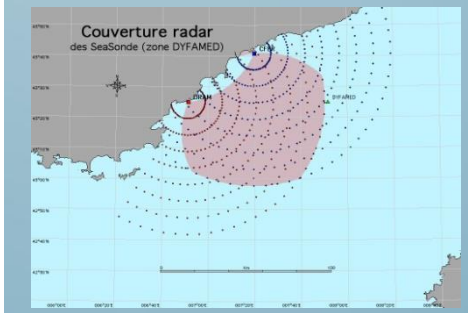
Strategy and equipments

6 moorings

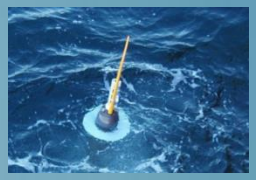


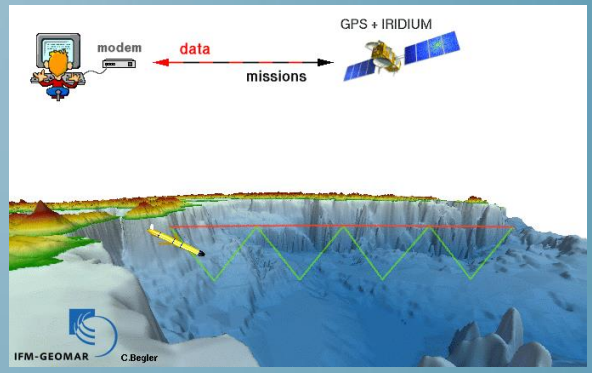


2 HF radars
Toulon - Nice



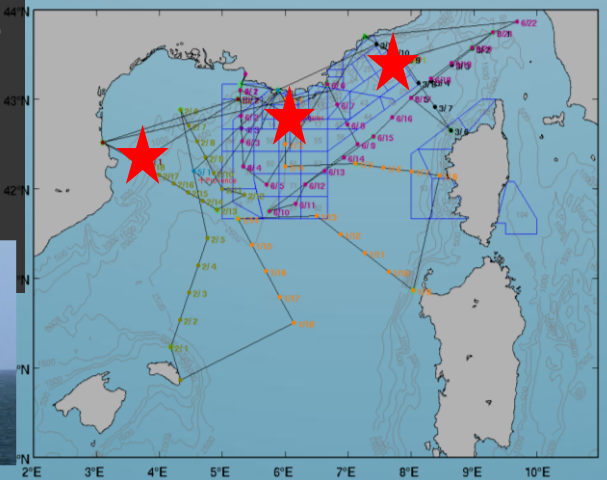
Gliders /flotteurs



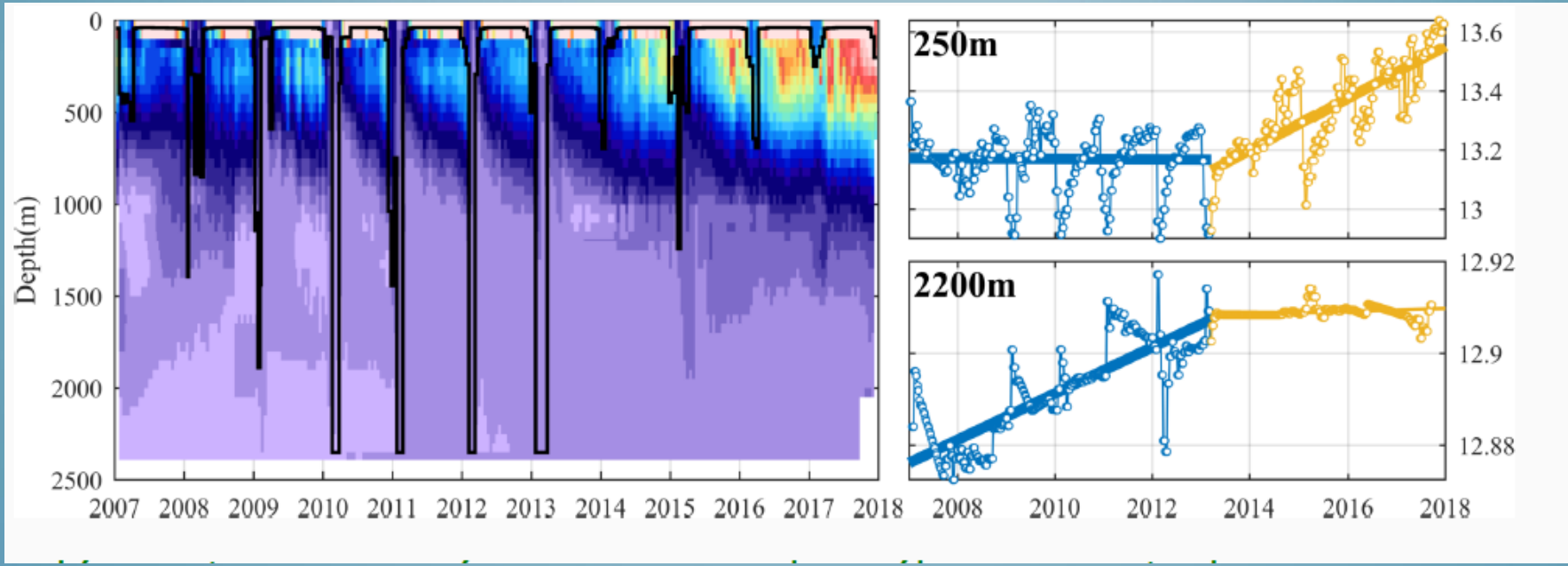


Oceanographic cruises

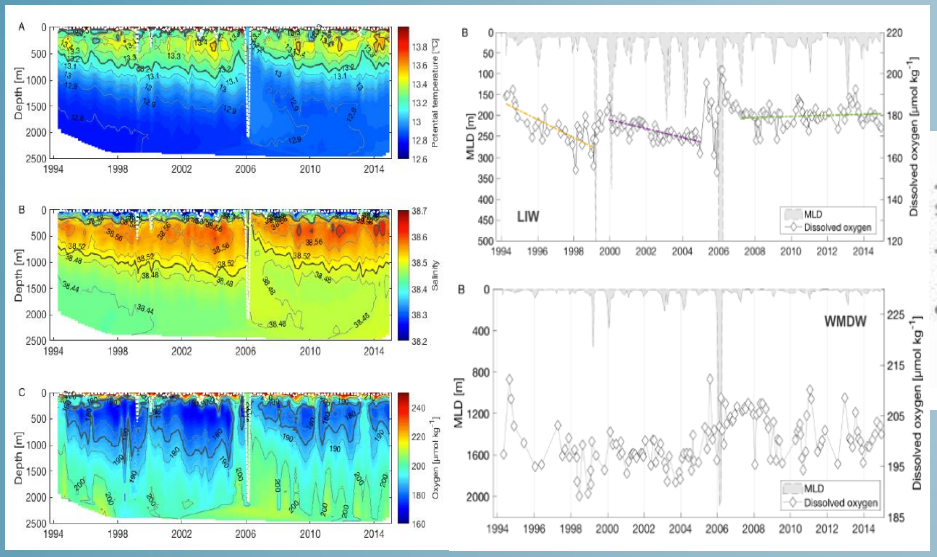
3 monthly stations
1 annual large scale cruise

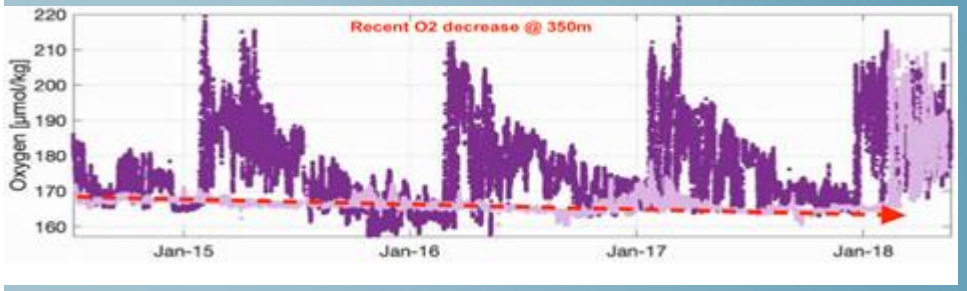


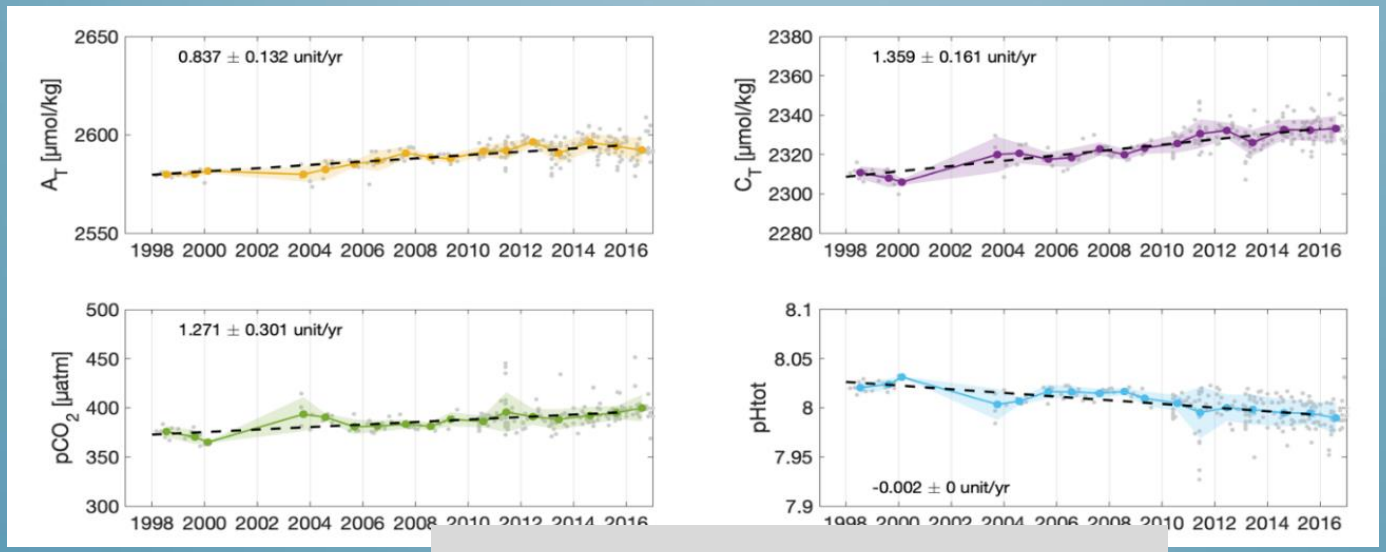
Temperature evolution in the Gulf of Lions



Cycles biogéochimiques

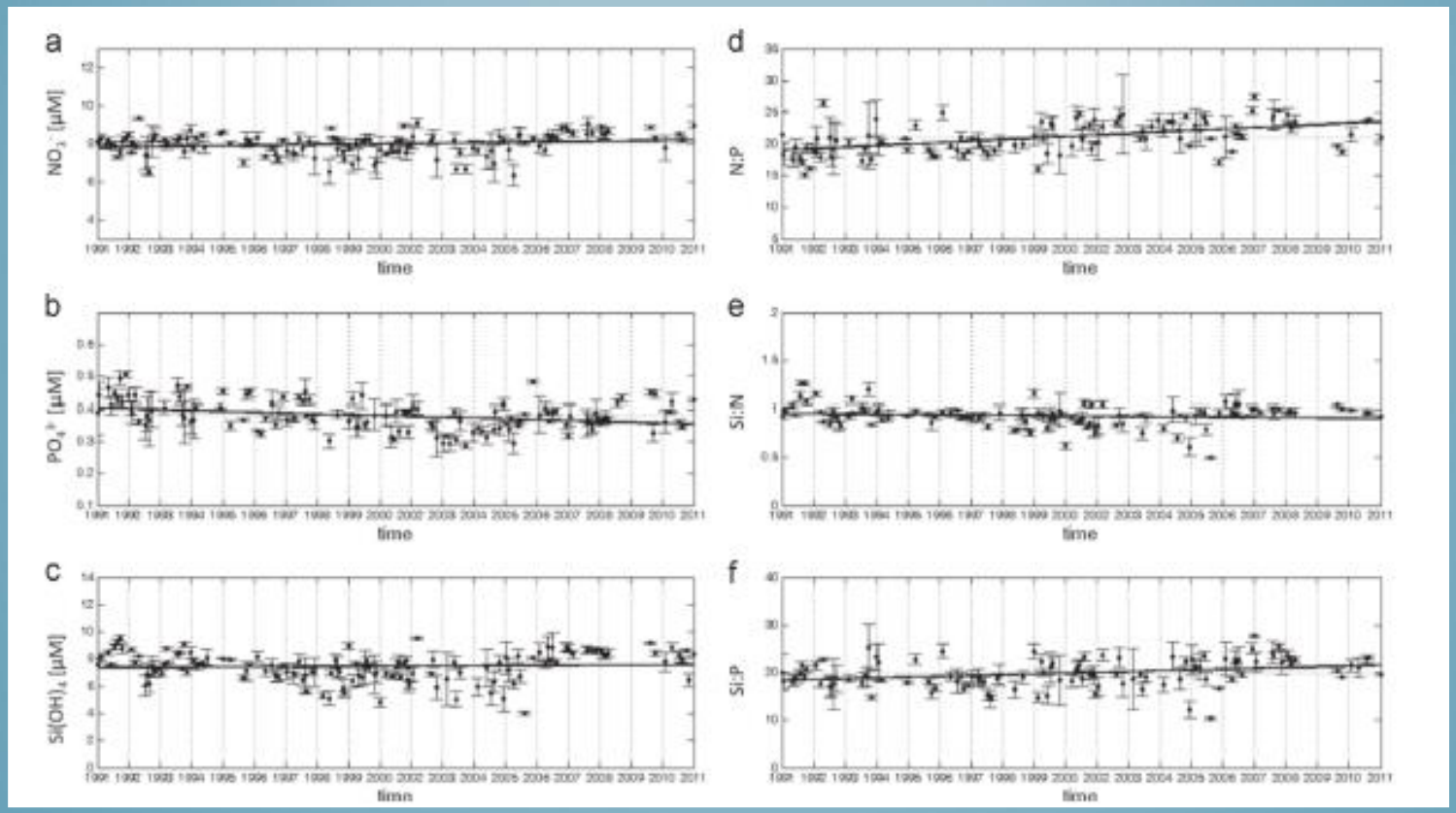






Oxygen, DIC, pH,

Cycles biogéochimiques



Nutrients change

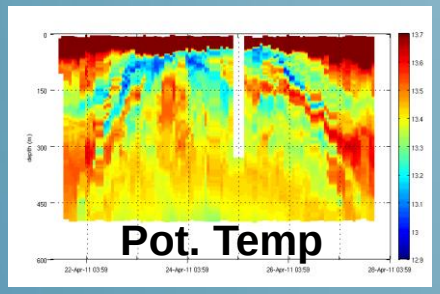
Long - term observations : example of MOOSE gliders

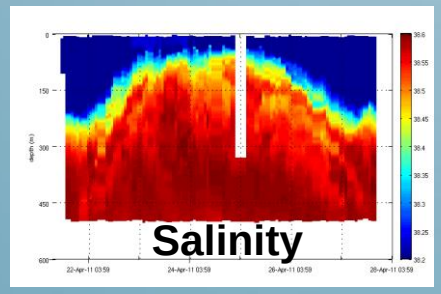
Presence at sea even during strong weather conditions

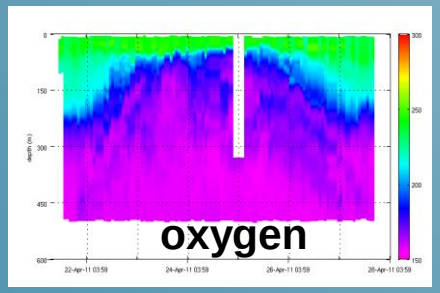
Repeat-sections
- ~10 days / ~300km
- profiles 0-1000m for T, S, O2 (and bio)
- high resolution/coverage (space/time)

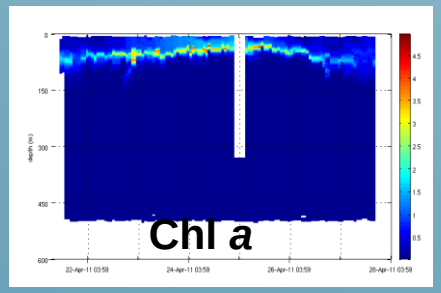
Multidisciplinary data at basin and meso/submeso scales over a year
For:

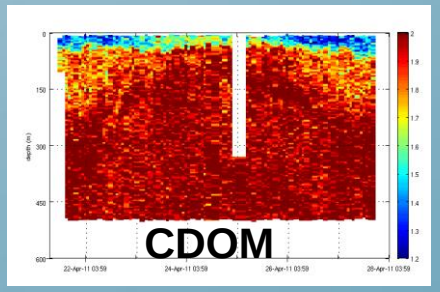
- **Climate change**
- **Process studies (turbulence, convection, overflows, …)**
- **Physical/biological coupling**
- **High trophic levels**
- **Modellings (global → regional → coastal)**

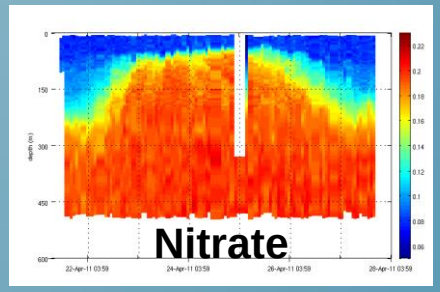








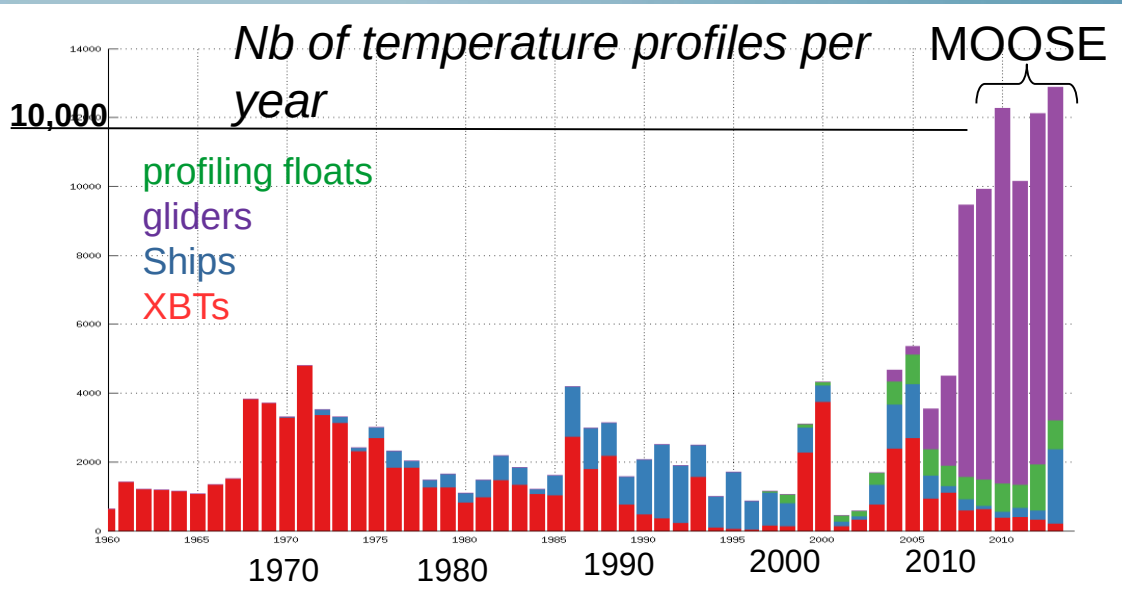


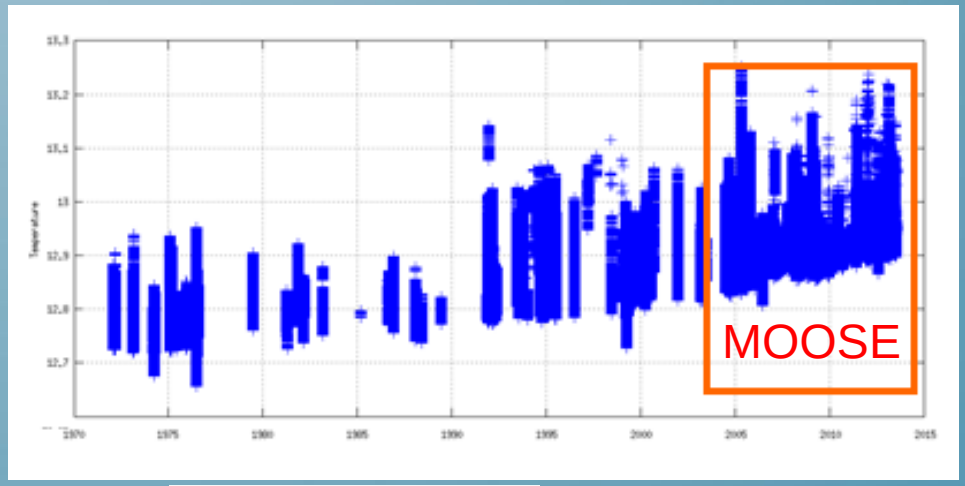


Scientific project
L. Coppola: CNAP MOOSE

Long term observations : example of MOOSE gliders

Year	Transect T00	Transect T02
	jours	jours
2010	90	90
2011	164	250
2012	95	294
2013	84	172
2014	28	198
2015	171	219
2016	124	195
2017	117	140
2018	225	
2019	150	
total	873	1558
Glider months		93,5





4 Thesis

20 Publications MOOSE
(JGR-Oceans DEWEX/HYMEX)

Data Base

Data management: free access and DOI

EGO Glider — Everyone's Gliding Observatories

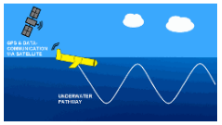
MOOSE T02_13 (EGO campe glider) deployment (Mediterranean Sea - Western basin)

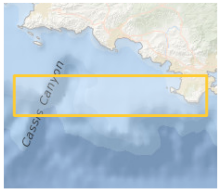
Date	2017-09
Temporal extent	2016-04-28 -2016-05-02
Author(s)	Testor Pierre[1, 3], Mortier Laurent[4], Coppola Laurent[4], Claustre Hervé[4], D'Ortenzio Fabrizio[2, 5], Bourrin François[5], Durrieu De Madron Xavier[6], Raimbault Patrick
Contributor(s)	Fuda Jean-Luc, Benabdelmoumène Hassane, Melkonian Jeanne, Duformentelle Pierrette, Tisne Lou, Diamond Emilie, De Liège Guillaume
Affiliation(s)	1 : LOCEAN, France 2 : CNRS, France 3 : ENSTAParisTech, France 4 : LOV, France 5 : CEFREM, France 6 : MIO, France
DOI	10.17882/51156
Publisher	SEANOE
Keyword(s)	sea water temperature, sea water electrical conductivity, sea water pressure, chlorophyll a signal from fluorescence sensor in sea water, volume absorption coefficient of radiative flux in sea water due to dissolved organic matter, volume scattering function of radiative flux in sea water 700, mole concentration of dissolved molecular oxygen in sea water, temperature of sensor for oxygen in sea water, uncalibrated phase shift reported by oxygen sensor, calibrated phase shift reported by oxygen sensor
Abstract	The observations of campe glider on mooset02_13 deployment (Mediterranean Sea - Western basin) are distributed in 4 files: ▪ EGO NetCDF time-series (data, metadata, derived sea water current) ▪ NetCDF profiles extracted from the above time-series ▪ Raw data ▪ JSON metadata used by the decoder The following parameters are provided : ▪ Particle backscattering at 532 nanometers ▪ Concentration of coloured dissolved organic matter in sea water ▪ Particle backscattering at 880 nanometers
Licence	CC BY-NC
Utilisation	EGO data are published without any warranty, express or implied. The user assumes all risk arising from his/her use of EGO data. EGO data are intended to be research-quality and include estimates of data quality and accuracy, but it is possible that these estimates or the data themselves contain errors. It is the sole responsibility of the user to assess if the data are appropriate for his/her use, and to interpret the data, data quality, and data accuracy accordingly. EGO welcomes users to ask questions and report problems to the contact addresses listed in the data files or on the EGO internet page.
User's manual	QC manual

Data

File	Size	Format	Processing	Access
51932.tar.gz	80 MB	NC, NetCDF	Quality controlled data	Open access

Click to download the data — DATA





Download metadata
TXT, RIS, XLS

Oceanographic cruises
MOOSE-GE 2016

Related datasets
Testor Pierre, Mortier Laurent, Coppola Laurent, Claustre Herve, D'Ortenzio Fabrizio, Bourrin Francois, Durrieu De Madron Xavier, Raimbault Patrick (2017). Glider MOOSE sections. SEANOE.

Share

Glider MOOSE sections

Date	2017-09
Temporal extent	2010
Author(s)	Testor Pierre[1, 3], Mortier Laurent[4], Coppola Laurent[4], Claustre Hervé[4], D'Ortenzio Fabrizio[2, 5], Bourrin François[5], Durrieu De Madron Xavier[6], Raimbault Patrick
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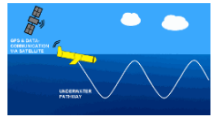
Affiliation(s)	1 : LOCEAN, France 2 : CNRS, France 3 : ENSTAParisTech, France 4 : LOV, France 5 : CEFREM, France 6 : MIO, France
DOI	10.17882/52027
Publisher	SEANOE
Keyword(s)	sea water temperature, sea water electrical conductivity, sea water pressure, mole concentration of dissolved molecular oxygen in sea water, temperature of sensor for oxygen in sea water, uncalibrated phase shift reported by oxygen sensor, mass concentration of chlorophyll a in sea water, volume absorption coefficient of radiative flux in sea water due to dissolved organic matter, volume scattering function of radiative flux in sea water 700
Abstract	The glider operations in the MOOSE network started to be deployed regularly in 2010 in the North Western Mediterranean Sea, thanks to the setup of national glider facilities at DT-INSU/Ifremer (http://www.dt.insu.cnrs.fr/gliders/gliders.php) and with the support of the European project FP7-PERSEUS. Two endurance lines are operated: MooseT00 (Nice-Calvi; Ligurian Sea) and MooseT02 (Marseille-Menorca; Gulf of Lion). The all dataset here corresponds to raw data in the EGO format.
Licence	CC BY-NC
Utilisation	EGO data are published without any warranty, express or implied. The user assumes all risk arising from his/her use of EGO data. EGO data are intended to be research-quality and include estimates of data quality and accuracy, but it is possible that these estimates or the data themselves contain errors. It is the sole responsibility of the user to assess if the data are appropriate for his/her use, and to interpret the data, data quality, and data accuracy accordingly. EGO welcomes users to ask questions and report problems to the contact addresses listed in the data files or on the EGO internet page.

Click to download the data — DATA



Download metadata
TXT, RIS, XLS

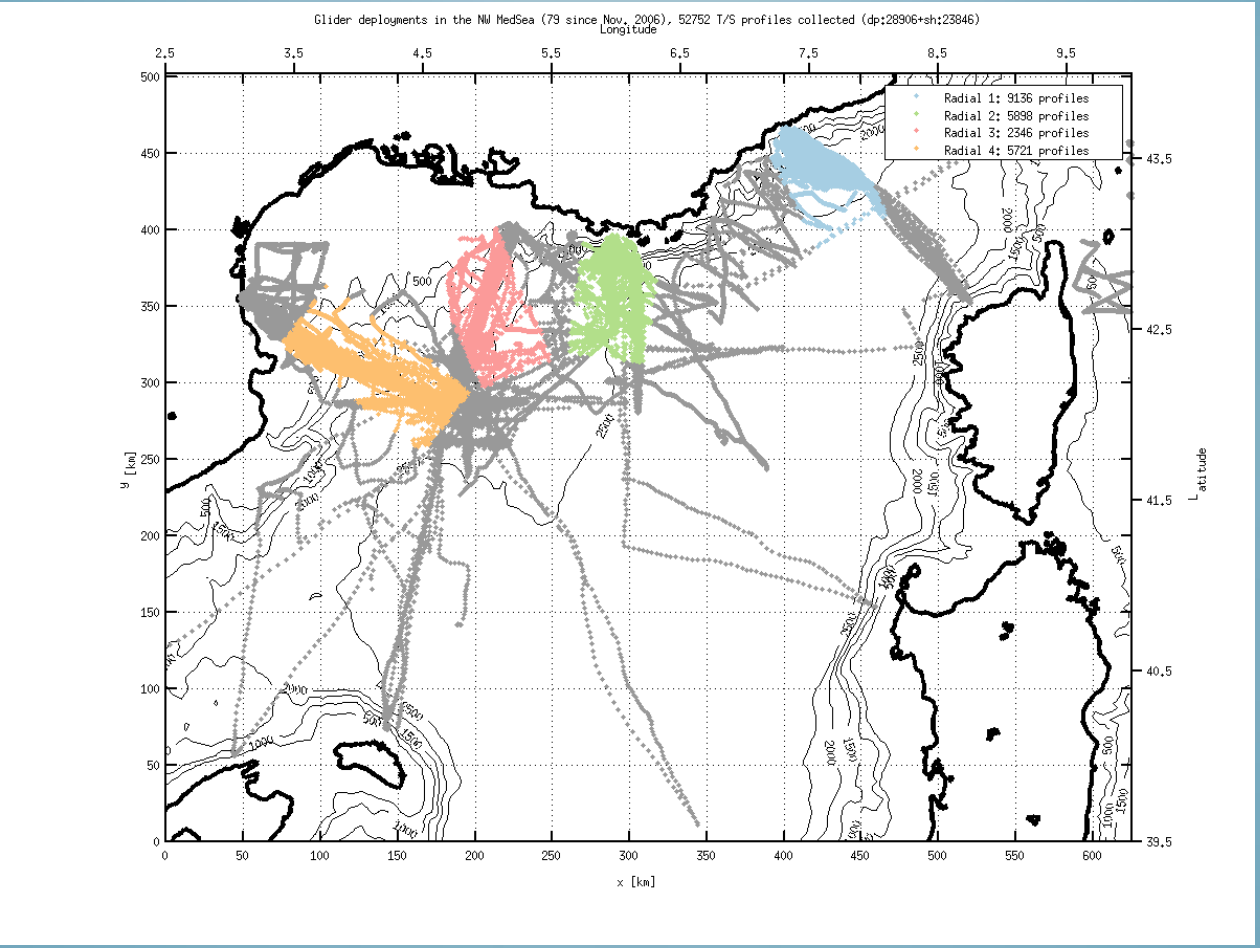
Oceanographic cruises
MOOSE-GE

Project(s) FP7/H2020
GROOM, PERSEUS

Related datasets
Coppola, Laurent (2017).

- Real time: CORIOLIS
- Delayed mode : SEANOE
- DOI/transect and global DOI global

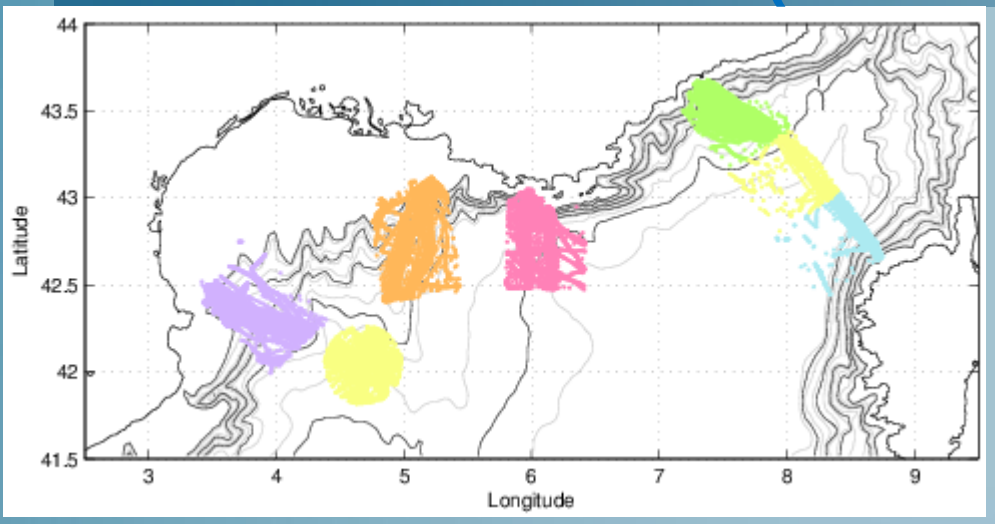
Large scale circulation : R/V+ moorings + gliders

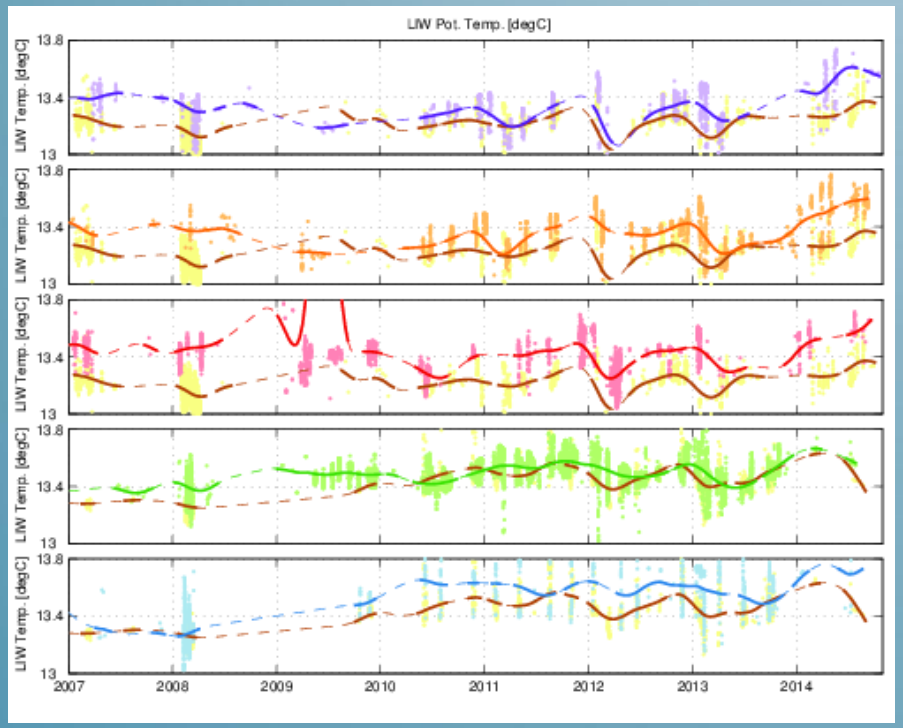


- Caractériser le CN selon plusieurs « sections » à haute résolution
- (intra)Saisonnalité du transport du Courant Nord
- Transport de chaleur/sel niveau LIW ➔ Bilan par boite ➔ Flux cote large

(Thèse A. Bosse, LOCEAN)

Integrated view of the variability of the Liguro-Provençal Basin (Thèse F. Margirier)





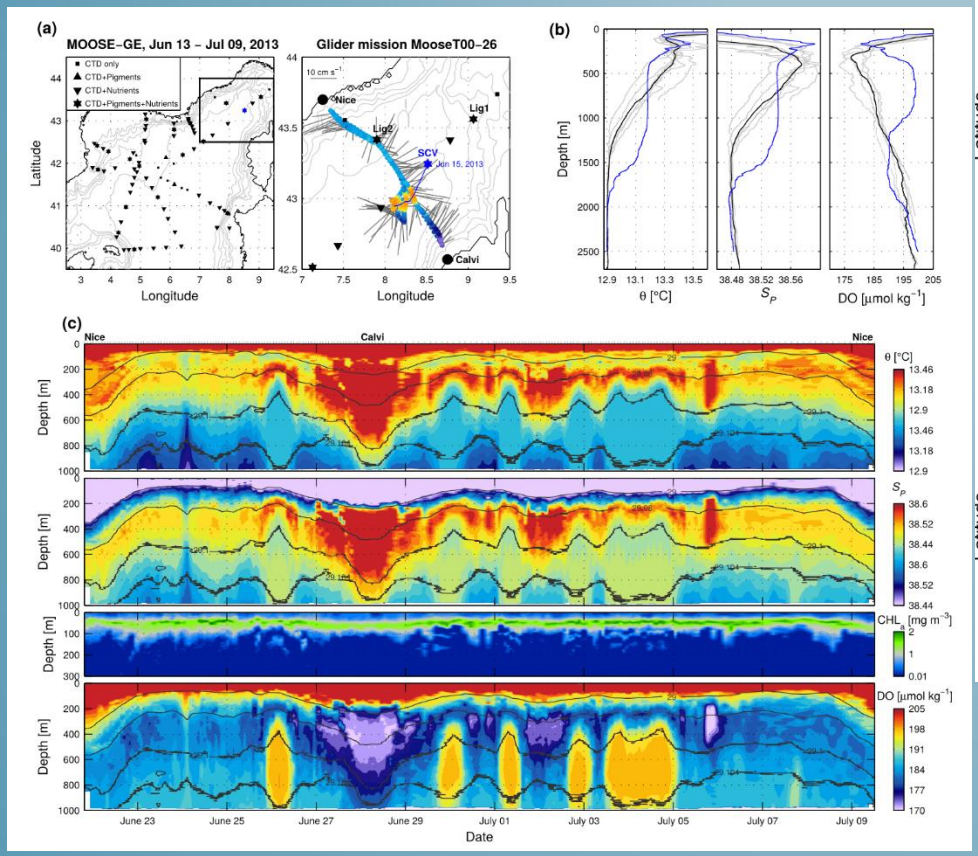
Coastal/offshore gradient

Surface water vs deep water

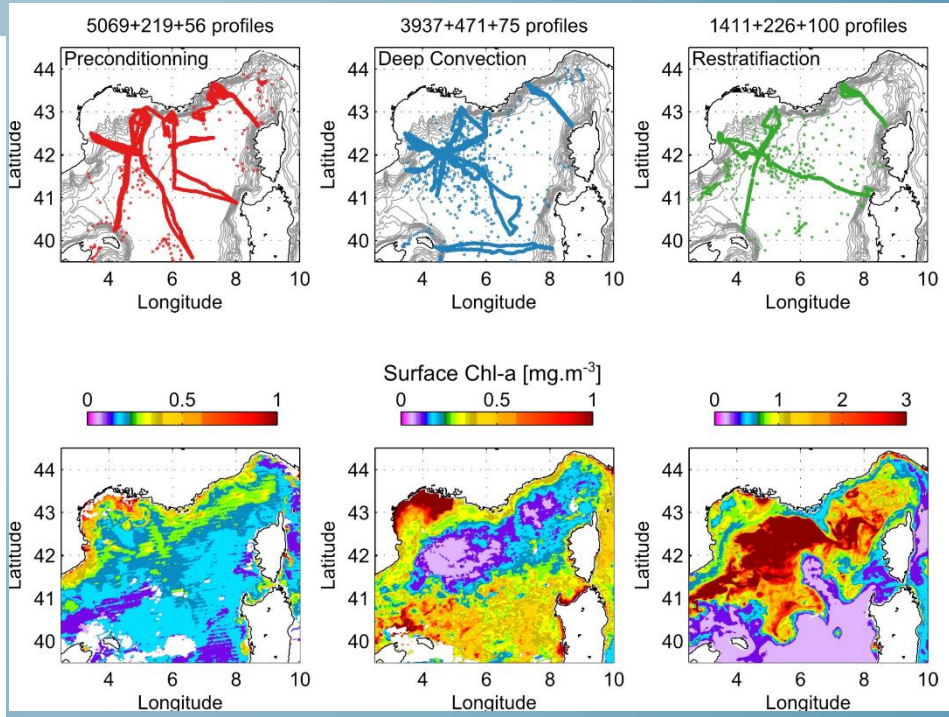
Variability Index

(marron/jaune : large ; autres couleurs : côtier, circulation de bord)

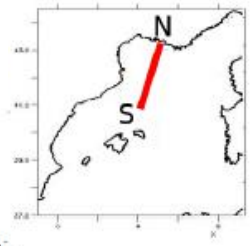
Observation des SCV et leur impact sur le contenu BGC (ex. en mer Ligure) Bosse et al. 2014, 2016 et 2017

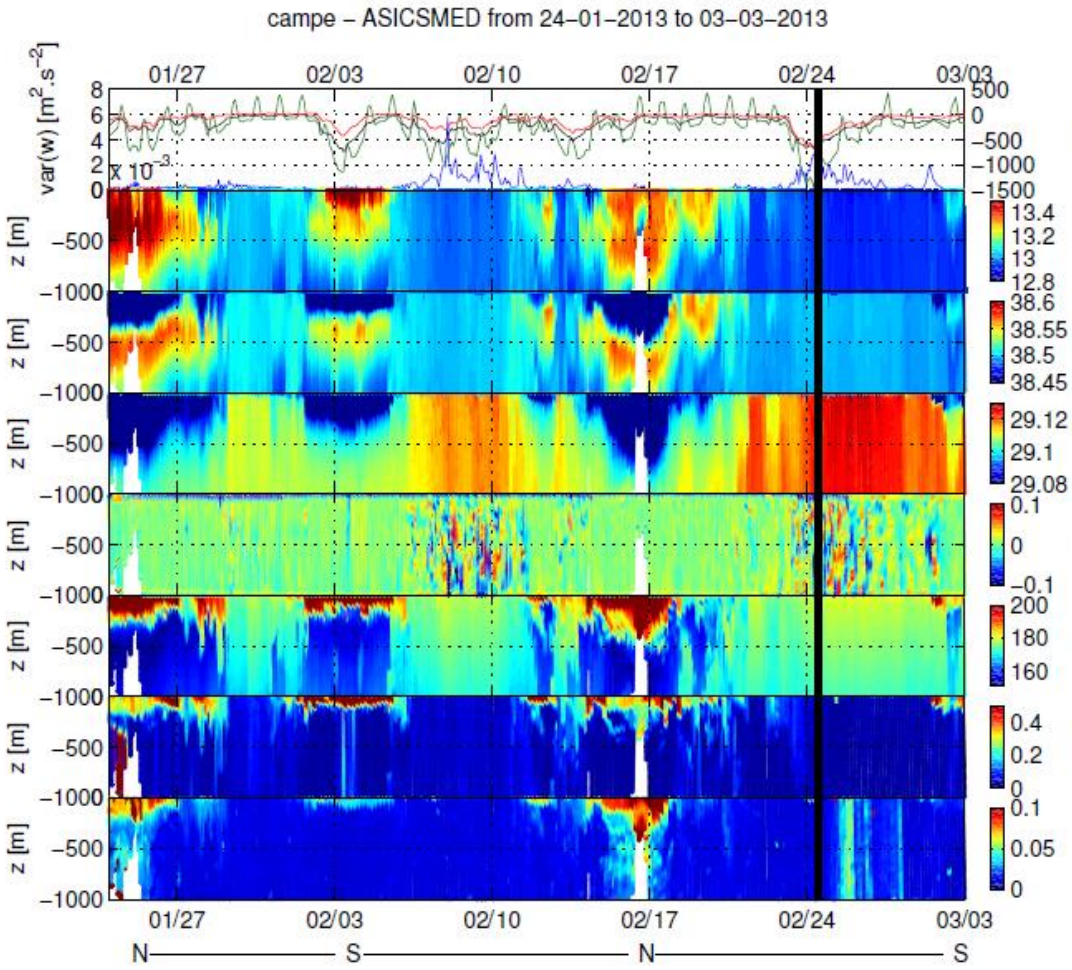


Observation des différentes étapes de la convection dans le bassin NW (pré à post convection). Testor et al., 2017



Violent Mixing : Plumes



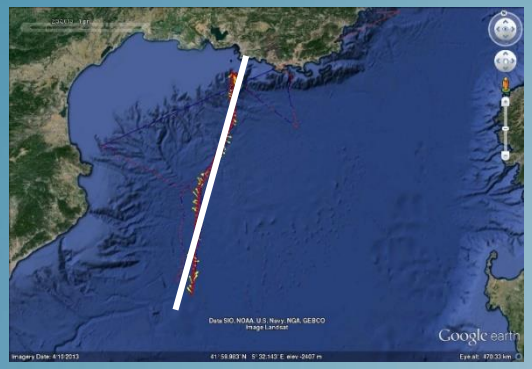


Downwelling plumes

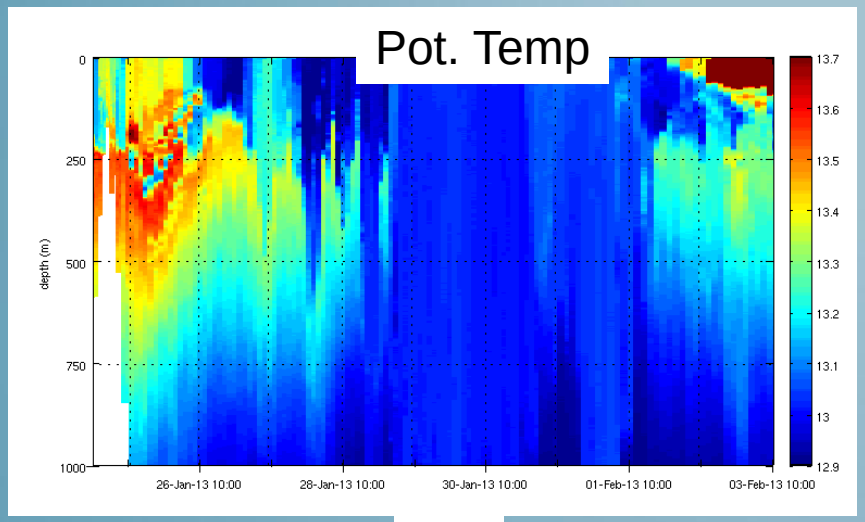
- w ~ -6cm.s^{-1}
- denser +7.5 10^{-4} kg.m^{-3}
- saltier +4.9 10^{-4} psu
- colder -1.8 10^{-3} °C
- more fluorescent +2.3 10^{-2} mg/m^{-3}
- oxygen/turbidity: no clear signal on average

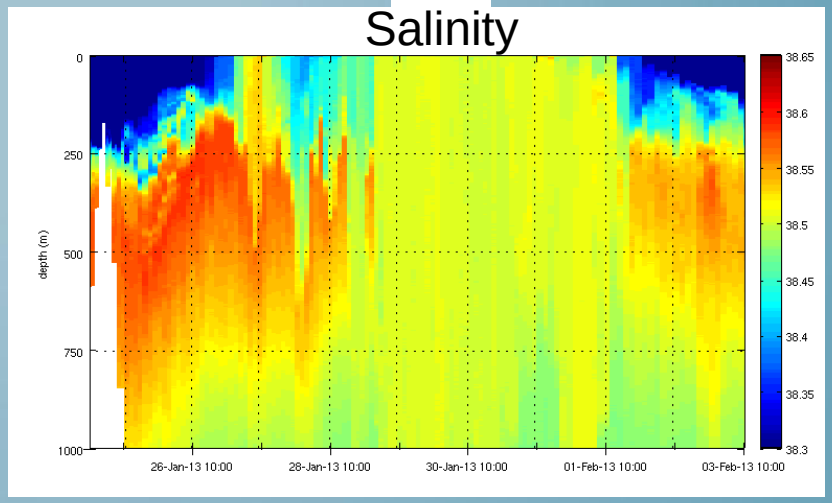
Mean radius 350m and mean distance between downwelling plumes 1.8km

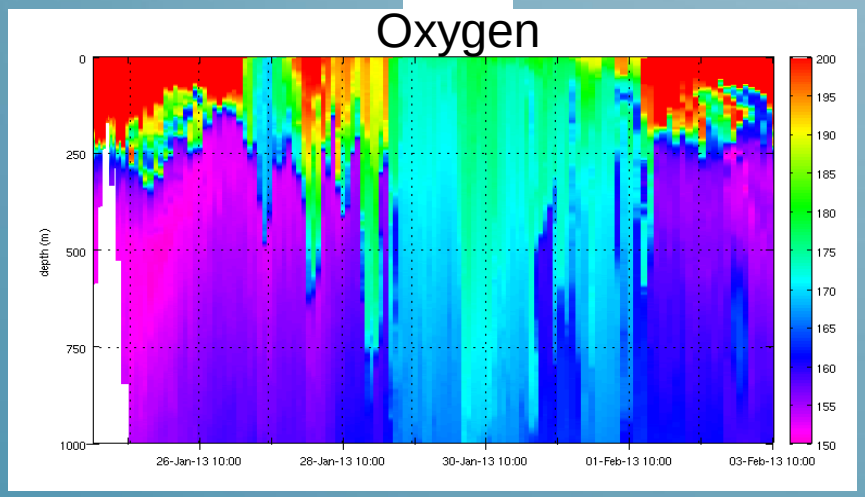
Negative velocities cover 40% of a glider track → 20% of the area of the mixed patch.

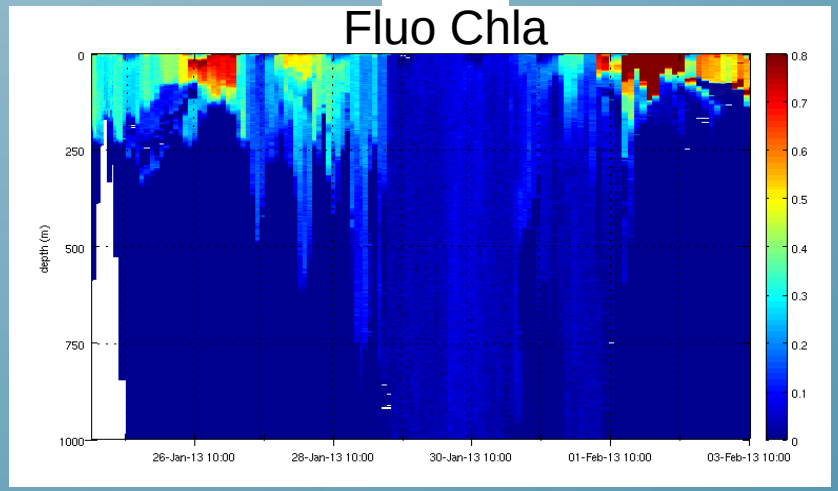


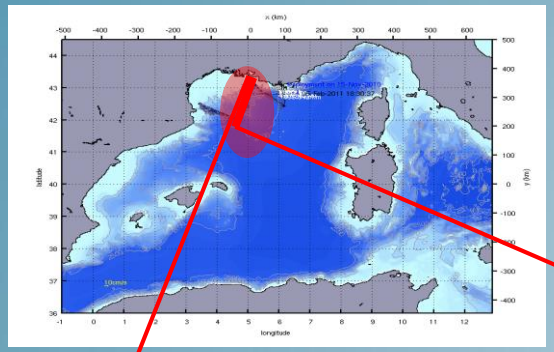
Small scale variability
physical-biogeochemical coupling



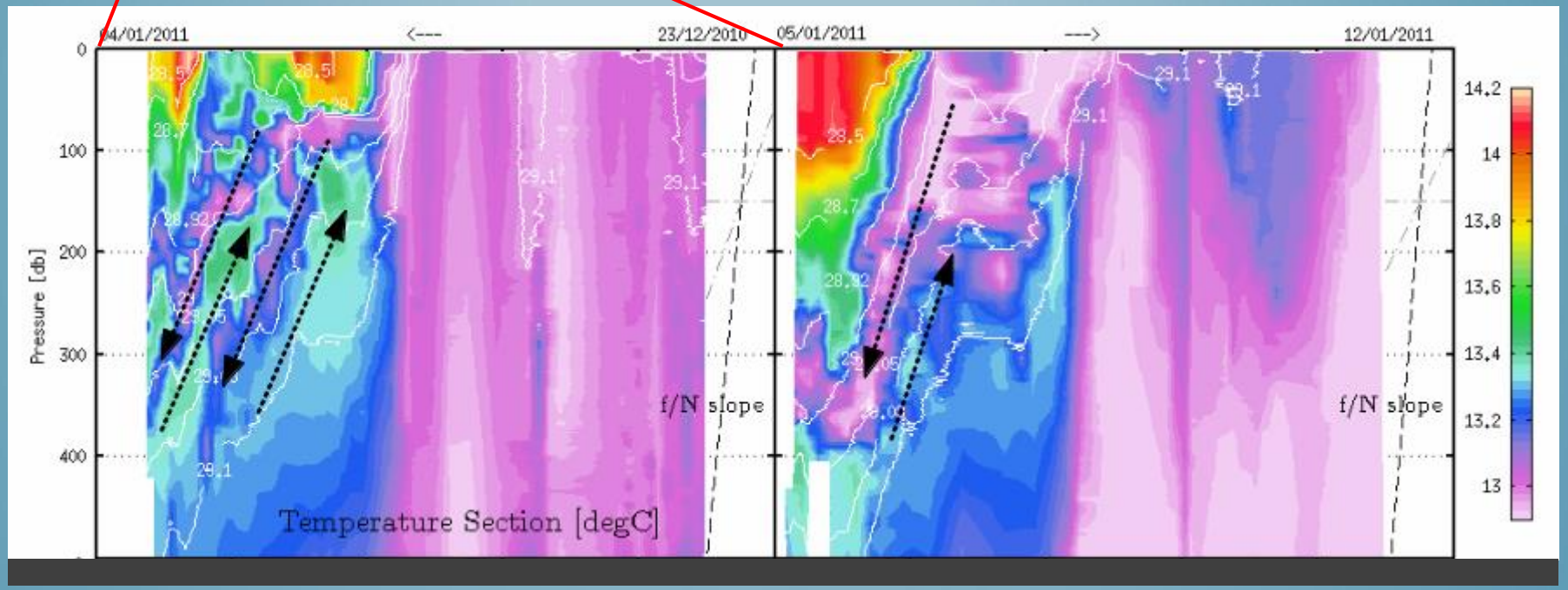








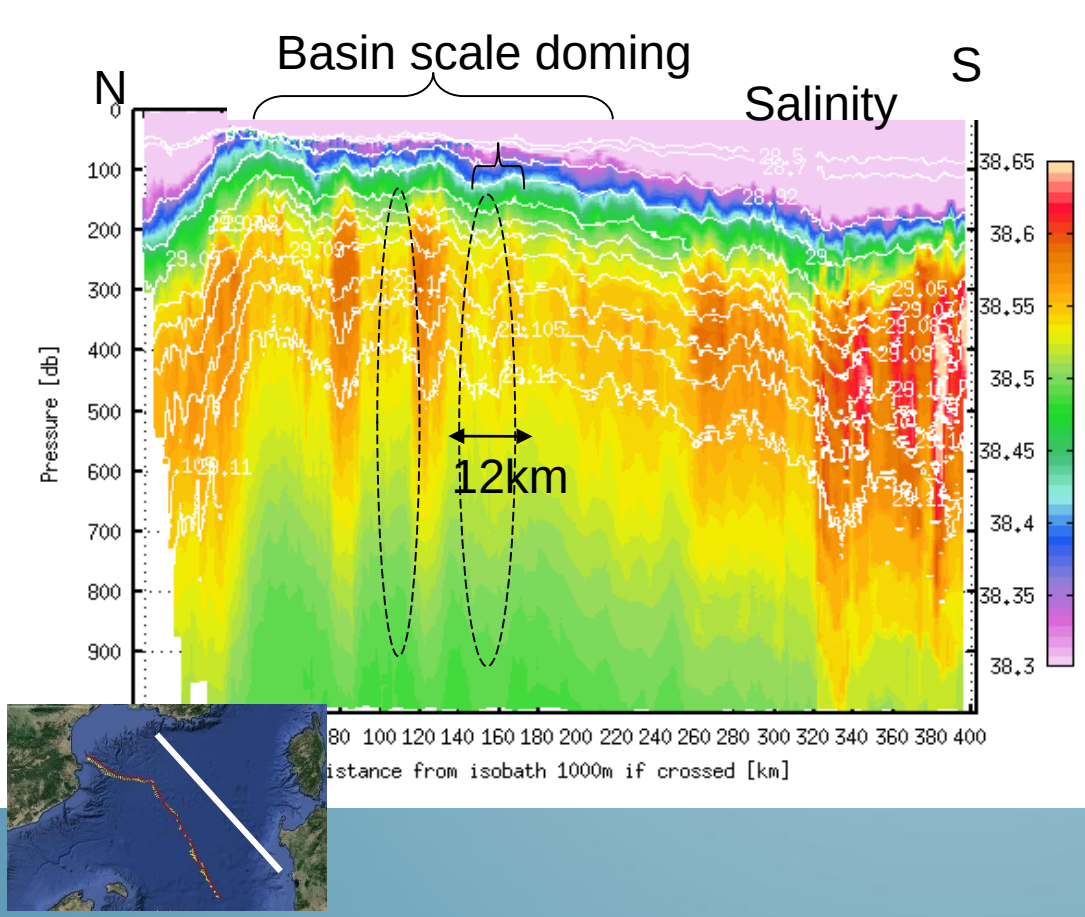
Nothern current and vertical mixing
Sub meso-scales processes: « layering »)
Gliders + modèle



Etudes fondamentales (thèse de A. Bosse, LOCEAN) : Diagnostiques (vorticité potentielle, angle de Turner, f/N, …)

- Instabilité symétrique
- Double diffusion
- Etirement du champs de T par la mésoéchelle
- …

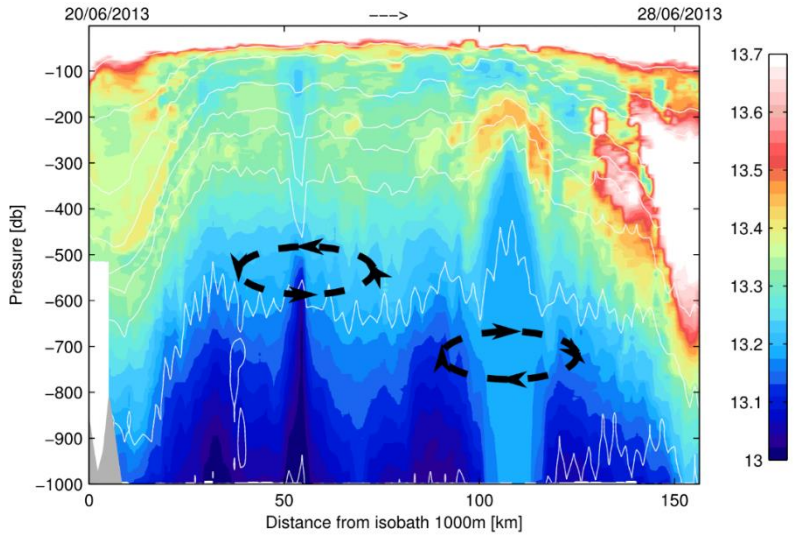
Preconditioning: LIW Submesoscale Coherent Vortices (SCVs)



LIW SCVs characteristics:

- Anticyclonic
- R ~ 6km,
- U ~ 8cm/s
- Ro ~0.3
- Bu ~0.7
- lifetime O(1 year)

WMDW SCVs

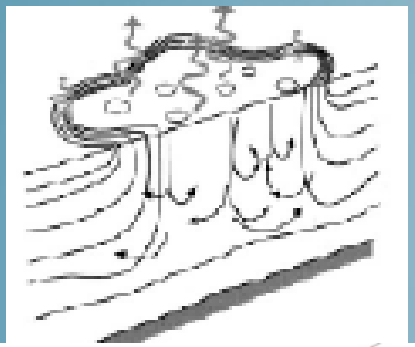


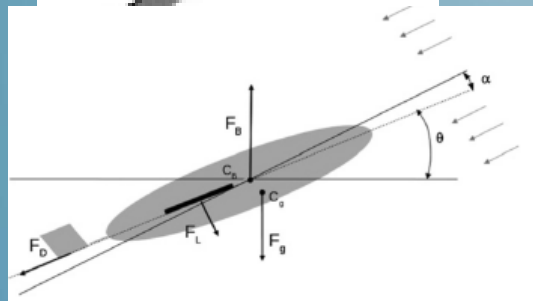
LIW SCVs → local doming preconditionning agents (local salt injection)

Numerous and likely formed at the NW tip of Sardinia.
Combined effect of "upwelling + slope curvature + vert. mixing (rough topography)"

Thèse A. Bosse

Characterization of convective plumes (Margirier et al., 2017)

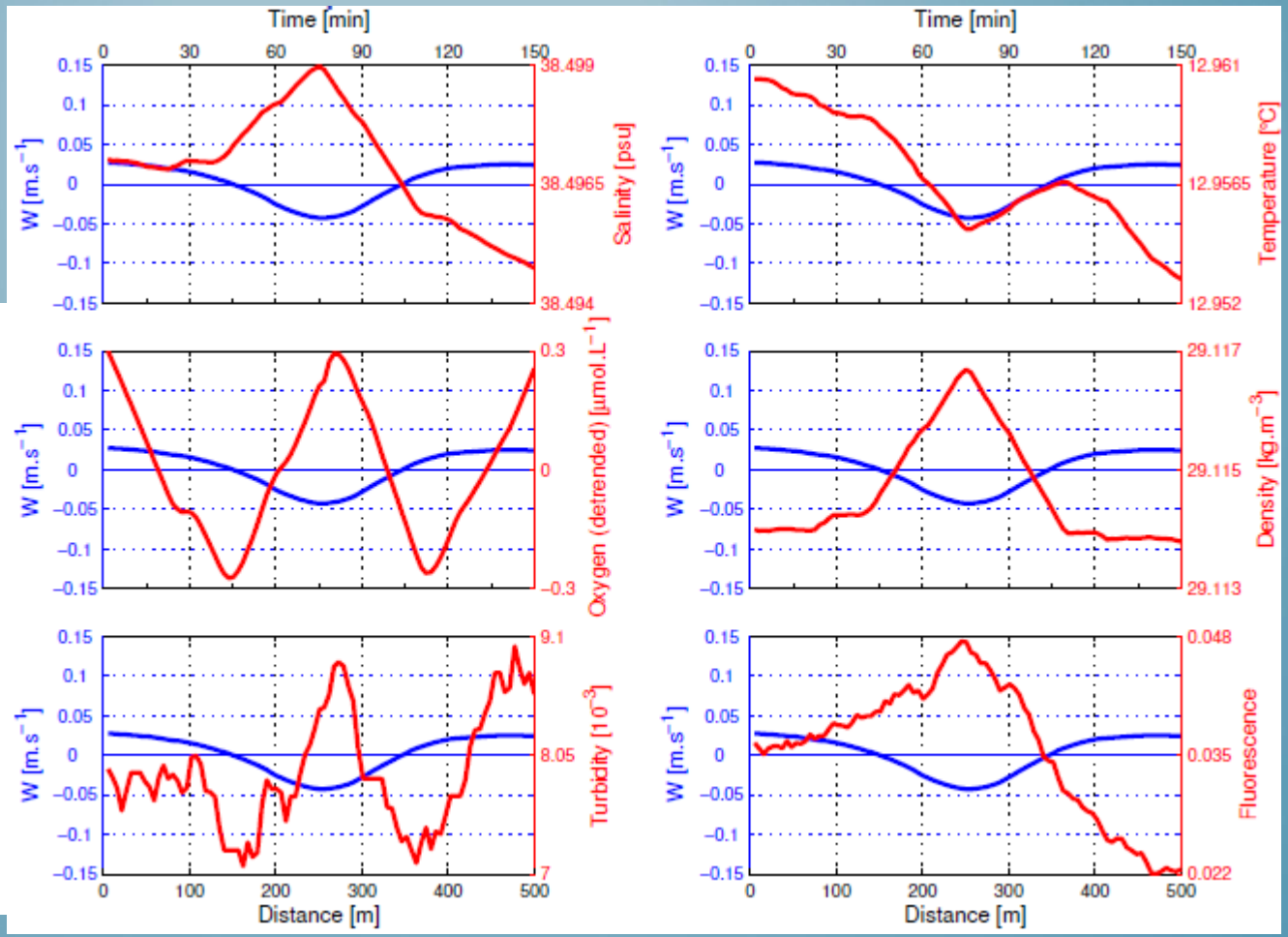




the gliderstatic flight model

$$F_B = g\rho(V_g(1 - \epsilon P + \alpha_T(T - T_0)) + \triangle V_g)$$
$$F_g = m_g g$$
$$F_L = \frac{1}{2}\rho S U^2 a\alpha$$
$$F_d = \frac{1}{2}\rho S U^2 (C_{D_0} + C_{D_1}\alpha^2)$$
$$\alpha = \frac{C_{D_0} + C_{D_1}\alpha^2}{atan(\theta+\alpha)}$$

$$W_{water} = W_{pressure} - W_{glider}$$



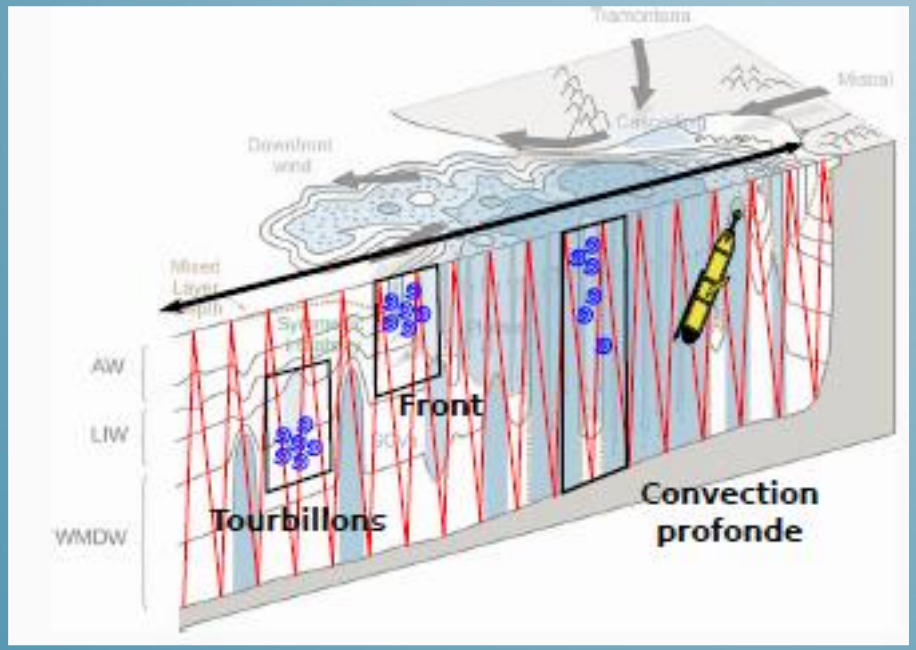
A global view of the deep winter convection (Testor et al. 2017)

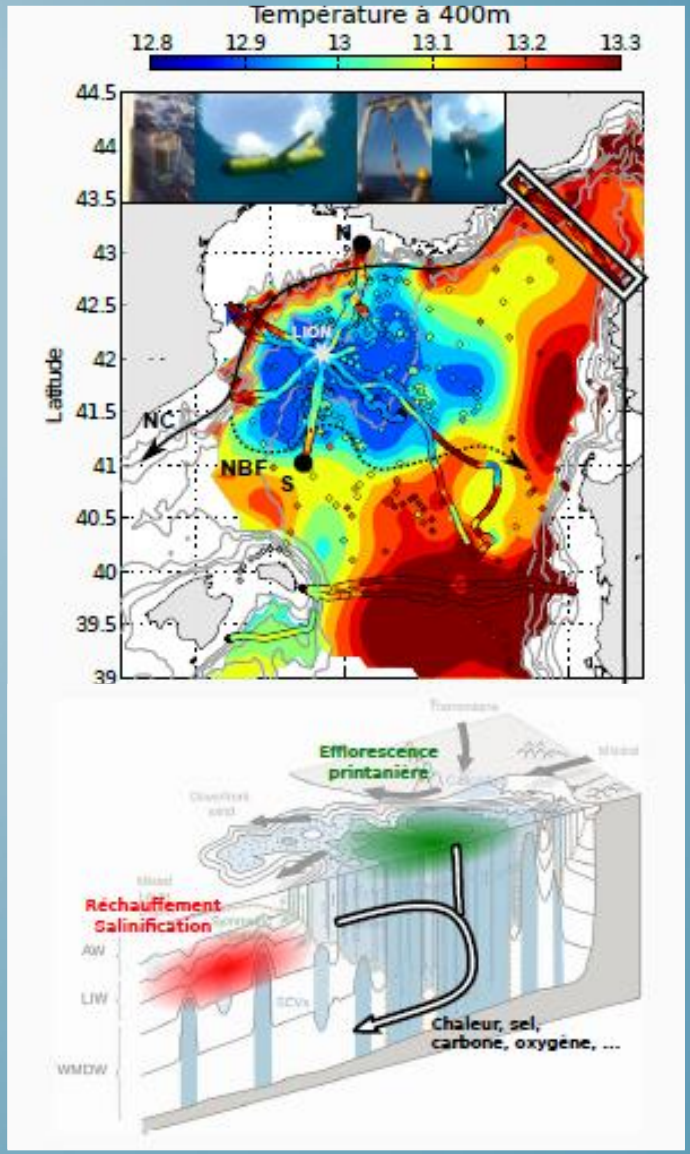
Oxygenation of deep water

Heat accumulation

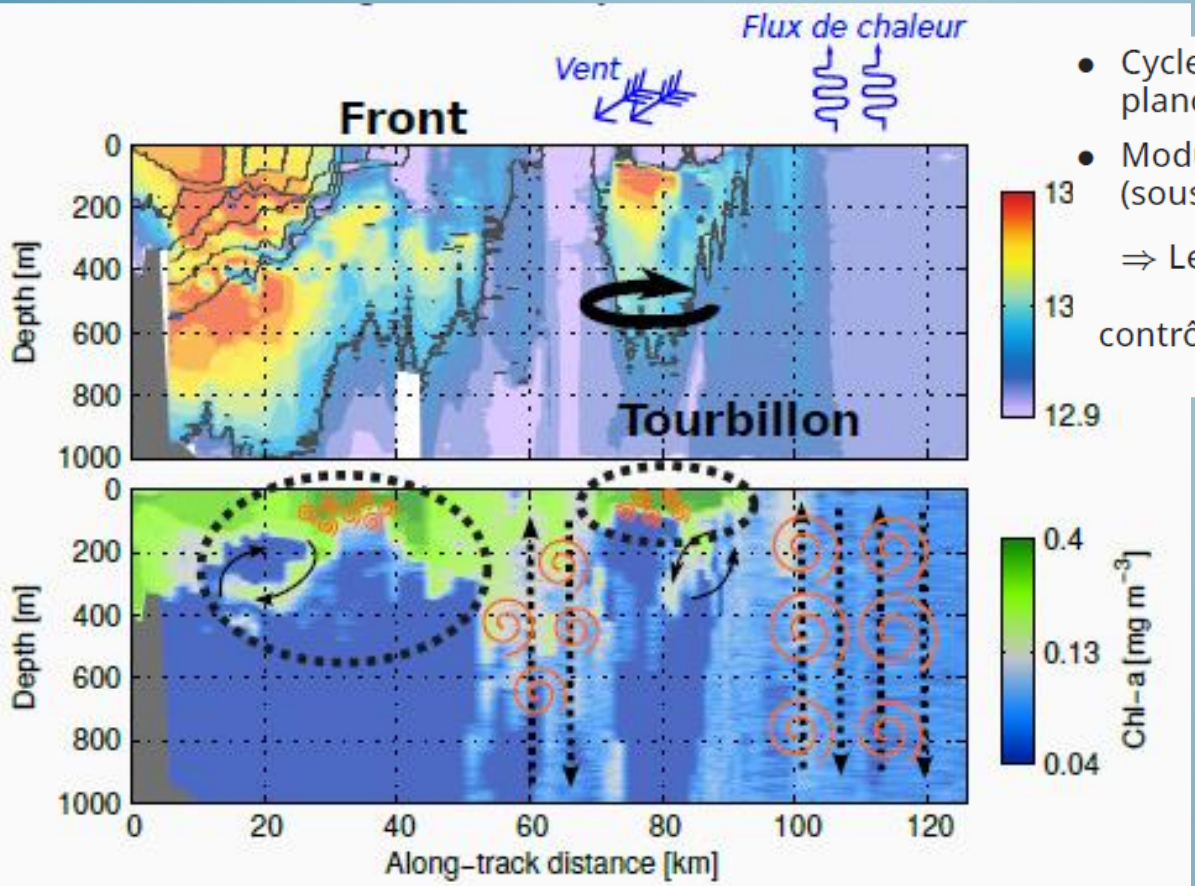
Nutrient enrichment in surface

Stimulation of primary production





Facteurs dynamiques de contrôle de la production primaire



- Cycle saisonnier de croissance du phyto-plancton Efflorescence printanière
- Modulation importante par la dynamique à (sous)mésoéchelle

⇒ Les échanges hor./vert. au niveau des **fronts** et des **tourbillons** contrôlent les **flux d'énergie et de matière**

Questions scientifiques: Bosse Anthony CNAP MOOSE

→ Compétition flux turbulents et vitesses verticales?

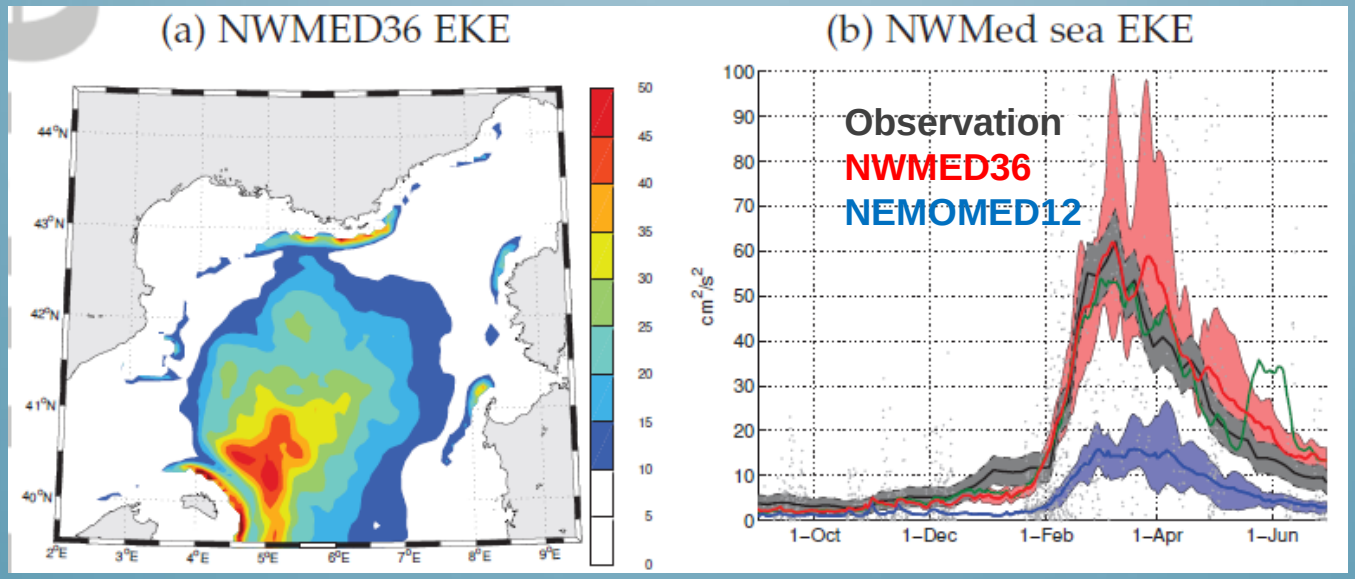
→ Rôle du forçage atmosphérique et de la dynamique océanique sur des transferts verticaux?

→ Impacts sur l'apport de nutriments, la croissance du phytoplancton et export de matière organique en profondeur?

Glider data used for modelling

Around 20 scienrific papers

- *Lagrangian transport of fine particles*
- *Water circulation*
- *submesoscale coherent vortices*
- *Dense water formation - Vertical mixing*
- *Climate variability*
- *Cascading events*
- *Impact on the biogeochemistry*
- *Carbon export*



"We need data, … models are becoming untestable" (Carl Wunsh 2010)

Glider MOOSE : bilan d'activité et financier

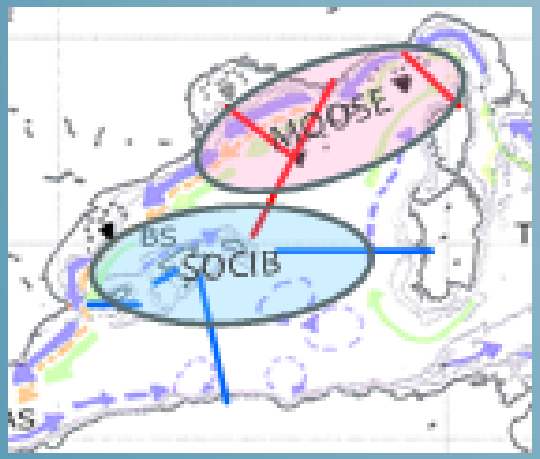
	ACTIVITY			BUDGET		
Year	Transect T00	Transect T02		Institutes	PERSEUS	Equipment
	jours	jours		euros	euros	euros
2010	90	90		36000		
2011	164	250		60000		60000
2012	95	294		48000		
2013	84	172		36000	110000	5000
2014	28	198		0		
2015	171	219		42000		
2016	124	195		36000		37941,6
2017	117	140		36000		
2018	225			48000		
2019	150			**97000**		**150 000**
total	873	1558		439000	110000	252942
Glider months		93,5		BUDGET		**801942**

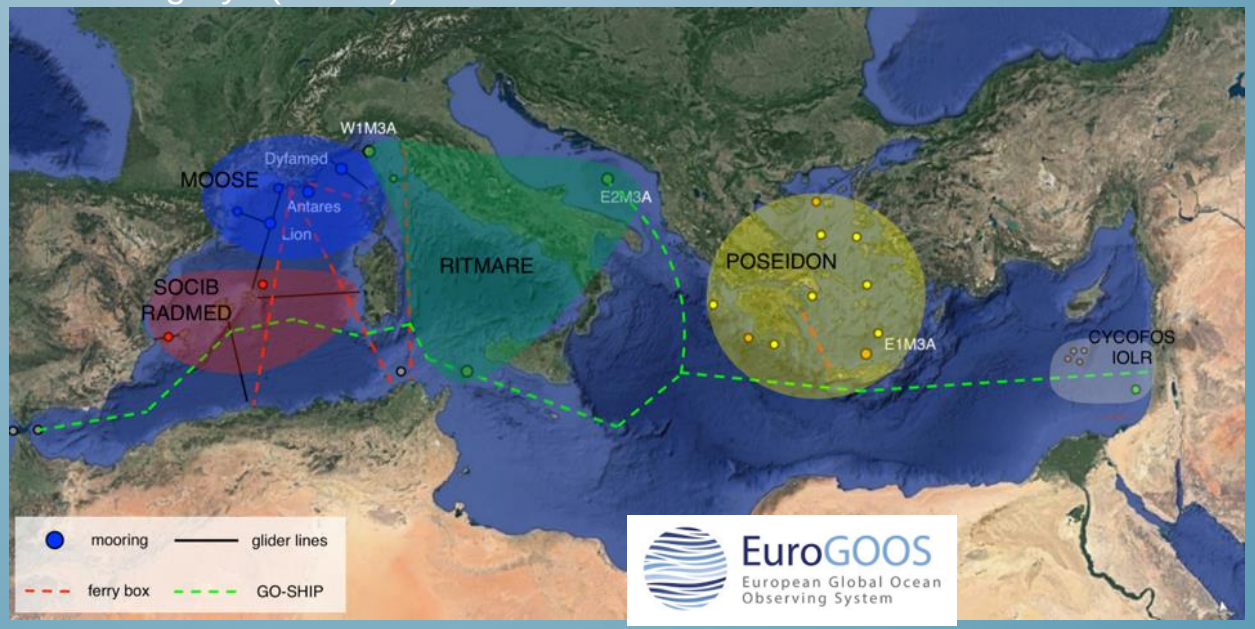
Ticket modérateur à 11 000 euros !!!

Soutien Région PACA

International collaboration

- MOOSE contributes to the new generation of observing systems with multiple and integrated sites and is designed to record the ecosystem changes in the northwestern basin
- MOOSE has created a solid integrated regional observing system, that provides operational service for the timely, continuous and sustainable delivery of high-quality marine data and information products.
- MOOSE is rooted in all the relevant existing European Research Infrastructure Consortium to contribute to the emerging European Ocean Observing Syst(EOOS).





- Gliders = EGO, GROOM
- Radars = JERICO NEXT
- Moorings = EMSO/OceanSites (Ligure node)
- Ships = GO-SHIP (planned ?)

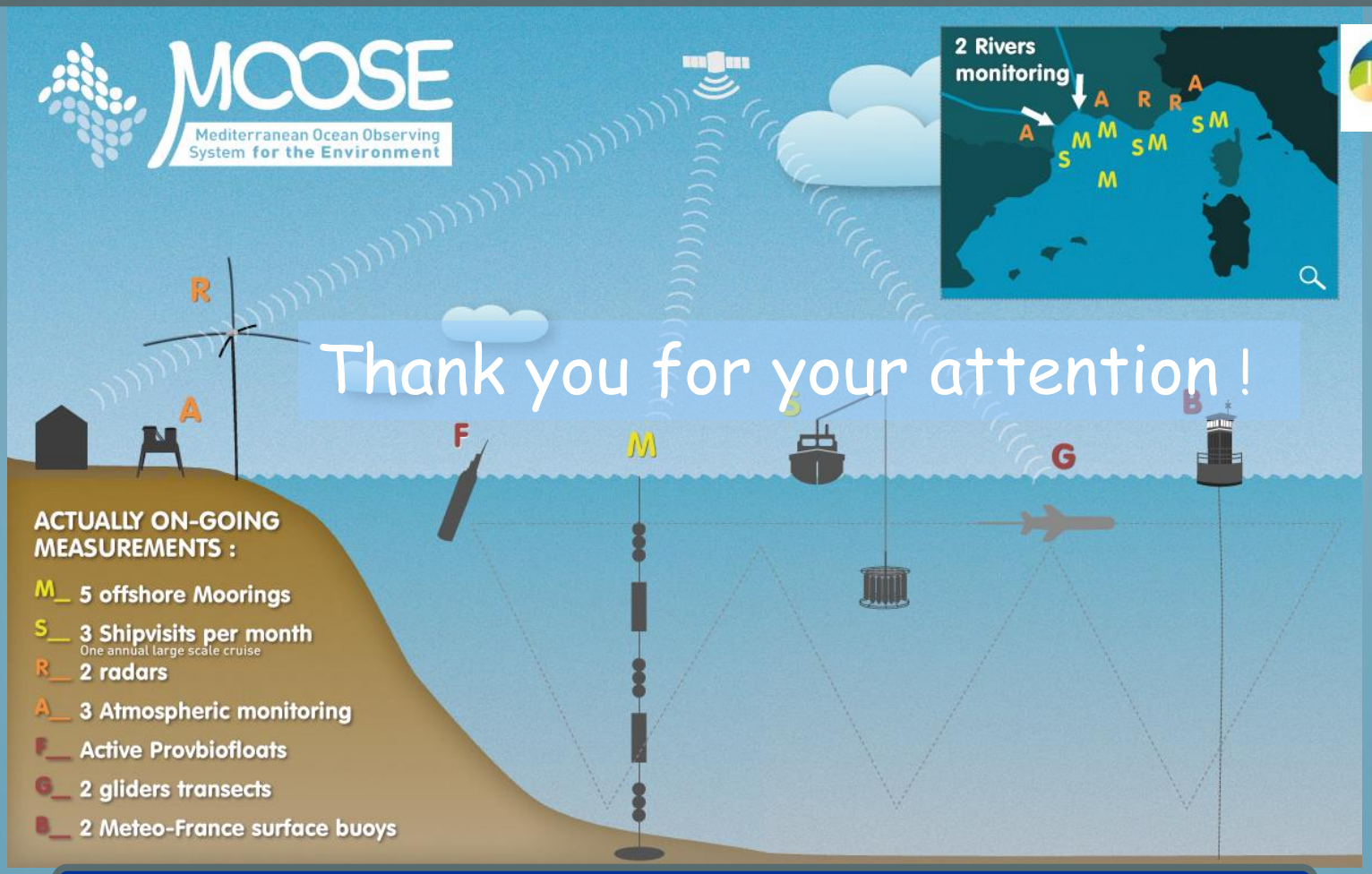
Share expertise, data, best practices
Main networking : CIESM, MonGOOS, EMSO-Link

MOOSE et les Gliders
CONCLUSIONS

Actions		Besoins
➢ Intérêt : OK ➢ Rendu scientifique OK	⇒	Maintien de la stratégie
➢ Soutien pour les évolutions techniques capteurs, traitement données	⇒	Etroite collaboration Utilisateurs /équipes techniques
➢ Apports co-financement	⇒	maintenance et jouvence plan pluri-annuel
➢ Soutien logistique/technique ➢ Facilité de programmation	⇒	maintien des équipes techniques
➢ Long-terme /pérennité	⇒	Coûts « adaptés »

MOOSE est un SERVICE NATIONAL D'OBSERVATION

An integrated network for long-term mediterranean observatory



TAKING THE PULSE OF THE NW MEDITERRANEAN SEA

MOOSE reinforces the French scientific community on the NW Mediterranean site, emphasizing its multidisciplinarity to mobilize it on a thematic continuum from coastal to offshore regions.

In this context, MOOSE aims to deliver time-series of data to anticipate the behaviour of this marine ecosystem from an interdisciplinary analysis conducted during the next decades.