Combining in situ and remote sensing biogeochemical observations -examples from the Mediterranean Basin

Sana Ben Ismail, IOCCP Regional Implementation

First Data Buoy Cooperation Panel Mediterranean Training Workshop on Ocean Observations and Data Applications (DBCP-Medi-1)-Part 2

Hybrid 2-4 of May 2023, Tunis, Tunisia

INSTM

National Institute of Marine Sciences and Technologies

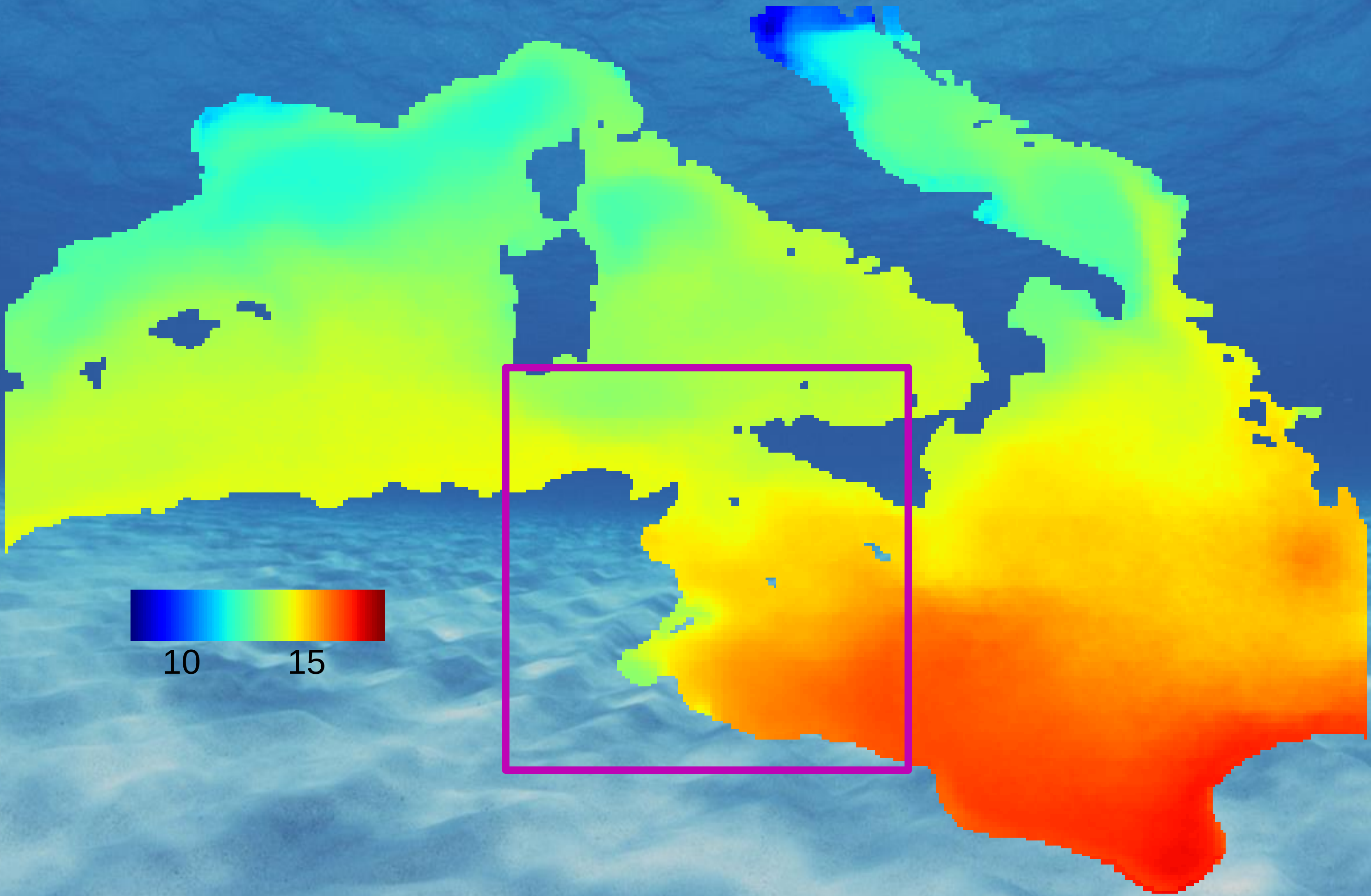
INSTM is one of the largest and widespread research center in Tunisia, founded in 1924 for the marine sciences and technologies.

Outline

- Introduction
- Approaches
- Implementation
    - Repeated sections
    - Extended stations
    - Drifters
    - Moorings
    - Gliders
    - Applications
- Perspectives and priorities

Study Area

The Central Mediterranean Sea



Temperature (°C) at -10 m in April (from Seadatanet climatologies)

Introduction

Key region

Exchange heat and salt between the Eastern Mediterranean Basin and the Western Mediterranean Basin

Distinct surface, intermediate & deep water masses circulating between west and east

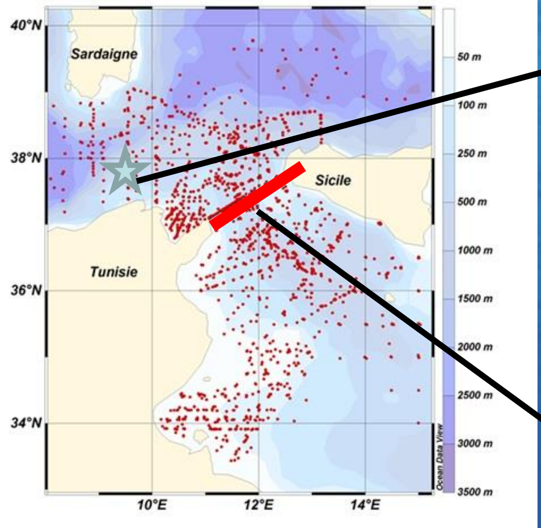
Useful for climate change studies

define a realistic survey strategy and capitalize existing time series, to understand the time scales variability and to provide elements of comparison and verification to models.

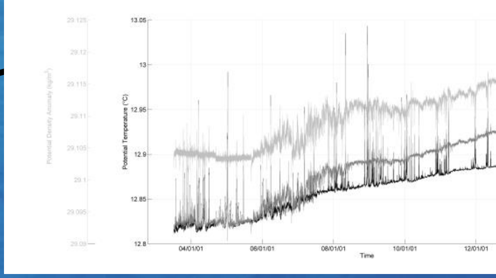
- documenting changes within it → anticipate similar changes in the global ocean
- understanding the role of key processes involved in climate change → inferences on those processes on the global scale

Approaches

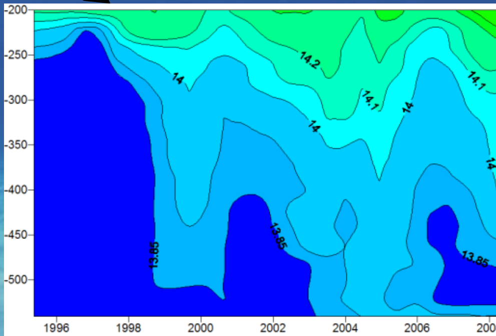
Continuous monitoring of the Central Mediterranean circulation and biogeochemical observation is necessary to detect possible changes when they happen and to understand their time scales.

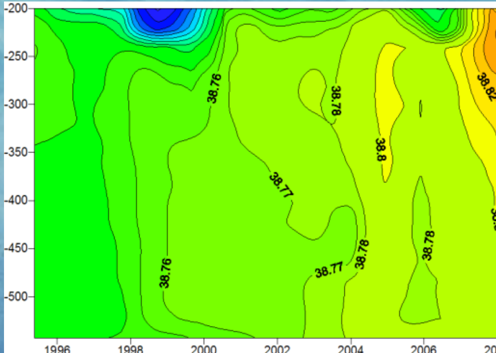


Mooring Time series



Long term evolution of Temperature an Salinity





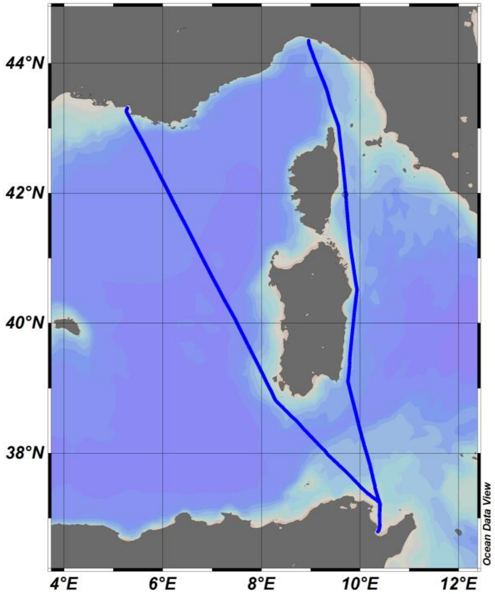
- Long-term monitoring of Tunisia-Sicily and Tunisia -Sardinia <u>straits</u>, to define the main interbasin exchanges
- Repeated observations in <u>sites of special interest</u>, to maintain a deep-basin monitoring with repeated CTD casts at fixed stations
- Large-scale monitoring, through <u>basin wide hydrographic surveys</u> with closed transect, a necessary tool for budget calculation,to initialize and validate general circulation models, and to be assimilated in models to improve their forecast capability

Implementation

Oceanographic cruises on board R/V Hannibal

FerryBox System Western Mediterranean Sea

FerryBox system installed on board C/f Carthage of the Tunisian Navigation Company (CTN)



ROUTES

Two zonal transects **Tunis-Marseilles** and **Tunis-Genoa**, crossing the Algero Provinçal basin, the Tyrrhenian Sea and the Ligurian Sea.

Parameters

T, S, Chla, Turbidity, dissolved Oxygen , pH and Cytometry

COPERNICUS Website

Satellites technologies provide various societies with essential services !

The European Union relies on space technology to **fight climate change**, **prevent disasters**, **manage transport**…

To achieve this mission, the **EU** needed its own independent access to **space services**:

COPERNICUS following GMES (Global Monitoring for Environment and Security), is the European program for the development of an Earth observation and monitoring capacity.

Research Projects

SeaDataNet

IEV CTFMED
Coopérer au-delà des frontières en Méditerranée

Projet financé par l'UNION EUROPÉENNE

REGIONE AUTÒNOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA

COMMON

CLAIM
CLEANING LITTER BY DEVELOPING & APPLYING INNOVATIVE METHODS IN EUROPEAN SEAS

JERICO next

INSTM

Glider Experiments in the Tunisia-Sardinia Channel (GETSCH)

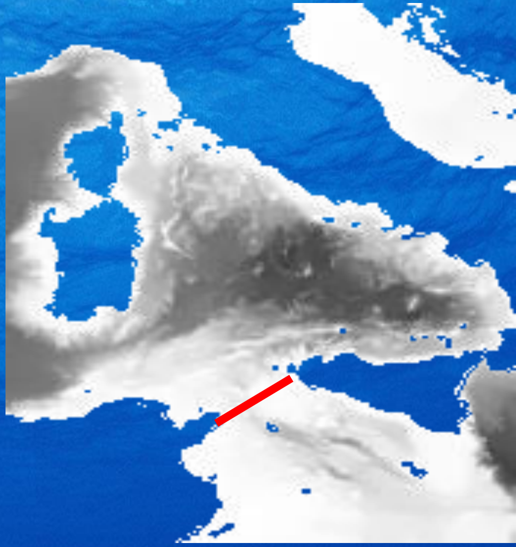
Dr. Sana Ben Ismail

La Syenne sur mer le 06 mars 2018

MERITE-HIPPOCAMPE
CAMPAGNE OCEANOGRAPHIQUE FRANCO-TUNISIENNE

Implementation

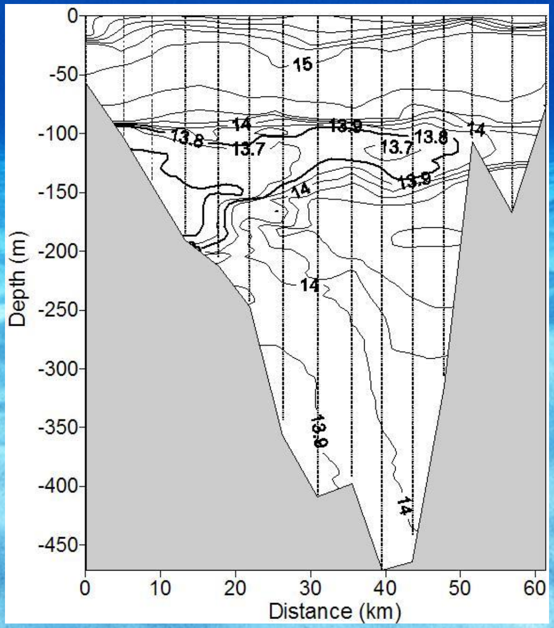
REPEATED SECTIONS

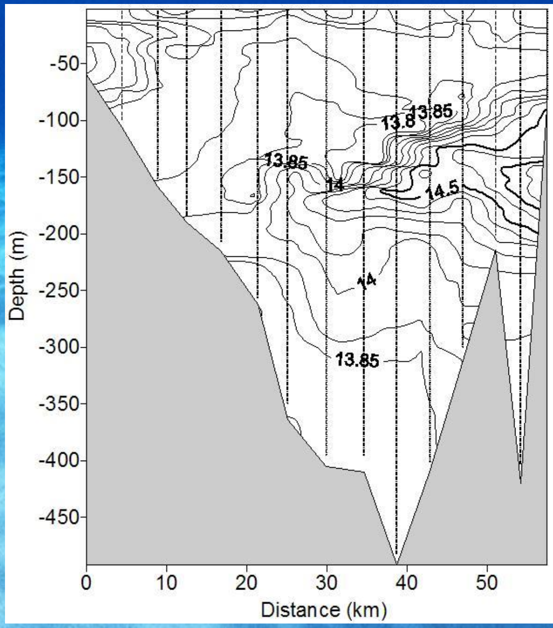


Since winter 2003 new water masses was identified in the Tunisia- Sicily Channel and important physical changes abrupt increase in the deep heat and salt contents in 2008,

It has been visited in 2003, 2005, 2006, 2007, 2009 by INSTM.

This section permitted to assess the exchange between the EMED and WMED

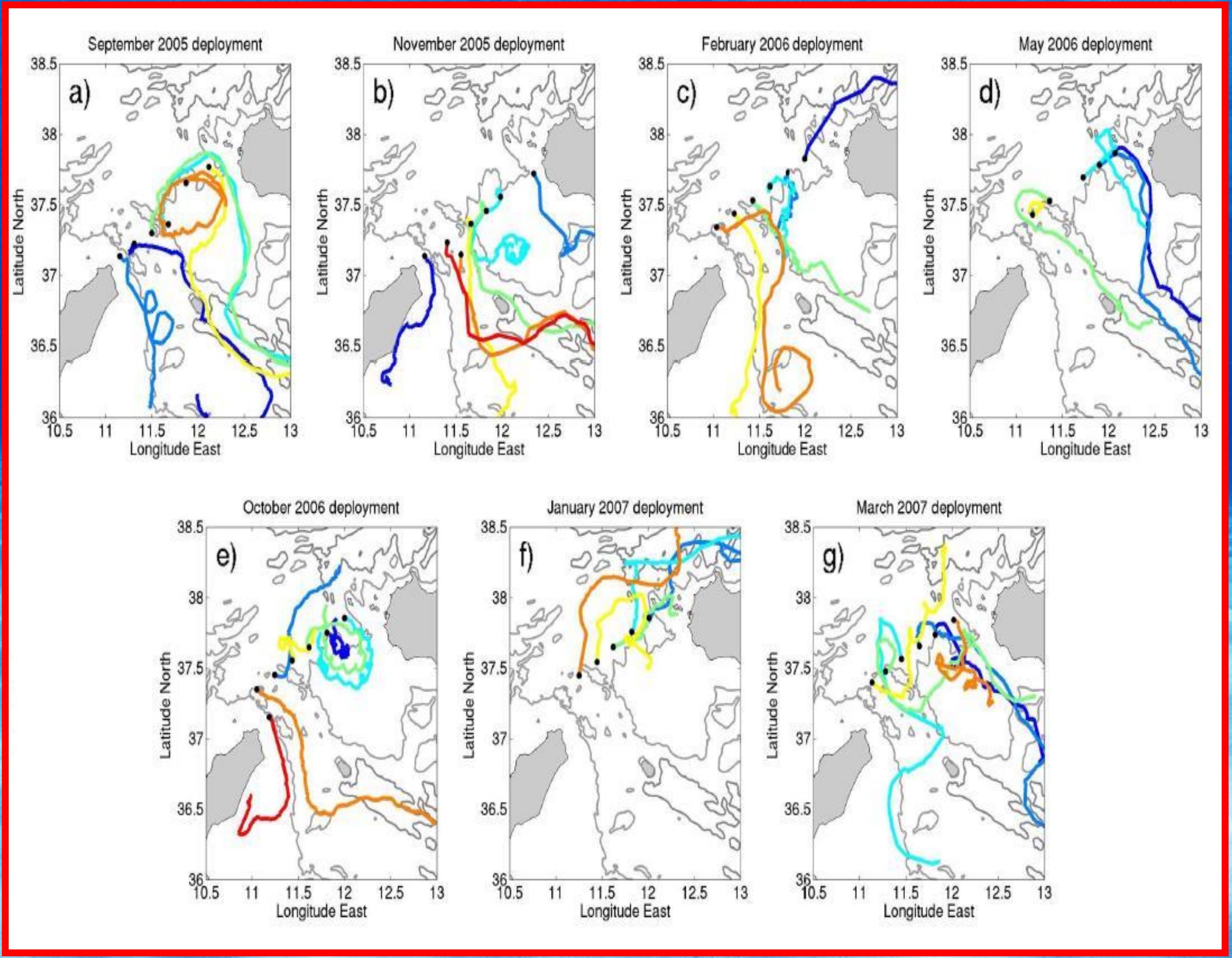




Ben Ismail et al., 2014

Implementation

DRIFTERS



Seasonal deployement from 2005 to 2007

Project Egypt/EGITOO

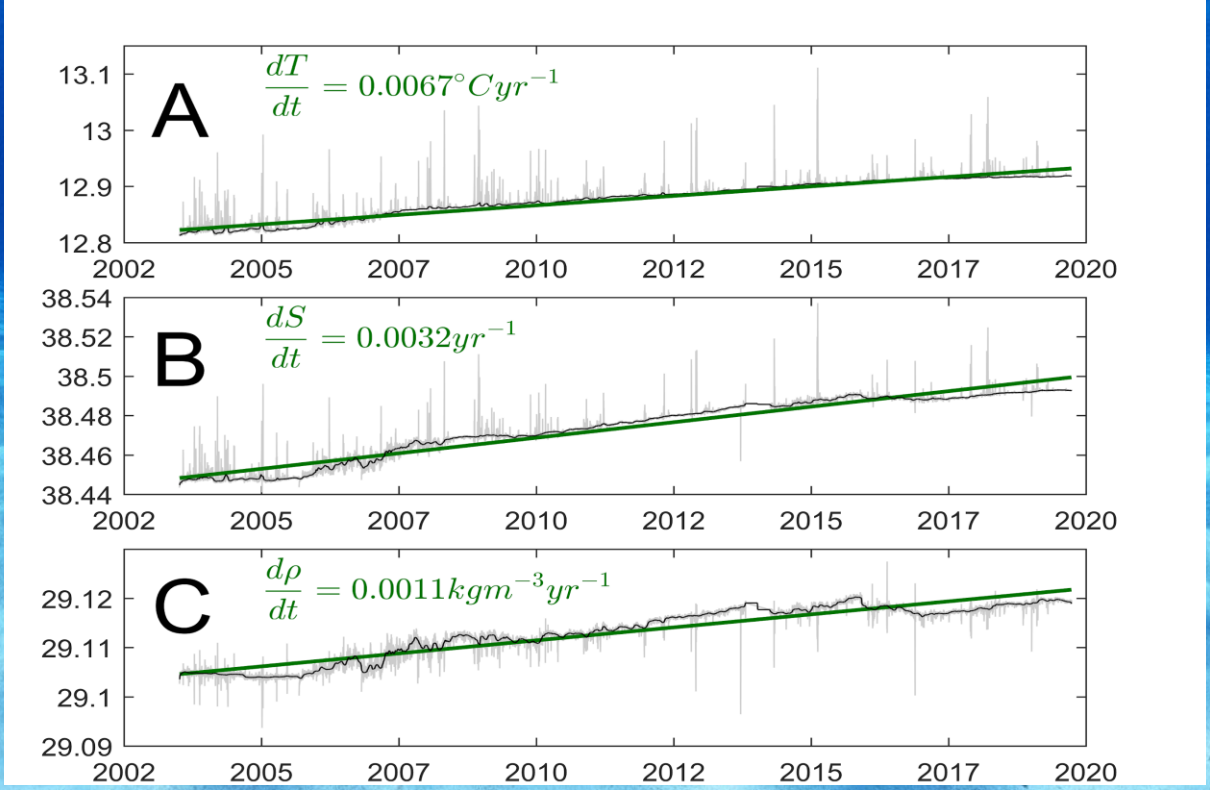
[Gerin et al., 2009]

Implementation

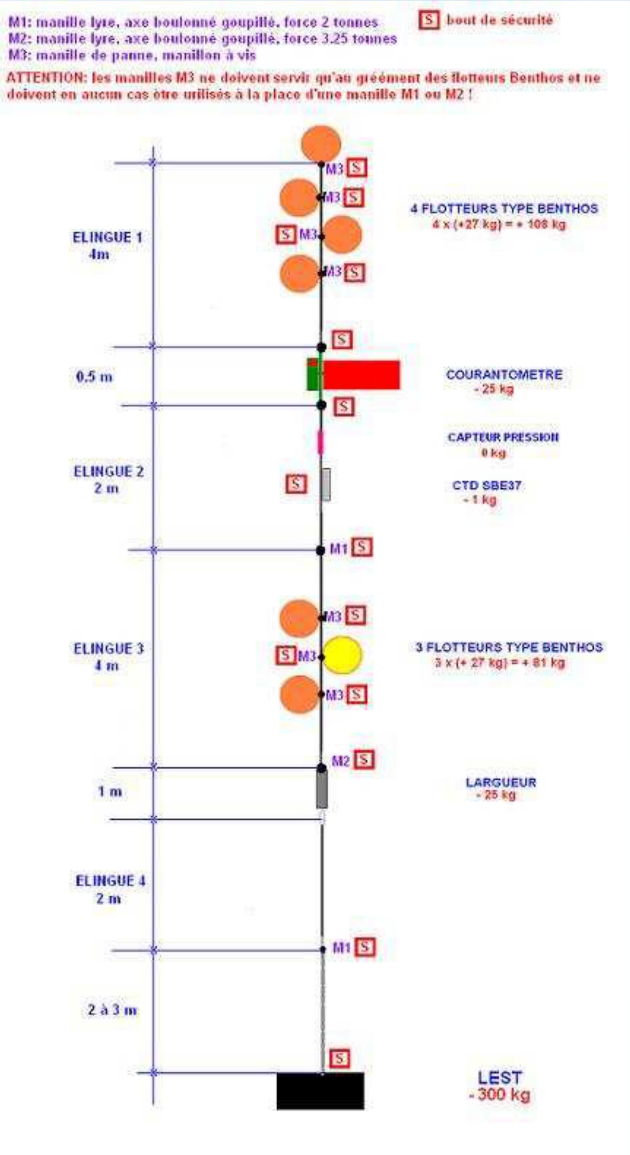
MOORING

(CIESM HYDROCHANGES & JERICO)

1 mooring the Tunisie -Sardiania Channel since 2003 , to monitor the exchanges between the WMED and Tyrrhenian Sea



17 years of T and S at 1900 m in the Tunisia-Sardinia Channel, Ben Ismail et al., 2021, Copernicus Marine Service OSR 5.



Implementation

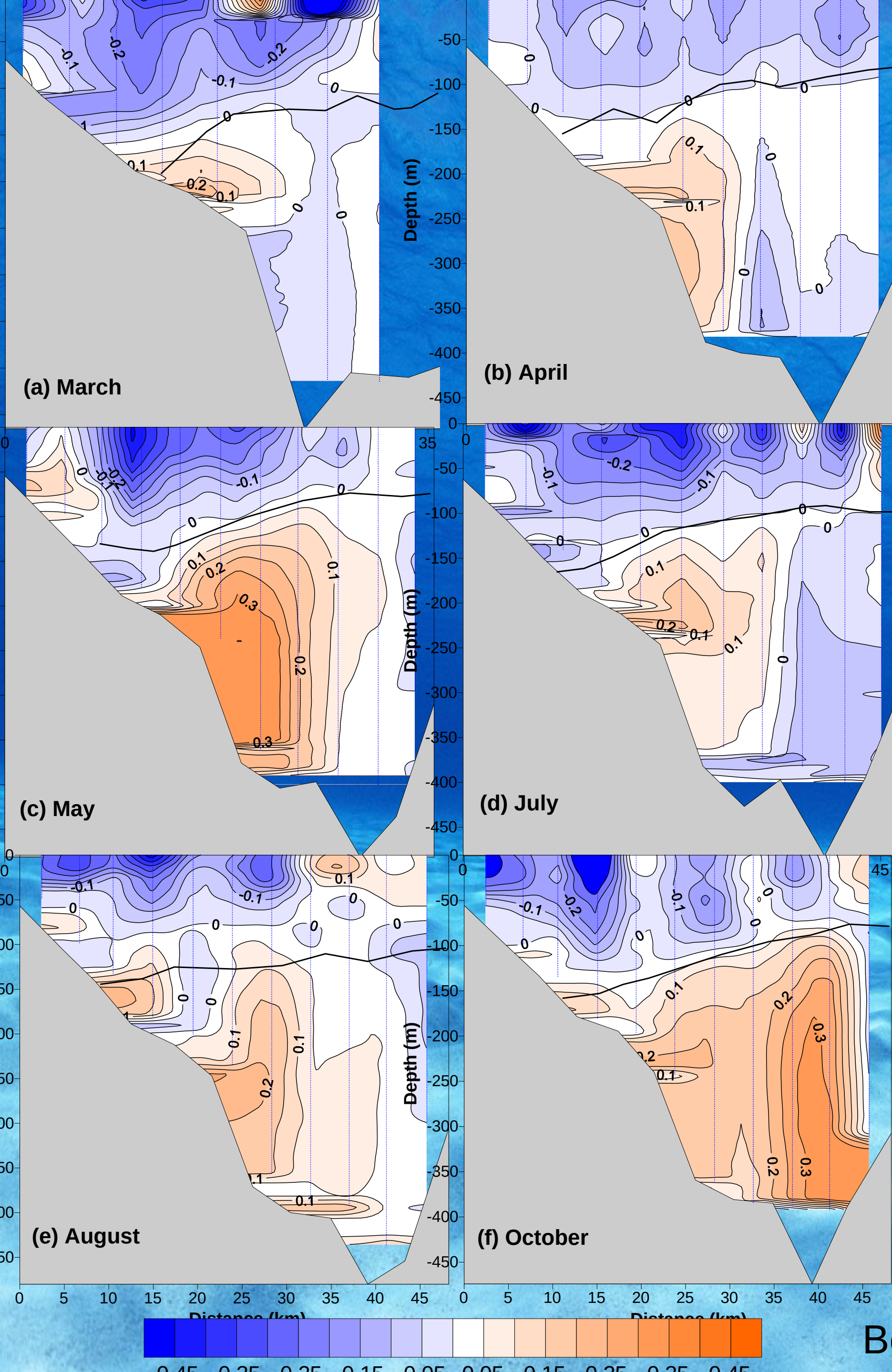
APPLICATIONS

The periodically visited transects and stations are planned in order to be useful for:

(i) Transport computations (of mass, heat, salt, biogeochemical components), i.e. with transects defining closed volumes of water

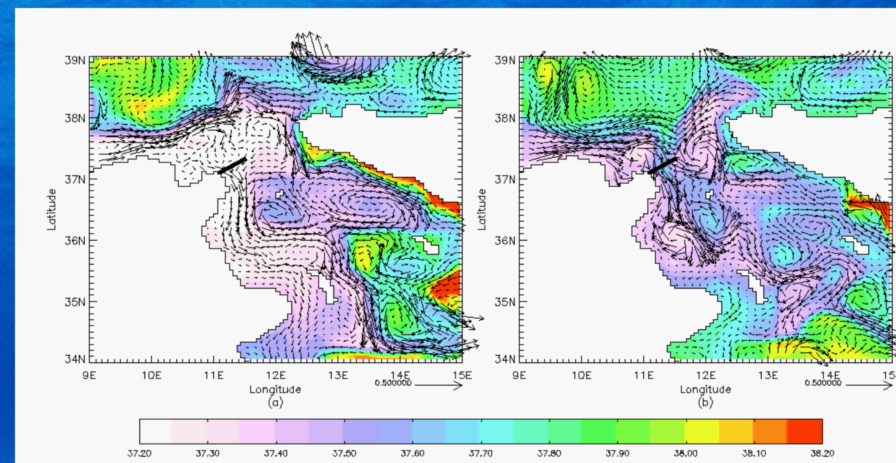
(ii) Long-term evaluation of anomalies of physical and biogeochemical properties, i.e. intercepting the main flow of water masses

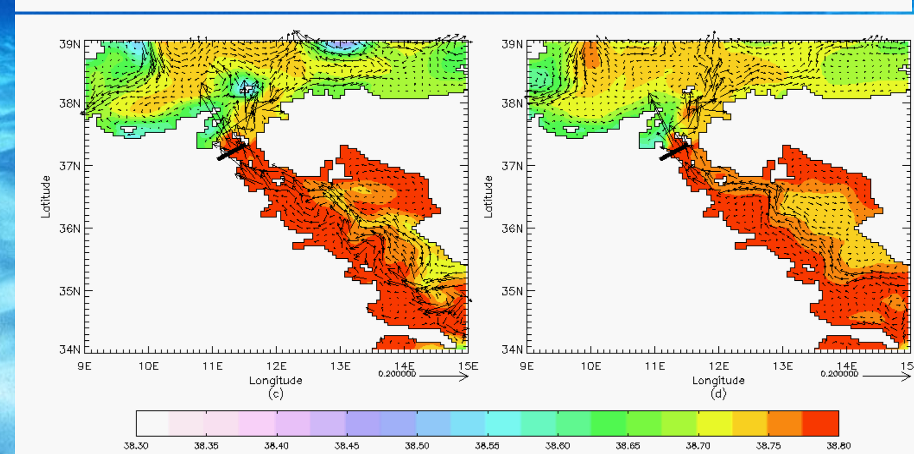
(iii) Quasi-synoptic view of the circulation along the Tunisian Coasts



Geostrphic velocities

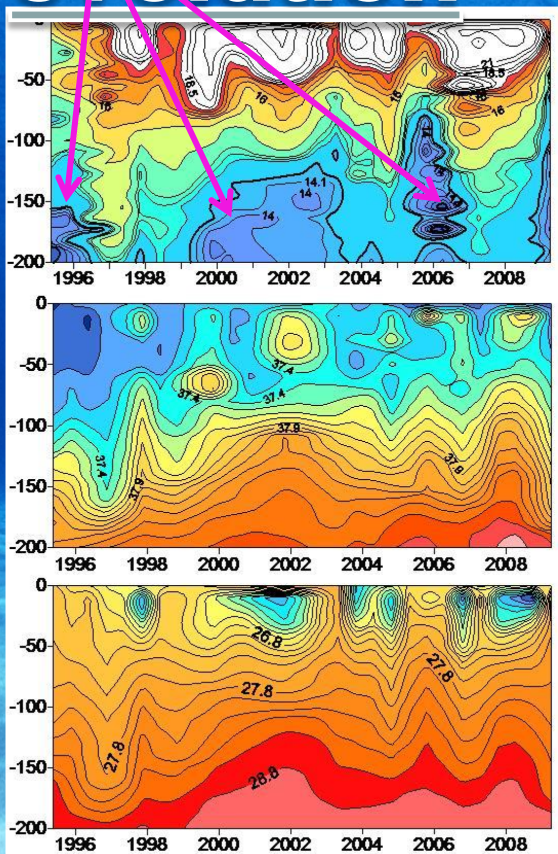
Computation of geostrophic velocities show a recirculation of the ATC which was also evidenced by high resolution model





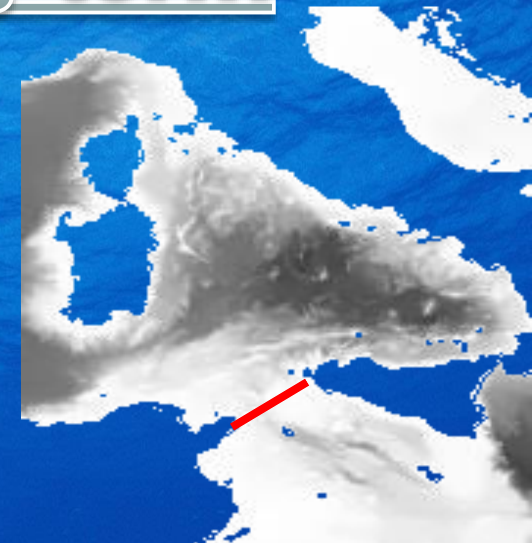
Ben Ismail et al., 2012

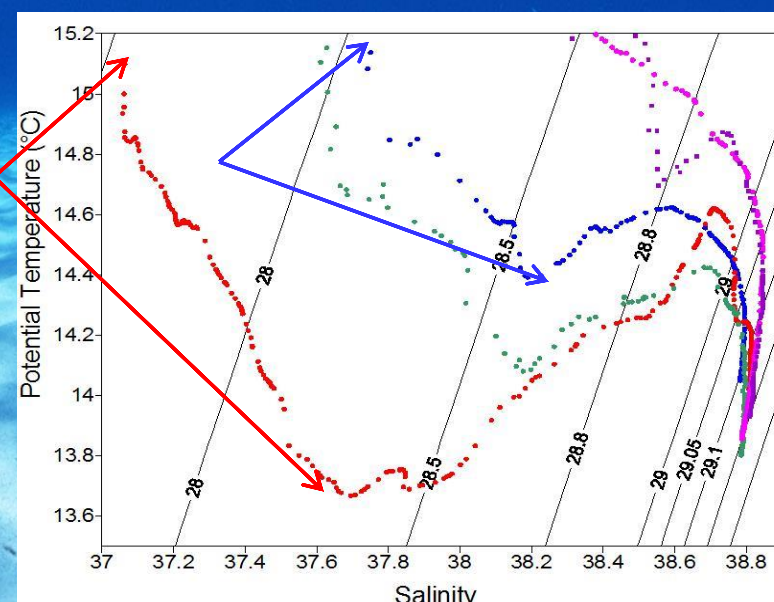
APPLICATIONS – Long-term evolution



Ben Ismail et al., 2014

In 2003 the WIW is colder up to 0.55 C. In 2005 the WIW is colder up to 0.85 ° C. This could be due to the unusual extension of the DWF in WMED during winter 2005 [Lopez-Jurado et al 2005, Salat et al, 2006]

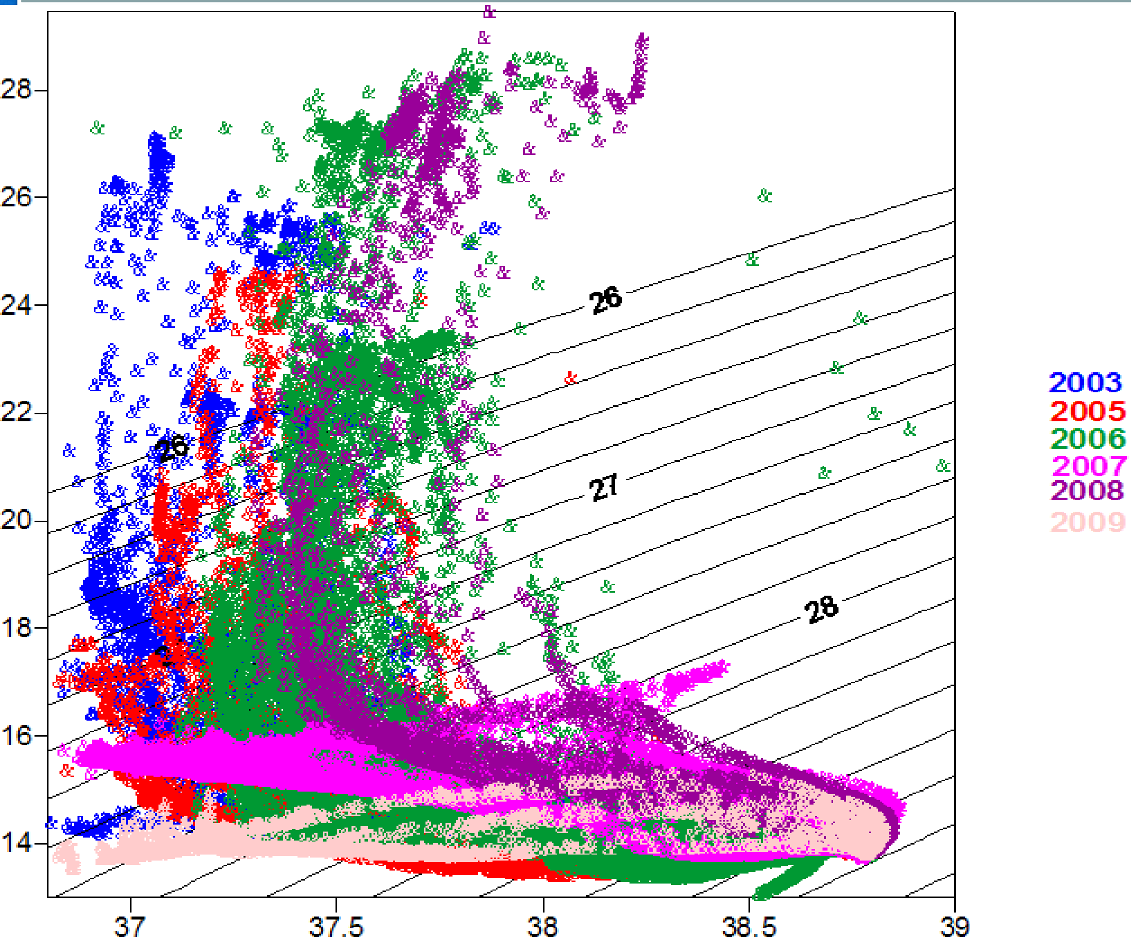


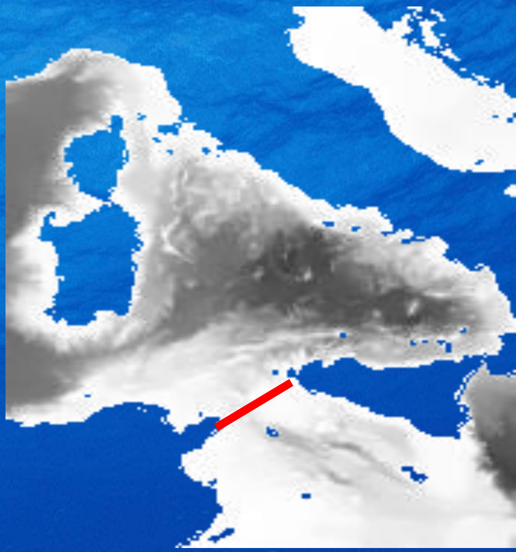


Ben Ismail et al., 2014

Cold-water intrusions in 1995, 2000-2003 2005-2006 and 2009.

Salinisation and warming



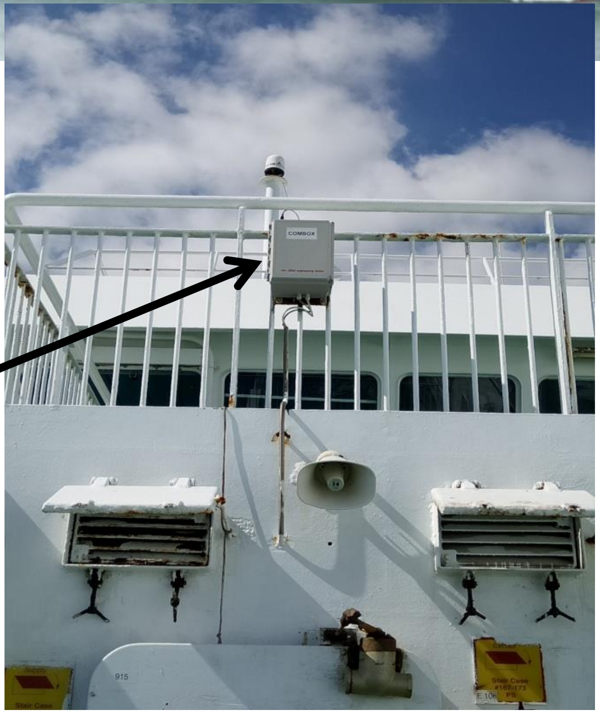


Deep waters in the Siculo-Tunisian Channel have become saltier and warmer during the last 20 years

Ben Ismail et al., 2014

0.007 et 0.03 per year within LIW
0.0047 et 0.0169 per year within tEMDW

FerryBox system sur c/f Carthage INSTM



Combox

FerryBox installed on board c/f Carthage since February 2016

Parameters

In water at 5m depth,
sampling frequency is evry 1 minutes for most parametre

- **Temperature,**
- **Salinity,**
- **Dissolved oxygen,**
- **Turbidity,**
- **ph**

Routes

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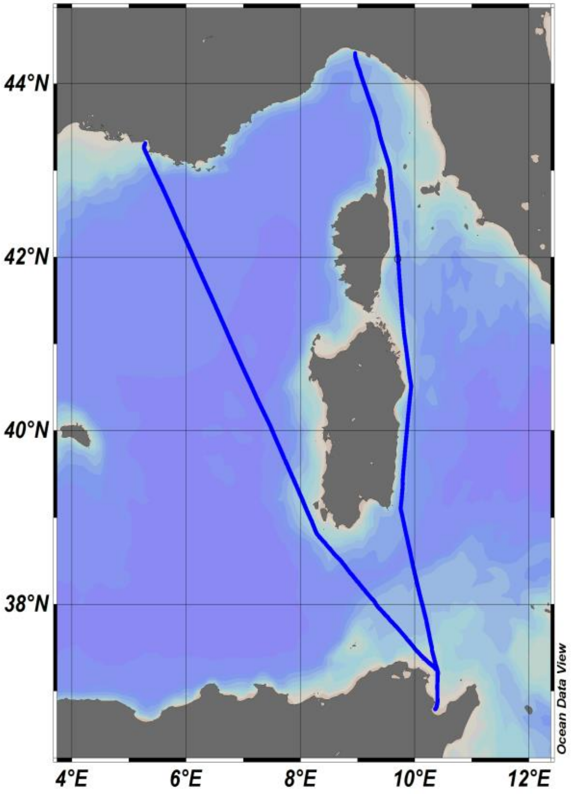
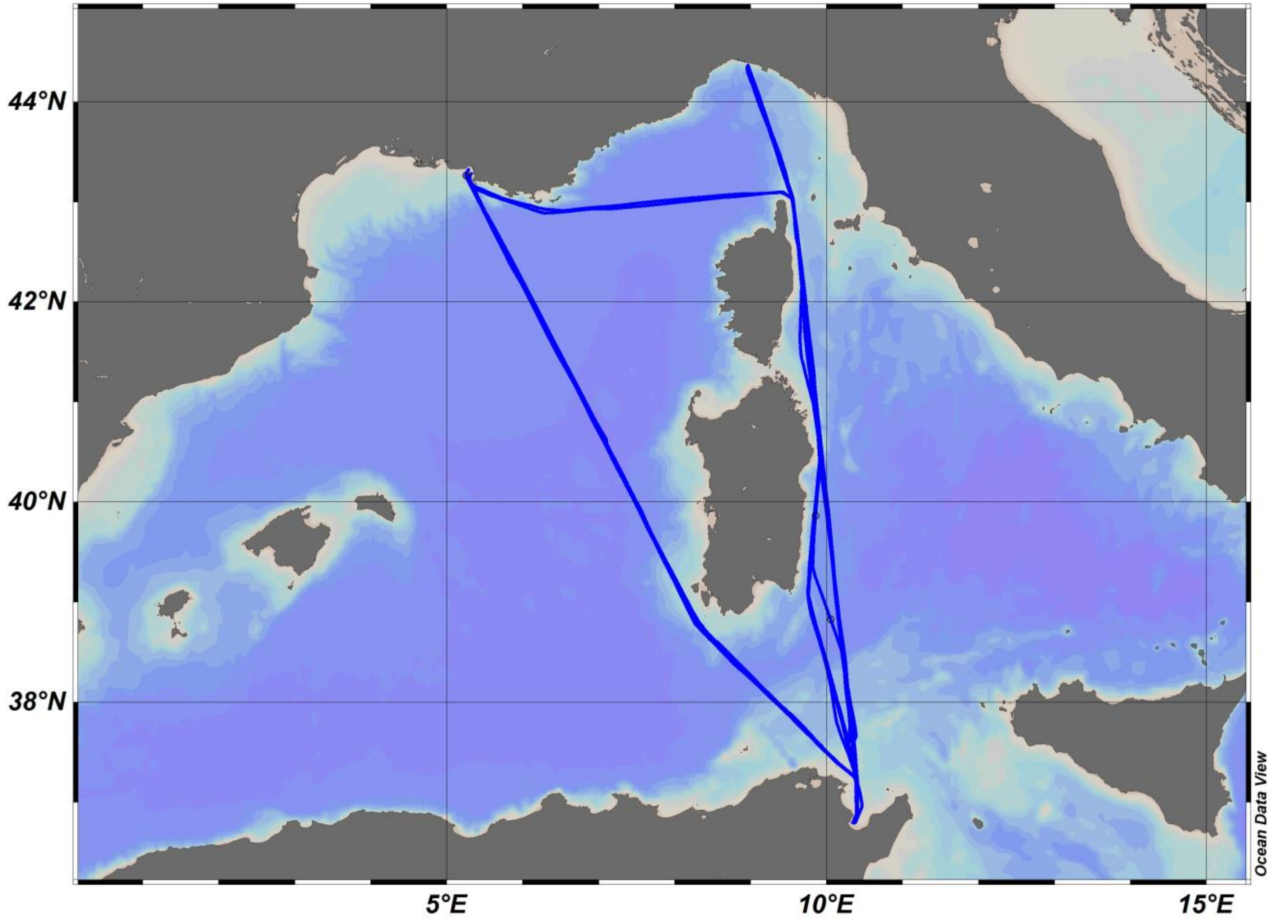


Planned routes



Reality

Salinity

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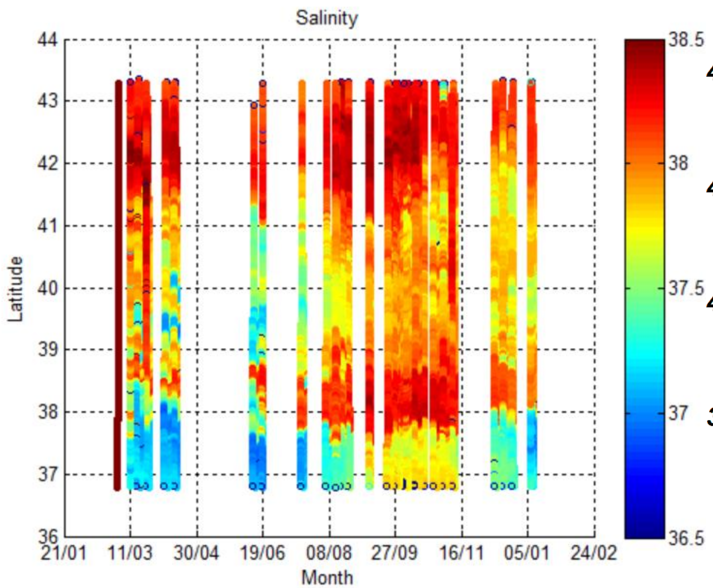
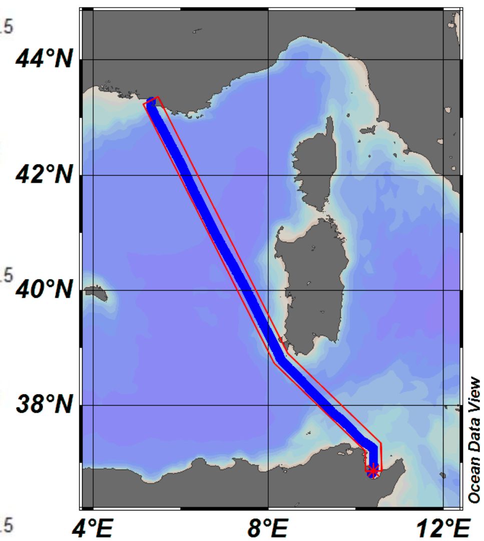
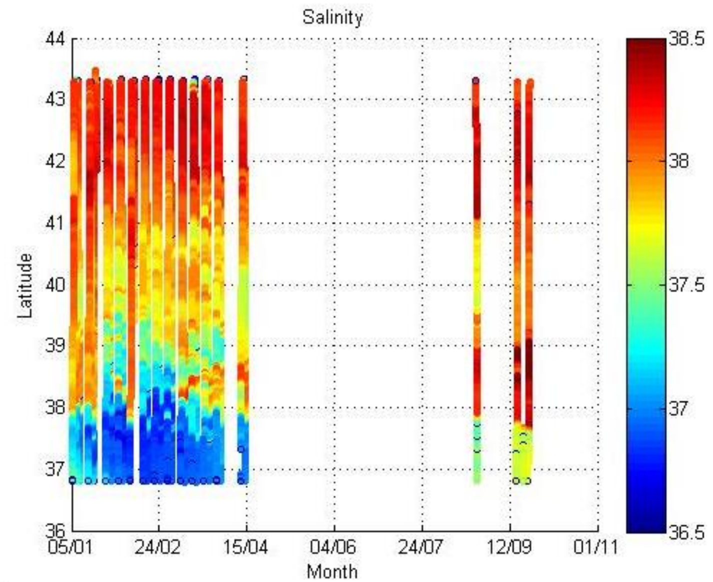
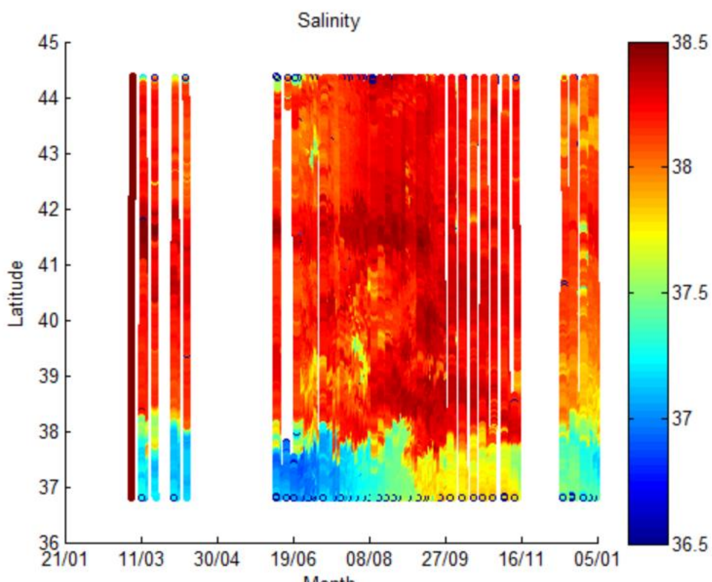
2016

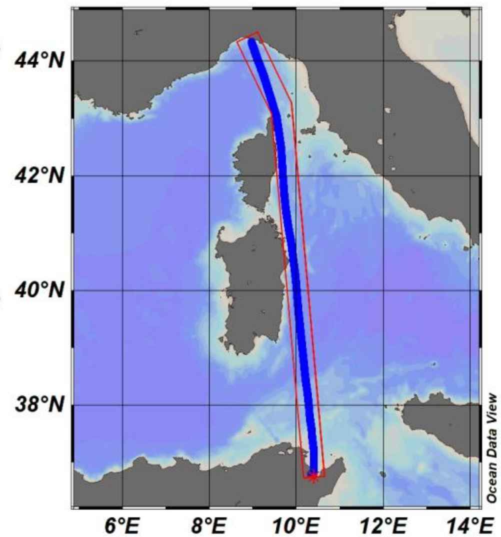
2017

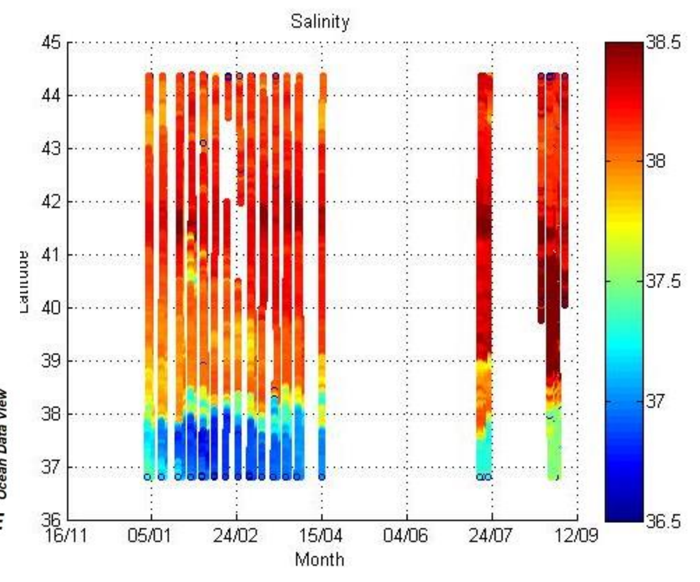












Temperature

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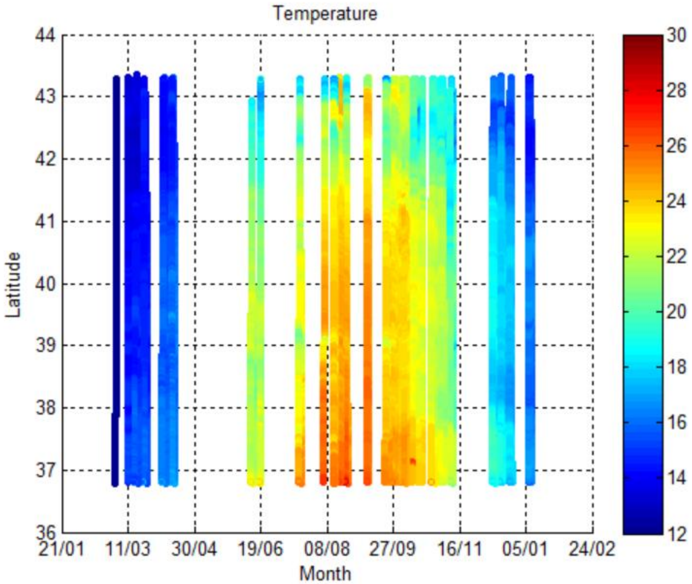
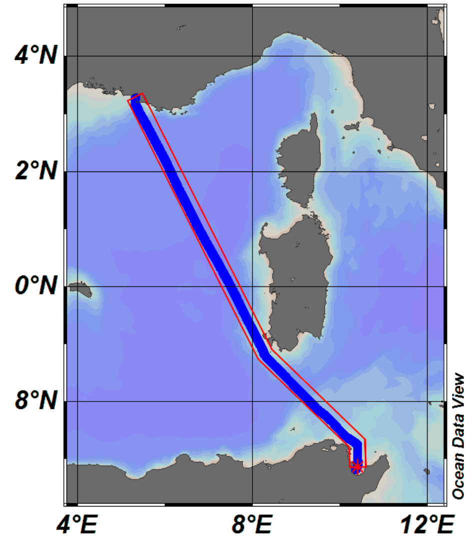
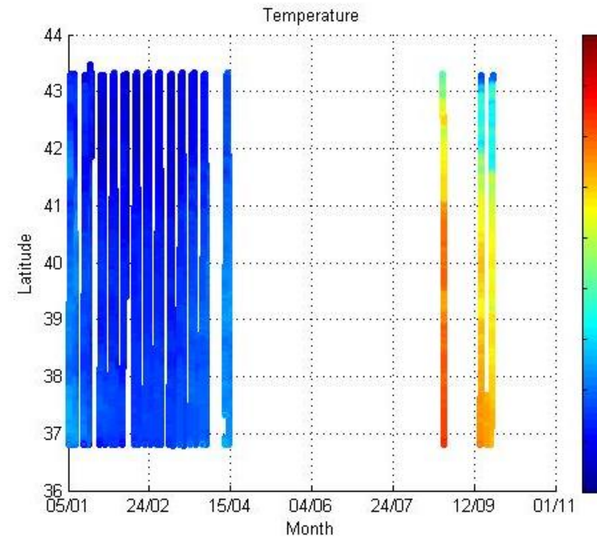
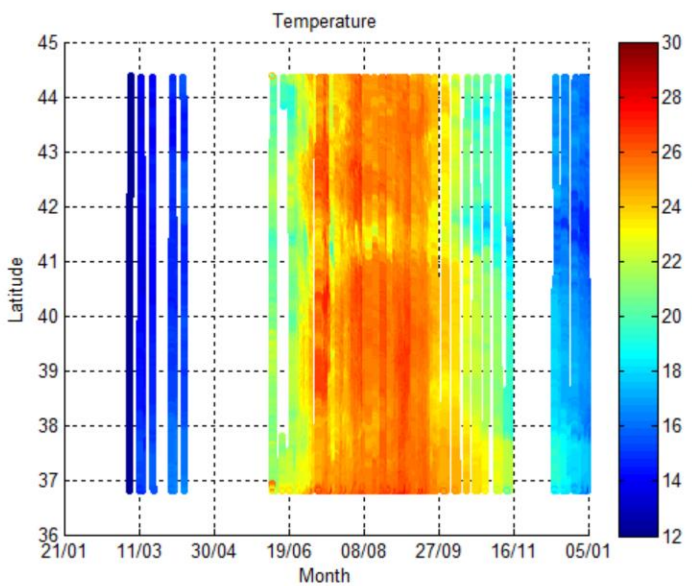
2016

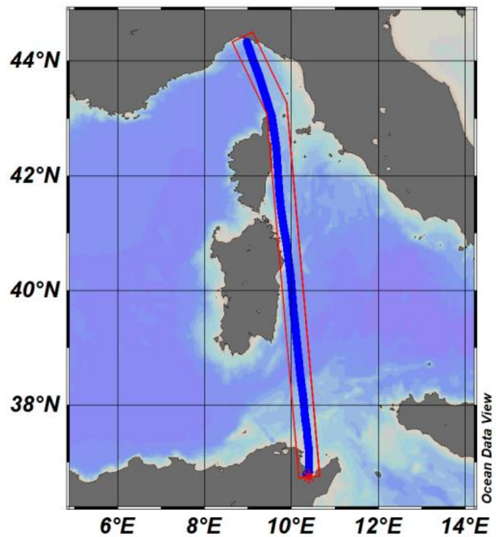
2017

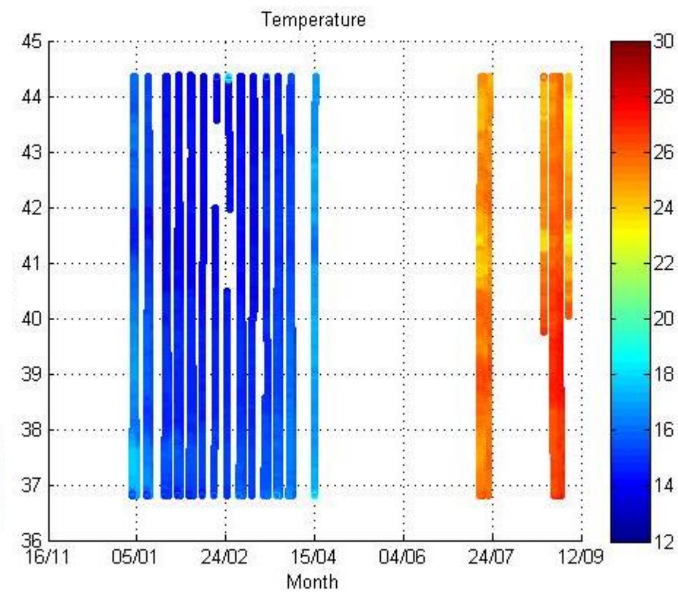












Oxygen saturation

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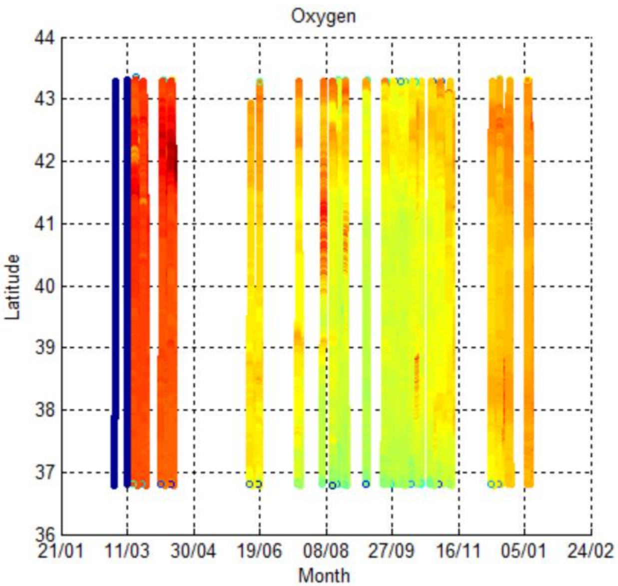
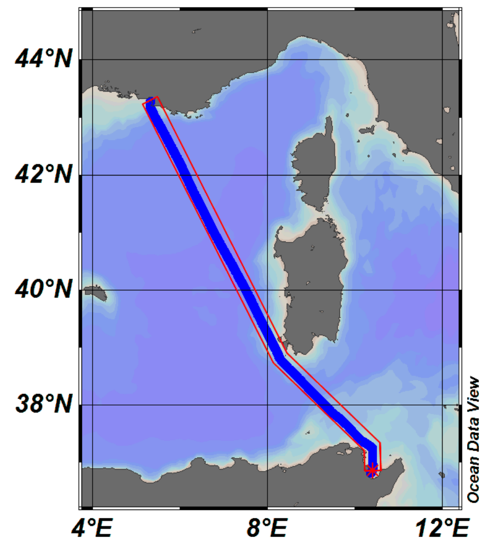
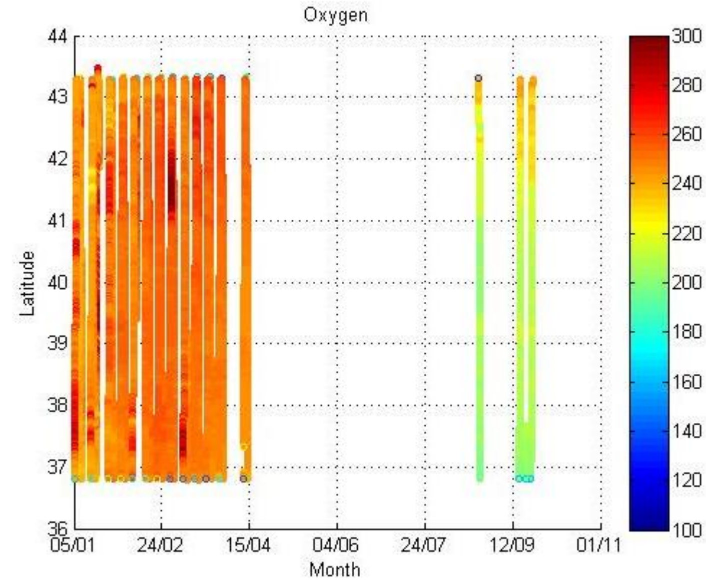
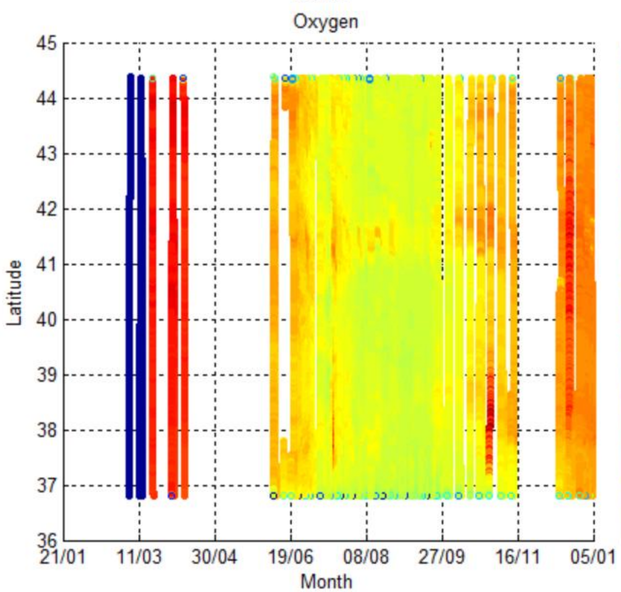
2016

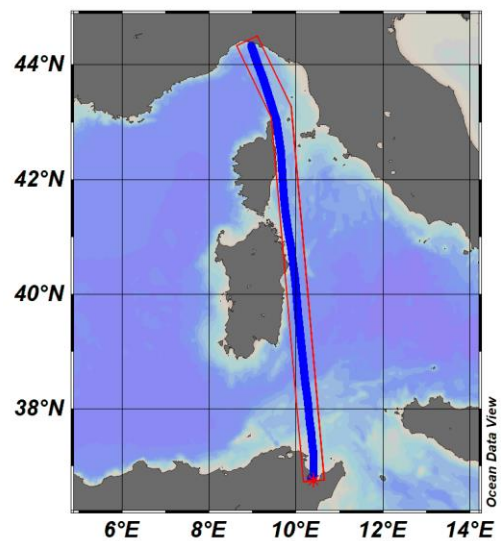
2017

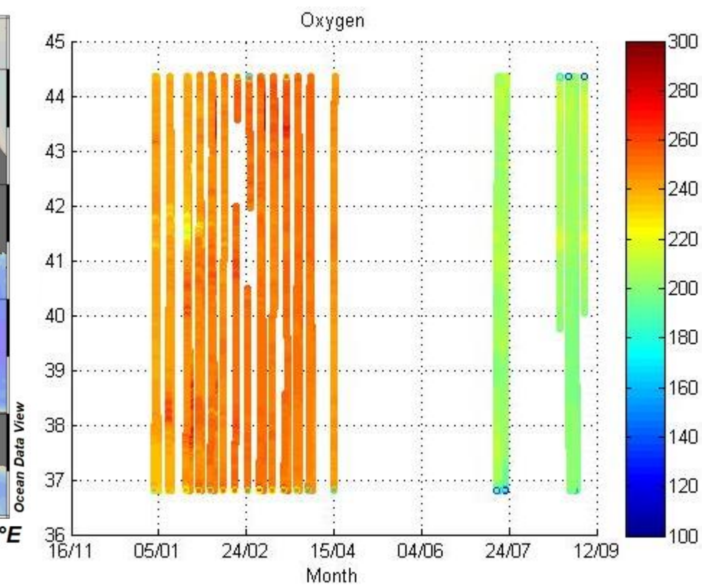












Chlorophyll a

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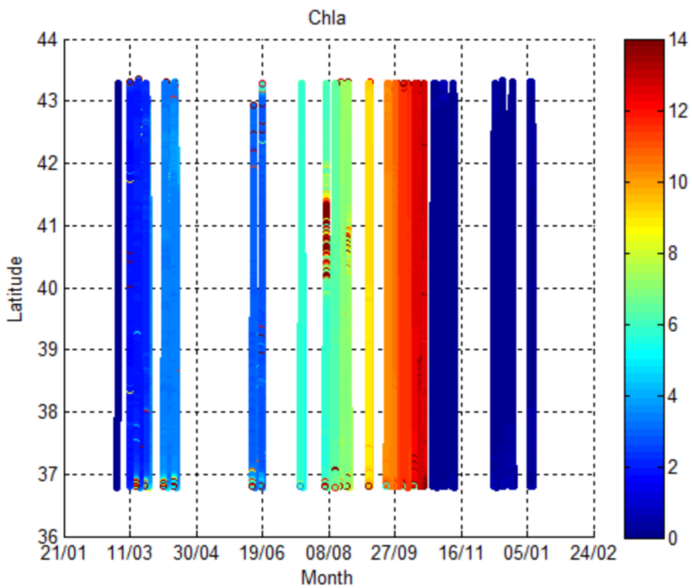
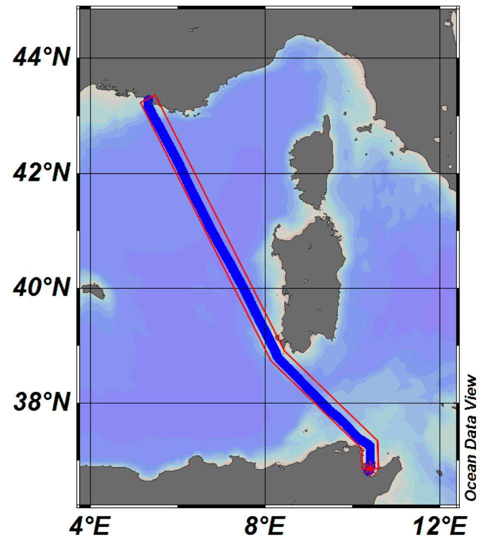
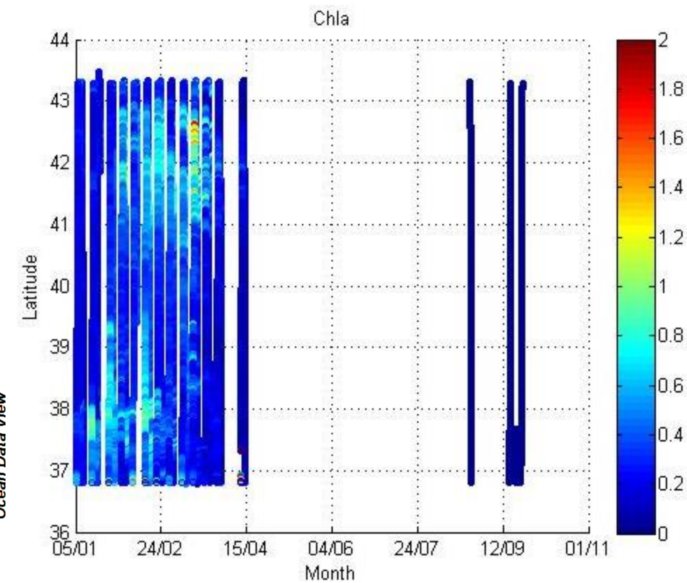
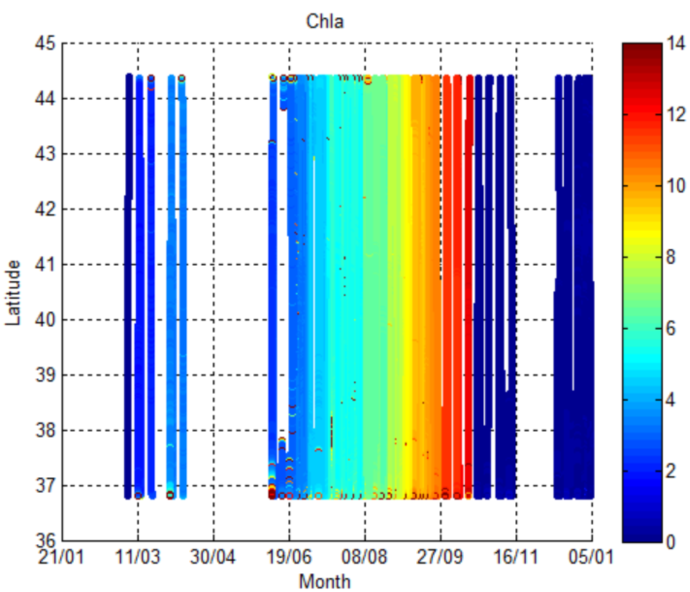
2016

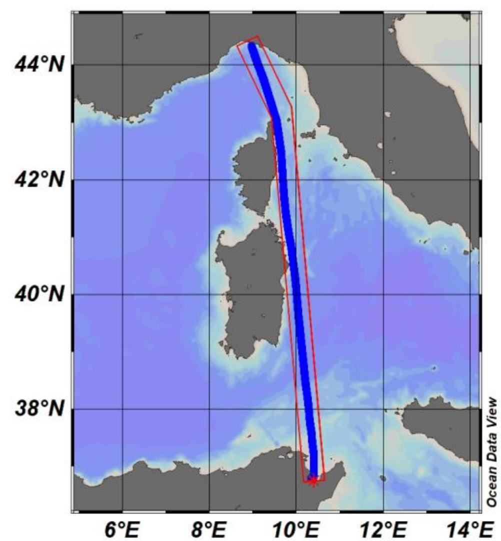
2017

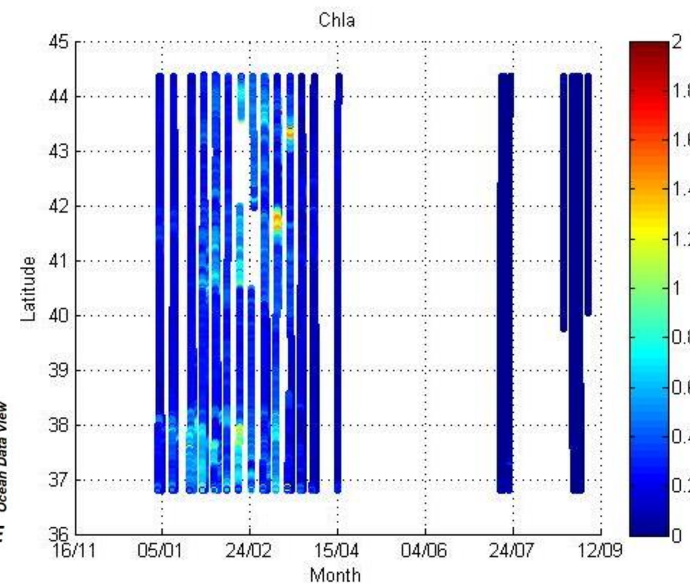






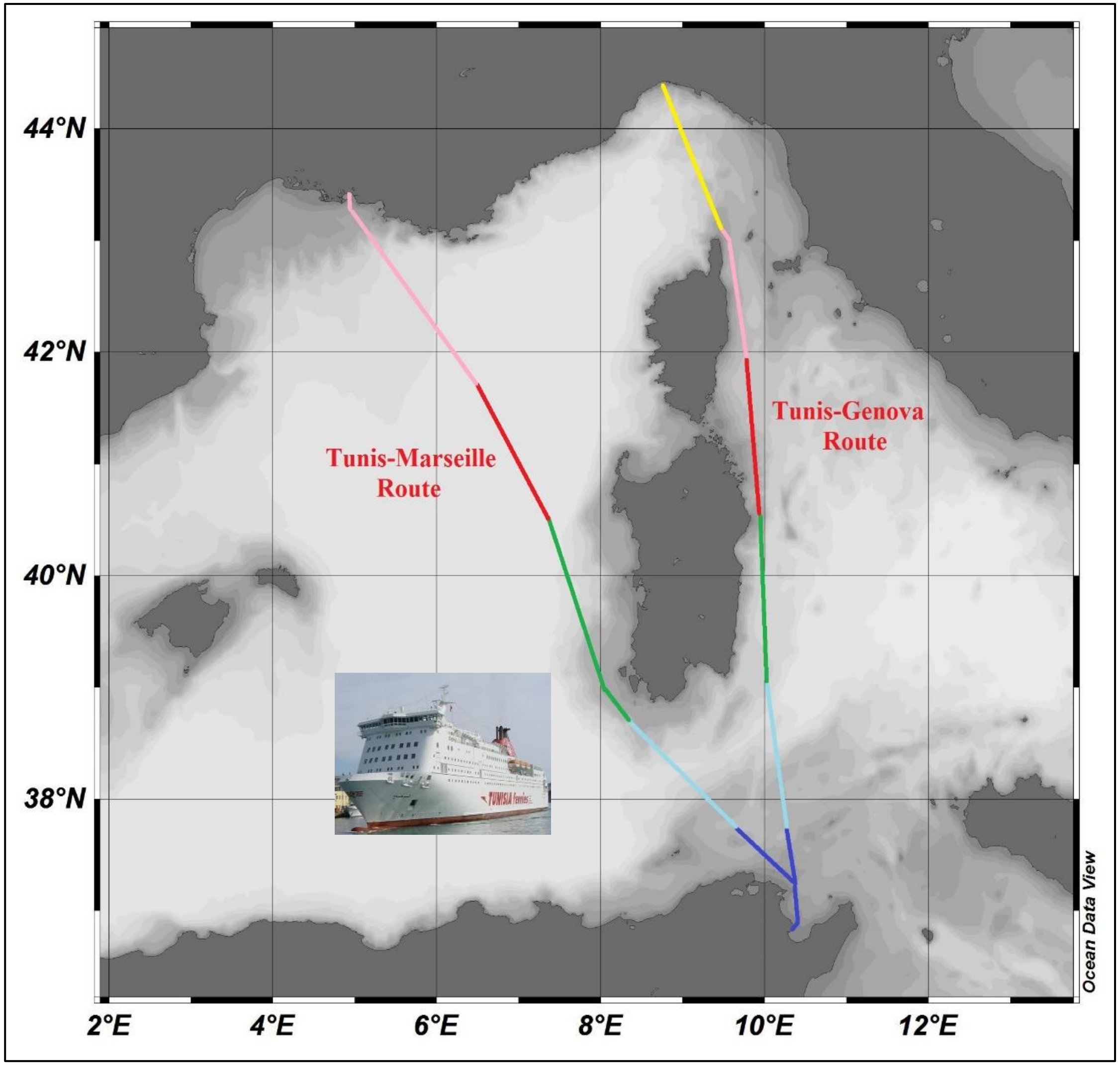






DATA ANALYSIS

- Interannual data analysis **FB :**



TM :

- ✓ M1 (lat <=37.5) : Les **B.** ***Alg*** et ***Sou-Aeg ;***
- ✓ M2 (37.5 < lat <=38.5) : ***Nor-Aeg*** ;
- ✓ M3 (38.5 < lat <=40.85) : Le front Nord-Baléares ;
- ✓ M4 (40.85 < lat <=42) : B. ***Provençal*** ;
- ✓ M5 (lat >42)) : Le Golf de Lion.

TG :

- ✓ M1 (lat <=37.5) : Les **B.Alg** et **Tyr** ;
- ✓ M2 (37.5< latitude <=39.1) : Le **B.Tyr** et les côtes de Sardaigne ;
- ✓ M3 (39.1 < lat <=40.5) : **Tyr** et passe par les côtes de **Sar** et celle de la Corse ;
- ✓ M4 (40.5 < lat <=42) : **Tyr** et les côtes de la **Cor** ;
- ✓ M5 (42 < lat <=43.1) : Les côtes de la **Cor** et traverse le **B.Lig** ;
- ✓ M6 (lat>43.1) : **Lig.**

DATA ANALYSIS

➢ Validation of sattelite data and **FB data**

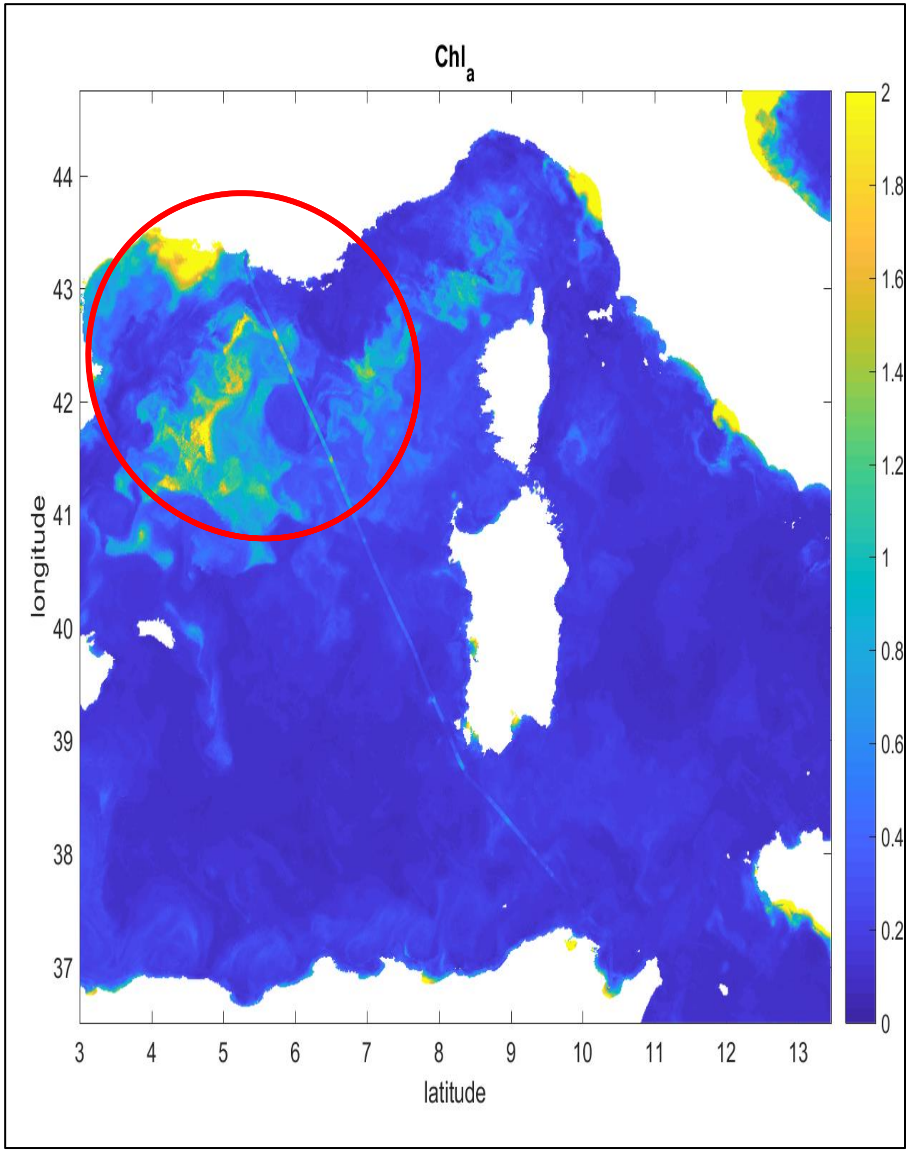
✓ Comparison of : Chlorophyll and surface temperature from FerryBox data and Satellite data.

✓ [Chl-a] and SST compared at the bloom days during 2017.

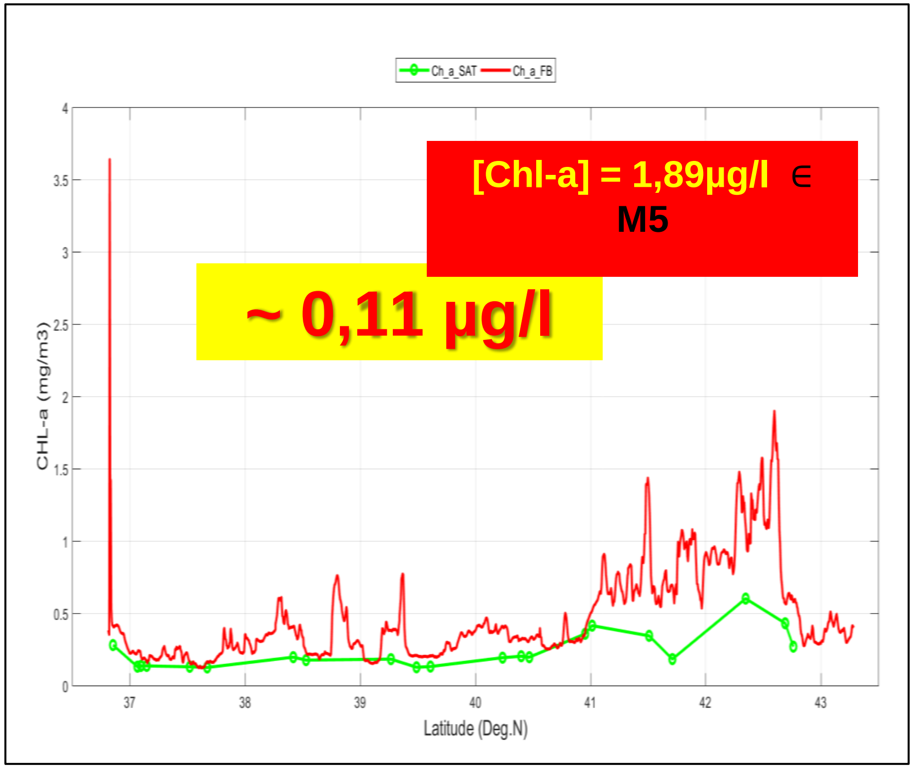
✓ To verify the seasonal distribution of Blooms observed from FB data, a daily Chrolophyll satellite dataset (MODIS) was generated to identify the seasonal distribution of [Chl-a] for each bloom event along 2017.

Validation of [Chl-a] and **FB data.**

TM



16/03/2017



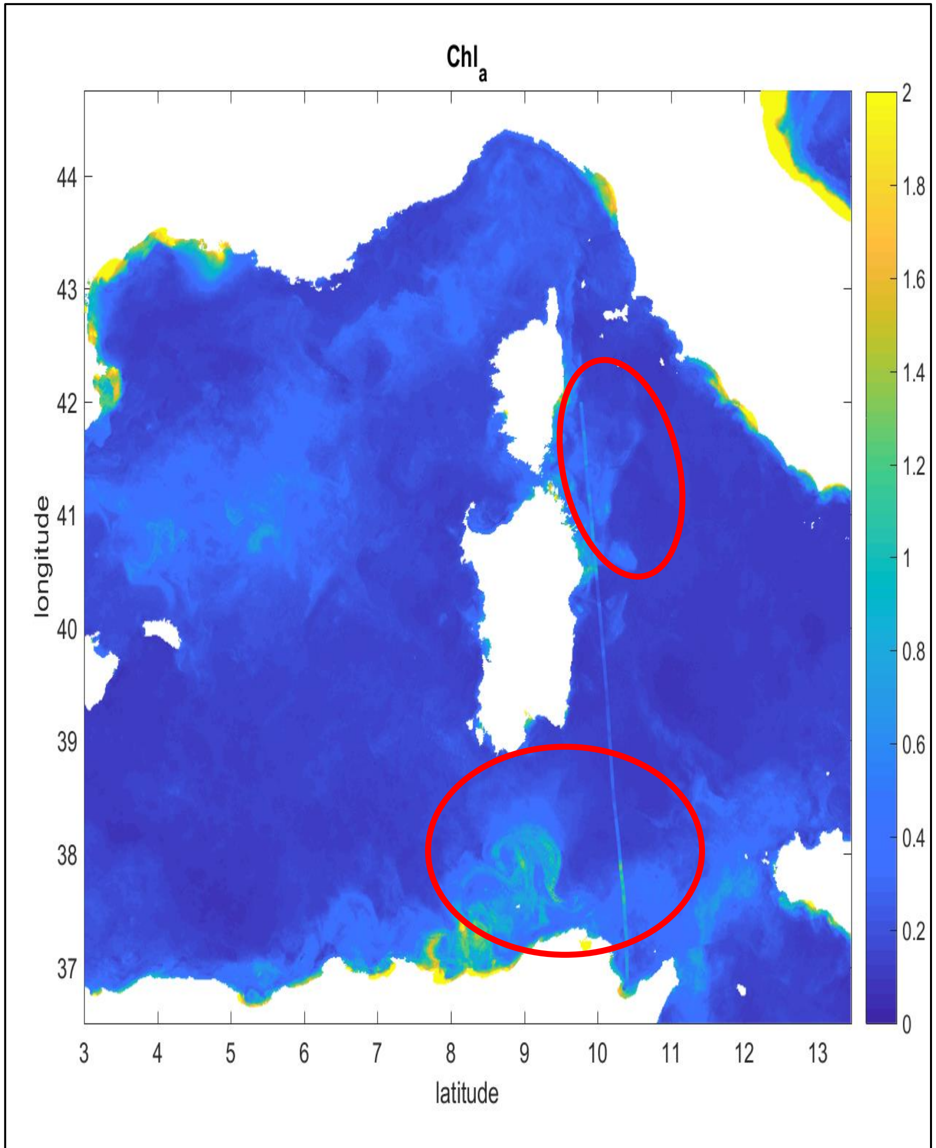
Nord MO➡ Deep Convection

(Marshall and Schott [1999])

Validation of [Chl-a] and FB data.

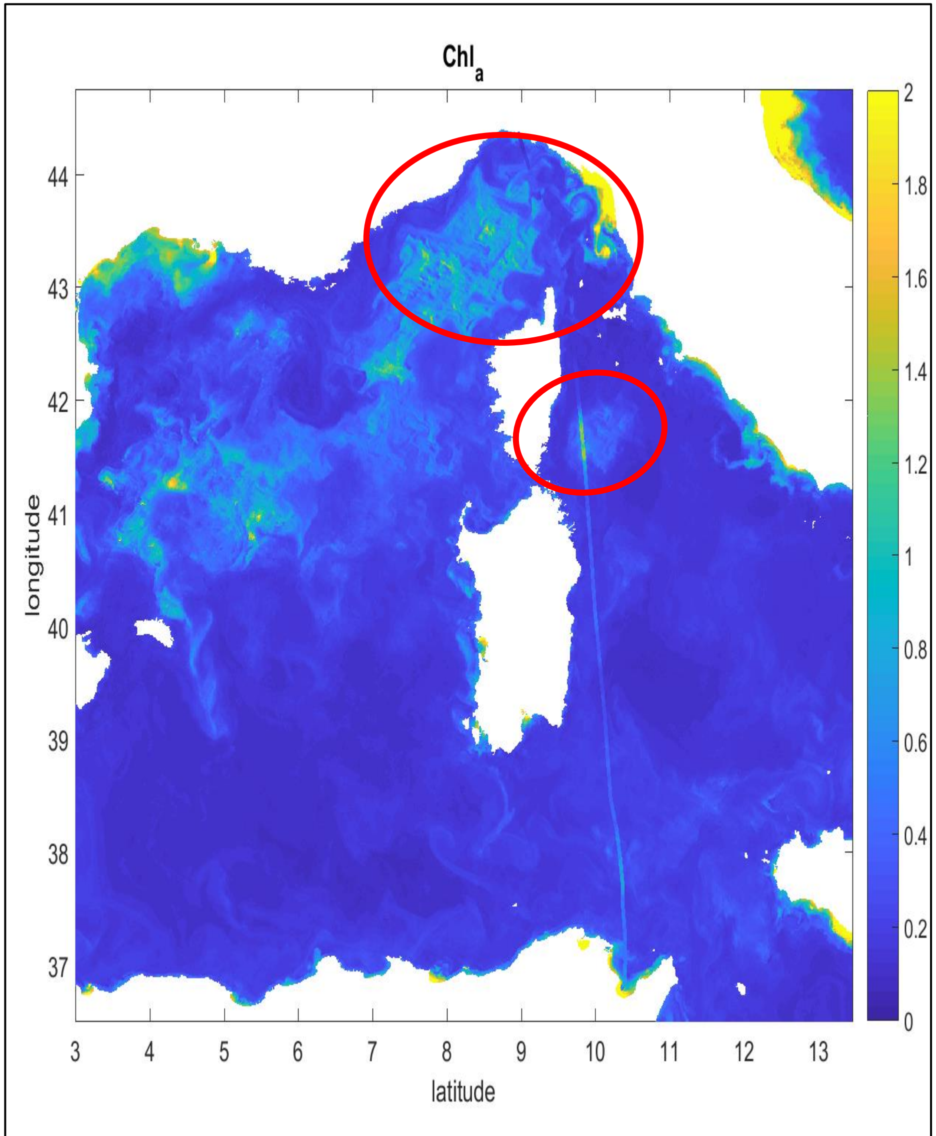
T G

17/02/2017

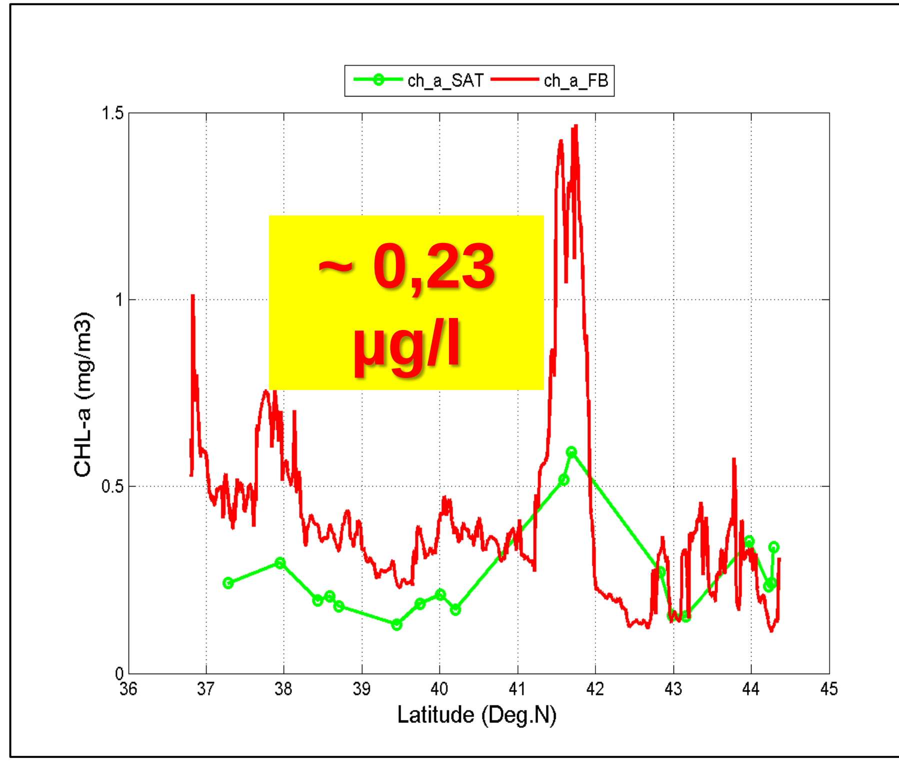


[Chl-a] = 1,38µg/l ∈ M1&M4

Validation of [Chl-a] and FB data.



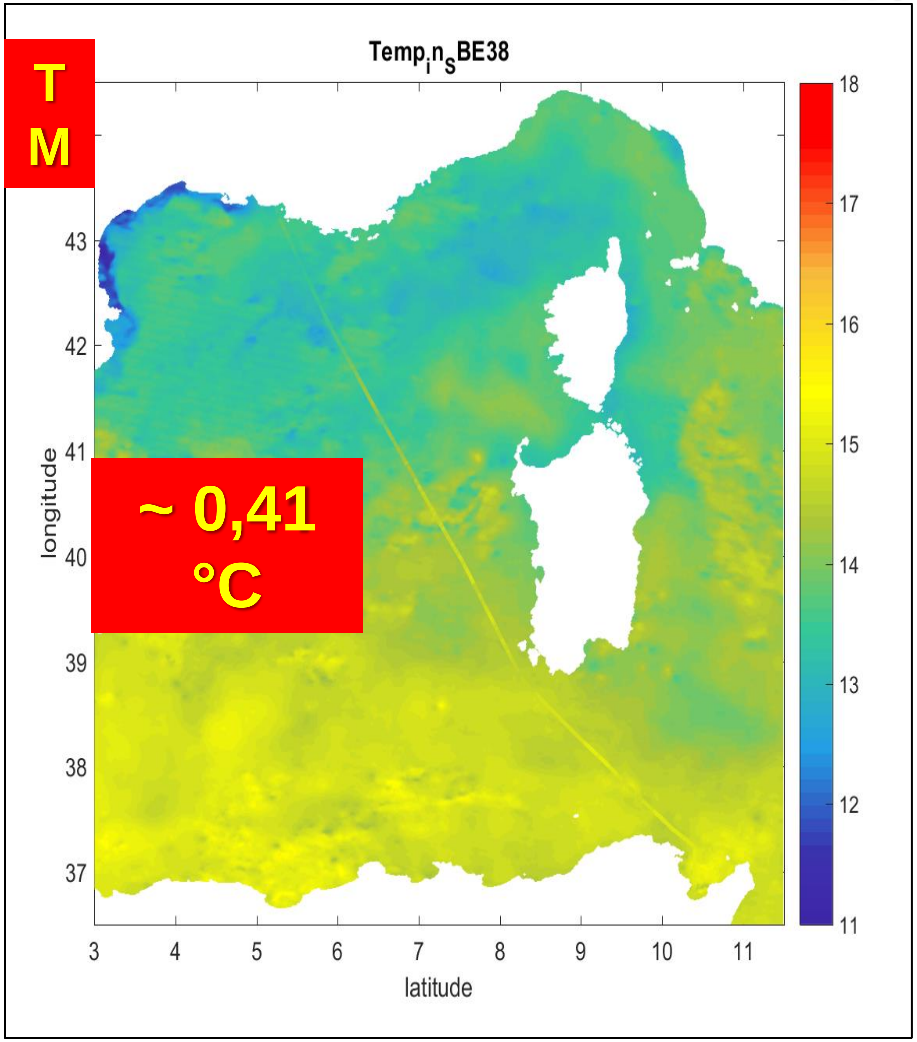
11/03/2017

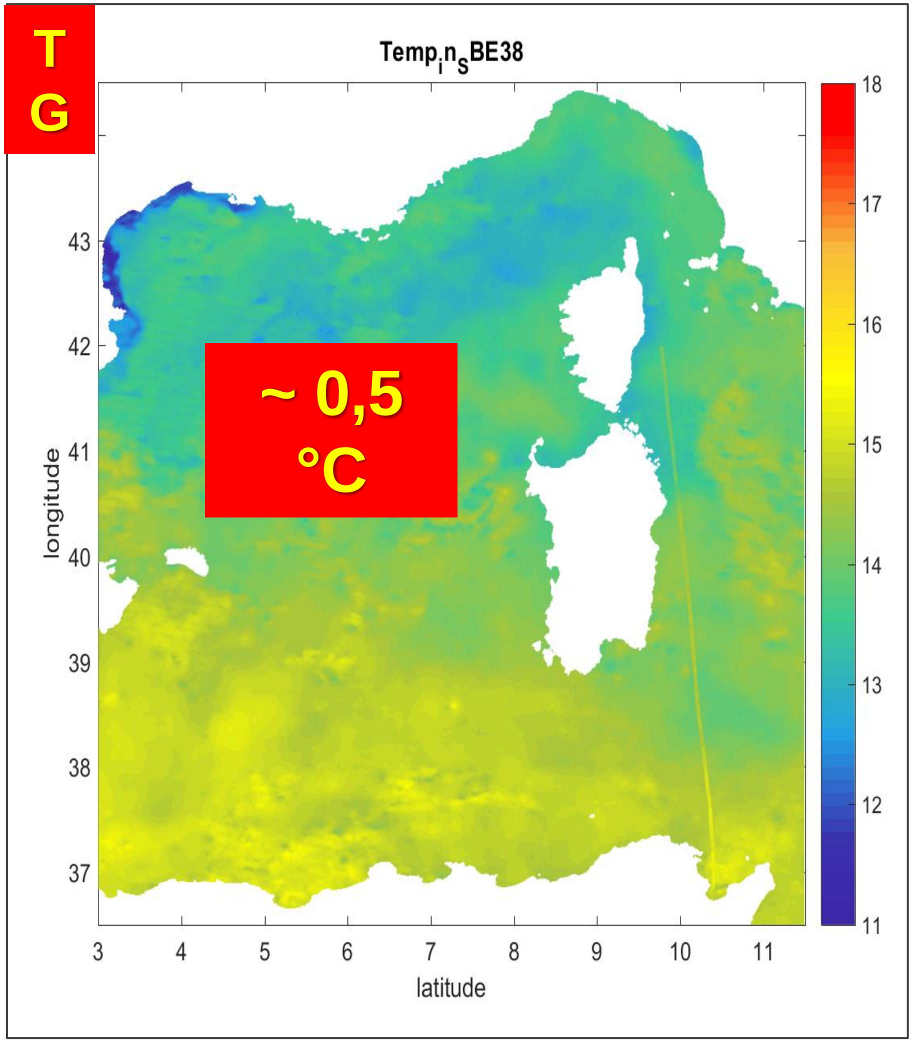


[Chl-a] = 1,34µg/l ∈ M4&M6

Validation of SST and FB data .

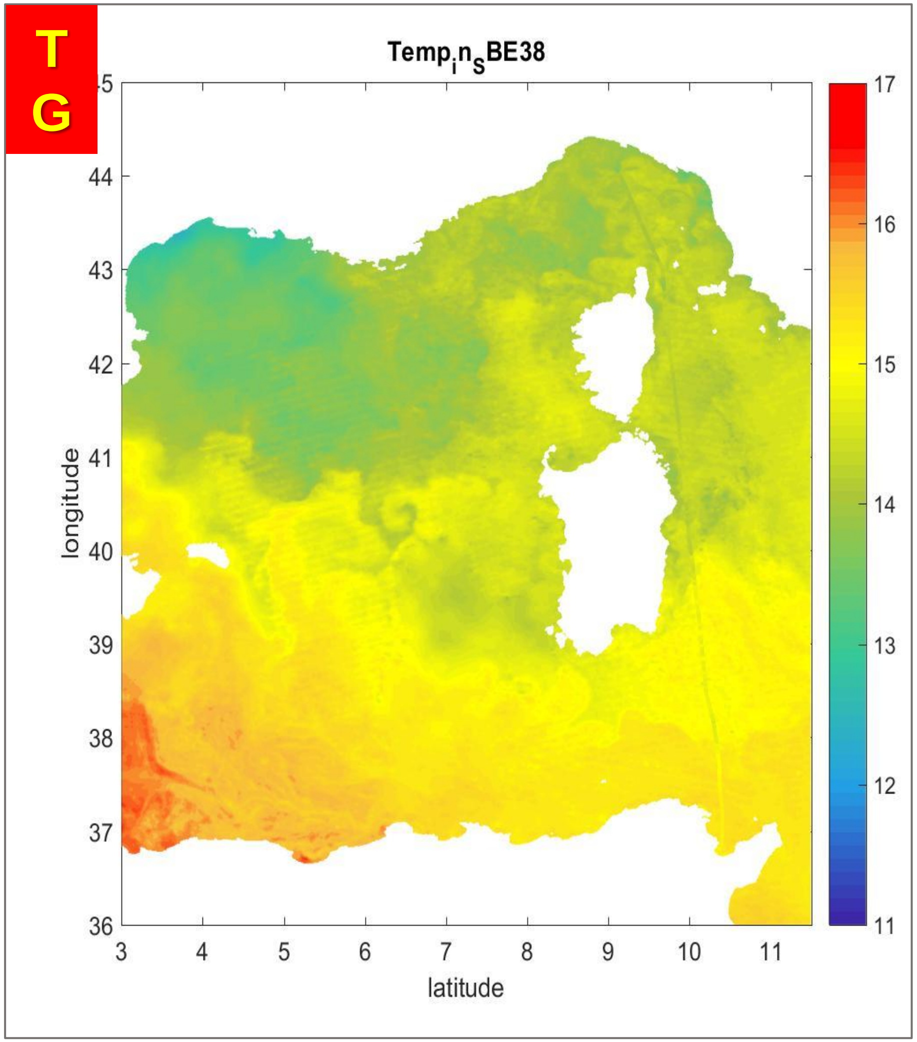
17/02/2017

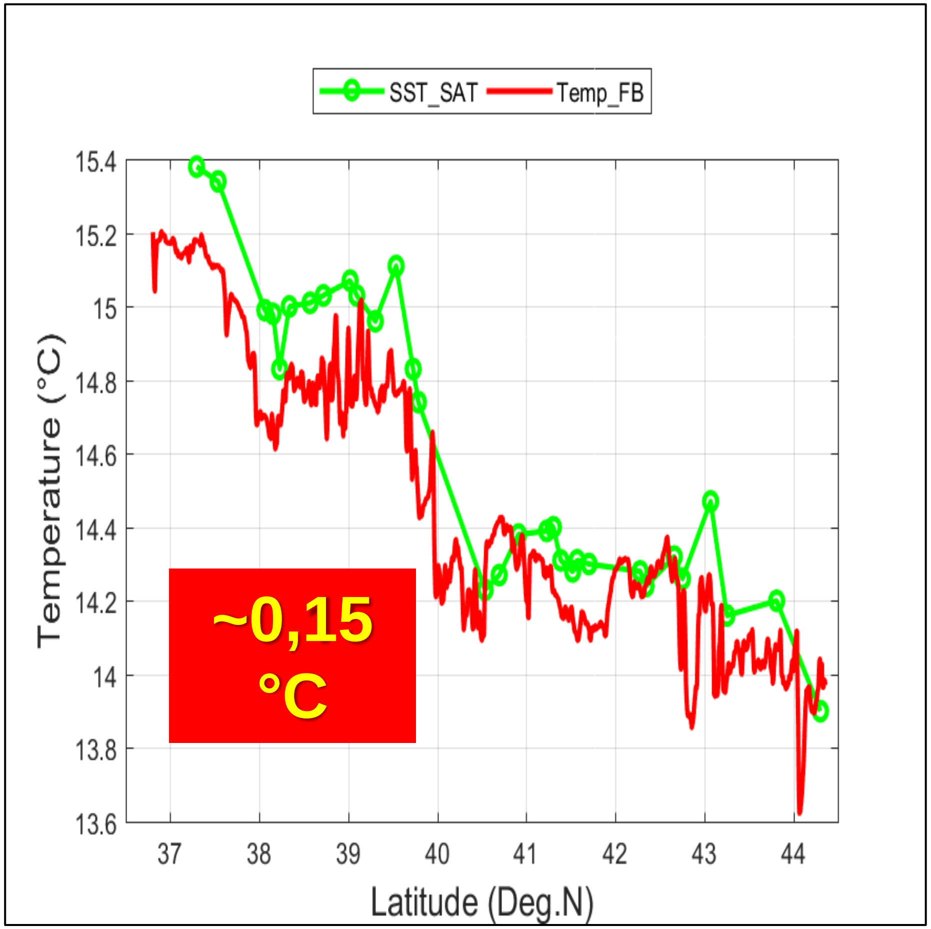




Validation of SST and FB data .

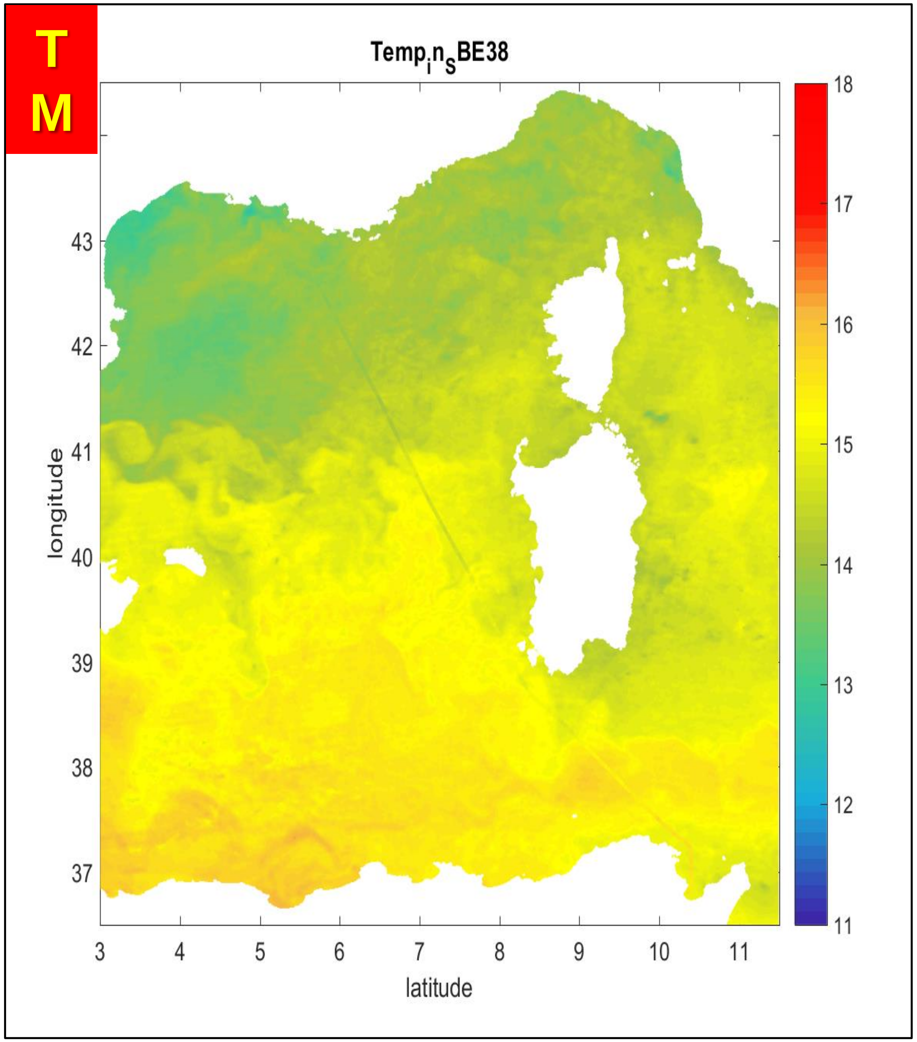
11/03/2017

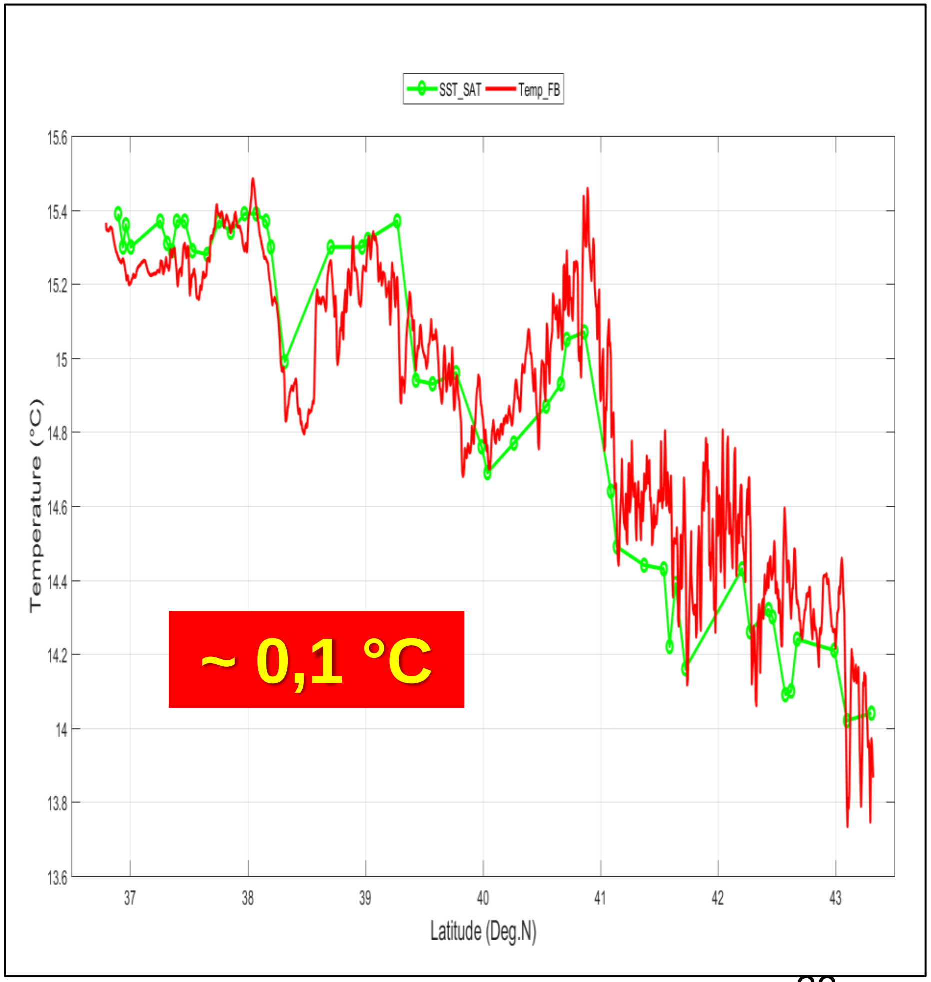


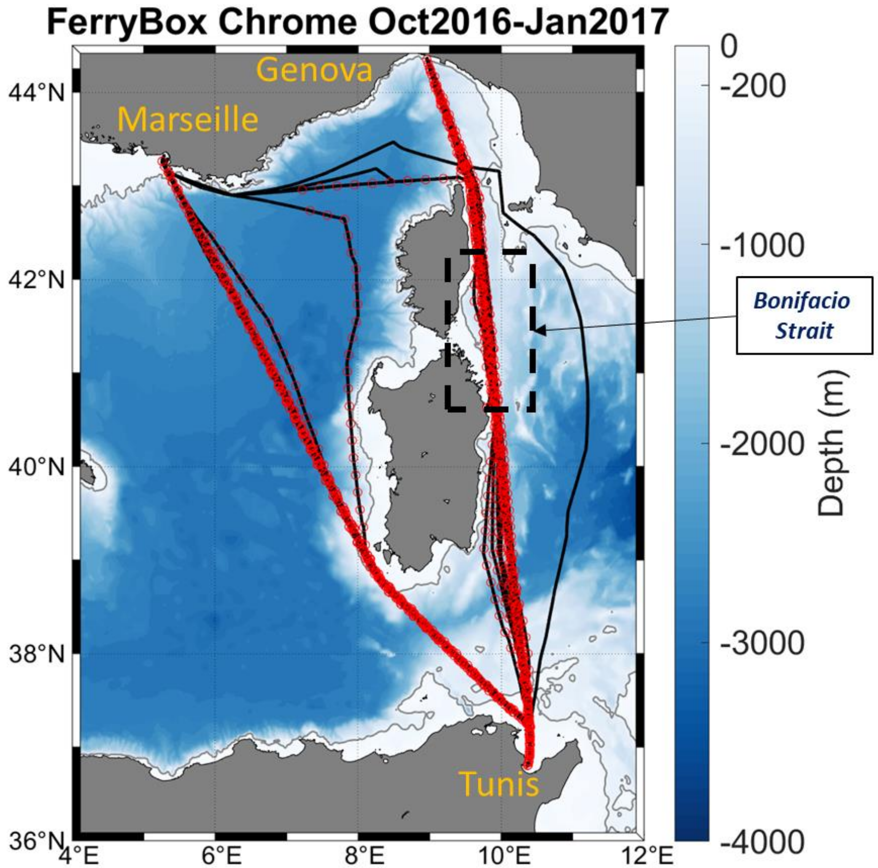


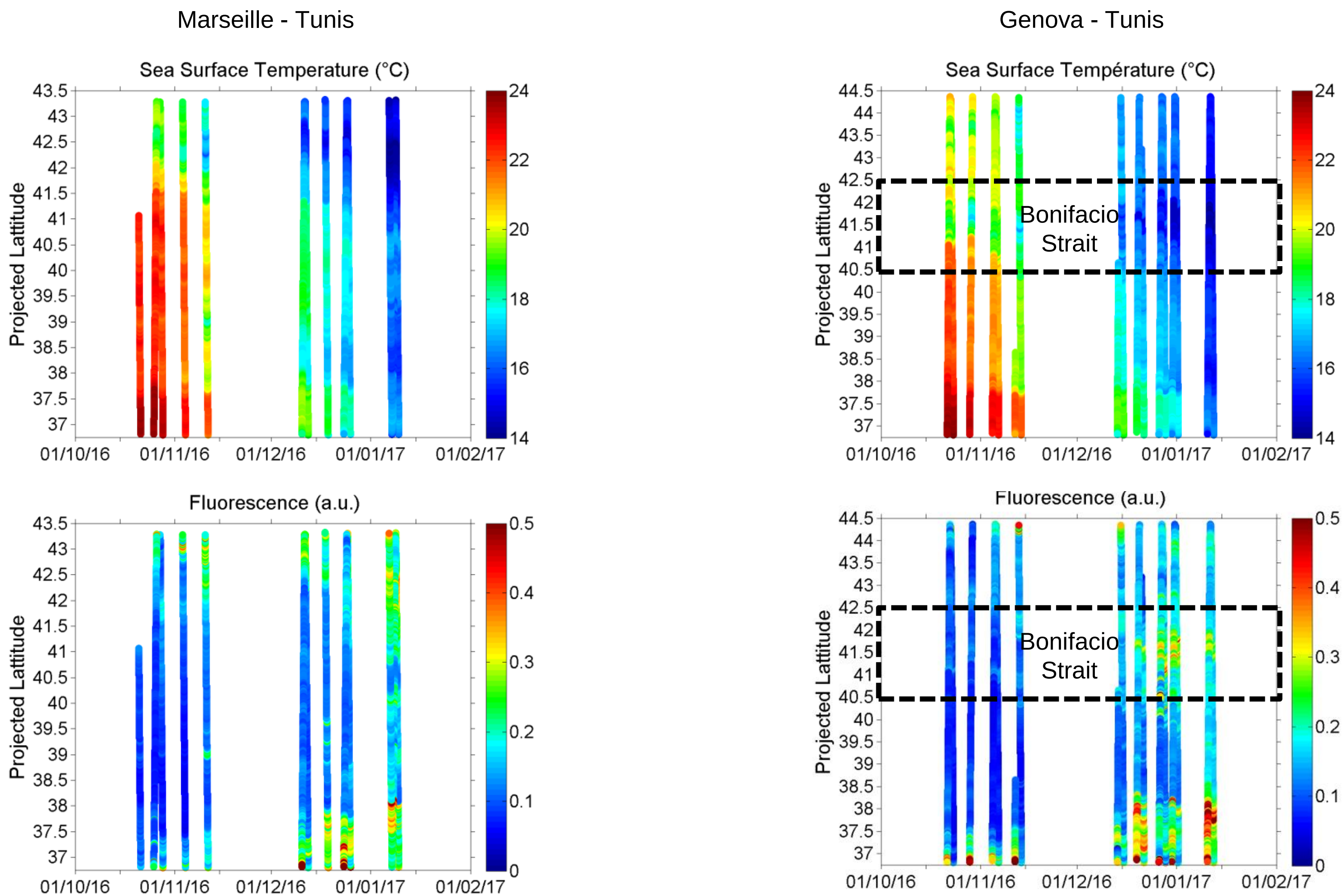
Validation of SST and FB data .

16/03/2017






FerryBox Chrome Oct2016-Jan2017
Genova
Marseille
Tunis
Bonifacio Strait
44°N
42°N
40°N
38°N
36°N
4°E
6°E
8°E
10°E
12°E
0
-200
-1000
-2000
-3000
-4000
Depth (m)

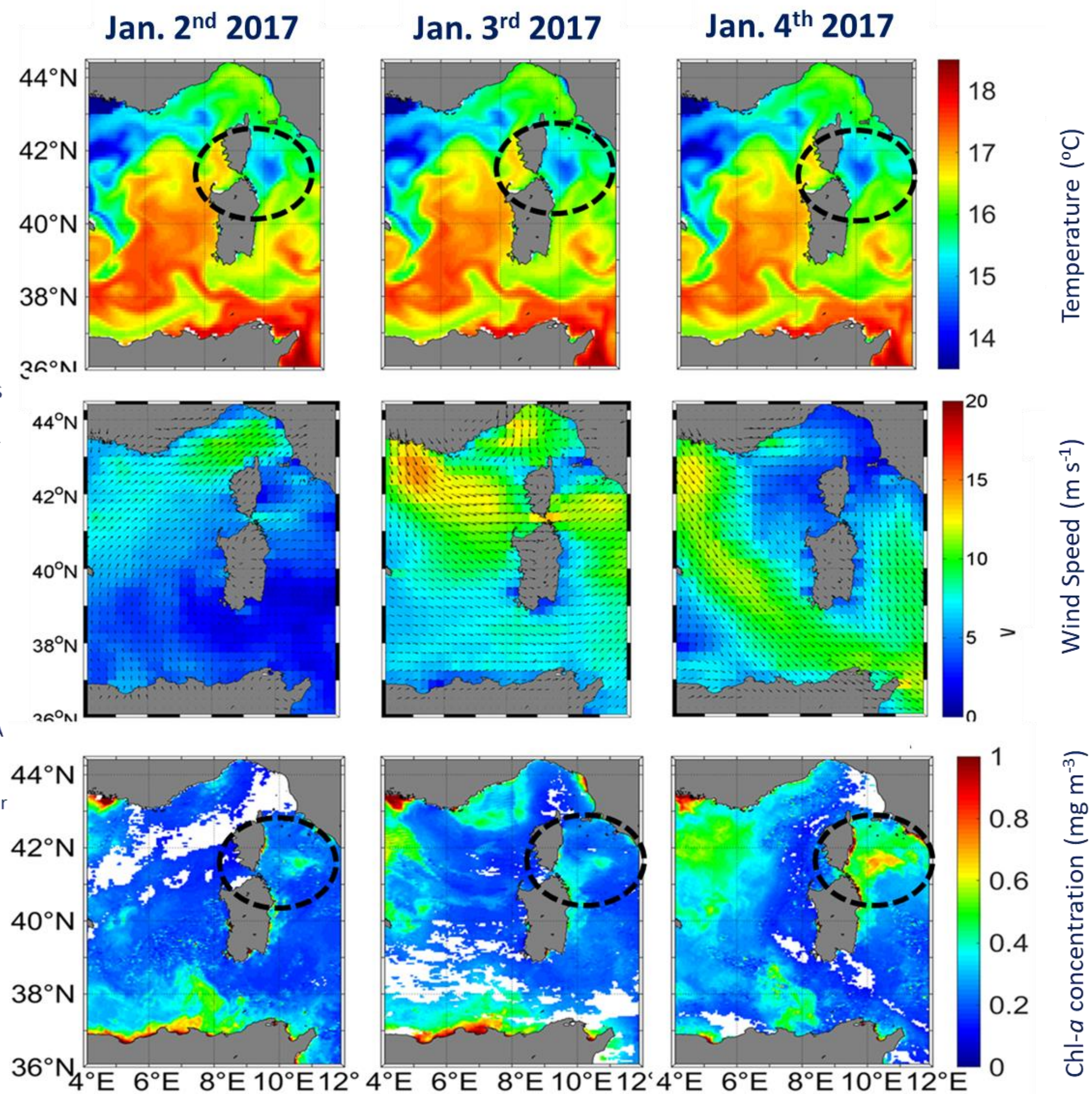


Marrec et al, 2021

Sea Surface Temperature:
daily mean fields from Global Ocean Physics Analysis and Forecast updated Daily. CMEMS data product. http://www.mercator-ocean.fr

Wind Speed:
Global Ocean - Wind Analysis - Blended ASCAT-SSM/I - 6 Hourly. CMEMS data product. IFREMER

Chl-*a* concentration:
OCEANCOLOUR_GLO_CHL_L3_REP_OBSERVATIONS_009_085 CMEMS product. http://www.globcolour.info



- ♦ Analysis of Glider data for 2018
- ♦ Inter-seasonal comparison of Glider data (2014-2018)
- ♦ Eddies characterization from detection methods

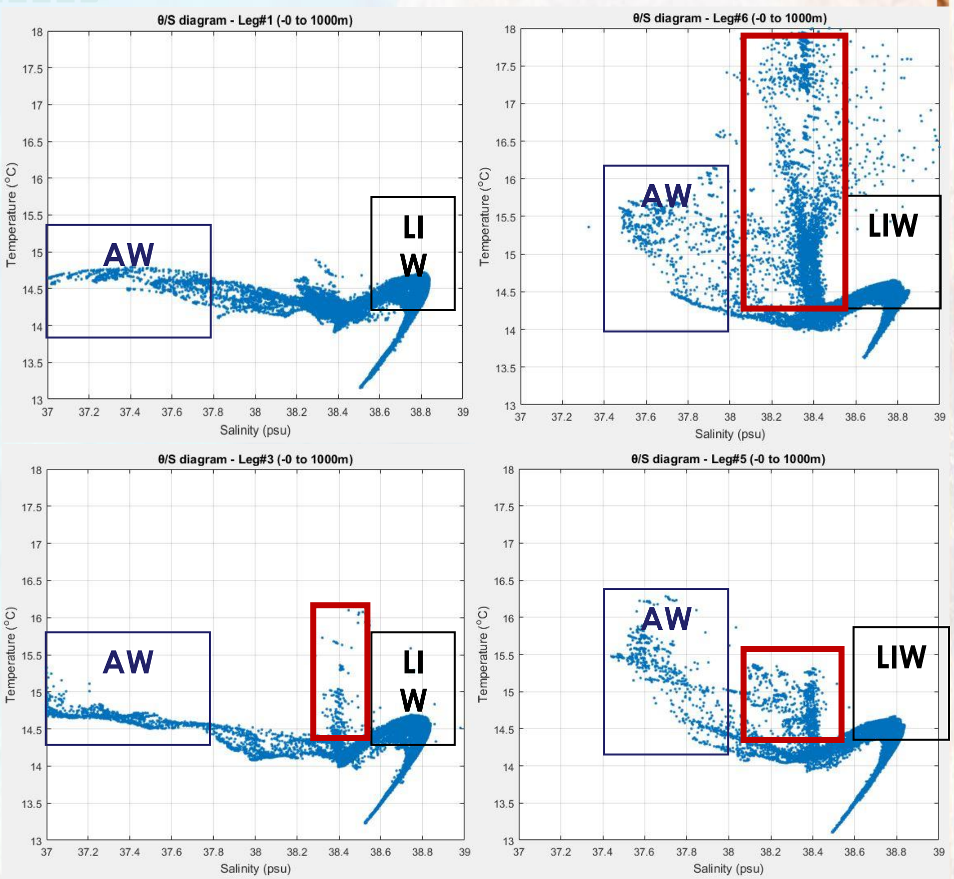
- ♦ Chlorophyll-a CHL satellite data
- ♦ Horizontal distribution of SST
- ♦ Horizontal distribution of Sea Surface Salinity
- ♦ Eddy Detection and Tracking Using Remote Sensing Products

Eddies Characterization from detection methods

Comparison along glider tracks for **2018 (GETSCh)**

Leg#1: we detected the signature of **AW** highlighted in green + **Leg#3**: the intrusion of warm waters masses (red): **15<θ<16.2 °C & S > 38.3** - these water masses lead to **mixture in Spring** we recognized **LIW** in Leg#1 & 3 with **θ=14.6°C** and **S=38.8**

These water masses dynamics are mainly related to Mesoscale Eddies generated to advect them

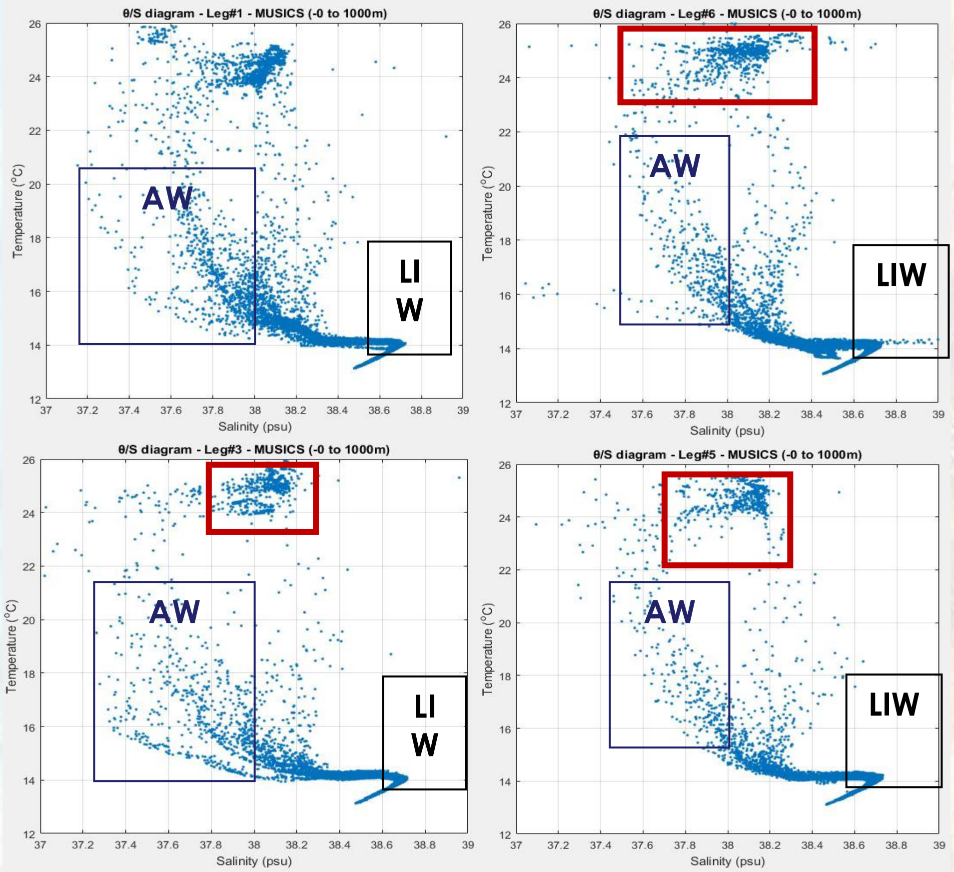


Eddies Characterization from detection methods

Comparison along glider tracks for **2014 (MUSICS)**

These diagrams confirm the signature of **LIW** for **S>38.7** which remained stable.
Then **Salinity** started to **increase** from **Leg#6**

water masses with high **T°C** values:
if we admit, that colder waters are necessarily of an Atlantic origin, we would expect fresh water in the AW !
There are reasons to believe that we have an upwelling !



Analysis of Satellite Data

CHL satellite data in STC

• through the satellite we are interested to the period when the bloom started to develop

• CHL was spectacular in this study area especially near the **Tunisian coasts** with a peak in the **10th March**.

• after examining the CHL dynamics that occurred since 10/03/2018 during the period previous to the Glider mission, we can validate and deduce the trajectory of this CHL concentration migration through **mesoscale eddies**.

Comparison between CHL Satellite data & Glider data

• unavailability of satellite data during the **14th** and **16th** of March 2018.

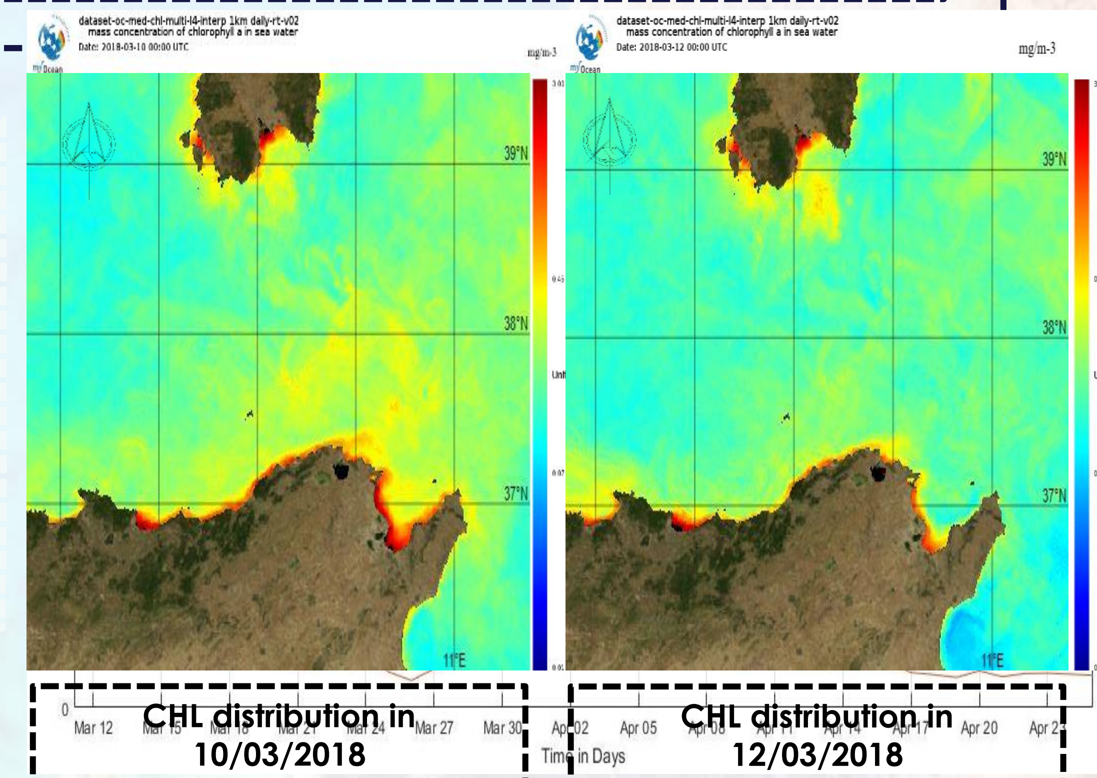
• We notice that Glider > Satellite ones, NO number of coincident points between both of sources.

• **1st peak** in **15/03/2018** (Glider)=1.69 mg/m3 & Satellite=0.47 mg/m3.

2nd peak in **23/03/2018** (Glider)=1.09 mg/m3 - satellite data = 0.13 mg/m3.

• We calculated the **average gap** between both of data sources and obtained **0.32 mg/m3**.

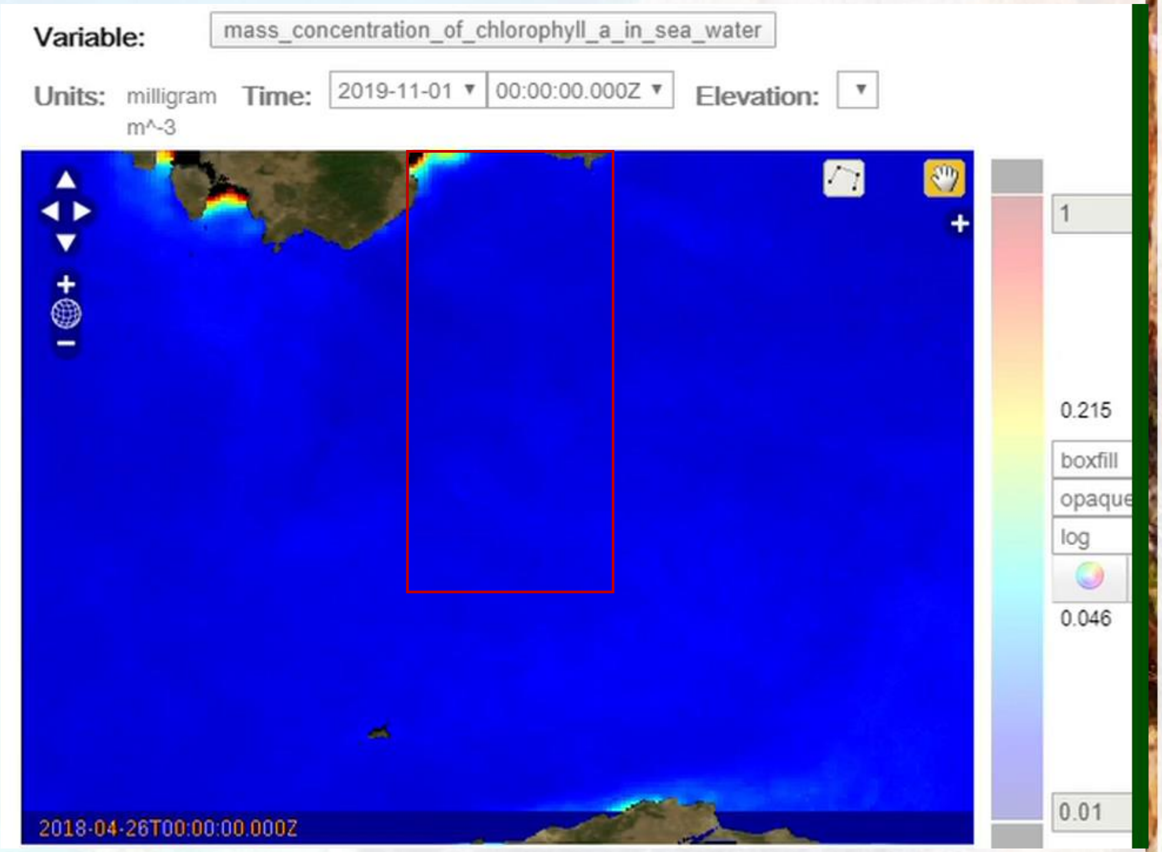
Horizontal distribution of CHL before GETSC & Glider mission



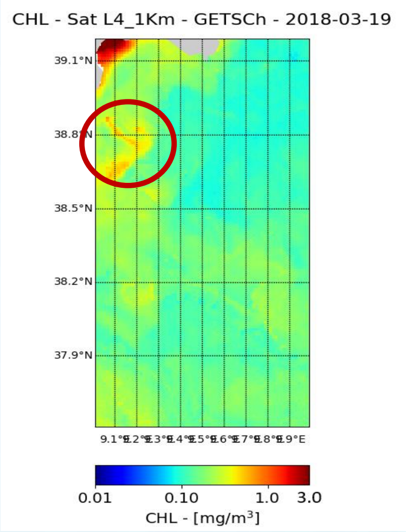
CHL distribution in 10/03/2018

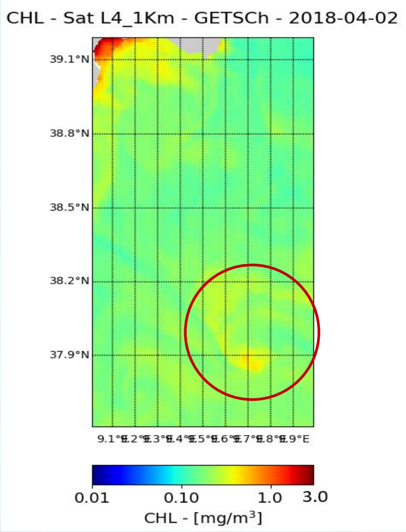
CHL distribution in 12/03/2018

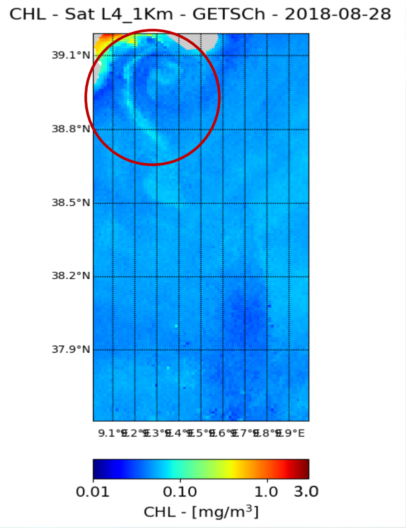
CHL satellite data in STC

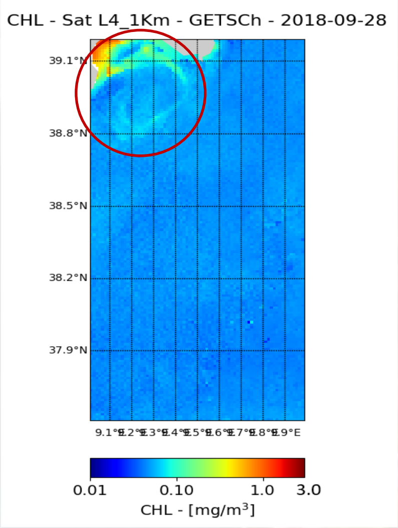


Inter-seasonal comparison between CHL Satellite products in Spring 2018 & Summer 2018









- We detected the shape of an **eddy** in the **North of STC** during March 2018. We have compared this eddy to **two chlorophyll eddies** during Summer 2018 in the same period of MUSICS mission.

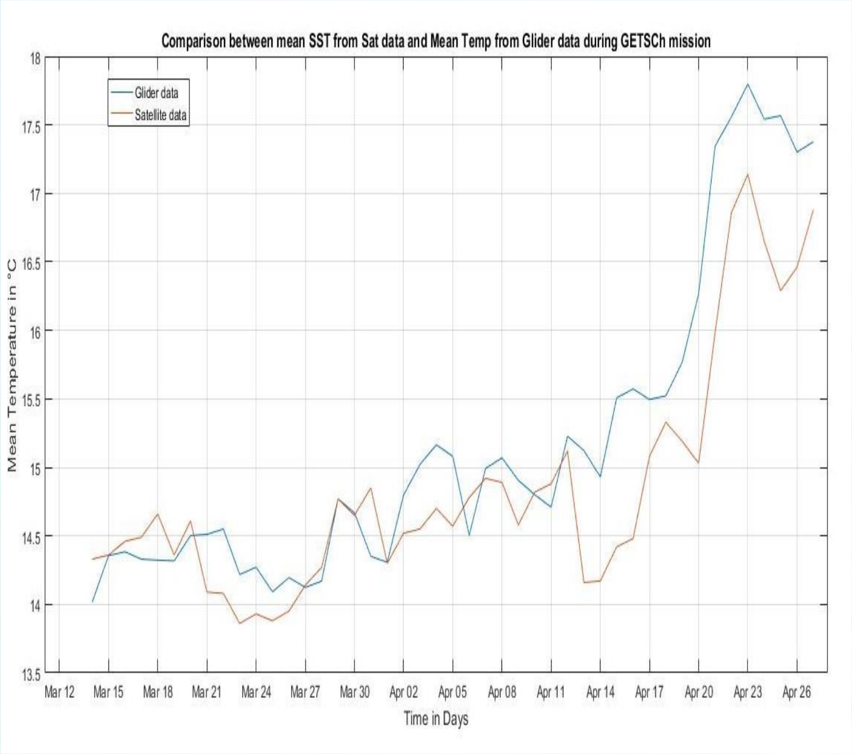
- In Summer 2018, an **eddy** that was generated and advected by the meandering of the **AC**, associated to **CHL** in the **Sardinian coasts**.

- The northernmost one in **19/03/2018** characterized by a CHL bloom, **after 15days**, we noticed **another mesoscale eddy** appeared in **02/04/2018** in the **southern part of STC**, this same eddy was detected in **Leg#3** which is confirmed by Glider data !

- This eddy appeared in 28/08/2018. Progressively, another cell of relatively higher CHL was created and observed at the sea surface, in the same area. The variability can change from a season to another in terms of mesoscale eddies generation and disappearance.

Horizontal distribution of SST in STC

Comparison between SST Satellite data & Glider data



We calculated the **average gap** between both of data products, which is **0.33°C**.

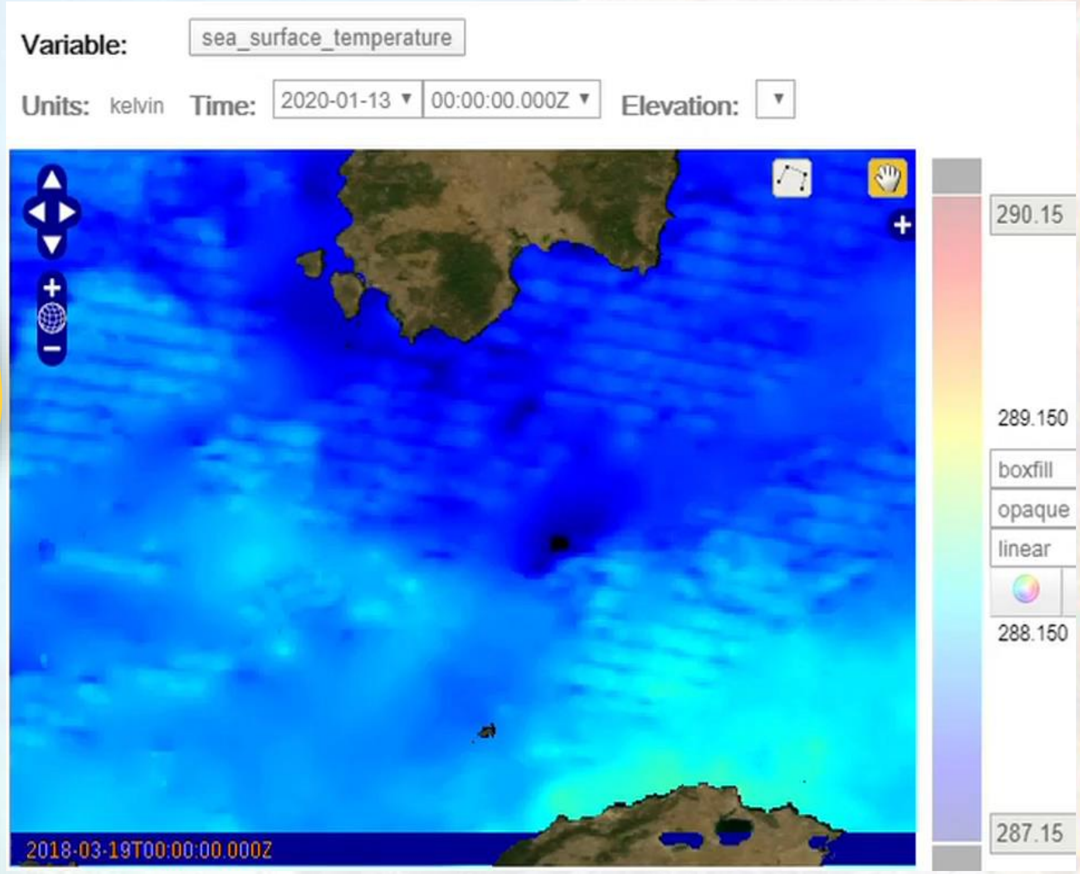
We can mainly notice **several coincidence points** between both of sources, which wasn't the case for CHL comparison

Starting from the **12th of April**, Glider Temperature data in the surface became **higher** than Satellite ones.
Both of them reached the **maximum in the same date though, 23/04/2018**, which is **14.22mg/m3** for Glider and **13.86 mg/m3** for Satellite.

Horizontal distribution of SST in STC

In **02/04/2018**, another **mesoscale eddy** was generated close to the **Tunisian coasts**, in the vicinity of **37.9°N**.
This bloom is associated to this eddy, which is colder than the surrounding waters.

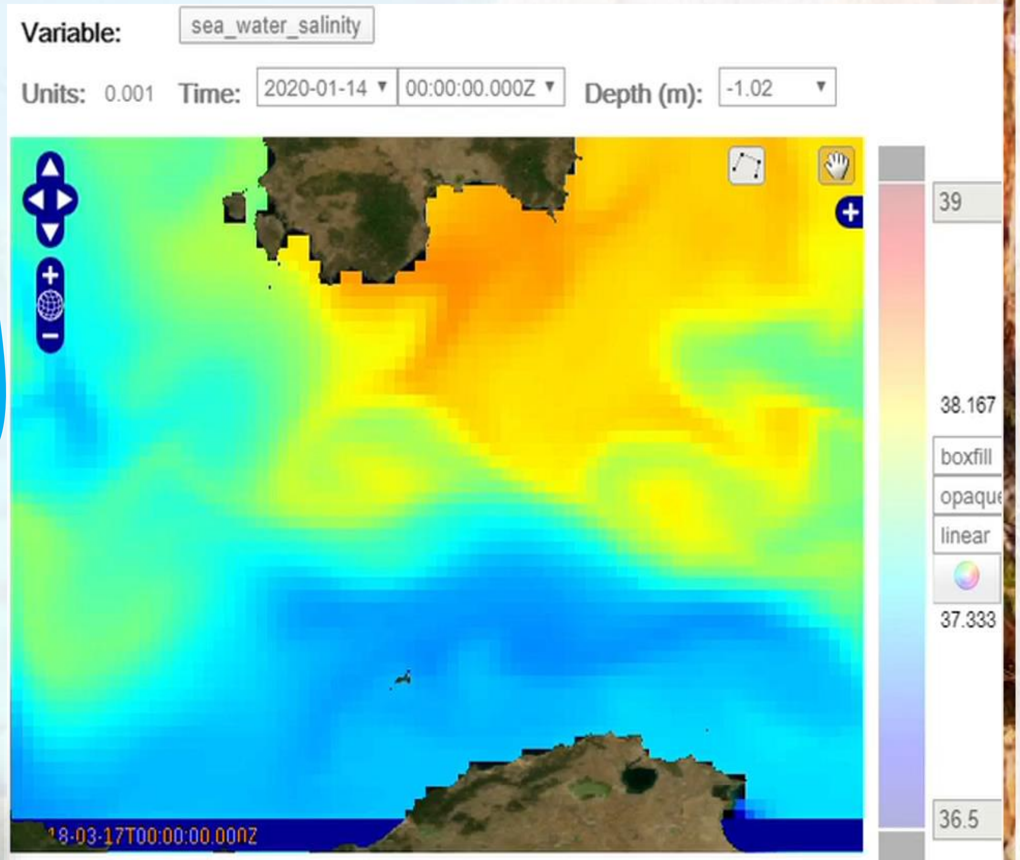
one particularly event occurred in leg#3,we do confirm the generation of **two main cells** of relatively **warmer waters** in the surface layer reaching **15°C** and **14.8°C** near Tunisian coasts.



Horizontal distribution of SSS in STC

We have here a **generated mesoscale eddy** already detected in the map of Surface CHL in **02/04/2018**, which is leading to a **Cyclonic shape** in the **North of STC**.
the cyclonic shape are generated near the Sardinian coasts by anticyclonic eddies near the Tunisian coasts.

Close to the **Sardinian continental slope**, the **LIW and TDW** coming from the Channel of Sardinia, flow **northward** in a well-marked vein (Send et al., 1999) & interactions between this vein and the Algerian Gyre are supposed to generate these Cyclonic Sardinian Eddies (SEs) (Testor and Gascard, 2003).



Eddy Detection and Tracking Using Remote Sensing Products

The trajectory of the **anticyclonic eddy** emerged from a **meander of the AC**, detached from the coast & travelled up to the **Sardinian coast**.
We can clearly see that this **eddy** generated **anticyclonic eddies** in the Southern edge of their trajectory.

• M g tr e e

•Ed ... interactions
play ... th-south mass exchanges.
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smal
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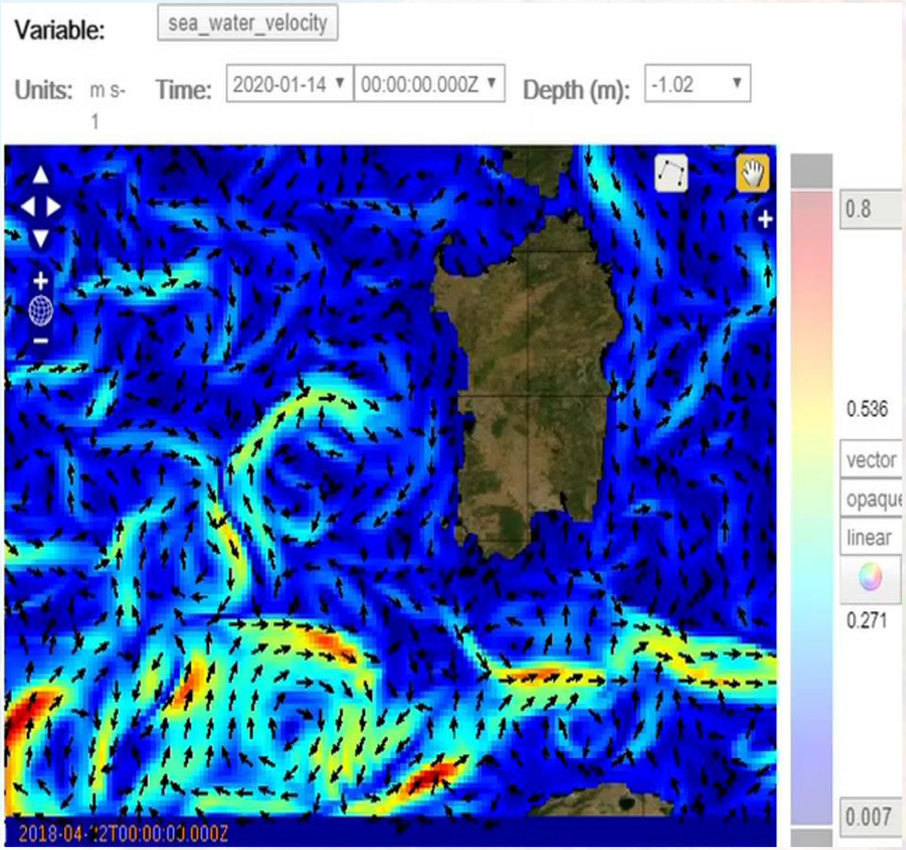
Through the **southward geostrophic flow**, the **eddy-eddy interactions** generated **anticyclonic eddies in the South of STC** and this vein deflected currents in the **Sardinian coasts** which generated a **Cyclonic eddy** already confirmed in the previous Glider profiles.



Conclusion and perspectiv

The Global Ocean Observing System
Biogeochemistry Panel

→Achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere, and of how this coupled system affects and is affected by climate and environmental change

→an internationally coordinated action should aim at document and understand the interactions between physics, biogeochemistry and biology, the interactions between the WMED and EMED, thus improving the interpretation and synthesis capability of new observations to assess feedbacks of Mediterranean dynamics on the global climatic system.

→a closer interaction with models is an important task able to improve both the model results and interpretation of observational data permitting to provide more confident scenarios of the Mediterranean conditions for the next decades.

The Global Ocean Observing System

Biogeochemistry Panel

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

A communication and coordination service for marine biogeochemistry

www.ioccp.org ***@ioccp_org***

Thank You!

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Phone: +48 58 731 16 10 / Fax: +48 58 551 21 30, **www.ioccp.org**