

Paradigm change in ocean studies: multi-platform observing and forecasting integrated approach in response to science and society needs

Combining Scientific Excellence & Technology Development
with... Impact and Relevance to and for Society

SOCIB & IMEDEA Team (Nov. 2104)



OUTLINE

1. New Technologies: Paradigm Change Ocean and Coastal Observation & Operational Oceanography
2. Marine Research Infrastructures, Ocean Observatories: SOCIB contributions to process studies and operational response
3. Innovation and Blue Growth: gliders disruptive innovation case study and data availability –

Discussion: Are we ready for these changes ? Do we have the framework and right structures to get all the benefits from these changes ?

Our goal... characterise Ocean State AND Variability at Different Scales (basin, sub-basin, local & coastal interactions)

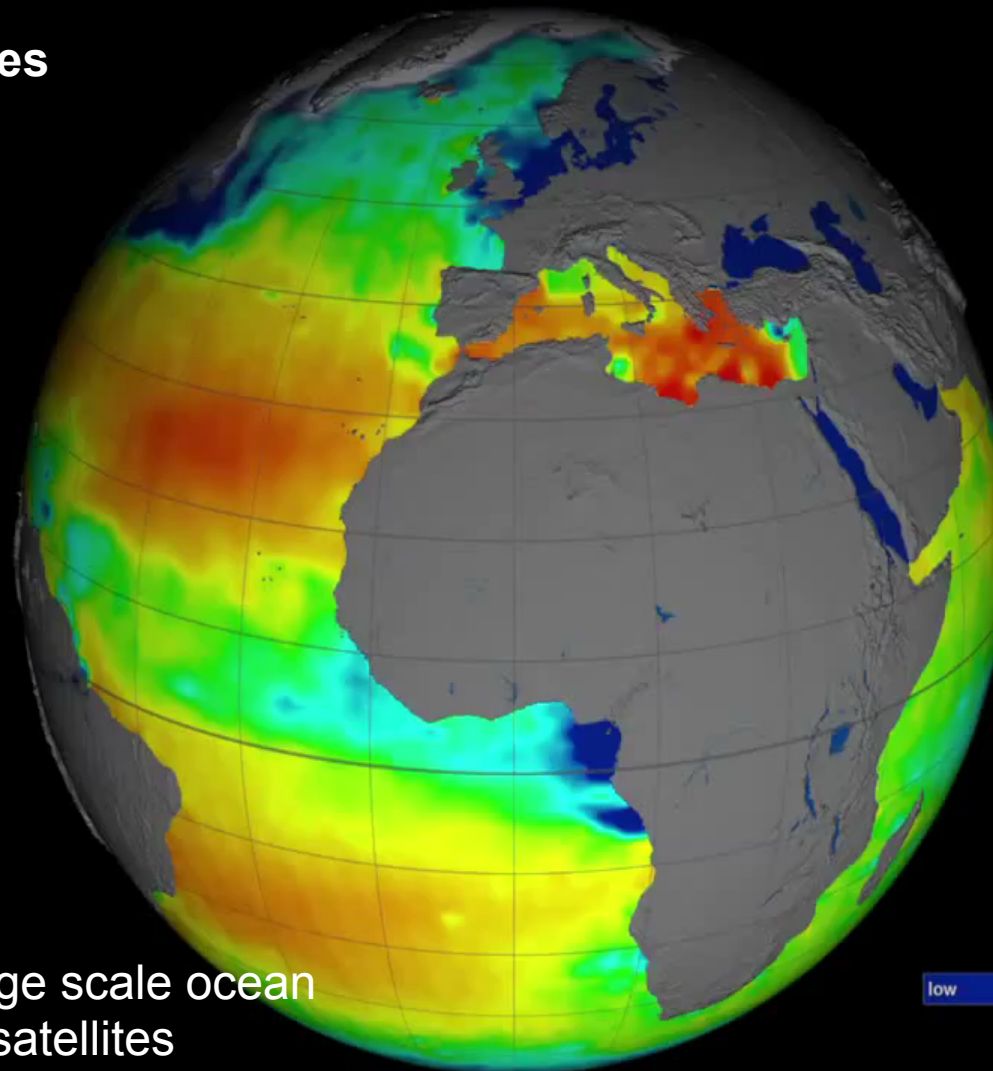
We need:

- Long time series
- Synoptic data

Walter Munk, 2001:
“The last century of
oceanography is
marked by the degree
of under-sampling”.

Carl Wunsch, 2010: “We
need data, ... models
are becoming
untestable”

Last decade: ok large scale ocean
circulation –Argo & satellites



Salinity
low high

Mediterranean Sea and Balearic Sub-Basin

1. Small Scale Ocean ($R_i=12$ km) characterised by:

- Thermohaline basin scale circulation
- Intense mesoscale variability

(Malanotte-Rizzoli et al., 2013)

2. Ideal Laboratory:

- Interactions between mesoscale eddies and the basin scale circulation
- Importance and need of adequately resolving mesoscale to understand the basin scale variability, seasonal, annual & inter-annual scales.

3. Balearic Sub-basin: ideal transition area Gulf Lion (D_W) and Alborán Sea (S_AW), strong mesoscale dynamics.

4. The Ibiza Channel, a key choke point

We need... Long time series ... YES.... BUT ALSO....

Synoptic data and ... Monitoring at the right scales

Synoptic data and ... Monitoring at the right scales

Mediterranean Sea: TH circulation & mesoscale e



24

A. Bergamasco and P. Malanotte-Rizzoli

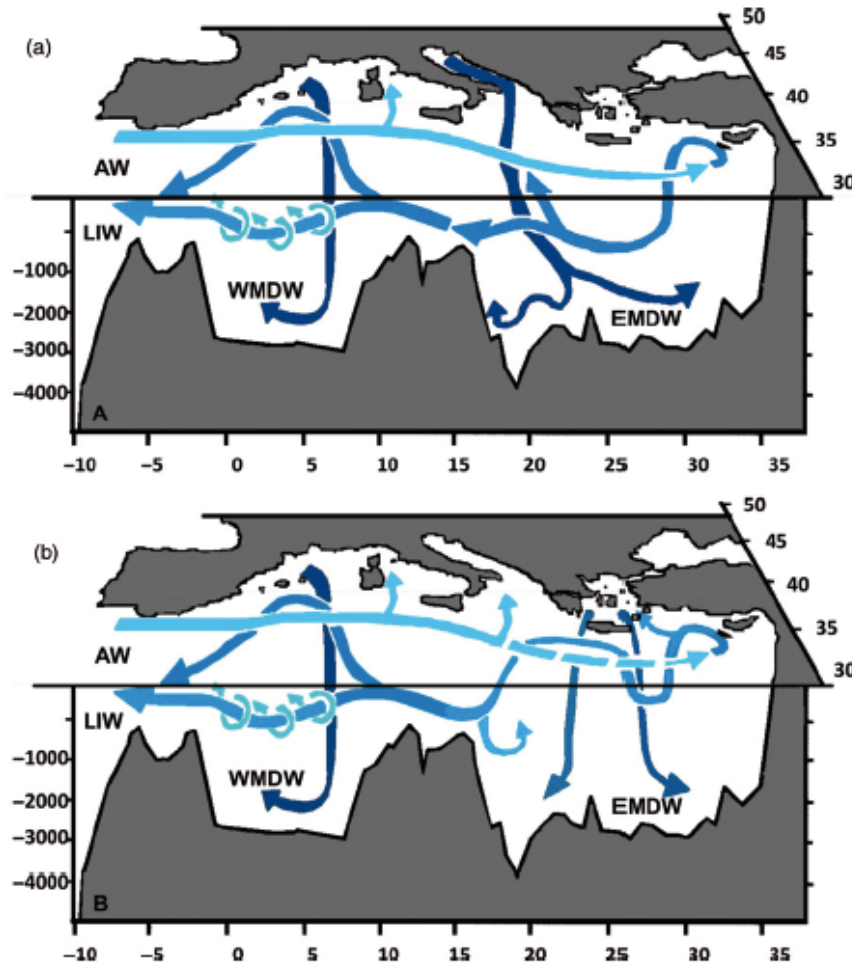
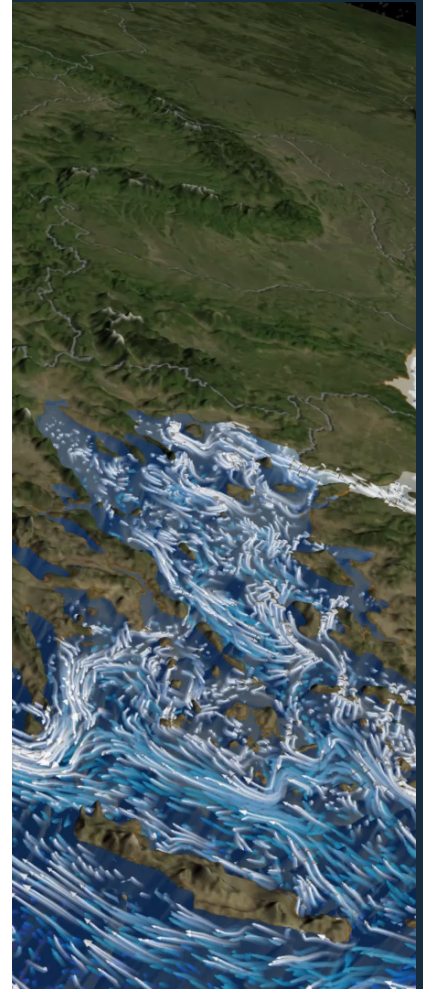


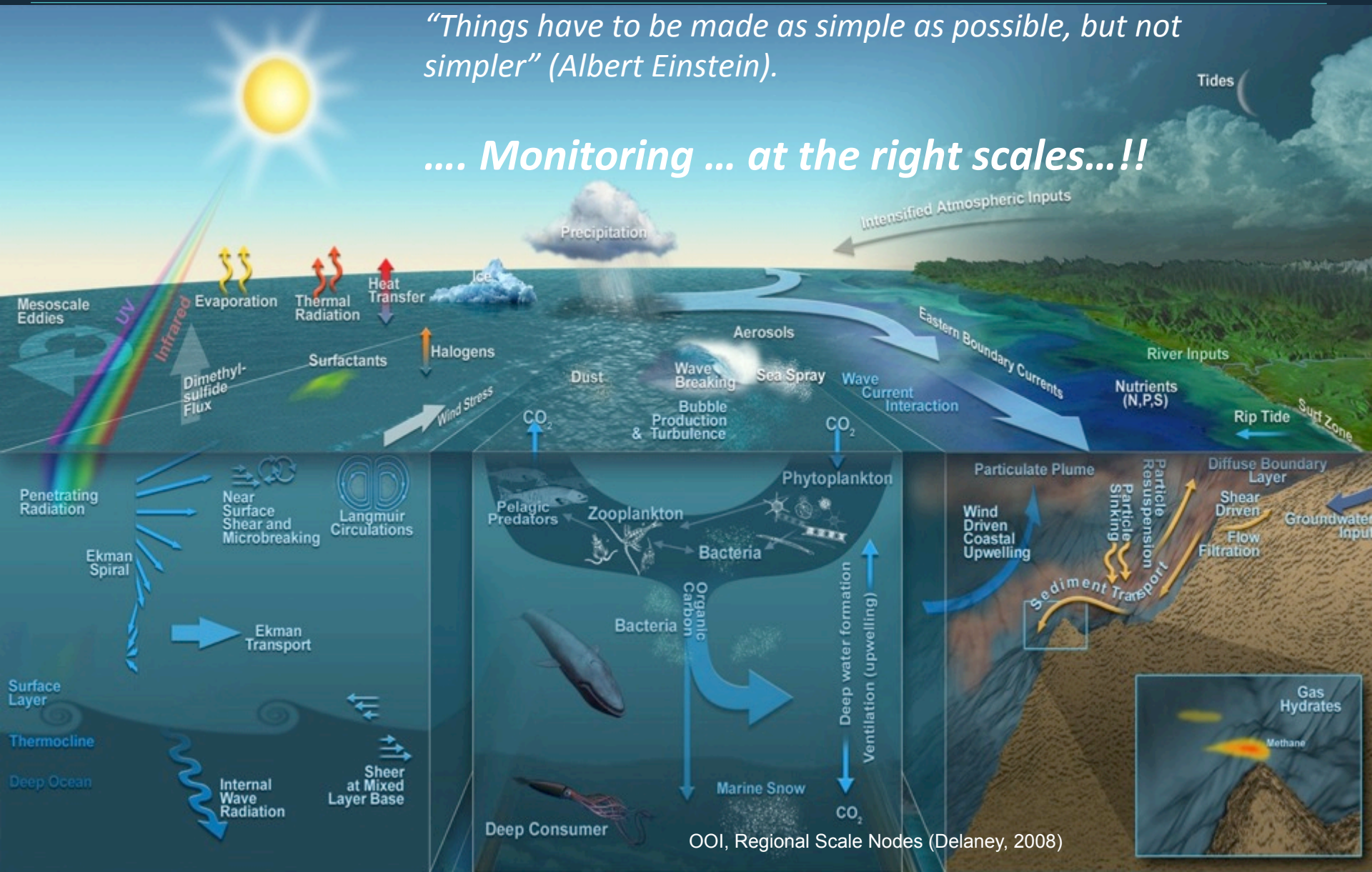
Figure 11. Mediterranean Sea Thermohaline Circulation Scheme (modified from [1]). Note the Eastern Mediterranean behaviour before (upper panel) and during (bottom panel) the Eastern Mediterranean Transient (EMT).



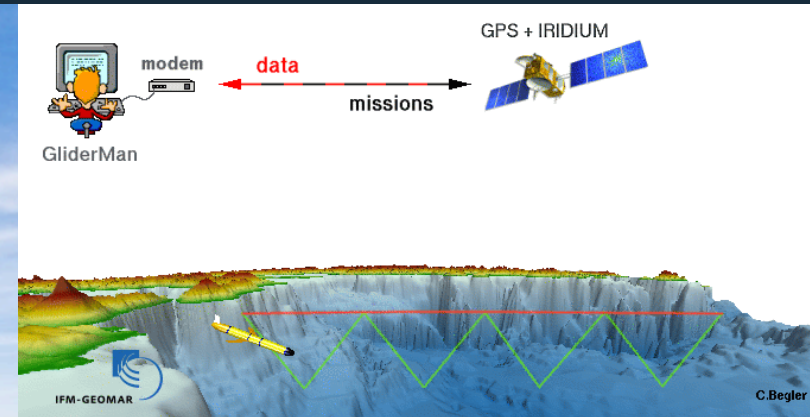
Oceans and coastal interactions. Scales interactions. Management is needed. No oversimplification.

"Things have to be made as simple as possible, but not simpler" (Albert Einstein).

.... Monitoring ... at the right scales...!!



New Technologies: drivers of change.... (gliders just an example)



SOCIB Glider Facility: 05/2006-04/20145

- 56 missions, days in water 960, 10.850 nm
- 26.885 profiles (30 Euros/profile)
- Bi-monthly routine operation (since 01/2011)

New Technologies: Paradigm Shift

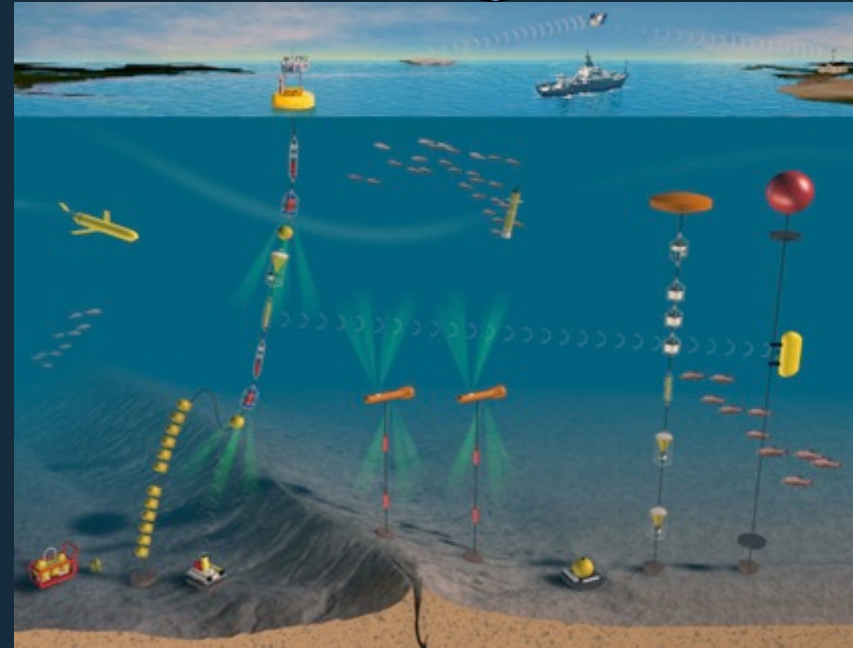
→ Ocean Observation

From: Single Platform - Ship based observation

To: Multi-platform observing systems

Network - distributed
Systems

Platform-centric
Systems



(Adapted from Steve Chien, JPL-NASA)

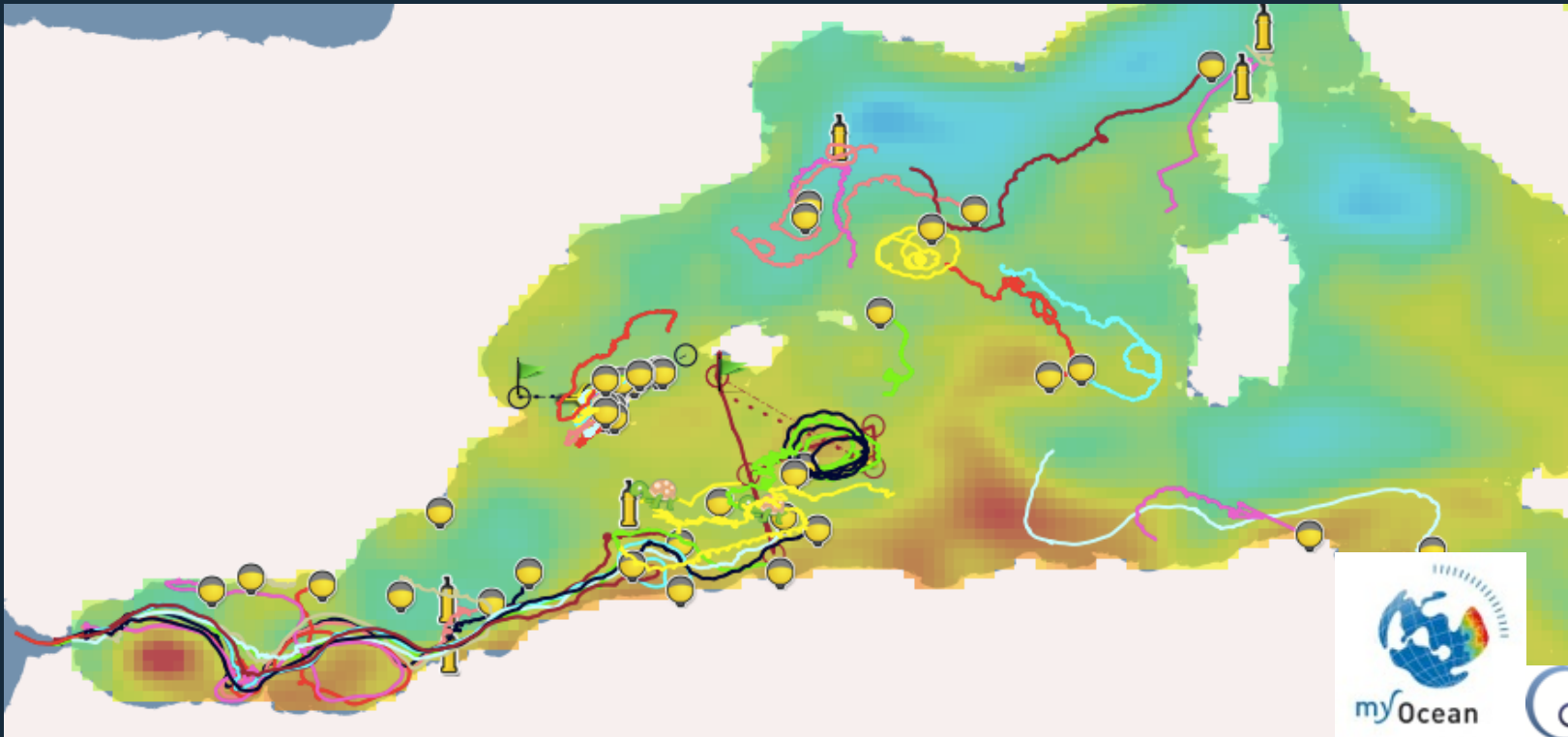
“A single ship can only be in one place at one time. We need to be present in multiple places in multiple times.” ([John Delaney, Nature, Sept. 25, 2013](#))

New Technologies: Paradigm Shift

SOCIB

➔ Data Availability (Real time and QC 'at one click')

Dapp SOCIB: multi-platform real time data available: 40 surface drifters, 4 Argo profilers, 2 sea-turtles, 2 gliders, 2 fixed moorings, 7 tide gages, 3 real time beach monitoring systems). **REALLY ALL AVAILABLE** (not just on paper...)



- ➔ SOCIETAL IMPLICATIONS: Alborán Gyres position and fisheries: (Ruiz et al., 2013: Anchovy landings x 10)
- ➔ SCIENCE IMPLICATIONS: adaptive sampling with gliders...

<http://apps.socib.es/dapp>

Why Ocean Observatories, why SOCIB, why now?

New Technologies triggered a paradigm change New Approach to Marine and Coastal Research

Allow three-dimensional real time observations, that combined with forecasting numerical models, and data assimilation, ...

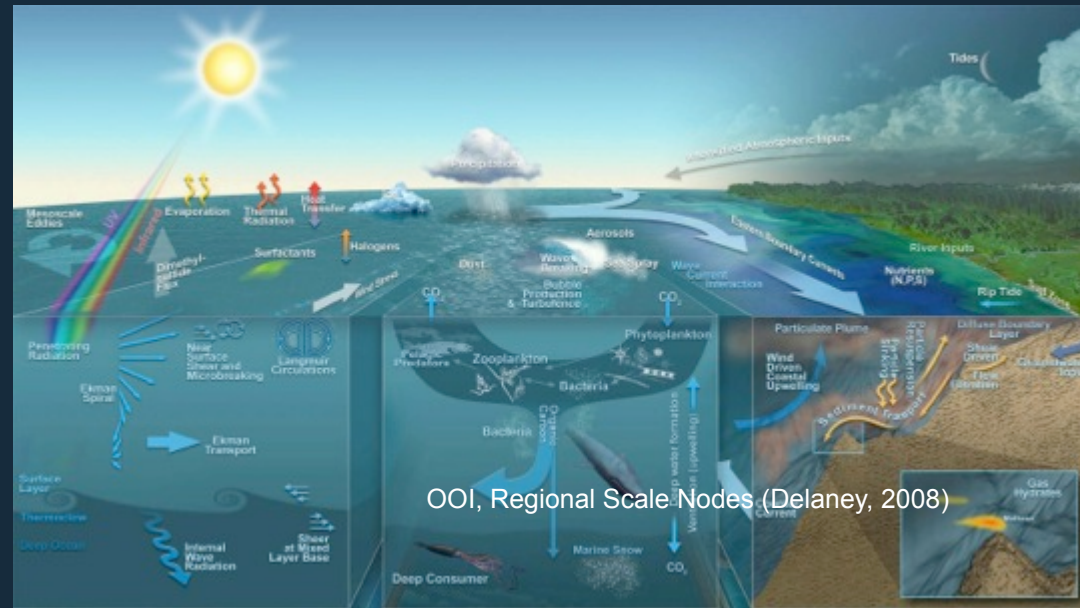


A quantitative major jump, in scientific knowledge and technology development



The development of a new form of Integrated Coastal and Ocean Management

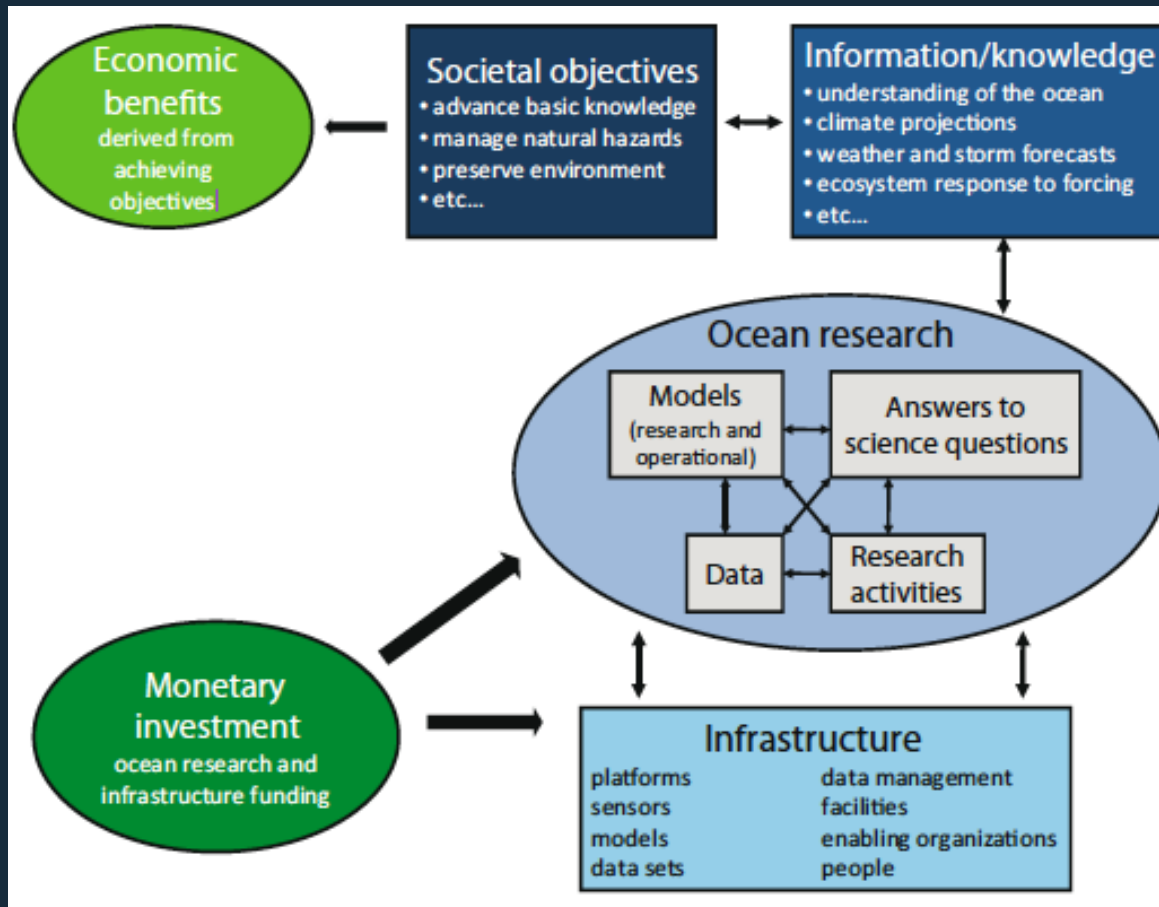
on a global change context (where climate change is one of the most important, but not the only one...), and following sustainability principles



- Are we ready for these changes?

We need to open our minds, adapt scientific and educational structures, management procedures

Ocean Observatories, Marine Research Infrastructures: International Frame



EOOS



[Committee on an Ocean Infrastructure: Strategy for U.S. Ocean Research in 2030. NRC \(2011\)](#)

SOCIB Principles

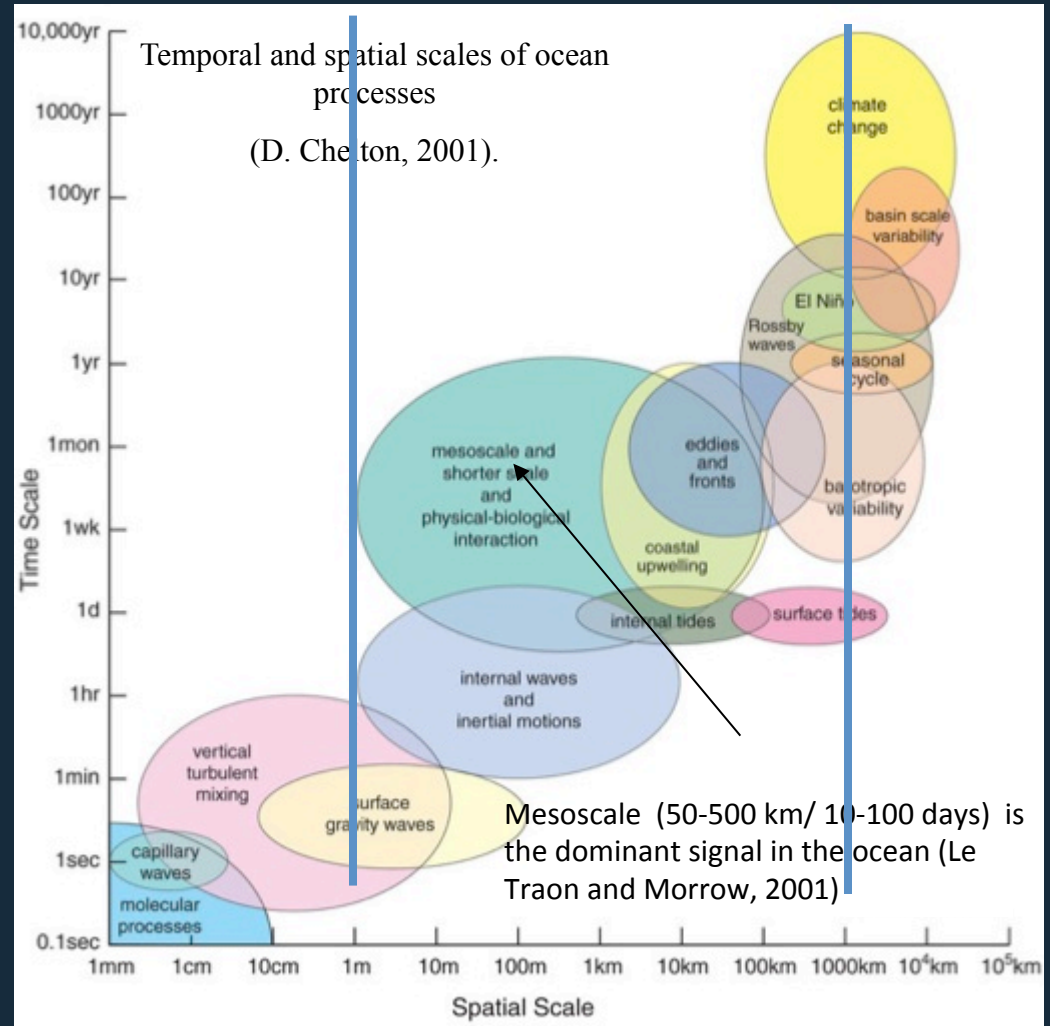
- Scientific and technological excellence through peer review
- Science, technology and society driven objectives
- Support to R&D activities in the Balearic Islands (existing and new ones);
- Systems integration, multiplatform and multidisciplinary coordination
- Sustained, systematic, long term, monitoring, addressing different scales
- Free, open and quality controlled data streams
- Baseline data in adherence to community standards
- Partnership between institutions

NOW we can....ocean variability at mesoscale/sub-mesoscale, interactions and ecosystem response

Theory and observations have shown that there is a maximum energy at the mesoscale (include fronts and eddies ~10-100km),

SOCIB focus: mesoscale & submesoscale and their interactions with general circulation and their effects on vertical motions, impact on ecosystem variability.

With inputs from 'both sides'....
(nearshore and coastal ocean and also seasonal/inter-annual and decadal variability)



SOCIB scales

What is SOCIB? A multi-platform observing system, from nearshore to open-ocean in Mediterranean

OBSERVING FACILITIES



Research vessel



HF Radar



Gliders



Lagrangian platforms

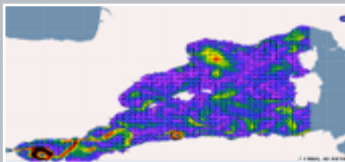


Fixed stations



Beach Monitoring

MODELLING FACILITY



Currents (ROMS)



Waves (SWAN)

STRATEGIC ISSUES & APPLICATIONS FOR SOCIETY



Integrated Coastal Management



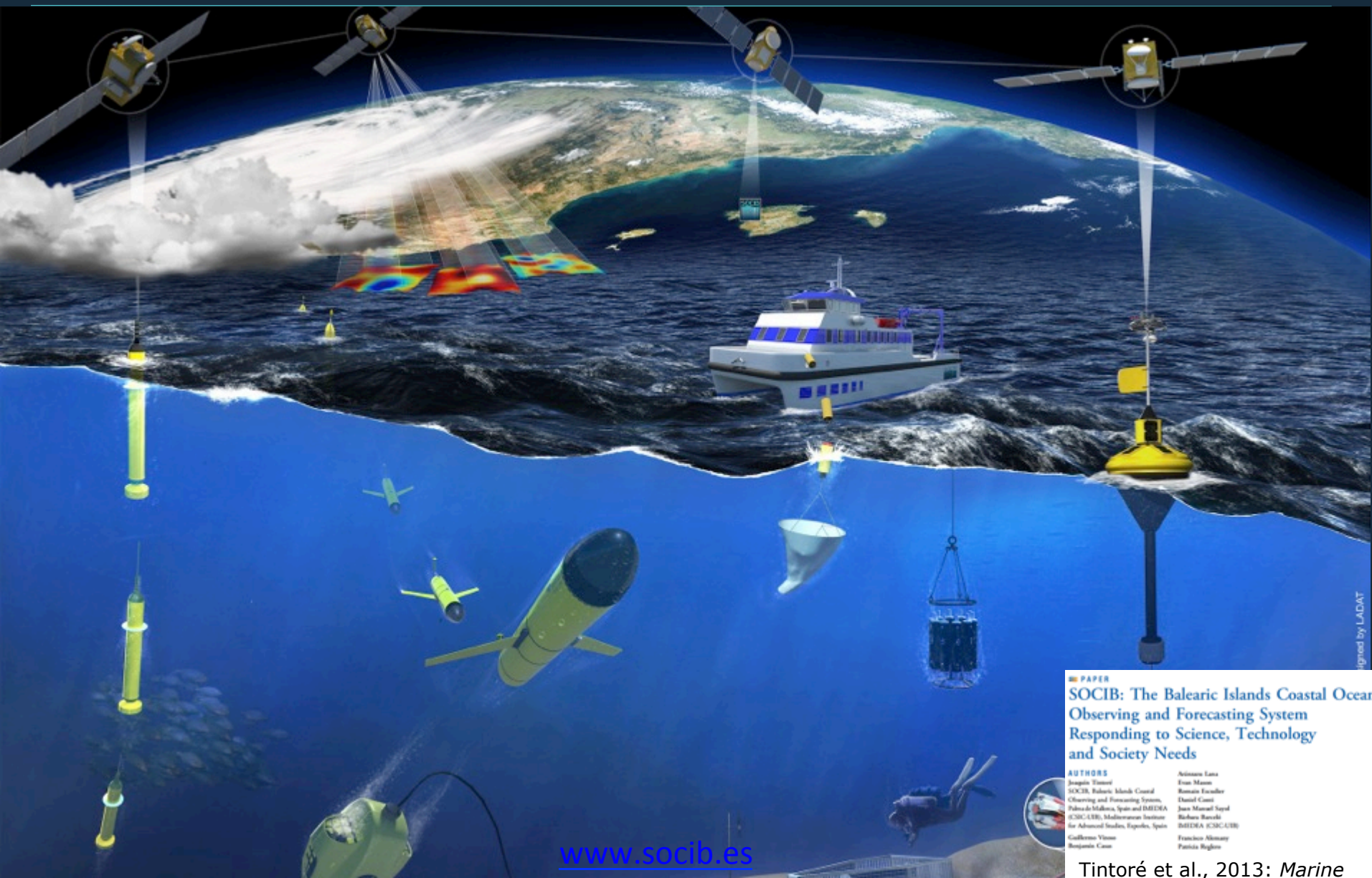
Marine Spatial Planning

DATA CENTER



Data access – Data Repository – Applications
Spatial data infrastructure – Real time monitor

What is SOCIB? A multi-platform observing and forecasting system, ...



PAPER

SOCIB: The Balearic Islands Coastal Ocean Observing and Forecasting System Responding to Science, Technology and Society Needs

AUTHORS

Joaquín Tintoré
SOCIB, Balearic Islands Coastal
Observing and Forecasting System,
Palma de Mallorca, Spain and IMEDEA
CSIC-UIB, Mediterranean Institute
for Advanced Studies, Esporles, Spain
Guillermo Vimeux
Benjamin Cane

Antonieta Lloret
Evan Mason
Romana Escudé
David Cusi
Joan Marnat Lloret
Roberto Rueda
IMEDEA CSIC-UIB
Francisco Almaraz
Patrik Riegler



www.socib.es

Tintoré et al., 2013: *Marine*

SOCIB & IMEDEA at Liege Colloquium - 2015:

www.socib.es



Charles Troupin



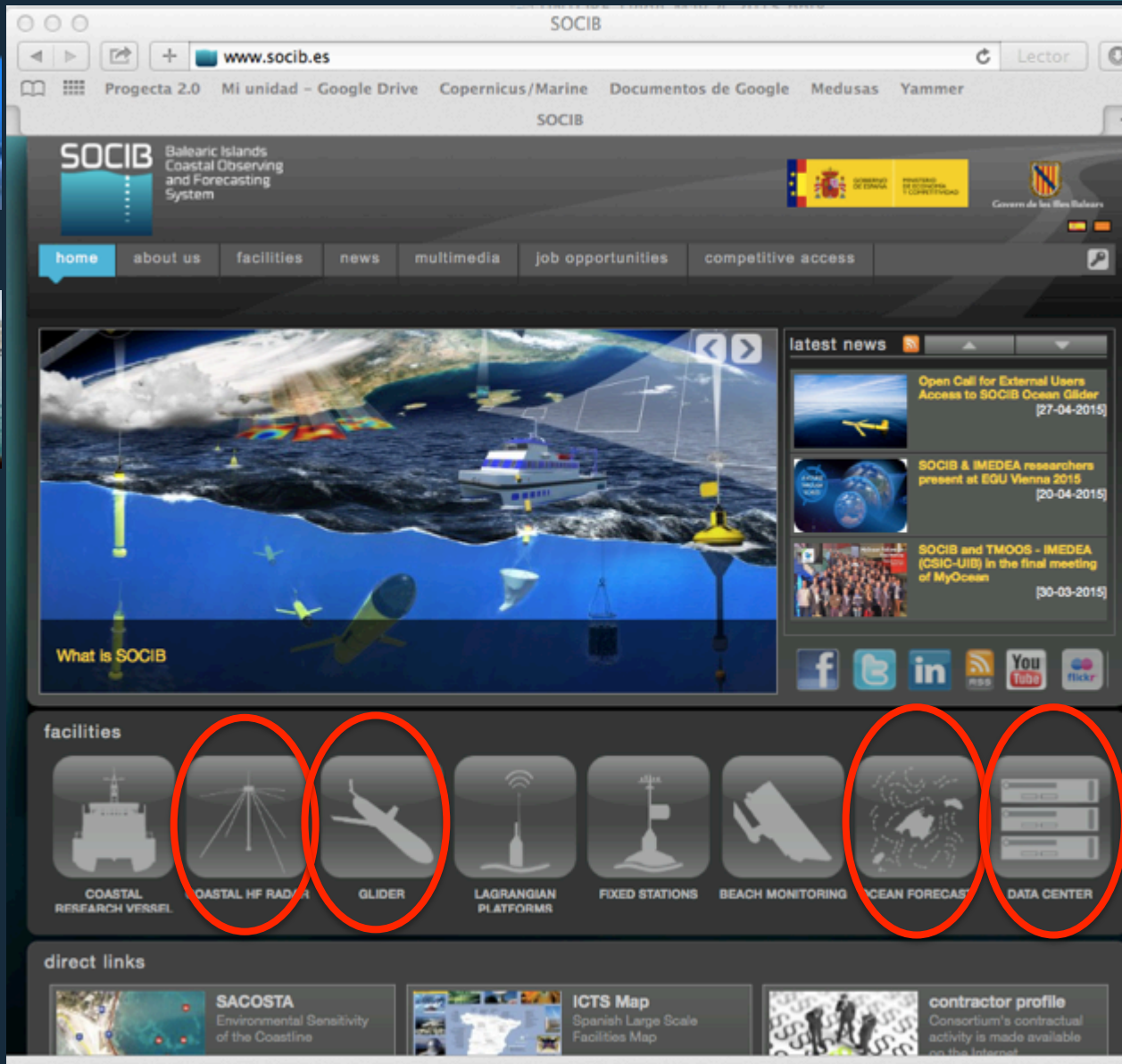
Emma Heslop



Ananda Pascual



Simón Ruiz



Drivers

Science priorities
Technology Dev.
Society Needs



Baptiste Mourre



Mélanie Juza



Arancha Lana

SOCIB Data Centre: Real Time, Free Access & Download, Quality Controlled, Interoperable Data



Charles Troupin



MedSea Portal

Glider, HF Radar, Modelling, Data Centre Facilities

SOCIB: MONITORING OCEAN STATE AND OCEAN VARIABILITY

Towards a better understanding of ocean variability, combining glider monitoring and numerical simulation, at a circulation "choke" point

Authors: E. E. Heupel, M. Juez, B. Moura, J. Tironé, J. Allen, J. López-Jurado, M. Torner. Contact: eheupel@socib.es

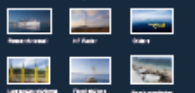
01 SOCIB: A new multi-platform integrated ocean observatory

SOCIB Mission: to characterize ocean state and ocean variability. In order to increase forecast skill, link physical process to ecosystem responses and detect the impact of climatic change.

The Mediterranean: a complex system, changing and under-observed

Carti-Monast 2010: "We need data, ... models are becoming unobservable"

SOCIB Observing Facilities



SOCIB Modelling Facility



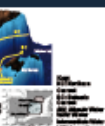
02 Glider monitoring of the Ibiza Channel 'choke'

- Narrowest point in the basin scale circulation
- Governs important north/south exchange of water mass
- Glider captures variability on days, to weeks, to annual timescales

Key findings:

- High frequency variability in the water mass exchange
- Changes of the same magnitude as seasonal cycle
- Caused by WW, eddies and AW inflows
- Seasonal cycle in southward flow (NC)
- Follows low-frequency, higher AW inflows driven from south

03 Model



WMOP 2009 - 2013:

- Regional configuration of the Regional Ocean Modelling System
- Spatial coverage: Gibraltar to Sardinia
- Spatial resolution: 1.6 to 2.3 km
- Vertical grid: 32 sigma levels
- Bottom topography: 30° FORCING
- Initial and boundary conditions from MFS, MyOcean
- Atmospheric forcing: NCEP (2h 1025)
- River runoff: daily averaged for Var, Rhône, Rade, Hérault, Ebro and Júcar

See poster by Moura et al. for further details.

Comparing repeated high resolution glider transects with model

04 Ibiza Channel transports



Transport through the Ibiza Channel (IC) provides a measure of comparing circulation and water mass exchange. Glider to model can use clear estimates and differences.

WMOP gets right:

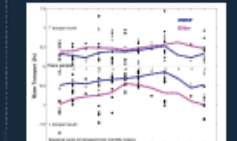
- Seasonal cycle in southward flow present, strongest in winter
- WW is present in winter
- AW inflows represented

WMOP key differences:

- LW is not always present
- Southward transport low

05 Seasonal Cycle

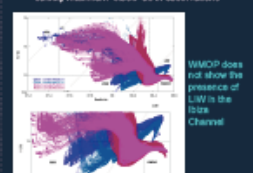
- WMOP shows seasonality in southward transport - BUT volume of flow clearly underestimated
- WMOP shows a similar order of magnitude for northward transport, suggesting mean inflows are reasonably well represented



Seasonal cycle in the transport of water masses, glider transects and WMOP (left). Volume of flow (right) is underestimated in WMOP. (left) Seasonal cycle in the transport of water masses, glider transects and WMOP (left). Volume of flow (right) is underestimated in WMOP.

06 Water masses 2011 and 2013

- Feb 2011 no LW is present in the model, deep waters mix to WW and flow to the surface
- Mar 2013 the waters with LW characteristics are not typical LW, there is no temperature and salinity maximum 'elbow' as in observations



WMOP does not show the presence of LW in the Ibiza Channel

05 Using glider insight to unravel the model

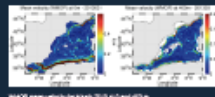
The comparisons highlight specific issues: no LW and low southward flow in the IC

- LW in WMOP: is geographically limited in this configuration of WMOP, not reaching the NW of the Western Mediterranean. It should be ubiquitous throughout
- At this stage, this limitation appears to be, at least in part, a function of the forcing from MFS. The role of circulation and model parameters is not yet fully understood on going work



WMOP Circulation:

- Low southward transport is, at least partly, due to a re-circulation flow pattern in the IC to the north of the Balearic basin
- To be quantified (work on going), this effect may be greater in the surface layer than at depth



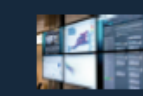
06 Implications and challenges

Implications: If LW is not well represented, modelling deep water formation will be compromised and the basin circulation poorly driven

If southward transport is low, the net flow through the IC is positive and the model representation of the basin scale circulation is flawed

Challenges:

Glider shows that WMOP is able to reproduce complex processes such as WW formation, however specific challenges remain in forcing, circulation and model parameters



An innovative approach:

High frequency, high resolution observations from gliders provide the detail required to compare observations and model, across timescales of days to years.

The differences identified at this 'choke' point provide meaningful insight into how to improve model dynamics

SOCIB: HF RADAR FACILITY

HF RADAR OCEAN SURFACE CURRENT OBSERVATIONS IN THE IBIZA CHANNEL: DESCRIPTION AND MODEL-DATA COMPARISONS

Authors: A. Lima (1), J. Marnett (2), W. Juez (2), J. Moura (2), A. Orús (1), V. Perdomo (2), A. Tironé (1,2), contact: alima@ciencias.usc.es (1) IMEDEA-UIB (CSIC) Esporles, Spain. (2) SOCIB, Palma de Mallorca, Spain (3) Environmental Consultant

01 ABSTRACT

The coastal HF Radar is a key observing facility from the Balearic Islands Coastal Observing and Forecasting System (COBS, Tironé et al. 2013), a multi-platform system that provides oceanographic data and modelling results. The HF radar derived current fields have been quantitatively validated against both moored current-meter and Lagrangian drifters. The analysis of the low-frequency circulation patterns shows that the southward flow in the channel is characterized by a marked seasonal cycle.

The SOCIB Western Mediterranean Operational Forecasting System (WMOP) provides high-resolution model outputs in the Ibiza Channel. A comparison exercise was performed between the model surface currents and the radar observations, aiming to evaluate the simulated surface velocities over the radar coverage.

02 IBIZA CHANNEL

Complex oceanographic processes affect the circulation in this area, influenced by the Northern (NC) and Balearic (BC) currents. NC provides old Mediterranean water masses from the Gulf of Lion, with strong current flow during winter and weaker during summer months. The NC through the Ibiza Channel can turn eastward probably due to a temporary blocking anticyclonic structure, or can continue southward to the Algerian Sea. The main patterns are highly influenced by density, strongly affected by the shallow topography, and by wind events. There is a high current variability in the area which makes it a challenge for oceanographic studies (Mason and Pascale, 2013).



Related posters: WMOP general presentation - Moura et al. WMOP data comparisons - Heupel et al. SOCIB Data Centre - Tironé et al. and SOCIB presentation - Tironé et al.

03 HF RADAR AND WMOP MODEL

HF RADAR QA/QC AND VALIDATION

QA/QC procedure - additionally to COGAD QC, based on international references, MARACOOS (Riley et al. 2012) and USCB (Ernsty and Venturini). Radial parameters selected as system performance quality

- Signal to Noise Ratio
- Total number of Radar Vector solutions
- Averaged Bearing of all radial vectors
- Correlation between model data and measured Bearing
- QC flags have been adopted based on SeaDataNet project.

VALIDATION - Total and radial currents have been compared against a surface current meter and an ADCP located at the mooring in the Ibiza Channel. This comparison gives a good correlation for the period from October 2013 to March 2014 except for some sea functioning periods. An intensive drifter validation exercise was performed in September 2014 (when the current meter and the Radar-HF have a correlation of 0.8 for U and 0.54 for V and RMSD of 3.08 and 4.07 cm/s respectively). For drifter analysis, the correlation coefficients vary between 0.74 and 0.85, and for Foraminifera analysis between 0.60 and 0.76.

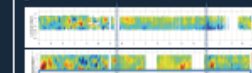
HF Radar system: Two Tx/Rx antennas situated at Ibiza and Formentor. Tx Central Frequency: 13.5 MHz. Bandwidth: 90 kHz. Radar Resolution: 1.5 km, angular resolution: 5 deg. Radar Range - 50 km. Temporal Coverage: 75 min, mooring average, hourly data. Grid resolution: 3 km

WMOP MODEL

- WMOP configuration:
 - ROMS
 - From Gibraltar to Sardinia (PWN-PC, 30°N-44°N)
 - Spatial resolution: 1.6 to 2.2 km
 - Vertical grid: 32 sigma levels
- Boundary conditions from MFS
- Atmospheric forcing from HIRLAM (2h, 1025)
- Rivers runoff
- Weekly model reinitialization from the outputs of a 3-week spin-up simulation initialized from MFS

04 COMPARING HF RADAR WITH WMOP MODEL

04.1 HÖVMOLLER DIAGRAMS (38.7°N)



- A seasonal variability appears for both data sets (high variability in winter, low variability in summer). No permanent and synoptic patterns appear in this area.
- Good spatial and temporal results in winter in both model and radar, with poor pattern correspondence.
- General overestimation of the current intensity in the model (maximum values approx. 30% higher).

04.2 ROTATORY SPECTRUM ANALYSIS:



- Rotatory power spectra estimates for HF radar and WMOP.
- distances circulation is constant
- the traveled frequency (around 10h in this area)
- diurnal frequency (daily 0.1)
- semidiurnal frequency at NC for the HF radar data (but frequency not included in the model)

04.3 ROOT-MEAN SQUARE DEVIATION:



- In general RMSD are higher for V-component.
- Seasonal variability appears, with higher RMSD in winter and lower RMSD in summer.
- This variability is related to the seasonal variability of the current data (higher in winter, lower in summer).

04.4 WIND EVENT SNAPSHOTS: Generally good agreements between model and radar surface currents are found during strong wind events.

05 PRINCIPAL MODES OF VARIABILITY IN BOTH WMOP AND RADAR

An EOF analysis has been applied to HF radar data (October 2013 to April 2015), to study the temporal evolution of the main large scale and mesoscale circulation features. Radar grid nodes with more than 80% of trajectory days are considered in the dataset. For each radar node, there is a continuous time series of 332 days. The observed and simulated modes 1 and 2, which explain 40 and 40% of the total variability respectively, have similar patterns. However, there are discrepancies in the time amplitude evolution.



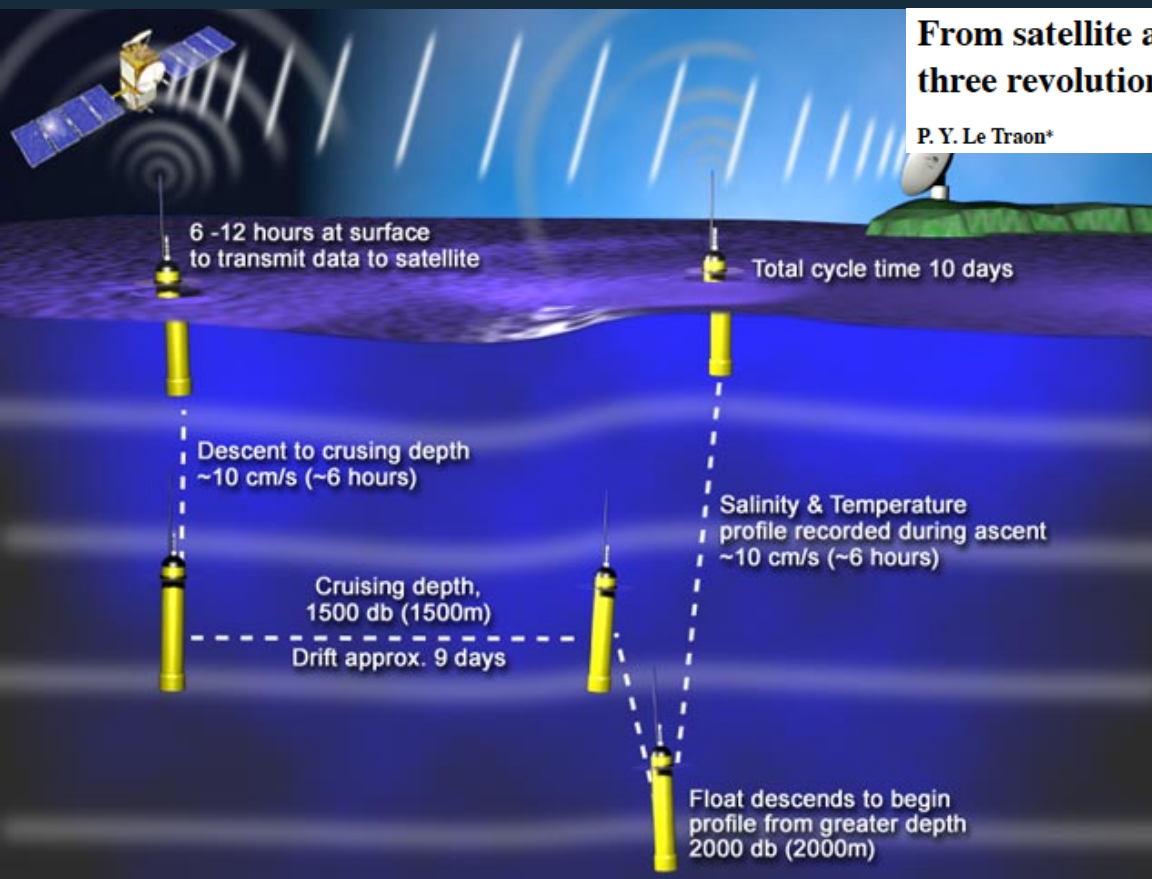
References:

- Ballesteros, J. 2012. Validation of the coastal HF radar system and its application to oceanographic and meteorological studies. PhD thesis, USC, 104 pp.
- Ernsty, M. 2012. Validation of the coastal HF radar system and its application to oceanographic and meteorological studies. PhD thesis, USC, 104 pp.
- Heupel, E. E., J. Marnett, W. Juez, B. Moura, J. Tironé, J. Allen, J. López-Jurado, M. Torner. 2013. Oceanographic and meteorological data and modelling results from the Balearic Islands Coastal Observing and Forecasting System (COBS). Environmental Modelling, 48: 1-15.
- Mason, J. 2013. Validation of the coastal HF radar system and its application to oceanographic and meteorological studies. PhD thesis, USC, 104 pp.
- Tironé, J. 2013. Validation of the coastal HF radar system and its application to oceanographic and meteorological studies. PhD thesis, USC, 104 pp.

06 SUMMARY AND CHALLENGES

- HF radar is a valuable tool to validate WMOP surface currents in the Ibiza Channel.
- An automated QA/QC procedure, based on the system performance, is implemented in COBS for radar facility.
- A drifter validation exercise was performed in September 2014, together with a continuous validation against a moored current meter in the Ibiza Channel to ensure the quality of the radar data.
- WMOP overestimates by about 30% of the surface current intensity with respect to the radar observations in the Ibiza Channel.
- There is a good agreement in the spatial structures between WMOP model and HF radar data for periods of strong high wind events.
- EOF analysis shows similar patterns, however, there is a discrepancy between amplitude evolution.
- HF radar data assimilation is expected to improve WMOP surface currents in the Ibiza Channel.

Last decade: successful Argo international programme -Euro-Argo-.

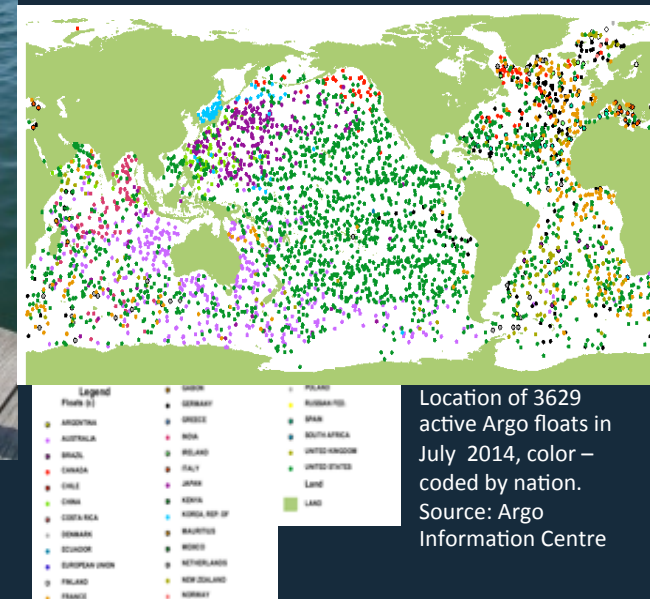


Schematic diagram of a single Argo float cycle

From satellite altimetry to Argo and operational oceanography: three revolutions in oceanography

P. Y. Le Traon*

Ocean Sci., 9, 901-915, 2013



Location of 3629 active Argo floats in July 2014, color-coded by nation. Source: Argo Information Centre

<http://www.euro-argo.eu>

262 floats with biogeochemical sensors
638 European floats (18%)

Argo Programme -combined with satellite altimetry- allowed characterisation:

STATE OF LARGE SCALE OPEN OCEAN CIRCULATION

Next decade... Ocean Variability

Changing currents: a strategy for understanding and predicting the changing ocean circulation

BY HARRY L. BRYDEN^{1,*}, CAROL ROBINSON² AND GWYN GRIFFITHS³

¹*Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, European Way, Southampton SO14 3ZH, UK*

²*School of Environmental Sciences, University of East Anglia, Norwich Research Park, Norwich NR4 7TJ, UK*

³*National Oceanography Centre, University of Southampton Waterfront Campus, European Way, Southampton SO14 3ZH, UK*

Within the context of UK marine science, we project a strategy for ocean circulation research over the next 20 years. We recommend a focus on three types of research: (i) sustained observations of the varying and evolving ocean circulation, (ii) careful analysis and interpretation of the observed climate changes for comparison with climate model projections, and (iii) the design and execution of focused field experiments to understand ocean processes that are not resolved in coupled climate models so as to be able to embed these processes realistically in the models. Within UK-sustained observations,

Marine research in the past 20 years has focused on defining the **present day** ocean circulation. From these measurements of ocean circulation, we begin to understand how biogeochemical distributions are set and how the ocean and atmosphere interact to determine the present climate [4].

The key issue for the next 20 years is to understand how the ocean circulation varies on inter-annual to decadal time scales

And we need... “Careful analysis and interpretation of climate changes”

In April 2009, the array recorded a 30% drop in average current strength that persisted for a year, reducing the amount of heat transported to the North Atlantic

Oceans under surveillance

Three projects seek to track changes in Atlantic overturning circulation currents.

BY QUIRIN SCHIERMEIER

In April 2009, the array recorded a 30% drop in average current strength that persisted for a year, reducing the amount of heat transported to the North Atlantic

EBB AND FLOW

The 'global conveyor belt' transports warm Atlantic Ocean surface water (orange) to the poles and cool deep water (blue) to the tropics.



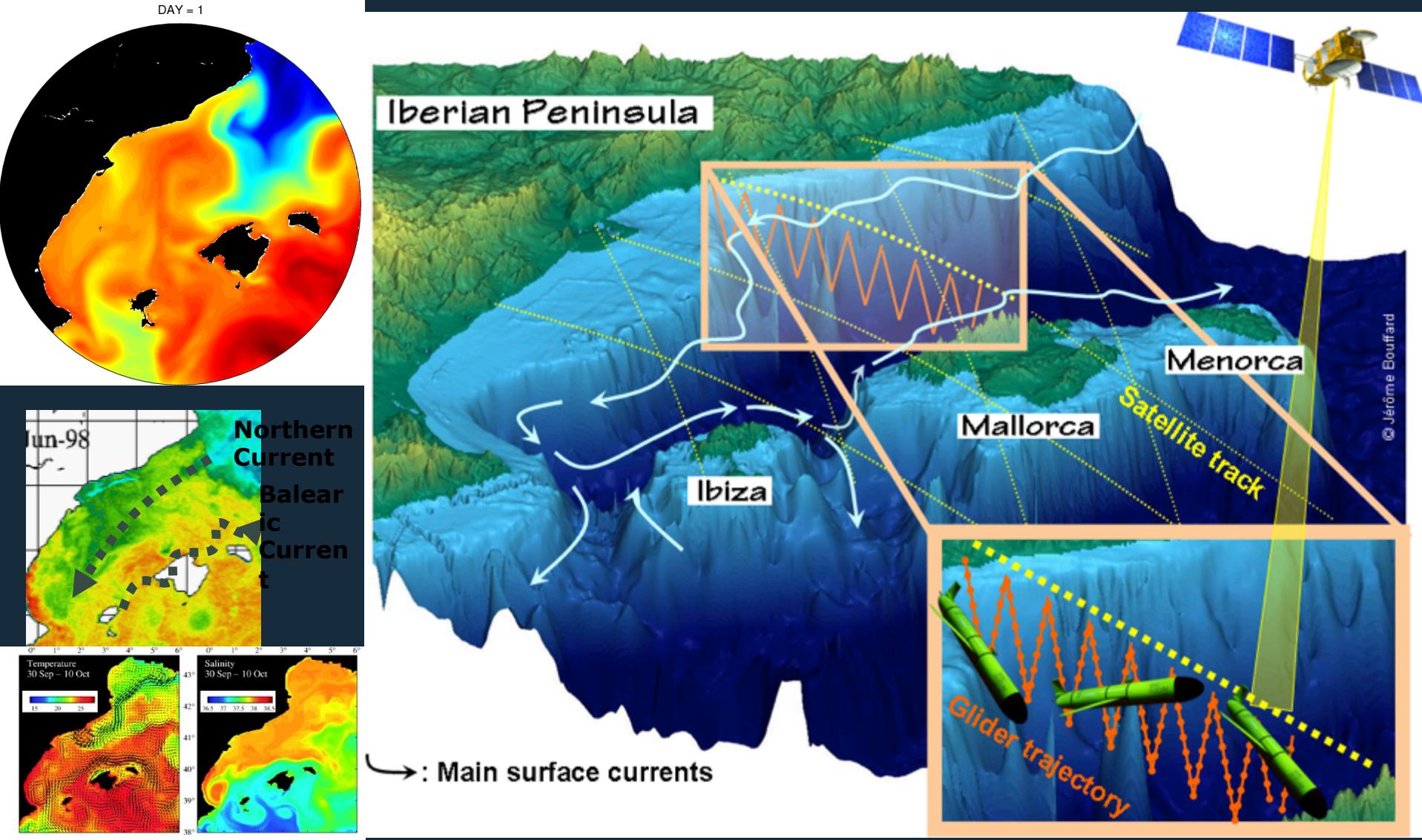
The real challenge for the next decade...:

To use and integrate these new technologies to carefully and systematically

- Monitor the variability at small scales, e.g. mesoscale/weeks, to
- Resolve the sub-basin/seasonal and inter-annual variability and by this
- Establish the decadal variability, understand the associated biases and correct them ...

Balearic basin (fronts, mesoscale eddies, blocking, hotspot, ecosystem response)

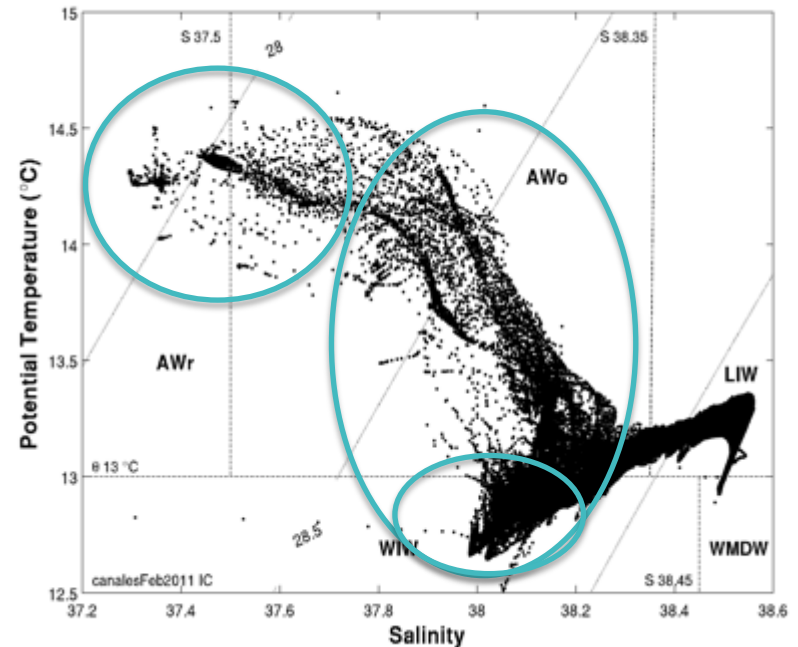
.... Ideal lab to study global ocean problems



Balearic Basin: Ibiza Channel 'choke point'



- Narrow channel with sill
- Northern Current – south
- Inflows Atlantic Water (AW) - north
- 'Blocking' eddies (WIW)
- Governs important N/S exchange
- Impact spawning grounds Atlantic bluefin tuna



Gliders Facility: Science



**Mesoscale – Submesoscale /
Vertical motions - biogeo effects**

**Eddy/mean flow interactions –
Blocking effects General Circulation**

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L14607, doi:10.1029/2009GL038569, 2009

Vertical motion in the upper ocean from glider and altimetry data

Simón Ruiz,¹ Ananda Pascual,¹ Bartolomé Garau,¹ Isabelle Pujol,² and Joaquín Tintoré¹

JGR, 2010

**Coastal and mesoscale dynamics characterization using altimetry
and gliders: A case study in the Balearic Sea**

Jérôme Bouffard,¹ Ananda Pascual,¹ Simón Ruiz,¹ Yannice Faugère,²
and Joaquín Tintoré^{1,3}

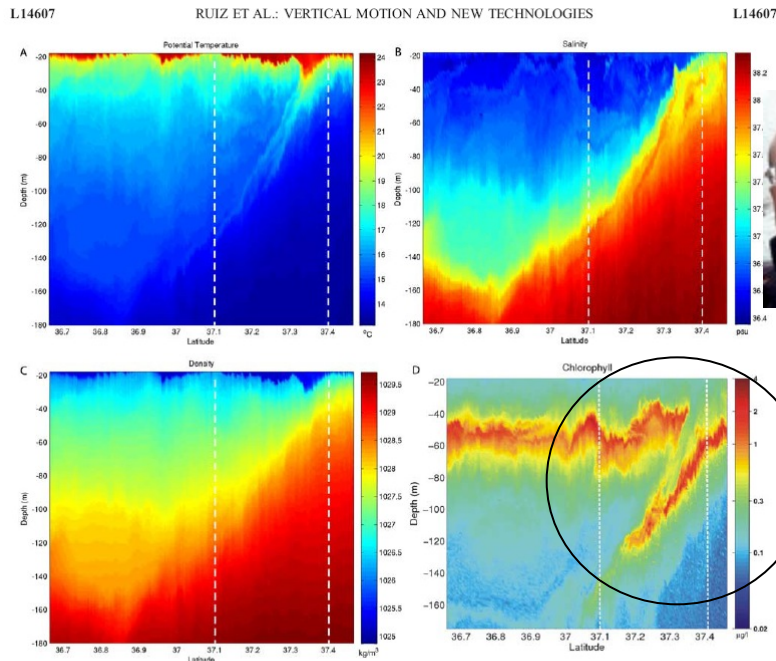
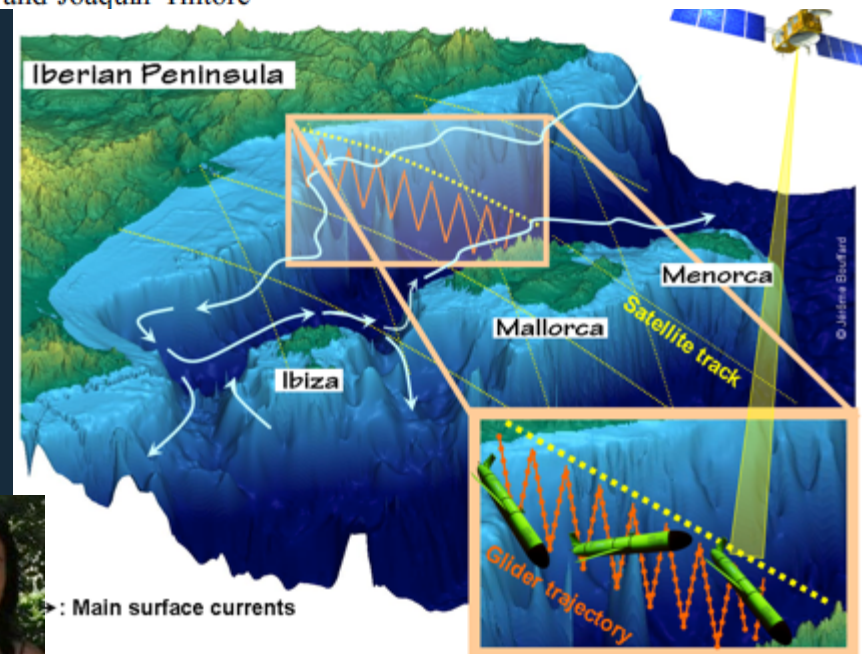


Figure 2. Vertical section of temperature (°C), salinity (PSU), density (kg/m³) and chlorophyll (µg/l) from glider section 2 (dashed magenta in Figure 1). White dashed lines define sub-section in the northern part of the domain.



Gliders Facility: Operational

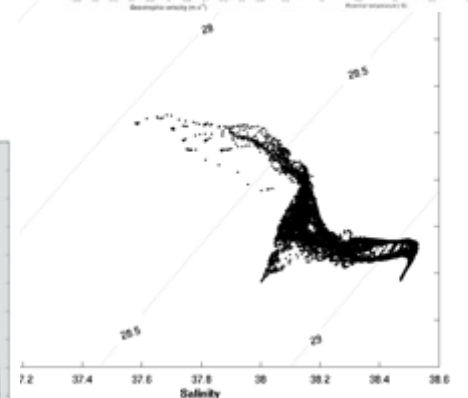
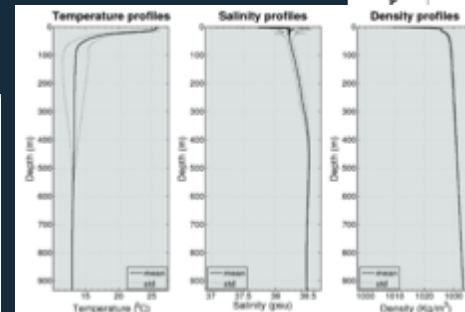
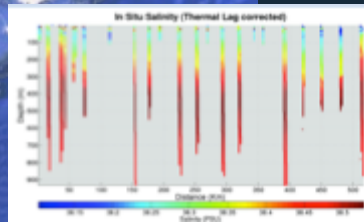
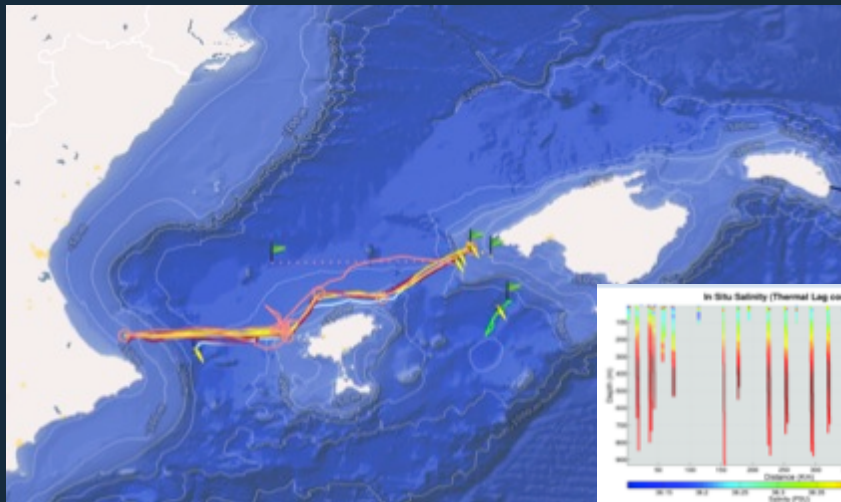
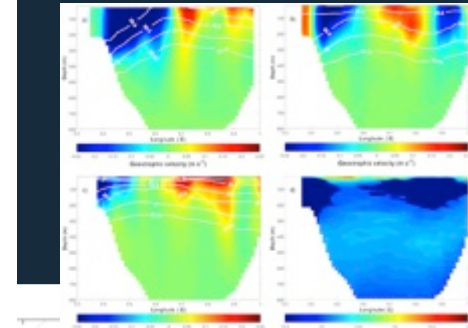
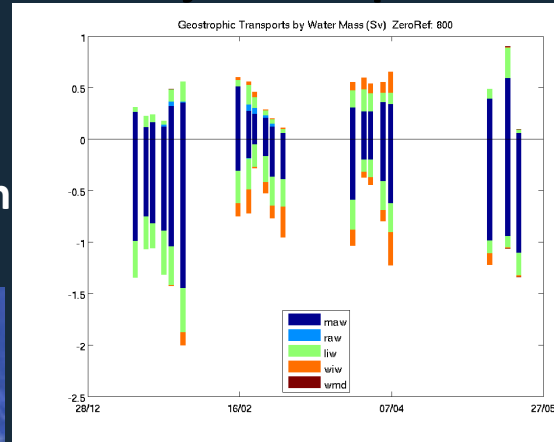
GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L20604, doi:10.1029/2012GL053717, 2012

Autonomous underwater gliders monitoring variability at “choke points” in our ocean system: A case study in the Western Mediterranean Sea

Emma E. Heslop,¹ Simón Ruiz,¹ John Allen,^{2,3} José Luís López-Jurado,⁴ Lionel Renault,⁵ and Joaquín Tintoré^{1,5}

- After 32 glider missions (started in 2006), + 17.000 profiles (30 Euros/profile)
- Since January 2011; routine operation

Major transport changes



Conclusions Ibiza channel choke point:

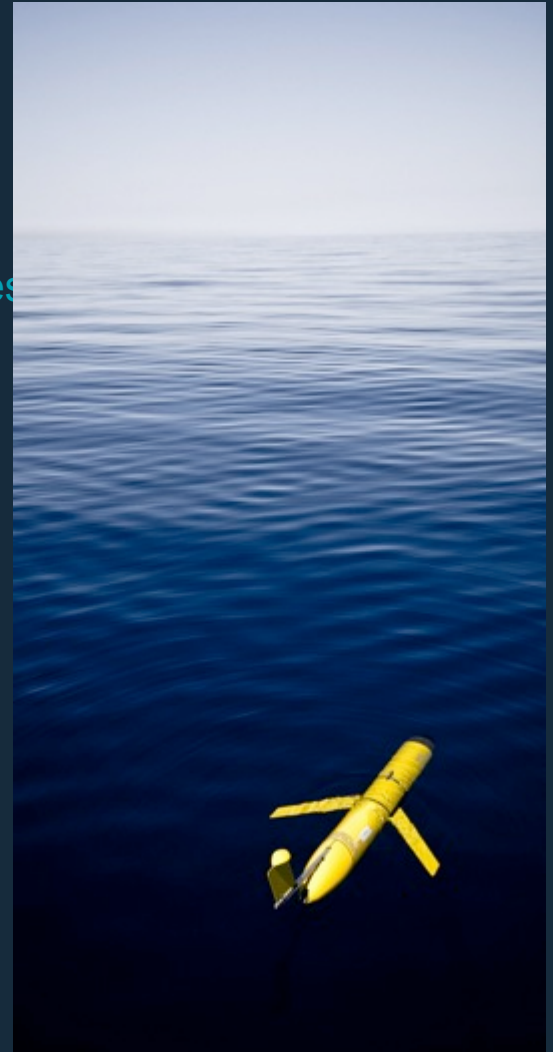
Unravel components of the variability:

- High sub seasonal variability - 3 causes
- Seasonal components are identified - NC and blocking eddies
- Non seasonal nature of inflows

Impact:

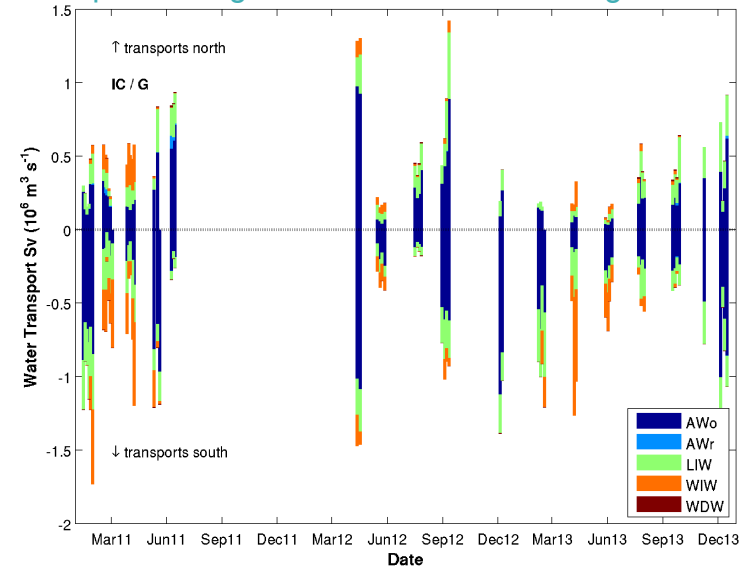
- Changes our view of the exchange
- Better constrain regional models
- Impact on fisheries
- Implications for basin scale circulation
- Place historical observations in context

>> a quiet revolution



Glider and Modelling Facilities; Ibiza channel choke point variability

Transport through the Ibiza Channel from gliders



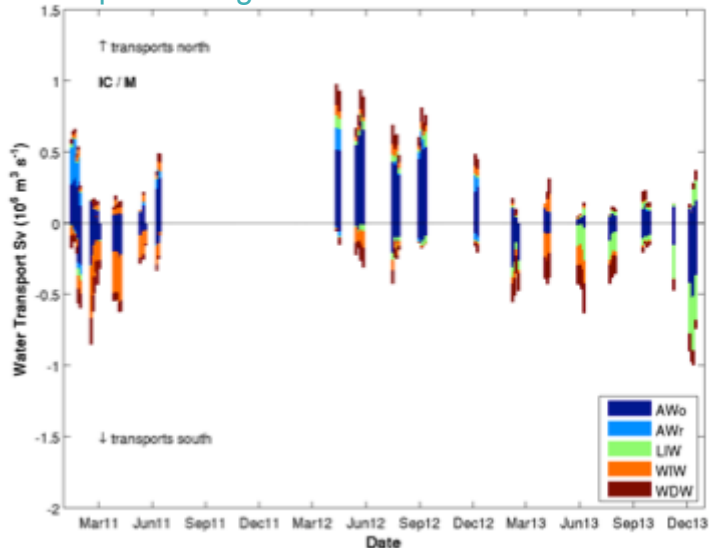
Ibiza Channel transports

Transport through the Ibiza Channel (IC) provides a method of comparing circulation and water mass exchange. Glider to model can see clear similarities and differences.

WMOP 'gets right':

- Seasonal cycle in southward flow present, strongest in winter
- WIW is present in winter
- AW inflows represented

Transport through the Ibiza Channel from WMOP

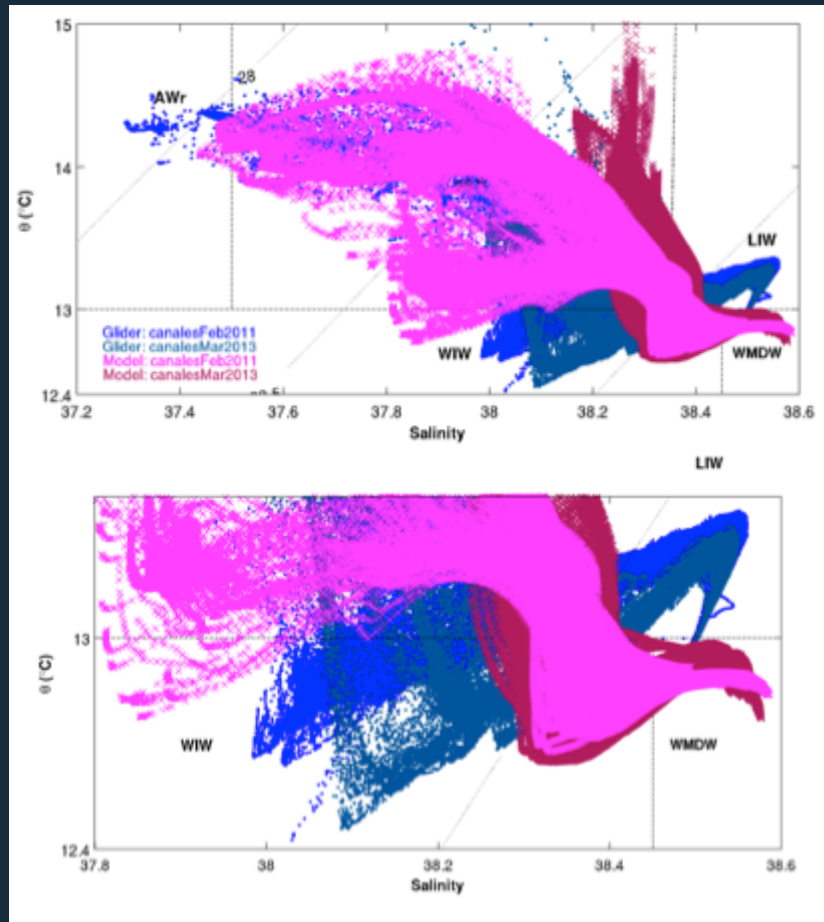


WMOP key differences:

- LIW is not always present
- Southward transport low

Geostrophic transport by water mass in the IC, from glider (above) and WMOP (below). Each bar represents the water mass transport for a single (2-day) transect of the deep (central) part of the IC. Total bar height is the total volume of water transported, water masses are in colour.

Glider and Modelling Facilities; Ibiza channel choke point variability



Water masses 2011 and 2013

- Feb 2011 no LIW is present in the model, deep waters mix to WIW and then to the surface
- Mar 2013 the waters with LIW characteristics are not typical LIW, there is no temperature and salinity maximum 'elbow' as in observations

Θ/S for glider (magenta) and WMOP (blue) in the IC for two missions canalesFeb2011 (02/2011) and canalesMar2013 (03/2013), glider and WMOP simulated.

SOCIB Ocean Forecasting Facility

Operational Modeling: ROMS, 2km, to reproduce and maintain mesoscale features, interactions.

Aim :

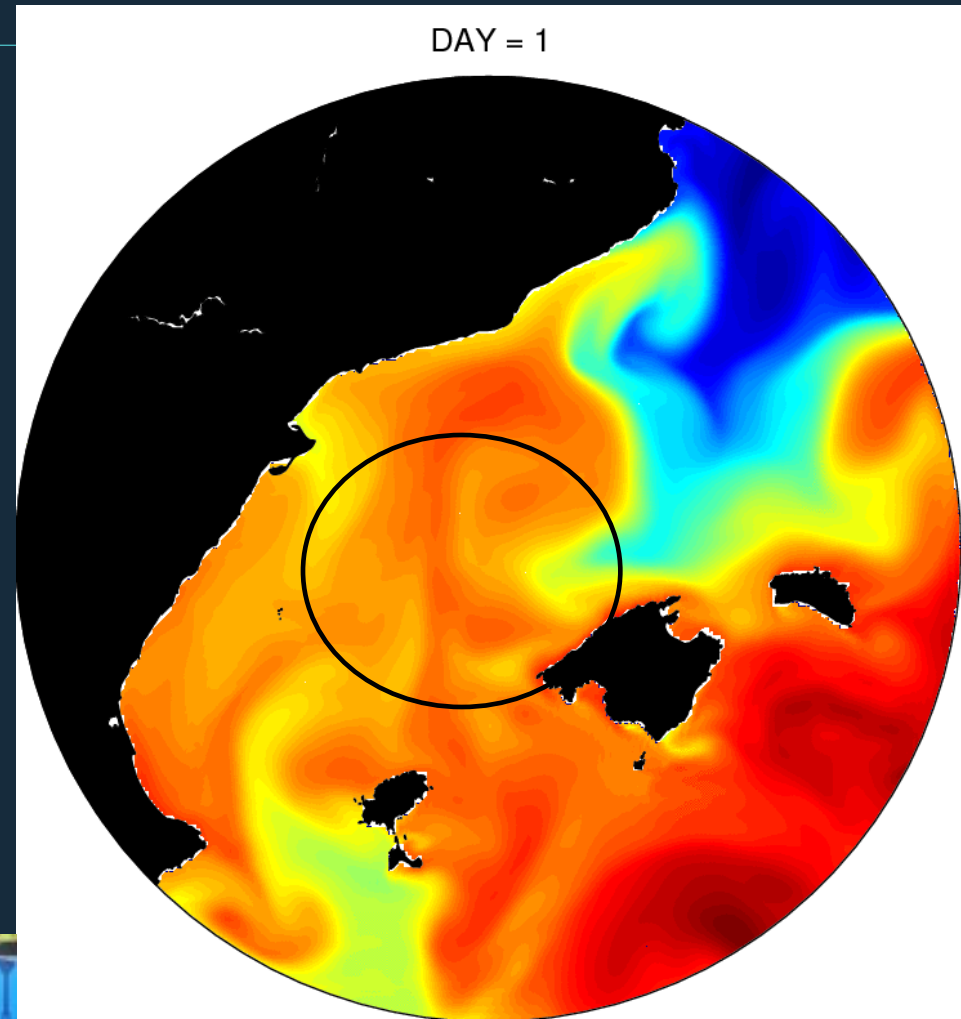
- Validate the model with measurement (gliders, ...)
- From available data and model simulation (5 years), study the formation of mesoscale structures.
- Understand impact of meso/submesoscale on circulation and on the ecosystem



Baptiste Mourre

Mélanie Juza

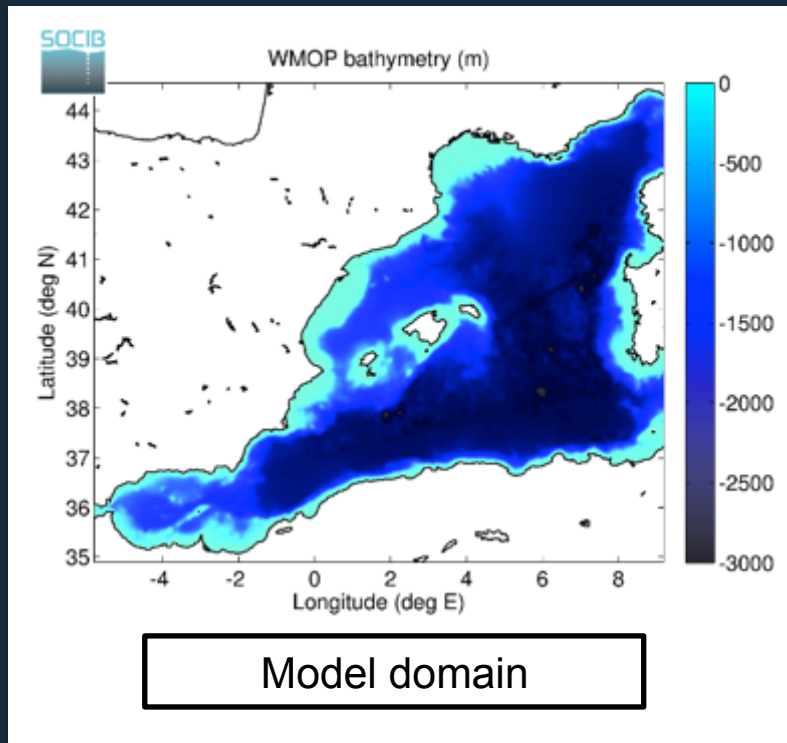
Romain Escudier



SST from 11/2008

SOCIB Ocean Forecasting Facility

WMOP: Western Mediterranean high-resolution Operational model



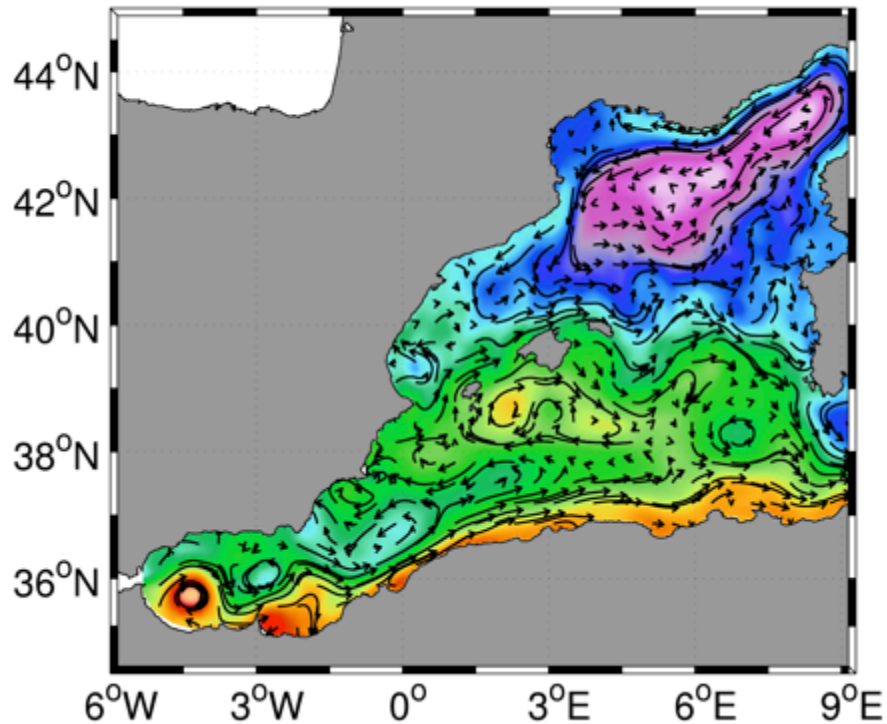
- ✓ Regional configuration of the ROMS model
- ✓ Horizontal resolution: $\sim 2\text{km}$ ($1/50^\circ$)
- ✓ Initial & boundary conditions: Mediterranean Forecasting System ($1/16^\circ$)
- ✓ Atmospheric forcing: AEMET Hirlam (3h, 5km)
- ✓ Rivers (Var, Rhône, Aude, Hérault, Ebro, Júcar)
- ✓ Output variables: temperature, salinity, currents, sea level, vertical velocities

➤ High resolution mesoscale resolving

WMOP simulations: HINDCAST

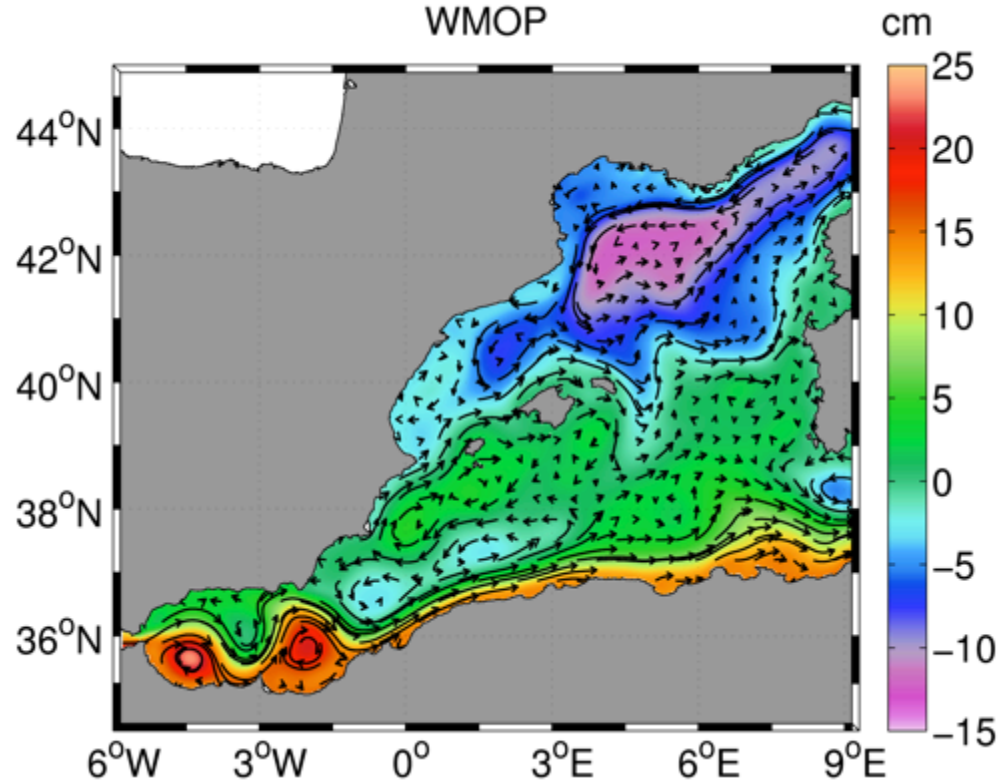
Mean dynamic topography
1993-2012

MDT (Rio et al., 2014)



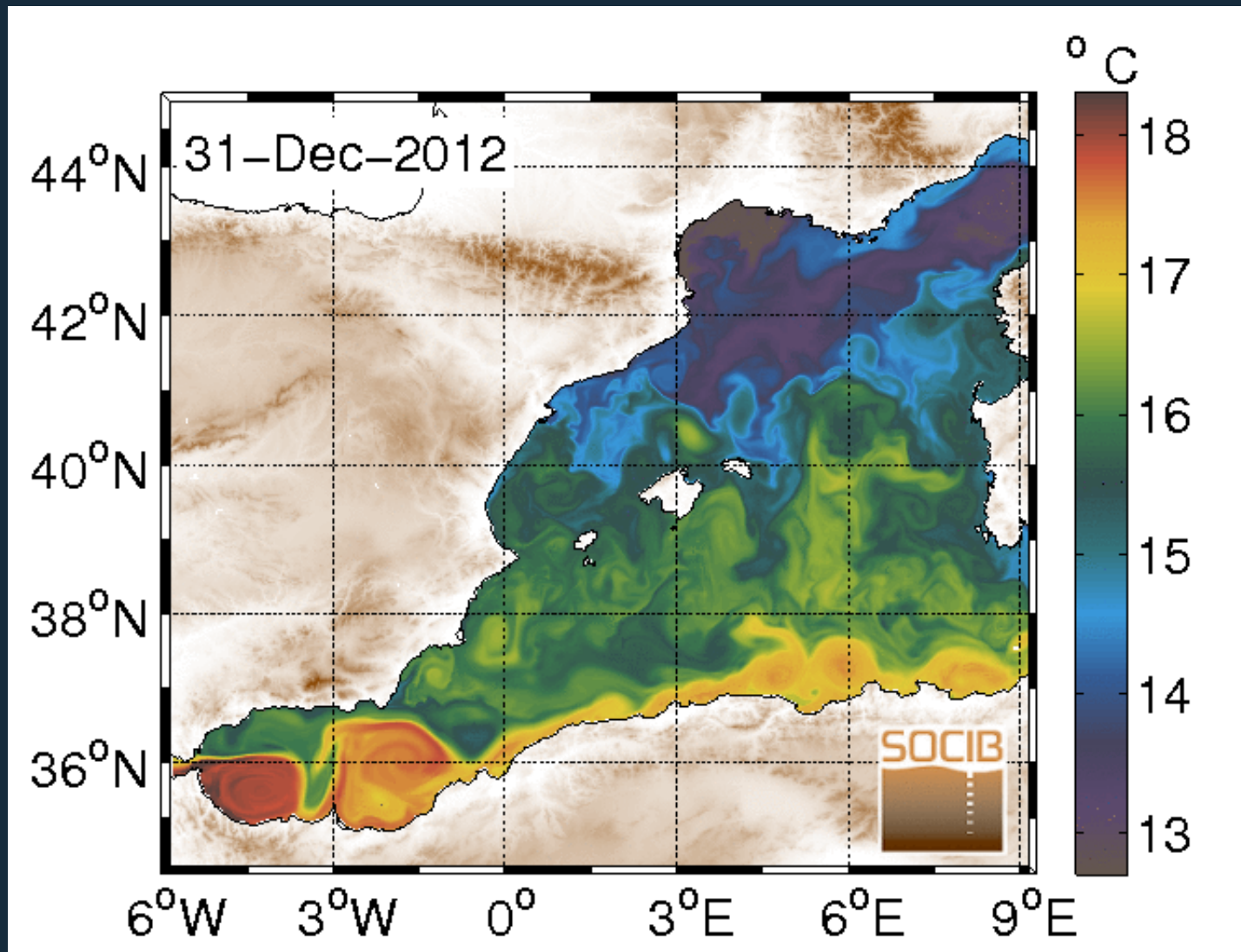
Mean WMOP sea level
2009-2013

WMOP



WMOP simulations: HINDCAST

Sea Surface Temperature evolution - 1 year, 2013



WMOP forecasts systematic evaluation

Delayed mode

Near real-time

www.socib.es



Satellite



Gliders



Ship-based CTDs

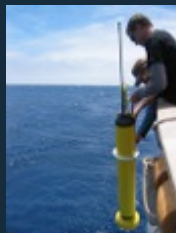


WMOP ocean forecasts

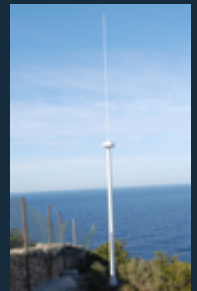
Moorings



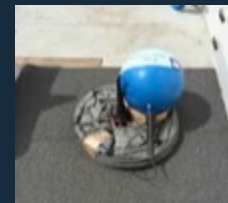
Argo floats



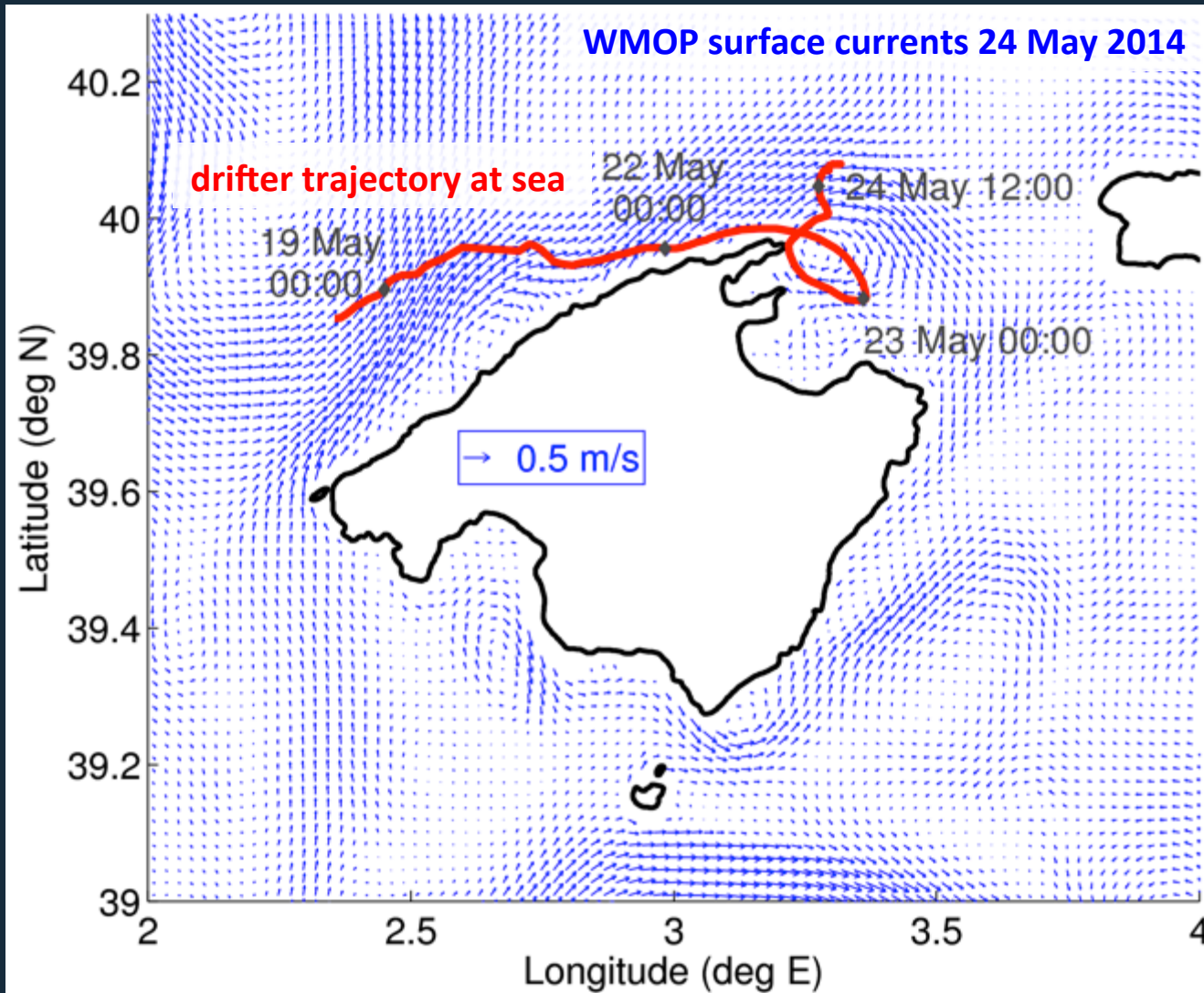
HF radar



Surface drifters



WMOP forecasts: surface currents validation



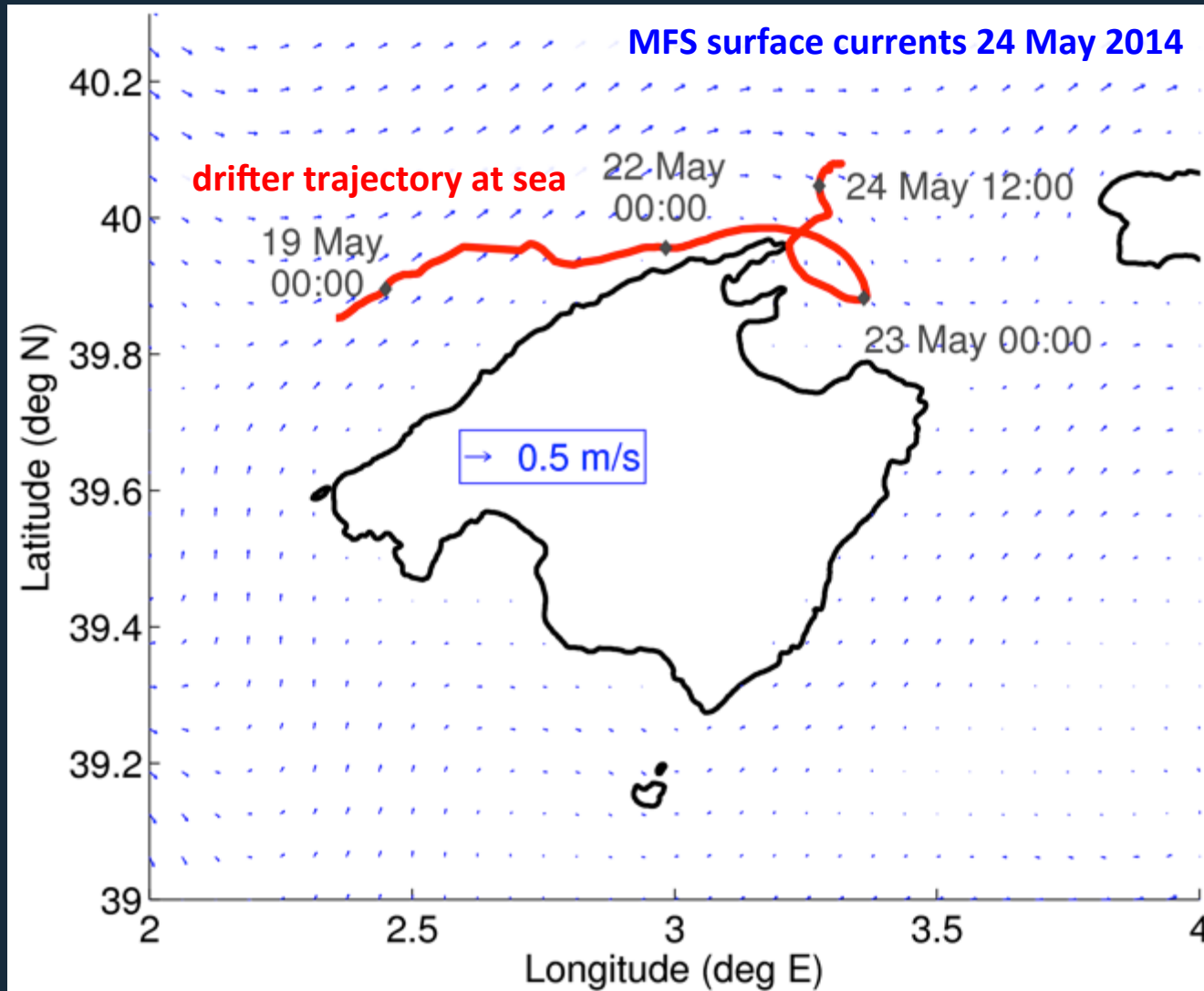
Mean velocity along
the drifter trajectory:

drifter → 0.30 m/s

WMOP → 0.28 m/s

MFS → 0.16 m/s

WMOP forecasts: surface drifter validation



Mean velocity along
the drifter trajectory:

drifter → 0.30 m/s

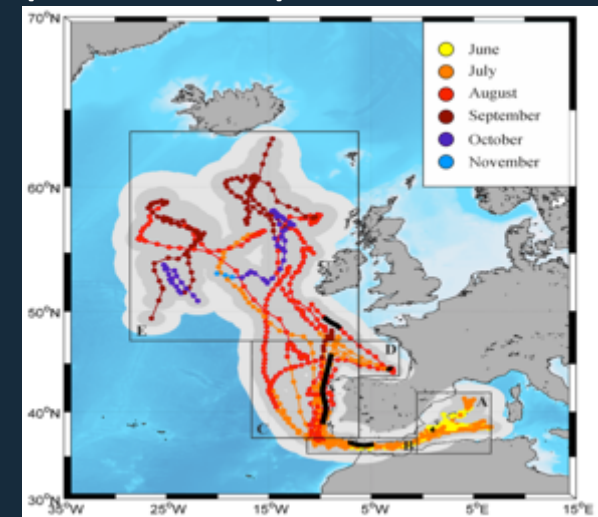
WMOP → 0.28 m/s

MFS → 0.16 m/s

Bluefin Tuna; developing an operational oceanography tool for predicting spawning habitat in W. Med



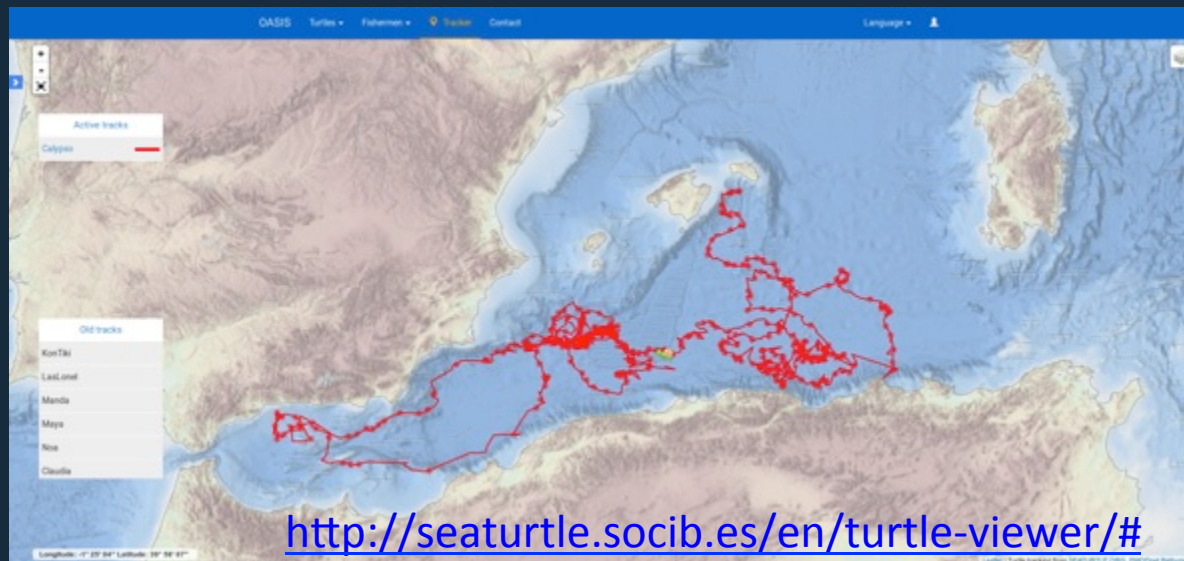
Migration patterns along the year
(Eastern Stock)



Aranda et al, PONE 2013



Sea turtles and its relation to the variability of ocean state – SOCIB&Alnitak OASIS project –



New Jellyfish programme; 2014...

• M1

✓ M2

• M3

• M4

• M5

• M6

• M7

Grumers Observations Observation routes Beach list Administration ▾ laura.prieto ▾ Change language ▾

Observation Map

Specie
Specie: all ▾

Created by
User: all ▾

Observation route
Route: all ▾

Observation station
Station: all ▾

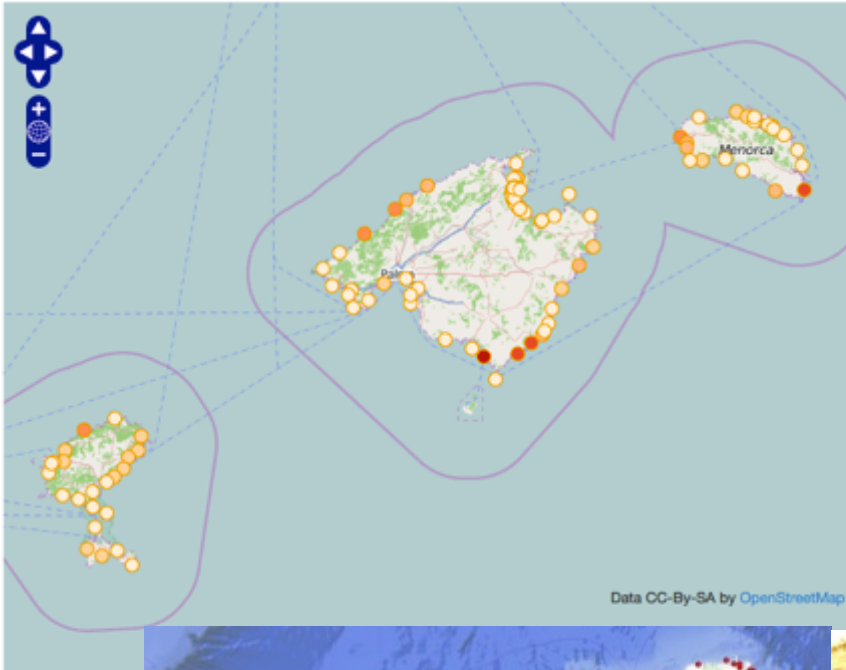
Source

From date

Filter **Export**

Show observation list

Show observation heatmap

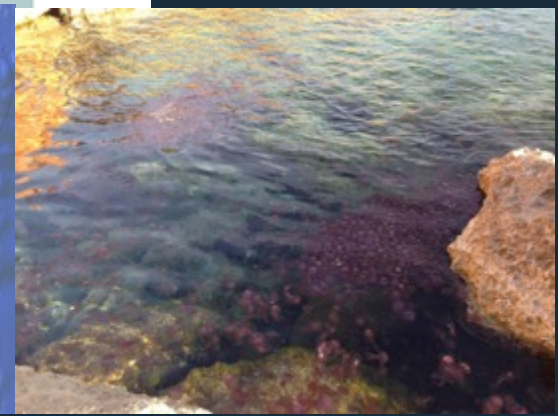


Data CC-BY-SA by OpenStreetMap

• 5 Áreas Marinas Protegidas (9 puntos de observación)

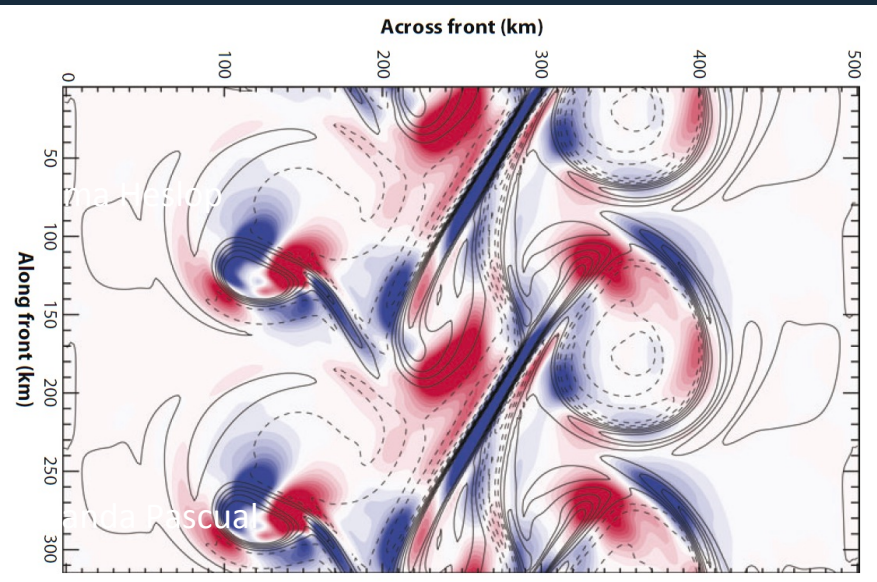
• 33 rutas de los servicios de limpieza con barcas (66 puntos obs.)

• 120 playas (DG Emergencia)

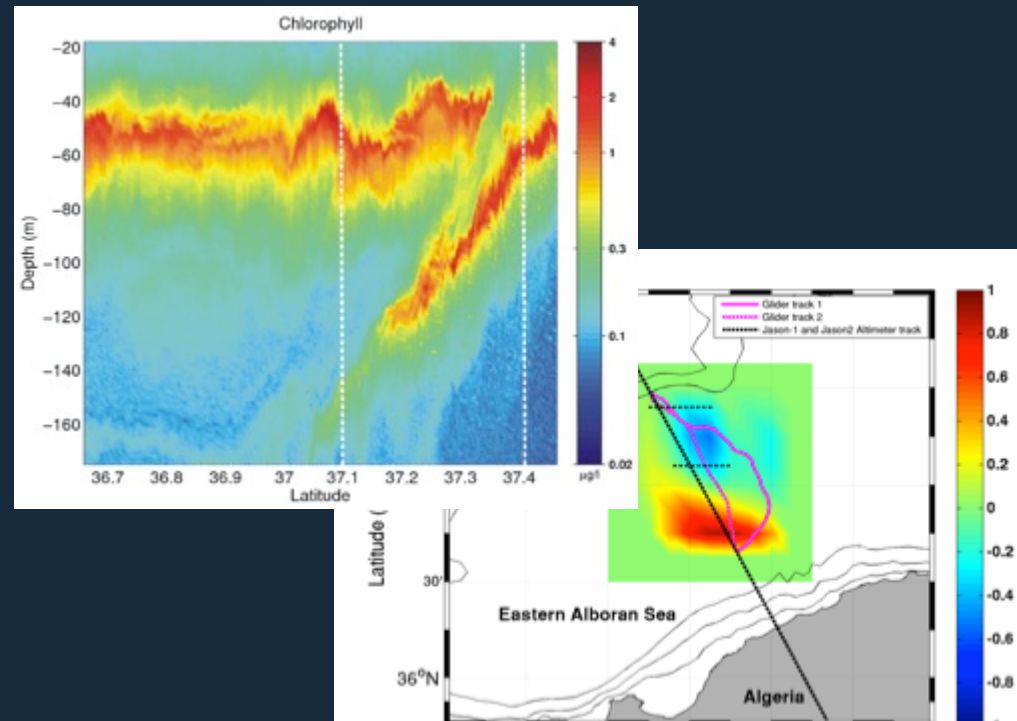


ALBOREX – Perseus project – May 2013. Multi-platform experiment in Alborán Sea

Scientific motivation: Capture the intense but transient vertical exchanges associated with mesoscale and submesoscale features, in order to fill gaps in our knowledge connecting physical process to ecosystem response.



Vertical velocities at 90 m from primitive equation simulations. Lévy et al. (2001); Klein & Lapeyre (2008).



Top: Vertical section of chlorophyll from glider data. Bottom: Quasi-geostrophic vertical velocity at 75 m. Units are $m day^{-1}$. (Ruiz et al. 2009)

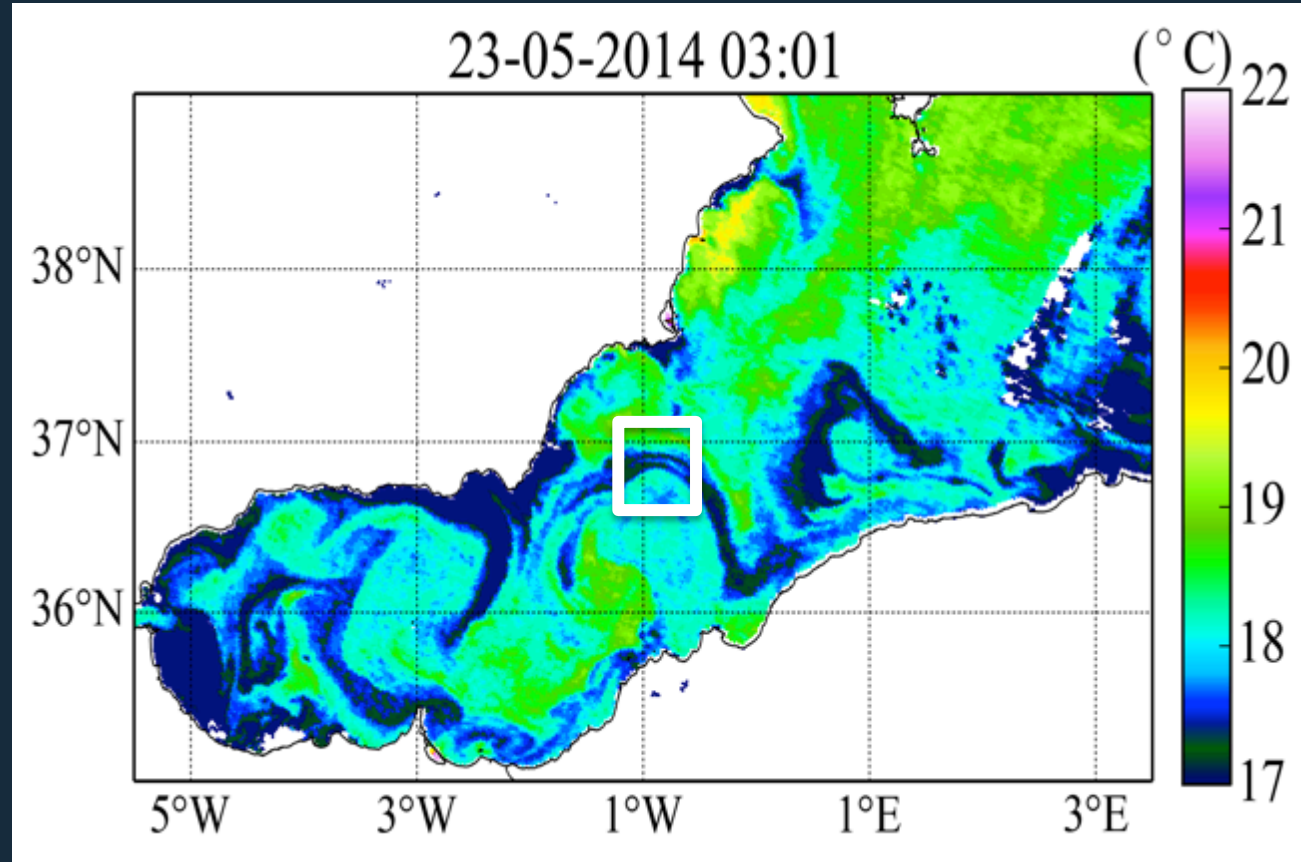
ALBOREX – Perseus project – May 2013. Multi-platform experiment in Alborán Sea

Dates: 24 May – 2 June 2014

Area: Eastern Alboran Sea

Ship: R/V SOCIB

- 25 drifters
- 2 gliders
- 3 Argo floats
- ADCP
- Thermosalinograph
- 80 CTDs
- Nutrients
- Chlorophyll
- Remote sensing
- Modeling



Lead by CSIC (Dr. Ananda Pascual) with strong involvement from SOCIB, OGS, CNR and collaborations with WHOI, IEO, UMA.

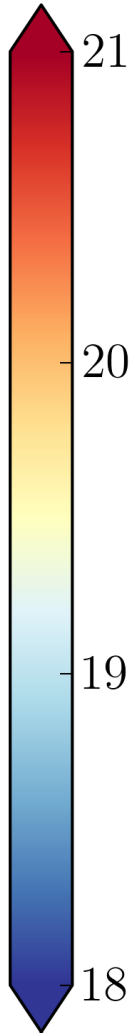
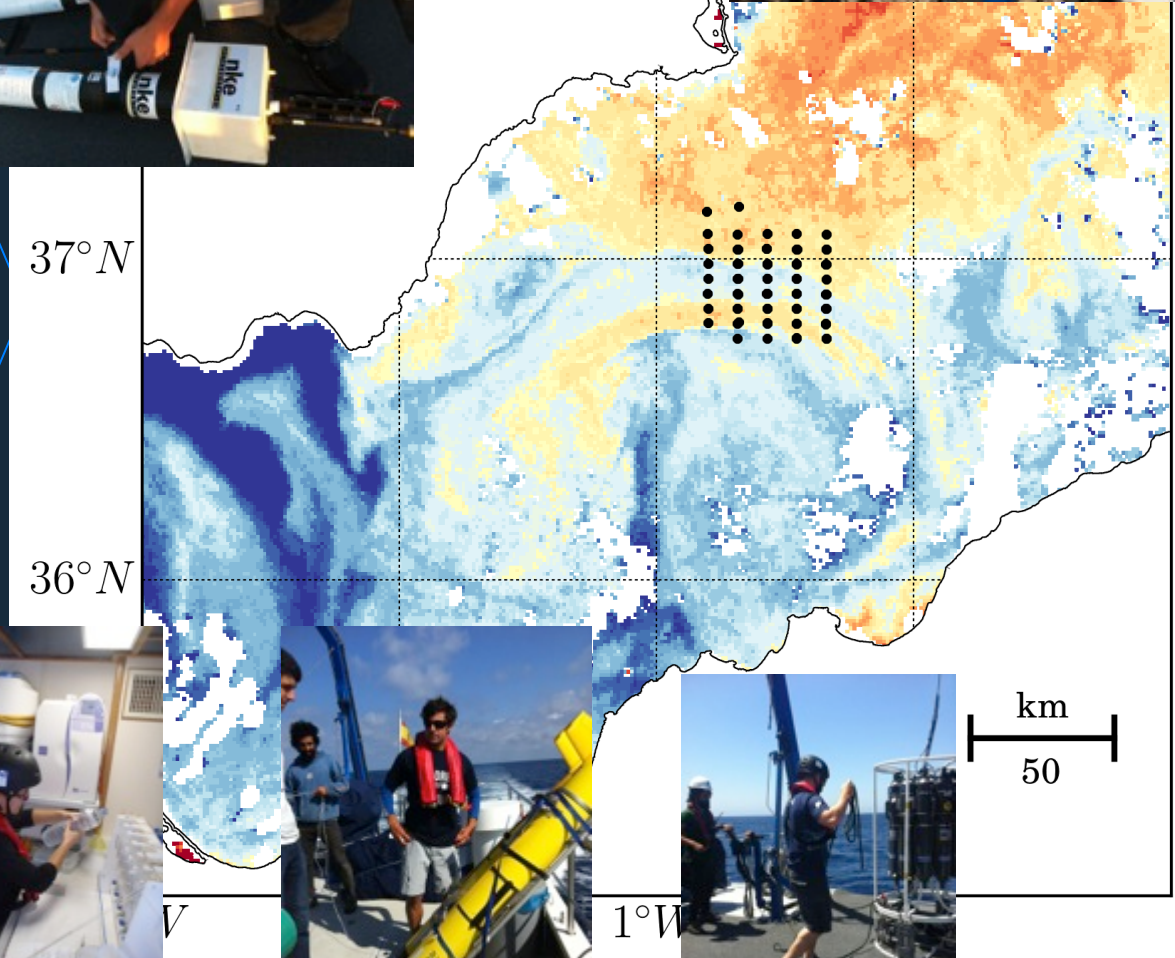


ALBOREX

Need for high-resolution observations (both in situ and satellite) and multi-sensor approaches in synergy with numerical simulations

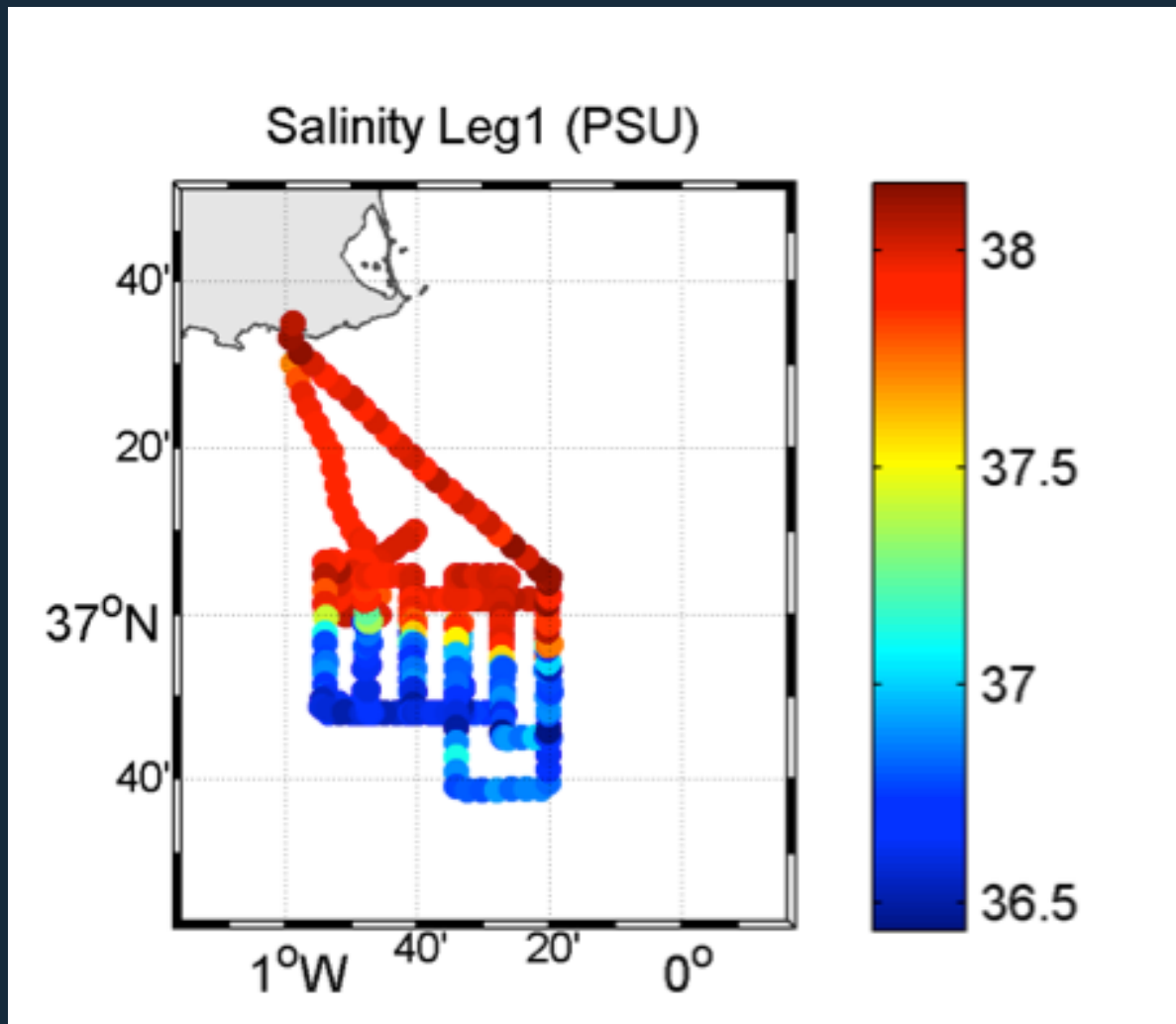


2014-05-



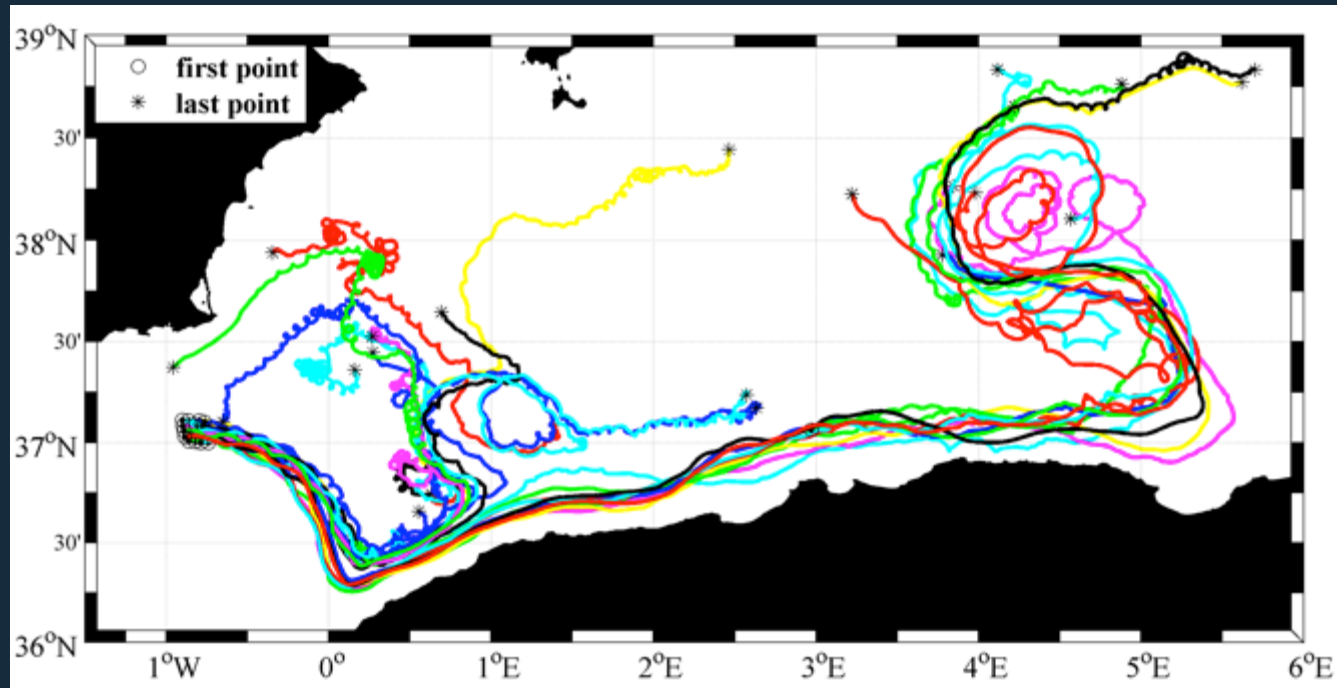
ALBOREX – Perseus project – May 2013. Multi-platform experiment in Alborán Sea

THERMOSALINOGRAPH: SHARP FRONT
CHANGES IN SALINITY FROM 36.4 TO 38.1



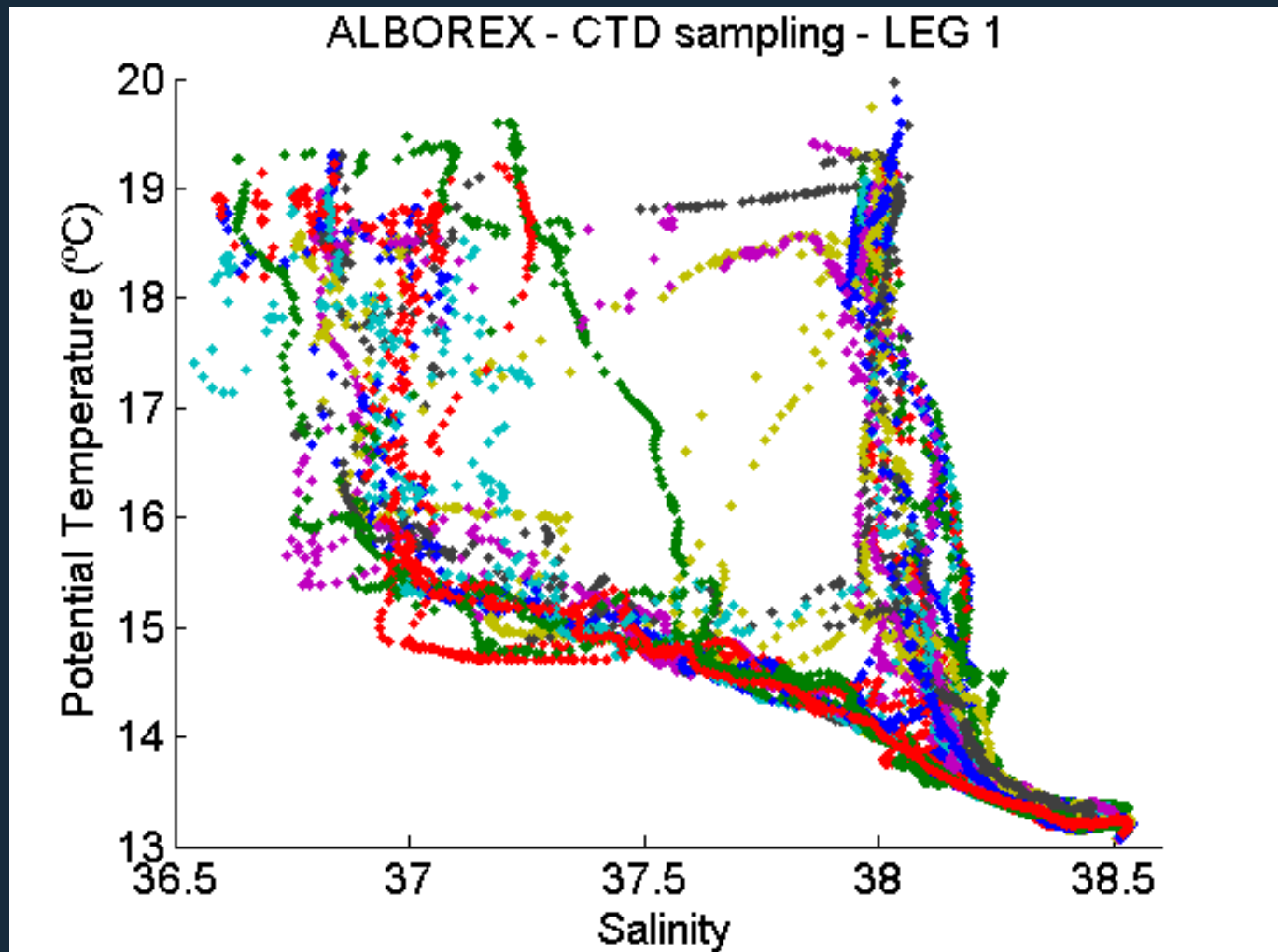
ALBOREX – Perseus project – May 2013. Multi-platform experiment in Alborán Sea

Drifters



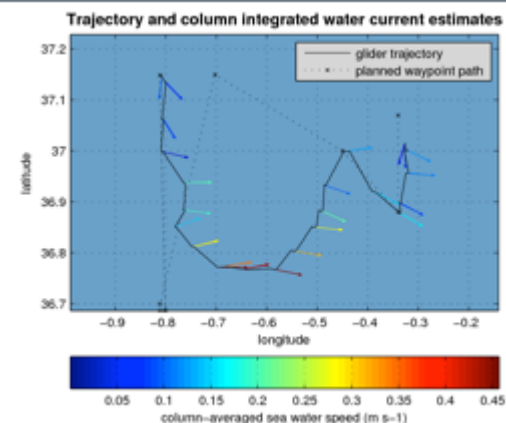
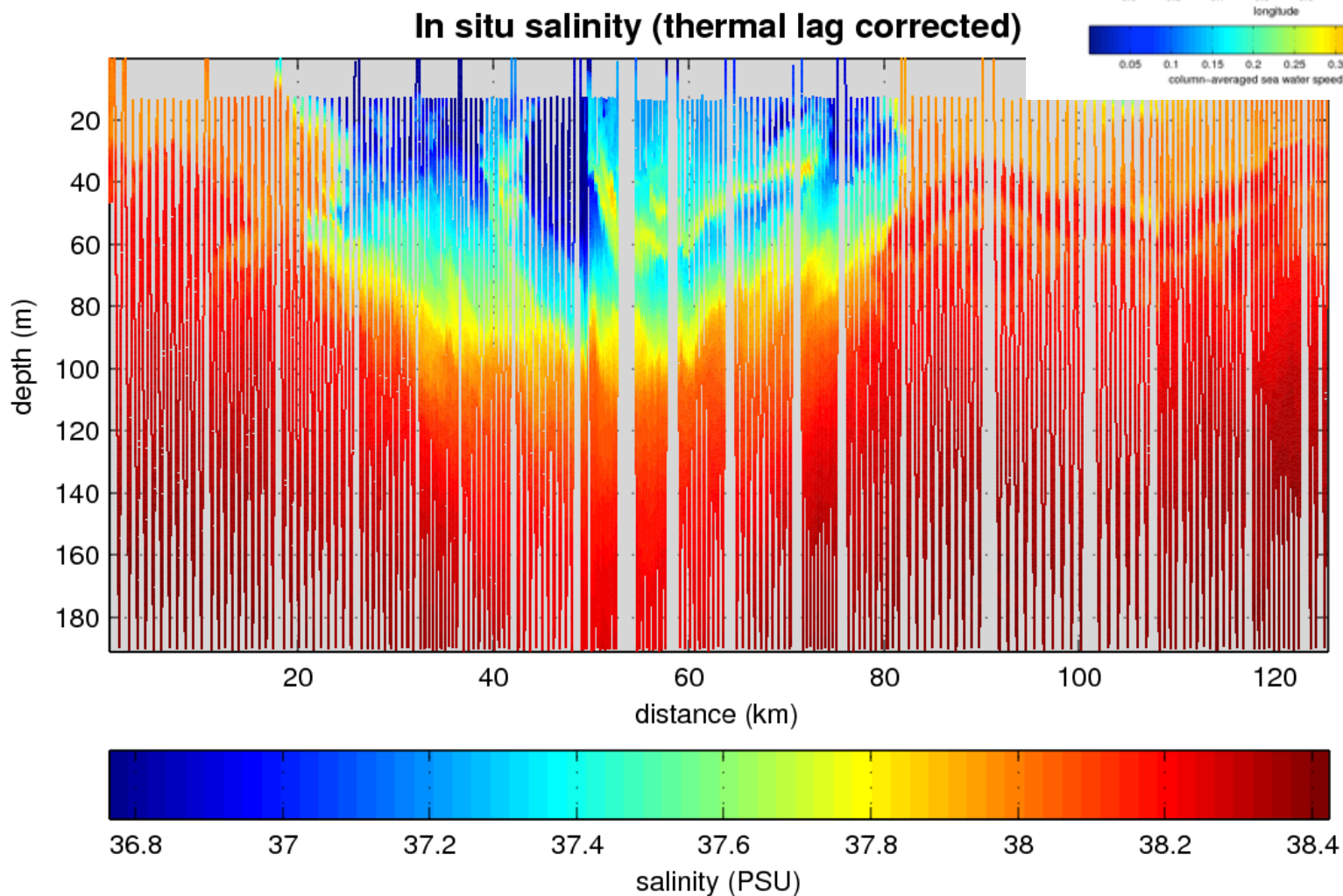
ALBOREX Multi-Platform Experiment

T-S DIAGRAM: ATLANTIC AND MEDITERRANEAN WATERS



ALBOREX Multi-Platform Experiment FINE STRUCTRE

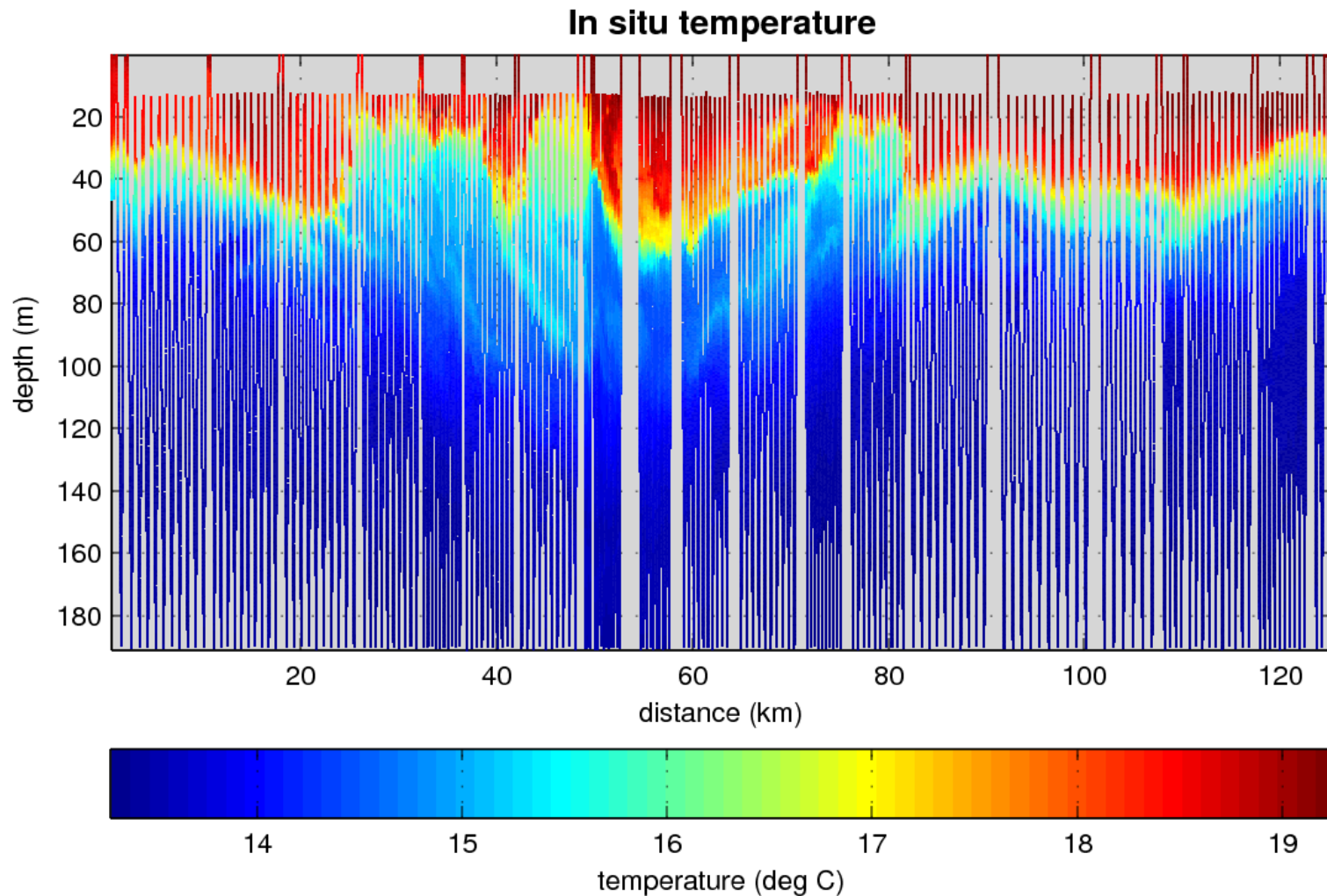
COASTAL GLIDER: RAW DATA



ALBOREX Multi-Platform Experiment

FINE STRUCTRE

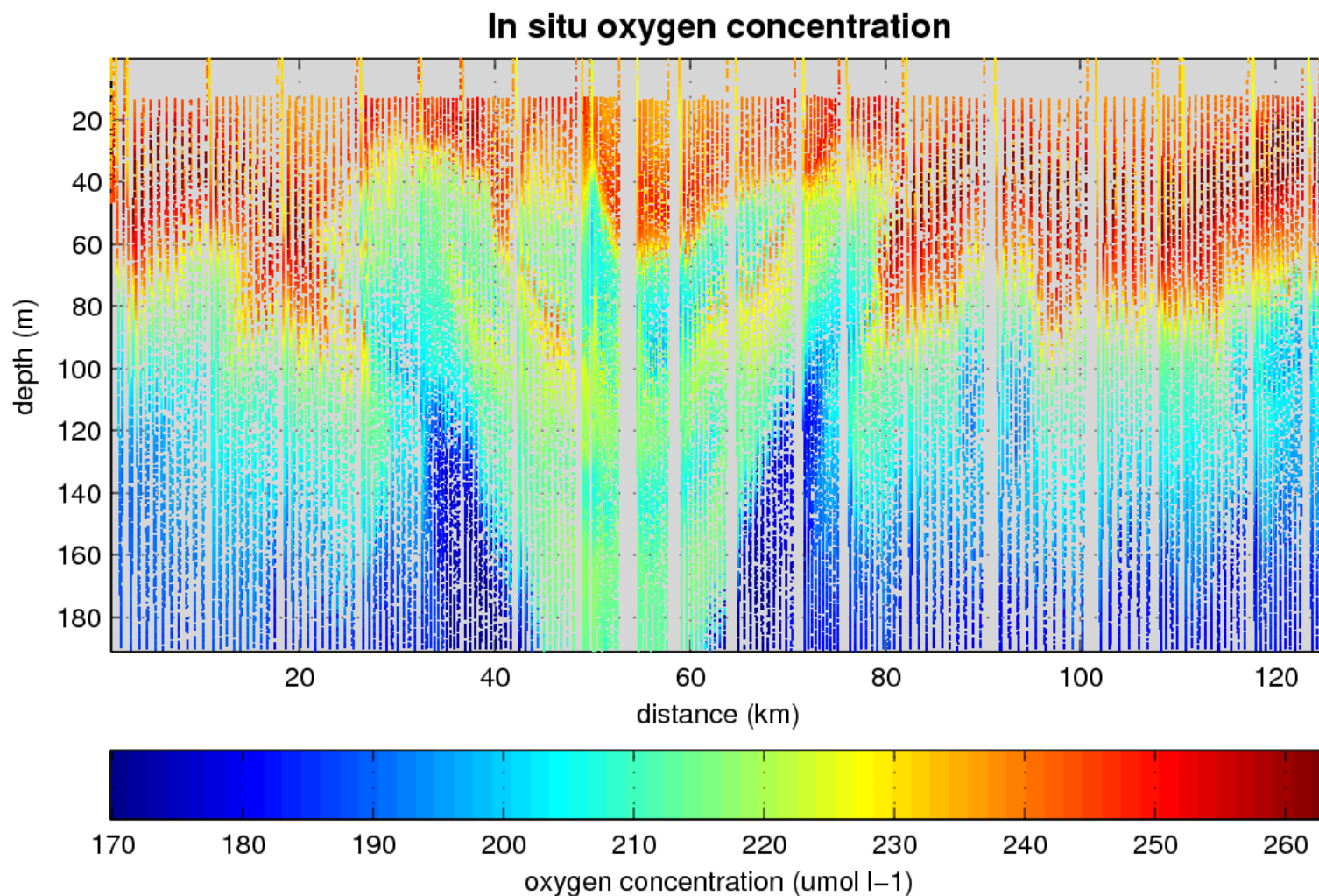
COASTAL GLIDER: RAW DATA



ALBOREX Multi-Platform Experiment

FINE STRUCTRE

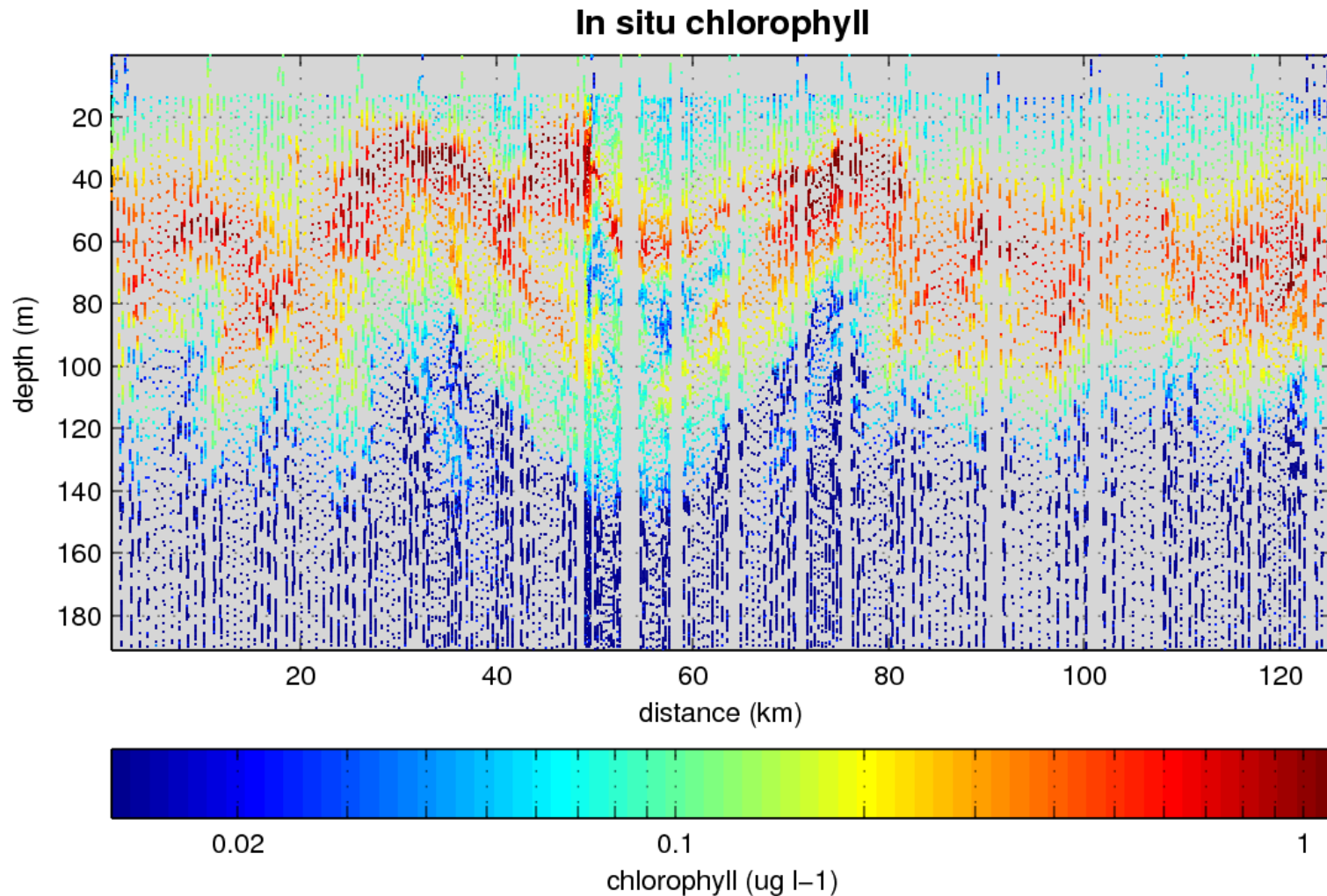
COASTAL GLIDER: RAW DATA



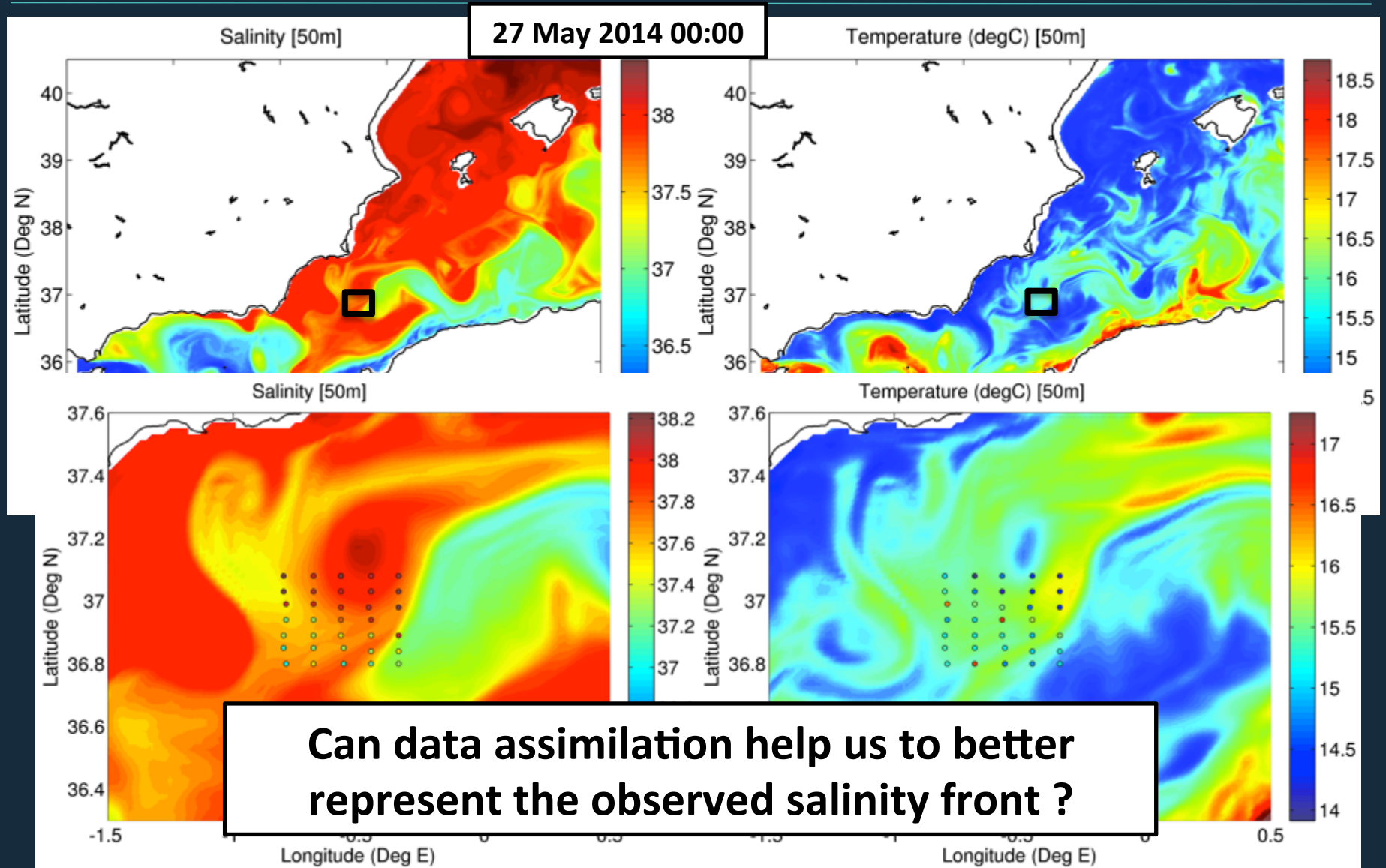
ALBOREX Multi-Platform Experiment

FINE STRUCTRE

COASTAL GLIDER: RAW DATA



ALBOREX: WMOP forecasts experiment



ALBOREX data assimilation experiment

Data assimilation approach:

Local Multimodel Ensemble Optimal Interpolation

→ Ensemble anomalies sampled from three 2009-2013 WMOP hindcast simulations.

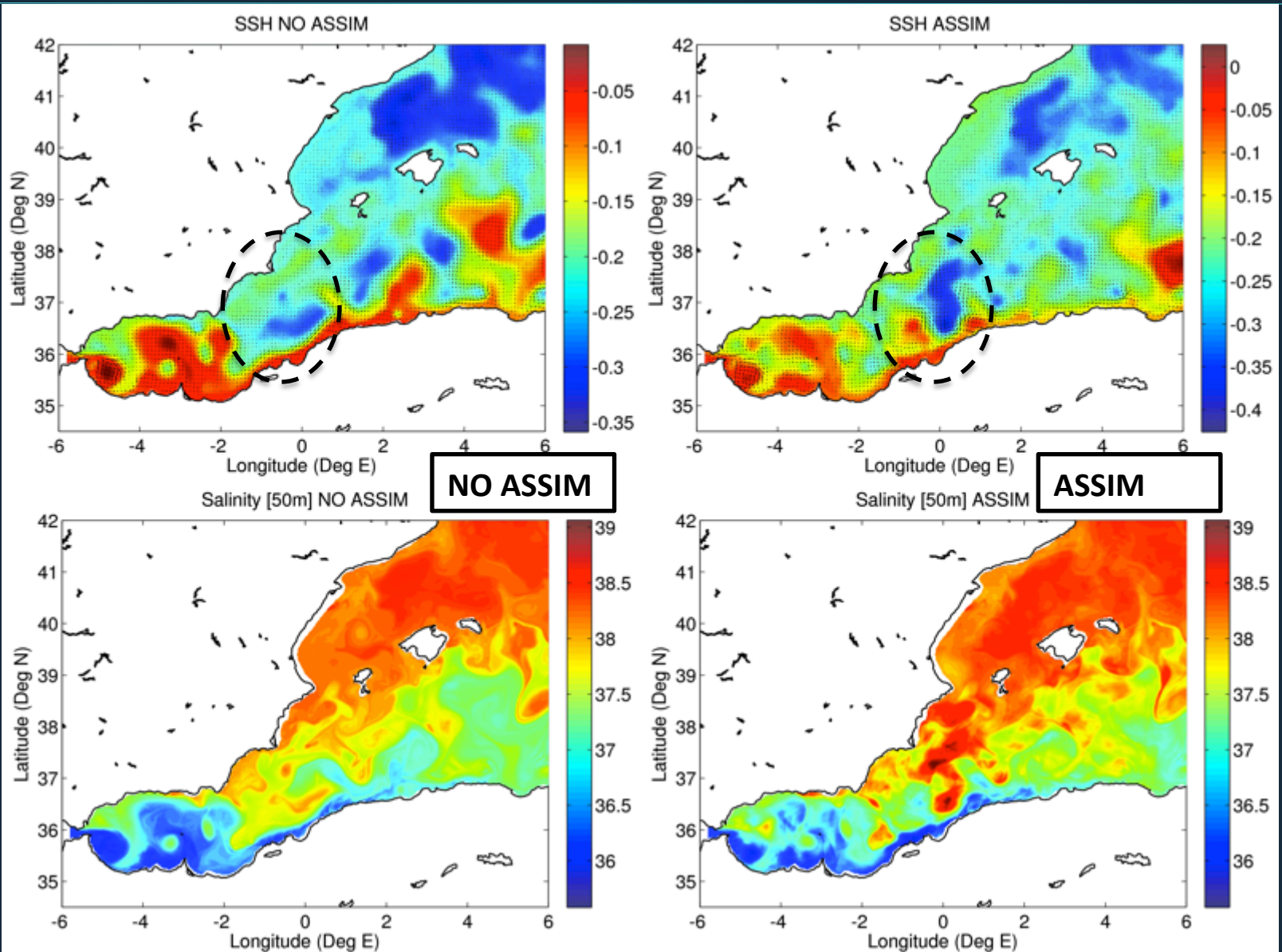
The anomalies are considered within the same season as the analysis date after having removed the seasonal cycle.

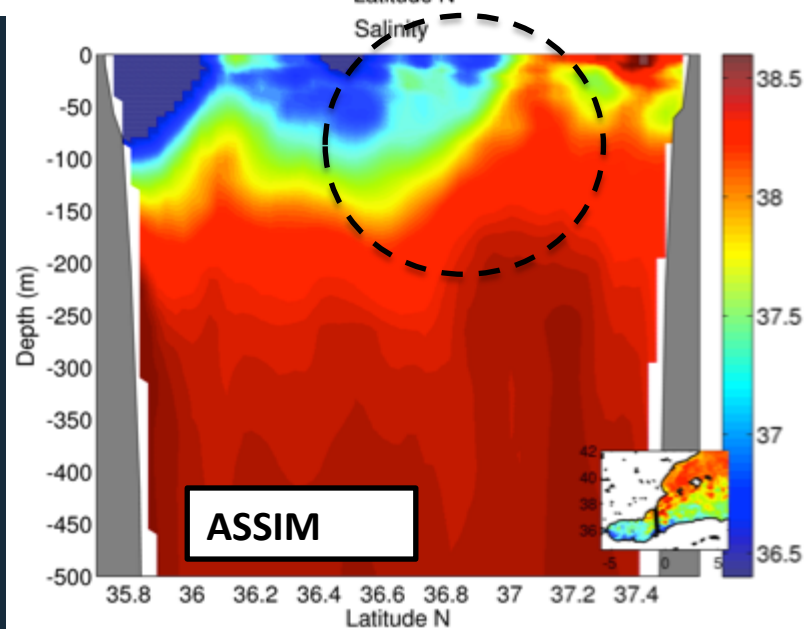
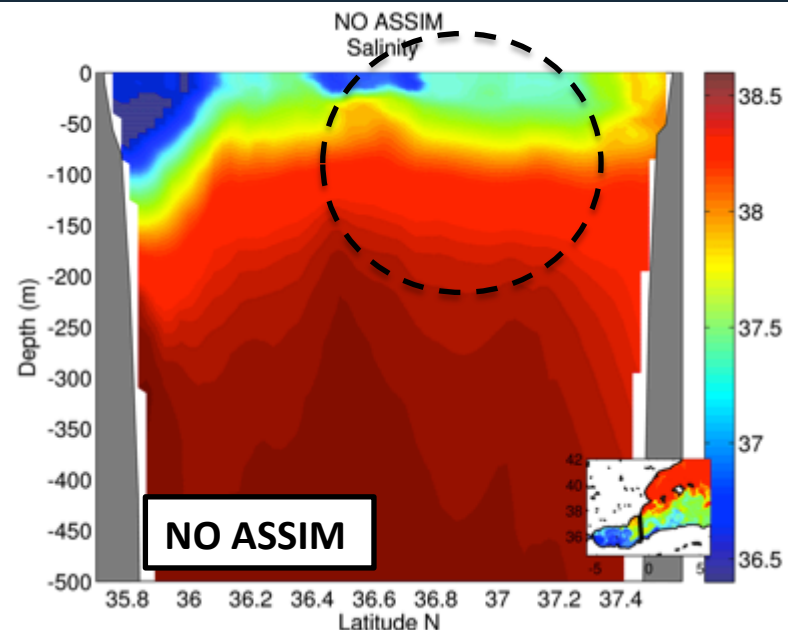
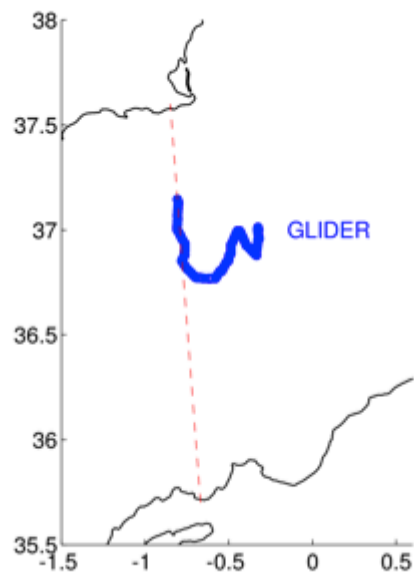
→ Multivariate, inhomogeneous and anisotropic model error covariances characteristic of the mesoscale variability of the season under consideration.

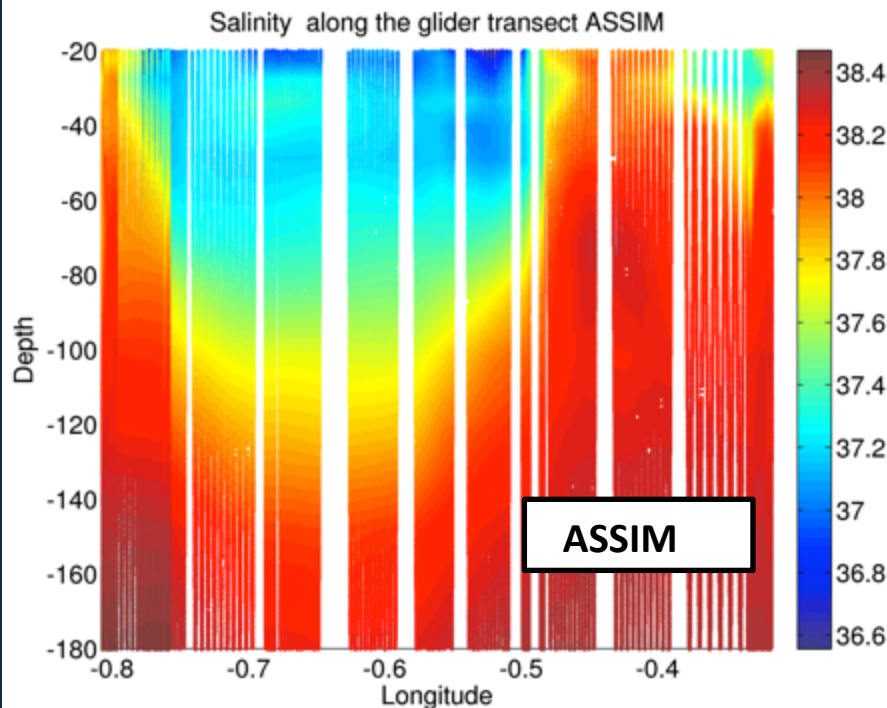
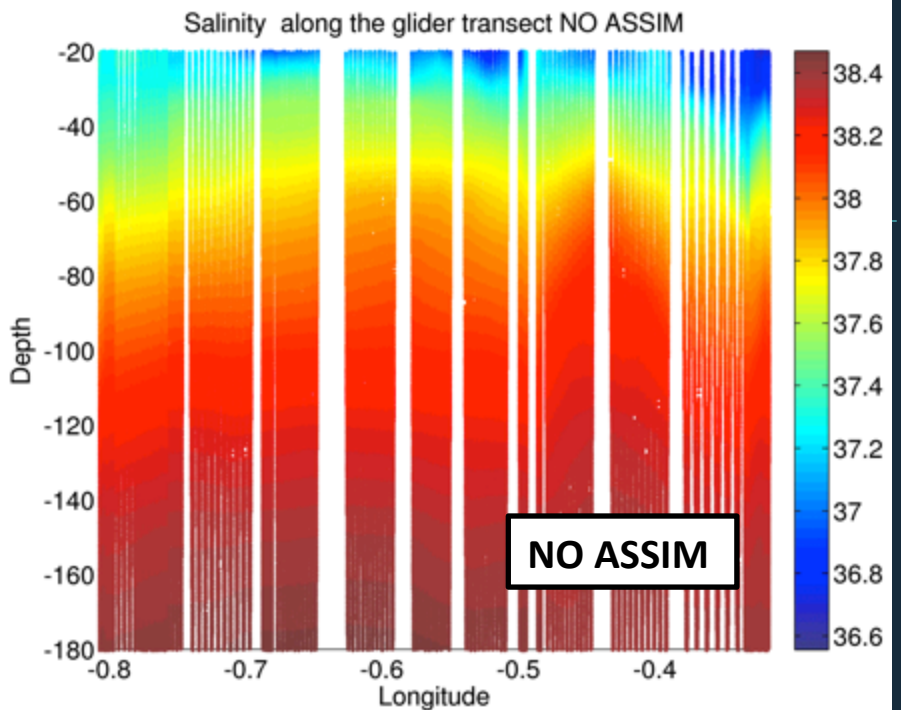
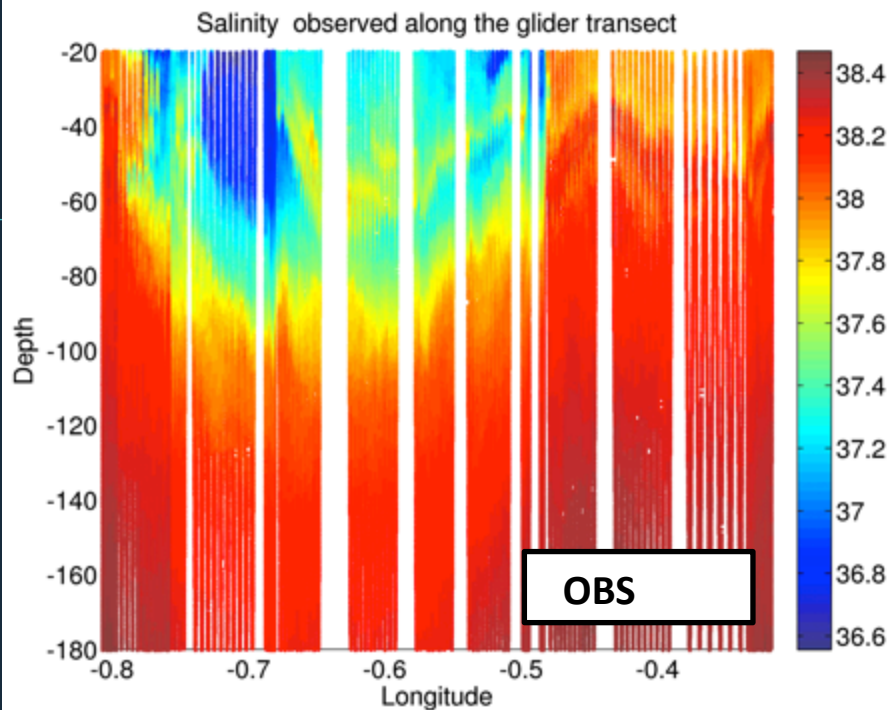
→ Localization radius = 200km

→ 80 ensemble members

WMOP forecasts during ALBOREX experiment (Assimilating SST, SLA, ARGO + CTD's)







**Validation against
independent glider data
crossing the salinity front**

ALBOREX data assimilation experiment

Conclusions

- Data assimilation has been implemented to assimilate ALBOREX observations into WMOP
 - first data assimilation experiments in WMOP
 - Other examples in Poster from REP14-MED
- Preliminary results indicate that the assimilation of CTDs (leg1) + Argo + SST + SLA allows to reconstruct the observed salinity front,

Innovation in oceanographic instrumentation

We need:

- Long time series
- Synoptic data
- γ λοοβητικός

-The innovation process: , Disruptive innovations and incubation time:

3

- Incubation time: 15-30 years (computer mouse, 30 years).

- Gliders 10 years.

WHY?

What is the the key to success?

Innovation in Oceanographic Instrumentation

BY THOMAS B. CURTIN AND EDWARD O. BELCHER

INTRODUCTION

The tools of oceanography include instruments that measure properties of the ocean and models that provide continuous estimates of its state. Major improvements in tool capabilities lead to leaps in understanding, and this increased knowledge has many practical benefits. Advances in tool capabilities are sometimes viewed as an objective of basic research, a viewpoint reflected in the basic research funding category of "science and technology" (S&T).

The complexities of and incubation times for advancing instrumentation are often not fully appreciated, resulting in unrealistic expectations and discontinuous support. Greater understanding of the process of innovative instrument development can contribute to sustaining it. Innovation can be incremental or radical depending on performance gains (Utterback, 1994), stimulated or suppressed depending on institutional factors (Van de Ven, 1989; Office of

Technology Assessment, 1995), and sustaining or disruptive depending on value propositions (Christensen, 1997). For example, going from a Nansen to a Niskin bottle was an incremental innovation, whereas going from bottle casts to CTD profiles was a radical innovation. Moored current meters incrementally advanced from film recording of gauges, to mechanically digitized signals on reel-to-reel tape, to solid-state analog, to digital conversion and memory. Radical innovation of current-field measurement came with the acoustic Doppler current profiler.

In large organizations, stimulated innovation often occurs in research departments, particularly when the projects have champions: "the new idea either finds a champion or dies" (Schon, 1963). In other parts of the same organization, innovation may be suppressed by the costs associated with re-integrating a system and minimal perceived competition. The incubation time of the

computer mouse from inception to wide use was 30 years. In oceanographic observation, where synoptic coverage is an objective, a sustaining innovation would be a sampling platform with improved propulsion that doubles its speed. A disruptive innovation would be a new platform with much slower speed, but with much longer duration and a low enough cost to be deployed in great numbers. Here, we will focus on radical, stimulated, disruptive innovation that involves both science and engineering.

To motivate continued investment in basic research, the histories of many radical innovations, ranging from the transistor to radar to the Internet, have been documented (Bacher, 1959; Hetrick, 1959; Becker, 1980; Hove and Gowen, 1979; Allison, 1985; Abbate, 2000). The Defense Acquisition History Team at the US Army Center of Military History is also preparing a document on this subject.). These cases clearly demonstrate that "rapid" innovation in

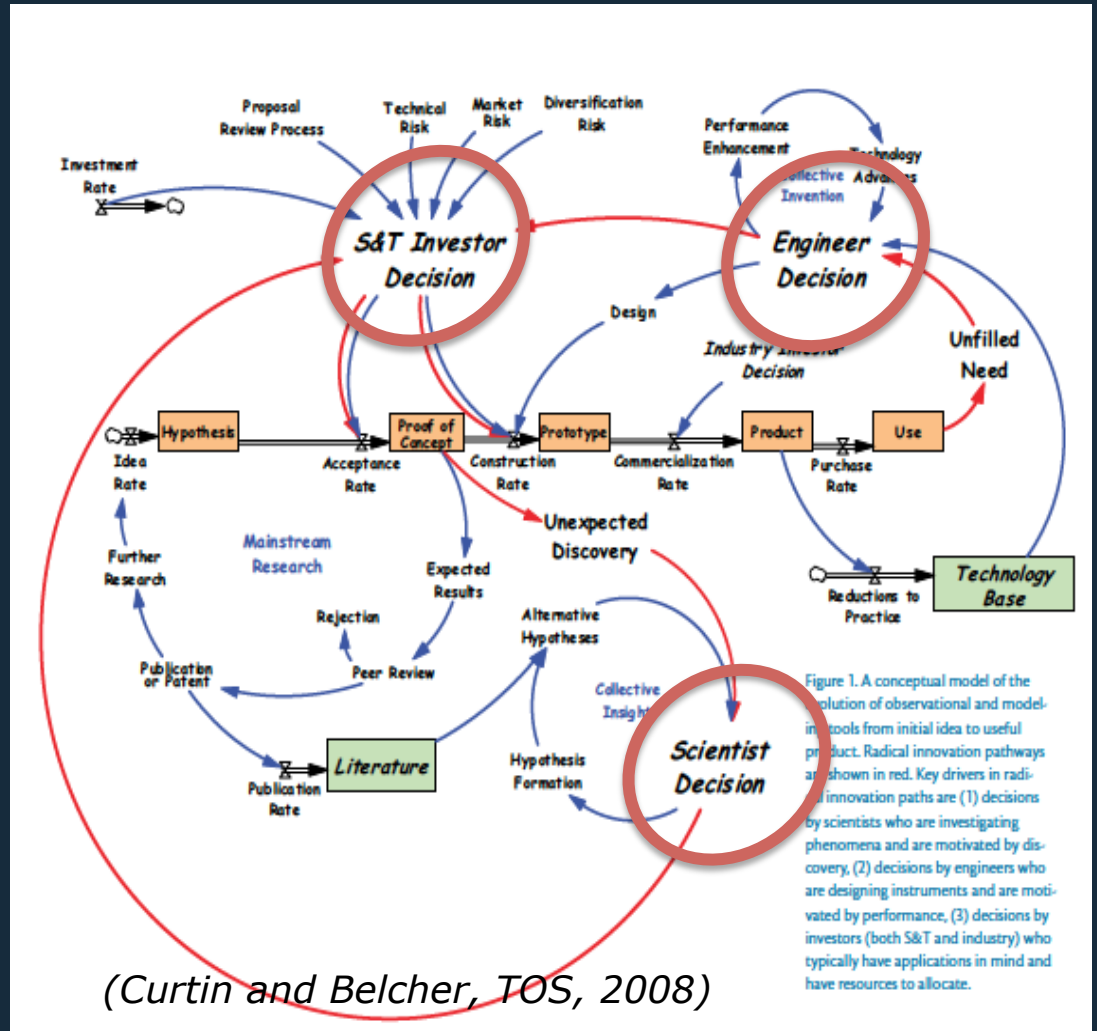
The innovation process

3 key decision centres:

3 PILARS As in H2020 - but here working together!-

3 PILARS, WORKING TOGETHER FOR A COMMON GOAL, WITH A WELL DEFINED STRATEGY...

- MULTI-DISCIPLINARY APPROACH
- INTEGRATION



Summary: the new role of Ocean Observatories/Marine Research Infrastructures-MRI-

➡ SOCIB, an example MRI capabilities to **respond to 3 drivers:**

- Science Priorities (ok!)
- Strategic Society Needs (more listening!: to policy makers & managers endorsement, MSFD -GES- Energy, Tourism, etc.).
- New Technology Developments (to reach companies, social society endorsement)

Summary; We NEED A STRATEGY FOR INTEGRATION..... & Combine Excellent Science with IMPACT ON SOCIETY....

1. New technologies/paradigm change Ocean Observation: Ocean Variability, with shift from Large Scale to Mesoscale and Coasts.
2. Marine Research Infrastructures/Observing Systems in Europe; international leadership -e.g., SOCIB-, & key elements in Blue Growth initiatives (**EU Oceans Innovation COM**) because their:
 - Critical mass
 - Multi-disciplinary approach
 - Integration capabilities of Science, Technology, Society

In other words: ...



New observing systems with real time open data are key elements for new advances in oceanography

The challenge for the
next decade....:

Excellent Science &
Technology Develop.
with
Impact on Society”



“Strong Science for Wise Decision”



Science with and for Society
Ciencia con y para la
sociedad

Excellent Science & Technology Development with IMPACT ON SOCIETY....” A Strategy for...”



Merci !

– “The real voyage of discovery consists not in seeking new landscapes, but in having new eyes”. (Marcel Proust)

“Le véritable voyage de découverte ne consiste pas à chercher de nouveaux paysages, mais à avoir de nouveaux yeux”

www.socib.es

PAPER
**SOCIB: The Balearic Islands Coastal Ocean
Observing and Forecasting System
Responding to Science, Technology
and Society Needs**

AUTHORS

Joaquín Tintoré
SOCIB, Balearic Islands Coastal
Observing and Forecasting System,
Palma de Mallorca, Spain and IMEDEA
(CSIC-UIB), Mediterranean Institute
for Advanced Studies, Esporles, Spain
Guillermo Vimeu
Benjamin Cane

Antonieta Llanos
Evan Mason
Romana Escudé
Daniel Cusi
Joan Marnat Irujo
Richard Raschke
IMEDIA (CSIC-UIB)
Francisco Almaraz
Patrik Riegler

Tintoré et al., 2013: *Marine*

