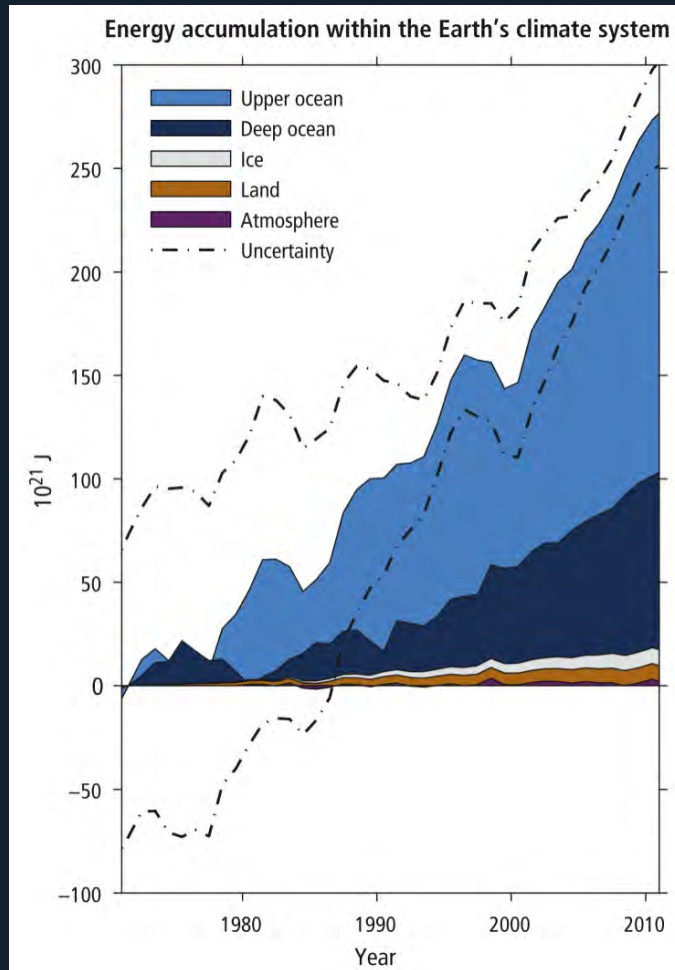


# ***Regional Digital twins : initial steps in the Western Mediterranean Sea, responding to science and society challenges from events to climate***

Joaquín Tintoré and all SOCIB & IMEDEA Team  
[jtintore@socib.es](mailto:jtintore@socib.es)

Scientific Excellence with Impact on Society

# OUR MAIN GOAL TODAY: Climate Change, global warming is ocean warming –

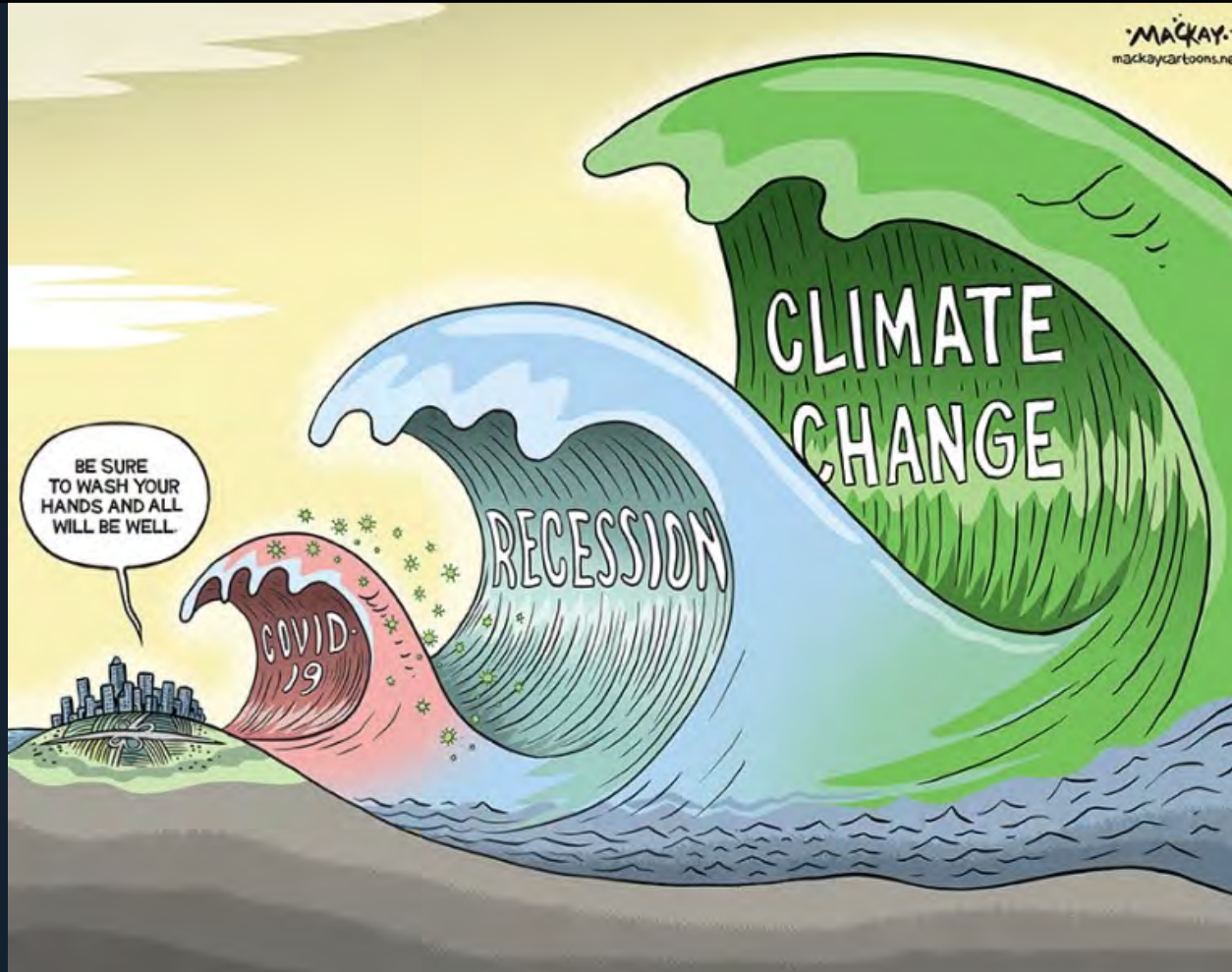


IPCC - Special Report Ocean & Cryosphere 2019



*Emergency situation: action and transformation required*

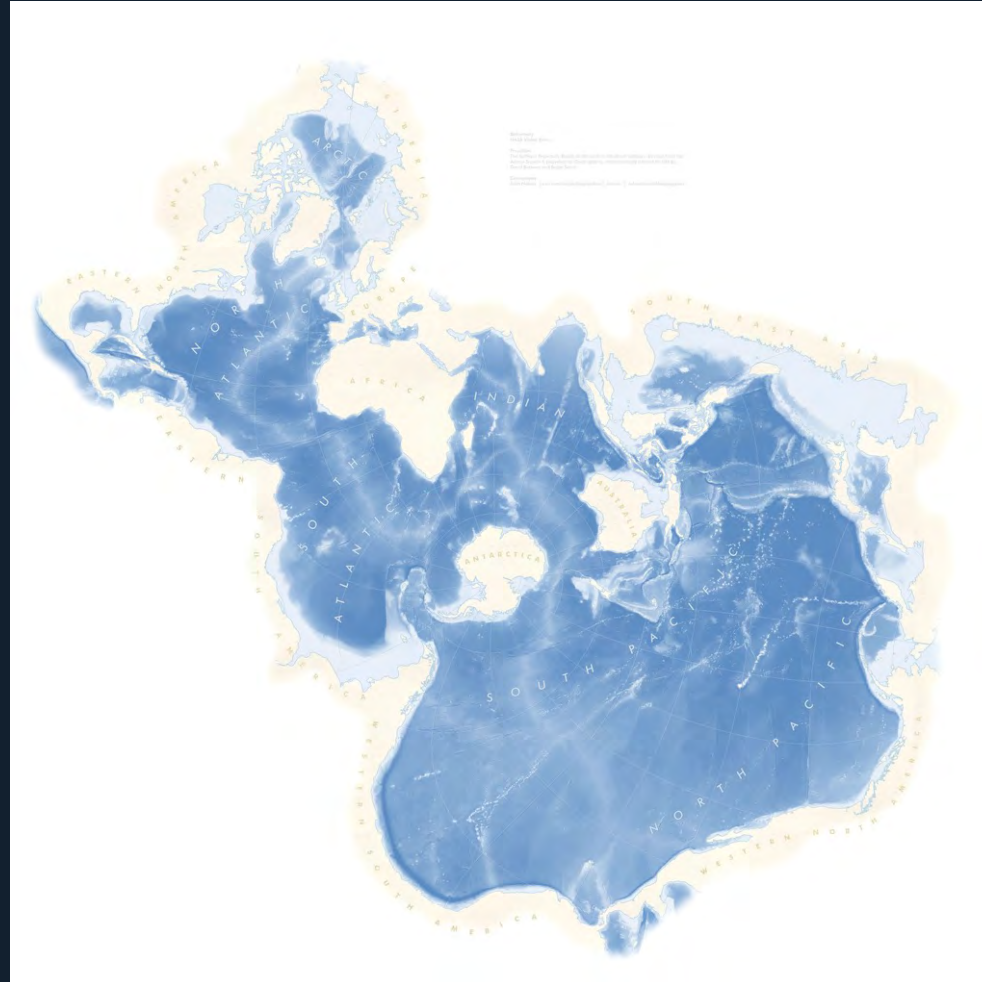
# OUR GOAL TODAY: Climate Change



“Climate change is much harder to solve than the pandemic, but the negative effects – if we don’t solve it – are also much, much greater”. Bill Gates, 2021.

*Acting together...*

# ONE OCEAN – ONE PLANET

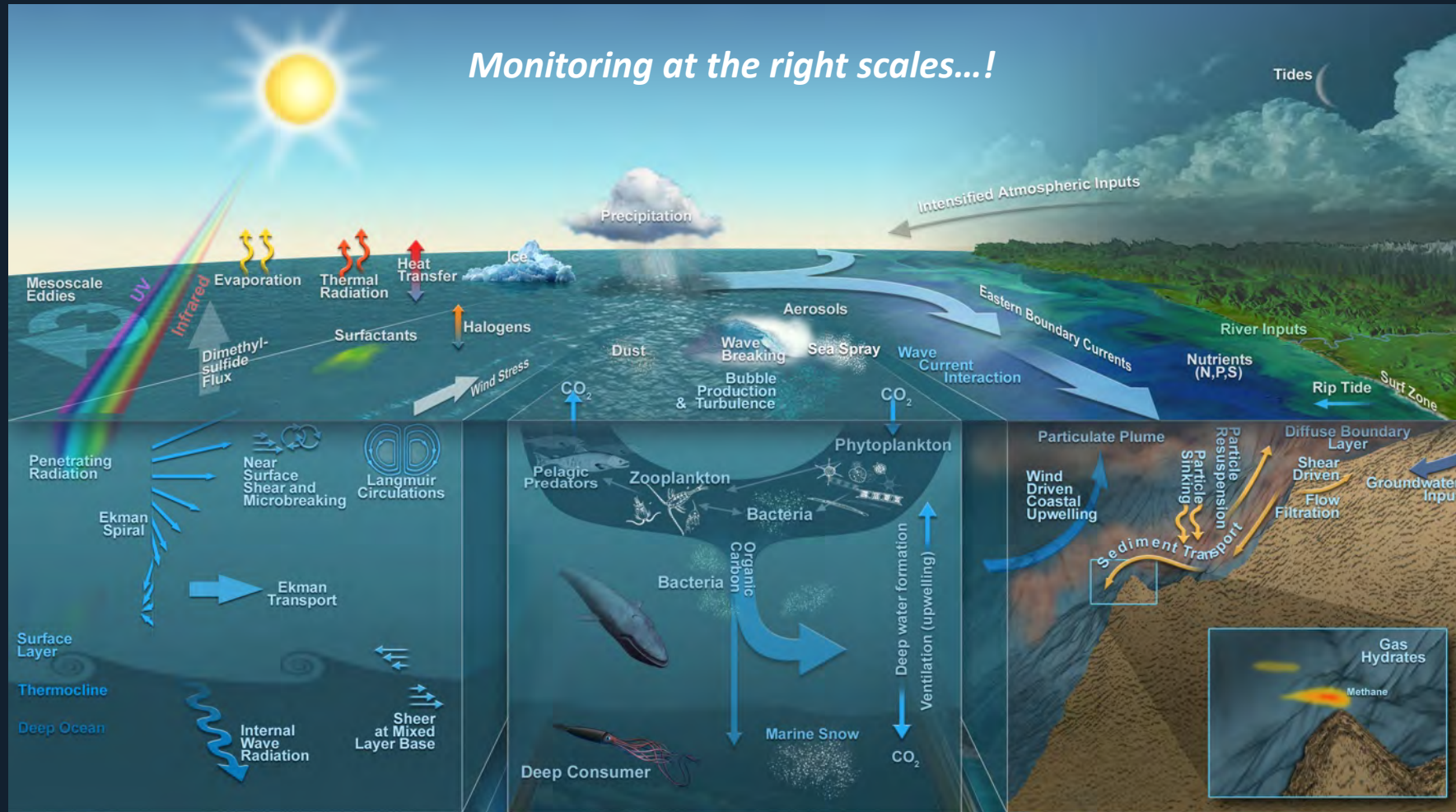


Spilhaus map - ESRI

Connectivity, Scales, Limits, Sustainability



# ONE OCEAN: A COMPLEX N-DIMENSIONAL SYSTEM OF SYSTEMS



OOI, Regional Scale Nodes (Delaney, 2008)

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

# INTERNATIONAL FRAME





# WHAT IS SOCIB?: a Research Infrastructure, a multi-platform ocean observing & forecasting system, from nearshore to open sea & from events to climate

## 3 DRIVERS

- Science priorities
- Technology Development
- Society Needs

## -> SYSTEMATIC & SUSTAINED OBSERVING

## -> OPEN DATA ACCESS

- Free/open data
- Endurance lines
- Competitive Open Access

## COLLABORATIVE

- CSIC, IEO, UIB

## INTERNATIONAL EVALUATION

- Every 4 years



Tintoré et al., 2013; 2019

[www.socib.es](http://www.socib.es)

## Timeline:

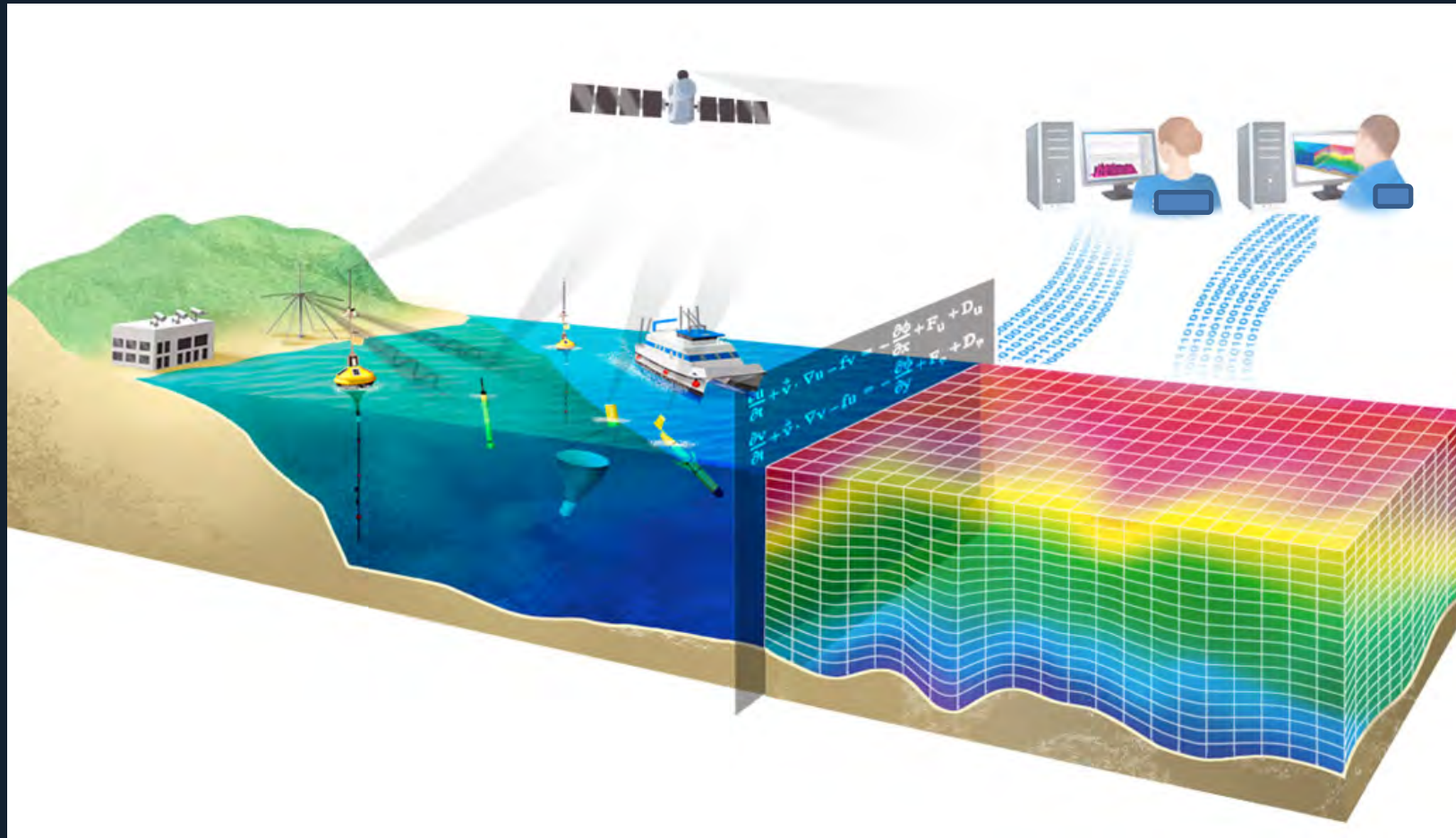
- Proposal 2006 & approved in 2009
- Designed & built 2010-2013
- Included in Large Scale RI Map, 2014

## KPI Scientific Production:

- 168 papers, 2011 - 2020
- 16 EU projects, 2014 – 2020
- 7 contracts private sector
- 7 agreements public sector
- External funding: > 5 M€
- Building trust and partnerships

**National, Collaborative Research Infrastructure  
Leadership - Partnership**

# SOCIB INTEGRATED APPROACH TO OCEAN OBSERVING

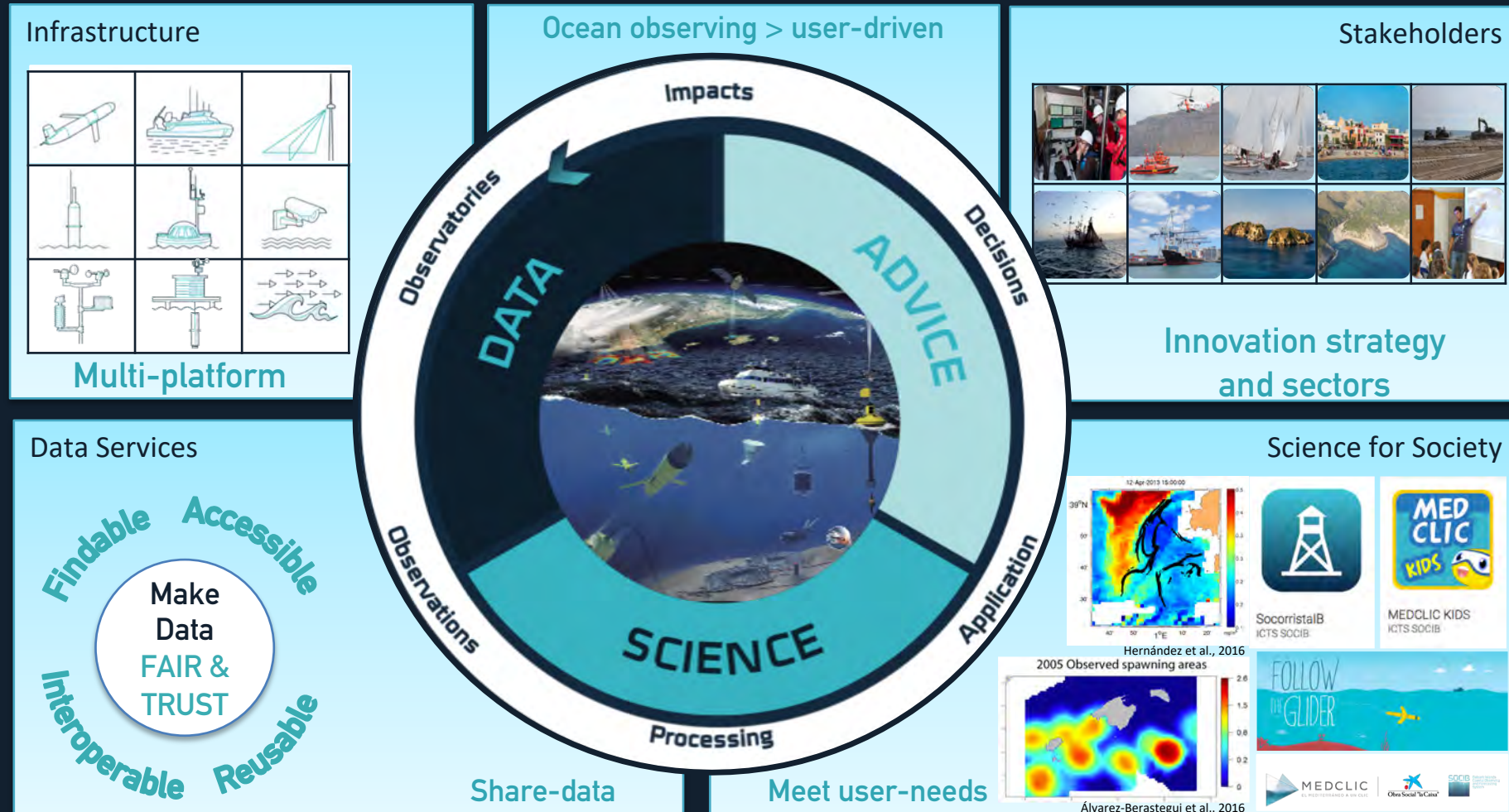


Data Quality: FAIR data and TRUST repositories  
Access to Resources & Metrics; Trans-National and Virtual

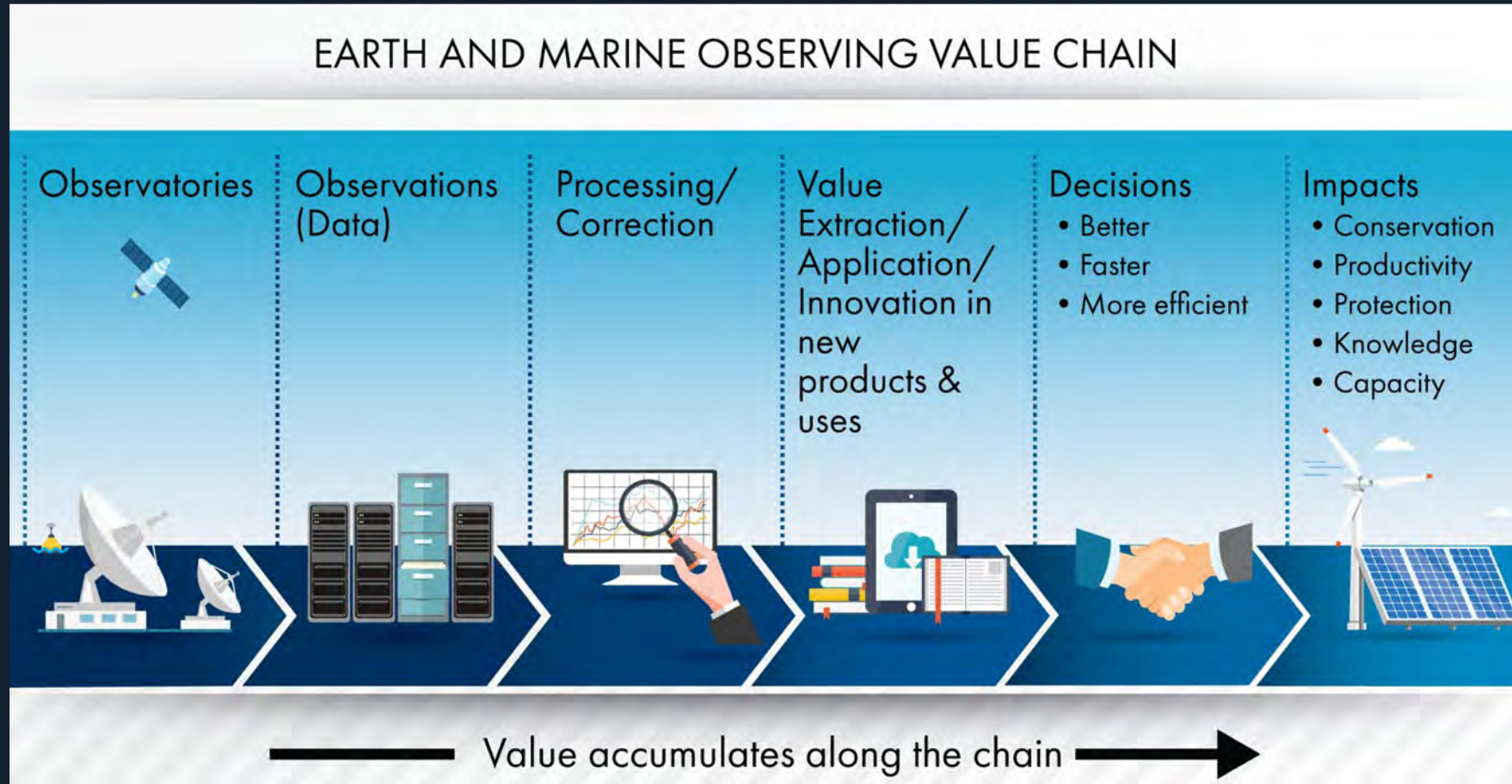




# SOCIB: A PUBLIC LARGE SCALE RESEARCH INFRASTRUCTURE. A STORY THAT STARTED IN 2009, OPERATIONAL 2014 AND TODAY ...



# DATA & OCEAN OBSERVING VALUE CHAIN



(Hodgson-Johnston, 2016)

*Marine observation data has potential for huge innovation through data collection, analysis & application*



# HIGHLIGHTS: SCIENCE → CALYPSO PROGRAM

## KPIs:

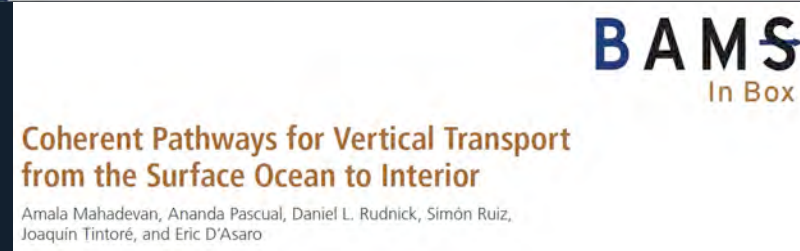
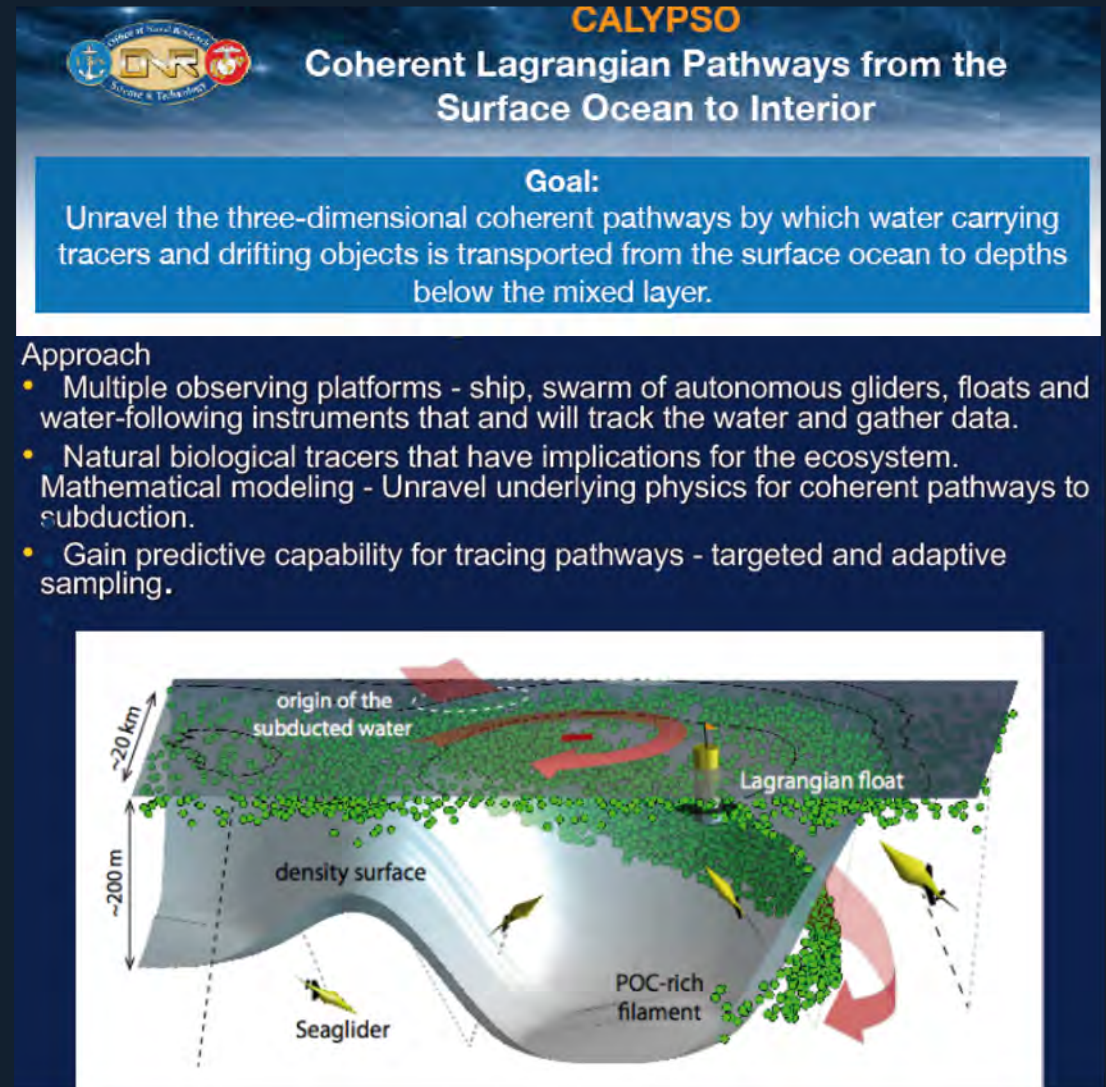
US-ONR Funded DRI in Spanish waters  
(Alborán & Balearic Sea); 2017-2023.

Funding: > 30 M\$ and + 10 outstanding US  
Teams involved; MIT, WHOI, Scripps, UW,  
etc.

IMEDEA & SOCIB international leadership

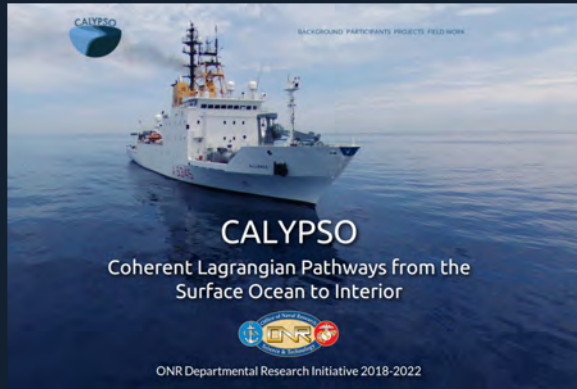
*At the fore-front of international science  
questions and discoveries*

*Mahadevan et al., 2020: BAMS*



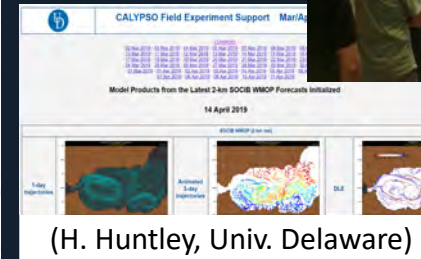
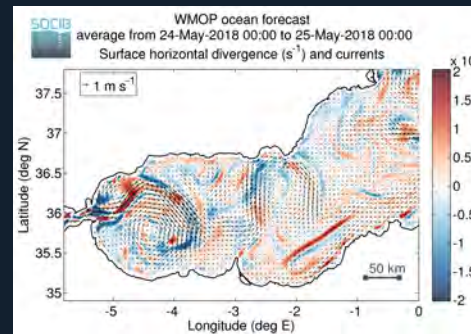


# CALYPSO: real-time support to sea trial experiments



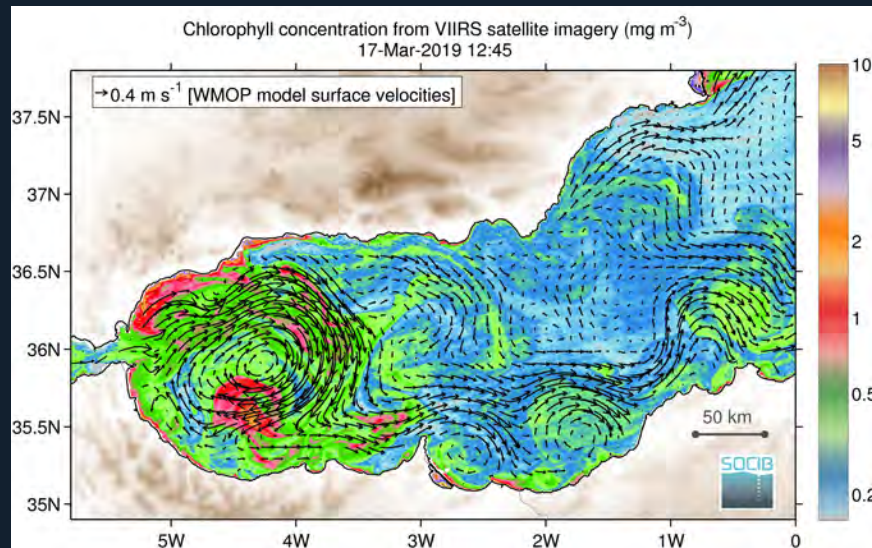
<https://calypsodri.who.edu/>

→ Focused on the understanding of three-dimensional pathways of water parcels in the upper ocean

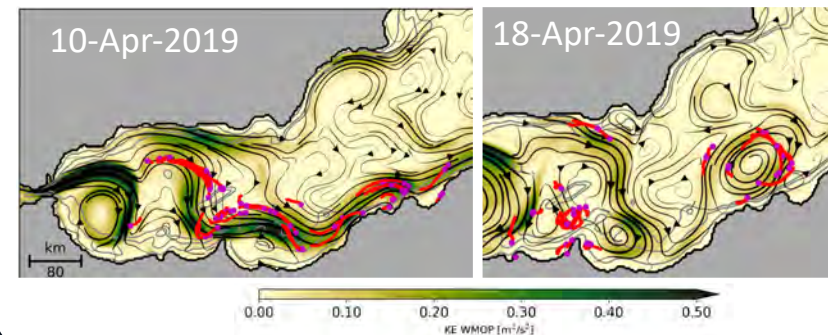


Real-time  
forecasting

Model assessment using high-res. ocean color images and surface drifters



2019 exp: 185 drifters deployed

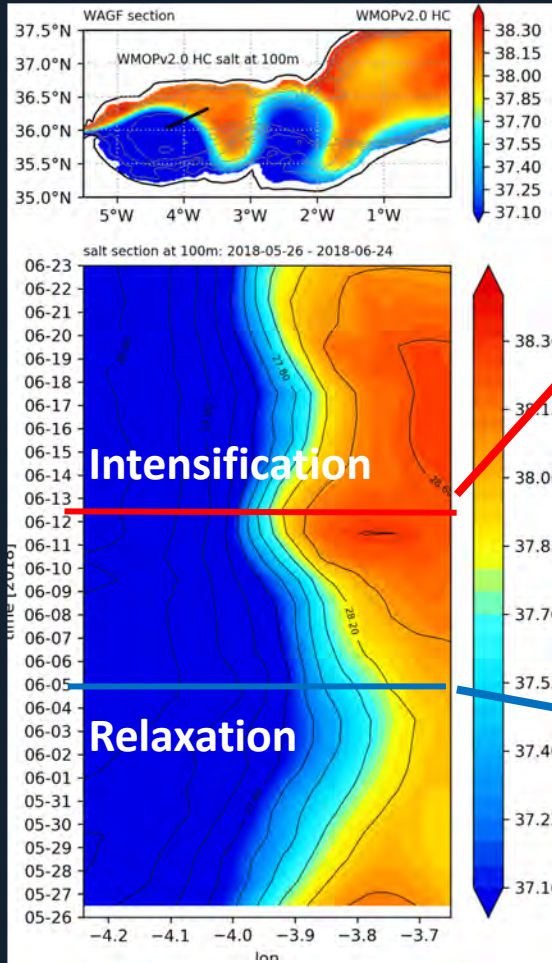




# Mechanisms for vertical velocities at the Alboran fronts

([Garcia-Jove et al. 2022](#); [Zarokanellos et al. 2022](#); J. Geophys. Res. Oceans)

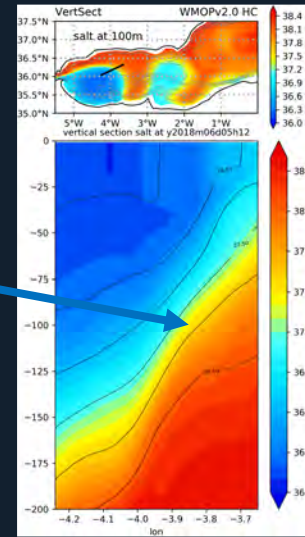
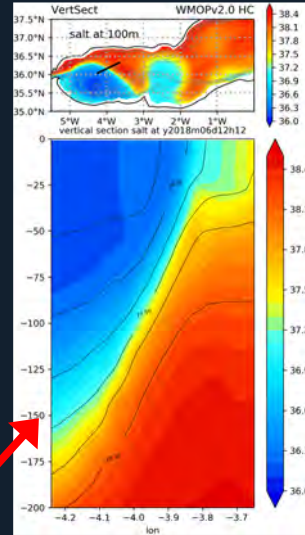
## Salinity@100m



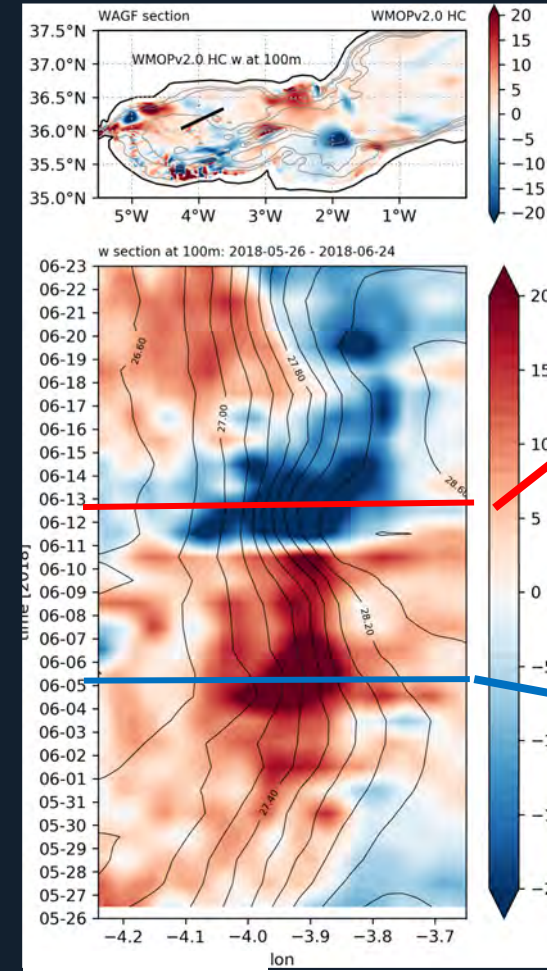
Intensification

Relaxation

Longitude



## w@100m



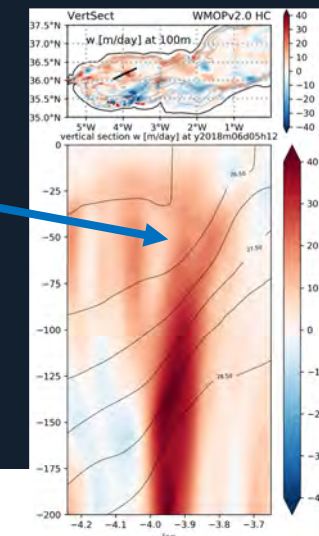
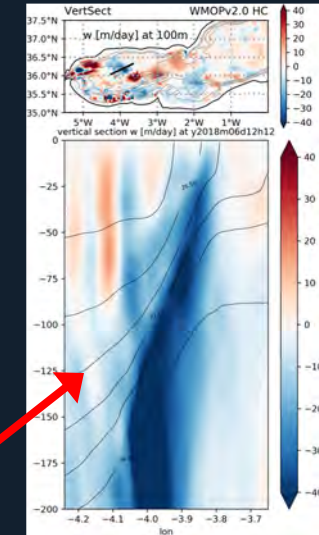
Longitude

w+ max = 42m/day @135 m

w- max = 8m/day @158 m

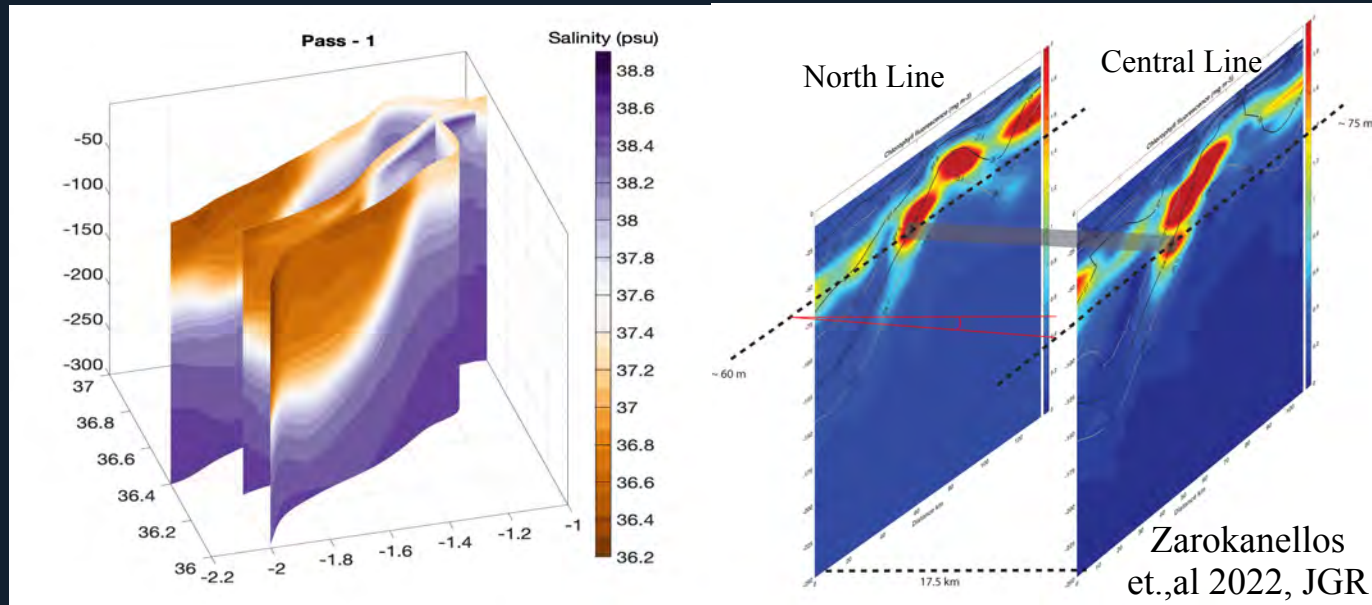
w+ max = 18m/day @57 m

w- max = 55m/day @156 m



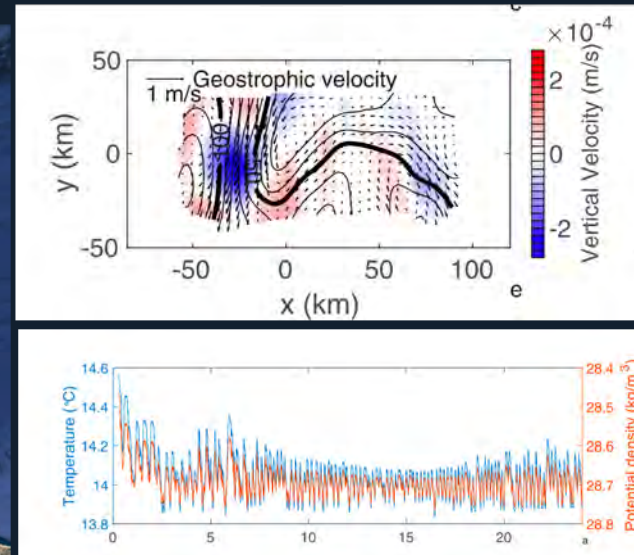
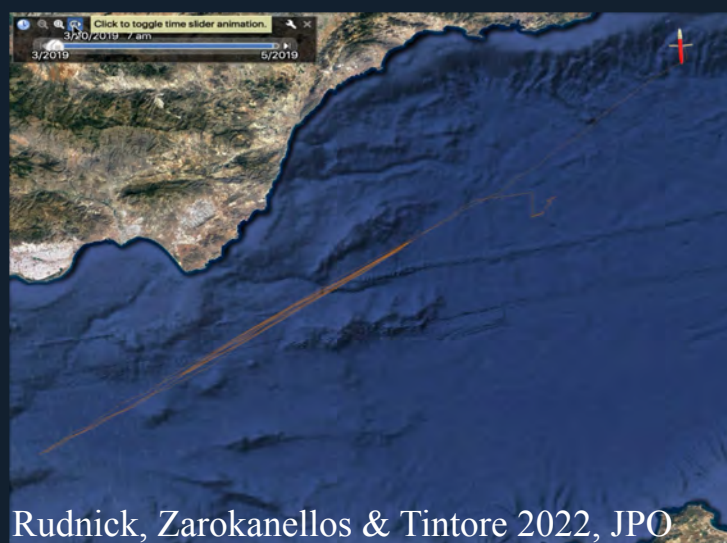
# CALYPSO Experiment 2018 & 2019

Observations are consistent with baroclinic instability and the propagation of wavelike meanders along the front



## Calypso 2018

- The glider network across the Almeria-Oran front gives us new insights about the 3-dimensional pathways of transport from the upper ocean to the interior and vice-versa



## Calypso 2019

- Peak downward vertical velocities were near 25 m/day in an event that propagated in the direction of the frontal jet
- Isothermal tracking



# CALYPSO Experiment 2022

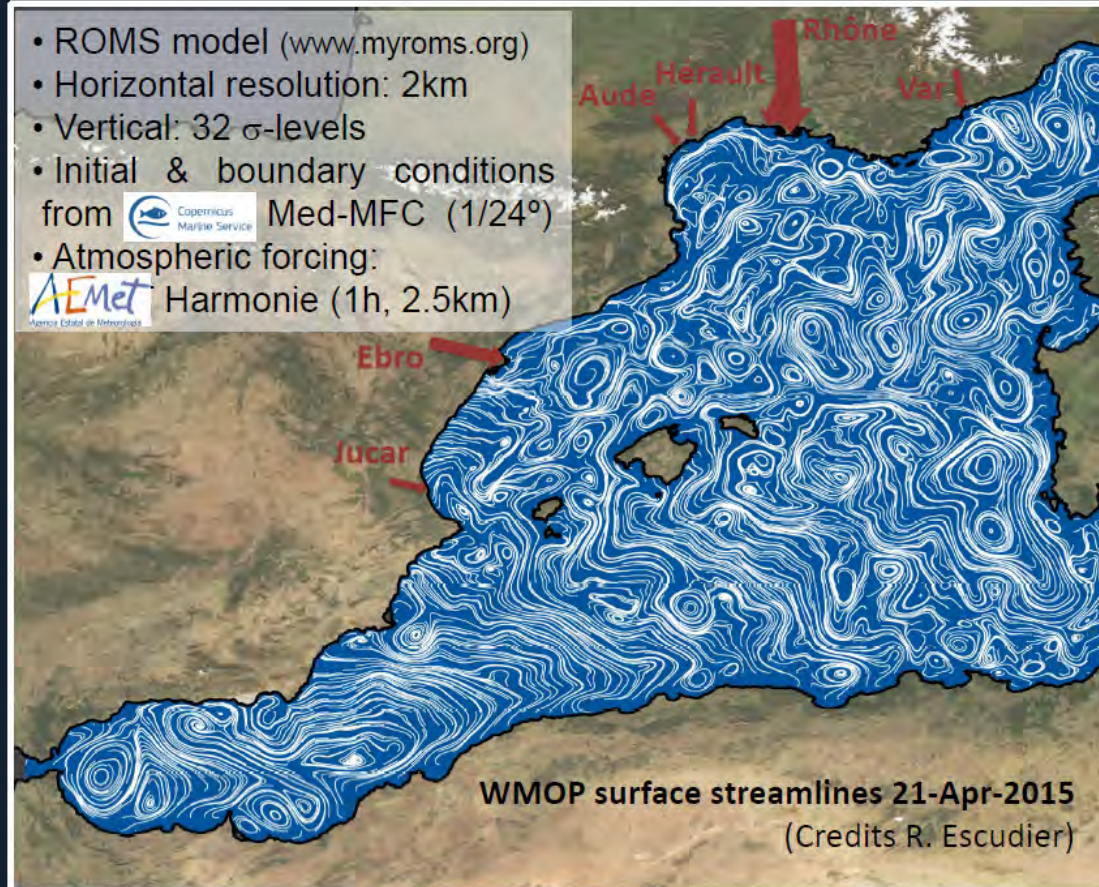


- **2 Ships:** R/V Pourquoi pas? & Pelagia
- Underway profiling to 200<sup>+</sup>m at 1 km resolution - CTD, oxygen, chlorophyll, backscatter
- Intake - CTD, oxygen, chlorophyll, backscatter
- ADCP velocity profiles
- More than 300 surface drifters drifters...
- 9 Profiling 'Argo like' floats
- Satellite SST and chlorophyll
- AUV and Lagrangian floats

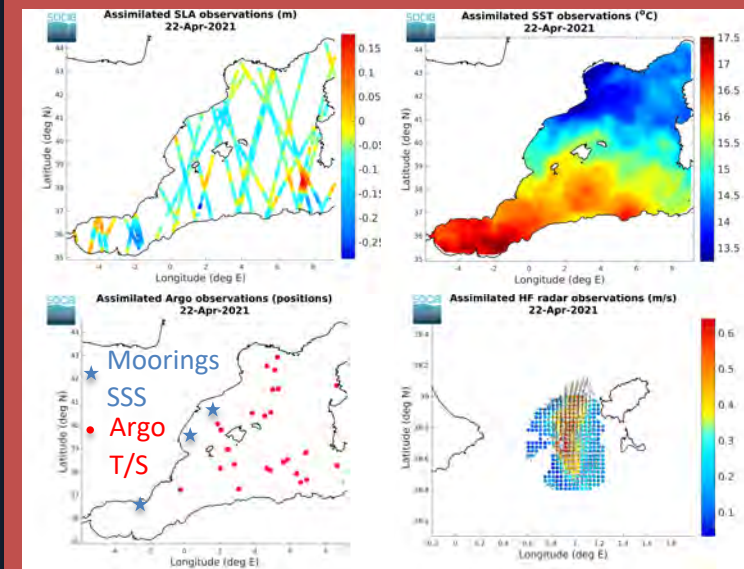


# HIGHLIGHTS: SCIENCE

## Integrated Modelling & Observation System



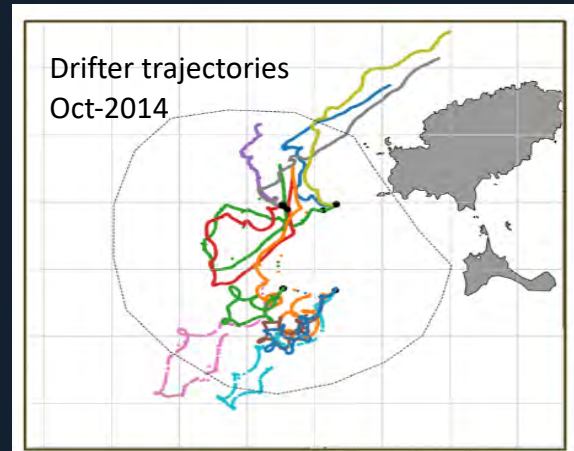
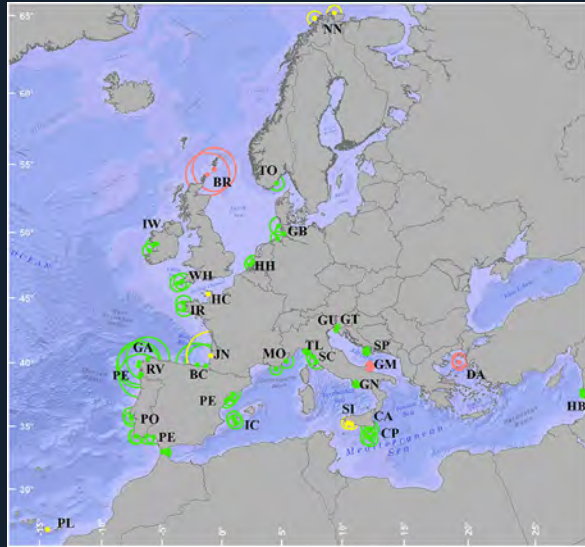
**Data assimilation:**  
Ensemble Optimal Interpolation  
with 3-day cycles



[Juza et al. 2016; Mourre et al. 2018; Hernández-Lasheras and Mourre 2018; Aguiar et al. 2020]

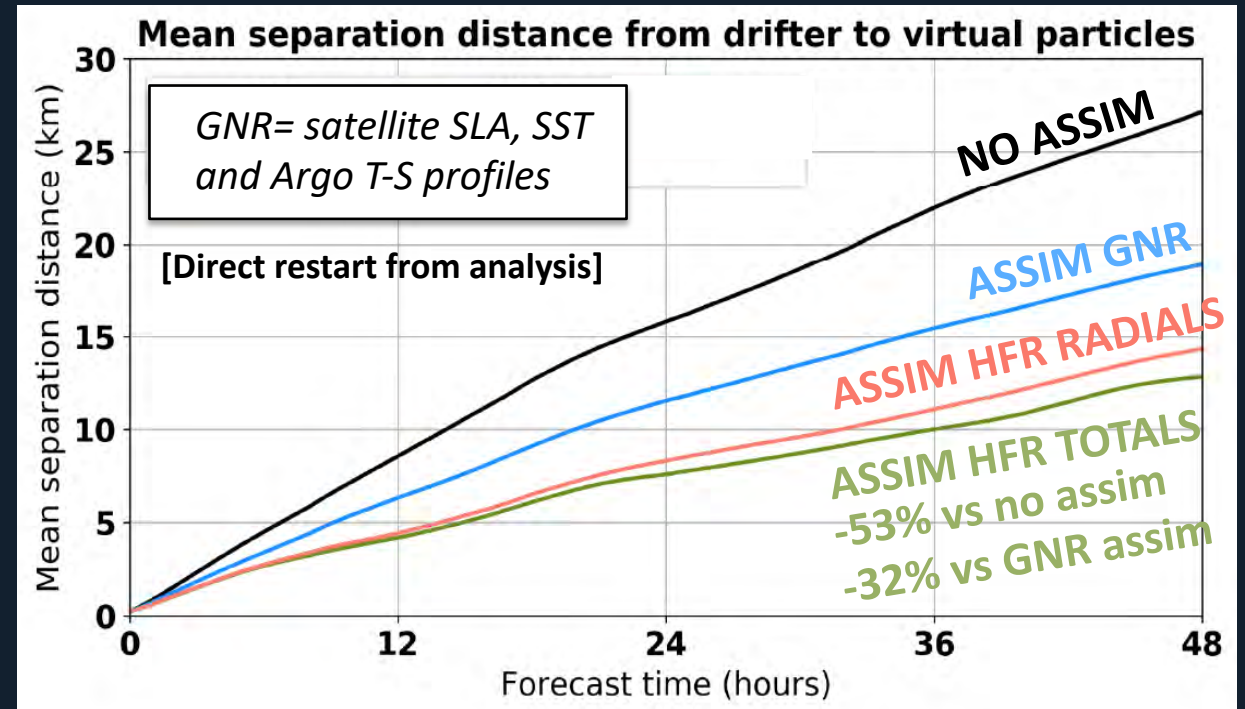
*Ibiza Channel HFR currents assimilated in the WMOP operational prediction system, together with satellite SST & SLA, moorings and Argo TS profiles*

## HIGHLIGHTS: SCIENCE - ASSIMILATION OF HF RADAR DATA



*Independent validation using trajectories of 14 surface drifters during 10 days*

# Ibiza Channel



*(Hernández-Lasheras et al., Ocean Science, 2021)*

→ Significant reduction of the separation distance between real and model drifters



# HIGHLIGHTS: MISSION DRIVEN INNOVATION STRATEGIES, & BLUE ECONOMY

**Today:** SOCIB is providing data, resources, knowledge & advice to 10 sectors of society

*From Science to Society: a well defined with a Mission oriented Innovation Strategy responding to society needs from solid grounds*

## SOCIB DECISION SUPPORT TOOLS EXEMPLARS:

- Rip-currents App for lifeguards & beach safety
- Sea level rise Balearic coasts & IPCC Scenarios
- Bluefin tuna spawning & ICCAT indices
- Meteo-Tsunami early warning
- Oil spill forecasting & coastal response
- Environmental Sensitivity Index web application
- Marine Heat Waves web tool
- ...



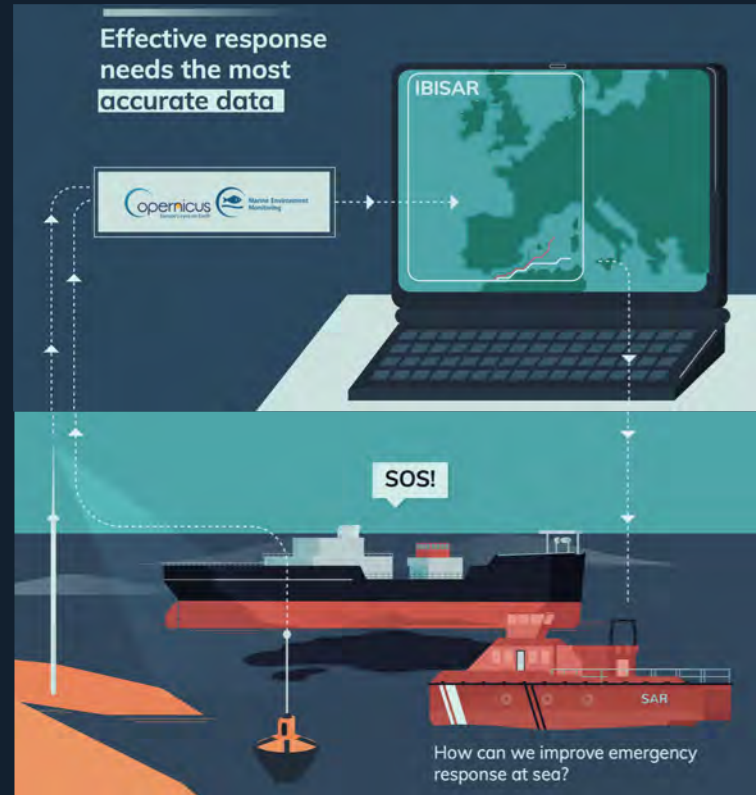
“The **Blue Economy** is a knowledge based economy looking to the sea, not really for extraction of natural goods but for data to address societal challenges and inspire solutions” R. Spinrad, NOAA - 2016.

# HIGHLIGHTS: SCIENCE, OPERATIONAL RESPONSE & SOCIETY, BUILDING TRUST - SASEMAR

PI: Dr. Emma Reyes, SOCIB

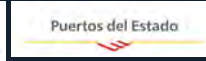


**IBISAR**: real-time data ranking in the IBI area for emergency and **SAR** operators



## KPIs:

*Revelard et al., 2021:  
Front. Mar. Sc.*



## IBISAR service

Provides **real-time** information of the **most accurate** ocean current **forecast** in the IBI area

Facilitates **decision-making** to SAR operators and emergency responders

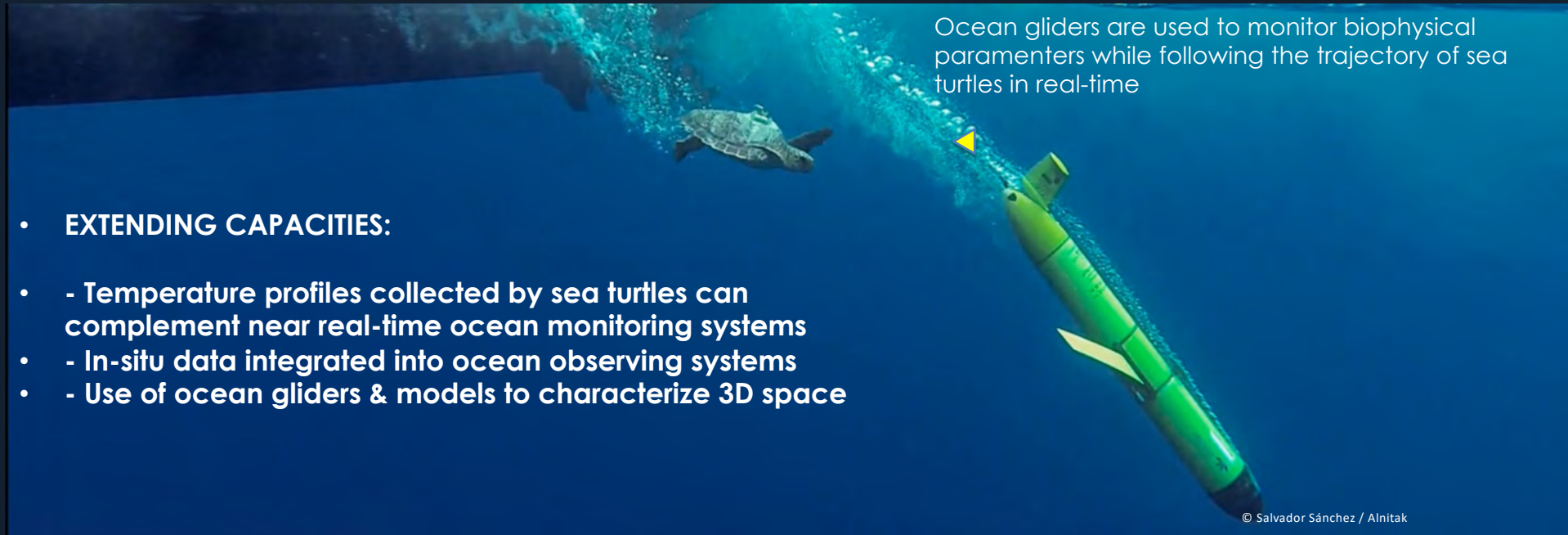
## End-users needs

**Reliable** current observations and forecasting are essential

**Easily interpretable metrics**

**User-friendly automated skill assessment**

# HIGHLIGHTS: NEW OBSERVING SYSTEMS, ANIMAL BORNE INSTRUMENTS



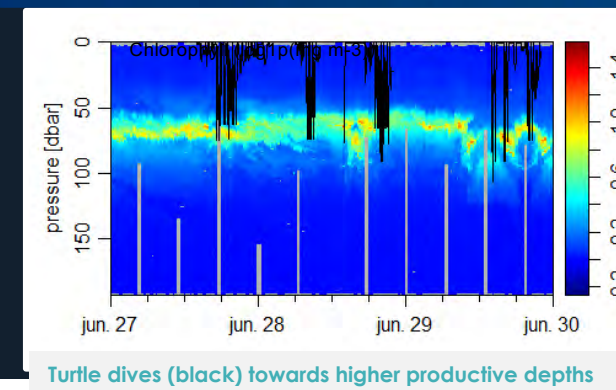
Ocean gliders are used to monitor biophysical parameters while following the trajectory of sea turtles in real-time

- **EXTENDING CAPACITIES:**
  - Temperature profiles collected by sea turtles can complement near real-time ocean monitoring systems
  - In-situ data integrated into ocean observing systems
  - Use of ocean gliders & models to characterize 3D space

© Salvador Sánchez / Alnitak

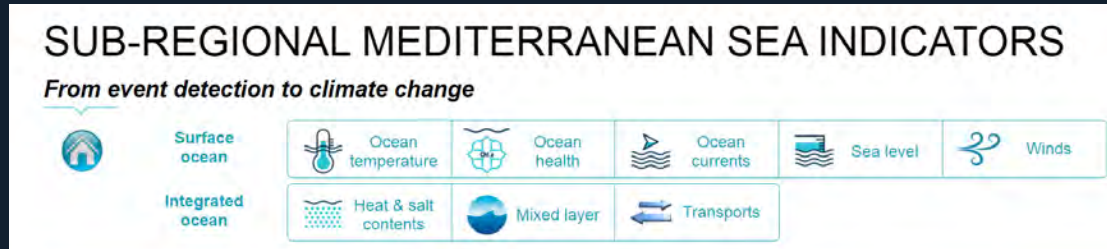
KPIs:

- AniBOOS

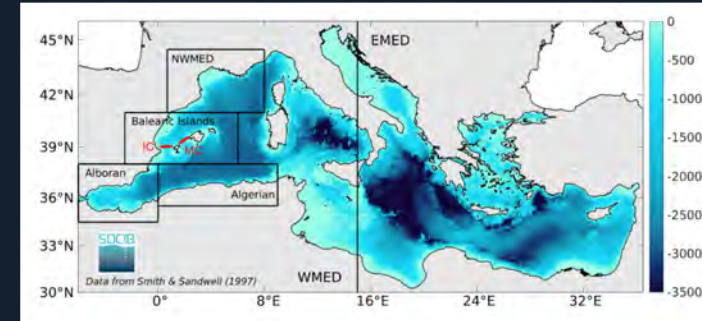




# HIGHLIGHTS TOOLS: Sub-regional Mediterranean Sea Indicators, from event detection to climate change



<https://apps.socib.es/subregmed-indicators>  
(updated daily)



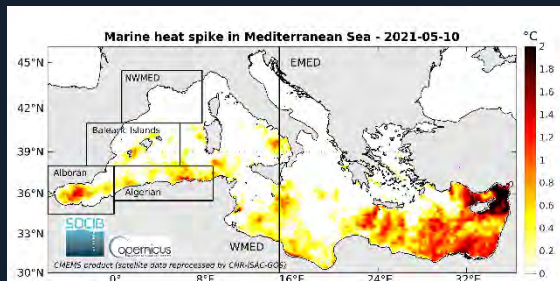
## Methodology

- Near real-time & historical, free, open access, quality-controlled data (satellite & in situ)
- **Sub-regional** approach (spatial variations, local/national decision-makings & actions)
- **Multi-scale** (daily, monthly, annual) monitoring in real time
- **Multivariate** indicators at surface & vertically integrated

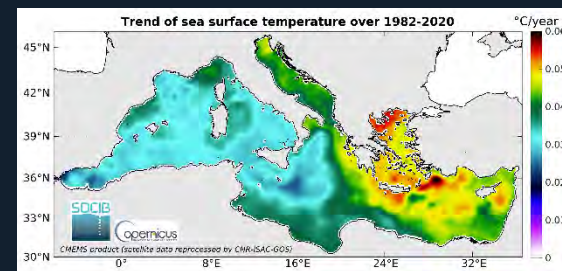
Juza & Tintoré (2021)

<https://doi.org/10.3389/fmars.2021.610589>

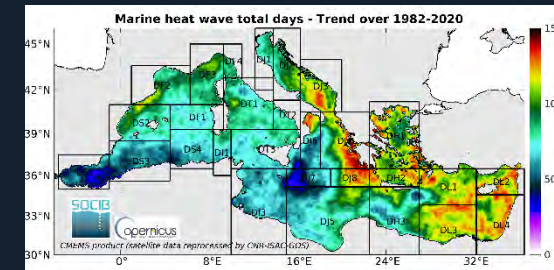
*Daily monitoring*



*Monthly monitoring*



*Annual monitoring*



From **event detection** (marine heat wave) to **long-term variations** (ocean warming, sea level rise)

# HIGHLIGHTS: SOCIB AND SOCIETY / STAKEHOLDERS

Aligned with SOCIB Research and Observing Mission and with the goal of **sharing** knowledge, SOCIB promotes ocean literacy **with activities to discover, learn, generate awareness, inspire, and empower citizens and stakeholders** towards protecting THE OCEAN.



We carry out  
events and trainings

On-site and  
Online activities  
for all audiences

**83** events & activities

**285.645** assistants



We organize  
contests

Online  
activities for  
all audiences

**4** national contests

**3.494** participants



We design  
resources

Focussing on  
the educational  
community

**76** resources & materials

**3** languages



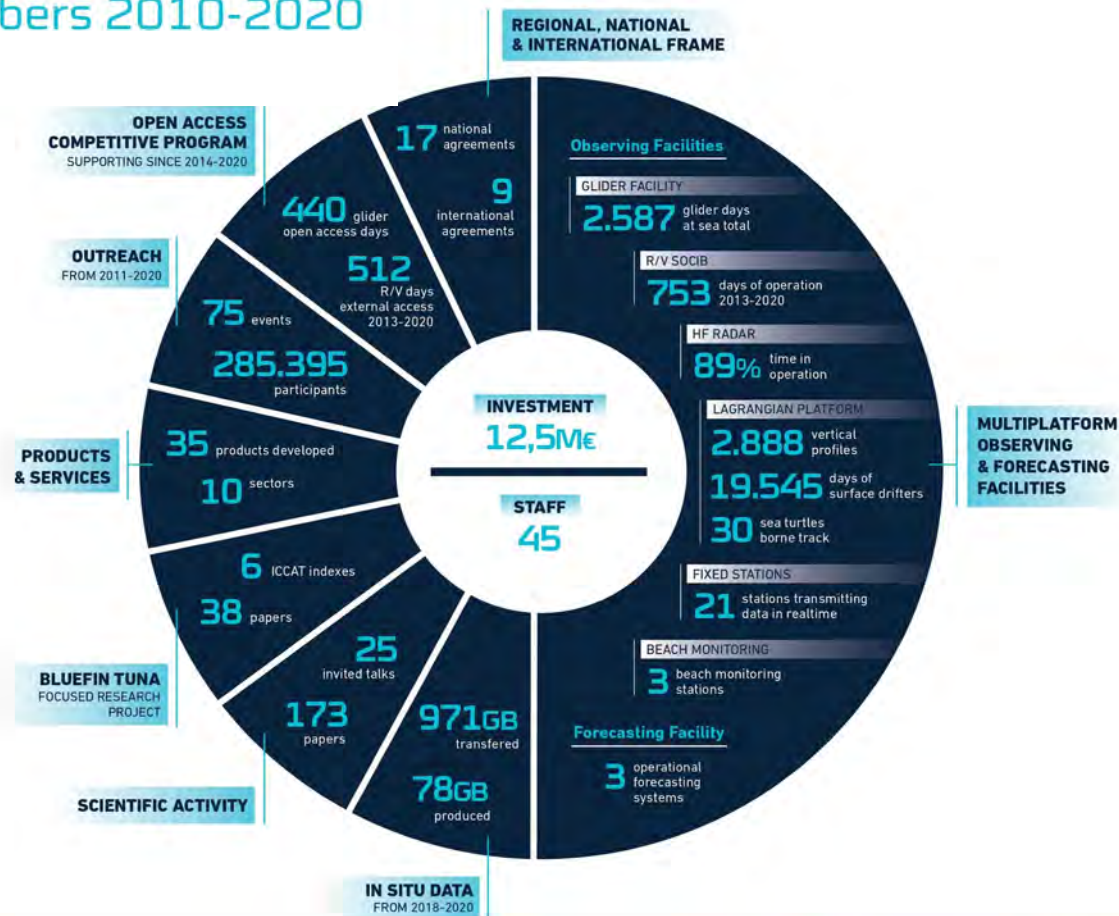
We communicate  
Radio, TV, Social  
Media

Research results,  
products, data,  
services and  
activities  
**1.314** news



# SOCIB Numbers 2011-2020: Science, Data and Society Highlights

## SOCIB numbers 2010-2020



BUT...





**We need real transformation in ocean observation,  
we need a real change: “*ocean integration*”  
for enhanced science and responding to  
society challenges**



# INTEGRATION



Riccardo Muti

“The diversity in the orchestra is to be combined with the need of integration to reach an overall common goal above each one of the elements”

**“The harmony on top of the different component”**

**“From egosystems to ecosystems”**

Gerd Leonhard &  
Xavier Ferras

+



Cristiana Figueres

“Optimism , which actually means courage, hope, trust, solidarity... the belief that we can work together...injecting optimism into the system”



# OCEAN INTEGRATION: a call for transformative organizational changes



(Revelard et al., 2022)

**To become truly integrated...  
... the ocean observing system needs  
organizational transformative changes,  
cultural, behavioral , management...**

Just initial steps, Please contact us to join the Ocean Integration transformation!!!

## Build a collective impact organisation

- Agreeing on a common agenda & principles
- Connecting the diverse communities
- Redesigning a robust governance structure
- Establishing clear design & implementation plan

## Reach sustainability

- Elaborating mission-based funding strategies
- Efficiently communicating the value of ocean observing
- Facilitating the transition from research to operations

## Promote a culture shift

- Redefining scientific "excellence"
- Fostering FAIR data, TRUST digital repositories & BPs

# THE RIGHT TIME FOR THE OCEAN & REGIONAL OCEAN OBSERVING SYSTEMS: DIGITAL TWINS OPPORTUNITY

- 1.- Changes in Science, Technologies, Science to Society relations...
- 2.- Regional & Coastal Ocean Observing Systems/Marine Research Infrastructures: key elements leading these changes because:
  - Critical mass, scientific excellence driven, and also...
  - Mission oriented, multi-disciplinary approach & Integration capabilities, leadership
  - Society Engagement, RRI & Ocean Optimism

**→ A sound ecosystem for Scientific Excellence with Impact on Society, effective synchronization elements, building eco-systems responding to a clear & well established common goal**

**In other words: ...**

**NOW... YES we do have the teams, the know-how and the capacities to address the complexities and the challenges of the global coastal ocean through Digital Twin initiatives & opportunities**



# SOCIB PARTNERS; integrating science, technology and society



*“Investigamos el mar, compartimos futuro”*

Thank you!

# CoastPredict EXPECTED OUTCOMES

1. Integrated knowledge of the global coastal ocean from events to climate (*advancing Knowledge*)
2. The design and implementation of an integrated river/estuarine/coastal/open ocean observing and modelling multidisciplinary system (*integrated observing and predicting*)
3. Improved coastal marine forecasting and extended range predictive capabilities for the coastal zone (*accurate predictions from hours to decades ahead*)
4. The development of methods for trusted data/information exchange and interoperability across the value chain and adaptation as best practices (*open and free access to coastal information*)
5. Innovative and sustainable applications for coastal solutions/services that directly benefit local populations, including well-being and human health (*solutions*)
6. Increased equitable education and capacity for observing and forecasting in the global coastal ocean (*capacity building*)
7. Strong engagement of Early Career Ocean Professionals and promotion of education, training and research under principles of diversity, equity and inclusion (*education, no-one left behind*)