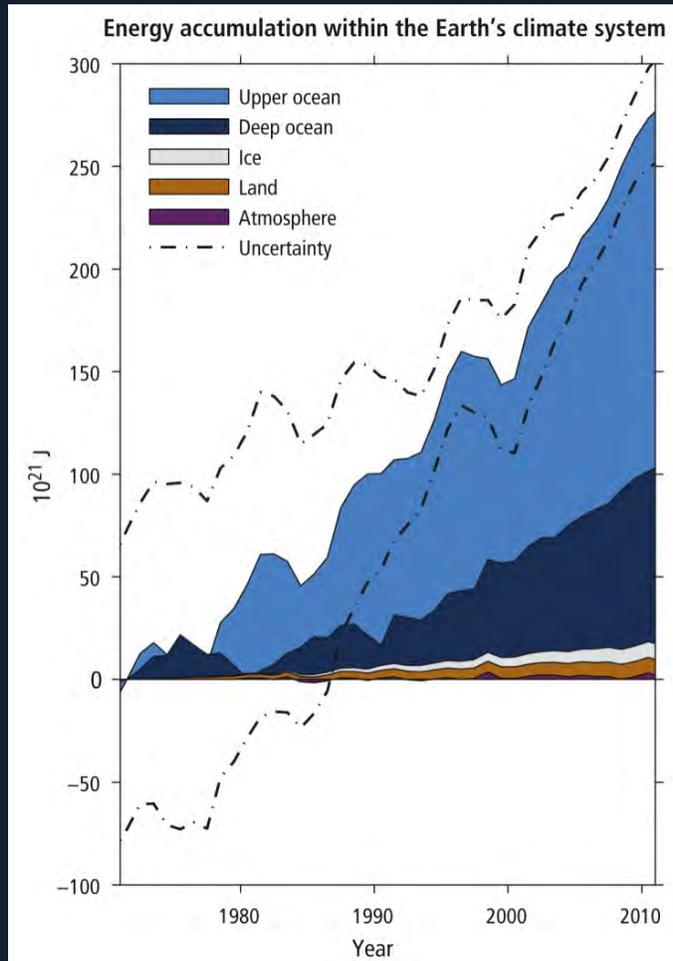


Regional Digital twins : initial steps in the Western Mediterranean Sea, responding to science and society challenges from events to climate

Joaquín Tintoré and all SOCIB & IMEDEA Team
jtintore@socib.es

Scientific Excellence with Impact on Society

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

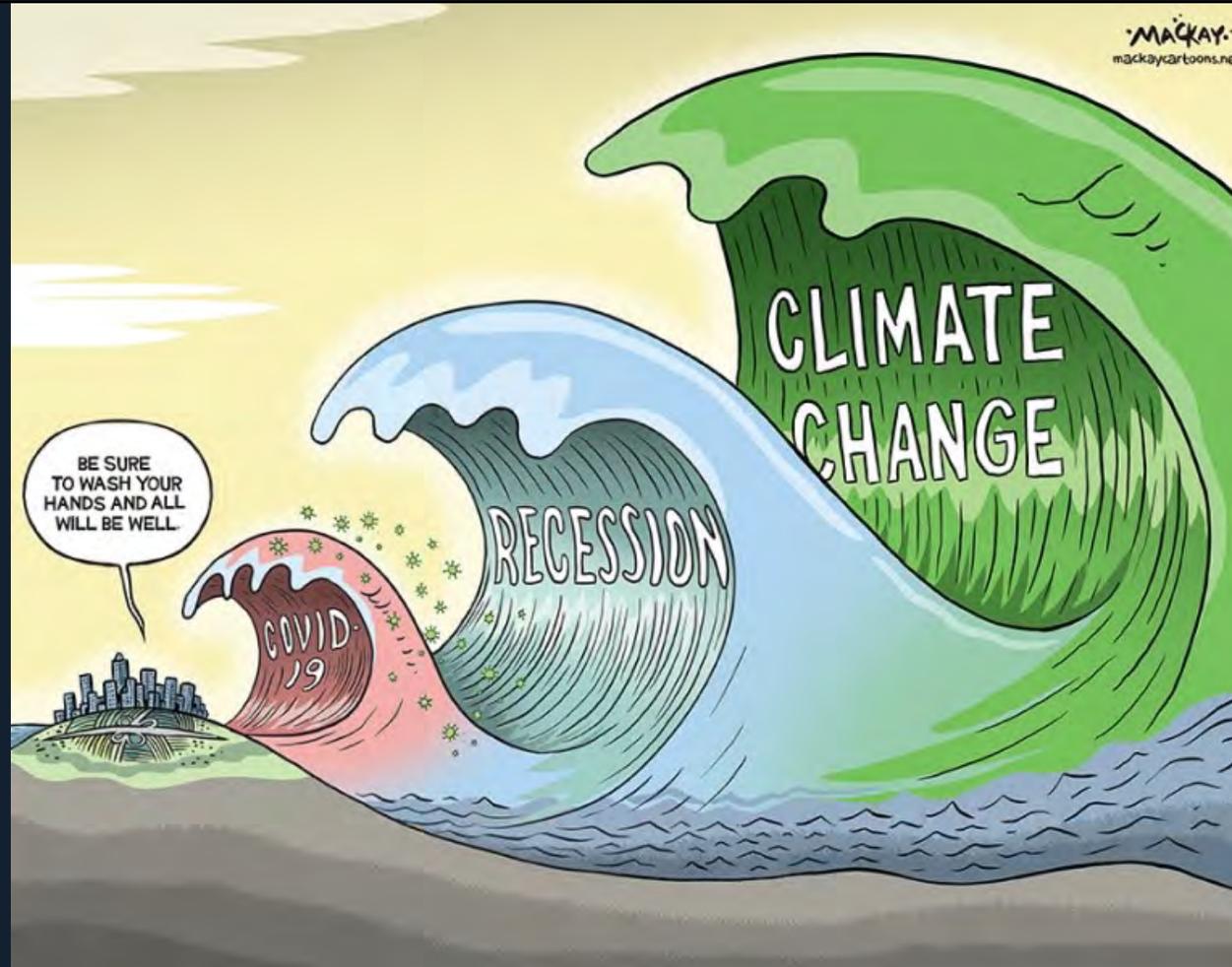


IPCC - Special Report Ocean & Cryosphere 2019



Emergency situation: action and transformation required

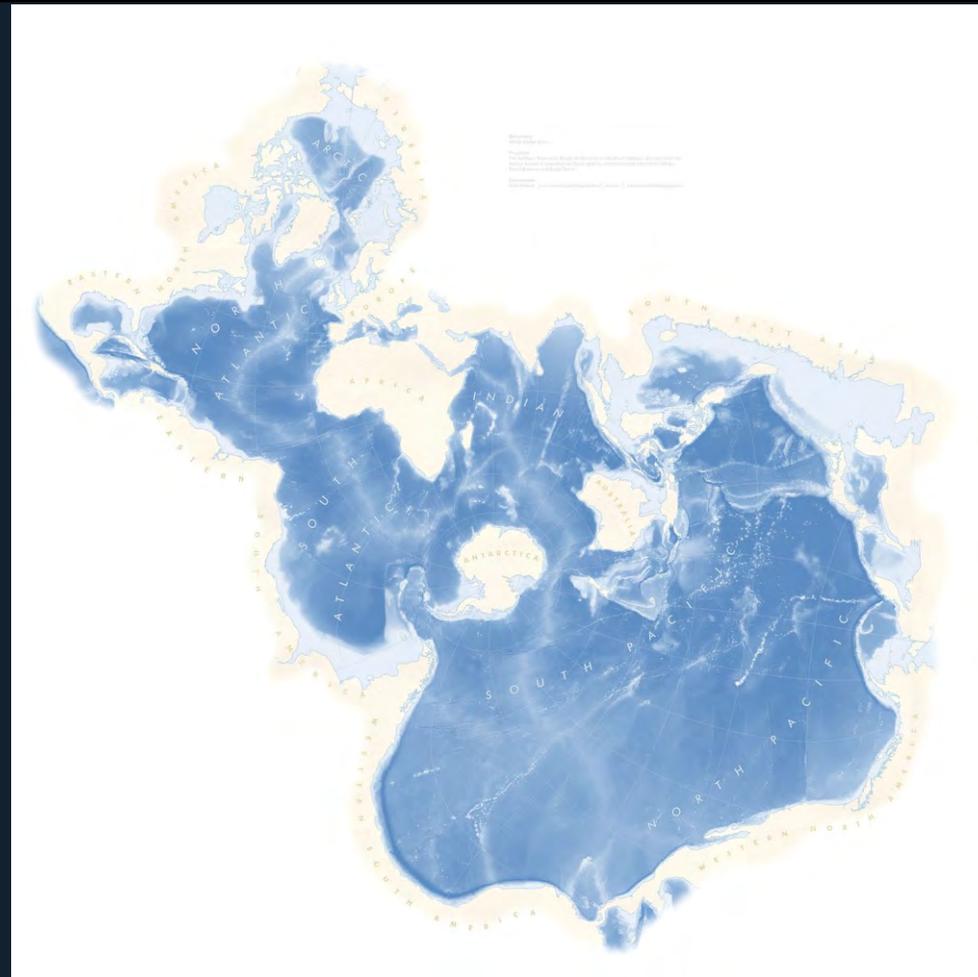
OUR GOAL TODAY: Climate Change



“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...

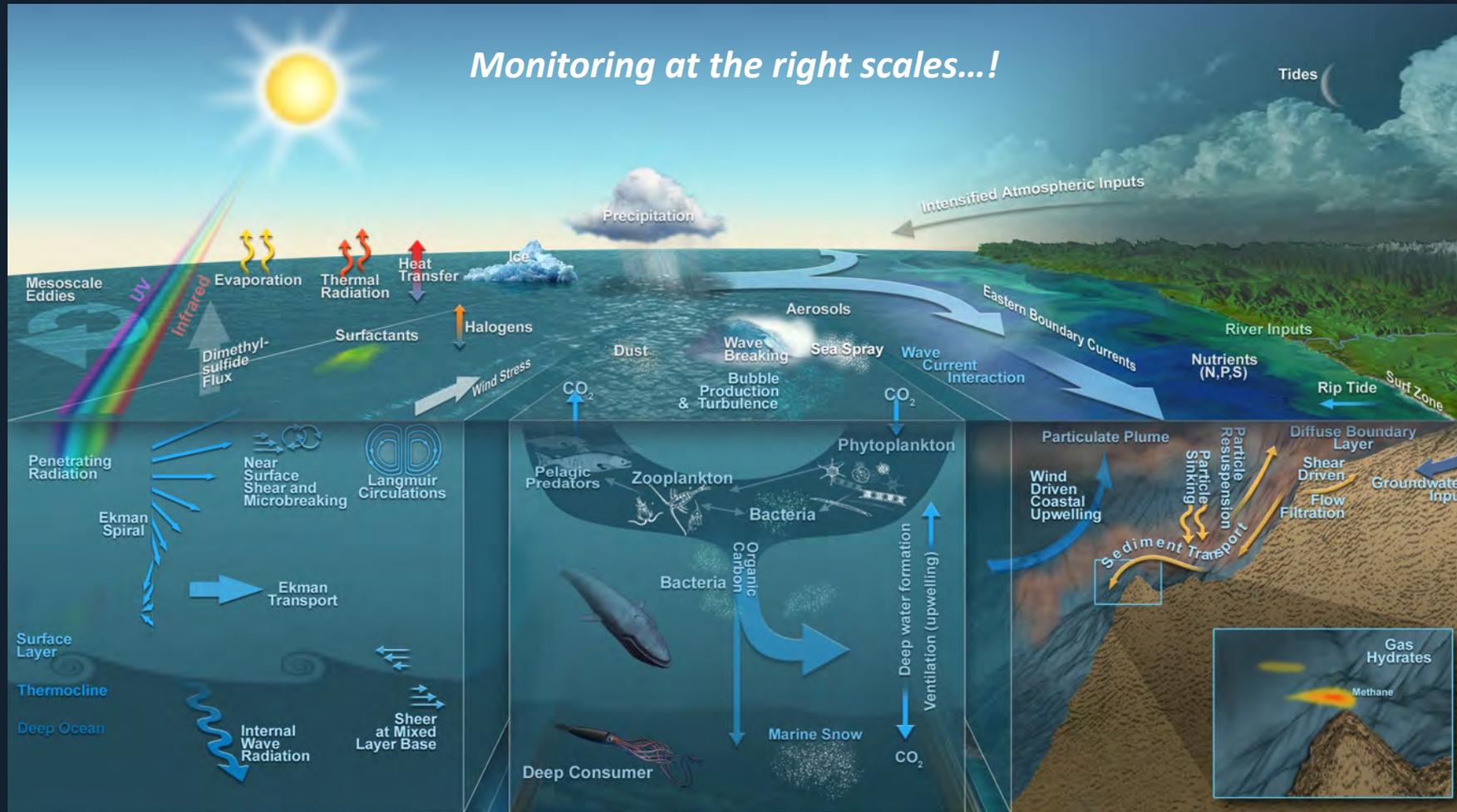
ONE OCEAN – ONE PLANET



Spilhaus map - ESRI

Connectivity, Scales, Limits, Sustainability

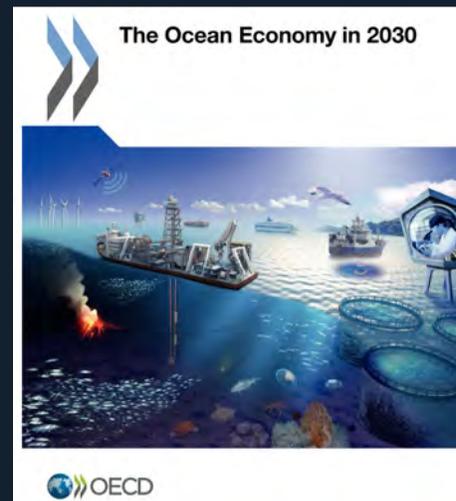
ONE OCEAN: A COMPLEX N-DIMENSIONAL SYSTEM OF SYSTEMS



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

Timeline:

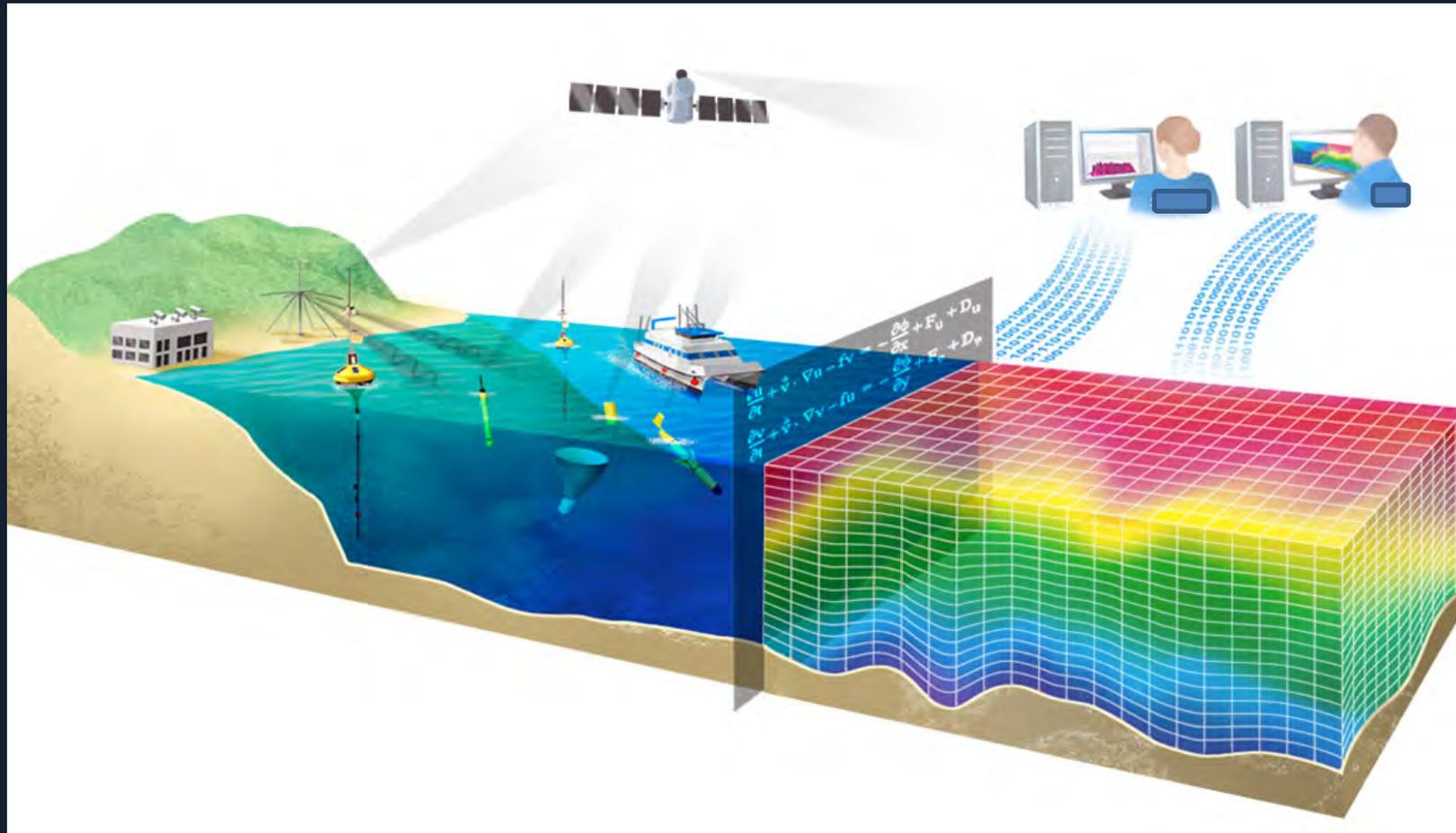
- Proposal 2006 & approved in 2009
- Designed & built 2010-2013
- Included in Large Scale RI Map, 2014

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**

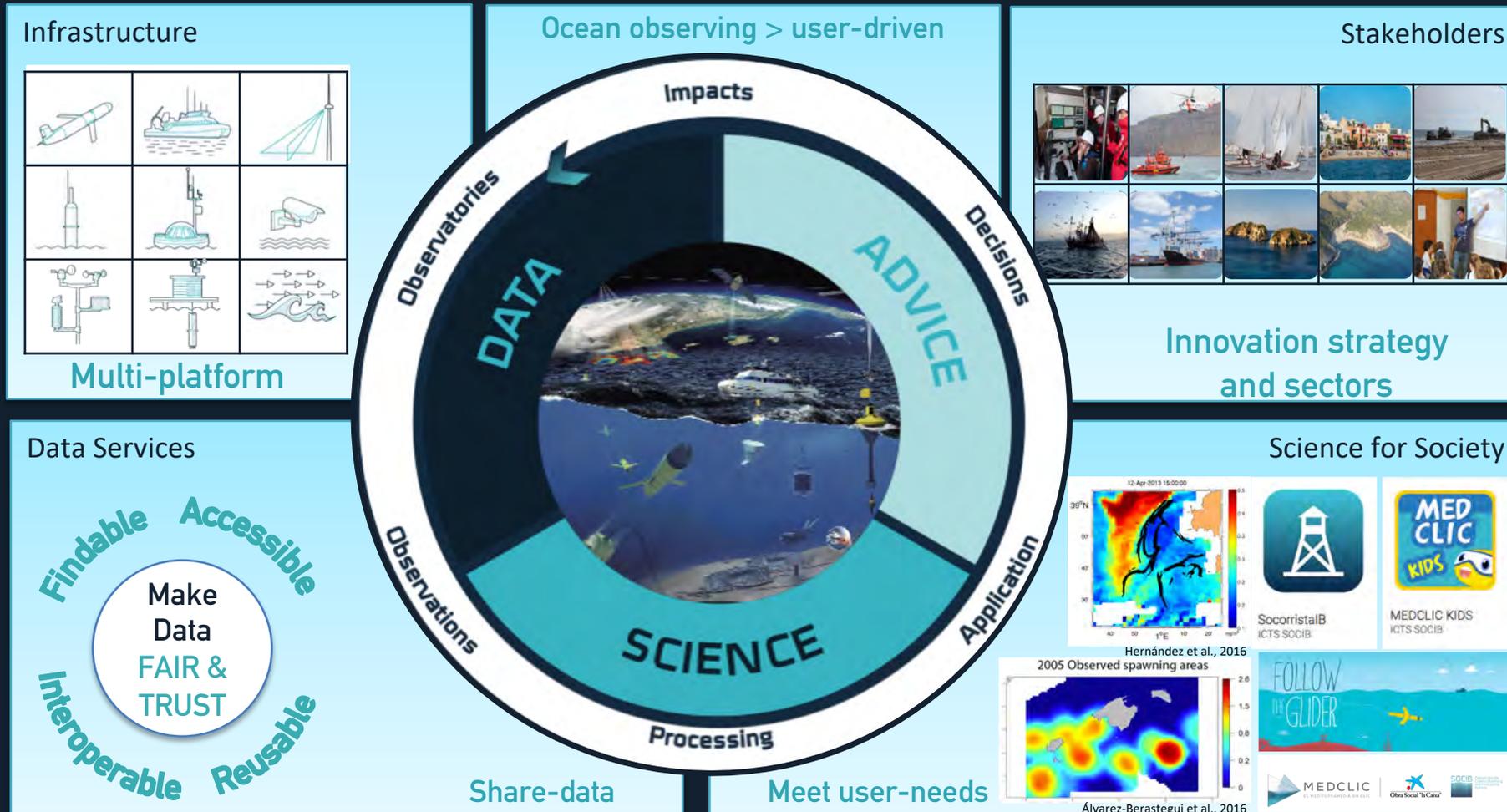
SOCIB INTEGRATED APPROACH TO OCEAN OBSERVING



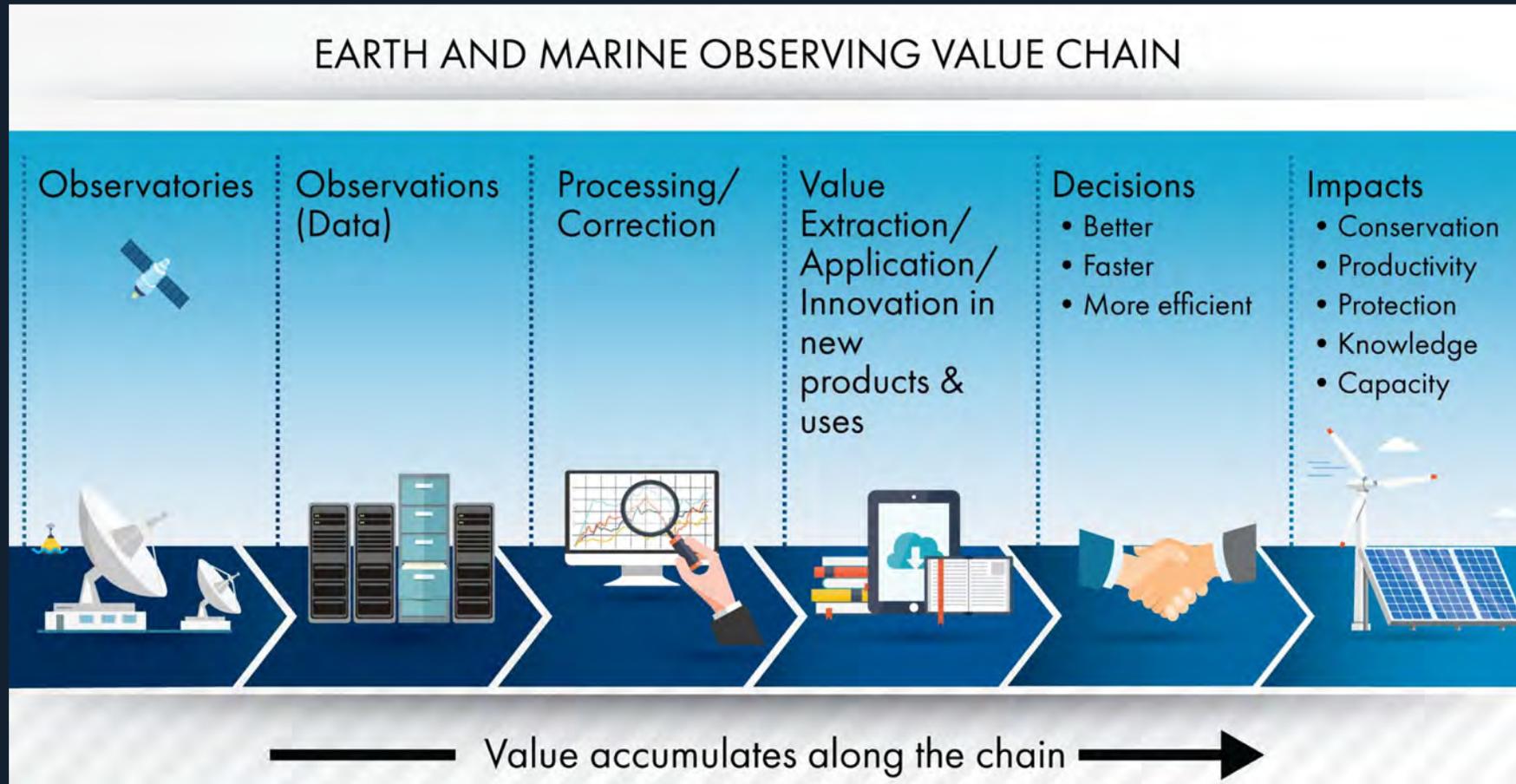
Data Quality: FAIR data and TRUST repositories
Access to Resources & Metrics; Trans-National and Virtual



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*

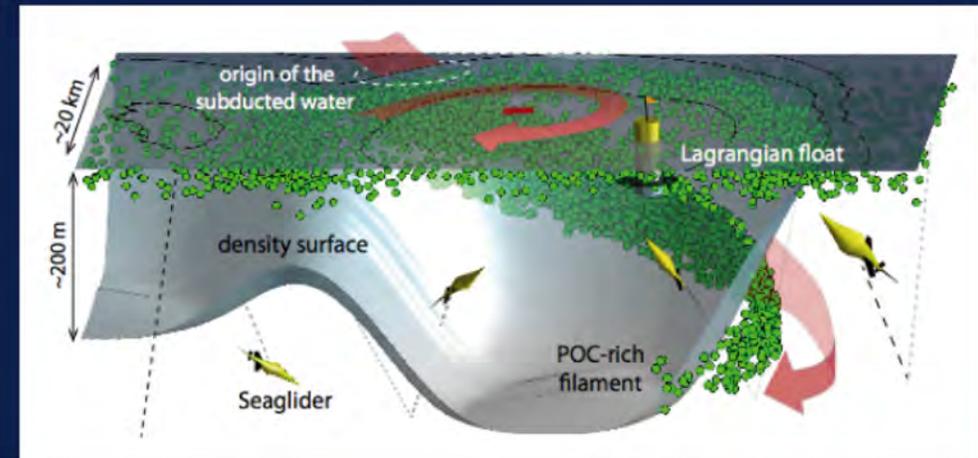
Mahadevan et al., 2020: BAMS

CALYPSO
Coherent Lagrangian Pathways from the
Surface Ocean to Interior

Goal:
Unravel the three-dimensional coherent pathways by which water carrying
tracers and drifting objects is transported from the surface ocean to depths
below the mixed layer.

Approach

- Multiple observing platforms - ship, swarm of autonomous gliders, floats and water-following instruments that will track the water and gather data.
- Natural biological tracers that have implications for the ecosystem.
- Mathematical modeling - Unravel underlying physics for coherent pathways to subduction.
- Gain predictive capability for tracing pathways - targeted and adaptive sampling.

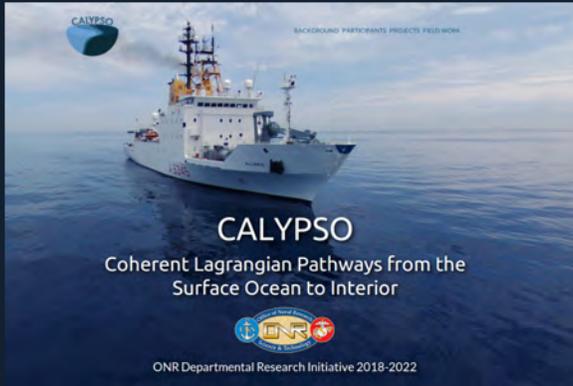


BAMS
In Box

Coherent Pathways for Vertical Transport
from the Surface Ocean to Interior

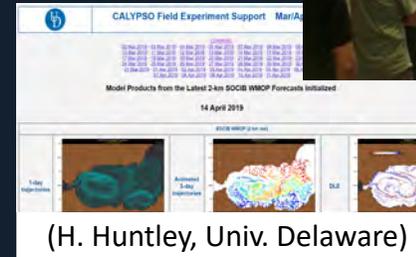
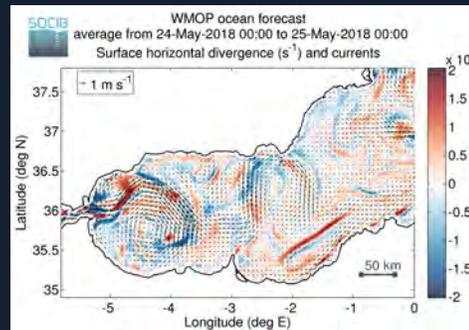
Amala Mahadevan, Ananda Pascual, Daniel L. Rudnick, Simón Ruiz,
Joaquín Tintoré, and Eric D'Asaro

CALYPSO: real-time support to sea trial experiments



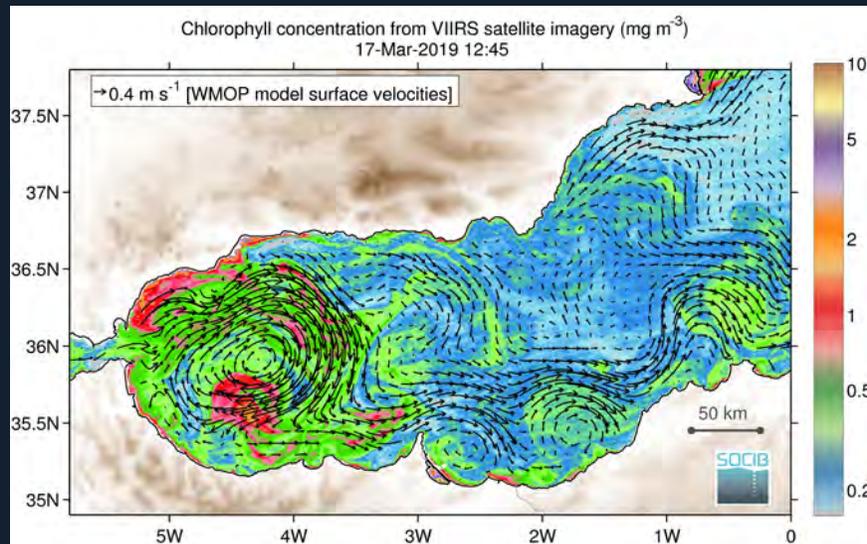
<https://calypsodri.who.edu/>

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

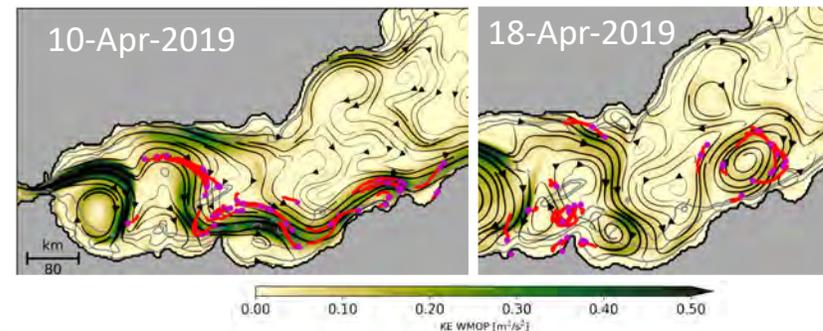


Real-time forecasting
(H. Huntley, Univ. Delaware)

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



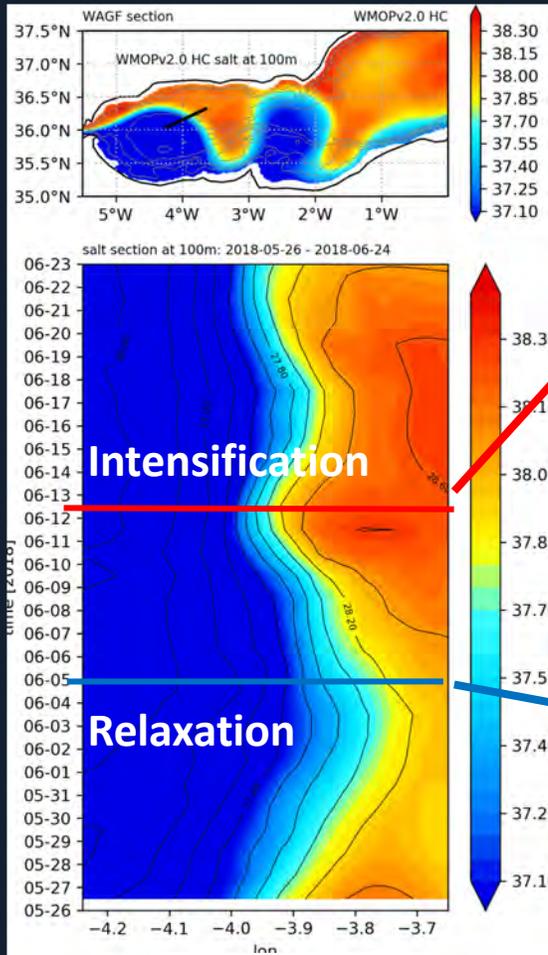
2019 exp: 185 drifters deployed



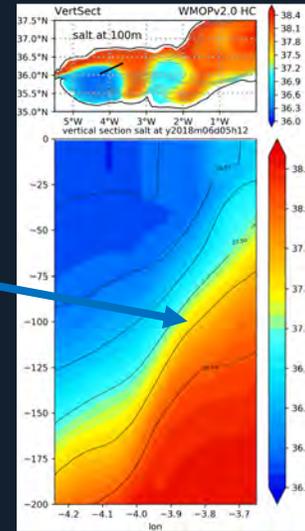
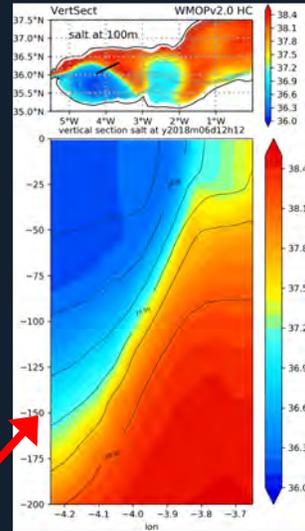
Mechanisms for vertical velocities at the Alboran fronts

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

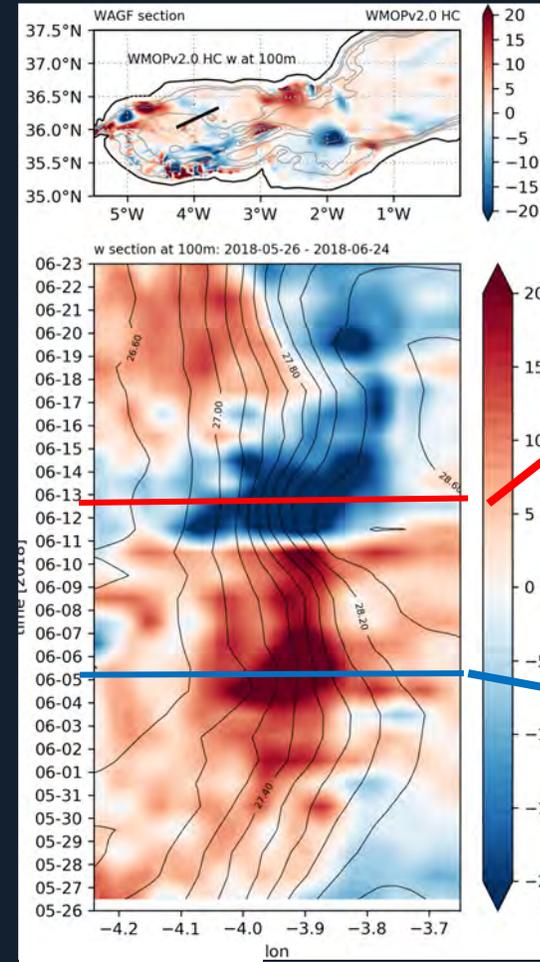
Salinity@100m



Longitude

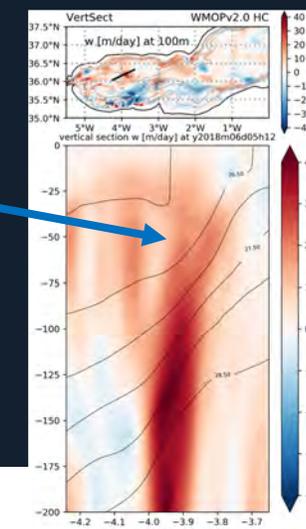
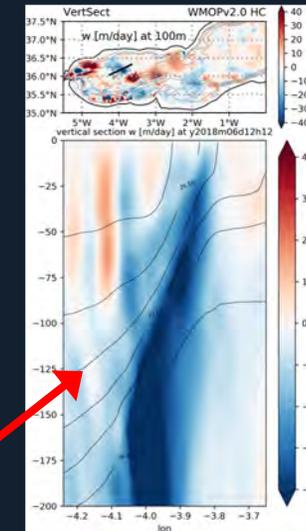


w@100m



Longitude

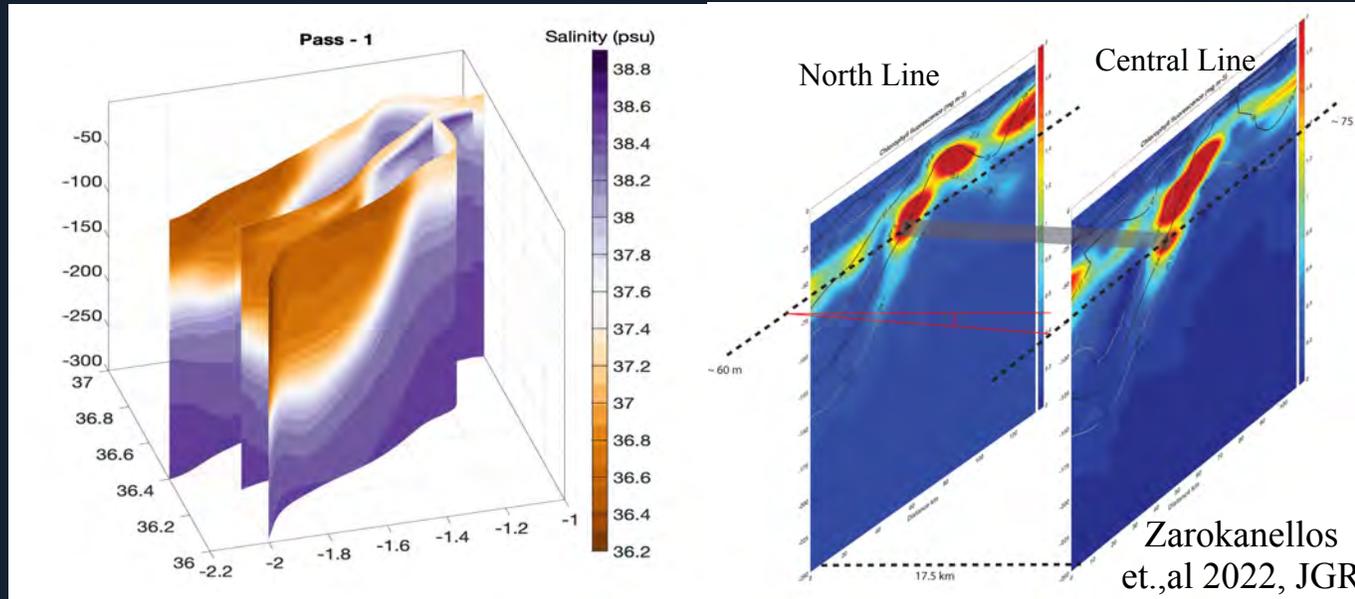
w+ max = 18m/day @57 m
 w- max = 55m/day @156 m



w+ max = 42m/day @135 m
 w- max = 8m/day @158 m

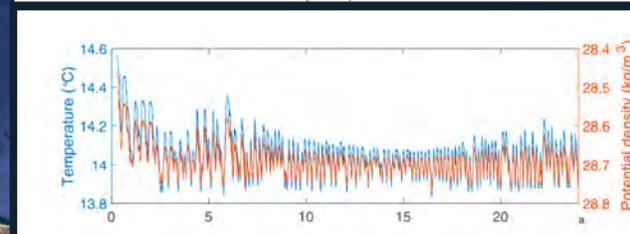
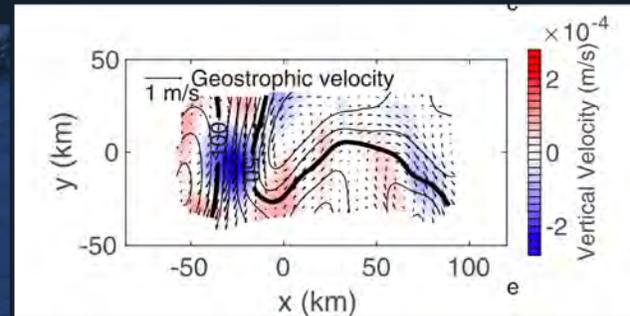
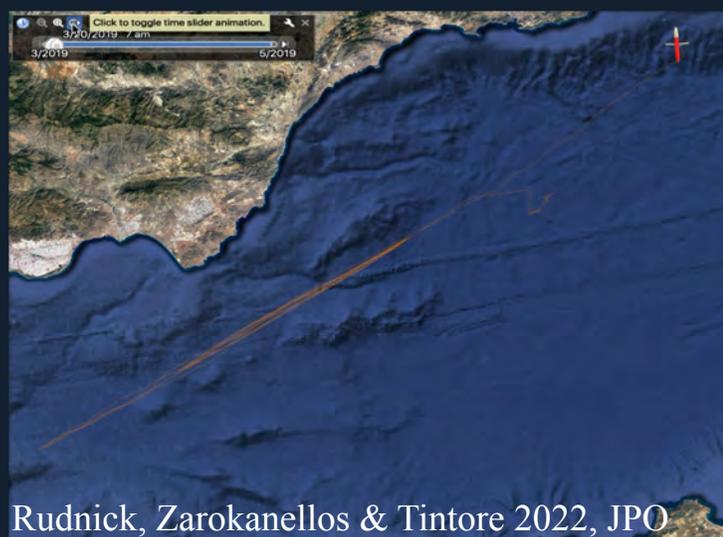
CALYPSO Experiment 2018 & 2019

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

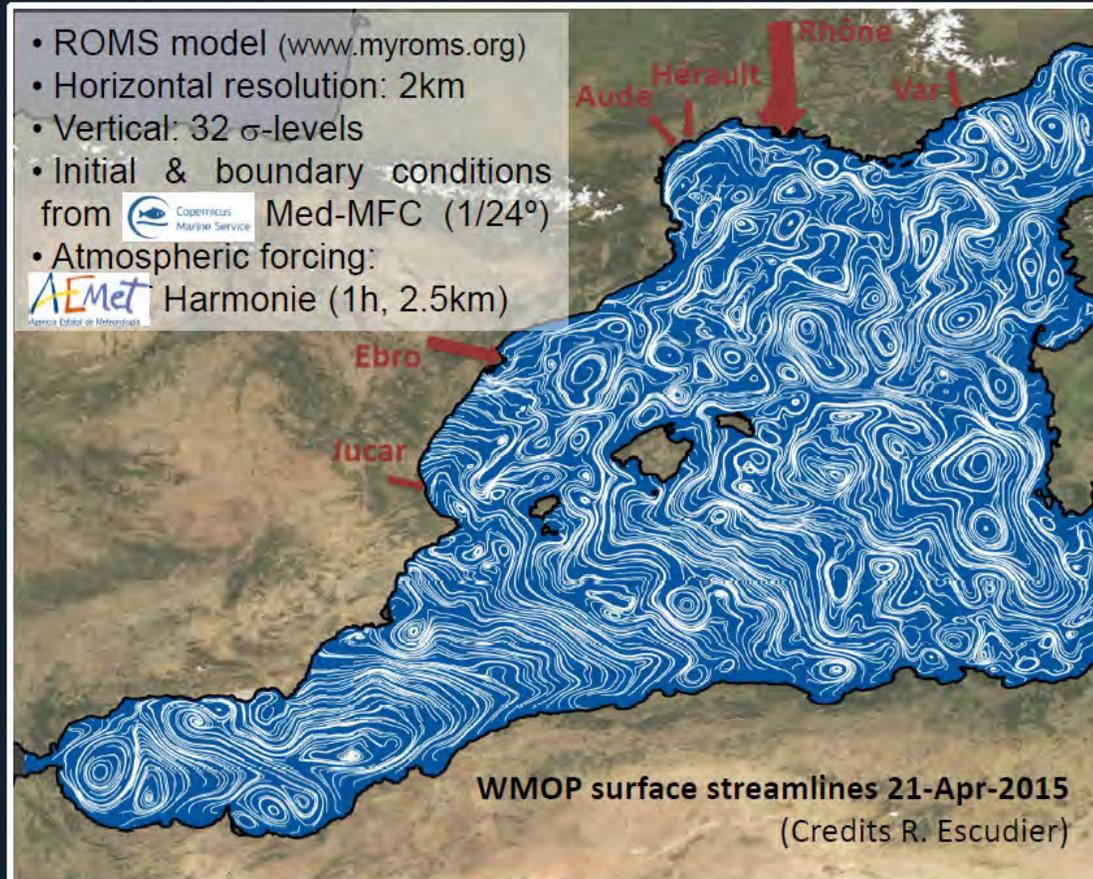
CALYPSO Experiment 2022



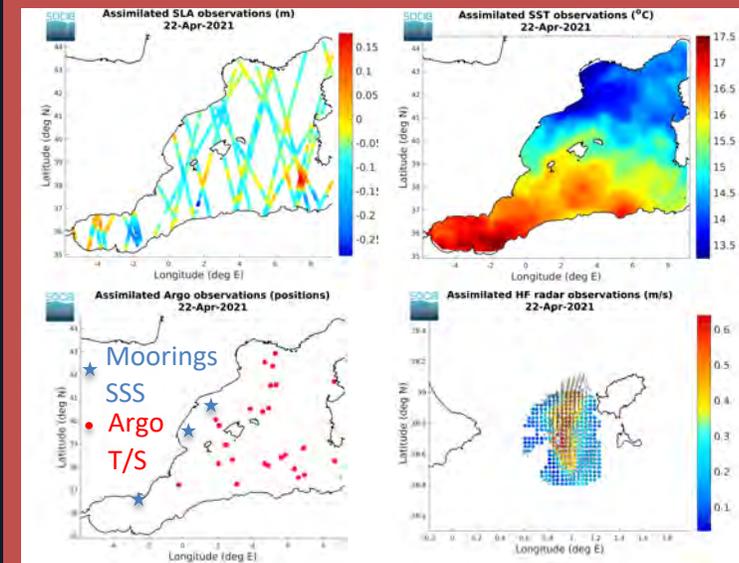
- **2 Ships:** R/V Pourquoi pas? & Pelagia
- Underway profiling to 200+m at 1 km resolution - CTD, oxygen, chlorophyll, backscatter
- Intake - CTD, oxygen, chlorophyll, backscatter
- ADCP velocity profiles
- More than 300 surface drifters drifters...
- 9 Profiling 'Argo like' floats
- Satellite SST and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

HIGHLIGHTS: SCIENCE

Integrated Modelling & Observation System



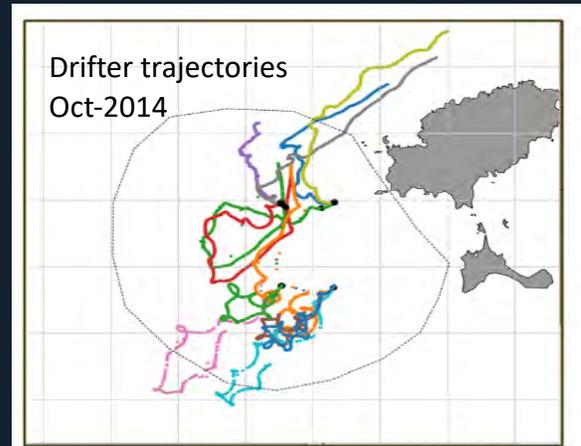
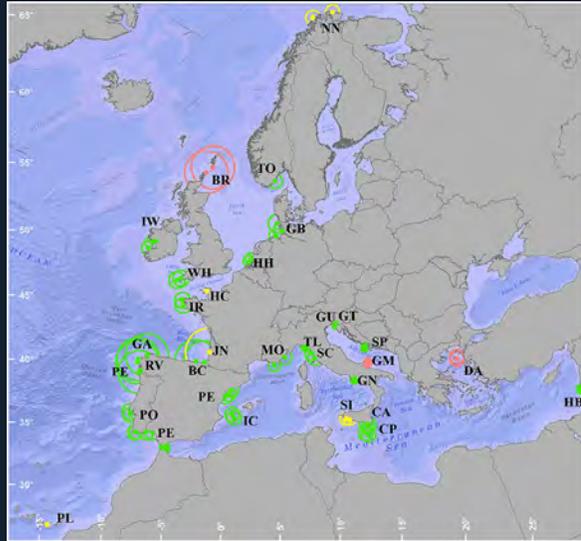
Data assimilation:
Ensemble Optimal Interpolation
with 3-day cycles



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

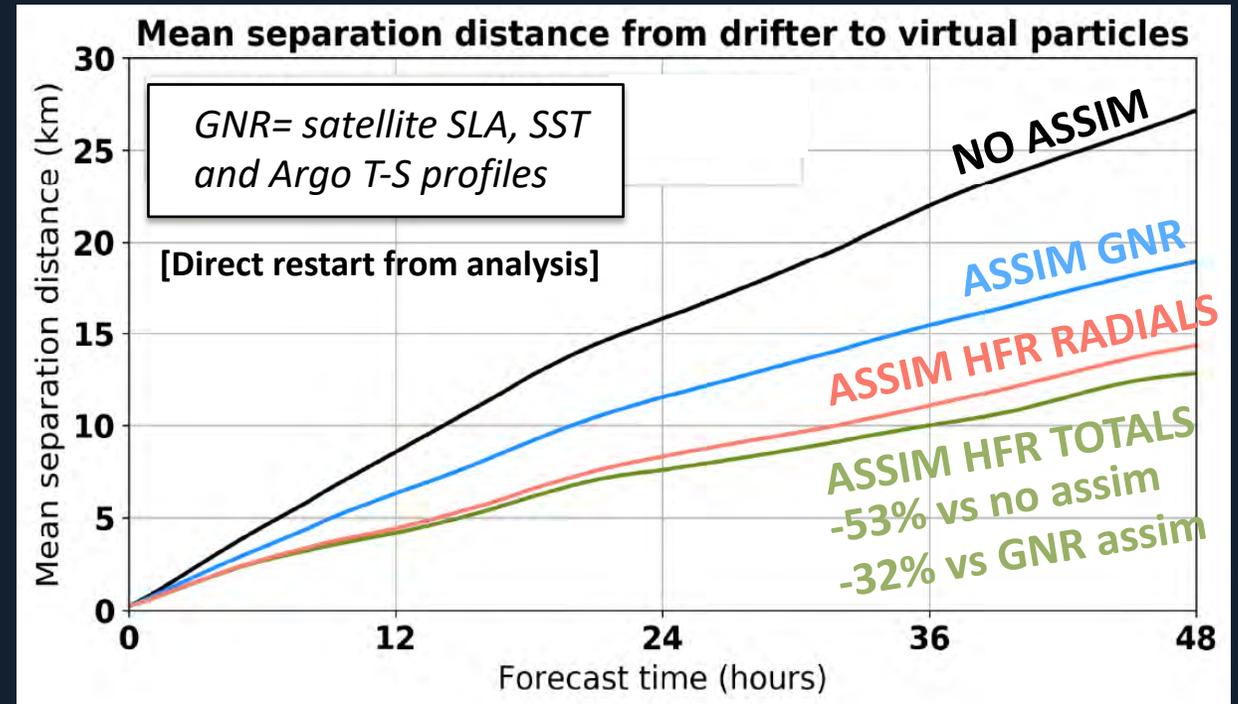
Ibiza Channel HFR currents assimilated in the WMOP operational prediction system, together with satellite SST & SLA, moorings and Argo TS profiles

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

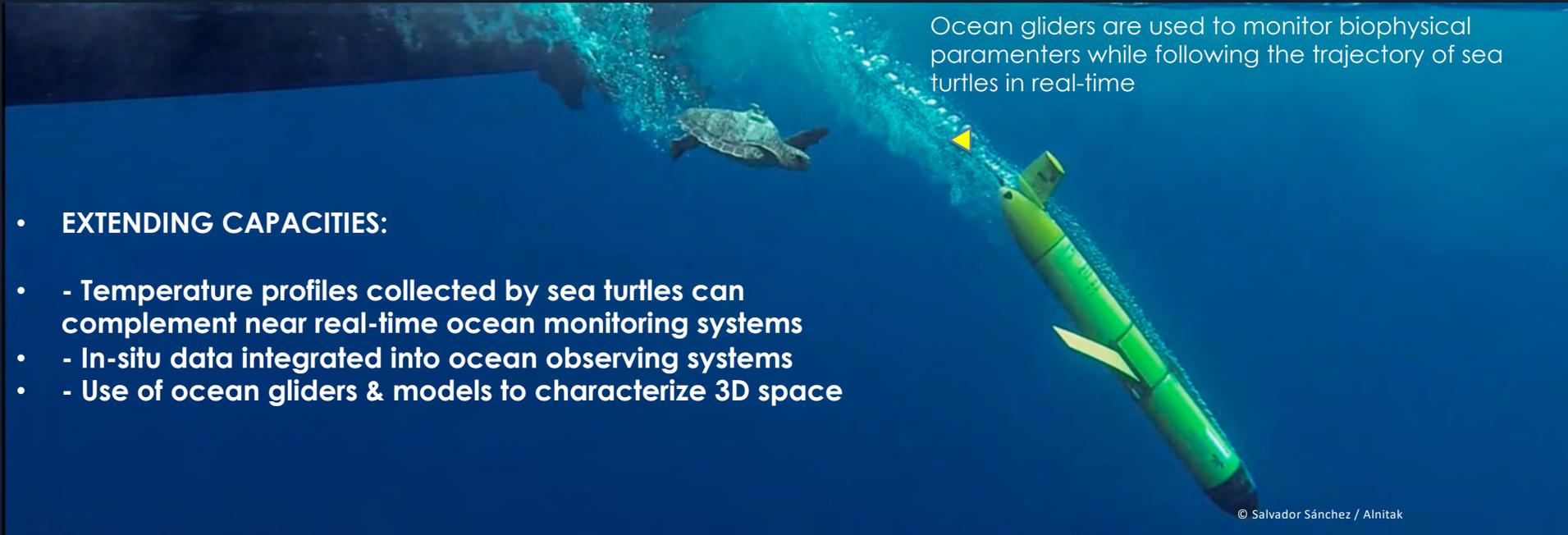
End-users needs

Reliable current observations and forecasting are essential

Easily interpretable metrics

User-friendly automated skill assessment

HIGHLIGHTS: NEW OBSERVING SYSTEMS, ANIMAL BORNE INSTRUMENTS



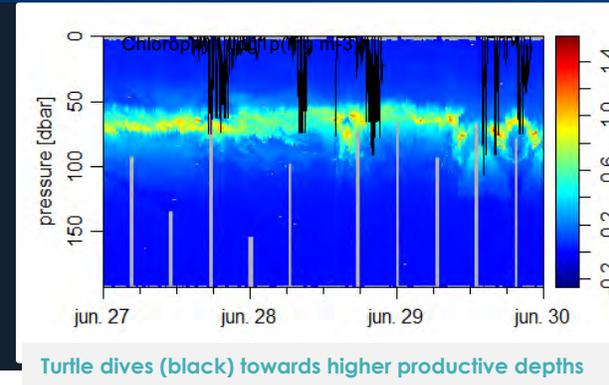
Ocean gliders are used to monitor biophysical parameters while following the trajectory of sea turtles in real-time

- **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

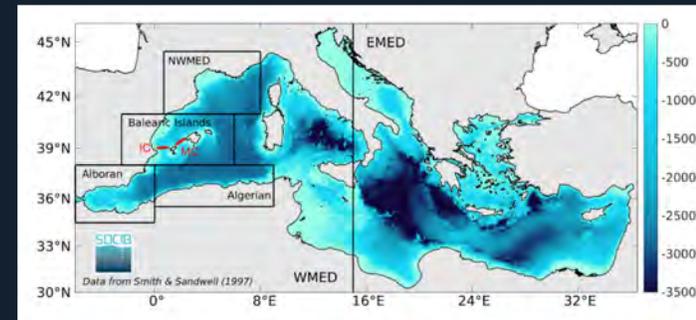


HIGHLIGHTS TOOLS: Sub-regional Mediterranean Sea Indicators, from event detection to climate change

SUB-REGIONAL MEDITERRANEAN SEA INDICATORS
From event detection to climate change

Surface ocean	Ocean temperature	Ocean health	Ocean currents	Sea level	Winds
Integrated ocean	Heat & salt contents	Mixed layer	Transports		

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



Juza & Tintoré (2021)
<https://doi.org/10.3389/fmars.2021.610589>

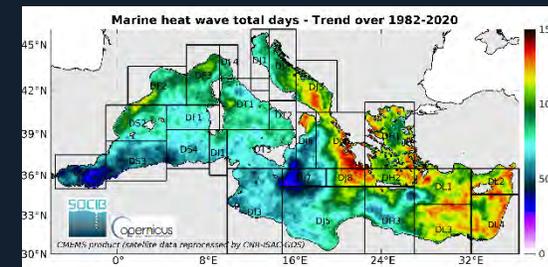
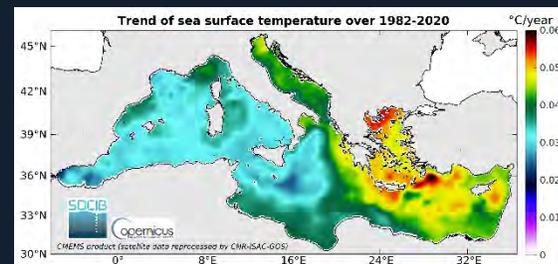
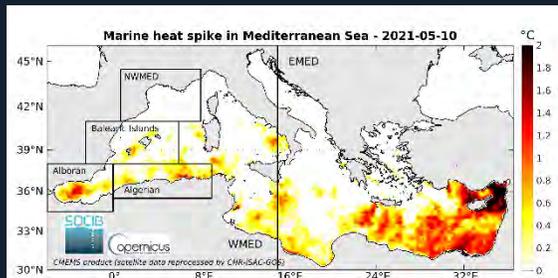
Methodology

- 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

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

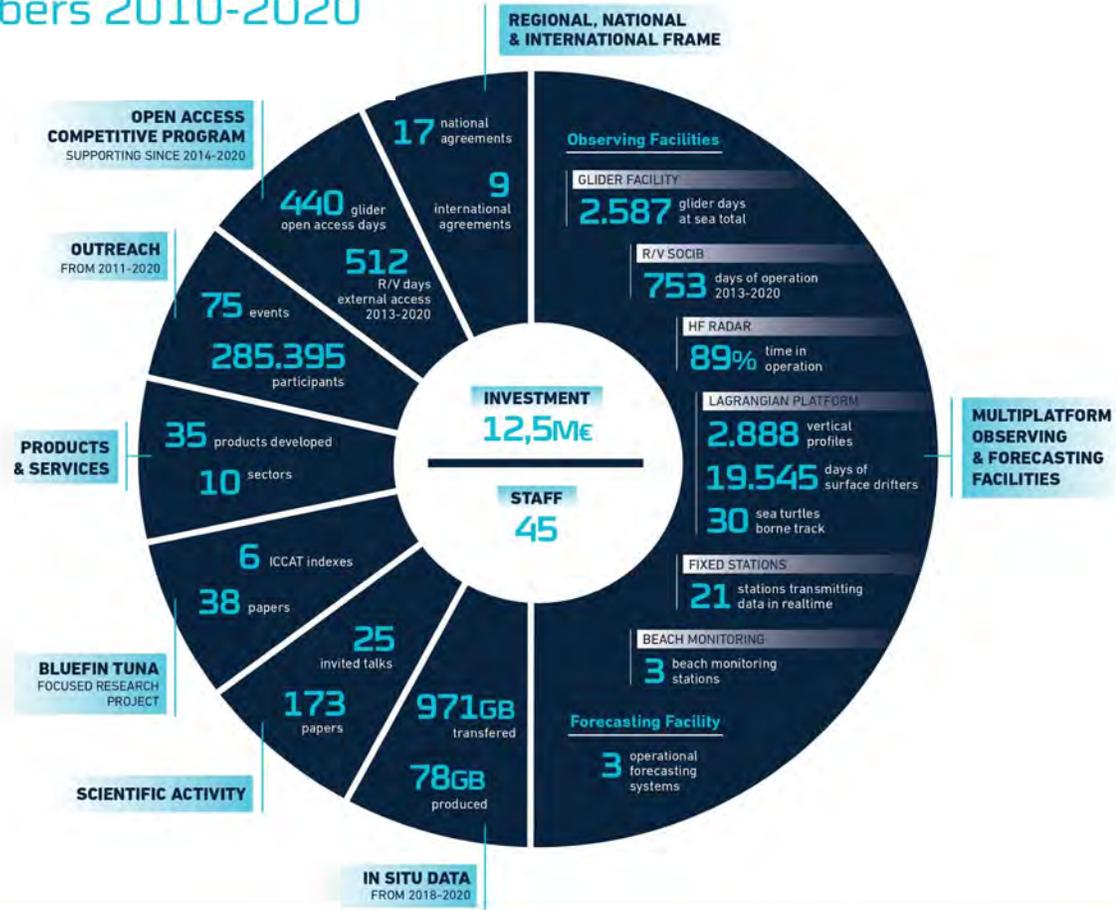


We communicate
Radio, TV, Social
Media
Research results,
products, data,
services and

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*)