The impact of new information infrastructures in understanding and forecasting the world's ocean

Joaquín Tintoré and the SOCIB/IMEDEA team

SOCIB and IMEDEA (UIB-CSIC)

http://www.socib.eu

OUTLINE

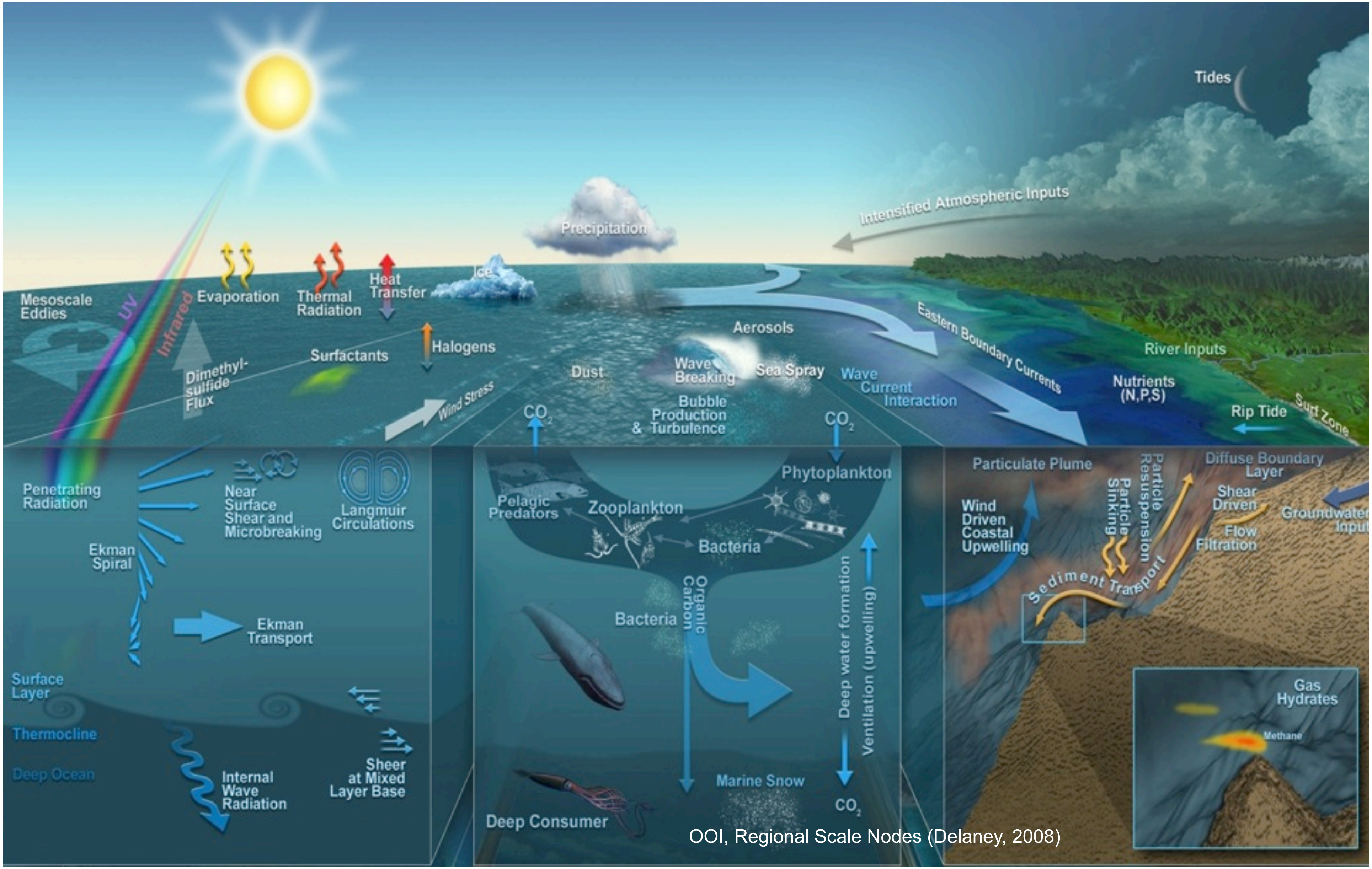
1. The Oceans' Challenges for Science, Technology and Society

2. Ocean Information for Society,… what we learned (scientific motivation and some examples of global problems addressed in a Lab. Ocean)

3. SOCIB, Ocean Observatories, a new multi-platform approach

4. The new role of Marine Research Infrastructures to respond to Science, Technology and Society needs

Oceans are complex and central to the Earth system



OOI, Regional Scale Nodes (Delaney, 2008)

The oceans are chronically under-sampled (1)

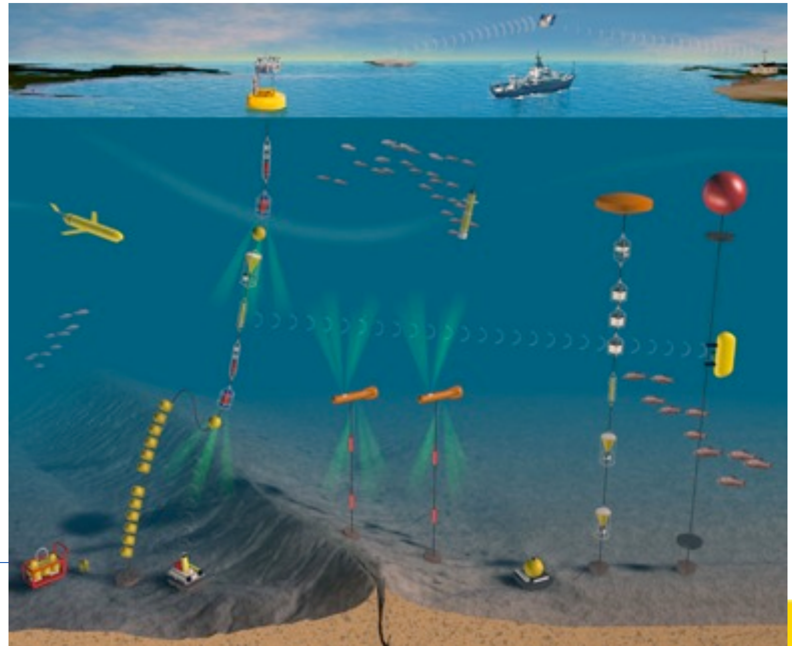
(Credit, Oscar Schoefield)

Paradigm Shift (1) in Ocean Observation

From: Ship based observation
To: Multi-platform observing systems

Platform-centric Sensing Systems

Net-centric, Distributed Sensing Systems



(Adapted from Steve Chien, JPL-NASA)

Paradigm Shift (2) in Data Availability

From: Data only available 12-24 months/years after cruises….
To: Quasi-real time quality controlled data available

Inter-comparison

Models ⟷ **Data**

…. For ….At sea mission re-definition, new models setup…

With… huge increase in human potential for analysis

A 2020 Vision for Ocean Science

JOHN R. DELANEY
University of Washington
ROGER S. BARGA
Microsoft Research

NEW CHALLENGES, TOOLS DEVELOPMENT, etc…

What is SOCIB? – Balearic Islands Coastal Observing System -

SOCIB is an Observing and Forecasting System, **a multi-platform distributed and integrated Scientific and Technological** Facility (a facility of facilities…)

- providing streams of oceanographic data and modelling services in support to operational oceanography
- contributing to the needs of marine and coastal research in a global change context.

The concept of Operational Oceanography is here understood as general, including traditional operational services to society but also including the sustained supply of multidisciplinary data and technologies development to cover the needs of a wide range of scientific research priorities and society needs.

In other words, SOCIB will allow a quantitative increase in our understanding of key questions on oceans and climate change, coastal ocean processes and ecosystem variability.

Why SOCIB, why Ocean Observatories, and **why now?**

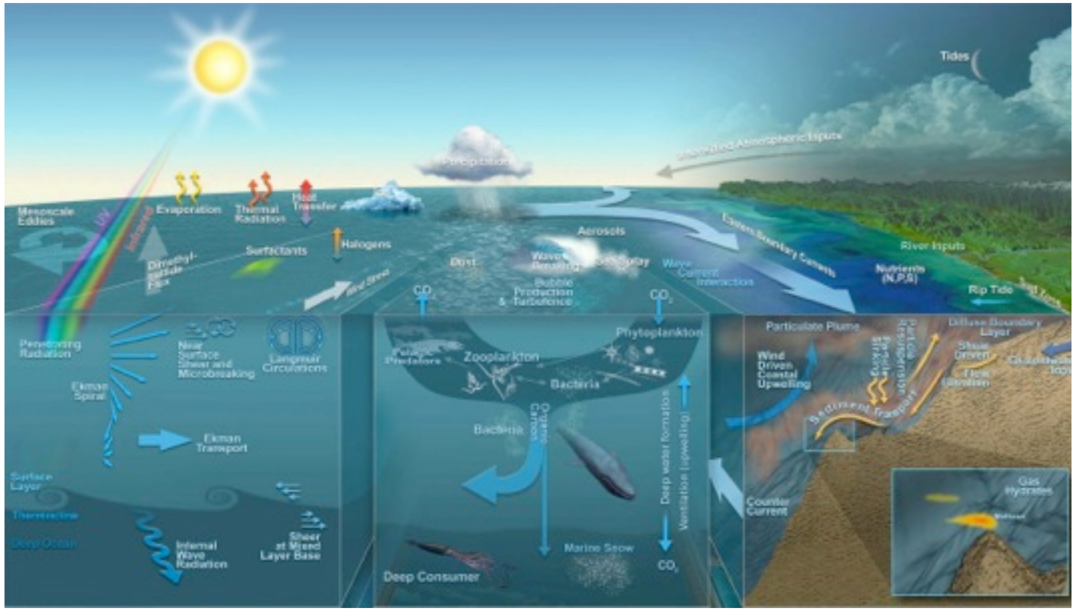
A New Approach to Marine and Coastal Research

New technologies now allow three-dimensional real time observations, that combined with forecasting numerical models, and data assimilation, …

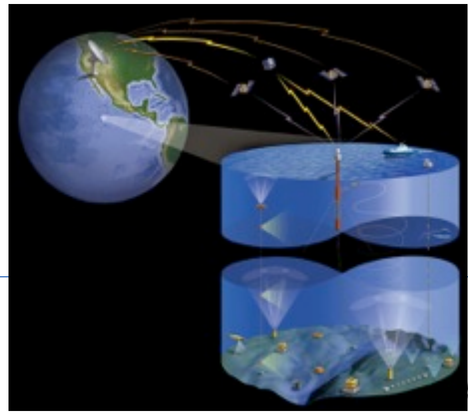
A quantitative major jump, in scientific knowledge and technology development

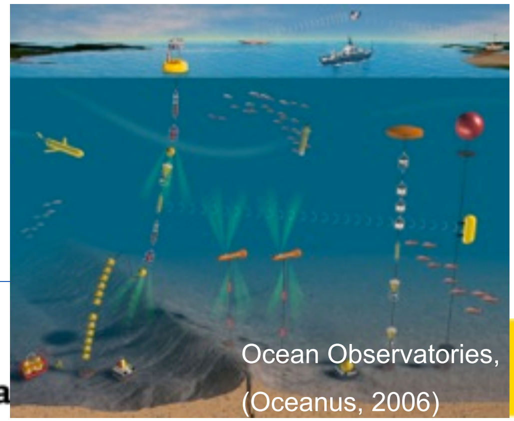
The development of a new form of Integrated Coastal Zone Management, based on recent scientific and technological achievements,

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



OOI, Regional Scale Nodes (Delaney, 2008)





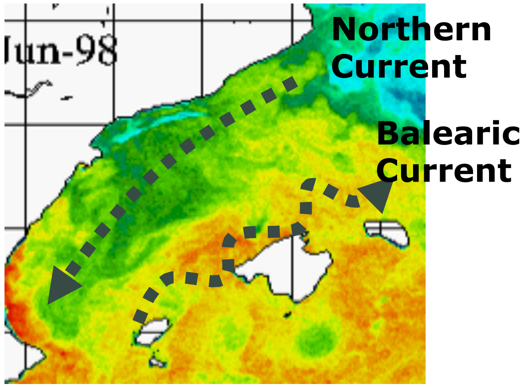
Ocean Observatories, (Oceanus, 2006)

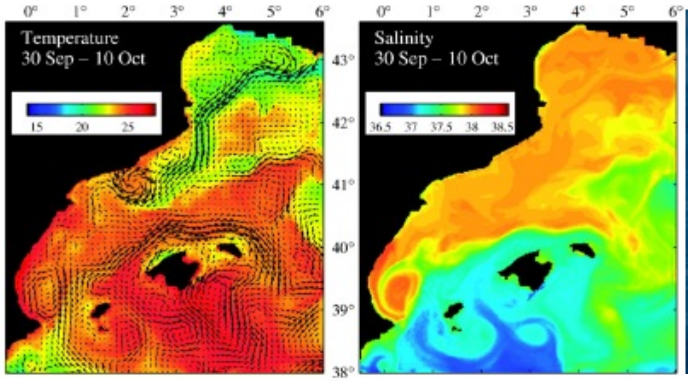
Balearic Islands Coastal Observing and Forecasting System

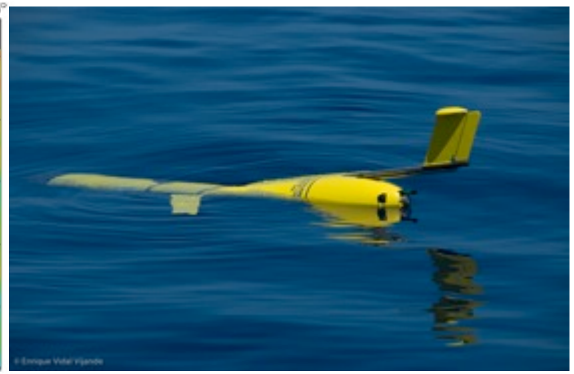
Why SOCIB, why Coastal Ocean Observatories, and **why now?**

New monitoring technologies are being progressively available for coastal ocean studies:

For example, **gliders** allow high-resolution sampling showing the existence of new features, such as submesoscale eddies with intense vertical motions that significantly affect upper ocean biogeochemical exchanges, an issue of worldwide relevance in the context of climate change (***Klein-Lapeyre, Ann Rev, 2008***).







These new technologies, used together, are delivering new insight into coastal ocean variability, which in turn will trigger new theoretical developments, increasing our understanding of coastal and nearshore processes and contributing to a more science based and sustainable management of the coastal area.

The SOCIB approach to sustained ocean observation…

To assure the real sustainability of the seas and oceans and of the observing systems, SOCIB was designed:

→ **RESPONDING TO 3 KEY DRIVERS**

- Science Priorities
- Strategic Society Needs
- Technology Developments

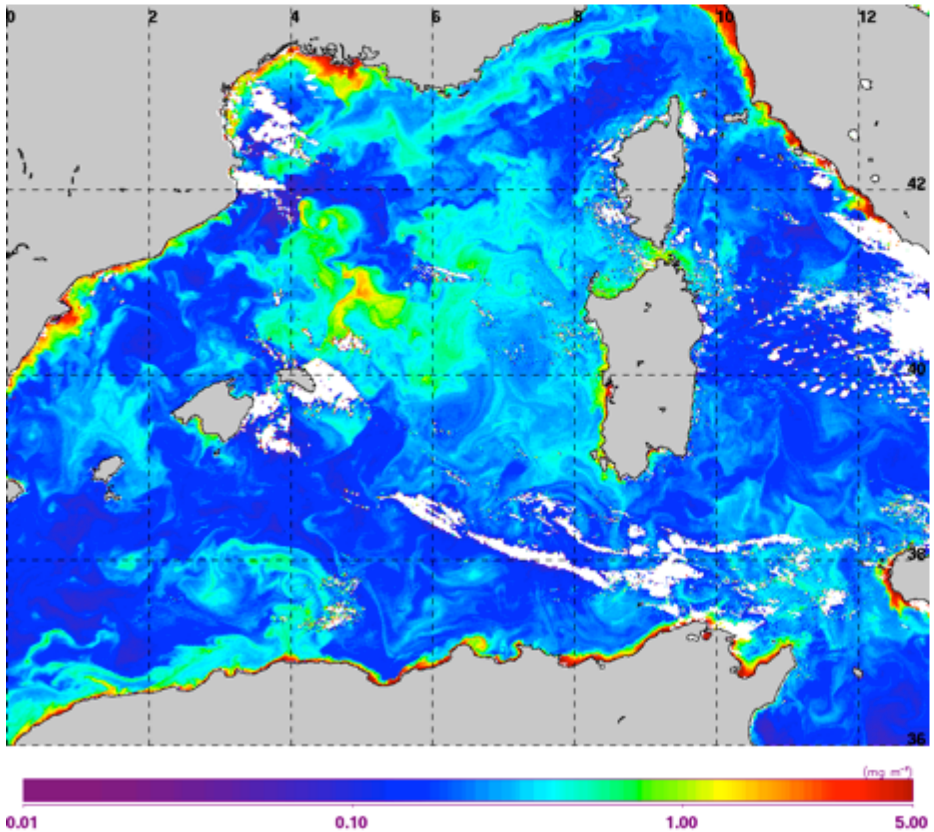
Scientific motivation

From Large Scale Picture --→

Mesoscale/eddy-mean flow interactions, heat, nutrient and/ or carbon fluxes, etc… :   1990's onwards…

Vertical motion associated with mesoscale features plays a major role in the exchanges of properties between the surface and the ocean interior (Klein-Lapeyre 2008).

Mesoscale and Submesoscale impacts on physical variability and ecosystem variability.



SeaWiFS chlorophyll image. Unites are mg m^{-3} . Mesoscale dynamics modulates biological responses.

Motivation: the background... IMEDEA work since 1990 's… - Strategic Plan 2010-2013

20 years of **peer reviewed 'basic' Research Activity**: fronts, mesoscale eddies, shelf/slope exchanges, shelf dynamics, satellite altimetry, waves, sediments, beach variability, etc…

that evolved incorporating …

Technology Development (both transfer of technological products –spin off AMT- and transfer of management technologies –beach management, recreational boating carrying capacity, tools for decision support; ESI/NOAA, sustainability indicators-)

that evolved as requested by society…

Applications to respond to society needs (beach erosion, beach response extreme events, sand re-nourishment, socio-economic valuation, ICZM, ICOM, MSP).

(Available pdf file at:

http://imedea.uib-csic.es/tmoos)

SOCIB Balearic Islands Coastal Observing and Forecasting System

CSIC

Govern de les Illes Balears

GOBIERNO DE ESPAÑA · MINISTERIO DE CIENCIA E INNOVACIÓN

SOCIB mission and general objectives:

Mission: to develop an Observing and Forecasting System, a scientific and technological infrastructure which will provide free, open, quality controlled and timely streams of data to:

General Objectives:

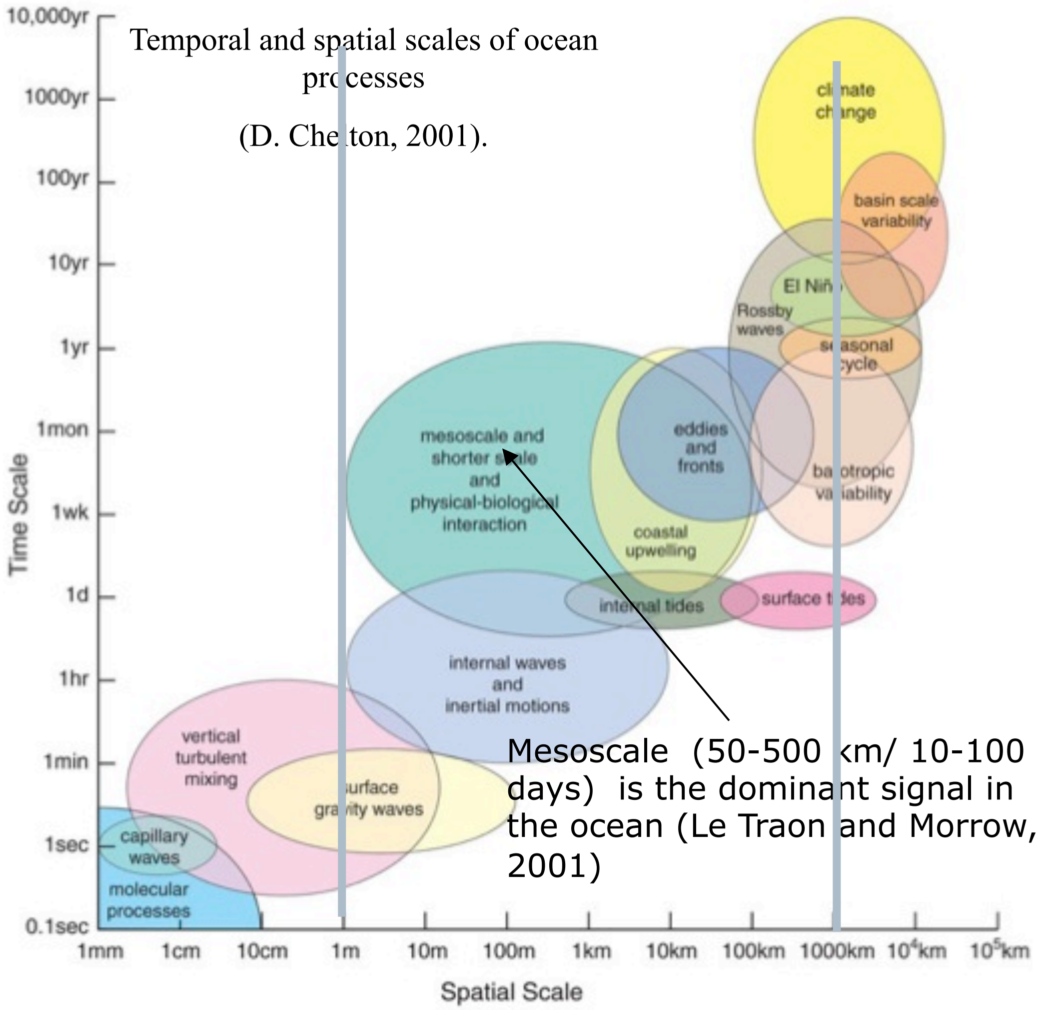
1. Support research and technology development on:
   - The role of the Mediterranean Sea in the climate system at inter-annual scale,
   - The interaction between currents and eddies at mesoscale and submesoscale, vertical exchanges and physical and ecosystems variability
   - The variability in nearshore morpho-dynamics and the sea level variability in response to climate change.
2. Support (on a longer term) strategic needs from society in the context of global change.
3. Support research in process oriented operational oceanography

SOCIB Scales Focus: 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),

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

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



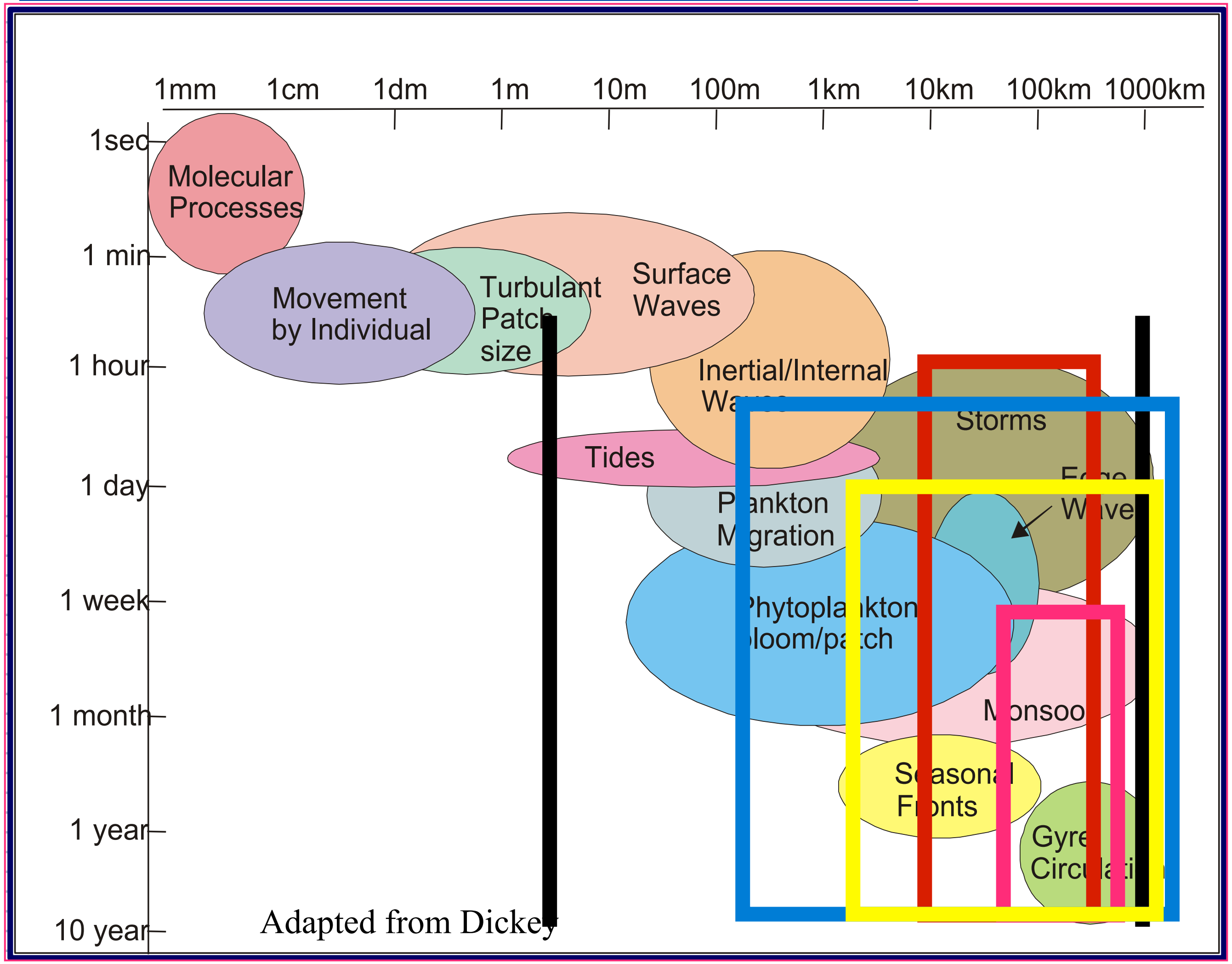
SOCIB scales

SOCIB Balearic Islands Coastal Observing and Forecasting System · CSIC · Govern de les Illes Balears · Gobierno de España · Ministerio de Ciencia e Innovación

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

SOCIB scales and monitoring tools



Gliders

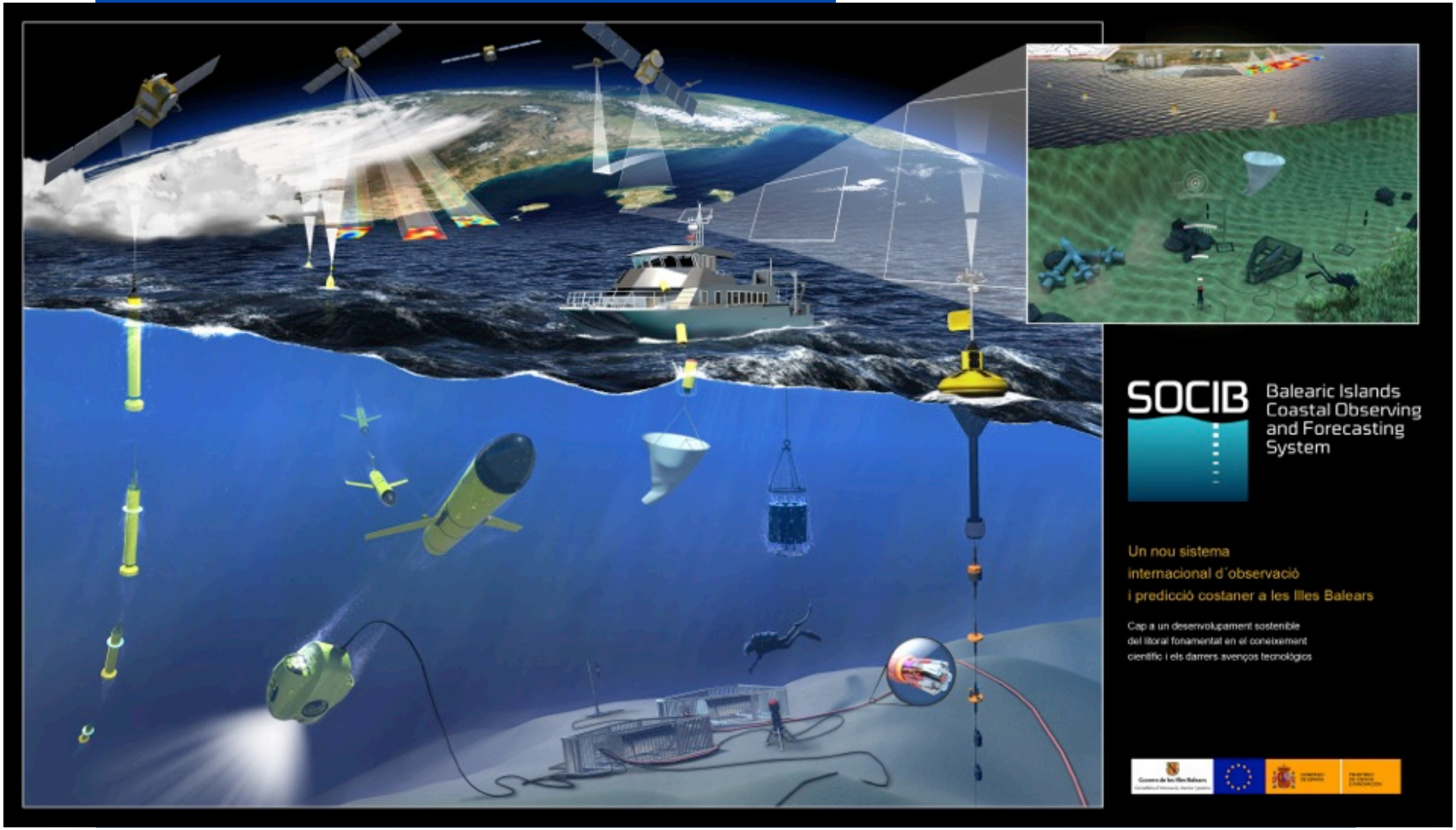
Fixed Platforms

HF radar

24 m R/V Catamaran

Satellite

SOCIB: the view….



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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 …

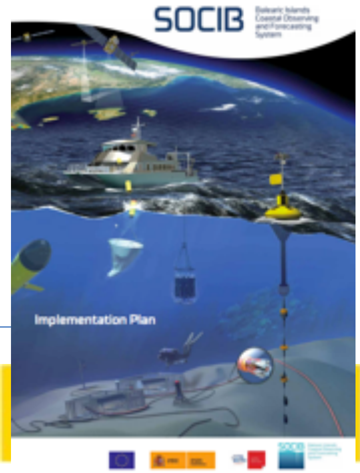
Implementation

	2009		2010				2011				2012		2013	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1/Q2	Q3/Q4	Q1/Q2	Q3/Q4
Systems, Operations and Support Division														
Observing Facilities:														
Coastal Research Vessel	CD	CD	PDP	LP	LP	C	C	C	C	C	IOC	OM	FOC	FOC
Coastal HF Radar	CD	CD	PDP	LP	LP	C	C	IOC	FOC	FOC	FOC	FOC	FOC	FOC
Gliders	CD	CD	PDP	LP	IOC	IOC	OM	OM	OM	OM	FOC	FOC	FOC	FOC
Drifters	CD	CD	PDP	PDP	PDP	PDP	LP	IOC	IOC	OM	FOC	FOC	FOC	FOC
Moorings	CD	CD	PDP	LP	C	IOC	OM	OM	FOC	FOC	FOC	FOC	FOC	FOC
Marine and Terrestrial Beach Monitoring	CD	CD	PDP	LP	C	C	C	C	C	C	IOC	FOC	FOC	FOC
Data Centre Facility	CD	CD	CD	PDP	PDP	IOC	IOC	OM	FOC	FOC	FOC	FOC	FOC	FOC
Modelling and Forecasting Facility	CD	CD	PDP	PDP	LP	C	C	IOC	IOC	OM	FOC	FOC	FOC	FOC
Engineering and Technology Development Division														
Facility Support and Technology Development	CD	CD	PDP	LP	IOC	IOC	OM	OM	FOC	FOC	FOC	FOC	FOC	FOC
Near Shore Station	CD	CD	CD	CD	PDP	LP	PDP	C	C	IOC	OM	FOC	FOC	FOC
Ships of Opportunity/Fishing Fleet Monitoring	CD	CD	LP	PDP	IOC	IOC	OM	OM	FOC	FOC	FOC	FOC	FOC	FOC
Strategic Issues and Application to Society Division	CD	PDP	IOC	IOC	OM	FOC	FOC	FOC	FOC	FOC	FOC	FOC	FOC	FOC
Services														
Management & Finance	PDP	IOC	OM	OM	FOC	FOC	FOC	FOC	FOC	FOC	FOC	FOC	FOC	FOC
Computing & IT	CD	C	OM	PDP	LP	C	IOC	OM	FOC	FOC	FOC	FOC	FOC	FOC
Outreach, Education, Training & Mobility	CD	CD	PDP	PDP	PDP	PDP	IOC	IOC	OM	FOC	FOC	FOC	FOC	FOC

Project Stages:

CD	Concept Development
PDP	Planning, Design and Pilots
LP	Legal Procedure/Purchase
C	Construction
IOC	Achieve Initial Operational Capability
OM	Operation and Maintenance
FOC	Final Operational Capability

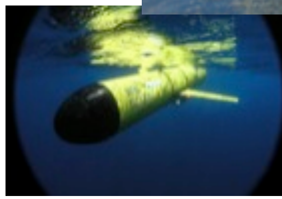
Table 2: Implementation Schedule Summary for the major SOCIB elements, detailed schedules are available in Annex 3. All available at www.socib.es



Systems Operations and Support Division

1. Observational Facilities (major elements)

- New Coastal Research Vessel (24 m LOA – 1.200 km coastline in the Islands)
- HR Radar
- Gliders
- Coastal stations and Satellite products
- Lagrangian Platforms
- Nearshore Beach monitoring



2. Forecasting sub-system

- Ocean currents (ROMS) and waves (SWAN) at different spatial scales, forced by Atmospheric model (WRF) and ecosystem coupling (NPZ)

3. Data Centre

- Quality control and Web access in open source
- Effective data archiving, internationally accepted protocols, delivery and communication

SOCIB Facilities and Services – 2012 www.socib.es

Already from SOCIB and/or in kind from CSIC, IEO and UIB and agreement with PE:

SYSTEMS OPERATIONS AND SUPPORT DIVISION

OBSERVING:

- Glider Facility (7 Slocum + 2 iRobot gliders)
- Satellite remote sensing products
- ARGO profiles and Surface drifters Facility (pilot)
- Coastal Buoys real time Facility (pilot)
- Nearshore beach monitoring Facility (pilot)

MODELLING

- Numerical Forecasting Facility

DATA CENTER

- Data Center

APPLICATIONS AND STRATEGIC ISSUES SOCIETY DIVISION

- ICZM and Science based sustainable coastal and ocean management

ENGINEERING AND TECHNOLOGY DEVELOPMENT DIVISION

- New technologies

SERVICES

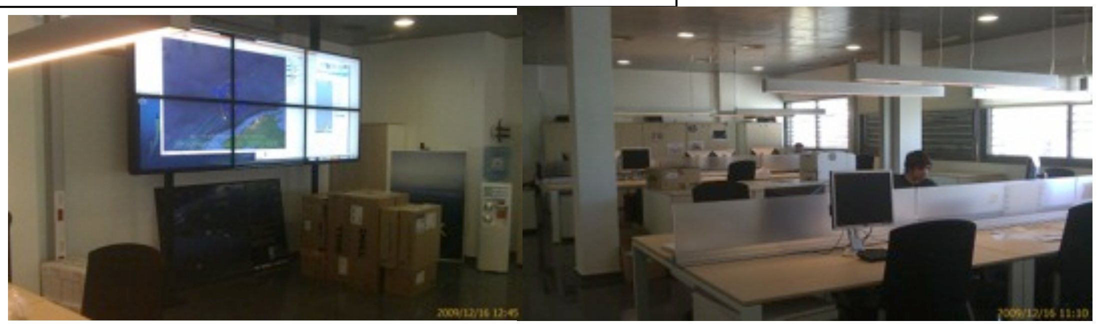
- Management and Finances
- Computing and IT's
- Outreach and Education

IMPLEMENTATION PLAN; approved July 2010

- Proven capability
- Pilot projects
- Non sustained

Bluefin Tuna target project

Parc Bit – office – Since August 2009



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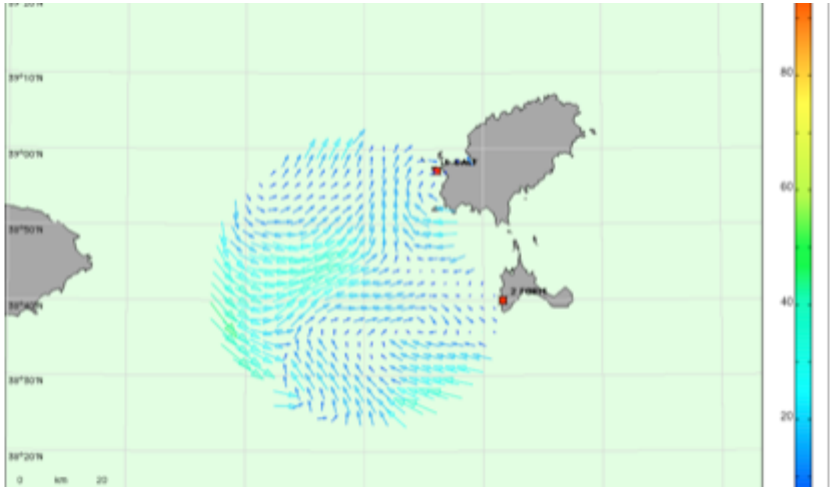
SOCIB new 2012 facilities



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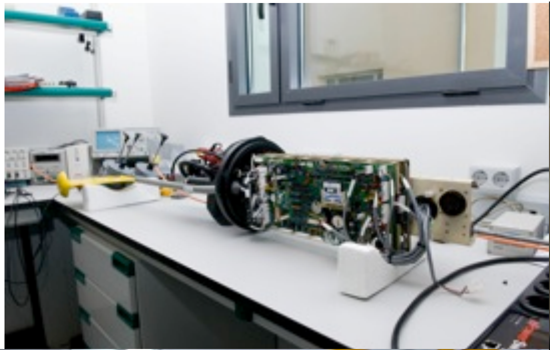
SOCIB Glider Facility

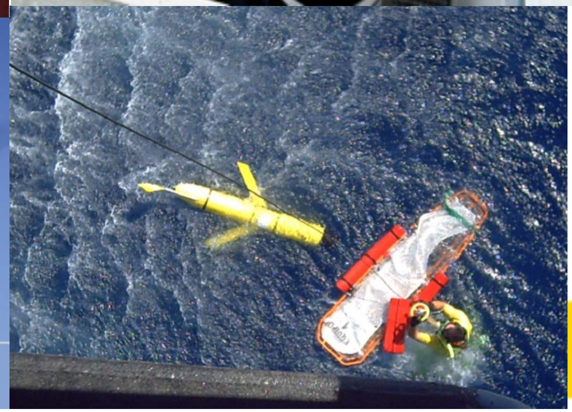
We have established new facilities for glider operations at IMEDEA

Electronics & Gliders Laboratory




Ballasting Lab & Pressure Chamber


Collaboration:
Search and Rescue
801 Squadron
and local authorities

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Gliders Facility: Science

Mesoscale – Submesoscale / Vertical motions - biogeo effects

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 Tintoré[1]

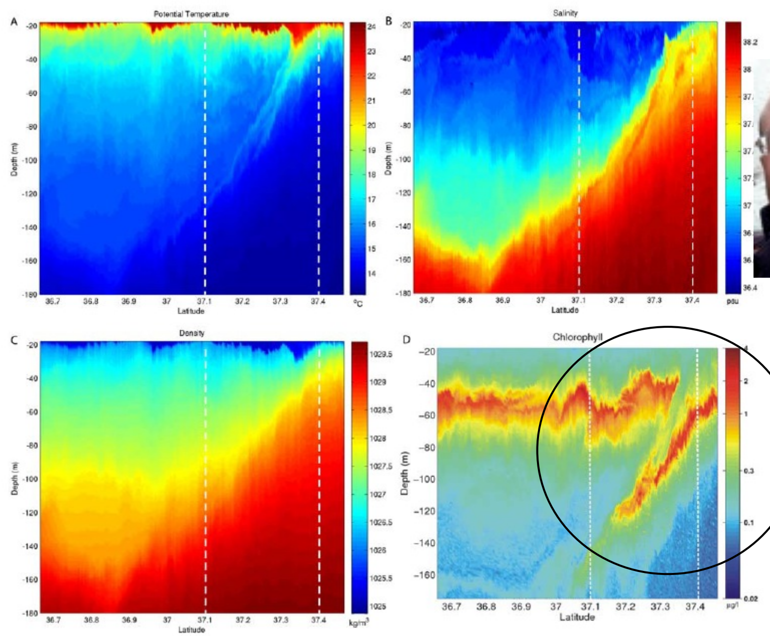


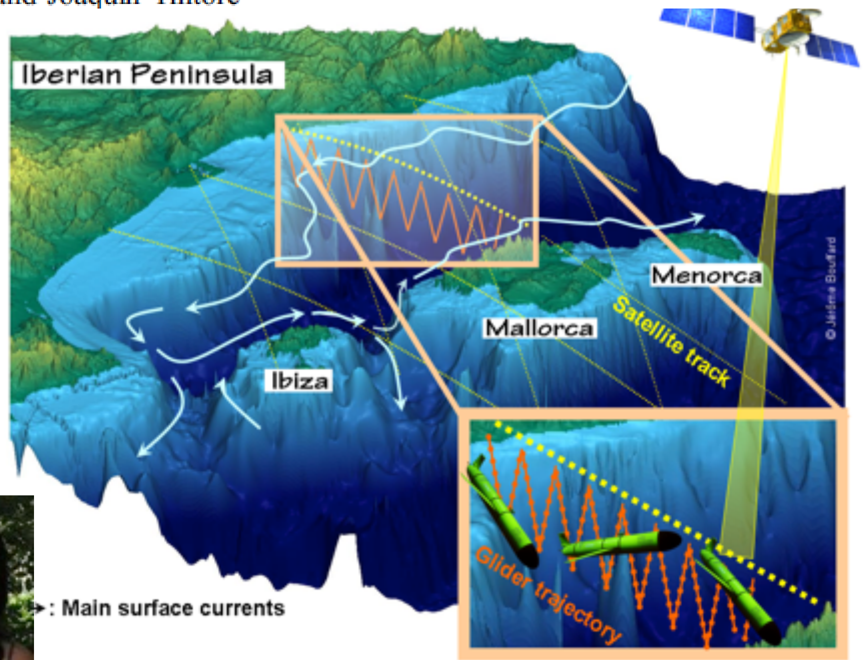
Figure 2. Vertical section of temperature (°C), salinity (PSU), density (kg/m^3) and chlorophyll (μg/l) from glider section 2 (dashed magenta in Figure 1). White dashed lines define sub-section in the northern part of the domain.

Eddy/mean flow interactions – Blocking effects General Circulation

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]

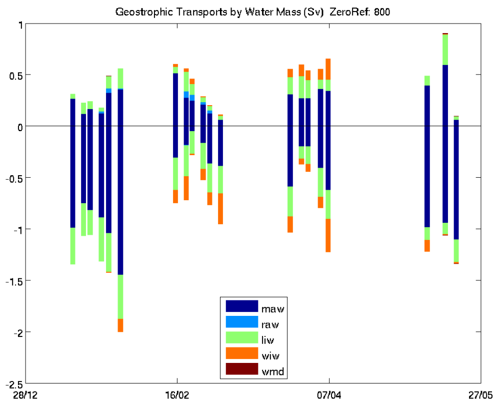


Gliders Facility: Operational

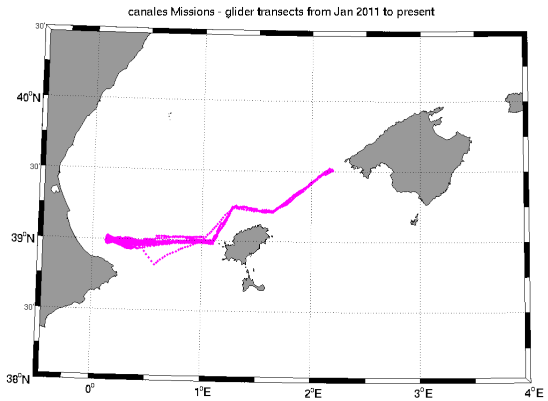
- **After 28 glider missions (started in 2006), + 10.000 profiles**
- **Since January 2011; routine operations in Ibiza and Mallorca Channels (150 miles section)**

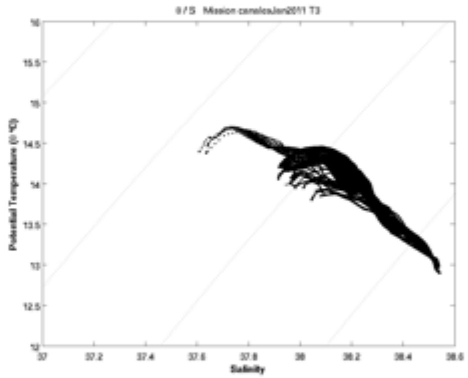
<u>NEED DEFINE KEY CONTROL SECTIONS EU and International level</u>

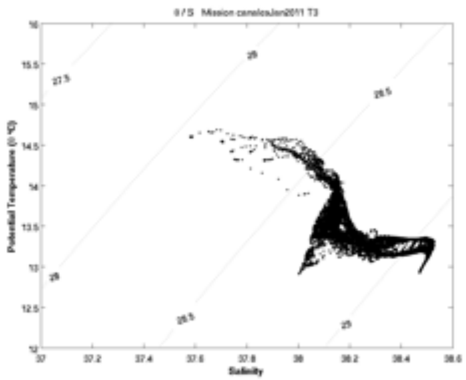
Major transport changes



TS diagrams ROMS / Glider







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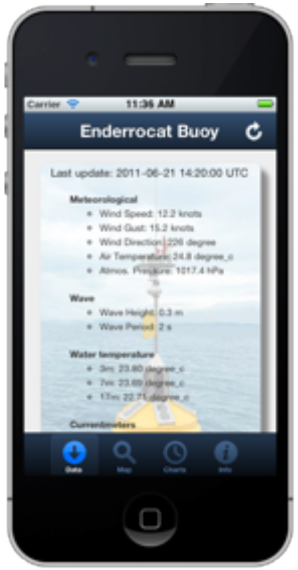
SOCIB Glider Facility (Summary)

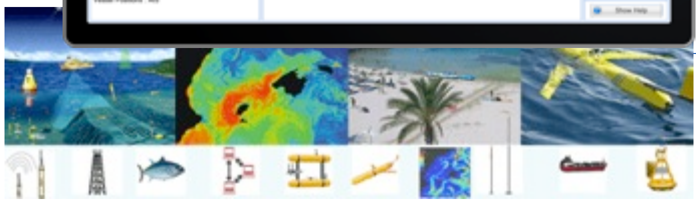
Gliders (a fleet of …) ?:

- They allow long term, sustained, multidisciplinary monitoring of the coastal ocean for example at key control sections.

- They are providing new evidences of the complexity of the coastal ocean, by resolving tridimensional mesoscale and submesoscale instabilities **never fully observed before**, showing the intrinsic dynamical relevance of theses instabilities, their interactions and effects on the mean circulation, and their role on the response of the ecosystem.
  - **A major observational breakthrough is appearing upfront**. It will trigger theoretical and numerical developments…
  - Examples from Balearic and Alborán Seas have been shown, suggesting the capabilities that will soon arise from monitoring with fleets of gliders, physical variability and ecosystem response at meso and submesoscale…

Data Centre (Technologies; example of Apps)





ICTS OceanBit

Govern de les Illes Balears
Conselleria d'Economia, Hisenda i Innovació
Direcció General de Recerca, Desenvolupament Tecnològic i Innovació

UIB

I·M·E·D·E·A

CSIC

Innovation in oceanographic instrumentation

3 elements:

- Oceans complexity imply and drive a need for improvement of instrumental capacities

- The innovation process, complexity and incubation time

- The key to success

(Curtin and Belcher, TOS, 2008)

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

Oceans complexity, needs for improvement of instrumental capacities

Rationale:

The Oceans; a complex system, changing, under-sampled: tools to study them include

- Instruments to measure properties
- Models for continuous estimates of states and evolution

Improvements in tools capabilities

↓

Increase understanding → **Major practical benefits**

The innovation process (for advancing oceanographic instrumentation)

Complexity of innovation process: needs to be known, to avoid unrealistic expectations and/or discontinuous support.

Incubation time: 15-30 years (computer mousse, 30 years). Gliders 10 years. ¿?

Innovation can be incremental or radical, stimulated or suppressed.

The innovation process (for advancing instrumentation)

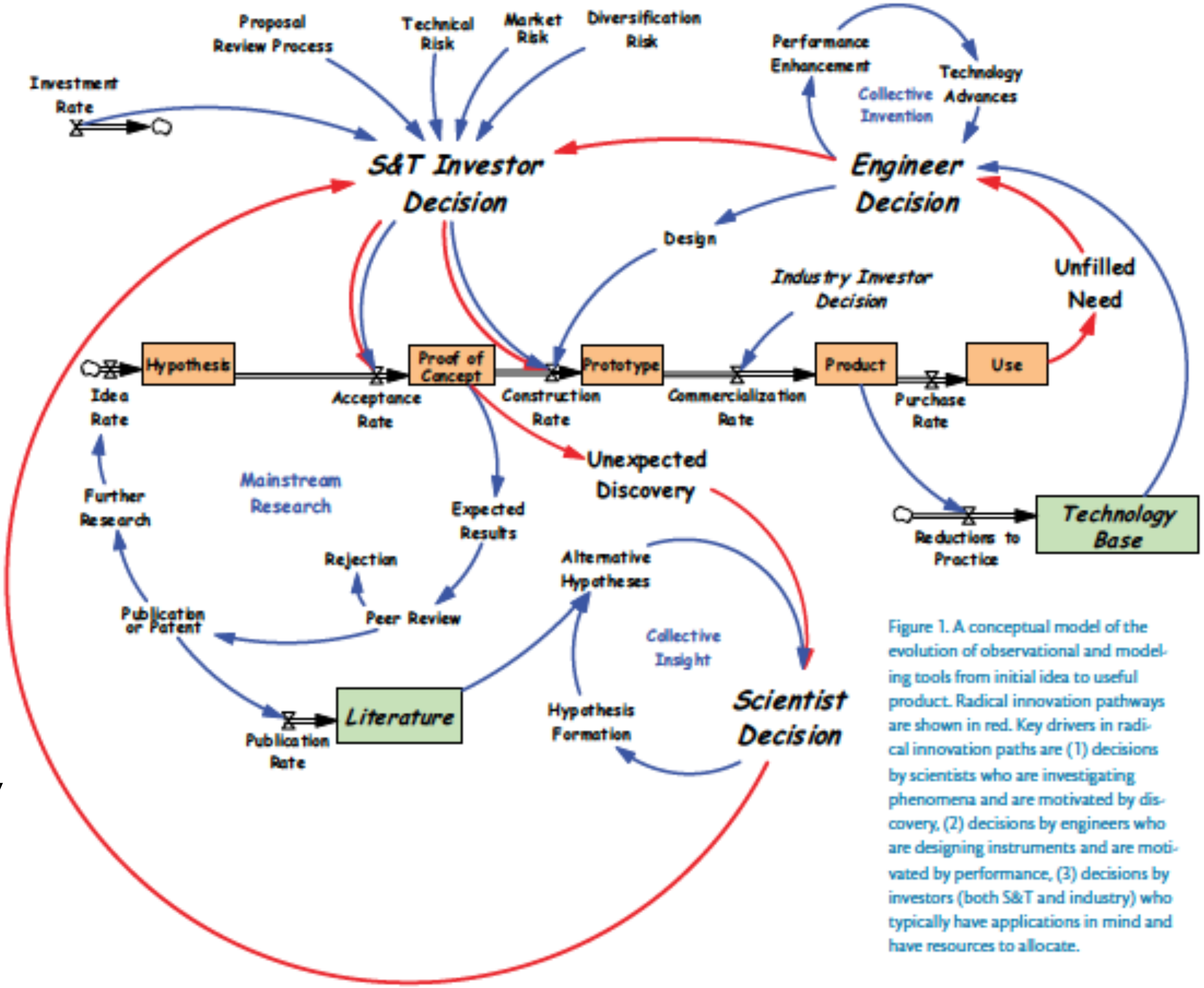


Figure 1. A conceptual model of the evolution of observational and modeling tools from initial idea to useful product. Radical innovation pathways are shown in red. Key drivers in radical innovation paths are (1) decisions by scientists who are investigating phenomena and are motivated by discovery, (2) decisions by engineers who are designing instruments and are motivated by performance, (3) decisions by investors (both S&T and industry) who typically have applications in mind and have resources to allocate.

(Curtin and Belcher, TOS, 2008)

The innovation process (for advancing instrumentation)

Why is it important? : we need synoptic coverage

And… "Every time a new instrument has arrived,

new key findings"…

Examples of innovations:

- Ships → Public – Private transfer
- Satellites → Ocean Weather…
- CTD → Micro-structure,
- Buoys- ARGO profilers →
- Currentmeters (rotor to ADCP) → Spectrum…
- Gliders → Submesoscale - …

The innovation process (disruptive, gliders)

Incubation time for gliders; ½

Why?:

… "A coherent set of scientists, engineers, and investors that envisioned the scientific goal, understood the technology potential and sustained the funding" (Curtin and Belcher, TOS; 2008).

The key to success for radical innovation in oceanographic instrumentation

1. Visionary leadership
2. Close coupling between science and engineering
3. A coherent investment strategy based on distributed, coordinated resources
4. Effective processes for communication, feedback, and contingency planning.
5. Incentive to assume responsibility for risky instrumentation development projects without undue career jeopardy.

In summary: work in collaborative, multidisciplinary teams, be tenacious and focused on long term objectives while producing short-term success, and find creative champions among funding agencies and investor organizations.

The role of new marine research infrastructures (MRI/ ICTS/Ocean Observatories….)

→ Need to…: **RESPOND TO THE 3 KEY DRIVERS**

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

<u>Coastal Observatories are particularly well placed</u>

<u>AND</u> → Need to define a **JOINT STRATEGY** (international level, more than coordination, <u>Partnership</u>…Marine Res Infrast !!!

SUMMARY... Coastal observatories and the future…

1. **Respond to 3 drivers: science, technology, society needs**

2. **Use and integrate new technologies to:**

- Monitor the variability at small scales, e.g. mesoscale/week, to

- Resolve the sub-basin/seasonal and inter-annual variability and by this

- Establish the decadal variability, understand the associated biases and correct them …

3. **Select key control sections for routine monitoring 'choke or control points' to characterise coastal ocean variability**

Thank you!!!

SOCIB Balearic Islands Coastal Observing and Forecasting System

CSIC

Govern de les Illes Balears

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN