# LAS GRANDES INFRAESTRUCTURAS DE INVESTIGACION, MOTOR DE CONOCIMIENTO, DE TRANSFERENCIA DE PRODUCTOS TECNOLOGICOS Y DE TECNOLOGIAS DE GESTION PARA EL SECTOR PUBLICO Y PRIVADO

Joaquín Tintoré Subirana and all the

SOCIB e IMEDEA (UIB-CSIC)/TMOOS team,

http://www.socib.es

# Resumen

Las Instalaciones Científico Tecnológicas Singulares (ICTS) o grandes infraestructuras de investigación, representan un motor de conocimiento y una oportunidad para la transferencia bidireccional y la innovación en tecnologías y servicios.

Partiendo de la presentación de la ICTS SOCIB, se mostrará la relevancia de la innovación tecnológica disruptiva y/o incremental en oceanografía y su contribución decisiva al avance del conocimiento a través de la comprensión de los procesos que rigen la evolución de los mares y océanos y sus interacciones con la atmósfera y la costa.

Este conocimiento es la base para responder a las preguntas actuales de la sociedad sobre, por ejemplo, el clima o la elevación del nivel del mar y es también la base de una gestión realmente sostenible de los océanos y las costas.

Se presentarán ejemplos concretos de innovación tecnológica ligados a la introducción de nuevos sistemas de medida (buques oceanográficos, CTD, satélites, boyas ARGO, o más recientemente gliders) y su impacto científico, social y económico, presentándose a continuación las capacidades de los nuevos sistemas de observación que, como la ICTS SOCIB, son multi-plataforma, integrados y multidisciplinarios con sistemas automatizados de control de calidad de los datos (tanto observaciones como modelos de predicción) y acceso libre a los mismos.

Este nuevo tipo de ICTS marinas permiten generar conocimiento, desarrollar y transferir tecnologías en sentido amplio, es decir tanto productos tecnológicos como tecnologías de gestión (herramientas de apoyo a la toma de decisiones), y responder a las necesidades de la sociedad, representando así, además, un puente a la colaboración sector público-sector privado

# Outline

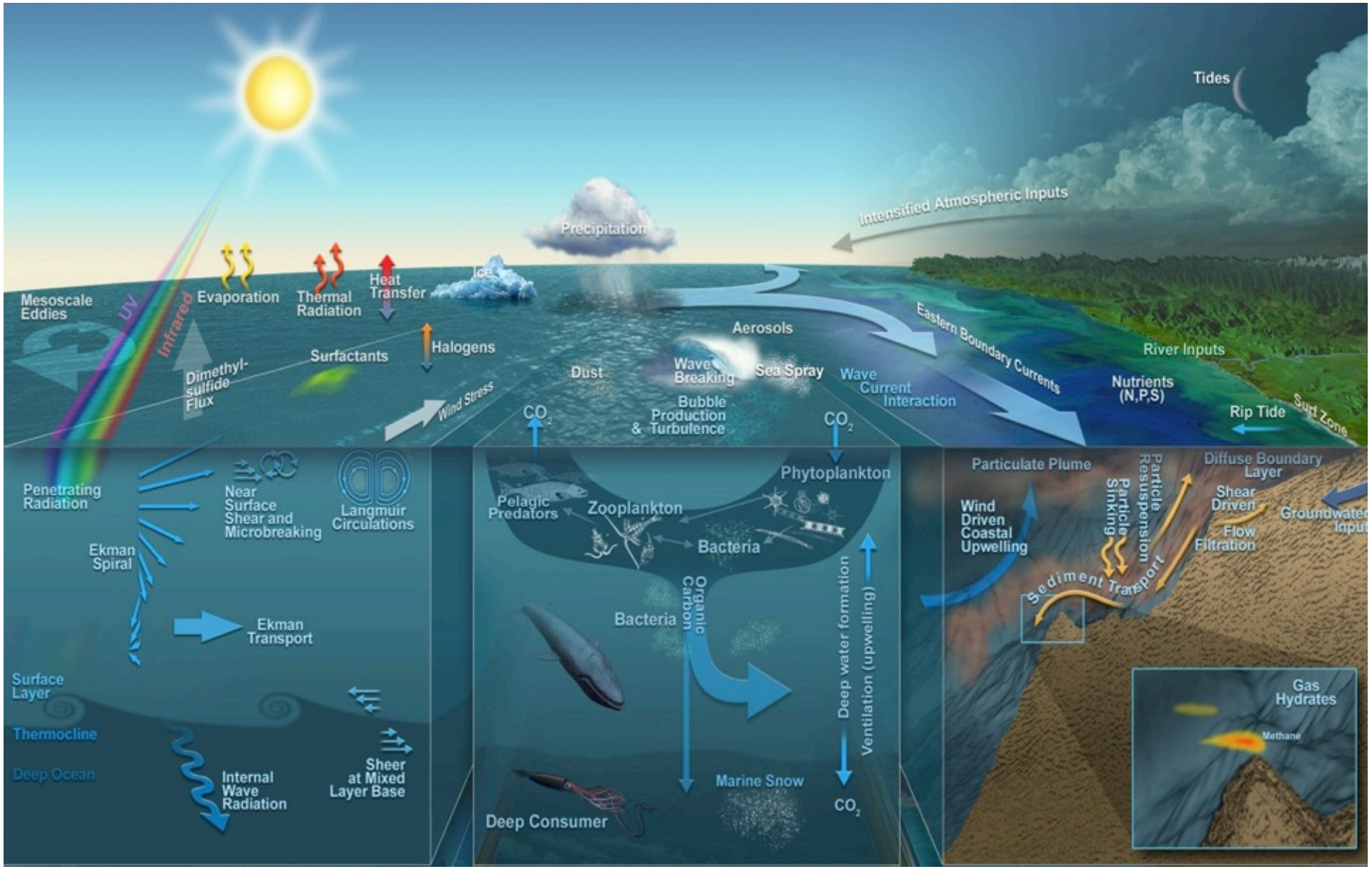
1. **SOCIB ICTS presentation**
2. **Innovation in oceanographic instrumentation**
3. **The new role of Research Infrastructures – ICTS SOCIB**

# Outline

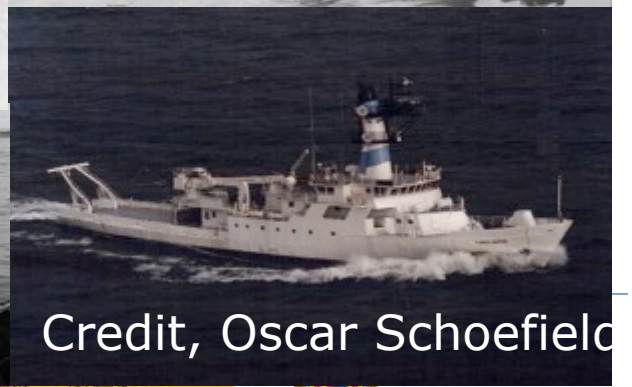
## 1. SOCIB ICTS presentation

- Oceans complexity and need for monitoring
- Why SOCIB and why now
- Scales and monitoring tools
- Drivers, structure and principles
- Products and services, benefits for society and chain value
- Examples of ongoing SOCIB activities on Research, Tec. Dev. (instruments & models/process studies), Tec. Dev. (tools for management); Innovation

# Oceans are complex and central to the Earth system



# The oceans are chronically under-sampled



Credit, Oscar Schoefield

# What is SOCIB?

SOCIB is a Coastal 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 Coastal Ocean Observatories, and **why now?**

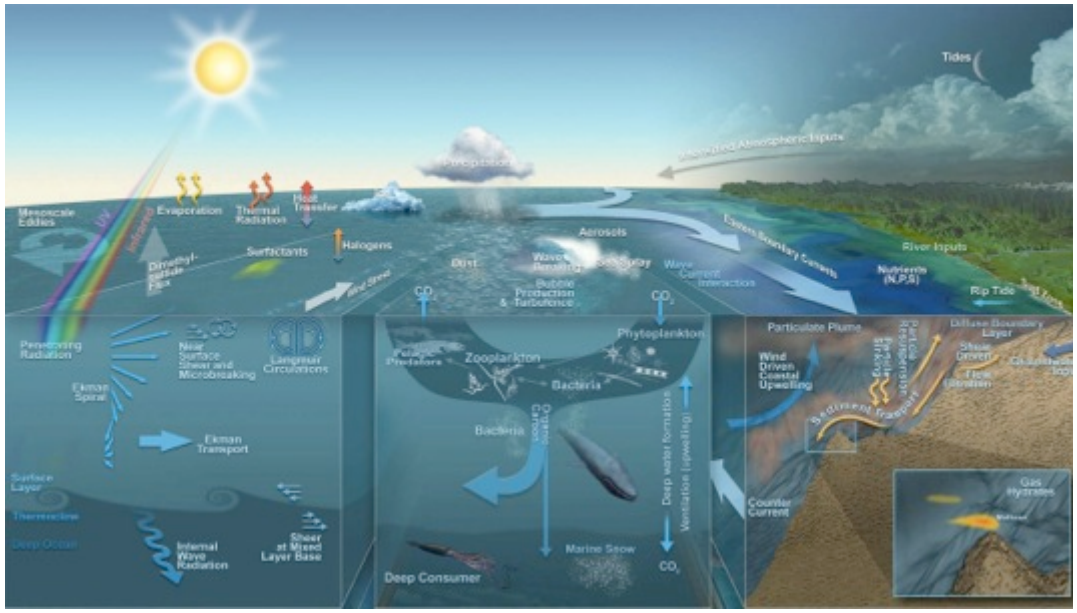
## A New Approach to Marine and Coastal Research

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

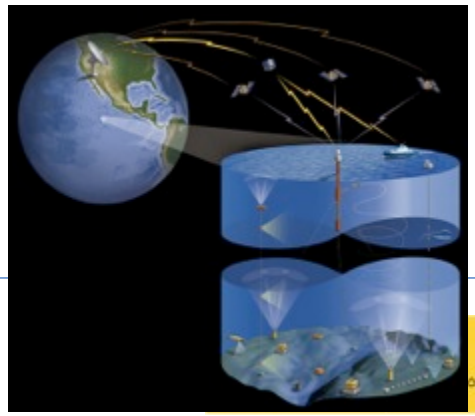
A quantitative major jump, in scientific knowledge and technology development

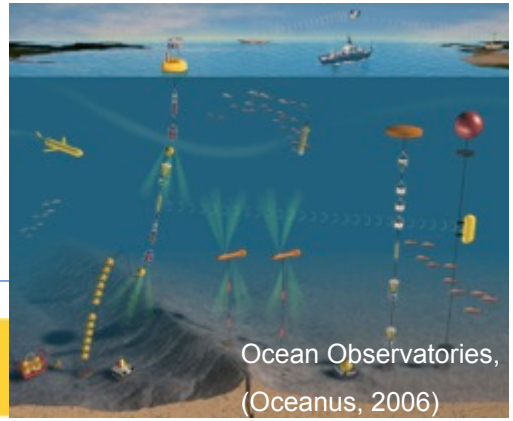
The development of a new form of Integrated Coastal Zone Management, based on recent scientific and technological achievements,

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)

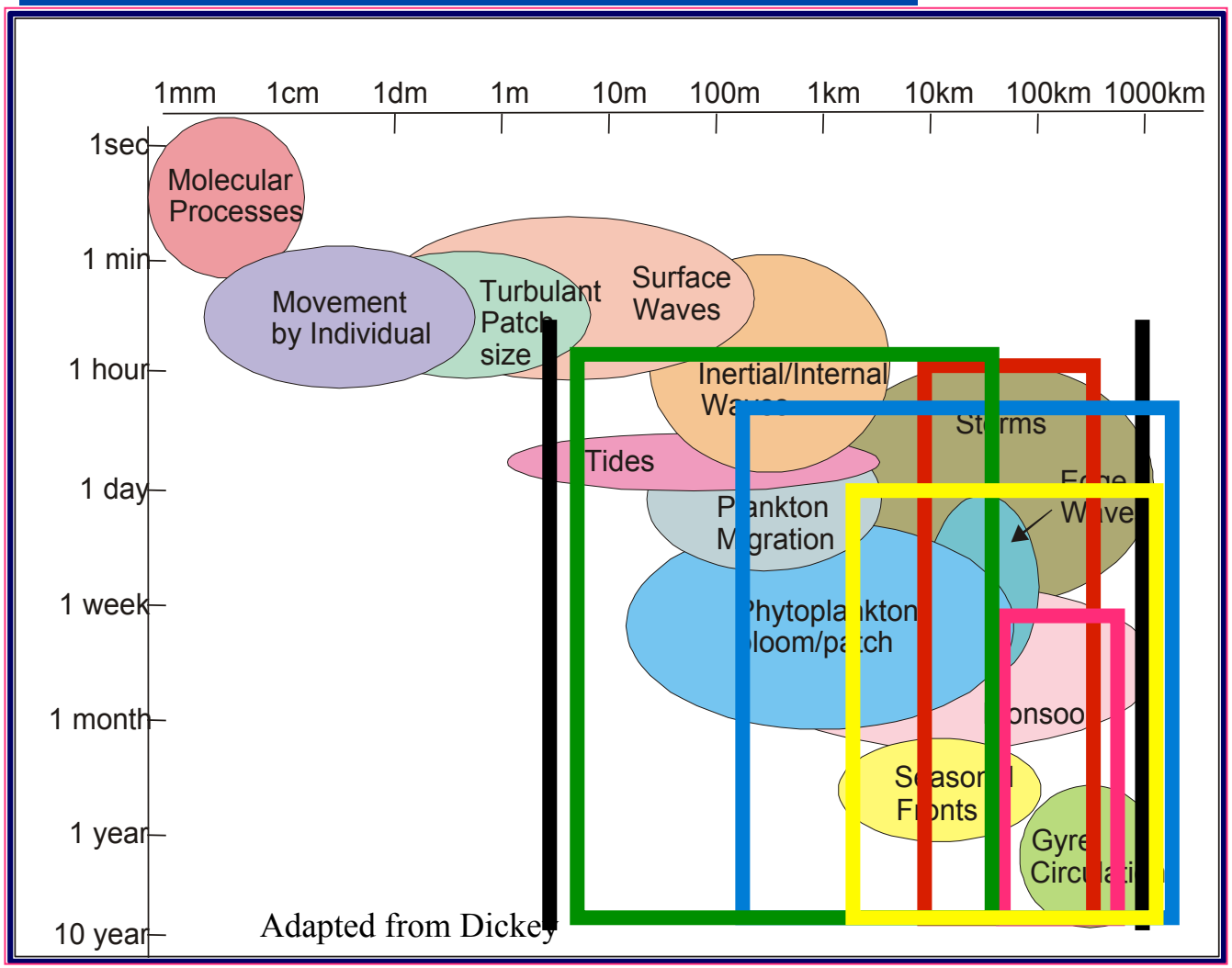




Ocean Observatories, (Oceanus, 2006)

SOCIB Balearic Islands Coastal Observing and Forecasting System

# SOCIB scales and monitoring tools




**Gliders**

**AUV's**

**Time series**

**HF radar**

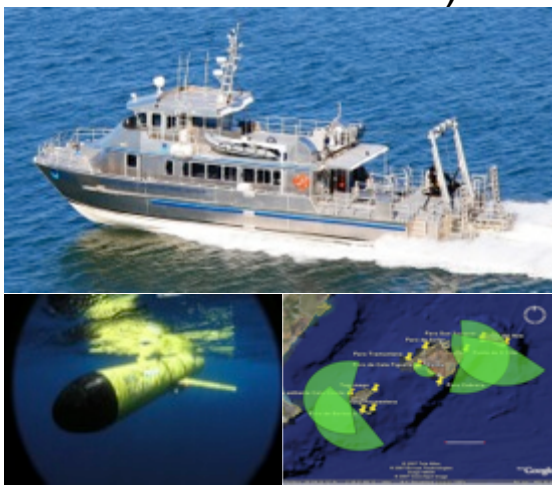
**Spatial survey**

Satellite

# SOCIB - Systems Operations and Support

## 1. Observational Facilities (major elements)

- New Coastal Research Vessel (25 m LOA – 1.200 km coastline in the Islands)
- HR Radar
- Gliders and AUV's
- Moorings, tide gages and satellite products
- ARGO and surface drifters
- Nearshore beach monitoring



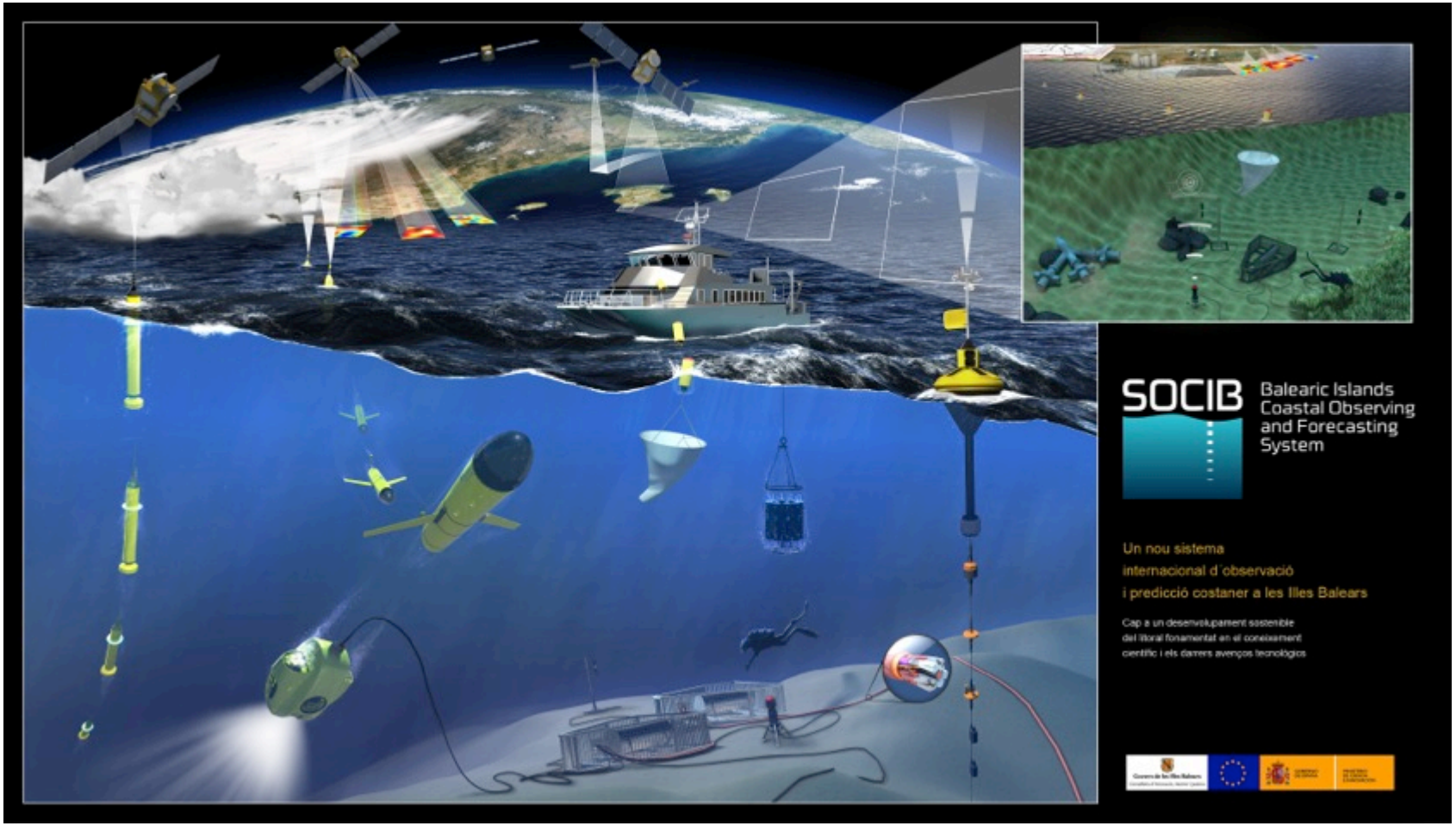
## 2. Forecasting sub-system

- 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: the view….



# European and international framework

## Spain: ICTS - MICINN

***http://web.micinn.es/files/2008-folletook.pdf***

## Balearic Islands: R&D Plan

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

*http://dgtic.caib.es/www/plaCiencia/plaCiencia.ca.htm*

**Europe:** (among other initiatives):

**Marine and Maritime Strategy**, **FP 7** projects (MyOcean, SESAME, ECOOP, etc…), **ESFRI** (European Strategy Forum on Research Infrastructures), **http://cordis.europa.eu/esfri/roadmap.htm**

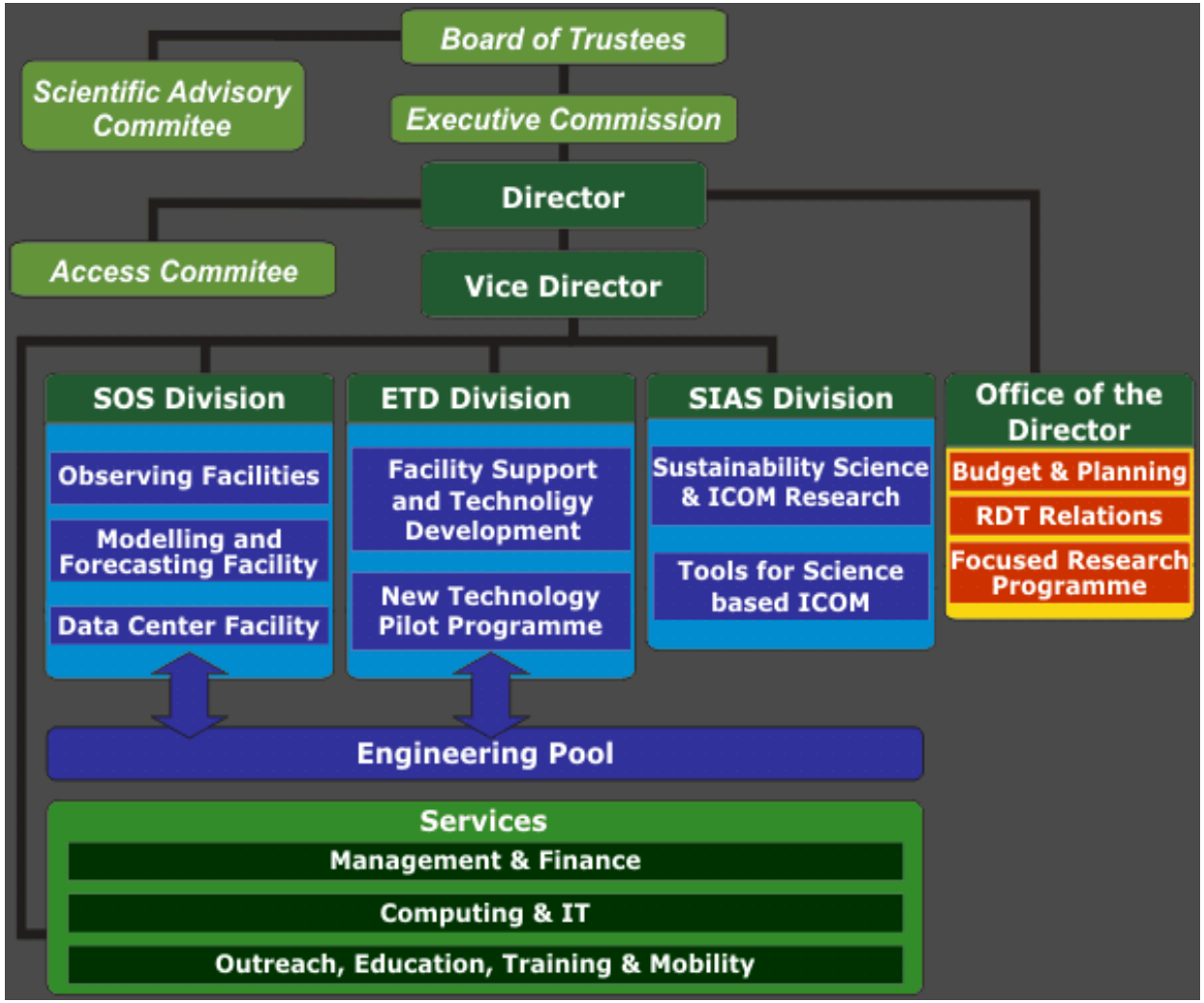
# SOCIB Drivers

SOCIB was designed in response to:

**3 KEY DRIVERS**

- Science Priorities (scientific excellence)
- Technology Developments
- Strategic Society Needs

# SOCIB Structure



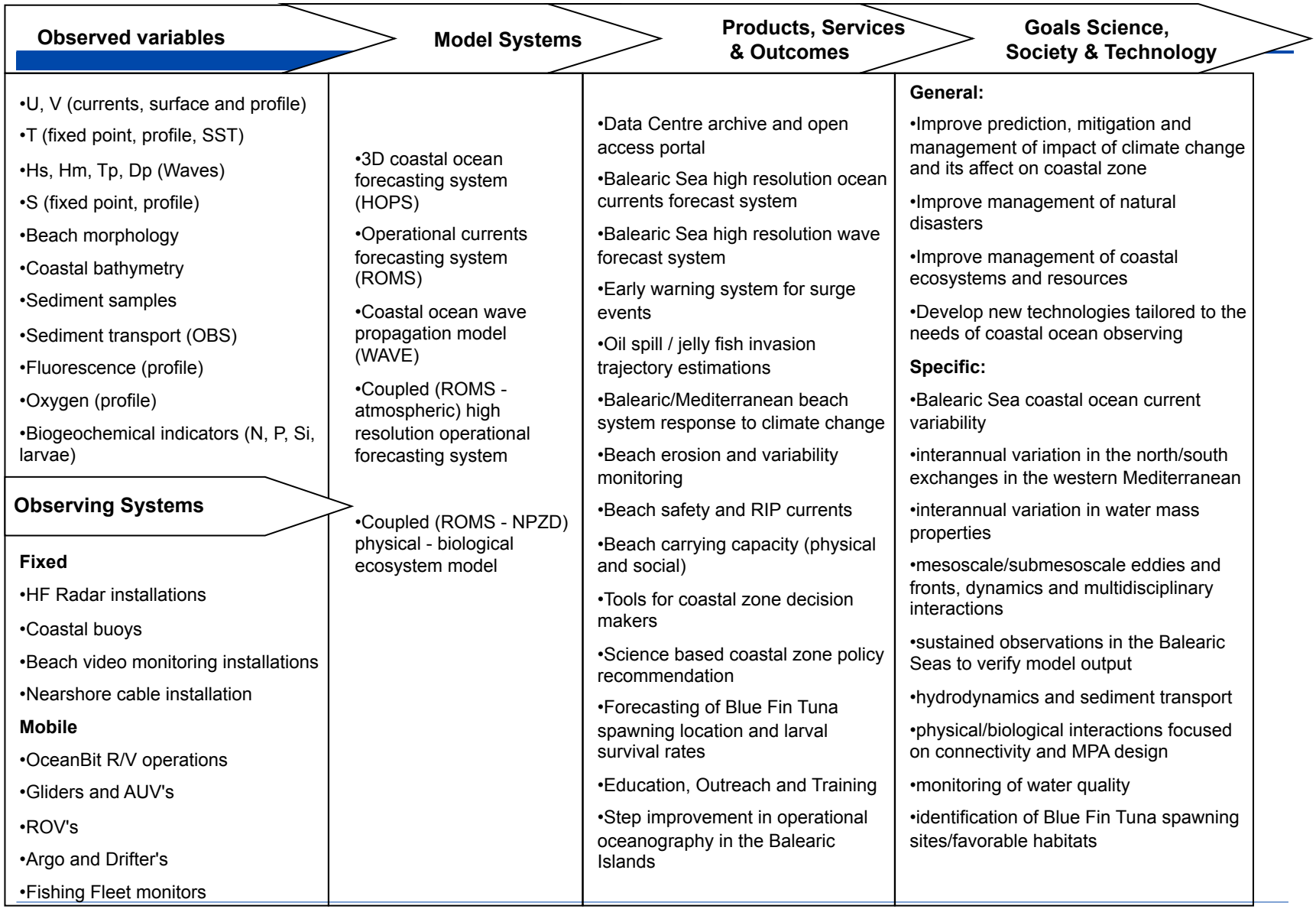
# SOCIB Principles

- 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

# Products and Services: benefits for society, examples

- **Marine and Coastal Environment**
  - Harbors oscillations
  - Water quality in the coastal areas
  - Beach erosion, sediment transport
  - Sustainability science, indicators, baseline data, science based limits
  - ICZM, new science based integrated, multidisciplinary management of the coastal zone
  - Pollution management, marine debris, coastal impacts
- **Marine Safety: development of science based decision support tools**
  - Search & rescue operations at sea
  - Response to spills and mitigation procedures at sea and at the coast
- **Climate and Seasonal Forecasting**
  - Ocean climate variability and indicators
  - Sea level changes and impacts on coastal zone
  - Ecosystem response and variability in the Mediterranean
- **Marine Resources**
  - Ecosystem modeling, Marine Protected areas optimization and design
  - Responsible fisheries, variability, natural and anthropogenic
- **Technology development**
- **Education, public outreach and science**

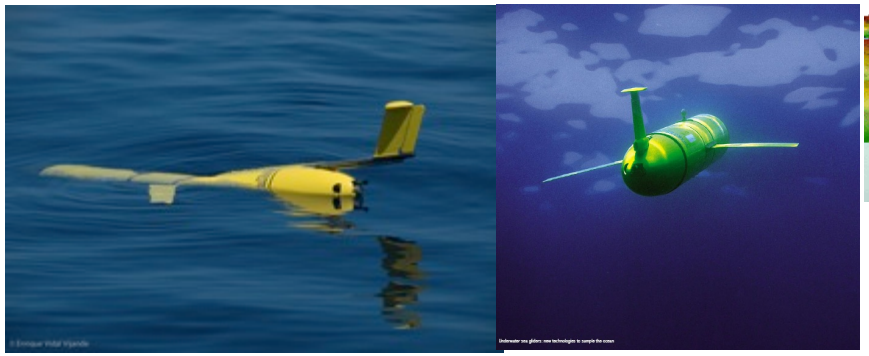
# SOCIB Value Chain

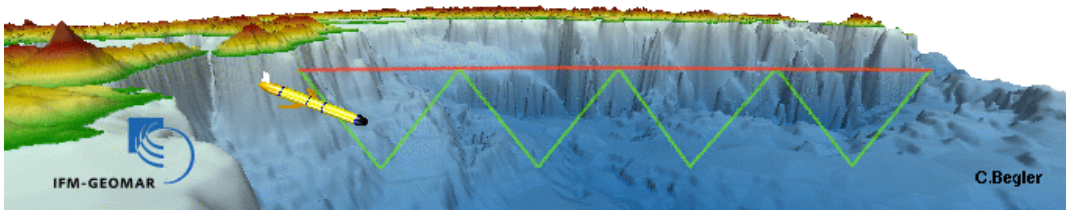


# Glider Facility Activities

## Glider data

- Variables: P, T, S
- Vertical extension: 10-180 m
- Horizontal resolution: 1km






## Envisat data

- Along track SLA (AVISO/CLS) + MDT (Rio et al.)
- Delayed time product
- Mediterranean product
- Horizontal resolution: 7 km

SOCIB Balearic Islands Coastal Observing and Forecasting System

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Govern de les Illes Balears

# 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]



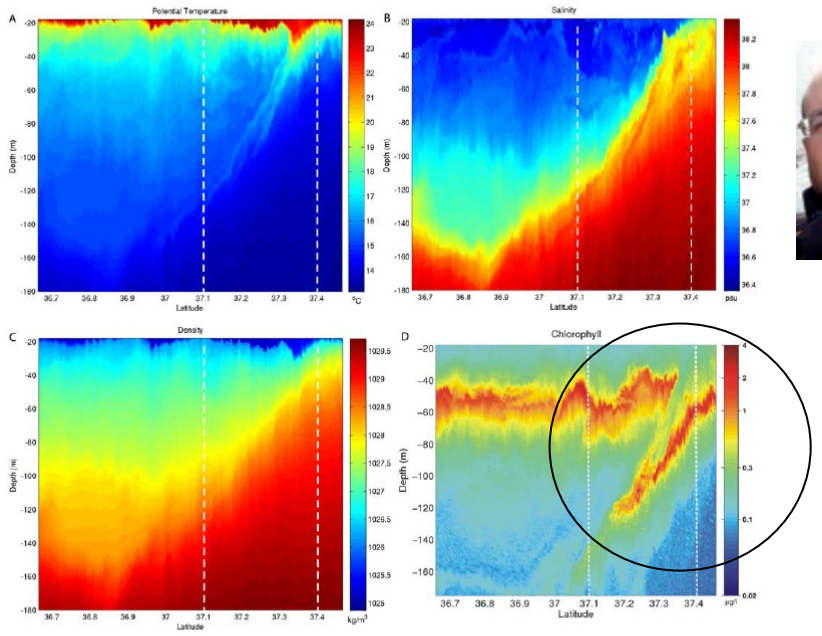


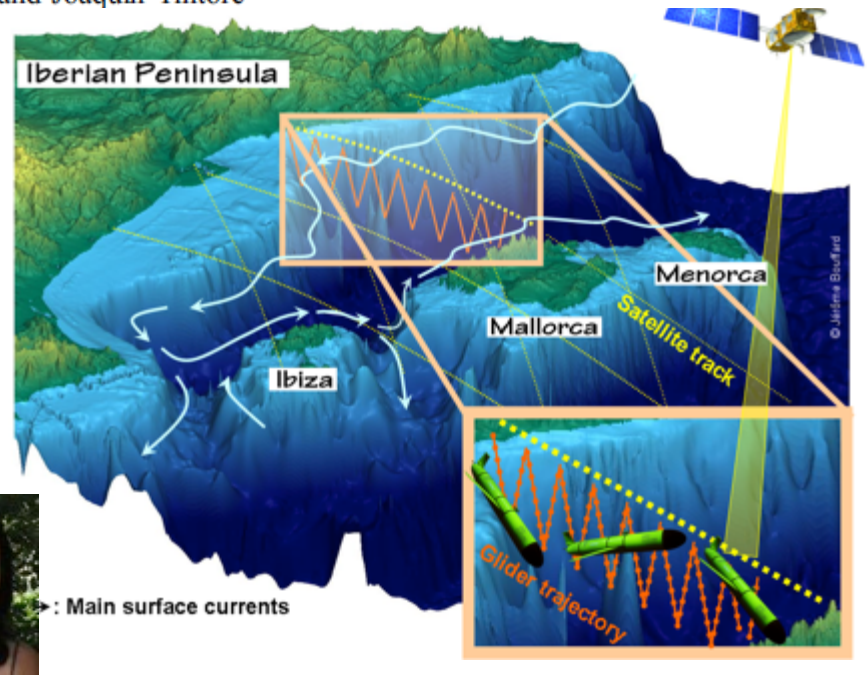

**Figure 2.** Vertical section of temperature (°C), salinity (PSU), density (kg/m$^3$) and chlorophyll ($\mu$g/l) from glider section 2 (dashed magenta in Figure 1). White dashed lines define sub-section in the northern part of the domain.

## 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]




SOCIB Balearic Islands Coastal Observing and Forecasting System

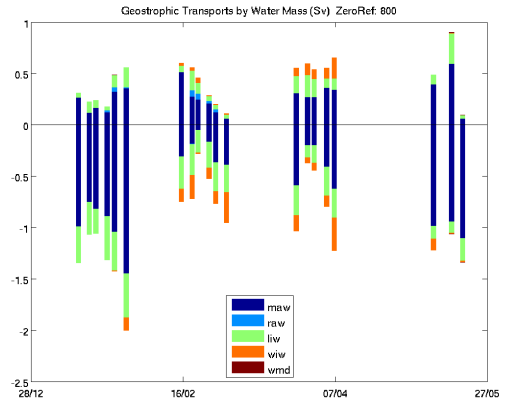
GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Govern de les Illes Balears

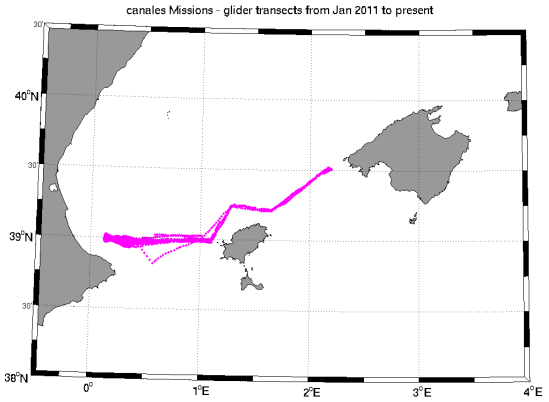
# Gliders Facility: Operational

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

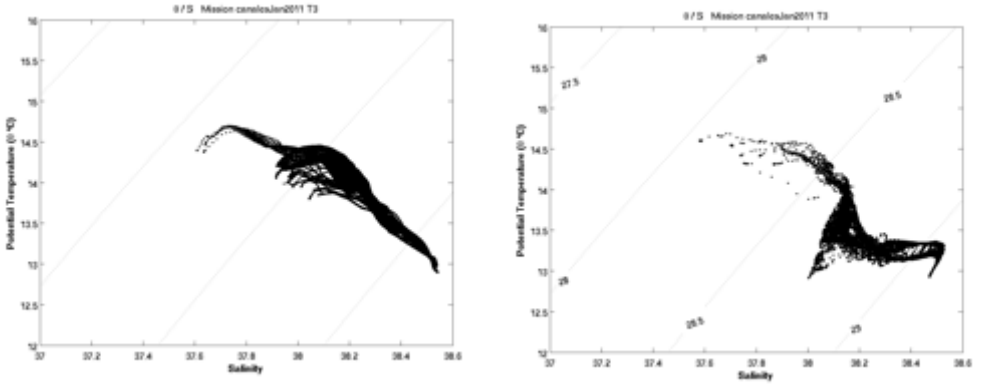
## Major transport changes



**<u>NEED DEFINE KEY CONTROL SECTIONS EU</u>**




## TS diagrams ROMS / Glider



# SOCIB Glider Facility (Summary)

Gliders (a fleet of …) ?:

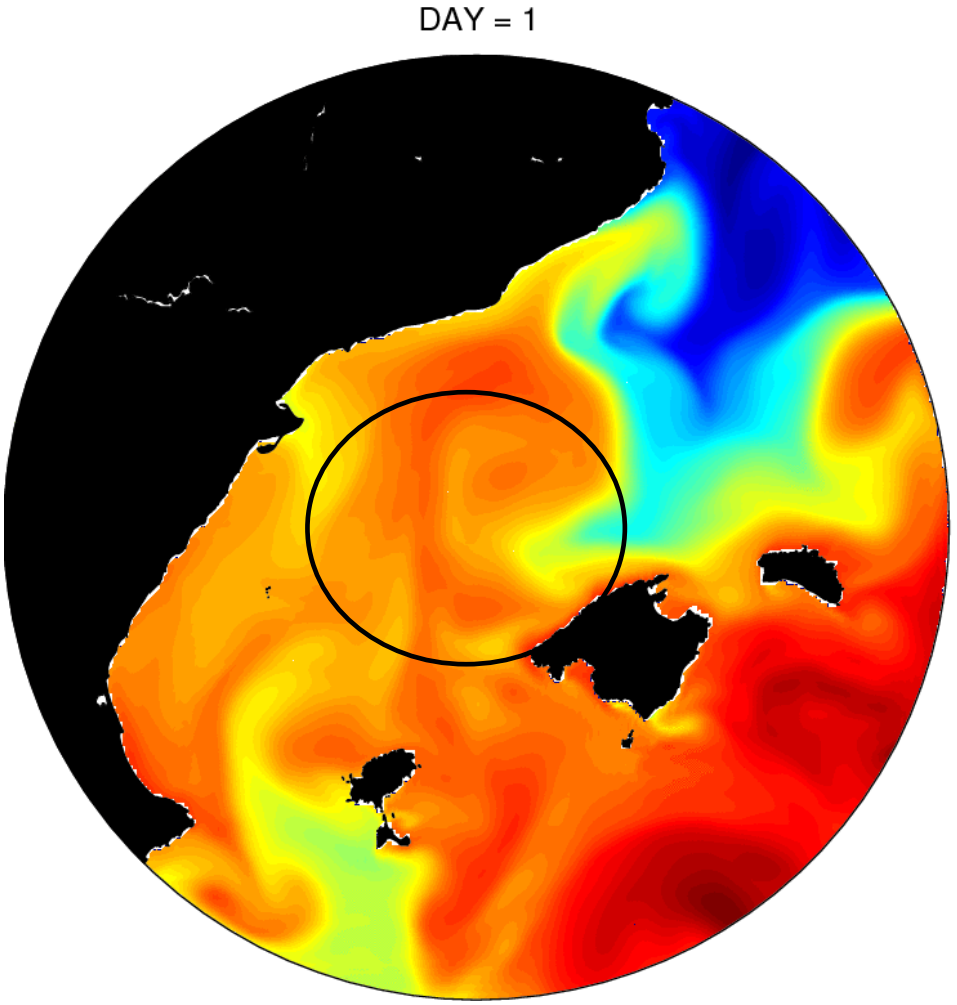
- They allow long term, sustained, multidisciplinary monitoring of the coastal ocean for example at key control sections.

- 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…

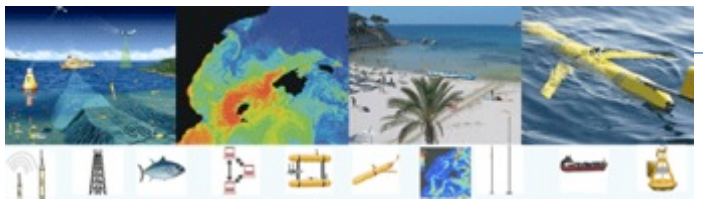
# Modelling Facility: Science

**<u>Operational Modeling:</u> ROMS,** 2km To reproduce and maintain mesoscale features, interactions. In collaboration with GKSS and Univ. Rutgers, in the frame MFS/MOON.
**WRF** Atmospheric Model
Also **SWAN** for coastal ocean wave Dynamics and Habors (with PE)

The aim :
- Validate the model with the measurement (gliders, ...)
- From the available data and the model simulation (5 years), study the formation of mesoscale structures.
- Understand impact on the ecosystem




SST from 11/2008



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

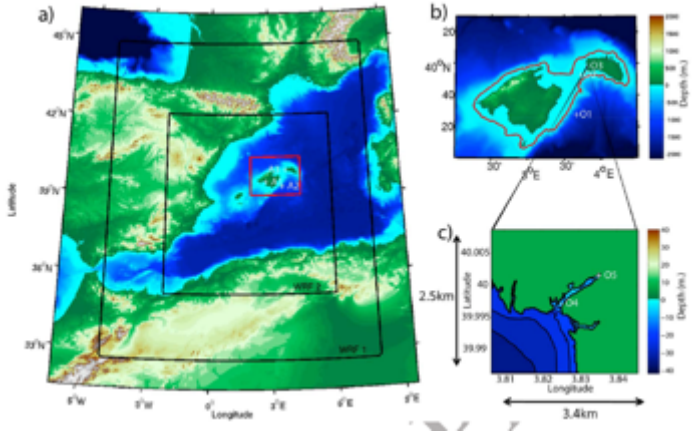
# Modelling Facility: Technology tools: pre-operational, meteotsunamis forecasting

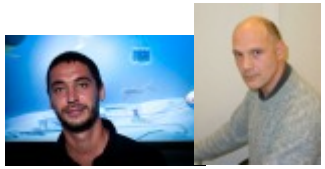
GEOPHYSICAL RESEARCH LETTERS, VOL. 38, LXXXXX, doi:10.1029/2011GL0

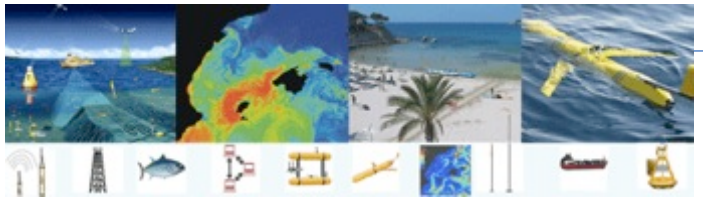
**Toward the predictability of meteotsunamis in the Balearic Sea using regional nested atmosphere and ocean models**

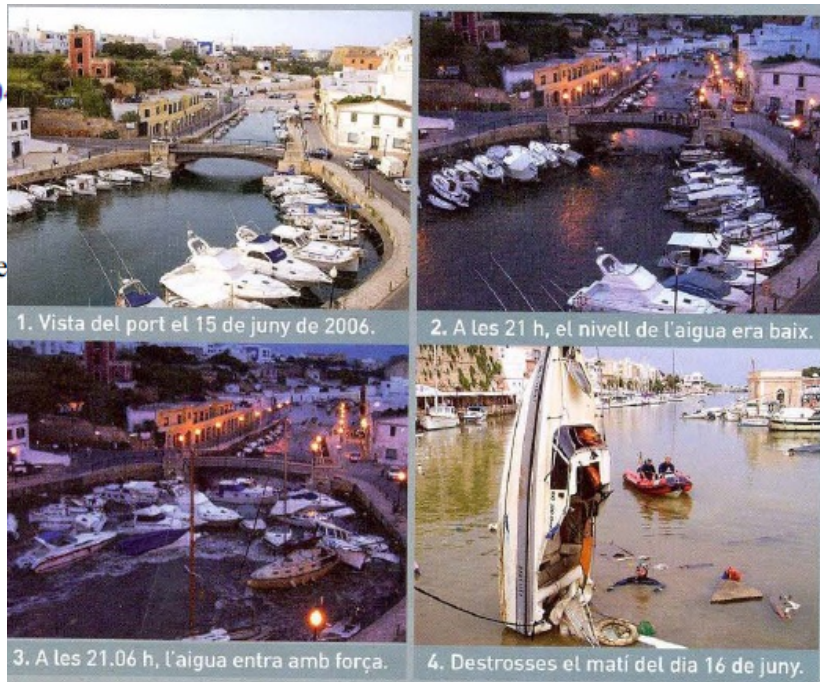
Lionel Renault,[1] Guillermo Vizoso,[2] Agustin Jansá,[3] John Wilkin,[4] and Joaquin Tintore

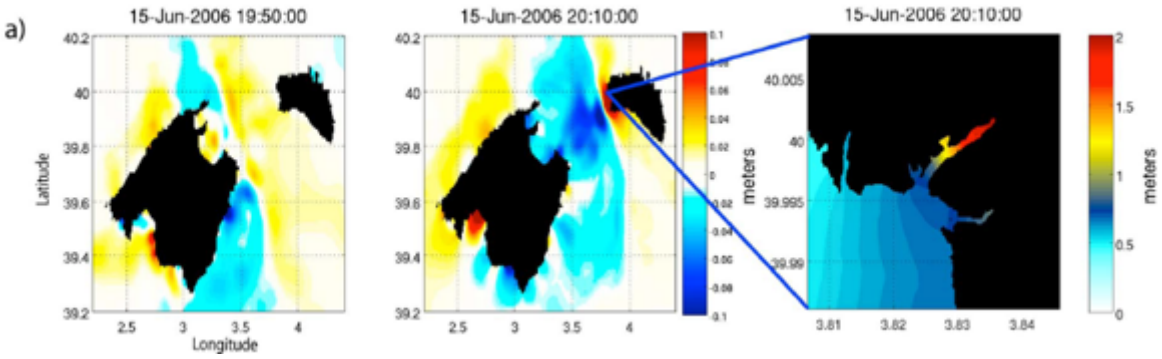
Received 4 March 2011; revised 29 March 2011; accepted 30 March 2011; published XX Month 2011.







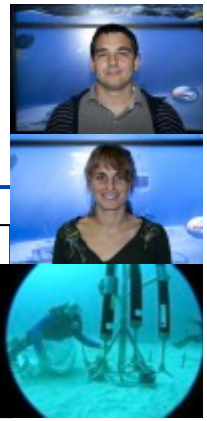

ICTS OceanBit

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

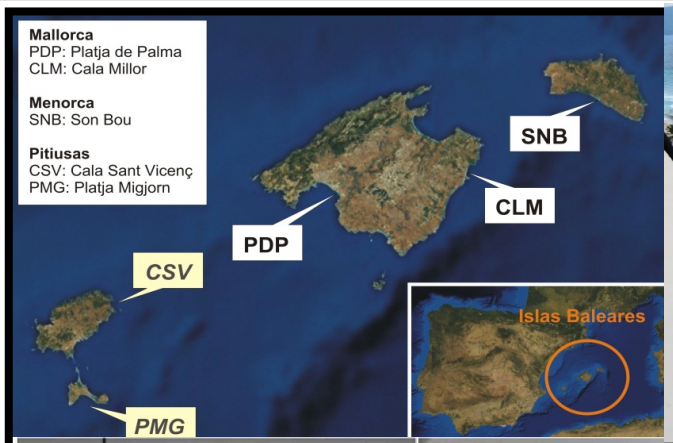
UIB

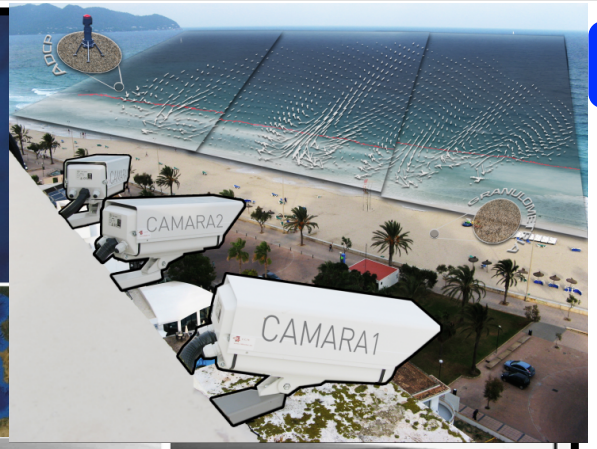
I·M·E·D·E·A
CSIC

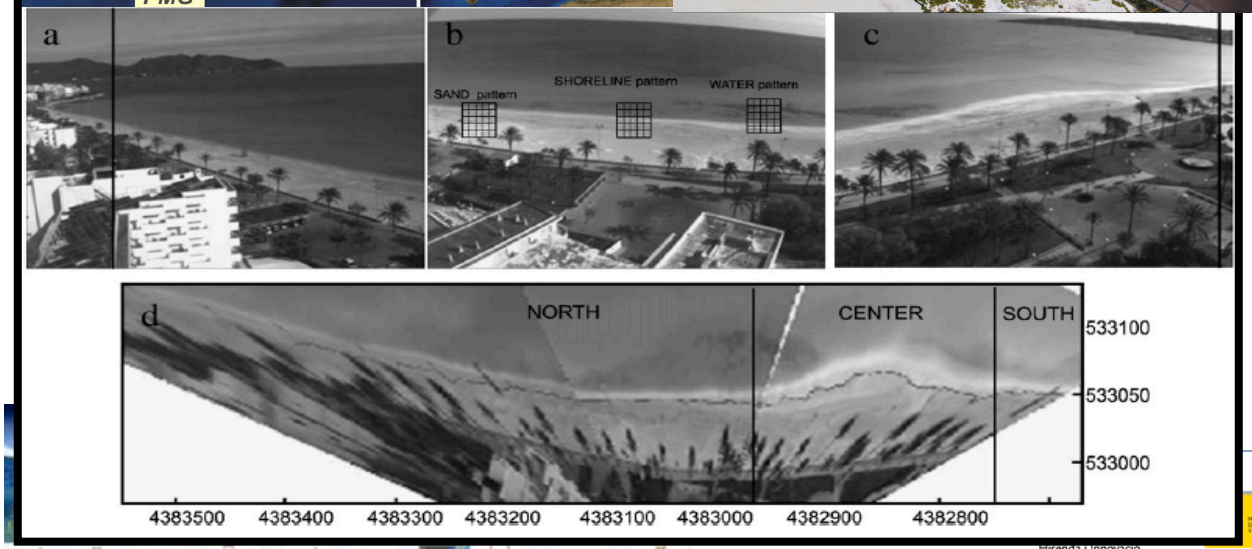
# Beach Monitoring Facility: Science & Technology



**TMTBMF is a MODULAR SYSTEM designed to monitor continuously and in an autonomous way short and long term physical beach hydrological and morphological parameters.**




## MOBIMS

- Beach videomonitoring (SIRENA)
- Waves and currents (ADCPs)
- Bathymetry and beach profiles surveys
- Sediment parameters

**PRODUCTS & SERVICES FOR BEACH MORPHODYNAMICS RESEARCH, BEACH SAFETY & COASTAL MANAGEMENT**

Hisenda i Innovació
Direcció General de Recerca,
Desenvolupament Tecnològic i Innovació

# Data Center: Science and Technology

To accomplish the full lifecycle data (from the modeling and observing systems ingestion up to the user), the data center has defined seven steps for the Data Management Process:

1. Platform management and communication
2. Quality Control assurance
3. Metadata Aggregation and Standardization
4. Data Archive
5. Data Search and Discovery
6. Data Policy and distribution
7. Data Viewing

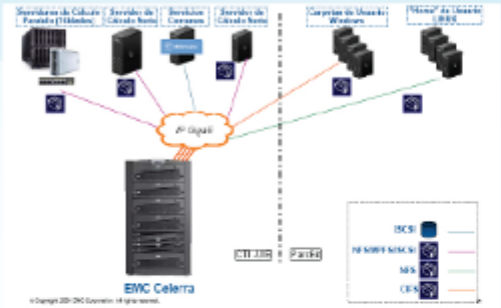
# Data Centre: Technologies

The main technologies used are: OPeNDAP / THREDDS server hosting CF-compliant NetCDF; the open-source RAMADDA as a content management system and collaboration services for Earth Science data. Those technologies permit the distribution, cataloging and discovery over the oceanographic data.

### 1. Multi Platform Management

**Alredyavailable:glidersdrifters,moorings,adcp, beach monitoring cameras, ...** Real time monitoring and wide descriptions of data sets (standardscompliant).

### 2. Data Archive




**Informatic infraestructure:** to securely archive data and metadata and retrieve them on demand.

### 3. Distribution

**OPeNDAP, WCS, WMS, HTTP, FTP, ...** to access the data in an interoperable manner from client applications.

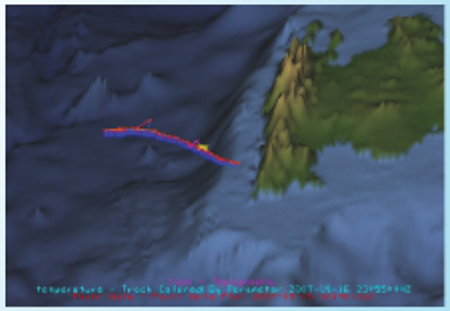
### 4. Catalog

**THREDDS to** organize data and Metadata to automatic harvesting.

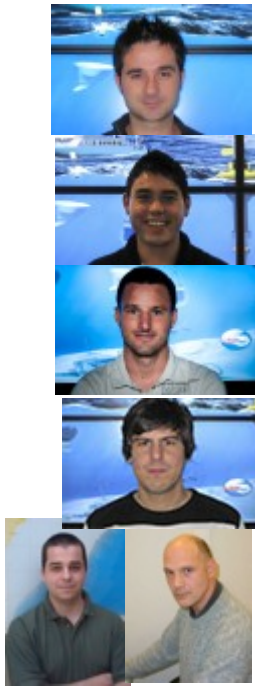
### 5. Discovery

**RAMADDA** to search for and find data sets of interest for human interaction.

### 6.Analisis and Visualization



**IDV, own Web Aplications, GODIVA, LAS,...** capability to provide an integrated viewing service.

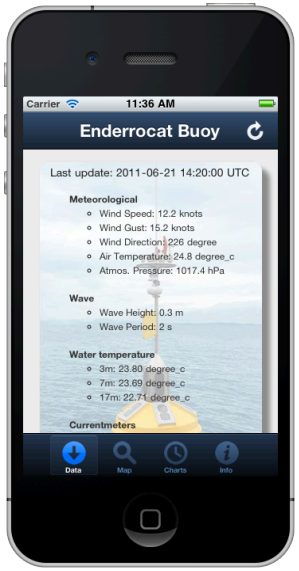


SOCIB Balearic Islands Coastal Observing and Forecasting System

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Govern de les Illes Balears

# Data Centre (Technologies; example of Apps)

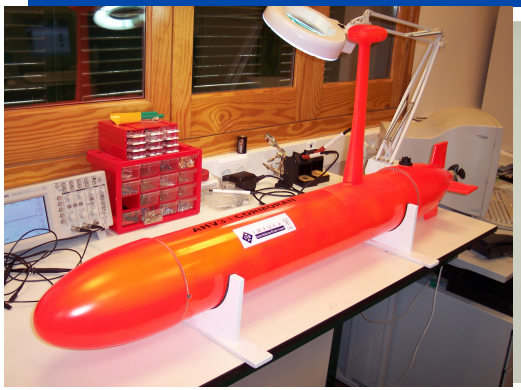


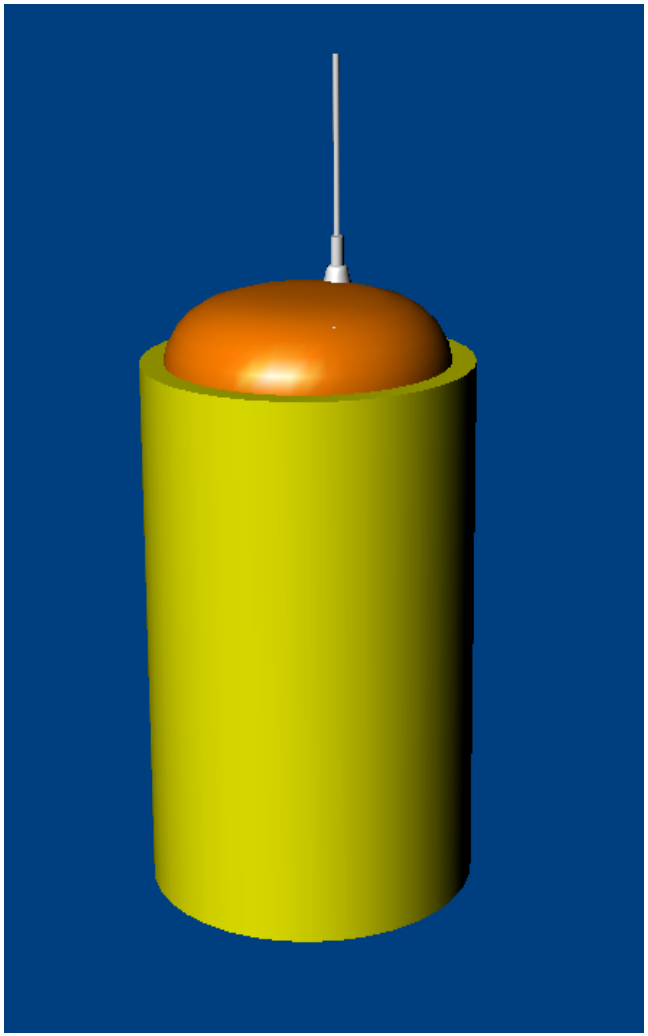
SOCIB Balearic Islands Coastal Observing and Forecasting System

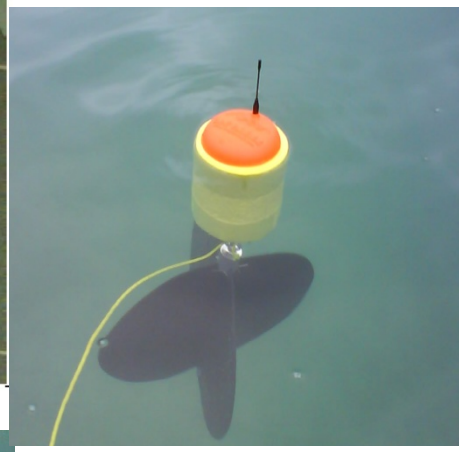
GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Govern de les Illes Balears

# Technologies Development: new instruments

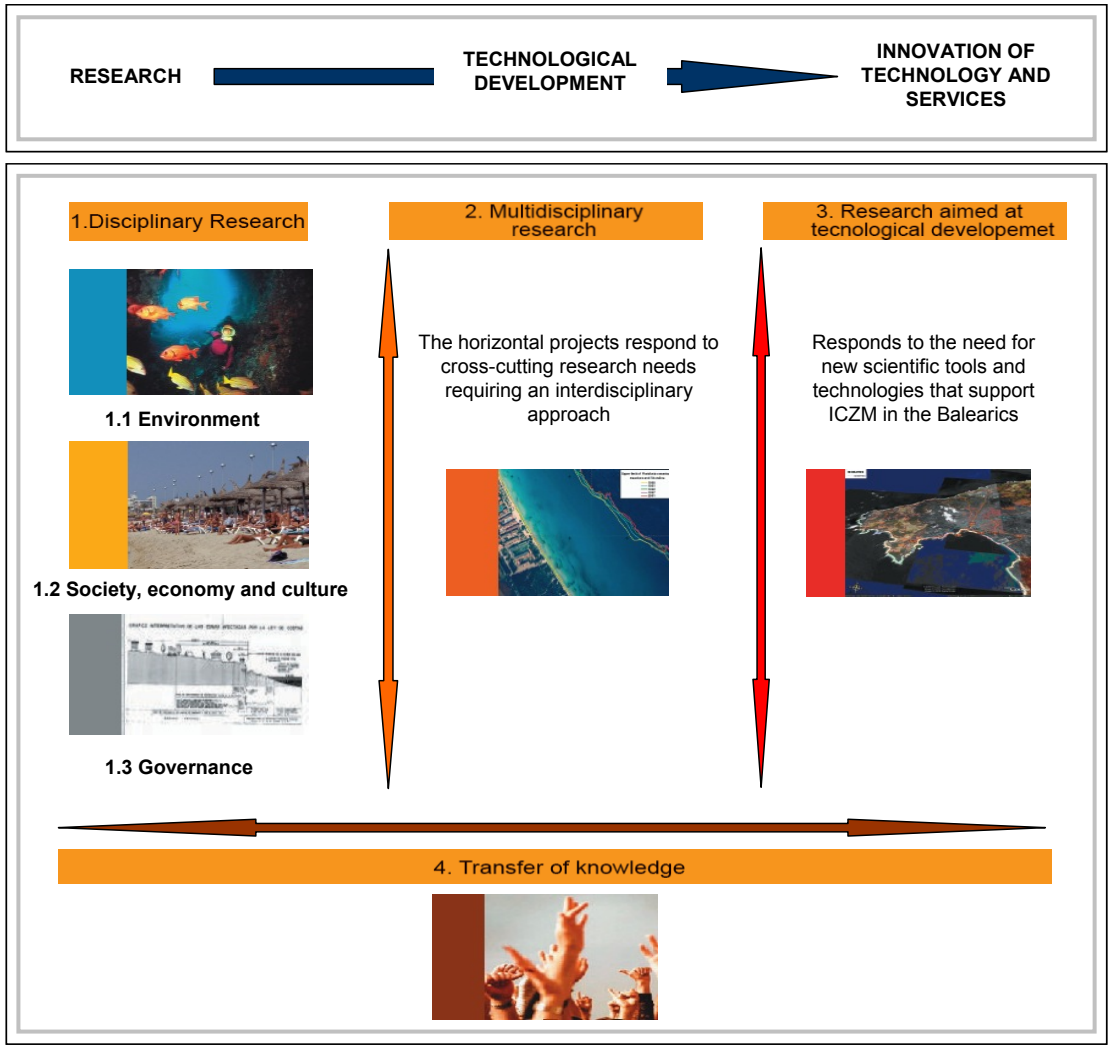






With:
TMOOS/IMEDEA
and AMT

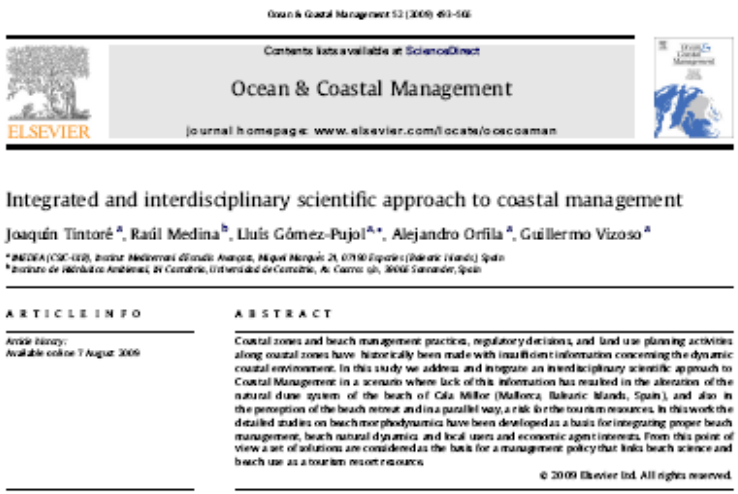
# Technologies (Management technologies): Applications and Strategic Issues Society




Initial interest from the Balearic Islands Government.

Sustainability Indicators – together with CES Council. -

http://www.costabalearsostenible.es



Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Integrated and interdisciplinary scientific approach to coastal management

Joaquín Tintoré [a], Raúl Medina [b], Lluís Gómez-Pujol [a,*], Alejandro Orfila [a], Guillermo Vizoso [a]

ARTICLE INFO

ABSTRACT

Coastal zones and beach management practices, regulatory decisions, and land use planning activities along coastal zones have historically been made with insufficient information concerning the dynamic coastal environment. In this study we address and integrate an interdisciplinary scientific approach to Coastal Management in a scenario where lack of this information has resulted in the alteration of the natural dune system of the beach of Cala Millor (Mallorca, Balearic Islands, Spain), and also in the perception of the beach retreat and in a parallel way, a risk for the tourism resources. In this work the detailed studies on beach morphodynamics have been developed as a basis for integrating proper beach management, beach natural dynamics and local users and economic agent interests. From this point of view a set of solutions are considered as the basis for a management policy that links beach science and beach use as a tourism resort resource.

© 2009 Elsevier Ltd. All rights reserved.

SOCIB Balearic Islands Coastal Observing and Forecasting System

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Govern de les Illes Balears

# Technologies (Management technologies): Applications and Strategic Issues Society

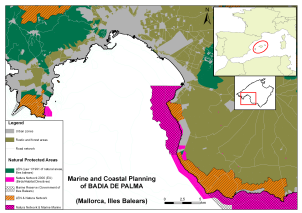
**Sustainability Science and Integrated Coastal and Marine Management, MSP**

We are…

- Developing and evaluating science-based decision-making tools and methods to support ICMM, with particular emphasis on the integration of environmental and social dimensions

- Identifying and implementing indicators to assess, monitor, and predict limits to growth and critical thresholds,

- Integrating research with environmental governance and management systems to assure sound transfer two sides science to society and back!.




SYSTEM OF INDICATORS
for Integrated Coastal Zone Management in the Balearic Islands

Marine Policy 34 (2010) 772–781

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Balancing science and society through establishing indicators for integrated coastal zone management in the Balearic Islands

A. Diedrich [a,*], J. Tintoré [a], F. Navinés [b]

[a] IMEDEA (CSIC-UIB), Mediterranean Institute of Advanced Studies, Calle Miquel Marqués, 21, 07190 Esporles, Mallorca, Balearic Islands, Spain
[b] CES, Economic and Social Council of the Balearic Islands, Palau Reial, 19, 07001 Palma, Mallorca, Balearic Islands, Spain

ARTICLE INFO

*Article history:*
Received 24 November 2008
Received in revised form
18 January 2010
Accepted 18 January 2010

*Keywords:*
Indicators
ICZM
Science-policy gap
Balearic Islands
Spain

ABSTRACT

This paper explores the process by which indicators may be developed as tools for communicating science to decision-makers using the participatory approach demonstrated by the Balearic Indicators Project. This initiative reflects a series of compromises considered necessary to achieve the objective of generating an indicator system that is scientifically viable, comparative internationally yet locally relevant, and to facilitate its implementation. The article highlights questions regarding the utility of science for addressing current global issues related to sustainability and why science often fails to promote change at the societal level.

© 2010 Elsevier Ltd. All rights reserved.

Ocean & Coastal Management 52 (2009) 493–501

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Integrated and interdisciplinary scientific approach to coastal management

Joaquín Tintoré [a], Raúl Medina [b], Lluís Gómez-Pujol [a,*], Alejandro Orfila [a], Guillermo Vizoso [a]

[a] IMEDEA (CSIC-UIB), Institut Mediterrani d'Estudis Avançats, Miquel Marqués 21, 07190 Esporles (Balearic Islands), Spain
[b] Instituto de Hidráulica Ambiental, IH Cantabria, Universidad de Cantabria, Av. Castros s/n, 39005 Santander, Spain

ARTICLE INFO

*Article history:*
Available online 7 August 2009

ABSTRACT

Coastal zones and beach management practices, regulatory decisions, and land use planning activities along coastal zones have historically been made with insufficient information concerning the dynamic coastal environment. In this study we address and integrate an interdisciplinary scientific approach to Coastal Management in a scenario where lack of this information has resulted in the alteration of the natural dune system of the beach of Cala Millor (Mallorca, Balearic Islands, Spain), and also in the perception of the beach retreat and in a parallel way, a risk for the tourism resources. In this work the detailed studies on beach morphodynamics have been developed as a basis for integrating proper beach management, beach natural dynamics and local users and economic agent interests. From this point of view a set of solutions are considered as the basis for a management policy that links beach science and beach use as a tourism resort resource.

© 2009 Elsevier Ltd. All rights reserved.

SOCIB Balearic Islands Coastal Observing and Forecasting System

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Govern de les Illes Balears

# Outline

## 2. Innovation in oceanographic instrumentation

- Oceans complexity, needs for improvement of instrumental capacities
- The innovation process, complexity and incubation time
- The key to success

# Oceans complexity, needs for improvement of instrumental capacities

## Rationale:

The Oceans; a complex system, changing, under-sampled
(Walter Munk-2001- “The last century of oceanography is marked by the degree of under-sampling”, cited by Chris Barnes/NEPTUNE yesterday; Carl Wunsh 2010: “We need data, … models are becoming untestable” and examples from Martin Visbeck  Atlantic Ocean meridional circulation yesterday), but that still needs to be managed

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)

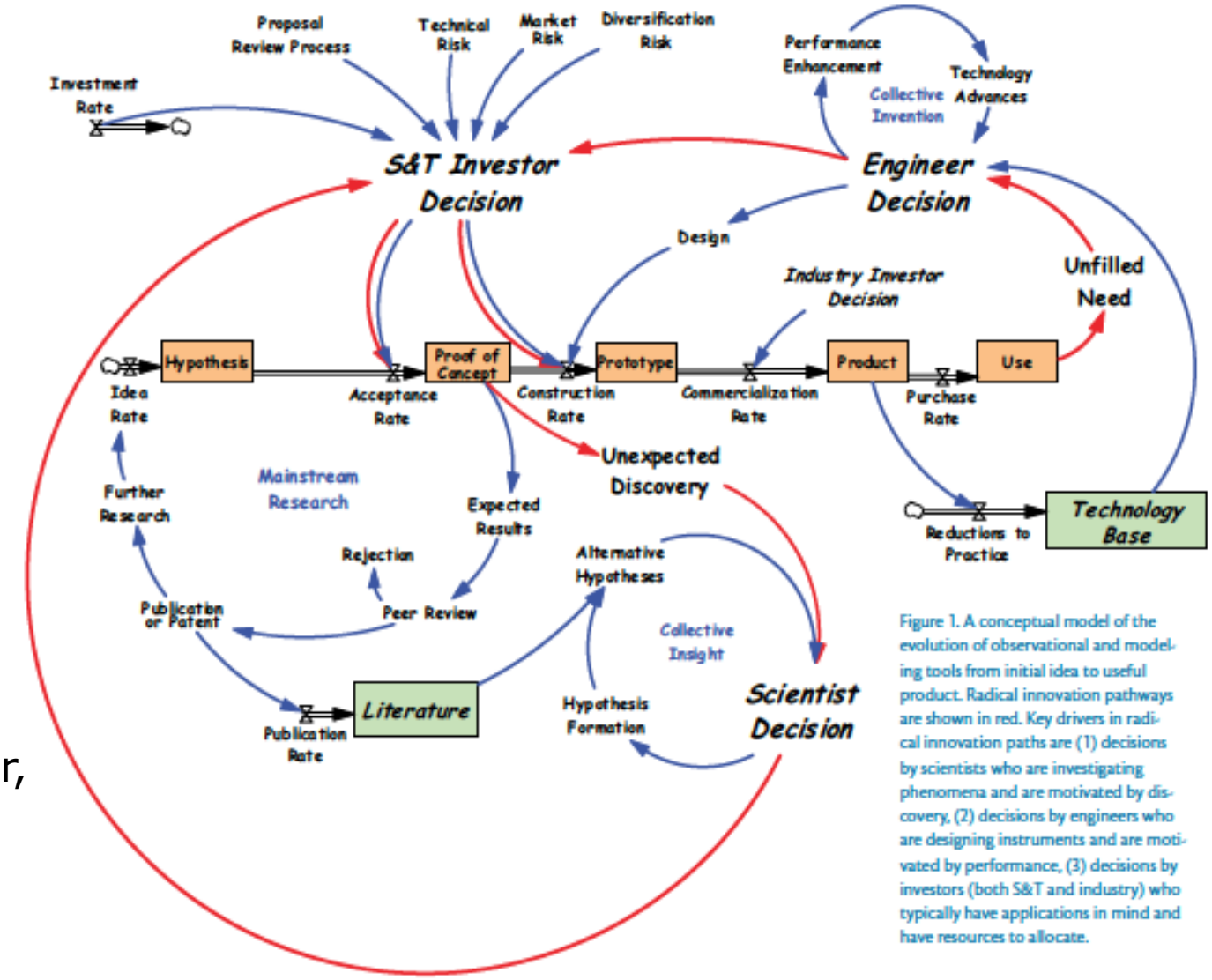



Figure 1. A conceptual model of the evolution of observational and modeling tools from initial idea to useful product. Radical innovation pathways are shown in red. Key drivers in radical innovation paths are (1) decisions by scientists who are investigating phenomena and are motivated by discovery, (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 ? : we need synoptic coverage

## Examples of innovations:

- Ships
- Satelites
- CTD
- Buoys- ARGO profilers
- Currentmenters (rotor to ADCP)
- Gliders

# The innovation process (disruptive, gliders)

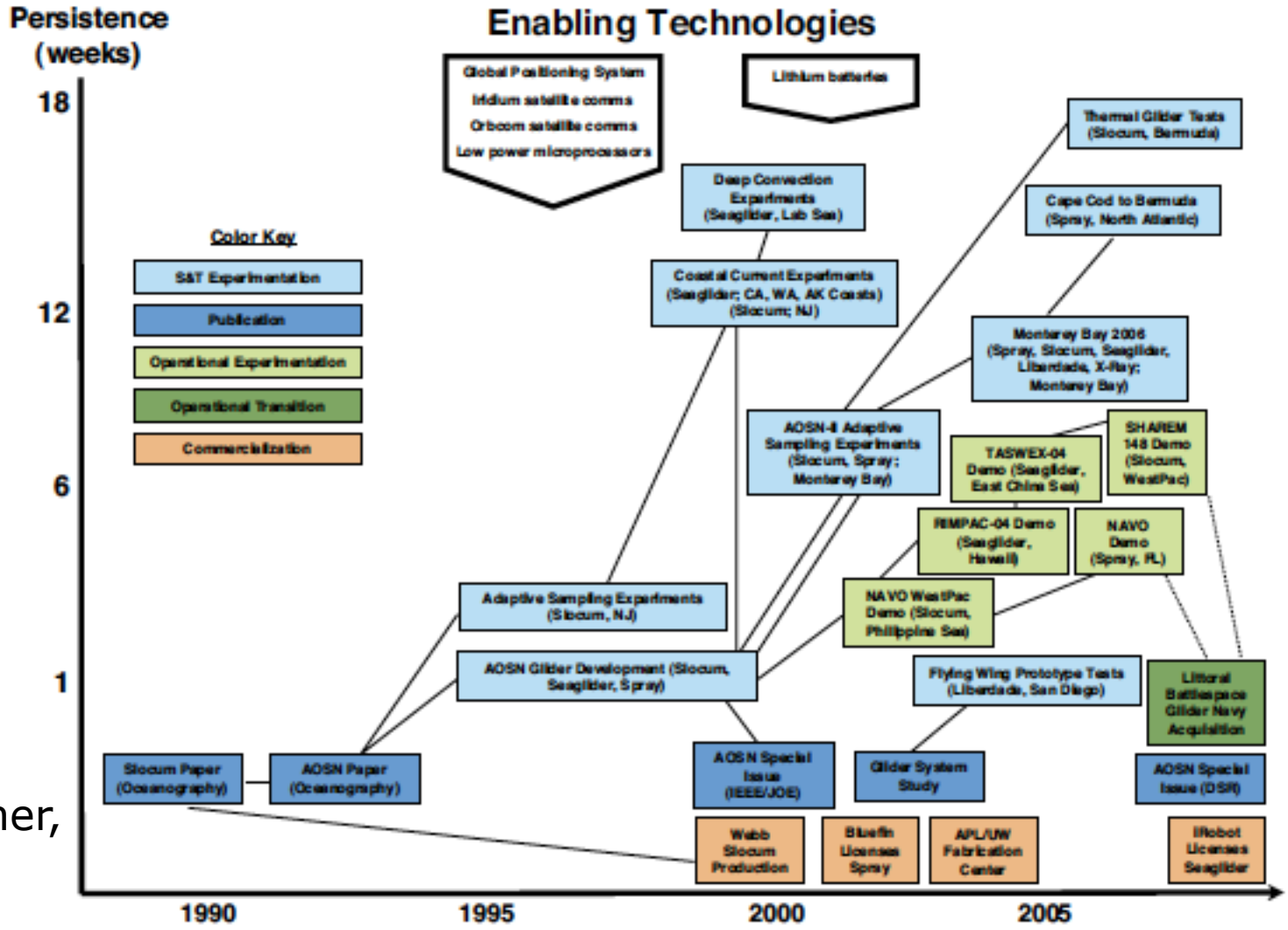



Figure 5. Events contributing to advances in underwater gliders. Progress hinged upon government-funded developments in GPS navigation and industry-funded developments in low-power, satellite communication. Other large-scale enablers include low-power microprocessors and associated sensors and signal processors and lithium-based batteries. In this case, funding was provided primarily by ONR in three parallel initial developments.

(Curtin and Belcher, TOS, 2008)

# 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, 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.

# Outline

## 3. The new role of Research Infrastructures – ICTS

- State of the art research capacity
- Technology development and development of management tools
- Ideal bridge for public-private sectors partnership

# The role of new research infrastructures, ICTS

→ 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 (social society endorsement)

**ICTS are particularly well placed for this challenge…**

**AND** → Need to define a **JOINT STRATEGY** (European/ national level in the international framework, more than coordination, Partnership…)

# The role of new research infrastructures, ICTS

SOCIB design is well suited to respond to theses 3 basic elements that lead to disruptive innovation.

- SCIENCE
- TECHNOLOGY
- SOCIETY

Ideal position for public / private cooperation

# Muchas gracias!!!

# References

NOTES JOAQUIN / LISBOA

History in oceanography and climate and how the observations have surprised us:...

Every time a new instrument has arrived, new....

- Example from the bathythermograph…

- First CTD's, from Stommel and Fedorov about small scale structures...

- Satellite era, Chelton paper small scale structures in the wind field,

- Satellite animation, high fluctuations at low latitudes... major changes... from a GCM constrained by altimetry....

- Current-meters: until they started to provide data, we did not understand really the different parts of the spectrum, inertial, geostrophy, etc... The duration of the record was a key issue

.

Again, we could not anticipate what would be the change, so we cannot really anticipate what will be the impact of altimetry...

. Altimetry:

Models can resolve now very small scales and can nowadays become untestable... This is very dangerous... The development of models is progressing with tests being mostly carried out by altimetry...

KEY IMPORTANCE OF NEW INSTRUMENTS FOR RESOLVING SCALES AND FOR MODEL TESTING IN COSTAL AREAS

# References

*Eos*, Vol. 92, No. 25, 21 June 2011

NEWS

## Determining Critical Infrastructure for Ocean Research and Societal Needs in 2030

PAGES 210–211

The United States has jurisdiction over 3.4 million square miles of ocean—an expanse greater than the land area of all 50 states combined. This vast marine area offers researchers opportunities to investigate the ocean's role in an integrated Earth system but also presents challenges to society, including damaging tsunamis and hurricanes, industrial accidents, and outbreaks of waterborne diseases. The 2010 Gulf of Mexico Deepwater Horizon oil spill and 2011 Japanese earthquake and tsunami are vivid reminders that a broad range of infrastructure is needed to advance scientists' still incomplete understanding of the ocean.

The National Research Council's (NRC) Ocean Studies Board was asked by the National Science and Technology Council's Subcommittee on Ocean Science and Technology, comprising 25 U.S. government agencies, to examine infrastructure needs for ocean research in the year 2030. This request reflects concern, among a myriad of marine issues, over the present state of aging and obsolete infrastructure, insufficient capacity, growing technological gaps, and declining national leadership in marine technological development; these issues were brought to the nation's attention in 2004 by the U.S. Commission on Ocean Policy.

increasing fundamental scientific understanding (10 questions). Many of the questions in the report (e.g., sea level rise, sustainable fisheries, the global water cycle) reflect challenging, multidisciplinary science issues that are clearly relevant today and are likely to take decades of effort to solve. As such, U.S. ocean research will require a growing suite of ocean infrastructure for a range of activities, such as high-quality, sustained time series observations or autonomous monitoring at a broad range of spatial and temporal scales. Consequently, a coordinated national plan for making future strategic investments becomes an imperative for addressing societal needs. Such a plan should be based on known priorities and be reviewed every 5–10 years to optimize the federal investment, the report states.

The committee examined the past 20 years of technological advances and ocean infrastructure investments (such as the rise in the use of self-propelled, uncrewed, underwater autonomous vehicles), assessed infrastructure that would be required to address future ocean research questions, and characterized ocean infrastructure trends for 2030. One conclusion was that ships will continue to be essential, especially because they provide a platform for enabling other infrastructure, such as autonomous and remotely operated vehicles; samplers and

—Deborah Glickson, Ocean Studies Board, National Research Council, Washington, D. C.; E-mail: dglickson@nas.edu; Eric Barron, Florida State University, Tallahassee; and Rana Fine, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Fla.

# References

# 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



SOCIB Balearic Islands Coastal Observing and Forecasting System

# MODELS – for….

1. Process studies
2. Forecasting/Operational
3. Management tools

In climate studies, 1 is maybe now as important as 2… not yet 3… - eg "Chilling out the winter sun, October 15, 2011. http://www.economist.com/node/21532246 "

away. There are other theories around seeking to explain the recent cold winters, too. Improving predictions of future cold winters on the basis of this work, as the researchers say they would like to do, may thus prove hard.

But though global warming has made people look to models as predictors of the future, that is not their strongest suit. Something they can do much better is look at what happens when a variable such as UV is altered, compare that with the data, and thus gain insight into the mechanisms by which climate works. This new research provides a good example of what such an approach can achieve.