BALEARIC ISLANDS COASTAL OBSERVING AND FORECASTING SYSTEM

OBSERVATIONS and MODELLING in the Western Mediterranean at basin, sub-basin, local and beach scale

(from scientifically based forecasting to operational forecasting)

Prof. Joaquín Tintoré and co-workers

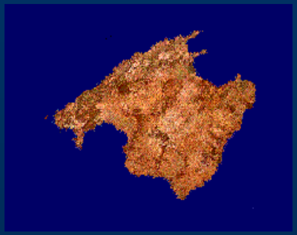
IMEDEA (CSIC-UIB)

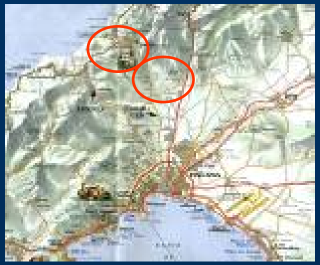
Formentor, POL Workshop,
22-24 October 2007

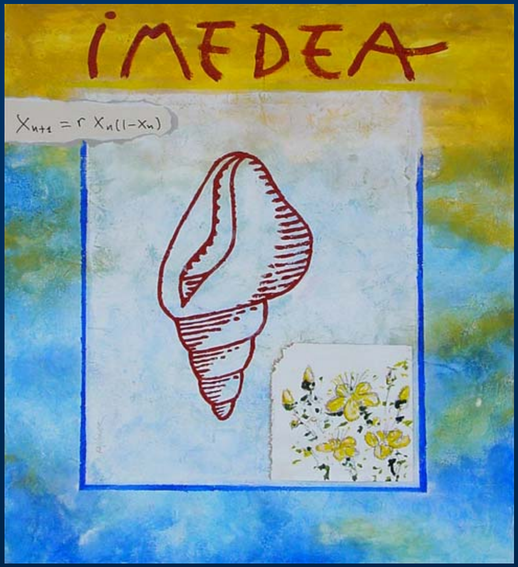
OUTLINE

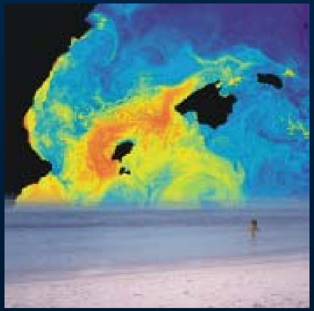
1. IMEDEA (CSIC-UIB)
2. Physical Oceanography and Coastal Dynamics
3. Some examples of contributions to process studies
4. Pilot Balearic Islands Observing and Forecasting System (MOON) - towards Science based Operational Oceanography
5. THE FUTURE: some ideas on an international, 'open access' Balearic Sea Observing and Forecasting Technological System

IMEDEA: The Mediterranean Institute for Advanced Studies









Mallorca Island, Esporles http://www.imedea.csic.es

General context and objectives

General context

- The preservation of marine and coastal ecosystems constitutes an outstanding problem to the sustainable development of coastal areas specially where the coastal environment covers an important part of their surface and its exploitation is the main economic resource.
- Global change is a further threat that marine, coastal and insular environments have to face.
- Damages generated by these threats are, among others, habitat loss for indigenous species, beach erosion and water pollution.

General objectives

- To promote scientific excellence: to strengthen and consolidate the existing framework of research, which is based on two major axes (Oceanography and Coastal Zone) and five major research lines.
- To promote connection with society: to demonstrate to policy makers and the broader society the benefits of adopting a wise, scientifically-based management of the environment, and foster the creation of an active platform for its development and update.

IMEDEA: The Mediterranean Institute for Advanced Studies

Mission

- To generate the scientific basis to better understand and predict the responses of marine, coastal and insular systems to anthropogenic pressures and the associated global change in order to improve the existing capacity for managing them in a sustainable, effective and adaptive manner.

- This will be achieved through interdisciplinary and proactive research addressing the multiple-scale interactions between the target environments.

Vision

- To become a reference center to the scientific community and environmental managers.

- To identify and elucidate the causes, mechanisms and impacts of anthropogenic and Global Change threats to marine, coastal and insular environments.

- To formulate proactive, integrated and adaptive knowledge in support of the prevention and mitigation of these impacts.

Research activities at IMEDEA

Two axis

The research activity is focused around two complementary axis:

- Global Change, including the role played by the oceans and the effects on the coastal zone
- Interdisciplinary and Integrated research in the Coastal Zone

Five research lines

- Biodiversity, Population Ecology and Marine Ecosystem Functioning
- Functioning of the Ocean System
- Operational Oceanography
- Coastal Zone Variability, including sustainability Science, Integrated Coastal Zone Management, Innovation and Tourism
- Ecology and Evolution in Insular Environments

Strategic objectives of IMEDEA in relation to society

One of the key objectives is to guarantee transfer of knowledge and technology to society.

We work to find synergies among researchers and coastal zone decision-makers in the Balearic Islands.

We work to create working groups among researchers and coastal zone decision-makers, using the most recent knowledge available.

We establish common objectives that address complex problems, like environmental quality in the coastal zone, and generate specific recommendations for improvement.

150 persons, 40 permanent researchers

100 ongoing research projects

120 peer reviewed papers/year

7 million Euros annual budget (40% obtained competitive basis)

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Physical Oceanography and Coastal Nearshore Dynamics at IMEDEA

Major research axis, 2006-2009

1. **Towards Operational Oceanography: science based Coastal Ocean Operational Oceanography**
   - Research lines
   - Operational Systems being implemented at IMEDEA
   - The future

2. **Science based quantitative sustainable Integrated Coastal Zone Management / Sustainability science**

3. **Marine Technologies, development new coastal instrumentation**

Physical Oceanography and Coastal Nearshore Dynamics at IMEDEA
Major research axis, 2006-2009

1. Towards Operational Oceanography: science based Coastal Ocean Operational Oceanography

Research lines

- **Circulation and dynamics. Scale interactions: basin, sub-basin and local scales**
  - Basin scale circulation and climatic effects
  - Sub-basin scale, mesoescale effects and interactions, shelf/slope exchanges
  - Local scale, interactions and residence time
- **Coastal zone variability and beach morphodynamics**
  - Beach erosion and sediment transport
  - Beach safety: longshore currents and rip currents
- **Physical-biological interactions at sub-basin and local scale**
  - Ecosystem variability as response to physical variability, scenarios
- **New tools for non linear systems forecasting: evolutionary computation**
  - Darwin Genetic algorithm (reg) : applications to ocean currents forecasting, wave heights, precipitation, etc

Operational Systems being implemented at IMEDEA

- **Prediction of currents in the Balearic Sea for risk assessment and environmental management**
- **Prediction of rip currents in beaches, optimization lifeguards response (pilot study at Cala Millor – Mallorca Island)**
- **Beach monitoring remote sensing system**
- **Long waves and seiches in harbors forecasting system (forced by atmospheric pressure pulses)**
- **Coastal area characterization and GIS management based system for decision support**

Physical Oceanography and Coastal Nearshore Dynamics at IMEDEA
Major research axis, 2006-2009

2. **Science based Sustainable Integrated Coastal Zone Management**

- **Scientific achievements, science based management and Sustainability principles**
- **New Observational networks, GIS tools and modeling predictive capabilities**
- **Innovation in services in the coastal zone, environmental innovation and sustainable tourism**

3. **Marine Technologies development, new coastal instrumentation at IMEDEA**

- **Development of autonomous ocean sampling platforms: Rov's, AUV's, gliders, buoys**
- **Integration of sensors and platforms for automatic sampling the coastal zone**

PHYSICAL OCEANOGRAPHY AT IMEDEA: STAFF PROJECTS, PAPERS, October 2007

Permanent Research staff

CSIC:
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Dr. Alberto Álvarez
Dr. Alejandro Orfila
UIB:
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Post docs

Dra. Ananda Pascual
Dr. Simón Ruiz
Dr. Gustavo Zarruck
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Dr. Sr. Pau Balaguer
Dra. Amy Diedrich
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Ph. D. students

Amaya Álvarez
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Alvaro Galán

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CSIC:
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Sr. Benjamín Casas

Technical staff under contracts

Sr. Miquel Martínez-Ledesma
Sr. Daniel Roig
Carlos Castilla
Pep Homar
Saul Pitarch

Projects: ongoing research projects funded by EU (MERSEA, SESAME, ECOOP), National Plan Research (COOL), Regional Balearic Gov (UGIZC), MMA (Cabrera), etc.

Papers: more than 100 peer reviewed publications. Around 15 papers/year in SCI journals.

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   - Some ideas for a Balearic Islands “Coastal” Observing and Forecasting System
   - The international context and sustainability

Towards Operational Oceanography at IMEDEA

1. IMEDEA modeling capabilities at different scales
2. IMEDEA observational capabilities at different scales
3. IMEDEA scientific examples of recent contributions on the variability of the Mediterranean at
   - basin scale
   - sub-basin scale
   - local scale
   - beach scale

Towards Operational Oceanography at IMEDEA

Scientific examples (observations and modelling) from basin to beach scale or… *what is it that we have done and published?*

Next, we present some specific examples of recent scientific results obtained at different scales:

Basin scale (10→5 km), since 1995 (*)**:** *large scale circulation, role of bottom topography, specific features, transport in detailed sections*

Sub-Basin regional scale (5→1 km), since 1992: *mesoscale/mean flow interactions, blocking basin scale circulation in specific sub-basins, circulation Alboran and Balearic Seas, etc.*

Local (1 km→500m), since 1993: *sub-basin-local interaction through canyons, shelf/slope exchanges, circulation in bays, residence times and water quality, etc.*

Towards… beach (500→10m), since 2004: *fine sediment resuspension by waves and recirculation and sediment transport by wind induced coastal currents in bays and beaches, (only still with PE non hydrostatic models and towards integration with wave models).*

(*) indicates year of the first paper published in the subject in peer reviewed journals

Process studies at IMEDEA – topics and scientific contributions

PROCESSES AND TOPICS OF GENERAL SCIENTIFIC INTEREST AND OF PARTICULAR RELEVANCE IN THE BALEARIC ISLANDS

- Mesoscale eddies, filaments, energy exchanges, eddy-mean flow interactions
- Mesoscale eddies, blocking effects, inter-annual variability mean flow
- Mesoscale eddies, vertical motions computation from observations, models
- Vertical motions and relation to phytoplancton size structure
- Sub-basin scale dynamics and effects on large, basin scale circulation, feedback (Alborán, Balearic)
- Inter-annual variability and ecosystem response, feedback
- HABS, residence time, terrestrial and open ocean inputs and exchanges in the coastal area
- Near inertial motions, shelf and slope, interactions with fronts
- Shelf/slope exchanges, canyons, numerical and field studies
- Long waves propagation and harbors resonance
- Near-shore studies, wave current interactions, sediment transport (fine sediments in low tidal environments), beach erosion
- Technology development
- ICZM – towards quantitative sustainability science/population dynamics

Mediterranean inter-annual variability: sub-basin basin scale interactions

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Mesoscale, seasonal and interannual variability in the Mediterranean Sea using a numerical ocean model

Vicente Fernández [a,*], David E. Dietrich [a], Robert L. Haney [b], Joaquín Tintoré [a]

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Received 4 November 2002; received in revised form 17 February 2003; accepted 2 July 2004
Available online 10 May 2005

Abstract

In this paper, we present the results from a 1/8° horizontal resolution numerical simulation of the Mediterranean Sea using an ocean model (DieCAST) that is stable with low general dissipation and that uses accurate control volume fourth-order numerics with reduced numerical dispersion. The ocean model is forced using climatological monthly mean winds and relaxation towards monthly climatological surface temperature and salinity. The variability of the circulation obtained is assessed by computing the volume transport through certain sections and straits where comparison with observations is possible. The seasonal variability of certain currents is reproduced in the model simulations. More important, an interannual variability, manifested by changes in currents and water mass properties, is also found in the results. This may indicate that the oceanic internal variability (not depending on external atmospheric forcing), is an important component of the total variability of the Mediterranean circulation; variability that seems to be very significant and well documented by in situ and satellite data recovered in the Mediterranean Sea during the last decade.

Keywords: Mediterranean sea; Ocean modelling; Interannual variability

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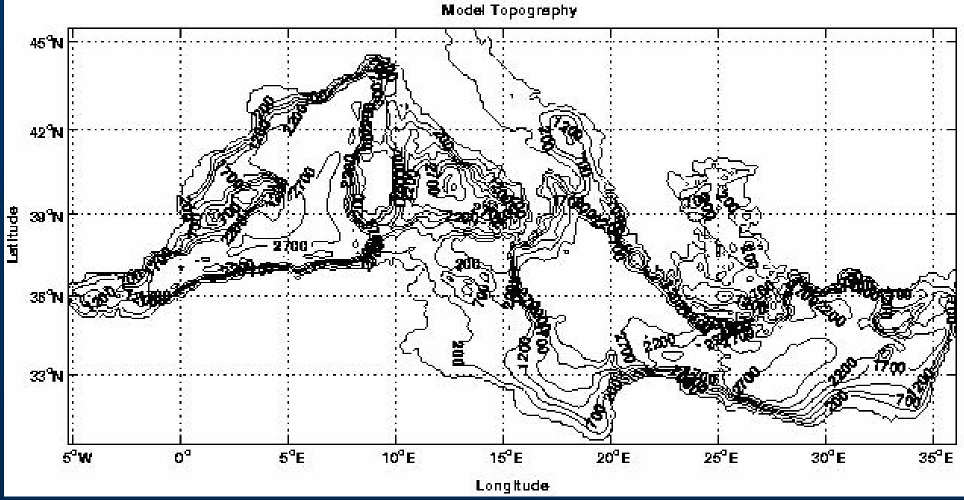
Mediterranean inter-annual variability: sub-basin basin scale interactions

Internal variability



DIECAST 3d PE OCEAN MODEL

- **Objective:** **study the existence of an internal variability in the Mediterranean, not linked to external forcing, that could be traced in observations.**

- **Metodology:** **"*Diecast* Ocean Model", model that simulates the circulation and dynamics in slope areas implemented at IMEDEA.**

Fernández, D. E. Dietrich, R. L. Haney, J. Tintoré*. Progress in Oceanography*. 2005

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Mediterranean variability: basin scale

DIECAST 3d PE OCEAN MODEL

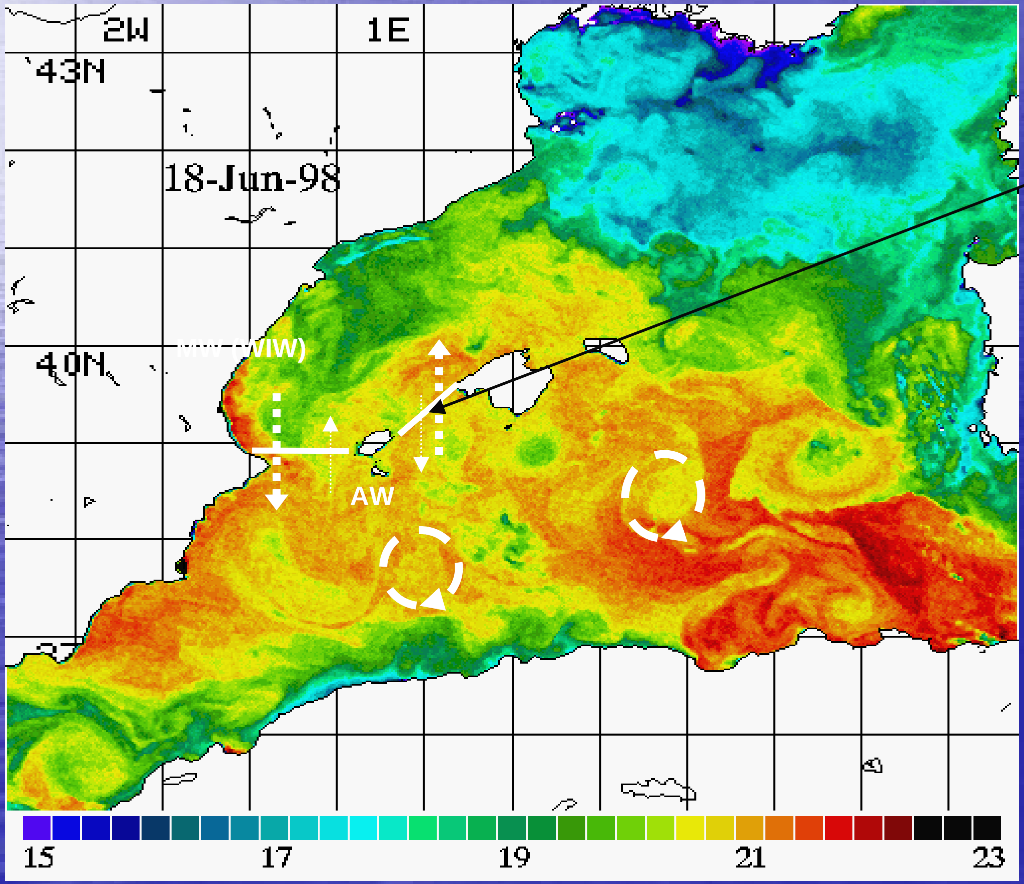
- 3d Primitive Equation, z level vertical coordinate
- Hydrostatic and rigid lid approximation
- Surface pressure treatment (elliptic equation for the surface pressure having zero divergence for the barotropic mode)
- Control volume based, with a blend of Arakawa grids "A" (control volume quantities) and "C" (fluxes across the cell faces).
- 4th order accurate numerical approximations for the advection and pressure gradients terms and for the interpolations between "A" and "C" grid locations.
- Reduced dispersion advection scheme

Low numerical dispersion and stable with low physical dissipation

Fernández, V., D. E. Dietrich, R. L. Haney, J. Tintoré. *Progress in Oceanography*. 2005

THE MEDITERRANEAN SEA

Increasing observational (and modelling) evidence of variability at seasonal and **interannual** time scales, at different subbasins (e.g. Balearic Sea, etc)



North-south transport exchange variability (seasonal and interannual) through the Balearic channels.

Due to atmospheric forcing variability…and to **internal eddy driven variability.**

MAIN OBJECTIVE

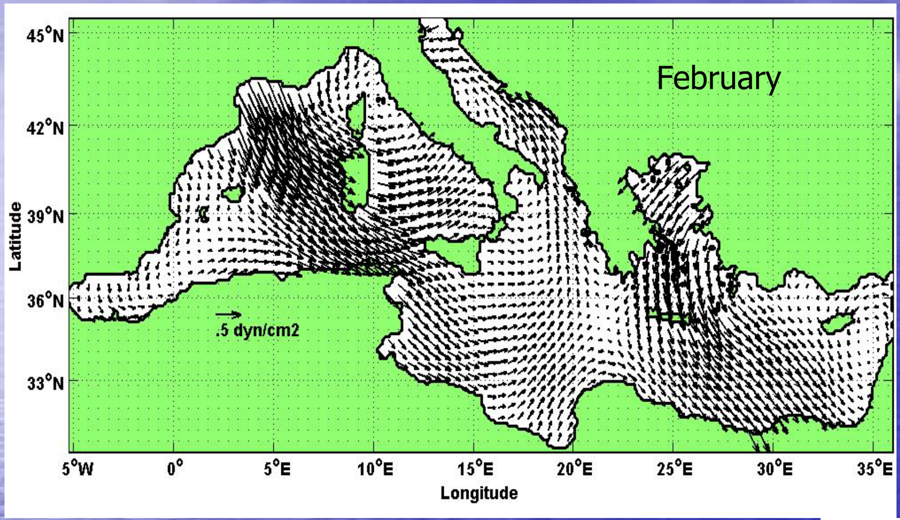
- To determine if there is an **internal variability** of the Mediterranean system, **not depending on external forcing**, that can be relevant to understand the observed interannual variability in some subbasins of the Mediterranean Sea.

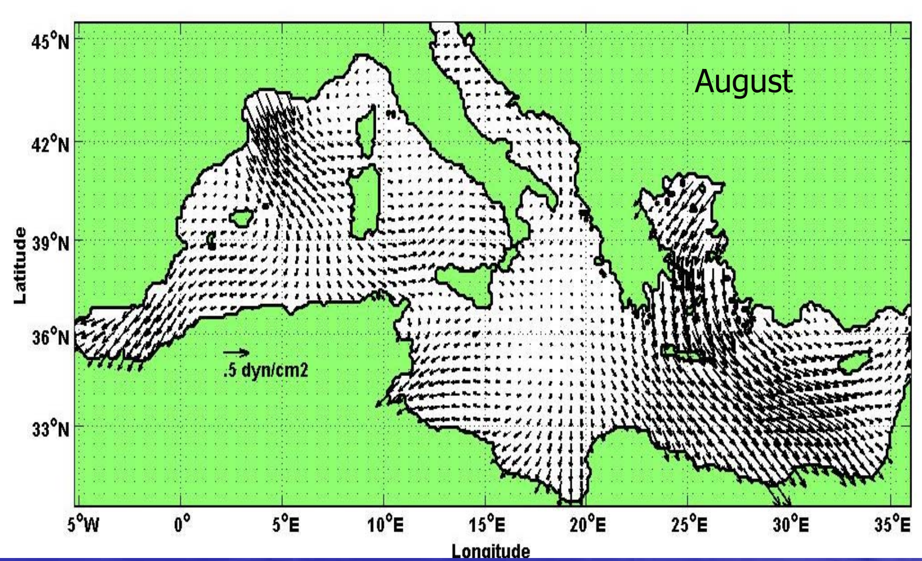
METHOD

- Using a numerical model of the Mediterranean Sea forced with a **yearly repeating** climatological atmospheric forcing (NO externally forced interannual variability) in such a way that the possible interannual variability in the model is due to internal dynamics mechanisms.

MODEL FORCING

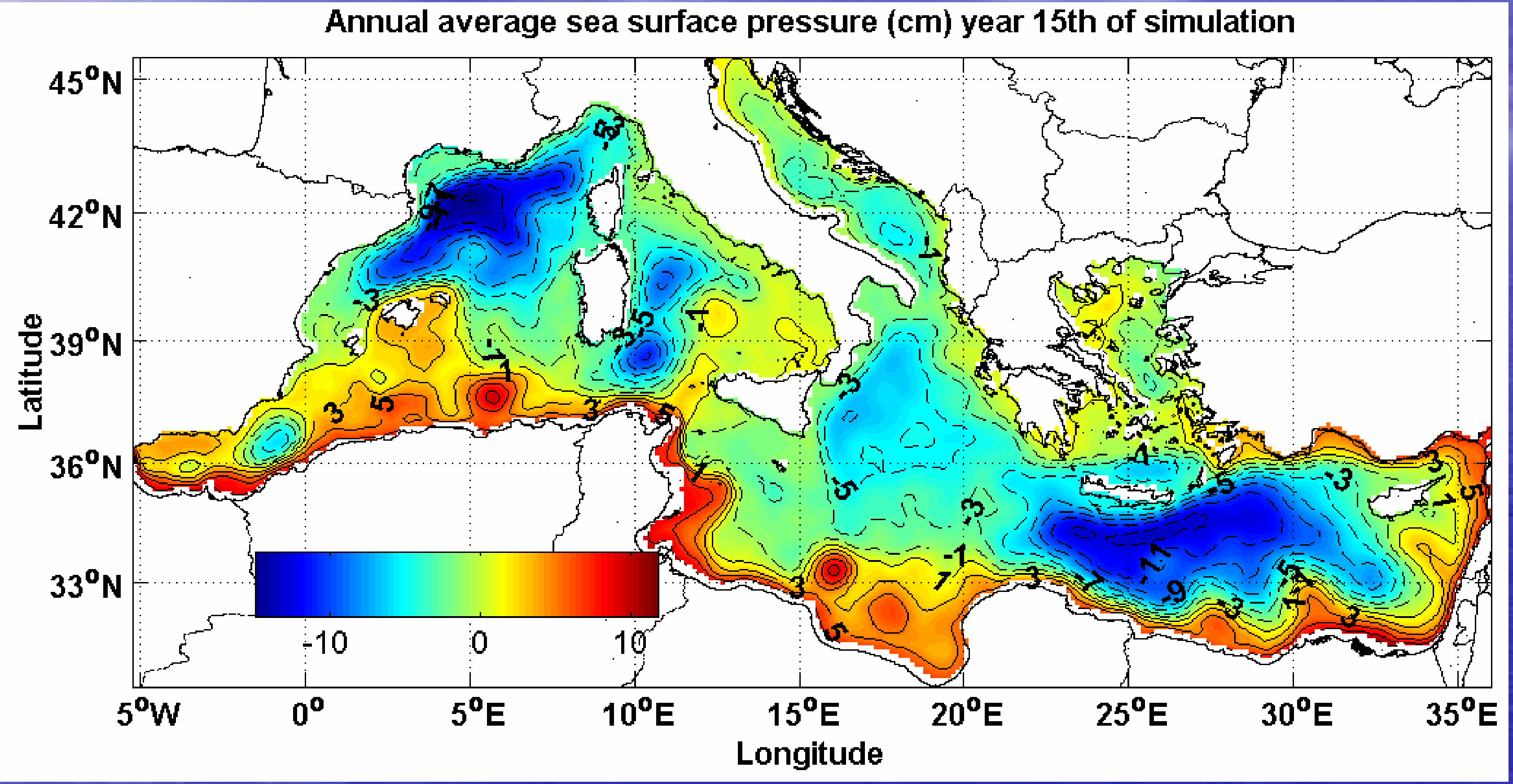
- **Momentum:** monthly climatological wind stress (yearly repeating cycle)





MODEL RESULTS

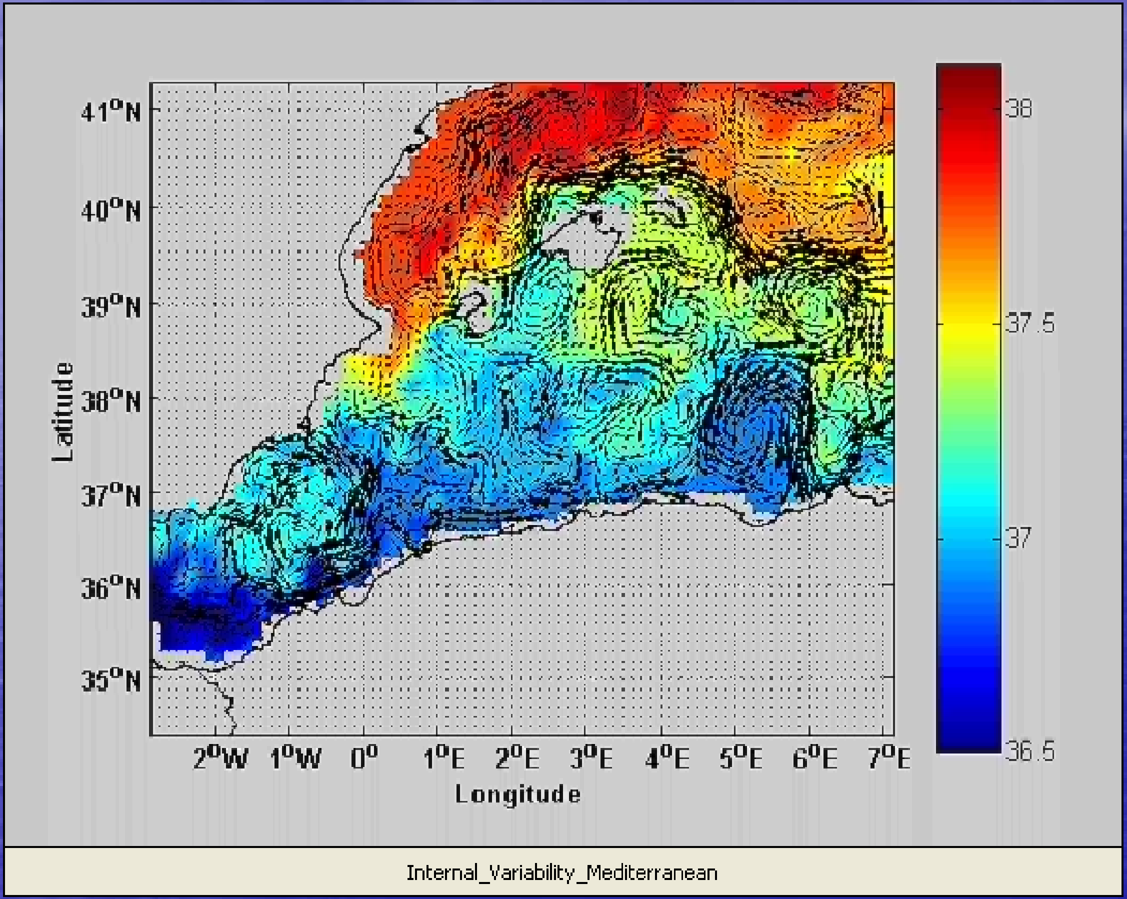
Year 15



We get correct **annual average surface circulation** with:

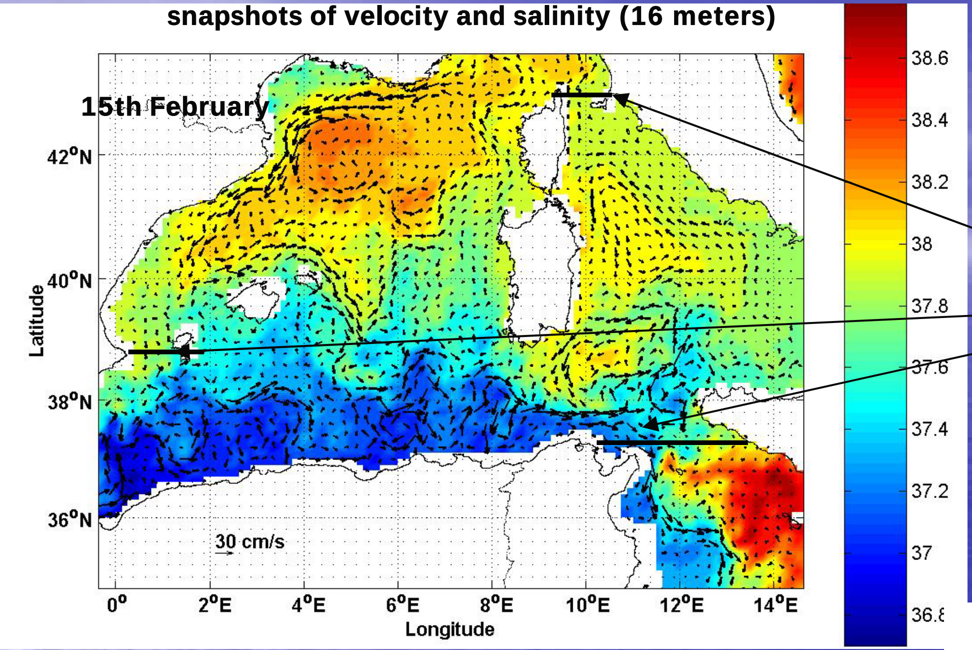
- coastal currents
- basin-scale gyres

MODEL RESULTS



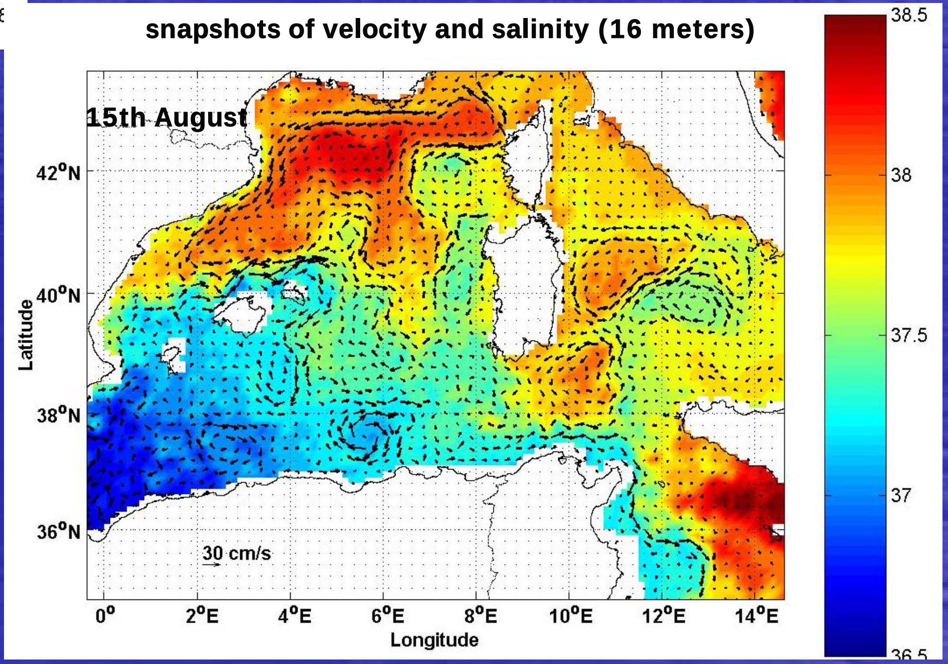
DieCAST model. One year simulation, salinity and velocity fields

SEASONAL VARIABILITY



INTEGRATED VOLUME TRANSPORTS THROUGH SECTIONS

Daily values (1Sv=10 ^{6} m^3/s)

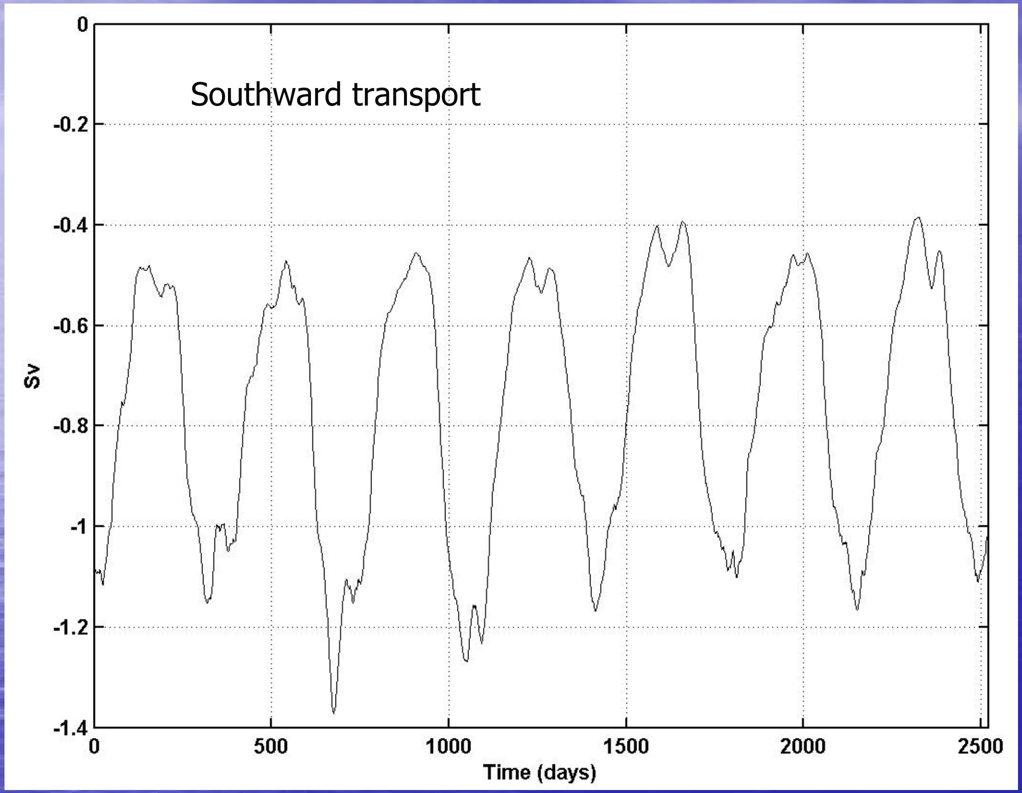


Differences:

- **Differences in the strenght of the currents**
- **The Algerian current**
- **Low salinity waters vary their possition**

...

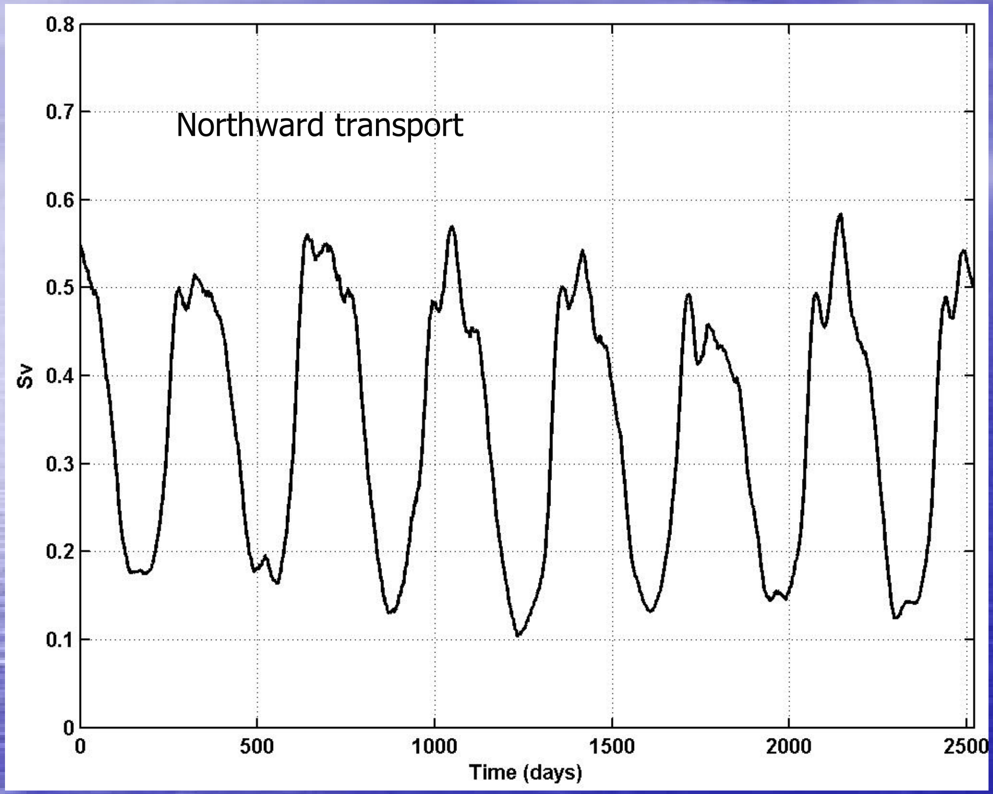
STRAIT OF SICILY



Mean: 0.7 Sv.
Crossing the strait

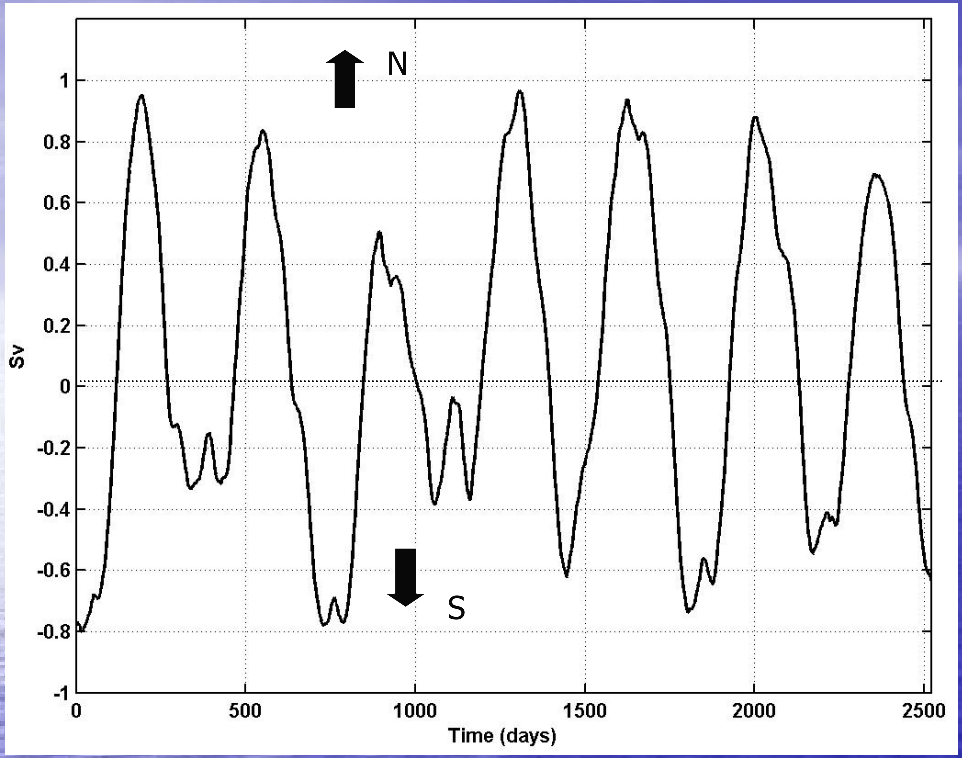
Observations: ~ 1.0 Sv
with a seasonal cycle

CORSICA CHANNEL



Observations:
seasonality ranging from 1.5 Sv in winter to .5 Sv in summer

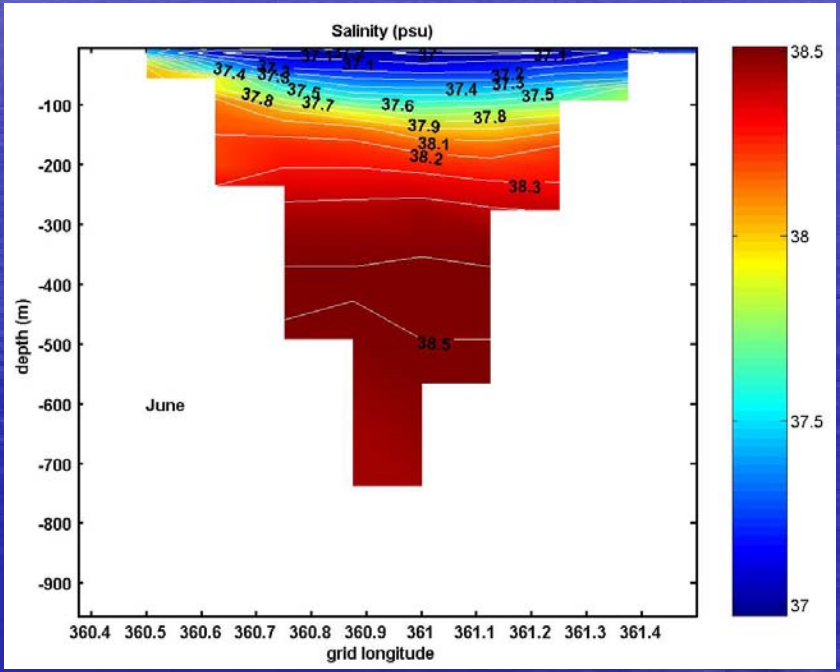
IBIZA CHANNEL



Observations:

Nortward intrusion of .2 to .7 Sv in the summer

Southward transport of 1 to 1.5 in winter



Northward summer intrusions of AW ⟷

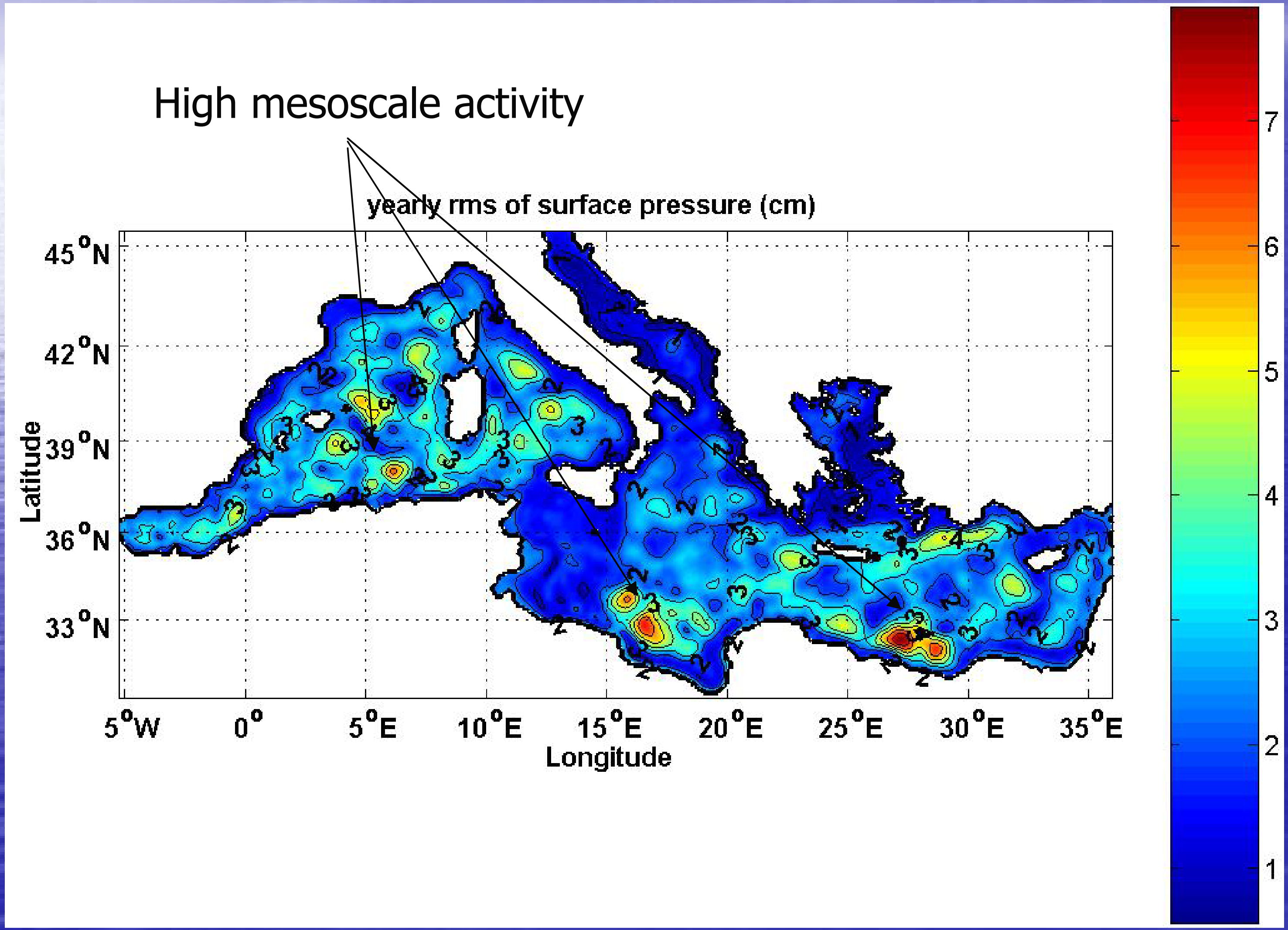
Interannual variability in transports

+

Repeating atmospheric forcing → **Eddy driven internal variability**

MESOSCALE VARIABILITY

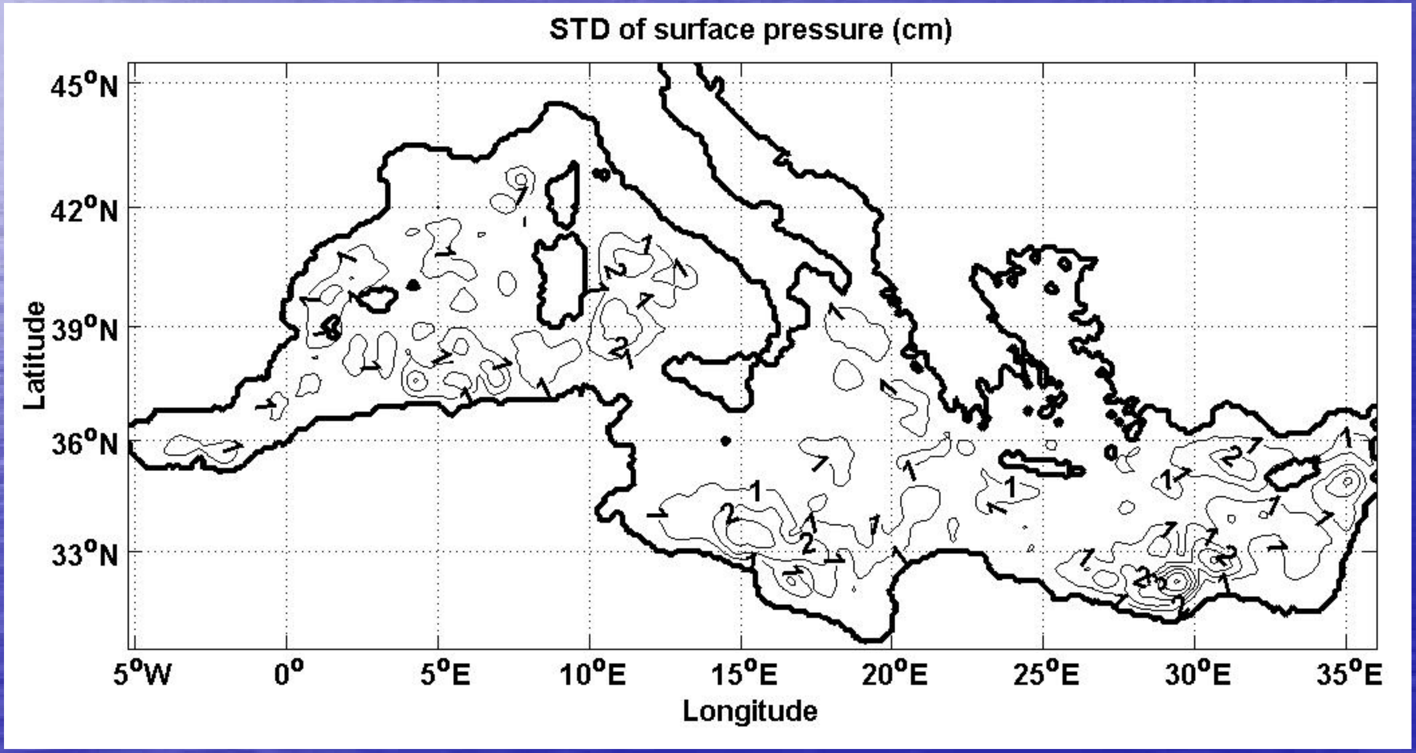
The model results present numerous small scale features distributed all over the basin. This is shown in the rms variability of the sea surface pressure.



rms variability larger than 4 cm is some places

INTERANNUAL VARIABILITY

- Altough the actual model configuration does not support directly forced inter-annual variability, the horizontal distribution of sea surface pressure differs from year to year.



CONCLUSIONS

- We have reproduced the general circulation of the Mediterranean Sea as well as the observed seasonal cycle of major currents.

- We have found a **signal of interannual variability** in some subbasins (e.g. the Balearic Sea), using DieCAST ocean model **forced with a repeating annual cycle of wind, heat flux and freshwater flux.**

Towards Operational Oceanography at IMEDEA

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Eastern Alborán Sea dynamics and basin scale interactions

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 100, NO. C5, PAGES 8571–8586, MAY 15, 1995

Time and space variability in the eastern Alboran Sea from March to May 1990

Álvaro Viúdez[1] and Joaquín Tintoré

Departament de Física, Universitat de les Illes Balears, Palma de Mallorca, Spain

Abstract. An intensive field experiment was carried out from March 6 to April 30, 1990, in the eastern Alboran Sea to understand the relationship between the large-scale circulation and the location of the transition zone between new and longer-resident Modified Atlantic Water (MAW). The detection of a strong jet (80 cm s^{-1}) of new MAW with anticyclonic curvature near the Morocco coast suggests that the Eastern Alboran Gyre (EAG) was not fully developed. A new state of the circulation in the eastern Alboran basin, intermediate between the EAG (Viúdez et al., 1995) and the Lanoix (1974) state, is presented. Also important is that the Almería-Oran Front was not present in the upper layer, that small-scale instabilities were detected in the northern region, and that significant nongeostrophic flows were observed. All these features are clearly indicative of the high spatial and temporal variability of a region where complex adjustments among density, velocity, and topography occur.

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Eastern Alborán Sea dynamics and basin scale interactions

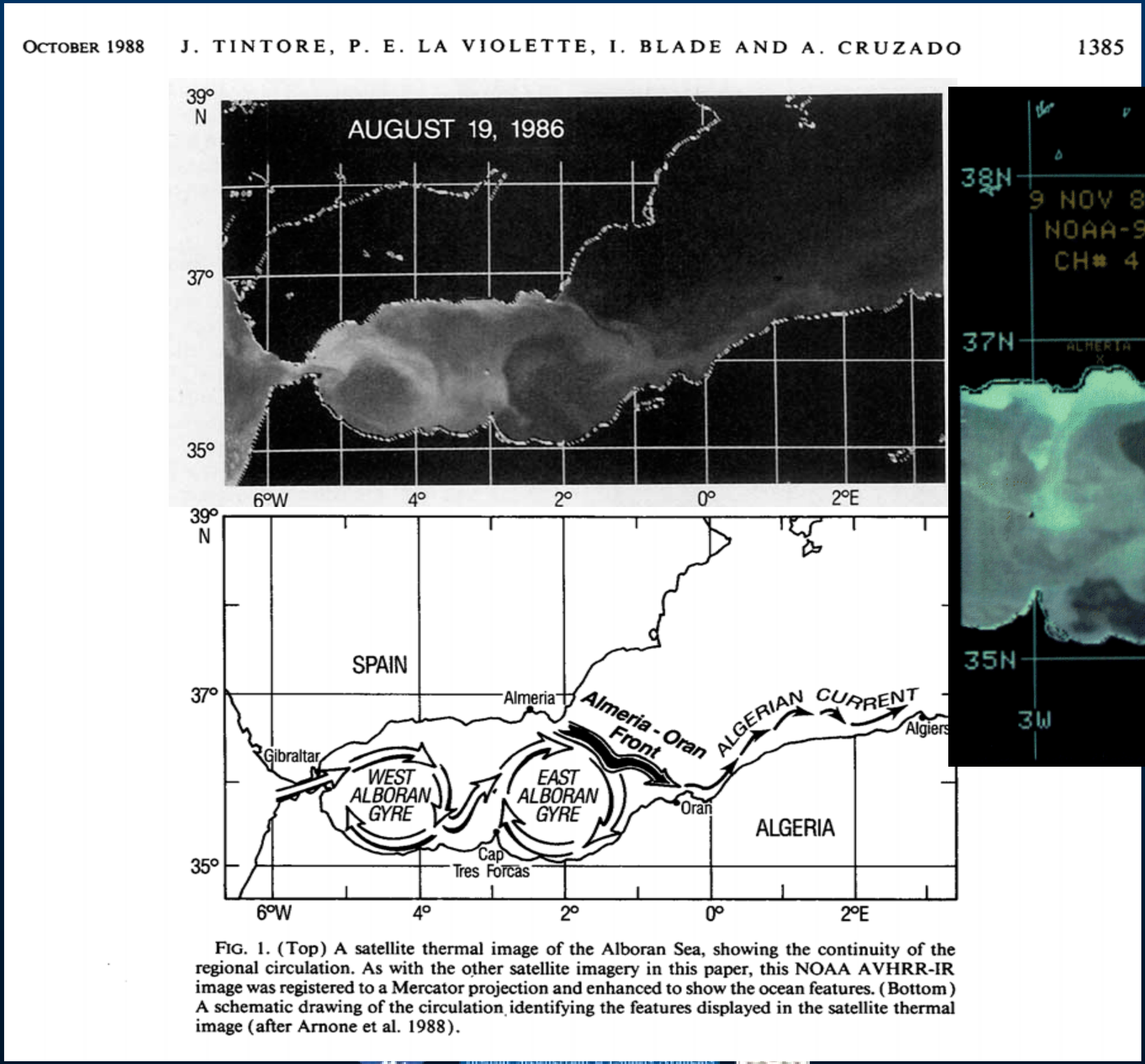
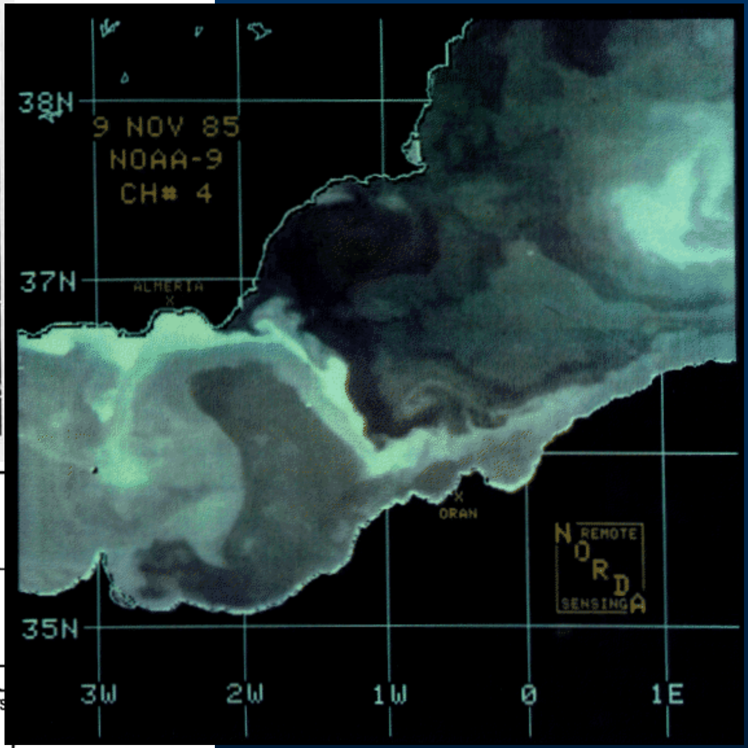


FIG. 1. (Top) A satellite thermal image of the Alboran Sea, showing the continuity of the regional circulation. As with the other satellite imagery in this paper, this NOAA AVHRR-IR image was registered to a Mercator projection and enhanced to show the ocean features. (Bottom) A schematic drawing of the circulation identifying the features displayed in the satellite thermal image (after Arnone et al. 1988).



Eastern Alborán Sea dynamics and basin scale interactions

VIUDEZ AND TINTORE: TIME AND SPACE VARIABILITY IN EASTERN ALBORAN SEA

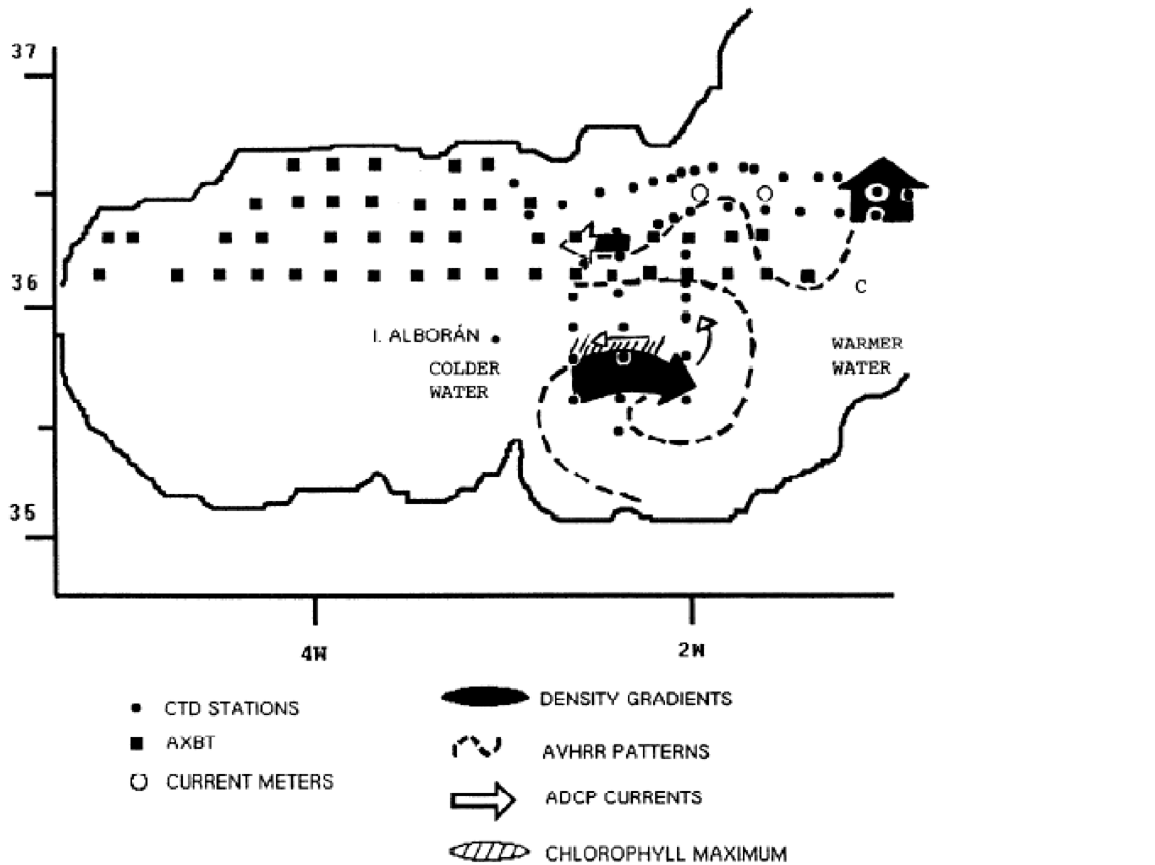


Figure 11. Upper layer circulation pattern.

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Vertical motions and size structure of phytoplankton – changes in populations ?

floras, angiosperms typically constitute only a very small percentage of the total diversity[15,17,29]—perhaps reflecting low pollen production and poor dispersal abilities associated with insect pollination. Similarly, with one strongly disputed exception angiosperm wood has not been recorded from Aptian or older rocks, and angiosperm leaves in Aptian or earlier floras are also extremely rare. However, exceptionally preserved whole plants reported from the Lower Cretaceous Crato Formation, Brazil, document that diverse herbaceous water plants were present by the Aptian–Albian and were a prominent part of the angiosperm assemblage of this flora[21]. These observations suggest that the apparent discrepancy between the diversity of angiosperm reproductive structures and the diversity of leaves and wood during the earliest phases of angiosperm diversification may in part be explained by the low potential of leaves and stems of herbaceous plants, including water lilies and monocots, to be preserved.

Received 20 October; accepted 15 December 2000.

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Acknowledgements

We thank P. K. Endress and J. Schönenberger for valuable comments and help; and P. von Knorring for preparing the reconstruction of the fossil flower. The work was supported by grants from the Swedish Natural Science Foundation (to E.M.F.), the Carlsberg Foundation (to K.R.P. and E.M.F.), the Danish Natural Science Research Council (to K.R.P.) and the US National Science Foundation (to P.R.C.).

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Mesoscale vertical motion and the size structure of phytoplankton in the ocean

Jaime Rodríguez*, Joaquín Tintoré†, John T. Allen‡, José Mª Blanco*, Damià Gomis†, Andreas Reul*, Javier Ruiz§, Valeriano Rodríguez*, Fidel Echevarría§ & Francisco Jiménez-Gómez*‖

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† *Institut Mediterrani d'Estudis Avançats (CSIC-UIB), 07071 Palma de Mallorca, Spain*
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Phytoplankton size structure is acknowledged as a fundamental property determining energy flow through 'microbial' or 'herbivore' pathways[1]. The balance between these two pathways determines the ability of the ecosystem to recycle carbon within the upper layer or to export it to the ocean interior[1]. Small cells are usually characteristic of oligotrophic, stratified ocean waters, in which regenerated ammonium is the only available form of inorganic nitrogen and recycling dominates. Large cells seem to characterize phytoplankton in which inputs of nitrate enter the euphotic layer and exported production is higher[2–4]. But the size structure of phytoplankton may depend more directly on hydrodynamical forces than on the source of available nitrogen[5–7]. Here we present an empirical model that relates the magnitude of mesoscale vertical motion to the slope of the size–abundance spectrum[8–10] of phytoplankton in a frontal ecosystem. Our model indicates that the relative proportion of large cells increases with the magnitude of the upward velocity. This suggests that mesoscale vertical motion—a ubiquitous feature of eddies and unstable fronts—controls directly the size structure of phytoplankton in the ocean.

The oceanic mesoscale, 10–100 km, is the equivalent of the atmospheric storm scale. It is generally considered to be the most energetic scale, and it is where fronts between water masses become unstable and strong three-dimensional circulations are set up. Fronts are places of enhanced biological activity and, from the biological point of view, vertical circulation is of great significance to primary productivity as it may explain the patchiness of primary productivity in the surface layers of the ocean and the patchiness of nutrient distributions[11]. During the OMEGA (Observations and

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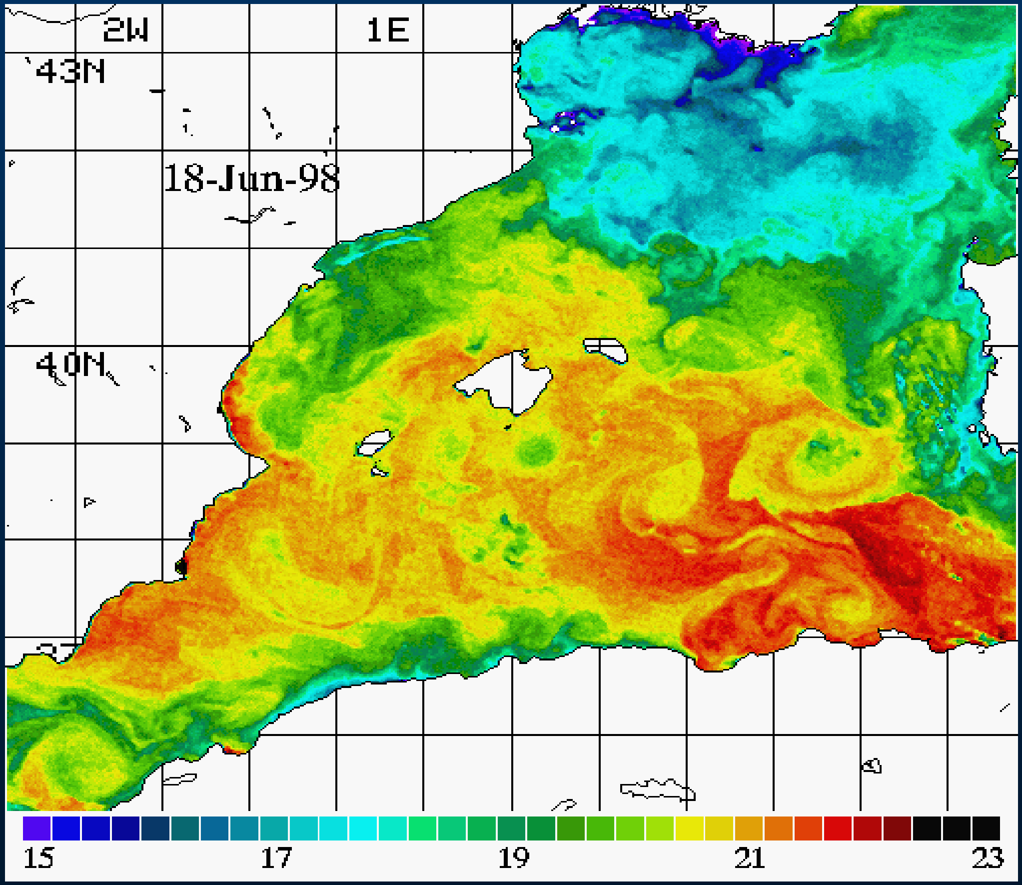
IMEDEA recent examples of Mediterranean variability at sub-basin scale (1)

Mesoscale variability



- Evidences of variability at different scales, Ri: 12 km
- Coupling between sub-basin and basin scale circulation through mesoscale interactions.
- Coupling between mesoscale, sub-basin and basin scale circulation. Nonlinear effects and inter annual variability.
- Specific result: Ibiza Channel fluxes variability generated by internal variability, blocking effects.

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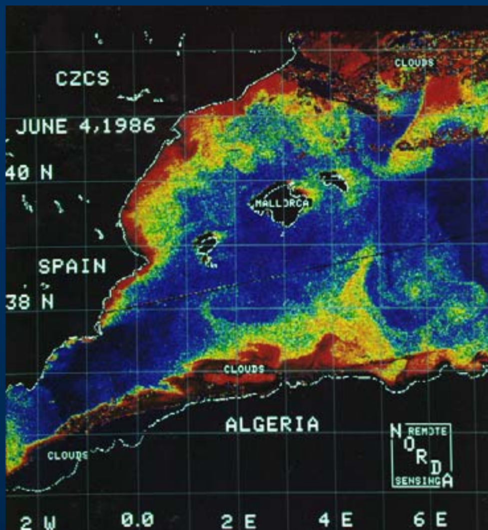
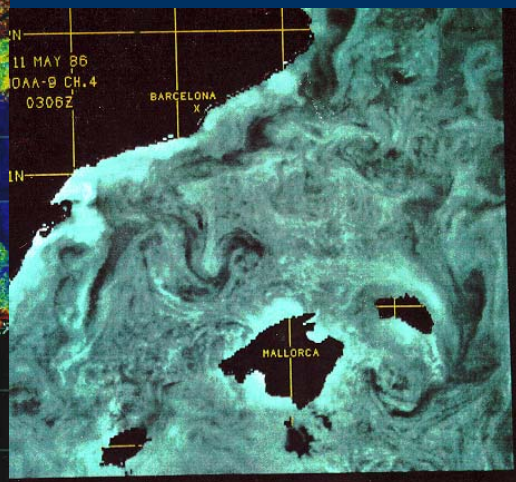
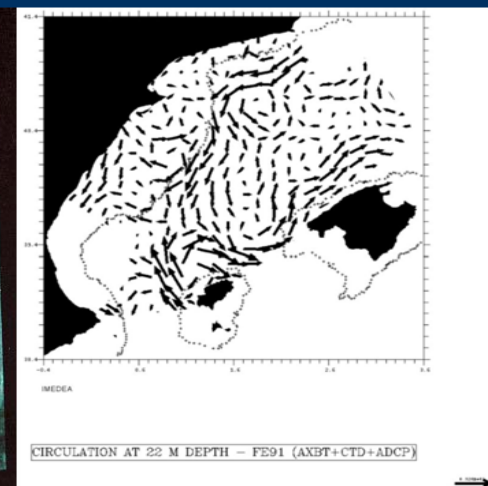
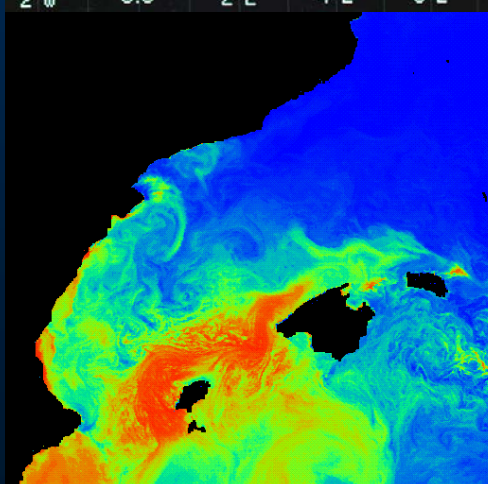
IMEDEA recent examples of Mediterranean variability at sub-basin scale (1)

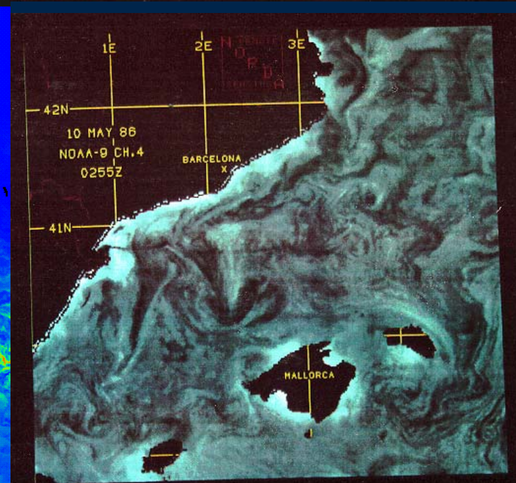
Mesoscale variability

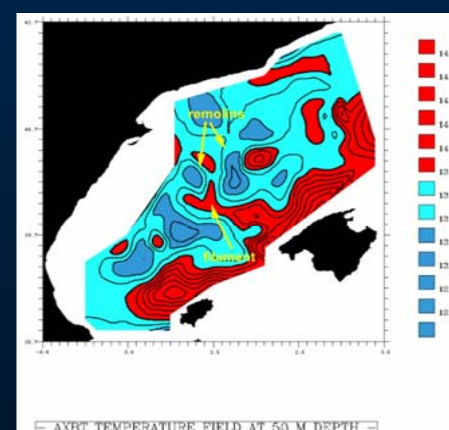












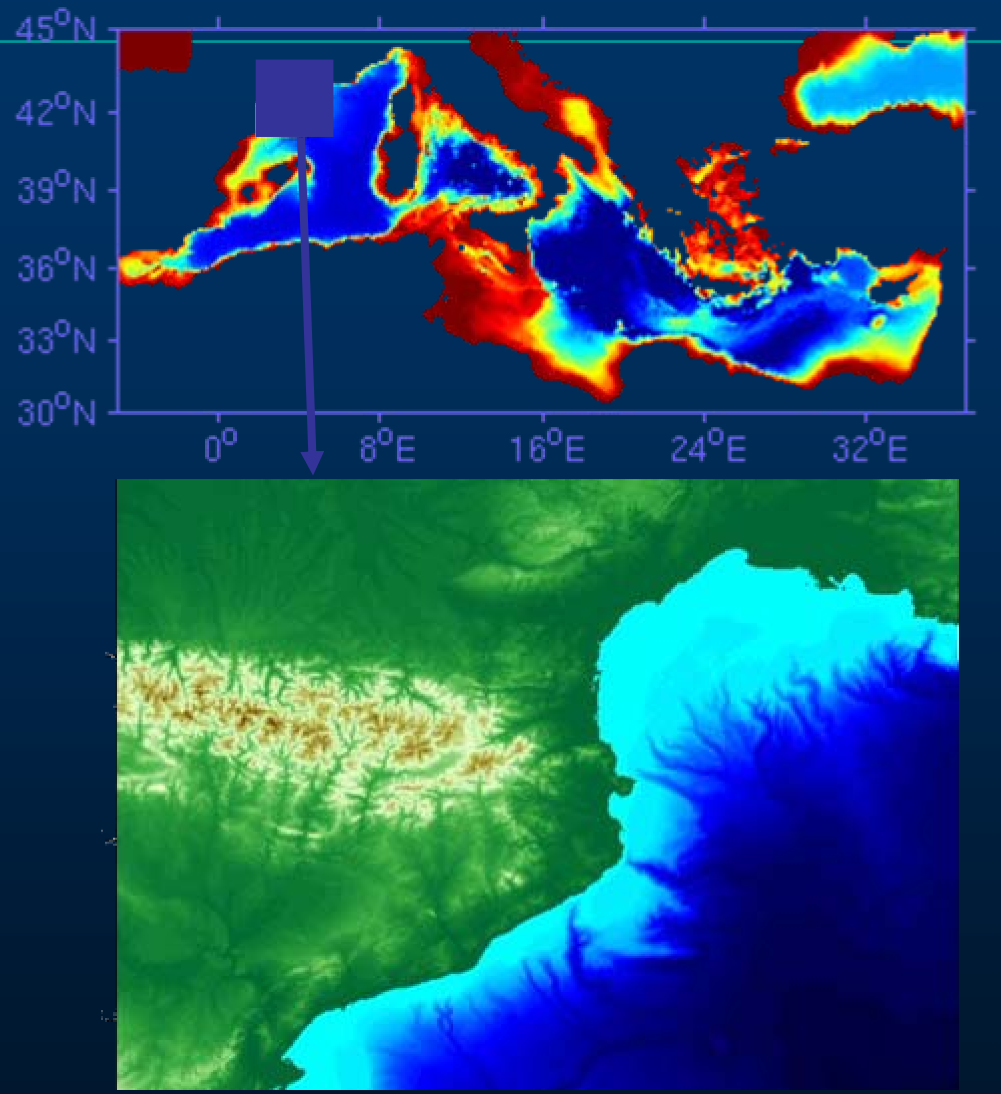
More than 20 papers in peer reviewd journal since 1988, mostly in Balearic and Alboran sub-basins

Introduction: Geographical area

Model domain includes shelf of northeastern edge of the NW Mediterranean.

Bottom topography is complex, the slope is indented by a series of submarine canyons.

Regional oceanography is dominated by a shelf-slope density front.



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Shelf / slope exchanges – canyons interactions – mean flow / frontal instabilities

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Shelf-slope exchanges by frontal variability in a steep submarine canyon

A. Jordi *, A. Orfila, G. Basterretxea, J. Tintoré

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Received 9 October 2002; received in revised form 25 March 2003; accepted 29 July 2004
Available online 13 May 2005

Abstract

We study the dynamics of a frontal jet and its short-timescale variability generated by the interaction with a submarine canyon using a limited-area fine-resolution three-dimensional coastal ocean model. The focus is on the steep and narrow Palamós Canyon located off the northeast Catalan coast (northwestern Mediterranean) that is characterized by the presence of a permanent along-slope density-driven current. First, we analyse the stationary circulation induced with different jet locations and show a deflection of the flow in the vicinity of the canyon. Significant vertical motions develop as a result of these current adjustments; the general pattern such as downwelling upstream of the canyon and upwelling downstream are always observed. Second, we analyse the circulation and exchanges associated with an onshore displacement of the jet; thus produces a meander propagating with the flow that interacts with the canyon. We find that the resulting three-dimensional patterns present an oscillation characterized by an intense downwelling followed by upwelling. As a result of this interaction, shelf-slope exchanges and vertical motions are enhanced in the area compared with the passing of a meander above a shelf that is not indented by a submarine canyon. The resulting horizontal transports through the Palamós canyon represent up to 10% of the along-shore fluxes on the shelf and appear to be sufficient to exchange the shelf water of the Gulf of Lions and Catalan sea in 2.5 years. Considering the number of canyons existing in the area, we can estimate an exchange of all the shelf waters in less than 3 months.

Keywords: Submarine canyon; Shelf-slope exchange; Numerical coastal ocean model; Frontal variability; Northwestern Mediterranean

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Introduction: Motivation

The complex topography and the strong dynamical processes that characterize the NW Mediterranean provide a good opportunity to analyze the effect of physical transport processes on the shelf-slope exchanges.

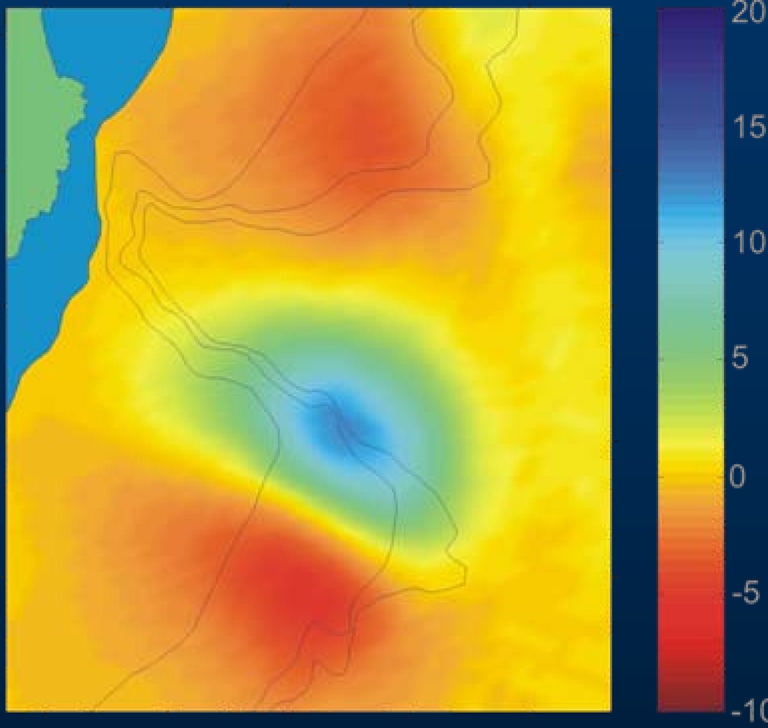

Figure: Vertical velocities (m/day) induced by the interaction of the Northern Current and the Palamós Canyon.

Previous observational and numerical studies at IMEDEA in the area:

Alvarez, A., Tintoré, J. & Sabatés A. (1996). Flow modification of shelf-slope exchange induced by a submarine canyon off the northeast Spanish coast. J. Geophys. Res., 101, 12043-12055.

Ardhuin, F., Pinot, J. M. & Tintoré, J. (1999). Numerical study of the circulation in a steep canyon off the Catalan coast. J. Geophys. Res., 104, 11115-11135.

Jordi, A., Basterretxea, G., Orfila, A. & Tintoré, J. (2005). Shelf-slope exchanges by frontal variability in a steep submarine canyon. Prog. In Oceanogr., 66, 120-141.

Jordi, A., et al. (2006). Scientific management of Mediterranean coastal zone: A hybrid ocean forecasting system for oil spill and search and rescue operations. Marine Pollution Bulletin

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Numerical model: Setup

▪ Numerical domain:	NW Mediterranean
▪ Horizontal resolution:	1/80º (~ 1.2 km) 332 x 262 grid points
▪ Vertical resolution:	Variable (Z-coordinate) 30 layers
▪ Topography:	Derived from the bathymetric chart of the NW Mediterranean (www.icm.csic.es/geo/gma/MCB). Without filtering or smoothing.
▪ Integration time:	30 days 1st – 31th December 2005
▪ Time step:	30 seconds 2880 time steps per day
▪ Atmospheric forcing	HIRLAM (0.16º) from INM updated at 3 hours intervals

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Numerical model: Initialization and boundaries

- Initialization: interpolated fields (u, v, T and S) using optimum interpolation from the global Mediterranean Sea model (MFS, INGV).

- Boundary conditions: one way nesting from the global Mediterranean Sea model (MFS, INGV). T, S, u and v are interpolated from daily MFS outputs and are used to force the two lateral open boundaries (south and east).

- The open boundaries allow perturbations generated inside the computational domain to leave it without deterioration of the inner model solution and allows physically important external information to advect inward using a pure upwind advective scheme.

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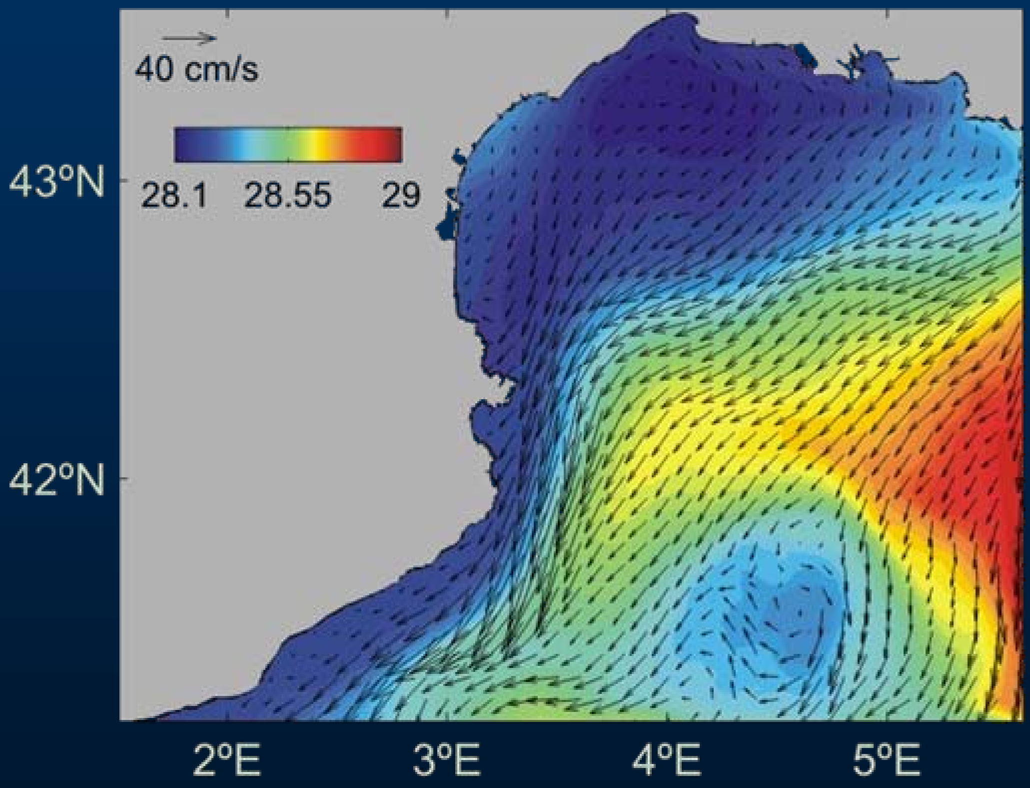
Results: General circulation

The temporal average of surface circulation during December 2005 reproduces the characteristic features of the circulation in NW Med.

Presence of the Northern Current signature following the topography.

Presence of an eddy to the south of the model domain. Similar structures described by Pascual et al. (2002) and Onken et al. (2005).

Strong NE winds blow during a significant part of December 2005



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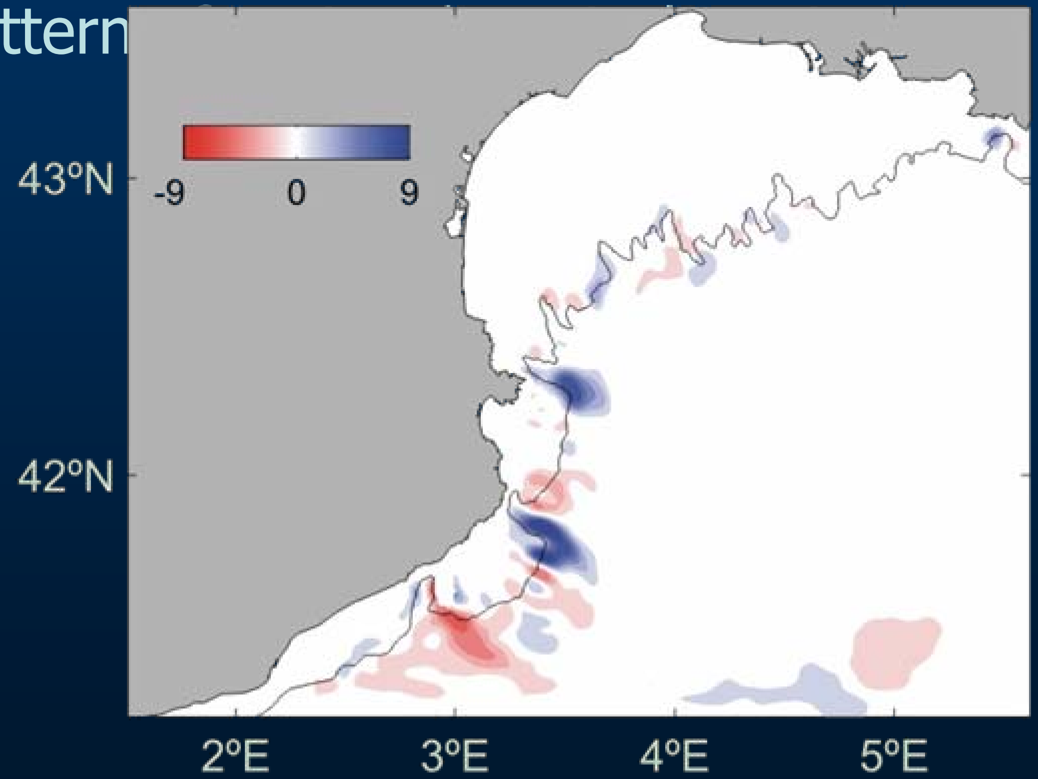
Results: Impact of canyons

The temporal average of vertical velocity at 95 m depth during December 2005 reveals the role of canyons modifying the spatial pattern

Antisymmetrical structure of vertical motions with downwelling on the upstream walls of the canyons and upward motions on the downstream edges.



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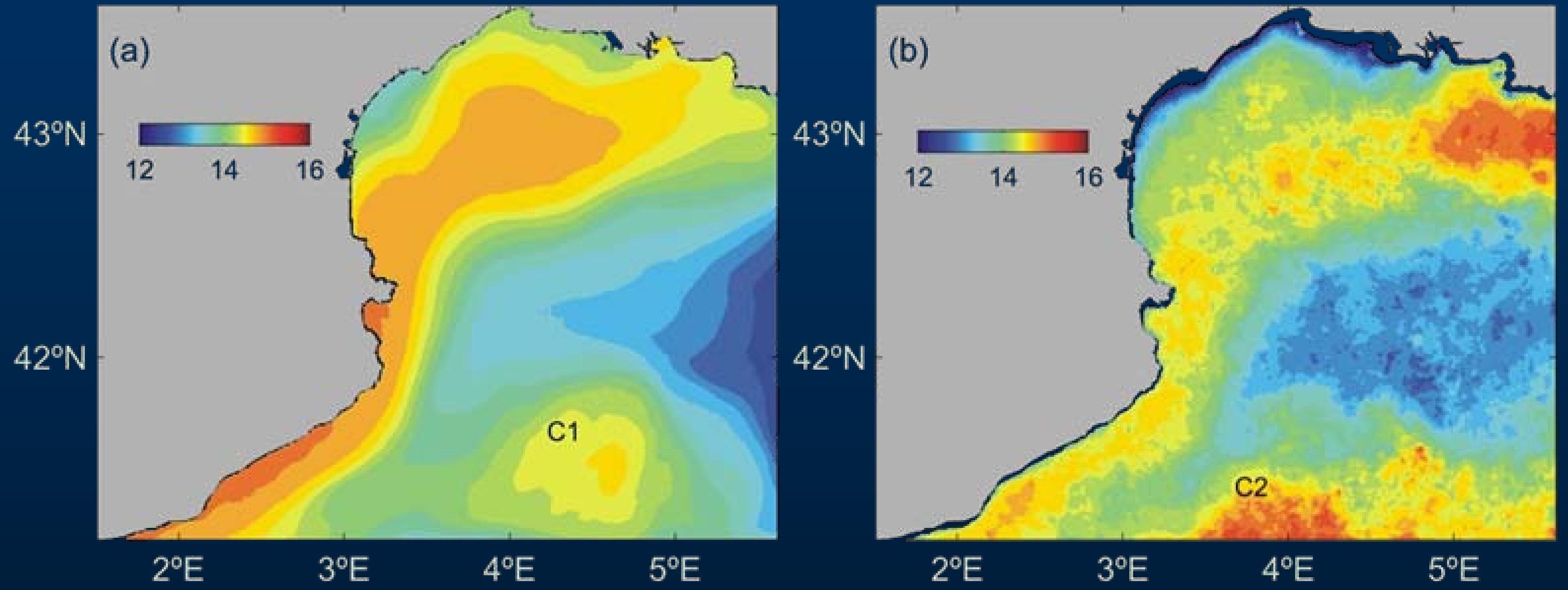
Results: Comparison with satellite data

Comparison between monthly averaged SST for December predicted by the model (a) and observed by satellite (b).



With some exceptions the large-scale pattern matches well with observations. Satellite temperature displays small-scale variability. The location of the anticyclonic eddy in the model (C1) is displaced to the northeast and presents a slightly colder core than satellite values (C2).

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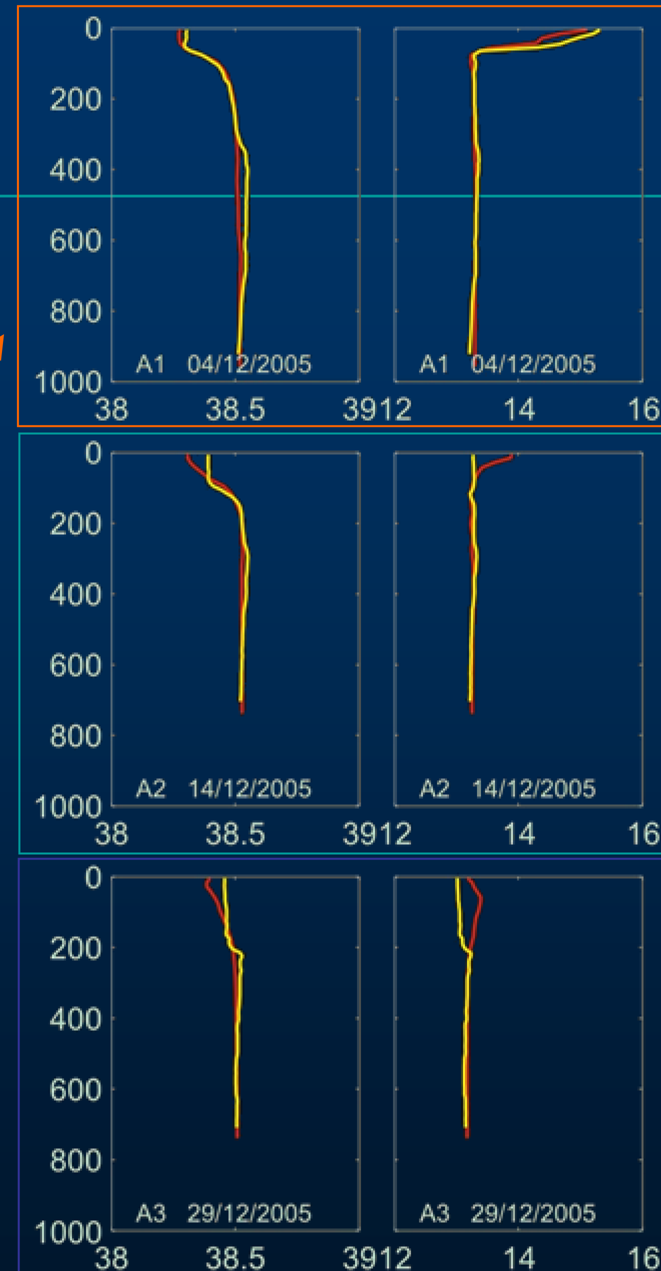
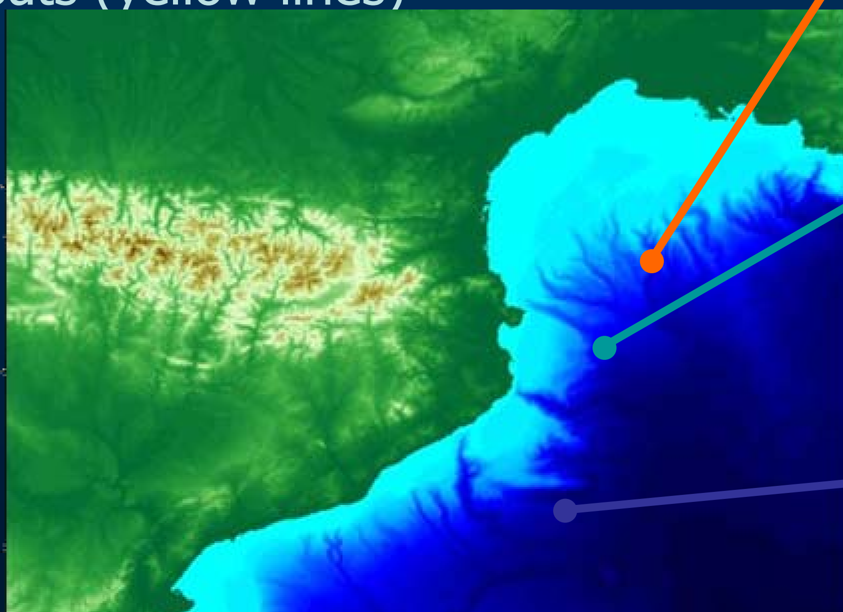
Results: Comparison with Argo floats



Comparison between predicted temperature and salinity profiles (red lines) with those measured by Argo floats (yellow lines)



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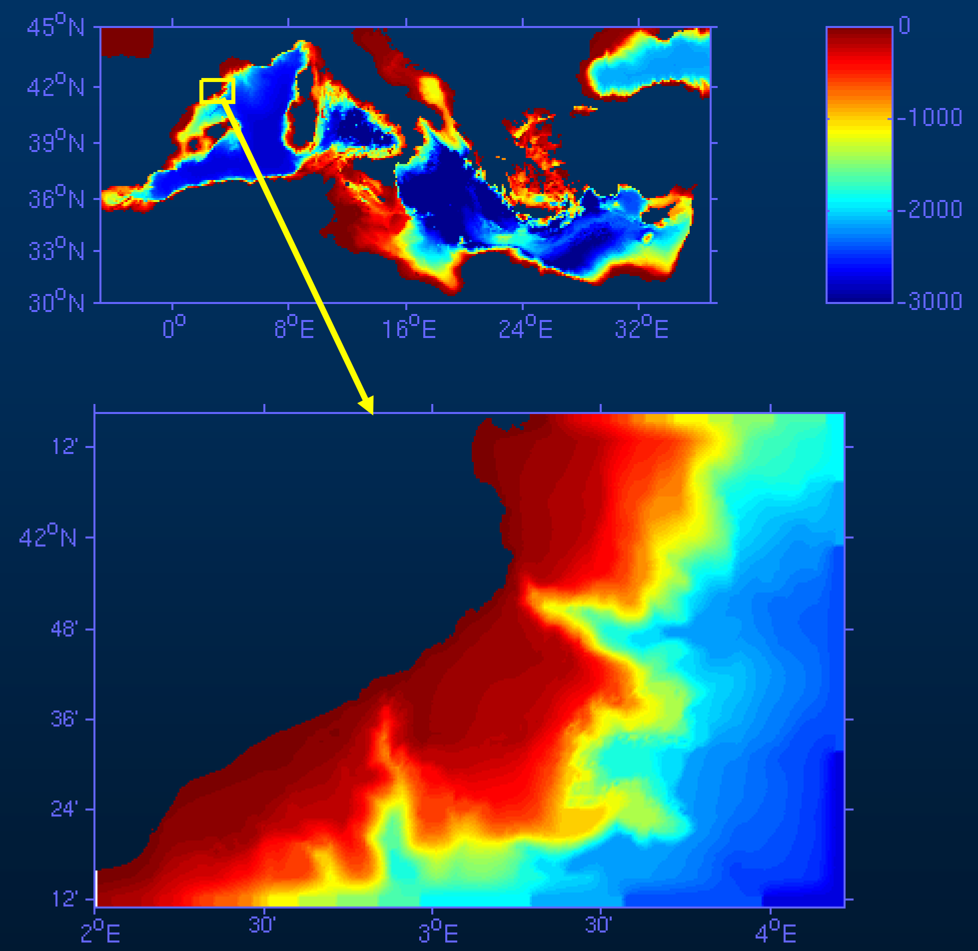
Models comparison: DieCAST & HOPS

HOPS was also implemented in the Catalan Shelf sea.



- Integration time: from 2^{nd} to 30^{th} January 2003.

- Initialization and boundaries: interpolated fields from the NW Mediterranean regional model (CNRS-POCT).

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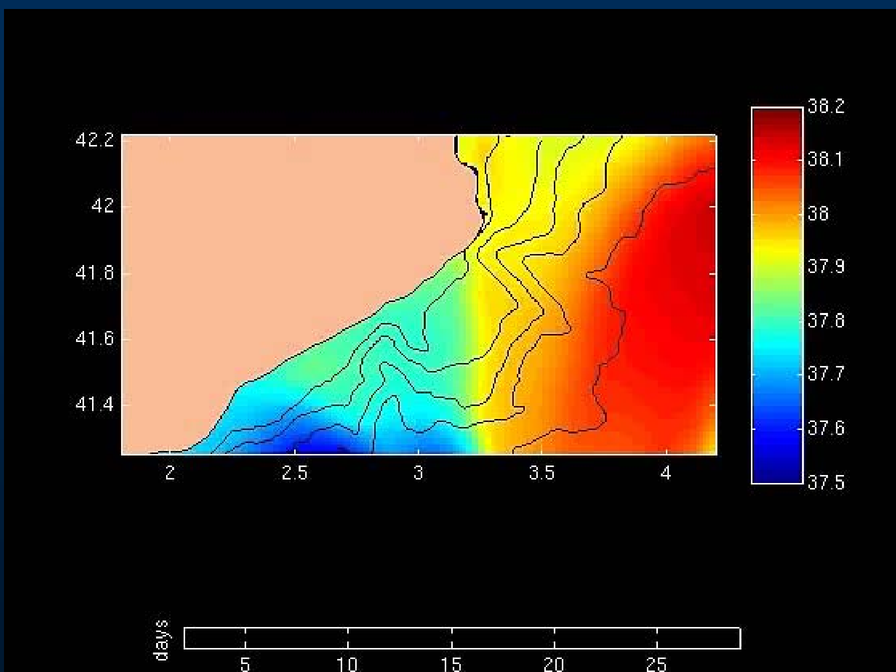
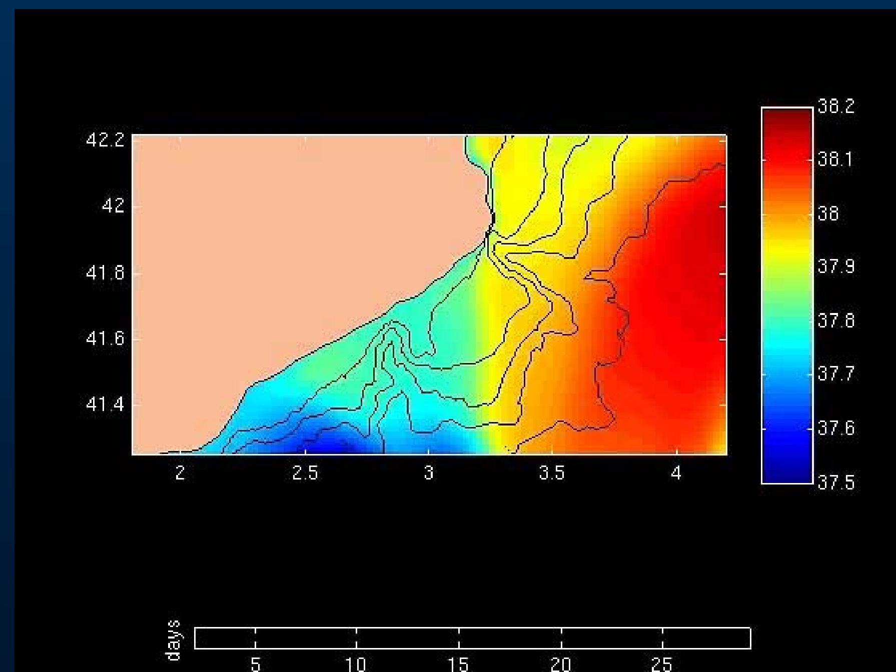
Models comparison: DieCAST & HOPS

Surface salinity during SVP (January 2003) for both models in the Catalan Sea shelf.

DieCAST



HOPS



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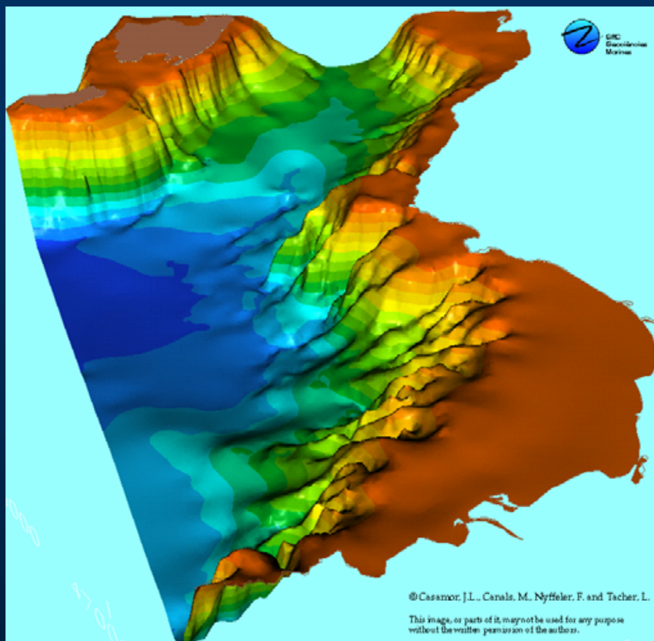
IMEDEA recent example of Mediterranean variability at local scale (2)

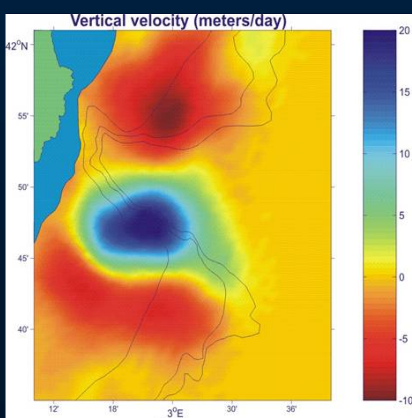
Main result: characteristic time scale for shelf-slope exchange 2 months



- Interaction of front meanders with Palamos canyon produce a transport of sufficient volume to exchange waters of the shelf of the Gulf of Lions and Catalan Sea in 2.5 years.

- Considering the whole global area (15 canyons), the replacement of shelf waters takes place in a few months (2-3).

(Jordi et al, Prog. In Oceanog., 2005)



Eddies are formed in the canyon area as a result of topographic adjustment.

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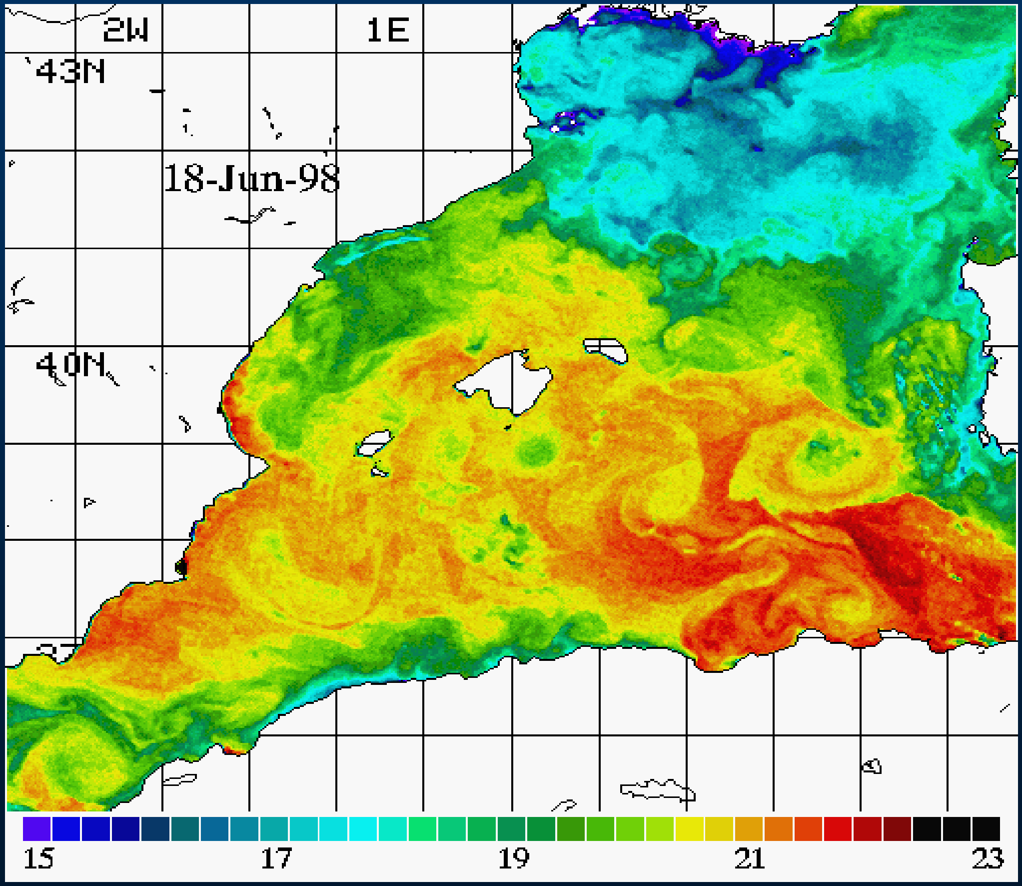
IMEDEA recent examples of Mediterranean variability at sub-basin scale (1)

Mesoscale variability



- Evidences of variability at different scales, Ri: 12 km
- Coupling between sub-basin and basin scale circulation through mesoscale interactions.
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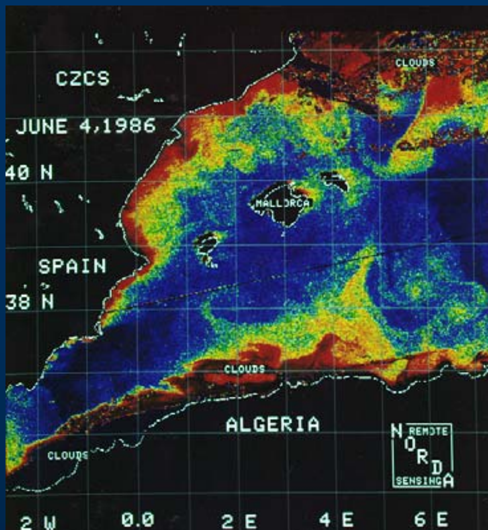
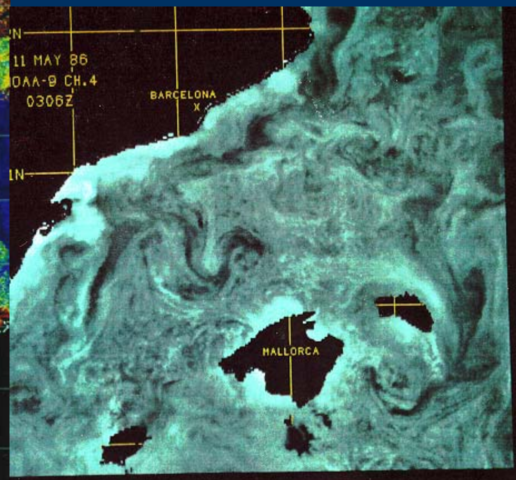
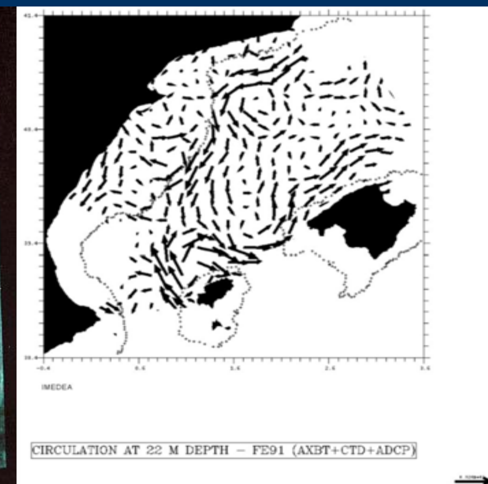
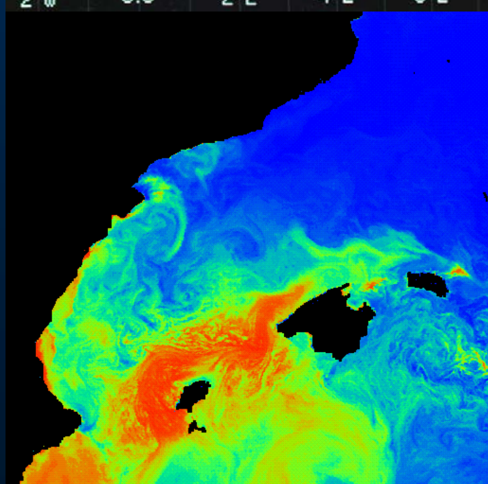
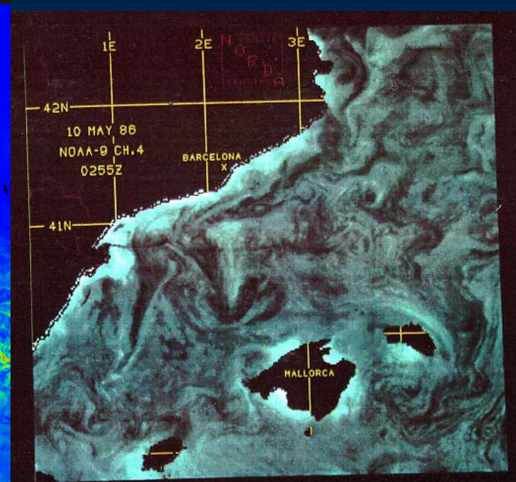
Mesoscale variability

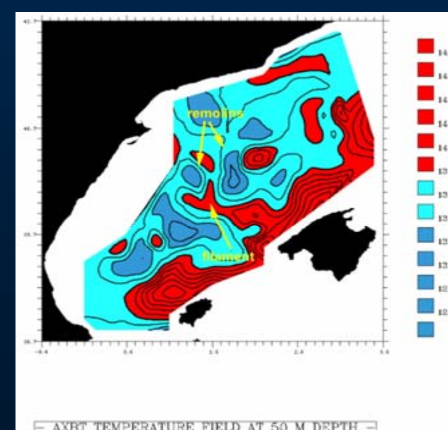










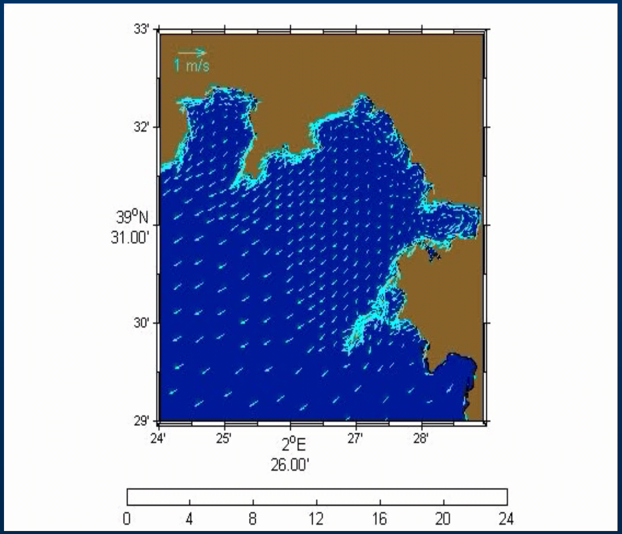


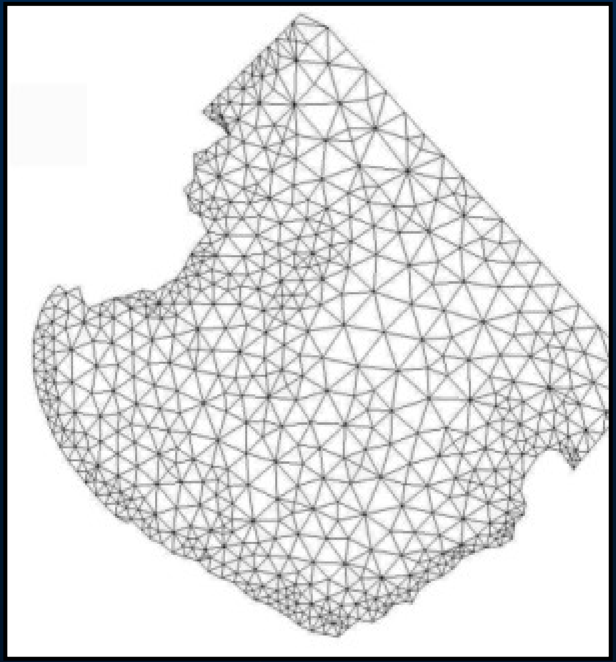
More than 20 papers in peer reviewd journal since 1988, mostly in Balearic and Alboran sub-basins

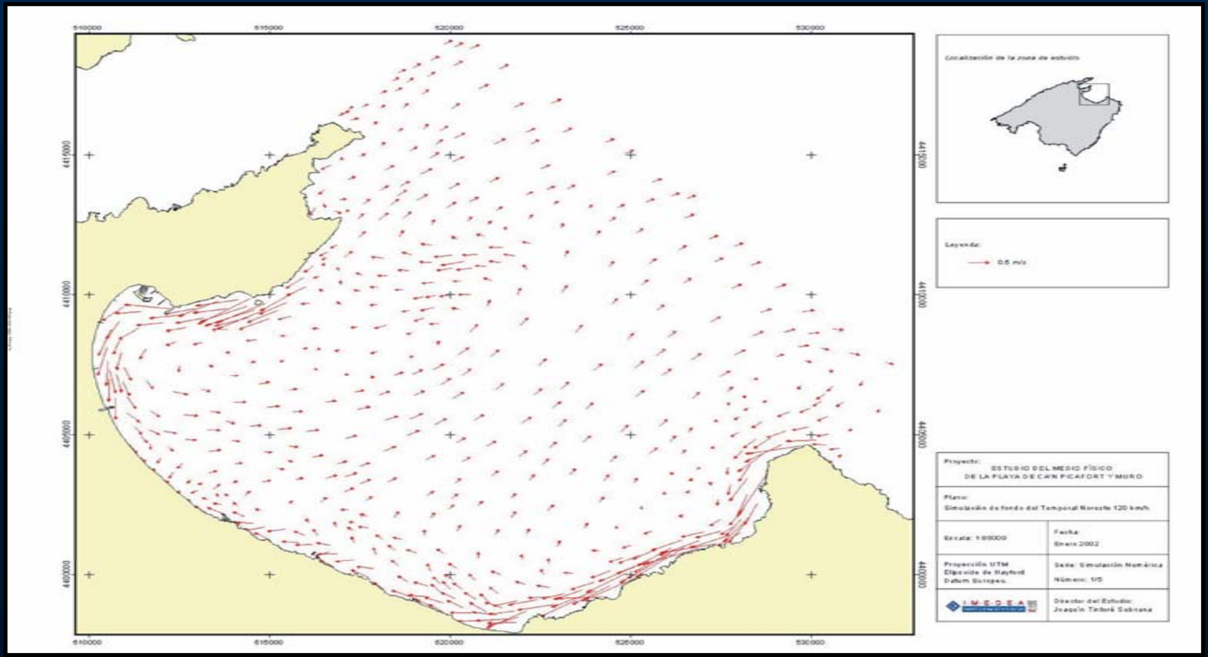
IMEDEA recent example of Mediterranean coastal variability

QUODDY (Lynch, Werner)
FE in the form of the wave eq. (Similar at Arakawa C)

Sigma coordinate in the vert,
FSBC->Tides, wind, fluxes at the surface
Mellor-Yamada 2.5



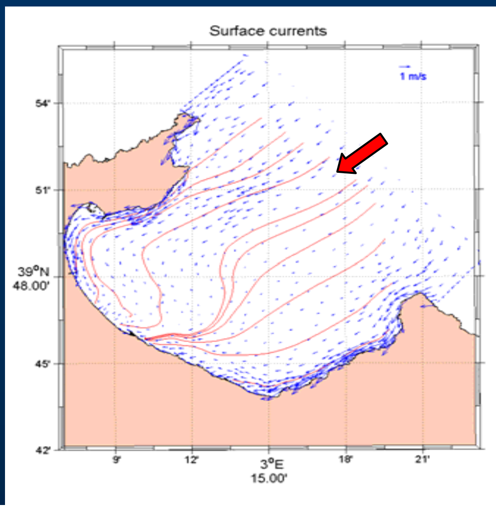


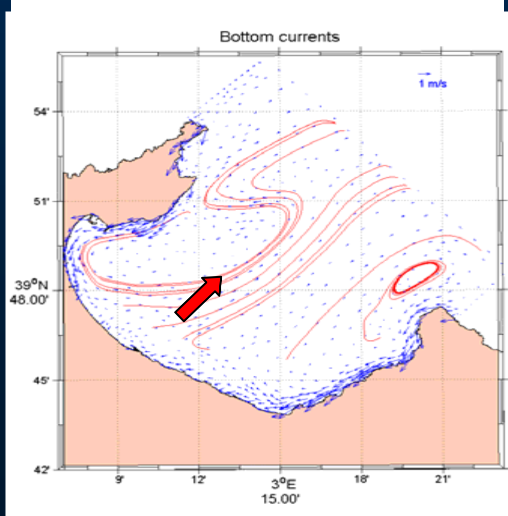


IMEDEA recent example of Mediterranean coastal variability

Alcudia Bay, Malllorca

Wind induced coastal currents and sediment resuspension





- Velocity fields for storm conditions indicate close-to-shore intensification of the flow both sides of the bay.

- In the middle of the bay, surface flow is shoreward with seaward bottom recirculation.

- The model emphasizes the importance of bottom recirculation in the suspended sediment transport.

Mediterranean variability at beach scale

Effects of severe weather over beaches

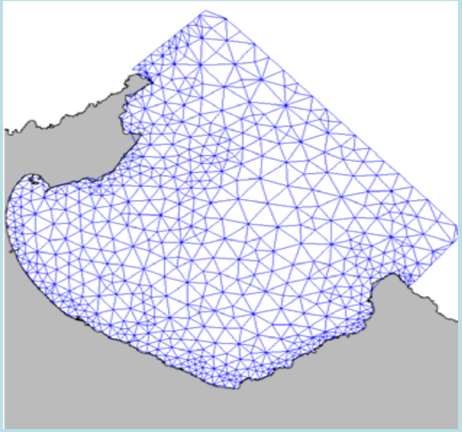
Wave modelling

Highly nonlinear and weakly dispersive equations are solved using a high-order Finite Difference squeme.

Alcudia Bay : mesh 900x612 grid points
Magalluf: mesh 630x590 grid points

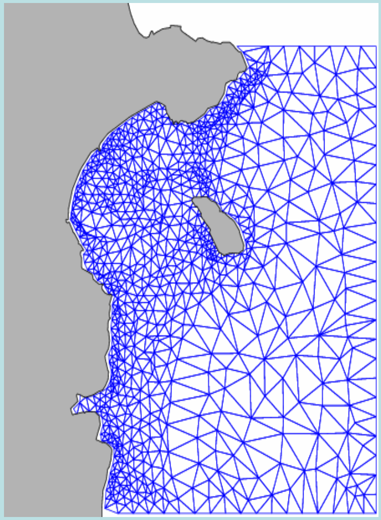
3-d Ocean Circulation

Linearized 3D shallow water equations with conventional hydrostatic and Boussinesq approximations and eddy vistosity closure in the vertical over a finite element mesh



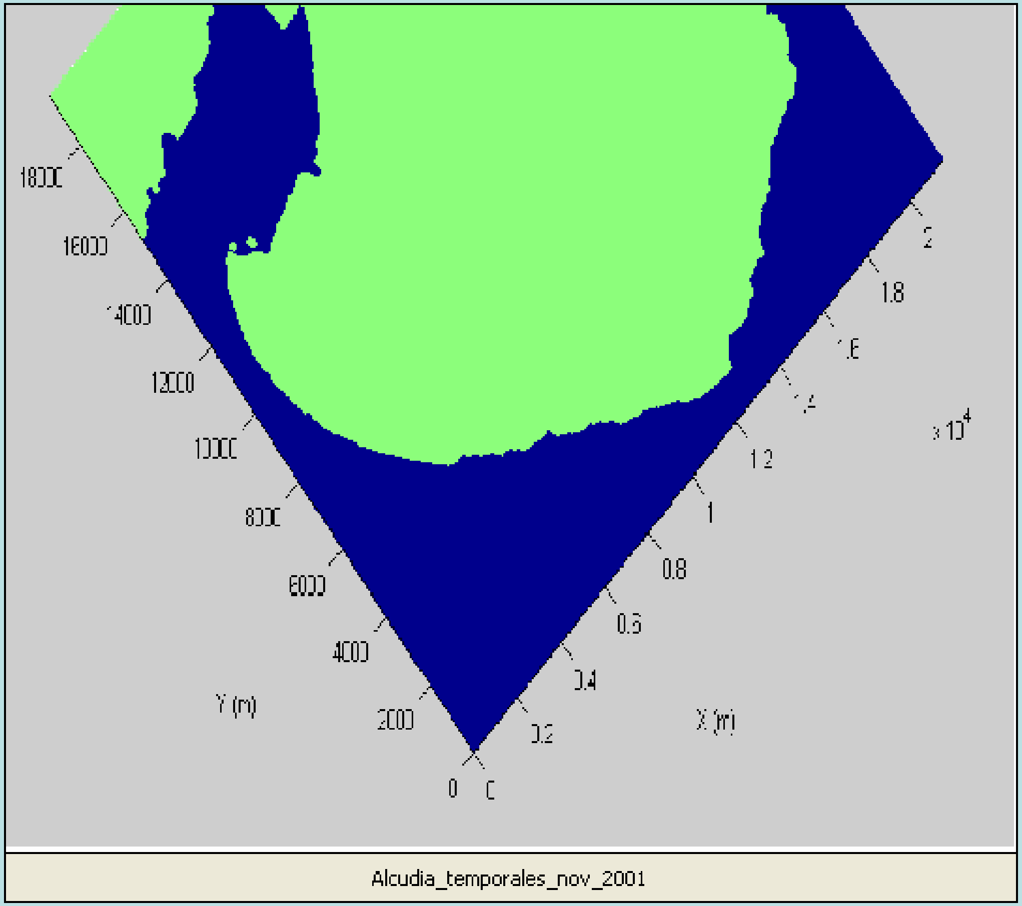
Ca'n Picafort-Muro:
675 nodes in x-y
and 1218 elements
11 vertical levels

Magalluf:
959 nodes in x-y
and 1756 elements
11 vertical levels



Mediterranean variability at beach scale

•Wave propagation in Alcudia Bay



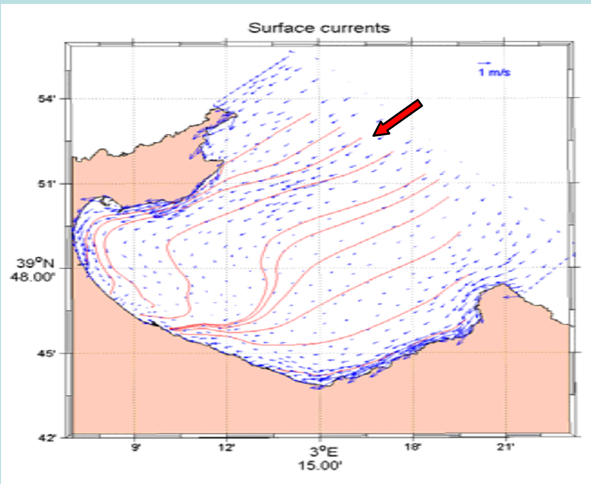
•Wave energy is dissipated across the bay inducing significant sediment resuspension.

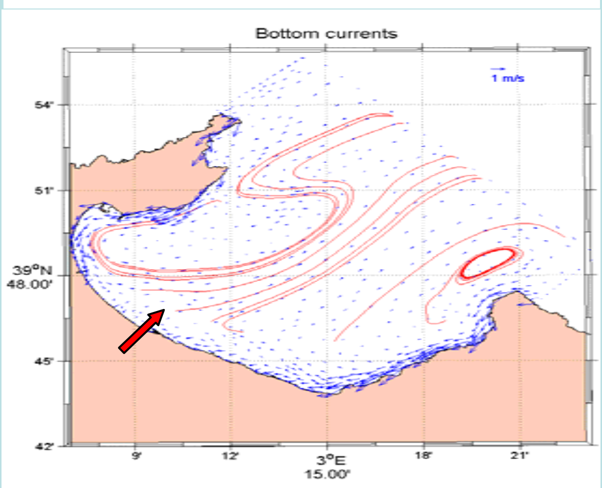
•Waves of Hs1.5 reach the beach

•Wave height intensification, caused by refractive processes, close to Can Picafort.

Mediterranean variability at beach scale

•*Wind currents in Alcudia Bay (NE)*





•Velocity fields for storm conditions indicate close-to-shore intensification of the flow both sides of the bay.

•In the middle of the bay, surface flow is shoreward with seaward bottom recirculation.

●The model emphasizes the importance of bottom recirculation in the suspended sediment transport.

Residence time – coastal – open ocean exchanges

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Continental Shelf Research 25 (2005) 1339–1352

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CONTINENTAL SHELF RESEARCH

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Residence time and *Posidonia oceanica* in Cabrera Archipelago National Park, Spain

A. Orfila[a,*], A. Jordi[b], G. Basterretxea[b], G. Vizoso[b], N. Marbà[b], C.M. Duarte[b], F.E. Werner[c], J. Tintoré[b]

[a] *School of Civil and Environmental Engineering, Hollister Hall, Cornell University, 14853 Ithaca, NY 14853, USA*
[b] *IMEDEA. Instituto Mediterráneo de Estudios Avanzados (CSIC-UIB), Miquel Marqués, 21, 07190 Esporles, Spain*
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Received 20 April 2004; received in revised form 22 January 2005; accepted 25 January 2005
Available online 19 March 2005

Abstract

Flushing time and residence time are studied in a small inlet in Cabrera National Park, Western Mediterranean Sea. Flushing time is studied using ADCP in situ data. Observed flushing time data are compared with the simulations from a three-dimensional coastal ocean numerical model. Residence time is assessed using virtual lagrangian particles and studying the number remaining within the analyzed domain. Results show a good agreement between observations and modeling estimations of the flushing time (i.e. 6 days from the ADCP data and 5.6 days from the numerical model). Residence time estimations yield a broad range of values, from 1 h in the Bay to over 30 days depending also on the horizontal and vertical position where particles were released. A continuous stirred tank reactor (CSTR) model for the Port yields a value of 8.7 days. Results obtained for the residence time appear to have a determinant impact over the meadows of the seagrass *Posidonia oceanica*, present inside the Port. Recirculation patterns and complex flows in coastal environments create a non-uniform distribution of the areas of accumulation of non-conservative properties that indicate that residence time concept is the correct approach when studying the impact of water transport over biological communities.

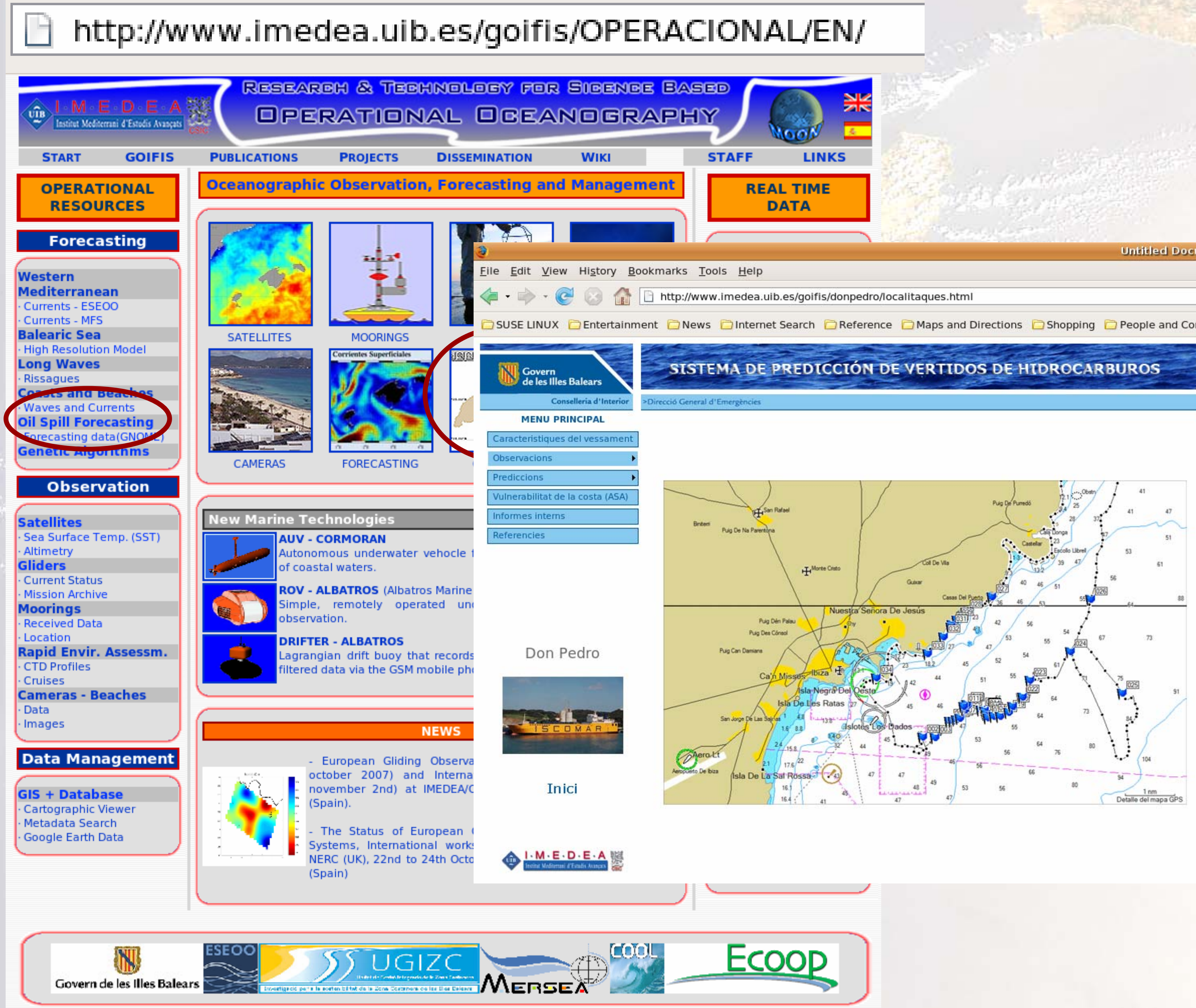
Keywords: Residence time; Flushing time; *Posidonia oceanica*

OUTLINE

1. IMEDEA (CSIC-UIB)
2. Physical Oceanography and Coastal Dynamics
3. Some examples of contributions to process studies
4. Pilot Observing and Forecasting System - towards Science based Operational Oceanography
5. THE FUTURE:

Pilot Observing and Forecasting System - towards Science based Operational Oceanography

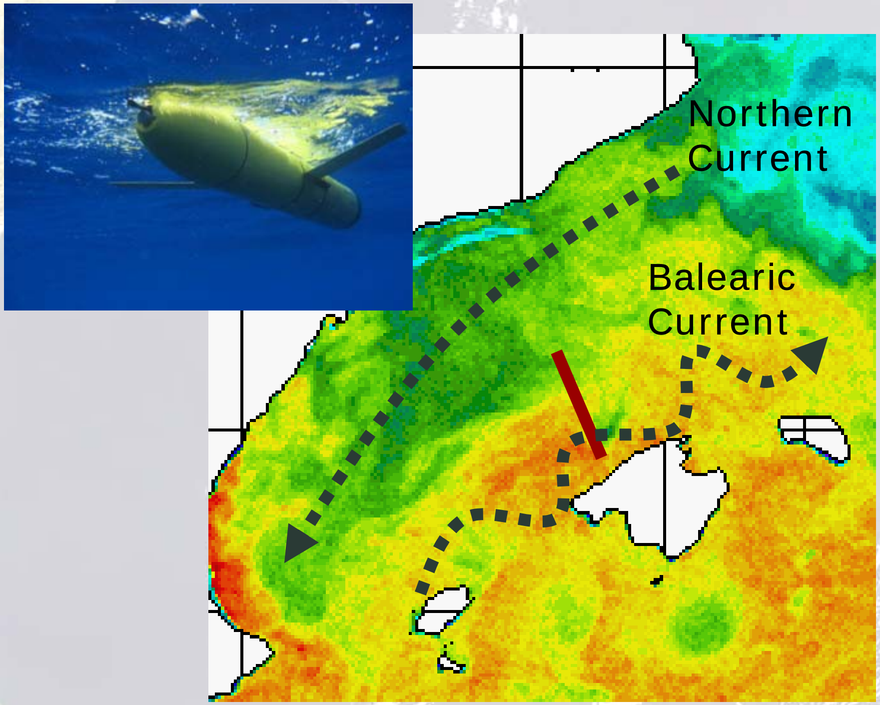
Pilot Observing and Forecasting System - towards Science based Operational Oceanography



Pilot Observing and Forecasting System - towards Science based Operational Oceanography

http://www.imedea.uib.es/goifis/OPERACIONAL/EN/

REA: ongoing observational experiment (Jul-Dec 07)



Glider mission along Envisat track 773 every 35 days

1st sampling: 6-13 July 2007

2nd sampling: 14-17 September 2007

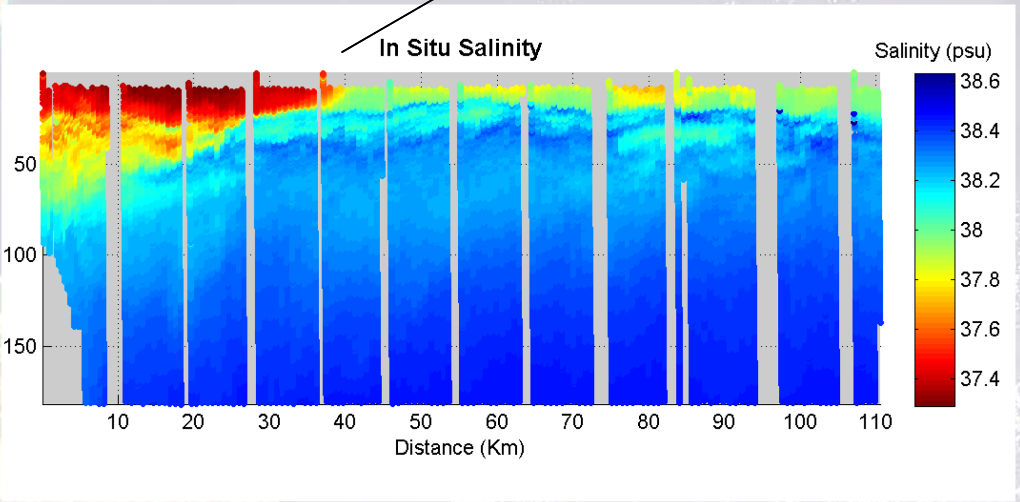
3rd sampling: 22-25 October 2007

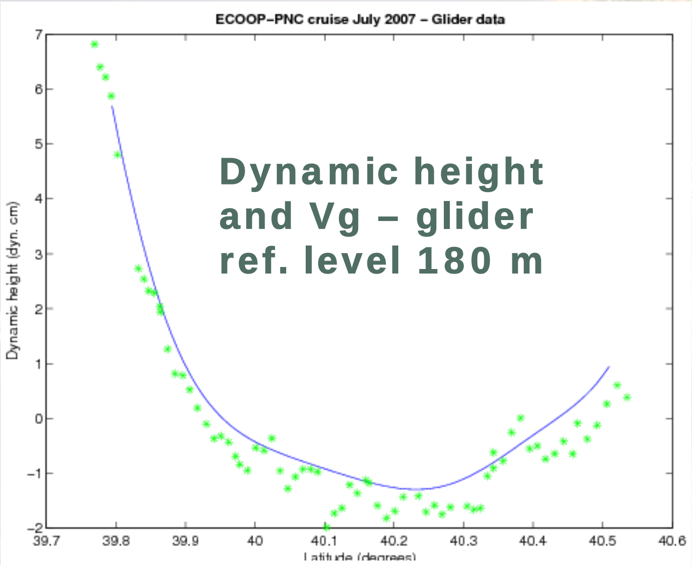
OBJECTIVES

- To characterize the Balearic front with new technologies
- To explore the use and limitations of altimetry data in the coastal area

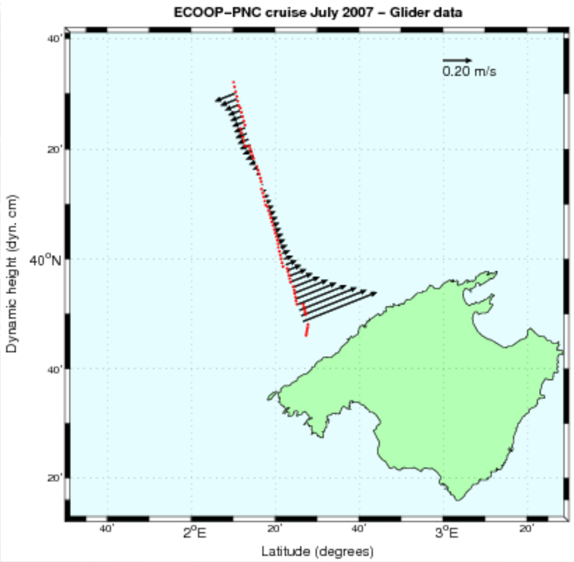
REA programme: glider data (1st sampling)

Balearic front





Dynamic height and Vg – glider ref. level 180 m

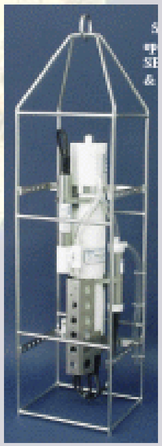


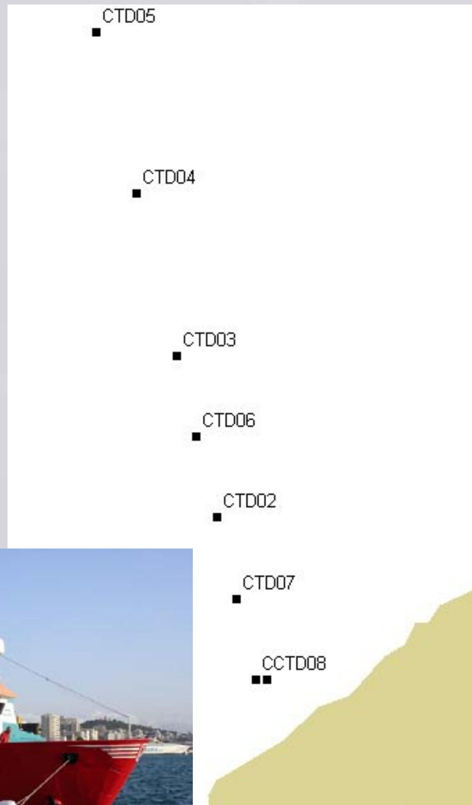
45-50 cm/s flowing Northeastwards

REA programme : CTD data (1st sampling)

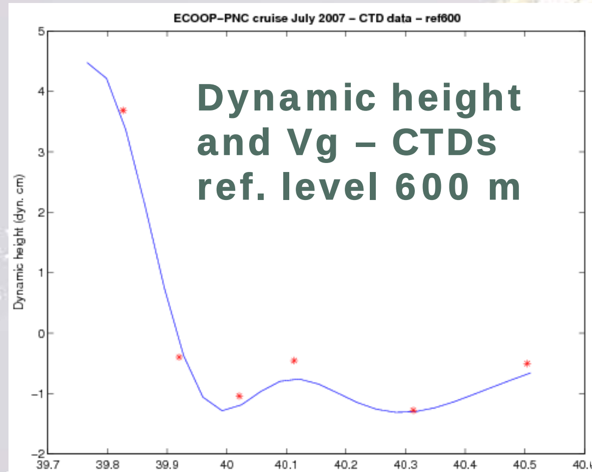
Simultaneous measurements with R/V Garcia del Cid (conventional cruise): 9 – 12 July 2007

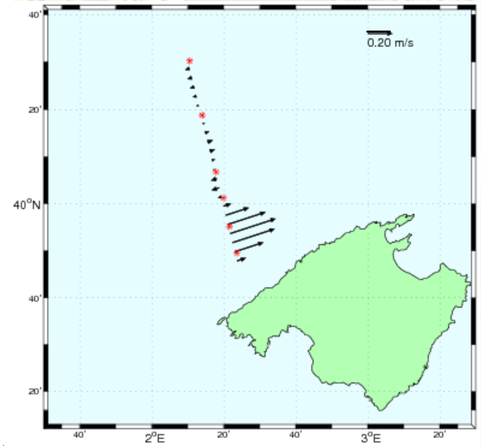
Following the 773 Envisat track

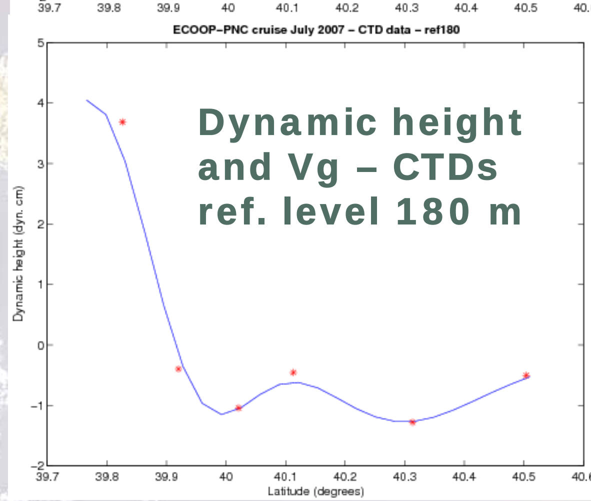


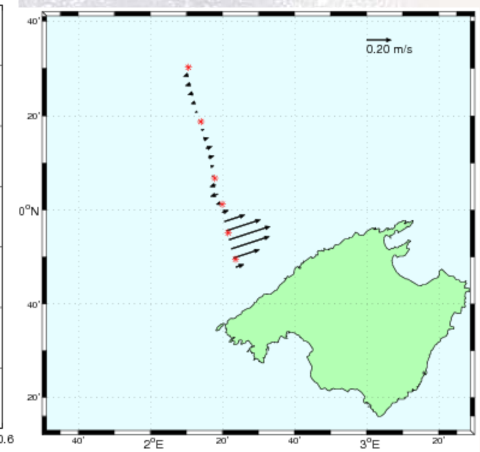


CTD stations





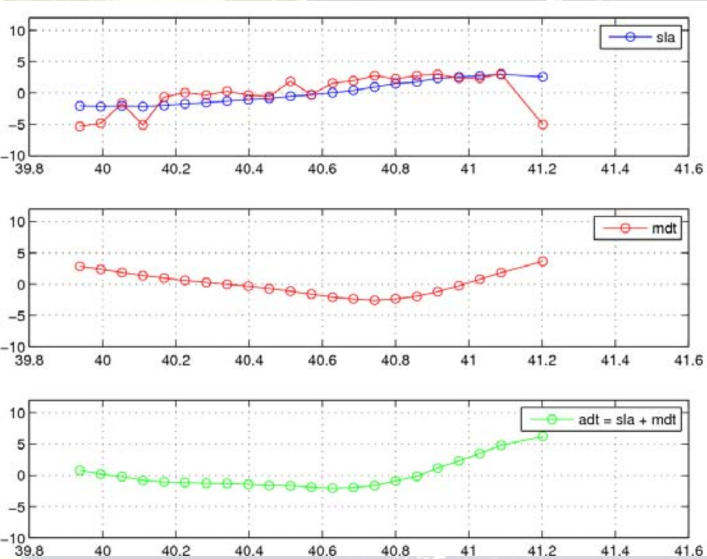


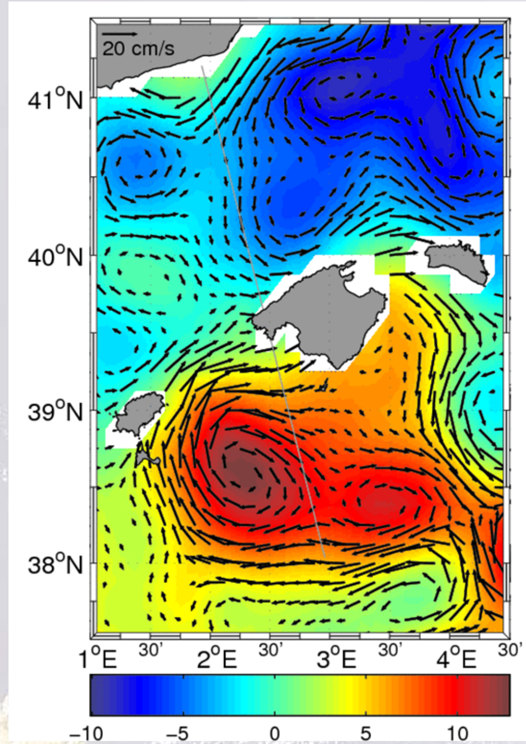


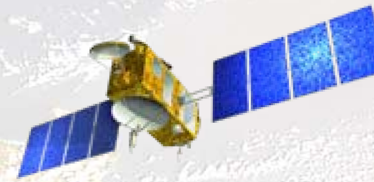
Small sensitivity to the ref. level.

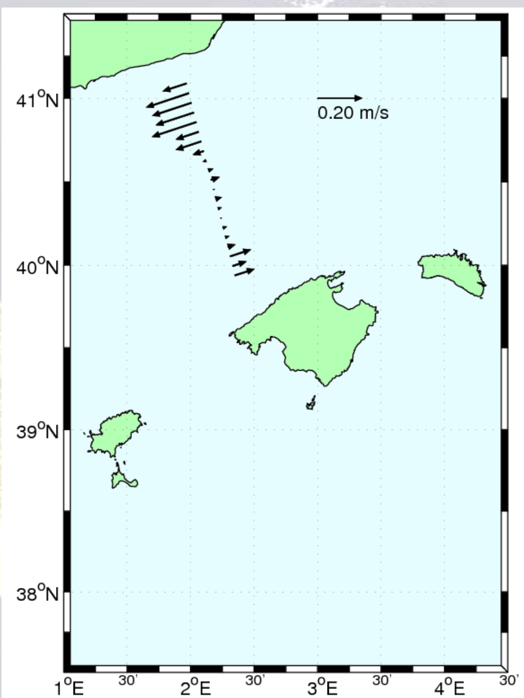
Coherence pattern with glider data (40-45 cm/s)

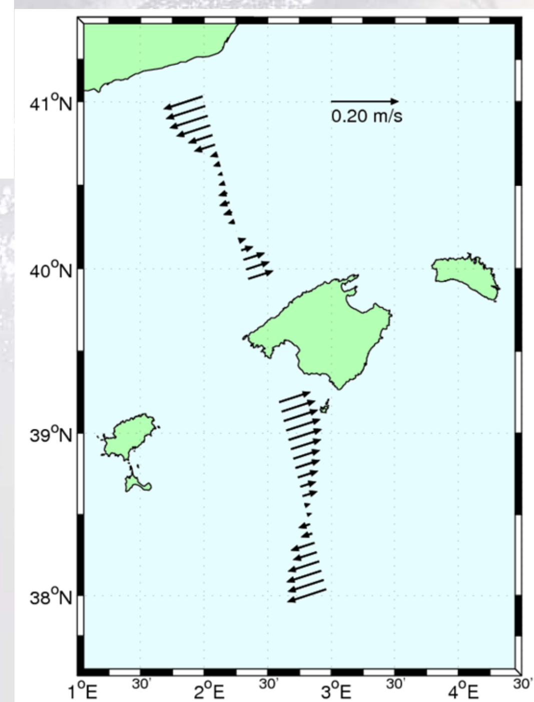
REA programme : altimetry data (1st sampling)







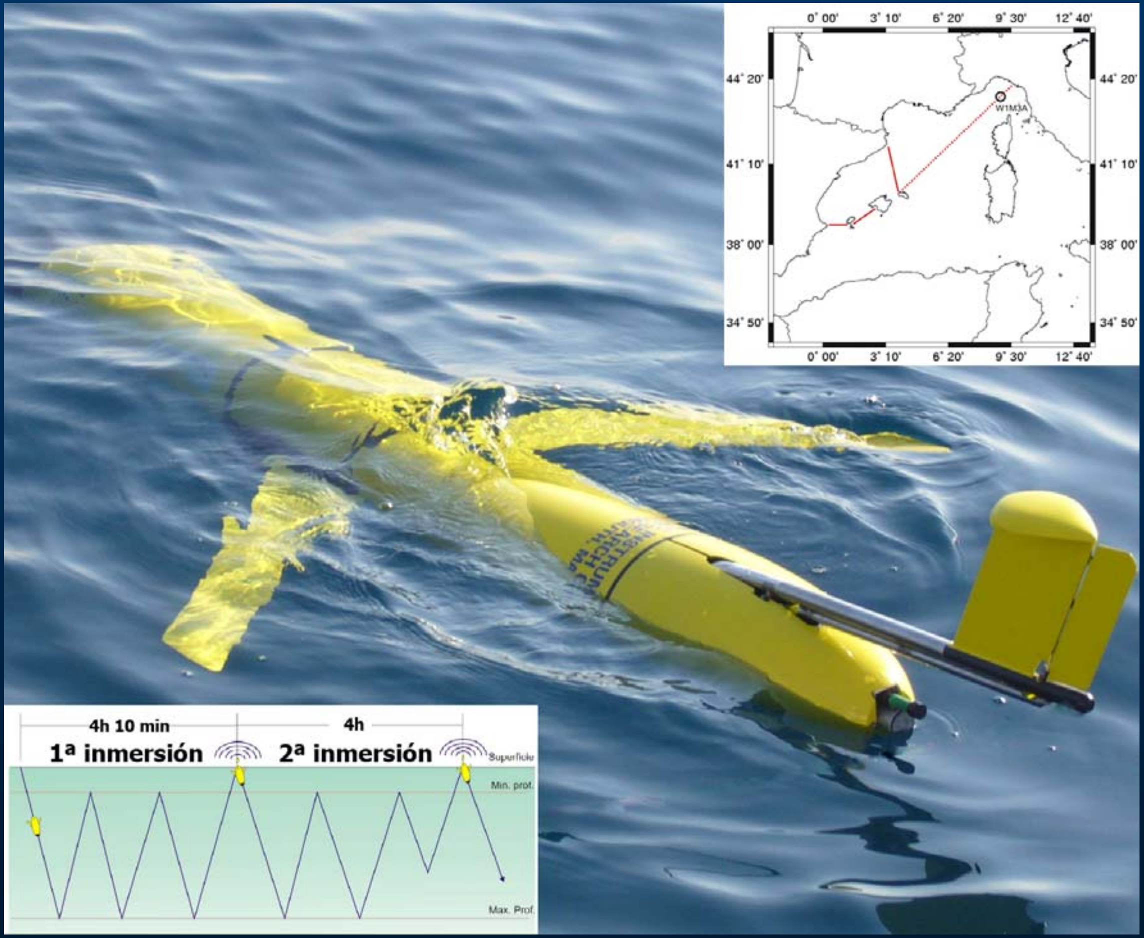




Present work in collaboration with CLS:

Improvement of Corrections:

- MOG2D HR
- Wet troposphere
- Tidal model
- Mean profile


0° 00'
3° 10'
6° 20'
9° 30'
12° 40'
44° 20'
41° 10'
38° 00'
34° 50'
W1M3A
4h 10 min
4h
1ª inmersión
2ª inmersión
Superficie
Min. prof.
Max. Prof.

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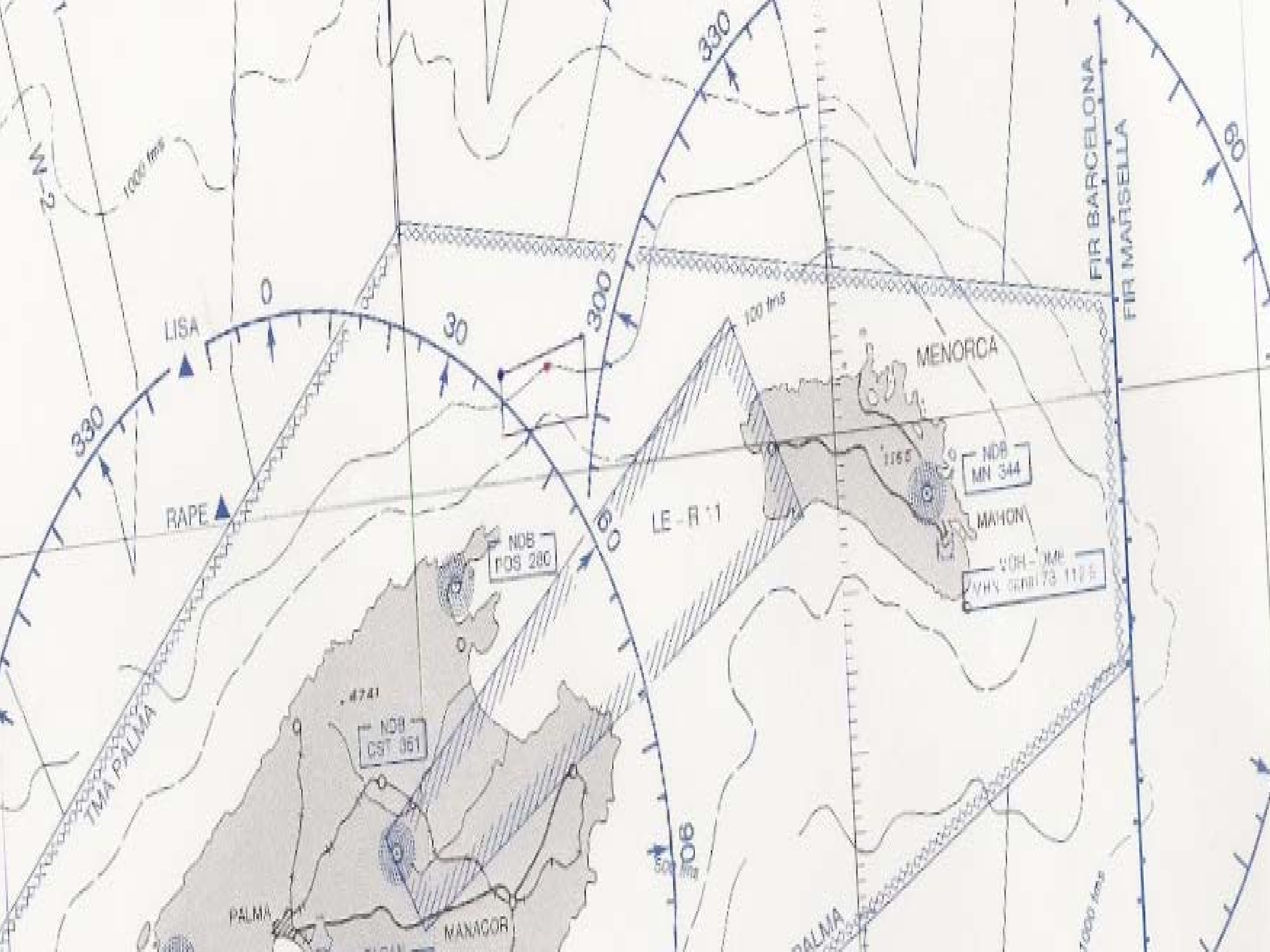
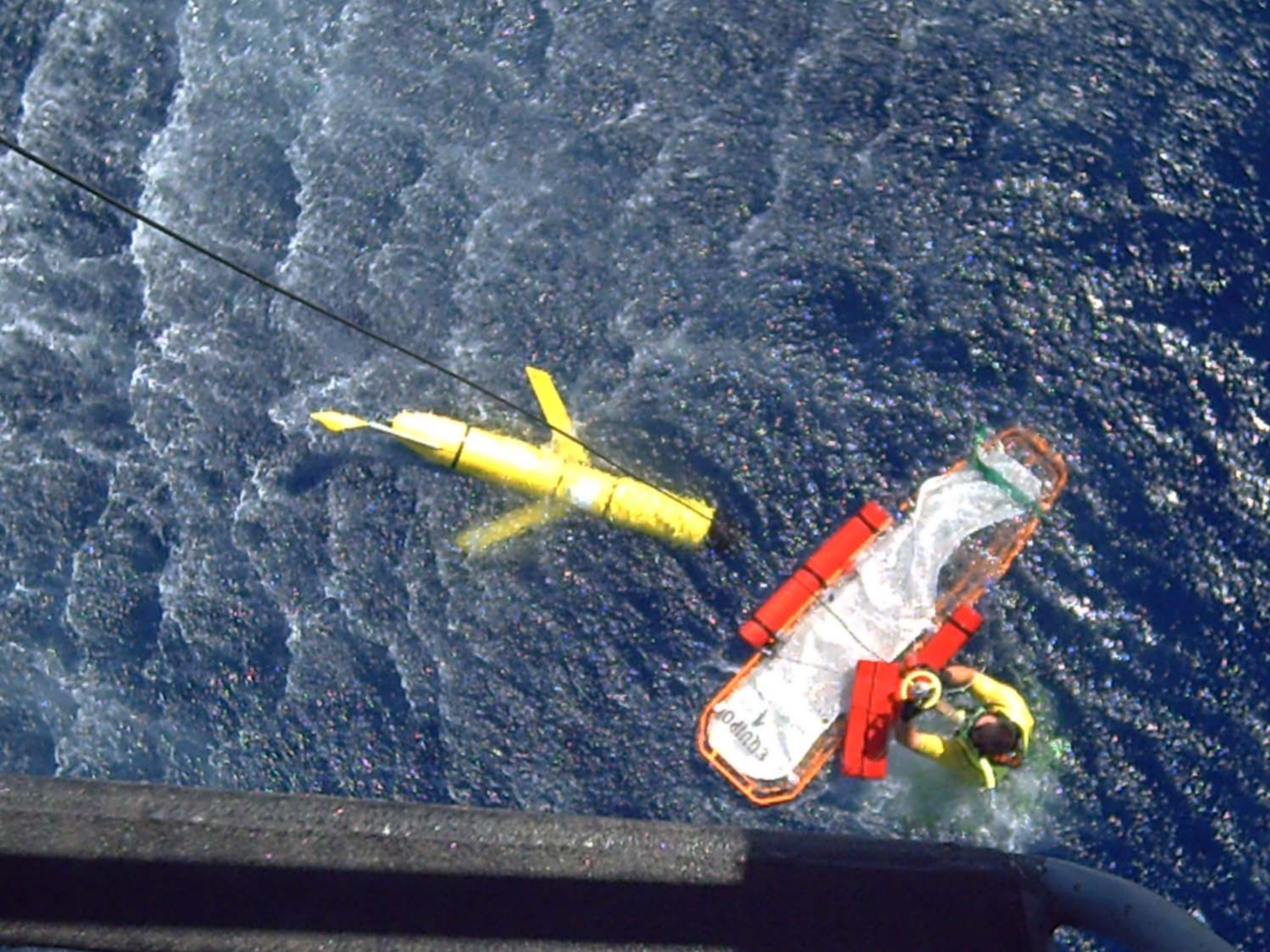
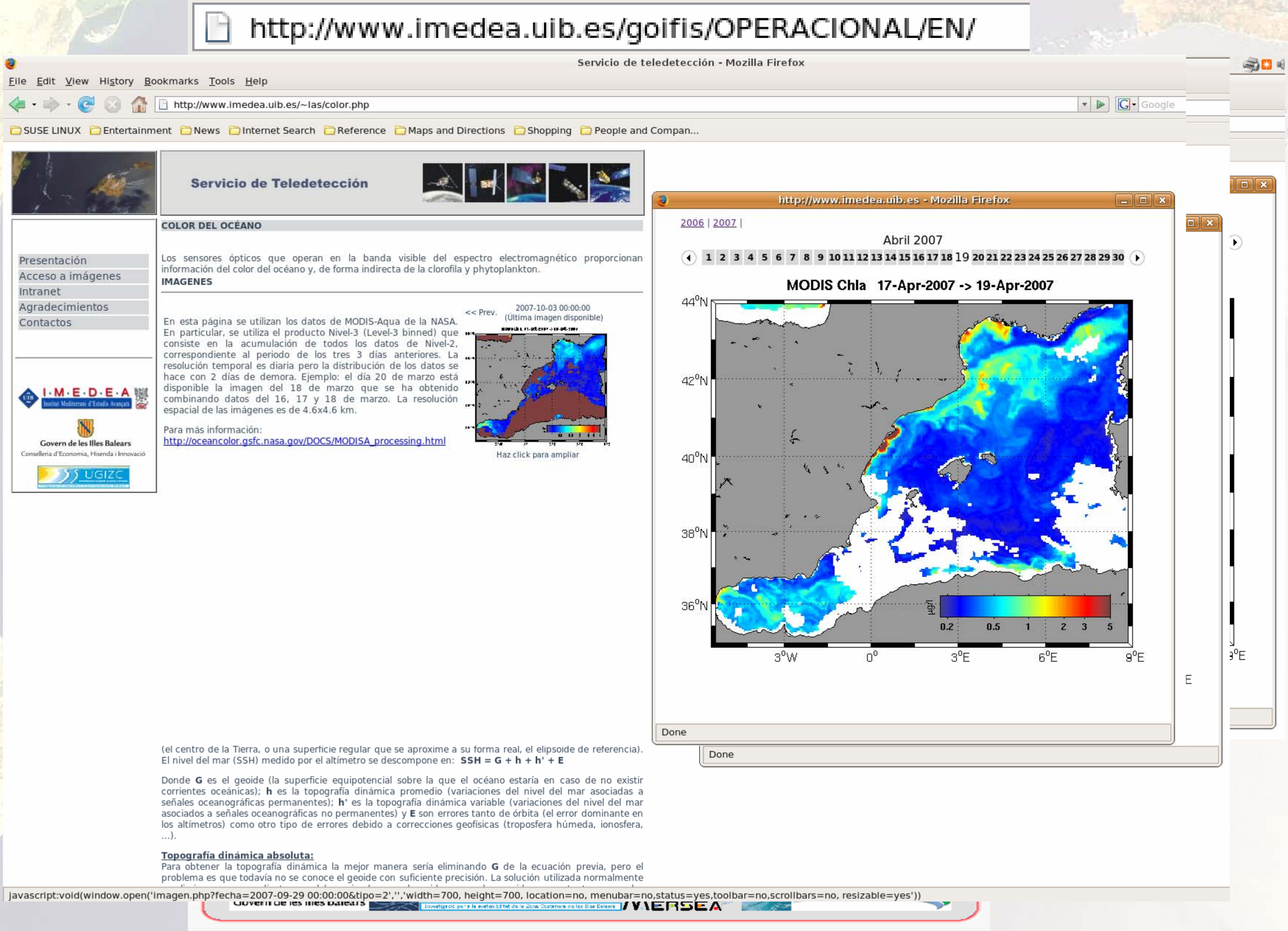

W-2
1000 fms
LISA
RAPE
0
30
60
90
330
300
FIR BARCELONA
FIR MARSELLA
100 fms
MENORCA
NDB
MN 344
MAHON
LE-R 11
NDB
NDB
TMA PALMA
500 fms
PALMA
MANACOR
PALMA
1000 fms

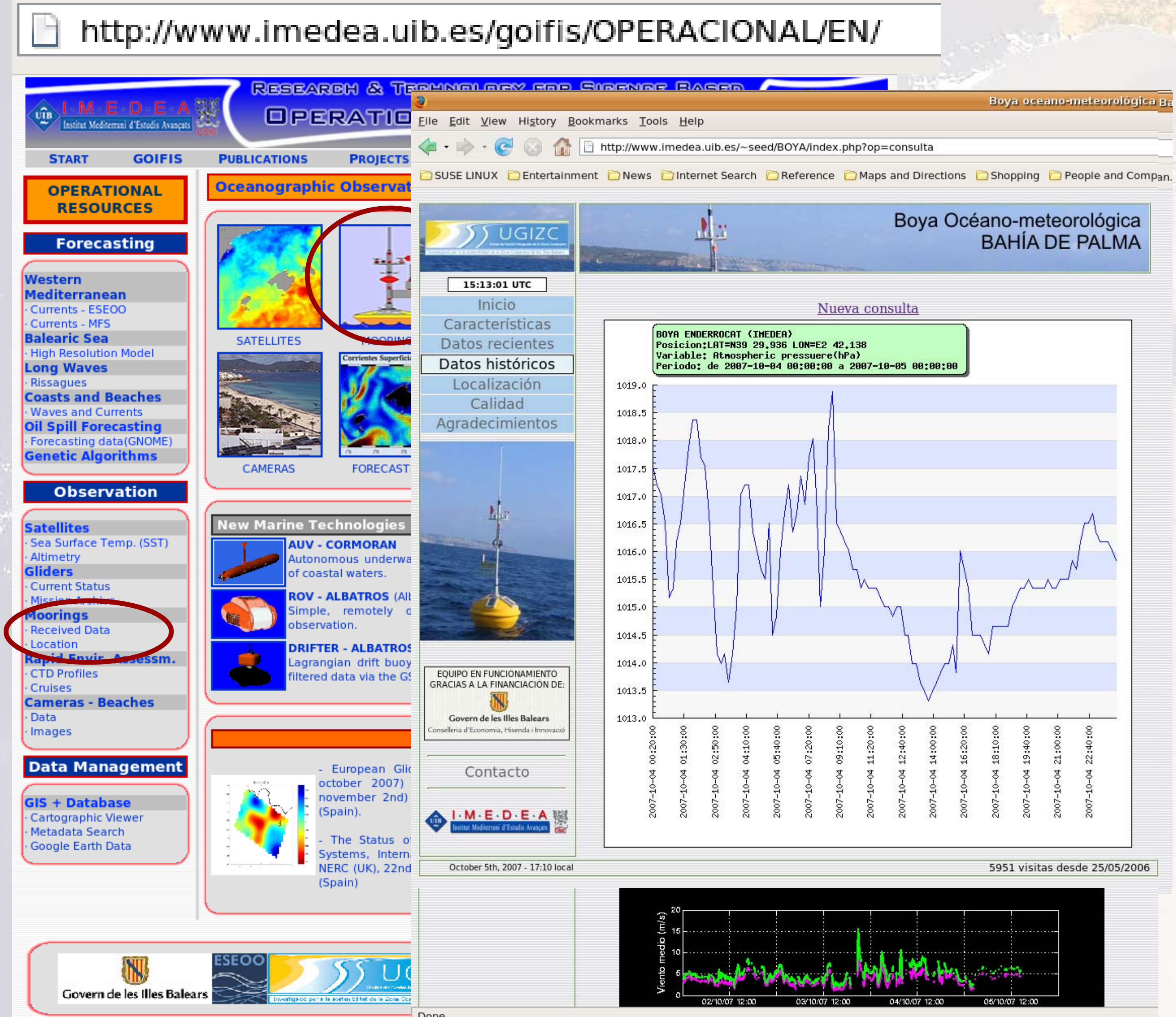

ALF. LERIDA



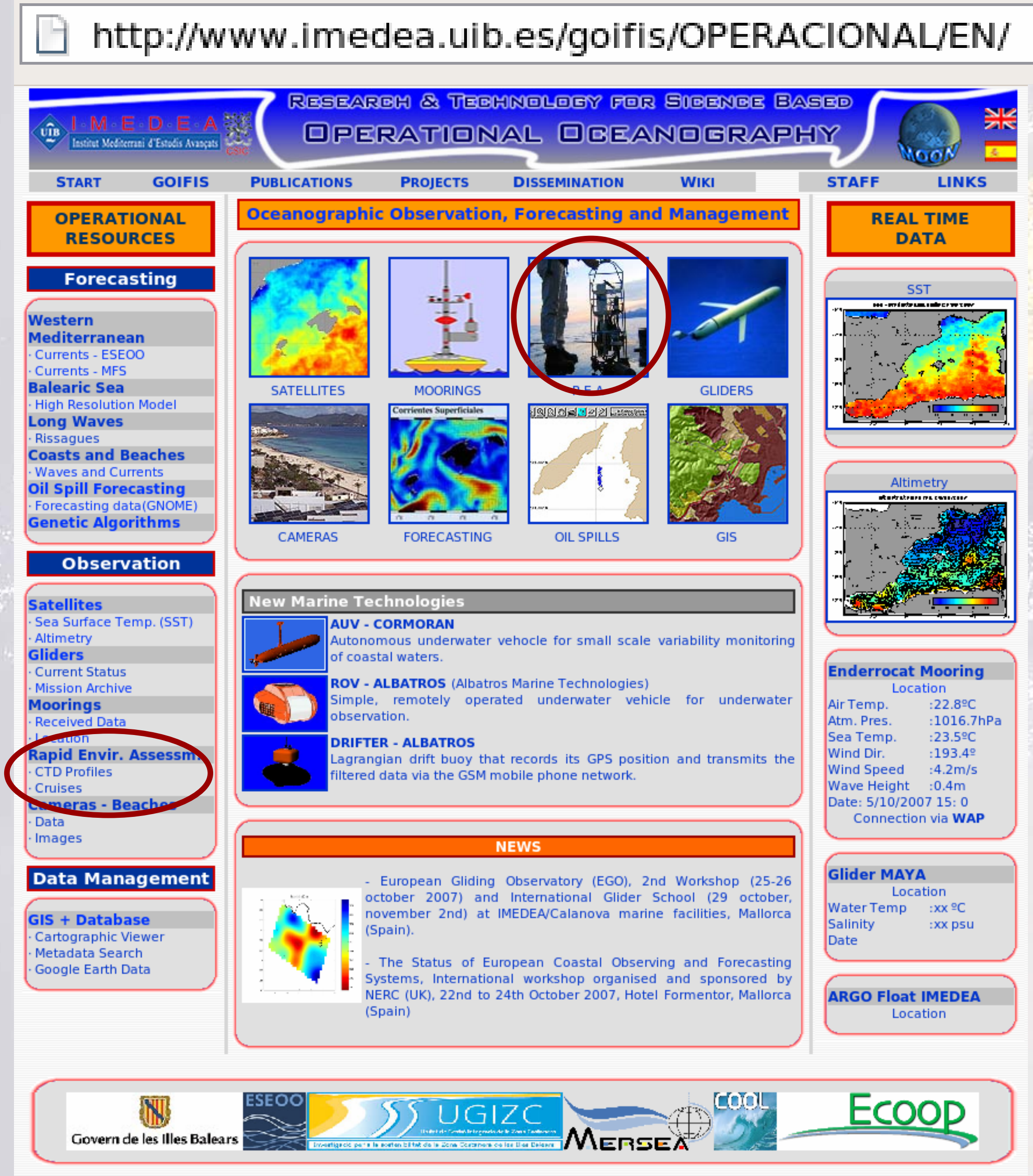
Pilot Observing and Forecasting System - towards Science based Operational Oceanography



Pilot Observing and Forecasting System - towards Science based Operational Oceanography



Pilot Observing and Forecasting System - towards Science based Operational Oceanography

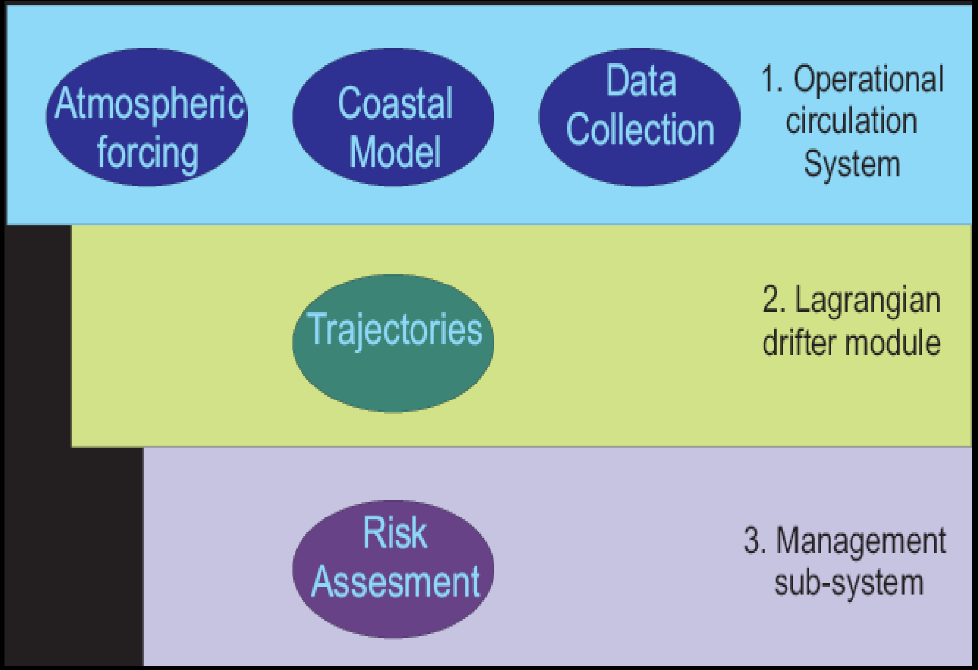


The IMEDEA Operational Forecasting system

IMEDEA is developing an operational circulation system in the Balearic Islands. The system is based upon three nested domains; real-time measurements are also taken into account via data assimilation.

The system is a tool to forecast oil spill trajectories, drifting objects, etc.

It is applied using a management subsystem based on GIS technology which aids for decision support to provide response to SAR operations or oil spill accidents.



The IMEDEA Operational Forecasting currents system

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Marine Pollution Bulletin 53 (2006) 361–368

MARINE POLLUTION BULLETIN

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Scientific management of Mediterranean coastal zone: A hybrid ocean forecasting system for oil spill and search and rescue operations

A. Jordi [a,*], M.I. Ferrer [a], G. Vizoso [a], A. Orfila [b], G. Basterretxea [a], B. Casas [a], A. Álvarez [a], D. Roig [a], B. Garau [a], M. Martínez [a], V. Fernández [a], A. Fornés [a], M. Ruiz [a], J.J. Fornós [c], P. Balaguer [a], C.M. Duarte [a], I. Rodríguez [d], E. Alvarez [d], R. Onken [e], P. Orfila [f], J. Tintoré [a]

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[b] *School of Civil and Environmental Engineering, Cornell University, 14853 Ithaca (NY), USA*
[c] *Departament de Ciències de la Terra, UIB, Crta. Valldemossa, km 7.5, Palma de Mallorca, Illes Balears, Spain*
[d] *Área del Medio Físico, Puertos del Estado, Antonio Lopez 81, Madrid E-28026, Spain*
[e] *Institute of Coastal Research, GKSS Research Centre, Max-Planck-Strasse 1, 21052 Geesthacht, Germany*
[f] *D.G. Emergències, Conselleria d' Interior del Govern de les Illes Balears, Spain*

Abstract

The oil spill from *Prestige* tanker showed the importance of scientifically based protocols to minimize the impacts on the environment. In this work, we describe a new forecasting system to predict oil spill trajectories and their potential impacts on the coastal zone. The system is formed of three main interconnected modules that address different capabilities: (1) an operational circulation sub-system that includes nested models at different scales, data collection with near-real time assimilation, new tools for initialization or assimilation based on genetic algorithms and feature-oriented strategic sampling; (2) an oil spill coastal sub-system that allows simulation of the trajectories and fate of spilled oil together with evaluation of coastal zone vulnerability using environmental sensitivity indexes; (3) a risk management sub-system for decision support based on GIS technology. The system is applied to the Mediterranean Sea where surface currents are highly variable in space and time, and interactions between local, sub-basin and basin scale increase the non-linear interactions effects which need to be adequately resolved at each one of the intervening scales. Besides the Mediterranean Sea is a complex reduced scale ocean representing a real scientific and technological challenge for operational oceanography and particularly for oil spill response and search and rescue operations.

Keywords: Oil spill; Risk assessment; Operational oceanography; Currents; Search and rescue; Mediterranean Sea

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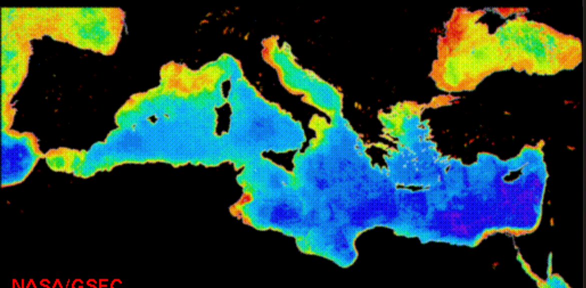
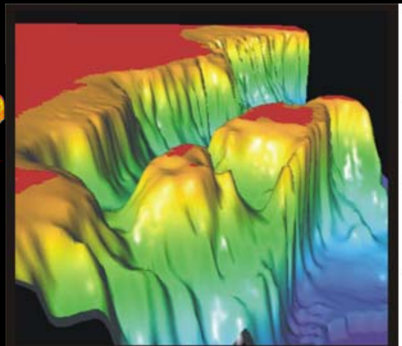
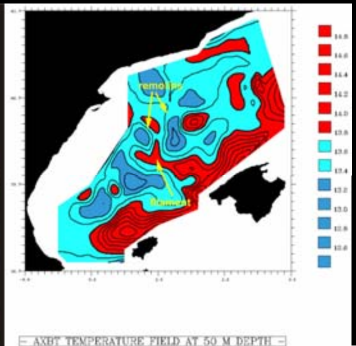
The System

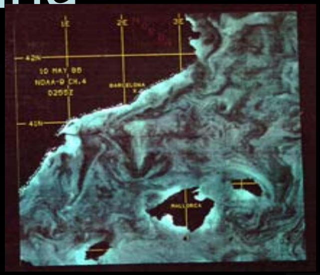
The system is applied to the Mediterranean Sea where the circulation is strongly affected by frontal dynamics through mesoscale features that can give rise to a wide range of ocean variability.

The system adequately addresses the different physical processes affecting the drift of spill and more generally drifting objects, which opens the possibility of supporting a wide range of scientific and operational services and applications.









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- The oil spill from Prestige tanker showed the importance of scientifically based protocols to minimize the impacts on the environment.
- IMEDEA is developing an oceanographic system to predict oil spill trajectories and their potential impacts on the coastal zone.
- The system is based upon three main components: an operational circulation sub-system, an oil spill coastal sub-system, and a management sub-system.
- Each sub-system is composed by one or more modules that interact between them.

The system is applied to the Mediterranean Sea where the circulation is strongly affected by frontal dynamics through mesoscale features that can give rise to a wide range of ocean variability.

The system adequately addresses the different physical processes affecting the drift of spills and more generally drifting objects, which opens the possibility of supporting a wide range of scientific and operational services and applications (oil spill monitoring, marine safety, search and rescue operations, etc).

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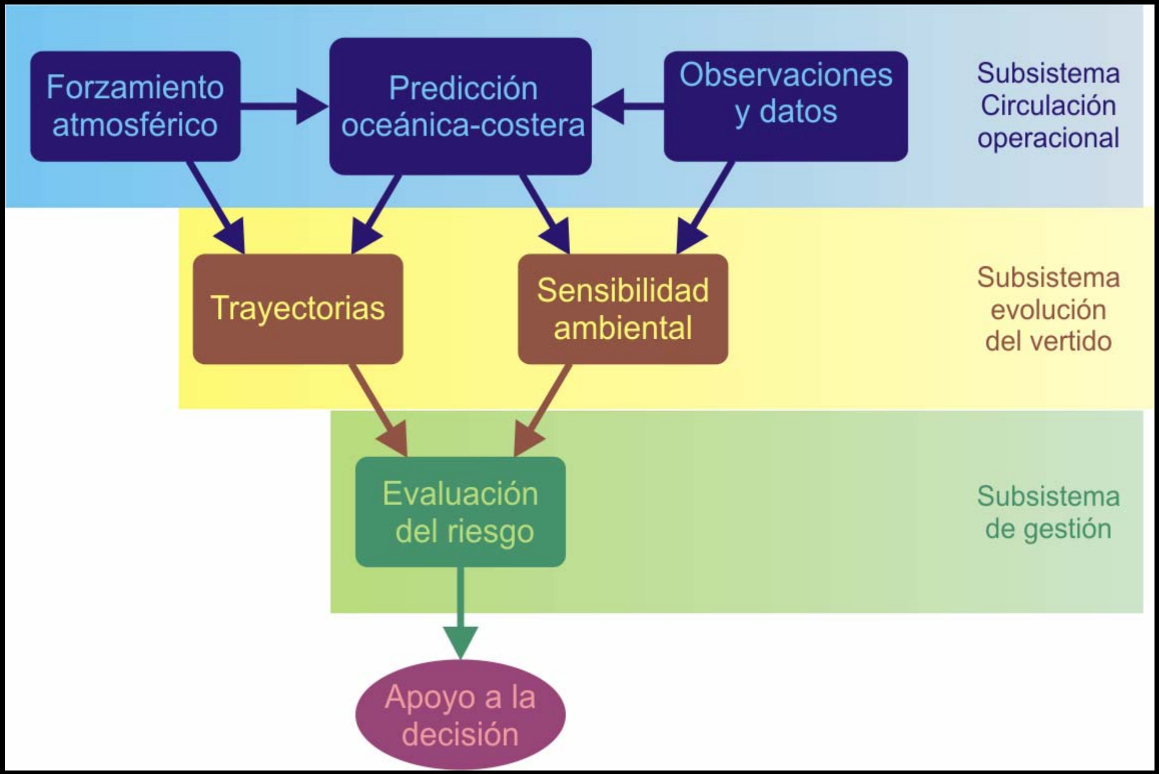
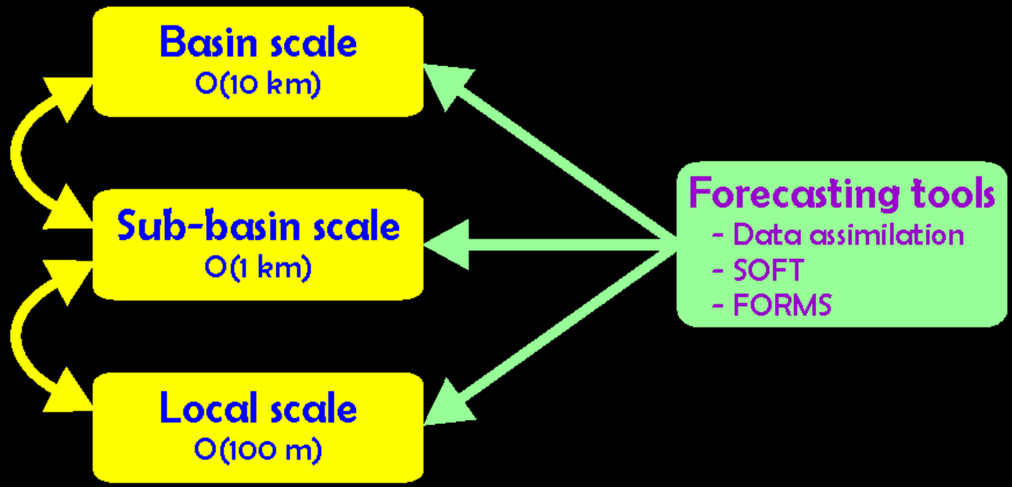
MERSEA ESEOO VERTIDOS UGIZC MFSTEP



Operational circulation sub-system
Coastal Ocean forecast

The goal of the operational sub-system is to provide, in near-real time, reliable information and forecasts for marine environmental conditions, to support all kind of activities at sea.

The Coastal Ocean forecast module is based on a hierarchy of models and a set of forecasting tools nested at different scales that include capacities for near-real time data assimilation together with new tools for initialization and/or assimilation



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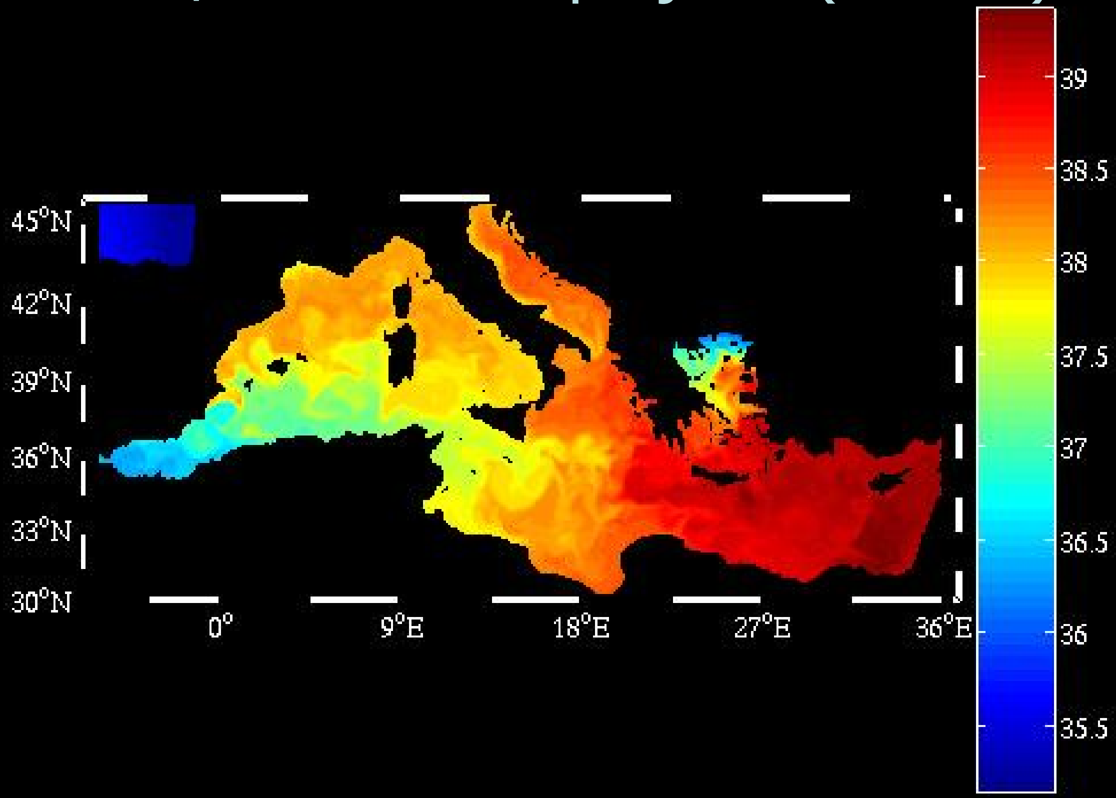
Coastal Ocean Forecast

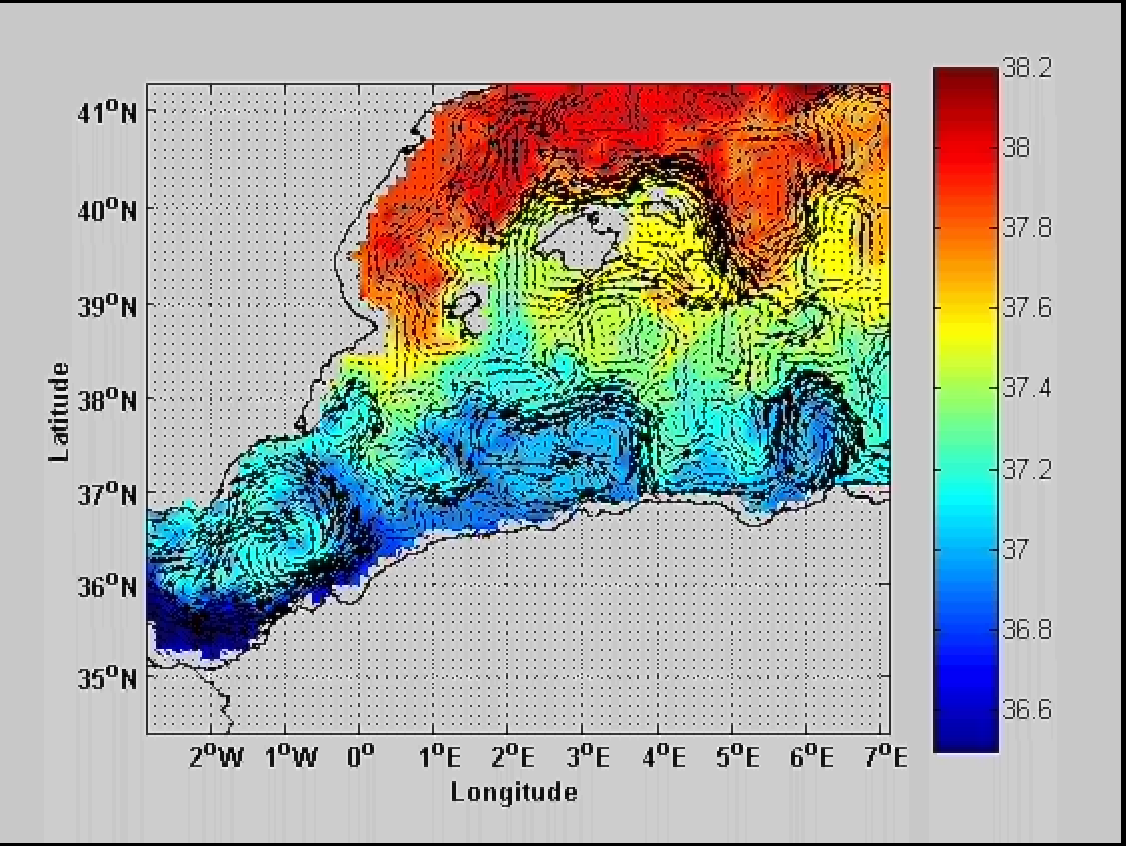
The operational system is based on a set of nested domains at different scales:

a) Basin scale: Mediterranean Forecasting System by MFS/MERSEA EC projects (Pinardi)



The model is OPA with 1/16º spatial resolution (10 days forecast)

IMEDEA recent examples of Mediterranean variability at basin scale



Fernandez, Dietrich, Haney, Tintoré,
Prog. Oceanogr., (2005)

DieCAST model. One year simulation, salinity and velocity fields

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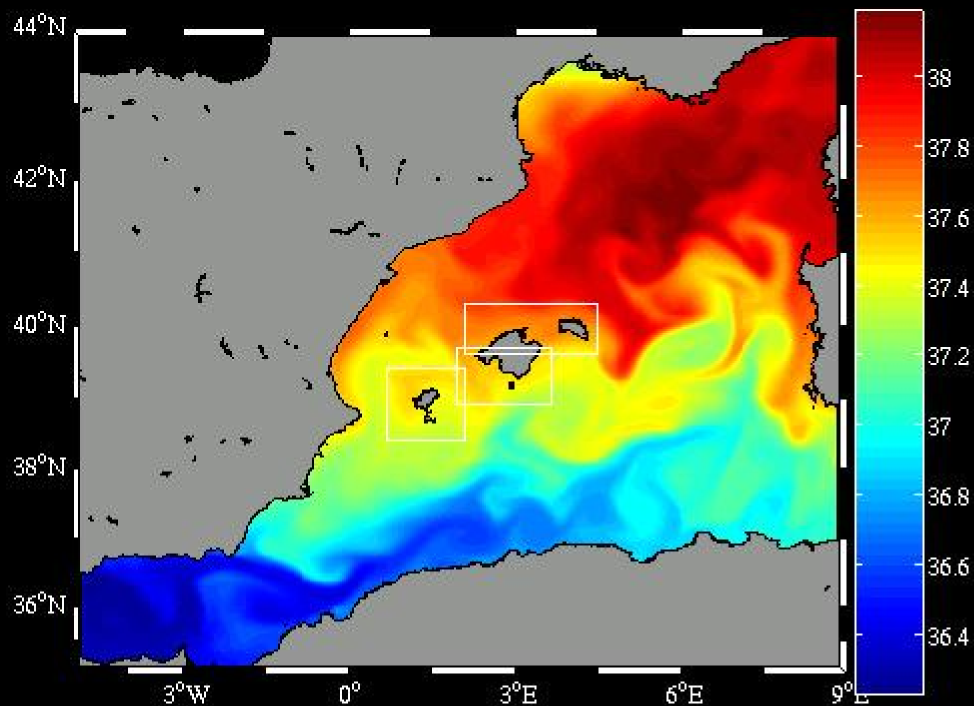
Coastal Ocean Forecast

b) Sub-basin scale: Harvard Ocean Prediction System (HOPS)

Model within 1km horizontal resolution and 20 vertical levels. The model is capable to assimilate temperature and salinity profiles.



Surface Salinity

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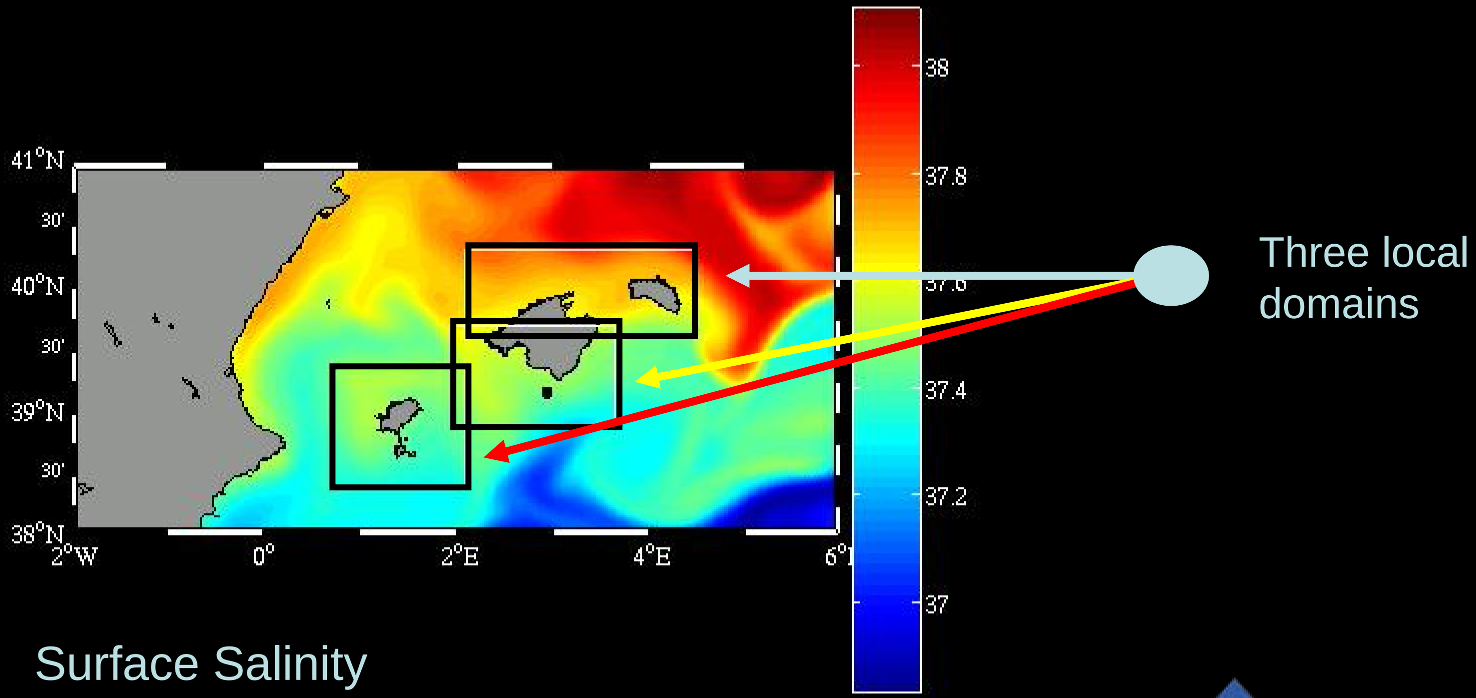
Coastal Ocean Forecast

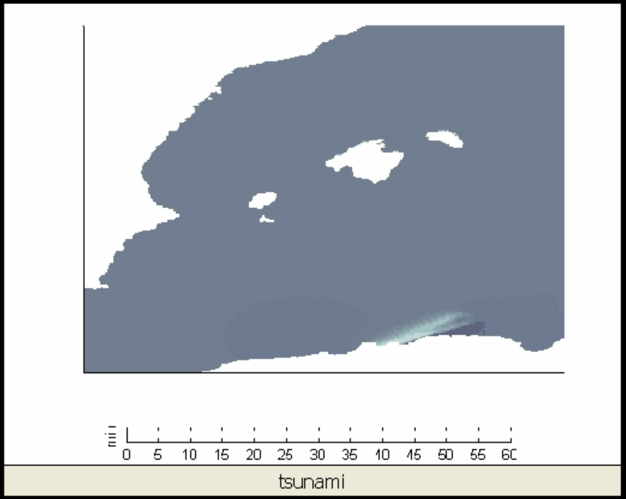
c) Local scale: HOPS model with 600m horizontal resolution. Data assimilation of new platforms, gliders, buoys, ...

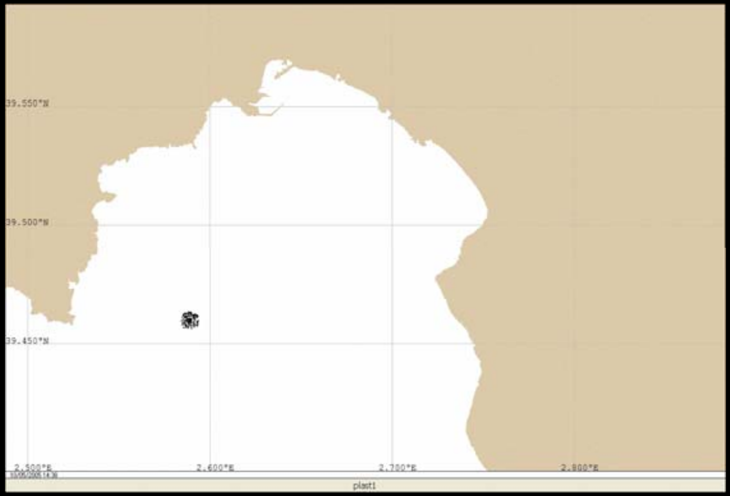


Surface Salinity

Operational systems being developped at IMEDEA

- Oil spill trajectories, SAR, coastal vulnerability.
- Rip currents in beaches
- Tsunami propagation





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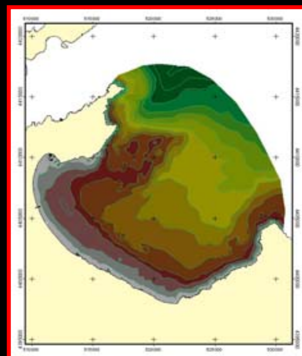
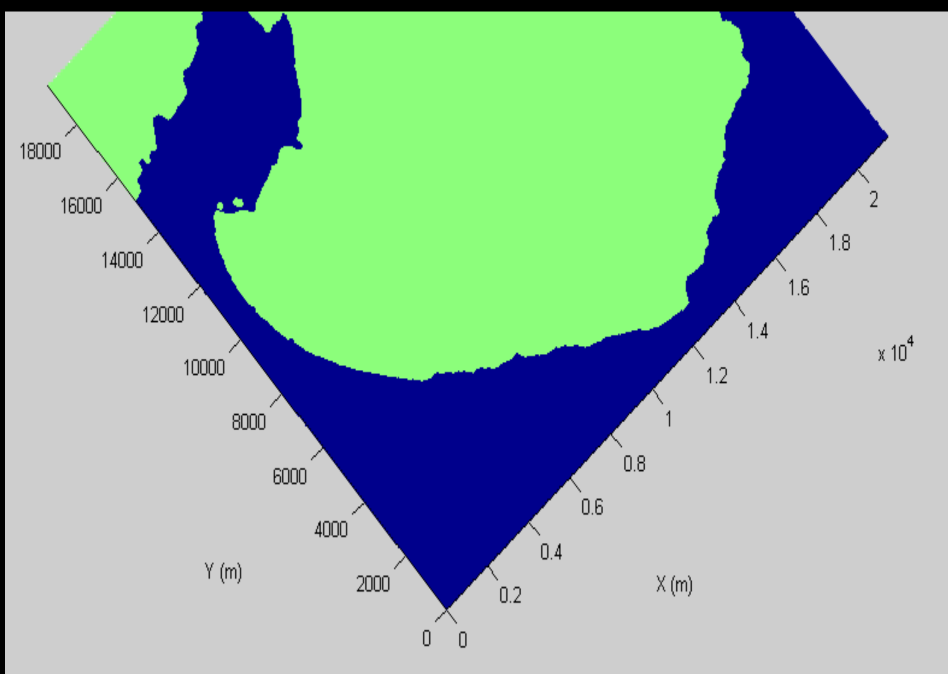
IMEDEA recent example of Mediterranean coastal variability (1)



Wave model



Alcudia Bay, Malllorca

- Wave energy is dissipated across the bay inducing significant sediment resuspension.
- Waves of Hs1.5 reach the beach
- Preliminary tests indicate wave height intensification, caused by refractive processes, close to Can Picafort harbour.

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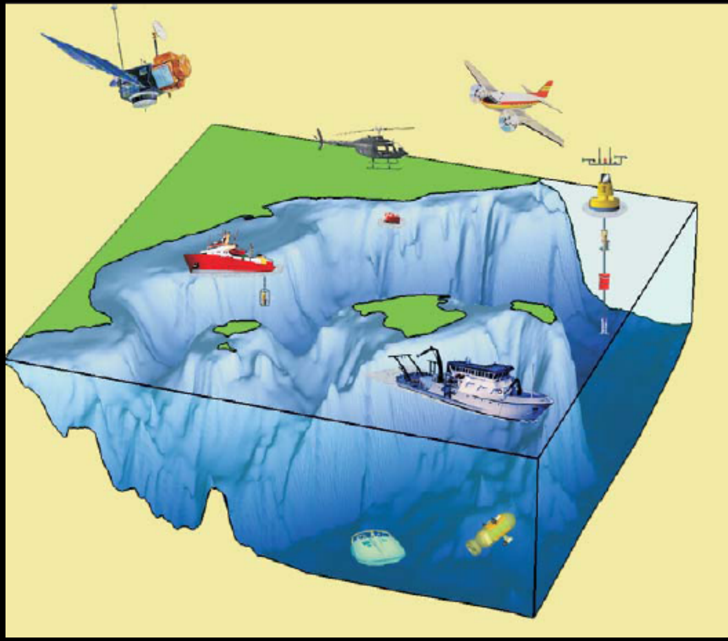
Ocean observations



Oceanic observations of the marine environment have been traditionally carried out by oceanographic ships and moorings using instrumentation like CTD, XBT or ADCP.

These data are required by the coastal ocean forecast module to correct deviations between model prediction and real ocean evolution.

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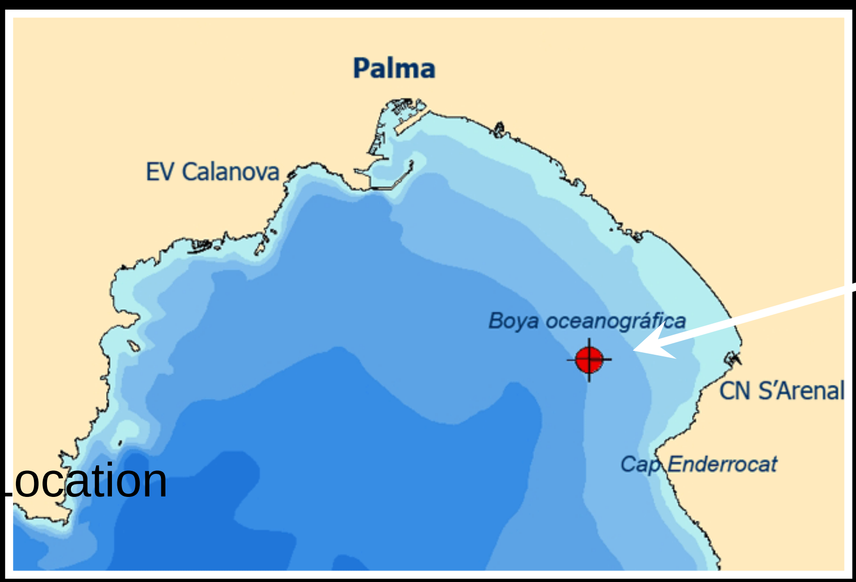
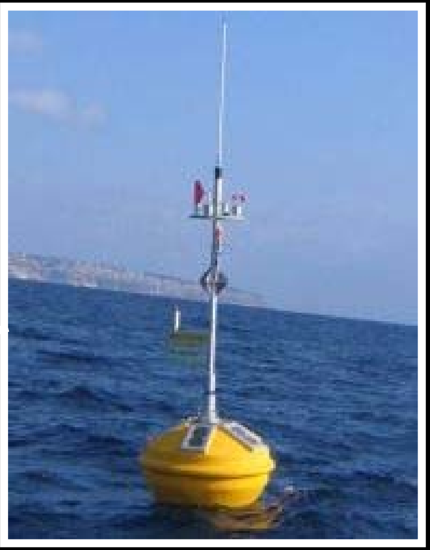
Ocean observations

Ocean-meteorological buoy in Palma Bay. Measures meteorological data: wind, atmospheric pressure, radiation, air temperature. Oceanic data: currents at 1m, 9m & 18 m; waves; conductivity; turbidity; chlorophyll; temperature at 10 levels.



Location



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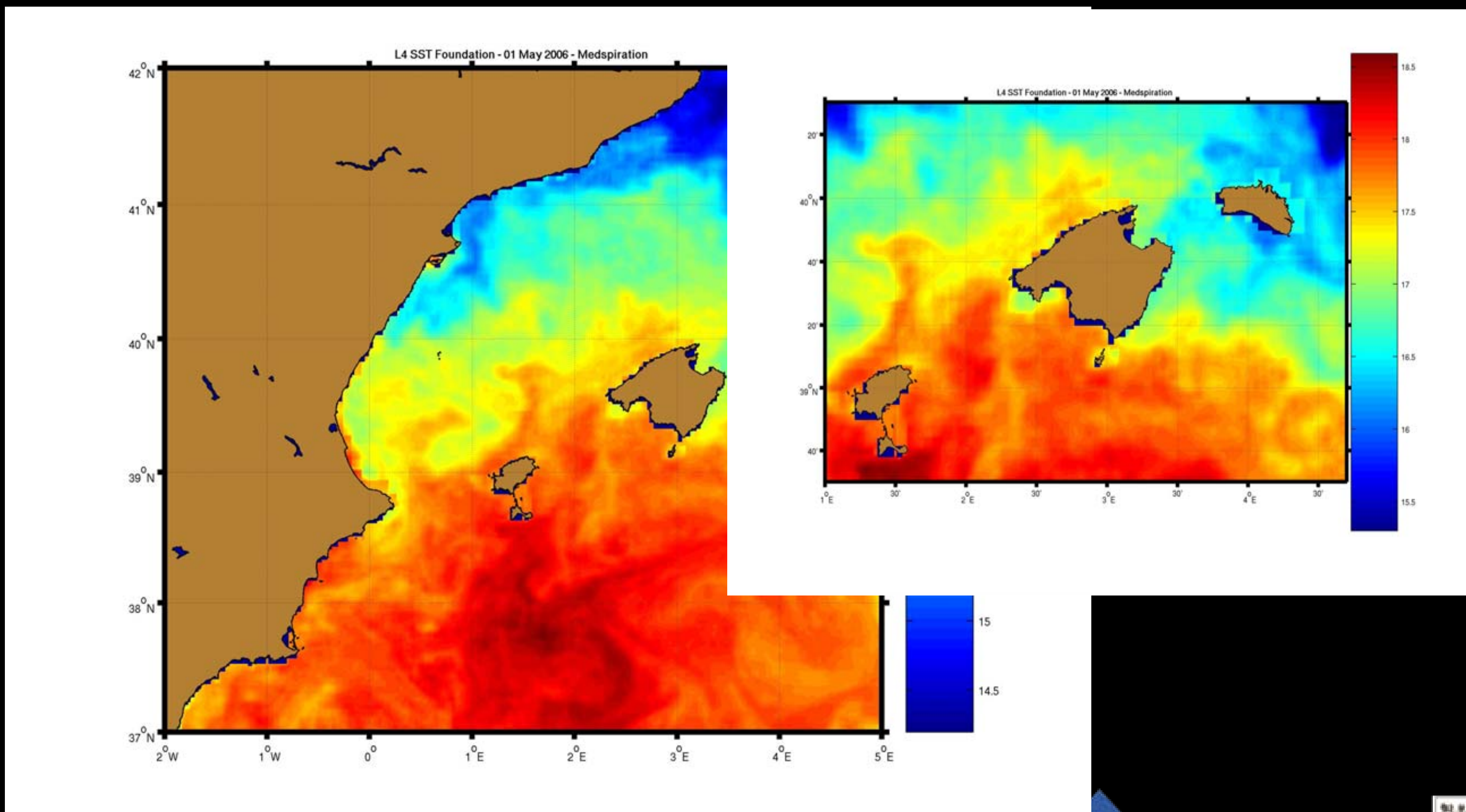
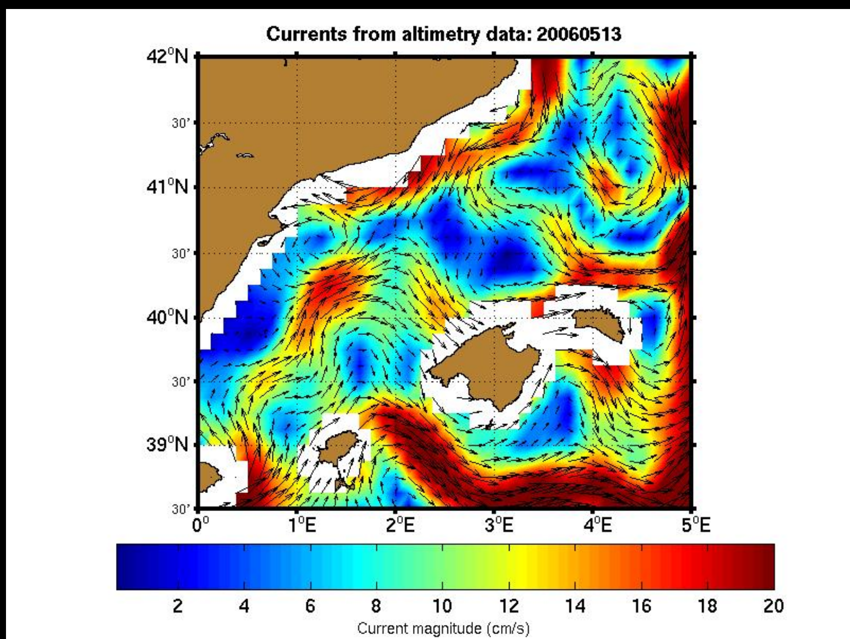
Ocean observations

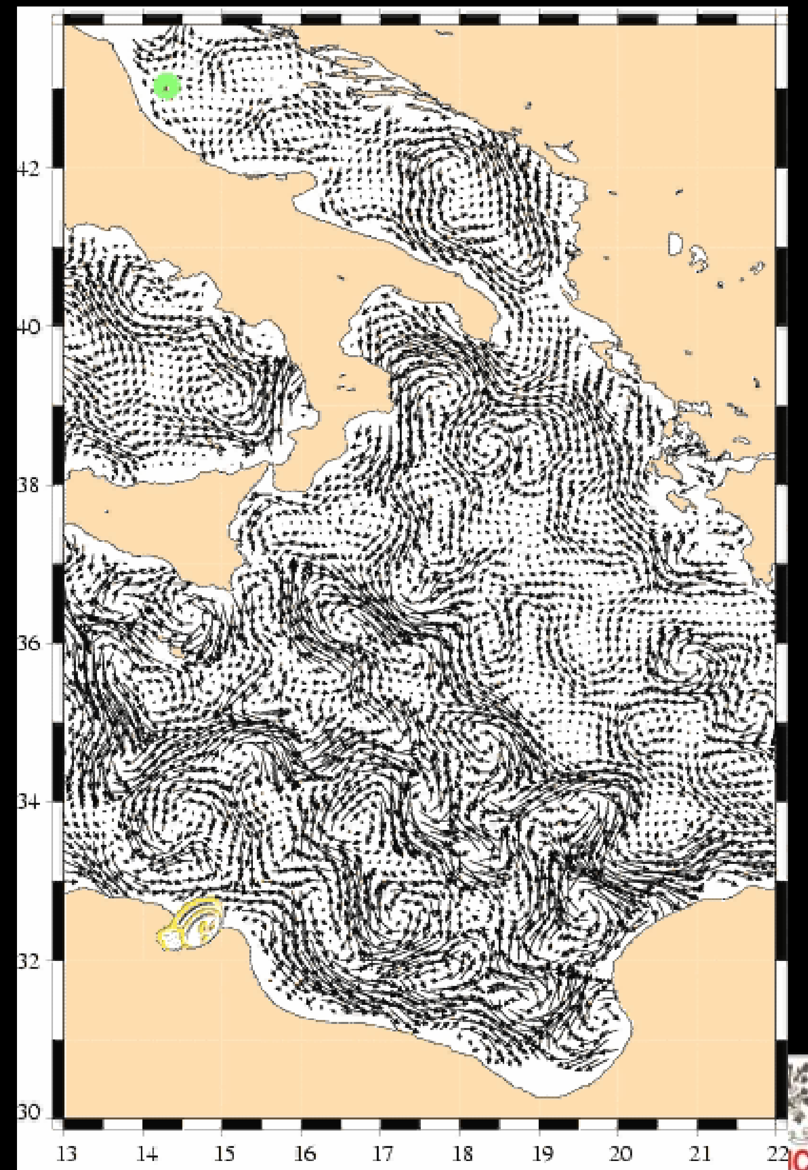
Example of high resolution SST Medspiration product, 01/05/2006



Ocean observations

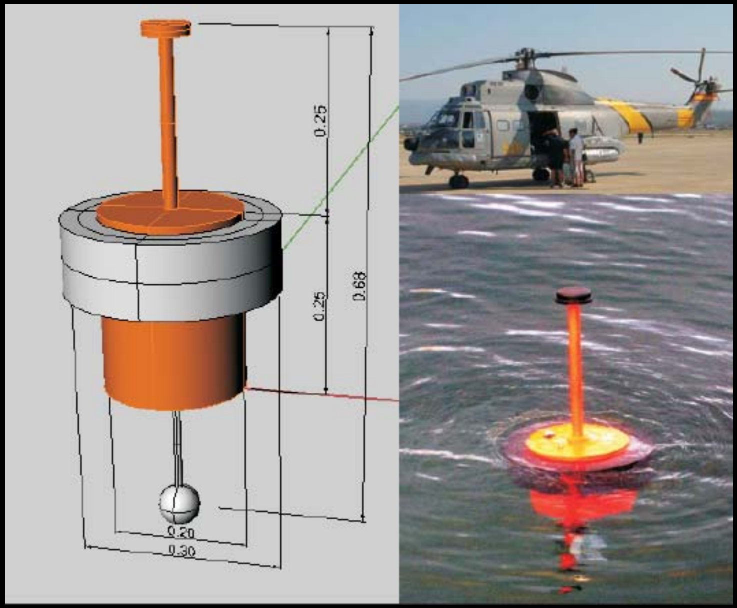
Example of altimetry data





New observing platforms

Limitations of conventional observing platforms, avoid to monitor the ocean at adequate spatial and temporal resolutions. For this reason and with the help of present technological development, new ocean observing platforms have been developed to carry out ocean measurements at high spatial and temporal resolutions.



Drifting buoy developed by IMEDEA. The buoy can be deployed from airplanes and helicopters

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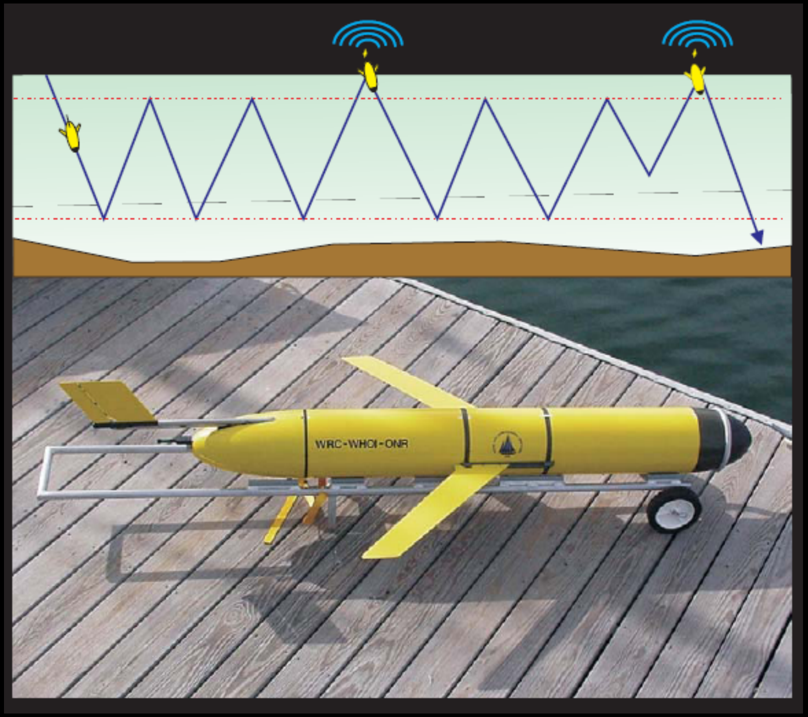
New observing platforms

SLOCUM glider (developed by Webb Research Corporation)



AHV3/CORMORAN AUV developed by IMEDEA

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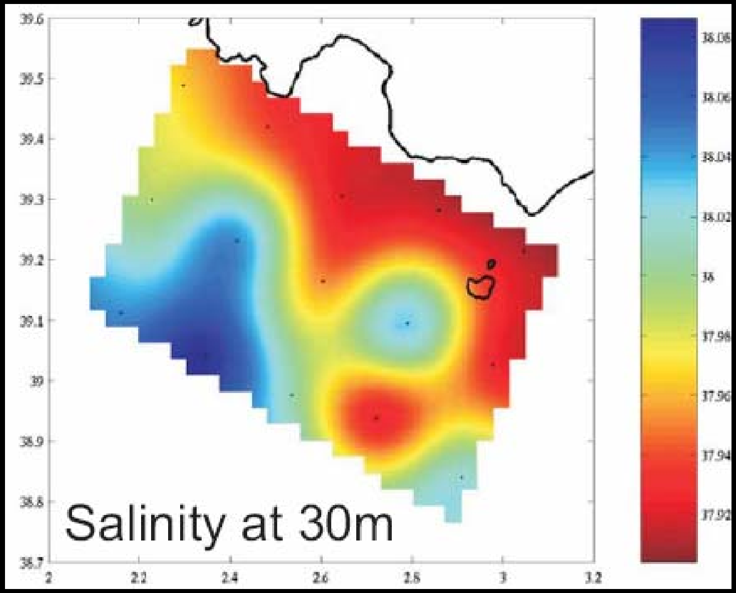
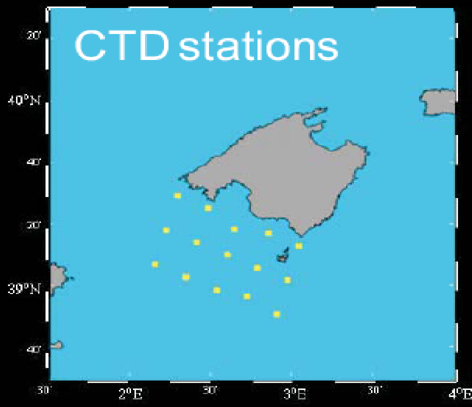
Rapid Environmental Assesment capability

During the SASEMAR-ESEOO experiment in May 2005, IMEDEA measured local conditions with CTD to assimilate the data into the HOPS model to provide more realistic currents.



DATA



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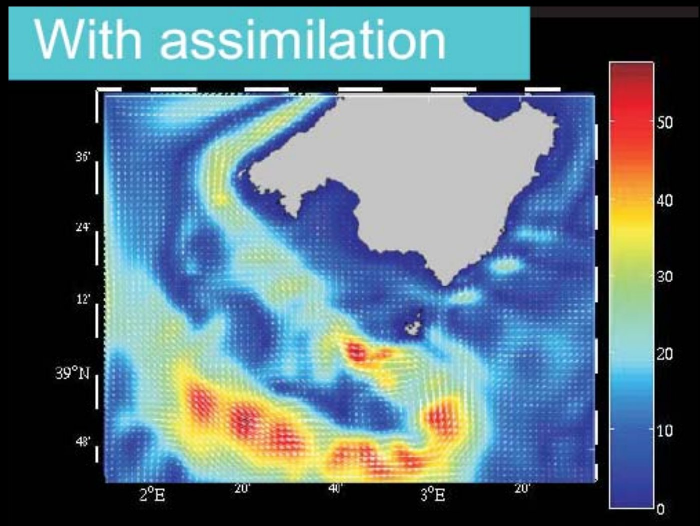
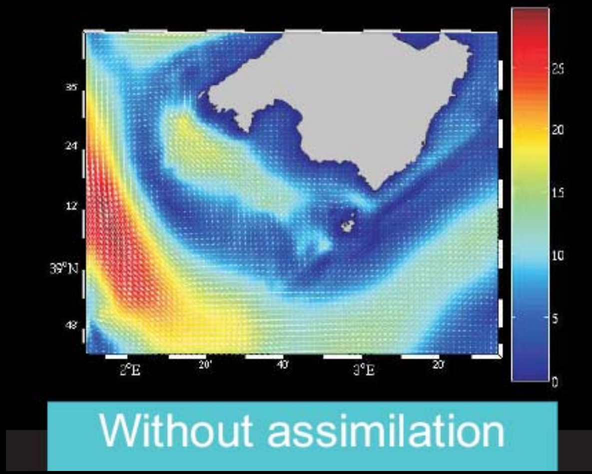
Data Assimilation

CTD data was assimilated into the local South Mallorca domain using an optimal interpolation technique.





HOPS model assimilating CTD data from 14th May 2005.

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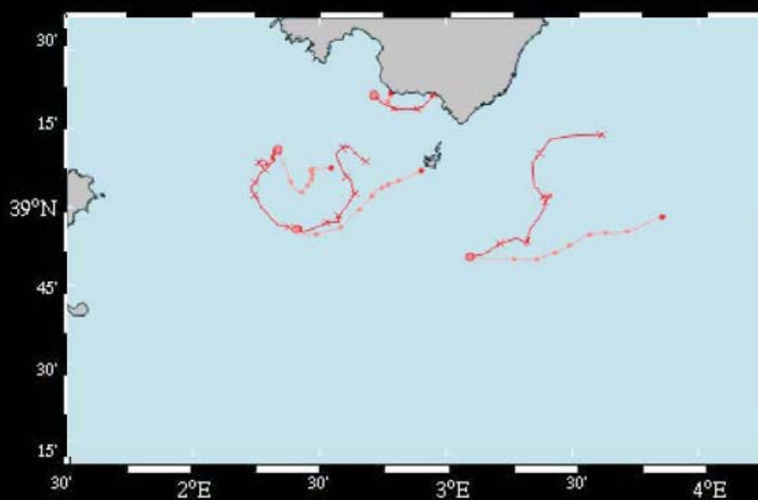
Forecasting oil spill trajectories

The oil spill coastal sub-system allows simulation of the trajectories and fate of oil released into the sea.

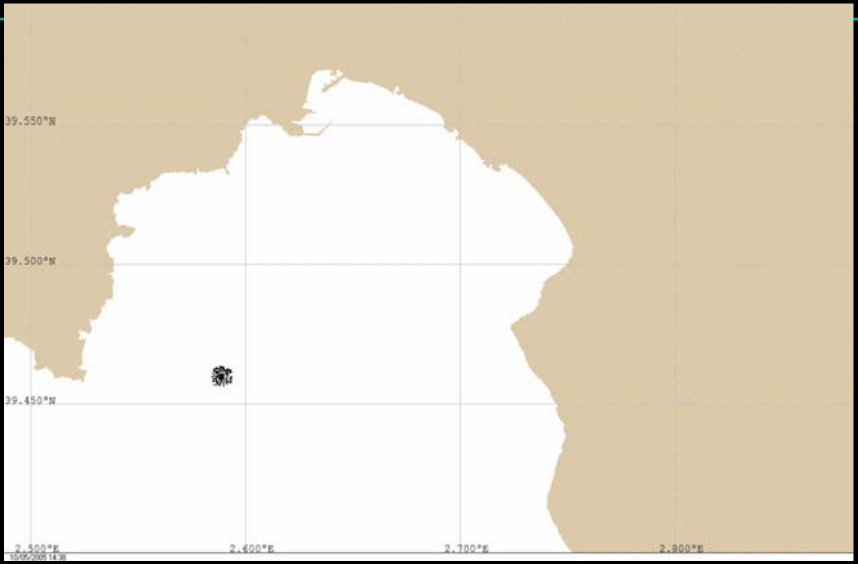
The trajectories module employs NOAA GNOME model (Beegle-Krause, 2001)



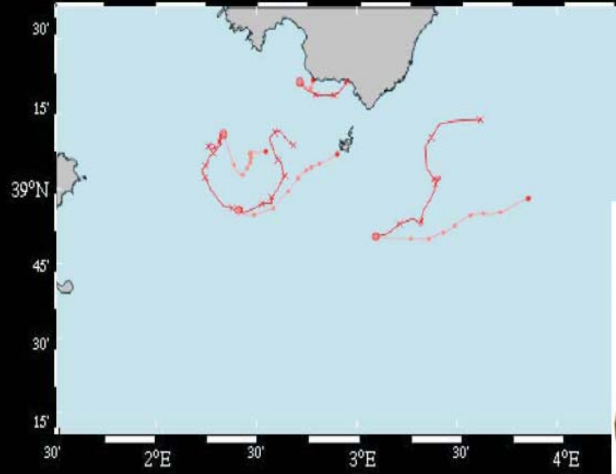
X dark color: real trajectory
O smooth color: forecast trajectory

Oil spill coastal sub-system

Trajectory model



The oil spill coastal system that allows simulation of the trajectories and fate of oil released into the sea together with evaluation of coastal zone vulnerability using environmental sensitivity indexes.

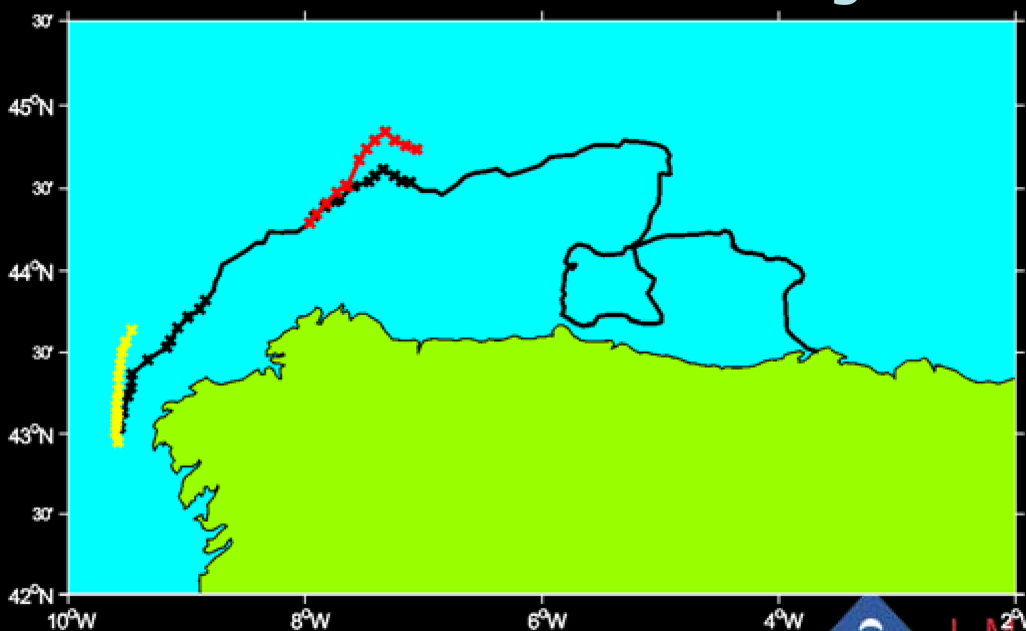


X dark color: real trajectory
O smooth color: forecast trajectory

4. Sistema de predicción de vertidos Mar Balear

The oil spill coastal sub-system incorporates the information associated with the response to oil spills.

The trajectories module predicts the spill trajectory taking into account the physical and chemical processes that affect the oil and is based on the General NOAA Oil Modeling Environment (GNOME).



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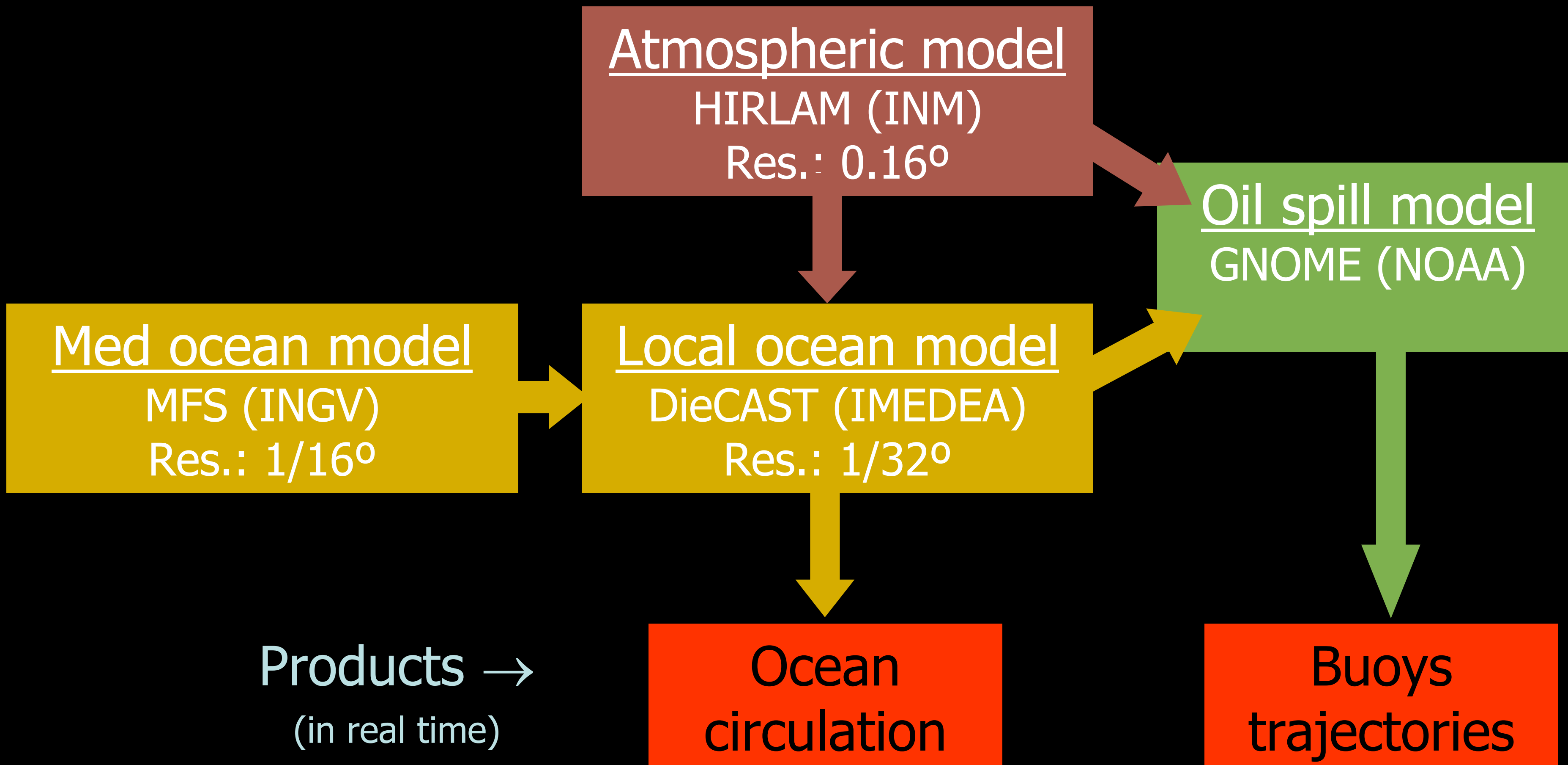
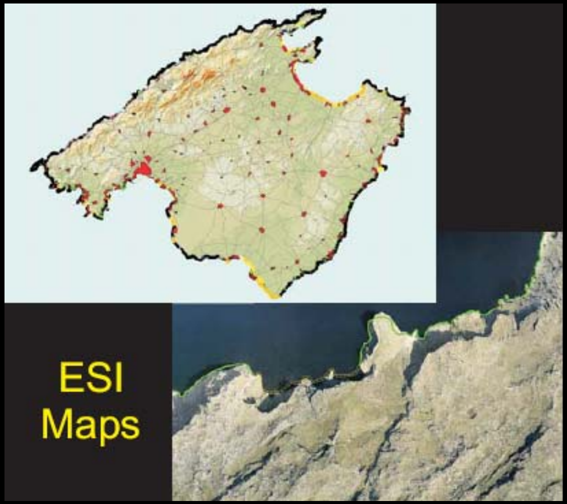
Operational system

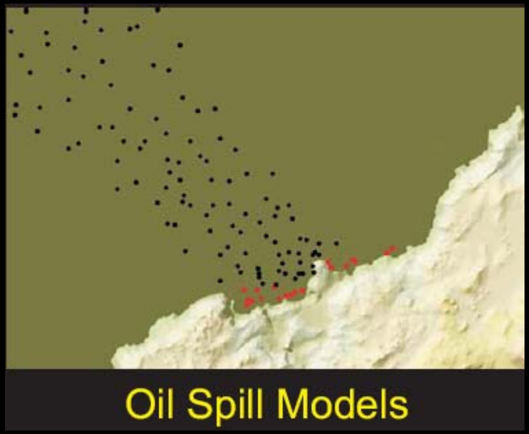


Coastal management

The management system is based on a geographical information system (GIS) for oil spill crisis management.

GIS are useful tool for storing, analyzing and displaying data to support management decisions and short term environmental protection planning.

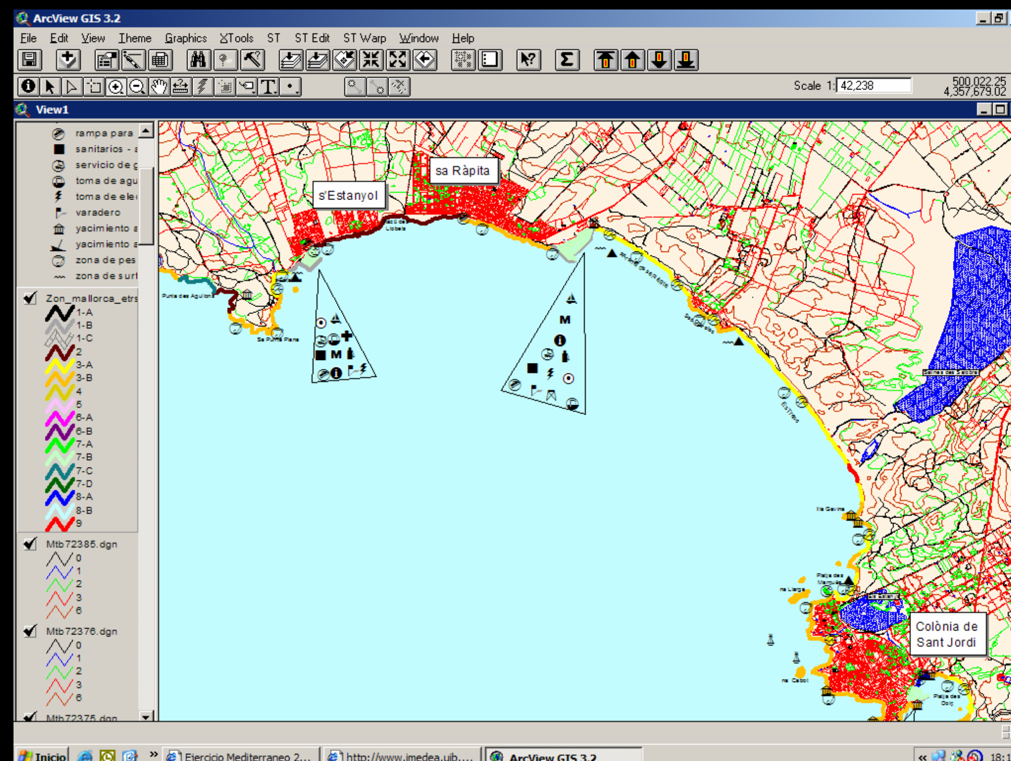




Coastal management

This system incorporates all the available information and identifies resources at risk, establishing protection priorities and identifying appropriate response.

ESI (Environmental Sensitivity Index)



TIPOS DE COSTA
(Según el Índice de Sensibilidad Ambiental -NOAA, 2002)

- Costas rocosas altas y acantilados expuestos a zonas de elevada energía
- Estructuras artificiales expuestas a zonas de elevada energía
- Costas rocosas altas con depósitos de derrubios y acumulación de bloques en la base expuestas a elevada energía
- Costas rocosas bajas expuestas
- Playas de arenas finas y de tamaño medio
- Escarpes y costas de perfil escalonado formadas por conglomerados, arenas, limos y calcarenitas
- Playas de arenas gruesas
- Playas mixtas, formadas por arenas y gravas
- Playas de gravas, cantos rodados y bloques
- Costas rocosas bajas expuestas, de perfil escalonado y cóncavo con presencia de bloques y/o playas
- Costas rocosas de altura variable localizadas en zonas de baja energía
- Estructuras artificiales localizadas en zonas de baja energía
- Costas rocosas bajas con presencia de bloques y/o playas en zonas de baja energía
- Costas rocosas altas con depósitos de derrubios en la base localizadas en zonas de baja energía
- Playas formadas por fangos y arenas en zonas de baja energía
- Playas de gravas, cantos y bloques en zonas de baja energía
- Litorales en contacto o próximos a albuferas y marismas

RECURSOS SOCIOECONÓMICOS

- Aeropuerto
- Base naval militar
- Club náutico - puerto deportivo - marina
- Duchas
- Emisario submarino
- Gasolinera - fuel
- Información meteorológica
- Mecánico motor
- Muelle - embarcadero
- Piscifactoria - centros de cría
- Playa
- Pórtico elevador
- Práctica de windsurf
- Primeros auxílios
- Puerto comercial
- Puerto pesquero
- Punto de inmersión de interés
- Rampa para embarcaciones
- Sanitarios - aseos
- Servicio de Grúa para embarcaciones
- Agua potable
- Toma de electricidad
- Varadero
- Zona de pesca recreacional
- Práctica del deporte de surf
- Yacimiento arqueológico submarino
- Yacimiento arqueológico subaéreo

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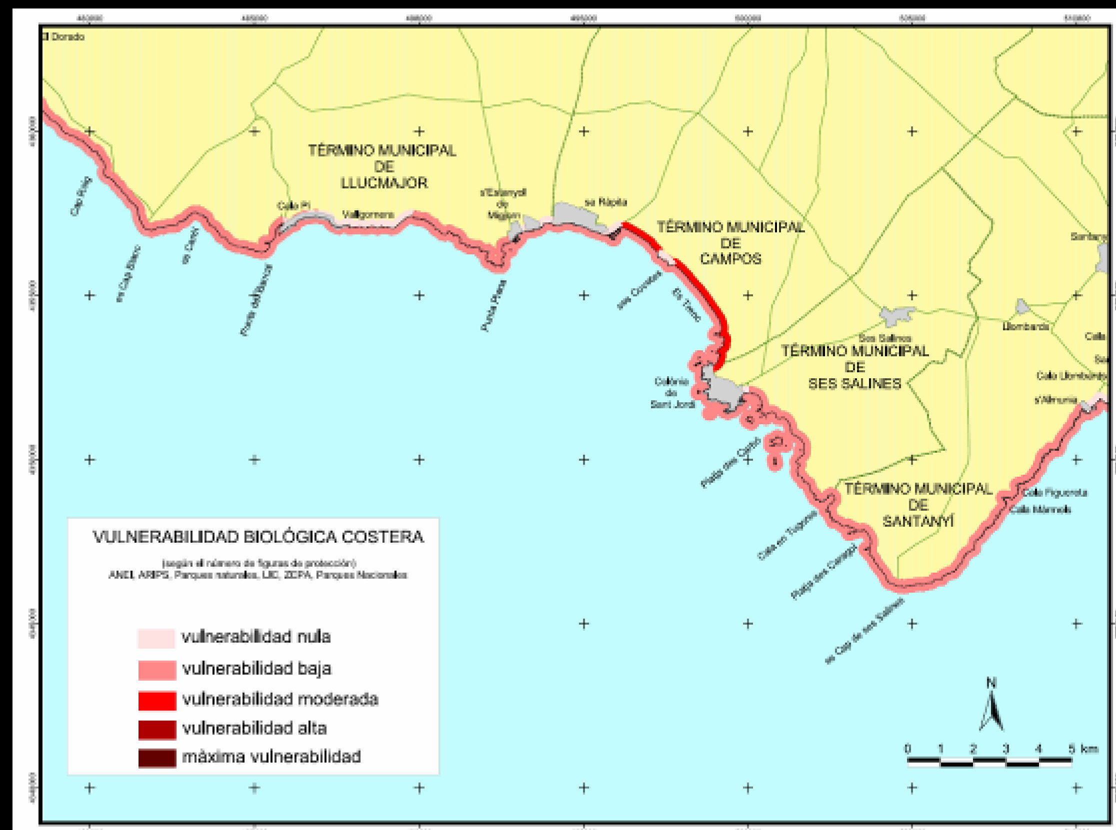
Coastal management

The Environmental Sensitivity Index (ESI) evaluates the coastal zone vulnerability combining physical, biological, geological and socio-economic parameters of the coastline into a single environmental sensitivity index to oil spills.



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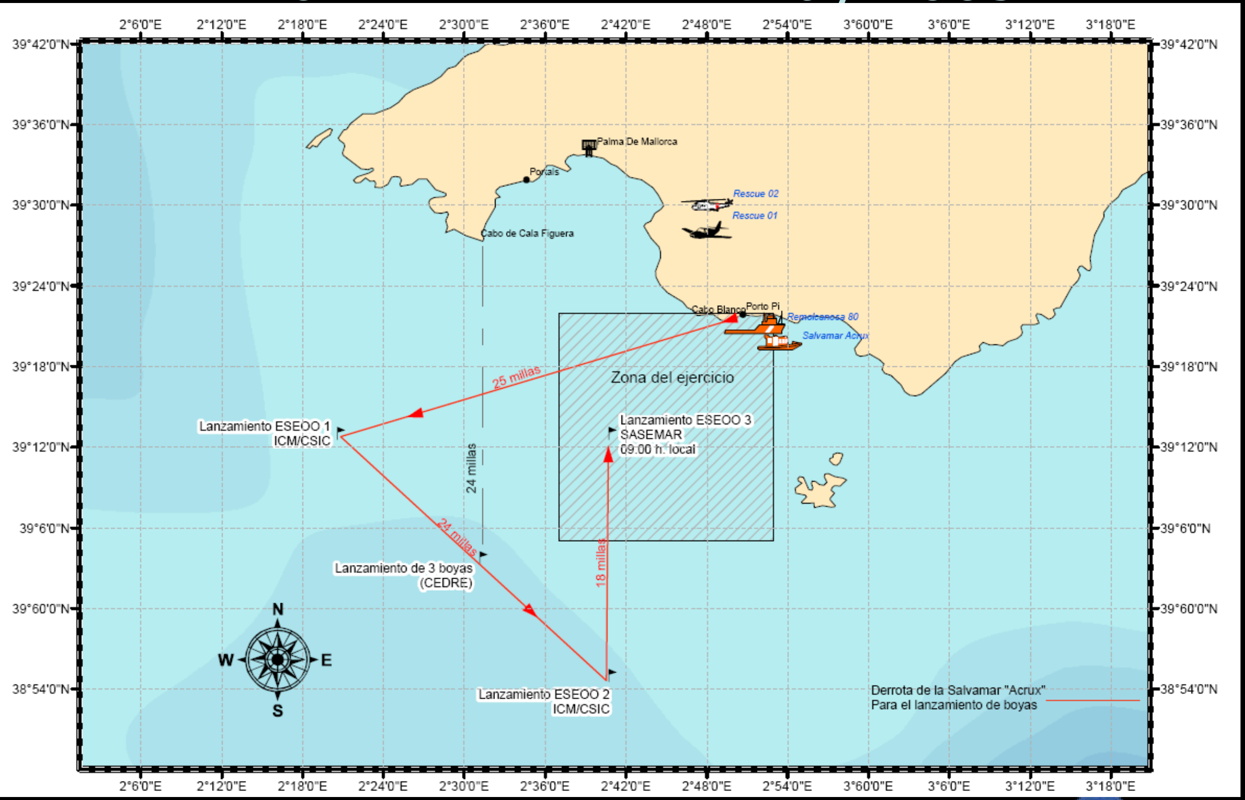
Application to Mallorca: MED05

MED05 exercise

10th – 11th – 12th May 2005



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MED05 (ESEOO-SASEMAR-MFS experiment)

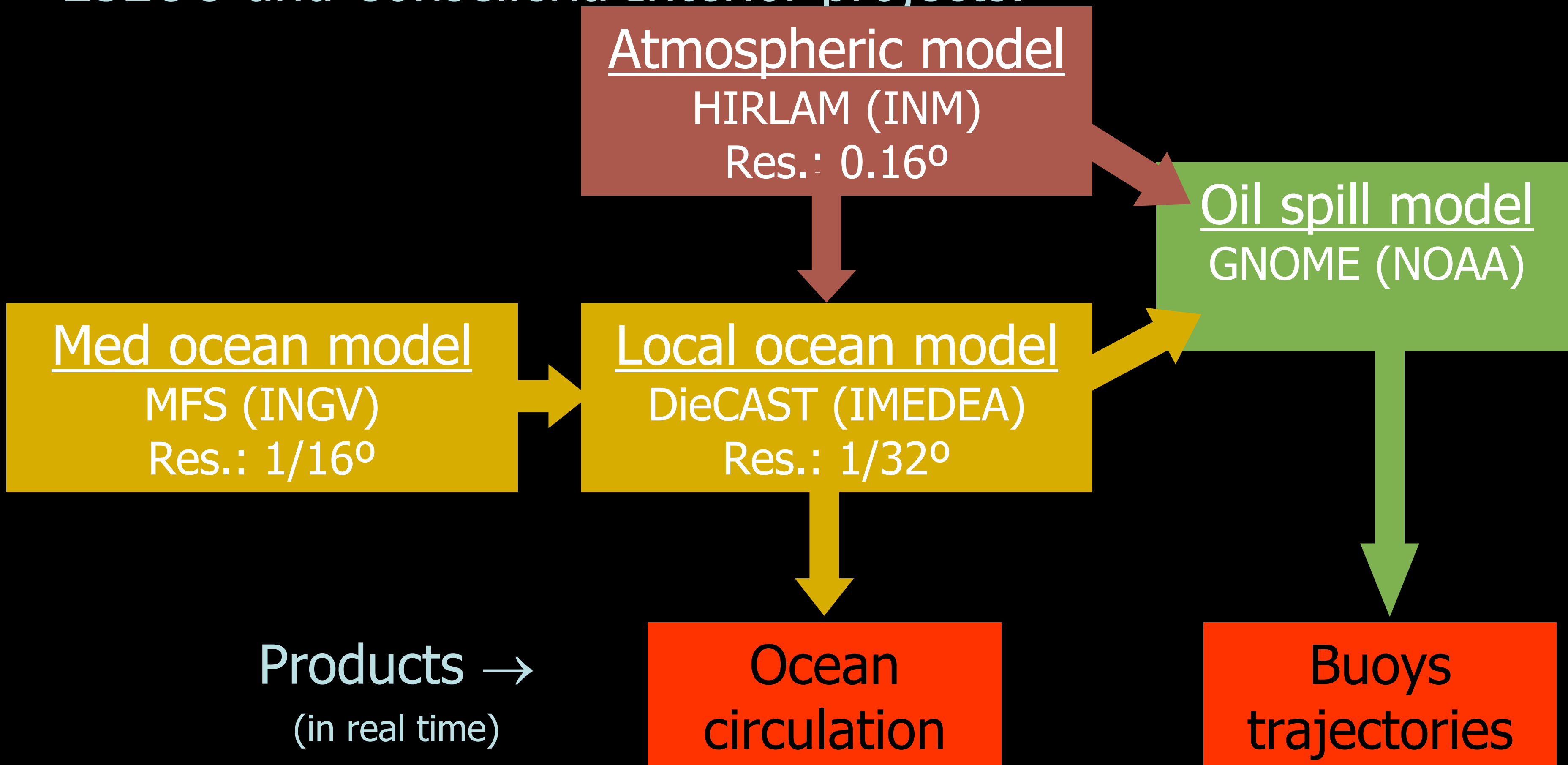
MED05 was a joint international experiment for oil spill emergencies carried out between 10-12 May 2005 in the south of Mallorca (Balearic Islands).

During the experiment, 3 drifting buoys were launched at the sea surface.

The task of IMEDEA was to forecast the ocean circulation and the buoys trajectories in real time.

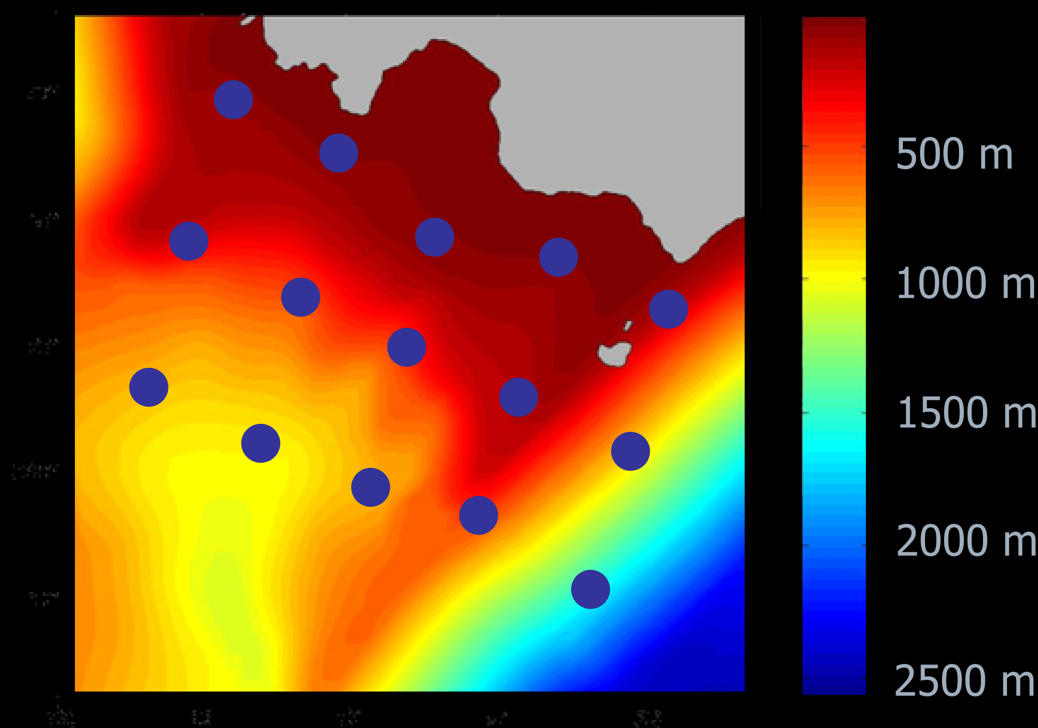
MED05: operational system

The operational system was developed in the frame of ESEOO and Conselleria Interior projects.

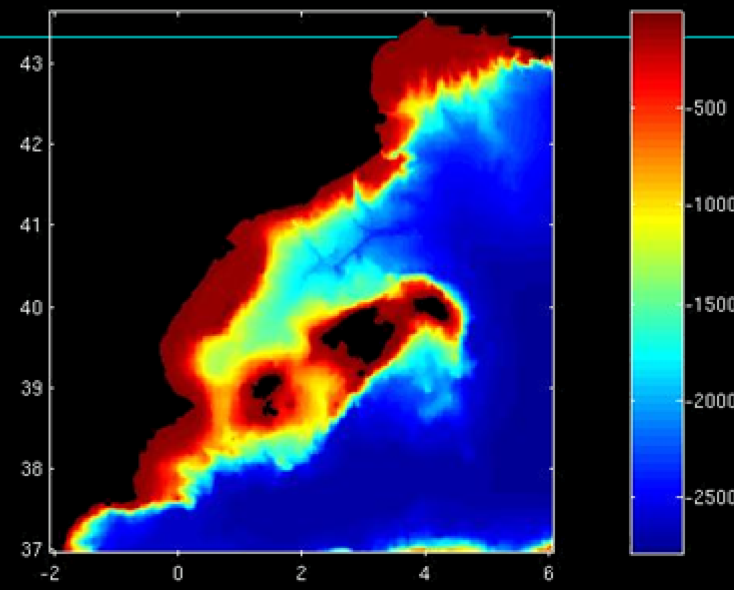


MED05: CTD stations

A CTD campaign was conducted covering the southern shelf of Mallorca on 11th May 2005, when buoys were launched.

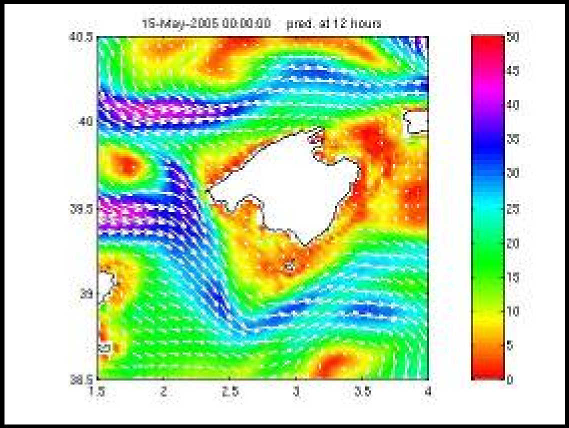


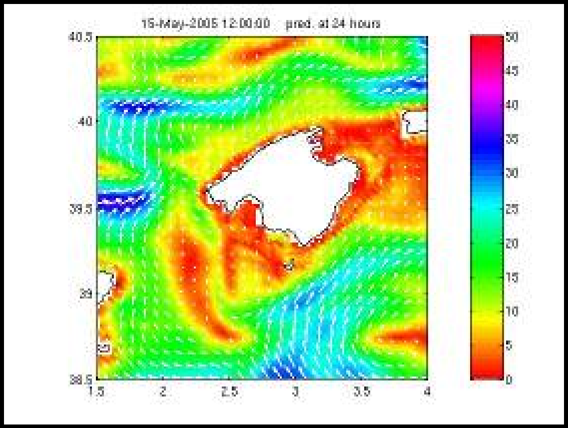
MED05: System configuration

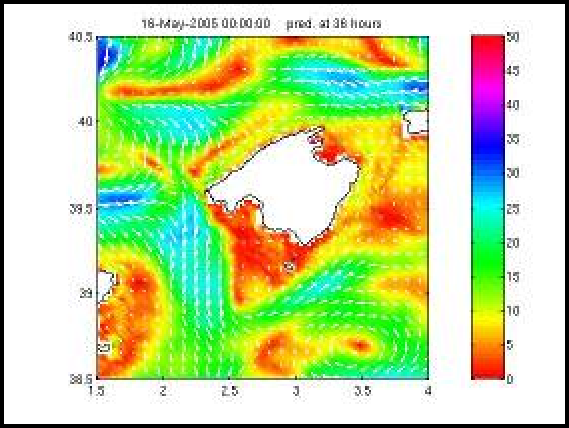


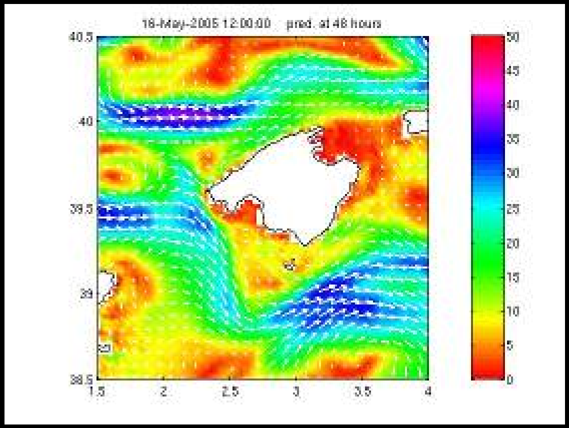
- Real time data
  - SST
  - CTD
- Atmospheric forcing
  - INM - HIRLAM (0.16º)
- Wave model
  - Puertos del Estado
- Oceanic circulation model
  - DieCAST (0.03º)
  - Nested to MFSTEP
- Oil spill model

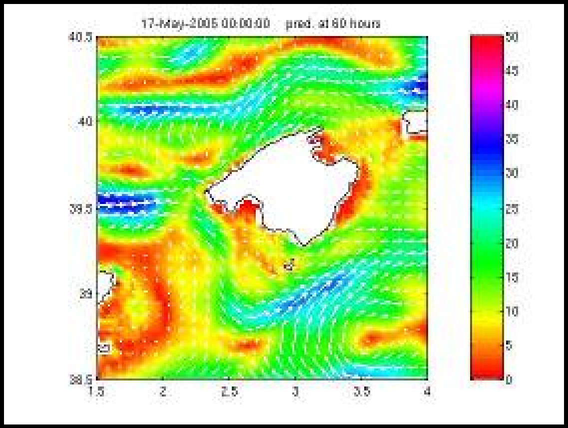
MED05: Currents

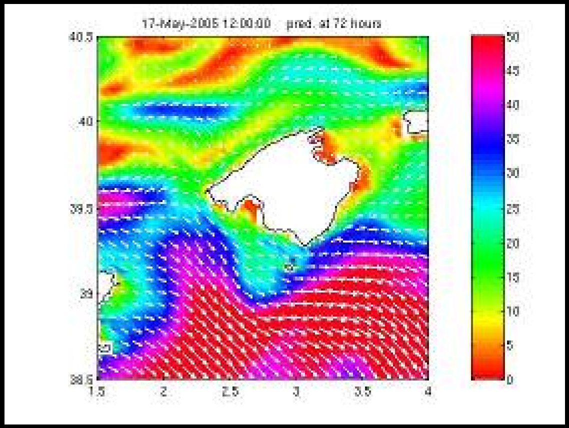












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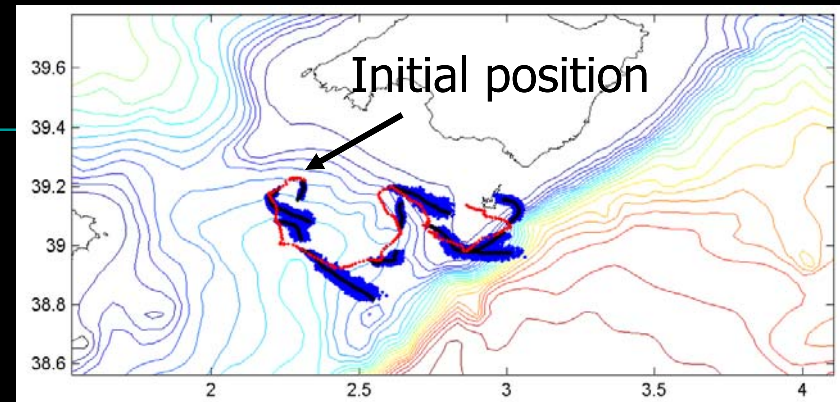
MED05: Results

Forecasts of buoys trajectories in real time

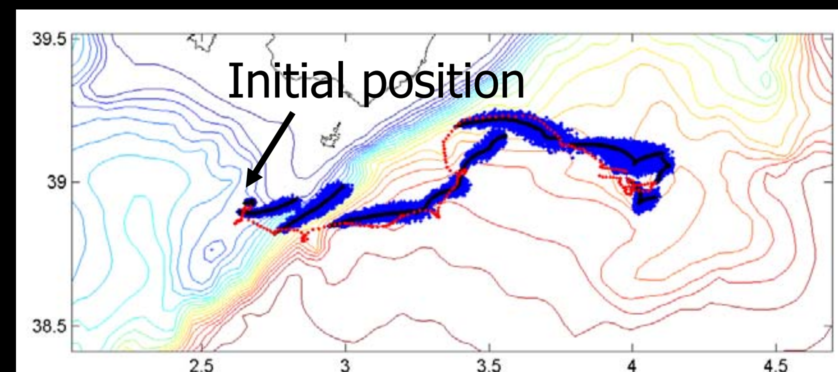
Simulations every 24 hours

— Real buoy
— Simulated buoy

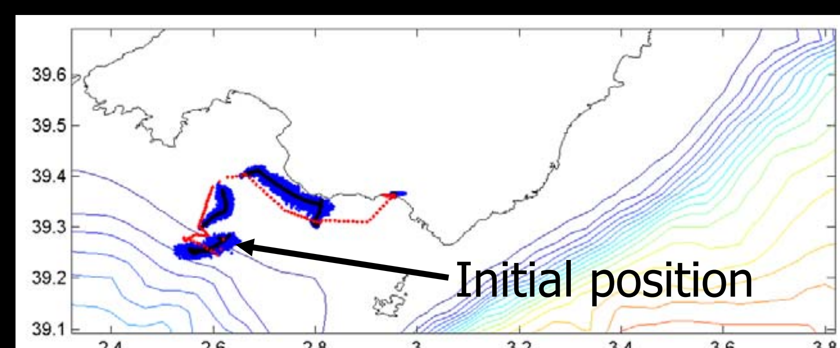
ESEOO1



ESEOO2



ESEOO3



Conclusions

- An ocean forecasting system for management of the Mediterranean coastal zone has been described.
- The system can be used for other applications like search and rescue operations.
- MED05 exercise demonstrates the capability of the system to provide real-time currents and drifting buoys predictions.
- MED05 exercise shows the importance of small scale variability in the Mediterranean Sea

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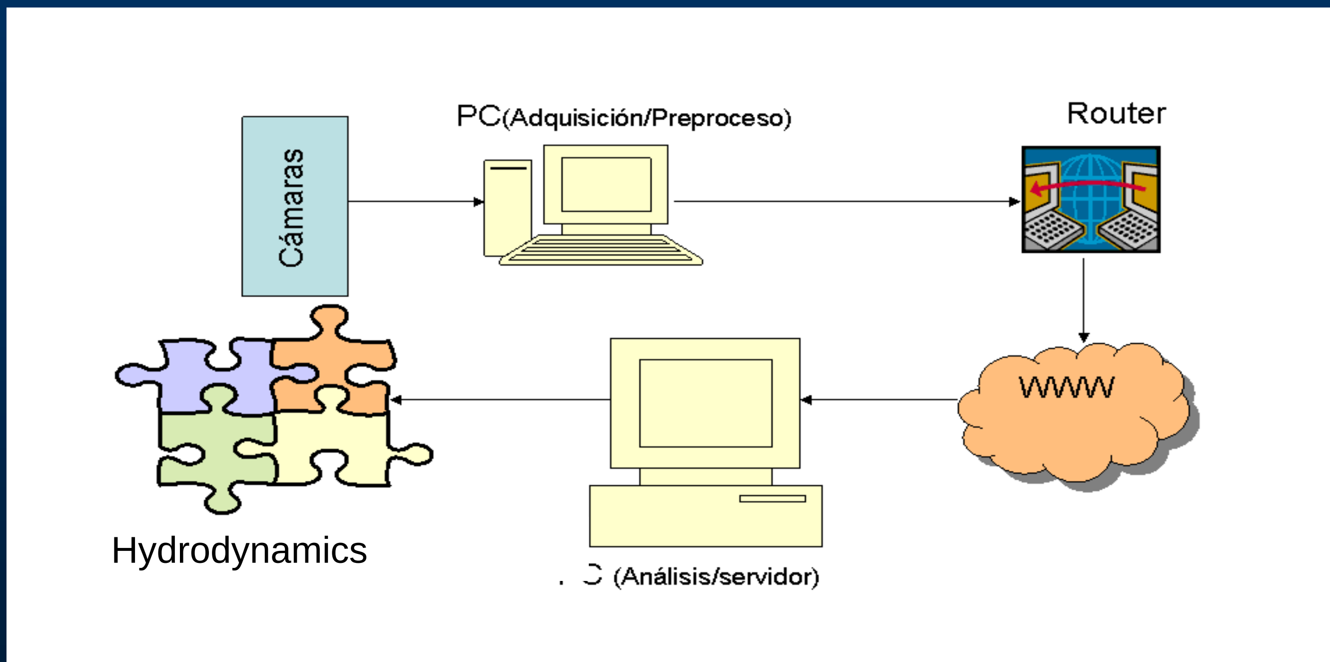
IMEDEA Remote Sensing/Camera beach monitoring system

System scheme



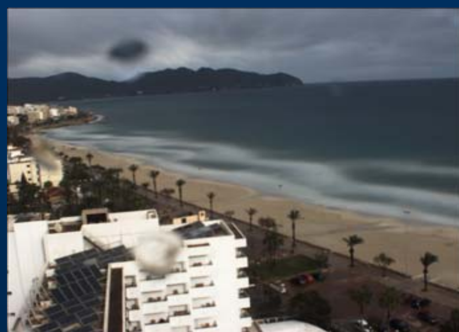
Statistical products. Mean, variance, timestacks and snapshots.
System fully developed at IMEDEA - public domain –

Presently in place at Cala Millor – Mallorca

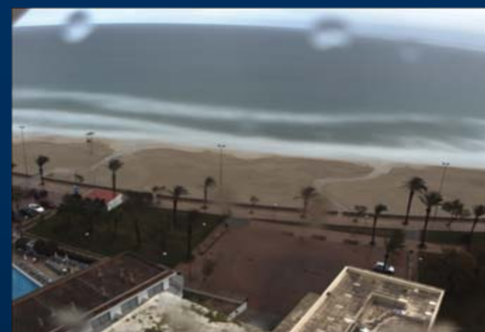
Work in progress - 2007

IMEDEA Remote Sensing / Camera beach monitoring system

The system acquires 4500 images every hour (10 minutes at 7.5 Hz) to obtain the wave climate (wave breaking, sand bars, wave direction, rip currents, etc.)

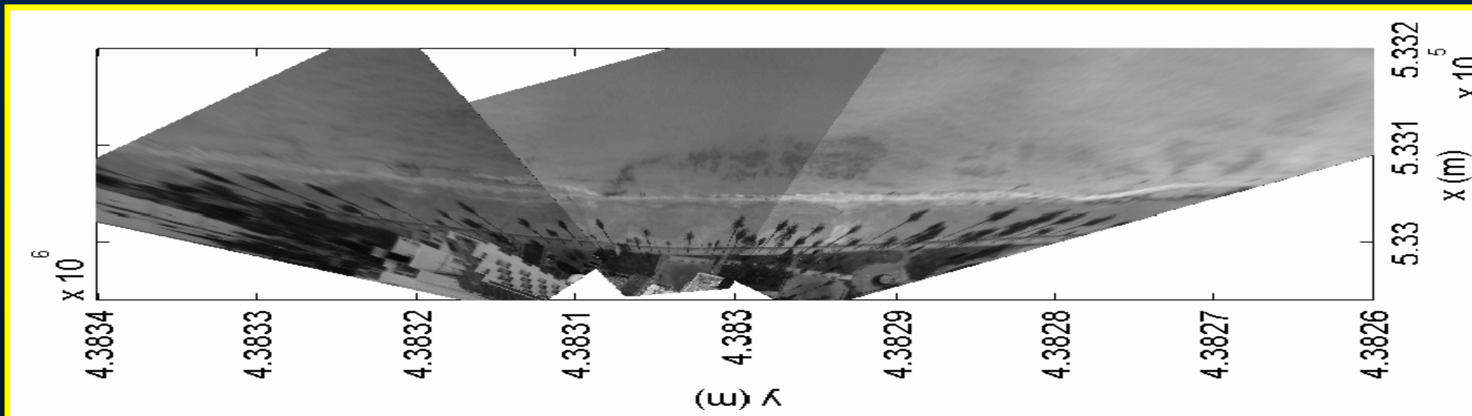


Cammera #1. North



Cammera #2 Middle

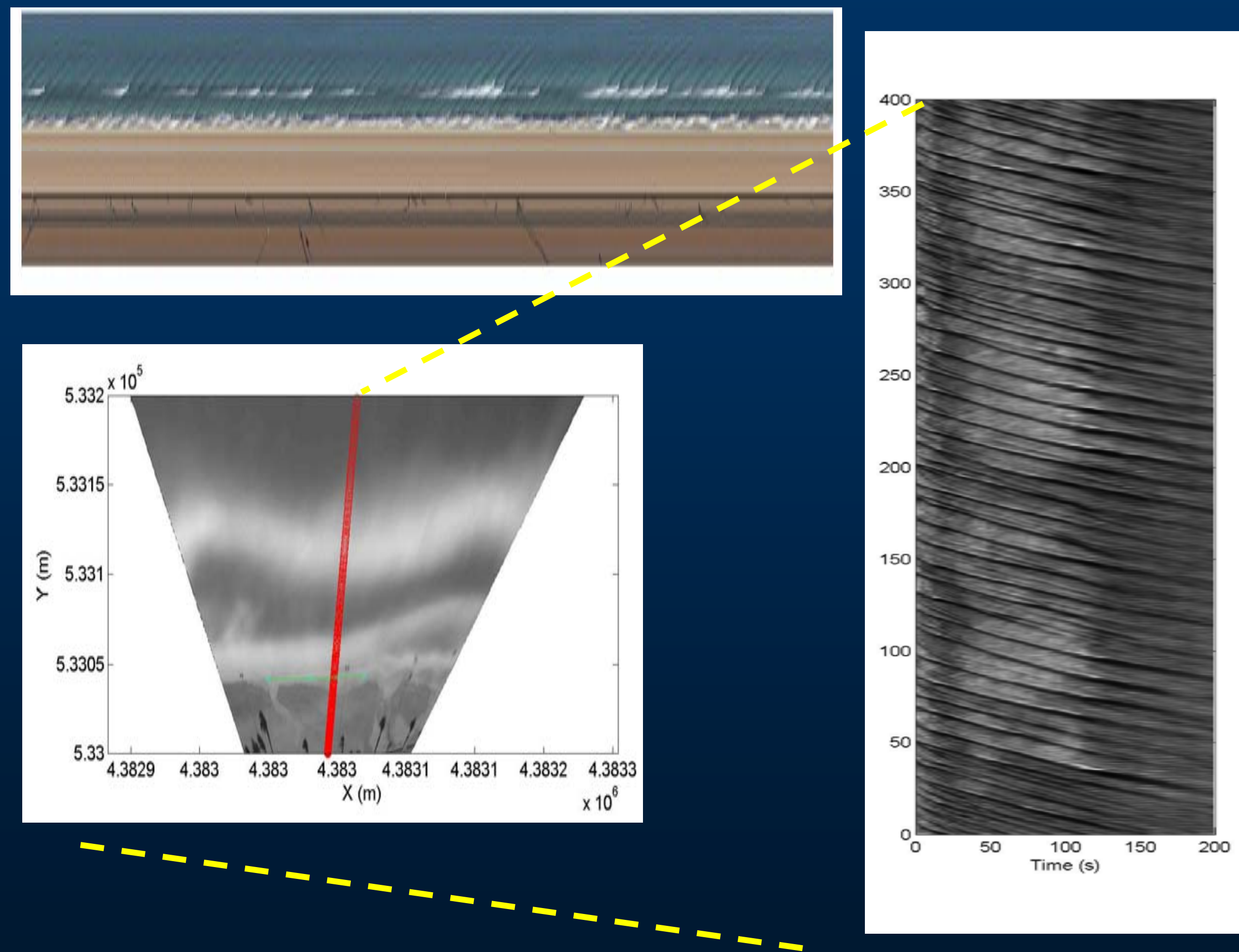
Cammera #3. South



Work in progress - 2007

IMEDEA Remote Sensing/Camera beach monitoring system

Time stacks



All pixel information at 7.5 Hz along a cross shore transect.

Wave celerity and bottom evolution. Bathymetries.

IMEDEA Long waves and seiches in harbors forecasting system

Following initial work from IMEDEA:

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 93, NO. C9, PAGES 10,797–10,803, SEPTEMBER 15, 1988

A Theoretical Study of Large Sea Level Oscillations in the Western Mediterranean

JOAQUÍN TINTORÉ, DAMIÀ GOMIS, AND SERGIO ALONSO

Departament de Fisica, Universitat de les Illes Balears, Palma de Mallorca, Spain

DONG-PING WANG

Marine Sciences Research Center, State University of New York, Stony Brook

Large sea level oscillations (up to 1-m amplitude and around 10-min period) have been observed in several bays and harbors of the western Mediterranean. These oscillations appear to be associated with short-period (10 min) atmospheric pressure fluctuations (amplitude of 1.5 mbar). Using a model with a flat shelf and a sloping-bottom harbor, we found that these oscillations were the result of a three-way resonant coupling between an atmospheric gravity wave, a coastally trapped edge wave, and the normal modes of a harbor. The amplification mechanism was studied for the harbor of Ciutadella. Good agreement between the predicted and the observed frequencies and amplitudes is found.

Work in progress - 2007

Tintoré et al., J. Geophys. Res., 1988
Monserrat and Thorpe, J.Geophys. Res., 1992
Gomis et al., J. Geophys. Res., 1993
Garcies et al., Geophys. Res., 1996.

IMEDEA Long waves and seiches in harbors forecasting system

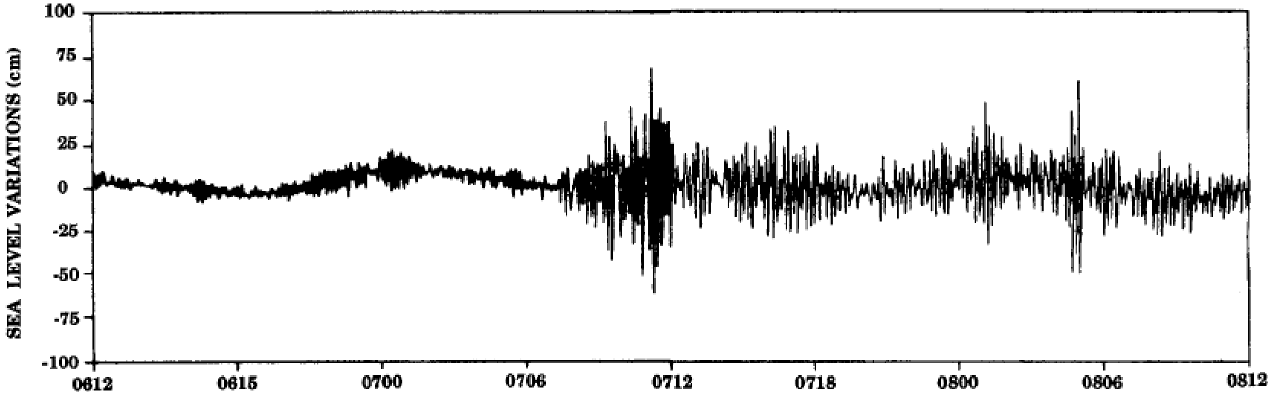


Fig. 2. Sea level record obtained in the inlet of Ciutadella, from July 6, 1988, at 1200 UT to July 8, 1988, at 1200 UT. The mean value has been subtracted, and periods shorter than 5 min have been removed by means of low-pass filtering. This record is the first instrumental evidence of the rissaga phenomenon. A more spectacular event, with sea level variat

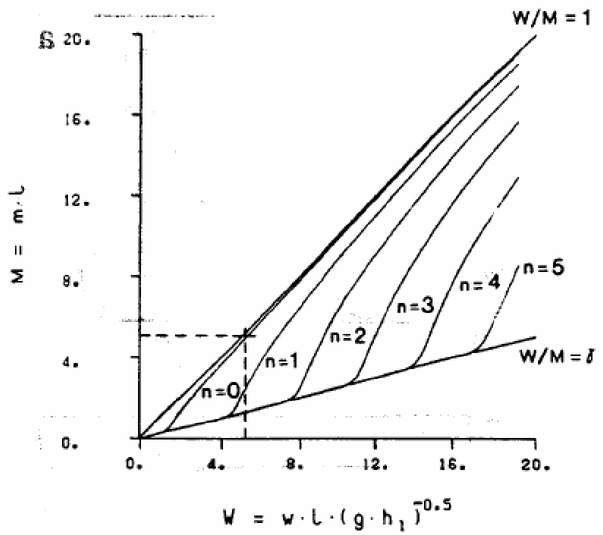


Fig. 4. Dispersion relation (in nondimensional variables) for trapped edge waves in the Balearic Sea. M is the nondimensional alongshore wavenumber, m is the alongshore wavenumber, and l is the shelf width (taken as 15 km). W is the nondimensional angular frequency, w is the angular frequency, and $\gamma = H_2/H_1 = 16$ [from *Tintoré et al.*, 1988]. Dashed lines correspond to the period of 10 min, a wavelength of 18 km, and a phase speed of 33 m s^{-1}.

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IMEDEA Long waves and seiches in harbors forecasting system

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 98, NO. C8, PAGES 14,437–14,445, AUGUST 15, 1993

Pressure-Forced Seiches of Large Amplitude in Inlets of the Balearic Islands

D. GOMIS, S. MONSERRAT, AND J. TINTORÉ

Group of Geophysical Fluid Dynamics, Departament de Física, Universitat de les Illes Balears, Palma de Mallorca, Spain

Large-amplitude harbor seiches usually occur in summer in the Balearic Islands. A significant correlation between sea level oscillations and atmospheric pressure disturbances has been found, though a proved physical mechanism to account for this atmosphere-ocean interaction is still missing. Using a flat bottom, shallow water model, we show that a direct coupling between atmospheric pressure and the free mode of an inlet is unlikely but that an oceanic wave of atmospheric origin can act as an intermediate mechanism and adequately force the inlet by resonance. The phase relationship derived from this mechanism is in good agreement with observations, provided the whole spectrum of oceanic waves is in opposite phase to the generating atmospheric disturbance. We also show that the very large oscillations observed at Ciutadella (an elongated, shallow inlet in the west coast of Menorca, Balearic Islands) can be explained in terms of the particular shape of this inlet.

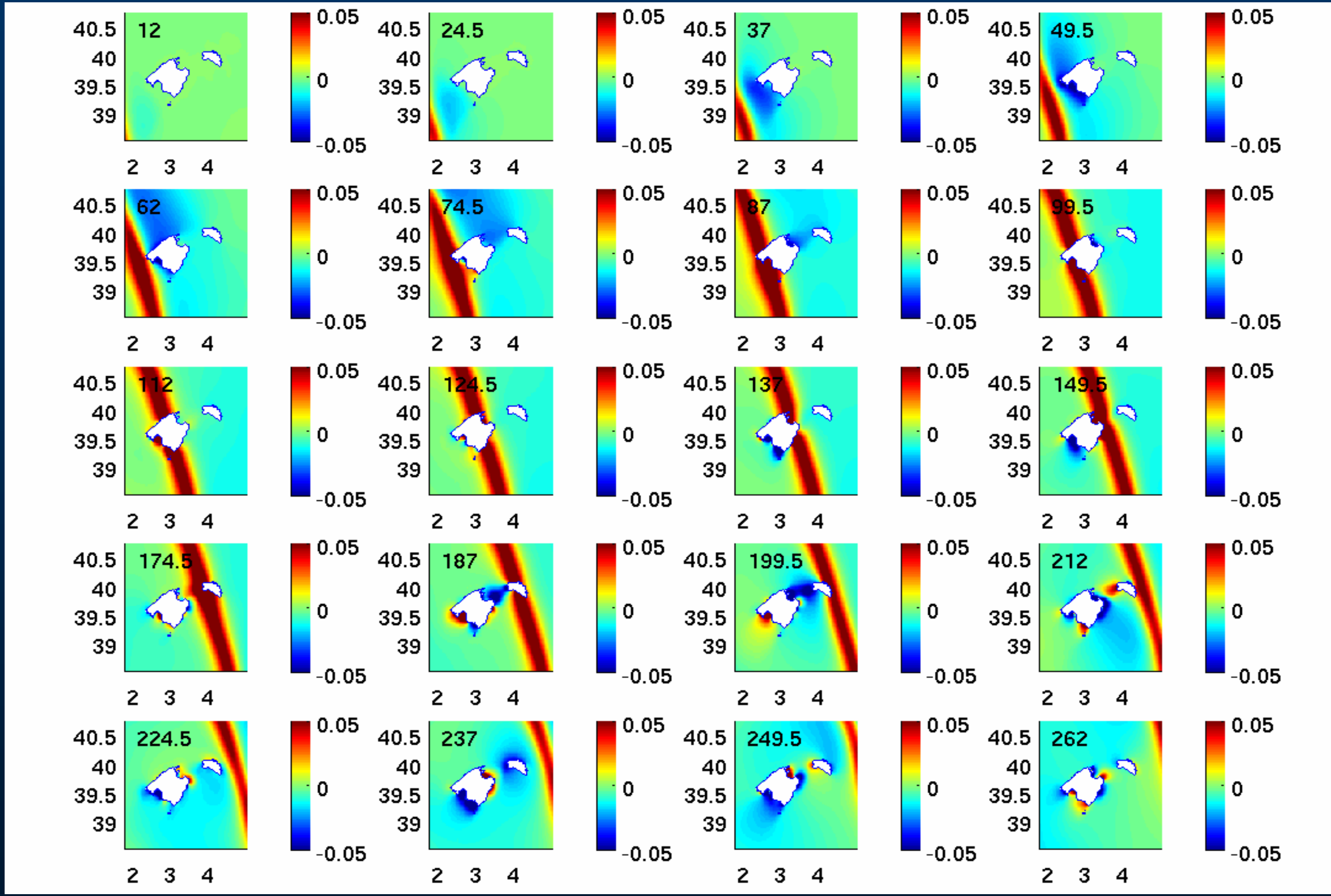
IMEDEA Long waves and seiches in harbors forecasting system

Pressure disturbance 5 hPa

Traveling at 30 m/s

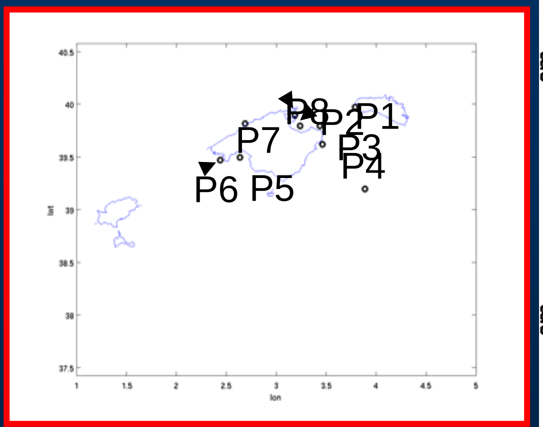
Model: ROMS

Free surface response



Propagating atmospheric disturbance and coastal ocean response

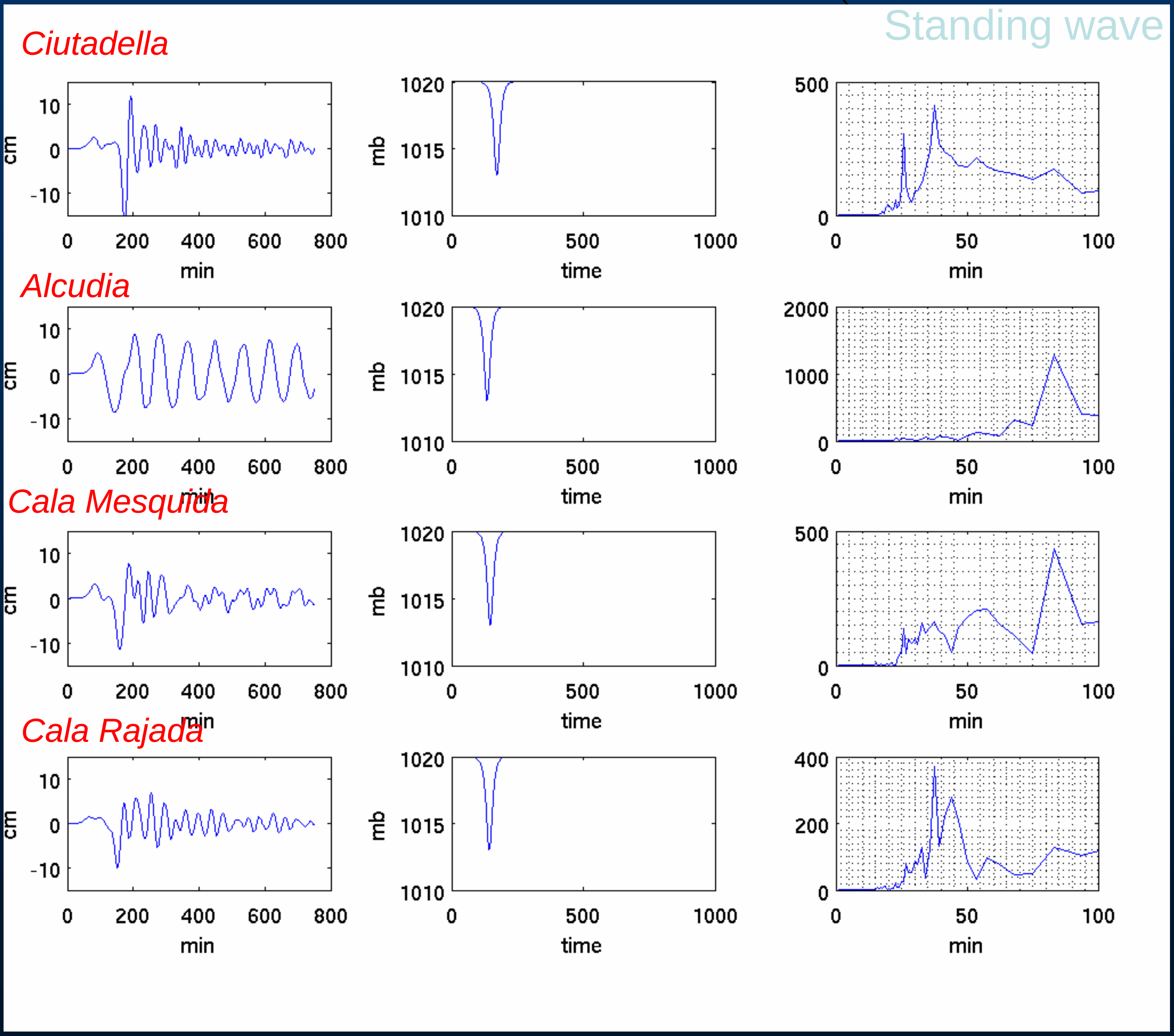
IMEDEA Long waves and seiches in harbors forecasting system



Response at different coastal locations

Identification of trapped waves

Edge waves



OUTLINE

1. IMEDEA (CSIC-UIB)
2. Physical Oceanography and Coastal Dynamics
3. Some examples of contributions to process studies
4. Pilot Balearic Islands Observing and Forecasting System (MOON) - towards Science based Operational Oceanography
5. THE FUTURE:
   - Some ideas for a Balearic Islands “Coastal” Observing and Forecasting System
   - The international context and sustainability of many coastal observing/forecasting systems
   - Cooperation, networking, sharing investments, unifying strategies, open access to facilities

Balearic Islands "Coastal" Observing and Forecasting System

The general objective is to develop a Technological Platform for Research in Operational Oceanography in the Balearic Islands with the aim to develop a singular and strategic open scientific infrastructure which will help:

- To answer the top scientific and technological challenges of the next decade related with the new capabilities in coastal ocean prediction,
- To consolidate and to support excellence research in operational oceanography
- To support the Balearic Islands as a key place for marine and coastal research.

Balearic Islands "Coastal" Observing and Forecasting System

FOR THIS, FOUR TYPE OF SPECIFIC OBJECTIVES HAVE BEEN IDENTIFIED:

I. Scientific objectives

II. Technological objectives

III. Strategic objectives

III. Transfer of knowledge

IV. Training of scientist, engineers and technicians

Balearic Islands "Coastal" Observing and Forecasting System

II. Technological objectives

- Development of new observing Technologies.
- Research in optimal monitoring strategies using new observing systems (AUV's gliders, profilers, etc.)
- Research in data transmission and package transfer.
- New strategies for data assimilation in numerical models.
- Development and implementation of operational numerical models at different scales, basin, sub-basin, regional, local and near-shore.

III. Strategic objectives

- Development of an ocean diagnostic and a coastal operational forecasting system for wave and currents in the Balearic Sea.
- Development of decision support systems for emergency response (search and rescue, oil spills, etc.)
- Development of beach security alerts and sea safety systems in real time.
- Development of a Integrated Coastal Management System

Balearic Islands "Coastal" Observing and Forecasting System

III. Transfer of knowledge

- Institutional coordination (different administrations and agencies).
- Provide information and formation of the coastal and marine environment.
- Increase scientific divulgation in coastal and marine oceanography at all levels of end-users.

IV. Training of scientist, engineers and technicians

- Programme for High School students.
- Programme for undergraduate students. Summer Research program.
- Programme for graduate students. PhD grants and research program.
- Programme for Technicians. Courses in marine instrumentation and marine technology
- Programme for postdoctoral research assistants.
- Program for international visiting scientists, engineers and technicians.
- International school in Operational Oceanography (every 2 years). .

Balearic Islands "Coastal" Observing and Forecasting System

The **general** **scientific objective** of this new infrastructure is to advance in the understanding of the physical and interdisciplinary processes as well as their non linear interactions directly related with Operational Oceanography in the coastal zone.

Thus, to detect and quantify changes in systems and ecosystems and understand the key mechanism controlling their changes with the aim to forecast their evolution under different scenarios.

Besides the scientific objective, this infrastructure will be able to perform a continuous multidisciplinary and integrated a **monitoring** of coastal variability in particular focussed in changes related to climate change as well as the development of **new tools and technologies**.

Balearic Islands "Coastal" Observing and Forecasting System

Scientific Objectives: Coastal Ocean – 3 areas:

- Near shore hydrodynamics and morpho-dynamics. Wave-current interactions and sediment transport.

2) Oceanography in the coastal, shelf and open seas. Marine resources sustainability.

3) Climate impact and climate variability effects in the Mediterranean Sea. Regional variability and ecosystems variability.

Balearic Islands “Coastal” Observing and Forecasting System

1) **Near shore hydrodynamics and morphodynamics. Wave-current interactions and sediment transport.**

- ***Coastal Hydrodynamics.***
  - Wave propagation from deep to shallow water
  - Hydrodynamic models of coastal zones
  - Wave-current interaction modelling
  - Numerical models for advection/diffusion of contaminants.
- ***Sediment transport and boundary layer***
  - Wave current turbulent bottom boundary layer
  - Bottom energy damping
- ***Beach morphodynamics***
  - Beach erosion/tilting and coastal variability
  - Rip currents and beach safety
- ***Shelf slope exchanges***
  - Shelf slope two way nesting models

Balearic Islands "Coastal" Observing and Forecasting System

2) Oceanography in the coastal, shelf and open seas. Marine resources sustainability.

- **Coastal variability and operational oceanography research in a local and regional scale.**
  - Diagnostic and forecasting of the Balearic Sea Variability.
  - Satellite oceanography
  - Development of a Regional Operational Oceanography System based in real time observations and modelling.
- **Mesoscale dynamics and fronts: processes, interactions, observations and modelling.**
  - Balearic front characterization, their variability and role in the North-South water masses changes in the Mediterranean Sea.
  - Characterization of the shelf slope exchanges. The role of submarine canyons in coastal water renewal.
- **Marine protected areas and global change**
  - Design and management of new protected areas based on connectivity studies.
  - Global change effects in the Western Mediterranean Sea.

Balearic Islands "Coastal" Observing and Forecasting System

3) Climate impact and climate variability effects in the Mediterranean Sea. Regional variability and ecosystems variability.

- **Mediterranean circulation in front of global change scenarios. Impact on ecosystems.**
  - Western Mediterranean scenarios.
  - Scenarios and variability of ecosystems.

- **Mesoscale and sub-mesoscale processes and their contribution in the 3d interanual variability of the Mediterranean upper ocean.**
  - Mesoscale variability. Variability scales.

Elementos principales

La Plataforma se concibe como un sistema integrado en el que se combinan 3 grandes sistemas:

(1) Sistema de observación (adquisición y transmisión de datos en tiempo real y su gestión),

(2) Sistema de predicción numérica conjugando modelos y asimilación de datos en diferentes modelos y

(3) Sistema de gestión de datos y

Elementos principales

1) Sistema de Observación: monitorización continua y en tiempo real del litoral

Plataformas fijas

Boyas océano-meteorológicas
Estaciones de monitorización costeras (incluyendo playas, tipo de fondo y calidad/variabilidad aguas litorales)
Radares costeros (corrientes y oleaje)

Plataformas móviles

Buque de investigación costero con equipamiento científico muestreo zonas litorales (<1.000 m)
Nuevos vehículos autónomos de muestro tridimensional: AUV’s, gliders, boyas a la deriva
Sistema marino y terrestre de caracterización de playas (emergida y sumergida)

Teledetección

Satélites de observación y monitorización aguas litorales
Nuevo sistema de monitorización de playas

2) Sistema de Predicción Numérica: asimilación de datos y predicción operacional en el litoral

Predicción de corrientes: oceanografía operacional, seguridad navegación, vertidos, náufragos, etc.

Escala regional, aguas del Mediterráneo occidental y del Mar Balear
Escala local, aguas del litoral Balear

Predicción variabilidad de los ecosistemas: sistemas acoplados físico-biológicos Mediterráneo

Escala regional, flujos biogeoquímicos y acoplamientos físico-biológicos Mediterráneo
Escala local (calidad de aguas litoral Islas Baleares)

Predicción de oleaje, propagación en aguas someras

Escala regional: modelos de propagación de Tsunamis
Escala local: corrientes y oleaje en playas, seguridad zonas baño

3) Sistema de gestión de datos y transferencia de conocimiento: transmisión de datos (TIC’s), archivo, usuarios, educación

Red de comunicaciones

Transmisión de datos (cable, radio, GSM, satélite, etc.), recepción, control calidad

Infraestructuras de Datos Espaciales

Calidad y fiabilidad datos
Acceso y disponibilidad distintos niveles de usuarios (expertos, divulgación, usuarios, sociedad)

Transferencia de conocimiento, usuarios finales, educación, divulgación, diseño de productos específicos usuarios finales, herramientas, innovación

OUTLINE

1. IMEDEA (CSIC-UIB)
2. Physical Oceanography and Coastal Dynamics
3. Some examples of contributions to process studies
4. Pilot Balearic Islands Observing and Forecasting System (MOON) - towards Science based Operational Oceanography
5. THE FUTURE:
   - Some ideas for a Balearic Islands "Coastal" Observing and Forecasting System
   - The international context and sustainability of many coastal observing/forecasting systems
   - Cooperation, networking, sharing investments, unifying strategies, open access to facilities

THANK YOU