



# The Portuguese Forecasting System

**MOHID**

 Water Modelling System

Instituto Superior Técnico  
Lisbon - Portugal

**Guillaume Riflet**, POL workshop, 22nd – 24th October, Mallorca



# Contents

- The portuguese in the ECOOP framework
- Observation system
- Regional forecasting systems
- Local models



Who we are



MARETEC – Instituto Superior  
Técnico, Lisbon

Research unit specialized  
in the numerical modeling  
of marine systems



# Who we are

## Development of a forecasting tool of the marine environment

- Universidade Técnica de Lisboa
- Universidade de Coimbra
- Universidade do Algarve







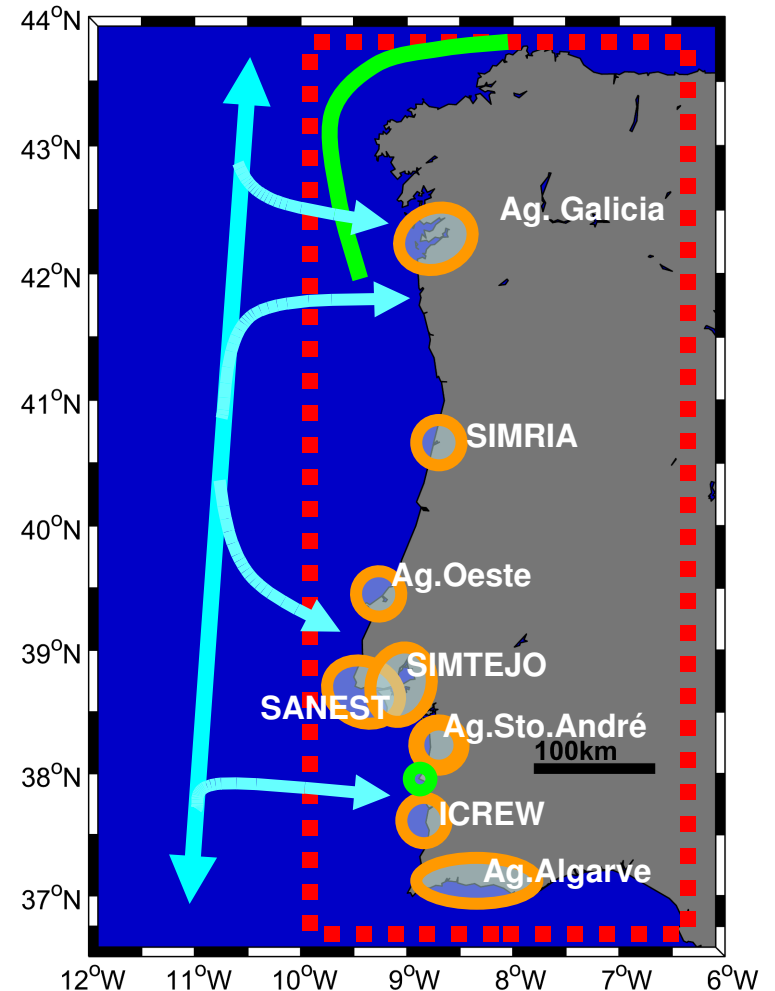
# Who are the end-users?

- Bathing and recreation
- Navigation
- Fisheries
- Aquaculture
- Human occupation
- Industry and agriculture
- Energy
- The natural ecosystem



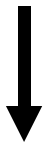
# Overview

-  **Waste waters**
-  **Pollutant dispersion/Oil spills**
-  **Navigation (debris, containers, people)**
-  **Monitoring (eutrophication, HAB's)**



# Objectives

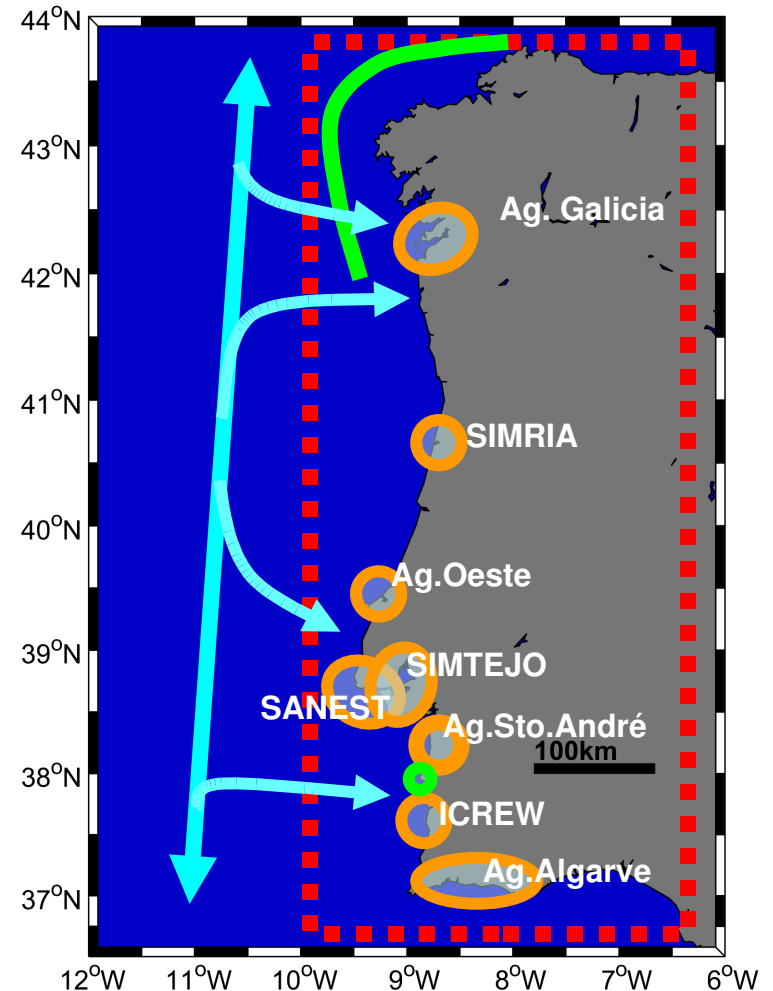
Build coastal  
management products  
for end-users



National authorities, institutes, public and  
private companies, researchers

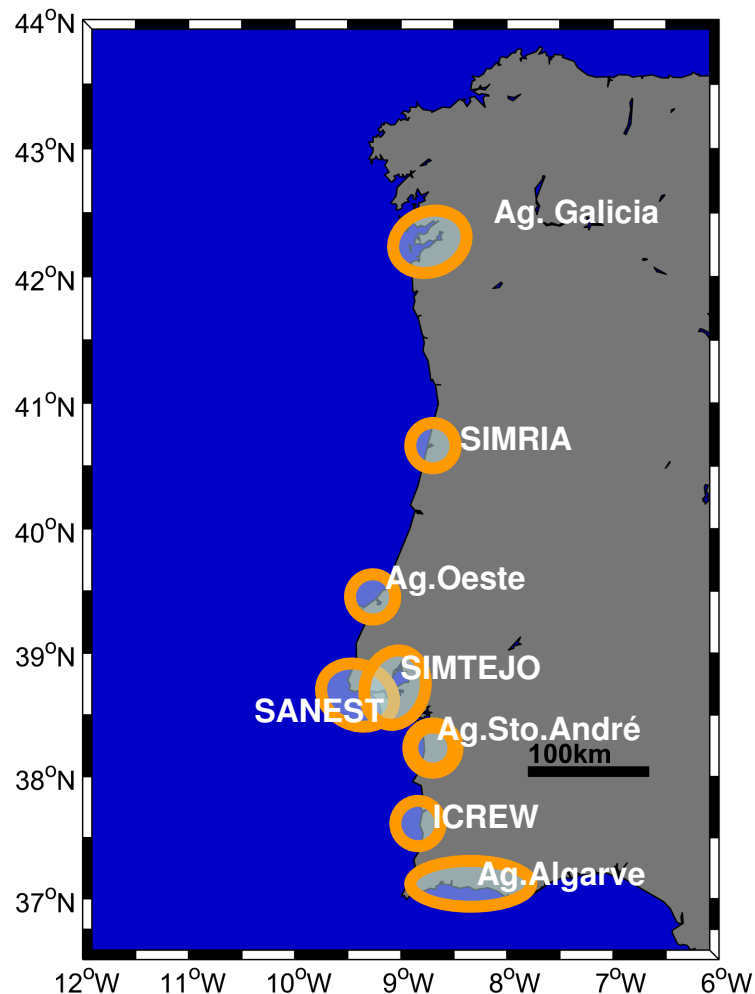


Regional and mostly local applications





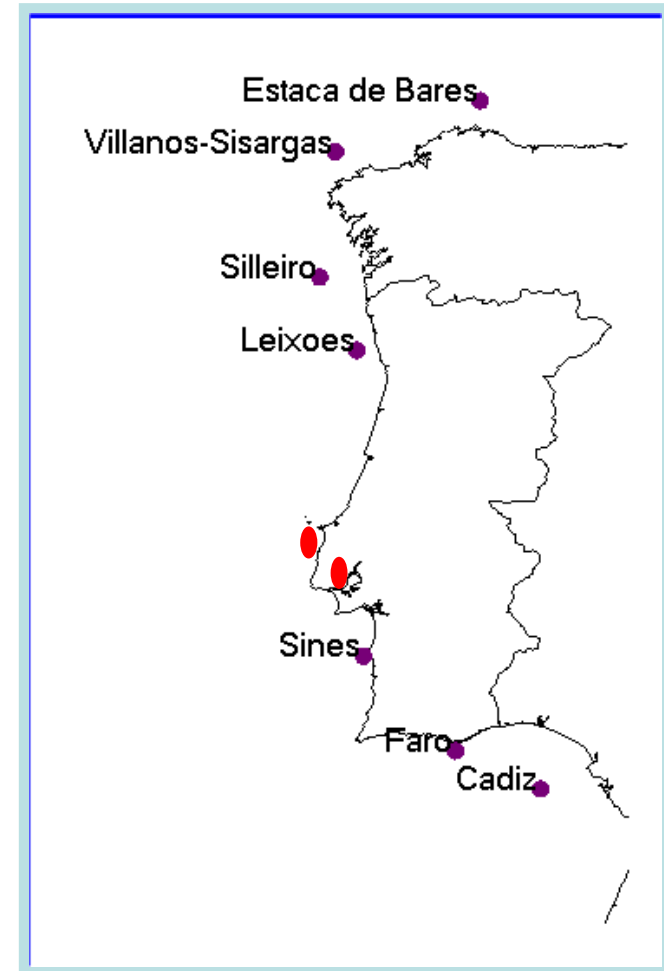
# Observation – field data



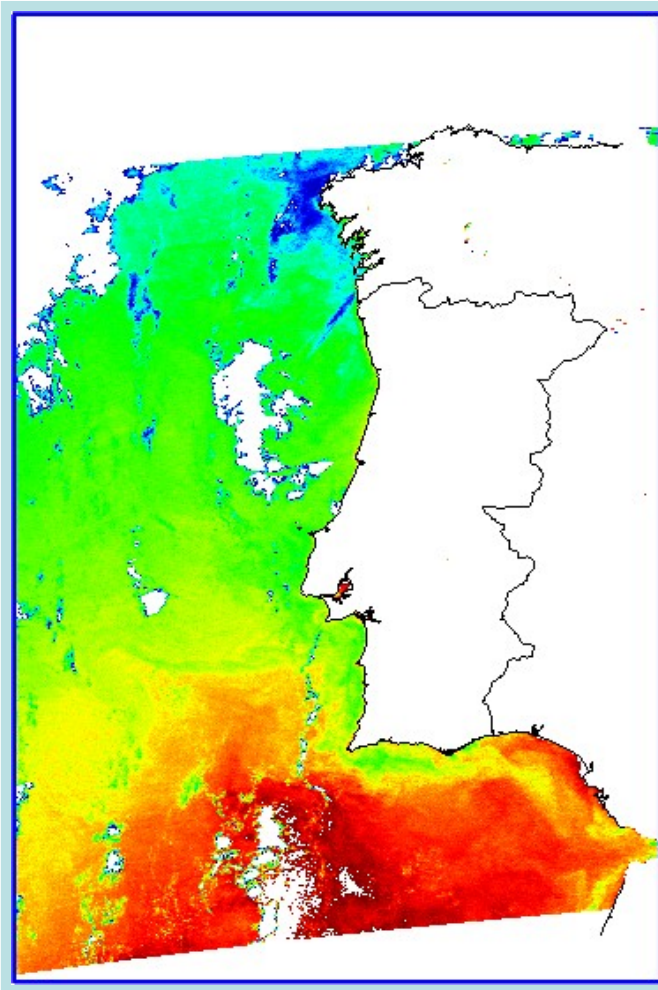


# Observation – stations, buoys

- Instituto Hidrográfico buoys which are setup in harbours (Lisbon, Sines, Leixões, Oporto) that provide waves direction and intensity;
- Meteorological stations (Guia de Cascais, Nazaré);
- Buoys which measure freshwater inputs (Tagus, Mondego, Guadiana, INAG data);



# Observation – remote-sensing data

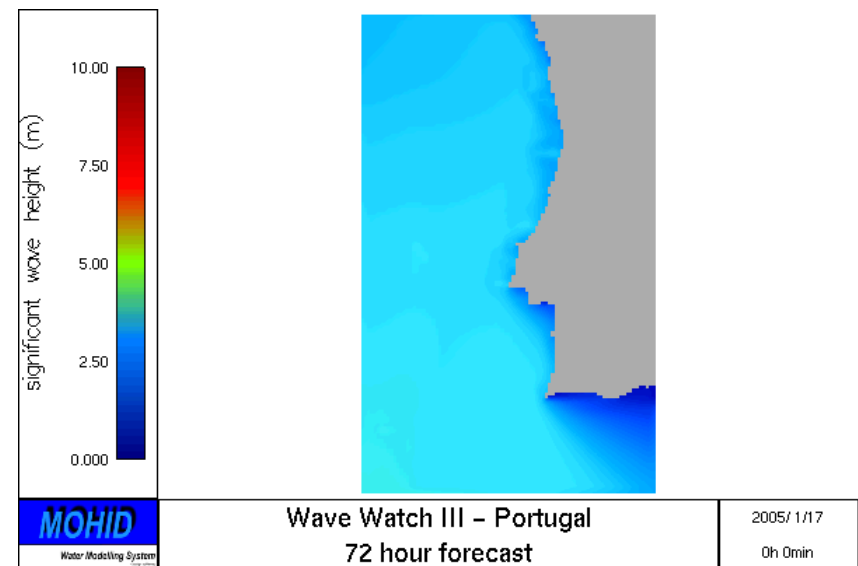
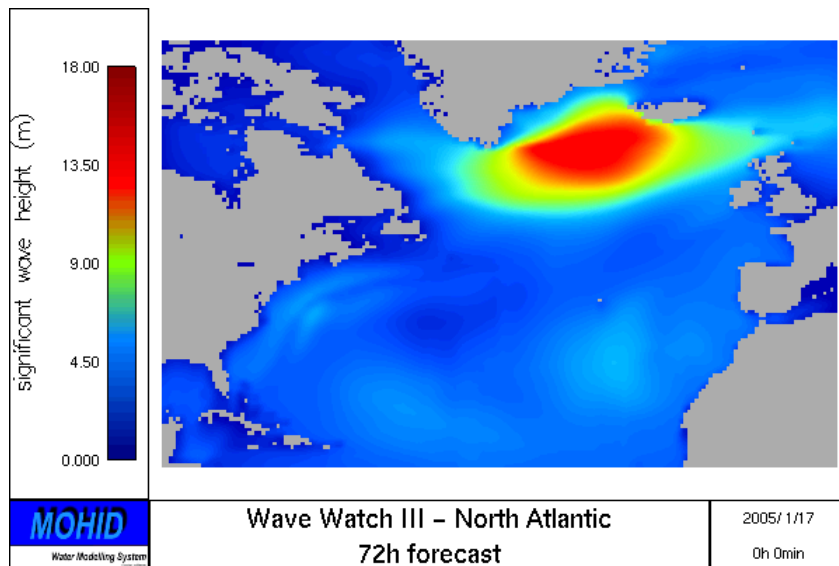


- MODIS
- SeaWifs

# Regional scale models

## Local models need regional models

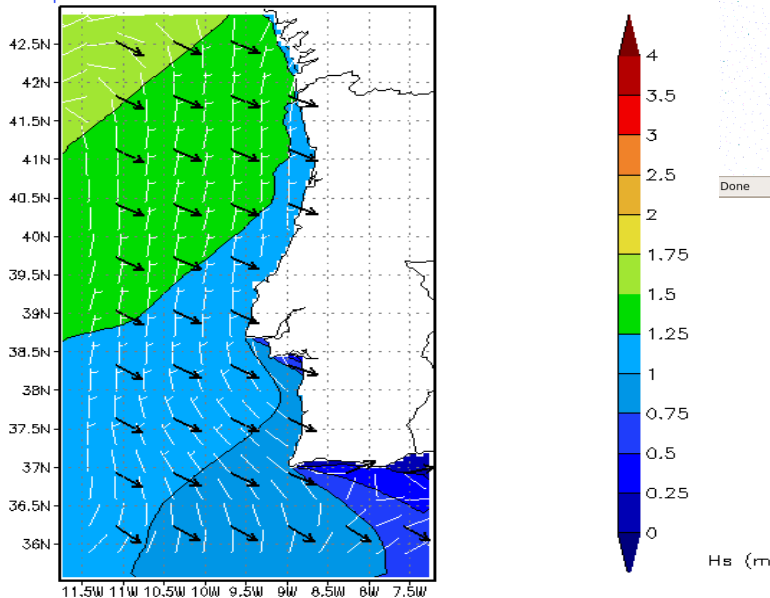
- ocean and atmospheric circulation
- waves



# Regional scale models

Wave model WW3, 3 day forecast.  
objective: couple to swan into local models - harbours.

Wave forecast for 09Z22OCT2007  
significant wave height (m), Arrows: wave direction, Barbs: wind velocity and direction  
Instituto Superior Técnico - Universidade Técnica de Lisboa

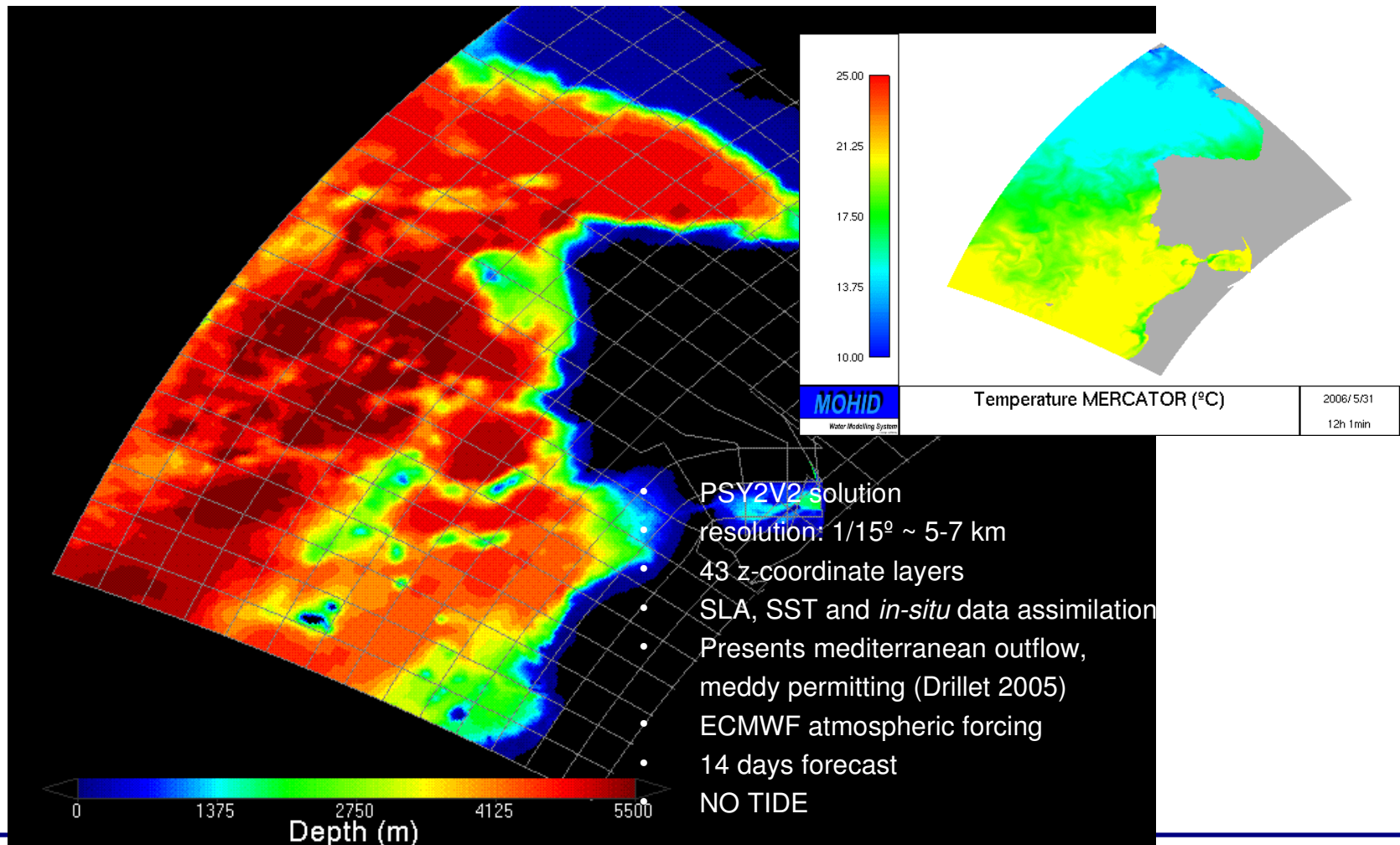


The screenshot shows a web browser window displaying the website 'IST - Wave Forecast for the Portuguese Coast'. The URL is 'http://www.maretec.mohid.com/ww3/'. The page features a navigation menu with links for Home, Forecast, Learn more, Links, Acknowledgements, and Contact Information. The main content area is titled 'Wave Forecast for the Portuguese Coast' and includes a brief description of the forecast. To the right, there is a 'What's New' section with bullet points and a 'Future work' section with bullet points. The browser's status bar at the bottom shows 'Done' and 'Open Notebook'.



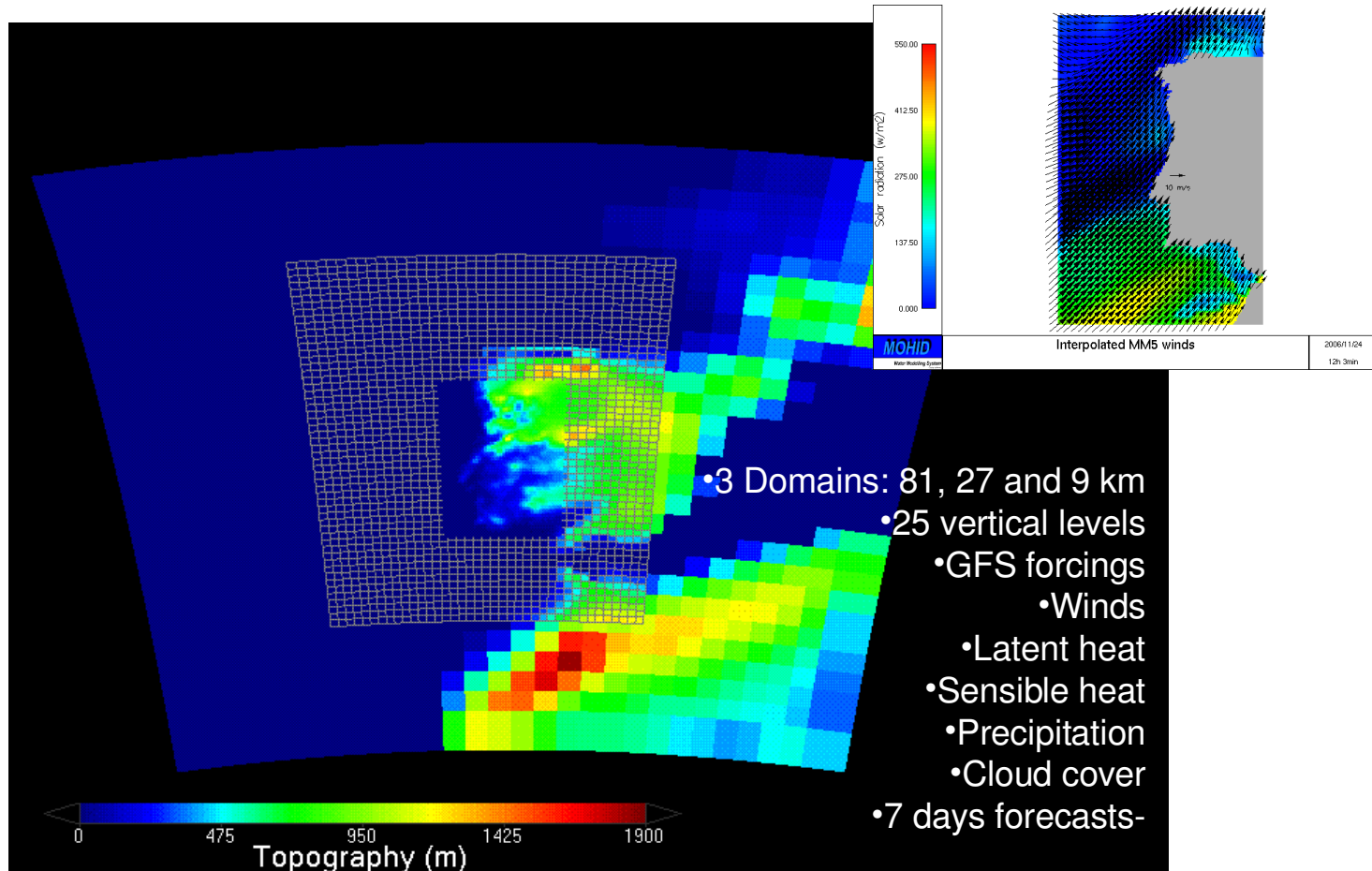
# Regional scale models

Hydrodynamical operational modeling of portuguese coast.



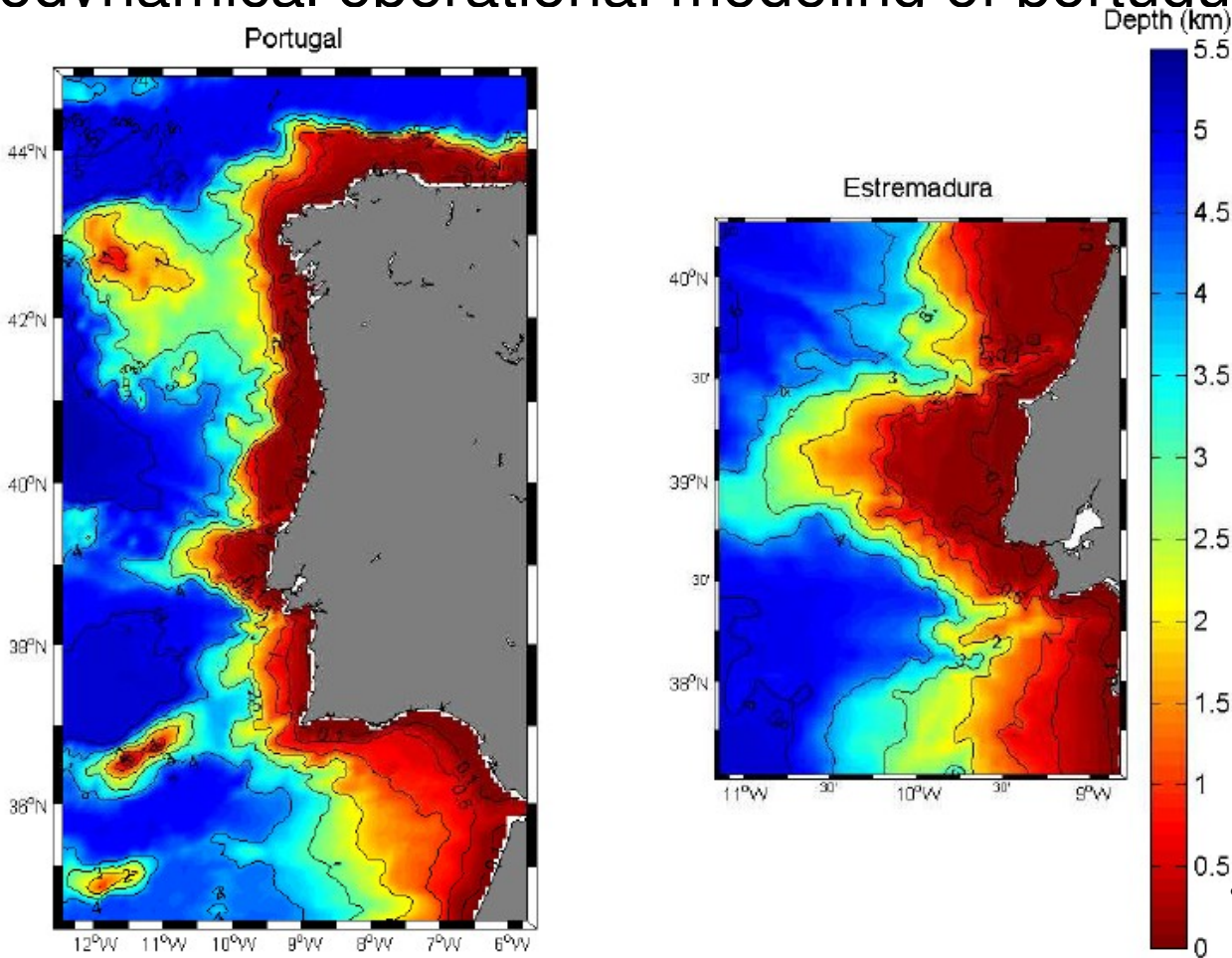
# Regional scale models

Hydrodynamical operational modeling of portuguese coast.



# Regional scale models

## Hydrodynamical operational modelina of portuguese coast.

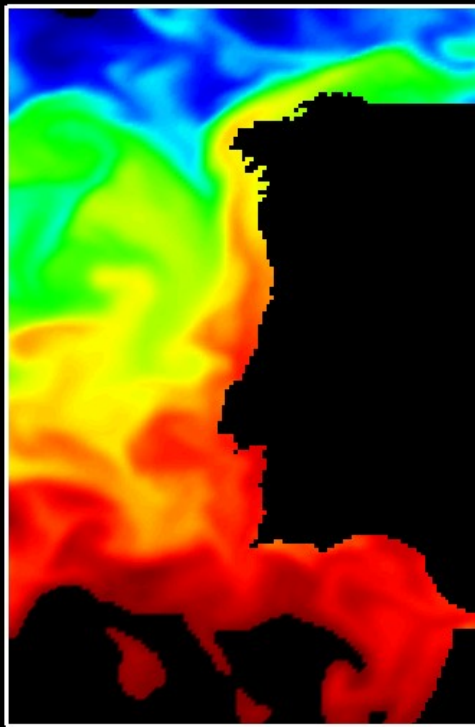


- One 2D domain (for recreating tide)
- Two 3D Domains:
  - 0.06° and 0.02°
  - 42 layers
- ETOPO2' baseline data interpolation
- 2D and 3D  $[-12.6^{\circ}, -5.5^{\circ}] \times [34.4^{\circ} 45^{\circ}] \text{N}$
- $[-11.2^{\circ}, -8.8^{\circ}] \times [37.5^{\circ} 40.3^{\circ}] \text{N}$

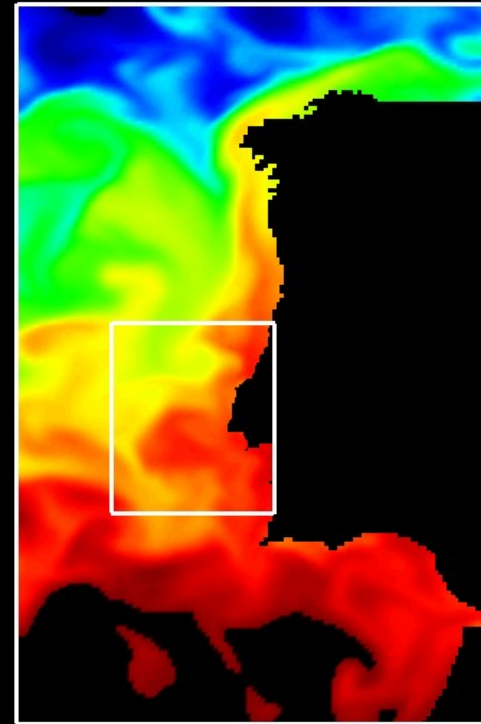


# Regional scale models

Hydrodynamical operational modeling of portuguese coast.



MOHID  
Water Modelling System  
Interpolated Mercator solution  
Temperature at the surface



MOHID  
Water Modelling System  
Nested models with atmospheric forcing  
Temperature at the surface

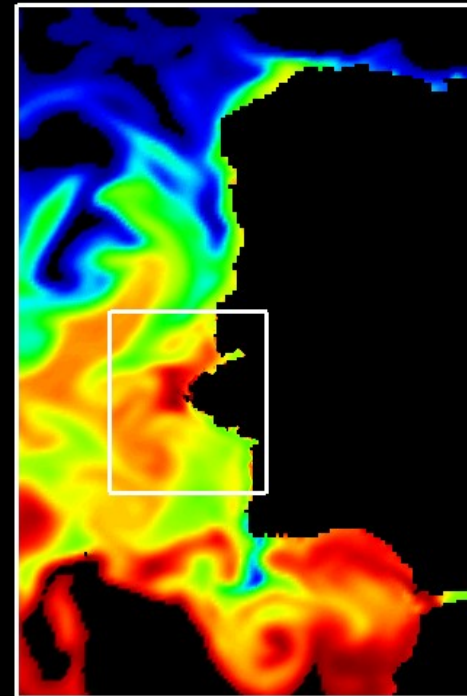
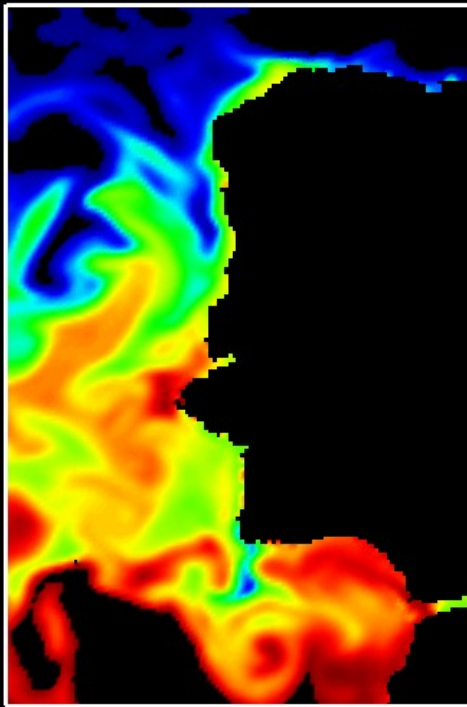


01-12-2006  
12:00



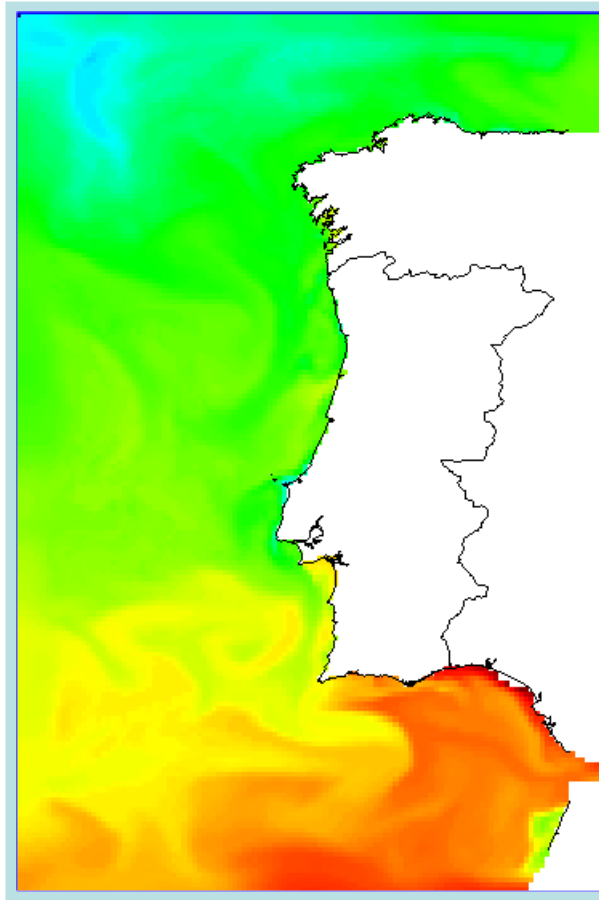
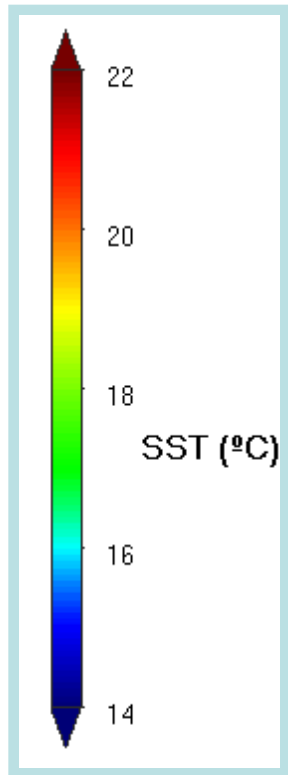
# Regional scale models

Hydrodynamical operational modeling of portuguese coast.

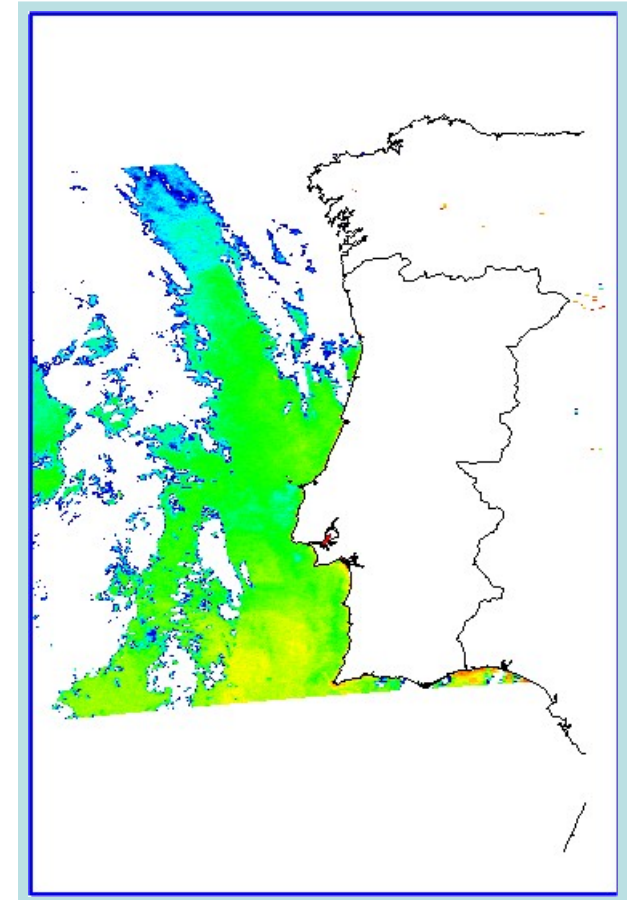


# Remote sensing comparison

9 June 2007



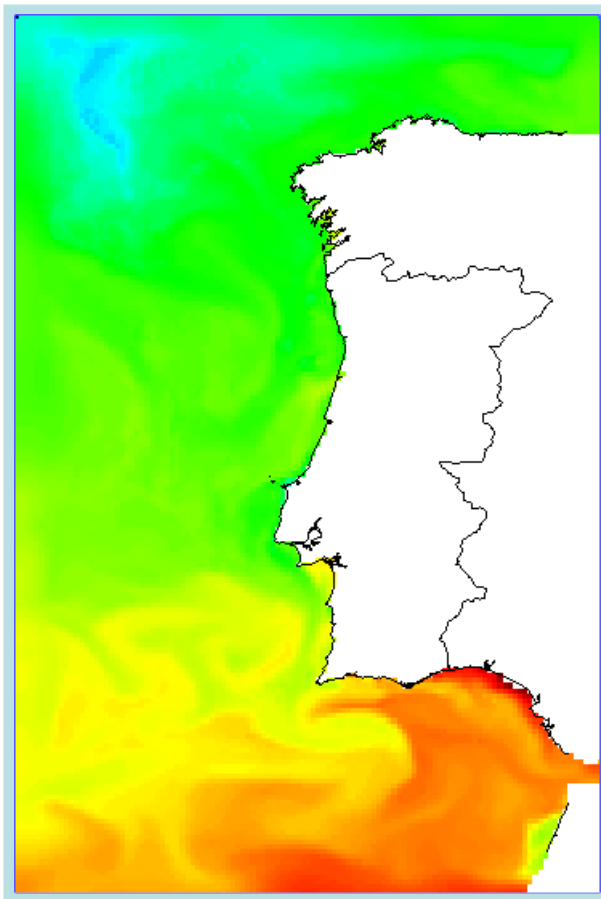
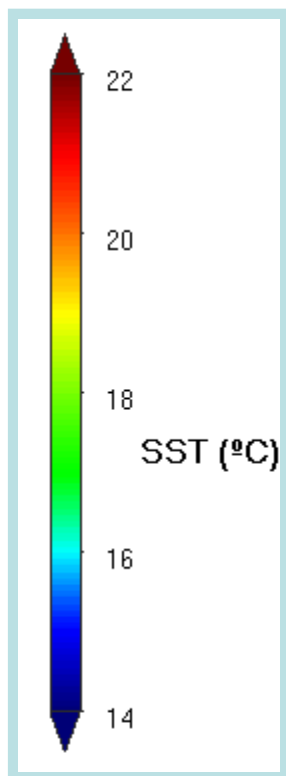
MOHID



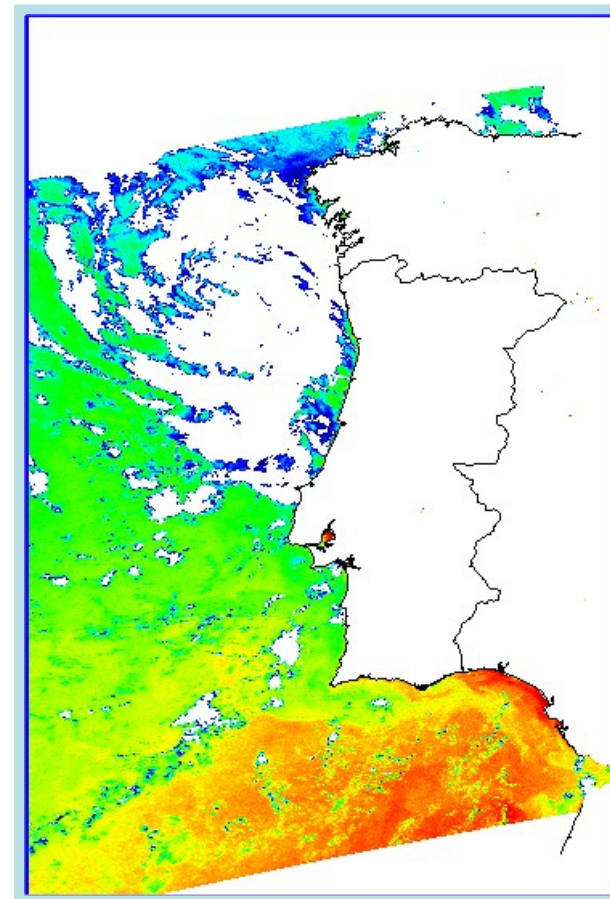
MODIS

# Remote sensing comparison

10 June 2007



MOHID

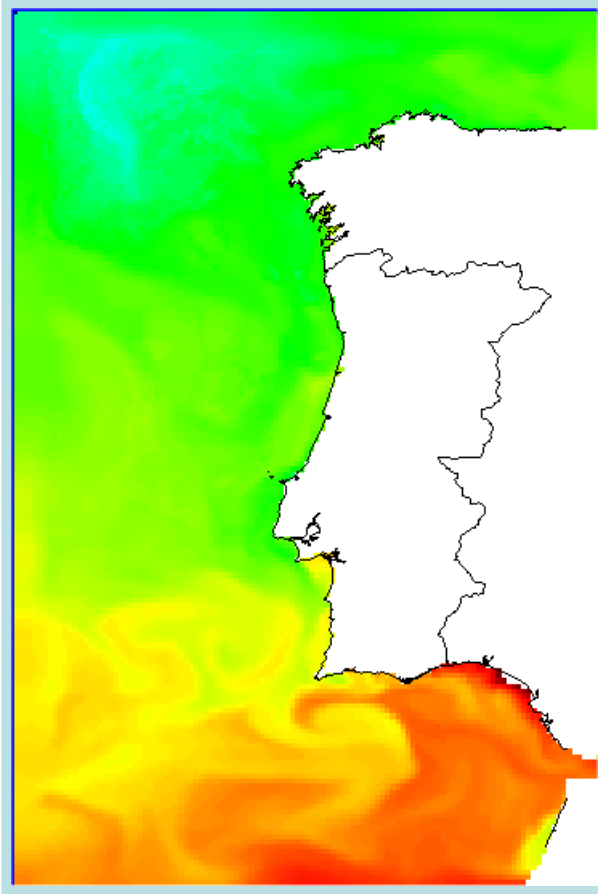
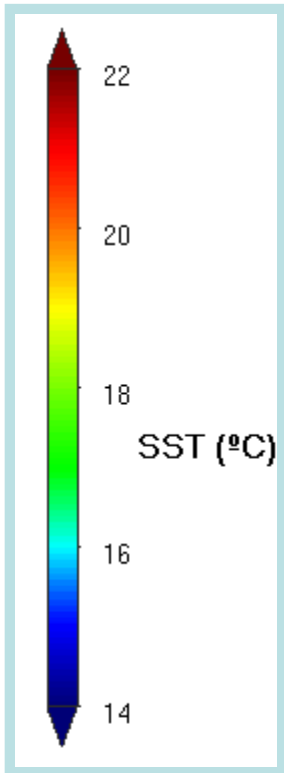


MODIS

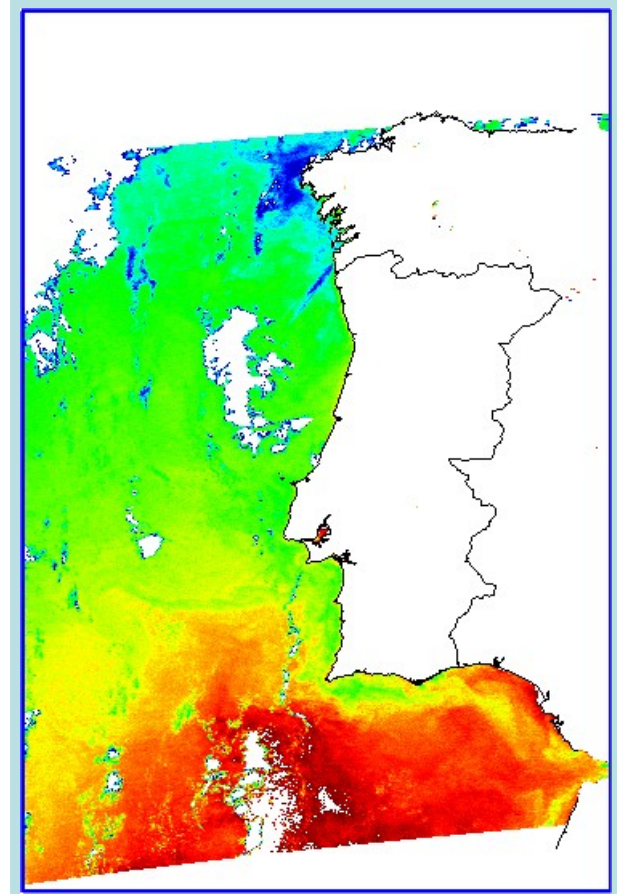


# Remote sensing comparison

11 June 2007



MOHID

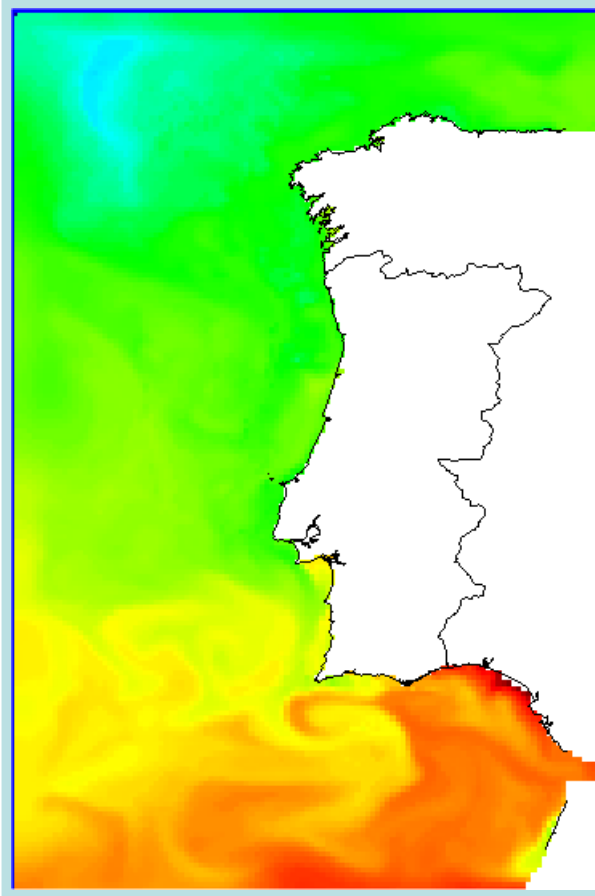
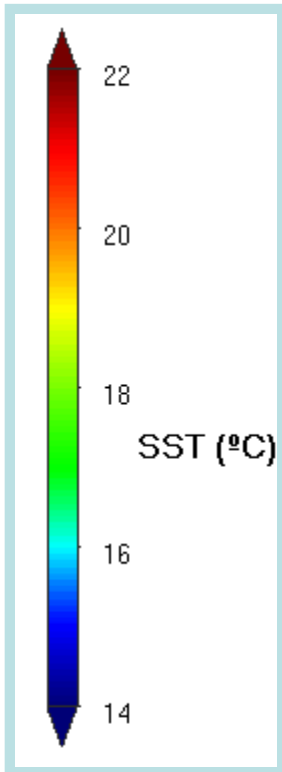


MODIS

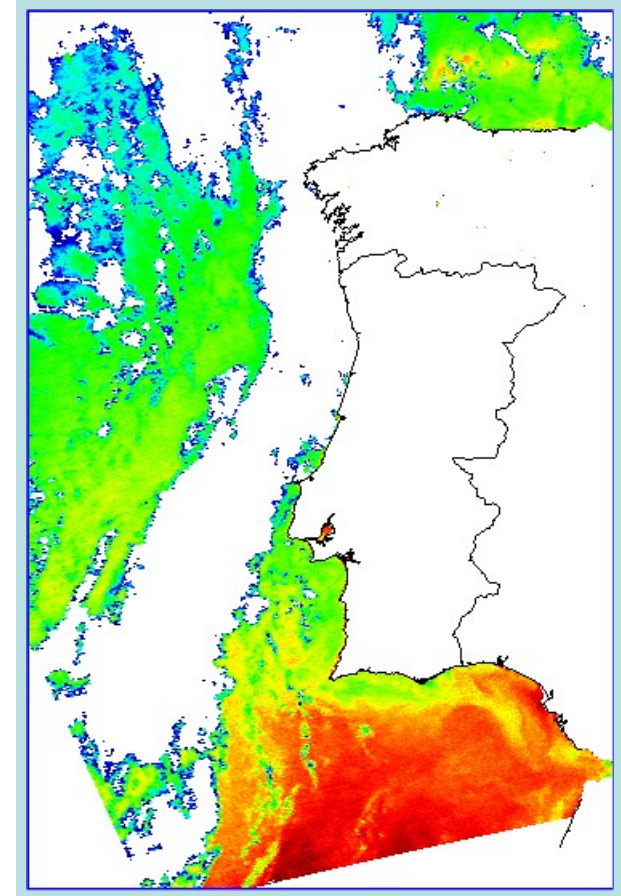


# Remote sensing comparison

12 June 2007



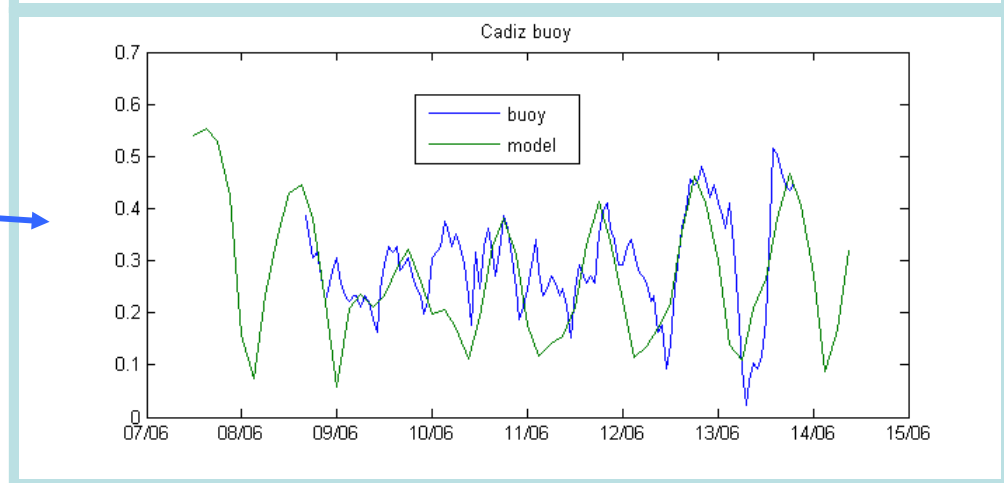
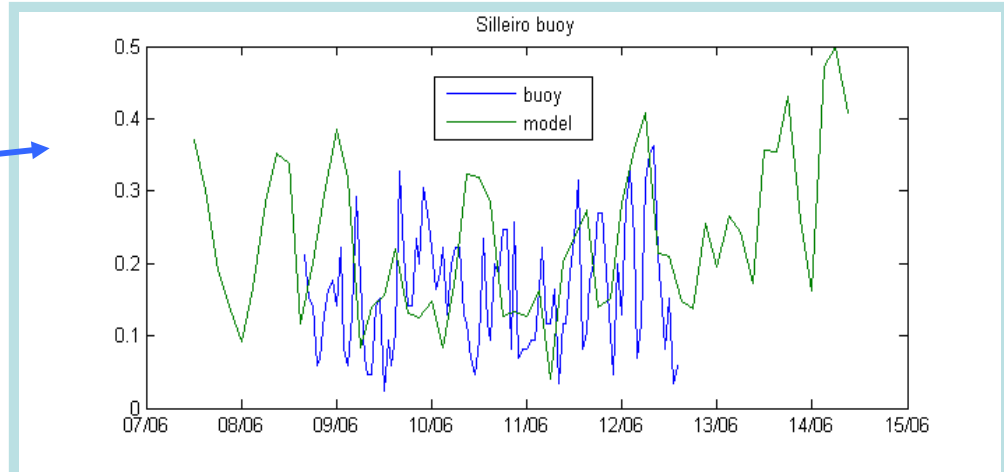
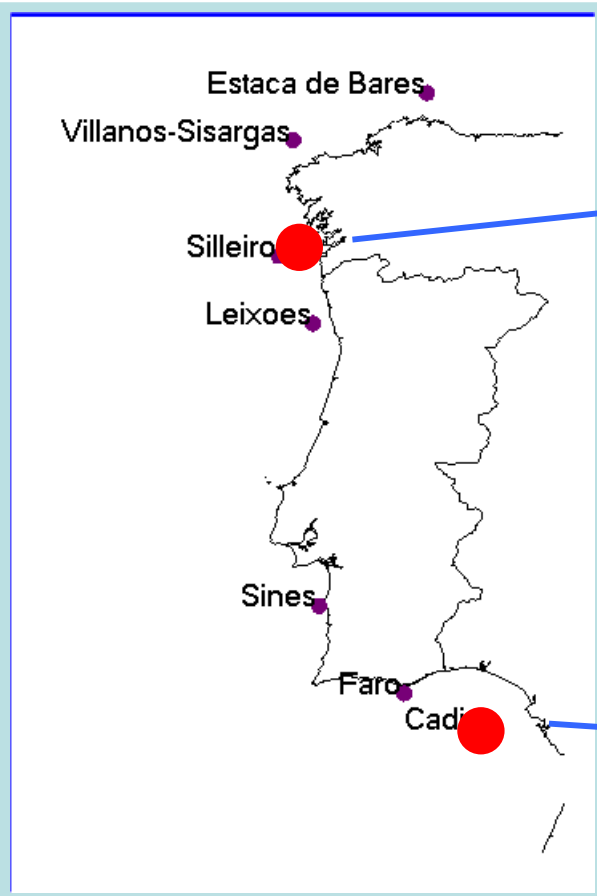
MOHID



MODIS

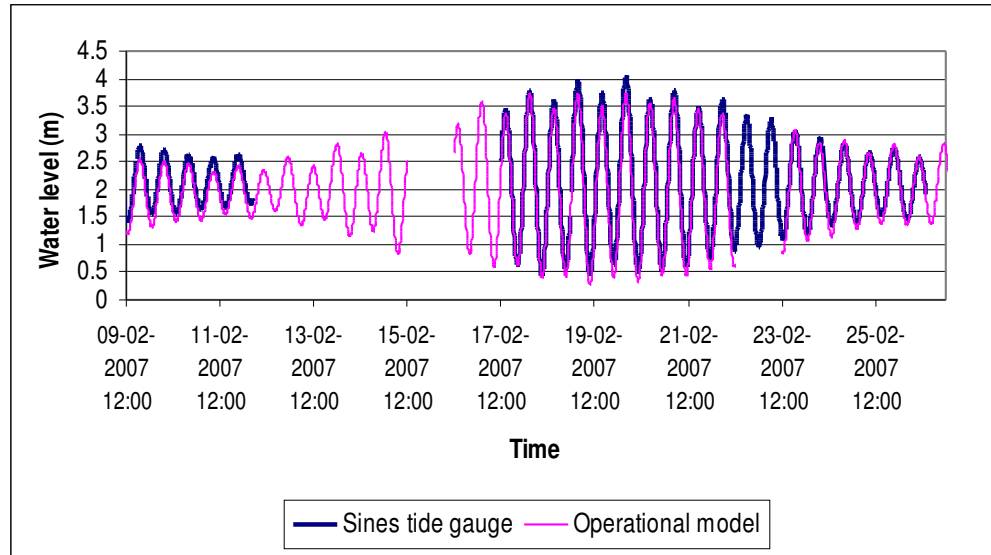
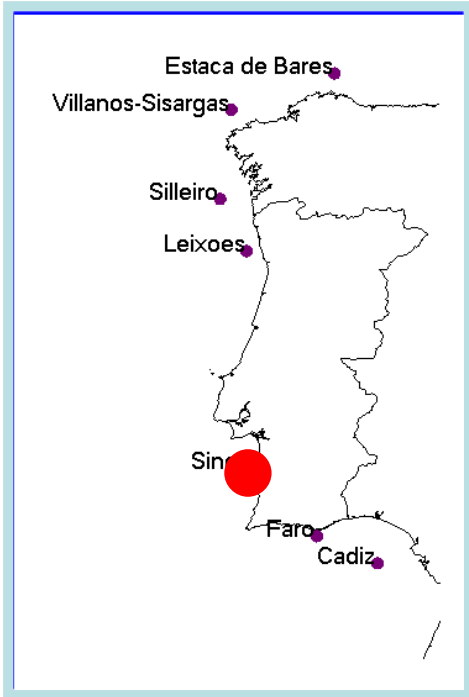
# Buoys comparison

## Surface velocity modulus



Buoy data kindly provided by Puertos del Estado

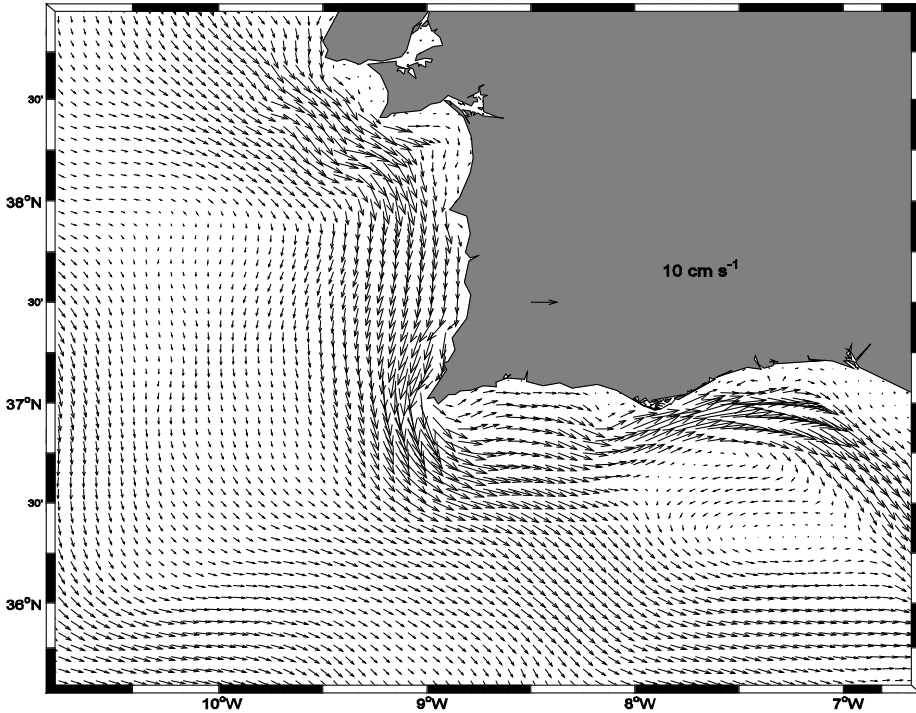
# Buoys comparison



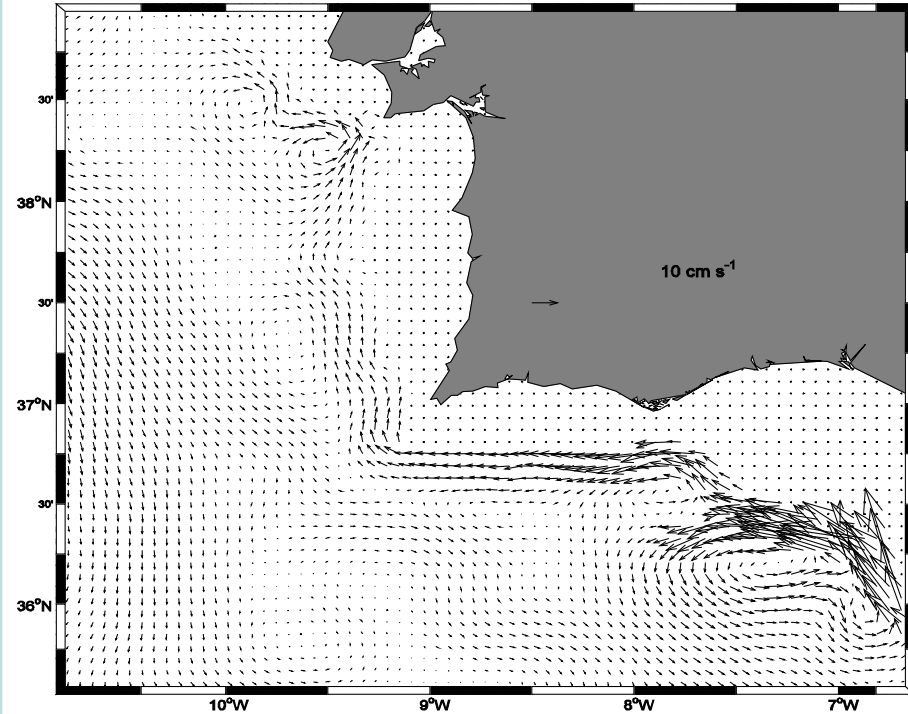
Water level from from a tidal station in pink located at  $37^{\circ}57'$  °N and  $8^{\circ}55'$  °W in Sines and illustrated in the the bathymetries figure. Water level from the pre-operational model in forecast mode for the same location. The correlation is  $0.99 + 5e-3$  and the RMSE is  $0.19 + 5e-3$  m.

# Integrated results mid-October 2006 mid-february 2007

Depth: 2 m



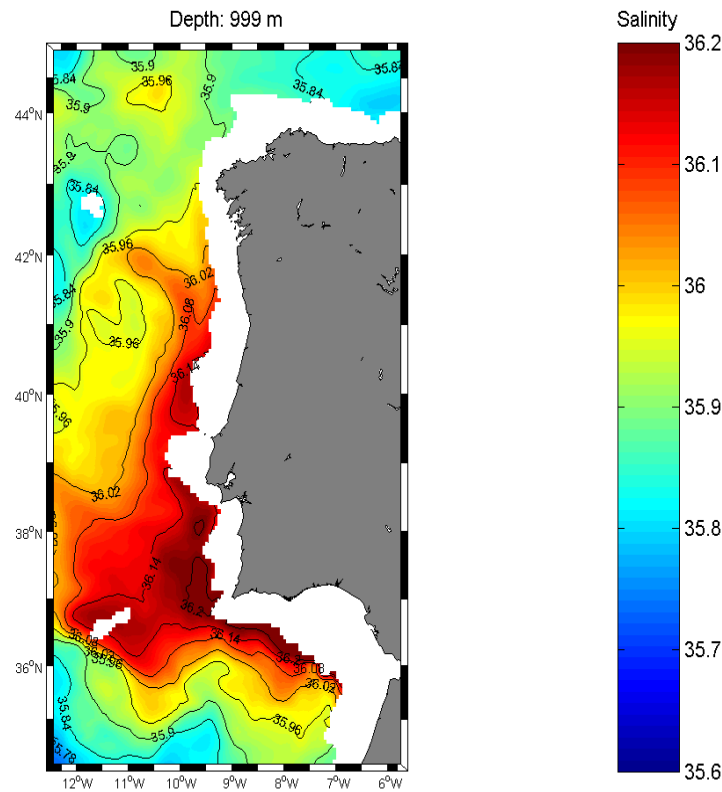
Depth: 645 m



Horizontal distribution of velocity ensemble average at 2 m depth for the top panel and 645 m depth for the bottom panel. Two main branches of the MW spreading pathways are well pronounced in the bottom panel. the poleward slope current branch, and the cyclonic recirculation flowing southward.

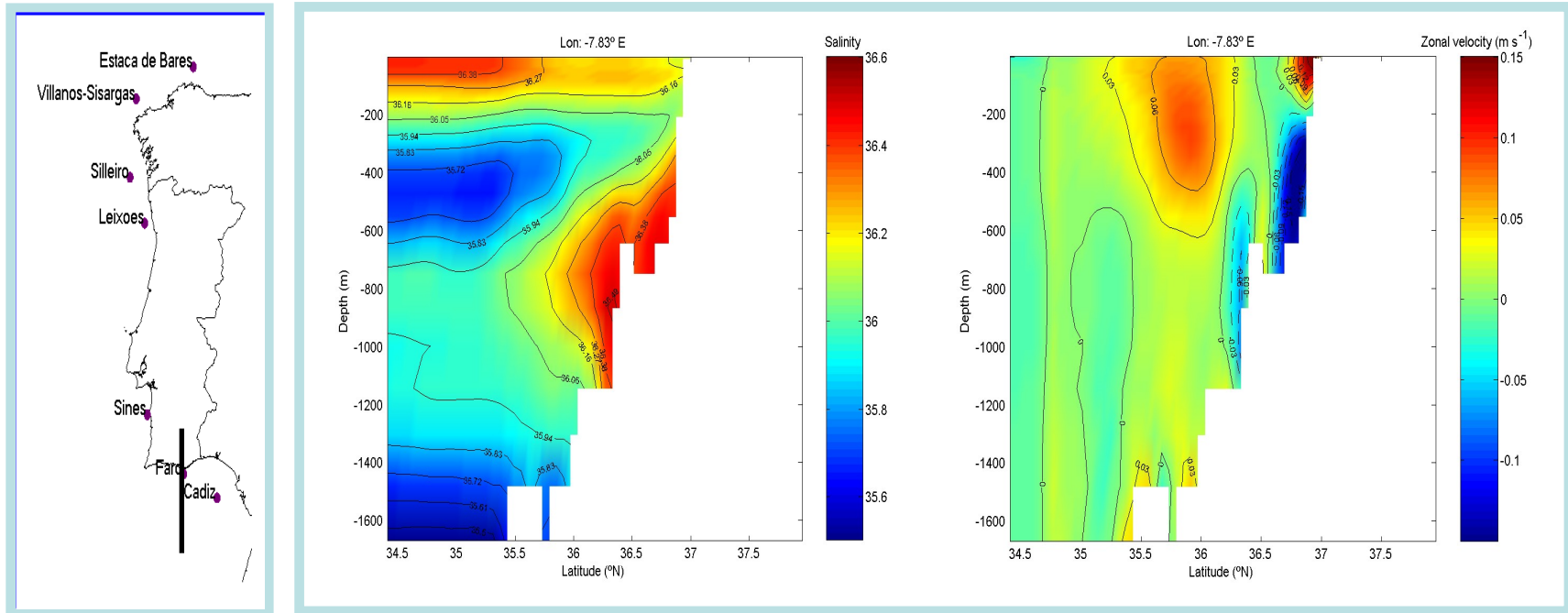


# Integrated results mid-October 2006 mid-february 2007



Colour map and contours of salinity distribution ensemble average at 1000 m depth ranging in interval [35.6 36.2] showing the spreading pathway of the MO off western Iberia. Contour lines are valued [35.6; 35.78; 35.84; 35.9; 35.96; 36.02; 36.08; 36.14; 36.2]

# Integrated results mid-October 2006 mid-february 2007



On the left panel, salinity contours of [35.5; 35.52; 35.83; 35.94; 36.05; 36.16; 36.27; 36.38; 36.49; 36.6] and color maps in the interval [35.5 36.6]. On the right panel, ensemble averages of zonal velocity contours of [-.15; -.12; -.09; -.06; -.03; 0; .03; .06; .09; .12; .15]  $\text{ms}^{-1}$  and color maps in the interval [-.15 .15]  $\text{ms}^{-1}$ . The plots are meridional sections in the Gulf of Cadiz at longitude 7.83 °W. The MO shifts from a bottom current to a buoyancy driven intermediate depth jet current. The cross sections are shown in the bathymetries figure.

# Results available on opendap



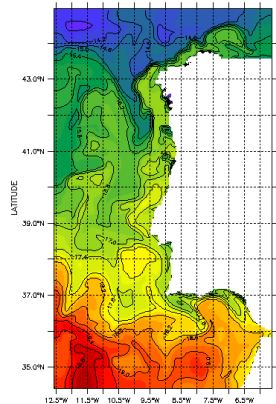
## MOHID Data Repository

### Data repository

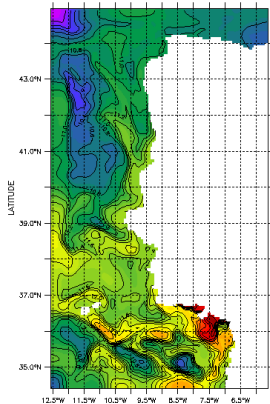
Click on a dataset to browse its content and extract data. To graphically inspect dataset NcBrowse, a java client. Download it here. To open a dataset in NcBrowse simply click copy/paste its data-url in the OpenDAP menu in NcBrowse.

Project	File	Attributes
Estremadura	20060609_Estremadura_Hydrodynamic.nc	info.dds.das
Estremadura	20060609_Estremadura_WaterProperties.nc	info.dds.das
Portugal	20060609_Portugal_Hydrodynamic.nc	info.dds.das
Portugal	20060609_Portugal_WaterProperties.nc	info.dds.das
Portugal	20061122_Portugal_Hydrodynamic.nc	info.dds.das
Portugal	20061122_Portugal_WaterProperties.nc	info.dds.das
Estremadura	20061129_Estremadura_Hydrodynamic.nc	info.dds.das
Estremadura	20061129_Estremadura_WaterProperties.nc	info.dds.das

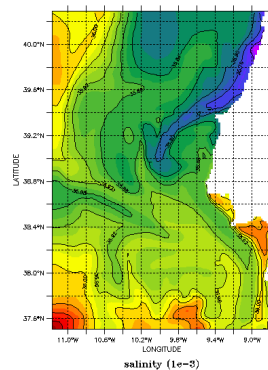
LAS 6.5.2.1/Ferret 5.81 --- NOAA/PMEL  
DEPTH (m) : 2.09  
TIME : DATASET:20060609\_Portugal\_WaterProperties



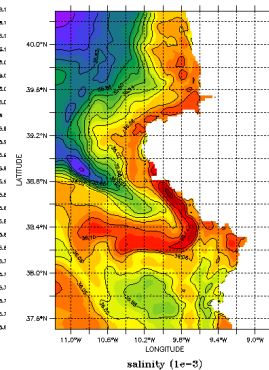
LAS 6.5.2.1/Ferret 5.81 --- NOAA/PMEL  
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TIME : DATASET:20060609\_Portugal\_WaterProperties



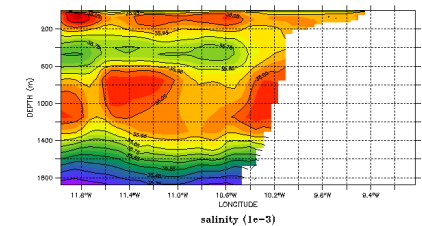
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DEPTH (m) : 2.099  
TIME : DATASET:20060609\_Estremadura\_WaterProperties



LAS 6.5.2.1/Ferret 5.81 --- NOAA/PMEL  
DEPTH (m) : 749.5  
TIME : DATASET:20060609\_Estremadura\_WaterProperties

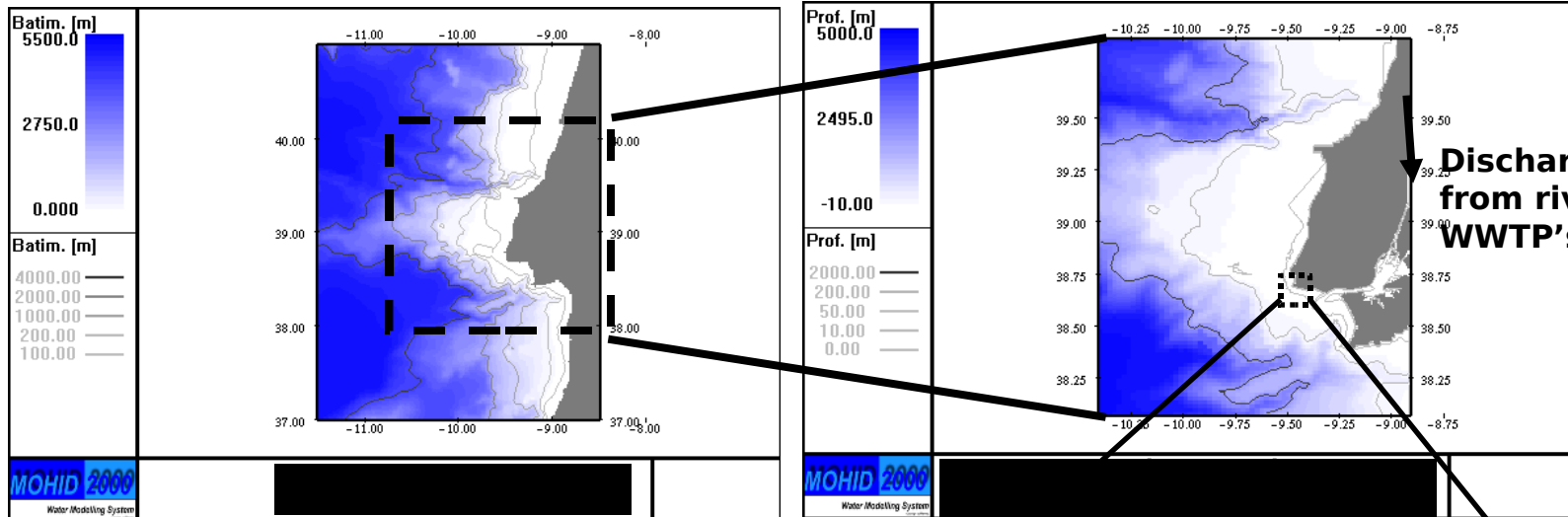


LAS 6.5.2.1/Ferret 5.81 --- NOAA/PMEL  
LATITUDE : 39N  
TIME : 14-JUN-2006 19  
DATA SET: 20060609\_Portugal\_WaterProperties

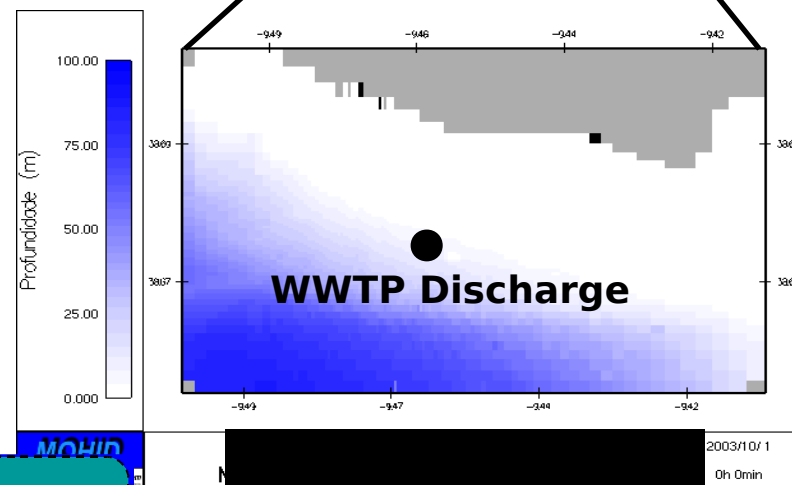
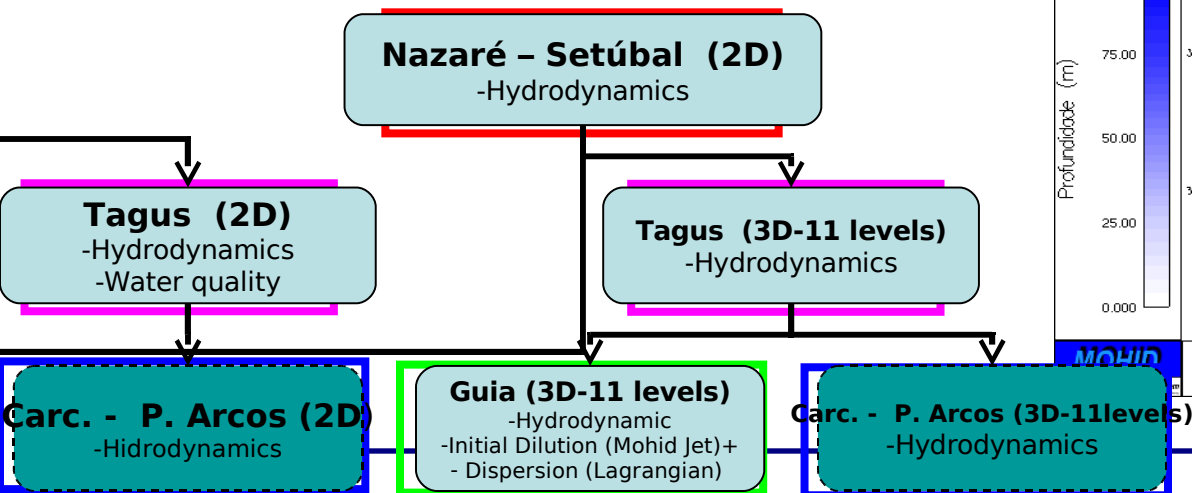




# Local scale models: Tagus estuary



Discharges from rivers / WWTP's





# Local scale models: Tagus estuary

Modelo Operacional do Estuário do Tejo - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address <http://www.mohid.com/tejo-op/>

MOHID Water Modelling System

Sexta-Feira, 03 de Fevereiro de 2006

## Sistema Operacional para o Estuário do Tejo

Início	Apresentação	Descrição do Sistema	Meio Atmosférico	Meio Aquático	Situação de Referência	Futuro	Mapa do Site	Contactos
--------	--------------	----------------------	------------------	---------------	------------------------	--------	--------------	-----------

Sistema Operacional para o Estuário do Tejo em tempo real sobre condições atmosféricas e oceanográficas

 Previsões Oceanográficas	 Previsões Meteorológicas
 Dados de Campo Automático - Estação Meteorológica da Guia - Bóia de Arco de Arcos - Estação Hidrométrica de Omnias (INAG)	 Dados de Campo obtidos em Campanhas
 Deteção Remota	 Aflúncias

Optimizado para uma resolução de 800x600 pixels  
© Maretec - IST 2003. Todos os direitos reservados  
Questões ou problemas no site - [webmaster@mohid.com](mailto:webmaster@mohid.com)

start | 3 Wind... | 8 Inter... | MSN Me... | 2 Mohi... | MohidSu... | Visual So... | Inbox - ... | C:\WIN... | Tagus Si... | Relatori... | PT | Internet | 12:10

# Local scale models: Tagus estuary

Modelo Operacional do Estuário do Tejo - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Refresh Print Mail Stop

Address http://www.mohid.com/tejo-op/Aq\_Prev\_Mapas\_Tejo.asp?go=1#picture

Google Search 37 blocked AutoLink AutoFill Options

de 2006 **Modelo Operacional para o Estuário do Tejo**

Início Apresentação Descrição do Sistema Meio Atmosférico Meio Aquático Situação de Referência Futuro Mapa do Site Contactos

Meio Aquático: Estuário | Previsões - Mapas Zona do Tejo

Data: Ano 2006 Mês 02 Dia 03 Hora 12:00 (GMT)

Parâmetro: Salinidade

Profundidade (m): Salinidade  
Oxigênio Dissolvido  
Clorofila a  
Nitratos  
Sedimentos Coesivos

<< hora >>  
<< dia >>

MOHID Water Modeling System

Velocidade e salinidade à superfície  
Modelo operacional do Estuário do Tejo

2006/2/3  
12h 0min

Optimizado para uma resolução de 800x600 pixels  
© Maretec - IST 2003. Todos os direitos reservados  
Questões ou problemas no site - webmaster@mohid.com

Done Internet

start Wind... 9 Inter... MSN Me... 2 Mohi... MohidSu... Visual So... Inbox - ... C:\WIN... Tagus Si... Relatori... PT 12:22

# Local scale models: Tagus estuary

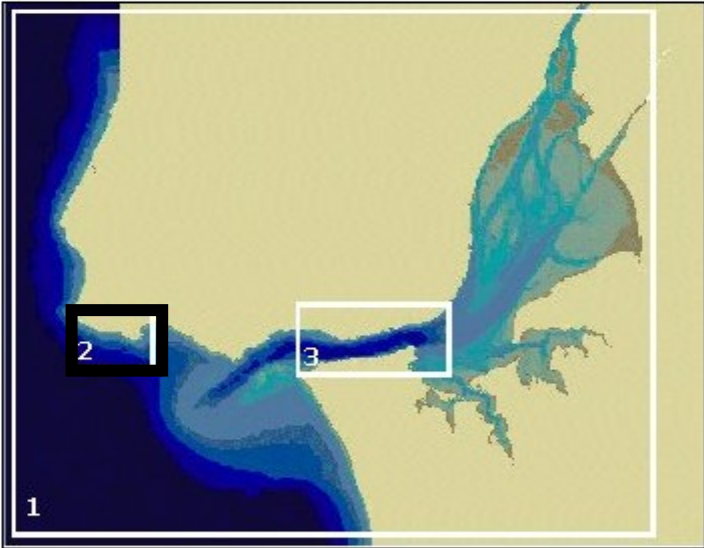
Modelo Operacional do Estuário do Tejo - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address [http://www.mohid.com/tejo-op/Aq\\_Prev\\_Mapas\\_Guia.asp?go=1#picture](http://www.mohid.com/tejo-op/Aq_Prev_Mapas_Guia.asp?go=1#picture)

Google

Escolha a zona de aplicação para as previsões pretendidas:



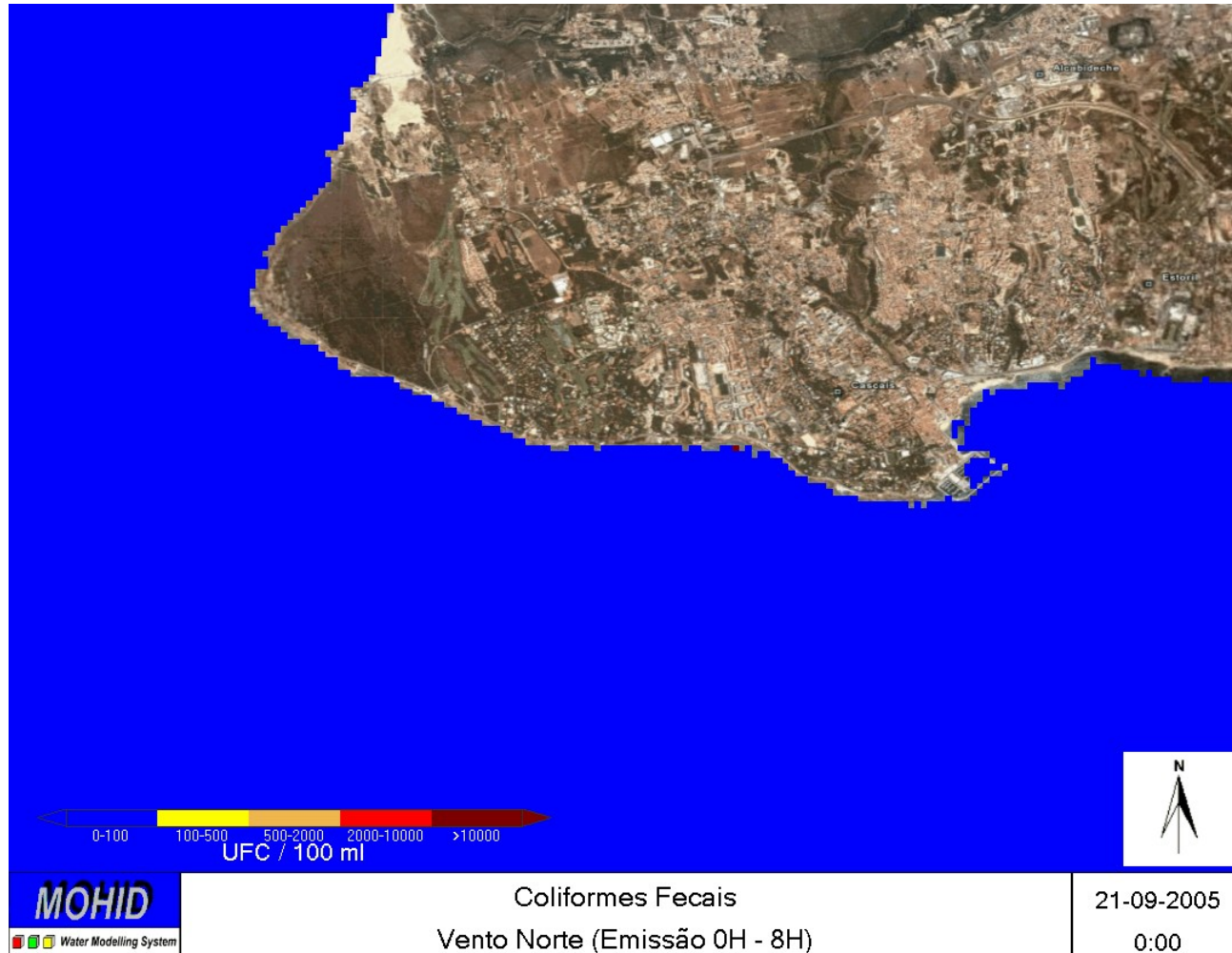
1 - Zona do Tejo

2 - Zona da Guia (Cascais)

3 - Zona do Canal

start 3 V internet 12:20

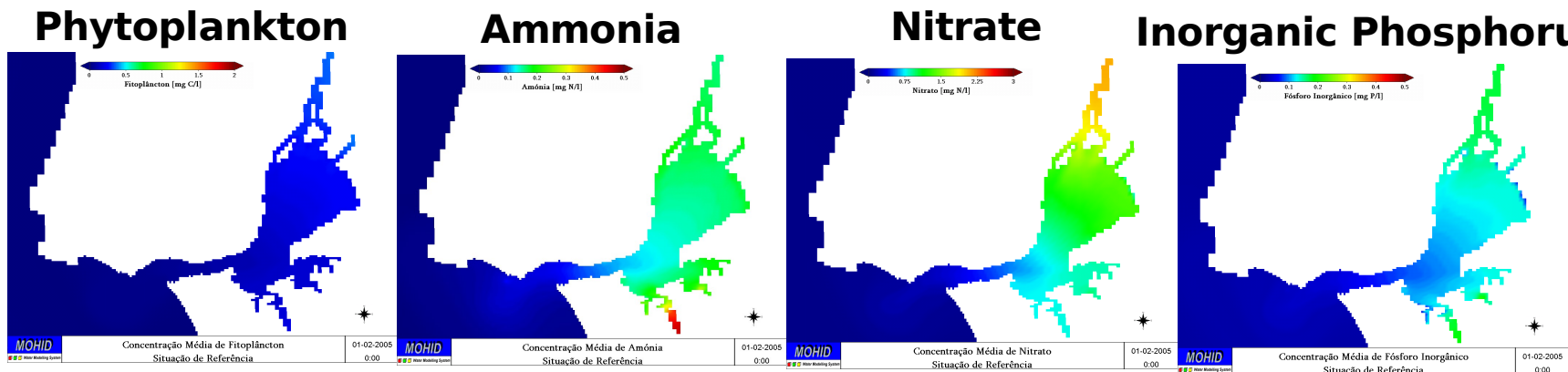
# Estoril coast – process studies



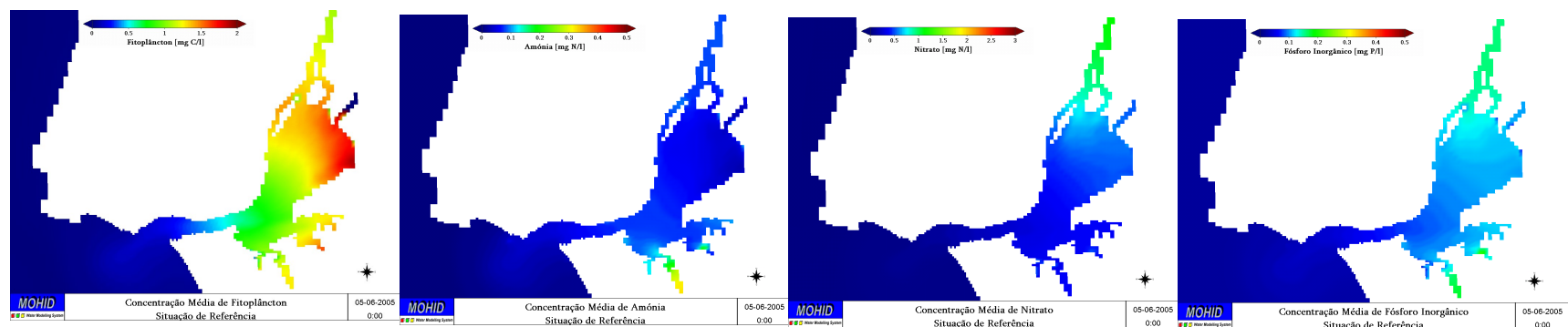


# Tagus estuary – process studies

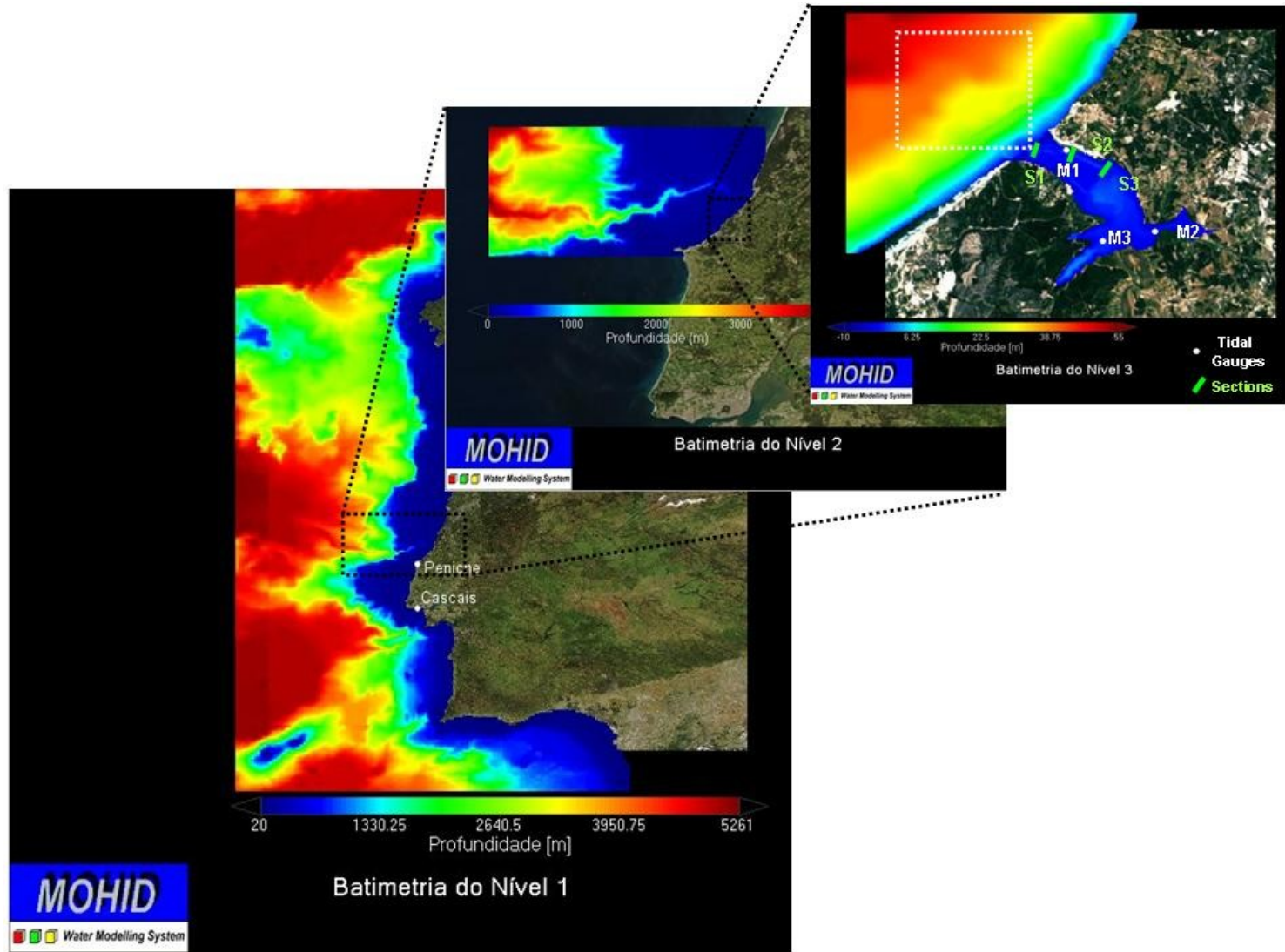
FEBRUARY



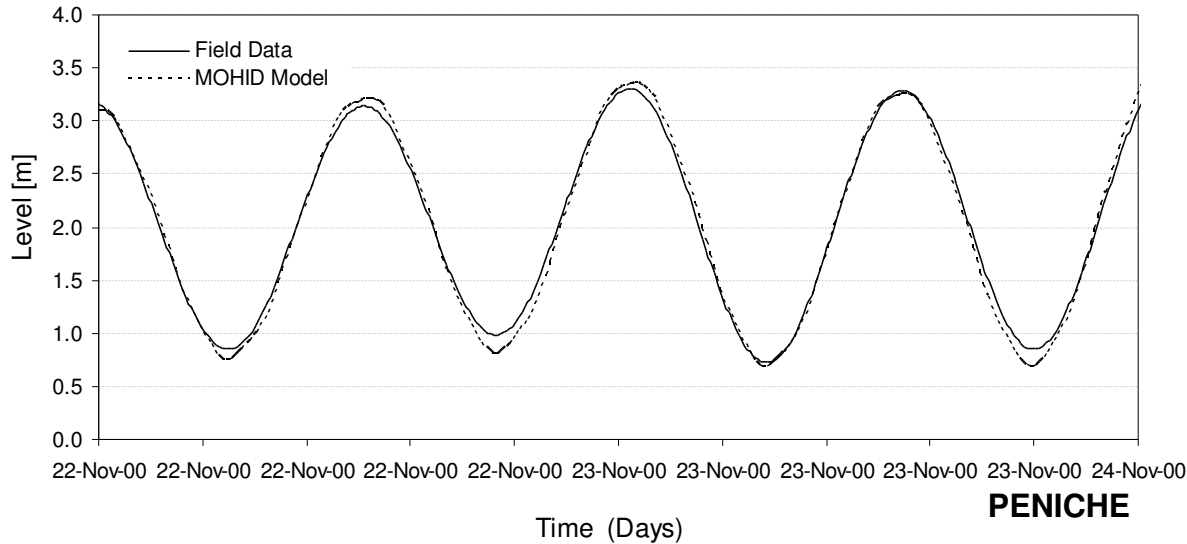
JUNE



# Foz do Arelho: lagoon + submarine outfall

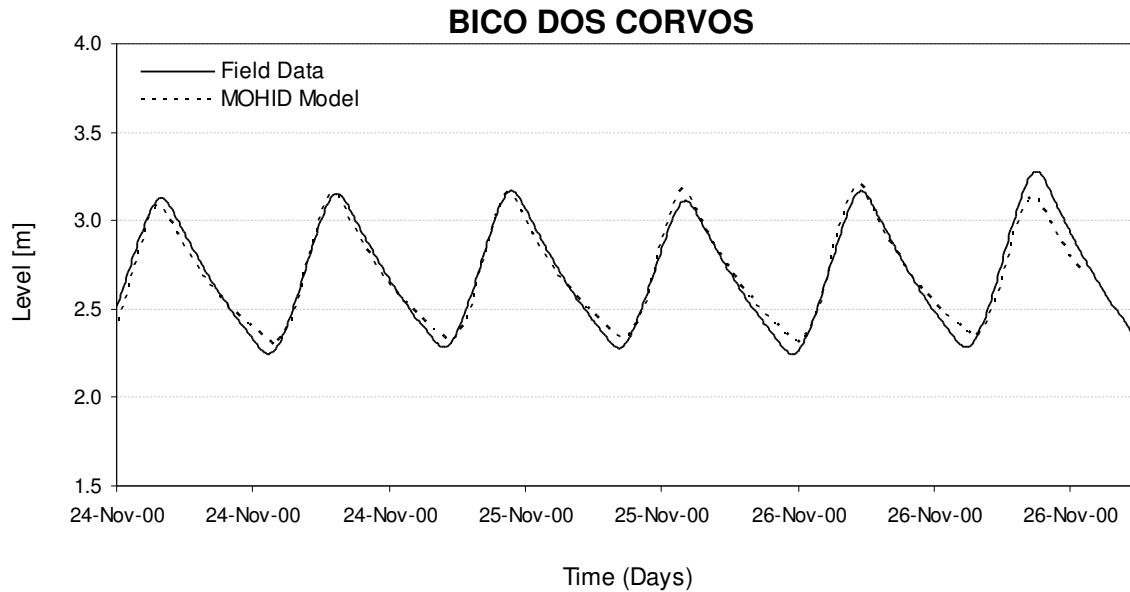


# Validation of coastal model



Tidal Stations	Average Value ( $\bar{x} \pm \sigma$ ) (m)		Correlation Coefficient (R)	Root Mean Square Error (RMSE) (m)	Bias (m)
	Model	Data			
Peniche	1.990±0.894	2.081±0.92 0	0.985	1.367	0.100
Cascais	2.030±0.735	2.030±0.74 2	0.992	0.4124	0.020

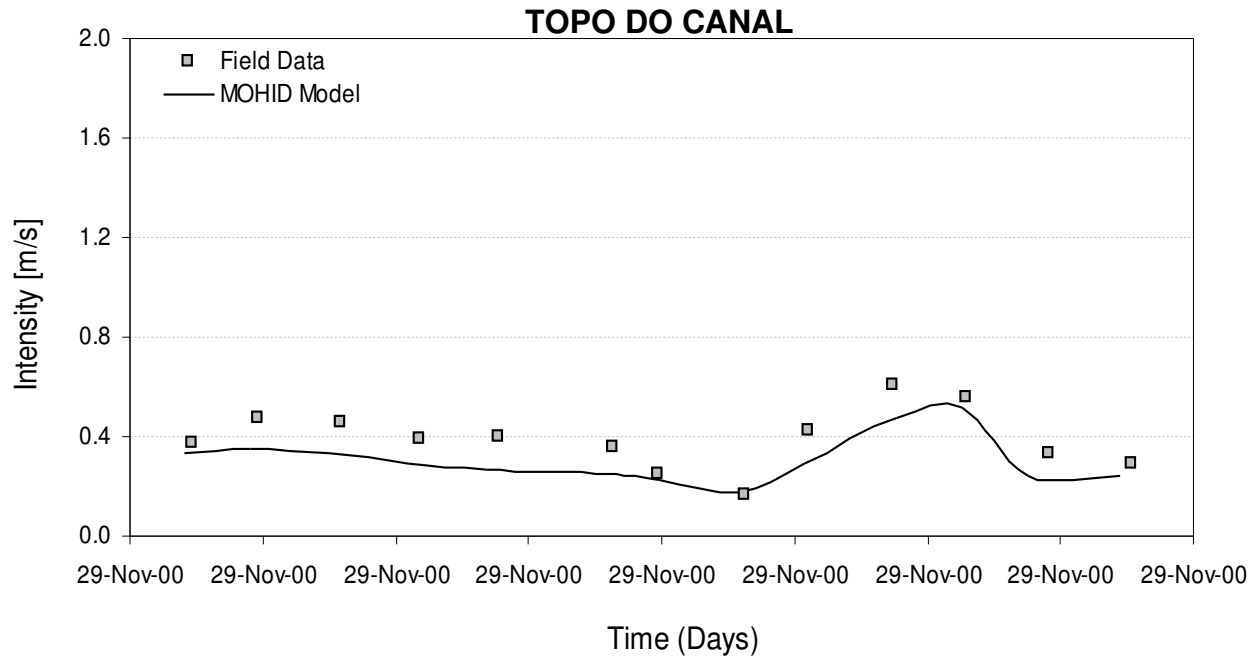
# Obidos lagoon model validation



Tidal Gauge Stations	Average Value ( $\bar{x} \pm \sigma$ ) (m)		Correlation Coefficient (R)	Root Mean Square Error (RMSE) (m)	Bias (m)
	Model	Data			
Cais da Foz do Arelho	2.691±0.290	2.667±0.230	0.987	0.081	0.025
Bico dos Corvos	2.695±0.266	2.719±0.299	0.988	0.072	0.024
Barrosa	2.704±0.273	2.706±0.299	0.989	0.062	0.001

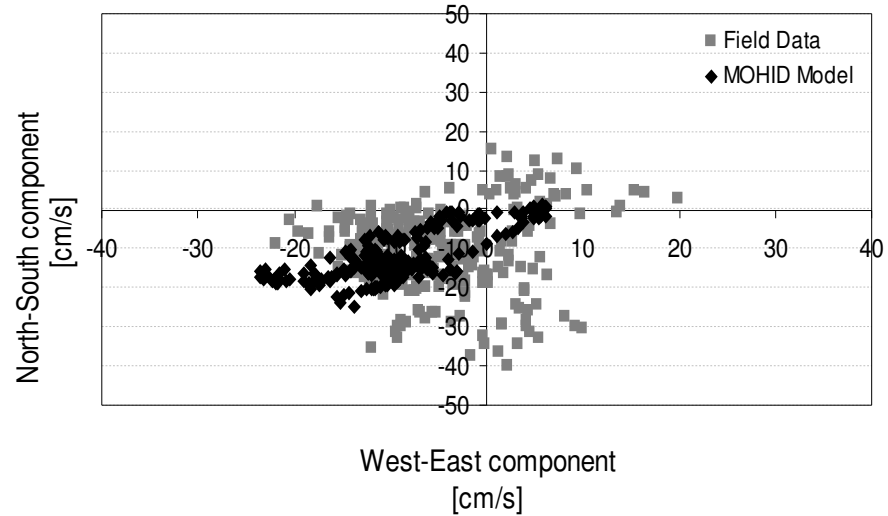
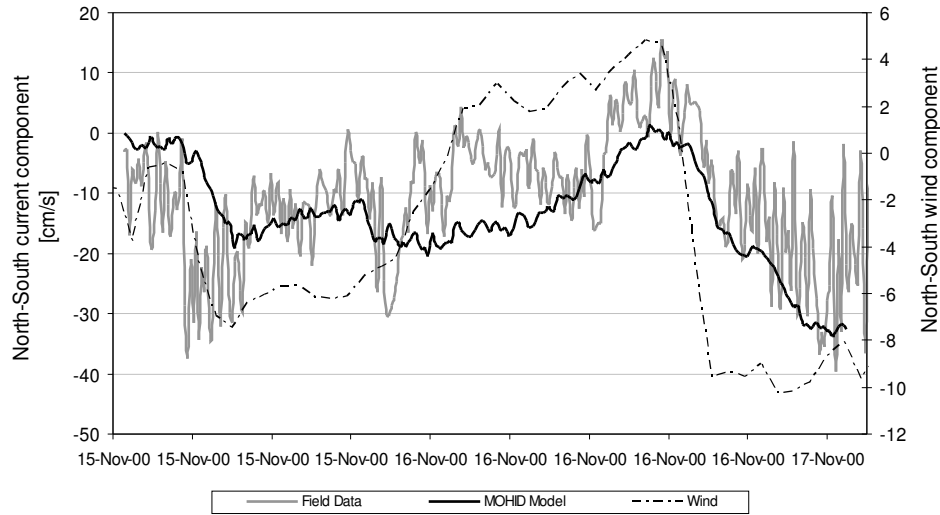


# Obidos lagoon model validation



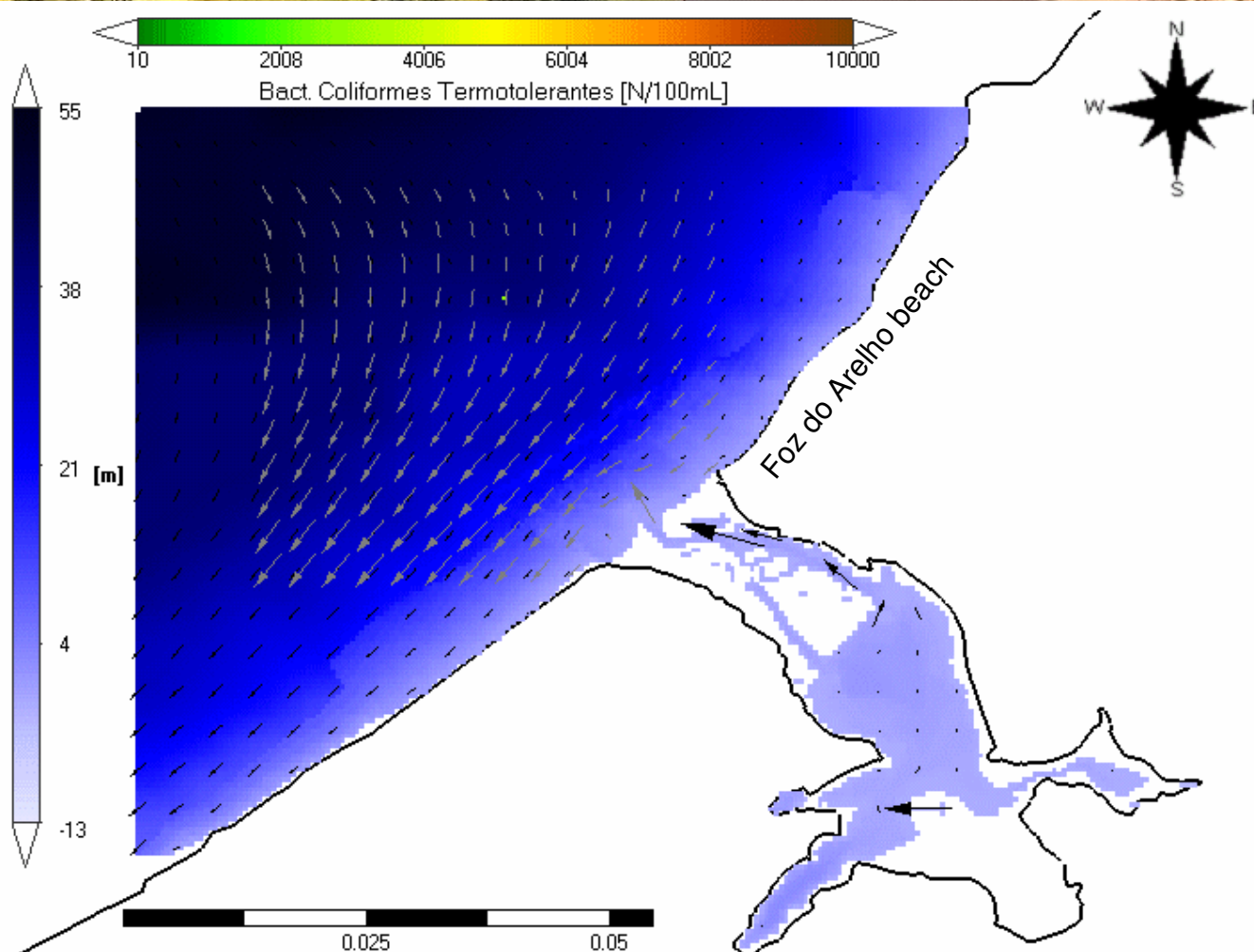
Currents transects stations	Average Value ( $\bar{x} \pm \sigma$ ) (m/s)		Correlation coefficient (R)	Root Mean Square Error (RMSE) (m/s)	Bias (m/s)
	Model	Data			
Cais da Foz do Arelho	$0.382 \pm 0.086$	$0.427 \pm 0.130$	0.891	0.090	-0.045
Topo do Canal	$1.103 \pm 0.445$	$0.974 \pm 0.372$	0.904	0.276	0.129
Barra	$0.307 \pm 0.097$	$0.392 \pm 0.110$	0.957	0.098	-0.086

# COASTAL AREA MODEL VALIDATION



Depth (m)	Average Value ( $\bar{x} \pm \sigma$ ) (cm/s)		Correlation Coefficient (R)	Root Mean Square Error (RMSE) (cm/s)	Bias (cm/s)
	Model	Data			
5	-13.380±8.389	-10.730 +10.528	0.711	10.109	3.007

# Animação



**MOHID**

Water Modelling System

Emissário da Foz do Arelho

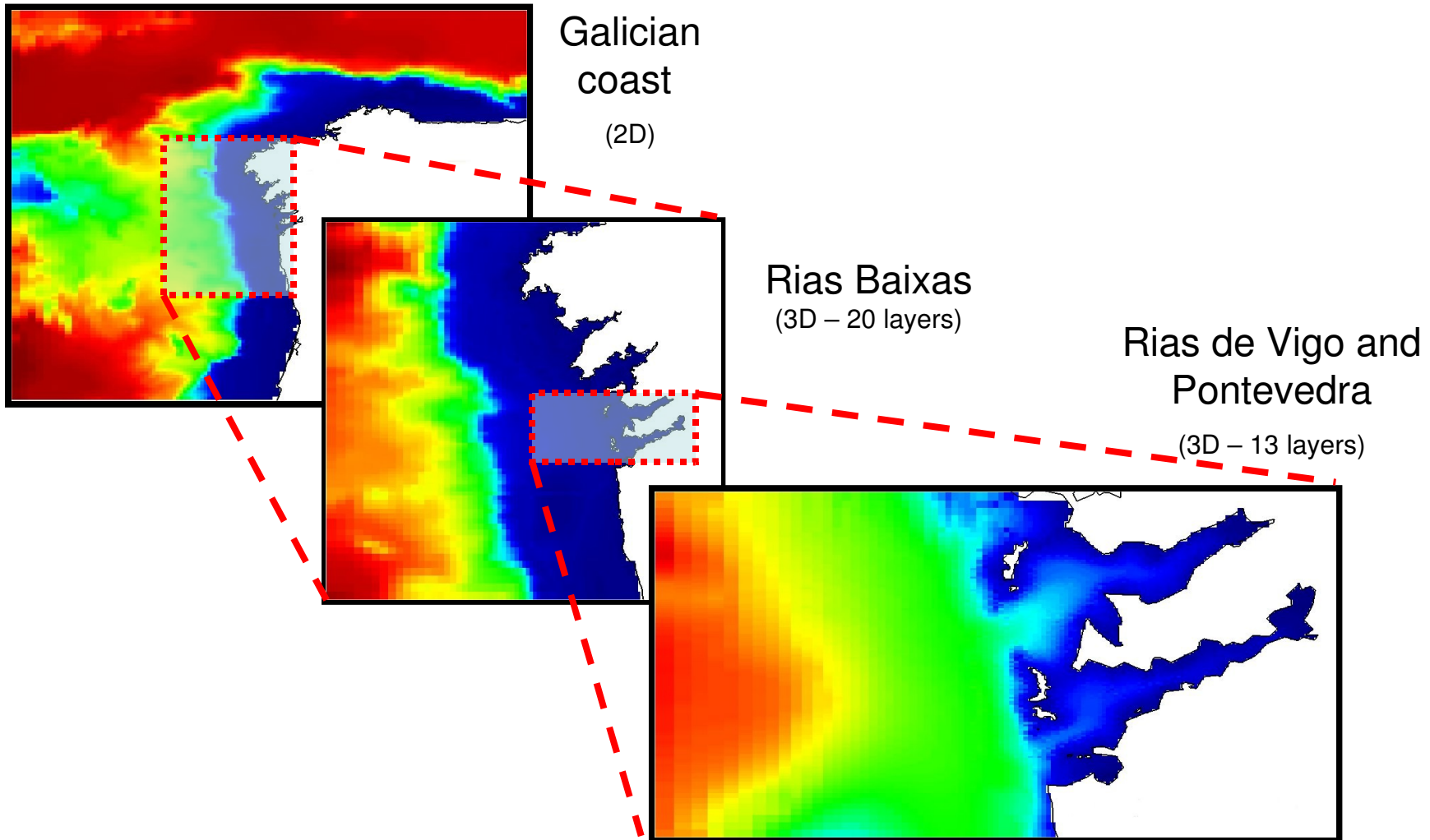
Bactérias Coliformes Termotolerantes

24-10-2005

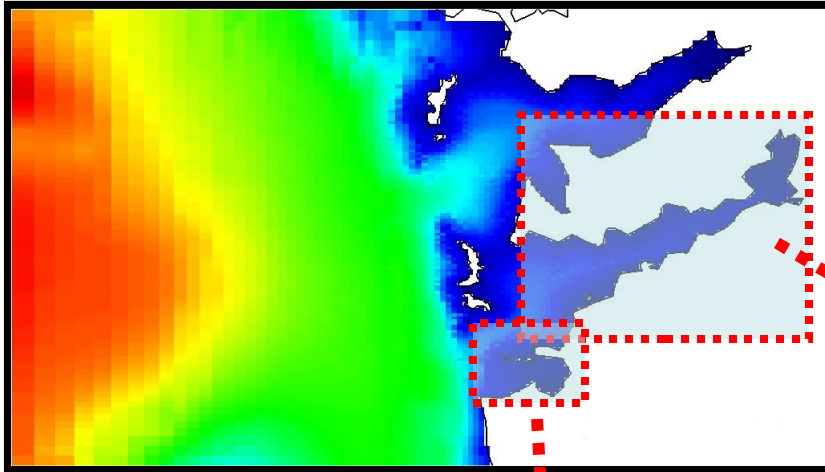
0:00



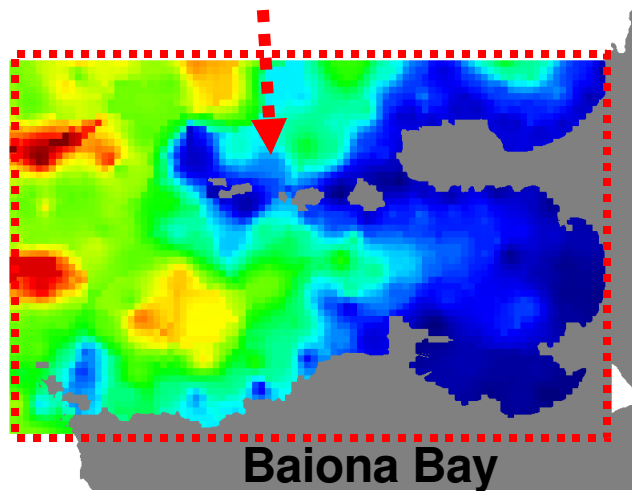
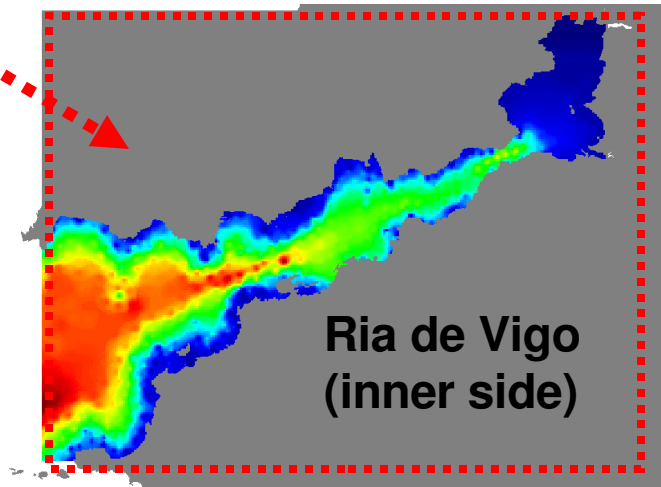
# Nesting



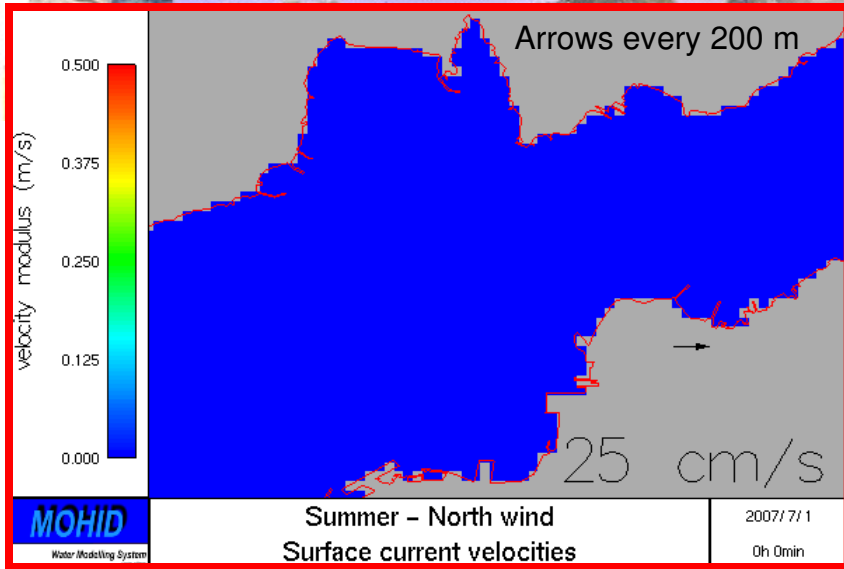
# Nesting



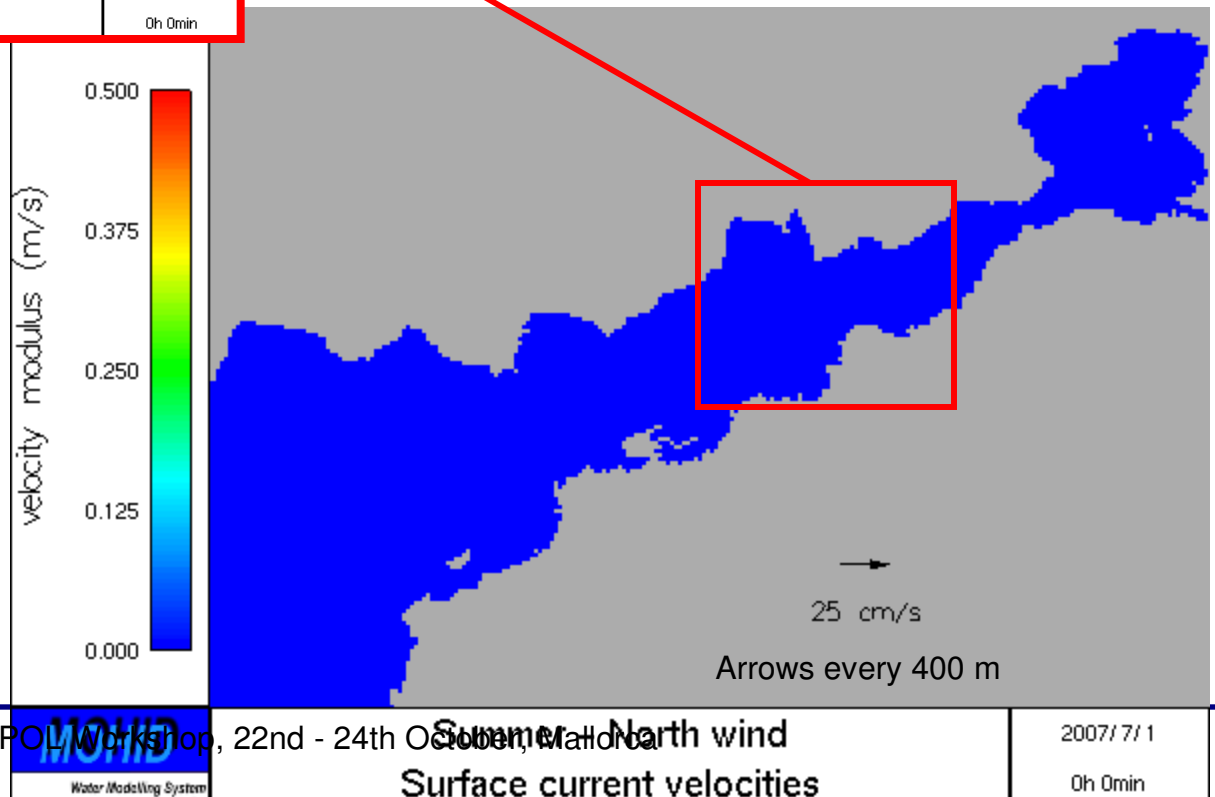
New sub-domains with  
grid resolution = 100m



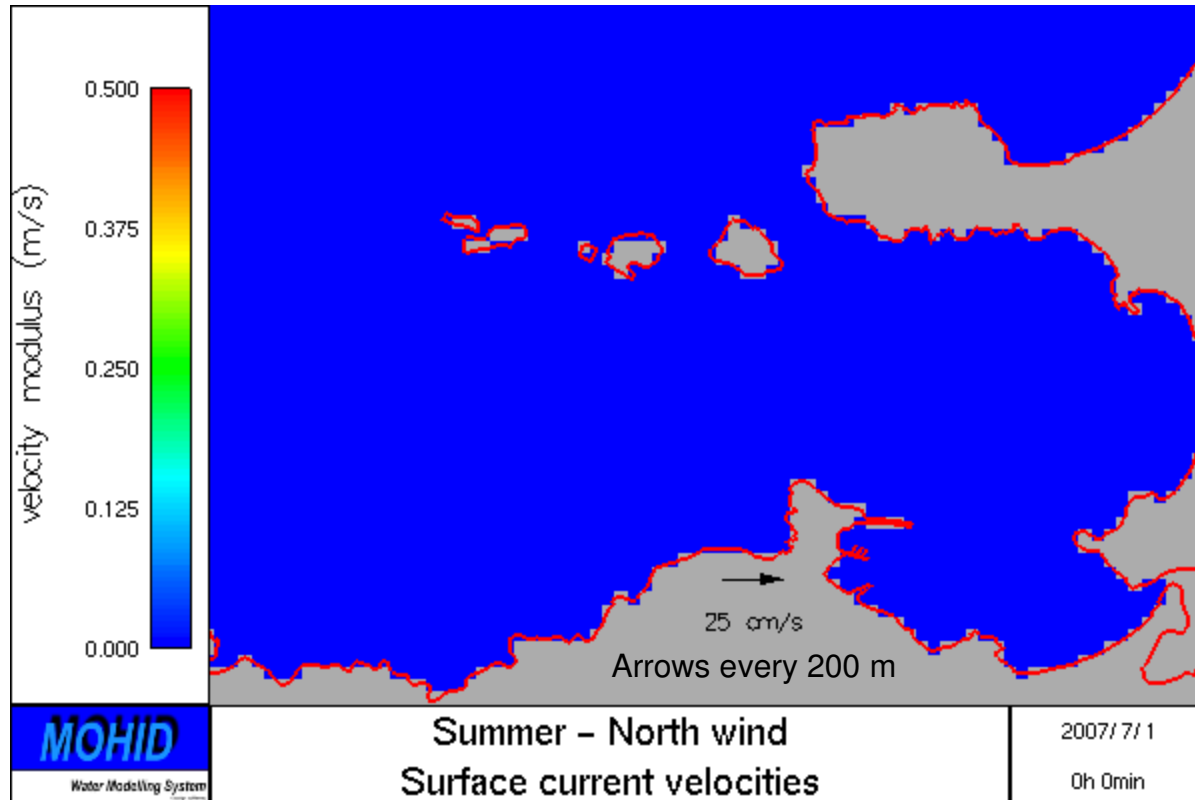
# Nesting



**Ria de Vigo (3D – 8 layers)**  
grid resolution = 100m



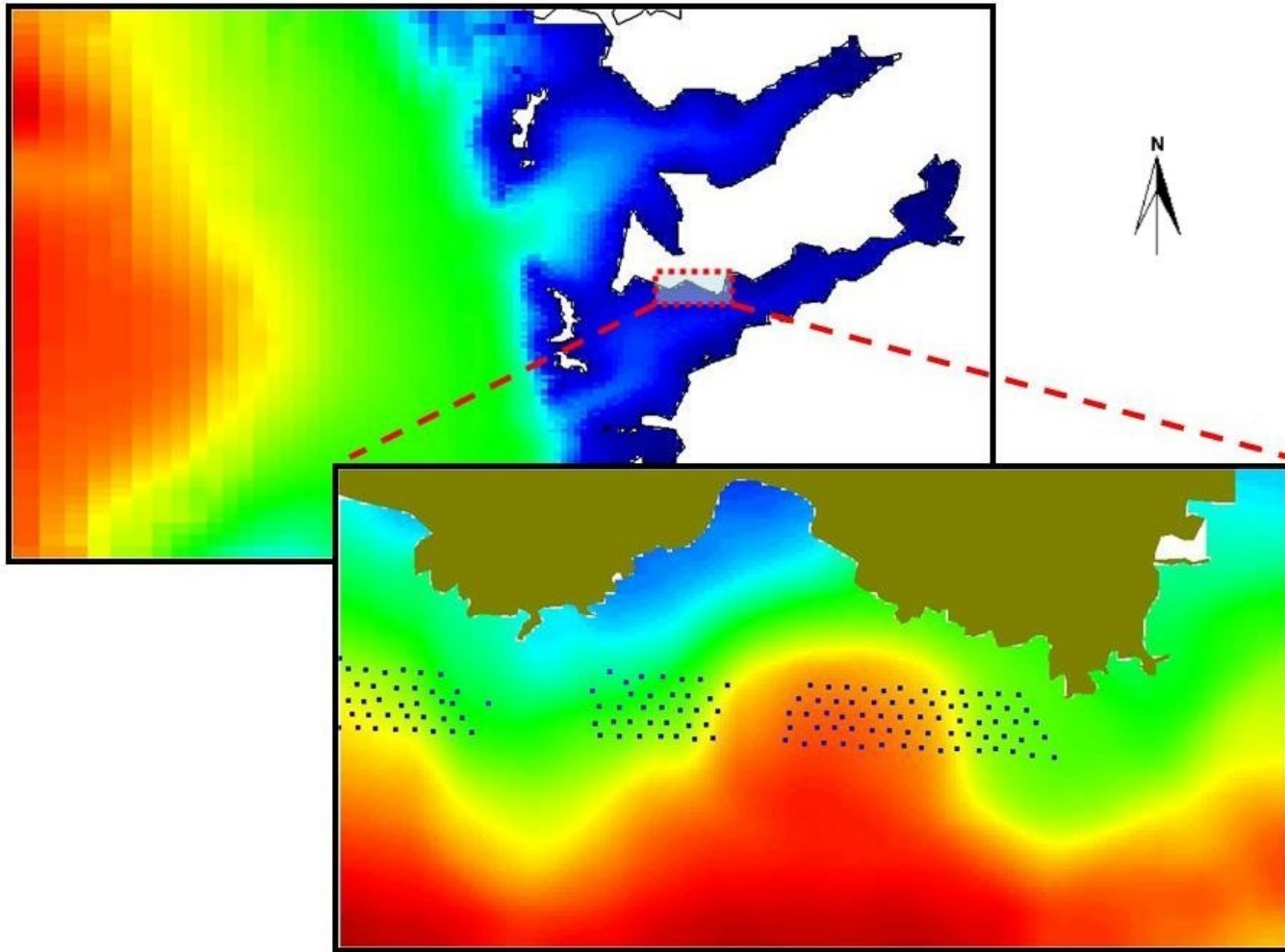
# Nesting



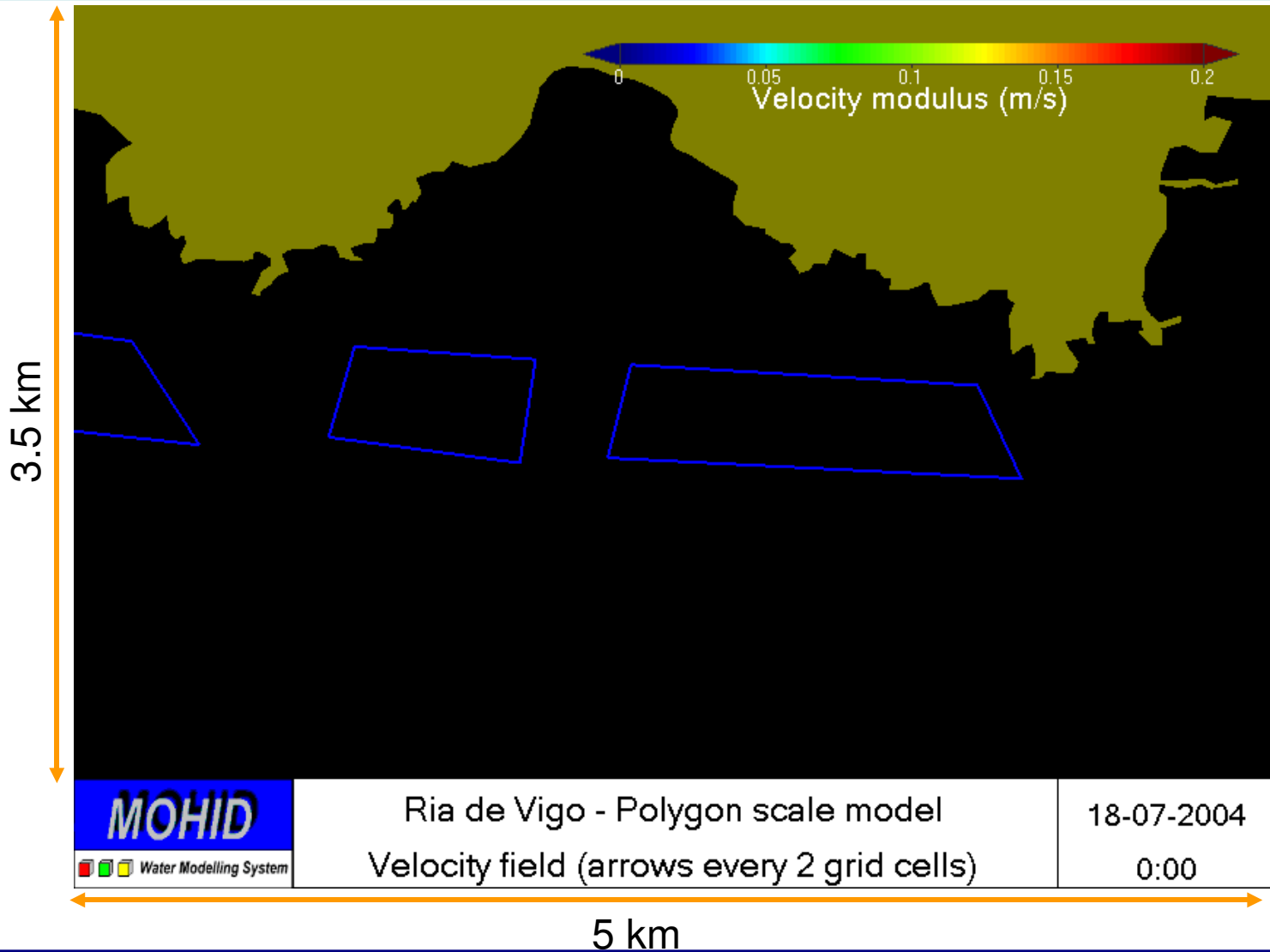
**Baiona (3D – 8 layers)**  
**grid resolution = 100m**



# MaBenE – Rafts' polygon scale



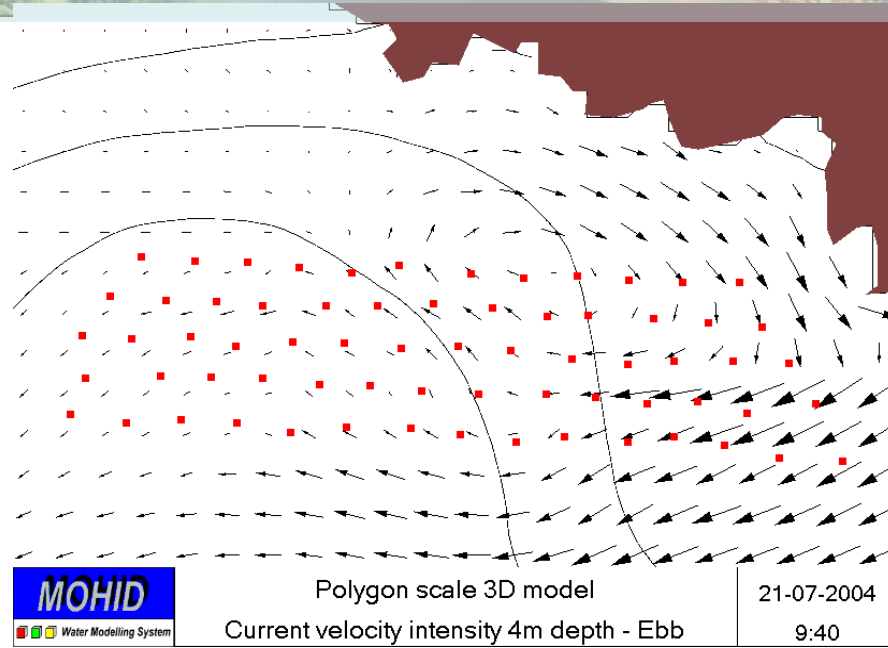
# MaBenE – Rafts' polygon scale



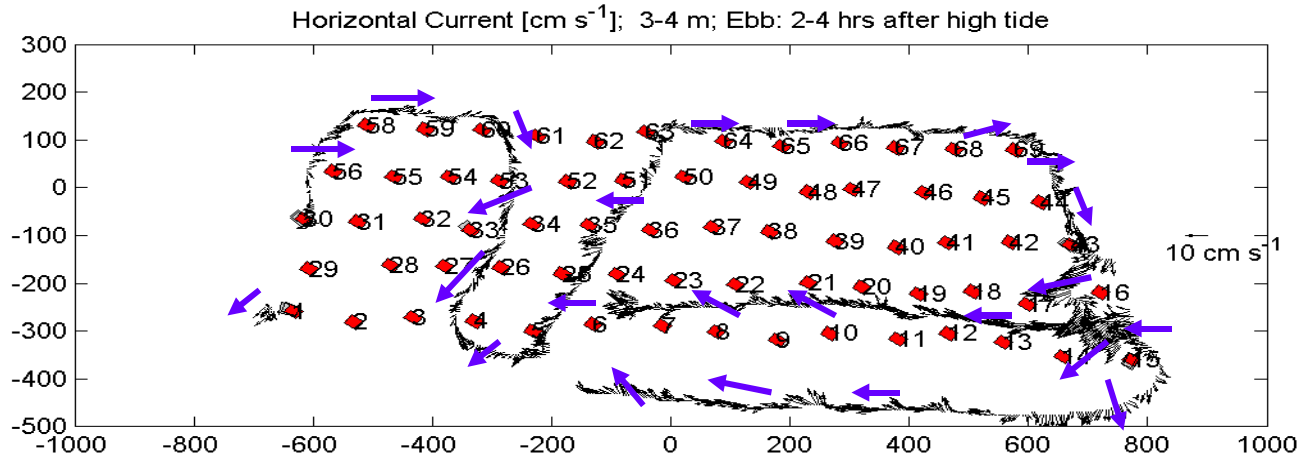
# MaBenE – Rafts' polygon scale

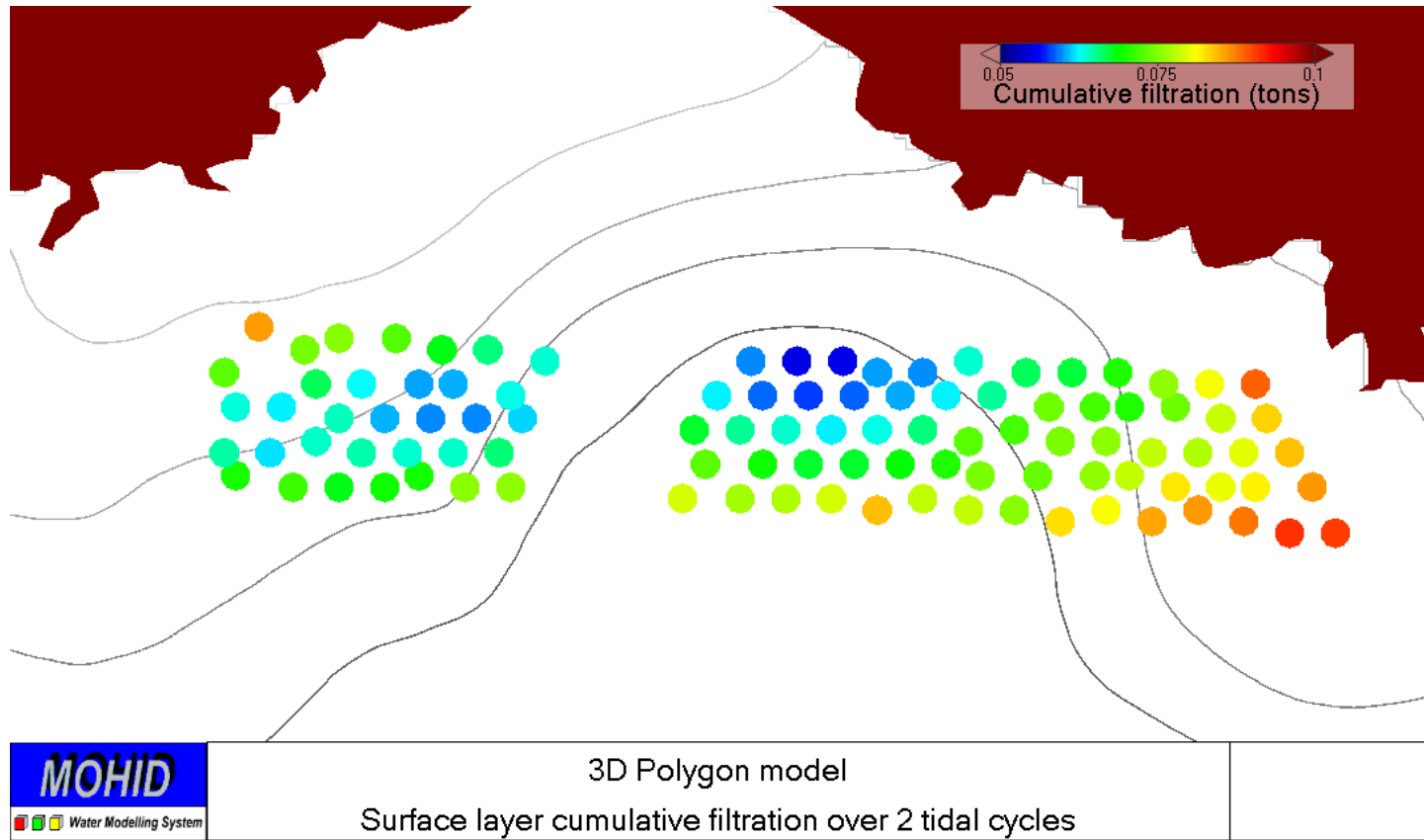
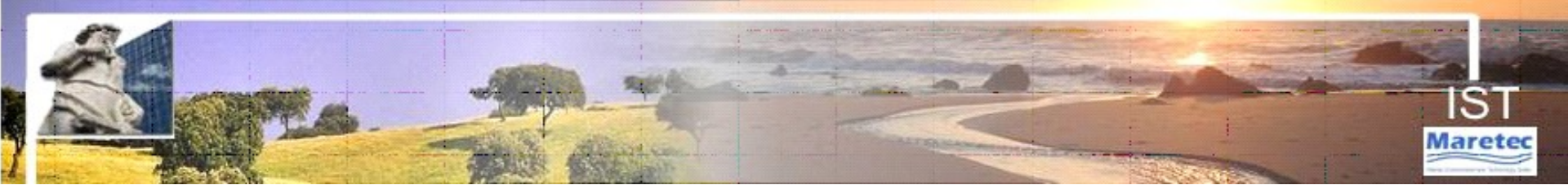
Model

3-4 meters layer  
EBB 2-4 hours after  
high tide



ADCP  
(GKSS)

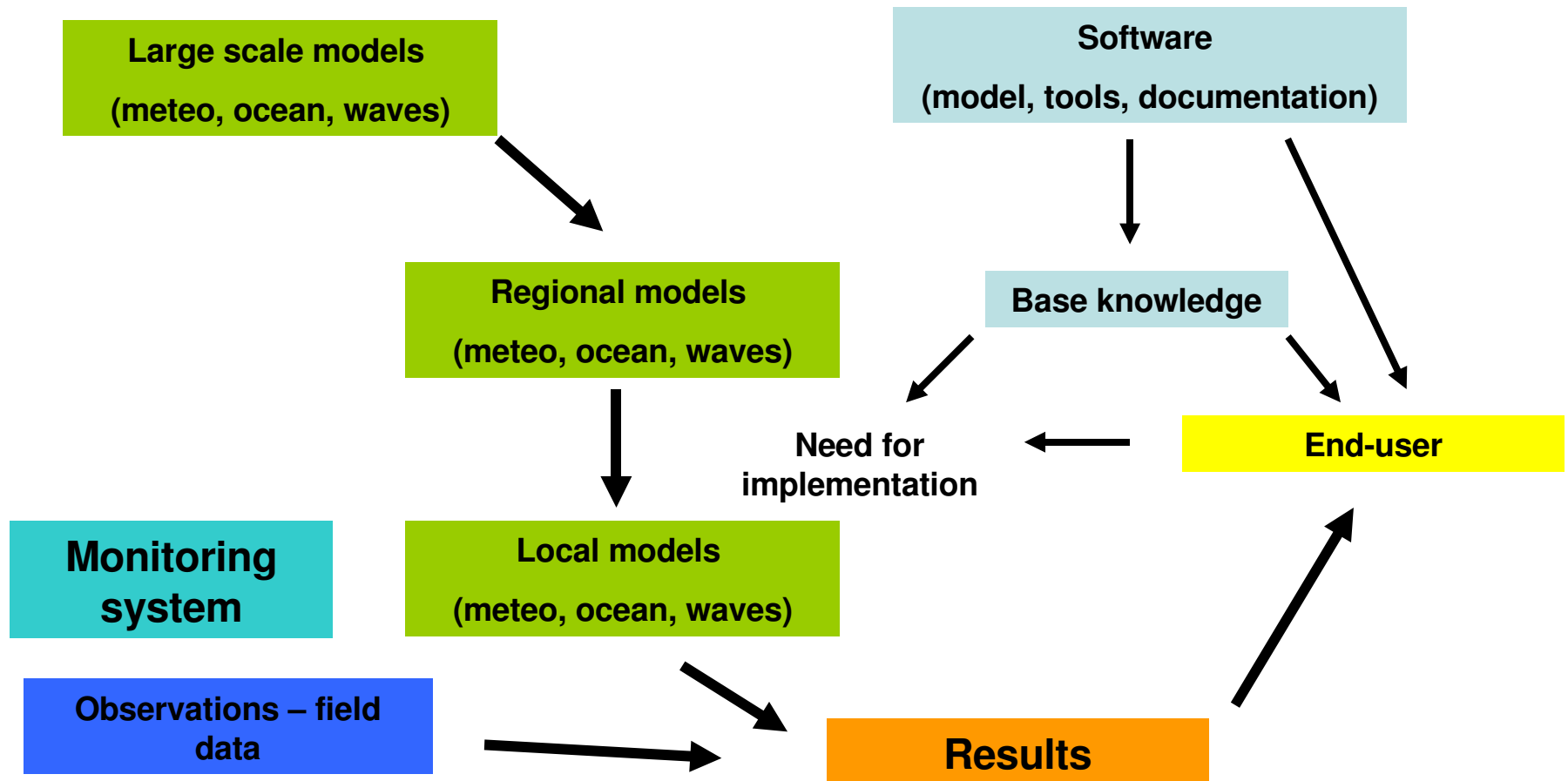


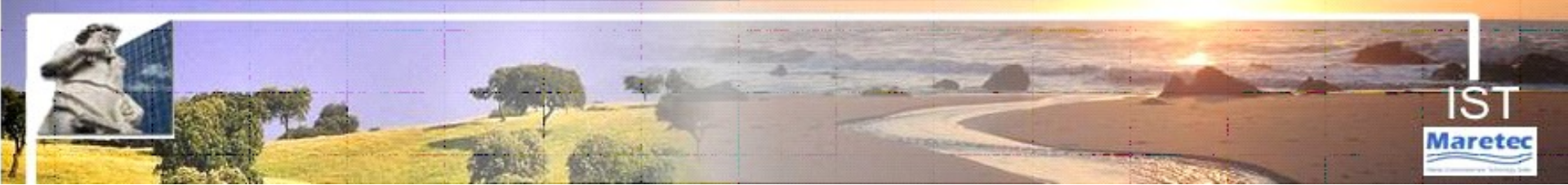




# Products

## Operational systems





Thank you