

# Modelling for the coastal environment



Ifremer



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*CERFACS PhD student 88-91 ; Ifremer 91- ; IRISA 99-00*



# Summary

- Environmental processes and types of modelling
  - Physical processes: circulation and waves
  - Biogeochemical processes
- Present computational effort
  - Coastal operational oceanography: Previmer system
  - Computing center: Caparmor
- Questions for more efficient numerical tools
  - Parallelization issues
  - Data assimilation techniques



# Summary

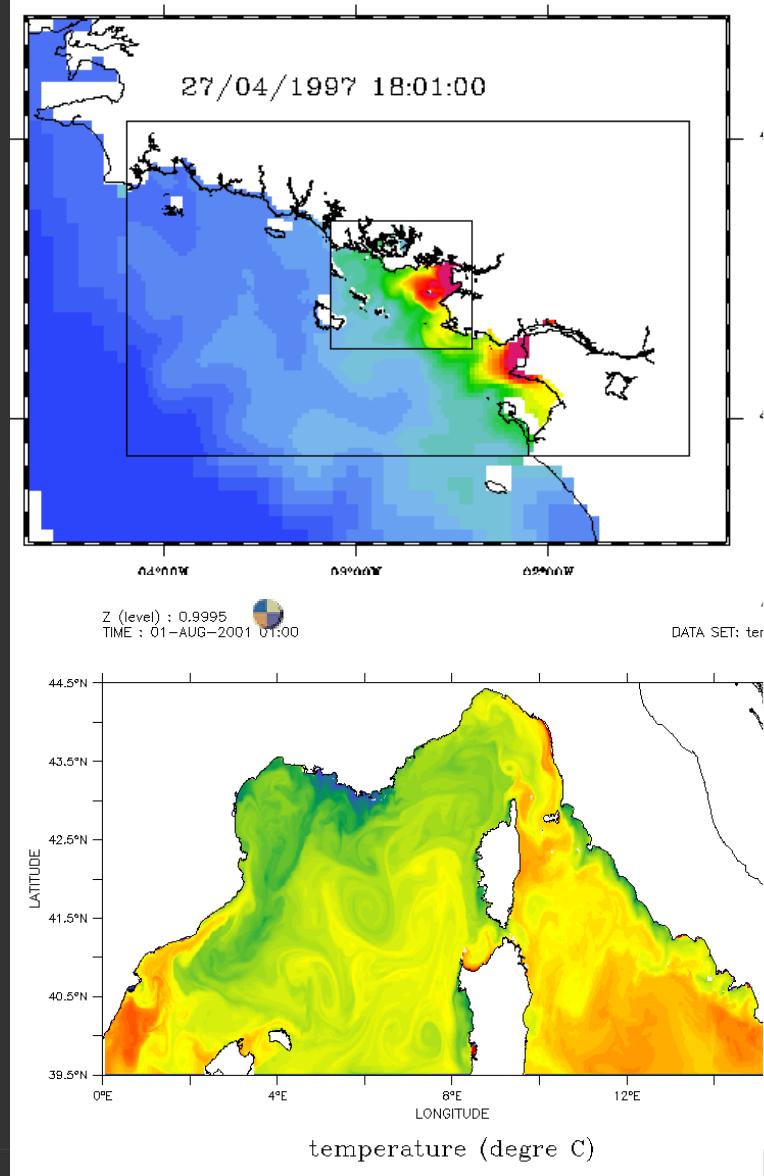
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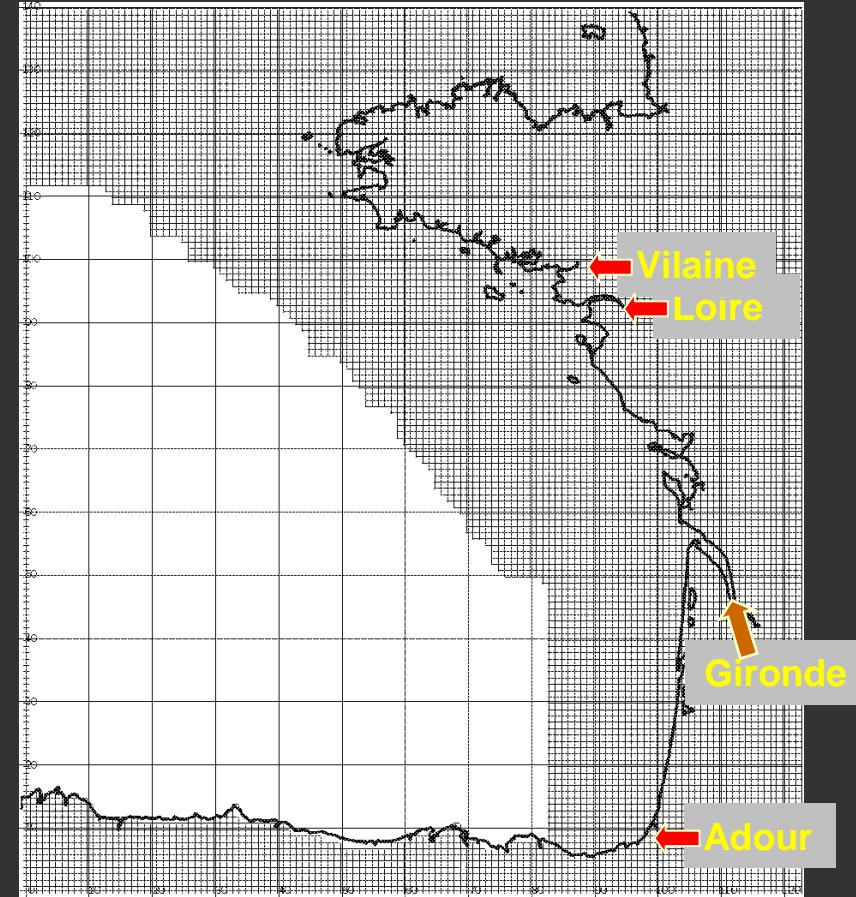
# Short term simulations: various forcing

- Meteorological forcing
  - Arpege / Aladin / Arome
- Ocean variability
  - Nested with Mercator
- Shelf processes
  - River flows and discharge
- Tidal process
  - Drying flats



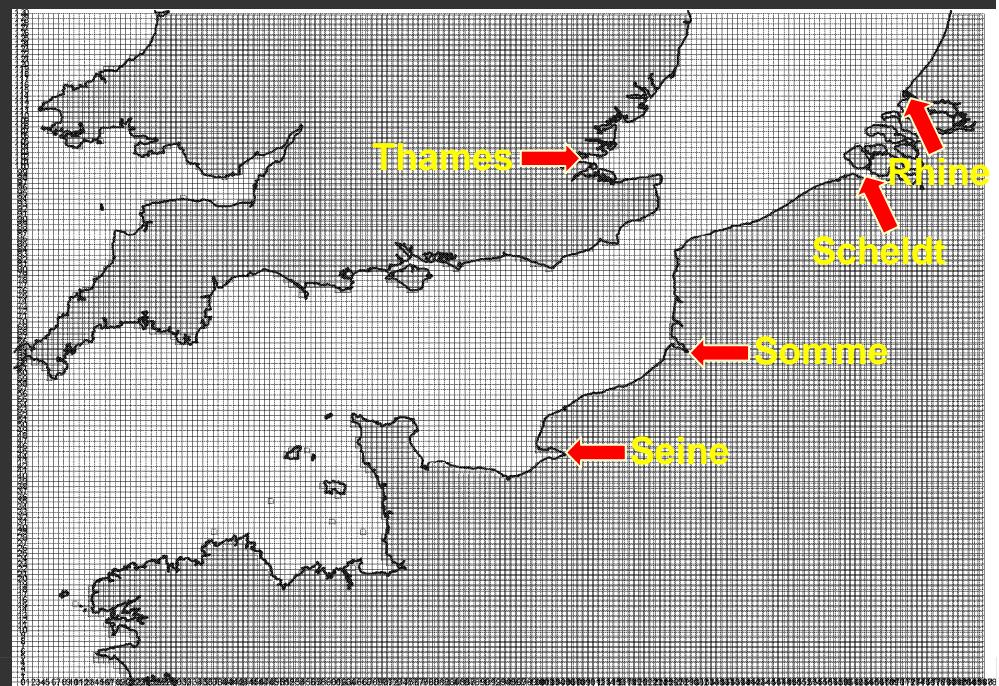
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# MARS3D Atlantic shelf models



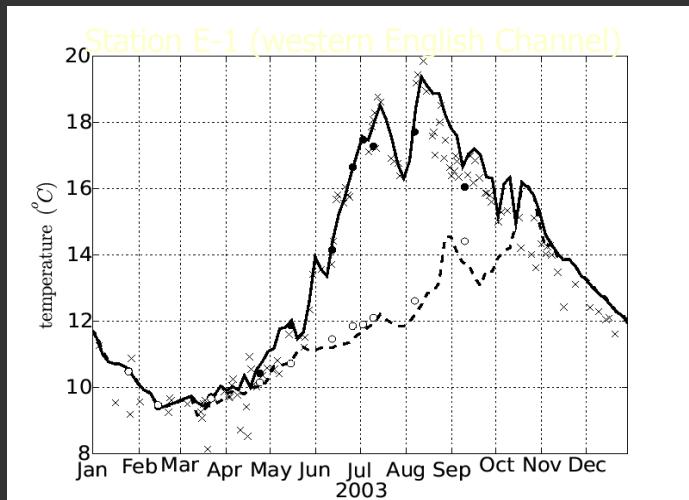
CHANNEL/Southern NORTH SEA  
(7715 square meshes 4x4km,  
12  $\sigma$  layers)

BAY OF BISCAY French Shelf  
( square meshes 5x5km,  
11  $\sigma$  layers)

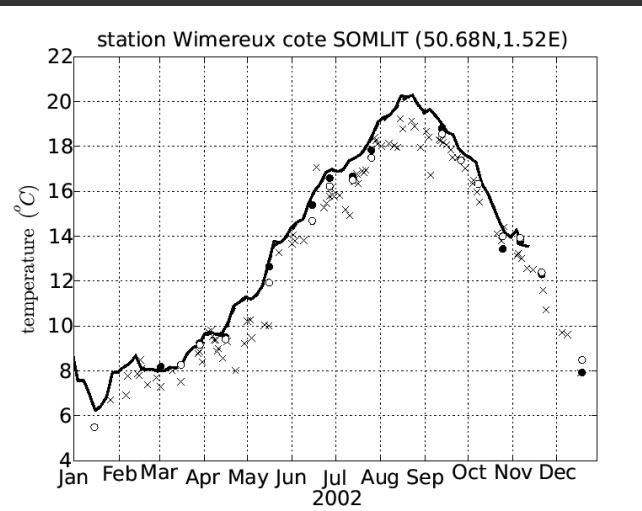


# Validation : synoptic and in situ data

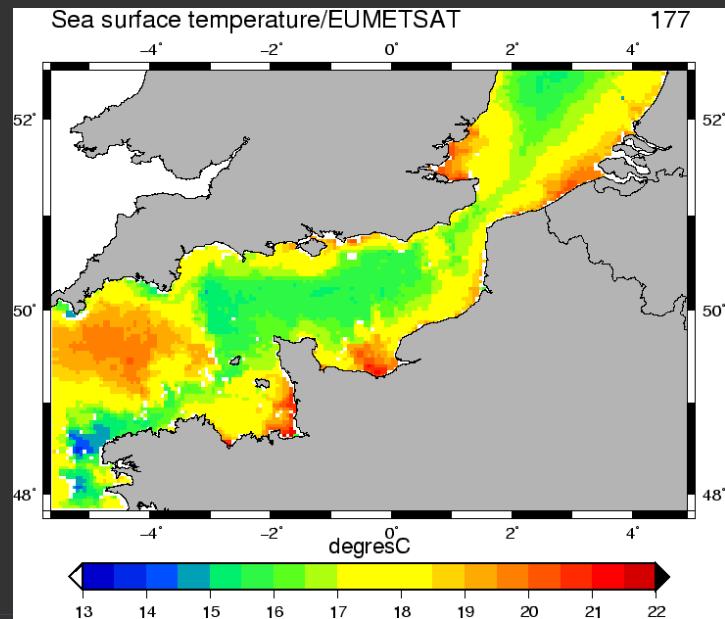
Stratified  
Station  
E1  
(bottom/  
Surface)  
2003



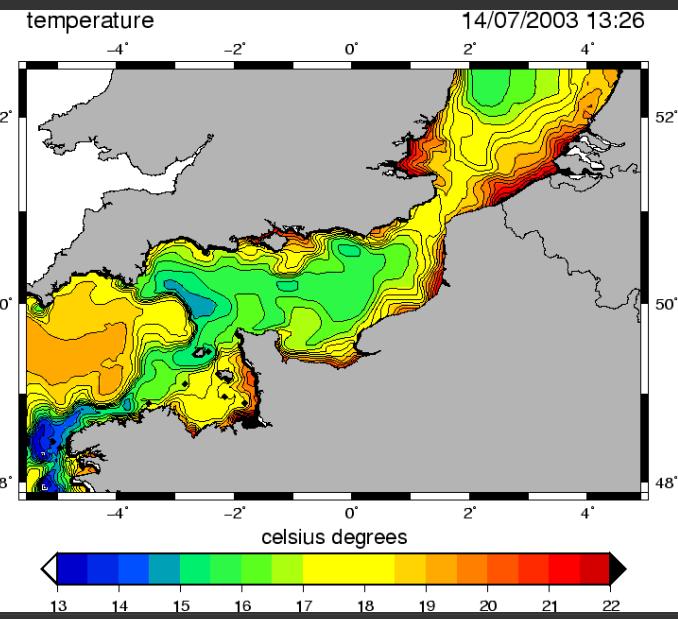
Mixed  
Waters  
Eastern  
EC  
(bottom/  
Surface)  
2002



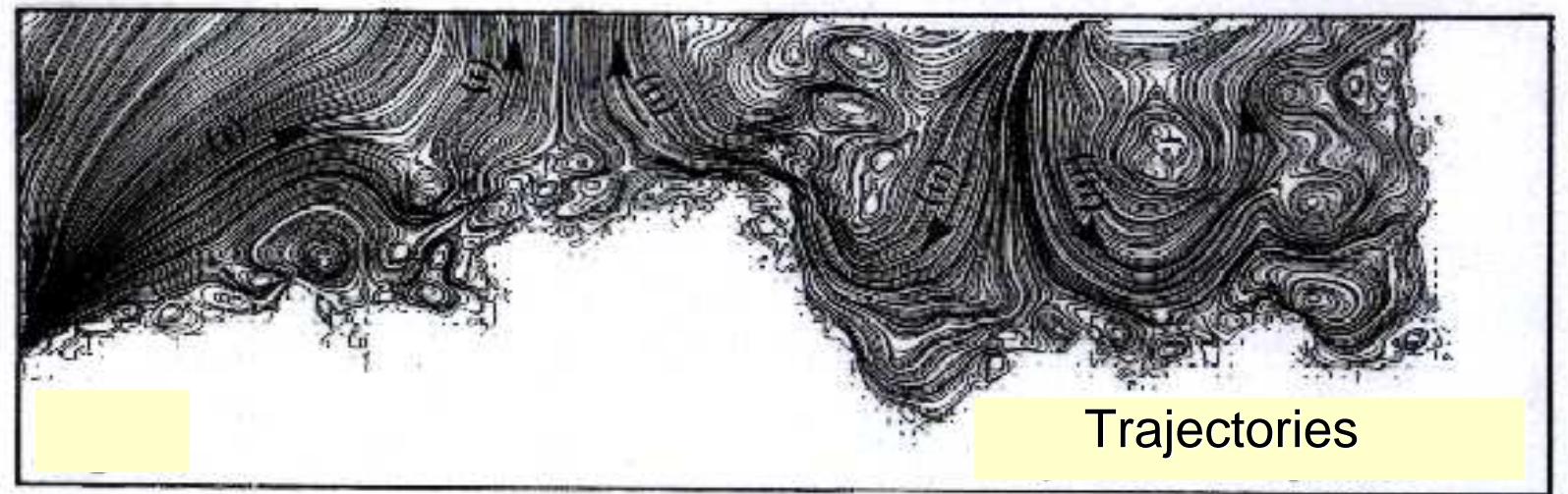
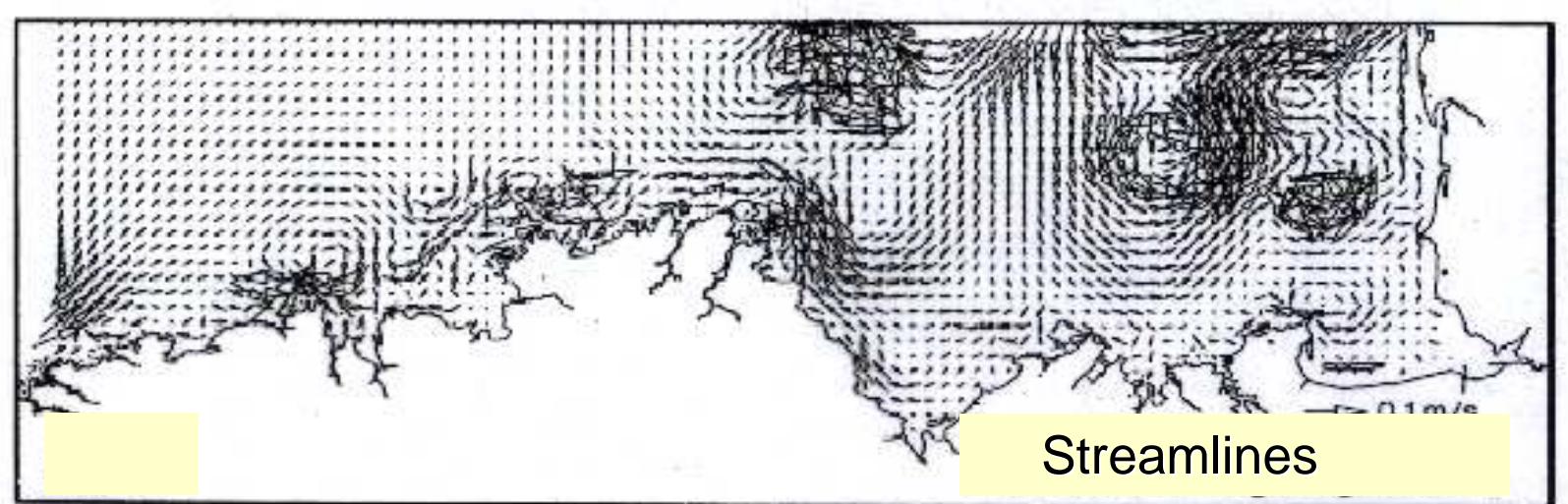
AVHRR  
13/07  
2003



Model  
14/07  
2003



# Long term simulations: residual currents



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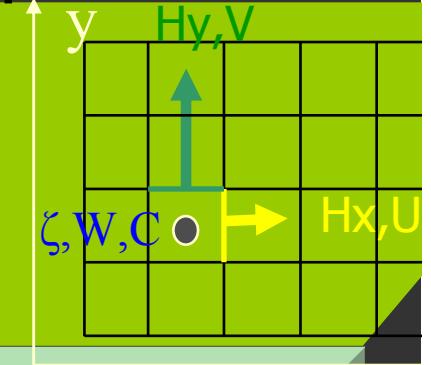
# Hydrodynamical model at Ifremer: MARS, Finite difference model for coastal applications

## MARS 2D

Saint Venant Equations

Semi-implicit ADI scheme

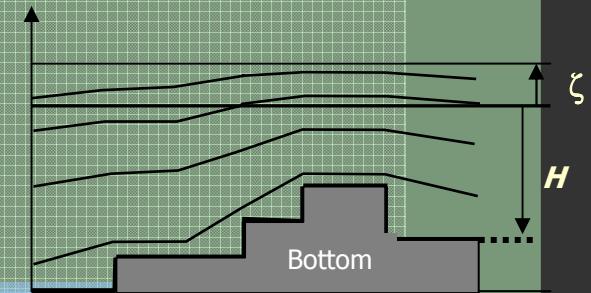
Tidal effects on foreshore



C Arakawa grid and stable TVD scheme

## MARS3D

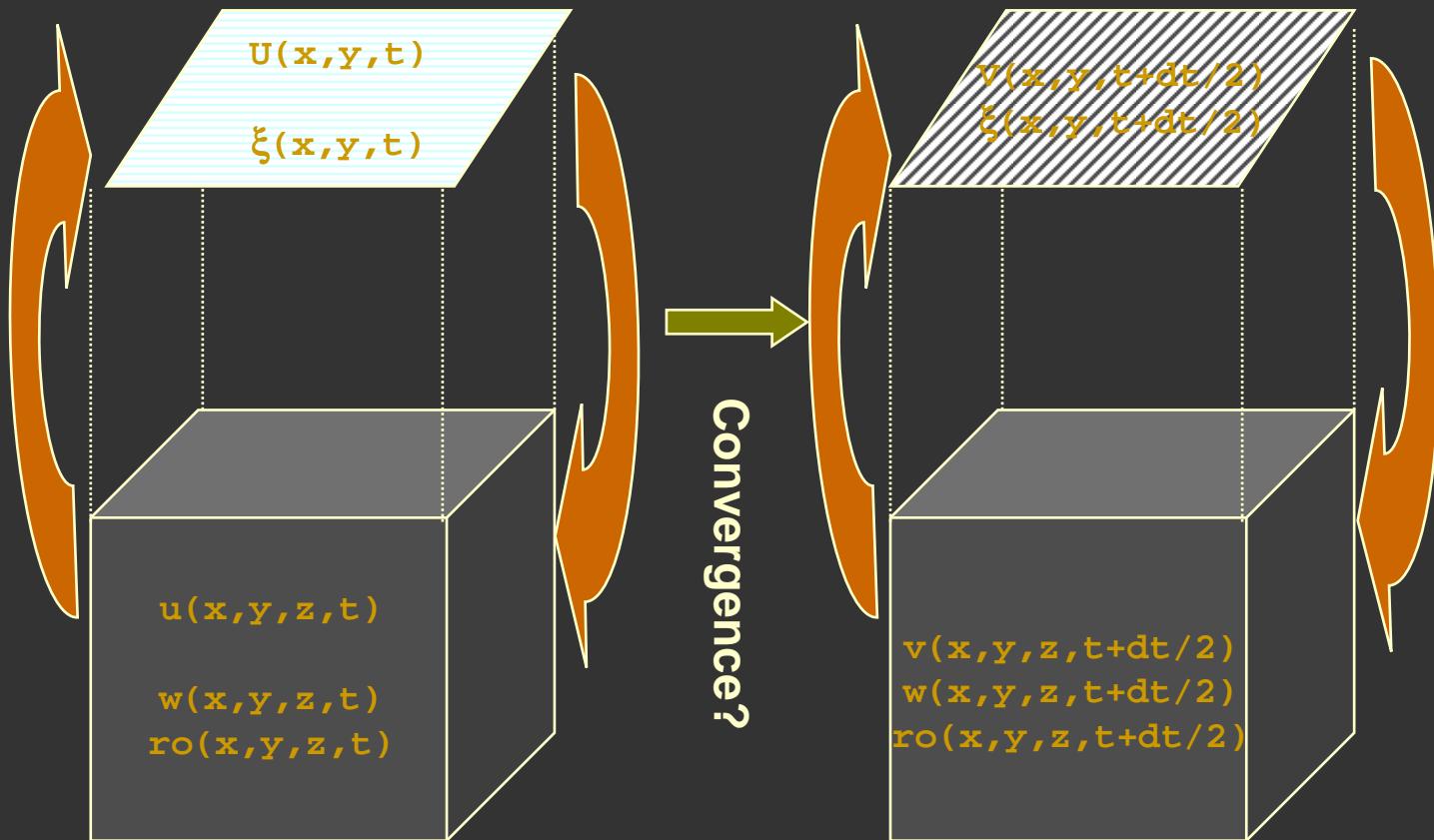
- Primitive Equations (hydrostatic ap.)
- Sigma coordinates
- Free surface and foreshore



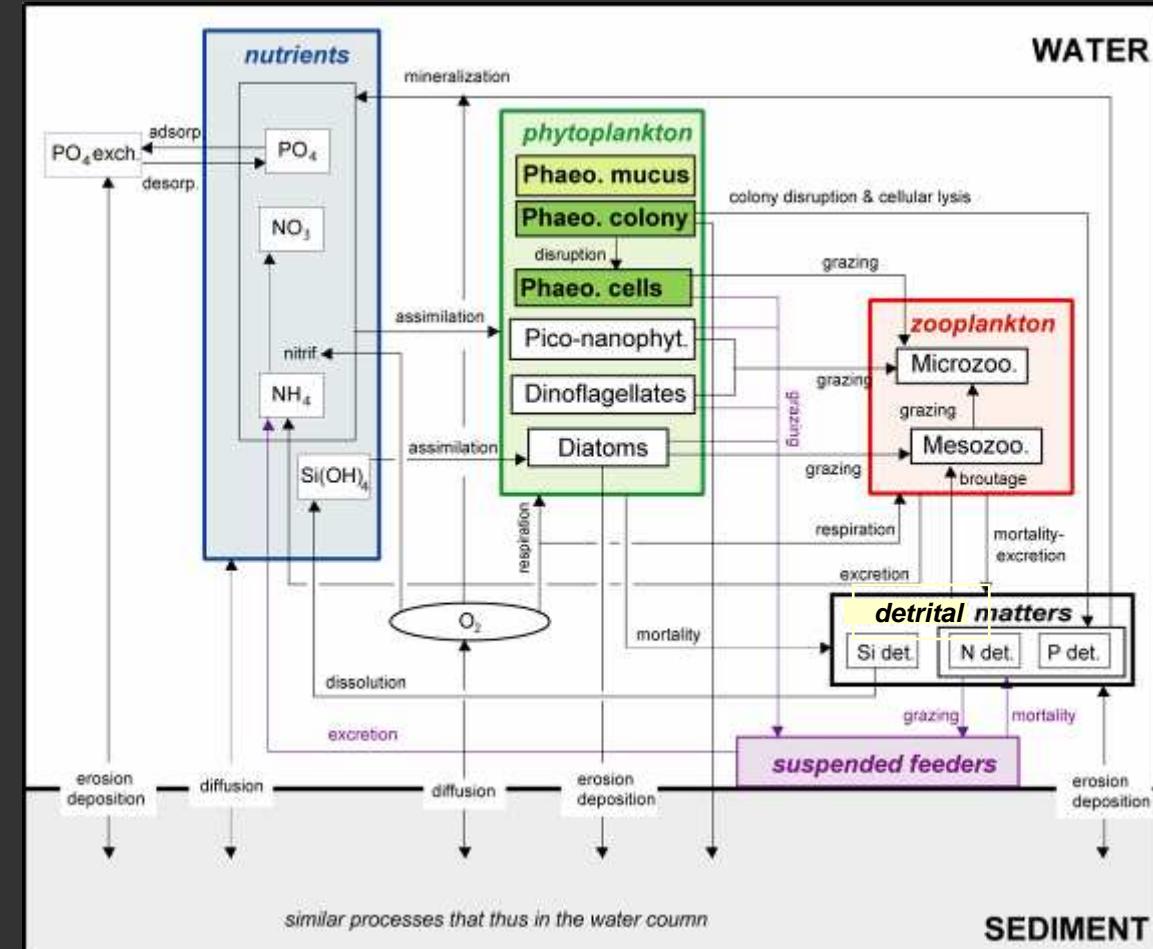
- Mode separation / semi-implicit 2D
- Iterative procedure for convergence of internal and external modes
- Large CFL timesteps:

# Mode splitting in MARS3D

- Explicit mode: ADI for barotropic mode (2D)
  - + iterations with internal baroclinic explicit mode



# Biological model in ECO-MARS3D



A NPZD model which can include "species of interest" submodels  
(e.g. harmful species)



Solve the transport equation for each parameter  
Then solve the ODE's

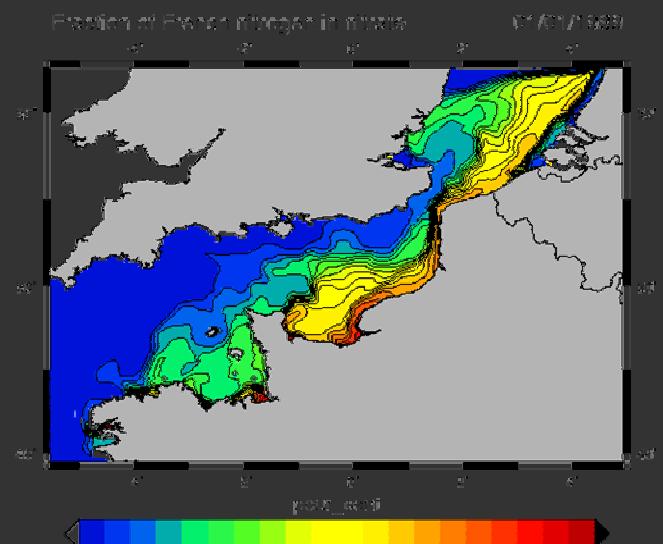
Example for « Diat » state variable :

Basic O.D.E equation:  $d\text{Diat}/dt = \mu \cdot \text{Diat} - m \cdot \text{Diat} - g \cdot \text{Mzoo}$

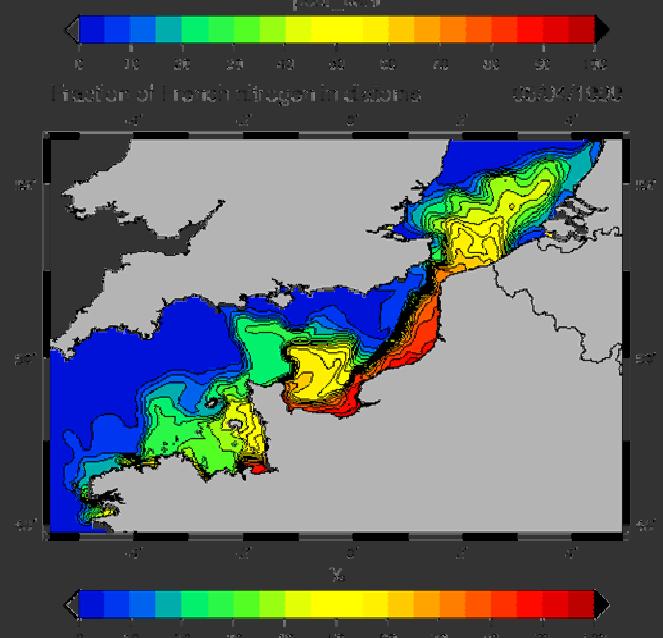
# Tracking the watershed-originated nitrogen into the marine foodweb

- Fractions in the peak concentrations

Nitrate from French rivers  
at the beginning of the year (%) :



Nitrogen from French rivers  
in diatoms at their peak period (%) :



This kind of simulation needs two years of spin up



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CERFACS Sparse days, October 2007

**www.previmer.org**

# Previmer

## Coastal Observations and Forecasts

Previmer



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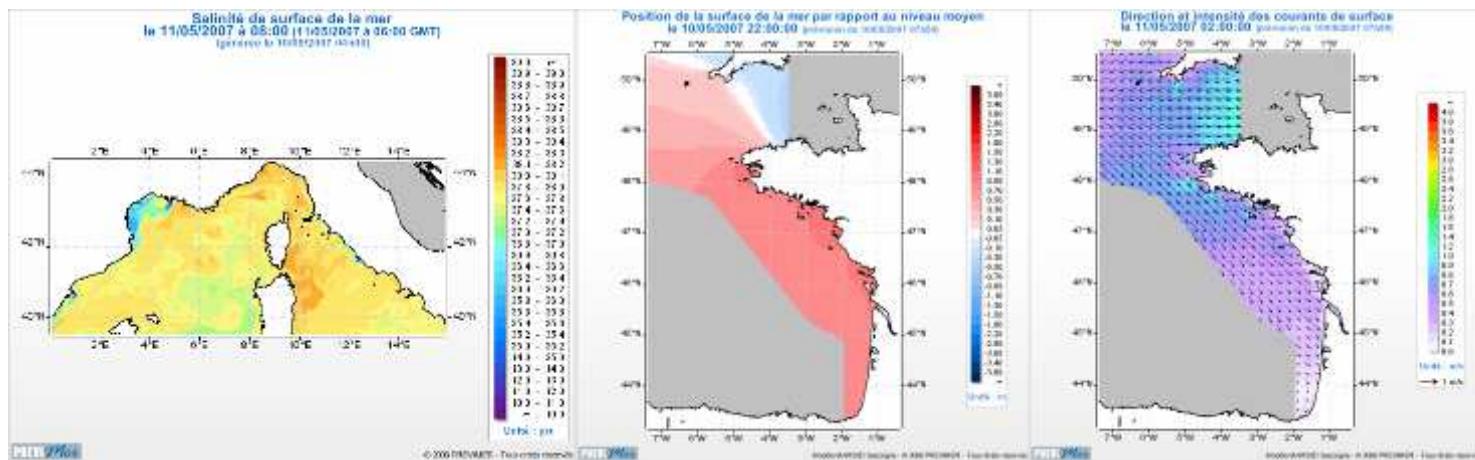
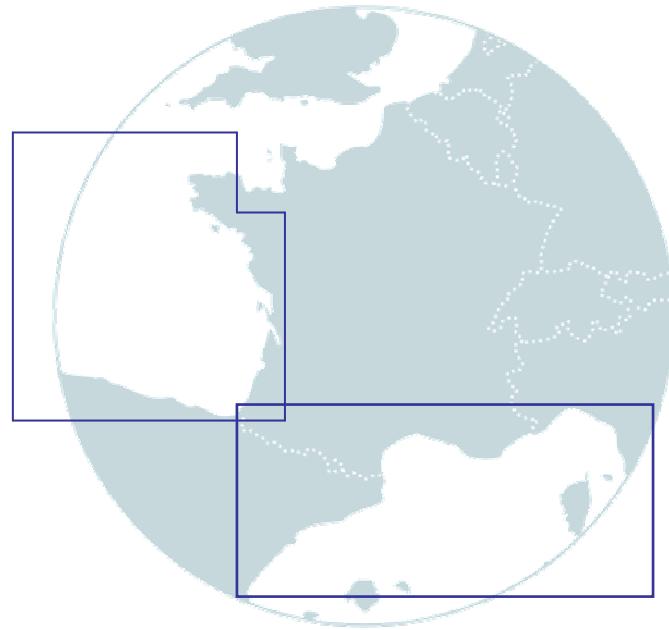
# Objectives

- ☛ PREVIMER provides observation data and 48h forecasts on coastal environment along the French coastlines over the Channel, the Atlantic Ocean, and the Mediterranean:
  - ☛ Current speed and direction,
  - ☛ Water temperatures on the surface and in the water column,
  - ☛ Sea level and surges,
  - ☛ Wave height, direction and frequency,
  - ☛ Salinity,
  - ☛ Particle and plankton concentration,
  - ☛ Sanitary quality...



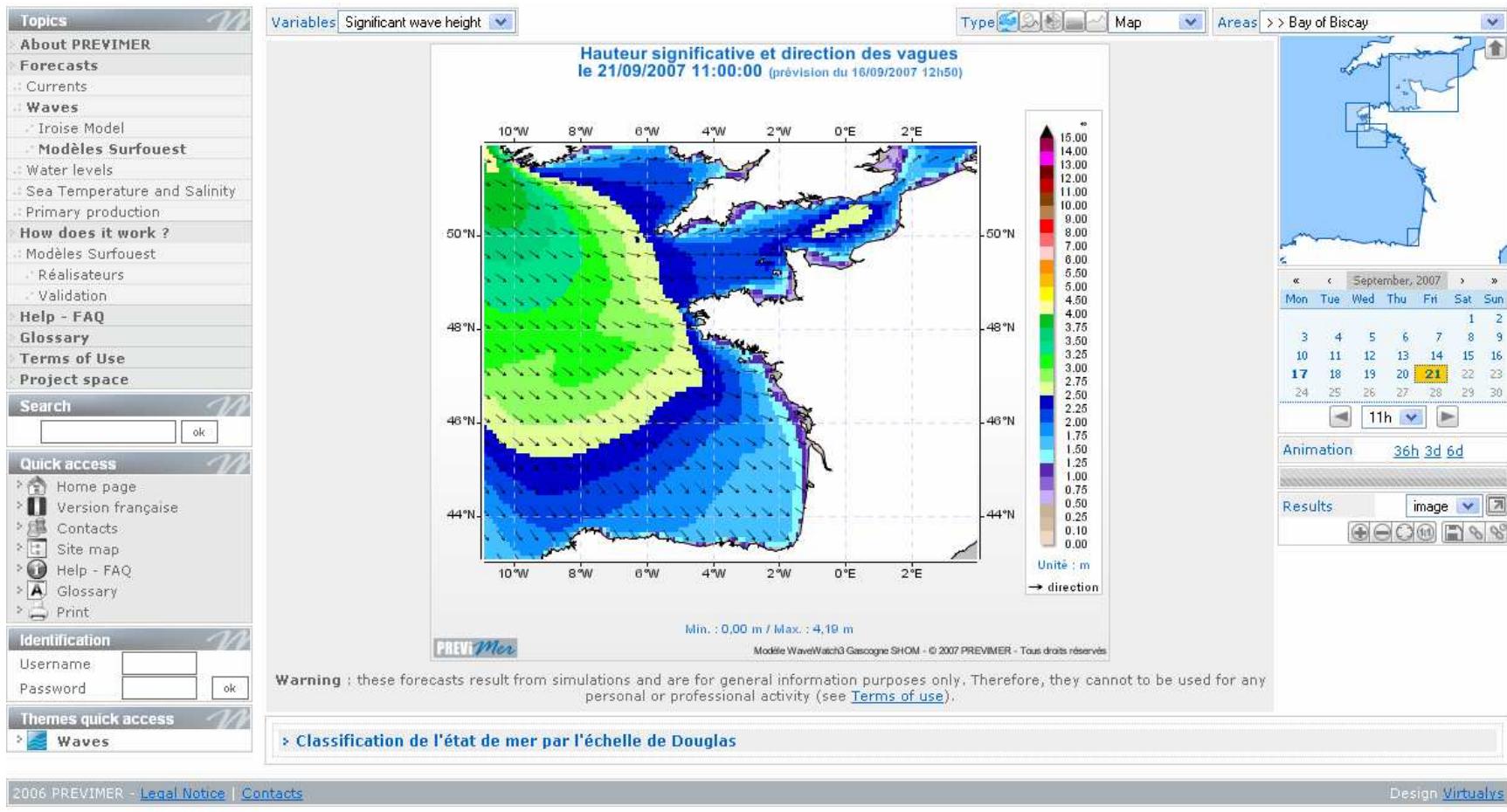
# Our global scale: the façades

- ➊ Temperature, salinity, currents and water height over the French maritime facades
- ➋ Ongoing development: extension to the Channel
- ➌ MARS3D code devoted to coastal modelling (Ifremer devt)
- ➍ No interaction with wave modeling



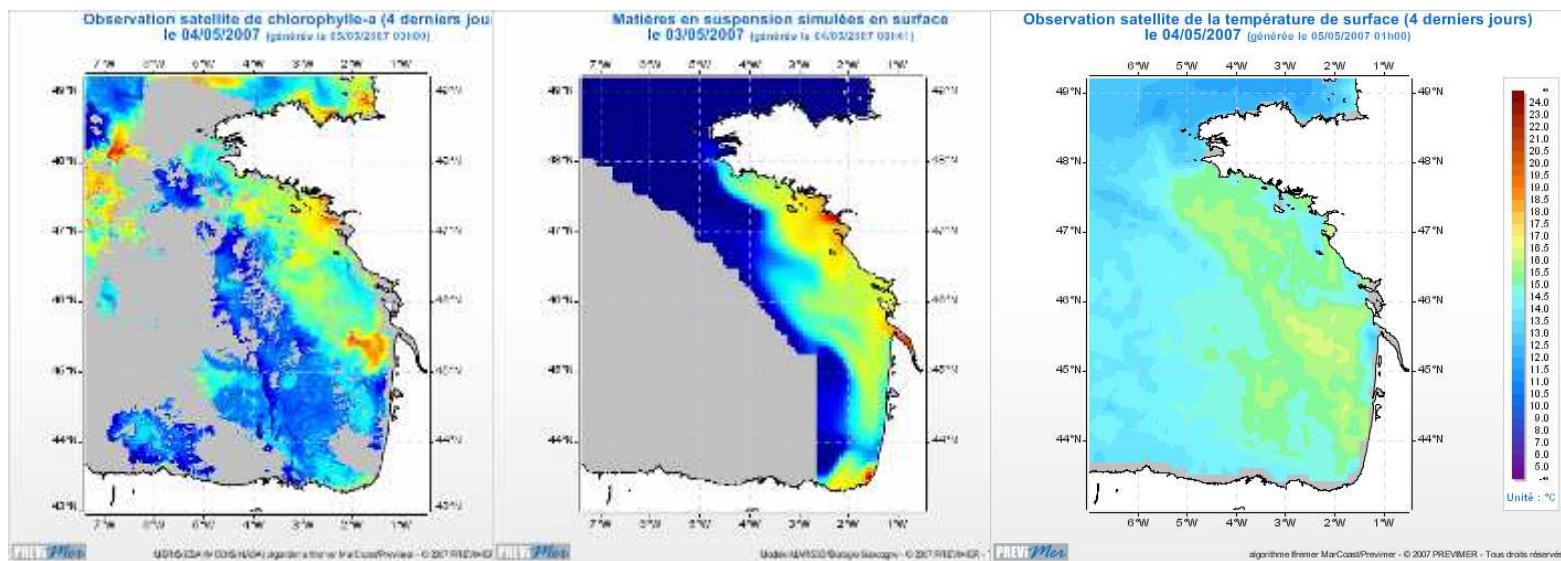
# Our global scale: the façades

- Wave height, period and direction
- WaveWatch3 models (SHOM)
- No interaction with circulation modeling



# Large scale primary production

- Modeling of the Bay of Biscay
- Zoom over Brittany
- Turbidity (impacting factor for plankton growth) from climatology out of sea color image processing



# Iroise Sea 3D hydrodynamical model

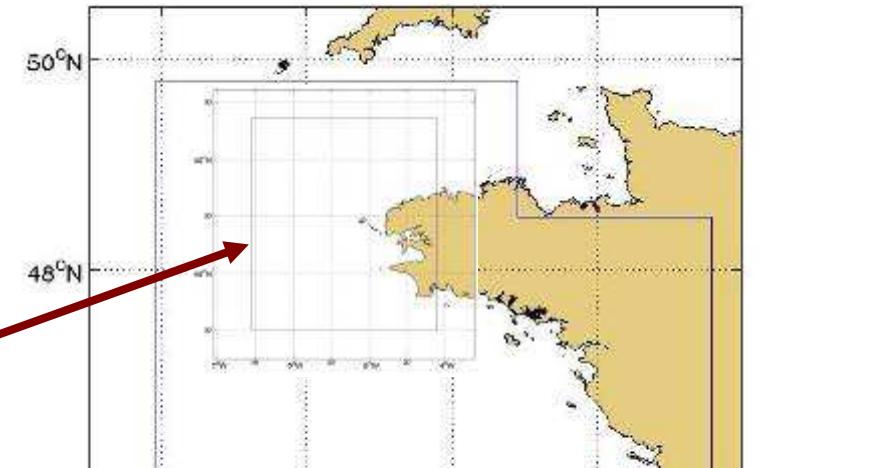
MARS 3D, Primitive equation model in finite differences and sigma coordinates

800 m resolution

15 vertical levels

OBC : U, zeta, T, S

Meteorological forcing :  
Wind, Pressure,  
Humidity, Cloud cover,  
Air temperature

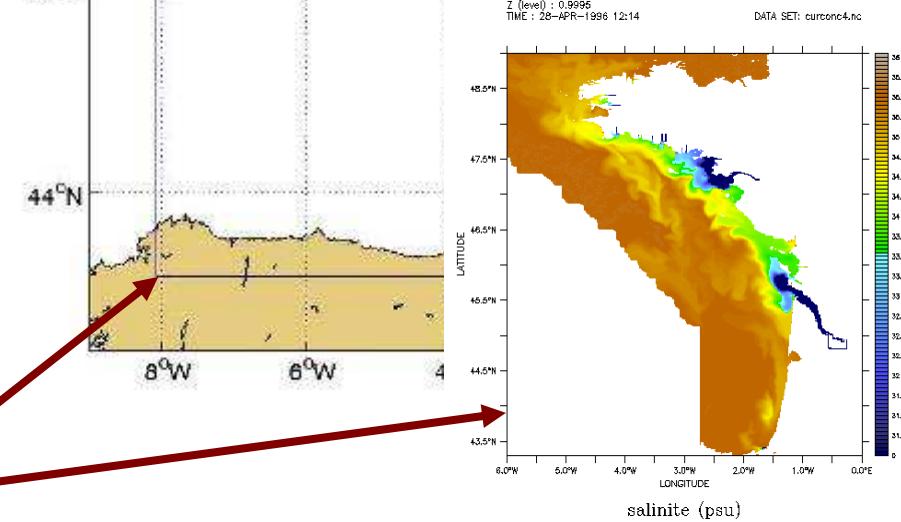


CERFACS Sparse days, October 2007

Broadcast information :

- Sea surface temperature
- Surface currents

nested in a 3D regional  
model of the Bay of  
Biscay (5km resolution)



# Wave models : Four model nesting (two levels)

Phase averaged energy transport models SWAN (Booij, et al 1999) and WaveWatch III (Tolman 1998).

Wavewatch III

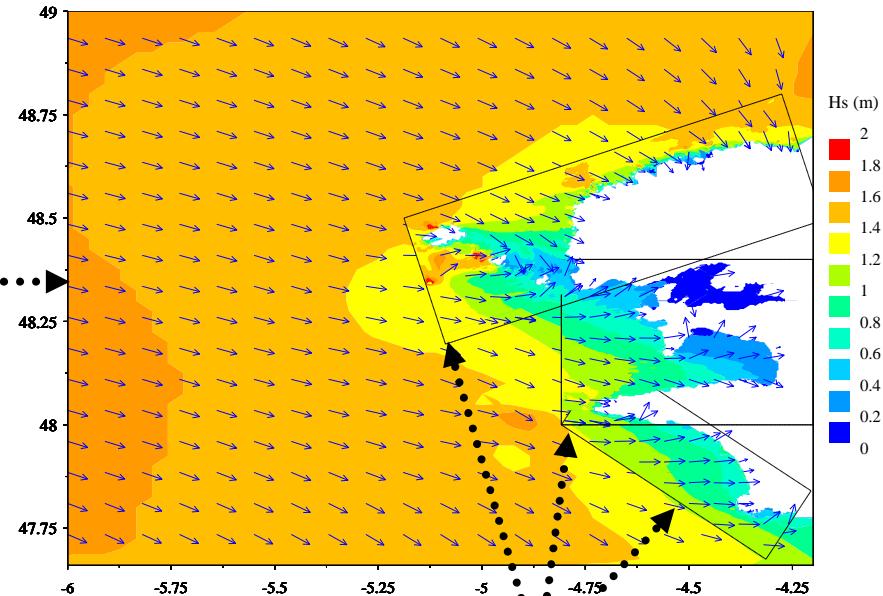
Resolution : 3 km

OBc from Bay of Biscay WWIII configuration (SHOM, F Ardhuin)

Aladin wind forcing

**Refraction due to currents and sea levels variations (MARS 2D model)**

Non-stationary



Broadcast information:

Significant wave heights

Peak period

Direction

Full spectrum

SWAN

Resolution : 300m

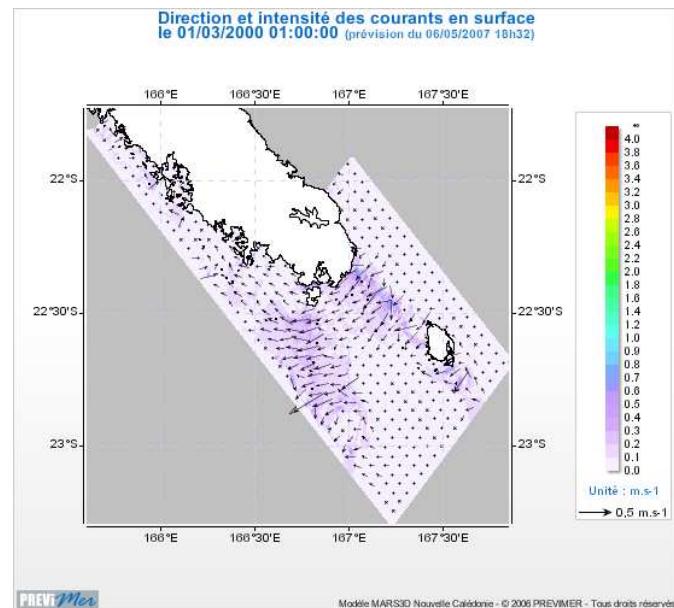
OBc from WWIII Iroise Sea

Aladin wind forcing

Refraction due to currents and sea levels variations (MARS 2D model).

Stationary computations

## ➤ Exchange between lagoon and ocean New-Caledonia



## ➤ on line end 2007

# Today's computing ressources for Ifremer, hence for Previmer operational system: a submerged cluster of 64 Compaq nodes

The screenshot shows a Mozilla Firefox browser window with the title "ouverturefichier - Mozilla Firefox : Ifremer". The address bar shows the URL <http://w3.ifremer.fr/intranic/nymphea/pagecache.php>. The page content includes the Ifremer logo and a banner image of a dolphin and waves. The main text on the page is "Résultat Résumé pour la queue "previd1p1" pour "juillet"". Below this, there is a section titled "- Informations sur la queue previd1p1" containing the following data:

Informations sur la queue previd1p1
Jobs soumis : 478
Jobs bien terminés : 470
Jobs erronés : 8
Temps moyen d'attente dans la queue: 172
Temps elapsed moyen : 1360
Temps moyen CPU : 4354
Temps total CPU : 2368004

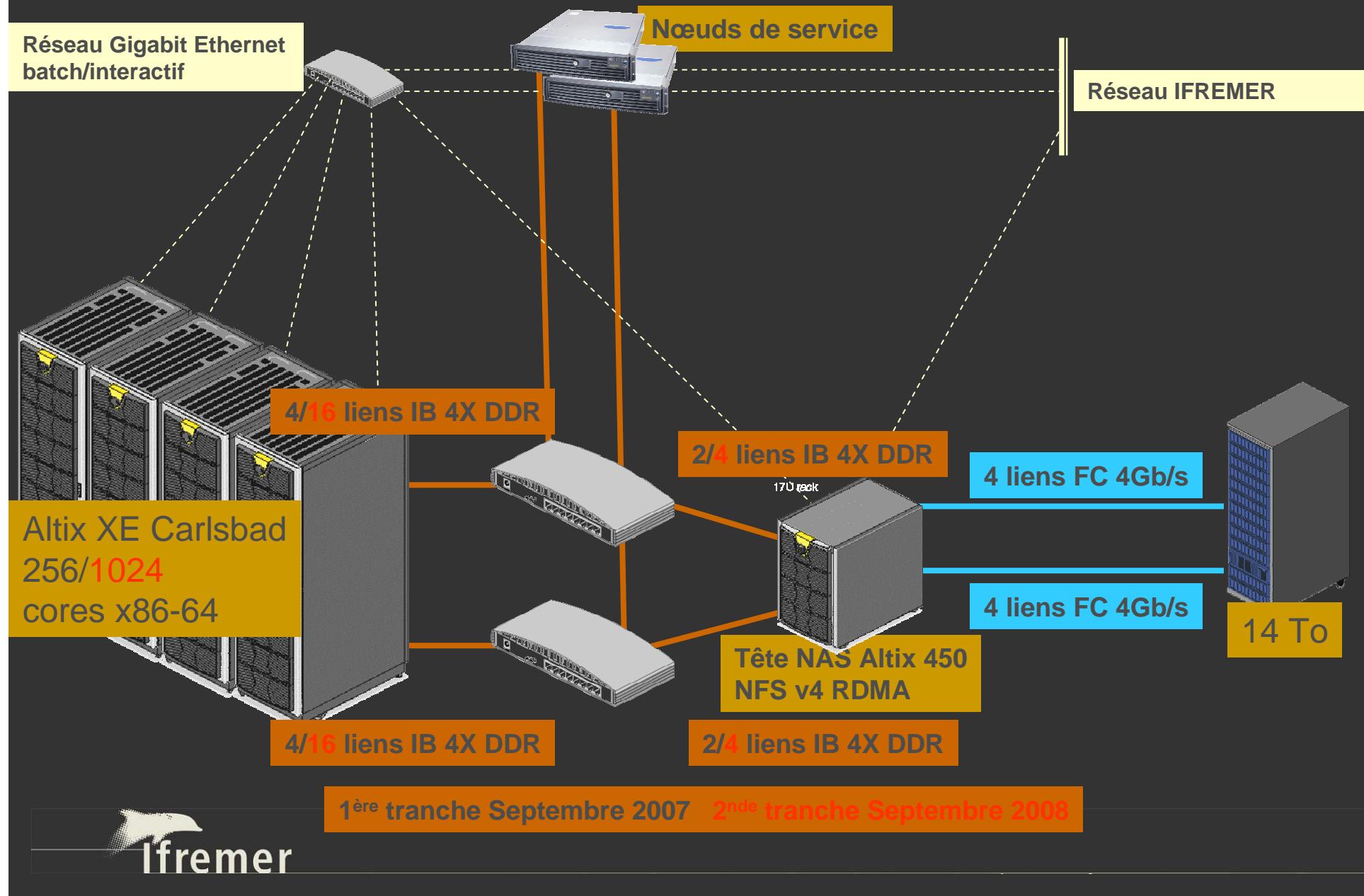
A note at the bottom states: "Tous les temps sont exprimés en secondes."

At the bottom of the page, there is a footer with the Ifremer logo and the text "[Accueil]". Below the footer, there is a note: "5 hours elapsed time a day" and "Most applications are parallelized with OpenMP and a speed-up of 3 (4 CPU nodes)".

# Landing of the 1st SGI Altix ICE 8200 in France: Brest, Aug. 22nd



# CAPARMOR configuration



# ICE 8200 customer list



- NASA Ames - 8 racks 512 nodes, 4096 cores
- NASA Langley - 2816 cores
- Naval Research Laboratory - 1536 cores
- Honda Racing F1 Team - 1024 cores
- Sandia National Lab - 512 cores
- Ifremer (France) - 256 cores
- Schlumberger - 192 cores
- Université de Rio de Janeiro - 152 cores
- Université d'Exeter - 128 cores
- Posdata (Ehys) - 40 cores
- Sikorsky Aircraft - 32 cores



## Ongoing

- > à 8000 cores ~100TFlops





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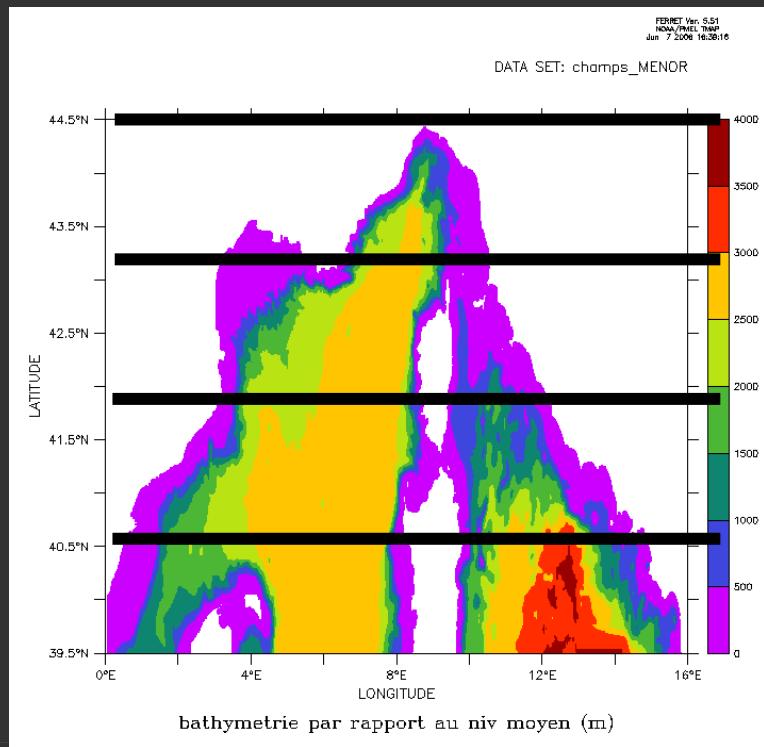
Ifremer



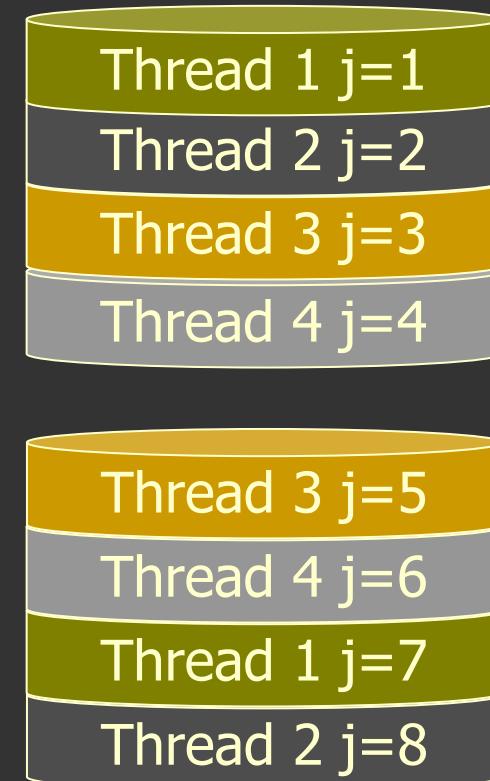
# MARS/OpenMP

Calculation task should be divided equally!

## STATIC

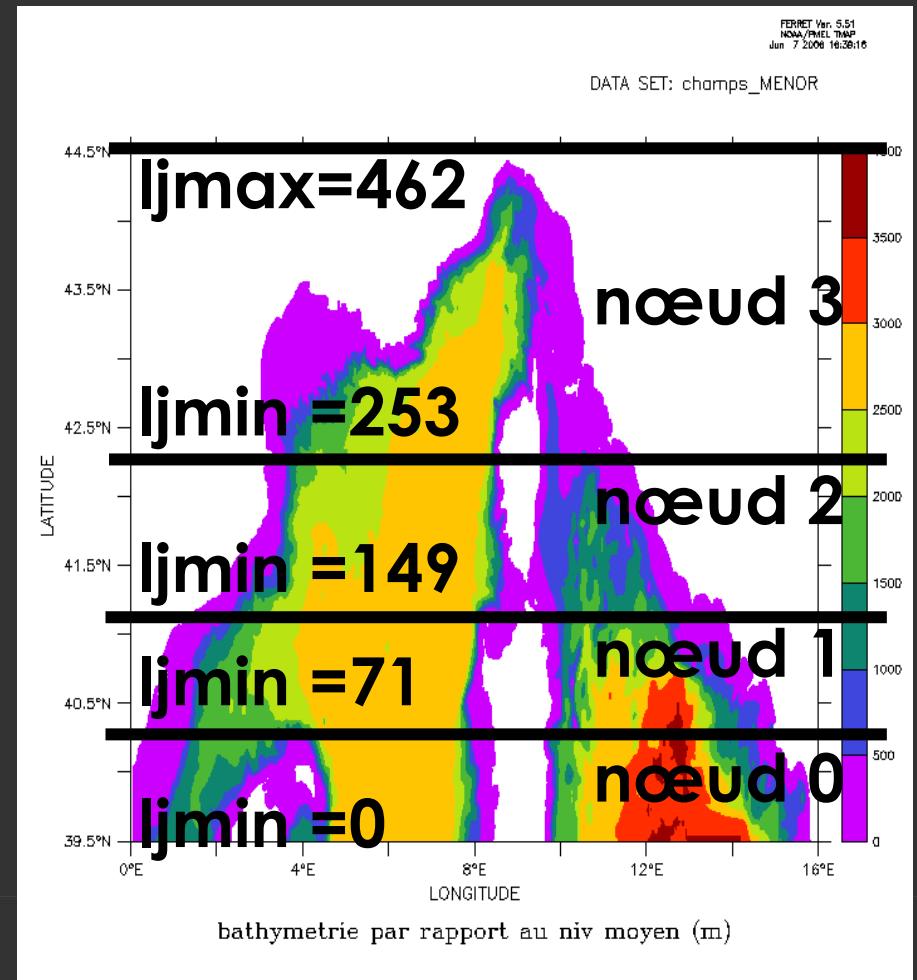


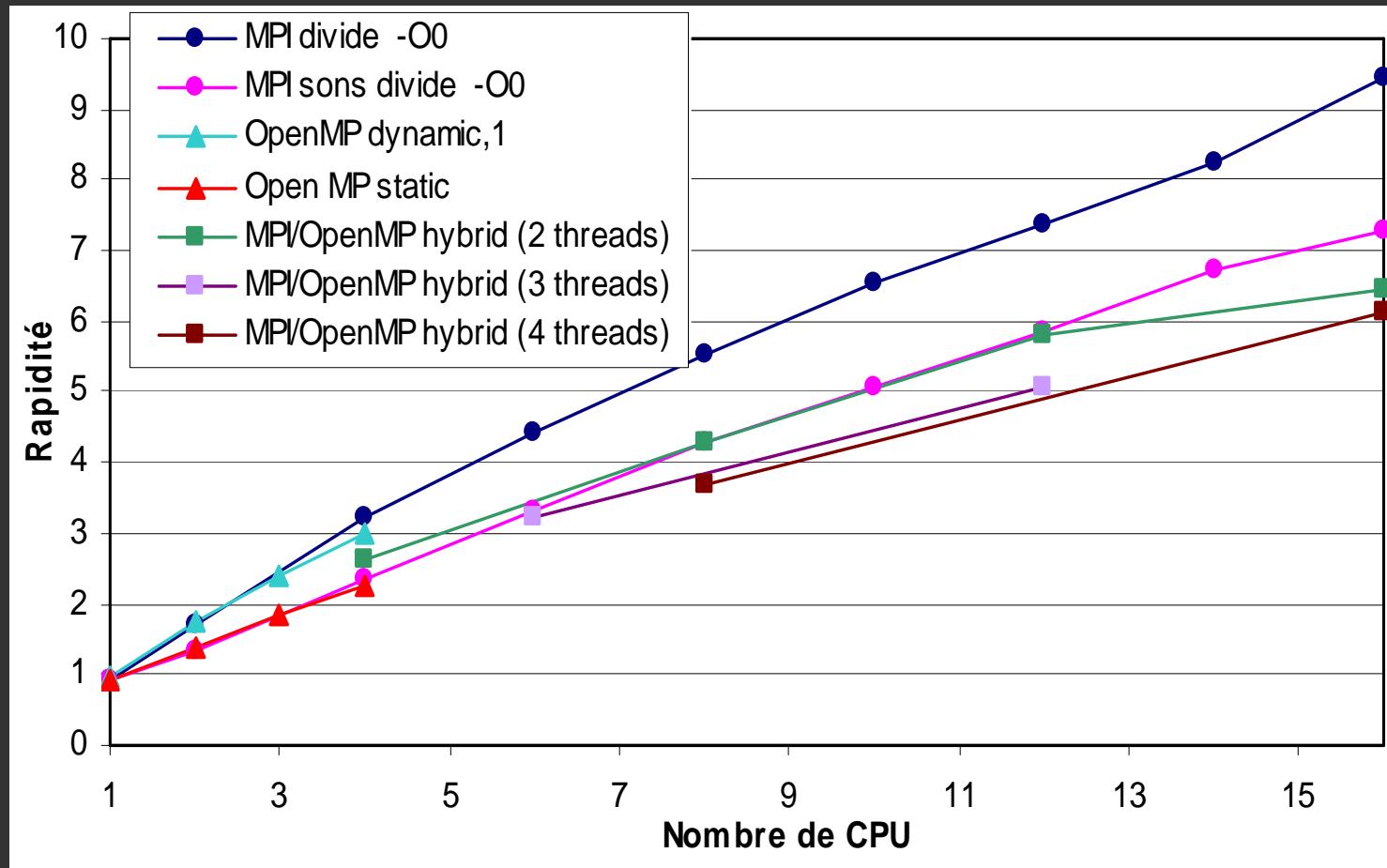
## DYNAMIC



# MARS/MPI

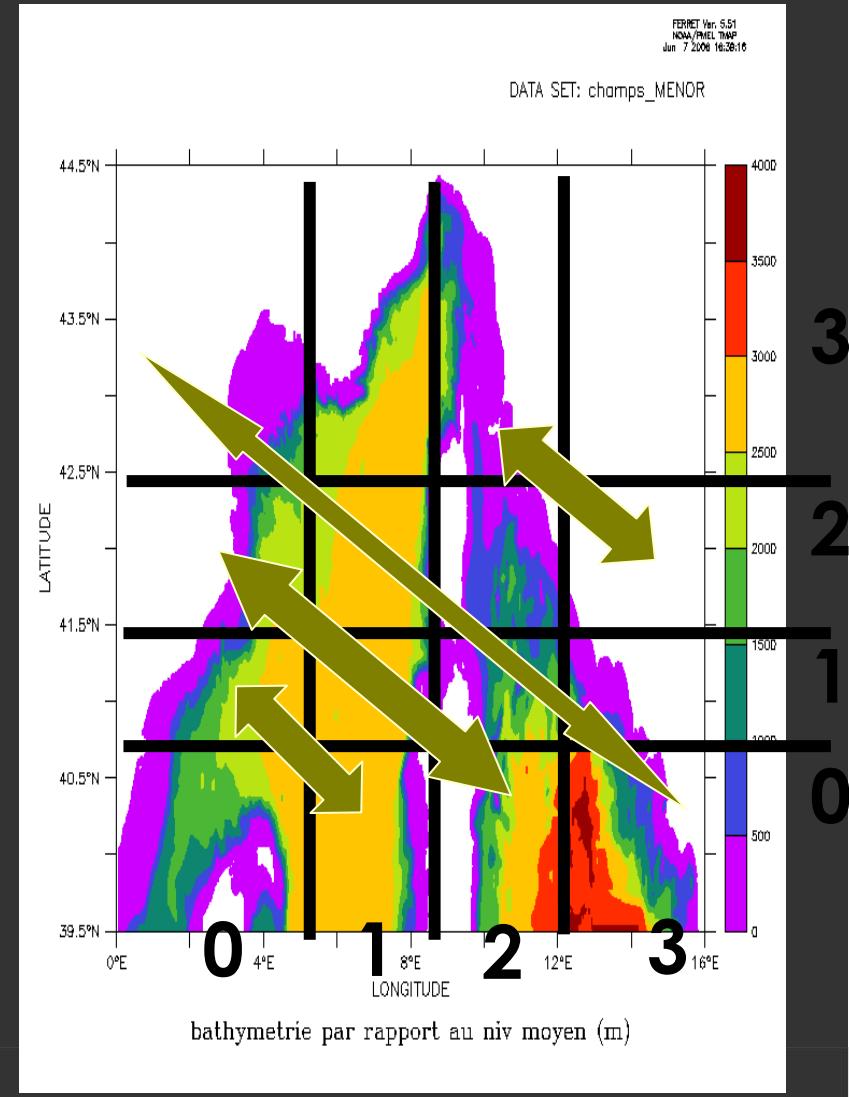
- Subroutine “divide”
  - Static load balancing
- without parallelization
  - 66 min. 32 s.
- MPI (4 nodes)
  - 20 min. 43 s.





# Data transfer for the ADI solver or full domain decomposition

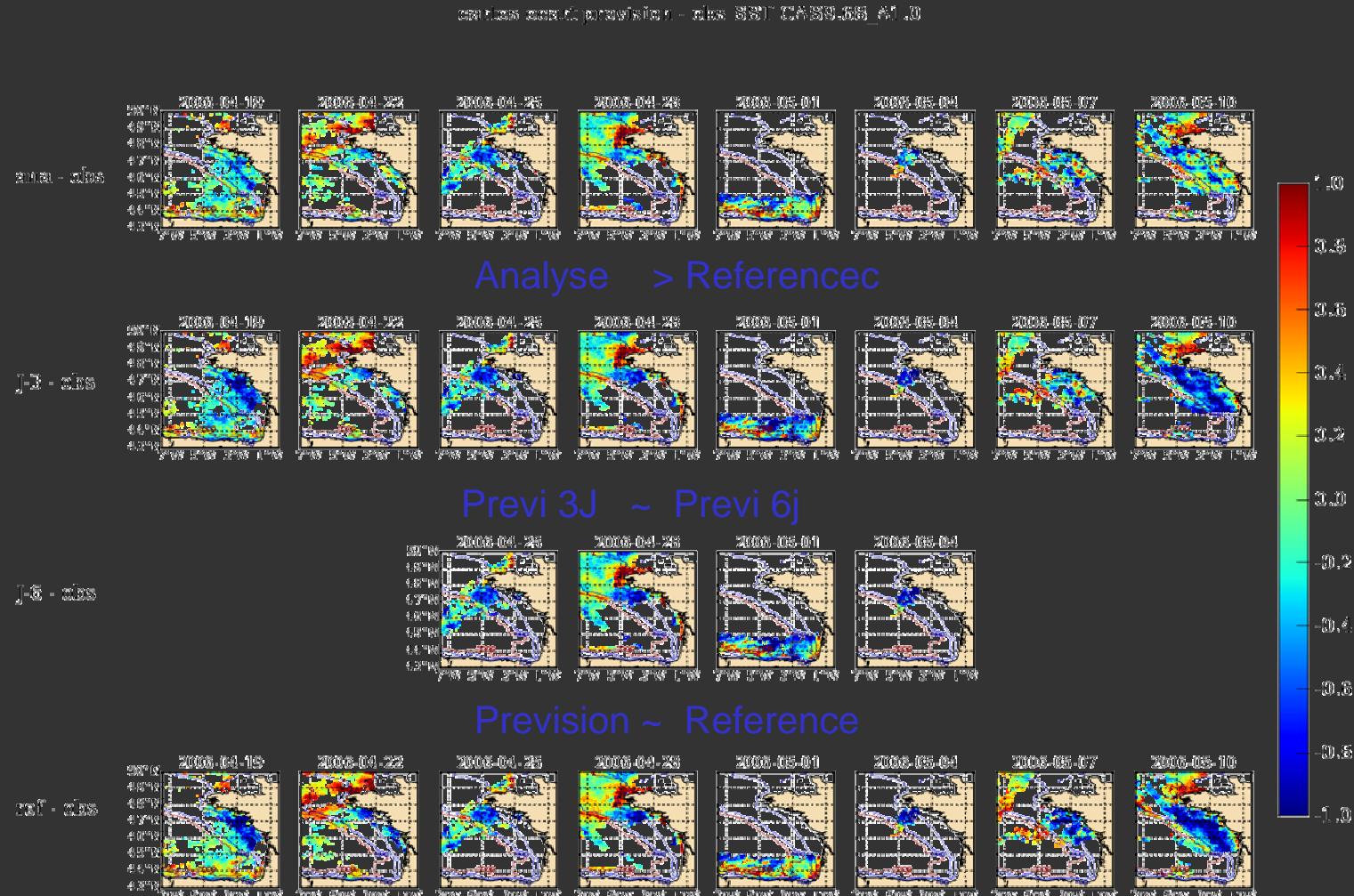
Useless to transpose  
and transfer



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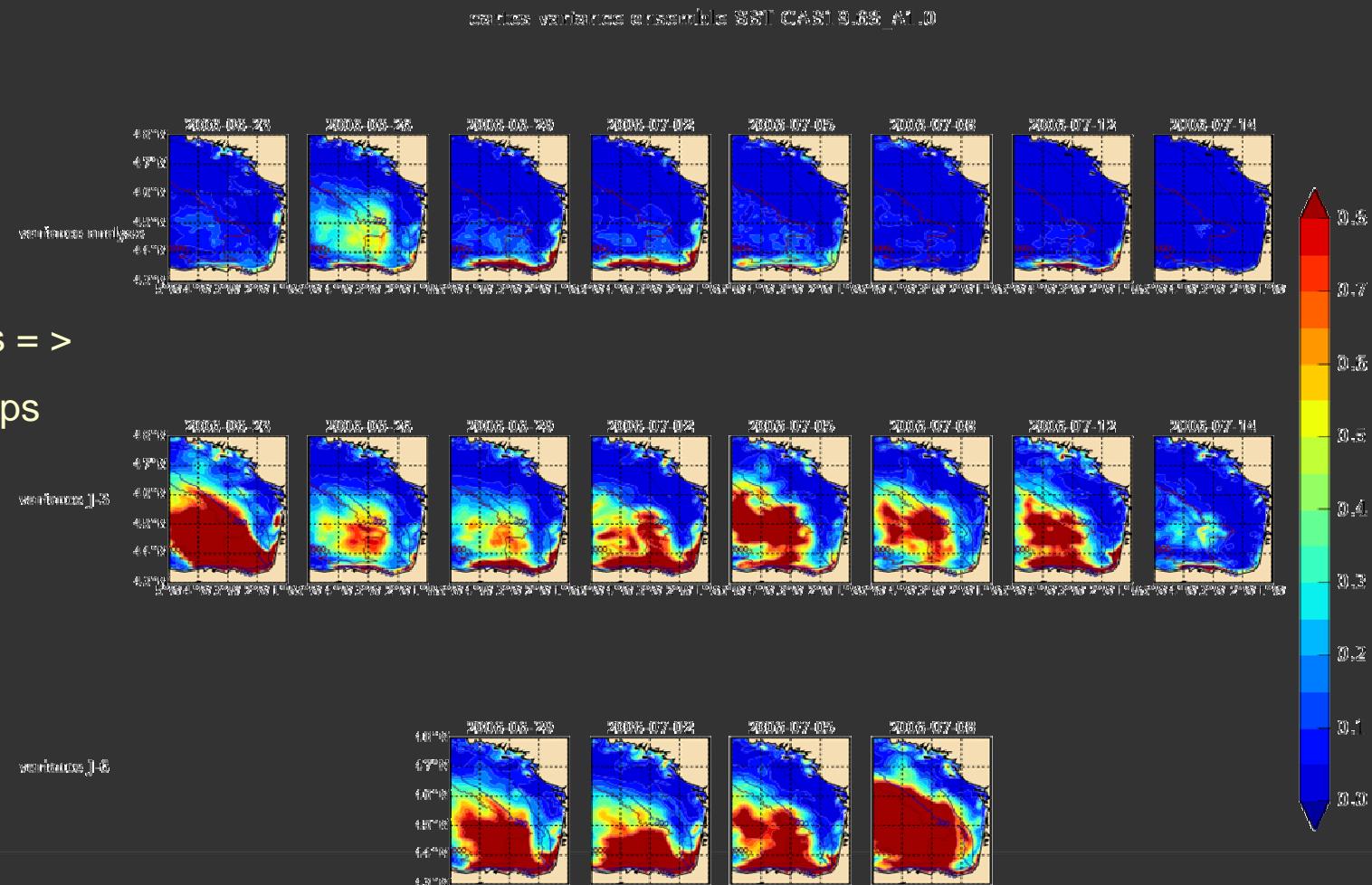
# Yet another issue: data assimilation

- Sea surface temperature is assimilated by clear sky



# Sequential Ensemble Kalman filter method

- 30 members in the ensemble evolve in parallel
  - No need to calculate the adjoint state / tangent code



# Questions?



Thanks for specific contributions of Tina Odaka, Valérie Garnier, Alain Menesguen, Franck Dumas, Philippe Riou from Ifremer,  
and of Philippe Cranéguy from Actimar  
Pictures : A. Le Magueresse, Ifremer