Observing the Ocean:

A changing Paradigm

A vision for Operational Oceanography

Jean-François Minster

Ifremer

Recent evolutions

- **Increasing perception of ocean issues**

  climate – resources – usages - environment

- **Knowledge and technology**

  allowing the establishment of operational systems (in particular WOCE, TOGA, JGOFS, LOICZ, CLIVAR…)

- **Demonstrations of preoperational systems**

Ocean issues
eg coastal ocean (GOOS)

- Improved security and efficiency of usages of coastal oceans
- Mitigation of natural hazards
- Detecting and monitoring – Impacts of climate change
- Reduction of risks for human health (HAB, virus)
- Protection and restoration of marine ecosystems
- Sustainable exploitation of marine resources
- Military operations

Many diverse issues

Ocean systems
eg coastal ocean

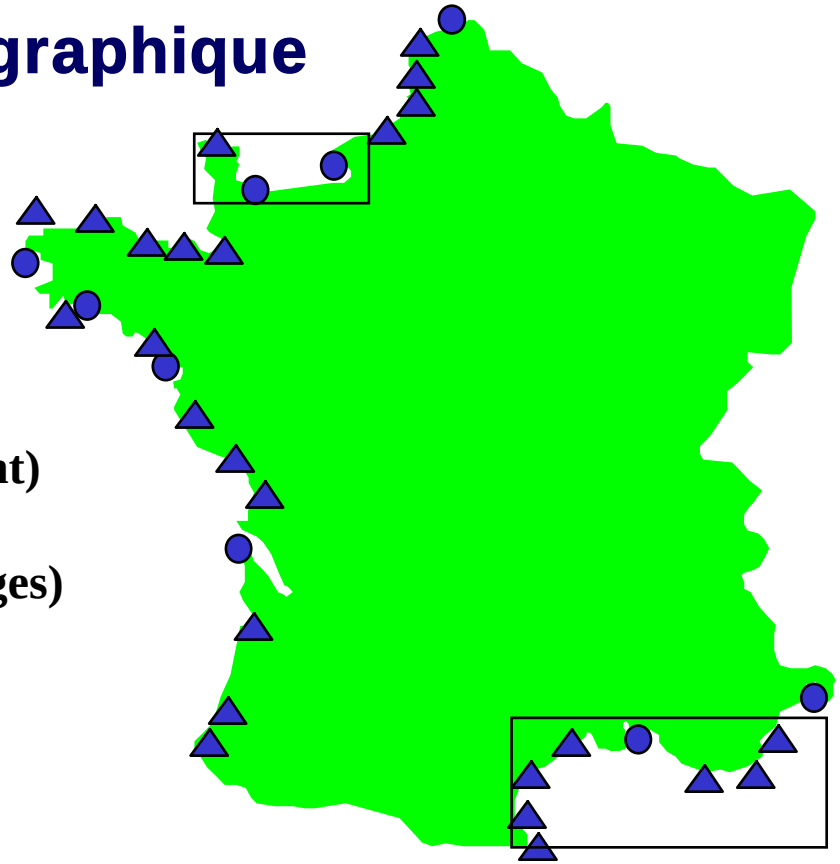
- Monitoring systems for risk assessment
- Impact study systems (eg coastal management)
- Prediction systems

Physical and ecosystem descriptions

Complementary systems

Les réseaux de surveillance RNO, REPHY et REMI

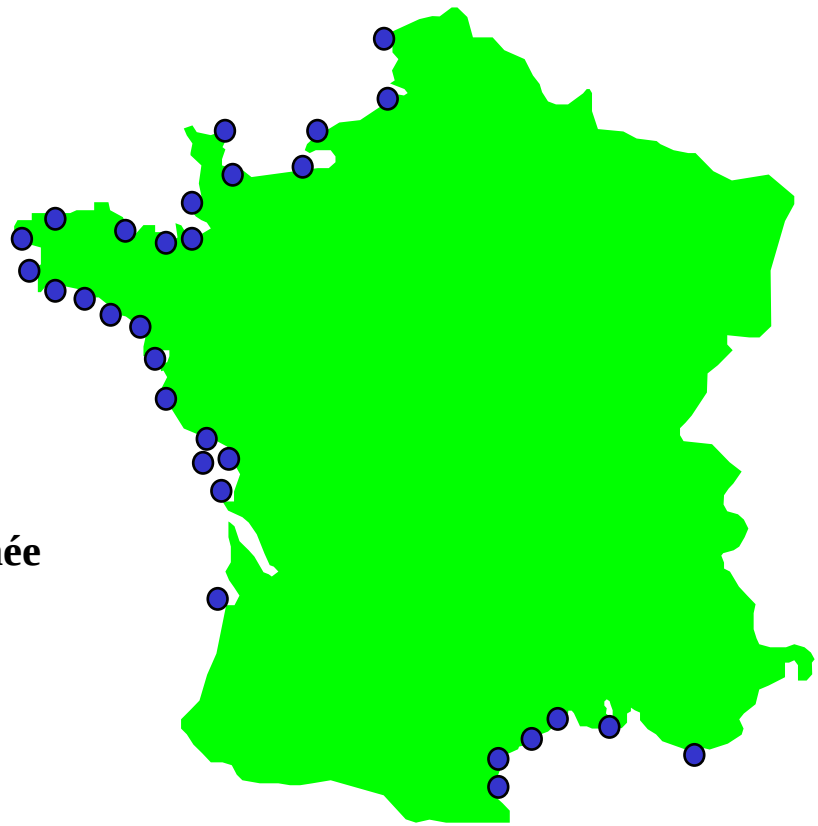
❑ RNO : Couverture géographique



- Qualité générale des eaux
- Contaminants (coquillages et sédiment)
- Effets biologiques (poissons, coquillages)

Les réseaux de surveillance RNO, REPHY et REMI

❑ REPHY : Couverture géographique

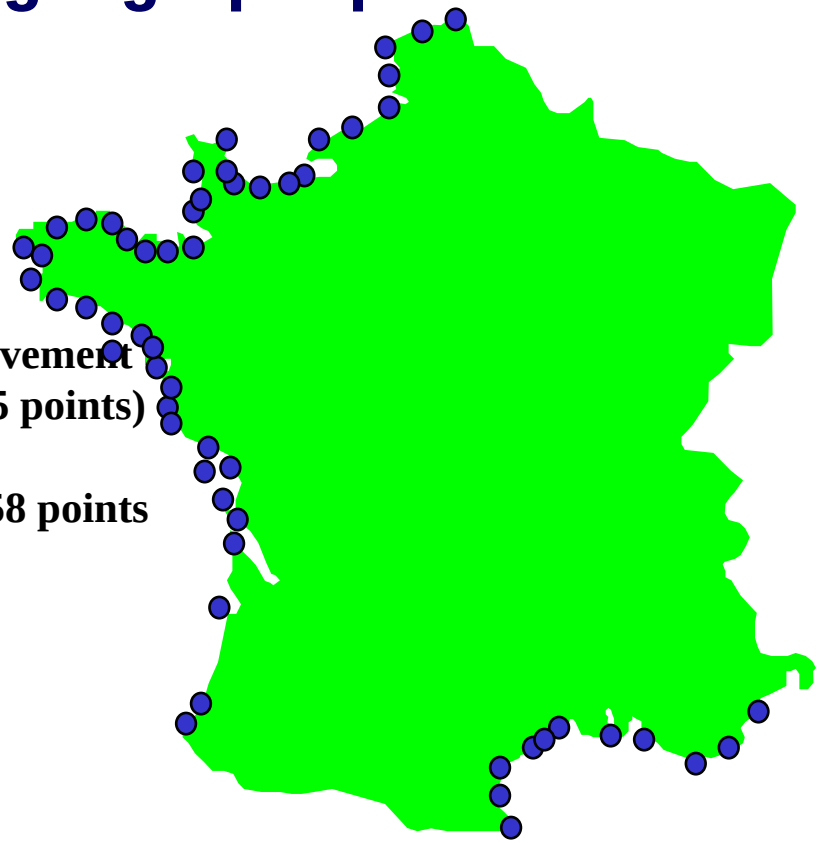


- **1 à 4 points de prélèvement du suivi REPHY**

Total : 33 points flore
140 points coquillages
62 points échantillonnés toute l'année

Les réseaux de surveillance RNO, REPHY et REMI

❑ REMI : Couverture géographique

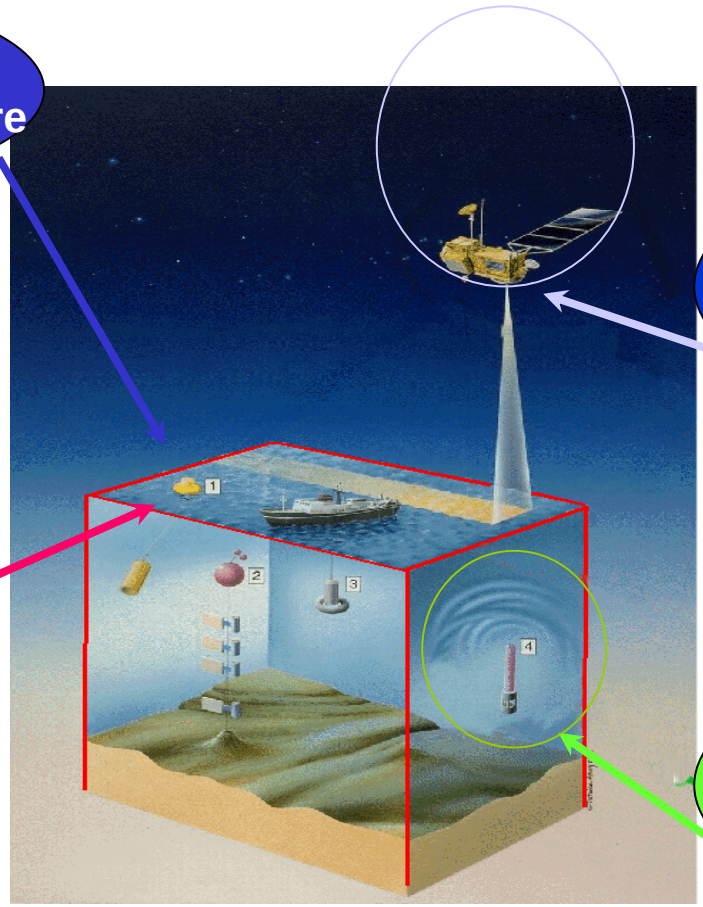


- **Jusqu'à 1996 : 1 à 6 points de prélèvement de la surveillance REMI (total : 345 points)**

  Depuis 1997 : 322 zones classées, 358 points

A 4D operational depiction of the ocean,
coherent with satellite and in situ observations

Satellite
Sea Surface Temperature



Satellite Altimetry
(Jason, Envisat, Gfo)

Salinity
climatology

In situ
Temperature & Salinity
Vertical profiles

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An international effort: the high-precision satellite altimetry program

From back to front side:

D. WILLIAMS (EUMETSAT)

B. SMITH (NOAA)

J.L. FELLOUS (then with CNES)

From back to front side:

T. MOHR (EUMETSAT)

G. WITHEE (NOAA)

G. ASRAR and A. CONDES (NASA)

Signature of the letters exchanged by CNES and EUMETSAT with NASA and NOAA on the Ocean Surface Topography Mission, Kyoto, 7 November, 2001

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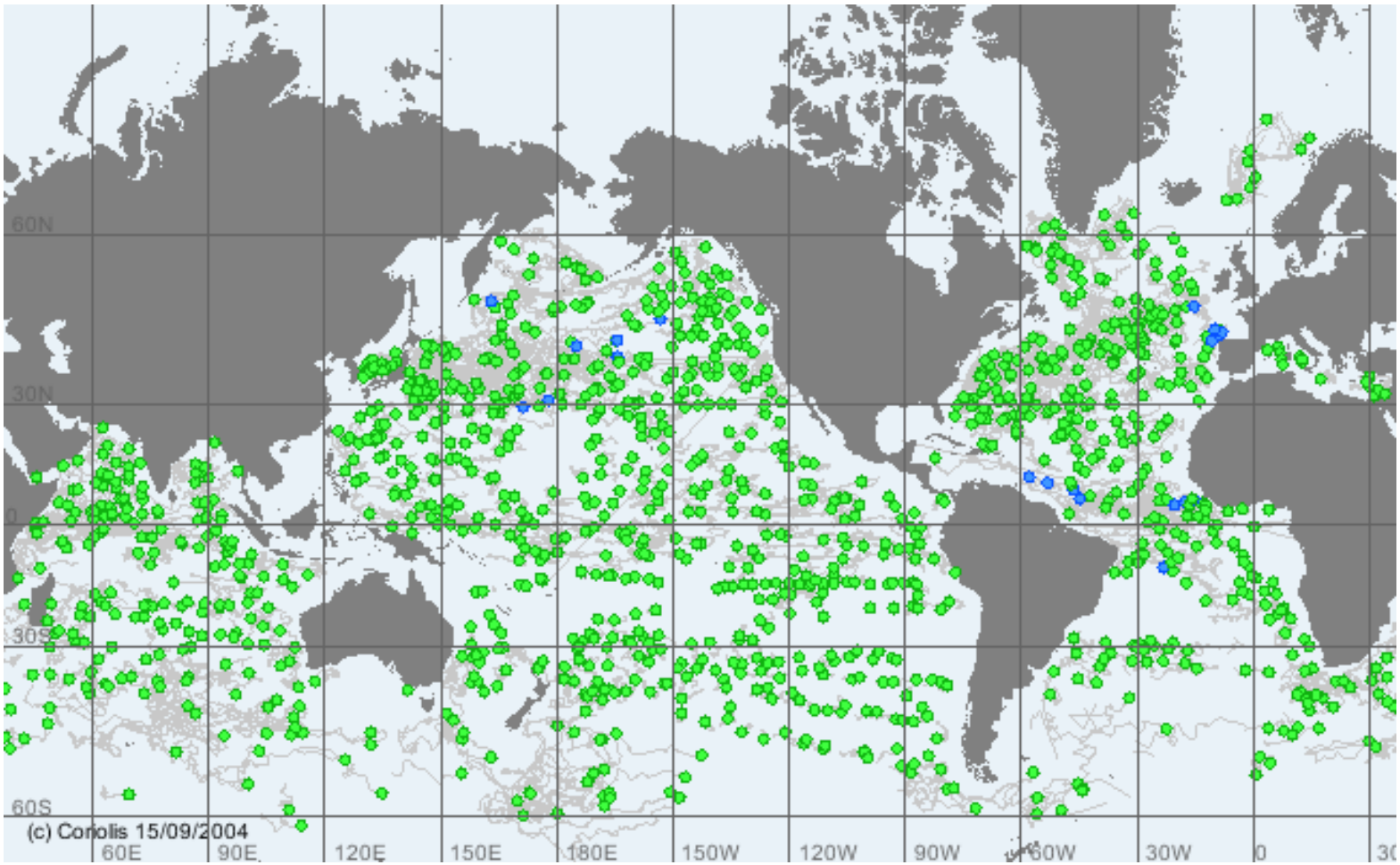
CORIOLIS 2004 data set



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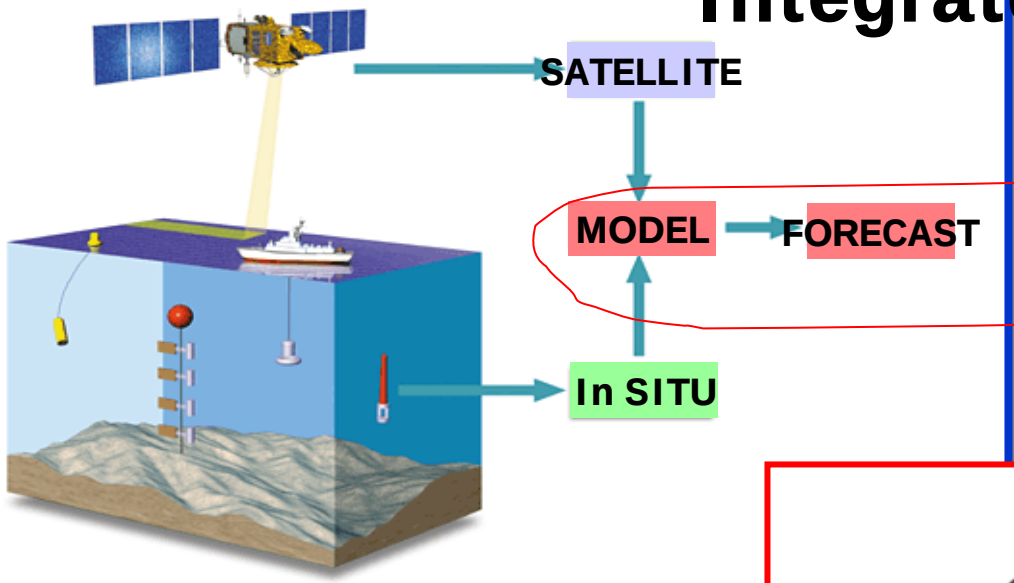
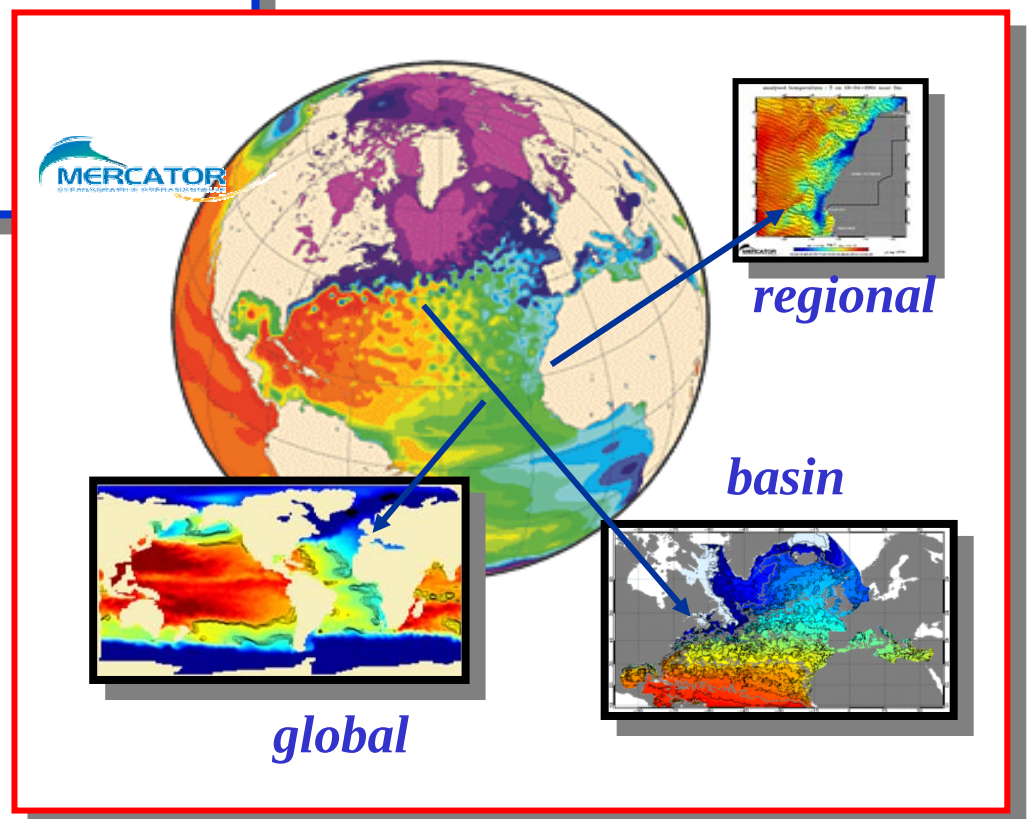
Integrated Oceanography



JASON, …

MERCATOR

CORIOLIS



- High Resolution Global to Regional **Ocean Monitoring and Forecasting**
- Operational Assimilation **of Satellite and In Situ Ocean Observations**
- **Serving** research, state **(military and civilian) service**, **and** commercial **needs**

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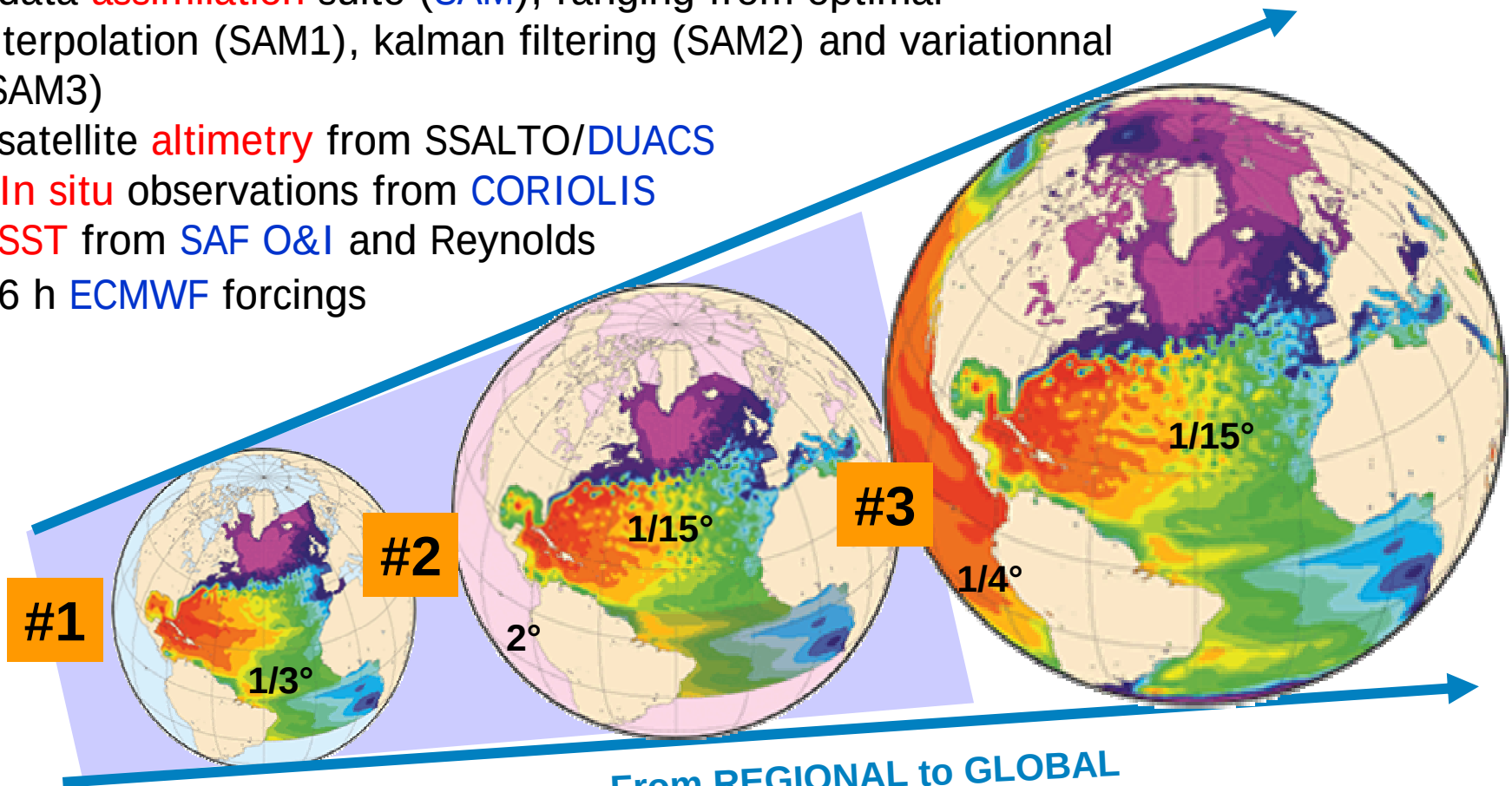
Main components and Implementation Plan

- ocean modelisation, using the european OPA code
- data assimilation suite (SAM), ranging from optimal interpolation (SAM1), kalman filtering (SAM2) and variationnal (SAM3)
- satellite altimetry from SSALTO/DUACS
- In situ observations from CORIOLIS
- SST from SAF O&I and Reynolds
- 6 h ECMWF forcings



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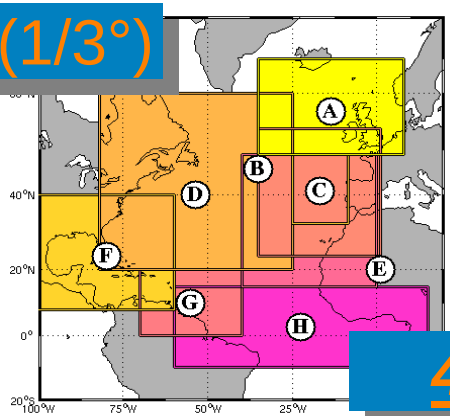
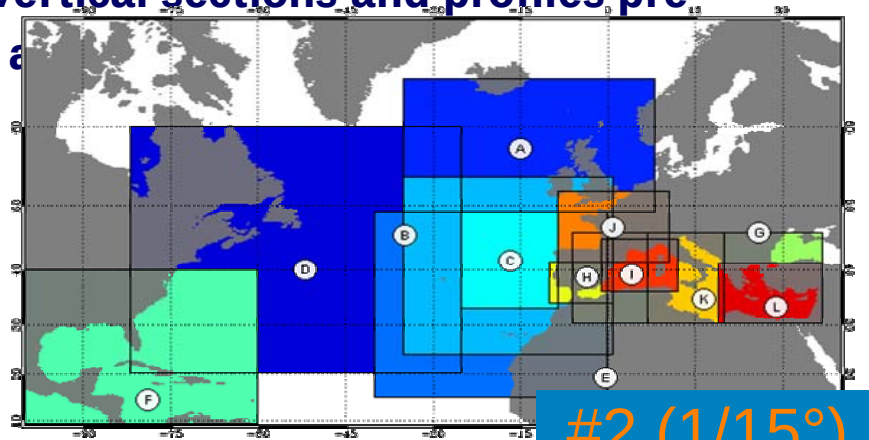
Ocean monitoring and forecasting

3 years of continuous experience of routine assimilation of NRT data

- Weekly bulletin : a full 4D description of the ocean **: Temperature, Salinity, Currents and Transports, Sea Surface Height, Mixed layer depth, ...**
- **Provided in real-time (**Nowcast **and 2-week** forecast**) and on a** hindcast **mode (Reanalysis)**
- **More than 3 years of** continuous operations **(171 bulletins)**
- **The « 3** validation **loops » organization well assessed : short loop (ocean forecasters : 3 h-3d) ; medium loop (Mercator R&D team : ~ 3 months) ; research loop (SWT : 1-3 years)**
- **Range of** Ocean products **: Regional zooms & vertical sections and profiles pre-defined (2000 maps/week), and 4D outputs a ; associated to forecasters** services
- **More than**

#1 (1/3°)





#2 (1/15°)

43 levels of depth

- 20 septembre 2004

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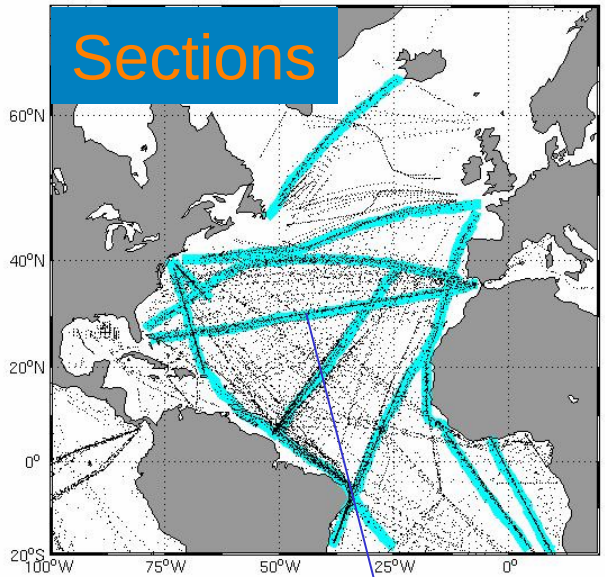
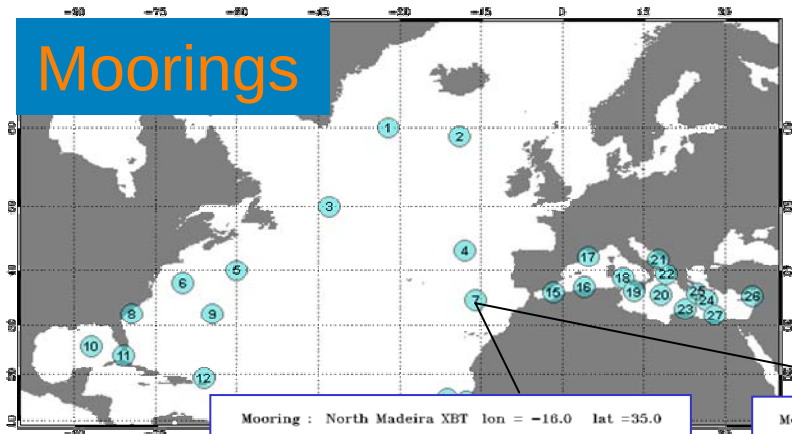
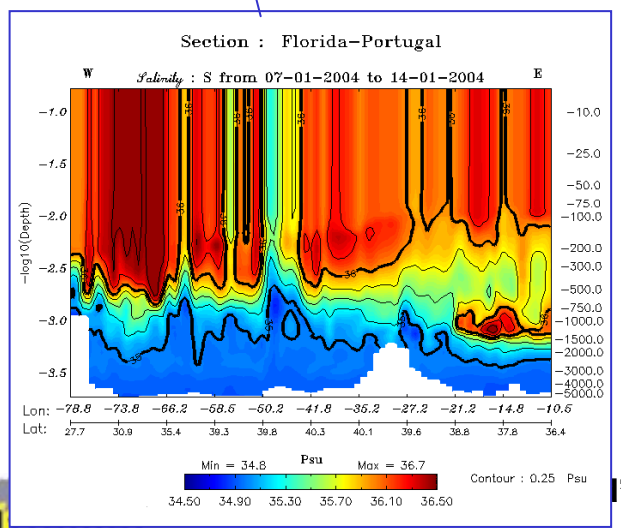
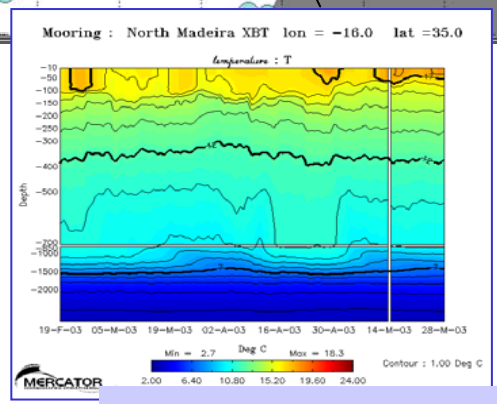
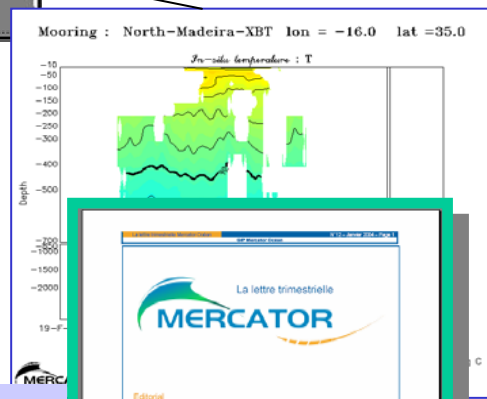
Validation and Quality Control









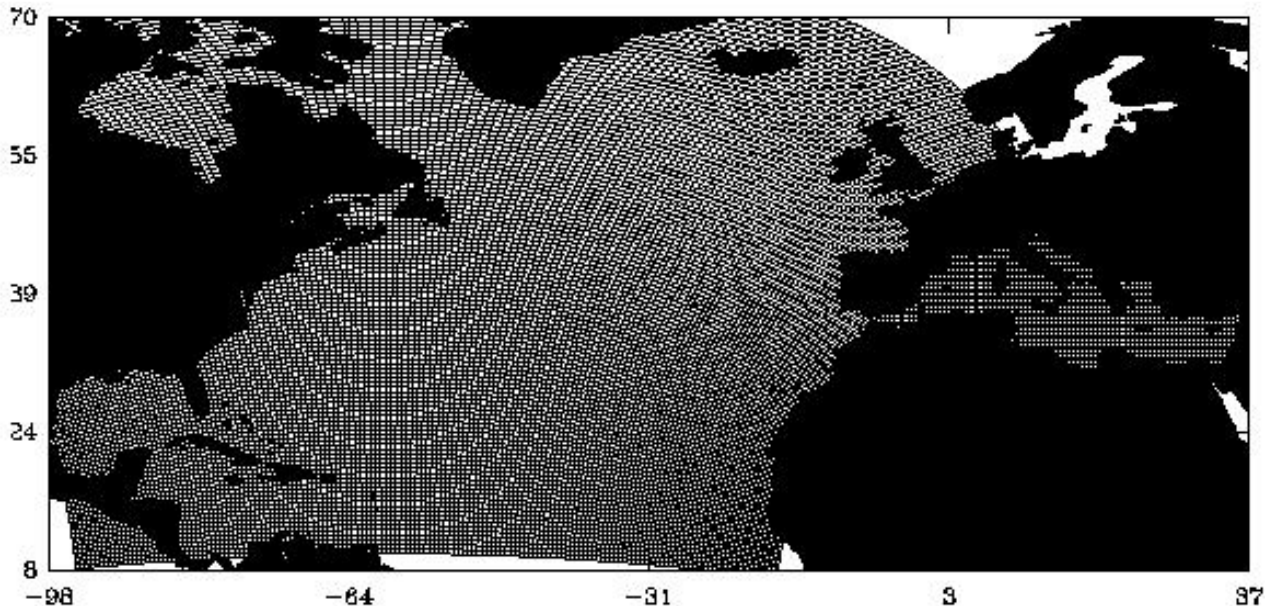


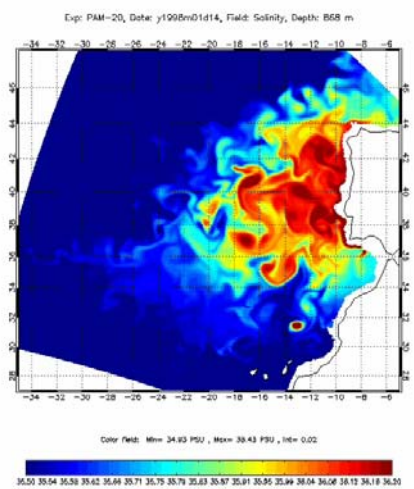
Mercator Newsletter
(cf. www.mercator-ocean.fr)

Mercator « PSY2 »
5-7 km model on N.Atl + Med Sea with the same SAM1v1 univariate OI assimilation code

The high resolution North Atlantic / Med Sea Mercator model

- horizontal: ~ 1/15° (5-7 km North Atlantic + 1/16° Med Sea)
- vertical: 43 levels





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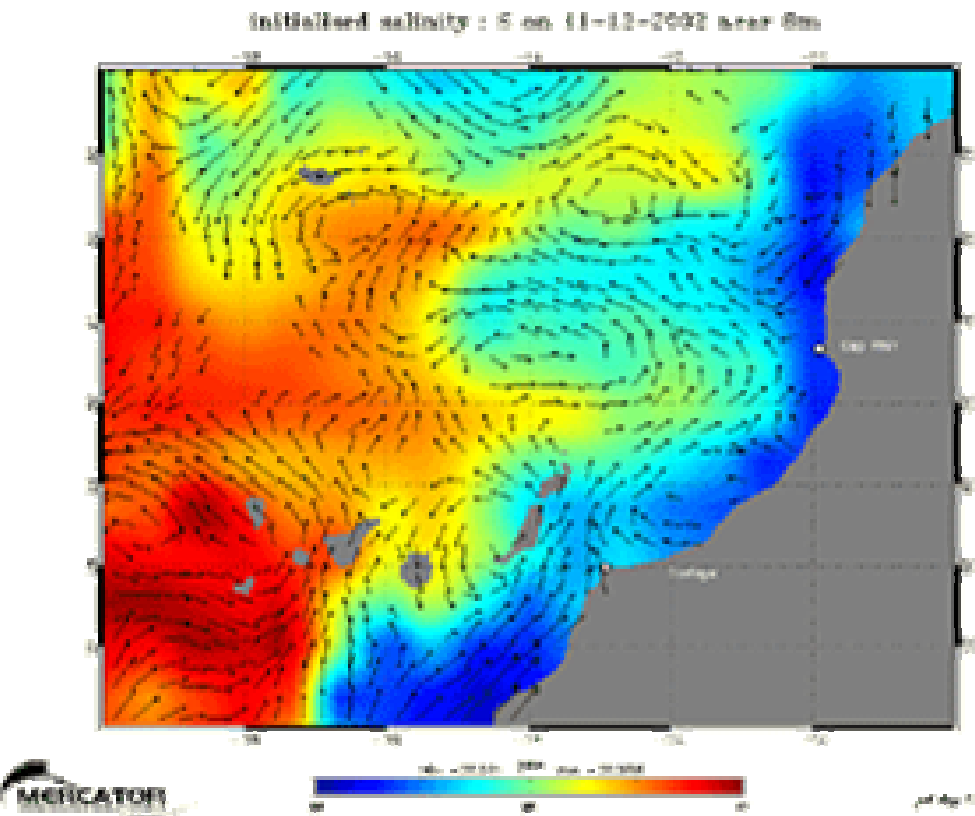
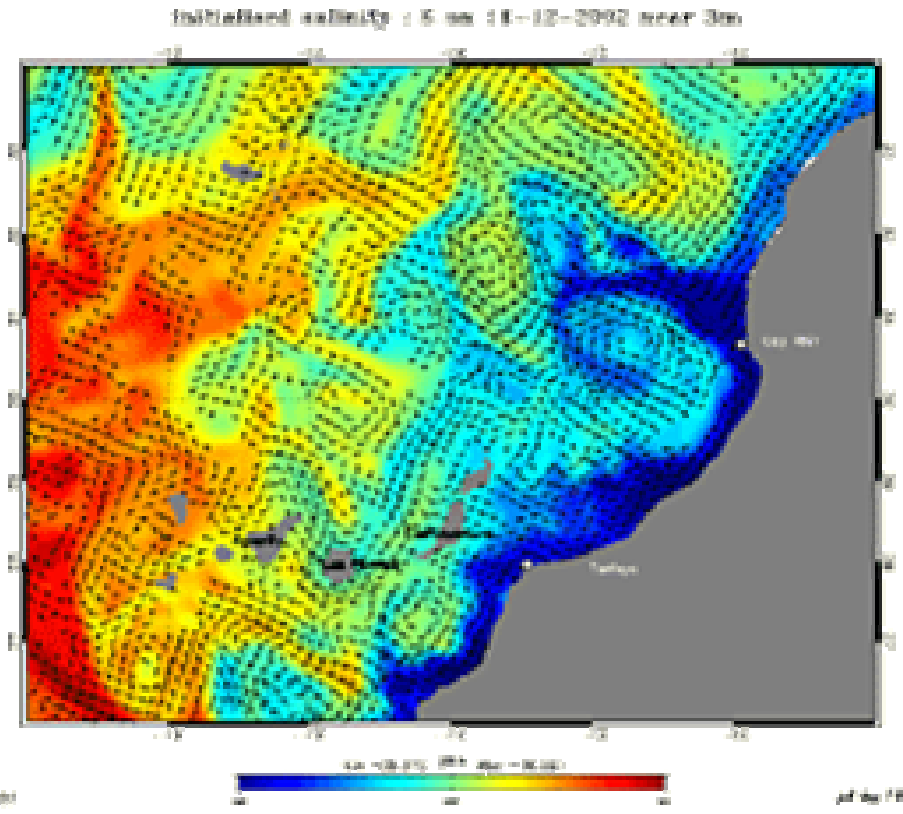
Western Africa Upwellings





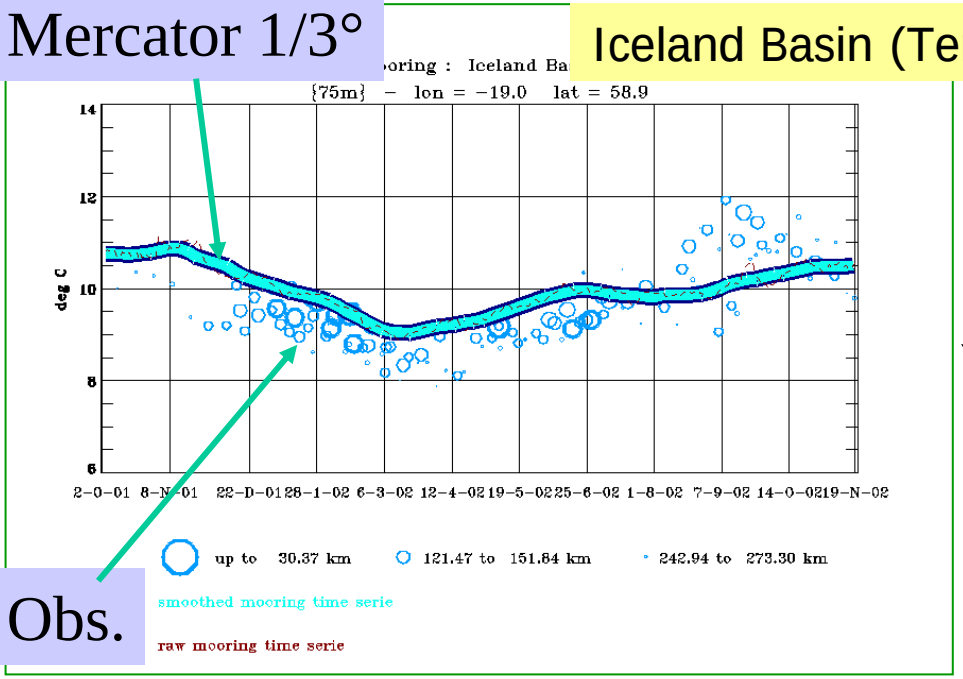
1/3° model
univariate assimilation
of SLA (3 satellites)

~ 1/15° model
univariate assimilation
of SLA (3 satellites)

VALIDATION

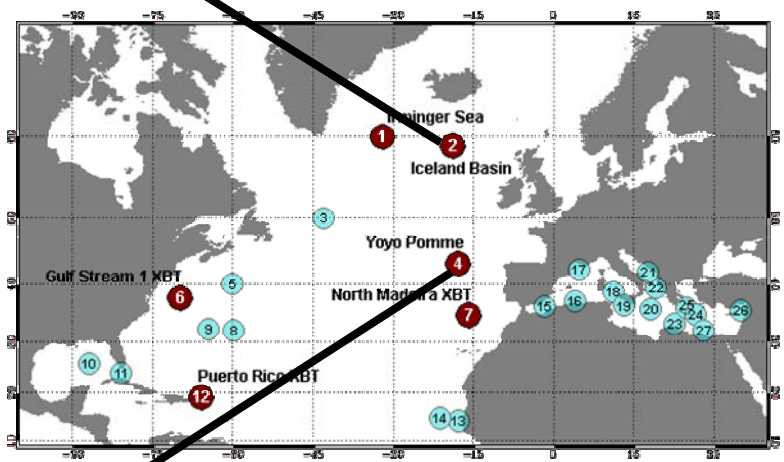
Mercator 1/3°

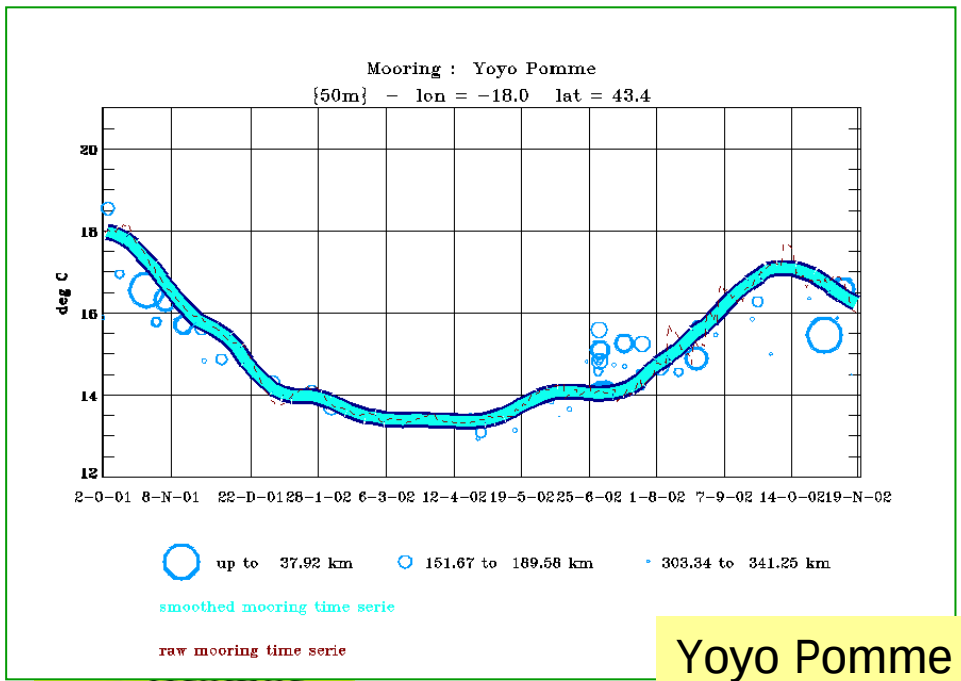
Iceland Basin (Temp. 75 m)



Obs.

Comparing to In Situ Mooring

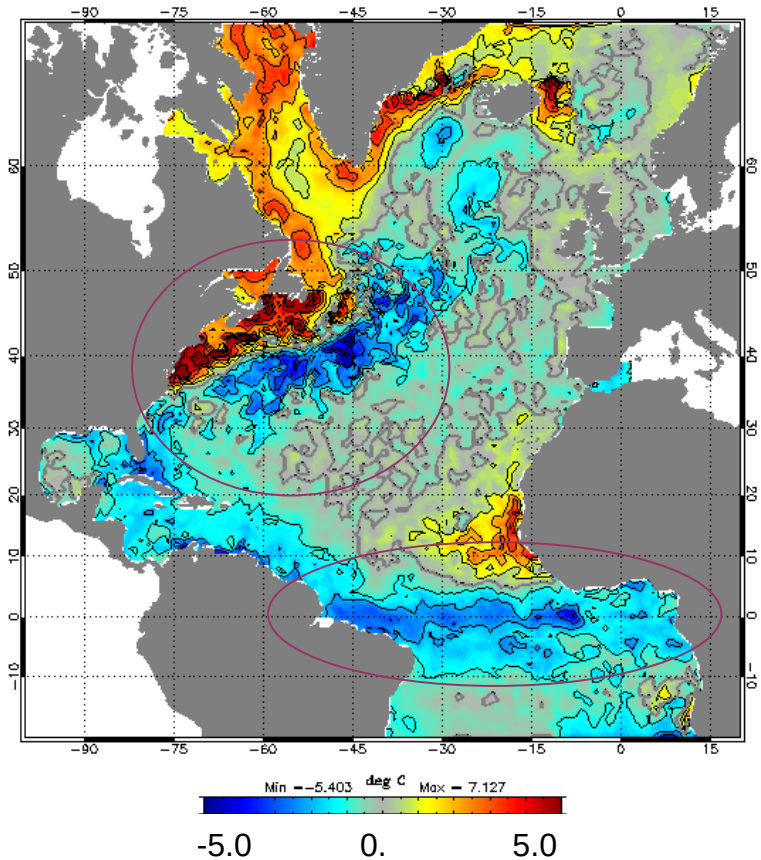




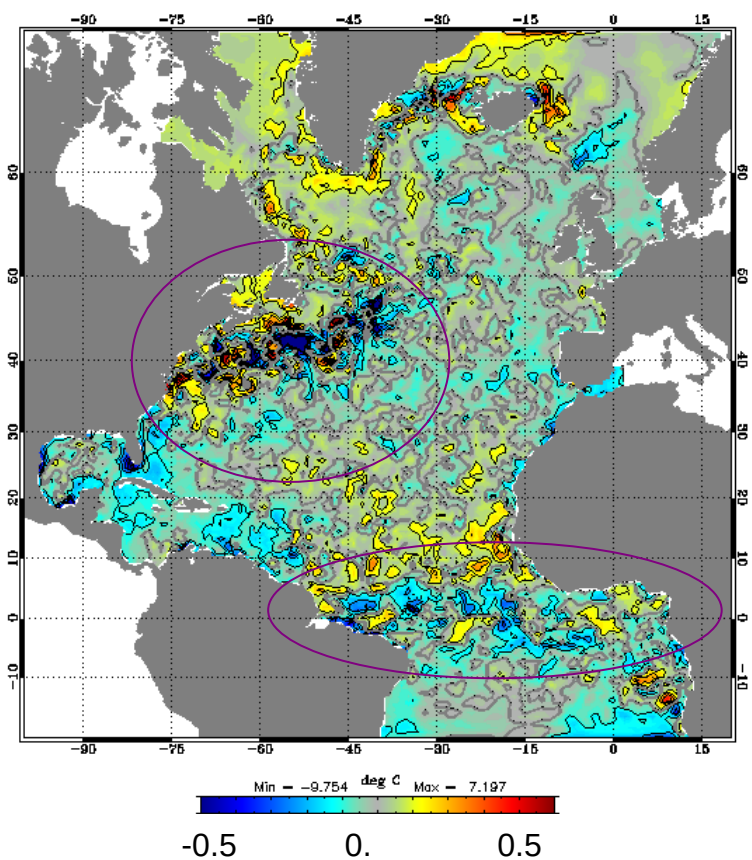
Yoyo Pomme (Temp. 50m)

Mercator SST minus **Reynolds SST**
12/06/2002

Univariate (Altimetry assimil)



Multivariate (Alti+SST+T/S)



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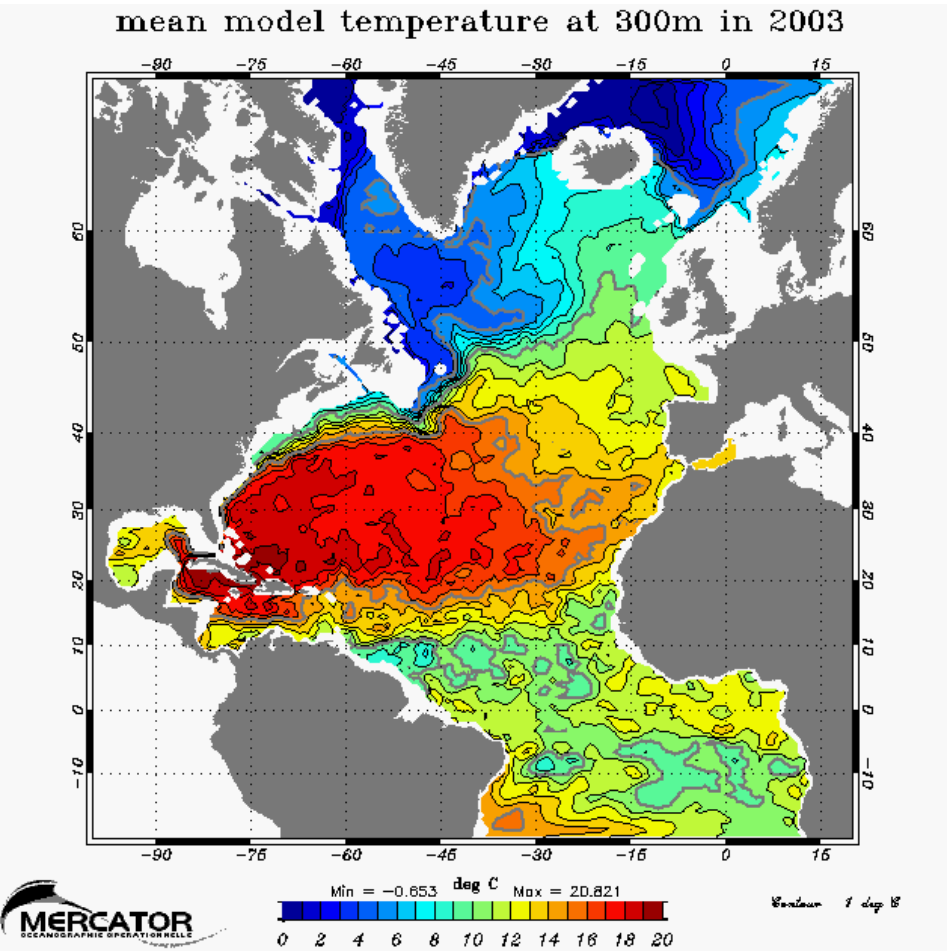
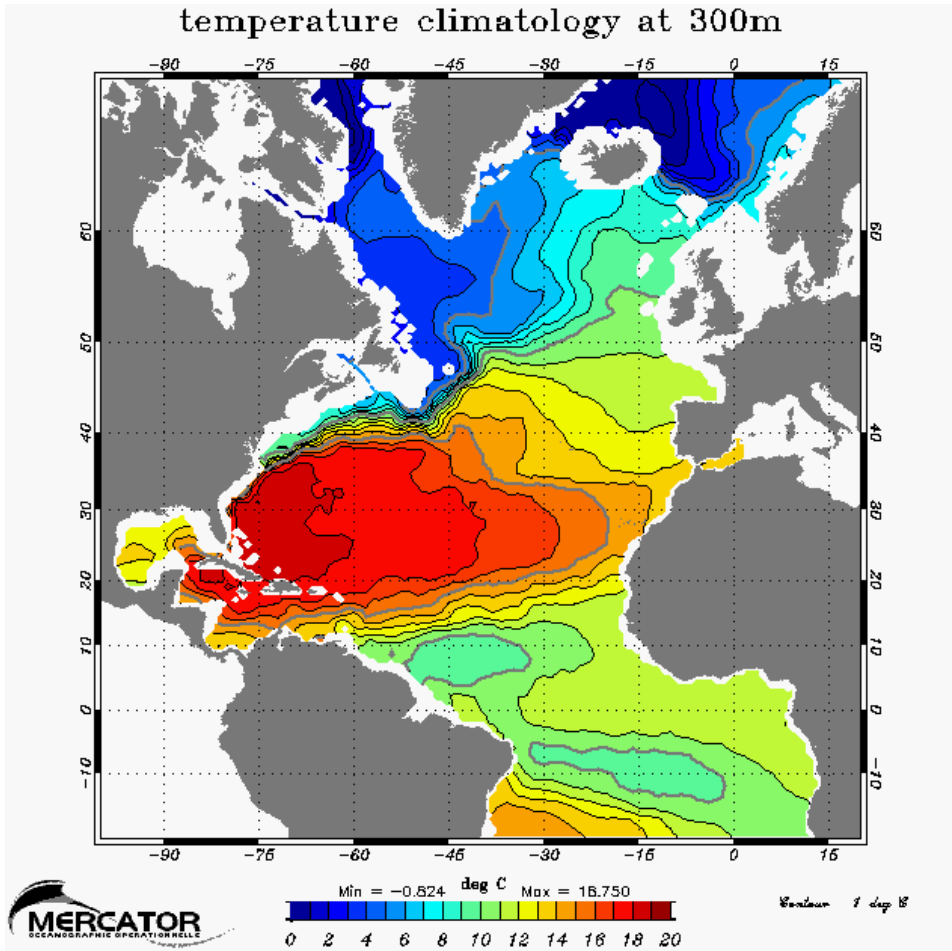
300 m Temperature : Mercator versus Climatology (2003 yearly mean)





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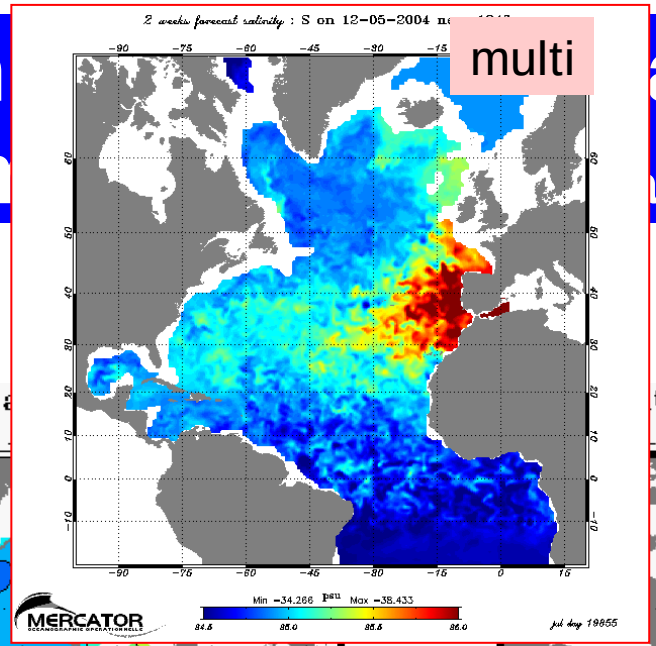
12 May 2004
2 week Forecast

Clim

multi



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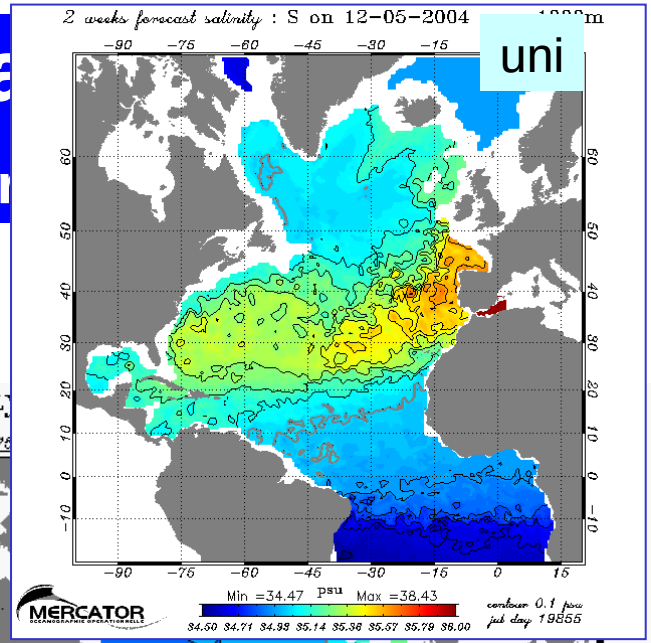
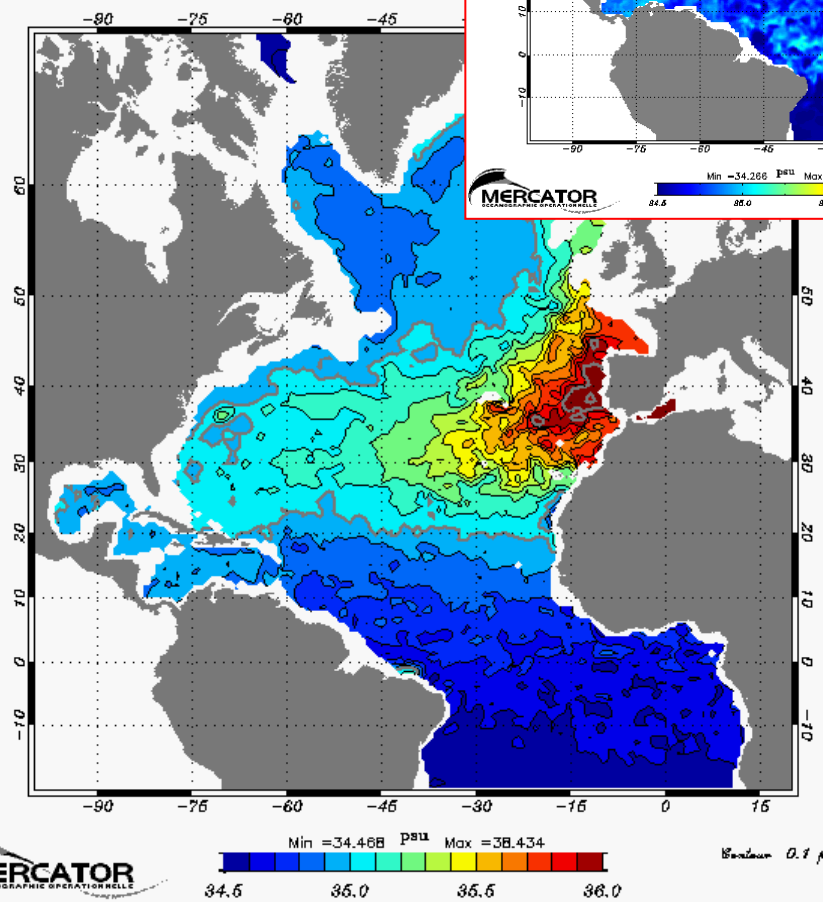
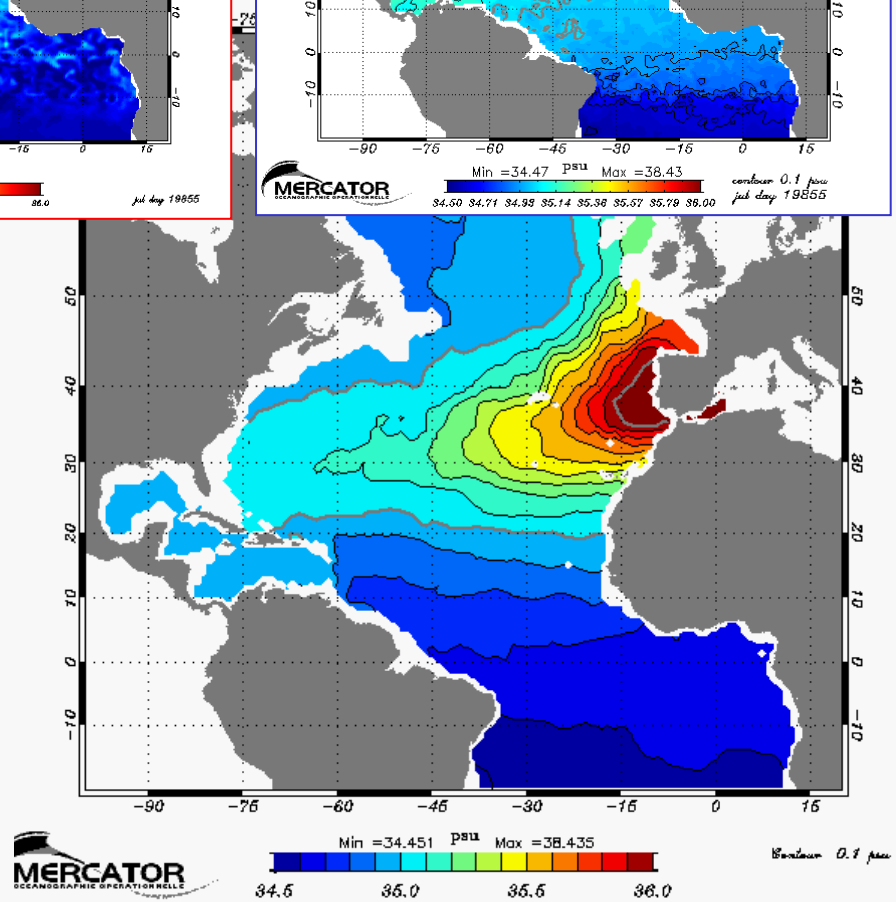


mean model salinity a





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MERSEA Strand1
Atlantic and Mediterranean Sea prototype Project:
An Inter-comparison of 5 Forecasting Systems

Laurence Crosnier , Christian Le Provost and Mersea Team

GOAL: **Evaluate the strength / weakness of**
[4 European + 1 US] Ocean monitoring and forecasting systems.

www.mersea.eu.org

Ecole d'Eté Océanographie Opérationnelle GODAE – 20 septembre 2004

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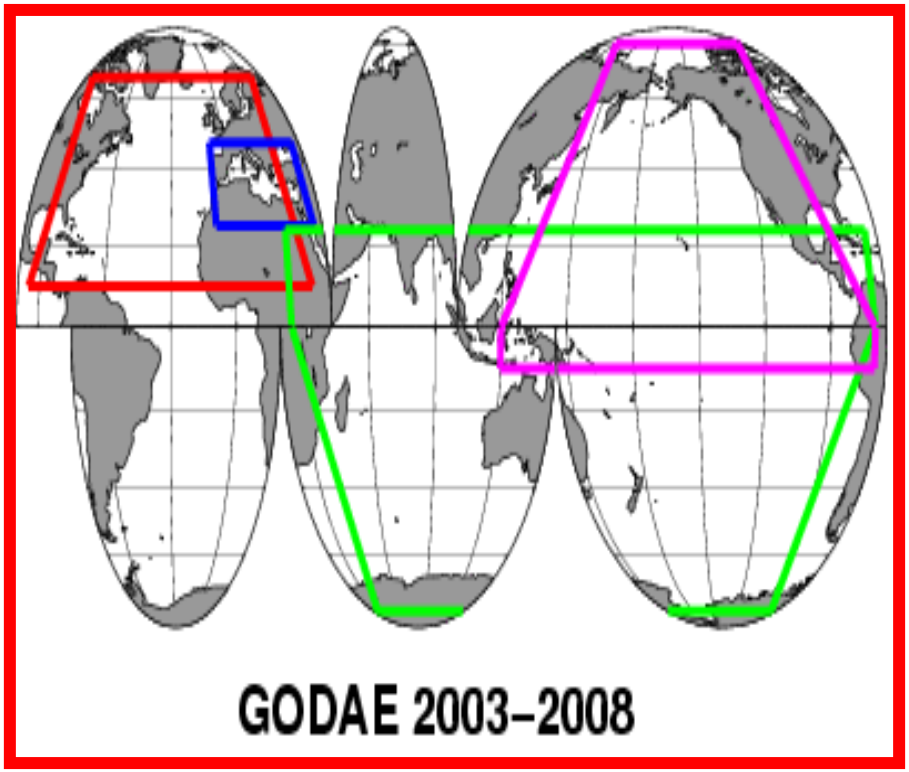
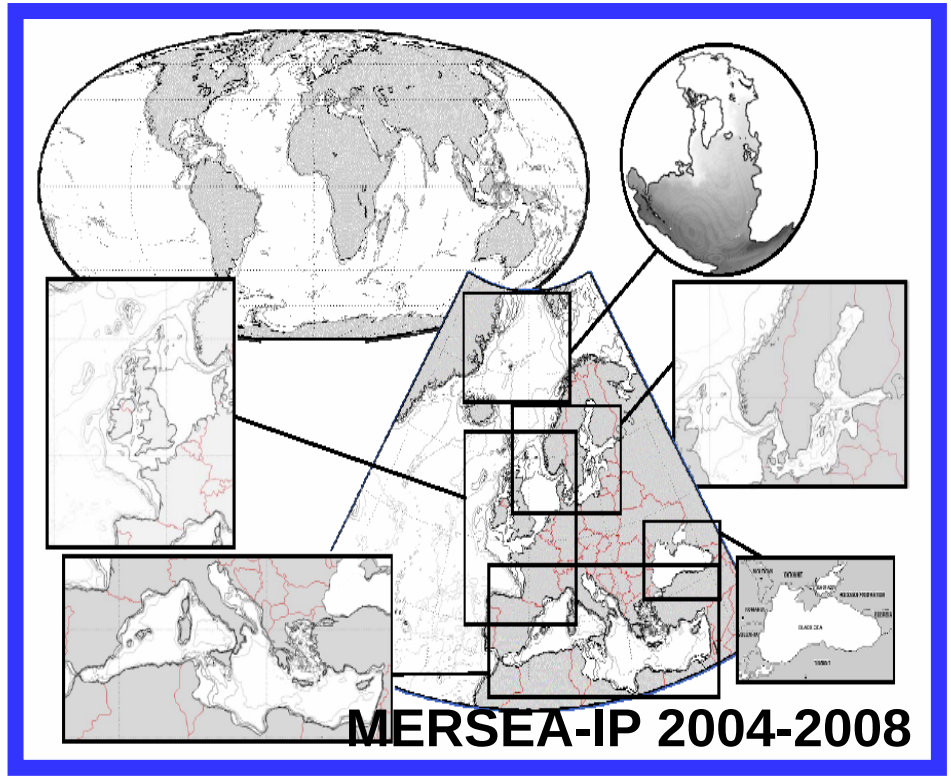
Consortium
18 Partners ; 9 countries

- NERSC, Norway
- CEFAS, UK
- CLS, F
- CNRS/LEGOS, F
- **DFMR, Cyprus**
- **DLR, Germany**
- **DMI, Danmark**
- **FIMR, Finland**
- IFREMER, F

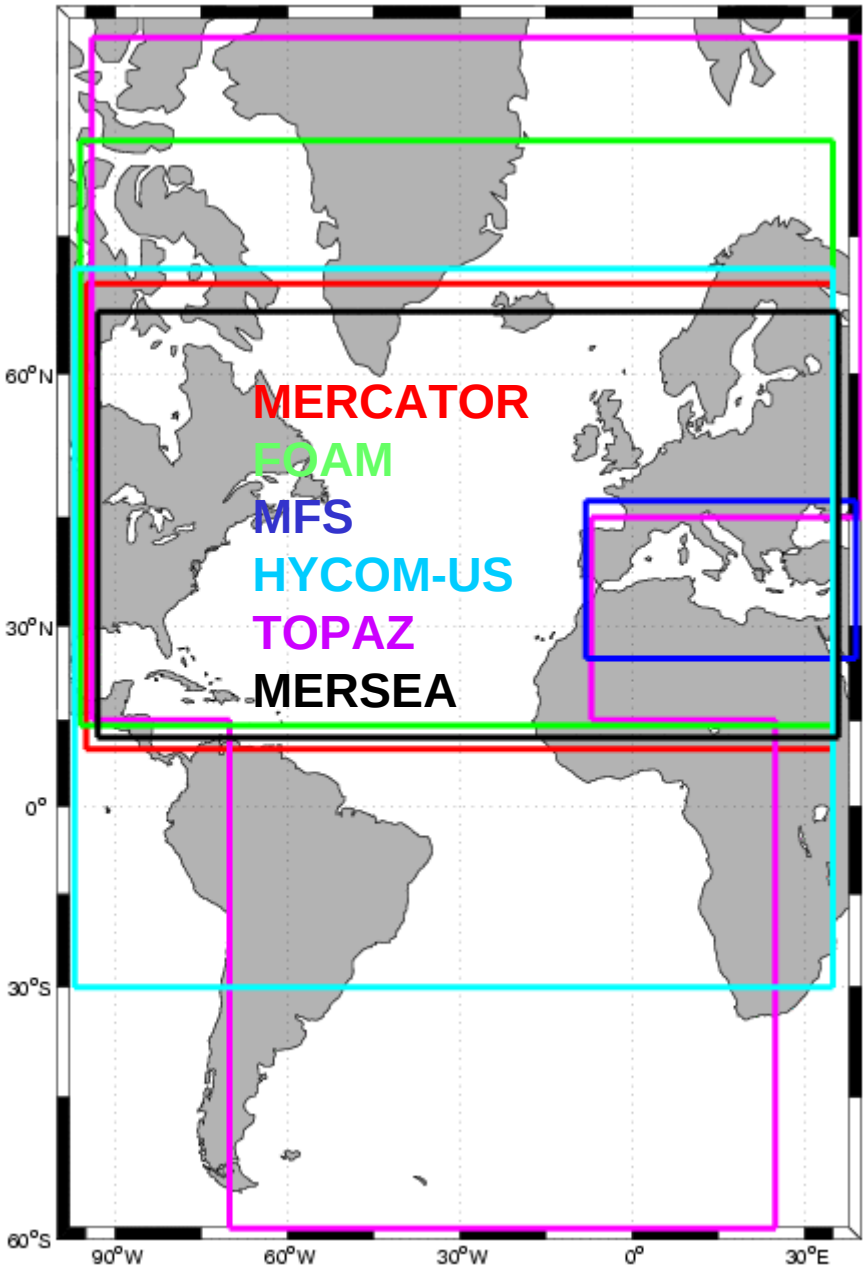
- **IMR, Norway**
- **INGV, Italy**
- Mercator Océan, F
- Met Office, UK
- Météo-France, F
- **Met.No, Norway**
- **NCMR, Greece**
- POL & PML, UK
- SOC, UK





GLOBAL (France, US)
North ATLANTIC + Mediterranean SEA (Mersea systems)
INDIAN , South PACIFIC, AUSTRAL Ocean (Blue Link, Australia)
North PACIFIC (Japan)

North ATLANTIC
Baltic
Arctic
Mediterranean Sea
(16 countries, 40 organizations)



MERSEA–STRAND1 2003–2004

Ecole d'Ete Ocea

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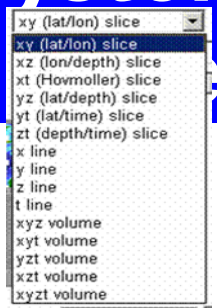
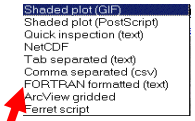
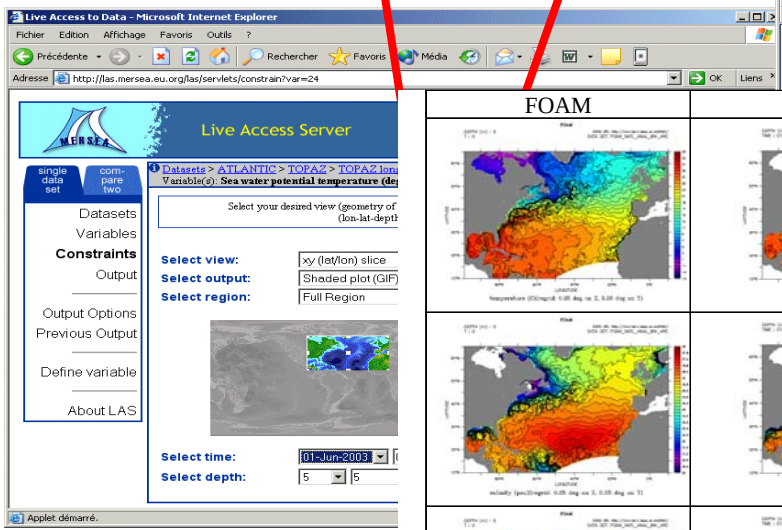
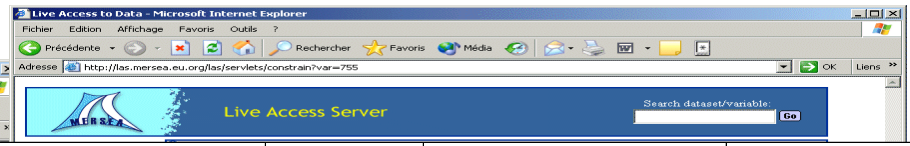
MERCATOR FR	OPA -Z coord./Rigid Lid -Simple thermo. ice model **-TKE**	-horiz. 1/15° (5-7km) 43 levels -Atl+Med **from 10 to 70°N.**
FOAM UK	HADLEY CENTRE -Z coord./Rigid Lid **-dyn./thermodynamic sea ice** **-Kraus-Turner**	-horiz. 1/9° (12km) 20 levels -Atl+Med **from 10 to 70°N.**
MFS IT	MOM -Z coord./Rigid Lid **-No ice model** **-cst vertical mixing+vertical adjustment**	-horiz. 1/8° 31 levels - Med only
HYCOM US	HYCOM *2.1* -Hybrid coord./Free surface **-No ice model** **-KPP mixing**	-Horiz 1/12° (6.5km) 26 hybrid layers -Atl+Med **from 28°S to 70°N, 98°W to 36°W.**
TOPAZ NO	HYCOM -Hybrid coord/Free surface **-dyn./thermodynanic sea ice** **-KPP mixing**	-horiz. 20 to 30km 22 hybrid layers -Artic+Atlantic **till 60°S.** No med basin.

Systematic InterComparisons
ely Access to Products





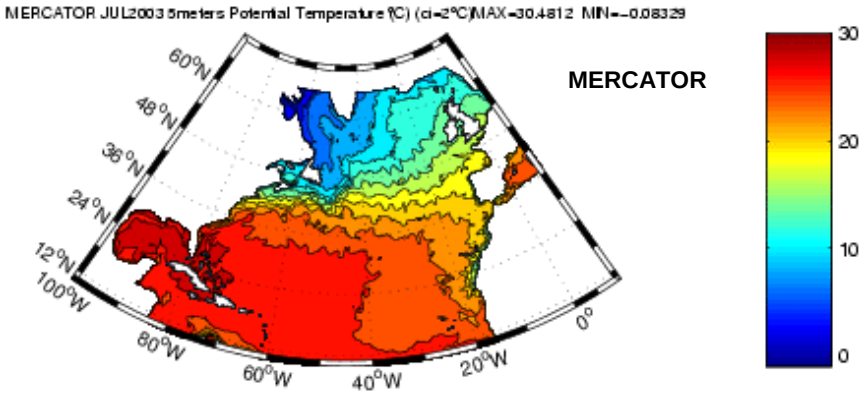




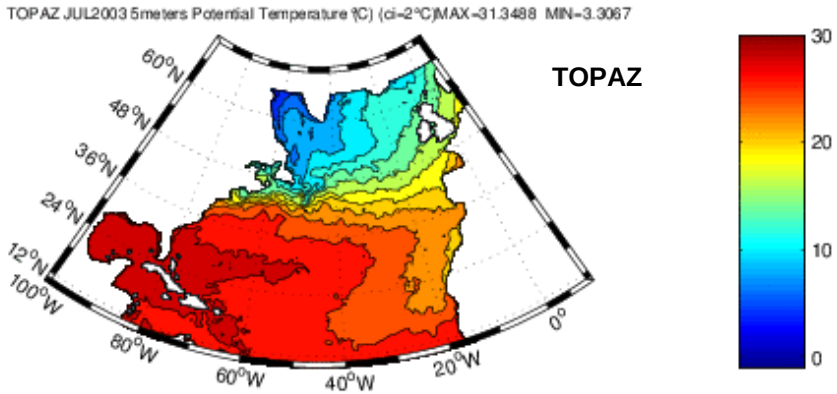
FOAM	MERCATOR	MFS	TOPAZ	HYCOM
		Not available		
		Not available		
		Not available		
		Not available		

The Atlantic Case

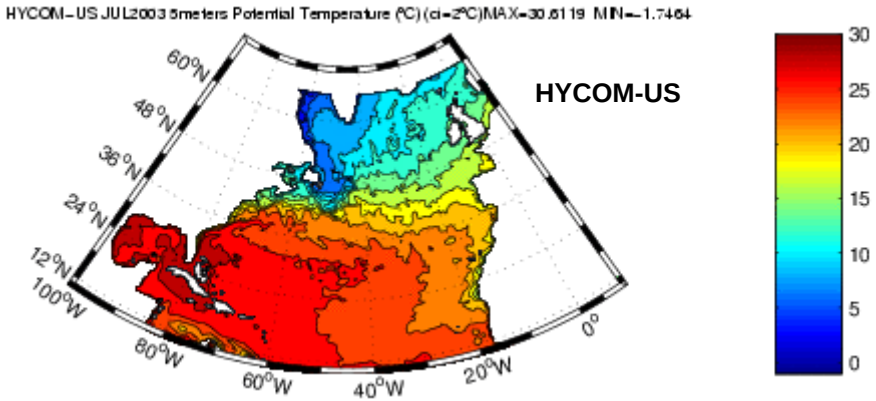
Potential temperature at 5 m depth (ci=2degC)



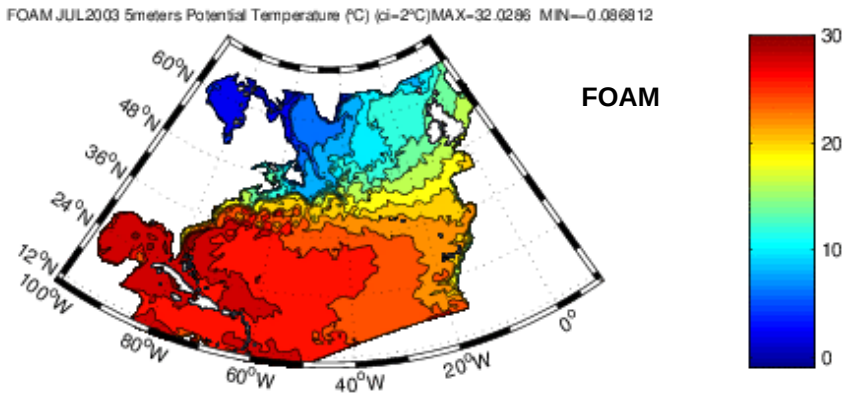
MERCATOR



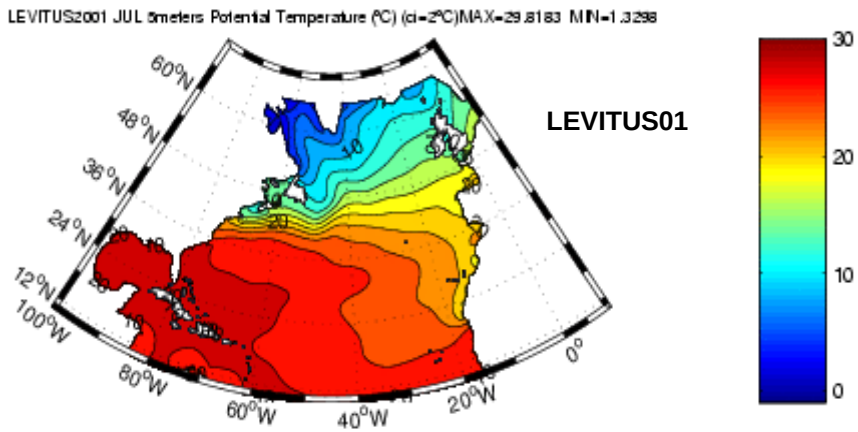
TOPAZ



HYCOM-US



FOAM



LEVITUS01

Data and Product Servers

Live Access to Data - Microsoft Internet Explorer

Fichier Edition Affichage Favoris Outils ?

Précédente Rechercher Favoris Média

Adresse http://las.mersea.eu.org/las/servlets/constrain_compare?var=188

Live Access Server

single data set | compare two

Dataset 1
Variable 1
Dataset 2
Variable 2
Constraints
Output

Output Options
Previous Output

1: Datasets > MEDITERRANEAN SEA > MERCATOR > Mercator
1: Variable(s): **Sea water potential temperature (degC)**
2: Datasets > MEDITERRANEAN SEA > MFS > MFS SY2 best es
2: Variable(s): **Sea water potential temperature (degC)**

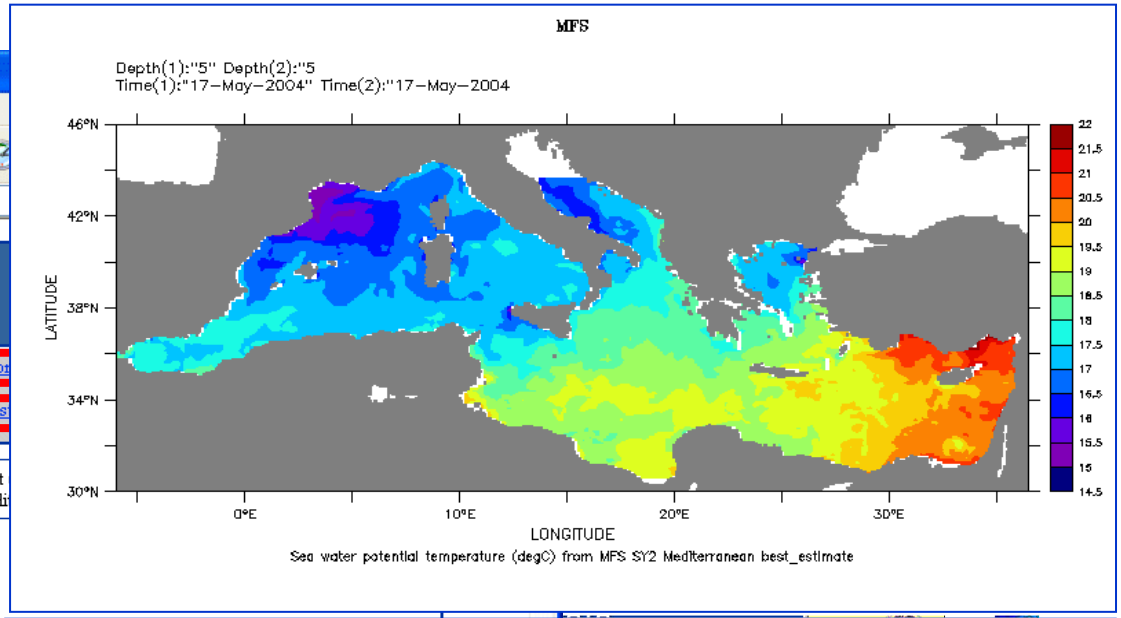
Select your desired view (geometry of output) and output (lon-lat-depth-time) and any addi

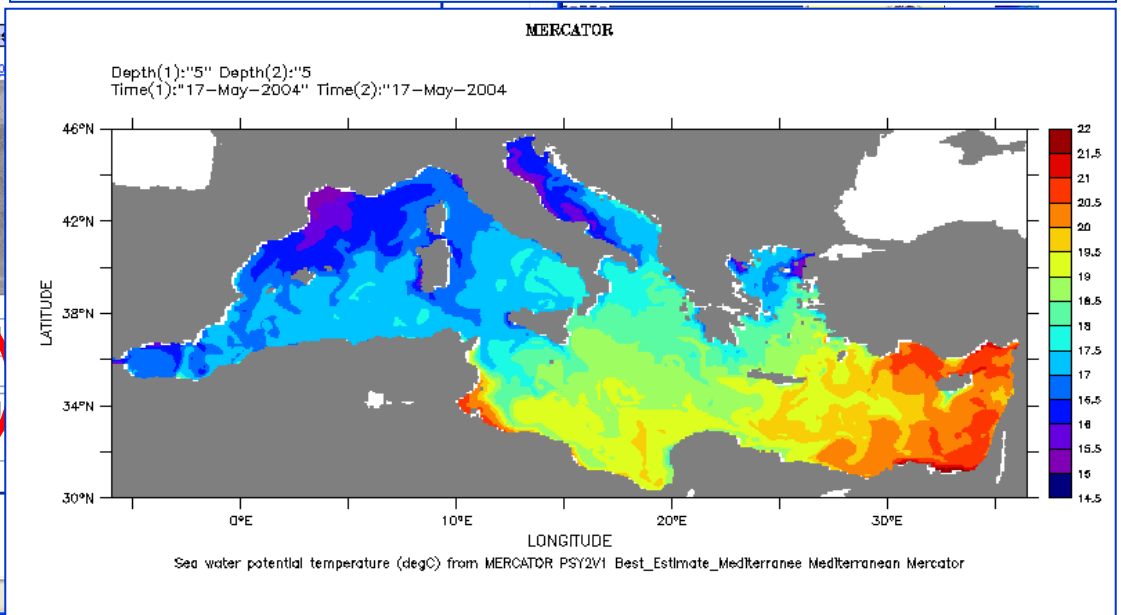
Select view: xy (lat/lon) slice
Select output: Comparison plot (GIF)
Select region: Full Region Refres

Don't use map ap

Select time for first variable: 17-May-2004
Select depth for first variable: 5 5
Select time for second variable: 17-May-2004
Select depth for second variable: 5 5

Get output for selected variable





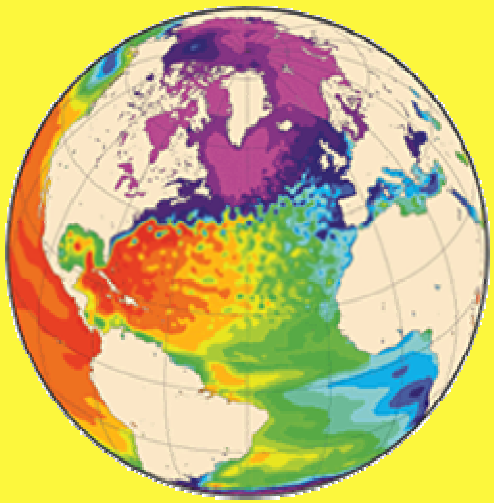
THE NEXT GENERATION

High Resolution Global Ocean

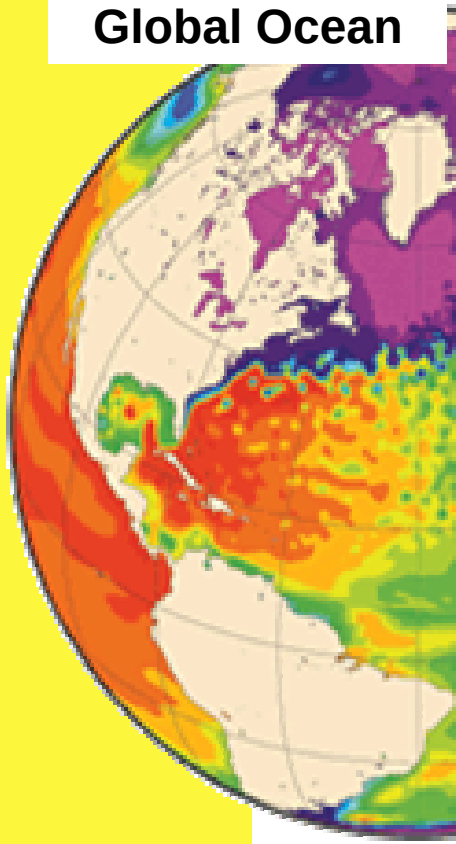
1/15°
European basins

2°
Global Ocean

1/4° (~ 25 km) Global Ocean
1/15° (~ 6 km) around Europe



Eddy-resolving
Global Ocean

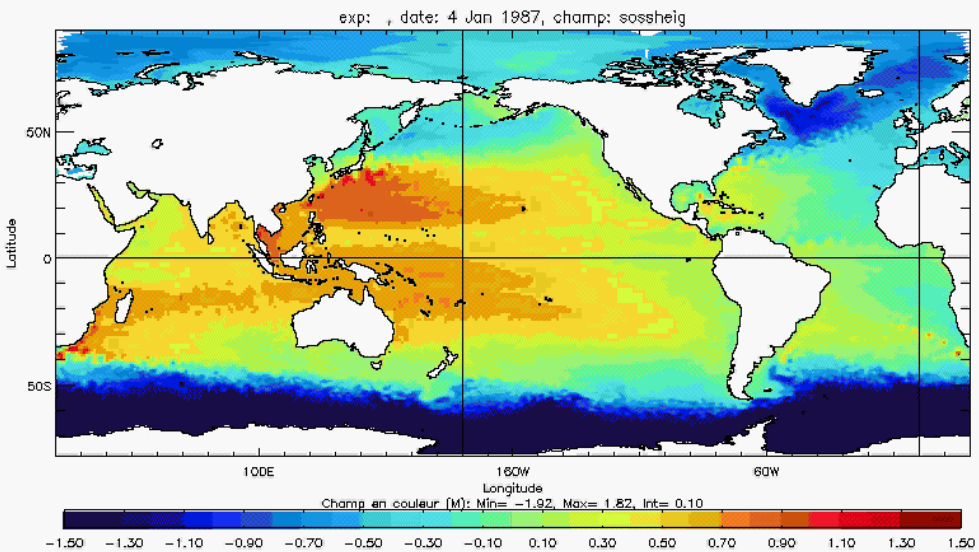


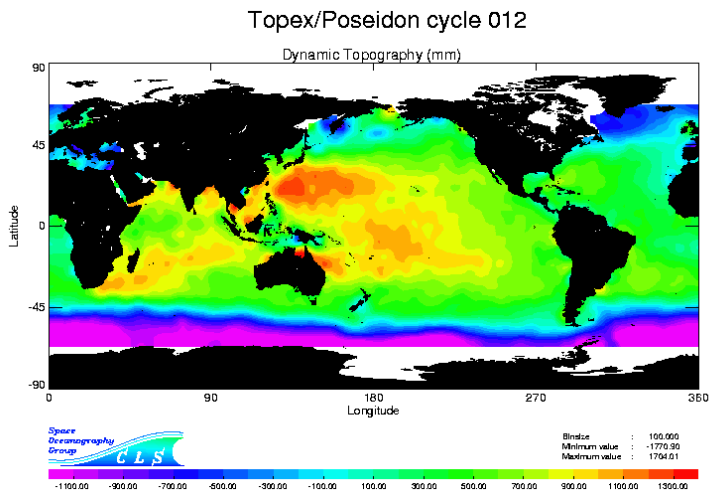
GMES Implementation Period
MERSEA IP

e 2004

Ifremer

The global ¼° prototype

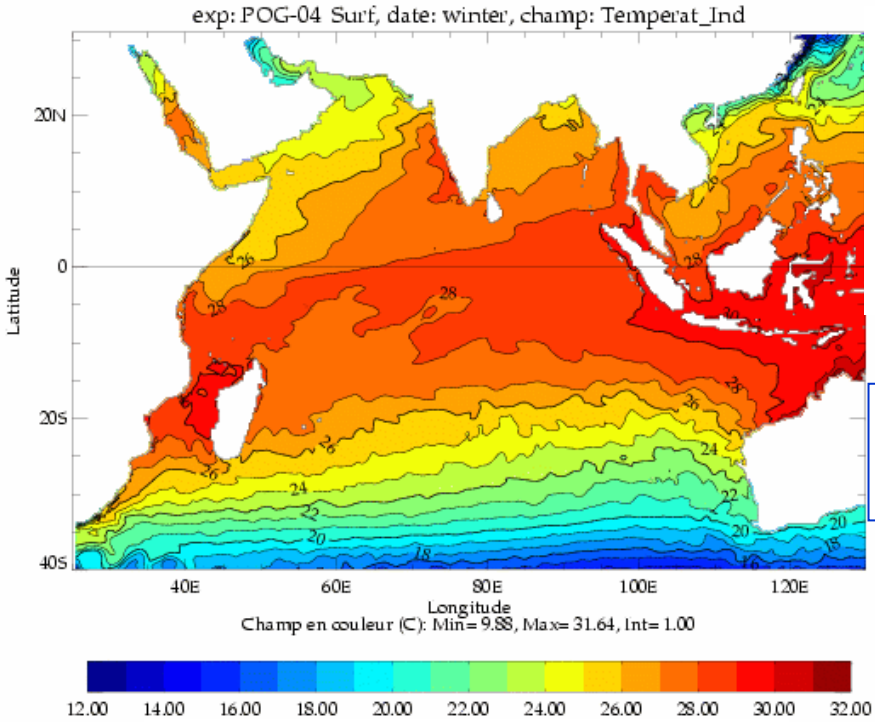




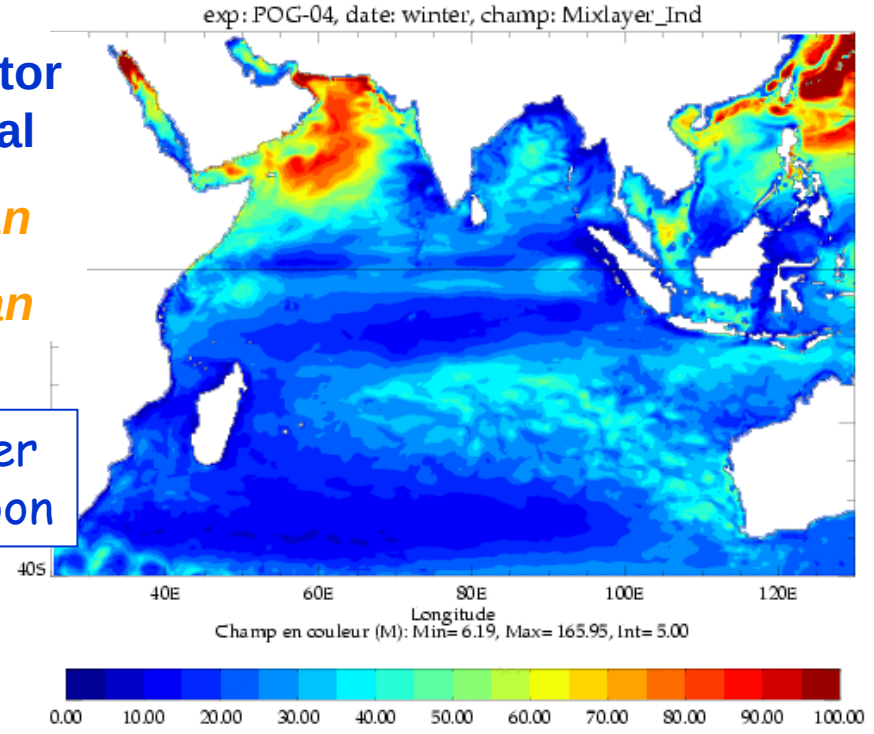
Ifremer

Mercator Global

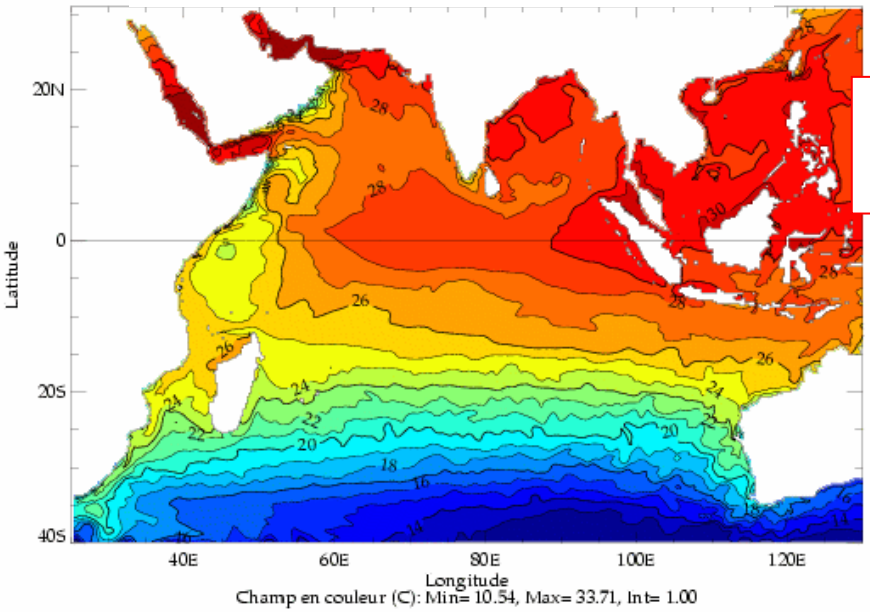
Indian Ocean



Winter Monsoon

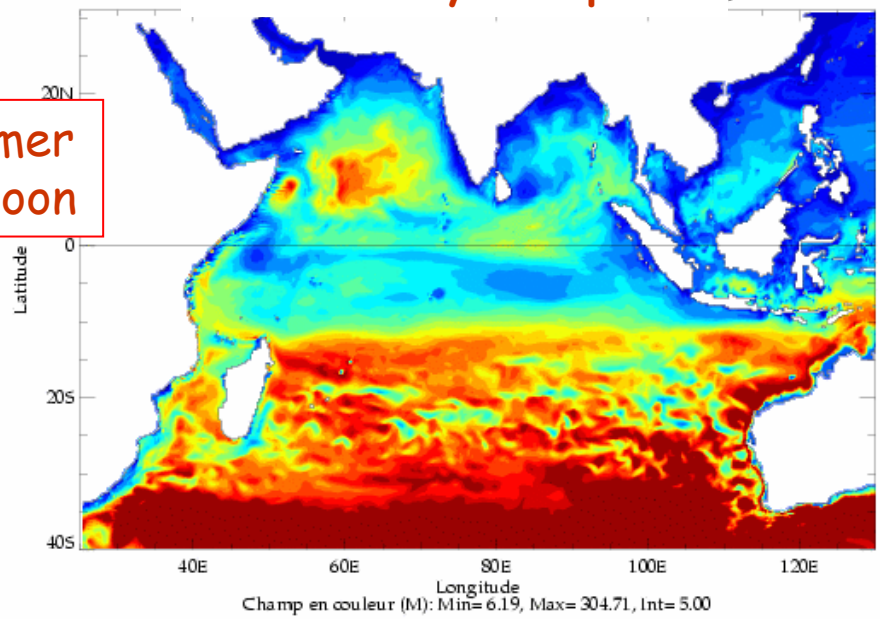


Sea Surface Temperature



Summer monsoon

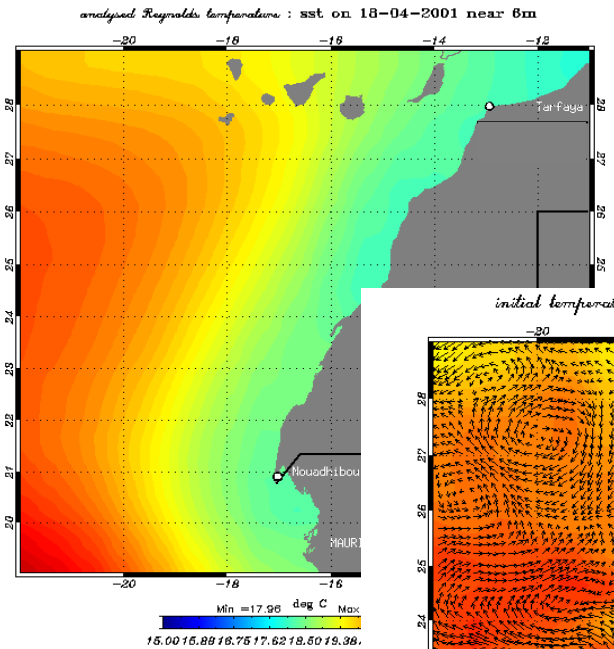
Mixed Layer Depth



anog

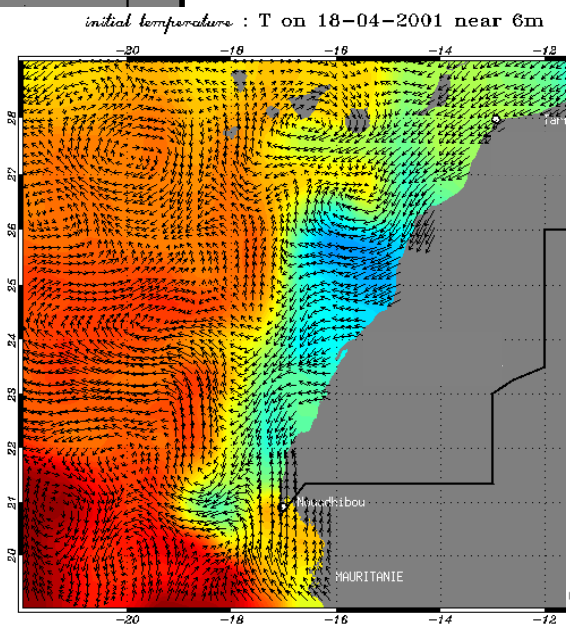
Global Ocean Component
Coupling Global-Regional

- Actual 1/15° Basin models are providing good Regional basis for 1/ Regional experiments and 2/ coupling coastal models
- Expand this capacity to a GLOBAL coverage is a GMES Challenge

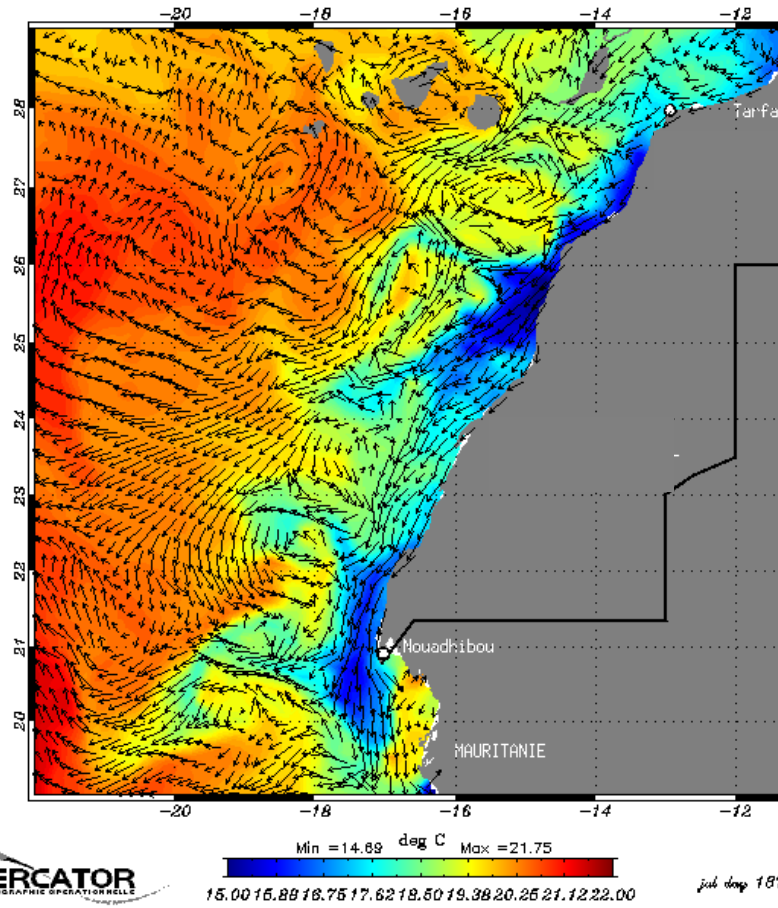


Satellite data (mean)

Sea Surface Temperature Mauritanian Upwelling



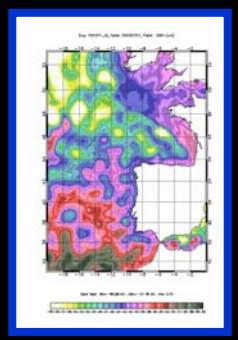
Mercator 1/3°

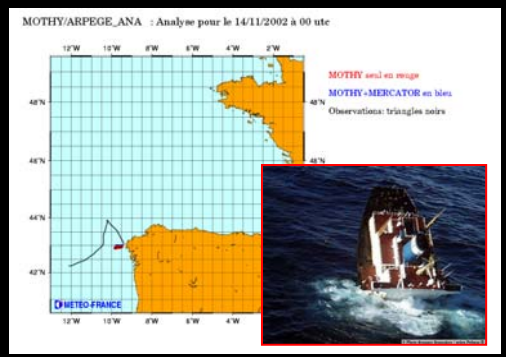


Mercator 1/15°

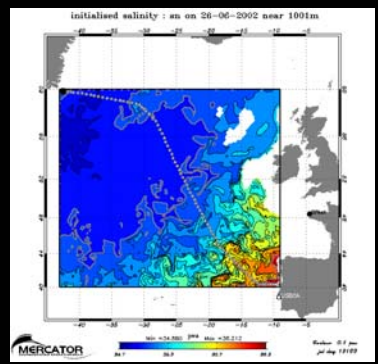
Mercator Ocean services

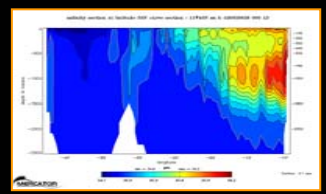
Operational Institutional Applications



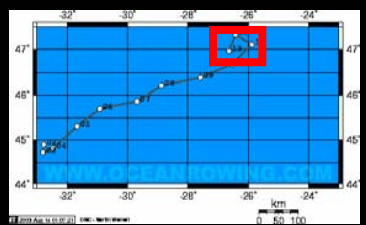


Research

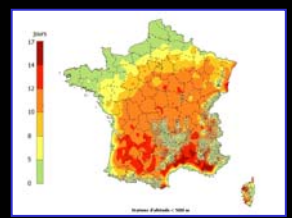


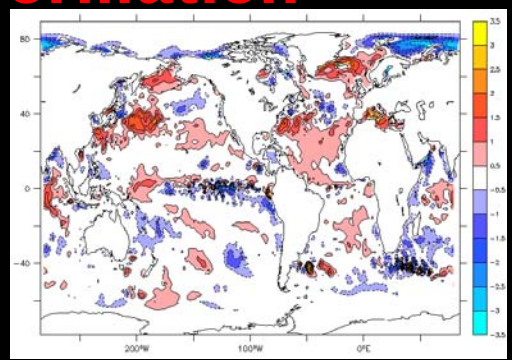


Operational Commercial Applications



Policy Makers Information

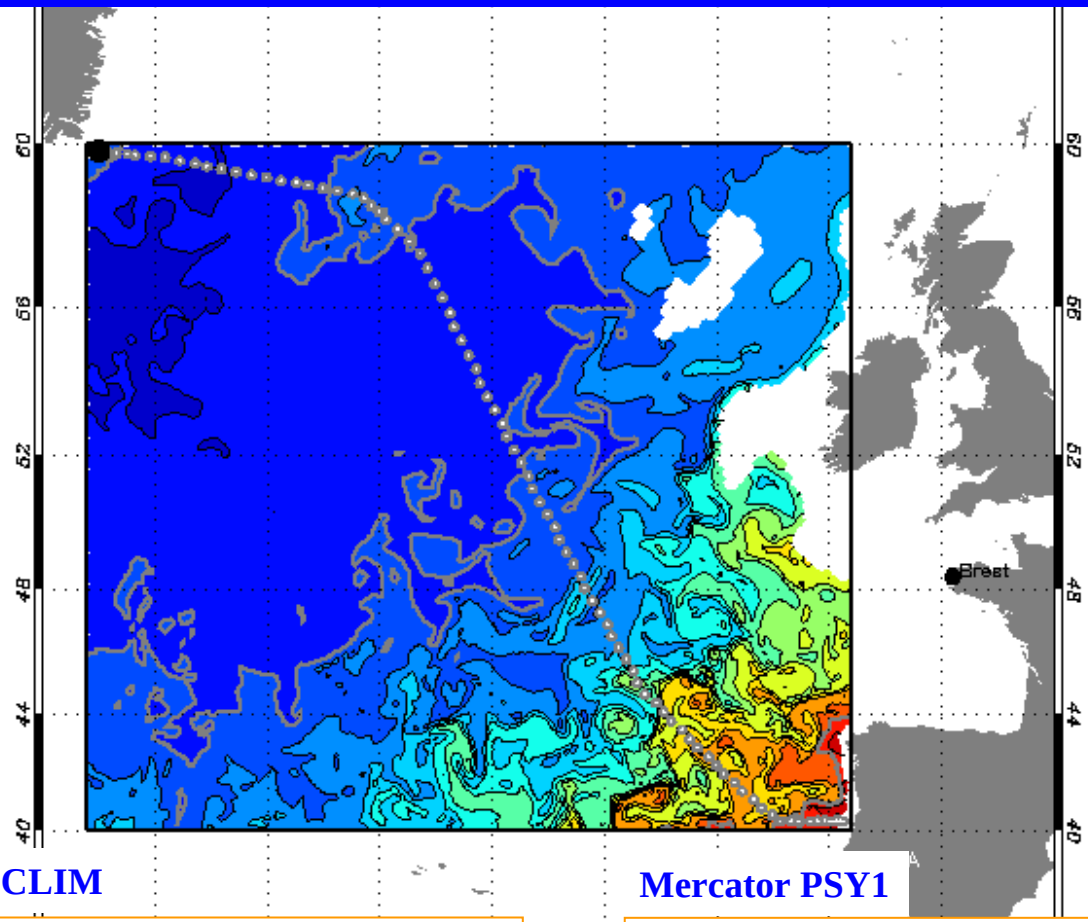




0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

jul day 19624

Information to scientific cruises

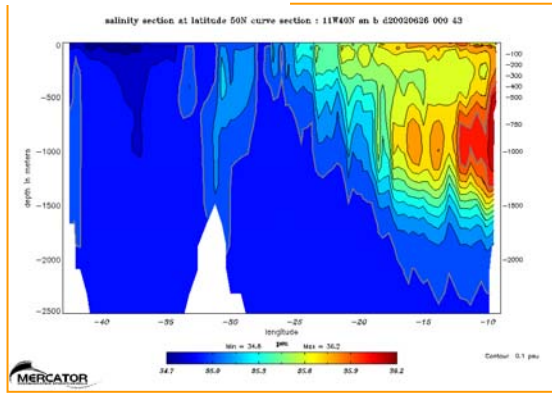


June 2002

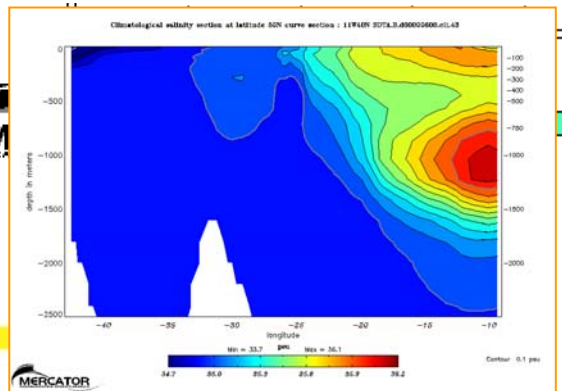
Scientific Cruise (OVIDE)

Salinity Field

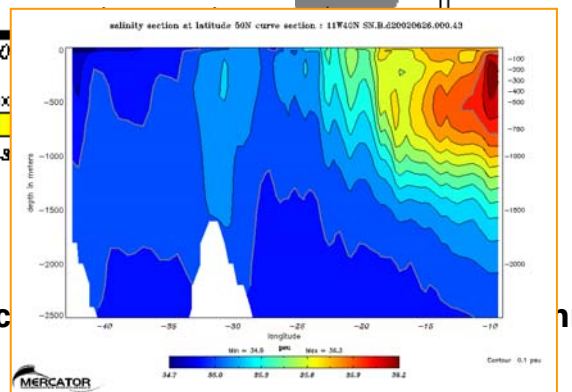
Mercator PSY2



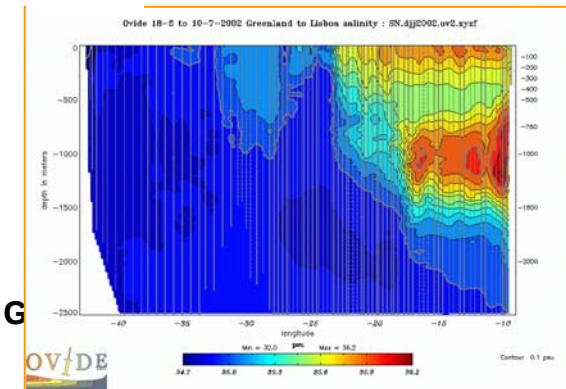
CLIM



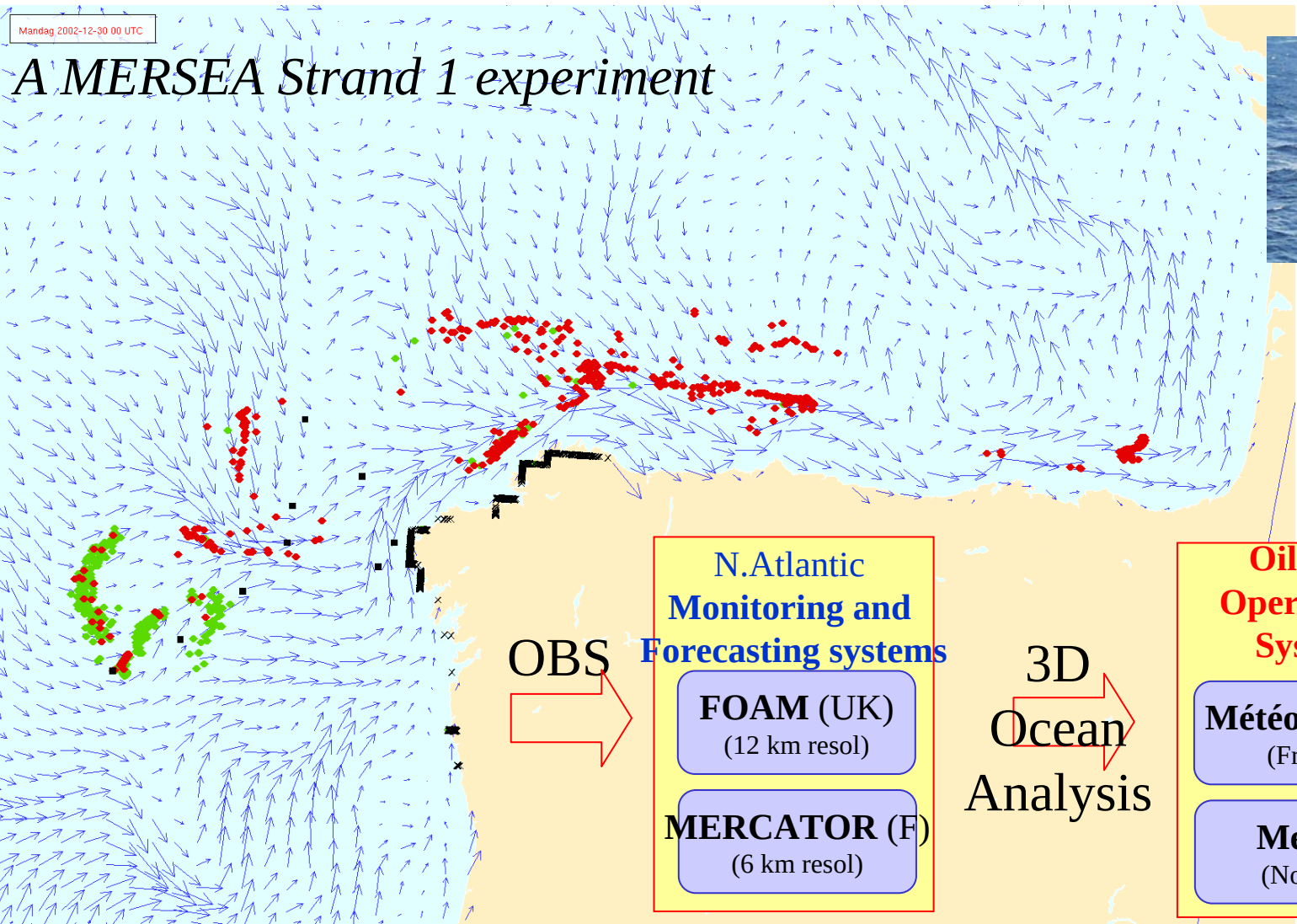
Mercator PSY1



CTD



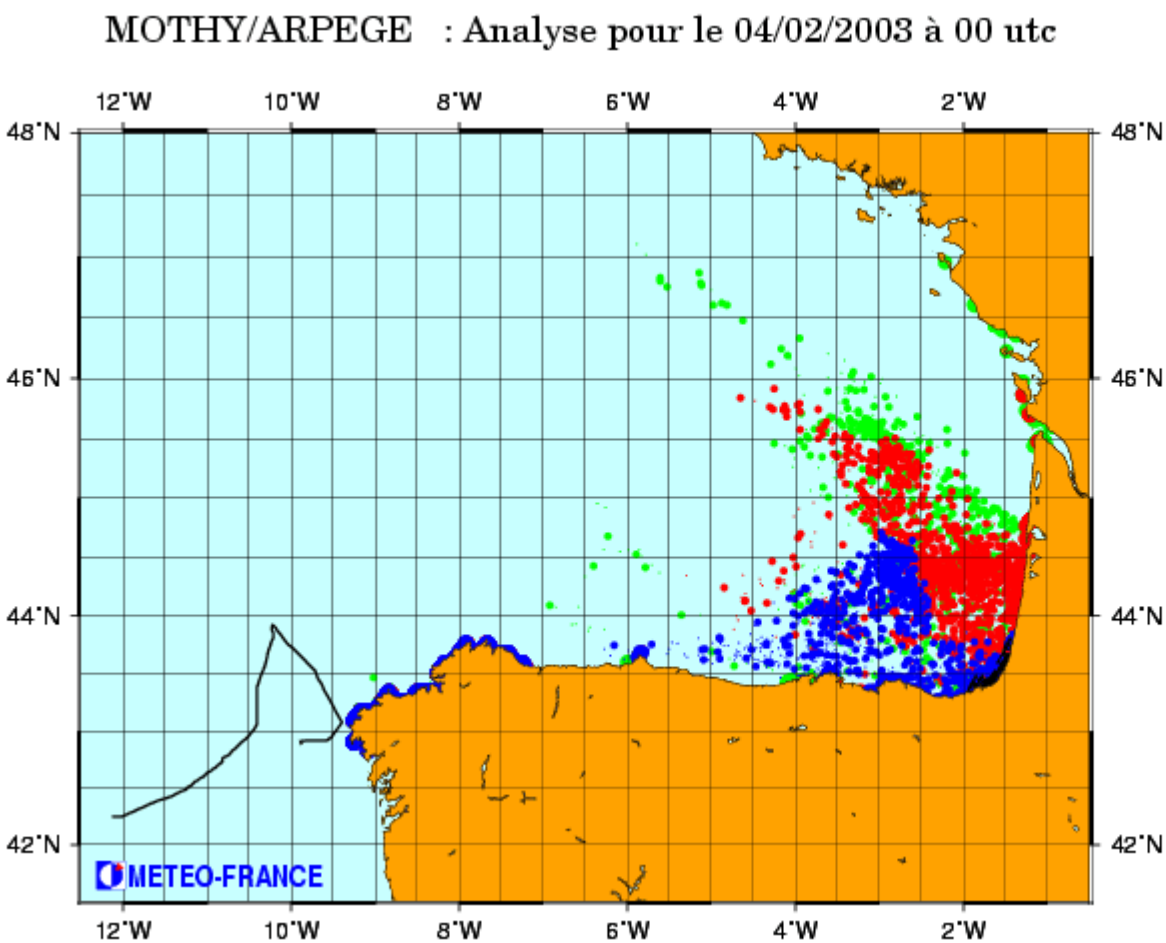
Oil Spill (with & without Mersea)

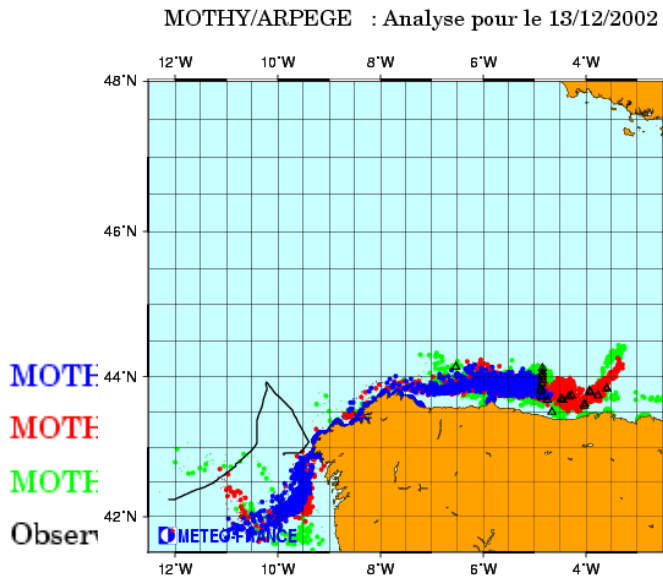


Ifremer

Courtesy of B.Hackett

MOTHY + Foam or Mercator



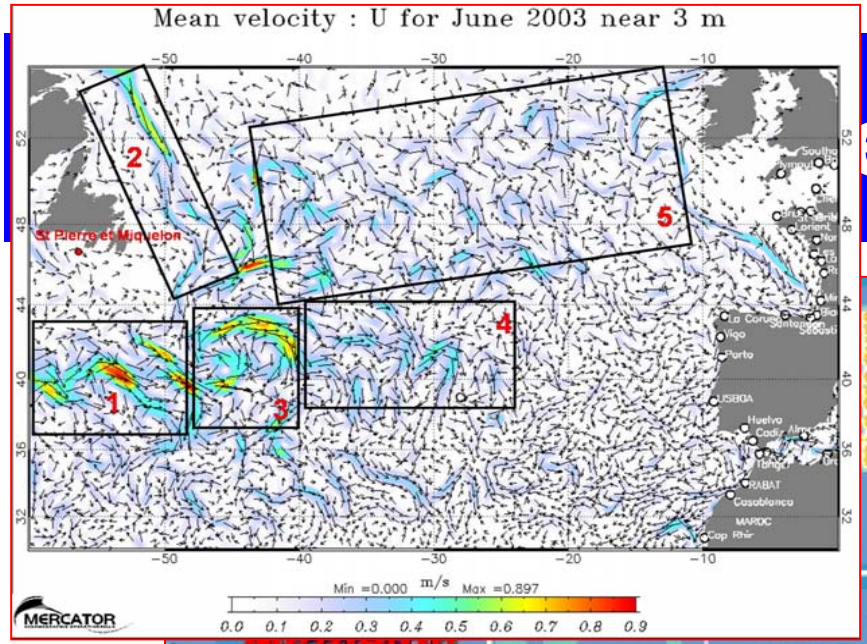


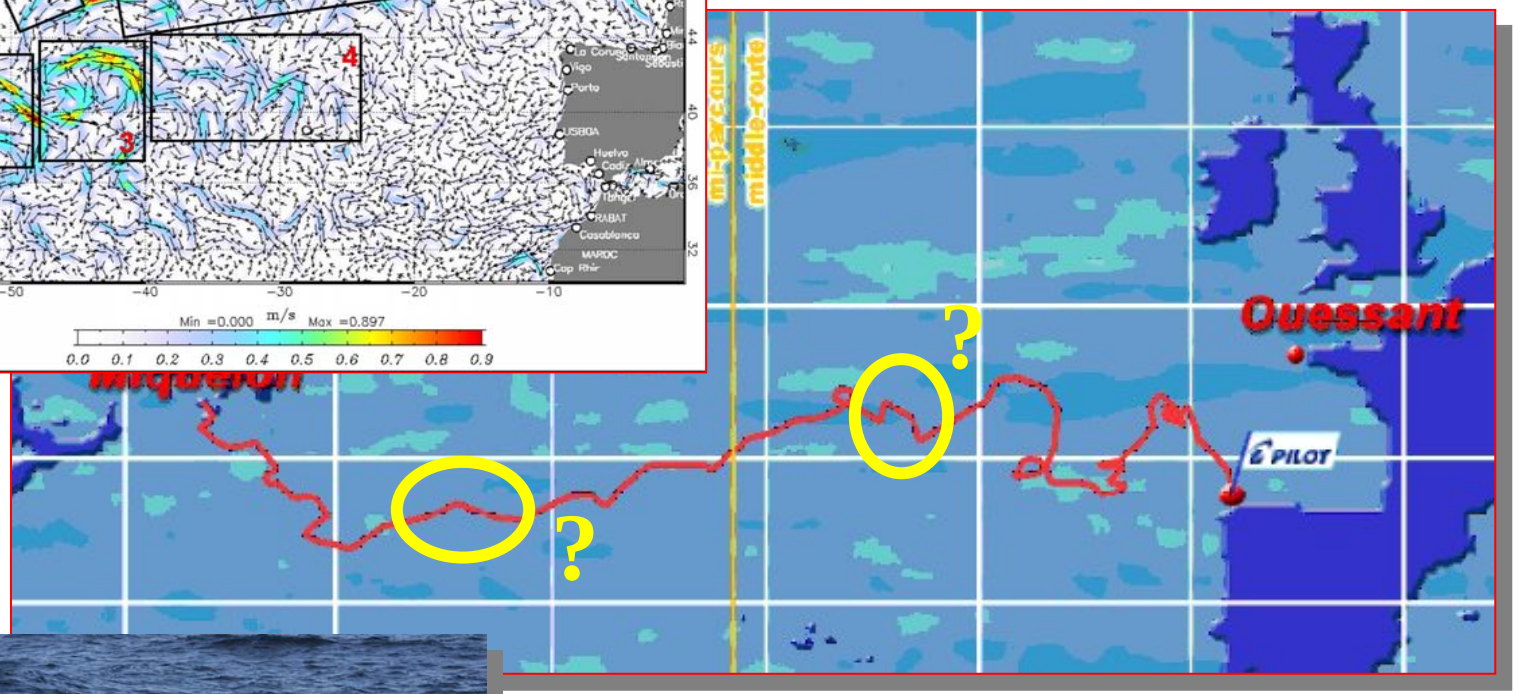
Météo-France Oil Drift Forecasting Operational team comparing
- **its own MOTHY operational system**
- **The same one but served by two different ocean inputs: Foam,and Mercator**

P.Daniel (Météo-France)

Ifremer

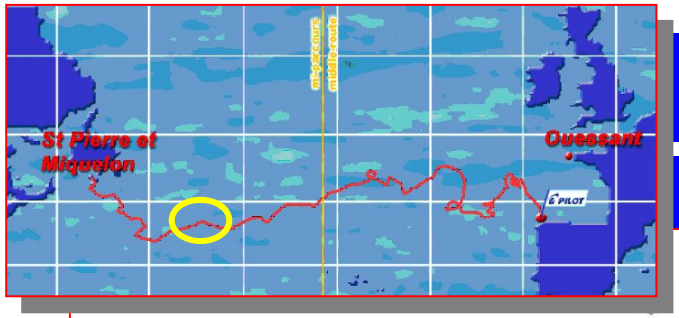
ed Feedback to ...





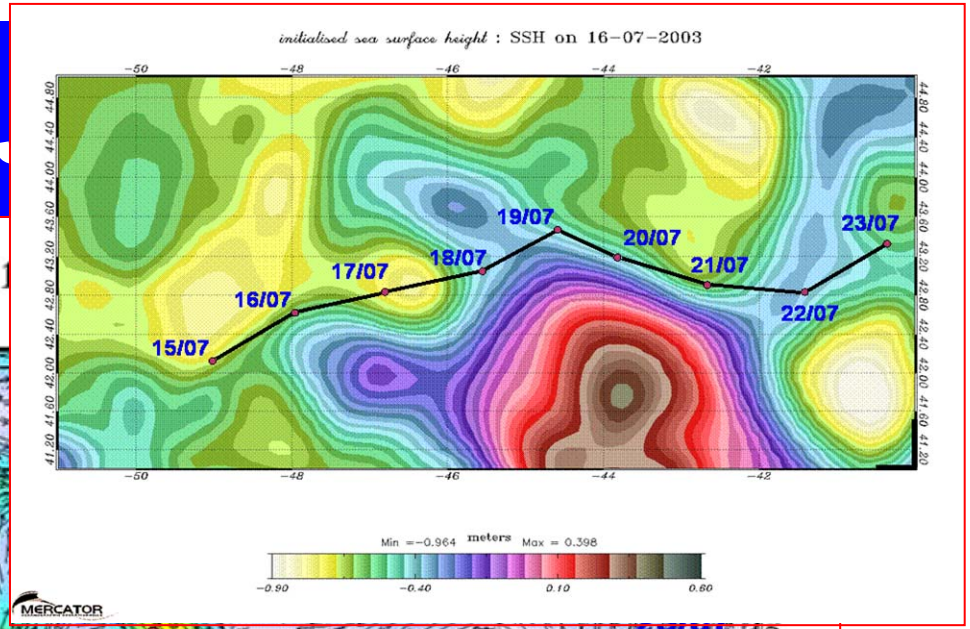
- Jun-Oct 2003 : 117 days
- Total Distance : 6707 km
- Direct route : 3726 km
- http://maudfontenoy.free.fr

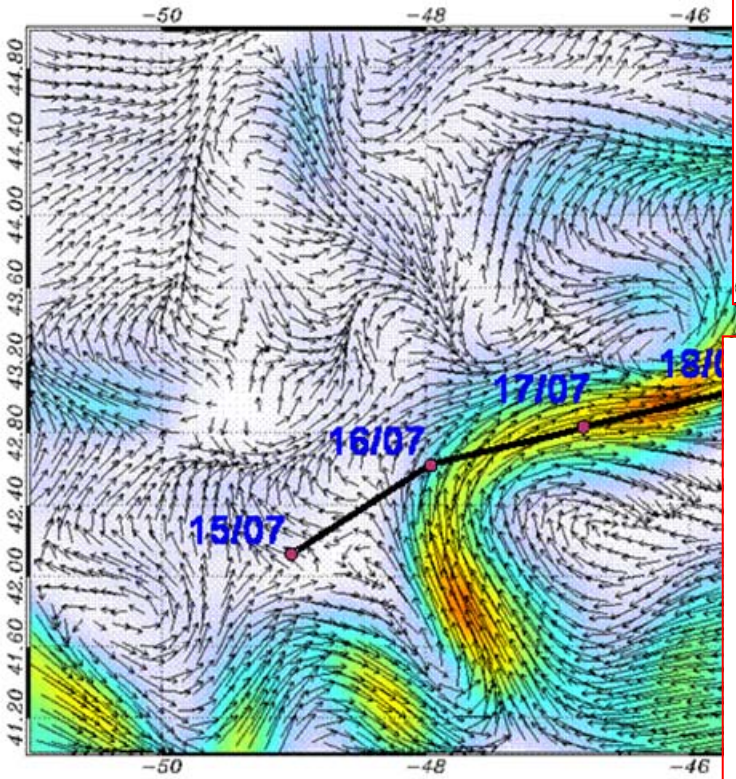
Ifremer

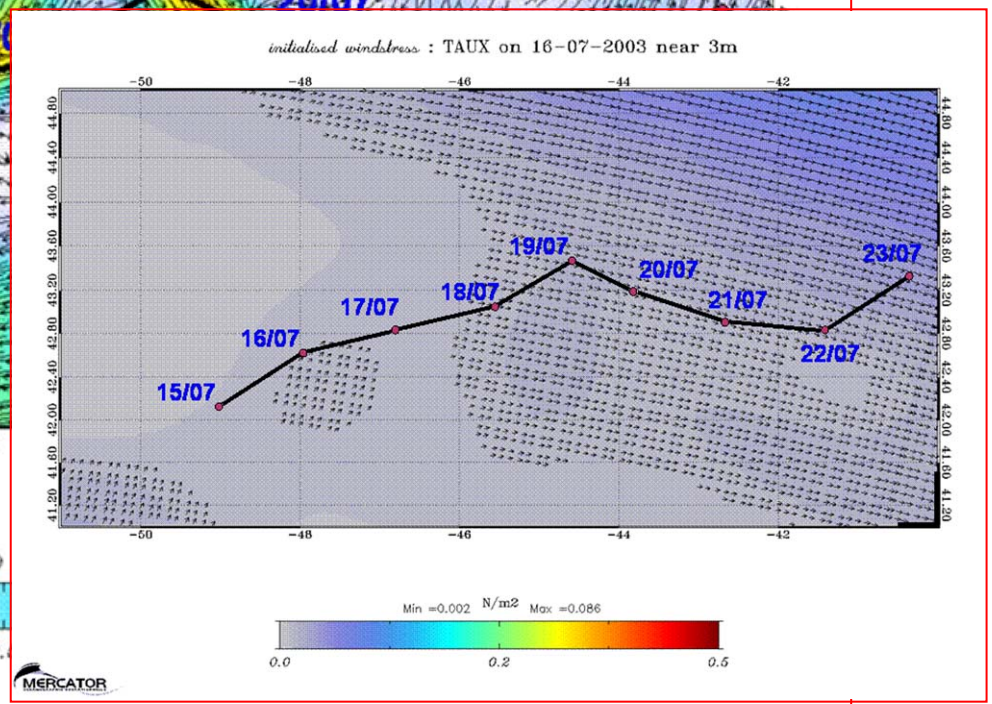

St Pierre et Miquelon
Ouessant
6' PILOT

-23 J

: U on


initialised sea surface height : SSH on 16-07-2003
15/07
16/07
17/07
18/07
19/07
20/07
21/07
22/07
23/07
Min =-0.964 meters Max = 0.398
MERCATOR


15/07
16/07
17/07
Min =0.039
MERCATOR


initialised windstress : TAUX on 16-07-2003 near 3m
15/07
16/07
17/07
18/07
19/07
20/07
21/07
22/07
23/07
Min =0.002 N/m2 Max =0.086
MERCATOR

Cost benefit ratio
eg Gulf of Marine Ocean observation System
Go MOOS

- **Users direct the organisation**
  - Commercial mariners
  - Coastal resource managers
  - Scientists
  - Educators
  - Search and rescue teams
  - Public health officials
- **Potential annual benefits**
  - 33 M US $
  - if 1% in lives-at-risk saved (90 to 91%)
    - 6 lives per year

Architecture of operational Oceanography

- **Long life « overall system »**

- **« Subsystems » (global, regional etc…)**
  - relying upon « components » transverse to subsystems
  - with varying life cycles
    - incremental evolutions
  - both research-pushed and technology-pulled

- **Implies**
  - Integrated subsystems
    not sensitive to evolutions of components
  - Minimum standardisation
    but clear interfaces

A system of systems
(GEO framework)

How to elaborate a managable system
Some potential principles

- **Elaborate a limited number of « integrated subsystems »**
  satisfying « similar » needs and requirements
  with limited sets of products
- **Decompose the « overall system »**
  in a limited set of components
  in order to increase synergies
- **Describe precisely interfaces between components**
  and each sub-system
- **Define the overall governance identifying :**
  - political ownership (global and regional)
  - strategic activity
  - policy and technical definition
  - implementation entities
    - for components
    - subsystems

Conclusion

- **Operational Oceanography**

  an identified set of needs

  an ongoing development and implementation

  a building up of governance
  on global
  and regional scales