mercator-ocean.eu

marine.copernicus.eu

Les réanalyses océaniques dans CMEMS et à Mercator Océan

Yann Drillet
Mercator Océan, Ramonville St Agne, France

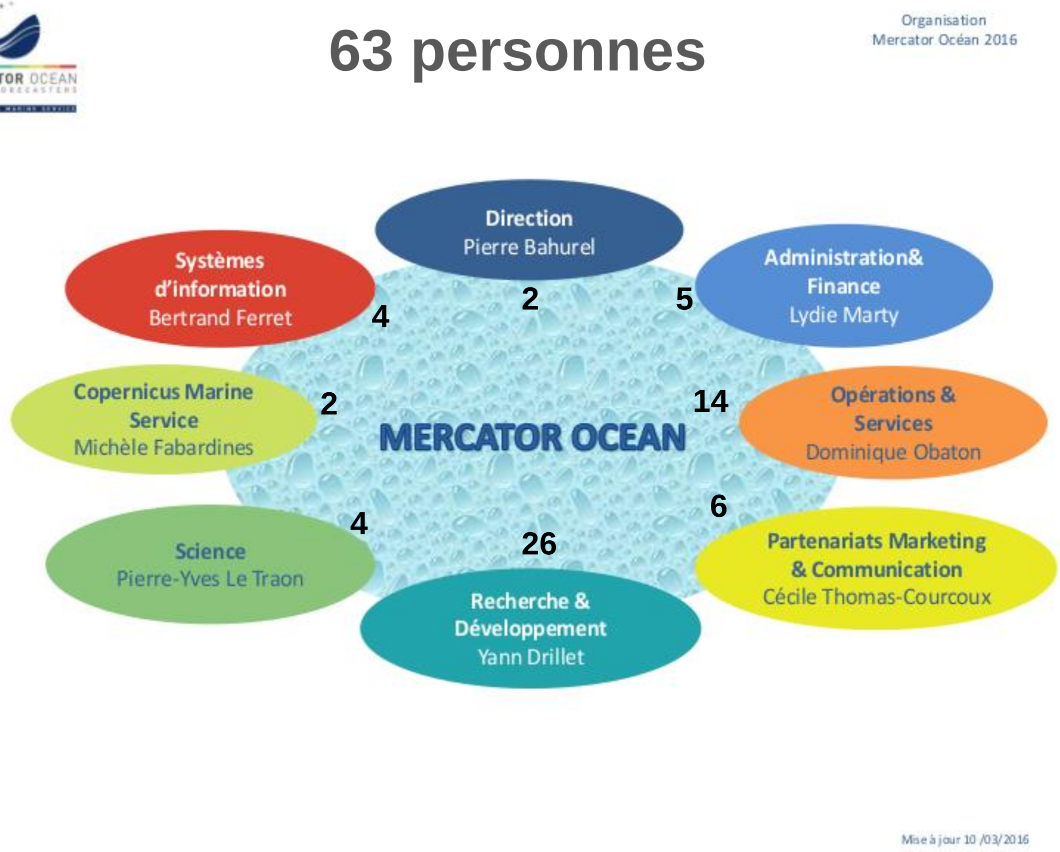
Plan

- **Mercator Océan et Copernicus Marine Environment Monitoring Service**
- **Les réanalyses océaniques : ce qui existe et qui est distribué**
- **Illustrations et résultats sur les réanalyses produites par Mercator Océan : GLORYS, IBIRYS, MEDRYS**
    - **Validation**
    - **Incertitudes**
    - **Physique et Biogéochimie**

Mercator Océan

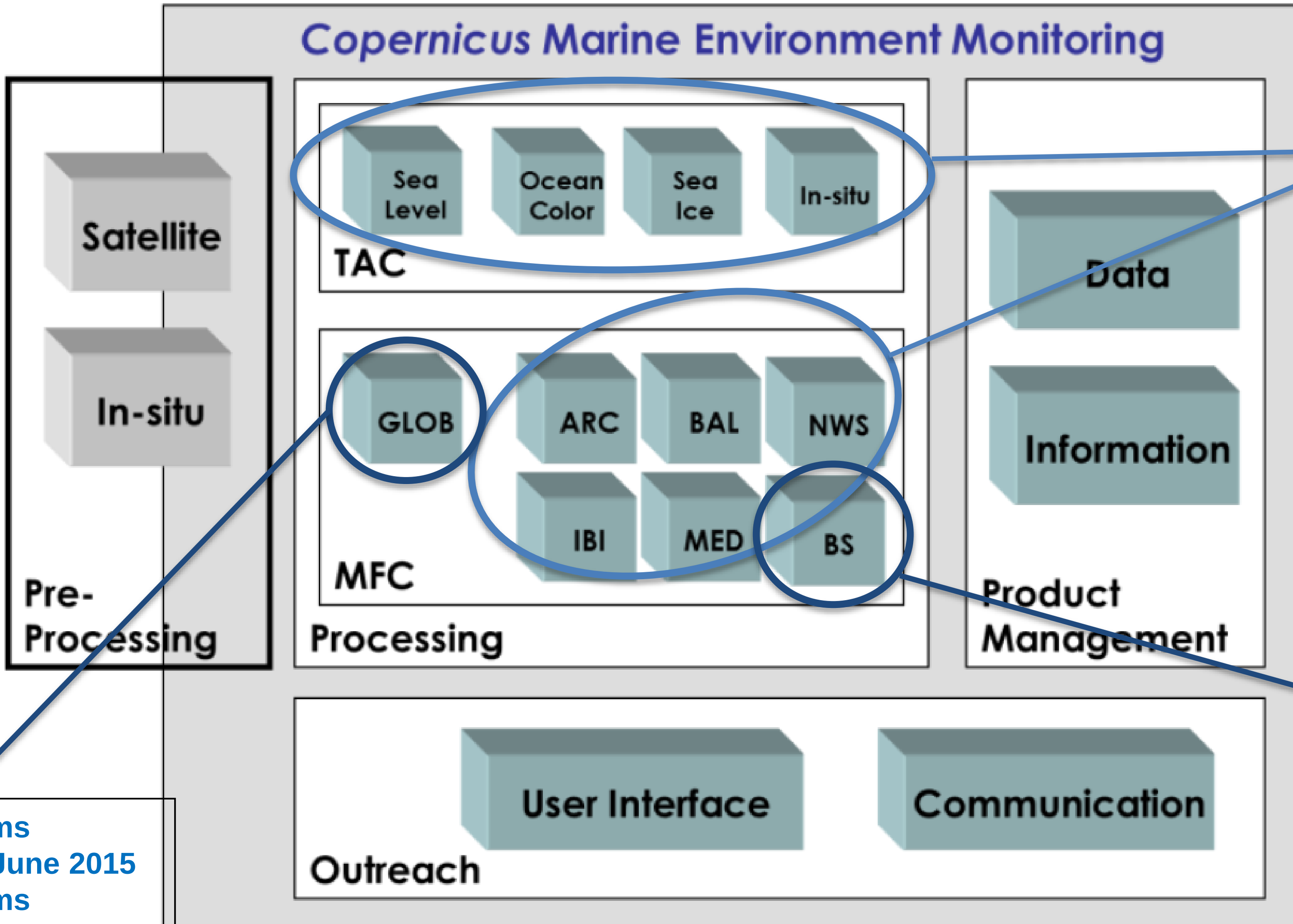
Quelques dates

- **1995 : Début de l’histoire avec le CNRS, IFREMER, IRD, Méteo France, SHOM et CNES**
- **2005 : Premier bulletin de prévision global**
- **2009-2015 : les projets MyOcean**
- **2013 : Création de la société civile**
- **2014 : Mercator Océan est délégataire de la commission Européenne pour mettre en place le service CMEMS**
- **2015 : Mise en place et ouverture du service CMEMS**



MERCATOR OCEAN

Organisation de CMEMS



9 consortiums selected in April 2015

1 consortium selected in march 2016

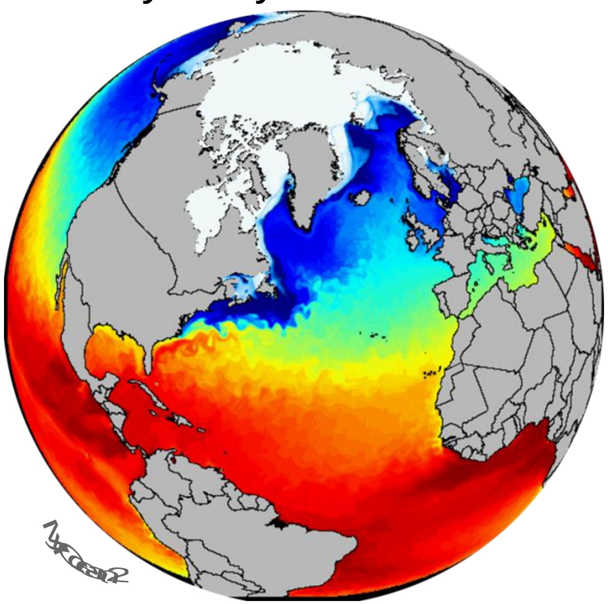
2 consortiums selected in June 2015
3 consortiums selected in Apr 2016

What is an Ocean reanalysis?

→ a comprehensive estimation of the ocean state ***global or regional*** over the last decades (mainly temperature, salinity, sea level and currents and biogeochemistry)

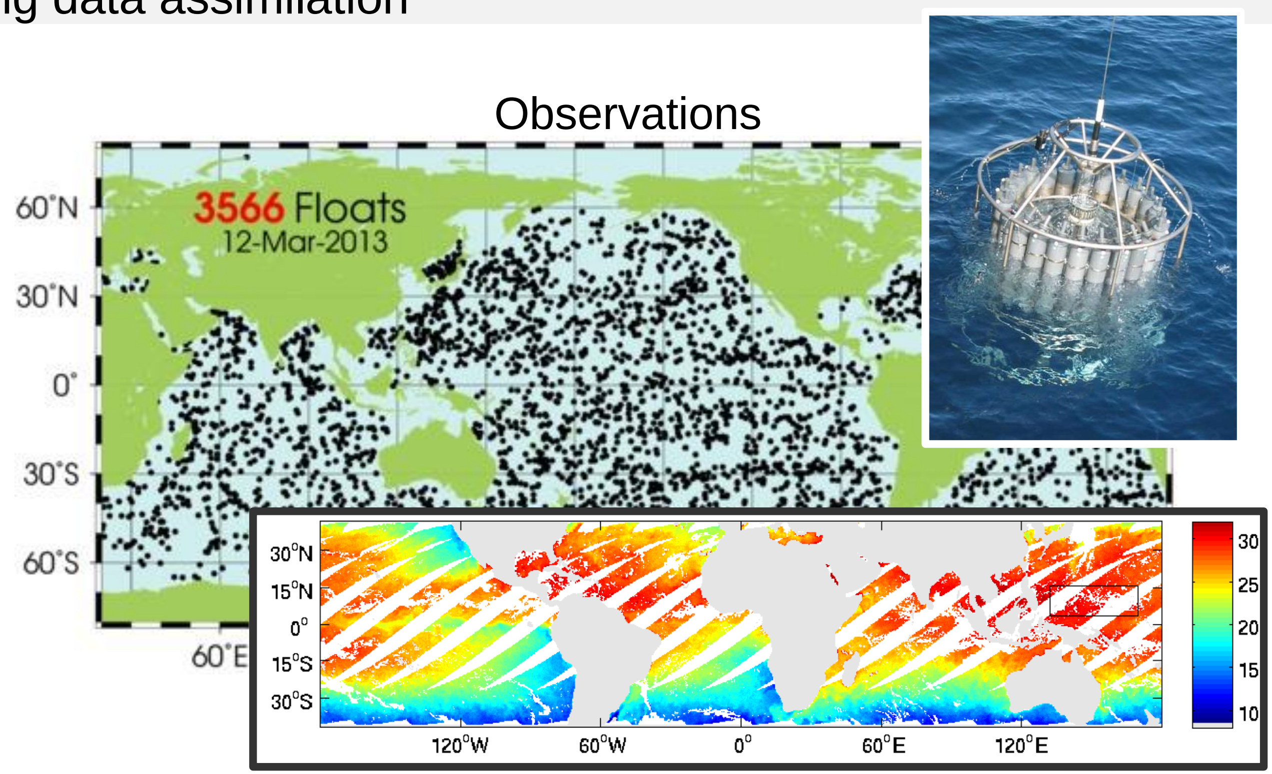
→ calculated by merging hydrodynamic ocean models and all available observations using data assimilation

Hydrodynamic model



\+

Observations



→ necessary reference for monitoring and forecasting the Ocean

→ critical to understand climate and to predict future change

The Copernicus Marine Environment Monitoring Service *CMEMS*

Currently **136 products** among which

- **25** ocean syntheses : model reanalysis or non assimilative hindcasts products *over regions 1 to 6*

- **29** Reprocessing products of Ocean Colour, Sea Level, SST, Sea Ice, Winds, In Situ observations.

MULTIYEAR MODELS

Models for areas NWS IBI and BALTIC include tidal component, meaning that all parameters include tide signal, especially UV and SSH.

AREA		PRODUCTS: REFERENCES (links to online catalogue here)	PARAMETERS	CHARACTERISTICS: HORIZONTAL AND VERTICAL RESOLUTIONS	TEMPORAL COVERAGE [START DATE; END DATE]	TEMPORAL RESOLUTION	UPDATE FREQUENCY	DATA ASSIMILATED
GLOBAL	Phy	001_009	T S UV SSH ICE MLD	1/4°-25km; 75 levels	[15/01/1993;15/12/2013]	M+D	A	black, red, purple, orange
		001_011	T S UV SSH ICE	1/4°-25km; 50 levels	[01/15/1982;15/12/2013]	M+D	A	black, red, purple, orange
		001_010	T S UV SSH ICE	1/4°-25km; 75 levels	[15/01/1993;15/12/2010]	M	NU	black, red, purple, orange
		001_017	T S UV SSH ICE MLD	1/4°-25km; 75 levels	[15/01/1979;15/12/2013]	M+D+5D	A	black, red, purple, orange
		001_004	T S UV SSH ICE	1/4°-25km; 75 levels	[15/01/1993;15/12/2011]	M	NU	
	Bio	001_018	CHL O2 N P Phyto PP Si Fe	1/4°-25km; 75 levels	[15/01/1998;15/12/2013]	M	A	
		001_019	CHL O2 N P Si	1/4°-25km; 50 levels	[15/01/1998;15/12/2013]	M	A	
ARCTIC	Phy	002_003	T S UV SSH ICE MLD	12.5 km; 12 levels	[15/01/1991;15/12/2013]	M	A	black, red, purple, orange
	Bio	002_005	CHL O2 N P Phyto Radflux	25 km; 12 levels	[15/01/2007;15/12/2010]	M	NU	black, red, orange, green
BALTIC	Phy	003_008	T S UV SSH ICE	3nm-5.5km; 50 levels	[01/01/1989;31/12/2013]	M+H+6H	A	black, purple, orange
		003_004	T S UV SSH ICE	6nm-11km; 25 levels	[01/01/1990;31/12/2009]	M	NU	purple
		003_005	T S UV SSH ICE	3 nm-5.5 km; 25 levels	[01/01/1990;31/12/2009]	M	NU	black, purple, orange
	Bio	003_009	CHL O2 N P NH4	2nm-3.7km; 83 levels	[01/01/1970;31/12/1999]	M+2D	NU	blue
NWS European North West Shelf Seas	Phy	004_009	T bedT S UV	7 km; 24 levels	[01/01/1985;01/07/2012]	M+D	A	black
		004_005	T S UV SSH	12 km; 24 levels	[01/01/1960;31/12/2004]	M	NU	
		004_006	T S UV SSH	12 km; 24 levels	[15/01/1985;15/12/2008]	M	NU	
		004_010	T S UV SSH	8 km ; 26 levels	[01/01/1993;31/12/2012]	M	A	black
	Bio	004_011	CHL O2 N P Phyto PP RadFlux	7 km; 24 levels	[01/01/1985;01/07/2012]	M+D	A	black
		004_007	CHL O2 N P Phyto PP RadFlux	12 km; 24 levels	[01/01/1967;31/12/2004]	M	NU	
		004_008	O2 N P Phyto PP Si	12 km; 24 levels	[31/01/1985;31/12/2008]	M	NU	
		004_012	O2 N P Phyto PP Si	8 km; 26 levels	[01/01/1993;31/12/2012]	M	A	black
IBI Iberia Biscay Ireland Regional Seas	Phy	005_002	T S UV SSH	1/12°-7.5km; 50 levels	[01/02/2002;23/12/2011]	M+D+H	NU	black, red, purple
	Bio	005_003	CHL O2 N P Phyto PP Si Fe NH4 Eup	1/12°-7.5km; 50 levels	[01/01/2002;23/12/2011]	M	NU	black, red, purple
MED Mediterranean Sea	Phy	006_004	T S UV SSH	1/16°-6km; 72 levels	[01/01/1987;31/12/2013]	M+D	A	black, red, purple
	Bio	006_008	CHL O2 N P Phyto PP	1/16°-6km; 72 levels	[01/01/1999;31/12/2012]	M	A	black, red, purple, green

Which codes are used in CMEMS Monitoring and Forecasting Centres?

<table>
<tr><th rowspan="2"><u>V5.0</u></th><th colspan="3">Near Real Time
(Analysis and Forecast)</th><th colspan="7">MULTI YEAR
(Non Assimilative Hindcast or Reanalysis)</th></tr>
<tr><th colspan="2">PHYS</th><th>BIO</th><th colspan="4">PHYS</th><th colspan="3">BIO</th></tr>
<tr><td>GLOBAL</td><td>NEMO3.1-LIM 1/12° with SEEK and 3DVAR (large scale TS) DA</td><td>NEMO3.4 coupled with atm UM-N216 with CICE. NEMOVAR-3Dvar 1/4°</td><td>Pisces/offline (no DA) 1/4° interp on 1/2°</td><td>NEMO 3.1-Glorys2v3 1/4° with SEEK and 3DVAR (large scale TS) DA 1993-2013</td><td>NEMO 3.2-Cglors 1/4° With 3DVar 1982-2013</td><td>NEMO 3.2-UR025 1/4° With OI DA 1993-2010</td><td>NEMO 3.4-ORAP 5 1/4° With NEMOVAR 3Dvar-FGAT DA 1979-2013</td><td>Pisces/offline (no DA for PHY and BIO) 1/4° 1998-2013</td><td colspan="2">BFM/offline (no DA for PHY and BIO) 1/4° 1998-2013</td></tr>
<tr><td>ARCTIC</td><td colspan="2">HYCOM 2.2.37 1/8° - 12.5km with EnKF DA;</td><td>Norwecom/online (no DA) 1/8° -12.5km</td><td colspan="4">HYCOM 2.2.12 12.5km with EnKF DA 1991-2013</td><td colspan="3">Norwecom/online 50km With EnKF DA 2007-2010</td></tr>
<tr><td>BALTIC</td><td colspan="2">HBM (no DA) 1nm ~2km</td><td>DMI-ERGOM/online (no DA) 1nm~2km</td><td>SMHI HIROMB-En3DVar 1989-2013 3nm</td><td colspan="2">DMI-HBM (with 3Dvar) 1990-2009 6nm</td><td>SMHI-HBM (with univariate OI) 1990-2009 3nm</td><td colspan="3">RCO-SCOBI/offline (EnOI) 1970-1999 2nm</td></tr>
<tr><td>NWS</td><td colspan="2">NEMO 3.4 7km with (SSTonly) NEMOVAR-3Dvar</td><td>ERSEM/online (no DA) 7km</td><td>NEMO3.4 AMM – with NEMOVAR 1985-2012 7km</td><td>POLCOMS (no DA) 1960-2004 12km</td><td>POM (no DA) 1985-2008 12km</td><td>ROMS IS4DVar 1993-2012 8km</td><td>POLCOMS-ERSEM/online 1967-2004 (no DA) 12km</td><td>POM-NORWECOM/offline 1985-2008 (no DA) 12km</td><td>ROMS-NORWECOM/offlin 1993-2012 (no DA) 8km</td></tr>
<tr><td>IBI</td><td colspan="2">NEMO 3.4 (no DA) 1/36°</td><td></td><td colspan="4">NEMO 2.3 (SEEK and 3DVAR (large scale TS) DA) 1/12° 2002-2012</td><td colspan="3">PISCES/online 1/12° 2002-2012</td></tr>
<tr><td>MED</td><td colspan="2">NEMO 3.4 1/16° With OceanVar DA Coupled to WaveWatchIII</td><td>OPATM BFM/offline 1/16° (with OceanVar DA)</td><td colspan="4">NEMO 2.3 1987-2013, 1/16° (with OceanVar DA)</td><td colspan="3">OPATM BFM V3.1/offline 1/16° 1999-2012 (with OceanVar)</td></tr>
</table>

Existing quality control of ocean syntheses

Current quality control : Assessment of the reliability of the reanalysis on average, or at basin scale

Model physics

- **Water masses**
- **Currents and transports**
- **Variability**
- **Mesoscale**
- **Waves, high frequencies, tides**

Data assimilation performance, error tunings

Stability over time (need for long hindcast)

Intercomparisons between reanalysis products (GOV/CLIVAR/GSOP ORA IP, CMEMS)

QC on assimilated data -> feedback to observation data centers

Non regression with respect to previous versions

CLIVAR-GSOP/GODAE OceanView
Ocean Reanalysis Intercomparison (ORA-IP, 2012-2014) followed by Real-Time Ocean Reanalyses Intercomparison

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Reanalysis production is an on-going activity, following the feedbacks and outcomes of GSOP 2006-2009

- Improved versions are produced approximately every 5 years (improved input observations, forcings, models and methods)

Intercomparison/validation to assess uncertainties among ocean reanalyses (model errors and bias, observing system reliability over time)

- benefits of the ensemble approach both to improve the estimation of the signals and to provide uncertainty ranges
- Synthesis by ocean essential variable: sea level, steric height, D20, MLD, salt and heat content, sea ice, fluxes and transports
- Facilitate the use of ocean reanalyses by other communities and from the existing maturity, start quasi-real time monitoring of the ocean (Balmaseda, Fujii, Xue proposal)

http://origin.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

Courtesy of M. Balmaseda

Variable	Responsible	Institution
Steric Height	Andrea Storto	CMCC
Sea Level	Fabrice Hernandez	Mercator Ocean
Ocean Heat Content	Matthew Palmer	UK MetOffice
Depth of 20 degree Isotherm	Fabrice Hernandez	Mercator Ocean
Mixed Layer Depth	Takahiro Toyoda	MRI-JMA
Salinity	Li Shi	BMRC
Surface fluxes and transports	Maria Valdivieso	University of Reading
Atlantic Meridional Overturning at 26N	Vladimir Stepanov/Keith Haines	University of Reading
Sea Ice	Gregory Smith	Environment Canada

ORAIP Variables and processing agents

More than 20 participating ORA's and observed products:

- some coupled
- from 1° to ¼° resolution
- different models, forcing, DA

See a summary at http://www.clivar.org/sites/default/files/Exchanges/Exchanges_64.pdf

Reanalyses Products entering ORAIP

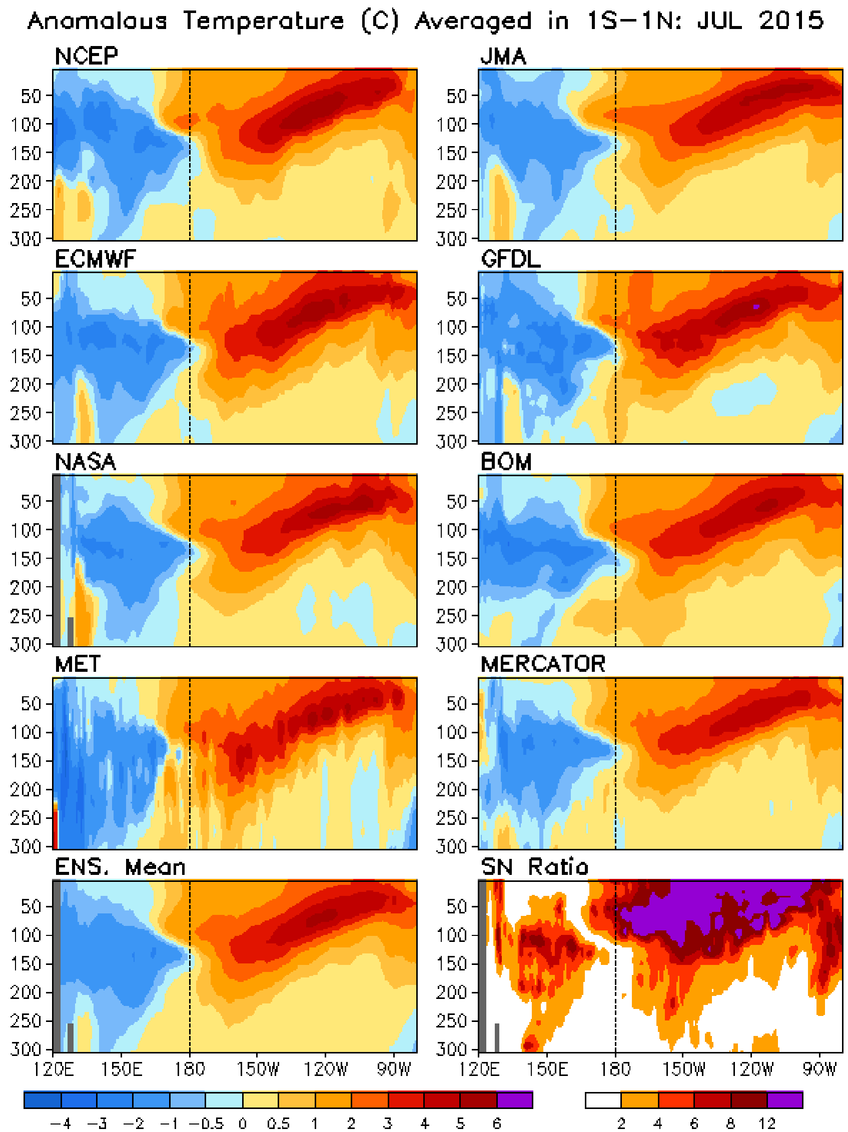
Product	Institution	Product	Institution
CFSR	NCEP	**ECCO-v4**	NASA/JPL
GODAS	NCEP	**GECCO2**	Hamburg University
Glosea5	UK MetOffice	**MOVE-C**	MRI/JMA
ORAS4	ECMWF	**MOVE-G2**	MRI/JMA
PEODAS	BMRC	**MOVE-CORE**	MRI/JMA
GLORYS	Mercator	**K7-ODA**	JAMSTEC
C-GLORS	CMCC	**K7-CDA**	JAMSTEC
UR025.4	Reading University		
GEOS5	NASA/GMAO	**ARMOR3D**	CLS (T/S/SLA)
ECDA	GFDL	**NODC**	NOAA (T/S)
SODA	University Meryland	**EN3**	MetOffice (T/S)
ECCO-NRT	NASA/JPL	**LEGOS**	LEGOS (SLA)

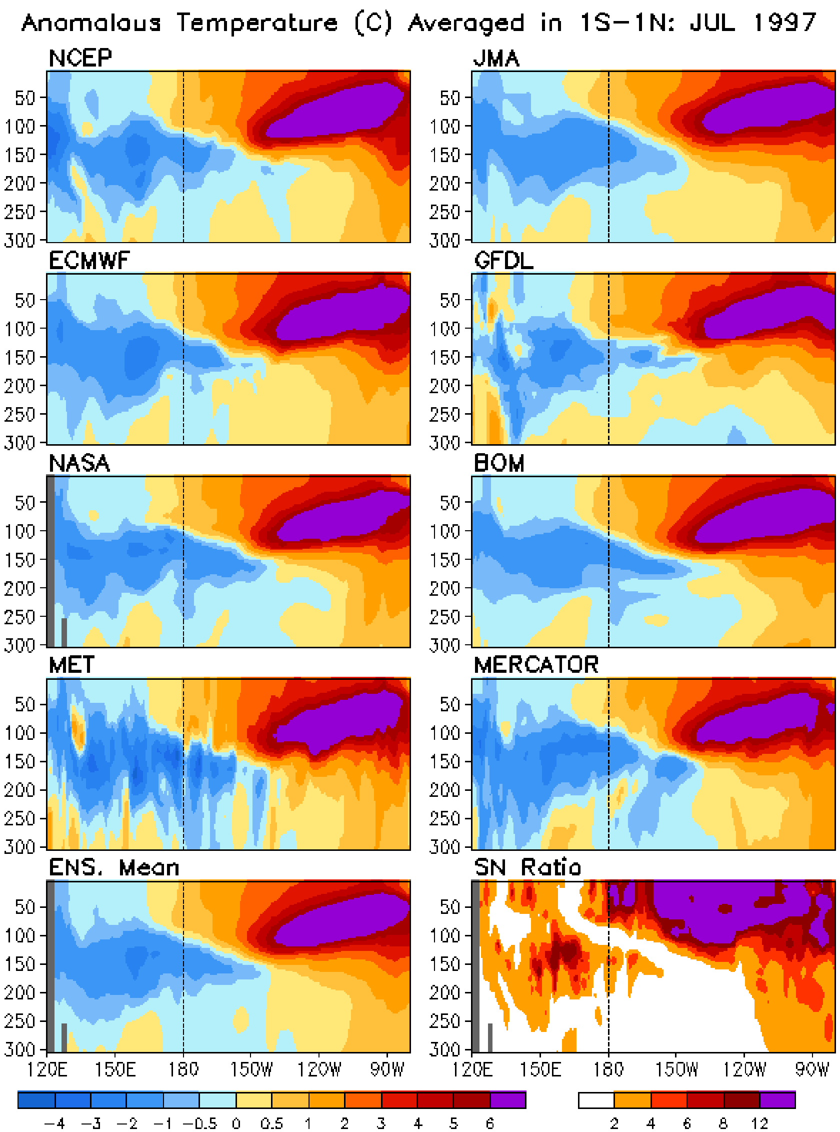
Balmaseda et al, The Ocean Reanalyses Intercomparison Project (ORA-IP), Journal of Operational Oceanography, 8:sup1, s80-s97, 10.1080/1755876X.2015.1022329, 2015.

And a series of accepted synthesis paper for Steric Height, Ocean Heat Content, MLD, transport and fluxes in Clim Dyn., 2015

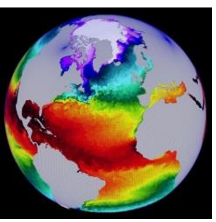
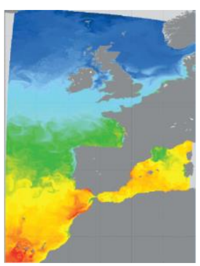
Real time Ocean monitoring with multi ORA

Yan Xue, NOAA/CPC





GLORYS, IBIRYS and MEDRYS reanalysis

	RAN	MODEL		ASSIM		FORCING	BIO	PERIOD
	GLORYS	NEMO	¼° 75L	SAM2 (T/S, SLA, SST) 3Dvar bias correction (T/S)	+ Sea Ice Concentration	ERA Interim (3h) correction Bulk	PISCES Offline ¼° forced by free simulation	1993-2014
	IBIRYS		1/12° 75L Tide atmos press		Filtering of tide and high frequency	ERA interim (3h) correction Bulk	PISCES online 1/12°	2002-2014
	MEDRYS		1/12° 75L (dedicated grid)		MDT Model equivalent for SLA	ALDERA (3h) Flux	NO	1993-2013

Mercator Global Reanalysis at ¼°
GLORYS (1992-2014)

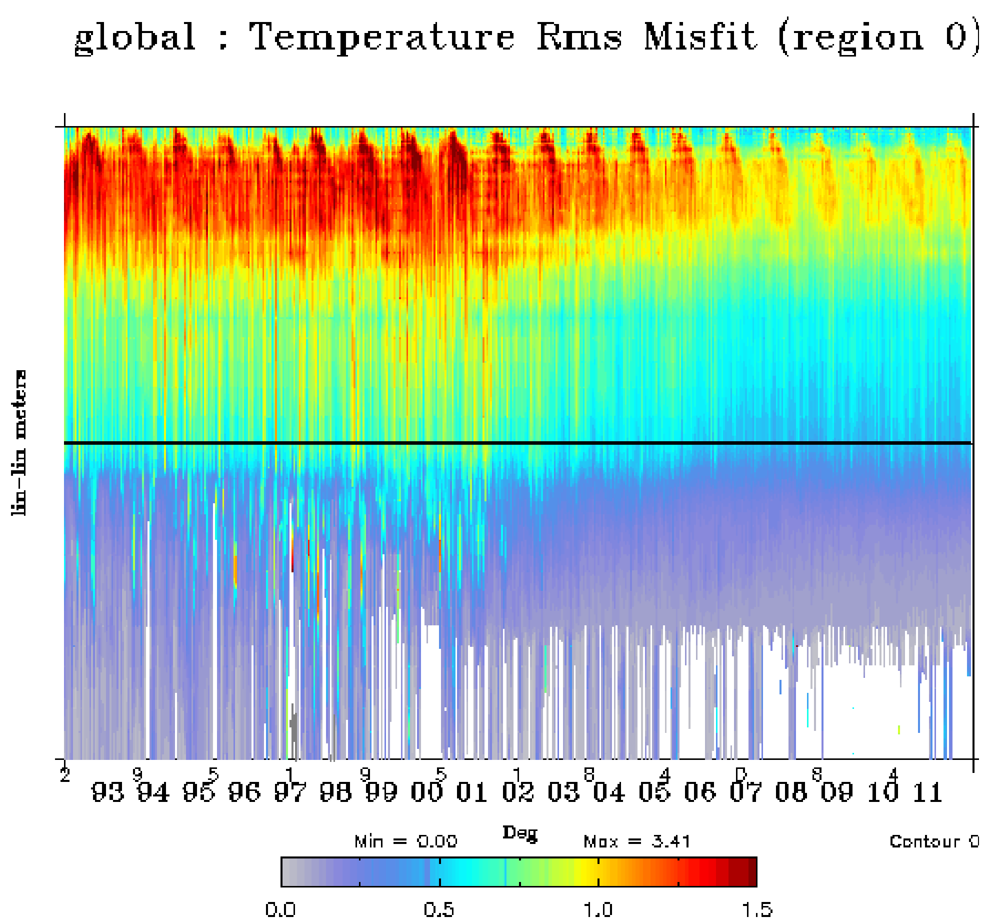
GLORYS2V3

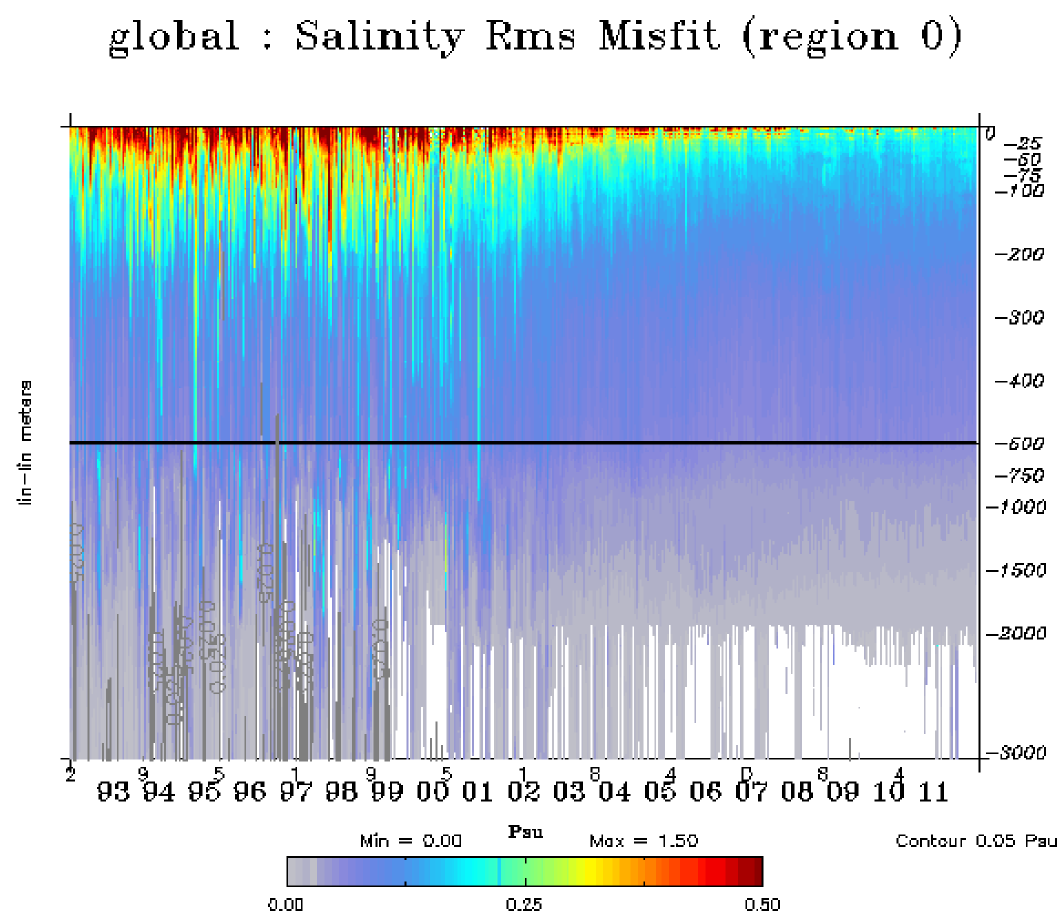
- The model component : NEMO3.1, ORCA025 (1/4° resolution), 75z-levels, LIM2.
- Initial Conditions : Levitus (1998) for (T,S), sea ice concentration from satellite obs., sea ice thickness from a forced run (starting in Jan 1979).
- Atmospheric Forcing: ERA-Interim (3h) with large scale bias correction towards GPCPV2.2 for rainfall and towards Gewex SRB3.0 for SW & LW fluxes. No corrections northward 65°N and southward 60°S. Runoff : Dai & Trenberth (2002) climatology
- No restoring.
- Assimilation scheme : SAM2 (EnKF, SEEK) + 3D-VAR biases correction (T,S).
- Observations assimilated : SST AVHRR (1/4°), in situ profiles (T,S) from CORA3v3, SLA on swath (+ MDT CNES-CLS09 hybrid), sea ice concentration (IFREMER/CERSAT).
- No assimilation of (T,S), SST & altimetry on ice covered areas.

Last release in April 2013; Next release October 2016.

QUID (Quality Control Document, CMEMS) example for GLORYS2V3 *(1992-2013)*

Summary of validation results

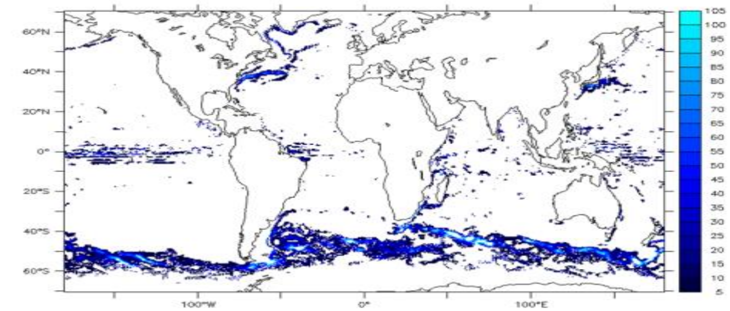




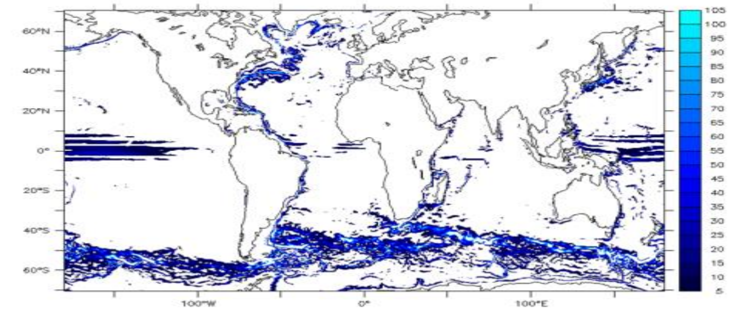
GLORYS2V3 validation results: main strengths

- Close to observations
- Realistic ocean and sea ice variability in most regions
- Ocean currents, EKE
- Daily outputs available

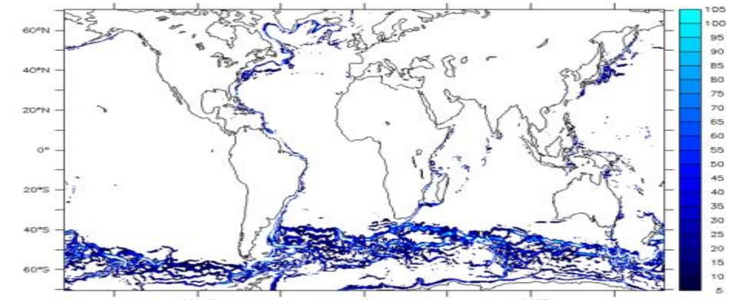
Mean Kinetic Energy at 1000m depth in $cm^2.s^{-2}$



Argo floats



GLORYS2V3

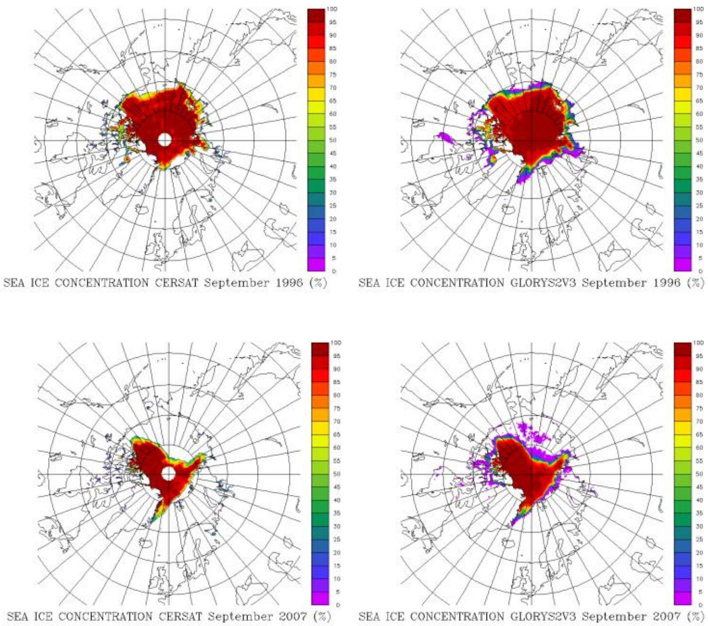


Control run

Arctic Sea Ice concentration for September 1996 (top), and September 2007 (bottom)

September 1996

September 2007

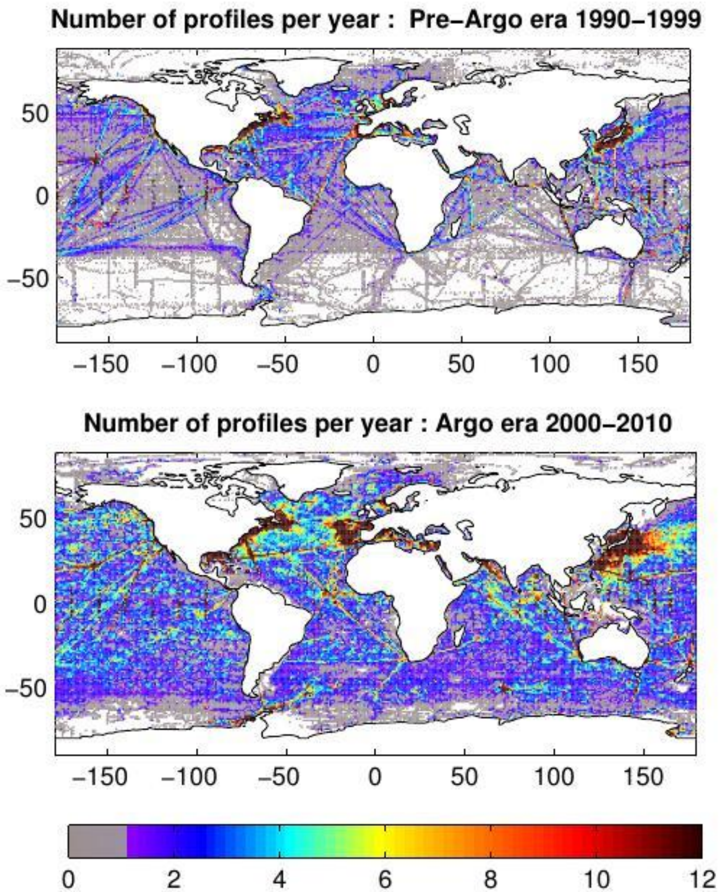


Observations

GLORYS2V3 validation results: main weaknesses

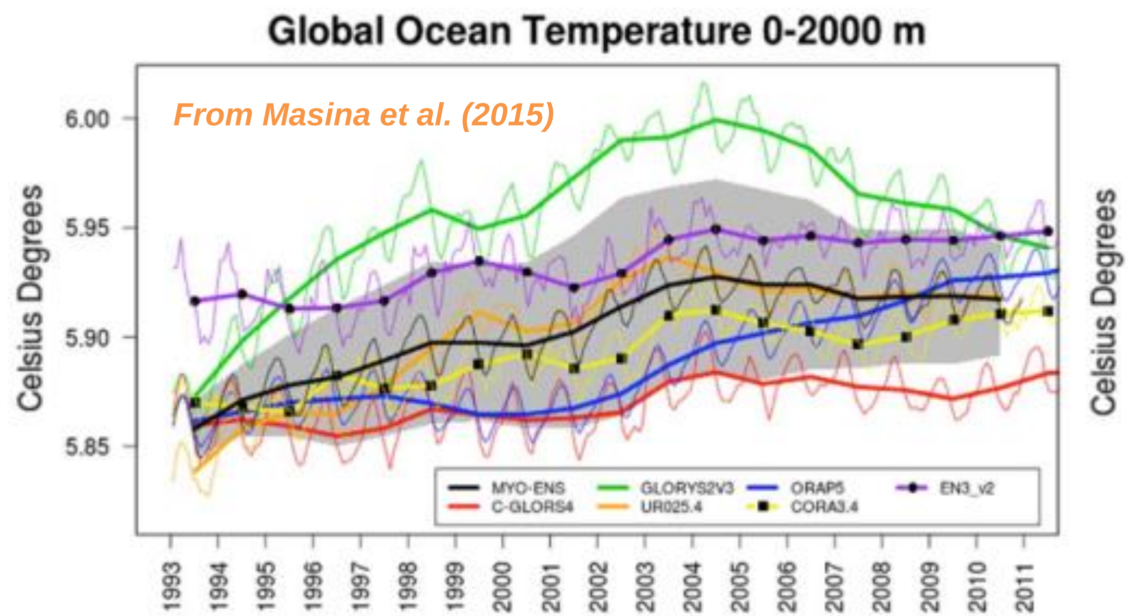
Initialisation in 1992 -> first decade is poorly observed

From Cabanes et al. (2013)

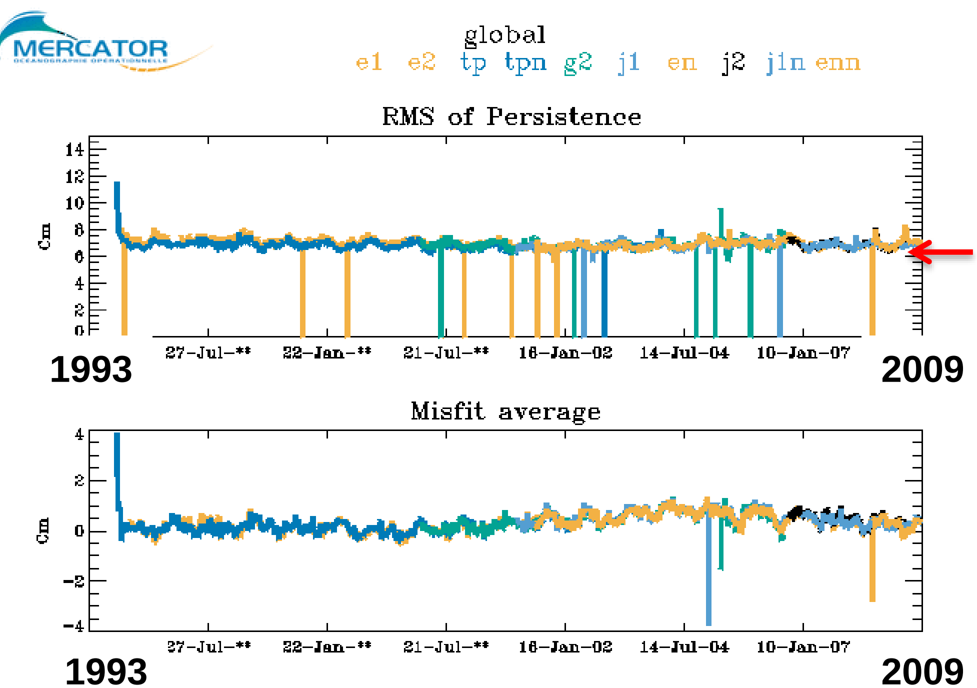


Large uncertainties on mass fluxes, MDT, heat fluxes:

With no specific constraints on salinity or flux corrections, drifts appear in less observed regions (including under 700m)

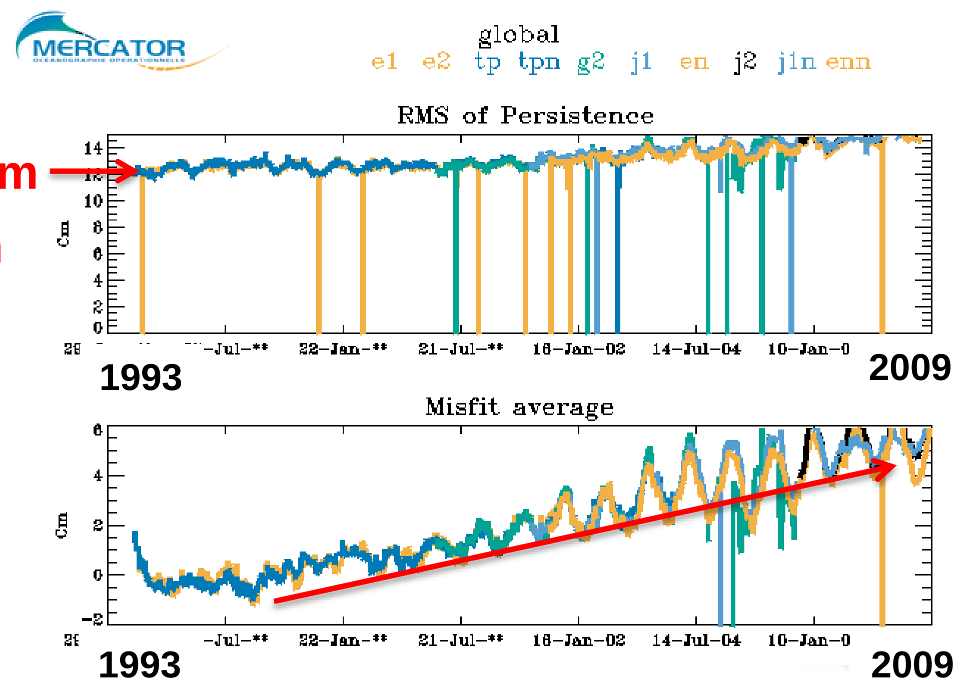


Comparaison à l'altimetrie



12 cm

7cm

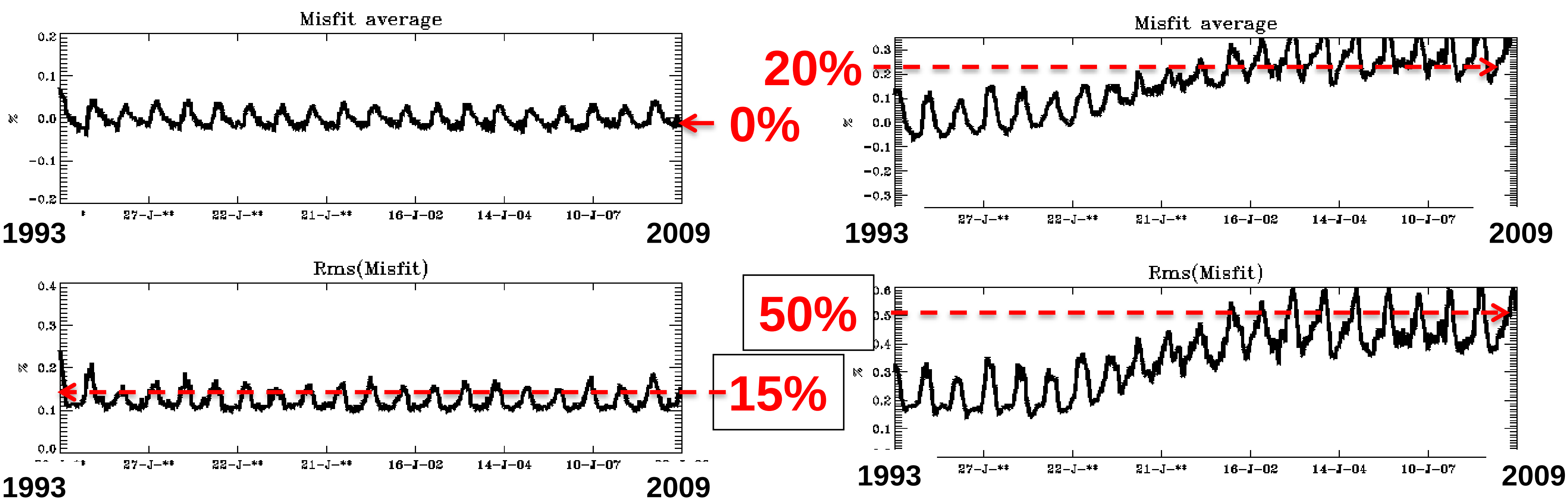


G2V3

Run de contrôle

Le run de contrôle dérive: 5 cm en 20 ans

Concentration de la glace de mer



G2V3

Antarctic

Run de contrôle

Le run de contrôle dérive en Antarctique: pas assez de glace

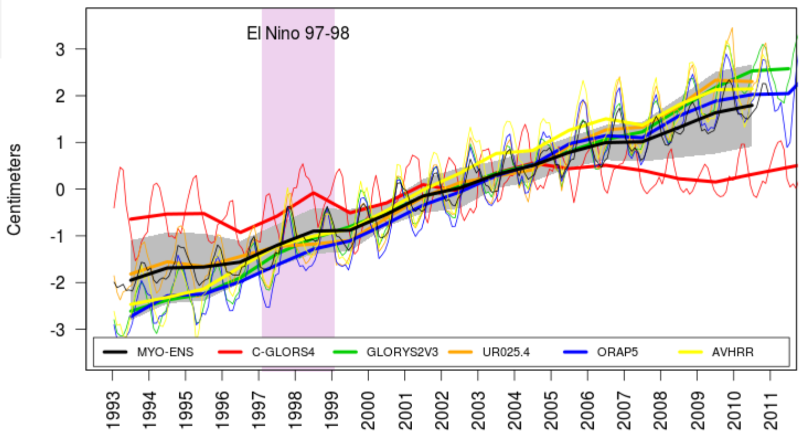
Estimations à partir de plusieurs réanalyses

MERCATOR OCEAN

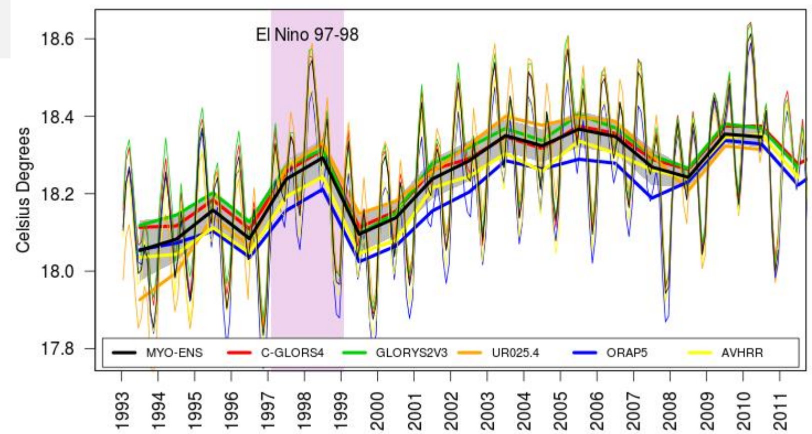
Intercomparison of MyOcean2 global reanalysis products

4 réanalyses globales

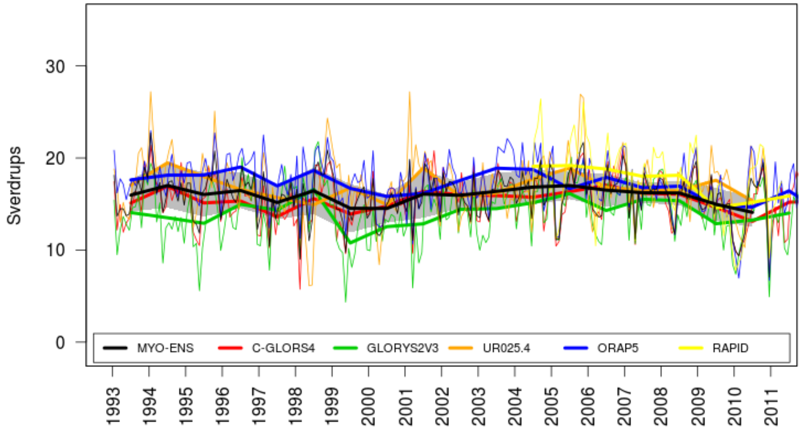
Global Sea Surface Height



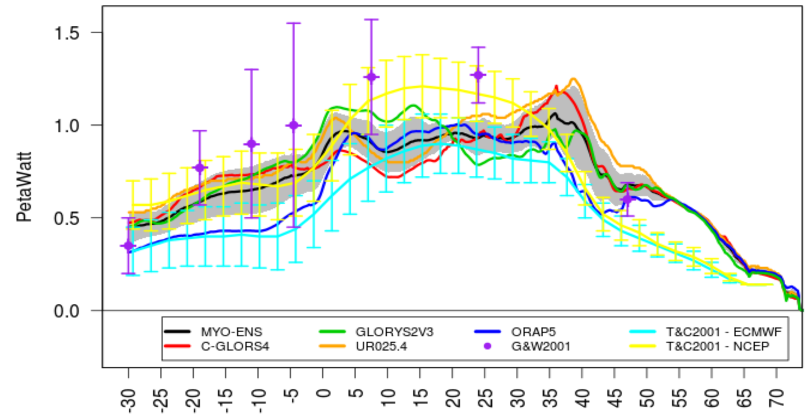
Global Sea Surface Temperature



Atlantic Meridional Overturning Circulation Maximum of Meridional Streamfunction at 26N



Meridional Heat Transport Atlantic Ocean

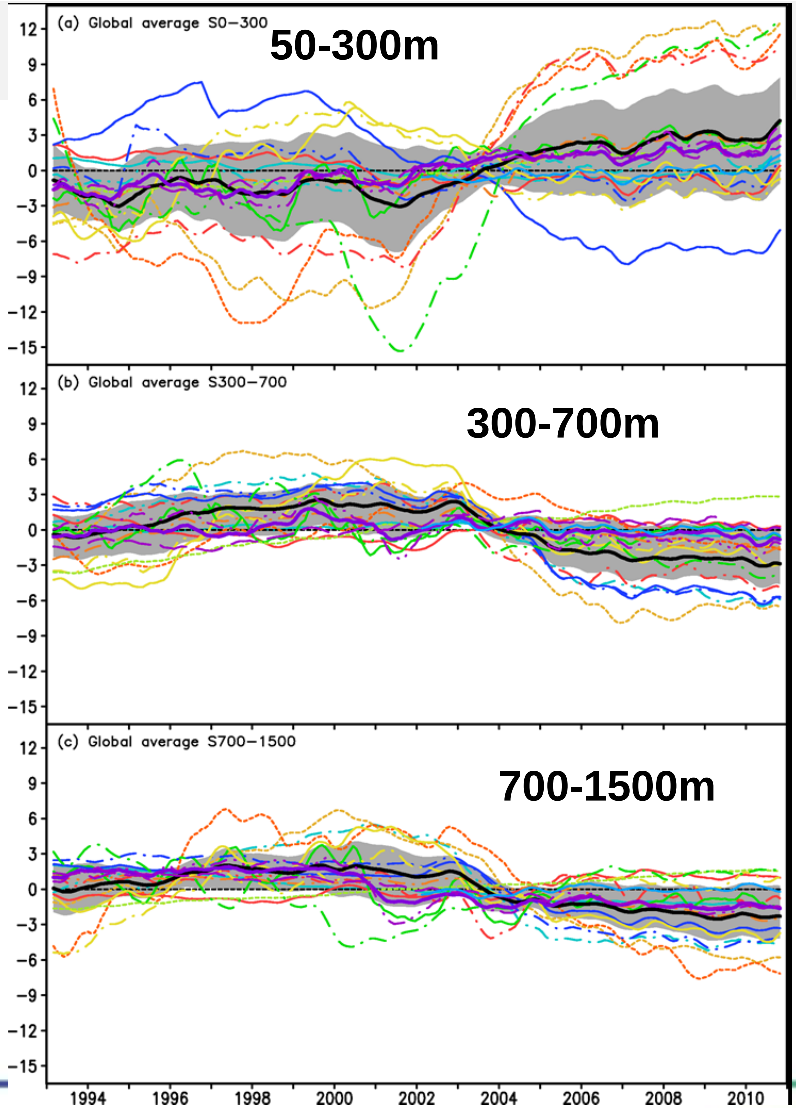


Masina et al , 2015

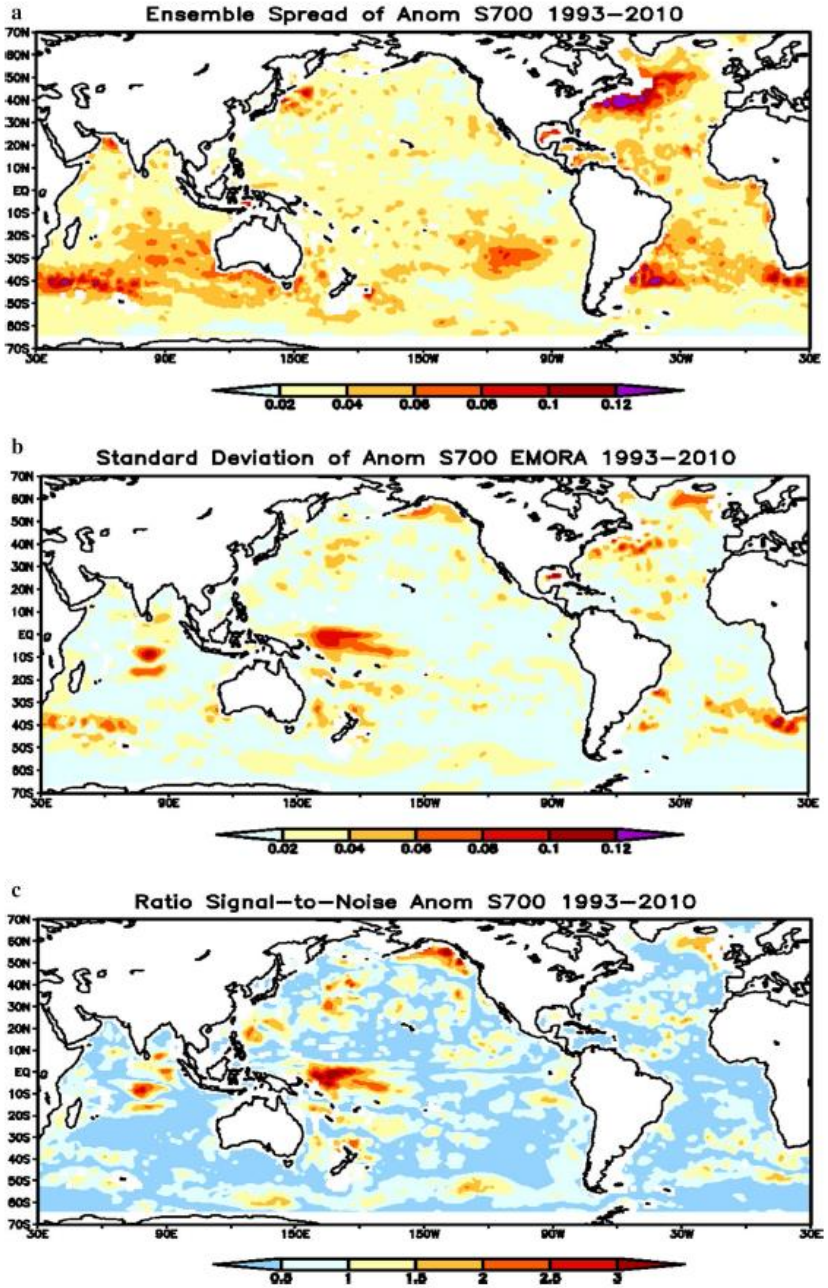
Estimations à partir de plusieurs réanalyses

MERCATOR OCEAN

Incertitude sur la salinité



14 réanalyses globales



Shi et al. (2015)

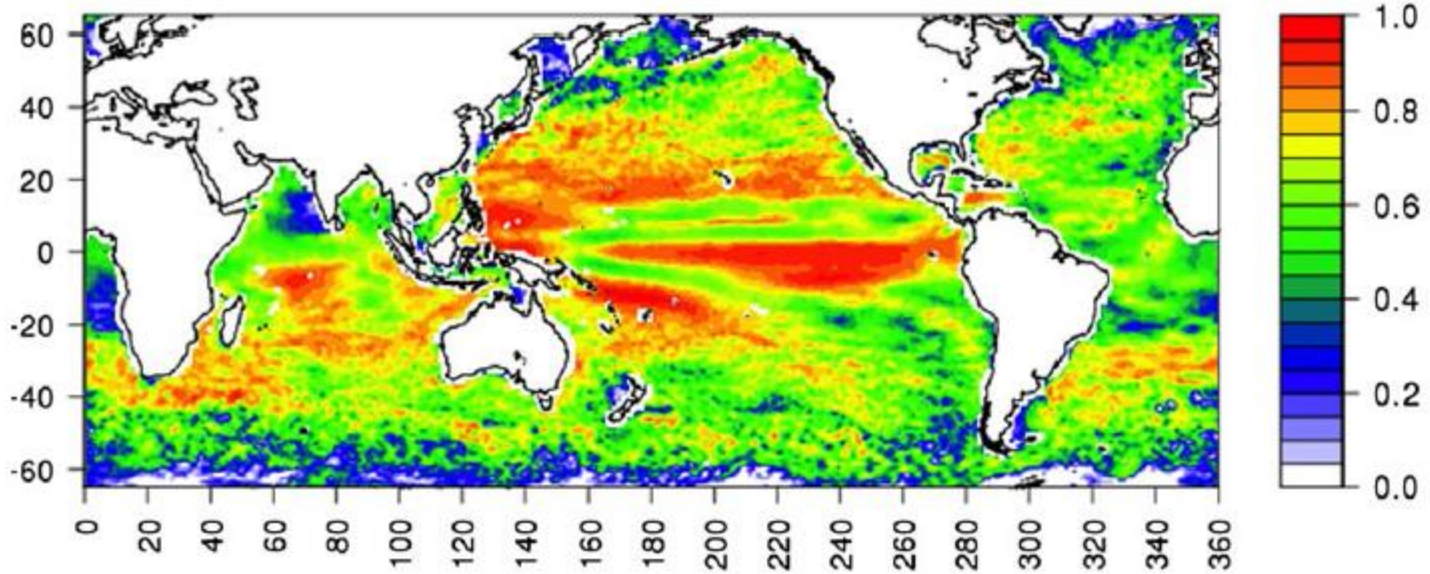
Estimations à partir de plusieurs réanalyses

Incertitudes sur le niveau de la mer

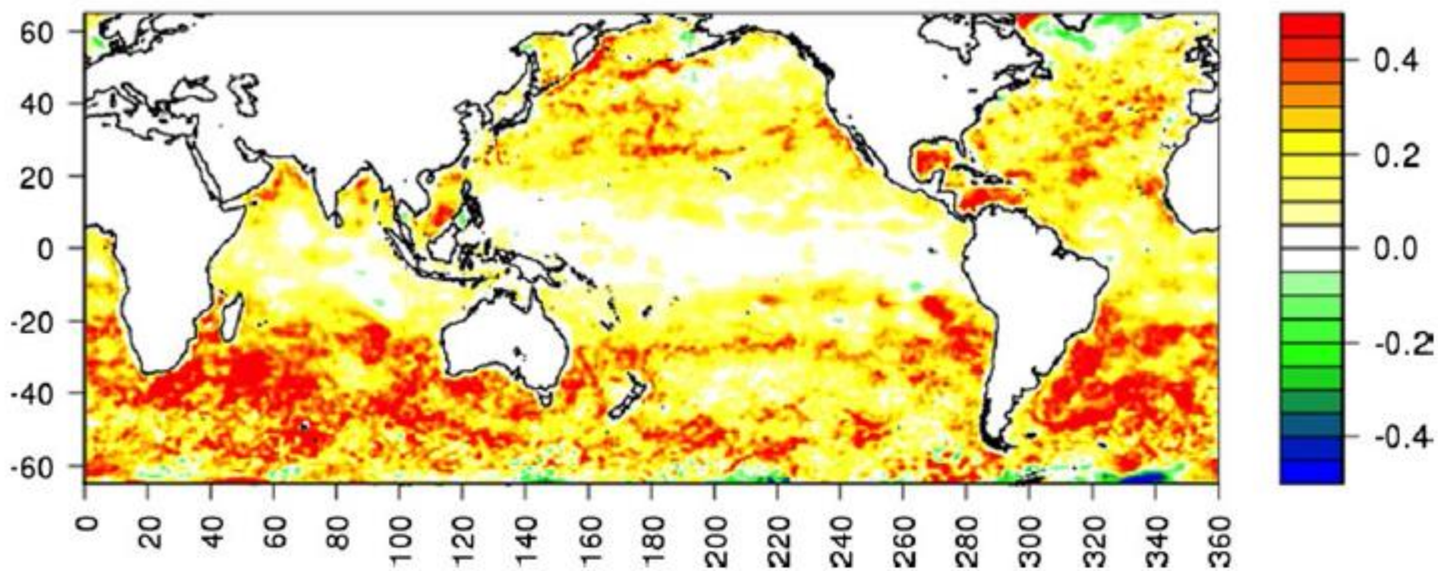
Composante stérique du niveau de la mer

- Référence : Estimation de la composante stérique du niveau de la mer à partir des observations altimétrique et gravimetrique
- 1 ensemble à partir de 16 produits de réanalyses (REAENS)
- 1 ensemble à partir de 4 produits d'observation (OAENS)

Correlation REF/REAENS



DIFF REAENS/OAENS



Storto et al. (2015)

Global Biogeochemistry reanalysis

MERCATOR OCEAN

Physical CONFIGURATION

NEMO 3.1, ORCA ¼°, 75 vertical levels, period: 1993– real time,

Start from rest and Levitus 98 climatology.

Sea Ice model LIM2-EVP,

Atmospheric forcing from ERAinterim, 3h frequency, CORE bulk formulae.

Simulation with and without data assimilation in the physics (along track altimetry, SST maps, in situ T/S profiles).

Biogeochemical CONFIGURATION

NEMO 3.2, PISCES, ¼°, 75 vertical levels, period 1993– real time,

Initial condition : WOA 2001 for NO3, PO4, Si, O2; GLODAP for Alkalinity and DIC; Iron and DOC from low resolution simulation (ORCA2 3000 ans) ; 16 constants,

Antropic part take into account for DIC

Output: weekly means

Coupling

Offline

1 day frequency for the physics

Specific treatment for vertical mixing : threshold (10^{-2} $m^2.s^{-1}$) and mean of log10(Kz)

Seasonnal cycle in the North Atlantic

Interannual simulation

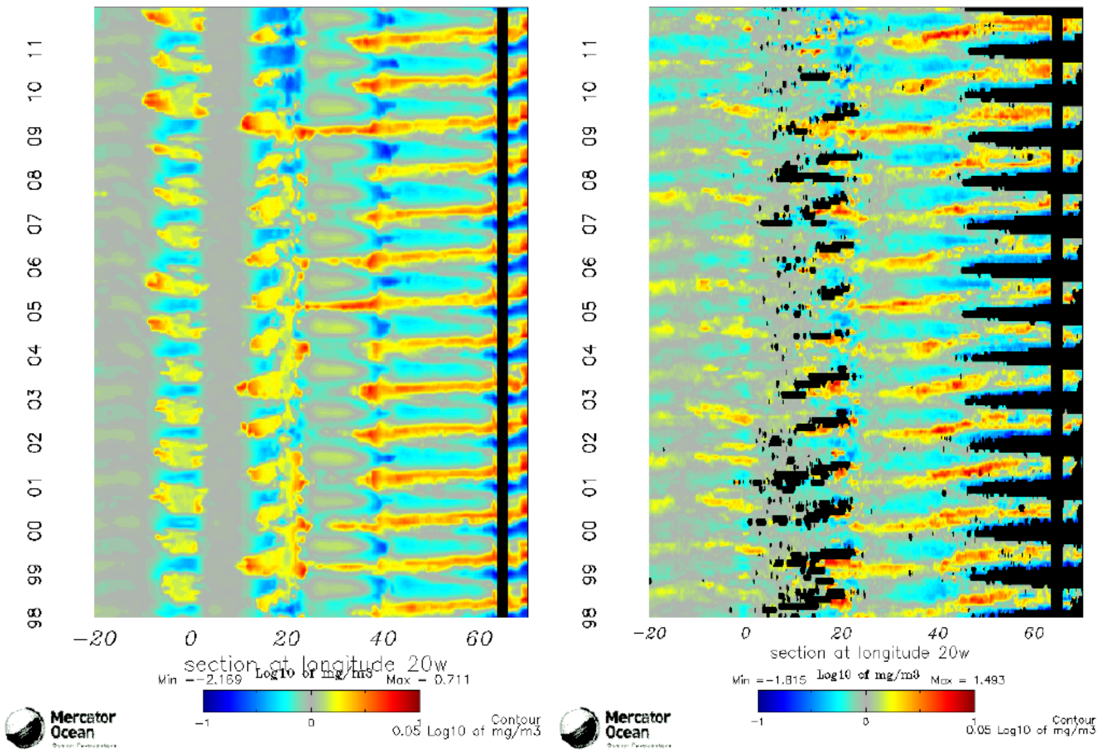
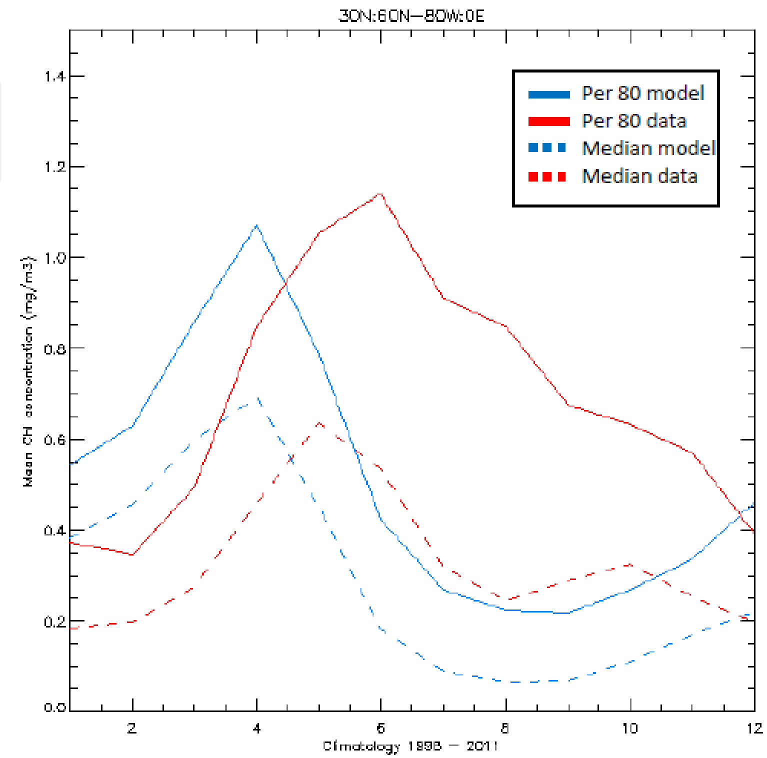


Figure 4: Hovmöller diagram of the chlorophyll anomaly (Log10(monthly mean) – Log10(mean over the whole period)) between 1998 and 2011 at 20°W in North Atlantic (20°S:70°N) . (left) model; (right) Globcolour data.

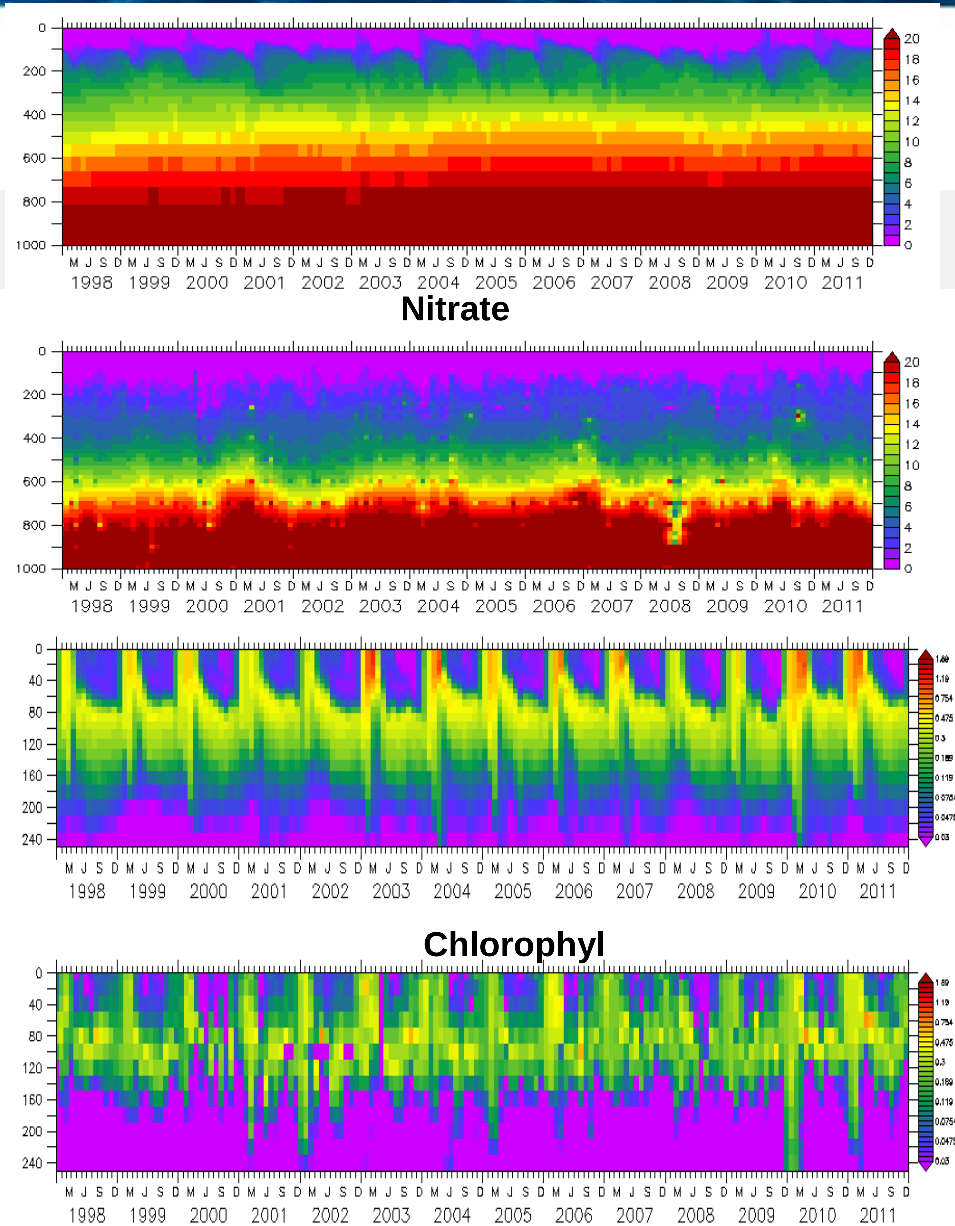


Good representation of the seasonnal cycle : bloom in spring and second event in fall.
interannual variability
Concentration during bloom
But the bloom occurs to early in spring

Seasonnal cycle in the North Atlantic

BATS Station

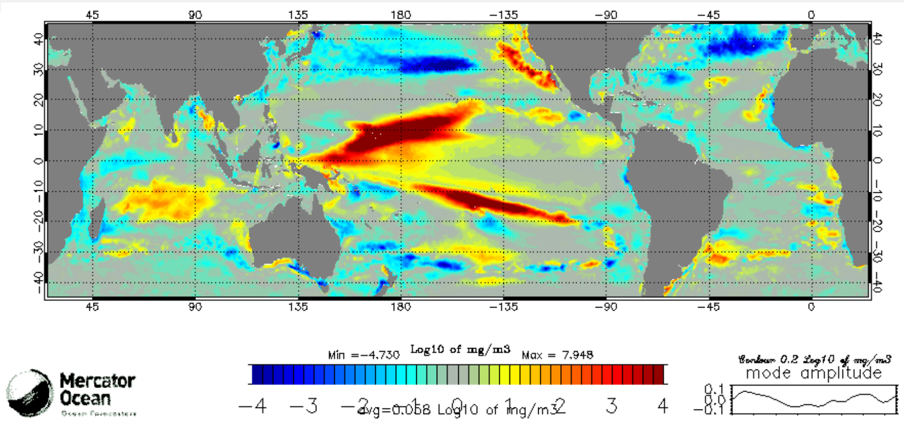
Nitracline too diffuse and not deep enough → spring bloom in the model is more driven by light penetration than by nutrient limitation.

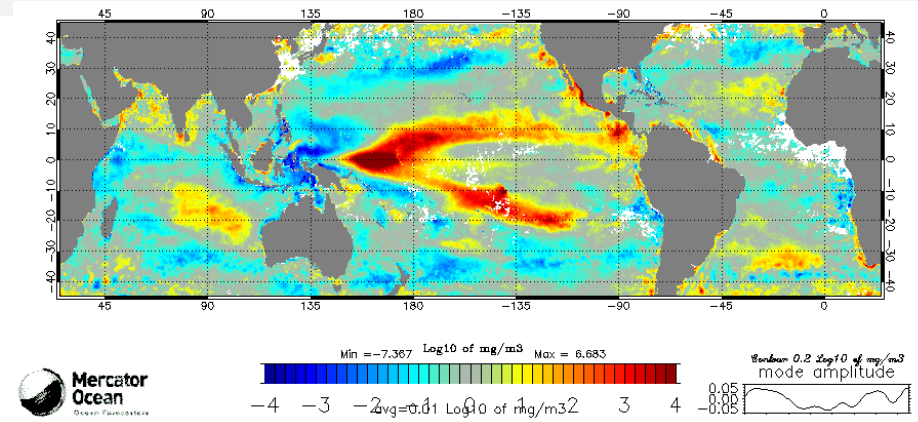


Interannual variability

EOF analysis : good representation of the 2 first modes

Mode #1

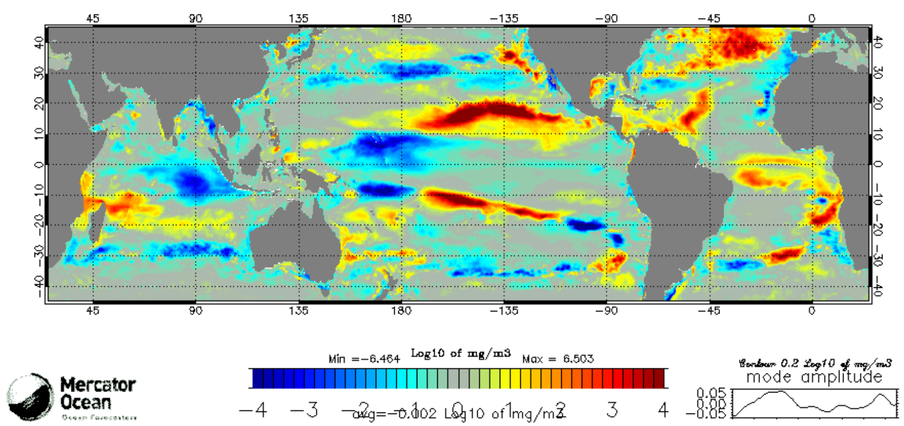


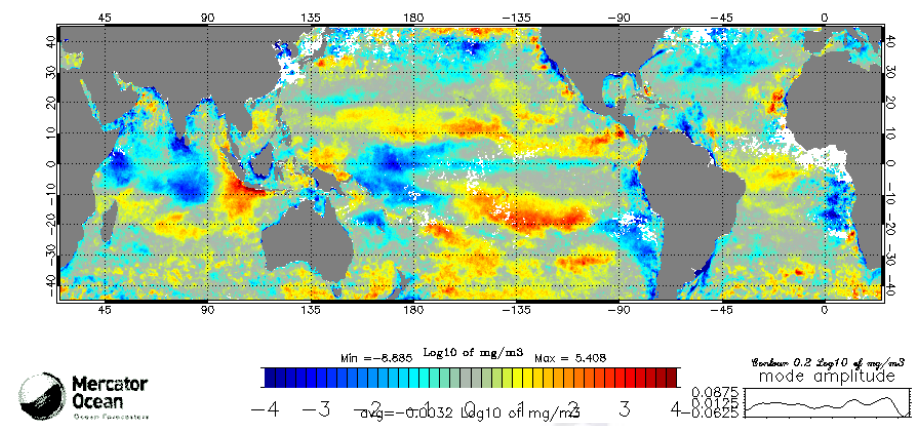


Model

Observations

Mode #2

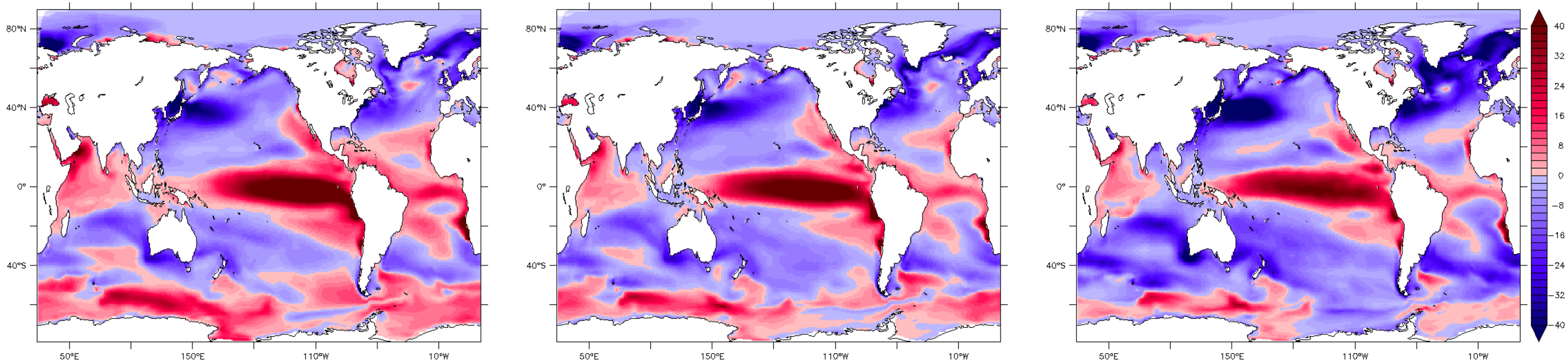




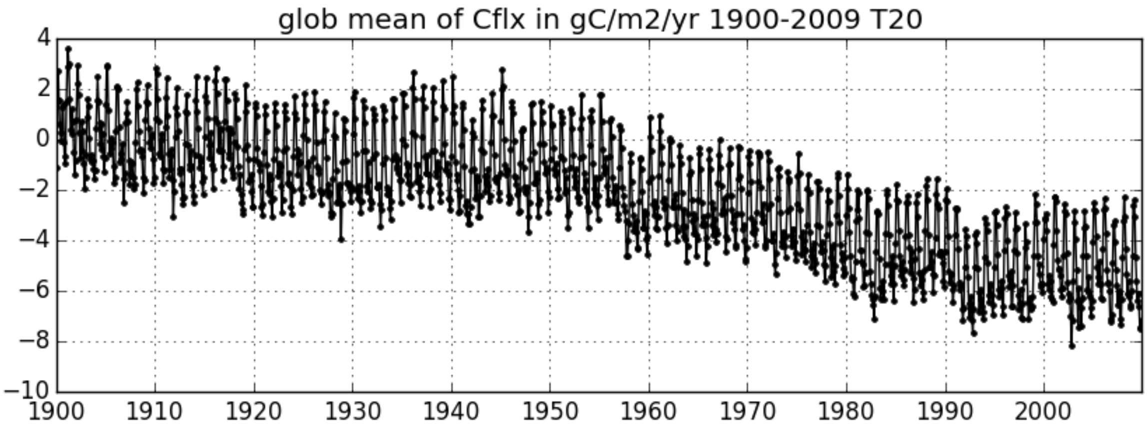
ERACLIM2 : Ocean biogeochimie

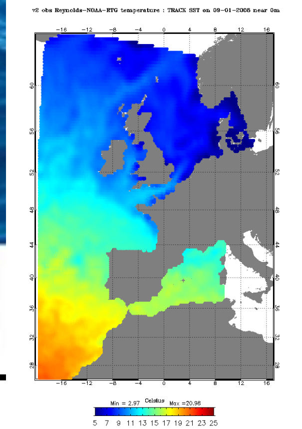
110 ans de simulation ORCA1_LIM3_PISCES forcé par ERA-20C

1900 **1950** **2000**



C flux T20 y190





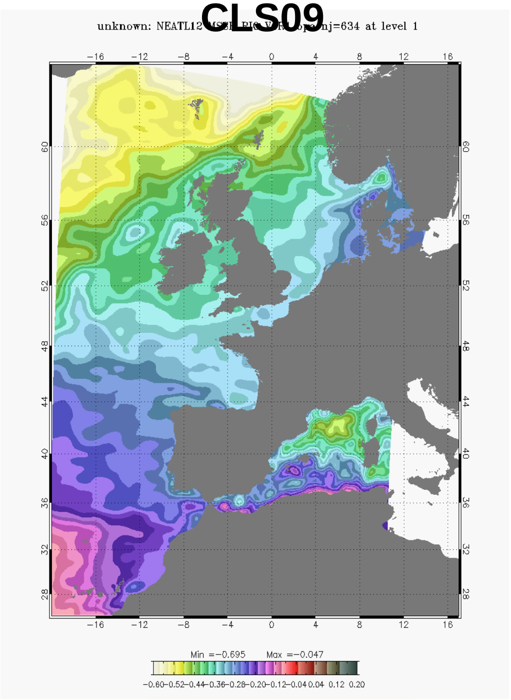
IBIRYS

	Reanalysis IBI V1 (2002-2014)
NEMO version	2.3
Horizontal resolution	1/12° (5-6 km)
Vertical coord.	z*=f(ssh) 75 levels Partial bottom cells
Bathymetry	Composite (GEBCO_08 + different local databases)
Free surface	Explicit, non-linear, time-splitting
Open boundary data	From daily 1/4° GLORYS2V3
Vertical mixing	k-epsilon
Tracer advection	QUICKEST + ZALEZAK
Rivers	As lateral point sources Merge of daily SMHI & PREVIMER & Monthly climatology (GRDC), 35 rivers
Atm. forcing	ECMWF ERA INTERIM (3h) + analytic diurnal cycle from daily short wave irradiance
Surge capability	Yes
Tides	Yes (11 tidal components, astro pot)
Ocean color effects	Merged SEAWIF/IFREMER kpar climatology
IC & OBCs	GLORYS2V3 ¼°
Data Assimilation	SAM2 (SEEK Filter) + IAU

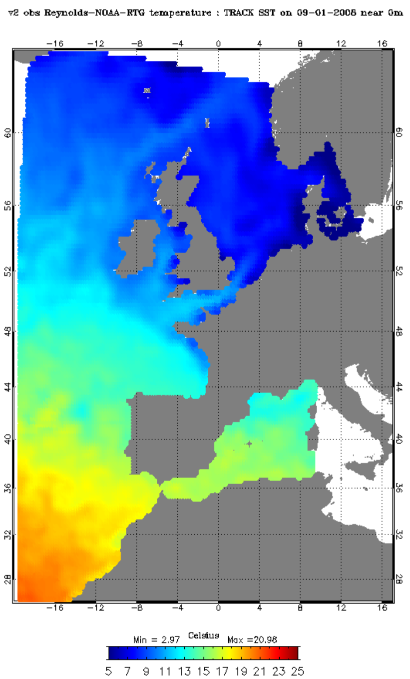
Assimilation obs. data

- Along track altimeter data **(AVISO ALTO/DUACS):** Jason1, Envisat and GFO
- In situ profiles Temperature and Salinity **(provided by CORIOLIS including ARGO)**
- Sea Surface Temperature : **AVHRR_SST (1/4° x 1/4°)**
- MADT : CNES_CLS09 *(Rio et al, CLS 2009)*

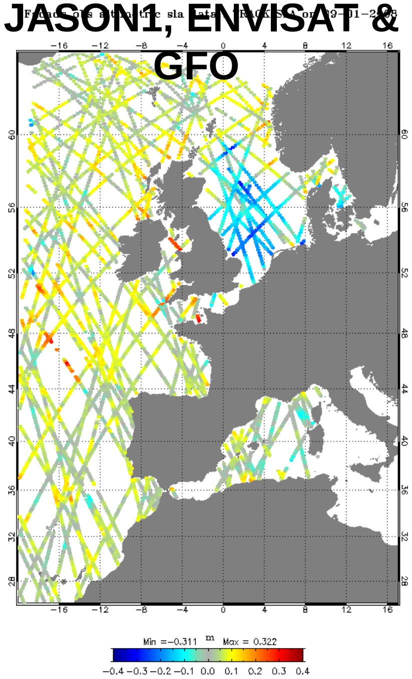
MDT_CNES-CLS09



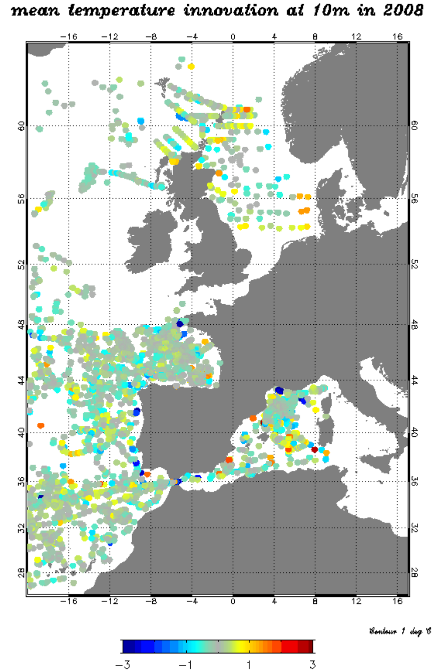
AVHRR _SST



SLA coverage for a week JASON1, ENVISAT & GFO



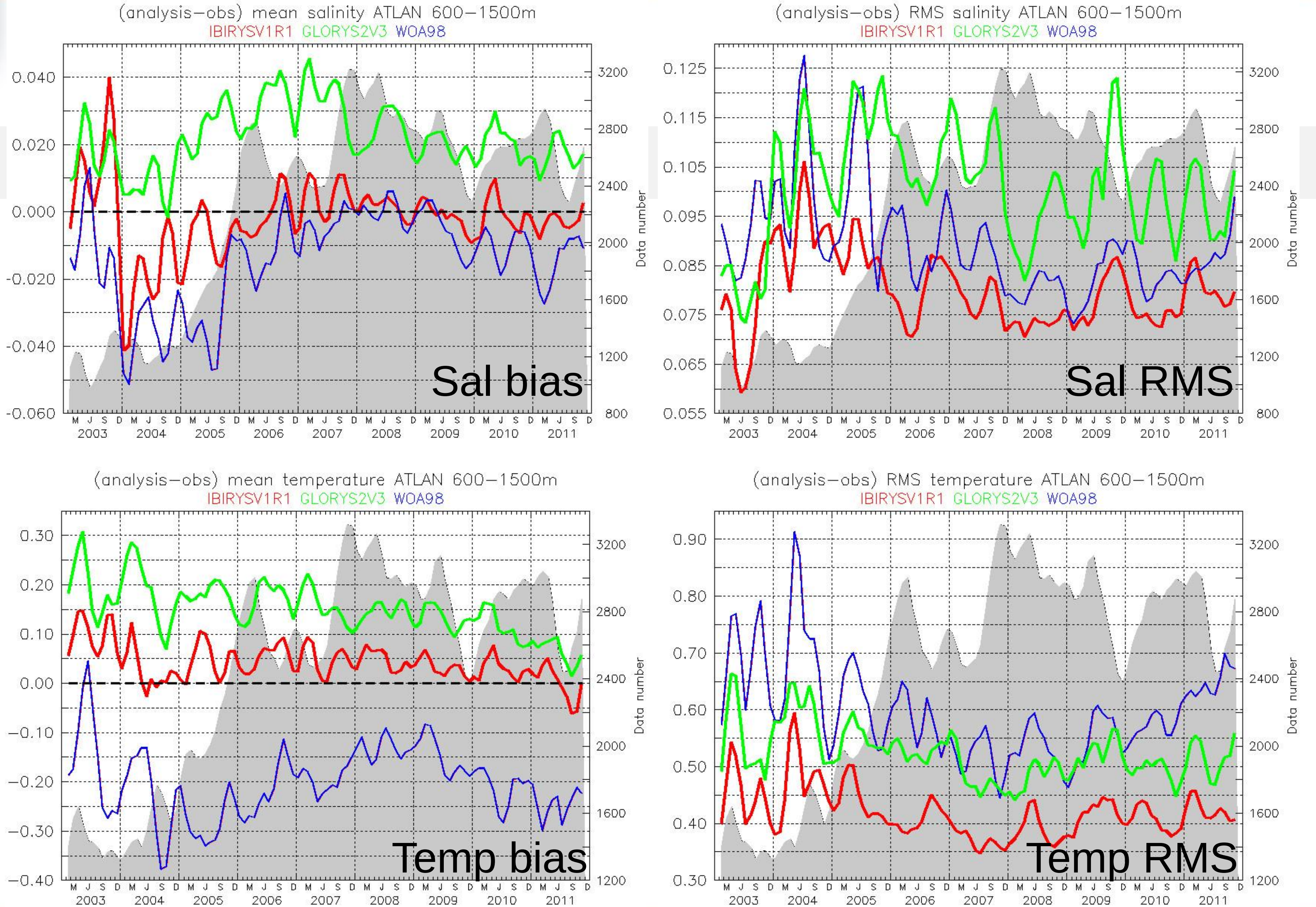
In situ TS- profiles 2008



CLASS4-LAYER

600-1500m layer Atlantic region

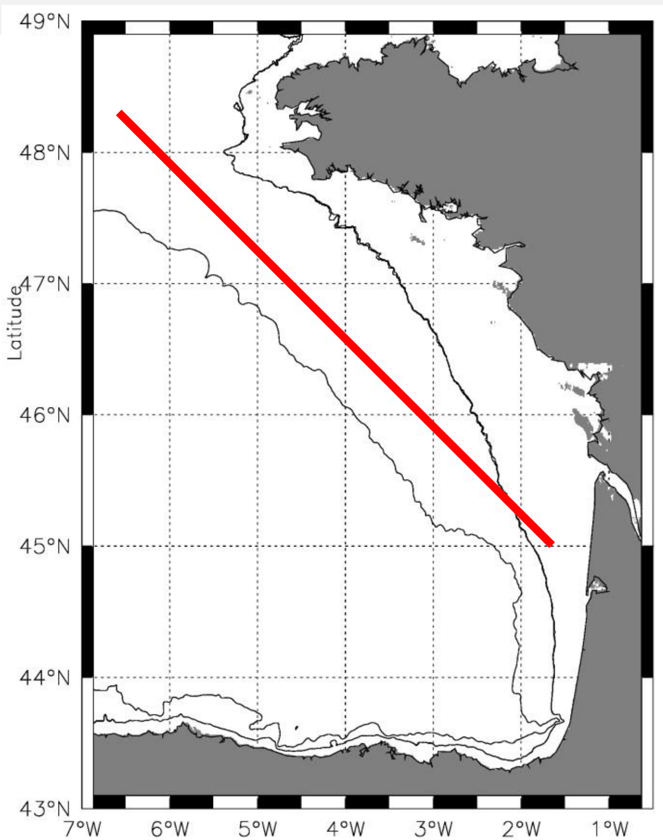
In-situ obs: CORA database

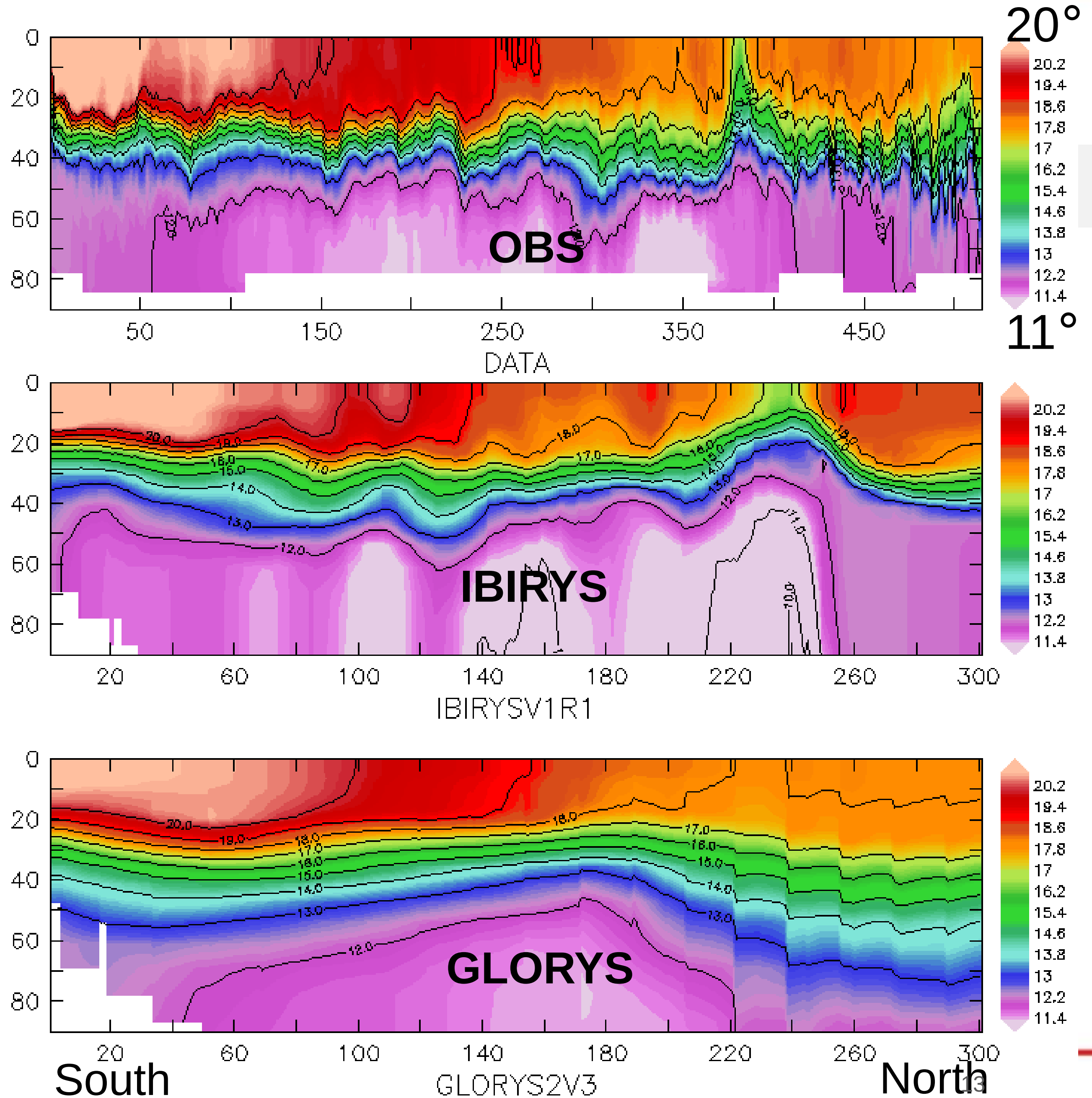


IBIRYS
GLORYS
WOA09

Bay of Biscay summer thermocline

Temperature section (ASPEX G)
September 2010





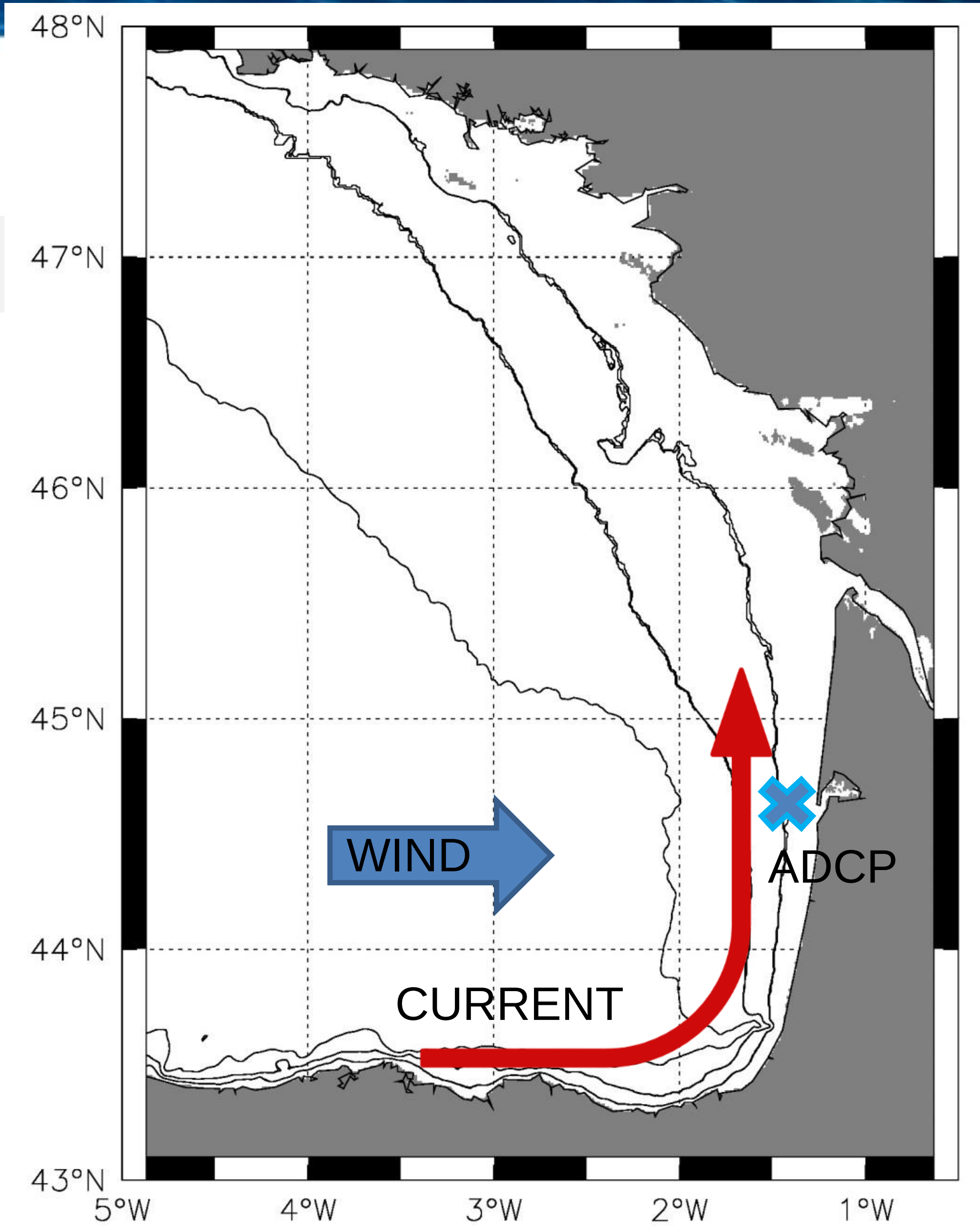
ASPEX cruise,
Le Boyer *et al* (2013)

Bay of Biscay coastal jet (1)

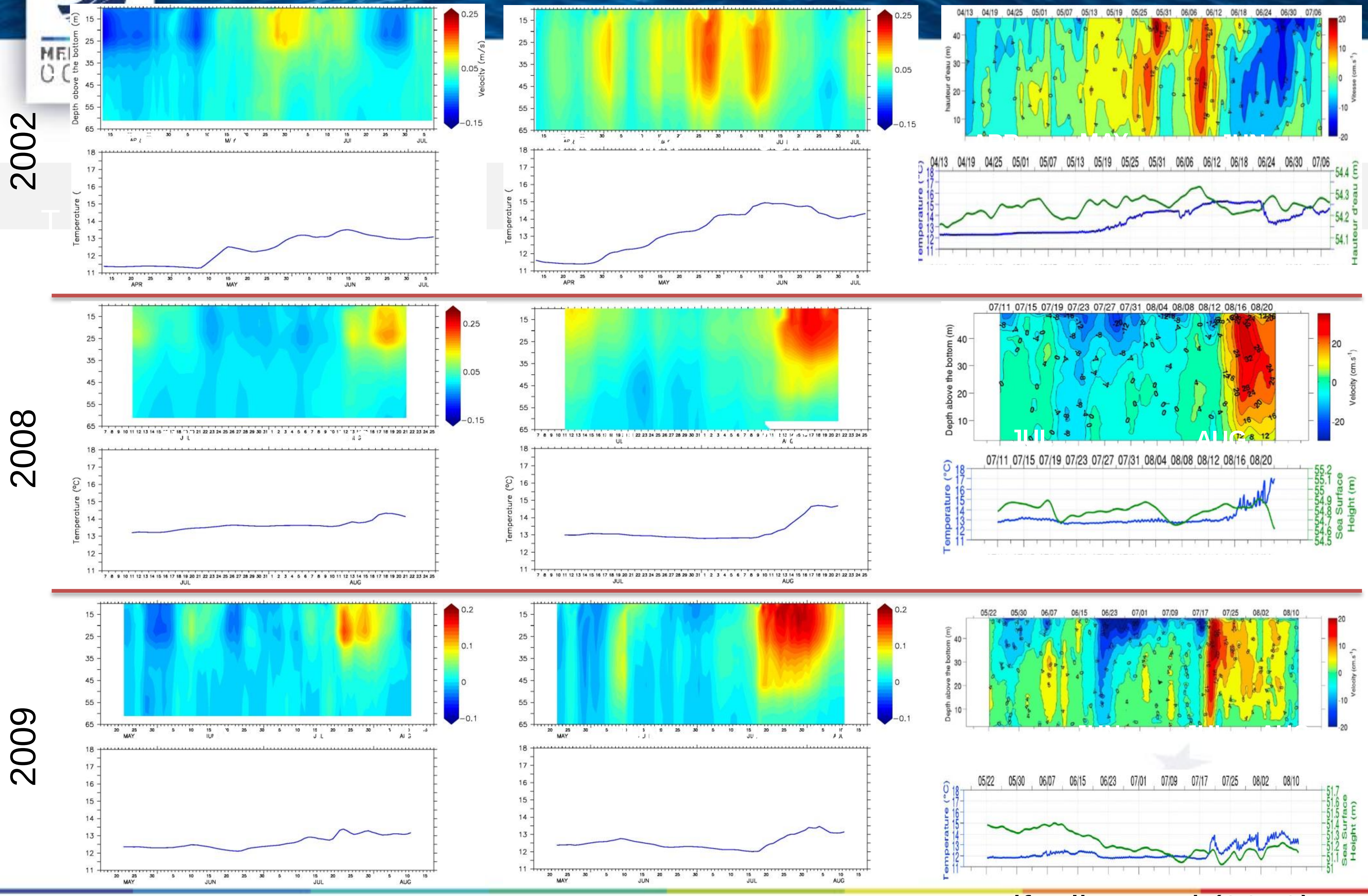
Batifoulier et al (2012):

Observations of poleward costal jets along the Aquitaine shelf, associated with increase of the bottom temperature.

The triggering mechanism is due to downwelling situation along the Spanish coast induced by westerlies winds.



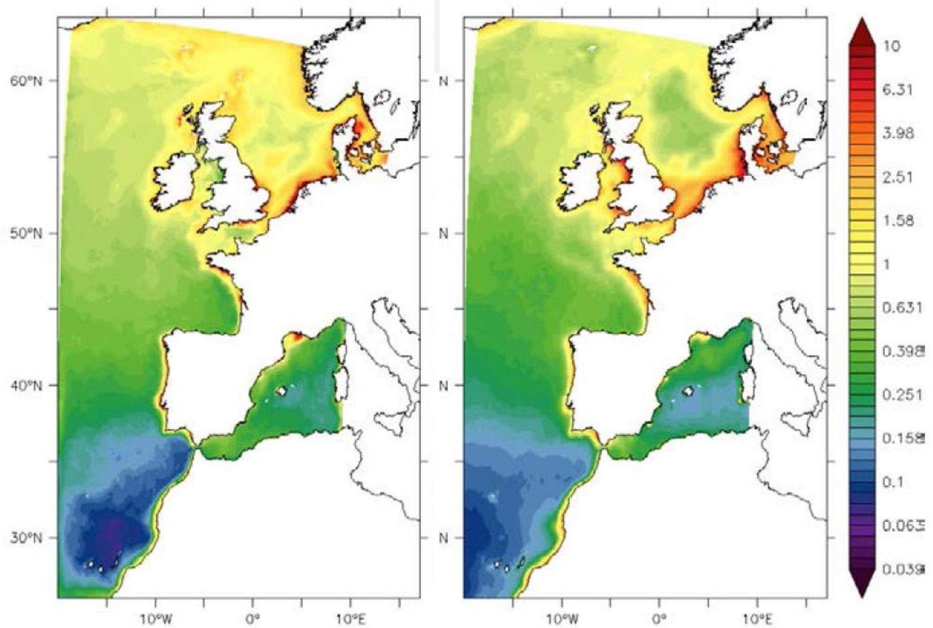
Bay of Biscay coastal jet (2)



Côtes Européennes
Simulation interannuelle au 1/12°

Chlorophylle-a (mg Chl m^{-3})

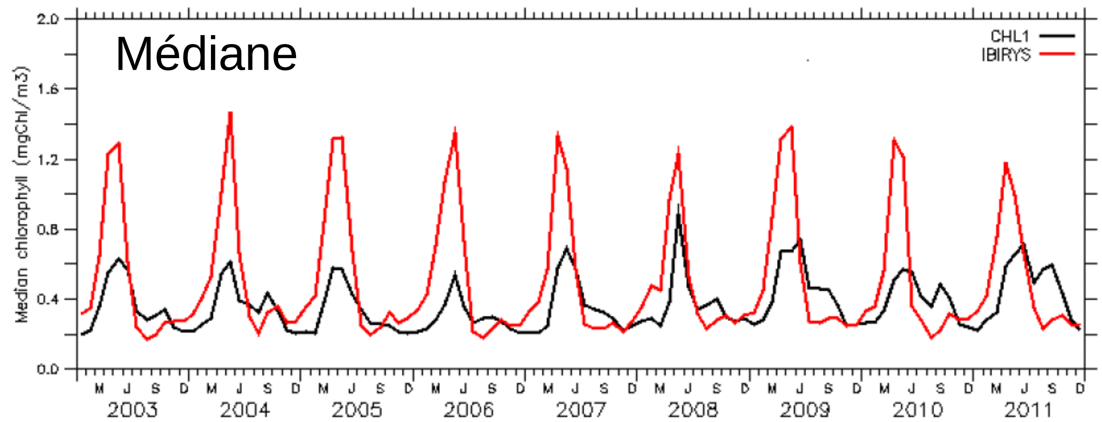
moyenne sur 2003-2011

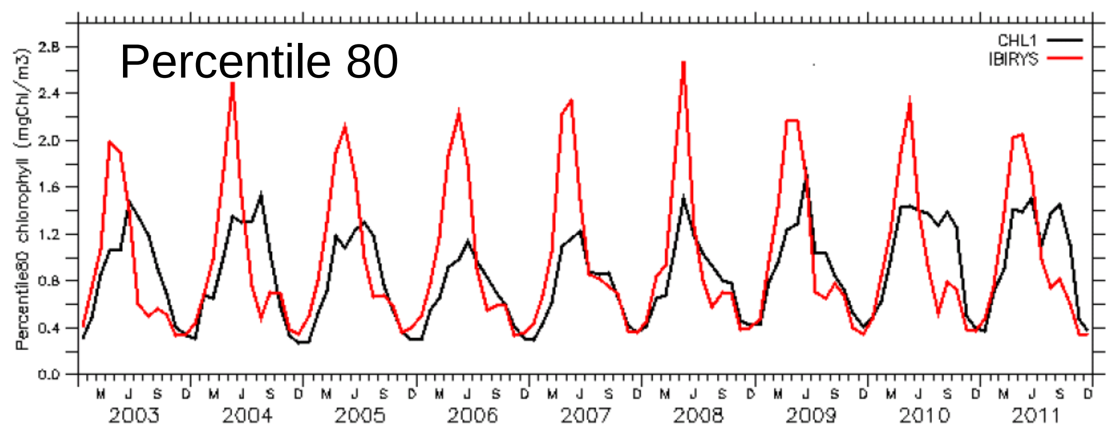


Modèle **GlobColour**

Série temporelle

GlobColour —
Modèle —





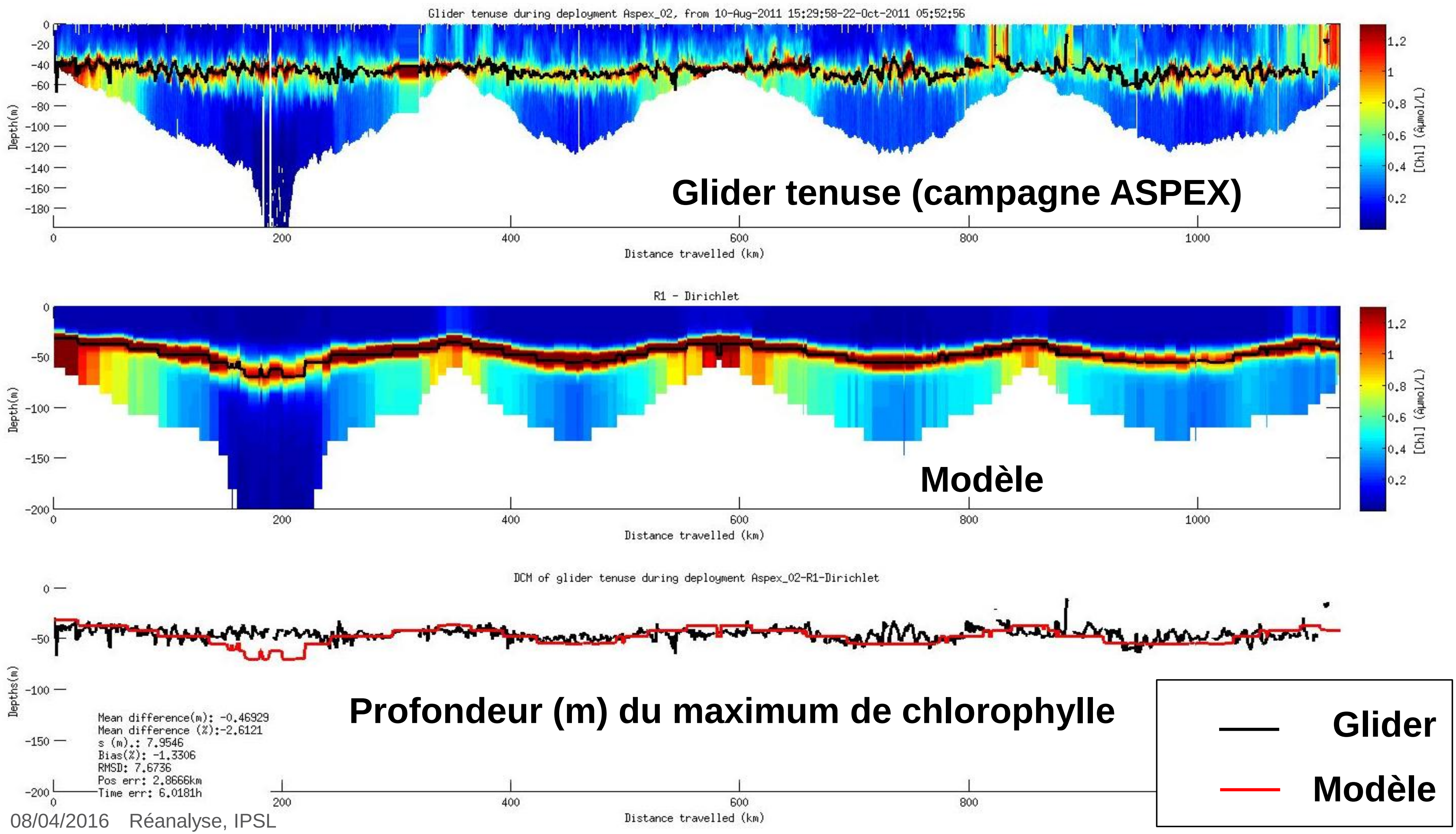
80% des [chloro] < percentile 80.
Cette métrique exclue les valeurs extrêmes

Côtes Européennes
Simulation interannuelle au 1/12°

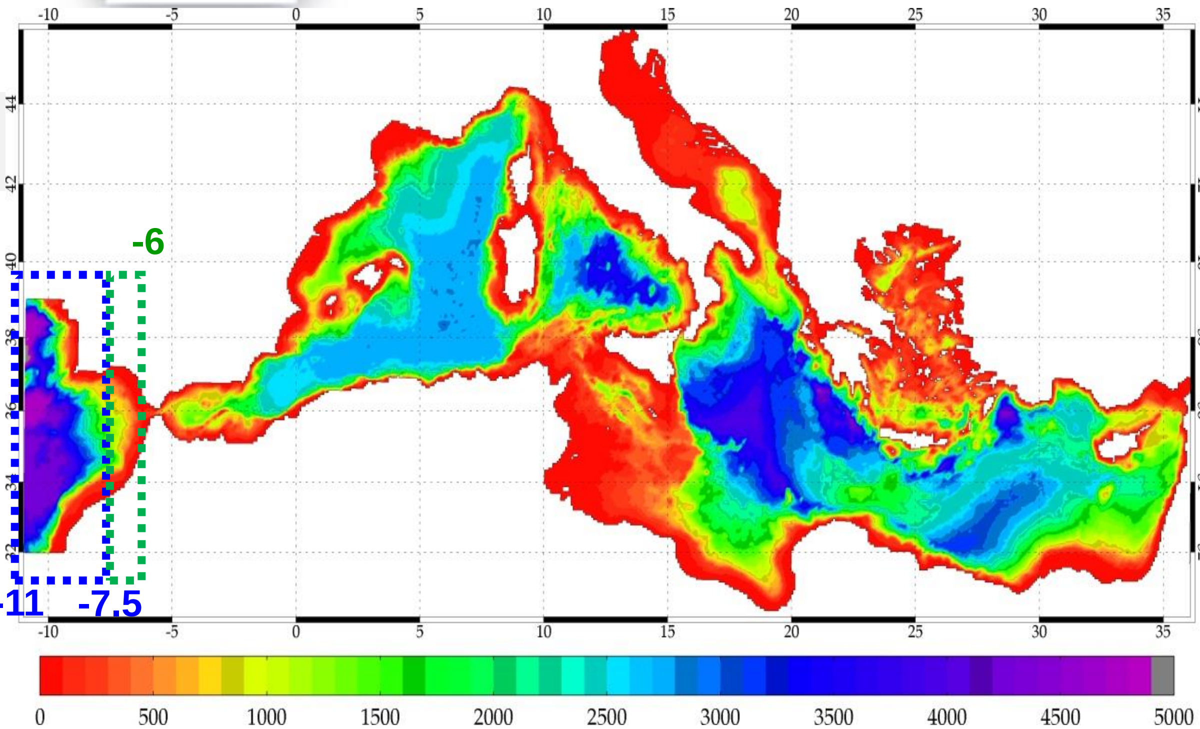
Projet AMICO-BIO (analyse d'Oliver Ross)

Simulation libre:
Pas d'assimilation des champs physiques

Chlorophylle-a (mg Chl m^{-3}): Distribution verticale.



MEDRYS



Bathymetry (m)

Atlantic buffer zone :
Newtonian dampings <u>to ORAS4 monthly anomalies</u> with following time scales τ :
θ and S (3D) : τ between 2 days -> 90 days
SSH : τ between 1.7 second -> 90 days

- NEMO v3.1 code (Mercator oper version at Météo-France HPC)
- Horizontal grid from ORCA12 at **6-8 km** < Rossby deformation radius ~10-15 km (eq. to a 1/14°-1/18° regular grid)
- Z vertical grid with **75 levels** (1m to 135m thickness)
- New high resolution bathymetry (MERCATOR-LEGOS v10 product at 1/120° resolution)
- **Closed boundary at 11°W**

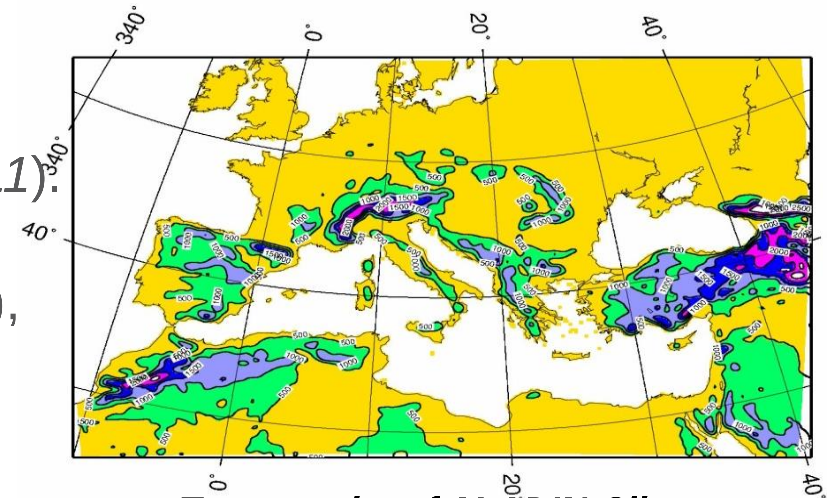
Hamon et al, 2016

Atmospheric forcings, initial and boundary conditions

- Free simulation starting in **October 1979** from Medatlas-1979 (*Rixen et al., 2005*) in the Mediterranean side and from WOA05 (*Levitus et al., 2005*) in the Atlantic side. The reanalysis starts from the state of the free run on the **30th September 1992** (beginning of the altimetry era).

- **12-km** and **3h**-atmospheric **fluxes** from ALDERA (CNRM), dynamical downscaling of the ERA-Interim reanalysis with ALADIN-Climate (*Herrmann et al. 2011*).

  SST retroaction for the free run (*Barnier et al. 1995*), coefficient of -40 W/m²/K (*CLIPPER Project 1999*). The total heat flux of the free run is used for the reanalysis (including the retroaction term).



Topography of ALADIN-Climate

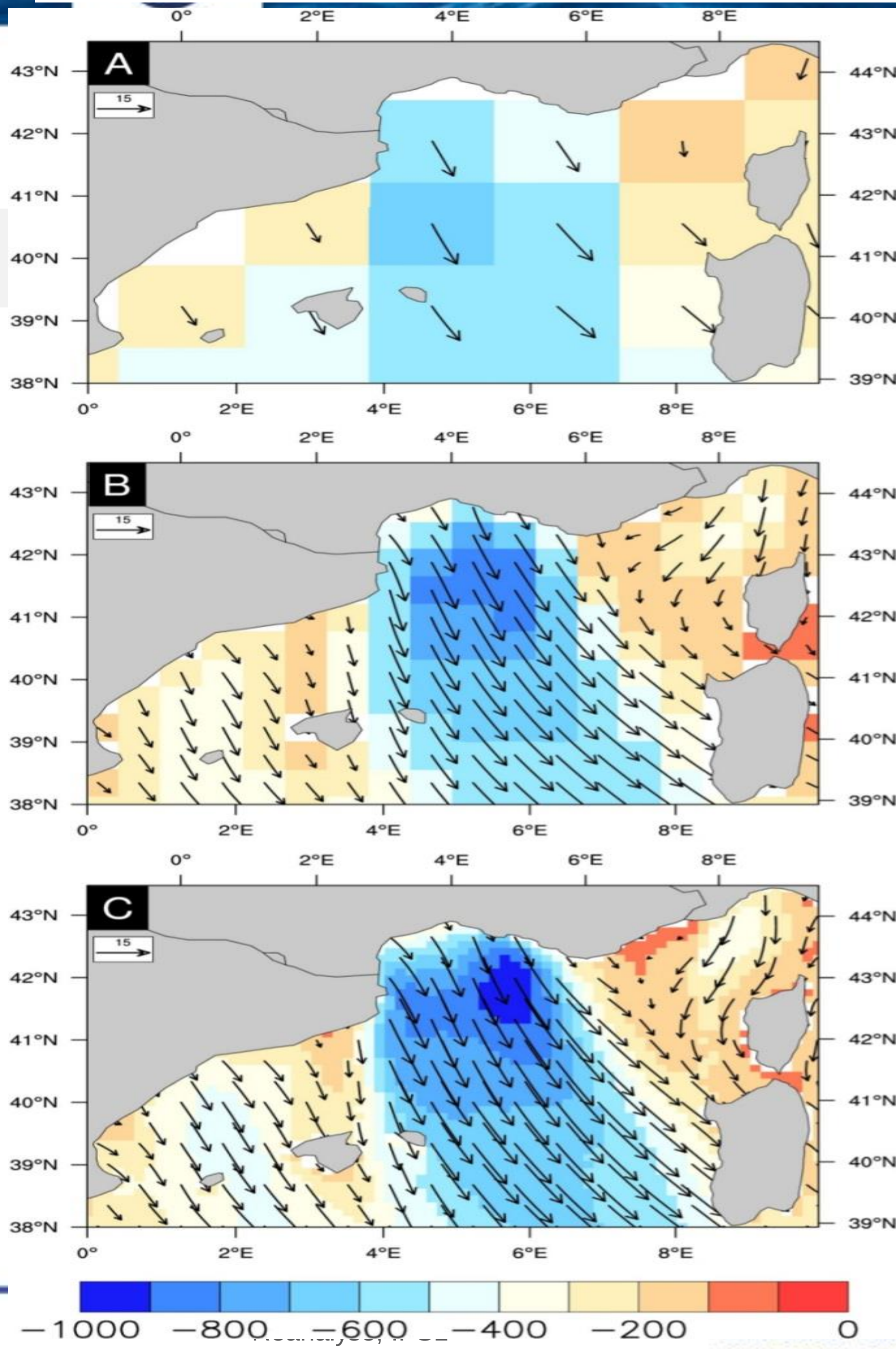
No SSS damping, 2D water flux correction in the water flux.

33 main rivers + Black Sea (**interannual** datasets from *Ludwig et al., 2009* and *Stanev & Peneva, 2002*): freshwater added as precipitation at mouth points + coastal runoff (residual land-surface freshwater budget).

Added value of the high-resolution in ALDERA

Wind and heat flux on the 14th March 2013

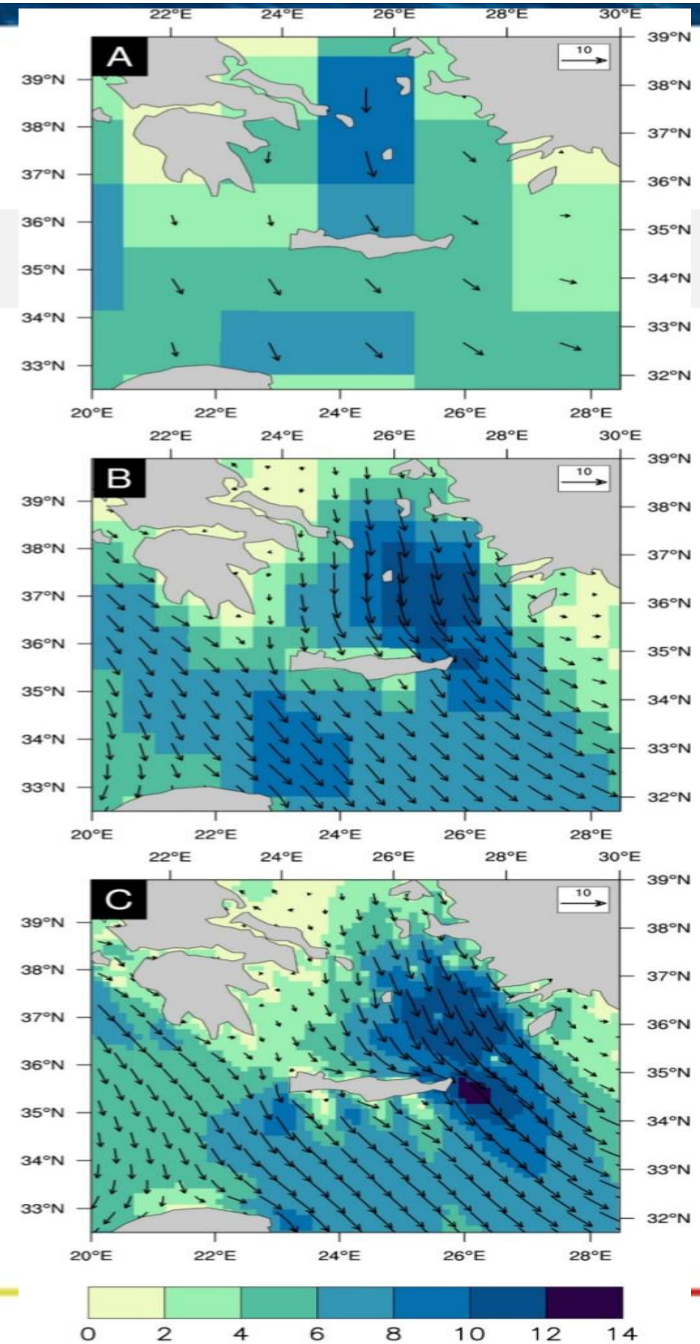
Wind direction and speed on the 16th September 2012



ALADIN-150km

ALADIN-50km

ALADIN-12km (ALDERA)

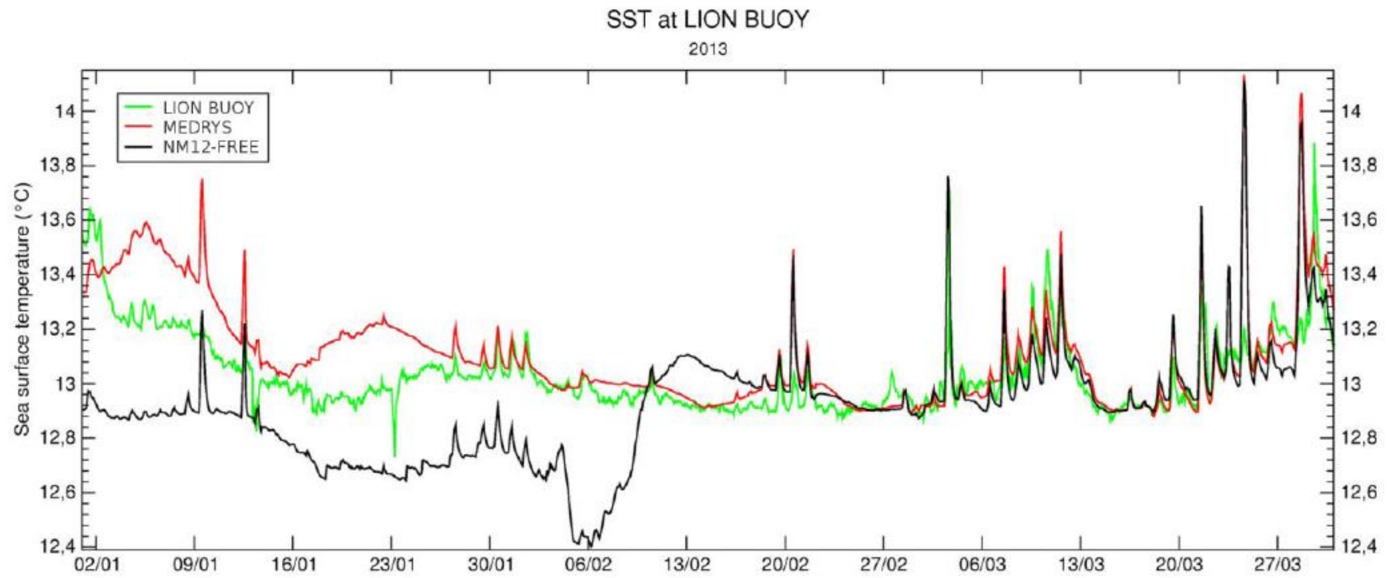


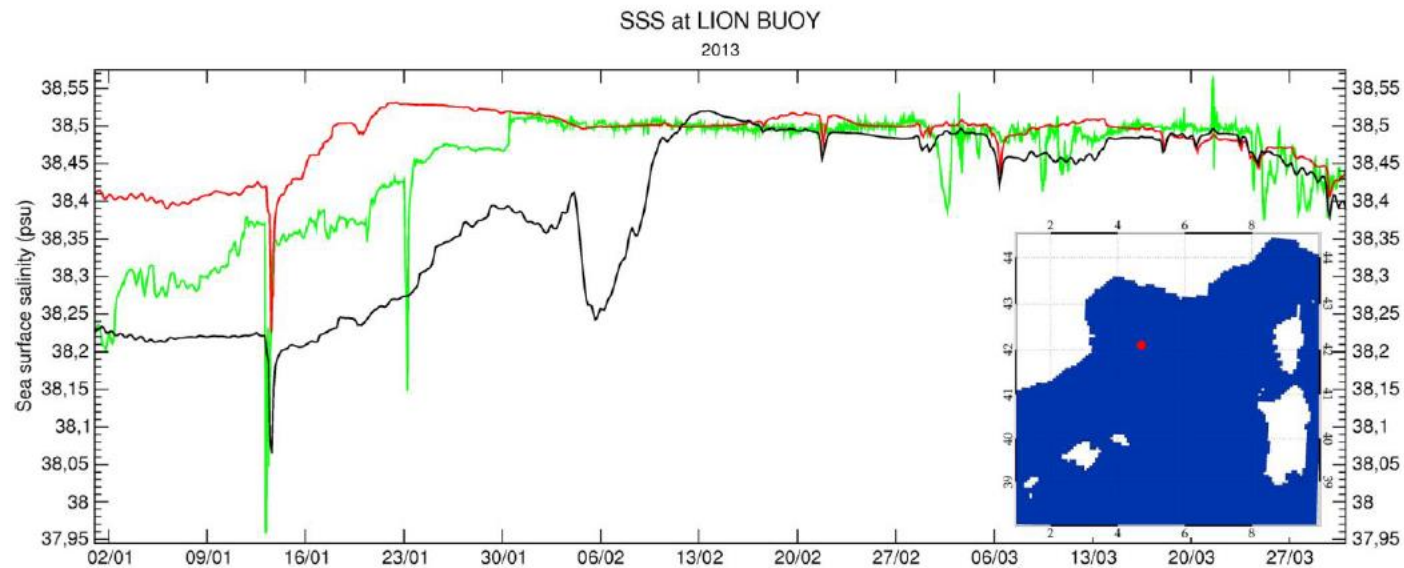
Comparison with observations

- **HyMEX SOP2 period**
- **Comparison with LION buoy**
- **SST and SSS not assimilated**

SST correlation 0.76/0.31

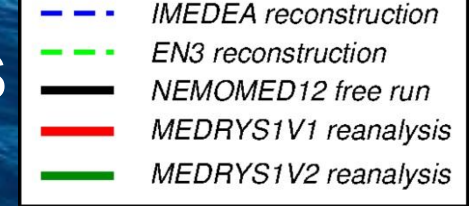
Bias during january



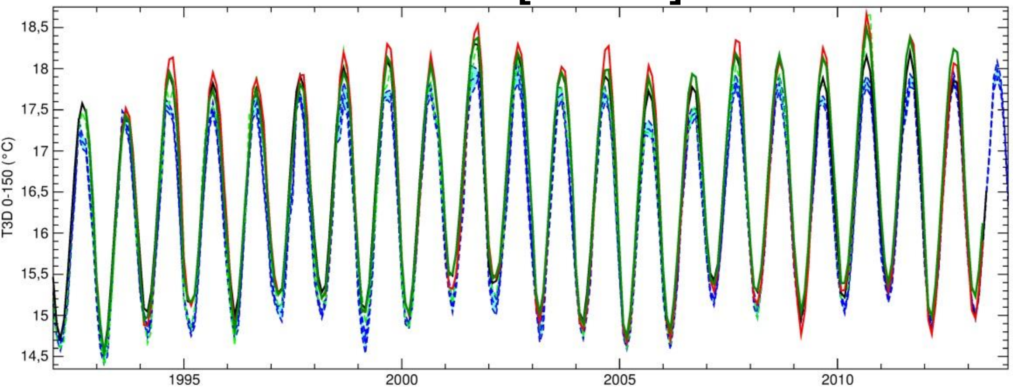


Monthly heat and salt contents

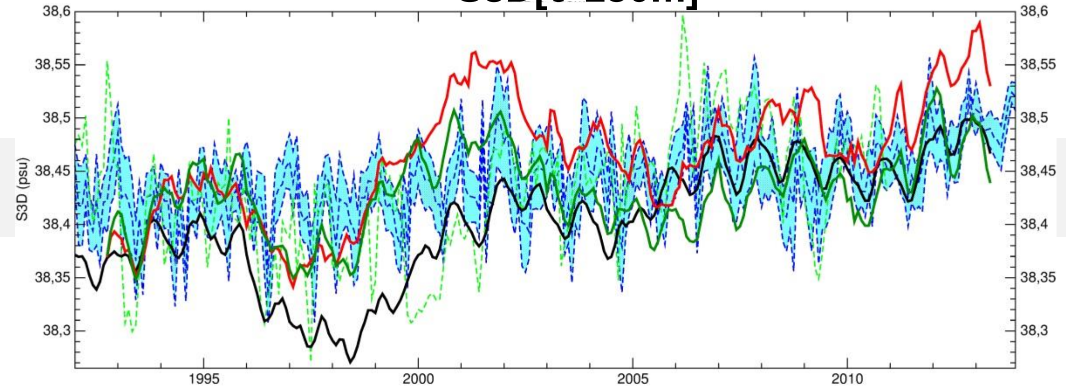
(courtesy G. Jorda for the IMEDEA construction)



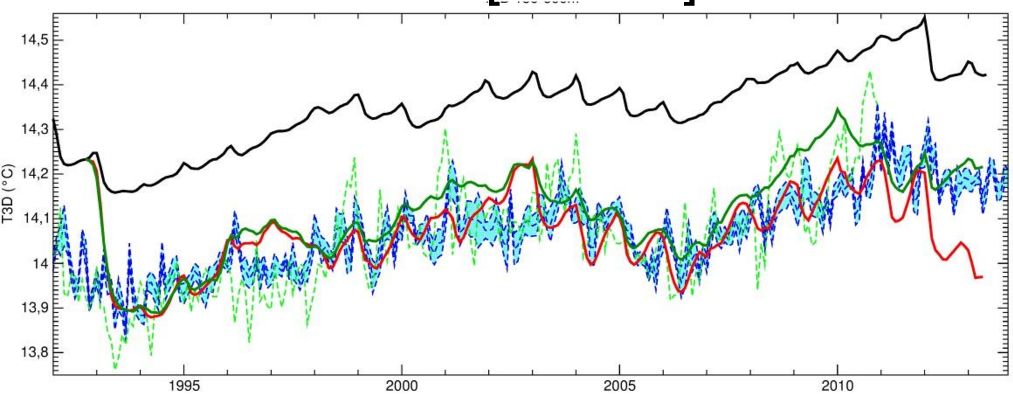
T3D[0-150m]



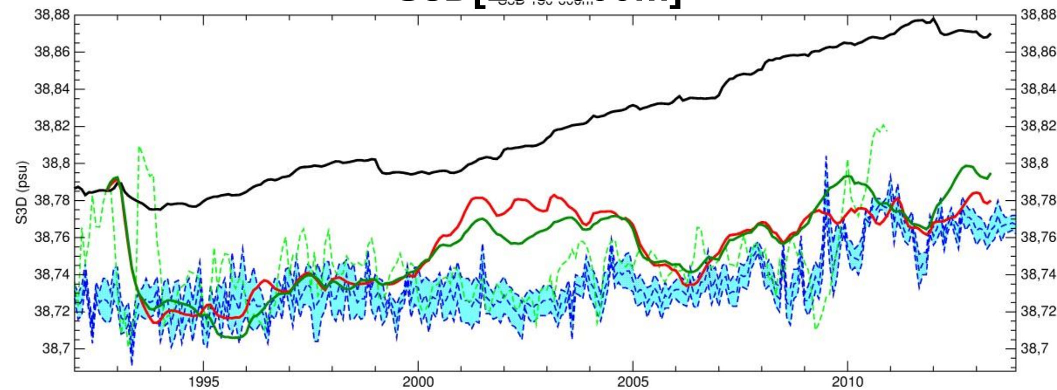
S3D[0-150m]



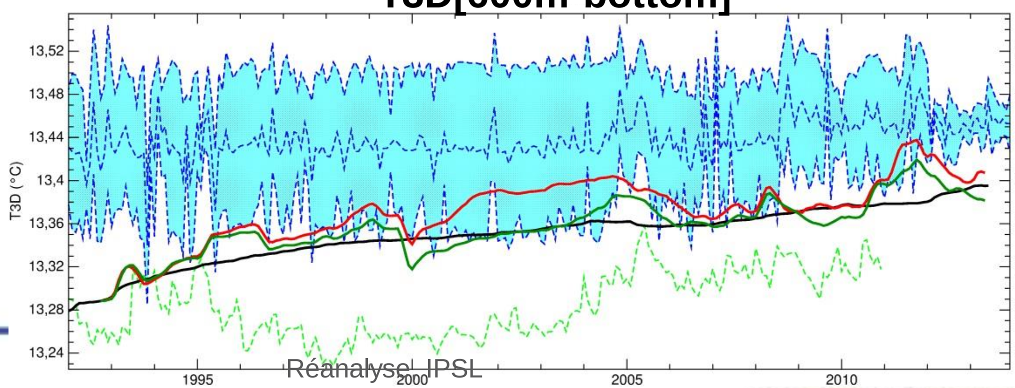
T3D[150-600m]



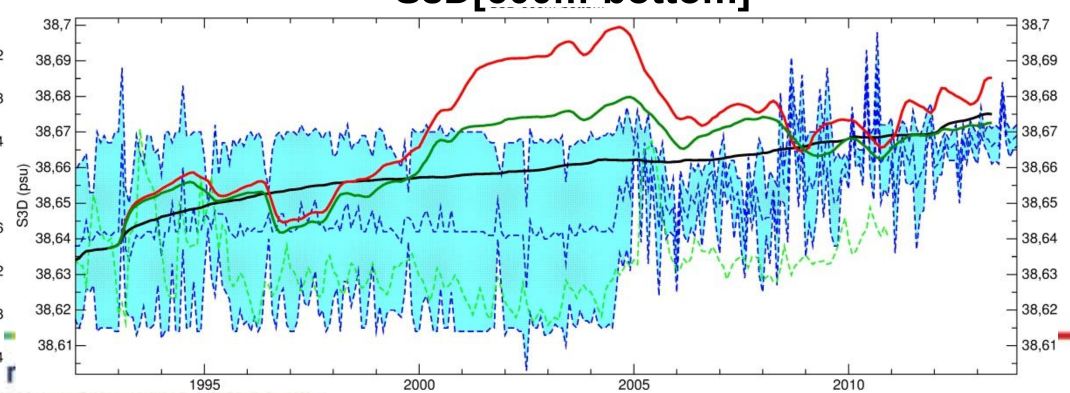
S3D[150-600m]



T3D[600m-bottom]



S3D[600m-bottom]



Conclusions

Apport de l'approche ensembliste et multi modèles

- Estimer, fournir, étudier les incertitudes

→ 2017 : Fourniture d'un ensemble (4 estimations globales au ¼°) moyenne, variance …

→ 2018/2019 : Développer des approches ensemblistes, générer des perturbations, contrôler le spread de l'ensemble

Apport de l'approche régionale

- Améliorer la résolution
- Adapter le modèle, des paramétrisations ou des forçages
- Focus sur des processus ou régions
- Améliorer les réanalyses globales

→ 2016 : Améliorer la résolution en globale, au 1/12° sur une période courte (2007-présent)

→ On peut envisager des réanalyses régionales à plus haute résolution (1/36°)

Conclusions

Produire des réanalyses proches du temps réel

- **Chaque année les réanalyses sont prolongées de 1 an**
- **Possibilité de raccorder les réanalyses avec les systèmes temps réel**

Produire un « Ocean State Report » annuel dans le cadre de CMEMS

- **Variables Océaniques Essentielles**
- **Mécanismes physiques**
- **Biogéochimie**
- **Monitoring d'évènements extrêmes**

Ce qu'il faut encore améliorer

Améliorer les produits :

- Qualité des réanalyses, réduire les biais, améliorer les tendances
- Améliorer la résolution spatiale et temporelle
- Etendre les périodes temporelles

Plus d'information :

- Il existe une large gamme de réanalyse, chacune réalisée pour des objectifs précis.
- Les réanalyses ne sont pas encore suffisamment évaluée, il y a des différences importantes entre les produits
- Il faut continuer l'effort de coordination entre les différents groupes
- Les utilisateurs de réanalyses océaniques n'ont pas facilement accès à :
  - Quels produits utiliser pour une application particulière
  - Quelle est la qualité des produits
  - Pourquoi une réanalyse est différente des autres

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