CNRS/LEGI in SANGOMA

Grenoble, France
http://www-meom.hmg.inpg.fr

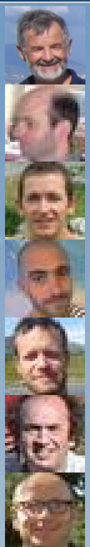
SANGOMA kick-off meeting – November 24-25, 2011

CNRS/LEGI in SANGOMA

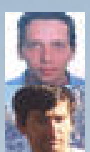
1. CNRS/LEGI: the MEOM group
2. Recent data assimilation activities
3. CNRS/LEGI contribution to SANGOMA
4. The SESAM software
5. The NEMO ocean model

1. CNRS/LEGI: the MEOM group

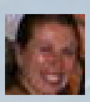
The MEOM group



B. Barnier	DR CNRS
P. Brasseur	DR CNRS
E. Cosme	MC UJF
J. Le Sommer	CR CNRS
T. Penduff	CR CNRS
J. Verron	DR CNRS
A. Wirth	CR CNRS



J. M. Brankart	IR CNRS
J. M. Molines	IR CNRS



J. Brasseur	CDI UJF

Postdoc	M. DORON	Postdoc ESA > BIOCAREX
	C. FONTANA	Postdoc OSS2015 (LOV)
	E. KPEMPLIE	Postdoc MYOCEAN
	S. GREGORIO	Postdoc MYOCEAN
Theses	C. AKUETEVI	Grant UJF
	P. A. BOUTTIER	*ANR VODA*
	N. DJATH	Contract INSU/CNES
	C. DUFOUR	CEA
	N. FREYCHET	MNER/UJF
	L. GAULTIER	Grant CNES-CNRS
	G. MAINSANT	Grant Région R-A
	M. MEINVIELLE	Grant CNES-CNRS
Engineers		
	M. JUZA	Contract INSU/CNES
	B. LEMIEUX	*IR CNRS NEMO Assim*
	R. DUSSIN	IE MYOCEAN
	A. LECOINTRE	IR CNRS-ORCA12
Administration		
	L. ISKANDAR	½ Gestion MYOCEAN

4 Postdoc
8 PhD students
4 Engineers
1 Administrative support

The MEOM group: research topics

High resolution modelling, from global (10 km) to regional (1 km)

Spatial and in situ ocean observations: Argo, Jason, SMOS, Altika,...

Data assimilation: reduced rank and ensemble filters, 4DVAR,...

RESEARCH & DEVELOPMENT

RESEARCH

ocean variability (global to submesoscale)

role of mesoscale processes in the general circulation

impact of physics on ocean biogeochemistry (model + observations)

DEVELOPMENT

model applications (NEMO)

data assimilation (SESAM)

diagnostic and validation tools

transfer to operational systems (Mercator, MyOcean)

Ocean data assimilation at CNRS/LEGI: past, present, future

<u>**In 4 main directions:**</u>

- **Methodological research**
- **Ocean specific applications**
- **Ocean observation systems**
- **Operational developments**

Methodological research - I

- **Reduced rank (and ensemble) Kalman filtering**

Pham D.T., Verron J. et Roubaud M.C., Singular evolutive extended Kalman filter with EOF initialization for data assimilation in oceanography. *J. of Marine Systems*, **16(3-4)**, 323-340, 1998.
Brasseur P., Ballabrera-Poy J. et Verron J., Assimilation of altimetric observations in a primitive equation model of the Gulf Stream using a Singular Evolutive Extended Kalman filter. *Journal of Marine System*, **22**, 269-294, 199.

Verron J., Gourdeau L., Pham D.T., Murtugudde R. et Busalacchi A.J., An extended Kalman filter assimilate satellite altimeter data into a non-linear numerical model of the tropical Pacific: method and validation. J*. Geophys. Res.*, **104(C3)**, 5441-5458, 1999.

Carme S., Pham D.T., et Verron J. Improving the singular evolutive extended Kalman filter for strongly nonlinear models for use in ocean data assimilation. I*nverse Problems*, **17**, 1535-1559, 2001

Ballabrera J., Brasseur P. et Verron J. Dynamical evolution of the error statistics with the SEEK filter to assimilate altimetric data in eddy-resolving ocean models.*Q.J.R. Met. Soc.*, **127**, 233-253, 2001.

Penduff T., Brasseur P., Testut C.E., Barnier B. et Verron J. Assimilation of sea-surface temperature and altimetic data in the South Atlantic ocean : impact on basin-scale properties. *Journal of Marine Research*, **60**, 805-833, 2002.

Brusdal K., Brankart J.M., Halberstad G., Evensen G., Brasseur P., Van Leeuwen P.J., Dombrowsky E.,Verron J. A demonstration of ensemble-based assimilation methods with a layered OCGM from the perspective of operational ocean forecasting systems. *J. Marine Syst.*, **40-41**, 253-289, 2003.

Brankart J.-M., Ubelmann C., Testut C.-E., Cosme E., Brasseur P., Verron J. Efficient parameterization of the observation error covariance matrix for square root or ensemble Kalman filters: application to ocean altimetry. *Monthly Weather Review*, **137(6)**, 1908-1927, 2009.

Brankart J.-M., Cosme E., Testut C.-E., Brasseur P. and Verron J. Efficient adaptive error parameterizations for square root or ensemble Kalman filters: application to the control of ocean mesoscale signals. *Monthly Weather Review*, **138(3)**, 932-950, 2010.

Brankart J.-M., Cosme E., Testut C.-E., Brasseur P. and Verron J. Efficient local error parameterizations for square root or ensemble Kalman filters: application to a basin-scale ocean turbulent flow. *Monthly Weather Review*, **139(2)**, 474-493, 2011.

Methodological research - II

- ## Variational methods

Luong B., Blum J. et Verron J., A variational method for the resolution of a data assimilation problem in oceanography. J*. of Inverse Problems*, **14**, 979-997, 1998.

Rémy E., Gaillard F., Verron J. Variational assimilation of tomography data: twin experiments in a quasi-geostrophic model. *Quaterly J. of the Royal Met. Soc.*, **128A**, 1739-1758, 2002.

Faugeras B., Lévy M., Mémery L., Verron J., Blum J., Charpentier I. Can biogeochemical fluxes be recovered from nitrate and chlorophyll data? A case study assimilating data in the Northwestern Mediterranean Sea at the JGOFS-DYFAMED station. *Journal of Marine Systems*, **40-41**, 99-125, 2003.

Robert C., Blayo E., Verron J. Reduced-order-4D-Var: a preconditioner for the full 4D-Var data assimilation. *Geophys. Res. Letters*, **33**, L18609, doi:10.1029/2006GL026555, 2006.

- ## « Inversion »

Galmiche M., Sommeria J., Brasseur P., Verron J. Using data assimilation in laboratory experiments of geophysical flows. *J. of Marine Systems*, **65(1-4)**, 532-539, 2007.

Titaud O., Brankart J.-M., and Verron J. On the use of Finite-Time Lyapunov Exponents and Vectors for direct assimilation of images in ocean models. *Tellus*, in revision, 2011.

Methodological research - III

- ## Hybrid approaches

Robert C., Durbiano S., Blayo E., Verron J., Blum J., Le Dimet F.X. A reduced-order strategy for 4D-Var data assimilation. *J. of Marine Systems*, **57(1-2)**, 70-82, 2005.

Robert C., Blayo E., Verron J. Comparison of reduced-order sequential, variational and hybrid data assimilation methods in the context of a tropical Pacific ocean model. *Ocean Dynamics*, **56(5-6)**, 624-633, 2006.

- ## Smoothers

Ourmières Y., Brankart J.M., Berline L., Verron J., Brasseur P. Incremental Analysis Update implementation into a sequential ocean data assimilation system. *J. Atmos. Ocean. Technol.*, **23(12)**, 1729-1744, 2006.

Cosme E., Brankart J.-M., Verron J., Brasseur P. and Krysta M. Implementation of a reduced-rank, square-root smoother for high resolution ocean data assimilation. *Ocean Modelling*, **33**, 87-100, 2010.

Cosme E., Verron J., Brasseur P. Blum J. and Auroux D., 2011: Smoothing problems in a Bayesian framework and their linear Gaussian solutions, *Mon. Weather Rev., in press.*

- ## Non-gaussian approaches

Lauvernet C., Brankart J.M., Castruccio F., Broquet G., Brasseur P., Verron J.
A truncated Gaussian filter for data assimilation with inequality constraints: application to the hydrostatic stability condition in ocean models. *Ocean Modelling*, **27**, 1-17, 2009

Béal D., Brasseur P., Brankart J.-M., Ourmières Y. and Verron J. Characterization of mixing errors in a coupled physical biogeochemical model of the North Atlantic: implications for nonlinear estimation using Gaussian anamorphosis. *Ocean Science*, **6**, 247-262, 2010.

Doron M., Brasseur P. and Brankart J.-M. Stochastic estimation of biogeochemical parameters of a 3D ocean coupled physical-biogeochemical model: twin experiments. *Journal of Marine Systems*, **87**, 194-207, 2011.

Brankart J.-M., Testut C.-E., Béal D., Doron M., Fontana C. Meinvielle M. and Brasseur P., 2011 : Towards an improved description of oceanographic uncertianties: effect of local anamorphic transformations on spatial correlations, *submitted to Ocean Sci.*

Ocean specific applications

- ## Coupled physical-biogeochimical models

Carmillet V., Brankart J.M., Brasseur P., Drange H., Evensen G. et Verron J.
A singular evolutive extended Kalman filter to assimilate ocean color data in a coupled physical-biochemical model of the North Atlantic ocean. *Ocean Modeling*, **3**, 167-192, 2001.

Magri S., Brasseur P., Lacroix G. Data assimilation in a marine ecosystem coupled to a mixed layer model of the upper ocean. *C.R. Géosciences*, **337**, 1065-1074, 2005.

Berline L., Brankart J.-M., Brasseur P., Ourmières Y., Verron J. Improving the dynamics of a coupled physical-biogeochemical model of the North Atlantic basin through data assimilation: impact on biological tracers. *J. Marine Syst.*, **64(1-4)**, 153-172, 2007.

Raick, C., Alvera-Azcarate, A., Barth, A., Brankart, J.M., Soetart, K., Grégoire, M. Application of a SEEK filter to a 1D biogeochemical model of the Ligurian Sea: twin experiments and real in situ data assimilation. *Journal of Marine Systems*, **65(1-4)**, 561-583, 2007.

Ourmières Y., Brasseur P., Levy M., Brankart J.M. and Verron J. On the key role of nutrient data to constrain a coupled physical-biogeochemical assimilative model of the North Atlantic Ocean. *Journal of Marine Systems*, **75(1-2)**, 100-115, 2009.

- ## Control of the atmospheric forcing

Broquet G., Brasseur P., Rozier D., Brankart J.-M., Verron J. Estimation of model errors generated by atmospheric forcings for ocean data assimilation: experiments in a regional model of the Bay of Biscay . *Ocean dynamics*, **58(1)**, 1-17, 2008.

Skachko S., Brankart J.-M., Castruccio F., Brasseur P., Verron J. Improved turbulent air-sea flux bulk parameters for the control of the ocean mixed layer: a sequential data assimilation approach. *Journal of Atmospheric and Oceanic Technologies*, **26(3)**, 538-555, 2009.

Skandrani C., Brankart J.-M., Ferry N., Verron J., Brasseur P. and Barnier B. Controlling atmospheric forcing parameters of global ocean models: sequential assimilation of sea surface Mercator-Ocean reanalysis data. *Ocean Science*, **5**, 403-419, 2009.

Ocean observation systems

- Impact studies

Blayo E., Mailly T., Barnier B., Brasseur P., Le Provost C., Molines J.M. et Verron J.: Complementarity of ERS-1 and Topex/Poseidon altimeter data in evaluation the ocean circulation : assimilation in a model of the North Atlantic. J*ournal of Geophy.Res.*, **102(C8)**, 18573-18584, 1997.

Birol F., Brankart J.M., Castruccio F., Brasseur P., Verron J. Impact of ocean mean dynamic topography on satellite data assimilation. *Marine Geodesy*, **27**(1-2), 59-78, 2004.

Birol F., Brankart J.-M., Lemoine J.M., Brasseur P., Verron J. Assimilation of satellite altimetry referenced to the new GRACE geoid estimate.*Geophys. Res. Letters*, **32**, L06601, doi:10.1029/2004GL02329,2005.

Castruccio F., Verron J., Gourdeau L., Brankart J.-M., Brasseur P. On the role of the GRACE mission in the joint assimilation of altimetry and TAO data in a tropical Pacific Ocean model.*Geophys. Res. Letters*, **33**, L14616, 2006.

Parent L. Testut C.E., Brankart J.M., Verron J., Brasseur P.,Gourdeau L. Comparative assimilation of Topex/poseidon and ERS altimeter data and of TAO Temperature data in the Tropical Pacific Ocean during 1994-1998, and the mean sea-surface height issue. Journal of Marine Systems, 40-41, 381-401, 2003.

Castruccio F., Verron J., Gourdeau L., Brankart J.-M., Brasseur P. Joint altimetric and in-situ data assimilation using the GRACE mean dynamic topography: a 1993-1998 hindcast experiment in the Tropical Pacific Ocean. *Ocean dynamics*, **58(1)**, 43-63, 2008.

- Observation system simulation experiments

Tranchant B., Testut C.-E., Renault L., Ferry N., Birol F. and Brasseur P. Expected impact of the future SMOS and Aquarius Ocean surface salinity missions in the Mercator Ocean operational systems: new perspectives to monitor ocean circulation. *Remote Sensing Env.*, **112**, 1476-1487, doi:10.1016/j.rse.2007.06.023, 2008.

Ubelmann C., Verron J., Brankart J.M., Cosme E., Brasseur P. Impact of upcoming altimetric missions on the prediction of the three-dimensional circulation in the tropical Atlantic ocean. *Journal of Operational Oceanography*, **2(1)**, 3-14, 2009.

Ubelmann C., Verron J., Brankart J.-M., Brasseur P., and Cosme E. Assimilating altimetric data from multi-satellite scenarios to control Atlantic Tropical Instability Waves: an Observing System Simulation Experiments study. *Ocean Dynamics*, submitted, 2011.

Operational developments

- **HYCOM**

Brankart J.-M., Testut C.-E., Brasseur P., Verron J. Implementation of a multivariate data assimilation scheme for isopycnic coordinate ocean models: Application to a 1993-96 hindcast of the North Atlantic Ocean circulation. *J. Geophys. Res.*, 108, 3074, doi:10.1029/2001JC001198, 2003.

Srinivasan A., Chassignet E.P., Bertino L., Brankart J.-M., Brasseur P., Chin M., Counillon F., Cummings J.A., Mariano A.J., Smedstad O.M., Thacker W.C. A comparison of sequential assimilation schemes for ocean prediction with the HYbrid Coordinate Ocean Model (HYCOM): Twin Experiments with static forecast error covariances. *Ocean Modeling*, **37(3-4)**, 85-111, 2011.

- **Mercator**

Testut C.E., Brasseur P., Brankart J.M., Verron J. Assimilation of sea-surface temperature and altimetric observations during 1992-1993 into an eddy permitting primitive equation model of the North Atlantic Ocean. *Journal of Marine Systems*, **40-41**, 291-316, 2003.

Ferry N., Remy E., Brasseur P., Maes Ch. The MERCATOR global ocean operational assessment analysis/forecast system: and validation of a 11-year reanalysis. J. Marine Syst., 65(1-4), 540-560, 2007.

Brasseur P., Bahurel P., Bertino L., Birol F., Brankart J.-M., Ferry N., Losa S., Rémy E., Schröter J., Skachko S., Testut C.-E., Tranchant B., Van Leeuwen P.J., Verron J. Data Assimilation for marine monitoring and prediction: The MERCATOR operational assimilation systems and the MERSEA developments. *Q. J. R. Met. Soc.*, **131**, 3561-3582, 2005.

- **GODAE**

Brasseur P., Gruber N., Barciela R., Brander K., Doron M., El Moussaoui A., Hobday A., Huret M., Kremeur A.-S., Lehodey P., Matear R., Moulin C., Murtugudde R., Senina I. and Svendsen E. Integrating biogeochemistry and Ecology Into Ocean Data Assimilation Systems. *Oceanography*, **22(3)**, 206-215, 2009.

Cummings J., Bertino L., Brasseur P., Fukumori I., Kamachi M., Martin M., Morgensen K., Oke P., Testut C.E., Verron J. and Weaver A. Ocean Data Assimilation Systems for GODEA. *Oceanography*, **22(3)**, 96-109, 2009.

Education, training

- ## Reviews

Brasseur P., Verron J. The SEEK filter method for data assimilation in oceanography: a synthesis. O*cean Dynamics*, **56(5-6)**

Rozier D., Birol F., Cosme E., Brasseur P., Brankart J.M., Verron J. A reduced-order Kalman filter for data assimilation in physical oceanography. *SIAM Rev.*, **49(3)**, 449-465, 2007.

- ## Summer school

Verron J.: Data assimilation and ocean modelling : Application to the North Atlantic. C*omputational Fluid Dynamics*, Les Houches Session LVIX, 1993, M.Lesieur, P.Comte et J.Zinn-Justin,eds 1996 North-holland Elsevier Science B.V., 634, 623-628, 1997.

Brasseur P., 2006 : Ocean Data Assimilation using Sequential Methods based on the Kalman Filter. In : *Ocean Weather Forecasting : an Integrated View of Oceanography (E. Chassignet and J. Verron Eds.)*, Springer Publ., 271-316.

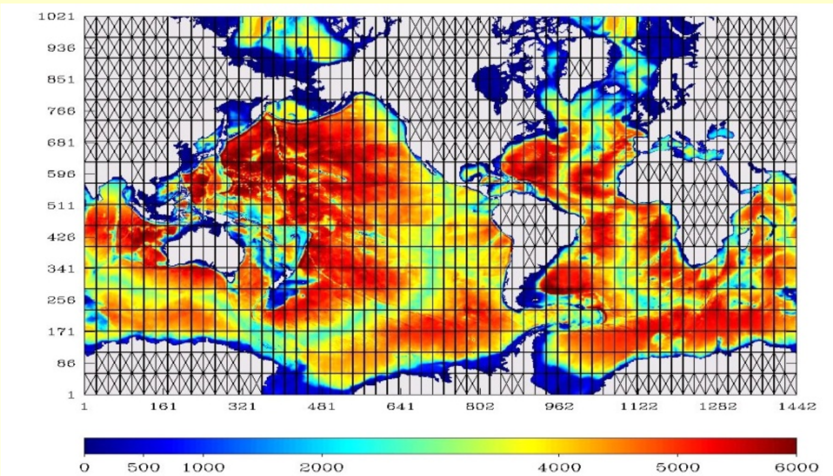
Brasseur P., 2011 : Ensemble-based Data Assimilation Methods: An overview of recent developments for computationally efficient applications in Operational Oceanography. In : *Operational Oceanography of the 21st century (A. Schiller and G. Brassington Eds.)*, Springer Publ., in press

- ## Postgraduate course

Cosme et al. Cours d'assimilation, Grenoble

Contribution to operational projects

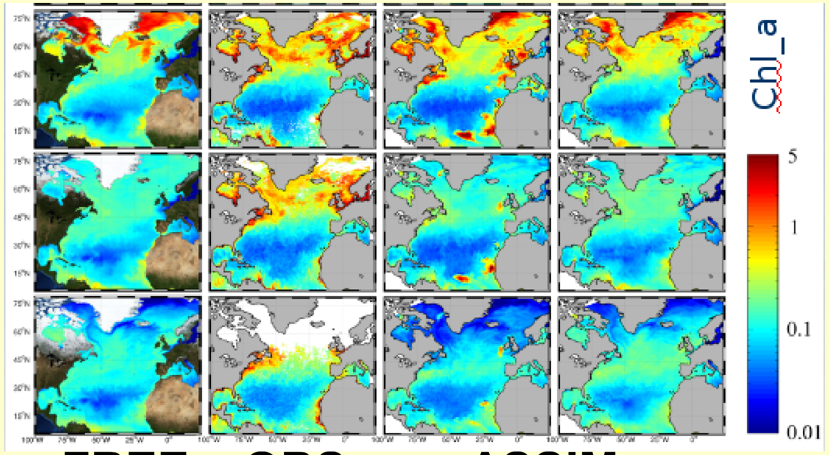
Development and validation of **model configurations**



ORCA025 : 1/4°   (1442 x 1021)
ORCA12 : 1/12° (4322 x 3059)

(by the DRAKKAR consortium)

Development and validation of **assimilation methods**



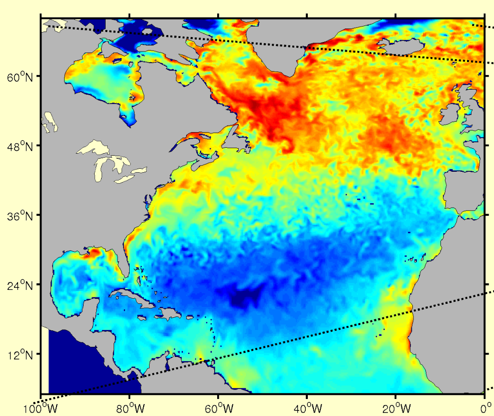
FREE   OBS   ASSIM

ocean colour data assimilation pre-operational prototype (Fontana et al., 2011)

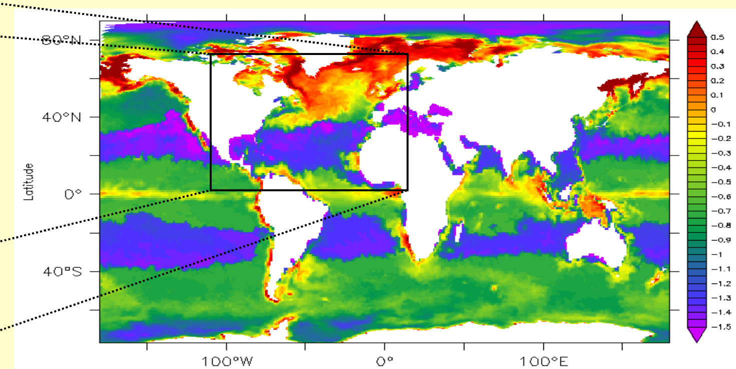
for MyOcean and Mercator-Ocean

Towards integrating biogeochemistry in the ocean operational systems

- **<u>Objectives</u>**: ocean colour data assimilation
  - Development of methods (Béal et al. 2010, Doron et al. 2011),
  - Setup of a pre-operational prototype (Fontana et al., 2011).
- **<u>Projects</u>**:
  - EU: FP7-**MyOcean-II** (2012-…), FP7-**OSS2015** (ACRI, 2012-...)
  - Bionuts/Green Mercator (2004-2010) , **Green Mercator phase-2** (2011-…)
  - ESA/ASSOCO (Changing Earth Science Network, 2009-2011)



R&D: NATL4/LOBSTER/SEEK



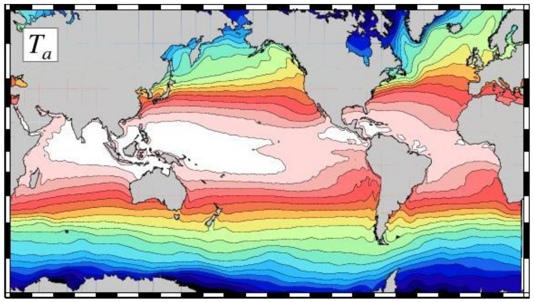
OP: PSY3/PISCES/SAM-2

2. Recent activities in data assimilation

List of NEMO configurations used for data assimilation studies

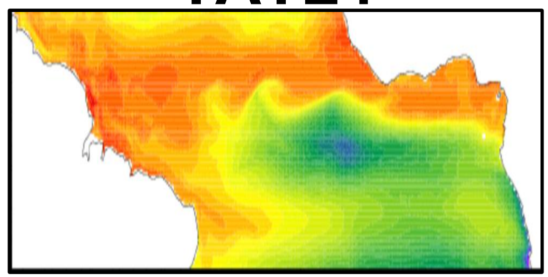
2°

ORCA2



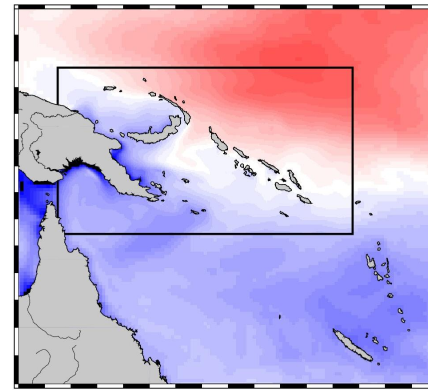
1/4°

TATL4



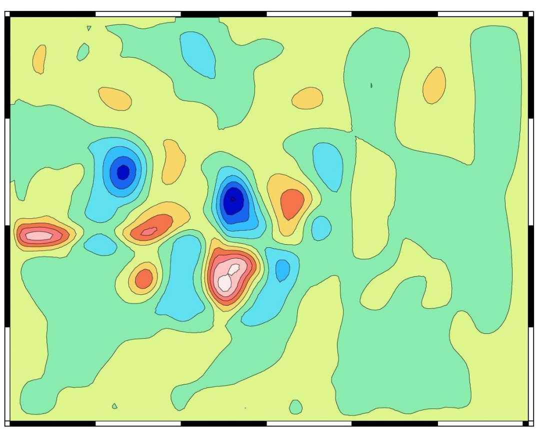
1/4°-1/12°

SOLWARA124



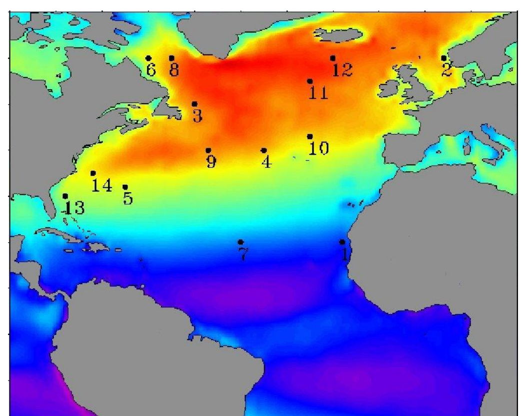
1/4°

SQB



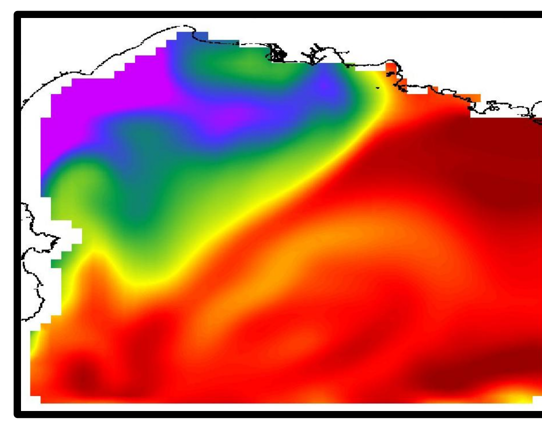
1/4°

NATL4/LOBSTER



1/16°

GDL16s



A. In a Gaussian framework
(for reduced order or ensemble KF)

1) Reduced-rank smoother algorithm:

applied to **SQB** and **TATL4**

2) Augmenting control vector with model parameters:

applied to **ORCA2** to correct atm. forcing parameters

3) Efficient parameterization of obs. error correlations, with augmented observation vector:

applied to **TATL4** to assimilate altimetry

4) Adaptive inflation factors for Pf and R:

tested with **SQB** (with altimetric observations)

5) Efficient covariance localization algorithm:

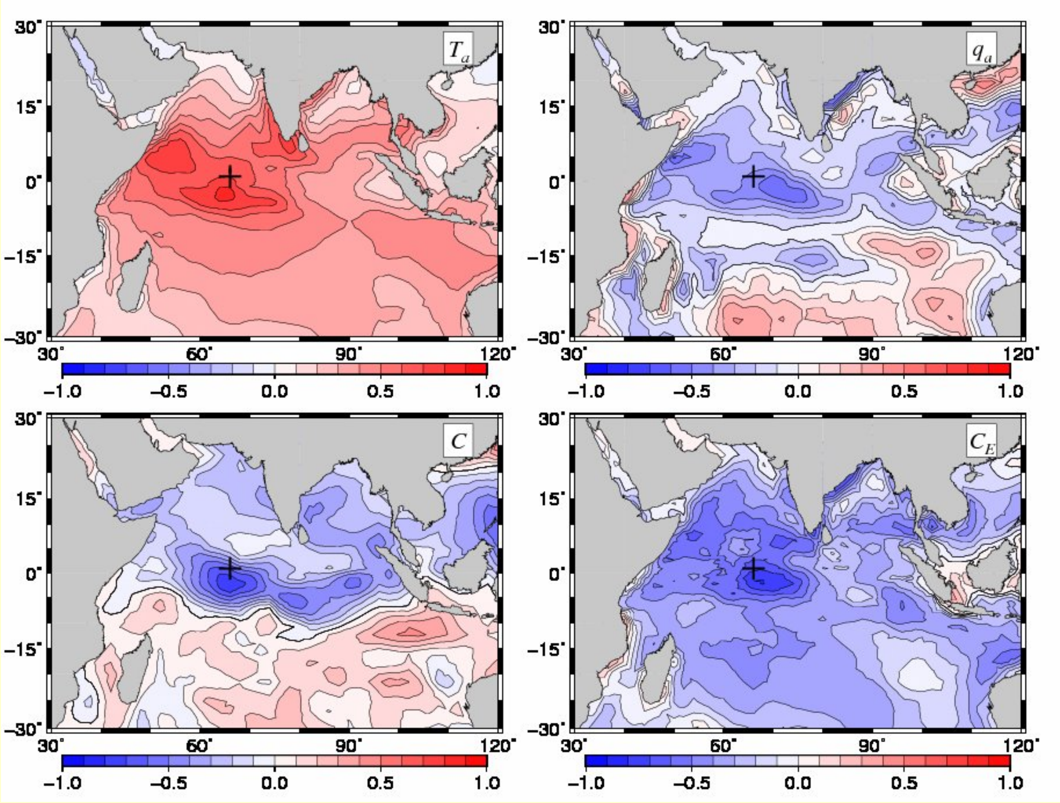
tested with **SQB** (with altimetric observations)

A.2 Augmenting control vector with model parameters

Applied to ORCA2 to control atm. forcing parameters

Requires ensemble forecast simulating the effect of parameter uncertainties

=> Covariance matrix in augmented control space



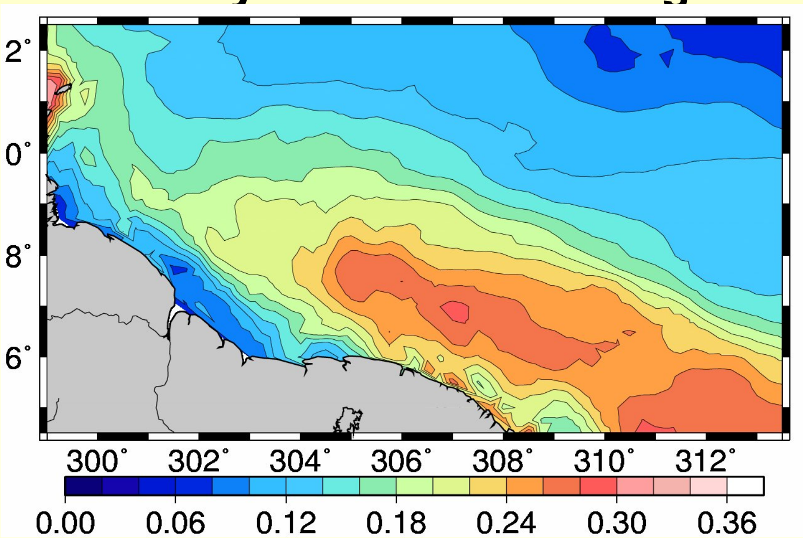
Example correlation structure between parameters and SST

A.3 Efficient parameterization of obs. error correlations

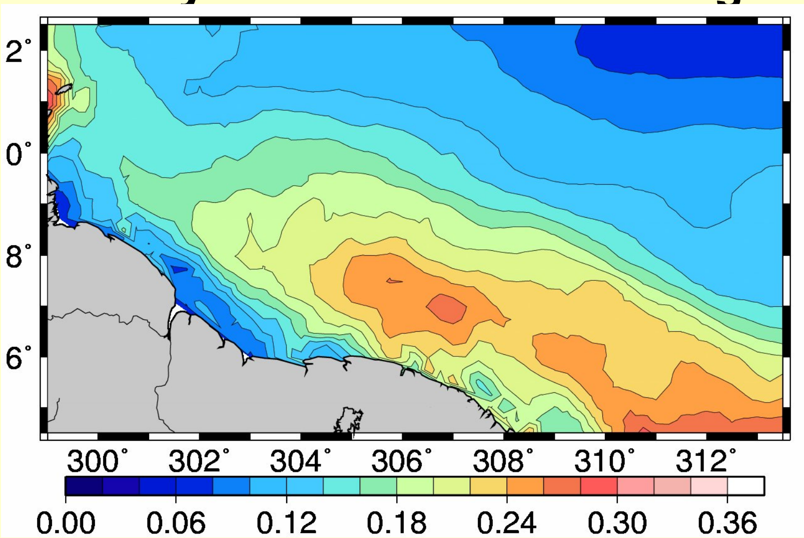
1) Augmenting the observation vector with observation differences is equivalent to assuming non-diagonal R

2) Very efficient to simulate non-diagonal R if the cost of the analysis (with diag. R) is linear in the number of observations

Velocity error std with diag. R



Velocity error std with non-diag. R



3) Gradients are more accurate with correlated observations.
==> Important to give the right importance to the observed gradient of altimetry to control surface velocity

B. In a non-Gaussian framework

1) Truncated Gaussian filter:

applied to **1D mixed layer model,**
applied to **1/3° North Atlantic Hycom configuration.**

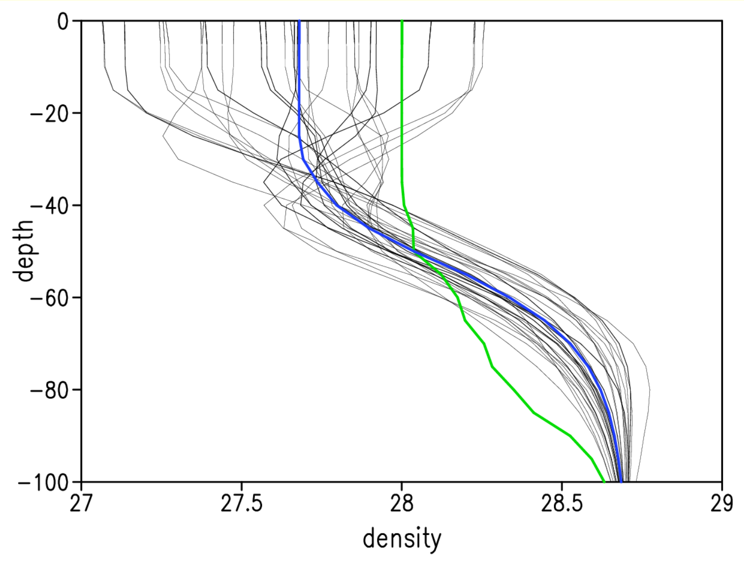
2) Local anamorphosis transformation (in space and time), as diagnosed from the ensemble forecast:

applied to **NATL4-LOBSTER,**

(i) with wind uncertainties,
(ii) with parameter uncertainties,
(iii) in MyOcean pre-operational developments,

applied to ice fraction in **ORCA025** (Mercator).

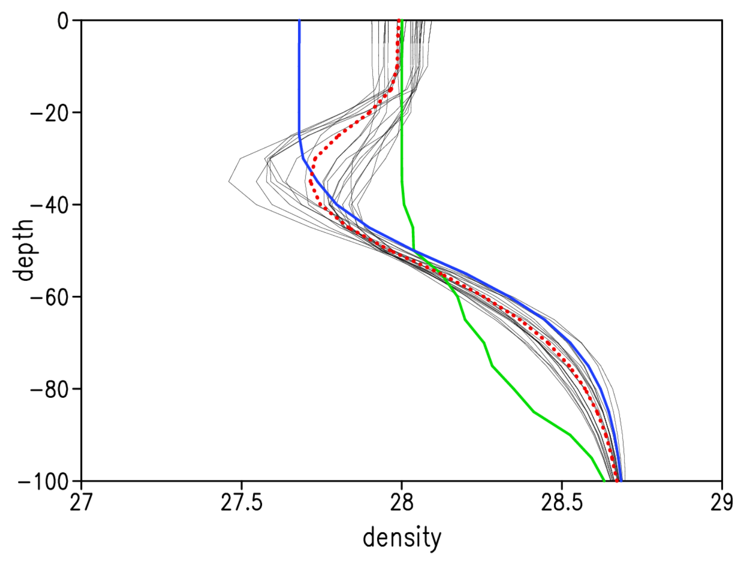
B.1 Truncated Gaussian filter

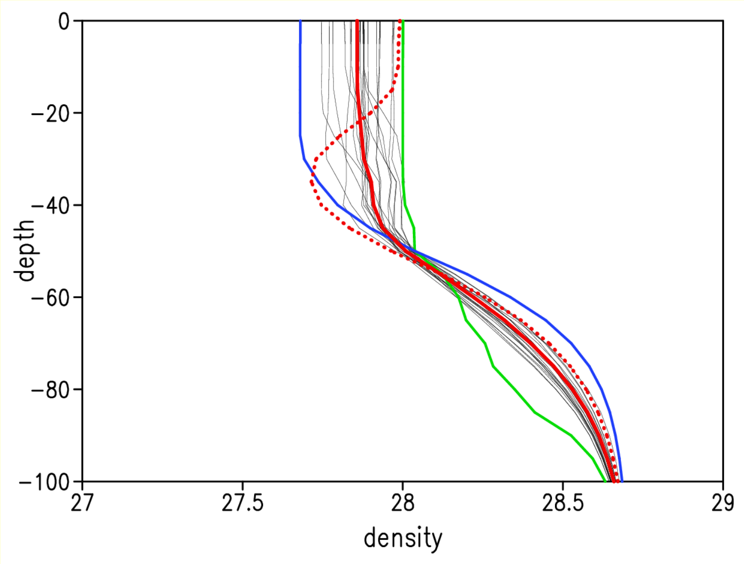


Truncated Gaussian pdfs

(i) can be updated efficiently (with linear formulas),

(ii) can be sampled efficiently (with Gibbs sampler).





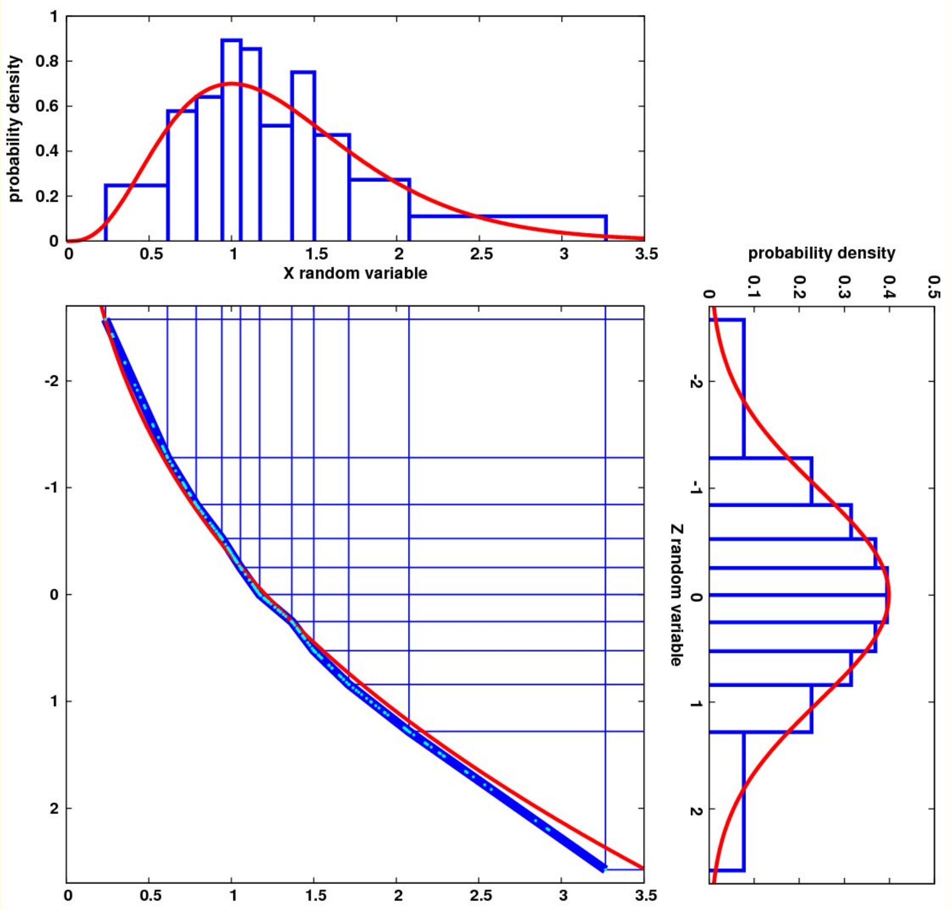
B.2 Local anamorphosis transformations

1) Computed locally in space and time

2) Diagnosed from the ensemble forecast, by remapping a set of ensemble quantiles on the Gaussian quantiles

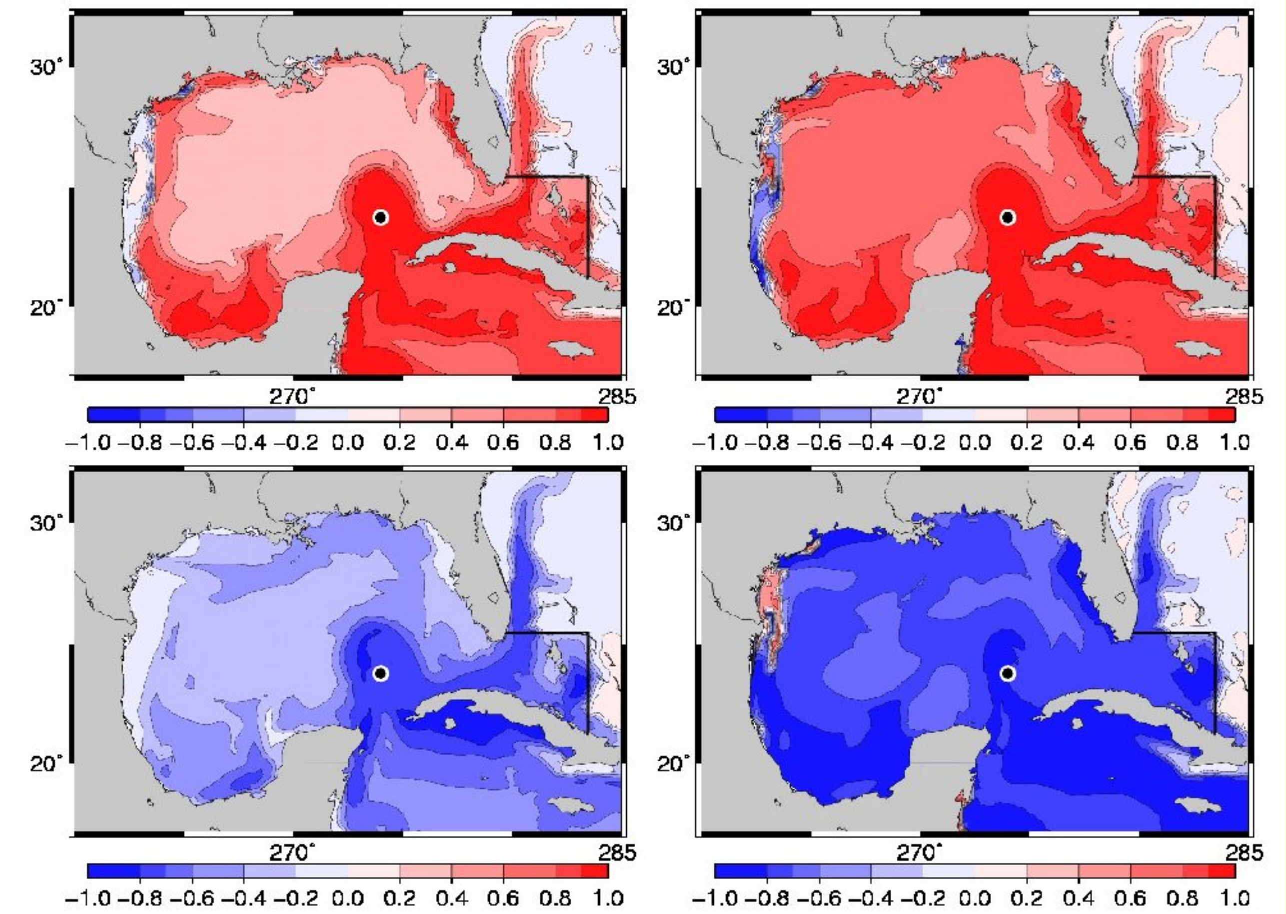
3) Numerically efficient

4) Accurate enough to improve the description of the marginal pdfs



B.2 Local anamorphosis transformations

Applied to NATL4-LOBSTER, with parameter uncertainties:



=> Reduce the number of degrees of freedom

3. CNRS/LEGI contribution to SANGOMA

CNRS/LEGI contribution to SANGOMA

1) Stochastic data assimilation method:

- Share existing tools (WP1 & WP2)
- Investigate non-Gaussian methods (WP3)

==> the SESAM software

2) Oceanographic applications:

- Define and run benchmarks (WP4, lead: CNRS)
- Impact of new observation systems (WP5)

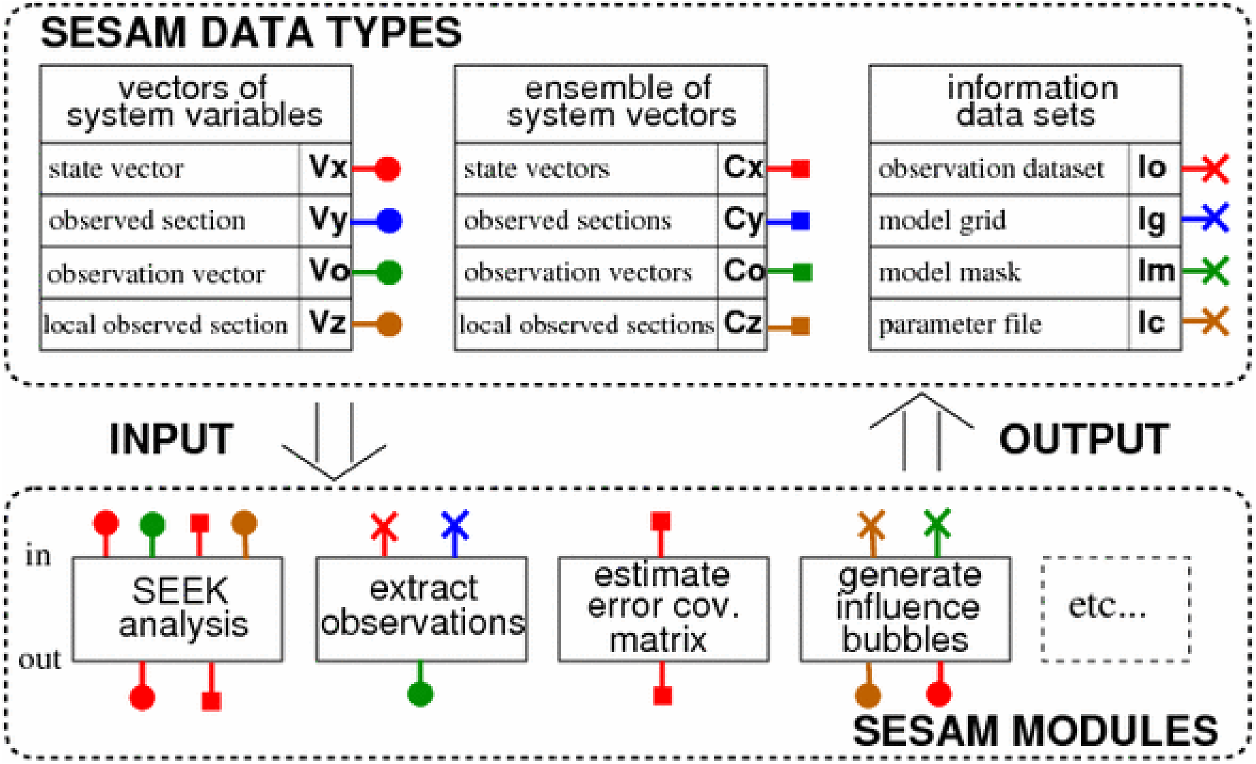
==> the NEMO ocean model

3) Knowledge transfer (WP6):

- Link with operational users (MyOcean)

4. The SESAM software

SESAM data types and SESAM modules



Vector: set of files

`xf#.nc`

`# = [ gridT gridU gridV`

Ensemble: directory

`ens0100.nc.bas`

Examples of SESAM commandline:

Computation of EOFs:

```
sesam -mode geof -inxbas ens0100.nc.bas -outxbas eof0100.nc.bas
```

Gaussian observational update:

```
sesam -mode groa -invar xf#.nc -inxbas Pf0100.nc.bas
     -inobs obs#.cobs -outvar xa#.nc -outxbas Pa0100.nc.bas
```

SESAM configuration

Configuration file

```
# CONTROL VARIABLES
# -----------------
VAREND=3
# Sea surface height:
VAR_NAM-1=SSH
VAR_DIM-1=2
# Zonal velocity:
VAR_NAM-2=U
VAR_DIM-2=3
# Meridional velocity:
VAR_NAM-3=V
VAR_DIM-3=3

# DEFINITION OF MASK FILES
# ------------------------
VARFMSK-1=mask_gridT.nc
VARFMSK-2=mask_gridU.nc
VARFMSK-3=mask_gridV.nc

# OBSERVED VARIABLES
#-------------------
DTA_ACT-1=.TRUE.
OBSNDBS-1=2
OBS_NAM-1:1=TP
OBS_NAM-1:2=ERS

# NetCDF FILE FORMAT
# ------------------
VARINAM-1=gridT
VARIFIL-1=sossheig
VARXDIM=x
VARYDIM=y
VARZDIM-1=deptht
VARTDIM=time_counter
```

1) A **configuration file** describing
   - -variables (name, dimensions,...),
   - -observations (name, type,...),
   - -file formats (model, databases).

2) **Mask files** for each variable.

Generic NetCDF file format
for model ans database files
including **NEMO** NetCDF conventions

Variables and observations are loaded in memory as **1D vectors**:
- Control vector: [SSH, U, V]
- Observation vector: [TP, ERS]

What is SESAM : summary

SESAM is a set of assimilation modules,
which can help you setting up your own system,
but it is not a data assimilation system per se.

SESAM operates offline,
with generic i/o Netcdf format
for model files or database files.

SESAM is configured dynamically,
with a configuration file describing
variables, observations, file formats,...
Compilation is only needed for developments.

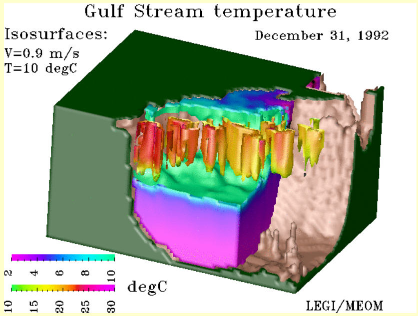
A flexible tool for a large variety of applications

SESAM applications at LEGI-MEOM

OPA-NEMO

North Atlantic

Testut et al, 2003, JMS
Berline et al, 2006, IJRS
Ourmières et al, 2006, JAOT



South Atlantic

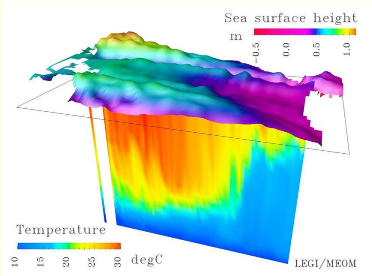
Penduff et al, 2002, JMR

Tropical Atlantic

Ubelmann et al, 2009, JOO
Brankart et al, 2009, MWR

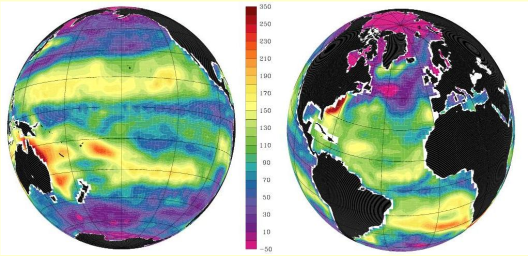
Tropical Pacific

Parent et al, 2003, JMS
Castruccio et al, 2006, GRL
Castruccio et al, 2008, OD



Global Ocean

Skachko et al, 2009, JAOT
Skandrani et al, 2009, en prép.



Idealized Ocean

Cosme et al, 2009, OM

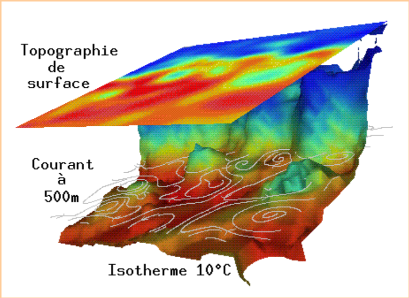
MIXED LAYER MODEL

Lauvernet et al, 2009, JMS

MICOM

North Atlantic

Brusdal et al, 2003, JMS
Brankart et al, 2003, JGR



Rotating tank

Galmiche et al, 2007, JMS

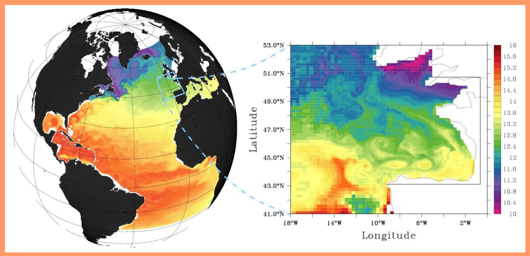
HYCOM

North Atlantic

Birol et al, 2004, MG
Birol et al, 2005, GRL
Rozier et al, 2007, SIAM

Bay of Biscay

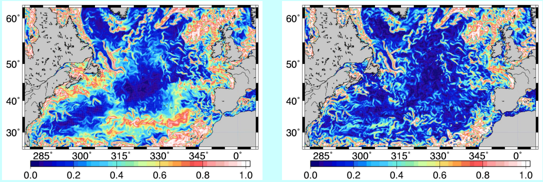
Broquet et al, 2008, OD



ECOSYSTEM

Coupled to OPA-NEMO

Berline et al, 2007, JMS
Ourmières et al, 2009, JMS
Béal et al, 2009, en prép.



Coupled to MICOM

Carmillet et al, 2001, JMS

Coupled to a 1D model

Raick et al, 2007, JMS

Example 1: Multigrid configuration

Configuration file

```
# CONTROL VARIABLES
# -----------------
VAREND=4
# TEM on coarse grid
VAR_NAM-1=TEM0
VAR_DIM-1=3
# SAL on coarse grid
VAR_NAM-1=SAL0
VAR_DIM-1=3
# TEM on fine grid
VAR_NAM-1=TEM1
VAR_DIM-1=3
# SAL on fine grid
VAR_NAM-1=SAL1
VAR_DIM-1=3

# DEFINITION OF MASK FILES
# ------------------------
VARFMSK-1=mask_gridT0.nc
VARFMSK-2=mask_gridT0.nc
VARFMSK-3=mask_gridT1.nc
VARFMSK-4=mask_gridT1.nc

# NetCDF FILE FORMAT
# ------------------
VARINAM-1=gridT0
VARIFIL-1=votemper
VARINAM-2=gridT0
VARIFIL-2=vosaline
VARXDIM=x
VARYDIM=y
VARZDIM=deptht
VARTDIM=time_counter
```

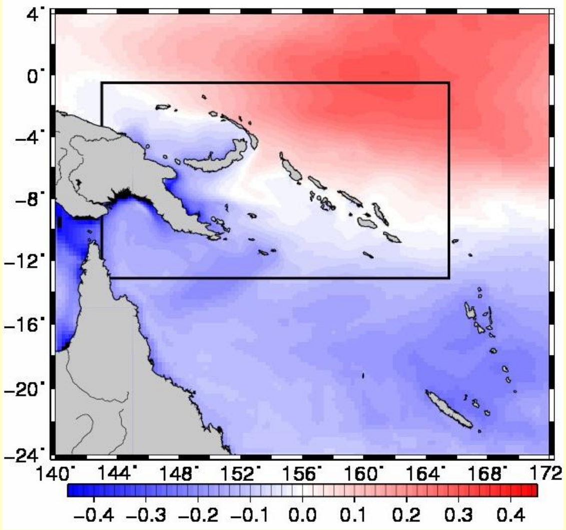
1/12° NEMO configuration for the **Solomon Sea** nested in a 1/4° configuration of the South Western Pacific (with **AGRIF**).

Computation of multigrid and multivariate EOFs

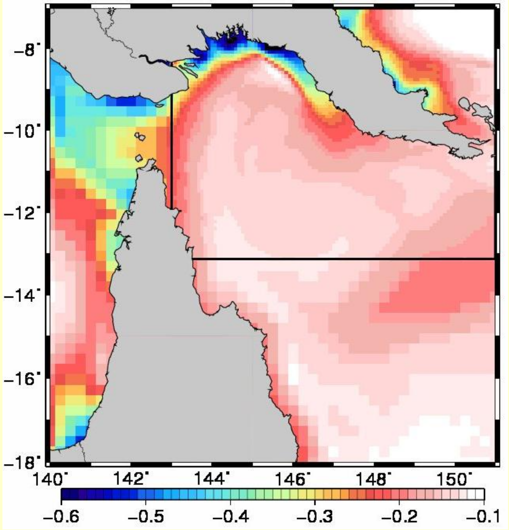
1) Prepare ensemble in input directory

2) sesam -mode geof -inxbas ens0100.nc.bas -outxbas eof0100.nc.bas

Multigrid EOF



Detail of the EOF



Example 1: Multigrid configuration

<u>Prepare partition and influence bubbles for covariance localization</u>

1) Define localization parameters (in ASCII file): `param.cfg`

2)
```
sesam -mode zone -incfg param.cfg
      -outpartvar part#.nc -outzon bub.czon
```

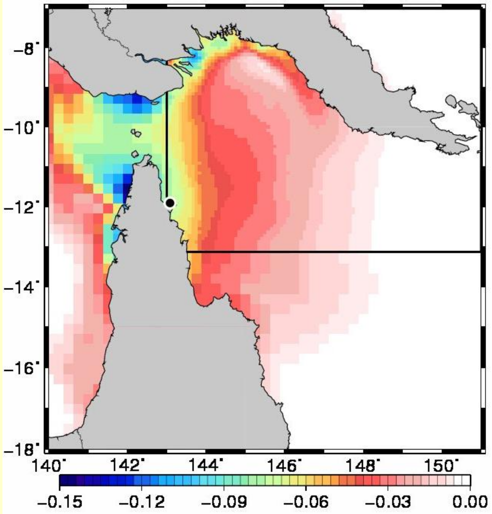
<u>Prepare « single observation » vector</u>

1) Prepare single observation data base (in ASCII): `oneobs.adbs`

2)
```
sesam -mode obsv -indbs oneobs.adbs
      -outobs oneobs#.cobs -affectobs TEM1
```

<u>Computation of multigrid and multivariate local observation increment:</u>

```
sesam -mode lroa -inobs oneobs#.cobs
      -invar zero#.nc -inxbas eof0100.nc.bas
      -outvar xa#.nc -outxbas Pa0100.nc.bas
      -inpartvar part#.nc -inzon bub.czon
```



Example 2: Estimation of atmospheric forcing parameters

Configuration file

```
# CONTROL VARIABLES
# -----------------
VAREND=8
# Ocean temperature:
VAR_NAM-1=TEM
VAR_DIM-1=3
# Ocean salinity:
VAR_NAM-2=SAL
VAR_DIM-2=3
# Air temperature
VAR_NAM-3=TA
VAR_DIM-3=2
# Air temperature
VAR_NAM-4=EA
VAR_DIM-4=2
# Precipitations
VAR_NAM-5=P
VAR_DIM-5=2
...

# DEFINITION OF MASK FILES
# ------------------------
VARFMSK-1=mask_gridT.nc
VARFMSK-2=mask_gridT.nc
VARFMSK-3=mask_param.nc
VARFMSK-4=mask_param.nc
VARFMSK-5=mask_param.nc
...

# OBSERVED VARIABES
#-----------------
DTA_ACT-1=.TRUE.
OBSNDBS-1=1
OBS_NAM-1:1=SST
```

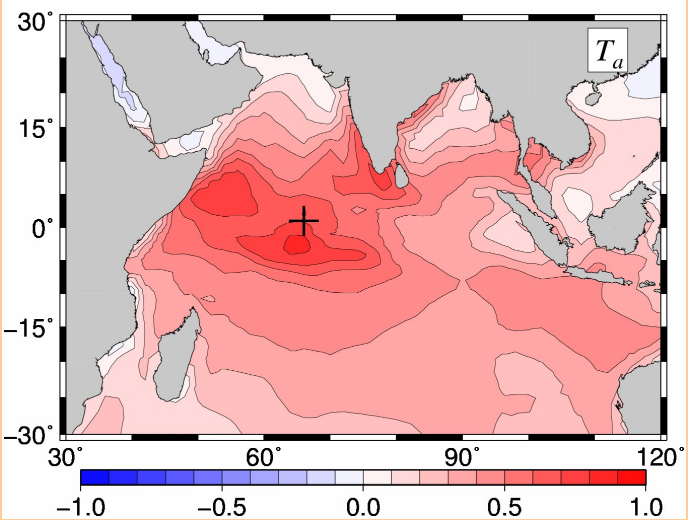
Low resolution NEMO configuration
for the **global ocean (ORCA2)**

Compute EOFs for the augmented control vector

```
1)Produce NEMO ensemble forecast
  with random atmospheric perturbations
2)sesam -mode geof -inxbas ens0100.nc.bas
        -outxbas eof0100.nc.bas
```

Diagnose correlation patterns

```
sesam
 -mode corr
 -inxbas
  eof0100.nc.bas
 -outvar
  correl#.nc
 -incfg par.cfg
```



Example 2: Estimation of atmospheric forcing parameters

... continued SESAM scripting ...

Extract observation from SST database file

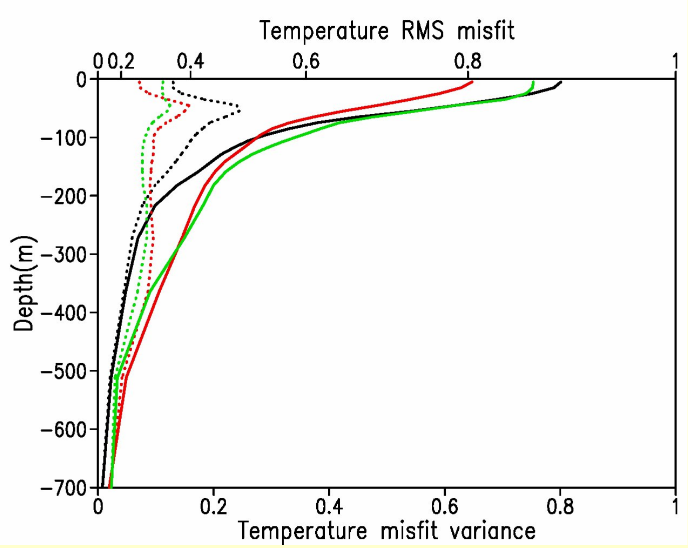
```
sesam -mode obsv -indbs sst_database.cdbs
                 -outobs obs#.cobs -affectobs SST
```

Estimate forcing correction (here with global observational update)

```
sesam -mode lroa -inobs obs#.cobs -invar xf#.nc -outvar xa#.nc
      -inxbas eof0100.nc.bas -outxbas Pa0100.nc.bas
```

Diagnose RMS misfit
with respect to observations

```
sesam -mode diff -inobs obs#.obs
      -diffobsref xf#.nc
      -configobs obs#.obs
```



Example 3: Coupled circulation/ecosystem configuration

Configuration file

```
# CONTROL VARIABLES
# -----------------
VAREND=8
# Temperature:
VAR_NAM-1=TEM
VAR_DIM-1=3
# Salinity:
VAR_NAM-2=SAL
VAR_DIM-2=3
# Chlorophylle:
VAR_NAM-3=CHL
VAR_DIM-3=3
# Zooplankton:
VAR_NAM-4=ZOO
VAR_DIM-4=3
...

# DEFINITION OF MASK FILES
# ------------------------
VARFMSK-1=mask_gridT.nc
VARFMSK-2=mask_gridT.nc
VARFMSK-3=mask_bio.nc
VARFMSK-4=mask_bio.nc

# OBSERVED VARIABES
#------------------
DTA_ACT-3=.TRUE.
OBSNDBS-3=2
OBS_NAM-1:1=MERIS
OBS_NAM-1:2=MODIS

# NetCDF FILE FORMAT
# ------------------
...
```

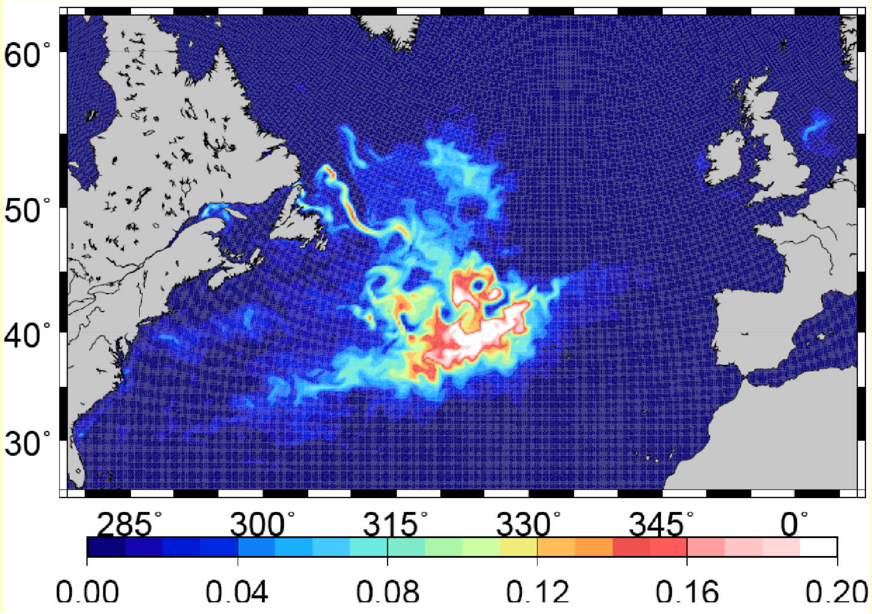
1/4° NEMO/LOBSTER configuration
for the **North Atlantic (NATL4)**

Diagnose statistics of model uncertainties

1) Produce NEMO/LOBSTER ensemble forecast simulating model uncertainties
2) Diagnose ensemble standard deviation:

```
sesam -mode oper -incfg list-of-files.cfg
      -outvar std#.nc -typeoper std
```

ZOO standard deviation



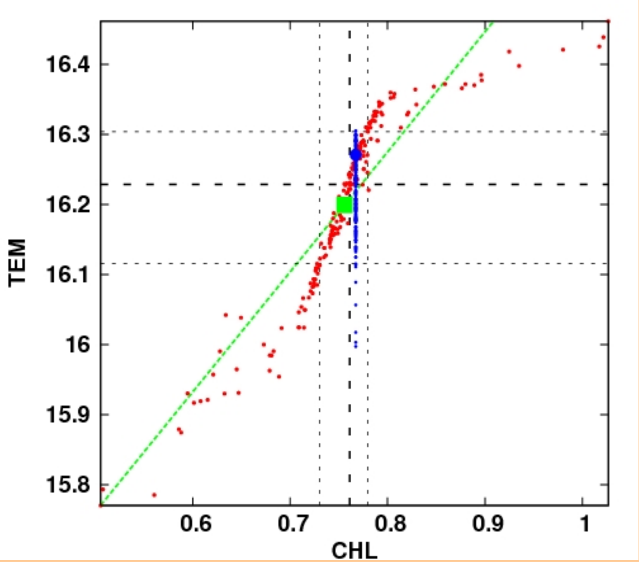
Example 3: Coupled circulation/ecosystem configuration

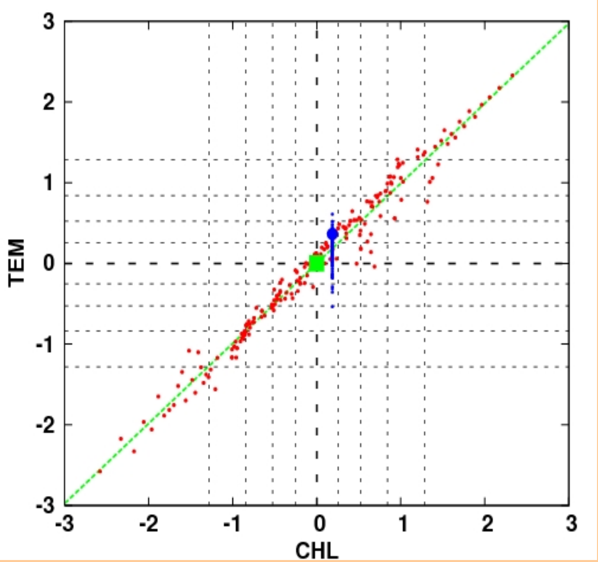
<u>Compute percentiles of the ensemble forecast</u>

```
sesam -mode anam -inxbas ens0200.nc.bas
                 -outxbasref perc0020.nc.bas
```

<u>Use these percentiles to transform each variable into quasi Gaussian variables **(anamorphosis)**</u>

```
sesam -mode anam
 -inxbasref
  perc0020.nc.bas
 -invar x#.nc
 -outvar y#.nc
 -typeoper +
```





It is then possible to perform **any other SESAM operation** using the transformed variables: EOFs, observational update, diagnostics,...

A few practical examples : summary

Illustrated modules:

-EOF computation
-Global and local Gaussian observational update
-Extraction of observations from a database
-Localization of covariance matrices
-Computation of correlations or representers
-Computation of RMS misfits
-Anamorphosis transformations

Non-illustrated modules:

-Estimation of adaptive inflation factors
-Sampling of a truncated Gaussian distribution

All examples performed with one single executable

SESAM in SANGOMA

SESAM governed by the CeCill public license.

SESAM is mainly used with NEMO,
but SESAM is not specific to NEMO,
not even to ocean models...

SESAM is basically a research tool:
intended to remain close to theoretical formulations,
flexible enough for generic developments,
efficient enough for realistic applications ($n \sim 10^8$).
No special design for extreme systems
(as in SAM2/Mercator).

SESAM website: http://www-meom.hmg.inpg.fr/SESAM

5. The NEMO ocean model

Ocean Modelling System developed and managed by the NEMO Consortium

Mercator	CNRS	CMCC	INGV	UKMO	NERC
Operational	Research	Climate	Operational	Operational	Research

WIDE and DIVERSE COMMUNITY OF USERS

Research ⟷ **Operational**

NEMO home page

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About NEMO | About Us

What is NEMO?

NEMO (Nucleus for European Modelling of the Ocean) is a state-of-the-art modeling framework for oceanographic research, operational oceanography seasonal forecast and climate studies.
NEMO includes:

- 5 major components
  - the blue ocean (ocean dynamics, NEMO-OPA)
  - the white ocean (sea-ice, NEMO-LIM)
  - the green ocean (biogeochemistry, NEMO-TOP) ;
  - the adaptative mesh refinement software (AGRIF) ;
  - the assimilation component NEMO_TAM
- some reference configurations allowing to set-up and validate the applications ;
- a set of scripts and tools (including pre- and post-processing) to use the system.

NEMO is used by a large community: 240 projects in 27 countries (14 in Europe, 13 elsewhere), 350 registered users (numbers for year 2008). See "NEMO Projects"

NEMO is available under the CeCILL license (public license).
To gain access to the system, you need to register (click here or on "Register" in top right panel).

The evolution and reliability of NEMO are organised and controlled by a European Consortium created in 2008 between

- CNRS (France),
- Mercator-Ocean (France),
- NERC (UK)
- UKMO (UK). , and since 2011
- CMCC (Italy)
- INGV(Italy)

"Purpose of the Consortium
The purpose of this Agreement is to set up appropriate arrangements for the successful and sustainable development of the NEMO System as a well-organised, state-of-the-art ocean model code system suitable for both research and operational work."

Text of the Consortium Agreement is here:
AC_NEMO_VF.txt.pdf 3.35 MB

NEMO is a shared reliable evolving system. These objectives rely on the work of the **NEMO System Team**.

News

NEMO Consortium
INGV and CMCC new members

2011 NEMO Users meeting
2011 NEMO Users meeting 29-30 June 2011

NEMO release nemo_v_3_3_1
Annoucement of nemo_v3_3_1 12 April 2011

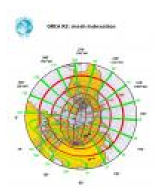
NEMO release nemo_v3_2_2 and its adjoint model (for dynamics)
Annoucement of nemo_v3_2_2 and adjoint 12 April 2011

« **November** »

Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	3	4	5	6
7	8	9	**10**	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Gallery

North pole meshmask



NEMO user guide

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User Guides | Configurations | FAQ | NEMO Browser | NEMO Mailing List Archives | Pre and post processing packages

Basics

NEMO Quick Start Guide

To allow easy set up of NEMO in your environement.

CPP keys V3_3

List cpp keys and functions

Detailed Launching Guide

This article is designed to give you the principal steps to install and lauch a simulation.
NEMO System (codes and environment) is available throught a general structure called MODIPSL, used for all models and configurations at IPSL.

Target platforms

Some computers on which NEMO is in use

Examples

You can find here some examples on common operations. This article is meant to be regularly updated as more typical use-cases can be found. Feel free to contribute !

ARCHIVES

Previous versions

Advanced

Using Trac

To start with Trac for NEMO

Using and developping with dynamical allocation

Implementation of dynamical allocation in NEMO (since tag v3_3_1)

How to set up one simulation

This article deals with setting up your simulation, from input files to run configuration (with comments for each parameter), as well as restart files and parallel runs.

How to add/ modify [new] modules or new cpp keys

Check out this article to know everything there is to know on CPP keys.

How to build a new configuration

Read this if your looking for information about building your configuration and preparing the necessary input files.

Getting and installing NEMO

NEMO Quick Start Guide

Table of contents

Installing NEMO using FCM (since nemo_V3_3)

For general information on the content of NEMO reference and differences between reference and specific configurations, see here

Requirements:

- bash installed
- perl installed
- svn installed
- fortran90 compiler installed
- netcdf installed

FCM (Flexible Configuration Manager, developped at UKMO ©Crown Copyright 2005-10) is used for build process only, i.e. from the source code to the executable.

Installation

Extract NEMOGCM (using the "my_login" /pw registered on this web site):

```
svn --username "my_login" co http://forge.ipsl.jussieu.fr/nemo/svn/tags/nemo_v3_3/NEMOGCM
```

The main script is called **makenemo,** located in the CONFIG directory.To identify the source code you need, build the makefile and run it:
RUN makenemo:

```
cd NEMOGCM/CONFIG; ./makenemo [options, see below]
```

Getting started with NEMO

1) Register to the NEMO website:
get login and password

2) Browse the documentation

3) Get the source code (with svn):
as explained in the Quick Start Guide

4) Compile one of the reference configuration,
e.g. the configuration GYRE_LOBSTER:
makenemo -n GYRE_LOBSTER -m ifort_linux

5) Run your first simulation:
with example parameter file in directory *'EXP00'*

NEMO website: http://www.nemo-ocean.eu/

Input required to run a NEMO configuration

For instance: DOUBLE_GYRE or NATL4_LOBSTER (medium and large case SANGOMA benchmarks)

1) Modifications to default NEMO source code (if any)

2) List of precompilation options (cpp keys)

3) Appropriate parameter file (NEMO namelist)

4) Input data (if any): bathymetry, model grid atmospheric forcing, river runoff, ...