Upper Ocean Model Physics Development

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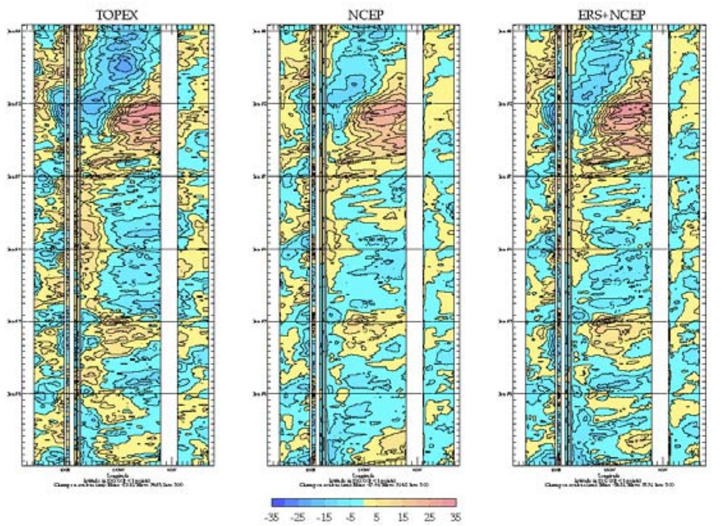
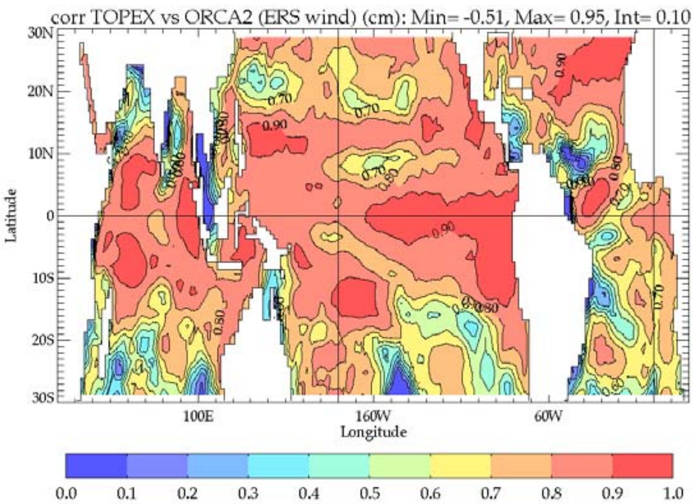
1 - *Tropical ocean dynamics*

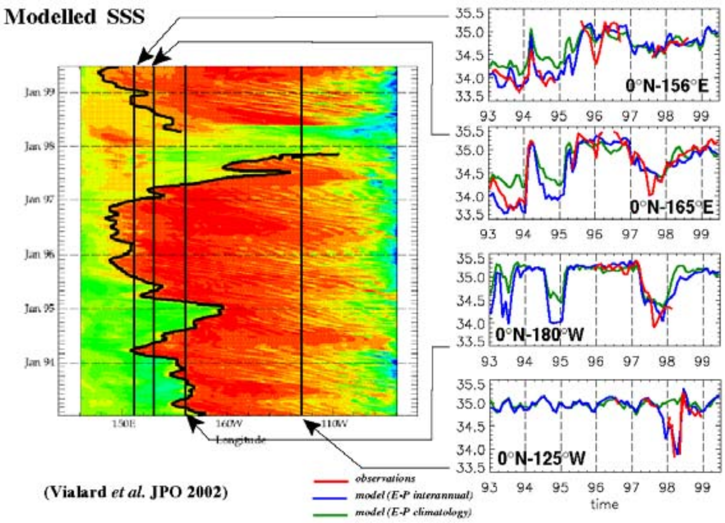
- *Now-a-day OGCM qualities and why (ORCA2 as a example)*
- *Incoming Problems with increasing resolution*
- *Recent development: isopycnal momentum mixing*

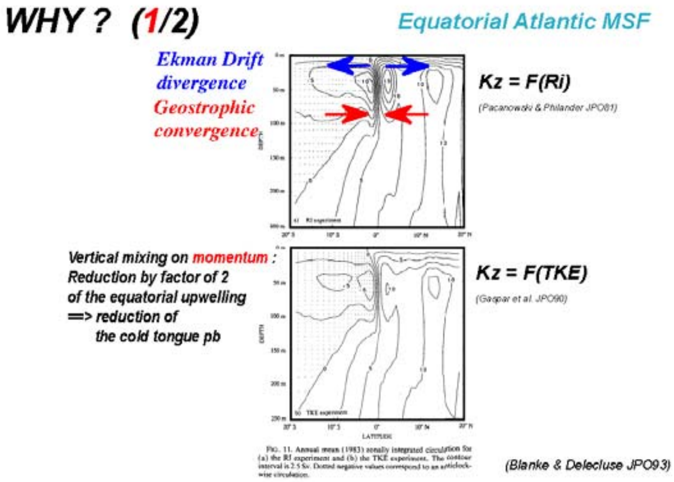
2 - *Mid and high latitudes dynamics*

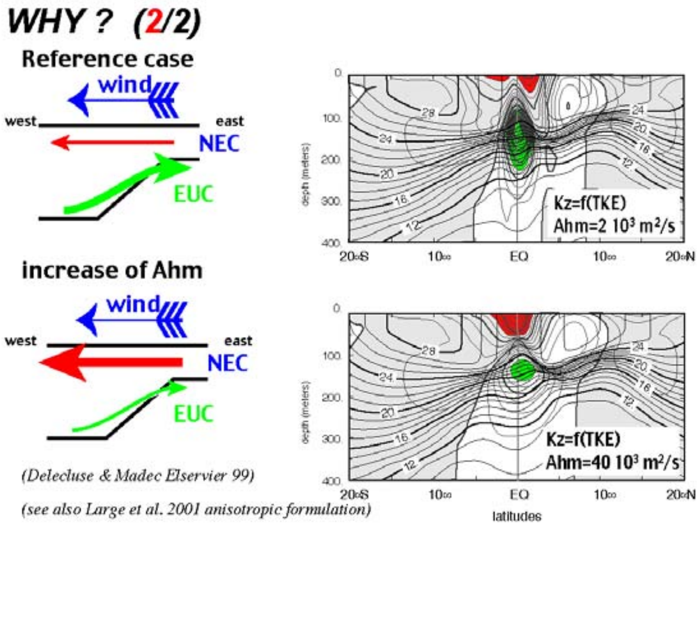
- *Lessons from HadOPA Coupled simulations*
  ==> Need of mixed layer improvment
- *Deep convection : the Labrador Sea example in CLIPPER projet*
  ==> Need of efficient way to better mimic the eddy effects even for "eddy resolving" configurations

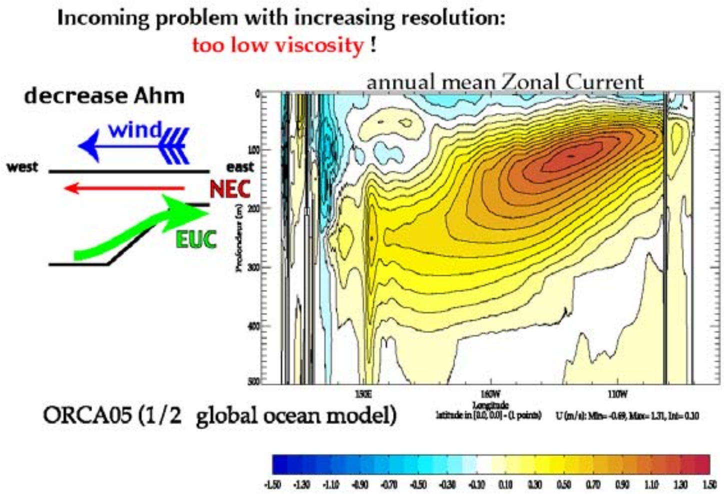


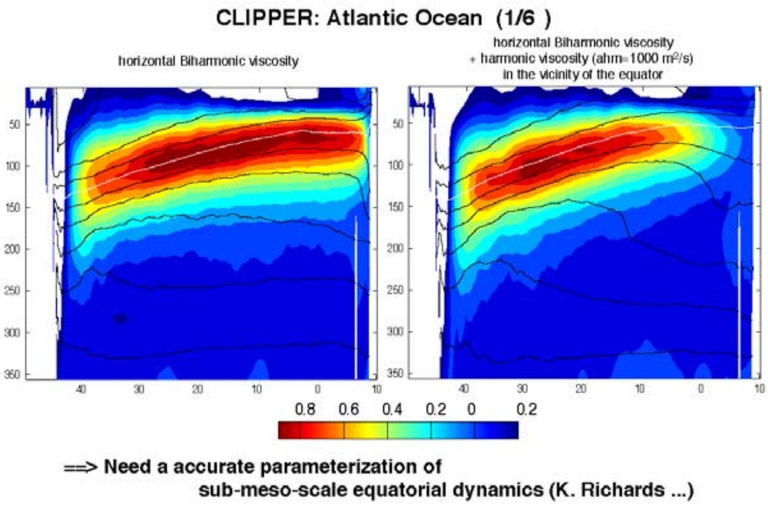


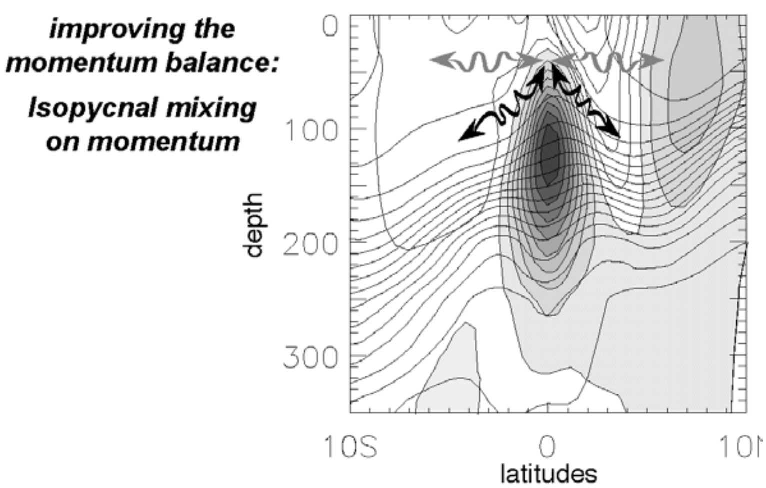

Modelled SSS
Jan 99
Jan 98
Jan 97
Jan 96
Jan 95
Jan 94
150E
160W
110W
Longitude
0°N-156°E
0°N-165°E
0°N-180°W
0°N-125°W
time
observations
model (E-P interannual)
model (E-P climatology)
(Vialard et al. JPO 2002)

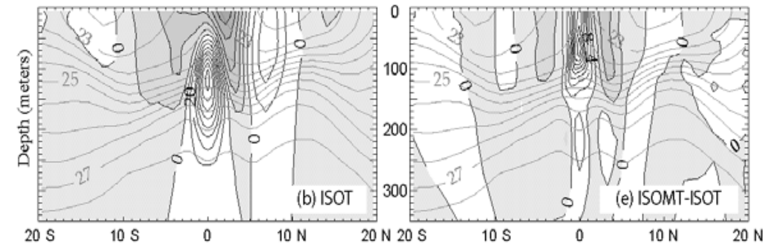

WHY ? (1/2)
Equatorial Atlantic MSF
Ekman Drift
divergence
Geostrophic
convergence
Kz = F(Ri)
(Pacanowski & Philander JPO81)
Vertical mixing on momentum :
Reduction by factor of 2
of the equatorial upwelling
==> reduction of
the cold tongue pb
Kz = F(TKE)
(Gaspar et al. JPO90)
(Blanke & Delecluse JPO93)

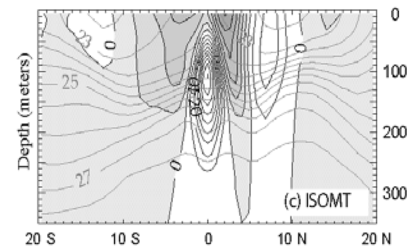

WHY ? (2/2)
Reference case
wind
west
east
NEC
EUC
Kz=f(TKE)
Ahm=2 10³ m²/s
increase of Ahm
wind
west
east
NEC
EUC
Kz=f(TKE)
Ahm=40 10³ m²/s
depth (meters)
latitudes
(Delecluse & Madec Elservier 99)
(see also Large et al. 2001 anisotropic formulation)


Incoming problem with increasing resolution:
too low viscosity !
decrease Ahm
wind
west
east
NEC
EUC
annual mean Zonal Current
ORCA05 (1/2 global ocean model)

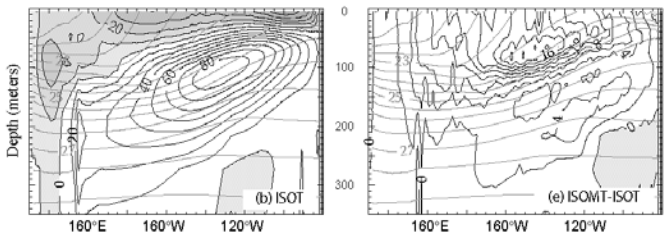

CLIPPER: Atlantic Ocean (1/6)
horizontal Biharmonic viscosity
horizontal Biharmonic viscosity
+ harmonic viscosity (ahm=1000 m²/s)
in the vicinity of the equator
0.8 0.6 0.4 0.2 0 0.2
==> Need a accurate parameterization of
sub-meso-scale equatorial dynamics (K. Richards ...)

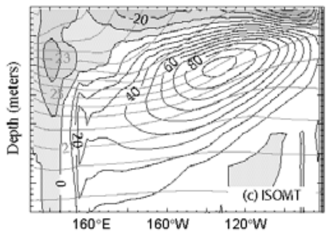

improving the
momentum balance:
Isopycnal mixing
on momentum
depth
latitudes
10S
0





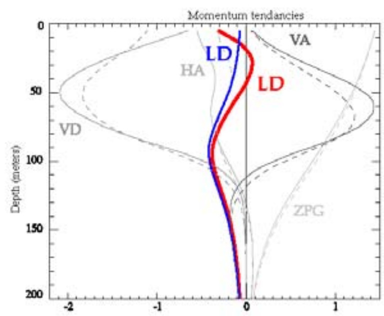
Meridional section of mean 1993-96 zonal current superimposed to density along 140 W for the ISOT, ISOMT, and ISOMT-ISOT.



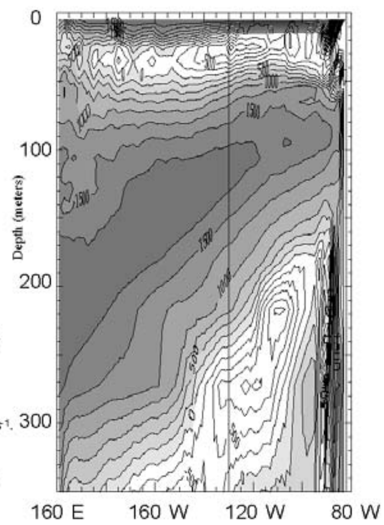


Equatorial section of mean 1993-96 zonal current superimposed to density for ISOT, ISOMT, and ISOMT - HOR.

(Lengaigne et al. 2003, submitted)



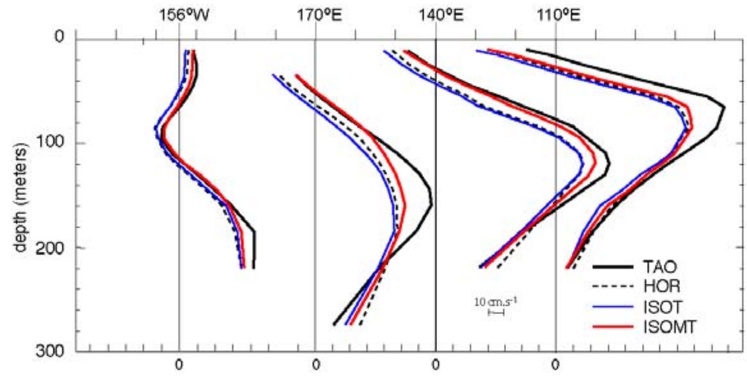
Vertical profiles of mean 1993-96 zonal momentum equation terms (10^6 m.s^{-2}) at the equator averaged at 140 W for ISOT (dashed lines) and ISOMT experiment (continuous lines).



Equivalent horizontal viscosity coefficient for ISOMT experiment. Contour interval is 500 m^2 s^{-1}.

==> Better mimic the observed eddy effect (Bryden & Brady JMR89, Lukas JGR87)

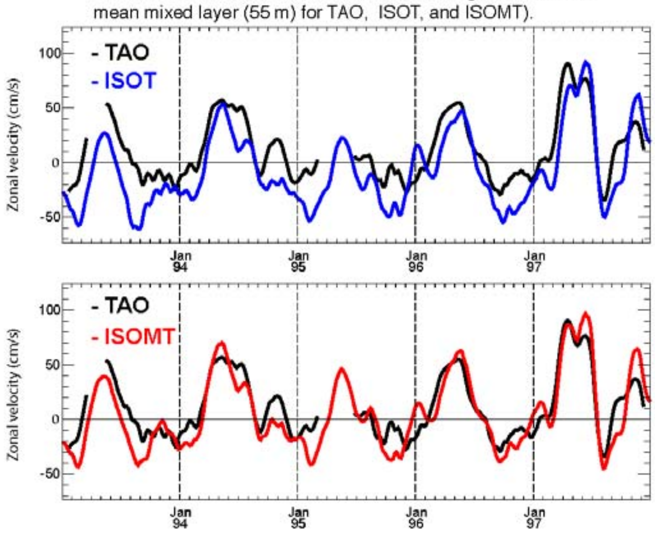
(Lengaigne et al. 2003, submitted)



mean 1993-96 zonal velocity profiles for TAO data and the three experiments (HOR, ISOT, and ISOMT) at TAO mooring locations: 156°E, 170°W, 140°W, 110°W.

(Lengaigne et al. 2003, submitted)

Time evolution of zonal currents at 140°W integrated over the mean mixed layer (55 m) for TAO, ISOT, and ISOMT).



OPA - Modelling System
LODYC - IPSL

Surface layer Ocean Physics Developments

Gurvan Madec

ECMWF, nov. 20002

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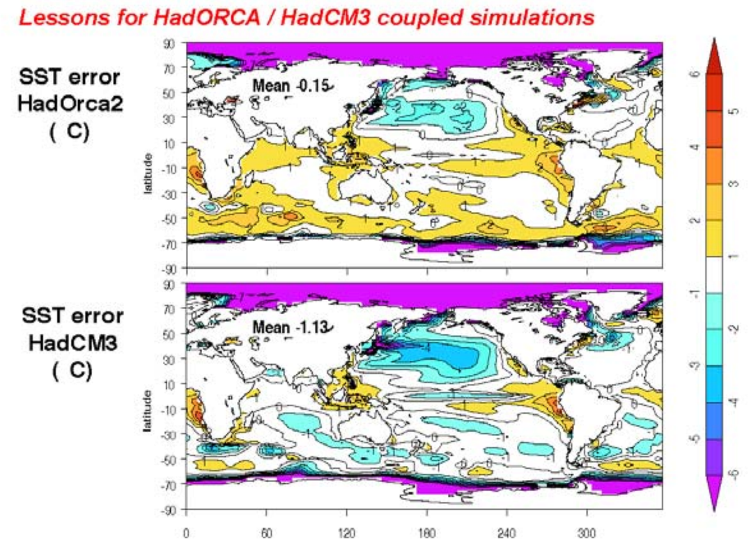
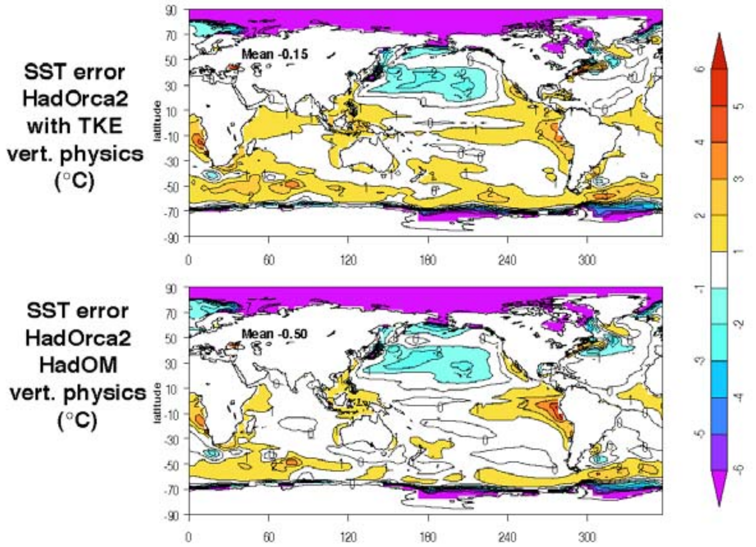
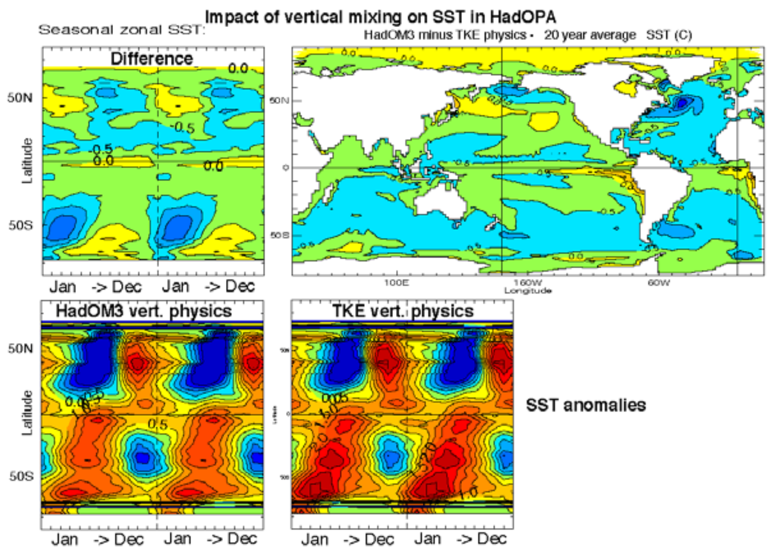


Lessons for HadORCA / HadCM3 coupled simulations
SST error
HadOrca2
(C)
Mean -0.15
SST error
HadCM3
(C)
Mean -1.13
latitude



SST error
HadOrca2
with TKE
vert. physics
(°C)
Mean -0.15
SST error
HadOrca2
HadOM
vert. physics
(°C)
Mean -0.50
latitude



Impact of vertical mixing on SST in HadOPA
Seasonal zonal SST:
HadOM3 minus TKE physics - 20 year average SST (C)
Difference
Latitude
Jan -> Dec Jan -> Dec
HadOM3 vert. physics
TKE vert. physics
SST anomalies
Longitude

Problem: ***summer warm biases associated with a too shallow mixed layer***

TKE does not represent the effect of wind steering in heating condition

Need to improve the Mixed layer formulation

Solution:

set of a minimum mixed layer depth based on Monin-Oboukov length
(as in KPP or Timmermann & Beckmann 2002))

but - bound by the Ekman depth
- taking into account the ocean vertical motions (upwelling)

Promising tests in forced mode already performed

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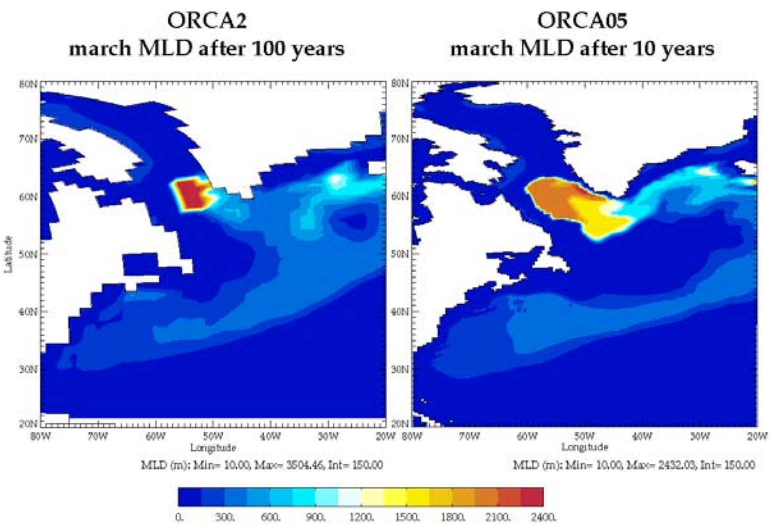
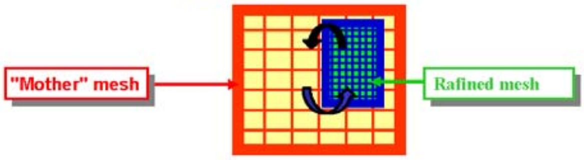


AGRIF: Adaptative Grid Refinement In Fortran

L. Debreu, E. Blayo



The two models runs simultaneously with information exchanges

From the mother model to the refined model (One way)

In both directions (Two ways)

Model Configuration

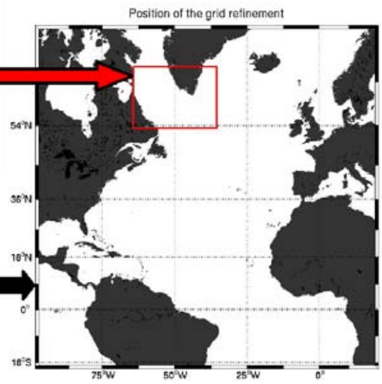
"Sister" mesh

- raffinement factor = 5 (1/15° ≈ 4 km)
- 432 x 322 x 43 points
- hor. biharmonic diffusion ($-2.\ E^{+9}\ m^{4}.s^{-1}$).
- bathymétry interpolated from NATL3

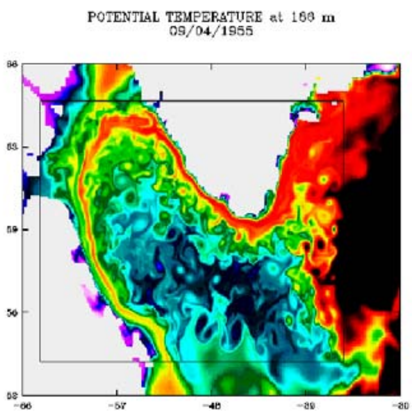
"Mother" mesh

NATL3 Configuration : 1/3°

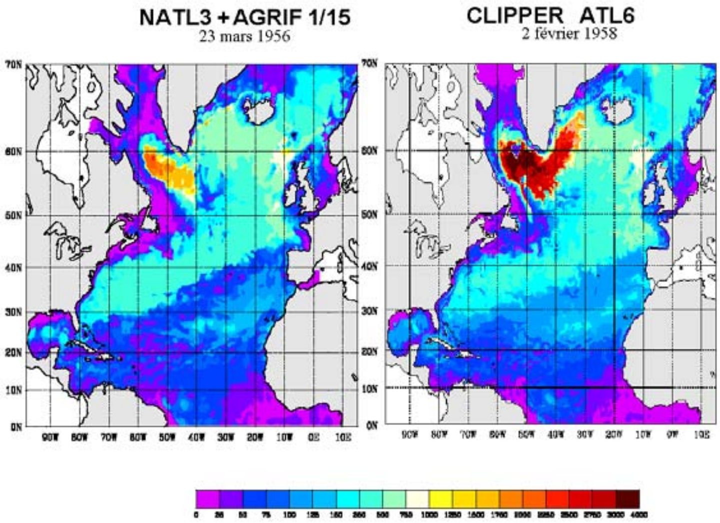
- TKE
- hor. Biharmonic diffusion ($-2.5\ E^{+11}\ m^{4}.s^{-1}$).
- monthly climatology
- Initial state: T. Reynaud. climatology

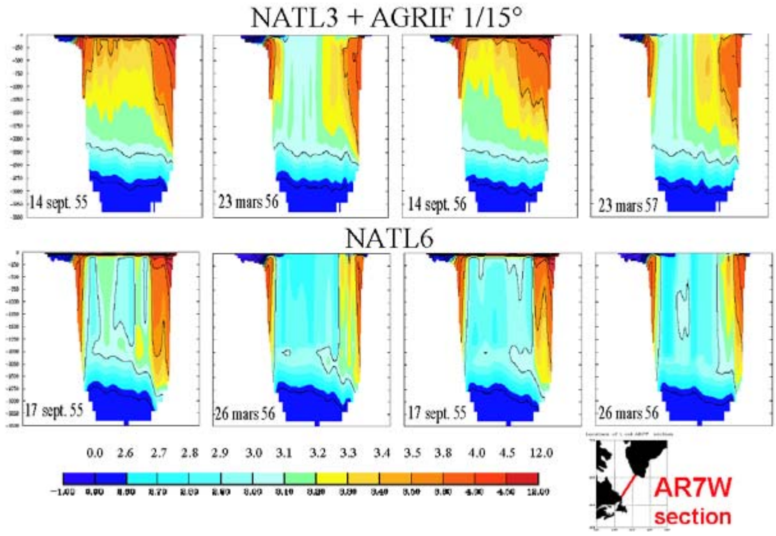


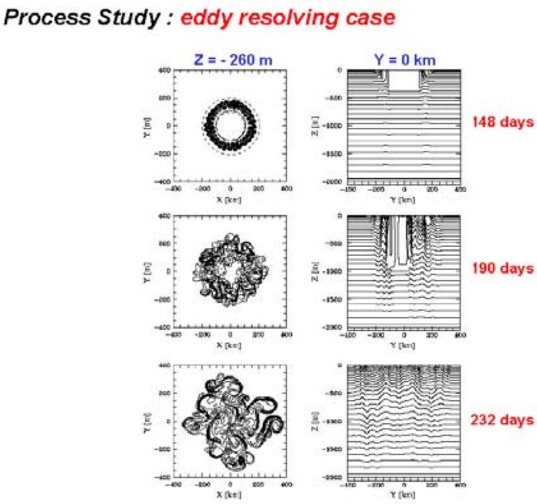
Time evolution of the Mixed layer



J. Chanut, B. Barnier, J.-M. Molines, A.-M. Tréguier & G. Madec


NATL3 +AGRIF 1/15
23 mars 1956
CLIPPER ATL6
2 février 1958


NATL3 + AGRIF 1/15°
14 sept. 55
23 mars 56
14 sept. 56
23 mars 57
NATL6
17 sept. 55
26 mars 56
17 sept. 55
26 mars 56
0.0 2.6 2.7 2.8 2.9 3.0 3.1 3.2 3.3 3.4 3.5 3.8 4.0 4.5 12.0
AR7W
section

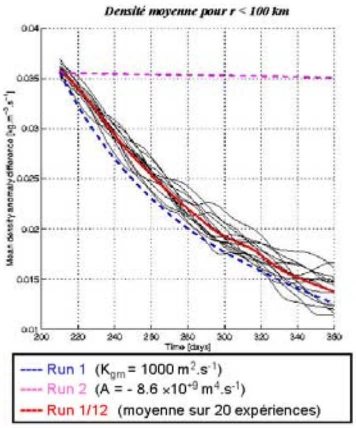

Process Study : eddy resolving case
Z = - 260 m
Y = 0 km
148 days
190 days
232 days

Process Study : non eddy resolving case

- Résolution 10 km (1/6)
- Conditions initiales : moyenne azimutale du profil de densité des 20 expériences au 1/12 à t = 210 jours + vitesses géostrophiques.

- Run 1 : **Gent McWilliams**
- Run 2 : **diffusion biharmonique**

==> Gent McWilliams OK with Aeiv = 1000 m²/s



Conclusion

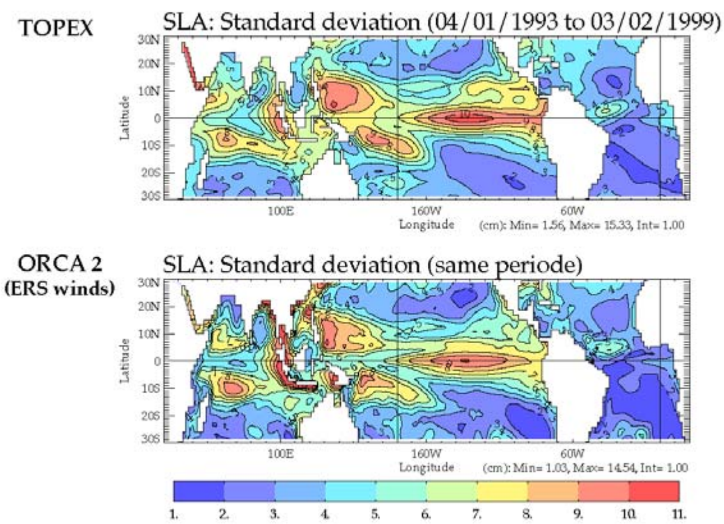
1 - Observed wind stress + TAO moorings ==> improved model physics in the tropics

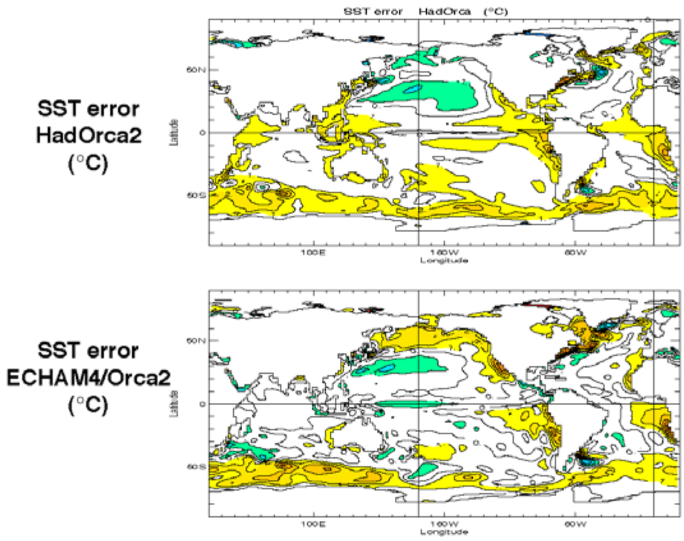
2 - With Now-a-day Climate OGCMs resolution :

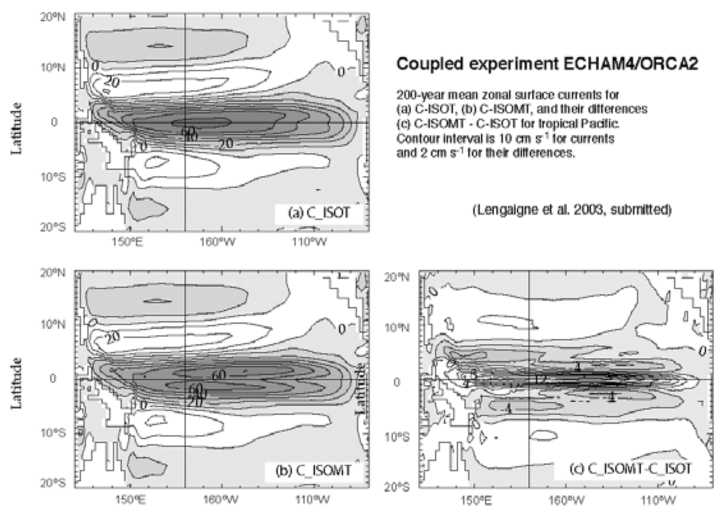
- ***lateral isopycnal physics for both dynamics and tracers (at least at the equator)***
- ***Eddy induced velocity in extra-tropics and better adjusted for deep convective area***
- ***vertical physics: TKE + wind steering parameterization (for mid/high latitudes)***

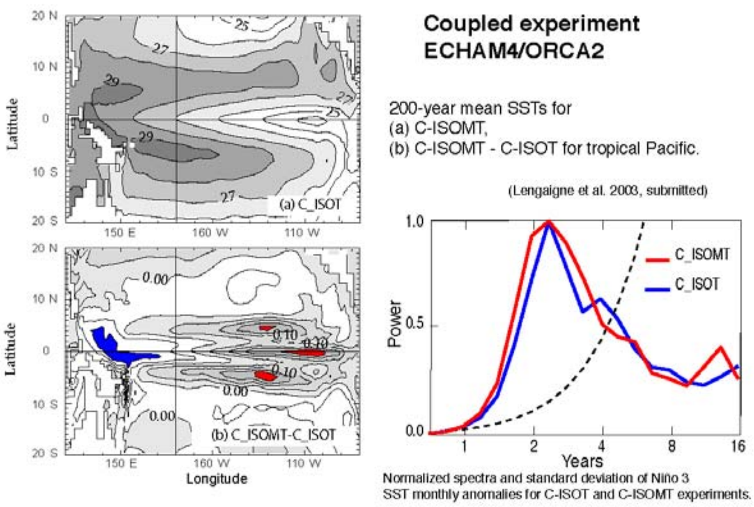
3 - Foreseen increase in resolution (up to 1/10) :

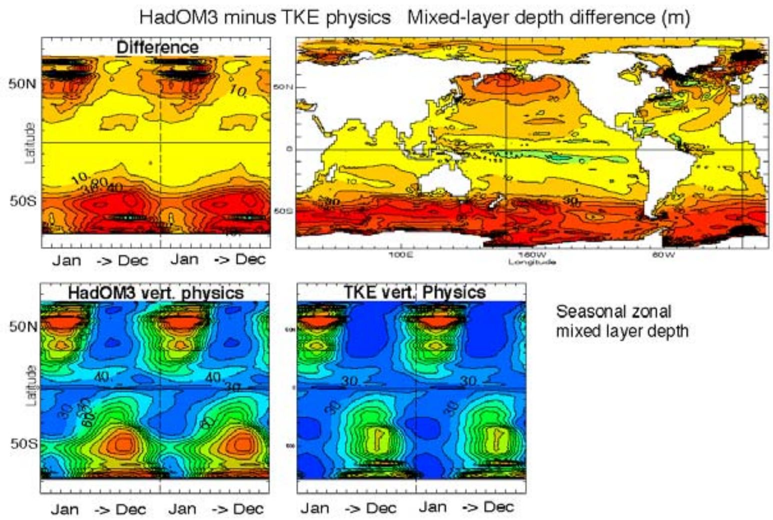
- ***Sub-meso-scale physics :***
  Need a physically based lateral physics at the equator (==> K. Richards....)
- ***still required eddy effect parameterisation :***
  Need a accurate parameterisation of restratification phase




SST error HadOrca (°C)
SST error
HadOrca2
(°C)
SST error
ECHAM4/Orca2
(°C)
Latitude
Longitude


Coupled experiment ECHAM4/ORCA2
200-year mean zonal surface currents for
(a) C-ISOT, (b) C-ISOMT, and their differences
(c) C-ISOMT - C-ISOT for tropical Pacific.
Contour interval is 10 cm s-1 for currents
and 2 cm s-1 for their differences.
(Lengaigne et al. 2003, submitted)
(a) C_ISOT
(b) C_ISOMT
(c) C_ISOMT-C_ISOT
Latitude
150°E
160°W
110°W


Coupled experiment
ECHAM4/ORCA2
200-year mean SSTs for
(a) C-ISOMT,
(b) C-ISOMT - C-ISOT for tropical Pacific.
(Lengaigne et al. 2003, submitted)
(a) C_ISOT
(b) C_ISOMT-C_ISOT
Latitude
Longitude
Power
Years
C_ISOMT
C_ISOT
Normalized spectra and standard deviation of Niño 3
SST monthly anomalies for C-ISOT and C-ISOMT experiments.


HadOM3 minus TKE physics Mixed-layer depth difference (m)
Difference
50N
Latitude
50S
Jan -> Dec Jan -> Dec
HadOM3 vert. physics
TKE vert. Physics
Seasonal zonal
mixed layer depth