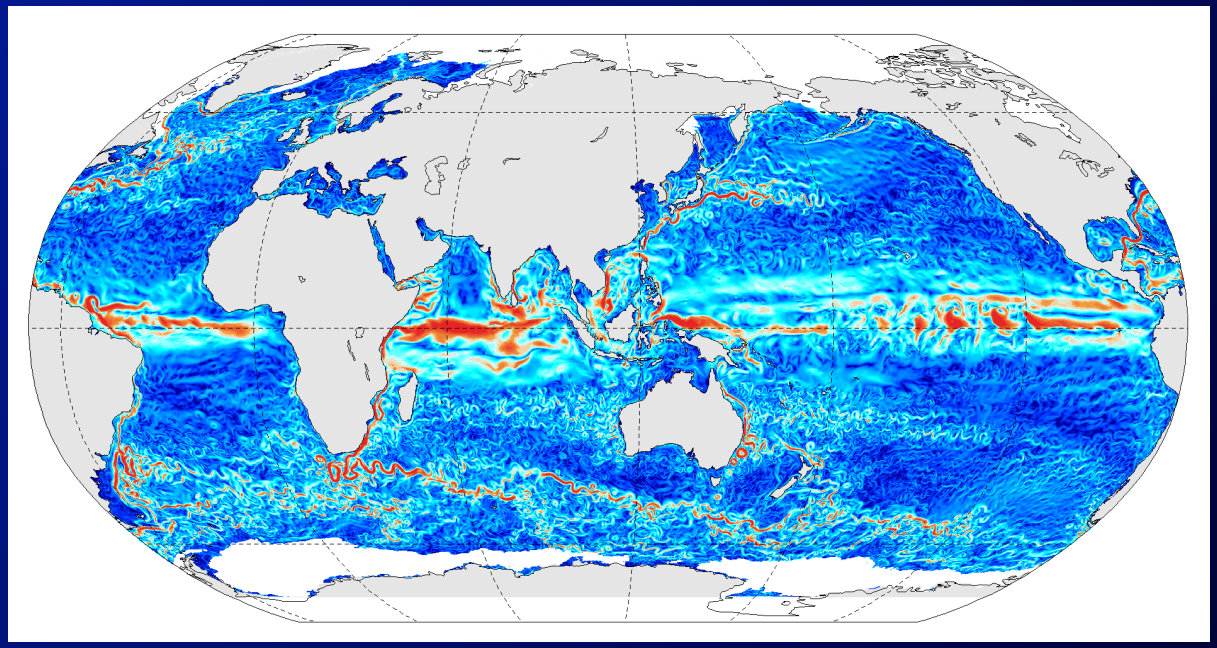
Challenges in high resolution global ocean modelling



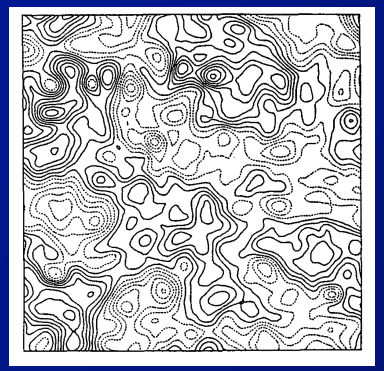
Instantaneous surface velocity in the 1/12° ORCA12 numerical model

A.M. Treguier, CNRS, LPO, Brest

With the Drakkar group and WGOMD

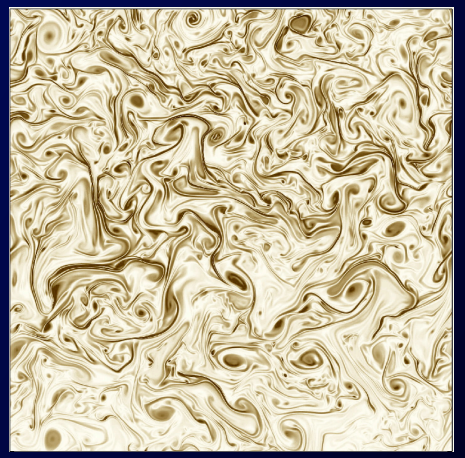
Ocean dynamics at high resolution

Dynamical scale: Rossby Radius



From 20km grid, Treguier and Hua (1987)

…. To O(1 km) grids (today)



Scale of the global ocean

First numerical model of the global ocean, Bryan and Manabe, JPO 1975.

6° by 4° grid

Why high resolution at the global scale?

1 – High resolution in forced ocean models, to resolve baroclinic eddies.

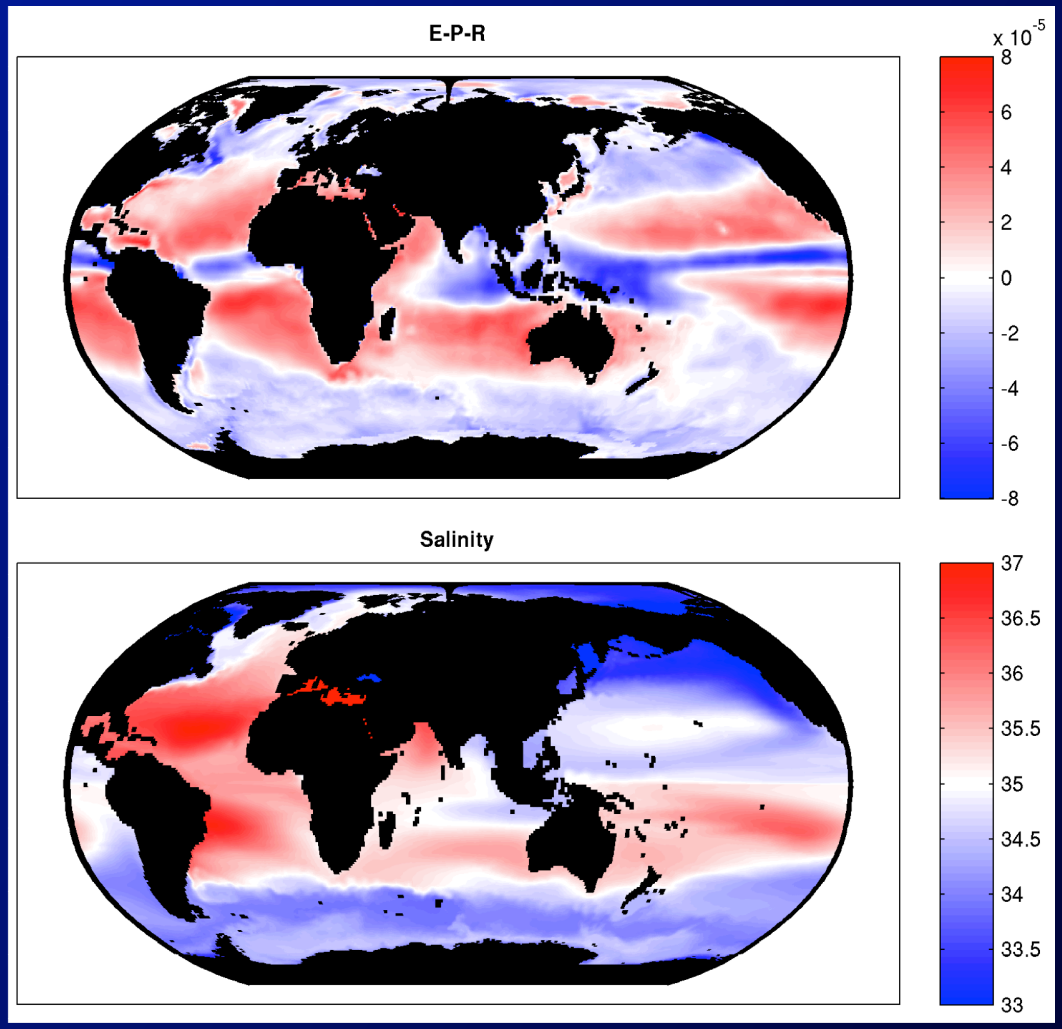
- Isopycnal mixing but also organization of diapycnal mixing
- Rectification: Neptune, intensification of eastward jets
- Transport by coherent structures and eddy-tracers correlations.

One exemple: Eddy transport of salt in the global ocean
(Treguier et al, Ocean Science 2014)

2 – High resolution ocean for coupled climate models:

Emergent processes?

What controls the distribution of salt in the ocean?



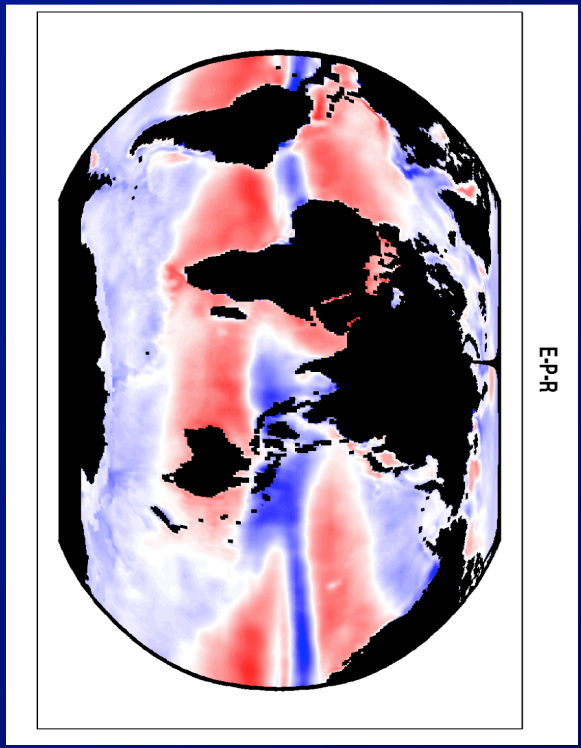
Balance between E-P-R …

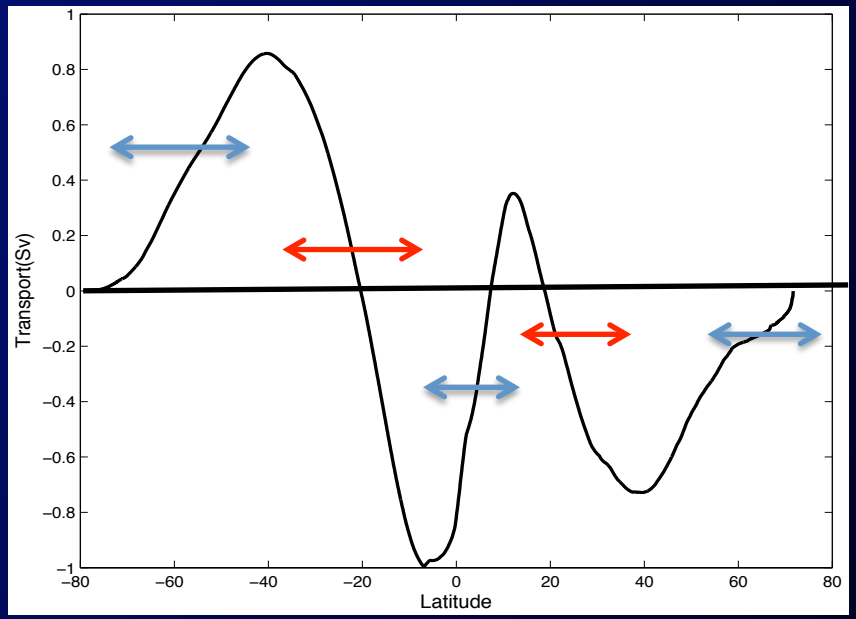
And transport by the ocean circulation

E-P-R: $Kg.m^{-2}s^{-1}$

Salinity (PSU) averaged over the top 200m

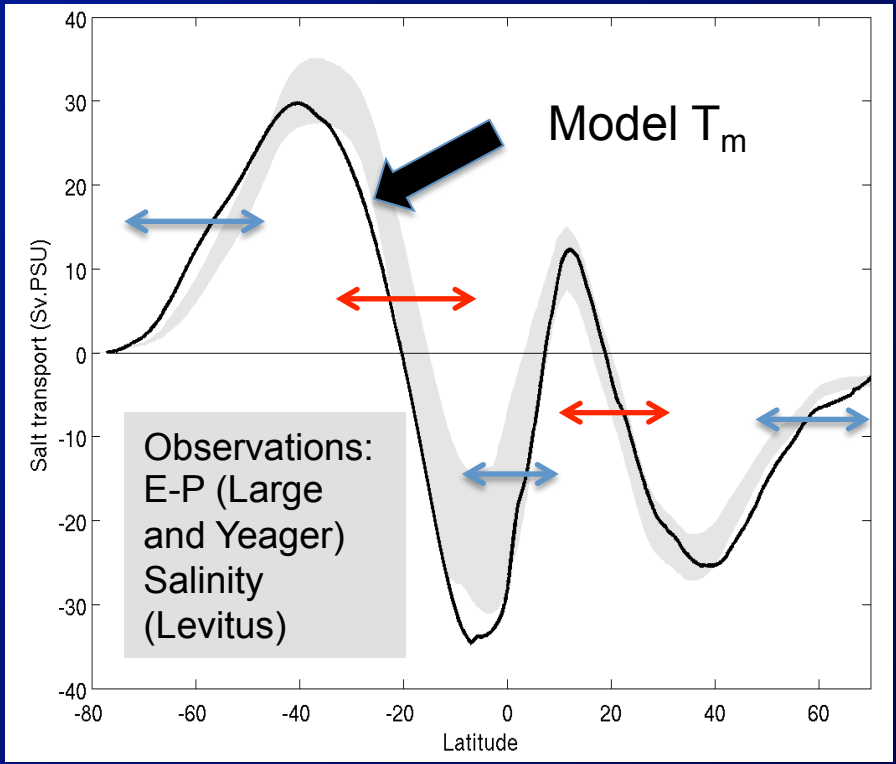
E-P-R: net mass transport





Total mass transport + salty water = transport of salt

Salt transport by the net mass flux



Numerical model:

DRAKKAR ORCA12 NEMO platform

84 years simulation

Climatological forcing

(Molines et al, LGGE, Grenoble)

www.drakkar-ocean.eu

How is the salt balance achieved?

$$F_0(y,t) = \iint_s v$$

$$S_0(y,t) = \frac{1}{A}\iint_s S$$

F_0 : volume flux across the section *s*
S_0 : salinity averaged over the section area *A*

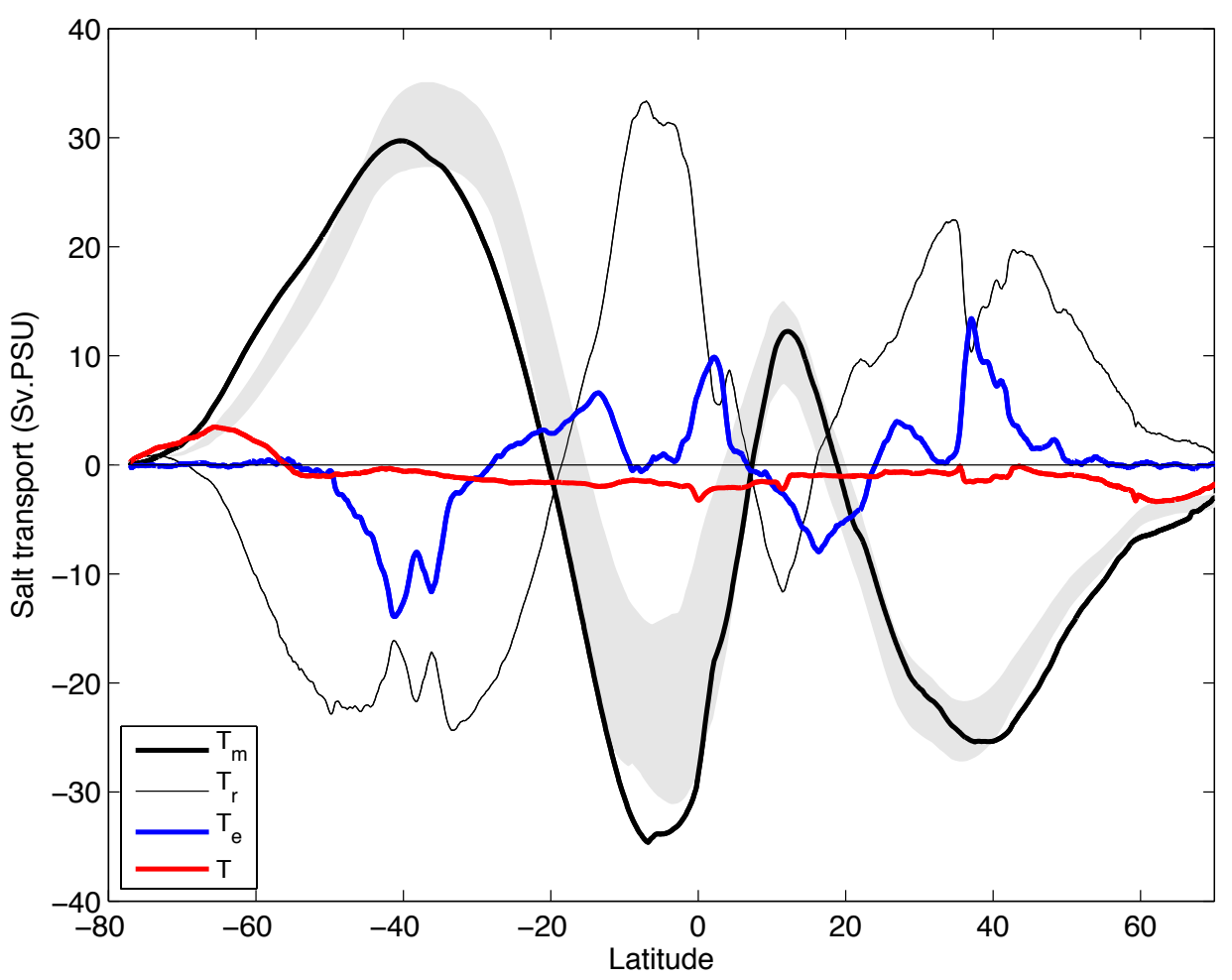
$$\iint_s vS = F_0 S_0 + \iint_s \overline{(vS)^*} + \iint_s \overline{v'S'}$$

T_m
Transport by net mass flux (related to E-P-R)

T_r
Transport by time-mean recirculation

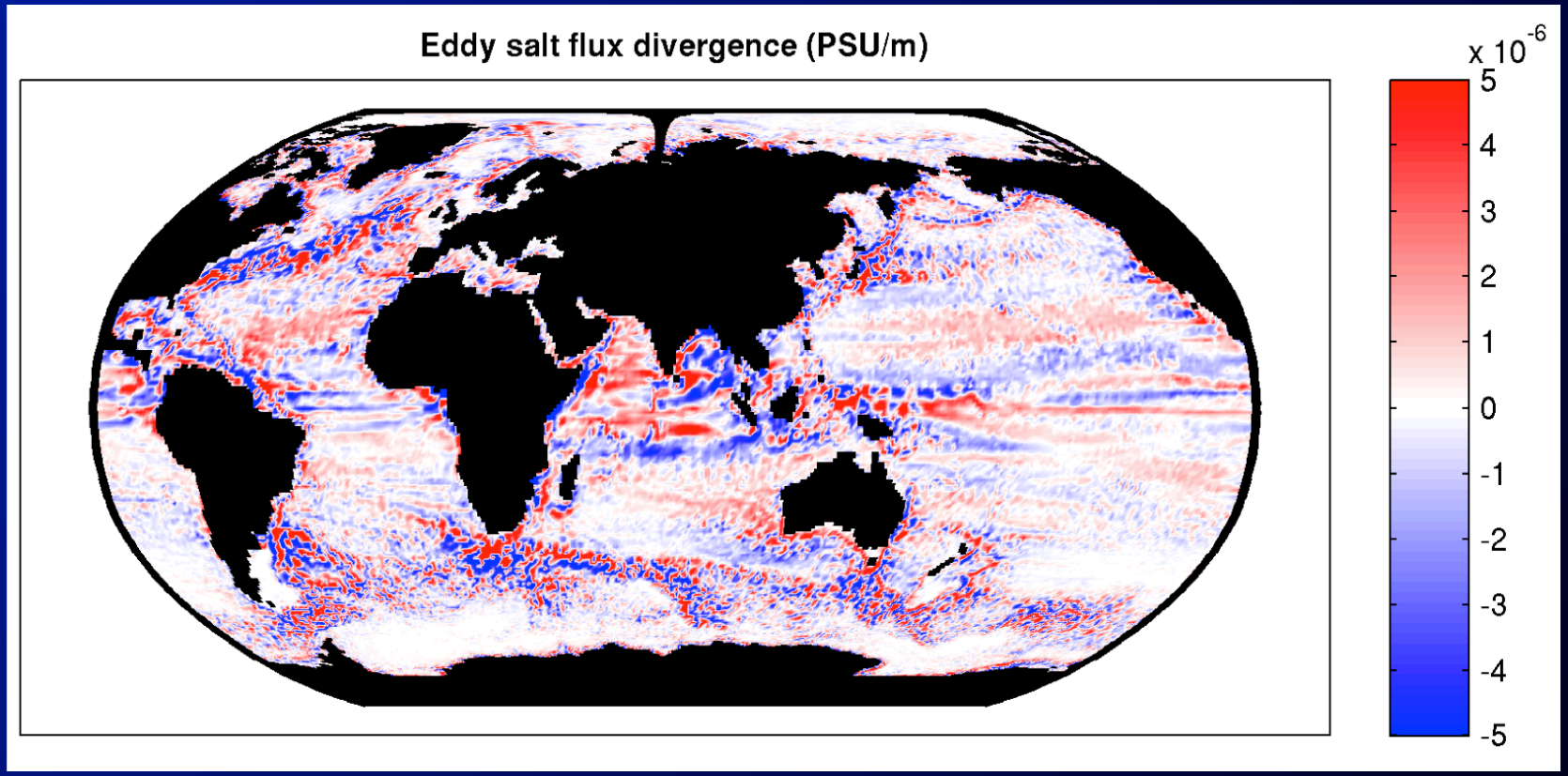
T_e
Transport by eddy fluctuations.

Eddies perform half the salt export out of the subtropical gyres!



Treguier et al, Ocean Science, 2014

Map of eddy salt flux divergence

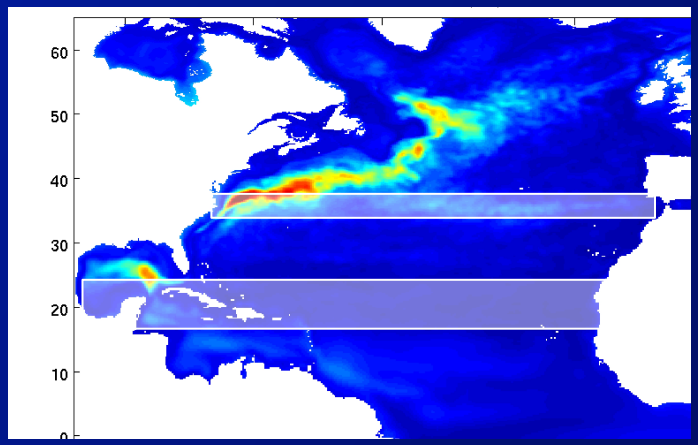


Equatorial region: waves, seasonal variability

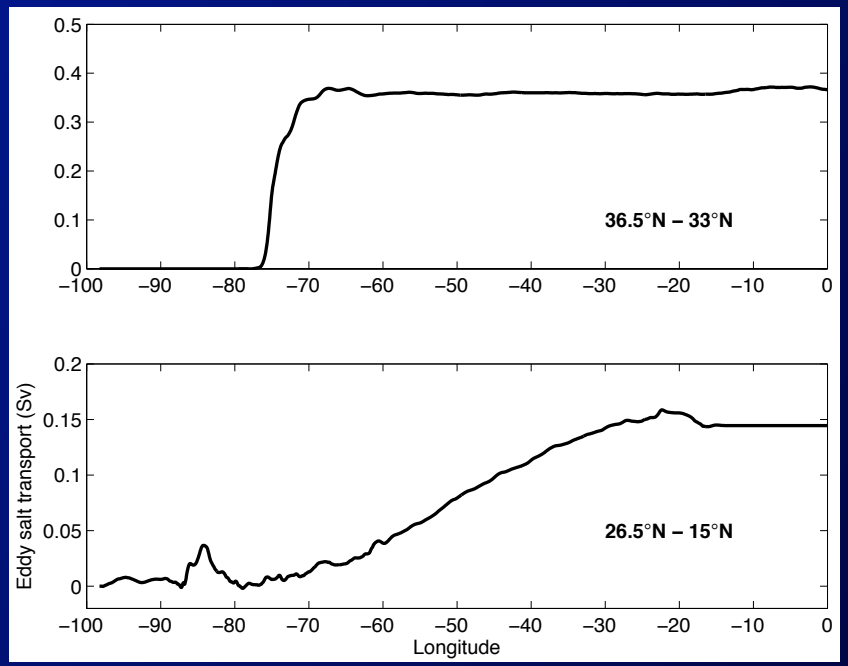
Tropics (15°-20°): basin-wide eddy propagation and waves

Mid latitudes (40°): western boundary currents

There is not just one mechanism for eddy transport



Divergence of eddy salt flux V'S' in a latitude band, cumulated as a function of longitude.



North of the subtropical gyre: transient behavior of the Gulf Stream separation

South of the subtropical gyre: westward propagating eddies and gyre (classical baroclinic instability?)

Treguier et al, JGR 2012

2- Ocean-atmosphere coupling at high resolution

GFDL: CM2.4 model, Ocean: ¼° isotropic grid.

Atmosphere: 1° *Farneti et al, 2010*

CM2.6 model, Ocean: 1/10°

Atmosphere: 50 km

UK MetOffice:

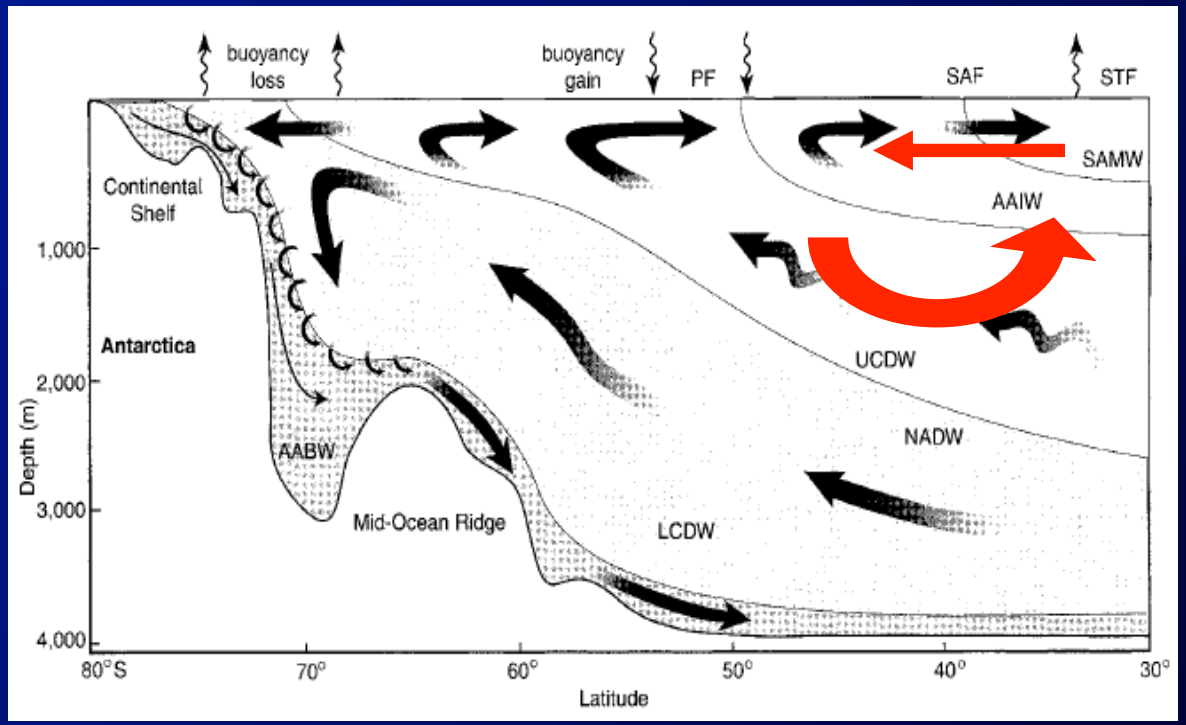
Use NEMO-ORCA025 (1/4°) for ocean forecasting, seasonal prediction and climate.

Plan for 2014: first ORCA12 coupled simulations with 17km atmosphere

Also presented in the WGOMD-Clivar workshop, Kiel, april 2014:

JMA/MRI, MIROC, NCAR, DOE MPAS, MPI-Hambourg, Cerfacs, EC-earth, CMCC, Bergen…

Eddy effect on Southern Ocean MOC?



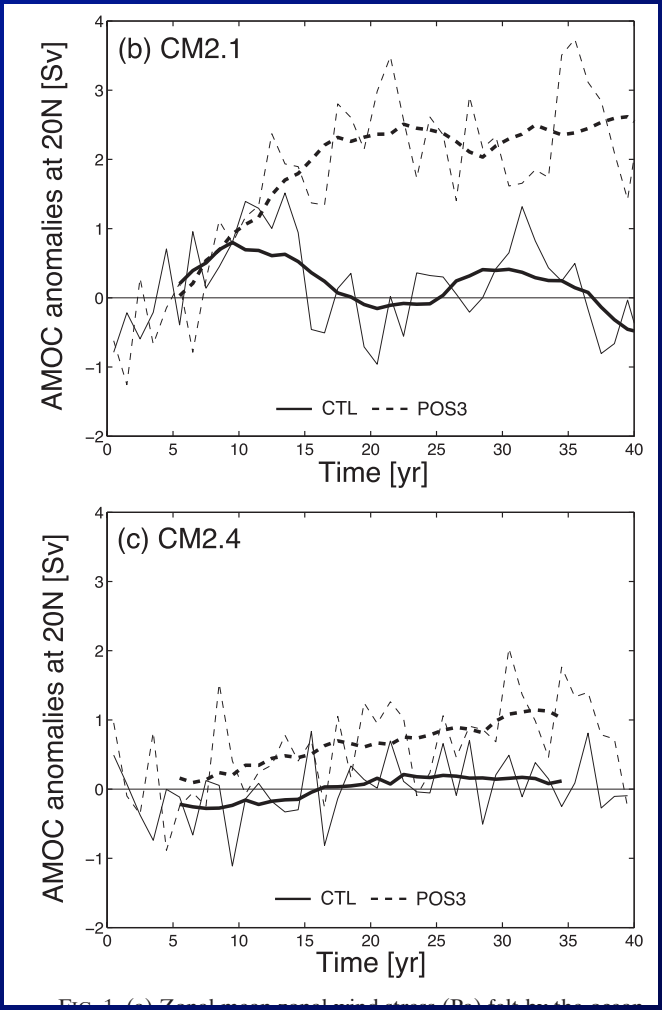
Mean flow: equatorward at the surface (Ekman)

Eddies: opposite direction (circulation tends to flatten isopycnals)

Speer et al, 2001: Ψ^* = residual MOC = diabatic Deacon cell

When Ekman transport increases (SAM increase from 1979 to 2000), do the eddies compensate?

Eddies dramatically change the coupled response to perturbations



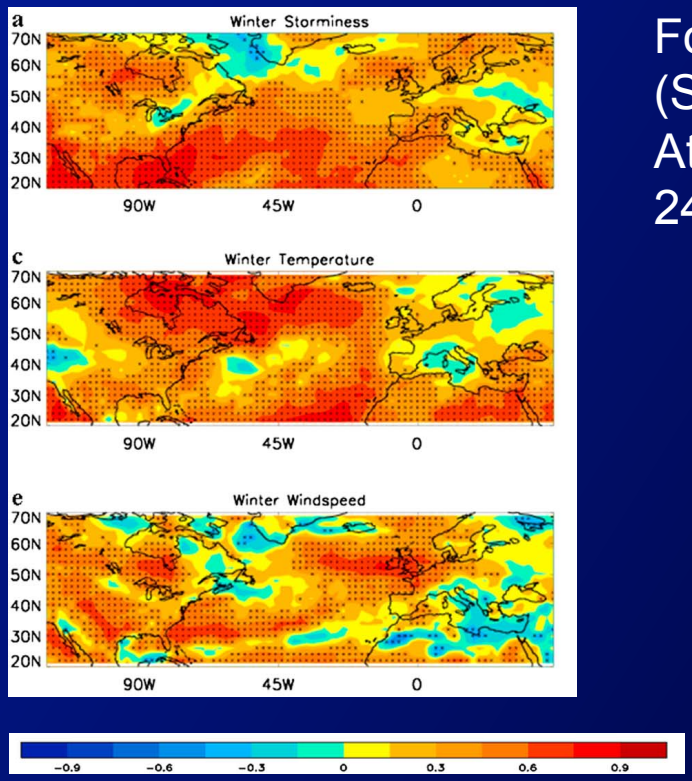
Farneti et al, JPO 201O.

Low resolution climate model: wind increase = MOC increase

Higher resolution, eddy permitting ocean: not much MOC increase. Eddy compensation.

Effects on predictability of the NAO?

High resolution atmosphere and ocean: better winter blocking, better air-sea fluxes (less bias in the northwest corner) Scaife et al 2011.



Forecast skill of surface winter conditions (Scaife et al 2014).
Atmosphere: 0.8°x0.5°, ORCA025,
24-member ensembles for winters 1993 to 2012.

Consequence: better representation of teleconnections, potential predictability of the winter NAO with 1 to 4 months lead time?

(Scaife et al GRL 2014)

… but what are the physical mechanisms?

Challenges for high resolution coupled ocean-atmosphere models

Ocean eddies have a significant contribution to large scale meridional transports, Southern ocean MOC, etc.

Coupling high resolution ocean and atmosphere: emergent behavior?

- High resolution models are required to understand processes : but analysis is a « big data » problem!

- Can high resolution models help design enhanced parameterizations?