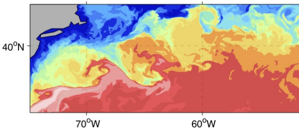
OCEAN TURBULENCE WITH BASILISK

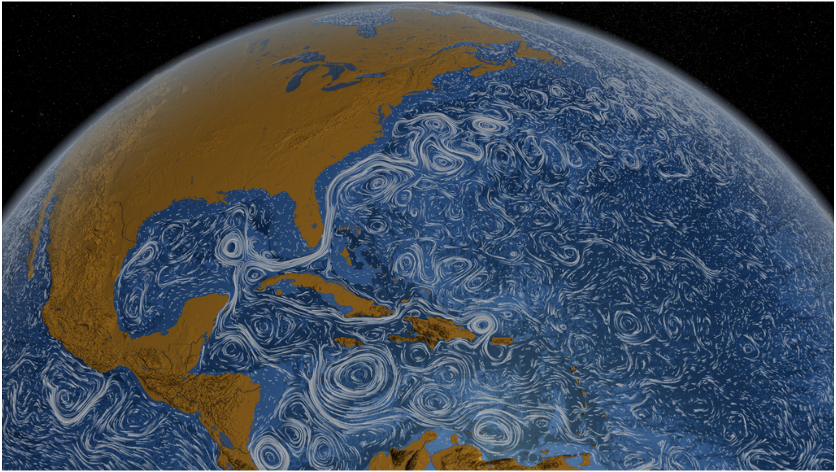


B. Deremble

June 17, 2019

BGUM, Paris

Surface currents in the ocean



From the ECCO reanalysis

CAN WE PARAMETERIZE OCEAN TURBULENCE IN CLIMATE MODELS?

Main equations

Primitive equations (incompressible and Boussinesq):

$$
\begin{aligned}
\frac{\partial u}{\partial t} + \boldsymbol{u}\nabla u - fv &= -\frac{\partial P}{\partial x} + \mathcal{F} + \mathcal{D} \\
\frac{\partial v}{\partial t} + \boldsymbol{u}\nabla v + fu &= -\frac{\partial P}{\partial y} + \mathcal{F} + \mathcal{D} \\
\frac{\partial P}{\partial z} &= -\rho g \\
\frac{\partial \theta}{\partial t} + \boldsymbol{u}\nabla \theta &= \mathcal{F} \\
\nabla \boldsymbol{u} &= 0
\end{aligned}
$$

Small parameters and multiple scales

As in the Reynolds decomposition, we want to split all variables into a small-scale and large-scale component

$$\theta \to \overline{\theta} + \theta'$$

But we also use the small parameters to simplify the equations

- $\rightarrow$ Aspect ratio $\epsilon = H/L$
- $\rightarrow$ Rossby number $Ro = U/fl$ (< 1: strong impact of rotation)
- $\rightarrow$ Froude number $Fr = U/NH$ (< 1: strong stratification)
- $\rightarrow$ Length ratio $\delta = l/L$

The multiple scale decomposition rely on a good scale separation between the turbulent eddy scale $l \sim \mathcal{O}(Rd)$ and the planetary scale L

cf. full derivation in Pedlosky (1984)

THE QUASI-GEOSTROPHIC EQUATION

The trubulent flow evloves according to the quasi geostrophic eqution from a vorticity equation to the QGPV equation

$$\frac{\partial q}{\partial t} + u\nabla q + \overline{U}\nabla q + u\nabla\overline{Q} = 0$$

$$q = \nabla^2\psi + \frac{\partial}{\partial z}\left(\frac{Fr^2}{Ro^2}\frac{\partial\psi}{\partial z}\right)$$

$\rightarrow$ No forcing other than the large scale flow

$\rightarrow$ Ro (Rossby number) and Fr (Froude number) are slowly varying in space

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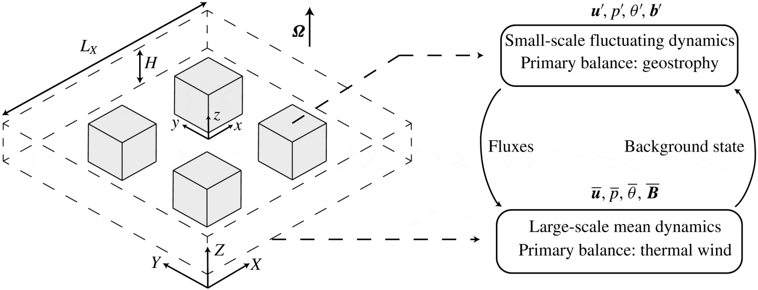
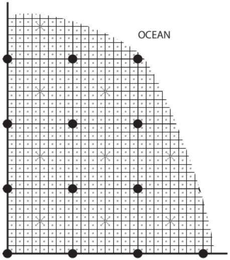
Numerical implementation with basilisk

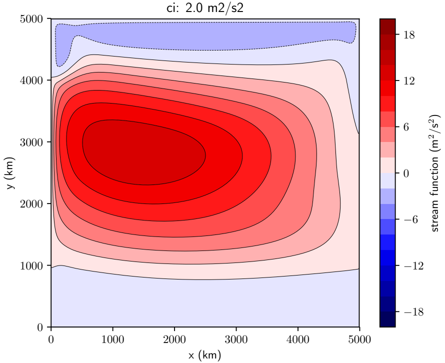


→ Well suited for a multiple scale problem

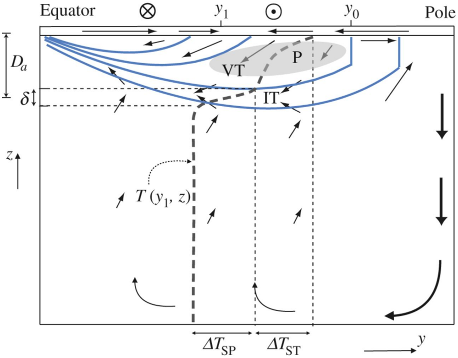
→ Good performance for the elliptic solver



The large-scale flow



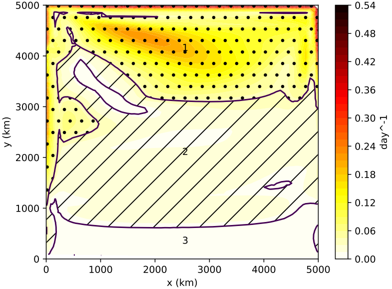
SSH



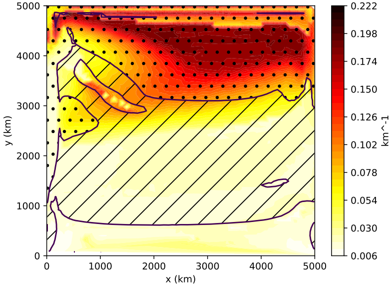
Vertical section

Samelson and Vallis (1997)

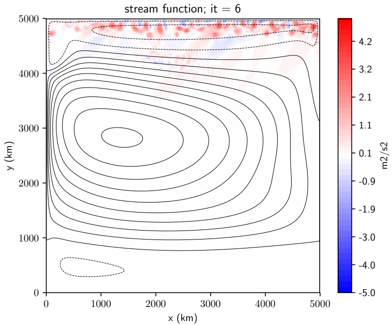
Linear stability analysis



Time scale of the most unstable mode



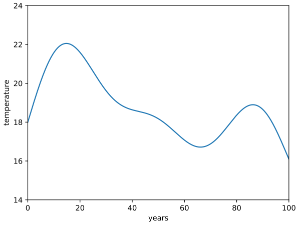
Length scale of the most unstable mode


stream function; it = 6
stream function; it = 20
5000
4000
3000
2000
1000
0
y (km)
0
1000
2000
3000
4000
5000
x (km)
4.2
3.2
2.1
1.1
0.1
-0.9
-1.9
-3.0
-4.0
-5.0
m2/s2

EDDY FEEDBACK ON THE LARGE-SCALE FLOW

Large-scale stratification
Large-scale currents

Planetary geostrophy



Baroclinic instability

Inverse cascade

Small-scale eddies

Quasi geostrophy