Diabatic processes controlling the growth of long baroclinic ocean waves
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Motivation – Hypotheses

Unstable modes grow about 3 times faster for a westward shear at meso-scale (Charney’s modes(1)), consistent with a weaker negative PV meridional gradient at subsurface (not shown)

What is the link between basin modes (B) and local unstable modes (C) ?

Analytical experiments

Adiabatic case

Unstable modes grow about 3 times faster for a westward shear at meso-scale (Charney’s modes(1)), consistent with a weaker negative PV meridional gradient at subsurface (not shown)

Application to a numerical model

Double Drake(5,6) configuration at 1°:

• 30-40 yr ‘A’ MOC variability associated with large scale Rossby waves(1,2)

Where and how these large scale waves are generated?

• 2 active regions at high latitudes:
  • Western boundary: \( \partial_x = 0 \) instability of the zonal current
  • Eastern boundary: \( \partial_y = 0 \) instability of the meridional current
  • Local instability of the oceanic mean state

Diabatic processes

• Most unstable modes found at low latitudes under the LW approximation
  • Weak coherency with the NL model solution
• Mid- and low-latitude unstable modes damped by surface restoring
• Eastern boundary current unstable for a wide range of length-scale

CONCLUSIONS

Growth of large scale Rossby waves in the North Atlantic does not satisfy the LW approximation(1,2), but is rather controlled by diabatic processes

Proposed mechanism for the Double Drake: Radiative baroclinic instability of the eastern boundary current(11)

Local linear Quasi-Geostrophic (QG) stability analysis

Filtering Charney’s mode

Linear growth rate \( \omega \) for a local problem, i.e. \( \partial_x = \partial_y = 0 \) for perturbations of the form \( \psi = f(x) e^{i y/k} \)

Most unstable eigenmode for the long waves in a baroclinic westerly current. Does not rely on the QG approximation

B/ Local linear QG stability analysis of the oceanic mean state

Growth rate of most unstable modes within the Atlantic-like basin for 3 stability analyses, i.e. a) under the LW approx. (eq. 2), b) with KEV only in eq. 2, and c) with an additional surface restoring in eq. (2)

A/ Diabatic case

• Unstable modes grow about 1000 times faster for a westward shear at large-scale (Green’s modes(2)), consistent with a much larger imaginary part of the longwave eigenvalue \( C \)

• The k-inematic eddy viscosity effect:
  • Westward shear: damping at all \( k \)
  • Eastward shear: increase growth rate for small wavenumners

• Result reproduced in a 2.5 layers QG model and under the Planetary-Geostrophic (PG) approx.
  • Does not rely on the vertical resolution nor the QG approximation

A/ Local linear QG stability analysis

• Linear theory of baroclinic instability(16) for a local problem, i.e. \( \partial_x = \partial_y = 0 \) for perturbations of the form \( \psi = f(x) e^{i y/k} \)

• General eigenvalue problem

Apparent growth rate of most unstable modes (green) and the local unstable modes (red) for the Quenouille-Mitchiner model (red line).