OS51A-1107

Role of coastlines, dissipation and frequency of perturbation on internal wave propagation examined in a *Finite Element Ocean Model*

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Motivation

Strong convection or ice melting events in the North Atlantic perturb watermass composition, thus isopycnals, and these perturbations spread over the entire ocean. Pure advection aside, wave processes represents one of the major ways of transferring these variability from one part of the ocean to the other.

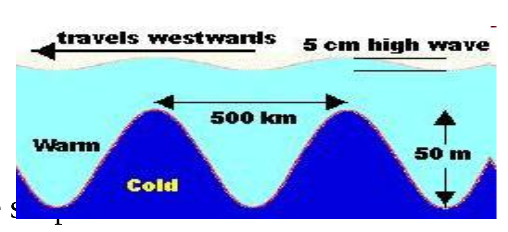
A reduced gravity set up is used to answer particular questions related to *the role of coastlines*, *the role of dissipation* on shaping the signals, and the sensitivity of the wave signal to *the frequency of the perturbation.* In the framework of a reduced gravity model, an elevated sea surface height (SSH) represents isopycnal displacement at the thermocline depth in the ocean.

Introduction

Kelvin Waves

- Low frequency gravity wave.
- Non-dispersive, dispersion relation $w = kc$
- Amplitude decreases exponentially with distance from the coast (Kelvin Waves are coastally trapped.)
- Equatorial Kelvin waves are trapped along the equator and always propagate eastward.

Rossby Waves



- Also called planetary waves as they owe their origin to the s
- Phase speed is westward for long waves.
- Speed is inversely proportional to the Rossby radius squared, hence it decreases as we move from the equator towards the poles.

Reduced Gravity

Reduced gravity is the acceleration of gravity scaled with relative jump in fluid density

$$g' = g\frac{\rho_2 - \rho_1}{\rho_2}$$

A reduced gravity model describes motion of a thin thermocline (upper layer) above resting abyss linked to interfacial displacements

Finite element ocean model:
- Ocean general circulation model developed at AWI.
- Unstructured triangular mesh.
- Prismatic volume elements.

Role of frequency and coastlines on wave propagation

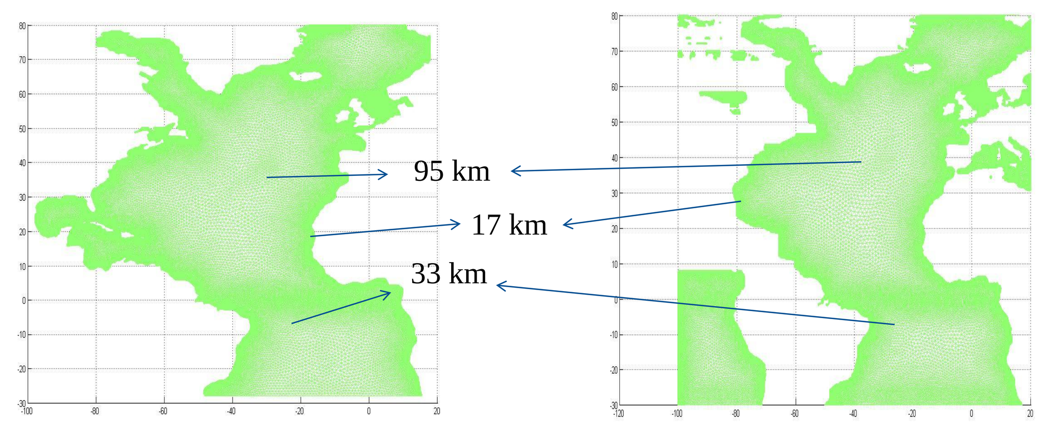


Figure 1: *The meshes above shows the Atlantic Ocean. The one on the left is with the Florida bay and the one on the right is without Gulf of Mexico/Carribean Sea*

- **Resolution:** 17 km at the coastal region, 33 km at the equatorial region, 95 km at the mid latitude interior ocean.
- A reduced gravity setup is used to model the propagation of the first baroclinic mode.
- The elevation is relaxed to a prescribed one over a limited area in the Labrador Sea. The prescribed elevation varies sinusoidally in time.

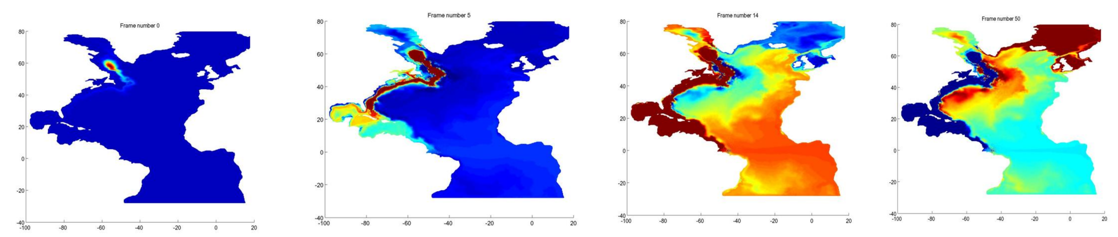


Figure 2: *As forcing is swinched on the perturbation (10 year period) a coastal Kelvin Wave towards the equator. At reaching the equator, the wave turns and propagates eastward. After reaching the eastern coast, the wave splits and propagates polewards as coastal Kelvin wave. While propagating polewards, the Kelvin Waves radiate westward propagating Rossby Waves.*

The experiments were performed on the two meshes from Figure 1 with forcing of
- 2 year period
- 5 year period
- 10 year period

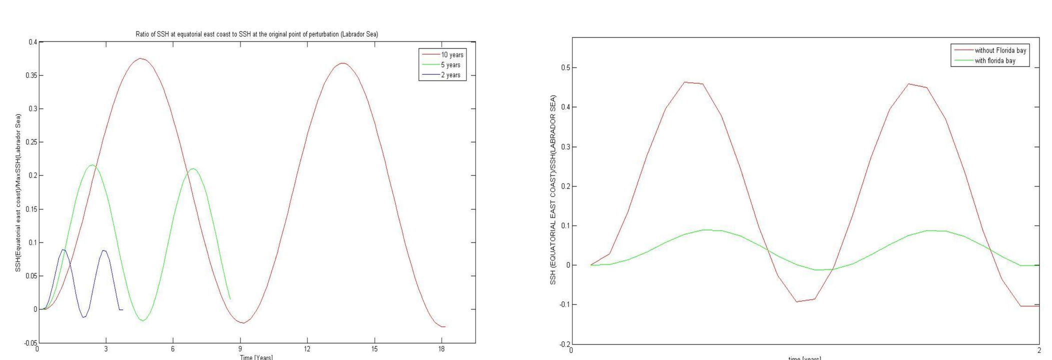


Figure 3: *The plots above show the elevation (in units of its amplitude in the forcing area) at the equatorial east coast.*
- The left panel shows the sensitivity to the forcing frequency corresponding to periods of 2 (blue), 5 (green) and 10 (red) years. The higher the period the higher is the amplitude at the eastern coast.
- The right panel compares signals at the eastern coast obtained with (green) and without (red) the Gulf of Mexico/ Carribean Sea for forcing with 2-year period. Clearly, the bay acts as a filter.

Role of dissipation on wave propagation

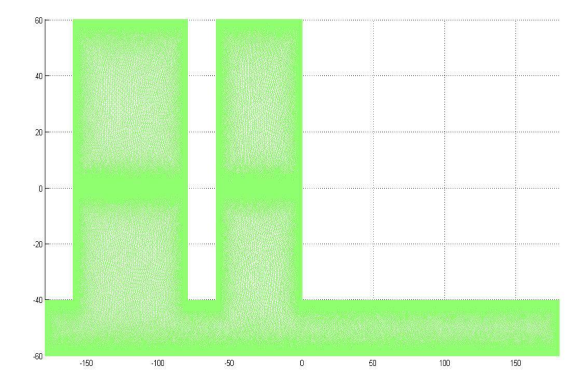


Figure 4:*The mesh of model global ocean. The two rectangular boxes represent the Pacific and Atlantic Oceans connected through the Southern Ocean. Resolution is the same as in Figure 1.*
- Forcing with period 5 years is applied in the north-east corner on the model Atlantic Ocean.

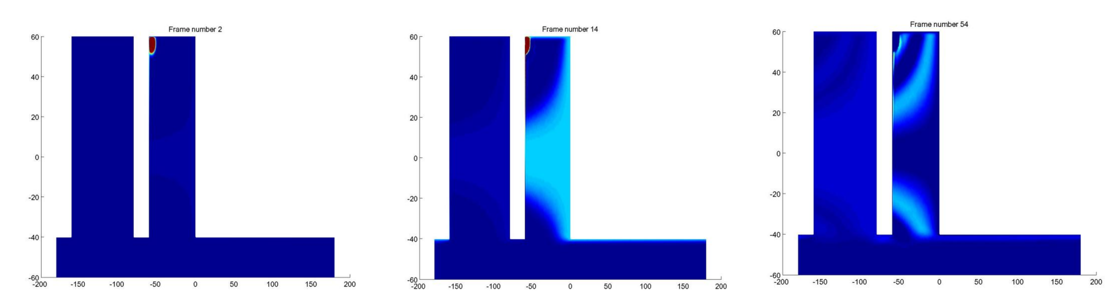


Figure 4: *On switching on the forcing the perturbation propagates as a coastal Kelvin wave towards the equator. At reaching the equator, the wave turns and propagates eastward. After reaching the eastern coast, the wave splits and propagates polewards as coastal Kelvin wave. While propagating polewards, the Kelvin Waves radiate westward propagating Rossby Waves. At the south-eastern boundary, the Kelvin wave travels along the northern boundary of the Southern Ocean to the Pacific Ocean basin. The signal travels towards the equator from the south and at reaching the equator, it propagates eastward and the same story as in Atlantic Ocean is repeated.*

Friction is modeled in the momentum equations ar a linear drag with a friction coefficient Fr having dimension of inverse time. *Fr* has units of time. The drag coefficient can be thought of as coming from the quadratic bottom drag, $Fr = \frac{-Cd|\vec{v}|}{h}$ (h is the depth 2000 m , Cd = 0.002 is the bottom friction coefficient, and $|\vec{v}|$ is the effective amplitude of bottom velocity). The inverse of Fr can be considered as the decay time. $\tau = \frac{1}{Fr} = \frac{h}{-Cd|\vec{v}|}$

Experiments: Two experiments forced in the north-west corner of the North Atlantic (forcing period is 5 years) have been performed, one damped with $\tau = 5days$ and the other one with $\tau = 30yr$. In the case $\tau = 5days$ the damping time is shorter than the Kelvin wave propagation time.

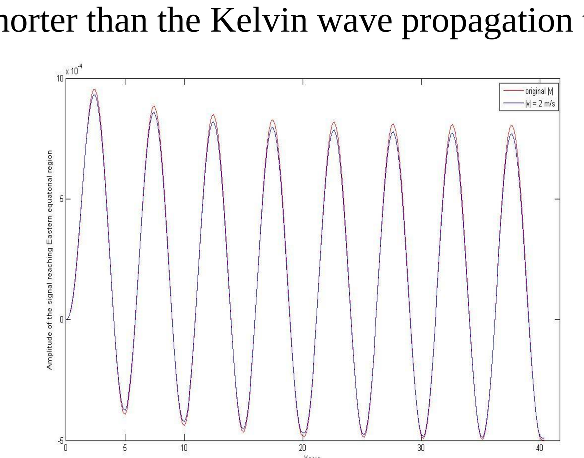


Figure 5: *The elevation at the eastern coast (scaled with the amplitude in the forcing region* $\tau = 30yr$ *(red) and* $\tau = 5days$ *(blue). One would expect to observe much higher dissipation in the latter case. We conclude that bottom drag has a very weak effect at low forcing frequencies.*

Conclusions

The frequency of forcing is one of the major factors influencing the amplitude of signals at eastern boundaries, in agreement with theory proposed by Johnson and Marshall (2002).

Forced Kelvin waves of low frequency are insensitive to the bottom friction.

Coastlines play a vital role in wave propagation and may act as an effective filter for low-frequency waves.

References

Gill, A *Atmosphere-Ocean Dynamics*, International Geophysics Series, Vol. 30
Johnson D. , Marshall H, 2001: *A Theory for the Surface Atlantic Response to Thermohaline Variability*, Journal of Physical Oceanography, 1121-1132
McCalpin, J. 1994: *Rossby Wave Generation by Poleward Propagating Kelvin Waves: The Midlatitude Quasigeostrophic Approximation*, J. Phys. Oceanography, 1415-1425
Vallis, G., *Atmospheric and Oceanic fluid dynamics*, 2006
Danilov, S., Schroeter, J. 2004: *A Finite Element Ocean Model: principles and Evaluation*, Ocean Modelling, 6, 125-15

For further information

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