Low-frequency intrinsic variability of Sea Surface Height in the global turbulent ocean: spatio-temporal scales

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Our focus: low-frequency oceanic intrinsic variability

The ocean spontaneously generates 1-10 year variability under repeated seasonal forcing. This variability may be strong but is still poorly-known.

Why ?
The strongly non-linear ocean dynamics may generate sub-harmonics (long space and time scales) given a forcing restricted to annual and shorter timescales

Two approaches to study it:
a) Academic process-oriented studies:

Intrinsic variability has imprint on:
- Western Boundary Currents (WBCs) and gyre systems [1]
- Modes waters reservoirs [2]
- Circumpolar current [3]

b) Eddy-resolving Ocean General Circulation Models (our approach):

1. Comparison with observations (e.g. Global ocean [4], Kuroshio Extension [5])
2. [6] showed there is no intrinsic variability in laminar ocean models
3. Atmospheric forcing
4. Non-linear detrending (LOESS, cut-off 20 years)
5. Removal of spatial and temporal mean and deseasonalization

How is low-frequency oceanic intrinsic variability distributed in space and wave number ?

Low-Frequency SSH variance: Small Scales

Low-Frequency Small-Scale variance is mostly driven by oceanic internal processes

A) Low-Frequency Large-Scale variance driven by the atmosphere over most regions

B) But there are three intrinsic large-variance regions at Large Scales:

- Gulf Stream
- Kuroshio
- Antarctic Circumpolar Current

Potential imprint of LS oceanic intrinsic variability on atmospheric and climate variability in a coupled mode

Current and upcoming work:

- Structure of low-frequency intrinsic variability in WBCs (EOFs, comparison with SSH modes found in idealized studies)
- Impact of a finer resolution (1/4° vs 1/12°)
- Diagnostics of spatio-temporal inverse cascade in the I-experiment through fluxes of kinetic energy in spectral domain (collaboration with B. Arbic [7])
- Ensemble simulations are coming... (OCCIPUT project)

Eddy forcing:
- Rectification of the low-frequency modes by eddy PV fluxes [1][8]
- Spatial and temporal inverse cascades of Kinetic Energy [7]
- Need statistical description of turbulent processes

Transitions between large-scale equilibria:
- The mean state of the ocean directly feeds low-frequency modes[2]
- Dynamical System Theory applied in academic context shows random transitions between multiple stable states [9]

Two paradigms:

1. Paradigm of inertial oscillations
2. Paradigm of low-frequency wavepacket

How is low-frequency oceanic intrinsic variability distributed in space and wave number ?

Low-Frequency SSH/SST variance: Large Scales

Main motivations:
- What is the contribution of low-frequency intrinsic variability in a realistic ocean ?
- Do we observe similarities with idealized studies (e.g. modes of variability) ?
- May intrinsic variability imprint on atmospheric and climate variability ?

Decomposition in space and time:
1. Removal of spatial and temporal mean and deseasonalization
2. Non-linear detrending (LOESS, cut-off 20 years)
3. Band-pass Filter in time and space (temporal cut-off 1.5 year, spatial cut-offs 12° and 6°)

Since air/sea interactions are important in these regions (e.g. largest values of $Q_{flux}$), WBCs might generate substantial decadal climate variability [8]

- Potential imprint of LS oceanic intrinsic variability on atmospheric and climate variability in a coupled mode

Questions

- How is oceanographic forcing related to the 10 year cycle? (how do we estimate the forcing?)
- Is there a specific role of WBCs in the inverse cascade in these regions? (why/why not?)
- What is the nature of these low-frequency waves in the WBCs? (are they inertial?)
- How are they generated? (by eddies?)
- What is the role of oceanic variability in these regions? (climate/air?)

References: