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

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1 Our focus: low-frequency oceanic intrinsic variability

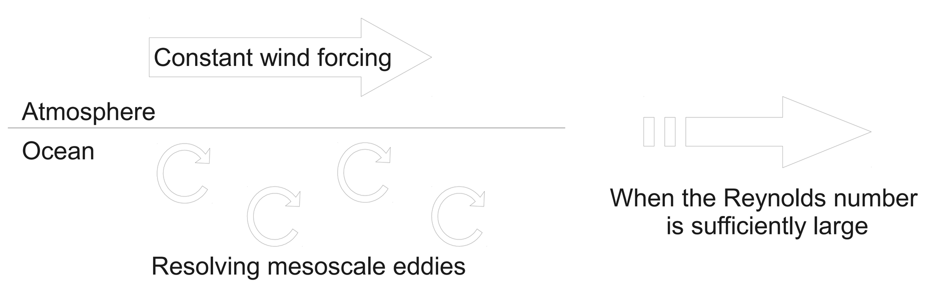
The ocean spontaneously generates 1-10 year variability under repeated seasonal forcing. This variability may be strong but is still poorly-known.

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 Bounary Currents (WBCs) and gyre systems [1]
- Mode waters reservoirs [2]
- Circumpolar current [3]

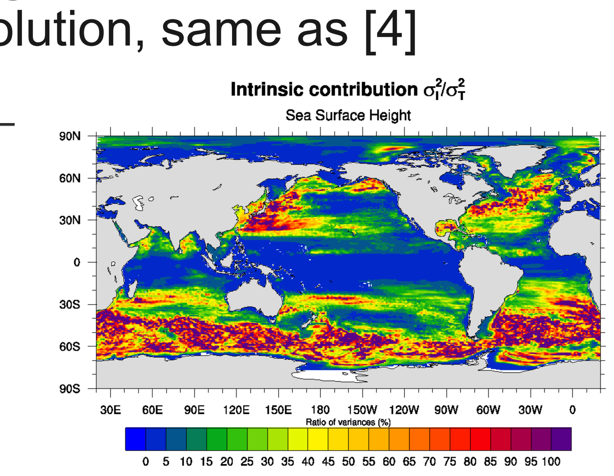
b) Eddy-resolving Ocean General Circulation Models (our approach):
- Comparison with observations (e.g. Global ocean [4], Kuroshio Extension [5])
- [4] showed there is no intrinsic variability in laminar ocean models

2 Our non-linear oceanic laboratory:

Forced Global Ocean Model (NEMO code), 1/4° resolution, same as [4]

Experiment	T-experiment	I-experiment
Forcing	Full range atmospheric timescales (reanalysis)	Repeated seasonal cycle
Objectives	Hindcast the "total" observed variability	Isolate the low-frequency intrinsic variability

Total = Forced + Intrinsic

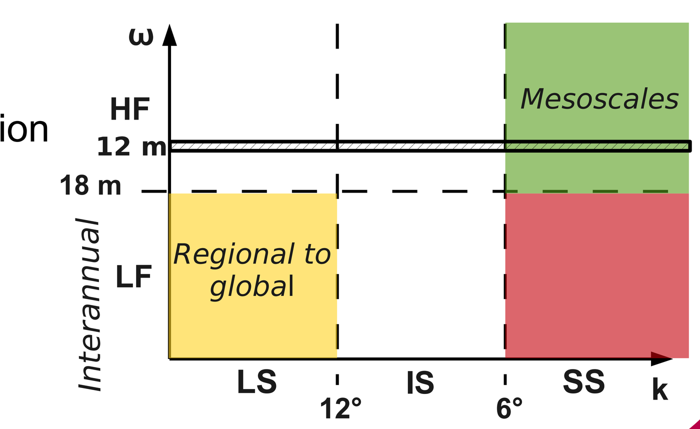


Main motivations:

- 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 ?

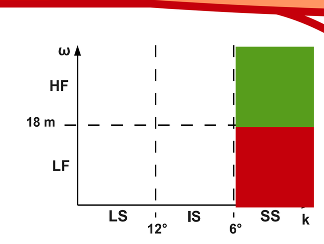
Decomposition in space and time:

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



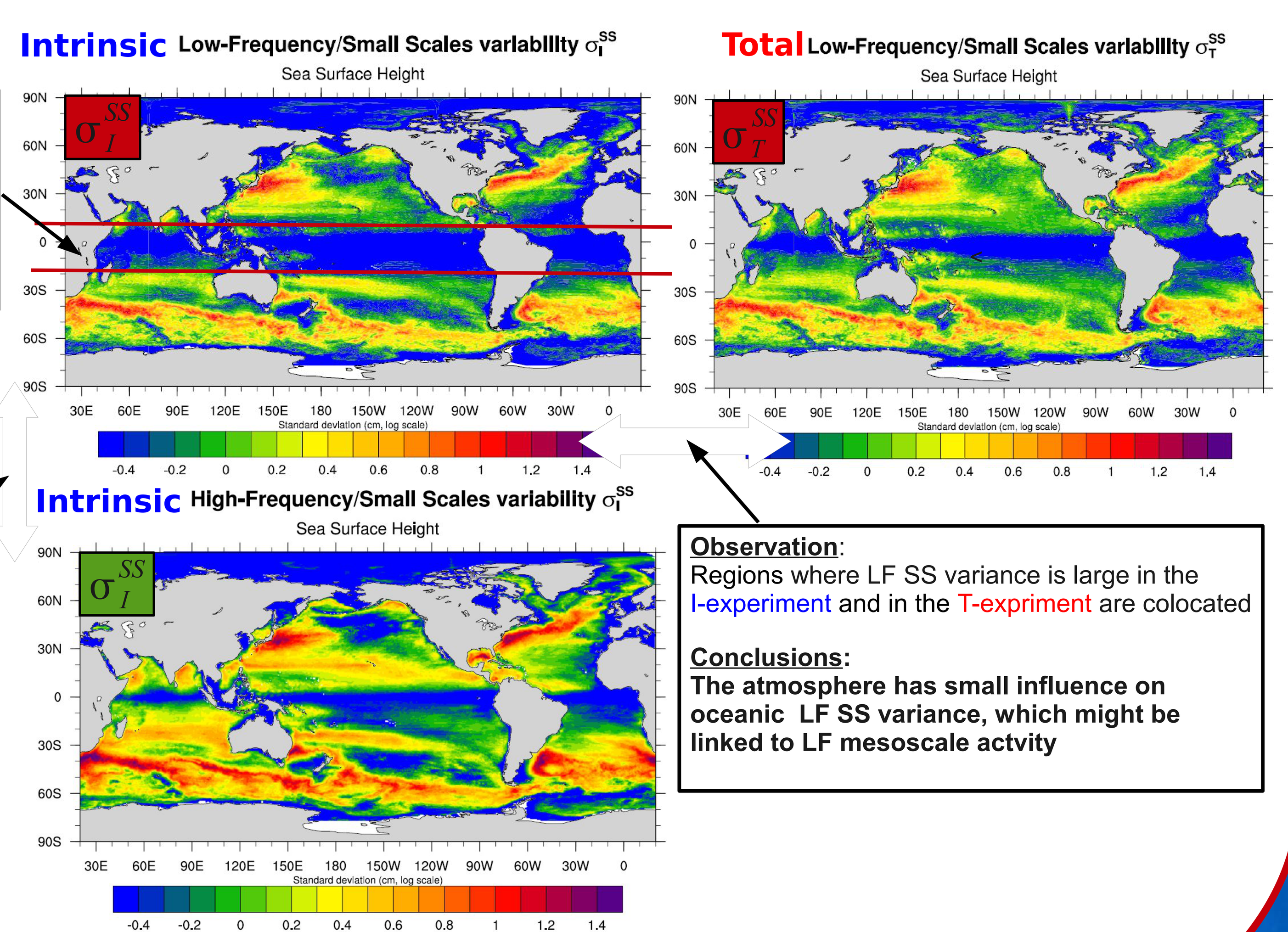
How is low-frequency oceanic intrinsic variability distributed in space and wave number ?

3a Low-Frequency SSH variance: Small Scales



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

→ The global average variance in the I-experiment accounts for 88 % of the variance in the T-experiment



Observation: LF SS variance is small at low latitudes

Why ? More linear processes Larger Rossby radii

Observation: Regions where LF SS variance is large are colocated with eddy-active regions (HF SS)

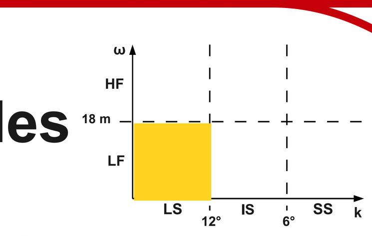
Question: How LF SSH variance is linked to HF eddy activity ? (see KE cascades in box 4)

Observation: Regions where LF SS variance is large in the I-experiment and in the T-expriment are colocated

Conclusions: The atmosphere has small influence on oceanic LF SS variance, which might be linked to LF mesoscale actvity

This map is related to mesoscale activity with HF SS structures → WBCs and ACC are eddy-active regions

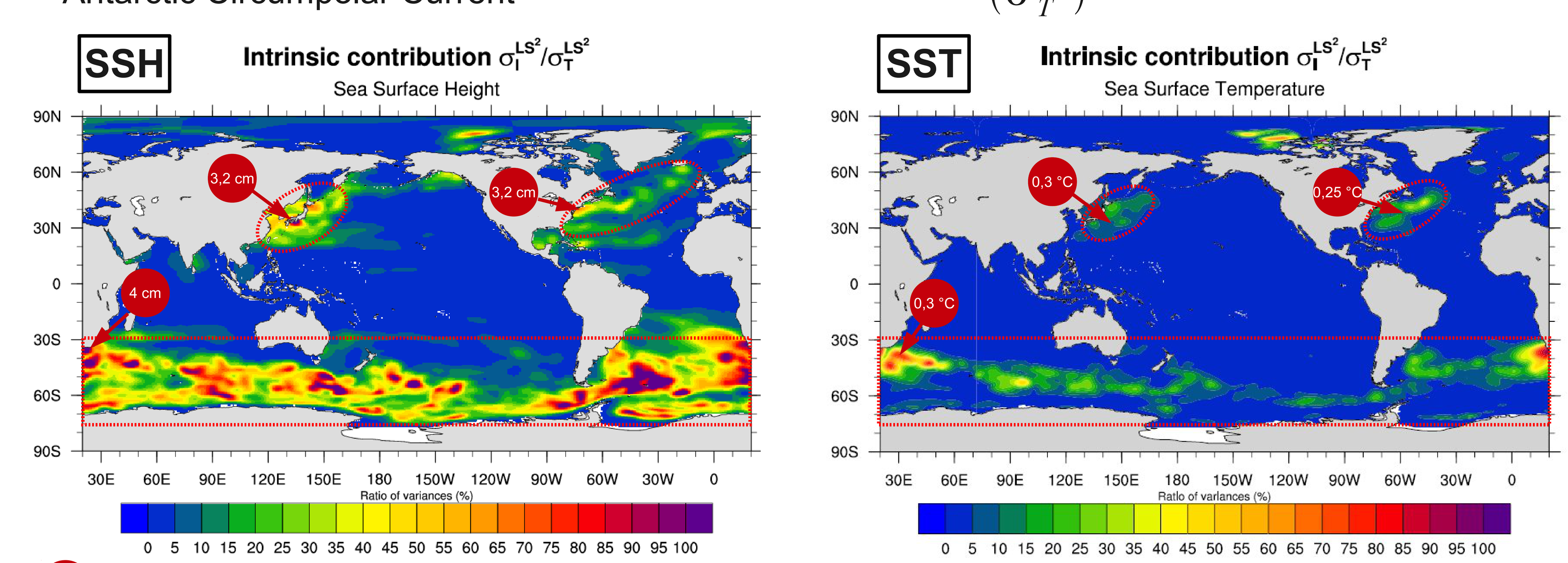
3b Low-Frequency SSH/SST variance: Large Scales



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

$$r = \frac{(\sigma_I^{LS})^2}{(\sigma_T^{LS})^2} > 50\ \%$$

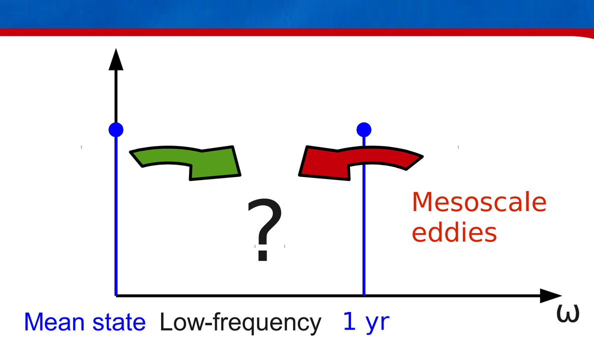


4 cm : maximum standard deviation

Since air/sea interactions are important in these regions (e.g. largest values of Q_{NET}), WBCs might generate substantial decadal climate variability [6]

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

4 Two paradigms:



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]

5 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)

Take-home message

- **Low-Frequency Small-Scale SSH variance (<6°) is mainly intrinsic and might be associated with low-frequency mesoscale activity**
- **Low-Frequency Large-Scale SSH/SST variance is forced over most of the ocean, but mostly intrinsic in WBCs and ACC (r>50%) where air/sea interactions are strong.**
- **The hypothesis of temporal inverse cascade is currently being tested**

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