Forced and chaotic interannual variability of regional sea level and its components over 1993-2015

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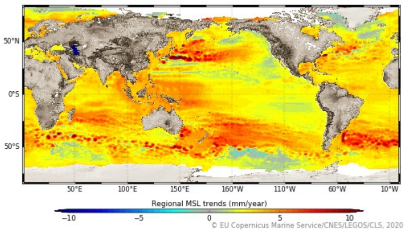
Context and objectives

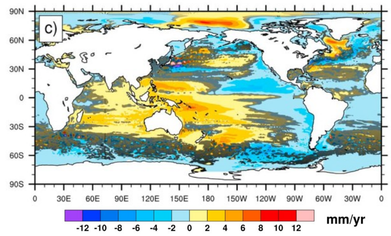
Context

- Global mean sea level rise of 3.3 mm/year with large regional variability
- Chaotic ocean variability may mask atmospherically-forced regional sea level trends over 38% of the global ocean area (black dots) from 1993 to 2015 (*Llovel et al., 2018, Penduff et al., 2019*)



Regional mean sea level trends (mm/yr)

Ensemble mean of sea level trends from the 50 members over 1993–2015



Objectives

➔ To disentangle the regional sea level (Δh) forced and chaotic variability at interannual time scales

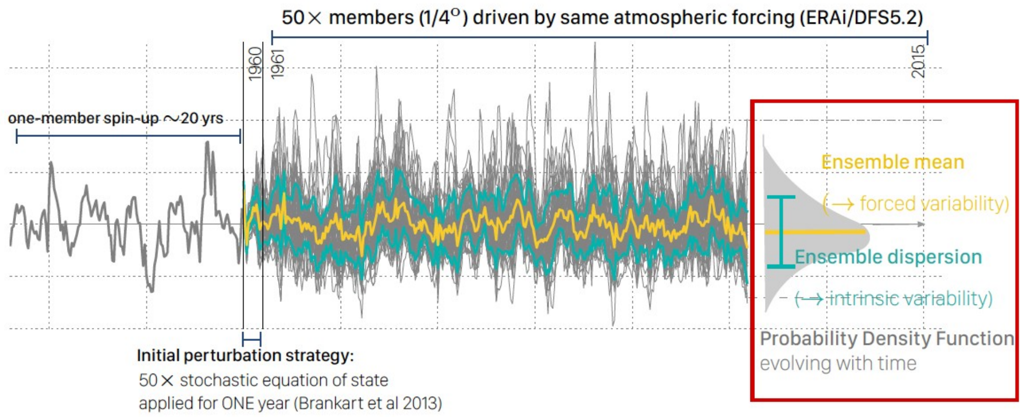
➔ To investigate the steric and manometric contributions $\Delta h = \Delta h_{steric} + \Delta h_{manometric}$

➔ To compare our methodology to previous studies on the subject (*Forget and Ponte 2015, Penduff et al., 2011*)

Methodology

OCCIPUT

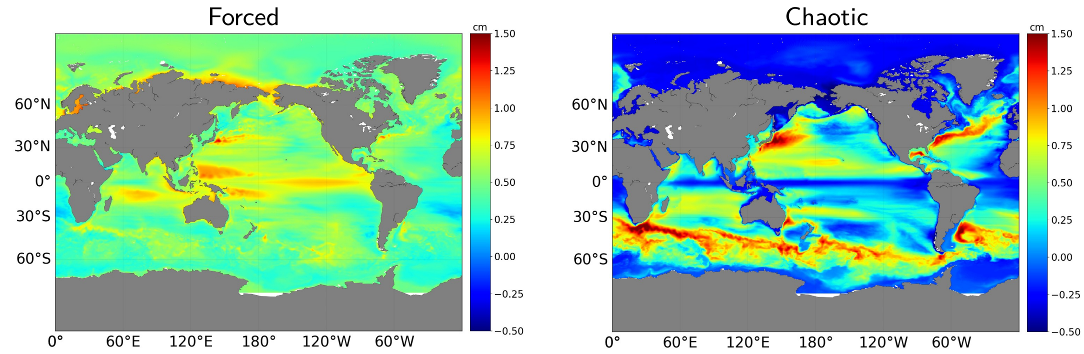
- Based on NEMO 3.5 model
- 50 member ensemble simulation
- Curvilinear grid : 1/4° resolution
- Period of the simulation : 1960 – 2015
- 20-year spin-up
- Initial perturbations x 50
- Same atmospheric forcings
- Variable studied : **sea level**



We used the OCCIPUT ensemble simulation.

Forced and chaotic variability

SLA

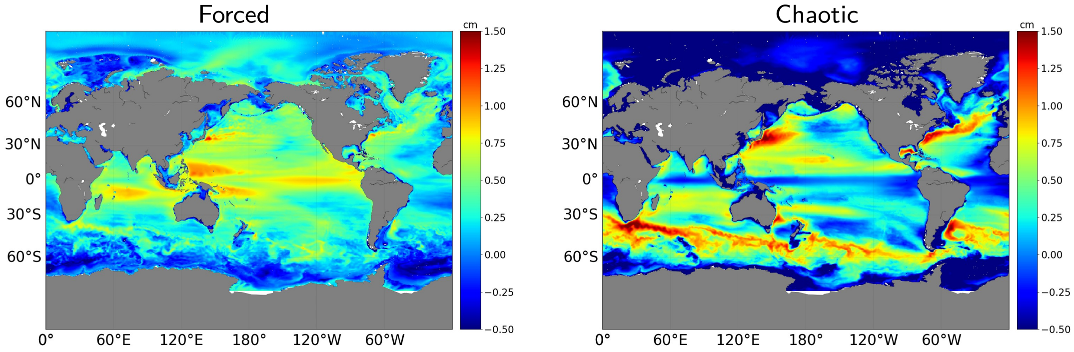


- The forced variability is important at low latitudes and near the coasts and weak in the South Atlantic Ocean
- The chaotic variability is important in the ACC, along the western boundary currents (Kuroshio, Gulf Stream) and weak along the equator
- The energetic system (western boundary currents) also have a forced component

The forced variability corresponds to the temporal standard deviation of the ensemble mean.
The chaotic variability corresponds to the temporal mean of the ensemble standard deviation.
Here are presented the corresponding maps for the SLA time series.

Forced and chaotic variability

Steric (0-6000m)

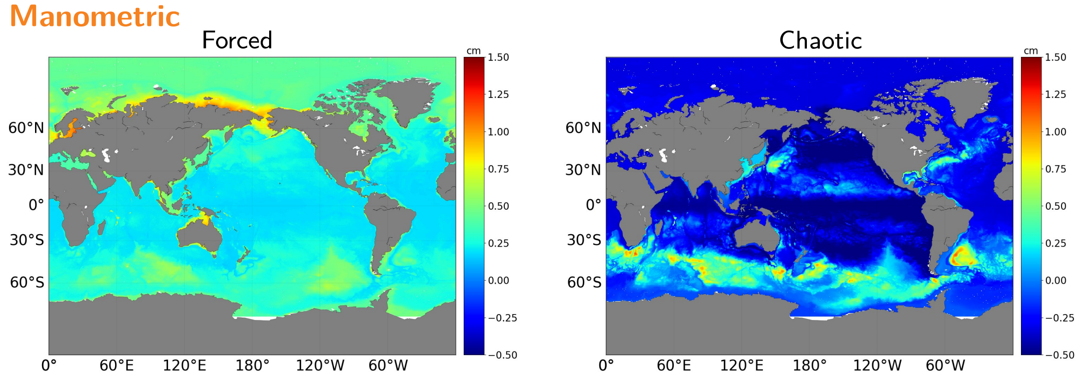


- ➔ The forced steric variability is high at low latitudes and the chaotic steric variability is high in the ACC and along western boundary currents.
- ➔ The SLA forced and chaotic variability spatial patterns are mainly explained by the steric variability spatial patterns
- ➔ However, they differ in coastal regions

Here are presented the corresponding maps for the steric time series.

Forced and chaotic variability

Manometric

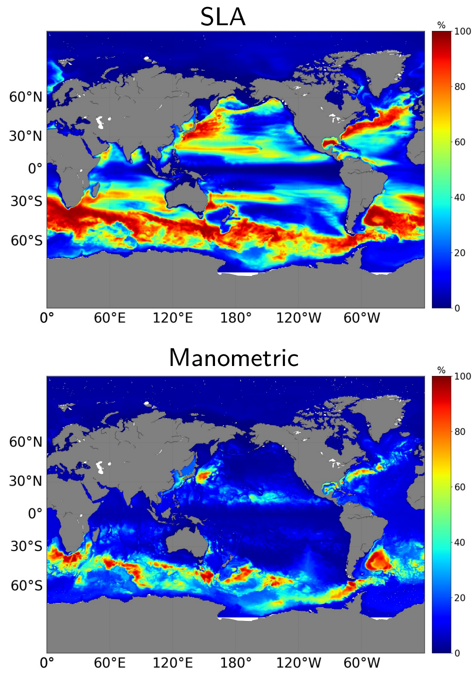


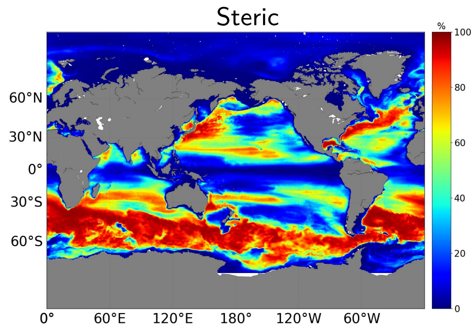
- ➔ The forced manometric variability explains the high SLA forced variability along the coasts and above 65°N (agreement with *Fukumori and Wang, 2013*)
- ➔ The chaotic manometric variability is important in the ACC, the western boundary currents and near the Chinese coast
- ➔ The higher variability near the coasts is caused by the increase of surface pressure due to higher greenhouse gases concentrations (*Penduff et al., 2019*)

Here are presented the corresponding maps for the manometric time series.

Explained variance

Identification of interannual chaotic variability hotspots





$$R = 100\,\% * \frac{A^2_{intrinsic}}{A^2_{intrinsic} + A^2_{forced}}$$

- The chaotic variability mainly explained the SLA and steric interannual variability in the western boundary currents, in the ACC
- At the equator, the variability is mainly forced, due to the strong winds
- The interannual variability of OBP is mainly forced

For the SLA, the steric and manometric sea level, the ratio R is computed. It represents to what extent the intrinsic variability explains the total SLA, steric and manometric sea level.

Explained variance

Identification of interannual chaotic variability hostspots

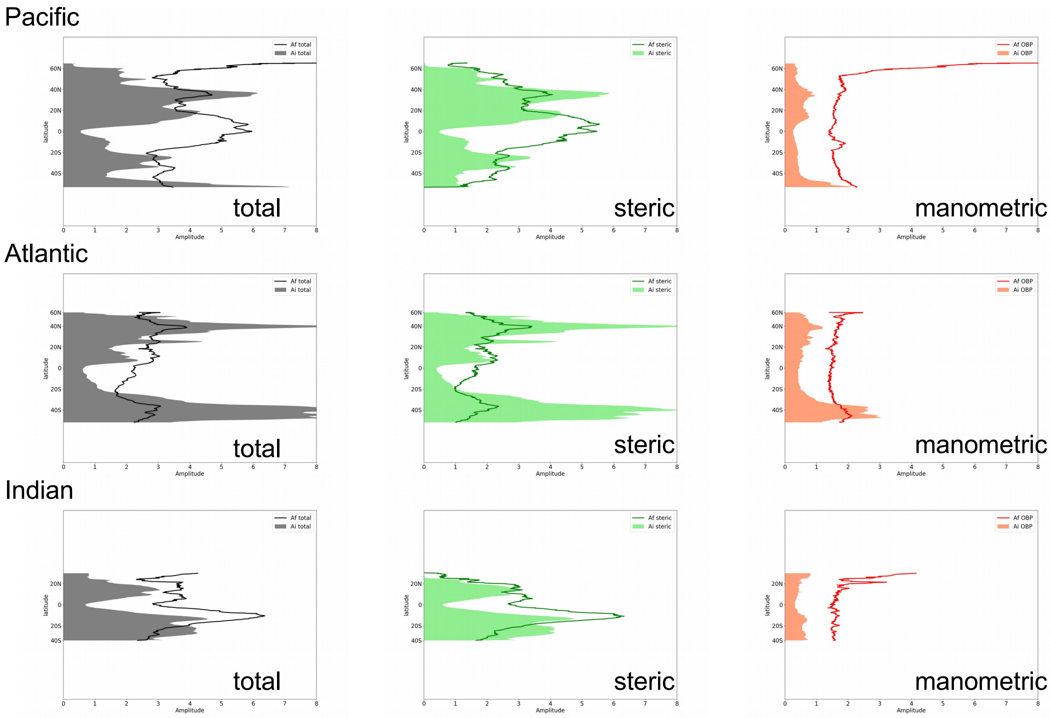
- Mean values of the explained variance R in some hotspots

	SLA	Steric sea level	Manometric sea level
ACC	$R_{mean} = 94\ \%$	$R_{mean} = 95\ \%$	$R_{mean} = 70\ \%$
Kuroshio	$R_{mean} = 86\ \%$	$R_{mean} = 88\ \%$	$R_{mean} = 43\ \%$
Gulf Stream	$R_{mean} = 90\ \%$	$R_{mean} = 90\ \%$	$R_{mean} = 45\ \%$
Gulf of Mexico	$R_{mean} = 94\ \%$	$R_{mean} = 95\ \%$	$R_{mean} = 41\ \%$
Equator (10°S - 10°N)	$R_{mean} = 11\ \%$	$R_{mean} = 13\ \%$	$R_{mean} = 5\ \%$

- Values $> 80\ \%$ for the steric explained variance near the Somalia coasts and around 20°N in the Pacific and Atlantic
- $R > 20\ \%$ over 56 %, 62 %, 28 % for the SLA, steric and manometric sea level

We focused on some hotspots : the ACC, the Kuroshio, the Gulf Stream, the Gulf of Mexico where the chaotic variability is important and the equatorial band where the forced variability is important. We quantified to what extent the chaotic variability explains the total variability.

Zonal average of regional sea level



To better understand and visualize the relative importance of the forced and intrinsic variability of the sea level and its steric and manometric contribution, we represent the zonal-averaged of the forced (solid lines) and intrinsic (shaded areas) amplitude in each ocean basin (Pacific, Atlantic, Indian).

The repartition of the steric, manometric, forced and intrinsic variability is quite varying from one basin to the other. In the Pacific, there is a very clear forced steric contribution compared to the Atlantic where the forced steric and manometric amplitude are quite equivalent (around 1.6 - 1.8 cm) at each latitude except in the Gulf Stream. In the Indian ocean, the steric forced amplitude is weaker than the manometric forced amplitude only northern 20°N. The manometric forced amplitude is almost constant for each basin, it is the steric forced amplitude which varies from 0.2 to 6.3 cm.

Conclusions and perspectives

Conclusions

- The forced and chaotic interannual variability mainly have a steric origin except in coastal areas
- In the ACC, the chaotic variability is strong for both the steric and manometric contributions
- In the western boundary currents, the forced variability can also be important
- The chaotic variability explains more than 20 % of the total interannual variability over 56 % of the global ocean for the sea level (62 % for the steric sea level and 28 % for the manometric sea level)

Perpectives

- Investigate the frequential domain through spectral analysis