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

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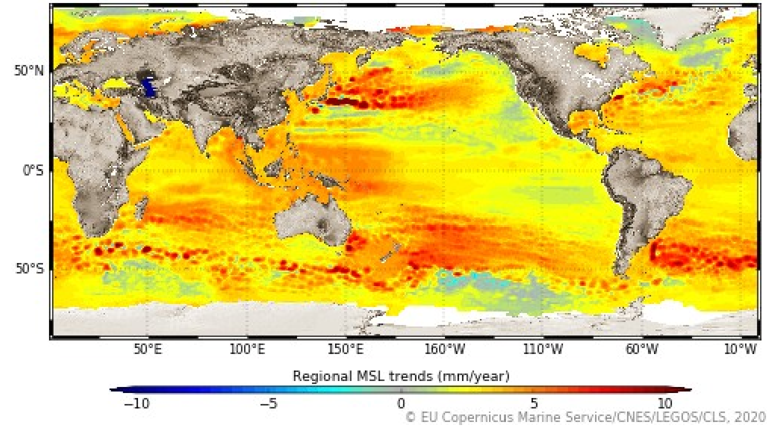
Living Planet Fellowship

Context and objectives

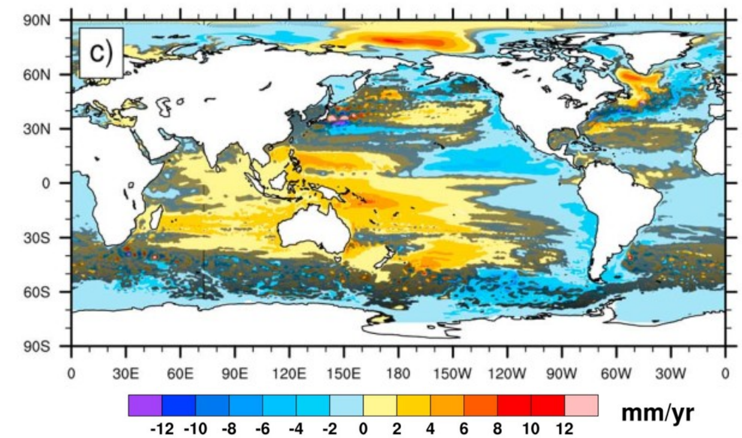
Context

- 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 (SSH) forced and chaotic variability at interannual time scales

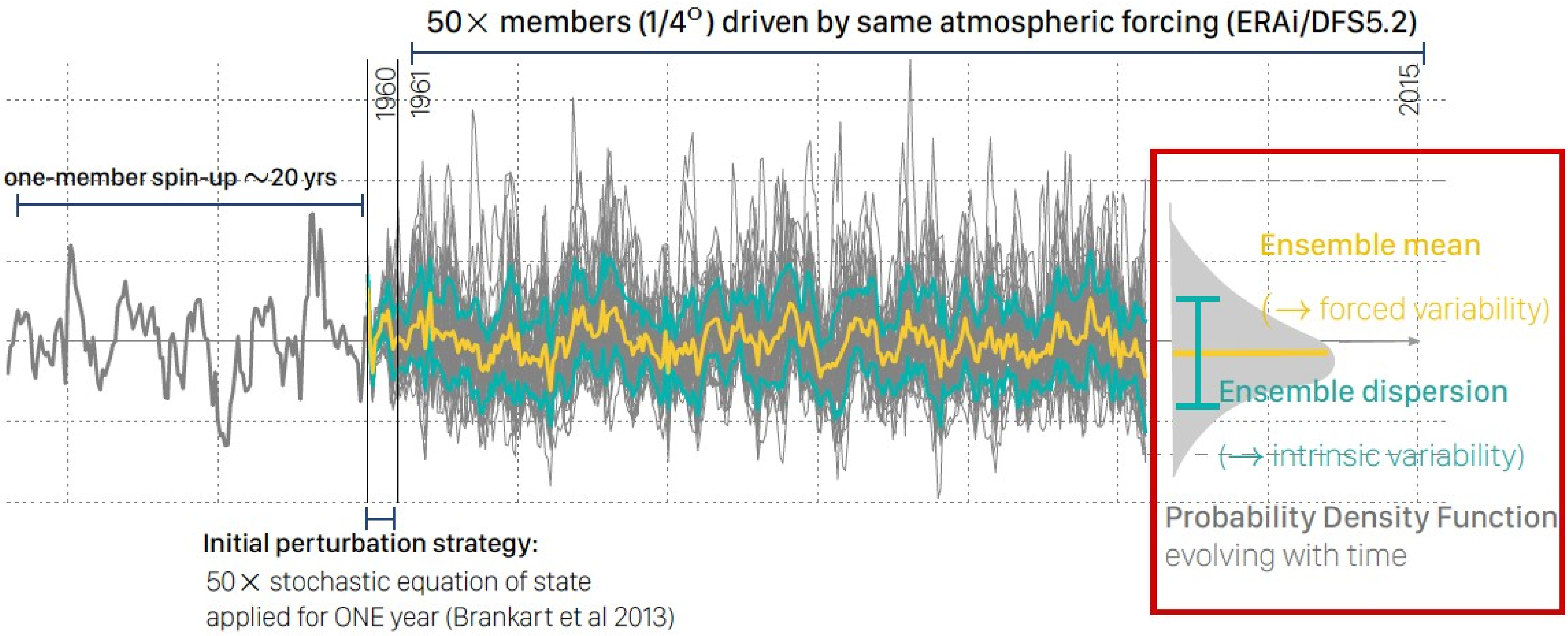
➔ To investigate the steric and manometric contributions $\Delta h = \Delta h_{steric} + \Delta h_{manometric}$

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

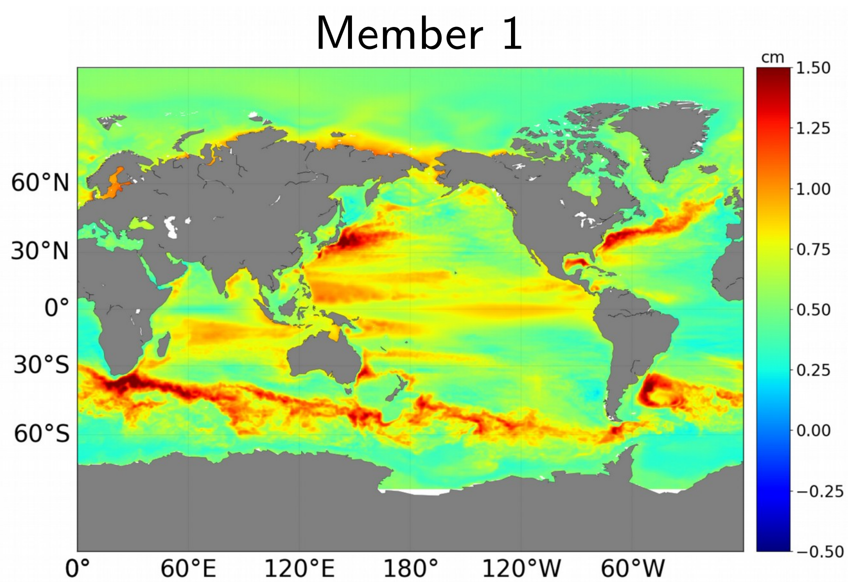
METHODOLOGY

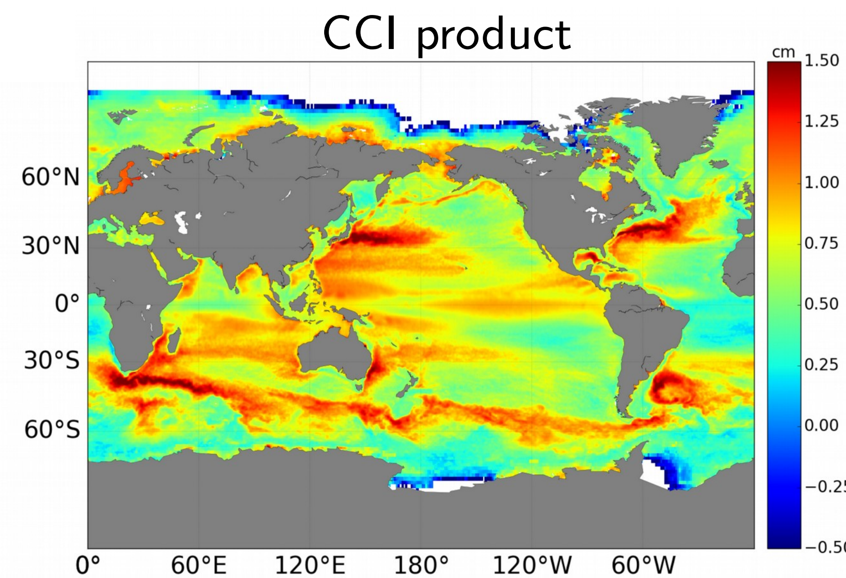
OCCIPUT

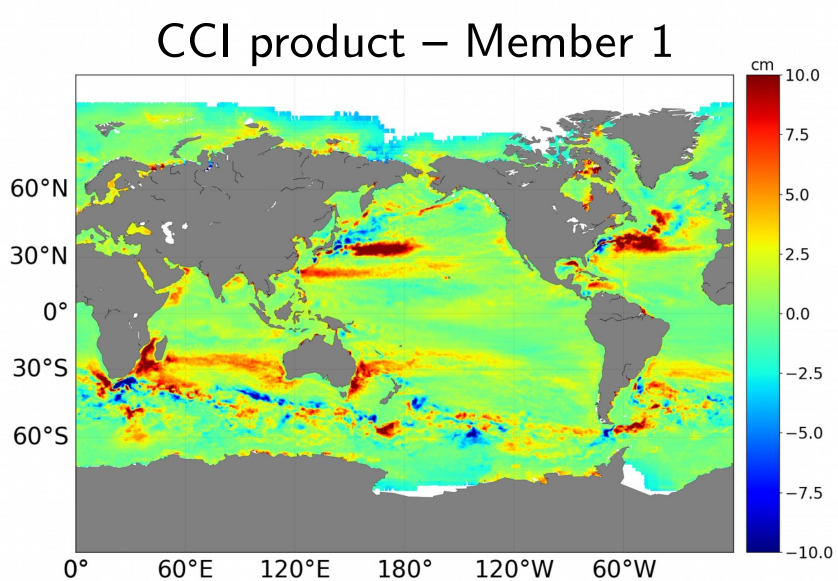
- Based on NEMO 3.5 model
- 50 member ensemble simulation
- Curvilinear grid : 1/4° resolution
- Period of the simulation : 1960 – 2015
- 20-year spin-up
- Initial perturbations x 50
- Same atmospheric forcings
- Variable studied : **sea level**



Standard deviation maps (SLA interannual variability)







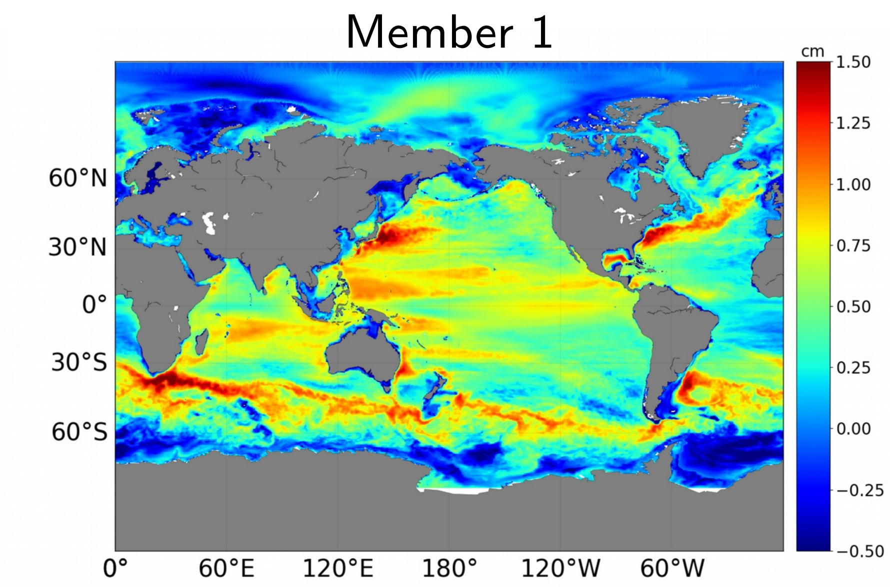
esa

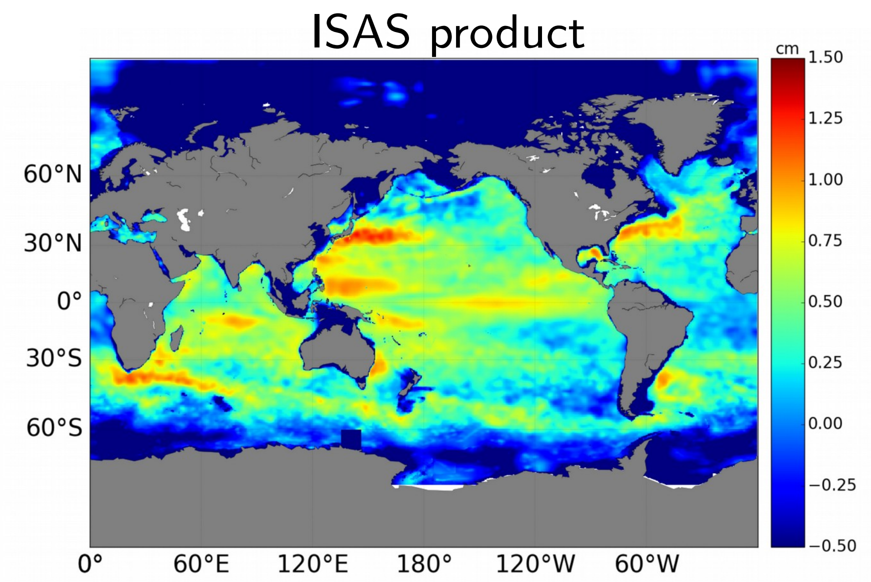
- CCI (Climate Change Initiative) product
- All available satellite : ERS-1/2, Envisat, TOPEX/Poseidon, Jason missions
- 1/4° resolution
- Period : January 1993 – December 2015

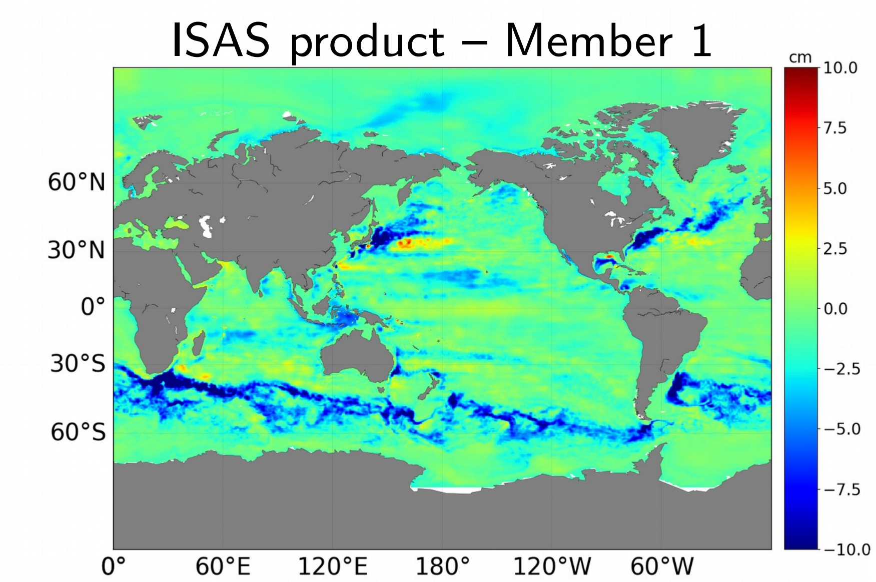
➔ Same spatial patterns with more variability in the CCI product (good agreement with *Forget and Ponte, 2015*)

➔ Differences located in the regions of intense mesoscale activity

Standard deviation maps (steric sea level interannual variability)





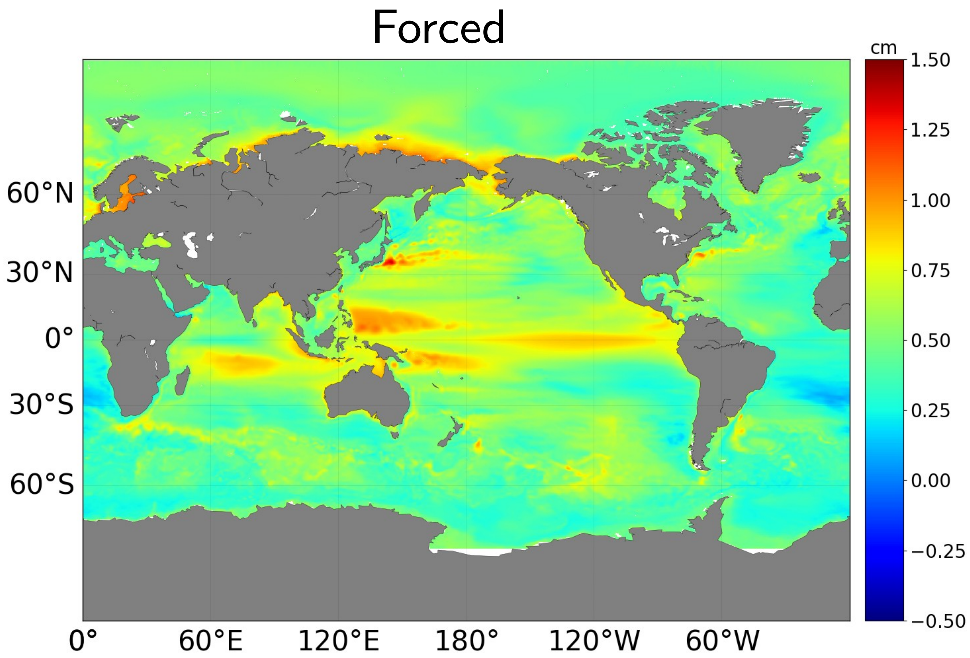


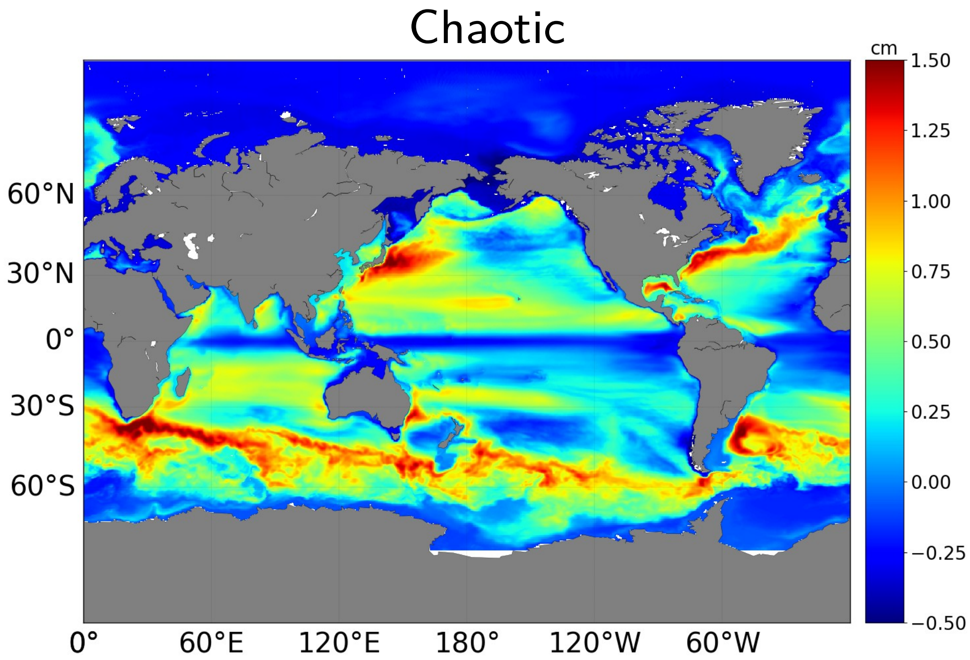
- ISAS (In Situ Analysis System) product
- Temperature ans salinity from vertical Argo profiles
- 1° resolution
- Period : January 2002 – December 2015

→ Good agreement in the spatial variability patterns

→ Differences higher in the high latitudes and in the energetic systems where there are less Argo data

SLA

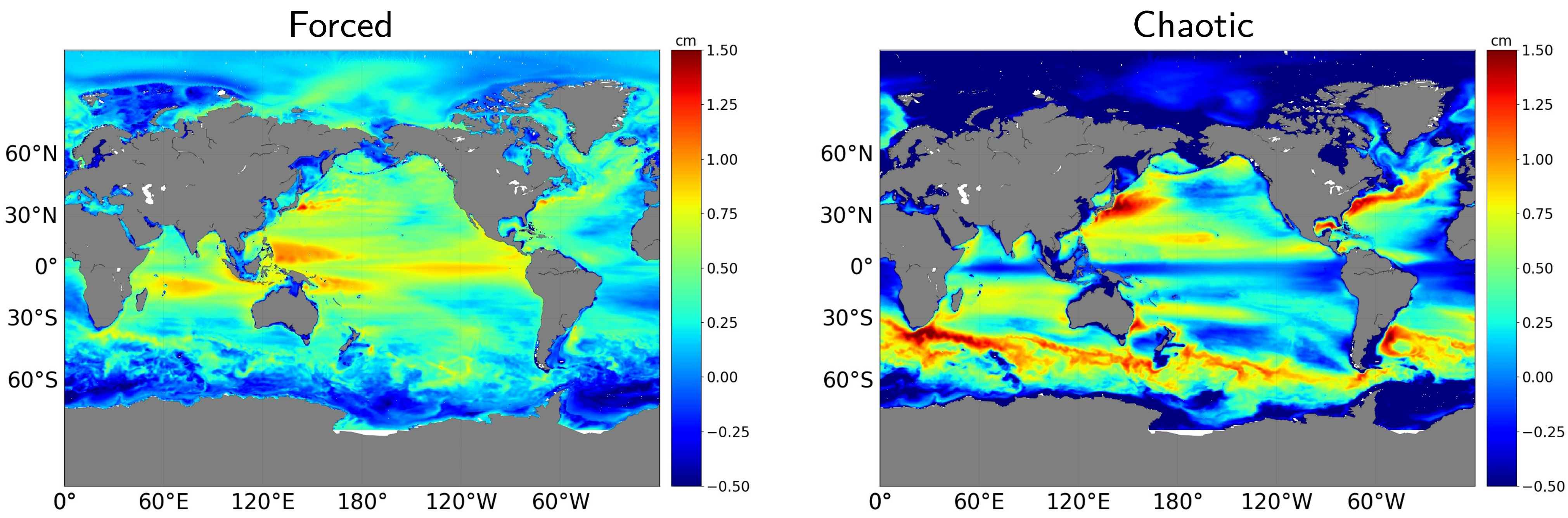




- The forced variability is important at low latitudes and near the coasts and weak in the South Atlantic Ocean
- The chaotic variability is important in the ACC, along the western boundary currents (Kuroshio, Gulf Stream) and weak along the equator
- The energetic system (western boundary currents)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

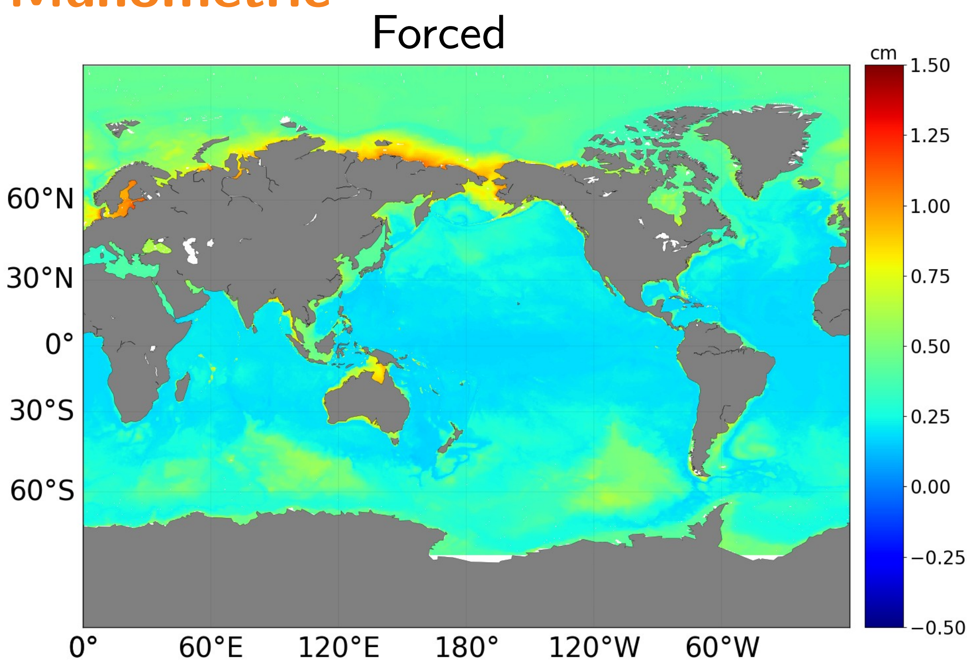
Forced and chaotic variability

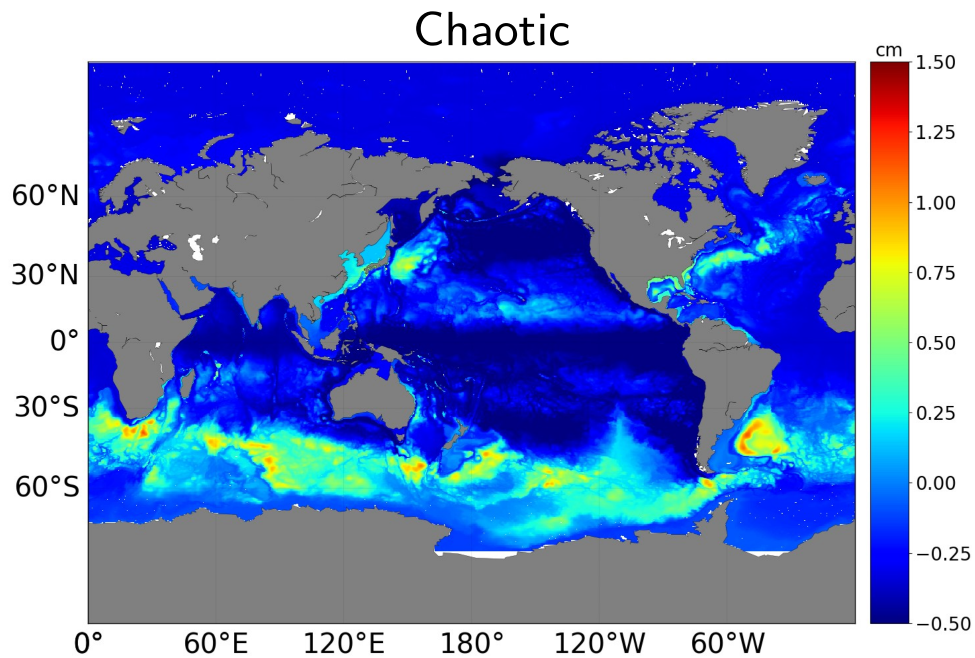
Steric (0-6000m)



- 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 SSH forced and chaotic variability spatial patterns are mainly explained by the steric variability spatial patterns
- However, they differ in coastal regions

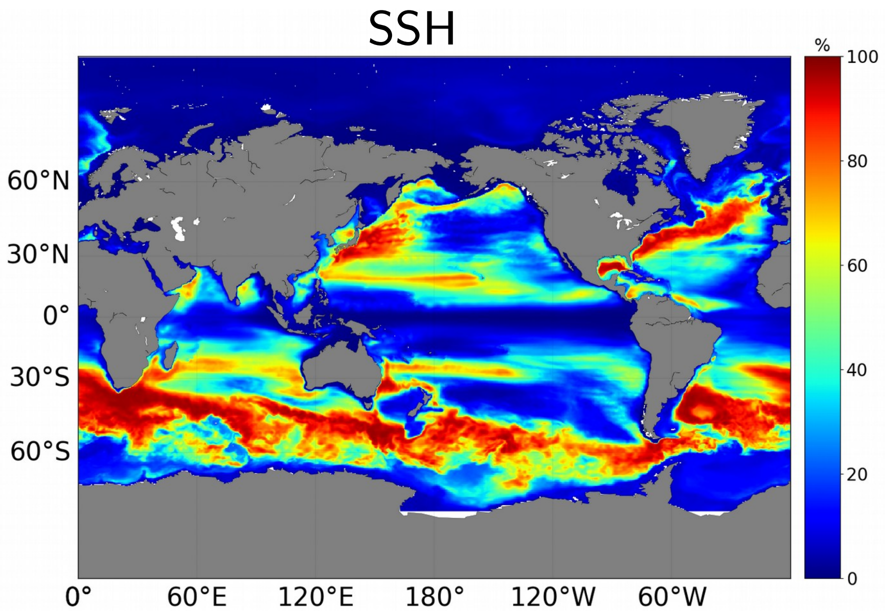
Manometric

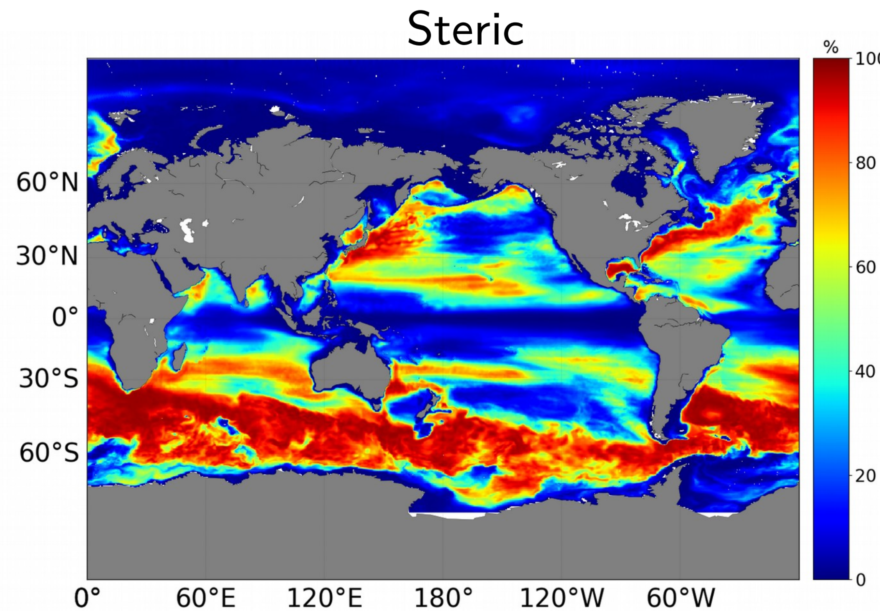


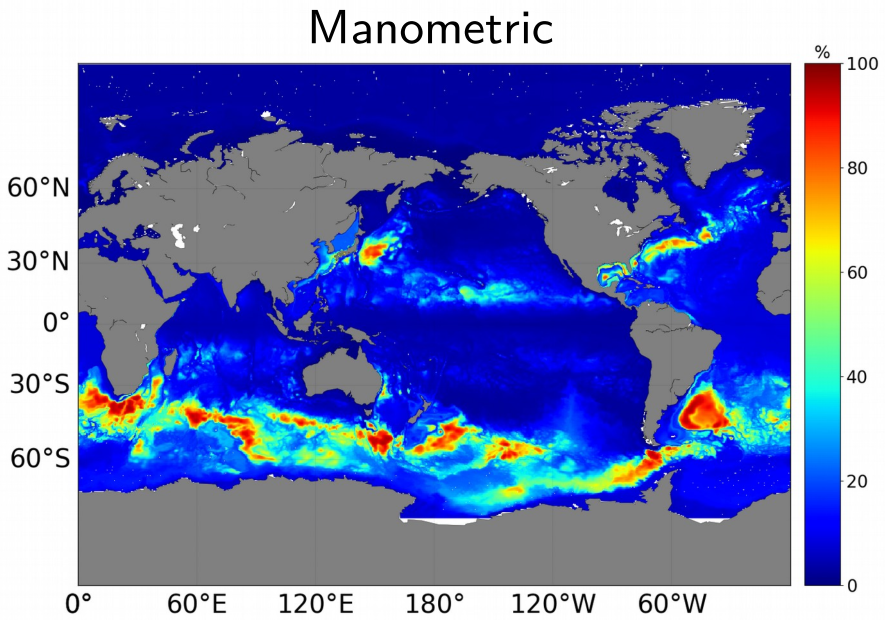


- The forced manometric variability explains the high SSH forced variability along the coasts and above 65°N (agreement with *Fukumori and Wang, 2013*)
- The chaotic manometric variability is important in the ACC, the western boundary currents and near the Chinese coast
- The higher variability near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

Identification of interannual chaotic variability hotspots







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

- The intrinsic variability mainly explained the SSH 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

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

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
- ➔ Apply the same diagnostics over the period 1980-2015