FINAL REPORT PROGRAM LEFE

LEFE/GMMC	**Project Title : CRATERE** **C**ontributions **R**espectives des forçages **A**tmosphériques et de la variabilité chaotique océanique sur les varia**T**ions régionales du niv**E**au de la me**R** et de ses caus**E**s	2020 – 2021

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Context

Regional sea level changes present large regional variability. Temperature and salinity changes explain these spatial patterns because of air-sea interactions and circulation/dynamic changes. A new driver (known as intrinsic/chaotic ocean variability) has been recently identified caused by oceanic non-linearity.

Objectives / scientific questions

CRATERE aims at quantifying the respective contribution of atmospherically-forced and intrinsic ocean variability to these regional sea level changes and their components over the altimetry period. The OCCIPUT ensemble simulations have been considered to partition these variabilities from subannual to interannual time scales.

Main results

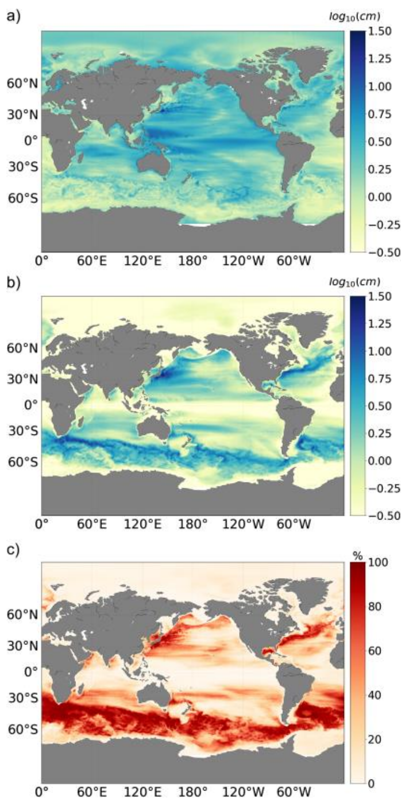

Fig1: Maps of the atmospherically forced (a) and chaotic (b) interannual variabilities of regional sea level in the OCCIPUT ensemble (over 1993-2015). The *R* ratio is shown in panel c. Panels a and b are shown with logarithmic scales, base 10. Units are cm in a and b, and percent in c.

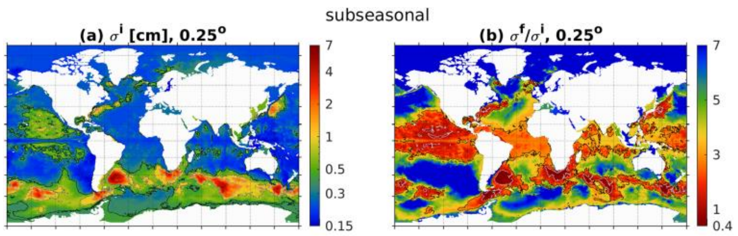

Fig2: Maps of manometric sea level (i.e., mass contribution) chaotic variability (σ^i [cm]) (a) and its atmospherically-forced response to the chaotic variability (σ^f/σ^i ratio) (b) for subseasonal signals (period <60 days). Black, dark gray and gray contours in (a) indicate σ^i values of 0.4, 0.8 and 1.5 cm. Gray and black contours in (b) indicate the ratio of 1 and 3.

The atmospherically-forced regional sea level interannual variability map (Figure 1a) shows maxima in the equatorial Pacific with three main hotspots: two on both sides of the equator in the west and one along the equator in the east. Figure 1b exhibits regions of strong chaotic sea level interannual variability especially in the western boundary currents, in the ACC, in the entire Northern Pacific, and in the Indian and Pacific Oceans between 10°S and 30°S. On the contrary, the chaotic variability is weak in the equatorial band where the atmospherically forced response is dominant. Regional sea level interannual variability is mostly chaotic in the western boundary currents and in the ACC, where there is a strong mesoscale activity (Fig1c shows the contribution of the chaotic variability to the total interannual sea level variability, Carret et al., 2021).

Fig2a shows the manomatric sea level (i.e., mass component) intrinsic variability in subseasonal band (periods < 60 days). Highest values (>1.5 cm) are found in regions where strong instabilities and intensive eddy generation are observed. Most basin interiors, in contrast, show very weak values (σ^i <0.2 cm), as expected from the relative lack of mesoscale instabilities. One exception is the eastern tropical Pacific, where σ^i can be up to 0.7 cm. The relatively stronger σ^i in these regions could be associated with eddy energy radiating from tropical instability waves or from the eastern boundary. We investigate the chaotic variability to the atmospherically-forced response in Fig2b. Low values suggest that the phase of *manometric sea level* variations are more "random" (i.e., less correlated with the forcing) and thus less predictable. In regions of high mesoscale activity and strongest σ^i, intrinsic variations can equal or even overpower forced variations. These oceanic intrinsic processes can play an important role in transporting physical and biological properties such as mass and chlorophyll in the subseasonal band (Zhao et al., 2021).

Future of the project:

The results of CRATERE have motivated the OST-ST IMHOTEP project which aims at partitioning the atmospherically-forced, chaotic variability and continental freshwater discharges (rivers and Greenland) to regional sea level changes and its causes.

Number of publications, communications and theses

Peer-reviewed publications

[4] - Germineaud, C., D. L. Volkov, S. Cravatte, and W. Llovel. 2023. "Forcing Mechanisms of the Interannual Sea Level Variability in the Midlatitude South Pacific during 2004–2020" Remote Sensing 15, no. 2: 352. https://doi.org/10.3390/rs15020352

[3] - Llovel W., N. Kolodziejczyk, S. Close, T. Penduff, J.-M. Molines and L. Terray, Imprint of intrinsic ocean variability on decadal trends of regional sea level and ocean heat content using synthetic profiles, Environ. Res. Lett. https://doi.org/10.1088/1748-9326/ac5f93

[2] - Zhao, M., Ponte, R. M., Penduff, T., Close, S., Llovel, W., & Molines, J.-M. (2021). Imprints of ocean chaotic intrinsic variability on bottom pressure and implications for data and model analyses. Geophysical Research Letters, 48, e2021GL096341. https://doi.org/10.1029/2021GL096341

[1] - Carret, A., Llovel, W., Penduff, T., & Molines, J.-M. (2021). Atmospherically forced and chaotic interannual variability of regional sea level and its components over 1993–2015. Journal of Geophysical Research: Oceans, 126, e2020JC017123. https://doi.org/10.1029/2020JC017123

Conference presentations

[3-4] Zhao, M., Ponte, R. M., Penduff, T., Close, S., Llovel, W., & Molines, J.-M. (2021). Imprints of ocean chaotic intrinsic variability on bottom pressure and implications for data and model analyses, AGU Ocean Sciences Meeting, Fev 2022 and GRACE/GRACEFO Science Team, Oct 2021.

[2] Llovel W.**,** Nicolas Kolodziejczyk, Thierry Penduff, Jean-Marc Molines, and Sally Close, Imprint of intrinsic ocean variability on ocean heat content and thermosteric sea level over 2005-2015, EGU 2021.

[1] Carret A., W. Llovel, T. Penduff and J.-M. Molines, Characterisation of the chaotic variability of the regional sea level and its components over 1993-2015 at interannual time scales, EGU, 2021.