Postdoc Position

Investigation of changes in extreme sea levels, using innovative data-driven methods

Starting date: **Oct. 2022**
18-months contract, already 100% funded (ANR ClimEx)
https://climex.ifremer.fr

Host Laboratory: **Ifremer**
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Jean-Marc **Delouis**, CNRS/LOPS

Deadline to apply: **15/06/2022**

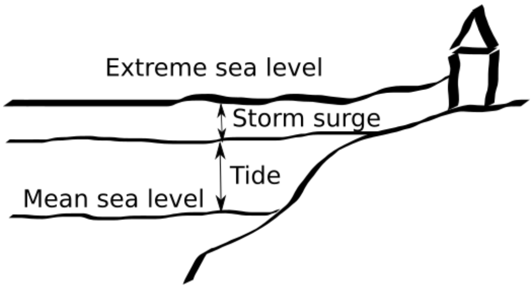
How to apply: Application (CV including a list of publications, cover letter) can be sent to lucia.pineau.guillou@ifremer.fr

Summary

Climate is warming. Changes have been reported in extreme sea levels. Here, we focus on the North Atlantic storms, that generate extreme sea levels along the coasts. The changes in extreme sea levels over the last century will be characterized. The data will be collected from multiple sources: long-term tide gauges, satellite altimeter data, numerical simulations. The physical causes behind the observed changes will be investigated using innovative data-driven methods. The use of such methods to learn more about the underlying ocean surface dynamics is a very active field of research, with promising results.

Context: the ClimEx project

ClimEx project (https://climex.ifremer.fr) aims to quantify and understand the evolution of extreme sea levels along North Atlantic coasts on decadal to secular time scale, with emphasis on the tide and the storm surges. ClimEx will detect changes in observed climate records, identify underlying external forcings, and attribute their individual and combined impacts. ClimEx will analyse together data from different sources, as tide gauges, wave pressure sensors, satellite altimeters and sismographs. Bringing together researchers from different disciplines (ocean science and mathematics), ClimEx will explore innovative data-driven methods and numerical experiments to understand the causes behind the observed sea level changes.



The extreme sea levels are impacted by any change in (0) mean sea level, (1) tide and (2) storm surges. ClimEx will focus on long-term changes in (1) tide and (2) storms surges, which has raised little attention up to now, compared to the mean sea level.

This is essential as any reliable forecast with climate models must be based on a good knowledge of the mechanisms underlying the observed extreme sea levels.

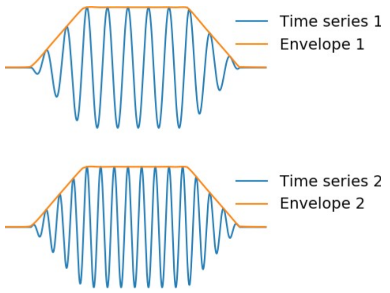
Objectives and details of the postdoctoral project

The objectives are to jointly analyse different sources of sea level data (in situ, remote sensing, numerical simulations) to **characterize and understand changes in extreme sea levels,** using **innovative data-driven methods**, going beyond classical correlation methods. Ideally, the candidate will model the time series using **decomposition methods** (e.g. dynamical mode decomposition), in the perspective of predicting possible changes in the future.

The first step aims at **identifying spatiotemporal patterns of extreme events**, from the analysis of observations (tide gauges, satellite altimeters) and numerical simulations in the North Atlantic. These extreme events will be classified and characterized with a **minimum of parameters**, thanks to methods of dimensionality reduction, based on data properties. The evolution of such parameters over the last century will be investigated.

The second step aims at **transforming the time series** (extreme sea levels and their possible drivers) **to better attribute the causes.** Indeed, some correlations can be hidden and not detected by classical methods. For example, two time series with similar structures, but with different scales of temporal variability, will not be correlated (See Figure 1 for an illustration: signal envelopes are correlated, while high-frequency harmonics are not). To tackle this problem, the data have to be transformed. At first order, they may be simply filtered, for example with a running average. Some filtering methods are more adapted, and take into account the scale interactions. Here, we will focus on different transformations including: the scattering transform (Bruna et al. 2015), the embedded sampling (Takens, 1981) and the Koopman decomposition (Mezić, 2013). These transformed variables will be the input variables to infer causality (see next step).

Figure 1: Illustration of the added value of innovative methods: using classical correlation methods, there is no significant correlation between these two time series (in blue), despite their structure is similar (in orange). Using innovative methods, the transformed time series (e. g. scattering transform represented by their envelopes in orange) are highly correlated.



The third step aims at **using a likelihood approach** (rather than a classical correlation approach) to consolidate our confidence in the data analysis. The correlations found with the classical methods (e.g. Pearson correlation, p-values) may be chance correlation, due to the noise in the signal (Wasserstein and Lazar, 2016). Here, we will check that the correlations are not fallacious. We will consider alternative methods – the Bayesian approach – to estimate the correlations (Nuzzo, 2017; Runge et al., 2019), with a likelihood analysis (Hamimeche and Lewis, 2008). The Probability Density Function (PDF) of the correlation will be evaluated considering the measured signal; the analysis of this PDF will allow to demonstrate if the correlation really exists.

The last step aims at **discovering the dynamics of the system**. The main idea is that the dynamics of the system is fully embedded in the data. Goals are to combine state-of-the-art data-adaptive methods to perform dynamical and empirical reductions of the transformed data. We will first apply a dynamic mode decomposition, in line with the Koopman linear operator (Mezić, 2013). From transformed variables, we will thus try to determine the dynamical system equation and its corresponding Probability Density Function, to investigate the extreme sea levels. Moreover, from this dynamical decomposition, we should be able to predict the variables on the past, but also in the future (based on climate simulations of the forcings), in the perspective of predicting future changes. Finally, the reduced model will be compared with the more classical ocean dynamics model.

References

[1] Bruna et al. (2015). Intermittent process analysis with scattering moments. Ann Stat

[2] Hamimeche and Lewis (2008). Likelihood analysis of CMB Temperature and polarization power spectra. Phys. Rev. D

[3] Mezić (2013). Analysis of Fluid Flows via Spectral Properties of the Koopman Operator. Annu. Rev. Fluid Mech.

[4] Nuzzo (2017). An introduction to Bayesian data analysis for correlations. PM&R

[5] Takens (1981). Detecting strange attractors in turbulence. Dynamical systems and turbulence, Springer

[6] Runge et al. (2019). Inferring causation from time series in Earth system sciences. Nat. Commun.

[7] Wasserstein and Lazar (2016). The ASA statement on p values: Context, process, and purpose. Am Stat

The candidate

Qualification
PhD in Marine Sciences, Physical Oceanography, Geosciences or Ocean Data Science.

Skills
Scientific curiosity.
Technical abilities in scientific programming (Python).
A training experience in artificial intelligence and/or ocean data analysis will be appreciated.
Good oral and written English is required.