Post-doctoral position, within the Horizon Europe ClimTip project (Climate Tipping Points).

Studying the sub polar gyre and AMOC tipping points using machine learning, emulators, and rare events algorithms

Supervised by *Freddy BOUCHET and co-supervised by Michael GHIL*.
Where: École Normale Supérieure ENS/PSL Paris and IPSL - Laboratoire de Météorologie Dynamique (LMD).
When: Starting as soon as possible.
Duration: A two-year post-doctoral position with a possible extension.

Scientific description:

This project aims to develop new tools which will be key for future studies for the tipping points of the North-Atlantic SubPolar Gyre (SPG) and Atlantic Meridional Overturning Circulation (AMOC).

In our group, we have recently demonstrated that rare event algorithms can lead to a gain of 100 to 1000 times in the computational cost required to compute rare events in climate models, for instance extreme heat waves [1,2,3]. This technique will probably have a huge impact in the future for the study of climate tipping points, allowing to compute transition trajectories [4] and computing the probabilities of early tipping which cannot be estimated otherwise.

We have also developed new machine learning [5,6] and emulator methodologies, aimed at determining precursors. Such prediction tools are critical to drive rare event simulations.

The first main goal of this project will be to develop new theoretical and mathematical approaches in order to use machine learning and emulators to determine precursors for tipping points, and prediction tools for tipping points. The second main goal will be to implement these prediction tools for the subpolar gyre tipping point. These studies for the subpolar gyre will be performed with the best available datasets and climate models.

As a complement to these studies for the subpolar gyre, we will also develop the prediction/rare event simulation methodology on simpler models and datasets. We will for instance study the coupling of machine learning and emulators with rare event simulations. The long-term goal will be the use of rare event simulations for studying the sub polar gyre and AMOC tipping points. Part of the project goal will be to study the feasibility of rare event simulations for the AMOC.

[1] F. Ragone, J. Wouters and F. Bouchet, 2018, Computation of extreme heat waves in climate models using a large deviation algorithm, Proceedings of the National Academy of Sciences, vol 115, no 1, pages 24-29, [pdf].
[2] F. Ragone and F. Bouchet, 2021, Rare event algorithm study of extreme warm summers and heat waves over Europe, Geophysical Research Letters, 48, e2020GL091197., *arXiv:2009.02519*, [pdf].

[3] C. Le Priol, J.M. Monteiro, and F. Bouchet, 2024, Using rare event algorithms to understand the statistics and dynamics of extreme heatwave seasons in South Asia Authors, accepted for publication in Environmental Research: Climate., arXiv:2404.07791

[4] F. Bouchet, J. Rolland, and E. Simonnet, 2019, A rare event algorithm links transitions in turbulent flows with activated nucleations, Phys. Rev. Lett. 122, 074502, https://doi.org/10.1103/PhysRevLett.122.074502, arXiv:1810.11057, [pdf]
[5] G. Miloshevich, B. Cozian, P. Abry, P. Borgnat, and F. Bouchet, 2023, Probabilistic forecasts of extreme heatwaves using convolutional neural networks in a regime of lack of data, Phys. Rev. Fluids 8, 040501, doi.org/10.1103/PhysRevFluids.8.040501 and *arXiv:2208.00971*, [pdf].
[6] D. Lucente, J. Rolland, C. Herbert and F. Bouchet, 2022, Coupling rare event algorithms with data-based learned committor functions using the analogue Markov chain, J. Stat. Mech. 083201, *arXiv:2110.05050*, [pdf].
[7] Bach, E., and M. Ghil, 2023: A multi-model ensemble Kalman filter for data assimilation and forecasting, J. Advances Modeling Earth Systems, 15, e2022MS003123, doi:10.1029/2022MS003123.

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Profile: Applications are invited from candidates with a PhD degree, either in the fields of physics, climate, mathematics, or computer and data sciences. The motivation of the candidate for climate studies within a multidisciplinary environment will be essential.

The Climtip project: Climtip is a H2020 project, gathering dozens of European teams and labs. The main aim is to quantify climate tipping points. The post-doc will benefit from this rich network, with regular meeting and strong collective endeavor.

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Application process: Applications must include a cover letter, a CV, 2 recommendations letters and be sent directly to Freddy.Bouchet@cnrs.fr.