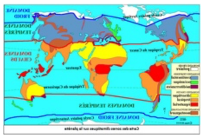
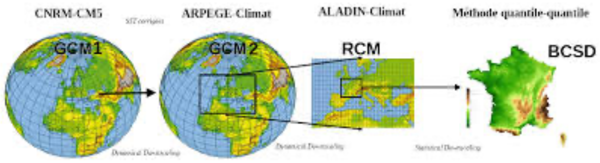
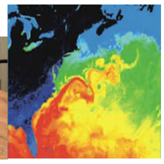
CEA Saclay –Service de Physique de l'Etat Condensé (SPEC) (page web)
Laboratoire *SPHYNX*
Laboratoire des Sciences du Climat et de l'Environnement (LSCE)

PROPOSITION DE STAGE/THESE 2023/2024

CAN WE PREDICT THE WEATHER OR THE CLIMATE?

According to everyone's experience, predicting the weather reliably for more than a few days seems an impossible task for our best weather agencies. Yet, we all know of examples of "weather sayings" that allow wise old persons to predict tomorrow's weather without solving the equations of motion, and sometimes better than the official forecast. On a longer scale, climate model have been able to predict the variation of mean Earth temperature due to CO_2 emission over a period of 50 year rather accurately.
How can we explain all these puzzling information?

In the late 50' and 60's, Lewis Fry Richardson, then Edward Lorenz set up the basis on the resolution of this puzzle, using observations, phenomenological arguments and low order models.

At first, it was thought that the predicibility problem lies in the difficulty of defining a meteorological chart with absolute precision. Then, due to chaos and sensitivity to initial condition of the governing fluid equations, any small departure from the true initial condition results in a large difference with the true weather state after a few days. Later, Lorenz realized that the main problem was more fundamental, and linked with the huge number of degrees of freedom of the geophysical fluids, combined with their singular nature in the inviscid limit, resulting in the famous "butterfly effect". This effect precludes the use of deterministic models to describe fluid motions, but it is conjectured that the statistical fluid organization is universal and possibly predictable, using relevent tools.

All these explanations were based on intuition and very rudimentary numerical simulations.
Present progress in mathematics, physics of turbulence, and observational data now allow to go beyond intuition, and test the validity of the butterfly effect in the atmosphere and climate. For this, we will use new theoretical and mathematical tools and new numerical simulations based on projection of equations of motion onto an exponential grid allowing to achieve realistic/geophysical values of parameters, at a moderate computational and storage cost.

The goal of this internship is to implement the new tools on real observations of weather maps, to try and detect the butterfly effect on real data. On a longer time scale (for a PhD), the goal will be to investigate the "statistical universality" hypothesis, to understand if and how the butterfly effect leads to universal statistics that can be used for climate predictions, and whether we can hope to build new "weather sayings" using machine learning, allowing to predict climate or weather without solving the equations.

This project combines advanced theoretical and numerical tools, based on non-linear and statistical physics. It will be co-supervised by B. Dubrulle (SPEC) and D. Faranda(LSCE). The internship subject requires a solid background as a physicist, particularly in non-linear and statistical physics, as well as a strong taste for numerics. It may lead to a funded PhD on a related topic, in co-tutella with D. Faranda (LSCE).

CONTACTS : Bérengère Dubrulle, **06 67 15 99 46**, berengere.dubrulle@cea.fr