Identification of climatic extremes by multi-fractal analysis of long climate data series

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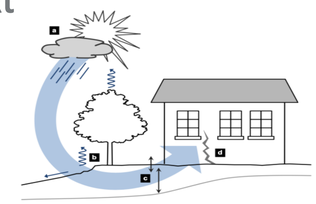
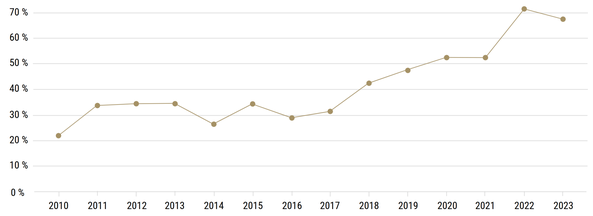
Context

- **Average annual cost** of **clay shrinkage and swelling** in France: **€1.35 billion**, with significant growth in claims in recent years.
- Clay shrinkage and swelling are **triggered by variations** in soil **moisture**:
  - If soil moisture is low, shrinkage occurs.
  - If soil moisture is high, swelling occurs.
- **Global warming** is increasing the frequency and intensity of extreme weather events, **exacerbating the phenomenon.**
- **French Agency for Ecological Transition finances projects** such as IRGAK, which is the subject of my thesis and which seeks **to develop solutions to remedy this phenomenon**.



Impact chain leading to building damage due to soil subsidence : Meteorology(a), soil interactions(b), shrinkage and swelling(c), building damage(d) (T. Corti, 2009)



Share of drought claims over a sliding 5-year period in France (Caisse Centrale de Réassurance, Bilan 1982-2023)

Data and method

The method presented here consists of identifying the statistical signatures of past extreme events and attempting to find them in climate projections:

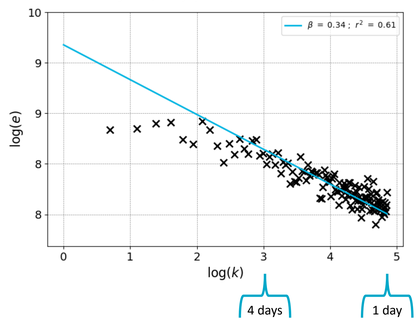
- Spectral analysis: Determines the conservative aspect of a field.
- Fractal analysis: Examines self-similar structures and scaling behaviors, helping to understand complexity and scale breaks.
- DTM (Double Trace Moment): Estimates precipitation distribution parameters (α and C1), considering both the frequency and intensity of rainfall events:
  - α (multifractality index), between 0 and 2, characterizes the speed of evolution of the intermittency. For a monofractal field, α = 0.
  - C1 (fractal co-dimension) characterizes intermittency, i.e., the inhomogeneity of a field. A value of 0 corresponds to a totally homogeneous field.
  - Physically, precipitation extremes increase with C1 and α.

These analyses are applied to several datasets:

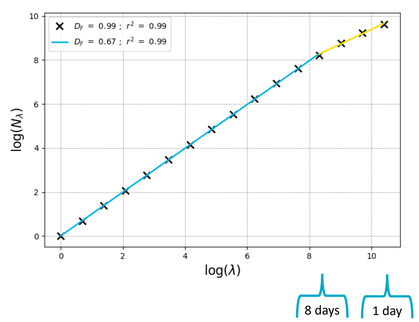
- From models, radar re-analyses, satellite data and ground measurement stations (from Météo-France).
- The project covers the whole of mainland France, with a maximum resolution of 1 km and hourly time steps.
- The data analyzed will cover the main parameters influencing soil moisture, namely precipitation and temperature.

Study cases

Spectral analysis (daily precipitation observation - Paris)



Fractal analysis (daily precipitation observation - Paris)



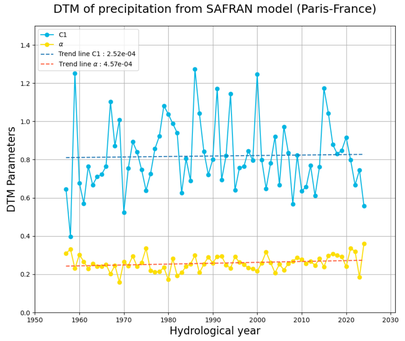
Spectral analysis:

- Scale invariance up to 4 days (log(k) = 3). After this threshold, the data no longer follow the slope.
- Value of **β = 0.34**. It is less than 1, **indicating a conservative field** (possibility of DTM analysis).

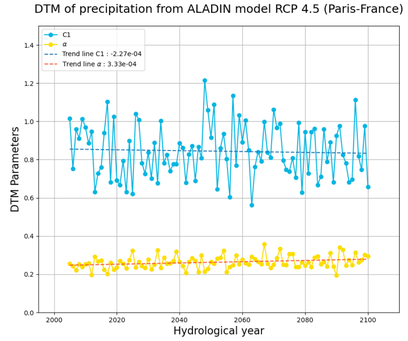
Fractal analysis:

- **Scale break** observed at 8 days (log(λ) ≈ 8,5).

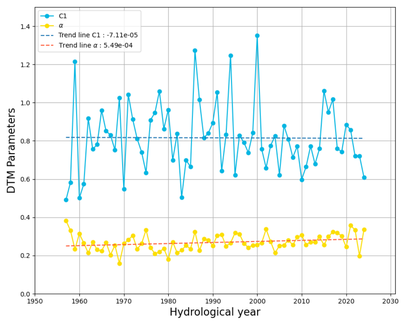
DTM of precipitation from SAFRAN model (Paris-France)



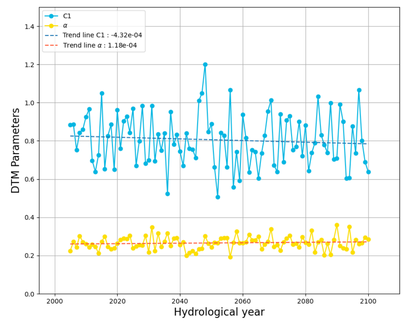
DTM of precipitation from ALADIN model RCP 4.5 (Paris-France)



DTM of precipitation from observation station (Paris-France)



DTM of precipitation from ALADIN model RCP 8.5 (Paris-France)



- DTM show on the left past precipitation data (simulated and observed) and on the right projections according to RCP scenarios (4.5 and 8.5).
- SAFRAN and ALADIN are Météo-France models covering France with a resolution of 8Km and a daily time step.
- Trend in **C1 increases** or does not vary over **past years**, while for **projections it decreases.**
- **α increases** over both past data sets and projections, with a more pronounced increase over past data.
- Even a **slight variation** in parameters **can indicate strong changes** in the precipitation regime.
- As **C1 and α vary in opposite ways on the projections**, further study is needed to determine the dominant parameter.

Conclusion and Outlook

- There is **no direct data on clay shrinkage and swelling.** Therefore, the analysis **results will be compared with the cost of the phenomenon.**
- Conducting the aforementioned analyses in different geographical areas of France for comparison purposes.
- **Developing a model to simulate future shrink-swell according to the scenarios used,** applicable to the whole of France**.**

This presentation participates in OSPP

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Sharing is encouraged

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