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Linking meteorological extremes to clay shrink–swell hazard: Insights from 65 years of climate data

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1. Motivation

Climate driver: Seasonal rainfall/drought cycles cause soil moisture fluctuations, triggering clay shrink-swell (CSS) behavior and ground movements.

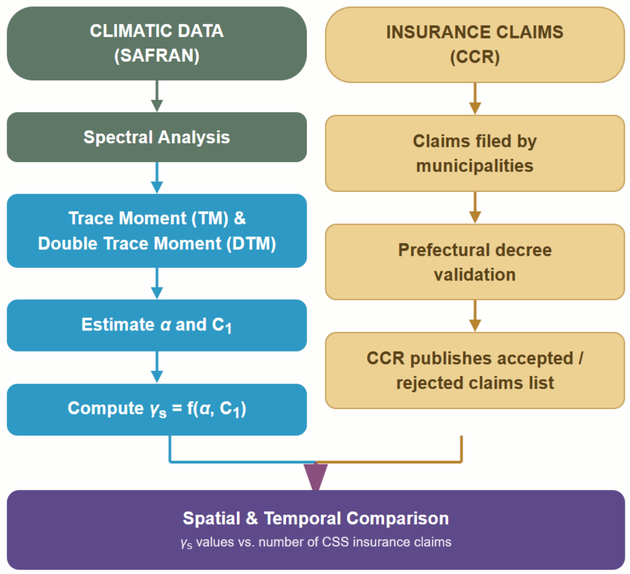
Infrastructure threat: CSS damages building foundations. The average annual claims cost rose from <€300 M (2016) to ~€1.35 B (2025).

Climate change amplifier: The increasing frequency and intensity of extreme weather events exacerbate CSS phenomena nationwide.

2. Objective

This study uses more than 65 years of climate data and Universal Multifractal (UM) analysis to characterize CSS dynamics and support risk mitigation within the IRGAK project.

3. Method



Scan for ORCID

EGU26-12716ECS

4. Results

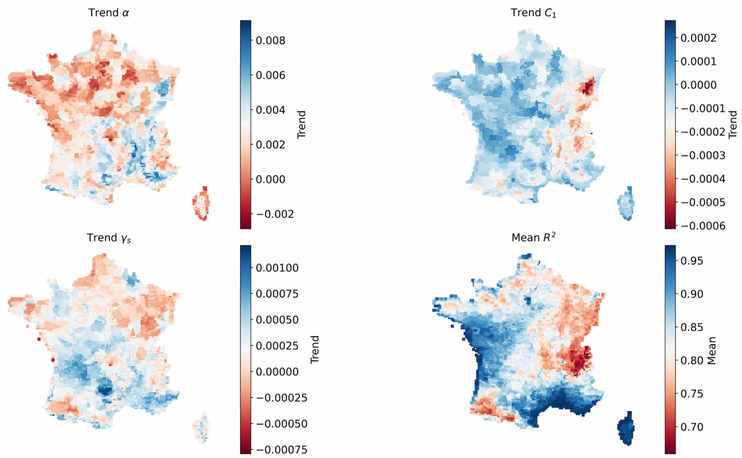
Geology: Metamorphic and granitic regions are generally unaffected by CSS.

Statistical significance: Dark blue pixels (p-value < 0.05) confirm that the observed relationship is unlikely to be due to chance (<5% probability).

Limits of the comparison: CSS depends on multiple climatic parameters and geological factors. This type of comparison only allows one parameter to be assessed at a time.

Data reliability: Claims data are derived from prefectural decrees and do not constitute direct measurements of the phenomenon.

Trends in UM parameters for AET - 1958-10-01 to 2025-09-30



Data

SAFRAN grid (8 km);
Insurance claims 1988–2024;
Pixels with fewer than 20 claims excluded (statistical reliability).

UM parameters for AET

Mean α = 1.4;
Mean C_1 = 0.06;
R^2 = 75-95% → indicating a robust UM analysis.

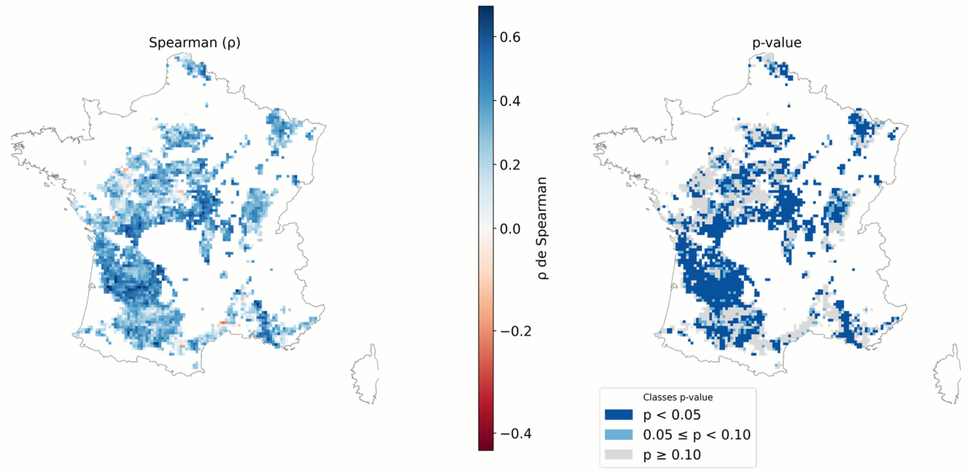
Trend Analysis

α slight increase in southern France;
C_1 increase in northern France and Aquitaine;
γ_s rising in Aquitaine (high CSS activity).

Correlation

A spatial correlation of ~60% is observed between AET γ_s values and CSS claims, suggesting a strong link between AET extremes and CSS intensity.

Correlation plot between γs(AET) and the number of CSS claims (1988-10-01 to 2024-09-30)



5. Conclusion

Results: A comparison of UM parameters with CSS claims data shows a strong correlation despite the low quality of the claims data and the complexity of the phenomenon.

Next, multifractal parameter assessment: Multi-parameter approach (Random Forest / GPBoost) integrating climate spatial (neighboring pixels) and temporal dependencies, beyond pixel-wise comparison.

Toward operational solutions: Results from feature importance analysis will help calibrate the soil stabilization solutions developed in the IRGAK project.

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