Evidence Of Climate Change Induced Seismicity

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Abstract

- The **geosphere** can dynamically respond to climate change.
- Climate change driven **heat waves** affect high-altitude cryosphere and can cause the snow to melt.
- This study confirms that most of Grandes Jorasses Earthquake Sequence (GJES) events which are known to be melt-water induced, follow heat waves.

Physics Informed Risk Analysis Of Seismicity

Climate change induced snow/glacier melt can increase seismicity. Data [2] shows an increase in the periodicity and intensity of such events. This work plainly constructs the **causality** proposed between **geosphere response to climate change** as observed previously by Gao et al. (2000) in California and hypothesized by Ben-Zion and Allam (2013) and Simone et. al (2025) using the notion of Heatwave Index by Russo et. al. towards a framework for risk analysis and management for alpine (and arctic) residents.

Statistical Analysis & Modeling

Non-Parametric Model: Permutation Test

Randomly shuffling heatwave events with GJES events, fewer than 50 permuted correlations out of 1,000 are as large as the observed one, hence the **95 % confidence interval**. Observed correlation is greater than 3σ away from null hypothesis. Fig. 4.

Bayesian Likelihood For Risk Analysis:

$$\mathcal{L}(\beta, S_0 | \{S_t, H_t\}_{t=1}^{T}) = \prod_{t=1}^{T} \frac{(S_0+\beta H_t)^{S_t} \exp(-(S_0+\beta H_t)}{S_t!}$$

Current and future research by this author employ Inverse modeling of seismic events over time by estimating the parameters of a model that includes a baseline seismic event rate, $S_0 \geq 0$. Binary Indicator for heatwave events is $H_t \in \{0, 1\}$ at time t. Keeping the period $T \in [90, 120]$ days range, allowing for soil consolidation while $t \leq T$. Poisson rate $\lambda_t = S_0 + \beta H_t$ assumes increase in the rate by β give a heatwave. $P(S_t | H_t, \beta, S_o) = \frac{\lambda_t^{S_t} e^{-\lambda_t}}{S_t!}$. **Model limitation:** the likelihood $\mathcal{L}$ provided here assumes seismic events themselves are independent of each other across time.

Data Availability

[1] Réseau Sismologique et géodésique Français.
French seismological and geodetic network: 8c network (2019).
https://seismology.resif.fr/networks/#/8C__2019, 2025.
Accessed: 2025-09-18.

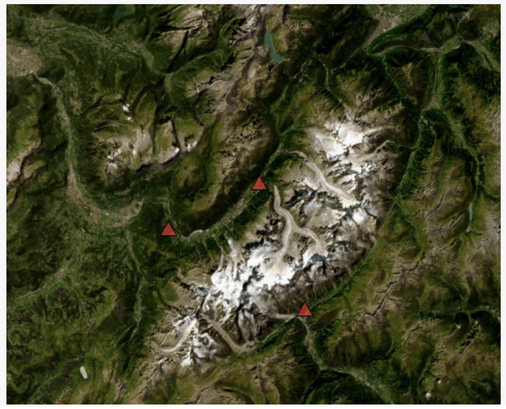
[2] Swiss Seismological Service (SED).
https://networks.seismo.ethz.ch/networks/ch/, 2025.
Accessed: 2025-09-18.

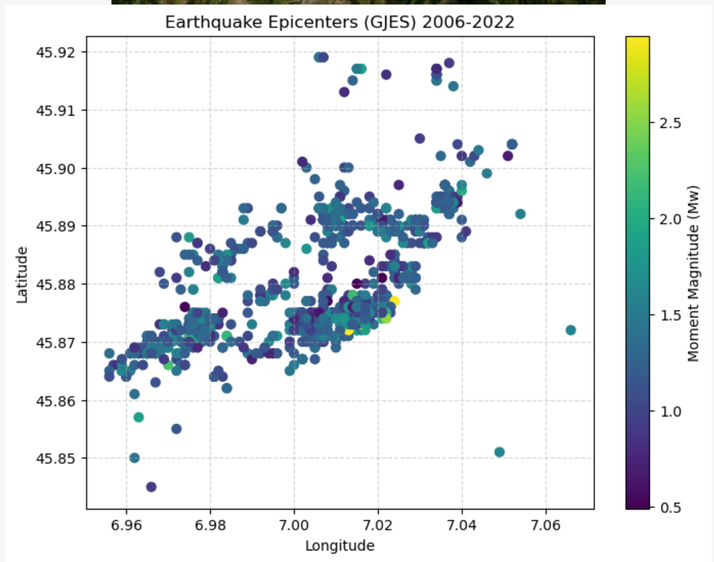
[3] Previsioni Meteo vda Regione Autonoma Valle d'Aosta.
Aosta valley weather forecast - autonomous region of aosta valley, italy.
https://presidi2.regione.vda.it/, 2025.

Case Study: Grandes Jorasses Earthquake Sequence (GJES)

Seismic Activity

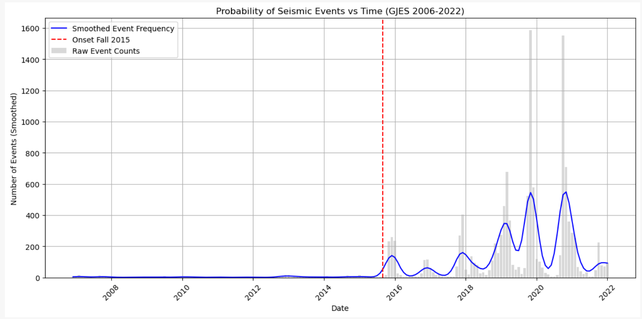
Seismic activities near Grandes Jorasses, Mont Blanc Massif, France/Italy are recorded by multiple nearby stations. Figure 1 shows the spatial distribution.



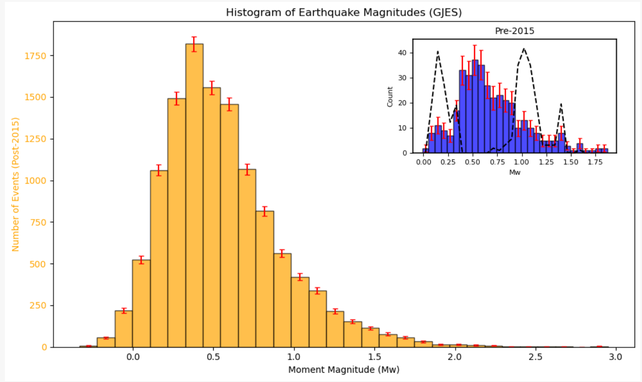


An aerial view of Grandes Jorasses, Mont Blanc Massif, France/Italy as well as the 3 seismic stations [1]. Up: Chemin du lavousse, 74056, Chamonix-Mont-Blanc, Haute-Savoie, Auvergne-Rhone-Alpes, France, Left: Ecole de Physique des Houches, 74143, Les Houches, Haute-Savoie, Auvergne-Rhone-Alpes, France, right: La Palud, 99127, Vallee D'aoste, Italy. Depths for each point can vary to a few kilometers.

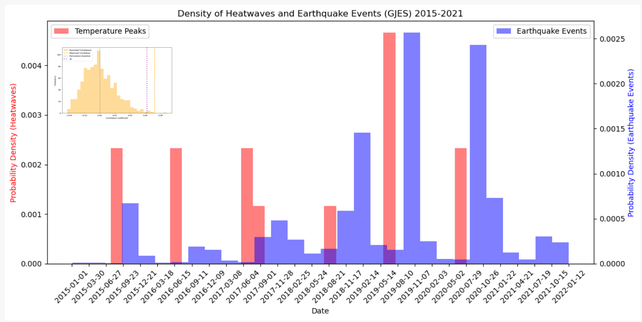
Data Analysis



Time series analysis of GJES seismic events based on raw seismic data [1]. Seasonal variations are noticeable in each region. The increase in the number of events post 2015 is suspected to be climate change (heat wave) induced. See Analysis section and fig. 4 for correlation analysis.



Pre-2015 vs Post 2015 seismic events (GJES). The number of post-2015 seismic events are two orders of magnitude higher than those of the pre-2015. A regression in the distribution of the magnitudes towards 0.5 Mw expectation value is also consistent with micro-seismicity caused by melt-water.



The causality relationship between temperature peaks (HWMI of temperature consistently $\geq$ 25 C) and seismic activity. Permutation Test for Heatwave Peaks (Data from [3]) vs. Earthquake Counts (Δ t = 120 days) show a statistical significance with observed correlation being 3.5 σ away from the null hypothesis. Further Bayesian parametric analysis as discussed can provide a risk management method for alpine residents.