

EGU21-2654

<https://doi.org/10.5194/egusphere-egu21-2654>

EGU General Assembly 2021

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Investigating the relationship between seismic sequences and hydrological loading in the Azores

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Hydrological loads can be either surface loads induced by precipitation, changes in water levels at crater volcanic lakes, or subsurface loads created by seasonal changes in groundwater levels. These may contribute to strain and stress transients that trigger small earthquake swarms at faults that are already near failure. This work focusses on how annual and multi-annual stress changes of hydrological origin may affect the generation of seismic sequences on several tectonic settings, such as the New Madrid Seismic Zone and the Azores. The New Madrid seismic Zone is used as a benchmark test study region, while the Azores has been chosen for its intense seismic activity of both tectonic and volcanic origin. The magnitude of the hydrologically derived variations in stress is small compared with the long-term tectonic stresses, so we look for seasonal and inter-annual modulations of the earthquake occurrence rate. This requires the manipulation of seismic catalogues and the use of statistical methods to check if the seasonal and inter-annual variations are statistically significant, and not the result of extreme climatic events. The impact of hydrologic loads on faults is addressed using high-quality time series of seismic sequences, rainfall and other loads produced by variations in water levels, methods of decomposition and reconstruction of geophysical time series (SSA and wavelet transform) to identify modes of oscillation, and correlation analysis to recognize common patterns in seismicity and water loads. The results provide the first assessment of cyclic variations in seismicity and its relationship with atmospheric disturbances and hydrologically-driven load in the Azores region, and contributes to improve our understanding of the physics of earthquake triggering processes. The authors would like to acknowledge the financial support FCT through project UIDB/50019/2020 – IDL. This is a contribution to the RESTLESS project PTDC/CTA-GEF/6674/2020.