



Locally triggered earthquake swarm in the low-deformation zone of Tinée Valley (Southwestern French Alps) following the extreme rainfall event associated with the 2020 Alex storm

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On 2nd October 2020, an unusual extreme rainfall event (600 mm) associated with the devastating “Alex storm” occurred in less than 24 hours in the Tinée valley, a low strain rate area (convergence rates of 0.3-0.9 mm/yr) of the Southern French Alps, located 20 kilometers from Nice city. This transitional zone between the Argentera Mercantour exhumed Alpine massif and the Nice/Castellane Arc, mainly filled with Cenozoic sediments covering inherited structures, has no clear active faults known and displays a low seismicity rate with only 60 events recorded between 2014 and October 2020 by the national RESIF-EPOS seismic network, with local magnitudes ranging from 0.6 to 2.6. However, in the days after the “Alex storm”, a sudden increase in the seismicity rate was observed, with 114 events detected by template matching (local magnitudes between -0.8 and 2.05). After a peak activity, reached on the 8th of October with more than 60 events detected, the seismic crisis ended around mid-December 2020. Here, we investigate how the intense rainfall can explain the seismic sequences and what are the triggering processes in such a low tectonically deformation area.

Basing our analysis on a precise relocation of the seismicity, using the double-difference relative method, three swarms successively activating from south to north, with focal depths around 5 kilometers have been revealed. The main swarm clearly presents a N160 alignment, which is quite consistent with the general orientation of the Southwestern Alps main faults. A geological field analysis has also shown the presence of major unmapped pluri-kilometers faults consistent with the seismicity location and orientation. Those faults may cross-cut the entire sedimentary layers, connecting more or less directly the ground surface to the deep basement with some highly-permeable channels for fluid flow. Moreover, this relocation analysis highlighted a bi-directional migration of the seismicity within the main swarm: northwestward with a velocity of 100 m/hr, compatible with aseismic slip-driven seismicity, and southeastward with a velocity of 4.5 m/hr, rather compatible with fluid diffusion-driven seismicity.

On top of that, preliminary numerical models, focusing on the analysis of Coulomb stress changes in response to the recorded rainfall rate, showed a correlation between the seismicity rate and the rainfall, which may indicate a rapid saturation of the shallow porous sedimentary layers with fluids after the storm. However, models of stress changes associated with increasing fluid pressure only

or including the effect of poroelasticity are not sufficient to explain the temporal evolution of seismicity and its rates. The contribution of other driving processes is necessary and aseismic slip processes could be more relevant to explain the 3 main bursts of seismicity, the migration pattern and the few-days delay with the rainfall episode. Those rainfall-induced aseismic fault slip may have triggered local seismic ruptures along small seismogenic portions of unknown inherited structures. Thus, our study reveals that the Tinée valley area is a good example to study the complexity of aseismic triggering processes of seismicity in association with shallow rainfall-driven hydraulic perturbations in an intraplate region with a low-deformation background rate.