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3-D deformation rates and processes driving seismicity in the Western Alps and Pyrenees (southern France, northern Spain, northern Italy)

Philippe Vernant (1), Stephane Mazzotti (1), Christine Masson (1), Hai Ninh NGuyen (1), Erik Doerflinger (1), Jean Chéry (1), Giorgi Khazaradze (2), and Eva Asensio (2)

(1) Géosciences Montpellier, Université Montpellier, Montpellier, France, (2) Departament de Geodinàmica i Geofísica, Facultat de Geologia, Universitat de Barcelona, Barcelona, Spain

Although subject to significant earthquakes, the region covering the Western Alps and Pyrenees in southern France, northern Spain, and northern Italy is characterized by very slow deformation rates (below 1 mm a-1), leading to on-going debates regarding the driving processes and characteristics of this seismicity. We present a new 3-D velocity field for nearly 500 GPS sites covering this area, with two main objectives: (1) Precisely define the level of velocity and strain rate signals that can be extracted from the GPS data, and (2) Characterize the patterns and amplitude of present-day deformation in both the Western Alps and Pyrenees to help constrain the geodynamic processes at play.

Statistical analyses of the GPS time series shows that a horizontal (resp. vertical) precision level of 0.2 mm a-1 can be achieved for series of $\sim$6 years (resp. $\sim$9 years), and that the velocity field for the entire Western Alps – Pyrenees region is stable at $\sim$0.2 mm a-1, indicating that horizontal deformation, where present, must be below this threshold. Significant horizontal strain rates are detected in the western Pyrenees, with up to 4 $\times$ 10-9 a-1 NNE–SSW extension, and to a lower level in the Western Alps (< 1 $\times$ 10-9 a-1 E-W extension). In contrast, we identify significant uplift rates in the Western Alps (up to 2 mm a-1) but not in the Pyrenees (0.1 $\pm$ 0.2 mm a-1).

As shown by numerical models and by the correlation between site elevations and uplift rates, fast uplift in the northern part of the Western Alps can be explained for the most part by postglacial rebound following the Würm glaciation. In contrast, the very slow uplift rates in the southern Western Alps and in the Pyrenees may be accounted for by erosion-induced rebound. These results suggest that the primary driving mechanisms for present-day seismicity in the Western Alps, the Pyrenees, and their foreland basins may be visco-elastic rebound. Other processes, such as regional tectonics, post-orogenic collapse, or crustal isostatic rebound lead to velocity and deformation patterns that do not match our new geodetic observations.