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Toroidal asthenospheric flow beneath the western Alps from seismic anisotropy

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Measuring mantle deformation beneath plate boundaries where lithosphere interacts with each other such as beneath active mountain belts is an important objective of «mantle tectonics» that may bring a new view on the depth extent to the Earth's surface observations. In the present study, we analyse data from about 50 broadband stations covering the Western Alps and we provide a cohérent picture of upper mantle anisotropy beneath the belt. Systematic analysis of SKS wave splitting has been performed at the various permanent and temporary broad band seismic networks: the Swiss permanent digital network provided data for 23 stations for the period 2006-2008, the Italian RSNI (Regional Seismic network of Northern Italy) provided data for 5 stations for the period 2006 to 2008, the French RLBP (Réseau Large Bande Permanent) provided data for 12 stations for the period 2000-2009 and the temporary deployment of 11 stations (Alps project P.I., H. Pedersen) has been recording during the period 2004-2007 along an EW transect between the French Massif Central and the Alps. These data allowed to perform about 2000 individual SKS splitting measurements, from which 1200 display clear evidence of splitting and 644 of which were of good quality. The resulting anisotropy pattern exhibits a continuous rotation of polarization azimuths of fast split shear waves that closely fit the trend of the Alpine belt: from EW in SE France to NS in the Jura area and NE-SW in eastern Switzerland. The observed delay times are rather high on average (1.4s) requiring strong mantle deformation, but interestingly, the strongest anisotropy is generally not located beneath the internal domains of the Alps but rather beneath the external units, suggesting that the mantle deformation may be not located within the lithosphere and not associated to the Alpine collision processes s.s.. Instead, it suggests that the recorded anisotropy may result from present-day or recent mantle flow in the sublithospheric mantle. We propose that the anisotropy pattern beneath the Western Alps is primarily dominated by a toroidal asthenospheric flow around the Eurasian slab presently plunging beneath the inner parts of the Alps and beneath the Apulian plate. The Western Alps could therefore join the other Mediterranean arcs characterized by toroidal asthenospheric flow around subducting lithospheres, such as the Apennines, the Calabrian, the Gibraltar and the Aegean arcs.