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Detection and characterization of ground surface deformations from wavelet analysis of GPS time series

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Ground surface is subjected to deformations from various origins, acting on very different time scales: fast break during an earthquake, diurnal/semi-diurnal/monthly and other periodic deformations related to tides, seasonal loads related to hydrological events etc.. The amplitude of these deformations is also very variable, from few millimeters up to few meters. GPS is one of the geodetic tools that can be used to quantify these deformations. The goal is then to identify and to differentiate the various mechanisms of deformation involved in a particular region from GPS time series.
The Fourier transform analysis allows the identification of periodic phenomena in GPS time series if the amplitude of the studied deformation is greater than the GPS measurement precision. The characterization of non-stationary signals is more difficult and requires specific analysis. Different methods of singularity detection exist, which have recently been adapted to the processing of GPS time series. This study proposes a method based on the wavelet transform. This time-frequency analysis is particularly adapted to detect and locate in time information of various frequencies contained in non-stationary signals. The wavelet transform is also robust in the presence of noise. Theoretical aspects are well known, but they require adaptation to the case of GPS time series, in particular for the choice of the best suited analyzing wavelet for the detection of deformation processes.
This method has been tested in the French Armorican massif where many GPS data are available. In this region, several phenomena are at the origin of ground surface deformations: 1- tides, with tidal amplitudes among the largest in the world. They generate deformations related to both ocean tide loading and earth tides, with amplitudes up to ten centimeters . 2- diffuse seismicity mainly related to regional tectonics. In this region, earthquakes of magnitude less than 3 are registered every 4 or 5 days, but regular seismic events of magnitude up to 4 can occur. The amplitude of the deformations associated with these events is small (<1 cm), but earthquakes of magnitude greater than 4 are likely to be recorded by GPS receivers. 3- more locally, changes in hydrological loads, seasonal or anthropogenic, within confined aquifers located in the fractured basement produce ground surface deformations up to few centimeters. This study shows that the wavelet transform method is particularly adapted to identify the different processes of deformation of the ground surface from GPS time series.