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Characterization of clay shrinking and swelling at the Chaingy site (Centre-Val de Loire) combining in situ extensometers, SMOS surface soil moistures and Sentinel-1 interferometric spaceborne measurements

André Burnol, Michael Foumelis, Sébastien Gourdier, and Daniel Raucoules
BRGM, Risks and Risk prevention Division (DRP), Orléans, France (a.burnol@brgm.fr)

In France, the risk due to clay shrinking and swelling is the second most important cause of financial compensation from insurance companies behind flood risk. In 2010, BRGM published a first global hazard map, based on the 1:50 000 geological map, geotechnical data and spatial distribution of building damages. The traditional way to improve this map consists of monitoring instrumented experimental sites. Since September 2016, a new site has been implemented at Chaingy (Centre-Val de Loire) by choosing a clayey soil in an urban context exposed to a semi-oceanic climate. Two *in situ* extensometers (E1, E2) have been installed to monitor vertical displacements due to a continuous clay layer at a depth between about 80 cm and 160 cm and capacitive sensors have been deployed inside boreholes at about 120 cm depth to track soil moisture variations in clayey soils.

During a three-year period (September 2016 – September 2019), the extensometers show that the swelling peak level is attained during the spring (with a maximum of 10 millimeters in only 4 months) and the peak of ground settlement during the fall. Another result is a strong spatial and temporal variability comparing the two extensometers, spaced only about 12 m apart: the expansion is up to three times higher at E2 than at E1 during this period.

Another innovative way to improve the swelling-risk map is to use Synthetic Aperture Radar Interferometry (InSAR) technique. During the same 3-year period, the Copernicus Sentinel-1 acquisitions were processed using the P-SBAS (Parallel Small BAseline Subset) service of CNR-IREA to monitor the temporal evolution of ground deformation. Using both ascending and descending tracks, the motion in the vicinity of E1 and E2 reflects roughly the seasonal variation of the clay swelling and settlement. Moreover, the estimated displacement rates are consistent to both extensometers linear trends, taking into account averaging effects due to the spatial resolution of the InSAR measurements.

During the same 3-year period, the 10-day SMOS surface soil moisture (SSM) products for descending acquisition geometry are also used to calculate the average of the median, minimum and maximum SSM values. These surface moistures are in phase advance with respect to the soil moistures measurements at 1.2 m depth. The cross wavelet transform (XWT) between SSM and

the vertical displacement at extensometer E2 reveals in the time/frequency space two different periods: 1) the seasonal period (one year), 2) another period (between 4 and 5 months). SSM shows an advance of phase with respect to vertical E2 displacement for both periods. This result is consistent with a water infiltration in the unsaturated zone followed by the swelling of the clay layer.

To a lesser extent, a similar correlation with a phase delay is observed using XWT between SSM and LOS displacement time series. As a perspective, the same method coupling both satellite acquisitions (Sentinel-1 and SMOS) may be generalized to improve the global French shrink/swell risk evaluation at a finer resolution.