# Soil moisture retrieved from multi-constellation and multi-frequency GNSS signals

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## Abstract

Global Positioning System (GPS), and later Global Navigation Satellite System (GNSS), was initially designed to provide high accuracy Position Velocity and Time (PVT) for military or civilian purposes. High accuracy information presupposes the elimination of both systematic and random errors. Unlike the strategy followed in precise positioning applications, in GNSS remote sensing one or multiple errors are isolated and exploited. In soil moisture estimation, we focus on the multipath effect and use the patterns of the signal-to-noise ratio (SNR) observations created by the interference between the direct and the reflected signal.

There were various experiments in the past showing the effectiveness of this method using only single-frequency GPS signals. When estimating soil moisture, one has to compare two or more interference patterns that occur in the same location. It is very convenient to use GPS signals because each reflection is repeated almost every day (the period is approximately 23h 56m or one sidereal day). On the other hand, Globalnaya Navigachionnaya Sputnivaya Sistema (GLONASS) and Galileo reflections are repeated every eight and ten sidereal days respectively. Our approximation combines observations from all three constellations mentioned above and frequencies (L1, L2 and L5) in a least-squares adjustment (LSA). We use observations from two stations located in northeast Germany (Marquardt and Fürstensee) and we use data from time-domain reflectometry (TDR) for control. We have tried various combinations and, in the best case, our solutions show a correlation of 0.8 and a root-mean-square error (RMSE) of 3% vol/vol.