Relationship Between the GNSS Signals and Soil Moisture During the SMOS Validation Rehearsal Campaign in 2008

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Introduction

Soil moisture is a variable that plays a crucial role in various processes that occur in soil-atmosphere interface. Determines the distribution of solar radiation and the distribution of rainfall into surface runoff or infiltration. It is also a factor in the growth and development of crops and plants in general, since it determines the available water content in top soil where they develop the roots of most crops in the early stages.

The GPS constellation consists of 24 satellites orbiting the earth at an altitude of about 20126.61 km on Ecuador. These satellites are designed so that at any point on Earth has at least 4 satellites available for three-dimensional navigation. Each satellite transmits a PRN (Pseudo Random Noise), a random code, but always the same for each satellite and orthonormal with respect to the other).

GPS signals will be increasingly operational and will be installed GPS sensors on future missions for Earth observation, so this poster intends to use test campaigns for the validation of SMOS at the Valencia Anchor Station to study relationship between soil moisture and the GPS signal.

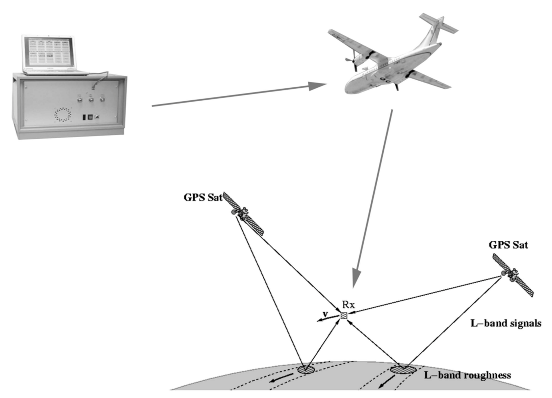
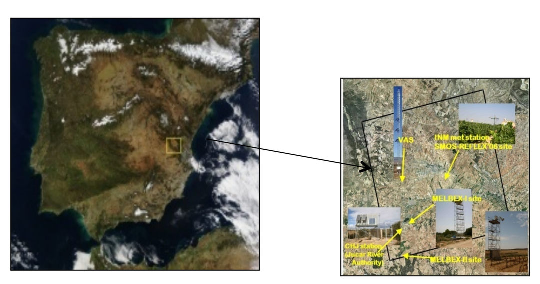


Figure1: GOLD-RTR and PAssive Reflectometry and Interferometry System (PARIS).

Location

The study area includes the reference area of the Valencia Anchor Station in the Natural Region of *La Plana de Utiel-Requena*, located west of the province of Valencia. It represents an area of about 2500 km^2 (The area is fairly homogeneous and is mainly dedicated to the cultivation of vineyards). The coordinates of the study area the following: **Latitude:39.838°-39.199°N Longitude:1.541°-0.884°W**



The area has a dry continental climate. Within this area, a control area 10 x 10 km^2 was established, heavily equipped with soil moisture measuring instruments and other meteorological sensors.

Methodology

1. Evolution of signal between a wet day (after a rain event) and dry day.

2. Comparison between the GPS signal and volumetric moisture values taken in situ.

3. Soil moisture continuous map obtained with soil moisture in situ measurements using geostatistical models.

4. Comparison of GPS data with soil moisture simulated data.

5. Nonlinear modeling between soil moisture content, sand-, silt- and clay-content and the GPS signal.

Results

2.1. Ground data vs GPS signal data

Comparison of the airborne data (amplitude) from a dry (02/05/2008) and a wet day (22/04/2008) for an area with approximately the same angle of elevation.

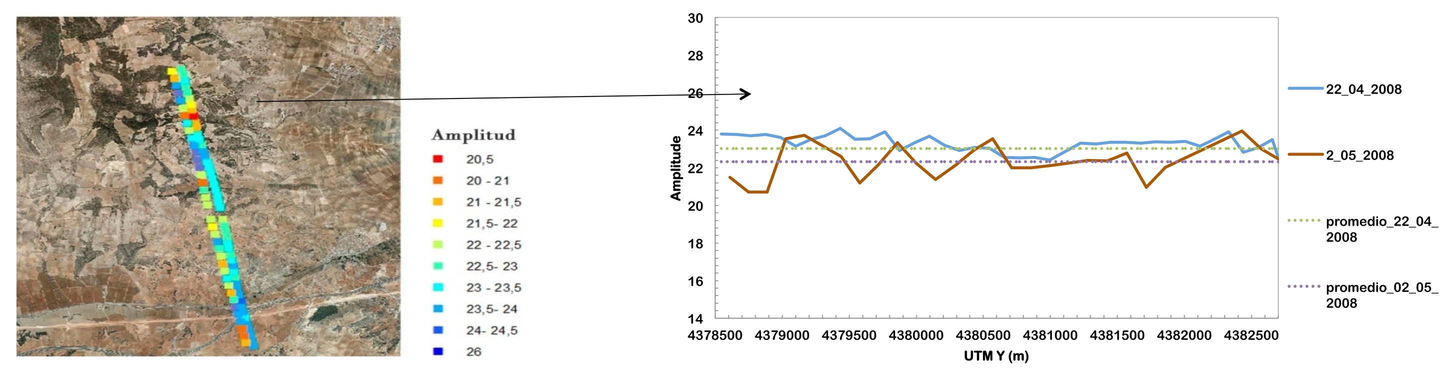


Figure 2: Variation of amplitude on a dry and wet day

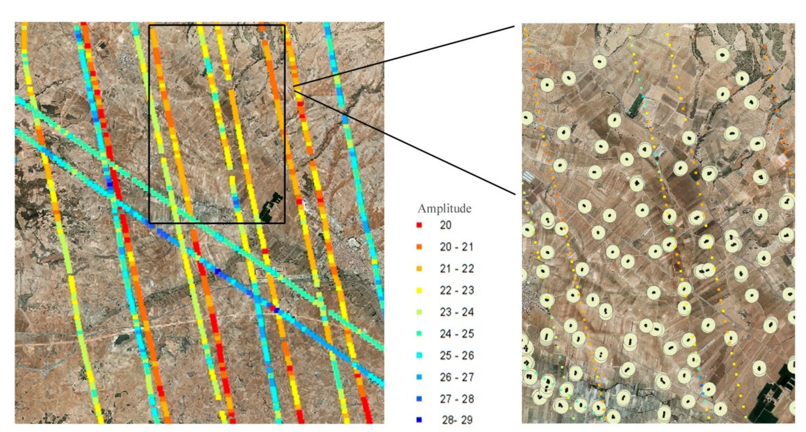


Figure 3: Airborne over 10 x 10 km2 in Utiel - Requena. Buffer between airborne data and in situ data.

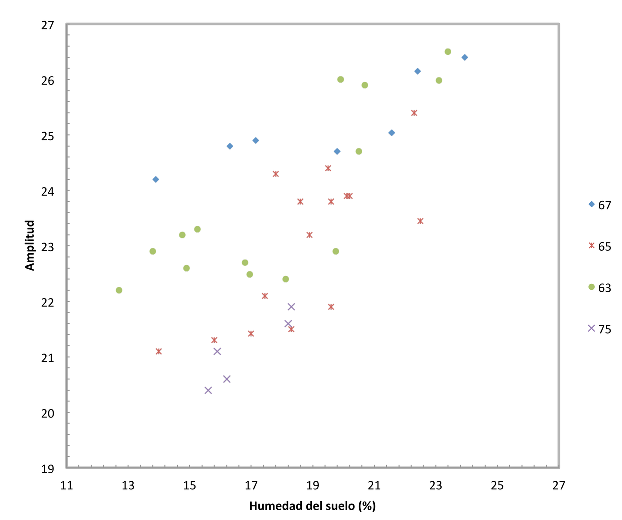


Figure 4: Amplitude variability with differents elevation angles.

Firstly, we compared the airborne data with in situ data. We observed that there was a variation large enought to distort the relationship between the signal amplitude and soil moisture with elevation angle, so we parameterized this relationship as a function of the angle.

In order to compare the airborne data with in situ data we chose small areas of 100 m diameters surrounding every sampling point and considered all the airborne data inside small areas.

Differents correlations between the signal amplitude and soil moisture for different observations angles are showed for relative homogeneous areas (figure 4).

2.2. Geostadistical data vs GPS signal data

In order to perform universal kriging we selected layers of information, such as clay content, sand content, environmental units and soil moisture of different sampling points. In order to adjust the semivariogram a Gaussian model was used.

Unit 54 was chosen for being significantly homogeneous with high sampling density ahd therefore with low variance. As shown in the following two pictures, exists a linear relationship between the signal amplitude of the waveform and soil moisture both for the raw data and using the geo.statistical model.

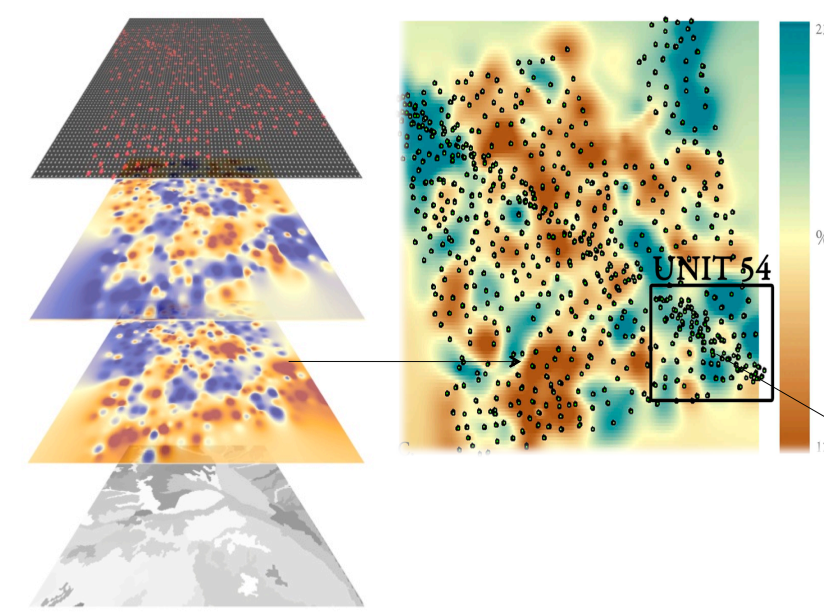


Figure 5: Soil moisture map derived by Universal Kriging from the available covariables

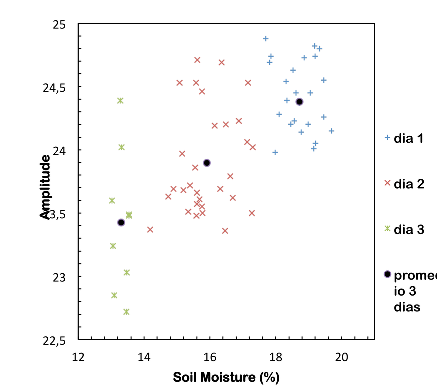


Figure 6: Comparison between soil moisture map and amplitude of the waveform. He also has represented the average of three days. Day 1 (22/04/2008) Day 2 (4/24/2008) and Day 3 (28/04/2008)

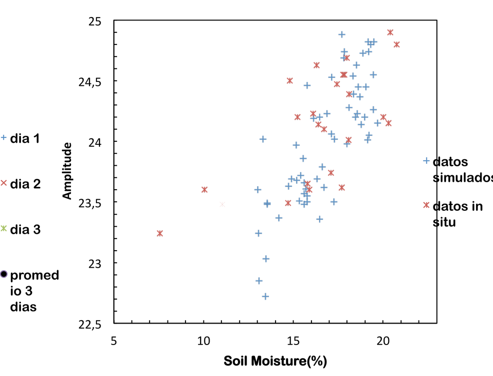


Figure 7: Simulation using the geostatistical model compared with in situ data for the days 22/04/2008, 24/04/2008 and 28/04/2008

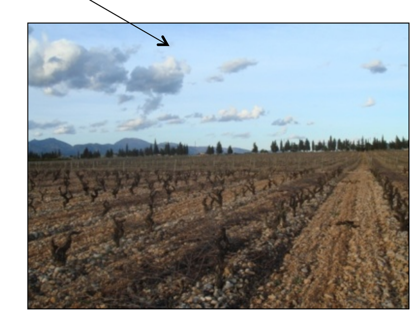


Figure 8: Photograph of environmental unit 54

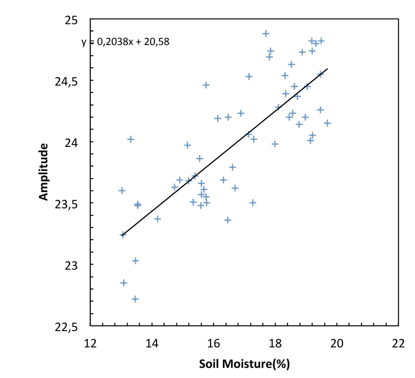


Figure 9: Linear fit between the GPS signal (amplitude) and soil moisture (%) for the days 22/04/2008, 24/04/2008 and 28/04/2008 without outliers. The correlation coefficient is R = 0.79

2.3. No-Lineal Modelization

Neuronal-Network Regression
Kernel-Ridge Regression

Day	N (Number data)	Number neurons	Epoch
22/04/2008	130	7	300
24/04/2008	139	4	300
28/04/2008	155	7	300
02/05/2008	111	7	300

Table 1: Parameters used in the regression

Day	R	RMSE (%)	Method
22/04/2008	0,65	2,7	KRR
24/04/2008	0,77	1,9	KRR
28/04/2008	0,76	2,68	NNR
02/05/2008	0,72	2,74	KRR

Table 2: Results from different days and the method has worked best in each case

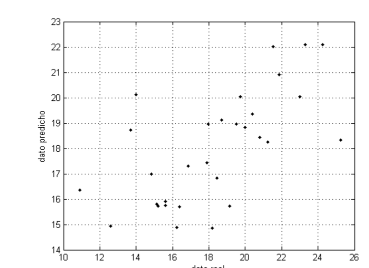


Figure 10: Model for day 22/04/2008 with 25 % of data.

The following table shows the parameters used for the regressions, as are the number of data each day, the number of hidden neurons used and the number of iterations in each case.

The network training has used approximately 60% of values , to validate the test 15% and 25% model.

Conclusion

-Comparing soil moisture measuraments in situ with GPS signal we see that there is an increasing linear relationship between two variables. However, we have seen some factors that distort the relationship such as, the elevation angle , land use or type of texture.
-The use of geostatistical models to predict soil moisture in our study area of 10 x 10 km2, is not very successful, but we can use those areas (diagonal flight line) where sampling density is high enough (see Figure 7 which compare the simulated data with the measures in situ).
-For the environmental unit 54, more homogeneous, we have compared the simulated soil moisture geostatistical model and amplitude, showing that there is better correlation with in situ measurements.
-The use of artificial neural networks (ANN) and Kernel Ridge Regression (KRR) for the regression is satisfactory, although it also shows that the small number of data significantly constrains these techniques. We note that the KRR method provided in this case better than neural networks.