TOWARDS AN OPERATIONAL DAILY SOIL MOISUTRE INDEX DERIVED FROM COMBINATION OF MODIS, ASAR AND AMSR-E DATA

C. Notarnicola[1], B. Ventura[2], L. Pasolli[1,3], F. Di Giuseppe[4], M. Zebish[1]

[1]EURAC-Institute for Applied Remote Sensing, Viale Druso 1, Bolzano, Italy.
[2]Dipartimento Interateneo di Fisica, Via Amendola 173, Bari, Italy.
[3]Dep. of Information Engineering and Computer Science, University of Trento, Via Sommarive, 14, I-38123 Trento Italy.
[4]ARPA-SrvizioIdroMeteoClima, Viale Silvani 6, Bologna, Italy

1. INTRODUCTION

Soil moisture in a key parameter as its variations strongly affects surface energy balance, regional runoff, land erosion and potential crop yields. Then soil moisture detection has many implications, for social, economic and environmental segments.

Techniques and methods to evaluate soil and vegetation water content includes as main instruments passive and active microwave methods but also some indirect measurements based on radiometric techniques in the optical-thermal range.

The retrieval of biophysical parameters, e.g. soil moisture, from remotely sensed data falls within the category of inverse problems where, from a vector of measured values, m, one wishes to infer the set of ground parameters, x, that gave rise to them. The inverse problem is typically ill-posed due to its non-linearity between remote sensing measurements and ground parameters. Furthermore, many aspects of the natural surfaces, such as surface roughness and the amount and type of vegetation, alter the radar backscatter.

Typical microwave sensors demonstrate a capability to detect soil moisture under a variety of topographic and vegetation conditions, especially for the case of SAR (Synthetic Aperture Radar) sensors [1]. These sensors can provide information on small scale (field scale), however their low temporal frequency of such sensors (around 30 days) make it difficult to create an operative observation system exclusively with their use. In the last years the exploitation of operational optical sensors, such as METEOSAT [2], has increased notably. Even with reduced resolution and consequently limited sensitivity to soil moisture content, these sensors can provide daily information on soil moisture status. On the other hand, these sensors can operate in cloud free conditions only, and this is in fact their main limitation. The approach presented in this paper aims at considering the advantages of both SAR and optical images. In greater detail, it considers the soil moisture estimates derived from SAR sensors and use them to calibrate the information coming from the optical data. For the latter, MODIS images have been exploited which have a higher resolution (1 km) if compared with METEOSAT images. The main advantage of this approach is to transform a soil moisture index derived from optical images (MODIS) in soil moisture values. In order to consider the variability from different areas, three main test sites have been chosen located in Italian regions with different meteorological and landscape characteristics.

2. METHODOLOGY

The retrieval algorithm is based on Bayesian techniques used to retrieve soil moisture from ASAR and ALOS SAR images. The algorithm is composed of two modules, one for the bare soil and the other for vegetated soil which includes also the use of optical images (LANDSAT or SPOT images) in order to take into account the vegetation contribution [3], [4].

The soil moisture values retrieved from images are used as a calibration tool for soil moisture index derived from MODIS images. In this case, the method to estimate soil moisture index from optical and thermal images is based on the calculation of the Apparent Thermal Inertia (ATI). The ATI is considered as an approximate (apparent) value of the thermal inertia and is obtained from spectral measurements of the albedo and the diurnal temperature range.

In order to calculate the ATI maps, from the MODIS images (MODIS AQUA level 1 B), the pre-processing steps required are [2]:

- Geometric calibration: MODIS 1B data sets are geo-referenced by using ENVI add-on module MODIS toolkit. The output of this process is a geo-referenced MODIS images with also the - bands transformed from the original DN to radiance values;
- Cloud screen: a cloud mask is applied to the image to reduce the influence of the cloud cover;
- Land-use maps to select mainly agricultural areas and the NDVI maps to select the areas with different levels of vegetation.

The Band 31 which corresponds to the 11 μm is then transformed in brightness temperature by using the inverse Planck law. The soil moisture from SAR images and the Soil moisture index, SMI, derived from ATI are compared in order to find a calibration curve which should cover the entire soil moisture values from saturation to residual moisture values.

Three main sites were chosen for the calibration experiment which exhibit different landscape and climatic characteristics. The Basento basin is located in Southern Italy and is characterized by long period of droughts. The Scrivia valley is flat alluvial plain measuring situated close to the confluence of the Scrivia and Po rivers in Northern Italy. The Cordevole watershed, located at the foothill of Mount Sella in Northern Italy is mainly covered by grassland [5].

.

3. RESULTS

The results over the three areas indicate a strong correlation between the SMI and the soil moisture estimates from SAR images as well as from ground measurements. The area chosen for the validation were mainly bare soil or agricultural fields. Dense vegetation areas were excluded due to the difficulty to apply the ATI concept in this case. The results are illustrated in Fig. 1. Fig. 2 compares the soil moisture values on the Scrivia valley derived from ATI after the calibration and SAR data, respectively.

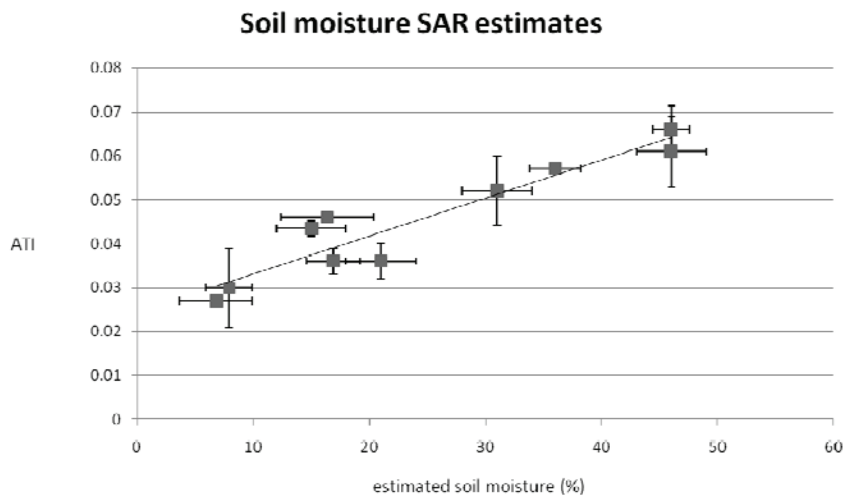

Figure 1. Comparison between ATI-MODIS values with soil moisture values derived from SAR images with the following fit ATI=$8.6*10^{-2}$*SMC+0.024 with R^2=0.89 (SMC expressed in cm^3/cm^3).

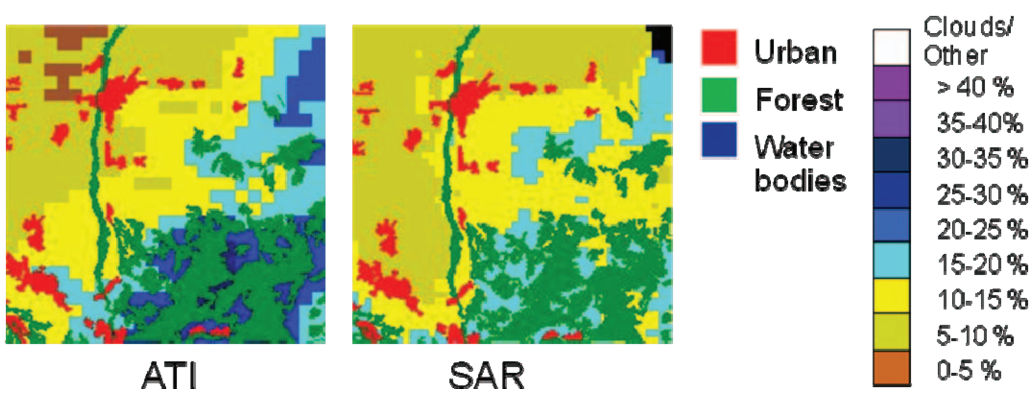

Figure 2. Comparison between the ATI and the SAR soil moisture estimates in the Scrivia valley. The SAR based soil moisture maps have been resampled to the same resolution of MODIS images.

The calibrated ATI has been applied to other data sets to further test the robustness of the methodology. In particular, it has been applied to data acquired in a long ground campaign carried out in Emilia Romagna region (Northern Italy) from June to August 2009. These data were used to further tune the algorithm. In order to capture the complete temperature variations of the day needed by the approach the acquisition of MODIS images should be as close as possible to noon and to midnight. Therefore, to understand the sensitivity of the methodology to the acquisition time, an impact analysis has been carried out and reported in Fig 3. The ATI values change with respect to the daytime acquisition while no trend was found for the nigh-time acquisition.

The correction factor is derived from AMSRE soil moisture maps [6]. Even though these maps have a low resolution (25 km), they provide useful prior information for the estimation of the soil moisture index from MODIS images. First results of the application of AMSR-E data as correction factor for the acquisition time improve the correlation coefficient between soil moisture measurements from 0.55 to 0.74.

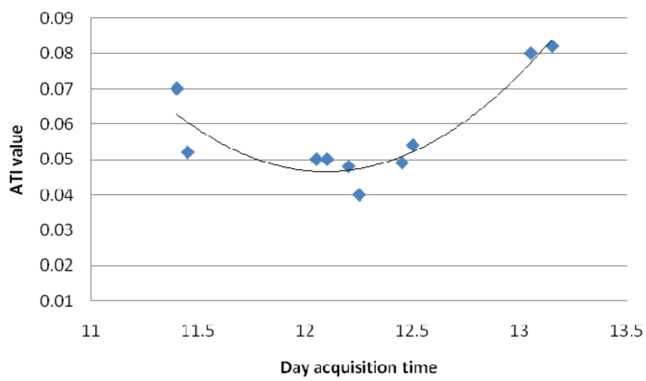

Figure 3. Relationship between the ATI values and the day acquisition time

4. REFERENCES

[1] M.S. Moran, D.C. Hymer, J. Qi, E.E.Sano, "Soil moisture evaluation using multi-temporal Synthetic Aperture Radar (SAR) in semiarid rangeland", Agriculture and Forest Meteorology, 105, 69-80, 2000.

[2] W.W. Verstaeten, F. Veroustraete, C.J. van der Sande, I. Grootaers, J. Feyen, "Soil moisture retrieval using thermal inertia, determined with visible and thermal spaceborne data, validated for European forest", Rem. Sens. Env. 101 (2006), 299-314.

[3] C. Notarnicola, Angiulli M. & Posa, F. (2006). "Use of radar and optical remote sensing data for soil moisture retrieval over vegetated areas". IEEE Trans. Geoscience Remote Sensing, 44(4).

[4] C. Notarnicola,. & Posa, F. (2007). "Inferring vegetation water content from C and L band images", IEEE Transactions on Geoscience and Remote Sensing, vol.45, no.10, p. 3165-3171.

[5] C.Notarnicola, B.Ventura, S. Pettinato, E. Santi, M. Zebisch, "Soil moisture retrieval from SAR images as a calibration tool for soil moisture index derived from thermal inertia with MODIS images", in *Proceedings of Spie Europe Remote Sensing 2009,* Berlin, Germany 2009, 7477-1U.

[6] E.G. Njoku, "Retrieval of land surface parameters using passive microwave measurements at 6-18 GHz," IEEE Transactions on Geoscience and Remote Sensing, 37, p. 79-93, 1999.