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Generation of soil moisture maps from ENVISAT ASAR images by using Artificial Neural Networks

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The sensitivity to soil moisture of the backscattering coefficient measured at low microwave frequencies is a well-known phenomenon. Indeed, research activities carried out worldwide in the past have demonstrated that sensors operating in the low frequency portion of the microwave spectrum (P- to L-band) are able to measure the moisture of a soil layer, the depth of which depends on soil characteristics and moisture profile. The retrieval of soil moisture at higher frequencies, such as C-band, is nevertheless still challenging, since the effects of soil surface roughness and vegetation cover on the backscattering coefficient is high, and needs the use of correcting procedures.

In order to verify the actual capabilities of ENVISAT/ASAR images in providing soil moisture maps of both flat agricultural and mountainous areas, several SAR images were collected in two sites in Italy (Alessandria and Arabba) in 2003 and 2004, along with ground measurements of soil moisture and roughness. The first site selected for the experiment was the watershed of Scrivia located close to Alessandria in Northwest Italy. The area is a flat alluvial plain of about 300 Km^2 situated close to the confluence of the Scrivia river with the Po river. It is characterized by large, homogeneous, agricultural fields of wheat, corn, sugarbeet, and some minor fodder crops. The second test area was the mountain zone on the Cordevole watershed (Arabba). This watershed, located at the foothill of Mount Sella in Northern Italy was selected because of its relatively smooth topography and availability of historical and topographic data. All the SAR images acquired at different dates over the Cordevole test site were geocoded by using a DEM of the area and the orbital parameters. Direct measurements of soil moisture (with a TDR probe) and fresh biomass of vegetation were carried out during the ENVISAT overpasses.

Unfortunately, due to the well-known user conflicts for the northern part of Italy, ENVISAT ASAR images in HH polarization were obtained only for the first test site, while for the Cordevole test area only VV polarization was available. This polarization was demonstrated to be less sensitive than the HH to the moisture of soil, due to the masking effects of vegetation: therefore backscattering coefficients were corrected for the contribution of vegetation cover by using a discrete elements model based on the radiative transfer theory.

The performances of an inversion algorithm based on Artificial Neural Networks (ANN) in retrieving several levels of soil moisture from backscattering data were tested and compared to ground measurements. The used ANN was a feed-forward neural network having some hidden layers of neurons between the input and output, trained by using the back-propagation (BP) learning rule. The available backscattering dataset was divided in two parts: the first portion was used to generate a training set and the second one to test the ANN performances. Furthermore, the experimental training set was increased by simulating radar backscattering through the Integral Equation Model, which was driven with soil data taken from ground measurements. Once the training set was generated, several configurations of hidden layers/neurons were tested to optimise the performances of the ANN.

The obtained results, compared with ground data, showed a satisfactory agreement and enabled us to generate maps with 4-5 levels of soil moisture of both the test sites from the available ENVISAT ASAR images.