

# Monitoring space-time soil wetness variations by a multi-temporal microwave satellite records analysis.



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## Introduction

The dielectric contrast between dry soil and water in the microwave range is at the basis of all the soil moisture retrieval techniques. In particular, a variation of soil water content produce variation in the slope of the soil emissivity plotted at different microwave frequencies (figure 1). By this way, a measurement of the gradient of soil emissivity, between higher and lower microwave channels, could lead to identify qualitative variations of soil water content. Such a gradient intensity is therefore related only on the differential contrast of soil emissivity in dry and wet conditions (which, although the decreasing of the real part of permittivity of water when frequencies increasing, still remain significant), regardless from the absolute value of the dielectric constant at a given frequency.

Starting from these considerations, an innovative AMSU Soil Wetness Variation Index (SWVI) has been recently proposed (Lacava et al., 2005). The SWVI is based on a general approach for multi-temporal satellite data analysis (RAT- Robust AVHRR Techniques, Tramutoli 1998). The RAT (Robust AVHRR Technique) approach is an automatic change-detection scheme that identifies signal anomalies in the space-time domain as deviations from a normal state that has been preliminarily identified (and usually given in terms of time average and standard deviation) on the basis of satellite observations collected during several years, under similar observational conditions for each image pixel. The starting point is the construction of a homogeneous historical satellite records series, produced using all the images acquired throughout the years, in the same month of the year (April, for the event presented in this paper) for more years (since 1999 up to now), and to the same hour of pass. From the analysis of this homogeneous data-set, we are able to characterize the signal measured, estimating its natural variability and its behavior in unperturbed conditions. A change detection procedure, is finally applied, to detect eventually signals anomalies. When RAT is applied to soil wetness monitoring, the measured signal is Soil Wetness Index (SWI) defined as the difference (SWI=T89GHz–T23GHz or SWI=T89GHz–T31GHz) between the radiance (expressed in Brightness Temperature) measured in AMSU (Advanced Microwave Sounding Unit) channels 15 (at 89 GHz) and 1 (at 23 GHz) or 2 (at 31 GHz), respectively. Finally, after the generation of the background references fields, the innovative Soil Wetness Variation Index (SWVI) has been defined.

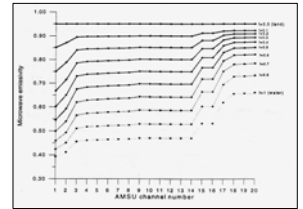
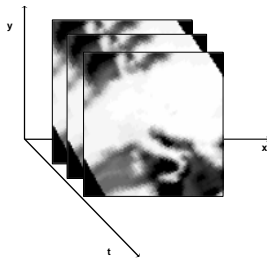
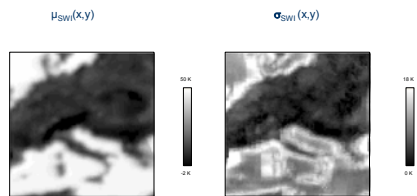


Figure 1. Variation of the AMSU superficial emissivity for different amount of surface wetness ( $\eta$ ) (adapted by Songyan et al., 2002). Note as for the same water content soil emissivity is higher for higher frequencies, and as the gradient in emissivity between higher and lower frequencies increases with  $\eta$ . Therefore, a measurement of the soil emissivity gradient between higher and lower AMSU frequencies (window channels), may give qualitative information about soil water content variations.

### 1) SELECTING HISTORICAL AND HOMOGENEOUS DATA SET OF SATELLITE IMAGES



### 2) COMPUTING THE BACKGROUND REFERENCE FIELDS



$$SWVI(x, y, t) = \frac{SWI(x, y, t) - \mu_{SWI}(x, y)}{\sigma_{SWI}(x, y)}$$

The SWVI(x,y,t) gives, for each pixel (x,y) and time t of observation, the actual SWI excess compared to its unperturbed conditions, weighted by the normal variability, historically observed under similar observational conditions.

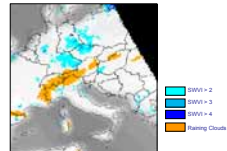


Figure 2. SWVI map for the AMSU image on 01/04/2006 at 06:44 GMT. Different values of SWVI(x,y,t) have been coloured in different shades of blue (higher SWVI values are shown in the darkest blue) and overlaid on the corresponding AMSU images (channel 1 at 23.80 GHz) represented in gray tones (higher brightness temperatures are shown in brighter gray tones); only land pixels have been analyzed. The raining clouds, identified by a screening test proposed by Grody et al. 2000, using AMSU data, are also shown (wherever they are present) in orange.

In order to avoid (or reduce) the clouds problem, we discarded from the successive analysis all the rainy pixels identified by means of an independent screening algorithm proposed by Grody et al. (2000).

## One application: the flood event of April 2006 in Central- Eastern Europe

The studied event has been caused by two extreme meteorological episodes happened during the last spring in Europe. The first one mainly affected Northern Germany, Czech Republic, Hungary and Austria during the last days of March and the first week of April and has been caused by heavy rains coupled on intensive snow melt due to a sudden increase of temperature. The second one (caused by less intensive rains), occurred between the 10 and the 20 of April, interested principally the regions of Romania, Bulgaria, Serbia, still Hungary and marginally Poland and Ucraina.

In order to study this event, all the AMSU data acquired during April since 1999 to present (about 500 images) have been collect to generate the reference fields. In particular two different data-sets (morning and afternoon NOAA pass) have been selected.

Figure 3 shows SWVI maps for several days of March-April 2006, in particular the upper sequence concerns the first phase of the event, while in the lower the maps regarding the second phase are shown.

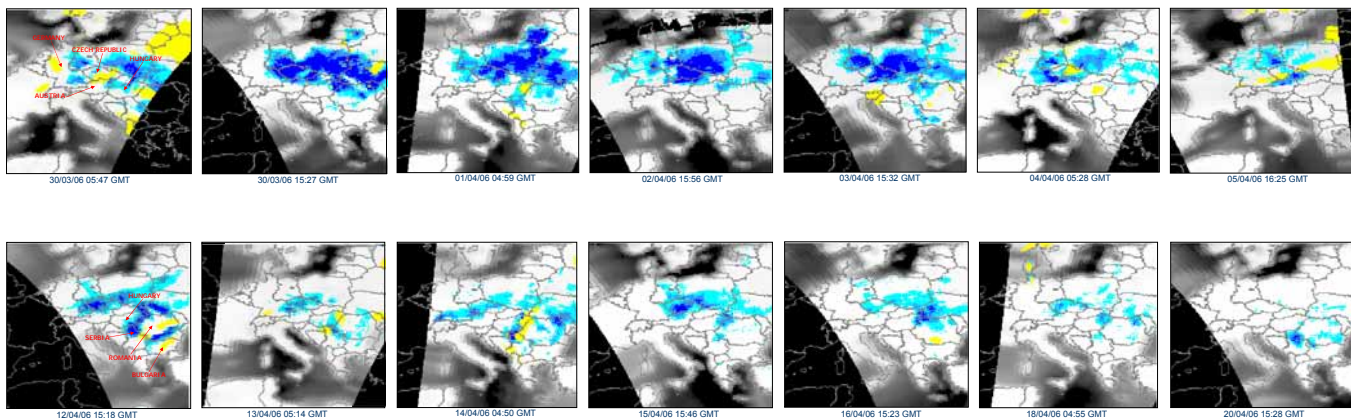


Figure 3. SWVI maps on several days of April 2006. The resulting values of SWVI have been depicted in different blue tones (darker blue identifies wetter conditions), and raining clouds, identified by a screening test, in yellow; the results have been overlaid on the corresponding AMSU images (channel 1 = 23.80 GHz) represented in gray tones (higher brightness temperatures are shown in brighter gray tones).

The analysis of the SWVI maps shows the sudden response (in terms of soil wetness variations) of the soil to the heavy precipitation fallen at the end of March in some European regions. Large areas are, in fact, interested by high SWVI values indicating the presence of anomalously wet soils. This effect, more evident in the first images, seems to slowly decrease in the following days (SWVI values are lower and areas involved are smaller) but does not completely disappear. The effects of the second meteorological event (less intensive) are evident but, they are not as strong as the first one. Such a different result is obviously related to the different amount of rains fallen during the two phases. However, also in this case, the effects tends to reduce in the days following the rains, indicating a slow return to "normal" conditions.

## Summary

A recently proposed robust approach (RAT) has been used to define a Soil Wetness Variation Index (SWVI), aimed at the improvement of soil wetness monitoring capabilities from space in the space-time domain and to possibly contribute to hydro-meteorological risk mitigation. The SWVI index has been implemented and tested on several recent flooding events occurred in Europe. In this poster preliminary results obtained in the analysis of the flooding event which occurred in Europe during April 2006 are presented. Preliminary results achieved seem to demonstrate the efficiency of the proposed indicator in detecting soil wetness variations in the space-time domain.

Furthermore, the proposed change detection scheme allowed us to overcome (or strongly limit) site effects, like those connected to the surface roughness or vegetation cover or due to the presence of stable water bodies within the sensor's IFOV. Further analyses, to be carried out also over an extended set of study cases (including no-extreme events), should be conducted in order to better assess the actual reliability and efficiency of such a technique. A possible future analysis can be devoted to a better evaluation of performances of the 22.5 GHz band, assessing the possible influence and impact of the Water vapour absorption band in SWVI retrievals. A sensitivity analysis of the proposed SWVI is now in progress. This analysis, performed by the comparison with ancillary data, like land cover maps, hydrological data, etc., will allow us to give a better evaluation of the reliability of SWVI in order to describe soil response to precipitations with different duration and intensity. The proposed methodology, now tested using AMSU data, is, for construction, easily exportable on other satellite sensors with better spatial/spectral/radiometric resolutions.

## REFERENCES

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