Relative soil moisture from C- and L-band SAR time series

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Abstract

Soil moisture is a key element in the global hydrologic, energy and carbon cycle. Knowledge about the location specific sensitivity of radar backscatter can be used for operational determination of relative soil moisture over large regions. This approach has been developed for C-Band scatterometer and transferred to C-Band ScanSAR within the ESA Tiger Innovator project SHARE (ENVISAT ASAR WS/GM; www.ipf.tuwien.ac.at/radar/share). This method relies on a high number of acquisitions in order to get a realistic estimate of a dry and a wet reference value and thus sensitivity. The performance of L-Band SAR has not been tested so far for this approach. A first comparison of ENVISAT ASAR Wide Swath and ALOS PALSAR Fine Beam Mode data over the Duero Basin in Spain is presented in this paper.

Keywords: ScanSAR; scatterometer; soil moisture; time series.

1. INTRODUCTION

The ERS C-band scatterometer system derived soil moisture has been proven suitable for the derivation of location specific near surface soil moisture variations, e.g. [1, 2]. ERS scatterometer time series are available since 1992 and are complemented by Metop ASCAT globally since 2007. The latter also provides an improvement of spatial resolution from 50km to 25km and increased daily coverage. Metop ASCAT will thus provide improved and operational global soil moisture retrieval [3]. ENVISAT ScanSAR data in ASAR Global Mode are less frequently acquired then scatterometer data but provide up to weekly samples on 1km resolution since December 2004. The soil moisture derivation approach developed by [4] has been first transfered to ENVISAT ASAR Wide Swath mode over Spain (Figures 1 and 2) within the MISAR project and then to ENVISAT ASAR Global mode over southern Africa within the SHARE project (Figure 3). SHARE is funded within the framework of the ESA TIGER initiative. SHARE aims at enabling an operational soil moisture monitoring service for the region of the Southern African Development Community (SADC) by using ASAR Global Mode data and ERS/METOP scatterometer data. With its service it addresses today's most severe obstacle in water resource management which is the lack of availability of reliable soil moisture information on a dynamic basis (weakly coverage or better). This paper presents results from a comparison of ENVISAT ASAR Wide swath and ALOS PALSAR Fine Beam Mode and dicusses the potential of the latter for mapping of soil moisture dynamics.

Figure 1: Location of Duero Basin, Spain

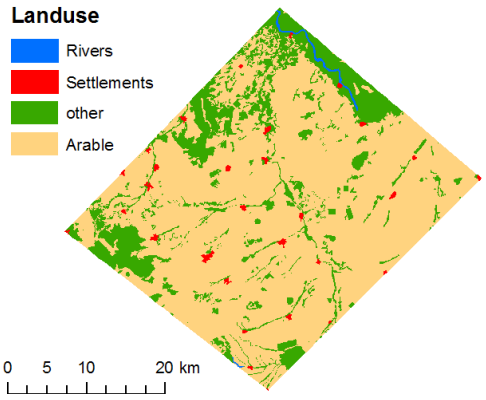

Figure 2: Landuse of Duero Basin, Spain

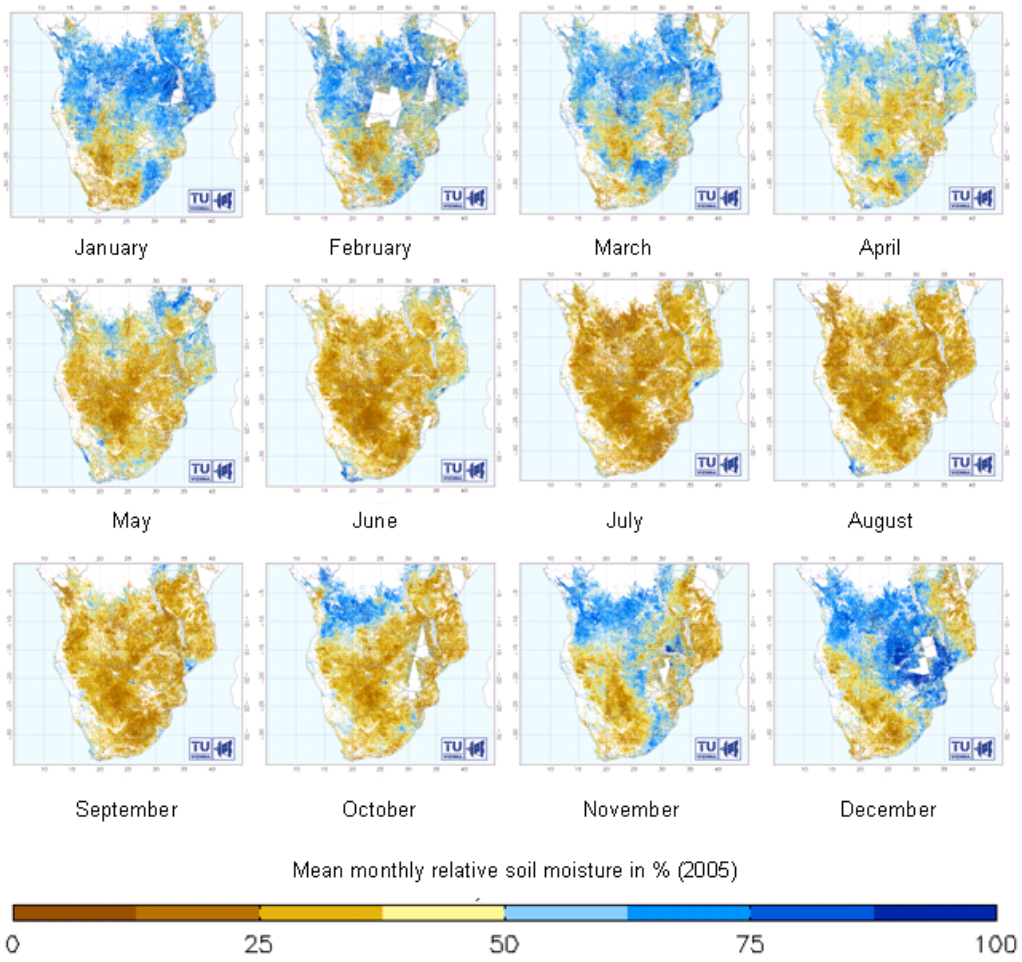

Figure 3: Monthly soil moisture composites from ENVISAT ASAR Global Mode, SADC 2005

2. DATA AND STUDY SITE

ENVISAT was launched by ESA (European Space Agency) in February 2002 into a sun synchronous orbit at about 800 km altitude and an inclination of 98.55. The ASAR (Advanced Synthetic Aperture Radar) instrument is one of the instruments installed aboard. ASAR provides radar data in different modes with varying spatial and temporal resolution and alternating polarizations in C-Band (5.6 cm wavelength). The presented studies utilize ASAR data acquired in Wide Swath (WS) Mode. Pixel Spacing for WS is 75 m (150 m resolution) and used polarizatin is VV. Each swath covers an area of 405 km width [5].

The Advanced Land Observing Satellite (ALOS) has been launched in January 2006. The polarimetric Phased Array L-band Synthetic Aperture Radar (PALSAR) is one of the three instruments on-board. The Fine Beam Mode provides data with 12.5 m pixel spacing. HH polarization data which were aquired during wet and dry conditions in 2007 (16.6. and 15.07. respectively) over the Duereo Basin (Spain) are selected for the comparison with ENVISAT ASAR WS.

The La Guarena test site covers an area of 1285 km^2 and is located in the central part of the Duero Basin in the central-northern part of the Iberian Peninsula. The area is characterized by a continental semi-arid Mediterranean climate with the typical summer drought. Due to the altitude of 700 to 800m the area experiences cold winter with 61 frost days per year (mean daily temperature 0^{o}C). The mean annual temperature is 12.1 ^{o}C with July as the hottest month (21.7^{o}C) and January the coldest (4^{o}C). The mean annual precipitation is around 400 mm with a dry season in summer and a maximum of the precipitation ion winter. The area of the La Guerana test site has been intensively exploited for agricultural use and nowadays is mainly used for dry farming of cereals and vineyards [6].

3. METHODS

Soil moisture plays an important role for runoff generation. Saturated soil moisture conditions cause increased runoff compared to dry soil moisture conditions. This hydrological parameter can be derived from ERS scatterometer (C-band) as a relative measure on global scale with

data records available since 1992 [7, 8]. The near surface soil moisture can be determined by time series analysis. A dry and wet reference is identified for each grid point and each single measurement scaled between these limits. By application of a simple infiltration model profile soil moisture is derived [4]. The latter is referred to as Soil Water Index (SWI) and available globally as 25km grid cells in 10 day intervals [8].

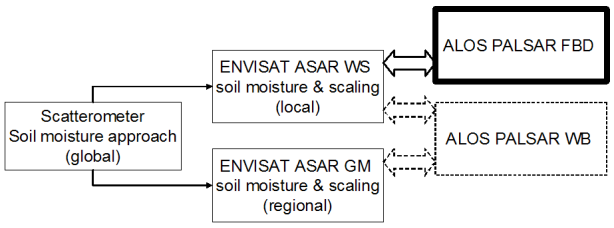

Figure 4: Transfer of soil moisture mapping approach: past (thin line), current (bold line) and future (dashed line) activities

Based on the experience with scatteromter data surface wetness has been derived from C-Band ScanSAR (ENVISAT ASAR; Figure 4). The study with WS was carried out using 71 scenes from 2002 to 2005. In comparison, the SADC area (Figure 3) was analysed using more the 2000 ASAR Global Mode images for the years 2005 and 2006. In a first analyses of the ALOS L-Band data, two images which which were acquired during wet and dry conditions are compared to the wet and dry reference derived from WS C-Band data with respect to landuse. The Alaska SAR Facility Data Conversion Tool (version 3.1.16) has been used for import and convertion to dB of the ALOS data on processing level 1.5. All images had to be re-referenced since irregular distortions between 1 and 2 km occured compared to reference data and between acquisitions.

4. RESULTS

The range between the dry and the wet reference represents the sensitivity (Figure 5) to soil moisture. The mean sensitivity value of ENVISAT ASAR WS for the entire Dureo Basin is 8 dB. Such high values are expected from agricultural area in C-Band. Mean dry reference is -11 dB. The L-Band backscatter values during dry conditions are generally lower than the dry reference from C-Band. The mean difference for forested areas and settlements is lowest with 1-2 dB. High values (5-6dB) are characteristic for agricultural areas. The backscatter difference for the wet conditions is larger (approximately twice) then for the dry case (Figure 8). The backscatter difference between dry and wet conditions for L-HH were much smaller than the observed C-VV sensitivity (Figures 6 and 7).

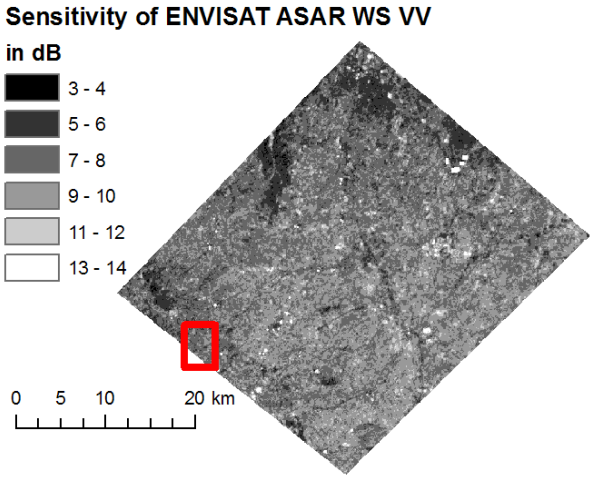

Figure 5: ENVISAT ASAR Wide Swath (VV) sensitivity for the Duero Basin, Spain; rectangle show extent of Figure 6

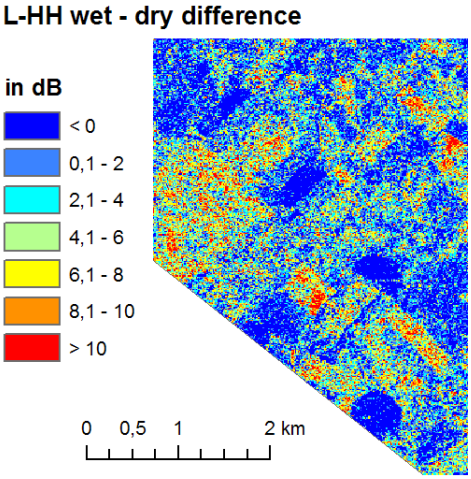

Figure 6: ALOS PALSAR L-HH backscatter difference between wet condition (16.06.2007) and dry conditions (15.07.2007); for location see Figure 5

5. DISCUSSION & OUTLOOK

The two available acquisitions of PALSAR FBD for the Duero Basin (Spain) are just one month apart. The dry reference image represents only the beginning of the summer drought. This may cause the low backscatter differences between the dry and wet conditions. No backscatter decrease from wet to dry conditions is observed for some Centre - Pivot irrigation systems (Figure 6). This 1) suggests that these areas have been irrigated and 2) confirmes that the surface conditions are generally drier during the second acquisition. Although backscatter change was small a relationship to soil moisture variations can be observed.

Although single acquisitions which are representative for very dry or very wet conditions may provide a first es-

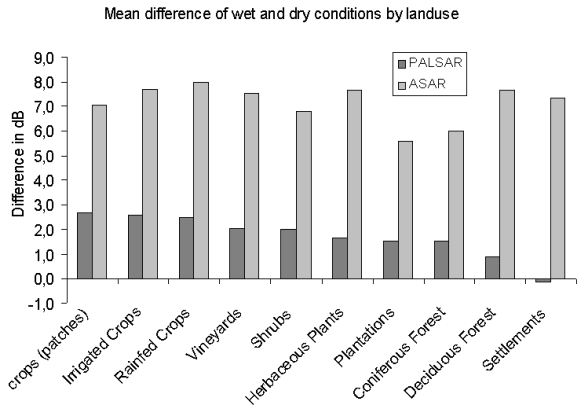

Figure 7: Mean sensitivity of ENVISAT ASAR Wide Swath C-VV (two years record with 72 scenes) and ALOS PALSAR FBD L-HH (two scenes only) by landcover class; analyses area as in Figure 6

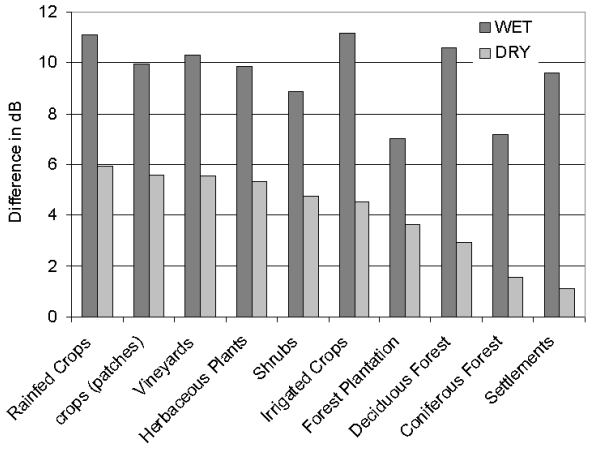

Figure 8: Mean difference between ENVISAT ASAR Wide Swath (VV) dry/wet reference and ALOS PALSAR FBD backscatter during dry/wet conditions by landuse category (C-VV - L-HH)

timate for a dry and wet reference, longer time series are needed to account for local differences. Some areas, landcover types or altitude levels may reach their driest or wettest state at other times, and probably not in all years.

Frequent and regular satellite data coverage supports the monitoring on regional scale. This has been exploited within the SHARE project. Monthly mean soil moisture maps could be extracted for entire SADC (Southern African Development Community). The derivation of sensitivity and then relative soil moisture from ALOS PALSAR WB mode is planned for the Niger inland delta in Mali. Weekly acquisitions distributed over at least one year would be required to capture both dry and wet reference. A longer calibration period is needed in case of episodically wet soil.

6. ACKNOWLEDGMENTS

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