The Global Soil Moisture Archive 1992-2000 from ERS Scatterometer Data: First Results

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Abstract – **Soil moisture is a key variable in a number of geophysical and ecological processes. Despite its importance, availability of information on soil moisture is limited. Only recently it could be demonstrated that low resolution radar data in combination with a change detection method can resolve this constraint. Experience gained in a number of successful pilot projects, lead to an initiative, setting up a global soil moisture archive.**

I. INTRODUCTION

The lack of global soil moisture observations is considered by many to be one of the most pressing deficiencies in satellite remote sensing and climate research [1]. Soil moisture is a key state variable of the global energy, water and carbon cycles and is of such crosscutting importance for a wide range of applications, from climate monitoring and ecological applications to the quantification of biogeophysical fluxes. Providing reliable soil moisture data is of direct benefit for managing global water resources, securing food production and studying climate change.

At microwave frequencies, radiation emitted from (passive techniques) and reflected by (active techniques) the earth's surface is strongly dependent on the moisture content of the soil due to the pronounced increase of the soil dielectric constant with increasing water content. Both passive and active techniques must account for the confounding effects of vegetation and surface roughness on the measured signal. In fact, accounting for these effects has proven to be a major scientific challenge. Currently it is held that using passive techniques the effect of soil moisture dominates over that of surface roughness, while the converse is true for radars. Therefore a passive microwave concept has been chosen for the Soil Moisture and Ocean Salinity Mission (SMOS), a mission dedicated to measuring soil moisture over land and ocean salinity over the oceans, to be launched in 2005.

Nevertheless, the view that soil moisture is only a secondary effect compared to surface roughness and vegetation is only true if one investigates spatial signal patterns. If one analyses temporal signal patterns the pronounced effect of soil moisture changes becomes apparent. Our research with the ERS Scatterometer has shown that, at C-band and regional scales, temporal soil moisture effects dominate over that of vegetation phenology, and surface roughness can in general be treated as a constant. This finding lead to the development of a soil moisture retrieval method, which is essentially a change detection approach.

II. ERS SCATTEROMETER

The ERS satellites are two nearly identical earth observation platforms launched by the European Space Agency. ERS-1 was launched in July 1991, followed by ERS-2 in 1995 providing the scientific community with an incomparable stream of high quality data during the previous ten years. Both satellites carry the Active Microwave Instrument (AMI) consisting of a SAR and a scatterometer system. The scatterometer operates at 5.3 GHz (C-band) vertical polarization. Backscatter measurements are collected at varying incidence angles ranging between 18° to 57°. Global coverage is achieved within 3 to 4 days.

III. METHODOLOGY

Since 1994 the Institute of Photogrammetry and Remote Sensing of Vienna University of Technology, in collaboration with other partners, has been working on a method to retrieve soil moisture from ERS Scatterometer data. The involvement of scientists from different fields in a number of pilot projects guaranteed a conscious validation and critical assessment of the results.

The method has been developed step by step over selected study areas. Over the Canadian Prairies the problem of varying incidence angles of the ERS Scatterometer measurements was addressed [2]. Over the Iberian Peninsula the effects of vegetation were studied in detail [3]. To estimate the water content in the soil profile from topsoil moisture as provided by the ERS Scatterometer a method was developed over Ukraine and Russia [4]. Using an extensive dataset of gravimetric field measurements the RMSE of the retrieved information was estimated to be in the order of 4-6 %Vol. The method can be regarded as change detection approach taking full advantage of the multi-viewing capabilities of the sensor, the availability of several years of backscatter data and the high temporal sampling rate of the sensor. The change detection strategy allows to circumvent problems emerging when using more sophisticated methods based on theoretical models. The problem of correctly interpreting backscatter measurements is reduced to the interpretation of temporal changes related

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to the surface dielectric properties (topsoil moisture, frozen/thawed) and the vegetation phenology. Static surface parameters influencing backscatter, e.g. surface roughness and land cover, are indirectly described by reference values retrieved once from long backscatter series. This way a knowledge base is set up, describing the specific scattering properties of each point on the earth surface, used consecutively for soil moisture retrieval.

Successful application over different climatic zones motivated the next steps: Apply the method on a global basis, collect an extensive global reference data set (currently several thousand *in-situ* soil moisture measurements over Illinois, Russia, Ukraine, India and China are available), validate the retrieved soil moisture data over regions with reliable reference data, and finally improve the method based on the findings of the validation effort.

IV. Products & Application

The processing of the Global Soil Moisture Archive has only recently been completed. Currently, the archive consists of historical soil moisture data on a decade basis for the period 1992-2000. Fig 1. shows first results of the archive. Spatial and temporal soil moisture patterns well reflect global hydrologic patterns, but inconsistencies in the absolute value and in the distribution of soil moisture are still evident. For example, along the lower course of the Yangtze river in China, unusually low values are often observed in summer, at the height of the rainfall season. A comparison with land use maps of China shows that paddy rice fields are abundant in this region, impacting the applicability of the method (obviously over open water surfaces soil moisture retrieval cannot be performed). Ongoing validation addresses these anomalies and in doing so such leads towards a harmonized global dataset. However, it should be noted that naturally the information provided applying a change detection method, is especially sensitive to relative temporal variations. Already simple difference maps give reasonable insight into the spatial and temporal extent of hydrologic phenomena such as droughts and upcoming floods. In such a manner, the data within the archive provides a view on variations of the synoptic land surface hydrology. Comparison of soil moisture anomalies with anomalies calculated from interpolated precipitation data [5], indicate the value of the retrieved information (Fig 2, Fig 3).

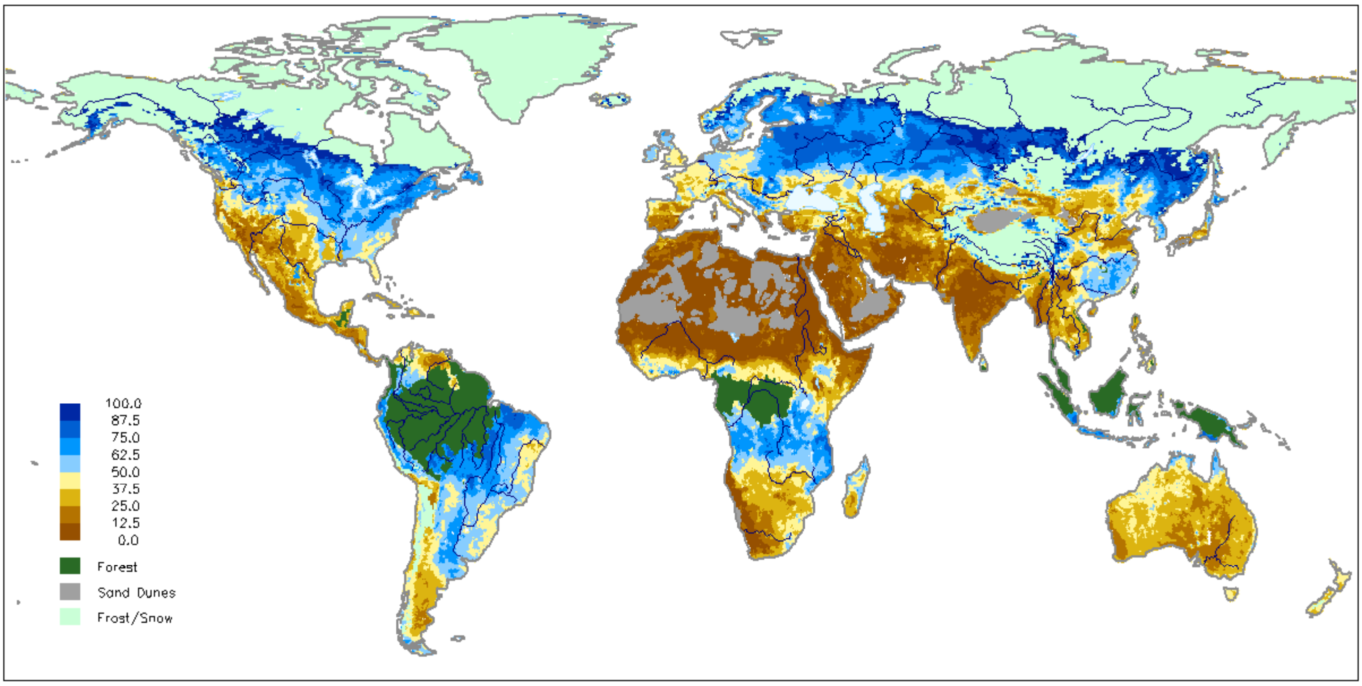

Fig. 1. Mean soil moisture in degrees of saturation (Soil Water Index) for the month of April. Values range from 0 (dark brown), representing values at wilting level, to 100 (dark blue) representing values at field capacity. Dark green represents closed forest cover, green, snow covered or frozen ground and gray, areas of strong azimuthal effects (occur over deserts) currently not considered in the retrieval method.

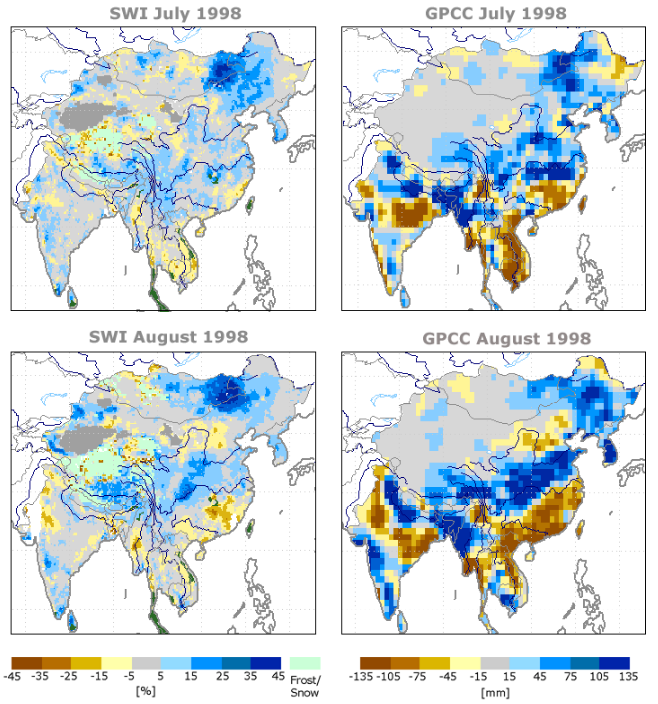

Fig.2. Difference of instantaneous profile soil moisture in degrees of saturation (left) and precipitation (right) to the respective 92-00 average some weeks before an extreme flood hit China (blue tones indicate a surplus brown tones a deficit; light green indicate frozen/snow covered ground).

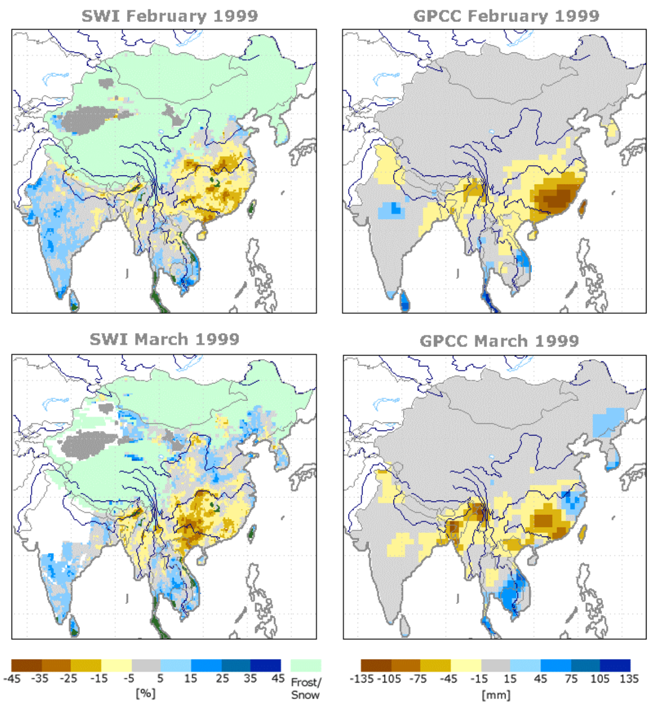

Fig.3. Same as Fig. 2. but for an extreme winter drought observed in 1999.

To increase the acceptance of this new source of information amongst the scientific community, soil moisture maps from the archive can be surveyed on the project website:

http://www.ipf.tuwien.ac.at/radar/ers-scat/home

On request, data will be made available to interested users. Free distribution of data is intended to familiarise potential users with the data. Taking advantage of user feedback will further lead to a more profound discussion of the retrieved information and such guarantee sound data validation and improvement.

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