Soil moisture monitoring using ALOS/PALSAR data in Areco watershed (Buenos Aires Province, Argentina): combining modeling, field work and data exploitation

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## Objective

Our main objective is to develop and to assess methodologies to soil water condition determination from SAR data and ancillary information using a Bayesian retrieval scheme.

The specific objectives of this proposal are:
- Assessing the capabilities of ALOS-2/PALSAR-2 to monitor water condition over bare soils.
- Comparing the capacities of SAR systems at different frequencies to monitor water condition over bare soils.

## Significance in the research field

Surface soil moisture content plays a key role in the interaction between the land surface and the atmosphere, and accurate knowledge about this variable is of interest for a variety of reasons. First, it is strongly related to vegetation development. Second, it determines the partitioning between rainfall into infiltration and runoff, which is strongly related to erosion of top soil through leaching. Third, when soil moisture is high, infiltration decreases and the risk of floods due to rainfall increases. And finally, soil evaporation and transpiration depends on soil moisture and therefore it influences the heat and mass transfers between the Earth and the atmosphere [1].

## Methodology

1. Area selection

We take advantage on current research at San Antonio de Areco study site, spanning an area of about 70x70 km in northern Buenos Aires province, Argentina (center coordinates 34° 15′ 43″ S/59° 28′ 0″ W), that is one of the Joint Experiment for Crop Assessment and Monitoring (JECAM) sites (http://umanitoba.ca/outreach/aesb-jecam/).

San Antonio de Areco study site belongs to the Argentine “Pampas” (Ecoregion: Rolling Pampa) at ~100 Km of Buenos Aires City. The area has a mild (temperate)-subhumid climate (1000mm mean annual rainfall) with the following features:

- Typical Field Size (Area): 20-30 hectares.
- Main Crops: Soybean, wheat and maize.
- Crop Growing Season: From June to April
- Soil type: Typical Argiudoll, with a well-developed B horizon.
- Soil Texture: Silty loam soils (silt content of 60-70%) up to 30 cm depth. From 30 cm depth, the textural B horizon is silty clay loam.
- Landscape Topology: Almost flat to undulating plains with slopes lower than 2% to 3%.
- Soil Drainage Class: Poor to imperfectly drained.

Field work is planned in several sites within the district.

2. Image selection and processing

Within this JECAM site satellite acquisitions from RADARSAT 2 (C-Band, FineQuad mode, HH/HV/VH/VV) and TerraSAR-X (X-Band, StripMap mode, HH/VV) can be scheduled over the study site. Moreover, the Satellite System for Emergency Management (SIASGE) agreement between the Italian (ASI) and Argentinean (CONAE) Space agencies in 2005 provides further X band data from COSMO-SkyMed (X-Band, Dual mode, HH/VV) over the study site. We believe that the possibility of adding L band data will considerably improve our results. We have the

skills and computer means for general image processing such as calibration, geometric correction, speckle reduction and others.

3. Forward and inverse modeling

We have experience in forward and inverse modeling [2]. We have already implemented well known models (such as Oh, IEM), that will be used to interpret satellite observations. Moreover, a complement Bayesian retrieval scheme based on a general soil forward model was implemented and will be tested with L-band data [3]. In this case, we believe that the polarimetric capabilities of ALOS-2 PALSAR-2 may improve soil moisture retrievals. In this methodology, a model for the soil backscattering and a model for the speckle are combined using the framework of the multiplicative model and Bayes' theorem. Therefore, this methodology is able to take into account terrain features as well as speckle noise to achieve a robust retrieval of soil parameters from SAR data. This Bayesian methodology: (1) needs only a forward model (as the Bayesian approach itself is the inversion procedure applied to forward model data), (2) gives an estimation of soil parameters as well as their associated error, (3) can include as many error sources as necessary, and (4) can include prior information in a systematic way.
If necessary, specific modeling work will be carried out regarding residue and vegetation cover.

4. Field data integration

Bayesian retrieval models have the outstanding feature of including ground truth data and/or ancillary information about soil parameters in a systematic, straightforwardly way through an "a priori" distribution. This "a priori" distribution expresses the level of prior information about soil parameters before the SAR acquisition is made. The Bayesian algorithm appropriately assimilates prior information on geophysical parameters to constrain the inversion of forward models improving its accuracy. Prior information can be available from historical records, estimations from other sensors, ground truth data and/or contextual information about soil texture/use.

**Algorithm to be used**

In order to estimate the soil water condition, a Bayesian model will be used [3]. Bayesian models are able to include forward model as well as prior information in a systematic way.
In the forward model, the speckle noise will be modeled by means of a Wishart distribution which involves a forward scattering model within the covariance matrix. Scattering models to be tested in the retrieval scheme are Oh, AIEM and IEMM [4,5].

Within this Bayesian model, two complementary approaches will be tested:

a) Retrieval based on HH- and VV-intensity images (real image): This approach is similar to that implemented in [2].
b) Retrieval based on Single Look Complex image (complex image): This is an ongoing research study framed within the Matias Barber's PhD thesis.

**Anticipated results**

The main result will be to test and validate soil the Bayesian soil moisture retrieval scheme over the study area. This result is relevant, since up to date there is no standard SAR-based soil moisture retrieval scheme. Moreover, the study area is located in one of the most productive parts of Argentina's Pampas, where water condition information is most relevant.

A secondary result will be to develop water condition maps over the study area (San Antonio de Areco area). Water condition maps are intended to point out the soil state in terms of dry, normal, wet and NA (not applicable) conditions (a four-class map). NA condition belongs to areas where retrieval does not apply (e.g. vegetated and urban areas, water beds, etc.). Thresholds separating classes will be defined accordingly to historical records.

**Kind of truth data and its acquisition plan (Area, Product level, Volume, Term, Season, etc.)**

Field work is planned for the period when bare o sparsely vegetated soil is present (from April to July) in several sites within the JECAM San Antonio de Areco study site. The field work protocol has been prepared according to international guidelines. Field work data will be analyzed and organized within a geographic database frame.

The following variables will be measured in every acquisition:

1. **Soil moisture**: Using dielectric probes at 10 cm depth. Two complementary methodologies will be used: (a) meteorological stations and (b) mobile measurement devices. The first implementation was developed to characterize soil moisture of a specific site in a systematic way, (every ~30 min). Other relevant agro-meteorological variables are also measured simultaneously for completeness. The second implementation is designed to characterize the spatial variability of soil moisture at field scale. To this end, a soil moisture dielectric probe (Hydra Probe II, http://www.stevenswater.com) and a GPS receiver were integrated via Bluetooth with a Tablet using *ad hoc* software. Surveys using mobile devices will be carried out in coincidence with acquisitions. Both stationary and mobile sensors are systematically cross calibrated with gravimetric measurements by means of the oven-heated method.

2. **Soil profile**: In order to study the scattering behavior of real agricultural surfaces, a 2D laser profiler was developed and will be used to acquire surface profiles over the agricultural fields. 2D surface soil roughness is characterized by RMS height and bi-dimensional autocorrelation function ACF, both of them estimated from the 2D profile. The laser profiler is capable of digitize a portion of soil surface of size 780 mm by 270 mm at a 1 mm resolution. Soil roughness will be measured in coincidence with acquisition provided that the tillage state of the soil remains unchanged with respect to the last acquisition.

3. **Other variables and/or properties**: Soil texture will be measured once within the study site. Soil temperature will be also determined simultaneously with soil moisture measurements.

4. **Vegetation parameters**: Wheat and soybean dry and fresh weight, LAI, yield and phenology will be measured as part of the JECAM site requirements in coincidence with different satellite acquisitions. Fallow samples will be also collected and their moisture content estimated using the oven-heated method.

**Product Utilization Plan (Product level, Volume, Term, Season, etc.)**

PALSAR-2 StripMap Ultra Fine Dual Mode (HH/VV) over the study site (center coordinates 34° 15′ 43″ S/59° 28′ 0″ W) from April to July (where soil is bare or sparsely vegetated) monthly over year 2014 and 2015. Processing level: 1.1.

PALSAR-2 StripMap High-Sensitive Full Mode (HH/HV/VH/VV) over the study site (center coordinates 34° 15′ 43″ S/59° 28′ 0″ W) from April to July (where soil is bare or sparsely vegetated) monthly over year 2014 and 2015. Processing level: 1.1.

**Work plan**

The foreseen tasks will be the following:

1. Requesting for SAR data (ALOS-2/PALSAR-2, RADARSAT 2, TerraSAR-X, COSMO Skymed).
2. Field campaign for the acquisition dates, giving priority to those dates when several sensors acquire data simultaneously.
3. Satellite data preprocessing (calibration, geometric correction, etc.)
4. Developing and implementation of soil moisture retrieval strategies within the Bayesian framework.
5. Sensitivity assessment of the Bayesian model in terms of X-, C- and L-band data.
6. Validation of soil moisture estimates using truth data from field campaigns.

| Task/Semester | 1st Semester | 2nd Semester | 3rd Semester | 4th Semester |
|---|---|---|---|---|
| 1 | x | x | x | x |
| 2 | x | x | x | x |
| 3 | x | x | x | x |
| 4 | x | x | x | |
| 5 | | | x | x |
| 6 | x | x | x | x |

**Data processing and analysis equipment**

The institute for Astronomy and Space Physics (IAFE, www.iafe.uba.ar/tele/) provides full institutional support for the realization of this project by its Remote Sensing Group. The Remote Sensing Group has an office equipped with state of the art computers that are appropriate for the realization of the proposed work plan. It also has the staff and logistical contacts to carry out the fieldwork, with the aid of the INTA's personnel. When necessary, large amount of data and model simulations can be processed onto a cluster at IAFE. Soil samples will be analyzed at the UNCPBA facilities.

**References**

[1] F. Grings, M. Salvia, H. Karszenbaum, P. Ferrazzoli, P. Perna, M. Barber, J. Jacobo Berlles, "Statistical Information of ASAR observations over wetland areas: an interaction model interpretation", ISPRS Journal o Photogrammetry and Remote Sensing, 2010. vol. 65 p.77-85.

[2] Y. Kerr, "Soil moisture from space: Where are we?," Hydrogeol. J., vol. 15, no. 10.1007/s10040-006-0095-3, pp. 117–120, 2007.

[3] M. Barber, F. Grings, P. Perna, M. Piscitelli, M. Maas, C. Bruscantini, J. Jacobo Berlles, H. Karszenbaum, "Speckle noise and soil heterogeneities as error sources in a Bayesian soil moisture retrieval scheme for SAR data", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, June 2012, vol. 5, n. 3 pp. 942-951.

[4] A. K. Fung and K. S. Chen, “An update on the IEM surface backscattering model,” IEEE Geosci. Remote Sens. Lett., vol. 1, no. 2, pp. 75–77, Apr. 2004.

[5] J. L. Álvarez-Pérez, “An extension of the IEM/IEMM surface scattering model”, Waves in Random Media, June 2001, vol. 11 n. 3, pp. 307-329.