MONITORING FLOODS IN THE LOWER BERMEJO RIVER BASIN USING MULTIFREQUENCY MICROWAVE SIGNATURES

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ABSTRACT

Using Microwave Remote Sensing techniques represents an important contribution to forecasting skill of regional scale flooding events occurring over time scales of days to weeks. Furthermore, it could add skills to predictions of flood peak timing and magnitude, besides climatic change predictions.
In this paper, the temporal trends of Polarization Ratio at some AMSR-E bands (C, X, and Ka) will be studied in order to show its potential in flood and rainfall monitoring. To this end ground truth data concerning rainfall and water level measurements in the lower Bermejo Basin in Argentina have been used, and a general correlation between variations of the Polarization Ratio and ground parameters has been found at the various AMSR-E frequencies.

Index Terms **— Microwave radiometry, Flooding**

1. INTRODUCTION

In the area of the Bermejo river (spanning Argentina and Bolivia), natural disasters have severely affected both rural and urban infrastructure and economic production systems (mainly crop and cattle areas). Clearing of land for cultivation and widespread overgrazing has created problems of erosion and desertification, aggravating sediment mobilization that has contributed to downstream environmental degradation.
Predictability of extreme events (in particular floods and rainfalls) is a way to improve rural workers' and indigenous communities' economy and quality of life, since moderate and extreme poverty is widespread in the basin.
Classical approaches of flood forecasting consist on ground based water balance models that use rainfall and river stage measurements with limited information about soil moisture. They are based on previous events experience, on an estimation of the effects using knowledge of soil infiltration, and on the persistence of high values of soil moisture after extreme events.
Using Microwave Remote Sensing techniques represents a key contribution to forecasting skill of regional scale flooding events occurring over time scales of days to weeks. In this work, the Polarization Ratio is proposed to represent, like an indicator, the spatial soil surface moisture content which could add skills to predictions of flood peak timing and magnitude [1], providing reliable and repetitive data.
The following section is devoted to the description of the selected study area. Then, in section 3, the temporal plots of the Polarization Ratio average values will be presented highlighting the correlation with flood events and local rainfalls at the various AMSR-E frequencies. Finally a spatial analysis will be carried out with the aid of colour maps.

2. SITE DESCRIPTION

The Bermejo River Basin extends over some 123,000 Km^2, originating in the Andes Mountains of northwestern Argentina and southern Bolivia. A general map is shown in Figure 1.
The river, which flows some 1,300 km, links two major geographic features: the Andean Cordillera and the Paraguay-Paranà Rivers. It is the only river that crosses completely the huge expanse of the Chaco Plains, behaving as a corridor for the connection of biotic elements of both the Andean mountains and the Chaco Plains.
This region presents subtropical characteristics, due to variations that reflect continental climate based on a real winter season. Flood events, caused primarily by river overflows during the rainy season (from December to March) severely affect 7% of the Basin area, while the less rainy months are June, July and August. Sediment loadings in the Bermejo waters are some of the highest in the world (8 kg/m^3). These sediments are mostly produced in the Upper Basin and flushed down along the Lower Basin during peak floods which regularly change the course of the river, preventing a rational use of water and land resources.

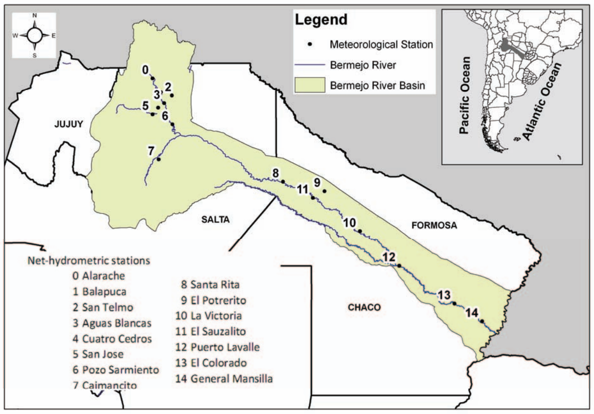

Fig. 1 - Bermejo Basin and its net-hydrometric stations location.

The site studied in this paper lies between the Chaco and Formosa provinces in the southern part of the Bermejo basin, where the courses have water all year round and are influenced by the backwaters of the Paraguay and Parana rivers. Here the river course is characterized by a flat topography with a low slope of 0.2 m/km, appearing in hydrographic network deviations caused by morphological and geological factors.

The presence of numerous streams and wetlands produce a regulatory effect, since the rainwater is stored and, after exceeding a certain level, it is drained by the channels.

3. DATASETS AND MATERIALS

A representative sample of Bermejo Lower Basin was investigated selecting an area between -27° and -23° S Latitude and -62° and -58° W Longitude. More detailed investigations have been carried out selecting a specific box near the river edge, between -26° and -25.5° S Latitude and -60° and -59.5° W Longitude. This area is covered by forests (dominated by (*Schinopsis balansae*) in the north, and low vegetation (like grassland) and agro forestry system in the south, as depicted by the red box in the map of Figure 2. This picture reports a land cover map covering part of Chaco and Formosa provinces. Daily series of all the available AMSR L2 data have been collected (http://nsidc.org/data/amsre/order_data.html), from January to October 2010 for both ascending and descending orbits [2]. Brightness Temperatures have been extracted at vertical and horizontal polarizations (T_{BV}, T_{BH}) for C, X and Ka bands at all resolutions.

Precipitation intensity and water level measurement data (http://www.corebe.org.ar) have been collected at the nearby El Colorado Station (-26.30° S Latitude and -59.38° W Longitude, see also Fig. 1) and they allowed us to compare satellite time series with ground ones.

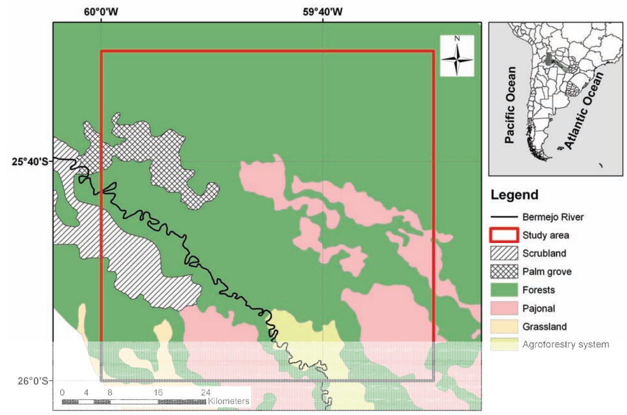

Fig. 2 - Lower Bermejo land cover

In order to eliminate the dependence on surface temperature, we have extracted the average Polarization Ratio (PR) defined as:

$$PR = \frac{(T_{BV} - T_{BH})}{(T_{BV} + T_{BH})}$$

In addition, for the whole Bermejo Basin area PR maps collected before and after some important rainfall and water level increment events have been analyzed, in order to understand the spatial properties.

4. RESULTS

Figure 3 reports the trends of multifrequency PR for ascending (a) and descending (b) orbits, as well as the temporal trends of measured rainfall (c) and Water Level (d). The effects of flooding and rainfall have been observed at C, X, and Ka band. As expected, the better dynamic ranges are achieved at the lower frequencies.

The increase of PR, at the very beginning of the year, is related to the increase of water level, since no significant rainfall occurred during that period. It is followed by a decrease of PR, corresponding to water receding, and then a new increase. In the interval between about 50 and 90 Julian Days, a raise of water level is observed but also a strong rain event. Afterwards, drying effects are well visible (between 90^{th} and 120^{th} Julian days). In the subsequent seasons, the water level continues to decrease while PR values vary according to rain events, as expected. While in summer (Julian Days 1-100) PR values as low as 0.01 are achieved in dry phases, in the subsequent seasons (autumn and winter) higher values are observed meaning that the radiometric response to the same rain quantity is strictly dependent on the season and soil saturation level.

For some events, the correlation is limited by the high spatial variability (compared against the spatial resolution of AMSR-E).

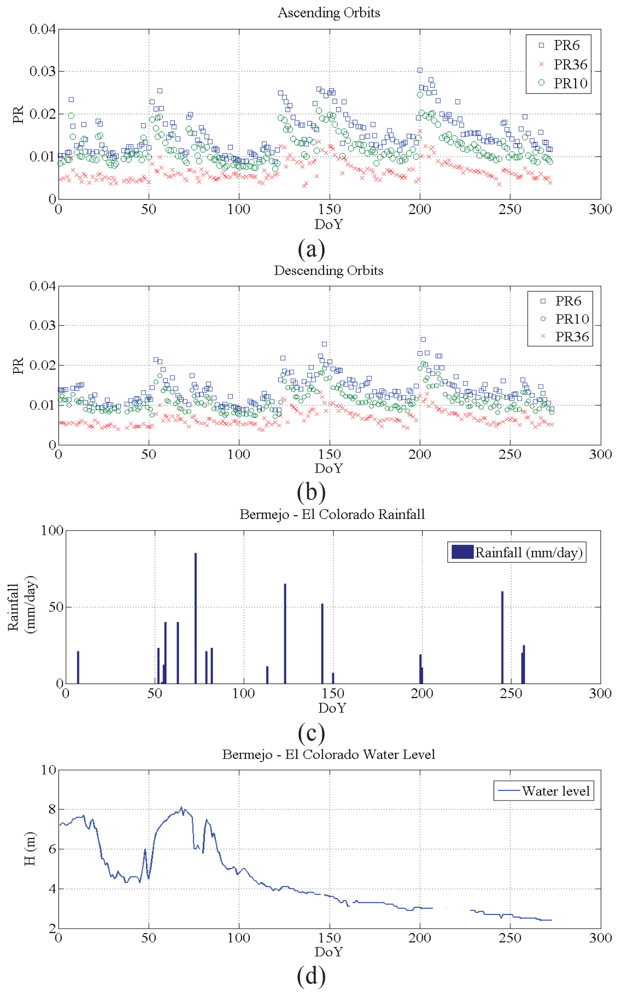

Fig. 3 - AMSR-E multifrequency Polarization Ratios and ground truth data from El Colorado Station, from January to October 2010
(a) Daily Satellite Polarization Ratio in Ascending Orbits
(b) Daily Satellite Polarization Ratio in Descending Orbits
(c) Daily Rain intensity histogram (mm/d)
(d) Daily Time series of Bermejo water level (m)

Further spatial analysis over these events is in progress (as well as investigations over different areas).
For descending orbits the effects of water level in the first months of the year are less visible, being the variations in PR values smaller. However, the correlation is still apparent and the difference between the two orbit types disappears in the second half of the year.
Some PR maps have been plotted in order to understand the spatial effects of the phenomena under study. In particular, Fig. 4(a) and (b) show the PR measured at C-band (on the left) and at the best spatial resolution of X-band (on the right).
These data were acquired on the 121st Day of Year (May 1st), corresponding to normal conditions, i.e., in absence of rain and flooding.

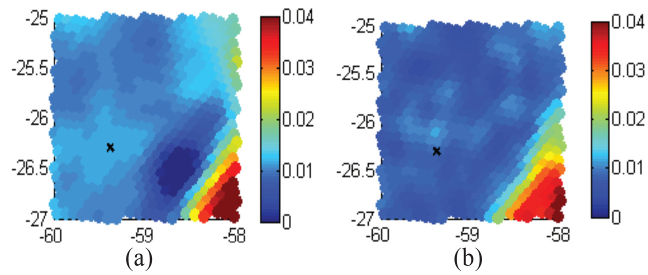

Fig. 4 - PR maps on normal conditions: C band (a), right X band high resolution (b)

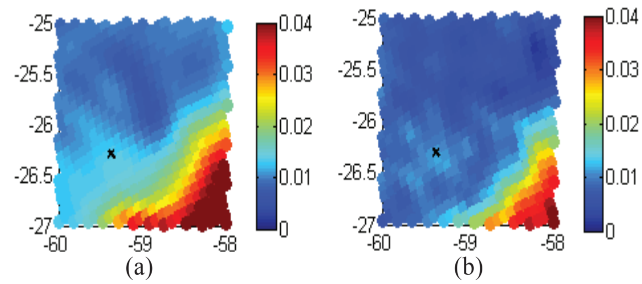

Fig. 5 - PR maps after flooding: C band (a), X band high resolution (b)

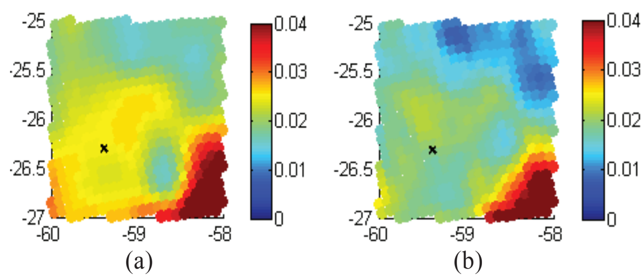

Fig. 6 - PR maps after rainfall: C band (a), X band high resolution (b)

The black marker represents the position of El Colorado Station. The highest values of PR are recorded in the right bottom corner of these maps, at all bands, and they shape a dark triangle, representing the confluence between the Bermejo River and the Paraguay River.
The second couple of maps in Fig. 5 (a) and (b) refers to January 13th, 2010, when a high water level of Bermejo has been recorded but no precipitations affected this area. The maps show an increment of PR concentrated around the Bermejo-Paraguay confluence, better visible at C band. Fig. 6(a) and (b) show a different spatial spread of PR: data were acquired on May 3rd (DoY = 123) close to a heavy rainfall, whose effects are clearly visible over an extended area, and also at X-band.

5. CONCLUSIONS

In this paper, the PR's derived by AMSR-E data were studied in view of rainfall and flood monitoring. The data collected over the Argentinean Bermejo Basin have been presented, and it has been observed that the time trend of the radiometric parameter is well correlated to both water level and rainfall measured by a ground meteorological station. The PR has been also studied in the form of color maps, which showed the different spatial distribution of floods and rainfall.

A quantitative analysis using flood extension retrieval algorithms [3]-[4] is in progress, in order to estimate flooded areas in various sections of the river, according to ground truth data availability. A significant improvement in the response is expected by investigations using L-band SMOS L1C data, particularly in areas covered by dense forests [5].

6. REFERENCES

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