Temporal analysis of polarimetric and coherence over Tropiscat data

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Abstract. This papers deals with ground experiments related to the future spaceborne BIOMASS mission for global forest biomass estimation. In the next, we present quickly the TropiScat campaign in French Guiana supported by the ESA and the CNES. The main aim of this campaign is to acquire a long term data acquisition that allows to estimate the temporal decorrelation and the radiometric signal of the tropical forest. The final data are calibrated in relative. Three months of data are exploited in terms of coherence and polarimetric intensity. The coherence exhibits daily cycles in period without rain but these cycles are perturbed by rain. Over the full period, the coherence is quantified showing a good behaviour. The intensities exhibit also this daily cycle but present a high stability over the full period.

Keywords: Biomass, radar, ground experiment, Radar polarimetry, coherence.

1. Introduction

The tropical forests are involved in many ecological processes (carbon cycle, water cycle, plants and animals biodiversity…) where they often play a protective role. They present the major part of the world forest biomass and their changes in biomass by deforestation and/or by forest regeneration affect strongly the terrestrial carbon budget. To measure with accuracy tropical forest biomass and its temporal change is one of the objectives of the BIOMASS mission [1], a candidate for the European Space Agency 7th Earth Explorer Mission.

BIOMASS will be the first spaceborne Synthetic Aperture Radar (SAR) operating at P-band (435 MHz). The possible retrieval algorithms currently developed for BIOMASS are based on the use of backscatter measurements derived from intensity, polarimetry and interferometry. However, these quantities are subject to evolution with the life cycle and the meteorological conditions at very different time scales, ranging from a few minutes to days, months… with the possibility that their changes may affect the inversion algorithms. A ground experiment has been set up to follow systematically these evolutions. It has been installed over a temperate tree and also over a tropical forest in French Guiana. Based on the use of a Vector Network Analyzer and adequate antennas, it may deliver P band polarimetric, interferometric impulse responses and 2D (range/height) imaging.

In the presentation the impulse response acquired by the full system are analysed with several time filtering and averaging. Section 2 presents briefly the experiment. Section 3 is dedicated to the data processing and section 4 is devoted to the obtained results for respectively coherence and intensity.

2. TropiSCAT campaign overview

Though the full system is described in detail in [2]-[3], for sake of completeness let us give here the main features of the experiment setup. The TropiScat ground based campaign was set to support the BIOMASS mission. The TropiScat campaign carried out over the tropical forest of the French Guiana is essential to better define the mission concept. A full polarimetric antenna system was set up on the top of the Guyaflux tower [4]-[5] at paracou in French Guyana (Figure 1). The French Guyana forest is a tropical forest characterized by high biomass density (> 300 t/ha) and complex structure. The installed system is composed of a Vector Network Analyzer (VNA), P band antennas, a computer and RF switches boxes. This RF box switch allow routing the signal between the antennas and the VNA to select a given polar (HH, VV or VH). A set of 20 antennas are installed on top of the tower (Figure 1).This set of antennas allows a vertical imaging to synthesize tomograms, though in this paper the various antennas pairs are used for obtaining independent samples for averaging. 5 antennas for transmit (TX-H) in horizontal polarisation, 5 antennas for transmit (TX-V) in vertical polarisation, 5 antennas for receive (RX-H) in horizontal polarisation and 5 antennas for receive (RX-V) in vertical polarisation. With this set of antennas we can make measurements with a 16 antennas virtual array of 2.8 meters length. Each measurement is done by choosing a couple of RX-TX antennas thanks to a RF switching system. The RX-TX quadpol measurements data are performed continuously each 15 minutes in the frequency band [400-600], [600-800] and [800-1000] MHz separately. In this paper we analyse the data just in the band [400-600] MHz since the BIOMASS satellite cover the band [432-438] MHz. Before each measurement an internal calibration of the VNA is done.

Figure 1. Tomographic array on the top of the Guyaflux tower, Paracou, French, Guiana

3. Data Processing

Before every set of measurements, an external calibration is performed with a reference loop, in order to ensure the quality of the results during all the experiment duration. The frequency domain complex data acquired are transformed into the time domain or range domain by IFFT, from which is derived the range backscattering profile. If Δf and ∂f are respectively the frequency bandwidth and the frequency step ($\Delta f = (Nf - 1) \times \partial f$) then the range resolution is $dr = \frac{c}{2\Delta f}$ and the unambiguous range $D = \frac{c}{2\partial f}$.
The data collected during the TropiScat campaign are raw data that require a post-treatment. In fact, in the radar equation applied to each range cell, the range has to be taken into account and also the antenna gain changes with the range, and finally the footprint has to be considered. So the range profiles have been normalized to account for the variation with range of the propagation losses, the antenna gain and the intercepted soil surface.

In fact, it was observed that the direct coupling between antennas varies during the period of rainfall. Or this direct coupling is supposed to be constant. Consequently, we have established a method to adjust data that corrects this effect and to normalize the level of direct coupling between antennas at the same level, which compensates the variation of emitted power (due to the system) during meteorological events.

4. Results

4.1. Coherence Results

The value of the coherence between the current measurement S1 and the reference measurement S2 is computed with the following formula:

$$\gamma_{pq} = \frac{\left| \sum_{r\,min}^{r\,max} S_{1pq}(r).S_{2pq}(r)^* \right|}{\sqrt{\sum_{r\,min}^{r\,max} \left|S_{1pq}(r)\right|^2 . \sum_{r\,min}^{r\,max} \left|S_{2pq}(r)\right|^2}} \qquad (1)$$

With $p = \left| {}^{H}_{V} \right.$ and $q = \left| {}^{H}_{V} \right.$, r_{min} and r_{max} correspond to the range min and range max.
The data set provided temporal separation of 15 minutes over a period of 3 months (from 6th December 2011 to 11th Mars 2011). Data has been filtered in distance in order to keep the range corresponding to the full forest.
Figure 2- Figure 4 show the temporal coherence of the polarimetric backscattering coefficients over a period of 3 months (from 6th December 2011 to 11th Mars 2011). The coherence is computed by constructing a large vector including all range cells complex backscattering value between r_{min} and r_{max} and for all antennas couples. We observe that the HH (Figure 2) keeps a very high coherence. The VV (Figure 3) has a high coherence but less than the HH. Concerning the HV (Figure 4), we denote that the coherence decreases faster than the HH and VV polarization. This can be explained by the fact that HV (volume effect) is more sensitive to leaves and branches growth/change than HH and VV for which in principle double bounce contribution is more important.
Figure 5 shows the temporal coherence of the polarimetric backscattering coefficients over a period of 5 days (from 15th December 2011 to 20th December 2011) during the dry period. We can observe a daily cycle, with a high coherence between nights, which confirms the results of a preliminary experiment [6]. The night/day decorrelation is mainly due to two phenomenas. When the wind speed is important, the movement of branches may be enough to lead to a significant decorrelation. A second effect is directly related to the evaporespiration of trees, during the day. We denote that main result are within the rainy season, only few days are free of rain.

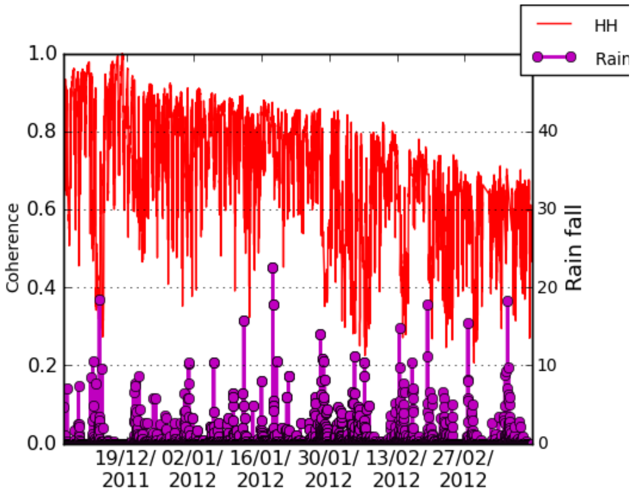

Figure 2. Temporal coherence HH over 3 months

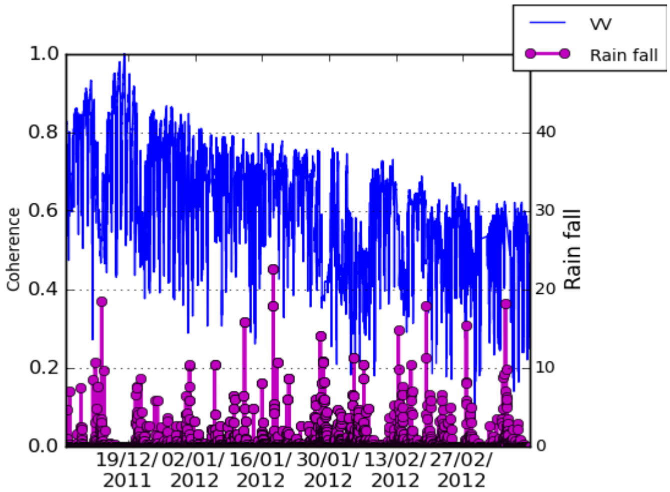

Figure 3. Temporal coherence VV over 3 months

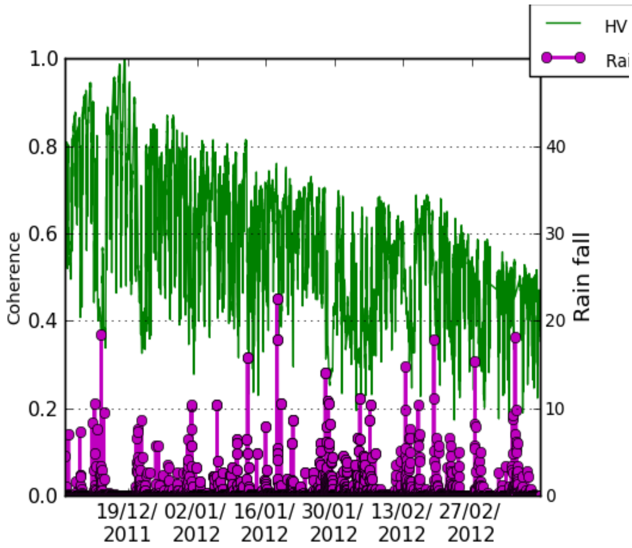

Figure 4. Temporal coherence HV over 3 months

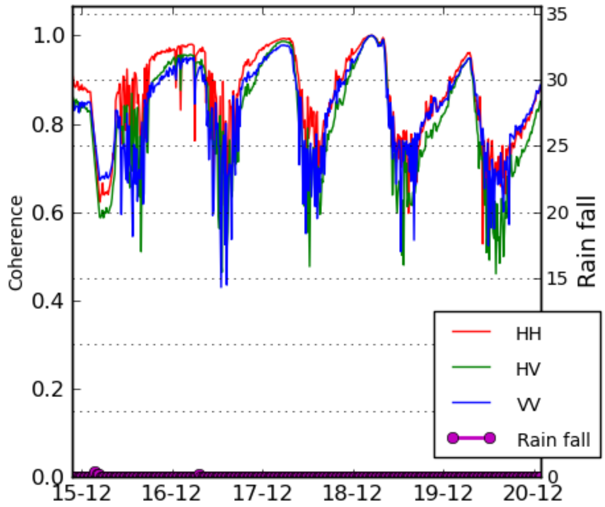

Figure 5. Temporal coherence over 5 days

4.2. Intensity Results

The measurements are performed in the frequency domain then transformed into the time domain or equivalent range domain by IFFT. The radiometric signal is calculated by averaging the range profile in distance, time and several couples successively. Figure 6 and Figure 7 show the backscattering intensity over the three months and averaged over one hour. We denote a stable level for each polarization.

However, HH intensity increases slowly along the period, while VV keeps a very stable level. As HH is related to double bounce (trunk-ground), soil moisture affects the HH level rather than VV. Figure 6 and Figure 7 starts at the beginning of wet season, when the ground is quietly dry, and soil moisture increases with time. We will confirm this fact at the beginning of dry season (July 2012). Figure 7 shows the Backscattering intensity over 3 months and averaged over one week. We observe a stable level for each polarization over the three months. However the HH intensity increases slowly along the time, which could be explained by the fact that with the rain the global humidity content in the soil increases and thereby enhances the HH in principle mainly sensitive to the double bounce.

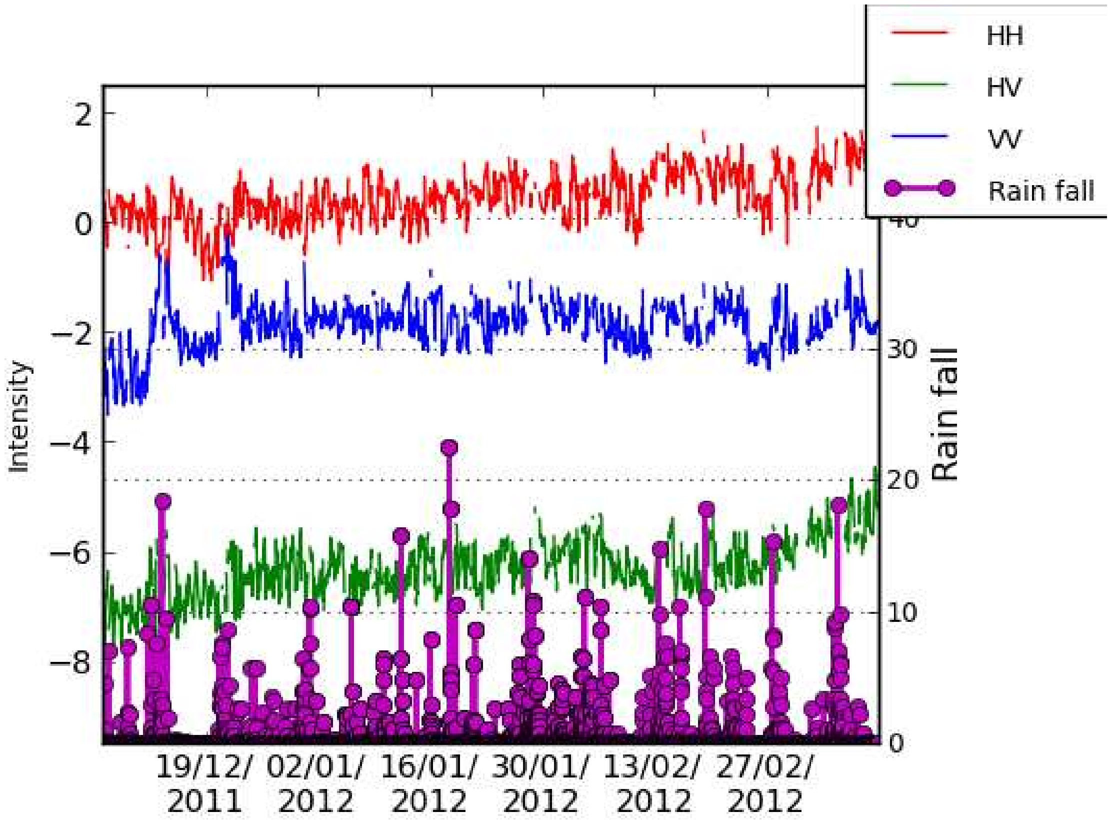

Figure 6. Backscattering intensity over 3 months and for range= 74m-84m (averaging over one hour)

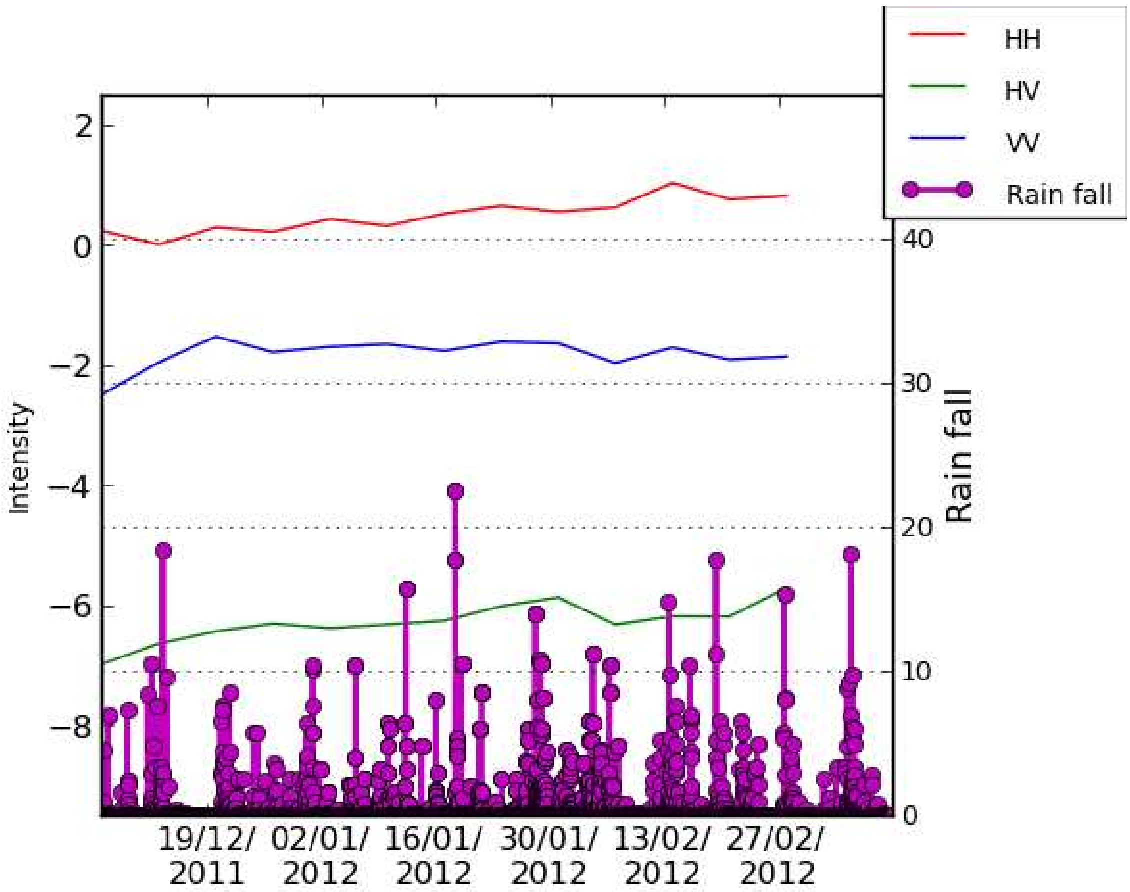

Figure 7. Backscattering intensity over 3 months and for range= 74m-84m (averaging over one week)

4. Conclusion

The TropiSCAT experiment has been deployed in French Guiana since October 2011 and is now operational. A dataset of three months have been treated in P-band. Automatic measurements are currently done every 15 minutes, until November 2012. In spite of the strong rainy conditions stable results in coherence and backscattering intensities are observed. Three months of data have been exploited. Over the full period, the coherence is quantified showing a good behaviour. The intensities exhibit also this daily cycle but present a high stability over the full period. Weather variations in precipitations and soil moisture induce changes in the complex radar backscattering properties of the full forest. Associated with in-situ meteorological data from the Guyaflux tower, this unique dataset will be used to improve the comprehension of forest backscattering mechanisms at P and L band.

5. References

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