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COMPARATIVE STUDY OF TEMPORAL DECORRELATION AT P, L AND C-BANDS: FIRST INSIGHTS FROM THE TROPISCAT-2 EXPERIMENT

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ABSTRACT

Following the past TropiScat and AfriScat tower-based scatterometer experiments conducted as part of the European Space Agency (ESA) BIOMASS mission preparation activities, a follow-up experiment referred to as TropiScat-2 has been undertaken since March 2018 in French Guiana. The main objectives of this new campaign consist in extending the previous time series at P and L bands, and also in investigating the possible synergies between P, L and C-band measurements thanks to the quasi-simultaneous multi-frequency acquisitions provided by the new instrument. In this paper, the differences between temporal decorrelation at P, L and C-bands are specifically analyzed based on a 67-day time series dating back to early August 2018. This study confirms previous results conducted at P and L-bands, with a specific focus here on the importance of the diurnal cycles and on the updated acquisition scenarios for the upcoming BIOMASS mission. Interestingly, this study also reveals the diurnal cycles at C-band, although the coherence values are much lower than those at P and L-bands. In addition to enhancing scientific insights regarding our understanding of microwave interactions, this study provides key figures for the design of new satellite missions.

Index Terms— Temporal decorrelation; P, L, C-bands; Time series; Tower-based scatterometer; Tropical dense forests;

1. INTRODUCTION

Time series in remote sensing are often determinant to disentangle the possible ambiguities between the multiple causes behind signal variations, making revisit and continuity of time series highly important. Although limited by a rather small footprint (typically about 1 ha), tower based remote sensing instruments enable a top view of a given region of interest, and thereby allow to mimic observation geometry from space, but with the core advantage of making possible a wide range of quasi-continuous and quasi-simultaneous measurements, together with in situ auxiliary data. As an example in the context of the ESA BIOMASS mission preparation activities, we can refer to the TropiScat [1] and AfriScat [2] experiments, respectively conducted in French Guiana (2011-2014) and Ghana (2015-2017). Both experiments were dedicated to tropical dense forests (primary objective of BIOMASS), and provided key results regarding the signal variability at P and L-bands, and particularly about temporal decorrelation [3] which is a core variable for the design of mission revisit and acquisition time [4]. More recently, a similar experiment has been undertaken to address these questions in the case of a boreal forest [5], considering also C-band acquisitions in addition to the P and L-band ones. Indeed, thanks to the stronger microwave penetration through such forests especially under frozen conditions that are also very favorable to limit temporal decorrelation [6], the sensitivity of C-band backscatter may be exploited and related to physical properties of the forest [7;8]. However, the use of C-

band to provide relevant information in the case of tropical forests is less obvious. This situation can first be explained by the lack of data in comparison to areas at higher latitude where the revisits related to heliosynchronous orbits are more frequent. Moreover, canopies in the tropics are denser and vegetation cover fraction is higher resulting in a stronger attenuation and weaker image contrast. Finally, the phenology of the different tree species in tropical forests is much more diverse and poorly known [9]. Indeed, this phenology cannot be characterized by strong seasonal changes such as freeze/thaw events, leaf-on/leaf-off or even more progressive Leaf Area Index (LAI) changes as for temperate forests [10, 11].

In a recent published paper we focused on the investigation of C-band temporal decorrelation at various time scales in the case of a tropical forest [12]. This study revealed that C-band coherences can reach higher than expected values during nighttime and that their evolution can be explained not only by convective winds but also by evapotranspiration. These promising results suggest further analysis of C-band measurements over tropical forests in parallel with those at P and L-bands in order to evaluate the possible synergies between these three bands and thereby to better exploit the future BIOMASS mission's P-band data.

With regard to all these concerns, we propose in this paper to exploit measurements of a 67-day time series from TropiScat-2 campaign, in order to analyze the differences between temporal decorrelation at P, L and C-bands. Next section focuses on a concise description of the experiment, while a brief recall of the coherence calculation formula is provided in section 3. before presenting some results in section 4. and then drawing a conclusion of the study in section 5.

2. DESCRIPTION OF THE EXPERIMENT

As introduced above, a similar P and L-band antenna array as for the previous TropiScat and AfriScat campaigns has been installed on the west side at the top of the Guyaflux (about 55 m high) [13]. We recall that this antenna array is made up of a set of 20 antennas forming 17 pairs, covering all 4 polarization

channels (VV, HH, VH, HV) and providing a vertical imaging capability (tomography). Measurements cover the two bands 400-600 MHz (P-band) and 800-1000 MHz (low L-band). To extend the measurements to C-band, a new Vector Network Analyzer (VNA) (Rhode&Schwarz ZNL-6, see www.rohde-schwarz.com) has been installed. Six new antennas dedicated to the C-band have been also set up at the VV polarization and equally split between the west and the northeast sides of the tower (see Fig. 1). C-band acquisition is segmented into three sub-bands of 200 MHz starting from 5.2 GHz (to be named A, B, C). Full acquisition cycles are performed every 15 minutes thanks to the radio frequency switches that sequentially route the signal between each receive-transmit pair and the VNA.



Fig. 1 Picture of the P and L-band antenna array (top) and the C-band antennas (bottom) with a scheme of the tower and the VNA.

3. COHERENCE COMPUTATION

Considering that data acquisition from the VNA is in the frequency domain, the processing consists first in an inverse fast Fourier transform to convert the measurements into the time domain. The resulting range impulse responses can then be used to compute

the temporal coherence, for a given spatial range (from range gates i_{\min} to i_{\max}), between the complex responses noted S_{i1} and S_{i2} acquired at two different times t_1 and t_2 , as detailed through the following formula:

$$\gamma = \frac{\sum_{k=1}^K \sum_{seq}^{(A,B,C)} \sum_{i_{\min}}^{i_{\max}} S_{seq,t1}^k(i) \cdot S_{seq,t2}^k(i)^*}{\sqrt{\sum_{k=1}^K \sum_{seq}^{(A,B,C)} \sum_{i_{\min}}^{i_{\max}} |S_{seq,t1}^k(i)|^2 \sum_{k=1}^K \sum_{seq}^{(A,B,C)} \sum_{i_{\min}}^{i_{\max}} |S_{seq,t2}^k(i)|^2}} \quad (1)$$

where ‘i’ is the range index between i_{\min} and i_{\max} , and ‘k’ to cover all the antenna pairs. The index ‘seq’ refers to the consecutive sequences A, B, C within a same acquisition cycle, used only for the C-band processing.

4. FIRST RESULTS

In order to better understand and investigate the evolution of temporal decorrelation at P, L and C-bands, we consider in this study all 18-day sub-series based on a 67-day time series dating back to August 1st 2018. For each sub-series, we set the reference time for the coherence computation at 6AM on the first day and then calculate the coherence of all measurements with respect to that reference. We then plot the resulting coherences of all sub-series on an 18-day scale as shown in Fig. 2, where the line curves represent the medians of the 50 coherences for each temporal baseline bounded by an outer envelope that defines the first and third quartiles. The choice of this computation approach is based on the acquisition scenarios of the future BIOMASS mission. Indeed, BIOMASS acquisitions are planned for dawn and dusk (6AM/6PM) with a revisit cycle of 18 days. On the three curves we can notice a diurnal cycle of the coherences with a high peak every day around 6AM. P-band coherences are globally very high up to 18 days especially around 6AM. Indeed, the median is higher than 0.8 during this time of day. Regarding the L-band, the dynamics of the coherences is more important as indicated by the width of the envelope representing the 1st and 3rd quartiles but the median remains higher than 0.6 for measurements acquired around 6AM up to 18 days. On the other hand, C-band coherences are lower but still form a diurnal cycle. Interestingly, the median of the coherences calculated

at 6AM is higher than 0.2 up to a temporal baseline of about 3 days and its corresponding 3rd quartile is higher than this same value up to more than 10 days. These results emphasize the temporal evolution of changes in the source of the scattering either for small forest components, which are subject to movement, at high frequencies, or changes at a larger scale at low frequencies.

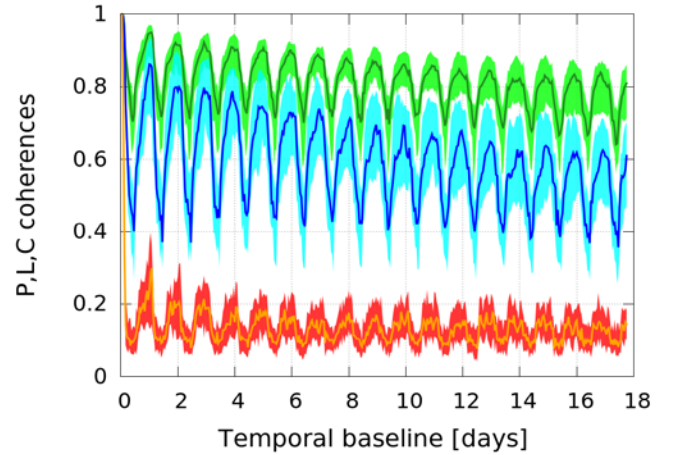


Fig. 2 Evolution of temporal coherences from 15 mn to 18 days considering reference time at 6AM. The green, blue and orange lines correspond respectively to the medians of P, L and C-bands coherences, and the indicated lower and upper bound refer to the first and third quartiles derived from all the acquisitions matching a specific temporal baseline.

5. FIRST CONCLUSIONS AND FURTHER WORK

Based on the recent acquisitions from the TropiScat-2 experiment, this work highlights the differences between temporal decorrelation at P, L and C-bands. In addition to the consolidation of previous results at P and L-bands, this work demonstrates that significant coherences can be reached at C-band for longer intervals than the expected few seconds or minutes, and that the diurnal cycles can be observed up to 18 days. Further work will be dedicated to a more quantitative assessment based on statistical analysis which can also serve for predictions within the framework of acquisition scenarios related to the upcoming missions using P-band (BIOMASS), L-band (ALOS-4, NiSAR) and candidate tandem or geostationary missions at C-band (Stereoid, G-Class). Moreover, the analysis of longer time series including a larger range of environmental conditions driven by the rainy and dry seasons will also enable to strengthen

the physical explanations of water content and convective winds effects on temporal decorrelation.

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