Use of PALSAR polarimetric data for tropical forest stratification

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In the context of the global warming and particularly regarding mitigation activities under the United Nations Framework Convention on Climate Change (UNFCCC) in the Land Use, Land-Use Change and Forestry (LULUCF) sector, it is important for governments and carbon project developers to find efficient ways and relying methods to quantify and monitor anthropogenic greenhouse gas (GHG) emission/absorption. Regarding the growing development of a future Post-Kyoto mitigation mechanism on Reducing Emissions from Deforestation and forest degradation (REDD), critical information is needed to facilitate forest carbon stocks estimation and to reduce uncertainties in the results of national or regional scale forest monitoring. Today, ground-based inventories are widely used to estimate carbon densities, applying specific or default regressions to tree metrics. But the cost and duration of ground-based forest inventories, inconsistency of inventory methods between areas, and the lack of local and adapted biomass regressions are major constraints to obtain reliable biomass estimation, and reduce the capacity to develop mitigation projects under UNFCCC as forest Clean Development Mechanism (CDM) or future REDD projects.

In this context, remote sensing is a valuable tool allowing repetitive observations over wide forested areas. In particular, SAR data are particularly well suited over tropical regions characterized by quasi-permanent cloud cover limiting optical observations.

Several spaceborne SAR sensors have been launched since 2007, operating at L band (ALOS-PALSAR), C band (RADARSAT-2) and X band (TERRASAR-X). The diversity of the frequency bands as well as the polarization configurations allows a better deiscriminaton of the ifferent land use / land cover.

The goal of this work is to assess potential of the ALOS PALSAR sensor for the forest stratification. The observations acquired at a large wavelength (λ=23.6 cm), able to penetrate the forest canopy, in a fully polarimetric configuration, sensitive to the forest geometrical structure make this sensor especially well suited for the estimation of forest stratification.

3 study sites are investigated, in Brazil, Cambodia, and Cameroon:

(1) The São Nicolau Fazenda, in Mato Grosso state - Brazil, which was clear cut in the early nineties and reforested between 1999 and 2003 with native and foreign species. Since1999, the Office National of Forestry International (ONFI) is conducting annually in the reforestation area a forest inventory (tree growth, mortality, biomass estimation, carbon stock assessment...) which constitutes an important ground truth to assess the potential of PALSAR data for forest stratification according to carbon and biomass growth

(2) The southern Cardamoms ecosystem, in Koh Kong Province - Cambodia, a tropical evergreen forest with smaller pockets of semi-evergreen and deciduous forests under high deforestation pressure. ONFI is collecting forest inventory data in a 200.000 ha in the framework of a climate mitigation project

(3) A large private forest concession area in Cameroon, where forest inventory (used to build the forest management plan) will be available for forest stratification

Fully polarimetric data content allow the analysis of the geometrical effects of the scattering mechanisms occurring within a resolution cell. Therefore they may be useful for land use discrimination. In addition to the coherency matrix elements representing the fully polarimetric measurements, other parameters containing polarimetric information are combined. These parameters include among other, the H/A/α parameters derived from the Cloude and Pottier decomposition [Cloude and Pottier, 1996], the ones based on the Pauli formalism, or the degrees of coherence between linear or circular polarizations.

The potential of partial radar polarimetry is also investigated by simulations from fully polarimetric data.

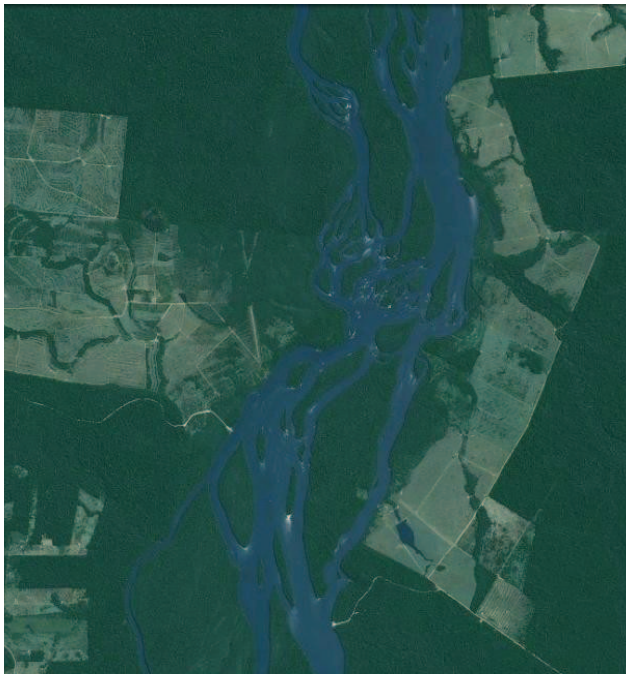
Different partial polarimetric modes are available on spaceborne SAR sensors, such as Alternate Polarimetric mode with ASAR or Dual Polarization mode with PALSAR or TERRASAR-X. In addition, a compact polarimetric mode has been presented [Souyris et al., 2005] allowing *a priori* a better performance for land use discrination. These partial polarimetric modes allow a twice wider swath (*i.e.* halving the revisit time) with respect to fully polarimetric mode, associated to a loss of polarimetric information. The aim is to assess their potential for forest stratification discrimination.

From each of these partial Polarimetric modes we extract different polarimetric indicators relative to these latter like the H/A/α parameters and the degree of coherence between the 2 measured polarizations. In addition, for the Compact Polarimetric mode, we investigate the interest of the reconstruction of the pseudo fully polarimetric information.

In each evaluated modes, we apply the Support Vector Machines (SVM) algorithm, [Burges, 1998], to classify our data. Indeed, this method is especially well suited to handle linearly non separable case by using the kernel method. It has been mostly applied to hyperspectral remote sensed data, but past studies have also shown its suitability for SAR data. As it is especially well suited to high dimension vectors, significant results has been obtained for full polarimetric SAR data [Lardeux et al., 2009].

In order to assess the monitoring of this tropical environment, different acquisition date are analyzed.

Primary results of the São Nicolau Fazenda in Brazil,, illustrated in the below table by the Pauli decomposition over the data acquired the 28 march 2009, show a good discrimination between the primary forest in Green, the riparian forest in bright yellow (double bounce between water and trunk), and between the reforested area which appear more darker than primary forest due to less volume scattering.

	
Palsar, Pauli decomposition Double bounce Volume scattering Single Bounce	Google Earth

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