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REDD

Reducing Emissions from Deforestation and Forest Degradation

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JAXA

New Eyes in the Sky: Cloud-Free Tropical Forest Monitoring for REDD
with the Japanese Advanced Land Observation Satellite (ALOS)

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Executive Summary

As UNFCCC negotiations lead to a powerful new mechanism for compensating tropical countries for their nation-wide reductions of greenhouse gas emissions from deforestation and forest degradation (REDD), an important, re-occurring question is: "can we monitor forests?" Most of the world's tropical forest countries still don't have high quality maps of their forests for multiple reasons including chronic cloud cover, and run the risk of being excluded from REDD. We report that pan-tropical monitoring of forests hidden by clouds will now be easier, thus strenthening existing global monitoring efforts. We present in this report two successful efforts to create large-scale, cloud-free mosaics of forests for two large tropical forest regions: the island of Bali (7,500 km^2) and the Xingu River headwaters in southeastern Amazonia (400,000 km^2). These mosaics were completed with a total of less than three weeks of processing time.

Cover Image: Radar image mosaic of the Island of Bali, Indonesia, site of the UNFCCC COP-13. Data were acquired during the period of September 9 to October 10 2007 by imaging radar on board the Japanese Advanced Land Observing Satellite (ALOS). ALOS radar imagery is draped over elevation data acquired by the NASA/DLR Shuttle Radar Topogaphy Mission (SRTM).

Image Processing: The Woods Hole Research Center.

Overview

The mapping of tropical forests with remote sensing satellites in support of monitoring needs for Reduced Emissions from Deforestation and Degradation (REDD) mechanisms is becoming more robust: On January 24th 2006 the Japanese Space Agency (JAXA) launched their newest space-borne Earth observing platform, the Advanced Land Observing Satellite (ALOS) featuring PALSAR[1], which is one of the most advanced imaging radar sensors currently deployed for civilian Earth observation, and which is particularly suited for forest and wetland observations. Because radar remote sensors can collect data night or day, through dense clouds and in nearly all weather conditions, images can in theory be reliably acquired at any point in time that the sensor passes over a given area of interest. In the case of ALOS, the same spot on Earth is revisited every 46 days.

The ALOS mission is particularly unique in that a global data acquisition strategy was specifically designed to systematically map all of Earth's land masses at least three times per year at 10 m, 20 m, and 100 m resolution. This acquisition strategy is currently fixed and will very likely continue through the lifetime of the mission, which should last more than 10 years, spanning the post-Kyoto commitment period of 2013 to 2017. Additionally, JAXA and several other space agencies are planning to deploy additional radar imaging sensors to become operational, ensuring data continuity for repeat observations. Overall, these characteristics make ALOS/PALSAR data ideally suited to complement the existing fleet of Earth remote sensing instruments by providing wall-to-wall high resolution image data that is acquired over short time frames and not impeded by cloud cover, hence further reducing uncertainties associated with quantifying forest loss and agricultural expansion across the tropics.

The Woods Hole Research Center, in cooperation with JAXA, has produced two of the first large-area image mosaics of ALOS/PALSAR from a global dataset which was acquired between June and October of 2007. Regions in the Amazon (Xingu Basin, Mato Grosso, Brazil), Western Africa (Gabon and Equatorial Guinea) and Southeast Asia (Bali, Indonesia) were selected to be the focus of initial research to demonstrate ALOS as an important new monitoring tool to support REDD initiatives.

What do we see in the ALOS radar image mosaics?

Because radar sensors are "active" remote sensing systems (i.e., they transmit and receive their own microwave energy and thus complement "passive" optical sensors which measure reflected sunlight), radar images are always visual (i.e., in the visible spectrum) representations of microwave energy received at and recorded by the sensor. Single radar information channels are typically displayed as grayscale images. When interpreting a radar image it is a general rule of thumb that increasing brightness corresponds to a greater amount of energy recorded by the sensor. Applying this rule of thumb to the interpretation of vegetated regions in an ALOS/PALSAR image, areas with a greater amount of vegetation biomass of a given structural type will appear brighter due to the greater amount of energy scattered back to and recorded by the sensor. If multiple radar information channels are available, color images can be generated by assigning a combination of distinct radar information channels to each of the visible red, green, and blue (RGB) channels commonly used for display on computer monitors.

The radar image mosaics presented in this report (Figures 1 and 2) were each generated using two distinct PALSAR information channels: a) Image data derived from microwave energy that was both transmitted and received by the sensors radar antenna in the horizontal direction, i.e. parallel to Earth's surface, and b) image data derived from microwave energy transmitted in the horizontal direction, but received in the vertical direction. The former case is referred to as HH-polarization while the latter case is HV-polarization. To create

[1] PALSAR = *Phased Array L-Band Synthetic Aperture Radar*

the RGB images included in this report, the HH information channel was assigned to red, HV was assigned to green, and the difference between the two (HH-HV) was assigned to blue. Hence, green and yellow tones correspond to instances where both HH and HV information channels have high energy returns e.g., over forested and urban areas. Blue and magenta colors are generally found in non-forested areas, where the HH polarized energy often exhibits a higher return from the surface than the HV polarized energy.

The ALOS/PALSAR Sensor and Imaging Modes

Since ALOS/PALSAR is based on phased-array L-Band antenna technology, the sensor can be operated in various imaging modes referred to as fine-beam single-polarimetric (FBS), dual-polarimetric (FBD), fully polarimetric (PLR), and wide-beam ScanSAR (WB). The latter mode allows for single-polarimetric image acquisitions at a swath width of ~350 km at 100 m resolution. FBS and FBD imagery have a 70 km swath width and resolutions of 10 m and 20 m, respectively. Additionally, the off-nadir look angle of the radar antenna can be adjusted to target specific regions of interest, such as natural disasters, or to fill specific multi-temporal acquisition needs.

The L-Band radar wavelength (~ 23 cm) has been shown in numerous studies to be particularly well suited for forest mapping applications. This research is based on nearly three decades of airborne, satellite-borne and space shuttle-based radar imaging missions, including the Japanese predecessor mission to ALOS, the Japanese Earth Resources Satellite (JERS-1).

The ALOS/PALSAR Observation Strategy

In the interest of producing globally consistent radar image datasets of the type first generated during the JERS-1 Global Rain Forest Mapping (GRFM) project of the mid-1990s, an international ALOS "Kyoto & Carbon Science Team" was formed, and a dedicated observation strategy was developed to support global forest monitoring needs[2] (Figure 3). In a wall-to-wall manner, PALSAR data will be systematically collected in HH (FBS and ScanSAR) and HH/HV mode to cover all of Earth's land masses at least three times each year. The observation strategy will be assessed and optimized after three years, and is likely to continue until the end of the mission. Because of the excellent positional accuracy of ALOS and the availability of advanced image processing methods, regional- to continental-scale image mosaics can readily be produced for any region that has been systematically imaged by the PALSAR sensor.

[2] Rosenqvist, A., Shimada, M and Watanabe, M. "ALOS PALSAR: A pathfinder mission for global-scale monitoring of the environment", IEEE Transactions on Geoscience and Remote Sensing, vol. 45, no. 11, pp 3307-3316, Nov. 2007.

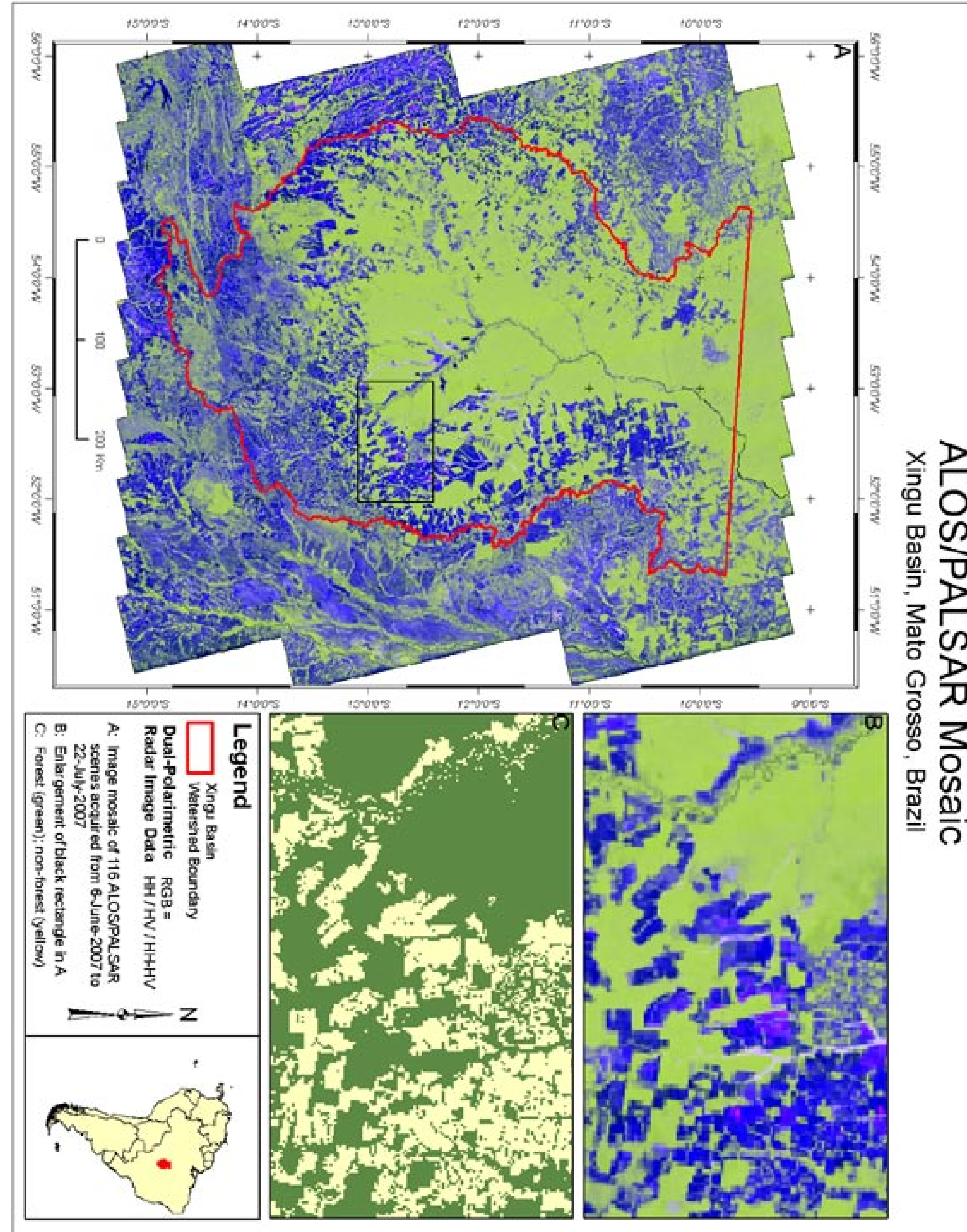
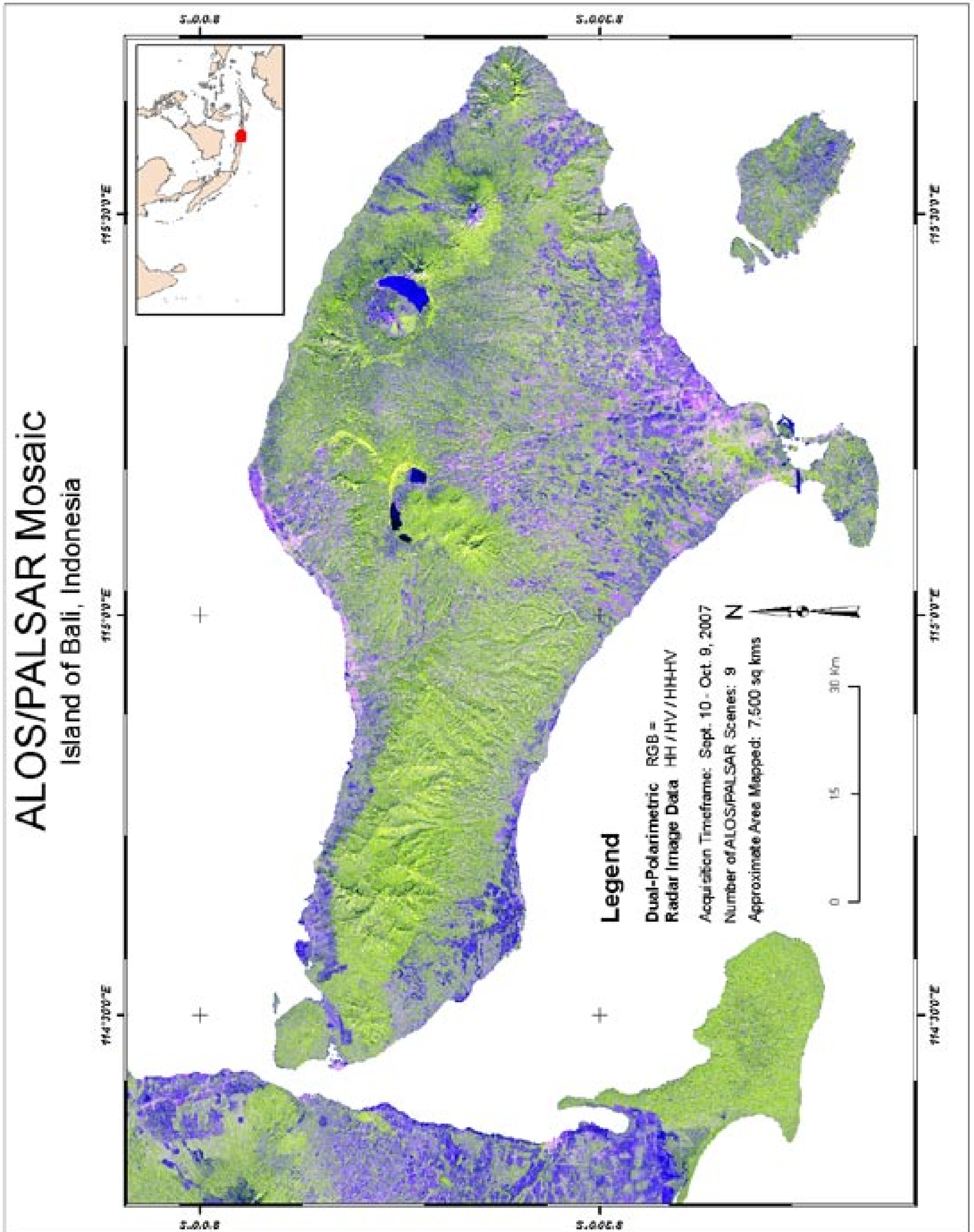
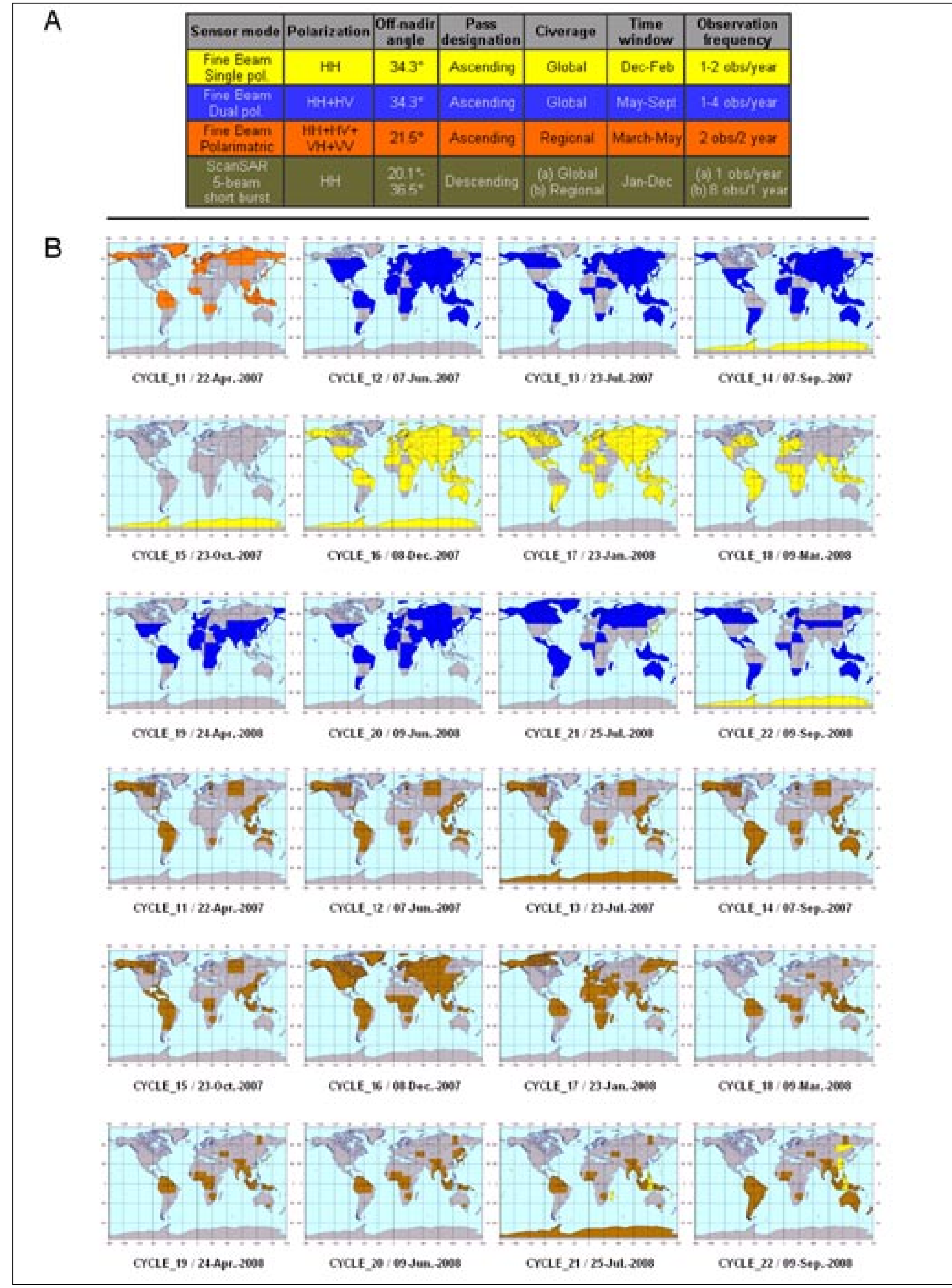


Figure 1: Xingu BasinWatershed, Mato Grasso, Brazil. The radar image mosaic, is a composite of 116 individual scenes (400,000 km²) acquired by the PALSAR sensor carried on board ALOS. The image acquisitions were made between June 8 and July 22, 2007. From the mosaic, Dr. Kellndorfer's group has generated a preliminary land cover classification with emphasis on producing an accurate forest/nonforest map. In the forested areas, the sensitivity of the PALSAR data to differences in aboveground biomass is also being investigated in collaboration with the Amazon Institute of Environmental Research (IPAM).



Fgure 2: Bali, Indonesia, host to the 2007 UNFCCC Conference of the Parties 13 (COP-13). The radar image mosaic is a composite of nine individual scenes (45,000 km²) acquired by the PALSAR sensor carried on board ALOS. The image acquisitions were made between September 9 and October 10, 2007.



Sensor mode	Polarization	Off-nadir angle	Pass designation	Civerage	Time window	Observation frequency
Fine Beam Single pol.	HH	34.3°	Ascending	Global	Dec-Feb	1-2 obs/year
Fine Beam Dual pol.	HH+HV	34.3°	Ascending	Global	May-Sept	1-4 obs/year
Fine Beam Polarimatric	HH+HV+ VH+VV	21.5°	Ascending	Regional	March-May	2 obs/2 year
ScanSAR 5-beam short burst	HH	20.1°-36.5°	Descending	(a) Global (b) Regional	Jan-Dec	(a) 1 obs/year (b) 8 obs/1 year

Figure 3: Global observation strategy for various ALOS/PALSAR sensor modes (Source: JAXA/EORC).