CEOS High Profile Publication

FIRST DRAFT to the GEO Forest Carbon Tracking Task section

April 9, 2010

Note:

All figures in this draft are temporary place holders.

Satellite images should be replaced by images selected by the contributing CEOS agencies, preferably using data acquired during the 2009/2010 FCT coordinated acquisition campaigns.

Text formulations to be refined jointly with contributing CEOS agencies and GEO-FCT Task team.

CEOS contribution to the GEO Forest Carbon Tracking Task

1. Background

Deforestation, degradation and peat fires represent up to 20% of the global anthropogenic CO_2 emissions according to the Intergovernmental Panel on Climate Change (IPCC). Compared with other measures, reducing deforestation and forest degradation is a relatively straight-forward action to rapidly reduce global CO_2 emissions, which in addition would bring positive side-effects in terms of environmental conservation and protecting biological diversity. This is the essence of the UNFCCC programme on Reducing Emissions from Deforestation and Forest Degradation (REDD+), which aims to engage developing countries, in particular in the tropical zone, to reduce emissions from deforestation and forest degradation, manage the role of conservation and sustainable management and enhance their forest carbon stocks.

One of the main challenges to the inclusion of forest protection in the post-Kyoto framework has been the question about the capacity to consistently monitor the vast areas required and to establish reliable systems for national measuring, reporting and verification (MRV) of forest carbon stocks and their changes. Both technology and political willingness have matured and the COP-15 Copenhagen Accord called for the "immediate establishment of a mechanism including REDD+", to be in operation by 2013. Furthermore, COP-15 Decision 4, 1(d) requests developing country Parties to establish robust and transparent national forest monitoring systems using a combination of remote sensing and ground-based forest carbon inventory approaches.

The GEO Forest Carbon Tracking Task was established to provide satellite-based observation support to countries on the path towards the establishment of sovereign national MRV systems, forming a global network of MRV systems that comply with IPCC guidelines and support REDD+.

Figure 1. *Amazon, Brazil. Rain forest cleared for pasture (Image credit: NASA LBA-EOC)*

2. The role of Earth Observation

A combination of optical and radar satellites is required to support the GEO FCT Task. Optical sensors provide a historical archive which goes back more than 35 years in time and is the only means available to establish a uniform 1990 baseline data set over the world's forest areas. The rich spectral information in the visible, near- and mid infrared bands allow, when coupled with ground-based information, detailed distinction of forest and vegetation types. Cloud cover remains a problem, in particular in the humid tropics, and additional data sources are needed to assure the annual coverage that is required for reliable national MRV system operations.

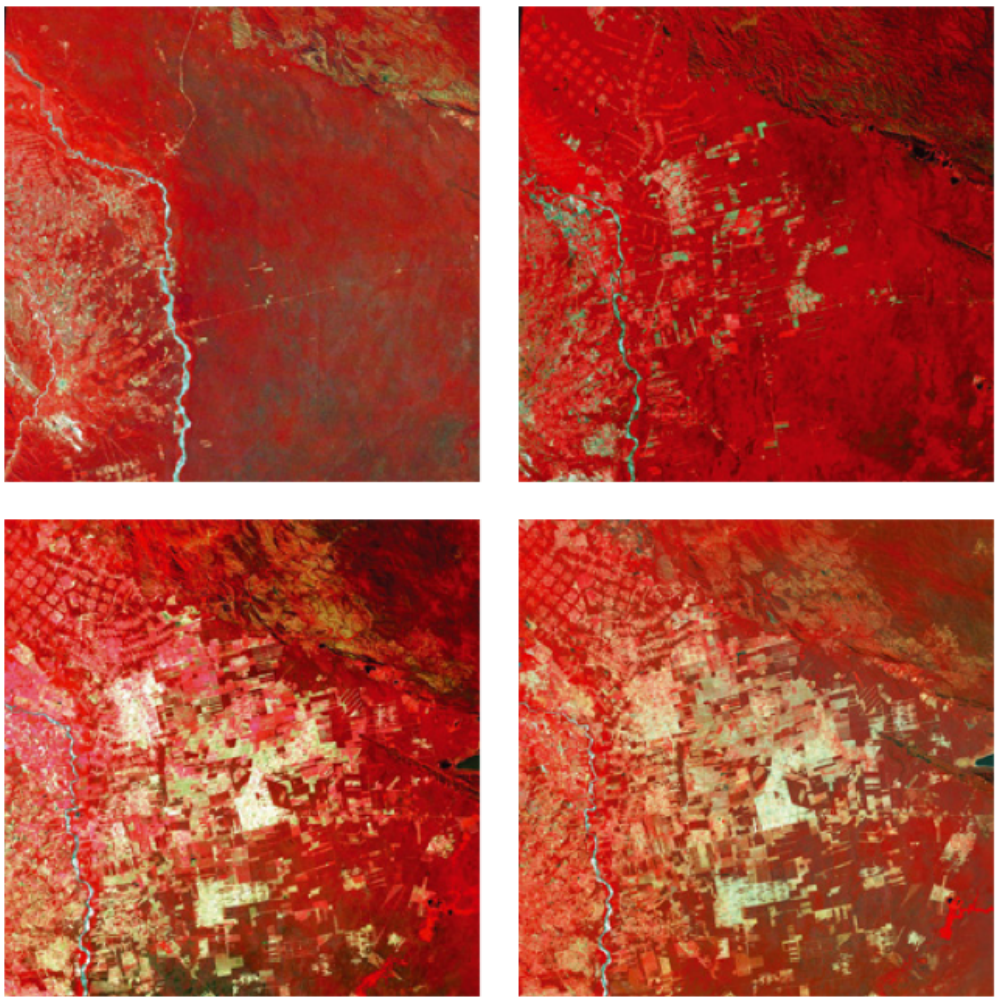

Figure 2. *Historical view of tropical deforestation in the Amazon 1975/1992/2000/2002 (Image credit: NASA)*

Space-borne radar systems have the capacity to acquire data regardless of cloud cover and sunlight, and can be programmed to cover whole nations and continents within a short and well-defined time window. The CEOS agency radar satellites operate with different wavelength bands, which are complementary to each other and sensitive to specific features on the ground, including above-ground biomass. With no cloud cover limitation, time series of radar data can feasibly be programmed to provide detailed information about the time, location and extent of changes in the forest cover.

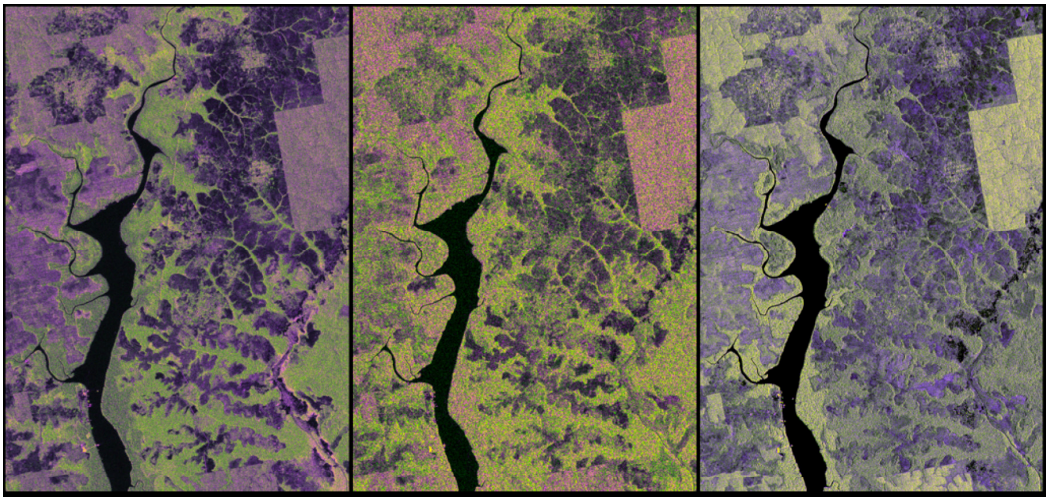

Figure 3. *Kalimantan, Indonesia. Multi-satellite view by CEOS agency radar satellites (Image credits: JAXA, ESA, DLR)*

Very High Resolution (VHR) satellite data (at resolutions around 1 m) from both optical and radar sensors are useful as a supplement to ground based information for calibration and validation of the MRV algorithms that are being developed. VHR data are particularly suitable for identification of small logging roads and forest degradation.

Figure 4. *Guyana. Logging road detected in Very Fine Resolution (1 m) radar data. (Image credit: DLR, Photo: Hoekman/U.Wageningen)*

3. CEOS coordination

Starting in June 2009, CEOS is leading its member space agencies in the coordination of a dedicated activity in support to GEO-FCT that pools the capacities of the participating space agencies and enhances interoperable and synergetic use of the different satellite systems. For the first time ever, nation-wide blanket coverages from a number of different satellites are being acquired in a coordinated, near-simultaneous manner over the GEO-FCT National Demonstrator countries, at a ground resolution of 30 m or better.

Optical satellites are requested at every feasible opportunity to minimise the influence of cloud cover, while radar observations are being undertaken during 2-month time windows every 6 months to provide the time-series necessary for active forest change monitoring and refinement of the MRV algorithms. VHR satellite data are requested over a number of key forest areas within each National Demonstrator on a monthly basis for intensive monitoring and validation.

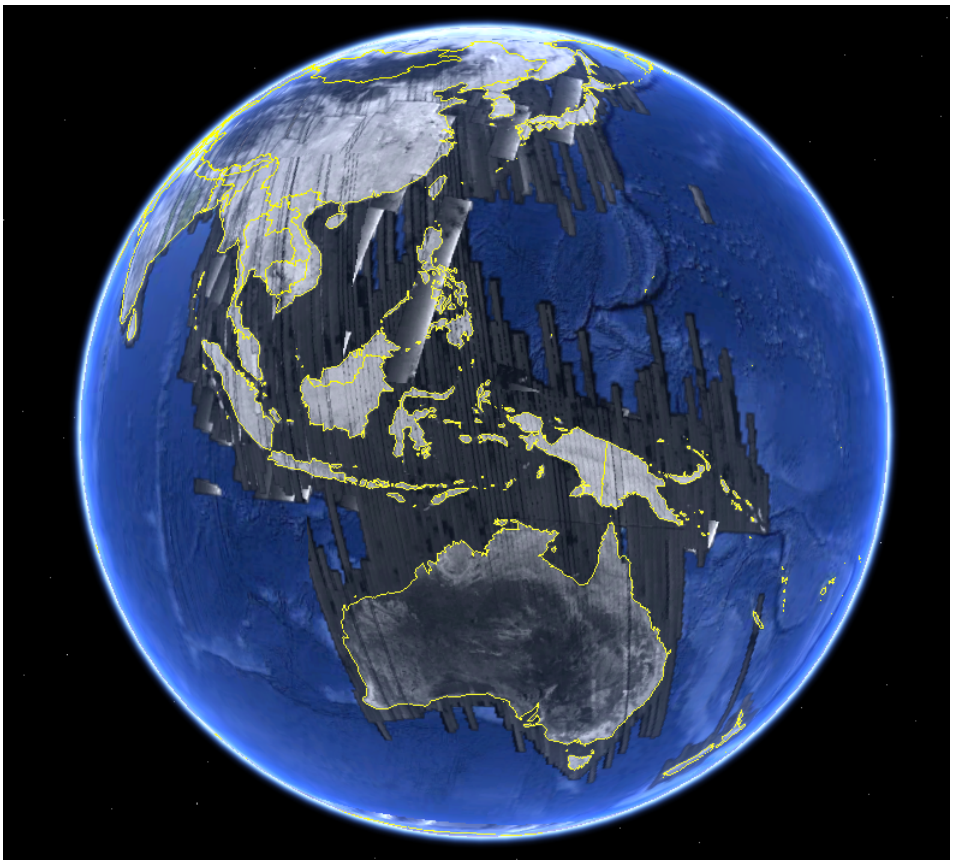

Figure 5. *The strength of radar: continental coverage acquired during short time window (July 28 – Sep 11, 2009) (Image credit: JAXA)*

Coordinated by CEOS, more than ten satellites are contributing to the GEO Forest Carbon Tracking Task.

Figure 6. *Optical satellites contributing to the GEO Forest Carbon Tracking Task*

The **Landsat** series of satellites has provided imagery over the global forest cover since 1972, starting the era of Earth Observation. It constitutes the longest record of the Earth's continental surfaces as seen from space. Launched by NASA and operated by the US Geological Survey (USGS), the Landsat 5 and 7 satellites are currently in orbit. The Thematic Mapper sensors (TM and ETM+) provide imagery in the visible, near-, mid- and thermal infrared wavelength channels, with the NIR and MIR bands being indispensable for vegetation mapping. Imagery are particularly abundant in areas covered by a network of national ground receiving stations. In 2012, NASA plans to launch the Landsat Data Continuity Mission (LDCM), or Landsat 8, to extend the Landsat program's contributions to global environmental monitoring.

The entire historical Landsat archive is available free of charge without restrictions for public use by USGS. To ease handling of the very large data amounts required for the GEO FCT Task, USGS is undertaking special processing of nation-wide wall-to-wall coverages over each of the FCT National Demonstrator countries, from 1990 until present.

Landsat data over northern South America, acquired in Brazil by the Brazilian Institute for Space Research (INPE), are made available free of charge by INPE.

CBERS-2B (China-Brazil Earth Resources Satellite) was developed jointly between China and Brazil, and is nearly identical to its predecessors, CBERS-1 and CBERS-2. It was launched in 2007 and carries two optical sensors. The fine resolution CCD sensor supports the analysis of phenomena whose duration is compatible with its temporal resolution (26 days). This temporal resolution can be improved as the CCD has the capacity of side view. It operates in the visible and near infrared bands and provides imagery at 20 m resolution.

CBERS data acquired in Brazil are openly available for public use without restrictions. The data are processed and distributed free of charge by INPE.

The first **SPOT** satellite was launched in 1986 by France, in collaboration with Sweden and Belgium. It was the first satellite to feature side-looking capacity to allow stereo viewing and provide improved observation frequancy over areas of intensive monitoring. SPOT 4 and 5 are presently in orbit, equipped with sensors operating in the visible, near and middle infrared bands, with a spatial resolution of 10-20 metres. Panchromatic data are available at 5 metre resolution.

A limited amount of SPOT-4 data are made available to the GEO FCT Task by the European Space Agency (ESA) under a Third Party Mission framework agreement with CNES.

Access to SPOT-5 data… (CNES TBD)

IRS-P6 (RESOURCESAT-1) is the tenth and most advanced satellite in the IRS series. It was launched by the Indian Space Research Organisation (ISRO) in 2003 and carries both panchromatic and multispectral sensors with resolutions ranging from 5 to 60 metres.

A limited number of IRS scenes will be made available by ISRO to the GEO FCT. IRS data acquired in Brazil, covering northern South America, are made available without restrictions and free of charge by INPE.

GeoEye and **IKONOS** are satellites in the Very High Resolution (VHR) category, operated by GeoEye Inc. With panchromatic imagery at 40–80 cm resolution, and multi-spectral data at 1.6–3.2 metres, VHR data are important for the GEO FCT task for detection of fine spatial changes in the forest cover, such as degradation and selective logging.

GeoEye is making a limited amount of VHR data acquired over a selection of GEO FCT local Verification Sites available free of charge.

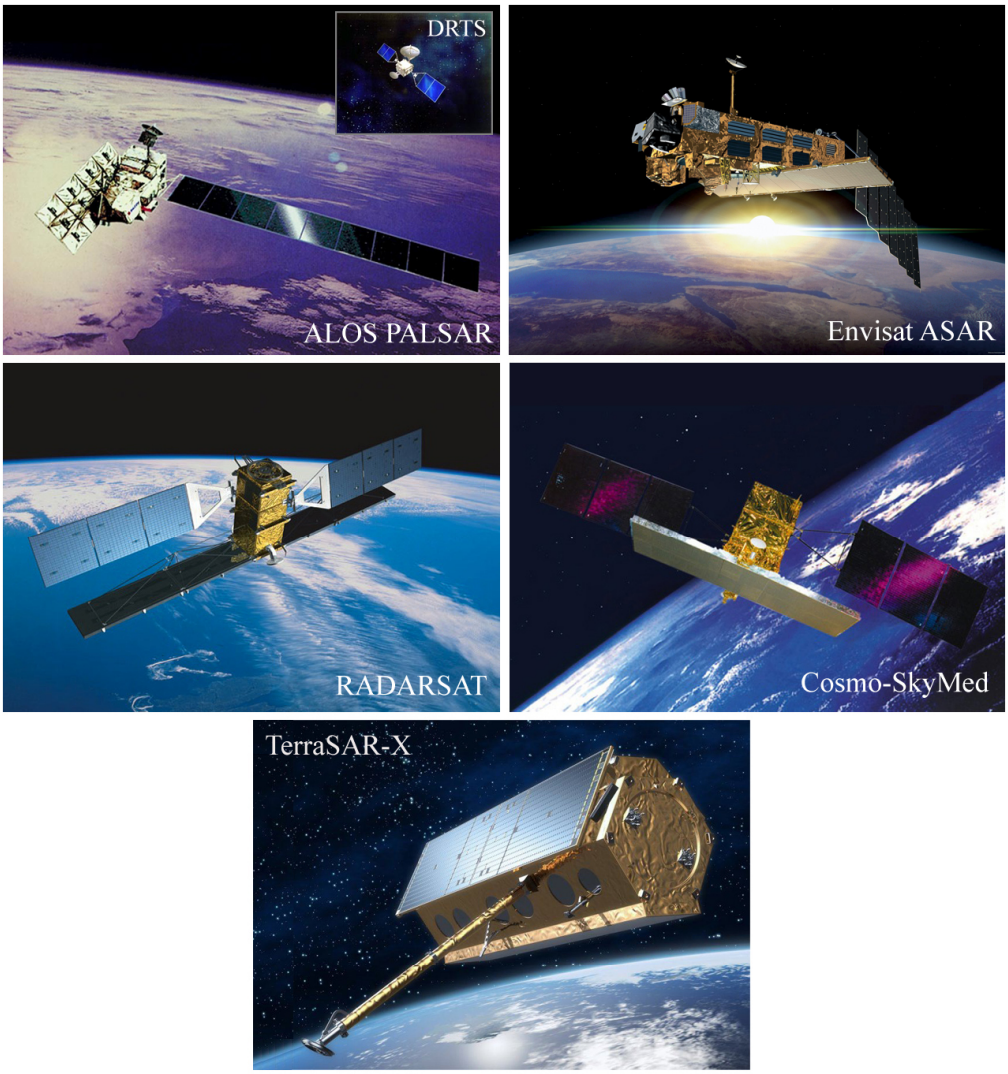

Figure 7. *Radar satellites contributing to the GEO Forest Carbon Tracking Task*

ALOS was launched in 2006 by the Japan Aerospace Exploration Agency (JAXA) as an enhanced follow-on mission to the JERS-1 satellite. ALOS carries two optical instruments and an L-band Synthetic Aperture Radar (PALSAR). PALSAR is the only spaceborne radar that operates in the long wavelength (L-band) domain, which in addition to cloud penetration and night-time operations provides sensitivity to vegetation structure and above-ground biomass. At least as important as the technical characteristics however, is the systematic data acquisition strategy which has been implemented for ALOS, designed to provide consistent, cloud-free wall-to-wall observations at fine resolution of all land areas on the Earth on a repetitive basis every 6 months. The L-band SAR observations will be continued by the ALOS-2 mission, which is scheduled for launch in 2013.

JAXA is making a limited amount of ALOS PALSAR data available free of charge to the GEO FCT Task, covering a selection of local FCT Verification Sites.

Envisat (ENVIronmental SATellite) is an advanced polar-orbiting Earth observation satellite, which provides measurements of the atmosphere, ocean, land, and ice. Launched in 2002 by the European Space Agency (ESA), it constitutes an enhanced continuation of the ERS C-band radar missions. Envisat carries nine different sensors to support Earth science research. The ASAR radar instrument operates in the C-band and provides cloud-free data in a range of different observation modes. Within the framework of the European GMES programme, the Sentinel-1 series of satellites will address the issue of C-band SAR data continuity over the world. The first Sentinel 1 satellite is planned to be launched before the end of the Envisat operations.

ESA provides wall-to-wall coverage of ENVISAT ASAR acquired over a selected number of the GEO FCT National Demonstrator countries available free of charge.

The **RADARSAT-1 and 2** satellites were launched by the Canadian Space Agency (CSA) in 1995 and 2007, respectively. The satellites carry C-band radar sensors, with RADARSAT-2 featuring a more advanced version with multiple polarization modes and a variety of acquisition modes. The spatial resolution varies between 1 and 100 metres. RADARSAT-2 is operated by CSA in collaboration with MacDonald Dettwiler (MDA), and it is a part of the European GMES Sentinel-1 fleet of satellites. The next-generation mission to RADARSAT-2 is the RADARSAT Constellation Mission (RCM), which will consist of three spacecrafts in operation simultaneously. The RCM will provide new applications, as well as continuing to provide C-band radar data.

CSA and MDA provide wall-to-wall coverage of RADARSAT-2 data acquired over a selected number of the GEO FCT National Demonstrator countries available free of charge to the Task.

COSMO-SkyMed (COnstellation of small Satellites for the Mediterranean basin Observation) is an Earth observation satellite system operated by the Italian Space Agency (ASI). It is a constellation composed of four satellites equipped with Synthetic Aperture Radar operating at X-band. The first satellite was launched in 2007 and the full constellation is planned to be operational by mid 2010. With four satellites simultaneously in orbit, he COSMO-SkyMed constellation has capacity for wide-area coverage at resolutions between 1 and 100 metres.

Access to COSMO-SkyMed data to the GEO FCT Task… (ASI TBD)

TerraSAR-X is a German Earth-observation satellite, launched in 2007. Its primary payload is an X-band radar sensor with a range of different modes of operation, allowing it to record images with different swath widths, resolutions and polarisations. It provides very hight spatial resolution for a a SAR sensor, from 1 - 3 metres in the spotlight and stripmap modes, to 18 metres in wide-beam ScanSAR modxe. The objective of the mission is to provide value-added SAR data in the X-band, for research and development purposes as well as scientific and commercial applications.

DLR is making a limited amount of TerraSAR-X data available free of charge to the GEO FCT Task, covering a selection of local FCT Verification Sites.

4. Spatial input to National MRV Systems

The satellite data collected during the coordinated acquisition campaigns are processed by the CEOS space agencies and provided to the National Demonstrators for analysis and generation of a suite of nation-wide forest information products that are to be generated at an annual basis:

- Forest/Non-forest maps (Horizon 1a)
- Land Cover maps (Horizon 1b)
- Changes in forest cover, including deforestation, degradation and regeneration (Horizon 2)

In accordance with guidelines on data analysis and ground-based verification and validation that are being developed within the GEO-FCT framework, and adapted to suit the unique conditions of each National Demonstrator country, nation-wide map products showing forest and land cover status and changes are derived on an annual basis, constituting the spatial input to the national MRV systems.

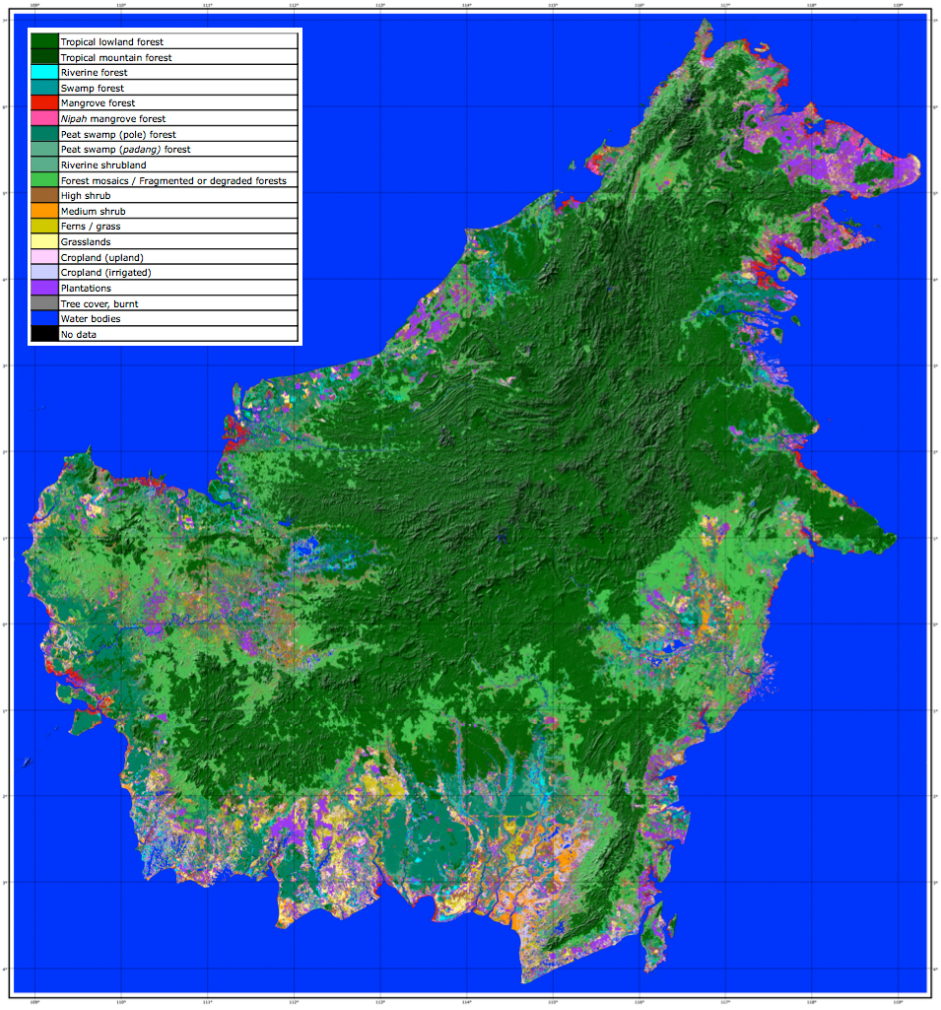

Figure 8. *GEO FCT Land Cover map (Horizon 1b product) over the Borneo Island National Demonstrator (Image credit: U. Wageningen/K&C/JAXA)*

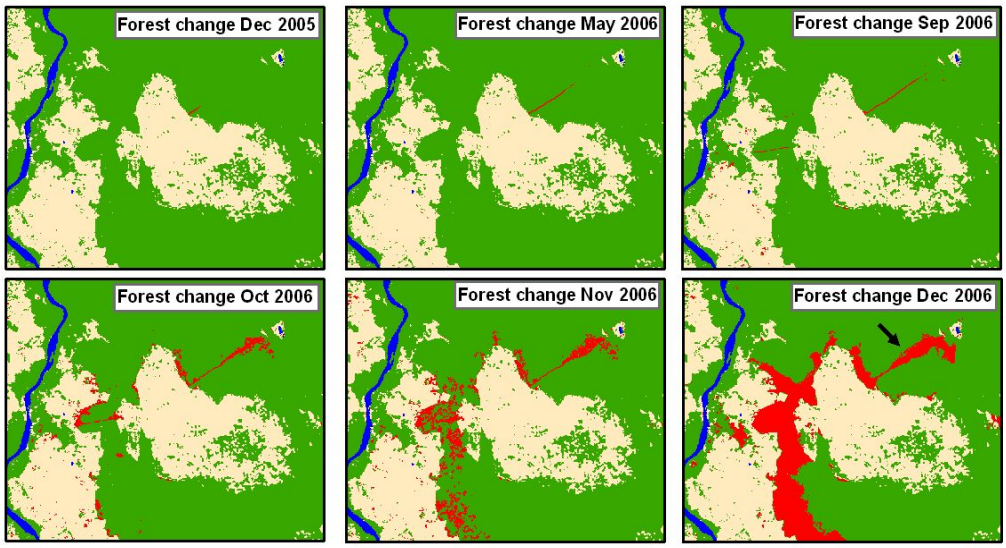

Figure 9. *Changes on forest cover (Horizon 2 product)*
(Image credit: U. Wageningen/ESA)

5. Towards a Global Forest Monitoring Network

The number of National Demonstrators that are covered within the GEO-FCT activity is gradually increasing as new countries are admitted, and CEOS is following this development with a corresponding expansion of the coordinated observations. This progress is in line with a general trend amongst the CEOS space agencies of moving towards the incorporation of systematic acquisition strategies as part of their satellite mission concepts.

The goal of the CEOS coordination activity for GEO-FCT is a global multi-satellite acquisition strategy and its data provision for demonstrating the space based data utilization for Forest and Carbon monitoring.

Figure references:

Figure 1: NASA LBA-ECO project (http://www.nasa.gov/centers/goddard/news/topstory/2006/amazon_crops.html)

Figure 2: Landsat 1975, 1992, 2000, 2002.
http://www.eohandbook.com/eohb05/ceos/part2_7.html

Figure 3: "Optimal SAR data modes and products for annual, medium-resolution forest-cover change monitoring. K&C input to the GEO Task on Forest Carbon Tracking" Report by Rosenqvist, Lucas, Hoekman, Kellndorfer and Milne. Forest Carbon workshop, Canberra, Australia, 7-9 April, 2009. (Image credits: JAXA, ESA, DLR)

Figure 4: TerraSAR-X 1 m image over Guyana. Image credits DLR and InfoTerra. Photo credit: D. Hoekman/U. Wageningen.

Figure 5: ALOS PALSAR coverage. Image credits JAXA EORC and Google Earth.

Figure 6: Optical satellites contributing to GEO-FCT. Image credits: NASA (Landsat), INPE (CBERS), CNES/SpotImage (SPOT), ISRO (IRS), GeoEye (GeoEye, IKONOS)

Figure 7: Radar satellites contributing to GEO-FCT. Image credits: JAXA (ALOS), ESA (Envisat), CSA (Radarsat), ASI (COSMO-SkyMed), DLR (TerraSAR-X)

Figure 8: Borneo Land Cover Classification from PALSAR. Image credits: Dirk Hoekman, U. Wageningen, JAXA EORC, ALOS Kyoto & Carbon Initiative

Figure 9: Rapid deforestation mapping by Envisat ASAR. Image credits: D. Hoekman, U. Wageningen, ESA.

Other references:

UNFCCC Report of the Conference of the Parties on its fifteenth session, Copenhagen 7-19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session. CCC/CP/2009/11/Add.1. Decision 4/CP.15 (1)(d) .

GEO-FCT Key document: Satellite-Derived Forest Information Product Specifications (v. Jan 5, 2010 (Alex Held).

Report Of The GEO Interim Working Group on Global Operational Forest Monitoring, 10-11 February 2010, Los Angeles, CA, USA.

Kormos, C., 2009. REDD+: Conservation's Role in the Fight Against Climate Change (http://www.wild.org/author/cyrilkormos/ April 24,2009)

CarbonPositive, 2009. REDD may yet survive Copenhagen failures (2009-12-21)

http://www.carbonpositive.net/viewarticle.aspx?articleID=1786

Landsat Data Continuity Mission info:
http://www.sti.nasa.gov/tto/Spinoff2009/er_9.html

CBERS info: http://www.satimagingcorp.com/satellite-sensors/cbers-2.html

SPOT info: http://www.cnes.fr/web/CNES-en/1415-spot.php

IRS info: http://www.isro.org/satellites/irs-p6resourcesat-1.aspx

Sentinel-1 info: http://www.esa.int/esaLP/SEMZHM0DU8E_LPgmes_0.html

RADARSAT-2: http://www.asc-csa.gc.ca/eng/satellites/radarsat2/

TerraSAR-X info: http://www.dlr.de/en/desktopdefault.aspx/tabid-4219/8885_read-15979/

COSMO-SkyMed: http://www.cosmo-skymed.it/en/index.htm