# GEO Forest Carbon Tracking Task
# Draft section to the CEOS High Profile Publication[i]

## 1. Forests, $CO_2$ and biodiversity

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 draft decision 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)*

---

[i] Note that all figures and satellite images in this draft should be replaced by images selected by the CEOS agencies themselves, and preferably data acquired during the 2009/2010 FCT coordinated acquisition campaigns.

## 2. CEOS satellites contributing to GEO-FCT

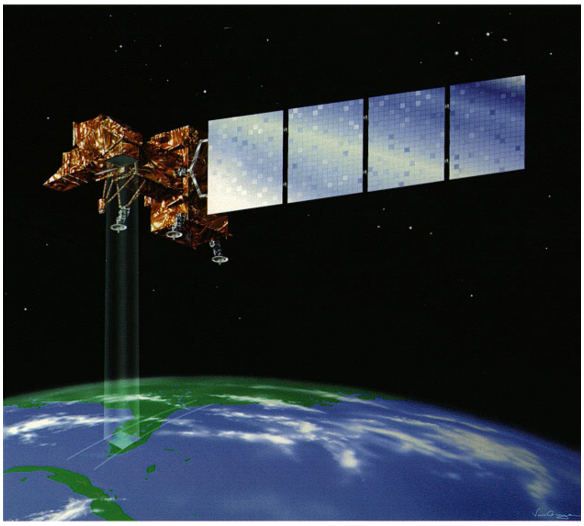

***Figure 2. Landsat-7*** *(Image credit: NASA)*

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 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 cartography, water management, natural disaster relief planning, and more.

***Figure 3. CBERS-2B***
*(Image credit: China Brazil Earth Resources Satellite/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.

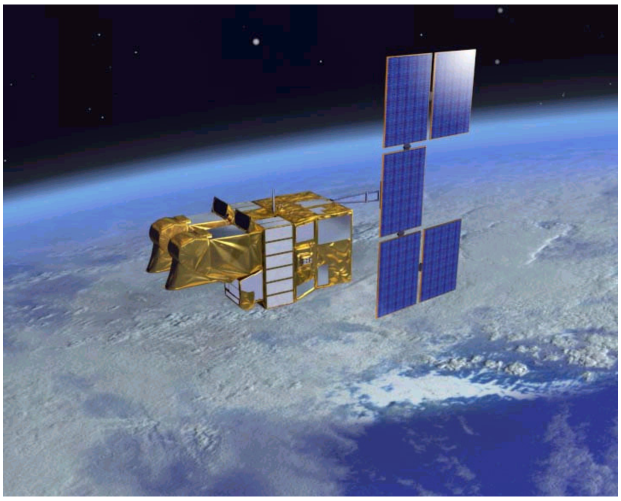

***Figure 4. SPOT-5*** *(Image credit: CNES)*

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.

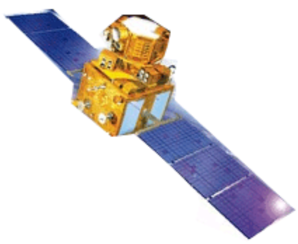

***Figure 5. IRS-P6*** *(Image credit: ISRO)*

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

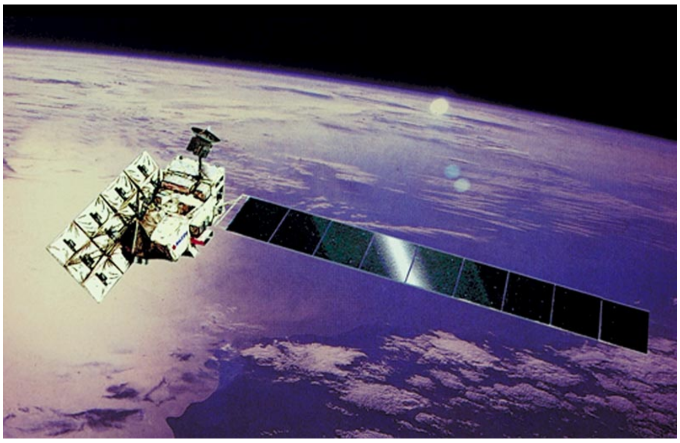

***Figure 6.*** *The Advanced Land Observing Satellite - ALOS*
*(Image credit: JAXA/METI)*

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 (PRISM and AVNIR-2) 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, which has been 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.

***Figure** 7. The ENVIronmental SATellite - Envisat*
*(Image credit: ESA)*

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 the follow-on to the ERS-1 and 2 C-band radar missions. Envisat carries as many as nine different sensors to support Earth science research and monitoring of the evolution of environmental and climatic changes. The Advanced Synthetic Aperture Radar (ASAR) instrument operates in the C-band domain like it predecessors, 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.

***Figure 8***. *RADARSAT-2 (Image credit: CSA/MDA)*

The RADARSAT-1 and 2 satellites were launched by the Canadian Space Agency in 1995 and 2007, respectively. To provide consistent observations, the satellites are placed in the same orbit, separated by half a cycle. While both satellites carry C-band Synthetic Aperture Radars, RADARSAT-2 features a more advanced version with multiple polarization modes and a variety of acquistion modes. The spatial resolution varies from 1 m in spotlight mode to 100 m in ScanSAR Wide Beam mode. RADARSAT-2, which is operated by CSA in collaboration with MDA, 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.

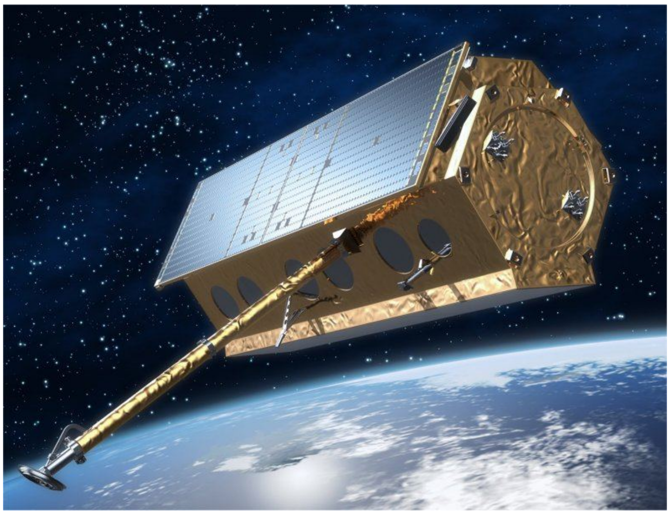

***Figure 9**. TerraSAR-X-2 (Image credit: DLR)*

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.

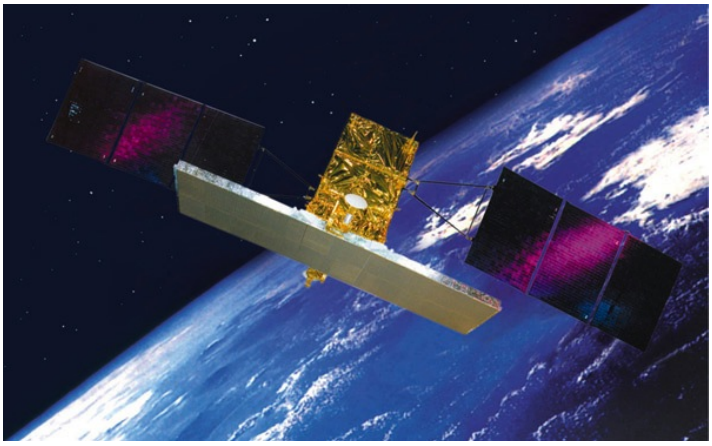

***Figure 10**. COSMO-SkyMed (Image credit: Thales Aliena Space)*

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.

## 3. Earth Observation and Forestry

A combination of optical and radar satellites is required for the task, where 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.

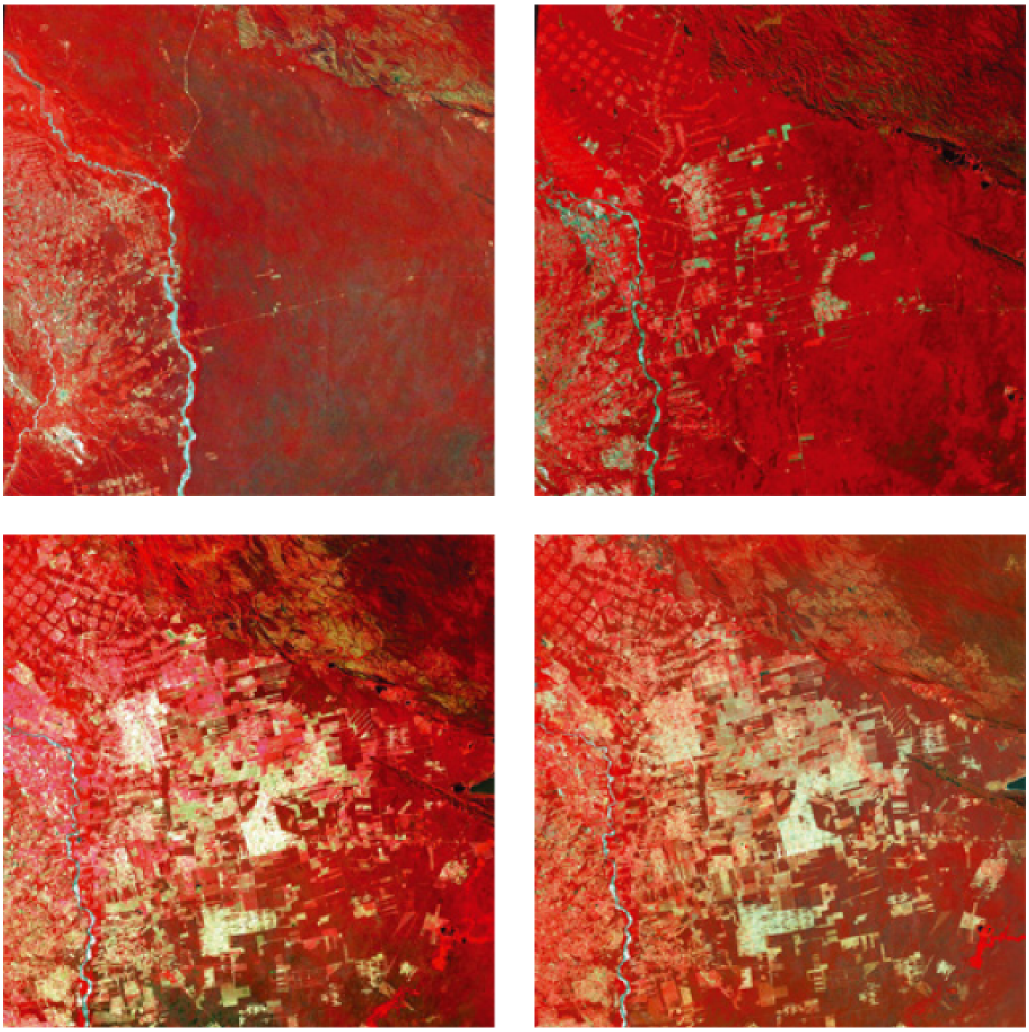

***Figure 11.*** *Historical view of tropical deforestation in the Amazon 1975/1992/2000/2002 (Image credit: NASA)*

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.

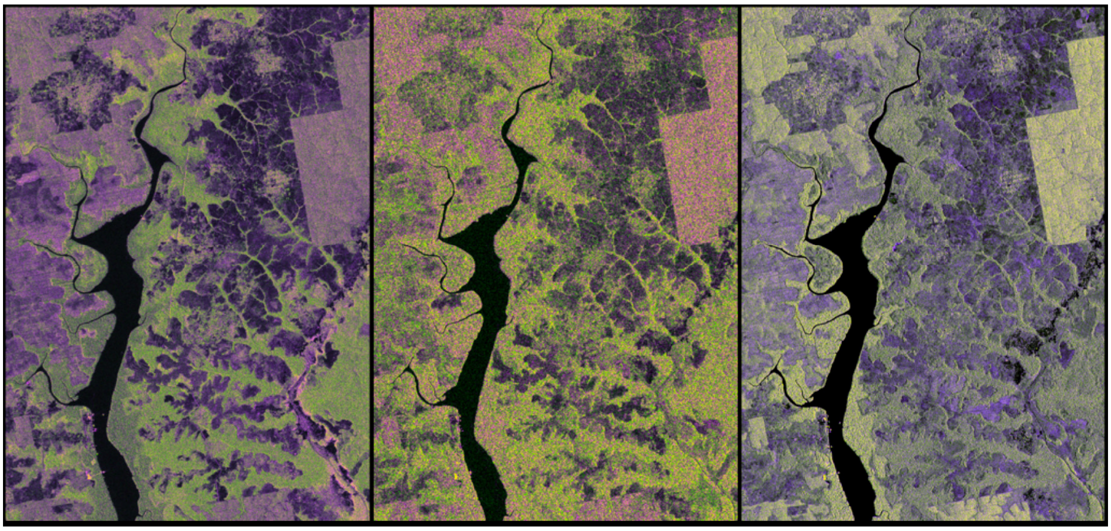

***Figure 12.*** *Kalimantan, Indonesia. Multi-satellite view by CEOS agency radar satellites (Image credits: JAXA, ESA, DLR)*
*(Note: this figure is to be replaced by a new figure showing an FCT National Demonstrator Verification Sire where Optical, L-, C- and X-band data are available )*

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

## 4. 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.

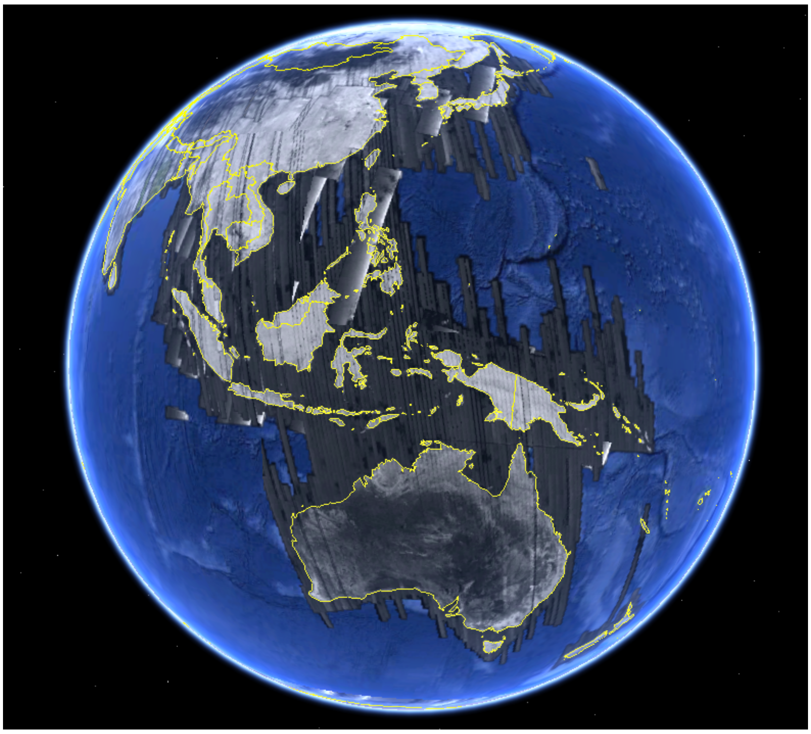

***Figure 14.*** *The strength of radar: continental coverage acquired during short time window (July 28 – Sep 11, 2009) (Image credit: JAXA)*

The satellite data collected during the coordinated acquisition campaigns are processed by the CEOS space agencies and provided to the National Demonstrators in forms of both scene-data and image mosaics. 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 conditions of each National Demonstrator, nation-wide maps products showing forest and land cover status and changes are derived on an annual basis, forming the spatial input to the national MRV system.

## 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.

**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: Dirk Hoekman/U. Wageningen)

**Figure 5:** ALOS PALSAR coverage (cycle 29). Provided by JAXA EORC. (Image credits JAXA EORC and Google Earth)

COP-15 draft decision (1)(d) http://unfccc.int/files/na/application/pdf/cop15_ddc_auv.pdf

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

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