The use of ATSR-2 for tropical forest mapping within the Joint Research Centre's TREES project

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ABSTRACT: Data from the ATSR-2 is being used to update regional scale maps of the humid forest extent in Africa, Asia and Latin America and to locate areas of rapid change. Certain types of forests such as mangroves and swamp forests are found to be spectrally more distinct on ATSR data than on sensors of similar spatial resolution. At the same time exceptional events such as fires and burnt areas are being monitored. The work is carried out in the framework of the Joint Research Centre's TREES project.

Introduction

The Joint Research Centre of the European Commission initiated the TRopical Ecosystem Environment observation by Satellite project (TREES I) in 1991 with the objectives of developing a system for the monitoring of the extent, condition and dynamics of the tropical forest belt at a global level.
The main tasks under TREES I were:

- to produce a consistent map of tropical forest cover from low resolution satellite data;
- to extrapolate forest area statistics from the above inventory through a correction process;
- to develop an information system, the Tropical Forest Information System (TFIS), capable of ingesting different types of spatially referenced data and analysing and reporting on the dynamics of tropical forest cover.

The global forest inventory was carried out using data from the low spatial resolution NOAA Advanced Very High Resolution Radiometer (AVHRR), at a nominal 1.1 km resolution. The second phase of the project, TREES II (1996-1999), has focused on the task of developing a prototype system for the operational monitoring of the tropical forest ecosystem. This prototype investigates the use of a multi-sensor remote sensing approach to provide information on the vegetation type, extent and condition, combined with the development of rapid methods of detecting deforestation hot spots and quantitatively estimating forest cover changes at a pan-tropical level. It is within the scope of the TREES II project that data from the ATSR-2 are being used. The application of these data falls into three areas:

– improving the thematic content of low resolution forest cover maps;
– highlighting areas of rapid change within the forest belt – “hot spot” detection;
– detecting and mapping areas of biomass burning, notably in the forest ecosystem:

Over 1000 ATSR images of the tropical belt have been acquired, some under ESA’s AO3, some directly purchased. A processing chain has been written to ingest the data, radiometrically calibrate the VNIR data to top-of-atmosphere reflectance and to remap the images, including brightness temperatures, to geographic projection at 0.01 degree resolution.

ATSR for global vegetation mapping and monitoring

The ATSR has several features which offer an improvement over existing low spatial resolution sensors:

- high geometric fidelity
- 12 bit radiometric resolution
- narrow spectral bands

- inclusion of short wave infra-red band (Corresponding the Landsat TM band 5)

From a data management point of view, the relatively low amount of interactive processing, due to high accuracy of the embedded geolocation points (a unique feature of the ATSR) allows a large number of ATSR images to be processed rapidly – hence making continental coverage and mapping possible.

However, several drawbacks exist due to the current (experimental) status of the instrument. This leads to lack of available data for some parts of the world, the continued absence of high bit rate data over coasts and over islands (notably Insular Southeast Asia and Madagascar).

Forest type discrimination

Under the first part of the TREES project low resolution data from the AVHRR were used to map the tropical forest belt to a very limited legend – dense forest / non-forest / and fragmented forest types.
These baseline forest coverage maps are now being augmented with ATSR-2 data with the aim of improving the thematic content for a number of forest ecosytems: mangroves and swamp forests.
The ATSR data has been assessed for these purposes. The inclusion of the 1.6 • m (SWIR) channel on the ATSR results in an improved discrimination of these classes over the AVHRR. The SWIR reflectance of swamp forests is much lower than the lowland rainforests (Figure 1). This is explained by the high soil and vegetation moisture content, which reduces the reflectance in this channel (Guyot *et al*., 1985). While ATSR data permit the accurate mapping of the large flooded forests of the Central Congo Basin, their spatial resolution precludes the reliable delineation of the swamp forests extending along the river network.

Table 1 gives the class separability between lowland terre firme and lowland swamp forests, estimated by transformed divergence measurement, which is considered as an optimal parameter for such assessments .

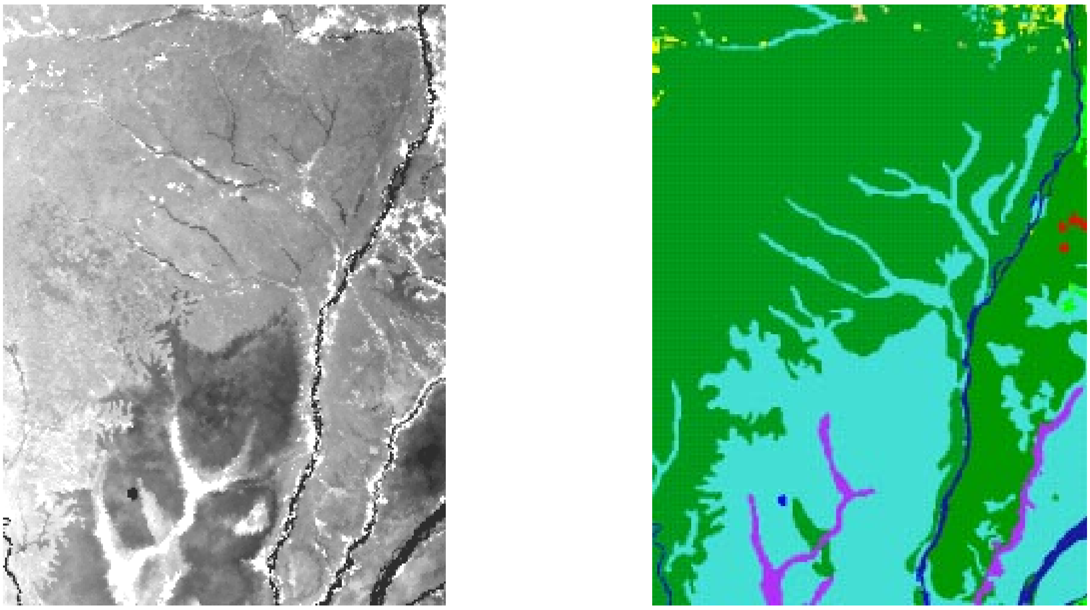


Figure 1: An ATSR-1 image (1.6 • m channel) over the rainforest of Central Africa is shown on the left. The dark region is a flooded forest area. On the right we have a map of the region derived from field survey, (Laudet, 1967) where green represents upland forest and blue flooded forest (From Mayaux et al. 1999)

Table 1:

Channel used	TD
AVHRR Ch1 (Red)	19
AVHRR Ch2 (NIR)	474
AVHRR Ch3 (MIR)	140
AVHRR Ch4 (TIR)	1746
ATSR-2 Ch1 (TIR)	1988
ATSR-2 Ch2 (TIR)	1963
ATSR-2 Ch3 (MIR)	1132
ATSR-2 Ch4 (SWIR)	2000
ATSR-2 Ch5 (NIR)	1897
ATSR-2 Ch6 (Red)	916
ATSR-2 Ch7 (Green)	1952

The transformed divergence (Swain and Davis, 1978) is defined as :

$$TD_{ij} = 2000\left[1 - \exp\left(-\frac{D_{ij}}{8}\right)\right]$$

where Dij is the divergence between classes i and j. Transformed divergence values between 0 and 2000 are possible, 2000 indicating the best spectral separability between class pairs.

Whilst single date imagery from the ATSR shows marked advantages over the AVHRR, the lower repeat cycle, reduces the possibilities of using the ATSR data for seasonal studies of vegetation.

Hot spot detection and mapping

To enable rapid estimates of tropical forest depletion to be assessed, the TREES project is developing a method for "hot spot detection". This method relies on using continual coverage of the tropical forest belt with low resolution optical satellite data (AVHRR, ATSR), along with expert consultation and fire activity, to identify strata of rapid change in forest cover (Achard et al. 1998). The hot spots identified are then monitored with a high sample of high-resolution data (SPOT, Landsat TM). This stratification is aimed at reducing the variance of regional forest change estimates.

To assess the potential of ATSR data for deforestation monitoring , ATSR-1 data were compared with AVHRR data for detecting new clearings in Acre State, Brazil (Eva et al. 1995). This analysis showed that the ATSR-1 short wave and thermal infra-red channels were more sensitive to clearings in the humid forest, than their counterpart channels on the AVHRR.

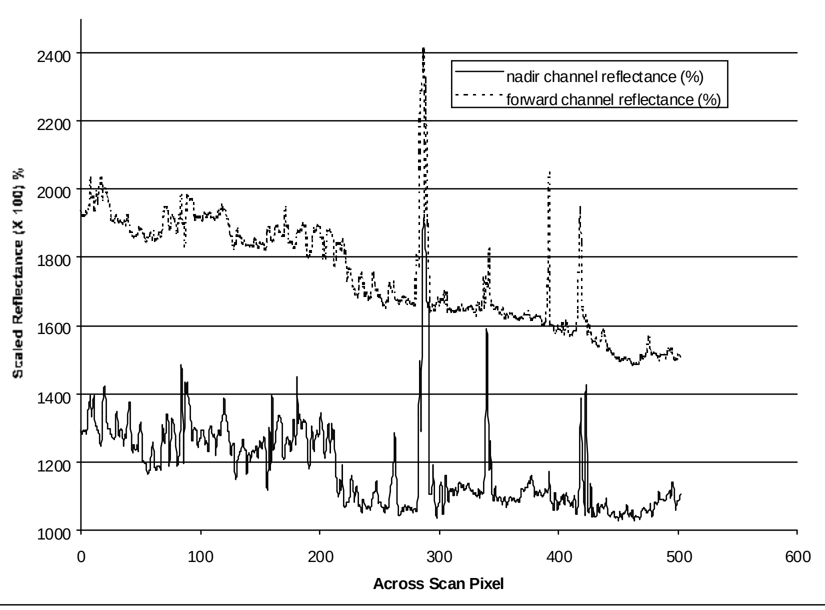
The ATSR is therefore being used to generate regional mosaics of the tropics, using different indices (highest brightness temperature, highest NDVI and moisture indices). These mosaics are then compared to the forest coverages produced under TREES I, so as to highlight areas of rapid change.

In mosaicing the ATSR data, differences in across swath reflectance, due to bi-directional effects, have yet to be resolved (Figure 2). These differences can lead to areas of dense forest on the west of a scene, having similar reflectances to regrowth and disturbed forest on the east of a scene.

Burnt area detection and mapping

An important part of forest monitoring is to detect indications of deforestation and exceptional events which destroy large areas of forest. Fire is a potential indicator of

Figure 2: Bi-directional effects over forest cover - 1.6 um channel



deforestation in a number of regions, and in an *El Niño* year a danger even to humid forests. The TREES project has been using ATSR data to detect burnt areas across the tropics. The ATSR-2 mosaics, generated from the database have proved useful in highlighting areas of fire activity. Two mosaics have been produced using different algorithms, one selecting images with the highest photosynthetic activity – i.e. at the end of the rainy season when crops and natural vegetation are at their "greenest", and the second to select images when the surface temperature is at its highest.
This second mosaic selects images with low vegetation cover – usually in the dry season and tends to pick up burnt areas.
The TREES project is involved in two ESA Announcement of Opportunities (AO3) for testing ATSR-2 data for burnt area mapping. One with ESRIN and the Technical University of Lisbon , for assessing different algorithms for detecting burnt areas. Under this AO3, different algorithms are proposed and tested on a range of ecosystems – Mediterranean vegetation, tropical forests, savannah interfaces. The results will be used to define what algorithms can be used for a global burnt area product. A second AO is being carried out with ESRIN using ATSR-2 in combination with ERS SAR to map forest regions threaten by fire in Borneo (Antikidis et al. 1998).

Conclusions

The data from the ATSR-2 has been shown to be a valuable tool within the scope of the TREES project. Its high radiometric technical specifications allow the discrimination of forest types, previously unresolved with low resolution data. At the same time, the accuracy of the imbedded geolocation points enables large amounts of data to be processed automatically to produce regional mosaics for deforestation "hot spot" monitoring.

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