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**OF THE EARSeL SPECIAL INTEREST GROUP ON FOREST FIRES**

**ADVANCES IN REMOTE SENSING AND GIS APPLICATIONS**
**IN FOREST FIRE MANAGEMENT**

# TOWARDS AN OPERATIONAL USE OF REMOTE SENSING IN FOREST FIRE MANAGEMENT

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## *Fire Effects Assessment*

# The global MODIS burned area product

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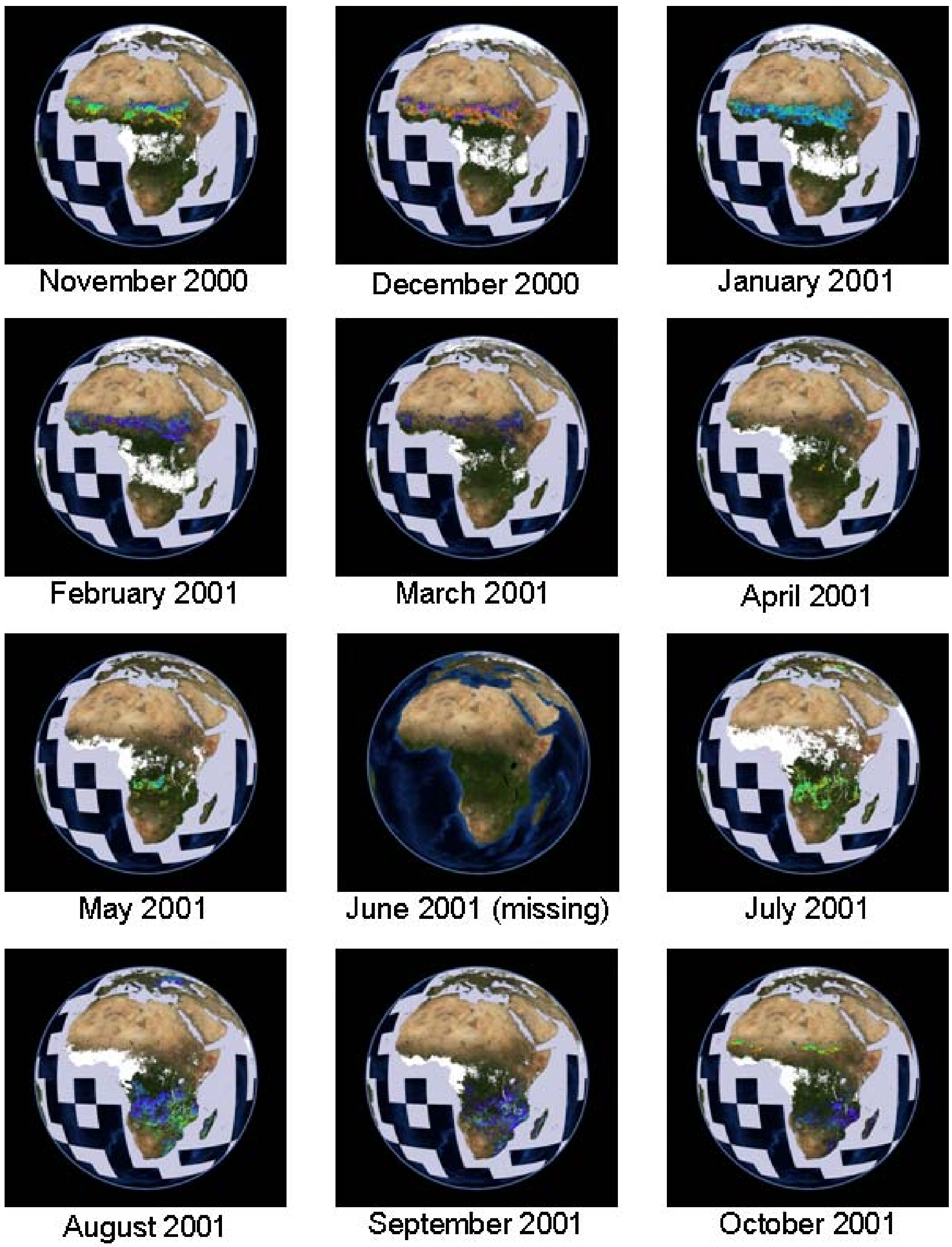
ABSTRACT: The global MODIS burned area product, part of the recent NASA Collection 5 MODIS land product suite, is presented. The algorithm uses the recently published Bi-Directional Reflectance Model-Based Expectation change detection approach and maps at 500m the location and approximate day of burning. The algorithm does not use training data but rather applies a wavelength independent threshold and spectral constraints defined by the noise characteristics of the reflectance data and knowledge of the spectral behavior of burned vegetation and spectrally confusing changes that are not associated with burning. Temporal constraints are applied capitalizing on the spectral persistence of fire-affected areas. The algorithm is applied to MODIS-Terra and MODIS-Aqua land surface reflectance time series. It has been implemented in the MODIS land production system as part of the standard MODIS land product suite to systematically map burned areas globally for the 6+ year MODIS observation record.

## 1 INTRODUCTION

As part of NASA's Earth Observing System, the Moderate Resolution Imaging Spectroradiometer (MODIS) is onboard the Terra (launched 1999) and Aqua (launched 2001) polar orbiting satellites and their data are being used to generate global coverage data products on a systematic basis (Justice et al. 2002a). The algorithm used to define the global 1km MODIS active fire product has been refined several times (Kaufman et al. 1998, Justice et al. 2002b, Giglio et al. 2003). A complementary MODIS algorithm defined to map burned area has been developed for global application (Roy et al. 2005a); this algorithm has been implemented in the MODIS processing chain to map burned areas globally. The present paper overviews the main characteristics of the MODIS global burned area product (MCD45A1).

Burned areas are characterized by deposits of charcoal and ash, removal of vegetation, and alteration of the vegetation structure (Roy et al. 1999). The MODIS algorithm to map burned areas takes advantage of these spectral, temporal, and structural changes. The algorithm detects the approximate date of burning by locating the occurrence of rapid changes in daily 500m surface reflectance time series data. It is an improvement on previous methods, through the use of a bidirectional reflectance model to deal with angular variations found in satellite data and the use of a statistical measure to detect change probability from a previously observed state. MODIS reflectance sensed within a temporal window of a fixed number of days is used to predict the reflectance on a subsequent day. A statistical measure is used to determine if the difference between the predicted and observed reflectance is a significant change of interest. Rather than attempting to minimize the directional information present in wide field-of-view satellite data by compositing, or by the use of spectral indices, this information is used to model the directional dependence of reflectance. This provides a semi-physically based method to predict change in reflectance from the previous state. A temporal constraint is used to identify and remove temporary changes, such as shadows, that are spectrally similar to more persistent fire induced changes. Further details are provided in Roy et al. (2005a).

*Figure 1: MODIS 500m Burned Areas for Africa (colors) shown overlain on MODIS surface reflectance. The rainbow colours (blue to red) indicate the approximate day of burning in each month, white indicates no decision because of persistent cloud cover or missing data, grey indicates no burning but snow detected, lilac indicates water. Data shown in the World Wind 3D Virtual Globe.*




## 2 PRODUCT FORMAT

The MODIS burned area product (MCD45A1) is a monthly gridded 500m product that describes the approximate day of burning. An annual summary 500m product and low resolution climate modeling grid product will also be made available. The product is produced in the standard MODIS Land tile format (Justice et al. 2002a), i.e., in the sinusoidal projection in enhanced Hierarchical Data Format, including summary metadata required for data ordering and product documentation. The monthly MCD45A1 product contains the following data layers that define for each 500m pixel:

- Burndate: Approximate day of burning from 8 days before the beginning of the month to 8 days after the end of the month, or a code indicating unburned, snow, water, or insufficient data to make a decision.
- Burn quality assessment: 1 (most confident detection) to 4 (least confident detection).
- Number of Passes: Number of observations that passed the temporal consistency test.
- Number Used: Number of observations used in the temporal consistency test.
- Direction: Direction in time in which burning was detected (forward, backward or both).
- Surface Type: Information describing the land, atmospheric, and sensing properties (e.g. water, snow, high aerosol, high view and solar zenith angles).
- Gap Range 1 and 2: Information describing the two largest numbers of consecutive missing/cloudy days (if any) in the time series and the gap start days.

## 3 EXAMPLE GLOBAL RESULTS & ANALYSIS

Figure 1 illustrates 12 months of the MCD45A1 burned area product for all of Africa. These data are shown visualized in the World Wind 3D Virtual globe (Boschetti et al. this edition). The non–burned pixels are shown as transparent to allow visualization of the background MODIS surface reflectance data in order to provide geographic context. The continental progression of burning is seen, with the burning season of the Northern hemisphere, from October to March, and the burning season of the Southern hemisphere, from May to October, clearly evident. No burned area product was produced in June 2001 because the MODIS instrument was off for several weeks due to an engineering problem.

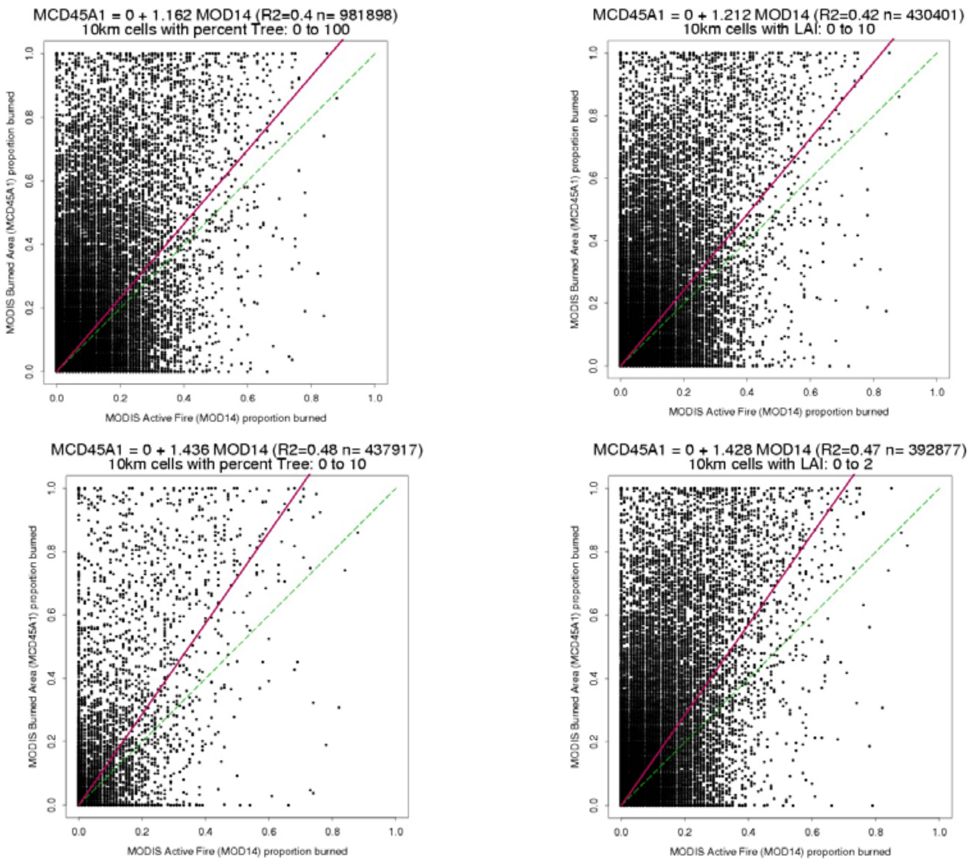
Figure 2 shows scatter plots comparing the global proportion burned as labeled by the 500m MODIS burned area product (y axis) and by the corresponding day and night 1km active fire detections (x axis) for August 2001. Each point on these plots corresponds to the proportions found in a 10x10km window. Evidently the MODIS burned area product detects more area burned globally at this scale than the active fire product, which is expected as the active fire product only detects fires that are burning at the time of cloud-free overpass (Roy et al. 2005a). The data are shown considering only those pixels falling within 0-100% and 0-10% percentage tree cover ranges (left column) and within 0-10 and 0-2 leaf area index (LAI) ranges (right column). Globally, at low tree cover and low LAI, the 500m MODIS burned area product detects more area burned than the 1km active fire product by approximately 44% and 43% respectively. At high tree cover and LAI the opposite is true (not shown due to insufficient space) with the burned area product underestimating the area burned relative to the active fire product. Further research is ongoing in these respects. These results are likely because under high %tree and LAI conditions, reflectance changes detected by MDC45A1 are not as easily discernable as hot spots detected by MOD14, and because the active fire detections may exaggerate the area burned.

## 4 SUMMARY

This paper has overviewed the MODIS burned area product and shown some initial global results. A comprehensive program of product validation is under development and international collaborations have been made and are sought with regional networks of fire scientists and product users through the GOFC/GOLD program and the CEOS Land Product Validation Working group. A prototype validation protocol has been developed using multi-date Landsat ETM+ data (Roy et al 2005b). The MODIS burned area algorithm may be enhanced further based on the results of these validation initiatives or if the performance of the MODIS instrument changes.

The MODIS burned area product may be obtained, with a Product User Guide, news and other supporting information, graphics and animations, at http://modis-fire.umd.edu/MCD45A1.asp.

*Figure 2: Global results: August 2001; Scatterplots of the proportion of area burned (y axes) and active fire pixels (x axis) with a linear regression line forced to pass through the origin shown in red. Percentage tree cover and leaf area index (LAI) ranges are defined by consideration of the annual 500m percent tree cover and monthly composited 8-day 1km LAI MODIS products respectively. Each point corresponds to the proportions found in a 10x10km window (cell); only cells with no missing data in the three products are used. Due to the large number of points (~1million, top left) many points are over plotted.*

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