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The collection 5 MODIS burned area product — Global evaluation by comparison with the MODIS active fire product

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ABSTRACT

The results of the first consecutive 12 months of the NASA Moderate Resolution Imaging Spectroradiometer (MODIS) global burned area product are presented. Total annual and monthly area burned statistics and missing data statistics are reported at global and continental scale and with respect to different land cover classes. Globally the total area burned labeled by the MODIS burned area product is 3.66×10^6 km^2 for July 2001 to June 2002 while the MODIS active fire product detected for the same period a total of 2.78×10^6 km^2, i.e., 24% less than the area labeled by the burned area product. A spatio-temporal correlation analysis of the two MODIS fire products stratified globally for pre-fire leaf area index (LAI) and percent tree cover ranges indicate that for low percent tree cover and LAI, the MODIS burned area product defines a greater proportion of the landscape as burned than the active fire product; and with increasing tree cover (>60%) and LAI (>5) the MODIS active fire product defines a relatively greater proportion. This pattern is generally observed in product comparisons stratified with respect to land cover. Globally, the burned area product reports a smaller amount of area burned than the active fire product in croplands and evergreen forest and deciduous needleleaf forest classes, comparable areas for mixed and deciduous broadleaf forest classes, and a greater amount of area burned for the non-forest classes. The reasons for these product differences are discussed in terms of environmental spatio-temporal fire characteristics and remote sensing factors, and highlight the planning needs for MODIS burned area product validation.

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1. Introduction

Mapping the timing and extent of fires is important as fire is a prominent disturbance factor affecting ecosystem structure and the cycling of carbon and nutrients and is a globally-significant cause of greenhouse gas emissions (e.g., Crutzen & Andreae, 1990; Bond et al., 2005). There is a growing debate on the relationship between fire and climate change (Weber and Flannigan, 1997; Siegert et al., 2001; Alencar et al., 2006; Westerling et al., 2006; Denman et al., 2007) and a perceived increasing incidence, extent, and severity of uncontrolled burning globally that has lead to calls for international environmental policy concerning fire (FAO, 2007).

Satellite data have been used to monitor biomass burning at regional to global scale for more than two decades using algorithms that detect the location of active fires at the time of satellite overpass, and in the last decade using burned area mapping algorithms that map directly the spatial extent of the areas affected by fires. The NASA Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra (morning) and Aqua (afternoon) satellites has specific features for fire monitoring and has been used to systematically generate a suite of global MODIS land products (Justice et al., 2002b) including a 1 km active fire product (Kaufman et al., 1998; Justice et al., 2002a; Giglio et al., 2003) and more recently a burned area product that maps the approximate day and extent of burning at 500 m resolution (Roy et al., 2005a). The MODIS burned area product was developed and tested only on a regional basis using data from Collection 1 (Roy et al., 2002a) and Collection 4 (Roy et al., 2005a). This collection numbering scheme is used to differentiate between different MODIS reprocessings, each applying the latest available version of the science algorithms to the MODIS instrument data and using the best available calibration and geolocation information (Masuoka et al. in press). The first global burned area product is now being generated as part of the MODIS Land Collection 5 product suite and is currently available, with supporting information, from the MODIS Fire website (WWW1).

This paper describes a global assessment of the Collection 5 MODIS burned area product. It is commonly accepted that satellite derived active fire products are less suitable for assessing area burned than products generated by direct mapping of area burned; for this reason, in the absence of accurate burned area products, previously, burned area assessments have been created based on calibrating the available active fire data from regional AVHRR (Scholes et al., 1996) and global

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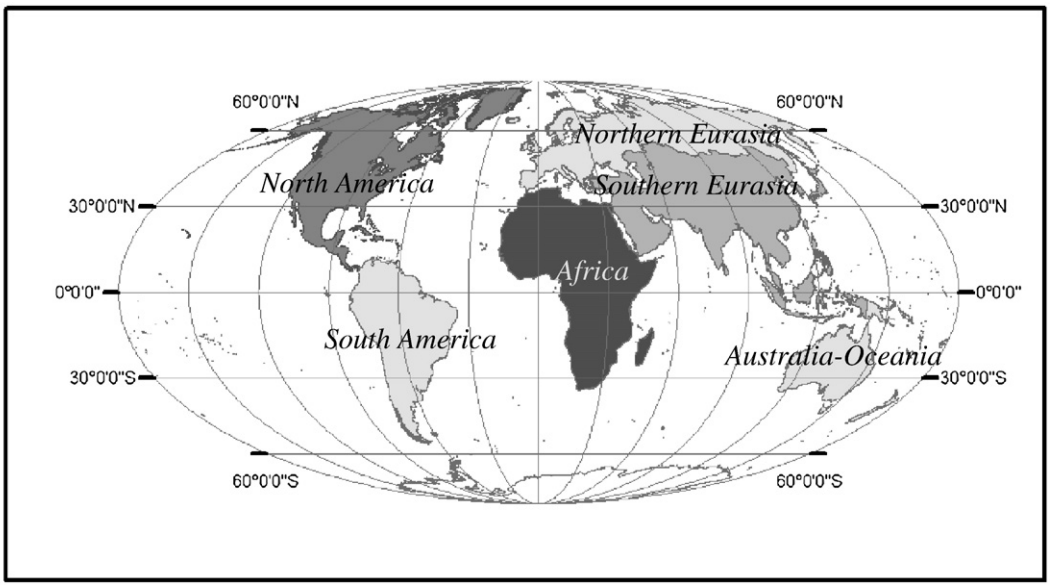

Fig. 1. Continental definition. All continents are considered together to derive the global results.

MODIS data (Giglio et al., 2006a). Although the global MODIS active fire calibration provided good agreement in some geographic regions it had and poor agreement in other regions and highlighted the complexity of the calibration task (Giglio et al., 2006a). Little research has been undertaken to examine the differences between active fire and burned area products generated by direct mapping. Limited comparison of the Collection 4 MODIS burned area and active fire products indicated several remote sensing, environmental, and fire behavior factors that may influence product differences, and, that in certain forested environments, counting active fire detections may provide greater total area burned estimates than generated by direct mapping (Roy et al., 2005a). In the Roy et al. (2005a) study, limited product comparisons were made temporally (~1 month) and spatially (~450×250 km) and the entire extent of the MODIS 1 km active fire and of the 500 m burned area product pixels was assumed to be burned. The MODIS burned area product labeled approximately three times a greater proportion of the landscape as burned than the active fire detection product in grassland and open woodland systems in Australia and Southern Africa. As only about 10% of the day and night MODIS active fire observations were labeled as cloud obscured it was concluded that this relative active fire under detection was due to the MODIS overpass occurring at times when the fires were not actively burning (Giglio, 2007) and/or to the active fires being insufficiently hot and/or large to be detected (Giglio et al., 2003; Giglio & Justice, 2003). Conversely, there was an observed under detection of the burned area product relative to the active fire product in forested regions of Brazil and of the Russian Federation. In these forested regions it was postulated that the active fire product may detect small active fires, if sufficiently hot, that were not detected in the burned area product if an insufficiently complete or large fraction of the MODIS 500 m pixel burned (Roy & Landmann, 2005). It was also suggested that under detection by the MODIS burned area product relative to the active fire product in these forested regions may have been due to obscuration of surface fires by overstorey vegetation, and/or because the active fire product overestimates the area burned where the majority of burned areas are smaller than 1 km pixels. This paper comprehensively documents these differences at global scale.

First the MODIS burned area algorithm and product are reviewed, then a statistical comparison of the Collection 5 MODIS burned area and active fire products is described with respect to global stratifications defined by percent tree cover and leaf area index ranges, then statistics of the annual and monthly total area burned defined by the two MODIS fire products are reported globally and for each continent with respect to land cover classes, and then the product differences discussed in terms of factors concerned with remote sensing and environmental spatio-temporal fire characteristics.

2. Overview of the MODIS global burned area algorithm and product

Burned areas are characterized by deposits of charcoal and ash, removal of vegetation, and alteration of the vegetation structure (Pereira et al., 1997; Roy et al., 1999). The MODIS algorithm used to map burned areas takes advantage of these spectral, temporal, and structural changes using a change detection approach (Roy et al., 2005a). It detects the approximate date of burning at 500 m by locating the occurrence of

Table 1
Total number of 1 km active fires [km^2] detected globally, July 2001 to June 2002, in each of the 12 MODIS UMD land cover classes

	Total active fires [km^2] low–med–hi confidence	Total active fires [km^2] only med–hi confidence	Decrease [%]
Evergreen needleleaf forest	2.71E+04	2.54E+04	6.45%
Deciduous needleleaf forest	9.43E+03	8.82E+03	6.45%
Evergreen broadleaf forest	1.71E+05	1.61E+05	6.09%
Mixed forests	5.09E+04	4.87E+04	4.28%
Closed shrublands	2.51E+04	2.41E+04	4.13%
Open shrublands	3.41E+05	3.27E+05	3.99%
Grasslands	2.11E+05	2.03E+05	3.84%
All vegetation classes	**2.90E+06**	**2.79E+06**	**3.80%**
Croplands	3.55E+05	3.43E+05	3.49%
Deciduous broadleaf forest	8.14E+04	7.86E+04	3.48%
Barren or sparsely vegetated	2.68E+04	2.58E+04	3.43%
Woody savannas	7.32E+05	7.07E+05	3.37%
Savannas	8.37E+05	8.10E+05	3.25%

The totals considering all active fire detections regardless of their confidence (high, medium and low confidence) and considering only high and medium confidence detections, and the percentage decrease between the two totals computed as (sum of low confidence detections/sum of all detections)*100, are tabulated. The rows are ranked in descending order of percentage decrease.

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