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# Quantifying the impact of cloud obscuration on remote sensing of active fires in the Brazilian Amazon

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**Abstract**

Vegetation fires remain as one of the most important processes governing land use and land cover change in tropical areas. The large area extent of fire prone areas associated with human activities makes satellite remote sensing of active fires a valuable tool to help monitor biomass burning in those regions. However, identification of active fire fronts under optically thick clouds is not possible through passive remote sensing, often resulting in omission errors. Previous analyses of fire activity either ignored the cloud obscuration problem or applied corrections based on the assumption that fire occurrence is not impacted by the presence of clouds. In this study we addressed the cloud obscuration problem in the Brazilian Amazon region using a pixel based probabilistic approach, using information on previous fire occurrence, precipitation and land use. We implemented the methodology using data from the geostationary GOES imager, covering the entire diurnal cycle of fire activity and cloud occurrence. Our assessment of the method indicated that the cloud adjustment reproduced the number of potential fires missed within 1.5% and 5% of the true fire counts on annual and monthly bases respectively. Spatially explicit comparison with high resolution burn scar maps in Acre state showed a reduction of omission error (from 58.3% to 43.7%) and only slight increase of commission error (from 6.4% to 8.8%) compared to uncorrected fire counts. A basin-wide analysis of corrected GOES fire counts during 2005 showed a mean cloud adjustment factor of approximately 11%, ranging from negligible adjustment in the central and western part of the Brazilian Amazon to as high as 50% in parts of Roraima, Para and Mato Grosso.


*Keywords:* Vegetation fires; Clouds; Geostationary satelite; Brazilian amazon

## 1. Introduction

Vegetation fires play a significant role in land and atmospheric processes globally. Their occurrence is particularly important in tropical regions where human activity is still heavily based on the use of fires for land use management and land cover change. In the latter case, deforestation and fires are found to be closely related eventually leading to important feedback processes that favor faster and more destructive depletion of the local forests (Cochrane et al., 1999; Nepstad et al., 1999). In contrast, at higher latitude regions a greater percentage of fires are caused by lightning or are accidental in nature and are highly influenced by the local weather and climate conditions (Kasischke et al., 2002). Fires in the tropics are influenced by local conditions too but will also present an equally important component due to the influence of human activities which are reflected in the spatial and temporal distributions observed across regional to global scales (Barbosa et al., 1999; Scholes et al., 1996).

Correct quantification of fire events is needed primarily for understanding the dynamics of land use and land cover change and therefore subsidize regional environmental programs, as well as for providing information for modeling of emission estimates from biomass combustion (Korontzi et al., 2004; Van der Werf et al., 2003). Consideration of the fire diurnal cycle is also required for biomass burning transport models, making high observation frequency a particularly important characteristic on active fire monitoring systems (Freitas et al., 2005; Giglio et al., 2006). Satellite sensors have been used to monitor vegetation fire activity for many years now, providing greater

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insight on the processes associated with fire dynamics at different scales (Bucini & Lambin, 2002; Carmona-Moreno et al., 2005; Di Bella et al., 2006; Dwyer et al., 2000; Giglio et al., 2006). In fact, the use of satellite data is the only way to assess fire activity at spatial and temporal scales required for land surface and atmospheric modeling studies. However, the remote sensing methods used for monitoring fires have limitations that tend to cause important biases in the final products (Boles & Verbyla, 2000; Cardoso et al., 2005; Eva & Lambin, 1998; Kasischke et al., 2003; Schroeder et al., 2005). A major factor influencing fire numbers derived from remotely sensed data is the effect caused by cloud obscuration. Because fires have their highest spectral emission values located in the mid-infrared band, active fire products exploit that part of the spectrum to distinguish biomass burning events from the surrounding background (Giglio et al., 1999; Justice et al., 2002). The presence of optically thick clouds along the atmospheric path between the target (fire) and the satellite sensor will, however, greatly reduce the ability to detect a fire due to severe attenuation of the spectral signal emitted by either flaming or smoldering phases of biomass combustion. The extent of the effect of cloud obscuration on fire detection will depend on the average cloud cover fraction. But it should be realized that clouds are needed to produce rain but are not necessarily followed by precipitation. Also the extent and degree of human activities will influence the spatial and temporal fire distributions.

Current methods used to compensate satellite active fire detection to account for fires missed due to cloud obscuration tend to rely on the assumption that fires occur with the same frequency under cloud covered areas as they do in the open (Cardoso et al., 2003; Giglio et al., 2003, 2006; Roberts et al., 2005). Despite being an attractive approach for its simplistic assumption, the adoption of such procedures becomes problematic in areas where fires are unevenly distributed in space. Under such conditions, the resulting adjustment numbers will be potentially influenced by the cell size selected to extrapolate the applicable clear sky fire density to the complementary cloud covered area. The major implication of such an approach is associated with the assumption of fires in areas with no burning activity which would lead to an overestimation of fire numbers. Here we present an approach that uses precipitation data and land use information to more precisely quantify the potential omission error associated with the cloud obscuration affecting satellite active fire detection products. The proposed approach is applied to a geostationary satellite fire data set, in order to characterize the cloud effect on fire detection over the entire diurnal cycle. The analyses are focused on the Brazilian Amazon where intense fire activity and frequent cloud cover are prevalent (Fig. 1). In the sections to follow we describe the data sets used and the method developed and present the results produced for 2005.

## 2. Data

### 2.1. Active fire product

In the past two decades multiple satellite-based active fire products have been designed using a variety of sensors (Elvidge et al., 1996; Giglio et al., 2000; Kaufman et al., 1990, 1998a; Menzel et al., 1991). The performance of individual products is found to be strongly dependent on the sensor's spectral characteristics and on the algorithm used, as well as on the imaging characteristics (e.g., pixel size, observation geometry) provided by the instruments and the orbital platforms on which

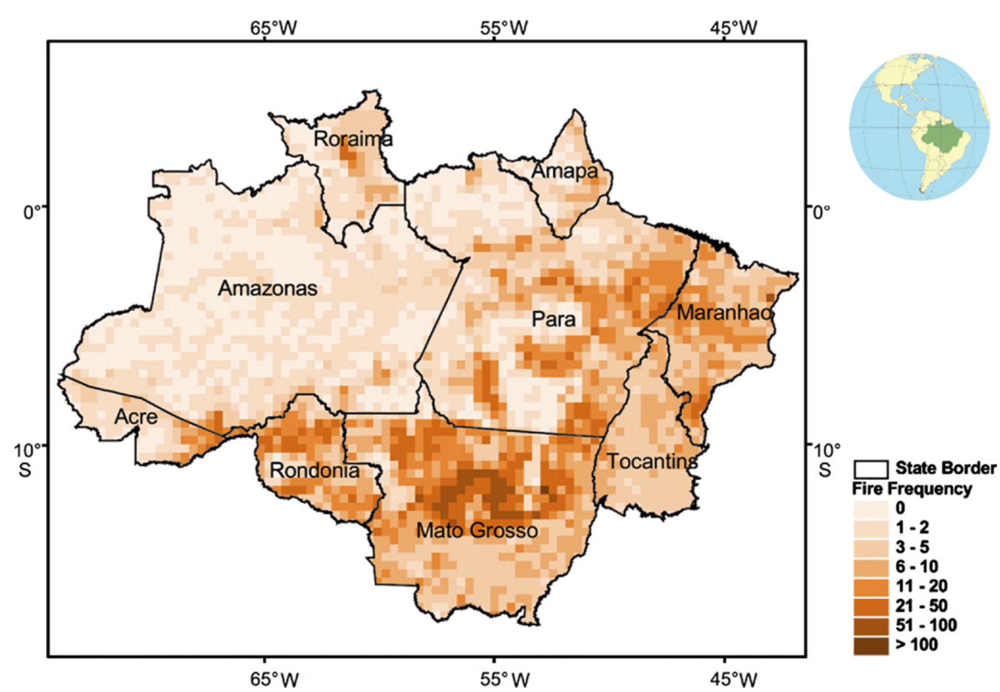


Fig. 1. Fire frequency (fires $10^{-2}$ $km^{-2}$ $year^{-1}$) across the nine Brazilian States in Amazonia. Values based on 3-year average (2003–2005) GOES WFABBA fire detection data using all observation hours available.