Implementation of the MODIS Direct Broadcast Burned Area Mapping Algorithm

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Abstract

We provide an overview of a Direct Broadcast implementation of an automated algorithm for mapping post-fire burned areas using 500-m MODIS imagery coupled with 1-km MODIS active fire observations. The algorithm identifies the date of burn, to the nearest day, for 500-m grid cells within individual MODIS Level 3 tiles. The software implementation has been packaged following the guidelines of the NPP In-Situ Ground System (NISGS) framework, thus allowing it to function as both a standalone process and a plug-in module to the International Polar Orbiter Processing Package (IPOPP) for operational processing.

Key words: MODIS, direct broadcast, burned area, fire, biomass burning, NISGS, IPOPP, SPA

1. Introduction

Operational fire monitoring via satellite-based sensors has become an important tool for fire managers and other members of the natural hazards community. To date, such monitoring has primarily consisted of the near-real time detection of actively burning fires with the Advanced Very High Resolution Radiometer (AVHRR) and GOES Imager (Prins and Menzel, 1992), and more recently with the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on-board NASA's Terra and Aqua satellites (Justice et al., 2002).

While active fire observations satisfy many of the needs of operational fire monitoring, certain applications require more precise mapping of the spatial extent of burns in near-real time. Such applications include air quality monitoring and the production of near-real time aerosol emissions estimates for other purposes. In this paper we describe a Direct Broadcast implementation of an automated algorithm for mapping post-fire burned areas using 500-m MODIS imagery coupled with 1-km MODIS active fire observations. While the resulting burned area maps are not yet produced in near-real time, our implementation requires relatively modest mass storage and computational resources and is thus well suited for use in a Direct Broadcast environment. In addition, a true Direct Broadcast implementation that will produce near-real time burned area maps is under development.

2. Burned Area Mapping Algorithm

The post-fire burned-area mapping approach we have implemented employs 500-m MODIS imagery coupled with 1-km MODIS active fire observations. The hybrid algorithm applies dynamic thresholds to composite imagery generated from a burn-sensitive vegetation index (VI) derived from MODIS short-wave infrared channels 5 and 7, and a measure of temporal texture. The VI is defined as

$$\mathrm{VI} = \frac{\rho_5 - \rho_7}{\rho_5 + \rho_7},$$

where ρ_5 and ρ_7 are respectively the band 5 and band 7 atmospherically corrected surface reflectance. Cumulative active fire maps are used to guide the selection of burned and unburned training samples and to guide the specification of prior probabilities. The combined use of active-fire and reflectance data enables the algorithm to adapt regionally over a wide range of pre- and post-burn conditions and across multiple ecosystems. A complete description of the algorithm is provided by Giglio et al. (2008), as well as the results of a preliminary validation.

3. Direct Broadcast Implementation

The original algorithm requires Terra and/or Aqua MODIS 500-m atmospherically corrected Level 2G daily surface reflectance products (Vermote and Justice, 2002), and the 1-km Terra and/or MODIS Level 3 daily active fire products (Justice et al., 2002). For Direct Broadcast purposes it is undesirable to replicate these products as they are computationally expensive and, in many respects, unnecessarily complex for near-real time applications. In our implementation we instead produce separate daily composites of corrected reflectance swath imagery (Descloitres et al., 2002) and the swath-level MODIS active fire product (Giglio et al., 2003).

In addition to the daily reflectance and active-fire imagery mentioned above, the burned area mapping algorithm requires a static land cover map for the region being processed. We use the Level 3 MODIS 96-day land cover product (Friedl et al., 2002), although it is straightforward for Direct Broadcast users to substitute an alternative map of their choosing.

3.1 Daily Corrected Reflectance Composites

Burned area mapping is a subset of the more general problem of change detection and, as such, the algorithm requires daily, coregistered reflectance imagery with which changes in reflectance (via the VI) can be tracked over time. Daytime Terra and/or Aqua corrected-reflectance swath imageries (Descloitres et al., 2002) are projected onto the MODIS sinusoidal grid (Section 3.3) at 500-m spatial resolution to produce a daily composite corrected reflectance product every day. Each composite contains the 250-m MODIS bands 1 and 2, degraded to 500-m spatial resolution, as well as band 3 through 7 in their native 500-m spatial resolution. The compositing criteria preferentially select for cloud-free, near-nadir observations, ultimately producing “clean” daily imagery that will subsequently be used by the burned area detection algorithm.

3.2 Daily Active Fire Composites

Production of the daily active-fire composites is simpler than in the case of corrected reflectance as the individual pixel classes in the swath-level MODIS fire product are arranged such that maximum value compositing produces the proper daily active-fire input required by the burned area detection algorithm. The active-fire composites are generated at 1-km spatial resolution to match the inherent resolution of the MODIS fire bands. As with the daily corrected reflectance composites, all Terra and Aqua overpasses for each day are combined into a single daily product to minimize the volume of input data that must be staged.

3.3 Tiling Scheme

The standard MODIS Level 3 products are produced on a global sinusoidal grid which is divided into fixed tiles approximately 10° × 10° in size (Wolfe et al., 1998) (Figure 1). For compatibility with the standard MODIS products, we employ this same tiling scheme within our Direct Broadcast implementation, i.e. the spatial extent of the final burned area map will always be a full MODIS tile. Because this scheme sometimes “breaks up” even relatively small areas of interest into multiple tiles (e.g., Sri Lanka), thus needlessly complicating the mapping of such areas, we have incorporated one important exception in our implementation: the center of the 10° × 10° tile can be positioned arbitrarily. Thus mapping burns in Borneo, for example, which would require that four separate MODIS tiles be processed under the standard MODIS tiling scheme, could be accomplished with just one of our “movable” MODIS tiles. Users who prefer to identically match the standard MODIS tile grid may simply locate the tile centers accordingly.

3.4 Current Processing Scheme

The IPOPP leverages the NISGS framework in order to fulfill a modular-component approach for Earth science data processing implementation that supports processing, visualization and evaluation of Earth science Direct Broadcast data from MODIS on Terra and Aqua, and the future NPP and NPOESS instrument suites (Coronado et al., 2008). Compatibility with the IPOPP is thus one of the important requirements for this Direct Broadcast version of the MODIS burned area algorithm, and is achieved through the application of DRL’s innovative algorithm wrapper technique (Coronado et al., 2008). The “wrapped” burned area mapping algorithm, referred to as the “burned-area Science Processing Algorithm (SPA)”, has two important features – (i) it can be seamlessly plugged into IPOPP for automated operational processing and (ii) it retains the ability to function in a standalone environment without IPOPP support. The public availability of the burned area SPA thus ensures that the Direct Readout community is able to run the algorithm in either standalone or operational mode.

Operational production of the burned area maps within the IPOPP is accomplished by means of two independent processes. The first process runs every 24 hours to produce the daily corrected-reflectance and active-fire composites from the Terra and Aqua overpasses acquired during the past 24 hours. The second process is run as needed (as often as once per day is practical) and generates a burned area map from some pre-specified start date up through approximately ten days prior to the current date (i.e., the burned area maps are always ten days behind real time). This lag reflects the fact that the mapping algorithm effectively needs to look ahead in the VI time series to ensure the spectral signature of any candidate burn persists for a sufficient period of time to improve classification accuracy.

3.5 *Near-Real Time Processing Scheme (Future)*

Our current implementation as described in Section 3.4 is not optimal for operational use at this time in three different respects. First, the burned area maps are never more recent than ten days behind real time, which is often undesirable from the fire management perspective. Second, when run frequently (e.g., daily) the burned area mapping process re-ingests and re-processes a subset of the daily reflectance and active-fire composites as many as 10 times, thus raising CPU and I/O demands on what may already be an overtaxed production system. This sub-optimal use of resources in fact reflects the non-Direct Broadcast origins of the mapping algorithm, which was first used by Giglio et al. (2006) as an alternative to the then-unavailable MODIS burned area product (Roy et al., 2008). To remedy this situation, we are in the process of implementing a dedicated, direct-broadcast-specific version of the mapping algorithm that will include the following features: 1) cumulative burned area maps will be produced on a daily basis; 2) burns will be mapped through the current day; 3) all pixels will include a per-pixel burned/unburned confidence parameter which will increase as subsequent overpasses are acquired over the next ~10 days; and 4) each daily corrected-reflectance and active-fire composite will be processed only once.

4. Algorithm Output and Example Results

As mentioned above, the algorithm identifies the date of burn, to the nearest day, for 500-m grid cells within the individual $10° \times 10°$ MODIS tile being processed. The date is encoded in a single data layer of the output product as the ordinal day of the calendar year on which the pixel burned (range 1-366), with a value of 0 for unburned land pixels and a special value of -1 reserved for both missing data and water pixels. An example of this data layer is shown in Figure 2. The output product contains additional data layers for diagnostic purposes and to facilitate uncertainty propagation into downstream products derived from the burned area maps, such as emissions estimates.

5. Discussion and Conclusions

We have described a Direct Broadcast implementation of an automated algorithm for mapping post-fire burned areas using 500-m MODIS imagery coupled with 1-km MODIS active fire observations. The hybrid algorithm applies dynamic thresholds to composite imagery generated from a burn-sensitive VI derived from MODIS short-wave infrared channels 5 and 7, and a measure of temporal texture. The algorithm is implemented as an SPA which allows the algorithm to be plugged into IPOPP for operational processing or be run in a standalone environment.

References

Coronado, P., Overton, J., Brentzel, K., 2008. International Polar Orbiter Processing Package Framework for Earth Remote Sensing Science Data processing, *Asian Journal of Geoinfomatics*, (This issue).

Descloitres, J., Sohlberg, R., Owens, J., Giglio, L., Justice, C. O., Carroll, M., Seaton, J., Crisologo, M., Finco, M., Lannom, K., and Bobbe, T., 2002, Geoscience and Remote Sensing Symposium, 2002. IGARSS '02, IEEE International, 1191-1192.

Friedl, M. A., McIver, D. K., Hodges, J. C. F., Zhang, X. Y., Muchoney, D., Strahler, A. H., Woodcock, C. E., Gopal, S., Schneider, A., Cooper, A., Baccini, A., Gao, F., Schaaf, C., 2002. Global land cover mapping from MODIS: Algorithms and early results. *Remote Sensing of Environment,* 83, 287–302.

Giglio, L., Descloitres, J., Justice, C. O., and Kaufman, Y. J., 2003, An enhanced contextual fire detection algorithm for MODIS. *Remote Sensing of Environment*, 87:273-282.

Giglio, L., Loboda, T., Roy, D. P., Quayle, B., and Justice, C. O., 2008, An active-fire based burned area mapping algorithm for the MODIS sensor. Submitted.

Giglio, L., van der Werf, G. R., Randerson, J. T., Collatz, G. J., Kasibhatla, P. S., 2006. Global estimation of burned area using MODIS active fire observations. *Atmospheric Chemistry and Physics*, 6, 957–974.

Justice, C. O., Giglio, L., Korontzi, S., Owens, J., Morisette, J. T., Roy, D., Descloitres, J., Alleaume, S., Petitcolin, F., Kaufman, Y., 2002. The MODIS fire products. *Remote Sensing of Environment* 83, 244–262.

Prins, E. M., and Menzel, W. P., 1992, Geostationary satellite detection of biomass burning in South America. *International Journal of Remote Sensing*, 13, 2783-2799.

Roy, D. P., Boschetti, L., Justice, C. O., Ju, J., 2008. The collection 5 MODIS burned area product – global evaluation by comparison with the MODIS active fire product. *Remote Sensing of Environment*, 112, 3690-3707.

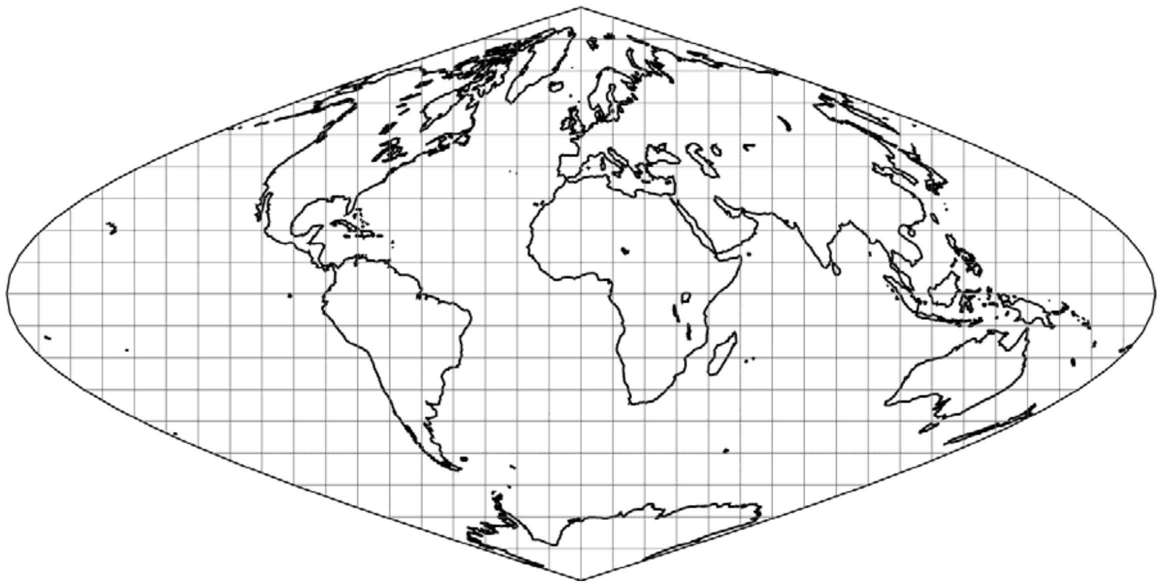
Vermote, E. F., Justice, N. Z. E. S. C. O., 2002. Operational atmospheric correction of the MODIS data in the visible to middle infrared: First results. *Remote Sensing of Environment*, 83, 97–111.

Wolfe, R. E., Roy, D. P., and Vermote, E., 1998, MODIS land data storage, gridding, and compositing methodology: Level 2 grid, *IEEE Transactions on Geoscience and Remote Sensing*, 36, 1324–1338.

Figure Captions

Figure 1: MODIS sinusoidal projection tiling scheme.

Figure 2: Final 500-m burned area map for the year 2005 in MODIS tile h12v10, located in the Brazilian Amazon. Unburned grid cells are black, with burned grid cells having their date of burn indicated by the color scale (dark red indicates the early part of the burning season, orange indicates later in the burning season). Light blue outline delineates the southwestern border of Mato Grosso state.



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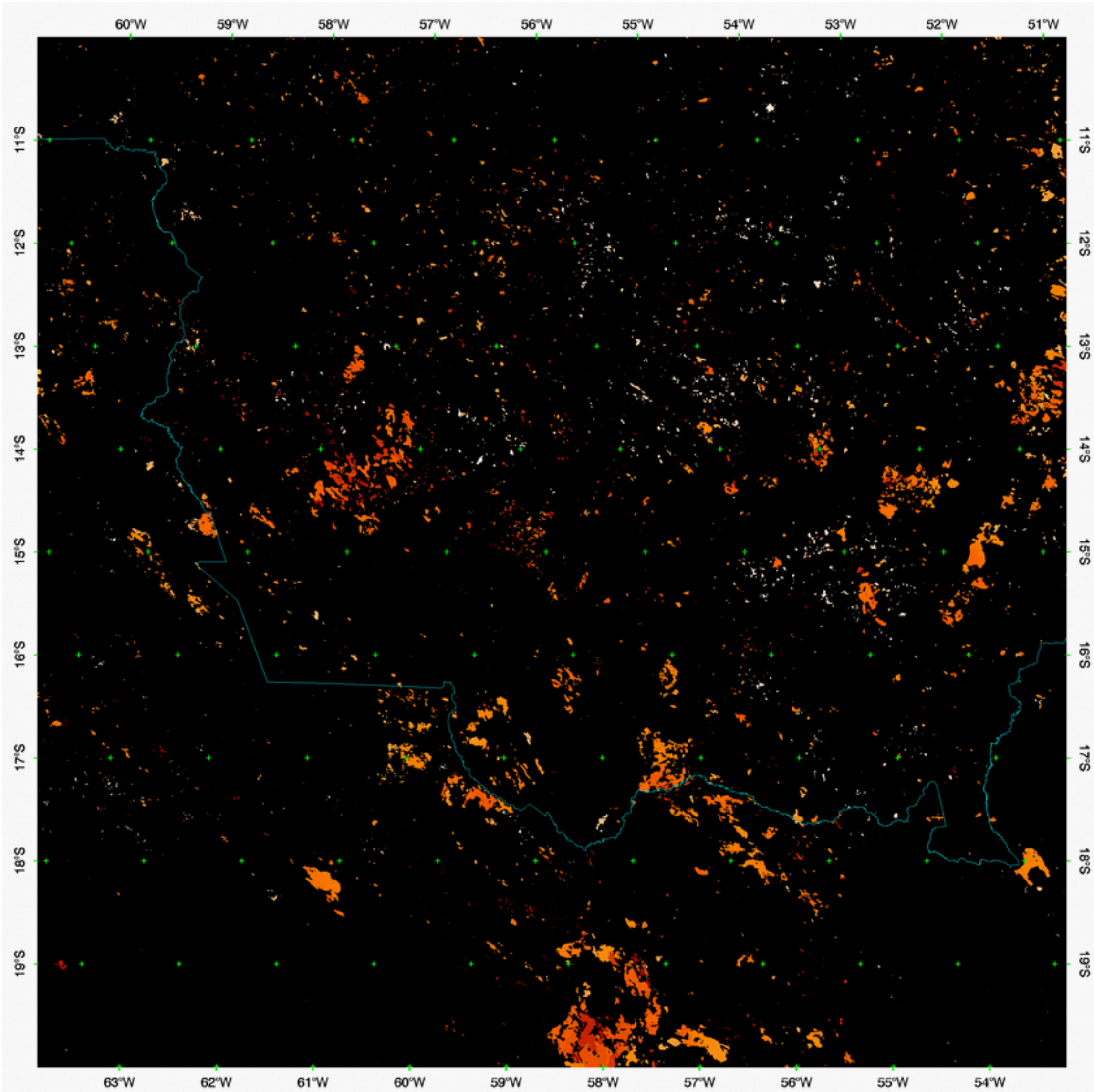

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