Error characterization of burned area products

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Abstract

This study presents a method to assess (1) the influence of intra-pixel burned area fragmentation and extent on the final global product binary prediction and (2) the relationship between error types (i.e. commission or omission errors) and land cover types. As an example of this methodology, we used the MERIS burned area product developed within the framework of the ESA fire CCI project. Reference data is generated from Landsat imagery for three study sites (Portugal, Brazil, and Australia), covering the 2005 fire season. Exploratory analysis of this study shows that burned are proportion affects the product estimates. Contingency table analysis shows that land cover affects significantly errors in two of the three study sites. Results indicate that, for at least some regions, error regimes may vary depending on land cover type.

Keywords: Burned Area, Validation, Error Characterization, Reference Data, Land Cover.

1. Introduction

Validation and error characterization is a critical step of any remote sensing based product, since it provides a quantitative assessment on its reliability and provides a sound framework for product use.

Over the last few years, several global and regional burned area (BA) products have been made available to the international community. Usually they have two categories, i.e. burned and unburned. The most widely used are GlobCarbon (2007), L3JRC: Tansey *et al.* (2008), MODIS MCD45A1: Roy *et al.* (2008), and GFED3: Giglio *et al.* (2010). The release of these products included a first stage validation, which was performed by comparing the global BA products with those derived from higher resolution images (most commonly Landsat-TM/ETM+). Even though these validation efforts were very relevant, frequently do not tackle error sources, which difficults the use of BA products as input to earth system models.

This study presents a method to assess (1) the influence of intra-pixel burned area (BA) fragmentation and extent on the final global product binary prediction and (2) the relationship between error types (i.e. commission or omission errors) and the land cover (LC).

As an example of this methodology, we used we used the MERIS burned area product developed within the framework of the ESA fire CCI project (www.esa-fire-cci.org). Reference data is generated for three study sites, located in Portugal, Brazil, and Australia, covering the fire season of 2005. Multitemporal Landsat images were used to generate the BA reference perimeters. LC vegetation information comes from the ESA GlobCover 2005 map (http://ionia1.esrin.esa.int).

2. Methods

1.2. Global product and reference data

The MERIS fire CCI BA global product has daily temporal resolution and for 300 m pixel size (Pereira *et al.* 2011). In each study site, annual reference data were produced based on two multitemporal pairs of Landsat imagery. Acquisition dates of images define the temporal periods with reference data available per year. A semi-automatic algorithm for BA mapping (Bastarrika *et al.* 2011), was used for generating this reference data. The files were generated following a standard protocol defined by the fire_cci project (Chuvieco *et al.* (2011), available online at http://www.esa-fire-cci.org/webfm_send/241), which follows the CEOS-Cal Val guidelines (Boschetti *et al.* 2009).

Since reference data have much finer spatial resolution than global products, it usually captures spatial heterogeneity within product pixels. Reference fire perimeters, acquired from Landsat images, have been rescaled and corregistrated to the product pixels, taking the BA proportion (*BAp*) classified as burned within each pixel. Cloud presence in the Landsat images and the SLC-OFF problem present in Landsat TM-7 caused no data available in some reference observations (pixels). Product pixels with more than 33 % of their surface covered by non-reference-data are excluded from the analysis. This threshold restricts the analysis to the central part of image frames when the SLC-OFF problem is present. All product pixels labeled as burned between Landsat acquisition dates are considered as burned, non-data product pixels are not considered, and all other falling within the Landsat scene are labeled as unburned.

1.2. Error characterization analysis

Ideally, a global product pixel would be labeled as unburned when less than half of it is really burned. A pixel would be labeled as burned when more than half of it is really burned. Global products usually have difficulties with intermediate situations, when global pixels are close to have burned halve of its surface. On the other hand, a product tends to improve its performance when pixels are "clean" of BA or are completely burned. The influence of BA extent in each pixel will be explored measuring the proportion of product pixels labeled as burned (p) across different intervals of *BAp*. P will be computed, for each study site, with the ratio between the number of pixels labeled as burned (n_{burned}) and the total number of pixels (n_{total}), within each *BAp* interval. P will be computed for a set of *BAp* intervals, when *BAp* is zero and from zero to one with 0.05 width intervals.

$$p_{BAp\ interval} = \frac{n_{burned,BAp\ interval}}{n_{total,BAp\ interval}} \quad (1)$$

Ideally, a global product would have p equal to zero for *BAp* less than 0.5 and p equal to one for *BAp* more than 0.5. However, global products have a gradual transition of p from low to high values of *BAp*. They tend to have low values of p when *BAp* is low and high values of p when *BAp* is high.

Different factors may affect errors on product estimates. This analysis try aims at identifying whether there is a “conflictive” LC or if errors are located similarly throughout all LC types. The following analysis will focus on the clearly burned pixels ($p > 0.8$) and on the clearly unburned ($p < 0.2$). The former pixels will be used to measure the relationship between LC and omision error and the later ones between LC and commision error. Relationships will be assessed by Contingency Table (CT) analysis (Averill 1972). For each study site, two CT are generated, one for each error type. CT will consist on two rows, error and non-error (commission and true unbured or omission and true burned) and one column for each LC type. The significant effect of LC over error occurrences will be assessed with the Chi square (χ^2) statistic at 0.05 significance level.

3. Results

Figure 1 shows the BA maps observed in the reference data (left column) and predicted by the global product (right column). Grey scale in the reference data figures represents the burned area proportion in each global product pixel. Product black pixels correspond to burned and grey to unburned. White areas represent observations with non-data. These are particularly large in Portugal, due to a Landsat LSC-OFF problem.

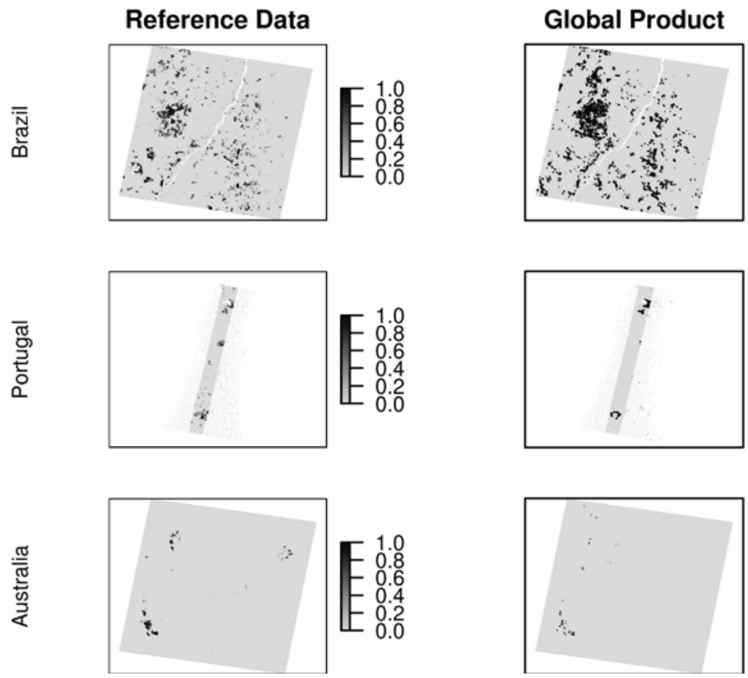

Figure 1: Reference data and global product for the three study sites, Brazil, Portugal and Australia. Grey scale in the reference data figures represents the burned area proportion in each global product pixel. Black pixels in the global product figures represent pixels labeled as burned and grey as unburned. White areas represent observations with non-data.

Figure 2 shows, on the left side, the *BAp* histogram (dotted line). In order to obtain a proper visualization *BAp* interval less than zero is not plotted. Pixels clearly burned or unburned (*BAp* > 0.8 and < 0.2 respectively) are more frequent, particularly for Brazil and Australia. As expected, *p* values are relatively low when *BAp* is low and high when *BAp* is high. The transition of *p* from low to high values of *BAp* tends to be gradual for the three study sites.

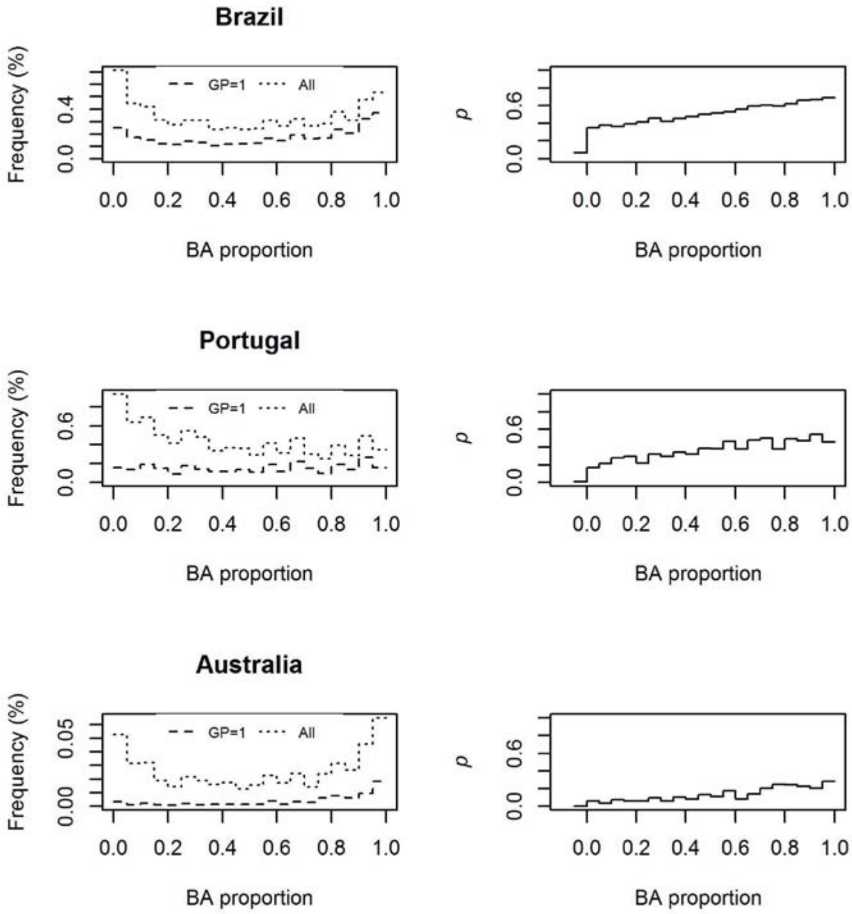

Figure 2: On the left side, the BA proportion (*BAp*) histogram when is higher than zero (All; dotted line) and the *BAp* histogram for pixels labeled as burned by the global product (GP=1; slashed lined). In order to obtain a proper visualization *BAp* interval less than zero is not plotted, as its frequency is always greatly larger than the plotted y axis range. On the right side, the proportion of product pixels labeled as burned (*p*) for each *BAp* intervals presented.

For this paper, CT analysis results are detailed only for Portugal and Australia. Table 1 shows the difference between the observed and the expected CT is larger in Portugal than in Australia. Particularly, in Portugal, forest&grass and shrubland tend to allocate smaller quantity of omission errors than expected. Based on the χ^2 statistic, LC affects significantly omission in Portugal, but not in Australia.

Table 1: Results of the contingency table between omission errors (O) or true burned (TB) and land cover (LC), in the study sites of Portugal and Australia.

Portugal		$\chi^2 = 220.38$		Hypothesis can be denied at the 0.05 significance level, LC affects significantly			
Observed	agro mosaic	clos. decid.	clos. needl.	forest& grass	mix.for	shrubl and	spar.veg.
O	2	19	203	46	25	134	25
TB	0	1	131	157	2	7	5
Expected							
O	1	12	200	122	16	85	18
TB	1	8	134	81	11	56	12

Australia		$\chi^2 = 0.20$	Hypothesis cannot be denied at the 0.05 significance level
Observed	grass& forest	shru- bland	
O	90	917	
TB	23	261	
Expected			
O	88	919	
TB	25	259	

Acronym	Name in the GlobCover legend
agromosaic	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)
clos.decid.	Closed (>40%) broadleaved deciduous forest (>5m)
clos.needl.	Closed (>40%) needleleaved evergreen forest (>5m)
mix.for	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)
forest&grass	Mosaic forest or shrubland (50-70%) / grassland (20-50%)
grass&forest	Mosaic grassland (50-70%) / forest or shrubland (20-50%)
shrubland	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)
spar.veg.	Sparse (<15%) vegetation

Table 2 shows the χ^2 statistic of the CT analyses for the three study sites. LC significantly affects omission and commission error in Brazil and Portugal, but not in Australia.

Table 2: χ^2 statistic scores for the contingency tables. χ^2 that show a significant effect (at the 0.05 significance level) are labeled with *.

Study Site	Contingency table χ^2 between omission error and land cover	Contingency table χ^2 between commission error and land cover
Brazil	873.64*	12034.7*
Portugal	220.38*	923.27*
Australia	0.20	11.35

4. Discussion and Conclusion

Distribution of *BAp* within product pixels varies through study sites (left side of Figure 2). Different distributions of *BAp* may occur in different regions, which may be consequence of the combined effect between fire patch fragmentation and spatial resolution of the product pixels. As expected, *BAp* affects the product binary estimates and the transition of *p* from low to high values of *BAp* tends to be gradual (right side of Figure 2).

Based on the χ^2 statistic of the CT analysis, LC affects significantly errors in two out of the three study sites. Results indicate that, at least for particular regions, error regimes may vary depending on land cover types.

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