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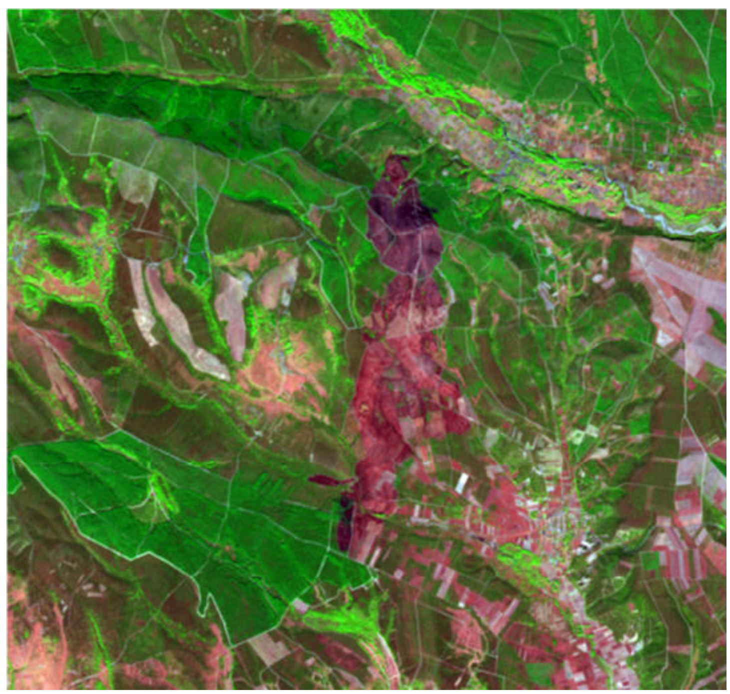
Editors



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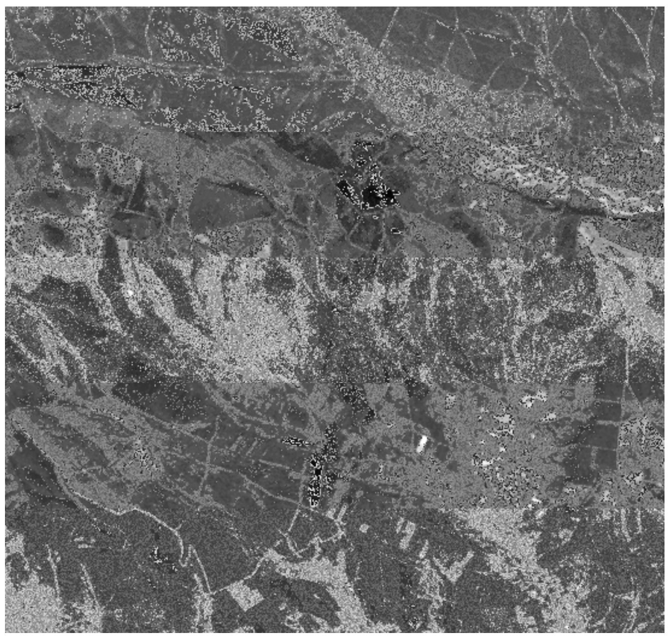

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AN INTEGRATED INDEX FOR THE MULTITEMPORAL VALIDATION OF BURNED AREA PRODUCTS

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Abstract

In the last decade multiple effort have been undertaken to map Burned Area (BA) at a global scale, as input data for different earth system models. The validation of BA products, as any other cartography, is a critical step for its acceptance by final users, which needs standard procedures to select the most accurate one. The validation efforts of the most common BA products use different methods and results are not directly comparable. Most commonly, they try to estimate accuracy, but other components of validation, such as precision and temporal consistency have not been previously covered.

In this study we present a synthetic index that summarizes all the error components of burned area (BA) products raised from its validation against independent reference data. The validation analysis comprises: the detection ratio of burned patches, information from linear regression for course grid cells, errors from confusion matrices and temporal stability of the errors.

Our validation scheme has been applied to a three different global multi-annual BA products (GlobCarbon, MCD45 and L3JRC) in three study areas situated in Brazil, Canada and Portugal from 2000 to 2006. For these study areas, annual reference data were produced based on pre and post-fire analysis of Landsat imagery. Acquisition dates of images define the temporal periods with reference data available in each year. A semi-automatic algorithm for BA mapping was used for the generation of these reference data. Results show that the MODIS product produces better results than L3JRC and Globcarbon, with higher precision and accuracy, but it has a lower temporal stability.

Keywords: Burned Area, Validation, Error, Reference Data, Temporal Consistency

Introduction

Validation 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. For this reason, international programs, such as Global Climate Observing Systems, have established specific requirements in terms of validation and error thresholds (GCOS 2010).

The Committee on Earth Observing Satellites Working Group on Calibration and Validation (CEOS-WGCV) defines validation as: "The process of assessing, by independent means, the quality of the data products derived from the system outputs" (http://lpvs.gsfc.nasa.gov/). This implies to compare those results with a reference source, which is assumed to be the ground truth. Validation should quantify the random and the systematic error components, which define the precision and the accuracy of the measurements, respectively. Validation should also explore the stability, the error variability through time, and the spatial consistency, the error variability across space or controlling factors.

During last years, several global and regional burned area (BA) products have been made available to the international community. The release of those products included a first stage validation, the GlobCarbon (2007), the L3JRC: Tansey et al. (2008), the MODIS MCD45A1: Roy et al. (2008), the GFED3: Giglio et al. (2010) or the Latin American AQL: Chuvieco et al. (2008). Results from those validation studies are not directly comparable as they use different validation methods. Little work has done to compare products using common validation methods and reference data. Roy and Boschetti (2009) and Chang and Song (2009) presented the first attempts on the inter-comparison of global products, the former study compared GlobCarbon, MCD45 and L3JRC products in Southern Africa, and the later compared MCD45 and L3JRC in Canada, USA, Russia and China.

International bodies, such GOFC-GOLD Fire Implementation Team, try to coordinate efforts for generating standard validation methods for operational products. This paper follows this aim, as it presents a synthetic index that summarizes all the validation components, i.e. precision, accuracy and consistency of burned area (BA) products raised from its comparison against the same independent reference data. This study also present an application of the validation scheme with real data, using GlobCarbon, MCD45 and L3JRC global BA products for 3 study areas situated in Brazil, Canada and Portugal. The time series ranges from 2000 to 2006. This validation exercise is part of the fire_cci project, funded within the ESA initiative for improving the use of satellite products in climate change studies.

Methods

1.1 *Global products and reference data*

The validation scheme presented here has been applied to the MCD45, L3JRC and GlobCarbon global multi-annual BA products in 3 study areas situated in Brazil, Canada and Portugal from 2000 to 2006. MCD45 is produced by the NASA, has daily temporal resolution and 500 m pixel size, and it is derived from MODIS data on board the Terra and Aqua satellites (Roy et al. 2005). L3JRC is produced by the Joint Research Center, has daily temporal and 1km spatial resolution, and is derived from SPOT Vegetation (Tansey et al. 2008). GlobCarbon is produced by the European Space Agency, and it has daily temporal resolution at 1km2 pixel size. It is derived from ERS2-ATSR2 and ENVISAT AATSR (Plummer et al. 2007). GlobCarbon consist in results from three separated algorithms, in the present study we refer to a merge of the three algorithms: BA is defined as where at least two of the three algorithms detect a pixel as burned and unburned elsewhere.

The spatial distribution of the validation sites should include the complete range of environmental factors that affect burned area mapping accuracy. In this exercise, three validation sites were selected, as to be representatives of boreal forest (Central West of Canada), Mediterranean ecosystems (Portugal) and tropical biomes (central Brazil). All have a significant fire activity. Even though it is a small sample of fire conditions, they serve as an example to test the use of an integrated validation index for Burned Area products. In the three study areas, annual reference data were produced based on pre and post-fire analysis of Landsat imagery. Acquisition dates of images define the temporal periods with reference data available in each year. For each validation site, 7 years of BA reference data was produced, using 21 Landsat scenes in total. A semi-automatic algorithm for BA mapping, published in Bastarrika et al. (2011), was used for the generation of these reference data. These steps follow the standard procedure established in the fire_cci project (Chuvieco et al., 2011), available online at http://www.esa-fire-cci.org/webfm_send/241).

1.2 *Validation analysis and their metrics*

Three spatial comparisons between BA and reference fire perimeters were performed to derive error measures: (i) cross-tabulation, (ii) linear regression and (iii) patches detection.

From the cross-tabulation analysis, the burned/unburned confusion matrix was generated, which made it possible to compute commission and omission errors and the Kappa coefficient (based on the difference between observed and expected agreement by chance; Congalton and Green 1999). Since cross-tabulation is a pixel by pixel comparison, this analysis can be notably affected by differences in spatial resolution and co-registration errors between reference and target BA products. To avoid those problems, some authors alternatively recommend using a linear regression analysis, built upon the proportion of burned area in the two BA products using a grid coarser than the pixel resolution of the target product (Boschetti et al. 2004). In this study, a 10x10 km grid was used. Correlation coefficient, slope and intercept of the best fitted line between target and reference data was computed from a nonparametric linear regression based on Kendall's rank correlation (Roy et al. 2008; Sen 1968; Theil 1950). A strong linear relationship (high value of Kendall) indicates that the target and reference product include a similar estimation of BA extent for 10x10 km cells. Ideally, the fitted line would have slope 1 and intercept 0. The proximity of the fitted line to the ideal one (Prox) is assessed measuring the area between the two products in the scatter plot:

$$\mathrm{P}rox = 0.5 - \int_0^1 \left| fitted\ .line(x) - identiy\ .line(x) \right| dx \qquad (1)$$

The third criterion of accuracy was the patches detection index, defined as the ratio between the number of patches detected by the BA product and all BA reference patches . A patch was accounted as detected when at least 10% of its area was included in the BA product. This approach made it possible to identify the patch size below which the detection rate of the target product was unreliable.

1.3 *Components of validation*

The validation can be divided in three major components: precision, accuracy and stability.

Precision is the ability to produce repeatedly similar measurements over the same measurand, with a small random error (GOFC-GOLD 2010). For this study, we measured it by the Kendall correlation coefficient derived from the linear regression analysis, providing information at regional scale (Roy and Boschetti 2009).

Accuracy is the ability to produce measurements with a distribution centered to the true value, with a small systematic error (GOFC-GOLD 2010) and may be evaluated at local and/or regional scales (Roy and Boschetti 2009). The accuracy at local scale can be effectively characterized through the accuracy indices derived from the cross-tabulation, while accuracy and precision at regional scale through the linear regression analysis (Roy and Boschetti 2009). Local accuracy was computed as the mean of the kappa index and the complementary of omission and commission errors, and regional accuracy was computed as the mean of the detection index and the Prox.

Scores of precision and accuracy varied from 0 to 1, and resulted from the aggregation of their metrics in each of the three study areas. Precision and accuracy were computed for each study area, with data for all years, and, for the final integration index, the average values were used.

Stability, *S*, was defined by the errors variability measured through time. According to the characteristics and sampling of the validation datasets, errors were measured once for each of the 7-years of the study period. A non-parametric measure of dispersion, the inter-quartile range, was used to estimate this parameter, for each metric *x*, and for each study site *ss*, through years *i*.

$$S_{ss,x} = 1 - IQR(x_{ss,i}) \qquad (2)$$

S will vary from 0 to 1 and will be the result of the average of stability indexes seen in each of the three study areas. Local stability is computed as the mean of stability indexes of kappa index and omission and commission errors, and regional stability is equal to the patches detection ratio.[1]

1.4 *Integration of validation components*

The final integrated index varied from 0 to 1, with high values indicating high reliability. The integrated index was computed as the mean between the three validation components (precision, accuracy and stability).Precision was equal to the Kendall coefficient (*k*) and accuracy index was the average between local and regional accuracy. Consistency index ideally should cover both spatial and temporal variation, but in this paper only the latter was considered, It was computed as the mean of local and regional S.

Results

The final integrated index and scores for the three validation components are shown in Table . MCD45 was the product with the highest precision and accuracy, although it showed lower stability values than L3JRC and GlobCarbon.

Table 1. Scores of the three validation components and the final integrated index

	Precision	Accuracy	Stability	Integrated Index
GlobCarbon	0.40	0.19	0.92	0.51
L3JRC	0.36	0.21	0.92	0.50
MCD45	0.59	0.44	0.83	0.62

Figure 1 shows local accuracy for each target product in the three validation sites through the 7-years of the study period. Accuracy and stability performances of the three global products agree, as expected, with scores of accuracy and stability components shown in Table 1. MCD45 was found slightly more accurate in Brazil and Portugal than L3JRC and GlobCarbon, which

[1] Similarly to the temporal stability, a spatial consistency (SC) index may be considered. It may related to how errors vary throughout space. SC could be assessed by errors variability found through ranges of different controlling factors. SC was not computed in this paper, since only three sites were available, but will be within the fire_cci project at a later stage.

showed similar results. Differences in performances were more important in Canada, where MCD45 was clearly the most accurate product, although with low stability, while L3JRC and GlobCarbon presented lower accuracy, but high statibility. Differences in product performances through validation sites suggested that they are affected by land cover or fire regimes of each study site. On the other hand, some degree of correlation was found on the temporal trends of local accuracy values within each study site, particularly in Portugal. Relative minimums coincide with low fire activity years (Figure 2), when fires patches are smaller and more difficult to detect by coarse spatial resolution sensors.

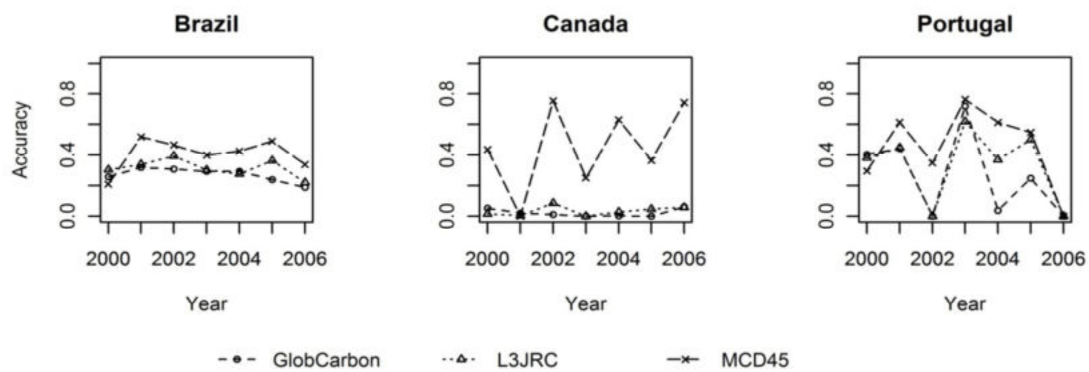

Figure 1. Local accuracy values for each global product in the three validation sites through the 7-years of the study period.

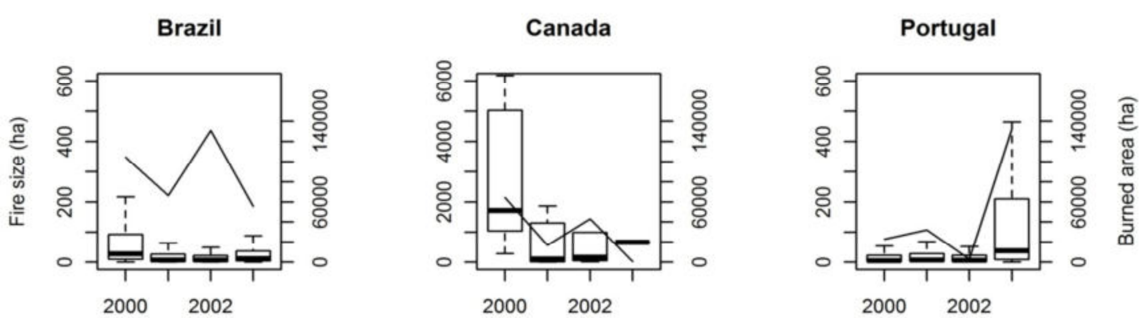

Figure 2. Fire size distribution (boxplots) and total annual burned area (lines, plotted on the secondary axis) in the three validation sites from 2000 to 2003, when fire sizes are available (years with Landsat images without the SLC-off problem)

Conclusions

A framework for validation is presented through a synthetic index that summarizes all the error components of burned area (BA) products, i.e. precision, accuracy and consistency, raised from its validation against independent reference data. Metrics derived from most common validation methods have been selected to be part of the three error components, according to their meanings.

The use of this validation scheme allowed to easily compare performances of three operational products, providing scores for precision, accuracy, temporal stability and for the integrated index. MCD45 showed highest precision and accuracy, however lower stability values. MCD45 is slightly more accurate than the two others in Brazil and Portugal, but much more in Canada, although with low stability, where L3JRC and GlobCarbon present low accuracy values, in a consistent way. Burned patches size and land cover may be two important factors in product performances and further research could be done to investigate their effects. The validation framework here presented will now be implemented for the validation of the BA products at a more extensive spatial scale around the globe.

References

Bastarrika, A., Chuvieco, E., & Martin, M.P. 2011. Mapping burned areas from Landsat TM/ETM+ data with a two-phase algorithm: balancing omission and commission errors. Remote Sensing of Environment, 115, 1003-1012

Boschetti, L., Flasse, S.p.P., & Brivio, P.A. 2004. Analysis of the conflict between omission and commission in low spatial resolution dichotomic thematic products: The Pareto Boundary. Remote Sensing of Environment, 91, 280-292

Chang, D., & Song, Y. 2009. Comparison of L3JRC and MODIS global burned area products from 2000 to 2007. Journal of Geophysical Research D: Atmospheres, 114

Chuvieco, E., Opazo, S., Sione, W., Del Valle, H., Anaya, J., Di Bella, C., Cruz, I., Manzo, L., López, G., Mari, N., González-Alonso, F., Morelli, F., Setzer, A., Csiszar, I., Kanpandegi, J.A., Bastarrika, A., & Libonati, R. 2008. Global Burned Land Estimation in Latin America using MODIS Composite Data. Ecological Applications, 18, 64-79

Chuvieco, E., Padilla, M., Hantson, S., Theis, R., & Snadow, C. 2011. ESA CCI ECV Fire Disturbance - Product Validation Plan (v3.1). In: ESA Fire-CCI project (http://www.esa-fire-cci.org/)

Congalton, R.G., & Green, K. 1999. Assessing the Accuracy of Remotely Sensed Data: Principles and Applications. Boca Raton: Lewis Publishers

GCOS 2010. GCOS-143 - Guideline for the Generation of Datasets and Products Meeting GCOS Requirements. In: Global Climate Observing System

Giglio, L., Randerson, J., T., van der Werf, G.R., Kasibhatla, P., Collatz, G.J., Morton, D.C., & Defries, R. 2010. Assessing variability and long-term trends in burned area by merging multiple satellite fire products. Biogeosciences Discuss, 7, 1171

GlobCarbon 2007. Demonstration Products and Qualification Report. In (pp. 1-69): ESA

GOFC-GOLD 2010. A sourcebook of methods and rocedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. In. Alberta, Canada: GOFC-GOLD Project Office, Natural Resources Canada

Plummer, S., Arino, O., Ranera, F., Tansey, K., Chen, J., Dedieu, G., Eva, H., Piccolini, I., Leigh, R., Borstlap, G., Beusen, B., Fierens, F., Heyns, W., Benedetti, R., Lacaze, R., Garrigues, S., Quaife, T., De Kauwe, M., Quegan, S., Raupach, M., Briggs, P., Poulter, B., Bondeau, A., Rayner, P., Schultz, M., & McCallum, I. 2007. An update on the GlobCarbon initiative: multi-sensor estimation of global biophysical products for global terrestrial carbon studies. In, Envisat Symposium 2007. Montreux, Switzerland

Roy, D., Jin, Y., Lewis, P., & Justice, C. 2005. Prototyping a global algorithm for systematic fire-affected area mapping using MODIS time series data. Remote Sensing of Environment, 97, 137-162

Roy, D.P., & Boschetti, L. 2009. Southern Africa validation of the MODIS, L3JRC, and GlobCarbon burned-area products. IEEE Transactions on Geoscience and Remote Sensing, 47, 1032-1044

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

Sen, P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association, 63, 1379-1389

Tansey, K., Grégoire, J.-M., Defourny, P., Leigh, R., Pekel, J.-F., Bogaert, E., & Bartholome, E. 2008. A new, global, multi-annual (2000-2007) burnt area product at 1 km resolution. Geophysical Research Letters, 35, L01401, doi:10.1029/2007GL03156

Theil, H. 1950. A rank-invariant method of linear and polynomial regression analysis. Nederlandse Akademie Wetenchappen Series A., 53, 386-392