Lessons to be learned from the comparison of three satellite-derived biomass burning products

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[1] Thematic maps of active fires or burned areas derived from low resolution remotely sensed data are widely used as an input for the estimation of the atmospheric emissions due to biomass burning. The present work considers three of the global products available for year 2000: two burned area datasets (GBA2000 and GlobScar) and one active fires dataset (World Fire Atlas) and analyses the relative agreements and disagreements in terms of areal extents and geographic location of the fire activity. The intercomparison of the three datasets shows that, while there is generally a good spatial agreement, the disagreement in terms of areal estimates is major. Without a quantitative validation and calibration using high resolution data, the uncertainty of the areal estimates significantly increases the variance of the estimation of atmospheric emissions. *INDEX TERMS:* 0305 Atmospheric Composition and Structure: Aerosols and particles (0345, 4801); 0312 Atmospheric Composition and Structure: Air/sea constituent fluxes (3339, 4504); 1610 Global Change: Atmosphere (0315, 0325); 1640 Global Change: Remote sensing; 4805 Oceanography: Biological and Chemical: Biogeochemical cycles (1615). **Citation:** Boschetti, L., H. D. Eva, P. A. Brivio, and J. M. Grégoire (2004), Lessons to be learned from the comparison of three satellite-derived biomass burning products, *Geophys. Res. Lett.*, *31*, L21501, doi:10.1029/2004GL021229.

1. Introduction

[2] In recent years the study of the variations of the chemical composition of the atmosphere has been one of the most relevant scientific topics and several studies have attempted to understand the influence of the greenhouse gases and aerosol produced by anthropogenic activities on these changes. Nowadays it is widely recognised that a significant fraction of the total amount of atmospheric emission is given by the phenomenon of biomass burning; as a result, numerous studies have been dedicated to the estimation of such a contribution by means of the monitoring of active fires and burned areas from remotely sensed data [*Generoso et al.*, 2003; *van der Werf et al.*, 2004; *Ito and Penner*, 2004]. However, two major limitations remain when estimating global emissions from biomass burning. First of all, the quantification of fuel loads and combustion factors is still a research issue, at those scales [*Kasischke and Penner*, 2004]. Second, the still limited number of global burned-area products does not allow the modelers to take into consideration the limitations and potential disagreements between the different source data available. For instance, *Schultz* [2002] used ''monthly composites of active fire observations from the ATSR sensor on board the ERS-2 satellite as a surrogate to burned area product''. *Hoelzemann et al.* [2004] concluded that modeling of emissions should rely on a combination of existing satellite products and not on a single dataset. The present study aims at clarifying the specificity of three major global fire products available for year 2000: two burnt area products, GlobScar and Global Burned Area 2000 (GBA) and an active fire product, World Fire Atlas (WFA).

[3] In this paper we examine the spatial, temporal and magnitude of the correspondence between these three datasets so as to highlight the potential pitfalls of using such data without taking adequate precautions.

2. Materials and Methods

2.1. Datasets

[4] The three datasets used have a number of intrinsic differences. Two datasets are of burnt areas, the other is active fires; two data sets come from the ATSR (Along Track Scanning Radiometer) one from the SPOT VEGETATION sensor. All the sensors have a nominal 1 km resolution.

[5] ATSR-2 sensor, onboard the ERS-2, has a 500 km swath, allowing a repeat cycle of 9 days at the equator. Two products are derived from the ATSR data, a burnt area product GlobScar, and an active fire product the (WFA). For the GlobScar product [*Simon et al.*, 2004] thresholds and statistical analysis are used to detect burnt areas using all channels. The detected burnt areas are available as global monthly thematic maps for the year 2000. The WFA consists of daily active fire maps derived from night-time ATSR data, using a threshold set in the middle infrared. Two active fire products are available, one with a conservative and one with a lower threshold. For this analysis we used the conservative approach. The VEGETATION instrument, a 1 km resolution sensor onboard the SPOT-4 satellite acquires data in the reflective part of the solar spectrum. It has a swath of 2000 km allowing almost daily global coverage. The GBA was derived using a set of regionally specific algorithms, designed to maximise detections [*Tansey et al.*, 2004]. The GBA thematic product consists of monthly non-accumulative binary (burnt - not burnt) maps for the whole of the globe for the year 2000. A discussion of the relative merits and drawbacks of the different sensors and algorithms would be outside the objectives of this work, which is intended as an analysis of the three products as they are available to the scientific community.

2.2. Method

[6] For comparing the spatial correlation each of the three data sets are aggregated by area in a reference grid. Thus

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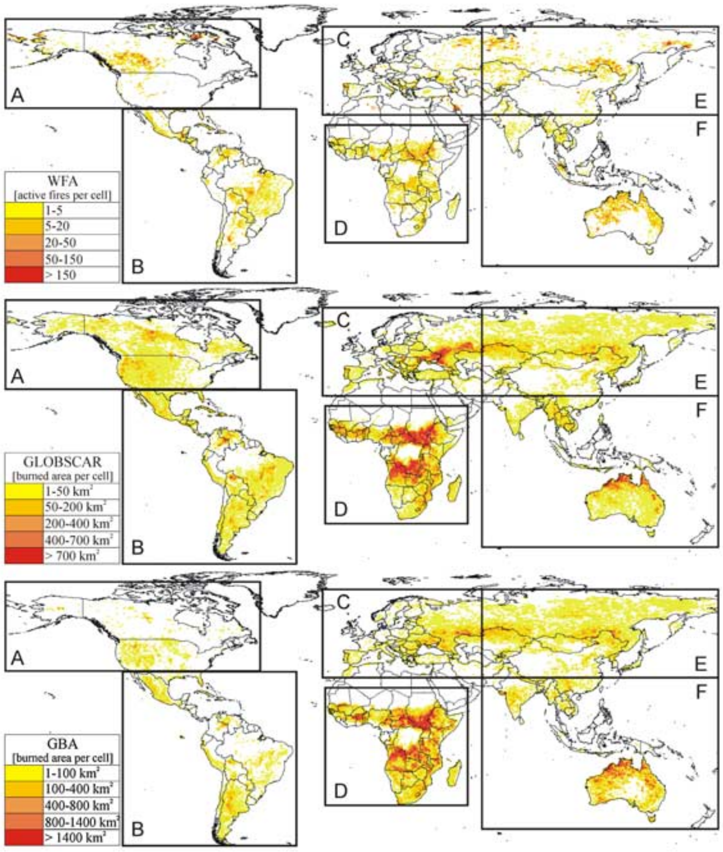

Figure 1. Burned areas detected by GBA2000 (bottom) and Globscar (middle) and number of active fires detected by WFA (top), aggregated at hexagon level.

the percentage of area burned detected by GBA and by GlobScar, as well as the number of active fires from the WFA, is computed.

[7] The spatial aggregation of the data removes the local scale discrepancies, but maintains the main burning patterns and allows a continental-scale analysis of the main differences between the three products. For temporal analysis we extract three temporal profiles of the monthly burned area in km^2 (GlobScar and GBA) and of the number of fires (WFA). Areal estimates of burnt areas and active fire counts are given by spatial window; the six continental-scale windows are outlined in Figure 1.

2.3. The Reference Grid

[8] The subdivision of the Earth's surface, in a number of cells of given area, identical shape and evenly distributed (regular tessellation) is made impossible by the fact that the only regular tessellations of the sphere are the platonic solids and the platonic solid of higher order is the icosahedron (20 equilateral triangles). Several sub-optimal tessellations are available in the literature, and can be the reference base for a global grid. One of the most widely used discrete grids in atmospheric chemistry is the latitude/longitude grid; such a grid has several advantages, but also some major disadvantages, such as the distortions which occur at high latitudes, which undermine its efficiency in modelling [*Sahr and White*, 1998].

[9] For this study we have used the hexagonal tessellation proposed by *Olsen et al.* [1998]. This has already been adopted as reference grid for the TREES project [*Achard et al.*, 2002; *Richards et al.*, 2000]. The cells of this tessellation are hexagons, whose centres are approximately 60 km apart and whose area is about 3000 km^2.

3. Results and Discussion

[10] Total surface of burned areas for the year 2000 is about 3.5×10^6 km^2 according to the GBA product and 2.0×10^6 km^2 according to GlobScar. Total number of 1 km pixels affected by active fires is 8.7×10^4 according to WFA, two orders of magnitude less than burned surface derived from satellite.

3.1. Temporal Analysis

[11] From Figure 2 we observe that while the temporal profiles of the two burned area datasets have similar behavior, there are significant differences with the WFA data. In particular the increase in fire activity in the WFA product for the July–August time period lags behind the GBA product, and the decrease in fire activity in the WFA product for August to November lags behind the Globscar product. The decrease in the fire activity between February and May is also much attenuated.

3.2. Spatial Analysis

[12] Results from spatial analysis are summarised in Table 1 as Pearson's correlation coefficients and as total amount per continental window. The relationship between

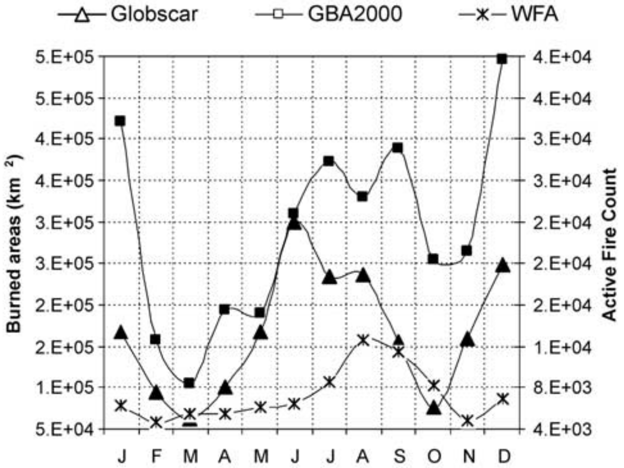

Figure 2. Temporal profiles of the three products. In this graph the daily active fire data have been aggregated at monthly scale.

different products in different regions can be additionally observed in the scatterplots. As an example Figure 3 shows the plots for Africa, while the scatterplots for the whole dataset are available as electronic auxiliary materials[1]. The spatial correlation measures between the two burnt area products, GBA and GlobScar range from weakly (over Europe) to moderately strongly (Africa) correlated ($R = 0.345$ to $R = 0.794$). Higher correlations are found in the tropical areas (Africa, South America and Australia) than the temperate and boreal zones. The spatial correlation between active fires from the WFA and the burnt area products ranges from non-significant at the 0.01 level (North America and Europe) to moderately significant (Africa) ($R = -0.031$ to $R = 0.469$). There are no large differences between the correlations found between the WFA and GBA and those between WFA and GlobScar.

[13] While the two burnt area products are seen to be correlated, they have largely different magnitudes of burnt area totals (Table 1) and the ratio is not constant. We also find that within hexagons, the spatial coherence of the fire patterns is not always constant (Figure 1). At the continental level the major inconsistency in the distribution of the two products is in Canada where GlobScar has a large region burnt, that is not on the GBA data set. The GlobScar product has far lower total burnt areas than GBA, but has detections in more hexagons. It is not possible to determine if this is a low level noise from errors of commission or not.

[14] The active fire product WFA corresponds spatially with the two burnt area products over largely savannah areas, Australia, Africa, South America. The correspondence over temperate and boreal forests is rather weak: the WFA picks up many of the agricultural and deforestation fires in South America and South East Asia whereas the burnt area products have fires in Siberia not detected by the WFA. Major areas of petrol production in the middle east are flagged as fires on the WFA, for which no burnt areas are detected.

[15] The lack of correspondence between the data sets does not necessarily mean that one or the other is inaccurate and relates to the spatial and spectral and temporal properties of the fires compared to the specifications of the satellite sensor [*Robinson*, 1991; *Justice and Dowty*, 1994; *Eva and Lambin*, 1998]. The active fires in the WFA come from night-time data. As most fires are human induced and lit in the afternoon, night-time fires tend to be those which last longest, i.e., forest fires or fires in open homogenous landscapes where the fire can progress. The burnt area products are both at 1 km spatial resolution, and hence only larger, spectrally distinct fires will be detected, such as large savannah fires. The fact that despite having similar resolutions (1 km) the two burnt area products detect significantly different numbers of fires is most likely due to the differences in number of available overpasses, as well as to the different algorithms adopted.

4. Conclusions

[16] A systematic comparison of three global scale biomass burning satellite derived products available for the year 2000 has been performed. The analysis was conducted at continental level, by means of a spatial aggregation based on a geodetic grid of hexagons. The comparison was focused on two objectives, the quantification of the differences of the areal estimates and of spatial correlation. The impact that these differences in area burnt have on emissions estimates is major. Large differences in areal estimates are particularly evident when comparing either burned area product with the active fire dataset, with a difference in the order of 10^2. More alarming is the large discrepancies in the areal estimates between the two burnt area products. This

Table 1. Correlation Coefficients for the Three Thematic Products, Grouped Window by Window[a]

	GBA2000	GlobScar	WFA	Total area
Window A (North America)				
GBA2000	1	**0.345**	**−0.031**[b]	37716
GlobScar	0.345	1	**−0.044**[b]	82877
WFA	−0.031[b]	−0.044[b]	1	13688
Window B (Central and South America)				
GBA2000	1	**0.570**	**0.188**	137021
GlobScar	0.570	1	**0.168**	162774
WFA	0.188	0.168	1	15535
Window C (Europe, Middle East and Northern Africa)				
GBA2000	1	**0.531**	**0.013**[b]	151729
GlobScar	0.531	1	**−0.003**[b]	174897
WFA	0.013[b]	−0.003[b]	1	8284
Window D (Sub-Saharian Africa)				
GBA2000	1	**0.794**	**0.469**	2267158
GlobScar	0.794	1	**0.465**	1206465
WFA	0.469	0.465	1	22715
Window E (Siberia, Mongolia, Northern China)				
GBA2000	1	**0.576**	**0.203**	280731
GlobScar	0.576	1	**0.166**	153927
WFA	0.203	0.16	1	13311
Window F (South-East Asia, India, Australia)				
GBA2000	1	**0.653**	**0.333**	655899
GlobScar	0.653	1	**0.280**	226164
WFA	0.333	0.280	1	17440

[a]Only the hexagons where fire activity has been detected at least by one product have been considered.
[b]The correlation is not significant at the 0.01 level.

[1]Auxiliary material is available at ftp://ftp.agu.org/apend/gl/2004GL021229.

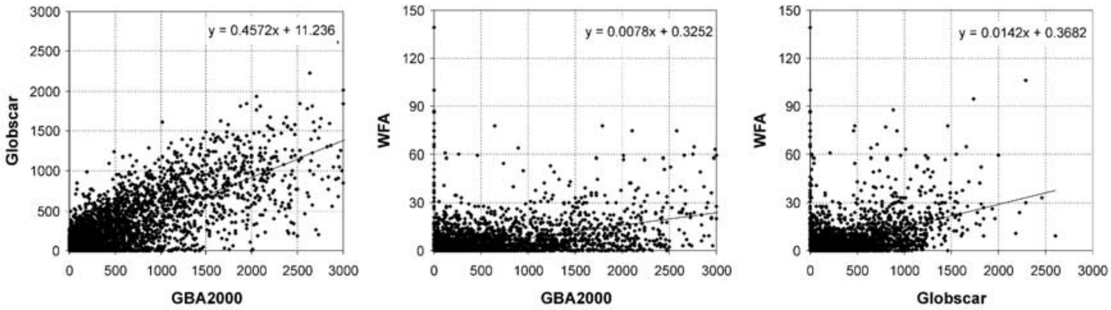

Figure 3. Scatter plots of the three products for window D (Africa). Burned areas are expressed in km^2, active fires in number of detections within each hexagon.

points to the need for calibration with high resolution data. Analysis of fire distribution patterns shows that in some areas the products are equivalent but in others are not. The temporal profiles of active fires and burned areas also show significant differences, with a shift in the detection of the peaks of seasonal fire activity. It should be noted that the year 2000 was year of low activity: some discrepancies might be explained by the fact that the extent of burned areas is very limited and the relative influence of residual noise is higher. The effect of the three products disagreeing in timing, magnitude and location means not only that we do not know how much biomass is burnt, nor do we know what has burn (with large impacts on the species and amounts), nor can we be sure of when it was injected into the atmosphere with subsequent implications for transport models.

[17] The large discrepancies detected, especially between active fire and burned areas products, agree with previous studies conducted at regional scale [*Li et al.*, 2000; *Kasischke et al.*, 2003; *Korontzi et al.*, 2004]. We therefore point to the need for validation, and, more generally, for the advantage of combining a series of satellite derived fire products, to take benefit of their respective strengths. The Globcarbon Project [*Plummer et al.*, 2004], coordinated by ESA, goes in that direction.

[18] On the calibration side, a validation strategy for the GBA product has been developed [*Boschetti et al.*, 2004] using high resolution calibration-validation dataset, and the results of such an exercise will help in reducing the variance associated with atmospheric emissions estimated from remotely sensed data.

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