Biomass burning emissions inventories over Africa: How to explain the differences observed between GFED and AMMABB inventories?

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1. **Introduction**: Over the past 20 years, several studies have estimated biomass burning emissions at both global and regional scales using either active fire, burned area products or both (Chin et al., 2002 Michel et al., 2005; van der Werf et al., 2006, Generoso et al., 2007; Stroppiana et al., 2010). However, large discrepancies still exist in the biomass burning emission inventories particularly over Africa (Liousse et al., 2010). These discrepancies exist for both gas and particulate emissions which is attributed to methodology applied and /or input data used such as fire products, land cover, emission factors. This work aims to investigate the differences between two bottom-up inventories namely African Monsoon Multidisciplinary Analysis Biomass Burning (AMMABB) and Global Fire Emissions Data version (GFED).

2. Methodology: For the purpose to reduce uncertainties induced by the use of different burned areas products, land cover maps and emission factors, the "bottom-up" methodology was applied to investigate emissions uncertainties over Africa between 2001 and 2012, using MODIS burned areas product (MCD45A), Global Land Cover (GLC) vegetation map with the same emission factors. While Biomass density (BD) and Burning Efficiency (BE) used by Global Fire Emission Database version 4 (GFED4) are gridded at the spatial resolution of 0.25° x 0.25°, they are ungridded in the AMMABB and only exists as mean value for each vegetation class (Oleson et al., 1985, Mayaux et al., 2004). Therefore, BE and BD maps for AMMABB have been reconstructed to facilitate spatial comparison. Sensitivity analysis on vegetation parameters such as BD and BE factors used for the AMMABB and GFED4 were conducted. Thus, two emission inventories were then generated: the "AMMABB-like" and the "GFED-like" with respective to AMMABB and GFED BD and BE values. Although we investigated both gas and particles emissions inventories, our present focus are on black carbon (BC) and organic carbon (OC).

3. Results

3.1. BE, BD spatial comparison

BE values are greater in GFED4 than in AMMABB except in the Horn of Africa, where AMMABB BE are slightly higher (~20%). In central Africa and Sahelian regions they show close agreement. Differences are more pronounced in humid and dry savannah (5° N to 15° N; 5° S to 20° S and Horn of Africa) where relative errors are found to be above 60% in absolute value (Figure 1). Figure 2 shows that BD used in AMMABB are higher than those of GFED4 with relative errors above 60% except in central part of Africa where these errors are around 40%. Therefore, the product BE and BD spatial distribution reveals that despite some compensations, these values in AMMBB are higher than those in GFED4 (Figure 3). While over Sahel and southern part of Africa positive relative errors (higher than 60%) dominates, negative relatives errors are observed over central Africa and the Horn of Africa.

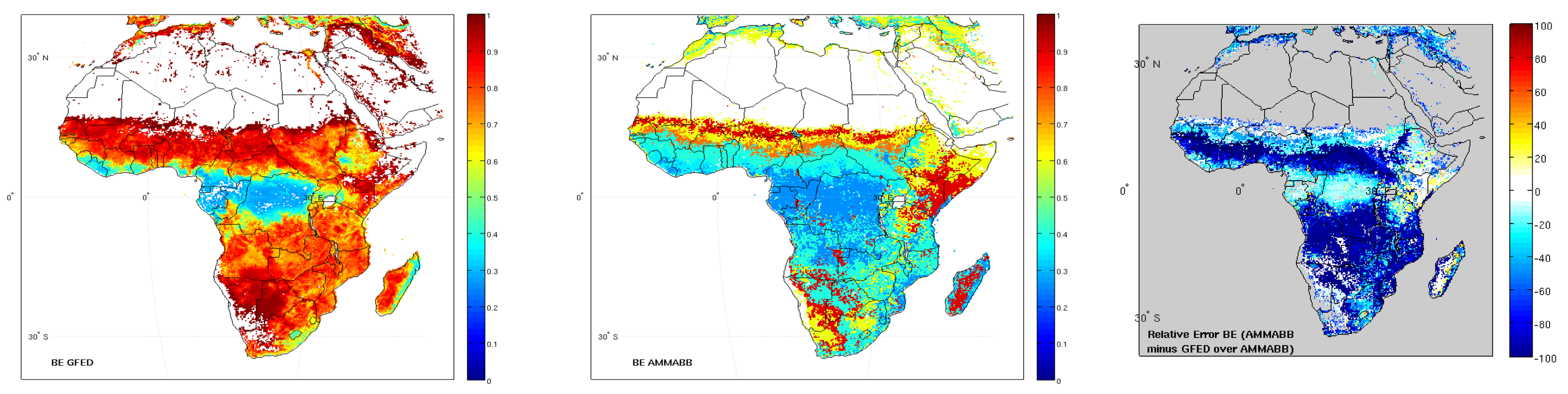

Figure 1: Comparison of BE spatial distribution from GFED4 and AMMABB and the corresponding relative errors in percentage.

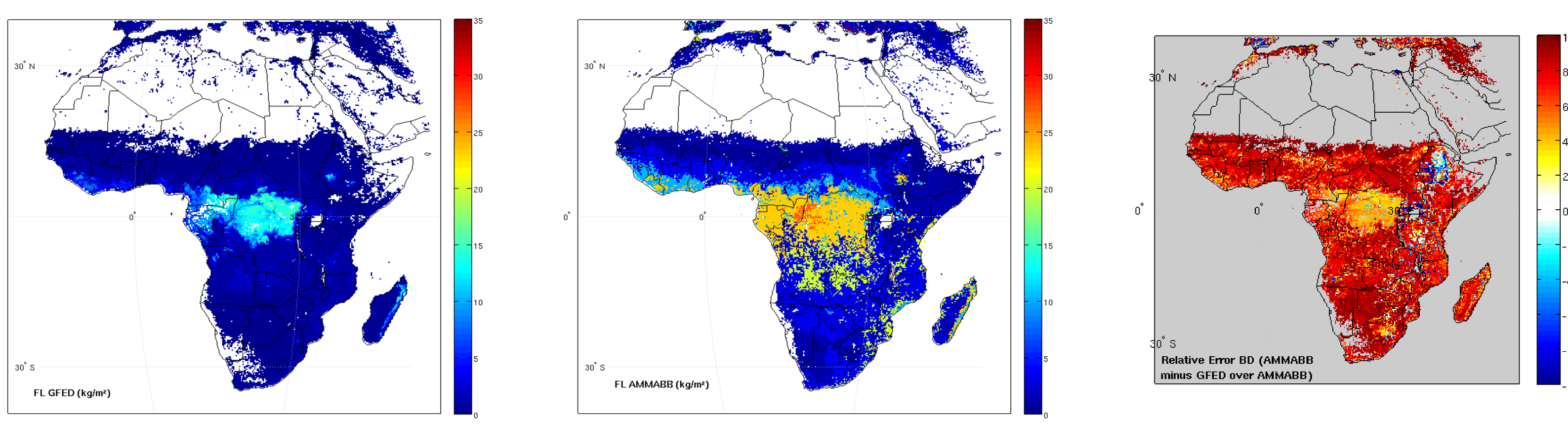

Figure 2: Comparison of BD spatial distribution from GFED4 and AMMABB and the corresponding relative errors in percentage.

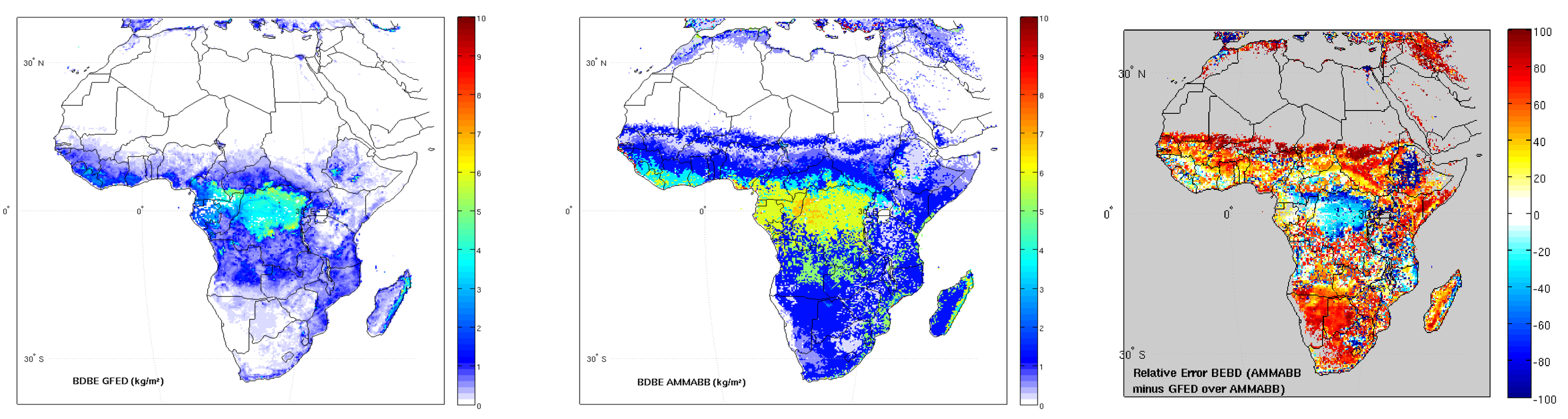

Figure 3: Comparison of BE x BD spatial distribution from GFED4 and AMMABB and the corresponding relative errors in percentage.

3.2 Burned vegetation

Year to year burned vegetation variability as shown in (Figure 4). Total burned vegetation per classes varies less in general during the study period. The vegetation class GLC12 (Shrub Cover Closed-open, Deciduous) is the most burnt over sub-regions Win09, Win10, Win11 and Win13 (See Figure 5 for the spatial extent), while GLC 3 (Tree cover Broadleaves Deciduous Open) is the dominated burnt class over sub-region Win12 and GLC13 (Herbaceous Cover Closed-open) is the main burnt vegetation in sub-region Win14. An increasing tendency in total amount of burnt vegetation is observed from 2009 in sub-region Win13 as against a decreasing tendency over sub-region Win09. Also, a similar decreasing tendency in total burned vegetation is observed over sub-region Win10 from 2010 to 2012.

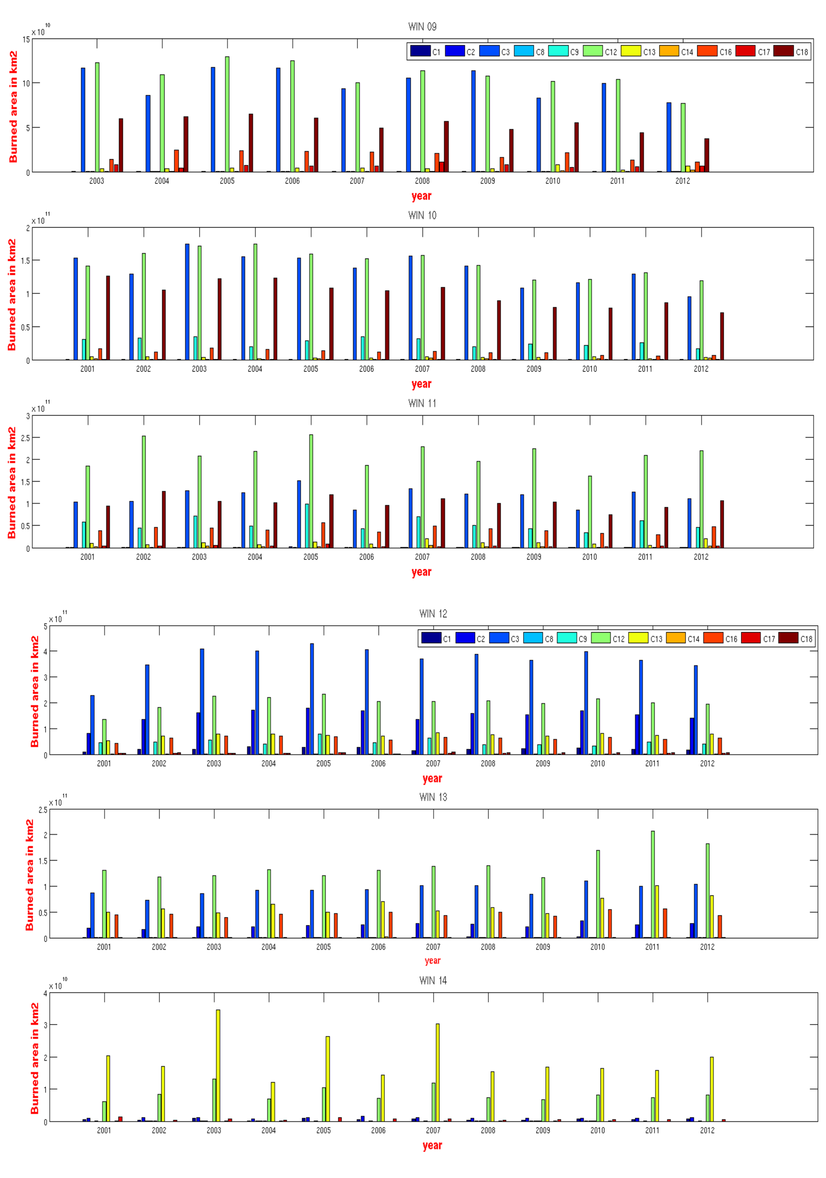

Figure 4: Yearly burned vegetation variability.

3.3 Emissions spatial distribution

Largest differences are observed between "GFED-like" and "AMMABB-like" during boreal winter and summer seasons which are associated with intense biomass burning occurring in northern and southern hemispheres of Africa respectively. This is coherent with previous studies using GFEDv2, GFEDv3 and AMMABB inventories (Liousse et al., 2010; Williams et al., 2012). Differences are more pronounced over the "hot spots". This implies that differences are not uniform in all GLC vegetation classes, some vegetation classes may impact more than others in the total emission.

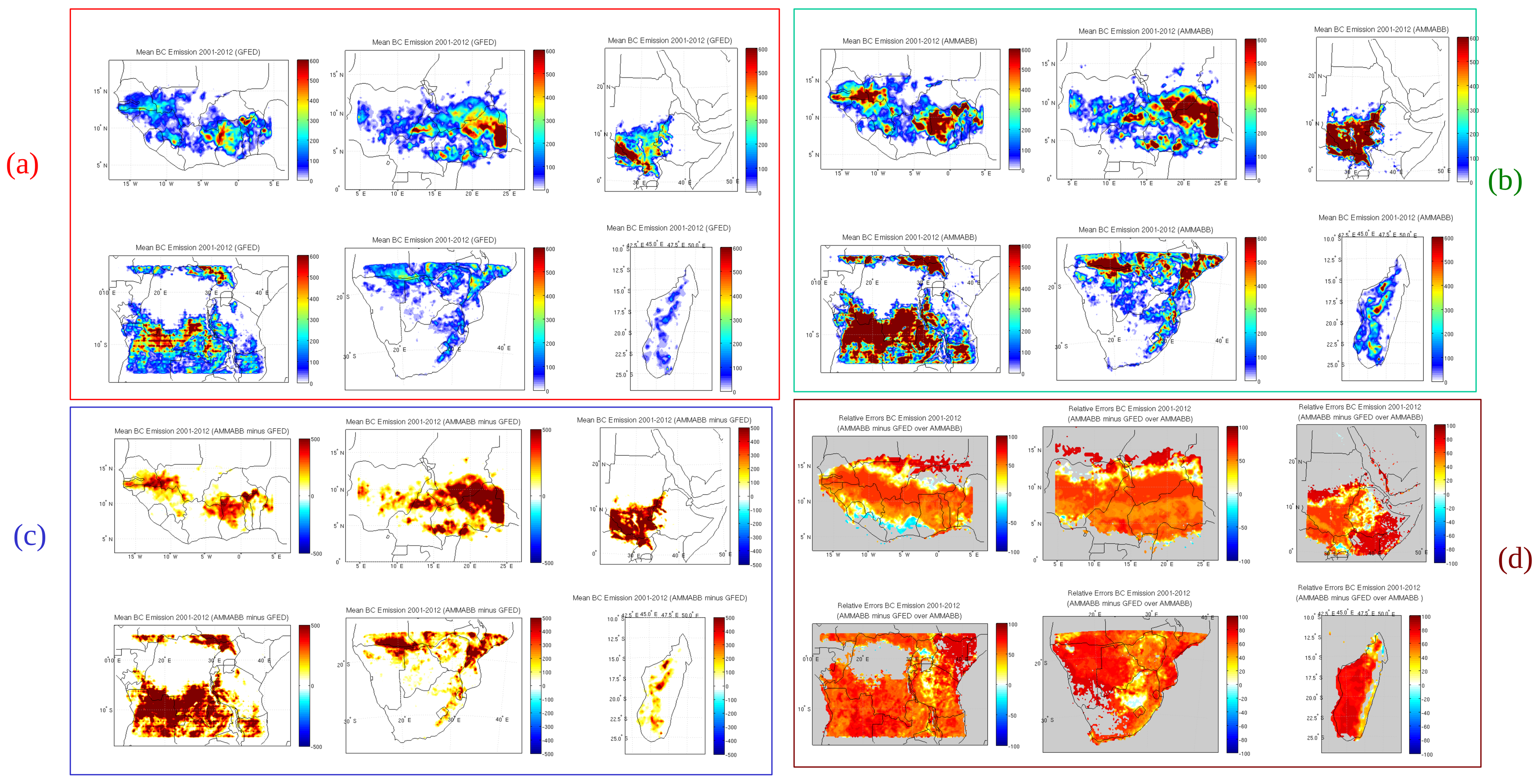

Figure 5: Spatial distribution of mean BC emissions using: (a) "GFED4-like", (b) "AMMABB-like" vegetation parameters. (c) Spatial distribution of BC differences between "AMMABB-like" and GFED4-like. (d) Spatial distribution of relative errors associated to BC emissions.

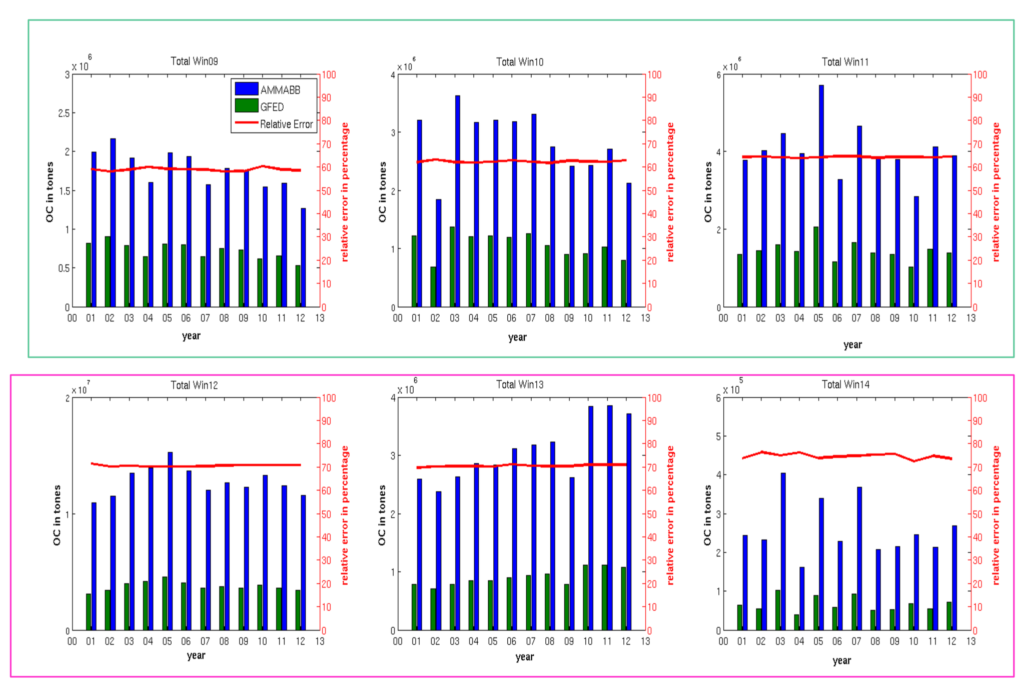

Figure 6: Total OC emissions and the corresponding relative errors in percentage.

3.4 Yearly total Emissions

Large differences were observed between reconstituted emissions "GFED4-like" and "AMMABB-like". Associated relative errors vary from 60 (northern hemisphere) to 75% (southern hemisphere) (Figure 6).

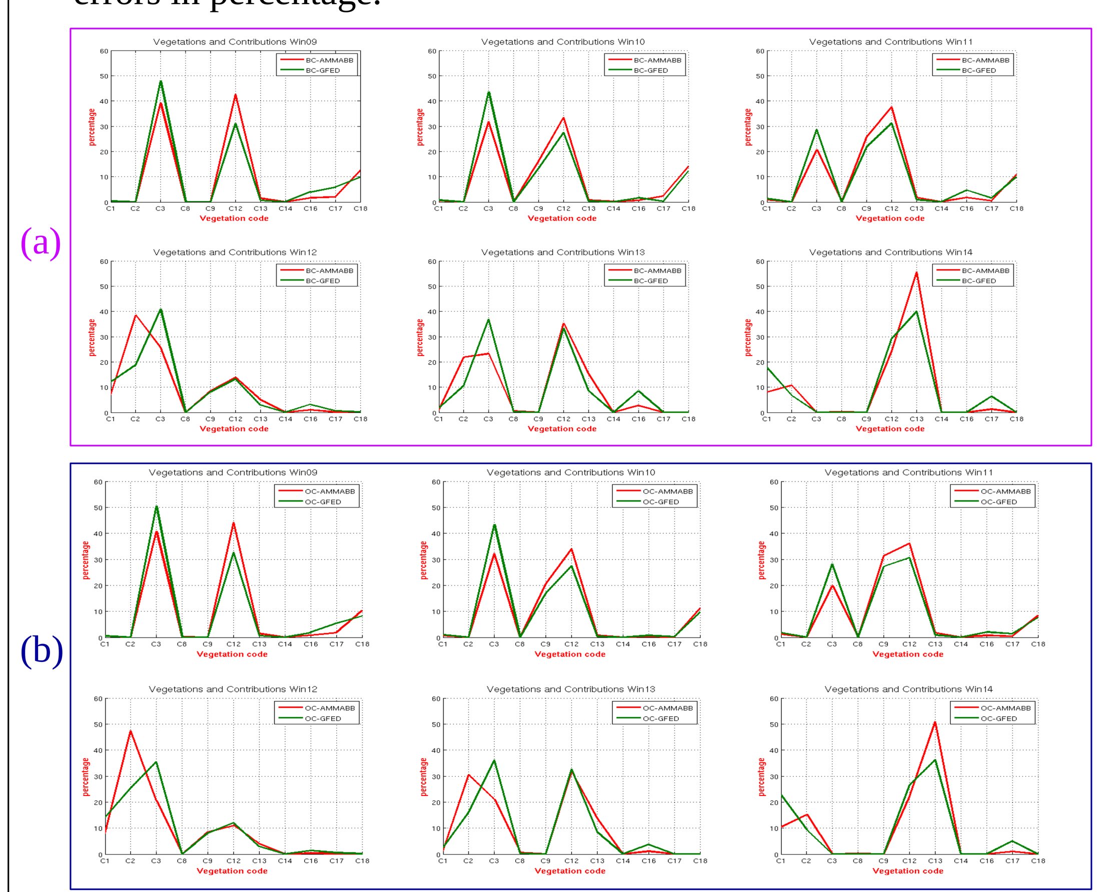

Figure 7: Vegetation types contribution to total (a) BC emissions and (b) OC emission for each African sub-region.

3.5 Vegetation contribution to emissions

Figure 7 shows that depending on the product ("AMMABB-like" or "GFED4-like") used, vegetation contributions to emissions are not the same. We suggest that vegetation class contribution to total emission is significant when their contribution is equal or higher than 10%. Therefore, the most important contributors to the observed differences between "AMMABB-like" and "GFED4-like" and their associated relative errors are in parenthesis:

Win09: GLC3 (94%) , GLC12 (84%), GLC18 (67%)

Win10: GLC3 (94%), GLC9 (69%), GLC12 (84%) GLC18 (67%)

Win 11: GLC3 (94%), GLC9 (69%), GLC12 (84%) GLC18 (67%)

Win12: GLC1 (44%), GLC2 (84%), GL3 (94%), GL12 (70%)

Win13: GLC2 (82%), GLC3 (94%), GLC12 (70%), GLC13 (82%)

Win14: GLC1 (44%), GLC2 (84%), GLC12 (70%) and GLC13 (82%).

GLC3 and GLC12 are common to all sub-regions. The highest rate of relative errors is found with GLC3 (94%) and the lowest for GLC17 (25%).

4. Conclusion: BD and BE are important parameters for biomass burning emissions in Africa and explain the large differences observed between "AMMABB-like" and "GFED4-like" emissions inventories using the "bottom-up" methodology. Relative errors related to the contribution of vegetation class emissions to total emissions varies between 25% for GLC 17 (Mosaic: Cropland/Tree Cover/Other Natural Vegetation) to 94% for GLC3 (Tree cover Broadleaf Deciduous open). We found that GLC3, GLC12, GLC13 and GLC18 are the main vegetation classes that explain the reported discrepancy factor of 2.4 between AMMABB and GFED2 inventories. Hemispheric-correlated discrepancies can also be noticed from this comparison. New BE and BD measurement would help decreasing such discrepancies.