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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global fire activity patterns (1996–2006) and climatic influence: ananalysis using the World Fire Atlas" *by* Y. Le Page et al.

Y. Le Page et al.

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We thank the referee for a helpful review which should bring significant improvements to the paper. As our reply required the use of Figures, which were not possible to include in the document, they are provided through an internet link. We recommend using Mozilla Firefox as we noted that Internet Explorer may experience some problems to properly display the Figures. Comments are in Italic, preceded by C, responses preceded by R.

General Comments

C: *Thanks to satellite derived fire information much is known about spatial patterns and interannual variability of fire. The authors use the longest timeseries available* *and apply sophisticated statistical techniques to further decipher spatial and temporal patters. The paper certainly deserves to be published in ACP because of the thorough analysis and the highly interesting statistical techniques used, which confirm some expected and also highlight new less expected patterns which are of interest to a wide range of people interested in fire. The paper is well written and the authors make good use of existing literature on the subject. I found the introduction lacking some coherency though, especially the first three paragraphs could be written more to the point and towards the objectives of the paper.*

R: The introduction has been modified, focusing more on features related to the objectives of the paper.

Specific Comments

C: *The strength and innovative part of the paper may also be its weakness; the statistical approach to better understand the spatial and temporal fire dynamics are exciting but they also leave the reader often wondering what their meaning and implications are. Everyone understands EOF1, but how about the less obvious ones, what physical basis or implications do they have? A more thorough discussion than currently provided (for example similar to those about the different clusters) would improve the interpretability of the paper. Because this point is also brought up by another reviewer I would encourage the authors to address this during the open discussion time frame. By making full use of the ACP interactive discussion the paper may be further strengthened.*

R: The two reviewers suggested that the methodological section was lacking clarity, Sect 3.3 has been re-written to give the readers a clearer understanding of the implication of PCA (see reply to the other reviewer). The reviewer also proposed to discuss more thoroughly each one of the EOFs (only EOF1 and EOF2 are shown in the paper),

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to get a better grasp on their - "global" as we understood - physical basis.

We justify not discussing all EOFs by the fact that it would be very redundant with the clusters discussion. The clusters are generally driven by 2 to 4 EOFs (Figure 7 in the paper), one being generally dominant, and thus the discussion about the clusters would overlap for a large part with a discussion about the EOFs. As an illustration, this is the case for Cluster 1, mainly driven by EOF1, both highlighting the same regions and temporal patterns. Cluster 3 and EOF2 also show similarities. Although this may be less evident for some clusters, discussing each EOF would not bring much more information about fire variability and the driving patterns than presented in the discussion of each cluster in section 5.2.

The global physical basis of each EOFs is highlighted with EOF1 and EOF2, their fire pattern being related to El Niño and time lagged worldwide impacts. EOFs 3-8 are not interpretable on such a global scale. They often represent various former reported fire events (either separated in time for the same region, or simultaneous for different regions), but with no common driving mechanisms, as is also the case for some clusters (CL4, CL7). No "global" meaning can thus be attributed to those EOFs, which contribute to reducing the dimensionality of the data by gathering those various events.

In the paper, besides the new Sect. 3.3, we added in the result section (Sect. 4.1 Deseasonalised EOF fire count analysis) after EOF1 and EOF2 description:

The various regional fire variability patterns represented by later EOFs, also merged through the PCA because of their spatial or temporal coherency, do not show such a coherent global driver as EOF1 and EOF2. Most of the patterns highlighted by these EOFs are however supported by former publications, although also several new features were found. They are further depicted through the clustering procedure (Sect. 4.2) as a base for a more detailed discussion (Sect. 5.2).

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C: *Another point of criticism would be that the ATSR data only detects fires at night time. Also, fires are only detected when the sky is cloud free. This itself already amplifies the number of fires seen during drought periods which are often accompanied by more cloud-free days. Both points are briefly addressed in the text, but it left me wondering what the influence really is. One potential solution is to also do the analysis with TRMM fire count product (Giglio et al., 2003), which sample the whole diurnal cycle and are corrected for clouds, and see whether the patterns are similar to those derived from ATSR. A caveat would be that 1997 is not included in the TRMM product and that it only covers the tropics and subtropics. Not sure how much the shorter time period would impact the analysis, although it would also be interesting to see how the analysis would change when excluding the extreme 1997-1998 period. If this can be done without too much work, it may improve the impact of the paper.*

R: More recent sources of active fire observations detect more fires than the ATSR product we have used here. ATSR-2/AATSR data, being acquired at night, under-represent fires in Africa, due to a strong diurnal cycle, low fire intensity and low nighttime activity, while TRMM characteristics reduced those biases (see below). The more recent MODIS data are up to now the most comprehensive global fire product available. However, these newer products lack the long time period or the global extent. For our purposes, a longer time period was crucial and we opted for the ATSR data. We have used anomalies, suggesting it decreases the bias due to varying detection rates, i.e. although ATSR may detect fewer fires, we take heart in the fact that the spatial and temporal variability found by ATSR matches satisfyingly that of newer products. We have compared fire representation (both incidence and variability) from the following 3 fire products for their overlapping period (01/2001 8211; 06/2006) and spatial extent (tropics and subtropics) to support this statement:

- ATSR active fires, overpass at 10pm locally, 3-4 day revisiting period, screened.
- TRMM active fires, overpass drifting each day, completing a daily cycle in 46 days, 1 to 2 observations a day (Giglio et al., 2003).

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- MODIS, burned areas estimated from MODIS daily active fires calibrated to MODIS 500m burned areas (Giglio et al., 2006).

For each of these, the total monthly fire activity was computed. The anomalies (without deseasonalisation) of the resulting global time series are shown in Figure 1a (http://docs.google.com/Presentation?id=dgtrfhtm_93gs3d9hn), to illustrate the detection rate variability among the sensors. Annual anomalies on complete years (2001-2005) are also provided (Figure 1b). We then deseasonalised and standardized each grid cell time series, as done in the paper, and compare their correlation coefficient between paired fire products, to study the influence it may have on our analysis (Figure 2, http://docs.google.com/Presentation?id=dgtrfhtm_93gs3d9hn).

Figure 1a clearly reveals that the time period with highest fire activity varies between the different products. Especially, estimation from the MODIS burned areas situates this peak over November-January, while it occurs around July-October according to the 2 active fire products. Fires in November to January mainly occur in sub-Saharan Africa, which confirms their under-representation in the WFA, and in a less extent in TRMM-VIRS data (which generally shows a corresponding higher peak). Sub-Saharan fires under-representation is due to the combination of:

- The relationship Burned area=f(active fires) is not constant over the ecosystems. It strongly depends on fuel loads, soil moisture and resulting fire spread speed and intensity. During an intense forest fire, active fires products, based on temperature threshold, have a good detection rate, while fire spread speed and thus burned area per day is relatively low. During a lower intensity grassland or savanna fire, like most of sub-Saharan fires, active fire products have a lower detection rate due to reduced temperature, while spread speed is generally high, resulting in large burned areas per day.

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- The satellite overpass timing further strengthens the bias considered above, mainly in the case of the WFA. Data are indeed acquired at nighttime, when a high proportion of forest fires keeps burning, while many grassland or savannahs fires do not. This increase the bias towards forest fires for the WFA.

Figure 1b illustrates the total annual anomalies (2001-2005), and suggests that the WFA raises significantly different results. Unlike the two other products, the year 2002 is shown to be the most active in WFA. This is likely to be the result of the global partitioning of fires this year, with forest fires in South East Asia and South America being favored by El Niño conditions, and another positive anomaly in boreal forests (see Discussion in the paper). As expected from the satellite characteristics discussed before, the yearly number of active fires in the TRMM-VIRS data is 3 times higher than in the WFA.

Figure 2 indicates that while TRMM-VIRS data may give a more balanced representation of absolute fire activity in different ecosystems than the WFA, their correlation with a burned area product is very comparable, although a slight improvement is observed with TRMM-VIRS over sub-Saharan Africa and Northern Australia. The maps suggest a positive correlation in most cases, in spite of the clearly inconsistent detection rate, supporting our assumption that anomalies reduces this divergence.

C: *It would also be interesting to see how the analysis would change when excluding the extreme 1997-1998 period.*

R: In the paper, p 17316, l.17, we added: The sensitivity of those regions to El Niño was tested by repeating the same analyses over 1999-2006 only, thus removing the extreme event of 1997-1998. The results (not shown), indicate that cluster 1 is merged with cluster 4 (see below), also showing a positive anomaly during the 2002 El Niño.

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This suggests a recurrent impact of ENSO on fires in Indonesia and South America, as was also indicated by EOF1 (Fig. 5). Clusters 2 and 3 do not show this sensitivity to weaker El Niño events.

C: *Justify more clearly why LEV is used, this gives more weighting to extreme events which are certainly more interesting, but this may make for an underrepresentation of the dominant fire patterns.*

R: The justification of using the LEV diagram has been rewritten within the new Sect. 3.3.

C: *17310: "The relatively low value of retained variance indicates that the dimensionality of space-time patterns of global fire anomalies is intrinsically high."; Please discuss what this in less abstract terminology means, i.e. what implications does this have?*

R: Replaced by: The relatively low value of retained variance from 9 EOFs indicates that fire anomalies are very scattered in time and space. They are less easily represented by a few dimensions through PCA than for example temperature, which classically has larger scale patterns and exhibits higher proportions of variance explained by the first EOFs.

C: *17305: "This product inherently screens out small, short duration fire events, mostly set for land use management. This was not considered very limiting since by considering anomalies" Daytime fires are not only limited to land use management fires, also other fires show a very strong diurnal cycle. In general, savanna fires have a stronger diurnal cycle than forest fires so these forest fires may be overrepresented in the ATSR product. This should be acknowledged in the text, and the implications*

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acknowledged. Even though the authors base their analysis on anomalies I still think the potential overrepresentation of forest fires may impact the analysis

R: This suggestion has been partly fulfilled in the comparison of the WFA with TRMM-VIRS and MODIS data (Sect. 3.1). Besides, in the same section, the following paragraph:
"We selected the WFA for its consistency, and the period of data available, which includes 2 minor El Niño events, and the large El Niño event of 1997-1998 followed by an equally important La Niña episode. This product inherently screens out small, short duration fire events, mostly set for land use management. This was not considered very limiting since by considering anomalies, the main results from our study are unbound to the absolute fire activity. Larger fires are also more likely to be under strong climatic control."

Was replaced by: We selected the WFA for its consistency and the period of data available, which includes 2 minor El Niño events (2002 and 2005), and the large El Niño event of 1997-1998 followed by an equally important La Niña episode. The WFA product inherently screens out small, short duration fire events, mostly land use management and savanna fires, which show a strong diurnal cycle and do often not burn overnight. Those fires are thus likely to be under-represented. However, because we based our analysis on anomalies, we reduced the dependency of our results to the absolute fire activity. Larger fires are also more likely to be under strong climatic control.

Technical Corrections:
- 18310 "exclusively in regions" -> exclusively on regions
Changed

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- 17311 "in equatorial Asia and northern South Brazil". I assume you mean northern South America here?
Yes, northern South America, it has been changed.

-17304: "During the years 1940 to 1998, 15 out of the 17 biggest fire years occurred under moderate to strong El Niño and were responsible for 63% of the area burned over the whole period." Add that this applies to Alaska, the reader may think it concerns the globe
Changed

-17305: "MODIS is only available since November 2000" early 2000 is also available
Changed

-17307: "There is another depression in the data over the equator, in spite on the strong 1997-1998 ENSO, because those fires are sporadic, only occurring under strong droughts, while at tropical latitudes, extensive savannah burning occurs regularly on an annual basis" Please split into two or three sentences.
Replaced by: There is another depression in the data over the equator, in spite on the strong 1997-1998 ENSO. Fires in most of those regions are sporadic, only occurring during strong droughts leading to low levels of moisture allowing for fire spread. Conversely, over tropical regions, extensive savannah burning occurs regularly on an annual basis due to the succession of wet and dry season and to agricultural activities.

-Fig 1. Negative anomalies are not shown, please consider replacing the graph with a color graph or add this caveat to the figure legend.
Negative anomalies mostly belonged to the same interval on the graph contour categories, much weaker than positive anomalies. We changed the legend to indicate

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this accordingly.

-Fig. 6: please add a legend to the x-axis
Added

References
TRMM and MODIS

Giglio L., Kendall J.D., Mack R.: A multi-year fire active dataset for the tropics derived from the TRMM VIRS, International Journal of Remote Sensing, 24:22, 4505-4525, 2003.

Giglio, L., van der Werf G.R., Randerson J.T., Collatz G.J., Kasibhatla P.S.: Global Estimation of Burned Area using MODIS Active Fire Observations, Atmospheric Chemistry and Physics, 6, 957-974, 2006.

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