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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 reviewer for his or her very valuable observations about the paper. Comments are in Italic, preceded by C, responses preceded by R.

General Comments

C: *The present paper makes use of the European Space Agency's World Fire Atlas (WFA) active fire dataset over a period of 10 years (1996 - 2006) to investigate temporal and spatial variations of fire occurrence, to identify areas with similar fire behavior, and to investigate climate influence on global fire patterns. The authors make use of EOF statistics and a cluster method to analyze WFA data. The performed analyses point out the role of ENSO on global fire variability. The study is interesting in* *general and particularly helpful for users of the WFA product. The paper is generally well written and I recommend its publication in ACP after some improvements.*

Specific Comments

C: *Since you are dealing with a global fire product I suggest using another expression than "Wildfires". In literature the word "wildfires" refers mostly to describe hazardous temperate or boreal forest fires. Since you deal with all kind of different fires the expression "wildland fire", or simply "vegetation fire" would be more correct.*

R: The expression "wildfires" was accordingly replaced by "vegetation fires".

C: *In my opinion the methodology part requires a better description (section 3). I suspect that many readers of ACP are not totally familiar with the applied statistical methods. In particular the "Standardisation" of the WFA exploratory analysis (section 3.2) is not totally clear to me, and the PCA description and cluster procedure is hard to follow (although the general purpose is clear). Maybe one or the other formulae would help a better understanding.*

R: We agree with the reviewer and an effort was made to improve the presentation of the statistical procedures as well as to explain why they were adopted.

1/ Standardisation

Pre-processing of data was done as follows:

Step 1, deseasonalisation: for each grid cell, we have removed from the time series of monthly (sect. 3.2, exploratory analyses) or seasonal (sect. 3.3, PCA and Clustering) values the presence of the annual cycle. This was achieved by subtracting to every monthly (seasonal) value of the time series, at a given grid cell, the grand mean of the corresponding month (season) for the considered 10-year period. Through this procedure, the obtained time series is deseasonalised in the sense that monthly (seasonal) values are replaced by monthly (seasonal) deviations from the grand means of the respective month (season) over the 10-year period. Therefore grand means of

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each month (season) of the deseasonalised time series will be identically zero.
Step 2, standardisation: for each grid cell, each monthly (seasonal) value of the deseasonalised time series (as obtained in step 1) is further divided by the standard deviation of the corresponding month (season) computed over the considered 10-year period. This procedure removes the effects due to the different magnitudes of inter-annual variability of each month (season) along the year. Each month (season) of the normalized time series will have therefore zero mean and unit standard deviation, for all grid cells.

As opposed to deseasonalized time series (which have the same physical units of the original time series), standardized time series are dimensionless; in fact, deseasonalized time series are sequences of absolute deviations whereas normalized time series are sequences of relative deviations. Normalization of time series ensures that differences in the average levels of fire activity on different grid cells do not have any impact on the overall results.

The following portion of the manuscript in section 3.2 of the original version of the paper:

"As we are interested in anomalous fire events, the fire seasonal cycle was removed by subtracting the 10-year mean monthly values. Standardisation of each grid cell time series was considered necessary, so that fire-sensitive ecosystems, rarely affected by fires but with less ability to rebound compared to other fire-dependent ecosystems (The Nature Conservancy, 2006), are not ignored. The only weighting factor applied after standardisation is the percentage of continental surface of each grid-cell containing ocean or inland water bodies."

was replaced by the following text:

As we are interested in anomalous fire events, the time series at each grid cell were deseasonalised, i.e. seasonal cycles were removed by subtracting to each monthly value the grand mean of the corresponding month for the considered 10-year period

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(Eq. 1.)

Eq. 1. Fds(m,y)=F(m,y)-$\Sigma(F(m))/10$

where F and Fds are respectively the fire activity and deseasonalised fire activity, at month m of year y in a given grid cell. Time series were subsequently standardized, i.e. each monthly value of the deseasonalised time series is further divided by the standard deviation of the corresponding month computed over the 10-year period (Eq. 2.). Standardisation was performed with the aim of enhancing those fire-sensitive ecosystems that although being rarely affected by fires possess less ability to rebound compared to other fire-dependent ecosystems (The Nature Conservancy, 2006). A weighting factor given by the percentage of continental surface of each grid-cell containing ocean or inland water bodies was finally applied to each standardized value (Eq. 2.)

Eq. 2. Fa(m,y)=Fds(m,y)/$\sigma(Fds)xLp$

where Fa is the anomaly, at month m of year y at the considered grid cell, sigma is the standard deviation of Fds of the considered month over the 10-year period and Lp is the land proportion in the grid cell.

2/ PCA and clustering procedure

We agree that our description may be improved in terms of clarity, and that the clustering method paragraph is too short. Because the objective here is to present a graspable definition of the method, and not to detail the whole mathematical process, we kept the section without equations. Readers who want to go deeper within the applied statistic methodology should easily find more information from the references given in the paper. Accordingly the whole section 3.3 was rewritten as follows:

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3.3 Principal Component Analysis and clustering procedure

Principal Component Analysis (PCA) is a multivariate statistical technique whose aim is to extract spatio-temporal information when dealing with datasets formed by a large number of variables that are not statistically independent. This technique allows computing an optimal new system of uncorrelated variables, referred to as Principal Components (PCs). Each PC is expressed as a linear combination of the original variables, the coefficients of the linear combination being referred to as the Empirical Orthogonal Function (EOF) of the corresponding PC. Since PCs are uncorrelated, the total variance of the original dataset may be expressed as the sum of the variances of each PC. PCs are usually ranked in terms of decreasing explained variance and the dimensionality of the dataset may be often reduced by retaining a relatively low number of PCs that explain a sufficiently high part of the total variance. Additional information on PCA applied to geosciences may be found in standard books, e.g. Wilks, 2005; von Storch and Zwiers, 2002.

PCA is a purely statistical procedure, in the sense that it is entirely based on computing the eigenvectors and eigenvalues of the covariance (or correlation) matrix of the data. However the first EOF/PC pairs often reflect physically meaningful patterns, which are associated to physical mechanisms whose signatures in the dataset are captured by PCA. When such is the case, besides reducing data dimensionality, PCA leads to a better characterisation and understanding of the original dataset.

As a first step, WFA data were seasonally aggregated (DJF-MAM-JJA-SON), in order to reduce the matrix dimensionality without loosing too much temporal resolution. The same pre-processing as described in the previous section was also applied to seasonal time series, i.e. data were deseasonalised and then standardized, the applied weights accounting as before for the continental fraction of each grid cell. Given the usage of a latitude-longitude grid, and because each grid cell is considered on an individually basis (i.e. no latitudinal aggregation), dependence of size on latitude was also taken into account. The final data matrix contains 2200 pixels (spatial dimension) and covers

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40 consecutive seasons (temporal dimension), from June-August 1996 to March-May 2006.

Since there is no optimal criterion to decide on the number of PC/EOF pairs that ought to be retained (Wilks, 2005), and taking into account that the aim of our study is to retain the most outstanding events, (and therefore not to maximise the variance explained), we adopted the approach based on the so-called Log-Eigenvalue (LEV) diagram (Craddock and Flood, 1969). The concept behind LEV is that the more dominant events represent a large proportion of variability, whereas the others explain an exponentially decreasing proportion of variance that appears as a decreasing near straight line towards the tail of the LEV diagram.

In order to further highlight the main modes of variability and better characterise their spatial organization, we peformed a cluster analysis on the space of retained EOFs (spatial patterns). For this purpose, we used a hierarchical clustering procedure, i.e points were incrementally merged into clusters, from singletons (i.e. cluster with one grid cell) up to one single cluster at the last step. The chosen merging procedure is based on the Ward's linkage method, that uses the increase in the total within-cluster sum of squares as a result of joining two clusters (Ward, 1963; Milligan, 1980). The resulting cluster tree allows identifying the loss of information from step to step, and in particular those merging steps that lead to high increases of the linkage distance. The cluster tree is accordingly used as a support to decide on the final number of clusters to be retained. Our discussion of spatial and temporal patterns of global fire activity, as well as on their relationship to climate and land cover, is ultimately structured around the resulting cluster map.

Minor Comments

C: *p. 17301, l. 24/25:ENSO teleconnections, i.e. statistically significant links in atmospheric interactions between widely separated regions, appear to be stronger throughout the tropics and in parts of North America and Oceania (Glantz, 2001). why? - Explain.*

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R: The location and intensity of atmospheric anomalies associated to ENSO is nowadays well understood but mechanisms involved are complex and their description is beyond the scope of our work. However we have tried to improve the text, which was modified as follows:

The above-described meteorological anomalies associated to ENSO are usually referred to as teleconnection patterns, which are characterized by recurring and persistent, large-scale patterns of atmospheric flow that encompass vast geographical areas and possess characteristic long time-scales of variability. Teleconnections are associated to statistically significant links between weather changes occurring in separated regions which, in the case of ENSO teleconnections appear to be stronger throughout the tropics and in parts of North America and Oceania (Glantz, 2001).

C: *p.17303, l. 12: Fire-ENSO relations are particularly strong, as would be expected, in SE Asia, and numerous studies have addressed the large fires during the two strongest recent El Niño events, namely in 1982-1983 and in 1997-1998 (Siegert et al., 2001; Schimel and Baker, 2002; Doherty et al., 2006). Why would that be expected, this is not intuitively clear.*

R: Replaced by: As pointed out in previous teleconnection studies, climate variability in SE Asia is highly determined by the ENSO signal. In particular, under El Niño conditions, rainfall is limited and long periods of droughts may be experienced, while La Niña generally implies wetter than average conditions. Fire-ENSO relations are thus expected to be particularly strong in this region, and numerous studies have focused on the large fires that were observed during the two strongest recent El Niño events, namely in 1982-1983 and in 1997-1998 (Siegert et al., 2001; Schimel and Baker, 2002; Doherty et al., 2006).

Technical Corrections

All of the technical corrections have been changed accordingly in the paper: *p. 17302, l. 5: insert "its" after "...impacts," l. 15: remove commas before and after "therefore"*

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p.17303, l. 15: remove "on" after "reported"
p. 17305, l. 3: for clarity better write: "We evaluated these datasets..." instead of "They were..."
p.17306, l. 3: replace "thresholdings" with "thresholds" l. 6: remove "the" before "date"
p.17307, l. 1: Replace "It" with "This feature..."
p.17309. l. 1: include coma after "Consequently"
p.17310, l. 5: delete "the" before "NOAA" l. 11: delete comma before "warm phases" l.21: replace "in" by "on" before "regions"
p. 17312, l. 6ff: put abbreviations for ecosystems in parentheses, remove the comas before the full name and delete semicolons l.18: replace "small" by "low" l.25: delete "as mentioned before"
p.17313, l. 1: put "be" after "also" l. 19: correct the "CO2"
p.17316, l. 17: expressions "and it hardly ever affected...", revise, very informal.
p.17317, l. 9: insert "be" before "an" Figure 2: legend: remove "the" before "NOAA"

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 17299, 2007.