Biogeosciences Discuss., 5, S2668–S2679, 2009
www.biogeosciences-discuss.net/5/S2668/2009/

Biogeosciences
Discussions

Interactive comment on “Annual and diurnal African biomass burning temporal dynamics” *by* G. Roberts et al.

G. Roberts et al.

Received and published: 12 January 2009

18b) Also, it remains unclear which method has been used, when reading the two sentences: The fact that so many fire pixels fail to be detected in more than on consecutive imaging slot suggests that harsh temporal filtering of the fire pixel results is not an appropriate method for minimizing false alarms over Africa. Instead detailed spectral and spatial filtering tests such as those used to derive the dataset used here should be employed. Was the harsh one used or not?

Here again the question from above comes up about the lateral length, whether it is of one pixel or it is the length of an agglomerate of pixels which allow recognition of a pattern. It would also be of interest to know how well two consecutive slots render the same area.

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The paragraph on page 3632/3633 has been rephrased to improve its clarity. We do not apply temporal filtering in our algorithm since the large number of active fire detections which persist for just one 15 min slot suggests that a temporal filter would remove a great number of real fire detections. Instead, the series of spectral and spatial thresholding tests, described in Roberts and Wooster (2008), are used to generate the active fire dataset discussed in this manuscript. Temporal filtering is used by the GOES ABBA Fire Detection Product, but over the region of South America, where it maybe necessary to limit the number of false detections and fire might be more persistent.

The paragraph now reads as :

Figure 6 shows information on fire pixel persistence, calculated as the number of consecutive 15 minute SEVIRI imaging slots that a fire pixel is detected at the same location. To a first approximation, the temporal pattern in the northern and southern hemispheres appears to be the inverse of one another, corresponding to durations being greatest during the period of peak burning in each hemisphere, and to the fact that outside of this period the majority of fire pixels are detected in only a single consecutive imaging slot. This pattern of short duration fire pixels outside of the peak fire periods is likely to be related to a combination of factors, (i) fires at this time may indeed last for shorter durations than at peak times due to non-ideal burning conditions; (ii) per-pixel FRPs tend to be lower at these times (Figure 4) and so more fire pixels approach the limit of detectability from SEVIRI, and thus they maybe detected on one slot but not the next even though they may actually still be burning; and (iii) cloud cover obscuration of fire affected areas increases outside of the main burning periods (Figure 2) and so may also lead to more intermittent fire pixel detections. It should also be remembered that fires move across the landscape as they consume fuel, and so in any case will not persist in one pixel indefinitely until the fire is extinguished. In addition to fire spread, the geometric stability of the SEVIRI dataset is also important to this analysis. The measured co-registration error of the SEVIRI instrument is typically less than 0.4km (at nadir) in both the north-south and east-west directions (EUMETSAT, 2006).

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The fact that so many fire pixels across Africa fail to be detected in more than one consecutive SEVIRI imaging slot suggests that temporal filtering of potential fire pixels during the fire detection process is an inappropriate method for minimizing hotspot false alarms in this environment. Fortunately the fire detection algorithm used here and detailed in Roberts and Wooster (2008) avoids this approach, instead relying on a series of detailed spectral and spatial filtering tests. The algorithm used to generate the GOES Automated Biomass Burning Algorithm (ABBA) fire products that cover the Americas (Prins and Menzel, 1992; Prins et al., 1998) does use a temporal filter to remove all fires pixels detected only once, but the conditions found over South Americas extensive and highly-cloud affected tropical forest region may make this approach necessary in that case.

19) page 3634 In which graph of Figure 7 do MOPITT surface data appear?

The MOPITT-derived CO mixing ratio data for 1000mb has been added to Figure 7.

20) The mean per pixel FRP could only be an indicator of combustion completeness, if fuel density remains constant.

The paragraph has been adjusted to reflect this :

This may in part be supported by the data of Figure 7b, which indicates that mean per-pixel FRP (which, assuming fuel density remains invariant, could be a potential indicator of combustion completeness) peaks at the same time as the CO concentration. Figure 4b indicates that this apparent southern African combustion completeness maxima is associated with simultaneous peaks in the per-pixel FRP data of grasslands and shrublands, though the former are burning a more significant amount of fuel (Figure 4a). The agreement between the trends in mean per-pixel FRP (i.e. the mean rate of biomass combustion per SEVIRI fire pixel) and the CO data suggests that with further refinement such FRP-derived measures might enable better parameterisation of emissions factor temporal evolution over the burning season.

21) page 3636 Is a notation like mgC/mˆ2/d is conform with SI rules? (Not more than one solidus should be used in the same expression unless brackets are used to eliminate ambiguity).

This has been corrected : mgC.m-2.d-1

22) S(d) has been explained but what is S(g.d)?

S(d) has been replaced with S(g.d)

23) page 3637 Could the absence of measured Fire Radiative Power during the night be due to pyrogenic haze formation in the shallow nocturnal boundary layer?

This seems unlikely. Smoke particulates are $<<$ 1 micron in diameter, and thus have relatively little effect on the MIR (3.7 micron) wavelength channel used to detect fires from SEVIRI. Furthermore, Elvidge et al. (2001) show that the low-light level visible channel sensor on the DMSP satellites does indeed detect fires at night over Africa, a technique that would be significantly impacted by haze that will affect these shorter wavelength observations much more significantly than those in the longer wavelength MIR region. Instead the reason for the small amount of FRP observed at night is the fact that there are far fewer fires burning at night. The fire diurnal cycle determined for southern Africa using the TRMM sensor indicates the strong daily cycle of fires over the African continent, with very many fewer fires at night than by day (Giglio, 2007). So the absence of significant SEVIRI-measured FRP at night is a direct function of the fact that there are few fires at night - which itself is a result of (a) biomass burning in Africa having a strong anthropogenic input, such as agricultural clearing, which reduce into the evening; and (b) the meteorological conditions such as temperature, wind and relative humidity being much less conducive to fire activity at night. Results from MODIS confirm this. For example the plot below illustrates the magnitude of the SEVIRI and MODIS observed FRP over a 10° x 10° region of southern hemisphere Africa in July 2004. Though MODIS sometimes failed to view the entire area on some acquisitions, what is clear is that it also records nighttime fire activity as being very much lower than

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daytime fire activity, in full agreement with the SEVIRI results.

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A secondary reason is that since SEVIRI cannot easily detect fire pixels with an FRP $<$ 40 MW, and with what fires that are still burning likely doing so less intensely at night than by day (due to the aforementioned reasons), SEVIRI may miss a greater proportion of fires by night than by day when compared to the higher resolution MODIS sensor.

Elvidge, C.D., Nelson, I., Hobson, V.R., Safran, J., Baugh, K.E. (2001) Detection of fires at night using DMSP-OLS data. Global and Regional Vegetation Fire Monitoring from Space: Planning a Coordinated International Effort. Edited by Ahern, F.J., Goldammer, J.G., Justice, C.O. SPB Academic Publishing, The Hague, The Netherlands, p. 125-144.

Giglio, L. (2007) Characterization of the tropical diurnal fire cycle using VIRS and MODIS observations. Remote Sensing of Environment. 108. 4. 407-421.

24) Combustion completeness of 100% is difficult to believe. By discussing temporal behavior of biomass fires the patchiness, especially at sub-pixel scale, should not be forgotten.

The 100% combustion completeness estimate in the example provided is unlikely to be true, for a number of reasons detailed at the end of the paragraph. These are:

1) Errors in fire pixel detection by SEVIRI (commission and omission) 2) Error in the atmospheric correction of the FRP 3) Overestimation/underestimation of NPP and/or burned area 4) Violation of the assumption that no fuel was present in the areas left over from the previous years fire event

To improved the clarity of this section the paragraph has been rephrased to the following (and in accordance to reviewer #2 comments on this section):

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For comparison to these burned area/NPP estimates of fuel consumption, the time-series of SEVIRI-derived FRP observations were used to calculate total FRE and thus fuel consumption using Equation 1. An example fire is shown in Figure 8, where it can be seen that combustion rate is highly variable in time and falls to zero at night. Evidently the fire was actually still burning, but was below the SEVIRI detection limit, since the next day the fire signal returns. Similar diurnal patterns were observed for all fires examined, and during the course of this particular 16 kmˆ2 fire, 18.25 10ˆ6 MJ of radiative energy was detected by SEVIRI, equivalent to 6700 tonnes of fuel burned. The pre-fire fuel load density was calculated as 420 g/mˆ^{2}, making the total available fuel also 6700 tonnes. Thus this fire exhibits essentially full (100%) combustion completeness. Of course, there are uncertainties in the parameterizations made here, including in fire pixel errors of omission and commission, FRP atmospheric correction, NPP estimation and burned area measure. Furthermore it may be that significant fuel remained after the 2003 fire events and that this subsequently burned in the 2004 fires. Nevertheless, the agreement in fuel consumption estimates provided by the two completely separate approaches is encouraging. The full set of FRE-derived and NPP/burned area based fuel consumption measures are shown in Figure 9, and these again show in general a strong agreement between the two approaches.

25) One would like to see the error bars in Figure 9.

Error bars have been added to Figure 9. Quantitative uncertainty analysis has been carried out on the method for deriving FRP (Wooster et al., 2005). This indicates that, between fire temperatures of 600-1300K, the uncertainty in estimating the FRP using the MIR channel compared to the true FRP is between +/- 12.5%. The error bars associated with the FRP dataset are a constant 12.5% reflecting the maximum uncertainty with which the FRP is estimated. The error bars which are attributed to the NPP/burned area derived fuel consumption estimates are the lower (83%) and upper (98%) bounds of combustion completeness in this region which have been taken from the literature.

For figures refer to either reviewer1_point25.doc or bgd-2008-0090_reply_reviewers_comments.doc on the ftp site

Wooster, M. J., Roberts, G., Perry, G. L. W., and Kaufman, Y. J. (2005) Retrieval of biomass combustion rates and totals from fire radiative power observations: FRP derivation and calibration relationships between biomass consumption and fire radiative energy release. Journal of Geophysical Research. 110. D24311. doi:10.1029/2005JD006318

26) The fuel consumption densities generally increase with increasing landcover class woody cover could also simply be a question of available combustible mass.

The estimates of the amount of material combusted are generally greater in land cover types that potentially contain a larger proportion of woody material. The implication is that the fuel consumption estimates are greater because there is more fuel available to burn. It is recognized that this isnt always the case and to make this clearer the sentence has been rephrased :

Results are shown in Figure 10, and indicate that fuel consumption density generally increases with increasing landcover class woody cover - which could indicate the increasing availability of combustible fuel.

27) page 3638 Is the 9 of 309 g mˆ-2 significant ?

This has been changed to 300 gm2 in all instances.

28) If it is likely that a combination of false detections in the SEVIRI dataset and an underestimation of burned area in the GFED data set contribute to overestimation, how much likely is that for the other data? It is unfortunate for the reader to rarely find tools in terms of error margin discussions in this manuscript to assess the stability of the reported data.

We were talking only about possible reasons for these two grid cells being outliers. The errors of omission and commission, and SEVIRI FRP measurement uncertainty have been discussed earlier in the paper and in Roberts and Wooster (2008). There is no information on the uncertainties associated with the published GFED database. We have however added error margins to Figure 9 to aid the reader in understanding levels of uncertainties within our comparison.

29) The time axes look curious with equidistant ticks and labels sometimes 3 and sometimes 4 hours apart. Is it possible that the designation of NHA/SHA and red/black were mixed up?

The x-axis has been altered to contain equal time intervals between tick marks.

30) For Figures 11 and 12 again as for Figure 8, could haze formation prohibit signal reception on the satellite? The dying of the fires almost simultaneously with the onset of the evening/nocturnal stratification of the atmosphere may point in that direction, as does the breaking up of the nocturnal boundary layer in the morning.

This is discussed in point 23 above.

31)page 3639 It is indeed difficult to integrate the pattern found in the landcover types mangrove and croplands, woody vegetation, both red lines, into the given explanations as is said later on.

For a number of the land cover types, the temporal dynamics of biomass burning in one or other of the hemispheres are somewhat noisy. This results from the limited number of fire observations for certain land cover types, the major influence of cloud cover in a few of the classes, and the fact that in one of the hemispheres the % cover of certain of the land cover types is in any case rather low. Land cover types containing fewer than 1% of the total number of fire detections typically display the greatest noise in the temporal profiles. For example, this is illustrated clearly in the case of the cropland/woodland cover type, where the temporal profile in northern hemisphere Africa is comparatively smooth (and where this cover type contains 9% of the active fire observations). Conversely, for the same cover type in southern hemisphere Africa contains less than 1% of the active fire detections, and the temporal profile is rather noisy. With respect to the mangrove class, the diurnal pattern in NHA is principally defined by the high degree of cloud cover that builds up in these coastal regions during the day. This is discussed on page 3640, line 13. To further clarify these issues, the paragraph discussing Figures 11 and 12 has been refined to the following:

Figures 11 and 12 present, respectively, an analysis of the diurnal cycle of active fire detections and FRP for northern and southern hemisphere Africa. The data were derived using the full 2004 SEVIRI-derived active fire dataset, and are categorized by the GLC2000 land cover class. We follow the method of Giglio (2007), displaying the normalized temporal cycle, and the location of the cumulative 25th, 50th and 75th percentiles as vertical dashed lines. Figure 11 indicates that a strong diurnal variability exists in fire pixel detections, and for most landcover types this exhibits the form of a skewed distribution with reduced fire activity between around midnight and 7:00 am local time. This is followed by an often rapid increase in fires, peaking around 2:00 pm local time. Afternoons are mostly characterized by ever decreasing burning, but with a slope that is less steep than the increase seen in the morning period. Similar active fire diurnal cycle characteristics were noted by Giglio (2007) using data from the low-earth orbiting Tropical Rainfall Measuring Mission (TRMM) satellite. The matching FRP diurnal cycle is shown in Figure 12, and for most landcover classes closely mirrors that of fire pixel detections. Both parameters typically peak at the same time, although during the afternoon FRP typically decreases at a slower rate than does fire pixel detections. Difference between these parameters is more evident for certain landcover types, for example, swamp bushland/grassland display a decrease in the number of fire detections around midday, something that is not evident in FRP. In most cases the temporal distribution of active fire detections and FRP for a particular landcover type is similar in both hemispheres. However, the temporal dynamics of land cover types with few observations ($<$1% of total fire detections), such as croplands/woody vegetation (SHA) and swamp forest (NHA), display rather noisy temporal profiles. In the case of lowland forest and mangrove, the results appear biased due to these particular cover types being strongly affected by the build up of daytime cloud cover, such that the retrieved diurnal cycles tend toward the inverse of those of all the other landcover classes.

32) trajectory: see page 3636

The use of the word trajectory has been replaced with profile.

33) What is background in Figures 13a and b?

This was a plotting error which resulted in a shift. The background category (which includes cities and water bodies) should not have been plotted, whereas irrigated croplands should have been included in order to be consistent with Figures 11, 12 and 14. The figures have been revised, although this error has not changed the context of the discussion (detailed below).

Results are shown in Figure 13, and in general most land cover types can be seen to have a diurnal width of less than 5 hrs. The narrowest distributions occur for woodland, shrubland and closed grassland, at between 2 and 4 hours. This is consistent with Giglio (2007), who suggest the increased woody fuels can limit the periods of the day when combustion can occur. In contrast, open and sparse grasslands have a more uniformly distributed biomass burning diurnal cycle, with a diurnal width of 4 to 8 hours. Such herbaceous cover types contain a high proportion of finer fuels that are capable of drying rapidly, most likely enabling fires to persist in an intense manner for a longer period of the day. The diurnal distribution of biomass burning for the more herbaceous land cover types actually suggests two peaks, particularly so in the case of open grassland where mid-morning and mid-afternoon peaks are separated by a relative dip around midday (Figures 11 and 12). To some extent this phenomenon has been seen with regard to fire pixel detections in the previous work of Pack et al. (2000) and Giglio (2007), and a possible cause is the specific land management practices followed in both hemispheres and both parts of the day (i.e. reduced burning around midday, possibly due to reduced anthropogenic ignitions). Another possibility is fire detection bias due to the contrast between fire pixels and surrounding non-fire pixels (upon which the fire detection algorithm partly depends; Wooster and Roberts, 2008) being reduced around solar noon. However, since the twin-peak phenomena is limited to only one land cover class this may not be a reliable explanation.

34) page 3640 It is curious to find the maximum per pixel FRP to be typically twice that of the nighttime value, if Figures 11 and 12 show that the nighttime values are close to zero.

This finding is fully consistent with the evidence. Some fires burn into the night. There are however relatively few of these due to the nighttime atmospheric conditions of wind speed, air temperature and relative humidity that generally inhibit combustion. Therefore the total FRP of an area at night will be far lower than during the day since there are far fewer fires burning typically far more than an order of magnitude lower. Furthermore, those fires that do burn into the night typically do so at reduced intensities compared to the day, so the per-pixel mean FRP will be lower at night than during the day. We find the nighttime per-pixel FRP to be around half of that seen in the day, and this is the same result found by Ichoku et al. (2008) using MODIS data.

Ichoku, C., Giglio, L., Wooster, M. J. and Remer, L. A. (2008) Global characterisation of biomass-burning patterns using satellite measurements of fire radiative energy. Remote Sensing of Environment. 112. 6. 2950-2962.

35) page 3641 Does section 6 warrant the title of a discussion?

The title of section 6 has been changed to Conclusion

36) Are numbers of 8% and 6% of the total significantly different?

This has been reworded to the following : In both hemispheres, the majority (86%) of fire detections occur in woodland and shrublands , with croplands (8%) and grasslands (6%) contributing significantly less.

37) The references section has been poorly prepared. Fourteen citations do not appear in the text. Several have year mismatch, misspellings or are incomplete, in one, for

instance, an author is missing, in another one the year.

We apologise for this error and have corrected the mistake in the references.

Interactive comment on Biogeosciences Discuss., 5, 3623, 2008.