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Discussions

Interactive comment on "Biomass burning emissions estimated with a global fire assimilation system based on observed fire radiative power" *by* J. W. Kaiser et al.

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Thank you very much for this encouraging review and the thorough and constructive comments which will certainly make the manuscript much clearer. In the final version, we will address your comments (below in **bold face**) as follows.

p7340 L13 - change to "contained in the FRP observations", to make it clearer.

OK.

7340 L21 "by a factor" not "with a factor"

OK.

7341 L8 "particularly in the remote..." [lightening fires also occur elsewhere]

OK.

7341 L10 "..are experiencing an.."

OK.

7341 L16 "...of biomass burning, emissions monitoring and forecasting must be based on satellite observations of the currently active fires" [makes it clearer]

OK.

7343 L9 Please make it clear here what time period the values are being summed over (e.g. the summation in Eqn. 1)...or if it is variable say so [in Section 2.1.5 it mentions that the integration period is changeable...maybe here you can discuss the details of the influences of the different integration periods e.g. daily vs hourly etc.] Also - eqn 1 seems to have a dependence on the integration period used to ultimately calculate the daily values. For example - if the integration is performed on an e.g. hourly basis then $< F >$ will essentially be calculated on a per-MODIS overpass, except at high latitudes. This means that that theta will be âĹij constant for an overpass within the grid cell of interest, so $< F >$ will just be the sum of the FRP measurements within the cell. $< F >$j will be the sum of Fi. And we now average the 24 different $< F >$j values to get the daily average values. Now if the system was changed to a 24 hr integration. $< F >$ will be the sum of Fi weighted by the view zenith angle, which will vary considerably for a grid cell over multiple overpasses. So the $< F >$ will be heavily weighted towards those overpasses where the grid cell was near the swath center. This seems to mean that $< F >$ calculated from the 24 hourly observations will not equal $< F >$ calculated direct from the daily integration (notwithstanding the issue of the %of grid cell area viewed, which is a separate weighting fn over and above that based on the view zenith angle). Is this correct - and in any case

please clarify the integration period and the effect that varying it has.

We will add clarifying paragraphs along the lines below to Sects. 2.1.2, 2.1.3 and 2.1.5.

The summations in Eqs. 1–5 are done for each individual MODIS granule, which corresponds to a time period of 5 minutes. So, yes, we agree with the reviewer that θ_i is about constant within each cell of the presented presented grid with resolution of 0.5 deg and could be omitted in Eqs. 1-4. It is, however, important in Eq. 5 because γ_j is used in Sect. 2.1.3 to merge several observations from different MODIS granules with appropriate weighting. The dependence on θ is implemented in Eqs. 1–4 to allow the consistent processing on grids with coarser resolution, where θ might vary considerably within one grid cell. Furthermore, Eqs. 1–4 are defined in such a way that the daily GFAS data do not depend on how many satellite products are included in their summations, see Sect. 2.1.3.

In the presented dataset, GFASv1.0, all the gridded representations of the MODIS observations during each day (00-24 UTC) as represented by Eqs. 4 and 5 are merged using Eqs. 9 and 10 of Sect. 2.1.3. Since the θ-dependence in Eq. 5 compensates the multiple observations near the swath edge, the weights depend on the number of MODIS overpasses and the cloud cover of each grid cell, but not on the grid cell's position in the swath of any of the MODIS overpasses.

It should be noted that substituting Eqs. 4 and 5 into Eqs. 9 and 10 yields a set of equations of the same form as Eqs. 4 and 5 but with the summations over satellite pixels i replaced with nested summations over MODIS products k and their individual satellite pixels, say i_k. This shows that identical merged GFAS products for any given time period would be obtained if several individual MODIS granules were processed during the initial gridding step described by Eqs. 4 and 5.

To improve the clarity of the description, we will furthermore describe only the generation of merged day-time and night-time observations in Sect. 2.1.5 and move all the discussion of the influence of integration and summation periods to Sect. 2.1.3.

7343 L15 There are influences in MODIS FRP data away from the swath edge in addition to the "bow tie" effect. For example, Figure 8 in Freeborn et al (2010) : doi:10.1016/j.rse.2010.09.017 shows how the min, mean and max FRP per pixel varies depending on the location of the swath. Please comment on how the cosËĘ2(theta) weighting factor affects these metrics - i presume by downgrading the weights of these off-nadir observations when you are calculating the integration over time, which seems sensible.

The particular geometry of the MODIS instruments leads to a scan-to-scan overlap for off-nadir pixels. It increases with the viewing angle and is often called “bow tie effect” Wolfe et al. (2002), Freeborn et al. (2010, Fig. 1(b)). This leads to multiple observations of the off-nadir surface areas within each MODIS granule. When calculating the total FRP of a a grid cell, the duplicate observations of an individual fire should be corrected for. In Eq. 3, it is automatically corrected for because the multiple observations affect the multiple observations of the off-nadir of burning and non-burning areas are included in Eq. 2 in just the same way in which the multiple observations of burning areas are included in Eq. 1. Therefore, the FRP density ρ of an individual granule is not affected by the scan-to-scan oversampling of the bow-tie effect.

However, γ from Eq. 5 serves as weight when several MODIS overpasses of a grid cell are merged as described in Section 2.1.3. Without the factor $\cos(\theta)$, the multiple observations of off-nadir areas would increase γ, giving these observations more weight than the those observed closer to the sub-satellite track. We find that the factor $\cos^2(\theta)$ in Eq. 5 reduces γ to similar values across the MODIS scan; thus giving the combined multiple observations near the swath edges the same weight as the single observations near the sub-satellite track. In this sense, it compensates the bow-tie effect, which is shown in Freeborn et al. (2010, Fig. 8(c)). The θ-dependence does not compensate for the increase of the detection threshold towards the swath edges shown in Freeborn et al. (2010, Fig. 8(a,b)).

7343 L12 It is the "...total observed FRP, and total satellite observed area, within

each global grid cell.."

OK.

7343 L16 You could explicitly say that "These equations are weighted summations, where the COSËĘ2(theta) weighting factor approximately...."

OK.

7343 L19. This gamma_i [fraction of observed area in each global grid cell] appears to have values potentially greater than 1 - indeed on P7344 L 3 it says this explicitly. This is because whilst the grid cell has a fixed area, if there are many overpasses then a cumulative area greater than that of the whole grid cell might be observed. This needs some more explaining.

This is true. For each individual observation product, γ_i can become somewhat > 1 due to oversampling and the merging of several products covering the same grid cell leads to γ_i becoming much larger. The merging of observations from several overpasses is described in Section 2.1.3 and we will include an explicite statement there.

7344 L15 "non-fire" not "no-fire"

OK.

7346 L20 The link between "FRP=0 observations being included in the processing", and the "consequent avoidance of assumptions regarding the diurnal cycle" needs fur- ther explanation. Also, the time-step at which emissions are passed to the atmospheric model requires clarification. If the time-step is more rapid than the availability of MODIS data - which Figure 2 seems to show is only 1 to 2 observations per day for each grid cell (with the proviso given below on this metric) - then the mechanics by which the shorter time-step emissions are generated should be further highlighted. Figure 2 - on a related point to the one immediately above, what is shown is not exactly the "number of observations of entire grid cells" is it? Since P7343 states that the total observed area is "non

unique" then a grid cell with a "2" in Figure 2 could in theory be derived e.g. by the whole cell being observed twice, or by e.g. 40% of the cell being observed 5 times.

It may be clearer to address these comments in reverse order:

Figure 2 shows $\eta\tilde{\gamma}$, as stated on P7346 L16. $\eta\tilde{\gamma}$ is the ratio of the sum of the observed areas in a grid cell over the 24 hour time period and the land area in the grid cell area, with minor corrections by the weighting with $\cos(\theta)$. It is therefore an “effective number of obervations” of each grid cell and a grid cell with a value of “2” could indeed have been observed twice completely or, say, five times with 60% cloud cover.

Fig. 2 shows typically 1–2 observations of the entire grid cell area per day for each grid cell from each of the MODIS instruments. Taking both instruments into account typically yields between 3 and 4 observations per day, from which a single daily emission rate is derived for use in the atmospheric models.

We assume that the observations provide a sufficiently representative sampling of the diurnal cycle of the fires. With this assumption, the daily mean value of FRP is simply the mean of the FRP ≥ 0 observations. Thus any assumptions on the diurnal fire cycle or duration of the observed fires is avoided. The inaccuracy introduced by assuming that the fire observations are representative would clearly be reduced by also taking geostationary fire observations into account, which is planned for future versions of GFAS.

L7350 L13 Here it should be mentioned there that the 0.368 kg MJËĘ-1 conversion factor was calculated on the basis of ground based experiments linking direct FRP observa- tions of small-scale fires to their fuel consumption. Since the MODIS FRP observations for sure miss some proportion of "small fires", and have no atmospheric correction im- plemented within them, then the corresponding factor linking the GFAS FRP density measure to the ’true’ fuel consumption would indeed be expected to be higher than this. This links to the next

point below

We will add this discussion.

L7350 L15 Whilst this is a very good strategy for delivering a realistic fuel consumption estimate from the GFAS system, the explanation behind it could be a little clearer, as could the caption for Table 2. Specifically, these are the "conversion factors" that interconvert between the GFASv1 FRP density measure and the GFEDv3.1 emissions, and it is these conversion factors that represent the ratio between these two products has been shown to have a dependence on landcover type. Whilst it may very well be that the conversion factor that links FRP density to the "true" fuel consumption does indeed depend on landcover type, that has yet to be demonstrated and we cannot really say that currently. What we can say is that the conversion factor between these two products depends on landcover type, but this (or some proportion of it) could, for example, presumably come from the fact that the relationship between the GFED BB emissions of an area and the "true" emissions of the same area have a dependence of landcover type. This could be, for example, because the burned area measures used in the GFED emissions calculation are more or less accurate in different landcover types, or similarly the fuel load estimates in GFED are more or less accurate depending on the landcover type. The point is to state that the landcover varying conversion factors are required to get agreement between GFAS and GFED, they may or may not represent the actual physics of the conversion factors required to link FRP to fuel consumption [at the scale of satellite FRP observations].

Thank you very much for the endorsement of our strategy. We will add a more detailed interpretation of the derived conversion factors following your arguments: The conversion factors are indeed linking MODIS FRP as per GFASv1.0 with the dry matter combustion of GFEDv3.1. We subsequently need to assume that GFEDv3.1 is sufficiently accurately describing the real fire activity to interpret the conversion factors

as link between the MODIS FRP and the real dry matter combustion rate in order to ultimately calculate realistic smoke species emission rates.

Table 2: The caption for this Table should indicate that these conversion factors link be- tween FRP and dry matter combustion rate, where the former is FRP density calculated from MODIS as per GFASv1 and latter is calculated from GFEDv3.1

OK.

References

Freeborn, P. H., Wooster, M. J., and Roberts, G.: Addressing the spatiotemporal sampling design of MODIS to provide estimates of the fire radiative energy emitted from Africa, Remote Sensing of Environment, 115, 475–498, 2010.

Wolfe, R. E., Nishihama, M., Fleig, A. J., Kuyper, J. A., Roy, D. P., Storey, J. C., and Patt, F. S.: Achieving sub-pixel geolocation accuracy in support of MODIS land science, Remote Sensing of Environment, 83, 31–49, 2002.

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