1. Reply to Anonymous Referee #1

We thank the Anonymous Referee #1 for the comments provided. The answers are included in blue Italics.

Plants live or dead and their residues are the combustible materials that funnel wildland fires. The diversity of plants or even of vegetation types prompted the need of reducing them to a number of sizable classes, i.e. fuel types, that could be manageable for a number of practical uses in relation to fire modelling. Pettinari and Chuvieco present here a world classification of fuels using the Fuel Characteristics Classification System. The approach is not novel, and has been previously applied to other areas, including a full continent, by various authors including those of this paper.
Please note that the main author of the other paper was the same person, as both articles are part of the same research. The Pettinari et al. (2014) article was a first attempt to derive a global product using FCCS, taking a continent as a study case, and it allowed us to test the method and include several improvements for this global product that are specified in the manuscript in Section 4.1.

A main problem with this approach is that, while promising, validation for the various purposes that is supposed to be utilized for, are, for the most part, still wanting. Presenting a global map of fuels when the support for even those most common fuel types for which this approach was initially developed, is premature. Validations are needed for each of the specific purposes that such an approach is supposed to be of use. Extending the approach to the global fuels without specifically validating it at least in a representative number of fuel types in each biome is problematic since, if used in the future, it could provide results that may not be warranted. Moreover, fuel types are developed in a very deterministic way, without providing a range of values that would arise using the main combination of species. Such calculations could provide a very much needed uncertainty range. This, at a minimum, would provide a basis for assessing the validity of this product.
The limitations regarding the use of mean values of canopy cover and canopy height, as well as a small number of species, have been addressed in the manuscript. We will continue to work, as stated, on the inclusion of more local variability. The use of ranges of values could be a good approach, and we will definitively consider it for an update of the product. Nevertheless, we believe that the fuelbed map still provides useful information with the data it currently includes, and at a much higher resolution than the PFTs that are commonly used for global models.

As a validation exercise, the authors related their product for one of the variables they computed (e.g. biomass) using other products independently derived. While their results are more or less comparable, this cannot be considered as a true validation. Actually, some of the papers they cite did such a validation against true ground data and highlighted the differences between the various products and the true ground data. Having a global fuels map is something very much needed, but the basis of such map need to be firm, and to achieve that, real validations are needed. Without that, being this exercise a notable one, it falls short of the rigor that it is needed to be accepted as a true progress in this field. I can but encourage the authors to use existing database to test their results against field data, at a minimum in a number of representative sites and, at a minimum as well, for at least one of the main purposes for which this product is supposed to be used. After this is made the paper may be subject to critical review.
The comparison of our results with the biomass products was not a validation, but a first assessment of our results, which we consider to be acceptable at this stage. Any global dataset

requires a generalization of the parameters, and that will make it unfeasible to validate the results in local sites.
Regarding the test of the results for some of the main purposes of the product, we are currently working on another article using this fuelbed map, along with climatic information, to obtain fire behaviour parameters such as reaction intensity and compare them with other related information (fire radiative power) that could improve the assessment of our product. The description of the inputs used, the methodology and the results entail the writing of another article, though, due to the extent of the information to be provided.

Minor comments The paper is generally well written and to the point. However, I recommend the authors to give to read to a professional native speaker of English, to eliminate some of the minor errors that inevitably slip through.
We will follow your suggestion and have it revised once more.

Following are some minor comments.
P2 20: The justification of the significance of fire for the Earth system needs an appropriate reference. The figure provided about fires being significant in 30% of the land-surface is misleading, because it refers to grid-cells where fires occur. Please, reword for clarity.
This information has been changed, to exemplify the significance using total burned area, as follows: "Fire is an important process in the Earth system, and global burned area is calculated to be in the range of 300-380 MHa per year (Giglio et al., 2013; Alonso-Canas and Chuvieco, 2015)."

23: "..natural history" is unclear. Is man included? Please, reword for clarity.
We have deleted the word "natural", to include human induced ignitions.

24: "…altering vegetation succession by damaging some plant types while promoting others,.." is unclear. What is meant by altering vegetation succession? What is meant by damaging? Do you mean that fires have altered vegetation composition and that, as a consequence, vegetation succession pathways are altered? Please, clarify this sentence.
We have changed the phrase to: "… altering vegetation composition by preventing the growth of some plant types while promoting others…"

P3 1: You need not to be exhaustive, but I would add CO, as this is an important fraction of emitted gases during fire.
As CO is not usually considered a greenhouse gas per se (as we were exemplifying), we can include it in the list, deleting the reference to "greenhouse gases".

3-4: You confront vegetation characteristics and fuels as if they were different things, which they are not. Please, reword for clarity.
By conditions of the fuels we refer to the moisture, the proportion of live vs dead fuels, etc., which are not intrinsic vegetation characteristics and can change over time. To clarify the meaning, we have changed the sentence to: "The characteristics of the vegetation and the environmental conditions affecting the fuels are…"

7-8: "…based on their fuel elements." Not really. Based on the various fuels characteristics, which includes various elements. Please, reword for clarity.
To clarify this we have changed the word "elements" to "characteristics".

10-11: The reference you provide for Mediterranean ecosystems is misleading, since this refers to study done at a particular area, which may or may not fully represent such ecosystems. Please, reword for clarity.

As there are no peer-reviewed articles describing the Prometheus fuel types, the Riaño et al. paper is usually used for that purpose. We have also added the reference to the European Commission Project that developed this fuel classification (Prometheus, 1999), although we do not know if it can be accepted as a reference by Biogeosciences.

20-21: "fuel behavior"? Do you mean, "fire behavior". Please, clarify.

Yes, that was a mistake that has been corrected.

P4 14: "relied in the use" Reword to "on the use"

We have changed it accordingly.

28: "we created.." This is not correct, since the authors are different. Please, reword. The sentences that follow in this paragraph would also need to be reworded to avoid this misunderstanding.

The sentence has been changed to: "In a previous study, a fuel map for South America was created using…". We believe that the following sentences are appropriate, since the description of the methodology used to create the South American fuel map, as well as the discussion on the limitations and future improvements could be used by any researcher to better the product.

P5 24: "… allow running FCCS.." Unclear what is meant here. Please, clarify.

The sentence was changed to "The fuelbed parameters can be input in the FCCS software, and the results…"

P9 5: "…spread can occur.". Provide reference.

A reference to Prichard et al. (2013) has been included.

P10 15: ".. variables populated.." Unclear. Please, reword.

The word "populated" was changed to "assigned" to clarify the meaning.

P11 19-20: A critical point here is to determine the validity of the RS methods to assess biomass. The paper cited indicates that there are large discrepancies between RS (you use both approaches used in that comparison) and ground-based methods. It is unclear how these discrepancies so fundamental can be reconciled.

The two biomass maps described in the cited paper were derived from both RS and ground-based information (Mitchard et al., 2013). The authors of both maps used field plot data to obtain relationships between the field AGB information and GLAS footprints in order to extrapolate that AGB to the GLAS covered area. In that sense, the authors do not see the differences between the two sources of information as discrepancies, but as complementary data that can very well be used together.

We also believe that approach to be useful, being one of the main advantages of the use of RS for different applications: the possibility to extrapolate field plot information into large areas using the data provided by RS, always acknowledging the limitations of these approaches, which are being reduced as more research is done in this field.

2. Reply to Anonymous Referee #2

We thank the Anonymous Referee #2 for the comments provided and the positive review. The answers are included in blue italics.

This is very interesting and well documented work that proposes a methodology of analysis of vegetation cover data as an analogous to a fuel that can support vegetation fires (also designated as forest fires). It provides a good database on vegetation data at global scale that can be used for various purposes, namely for fire behaviour prediction. Being based in remote sensed data it can be updated in a relatively short period of time. Can the Authors provide some indication of the time or effort required to update the global map assuming that the same set of criteria are adopted?
If the land cover product was updated, using the same set of criteria it would approximately take a few months to create the new fuelbeds, as they will depend on the categories used (desirably the same LCCS classification), the minimum area of each fuelbed to decide if some fuelbeds should be aggregated, the minimum areas of fuelbeds of different canopy covers for the sub-fuelbed classification, etc. If only the canopy cover or canopy height products were updated, it would take a few weeks to update.
We are currently analysing approaches to further automate this classification and simplify further updates, but it is still a work in progress.

The application of the results of this study for fire behaviour prediction is justified if local more detailed data are not available. The Authors should nevertheless explain how this downscaling can be performed for a smaller area if a more detailed fuel map is required.
As we have stated in the other comments and in the text (P17 L21-24), the objective of this map is for global and regional applications, and is not intended to be used for local fire behaviour prediction. The global fuelbed parameters were created using mean information of canopy cover and height globally, as well as several representative existing fuelbeds of Photo Series. To obtain a local fuelbed map, we would suggest creating a custom map with the same methodology for the creation of the global map, using the same data sources (or even better, local sources of information if available). In that way, if mean values need to be obtained they would only include local variation and would better describe local conditions. Part of our current analysis of automation will tackle this issue.

The paper is very well written and well organized. It has some minor spelling errors that can be easily corrected by the authors eventually with the help of a native English speaker.
We will have the paper revised once more by a native English speaker to correct those mistakes.

Some aspects of the outputs of this work may not be fully validated like the parameters provided for fire behaviour analysis. But the fact that this work provides such data at a global scale is in itself of great relevance. I propose that the Authors give a name and acronym to their global fuel map. I recommend that this paper is accepted after revisions.
We could analyse the possibility of giving an acronym to the map.

Details:
Page 2 It is mentioned that "… fires have multiple biophysical and ecological consequences". Perhaps the authors should mention socioeconomic consequences as well.
We have added that to the text.

In the caption of Figure 4 classes A, B and C that were not mentioned or defined with these names in the main text.

We have included that in the explanation. The sentence in P9 L3 now says: "… the percentage of CC was subdivided into 3 classes: 0-40% (named class A), 40-70% (class B) and 70-90% (class C), as shown in Fig. 4."
Later in the text, in Section 3.1, the sub-fuelbeds are referenced with those letters (e.g. 1040a, 6091b, etc.

Remarks to other comments: Regarding the comment of P. Fernandes that the fact that the authors used the FCCS approach to select and present their fuel bed parameters is a limitation of the work and of its applications. I understand that the parameters that are provided are basic ones and can be used by other fire behaviour models rather than Rothermel. For example the assessment of crown fires requires parameters that are available in this database and not present in common databases. I recommend that the Authors justify better their option of selecting FCCS and explain if it is or not a limitation of the work.
We appreciate your comment. We have included some more information on the reasons for using FCCS in the answer to Dr. Fernandes (below), which could also be included in the text.

Regarding the objection made by Reviewer #1 about the lack of validation of the mm and on that it is premature to publish it without making this validation I do not agree with it. The paper is relevant for itself for proposing the methodology that has innovative contributions. Besides this any validation would require a couple of years to conclude and in the meantime the proposed maps would be outdated.
We very much appreciate your remark. As we have stated in the article in Section 2.3, a direct validation of the results is not viable because there are no other comparable global products, and the generalization required for a global product impedes the direct comparison with field plot information.
We continue to work on the analysis of our results, but as you say, it is still work in progress, that we plan to publish as another article.

3. Reply to Short Comment

Dear Dr. Fernandes,

Thank you for your comments regarding our manuscript. We appreciate your suggestions, but disagree on some of them.

Certainly FCCS is still less extended than other fuel classification systems, but it is being adopted by different forest fire managers and researchers in several US regions such as Washington, Oregon, California, Nevada, New Mexico and Arizona (http://www.fs.fed.us/pnw/fera/fccs/applications.shtml). FCCS has also been integrated into US National Applications. For example, LANDFIRE includes a 30-m fuel map based on the FCCS fuelbeds as one of its standard products. The Wildland Fire Emissions Inventory System (WFEIS) uses a 1-km aggregated FCCS fuel map at the base of their natural fuels emissions calculations, and FCCS is also integrated into the USFS BlueSky Modeling Framework. Other researchers have also used the Fuel Characteristic Classification System for their work, both at a national (Hudec and Peterson, 2012; Yue et al., 2013) and international scale (Choi et al., 2013).

All the modifications to the original Rothermel equations have been clearly described both in Sandberg et al. (2007) and in Prichard et al. (2013). The Rothermel models were developed for uniform continuous fuels, and are weighted toward fine fuels as the main carriers of fire (Rothermel, 1983). Also, the 13 Rothermel fuel models were designed for the severe period of the fire season (Anderson, 1982), but are not as adequate for other applications such as prescribed fires or assessing fuel treatments. They also do not describe fuels with higher live fuel moisture or that burn well at high humidity, which derived in the creation of other fuel classifications (Scott and Burgan, 2005) complementary to the original ones. FCCS, meanwhile, allows creating fuelbeds for environments not contemplated by the Rothermel's 13 models such as moist ecosystems, which are found in several parts of the world (mainly the tropics). This was one of the reasons why we chose this system for the creation of the global fuelbeds. Also, as FCCS includes a wide set of parameters, it has other applications besides predicting fire behaviour, such as giving information on potential crown fires, or estimations of biomass for carbon emissions, which we also considered an advantage.

The spatial resolution of the fuelbed map is of approximately 300x300 m (0.0027 degrees), as it is the spatial resolution of the land cover product that we used to characterize the fuelbeds (GlobCover, based on MERIS data). The aggregation of the biomass results to 0.5 degrees was only done to facilitate the comparison of the results with other products, as they have different scales. At our scale, we do not intend to be able to predict "real-world" fire behaviour at a local scale, especially considering that we are describing fuelbeds at a global scale, with the necessary generalization that that implies. For assessing realistically local fire behaviour we would need much finer spatial resolution of the fuelbeds and equally detailed weather information, such as the one required by Flammap or FARSITE.

The goal of the fuelbed map is to provide fuel information that has been created with global data and a homogeneous methodology, and as such could be used for continental or global analyses. We included parameters that could provide an estimation of fuel potentials or fire behaviour for the purpose of regional to global fire risk assessment, and biomass estimations to be used for fire effects assessment, such as emissions inventories. These data provide more detailed information than the PFTs that are usually the input of global fire models.

4. References

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