Referee # 2

The study is aimed to introduce the sensitivity of the vegetation optical depth (VOD) at L band to the biomass. Different SMOS datasets, produced by different algorithms, are compared to some above ground biomass (AGB) datasets over Africa. The analysis is carried out to show the higher correlation of the L band VOD with respect to higher frequencies VOD and optical vegetation indices. The paper also presents the correlation of the SMOS VOD with other parameters like tree height and cumulated precipitations.

We thank the reviewer for his/her constructive comments.

General comments:

The study's goal is well defined in the paper introduction where the authors claim that the retrieval of the VOD at L band can provide an important tool for the monitoring of the vegetation properties at large scales. In the first section of the manuscript is highlighted that, besides optical measurements, passive microwave observations acquired by the SMOS radiometer can provide an important complementary information to infer the state of vegetation. Here, several references are correctly reported to introduce the study and it is emphasized how the L band observations are less attenuated through the vegetation canopy. Therefore, L band VOD is expected to sample the vegetation layer up to higher biomass values compared to higher frequency observations. This aspect represents the key point of the manuscript and it is supported by the figure 4 of the results section. Anyway, just few comments are deserved to this point while a deeper explanation of the high sensitivity of the L band should be provided in the last section of the results.

First, following comments by reviewer #1, we have improved the presentation and the explanation of former Fig. 4. Sect 4.4 will be moved to the discussion as the description of this figure, in particular using the curves of Fig S4 by Liu et al. 2015 is basically a discussion of new results on L-VOD/AGB with respect to published results by Liu et al. And we would like to avoid misunderstandings on this point. The new figure has two panels. In the left panel L-VOD and NDVI were normalized to 1 using their maximum values. This is needed to plot the two quantities in the same figure. In the right panel, L-VOD and K/X/C-VOD relationship to Saatchi AGB are shown without using any normalization, because they span basically the same range and following comment 2 by reviewer 1, we want to emphasize that the curves plotted here for the K/X/C-VOD are just those of Figure S4 from Liu et al., which were computed using Saatchi AGB and the same method that we used in the current study. Liu et al fitted their relationship using K/X/C-VOD data in the period 1998-2002 and Saatchi data acquired from 1995 to 2005 (page 6 of their supplementary information document). The fact that the dates of the different datasets vary will also be reminded explicitly in the text. We will also remark that the non-linearity of the curve and the difference sensitivity to high AGB from different frequencies is driven by the high AGB values in the dense equatorial forest, which is not supposed to vary strongly in a few years time.

Finally, as suggested by reviewer #2, we will remind that the different shapes of L-VOD vs AGB and K/X/C-VOD vs AGB curves in agreement with what it is expected from the radiation transfer theory (Wigneron et al. 1995, 2004, Ferrazzoli and Guerriero 1996) and previous results on L-VOD and X/C-VOD comparison by Grant et al. 2016 and Vittucci et al. 2015 (already cited in first paragraph of page 3). For instance, the right panel of the figure below clearly shows that for a given AGB, L-VOD is lower than VOD at higher frequencies, as expected. This will be added explictly to the text discussing the new Figure.

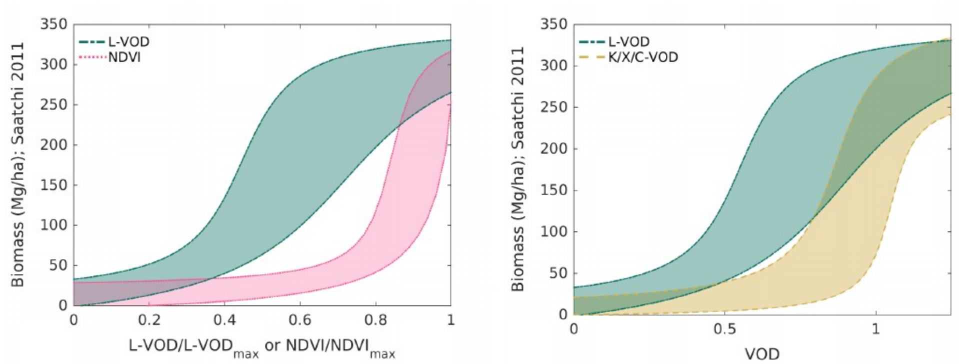


Figure 5. Left: Fits of the 5th and 95th percentile curves of the Saatchi et al. (2011) AGB with respect to SMOS-IC L-VOD (green) and NDVI (pink). To plot both distributions with the same scale, VOD and NDVI were normalized from 0 to 1 using their respective maxima (0.83 for NDVI and 1.24 for L-VOD). Right: Fits of the 5th and 95th percentile curves of the Saatchi et al. (2011) AGB with respect to SMOS-IC L-VOD (green) overlaid in the K/X/C-VOD versus Saatchi et al. (2011) AGB curves of Fig. S4 from Liu et al. (2015) (brown). No normalization is needed in this case as both VODs span a similar range of values.

Moreover, it seems that the presented research is a progress of a previous work in which some of the authors have already addressed the topic in 2016, including some results about the SMOS VOD sensitivity to tree height and AGB. I would suggest citing also this preliminary study in the introduction (doi 10.1109 / IGARSS.2016.7730383).

This research took, of course, as starting point a literature review and we tried to cite since the introduction all previous relevant studies. For instance, results about the SMOS VOD relationship to tree height were shown by Rahmoune et al. 2014 and Vittucci et al. 2016 (RSE 180). This last paper also included some results with respect to AGB. Both references are cited and commented in the manuscript. The conference contribution cited by the reviewer corresponds to the Vittucci et al. 2016 RSE paper. We reckon that there is not need to cite a conference paper with preliminary results when the full study has already been published in a peer-review journal.

Another general concern it is related to the use of three different VOD datasets derived from the SMOS data (L2, L3 and SMOS IC) that could confuse the reader. In my opinion, this point of view is interesting but can defocus the attention from the study objective, that it is claimed in the manuscript title. In some parts of the article it seems that too much importance is given to the intercomparison of the different VOD retrieval algorithms, instead of supporting the relevance of the VOD at L band for AGB monitoring. Furthermore, a potential user of SMOS data, could ask himself what is the product to adopt between the L2, L3 and SMOS IC for vegetation monitoring, since the strengths and weaknesses of the different approaches can be highlighted more clearly. A suggestion to address this point could be to provide a general overview of the specific aims of the different products and maybe to update the title of the research to highlight that different L-band products are compared.

Title: referee #1 did also think that the title should be changed. Therefore, we decided to change the title to:

An evaluation of SMOS L-band vegetation optical depth (L-VOD) data sets: a high sensitivity of L-VOD to above-ground biomass in Africa

Comparison of SMOS L-VOD products: we agree completely with the reviewer, that is the reason we added most of the results on SMOS L2 and SMOS L3 as supplementary information. We will leave that information as supplement. However, Table S1 will be improved with information on single scattering albedo and roughness parameters for the three approaches as recommended by reviewer #1 and by reviewer #2, here below.

In addition, lines 2-8 of page 4 will be moved above Sect. 2.1.1 to strength that those details are common to the three algorithm and so to focus Sects 2.1.1-2.1.3 on the differences.

Furthermore, the presentation of the results for different SMOS L-VOD data sets in Sect. 4.1 will be developed adding the discussion on Spearman and Kendall rank correlation values as follows:

The rank correlation values with respect to all the evaluation datasets are also higher for IC L-VOD (rho 0.78-0.91, tau 0.61-0.75), followed by L2 L-VOD (rho 0.67-0.83, tau 0.50-0.65) and L3 L-VOD (rho 0.66-0.80, tau 0.49-0.62). These results are in agreement with those obtained with the Pearson correlation and imply that the lower Pearson correlation values obtained for the L3 and L2 datasets are not due to a correlation that could be better but more non-linear than that of the IC dataset. Therefore, using eight vegetation-related evaluation data sets and three different metrics, the most consistent SMOS L-VOD data set is SMOS-IC. This result implies *that, currently, the SMOS-IC dataset is the best SMOS L-VOD product to perform vegetation studies, and the rest of the current study will focus on SMOS-IC L-VOD.*

We hope that a potentially interested reader asking himself what is the product to adopt between the L2, L3 and SMOS IC for vegetation monitoring would have a clearer statement to make a choice.

The relevance of L-VOD for AGB monitoring is addressed in the rest of Sect 4 and in the new Sect. 5 proposed to discuss the new Fig. 4 as explained above.

Despite these general issues I believe that the topic is relevant, the results are obtained with a sounding scientific approach and the supporting figures and tables are clear. Therefore, I would recommend the paper for publication after a careful revision process.

We thank the reviewer for these encouraging comments.

Specific comments:

In the section 2, "Data", is introduced the SMOS mission and the three different algorithms, considered to retrieve the L band VOD from the SMOS brightness temperature. At line 28 of page 2 is stated that only ascending orbits are considered in the study but the declaimed better overall quality of ascending pass acquisitions appears not justified. Therefore, the authors should provide a better explanation about this important constrain.

It is not really a constrain. The results do not depend significantly on the year or the type or orbits used as reference. The shape of the scatter plots is very similar using data for next years. See for instance the next figure and compare to Fig S3.

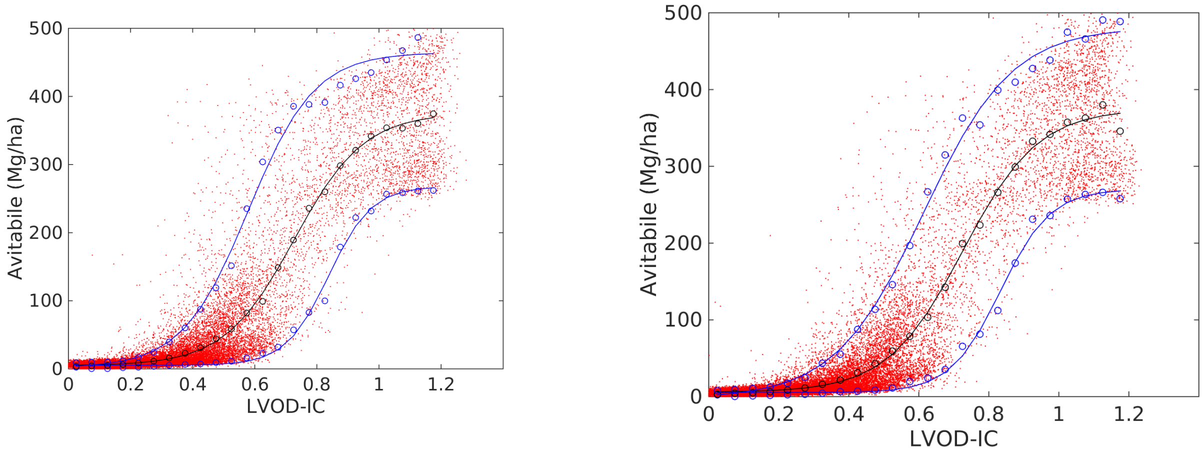


Fig. Left : 2012 Ascending orbits. Right: 2012 Descending orbits

The next table shows the parameters of the fits using ascending or descending orbits in 2012. The values can be compared to those of Table S2. They have almost the same numeric values.

AGB	Year	Orbit	curve	a	b	c	d	R^2
Avitabile	2012	A	05th	262.697	14.406	0.838	5.347	0.99548
Avitabile	2012	A	Mean	370.615	8.920	0.727	4.915	0.99917
Avitabile	2012	A	95th	462.962	9.398	0.580	1.613	0.99243
Saatchi	2012	A	05th	333.496	4.642	0.906	-3.338	0.99080
Saatchi	2012	A	Mean	280.675	6.686	0.684	14.439	0.99334
Saatchi	2012	A	95th	291.444	9.661	0.545	32.436	0.99372
Baccini	2012	A	05th	497.748	2.673	1.024	-41.748	0.98810
Baccini	2012	A	Mean	414.033	3.503	0.717	-27.346	0.99882
Baccini	2012	A	95th	383.823	4.950	0.550	-1.911	0.99757
Bouvet-Mermoz	2012	A	05th	292.291	4.800	0.963	4.717	0.97445
Bouvet-Mermoz	2012	A	Mean	319.123	5.261	0.760	7.879	0.99616
Bouvet-Mermoz	2012	A	95th	358.172	7.290	0.581	17.621	0.99226
Avitabile	2012	D	05th	264.867	13.984	0.833	5.353	0.99548
Avitabile	2012	D	Mean	368.991	9.271	0.726	5.795	0.99765
Avitabile	2012	D	95th	483.476	7.893	0.614	-2.245	0.99585
Saatchi	2012	D	05th	332.540	4.976	0.890	-5.476	0.99111
Saatchi	2012	D	Mean	287.547	6.436	0.691	12.981	0.99499
Saatchi	2012	D	95th	291.493	8.979	0.543	30.449	0.99324
Baccini	2012	D	05th	606.345	2.250	1.168	-53.195	0.98742
Baccini	2012	D	Mean	398.354	3.688	0.706	-21.945	0.99806
Baccini	2012	D	95th	379.008	5.076	0.567	6.162	0.99538
Bouvet-Mermoz	2012	D	05th	308.430	4.441	0.965	0.250	0.98165
Bouvet-Mermoz	2012	D	Mean	317.532	5.425	0.764	10.022	0.99729
Bouvet-Mermoz	2012	D	95th	375.791	6.420	0.604	12.619	0.99451

Therefore, there is no real impact of using just one year or using ascending or descending orbits. However, in a revised version of the manuscript we will use two years of data both for ascending and descending orbits. The results will not change but they would look more robust to the reader. This will be discussed in a revised version of the manuscript. See also answer to General Comment 3.

In the following subsection are introduced the ESA L2 algorithm, the CATDS L3 algorithm and the INRA-CESBIO algorithm that were applied to obtain three different L band VOD data sets. If the Authors are inclined to stress the intercomparison between the outcomes of the different retrieval approach, a deeper discussion about the different algorithm could be effective to introduce the subsequent results, i.e. figure 1 and table 1. This choice, could be a good solution to solve some ambiguities between the study aim, as claimed on the paper title, and the interesting overview of the different algorithms performances. Anyway, a better explanation on the assumptions (i.e. soil roughness and albedo) under which the three different algorithms are based should be provided.

Thanks for pointing this out. This point has also been raised by referee #1.

In a revised version, first, the albedo will be cites earlier since the introduction citing presenting the tau-omega model. Therefore, the lines 10-14 of page 2 :

In the presence of vegetation, part of the soil emission is absorbed and scattered. This extinction effect is parameterized by the vegetation optical depth (VOD) that can be estimated using radiative transfer theory […] Wigneron et al. 2007).

It will be rephrased to:

In the presence of vegetation, part of the soil emission is absorbed and scattered. These effects can be parameterized using radiative transfer models such as the so-called tau-omega model (Refs), were tau is the optical depth and omega is the single scattering albedo. Tau was shown to be linked […] Wigneron et al. 2007). Therefore, tau is commonly known as Vegetation Optical Depth (VOD).

Regarding the actual values used for different SMOS product, the information will be added more clearly in Sect. 2 and in Table S1. For SMOS IC the roughness and single scattering parameters are assigned per IBGP classes, based on Parrens et al. (2017a, b), and are averaged per pixel according to the fraction of classes present in the pixel (Fernandez-Moran et al. 2017).

For SMOS L2 and L3 algorithms, single scattering albedo and roughness values depend on the surface type and are taken from literature and/or specific SMOS studies. For low vegetated area the single scattering albedo is set to 0 and roughness set to 0.1. For forested areas the single scattering albedo is set to 0.06 for tropical and subtropical forest and 0.08 for Boreal forest and roughness set to 0.3 (Rahmoune et al. 2013,2014, Al Bitar et al. 2017).

Marie Parrens, Jean-Pierre Wigneron, Philippe Richaume, Ahmad Al Bitar, Arnaud Mialon, Roberto Fernandez-Moran, Amen Al-Yaari, Peggy O'Neill, and Yann Kerr, 2017. Considering Combined or Separated Roughness and Vegetation Effects in Soil Moisture Retrievals, International Journal of Applied Earth Observation and Geoinformation 55, 73-86.

M. Parrens, A. Al Bitar, A. Mialon, R. Fernandez-Moran, J.-P. Wigneron, P. Ferrazzoli, and Y. Kerr, 2017. Estimation of the L-band Effective Scattering Albedo of Tropical Forests using SMOS observations, IEEE GRS Letters 2017, 14, 1223-1227

After the introduction of the VOD datasets the different benchmark sets are presented. In the section 2.2.1 it is introduced the Worldclim data set, that is used to infer the relationship between the L band VOD and the mean annual precipitation. This analysis seems meaningless since, as it is reported at line 15 of page 5, the considered precipitation is extracted from a dataset ranging only between "1970-2000". This point should be clarified also considering that the relationship between the precipitation and the VOD are not well commented in the paper.

The regime of precipitations can be a driver of the vegetation conditions. In a revised version, precipitations will be discussed independently of the other datasets. First, Fig S6 will be moved to the main documents and all IGBP classes will be discussed independently instead of grouping some of them. Panels c and d of figure 3 will be now a single new figure. The rest of the panels of Fig. 3 will be removed as they will be redundant with those of the new figures showed above. Here, showing only two groups of biomes is pertinent as we want, as the reviewer says, to show the possible link of precipitation as one of the drivers of the vegetation properties. Thus, we show that there are basically two regimes. In the first one, as precipitation increases the amount of vegetation as traced by AGB maps, VOD or NDVI/EVI increases. In contrast, there is threshold of ~1500 mm/year over which AGB, VOD and NDVI are decoupled from the amount of the annual precipitations.

Taking this into account, lines 13-17 of page 10 will be replaced by :

Regarding the relationship with respect to annual precipitation, Fig. 7 shows the precipitations and L-VOD scatter plots for two land cover groups: (i) grasslands, croplands, shrublands, savannahs and woody savannahs and (ii) ever- green broadleaf forest. For the first group, L-VOD increases with increasing annual precipitations until a value of ~ 0.7 for ~ 1500 mm. In this range of L-VOD all other vegetation tracers increase as well. For instance, Bouvet-Mermoz and Saatchi's AGB increase up to 85 Mg/h and ~ 100 Mg/h, respectively, and NDVI and DVI increase up to ~ 0.7 and ~ 0.45, respectively (Fig. 6). In contrast, over that threshold of ~ 1500 mm of annual precipitations, which occurs basically in the evergreen broadleaf forest, L-VOD and the other vegetation tracers are not linked to the amount of precipitation.

In the section 2.2.4 are presented the different AGB datasets considered as benchmarks. Here the sentence "This study used four static AGB benchmark maps (Baccini et al., 2012; Saatchi et al., 2011; Avitabile et al., 2016; Bouvet et al., 2018) each with specific strengths and limitations to assess L-VOD's ability to reflect aboveground biomass in different" is questionable and not well supported by the results. In particular, the Avitabile dataset is obtained by the fusion of the Baccini and Saatchi maps through a machine learning approach and it is proved to outperform the previous datasets in terms of retrieved AGB accuracy. The Authors should argue better the aspects related to the analysis carried out with these three different AGB data sets. On the contrary the consideration of the Bouvet dataset is very interesting and should be emphasized.

We are afraid we disagree. We do not see clear evidence that the Avitabile "outperforms" any other AGB dataset. We do think that AGB estimation from remote sensing measurements is complex and the errors of different retrieval methods are not easy to characterize. The fact that the Avitabile dataset is so different to both the Baccini and Saatchi maps used as input is actually puzzling, for instance the sharp decrease AGB from the Equatorial region with distance is not seen in any other AGB map. The Avitabile method can be biased to high AGB values because most of the plots used as reference are in dense forest. Furthermore, a totally independent observable such as L-VOD shows clear relationships for low AGB for all the datasets but Avitabile.

Otherwise, the analysis is performed in exactly the same way for all AGB datasets and the more considerations on Bouvet dataset are proposed to be more taken into account by moving Fig. S6 to the main manuscript and discussing in more details the results for different biomes:

The best correlations of AGB and L-VOD are found with (i) Bouvet-Mermoz for Shrublands and Savannahs (ii) Baccini for croplands and equatorial forest (iii) Saatchi for grasslands. Regarding natural vegetation and woody savannah the correlation values obtained with Saatchi and Baccini are very similar. One should note that correlation values obtained with Bouvet-Mermoz for woody savannah are degraded to the fact that for the highest values of AGB found in this class, at the SMOS resolution, the AGB estimation is a mix of Bouvet and Mermoz approaches. Therefore, all AGB datasets except that of Avitabile performs the best for a few land cover classes.

Interpreting where do this differences come from is not easy. Radar observations in low vegetation regions such as shrublands and grasslands are thought to be very sensitive to biomass variations, in spite of a significant sensitivity to soil moisture. The high correlation of the two AGB maps mainly based of radar data (Saatchi and Bouvet-Mermoz) with SMOS L-VOD in grasslands would confirm this fact, as the high correlation in shrublands for Bouvet-Mermoz.

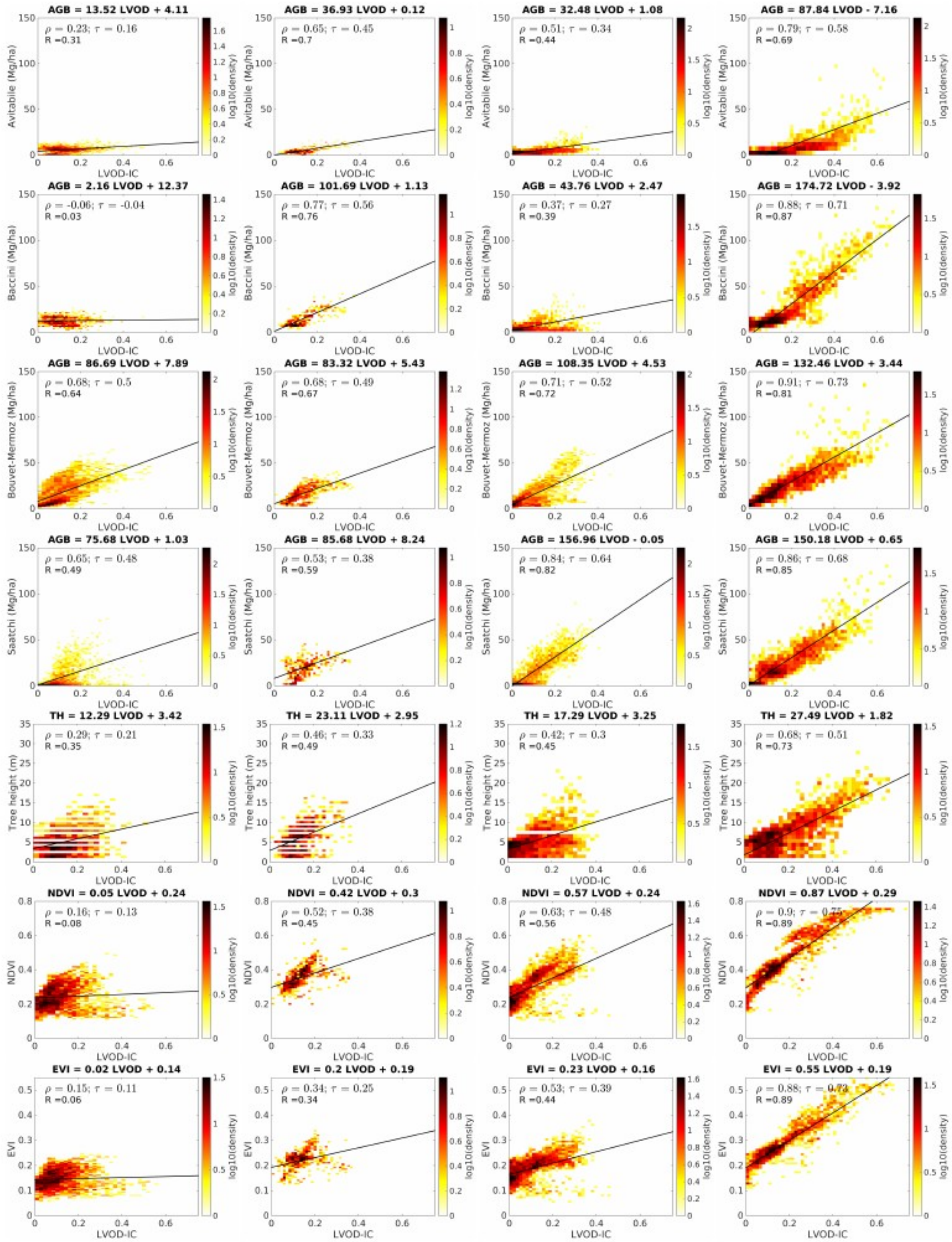
The scatter plot found with Avitabile for woody-savannah resembles an overlay of the scatter plot obtained with Baccini and the scatter plot obtained with Saatchi. The low AGB vs L-VOD slopes obtained for low vegetation classes, significantly lower than those found with the original Saatchi and Baccini datasets, are rather difficult to understand. The strange behavior of Avitabile AGB probably comes from the fact that it is pure data driven method and that it is therefore very sensitive to the data used to train the method. In their training database, high AGB plots could be over-represented.

In addition as mentioned above, the distribution of Baccini AGB for woody savannah is significantly different to the other datasets, which much higher values.

These elements will be added to the results section when discussing the new figures that will replace Fig. 3 and S6.

In the Results section it should be provided a deeper explanation of the research outcomes, in particular the scatterplots reported in figure 2 need to be better commented.

We agree. We have realized from comments by Referees #1 and #2 that the explanation of the results should be improved. Therefore, as already mention in the answer to the previous comment, Fig. S6 will be moved to the main manuscript and more details on the results for different biomes will be given as proposed in the answer to the previous comment. This will make clear than the relationships shown in Fig. 2 are actually a composition of different relationships for different biomes. See below the new figures:



gure 4. SMOS IC L-VOD relationships to the AGB and tree heigh evaluation datasets for different land cover classes: From left to right: Open shrublands. *(ii)* Croplands, *(iii)* Grasslands, and *(iv)* Cropland/natural vegetation mosaics. See Table S2 for more details on these ıd cover classes.

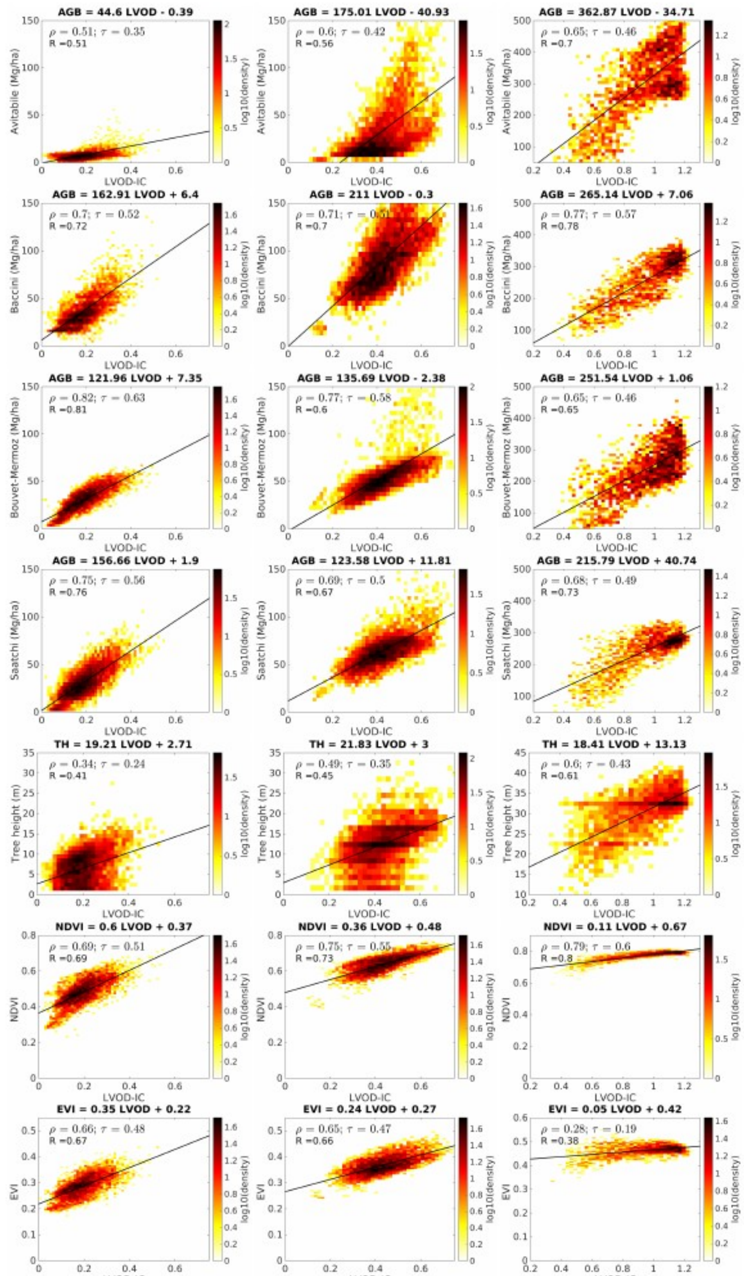


Figure 5. SMOS IC L-VOD relationships to the AGB and tree heigh evaluation datasets for different land cover classes: From left to right: *(i)* Savannah *(iii)* Woody savannah and *(iv)* Evergreen broadleaf. See Table S2 for more details on these land cover classes.