Answer to reviewer comments

Manuscript: AnisoVeg: Anisotropy and Nadir-normalized MODIS MAIAC datasets for satellite vegetation studies in South America

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Reviewer comments are colored black, our answers are colored blue

Reviewer #1 – RC1

GENERAL COMMENTS BY REFEREE

This is an extremely useful dataset based on two decades of MODIS surface reflectance for all of South America, with interesting example applications clearly presented by the authors.

The introduction provides a succinct explanation of view-and illumination angle effects, for Modis satellite images, on the reflectance of a textured forest canopy. This problem is removed by an empirical inversion that requires several images close in time with different view and illumination angles. This is the Nadir Adjusted Reflectance (NAD) product which the authors provide, with the additional benefit of state-of-the-art MAIAC cloud removal algorithm. It is already standardized to a fixed nadir view and a fixed illumination angle, facilitating its use by a much larger number of educators and scientists.

The authors then up their game by extracting useful information from this view and illumination angle "artifact", rather than just treating it as something to be removed. This is their anisotropy (ANI) product: the difference between reflectance under a standardized back-scatter geometry and a standardized forward scatter geometry. This is like the difference between the brightness of a highly irregular textured surface photographed with the sun behind the photographer and the same surface with the photographer facing the sun. Intuitively, the difference in reflectance (or in vegetation indices) will be greater for more irregular surfaces and lesser for smoother surfaces. They show this ANI difference is useful for detecting canopy height in the Amazon, presumably because a canopy with tall trees and large crowns is more irregular than a canopy of shorter trees of similar height, that make a smoother canopy.

The paper provides three interesting examples of applications. First, they show that the Anisotropy attribute, as expressed in a single month of EVI vegetation index, distinguishes three Amazon forests which are not separable using the typical nadir Adjusted EVI. They then show that their very novel Anisotropy product is useful for estimating forest height across the entire Amazon, by comparing to GEDI lidar heights. Finally, they show that each of nine distinct leaf phenology regions of the Amazon (from an independent study) are corroborated by distinct ANI and NAD seasonal curves for the EVI vegetation Index.

ANSWERS TO REVIEWER GUIDANCE QUESTIONS IN CAPS

Are the data and methods presented new? YES

Is there any potential of the data being useful in the future? VERY HIGH

Are methods and materials described in sufficient detail? YES

Are any references/citations to other data sets or articles missing or inappropriate? NO

Is the article itself appropriate to support the publication of a data set? YES. THE ARTICLE PROVIDES EXAMPLES OF VERY USEFUL APPLICATIONS. THEIR ANISOTROPY PRODUCT WILL VERY LIKELY LEAD TO A SUITE OF NEW PAPERS ON FOREST STRUCTURE AND PHENOLOGY

Check the data quality: is the data set accessible via the given identifier? YES, I accessed the main Zenodo datasets and the two auxilliary sets. The latter allow calculating several indices based on hotspot and darkspot, that are described in Table 3 of the ESSD submission. All datasets are explained succinctly on Zenodo and in item 5 of the ESSD submission. I was also able to access the Earth Engine repository containing two Image Collections, one for anisotropy of EVI and one for Nadir-adjusted EVI. Both worked fine, using the sample code provided.

Is the data set complete? Are error estimates and sources of errors given (and discussed in the article)? Are the accuracy, calibration, processing, etc. state of the art? Are common standards used for comparison? REPLY: The authors provide the number of observations per month as a proxy for error estimation. More observations provide not only more complete data but also a more reliable BRDF inversion. The cloud masking algorithm is state-of-the-art and its originator is among the authors.

Is the data set significant – unique, useful, and complete? VERY SIGNIFICANT for scientists and educators that make use of MODIS reflectance for vegetation studies. The BRDF problem with MODIS data has been a subject of much discussion and controversy relating to Amazon forest resilience in the face of normal and extreme droughts. Here the authors not only provide corrected data, but they also turn lemons into lemonade by showing that forest structure (including canopy height) and forest leaf phenology in the Amazon are detectable by exploiting the BRDF as a measure of the anisotropic reflectance properties of canopies. So the data is also very useful. Because so much processing time is required and because few studies have previously explored the anisotropy as a useful property rather than as noise or bias, the data is unique. It is spatially complete, covering all of south America.

Consider article and data set: are there any inconsistencies within these, implausible assertions or data, or noticeable problems which would suggest the data are erroneous (or worse). If possible, apply tests (e.g. statistics). Unusual formats or other circumstances which impede such tests in your discipline may raise suspicion. NO PROBLEMS DETECTED HERE

Is the data set itself of high quality? YES

Check the presentation quality: is the data set usable in its current format and size? Are the formal metadata appropriate? THE DATA IS ACESSIBLE IN POPULAR FORMATS

Check the publication: is the length of the article appropriate? ARTICLE IS WELL WRITTEN WITH KEY EXAMPLES OF DATA APPLICATION

Is the overall structure of the article well-structured and clear? CLEAR AND CONCISE

Is the language consistent and precise? GOOD WRITING STYLE

Are mathematical formulae, symbols,abbreviations, and units correctly defined and used? YES

Are figures and tables correct and of high quality? YES.

Is the data set publication, as submitted, of high quality? YES

Reply: Thanks for your time on reading and reviewing the paper and the dataset.

LINE BY LINE COMMENTS

Lines 179-180 You obtained RTLS BRDF inversion parameters from pixels observations (having different view and solar angles) within eight day periods. What is the minimum number of pixel observations required to run the inversion in an eight-day period?

Reply: Thanks for pointing this out. It is required a minimum of three valid observations to do the inversion. We included this information on the Methods section of the updated manuscript: "A minimum of three observations in the eight-day window was required to accurately model the signal".

Lines 195-197 Are these pixel observations required for RTLS BRDF inversion conceptually identical to the "per-pixel number of samples (or observations) for each monthly composite", which is provided as ancillary data?

Reply: Yes, that is correct.

Figures 3 and 5 -- Topographic effects on ANI? In Figure 5, ANI data linearly predict forest height with R2 = 0.55, presumably because the more coarsely textured surface of tall-tree canopies makes the shaded sides of trees and of large crowns occupy a greater fraction of a pixel viewed in forward scatter situation, if compared with a smooth canopy such as grassland or more even-height dicotyledon forest canopy. But your data are at 1 km resolution, so there will also be topographic irregularities within each pixel, which might also contribute to higher ANI. Have you looked into the grain and/or amplitude of topographic roughness (from SRTM) as additional explanatory variables for your scatter-plot relating ANI to forest height (Figure 5)? Do you think this will in fact be relevant?

Reply: Thanks for pointing this out. This is a good point that we missed in the original manuscript. We inspected the ANI and the SRTM data and verified similar topographic effects of higher ANI values in rough terrain. To clarify this in the manuscript, we added this paragraph below, citing a reference that showed evidence for that effect:

"EVI_{ANI} results of Figures 3, 4 and 5 were affected to some extent by terrain illumination effects observed locally at some sites. For instance, topographic effects on EVI_{ANI} occurred probably at the São Felix do Xingu site where topographic roughness, observed in SRTM data (results not shown), was coincident with increased EVI_{ANI} values in Figure 3E. Furthermore, even in relatively flat terrains, variations in topographic aspect (surface orientation to Sun) can affect the EVI variability in MODIS data because of the different amounts of energy reflected in the NIR towards the sensor by inclined surfaces in the forward and backscattering view directions. Such effects have been observed in southern Brazil with MODIS at 250-m spatial resolution and increased in magnitude at higher spatial resolution data obtained by other sensors (Galvão et al., 2016). Therefore, it may prove useful to include topographic variables in modelling exercises to offset these effects."

Galvão, L. S., Breunig, F. M., Teles, T. S., Gaida, W., & Balbinot, R. (2016). Investigation of terrain illumination effects on vegetation indices and VI-derived phenological metrics in subtropical deciduous forests. GIScience and Remote Sensing, 53(3), 360–381. https://doi.org/10.1080/15481603.2015.1134140

In the lower three panels of Figure 3, Tapajós and Xingu Park are flat relief, so the ANI should be showing differences in canopy texture (which generally increases with canopy height in the Amazon), not topographic effects. However, I looked at the forested areas at or near the sample site in the São Felix window using SRTM and see that it is a mixture of some patches of flatter and others of more irregular relief. The ANI data there is also patchy in regions of intact forest. Is there some direct effect of topographic relief on ANI taking place in the São Felix site? Or is the patchy mosaic of low and high ANI within forest there mostly related to patchy change in canopy height/smoothness?

Reply: The reviewer is correct. This was answered in the previous answer.

Lines315-320 Fascinating. Your data is opening up new avenues for understanding leaf phenology

Reply: Thanks!

Line 315 Fix the grammar

Reply: The word 'are' was removed to fix grammar.

Line 320 change to "the central"

Reply: Corrected.

Line 350 change "on" to "for"

Reply: Corrected.

Line 355 change "consists in" to "is"

Reply: Corrected.

Line 366 change to "in the northwest"

Reply: Corrected.

Figure 6 Great figure, Distinct mutual relationships between the two indices in each pheno-region lend credence to the pheno-region classification of Xu et al (2015)

Reply: Thanks!