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Interactive comment on "Bioclimatic traits in statistical properties of daily photosynthetically active radiation" *by* Estefanía Muñoz and Andrés Ochoa

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Dear Referee 3,

We appreciate the time and effort to provide feedback on our manuscript and are grateful for your valuable suggestions. We will incorporate these suggestions in the final version of the manuscript. Please see below for a point-by-point response to your comments.

1. This was an interesting paper about the atmospheric attenuation of photosynthetically active radiation (PAR). The paper addresses the spatiotemporal variability in at-

mospheric attenuation of PAR by analyzing and characterizing the clearness index and the clearday index calculated from long-term observational PAR data for near-globally dispersed sites. The paper provides us with the patterns in atmospheric attenuation of PAR that can be expected for various ecosystems according to their position on the Holdridge triangle or their Köppen climate classification. I enjoyed reading about the indices and the spatiotemporal patterns the researchers have found on a large scale, but the reasons for undertaking the research could be expanded upon. Author response: Thank you for your comment. What led us to undertake this research was the need for a probability model of daily radiation to investigate the stochastic dynamics of soil water, nitrogen and carbon contents in energy-limited ecosystems, just as it has been done for water-limited ecosystems (e.g. Ridolfi et al. (2003), Manzoni et al (2004), Botter et al. (2018), Runyan and D'Odorico (2019), Manzoni et al. (2020)). Our ultimate goal is to extend the ecohydrological model of Rodríguez-Iturbe and coauthors from water-limited to energy-limited ecosystems. We are currently working on it (see Muñoz et al. (2020)). We will expand the introduction with this context. Botter, G., Daly, E., Porporato, A., Rodríguez-Iturbe, I., & Rinaldo, A. (2008). Probabilistic dynamics of soil nitrate: Coupling of ecohydrological and biogeochemical processes. Water Resources Research, 44(3), n/a-n/a. https://doi.org/10.1029/2007WR006108 Manzoni, S., Porporato, A., D'Odorico, P., Laio, F., & Rodriguez-Iturbe, I. (2004). Soil nutrient cycles as a nonlinear dynamical system. Nonlinear Processes in Geophysics, 11(5/6), 589–598. https://doi.org/10.5194/npg-11-589-2004 Manzoni, S., Chakrawal, A., Fischer, T., Schimel, J. P., Porporato, A., & Vico, G. (2020). Rainfall intensification increases the contribution of rewetting pulses to soil respiration. Biogeosciences Discussions, 1–25. https://doi.org/10.5194/bg-2020-95 Muñoz, E., Ochoa, A., Poveda, G., & Rodríguez-Iturbe, I. (2020). Probabilistic soil moisture dynamics of water- and energy-limited ecosystems. EarthArXiv. https://doi.org/10.31223/osf.io/au4tb Ridolfi, L., D'Odorico, P., Porporato, A., & Rodriguez-Iturbe, I. (2003). The influence of stochastic soil moisture dynamics on gaseous emissions of NO, N2O, and N2. Hydrological Sciences Journal, 48(5), 781–798. https://doi.org/10.1623/hysj.48.5.781.51451 Run-

yan, C. W., & D'Odorico, P. (2019). Modeling of Phosphorus Dynamics in Dryland Ecosystems. In Dryland Ecohydrology (pp. 309–333). Springer International Publishing. https://doi.org/10.1007/978-3-030-23269-6_12

2. Title: The impression I got from the paper is that it characterizes the site level patterns in atmospheric attenuation that impact how much PAR reaches the ground. The title could be a bit more detailed to include the indices or atmospheric attenuation rather than just "daily PAR". Author response: We will change to "Bioclimatic traits in atmospheric attenuation of daily photosynthetically active radiation".

3. Abstract: The abstract does not communicate why this research was undertaken. The importance of PAR is briefly described in the introduction, but there is no mention of it in the abstract. A sentence about why we should analyze the variability in atmospheric attenuation of PAR in the beginning and another sentence about why the findings or methods are important in the end could help form a complete abstract. Author response: the abstract will be completed according to your suggestions. We will mention that PAR is the main source of energy in photosynthesis and evapotranspiration and that the amount of energy reaching the Earth's surface at a given time and space depends on part of the atmospheric attenuation. Besides, we will add that the results found here show that the stochastic component of PAR radiation at a site can be associated with its Holdridge life zones and Köppen climate.

4. Introduction: At lines 21 and 22, the authors introduce the indices and mention their wide use by other researchers to "quantify the random nature of atmospheric light attenuation" without references to research. The introduction could be expanded to clarify the purpose of studying the variability in atmospheric attenuation of PAR. Some questions below might help expand the introduction: 1. Which studies used the indices to study the variability of atmospheric attenuation? 2. What did those studies find and how does this current research build on previous studies of atmospheric attenuation? 3. Has the variability in the indices been characterized according to climate in the past? If not, why do the authors believe it is important to characterize the variability in atmospheric attenuation by life zone or climate? Author response: Thank you for your suggestions. We will complete the introduction with references to previous work about the indices (e.g., Engerer & Mills (2014), Tran (2013), Hollands & Suehrcke (2013), Harrouni (2008), Ianetz & Kudish (2008), Polo et al. (2008), Allen et al. (2006), Hansen (1999), Skartveit & Olseth (1992), Gordon & Hochman (1984), Olseth & Skartveit (1984), Bendt et al. (1981), and Liu & Jordan (1960)). We will also respond to the three questions suggested based on the results of the mentioned (and others) works.

Allen, R. G., Trezza, R., & Tasumi, M. (2006). Analytical integrated functions for daily solar radiation on slopes. Agricultural and Forest Meteorology, 139, 55–73. https://doi.org/10.1016/j.agrformet.2006.05.012 Bendt, P., Collares-Pereira, M., & Rabl, A. (1981). The frequency distribution of daily insolation values. Solar Energy, 27, 1–5. Engerer, N. A., & Mills, F. P. (2014). KPV: A clear-sky index for photovoltaics. Solar Energy, 105, 679–693. https://doi.org/10.1016/j.solener.2014.04.019 Gordon, J. M., & Hochman, M. (1984). On the random nature of solar radiation. Solar Energy, 32(3), 337–342. https://doi.org/10.1016/0038-092X(84)90276-7 Hansen, J. W. (1999). Stochastic daily solar irradiance for biological modeling applications. Agricultural and Forest Meteorology, 94(1), 53–63. https://doi.org/10.1016/S0168-1923(99)00003-9 Harrouni, S. (2008). Fractal Classi cation of Typical Meteorological Days from Global Solar Irradiance: Application to Five Sites of Different Climates. In V. Badescu (Ed.), Modeling Solar Radiation at the Earth's Surface (pp. 29–55). Retrieved from http://link.springer.com/chapter/10.1007/978-3-540-77455-6_2%0Ahttp://files/1185/Harrouni - 2008 - Fractal Classification of Typical Meteorological D.pdf%0Ahttp://files/1192/10.html Hollands, K. G. T., & Suehrcke, H. (2013). A three-state model for the probability distribution of instantaneous solar radiation, with applications. Solar Energy, 96, 103–112. https://doi.org/10.1016/j.solener.2013.07.007 Ianetz, A., & Kudish, A. (2008). A method for determining the solar global and defining the diffuse and beam irradiation on a clear day. In V. Badescu (Ed.), Modeling Solar Radiation at the Earth's Surface: Recent Advances (pp. 93–113).

https://doi.org/10.1007/978-3-540-77455-6_4 Liu, B. Y. H., & Jordan, R. C. (1960). The interrelationship and characteristic distribution of direct, diffuse and total solar radiation. Solar Energy, 4(3), 1–19. https://doi.org/10.1016/0038-092X(60)90062-1 Olseth, J. A., & Skartveit, A. (1984). A probability density function for daily insolation within the temperate storm belts. Solar Energy, 33(6), 533–542. https://doi.org/10.1016/0038-092X(84)90008-2 Polo, J., Zarzalejo, L. F., & Ramírez, L. (2008). Solar Radiation Derived from Satellite Images. In V. Badescu (Ed.), Modeling Solar Radiation at the Earth's Surface (pp. 449–461). Springer-Verlag Berlin Heidelberg. Skartveit, A., & Olseth, J. A. (1992). The probability density and autocorrelation of short-term global and beam irradiance. Solar Energy, 49(6), 477–487. https://doi.org/10.1016/0038-092X(92)90155-4 Tran, V. L. (2013). Stochastic models of solar radiation processes. Université d'Orléans.

5. Line 12 on pg 6 mentions that the data was separated into rainy and dry days using precipitation. No precipitation dataset is described in the data section. Adding a description of the source for the precipitation dataset will be helpful. Author response: we got rainfall data from the same database of PAR (FLUXNET). This will be clarified in the text.

6. Line 18 on pg 6 says: "The time series, annual cycle, and autocorrelogram of PAR, c and k were calculated and plotted for each site." Is this referring to PAR0 or PARobs? Author response: Time series (panel a) and annual cycles (panel b) are shown for PARobs (observed), PAR0 (no atmosphere) and PARcda (clean and dry atmosphere), while the ACF (panel c) shows only PARobs. This will be explained in the text.

7. It might be helpful to add that the time series, annual cycle, and autocorrelogram were calculated for PAR in the methods section. Author response: It will be added in Section 3.3 (Statistical properties of k and c).

8. Figure 2 and the corresponding supplementary figures show what appears to be a confidence interval for the ACF with a dotted line. Which level of confidence does

that interval mark? Author response: It refers to the 95% confidence interval. It will be stated in the figures.

9. Figure 2 and figures S1 - S28 need legends with a clarification on which PAR measurement is plotted (PAR0 or PARobs). Author response: black solid lines in Figure 2(a,b) indicate the PAR for no-atmosphere and thick green solid lines indicate the modeled global radiation. The thin green solid line in Fig. 2(a) is the time series of the observed PAR and the dots in Fig. 2(b) are the mean of PARobs of each day of the year during the record. We will explain this in the legends or captions of Fig. 2 and Figs. S1-S28.

10. It is really hard to read the numbers on the figures with the CDF labeled with numbers (figure 5 and figures S57- S84). Author response: We will use symbols instead of numbers.

11. Throughout the paper and figure captions, the parentheses come before the variable they describe. For example: "(a-b) c and (c-d) k". It is a bit easier to read if the variable is mentioned first: "c (a-b) and k (c-d)". Author response: We will change this.

12. At points in the results/discussion, the figures are introduced by describing the figure. For example: " Fig. 4 shows the PDFs (left panel) and the CDFs (right panel) for wet (blue) and dry (red) days of c (a–b) and k (c–d)." (Pg. 8, line 17). This seems redundant. A good descriptive caption for the figure or a complete legend should take care of this and the text in the results/discussion does not need to mention it. Author response: We will correct the legends and separate the Results and Discussion sections.

13. Line 18 on pg. 8 should read: "Figs. S26 to S56 show the results of the 28 sites analyzed." Author response: This will be corrected.

14. Regarding lines 11 - 14 on pg. 7: "We classified the pdfs of c and k in three types: Bimodal, Unimodal I (unimodal with low dispersion), and Unimodal II (unimodal

with high dispersion). Sites in the extratropical northern hemisphere (except the site in the United States US-Fep) have bimodal distributions; sites in tropics, subtropics, and USFpe have Unimodal II distributions; and sites in tropics have Unimodal II distributions." This appears to be in disagreement with figure 3. US-Fpe looks like it has a Unimodal I distribution in figure 3. Author response: Thank you for pointing this out. The paragraph should be rewritten as: We classified the pdfs of c and k in three types: Bimodal, Unimodal I (unimodal with high dispersion), and Unimodal II (unimodal with low dispersion). Sites in the extratropical northern hemisphere (except the site in the United States US-Fep) have bimodal distributions; sites in tropics, subtropics, and USFpe have Unimodal I distributions; and sites in tropics have Unimodal II distributions.

15. If possible, harmonizing the terminology that describes the PDFs between the abstract, results, figures, and conclusion would be helpful. For example, eliminating unimodal I and II altogether and keeping unimodal low and unimodal high to describe the unimodal PDFs throughout the paper and figures should provide consistency for the reader. I also find unimodal low and unimodal high to be more descriptive. Author response: We will revise this issue in the whole manuscript.

16. When talking about the PDFs on pg. 7 and 8: The current organization of paragraphs: Discusses the PDFs' latitudinal variability on pg. 7 - top of pg. 8, then talks about the Köppen classification, and then talks about the Holdridge triangle with mention of latitudinal variability. Consider moving the paragraph about the Köppen classification (lines 3 - 7, pg. 8) before mentioning the Holdridge triangle and latitudinal variability so that the discussion on the latitudinal variability is continuous. An order such as: Introduce the classification of the PDFs, then discuss Köppen classification of site PDFs, and then discuss Holdridge triangle position and latitudinal variability of site PDF. Author response: We think this is an excellent suggestion, we will consider it in the corrected manuscript.

17. What does "NEP-WCMC" stand for on pg 3 line 12? Author response: It is a typing error, the correct is UNEP-WCMC (https://www.unep-wcmc.org/resources-and-

data/holdridges-life-zones). Also, it lacks the complete reference. We will fix it.

18. There seems to be some disagreement between the abstract and the conclusion. The abstract says: "Unimodal distributions with high dispersion are concentrated in the moist forest life zone in subtropical and tropical regions and humid province; and unimodal distributions with low dispersion are concentrated in dry forest, very dry forest, and thorn woodland in tropical and subtropical regions between arid and subhumid humidity provinces." The conclusion says: "High latitudes sites exhibit bimodal distributions, arid to sub-humid climates exhibit unimodal distributions with high dispersion, and humid tropical regions exhibit unimodal distributions with low dispersion." Author response: The appropriate remark is that of the abstract. We will improve the conclusions, especially in relation to the humidity provinces.

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