Evapotranspiration seasonality across the Amazon basin

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Paper review

Summary

This paper uses a water balance approach to calculate evapotranspiration (ET) in five sub-basin of the Amazon River. It focusses on seasonal variability of ET and its relationship with precipitation, radiation and vegetation greenness. It also compares water-balance ET with model-calculated ET. Overall, the paper is very clearly written and is a valuable input to the literature. It confirms the highly variable nature of ET across the Amazon basin, and the difficulty models still have to capture ET seasonality in that region. However, there are significant problems in the calculation, presentation and interpretation of the results that will need to be addressed. In general, some claims are not clearly demonstrated in the corresponding figures, conclusions are often contradictory throughout the paper and some figures have interesting patterns that are not clearly addressed. Also, the discussion about uncertainty is not integrated in the interpretation of the results, leading to constant contradictory comments.

General Comments

For equation 2: if for any given month *n*, the monthly change in water storage is defined as

$$dS_n = TWSA_n - TWSA_{n-1}$$

then, the three-months sliding window should be

$$dS_n = TWSA_{n+1} - TWSA_{n-2}$$

assuming that the window includes both month that precedes and follows month n. This should be corrected and ET recalculated accordingly.

Throughout the paper, it would be useful to have radiation, ET and rainfall in the same units, to be able to see the relative magnitudes of those values. This is especially true when doing a Radiation/Rainfall ratio, as in figure 5, or a scatterplot as in figure 6, and would greatly improve the legibility in figure 3 as well.

Every term in the water balance, as well as the additional terms of radiation, PET and EVI come from different datasets, with different assumptions, instruments and uncertainties. Even if it is very difficult to assess the overall uncertainty of the ET calculation, data could show problems that are only mentioned at the end of the paper, but never integrated in the result discussion, particularly when it is hard to make physical sense of the results. As examples, there are negative values in figure 4 (Solimões) or an unexplained decrease in ET in Solimões for August-November.

Even through the authors claim to find some water-limitation in a few basins, those claims are not well supported by their results, particularly in figure 3. Even though ET > P in Purus, Madeira and Tapajós for the months of May-September, ET is generally increasing in those months, showing that plants have access to water storage and are probably not water stressed, but respond to an increase in radiation. This is also shown in figure 4, where ET < P-dS for all basins and all months. There should be further discussion about PET > ET (figure 4) for Purus, Madeira and Tapajós for the months of May-September. The addition of MODIS PET in figure 3 could help with that discussion.

The paper makes a couple of claims about inter-annual variability of climatic factors and ET (e.g. page 11, line 6) without clearly analyzing or showing the relative magnitudes of those variabilities. The paper can either clearly analyze the inter-annual variability and discuss it, or drop the claims.

Specific comments

Figure 3 would highly benefit of having consistent units between radiation, precipitation and evapotranspiration. It would also benefit of a superposition of radiation and ET. The addition of runoff would add important information. Even though runoff is a major part of the model equation, it is never shown in the figures, making it harder to understand the entire water balance. Also, the figure should probably show dS/dt and not TWSA, which is the term used in the equation and the next figure.

Another interesting addition to figure 3 would be to add MODIS PET. It is used in figure 4 to calculate the Budyko dryness index, but understanding its relationship to ET in figure 3 would be very useful. A graph with radiation (unit converted), ET and PET together would be beneficial.

Figure 4 has inconsistencies. There are problematic negative values of AET/P-dS in the Solimões graph that are not present in the all-basin graph. If those values are correct, there must be problems in the data that are not mentioned.

Figure 4 is the main source indicating the water-limitation in Purus, Madeira and Tapajós. Even though, PET/P-dS > 1, most corresponding values of ET/P-dS are not close to 1, suggesting that there is a lot of water that is not used/available for ET, or that ET is underestimated. More discussion should address this point. The addition of another source of PET (derived from the Radiation data, with a Priesley-Taylor equation for example) could also add some information.

Figure 5 is very misleading. First the units should be corrected so that the ratio has some physical consistency and would represent some fashion of a dryness index. Even though the seasonality should not be affected by the unit conversion, the interpretation of this figure is weak. The decline in the radiation/rainfall ratio from August to October is due to a higher increase in rainfall than radiation but both values are increasing according to figure 3. If ET would “maximize its use of radiation and water”, as stated on page 7, lines 21-22, then ET would still increase during those months, having both more radiation and more water available. Figure 3 shows that ET is always smaller than P, which suggests, as the authors pointed out (page 10, line 25), that the basin is never water-limited. Figure 3 also shows that ET is slightly out of phase with Radiation, which is puzzling and should be discussed. In short, figure 5 does not add valuable physical understanding of ET in Solimões, and more discussion should address the intriguing results of that particular basin (especially in the light of figure 2, low ET).

Figure 6 aggregates all basins into one figure, which can be debatable if there are to be differences in ET responses to climatic drivers in different regions. Nonetheless, the lowest ET values are mainly located in the mid-range of both radiation and rainfall, which is not discussed. High ET in relative low radiation and high precipitation could indicate that the ET is not limited by either climatic factor. On the other hand, the relatively low ET values when both radiation and precipitation are low can indicate a combined effect or either one of them, but with the units not being consistent it is hard to interpret. In short, the figure is not discussed in its full potential, and claims are weak.

Page 6, line 25-26. The sentence “Furthermore, …” is unclear because if part of the basin is at higher elevation with less rainfall, then it does not explain why the annual rainfall is still similar to that in Purus, or the relatively low ET.

Page 7, lines 1-3. ET>rainfall does not indicate a limitation in water availability, because of possible water storage and root access to deep water. Even if the lowest ET values were found when rainfall was in decline, ET increases in the lowest rainfall months. Those statements need to be rephrased.

Page 7, lines 8-10. There is confusion between seasonal and inter-annual variation in that first sentence. ET shows small seasonal variation (or none) but huge inter-annual variation (figure 3), but it does not read that way! As stated, that basin is probably operating at PET all year, having enough energy and water all the time (but that could be interesting to see, with added PET on figure 3)

Page 7, lines 19-22. See comments for Figure 5 above. If “ET maximizes the use of both solar radiation and water” then why is ET decreasing when both Radiation and rainfall increase? More discussion or analysis are needed to understand this region.

Page 7, lines 23-27. See comments for Figure 6 above.

Paragraph 3.3 is very interesting. More emphasis could be put on the fact that the relationship between greening and ET is weak (low r^2 and low/no slopes). The best correlation is in Solimões where the relation is opposite to the one in the other basins. In Tapajós, there is no correlation between EVI and ET, if anything ET is more variable (scattered) with higher EVI.

Page 8, lines 15-18. In the Solimões basin, the two models agree in their seasonal pattern of ET. They can be both misrepresenting what is happening, but given that the water-balance estimate of ET is hard to understand, some discussion about the water-balance method uncertainties (here or in paragraph 4.3) seems necessary.

Page 11, lines 10-15. Even though water balance methods are adequate alternative, the entire discussion lacks any perspective on uncertainties. In particular in places were ET seasonality is difficult to understand, like in Solimões.

Page 9, lines 26-30. This discussion would suggest that there is no water-limitation. This is inconsistent with figure 4 and some previous comments and discussion. It is also directly contradicted in page 10, line 9.

Page 10, line 25-26 is inconsistent with the statement on page 10, line 9, but in agreement with the previous discussion on page 9.

Paragraph 4.2. The discussion is interesting and maybe it could be more clearly stated that ET and EVI don't seem to have any causal relationship. Therefore using EVI for modeling ET is not advisable.

Page 11, line 5-6. There is no inter-annual analysis in this paper.

Page 11, line 7. See comment for figure 5. This statement is not backed by data.

Page 12, lines 3-13. This discussion should be integrated in the interpretation of figure 4, as suggested above. PET is likely overestimated in Madeira, Purus and Tapajós as well as Solimões, as discussed on page 9, lines 26-30.

Minor comments

Equation 1, page 3 line 27, should read

$$ET = P - R - \frac{dS}{dt}$$

time is in a lowercase format by convention (needs to be corrected in the following line 28 as well)

Page 9, lines 16-17 should read P-dS (capital S)

If possible, clean the connection of the upper/lower parts on figure 1 (around 13S) to eliminate the artificial line/disconnect.

Figure 4

- A great proportion of the figure is blank. It would be much clearer if the scale on the y-axis was only up to 1, therefore spreading out the data points
- Why is the graph not positioned at (0,0)? Why are there negative values of AET?
- The legend doesn't need to be repeated 5 times, thus gaining some space for the data

Figure 7. The values of Table 2 could be added to the figure, then the reader would not need to go back and forth from both of them.

Page 12, line 3 "therefore" means thus and should be spelled "therefore".