

***Interactive comment on* “Exploring the relationship between warm season precipitation, potential evaporation, and “apparent” potential evaporation at site scale” by Xi Chen and Steven G. Buchberger**

Anonymous Referee #2

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GENERAL COMMENTS:

This paper is an observational study of the relationships between various idealized fluxes of evaporative demand as they are manifest in two paradigms: the Budyko framework and the complementary relationship between regional evapotranspiration and evaporative demand. While the paper does not break new theoretical ground beyond combining the complementary relationship and Budyko paradigms, it nevertheless provides essential, continental-scale verification of these relationships through observation, and, as such, should make a significant impact on the field. The authors

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are to be commended for avoiding the common pitfalls of working with pan evaporation data (for their Epa data): measurement uncertainty due to heterogeneity and the dataset's pronounced regional bias. To isolate the effects of artificial uncertainties introduced to their Epa analyses, they compare to a smaller, homogenized pan evaporation dataset. And they limit the period of analysis of their data to only those months for which they have complete data: they do not attempt to scale up to complete years, which would otherwise introduce spurious, unknown biases. The paper is written and structured well and requires only technical revisions.

SPECIFIC COMMENTS: Following are the main issues to address:

1. In general, dealing with the hornet's nest of terminology is difficult but essential. The authors have done a tremendous job of introducing the various terms involved in the CR and the Budyko framework, and of keeping them distinct. However, to forestall initial confusion on the parts of readers who may already use different terminology (for example, what is called "apparent potential evaporation" here I call "potential evaporation," but what is called "potential evaporation" I call "wet environment evaporation"), they should state at the beginning of the Introduction that terms will be used in a way unfamiliar to some readers and then make reference to a table that compares them (I refer here to a table that was included in an earlier iteration of this manuscript).

2. This is the only outstanding comment from the previous review I gave to this manuscript: No process-scale explanation of either the surface-atmosphere feedbacks that drive the complementary relationship (including asymmetry vs. symmetry in the CR), nor the attribution of the water and energy budgets in the Budyko framework. This should be the text for their Figure 1. Also, the spatial scale-dependent homogeneity assumptions and the physical land-atmosphere feedbacks that underpin the CR need to be explained, as do the timescale-dependent assumptions of the Budyko framework. This would explain both the independence observed between P and E_p but also the dependence of E_p on P .

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3. While the authors have changed to using warm-season data only since the earlier iteration I reviewed, they should also use the full-year (annual) data where it is available, i.e., the southern states. This would only strengthen their observations and credibility.

4. They demonstrate the inter-relations of E_p , E_{pa} and P through time at single points, although this analysis seems less than satisfying as currently presented. Below, I have suggested different graphics.

SPECIFIC COMMENTS: Minor issues to address:

L 47: Here, by “surface vapor pressure” I believe the vapor pressure directly at the surface is meant here, rather than the more-familiar height of 2 m. If so, this should be specified.

LL 122-123: This is a little misleading as it makes it appear possible that E_{pa} can be less than E_p in some circumstances.

LL 166-189: Nowhere is it specified what is meant by “warm-season.” Is it the period at each pan for which air temperatures are above freezing, or May through-October for all pans, or something else?

L 189: What is the value of the pan coefficient for Eq. (3), 0.7?

L 190: That this is also called the “partial equilibrium evaporation rate” should probably be mentioned.

LL 193-195: What are the units, dimensions?

LL 247-248: There are many more reasons than this that this dataset was homogenized, and they bear mentioning here.

LL 275-276: I don’t think these different mechanisms are ever explained; they should be.

LL 282-290: See comment on Fig. (6) below.

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LL 310-311: The reasoning behind the asymmetry should be summarized here. E.g., symmetry (when $b = 1$) implies that all energy released as increased sensible heat as latent heat declines goes to increase E_{pa} by the same amount that latent heat declines.

LL 336-339: I think this thought needs more development: perhaps a hypothesis as to a causal relationship?

Figure 6: I believe I called for these time-series plots in my review of an earlier version, but now I see that they are actually not that explicative. As presented these time-series don't clearly demonstrate the inter-relations under discussion. In the long-term, multi-annual; complementarity is evident in Fig. (6c), but one has to look really hard to observe the CR at the inter-annual timescales, which is the scale to which the text refers. Perhaps it would be better to either plot these as X-Y scatterplots, or with each flux plotted as an anomaly around its climatological annual mean.

TECHNICAL COMMENTS: There are some hyphenation issues: there should be no hyphens after words ending in *-ly*, e.g., use “physically based” not “physically-based”; however, “warm season” should, in general, be hyphenated—i.e., “warm-season”—particularly where it is used as a compound adjective (more often than not in this manuscript). “As well as” should always simply be “and.” I have pointed out a few points where there was repetition.

L 1: “Warm season” should be hyphenated, here and wherever it is used as a compound adjective throughout the manuscript (which is almost everywhere).

L 30: “Missing word: use “. . .93% of the study weather stations. . .”

L 65: Use “. . .the Budyko framework and Bouchet's complementary. . .”

L 66: Use “. . .use the Fu equation. . .”

LL 78-81: This is repeated from earlier in this section.

L 90 and 93: Use “relationships” – plural.

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L 123: Use “conditions” – plural.

L 124: Missing word: use “. . .the ratio of E over Epa. . .”

LL 142-147: To clean this section up to eliminate repetition and extraneous text, try: “Ep is a horizontal line in the CR that is parallel to the x-axis (Fig. 1a). Therefore, the modified CR indicates that P and E_p are independent. On the other hand, the upper curve of the CR, representing “apparent” potential evaporation E_{pa}, declines along the x-axis, indicating that E_{pa} and P are not independent. For a dimensionless CR, we normalize the x and y axes. The normalized CR describes the relationship between. . .”

L 149: Try “To connect the Budyko framework with the normalized CR toward formulating the. . .”

L 196: Here, “long-term” needs a hyphen (as does “warm-season”).

LL 214-217: Try “In the 259 weather stations, 93% of the stations have a negative correlation between P and E_{pa} (Fig. 4a), but only 43% are statistically significant ($p < 0.05$; Fig. 4b). All significant P, E_{pa} correlations are negative.”

L 219: Try “. . .climate characteristics: the eastern region. . .”

LL 223-235: This is repeated from above.

LL 228-229: Try “All the warm-season P vs. E_{pa} relations (i.e., all years, all seasons, for a total of 5312 data) are shown in Fig. 5a.”

LL 235-245: For clarity (and less superfluous text), try the following: “The right side of the cloud generally represents the northeastern and southeastern US (green and brown, respectively), while the left side of the cloud generally represents the northwestern and southwestern US (yellow and red, respectively). The left side cloud is more vertically oriented, indicating that the western US has higher E_{pa} variability than P variability. The southwestern US has the highest E_{pa} (red and orange). The north-

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western US has much lower Epa (yellow). On the other hand, the right side of the cloud is more horizontally oriented, indicating that the eastern region has higher P variability than Epa. Unlike in the western US, the difference between the northeastern and southeastern regions is not clear. The southeastern region of the US has a wide P range; while points of the northeastern region are more concentrated.”

LL 252-253: Try “Only 41% of the stations have statistically significant relationship ($p < 0.05$); all negative.”

L 279: Try “. . .four weather stations from the four quadrants of the conterminous US to show the warm-season P, . . .”

L 281: Use “Epa” for “pan evaporation.”

LL 281-283: Try “. . .only have Epa data for six or seven months of each year, . . .”

L 283: Delete “selected” here.

L 313: Try “. . .Bouchet-Budyko curve, above which Epa exceeds Ep.”

L 329: Use “According to” instead of “Similar with.”

L 347: “Water-limited” should be hyphenated.

LL 370-372: This sentence is repeated from LL 354-356.

L 377: Hyphenation: use “warm-season.”

L 379: For “. . .in 93% of the study locations.” just use “. . .at 93% of the stations.”

LL 382-383: Delete the redundant phrase “on the relationship between warm season P and Ep”

Figure 3: The caption for panel (b) should specify that these are the homogenized data that overlap the 259-station dataset.

Figure 4: Hyphenation: use “point-scale” not “point scale” in the caption.

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Figure 7: In the caption, state what the lower dotted line represents.

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