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Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Can we trust remote sensing ET products over Africa?" *by* Imeshi Weerasinghe et al.

Imeshi Weerasinghe et al.

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Overview

We want to thank the reviewers for their dedication in reviewing the manuscript. We also are thankful for their thoughtful and constructive suggestions and comments. We have addressed all the comments raised by the reviewers and the manuscript has improved from the proposed changes.

Reviewer 1

Summary

The manuscript has followed a commendable approach to evaluate eight diverse ET

products and presented a ranking of the different products on data sparse region. The method evaluated 8 products using a basin water balance ET and Budyko curve over several basins across Africa using the average of three precipitation products along with observed runoff data. Care was taken to ensure the assumption of negligible storage change over several years by removing basins that showed trends using the MK test. The manuscript is well-written with a useful application and contribution to the remote sensing community. I have a few general and specific comments that could improve the manuscript.

Authors Response

We thank Reviewer 1 for his/her overall support for our study and the constructive suggestions and feedback that he/she has given for the improvement of the manuscript. Below, we address the issues that were raised for the improvement of the manuscript

Reviewer 1, General Comment

Considering Figure 6, 7 and 8 are key results for the ranking shown in Table 3, the method needs to flesh out how the data points are generated. For example, in Figure 6 seems to show correlation (r) across basins using the mean value for RS and WB ET. As indicated the correlation values are strong for all, but a root mean square error (RMSE) may have been a more useful metrics to compare the different models as that includes bias information. Also, it is not clear if the r difference between adjacent models is significantly different to rank them in a different order. I would think assigning a different rank order when the "r" are not significantly different may inflate the order. But the use of RMSE in the ranking may be more robust and it is not clear why this are not used. Similarly, Figures 7 and 8 could benefit from statement that the table values represent one data point for each basin and the average is the average of all basins, if that is correct? But unless the values in Figures 7 and 8 are missing negative biases, it is not clear how the average becomes so small when the percentage difference in each basin is much higher, as much as 73%. The difference between Figures 7 and 8, i.e., average and weighted average is not clear. Are the weights (basin area) assigned only to the RS ET or to both RS and WB ET and in that case does this mean volumetric ET difference? Again, a more detailed description is required in the methods section. Landcover: it is not clear why the study did not include more land cover types, especially knowing the chosen two landcovers (water and irrigated lands) may not be handled well by some of the models.

Authors Response

1. We have included a description how the data points are generated in the manuscript. (P5,L20), (P5,L26), (P6,L11)

2. We have also included both RMSE and basin area weighted RMSE along with correlation (r) in the study. We kept r in the study due to the correlation assessing solely the patterns of ET variability between basins rather than also the magnitude. There is not a significant difference between the correlations between the products. But what we do see here is that different products rank higher in this statistical criteria and feel it may be an interesting statistic for a reader depending on their study of interest. In terms of inflating the statistics, due to there being several statistical criteria included in the catchment water balance ranking, we feel this should not drastically change the results. (P6,L12) and Table 5.

3. We have included in the methodology the calculation steps for ET, including where basin areas where taken from and that the mean ET from the basin was recorded. Thss indicats one data point (mean) for each basin. (P6,L11)

4. The difference between average and weighted average is dependent on the area of each basin. This is now explained in the manuscript. It is not volumetric ET difference but difference in mm/year between calculated WB ET and ET estimated by products when considering the basin area weights. Therefore basins with larger areas have a stronger weight than basins with a smaller area as given by the used shapefile areas. (P5,L20), (P6,L12), (P6,L14)

5. Land cover: Since we have to use large land cover types in order to visually see difference at the African scale, we only used large irrigated areas and large water bodies. We have now also included large forested areas, the Congo forest, in our study and have not zoomed into a particular section of Africa but looked at it as a whole. (P8,L2)

Authors Changes in Manuscript

1. “Catchment or basin areas were taken from the ’Major River Basins of the World’ (MRBW) shapefile. Discharge was converted from cubic meters per second to millimetres per year using the above mentioned catchment areas for all years of data availability for each basin.” “Long-term ETWB was calculated by using the long-term average discharge and precipitation data for each catchment.” “Basin average ETWB was calculated according to the MRBW shapefile boundaries and the basin mean was recorded.”

2. “The Root Mean Square Error (RMSE), the basin area weighted RMSEaw, the correlation coefficient (r), bias and basin area weighted biasaw with calculated long-term average ETWB versus ETRS for all basins were found. “

3. “Basin average ETWB was calculated according to the MRBW shapefile boundaries and the basin mean was recorded.”

4. “Catchment or basin areas were taken from the ’Major River Basins of the World’ (MRBW) shapefile.” “The Root Mean Square Error (RMSE), the basin area weighted RMSEaw, the correlation coefficient (r), bias and basin area weighted biasaw with calculated long-term average ETWB versus ETRS for all basins were found.“ “Basin area weighted bias and RMSE were found due to a large difference in basin areas. Therefore, basins with larger areas had more weight in the basin area weighted statistics than basin with smaller areas.”

5. “Three types of land cover elements were evaluated in this study, irrigated areas,

water bodies and forested areas."

Reviewer 1, Specific Comment 1

Tables and figures would need improved captions and header names that would help them stand alone.

Authors Response

Many of the section headers and figures in the paper have changed and the captions added or updated to reflect the content and to be able to stand alone. (Throughout the manuscript)

Previous headers and figure captions:

1. Introduction

2. Data

2.1. Remotely Sensed ET products

2.1.1. GLEAM

2.1.2. WaPOR

2.1.3. MOD16

2.1.4. SSEBop

2.1.5. WECANN

2.1.6. FLUXNET-MTE

2.1.7. ETMonitor

2.1.8. CMRSET

2.1.9. Multi-Product Mean

2.2. Precipitation data

2.2.1. EWEMBI

2.2.2. CHIRPS

2.2.3. MSWEP

2.3. Discharge data

2.4. Reference potential evapotranspiration data

3. Methodology

3.1. Preprocessing and data analsysis

3.2. Comparison using WB inferred ET estimates

3.3. Performance with characteristics land cover elements

3.4. Evaluation using the Budyko curve

4. Results

4.1. Catchment water balance

4.1.1. Preprocessing and data analsysis

4.1.2. Comparison using WB inferred ET estimates

4.1.3. Performance with characteristics land cover elements

4.1.4. Evaluation using the Budyko curve

5. Discussion

6. Conclusions

Fig 1: left) distribution of flux towers with LE data across Africa. (right) Number of years of available data at the six flux tower sites across Africa for both gap filled and bias corrected LE

Fig 2: (left) All major basins in Africa and all discharge stations; (right) Major basins in Africa with available discharge data at outlet

Fig 3: Budyko curve showing the energy limit and water limit

Fig 4: (right) ET estimation for 28 major basins in Africa using P-Q (left) Final basins being analysed after trend analyses

Fig 5: Dendogram after performing a cluster analysis showing the overall level of similarity between the RS products and MPM

Fig 6: Correlation between long-term mean WB inferred ET and RS derived ET across basins using three different precipitation products (EWEMBI (left), CHIRPS (middle) and MSWEP (right))

Fig 7: Percentage difference between long-term mean WB inferred ET and RS derived ET across basins using three different precipitation products (EWEMBI (left), CHIRPS (middle) and MSWEP (right))

Fig 8: Weighted average (based on area) percentage difference between long-term mean WB inferred ET and RS derived ET across basins using three different precipitation products (EWEMBI (left), CHIRPS (middle) and MSWEP (right))

Fig 9: Comparison of RS products in representing irrigated areas. Zoomed to part of the Nile basin.

Fig 10: Comparison of RS products in representing water bodies. Zoomed to part of the Nile basin.

Fig 11: Average difference across long-term ET and PET estimates using (top) P-M (middle) P-T and (bottom) Hargreaves approaches for irrigated areas

Fig 12: Average difference across long-term ET and PET estimates using (top) P-M (middle) P-T and (bottom) Hargreaves approaches for water bodies

Fig 13: Evaluation of EWEMBI WB and RS derived ET estimates using the Budyko curve with PET estimates from Hargreaves, PM and PT approaches. Figure (a) WECANN ET estimations (smallest difference with Budyko curve), Fig. (b) WB ET estimations and Fig. (c) GLEAM ET estimations (largest difference with Budyko curve) plotted on the Budyko curve.

Fig 14: Evaluation of CHIRPS WB and RS derived ET estimates using the Budyko curve with PET estimates from Hargreaves, PM and PT approaches. Figure (a) WECANN ET estimations (smallest difference with Budyko curve), Fig. (b) WB ET estimations and Fig. (c) GLEAM ET estimations (largest difference with Budyko curve) plotted on the Budyko curve.

Fig 15: Evaluation of MSWEP WB and RS derived ET estimates using the Budyko curve with PET estimates from Hargreaves, PM and PT approaches. Figure (a) WECANN ET estimations (smallest difference with Budyko curve), Fig. (b) WB ET estimations and Fig. (c) CMRSET ET estimations (largest difference with Budyko curve) plotted on the Budyko curve.

Authors Changes in Manuscript

“. . . 1. Introduction

2. Data and Methods

2.1. Data

2.1.1. Evapotranspiration products

2.1.2. Precipitation products

2.1.3. Discharge data

2.1.4. Reference potential evapotranspiration products

2.2. Methods

2.2.1. Catchment water balance evapotranspiration (ETWB)

2.2.2. Evaluation using the Budyko curve

2.2.3. Spatial variability assessment

2.2.4. Assessment of similarity

3. Results

3.1. Catchment water balance

3.1.1. Comparison of precipitation and potential evapotranspiration products

3.1.2. Basins used in analyses

3.1.3. Catchment water balance comparison

3.2. Evaluation using the Budyko curve

3.3. Spatial variability assessment

3.4. Product similarity assessment

3.5. Ranking of products

4. Discussion

5. Conclusion ...”

Fig 1: “(left) distribution of flux towers worldwide. (right) distribution of flux towers across Africa”

Fig 2: “(left) All major basins in Africa and all available discharge stations; (right) Major basins in Africa with available discharge data at outlet”

Fig 3: “Budyko curve showing the energy limit and water limit for reference ET condition

by partitioning precipitation into discharge and evapotranspiration”

Fig 4: “Selected land cover elements represented by the IFL, WB GRanD and AEIai maps with areas selected for visual assessment highlighted”

Fig 5: “Comparison of the EWEMBI, MSWEP and CHIRPS precipitation products on their prediction of mean P across the basins”

Fig 6: “Comparison of the P-M, P-T and Hargreaves potential evapotranspiration products on their prediction of mean PET across the basins”

Fig 7: “(right) ETWB estimation for 28 major basins in Africa using P-Q (left) Final basins being analysed after analyses to discount basins with trends in ETWB, P and/or Q.”

Fig 8: “Percentage bias and basin area weighted percentage bias between the long-term annual average calculated ETWB and ETRS for all basins and the average of the 20 basins”

Fig 9: “Evaluation of the calculated ETWB and ETRS from products using the Budyko curve calculated using average P and PET from three products”

Fig 10: “Spatial assessment across Africa of each ET product based on selected land cover elements, forest, irrigated areas and water bodies”

Fig 11: “Comparison of mean ET across the selected forested area for each product versus mean ET found from literature”

Fig 12: “Comparison of the calculated kc for each product using average of the three PET products versus the average kc from maize, wheat and sugarcane from FAO.”

Fig 13: “Comparison of mean ET across water bodies estimated by each ET product and PET using the average of three PET products”

Fig 14: “Cluster analysis based on the pairwise Euclidean distance between each pixel for each ET product to assess overall similarity between data sets”

Reviewer 1, Specific Comment 2

Figures 7 and 8 may benefit from one more panel which shows the average of the three precipitation products as the ranking is based on the average the three.

Authors Response

We have taken out the statistics based on each different precipitation product and have used the average of the three products after a comparative analysis of the three precipitation products. In this way, instead of including a separate column with the average of the three products in figures 7 and 8, we have included one figure (figure 8) which shows the percentage bias and percentage basin area weighted bias between calculated water balance ET and ET estimates from products across the basins. This includes positive and negative biases giving an idea of under or over estimation by each product across different basins or the average of all basins. (P5,L23) and Figure 8.

Authors Changes in Manuscript

“Since direct observations of precipitation from gauges were not used, precipitation was taken as the average of the three data products EWEMBI, CHIRPS and MSWEP.”

Reviewer 1, Specific Comment 3

Zoom-in maps: it is hard to see the differences in Figures 9 and 10 among models. Maybe it is better to show deviations from the MPM data, i.e., show MPI in mm but the rest of the models as differences from MPM. Also remove the grid lines, hard to read the maps. A better color ramp will help readability.

Authors Response

We have not zoomed into a particular area but have looked at the land cover elements with respect to the entire continent. The colour ramp used is now clearer between

the selected land cover elements and each element has been highlight with a box. The multi-product mean (MPM) was not used anymore as for the multi-product we used a different existing product. This was used instead of calculated the MPM from our products due to a comment by another review which asked to look at a weighting system for its calculation which was not in the scope of this study. (Figure 10)

Authors Changes in Manuscript

Figure 10

Reviewer 1, Specific Comment 4

Revisit carefully the description and citation of some products. For example, SSEB vs SSEBop. As far as I know the global product is from SSEBop with a different citation with a 10-day (dekad) time scale, not monthly. Model’s pre-defined boundary limits are described in SSEBop’s work and not in the indicated citations.

Authors Response

We have carefully revisited the descriptions and citations of the products used in this study. The SSEBop product as far as I have found in the USGS FEWS NET data portal the product is only available at monthly and yearly time scales when looking at the global scale and decadal for continental Africa. For this reason I used the monthly products. The citation was updated. (Table 1)

Authors Changes in Manuscript

Table 1

Reviewer 1, Specific Comment 5

It will be useful to include data source (website link) of the different models for access and discuss why the different models appear to discontinued

Authors Response

We have included an access link in Table 1. We have not discussed why different models have been discontinued but have mentioned which models are discontinued to take into consideration when selecting a product to use. (Table 1), (P20,L20)

Authors Changes in Manuscript

Refer to Table 1 under Reviewer 1, Specific Comment 4

“LandFlux-EVAL and MTE also have early starting years however only go up to 2005 and 2012, respectively. ETMonitor is also no longer being extended and is not openly accessible or available for use.”

Reviewer 1, Specific Comment 6

Include some discussion on the performance of MTP in relation to the WB ET (rank 5) and the value for MTP or ensemble products for future use.

Authors Response

We have used an existing ensemble product, LandFlux-EVAL as the multi-product within study due to questions regarding the calculation of the MPM. This product was used also due to the initiative to create a benchmark product with the ET datasets using a range of different products for two long periods. We found this product ranked well even considering the coarseness in spatial resolution, which showed promise for ensemble products in the future. (P19,L29)

Authors Changes in Manuscript

“LandFlux-EVAL, with the coarsest spatial resolution, ranked fourth in the final ranking only outranked by the products with the three highest spatial resolutions in this study, CMRSET, SSEBop and WaPOR. Therefore, LandFlux-EVAL performs well overall regardless of it’s coarse resolution and is interesting due to being an ensemble product. Therefore, continuation or commencement of a similar initiative to develop a benchmark product using a range of ET data sets including high resolution products ranked

within this study may improve the ensemble product for future use.”

Reviewer 1, Specific Comment 7

Table 2: not clear what “not enough data” is referring to.

Authors Response

This means that from the calculated ETWB, there are less than 10 years of data available to calculate the MK test. This has been amended in the table to be clearer it is regarding the ET data points. (Table A1) Authors Changes in Manuscript

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-233, 2019.

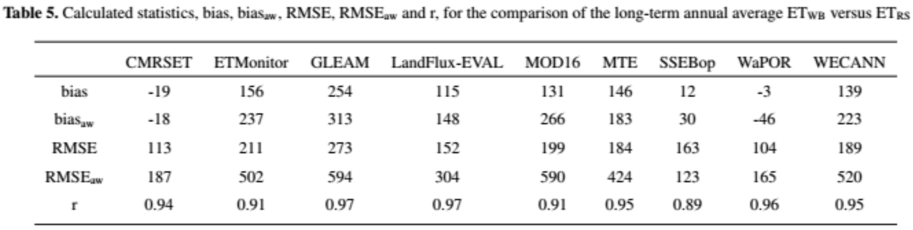
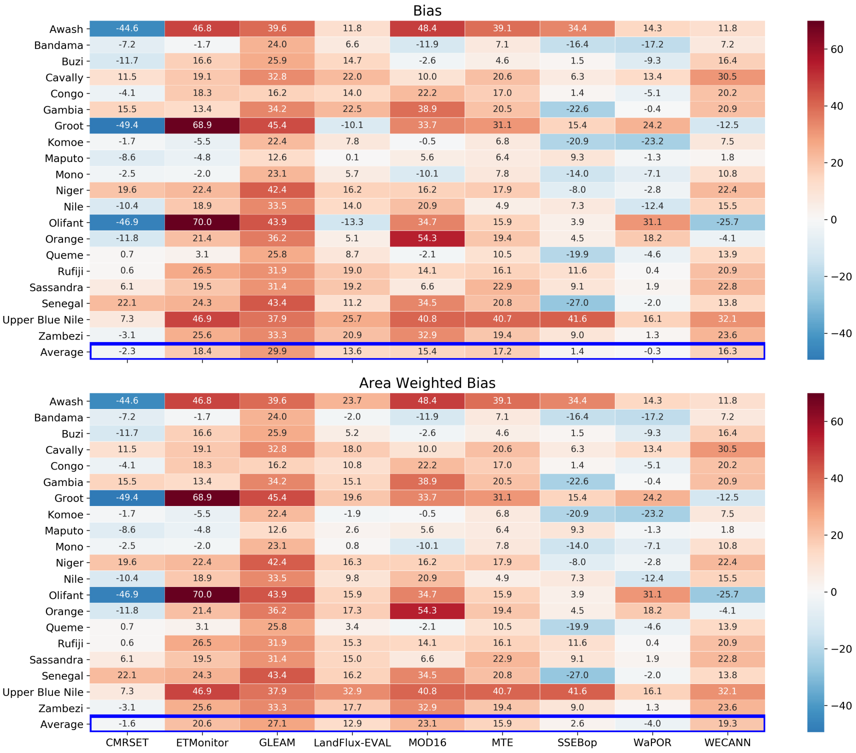


Table 5. Calculated statistics, bias, bias$_{aw}$, RMSE, RMSE$_{aw}$ and r, for the comparison of the long-term annual average ET$_{WB}$ versus ET$_{RS}$

	CMRSET	ETMonitor	GLEAM	LandFlux-EVAL	MOD16	MTE	SSEBop	WaPOR	WECANN
bias	-19	156	254	115	131	146	12	-3	139
bias$_{aw}$	-18	237	313	148	266	183	30	-46	223
RMSE	113	211	273	152	199	184	163	104	189
RMSE$_{aw}$	187	502	594	304	590	424	123	165	520
r	0.94	0.91	0.97	0.97	0.91	0.95	0.89	0.96	0.95

Fig. 1. Table 5: Calculated statistics, bias, bias_aw, RMSE, RMSE_aw and r for the comparison of the long-term annual average ET_WB versus ET_RS



Bias

	CMRSET	ETMonitor	GLEAM	LandFlux-EVAL	MOD16	MTE	SSEBop	WaPOR	WECANN
Awash	-44.6	46.8	39.6	11.8	48.4	39.1	34.4	14.3	11.8
Bandama	-7.2	-1.7	24.0	6.6	-11.9	7.1	-16.4	-17.2	7.2
Buzi	-11.7	16.6	25.9	14.7	-2.6	4.6	1.5	-9.3	16.4
Cavally	11.5	19.1	32.8	22.0	10.0	20.6	6.3	13.4	30.5
Congo	-4.1	18.3	16.2	14.0	22.2	17.0	1.4	-5.1	20.2
Gambia	15.5	13.4	34.2	22.5	38.9	20.5	-22.6	-0.4	20.9
Groot	-49.4	68.9	45.4	-10.1	33.7	31.1	15.4	24.2	-12.5
Komoe	-1.7	-5.5	22.4	7.8	-0.5	6.8	-20.9	-23.2	7.5
Maputo	-8.6	-4.8	12.6	0.1	5.6	6.4	9.3	-1.3	1.8
Mono	-2.5	-2.0	23.1	5.7	-10.1	7.8	-14.0	-7.1	10.8
Niger	19.6	22.4	42.4	16.2	16.2	17.9	-8.0	-2.8	22.4
Nile	-10.4	18.9	33.5	14.0	20.9	4.9	7.3	-12.4	15.5
Olifant	-46.9	70.0	43.9	-13.3	34.7	15.9	3.9	31.1	-25.7
Orange	-11.8	21.4	36.2	5.1	54.3	19.4	4.5	18.2	-4.1
Queme	0.7	3.1	25.8	8.7	-2.1	10.5	-19.9	-4.6	13.9
Rufiji	0.6	26.5	31.9	19.0	14.1	16.1	11.6	0.4	20.9
Sassandra	6.1	19.5	31.4	19.2	6.6	22.9	9.1	1.9	22.8
Senegal	22.1	24.3	43.4	11.2	34.5	20.8	-27.0	-2.0	13.8
Upper Blue Nile	7.3	46.9	37.9	25.7	40.8	40.7	41.6	16.1	32.1
Zambezi	-3.1	25.6	33.3	20.9	32.9	19.4	9.0	1.3	23.6
Average	-2.3	18.4	29.9	13.6	15.4	17.2	1.4	-0.3	16.3

Area Weighted Bias

	CMRSET	ETMonitor	GLEAM	LandFlux-EVAL	MOD16	MTE	SSEBop	WaPOR	WECANN
Awash	-44.6	46.8	39.6	23.7	48.4	39.1	34.4	14.3	11.8
Bandama	-7.2	-1.7	24.0	-2.0	-11.9	7.1	-16.4	-17.2	7.2
Buzi	-11.7	16.6	25.9	5.2	-2.6	4.6	1.5	-9.3	16.4
Cavally	11.5	19.1	32.8	18.0	10.0	20.6	6.3	13.4	30.5
Congo	-4.1	18.3	16.2	10.8	22.2	17.0	1.4	-5.1	20.2
Gambia	15.5	13.4	34.2	15.1	38.9	20.5	-22.6	-0.4	20.9
Groot	-49.4	68.9	45.4	19.6	33.7	31.1	15.4	24.2	-12.5
Komoe	-1.7	-5.5	22.4	-1.9	-0.5	6.8	-20.9	-23.2	7.5
Maputo	-8.6	-4.8	12.6	2.6	5.6	6.4	9.3	-1.3	1.8
Mono	-2.5	-2.0	23.1	0.8	-10.1	7.8	-14.0	-7.1	10.8
Niger	19.6	22.4	42.4	16.3	16.2	17.9	-8.0	-2.8	22.4
Nile	-10.4	18.9	33.5	9.8	20.9	4.9	7.3	-12.4	15.5
Olifant	-46.9	70.0	43.9	15.9	34.7	15.9	3.9	31.1	-25.7
Orange	-11.8	21.4	36.2	17.3	54.3	19.4	4.5	18.2	-4.1
Queme	0.7	3.1	25.8	3.4	-2.1	10.5	-19.9	-4.6	13.9
Rufiji	0.6	26.5	31.9	15.3	14.1	16.1	11.6	0.4	20.9
Sassandra	6.1	19.5	31.4	15.0	6.6	22.9	9.1	1.9	22.8
Senegal	22.1	24.3	43.4	16.2	34.5	20.8	-27.0	-2.0	13.8
Upper Blue Nile	7.3	46.9	37.9	32.9	40.8	40.7	41.6	16.1	32.1
Zambezi	-3.1	25.6	33.3	17.7	32.9	19.4	9.0	1.3	23.6
Average	-1.6	20.6	27.1	12.9	23.1	15.9	2.6	-4.0	19.3

Fig. 2. Figure 8: Percentage bias and basin area weighted bias between the long-term annual average calculated ET_WB and ET_RS for all basins and the average of the 20 basins

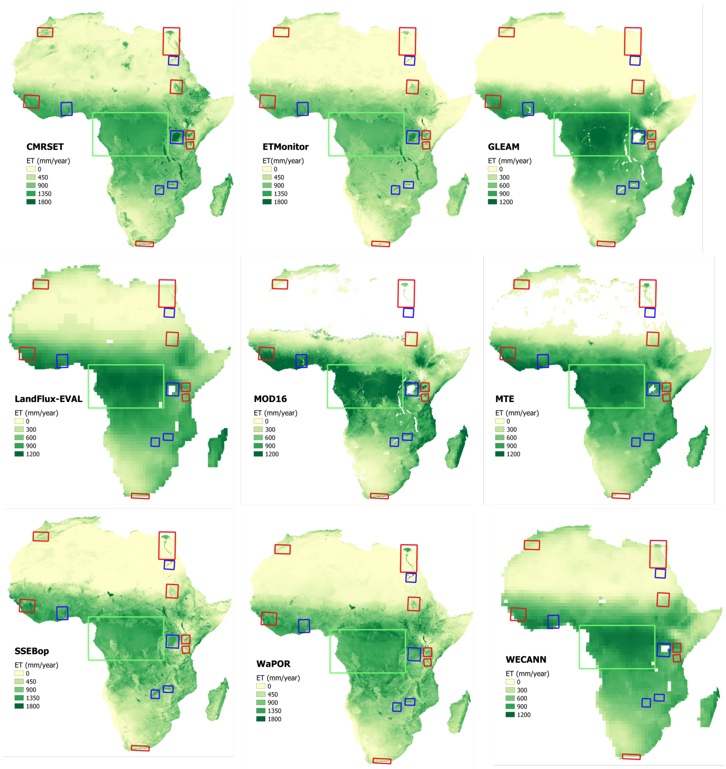


Fig. 3. Figure 10: Spatial assessment across Africa of each ET products based on selected land cover elements, forest, irrigated areas and water bodies

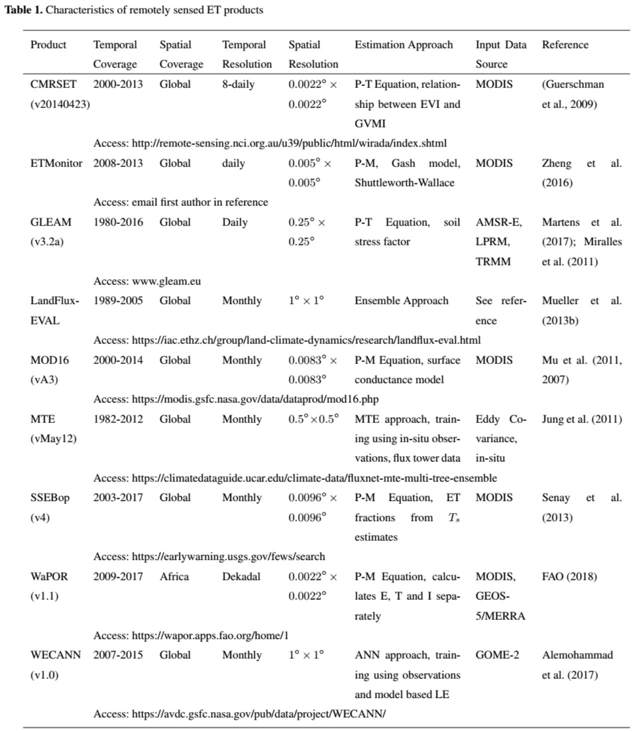
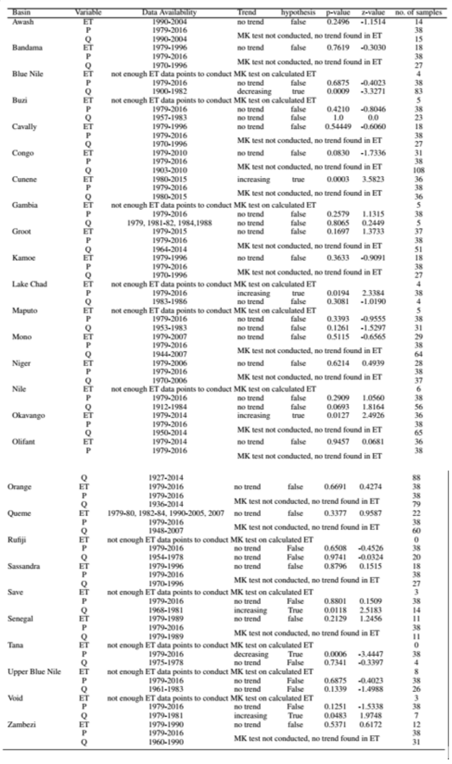


Table 1. Characteristics of remotely sensed ET products

Product	Temporal Coverage	Spatial Coverage	Temporal Resolution	Spatial Resolution	Estimation Approach	Input Data Source	Reference
CMRSET (v20140423)	2000-2013	Global	8-daily	$0.0022° \times 0.0022°$	P-T Equation, relationship between EVI and GVMI	MODIS	(Guerschman et al., 2009)
	Access: http://remote-sensing.nci.org.au/u39/public/html/wirada/index.shtml						
ETMonitor	2008-2013	Global	daily	$0.005° \times 0.005°$	P-M, Gash model, Shuttleworth-Wallace	MODIS	Zheng et al. (2016)
	Access: email first author in reference						
GLEAM (v3.2a)	1980-2016	Global	Daily	$0.25° \times 0.25°$	P-T Equation, soil stress factor	AMSR-E, LPRM, TRMM	Martens et al. (2017); Miralles et al. (2011)
	Access: www.gleam.eu						
LandFlux-EVAL	1989-2005	Global	Monthly	$1° \times 1°$	Ensemble Approach	See reference	Mueller et al. (2013b)
	Access: https://iac.ethz.ch/group/land-climate-dynamics/research/landflux-eval.html						
MOD16 (vA3)	2000-2014	Global	Monthly	$0.0083° \times 0.0083°$	P-M Equation, surface conductance model	MODIS	Mu et al. (2011, 2007)
	Access: https://modis.gsfc.nasa.gov/data/dataprod/mod16.php						
MTE (vMay12)	1982-2012	Global	Monthly	$0.5° \times 0.5°$	MTE approach, training using in-situ observations, flux tower data	Eddy Covariance, in-situ	Jung et al. (2011)
	Access: https://climatedataguide.ucar.edu/climate-data/fluxnet-mte-multi-tree-ensemble						
SSEBop (v4)	2003-2017	Global	Monthly	$0.0096° \times 0.0096°$	P-M Equation, ET fractions from T_s estimates	MODIS	Senay et al. (2013)
	Access: https://earlywarning.usgs.gov/fews/search						
WaPOR (v1.1)	2009-2017	Africa	Dekadal	$0.0022° \times 0.0022°$	P-M Equation, calculates E, T and I separately	MODIS, GEOS-5/MERRA	FAO (2018)
	Access: https://wapor.apps.fao.org/home/1						
WECANN (v1.0)	2007-2015	Global	Monthly	$1° \times 1°$	ANN approach, training using observations and model based LE	GOME-2	Alemohammad et al. (2017)
	Access: https://avdc.gsfc.nasa.gov/pub/data/project/WECANN/						

Fig. 4. Table 1: Characteristics of remotely sensed products



Basin	Variable	Data Availability	Trend	hypothesis	p-value	z-value	no. of samples
Awash	ET	1990-2004	no trend	false	0.2496	-1.1514	14
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1990-2004					15
Bandama	ET	1979-1996	no trend	false	0.7619	-0.3030	18
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1970-1996					27
Blue Nile	ET	not enough ET data points to conduct MK test on calculated ET					4
	P	1979-2016	no trend	false	0.6875	-0.4023	38
	Q	1900-1982	decreasing	true	0.0009	-3.3271	83
Buzi	ET	not enough ET data points to conduct MK test on calculated ET					5
	P	1979-2016	no trend	false	0.4210	-0.8046	38
	Q	1957-1983	no trend	false	1.0	0.0	23
Cavally	ET	1979-1996	no trend	false	0.54449	-0.6060	18
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1970-1996					27
Congo	ET	1979-2010	no trend	false	0.0830	-1.7336	31
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1903-2010					108
Cunene	ET	1980-2015	increasing	true	0.0003	3.5823	36
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1980-2015					36
Gambia	ET	not enough ET data points to conduct MK test on calculated ET					5
	P	1979-2016	no trend	false	0.2579	1.1315	38
	Q	1979, 1981-82, 1984,1988	no trend	false	0.8065	0.2449	5
Groot	ET	1979-2015	no trend	false	0.1697	1.3733	37
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1964-2014					51
Kamoe	ET	1979-1996	no trend	false	0.3633	-0.9091	18
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1970-1996					27
Lake Chad	ET	not enough ET data points to conduct MK test on calculated ET					4
	P	1979-2016	increasing	true	0.0194	2.3384	38
	Q	1983-1986	no trend	false	0.3081	-1.0190	4
Maputo	ET	not enough ET data points to conduct MK test on calculated ET					5
	P	1979-2016	no trend	false	0.3393	-0.9555	38
	Q	1953-1983	no trend	false	0.1261	-1.5297	31
Mono	ET	1979-2007	no trend	false	0.5115	-0.6565	29
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1944-2007					64
Niger	ET	1979-2006	no trend	false	0.6214	0.4939	28
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1970-2006					37
Nile	ET	not enough ET data points to conduct MK test on calculated ET					6
	P	1979-2016	no trend	false	0.2909	1.0560	38
	Q	1912-1984	no trend	false	0.0693	1.8164	56
Okavango	ET	1979-2014	increasing	true	0.0127	2.4926	36
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1950-2014					65
Olifant	ET	1979-2014	no trend	false	0.9457	0.0681	36
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1927-2014					88
Orange	ET	1979-2016	no trend	false	0.6691	0.4274	38
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1936-2014					79
Queme	ET	1979-80, 1982-84, 1990-2005, 2007	no trend	false	0.3377	0.9587	22
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1948-2007					60
Rufiji	ET	not enough ET data points to conduct MK test on calculated ET					0
	P	1979-2016	no trend	False	0.6508	-0.4526	38
	Q	1954-1978	no trend	False	0.9741	-0.0324	20
Sassandra	ET	1979-1996	no trend	false	0.8796	0.1515	18
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1970-1996					27
Save	ET	not enough ET data points to conduct MK test on calculated ET					3
	P	1979-2016	no trend	False	0.8801	0.1509	38
	Q	1968-1981	increasing	True	0.0118	2.5183	14
Senegal	ET	1979-1989	no trend	false	0.2129	1.2456	11
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1979-1989					11
Tana	ET	not enough ET data points to conduct MK test on calculated ET					0
	P	1979-2016	decreasing	True	0.0006	-3.4447	38
	Q	1975-1978	no trend	False	0.7341	-0.3397	4
Upper Blue Nile	ET	not enough ET data points to conduct MK test on calculated ET					8
	P	1979-2016	no trend	False	0.6875	-0.4023	38
	Q	1961-1983	no trend	False	0.1339	-1.4988	26
Void	ET	not enough ET data points to conduct MK test on calculated ET					3
	P	1979-2016	no trend	False	0.1251	-1.5338	38
	Q	1979-1981	increasing	True	0.0483	1.9748	7
Zambezi	ET	1979-1990	no trend	false	0.5371	0.6172	12
	P	1979-2016	MK test not conducted, no trend found in ET				38
	Q	1960-1990					31

Fig. 5. Table A1: Mann-Kendall test results for all basins on evapotranspiration, precipitation and discharge