Evapotranspiration Models Intercomparison and the Need for a Common Framework

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INTRODUCTION

Different remote sensing based modeling approaches are currently available to estimate actual evapotranspiration (ETa) for agricultural water management applications. These models have a wide range of complexity from simple empirical- to complex physically-based, different types of weather forcing and remote sensing input data requirements, and can estimates of ETa at different spatial scales that can range from sub-field to regional scales. These combined set of issues and model applicability can certainly affect the accuracy of ETa estimates. In general, these models can provide reasonable but variable level of accuracy when applied over different types of surface and climatic regions. However, agreement on model performance among users is yet to be addressed considering the aforementioned issues. The results of a model intercomparison analysis indicated that there is a need for a common framework that defines acceptable levels of model estimate accuracy in order to apply such models for regional agricultural water management.

DATA and METHODS

Data from two agricultural fields (*Fig. 1*) at the Palo Verde Irrigation District (PVID), CA and Mead, NE are used in the analysis. The PVID is an irrigated agriculture area (440 km^2) covered with alfalfa (70%), cotton (15%) and mixed vegetable crops (15%). The irrigation water is from the Colorado River via a diversion dam at Palo Verde and a network of irrigation and drainages canals supports the gravity-fed surface irrigation system. The PVID is located in an arid to semi-arid climatic region that receives an average annual precipitation of 50 mm.

The Mead site consist of irrigated and dryland agricultural fields located at the University of Nebraska Agricultural Research Center, Lincoln, NE. There are three fields cultivated with maize crop at two fields supported with pivot irrigation system and the third is a dryland system. Planting and harvesting of the maize crop occur during summer between Late April/ Early May and Late October, respectively.

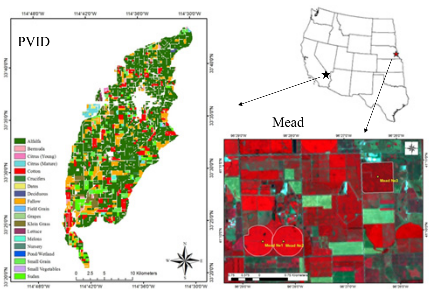


Fig. 1. Location of the study sites PVID and Mead. Land use of PVID during 2008 (Left) and false color image (NIR, RED, Green) for Mead with two center pivot irrigated fields (yellow circles) and dryland field (yellow rectangle)

Five candidate models were used in this analysis including DisALEXI (Norman et al., 2003), METRIC (Allen et al., 2007), ReSET (Elhaddad and Garcia, 2008), SEBS (Su, 2002), and SSEBop (Senay et al., 2013).

RESULTS

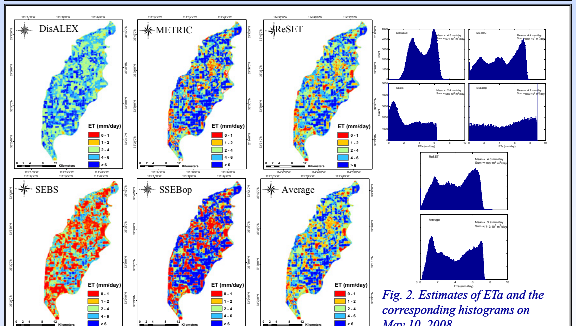


Fig. 2. Estimates of ETa and the corresponding histograms on May 10, 2008.

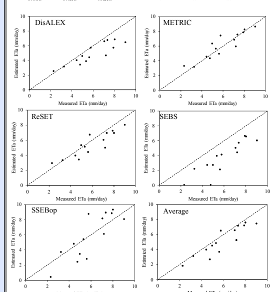


Fig. 3. Comparison of estimates and measurements of ETa during satellite overpass dates for PVID.

Visual inspection of *Fig. 2* clearly showing considerable spatial variability when comparing models estimates to each other. While METRIC and ReSET models ETa estimates showed relatively similar frequency distribution each one of the other models showed its own different behavior. These histograms clearly show how these ETa estimates could be different in terms of spatial variability of ETa. The area-average ETa values varies within a range of 0.5 mm/day when excluding SSEB model. The mean values are 4.5, 4.4, 4.0, and 4.2 for DisALEXI, METRIC, ReSET, and SSEBop, respectively. SEBS model provided 2.4 mm/day which is nearly half of all others. Considering the total area of the PVID of 440 km^2 (or 439,094, 000 m^2) a small ETa difference of 0.5 mm/day will result in a total volume water of 220 x 10^3 m^3/day or 58 Million gallon/day.

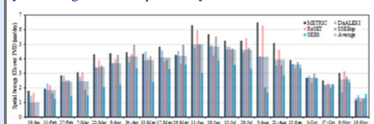


Fig. 4. Average ETa over the PVID during all Landsat 5 overpass dates.

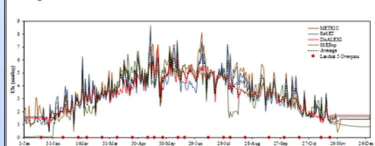


Fig. 5. Seasonal average ETa over the PVID during 2008.

Such variable models behavior during satellite overpass dates throughout the growing season supports the fact that evaluating crop water requirements, irrigation scheduling, and water stress conditions using different models could result in variable crop water management. ReSET and METRIC showed (*Fig. 3 & 4*) a narrow scattering around the 1:1 line while SSEBop showed slightly larger scatter. DisALEXI showed a slight underestimation while SEBS showed considerable underestimation. Based on the RMSD (*Table 1*) the models performance can be ranked as METRIC with the lowest value followed by ReSET, SSEBop, DisALEXI, and SEBS.

RESULTS

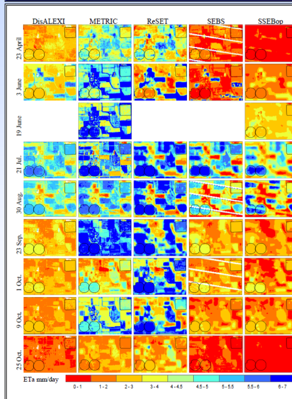


Fig. 6. Maps of ETa during Landsat overpass dates based on DisALEXI, METRIC, ReSET, SEBS, and SSEBop.

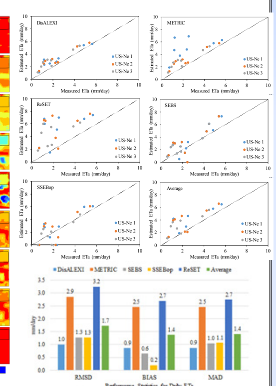


Fig. 7. Comparison between model estimates and measurements of daily ETa during satellite overpass dates along with summary of performance statistics.

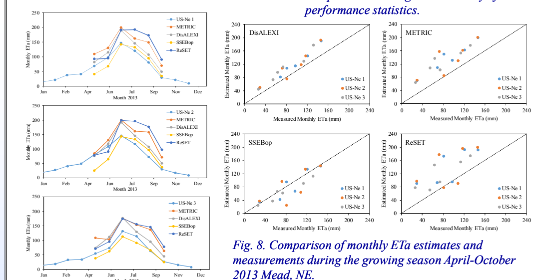


Fig. 8. Comparison of monthly ETa estimates and measurements during the growing season April-October 2013 Mead, NE.

METRIC and ReSET showed (*Fig. 6*) similar behavior throughout the growing season when compared to each other. The other three models DisALEXI, SEBS, and SSEBop behaved relatively similar when compared to each other but as one group they behaved differently compared to METRIC and ReSET.

Daily ETa estimates (*Fig. 7*) based on DisALEXI resulted in the lowest RMSE and the highest was from ReSET followed by METRIC. The other models showed relatively similar behavior with RMSD of 1.3 mm/day.

METRIC and ReSET (*Fig. 8&9 and Table 4&5*) provided the largest overestimation of monthly ETa followed to a lesser extent by DisALEXI when compared with measurements. The SSEBop model underestimated monthly ETa during the April-August and overestimated on the rest of the growing season. DisALEXI and SSEBop provided a narrow scatter of data around the 1:1 line while METRIC and ReSET showed wider scattering away from the perfect match line.

SSEBop and DisALEXI models resulted in relatively low values of RMSD of 23 and 28 mm, respectively, for monthly ETa higher than those for METRIC and ReSET with RMSD of 49 and 59 mm, respectively. Overestimation of monthly ETa values is evident for DisALEXI, METRIC, and ReSET opposed to the underestimation by SSEBop. DisALEXI slightly overestimated monthly ETa by a BIAS of 25 mm while METRIC and ReSET provided considerable overestimation by BIAS of 45 and 46 mm, respectively. SSEBop slightly underestimated monthly ETa by a BIAS of -8 mm.

RESULTS

Comparison of seasonal ETa estimates with water balance ETa_WB at PVID (*Fig. 5; Tables 2&3*) showed that SSEBop and DisALEXI underestimated ETa_WB (1267 mm ±6.3% at 95% confidence level) by -13.95 and -8.6%, respectively, falling beyond the 95% confidence level. ReSET and METRIC models provided seasonal ETa that fall within the 95% confidence level with underestimation of -3.6% and overestimation of +3.5%, respectively. When considering the unmeasured return flow as part of the water balance ETa_WB becomes 1128 mm ± 8.0% at 95% confidence level. The comparison in this case indicated that METRIC and ReSET models provided ETa that fall beyond the 95% confidence level of ETa_WB with overestimation by +16.3% and +8.4%, respectively. SSEBop and DisALEXI in this case provided ETa that fall within the 95% confidence level with underestimation by -3.2% and overestimation by +2.8%, respectively.

Table. 1. Summary of models performance statistics for daily ETa at PVID.

	RMSE mm/day	BIAS mm/day	MAE mm/day	Mean mm/day	Std. Dev. mm/day
Measured				6.55	2.4
SSEB	1.5	-0.2	1.3	6.35	2.8
SEBS	2.7	-2.5	2.5	4.09	2.1
METRIC	0.9	-0.1	0.6	6.45	1.9
ReSET	1.3	-0.8	1.1	5.70	1.7
DisALEXI	1.8	-1.4	1.7	5.20	1.4
Average	1.3	-1.0	1.4	5.54	1.9

Table. 2. Summary of water balance components at PVID for year 2008.

Water Balance Components	Water Balance	Uncertainty
Precipitation (mm) [a]	75	± 16.8%
Inflow Main Canal (mm) [b]	2,475	± 17.6 %
Canal Spills + Outfall Drain (mm) [c]	1,283	± 11.6 %
Unmeasured Returns [d]	139	± 16.8 %
ETa [e] $(e = a + b - c - d)$	1,128 (1,267)[#]	± 8.0 % (± 6.3 %)[#]

Table. 3. comparison of remote sensing ETa estimates and water balance ETa_wb at PVID for year 2008 at .

	Water Balance	METRIC	ReSET	DisALEXI	SSEBop
ETa (mm)	1,128 (1,267)	1,312	1,223	1160	1,092
Uncertainty (%)	±8.0 % (± 6.3%)	+16.3% (+3.5%)	+8.4 (-3.6%)	+2.8% (-8.6%)	-3.2 (-13.9%)
Total Inflow (mm)	2,550	2,550	2,550	2,550	2,550
Total Outflow (mm)	2,550	2,595	2,506	2,443	2,375
Inflow – Outflow (mm)	(0)	+45	-45	-108	-175

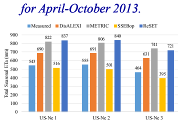
Table. 4. comparison of daily ETa estimates with EC measurements at Mead during 2013.

	DisALEXI	METRIC	SEBS	SSEBop	ReSET	Average
RMSD (mm/day)	28	49	57	23	33	28
BIAS (mm/day)	25	45	46	-8	0.0	25
MAD (mm/day)	25.5	45	49	18	30	25.5

Table. 5. comparison of total seasonal ETa estimates with EC measurements at Mead for April-October 2013.

	Total Seasonal ETa (mm)			Difference (%)			
	US-Ne 1	US-Ne 2	US-Ne 3	US-Ne 1	US-Ne 2	US-Ne 3	Average
Measured	**543**	**555**	**464**				
DisALEXI	690	691	631	27%	25%	36%	29%
METRIC	822	806	741	51%	45%	60%	52%
SSEBop	516	501	395	-5%	-10%	-15%	-10%
ReSET	837	840	721	54%	51%	55%	54%

Fig. 9. Monthly estimated and measured ETa at Mead for April-October 2013.



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