Validation of Satellite-Based Rainfall Products for Western Uganda

Jeremy E. Diem
Department of Geosciences
http://geosciences.gsu.edu/
jdiem@gsu.edu
Georgia State University

Joel N. Hartter
Department of Geography
http://www.unh.edu/geography/
University of New Hampshire

Michael W. Palace
Institute for the Study of Earth, Oceans, and Space
http://www.eos.unh.edu/

Sadie J. Ryan
Department of Environmental and Forest Biology
http://www.esf.edu/efb/
ESF
State University of New York College of Environmental Science and Forestry

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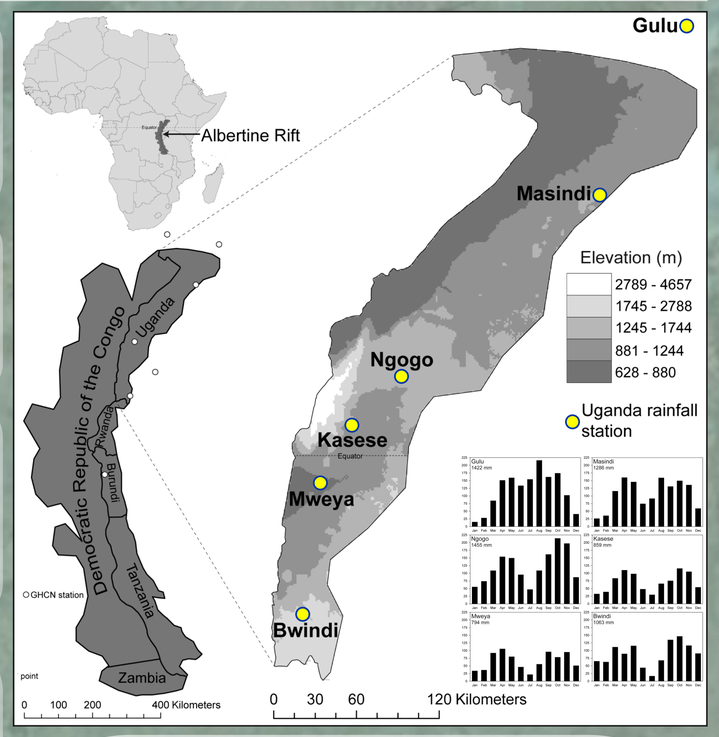
Abstract: The Albertine Rift region in Africa is a high-priority area for conservation that is severely deficient in ground-measured rainfall data; therefore, the use of satellite-based rainfall products is an option to better understand rainfall in the region. This study assesses the accuracy of three satellite-based rainfall products for the Uganda portion of the Albertine Rift for the 2001–2010 period. The three products are ARC2 (African Rainfall Climatology Version 2), RFE2 (African Rainfall Estimation Algorithm Version 2), and TRMM7 (Tropical Rainfall Measuring Mission Version 7). All three products have daily rainfall estimates, and ARC2 and RFE2 report those estimates at 0.10° resolution while TRMM7 has a 0.25° resolution. Rainfall totals from six rain gauges in western Uganda were used to assess the accuracy of the satellite-based rainfall totals. The main methods involved calculating error statistics for the three satellite products for the prediction of rainfall days and the prediction of four-day, 11-day, and 22-day rainfall totals. ARC2 was the best product for identifying rainfall days. RFE2 was the most accurate product for estimating rainfall totals. The use of microwave data in the estimation of RFE2 rainfall totals improves that product over ARC2. TRMM7 also employs microwave data, but that product was only similar in accuracy to ARC2. There was a decrease in accuracy of all three satellite products when moving from the northern portion to the southern portion of western Uganda; none of the products were sufficiently accurate at predicting rainfall totals at the four-day and 11-day resolutions. ARC2, which has a beginning year 1983, is the only satellite product that can be used for climatological purposes at the present time. ARC2 data may prove useful in making gauge-based time series serially complete and determining season onset and demise in the northern portion of the region.

Problem: There is a dearth of long-term rain gauges, especially gauges with continuous daily records, in the Albertine Rift region, which is one of the world's hotspots for biodiversity and it is threatened by dense intensive smallholder agriculture, high levels of land and resource pressures, and high rates of habitat loss and conversion.

Aim: To assess the accuracy of three satellite-based rainfall products for the Uganda portion of the Albertine Rift. There is a further consideration of whether a long-term product, ARC2, is comparable in accuracy to the other two products, ensuring its utility for climatological analyses in the region.



Data

1. Daily rainfall data from 2001-2010 for six precipitation stations (Gulu, Masindi, Ngogo, Kasese, Mweya, and Bwindi)
2. Gridded daily rainfall data from ARC2 (African Rainfall Climatology Version 2), RFE2 (African Rainfall Estimation Algorithm Version 2), TRMM7 (Tropical Rainfall Measuring Mission Version 7). ARC2 and RFE2 have a 0.10° resolution; TRMM7 has a 0.25° resolution. ARC2, RFE2, and TRMM7 extend back to 1983, 2000, and 1998, respectively.

Methods

1. Frequency bias and Heidke Skill Score were used to assess the accuracy of the satellite products in predicting daily rainfall events.
2. Mean biased error as a percent of the mean observed value, mean absolute error, root-mean-squared error, and the coefficient of efficiency were calculated for four-day rainfall totals, 11-day rainfall totals, and 22-day totals.
3. Coefficients of efficiency also were calculated for four-day totals for each season.

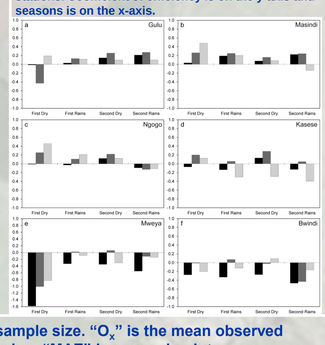
Results

Frequency bias values and Heidke Skill Scores for ARC2, RFE2, and TRMM7 at the six stations over the 2001-2010 period.

	Frequency Bias			Heidke Skill Score		
Station	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7
Gulu	0.88	1.16	1.22	0.57	0.55	0.49
Masindi	0.95	1.30	1.22	0.52	0.49	0.41
Ngogo	0.77	1.12	0.94	0.38	0.46	0.49
Kasese	0.88	1.22	1.71	0.48	0.47	0.14
Mweya	1.39	2.07	1.41	0.31	0.28	0.30
Bwindi	0.93	1.47	1.05	0.34	0.36	0.44

- ARC2 was the most accurate product based on frequency bias
- ARC2 also generally had the highest skill scores
- There were higher skill scores at the northern stations than at the southern stations

Seasonal four-day coefficients of efficiency for ARC2 ■, RFE2 ■, and TRMM7 □ during 2001-2010 at the six stations. Coefficient of efficiency is on the y-axis and seasons is on the x-axis.



- The three products generally had positive coefficients of efficiency at Gulu, Masindi, and Ngogo during all seasons
- The products performed poorly at Kasese, Mweya, and Bwindi during most seasons

Evaluation statistics at the Gulu station over 2001-2010 for both four-day totals and 11-day totals, and 22-day totals. "N" is the sample size. "O_x" is the mean observed rainfall total. "P_x" is the mean predicted rainfall total. "MBE%" is the mean biased error as a percentage of the mean observed value. "MAE" is mean absolute error. "RMSE" is root mean squared error. "E" is the coefficient of efficiency.

Northern Stations

Gulu	4 Days			11 Days			22 Days		
	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7
N	880	878	880	316	314	316	155	153	155
O_x	15.4	15.4	15.4	42.3	42.1	42.3	84.0	83.1	84.0
P_x	13.9	13.3	16.2	38.5	36.8	44.6	76.9	73.5	89.1
$MBE_{\%}$	-10	-14	5	-9	-13	5	-9	-12	6
MAE	10.0	9.5	11.2	19.4	18.6	18.6	30.0	29.8	25.9
RMSE	17.4	16.7	17.5	29.0	28.3	25.9	42.6	43.2	35.5
E	0.23	0.28	0.22	0.41	0.44	0.53	0.52	0.51	0.67

Masindi	4 Days			11 Days			22 Days		
	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7
N	858	856	858	309	307	309	153	152	153
O_x	13.9	14.0	13.9	38.5	38.5	38.5	77.0	76.7	77.0
P_x	12.7	11.8	13.6	35.1	32.6	37.5	69.9	64.9	75.0
$MBE_{\%}$	-9	-15	-2	-9	-15	-2	-9	-15	-3
MAE	9.3	8.6	10.0	18.0	17.4	17.0	27.4	26.8	25.1
RMSE	15.3	14.6	15.7	26.9	26.4	25.8	37.5	38.0	35.4
E	0.23	0.30	0.19	0.37	0.40	0.42	0.52	0.50	0.57

Ngogo	4 Days			11 Days			22 Days		
	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7
N	913	911	913	332	330	332	166	164	166
O_x	15.9	15.9	15.9	43.8	43.8	43.8	87.7	87.2	87.7
P_x	13.4	11.9	14.7	36.9	32.7	40.3	73.8	65.1	80.6
$MBE_{\%}$	-16	-25	-8	-16	-25	-8	-16	-25	-8
MAE	11.6	10.8	10.8	23.1	21.9	19.6	37.4	36.5	29.5
RMSE	17.7	16.9	16.4	31.5	30.8	26.6	49.8	50.1	38.3
E	0.10	0.18	0.23	0.22	0.26	0.44	0.28	0.27	0.57

Southern Stations

Kasese	4 Days			11 Days			22 Days		
	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7
N	896	894	896	325	323	325	161	159	161
O_x	9.3	9.3	9.3	25.7	25.7	25.7	50.9	50.9	50.9
P_x	9.8	9.0	12.5	27.1	24.9	34.5	53.9	49.5	68.6
$MBE_{\%}$	6	-3	35	6	-3	34	6	-3	35
MAE	7.5	6.9	9.5	15.5	14.2	18.8	26.0	22.9	29.2
RMSE	12.8	11.6	13.9	23.1	20.8	25.3	35.4	31.2	36.9
E	0.00	0.18	-0.18	0.11	0.28	-0.07	0.17	0.36	0.10

Mweya	4 Days			11 Days			22 Days		
	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7
N	745	743	745	270	268	270	136	132	134
O_x	8.7	8.7	8.7	24.0	24.1	24.0	47.4	48.1	47.7
P_x	13.0	10.5	11.3	35.6	28.9	31.1	71.2	57.3	62.2
$MBE_{\%}$	49	20	29	48	20	29	49	19	30
MAE	10.6	8.8	9.0	21.3	17.0	17.6	35.5	26.8	28.9
RMSE	16.2	13.9	14.4	29.0	23.8	24.9	43.7	34.9	37.7
E	-0.47	-0.07	-0.15	-0.37	0.08	-0.01	-0.30	0.18	0.03

Bwindi	4 Days			11 Days			22 Days		
	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7	ARC2	RFE2	TRMM7
N	621	620	621	181	180	181	67	66	67
O_x	11.1	11.1	11.1	30.7	30.9	30.7	59.5	59.9	59.5
P_x	11.9	11.2	11.6	31.4	30.6	31.2	65.0	61.8	62.1
$MBE_{\%}$	7	1	4	2	-1	2	9	3	4
MAE	10.6	9.5	9.4	22.7	20.2	19.8	35.2	30.6	32.0
RMSE	16.3	14.6	14.8	31.2	27.9	29.8	45.9	39.8	47.2
E	-0.26	-0.01	-0.04	-0.08	0.14	0.01	-0.06	0.21	-0.13

- The products were most accurate at Gulu and Masindi
- The products were least accurate at Mweya and Bwindi
- Accuracy increased with a decrease in temporal resolution
- The products generally underpredicted rainfall totals at the northern stations and overpredicted rainfall totals at the southern stations

Conclusions

- There were not huge differences in the performances of the products; nevertheless, RFE2 was the most accurate product. ARC2 was equivalent to TRMM7.
- All three products were more accurate in the northern portion of the region compared to the southern portion.
- ARC2, which has a beginning year of 1983, is the only satellite product that can be used for climatological purposes at the present time. Daily ARC2 rainfall data also could prove vital for making gauge records serially complete.