1

Assessment of bias corrected satellite rainfall products for streamflow simulation: A TOPMODEL application at the headwater catchment of the Zambezi Basin

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2

Outline

a. Our approach
b. Satellite rainfall estimates (SREs) as influenced by:
   - elevation
   - seasons
c. Satellite estimates versus gauge rainfall (reference)
d. Sources of SREs errors
e. Comparison of bias correction algorithms
f. TOPMODEL hydrologic evaluations of bias corrected SREs
g. Water balance closure assessments in the Zambezi Basin

3

Introduction

- *In-situ* meteorological data limitations:
  - Non-existence and unequally distributed rain gauges
  - Poor spatial coverage by rain gauge networks
  - Incompleteness of in-situ rainfall time series
- SREs prone to error.
- SREs accuracy is affected by seasonal variations.
- Use of bias corrected SREs in streamflow simulations is yet to be explored in Kabompo.

4

Objectives

Assess performance of bias corrected daily rainfall time series for TOPMODEL streamflow simulation (2008-2012).

Specifically to:

a) evaluate the effect of elevation and seasonality on CMORPH, TMPA and CHIRPS satellite rainfall detection.

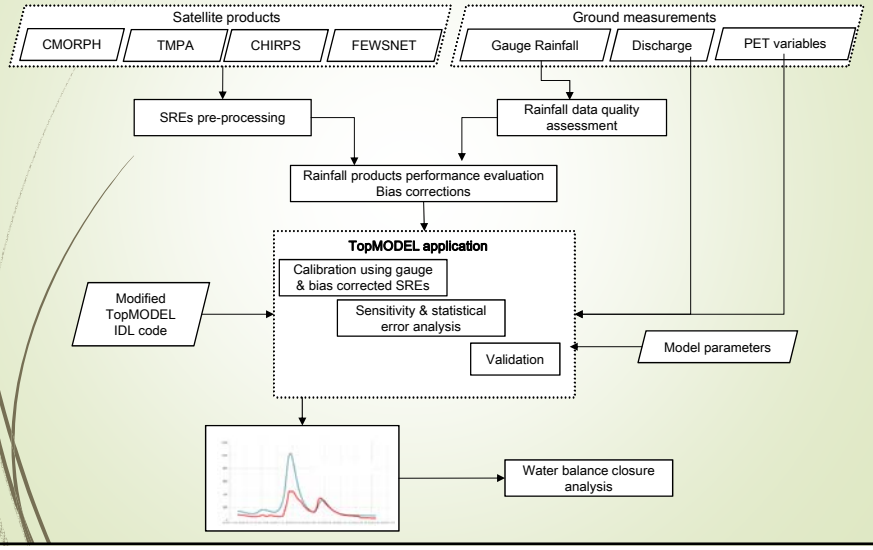
b) apply and compare SREs bias correction schemes (DT and STB) for different rainfall rates and seasons.

c) parameterize TOPMODEL rainfall-runoff model using RS data.

d) assess water balance closure using TOPMODEL as affected by use of bias corrected satellite rainfall.

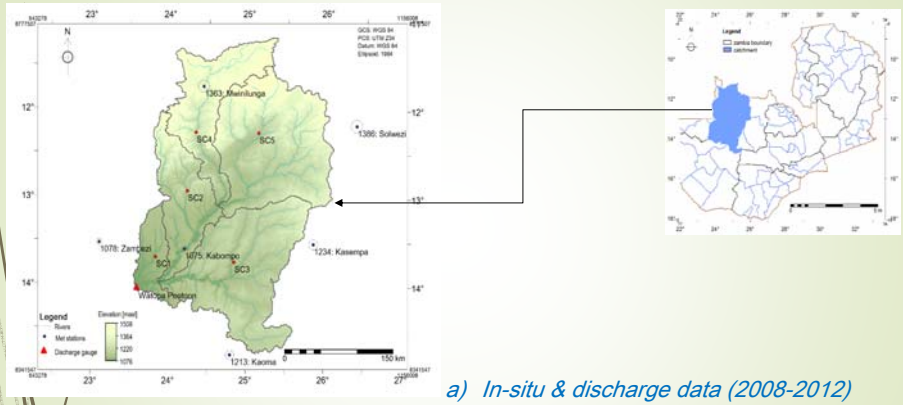
5

Approach



6

Materials and Methods



a) In-situ & discharge data (2008-2012)

Station		Coordinates of station		Type of meteorological variable from the station						
ID	Name	Lat.	Lon.	Altitude	P	Tmax	Tmin	RH	WS	SS
675430	Kabompo	-1360	+02420	+1075	x	x	x	x	x	
676410	Kaoma	-1480	+02480	+1213	x	x	x	x	x	
675410	Kasempa	-1353	+02585	+1234	x	x	x	x		
674410	Mwinilunga	-1175	+02443	+1363	x	x	x	x	x	x
675510	Solwezi	-1218	+02638	+1386	x	x	x	x	x	
675310	Zambezi	-1353	+02311	+1078	x	x	x	x	x	x

P –rainfall, Tmax - daily maximum temperature. Tmin – daily minimum temperature, RH – relative humidity, WS – wind speed and SS – sunshine hours

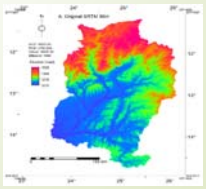
7

Overview of satellite data

b) Satellite rainfall estimates products

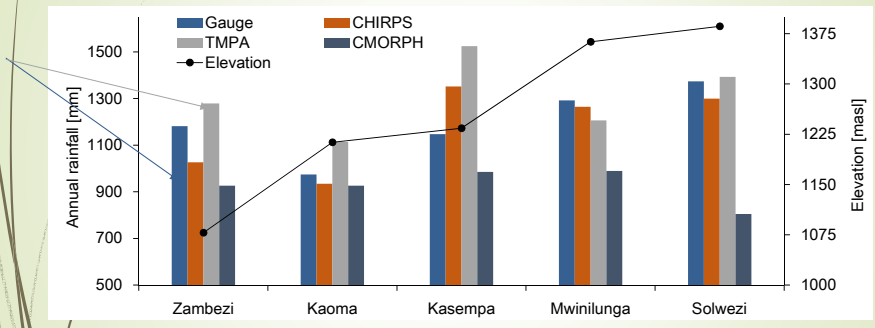
Rainfall product	CMORPH	TMPA	CHIRPS
Provider	NOAA-CPC	NASA	CHG, USGS
Spatial coverage	60°N to 60°S, globally	50°N to 50°S, globally	50°N to 50°S, across all longitudes
Temporal coverage	Since 01.01.1998	since 01.01.1998	Since 01.01.1981
Period tested	2008-2012	2008-2012	2008-2012
Original/ used spatial resolution	0.07° / 0.05°	0.25° / 0.05°	0.05°
Original/ used time step	½ h / 24 h	3 h / 24 h	24 h

c) SRTM 90m digital elevation model



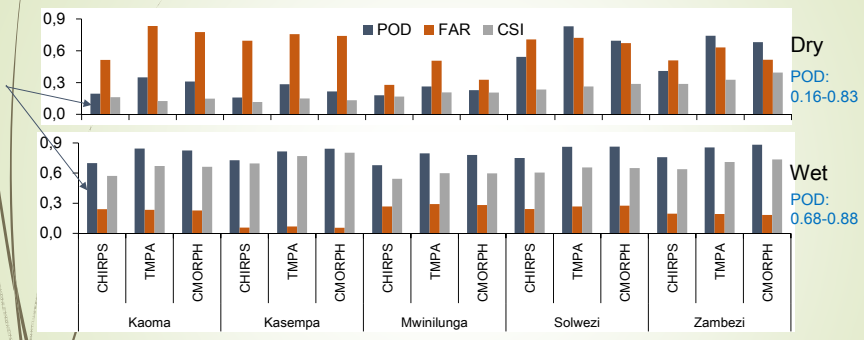
8

Elevation influence on SREs detections



- Elevation ≠ SREs rainfall measured at the stations.
- TMPA > Gauge rainfall accumulations unlike CMORPH & CHIRPS.
- CMORPH underestimates mean annual gauge rainfall.

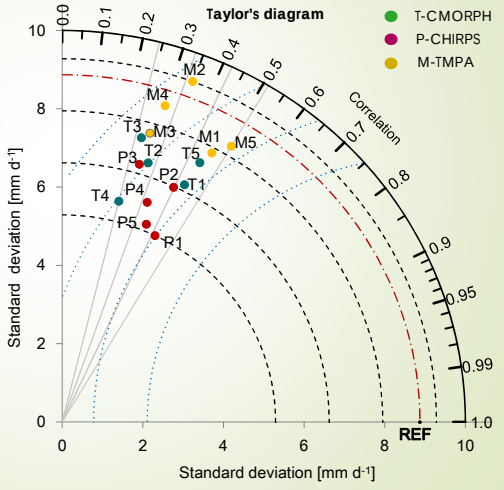
9 Seasonal influence on SREs detection



- Better detections during wet than dry seasons.
- CHIRPS poorly detects rainfall (reducing to 20% for dry seasons).
- CMORPH best CSI (0.69), TMPA highest POD (0.88) and CHIRPS least FAR<0.1.

10 Satellite estimates versus gauge rainfall (reference)

- SREs underestimated (Max & $\bar{P}$) gauge rainfall depths
- CHIRPS had the largest daily deviation (1.05 mm) from $\bar{P}$.
- CMORPH shows highest bias (1.56 mm d^{-1}) while TMPA (<0.05 mm d^{-1}).
- Rainy seasons and high rainfall events exhibit higher bias.



1: Kaoma, 2: Kasempa, 3: Mwinilunga, 4: Solwezi, 5: Zambezi

11 Sources of SREs errors

- CHIRPS, TMPA and CMORPH's main error source are miss, false and hit bias, resp.
- Error sources are season dependent, conforming to Ward et al. (2011).
- Hit and false bias prevailed for wet and dry periods, resp.

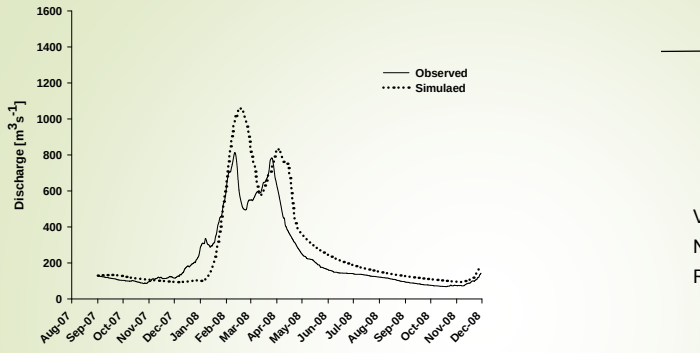
12 Bias correction algorithms compared

1st rank 2nd rank 3rd rank

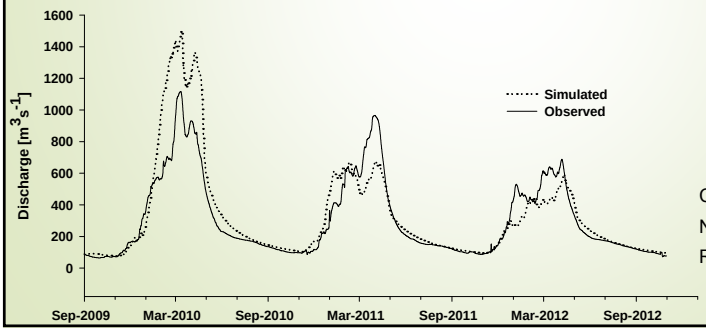
Evaluation coef./ BC	DT	TVSV	TVSF	TFSV	TFSF
Total P depth	3rd	2nd		1st	
Maximum	1st	2nd			
Mean	3rd	2nd		1st	
STD	1st				2nd
Correlation coef.	1st	3rd	2nd		
RMSE	1st				
Error reduction	2nd	1st		3rd	
Rain rate patterns	1st	3rd	2nd		

- Effectiveness vary depending on evaluation indicator.
- Deterioration on correction (e.g. BF DT: 1.14 vs uncorrected CMORPH: 0.95).

Topmodel simulations (Gauge)

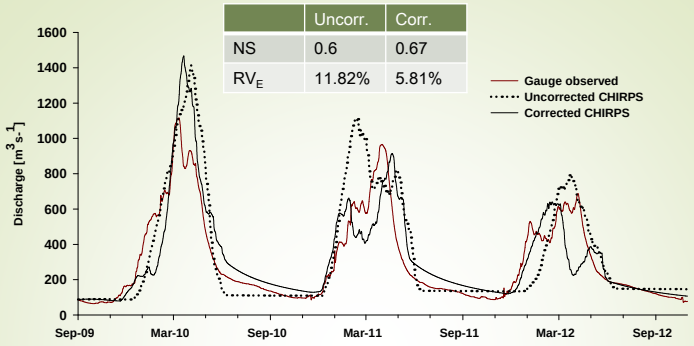


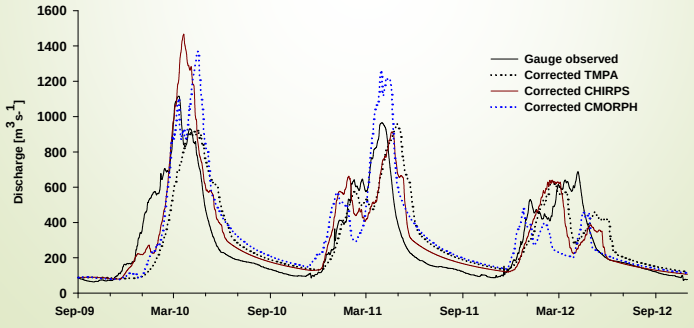
Validation (09/2007-11/2008)
NS: 0.57
RV_E: 21.2%



Calibration (09/2009-08/2012)
NS: 0.65
RV_E: 10.03%

	Uncorr.	Corr.
NS	0.6	0.67
RV_E	11.82%	5.81%





15

Water balance closure assessment

WB components [mm]	In- situ	Un-corrected TMPA	Un-corrected CHIRPS	Un-corrected CMORPH	Corrected TMPA	Corrected CHIRPS	Corrected CMORPH
Precipitation	2414	4006	3639	3026	2655	2649	2635
Actual ET	1950	2424	2566	2440	2207	2199	2207
Simulated Q	479.2	493.7	489.9	366.9	457.7	463.8	437.0
Root zone storage deficit	9.0	69.3	100.0	97.8	16.8	20.2	23.4
Catchment Sat. deficit	52.4	1963.0	678.7	275.5	38.9	41.7	97.0
WB Closure Error	46.2	3120.6	1361.8	592.4	46.0	48.1	111.4
WB Closure Error, [%]	1.9	77.9	37.4	19.6	1.7	1.8	4.2
NS [-]	0.64	0.78	0.60	0.45	0.53	0.67	0.52
RV_E [%]	10.03	11.82	11.82	-16.42	4.80	5.81	9.99

- SREs over-simulated P, ETa and RZ storage vs *in-situ* forcing.
- Bias corrected satellite rainfall result in improved water balance closure.
- Compared to in-situ, corrected CMORPH resulted in deteriorated WB closure

16

Conclusion and Recommendation

Conclusion:

- Satellite rainfall detection can be related to seasonal variations in Kabompo.
- Bias corrected satellite rainfall resulted in improved water balance closure.
- No perfect fit of observed Q could be modelled by respective rainfall forcings.

Recommendation:

- Incorporate omitted rain gauge stations in CHIRPs blending procedure.
- Further investigations a/o validation of rainfall and discharge time series OR increase no. of met. stations in the basin.
- An automated TOPMODEL optimization routine.


Thank you.