UNIVERSITY OF TWENTE.

VALIDATION OF SATELLITE-BASED RAINFALL IN KALAHARI

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MR. M. LEKULA
DR. M.W. LUBCZYNSKI
PROF. E.M. SHEMANG
PROF. W. VERHOEF

ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

PRESENTATION OUTLINE

- INTRODUCTION
- DESCRIPTION OF STUDY AREA AND DATA
- METHODOLOGY
- RESULTS AND DISCUSSION
- CONCLUSIONS

INTRODUCTION

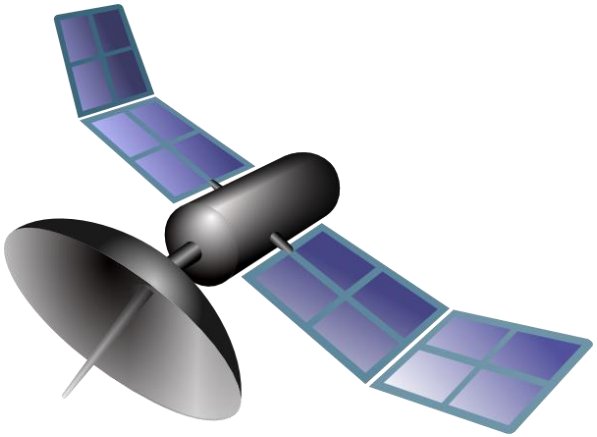
- Accurate measurements of rainfall in a variety of space and time important to a wide range of researchers including hydrologists.

- It is still common in hydrological studies to use extrapolated rain gauge data as model input, irrespective of their spatial distribution and density.
  - Justified if test area small.
  - Rainfall variability low (temporally and spatially) and rain gauge density sufficiently high.

- However, in large scales of rainfall assessments (arid and semi-arid with large spatio-temporal rainfall Variability) rain gauges measurements are not sufficient to retrieve that Variability.

INTRODUCTION CONT….

- Satellite-based rainfall products are valuable alternatives, particularly if combined with ground-based rain gauge data.
  - Provide large spatial and temporal rainfall coverage.



INTRODUCTION CONT….

- However, Satellite rainfall estimates are known to suffer estimation inaccuracies such as systematic (bias) and random error.

- This calls for Inter-comparison of satellite rainfall estimates and their validation with rain gauge data before being used to quantify the bias and settle for an optimal one to use.

MOTIVATION

- Very few satellite rainfall-related studies carried out in Southern Africa
- No satellite rainfall assessment study in the Kalahari Region
  - Evaluating performance of different satellite-based rainfall detection algorithms on daily basis

OBJECTIVES

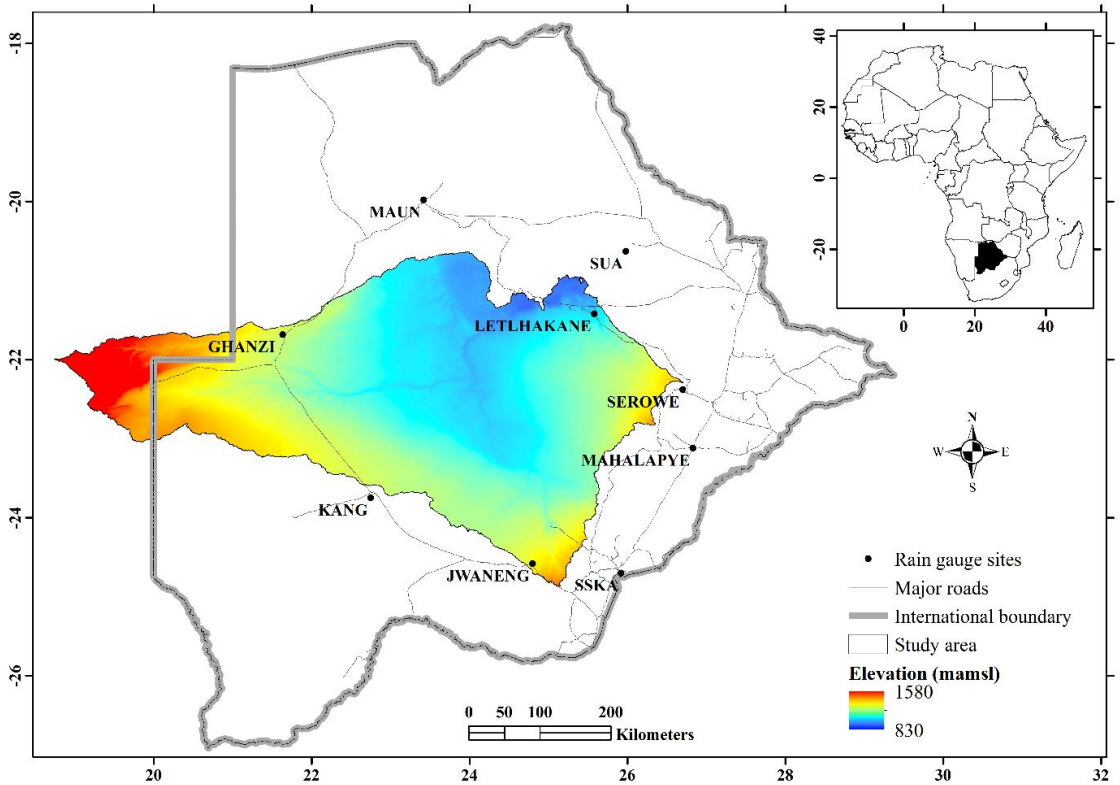
- Evaluating and validating daily rainfall performance 4 satellite rainfall products in the Central Kalahari Basin (CKB) to select the best performing one in terms of daily rainfall detection.

Satellite estimate	Version	Spatial resolution	Abbreviation
FEWS-Net RFE	2	~11 Km	RFE
TRMM-3B42	7	~27 Km	TRMM
CMORPH		~27 Km	$CMOPH_{27}$
CMORPH		~8 Km	$CMORPH_{8}$

- To derive, analyze and present spatio-temporal variability of rainfall in the CKB

- ***Daily rainfall meant as Input for integrated hydrological model of CKB***

STUDY AREA AND DATA



- Catchment of fossil Okwa & Mmone rivers
- Area: ~ 164, 000 km^2
  - ~ 150, 000 km^2 (BOTS), ~14, 000 km^2 (NAM)
- Generally flat, ~90% being Kalahari desert.
- Semi-arid to arid with convectional rainfall
- Rainfall: 250 – 550 mm yr^{-1} (Sep – April)
- Winter temperature: 6°c – 25°c
- Summer temperature: average Max 35°c

STUDY AREA AND DATA CONT…

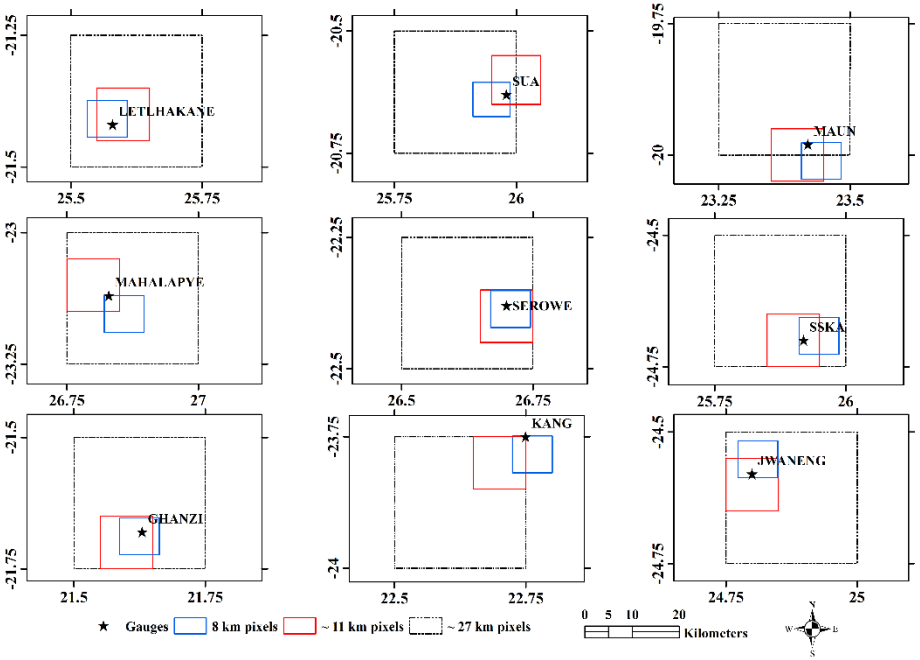
DATA:

Study period: 5 years from 01/01/2001 to 31/12/2005

DATA	TEMPORAL RESOLUTION	SPATIAL RESOLUTION	SOURCE
RAIN GAUGE(9)	Daily	POINT DATA	Department of Meteorological Services (DMS)
RFE	Daily	0.1^{o}	USGS: http://earlywarning.usgs.gov/fews
TRMM	Daily	0.25^{o}	NASA: http://mirador.gsfc.nasa.gov/
$CMORPH_{27}$	Daily	0.25^{o}	ILWIS ISOD Tool box
$CMORPH_{8}$	Daily	0.07^{o}	ILWIS ISOD Tool box

METHODOLOGY

SATELLITE RAINFALL EVALUATION



- Performance done by inter-comparison of satellite estimates with gauge data
- Satellite estimates extracted for pixels coinciding with 9 gauges
- Methods:
  - Visual verification
  - Descriptive statistics (*CC*, *ME*, *MAE*, *RMSE*,)
  - Categorical statistics (*FB*, *POD*, *FAR*, *CSI*, *ACC*)
  - Bias decomposition *(HB*, *FB*, *MB*, TB_c*)*

METHODOLOGY CONT…

SPATIO-TEMPORAL VARIABILITY OF RAINFALL IN CKB

- Evaluated through:
  - Number of rainy days, total accumulated rainfall for rain gauges and corrected best performing satellite rainfall product.
  - Spatial correlation function :

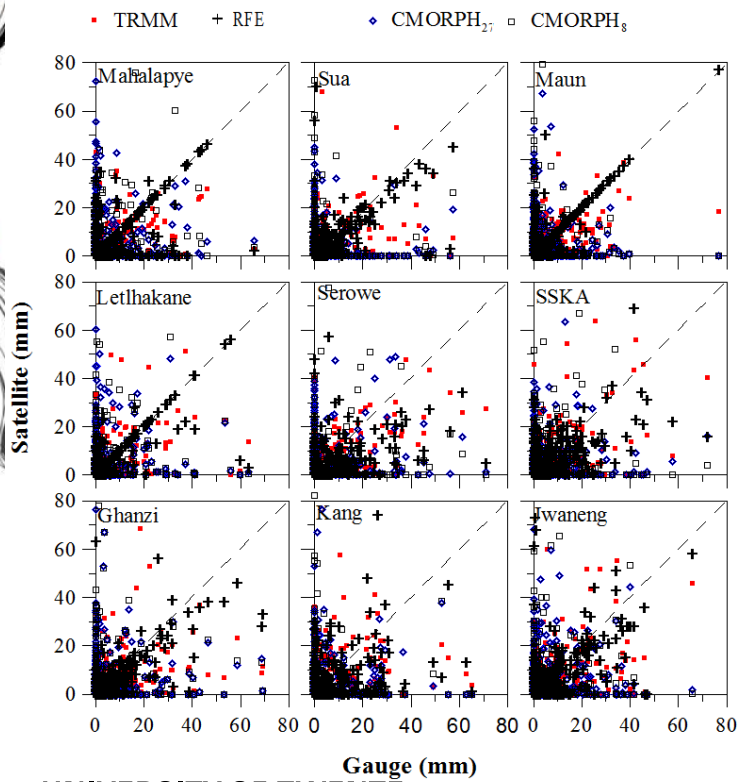
$$\rho = c_0 \exp[-(d / d_0)^2]$$

  - ρ - correlation coefficient, d - separation Euclidian distance between the two rain-gauge/pixel centers, c_0 - correlation value for the near-zero distances (nugget parameter), d_0 - correlation distance and s - shape parameter.
  - estimation of d_o and s was done by minimizing the root mean square error (RMSE) between the model values and inter-rain-gauge correlation coefficients while constraining $c_o = 1$

RESULTS

SATELLITE RAINFALL EVALUATION

- Visual evaluation

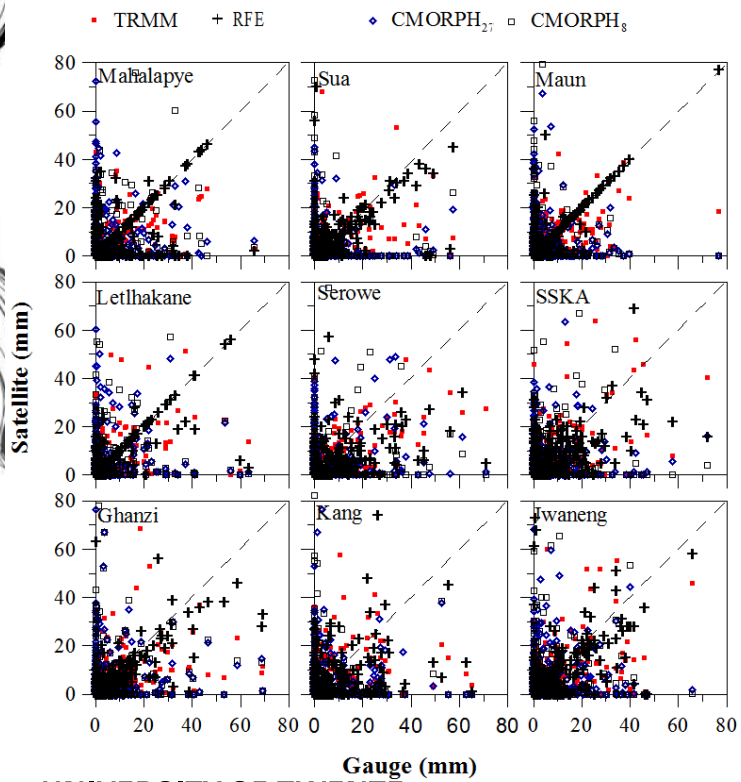


- Strong scatter for all the 4 satellite rainfall estimates
- RFE with more points along the one on one line
  - Strong correlation in Mahalapye, Sua, Maun, and Letlhakane because already inherently bias corrected.
  -
  - Weak correlation at Ghanzi and Jwaneng due to GTS non-reporting.
  - Four sites with strong correlation located in north-eastern side.
- Even three non-GTS sites, RFE has relatively more data along one on one line than other three.

RESULTS CONT…..

SATELLITE RAINFALL EVALUATION

- Visual evaluation



- for all the four satellite products there are several data points along the x- and y-axis.
- Points along x-axis indicate missed rain by satellite algorithms
  - Can be due to satellite retrieval limitations of combined TIR and passive microwave sensors used to detect rainfall.
- Points along y-axis indicate non-zero (false) rain by satellite algorithms.
  - This can be due to gauge spatial representation within a satellite pixel.
  - Can be associated with hot and dry vertical profiling of the CKB, where low rainfall intensities can evaporate before reaching ground
- RFE preformed better than the other three.

RESULTS CONT…..

SATELLITE RAINFALL EVALUATION

- Descriptive statistics

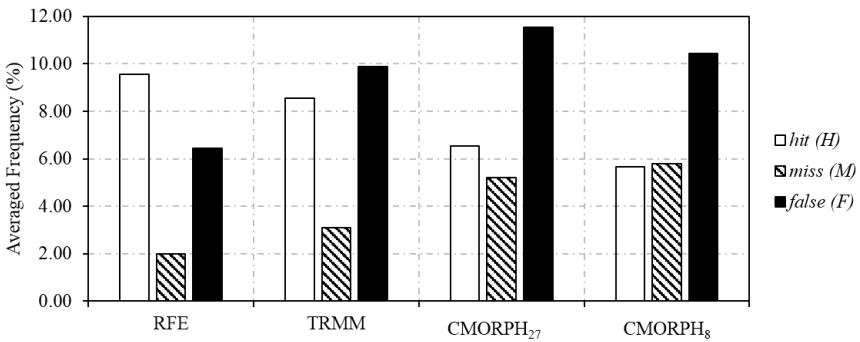
	RFE			TRMM			$CMORPH_{27}$			$CMORPH_8$		
	Mean	**MIN.**	**MAX.**	**Mean**	**MIN.**	**MAX.**	**Mean**	**MIN.**	**MAX.**	**Mean**	**MIN.**	**MAX.**
CC	**0.58**	0.3	0.82	**0.38**	0.25	0.48	**0.02**	-0.1	0.09	**0.02**	-0.06	0.15
ME	**0.4**	-0.4	1.4	**0**	-1.2	0.5	**0.2**	-1.4	1.2	**-0.2**	-2.9	1.1
MAE	**4.4**	2.2	7.1	**5.6**	4.7	6.4	**7.4**	6.5	8.1	**7.7**	6.1	10.3
RMSE	**8.8**	5.5	12.2	**10**	7.5	11.7	**12.9**	11.2	15.1	**13.6**	11	16.7

- Largest ***CC***, lowest ***MAE*** and ***RMSE*** suggest best performance of RFE

RESULTS CONT…..

SATELLITE RAINFALL EVALUATION

- Categorical statistics



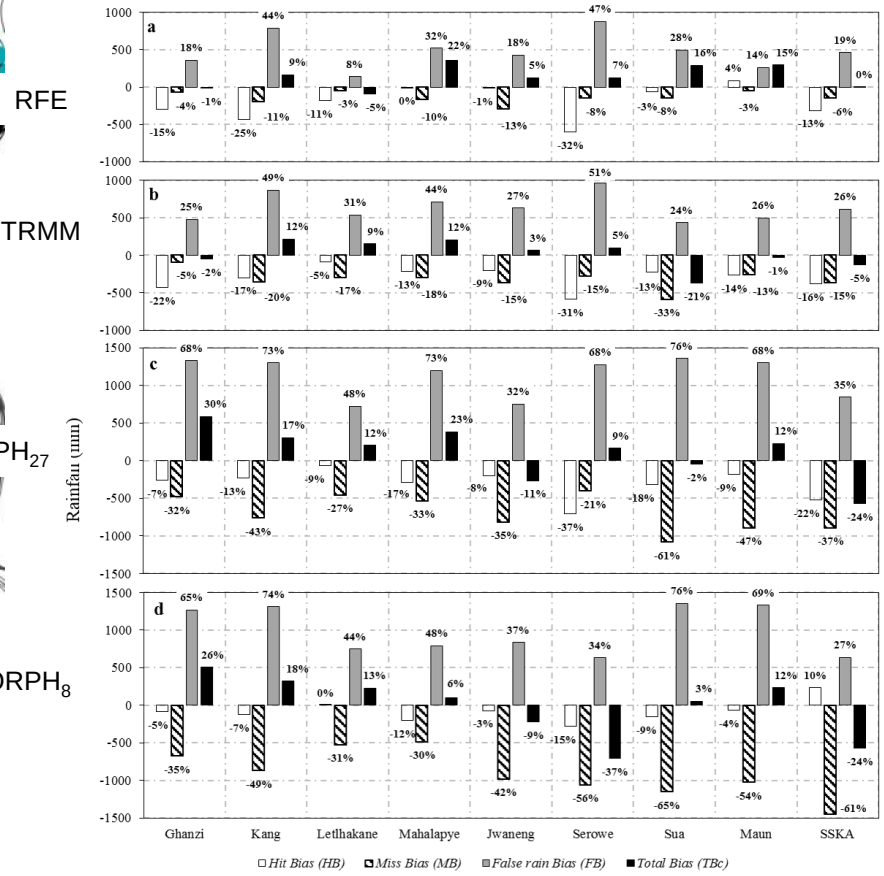
	RFE	TRMM	$CMORPH_{27}$	$CMORPH_8$
FBS	**1.47**	1.69	1.65	1.42
POD	**0.82**	0.73	0.57	0.49
FAR	**0.40**	0.55	0.64	0.65
CIS	**0.54**	0.38	0.28	0.26
ACC	**0.91**	0.87	0.83	0.84

- RFE best detects daily rainfall in the CKB because of high ***POD***, low ***FAR***, high ***CSI*** and high ***ACC.***

- Best criterion to select satellite rainfall algorithm seems to be the *miss* as it directly indicates sensitivity of satellite to rain detection.

RESULTS CONT…..

SATELLITE RAINFALL EVALUATION

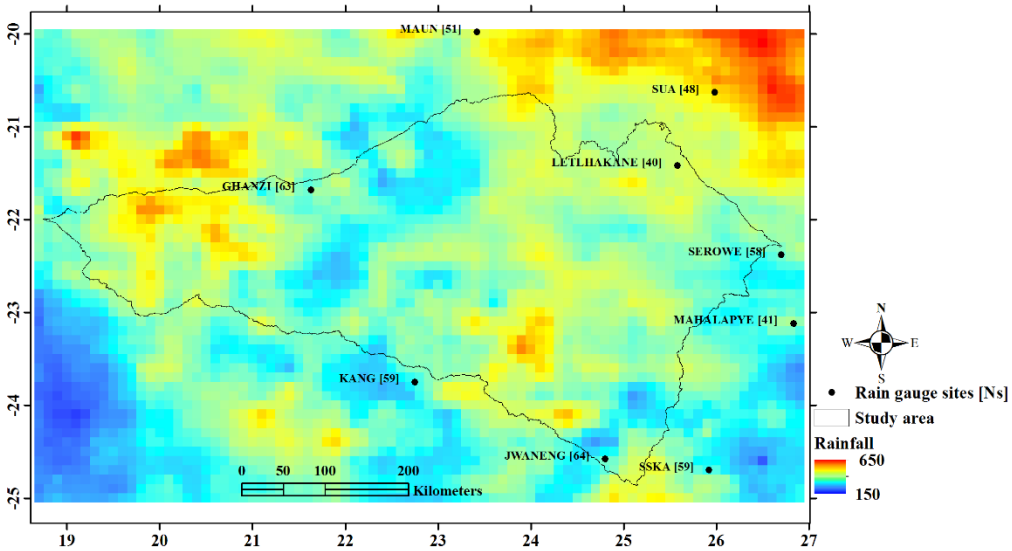


- Total bias decomposition
  - Even by quick inspection, RFE bias components lower than that of the other three satellite algorithms
  - ***TB_c*** for all the four satellite rainfall estimation algorithms varying over a wide range with both underestimation (-) and overestimation (+) of the total rainfall measured.
  - Almost all ***HB*** negative signifying underestimation of recorded rain at gauge
  - Overestimation of satellite rainfall due to high ***FB*** also showing highly localized rainfall in CKB

RESULTS CONT…..

SPATION-TEMPORAL VARIABILITY OF RAINFALL IN CKB

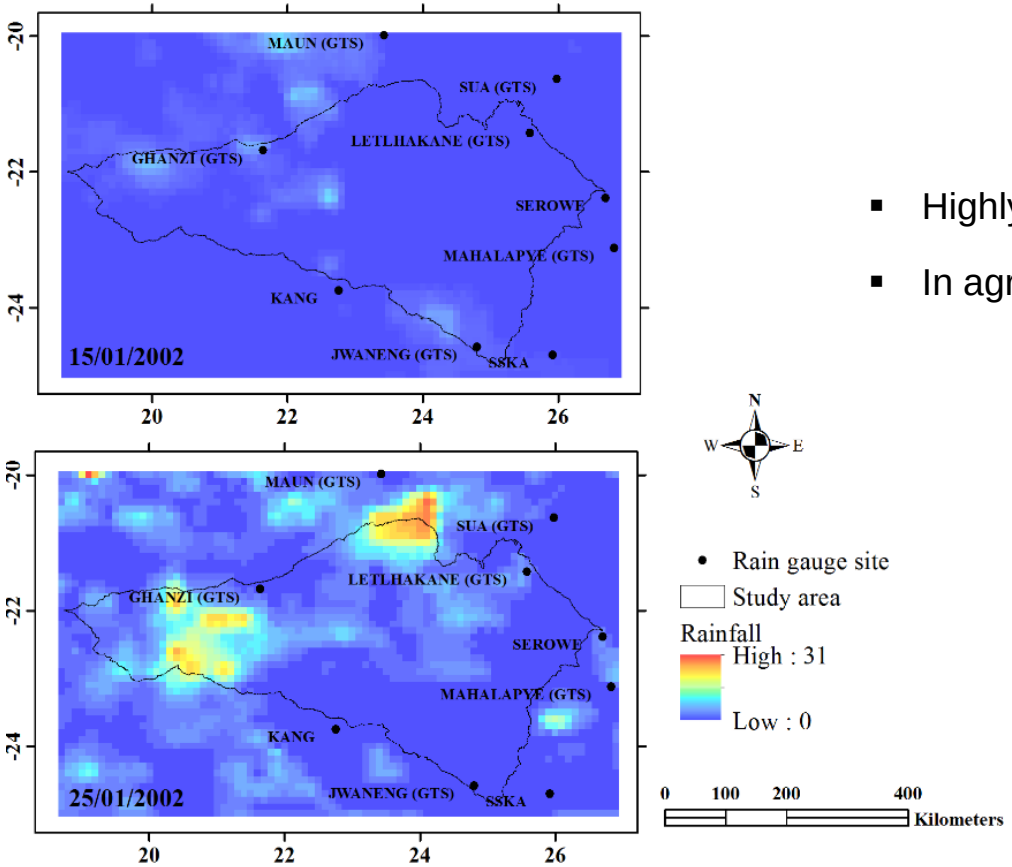
- 2005 RFE annual rainfall



- Annual rainfall highly variable from 249 mm in SE and 279 in central parts to 368 mm in W and 446 mm in most S part of the CKB.

RESULTS CONT…..

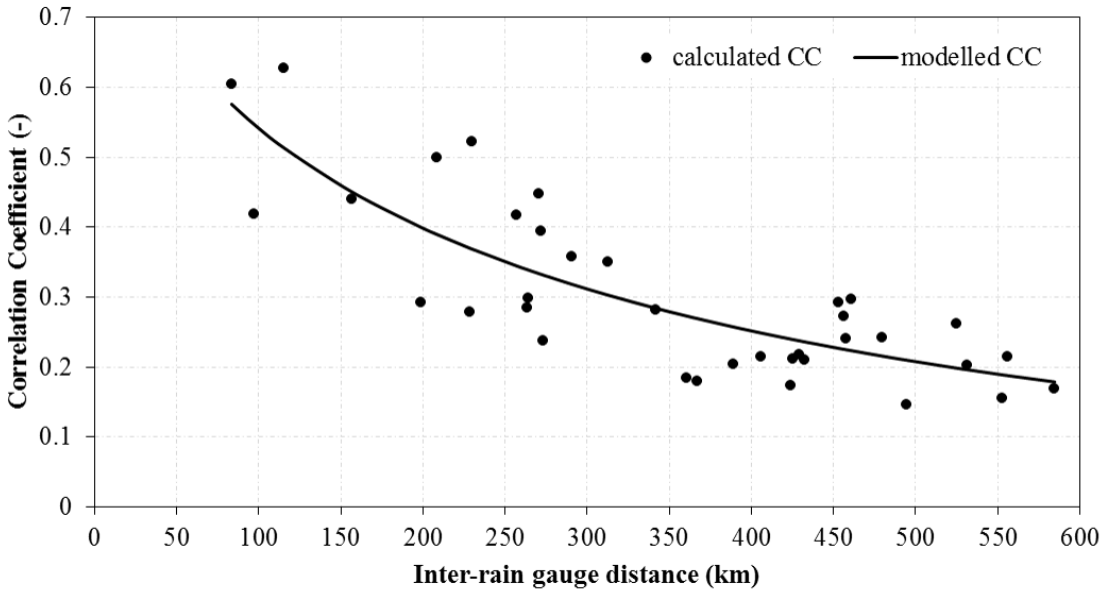
SPATION-TEMPORAL VARIABILITY OF RAINFALL IN CKB



- Highly variable daily rainfall in CKB.
- In agreement with previous studies

RESULTS CONT…..

SPATION-TEMPORAL VARIABILITY OF RAINFALL IN CKB



- Decrease in correlation between rain data pairs with increase in inter-gauge distance.
- Good correlation of daily rainfall data from the network of gauges in the CKB require maximum gauge separation distance of ~230 km.

CONCLUSIONS

- RFE exhibited the best performance in all the types of analysis applied.
  - May be because of inherently bias corrected
- Differences between satellite estimates and gauged data we attributed to:
  - Scale differences between satellite and gauge assessment
  - Large spatio-temporal variability of rainfall in CKB
  - Error in satellite rainfall retrieval particular "***miss"*** rain events
- Throughout the validation process:
  - "***miss***" rainfall seems to be the most reliable indicator of the satellite rainfall performance
  - Total bias decomposition was very useful in satellite performance assessment.

CONCLUSIONS CONT….

- Rainfall in CKB is highly variable both spatially and temporally.
- Rain gauge network in CKB insufficient
  - Upgrading of existing rain gauge network recommended
  - With a upgrade rain gauge network and RFE, will allow to monitor rainfall accurately not only in CKB but in the whole of southern Africa.

THANK YOU FOR YOUR ATTENTION

KEA LEBOGA