SOUTHERN AFRICA SATELLITE DERIVED RAINFALL ESTIMATES VALIDATION

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ABSTRACT

Satellite estimates of 24 hour accumulated rainfall are validated against 24 hr raingauge and weather radar over southern Africa. The satellite rainfall estimates and raingauge data are validated at quarter degree latitude-longitude grid for the period 1 October 2005 to 31 March 2006. The validation method used was developed by the Bureau of Meteorology. Additionally, the infrastructure and future rainfall infrastructural developments in South Africa related to quantitative precipitation estimation are discussed.

1. INTRODUCTION

Southern Africa is a water scarce region. The rainfall is highly variable in time and space and predominantly produced by summer convective storms. The highest annual rainfall total exceeding 1000 mm is measured along the eastern escarpment of the Drakensberg Mountains and along the eastern coast. Rainfall decreases to 400 mm over the central region and below 100mm in the west. Rainfall is mainly caused by westerly propagating baroclinic systems, while occasional tropical system can impact the northern regions of the country in late summer. Tropical cyclones also contributed about once a decade to disastrous torrential rain, exacerbated by orography with resulting widespread flooding as witnessed during 2000 over Limpopo River basin. Improved rainfall estimation of rainfall events can assist greatly in advancing application in disaster mitigation, hydrological modelling, agricultural and social development in Africa. In general ground based raingauge infrastructure and weather radar networks are not well developed in Africa. Remote sensing from space platforms poses the largest benefit especially over Africa with its limited ground infrastructure.

Satellite derived rainfall estimates were developed to compliment ground based raingauges and assist in rainfall estimation over the oceans. Passive microwave instruments on satellites (geostationary and polar orbiting) have global coverage and can make an indirect measurement of rainfall rate. Several validation efforts are been conducted to compare results from global satellite derived rainfall algorithms with raingauges. This has however not been performed over Southern Africa and is not done routinely over Africa.

The objective of this study is to validate the results of 4 different rainfall estimation algorithms with ground raingauges over South Africa. Hereby a contribution can be made to support the goals of IPWG by letting algorithm developers be aware of possible errors in satellite algorithms over varying surfaces and climatic regimes. The satellite derived estimates were validated against daily accumulated data from South Africa raingauges.

2. DATA AND METHODS

The 24 hour accumulated raingauge data over South Africa were averaged into 0.25 degree grid for the period 1 October 2005 to 31 March 2006. This period covers the main rainfall season in South Africa with record monthly rainfall recorded in January and February 2006. The raingauges data used to perform the validation were from approximately 1630 rainfall stations of South Africa. The raingauge data were averaged into the grid boxes. Most grid boxes has at least one raingauge as can be observed on figure 1, 570 grids had 1 raingauge. Each grid represents an area of approximately $650km^2$. The validation values should be used with caution as most many rainfall events are convective and spatially variable. Daily rainfall from raingauges spaced only a few kilometres apart has been found to have a correlation of less than 0.5 over South Africa. The 4 satellite derived precipitation estimation algorithms validated over South Africa were PERSIANN, CMORPH, 3B42 and NRLB. These satellite estimates were developed using pixel by pixel of quarter degree resolution and they were provided via the University of Maryland.

PERSSIAN uses artificial neural network to estimate rainfall from geosynchronous satellite longwave infrared imagery (GOES-IR) (Sorooshian, et.al., 2000). CMORPH is CPC morphing technique that is used to estimate precipitation from passive microwave and infrared data (Joyce, et.al. 2004). 3B42 is the combination of high quality microwave estimates (3B40) and variable rain rate infrared estimates (3B41) that are rescaled to monthly data (Huffman, et.al., 2003). NRLB is a blended technique which blends Low Earth-orbiting (LEO) passive microwave data and geostationary infrared data in an automated manner (Turk, et.al, 2003). Satellite estimates were validated against raingauge using validation code provided by Beth Ebert (Ebert, 2002) which produces maps and statistical tests that are frequency bias, root mean square error (RMSE), correlation coefficient, Heidke skill score and equitable threat score. The validation code was modified for South African domain which is between 16 – 36 degrees east and 20 - 35 degrees south. A surface mask was used over South Africa to differentiate between the land and ocean surfaces.

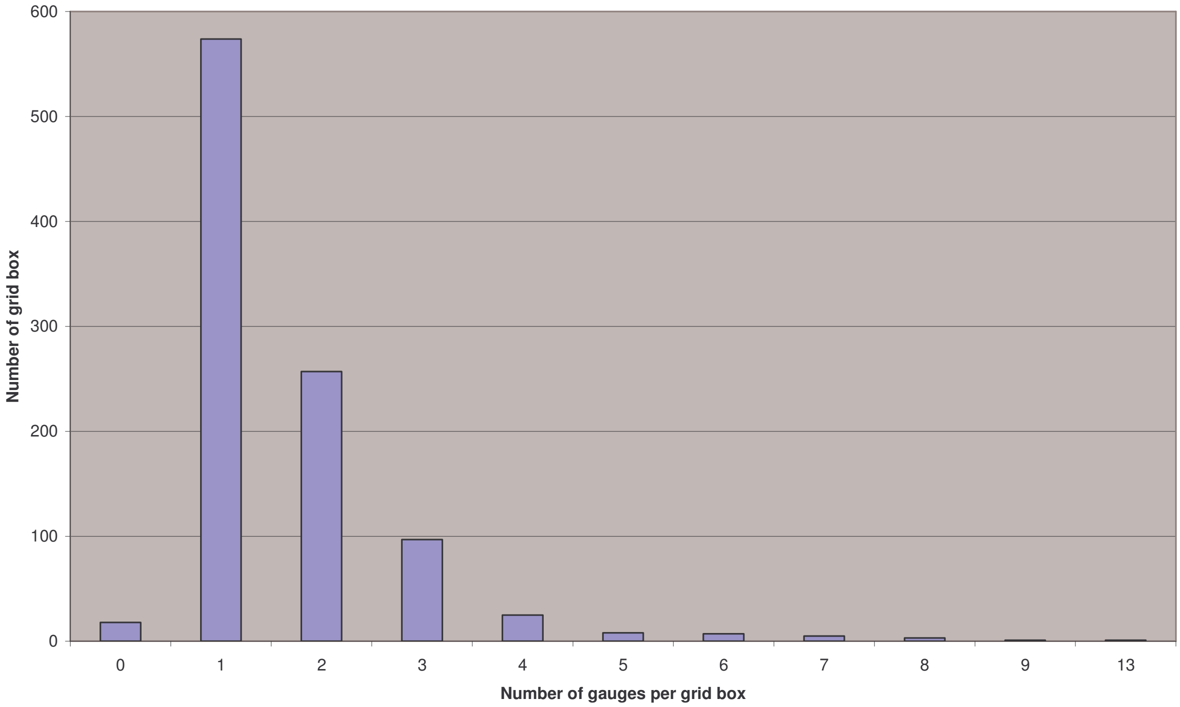

Figure 1. Distribution of number of rain gauges per grid box

3. VALIDATION RESULTS

The validation software generated output of daily results as shown in figure 2 with the satellite estimates on the left and raingauge analysis on the right as well as verification statistics at the right hand corner below. An example of CMORPH algorithm on 19 November 2005 which represents one of the best results for the study period in shown. A variety of statistical methods are available for judging the performance of different schemes. The investigation of the performance by the satellite rainfall algorithms was accomplished by analysing correlation coefficient, frequency bias, critical success index (CSI) and root-mean-square (RMSE). Correlation coefficient indicates correspondence between satellite estimates and raingauge analysis.

The critical success index is a function of both false alarm ratio (FAR) and probability of detection (POD). Understanding its behaviour can help to identify which satellite algorithm performed the best. Figure 3, 4 and 5 show comparisons of CSI among PERSIANN and CMORPH, 3B42 and NRLB, respectively. All three schemes shows in general higher CSI values compared to PERSIANN. The CMORPH and 3B42 comparison in figure 6 shows a good correlation between CMORPH and 3B42 as the best schemes for this data. The CSI values were ranked from highest to lowest 20 best were chosen as shown on figure 7. It shows that December was a dry month and rainfall onset occurred late. The satellite algorithms estimates seems not to be dependant upon the early or later rainfall season as there was good spread of high CSI values between November to March. The RMSE provides an insight into the accuracy of the satellite algorithms. All satellite algorithms showed the large RMSE as on figures 8, 9 and 10. The average RMSE over the six month period for CMORPH was 5.08 mm^2, 5.68 mm^2 for 3B42. 6.58 mm^2 for PERSIANN and 7.76 mm^2 for NRLB

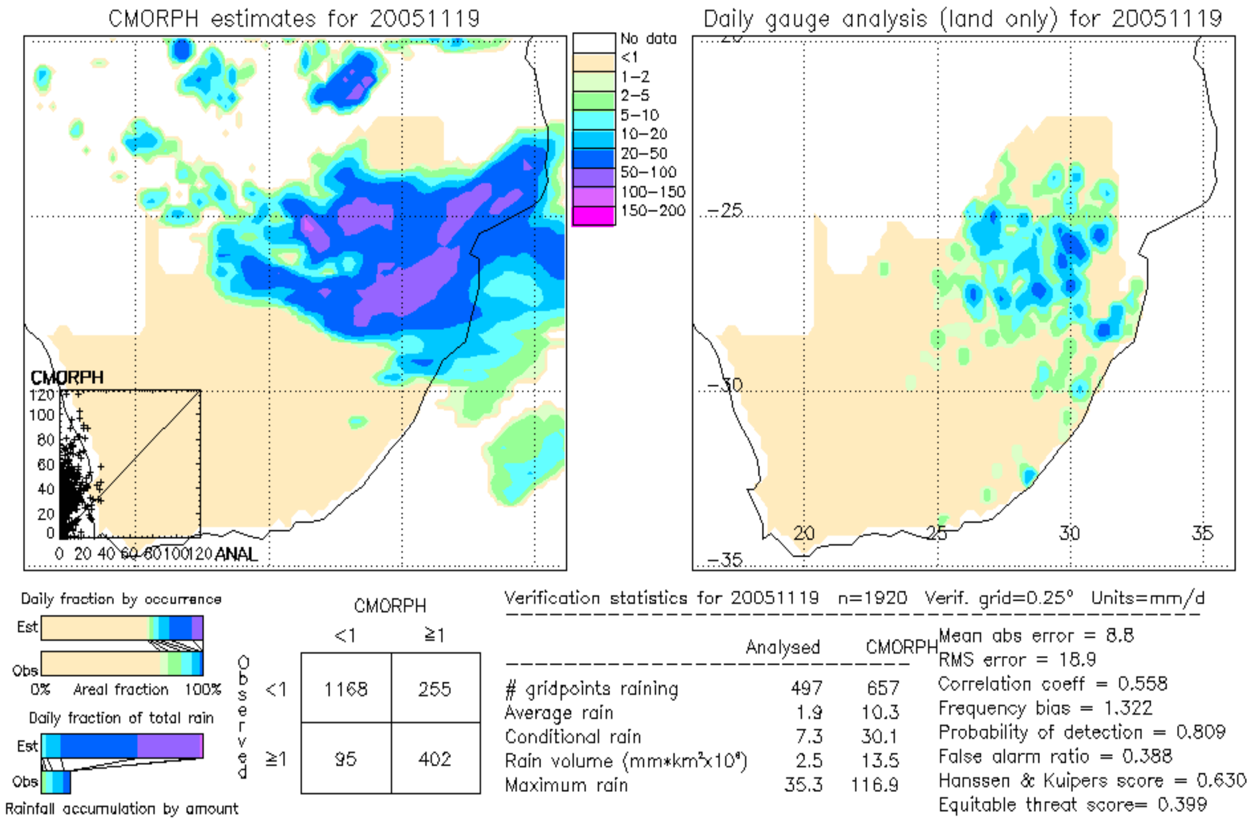

Figure 2. Comparison between raingauges and the CMORPH scheme for 19 November 2005

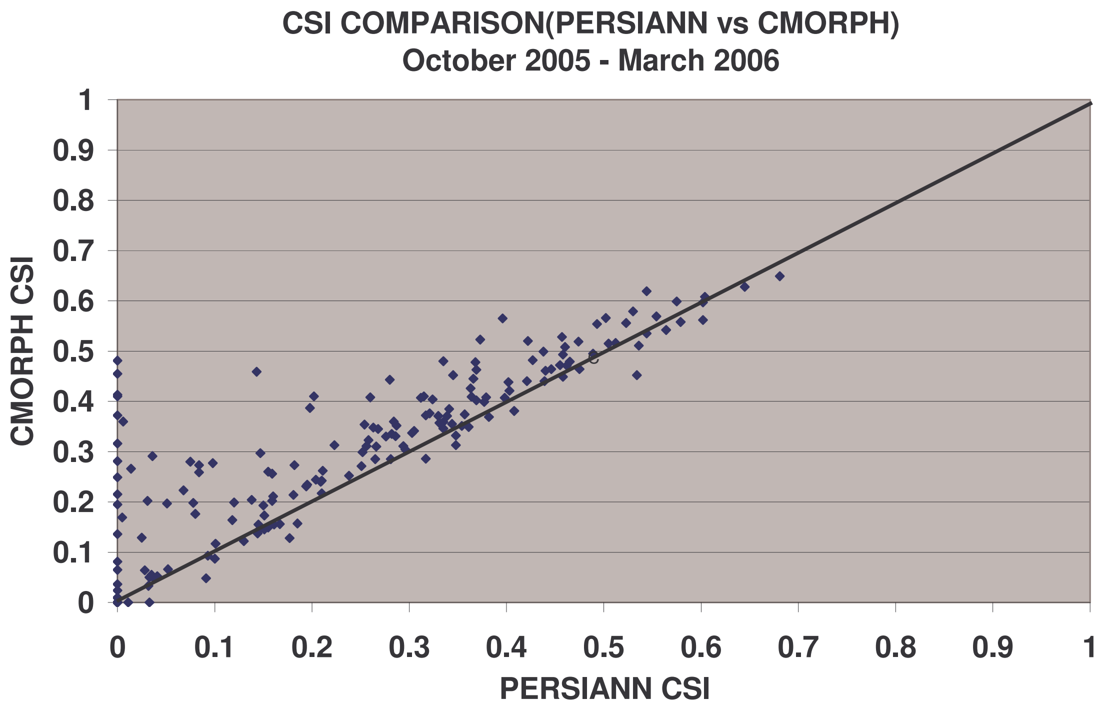

Figure 3. Critical Success Index CMORPH versus PERSIANN for October 2005 to March 2006

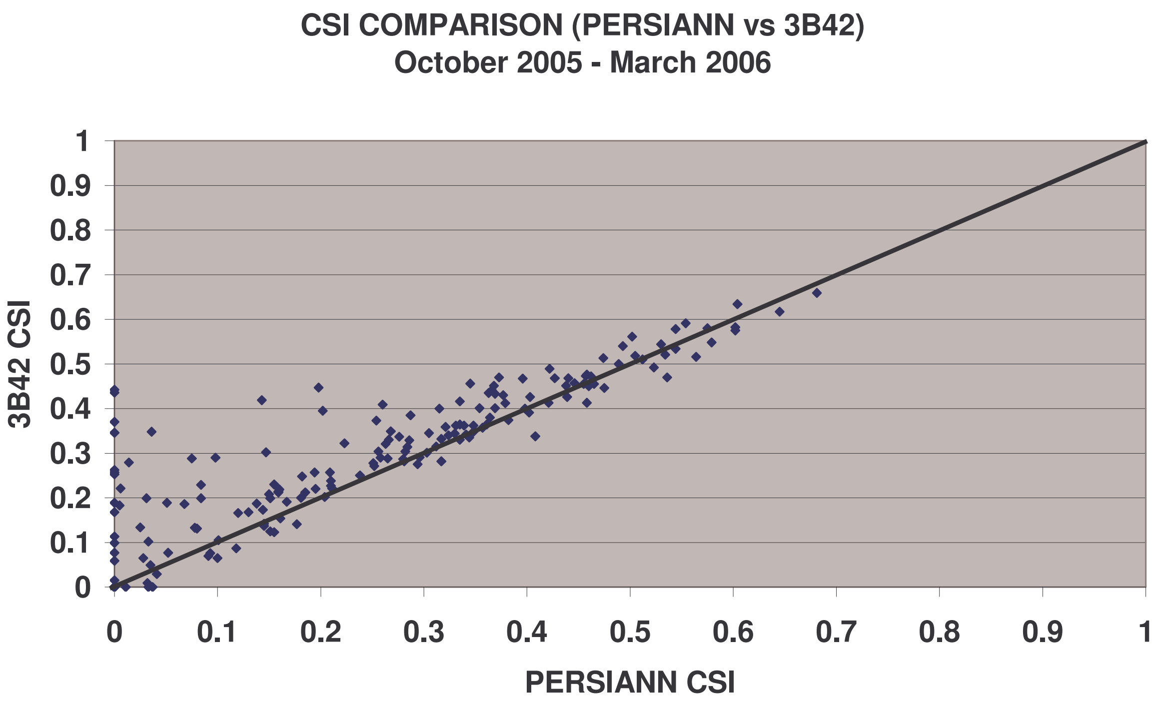

Figure 4. Critical Success Index for 3B42 versus PERSIANN for October 2005 to March 2006

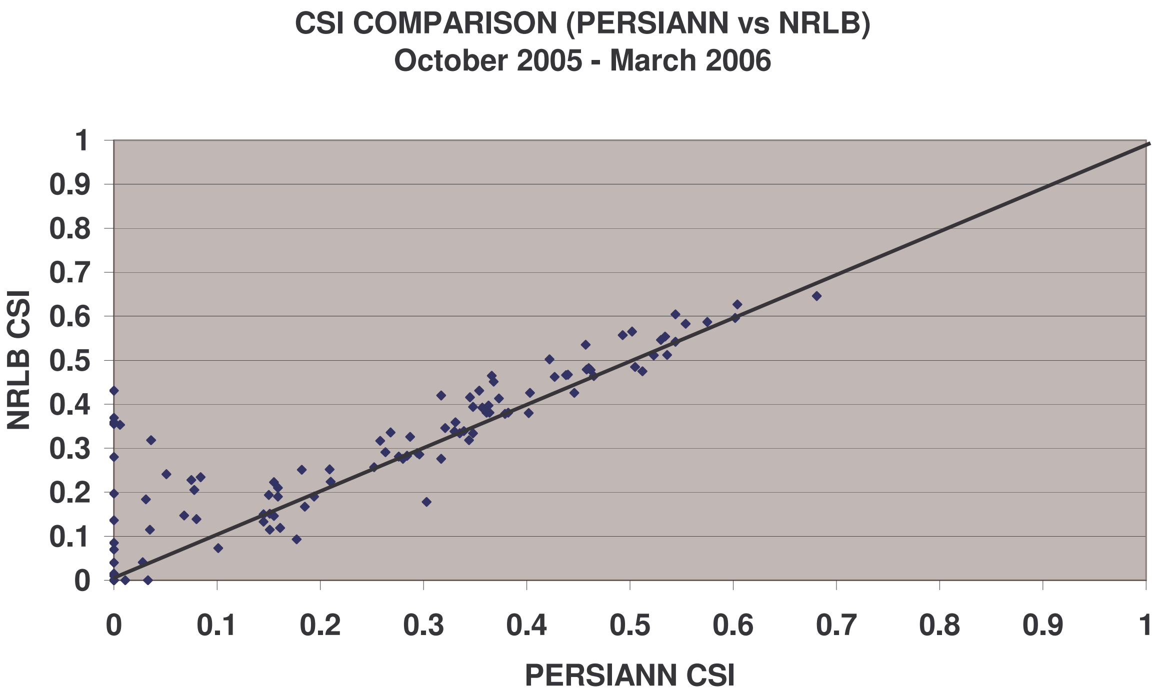

Figure 5. Critical Success Index for NRLB versus PERSIANN for October 2006 to March 2006

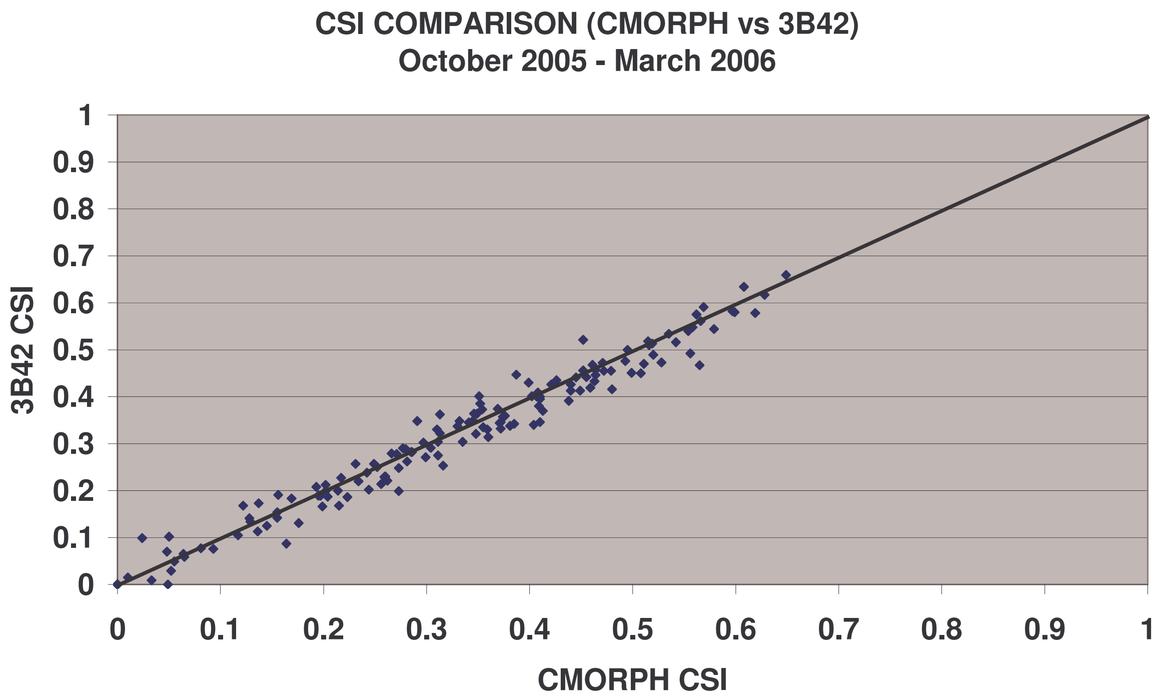

Figure 6. Critical Success Index for CMORPH versus 3B42 for October 2006 to March 2006

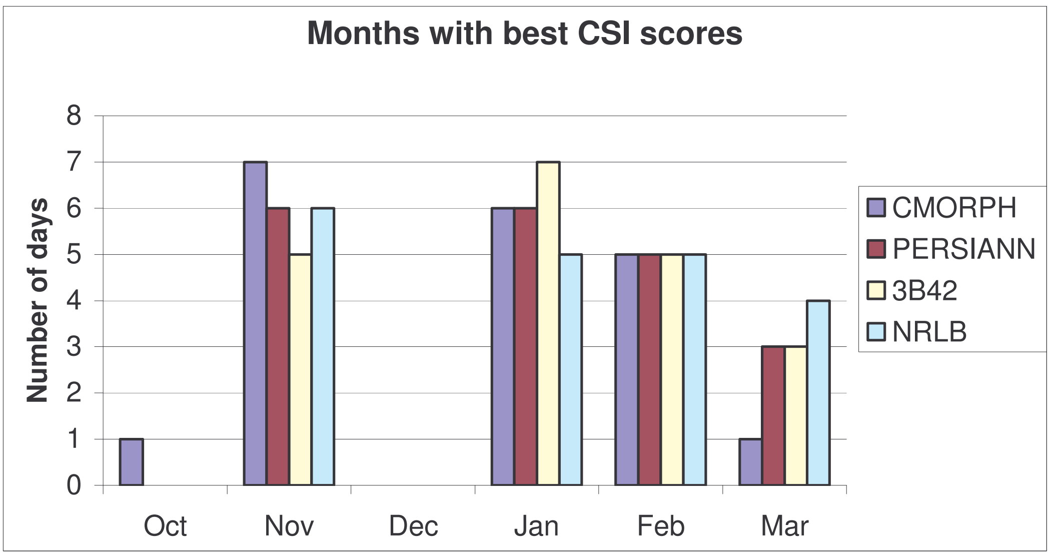

Figure 7. Monthly distribution of the twenty best Critical Success Index values for October 2006 to March 2006 for the all algorithms.

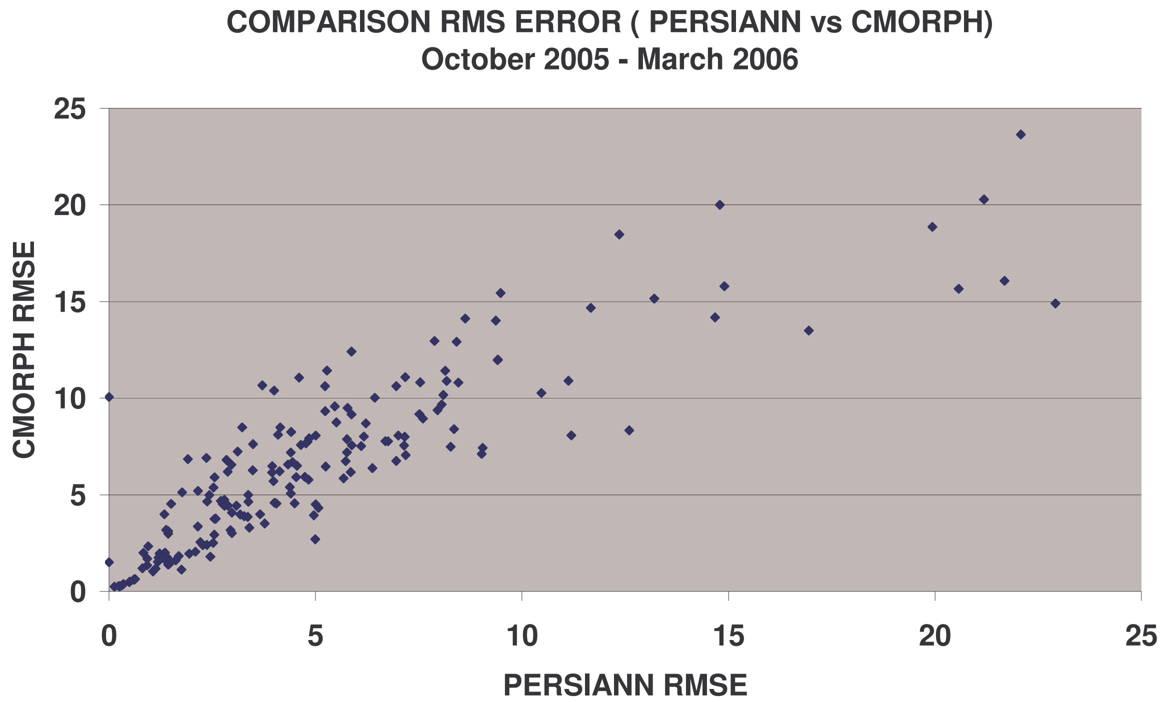

Figure 8. RMSE for CMORPH versus PERSIANN for October 2005 to March 2006

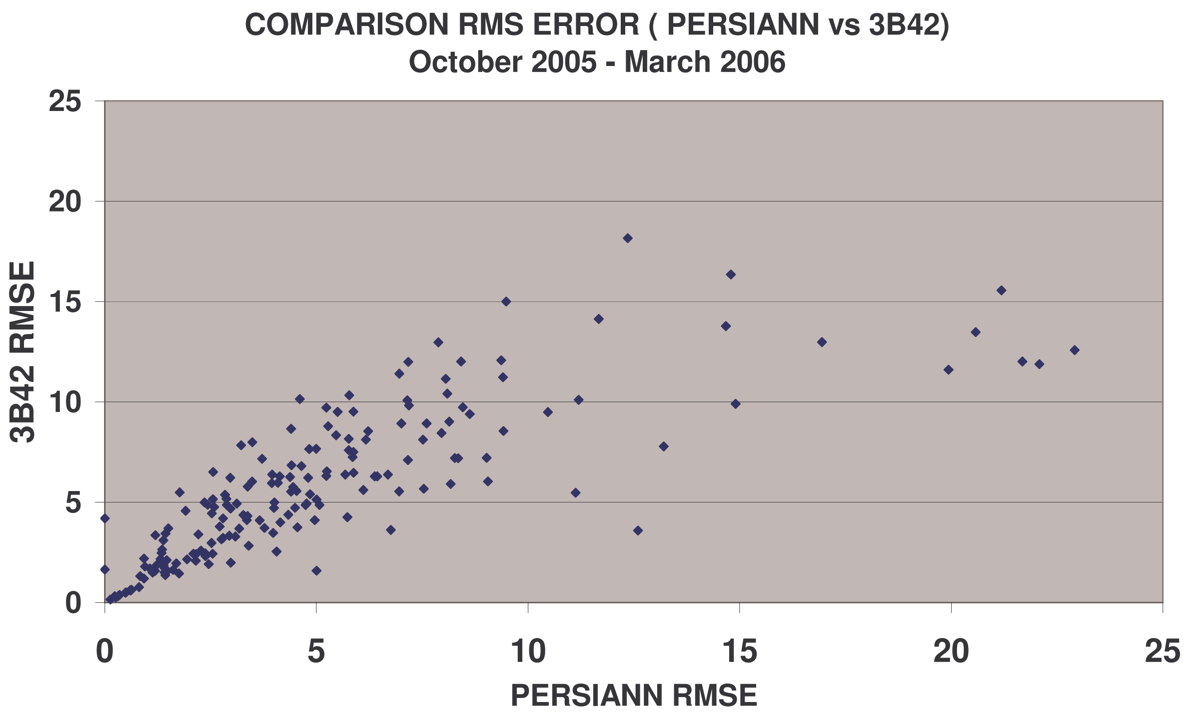

Figure 9. RMSE for 3B42 versus PERSIANN for October 2005 to March 2006

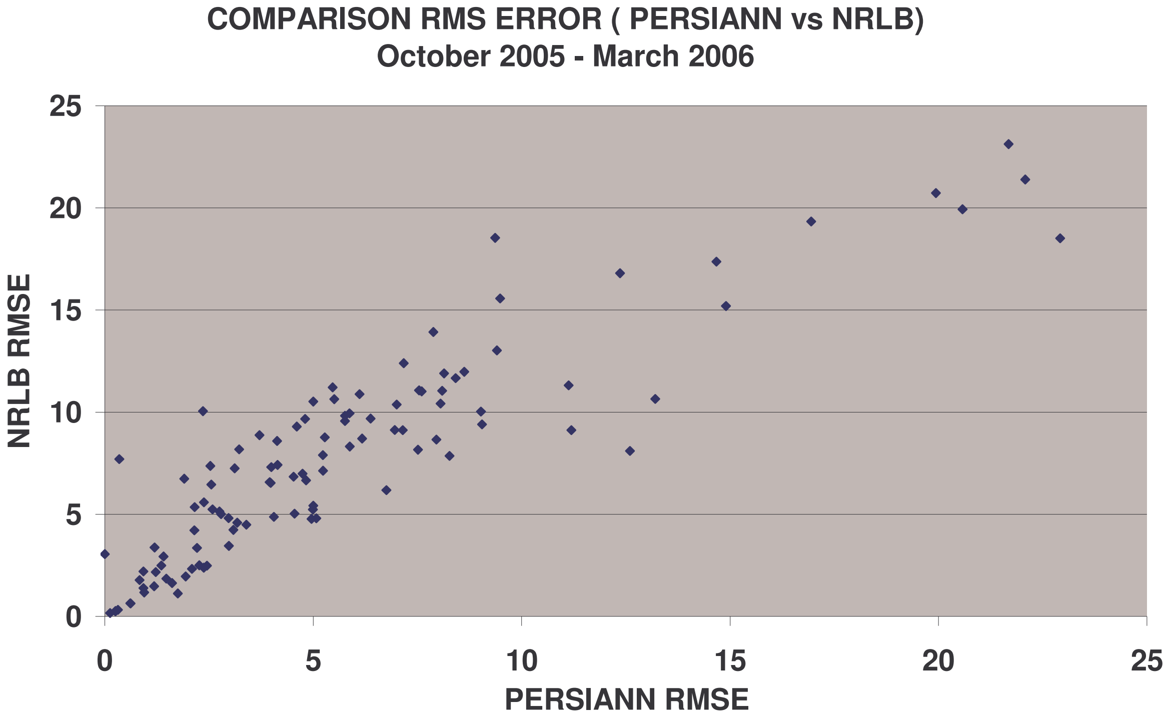

Figure 10. RMSE for 3B42 versus PERSIANN for October 2005 to March 2006

4. CONCLUSION

This was a first attempt to validate several satellite rainfall algorithms from space based remote sensing platforms over South Africa. This was conducted for a period of 6 months during the main rain season of the region. Although there exists a substantial rainfall infrastructure in South Africa, a substantial number of grid boxes only had one gauge. Therefore, great care should be taken in the ability of the gauges to observe the predominantly convective nature of rainfall events over South Africa. This is however the most widespread and dense rainfall infrastructure in Africa. In imperfect ground observations could greatly mask the usefulness of the spatial rainfall estimation by the algorithms. All the algorithms overestimated rainfall in quantity and spatially over the region. This is a persistent feature of all algorithms. There does not seem to be a seasonal variation in the effectiveness of the algorithms.

By considering statistical methods used to evaluate performance of satellite algorithm none of these outperformed the other. CMORPH and 3B42 seem to have performed better than PERSIANN and NRLB according to critical success index. Most of the raingauge information used here are not available within 24 hours, but is received several months later.

The use of weather radar rainfall estimation, also with its own limitation and accuracies, could greatly contribute to improved rainfall estimation. The satellite algorithms, however provides a great platform for improved rainfall observation in Africa with its limited ground infrastructure.

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