COMPARING A MULTI-CHANNEL GEOSTATIONARY SATELLITE PRECIPITATION ESTIMATOR WITH THE SINGLE CHANNEL HYDROESTIMATOR OVER SOUTH AFRICA

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ABSTRACT

The Hydroestimator (HE) is a satellite base precipitation estimator run in real time making use of a single channel (IR10.8) of Meteosat Second Generation (MSG) to estimate rainfall based on cloud top temperatures. This product has been running operationally over southern Africa since 2007 using the local version of the Unified Model as numerical weather prediction input to the algorithm. The EUMETSAT Satellite Application Facilities (SAF) are dedicated centers of excellence for processing satellite data (http://www.eumetsat.int). The Nowcasting and Very Short Range Forecasting SAF, (or SAFNWC) has developed a precipitation estimator called the Convective Rainfall Rate (CRR) that provides real time information on convective and the associated stratiform precipitation. The CRR makes use of either two (IR108 and WV062) or three MSG channels (including VIS006 during day light hours). To take into account the influence of environmental and orographic effects on the precipitation distribution, some corrections are applied to the basic CRR value, based on input from numerical weather prediction models. The South African Weather Service (SAWS) has acquired a license to obtain the software developed by the SAFNWC and is using the local version of the Unified Model as input to the algorithm. Comparisons are shown to determine which of the two algorithms is performing best in South Africa. Results of initial tests are shown using days with different types of precipitation. The two algorithms were compared against the 24-h total measurements from rain gauges across the country. Different thresholds were tested in order to establish how well light, moderate and heavy rainfall events are captured by both algorithms.

1. INTRODUCTION

The South African Weather Service issues operational forecasts on a regular basis. Satellite precipitation estimates (SPE) offer an excellent way to compensate for some of the limitations of other rainfall data sources such as point measurements by gauges or radar rainfall. In an operational environment where forecasters have to make decisions for nowcasting purposes, all information needs to be updated as regularly as possible. Although methods exist to estimate precipitation very accurately by low-level orbiting satellites, the drawback is that the information is only available during an overpass which can be two to four times per day. Geostationary satellites such as Meteosat Second Generation (MSG) provide updated information every 15 minutes and offer a full view of the African continent. Satellite based Quantitative Precipitation Estimation (QPE) from MSG is thus ideally suited for nowcasting purposes, although less accurate than the estimates from polar orbiting satellites. For nowcasting purposes in an operational weather office, SPE based on geostationary satellites are best suited in order to have updates on a regular basis. SPE should never be considered as a replacement for radar estimates and gauges, but rather as complementary to the other data sources (Scofield and Kuligowski, 2003).

The Hydroestimator (HE) is a satellite base precipitation estimator run in real time making use of a single channel (IR10.8) of Meteosat Second Generation (MSG) to estimate rainfall based on cloud top temperatures and input from numerical weather prediction models. This product has been running operationally over southern Africa since 2007 using the local version of the Unified Model as numerical weather prediction input to the algorithm. Another algorithm which also runs operationally (mostly in European countries) is the Convective Rainfall Rate product, which was developed by the Nowcasting and Very Short Range Forecasting SAF, (or SAFNWC). The CRR makes use of either two (IR108 and WV062) or three MSG channels (including VIS006 during day light hours). A research version of the 2011 version of the CRR was tested over the South African region, also making use of the local version of the Unified Model as input to the algorithm. Comparisons were done to determine which of the two algorithms is performing best over the South African region.

2. CASE STUDIES

Different types of precipitation in different seasons were chosen to test the two algorithms against the daily rain gauge data. Both of the two algorithms are intended for convective rainfall events and the associated stratiform precipitation, but not for warm rainfall processes in lower clouds. Events which are the result of cold fronts and occur in winter months were thus not included in the study. Table 1 lists the cases which were considered, with the season as well as the type of precipitation which occurred on each of the case days.

Case date	Season	Type of Convection
6 Dec 2009	Summer	Convection with heavier falls in various places
19 Dec 2009	Summer	Convection with heavier falls in various places
24 Jan 2010	Summer	Tropical showers with embedded convection with heavy falls in various places
26 Feb 2010	Summer	Convection with heavier falls in some places
2 Mar 2010	Autumn	Convection with heavier falls in some places
18 April 2010	Autumn	Convection with heavier falls in some places
19 April 2010	Autumn	Convection with heavier falls in some places
1 May 2010	Late autumn	Showers and thundershowers

Table 1. Case study dates, season and type of precipitation

3. RESULTS

For each case study daily total rainfall was used, from 0600 UTC to 0600 UTC. CRR2D will represent the CRR code using only IR108 and WV062 for the entire 24 hour period, CRR3D will represent the CRR code using the IR108 and WV062 as well as the VIS006 channel for daylight hours, and only IR108 and WV062 for the non-daylight hours. All the fields from the CRR, HE as well as the gauges were interpolated to a 0.5°X0.5° grid resolution using a Cressman interpolation. A mask was applied to the field to exclude QPE rainfall outside the boundaries of South Africa where rain gauges are not available. To evaluate the fields against the rain gauge data in a quantitative manner, a number of statistical scores were calculated, including: Correlation coefficient, the mean rainfall, the maximum rainfall, the mean absolute error and the root mean square error. Contingency table scores were also calculated for three thresholds – 1 mm, 10 mm and 20 mm – including, Probability of Detection (POD), False Alarm Ratio (FAR), Hanssen Kuiper Score (HK), Equitable Threat Score (ETS) and Heidke Skill Score (HeidkeSS).

3.1 Example: 6 Dec 2009

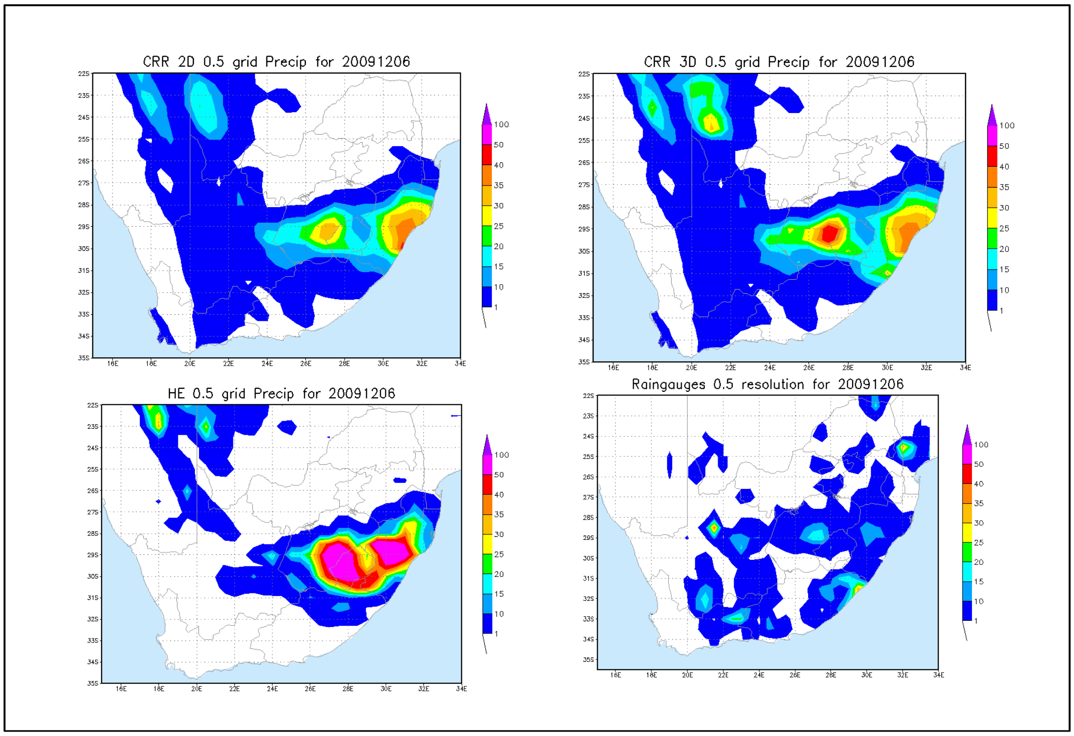

Figure 1 CRR2D (top left), CRR3D (top right), HE (bottom left) and rain gauge (bottom right) daily totals for 6 Dec 2009.

Figure 2a shows the contingency table scores for this case, using the 1 mm threshold and Figure 2b for the 10 mm threshold. The CRR algorithms performed slightly better than the HE in this case.

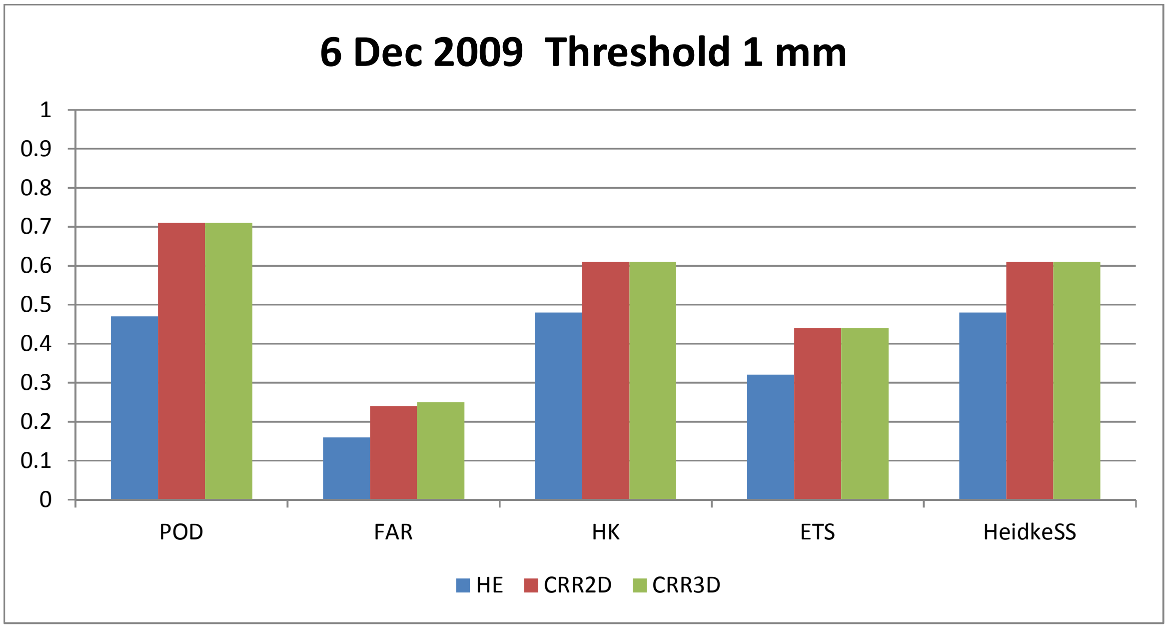

Figure 2a POD, FAR, Hanssen Kuiper, ETS and Heidke Skill Score for 6 Dec 2009, using a 1 mm threshold. HE is indicated in blue and CRR2D in red and CRR3D in green.

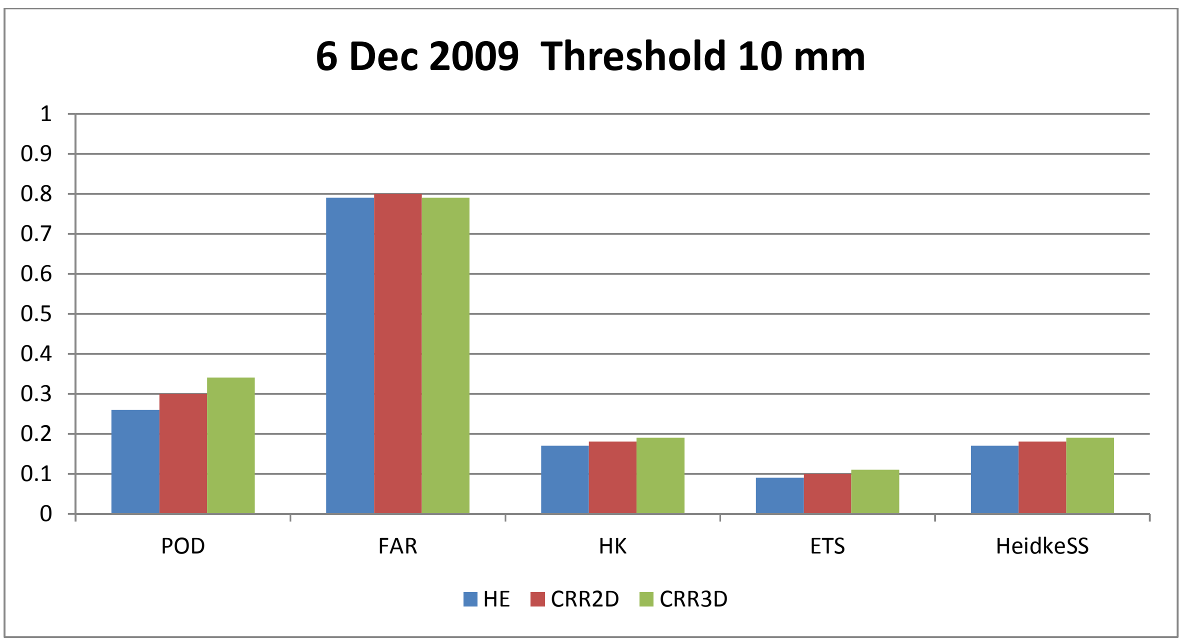

Figure 2b As Figure 2a but for 10mm threshold.

3.2 Example: 19 December 2009

In this example the HE outperformed the CRR algorithm for 1 mm (Figure 3a) and 10 mm (Figure 3b) thresholds.

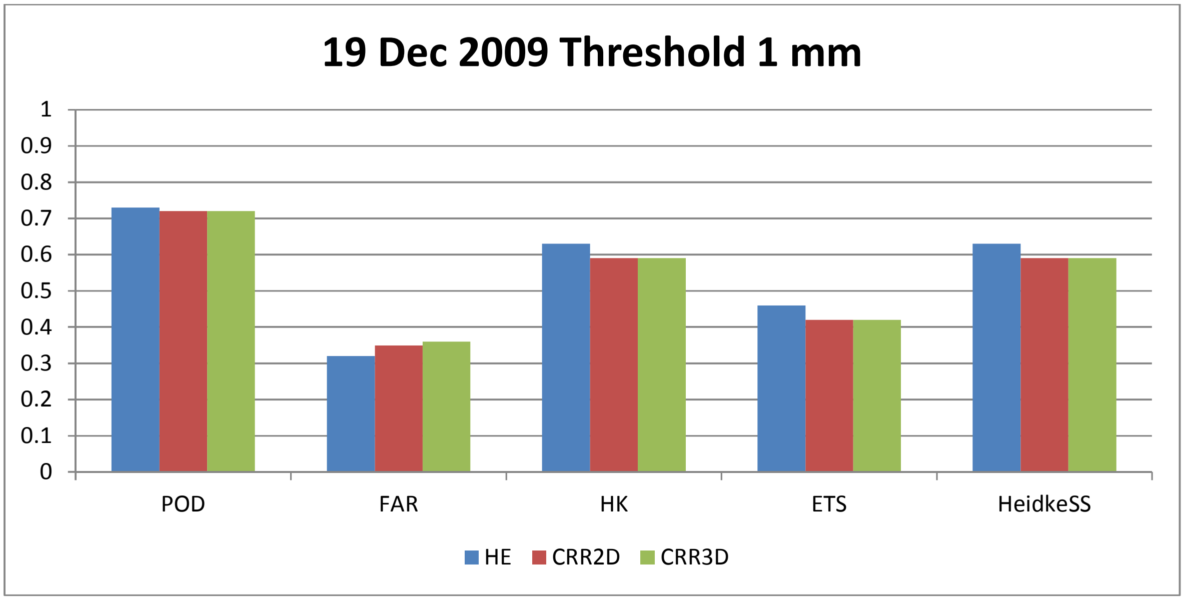

Figure 3a POD, FAR, Hanssen Kuiper, ETS and Heidke Skill Score for 19 Dec 2009, using a 1 mm threshold. HE is indicated in blue and CRR2D in red and CRR3D in green.

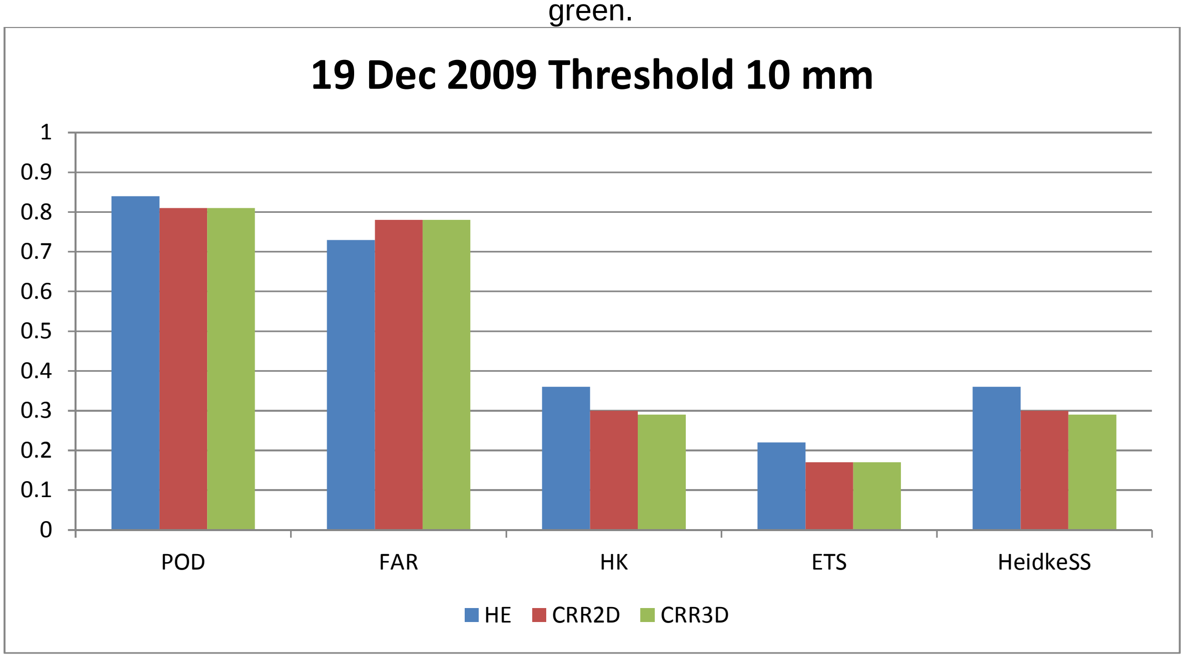

Figure 3b As Figure 3a but for 10 mm threshold.

3.3 Summary of all cases

The Heidke Skill Score has a minimum value of negative infinity and maximum of 1; 0 indicates no skill and 1 is the perfect score. For the 1 mm threshold (Figure 4a), the HE was better (in most cases significantly better) than the other algorithms for six of the eight cases. For the 10mm threshold (Figure 4b), the HE was better than the CRR algorithms in six of the cases. In three of these cases the HE had point with rainfall exceeding 10mm and neither the CRR2D nor the CRR3D had any point with rain more than 10mm. For the 20mm threshold (not shown) the HE was better than the other algorithms in three of the cases while the CRR algorithms did not have any skill at all.

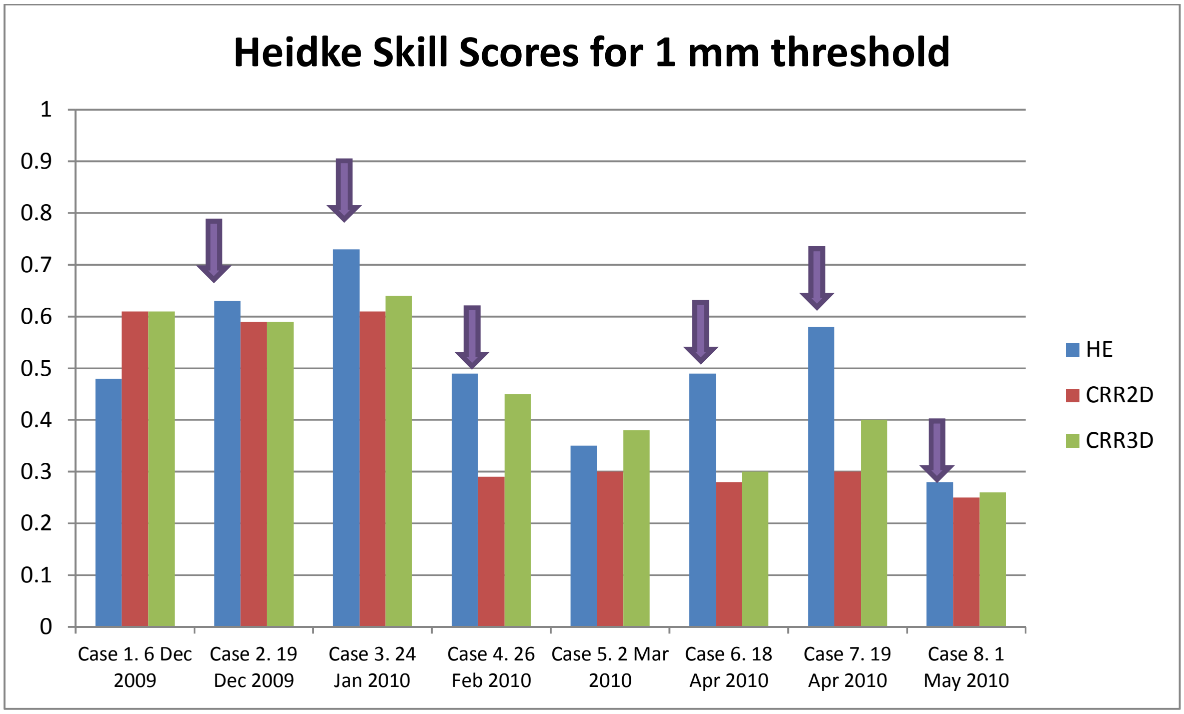

Figure 4a. Heidke Skill Score for 1 mm threshold for all 8 cases. HE in blue, CRR2D in red and CRR3D in green

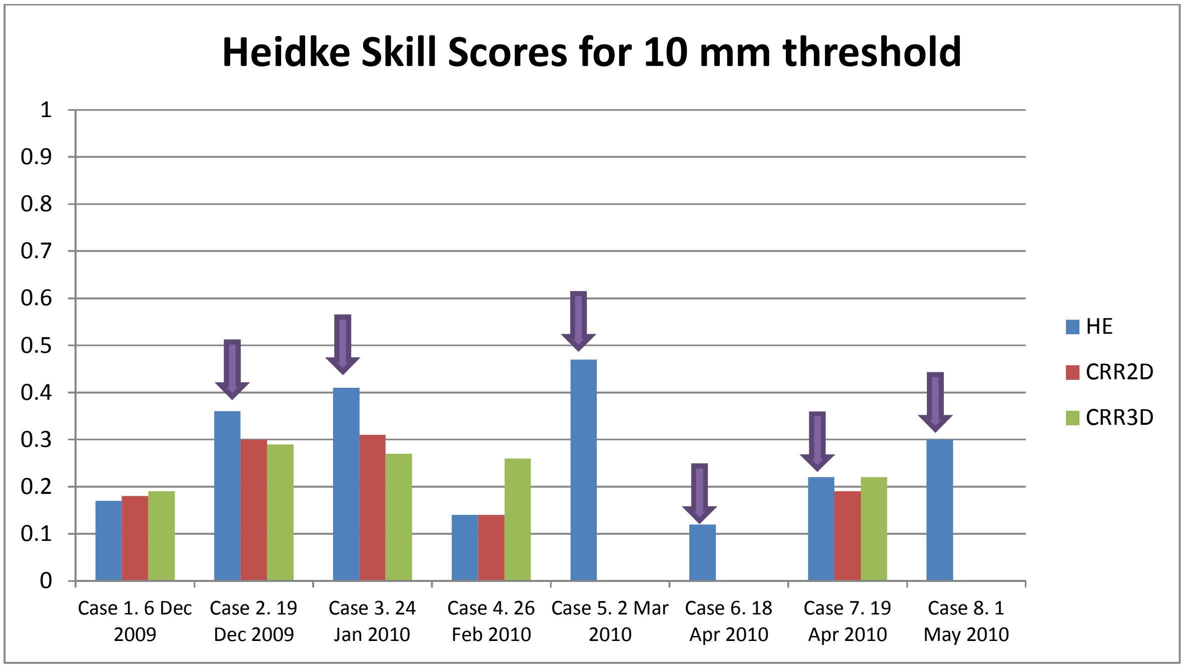

Figure 4b As Figure 4a but for 10 mm threshold

4. SUMMARY AND CONCLUSION

Initial tests using eight cases with different types of precipitation were done to compare the HE and the CRR algorithms against the daily rain gauge totals. Based on these test it seems that the CRR methodology is not conclusively better than the HE algorithm. One reason for this inconclusive result can be the use of the “calibration matrices” which was set up over Europe and might not be applicable or suitable over southern Africa. Another possibility is that the channel difference which is used for estimating cloud depth (IR108 – WV062) is proving to be ambiguous. Setvak (2012) argues that the Brightness Temperature Difference (BTD) between these two channels can indeed reach its maxima approximately above the coldest pixels, but in many other cases the BTD maxima are not above the coldest parts of the storm top. This BTD should thus be used with caution, as it does not have to be related to precipitating clouds only.

A new version of the CRR should be available in 2013 and the methodology has been adjusted to exclude the use of calibration matrices and rely more on cloud physical properties. Initial tests done in Spain with the new methodology shows an improvement over the current method. Once the newer version of the CRR is available, this will again be tested over the southern African region.

5. REFERENCES

Scofield, R. A. & Kuligowski, R. J. (2003). Status and outlook of operational satellite precipitation algorithms for extreme-precipitation events. *Wea. Forecasting*, 18, 1037-1051.

Setvak, M. (2012). Satellite observations of tops of convective storms (Part 3). SAWS – EUMETSAT 2nd Satellite Application Course for Southern Africa, Pretoria, South Africa, 23 – 27 April 2012.