USING SATELLITE DATA TO IDENTIFY AND TRACK CONVECTION OVER SOUTHERN AFRICA

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

BACKGROUND

Nowcasting is the science of anticipating the ordinary and severe weather events in the next few hours. Severe weather events can include heavy rainfall, strong wind, hail and/or tornadoes. Various sectors of society need to be able to prepare for these events when they occur and the issuing of weather-related warnings for such events in South Africa is the mandate of the South African Weather Service (SAWS). In an ideal world, radar systems provide the most useful information about the intensity, movement and characteristics of severe weather events, but these data sources are expensive to obtain and require extensive maintenance. Even in South Africa, radar systems do not provide coverage of the entire country and this leaves gaps between radars. In other southern African countries, very few operational radar systems exist. Despite the shortcomings in data resources, all meteorological centres still have to warn the public of pending severe weather events. The geostationary Meteosat Second Generation (MSG) satellite provides data coverage over all African countries and the operational use of satellite data as a possible solution for nowcasting of severe weather events in data-sparse regions is increasingly being considered by satellite users.

In order to optimise the use of satellite data, different centres were established in the European region to develop derived products for different purposes, including nowcasting. The Nowcasting Satellite Application Facility (NWC SAF) developed various tools, which can be very useful for the nowcasting of severe weather events. One of the products, developed within the NWC SAF framework by Meteo-France, is called the “Rapid Development Thunderstorms” (RDT) product. The aim of this product is to use data from satellite and a numerical weather prediction model to identify and track the more intense parts of thunderstorms. The software to generate this product can be downloaded from the NWC SAF website by any user.

The aim of this Water Research Commission (WRC) funded project was to implement and test the RDT product over the South African as well as southern African domain to show the possible benefit of this product in data-sparse regions.

METHODOLOGY

European countries that make use of the RDT product mostly use data from the European Centre for Medium-Range Weather Forecasts (ECMWF) model as input to the product. In South Africa, the software had to be adjusted to use the local version of the UK Meteorological Office (UKMO) Unified Model (UM). This model is run once a day in South Africa, using a 12 km horizontal resolution and 38 vertical levels. The UM has an hourly output for up to 48 hours ahead. Satellite data from the MSG are readily available every 15 minutes.

The 2012 version of the NWC SAF software was installed on a server at the SAWS and several case studies were conducted, ten of which over the South African domain and ten over the southern African domain. Quantitative validation of the RDT product over the South African region was done using lightning data from the South African Lightning Detection Network (SALDN), while visual comparisons were also done using radar images (where available) and images from the MSG satellite. Over the southern African domain, the visual validation was performed using MSG images as well as rainfall data derived from the Tropical Rainfall Measuring Mission (TRMM), while quantitative validation was done using lightning data from the World Wide Lightning Location Network (WWLLN).

RESULTS

The results of ten case studies over the South African domain were used to determine whether the 2012 version of the RDT software could identify the more intense part of thunderstorms. The results

indicated that the RDT product compared well with the radar data in most cases and sometimes complemented the radar data in areas where no radar systems were available. Visual comparisons with MSG data showed that the intense parts of rapidly developing thunderstorms could be distinguished from the non-intense parts. When comparing the occurrence of lightning in the 10 minutes before until 10 minutes after each RDT time step, a large percentage of the moderate to intense lightning occurred inside the RDT polygons. The Hanssen-Kuiper discriminant (HK) showed that there was a good correlation between the moderate to intense lightning and the RDT polygons.

The results of the case studies over the southern African domain were visually compared to MSG images as well as the occurrence of rainfall (using the TRMM data set). Growing and mature RDT polygons coincided well with the more intense parts of thunderstorms as identified by the satellite images, while highlighting the more intense cores of the storms. The RDT polygons also showed good correlation with the occurrence of more intense rainfall, as estimated by the TRMM. The lightning data from the WWLLN has a very low detection efficiency (DE) – almost a tenth of the lightning data recorded by the SALDN. Despite this shortcoming, large percentages of the lightning still occurred inside the RDT polygons and good contingency table scores were recorded.

DISCUSSION AND CONCLUSION

The implementation of the 2012 version of the NWC SAF software to test whether the RDT product can be used over the South African and southern African regions proved to be successful. The results of the cases that were considered show promising results that this product could provide additional information on possible severe storms in regions that are not covered by radar systems. This product may be useful particularly for aviation purposes in regions of Africa and could assist in navigating air traffic around the more intense storms, which could contain hail and/or heavy rainfall.

Several occasions were utilized to demonstrate the RDT product to operational forecasters in South Africa as well as in the southern African region through workshops as well as the annual Severe Weather Forecasting Demonstration Project (SWFDP) training events. Positive feedback has already been received about this new nowcasting tool. The results of the research were also presented at several national as well as international forums and, in general, the response to the fact that South Africa has succeeded in running the RDT software operationally has been very positive. Other African countries have expressed the need to share in the output of the RDT product.

The 2013 version of the NWC software was made operational at SAWS during the second half of 2014. The RDT images are available on the FCAST website to forecasters in South Africa, but also on the Regional Specialized Meteorological Centre (RSMC) website for forecasters from our neighbouring countries. This version already contains updates and improvements on the 2012 version. Several new options are available in the 2013 version of the software, which have not all been implemented yet. This will form part of future research on this topic.

RECOMMENDATIONS

The results of the RDT case studies conducted to date are very encouraging. Several options exist for future work:

- Upgrading the NWC SAF software whenever a new version becomes available to keep up-to-date with the latest improvements to the system.
- Using lightning data as input to the RDT product to enhance the identification of intense thunderstorms.
- Using some of the other NWC SAF products, such as the Convective Rainfall Rate (CRR) algorithm as real-time satellite rainfall estimate.

- Improving on the verification methodology using object-oriented-methodology (OMM), instead of grid-box-based verification methods.
- Validation studies over several months and/or seasons to establish when and where the RDT performs best.

The project team is optimistic about all the new possibilities that exist to use, improve and validate the RDT and other NWC SAF products.

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ABBREVIATIONS

AARSE - African Association of Remote Sensing of the Environment

BUFR - Binary Universal Form for the Representation of meteorological data

CBS - Commission for Basic Systems

CG - Cloud to Ground

ConvRGB - Convection Red-Green-Blue combination

CRR - Convective Rainfall Rate

DC - Developing Countries

DRC - Democratic Republic of Congo

ECMWF - European Centre for Medium-Range Weather Forecasts

EPS - Ensemble Prediction System

EUMETSAT - European Organization for the Exploitation of Meteorological Satellites

FAR - False Alarm Ratio

HK - Hanssen-Kuiper discriminant

HRV - High Resolution Visible

HRVRGB - High Resolution Visible Red-Green-Blue combination

IC - Intra-cloud

INM - Institute for National Meteorology (Spain)

IR - Infrared

KZN - KwaZulu-Natal

LDC - Least Developed Countries

MSG - Meteosat Second Generation

NOAA - National Oceanic and Atmospheric Administration

NWC SAF - Nowcasting Satellite Application Facility

NWP - Numerical Weather Prediction

POD - Probability of Detection

POFD - Probability of False Detection

RDT - Rapid Development Thunderstorms

RGB - Red-Green-Blue

RSMC - Regional Specialized Meteorological Centre

RTC - Regional Training Centre

SAF - Satellite Application Facility

SALDN - South African Lightning Detection Network

SASAS - South African Society for Atmospheric Scientists

SAWS - South African Weather Service

SWFDP - Severe Weather Forecasting Demonstration Project

TM - Task Manager

TRMM - Tropical Rainfall Measuring Mission

UM - Unified Model

VIS - Visible

VLF - Very Low Frequency

VSRF - Very Short Range Forecasting

WMO - World Meteorological Organization

WV - Water vapour

WWLLN - World Wide Lightning Location Network

CHAPTER 1: BACKGROUND

1.1 RATIONALE OF THE STUDY

Nowcasting "comprises the detailed description of the current weather along with forecasts obtained by extrapolation for a period of 0 to 6 hours ahead" (World Meteorological Organization (WMO), http://www.wmo.int/pages/prog/amp/pwsp/Nowcasting.htm). The latest radar, satellite and observational data are powerful tools when operational forecasters have to warn the public of hazardous, high-impact weather such as thunderstorms, tornadoes, lightning strikes and destructive winds. Effective and accurate nowcasting contributes to the reduction of fatalities and injuries, reduction of damage to property as well as improved efficiency for various industries including transport and agriculture. Nowcasting also plays a key role in aviation weather forecasts – both at the terminal as well as in the en-route environment.

The biggest advantage of nowcasting lies in the fact that it provides location-specific forecasts of the initiation, growth, movement and dissipation of weather phenomena. In an ideal world radar systems are the most important part of nowcasting, since they provide information on the size, shape, intensity, speed and direction of movement of individual storms on a continuous basis. The harsh reality, however, is that many developing countries (DC) and even more so least developed countries (LDC) do not have operational radar systems at all, and the countries which are fortunate enough to have radar systems, are struggling to maintain and sustain these powerful data sources (de Coning, 2013).

If the focus is on nowcasting systems for *developing countries and/or least developed countries*, it implies that one would have to look beyond the use of only ground-based radar systems. The emphasis should be on using what is available, without giving up on efforts to try, with international assistance when possible, to build upon and improve the observational network of sensors (e.g. surface rain-gauge stations, radar data, etc.).

One way of trying to develop nowcasting systems for the very important high-impact weather events in DC and LDC is through the WMO Commission for Basic Systems (CBS) Severe Weather Forecasting Demonstration Project (SWFDP).The SWFDPs aim specifically to improve severe weather forecasting in DC and LDC by providing access to current forecasting information that forecasters do not usually have access to, such as Numerical Weather Prediction (NWP) and Ensemble Prediction Systems (EPS). There are several SWFDPs around the world, one of which has been successfully implemented in the southern Africa domain. Although these SWFDP projects were initially designed to focus mainly on numerical weather prediction output and synoptic scale events, it is becoming clear that more than model output is needed. At the fourth meeting of the CBS-SWFDP Steering Group in Geneva, 2012 (CBS-DPFS/SWFDP-SG-4/Final Report) it was recognized that one of the main challenges for the SWFDP was "the need for very short-range forecasting (including the first 12 hours) tools, to address especially the rapid onset of localized severe thunderstorms which can produce heavy precipitation and strong winds, given the absence of adequate real-time observational networks, especially weather radar coverage." The usefulness of Meteosat Second Generation (MSG) products for nowcasting purposes was recognized and it was also agreed that real-time satellite rainfall estimates have proven particularly useful in regions where rain gauges and radar coverage are not available.

Satellite Application Facilities (SAF) are dedicated centres for processing satellite data, by utilizing specialist expertise from the European Union Member States. The Agreement of Co-operation of a Satellite Application Facility on support to Nowcasting and Very Short-Range Forecasting (VSRF) was signed by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) and Institute for National Meteorology in Spain (INM) in December 1996. The project commenced in February 1997 aiming to produce the software to deal with nowcasting and very short range forecasting using the characteristics of the Meteosat Second Generation (MSG), the National Oceanic and Atmospheric Administration (NOAA) and other data from polar-orbiting satellites (EUMETSAT, http://www.eumetsat.int/Home/Main/Satellites/GroundNetwork/ApplicationGroundSegment/SAFs/WhatisaSAF/index.htm?l=en).

1.2 Definition of the RDT product

Amongst the list of products developed by the Nowcasting SAF (NWC SAF) is a so-called “Rapid Development Thunderstorms” (RDT) product. It uses mainly geostationary (MSG) satellite data and provides information on clouds related to significant convective systems, from mesoscale down to smaller scales (< 1 km). (NWC SAF, Algorithm Theoretical Basis Document for RDT, 2013).

The objectives of RDT are to:

- identify, monitor and track intense convective system clouds and
- detect rapidly developing convective cells.

The object-oriented approach underlying the RDT product adds value to the satellite image by characterizing convective, spatially consistent storm cells. From an aviation point of view, it is becoming more and more important to improve the decision-making for the mitigation of thunderstorm impacts on the aviation system. The need for improved decision-making is expected to be even more critical with expected future increases in demand for air travel. “The rapidly changing nature of convective weather places a premium on making good decisions in a short amount of time” (Weber et al., 2007). RDT thus is a tool for meteorological forecasters, but can also be used by research teams and end-users such as those working in the aeronautical industry (NWC SAF documentation, Algorithm Theoretical Basis Document for RDT, 2013).

The RDT is one of the various satellite- and NWP-based applications which can be extremely useful in data-sparse countries. The product is operationally available in Europe, but has not been tested over regions in Africa. An objective validation of the RDT (using the 2011 version of the software) was conducted over Europe from April 2008 to October 2009 (Northern Hemisphere summer). Lightning activity was used as ground truth. The overall probability of detection was found to be 74%, the probability of false detection was 2%, the false alarm ratio was 22% and the threat score was 61%. The conclusion of the validation report states: “RDT provides an accurate depiction of convective phenomena, from triggering phase to mature stage. The RDT object allows pointing out some areas of interest of a satellite image. It provides relevant information on triggering and development clouds and on mature systems. Even if the precocity on the first lightning occurrence remains to be improved, the subjective evaluation confirmed the precocity usefulness on moderate lightning activity” (NWC SAF documentation, Validation Report for RDT, 2013). Using the NWC SAF documentation (Algorithm Theoretical Basis Document for RDT, 2013) the following summary is provided of the background of the RDT product:

1.2.1 Input data

The NWC SAF software can be downloaded from the NWC SAF website (http://www.nwcsaf.org) free of charge. It is up to the user to install this in their own environment, but ample documentation is provided to guide the users in the process. A helpdesk facility also exists to deal with specific enquiries.

a) Satellite data

The RDT algorithm makes use of MSG channels to detect convective objects; discrimination parameters are calculated from the following mandatory MSG channels:

- Water Vapour 6.2
- Water Vapour 7.3
- InfraRed 8.7

- InfraRed 10.8
- InfraRed 12.0.

b) Numerical Weather Prediction data from the local version of the Unified Model (UM)
In order to complement the satellite data, the RDT algorithm also makes use of the following hourly NWP fields:

- surface pressure
- surface temperature
- 2m temperature
- 2m dew point temperature
- 2m relative humidity
- surface geopotential
- total column water vapour
- altitude/topography
- land/sea mask
- tropopause temperature
- temperature, geopotential height, u and v components of the wind and humidity at all pressure levels from 1000 hPa to 100 hPa in 50 hPa intervals.

In other countries the ECMWF NWP model is used for calculation of the RDT, but in South Africa the only NWP model which can provide the required input fields is the UK Met Office Unified Model (UM).

1.2.2 The RDT algorithm
Thunderstorm detection by PGE11 is a mix of physical and statistical approaches. The first step is to identify and track cloud system and then to define satellite characteristics of these cloud systems during the different phases (triggering, development and mature) of the storms. The RDT algorithm could be divided into three parts:

- The detection of cloud systems
- The tracking of cloud systems
- The discrimination of convective cloud objects.

a) The detection of cloud systems
The detection algorithm defines “cells” which represent the cloud systems. In the RDT algorithm, “cells” are identified by infrared channel (IR10.8) by applying an adaptive threshold which is specific to each cloud system and which is based on local brightness temperature patterns. The cloud objects or cells are defined by cloud towers with a significant vertical extension (at least 6°C colder than the warmest pixels in its surroundings).

b) The tracking of cloud systems
The tracking algorithm is mainly built on the overlapping between cells in two successive images. The previous cells are moved according to their (formerly analyzed) movement and speed. The time series of clouds’ characteristics (peripheral gradient, volume, cooling rate) are key input for the discrimination algorithm.

c) The discrimination of convective objects
The goal of the discrimination method is to identify the convective RDT objects among all cloud cells. The discrimination phase makes use of discrimination parameters calculated from five MSG channels: IR 10.8µm, IR 8.7µm, IR 12µm, WV 6.2µm and WV 7.3µm as well as NWP data. Both spatial and temporal characteristics are used as discrimination parameters. The discrimination scheme is a mix between empirical rules and statistical models tuned on a learning database. The different phases of

the storms are determined by using the history of the cell, the temperature trend (cooling or warming), the vertical extent (extending or shrinking), the expansion of the cell as well as whether there is convective or non-convective activity in the storm (if lightning data are used as input). A mature storm is defined as an object with a cloud-top temperature of less than -40°C for at least 45 minutes. Growing storms are identified by using different phases – warm or cold transitions – with cloud-top temperatures of between -25°C and -35°C and temperatures at the base of the cloud tower ranging from -15°C to -25°C. NWP data are used to identify areas which are stable and where no convective development should occur, thus reducing the false alarms.

d) Visualization

Finally, the outcome of the RDT is a map with polygons, identifying the different phases of thunderstorms from triggering, to growing, mature and decaying. Each of these is depicted in different colours to make it easy to discern when overlaid on a satellite image.

1.3 The aims of the study

The aims of this research project were to:

- install and implement the RDT software (based on MSG and Unified (UM) data) on a server at the South at the South African Weather Service (SAWS) to run over the South African and southern African regions to provide information to forecasters, aviation meteorologists and hydrologists about the development, life cycle and dissipation of convection in regions where radar systems do not provide coverage (in-between radars over South Africa) or where no radars systems are available (most of South Africa's neighbouring countries);

- validate the RDT against lightning data over the South African and southern African region by means of case studies to show the value of this product;

- present the outcome of the studies to relevant audiences nationally and internationally;

- transfer skills to the relevant forecasters; and

- implement the system operationally to provide real-time feed of the RDT to forecasters in the southern African region.

The implementation and distribution of the RDT product to the relevant forecasting offices, has been shown to improve the nowcasting system to monitor and predict (up to 2 hours) the stages of development, intensity and movement of thunderstorms. The implementation of the RDT tool can play a vital role in early warning systems. Knowing where thunderstorms are developing and whether or not they are growing and becoming more severe can assist in extending warning lead times for severe weather events. In South Africa the existing radar network does not cover the northwestern part of the country. Radar systems in our neighbouring countries are not available in the operational radar mosaic, yet most of our country's summer time convection originates northwest of our own country. The RDT would enable forecasters to identify the more prominent thunderstorms and their movement. Knowledge of thunderstorm activities is vital for the aviation industry and assists the route planners in the daily planning and operation of flights over/into Africa. When flights have to be delayed or re-routed it has a serious impact on fuel consumption of the airplanes. Aviation forecasters are required to issue special warnings including information on the onset, cessation or change in intensity of thunderstorms – the RDT could provide this information in real time, every 15 minutes (with MSG). Destruction and disruption due to thunderstorms and severe thunderstorms amount to millions of rands in damage each year. More accurate monitoring of thunderstorms, their intensity as well as their movement will contribute to more timely warnings to save lives and property.

1.4 LAYOUT OF THE REPORT

In this chapter, the motivation and aims for undertaking this research project were given. A summarized version of the background of the “Rapid Development Thunderstorms” (RDT) product was provided, including the required input data and the final output. In the next chapter, an RDT data flow chart is provided which illustrates the sequence of the processes followed to provide information on the configuration and installation of the software. In chapter three, the validation of the RDT product will be demonstrated over the South African as well as southern African regions. Chapter 4 will provide details on the implementation and applications of the RDT, together with capacity building activities undertaken during the project. The last chapter will conclude the results and list recommendations for further work.

CHAPTER 2: CONFIGURATION and INSTALLATION OF NOWCASTING THE SAF SOFTWARE AT THE SOUTH AFRICAN WEATHER SERVICE

2.1 INTRODUCTION

The 2012 version of the Nowcasting SAF software was downloaded and installed at SAWS during 2013. A data set with MSG as well as numerical weather prediction data from the ECMWF model is supplied with the software. In this way, it is possible to test that the software is installed properly and can produce the desired output. A test was conducted with this data set and output could be generated successfully.

Subsequent to the initial test that the RDT software could run on the provided data set, the input data had to adjusted to use files from the local version of the Unified Model instead of the ECMWF NWP fields (SAWS does not receive operational ECMWF data, but runs the Unified Model locally at a 12 km resolution).

A date was selected when UM data as well as raw, archived MSG data were available and it was decided to make use of 06 September 2012 – on this day extensive convection occurred over the country, providing a perfect opportunity to demonstrate the capability of the RDT product. Several technical issues had to be solved in this process, including unpacking archived MSG data, but the test completed successfully. Figure 2.1 demonstrates the output of the RDT over South Africa at 0830 UTC on 06 September 2012 (left) together with the occurrence of lightning in the 30 minutes (0830 to 0900 UTC) subsequent to the RDT product (right).

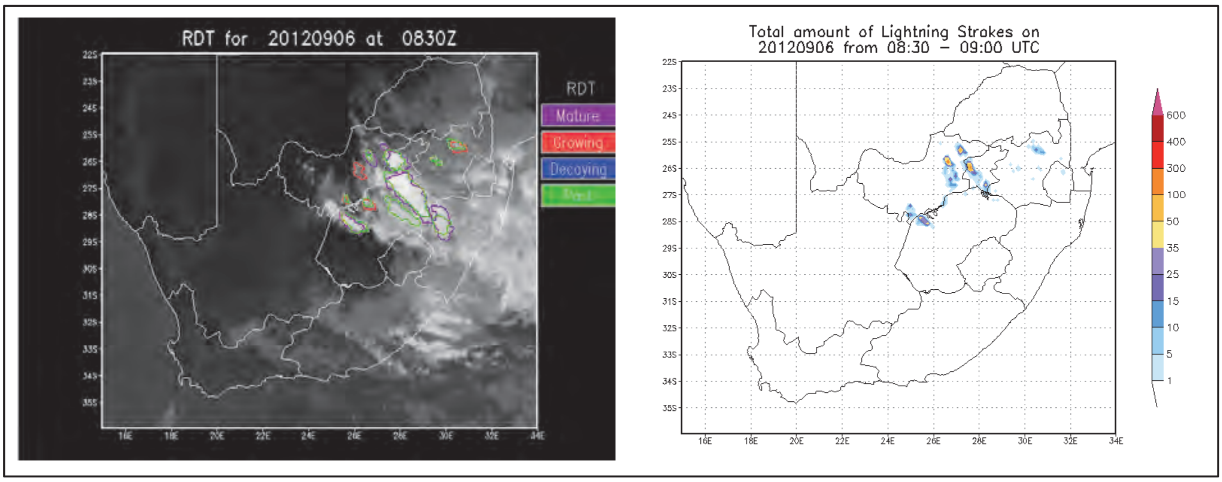

Figure 2.1 RDT image at 0830 UTC on 06 September 2012 (left) and occurrence of lightning between 0830 and 0900 UTC on 06 September 2012 (right)

2.2 SOFTWARE FOR CASE STUDIES

For all case study dates, archived UM data were acquired from an archive server and MSG data were ordered from EUMETSAT. The procedure for creating the RDT output followed in the script is as follows:

a) The process starts with decompression of the archived satellite data and then the NWP data are transferred from the model data archive and processed into hourly files, containing the variables required by the SAFNWC system.

b) A script is run which asks for the date and times of the case study to be processed, where after it runs automatically through all the steps of the satellite and model data processing, and the creation of the RDT products.

c) To calculate the RDT output, four of the other SAF products are required as input – cloud mask, cloud type, cloud-top temperature and height as well as convective rainfall rate. This enables the creation of the RDT product. Figure 2.2 illustrates the sequence of the operations followed.

d) Once the RDT has been created, an image is created for every 15-minute period between the specified start time and end time.

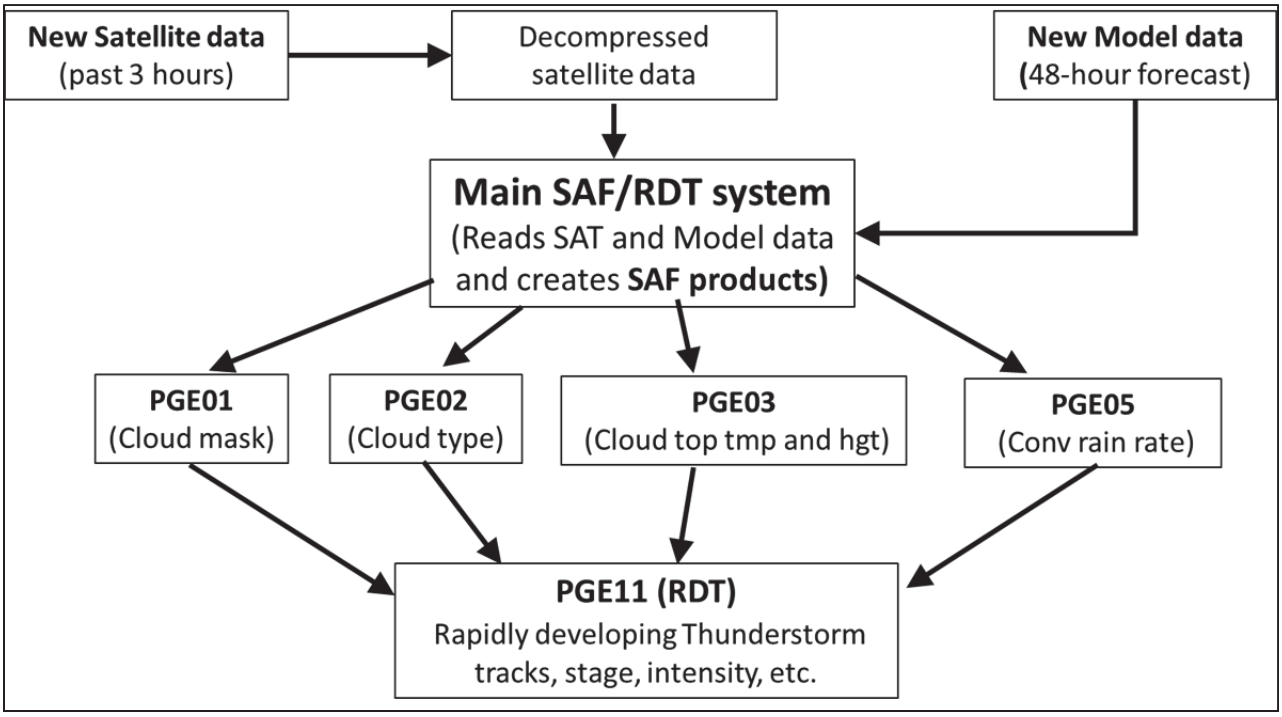

Figure 2.2 RDT process flow chart

When displaying the RDT storm cells, various attributes are available for each cell. The most important of these attributes are the phase and the nature of the storm cell. The nature of the storm cell is given as a code to indicate whether the cell is convective or not. Only the convective cells are plotted in the RDT display. The phase of the storm cell on the other hand indicates whether the cell is in the mature phase, growing or decaying. Each storm cell can then be displayed in separate colours to distinguish between the phases of the cell. For the case study display only mature (purple) and growing (red) cells that have a convective nature are displayed.

2.3 SOFTWARE FOR OPERATIONAL USE

The operational RDT system is controlled by a program is called the task manager or TM. This TM starts programs to process the satellite and the NWP data into a format suitable for the RDT calculations. The output is stored in BUFR format (Binary Universal Form for Representation for observed data). The TM does all the necessary “housekeeping”, from checking the availability of new data to cleaning of working directories and updating of logs.

As with the case study display, only the cells that have a convective nature are displayed operationally. The cells that are in the mature phase are displayed in purple and the cells that are growing in red. Another feature that has been added to the operational display is a wind arrow, which indicates the direction and speed at which the storm cells are moving.

2.4 SUMMARY

In this chapter the procedures for running the RDT product at SAWS were explained. For case studies archived data were used and the procedure was slightly different than it is for the operational runs. The latter is controlled by a Task Manager script which prepares files, calculates the required products and then cleans the directories and obsolete files at the end of the process. Visual display of the RDT product was done to indicate the convective storms in their growing and mature phases, which are the most relevant for operational forecasters. The next chapter provides the results of case studies conducted over the South African domain.

3.1 VALIDATION METHODOLOGY

3.1.1 Validation methodology over South Africa

A grid-box based methodology was used to the validation of the RDT agianst the occurrence of lightning. In order to achieve this, a 0.1112 x 0.110 degree grid was defined over the evaluation domain.The grid point tested was taken as the centre point of a 0.1112 x 0.110 degree grid box. If a grid point falls inside a RDT polygon, then the grid box for where this grid point is the centre point, as well as the top, top-right, right, bottom-right, bottom, bottom-left, left, and top-left grid boxes were taken to fall inside the RDT polygon. This process then converts a RDT polygon into a grid. These additional grid boxes included in the polygon around the grid box being tested were included to take into account the lightning strokes falling outside the core of a thunderstorm. Figure 3.1 shows the process of how the polygon is converted into a grid. The dark grey grid boxes are the ones falling inside the polygon while the light grey grid boxes are included to take into account the lightning strokes falling outside the polygon.

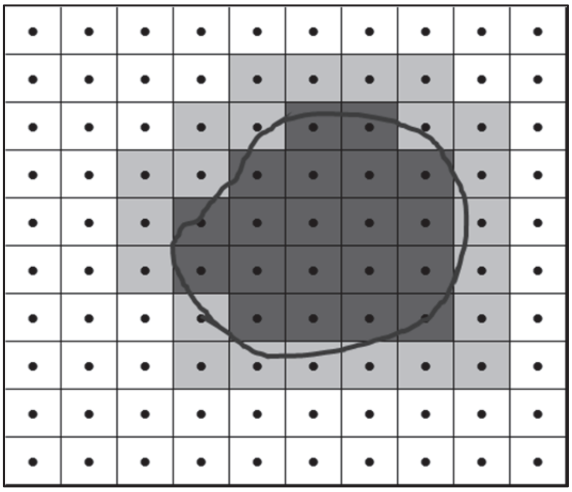

Figure 3.1 Image showing the grid boxes used when converting a polygon into a grid

The exact same grid was used for the lightning data. The number of lightning stokes falling inside each grid point for the 10 minutes period before until 10 minutes after the RDT time step was calculated. The RDT polygons and the lightning occurrences could then be compared on a gridbox-by-gridbox basis

The RDT product was evaluated against cloud-to-ground lightning data from the South African Lightning Detection Network (SALDN). The SALDN detects only CG lightning (lightning that strikes the earth’s surface) and thus does not capture the intra-cloud (IC) lightning as well as cloud-to-cloud lightning (Gijben, 2012). During the developing phase of a thunderstorm predominantly IC lightning is found, while in the mature phase of a storm the maximum IC lightning occurs together with a significant amount of CG. Since the developing and mature phases of a thunderstorm are most important for operational forecasters, these two phases were considered in the RDT evaluation. The large fraction of IC lightning in both the developing and mature phase of a thunderstorm is not detected by the SALDN and this is a limitation in terms of the statistical evaluation scores.

All lightning activity was considered in the 10 minutes before until 10 minutes after each RDT time step. In the South African domain sufficient lightning data are available to distinguish between light, moderate and intense lightning strokes. Similar to the methodology followed by the developers of the RDT product in their validation report, the lightning occurrences in the South African cases studies were divided into three categories – light (>3 strokes), moderate (>15 strokes) and intense (>60 strokes) in each grid box. Since the RDT product is aimed at the identification of intense or rapidly developing storms or parts of storms, one would expect that the moderate to intense lightning occurrences would correspond best with the RDT polygons and the less intense lightning events might fall outside the RDT polygons. For all the cases the seven hours from 1100 UTC to 1800 UTC (13:00-20:00 SA time) were used as this usually is the convectively active part of the day. This approach was used in the calculation of all statistical scores and will be shown in the respective graphs provided in this chapter.

The SALDN detects lightning with a detection efficiency of 90% over the country, meaning that 90% or more of all the cloud-to-ground lightning is detected. To compensate for the areas falling outside this 90% detection efficiency range, a mask was applied to the evaluation domain so that only accurate lightning data were used for the evaluation. Figure 3.2 shows the mask that was used for the evaluation, where the white areas were included in the evaluation while the grey areas were masked out.

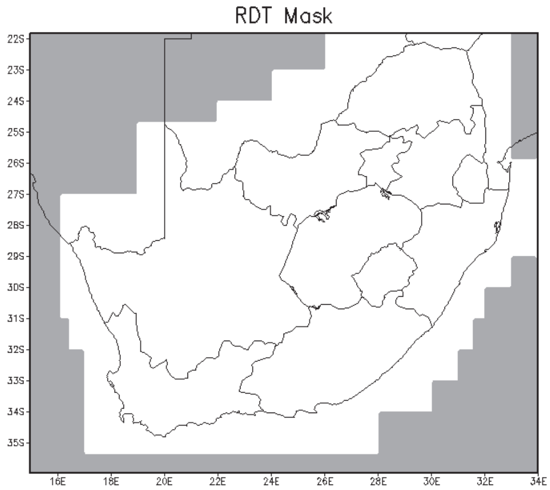

Figure 3.2 Map indicating the evaluation domain. White areas were included in the evaluation while grey areas were masked

a) Percentage of total lightning inside the RDT polygons

The first evaluation method used, was to determine what percentage of all the lightning strokes detected fell inside the RDT polygons in the 10 minutes before until 10 minutes after each RDT time step. This was accomplished by using an algorithm which determines whether a point (in this case a lightning strike) falls inside, on the edge or outside a polygon. The total number of lightning strokes inside the RDT polygons was calculated as well as the total number of all the lightning strokes that had been recorded. From this the percentage of lightning strokes falling inside the RDT polygons was calculated.

b) Contingency table scores

The second evaluation method used, was touse a contingency table to calculate scores as indicated in Table 3.1. The definition and desired values for the statistical scores used in this report are indicated in Table 3.2 (Wilks, 1995).

Table 3.1 Contingency table

Contingency Table				
		Observed		
		yes	no	Total
Forecast	yes	***hits (A)***	***false alarms (B)***	***forecast yes***
	no	***misses (C)***	***correct negatives (D)***	***forecast no***
	Total	***observed yes***	***observed no***	***total***

Table 3.2 Statistical scores used for the evaluation of the RDT

Score	FORMULA	Answers the question:	Range	Perfect score
Probability of Detection	A / (A+C)	What fraction of the observed 'yes' events were correctly forecast?	0 to 1	1
Probability of False Detection (or False Alarm rate)	B / (B+D)	What fraction of the observed 'no' events were incorrectly forecast as 'yes'?	0 to 1	0
Hanssen-Kuipers discriminant (or True Skill Statistic)	POD – POFD	How well did the forecast separate the 'yes' events from the 'no' events?	-1 to 1	1

c) Comparison with MSG and radar images

The RDT product for the case studies was also compared to the MSG images, including Red-Green-Blue (RGB) combinations of the individual channels. The satellite RGBs that were used, are: a) the High Resolution Visible (HRVRGB) and b) the Convection RGB (ConvRGB). These RGB combinations enhance and identify particular features that are not captured by single channel imagery alone.

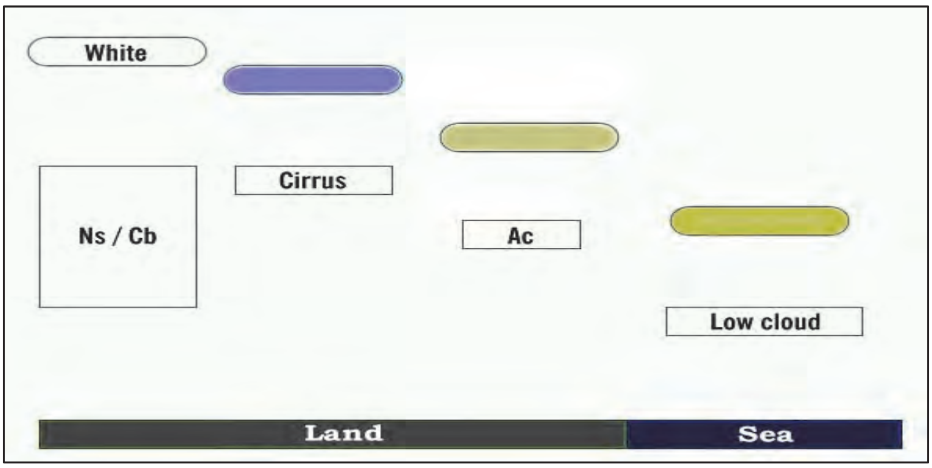

Figure 3.3 Description of colour palette for the HRVRGB imagery (Kerkmann, 2005)

The HRVRGB (Figure 3.3) uses the High Resolution Visible channel (Channel 12) in both the red and green beams, and the inverted IRI10.8 (Channel 9) in the blue beam. This RGB combination of channels enhances convective clouds when compared to low clouds. As seen in Figure 3.3, white in the imagery shows thick clouds such as cumulonimbus or even nimbostratus clouds. Blue indicates cirrus clouds, light yellow indicates mid-level clouds such as altocumulus, and darker yellows are low clouds. Land and sea features are displayed in darker colours.

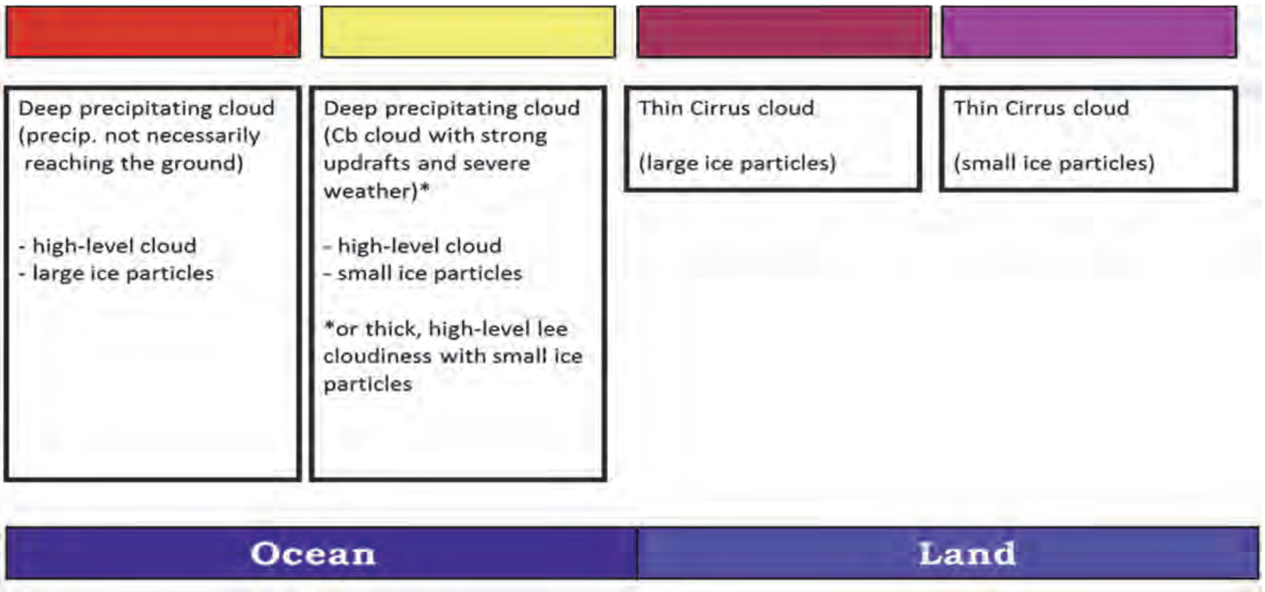

Figure 3.4 Description of the ConvRGB colour palette (Kerkmann, 2005)

The ConvRGB colour palette (Figure 3.4) is useful to enhance the features of convective storms.This RGB uses a difference between the WV channels in the red beam, a difference between IR channels in the green beam and a difference between VIS channels in the blue beam. Bright red in the images indicates deep precipitating clouds with large ice particles, while yellow indicates a deep precipitating cloud with small ice particles and strong updrafts, which could indicate severe weather features.

3.1.2 Validation methodology over the southern African region

The RDT product was quantitatively validated over the southern African domain (continent south of the equator) against lightning data from the World Wide Lightning Location Network (WWLLN). WWLLN is a global ground-based lightning detection network, which made its first measurements in 2004 (Virts et al., 2013). This network, managed by the University of Washington (WWLLN, see http://wwlln.net/new/), detects very low frequency (VLF) radio waves and identifies lightning sferics (Collier et al., 2010). A time-of-arrival technique then determines the location of the lightning stroke (Virts et al., 2013). By detecting VLF waves, WWLLN is able to detect lightning occurrence globally by using only a small number of sensors since the attenuation of the VLF waves is much lower (Collier et al., 2010). The disadvantage of using only a limited amount of sensors is that the detection efficiency is reduced quite significantly. Studies have shown that when the WWLLN network is compared to local lightning detection networks, the detection efficiency of WWLLN is approximately 10%, which means that only about 10% of all the lightning that occurs is detected by WWLLN (Virts et al., 2013). WWLLN also misses most lightning strikes with a polarity below 25kA (Collier et al., 2010).

Figure 3.5 displays the average lightning strike density map that was produced from data from the South African Lightning Detection Network (SALDN) for the period October 2011 to March 2012 (left), and the average lightning strike density map that was produced from data measured by the WWLLN for the same period (right). It is clear that WWLLN records much less lightning activity than the

SALDN. Note that the colour legend for the SALDN is ten times larger (ranging from 0.1 to 50) than the colour legend in the WWLLN graph (ranging from 0.01 to 5). Some areas show that WWLLN recorded values lower than 10% of those on the SALDN map.

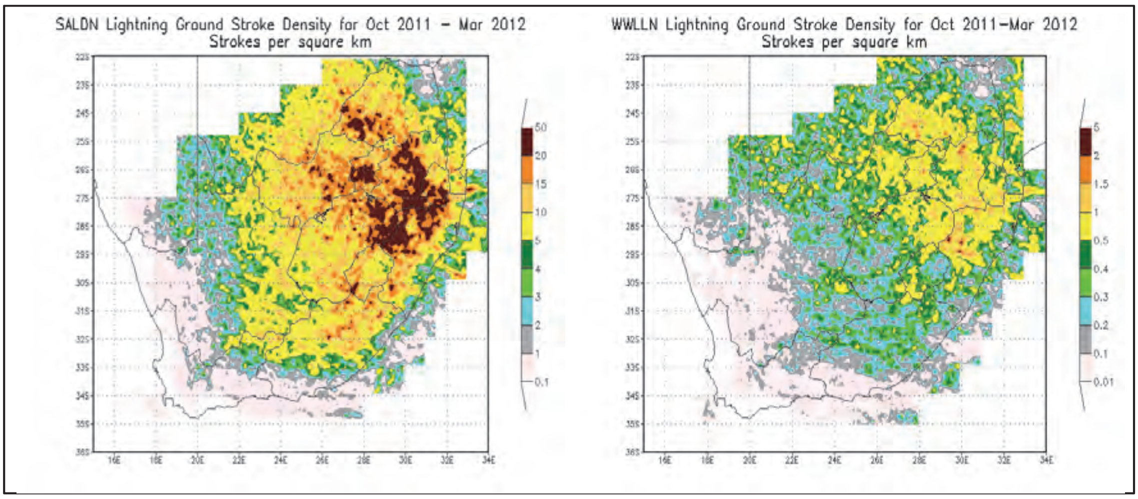

Figure 3.5 The average lightning stroke density for the SALDN (left) and for WWLLN (right) for the period October 2011 to March 2012

These limitations mean that the statistical scores calculated for the validation of the RDT product over southern Africa can appear more negative, since about 90% of all the lightning that occurred was not detected by the WWLLN. Even with the shortcomings of the WWLLN network, most thunder-producing storms are at least identified (Virts et al., 2013) which makes WWLLN the only option for verification purposes of thunderstorm products over an area with limited observational networks.

Each RDT time step was evaluated against lightning that occurred in the 30-minutes following the period of interest. The first evaluation method used, was to determine what percentage of all the lightning detected in the 30-minutes subsequent to the RDT time step occurred inside the RDT polygons. As the WWLLN has such a low DE, it was not possible to distinguish between light, moderate and intense lightning as was done for the South African domain cases. The second evaluation method used, was to calculate statistical scores to validate the performance of the RDT, similar to the method followed in Chapter 3 for the South African domain.

The cases were also evaluated using the ConvRGB and the HRVRGB as well as Tropical Rainfall Measuring Mission (TRMM) rainfall estimates. The TRMM data give only an estimate of precipitation accumulations from polar-orbiting satellites, and thus are not ground truth observations, but in the absence of adequate verification data over the SADC region, these TRMM data at least offer a way to determine which clouds produced rainfall.

3.2 Validation results over South Africa

Ten cases were selected on the basis of availability of UM data as well as raw, archived MSG data to test the RDT product in different months and for different weather conditions. Validation of the RDT could be done using a) lightning data in the 10 minutes before until the 10 minutes after each RDT time step, b) visual comparison with radar images (where possible) and MSG images. The dates selected for evaluation are indicated in Table 3.3. These particular cases were selected on the basis of being good convective cases, where some form of severe weather was associated with particular storms on these days. For all the cases the 2012 version of the NWC SAF software was used.

Table 3.3 The ten case dates selected for evaluation of the RDT for the South African region

Case study dates	
31 December 2011	20 October 2012
23 June 2012	8 November 2012
6 September 2012	9 November 2012
9 October 2012	10 December 2012
17 October 2012	19 January 2013

3.2.1 Case 1: 23 June 2012

On 23 June 2012, a cut-off low system was prevalent over the western parts of the country. At the eastern edge of the cut-off low system, a band of convective cells formed which later moved through the Free State. The majority of these convective cells over the Free State produced severe weather – there was even an alleged tornado near Bethlehem. Due to the fact that this is a winter time case, the storms were not deep convective storms as would be the case during typical summer convection.

Figure 3.6 shows the storms over the Free State at 1230 UTC. This image includes the lightning which occurred in the 20 minute interval from 1220 to 1240 UTC – i.e. from 10 minutes before the RDT time step until 10 minutes after the RDT time step. It is clear that the location of the mature storms corresponded well with the highest incidence of lightning. Lightning was also associated with the growing storms, but in smaller numbers. Compared with the radar imagery, the mature storms corresponded very well with the high reflectivity areas of the radar imagery. The growing storms corresponded with the areas of lower radar reflectivity.

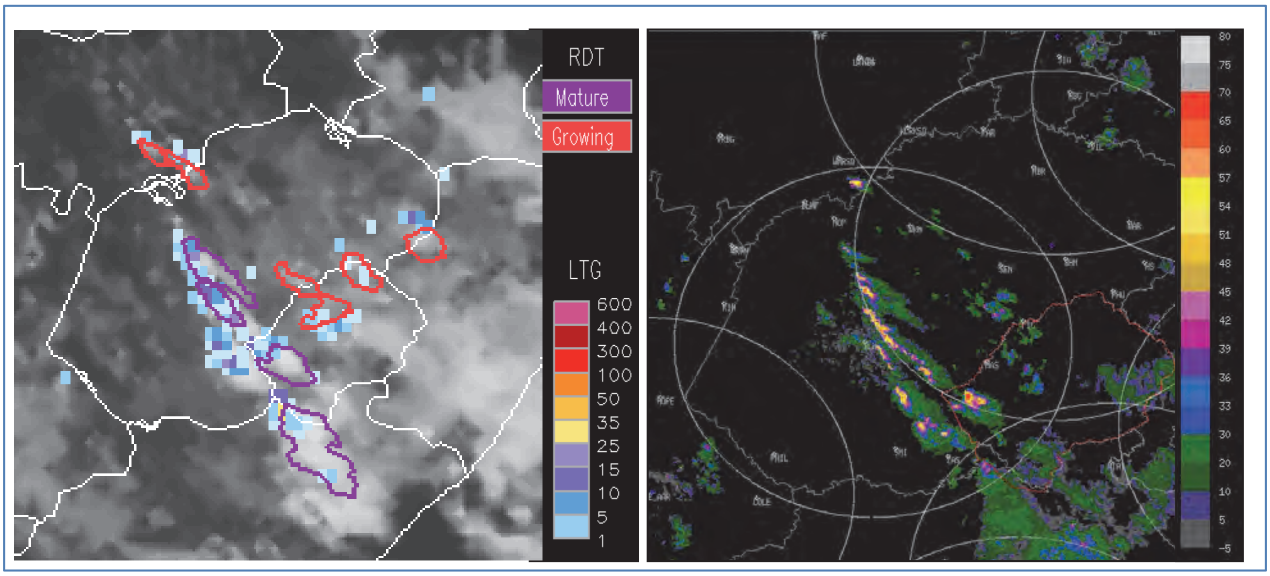

Figure 3.6 Growing and mature storms identified by the RDT with an overlay of lightning strokes (left) and radar reflectivity for 23 June 2012 at 1230 UTC (right) over the Free State Province

Comparing the percentage of lightning that occurred within the polygons for each time step (Figure 3.7), it is clear that large percentages of the moderate (orange) to intense (grey) lightning strokes were detected inside the RDT polygons (>60%). At eight of the time intervals all the intense lightning occurred inside the RDT polygons (grey bars). Very little lightning activity was observed before 1200 UTC.

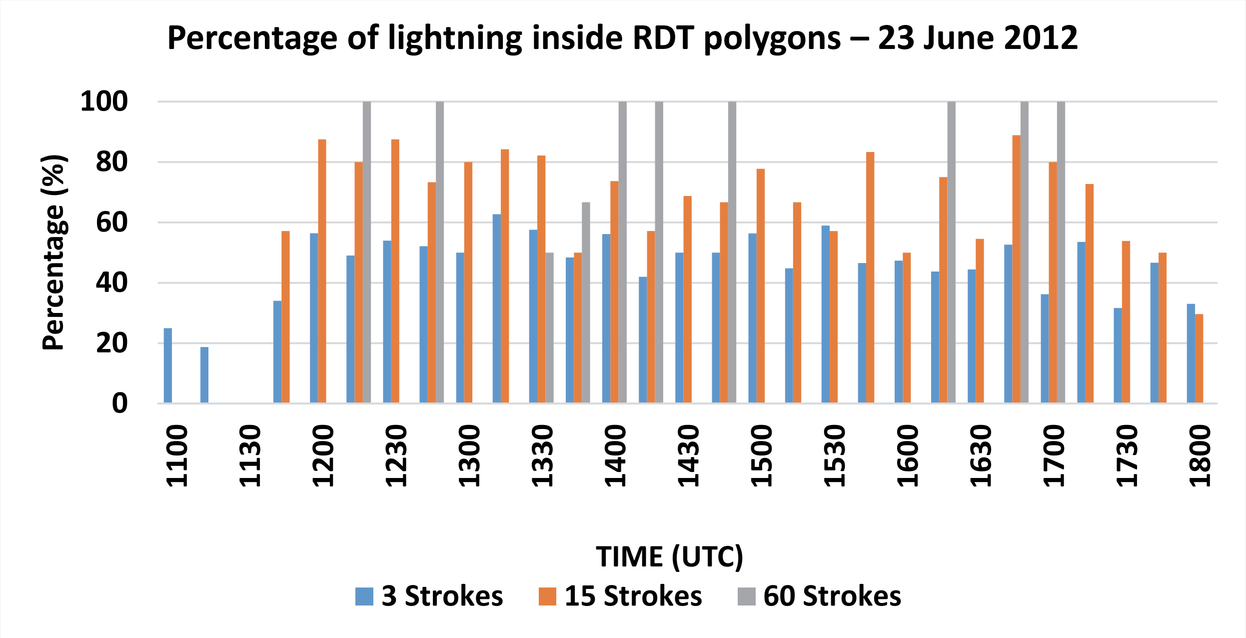

Figure 3.7 Percentage of lightning (> 3 strokes, blue), moderate (>15 strokes, orange) and intense (>60, grey) lightning which fell inside the RDT polygons between 1100 and 1800 UTC on 23 June 2012

An analysis of the Hanssen-Kuiper discriminant (Figure 3.8) reveals that this score attained its highest values where moderate to intense lightning occurred. Intense lightning (>60 strokes) did not occur at all the time steps (lack of a green bar), but it is clear that in many time steps the HK exceeded 0.6 (up to 0.8) for the moderate lightning (red) between 1200 and 1700 UTC.

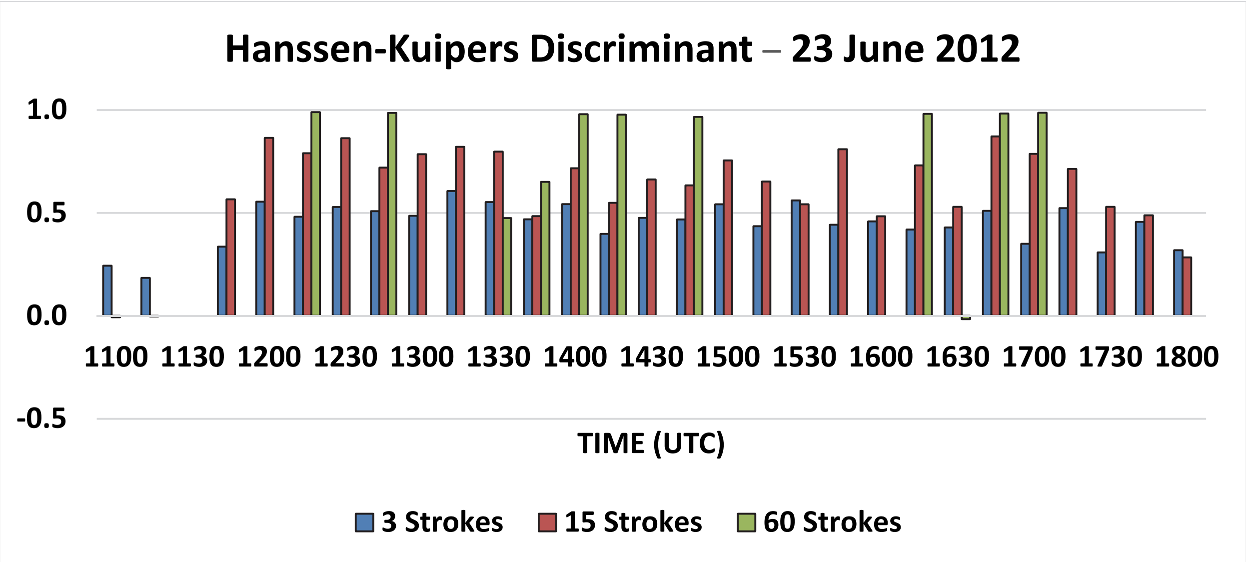

Figure 3.8 Hanssen-Kuiper discriminant for the RDT polygons against light (blue), moderate (red) and intense (green) lightning which occurred from 10 minutes before until 10 minutes after each RDT time step from 1100 to 1800 UTC on 23 June 2012

3.2.2 Case 2: 09 October 2012

On 09 October 2012, a cold front passed over the country. Convective storms started developing from 1000 UTC over the Free State and Eastern Cape. With the further eastward movement of the cold front, more storms developed and became well organised into a squall lines. By 1530 UTC, the convective system had reached KwaZulu-Natal (KZN) (Figure 3.9). At this time, the RDT identified two small mature storms out of a large cloud mass (indicated by the arrows). These storms indicated by the RDT coincided with the most intense convective cells within the radar imagery. These storms also corresponded well with the highest incidence of lightning stokes (as seen in the RDT imagery). Within the stratiform part of the cloud system there was some lightning recorded, but the RDT did not identify storms within these regions. Due to a lack of NWP field data to serve as input to the RDT on this day, the RDT did not function optimally until 1300 UTC. The validation statisctics will only be shown after 1300 UTC.

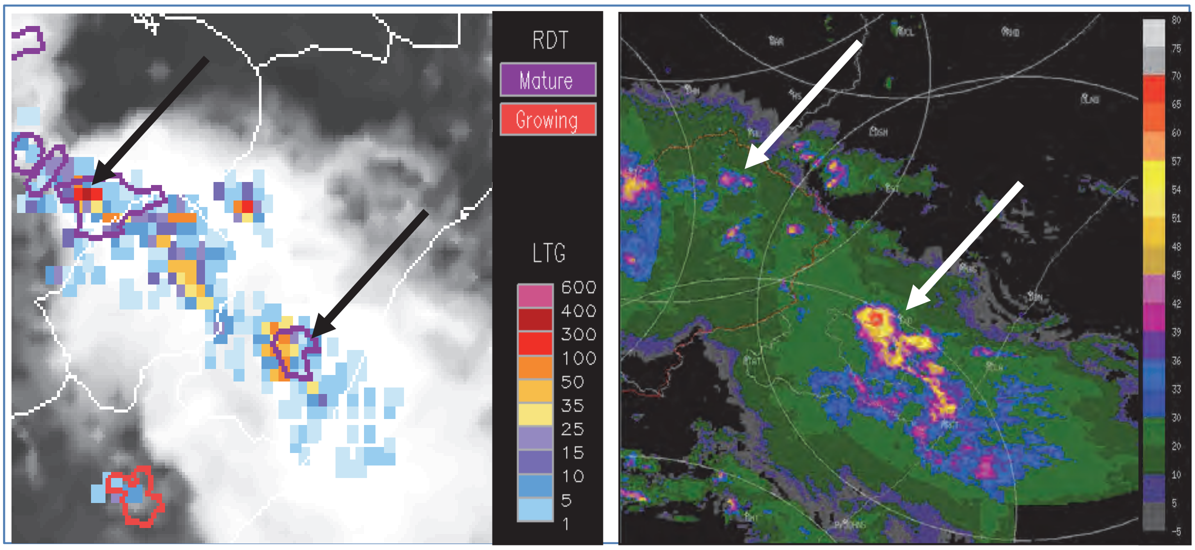

Figure 3.9 As in Figure 3.6 but for 09 October 2012 at 1530 UTC over the Free State and KZN Provinces

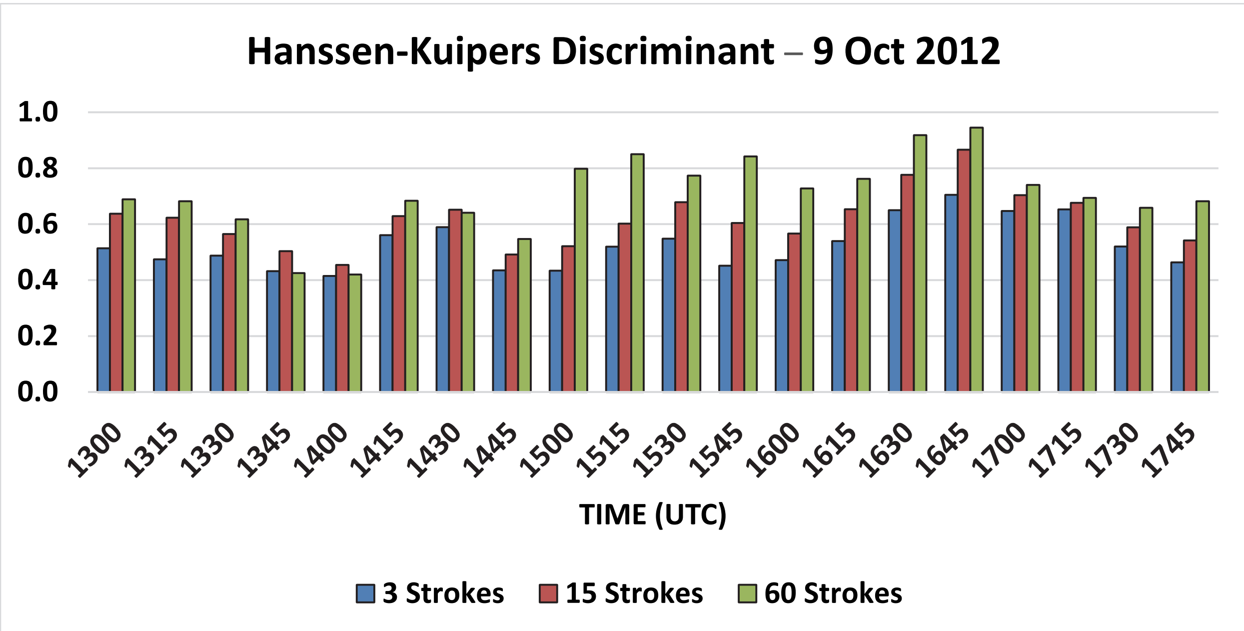

Figure 3.10 As in Figure 3.8, but from 1300 to 1800 UTC on 09 October 2012

The HK for moderate to intense lightning was generally above 0.55 in the second half of the day (after 1400 UTC). The RDT corresponded best with the intense lightning (green).

3.2.3 Case 3: 17 October 2012

On 17 October 2012, two significant storm systems were present over the country. One of the systems was a large storm that produced large hail over Sun City at about 1615 UTC, while the other system was a squall line that extended through KZN and produced very strong winds which persisted until the early evening. The occurrences of these two convective systems were were selected to validate the RDT product on this particular case day. Comparing the RDT image for 1615 UTC to the radar image for the same time step over the Gauteng region (Figure 3.11), there was a good correlation between the indicated mature and growing storms and the locations of the most intense areas of radar reflectivity. The lightning occurences also correlated well with the RDT polygons.

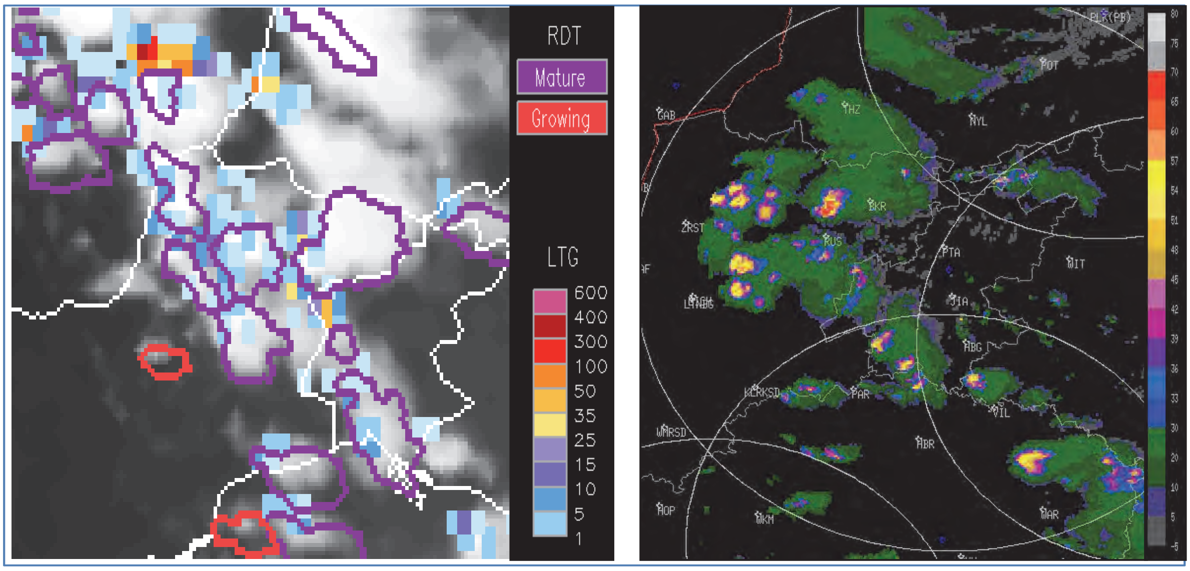

Figure 3.11 As in Figure 3.6 but for 17 October 2012 at 1615 UTC over the North West and Gauteng Provinces

Figure 3.12 depitcs the squall line at 1615 UTC over KZN for 17 October 2012. The RDT classified a number of mature storms which corresponded well with the strong radar reflectivity values (where radar signatures were available), and these storms also corresponded very well with the location of the highest incidence of lightning . There was one exception to the good performance of the RDT; a large mature storm that was indicated in the RDT image (indicated by the arrow), corresponded to an area with low radar reflectivity values and almost no lightning occurrences.

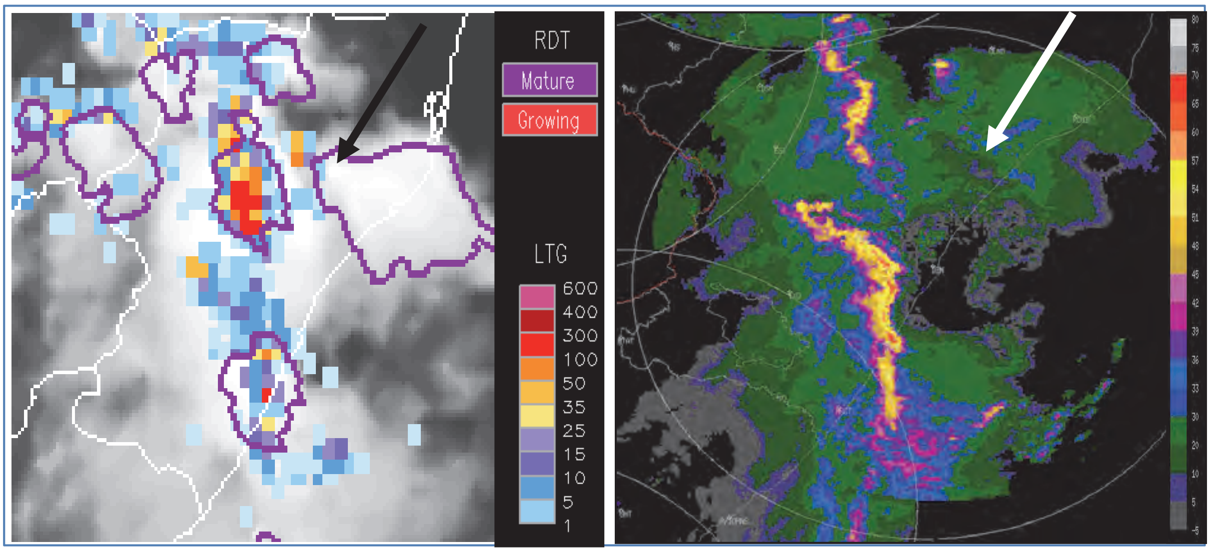

Figure 3.12 As in Figure 3.11 but for 1615 UTC over KZN

The total amount of lightning which occurred within the storm polygons tended to be above 60% for moderate to intense lightning. During the latter part of the day (after 1600 UTC), >80% of the more intense lightning occurred inside the RDT polygons (Figure 3.13).

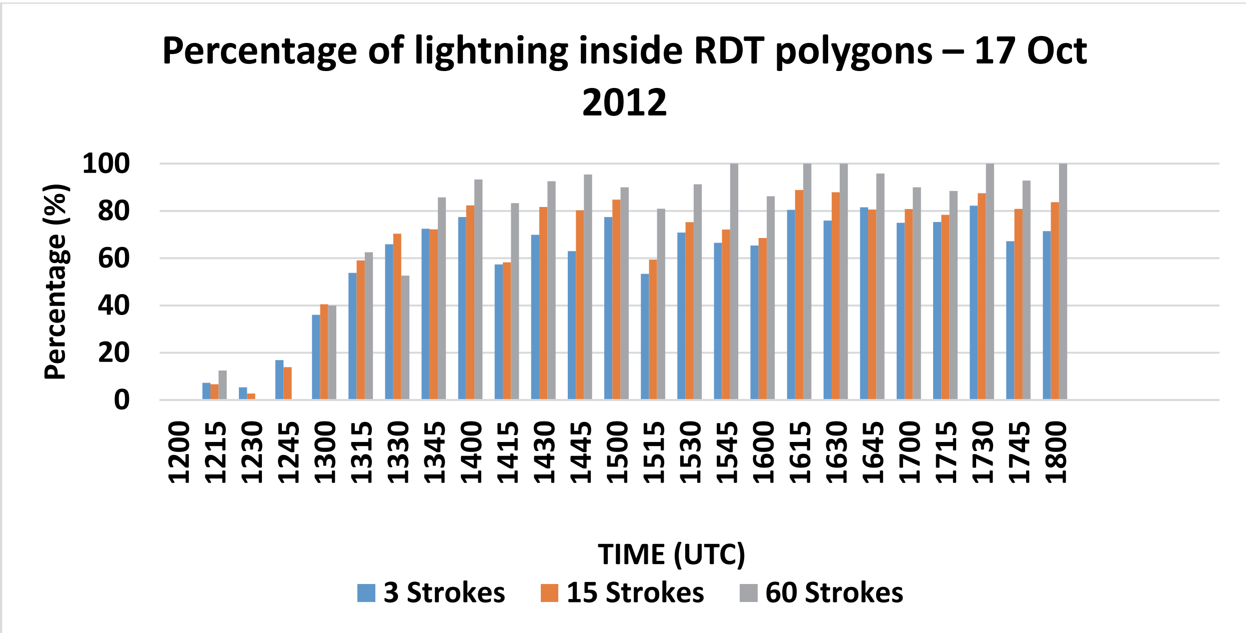

Figure 3.13 As in Figure 3.7 but for 17 October 2012

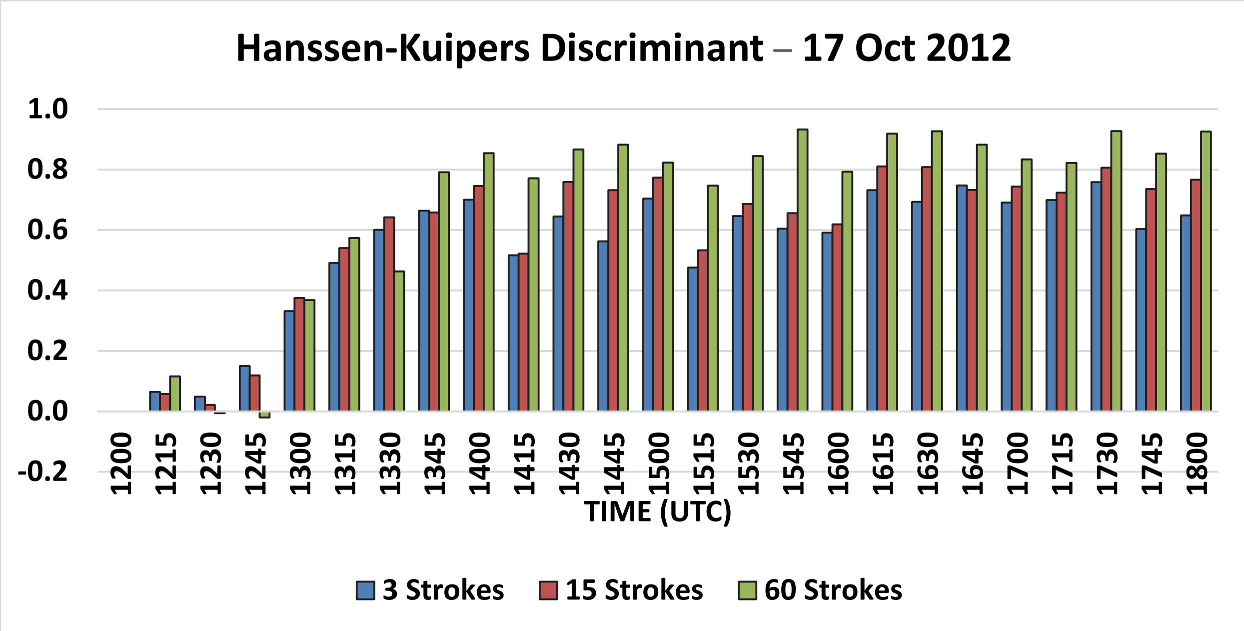

Figure 3.14 As in Figure 3.8 but for 17 October 2012

The HK for moderate to intense lightning (Figure 3.14) was above 0.6 for a large part of the day. These scores, in conjunction with the visual comparisons, indicate that the RDT performed well.

3.2.4 Case 4: 08 November 2012

On 08 November 2012, a trough system, associated with a cold front, created a convergence line that encouraged storm development from the early hours of the morning. Some of the storms that developed later in the morning, produced hail (3 cm in diameter) over Bapsfontein and all aircraft at OR Tambo International Airport were grounded due to intense wind. These storms passed over Gauteng Province from about 0900 UTC. There were storms for the duration of the day, with many of them merging into one bigger storm towards the end of the evaluation time. Towards the end of the period the lightning occurrence was mostly over Limpopo, Botswana and Zimbabwe and fell outside the RDT polygons.

When comparing the RDT image against the radar image at 1300 UTC (Figure 3.15), it is observed that the mature storm northwest of Gauteng coincided with the most intense convective cells within the radar imagery and also the highest number of lightning occurrences. Convective signatures were captured from the Irene and Ermelo radars where more intense reflectivity values as well as moderate amounts of lightning were indicated along the Limpopo/Mpumalanga provincial border. The RDT did not idemtify any storms for this area. The Hanssen-Kuiper discriminant (Figure 3.16) indicated high values for moderate to intense lightning for a large part of the specific time window.

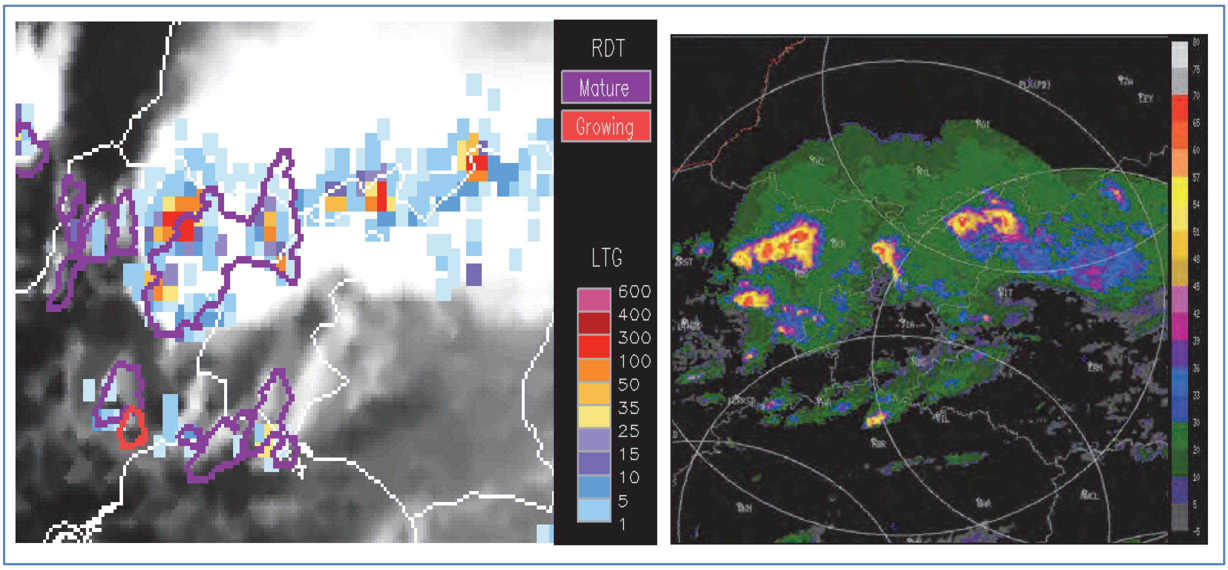

Figure 3.15 As in Figure 3.6 but for 08 November 2012 at 1300 UTC over North West, Gauteng and Mpumalanga Provinces

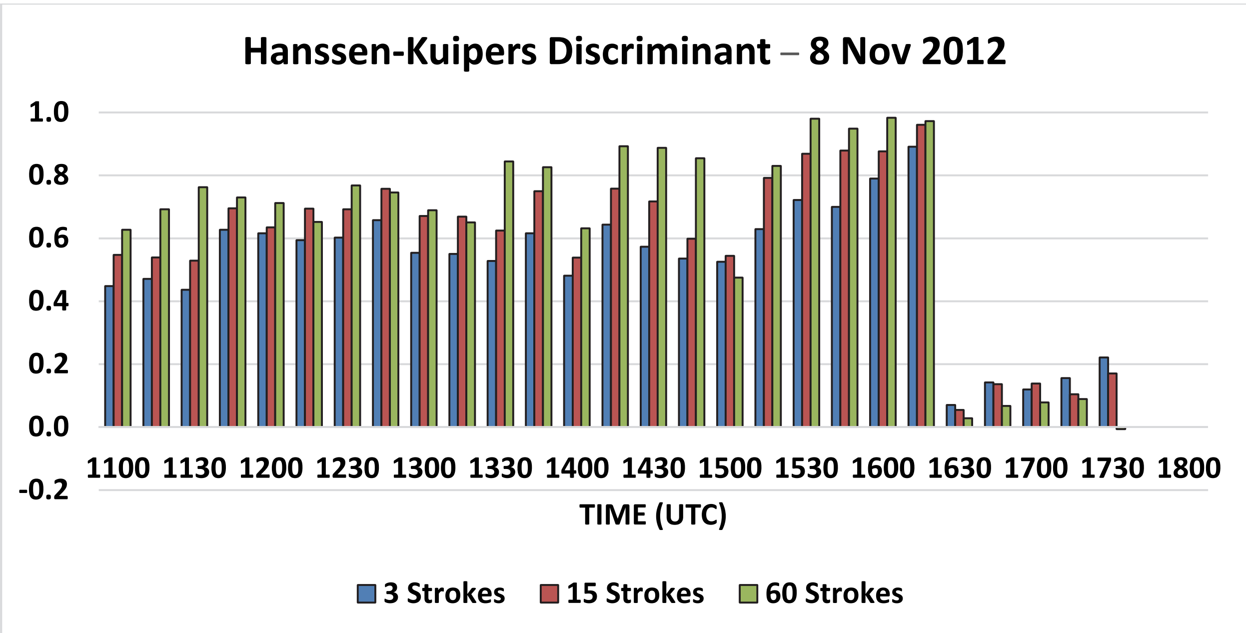

Figure 3.16 As in Figure 3.8 but for 08 November 2012

3.2.5 Case 5: 10 December 2012

On 10 December 2012, there was a cut-off low present over the country with a cold front ahead of it at the surface. These systems affected the country for three days, from 9 to 11 December, and as such there was very heavy rainfall that resulted in floods, leaving at least 10 people dead and many others homeless (NATDIS, 2012). Figure 3.17 shows that there was an extensive cloud shield associated with the cut-off low system over the central parts of South Africa, with many high-level cirrus clouds. The areas with moderate to intense lightning activities were captured within the RDT polygons.

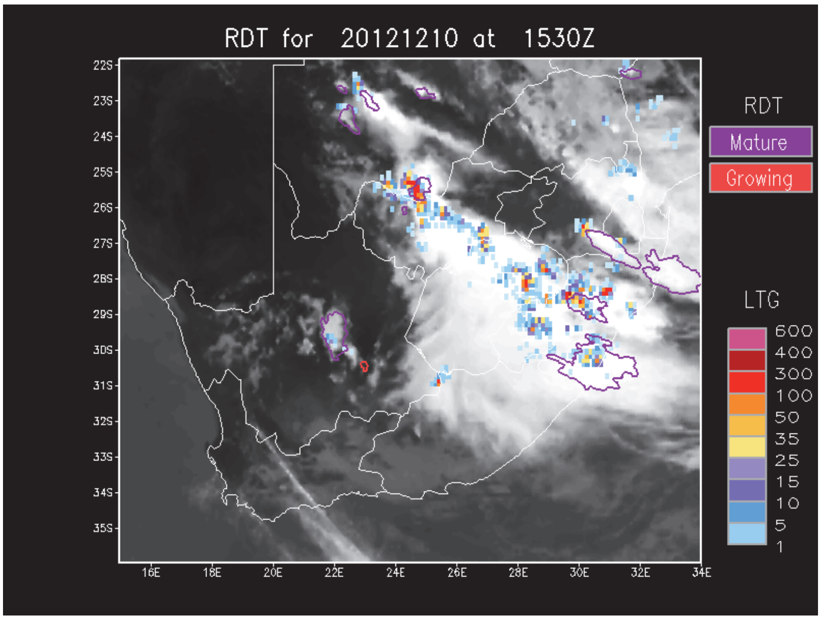

Figure 3.17 RDT image with lightning overlay for 10 December 2012 at 1530 UTC

Taking a closer look at the storm on the northern end of the cut-off low cloud system (indicated by the circle in Figure 3.18), the RDT identified a mature storm in an area where a high incidence of lightning occurred as well as high radar reflectivity values. However, even though high reflectivity values south-west of Gauteng could be detected on the radar, which also corresponded with lightning activity (indicated by the arrows), the RDT did not identify a storm for that area.

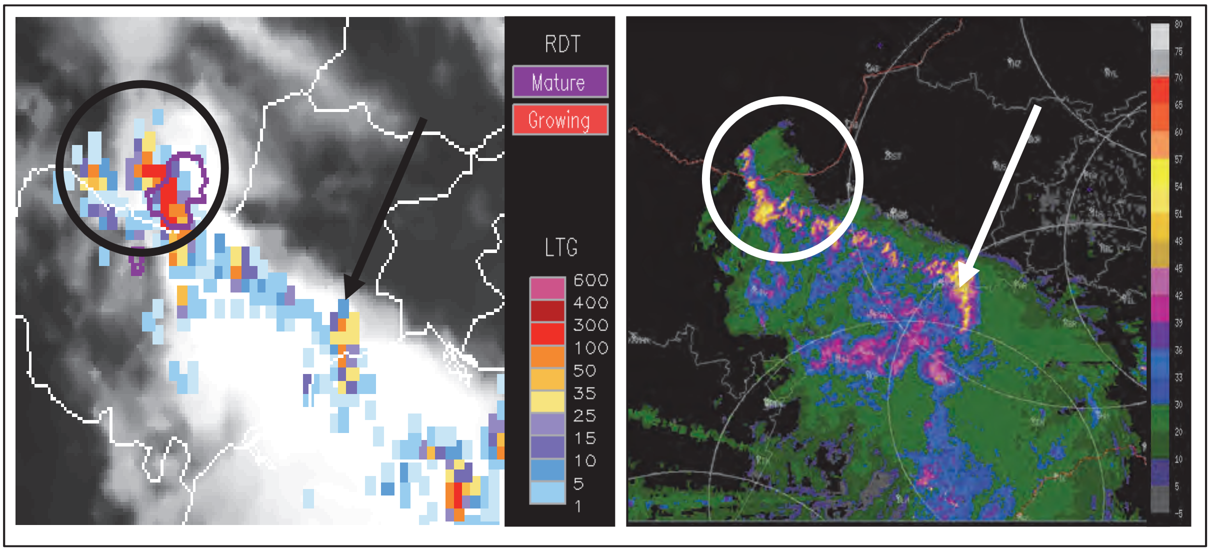

Figure 3.18 As in Figure 3.6 but for 10 December 2012 at 1530 UTC over the North West, Free State and Gauteng Provinces

The percentage of lightning captured inside the RDT polygons was around 60% , but reached 70-80% for moderate to intense lightning at some time intervals (Figure 3.19). The HK remained above 0.6, with moderate and intense lightning reaching values of up to 0.8 (Figure 3.20) for some time intervals.

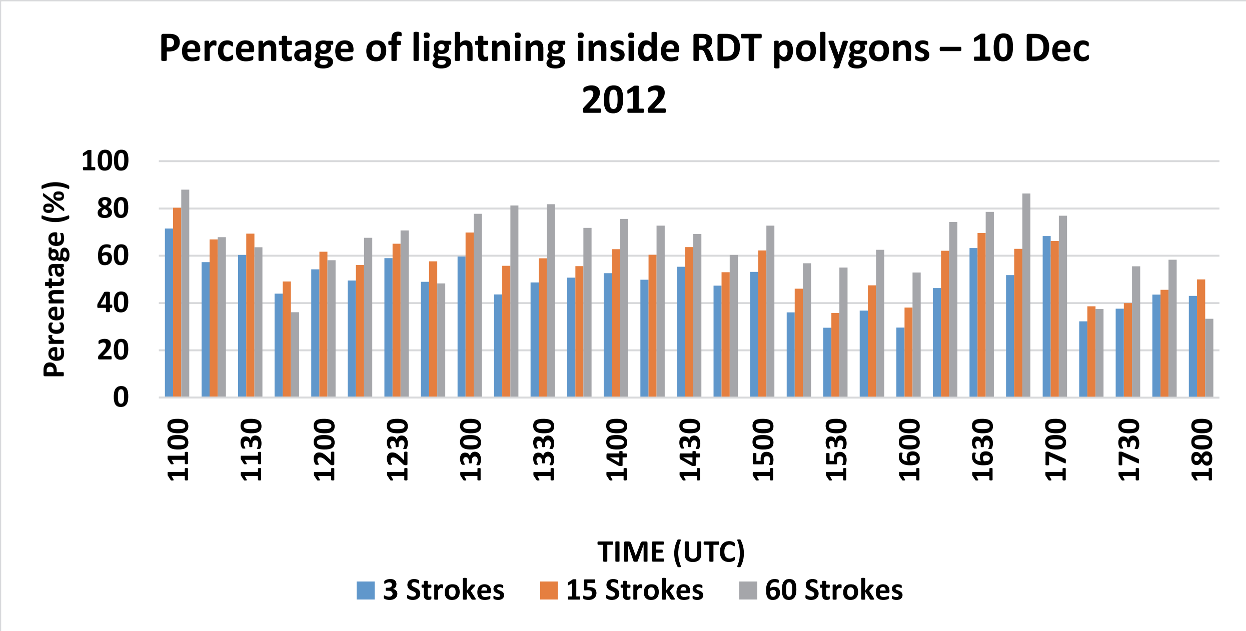

Figure 3.19 As in Figure 3.7 but for 10 December 2012

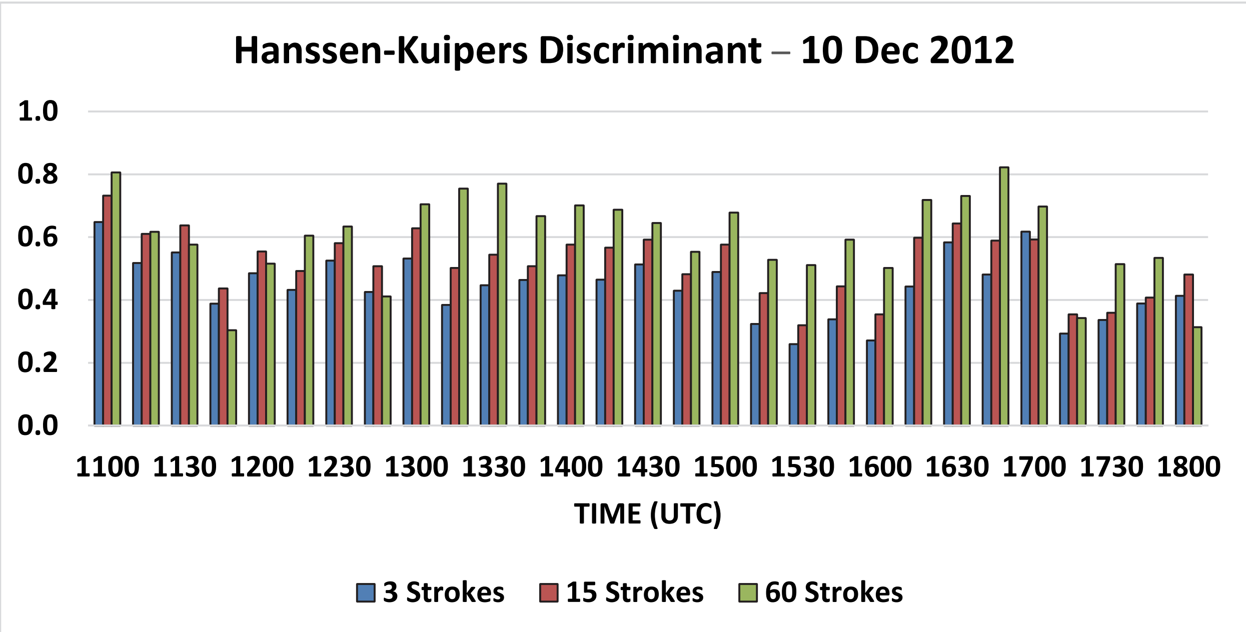

Figure 3.20 As in Figure 3.8 but for 10 December 2012

3.2.6 Case 6: 20 October 2012

On 20 October 2012, a surface trough was positioned over the northern parts of the country associated with an upper-air cut-off low over the western parts of the country. Heavy falls occurred in places over the Western and Eastern Cape, KZN, Mpumalanga and the Free State. (Daily Weather Bulletin, October 2012). The NATural DISasters News (NATDIS, 2012) reported that a heavy rainfall event impacted the south-eastern region of South Africa and left eight people dead and caused damage to property. The heavy rain began on Friday (19 October 2012), resulting in over a thousand people being evacuated from their homes and businesses. SAPA (2012a) reported that Gauteng experienced rain accompanied by large hail for about five minutes on 20 October between 14:00 and

15:00 SA local time. The hail appeared to have been heaviest in Edenvale, Midrand, Germiston, Boksburg and Benoni.

In Figure 3.21 the RDT tracks are compared to the Convection Red-Green-Blue (RGB) product at 1200 UTC on 20 October 2012. Using the ConvRGB, deep, precipitation clouds with strong updrafts and small ice particles are indicated in bright yellow colours (Kerkmann, 2005). In this case, the ConvRGB shows convective clouds (bright yellow) over Gauteng, Free State and KZN (circled areas) and the RDT also identified mature and growing storms in this region. Rainfall in the Eastern Cape was more stratiform in nature (reddish colour) and thus not indicated (detected) by the RDT.

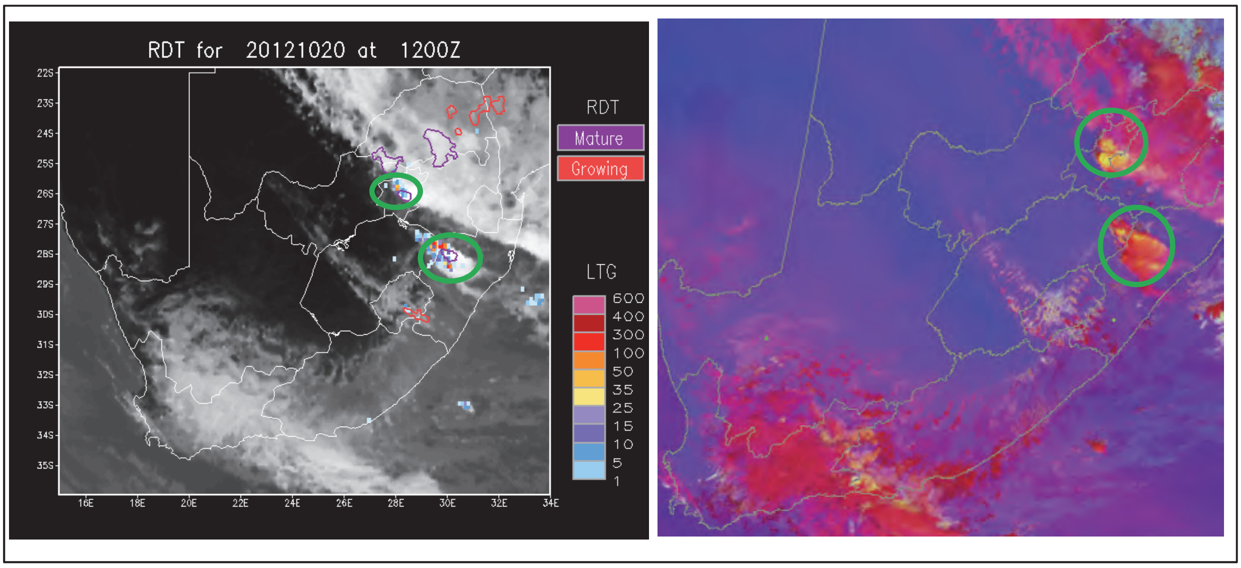

Figure 3.21 RDT image (left) and ConvRGB image (right) for 20 October 2012 at 1200 UTC

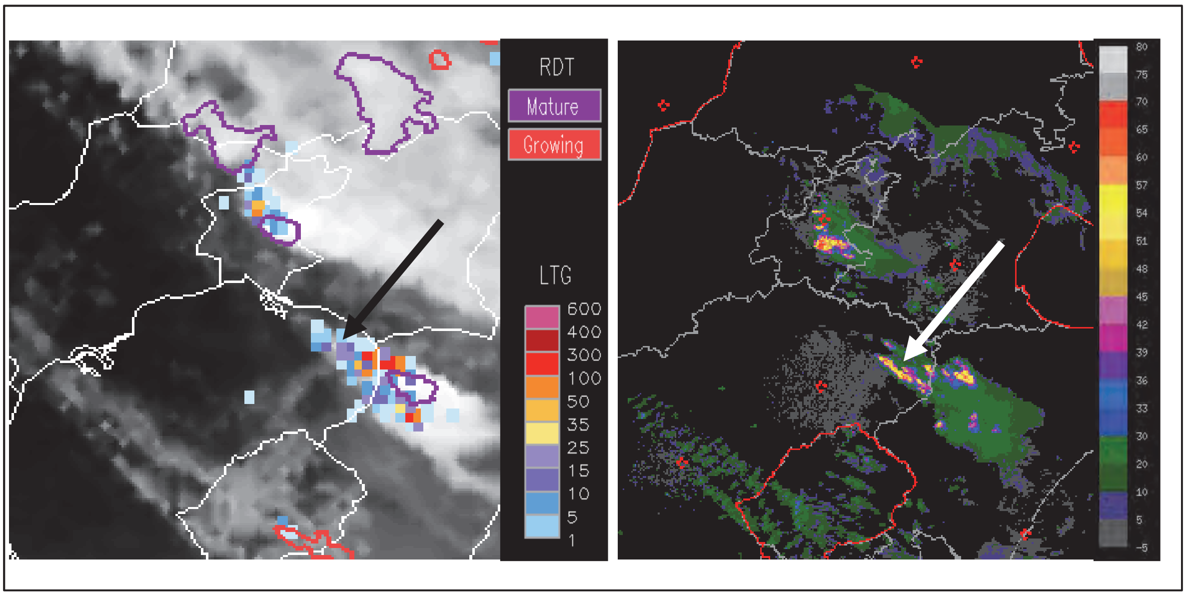

Figure 3.22 As in Figure 3.6 but for 20 October 2012 at 1200 UTC

Figure 3.22 shows that the severe parts of the storm as indicated on the ConvRGB image (Figure 3.21) had a high incidence of lightning as well as high radar reflectivity values (>50 dBz). The RDT detected the most severe part of the storms in Gauteng and KZN, but not the part in the Free State (indicated by the arrow).

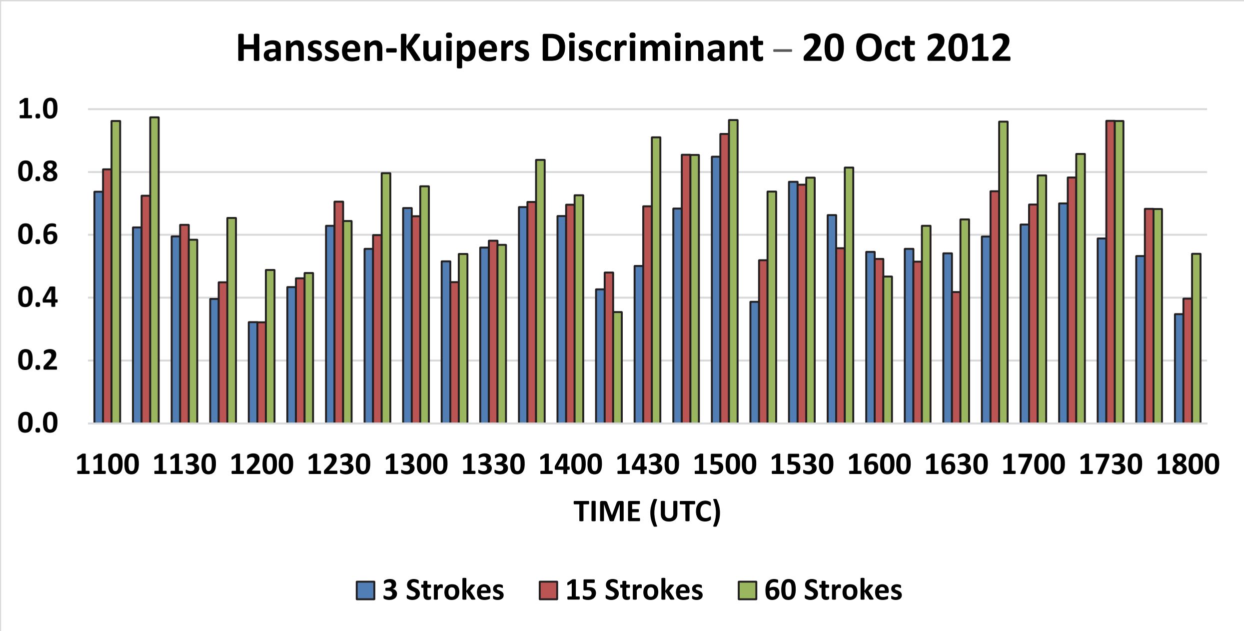

Figure 3.23 As in Figure 3.8 but for 20 October 2012

Figure 3.23 shows that the HK was above 0.6 in many time intervals, even reaching values of up to 0.9 in some time intervals.

3.2.7 Case 7: 09 November 2012

On 09 November 2012, a surface trough extended from the northern parts of Namibia to a low-pressure system over the central interior (Daily Weather Bulletin, November 2012).

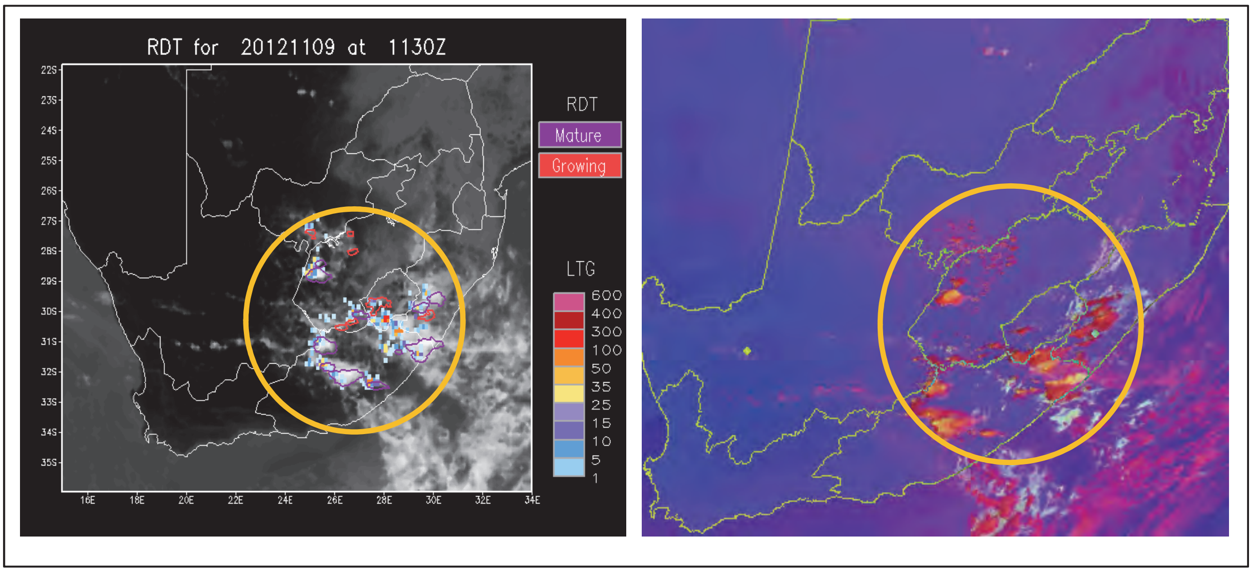

Figure 3.24 As in Figure 3.21 but for 09 November 2012 at 1130 UTC

The images given in Figure 3.24 show that the RDT identified growing and mature storms over the south-eastern parts of the country at 1130 UTC. The ConvRGB is also indicating possible severe convective activity (bright yellow areas) where mature storms were identified by the RDT and bright red areas (clouds with large ice particles) where the RDT identified growing storms.

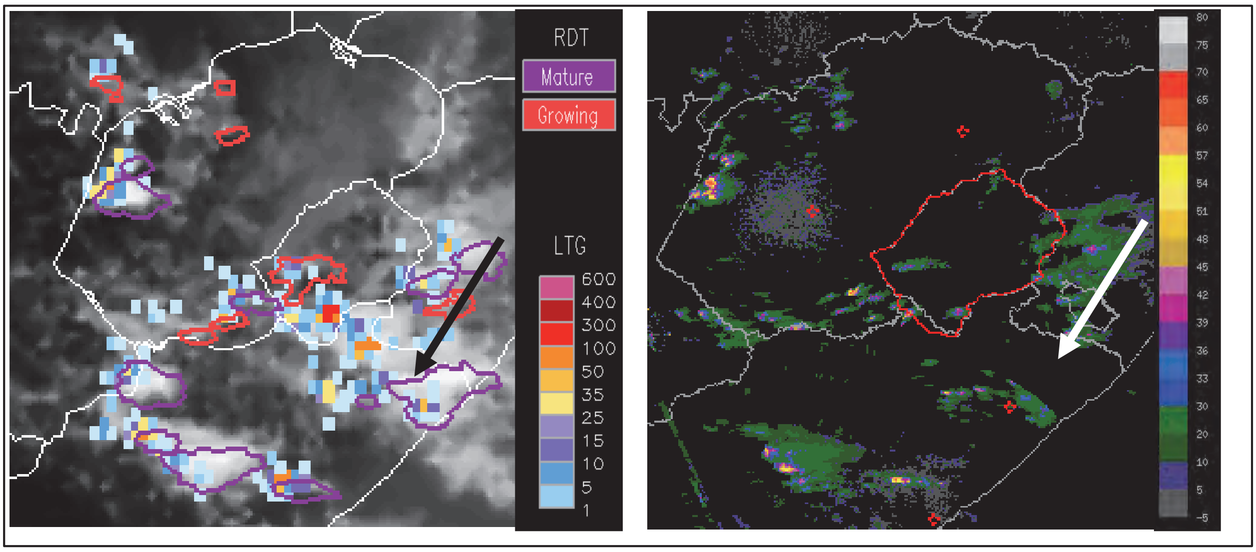

Figure 3.25 As in Figure 3.6 but for 09 November 2012 at 1130 UTC

All the polygons depicted on the RDT image (Figure 3.25, left) were associated with lightning. The radar image (Figure 3.25, right) is indicating storm over the same area as the RDT polygons, with the mature storms (purple) corresponding to the high reflectivity storms in the Free State and Eastern Cape. Over the north-eastern corner of Eastern Cape (indicated by the arrow) the RDT identified a mature storm with lightning, and this area also corresponds to the bright yellow areas in Figure 3.24. However, no radar reflectivity is indicated due to no radar coverage in that area. This observation illustrates the benefit of using the RDT product in areas where radar systems are not operational or where there is no radar coverage.

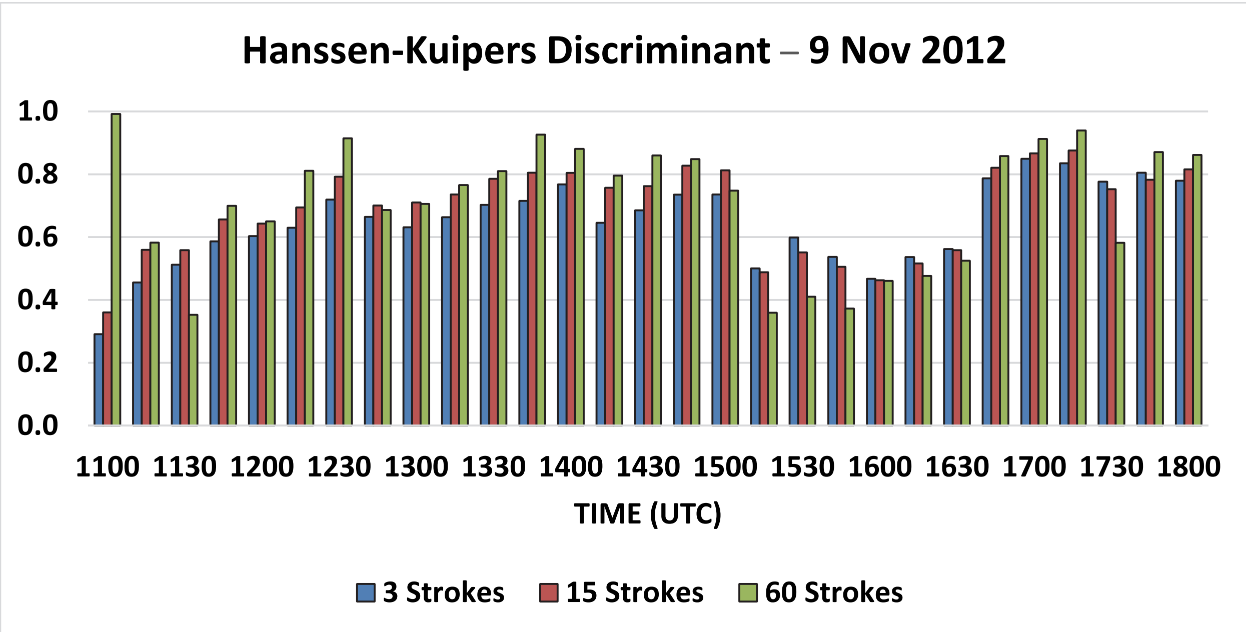

Figure 3.26 As in Figure 3.8 but for 09 November 2012

The statistical scores (Figure 3.26) decpict generally high HKs (around 0.7-0.8) indicating a good performance of the RDT.

3.2.8 Case 8: 31 December 2011

On the 31 December 2011, a surface trough was situated over the central interior and with a high-pressure system east of the country. Showers and thundershowers occurred over the eastern half of the country (Daily weather bulletin, December 2011). Two people were reported dead and three missing after the storms in the Midlands of KZN. Many homes in Mooi Rivier, Umsinga, and Umvoti were badly damaged (SAWDOS, 2012).

The ConvRGB image at 1215 UTC (Figure 3.27, right) is showing convective activity over the eastern part of the country. The RDT (Figure 3.26, left) identified mature storms over the same area. Over the North West Province growing storms were identified by the RDT product, which coincided with the less severe convective storms (indicated in bright red) in the ConvRGB image (indicated by arrows). The HK (Figure 3.28) was generally above 0.6 up to 0.85.

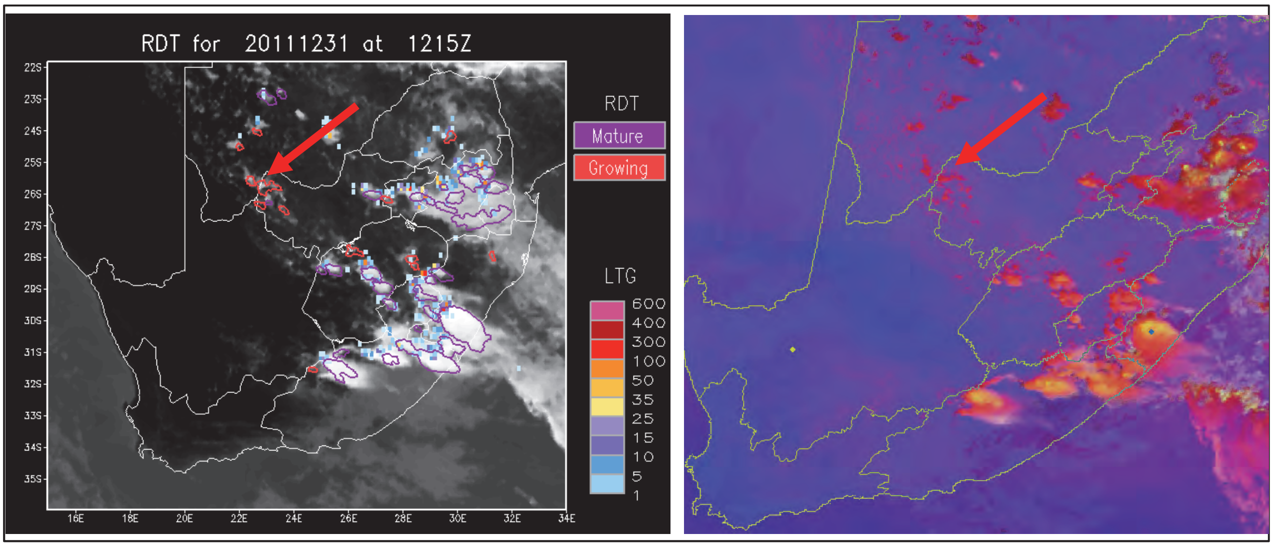

Figure 3.27 As in Figure 3.21 but for 31 December 2011 at 1215 UTC

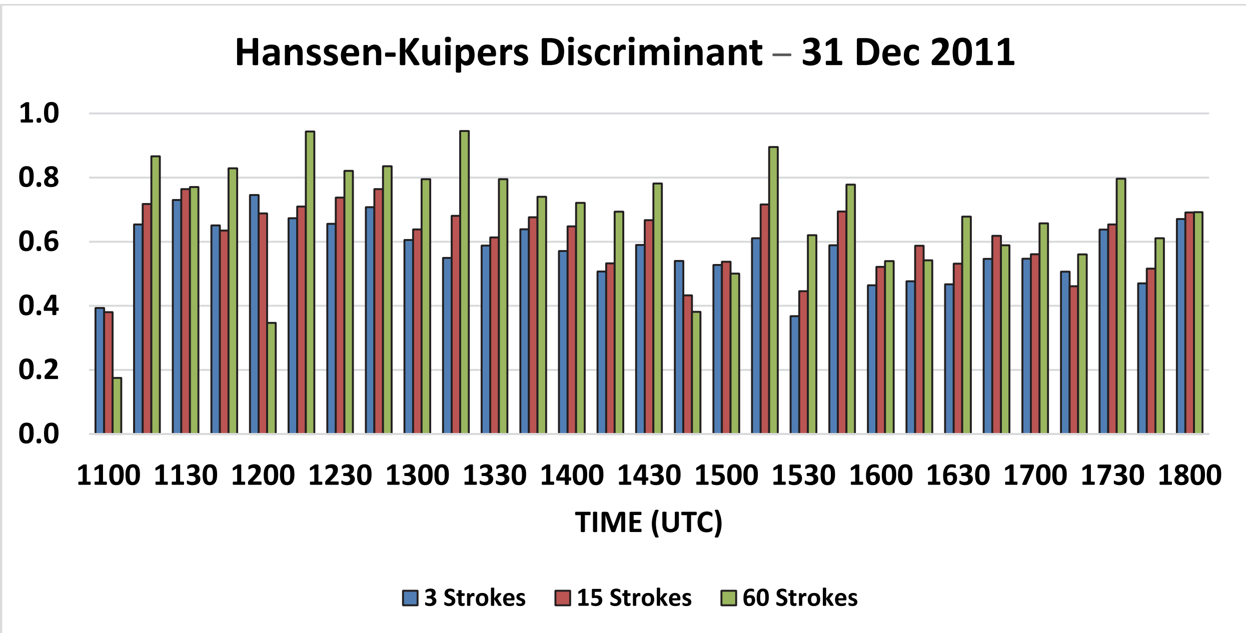

Figure 3.28 As in Figure 3.8 but for 31 December 2011

3.2.9 Case 9: 19 January 2013

Between 06 and 21 January 2013, a tropical low-pressure system formed and affected various southern African countries. Significant floods occurred due to the system being quasi-stationary, which meant that areas were subjected to heavy rainfall for prolonged periods of time (SAPA, 2013a). Heavy rains continued to fall across most parts of the country on 19 January (SAPA, 2013b). A closed upper level low-pressure system as well as a surface low-pressure system were located over Botswana extending to the north-eastern parts of the country, increasing chances of heavy rainfall over those areas. A surface high-pressure system was located south-east of the country, contributing to the moisture over the eastern parts of the country.

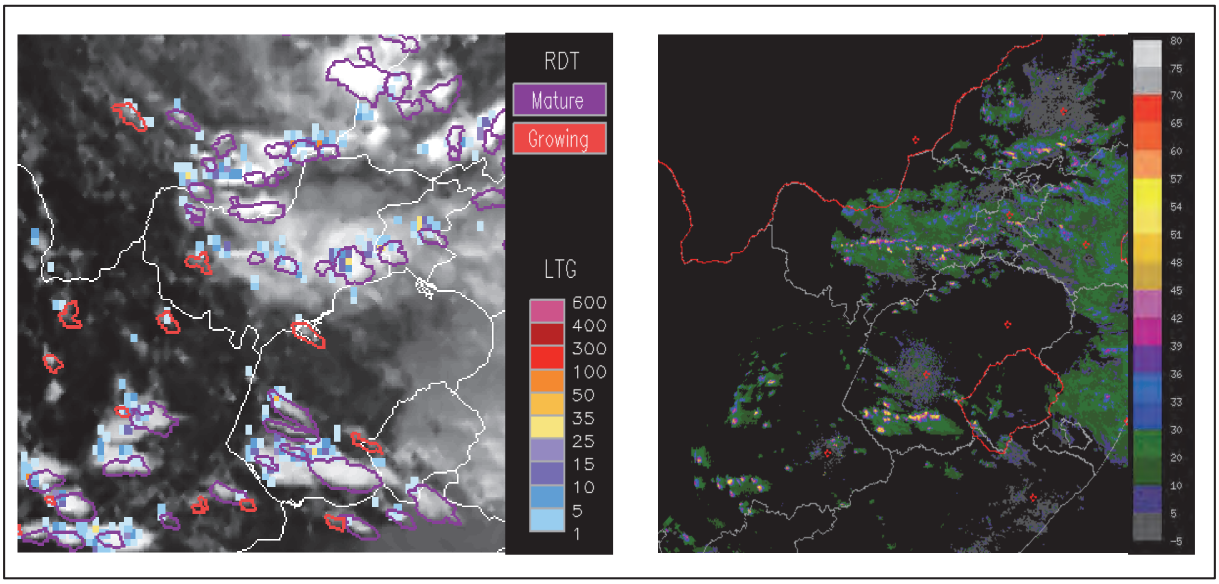

Figure 3.29 As in Figure 3.6 but for 19 January 2013 at 1200 UTC

The RDT product identified mature and growing storms over a large area, which also corresponded with the higher reflectivity values in the radar image (Figure 3.29), especially over the southern Free State.The RDT did not identify any storms over KZN where heavy rainfall was reported, but the radar image shows that only stratiform rainfall occurred in that area (indicated in green colours of lower reflectivity). In Figure 3.30, it is shown that generally more than 60% of the lightning fell inside the RDT polygons, with the intense lightning being the most accurate.

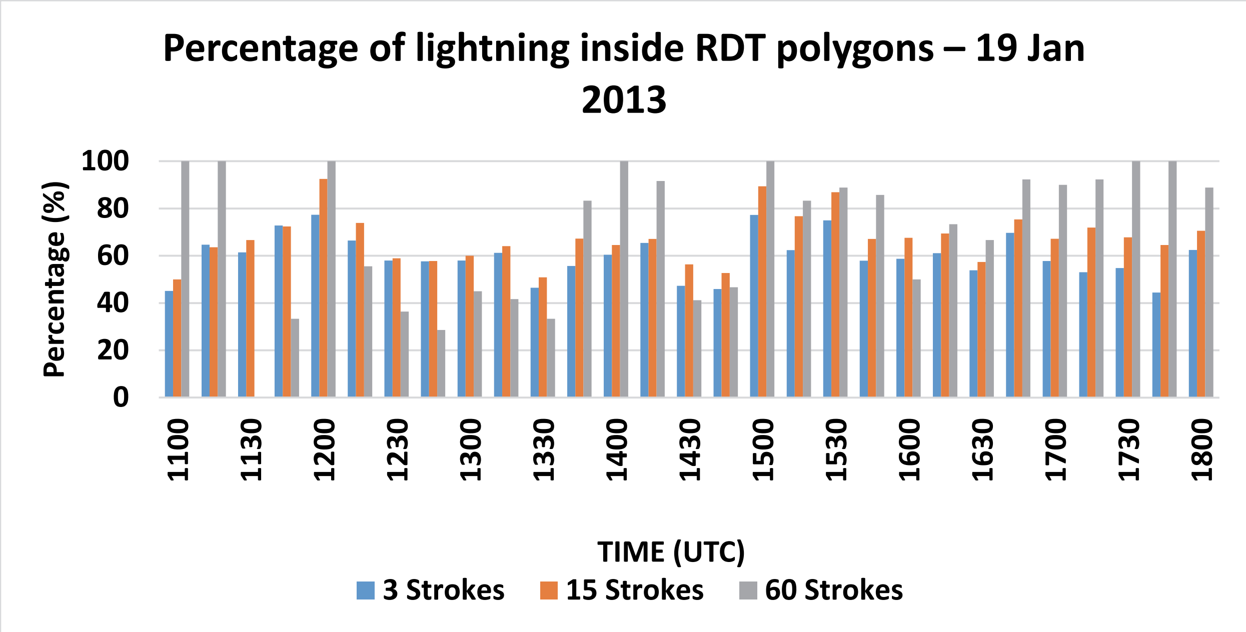

Figure 3.30 As in Figure 3.7 but for 19 January 2013

3.2.10 Case 10: 06 September 2012

On 06 September 2012, a broad surface trough was situated over the country, with upper air cut-off low over the central interior. A high-pressure system was east of the country. Thundershowers as well as heavy rain occurred over almost the entire country, except over the Northern Cape and Western Cape (Daily Weather Bulletin, September 2012).

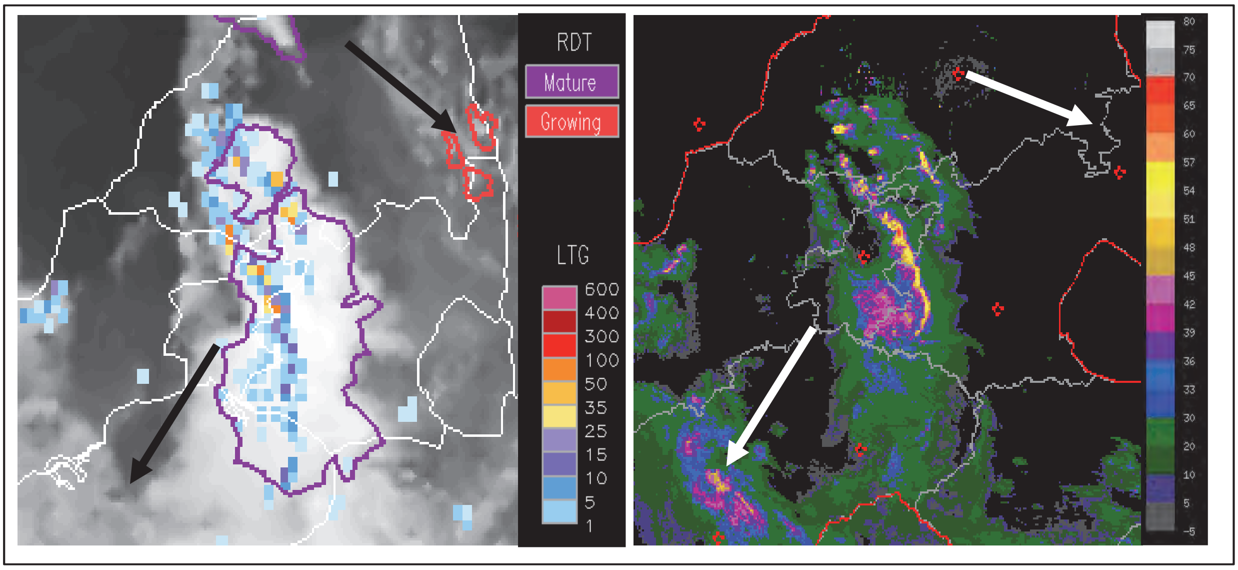

Figure 3.31 As in Figure 3.6 but 06 September 2012 at 1530 UTC

The RDT identified mature and growing storms over parts of Gauteng, Mpumalanga and Limpopo Provinces (Figure 3.31, left). The high reflectivity storm shown on the radar image correlated well with the mature storms depicted by the RDT (Figure 3.31, right). The growing storm depicted by RDT over Limpopo (arrow) is not seen on the radar, but the Polokwane radar was not operational on this day. The storm over the Free State shown on the radar image (arrow) was not identified by the RDT, but there was no lightning in that area. It is possible that the radar reflectivity values were overestimated and that the storm was not as intense as it seemed to be on the radar images.

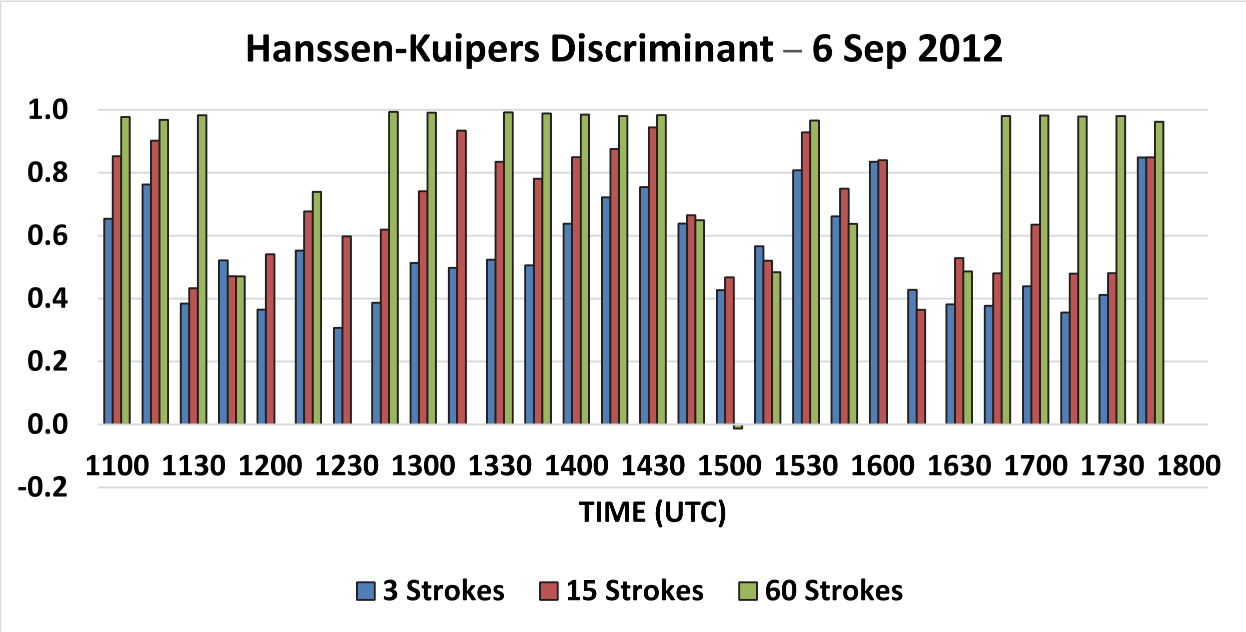

Figure 3.32 As in Figure 3.8, but for 06 September 2012

The HK (Figure 3.32) indicate that the moderate to intense lightning correlated well with the RDT polygons with scores of greater than 0.8 in many time intervals.

3.3 Validation of results over the southern African region

Ten case study dates were selected where UM data as well as raw, archived MSG data were available to test the RDT product in different summer months over the area south of the equator. Validation of the RDT could be done visually using a) MSG images, which are useful in depicting deep convective development and/or convective storms and b) rainfall estimation from the TRMM data set. Lightning data from the World Wide Lightning Location Network (WWLLN) were used to calculate statistical scores. The dates selected for evaluation are indicated in Table 3.4. These cases were selected on the basis of being good convective cases, with elevated convective activity of where a number of large storms were present. For all the cases, the 2012 version of the Nowcasting SAF software was used.

Table 3.4 The ten case-study dates selected for evaluation of the RDT for the southern African region

Case study dates	
3 November 2013	4 December 2013
3 November 2013	3 December 2013
9 November 2013	2 January 2014
0 November 2013	4 January 2014
1 November 2013	0 January 2014

3.3.1 Case 1: 08 November 2013

On 08 November 2013, a trough moved through the SADC region which caused much storm activity over this region (Figure 3.33). Most notably were storms over Zimbabwe and Zambia, which were associated with the trough. Unrelated to the trough was also a cluster of smaller storms that formed over the Democratic Republic of the Congo (DRC). These storms and systems were most notable between 1200 and 1300 UTC.

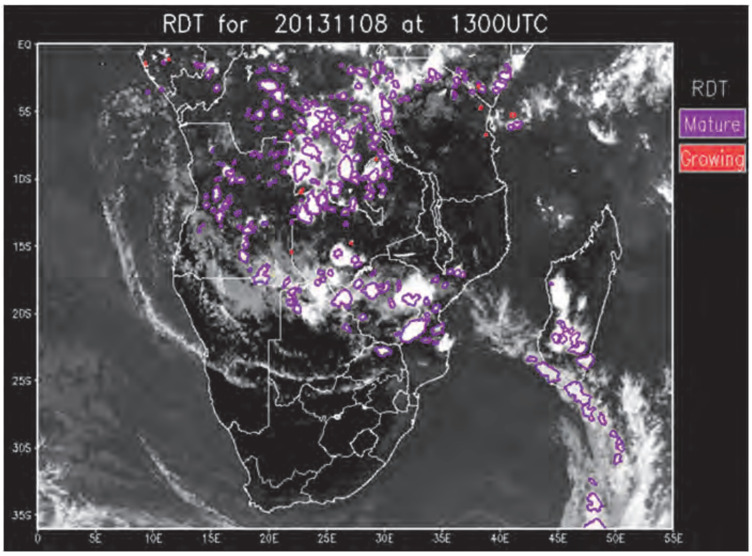

Figure 3.33 RDT image for the SADC region for 08 November 2013 at 1300 UTC

In the HRVRGB image (Figure 3.34, top right), a number of deep convective cells (seen as bright white in the imagery) can be seen with overshooting tops (yellow circle) and these were identified by the RDT (Figure 3.34, top left) as mature storms. In the ConvRGB image, the most convectively active storms (bright yellow) correspond to the storms indicated as mature in the RDT imagery (circled). In the IR10.8 colour-enhanced imagery (Figure 3.43, bottom right), the coldest regions corresponded well with mature RDT cells (circled).

Figure 3.35 shows an example of the RDT product over the SADC domain for 20 November 2013 at 1715 UTC (left) and the lightning data recorded by WWLLN (right-hand image) in the 30 minutes after the RDT time step (1715 to 1745 UTC) on the right. By comparing the RDT product with the WWLLN lightning data that were used for the quantitative evaluation of the RDT product, it is clear that the lightning counts are very low in the 30-minutes following the RDT time step. Since the WWLLN network detects only about 10% of all the lightning that occurred, this comparison gives an indication of the limitations encountered when evaluating the RDT product, and thus also shows why the statistical scores could have been negatively affected.

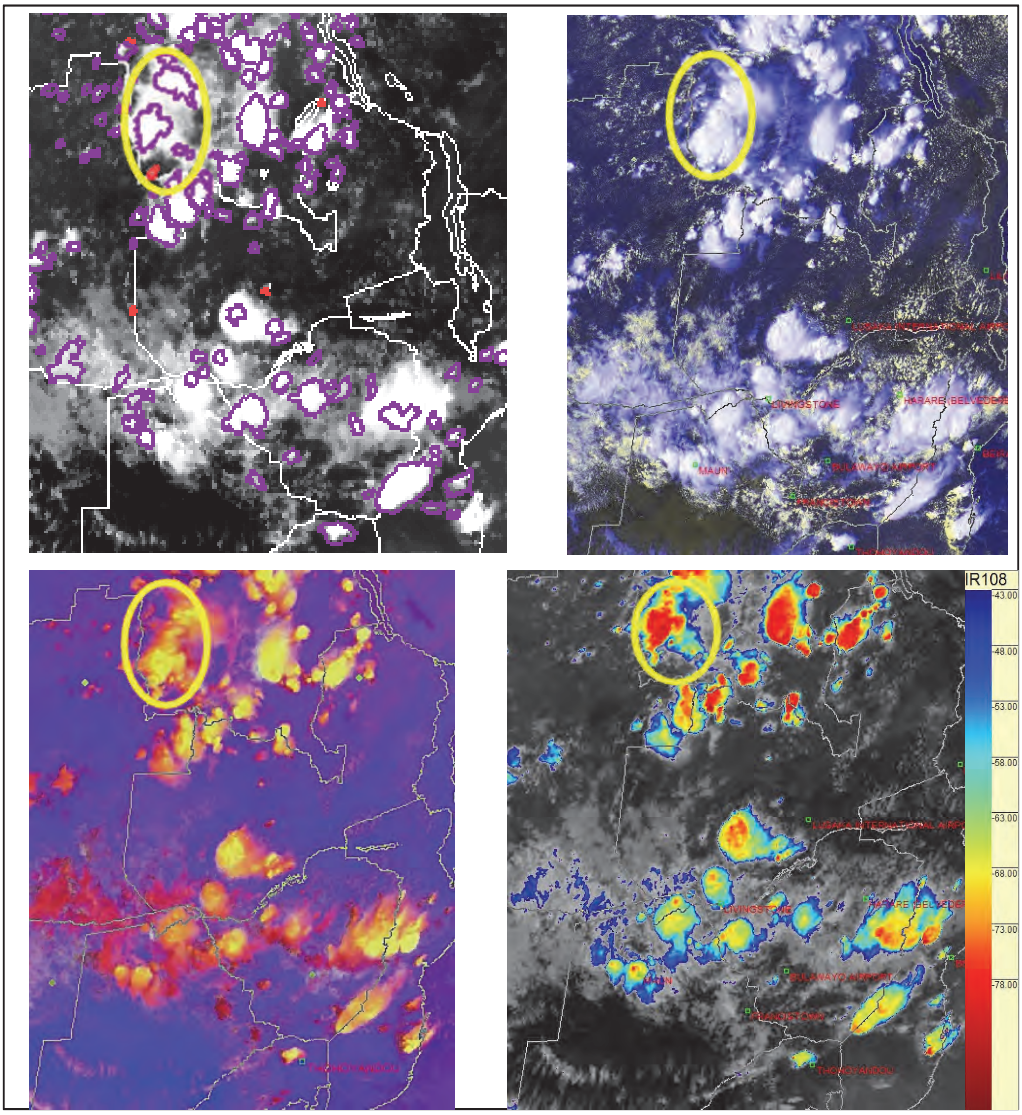

Figure 3.34 Images for RDT (top left), HRVRGB (top right), ConvRGB (bottom left) and IR10.8 clour-enhanced imagery (bottom right) for 08 November 2013 at 1300 UTC

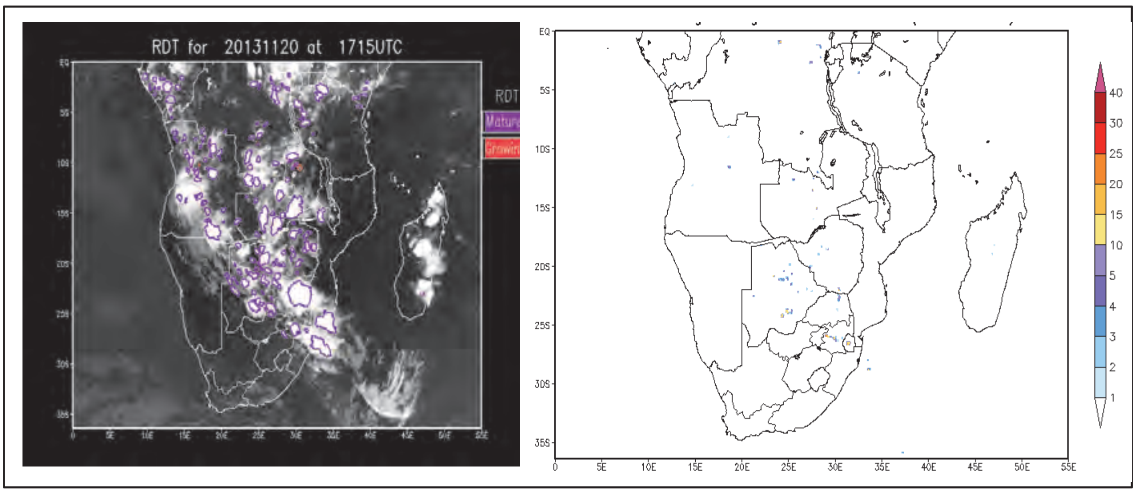

Figure 3.35 The RDT product over SADC on 20 November 2013 at 1715 UTC (left) and the lightning that was recorded by WWLLN on 20 November 2013 between 1715 and 1745 UTC (right)

The average percentage of lightning that fell inside the RDT polygons for this day (Figure 3.36) was 47.75%. The minimum percentage of 35.86% occurred at 1230 UTC and the maximum percentage of 59.21% at 1615 UTC. For this case, the performance of the RDT product improved slightly from 1545 to 1730 UTC, when the percentage of lightning inside the RDT polygons was above 50%.

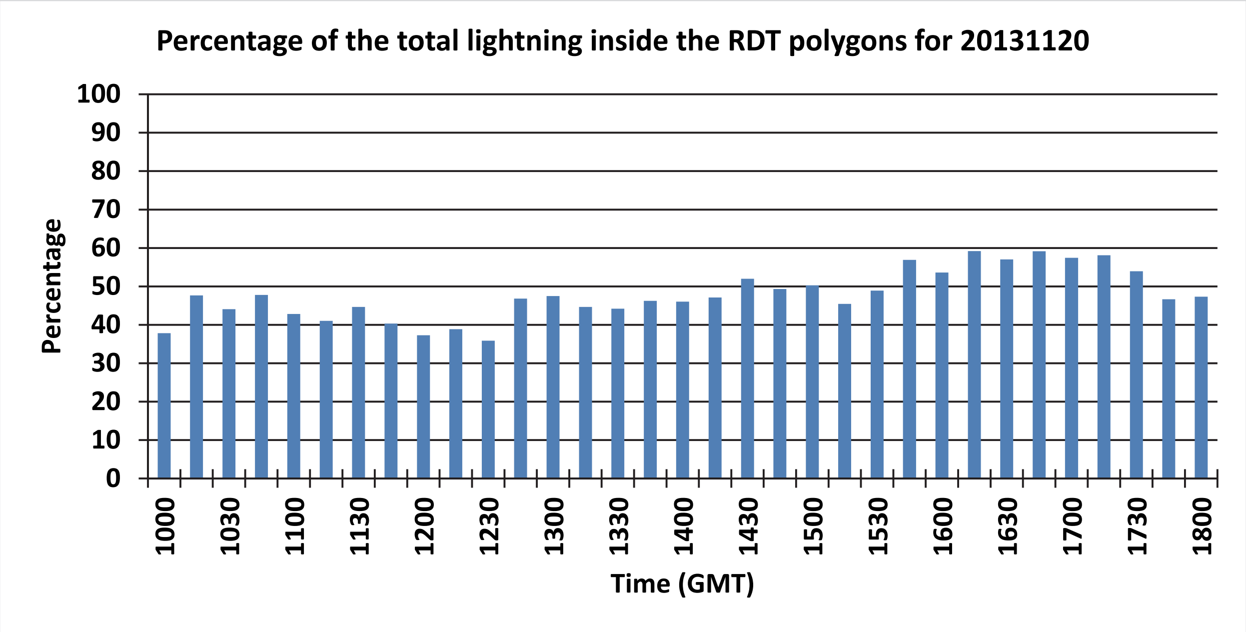

Figure 3.36 The percentage of total lightning that fell inside the RDT polygons in the 30 minutes following the RDT time step for 20 November 2013

Figure 3.37 depicts the statistical scores for 20 November 2013 between 1000 and 1800 UTC. The average POD for the period was 0.609, the average POFD was 0.052 and the average HK was 0.557.

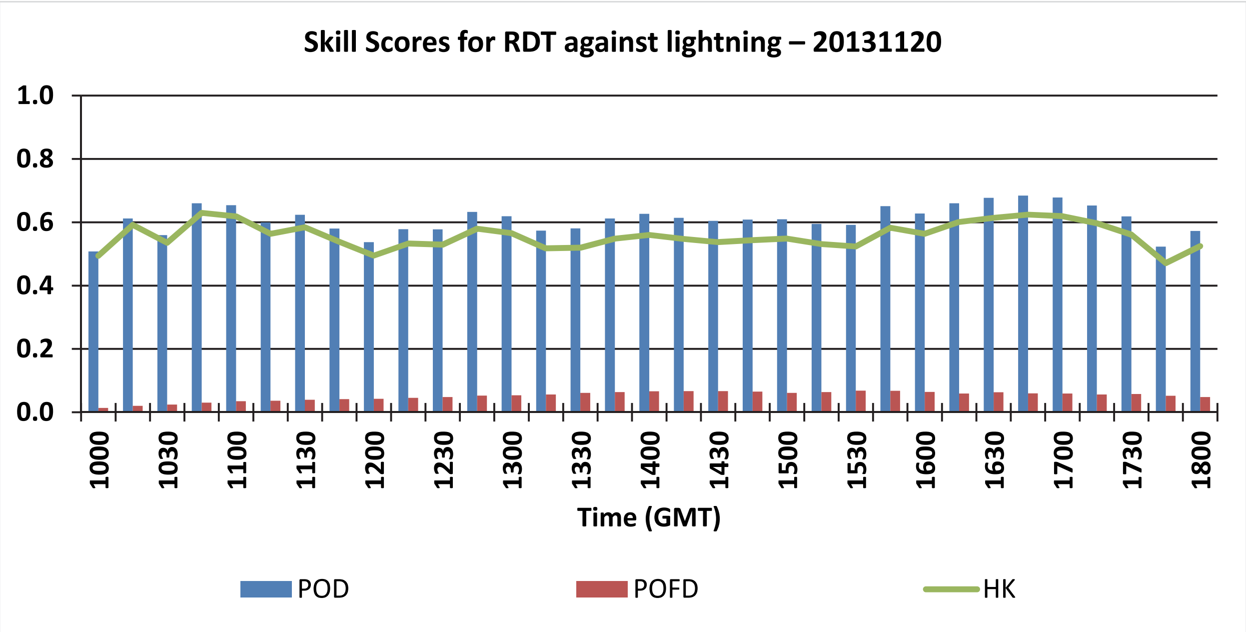

Figure 3.37 POD, POFD and HK for the RDT polygons against lightning in the 30 minutes following the RDT time step for 20 November 2013 between 1000 and 1800 UTC

3.3.2 Case 2: 13 November 2013

On 13 November 2013, a large low-pressure system was situated over the DRC and Angola. This low-pressure system contributed to the development of a large number of storm cells over this area. Many of these storms developed extensive cirrus cloud shields. In the HRVRGB image (Figure 3.38, top right), individual storm cells can be distinguished from the extensive amounts of cirrus clouds (light purple). In the ConvRGB (Figure 3.38, bottom left), the individual storm cells are even easier to identify, as they are predominantly yellow (deep precipitating clouds with strong updrafts), and this means that the most intense areas of the clouds are classified as mature by the RDT. In the IR10.8 colour-enhanced imagery (Figure 3.38, bottom right), the individual cells are clearly discernible, with most of them being categorised as red (very cold) in the imagery. This shows that the most intense and coldest clouds are categorised correctly by the RDT software. However, one storm was not captured by the RDT (as indicated by the arrow in Figure 3.38). Although the HRVRGB would indicate that this was a thick cloud, the ConvRGB and colour-enhanced IR10.8 images do not identify this as a very convective storm or a very cold storm. Thus, the RDT product could have been correct in omitting this storm from classification as growing or mature.

On this day, the average percentage of lightning that fell inside the RDT storm polygons was 50.14%, while the minimum percentage was 37.15% at 1630 UTC and the maximum was 59.2% at 1800 UTC (not shown). These percentages seem quite low, but considering the limitations of the WWLLN network, the results are satisfactory.

The skill scores for 13 November 2013 between 1000 and 1800 UTC (Figure 3.39) show that all POD values were above 0.5. The maximum POD for the day of 0.726 was observed at 1130 UTC, while the lowest POD value of 0.543 was observed at 1630 UTC. The average POD for the day was 0.639. The POFD remained low for the entire period, with an average of 0.049. The HK recorded a minimum value of 0.498 at 1630 UTC and a maximum value of 0.699 at 1015 UTC. Overall, the average HK equated to 0.591.

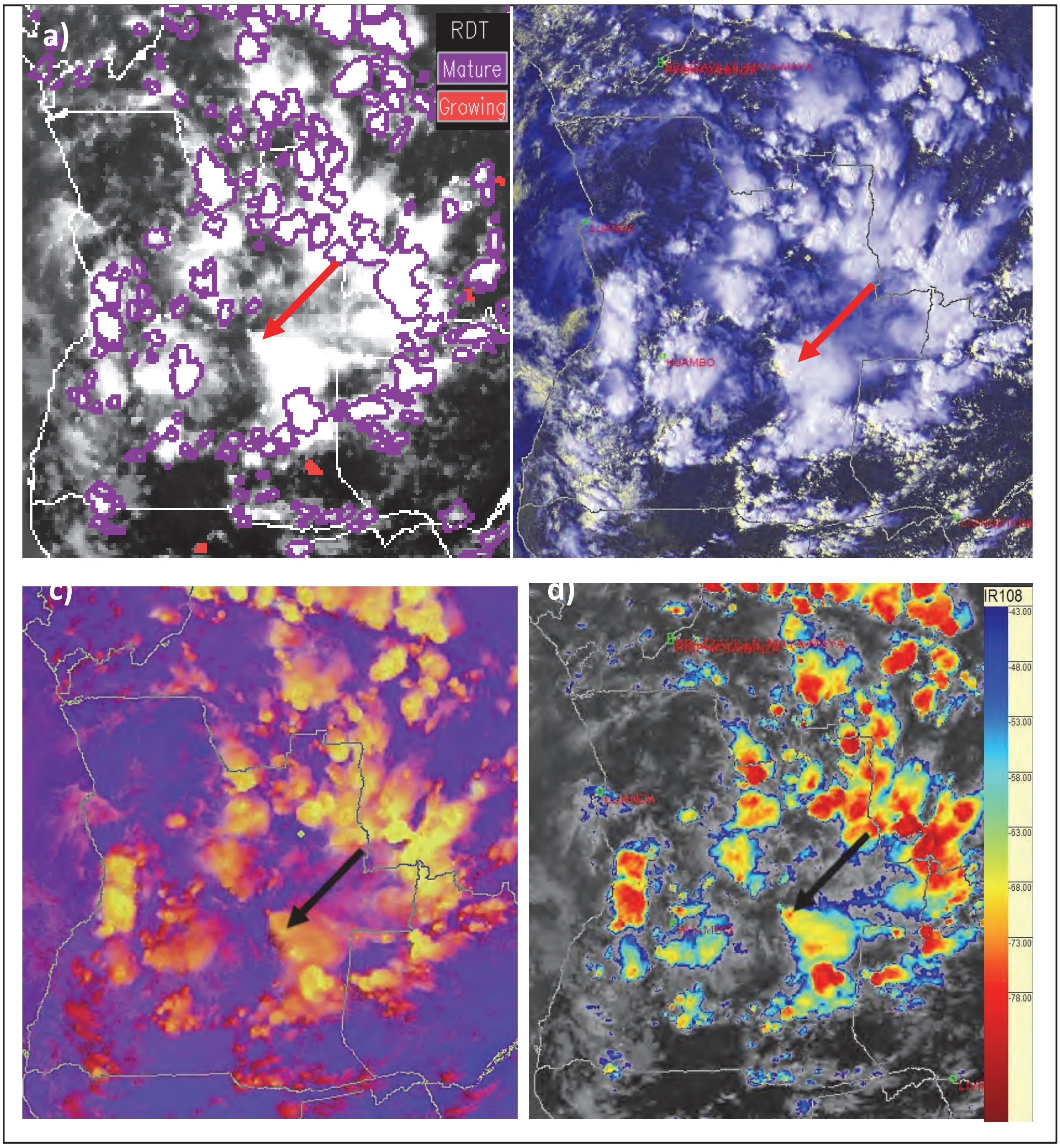

Figure 3.38 As in Figure 3.34 but for 13 November 2013 at 1400 UTC

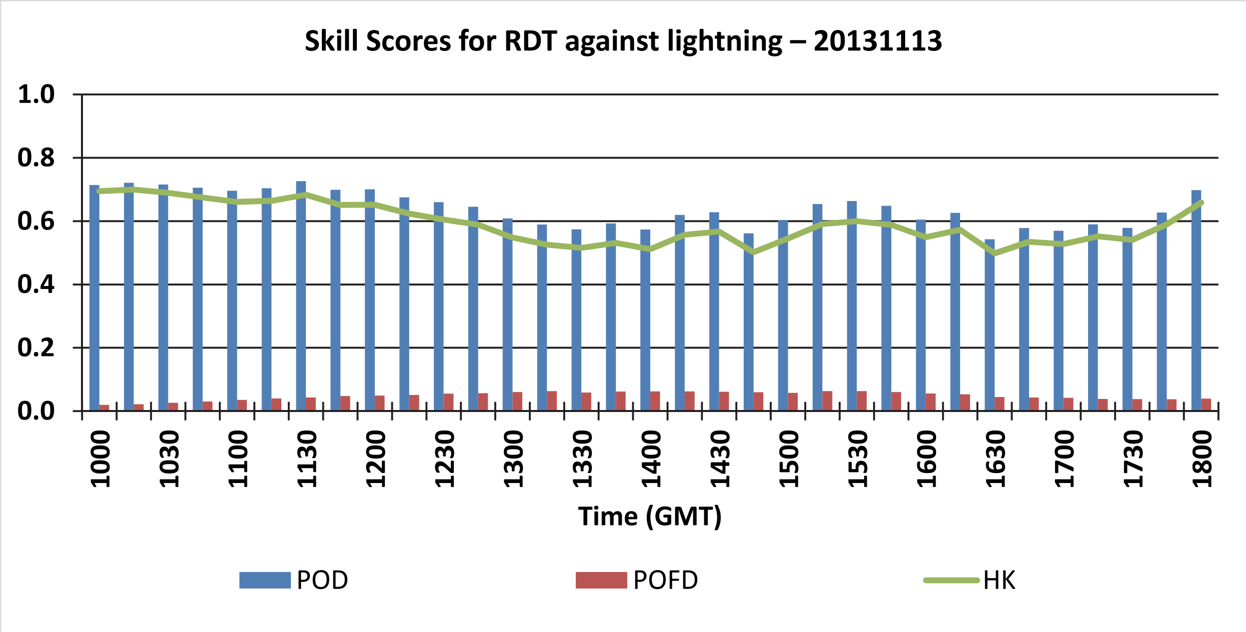

Figure 3.39 As in Figure 3.37 but for 13 November 2013

3.3.3 Case 3: 21 November 2013

An upper air trough passed through the SADC region on 21 November 2013 and, together with the typical heat effects of the tropics, this resulted in large storms over Zambia and Zimbabwe, while multiple small storm cells formed over Angola and a squall line over the DRC.

In the HRVRGB imagery (Figure 3.40 top right), a large cirrus shield (seen as bluish cloud in the imagery) indicates optically thick clouds. The RDT (Figure 3.40, top left) identified only these optically thick areas as mature cells. A number of smaller cells are also present that are all individually classified as mature by the RDT. These are all seen as thick convective cells in the HRVRGB imagery. In the ConvRGB (Figure 3.40, bottom left) imagery, the large yellow storm cells (most convectively active parts of the storms) correspond well with cells that were identified as mature by the RDT. The smaller mature cells also appear as yellow or orange cells in the ConvRGB imagery, and thus are developing storms. In the IR10.8 colour-enhanced imagery (Figure 4.9, bottom right), the coldest regions of cloud (within the cirrus shield) are seen as red in the imagery and these regions correspond well with the cells that were identified as mature by the RDT.

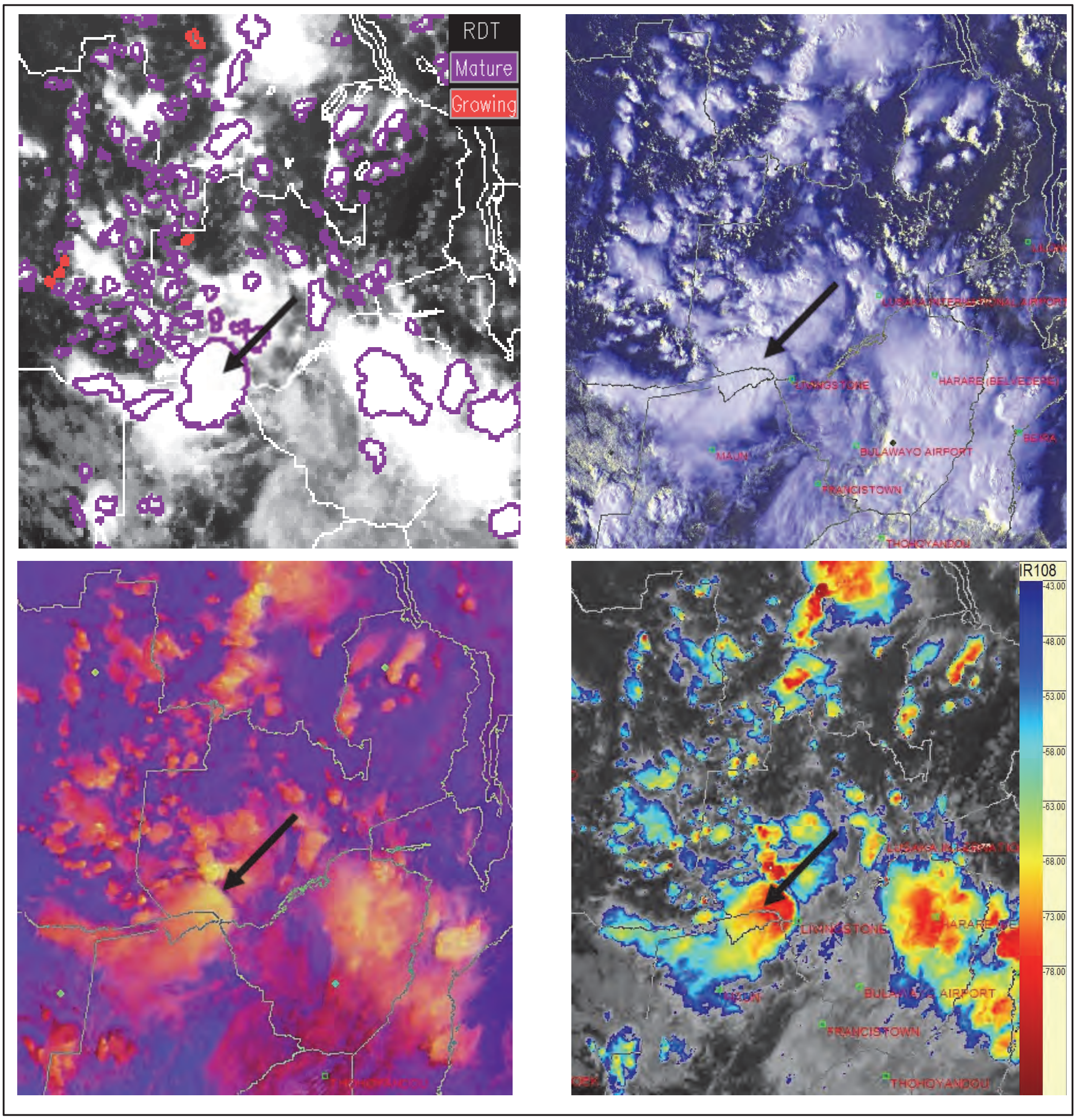

Figure 3.40 As in Figure 3.34 but for 21 November 2013 at 1500 UTC

The percentage of lightning inside the RDT polygons (not shown) indicated that the average percentage of lightning in the RDT storm cells was 51.3% while the maximum value of 59.27% occurred at 1500 UTC.

Figure 3.41 shows the statistics, which were calculated comparing the WWLLN lightning and the RDT product for 21 November 2013 between 1000 and 1800 UTC. At 1000 UTC, no lightning occurred in the RDT polygons, which resulted in the scores having zero values. At 1100 UTC, there was a sharp drop in the performance of the RDT product, which was restored, again in the next time step. This might be due to a problem in the WWLLN data. When the 1000 UTC time is excluded, the minimum POD was 0.269 at 1100 UTC, while the maximum POD of 0.722 was observed at 1115 UTC. The average POD for the entire period was 0.612. The average POFD for the day was 0.046. The average HK for the period was 0.567, while the minimum HK was 0.254 and the maximum 0.691.

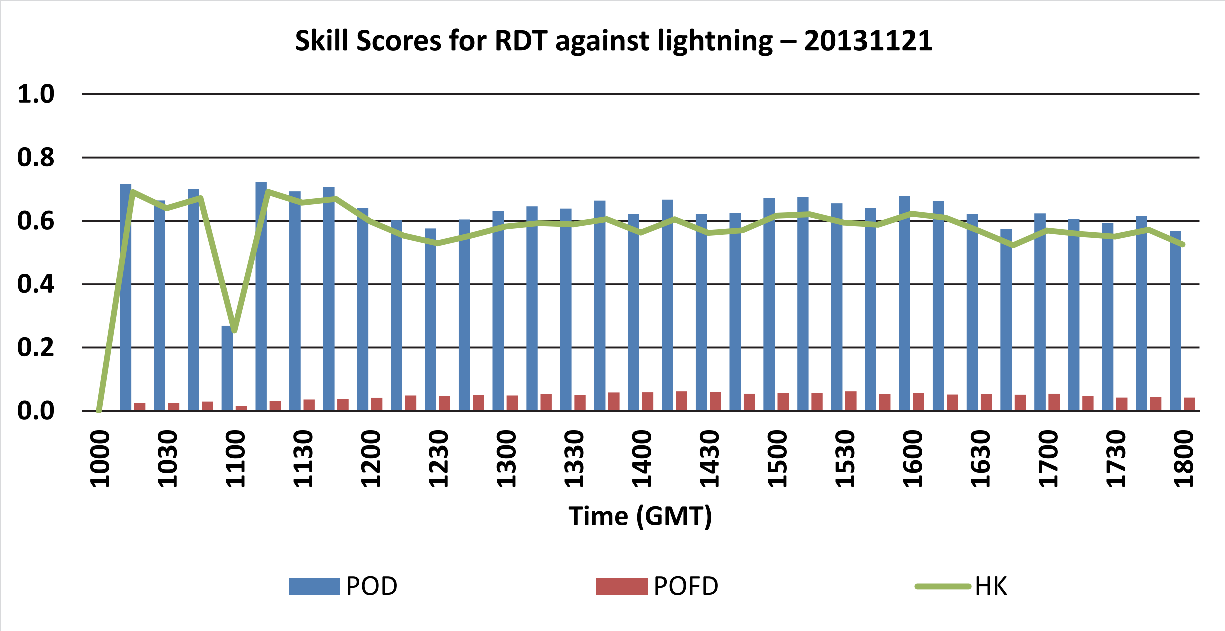

Figure 3.41 As in Figure 3.37 but for 21 November 2013

3.3.4 Case 4: 02 January 2014

On 02 January 2014, a large tropical low-pressure system was prevalent over Botswana, Angola and Zambia (Figure 3.42).

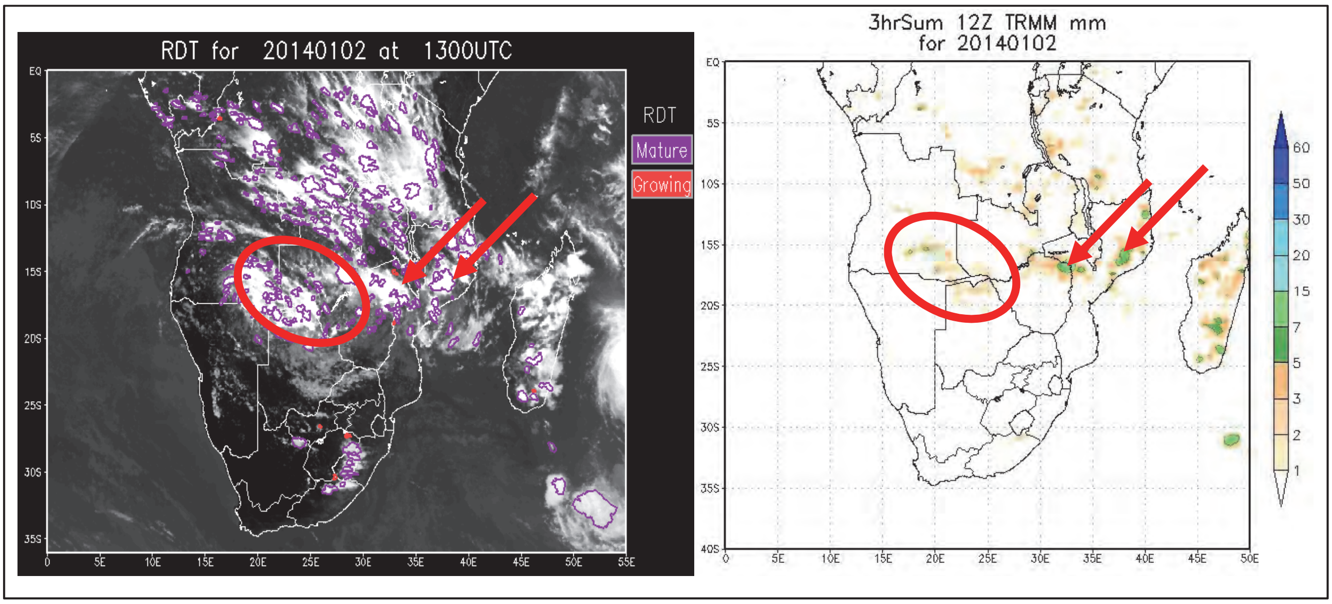

Figure 3.42 RDT image for the SADC region (left) at 1300 UTC and TRMM 3-hourly accumulation (right) between 1030 and 1330 UTC for 02 January 2014

Comparing the RDT image (Figure 3.42, left) for the SADC region against the TRMM 3-hourly accumulation (Figure 3.42, right), one can see that the heaviest rainfall locations within the TRMM image correspond to locations where the RDT classified storms as mature (indicated by the arrows). The smaller RDT cells correspond with a small amount of rainfall (the circled areas). TRMM data are still useful in the RDT verification procedure in the absence of other data.

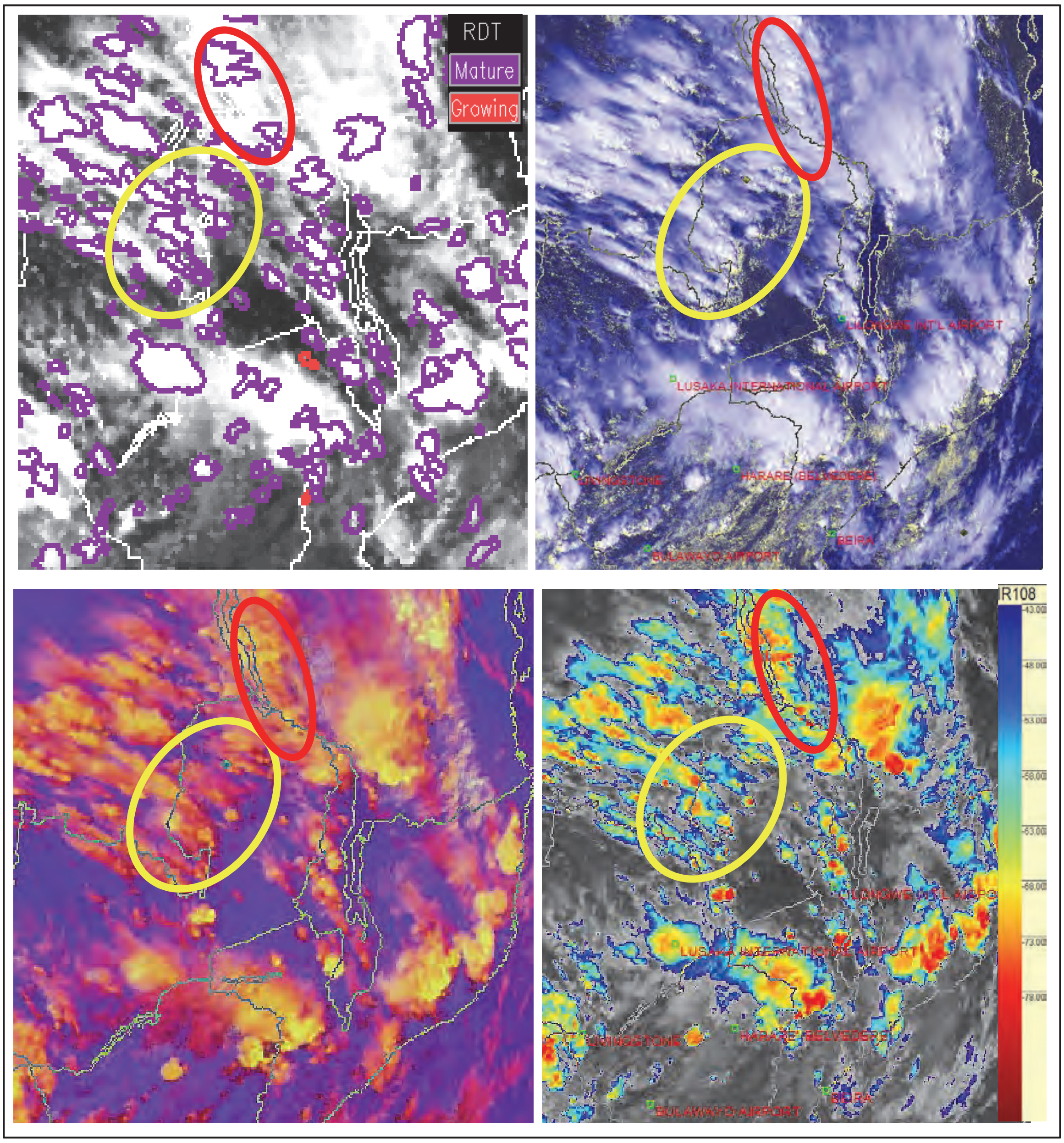

Figure 3.43 As in Figure 3.34 but for 02 January 2014 at 1300 UTC

In the HRVRGB image (Figure 3.43, top right), a number of optically thick cells are visible (in the yellow circle), and these storms are classified as mature by the RDT (yellow circle in Figure 3.43, top left). In the red circles, there is a line of optically thick clouds in the HRVRGB image and some of these were classified as mature by the RDT. In the ConvRGB (Figure 3.43, bottom left), the clouds within the yellow circle are convectively active storms with strong updrafts. These storms were all identified by the RDT as mature storms. In the red circle, only the yellow areas were classified by the RDT as mature storm cells. In the IR10.8 imagery (Figure 3.43, bottom right), there are a number of colder cells identified (in the yellow circled area) by orange and red colours and all of these cells were well captured by the RDT as mature storms. These clouds are then significantly colder than their surroundings, and thus are classified as mature. This indicates that the most intense regions of the storm systems are identified by the RDT.

On average, the percentage of lightning inside the RDT polygons (not shown) for 02 January 2014 was only 38.43%. The minimum percentage was 32.47% at 1430 UTC while the maximum was

46.36% at 1230 UTC. On 02 January 2014, the statistics (Figure 3.44) indicate that the average POD was 0.53. The minimum POD of 0.458 was observed at 1700 UTC, while the maximum POD of 0.607 was recorded at 1215 UTC. The average POFD for the day was 0.068 while the average HK for the period was 0.461.

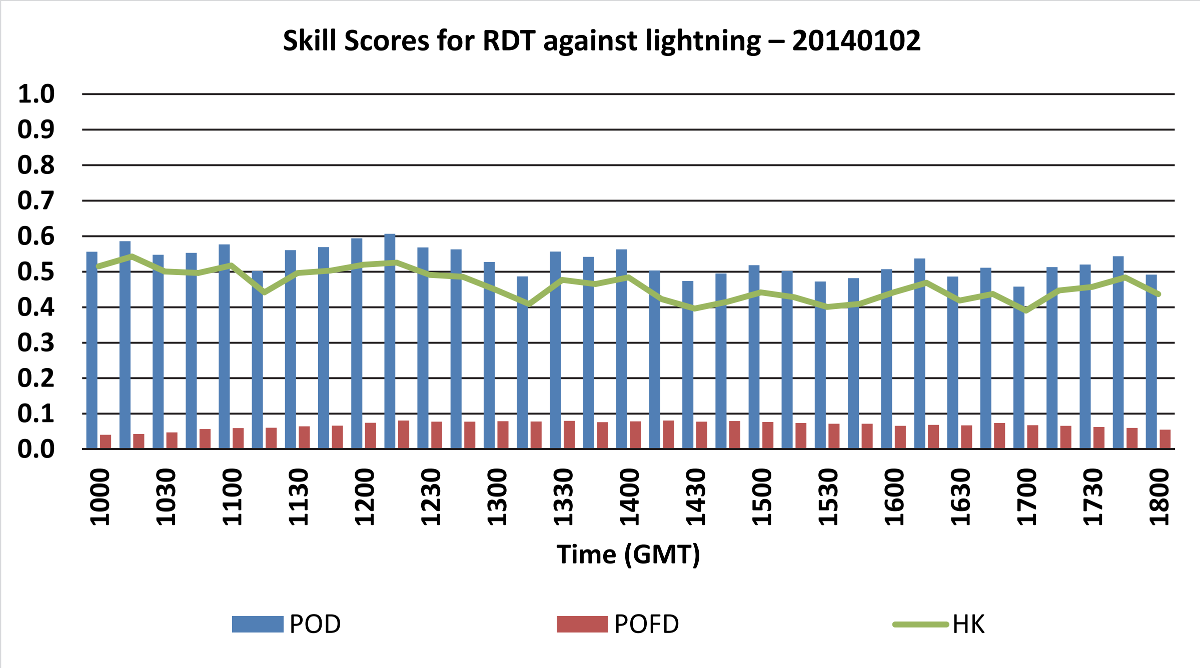

Figure 3.44 As in Figure 3.37, but for 02 January 2014

3.3.5 Case 5: 04 January 2014

On 04 January 2014, a large tropical low-pressure system was prevalent over Botswana, Zambia and Namibia. This system had moved slowly south-eastwards since 02 January. In the HRVRGB image (Figure 3.45, top right), there are a number of storm cells present within the larger tropical low-pressure system (in the yellow circle). The RDT identified these individual cells as mature (Figure 3.45, top left). In the imagery, there is also a noticeable line of cells (arrow), which were identified as mature storms by the RDT. The areas where cirrus clouds occurred were not identified by the RDT. This is a positive indication that the RDT is correctly identifying only the convective storms. In the ConvRGB (Figure 3.45, bottom left), the noticeable storm cells from the HRVRGB image all appear as bright yellow clouds, which is indicative that deep precipitating clouds are present with strong updrafts. The intense areas all correspond well with the mature storms identified by the RDT product (within the circled areas). The line of storms (indicated by the arrow) also appears as yellow or orange storm cells, these cells were classified by the RDT as mature. In the IR10.8 colour- enhanced imagery (Figure 3.45, bottom right), the storm cells are predominantly red in the imagery, thus indicating they are the coldest, highest clouds present. These coldest cells are all classified by the RDT as mature storms (in the circled area). The line of storms (indicated by the arrow) appears as a thin line with some red and yellow colours associated with the cells. A comparison between RDT and the various satellite images reveals that the RDT appears to compare well and captures the most intense and/or rapidly growing storms.

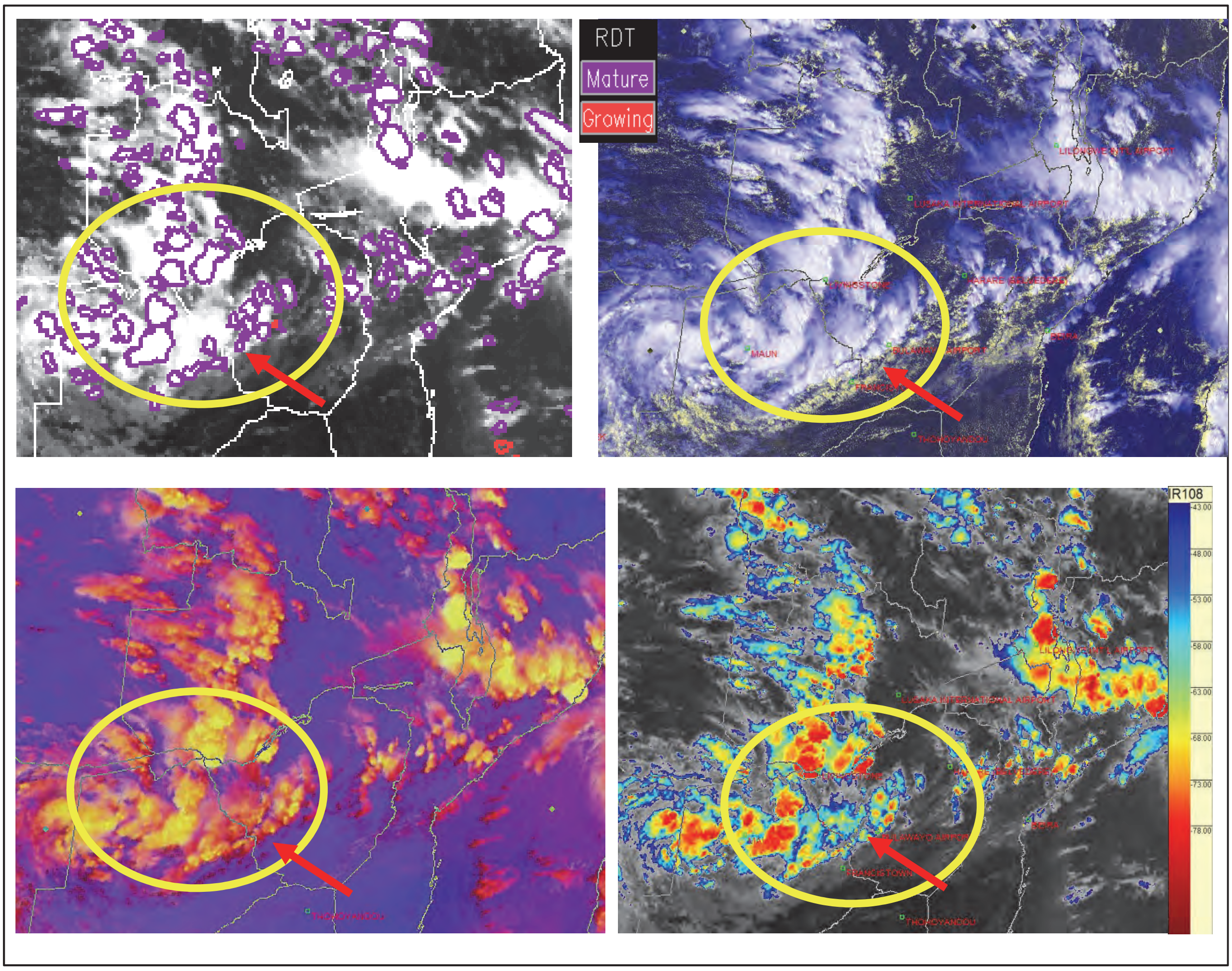

Figure 3.45 As in Figure 3.34, but for 04 January 2014 at 1300 UTC

On this day, the average percentage of lightning that fell within the RDT storm polygons (not shown) was 53.72%. The minimum percentage of 34.42% occurred at 1745 UTC while the maximum percentage of 69.94% was observed at 1700 UTC. Although these values do not appear to be very high, they are still considered acceptable considering the limitations when the evaluation was performed.

Figure 3.46 displays the statistical scores for 4 January 2014. On this day, the POD values for the entire period were all above 0.5. The minimum POD of 0.515 was recorded at 1745 UTC and the maximum POD of 0.748 at 1030 UTC. The average POD for the period was 0.636. POFD values remained low with an average value of 0.058 for the entire period. The HK values reached a minimum of 0.467 at 1745 UTC and a maximum of 0.7 at 1030 UTC. The average HK was 0.579.

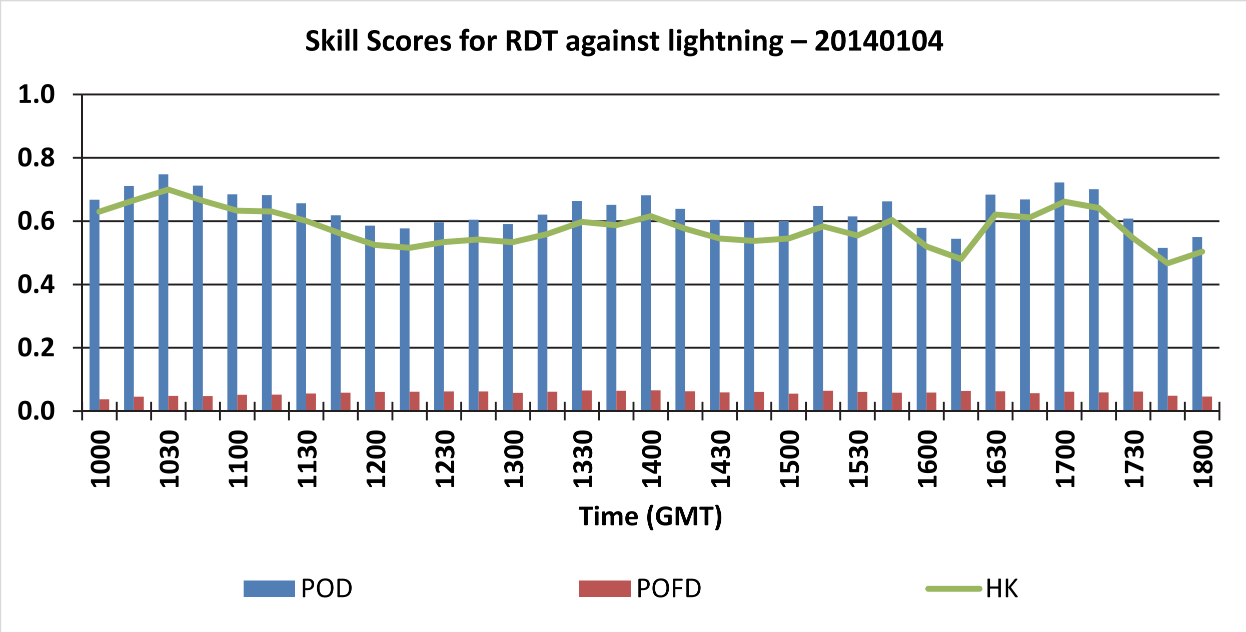

Figure 3.46 As in Figure 3.37, but for 04 January 2014

3.3.6 Case 6: 19 November 2013

On 19 November 2013 (Figure 3.47), a surface trough was located over the SADC region that triggered storm development over that area. Deep precipitating clouds with strong updrafts and small ice particles (bright yellow) are observed on the ConvRGB over Angola, Democratic Republic of Congo (DRC), Zambia, and Botswana. RDT identified mature and growing storms in similar regions.

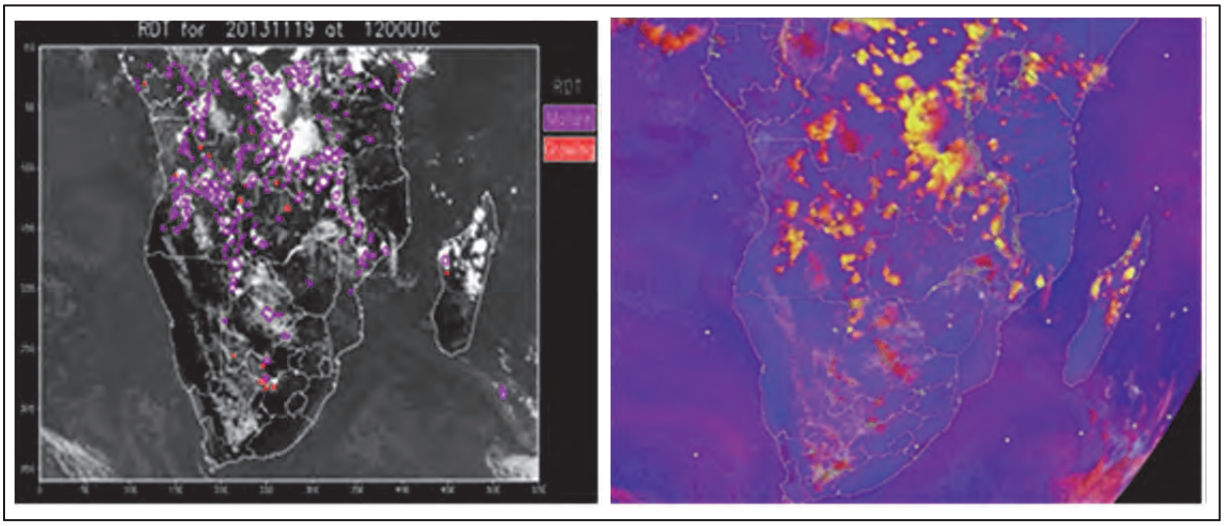

Figure 3.47 Images for RDT (left) and ConvRGB (right) for 19 November 2013 at 1200 UTC

On 19 November 2013, an average of 37.37% of the lightning occurred inside the RDT polygons. Figure 3.48 shows that the maximum POD value was 0.67. The average POD for the period was 0.524. All the POFD values over the period were below 0.1, with an average value of 0.054. The HK average was 0.47.

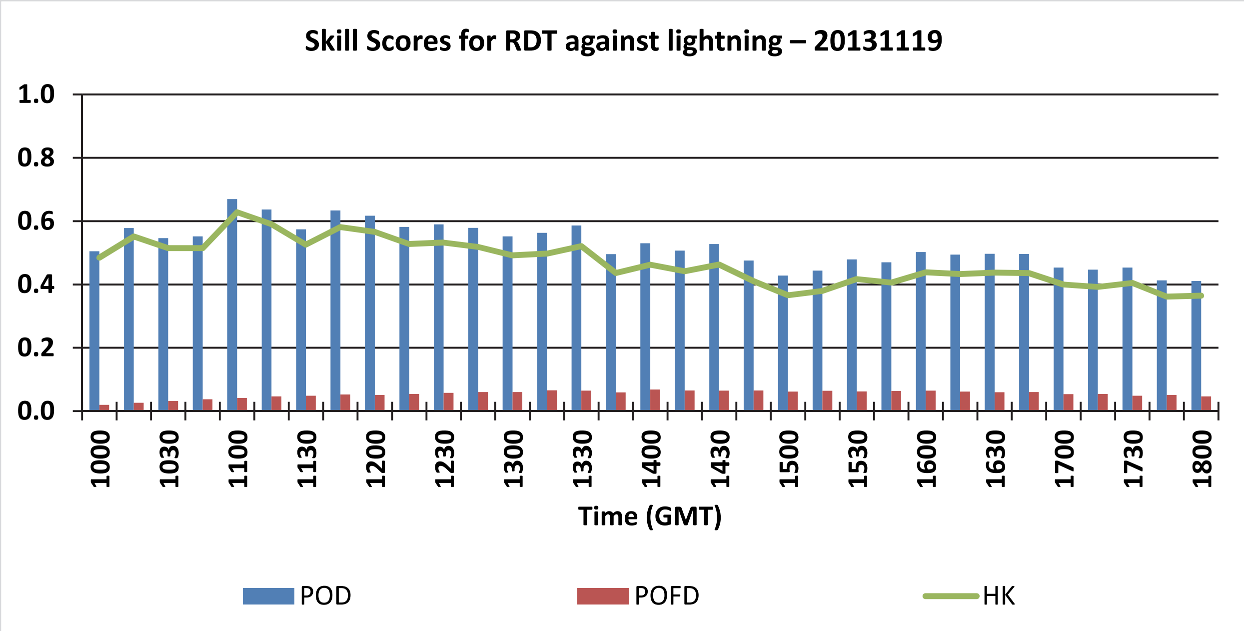

Figure 3.48 As in Figure 3.37, but for 19 November 2013

3.3.7 Case 7: 20 November 2013

On 20 November 2013, a trough was moving through the SADC region, extending to the north-eastern parts of South Africa. The RDT identified mature and growing storms over the Angola region (Figure 3.49, top left) in the same areas where thick, high-level clouds were visible in the HRVRGB (Figure 3.49 top right). The RDT polygons also coincided with the areas of strong updrafts and small ice particles in the ConvRGB (Figure 3.49, bottom left) as well as where the coldest cloud-top temperatures were reported (Figure 3.49, bottom right).

The average percentage of lightning that fell inside the RDT polygons for this day (not shown) was 47.75% while the minimum percentage of 35.86% occurred at 1230 UTC and the maximum percentage of 59.21% at 1615 UTC. For this case, the performance of the RDT product improved slightly from 1545 to 1730 UTC with all the percentages of lightning inside the RDT polygons being above 50%. Figure 3.50 depicts the statistical scores for 20 November 2013 between 1000 and 1800 UTC. The average POD for the period was 0.609, the average POFD was 0.052 and the average HK was 0.557.

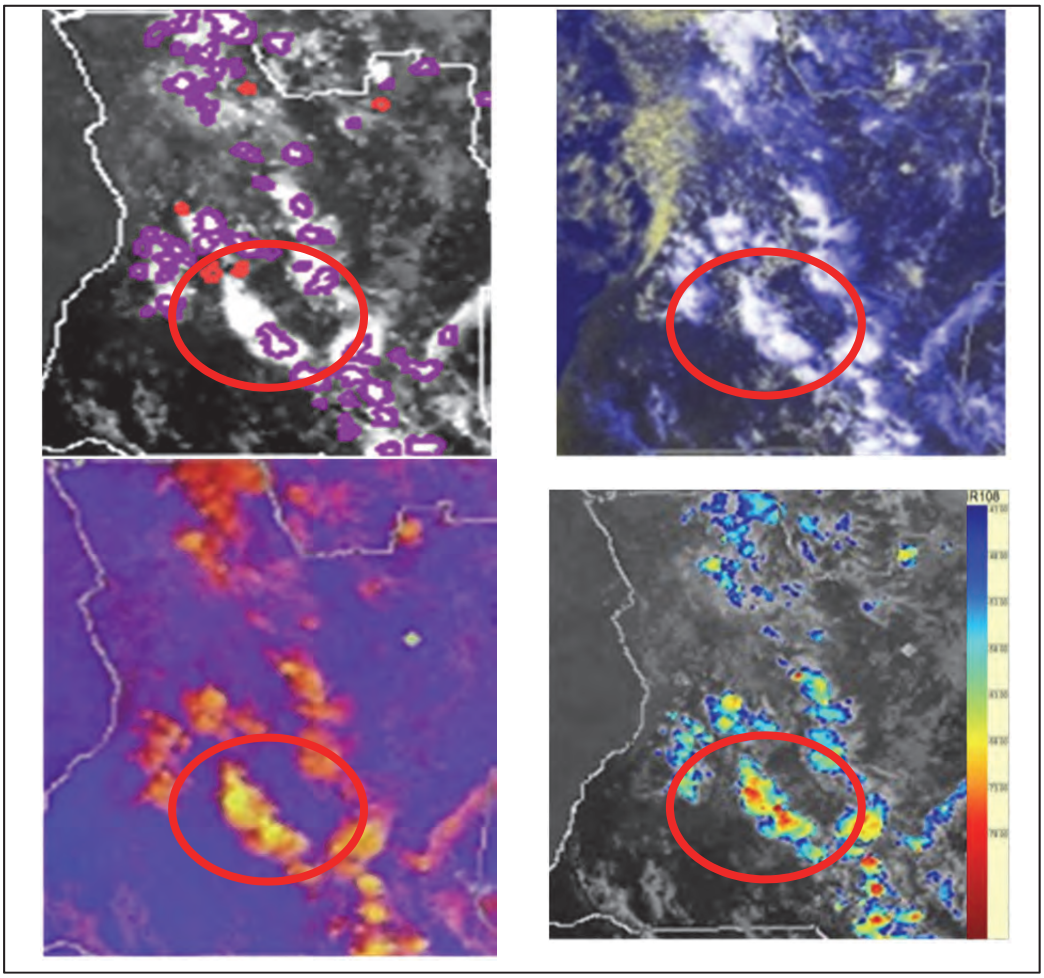

Figure 3.49 As in Figure 3.34, but for 20 November 2013 at 1200 UTC

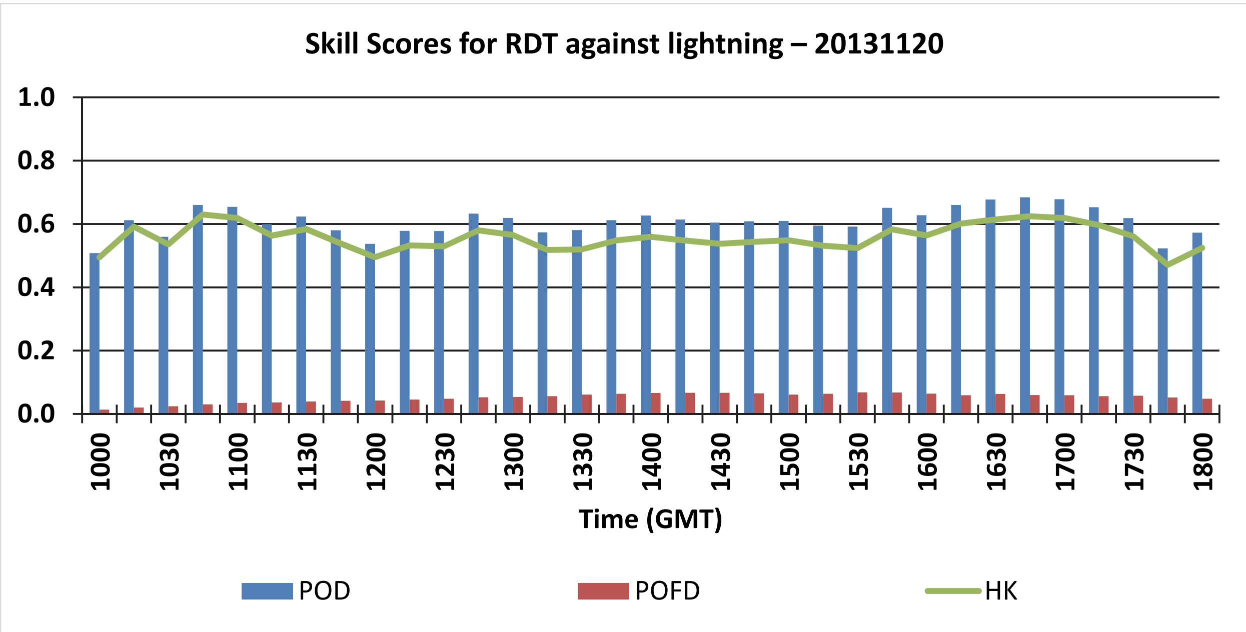

Figure 3.50 As in Figure 3.37, but for 20 November 2013

3.3.8 Case 8: 24 December 2013

Intense storms are evident over DRC, Angola, and Namibia on 24 December 2013. Figure 3.51 shows a storm that was not identified by RDT at 1200 UTC over DRC (black arrow), which portrays clouds with cold cloud-top temperatures of less than 73˚C. The storm indicated in the red circle was, however, identified as a mature storm by the RDT product and this was validated by all the other MSG images.

The average percentage of lightning that fell inside the RDT polygons (not shown) for the entire period was 53.6%. The minimum percentage of lightning that occurred inside the RDT polygons was 37.66% at 1015 UTC while the maximum percentage was 65.18% at 1600 UTC. The statistics for the 24 December 2013 (Figure 3.52) indicate that all POD values were above 0.5, and all POFD values were below 0.1. The average POD for the period was 0.668 and the average POFD was 0.062. For the HK, the lowest value of 0.488 was recorded at 1000 UTC while the highest value of 0.696 was observed at 1030 UTC. The average HK for the period was 0.606.

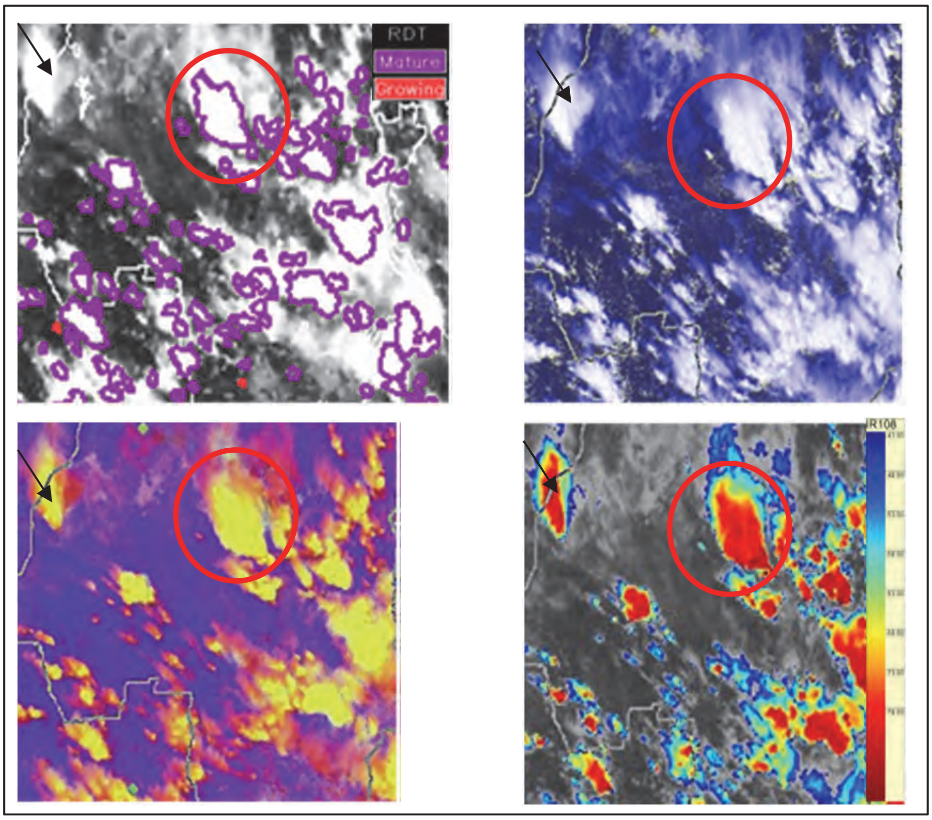

Figure 3.51 As in Figure 3.34, but for 24 December 2013 at 1200 UTC

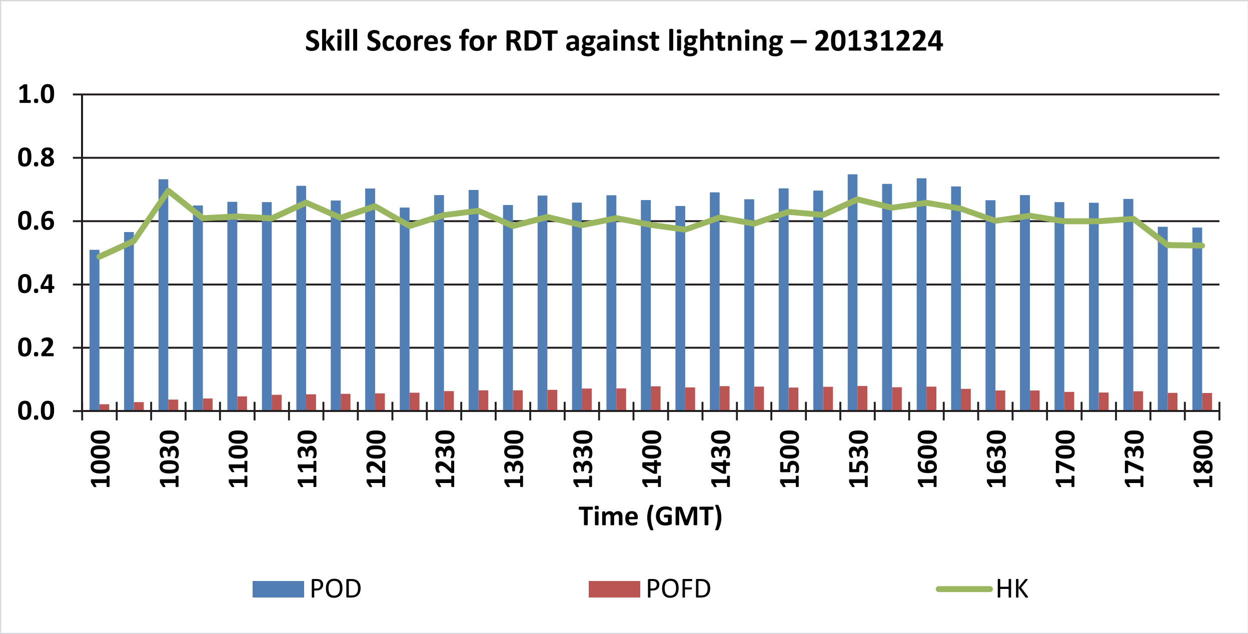

Figure 3.52 As in Figure 3.37, but for 24 December 2013

3.3.9 Case 9: 28 December 2013

The RDT product identified several mature and growing storms over the SADC region on 28 December 2013. Figure 3.53 shows that the most convective cells (bright yellow in Figure 3.53, bottom left) were associated with the higher amounts of rainfall as estimated by TRMM (Figure 3.53, top right), as well as the clouds with the coldest temperature (Figure 3.53, bottom right). The RDT identified two relatively large mature storms (top left) in the same area.

The average percentage of lightning that occurred inside the RDT polygons for this day was 44.12%. The statistical scores for 28 December 2013 are shown in Figure 3.54. The average POD, POFD and HK values for the period between 1000 and 1800 UTC were 0.605, 0.071 and 0.534, respectively.

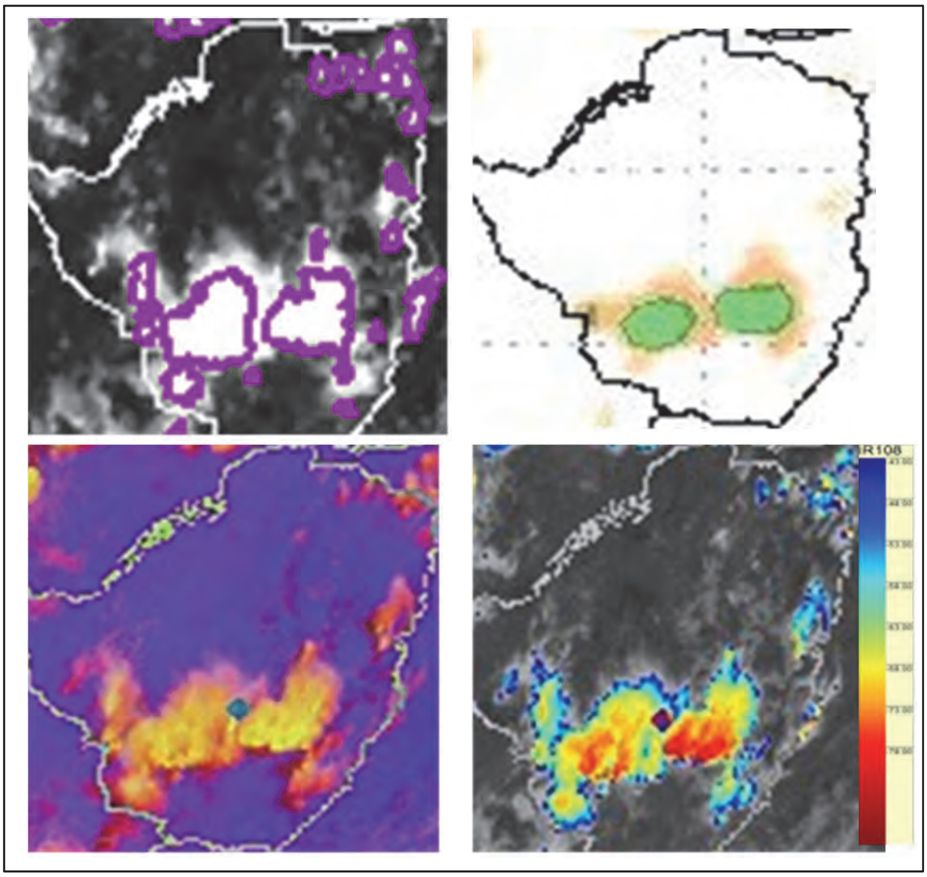

Figure 3.53 Images for RDT (top left), TRMM rainfall (top right), ConvRGB (bottom left) and IR10.8 colour-enhanced imagery (bottom right) for 28 December 2013 at 1200 UTC

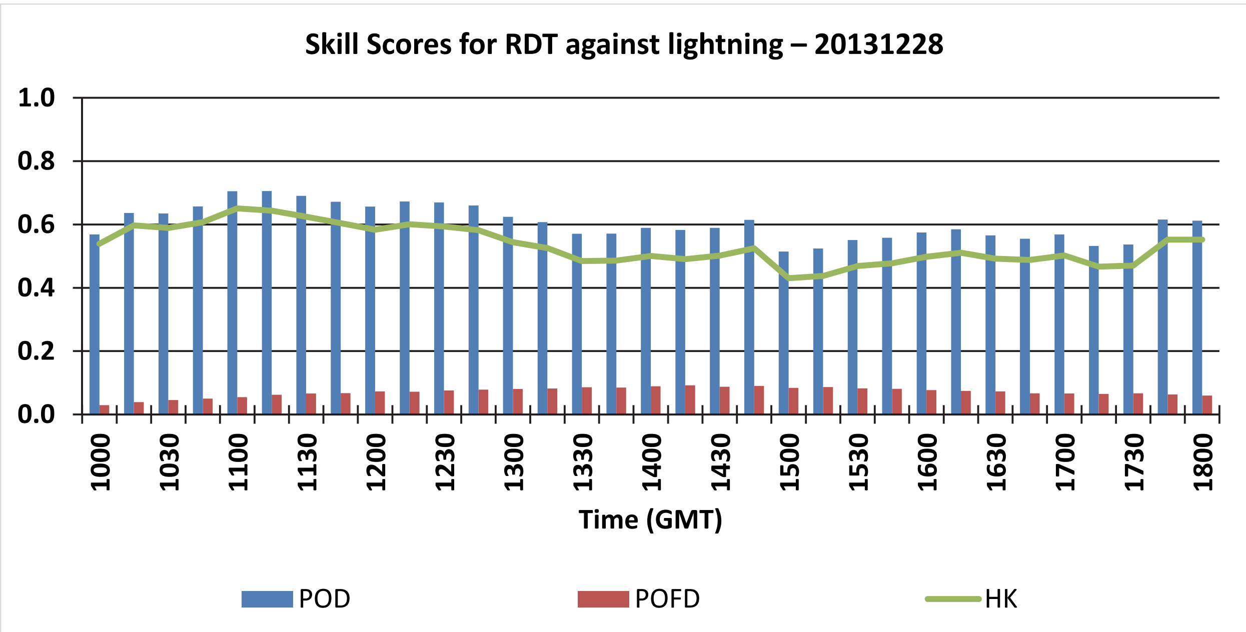

Figure 3.54 As in Figure 3.37, but for 28 December 2013

3.3.10 Case 10: 10 January 2014

On 10 January 2014, a trough was located over the SADC extending to the north-eastern parts of SA. The RDT product identified mature and growing storms (Figure 3.55, left) over the same region as where the ConvRGB indicated the bigger storms (bright yellow) (Figure 3.55, right).

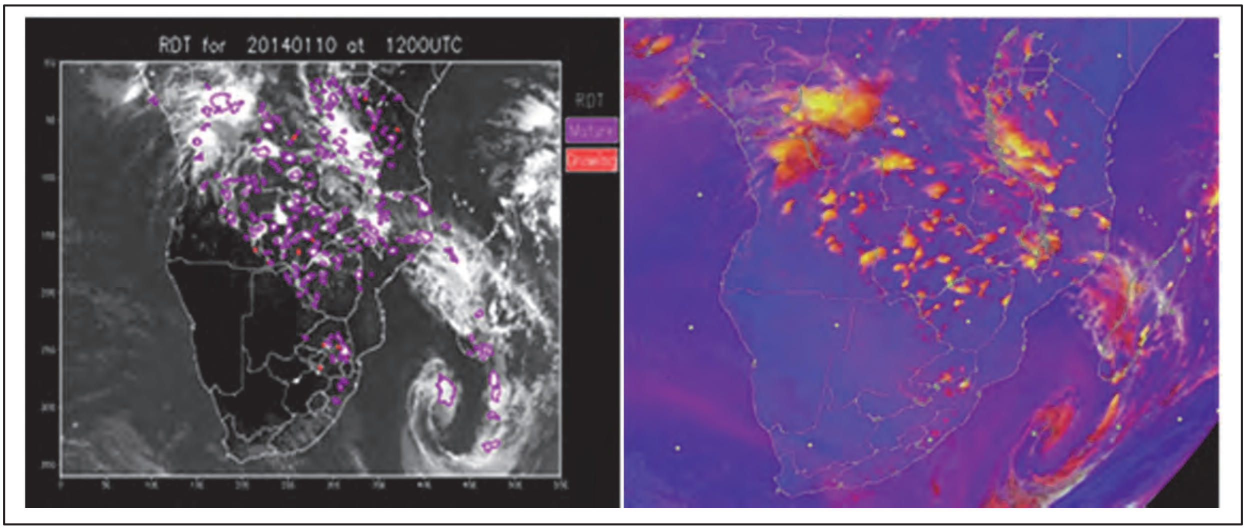

Figure 3.55 As in Figure 3.47, but for 10 January 2014 at 1200 UTC

The statistical scores for 10 January 2014 indicate that the average percentage of lightning that occurred inside the RDT polygons was 42.72%. Figure 3.56 displays the statistical scores for 10 January 2014. The average POD for the period was 0.572. The average POFD was 0.049, while the HK recorded a minimum of 0.438 at 1400 UTC and a maximum of 0.612 at around 1100 UTC. The average HK for the period was 0.523.

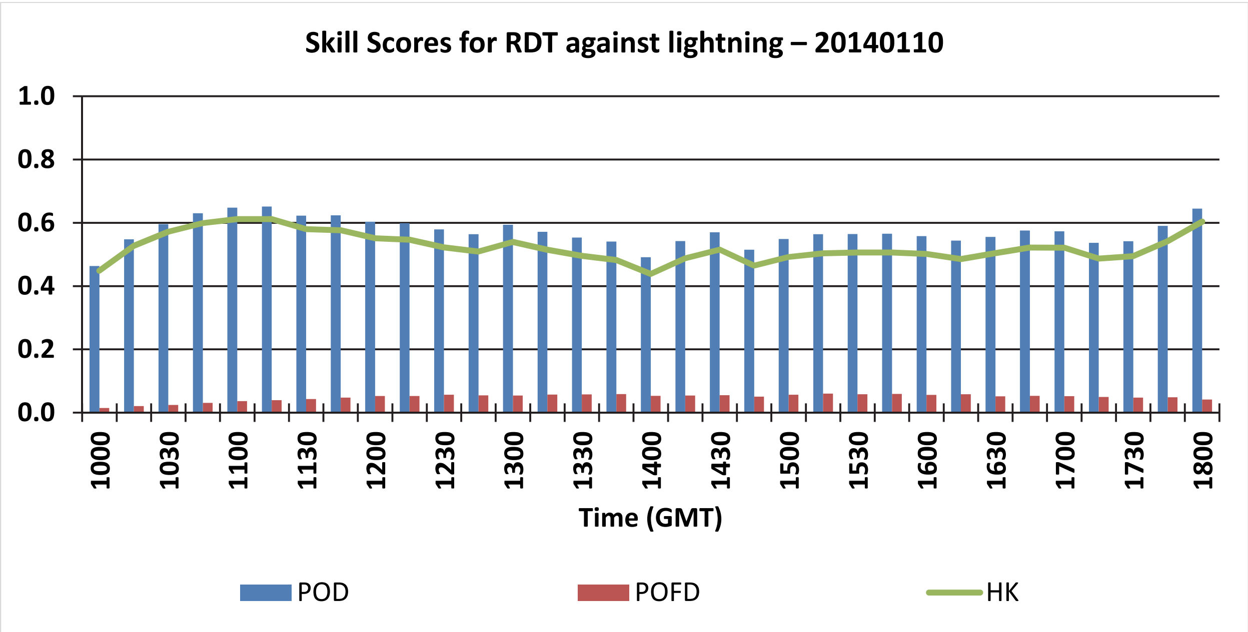

Figure 3.56 As in Figure 3.37, but for 10 January 2014

3.4 Summary of results

3.4.1 Results over South Africa

Figure 3.57 shows the percentage of lightning inside the growing and mature storm polygons for all ten cases that were conducted over the South African domain. It is clear that the moderate to intense lightning strokes were most successful with the highest percentages (>60%) in most time intervals. Figure 3.58 shows the HK for all the time intervals for all ten cases. The HK for moderate to intense lightning strokes was above 0.6 for many time intervals, especially after 1300 UTC.

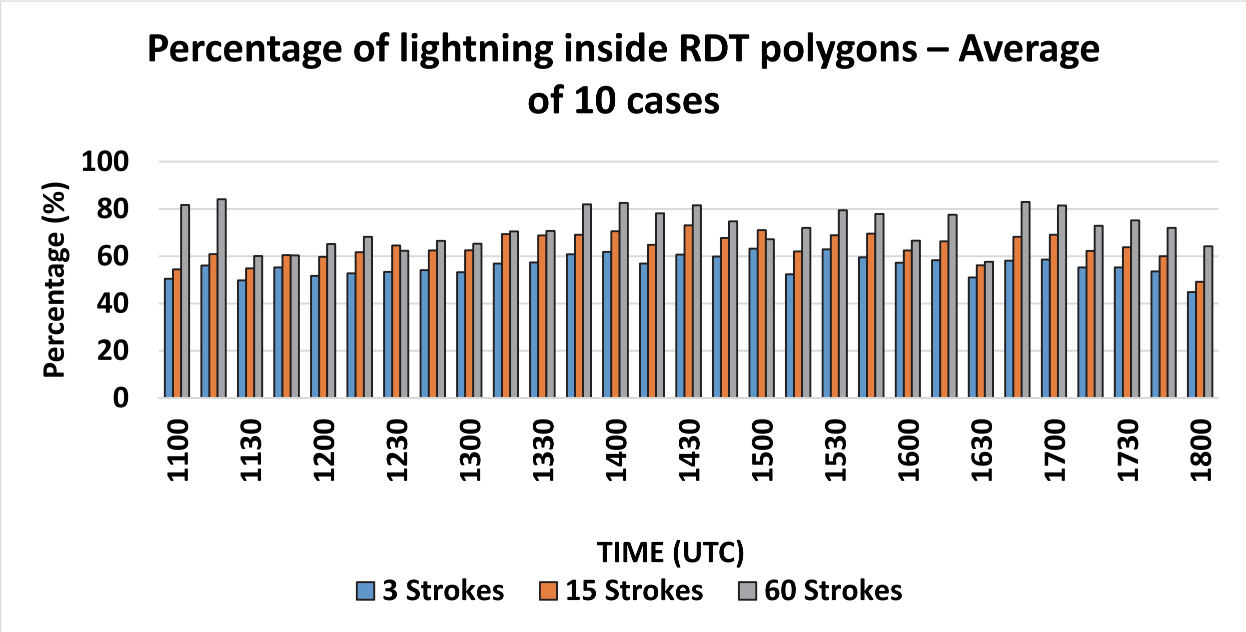

Figure 3.57 As in Figure 3.7, but for all ten cases over the South African region

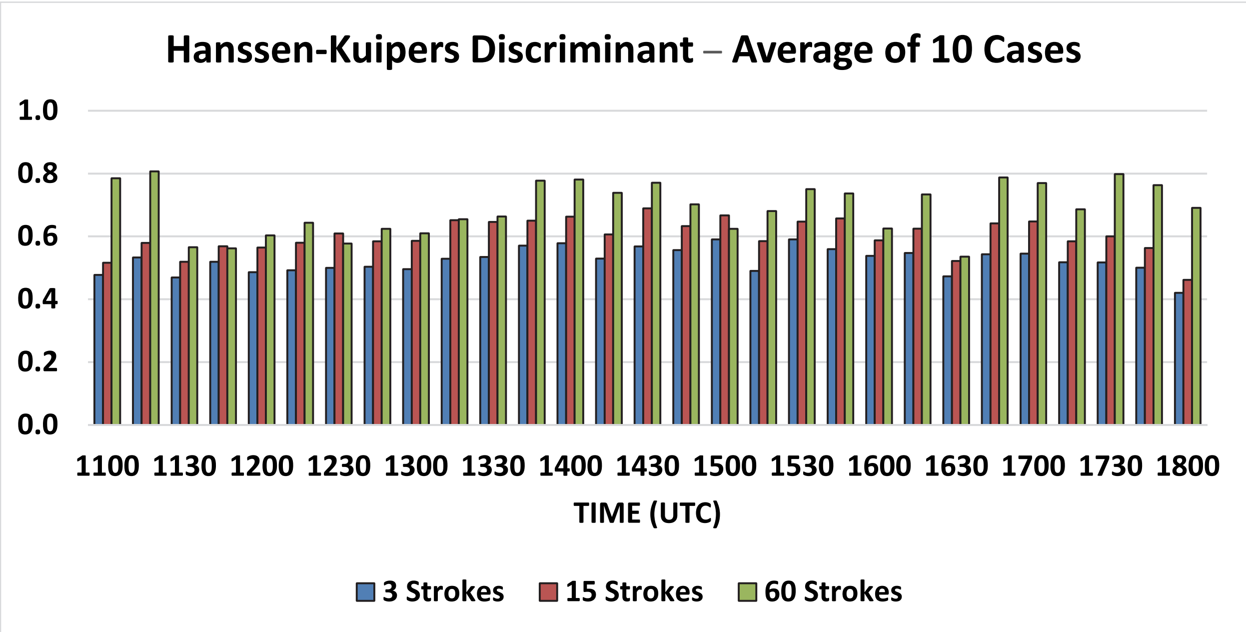

Figure 3.58 As in Figure 3.8, but for all ten cases over the South African region

Ten cases were selected to validate the RDT product over South Africa. Visual comparisons were carried out against MSG images and radar images. Statistical scores were calculated using the cloud-to-ground (CG) lightning data from the South African Lightning Detection Network. The ten cases studied thus far show that the RDT product is performing well when compared to CG lightning in the 10 minutes before until 10 minutes after each RDT time step. The value of RDT product to identify and track convective activity is also evident in areas where radar systems are not available or not operational. In the next chapter, more cases will be examined over the southern Africa region to establish the usefulness of the RDT product for countries outside South Africa where radar systems are not available.

3.4.2 Results over southern Africa

Figure 3.59 displays the average percentage of lightning, which fell inside the RDT polygons for all ten case days. The minimum percentage of lightning within the RDT polygons, with a value of 40.58%, occurred at 1000 UTC, while the maximum percentage of 50.82% was recorded at 1030 UTC. The average percentage of lightning inside the RDT polygons for the ten case days was 47.3%. One has to keep in mind, however, that lightning could have also occurred in thunderstorms that are not rapidly growing or are in different stages of development. The WWLLN detection efficiency is only 10%, thus a large part of the lightning activity that occurred, could not be used in the validation procedure.

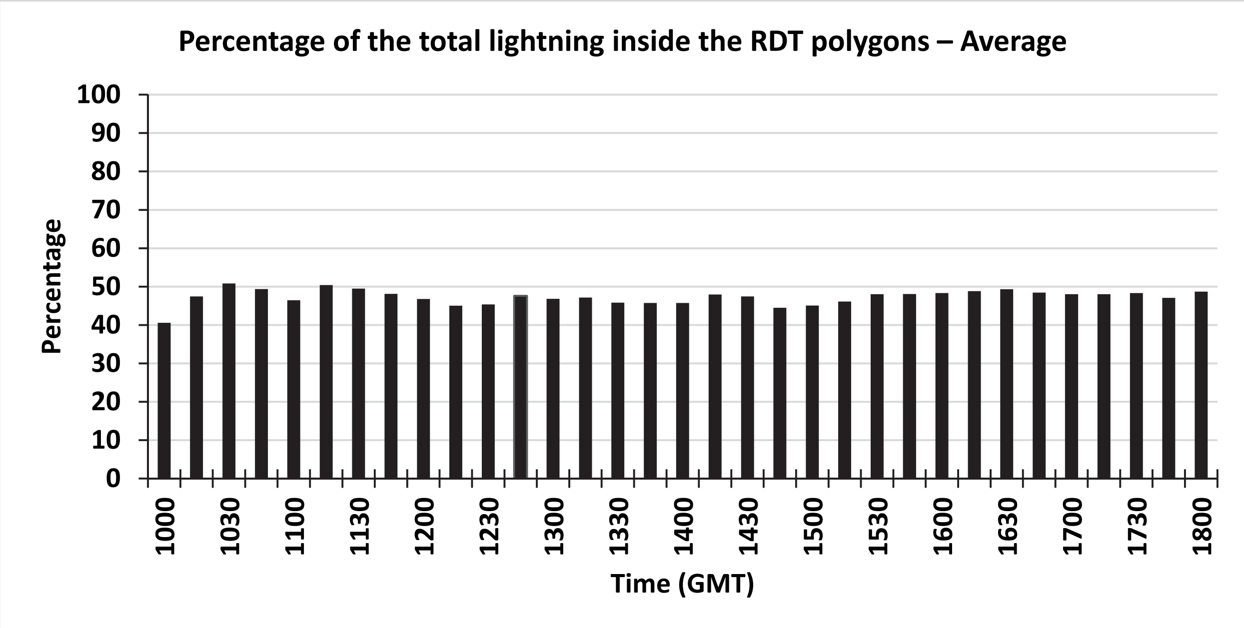

Figure 3.59 As in Figure 3.36, but for all ten cases over the southern African region

From the average statistical scores for the ten case days (Figure 3.60), it is clear that the RDT product performed quite well. Even with all the limitations that were present when evaluating the product, like WWLLN only detecting about 10% of all the lightning activity, only rapidly developing thunderstorms in the growing and mature phases were considered, and in view of the fact that lightning frequently strikes just outside of a thunderstorm, the results are encouraging. The average POD for the entire period was 0.6 while the minimum POD recorded was 0.52 and the maximum was 0.66. POFD values remained low throughout the entire period. The average POFD was 0.06, the minimum 0.02 and the maximum was 0.07. For the HK, the average value was 0.55, with a minimum of 0.49 and maximum of 0.62.

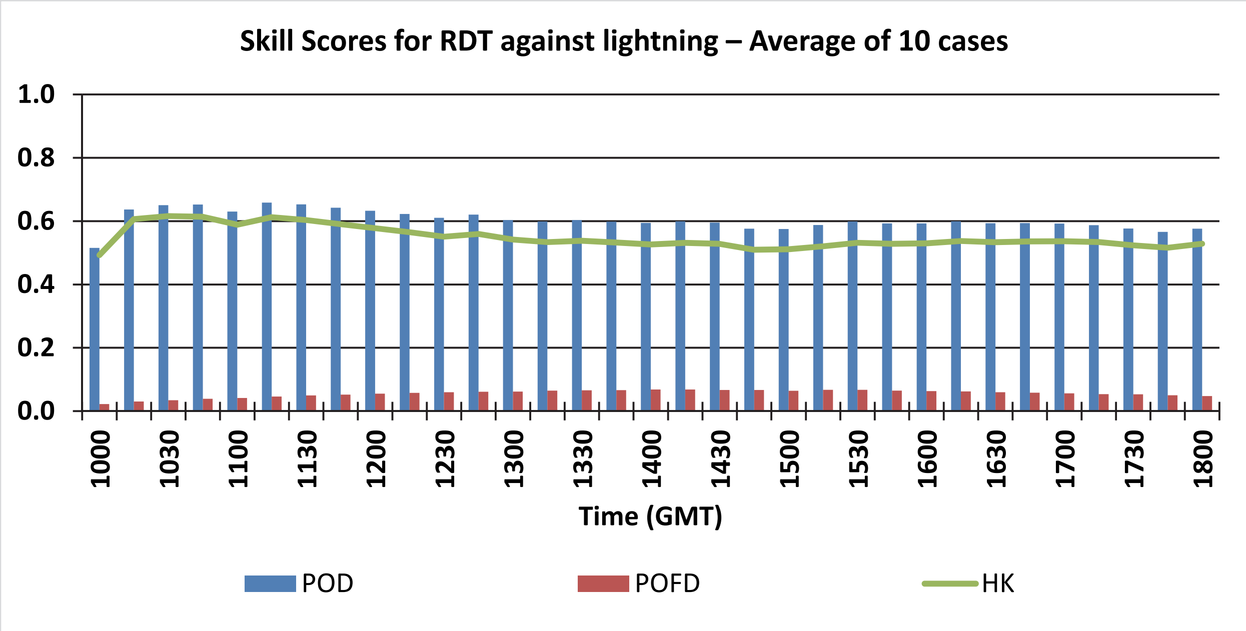

Figure 3.60 As in Figure 3.37, but for all ten cases over the southern African region

The performance of the RDT product was tested over the southern African region. Validation was performed visually against MSG imagery and TRMM rainfall and quantitatively against lightning data from the WWLLN network. For this purpose ten cases were identified in the past summer season. It was shown that the RDT performed well over the southern African region. From visual comparisons with the satellite imagery, there are many positive signs that the most intense storms were generally captured by the RDT. The RDT identification of mature and growing storms excluded the dissipating storms and thin cirrus shields, which is a positive indication of how well the system is able to identify only the most intense cloud structures within the imagery. The RDT product identified storms that were rapidly developing, which added value to the satellite images. Some storms were not detected, but this happened infrequently with only a small number of storms. Even though the WWLLN has a detection efficiency of only 10%, evaluating the RDT polygons against the WWLLN data was the only way to obtain a quantitative validation score. Despite the limitations of the methodology, the statistical scores looked encouraging. The RDT could serve the southern African region well in lieu of having insufficient ground-based data sources such as operational radar systems for the region.

Thus far, a grid-box-based methodology was used to validate the RDT against the occurrence of lightning. The developers of the RDT product recommend that an object-oriented methodology would be preferable to validate a product such as the RDT. First efforts were made to use the R software package to compare the RDT polygons and the lightning occurrences as objects. Different statistical scores were used than in the grid-box-based methodology, but there is a good indication that the object-oriented methodology provides better results than the grid-box-based method. This methodology is recommended for future validation of the RDT product.

CHAPTER 4: IMPLEMENTATION, APPLICATION OF THE RDT AND CAPCITY BUILDING

4.1 IMPLEMENTATION AND APPLICATION

The RDT product has been implemented operationally via the FCAST website for forecasters in South Africa, but also via the RSMC website to forecasters from our neighbouring countries. This satellite-based methodology has been proved to identify and track the more intense parts of thunderstorms, which complement radar data, where that is available, but which adds valuable information in areas which are not covered by radar systems inside and outside South Africa. Users from the Aviation community expressed specific interest in the product for flights from South African to Europe.

4.2 CAPACITY BUILDING WITH FORECASTERS FROM SOUTH AFRICA AND SOUTHERN AFRICA

Several occasions were used to transfer skills to forecasters during the two-year project period:

4.2.1 Information session for forecasters at the National Forecasting Office (June 2014)

A short presentation was done to explain the RDT product to forecasters, showing case study results as well as recent examples of the RDT. This session was attended by seven forecasters on 9 June 2014 and four forecasters on 11 June.

4.2.2 Information session for forecasters at OR Tambo International Airport (June 2014)

A short presentation was done to explain the RDT product to aviation forecasters from OR Tambo weather office, showing case study results as well as recent examples of the RDT. This session was attended by five forecasters on 12 June 2014.

4.2.3 Information session for forecasters from the SADC region during an online training event (July 2014)

A short presentation was done online via the Regional Training Centre (RTC) in SAWS to explain the RDT product to forecasters from the SADC region, showing case study results as well as recent examples of the RDT. This session was attended by seven forecasters on 25 July 2014.

4.2.4 Workshop on current and new nowcasting tools (October 2014)

A workshop was organized on 21 October to highlight current and new nowcasting tools to forecasters from all the regional forecasting offices. This event was attended by representatives from the Aviation Forecasting Office at OR Tambo International Airport, Cape Town Weather Office, Port Elizabeth Weather Office, the Regional Training Centre, Bloemfontein Weather Office, Nelspruit Weather Office, National Forecasting Centre (Pretoria) and the Department of Water and Sanitation (DWS) – Flood Monitoring and Forecasting and Drought Monitoring. The programme for this workshop focused on all nowcasting tools, but the RDT was a prominent feature during the afternoon session.

4.2.5 Presentation during the WMO Severe Weather Forecasting Demonstration Project (SWFDP) training event in Pretoria, November 2013

Estelle de Coning presented the initial results of three case studies during the WMO SWFDP training event, which was held in Pretoria in November 2013. This event was attended by 15 delegates from the Southern African Developing Community (SADC). The list of attendees is given in APPENDIX A.

4.2.6 Presentation during the EUMETSAT training event in Pretoria, December 2013.

Estelle de Coning presented the initial results of five case studies during the EUMETSAT training event, which was held in Pretoria. This event was attended by 20 delegates from the SADC. The programme of this event and the attendance register are attached as APPENDIX B.

4.2.7 Presentation of the results of the SA and SADC region cases as well as recent operational examples at the annual Severe Weather Forecasting Demonstration Project (SWFDP) training event in November 2014

Estelle de Coning presented the results of case studies as well as recent examples during the WMO Severe Forecasting Demonstration Project training event, which was held in Pretoria. This event was attended by 20 delegates from the SADC. The programme of this event and the attendance register are attached in APPENDIX C.

4.3 PRESENTATIONS AT NATIONAL LEVEL

During the two-year project period, the research results were presented at several occasions nationally and internationally.

4.3.1 Presentation at the national SASAS conference in Shaka's Rock, September 2013.

In an oral presentation, Bathobile Maseko presented the initial results of the first RDT case study at the SASAS conference in September 2013. The topic of her presentation was: Preliminary results of the Rapidly Developing Thunderstorm product over South Africa. The extended peer-reviewed abstract is in APPENDIX D.

4.3.2 Presentation of the results of the SA and SADC region cases as well as recent operational examples at the quarterly stakeholders' meeting (ACAMS Meeting) in November 2014

Estelle de Coning presented the results of case studies as well as recent examples at a meeting with members of the aviation industry in November 2014. The RDT product was welcomed by members of the meeting. Follow-up presentations will be given to aviation industry stakeholders in the near future. The attendance register is included as APPENDIX E.

4.3.3 The RDT product and its validation were presented at the SASAS conference in Potchefstroom in October 2014

Morne Gijben was the lead author of a paper presented at the SASAS conference, which was held in Potchefstroom from 1-2 October 2014, entitled: The Rapidly Developing Thunderstorms product – results of case studies and future plans. The extended peer-reviewed abstract is in APPENDIX F.

4.4 PRESENTATIONS AT INTERNATIONAL LEVEL

4.4.1 Presentation of the preliminary results of RDT case studies at the European Nowcasting Conference in Vienna, Austria, April 2014.

Estelle de Coning presented the preliminary results of RDT case studies over South Africa and southern Africa at the European Nowcasting Conference in Vienna, Austria. The abstract of the work that was presented is included in APPENDIX G. This conference was attended by 50 delegates from around Europe, including delegates from the USA to share knowledge and expertise on nowcasting tools.

4.4.2 Presentation of the results of Nowcasting SAF products (RDT and rainfall products) at World Weather Open Science Conference (WWOSC) in Montreal, Canada in August 2014.

Estelle de Coning presented the results of all SA as well as SADC case studies using the RDT as well as the Convective Rainfall Rate (CRR) products from the Nowcasting SAF at the WWOSC. The abstract that was submitted for this conference is given in APPENDIX H. The conference was attended by more than 1000 delegates from all over the world to exchange information and expertise on all aspects of meteorology, e.g. from nowcasting to decadal-scale scenarios in a seamless fashion.

4.4.3 Presentation at the 11th EUMETSAT African User Forum

Estelle de Coning presented a talk entitled: "Using the Nowcasting SAF products over South Africa and southern Africa to enhance nowcasting capabilities in data sparse regions" for the 11th EUMETSAT African User Forum, which was held in Benoni from 8-12 September 2014. The abstract for this presentation is given in APPENDIX I.

4.4.4 Presentation at the Nowcasting Satellite Application Facility 2015 Users' Workshop

Estelle de Coning presented a talk entitled "Using the Nowcasting SAF products over South Africa and southern Africa to enhance nowcasting capabilities in data sparse regions" at the NWC SAF users' workshop (Abstract provided in APPENDIX J).

4.5 Publications

4.5.1SASAS 2013

Bathobile Maseko was the lead author of a peer reviewed extended abstract for the SASAS conference in September 2013. The topic of her presentation was: Preliminary results of the Rapidly Developing Thunderstorm product over South Africa. (APPENDIX A).

4.5.2SASAS 2014

Morne Gijben was the lead author of a peer reviewed extended abstract for the SASAS conference in October 2014. The topic of his presentation was: The Rapidly Developing Thunderstorms product – results of case studies and future plans. (APPENDIX D).

4.5.3 Submission to SA Journal of Science 2014

A paper was submitted to the *SA Journal of Science* on 18 November 2014 and accepted for publication in February 2015.

4.6 Enrolment for MSc study

Morne Gijben enrolled for his M.Sc. at the University of Pretoria in 2015. He plans to complete the study by the end of 2015.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion of the project

The aims of this research project were to:

- install and implement the RDT software to run over the southern African region, on a server in the South African Weather Service (SAWS) based on MSG and Unified Model (UM) data to provide information to forecasters, aviation meteorologists and hydrologists about the development, life cycle and dissipation of convection in regions where radar systems do not provide coverage (in between radars over South Africa) or where no radars systems are available (most of South Africa's neighbouring countries);

- validate the RDT against lightning data over the South African and southern African region by means of case studies to show the value of this product;

- present the outcome of the studies to relevant audiences nationally and internationally;

- transfer skills to the relevant forecasters; and

- implement the system operationally to provide real-time feed of the RDT to forecasters in the southern African region.

The implementation of the 2012 version of the NWC SAF software to test whether the RDT product can be used over the South African and southern African regions was successful. The results of the cases that were considered show promising results that this product could provide additional information on possible severe storms in regions that are not covered by radar systems. This product may be useful particularly for aviation purposes in regions of Africa and could assist in navigating air traffic around the more intense storms, which could contain hail and/or heavy rainfall.

Several occasions were utilized to demonstrate the RDT product to operational forecasters in South Africa as well as in the southern African region through workshops as well as the annual Severe Weather Forecasting Demonstration Project (SWFDP) training events. Positive feedback has already been received about this new nowcasting tool. Other African countries have expressed the need to share in the output of the RDT product.

The 2013 version of the NWC software was made operational at SAWS during the second half of 2014. The data is archived on a server in SAWS. The RDT images are available on the FCAST website to forecasters in South Africa, but also on the Regional Specialized Meteorological Centre (RSMC) website for forecasters from our neighbouring countries. Satellite based nowcasting tools such as the RDT product can be very useful to identify and track the more intense parts of thunderstorms in data sparse regions.

5.2 Recommendations

The 2012 version of the NWC SAF software was used for all the case studies presented in this project. The 2013 version of the NWC SAF software is now running operationally in South Africa. This software includes some changes and improvements to the 2012 version, which was tested during the project. It would be useful to test the 2013 version over several months as well as to obtain some feedback from the forecasters who are using it.

The new version of the software has additional options to including identification of overshooting tops – which could be input to the RDT. It would be beneficial to test the additional options to see if this improves the RDT product. These additional options should be tested to establish whether they would improve the performance of the RDT product. Another option is to include lightning data as input to the algorithm – this also needs to be tested in the near future.

The SAWS hopes to upgrade the local version of the UM to include better scientific packages as well as an increase in resolution to improve on the current 12 km grid to a 4 km or even 1.5 km grid length during 2015. An improvement in resolution should also be of benefit to the RDT product.

The verification methods used thus far were grid-box-based. This is not the optimal way to validate objects such as RDT polygons. The developers of the RDT product showed that they obtained better results using an object-oriented methodology. Initial results using an object-oriented methodology showed much better results than the grid-box-based methods used during this project. This methodology is recommended for future validation of the RDT product.

The developers also indicated that some updates of the software would be available in 2015. New versions of the software are made available through the NWC SAF website and these will be downloaded and installed as soon as they are released.

Several ways exist to improve on results achieved thus far and this product certainly holds promise for the future of nowcasting tools. The project team is prepared to make use of every opportunity to improve on the RDT product as well as any of the other products (such as the Convective Rainfall Rate), which form part of the NWC SAF product suite.

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APPENDIX A

FORECASTERS 10-22 NOVEMBER 2013

COUNTRY	NAME	E-MAIL ADDRESSES
Angola	Mr Guido Gasper Teca	guido.teca@inamet.gov.ao
Botswana	Ms Alice Oabile	_
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APPENDIX B

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APPENDIX C

Severe Weather Forecasting Demonstration Project
SWFDP - Southern Africa

Training Workshop on Severe Weather Forecasting and
Public Weather and Warning Services
Regional Training Centre Pretoria
Pretoria, South Africa
November 2014

PROGRAMME for GDPFS

(Week 1: 3 – 7 November 2014)

Day 1: Monday 3 November		
0900-1030	**OPENING AND INTRODUCTION**	
	Opening, Welcome and Introduction	
	WMO activities and global SWFDP programme, Purpose of this workshop	
1030-1100	***Coffee break***	
1100-1200	**SWPFD-Southern Africa**	
	SWFDP-SA: • Latest developments for Southern Africa	EP
	RSMC Pretoria Products: • Webpage demonstration: layout and access to different systems used in this course • Daily guidance products	ES
1200-1400	***Collection of per diems, Lunch break***	
1400-1700 *(Coffee break: 1530-1545)*	**GLOBAL MODELLING: Description of models and their products for SWFDP-SA**	
	Numerical Weather Prediction Process • Basics: data assimilation, resolution, physical parameterisation	SL
	Numerical Weather Prediction Access Demo • ECMWF, products on the RSMC website • MOGREPS, products on the RSMC website • NCEP, products on the RSMC website	ES
	Cocktail for all participants at Schoongezich at 1800 for 1830	

Day 2: Tuesday 4 November		
0900-1230 (*Coffee break: 1030-1045)*	**REGIONAL MODELLING: Overview**	
	Concepts of limited area modelling: • Overview: Scientific and Operational aspects, boundary conditions, topography • Application in the UM-SA12 in Southern Africa, introduction to upgrade • UM SA12 products: availability, strengths, weaknesses • Météo-France Aladin-Réunion products: availability	SL SL ES ES
	ENSEMBLE PREDICTION SYSTEMS (EPS) AND PROBABILISTIC FORECASTING	
	General concepts • Uncertainty – why do we need EPS? • Deterministic vs probabilistic forecasting • Basics of EPS: scientific basis, operational production, clustering	SL
1230-1400	***Lunch break***	
1400-1730 (*Coffee break: 1530-1545)*	Operational use of EPS vs deterministic forecasts - Practical • Forecaster decision-making process blending EPS and deterministic (LAM) forecasts • Using EPS/deterministic forecasts for severe weather forecasting • Quantitative Precipitation Forecasts (QPF) and Probabilistic QPF (PQPF)	ES
Day 3: Wednesday 5 November		
0900-1230 (*Coffee break: 1030-1045)*	**NOWCASTING**	
	Nowcasting: • Improved observation of real time events • Improved lead time of convective events • Improved indication of where systems are moving towards	EdC
1230-1400	***Lunch break***	
1400-1730 (*Coffee break: 1530-1545)*	How does this work in practice?	EdC
Day 4: Thursday 6 November		
0900-1230 (*Coffee break: 1030-1045)*	Live weather forecasting practical in small groups: • Nowcasting, feedback to larger group • Days 1-5 forecasting practical in small groups, feedback to larger group	ES, EdC, SL

1230-1400	***Lunch break***	
1400-1730 (*Coffee break: 1530-1545)*	• Nowcasting validation	ES, EdC, SL
Day 5: Friday 7 November		
0900-1230 (*Coffee break: 1030-1045)*	**FORECAST VERIFICATION**	
	Verification overview: • Concepts • Methods • Guidance forecast verification (Stephanie Landman)	LW
1230-1400	***Lunch break***	
1400-1600 (*Coffee break: 1530-1545)*	Verification practical session	LW
1600-1700	Conclusion of Week 1, Completion of workshop questionnaire	Participants

ES Ezekiel Sebego
EdC Estelle de Coning
LW Laurie Wilson
WJ Winifred Jordaan
SL Stephanie Landman
EP Eugene Poolman

o.	Name	Surname	Country
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4	Ezekiel	Sebego	SA
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6	Eugene	Poolman	SA
7	Guido Manuel Gasper	Teca	Angola
8	Prithiviraj	Booneeady	Mauritius
9	Aliani Toiha	Saifou-Dine	Comoros
10	Estelle	de Coning	SA
11	Lucy Samvura	Motsi	Zimbabwe
12	Shamim	Mushi	Tanzania
13	Rivo Solomampionona	Randrianarison	Madagascar
14	Alice	Oabile	Botswana
16	Stephanie	Landman	
17	Mfutila	Muteba	DRC
18	Yobu Ezra	Kachiwanda	Malawi
19	Luis Adriano	Chongue	Mozambique
20	Oliver	Mudenda	Zambia
21	Dipuo	Tawana	SA
22	Abdoulaye	Harou	WMO

APPENDIX D

PRELIMINARY RESULTS OF THE RAPIDLY DEVELOPING THUNDERSTORM PRODUCT IN SOUTH AFRICA

Bathobile Maseko, Cassandra Pringle, Mornè Gijben

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ABSTRACT

The Rapidly Developing Thunderstorm (RDT) product was developed in Europe to use Meteosat geostationary satellite data to identify, classify and track thunderstorms. It is currently being implemented at the South African Weather Service to assist forecasters in identifying potentially hazardous convective cells, particularly for use in data sparse areas. It uses geostationary satellite Brightness Temperature thresholds along with Numerical Weather Prediction (NWP). It can display past, growing, mature and decaying storms using cooling rates to determine which phase the storms are in. The RDT will be verified for a severe storm case day of 6 September 2012.

KEYWORDS: Convective activity, Nowcasting, Geostationary Satellite, Brightness Temperature, NWP

1. Introduction

The nowcasting of storms is one of the challenging activities of meteorology. Accurate estimations of location and intensity of the initial convection, development and storm trajectories are very important for warning purposes (Pajek *et al.,* 2008). Radar and numerical weather prediction (NWP) model output are useful for nowcasting storms, but radar systems are not always available in many countries, such as many of those of the Southern African Development Community (SADC) region. Geostationary imagers provide an opportunity to devise an algorithm using infrared measurements to monitor convective cloud growth and nowcast convective initiation with up to 1-hour lead-time (Sieglaff *et al.,* 2010). Satellite data from the Meteosat Second Generation geostationary satellite can help to address this issue, as it has extensive coverage and is available in near real time (15 min temporal resolution) over the entire African region.

The Rapidly Developing Thunderstorm (RDT) software, included in the Satellite Application Facility for Nowcasting (SAF/NWC), is used to detect, track and discriminate between different convective cloud systems, ranging from mesoscale (200-2000 km) down to microscale.

The input data for the RDT includes five satellite channels, where the Brightness Temperature (BT) from the IR10.8 µm channel is compulsory for convective cell identification. The RDT also makes use of Numerical Weather Prediction (NWP) data from the Unified Model (UM) to improve the identification and classification process. The diagnosis of convective phases depends on BT thresholds specified in the RDT software (RDT documentation, 2012).

The software was recently installed on servers at the South African Weather Service (SAWS) and a first, preliminary case study was conducted to demonstrate the usefulness and performance of the RDT product. Visual evaluations using lightning data will be used to evaluate the performance of the RDT storm tracks.

2. *Data and Methods*

The RDT software can employ a number of datasets. The RDT uses a physical and statistical approach to detect and track thunderstorms. The basic methodology that is followed starts with identifying and tracking cloud systems. It then determines specific characteristics of the selected cloud systems to isolate only the convective storms. These convective storms are then classified as growing or decaying according to the cooling rates determined from the BT data (RDT documentation, 2012).

The detection phase of the RDT algorithm involves defining cells, which represent entire cloud systems within the IR10.8 imagery. Different features of these cells are identified using an adjustable BT threshold, which uses BT differences. These temperatures determine which category of storm is present (RDT documentation, 2012).

The tracking phase is conducted using a sequence of infrared images, where the RDT programme identifies the overlapping of cells in two consecutive images. Once a cloud system is detected, a tracking element of the RDT software allows one to follow the path of the detected cloud systems at different developing stages.

To discriminate between convective and non-convective cells, the RDT uses statistical methods. The statistical decisions are applied to cloud objects within the MSG satellite imagery to check the convective status of the elements. The NWP data are used to remove stable regions from being processed, which reduces processing time. An empirical rule is then used to declassify the objects using MSG and NWP data for pre-tuning of parameters. These empirical rules are based on cooling parameters for the triggering and development phases, and then cooling and global convective indices for the mature phase. The NWP models are used as an initial guidance before RDT attempts to diagnose the cloud elements, and this reduces false alarms.

RDT tracks are overlaid onto IR10.8 satellite images with the storms identified as past storms (in the preceding 15 minutes) and present storms are shown as either growing, mature or decaying (see Fig. 1).

For a preliminary evaluation, the RDT images are compared against lightning images using eyeball verification methods. A statistical evaluation will be done as more progress is made with the testing of the RDT.

3. *Results*

On 6 September 2012, an extensive surface trough was situated over the country and with upper-air cut-off low over the central interior as well as a high-pressure system east of the country. Conditions were favourable for convection initiation.

From Fig. 1, the RDT outputs different tracks for the storms on the 6th of September 2012. The magenta polygons depict mature storms, red polygons indicate growing storms; blue polygons indicate decaying storms and the green polygons show the locations of the storms at the previous time step. Storm cells categorized as growing (or mature) at 10:30UTC (Fig. 1a) did develop into larger (or larger mature) cells by 10:45UTC (Fig. 1b), showing that these cells were categorized correctly over the border of North West and Mpumalanga provinces. The areas in the RDT product images seem to be in good agreement with the weather reports in Lanseria airport of storm occurrence around 10:30UTC.

This case was just a preliminary evaluation. A more detailed evaluation of this case will be conducted using lightning locations to determine if the RDT product accurately depicts growing and decaying storms in the near future.

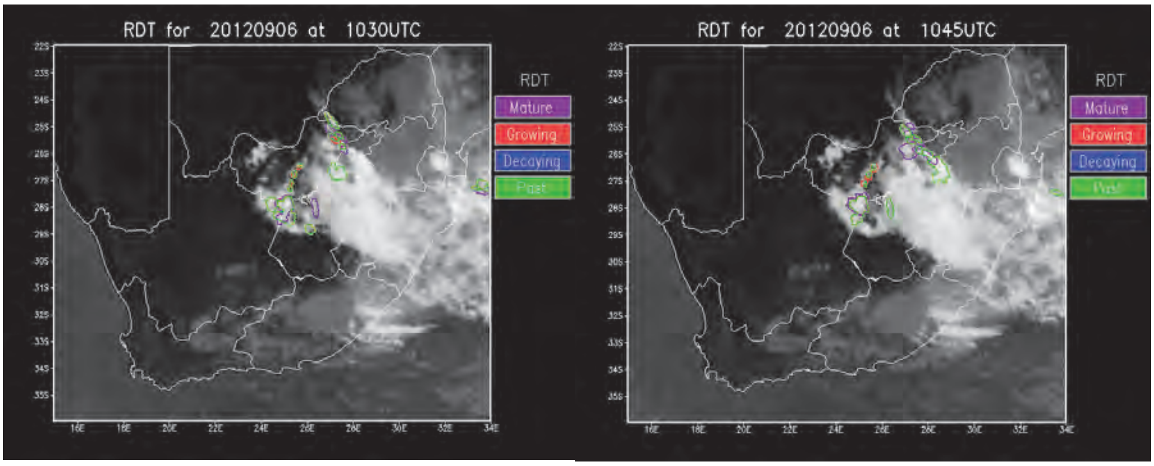

Figure 1: RDT output displays for a) 1030UTC, b) 1045UTC on 6 September 2012.

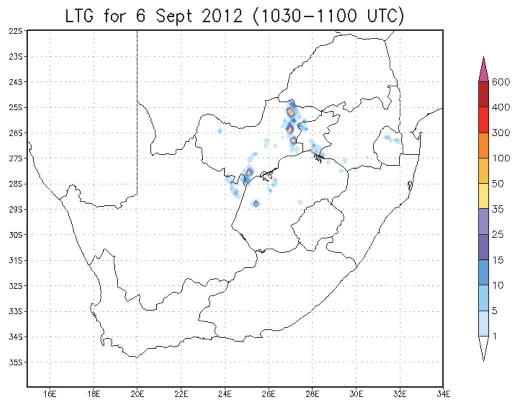

Figure 2: Lightning maps for 1030-1100UTC on 6 September 2012.

In Fig. 2 the lightning map depicts lightning that occurred in some of the areas where storms were detected. Most of the lightning strokes seen in Fig. 2 were in Gauteng, the North West Province and Free-State. Some lightning strokes were observed in Mpumalanga even though RDT did not indicate any storms in Mpumalanga (Fig. 1). From these visual evaluations, there seems to be a good correspondence between RDT cells and the lightning locations. It should also be kept in mind that this event happened in early spring and also early in the day. It is thus not a typical summer convection case where thunderstorms develop in the afternoon due to heat-driven convection, which usually causes more lightning.

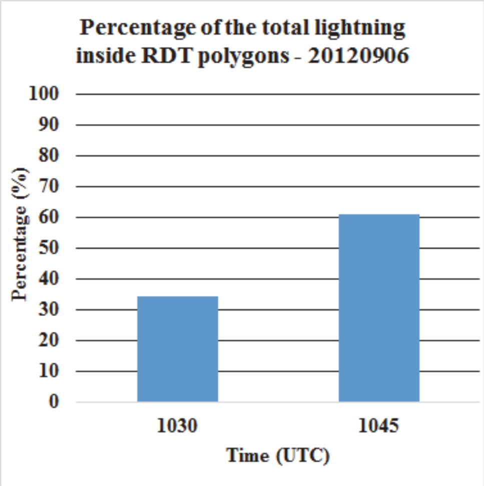

Figure 3: A graph of percentage of total lightning strokes, at each time step, located within the storm polygons.

Fig. 3 shows the total amount of lightning (as a percentage of total lightning available) for 30 minutes after the RDT, output captured within the RDT polygons. From Fig. 3, it can be seen that much of the lightning was captured within the storm polygons at 10:45UTC, and that the percentage increased with more mature storm cells being present.

4. Conclusion

The RDT uses input from MSG and NWP in order to classify, discriminate and track convective storms. RDT for this 6 September 2012 case did detect, track and discriminate different cloud systems. The occurrence of lightning maps showed lightning strokes in some of the areas where storms were located. From these preliminary results, this product will prove very useful in servicing the SADC region in nowcasting, identifying and tracking severe storms, especially for aviation purposes. More case studies will need to be considered to obtain a more thorough understanding of the RDT software and its performance.

5. References

Pajek, M., Iwanski, R., König, M., & Struzik, P. (2008). Extreme Convective Cases – The Use of Satellite Products for Storm Nowcasting and Monitoring, Proc. 2008 EUMETSAT Meteorological Satellite Conference, accessed 10 July 2013, https://www.eumetsat.int/cs/idcplg?IdcService=GET_FILE&dDocName=pdf_conf_p_s5_34_pajek_v&allowInterrupt=1&noSaveAs=1&RevisionSelectionMethod=LatestReleased

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Sieglaff, J.M., Cronce, L.M., Feltz, W.F., Bedka, K.M., Pavolonis, M.J., & Heidinger, A.K. (2010). Nowcasting Convective Storm Initiation Using Satellite-Based Box-Averaged Cloud-Top Cooling and Cloud-Type Trends, Journal of Applied Meteorology and Climatology, 50.

APPENDIX E

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Ms. Nokukhanya Kunene (NK)	SAWS: Scribe
Mr. Sandile Maphanga (SM)	CAMU: Manager
Ms. Adele Cloete' (AC)	COMAIR: OPS Control
Mr. Koos Pretorius (KP)	SACAA : Manager
Mr. Ntobeko Nkangane (NN)	SAWS: Unit Manager
Mr. Gavin Kova'cs (GvK)	SAA: Manager: Flight Dispatch
Mr. John Murray (JM)	AOC-AOA-BARSA: Manager
Mr. Francois Coetzee (FC)	ATNS: SM AI
Mr. Trevor Teegler (TT)	ACSA: Corp Specialist
Ms. Renee Muller (RM)	SAAF: S0 ATM
Mr. Johann Bierman (JB)	DoT: D:AA
Mr. Ruan Erasmus (RE)	Netsys: Web- Developer
Mr. Maluta Tshifaro (MT)	SAWS: Compliance Officer
Dr. Estelle de Coning (EdC)	SAWS: Chief Scientist

APPENDIX F

The Rapidly Developing Thunderstorm Product – results of case studies and future plans

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In the past year the Nowcasting Satellite Application Facility's software was installed and tested over the South African and southern African domains. The Rapidly Developing Thunderstorms product promised to be a very useful tool for nowcasting purposes, especially in regions where radar systems are not available or operational. If intense and/or severe convective systems can be detected using satellite (and numerical weather prediction model data) input, this could be beneficial for data sparse regions, such as Africa. The usefulness of the RDT product was validated using case studies from the recent summer periods. Both the quantitative as well as qualitative evaluations delivered favourable results. There is a good visual agreement between the RDT product and radar as well as lightning, while statistical scores show that RDT identified close to 70% of the moderate to intense lightning cells detected by the SALDN for 10 cases. Evaluations of RDT against WWLLN data indicates that HK ranged between 0.5 and 0.6 for 10 cases.

Keywords: satellite, numerical weather prediction models, thunderstorms, data sparse regions.

Introduction

Remote sensing tools, such as radar systems, lightning detection networks and satellites, play an important role in the nowcasting (0-6 hour forecasts) of thunderstorms (de Coning *et al*., 2011). Radar systems are the most important tool for nowcasting, since it provides continuous information on the size, shape, intensity, speed and direction of movement of individual storms (VAISALA 2010). Unfortunately many developing and especially least developed countries do not have access to radar or lightning systems. Alternative solutions, which do not require expensive ground-based systems, need to be utilized for the nowcasting of thunderstorms.

The Meteosat Second Generation (MSG) satellite has proved to be particularly useful in data sparse regions where the Infrared (IR), Visible (VIS) and Water Vapour (WV) single channels as well as combinations of the channels can be applied for the nowcasting of thunderstorms (de Coning *et al.*, 2011; Siewert *et al.,* 2010).

Satellite Application Facilities (SAF) are centres of excellence with experts in various fields, which aim to process satellite data to develop products for specific purposes. One of the products developed by the Nowcasting SAF is the Rapidly Developing Thunderstorm (RDT) product. The aim of the RDT product is to identify, monitor and track intense cloud systems and also to detect rapidly developing storm systems (NWC SAF http://www.nwcsaf.org).

The RDT product was recently implemented at the South African Weather Service (SAWS). MSG satellite data are used as initial input and numerical weather prediction model data from the local version of the Unified Model (UM) is utilised to enhance the RDT product. An advantage of the RDT product is that output is available every 15 minutes when the new satellite data are received.

Evaluations over the South African domain as well as the Southern African Development Community (SADC) region proved that the RDT product can be useful for the nowcasting of intense thunderstorms when used in addition to other ground based observations such as radar and lightning systems in South Africa (SA). In regions without radar and lightning detection systems, such as SADC, this product will certainly benefit nowcasting procedures.

Data and Methods

Qualitative, as well as quantitative, evaluations were performed on the RDT product over both the SA and SADC domains. Ten case study dates were used over the SA domain and 10 cases over the SADC domain. Visual evaluations between the RDT product and radar as well as satellite imagery were done for the SA region, while for the SADC region only satellite imagery could be used due to the absence of radar systems over the subcontinent. Quantitative evaluations were performed against lightning data from the South African Lightning Detection Network (SALDN) and the World Wide Lightning Location Network (WWLLN) over the SA and SADC regions, respectively.

The SALDN detects cloud-to-ground (CG) lightning with a detection efficiency of 90% over most of the country (Gijben, 2012). The WWLLN network, operated by the University of Washington, is a global ground-based lightning detection network, which detects very low frequency (VLF) radio waves and identifies lightning sferics (Collier et al., 2010). WWLLN is able to detect lightning occurrence globally by using only a few sensors since the attenuation of the signal for VLF waves is much lower (Collier et al., 2010). By using only a limited amount of sensors the detection efficiency is reduced quite significantly. Studies have shown that when the WWLLN network is compared to ground-based LDN (such as the SALDN) , the detection efficiency of WWLLN is approximately 10%, which means that only about 10% of all the lightning that occurred was detected by WWLLN (Virts et al., 2013).

Each of the lightning detection networks has its own limitations when evaluating the RDT product. The SALDN detects primarily CG lightning. This means that the intra-cloud (IC) lightning, which contributes more to the total amount of lightning, could not be used in the evaluation of the RDT product. Since the RDT product deals with developing and mature thunderstorms, the lack of IC lightning could have negatively affected the statistical scores since IC lightning dominates in these two phases of the storm. The WWLLN network only detects about 10% of the total lightning, which means that statistical scores will be negatively affected by the 90% of lightning strokes not detected by the network.

Every RDT time step was evaluated against lightning that occurred in the 30-minutes following the period of interest. For SA, the first evaluation method looked at the percentage of grid boxes containing more than 20 lightning strokes which fell inside the RDT polygons. The second method used a contingency table approach for grid boxes with more than 20 lightning strokes. The 20 lightning stroke threshold is used to consider only moderate to intense lightning cells in order to filter out all the weak lightning cells not associated with intense and/or rapidly developing thunderstorms. This approach was also followed by the validation reports of the RDT product (NWC SAF http://www.nwcsaf.org). Over the SADC region all grid boxes with one or more lightning strokes were compared to the RDT polygons.

Results

Figure 1 (a) illustrates the RDT and lightning and Figure 1 (b) the coinciding radar reflectivities on 9 October 2012 at 15:30 UTC. The storms indicated by the arrows show that the RDT polygons correlate well with the areas where large amounts of lightning as well as high radar reflectivities occurred. In the circled area, intense lightning and relatively high reflectivity patterns could be seen where the RDT did not identify a storm polygon. The RDT thus missed this storm.

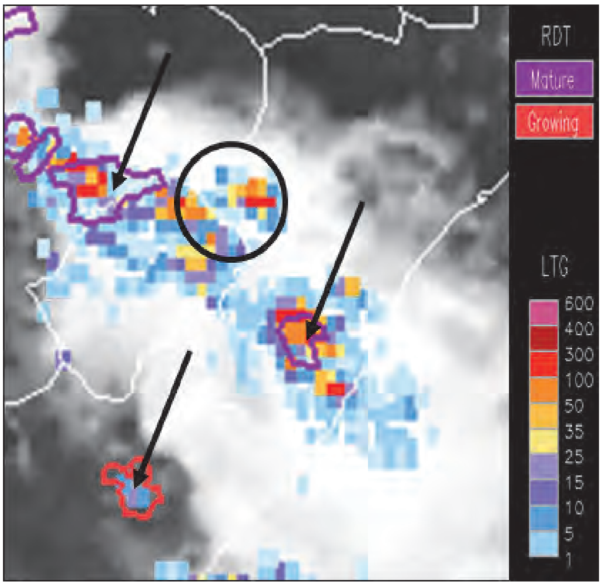

Figure 1. a) Visual comparison between the RDT product and the occurrence of lightning on 9 October 2012 at 15:30 UTC.

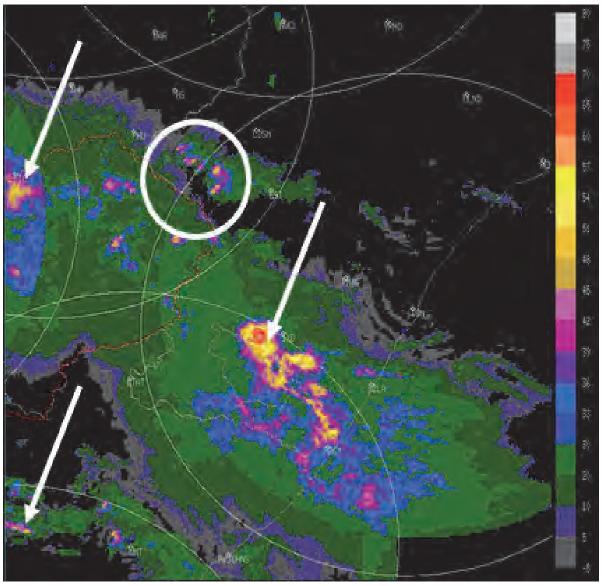

Figure 1. b) The radar reflectivity pattern which coincides with the RDT and lightning on 9 October 2012 at 15:30 UTC

Figure 2 shows another example on 9 November 2012 at 11:30 UTC where the (a) RDT could identify a storm in the KZN area (arrow), where no radar data were available (b). This illustrates the usefulness of this product in areas without radar systems or when radar systems are down. Intense lightning cells were also detected well with RDT and corresponds with the storms on the radar.

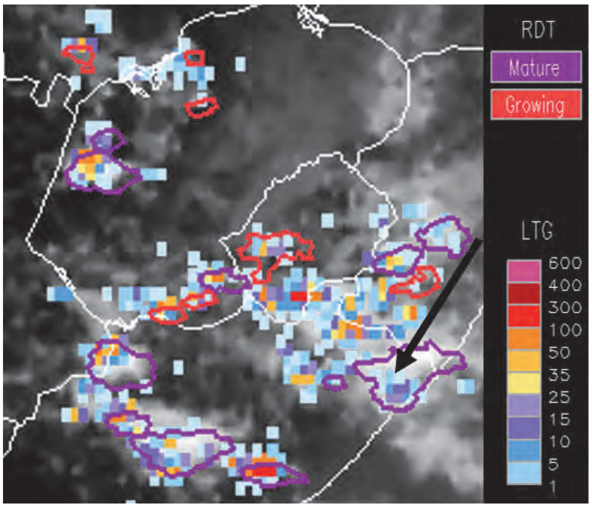

Figure 2. a) Visual comparison between the RDT product and the occurrence of lightning on 9 November 2012 at 11:30 UTC

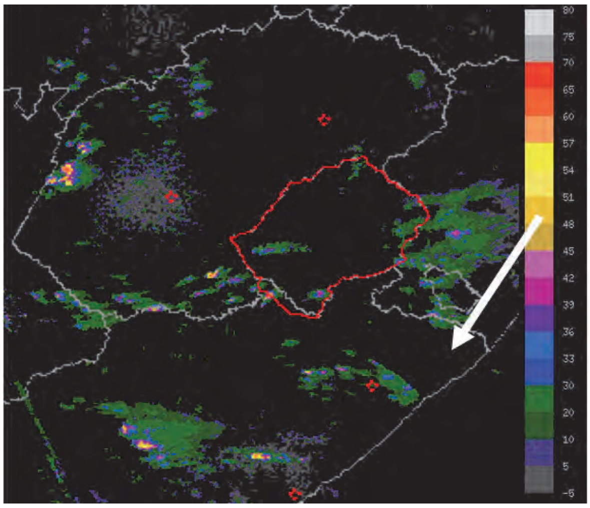

Figure 2.b) The radar reflectivity pattern which coincides with the RDT and lightning on 9 November 2012 at 11:30 UTC

Figure 3 shows (a) the RDT over the southern parts of Zimbabwe on 28 December 2013 at 12:00 UTC and (b) the TRMM rainfall for the 3hour period surrounding the RDT time (10:30 UTC – 13:30 UTC). It is clear that intense rainfall occurred in the same area where the RDT identified a mature storm indicated by the purple polygon.

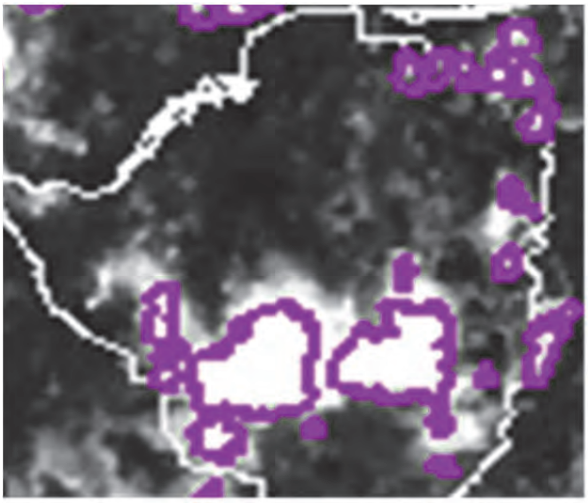

Figure 3. a) The RDT product on 28 December 2013 at 12:00 UTC

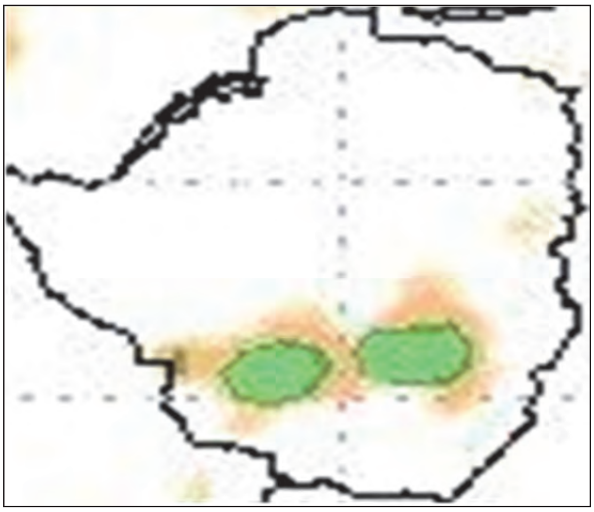

Figure 3. b) TRMM rainfall on 28 December 2013 from 10:30 UTC to 13:30 UTC.

In Figure 4 the validation of the RDT is shown. For the purpose of this more quantitative validation, the lightning intensity was divided into 2 categories – light lightning was defined as grid boxes with less than 20 strokes of lightning, while moderate to intense lightning was defined as more than 20 strokes of lightning per grid box in the 30 minutes following the RDT time. In Figure 4 the percentage of moderate to intense lightning is calculated which fell inside the RDT polygons. It is clear that RDT identified close to 70% of the moderate to intense lightning cells for the 10 cases.

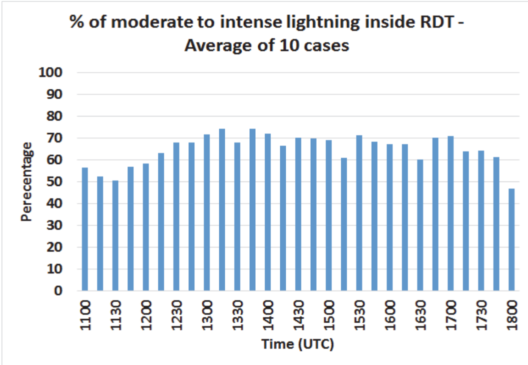

Figure 4. The average percentage of all grid boxes with more than 20 lightning strokes that occurred inside the RDT polygons over South Africa.

For the SADC region a contingency table approach was followed. It was not possible to use only moderate to severe lightning, since the amount of lightning captured by the WWLLN is already quite low. In Figure 5 the Hanssen-Kuiper scores (red line) show that the RDT product identified the lightning cells for the 10 cases reasonably well, especially if one considers that the WWLLN lightning network only detects about 10% of the lightning.

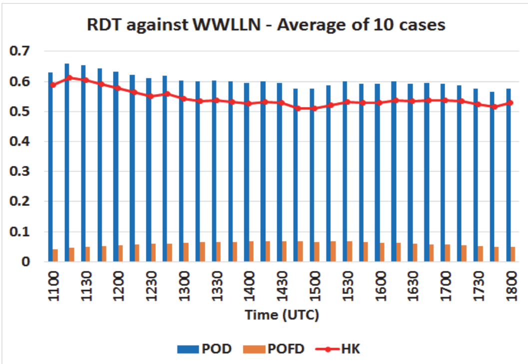

Figure 5. The average Probability of Detection (POD), Probability of False Detection (POFD) and Hanssen-Kuiper (HK) scores for RDT validated against WWLLN data over SADC for 10 cases.

Summary and future work

Both the qualitative and quantitative evaluations show that the RDT product performs quite well over the SA and SADC domain. Over SA the qualitative evaluations of RDT against radar and lightning images show excellent agreement while quantitative evaluations showed that RDT identified close to 70% of the moderate to intense lightning cells detected by the SALDN for the 10 cases. Over the SADC domain the quantitative evaluations of RDT against WWLLN data indicates that HK ranged between 0.5 and 0.6 for the 10 cases, which is quite good considering that WWLLN only detects about 10% of all the lightning.

All of the evaluations were performed with the 2012 version of the NWC SAF software. More recently the 2013 version of the software was made operational at SAWS in real time. Future work can include the testing of the new 2013 software and also to include and test the option of the RDT software to add lightning data in order to enhance the product.

Permission to Publish

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Initial results of Nowcasting SAF products tested over the South African domain.

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Nowcasting of severe weather events is not only important but also challenging. This challenge becomes even bigger when nowcasting has to happen in regions where observation data are sparse. Large parts of the world, especially the African continent, lack surface and remote sensing observations. Nevertheless, the need still exists to warn the public of pending severe weather events. Geostationary satellites and the use of Numerical Weather Prediction (NWP) models are sometimes the only tools available for the important task of issuing warnings to the public. The Meteosat Second Generation (MSG) satellite has proven extremely valuable for African countries to monitor weather events. When the MSG data are used in combination with NWP, a number of applications have been developed. The Nowcasting Satellite Application Facility (SAF) has developed several products to aid nowcasting. Examples of some of the products will be shown. Rain gauges and lightning data over South Africa will be used for validation.

Nowcasting in data sparse regions

Estelle de Coning

Nowcasting of severe weather events is not only important but also challenging. This challenge becomes even bigger when nowcasting has to happen in regions where observation data are sparse. Large parts of the world, especially the African continent lack observations systems – not only at the surface (rain gauges), but also remote sensing observation systems such as radar networks. Nevertheless the need still exists to warn the public of pending severe weather events. Geostationary satellites and the use of Numerical Weather Prediction (NWP) models are sometimes the only tools available for the important task of issuing warning to the public. The Meteosat Second Generation (MSG) satellite has proven extremely valuable for African countries to monitor weather events. When the MSG data are used in combination with NWP, a number of applications have been developed. The Nowcasting Satellite Application Facility (SAF) has developed several products to aid nowcasting. These include precipitation products, satellite based instability indices as well as identification and tracking of Rapidly Developing Thunderstorms (RDT). This software has been installed in South Africa and examples of some of the precipitation products as well as the RDT product will be shown. These products will be validated against rain gauges and data from the lightning detection network in South Africa to demonstrate how these can benefit nowcasting in data sparse regions.

Using the Nowcasting SAF products over South Africa and southern Africa to enhance nowcasting capabilities in data sparse regions

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Nowcasting of severe weather events is not only important but also challenging. This challenge becomes even bigger when nowcasting has to happen in regions where observation data are sparse. Large parts of the world, especially the African continent, lack observations systems – not only at the surface (rain gauges), but also remote sensing observation systems such as radar networks. Nevertheless, the need still exists to warn the public of pending severe weather events. Geostationary satellites and Numerical Weather Prediction (NWP) models are sometimes the only tools available for the important task of issuing warning to the public. The Meteosat Second Generation (MSG) satellite has proven extremely valuable for African countries to monitor weather events. When the MSG data are used in combination with NWP, a number of applications have been developed. The Nowcasting Satellite Application Facility (SAF) has developed several products to aid nowcasting. These include precipitation products, satellite based instability indices as well as identification and tracking of Rapidly Developing Thunderstorms (RDT). This software has been installed in South Africa and examples of precipitation products as well as the RDT product will be shown. These products were validated against rain gauges and data from the lightning detection network in South Africa. Over the SADC domain, it was validated against TRMM rainfall data and the WWLLN lightning networks, respectively. It will be shown how these MSG and NWP combination products can benefit nowcasting in data sparse regions over Africa.

APPENDIX J

Using the Nowcasting SAF products over South Africa and southern Africa to enhance nowcasting capabilities in data sparse regions

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Nowcasting of severe weather events is not only important but also challenging. This challenge becomes even bigger when nowcasting has to happen in regions where observation data are sparse. Large parts of the world, especially the African continent, lack adequate observations systems – not only at the surface (rain gauges), but also remote sensing observation systems such as radar networks. Geostationary satellites and Numerical Weather Prediction (NWP) models are sometimes the only tools available for the important task of issuing warning to the public. The Meteosat Second Generation (MSG) satellite has proven extremely valuable for African countries to monitor weather events. When the MSG data are used in combination with NWP, a number of applications have been developed. The Nowcasting Satellite Application Facility (SAF) software was installed in South Africa during 2014 using input from MSG and the local version of the UKMO Unified Model on a 12 km resolution. Examples of the Convective Rainfall Rate (CRR – PGE05) and the Rapidly Developing Thunderstorms product (RDT – PGE11) will be shown for the southern African domain. These products were validated against rain gauges (CRR) and data from the lightning detection network (RDT) in South Africa. Over the SADC domain, the CRR was validated against TRMM rainfall data and the WWLLN lightning networks. It will be shown how these MSG and NWP combination products can benefit nowcasting in data sparse regions over Africa.