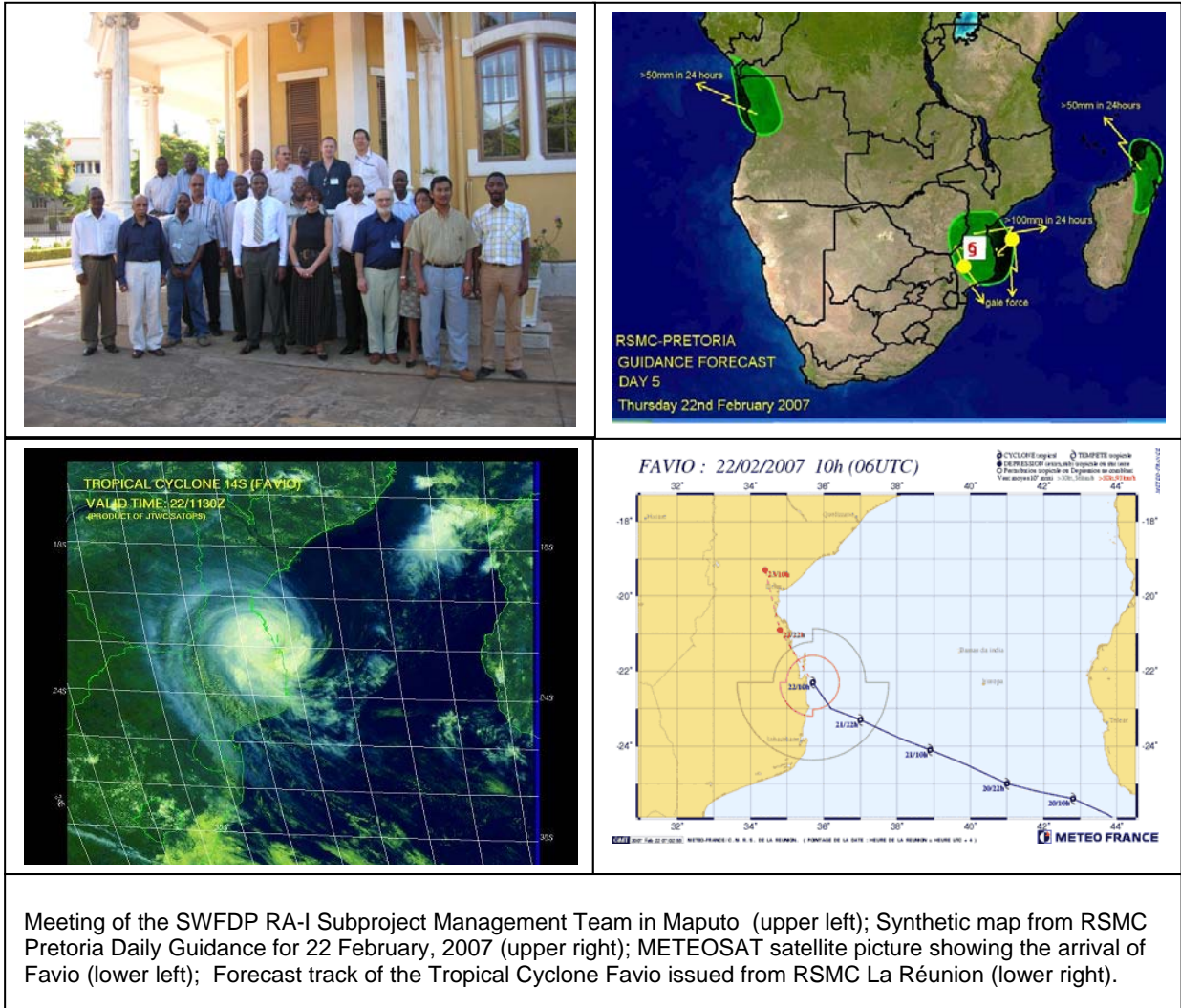


SEVERE WEATHER FORECASTING DEMONSTRATION PROJECT - REGIONAL SUBPROJECT IN RA I – SOUTHEAST AFRICA

FINAL REPORT

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Final Draft Version
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Meeting of the SWFDP RA-I Subproject Management Team in Maputo (upper left); Synthetic map from RSMC Pretoria Daily Guidance for 22 February, 2007 (upper right); METEOSAT satellite picture showing the arrival of Favio (lower left); Forecast track of the Tropical Cyclone Favio issued from RSMC La Réunion (lower right).

Foreword

Numerical Weather Prediction (NWP) systems have become increasingly relevant and indeed essential to the severe weather forecasting process, with a growing number and variety of sophisticated outputs, currently available from NWP producing centres, which could be beneficial to many National Meteorological and Hydrological Services (NMHS).

The Severe Weather Forecasting Demonstration Project (SWFDP) was organized as potentially a series of regional subprojects to explore and test the usefulness of the products currently available from NWP centres, or products which could be readily made available from current NWP systems of global and regional meteorological centres, with the goal to improving severe weather forecasting services in countries where sophisticated model outputs are not currently used. The principal focus of the project is on the phenomena of heavy precipitation that could cause serious flooding, and strong destructive winds.

The meeting of the CBS Project Steering Group held in Geneva (14-16 December 2005) recommended the following regional subproject most suitable for implementation in 2006, with the following participants:

- NMHSs: Botswana, Madagascar, Mozambique, Tanzania, Zimbabwe;
- Regional Centres: Pretoria, La Réunion, ACMAD;
- Global Products Centres: Exeter (Met Office UK), Washington (NCEP USA), and ECMWF.

RSMC Pretoria made available on a dedicated Web site and portal the required datasets from the Global Products Centres and output from its own limited area UM-SA12 model. Moreover RSMC Pretoria prepared and issued the RSMC Daily Guidance including descriptive text, maps and risk and probability tables, according to the agreed format, in order to help forecasters to prepare their own forecasts and warnings.

At the mid-term of the severe weather season, at a meeting of the Regional Subproject Management Team (RSMT) aspects related to Public Weather Services were introduced through the invitation of representatives of national disaster management and civil protection authorities (DMCPA).

By using the quarterly progress reports provided by the NMHSs, Quarterly Project Status Reports were prepared to summarize the occurrence of severe weather events throughout the quarter, to assess the utility and quality of the RSMC Daily Guidance, the relevance and the skill of the various NWP products relative to severe weather, the pertinence of the severe weather warnings issued by the NMHSs, and the improvement of the services they delivered to DMCPAs.

This final report, with the end of the experimentation phase, on 9 November 2007, is a synthesis of the four Quarterly Status Reports. It is a comprehensive evaluation of the organization and procedures carried out under the framework of the SWFDP. It attempts to describe the shortcomings as described by the participants and proposes improvements in order to ensure the sustainability of the Cascading Forecasting Process and the organization among the participating centres of the GDPFS, as well as to further enhance public weather services and other meteorological services, and to facilitate an extension of the system to other NMHSs of the southern Africa region.

1 – Introduction

1.1 – The Severe Weather Forecasting Demonstration Project (SWFDP) was designed to check the usefulness of the products currently available from NWP centres, or products that can be made available from current NWP systems, with the goal to improve severe weather forecasting services in NMHSs where sophisticated model outputs are not currently used. By using a Cascading Forecasting Approach this demonstration project was expected to provide greater lead-time for severe weather warnings and at the same time to contribute to capacity building in the area of weather forecasting and improving links with Disaster Management or Civil Protection Authorities (DMCPAs). The first SWFDP regional subproject demonstration was chosen to be in the geographical area of Southeast Africa, and its field period was from 6 November 2006 to 9 November 2007, chosen for the season of heavy rain and strong winds in the region.

1.2 – According to the recommendations of the CBS-XIII (2005) the goals of the SWFDP were defined by SWFDP Steering Group in Geneva (14-16 December 2005) as follows:

- to improve the ability of NMHSs to forecast severe weather events;
- to improve the lead time of alerting of these events;
- to improve interaction of NMHSs with DMCPAs before and during events;
- to identify gaps and areas for improvements;
- to improve the skill of products from GDPFS Centres through feedback from NMHSs.

1.3 – The implementation of the SWFDP Regional Subproject in RAI (South-eastern Africa) was decided by the Regional Subproject Management Team (RSMT) during the meeting held in Pretoria (South Africa, 31 July – 3 August 2006). The final report of this meeting is available at the following Web address:

http://www.wmo.ch/pages/prog/www/DPFS/Reports/SWFDP-RAI_Pretoria2006.pdf

1.4 – The Services and Centres that participated include the following:

- NMHSs: Botswana, Madagascar, Mozambique, Tanzania, Zimbabwe;
- Regional Centres: Pretoria, La Réunion, ACMAD;
- Global Products Centres: Exeter (Met Office UK), Washington (NCEP USA), and ECMWF.

1.5 – Role of the Global Products Centres. According to the organization of the Global Data-processing and Forecasting System (GDPFS), the Global Products Centres participating in the SWFDP provided the NMHSs and RSMC Pretoria with analyses and forecasts products issued from global models but also developed tailored products that proved to be very useful for severe weather forecasting.

1.6 – Role of RSMC Pretoria. RSMC Pretoria played a central role in the development of the Regional Subproject in RA I. It completely fulfilled the responsibilities of a RSMC with geographical specialization. It made available model output from its UM-SA12 Limited Area Model with coverage over southern Africa, as well as processed some output from global centres for use in the region. Moreover, RSMC Pretoria prepared and issued every day the RSMC Daily Guidance resulting from a careful analysis of the model data and products with special emphasis on the possibilities of severe weather events over the countries participating to the SWFDP, up to 5 days in advance. All this information has been made available on the RSMC Pretoria Web site and portal especially maintained in the framework of the SWFDP.

1.7 – Role of RSMC La Réunion. RSMC La Réunion provided RSMC Pretoria and NMHSs participating in the SWFDP with tropical cyclone warnings and other related information issued in the framework of its normal RSMC responsibilities and activities. RSMC La Réunion provided input to the project's reporting regarding Tropical Cyclone events during the demonstration period.

1.8 – Role of ACMAD. During the experimentation phase of the SWFDP, ACMAD has continued to provide its existing products to be included as input to RSMC Pretoria as part of the Regional Subproject. ACMAD concentrated its work on archiving data and products which can be used in the future for case studies.

1.9 – Given that the season when severe events of heavy rain and strong winds are likely to occur in this part of southern Africa is from November to the following May, it was decided to organize the preparatory training session in Pretoria just prior to the season, from 31 October to 3 November 2006, at RSMC Pretoria and to start the one-year field phase on 6 November 2006. Due to technical difficulties RSMC Pretoria's daily severe weather forecasting guidance products were archived only starting from 15 November 2006.

1.10 – At the mid-term of the severe weather season, a meeting of the Regional Subproject Management Team (RSMT) took place in Maputo, Mozambique (27 February – 2 March 2007). This meeting reviewed the status of the implementation and the ongoing work, refined the procedures necessary to perform the evaluation of the SWFDP Regional Subproject, and introduced aspects related to Public Weather Services through the invitation of representatives of national DMCPAs to participate with the Management Team. The final report of this meeting is available at the following Web address:

http://www.wmo.ch/pages/prog/www/DPFS/Reports/SWFDP-RAI_Maputo2007.doc

1.11 – The meeting agreed to focus the evaluation with respect to the following four aspects:

- RSMC Pretoria daily guidance,
- NWP products,
- Severe weather warnings issued from NMHSs,
- NMHS coordination with DMCPA, for improved communications and service delivery.

1.12 – The meeting agreed that each NMHS should prepare 4 quarterly reports and to include for each quarter a case study related to a severe weather forecasting episode. In order to assist NMHSs to produce these reports, the meeting agreed on the quarterly report structure and content. These quarterly reports, which contain all the details about the severe weather events recorded by the various participating countries as well as summary Quarterly Project Status Reports, were regularly published.

1.13 – An additional training workshop was conducted 29 October to 9 November 2007 at RSMC Pretoria, to further build the base of knowledge and skills for operational forecasters in NMHSs of southern Africa, and those of a few other African NMHSs.

2 – Information available for the evaluation

2.1 – This final report, which summarizes the results obtained at the end of the field phase of the SWFDP Regional Subproject in RA I (15 November 2006 to the 9 November 2007), is based on three main sources of information:

- the RSMC Severe Weather Forecasting Daily Guidance Product, or “RSMC Daily Guidance” bulletins issued by RSMC Pretoria, including probability tables for medium-range (days 3-4-5) and risk table for short-range (days 1-2);
- the quarterly progress reports provided by the NMHSs participating in the SWFDP Regional Subproject (Botswana, Madagascar, Mozambique, Tanzania and Zimbabwe);
- additional information obtained through documentation or discussions during the meeting of the SWFDP Regional Subproject Management Team in Maputo (February 2007), and other related correspondence and exchanges.

2.2 – This report has used as much as possible, wording provided in the reports and feedback from the participating centres, while for the sake of clarity and combining various information,

2.3 – The presentation format of the RSMC Daily Guidance, the event evaluation form, and the template of the quarterly progress reports were all adopted by the SWFDP Regional Subproject Management Team, and can be found in the document: “Principles for the evaluation of the SWFDP Regional Subproject in RAI”, available at the following Web address:

http://www.wmo.ch/pages/prog/www/DPFS/Reports/Evaluation_swfdp_pc.pdf

2.4 – By using the quarterly progress reports provided by the NMHSs, Quarterly Project Status Reports have been prepared in order to summarize the occurrence of severe weather events throughout the quarter and to assess the utility and quality of the RSMC Daily Guidance, the relevance and the skill of the various NWP products, the pertinence of the severe weather warnings issued by the NMHSs and the improvement of the services they deliver to DMCPAs. All available quarterly reports are posted at the following Web address:

<http://www.wmo.ch/pages/prog/www/CBS-Reports/DPFS-index.html>

2.5 – This final report is a synthesis of the Quarterly Project Status Reports. It gives a comprehensive evaluation of the organization and procedures carried out in the general framework of the SWFDP. It also tries to identify the shortcomings and to propose improvements in order to ensure the sustainability of the cascading forecasting process and the organization among the participating centres of the Global Data-Processing and Forecasting System, as well as to facilitate an extension of the system implemented for the project to other NMHSs of the same geographical region.

3 – Severe Events reported by the NMHSs

3.1 – Over the geographical area of the project (south-eastern Africa, including the surrounding waters of western Indian Ocean), the first quarter of the demonstration period (November 2006 to February 2007) was dominated by passages of tropical lows or tropical cyclones that effectively hit several countries involved in the SWFDP Regional Subproject and caused major damage. This type of meteorological situation is also favourable to the development of instabilities that support significant convective events (thunderstorms, convective complexes) resulting in high rainfall rates and flash floods, and destructive winds and gusts. Many of these severe weather related events were rapid onset and localized phenomena. The severe weather activity weakened during the second quarter (March to May 2007), which was drier than normal years over continental areas (over Botswana especially). During the third quarter (June to August) no severe weather fitting the SWFDP criteria occurred with one exception (strong wind in Maputo at the very beginning of the quarter. Dry weather also prevailed during the third quarter with scattered showers and

rainfalls at the end of September. The onset of the rainy season occurred toward mid-October: a few significant rainy episodes were only recorded in Botswana and Mozambique before the end of the experimentation period (9 November 2007).

3.2 – Many of the severe weather events were linked to the presence of tropical lows or tropical cyclones over or influencing the Regional Subproject's geographical domain. Indeed 8 tropical cyclones were identified and tracked by the RSMC La Réunion (Activity Specialization in Tropical Cyclone Forecasting) during the demonstration period, several of which affected Madagascar and Mozambique leading to episodes of heavy precipitation, flooding, and strong winds. These episodes during which the countries involved in the SWFDP were affected have been obtained with help of the Tropical Cyclones' tracks established by RSMC La Réunion (Figure 1), are given below:

Anita:	29/11/06 – 04/12/06,
Bondo:	21/12/06 – 28/12/06,
Clovis:	02/01/07 – 04/01/07,
Enok:	09/02/07 – 13/02/07,
Favio:	18/02/07 – 23/02/07,
Gamède:	19/02/07 – 06/03/07,
Indlala:	12/03/07 – 19/03/07,
Jaya:	04/04/07 – 08/04/07,
Extra-Tropical Low n° 15:	09/04/07 – 12/04/07.

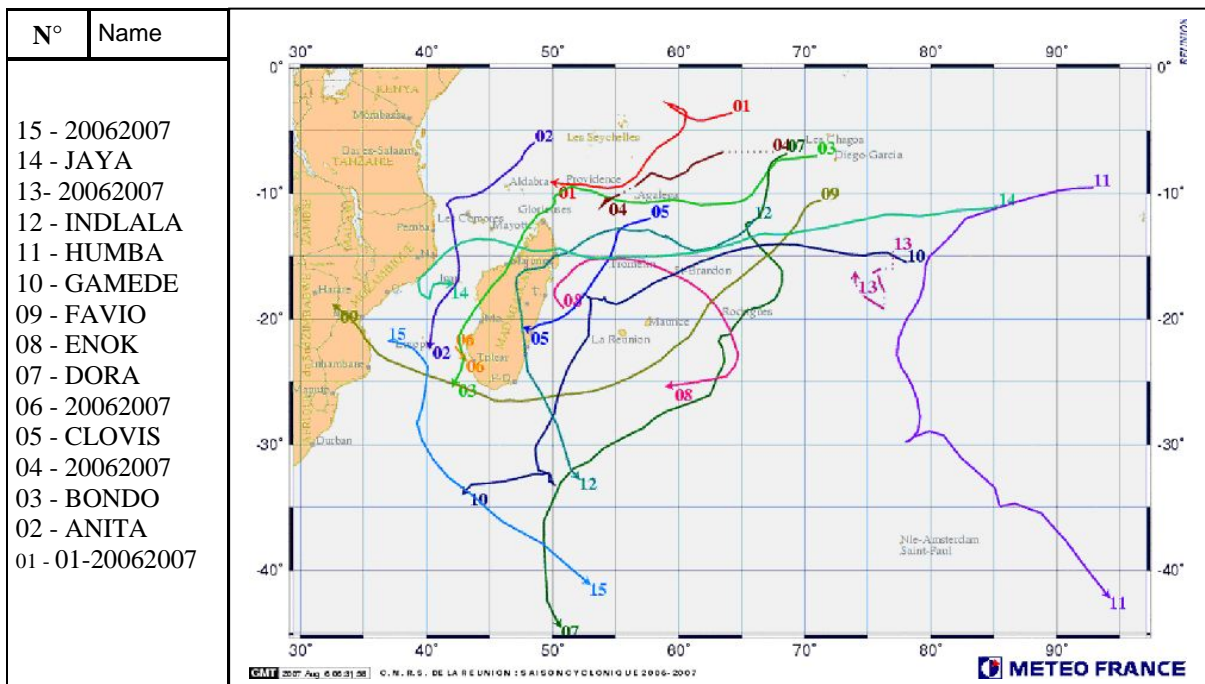


Figure 1 - Trajectories of tropical lows and tropical cyclones over the south-western Indian Ocean during the cyclonic season 2006-2007 (origin: RSMC La Réunion)

3.4 – The occurrences of severe weather events (heavy precipitation or strong wind) as recorded by the NMHSs participating in the SWFDP are given in Figures 2a to 2e. It is important to note that November 2006 corresponds to the period 15 – 30 November and November 2007 to the period 1 – 9 November. The black bars correspond to the number of

recorded or reported events (which can last several days) while the grey ones indicate the number of events indicated as associated with mesoscale/convective activity.

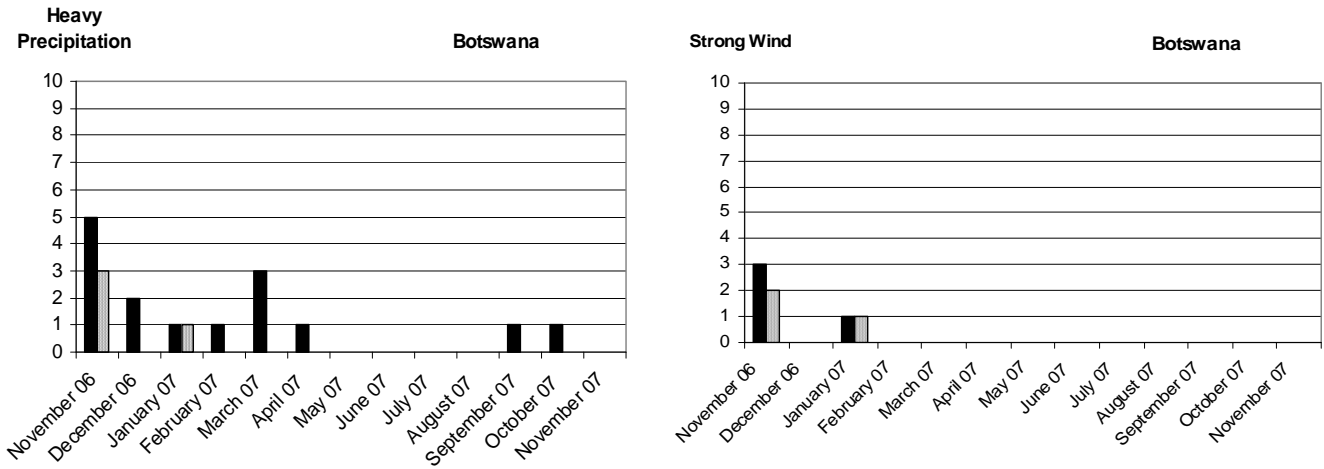


Figure 2a: Occurrence of severe weather events in Botswana.

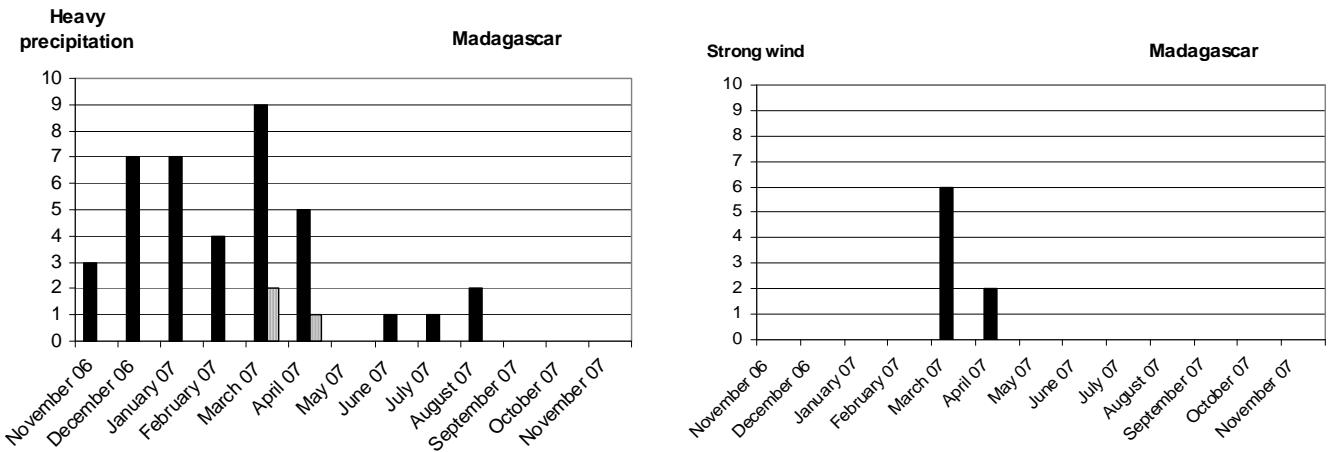


Figure 2b: Occurrence of severe weather events in Madagascar.

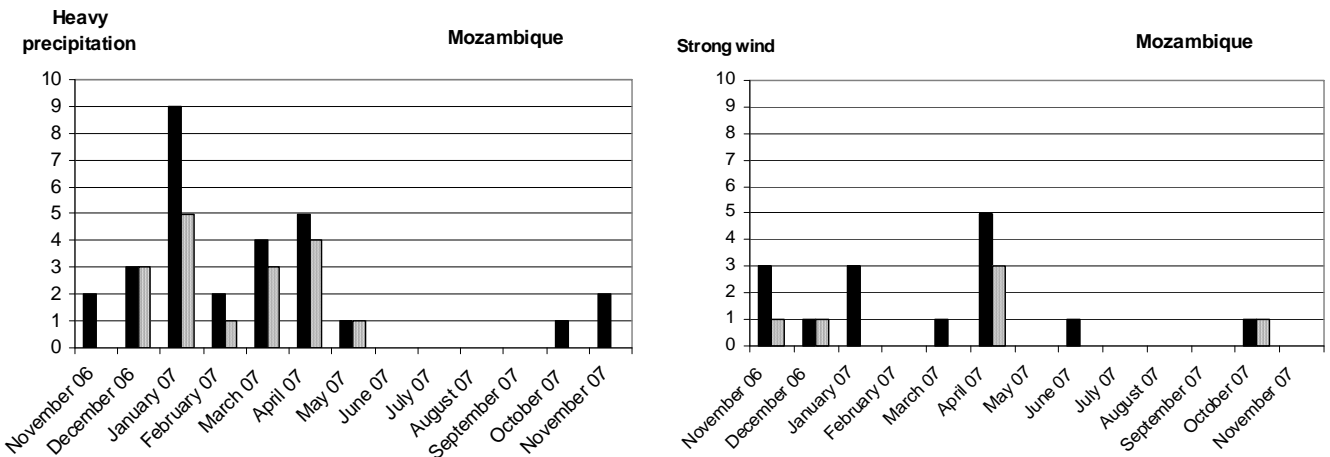


Figure 2c: Occurrence of severe weather events in Mozambique.

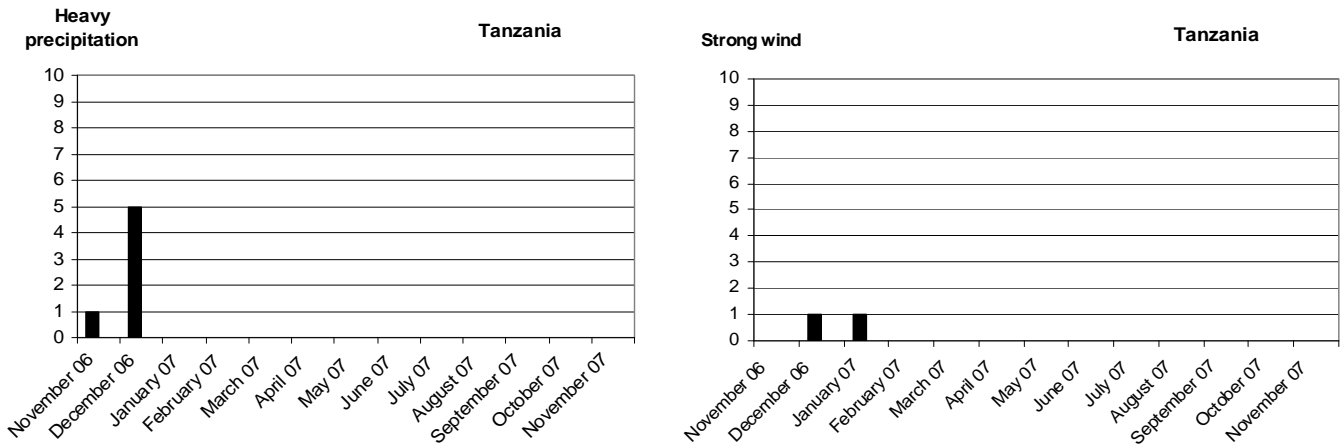


Figure 2d: Occurrence of severe weather events in Tanzania.

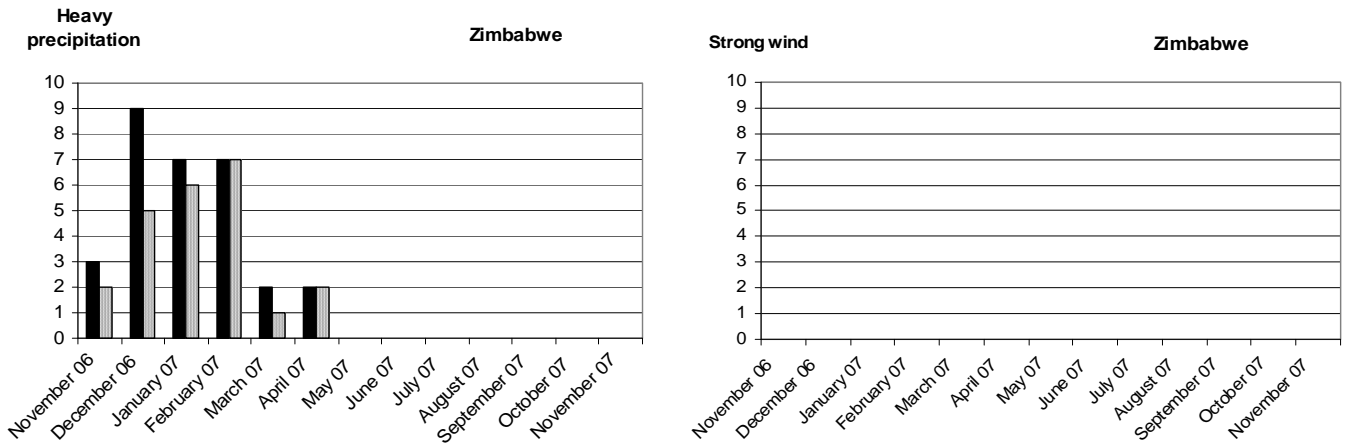


Figure 2e: Occurrence of severe weather events in Zimbabwe.

4 – Performance of warnings issued by the NMHSs

4.1 – A common way to evaluate the performance of a warning system is based on the “2 x 2” contingency table matrix including the number of justified warnings “A” (“hits”), the number of missed severe events “B”, and the number of false alarms, “C”. From such a contingency table, the POD index (Probability of Detection) is defined as the ratio of the number of hits by the total number of severe events, i.e., $A/(A+B)$; the FAR index (False Alarm Ratio) is defined as the ratio of the number of false alarms by the number warnings issued, i.e., $C/(A+C)$.

4.2 – Table 1 summarizes the number, the type of severe weather events that were reported, and the number of warnings issued by the NMHSs during the experimentation period.

Because there is a lack of confidence in the completeness of observational information for severe weather events, instead of computing a POD for Warnings, this table computes an index, "PW" (percentage of observed severe weather events when a warning was issued). The index named "PW" gives an indication of the ability of the NMHS to detect the event in advance, but does not account for warning-misses; PW equals POD if all warnings were hits.

NMHS	Total number of severe events	Number of Synoptic scale events	Heavy precip. events	Strong wind events	Heavy precip. and strong wind	Number of warnings	Index PW
Botswana	16	11	12	1	3	5	31 %
Madagascar	35	32	27	0	8	5	14 %
Mozambique	36	19	21	7	8	26	72 %
Tanzania	12	12	10	1	1	9	75 %
Zimbabwe	30	7	30	0	0	19	63 %

Table 1: Summary of the severe events which occurred during the experimentation period and performance of the warnings.

4.3 – It has to be emphasized that the interpretation of the figures of the Table1 has to be made with care and caution. Indeed it is difficult to define and determine objectively what is an occurrence of a severe weather event. Should it only be based on locally recorded amounts of precipitation and wind gusts? What if observational networks "under-catch" qualifying events? In addition, the decision to issue a warning not only depends on the anticipated intensity of the event but also on the anticipated impacts and consequences for life and property (to be potentially mitigated by using warnings). Moreover none of the NMHSs reported false alarms. For these reasons, taking into account the diversity of the practices and standards relative to the issuing of warnings, it is felt that the information base could be incomplete so that it would be difficult if not unjustified to evaluate the respective performances of the NMHSs based on these indices alone. Qualitative and anecdotal information could supplement the indices to assess performance.

5 – RSMC Pretoria Daily Guidance for Severe Weather Events

5.1 – The RSMC Daily Guidance prepared and issued by the forecasters at RSMC Pretoria consists of 2 bulletins: the first one focuses on short-range forecasts (day-1 and day-2), issued in the morning, while the second addresses the medium-range forecasts (day-3, day-4, and day-5). Each comprises a Discussion about forecasted evolution often supported by typical figures (model output or satellite image), a table giving for each day the risk or probability of occurrence of severe weather in the countries participating in the SWFDP, and a synthetic map indicating the critical areas for heavy rain or strong winds over the entire Southern Africa region (see example in Annex 1), with the day-1 map overlaid on a current satellite image.

5.2 – The demonstration period began on the 6 November 2006 but archived guidance from RSMC Pretoria is available from the 15 November 2006 only, due to start-up problems. The analyzed period is from the 15 November 2006 to the 9 November 2007.

5.3 – An examination of the forecasting of severe weather episodes during the experimentation phase is summarized by the short-range risk table and the medium-range probability table that comprise the Daily Guidance issued by RSMC Pretoria. The Tables 2-a and 2-b concern heavy precipitation. Table 2-a summarizes the number of days when medium or high risk were predicted in the RSMC regional short-range guidance and the Table 2-b summarizes the number of days when medium or high probability of occurrence were predicted in the RSMC medium-range guidance. Table 3-a and Table 3-b summarize the guidance for predictions of strong wind.

Number of days when medium or high risk of heavy precipitation were notified in the RSMC regional short range guidance				
Country	Day 1 Risk		Day 2 Risk	
	Med.	High	Med.	High
Botswana	3	0	1	0
Madagascar	63	47	58	40
Mozambique	51	16	39	9
Tanzania	46	3	30	4
Zimbabwe	16	5	7	3

Table 2-a.

Number of days when medium or high probability of heavy precipitation were notified in the RSMC regional medium range guidance						
Country	Day 3 Probability		Day 4 Probability		Day 5 Probability	
	60 %	80 %	60 %	80 %	60 %	80 %
	Botswana	2	0	4	0	3
Madagascar	58	30	61	10	43	5
Mozambique	29	4	28	1	20	2
Tanzania	29	0	15	5	7	6
Zimbabwe	9	2	7	2	1	0

Table 2-b.

Number of days when medium or high risk of strong wind were notified in the RSMC regional short range guidance				
Country	Day 1 Risk		Day 2 Risk	
	Med.	High	Med.	High
Botswana	0	0	0	0
Madagascar	56	23	39	28
Mozambique	27	6	21	5
Tanzania	2	0	2	0
Zimbabwe	2	1	1	0

Table 3-a.

Number of days when medium or high probability of strong wind were notified in the RSMC regional medium range guidance						
Country	Day 3 Probability		Day 4 Probability		Day 5 Probability	
	60 %	80 %	60 %	80 %	60 %	80 %
	Botswana	0	0	0	0	1
Madagascar	27	20	33	7	31	4
Mozambique	14	3	7	1	10	1
Tanzania	0	0	1	0	1	0
Zimbabwe	0	0	0	0	0	0

Table 3-b.

5.4 – An examination of these tables shows that heavy precipitation periods were predicted mainly over Madagascar and Mozambique and at a lesser degree over Tanzania and Zimbabwe; only low probability (risk) was predicted for Botswana. Concerning strong winds events, the situation is similar but the number of “risky” days is less than for days of heavy rain.

5.5 – The Figures 3a to 3e show for every month the number of days of high risk of heavy precipitation and strong wind that were predicted at short-range for the various countries involved in the SWFDP. The examination of these figures confirms the preceding results about the countries the most affected by severe weather events and indicate that the important period for heavy rain and strong winds is from November to the following May.

5.6 – The comparison between Figures 2a to 2e which summarize the reported occurrences of the severe weather events and Figures 3a to 3e, which summarize the number of high risk short-range prediction issued from RSMC Pretoria, show that there is a rather good qualitative agreement. However it is important to note that most of the severe events associated to mesoscale/convective activity in Zimbabwe were not predicted at short-range. As it will be explained, many of these severe weather events corresponded to rapid onset,

localized convective events that were not caught by NWP models nor taken into account in the RSMC Daily Guidance. This suggests a gap in the tools needed for very short-range forecasting.

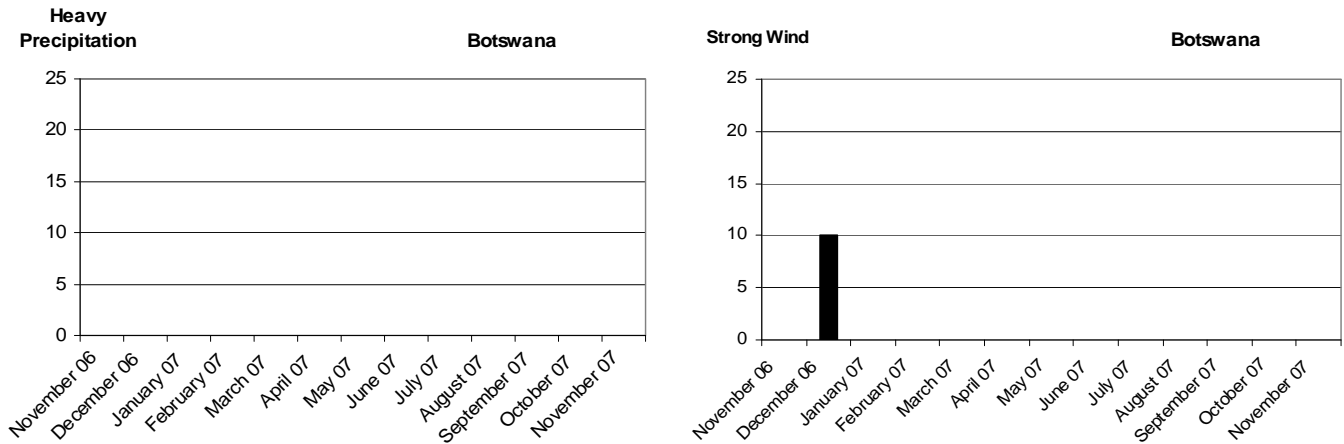


Figure 3a: Occurrence of risky days according to RSMC Pretoria Daily Guidance in Botswana.

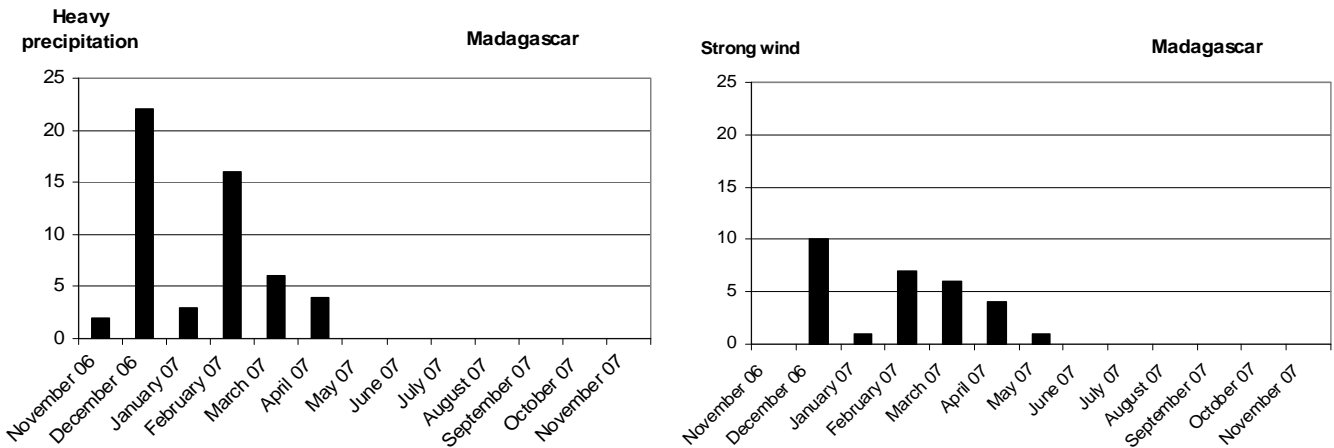


Figure 3b: Occurrence of risky days according to RSMC Pretoria Daily Guidance in Madagascar.

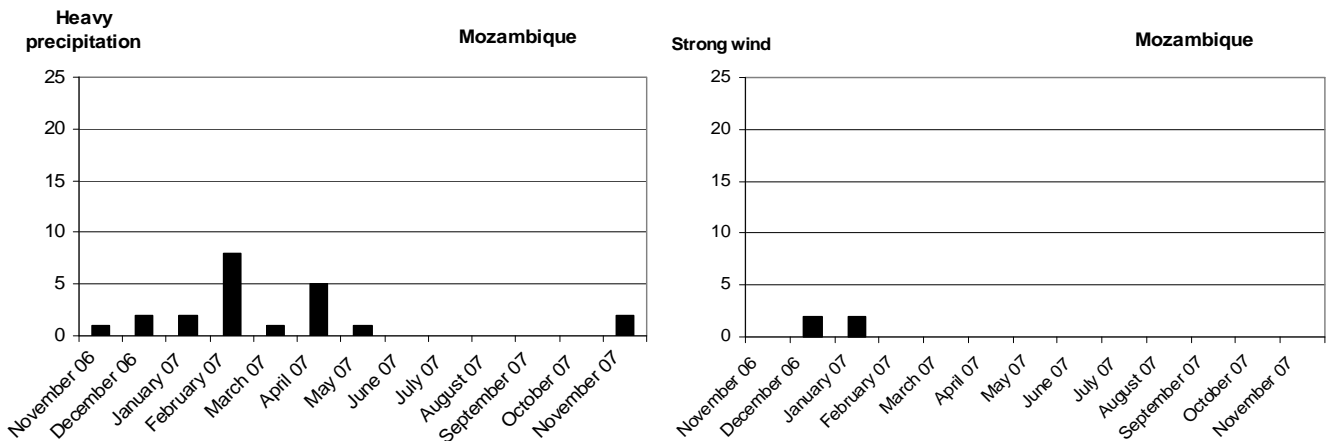


Figure 3c: Occurrence of risky days according to RSMC Pretoria Daily Guidance in Mozambique.

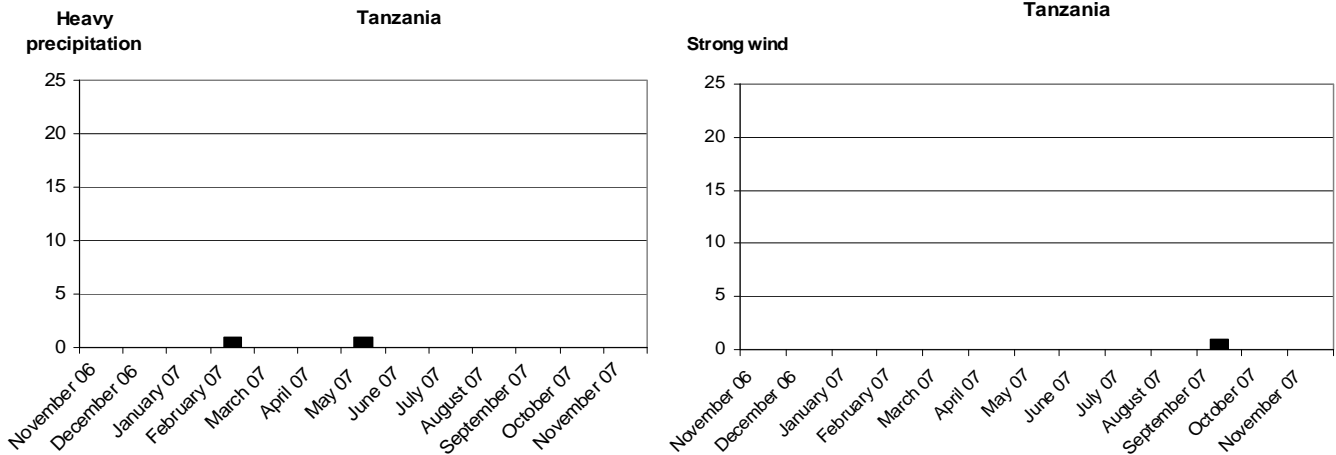


Figure 3d: Occurrence of risky days according to RSMC Pretoria Daily Guidance in Tanzania.

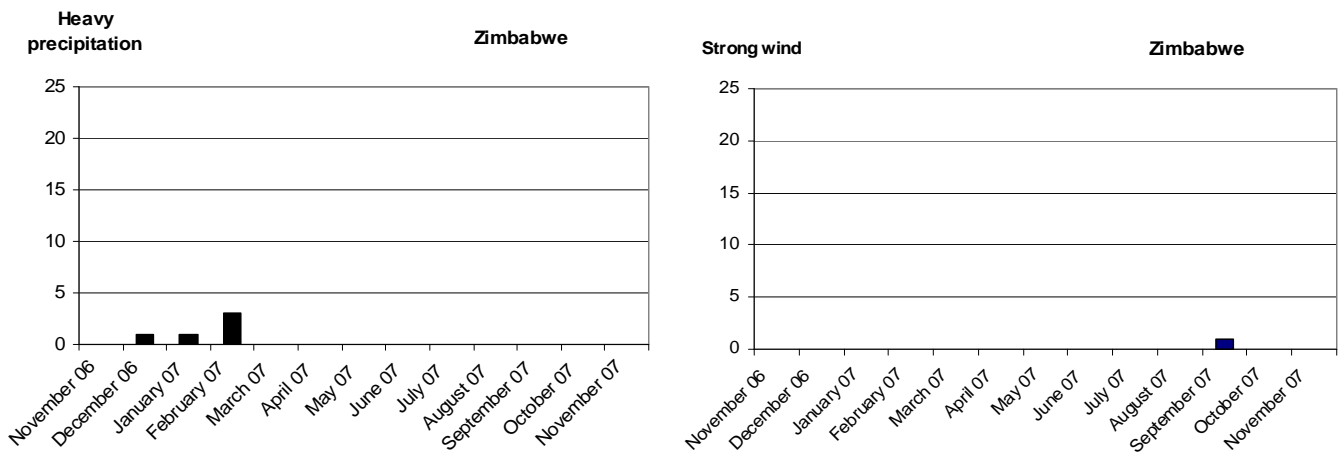


Figure 3e: Occurrence of risky days according to RSMC Pretoria Daily Guidance in Zimbabwe.

5.7 – The comparison of the severe events recorded by the NMHSs with the predicted information contained in the risk and probability tables issued every day by RSMC Pretoria enables us to assess the relevance of the RSMC Daily Guidance Product for the various countries by means of the contingency tables. These contingency tables allow us to compute for the various countries the POD and FAR indices (insofar as the relevant cells contain non-zero values) associated with the RSMC Daily Guidance. POD and FAR indices for short-range forecasts were calculated by assuming that medium or high risk forecast counts for an “alarm”. For medium-range an “alarm” is assumed to take place when the predicted probability is higher than 60%.

5.8 – Table 4a and Table 4b contain the POD and FAR indices corresponding to heavy precipitation predictions for short-range (day-1 and day-2) and medium-range (day-3, day-4, and day-5), respectively. The same indices corresponding to strong wind events are not given here: indeed these indices are not statistically significant or cannot be calculated because of the small sample of events. As emphasized earlier in this report regarding these indices, the POD and FAR indices given in Table 4a and 4b have to be interpreted with caution: A quick look on the Figures 2a to 2e show that the number of high risk predictions is very small for Botswana, Tanzania and Zimbabwe so that the value of the indices are not significant. In addition, logically one may expect that as and when the forecast range increases the POD decreases while the FAR increases. This behaviour is approximately observed for the indices that have been obtained for Madagascar and Mozambique and shows a certain consistency of the RSMC Pretoria Daily Guidance.

Country	Botswana		Madagascar		Mozambique		Tanzania		Zimbabwe	
Indices	D1	D2	D1	D2	D1	D2	D1	D2	D1	D2
POD	0.00	0.00	0.77	0.67	0.61	0.58	0.25	0.17	0.25	0.09
FAR	1.00	1.00	0.54	0.55	0.70	0.60	0.94	0.94	0.62	0.70

Table 4a: POD and FAR indices for day-1 and day-2, calculated according to the RSMC short-range guidance.

Country	Botswana			Madagascar			Mozambique			Tanzania			Zimbabwe		
Indices	D3	D4	D5	D3	D4	D5	D3	D4	D5	D3	D4	D5	D3	D4	D5
POD	0.00	0.00	0.00	0.55	0.50	0.29	0.30	0.20	0.10	0.00	0.00	0.00	0.16	0.16	0.03
FAR	1.00	1.00	1.00	0.60	0.56	0.63	0.73	0.79	0.86	1.00	1.00	1.00	0.55	0.44	0.00

Table 4b: POD and FAR indices for day-3, day-4 and day-5, calculated according to the RSMC medium-range guidance.

5.9 – The NMHS were asked to assess the usefulness of the RSMC Daily Guidance by giving a mark ranking from 1 to 4 (1 for “misleading”, 2 for “not useful”, 3 for “useful” and 4 for “very useful”, for each severe weather event). The results are given in the Table 5.

5.10 – Table 5 shows the near majority of the assessments that the RSMC Daily Guidance for forecasting severe weather events is useful. If we exclude convective/mesoscale events the percentage of useful to very useful guidance is further increased. This result is entirely consistent with the descriptive reports from the NMHSs confirming the ability of the available guidance to predict synoptic events, and their inability to predict localized, sudden onset type

of convective events. It is left to be further determined whether such NWP guidance could be used to assess the favourable environments for such convective events, even if the

Value of the Daily Guidance	Botswana	Madagascar	Mozambique	Tanzania	Zimbabwe
Total number of events	16	35	36	12	30
Unavailable information	1	21	0	3	0
Misleading	5(4c)	0	9(6c)	0	0
Not useful	2	0	2	2	6
useful	3	6	5	6	7
Very Useful	5	8	20	1	17
% Useful-Very useful	53% (73%)	100%	69% (83%)	78%	80%
<p>NOTES;</p> <ul style="list-style-type: none"> the row "unavailable information" corresponds to the events whose usefulness is not specified in the NMHS report or to the case when Daily Guidance was not timely, or unavailable (e.g. during the first quarter for Madagascar); in the row corresponding to "Misleading" the number of events corresponding to convective/mesoscale events is indicated within parenthesis; in the bottom row the percentage of "Useful-Very useful", is calculated by taking into account only those events whose information about usefulness of the guidance was provided; the percentages given within the parentheses are obtained when localized convective/mesoscale events were excluded. 					

convective cells themselves are not specifically predicted.

Table 5 : Feedback on the usefulness of the RSMC Daily Guidance according to reports from NMHSs.

6 – General Comments about the Products

6.1 – Usefulness of RSMC Daily Guidance

6.1.1 – As it clearly appears when looking at the numbers of the Table 5, the NMCs that used the RSMC Pretoria Daily Guidance are very satisfied with this product. It is a very useful tool to help forecasters in routine forecasting and in issuing warnings. It directly supports the extension of the lead-time of anticipating and prediction of significant meteorological events, and reinforces the forecasters' confidence in their own forecasts. It is important to note that this guidance is not limited to the process of severe weather forecasting but also useful for the day-to-day routine weather forecasting and in meteorological applications. As a single guidance product for the entire region of southern Africa, it also serves to harmonize the day-to-day forecasts of the NMHSs over the entire region.

6.1.2 – The short-coming identified is essentially directed to the lack of useful guidance information and tools to forecast localized strong winds or heavy precipitation events. This problem points to a lack of capability, which is a combined effect of the inability of the currently available NWP models to catch such small scale phenomena, inadequate observational data, and the lack of tools for very short-range forecasting.

6.1.3 – Based on reports from RSMC Pretoria, there is improvement to be made in the Daily Guidance, in particular in the narrative prepared by the senior forecaster for the Southern

Africa region. One aspect that was emphasized is to ensure the consistency between the Guidance prepared by successive forecasters.

6.1.4 – The RSMC Daily Guidance could be improved on a continuous basis on timely feedback routinely provided by the participating NMHSs to RSMC Pretoria. Over time and experience in analysing severe weather cases, RSMC Pretoria forecasters will gain in understanding and better recognize synoptic patterns that are associated with heavy rainfall and strong wind (and other meteorological hazards) over the entire southern Africa region. While an operational mechanism was put in place (shared 24/7 telephone, fax, and e-mail contacts), RSMC Pretoria reported that its senior forecaster on duty was rarely contacted by the NMCs. Perhaps a useful practice could have been to conduct a planned weekly communications test.

6.2 - Usefulness of SWFDP NWP/EPS Products and RSMC Limited Area Model: UM-SA12

6.2.1 – Every day, a large spectrum of deterministic and probabilistic NWP model products are made available on Web sites, accessible via Internet by the NMC's. It is clear that for most NMCs, the generally limited bandwidth of their Internet connection limits their access to the large variety of products, which are mainly images but also some data files. That is the reason why it is important and practical that the RSMC Daily Guidance points to the most relevant analysis and forecast fields and products to be scrutinized for a given anticipated severe weather situation. All these products are really useful for the forecasters even if the actual weather does not occur exactly according to that predicted by the guidance, especially for small scale potentially severe events.

6.2.2 – The deterministic products available from the global centres are generally well used to acquire an overview on the evolution of the synoptic patterns. Furthermore, medium-range probabilistic products, which provide indications of uncertainty, allow forecasters to increase their confidence in their diagnostics and in the forecasts, and to extend the forecasts' lead-times.

6.2.3 – Predicted precipitation fields and vertical structures (forecast tephigrams, stability indices) from the ECMWF's model are most used for the preparation of the RSMC Daily Guidance. It is also found that the ECMWF upper level wind fields handled the development and movement of tropical lows very well, even when predicting beyond three days. Similarly the NCEP GFS forecasts were found to be very useful and the convective instability indices are very much used and appreciated by forecasters.

6.2.4 – The 12-km resolution Unified Model (UM-SA12) run by the South African Weather Service performs well and helps forecasters identify potentially severe weather situations. A weak point is the lack of convective instability indices but such products are now computed in the model and will be made available soon. This model that became operational shortly before the commencement of the demonstration project is available on the RSMC Web site, and covers Southern Africa to the equator at 12-km resolution and is more and more used by the forecasters in the NMCs. The quality checks performed by the forecasters at RSMC Pretoria indicate that rainfall areas and times of occurrence are better forecast by UM-SA12 than any other NWP model used by RSMC for the first two days of the forecast period.

6.2.5 – The stability indices are generally useful for diagnostics, in conjunction with other atmospheric fields and structures, and help to delineate potentially convective areas where some local severe phenomena are likely to occur. Unfortunately they alone cannot clearly indicate the expected heavy rainfall amounts. Nevertheless, the availability of stability indices from analysis time to medium-range forecast periods permits the assessment of trends into the future, anchored on actual developments in the recent period.

6.2.6 – All ensemble prediction system products of the global centres were found to be useful and in particular the 50-mm per 24-hour, and the 20-knot threshold charts which help the preparation of the RSMC Daily Guidance. The forecasters are very satisfied with the clear information contained in the EPSgrams. Indeed this particular product provides the forecaster with a local prediction and outlook out to day-10, indicating well in advance the expected weather conditions, and is therefore really helpful for preparing medium-range forecasts. It has been mentioned that the name list of ten stations for each of the five countries does not facilitate rapid access to the product of relevant stations. Access would be more efficient if a regional map were provided with clickable station dots (hyperlinked to the EPSgram) that indicate (in the label) the location names where EPSgrams are available. It is also important to mention that the ECMWF Extreme Forecast Index (EFI) field for precipitation was very helpful to draw attention to potential severe weather areas.

Impact of SWFDP on South African Weather Service national operations

6.3 – Even though South Africa was not a target country for the SWFDP, the RSMC Pretoria guidance products did have a positive impact on the national warning service of the South African Weather Service (SAWS). The forecasters preparing the RSMC guidance products were also responsible for the daily national guidance of severe weather to forecasting offices in Durban, Port Elizabeth, Cape Town and Bloemfontein. Consequently the additional information used by them to prepare the RSMC guidance products also informed the local guidance products to these SAWS regional forecasting offices. The SWFDP NWP and ensemble information contributed very positively to the capacity building of SAWS forecasters in severe weather forecasting. The SAWS is now in the process of enhancing its own national guidance system by integrating it with the RSMC Pretoria guidance system. Additionally the SWFDP played an important role in the enhancement of the delivery of services by SAWS to comply with its role as RSMC.

7 – Project evaluation against SWFDP goals

The general goals of the SWFDP were adopted at CBS. The participating NMHSs were requested to indicate how the project has fulfilled each of the goals.

7.1 - To improve the ability of NMCs to forecast severe weather events: **Significantly Improved.**

All the participating NMHSs noted definite positive impact of daily use of SWFDP products (RSMC Daily Guidance, and NWP outputs) that allow forecasters to improve their understanding of the weather systems and phenomena and visualization of the meteorological situation and its evolution. The availability of the new products with the guidance from RSMC Pretoria helped forecasters to make more effective use of time and resources, and also to boost their confidence and reinforce their credibility in front of their various decision makers and customers.

7.2 – To improve the lead-time of alerting these events: **Significantly Improved.**

All the NMHSs recognized that the implementation of the SWFDP Regional Subproject has led to an increase in the lead-time for alerting their users and customers to anticipated important or severe weather events. The possibility to alert responsible authorities in some cases as much as 4 or 5 days (or more) in advance with increased confidence supports the dissemination of timely press releases and broadcasts and in turn to carry out earlier mitigation activities.

7.3 – To improve the interaction of NMHSs with DMCPAs before, during and after severe weather events: **Progressing.**

The SWFDP Regional Subproject has given the opportunity to strengthen the links between the NMHSs, and their respective Disaster Management (DM) Services and the Water Management (WM) Services, but the situation varies from country to country. In Botswana there is a lack of cooperation while there is real fruitful cooperation between the NMHSs and the other concerned services in Madagascar and Mozambique (where 2 meteorologists have been attached to the DMCPA during the rain season). In Tanzania and in Zimbabwe the situation is improving and the exchanges between NMHS, DM and WM became more frequent during severe weather periods. This increased cooperation also allowed the organizations to identify the gaps where improvements in the transmission of the information between these services and to the public are needed, and to point out the need to involve additional concerned services (health service, for example).

7.4 – To identify gaps and areas for improvements: **Significant forecasting gap Identified.**

All the NMHSs noted under this item the difficulty to obtain reliable heavy rainfall predictions (occurrence and amounts) for heavy precipitation (often underestimated) and to forecast strong destructive winds associated with convective events.

7.5 – To improve the skill of products from Global Centres through feedback from NMCs: **Case studies, problem identification in NWP, and feedback need to be increased.**

All the NMHSs have pointed out the weakness of the NWP model products to forecast the right amount of precipitation even when it originated from large scale processes. Of course this shortcoming is more marked for localized convective events associated with heavy precipitation giving flash floods, or damaging wind gusts. These phenomena are not presently well treated by the NWP models. Forecasters nevertheless could increase use of diagnostic methods, such as the stability indices, and increase use of satellite-based diagnostics to identify areas of high risks of localized deep or severe convection.

8 – Evaluation of public weather warnings

8.1 - Feedback from the public: **Progressing.**

The feedback from the public is not easy to assess due to a general lack of regular mechanisms of evaluation. Overall the NMHSs noted that the public gives positive feedback (when the formulation of the warnings is not too “technical”) and appreciates the increasing lead-time of the warnings. Nevertheless as they do not know what are the limitations of NWP they do not well understand why there are failures in predicting heavy precipitation of strong winds due to mesoscale convective type of events.

8.2 – Feedback from DMCPAs: **Progressing well.**

The feedback from the DMCPAs varies from country to country depending on the degree of cooperation these agencies maintain with their respective NMHSs. Generally national DMCPA noted improvement in the timeliness and the relevance of the information provided by NMHS. The feedback is not always positive because of the shortcomings encountered when localized storms were poorly predicted during the dry season. The improvement of the forecasts and the increase of their lead-time as a consequence of the SWFDP has given the opportunity to develop and improve cooperation between NMHSs and DMCPAs especially in the countries where the relationships were not well established.

8.3 – Feedback from the media: **Progressing.**

The media appreciated the increased lead-time of the warnings on severe weather events but remained sceptical about the capabilities of the meteorological science when events like very strong local destructive winds were not forecast. There is really a need to better explain the actual capabilities of a meteorological service relative to of a large variety of meteorological events and phenomena, with different scales, through seminars or meetings gathering people from the media and weather services (as it is planned in NMHS Mozambique).

8.4 – Verification by the NMCs: **Problematic area.**

The verification of the warnings by the NMCs is often problematic due to the difficulties in obtaining reliable observations and information about the occurrence of severe events, impacts and damage. It is often difficult to access and survey affected areas away from meteorological stations. In the framework of SWFDP the NMHSs have undertaken some systematic evaluation of the performance of their warning procedures in cooperation with the DMCPAs. This work must be continued to identify the weaknesses in the alerting process and to implement improvements, including the use of suitable verification measures.

9 - Conclusion

9.1 – Improved weather forecasting and warnings services

9.1.1 – The SWFDP has been a very positive contribution to improved weather forecasting and warning services, in several aspects. Through implementing the “Cascading forecasting process”, better use of existing medium-range deterministic, probabilistic, and high-resolution NWP products, and supported by the newly implemented severe weather forecasting daily guidance provided by a designated RSMC, these services have significantly improved in quality and usefulness, including increased lead-times of forecasts and warnings, and increased confidence of the forecasters. Improvements are sustainable if the elements, established through the SWFDP are maintained. Letters from Members (Permanent Representatives with WMO), as well as one from the Meteorological Association of Southern Africa, have been received, recognizing the important successes of the SWFDP, and requested the continuation of the project’s elements and benefits into the future. These letters are found in Annex 2.

9.1.2 – A crucial and pivotal feature to realizing improvements is the role of the designated regional centre: RSMC Pretoria. The RSMC Daily Guidance is unanimously appreciated by forecasters: it points them directly to the more relevant NWP products of the day for the weather situation, refers to the most important features, and reinforces their own thinking, skill, and confidence. As well, the forecasters used the SWFDP to incorporate into practice, in real-time what they learned during training sessions (conducted twice for the project), thereby gaining real on-the-job experience with the various products. The Daily Guidance acted as a technical preview of the anticipated severe weather situation for the region, by country, available every day at fixed times, for example to assist the forecaster at the beginning of a work shift. All the NMHSs involved in this project emphasised the positive contribution of the support implemented at RSMC Pretoria.

9.1.3 – One very important facility implemented and maintained by RSMC Pretoria is its dedicated Web site that acts as a single portal for the SWFDP forecasters to access all relevant Web pages for NWP products, as well as the RSMC Daily Guidance and RSMC's high-resolution NWP products windowed on Southern Africa. This single-point-of-entry streamlines the forecasting process for the forecasters, in a very practical way.

9.1.4 – The forecasters benefited from the real experience with the new NWP and EPS products, which helped increase their own confidence; they cannot now really imagine performing their forecasting duties without the components that SWFDP has brought. They are recommending the continuation of the system established during the demonstration.

9.1.5 – One of the goals of the SWFDP is to strength links between the NMHSs and their respective disaster management and civil protection authorities (DMCPA), including flood and water management services. While some progress has been mentioned in several countries, the process of building links can take a long time depending on the existing national organizational structures. Nevertheless, it is important to stress the necessity to have discussions with all the users concerned by severe weather events, to clearly understand and define information they need, and the most efficient way to alert them in a timely fashion. Moreover, the implementation of a regular evaluation programme supports regular assessment of the efficiency and effectiveness of the alerting system and to identify areas for improvement. Evaluation should take into account the lead-time of the warnings, the transmission of the information to the concerned users and stakeholders, the mitigation actions, and the feedback from the end users during and after the event. NMHSs need to continue to work with the DMCPAs to ensure that the warning services meet the requirements, and to sustain and continue to improve these services beyond the SWFDP demonstration.

9.2 – Effectiveness of the SWFDP's process

9.2.1 – The SWFDP, through this experience as the first demonstration, showed how effective it was as a process for accelerating the transfer and implementation of exiting and proven NWP technologies and products, such as EPS-based outputs. Existing NWP products, some of which have been available from the global centres for many years but were rarely seen in developing countries, became the products of preference for these forecasters (e.g. probabilistic information) over the one-year experience. The demonstration project implemented a basic working framework, management and operational, that facilitated the Cascading Forecasting Process. The basic framework is now in place in southern Africa to be further exploited by the region, for future demonstrations and implementations. The one-year demonstration has also provided region-specific information about the status of different components of the end-to-end system of forecasting and warnings services, where and what are its shortcomings and where the most important ones require earliest attention.

9.2.2 – The SWFDP as a process has laid the way for a quality assurance and technology transfer mechanism within a subregion. The management team, representing participating countries and the RSMC, would be the group that evaluates and recommends all changes to the operational system. Any proposal for a new or improved component would have to be agreed to by the management team, and then undergo a period of demonstration and assessment, as well as any additional adjustments, before operational implementation. This approach would assure the quality of the operational system, at the same time as advancing the production system.

9.2.3 – This demonstration project was intended to first rapidly establish a well functioning GDPFS component, including the system for making global NWP products available, high-resolution NWP production, and the RSMC Daily Guidance and functions. NMHSs were effectively backed by global and regional centres, with the integrating and synthesizing role of the RSMC. Once in place, the project invited participation of Public Weather Services, and representatives of civil protection organizations, thereby connecting the improved severe weather forecasting process, with the provision of important meteorological services by NMHSs. This approach permitted the orderly management of improved services.

9.2.4 – This first regional subproject is a valuable experience to improve the overall concepts of the SWFDP for future implementations.

9.3 – Issues and challenges – NWP

9.3.1 – Despite the success the SWFDP in improving the NMHSs in forecasting severe weather events, the available NWP products did not accurately or reliably predict rainfall amounts, or strong wind events associated with localized convective activity. The various charts of indices of convective activity only delineated areas where strong convection could likely occur. Forecasters could not use the NWP predicted rainfall (i.e. QPF) alone to decide whether to issue warnings; instead they have to interpret the various model fields and use their own experience and judgement of these products to decide whether the meteorological pattern is likely to lead to severe weather event.

9.3.2 – Notwithstanding, the set of products could be enriched with additional fields such as convective instability indices issued from the UM-SA12 fine mesh model, or streamlines derived from model fields for indicating convergence zones, which proved to be helpful to identify areas of heavy precipitation and strong wind.

9.3.3 – In relation to the difficulty in forecasting localized sudden-onset convective activity which was the general experience during SWFDP, limited area meso-scale NWP models continue to evolve, especially with improving data-assimilation and blended methods with observational systems to be able to catch reliably very small scale developments. This describes weather forecasting in the Very Short-range (forecasting up to 12-hours ahead) in particular of localized convective events. Within this range, forecasting up to 2 hours ahead, “nowcasting”, usually imply the use of radar and satellite imagery. In this context, in a region of few radars, it is important to point out a product developed by the Co-operative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin: CIMSS use Meteosat-7 and perform cloud-drift winds as well as post-processed parameters such as low-level vorticity, low-level convergence and upper divergence. This product, updated at 3-hourly intervals is available on the CIMSS Tropical Webpage and proved to be very useful at RSMC Pretoria.

9.4 – Issues and challenges – telecommunication

9.4.1 – Some NMHSs reported difficulties to access NWP model outputs (images) through the RSMC Pretoria Web portal. Even local problems with email and power supply were mentioned. It is therefore important to secure the power supply to the computers and essential equipment in order to assure an uninterrupted capability round the clock.

9.4.2 – Since the products of the various Centres are made available from the RSMC Web portal, the efficiency of the Internet connectivity is a key requirement of the working environment; in particular, a broadband access is essential to really benefit from the large variety of the available products. At the same time, other possible distribution methods such

as Eumetcast broadcast have to be investigated to make the most relevant SWFDP products available.

9.5 – Issues and challenges – feedback for improved products and guidance

9.5.1 – Data and information regarding the actual occurrence of severe weather events is crucial for verification of warnings and establishing the necessary future improvements of the forecasting and warnings system. It was often mentioned that observational data in affected areas and information on damage and impacts were generally sparse or not available.

9.5.2 – While the SWFDP called for enhanced interactions among the operational centres, ongoing feedback and interactions in real-time very rarely or did not occur. Operational contact information (telephone, fax, e-mail) were exchanged as part of the implementation. Perhaps, it would be useful to carry out regular (weekly) communication tests, as a facilitating measure.

9.5.3 – It is necessary to improve the feedback from NMHS. After each observed (or forecast) severe event, it was difficult to obtain from the NMHS the required Event Evaluation Form designed by the Regional Subproject Management Team to be used to regularly assess the usefulness and quality of the RSMC Daily Guidance issued by RSMC Pretoria. The Management Team agreed that its simplified format should help gather relevant information about the individual events. The lack of such returns could indicate that: 1) during severe weather periods forecasters are simply too busy to fill in immediately such event evaluation forms; 2) the verification of the guidance, forecasts and warnings against actual occurrence of severe weather is often difficult because relevant meteorological observations or damage reports are not available.

9.5.4 – Timely real-time feedback to RSMC Pretoria is essential to improve the skill of the senior forecasters who have to prepare the RSMC Daily Guidance for the entire southern Africa region. Moreover it is only with this information that it is possible to evaluate objective measures of quality (FAR and POD), and their trends over time. It was suggested that forecaster at NMCs should contact the RSMC prior to issuing forecasts and warnings during anticipated severe weather situations, to discuss and confirm the latest data and information available. This did not occur.

9.5.5 – As part of every quarter's report of the SWFDP, the NMHSs were requested to prepare case studies and to archive the complete documentation (relevant NWP fields, satellite images, warnings, and observations). In principle this material is very important for modellers and developers to use them as test cases, to run improved models, and as well be used to for training forecasters. So far, little use has been made of these case studies, although they serve as important illustrations of severe weather forecasting in this region.

9.5.6 – A number of relevant datasets have been archived by RSMC Pretoria and ACMAD and are now available to NHMSs for developing detailed case studies. The description of the ACMAD archives and the procedure to retrieve them are available at the following Web address:

http://www.wmo.ch/pages/prog/www/DPFS/Reports/Final_Report_ACMAD.pdf

10 – Reference

10.1 – Abbreviations that have been used in conjunction with the SWFDP and appearing in this report are explained in **Annex 3**.

10.2 – A list of the available documentation related to the implementation and status reports of SWFDP Regional Subproject RA I are found in **Annex 4**.

11 – Acknowledgement

This report has been made possible by the inputs of regular reports and other communications from the participating centres of the SWFDP, including global products centres, Regional Centres, and National Meteorological Centres of Botswana, Madagascar, Mozambique, Tanzania, and Zimbabwe. Encouragement and guidance was provided by Dr John L. Hayes, former Director of the World Weather Watch Department.

ANNEXES

Annex 1: Example of the RSMC Pretoria Guidance.

Annex 2: Letters received from Permanent Representatives with WMO

Annex 3: List of Abbreviations

Annex 4: List of the available documentation related to the implementation and reports of SWFDP Regional Subproject RA I