CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The De Aar BSRN system became operational on 29 July 1999. Since that day, through the sustained operational activities of the system, a continuous learning process towards establishment a perfect operational system was initiated, some of which precipitated in this dissertation. Although the system can now be regarded as fully operational, it is certainly not perfect, and the recommendations verbalised in this final chapter should be seen as fruits of the development process and honest pointers for a better way forward. It is the wish of the author that they be considered for implementation as capacity (resources and time) permits.

6.1 MAIN ACHIEVEMENTS

The South African BSRN station at De Aar, number 40 in the global network, was established in 1999 using WMO-donated instrumentation and the minimum funding from local sources. A combination of local expertise, as well as generous help from abroad in the form of ideas, encouragement and fragments of program code, aided in the process.

The station had several setbacks. The most severe setbacks were caused by lightning strikes that disabled the on-site computer on three occasions, i.e., February 2000, September 2001 and December 2002. Additionally, numerous power failures occurred, the majority of which could be filled in by the Uninterrupted Power Supply (UPS) without disruption of the tracker and ventilators. There were, however, a number of power failures that exhausted the UPS and left the system stranded for several hours, resulting in the rejection of all data for that period, except global (DSGL2) radiation.

Notwithstanding these setbacks, a relatively small number of data points overall were lost, as illustrated in Figure 6.1. This can be attributed mainly to timely reporting of system failures by site personnel, but also to a good design of data storage capacity in the logger as discussed in Section 3.1.6. This design allows roughly one week's data to be accumulated in the logger before being overwritten by fresher data. The time window of one week allows for timely execution of plans to repair the system and, since station establishment, resulted in at least one occasion when not a single datapoint was lost, despite a computer failure of almost a full week.

Apart from lightning strikes and power failures, the other reasons for data loss are all “natural”, viz., due to maintenance. This includes daily and monthly radiometer maintenance and the six-monthly pyrheliometer calibration and global/diffuse exchange. Datapoints lost in this way, are the trade-off for good data for the rest of the time and is, in fact, a small price to pay.

The number of missing datapoints for the three-year evaluation period of Section 4.3 (June 2000 to May 2003) is shown in Figure 6.1 as a time-series graph of monthly percentage values.

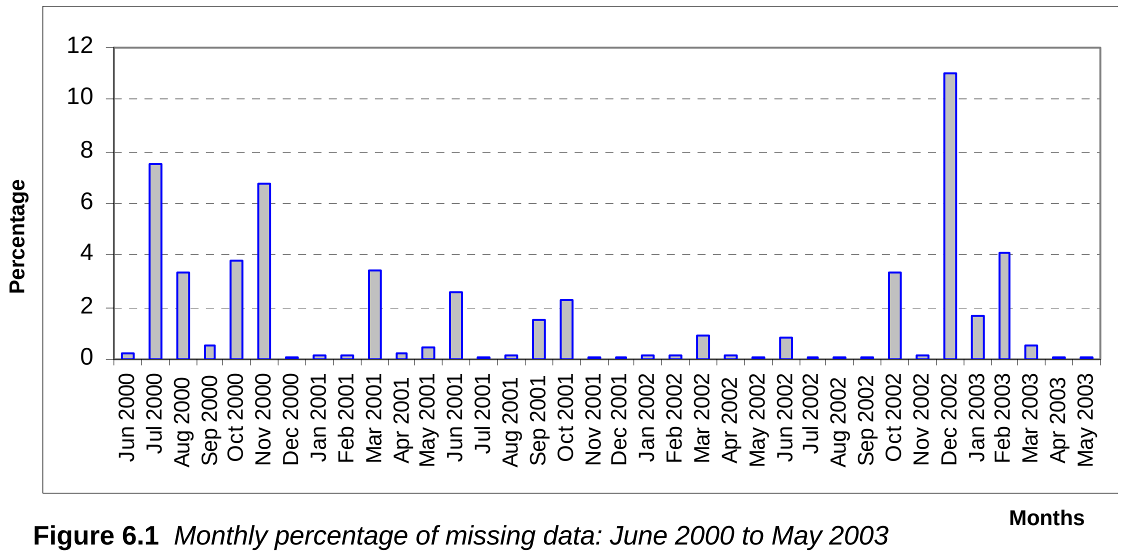

Figure 6.1 *Monthly percentage of missing data: June 2000 to May 2003*

December 2002 is the month having the most missing datapoints (11.0%), followed by July 2000 and November 2000. All other months have 4% missing data or less. The high percentage of missing data in December 2002 results is due to the severe lightning strike and subsequent loss of LW data, as discussed in Section 4.3.1.4. All months have at least 23 missing datapoints (about 0.05% per month) due to daily cleaning of the radiometers resulting in the loss of at least one, but no more than three, minutes of data per cleaning session. The total number of missing datapoints for the 36 months between June 2000 and May 2003 is 31873, which translates to 2.02 % of all possible datapoints.

Currently, a full basic set of BSRN data is measured. Regular maintenance is carried out, data management systems that were put in place, are fully functional, and datasets are cast in specific formats using in-house developed suitable Fortran programs. The monthly datasets are regularly submitted to the WRMC in Zürich, all of which were accepted and inserted in the international BSRN database at the time of writing this document.

The De Aar BSRN station gained international recognition in the BSRN network and to the author's knowledge, three international researchers were using the De Aar data.

6.2 THE WAY FORWARD

Regular reflection on any activity also includes meditation on achievements, the way forward and a contextualization between the two. The following questions need to be answered with regards to the De Aar BSRN station:

- Is the current system justifying its existence – viz., was the capital investment put to good use ?

- What are future scenarios in terms of its strategic positioning within SAWS, regionally, as well as internationally ?

6.2.1 Justifying its existence

The scientific plan of Chapter 2 and the system design of Chapter 3 are aimed towards enabling the South African BSRN station to fulfil its obligation towards the international BSRN community, and also towards the SAWS as a regional GAW observation site. The strategic international geographic positioning of the South African BSRN station as discussed in Section 1.2.1, the regular submission of data to the WRMC database and acceptance of the datasets, plus the expressed international research interest in the data, already justifies its existence.

6.2.2 Present and future role in SAWS

The BSRN project and associated activities are fully integrated in the GAW group within the SAWS. De Aar is regarded as a regional GAW station, along with only a handful of its kind in South Africa. The existence of the BSRN project has attracted additional international attention to South Africa's GAW activities and in particular the only Southern African Global GAW station situated at Cape Point doing internationally renowned atmospheric trace-gas monitoring and research.

Continued operation of the De Aar BSRN station shall lead to fulfilling its long-term obligation towards the WMO, the international BSRN community, and also towards the SAWS justifying sustained capital investment.

6.2.3 NEPAD potential

The New Plan for African Development (NEPAD) initiated in 1998 by the South African Government has, as one of its goals, the initiation of sustained development of partnerships and sharing of expertise between African countries. The BSRN site currently has a radiometric system directly traceable to the WRR, and arguably the best of its kind in the SADC region.

The high-quality instrumentation at De Aar has the potential to be used for other applications besides radiation monitoring, like calibrating operational radiometers of other radiation-monitoring institutions, not only in South Africa, but also elsewhere in Africa. This could be performed in years between International Pyrheliometric (IPC) events which are held only every five years. The SAWS has, apart from the BSRN equipment, also a PMO-6 radiometer which is still the standard radiometric reference instrument, which participated in the last IPC event the SAWS attended. If such calibration services can be initiated and sustained, it has the potential to generate funds and foster more international recognition for the SAWS.

As a regional GAW Radiation Station, De Aar BSRN has potential to be the focal point for radiation in the SADC region. It can also be a cornerstone for further BSRN activities in Africa or the SADC region, should plans develop to establish a second Southern African BSRN station.

6.2.4 International potential

Naturally, the benefits of a national asset are more significant towards the hosting country, but the exploration of international potential for that national asset should never be disregarded. One possibility for the South African BSRN station is its “twinning” with a similar site in another country, in a similar way that global GAW sites have “twinning” partners. This practice of “twinning partners” leads to the in-depth sharing of expertise and resources and creates unique partnership opportunities, that would not have been possible otherwise. The BSRN station produces data in this region so abundant in solar energy, that it can offer unique study opportunities to scientists and students alike, possibly from neighbouring countries or internationally.

Another international potential is the possibility of South Africa hosting a future BSRN workshop and conference (typically 80 delegates, held usually every two years). Such a workshop would attract a wealth of international attention and expertise towards the SAWS, and unlocks tourism potential for the hosting province and our country. Such an event would most likely be held in or around Cape Town, since the facilites at De Aar itself, would not be adequate to host a conference of this magnitude. The traditional site excursion during such an event can be the SAWS global GAW station at Cape Point, which is not a BSRN station, but is very likely to draw more international attention to the SAWS GAW activities.

6.3 RECOMMENDATIONS

One corollary flowing from sustained interaction with academic and practical material during the establishment of a dissertation, is the spontaneous identification of specific areas where improvements are needed. They are recommended here, grouped into three categories:

6.3.1 BSRN in general

1. The instatement of BSRN site audits either exclusive to BSRN or in partnership with related institutions, as discussed in Section 2.1.3.2, have the potential to add significant value to measurements. The added advantage of such audits would be, that other developing sites could be given correct guidance in measurement techniques, in order to take necessary and correct steps in recording useful data from day 1 of site establishment.

2. The WRMC database procedures, as discussed in Section 4.3 and highlighted in Section 4.3.2.4, can be refined, both theoretically and empirically, to be more site-specific and in such a way, render an honest and unbiased evaluation of data

recorded at a specific site. In a global network, this kind of refinement could be a step towards improvement of data evaluation.

6.3.2 Site improvement

The studies have identified the following shortcomings in the current operational system:

1. The exact times of tracker failures must be noted and reported as frequently and as accurately as possible. A non-operative tracker is difficult and sometimes impossible to identify in the recorded data alone, as discussed in Section 3.1.4.2. If no report of a stationary tracker is received, it can happen that data recorded when the tracker was stationary, is regarded as "good". Over and above regular inspection, one recommendation is an alarm device attracting attention to a standing tracker and/or a device logging tracker performance on a continuous basis.

2. The upgrading of the present passive tracker to an active tracker using a quadrant sensor, as discussed in Section 3.1.4.1, should be seriously considered. The majority of global/diffuse/direct mismatches, as analyzed in Section 4.3.3.4, can be attributed to the passive tracker drifting off track. The added advantage of a quadrant sensor is that its output, if correctly evaluated, can also be utilized to provide additional radiation data in the applicable spectral band, since the quadrant sensors have specific spectral characteristics.

3. More frequent inspection of the pyrheliometer sunspots should be undertaken, in order to identify and possibly quantify tracker drifts or consistent misalignments, should be undertaken until the tracker is upgraded to an active tracker. A practical solution suggested here, is sunspot inspections carried out on three different times of the day (middle of the morning, around solar noon and middle of the afternoon). The comparable solar zenith angle during the morning and afternoon inspections can best reveal tracker deviations as a result of time-offsets or misalignment towards solar declination. If there are days where clouds interfere with inspections, it should be carried out once it is observed that the sun casts a discernible shadow, regardless of the time of day.

4. Frequent checking of the pyranometer levels should be undertaken, since slight

skewness can lead to erroneous readings, as pointed out in Sections 4.2.3.2 and 4.3.2.1. Presently, the levels are checked on a monthly basis, but more frequent checking (weekly) and reporting, in order to timeously identify the causes of error, is recommended.

5. Further refinement and integration of current quality assurance procedures to resemble Section 4.2 is recommended. This can be executed on recorded data prior to WRMC submission, as an addition to the current Fortran programs. This can also include the development of site-customized quality assurance boundaries applicable specifically to South African conditions.

6. Thermal offsets of the thermopile instruments, as discussed in Section 3.1.2.3, must be addressed in a scientifically accountable way. At the moment all pyranometers are ventilated with devices designed by the manufacturers, in an attempt to make the thermal offset negligible. However, ventilator fans can stop without warning and the exact downtimes are often unknown to data collectors. A new strategy, comprising responsibly reporting fan failures and how to properly compensate for these errors, should be investigated. Possibly adopting and adapting the Australian model, as discussed in Section 3.1.2.3, is a consideration.

7. Tracker failures have a specific impact on LW radiation, as discussed in Section 3.1.4.2, specifically since the dome compensation term (term 3) of the LWD equation (Equation 3.4) becomes too large and therefore invalid when the dome is not shaded. Instead of simply rejecting LW data affected by tracker failures, a means of developing a more applicable dome constant can be investigated. If successful, the missing percentage of 1.3% for LWD data, as mentioned in Section 4.3.1.4, can be halved. However, a thorough assessment of the usefulness of this data must be performed before proceeding.

8. The measurement of upwelling LW and SW quantities from raised structures such as 10 - 30 m towers, should be seriously considered. If upwelling quantities are measured simultaneously with the basic downwelling quantities, an additional check and balance for the all involved quantities exists in both the LW and SW case as encountered in Sections 4.3.1.5, 4.3.2.2, 4.3.2.5, 4.3.2.6 and 4.3.3.2. Upwelling LW minus downwelling LW radiation can control pyrgeometer thermopile irradiance (Term 1 of Equation 3.4). In the case of upwelling

(reflected) SW, the ratio between reflected and downwelling SW irradiance equals surface albedo, which can add in the usefulness of the De Aar data, as ground-truthing of remote measurements, as well as a control of albedo measurements obtained by other means.

6.3.3 System upgrading

Since instrumentation is very expensive, especially in the South African context of a variable currency, the capital purchase of instruments is a long-term budget item. However, this should not be a reason for not considering upgrading. The following items are placed here on a wish list as possible upgrades, in order of priority in the opinion of the author:

1. The most important recommendation is upgrading the current passive solar tracker to an active tracker. Terminology: a passive tracker follows the sun “blindly”, i.e., depends upon calculations of solar position and the operation of stepper motors to point an instrument or array of instruments continuously at the sun. If the tracker time is not regularly updated, the tracker drifts off, pointing is erroneous and stays that way until external rectifications can be done. An active tracker combines the infrastructure of passive tracking with an array of sensors providing “feedback” to the tracker stepper motors to point the tracker continuously at the sun. A significant percentage of erroneous or semi-erroneous measurements was a result of the tracker being passive.

2. Another important recommendation is to consider the introduction of some form of sun photometry. Data resulting from this type of measurement, provide insight into spectral characteristics of transmitted radiation and can largely aid in satellite applications and the validation of radiative transfer models. Furthermore, a form of spectral measurement yields valulable insight in the gaseous composition of the atmosphere and aerosol optical depth (AOD), especially as a function of time, season, land usage, and other activities, such as biomass burning. The AOD at a clean-air site such as De Aar, can also provide valuable insight referring to background air quality in a South African context and aid in the growing understanding of diffuse radiation, as discussed in Section 2.1.3.3. This is one area of expertise where global GAW activities and BSRN activities have areas of overlapping and potential for co-operation. The current BSRN solar tracker at De Aar can accommodate at least one more 35 mm tubular instrument, such as a multifilter

rotating radiometer, having typically a four-wavelength filter.

3. The measurement of screen temperature and humidity in one-minute increments (the same time-resolution as irradiance quantities) using a separate, dedicated temperature-humidity probe instead of relying on the five-minute dataset from the AWS, will be a good step forward. This would not only provide better resolution surface data leading to a better understanding of LWD, but can also be a backup measurement for the AWS and a second control measurement which can fill data gaps in case of AWS breakdowns. In other words, this has the potential to enhance SAWS-AWS measurements, which in itself is a good motivation towards the procurement of such an item. The logging capacity to execute this measurement is already present at De Aar, so this is possibly the most feasible, executable and worthwhile option, if a useful site upgrade is considered in the near future.

4. The following list of parameters were selected from the list of possible extended measurement parameters (Table 2.5). Instatement of the measurement of one or more of these quantities in the future taking available resources, as well as usefulness of the data into account, can be considered as a long-term project:

- Surface narrowband UV radiation to complement the existing measurements of erythemal UVB as part of the SAWS sunburn awareness programme. The current 7-site SAWS sunburn monitoring network frequently has De Aar as the site with the highest daily maximum UV radiation intensity.
- Photosynthetically active radiation (PAR), using newly developed Kipp & Zonen radiometers.
- Precipitable water vapour (PWV) - possibly also indirectly by means of newly developed GPS methods – there is an established GPS reference station on site.
- Spectral downwelling parameters and/or spectral albedo using a sunphotometer by possible interaction with the NASA-GSFC-AERONET network.
- Surface ozone (De Aar is a non-industrial site with low background values; thus, possible ozone transport, resulting from biomass burning could be well identified).
- Total (column) ozone by a ground-based instrument, such as the Dobson or Brewer spectrophotometer. A Dobson instrument shall enhance the existing SAWS measurements at Irene (Gauteng) and Springbok (Namaqualand).
- Ozonesoundings (vertical profile of ozone distribution). Conventional rawinsonde upper-air facilities already exist at De Aar.