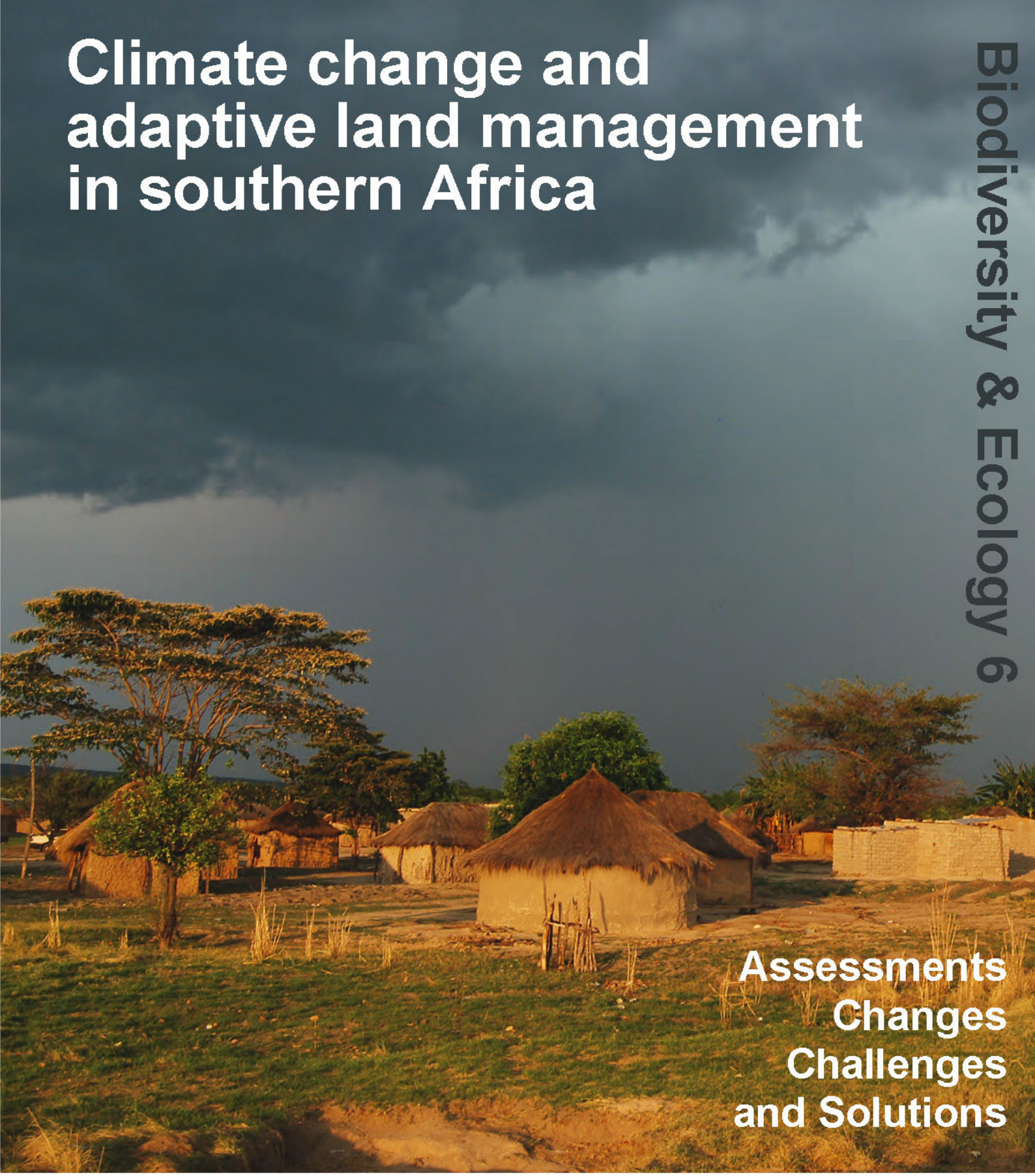
Climate change and adaptive land management in southern Africa

Biodiversity & Ecology 6



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Climate change and adaptive land management in southern Africa

Assessments, changes, challenges, and solutions

Edited by

Rasmus Revermann[1], Kristin M. Krewenka[1], Ute Schmiedel[1],
Jane M. Olwoch[2], Jörg Helmschrot[2,3], Norbert Jürgens[1]

1 Institute for Plant Science and Microbiology, University of Hamburg
2 Southern African Science Service Centre for Climate Change and Adaptive Land Management
3 Department of Soil Science, Faculty of AgriSciences, Stellenbosch University

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Cooperation of meteorological services within SASSCAL on improving the management of observed climate data

Rafael Posada[1], Jens Riede[1], Frank Kaspar[1]*, Albert Mhanda[2], Mesho Radithupa[2], John Stegling[2], Domingos Nascimento[3], Lutumba Tima[3], Joseph Kanyanga[4], Edson Nkonde[4], Martin Swaswa[4] and David Waitolo[4]

1 Deutscher Wetterdienst (DWD), Frankfurter Straße 135, 63067 Offenbach, Germany

2 Botswana Department of Meteorological Services (DMS), Corner Maaloso/ Metsimothlaba Rd, Gaborone Village, P.O.Box 10100, Gaborone, Botswana

3 Instituto Nacional de Meteorologia e Geofísica (INAMET), Rua 21 de Janeiro, Rotunda do Gamek a direita S/N RC Luanda, Angola

4 Zambia Meteorological Department (ZMD), Haile Selassie Ave, Lusaka 30200, Zambia

* Corresponding author: frank.kaspar@dwd.de

Abstract: Consistent and reliable climate observations for Southern Africa are an important source of information for climate service-related activities. Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) supported the cooperation among the national meteorological services of Angola, Botswana, Germany, and Zambia to improve the management of observed climate data in the region. This cooperation allowed the stablisation of a climate data management system in which CLIMSOFT – a freely available software suite for storing climate data – is the main component. Additional open-source applications have been developed to provide an easy-to-use interface to visualize, download, digitize, and import climate data from and into CLIMSOFT. Besides that, substantial progress in the storage, quality control, and management of present and historical climate data recorded in paper media has been achieved. The measures taken were accompanied by continuous training and support to ensure the long-term maintenance of the new data management.

Resumo: Observações climáticas consistentes e fiáveis da África Austral são uma fonte importante de informação para actividades relacionadas com serviços climáticos. O SASSCAL ("Southern African Science Service Centre for Climate Change and Adaptive Land Management" ou Centro de Serviços Científicos da África Austral para as Alterações Climáticas e a Gestão Adaptativa das Terras) apoiou a cooperação entre os serviços meteorológicos nacionais de Angola, Botswana, Alemanha e Zâmbia, de modo a melhorar a gestão dos dados climáticos observados na região. Esta cooperação permitiu o estabelecimento de um sistema de gestão de dados climáticos, em que o CLIMSOFT – um software disponível gratuitamente para o armazenamento de dados climáticos – age como o principal componente. Outros aplicativos de código aberto foram desenvolvidos, de modo a oferecer uma interface fácil de usar para visualizar, descarregar, digitalizar e importar dados climáticos, de e para o CLIMSOFT. Para além disso, foram realizados progressos substanciais no armazenamento, controlo de qualidade e gestão de dados climáticos actuais e históricos registados em papel. As medidas tomadas foram acompanhadas por formação e apoio contínuos, de modo a garantir a manutenção a longo prazo da nova gestão de dados.

Introduction

Climate data are needed to support climate research, climate adaptation measures and climate services to mitigate the effects of severe weather conditions, such as the drought associated with El Niño in 2016 that affected parts of the Southern African region (UNOCHA, 2016). Under such conditions, historical climate observations provide an important source of information for decision-makers to estimate the regional effects of climate variability and change. In comparison with other regions, however, the availability of high-quality, high-density climate observations is still low in some parts of Southern Africa. Here, we use the term "climate data" for meteorological observations taken by regular surface weather stations either by manual observers or automatic sensors. Typical parameters observed at such stations are air temperature, precipitation, pressure, humidity, wind, solar irradiance, etc. They are most useful for climate assessments if these stations are operated over a sufficiently long period of time (i.e., preferably decades). Metadata provide supplementary information on the stations, such as on the technical configuration or observation procedures (see, e.g., WMO, 2014).

In addition, the accessibility of long historical climate records for several Southern African countries is limited in that they have been recorded on paper and are not yet available in digital form (Kaspar et al., 2015a).

Concerning the present-day ground-based climate observations, SASSCAL has supported the installation of automatic weather stations (AWSs) in the region to address the lack of such observations. Currently, the SASSCAL's AWS network comprises 145 stations, and their data are freely available on the website of the SASSCAL-WeatherNet (see http://www.sasscalweathernet.org/). For more information about the SASSCAL-WeatherNet, please refer to the (Muche et al., 2018).

Currently, only a few weather stations in the region are transferring data to international data centres (Fig. 1). The exchange of such data is essential to improving the reliability and accuracy of regional and global climate analysis, climate data products, and various types of models of the components of the Earth's climate system.

The need to improve the capacities of national meteorological services (NMSs) in some regions is widely acknowledged. In this context, the World Meteorological Organization (WMO) initiated the Global Framework for Climate Services, a coordination framework of which capacity building is one of the key components. Cooperation is essential for the success of this global framework, especially between national and regional meteorological services. The collaboration between NMSs presented here and focused on improving local skills to provide better advice for decision-makers and stakeholders is an example of such a cooperative activity.

In this context, the NMSs of Angola, Botswana, and Zambia have been working closely together with Germany's national meteorological service, Deutscher Wetterdienst (DWD), to improve the management of climate data. The long experience of DWD on climate observation, climate data service provision, and data rescue (Kaspar et al., 2013; Kaspar et al., 2015b) makes it a valid partner to provide expertise and support to the meteorological services in the region. The cooperation focused specifically on (1) the implementation of a climate data management system (CDMS), (2) data rescue activities, and (3) capacity building on climate data management.

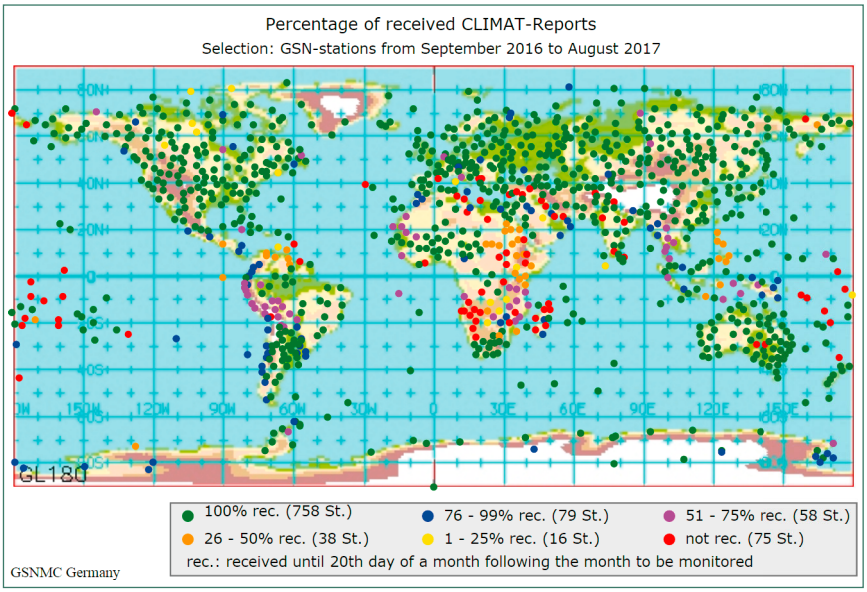

Figure 1: Percentage of received monthly CLIMAT-reports from the Global Climate Observing: System Surface Network stations (GSN) for the period of September 2016 to August 2017. Colours indicate the percentage of reports that were received by the GSN Monitoring Centre of DWD up to the 20th day of the month following the month observed.

The methods used to achieve these goals and the main results of the cooperation are presented in the following sections.

Methods

Implementation of a climate data management system

The cooperation aimed to implement a reliable CDMS, which is defined by WMO as "an integrated computer-based system that facilitates the effective archival, management, analysis, delivery and utilization of a wide range of integrated climate data" (WMO, 2014). The delegates of the NMSs of Angola, Botswana, Zambia, and Germany discussed the different existing CDMSs during a SASSCAL workshop held in Namibia in April 2014. It was agreed that CLIMSOFT ("CLIMatic SOFTware") would be the preferred option, since all countries had already used this software occasionally (Hänsler, 2014).

CLIMSOFT was developed by an African team to provide a free and easy-to-use CDMS (Stuber et al., 2011). It has an intuitive graphical user interface with a key-entry module, quality control procedures, and data import options that allow the importation of data from various sources, including data from automatic weather stations (Kaspar et al., 2015a). The import option for the data recorded by the AWSs, called "AWS-Real time", is able to read the ASCII files generated by the AWS once a user specifies the structure of the data saved in the files. The transfer is typically carried out every 10 minutes and imports the data from the last 2 hours. However, these time steps can be adjusted by the user.

The newest version of CLIMSOFT (version 4.0) is supported by a large community of developers and is based on WMO's climate data management system specifications (WMO, 2014), so that most of the components that are required for a CDMS will be featured in the software. More information about CLIMSOFT and its future releases can be found at http://www.climsoft.org. It should be noted that although CLIMSOFT provides a reliable option for storage of climate data, it was necessary to improve the accessibility of these data for subsequent analysis. In this context, we developed an open-source tool for the visualization, analysis, and download of data stored in any CLIMSOFT database. This tool, called

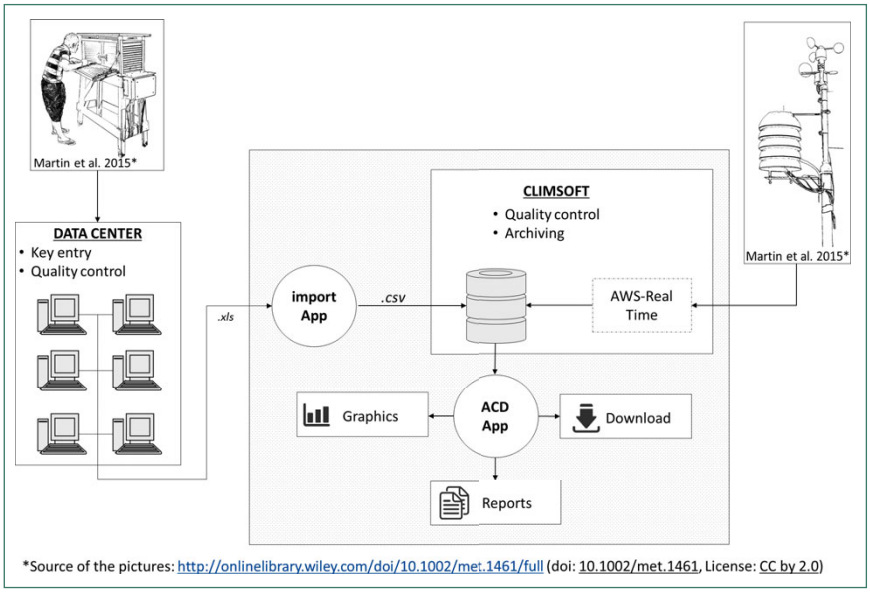

Figure 2: Data flow at INAMET. The CLIMSOFT database is the core of the CDMS, as it stores the data coming from the manual weather stations (left side) and AWSs (right side). The ACD-App allows users to create different types of products using the data stored in the database.

Analysis of Climate Data (hereafter ACD-App) is described in more detail in Posada & Riede (2018a).

Data rescue

As defined by Tan et al. (2004), data rescue is "the ongoing process of (1) preserving all data at risk of being lost due to deterioration of the medium and; (2) digitizing current and past data into computer compatible form for easy access". This is an important aspect of the cooperation, especially at the meteorological services of Botswana and Zambia, where digitization of on-paper data is of high priority.

To facilitate the digitization, the SASSCAL team has developed an open-source tool in which users can enter the data into a table with the same structure as the on-paper form. This tool, called keyEntry App, is described in detail in Posada & Riede (2018b). The data entered with this tool can also easily be imported by CLIMSOFT using a recently developed tool called import-App, which is described in Posada & Riede (2018c).

Capacity building on climate data management

Visits of DWD staff to the NMSs were performed periodically and were intended as an opportunity to transfer knowledge to the NMS staff in the fields of metadata, importance of data management, application of a CDMS, quality control, and many further issues related to the management of observed climate data. In addition, trainings in programming languages and international data transfer standards have been carried out.

Results

The cooperation of the NMSs of Angola, Botswana, and Zambia with DWD started in 2014 with the evaluation of the facilities and resources concerning climate data management in each NMS. These led to identifying the actual needs of each country, which differ from one to the other. This section summarizes the main results achieved in each meteorological service.

Instituto Nacional de Meteorología e Geofísica, INAMET, Angola

Implementation of a CDMS

The cooperation between DWD and INAMET started in April 2014. At that time, the NMS was not operating any CDMS. The climate data from manual weather stations were entered manually into electronic spreadsheets without a standard template. These spreadsheets were saved in unnetworked PCs and in different folders, making it difficult to know which data were already available in digital form. In addition, the data recorded by AWSs were automatically transferred from the stations to a server located at INAMET in ASCII formats.

As a first step to improve this situation, a new data-flow scheme was designed so that the climate data could be collected in a proper CDMS (see Fig. 2). As stated in Section 2, the preferred CDMS was CLIMSOFT, since it had been used once at INAMET back in 2007. INAMET started by giving a unique local identifier to each manual weather station and creating an internal network to connect all the PCs used for data entry. Spreadsheet templates have been designed to facilitate the data entry process and to avoid inconsistencies between the different files. The data entered in the new format can be easily imported into CLIMSOFT by using an application programmed with R for this purpose. It is expected that in the near future, the keyEntry-App will replace the spreadsheets for entering data from manual weather stations.

Regarding the data recorded by INAMET's AWS network (including the stations from the SASSCAL-WeatherNet), it was possible to set up CLIMSOFT's "AWS-Real time" feature to automatically transfer these data into the database.

Finally, the ACD-App developed in the framework of SASSCAL has been installed and is currently used for quality control and downloading the data.

Data rescue

According to WMO (2016), the first task of data rescue is to locate the data. As part of this search process, WMO recommends cross-checking available digital records to determine whether historical observation records have already been digitized, identify significant gaps, and complement the data already organized, digitized, and managed within the NMS. This is of special interest in countries with a colonial history, since their records are often hosted elsewhere. Following this recommendation, INAMET decided to collect historical observation datasets from Angola that have already been digitized and that are available at international archives. To date, a total of seven dif-

ferent datasets have been identified that contain data from Angola (see Tab. 1). Some of these data were already digitized in INAMET, but a thorough cross-check of these data against those stored in INAMET's main database is still required to fill in the gaps. Therefore, the historical data from the international archives are being kept in a separate CLIMSOFT database until this cross-check has been carried out and completed.

Furthermore, efforts have concentrated on rescuing historical data entered on paper forms. As a first step, INAMET's archive has been reorganized so that the digitization of the data can start at any time. The keyEntry-App could be used to facilitate the key-entry of the historical data.

Capacity building

As capacity building is one of SASSCAL's main objectives, the cooperation between DWD and INAMET also focused on strengthening capacities in climate data management, especially among those staff responsible for maintaining the CDMS. The first training activities focused on basic concepts related to climate data such as the relevance of metadata and their importance to identifying inhomogeneities in a given dataset. In addition, the meteorological staff was also trained in CLIMSOFT and in an open-source computing language to facilitate future statistical analysis of the data. The main training activities made at INAMET are listed in Table 2. Furthermore, continuous supervision was provided by DWD not only through several working visits but also remotely from Germany. The aim of these activities was to ensure the proper functioning of the CDMS and the open-source apps and to improve the staff's technical capacity so that the system could run sustainably once the SASSCAL initiative had finished. A photo of a training event at INAMET is shown in Fig. 3. Further information regarding the cooperation between DWD and INAMET is given by Posada et al. (2016).

Figure 3: Training activity at INAMET on 11 August 2014. The local technician Mr. Dario Pimentel provides support to the INAMET Data Centre team on how to enter on-paper data into the new electronic forms.

Table 1: Overview of Angolan data availability in international datasets. An extended overview – which includes further information such as the element variables available in each dataset – is given by Posada et al. (2016)

Dataset Name	Dataset Description	Time resolution	Source
DWD (WMO Reports)	Deutscher Wetterdienst	DAILY	DWD Database (data not available online)
		MONTHLY	DWD Database (data not available online)
GPCC	Global Precipitation Climate Centre	MONTHLY	Data requested by INAMET
GHCN	Global Historical Climatology Network	DAILY	http://doi.org/10.7289/V5D21VHZ (Menne et al., 2012a,b)
		MONTHLY	http://www.ncdc.noaa.gov/ghcnm/v3.php (Lawrimore et al., 2011) http://www.ncdc.noaa.gov/ghcnm/v2.php (Peterson & Vose, 1997)
RBIS	River Basin Information System	DAILY	http://leutra.geogr.uni-jena.de/sasscalRBIS/metadata/start.php
ISTI	International Surface Temperature Initiative	MONTHLY	ftp://ftp.ncdc.noaa.gov/pub/data/globaldatabank/monthly/stage2/colonialera/ (Thorne et al., 2011)
CDIAC	Carbon Dioxide Information Analysis Center	HOURLY	ftp://cdiac.esd.ornl.gov/pub/ndp026c/ (Hahn & Warren, 2009)
IDL	Instituto Dom Luis	HOURLY	Data provided through personal communication (data not available online)
		DAILY	Data provided through personal communication (data not available online)

Table 2: List of training events carried out in each country

NMS (Country)	Training	Dates
INAMET (Angola)	Training on keyEntry-App, import-App, and ACD-App	11–15 September 2017
	Climate data management	18–20 March 2015
	CLIMSOFT and R software	24–25 March 2015
	CLIMSOFT installation and data entry	8–13 August 2014
DMS (Botswana)	Training on keyEntry-App and import-App	4–6 October 2017
	Data rescue management (II)	3–10 March 2016
	Climate data management	23–26 February 2015
	Data rescue management	16–19 November 2015
	Data management and R tool installation guidance for technicians	17–18 November 2015; 29 February–4 March 2016
ZMD (Zambia)	Training on keyEntry-App, import-App, and ACD-App	18–22 September 2017
	R for climate products	22 January 2016
	Importance of archiving on-paper documents	19–29 April 2016
	Climate data management	23 June–1 July 2015
	Climate data management systems: CLIMSOFT	12–18 November 2014

Department of Meteorological Services, DMS, Botswana

Implementation of CDMS

At the beginning of the project, there was no properly functioning database at the DMS Botswana. No main database including all observational climate observations existed. Instead, the observational climate data were stored in several CLIMSOFT databases of different contents, with some of the information being redundant and other data missing.

In agreement with the department's management, the focus was set on installing CLIMSOFT version 4.0. As a second step it was necessary to incorporate all data from the different databases into the new main database system. Therefore, DMS got also involved in the development of CLIMSOFT version 4.0 by testing the new version and reporting bugs to the developers.

Additionally, the ACD-App was installed to allow for initial quality control of the data stored in CLIMSOFT, and the import-App to allow entry of historical climate observation into the new CLIMSOFT database. Monthly climatological data has been compiled using CLIMSOFT version 4.0 and transmitted to international data centres based on WMO standards using the global telecommunication system (GTS), a system of telecommunication facilities and arrangements for the rapid collection, exchange, and distribution of observations and processed information.

Data rescue

Data rescue started by collecting information about the quantity of paper documents at the DMS. These documents have been stored in three different archive rooms located in several buildings at the headquarters. However, none of the archives met the WMO requirements according to the WMO guidelines on "Best Practices for Climate Data Rescue" (WMO, 2016). To support DMS, it was necessary to get additional external funding. Support provided by the Global Climate Observing System made possible the reconditioning of these rooms by purchasing new shelves and more than 1,000 archiving boxes. Furthermore, this organization provided DMS with digitization equipment including two digital cameras and a scanner. Additional information on the data rescue activity carried out at DMS can be found on the webpage of the International Data Rescue portal (Riede, 2015, 2016). A former training room at the main building was rearranged to be used as an archive and digitizing room. Paper records were imaged using the new cameras and scanner. The resulting digital files were then stored on an external drive. In total, more than one million pages of climate documents are available for digitization. To support the data rescue processing, the keyEntry-App has been installed together with the import-App to import the entered data into the CLIMSOFT database.

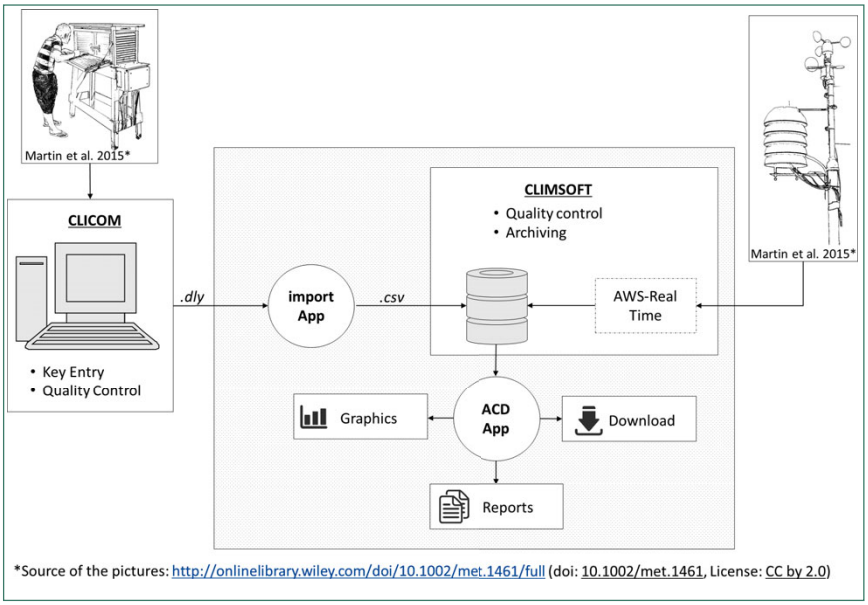

Figure 4: Data flow at ZMD. The CLIMSOFT database is the core of the CDMS, as it stores the data coming from the manual weather stations (left side) and the AWSs (right side). The ACD-App allows users to create different types of products using the data stored in the database.

Capacity Building

Similarly to INAMET, several training activities have been performed since 2014. The local staff have been trained in the use of the apps, in the open-source programming language employed to develop them, and in the CLIMSOFT software. Several training events on data rescue have also been carried out throughout the years of the project. The first training event addressed how to organize data rescue and the importance of historical climate data. The focus of the further training activities was on using the electronic equipment, storing the content in a digital format, and maintaining the archive.

Zambia Meteorological Department, ZMD, Zambia

Implementation of a CDMS

ZMD has been using the CLImate COMputing system, CLICOM (WMO, 1989) since the late 1980s as its CDMS. It was developed in 1985 by the National Oceanic and Atmospheric Administration of the United States as a PC-based database running on MS-DOS but it cannot be operated on the newer commercial operating systems (Martin et al., 2015).

Although CLICOM is running properly and kept up-to-date at ZMD, its low compatibility with modern operating systems makes it difficult to work with the climate database. It was therefore agreed that, with the support of SASSCAL, CLICOM should be replaced with a more modern CDMS. CLIMSOFT was identified to be the best solution since it has been already used at ZMD in the past.

The efforts have focused on the installation and use of CLIMSOFT in an operational mode. The software was installed in 2014, accompanied by a new data-flow scheme to ensure the appropriate storage of climate data (see Fig. 4). Since CLICOM has been running for over 30 years, it was agreed to run it in parallel with

CLIMSOFT to avoid any loss of data. In fact, data from manual weather stations are still being entered into CLICOM and then imported into CLIMSOFT. This import was done first with an open-source tool developed specifically for ZMD, although it has been replaced with the more reliable tool import-App.

In the same way as with INAMET, the observation data recorded by the AWS network of ZMD (including the stations from the SASSCAL network) are being transferred automatically into the CLIMSOFT database through the "AWS-Real time" feature.

The ACD-App developed in the framework of SASSCAL has been installed and is currently in use for quality control and downloading of the data.

Data rescue

ZMD is currently very active in data rescue activities. The Climate Information and Early Warning Systems (CIEWS) project was already supporting data rescue at ZMD (UNDP, 2012) when SASSCAL started. Therefore, it was agreed that SASSCAL would complement the efforts of CIEWS in this matter. Whereas CIEWS provides the meteorological service with data rescue equipment for digitization (e.g., computers, scanners, cameras), SASSCAL has focused on the reorganization of the archive by providing archive boxes and setting up a master plan for the allocation of the on-paper documents (see Fig. 5).

Capacity building

Similarly to INAMET, the training activities carried out since late 2014 were aimed at strengthening capacities in the management of climate data, especially those of the staff responsible for maintaining the CDMS. Therefore, training focused on basic concepts related to climate data, such as the relevance of metadata and its importance to identify inhomogeneities in a given dataset was carried out. In addition, staff were also trained in CLIMSOFT and an open-source computing language to facilitate future statistical analysis of the data (Tab. 2). As in the other countries, continuous support was provided by DWD to ensure the proper operation of CLIMSOFT and the apps and to ensure that the system could function sustainably.

Summary, conclusion and outlook

The SASSCAL initiative has served as a platform for the NMSs of Angola, Botswana, and Zambia to improve their management of climate data in a sustainable manner. DWD's collaboration and support of the technical staff aimed to ensure that the NMSs can operate and maintain the new data management system implemented in each country in the long term, even after the end of this cooperation. All partners have received at least six working visits by DWD staff during the project, which included training or technical support. Furthermore, remote assistance from Germany was provided to support the progress in data management and data rescue.

As a result, all countries are using CLIMSOFT as their core CDMS in an operational mode. To complement the CDMS, open-source tools have been developed to fulfil the specific needs of the NMSs in the region. These include the ACD-App (see Posada & Riede, 2018a); the keyEntry-App (see Posada & Riede, 2018b) and the import-App (see Posada & Riede, 2018c). The apps are freely available and open source so that end users with programming knowledge are able to modify the source code to implement new functionalities.

All actions taken are intended to provide a long-term and sustainable solution for the management of climate data by the NMSs. Although these actions were based on the specific needs and capacities of each service, some common challenges were identified:

- The activities should be communicated to all levels of the hierarchy (e.g., from the director to the technical staff). It was found that many persons were initially sceptical of the cooperation since many former projects had already provided tools and equipment that were not being used in the end. Therefore, a long-term collaboration that includes all levels of NMS staff is essential for introducting new climate products, especially in many African countries, where a lot of support is needed for running and maintaining these products.
- The maintenance of the data management systems relies mainly on the technical staff of the NMSs; as a result, high turnover of employees could lead to the breakdown of the system. To minimize the effects of such staffing fluctuations, the NMSs should keep complete

Figure 5: Data rescue activities in Botswana (left) and paper archive in Zambia (right): (a) before and (b) during the ongoing reorganization.

documentation of the processes related to climate data management so that the new staff can easily take over.

- Technical support of CLIMSOFT users is strongly recommended, especially for upgrading the software to the most recent version (version 4.0), so that the NMSs run the same CMDS version. This, in turn, could lead to an easy exchange of data between meteorological services in the future. The international exchange of climate data would be extremely beneficial for the region, for climate analysis and weather forecasts. This exchange is typically done through the WMO's global telecommunication system, but use of that system is limited among the NMS partners. Further support to the NMSs will be required to encourage the use of the system.
- Although data rescue activities are currently being carried out, there is still a great need for financial support (e.g., hiring temporary staff, purchasing archive boxes, maintaining paper archive) to complete these activities.

The results of this activity are a starting point for developing further observation-based climate services. Regularly updated time series of observations provide the basis for continuous climate monitoring (e.g., by providing monthly updates of climatological maps for the region). Creating monthly regional air temperature maps based on the SASSCAL AWS network was tested by Eiselt et al. (2017) (see Riede & Eiselt, 2018). This could be extended to other meteorological parameters, such as precipitation, and could serve as a basis for an online climatological information portal, as is already available for other geographical regions of the world (e.g., the German Climate Atlas) (Kaspar et al., 2013).

Finally, it should be noted that identifying synergies between ongoing international activities in the region would help optimize resources and achieve long-term sustainable solutions for the specific needs of national meteorological services. The SASSCAL activity presented here is an example of such an exchange between initiatives, as can be seen in the efforts in data rescue in the meteorological services of Botswana and Zambia. Other regional institutions, such as the Climate Services Centre of the Southern African Development Community (SADC), based in Gaborone, could be potential partners for future collaboration.

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References

Eiselt, K.-U., Kaspar, F., Mölg, T., Krähenmann, S., Posada, R. & Riede, J. (2017). Evaluation of gridding procedures for air temperature over Southern Africa. *Advances in Science and Research*, **14,** 163–173. doi: 10.5194/asr-14-163-2017

Hahn, C. J. & Warren, S. G. (2009). Extended edited cloud reports from ships and land stations over globe, 1952–1996 (2009 update). *Carbon Dioxide Information Analysis Center.* doi: 10.3334/CDIAC/cli.ndp026c

Hänsler, A. (2014). *Minutes – SASSCAL Thematic Workshop Climate*. Available at http://www.sasscal.org/downloads/Minutes_SASSCAL-ClimateWorkshop_August2014_FINAL.pdf (last accessed 7 July 2017)

Kaspar, F., Helmschrot, J., Mhanda, A., et al. (2015a). The SASSCAL contribution to climate observation, climate data management and data rescue in Southern Africa. *Advances in Science and Research*, **12,** 171–177. doi: 10.5194/asr-12-171-2015

Kaspar, F., Tinz, B., Mächel, H. & Gates, L. (2015b). Data rescue of national and international meteorological observations at Deutscher Wetterdienst. *Advances in Science and Research*, **12,** 57–61. https://doi.org/10.5194/asr-12-57-2015

Kaspar, F., Müller-Westermeier, G., Penda, E., Mächel, H., Zimmermann, K., Kaiser-Weiss, A. & Deutschländer, T. (2013). Monitoring of climate change in Germany – data, products and services of Germany's National Climate Data Centre. *Advances in Science and Research*, **10,** 99–106. https://doi.org/10.5194/asr-10-99-2013

Lawrimore, J. H., Menne, M. J., Gleason, B. E., Williams, C. N., Wuertz, D. B., Vose, R. S. & Rennie, J. (2011). An overview of the Global Historical Climatology Network monthly mean temperature data set, version 3. *Journal of Geophysical Research*, **116** (D19121), 1–18. doi:10.1029/2011JD016187

Martin, D. J., Howard, A., Hutchinson, R., McGree, S. & Jones, D.A. (2015). Development and implementation of a climate data management system for western Pacific small island developing states. *Meteorological Applications*, **22,** 273–287. doi:10.1002/met.1461

Menne, M. J., Durre, I., Korzeniewski, B., McNeal, S., Thomas, K., Yin, X., Anthony, S., Ray, R., Vose, R.S., Gleason, B.E. & Houston, T.G. (2012a). Global Historical Climatology Network - Daily (GHCN-Daily), Version 3.20. NOAA National Climatic Data Center. doi:10.7289/V5D21VHZ

Menne, M. J., Durre, I., Vose, R. S., Gleason, B.E. & Houston, T.G. (2012b). An overview of the Global Historical Climatology Network daily database. *Journal of Atmospheric and Oceanic Technology*, **29,** 897–910. doi:10.1175/JTECH-D-11-00103.1

Muche, G., Kruger, S., Hillmann, T. et al. (2018) SASSCAL WeatherNet: present state, challenges, and achievements of the regional climatic observation network and database. This volume.

Peterson, T.C. & Vose, R.S. (1997). An overview of the Global Historical Climatology Network temperature database. *Bulletin of the American Meteorological Society*, **78**, 2837–2849.

Posada, R., Nascimento, D., Neto, F.O.S., Riede, J., & Kaspar, F. (2016). Improving the climate data management in the meteorological service of Angola: experience from SASSCAL. *Advances in Science and Research*, **13,** 97–105. doi: 10.5194/asr-13-97-2016

Posada, R. & Riede, J. (2018a). Analysis of Climate Data Application (ACD-App). This volume

Posada, R. & Riede, J. (2018b). Key Entry Form Application to digitize climate data (keyEntry-App). This volume

Posada, R. & Riede, J. (2018c). Application to import climate data into CLIMSOFT (importApp). This volume

Riede, J. (2015). Climate data rescue implementation plan for the Department of Meteorological Services Botswana. WMO, International Data Rescue Portal. Available online at https://idare-portal.org/sites/default/files/DARE_Botswana_Recommendation.pdf (last accessed 3 July 2017)

Riede, J. (2016). Climate data rescue progress report, Department of Meteorological Services Botswana. WMO, International Data Rescue Portal. Available online at https://idare-portal.org/sites/default/files/2016DARE_Botswana.pdf (last accessed 3 July 2017)

Riede, J. & Eiselt, K.U. (2018). Gridded maps of climate data for southern Africa. This volume

Stuber, D., Mhanda, A. & Lefebvre, C. (2011). Climate data management systems: status of implementation in developing countries. *Climate Research*, **47,** 13–20. doi:10.3354/cr00961

Thorne, P.W., Willett, K.M., Allan, R.J., et al. (2011). Guiding the creation of a comprehensive surface temperature resource for twenty-first-century climate science. *Bulletin of the American Meteorological Society*, **92,** ES40–ES47. http://dx.doi.org/10.1175/2011BAMS3124.1

Tan, L.S., Burton, S., Crouthamel, R., van Engelen, A., Hutchinson, R., Nicodemus, Peterson, T.C. & Rahimzadeh, F. (2004). *Guidelines on climate data rescue*. WMO/TD no. 1210. Geneva: World Meteorological Organization

United Nations Development Programme (UNDP) (2012). Strengthening climate information and early warning systems in Zambia. Description available at http://adaptation-undp.org/projects/ldcf-ews-zambia (last accessed 27 June 2017)

United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) (2016). Overview of El Niño response in East and Southern Africa. Available at http://www.unocha.org/sites/dms/Documents/2016_11_El-nino_Africa_Breakfast_meeting_FINAL.pdf (last accessed 5 February 2018)

World Meteorological Organization (WMO) (2014). *Climate data management system specifications*. WMO no. 1131. Geneva: World Meteorological Organization. Available at http://library.wmo.int/pmb_ged/wmo_1131_en.pdf (last accessed 7 July 2017)

WMO (2016). *Guidelines on best practices for climate data rescue*. WMO no. 1182. Geneva: World Meteorological Organization. Available at https://library.wmo.int/opac/doc_num.php?explnum_id=3318 (last accessed 7 July 2017)

WMO (1989). CLICOM Project (climate data management system). WMO/TD no. 299. Geneva: World Meteorological Organization. Available at https://library.wmo.int/pmb_ged/wmo-td_299_en.pdf (last accessed 7 July 2017)

References [CrossRef]

Eiselt, K.-U., Kaspar, F., Mölg, T., Krähenmann, S., Posada, R. & Riede, J. (2017). Evaluation of gridding procedures for air temperature over Southern Africa. *Advances in Science and Research*, **14,** 163–173. CrossRef

Hahn, C. J. & Warren, S. G. (2009). Extended edited cloud reports from ships and land stations over globe, 1952–1996 (2009 update). *Carbon Dioxide Information Analysis Center*. CrossRef

Hänsler, A. (2014). *Minutes – SASSCAL Thematic Workshop Climate*. Available at http://www.sasscal.org/downloads/Minutes_SASSCAL-ClimateWorkshop_August2014_FINAL.pdf (last accessed 7 July 2017)

Kaspar, F., Helmschrot, J., Mhanda, A., et al. (2015a). The SASSCAL contribution to climate observation, climate data management and data rescue in Southern Africa. *Advances in Science and Research*, **12,** 171–177. CrossRef

Kaspar, F., Tinz, B., Mächel, H. & Gates, L. (2015b). Data rescue of national and international meteorological observations at Deutscher Wetterdienst. *Advances in Science and Research*, **12,** 57–61. CrossRef

Kaspar, F., Müller-Westermeier, G., Penda, E., Mächel, H., Zimmermann, K., Kaiser-Weiss, A. & Deutschländer, T. (2013). Monitoring of climate change in Germany – data, products and services of Germany's National Climate Data Centre. *Advances in Science and Research*, **10,** 99–106. CrossRef

Lawrimore, J. H., Menne, M. J., Gleason, B. E., Williams, C. N., Wuertz, D. B., Vose, R. S. & Rennie, J. (2011). An overview of the Global Historical Climatology Network monthly mean temperature data set, version 3. *Journal of Geophysical Research*, **116** (D19121), 1–18. CrossRef

Martin, D. J., Howard, A., Hutchinson, R., McGree, S. & Jones, D.A. (2015). Development and implementation of a climate data management system for western Pacific small island developing states. *Meteorological Applications*, **22,** 273–287. CrossRef

Menne, M. J., Durre, I., Korzeniewski, B., McNeal, S., Thomas, K., Yin, X., Anthony, S., Ray, R., Vose, R.S., Gleason, B.E. & Houston, T.G. (2012a). Global Historical Climatology Network - Daily (GHCN-Daily), Version 3.20. NOAA National Climatic Data Center. CrossRef

Menne, M. J., Durre, I., Vose, R. S., Gleason, B.E. & Houston, T.G. (2012b). An overview of the Global Historical Climatology Network daily database. *Journal of Atmospheric and Oceanic Technology*, **29,** 897–910. CrossRef

Muche, G., Kruger, S., Hillmann, T. et al. (2018)SASSCAL WeatherNet: history, state of Measuring Network, database and online presentation, challenges & success. This volume. CrossRef

Peterson, T.C. & Vose, R.S. (1997). An overview of the Global Historical Climatology Network temperature database. *Bulletin of the American Meteorological Society*, **78**, 2837–2849. CrossRef

Posada, R., Nascimento, D., Neto, F.O.S., Riede, J., & Kaspar, F. (2016). Improving the climate data management in the meteorological service of Angola: experience from SASSCAL. *Advances in Science and Research*, **13,** 97–105. CrossRef

Posada, R. & Riede, J. (2018a). Analysis of Climate Data Application (ACD-App). This volume. CrossRef

Posada, R. & Riede, J. (2018b). Key Entry Form Application to digitize climate data (keyEntry-App). This volume. CrossRef

Posada, R. & Riede, J. (2018c). Application to import climate data into CLIMSOFT (import-App). This volume. CrossRef

Riede, J. (2015). Climate data rescue implementation plan for the Department of Meteorological Services Botswana. WMO, International Data Rescue Portal. Available online at https://idare-portal.org/sites/default/files/DARE_Botswana_Recommendation.pdf (last accessed 3 July 2017)

Riede, J. (2016). Climate data rescue progress report, Department of Meteorological Services Botswana. WMO, International Data Rescue Portal. Available online at https://idare-portal.org/sites/default/files/2016DARE_Botswana.pdf (last accessed 3 July 2017)

Riede, J. & Eiselt, K.U. (2018). Gridded maps of climate data for southern Africa. This volume. CrossRef

Stuber, D., Mhanda, A. & Lefebvre, C. (2011). Climate data management systems: status of implementation in developing countries. *Climate Research*, **47,** 13–20. CrossRef

Thorne, P.W., Willett, K.M., Allan, R.J., et al. (2011). Guiding the creation of a comprehensive surface temperature resource for twenty-first-century climate science. *Bulletin of the American Meteorological Society*, **92,** ES40–ES47. CrossRef

Tan, L.S., Burton, S., Crouthamel, R., van Engelen, A., Hutchinson, R., Nicodemus, Peterson, T.C. & Rahimzadeh, F. (2004). *Guidelines on climate data rescue*. WMO/TD no. 1210. Geneva: World Meteorological Organization

United Nations Development Programme (UNDP) (2012). Strengthening climate information and early warning systems in Zambia. Description available at http://adaptation-undp.org/projects/ldcf-ews-zambia (last accessed 27 June 2017)

United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) (2016). Overview of El Niño response in East and Southern Africa. Available at http://www.unocha.org/sites/dms/Documents/2016_11_Elnino_Africa_Breakfast_meeting_FINAL.pdf (last accessed 5 February 2018)

World Meteorological Organization (WMO) (2014). *Climate data management system specifications*. WMO no. 1131. Geneva: World Meteorological Organization. Available at http://library.wmo.int/pmb_ged/wmo_1131_en.pdf (last accessed 7 July 2017)

WMO (2016). *Guidelines on best practices for climate data rescue*. WMO no. 1182. Geneva: World Meteorological Organization. Available at https://library.wmo.int/opac/doc_num.php?explnum_id=3318 (last accessed 7 July 2017)

WMO (1989). CLICOM Project (climate data management system). WMO/TD no. 299. Geneva: World Meteorological Organization. Available at https://library.wmo.int/pmb_ged/wmo-td_299_en.pdf (last accessed 7 July 2017)