Adv. Sci. Res., 13, 97–105, 2016
www.adv-sci-res.net/13/97/2016/
doi:10.5194/asr-13-97-2016

Advances in Science & Research
Open Access Proceedings

15th EMS Annual Meeting & 12th European Conference on Applications of Meteorology (ECAM)

Improving the climate data management in the meteorological service of Angola: experience from SASSCAL

Rafael Posada[1], Domingos Nascimento[2], Francisco Osvaldo S. Neto[2], Jens Riede[1], and Frank Kaspar[1]

[1]Deutscher Wetterdienst, National Climate Monitoring, Frankfurter Str. 135, 63067 Offenbach, Germany
[2]Instituto Nacional de Meteorologia e Geofisica (INAMET), Luanda, Angola

Correspondence to: Rafael Posada (rafael.posada-navia-osorio@dwd.de)

Received: 15 January 2016 – Revised: 20 April 2016 – Accepted: 7 June 2016 – Published: 20 June 2016

Abstract. The knowledge on climate variability in parts of Southern Africa is limited because of the low availability of historic and present-day ground-based observations (Niang et al., 2014). However, there is an increased need of climate information for research, climate adaptation measures and climate services. To respond to the challenges of climate change and related issues, Angola, Botswana, Germany, Namibia, South Africa and Zambia have initiated the interdisciplinary regional competence centre SASSCAL, the "Southern African Science Service Centre for Climate Change and Adaptive Land Management". As part of the initiative, Germany's national meteorological service (Deutscher Wetterdienst, DWD) cooperates with the meteorological services of Angola, Botswana and Zambia in order to improve the management and availability of historical and present-day climate data in these countries. The first results of the cooperation between the German and the Angolan Meteorological Services are presented here. International assessments have shown that improvements of the data management concepts are needed in several countries. The experience of this cooperation can therefore provide hints for comparable activities in other regions.

1 Introduction

The global climate change issue is stretching the requirements for climate data and data management systems far beyond those originally conceived when the original observational networks were established (WMO, 2011). However, the lack of adequate data and observation systems in Africa seriously hinders the ability of scientists to assess the past and current state of the climate in the region (ACC, 2013). This also applies to parts of Southern Africa, where the knowledge on climate variability is limited because of the low availability of historic and present-day ground-based observations (Niang et al., 2014)

To contribute to reduce this lack of data, the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) initiative supports, among others, activities focused on the installation and reparation of Automatic Weather Stations (AWS) within the SASSCAL region: Angola, Botswana, Namibia, South Africa and Zambia (Kaspar et al., 2015a). The current[1] AWS Network of SASSCAL comprises 132 AWSs.

To meet the expanding needs of climate information for research, climate adaptation measures and climate services it is very important that climate data, both current and historical, are managed in a systematic and comprehensive manner (WMO, 2011).

Climatological data are most useful if they are edited, quality-controlled and stored in a national archive or climate centre and made readily accessible in easy-to-use forms. Although technological innovations are occurring at a rapid pace, many climatological records held by National Meteorological and Hydrological Services (NMHSs) are still in non-digital form. These records must be managed along with the increasing quantity of digital records. A climate data man-

[1]Status as of 31 March 2016. The data collected by the AWS Network can be accessed online through the website of the SASSCAL WeatherNet: http://www.sasscalweathernet.org.

agement system (CDMS) is a set of tools and procedures that allows all data relevant to climate studies to be properly stored and managed (WMO, 2011). A well-constructed CDMS facilitates all the key processes associated with data collection, quality assurance and archival, and is central to the development of all interactive data and information services (GFCS, 2014).

In this context, the SASSCAL initiative supports an activity focused on the improvement of the historical and ongoing climate data management at the NMHS of Angola, Botswana, Namibia and Zambia in cooperation with Germany's national meteorological service (Deutscher Wetterdienst, DWD). However, the NMHS that actually showed interest in cooperating with the DWD for improving their data management were the Instituto Nacional de Meteorología e Geofísica of Angola (INAMET), the Department of Meteorological Services of Botswana (DMS) and the Zambia Meteorological Department (ZMD).

An overview of the status and first results of the cooperation between the DWD and INAMET is presented here.

2 Management of historical and current climate data

The cooperation between the NMHSs is focused on improving the management of climate data in each country in order to make them available for scientific use and for decision makers and diverse stakeholders. More specifically, the cooperation focuses on:

- implementing a Climate Data Management System (CDMS);
- developing operational concepts for the CDMS;
- archiving current meteorological observations;
- collecting and archiving of already digitized historic climate data;
- digitizing and archiving of historic climate data;
- capacity building on Climate Data Management.

The core of the cooperation is to implement a reliable CDMS; "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).

During the last decades different CDMS with diverse development approaches have been in use in developing countries (see Stuber et al., 2011), and the delegates of the NMHSs of Angola, Botswana, Zambia and Germany had the opportunity to discuss the different options available during a SASSCAL Workshop held in Namibia in April 2014. At the end of the Workshop it was agreed by all the participants that CLIMSOFT ("CLIMatic SOFTware") is the preferred option, considering that all countries had used this software at some point (Hänsler, 2014).

CLIMSOFT was first developed by an African team of 3 developers located in Zimbabwe (namely Albert Mhanda), Kenya (Samuel Machua) and Guinea (Barry Aziz) to provide a free and easy-to-use CDMS for developing countries (Stuber et al., 2011). As described in Kaspar et al. (2015a), it has an intuitive Graphical User Interface with a key-entry module, quality control procedures and data import options which allow the import of data from various sources, including data from automatic weather stations. The software is currently based largely on the data base management system (DBMS) Microsoft® Access© and Microsoft Visual Basic 6®, but modifications to the software, and a switch to open-source database systems are currently in preparation. One of the most important features of the CLIMSOFT software is its free availability and the fact that it is becoming supported by a large community of developers. The next version of CLIMSOFT is being developed based on the "Climate Data Management System Specifications" of the WMO (WMO, 2014), so that most of the required components are included in the software.

3 Cooperation between INAMET and DWD

3.1 Development of a new data flow at INAMET

The contact between the DWD and INAMET began in 2013 under the SASSCAL framework but it was in April 2014 when an evaluation of the facilities and resources concerning climate data management was accomplished. At that time, the Angolan NMHS did not have an operational CDMS[2] and the records of manual weather stations were key-entered in Microsoft® Excel© (hereafter MS-Excel) tables. These tables were saved in files with different nomenclature at isolated PCs, which made it difficult to identify which data were already digitized and where they were located. Furthermore, an up-to-date inventory of the weather station network was not available, and a unique identifier was not assigned to each station. Data recorded by AWS were automatically sent to a server located at INAMET in ASCII format (text files). The need of an improved documentation in data management procedures was also acknowledged.

After recognizing the needs at INAMET, a data flow structure was designed to avoid inconsistencies in the storage of climate data (see Fig. 1). As a first step, a unique local identifier was assigned to each weather station operated by INAMET. For manual weather stations, the identifier was assigned based on an on-paper inventory which was available at the headquarters whereas for AWS, a unique number was newly assigned to each station.

[2]CLIMSOFT was installed once in 2007 but it never became operational due to difficulties in its management.

Table 1. Overview of Angolan data imported in the CLIMSOFT database from the MS-Excel sheets.

Dataset	Time resolution	Element available	Number of stations	Date of first record	Date of last record	Max. number of records
INAMET	Daily	Daily precipitation	11	2 Jan 1992	31 Dec 2014	1340
		Pressure at station level	2	1 Mar 2005	31 Dec 2011	203
		Relative humidity	2	1 Mar 2005	31 Dec 2011	234
		Maximum temperature	4	1 Jan 1948	5 Jan 2014	333
		Minimum temperature	3	1 Jan 1948	31 Dec 2011	230
		Mean temperature	1	1 Mar 2011	31 Dec 2011	225
		Visibility	1	1 Mar 2011	31 Dec 2011	180
	Monthly	Evaporation	9	1 Jan 1952	1 Jun 1975	243
		Monthly precipitation	16	1 Jan 1951	1 Jul 2012	584
		Pressure at station level	11	1 Jan 1951	1 Dec 2012	616
		Relative humidity	14	1 Jan 1951	1 Dec 2012	598
		Sunshine duration	7	1 Jan 1952	1 Nov 1991	416
		Mean temperature	14	1 Jan 1951	1 Dec 2012	640
		Maximum temperature	17	1 Jan 1951	1 Dec 2012	640
		Minimum temperature	14	1 Jan 1951	1 Dec 2012	640

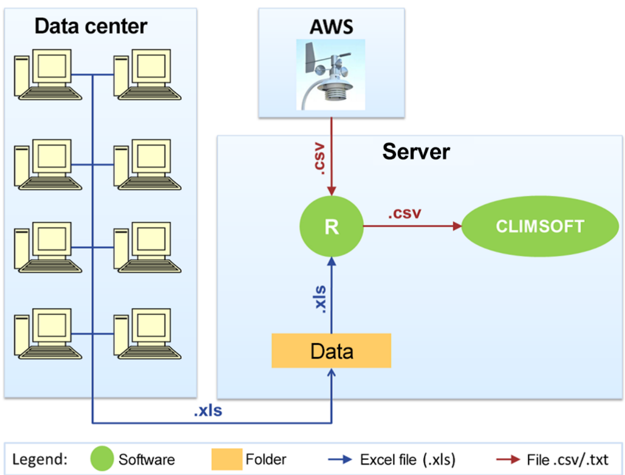

Figure 1. Current dataflow at INAMET: from the key entry of data in MS-Excel tables at the Data Centre to the import of the data into CLIMSOFT through R.

According to the agreement achieved during the SASSCAL Workshop in April 2014, the CLIMSOFT v3.2 was installed to be used as the CDMS in which meteorological data from both, manual and automatic weather stations are to be stored. The software includes features to key-enter historical data directly into the database. However, it was agreed with the Technical Directorate of INAMET to take advantage of the experience of the personnel in MS-Excel and keep this software as the key-entry system for historical and current data recorded at manual weather stations. Table templates have been created based on the original structure of the MS-Excel tables used previously at INAMET. These templates ensure that the entered data are saved in MS-Excel files with the identical structure. The MS-Excel files with data entered before the new data management strategy was implemented have been re-formatted to match the format of the table templates.

These files are then saved in a server instead of in isolated computers using a standardized nomenclature. The technicians, responsible for the import of data and maintenance of the CDMS, can access the data directly from the server and proceed with the import into CLIMSOFT. For this to be done, a format conversion of the MS-Excel files is needed, since CLIMSOFT requires the data to be saved in comma-separated values (".csv") files. An easy-to-use routine called "conversao e importaçao" has been developed specifically for INAMET to facilitate the conversion and later import of data. This application programmed with R (R Core Team, 2015), guides the user through the conversion and import of data following three steps: (1) import of station metadata; (2) conversion of MS-Excel files into ".csv" files; and (3) import the data into CLIMSOFT v3.2 (see Fig. 2). The routine is run once a week to update the database with new key-entered data. The key-entered data available in the database are listed in Table 1.

Concerning the data recorded by AWS, CLIMSOFT provides a tool to import them automatically into the database. This tool is being used to import the data of the AWSs installed by SASSCAL and operated by INAMET. The tool checks every two hours whether there are new records from the AWS and, if so, they are entered automatically into the database.

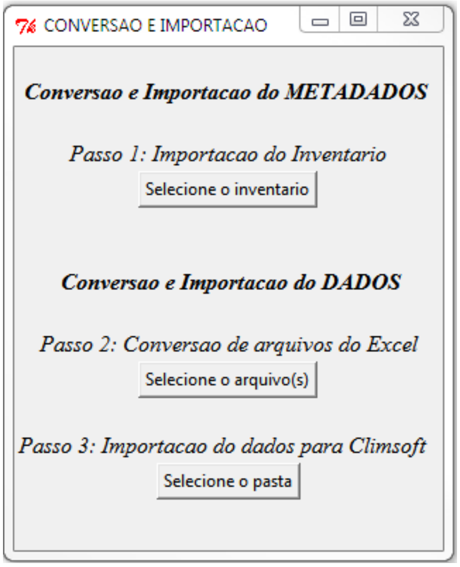

Figure 2. User interface of the "conversao e importaçao" developed specifically for INAMET.

3.2 Quality control

CLIMSOFT provides a number of quality control (QC) checks that are being used at INAMET to control the quality of the data stored in the main database. They include:

– Limits check (based on standard deviation). It checks which observed values of a given element are above (below) a specific upper (lower) threshold. The thresholds are calculated based on the monthly mean of that element plus (minus) "n" times the standard deviation.

– Absolute limits check. It checks which observed values of a given element are above (below) a specific upper (lower) threshold. The thresholds are defined by the user in CLIMSOFT and can be modified according to the climate pattern of the country.

– Inter-element comparison. It compares (a) maximum temperature against minimum temperature; (b) dry bulb temperature against wet bulb temperature; (c) maximum temperature against dry bulb temperature; and (d) dry bulb temperature and dew point temperature.

– Daily range. It checks if the daily differences between maximum and minimum temperature are above (below) the mean long-term difference plus (minus) "n" times the standard deviation.

– Consecutive days consistency check. It checks if the difference of observed values between consecutive days are above (below) the monthly mean difference plus (minus) "n" times the standard deviation.

– Consecutive hours consistency check. It checks if the difference of observed values in consecutive hours is above (below) the monthly mean plus (minus) "n" times the standard deviation.

Besides the QC checks provided by CLIMSOFT, an easy-to-use tool has been developed with R to carry out a visual QC of the data stored in CLIMSOFT. This tool allows the user to create a variety of plots (time-series, histogram and wind roses) to facilitate the identification of inconsistencies within the datasets. For instance, time series plots led to the identification of rapid changes exceeding a specified threshold or the detection of gaps within a dataset, as shown in Fig. 3.

The interactivity of these graphics is aimed to allow the user get information from the dataset by navigating through the graphic. These graphical products are being developed as part of a collaborative development project called ClimateObject; an R-package that aims to create a great number of graphical products based on climate data. More information about this project can be found in GitHub, a code-hosting repository based on the GIT version control system (Dabbish et al., 2012): https://github.com/StatisticalServicesCentre/ClimateObject. These new features are operational at INAMET since January 2016.

3.3 Collection of historical data

Another task carried out as part of the cooperation is the collection of historical and current data from Angola that are stored in international archives. Up to date, a total of seven different datasets with digitized meteorological data from Angola were identified (see Table 2).

The data were either downloaded from or directly requested from these sources. These data are being stored in a separate Microsoft® Access© database until they are checked against those data stored at the INAMET database. In this manner it is ensured that there are no inconsistencies in the main database of the NMHS. This second database is also accessible with CLIMSOFT.

More meteorological data from Angola might still exist in non-digital form in archives of other meteorological services, such as in the DWD (Kaspar et al., 2015b), which could complement the dataset already available at INAMET.

Besides the collection of data, INAMET and the Global Precipitation Climate Centre (GPCC) have come to an agreement by which INAMET approves supplying additional daily precipitation data from the weather stations to contribute to the global gridded precipitation analyses carried out by the GPCC (Becker et al., 2013). This will contribute to substantially improve the data coverage and consequently the reliability of the GPCC precipitation analyses across Angola.

3.4 Capacity building

An important aspect of SASSCAL is its educative nature. Having the capacity building activities as one of the main objectives of the initiative, the cooperation between DWD

Table 2. Overview of Angolan data availability in international datasets.

Dataset	Time resolution	Source	Element available	Number of stations	Date of first record	Date of latest record	Max. number of records
DWD (WMO reports)	Daily (SYNOP)	Data requested by INAMET	Maximum temperature	19	2 Oct 2001	21 Mar 2016	695
			Minimum temperature	22	3 Dec 1998	22 Mar 2016	1226
			Daily precipitation	22	11 May 1998	22 Mar 2016	2138
	Monthly (CLIMAT)	Data requested by INAMET	Mean temperature	17	1 Jan 1949	1 Feb 2014	428
			Days with precipitation	16	1 Jan 1968	1 Feb 2014	199
			Monthly precipitation	17	1 Jan 1949	1 Feb 2014	429
			Sea level pressure	7	1 Jan 1949	1 Feb 2014	426
			Water vapor pressure	16	1 Jan 1968	1 Feb 2014	195
			Relative humidity	14	1 Jan 1949	1 Nov 1967	227
			Geopotential	9	1 Jan 1956	1 Apr 1985	202
			Sunshine duration	3	1 Jan 1980	1 Nov 2013	2
			Quintile	11	1 Jan 1957	1 Mar 1985	288
			Pressure at the station	5	1 Feb 1985	1 Feb 2014	35
			Minimum mean temperature	1	1 Aug 2010	1 Feb 2014	34
			Absolute minimum temperature	1	1 Aug 2010	1 Feb 2014	34
			Maximum mean temperature	1	1 Aug 2010	1 Feb 2014	33
			Absolute maximum temperature	1	1 Aug 2010	1 Feb 2014	34
GPCC	Monthly	Data requested by INAMET	Monthly Precipitation	198	1 Jan 1901	1 Dec 2006	1268
GHCN	Daily	Menne et al. (2012a, b)	Maximum temperature	6	28 Jan 1955	20 Feb 2016	2774
			Minimum temperature	6	28 Jan 1955	18 Feb 2016	3284
			Daily precipitation	6	28 Jan 1955	15 Feb 2016	3165
	Monthly	Lawrimore et al. (2011a)	Mean temperature	17	1 Jan 1901	1 Feb 2016	1033
		Peterson and Vose (1997a)	Absolute minimum temperature	17	1 Jan 1901	1 Feb 2016	1033
			Monthly precipitation	104	1 Feb 1879	1 Mar 1992	1271
RBIS	Daily	http://leutra.geogr.uni-jena.de/sasscalRBIS/metadata/start.php	Observed temperature	16	4 Jan 1955	19 Oct 2014	6594
			Dew point temperature	16	4 Jan 1955	19 Oct 2014	6424
			Sea level pressure	4	3 Sep 1957	25 Sep 2013	3269
			Pressure at the station	3	4 Jan 1955	31 Oct 1962	1079
			Mean visibility	15	4 Jan 1955	19 Oct 2014	6566
			Wind speed	16	4 Jan 1955	19 Oct 2014	6594
			Maximum wind speed	16	4 Jan 1955	19 Oct 2014	6532
			Wind strength	2	20 Oct 2001	27 Sep 2014	12
			Mean maximum temperature	17	4 Jan 1955	19 Oct 2014	6582
			Mean minimum temperature	17	4 Jan 1955	19 Oct 2014	6577
			Daily precipitation	17	4 Jan 1955	15 Oct 2014	3613
	Monthly	http://leutra.geogr.uni-jena.de/sasscalRBIS/metadata/start.php	Monthly precipitation	92	1 Jan 1948	1 May 2010	637
			Potential evaporation	17	1 Jan 1948	1 May 2010	605
			Pressure at the station	17	1 Jan 1948	1 Jun 2010	615
			Maximum mean temperature	45	1 Jan 1948	1 Jun 2010	652
			Minimum mean temperature	45	1 Jan 1948	1 Jun 2010	644
			Observed temperature	45	1 Jan 1948	1 Jun 2010	654
			Relative humidity	44	1 Jan 1948	1 Jun 2010	652
			Sunshine duration	15	1 Jan 1948	1 Aug 1992	416

Table 2. Continued.

Dataset	Time resolution	Source	Element available	Number of stations	Date of first record	Date of latest record	Max. number of records
ISTI	Monthly	ftp://ftp.ncdc.noaa.gov/pub/data/globaldatabank/monthly/stage2/colonialera/ (Thorne et al., 2011)	Maximum mean temperature	6	1 Jan 1879	1 Dec 1973	1080
			Minimum mean temperature	6	1 Jan 1879	1 Dec 1973	1080
CDIAC	Hourly	ftp://cdiac.esd.ornl.gov/pub/ndp026c/ (Hahn and Warren, 2009)	Sea level pressure	25	1 Jan 1971	28 Dec 1996	8883
			Wind speed	31	1 Jan 1971	28 Dec 1996	8807
			Wind direction	31	1 Jan 1971	17 Nov 1996	8519
			Observed temperature	31	1 Jan 1971	28 Dec 1996	8906
			Dew point temperature	31	1 Jan 1971	28 Dec 1996	9116
IDL	Hourly	Data requested by INAMET	Actinometry	1	1 Jan 1917	31 Dec 1944	30 067
			Total cloud cover	3	1 Jan 1880	31 Dec 1946	43 822
			Water vapor pressure	3	1 Jan 1880	31 Dec 1944	41 631
			Sea level pressure	1	1 Jan 1880	31 Dec 1887	8761
			Pressure at the station	3	1 Jan 1915	31 Dec 1946	35 059
			Relative humidty	3	1 Jan 1880	31 Dec 1946	43 821
			Observed temperature	3	1 Jan 1880	31 Dec 1946	43 822
			Soil temperature at 0 m	1	1 Jan 1921	5 Jan 1921	5
			Soil temperature at 0.3 m	1	1 Oct 1916	31 Dec 1920	1551
			Soil temperature at 0.5 m	1	1 Jan 1916	31 Dec 1944	10 579
			Soil temperature at 0.8 m	1	1 Oct 1916	31 Dec 1944	10 315
			Soil temperature at 1.0 m	1	1 Oct 1916	31 Dec 1944	10 298
			Soil temperature at 1.5 m	1	1 Jan 1916	31 Dec 1944	10 578
			Visibility	1	1 Jan 1945	31 Dec 1946	730
			Wind direction	3	1 Jan 1880	31 Dec 1946	41 666
			Wind speed	3	1 Jan 1880	31 Dec 1946	42 087
	Daily	Data requested by INAMET	Evaporation	1	1 Jan 1880	31 Dec 1887	2919
			Evaporation (9–9 h)	3	1 Jan 1915	31 Dec 1946	11 675
			Grass maximum temperature	1	1 Jan 1916	31 Dec 1944	9568
			Grass minimum temperature	1	1 Jan 1916	31 Dec 1944	10 549
			Percentage of insolation	1	1 Jan 1945	31 Dec 1946	730
			Total insolation 0–24 h	1	1 Jan 1945	31 Dec 1946	729
			Ozone	1	1 Jan 1880	31 Dec 1887	2918
			Daily precipitation	1	1 Jan 1880	31 Dec 1887	2907
			Daily precipitation (9–9 h)	3	1 Jan 1915	31 Dec 1946	11 649
			Precipitation hours (9–9 h)	1	15 Aug 1919	31 Dec 1944	3009
			Sunshine duration	1	1 Jan 1916	31 Dec 1944	10 319
			Minimum temperature	3	1 Jan 1880	31 Dec 1946	14 610
			Maximum temperature	3	1 Jan 1880	31 Dec 1946	14 609
			Maximum irradiation temperature	1	1 Jan 1916	31 Dec 1944	10 575
			Minimum irradiation temperature	1	7 Jan 1925	31 Dec 1939	5099
			Wind speed	1	1 Oct 1882	31 Dec 1946	12 842

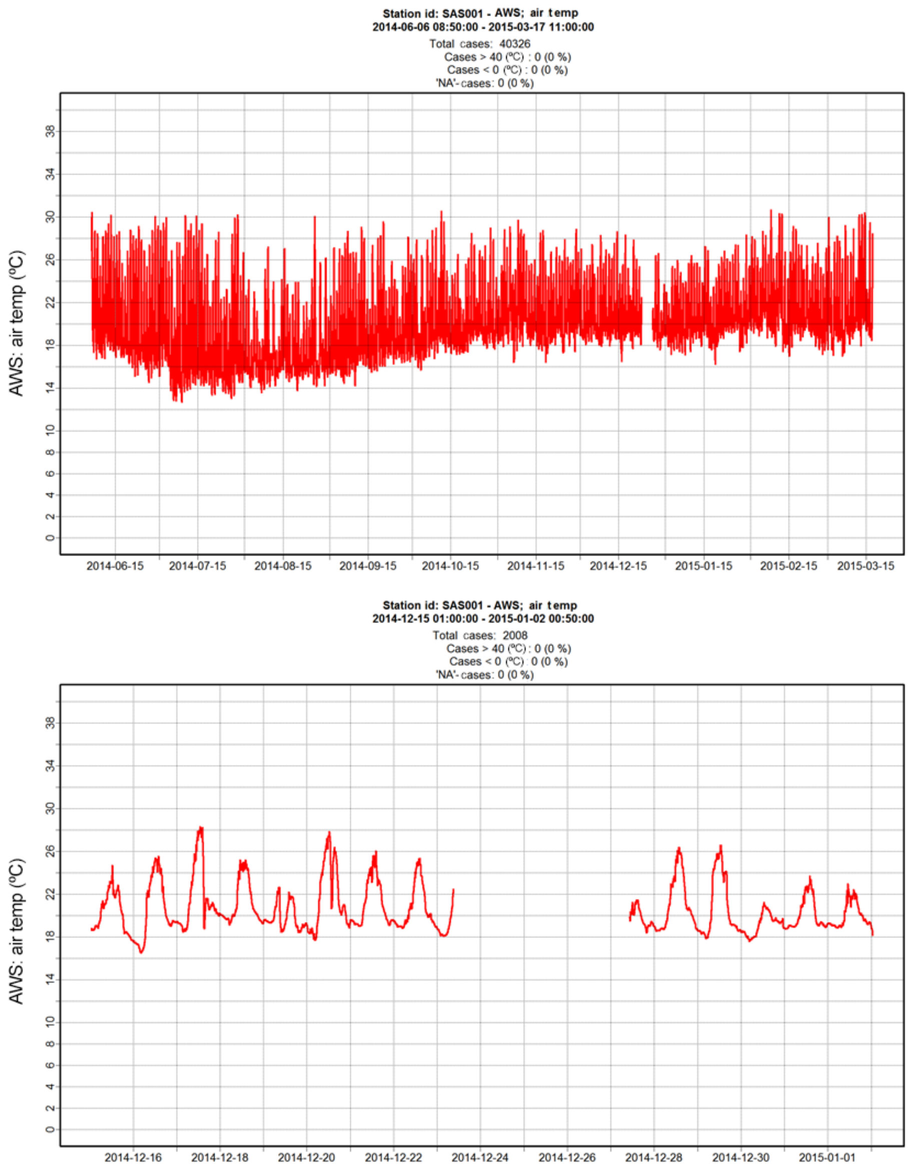

Figure 3. Time series of air temperature in Dambo, Uige (Angola). 10 min measurements made by a SASSCAL AWS (top panel) between 6 June 2014 and 17 March 2015. In the bottom panel a zoom of the gap of data, between 23 and 27 December 2014.

and INAMET is highly focused on developing the local capacities in the country. Several training activities have been carried out since April 2014. The first training activity, focused on CLIMSOFT, took place between 8 and 13 August 2014 and was addressed to the local staff of INAMET. In March 2015 the training activities were extended to other institutions and focused on clarifying basic concepts related to climate and climate data management. Besides the local staff of INAMET, representatives of the Fire-Department, as well as of the Food Security Cabinet were taking part of the training. The aim was to improve the awareness on the importance of good practices for the management of climate data. For this, concepts such as metadata and homogenization were explained, and the importance of rescuing historical data was stressed (see Fig. 4)

Both, in August 2014 and in March 2015 training in R has been given to the INAMET technicians. This is of special relevance, since proper skills in R programming will allow the technicians to properly understand and manage the software developed to convert and import climate data as well as to create graphical products (see Sects. 2.1 and 2.2). The final aim is to improve their programming skills so that they can create their own applications according to INAMET needs.

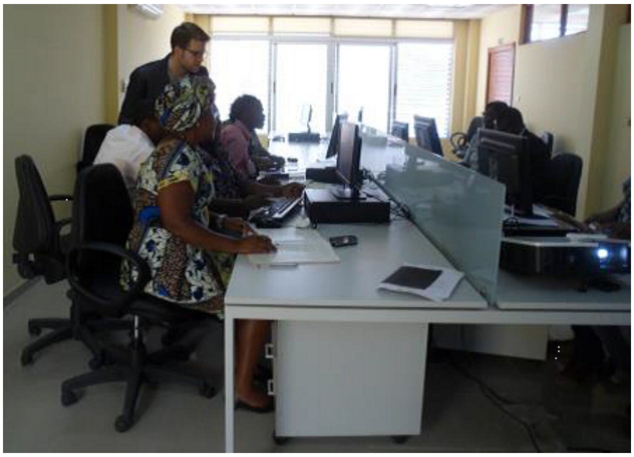

Figure 4. Photo of the training on Climate Data Management at INAMET in March 2015.

4 Conclusions

Efforts have been done within SASSCAL to improve the availability of climate data in Southern Africa. Besides the installation and repair of AWSs, activities focused on the improvement in the management of historical and current climate data are being carried out in the NMHSs of the region in cooperation with the DWD. The experience described here shows the steps done at INAMET in this matter. A new data flow scheme has been developed and implemented, and CLIMSOFT v3.2 has been installed to serve as the core of a proper CDMS, allowing the management of historical and ongoing climate data at INAMET. Furthermore, the R programming language has been used to facilitate visual quality controls and navigate through the data stored in the CLIMSOFT database, as well as to allow the migration of data from MS-Excel sheets to the database. Therefore, the R routines developed can be seen as part of the CDMS, since it extends the functionality of CLIMSOFT. The Climate Data Management System Specifications of the WMO itself (WMO, 2014) states that a CDMS is not expected to contain all of its functionality within a single software package.

These actions are destined to provide a long-term and sustainable solution for the management of climate data at the NMHS. Although the cooperation between the DWD and INAMET is still on-going, the experience so far has led to acknowledge that:

- An evaluation of the human and technical resources at the NMHS is essential to recognize the actual local capacities.
- The actions aimed to improve the management of climate data should fit the local capacities to ensure their implementation.
- A complete overview of the work flow at the NMHS is required prior taking any action concerning climate data management.
- The directorate of the NMHS has to agree with the actions proposed and should encourage the personnel to implement them.
- It is important that the personnel see the advantages of implementing a new system.
- The CDMS should take advantage of the local expertise when new tools are developed. For example, at INAMET, it was decided to keep MS-Excel as key-entry system because the staff were very familiar with this software.
- Capacity building activities are pillar to make people aware of the importance of having a comprehensive CDMS. At INAMET, basic concepts such as metadata or homogenization were introduced to encourage the employees in charge of the management of climate data to treat the data carefully.
- The implementation process should be monitored to assist as soon as any problem arises.

The joint interest of DWD and INAMET is to maintain the cooperation until end 2017 to monitor the improvements made so far and also to take a closer look at other aspects related to climate data management, such as (a) cross-checking Angolan data obtained from international datasets with those stored at INAMET, (b) carrying out quality control of the digitized data stored in the CDMS and (c) locating and organizing on-paper historical records and, if required, supporting data rescue activities for data not yet digitized.

By the end of the cooperation, the improved accessibility of the observational data will allow the application of these data for verification of the national weather forecast run at INAMET. This is of high priority for the NMHS as it will support the provision of more accurate products to end-users and stakeholders, including the scientific community. Understanding predictability and predictive skills of numerical weather prediction models is an important area of research on the weather and seasonal scale (Bauer et al., 2015).

5 Data availability

Some of the international datasets described in Table 2 provide on-line access to Angolan data. This is the case of the Global Historical Climatology Network (GHCN), the River Basin Information System for SASSCAL (RBIS), the International Surface Temperature Initiative (ISTI) and the Carbon Dioxide Information Analysis Center (CDIAC). The links and references to these datasets are provided in the table. The other sources mentioned in Table 2 (i.e. the German

Meteorological Service, DWD, the Global Precipitation Climate Centre, GPCC; and the Instituto Dom Luiz, IDL) provided the data to INAMET under request.

Acknowledgements. DWD's contribution to SASSCAL is funded by Germany's Ministry for Education and Research (BMBF, grant no. 01LG1201J). We thank Maria Antónia Valente (Instituto Dom Luiz, Lisbon, Portugal) for the provision of digitized climate observations.
Edited by: I. Auer
Reviewed by: O. Baddour and one anonymous referee

References

ACC: Final Declaration, Africa Climate Conference 2013, 15–18 October 2013, Arusha, Tansania, available at: http://www.wmo.int/amcomet/sites/default/files/field/doc/events/acc2013_final_declaration.pdf (last access: 17 February 2016), 2013.

Bauer, P., Thorpe, A., and Brunet, G.: The Quiet Revolution of Numerical Weather Prediction, Nature, 525, 47–55, 2015.

Becker, A., Finger, P., Meyer-Christoffer, A., Rudolf, B., Schamm, K., Schneider, U., and Ziese, M.: A description of the global land-surface precipitation data products of the Global Precipitation Climatology Centre with sample applications including centennial (trend) analysis from 1901–present, Earth Syst. Sci. Data, 5, 71–99, doi:10.5194/essd-5-71-2013, 2013.

Dabbish, L., Stuart, C., Tsay, J., and Herbsleb, J.: Social coding in GitHub: transparency and collaboration in an open software repository, in: Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work, ACM, 11–15 February 2012, Seattle, Washington, USA, 1277–1286, 2012.

GFCS: Annex to the Implementation Plan Of the Global Framework for Climate Services – Climate Services Information System Component, World Meteorological Organization, Geneva, Switzerland, 71 pp., 2014.

Hahn, C. J. and Warren, S. G.: Extended Edited Cloud Reports from Ships and Land Stations over Globe, 1952–1996 (2009 update), Carbon Dioxide Information Analysis Center Numerical Data Package NDP-026C, Carbon Dioxide Information Analysis Center Numerical, Tennessee, USA, 79 pp., 2009.

Hänsler, A.: Minutes – SASSCAL Thematic Workshop Climate, available at: http://www.sasscal.org/downloads/Minutes_SASSCAL-ClimateWorkshop_August2014_FINAL.pdf, (last access: 16 February 2016), 2014.

Kaspar, F., Helmschrot, J., Mhanda, A., Butale, M., de Clercq, W., Kanyanga, J. K., Neto, F. O. S., Kruger, S., Castro Matsheka, M., Muche, G., Hillmann, T., Josenhans, K., Posada, R., Riede, J., Seely, M., Ribeiro, C., Kenabatho, P., Vogt, R., and Jürgens, N.: The SASSCAL contribution to climate observation, climate data management and data rescue in Southern Africa, Adv. Sci. Res., 12, 171–177, doi:10.5194/asr-12-171-2015, 2015a.

Kaspar, F., Tinz, B., Mächel, H., and Gates, L.: Data rescue of national and international meteorological observations at Deutscher Wetterdienst, Adv. Sci. Res., 12, 57–61, doi:10.5194/asr-12-57-2015, 2015b.

Lawrimore, J. H., Menne, M. J., Gleason, B. E., Williams, C. N., Wuertz, D. B., Vose, R. S., and Rennie, J.: An overview of the Global Historical Climatology Network monthly mean temperature data set, version 3, J. Geophys. Res., 116, D19121, doi:10.1029/2011JD016187, 2011a.

Lawrimore J. H., Menne M. J., Gleason, B. E., Williams, C. N., Wuertz, D. B., Vose, R. S., and Rennie, J.: Global Historical Climatology Network – Monthly (GHCN-M), Version 3.2, NOAA National Centers for Environmental Information, doi:10.7289/V5X34VDR, 2011b.

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

Menne, M. J., Durre, I., Vose, R. S., Gleason, B. E., and Houston, T. G.: An Overview of the Global Historical Climatology Network-Daily Database, J. Atmos. Ocean. Tech., 29, 897–910, doi:10.1175/JTECH-D-11-00103.1, 2012b.

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J., and Urquhart, P.: Africa, in: Climate Change 2014: Impacts, Adaptation, and Vulnerability, Part B: Regional Aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change edited by: Barros, V. R., Field, C. B., Dokken, D. J., Mastrandrea, M. D., Mach, K. J., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C., Girma, B., Kissel, E. S., Levy, A. N., MacCracken, S., Mastrandrea, P. R., and White, L. L., Cambridge University Press, Cambridge, UK and New York, NY, USA, 1199–1265, 2014.

Peterson, T. C. and Vose, R. S.: An overview of the Global Historical Climatology Network temperature database, B. Am. Meteorol. Soc., 78, 2837–2849, 1997a.

Peterson, T. C. and Vose, R. S.: Global Historical Climatology Network – Monthly (GHCN-M), Version 2, NOAA National Centers for Environmental Information, doi:10.7289/V5X34VDR, 1997b.

R Core Team: R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org/, last access: 20 October 2015.

Stuber, D., Mhanda, A., and Lefebvre, C.: Climate Data Management Systems: status of implementation in developing countries, Clim. Res., 47, 13–20, 2011.

Thorne, P. W., Willett, K. M., Allan, R. J., Bojinski, S., Christy, J. R., Fox, N., Gilbert, S., Jolliffe, I., Kennedy, J. J., Kent, E., Tank, A. K., Lawrimore, J., Parker, D. E., Rayner, N., Simmons, A., Song, L., Stott, P. A., and Trewin, B.: Guiding the Creation of A Comprehensive Surface Temperature Resource for Twenty-First-Century Climate Science, B. Am. Meteorol. Soc., 92, ES40–ES47, doi:10.1175/2011BAMS3124.1, 2011.

WMO: WMO-No. 100: Guide to Climatological Practices, World Meteorological Organization, Geneva, Switzerland, 117 pp., 2011.

WMO: WMO-No. 1131: Climate Data Management System Specifications. World Meteorological Organization, Geneva, Switzerland, 170 pp., 2014.