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DACCIWA

"Dynamics-aerosol-chemistry-cloud interactions in West Africa"

Deliverable

D 7.1

Surface climatology

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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Nature of Deliverable		
R	Report	**x**
P	Prototype	
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Authors

Author	Beneficiary Short Name	E-Mail
Andreas H. Fink	KIT	andreas.fink@kit.edu
Peter Knippertz	KIT	peter.knippertz@kit.edu
Lukas Leufen	KIT	lukas.leufen@student.kit.edu
Marlon Maranan	KIT	marlon.maranan@kit.edu

Changes with respect to the DoW

Issue	Comments
- Despite substantial efforts from DACCIWA scientists, not as much data as hoped for have been digitised up to now. This is to some extent due to relatively slow responses from some of the involved weather services. Differences between countries, however, are large. For example, activities in Ghana, where contacts were well established already before DACCIWA, have progressed quickly.	- A new strategy has been developed for Benin and Ivory Coast that involves local universities in addition to weather services. Memoranda of Understanding and Subcontracts have been developed to provide a legal basis for the activities. Thus progress is expected soon. - To better merge new data with existing information from a range of sources, a new database system has been developed at KIT, based on an older system from the University of Cologne. This was not foreseen in detail in the DoW, but will prove extremely handy for incorporating new data in the future and particularly for the exchange of data within DACCIWA and with external partners. - Data unavailable at the time of the beginning of the project, which we received from other sources, have already been incorporated into the database (see report below for details).

Dissemination and uptake

Target group addressed	Project internal / external
Scientific community	Internal and external

Document Control

Document version #	Date	Changes Made/Comments
v0.1	01/10/2015	First version submitted to DACCIWA partners for comments.
v1.0	29/10/2015	Final version

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Acronyms

GTS	Global Telecommunication System of the World Meteorological Organisation
ICAO	International Civil Aviation Organisation
IGM	Institute of Geophysics and Meteorology of the University of Cologne
ISD	Integrated Surface Data
KASS-D	KIT African Surface Station Database
METAR	Aerodrome routine meteorological report
MoU	Memorandum of Understanding
NCDC	U.S. National Climatic Data Center
SOP	Special Observing Periods
SYNOP	standard surface synoptic observation

1 Introduction

This report provides a description of the activities conducted in DACCIWA WP7 Task 7.1 "Digitisation of station data". For a regional evaluation of model and satellite data beyond the period of the DACCIWA field campaign in 2016, standard surface observations from routine weather stations are the only possible source of information. One principal aim of DACCIWA is therefore to improve the availability of long-term ground-based observations from weather stations. This especially pertains to

(a) hourly eye observations of low-level clouds that are often obscured by higher-level clouds in satellite cloudiness products (van der Linden et al. 2015);

(b) daily accumulated rainfall that is often underestimated by satellite rainfall products (Sanogo et al. 2015); and

(c) the availability of multi-year measurements of surface radiation (see Knippertz et al. 2011)

Surface weather stations have been operated by the respective National Weather Services of the countries along the Guinea Coast since many decades. The standard surface synoptic observations (SYNOP) are supposed to be fed into the Global Telecommunication System (GTS) of the World Meteorological Organisation (WMO) on a three- to six-hourly basis. However, for various reasons, the information is often not available on the GTS. SYNOP data from African stations in the GTS are also prone to coding errors. A second type of observations is the aerodrome routine meteorological report (METARs). They are only available for international airports at the Guinea Coast in the International Civil Aviation Organisation (ICAO) database, but data gaps are less frequent than for SYNOPs. SYNOPs and METARs generally contain similar information in a similar format, but for example the codes for cloud types and cover, a particularly important parameter for DACCIWA, differ.

Given this situation, DACCIWA has aimed at:

(a) merging the SYNOP and METAR international databases with respect to cloud observations;

(b) adding existing station data from earlier campaigns and projects that are currently not in international databases;

(c) actively digitising data in collaboration with West African weather services; and

(d) putting all available data into one common, documented database to facilitate use by other DACCIWA scientists and beyond.

The purpose of this report is to document the current status of the database, both with regard to content but also with regard to functionality. This will include a short summary of the state of affairs with regard to our negotiation with African weather services on digitisation efforts. Moreover, some first climatological results based on data from the database will be presented to illustrate the capability of the database.

2 Data sources

Generally, there are a number of different types of information gathered in the database: (a) SYNOPs and METARs reported digitally into international networks, (b) digitised data from meteorological registers during past campaign periods, (c) newly digitised data in the framework of DACCIWA and (d) some radiation measurements from earlier German and EU projects.

2.1 SYNOPs & METARs

The SYNOP and METAR observations, both described in WMO (2010), contain general information about the current meteorological conditions but differ in reported variables, reporting frequency and coding. While

METAR information is often constraint to observations of visibility, cloudiness, temperature and present weather to satisfy aviation safety purposes, they have the advantage of being available on at least an hourly basis. SYNOP reports are usually disseminated every three or six hours, but have a denser network and contain further important quantities such as precipitation amounts.

Both SYNOP and METAR reports are merged and stored into the Integrated Surface Database (ISD; Smith et al. 2011) compiled by the U.S. National Climatic Data Center (NCDC). The information is checked for validity, consistency and continuity by 54 quality control algorithms and is ultimately transformed into a unified ISD code. However, the source data are still available in their original format. Redundant information is treated in a hierarchical manner. ISD data display primarily SYNOP information but are filled up with values from METAR if records are missing or incomplete. If both data sources lack a particular quantity, a 'missing value' flag is set.

The result of data merging can be illustrated with the cloud information in ISD. Both SYNOPs and METARs typically report information for each visible cloud layer, with SYNOP being the preferred source (group 333 in the code). However, the ISD cloud information data is extended in case that more layers are reported in the accompanying METAR. Additional information is delivered by the SYNOP information from its first group that contains, amongst others things, the total cloud cover that completes the final ISD cloud data.

2.2 Data from past campaigns

In 2002, a radiosonde campaign was conducted in Parakou (Benin) by the German IMPETUS (An Integrated Approach to the Efficient Management of Scarce Water Resources in West Africa) project (Speth et al. 2010). Within this campaign, the Institute of Geophysics and Meteorology (IGM) of the University of Cologne collected a complete data set of three-hourly reports for six Beninese SYNOP stations from the Direction Nationale de la Météorologie (DNM). As a partner of the EU-funded AMMA (African Monsoon – Multidisciplinary Monsoon) project (grant agreement 004089), IGM repeated this effort for the AMMA Special Observing Periods (SOPs) year of 2006. In addition, hourly cloudiness observations for August and September 2006 were digitised for six Beninese stations (for Bohicon a complete record for 2006 is available) within the IMPETUS project. A complete set of Ghanaian SYNOP reports at 06 UTC for the period June-October 2006 used in Schrage and Fink (2012) was also retrieved within the German IMPETUS project. Hourly cloudiness observations for the DACCIWA supersite at Kumasi (Ghana) are available from the same project for the May–August 2010 period.

Multi-year radiation measurements are very rare in West Africa with less than half a dozen stations in total. DACCIWA will use and make available shortwave and longwave incoming and outgoing radiation data from the IMPETUS stations in Parakou (2001–recent) and Cotonou (2001–2008, resumed by DACCIWA in July 2015, both located in Benin) with a 10-minute resolution. The same holds for radiation measurements in Kumasi (Ghana) between 2010 and 2012 in the framework of the EU project QWECI (grant agreement 243964).

Finally, daily rainfall data from the KIT African Surface Station Database (KASS-D, see detailed description in section 3) were extracted for the DACCIWA study countries Nigeria, Benin, Togo, Ghana and Ivory Coast. The database, formerly located at IGM, is described in Sanogo et al. (2015) and has been updated and further developed since then.

2.3 DACCIWA digitisation efforts

Efforts to digitise hourly meteorological data from the registers of SYNOP stations have been launched in Benin, Ghana and Ivory Coast. In Ivory Coast, a Memorandum of Understanding (MoU) has been signed between Société d'exploitation et de développement aéroportuaire, aéronautique et météorologique (SODEXAM), Université Felix Houphouët-Boigny (UFHB) and KIT, which describes the general framework of the data digitisation and sharing strategy (see Appendix). A similar MoU is about to be signed among Direction national de la météorologie (DNM) Benin, Université d'Abomey Calavi (UAC) and KIT. Subcontracts have been negotiated that describe the details of data digitisation for six (Ivory Coast) and five (Benin) SYNOP stations for the year of 2014. Follow-up subcontracts are planned to govern digitisation efforts for 2006 (the AMMA field campaign year) and the DACCIWA campaign years (2015–2017). In Ghana, DACCIWA partner KNUST has coordinated first efforts to digitise data for 2007 by KNUST students during their off-campus training at GMET (Ghana Meteorological Agency). Charles Yorke from GMET currently coordinates data digitisation for Accra and Kumasi for 2014 and 2006. The respective Ghanaian datasets have been received and inserted into KASS-D. Priorities for the next years to be digitised from Ghana are 2–3 additional stations for the same periods as in Ivory Coast and Benin (see above).

Currently there are no plans to digitise data from Togo and Nigeria. SYNOP stations in Togo frequently report to the GTS leaving smaller gaps in the data records than in some of the neighbouring countries. In addition, the orography of Togo makes the existing stations less interesting for DACCIWA, where a focus is set on the extensive flat areas of southern West Africa. Access to data not available from international data sources for Nigerian stations is currently provided through the involvement a PhD student at DACCIWA beneficiary OAU (Sabastine Francis), who is also affiliated with the Nigerian weather service NIMET.

3 The database

The precursor of KASS-D was developed by Robert Redl at the University of Cologne and originally contained daily and monthly rainfall data only. During the last few years, other parameters such as maximum/minimum temperature and relative humidity were added to the database. With support from Robert Redl, the database has been transferred to KIT and developed further to better meet DACCIWA needs. In this context, shorter time intervals and the inclusion of various cloud parameters are noteworthy. Several KASS-D functionalities have been expanded for the use in DACCIWA and projects beyond.

3.1 General structure and data integration

KASS-D is a relational database based on SQLite. This software library allows the usage of the database without setting up and configuring an SQL server. Thus, the database can be directly used on various platforms. All available observations are stored in a table 'observations' with cross references to other tables containing further information about the stations, variables, observation intervals and data sources. The cross references prevent the storage of redundant information. The KASS-D interface has been developed to simplify the access to the database. This interface is a Python script performing SQL commands to communicate with the database.

For cloud data from ISD a special conversion is necessary. In KASS-D, all information on clouds is stored in the original format as reported in ISD. That implies that some conversions are necessary for importing SYNOP data. Sometimes SYNOP reports code the height of clouds in several intervals, but KASS-D expects an exact height as in ISD. In this case KASS-D only uses the centre height of the interval. A special treatment is conducted for intervals where one boundary is specified as "lower than" or "higher than". In this case, the lower and upper boundary values were taken for the lowest and uppermost interval, respectively. When being integrated into/updated in the database, ISD has, however, a lower priority when compared to data digitized by DACCIWA or from previous campaigns.

3.2 User functionality

KASS-D has numerous functions to select, filter and analyse data:

- For a short overview the function *'info'* lists all stored variables with their time intervals. Additionally, this command yields the date of the first and last report and the number of observations and reporting stations per variable and in total. Special commands allow further extracting information about the number of missing reports or the sources included in the database.

- With the *‘export’* command it is possible to write selected data into netCDF, ASCII or Excel files.
- The command *'selstation'* filters the database with respect to individual stations. One option is to select stations with a given minimum percentage of observations available in total, per year or per month. Furthermore, KASS-D can select stations using their IDs or names, or choose all stations in a specified rectangular area.
- The function *‘seltime’* selects only reports in the denoted interval.
- Similar to the *‘selstation’* command, *‘selvar '* outputs observations of specified variables.
- Simple statistics are possible using the *‘timestat'* command. KASS-D calculates sums, means, maxima and minima for each month or year using a set maximum percentage of missing values.
- For a quick overview of available stations and data, KASS-D allows creating simple plots. The most important plot functions are *'stat_pos_perc'*, *'stat_per_time'* and *'stat_time_box'*. The first gives a map of the chosen stations. On this map, all stations are marked by circles, the sizes of which are proportional to the number of reports at this station (see Fig. 1). With the second command, KASS-D generates a plot with the number of total observations per year. The third command can be used to visualise the temporal data availability of each station as blocks of non-missing data periods.
- With the integrated interpolation functions, KASS-D is able to interpolate data in space or time. Methods like linear or cubic interpolations are implemented. Thus the irregularly distributed station data can be transformed to a regular grid.

Finally it is possible to work with own Python scripts on KASS-D to perform custom operations.

3.3 Current content

KASS-D currently contains more than 41 million daily observations of 3140 stations in Africa that were gathered from 68 different data sources. Nearly 70% of the observations are from 3056 rain gauges, and about 30% are daily temperature minima and maxima. For a few stations, relative humidity, sunshine duration and wind speed is also available. The earliest observations date back to 1838. Furthermore, hourly data of rainfall, air temperature and cloudiness have been imported from ISD. Type, altitude and fraction of low, mid and high clouds are reported for over 1300 stations since the 1930s.

The largest amount of daily measurements is available for West Africa (more than 24 million observations). Figure 1 shows the data availability (i.e. the number of observations divided by the number of days between the first and last observation of a station) of precipitation observations for West Africa. This map can be automatically generated with KASS-D using the *‘stat_pos_perc’* command to give a quick overview of the coverage and completeness of the station data. Benin, Togo, Ghana, Ivory Coast and Burkina Faso show a good coverage with several stations having almost no data gaps, whereas only few observations are available for Sierra-Leone and Liberia.

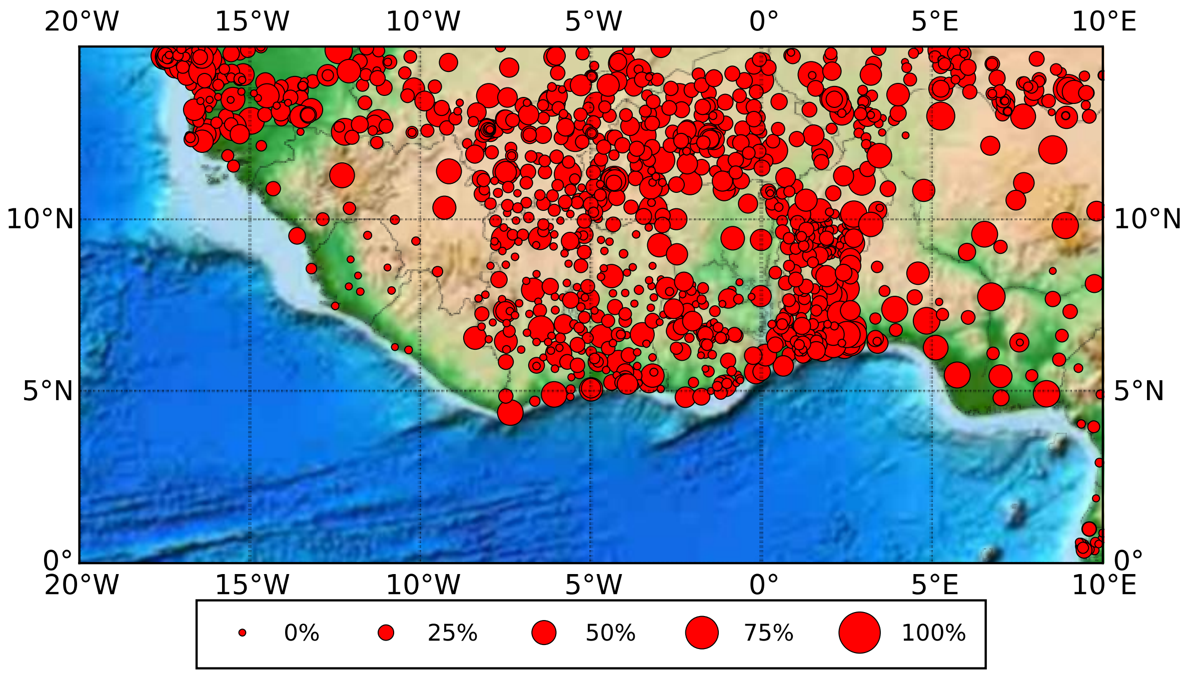

Figure 1: Data availability of precipitation observations in % in West Africa, i.e. the number of available measurements divided by the number of days between the first and last observation of a station.

3.4 Sharing of data with other scientists

An important element of DACCIWA is to share data between WPs and participating institutions. Information from surface stations are of importance for many DACCIWA scientists, e.g. for model or satellite retrieval validation or for the planning of the field campaign. KASS-D greatly facilitates the filtering and exporting of data tailored to the needs of individual groups. Currently, DACCIWA scientists can request and receive data via e-mail. The Toulouse project meeting in October 2015 was used to inform all project members about the functionality and content of KASS-D. In addition meta-information on data availability can be vied on the DACCIWA Sharepoint to facilitate targeted data requests. In the longer run, all newly digitised data as well as data from previous campaigns will be integrated in the freely accessible SEDOO database, as outlined in the DACCIWA DoW, pending on an embargo period of two years for the former data as laid out in the DACCIWA data protocol.

4 Climatological examples

KASS-D interface allows a quick access to the data of interest. To give an example of its application for climatological purposes, the daily rainfall data of four stations in the DACCIWA target area have been extracted, using the commands *'selstation'* and *'export'*, and analysed using the plotting software NCL.

Figure 2 shows the mean daily rainfall distributions of the four stations Parakou (Benin), Savé (Benin), Kumasi (Ghana) and Axim (Ghana). The different shapes highlight the regional differences in the precipitation regime. In Parakou, daily rainfall amounts of 15–20 mm contribute most to the annual sum. The peak shifts to lower rain rates when going southwards to the Guinea Coast. At the same time, the number and percentage of weak events with less than 5 mm per day increases. In Axim, the largest contribution comes from 5–10 mm, and over 50% of all rain events are below 5 mm per day. This already hints at the role of different rainfall types as studied in WP 6.

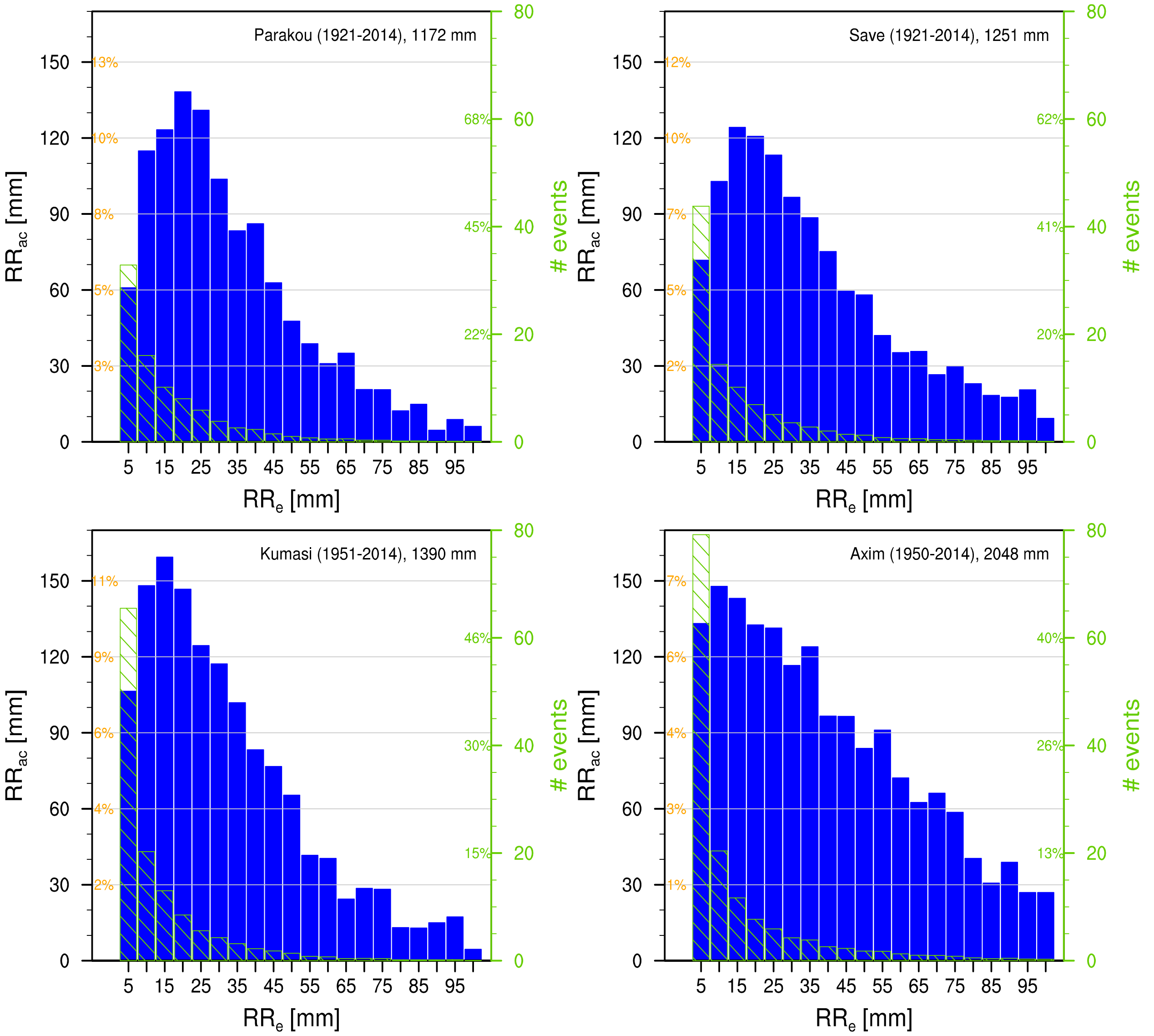

Figure 2: Accumulated rainfall in mm per 5 mm interval (blue bars) and percentage of the annual total (brown numbers, left axis). Number of rainfall events per 5 mm interval in % of total and number (green hatching, right axis).

The annual rainfall sums between 1960 and 2014 of the four stations are depicted in Fig. 3. In addition, the 11-year running average and the linear regression show the long-term trend. Most striking is a pronounced decreasing trend of the rainfall in Axim. This coastal station had annual sums above 3000 mm in the 1960s, but since the late 1980s the peaks have not exceed 2500 mm. Kumasi and Savé also show a decreasing trend. Only Parakou does not show a long-term change of the annual rainfall.

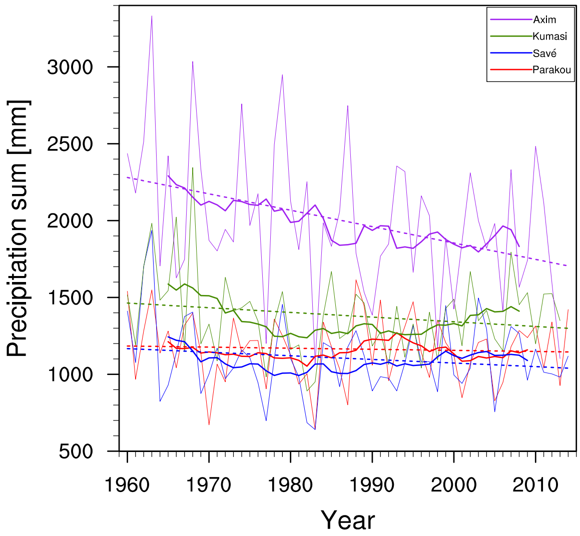

Figure 3: Annual precipitation sum in mm (thin solid lines), 11-year running average (thick solid lines) and linear regression (dashed line).

5 Summary

Data digitisation and collecting efforts in DACCIWA in combination with merging free and earlier campaign data have already and will further improve station data availability along the Guinea Coast substantially. Collaborations with West African weather services have been established (DACCIWA Milestone 1), and formalised in some cases through MoU and subcontracts, to advance data exchange and digitisation of meteorological records only existing on paper. The recently developed and updated database system KASS-D extends the availability of meteorological observations from frequently used parameters like rainfall and temperature to infrequently used parameters like radiation and cloudiness and makes these easily available to partners within DACCIWA. For example, SYNOP cloudiness data have been shown to provide valuable climatologies and to be indispensible for the validation of satellite products (van der Linden et al. 2015) and regional climate models (Schuster et al. 2013). In the long run, free data from KASS-D will be transferred to the DACCIWA Sedoo database, where the data will be available for external researchers and future projects.

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