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DACCIWA

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

Deliverable

D6.1 Radiosonde dataset

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Dissemination level		
PU	Public	**x**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Nature of Deliverable		
R	Report	
P	Prototype	
D	Demonstrator	
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Changes with respect to the DoW

Issue	Comments
Additional radiosonde station at Lamto in response to the non-availability of a dropsonde facility on changed UK aircraft Cancellation of RS campaign at Abuja due to logistical reasons Movement of Ghanaian site from Tamale to Accra due to logistic and meteorological reasons	Potential failures of activation of stations and re-location was foreseen in the proposal already. The changes did not significantly affect the scientific output.

Dissemination and uptake

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

Document Control

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1.0	28.11.2016	Final Version

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1 Introduction

Operational upper-air stations are very sparsely distributed over West Africa, resulting in the need to enhance upper-air observations for the DACCIWA experimental period. Modern radiosonde systems generate high-quality upper-air measurements at every 1-2 second, corresponding to a vertical resolution of 5-10 m. For the June-July 2016 DACCIWA campaign, WP6 realized seven upper-air stations that conducted up to five-times daily vertical soundings well into the tropical stratosphere, i.e. reaching bursting altitudes higher than 17 km. Not only did WP6 deliver the ensuing high-resolution data set to the DACCIWA database, but due to successful actions before the campaign, the real-time submission of upper-air messages to the Global Telecommunication System (GTS) could be realized. This ensured that the observations were assimilated at worldwide Numerical Weather Prediction (NWP) centers leading to improved analyses over the DACCIWA study region. Finally, due to established relations to the Nigerian Meteorological Agency (NIMET), high-resolution upper-air data from Lagos and Abuja have also been obtained at the time of writing.

This report provides a detailed description of the activities conducted in DACCIWA WP6 Task 6.1: “Radiosonde dataset: Quality-controlled radiosonde dataset from field campaign” that ultimately led to a spatial density of in-situ upper-air information in southern West Africa that is unprecedented. It will also describe failures and their reasons, as well as contingency actions in response to this. Finally, it will describe data formats and quality issues.

2 Preparation of the radiosonde campaign

From its outset, the DACCIWA radiosonde campaign had three pillars (a) enhancing soundings at operational or quiescent AMMA (African Monsoon – Multidisciplinary Analyses) radiosonde stations; (b) launching sondes at DACCIWA supersites and two additional DACCIWA field sites; and (c) collecting standard and – if possible – high-resolution data from other operational stations.

2.1 Operational and quiescent AMMA stations

During the pre-campaign investigation of the status quo of operational stations, three surprises were encountered. Firstly, the Vaisala ground station furnished in 2006 by the AMMA EU project to the NIMET (Nigerian Meteorological Agency) station of Abuja (WMO (World Meteorological Organisation) number 65125) was in operational use; Abuja regularly did once-daily 12 UTC soundings, but almost none of them were received on the Global Telecommunication System (GTS) due to transmission problems. Secondly, Cotonou (Benin, WMO number 65344) resumed 12 UTC soundings in September 2012 using the MODEM ground station provided by the same EU initiative. However, while being on the GTS, the use of TEMPS[1] from Cotonou in databases and data assimilation for weather prediction appeared to be impeded by the lack of meta-information in the WIS (Weather Information System of the WMO). Nonetheless, the discovery of these two legacies of AMMA was a positive surprise since it facilitated the enhancement of soundings at Cotonou and, in retrospection, ensured that at least one-daily upper-air data from Abuja were available. Thirdly, the Nigerian Meteorological Agency (NIMET) operated three additional RS

[1] TEMP messages contain coded upper-air data in ASCII Format

stations, namely Lagos (65202), Kano (65046), and Enugu (65257) (see Fig. 1 for station locations), from which only Kano TEMPs appeared on the GTS before the campaign.

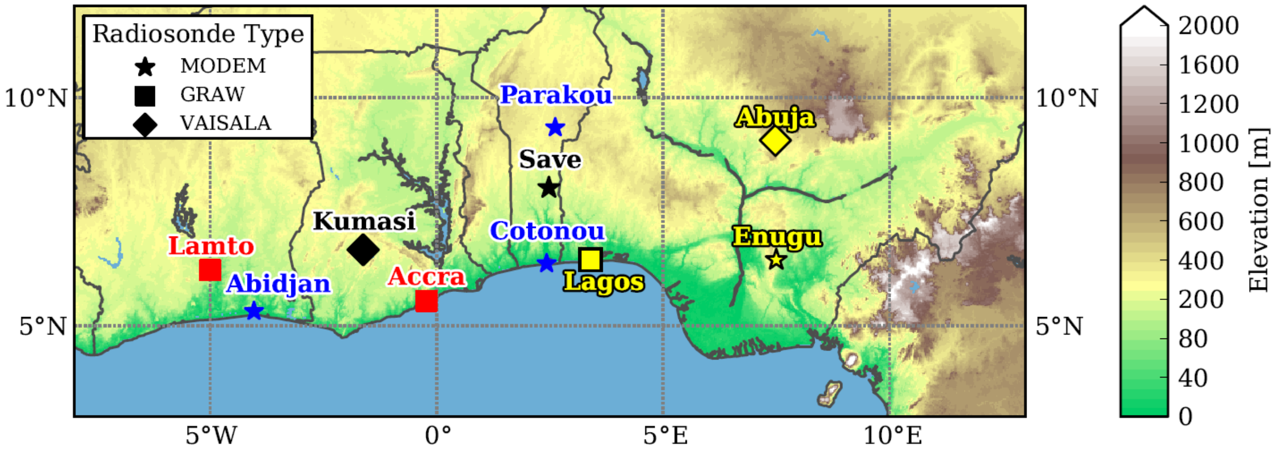

Figure 1: *DACCIWA Radiosonde network and deployed sonde types during June-July 2016. Blue: Operational or re-activated AMMA stations with four-times daily sounding frequencies; Black: DACCIWA super-sites performing 06 UTC plus additional 12, 18, and 00 UTC launches on Intense Observation Period (IOP) days; Red: DACCIWA stations operated by KIT, GMet, UFHB and the LAMTO Geophysical Observatory with up to 5 soundings per day; Yellow: Operational Upper Air station in Nigeria with 12 UTC soundings. The shape of the marker indicates sonde type.*

The management of the four stations Abuja, Abidjan, Cotonou and Parakou, the latter having been silent as a radiosonde station since the end of the AMMA campaign in 2007, was subcontracted to the company AeroEquipe that is run by two former employees of ASECNA (Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar). It shall be noted that ASECNA operates Abidjan, Cotonou, and the PILOT[2] balloon station Parakou. In the subcontract, AeroEquipe was charged with getting the radiosonde consumables out of customs, transporting them to the stations, negotiating and paying additional salaries for overtime service of the station staff, ensuring real-time submission to the GTS, and providing the high resolution data to the DACCIWA project. As foreseen, the consumables were purchased by DACCIWA via KIT. As will be mentioned below, Abidjan, Cotonou, and Parakou had an almost 100% success rate, whereas a few weeks before the campaign, plans for Abuja (Nigeria) had to be dropped due to non-acceptable regulations imposed by the Nigerian authorities to import the radiosondes and the chemicals needed to locally produce hydrogen into Nigeria.

2.2 DACCIWA field sites

The logistics and operations of the normal radiosonde launches at the DACCIWA supersites in Savé and Kumasi (Figure 1) was managed by WP1 (cf. Deliverable 1.1 Campaign). Contrary to the plans described in the proposal, the former AMMA station Tamale in north-central Ghana was not re-activated due to both logistical and meteorological reasons; in meetings with the Ghana Meteorological Authority (GMET), it turned out that neither the staffing nor the status of the former Vaisala ground station and hydrogen generators were adequate, thus making a reactivation very

[2] PILOT balloon stations launch hydrogen-filled read balloons that are tracked by a theodolite. They deliver wind direction and speed only, whereas TEMP stations additionally provide temperature, humidity and pressure.

expensive, removing the opportunistic argument of using existing infrastructures in a region where the low-level stratus is infrequent (van der Linden et al., 2015). In discussions with GMET, it was decided to operate a mobile TEMP station in Accra on the grounds of the GMET headquarters (HQ). From the meteorological and collaboration point of view, this was a gain since (a) three (i.e. Abuja, Accra, and Cotonou) coastal stations were active in June-July 2016, allowing for a better assessment of the strength and depth of the low-level monsoon inflow and the land-sea breeze, and (b) it allowed for a better involvement of GMET staff and a cohort of KNUST meteorology students that carried out an internship at GMET HQ.

Another response by WP6 was provoked by the necessary change in the UK aircraft that went along with the loss of dropsonde capabilities (see D4.1). It was decided by the DACCIWA Steering Committee to enhance upsonde activities instead, taking advantage of a newly established, good collaboration with Ivorian partners. A recce visit by Andreas Fink (Karlsruhe Institute of Technology, KIT) to Abidjan and the Lamto Geophysical Observatory (cf. map in Figure 1) disclosed the opportunity to launch upsondes at Lamto, this Ivorian location being, according to van der Linden et al (2015), located in the peak climatological region of low-level stratus. Like in the case of Accra, this resulted in an involvement and capacity development of Lamto staff and two students from the Université Félix Houphouët-Boigny (UFHB, Abidjan, Ivory Coasts).

2.3 Other operational upper-air stations in southern West Africa

As mentioned in Section 2.1, NIMET operated at least three radiosonde station that are not recognized internationally due to missing appearance of their data on the GTS. Before, the campaign, WP6 interacted with NIMET and the German Weather Service (DWD) to improve real-time submission of NIMET stations to the GTS, which was successful for Abuja; the Abuja station sent FM 35 TEMP messages via e-mail to the DWD HQ where these messages were ingested in real-time into the GTS. Trials to correct errors in e-mail messages from Kano (WMO no. 65046, Nigeria) failed. Furthermore, the a posteriori provision of data from Kano, Abuja, Lagos, and Enugu (see section 2.1) was negotiated. Finally, the usually reliable active, ASECNA-operated Cameroonian station Douala (WMO no. 64910) and the second upper-air station in Cameroon, Ngaoundere (64870) were unfortunately silent during the AMMA campaign due to missing consumables.

3 Execution of the radiosonde campaign

The first DACCIWA radiosonde went into the African sky in Kumasi on 11 June 2016 with Savé following on 13 June, both dates being about the planned start of the campaign (Figure 2a). Accra started 12 UTC soundings almost two weeks later than planned due to the fact that the helium bottles, shipped from Karlsruhe to Ghana, were stuck in customs at Tema harbour. It shall be stressed that GMET undertook enormous efforts to achieve customs clearing and eventually succeeded, bearing all the cost on their budget. Extra 09 UTC soundings were added to the Accra sounding plan in July after the end of the aircraft campaign on 17 July (Figure 2b) with the idea to use up the consumables and to improve the probing of the early morning land-sea breeze. Between 20 and 27 June 2016, the latter date being initially planned as the first aircraft science day, the three stations Abidjan, Cotonou, and Parakou slowly increased launching frequency to the planned four-times daily ascents (Figure 2a). These stations performed 96% of their planned DACCIWA soundings between 21 June and 17 July, the missing 4% mainly related to a failure of the UHF antenna at Cotonou between 6 and 8 July (Figure 2b). The company AeroEquipe managed to get an unused AMMA-EU antenna from Parakou to Cotonou to resume soundings within 48 hours. Finally, soundings at Lamto did not commence until 06 July 2016, seven days after the start of aircraft science flights on 29 June 2016. The postponed start was again due to week-long problems in clearing helium, the radiosondes, the balloons, as well as the ground station equipment from Ivorian harbour and airport customs. To make the best use of the consumables at Lamto, soundings were enhanced to 5 per day (additional 09 UTC soundings) and extended three days after the termination of the aircraft campaign on 17 July 2016. Altogether, some 756 DACCIWA sondes were launched and apart from the above-referenced logistic delays and the 48-hour gap at Cotonou, no interruptions of operations were encountered. Given the challenging, partly remote sounding environments, this is an enormous success of all teams involved.

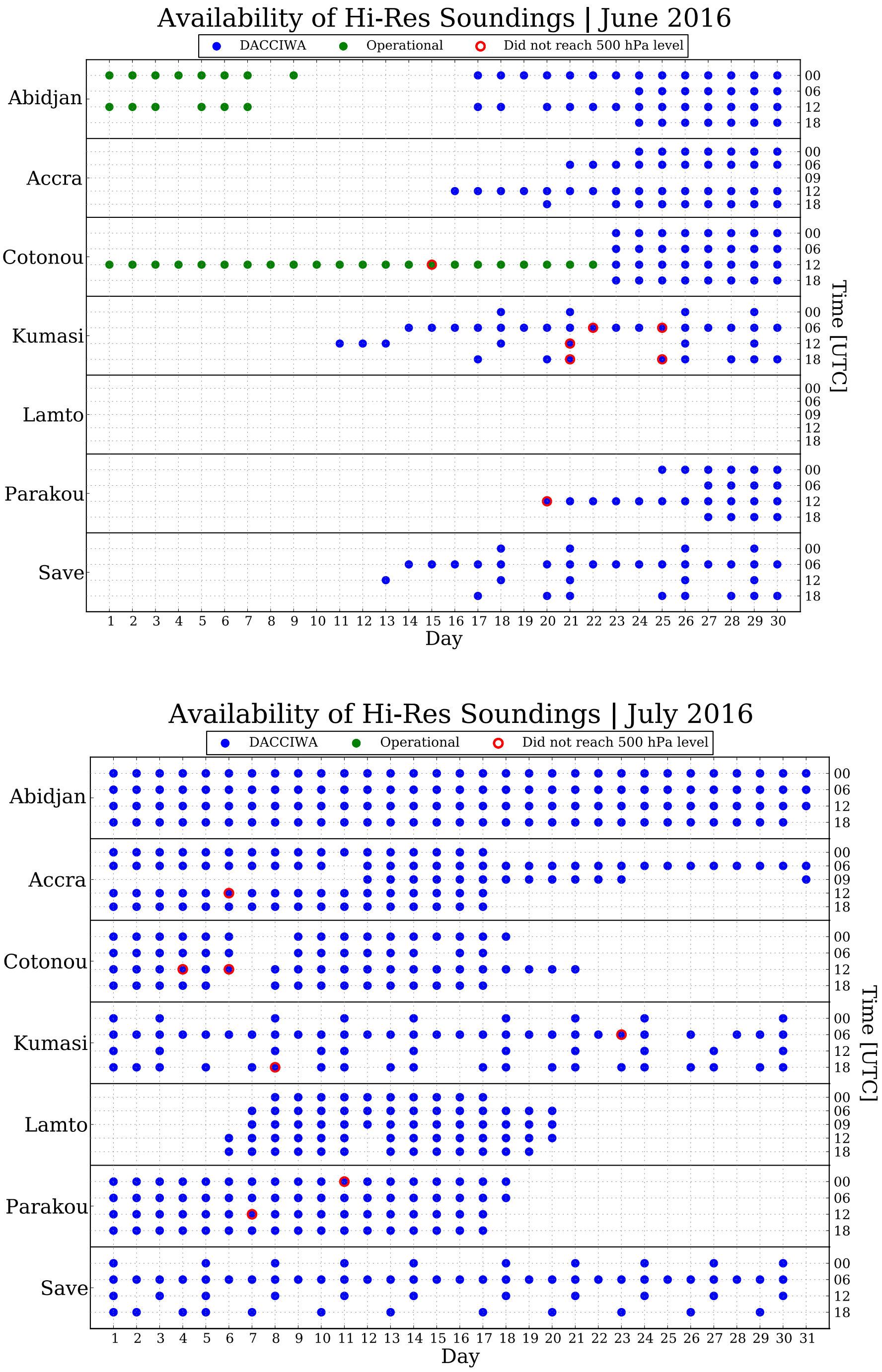

Figure 2: *Launching frequencies at the seven DACCIWA radiosonde stations in June (a) and July 2016 (b). Green dots: operational data, blue dots: DACCIWA sondes, with red markers indicating that the sonde was lost before reaching 500 hPa. Data are available at high vertical resolution of 5-10m.*

High priority was given to submit the radiosonde data in real-time into the GTS such that the data are used at ECMWF (European Centre for Medium-Range Weather Forecast), Meteo France, UK

MetOffice and DWD in data assimilation of operational numerical weather prediction models. This turned out to be another success story due to (a) the great support from Bernd Richter (Head, Data Traffic Management, DWD) and his team and (b) the professional work of the AeroEquipe company. Lamto, Accra, Kumasi and Parakou e-mailed so-called FM 35 TEMP mobile messages to an authorized DWD e-mail address. After the prescribed header and format was used, they were automatically ingested into the GTS. Savé was routed via Météo France to the GTS and Cotonou and Abidjan used their normal route to the GTS, with AeroEquipe closely monitoring the performance. Figure 3 (left) shows fixed and mobile upper-air soundings available at ECWMF on 14 July 2016 12 UTC for data assimilation. Compared to Europe, Africa is a data sparse continent, but a clustering of upper-air soundings is clearly visible in southern West Africa. The blue TEMP mobile stations from west to east are Lamto, Kumasi, Accra (somewhat obscured by the black zero meridian line) and Parakou. The red dot to the east of Parakou is Abuja that submitted TEMPS in real time during the DACCIWA campaign thanks to joint efforts of NIMET, DWD, and KIT. The red dots at the coast are Abidjan in the west and Cotonou in the east. Savé is missing on the map, the reason being that it submitted their message in the new, WMO-approved binary BUFR TEMP mobile format that both ECMWF and DWD had problems to process – likely because it was one of the first, if not the first, appearance of this format on the GTS.

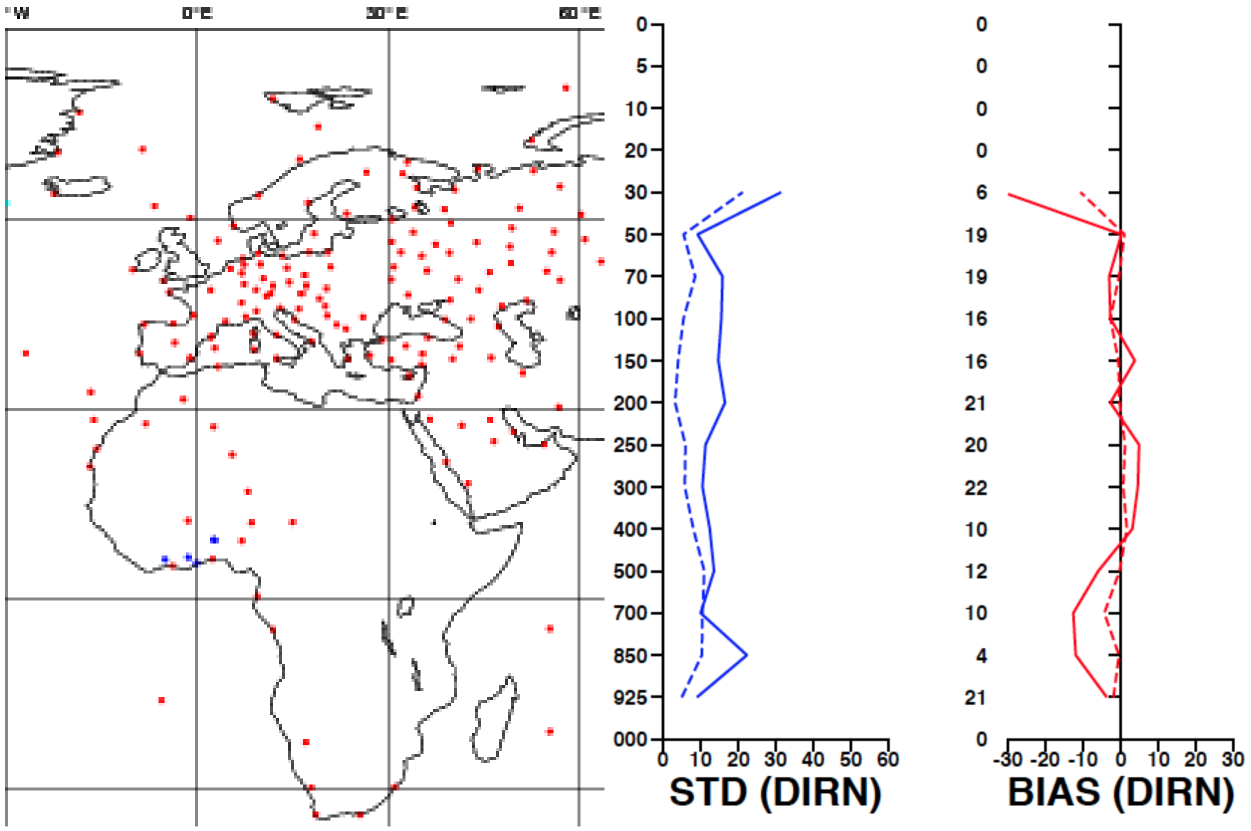

Figure 3: *Real-time submission and impact on quality of the ECWMF operational analysis. (Left) ECMWF data coverage by TEMP messages on 14 July 2016 12 UTC. Red dots are fixed land stations, blue dots are TEMP mobile stations. (Right) Standard deviation (blue lines) and bias (red) of the wind direction in degrees at Accra (station GHKUM) for June-July 2016 00 UTC. First guess – observations (solid lines) and first guess – observations (dashed lines). For more details see text. Sources: ECMWF*

Except Savé, data from the six other DACCIWA stations were assimilated both at ECMWF and DWD. Météo France assimilated all DACCIWA stations. The observations were of high quality and improved the operational analyses at ECWMF, DWD, and Météo France. This is exemplified for the 00 UTC ECWMF analysis and Accra in Figure 3 (right panel); both the standard deviation and bias was reduced as can bee seen by the dashed line of the operational analyses being closer to the zero line. Especially the bias in the important low-level monsoon wind direction was reduced. In general, wind and partly relative humidity were the variables that were improved the largest by the campaign data. This fact is very encouraging since the improved DWD, ECMWF and Météo France operational analyses are used in DACCIWA process studies and in initialisation and boundary conditions of DCCIWA model studies.

4 Data storage and quality

The full set of different data formats were received at KIT, except for Kumasi and Savé. For these two stations, the instrument PIs B. Brooks (ULeeds) and F. Lohou (UPS) will upload the quality-checked data on the DACCIWA SEDOO data server. Three basic formats will be uploaded:

(a) The FM 32/35 TEMP formats in ASCII – these formats are the old standard formats on the GTS and are widely used in international archives and data assimilation
(b) The FM 94 BUFR format that is new binary standard for fixed and mobile upper-air data
(c) The high-resolution ASCII tables with data for every 1-2 second/every 5-10 meters

Not uploaded will be additional files necessary to re-simulate the soundings, which requires costly licenced software from the RS manufactures. Meta-information for each DACCIWA station listed in Table 1 will be added in Readme files.

Table 1: *List of DACCIWA radiosonde stations, the operating agency, sonde type and launch times. Station in italics are operational upper-air stations. ASECNA: Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar; SODEXAM: Société de Développement et d'Exploitation Aéroportuaire et Maritime; DNM: Direction National de la Météorologie; NIMET: Nigerian Meteorological Agency; IC: Ivory Coast. UFHB: Université Félix Houphouët-Boigny; KNUST: Kwame Nkrumah University of Science and Technology; GMET: Ghana Meteorological Agency; KIT: Karlsruhe Institute of Technology; UPS: Université Paul Sabatier;*

Station (Country)	**WMO No./ or Mobile TEMP name**	**Lat.**	**Lon.**	**Alt. (m)**	**Operated**	**Sonde**	**Campaign Launch hours UTC**
Abidjan (IC)	*65578*	*5°15'N*	*3°56'W*	*7*	*SODEXAM/ ASECNA/*	*MODEM M10*	*00, 06,12, 18*
Cotonou (Benin)	*65344*	*6°21'N*	*2°23'E*	*5*	*DNM Benin/ ASECNA*	*MODEM M10*	*00, 06,12, 18*
Parakou (Benin)	*65330*	*9°21'N*	*2°37'E*	*392*	*DNM Benin/ ASECNA*	*MODEM M10*	*00, 06,12, 18*
Kumasi (Ghana)	GHKUM	6°40'N	1°33'W	279	Univ. Leeds/ KNUST	Vaisala MW41	06 UTC every day 00,12, 18 UTC IOP days
Save (Benin)	*LA-Save*	8°00'N	2°26'E	166	UPS/ KIT	MODEM M10	06 UTC every day 00,12, 18 UTC IOP days
Accra (Ghana)	GHACC	5°42'N	0°01'W	84	GMET/KIT	GRAW DFM09	00, 06, 12, 18 UTC

Station (Country)	WMO No./ or Mobile TEMP name	Lat.	Lon.	Alt. (m)	Operated	Sonde	Campaign Launch hours UTC
							partly 09 UTC
Lamto (IC)	IVLAM	6°13N	5°01°W	155	UFHB/ KIT	GRAW DFM09	00, 06, 12, 18 UTC partly 09 UTC

In addition, FM 35 or high-resolution data shall be obtained from NIMET for the stations listed in Table 2. These data are not available internationally. At the time of writing, data from Lagos and Abuja have been received.

Table 2: *Other operational RS station in Nigeria for which data for June-July 2016 shall be obtained via NIMET.*

Station (Country)	WMO No.	Lat.	Lon.	Alt. (m)	Sonde	GTS	Hours UTC	Data received
Kano	65046	12°03'N	8°32'E	476	GRAW	Almost nil	12	No
Abuja	65125	9°15'N	7°00'E	344	GRAW	Almost nil	12	Yes, high-res
Lagos-Oshodi	65202	6°30'N	3°23'E	5	GRAW	Almost nil	12	Yes, high-res
Enugu	65257	6°28'N	7°33'W	133	MODEM	No	12	No
Calabar	65264	4°48'N	8°21'W	63	Not-known	No	12	No, to be verified if active

Investigations into data quality yielded suspect relative humidity (RH) values for GRAW sondes in Accra and Lamto. Figure 4 shows values of RH at Accra around the lowest cloud layer as observed and coded by the observer at Accra airport. Suspiciously, RH values never exceeded 95%, though theoretically 100% RH shall be reached in cloud layers. However, it is not uncommon for RH sensors on sondes to report values below 100% and further investigations will be conducted in early 2017 by comparing relative humidities of Vaisala and GRAW sondes in the climate chamber at partner ULeeds and possible at KIT. In case of reproducible errors, the manufacturer will be consulted for RH humidity correction – as was necessary for Vaisala and MODEM sondes after the AMMA 2006 campaign (cf. Nuret et al., 2008; Agustí-Panareda et al., 2009). In terms of the database, RH values from Accra and Lamto will be flagged with a cautionary note in the Readme File and, if available, corrected RH values will be uploaded in the course of 2017.

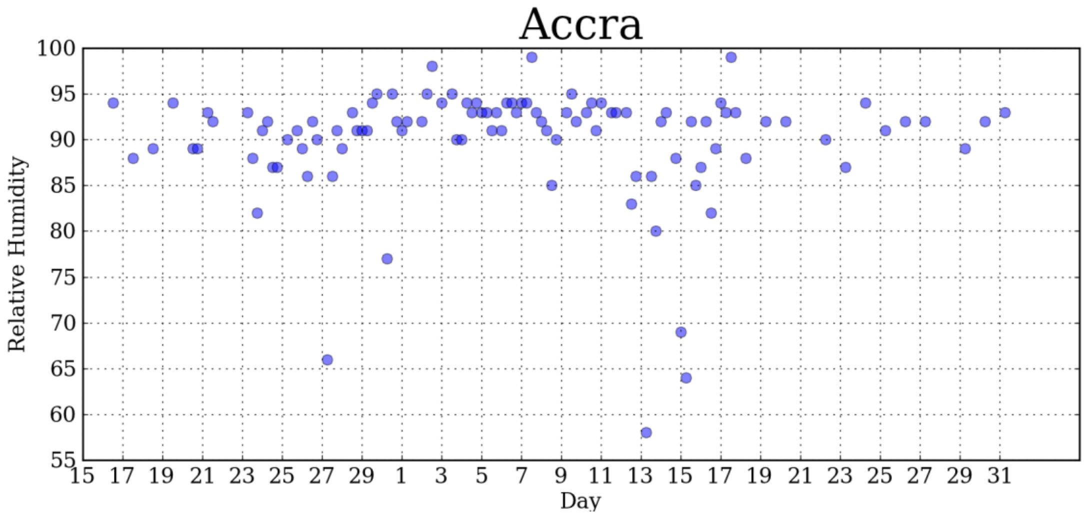

Figure 4: *Values of RH at Accra around the lowest cloud layer as observed and coded by the observer at Accra airport*

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