AUTOMATIC WEATHER STATIONS IN THE SOUTHWEST OF ANGOLA THE 141 TASK – SASSCAL & ISPT

Report of The AWS Installation And Recommendations

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Abstract

Ten (10) AWSs were installed in the southwest of Angola in October 2014, the installation process and sensors types is described. UCD AWS is used as recommendation as well as some advices according to WMO recommendation on meteorological observation.

Some graphs with data management in octave shows that the program is suitable to run Old and New data and compares can be done in the future using this free software.

1 Introduction

In order to use my work placement in favour of the work I will develop back in Angola, after finishing my Global Change Master course, I will be doing research, supervised by Dr. Conor Sweeney from the UCD Meteorology and Climate Centre. In this internship, I will learn in the field about the Meteorological information, equipment and some programming in a language program.

I will write a report about the Meteorological stations installed back in Angola. I intent to report all the information from the installation of the Meteorological station as a first step. As a second step intent to report, not only, the installation processes but also the type of equipment's capacity and quality of measurements as well as the national and international standards and compare them. Besides this I also aspire to develop a few alternatives or recommendation in order to improve and reach reliable international standards.

This paper will be reporting the installation of 10 (ten) Automatic Weather stations, the type of equipment used, its locations and the quality of information which will be gathering as well as the purposes of the gathering of the information. Fundamental in this report will be the recommendation to international standards which will be appealing for the project SASSCAL and Angola's Meteorology Systems to be in the developing reliable and easy access of meteorological data for the most diverse fields in need. Also, some learning on Octave programing and graph results on temperature measurements of the New data collected in the New automatic weather stations as well as the Old data from the project back in Angola.

The report has the plan to provide learning and understanding in meteorology measurement equipment, software and data display, recommendation from WMO and some work on octave programing software.

The layout is displayed as such:

- Introduction
- The sites
- The Equipment
- The Sensors
- The Installation Process Installation
- Measurements
- Recommendations
- The UCD Automatic Weather Station
- Analysing data and Programing
- Future expectations
- Conclusion

Obs.: All the information regarding to the New AWS, such as the New AWS siting Georeferencing and installation process came from the ones involved in the process itself. Although no report has been done on this matter and only a few spread information was kept and send it to me by email.

1.1 Background

I've been working in the SASSCAL project in Angola for the past year where I was handling meteorological data, old data, collected by the Portuguese before the independence process and Civil war. I digitalized 14 years of meteorological data from the South of Angola and another colleague will finish the North of the Country, and together, this meteorological information will be available for the fields in need of this information, besides being useful as a database.

SASSCAL - Southern African Science Service Centre for Climate Change and Adaptive Land Management. SASSCAL is a Regional Science Service Centre (RSSC) in Southern Africa. It is an initiative that puts together Angola, Botswana, Namibia, South Africa, Zambia, and Germany, responding to the challenges of global change and adding value the whole region (SASSCAL).

Problem-orientated research on the area to adaptation to climate and change as well as sustainable management and to provide evidence based advice for all stakeholders and decision makers to improve the livelihoods of people in the region and as a contribution to the creation of a knowledge based society is the overall project mission (SASSCAL).

1.1.2 ISPT and Task 141

In Particular, to Angola and specifically to 141 Task is the development of meteorological observation in the Southwest of the Country, covering Namibe province, the western slopes of Serra da Chela and Huíla province as well. (SASSCAL 2013).

New meteorological stations have started recording data which will be highly useful not only as a reliable data base for Civil Engineering, Agriculture and Aviation but for further long and short term weather forecast at regional and national levels. This data base will be immediately helpful in the building of new infrastructures (i.e. Bridges and hydraulic aqueducts) having in account the water regime and also preventing human lost from flooding and draughts as well as supportive programmes. (SASSCAL 2013).

The ISPT (Instituto Superior Politécnico Tundavala), is a Superior Institute and is responsible for the 141 Task of the SASSCAL project. The responsible is the Engineer Carlos Ribeiro, my direct supervisor in the project and responsible for the maintenance and management of the Meteorological stations and for the development of the students that are working together in the project with data digitalization and analysis as well as their academic training. The overall project is sponsored by the SASSCAL and Germany Government.

Basically, and recapitulating, the Institute itself, having Eng. Carlos Ribeiro as the Head of the project are the responsible for the work of two students, me (Nídia Loureiro) completing Master's degree and Silvio G.M. Filipe finishing Bachelor's degree. Both of us are still working in the digitalization of the old data to turn it available.

In October 2014, Meteorological station were installed in different and distinct places and interconnected to the same informatics system and in a web server with a public display.

Ten (10) Automatic weather station were installed in the southwest of the country, covering Namibe province, the western slopes of Serra da Chela and Huíla province. This project covers two Task, the 141 and 139. The meteorological observations will be used by both although the meteorological data is the 141 focus and responsibility, in which this report is about.

2 - The Sites

The Sites were chosen for the 141 and 139 Task, in order be placed in Namibe and Huíla, adding the slopes of Serra da Leba. Some places were chosen to try to match the old places where the previous data was collected, or very close by, so it gives us a possibility of making a better analyse in order to compare new and old data in the future.

The AWS's were installed in two different provinces of the Southwest of the Country, Huíla and Namibe (See Table 1).

HUÍLA	NAMIBE	SENSORS
Campus ISPT	Caraculo	Rain Gauge; Wind Speed; Wind Direction; Barometric Pressure; Thermometer; Hygrometer; Pyranometer;
Barragem das Neves	Bibala	
Estação Agronómica Humpata	Kapangombe	
Tundavala	Mucungo	
	Bentiaba	
	Namibe	

Table 1 - The AWS's, Sites names, location and the sensors installed

Geographical information about the sites location; The New AWS's in the google. Available at: www.isptundavala.dynalias.com.mapa

as well as in Sasscal webpage.

Figure 1- The 10 AWS in the Google earth.

Figure 2- The Namibe and Huíla provinces in the Google earth.

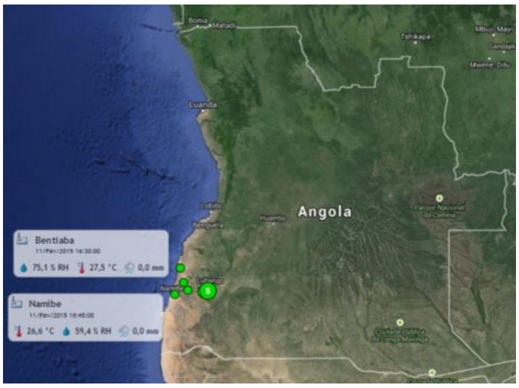

Figure 3- The AWS in the Country (Angola) in the Google Earth.

2.1 Georeferencing of the New AWS

NAME	LAT	LONG	ALT(m)
Bentiaba	-14,257	12,387	11
Namibe C.	-15,159	12,178	11
Bibala	-14,808	13,341	1061
Mukongo	-14,749	12,505	390
Kapangombe	-15,096	13,138	535
Caraculo	-15,019	12,656	470
Tundavala	-14,845	13,407	2060
Humpata	-15,069	13,351	1880
Campus ISPT	-14,958	13,445	2047
Barragem das Neves	-14,958	13,363	2074

Table 2 – The New AWS's and it's Georeferencing

2.2 Old Data and New data

In this table below it is possible to see the New and Old location with close proximity and in which compares can be done in the future.

OLD DATA				
DISTRICT	LOCATION	LAT	LONG	ALT (m)
Moçâmedes	Caracul	15 01	12 40	440
Moçâmedes	São Nicolau	14 16	12 23	30
Moçâmedes	Moçâmedes (S.M.A.)	15 12	12 09	44
Moçâmedes	Capangombe - Munhino	14 57	12 59	400
Huíla	Humpata (Centro de Estudos)	15 03	13 24	1,850
NEW DATA				
PROVINCE	LOCATION	LAT	LONG	ALT (m)
Namibe	Caraculo	-15.019	12.656	470
Namibe	Bentiaba	-14.257	12.387	11
Namibe	Namibe	-15.159	12.178	11
Namibe	kapangombe	-15.096	13.138	535
Huíla	Humpata	-15.069	13.351	1888

Table 3 – New and Old station for weather observation at the same sites or close by. (Old-1961-1974 and New-2014-2015) Serviço Meteorológico de Angola (1961-1974).

The Old data which I have digitalized covers the south of the country, and the 141 Task, so taeh New AWSs covers Huila and Namibe provinces on the south of the country as well. This gives opportunity to compare New and Old data.

After the independence, some names have changed and others remain the same. By the time of the collection of the Old Meteorological data, Provinces were Districts and Namibe was Moçamedes, Bentiaba was São Nicolau and Kapamgombe were wrote with C, Capangombe and Caraculo was Caracul.

2.3 Huíla and Namibe Provinces in Angola

In This section the information relies on the Angola Government Portal (http://www.huila.gov.ao) and (Plano Directório do Namibe, 2013) which Portuguese is the only language available, and 'google translate' was used for translation. This are general information about the territory and climate.

2.3.1 Huíla

Figure 4 – Huíla highlighted in Angola's Map

The Huila province is located in the southwest of Angola, having a rectangular shape. The territory is part of the wide range of plateau surfaces of the Angolan interior with altitudes between 1000 and 2300 meters. The lower altitudes correspond to transition levelling and for the west and northwest or south and southwest, with an area of intermediate altitudes 1400-1800 meters, corresponding to the southern part of the Central Plateau.

The areas of higher altitudes 1900-2300 meters, are part of the Plateau of Humpata, especially the Bimbe, which is the highest flattening of the Angolan Southwest. The province accounts for an approximate area of 79,023 km² and an estimated population of about 3,334,456 million.

The climate of the province ranges from the tropical altitude in the North Central and in the Humpata Plateau is semi-arid areas of lower altitude.

There is the existence of two seasons across the length of the Area:

• Rainy season: October to April, characterized by average temperatures between 19 and 21 C and rainfall averages between 600 and 1200 mm;

• Dry season (Cacimbo), in the remaining months of the year, with average temperatures ranging between 15.5 and 19 ° C, marked daily temperature range, lack of rainfall and consequently quite low air humidity (huila.gov.ao. , 2011)

2.3.2 Namibe

Figure 5 – Namibe highlighted in Angola's Map

Namibe is located in the south of the Country, with a total area of 56.389 km², with 420 km of extension in a coastal area, and estimated population of 1.195.779 people.

The climate of the province is characterized as arid over a wide range and Western. Semiarid in the remainder, except a narrow range in the province NE with climate sub-humid dry. The air temperature is influenced by the Benguela current and topography as well.

It is observed that in the coastal zone temperature increases from south to north. Inwardly mean air temperature increases, reaching 23.7 ° C (Bibala). In the mountainous area, the relief influence is felt by the decrease on the temperature.

The relative humidity decreases from the coast to the interior, with the order of 75-80% by the

Coast and 55-60% in the highlands. In the coastal zone the highest values occur from June to August, amounting to approximately 85%. Within higher values about 70% are observed.
In March, minimum values of relative humidity occur in November - December on the coast (72-77%) and between May and August in the interior (30-40%). Concerning the winds are characterized by being in the Province fairly regular direction or in both intensity throughout the year. The annual sunshine increases the coast, with an average value Annual order of 2300 hours (Mocamedes Station), into which the average value of annual insolation reaches exceed 2600 hours (Lubango Station) Rainfall is in the Coast extremely low, several years checking where the annual rainfall is even zero (Namibe, Tômbwa, and Bay of Tigers). Precipitation increases towards the interior (the average value of Caraculo rainfall is 170 mm) as the effect of the cold stream will be attenuated. On the slopes and in the upper plateau annual precipitation is 800-900 mm as stated in (Plano Directório do Namibe, 2013).

3 - The Equipment

3.1 The Automatic weather stations

Automatic Weather Stations are equipments used in the measurements of weather conditions. Due to the facilyty of their performance, particularly in remote areas, this stations are widly used . They gather a range of four to six or more instruments in the same mast, all supported by a small solar system. The readings are sometimes caped in a flash card with enougth memory for, in some cases, six months. Some systems use GSM mobile phone tecnology or satellite. This system are automatic and need very litle maintainance althougth a duplicate of sensor are essencial for relyability of the AWS (Arcsin, 2007).

Figure 6 - An Automatic Weather Station

Usualy this AWSs have Thermometer, which measures temperarture, Hygrometer, measuring relative humidity, Anenomther measures wind speed and wind vane for wind direction, Rain Gauge is used to measure rain or precipitation , Barometric Pressure for amospheric pressure and the Pyranometer measures solar radiation flux density and sometimes Ceilomters, not very trustfulls,at measuryng clouds heigth (Arcsin, 2007). Soil temperature and humidity as well as other variables are also measured. In this type of AWS the number of sensors tend to vary and it's dependent on the ending purpose.

3.2 The AWS used in Angola for the 141 Task

In this picture its possible to see an AWS and its sensors.

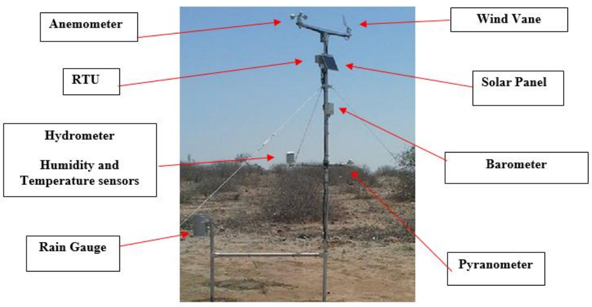

Figure 7 - The Automatic Weather Station installed in Angola with the equipment.

In this picture its possible to see an AWS and its sensors.

In the AWSs installed, the sensors take measures every minute and make a meam in every 15 minutes and data logger send it to the base station or the oder way around, the base station colects from the data logger every 15 minutes. The base station (a A850 Telemertry Gateway is a monotoring network device wich checks the RTU ID and concetion hourly although keeps recievind data every 15 minuts. This equipment recieves data form the UTR in which all the sensors are connected at the mast. The A850 Telemertry Gateway equipment run the Linux software , a data manager (addVANTAGE pro 6.4) which is the softwre that displays the data in the website (dcon Telemetry, 2006)

The Hard and software behind the AWS station are provided by Adcon Telemetry, and made in Germany (besides Barometric pressure made in Switerzland).

3.3 UTR's

The addWAVE GSM/GPRS is a complete new designed RTU. It is an extremely flexible logger with a great amount of resolution, I/O ports and can be set up in a great amount of applications like in agriculture, hydrography and also in professional meteorology. Has great resolution, memory and obedient to WMO measuring methods requirements. It is very widely used from AMR (Automatic Meter Reading) to leak detection, for monitoring solar power and wind energy (Adcon telemetry).

An RTU is a Remote Terminal Unit or Remote Telecontrol Unit, it is a device that links or connects physical objects to a distributed control system. It receives data from other devices and sends to a transformation device that connects to a computer in order to be displayed, or the other way around.

In this particular situation, the sensors in the AWS are connect to the RTU with a connection to a mobile phone. This way the information is being sent by a mobile phone throw internet connection to a transformative devise or a monitoring network device that is in turn connected to a Computer with a software capable of displaying such information (Adcon telemetry).

Figure 8 - An RTU (Remote Terminal Unit

The UTR used in the AWS's, showed in the picture nº 5, have its own characteristics. It is encased in an Aluminium powder coated, with an IP-67 protection [1], with small dimensions (160 x 60 x 80 mm/1200gr.).

1 - *IP stands for 'Ingress Protection'. An IP number is used to specify the environmental protection of enclosures around electronic equipment. Determined by specific tests, the IP number is composed of two numbers, the first referring to the protection against solid objects and the second against liquids. The higher the number, the better the protection (Aceeca Limited, 2012).*

The logger has temperature operation that ranges between -20°C ... +65°C / -4°F ... 149°F , and extended temp. Range from -30°C ... +75°C / -22°F ... 167°F upon request (Adcon telemetry).

Holds a 2MB memory for up to 500.000 values, depending on types of sensors attached (SDI-12 typically needs more memory than analogue, and can be stored for 6 months. With a programmable battery system, unregulated battery voltage from 5.5V ... 7.5V and stabilized voltage, programmable from 3.3V ... 5.5V in 0,1V increment. Power Supply internal 6.2V battery, charged by solar panel or mains power supply, and also uses internal power supply 6.2V battery, charged by solar panel or mains power supply (Adcon telemetry).

This devise uses a GPRS connection. Permanent or scheduled connection settings from 1 x per minute to 1 x per day, can hold a SIM card with PIM-code protection. Having different types of connections such as GPRS, GSM and UMTS (Wikipedia, 2015).

GPRS means General Packet Radio Service and is an oriented mobile data service available to Global System for Mobile Communication (GSM) and IS- 136 mobile phones. It provides data rates from 56 up to 114 kbps. Used in Wireless Application Protocol services (WAP) access, Short Message Service (SMS), Multimedia Messaging Service (MMS), and for Internet communication services such as email and World Wide Web access (Wikipedia, 2015).

3.4 The Base station

(A850 Telemetry Gateway)

This a base station, is a device that allows the transmition of the data from the UTR's to a computer. So it works as a gateway or proxy, the device converts the information or establish a mutuall acceptable procedure between networks (dcon Telemetry, 2006)

Figure 9- The Base Station (Gateway)

The measerments are sent from the sensors to the UTR and form this one by radio, or, by a mobile phone using a GSM /GPRS system and the base station (A850 Telemetry Gateway) makes it possible to be displayed in a computer. This device is of great importance and very much useful in order to make possible the management of the AWS from kilometres away. This equipment gives information about all the sensors performance and functioning, allowing diagnostically data (Adcon Telemetry, 2006).

The base station, the A850 Telemetry Gateway, it's the device that work as a bridge between the data logger and the computer that displays the data, with a genuine software. The Linux operating system runs in a strong 32bit processor in the gateway. It brings a hard disk MB RAM and flash disc 16-MB EPROM. Also has a low-power, battery-backed device and with a variaty of available interfaces such as Ethernet, V34 modem, RS-232 serial, and RS-485 multidrop serial. If without mains power, can work for 24 hours due to a rechargebale battery. This is depended on the number of RTU's connected which the gateway has to poll. The gateway software can be upgraded in the field (Adcon Telemetry. 2006). If is working with the radio, which is a much simple connection, the battery is suitable for 24h which does not happen once the number of RTU's is large. The gateway use a modem the (A440 Wireless Modem) that is useful also when there's radio connection, in order to send information to the network where the data is being saved and displayed live (Adcon Telemetry. 2006).

3.5 The Advantage Pro 6.4

The advantage pro 6.4 is a visualization programme which process the data and places available live data, in a website for million users as well as companies or organization. It runs fast and is based in a HSQL database engine (is a relational database software written in Java, is fast supporting high performances, multithreaded and transitional database, (Hypersol and Dice, 2015).

The AddVANTAGE Pro 6.4 is “a browser-based, fully Internet enabled, data visualization, data processing and data distribution platform, offering customizable trends, tables, statistics, alarms and events, disease and irrigation models, for all kinds of environmental and industrial data” as it is in (Adcon telemetry).

It has an integrated web server which allows users from getting access worldwide form any place, only needing an internet connection, having no need for PC software installation. All these features turn it into an optimal tool for weather and environmental data but no only, being very useful in other fields as leak detection, pump monitoring and a variety of other applications. (Adcon telemetry).

It is also important to notice that the software is able to manage more than 2000 RTU’s and offer a heath panel where a range of issue is displayed such as:

- ✓ available hard disk space for the database and the backups,
- ✓ when the last backup was performed,
- ✓ if the backup was successful and the DB consistent,
- ✓ how many users are logged in,
- ✓ how many RTUs are present on this server,
- ✓ how much time extensions take to calculate,
- ✓ how much memory and CPU power are being used,
- ✓ how many extensions are in the queue.

4 The sensors

The sensors used in the meteorological stations in Angola were provided by Adcon Telemetry. And in this section, all the information about it is provided.

4.1 Temperature and Humidity Sensor

(The SEN-R Combisensor Temp/RH Adcon TR1) The temperature and humidity sensors are enclosed in a protected radiation shield which with its developed design reduce overheat. It is extremely important in order to reduce error when solar radiation is high while speed is low, and in winter when sun's angle is low or when there is snow reflection. (MetSpec 2014). Solid UV resistant elements reflect radiation on their white surface, while the black inside absorbs accumulating heat. It is a virtually maintenance free sensor, highly accurate and with long time stability. Humidity sensor is dust and dirt protected by a coating which reduces sensor drifting eliminates corrosion and maintain accuracy over long time. A plastic cap with a metal screen shields both sensing elements against insects, chemicals and all kinds of dirt (Adcon Telemetry).

Figure 10 - Temperature and Humidity sensor

4.1.1 Temperature sensor (Thermometer)

The temperature is measured by a resistive temperature device (RTD), a platinum resistor is built in a glass or ceramic plate. Changes in the temperature does reflection in the electric resistance. Measuring the values of the resistance gives an analogue expression to the actual temperature. Platinum is used for being stable and for not being affected by corrosion and oxidation (OMEGA Engineering, 2015). It is a digital thermometer which allows accurate readings.

Platinum is one of the common resistant materials for RTD's, but there's others such as:

- Platinum (most popular and accurate)
- Nickel
- Copper
- Balco (rare)
- Tungsten (rare)

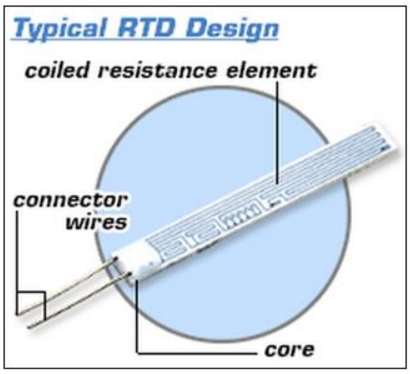

Figure 11 - RTD Design

4.1.2 Humidity sensor (Hydrometer)

Humidity is measure in a similar way but with a capacitive humidity sensor. Two adjacent metal plates are located in the centre of a cylinder that collects moisture in the air. The accumulation of moisture in the cylinder occurring an interaction between the metal plates producing a voltage. Differences In the voltage generate an analogue signal that is converted into a digital form and sent to data loggers (OMEGA Engineering, 2015).

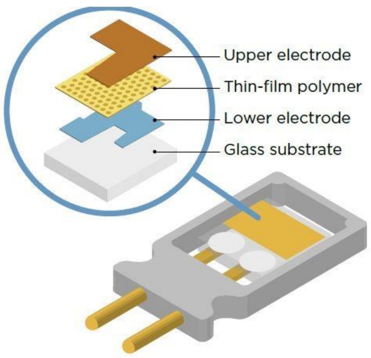

Figure 12 - Design of Capacitive

The use of RTD and capacitive technology allows more accurate readings form the instruments generating more reliable and precise measurements from the equipment.

Air temperature is used to calculate air density and air specific humidity because air temperature is a function of humidity. This brings the necessity of having these two sensors together and protected.

Parameters:

Temperature: The Thermometer measuring range is around -40°C ... +60°C -40°F ... +140°F with accuracy at +20°C of ±0, 2°C.???

Relative Humidity: The humidity sensor measuring Range is around 0 - 100%rH. With accuracy at +20°C from 0 - 90% rH of ±1% rH and from 90% - max. rH of ±2% rH, with a Temperature dependence of ±0.03% rH /°C. Long-term Stability <1% rH per year (Adcon Telemetry).

4.2 Precipitation sensor (Rain Gauge)

RG1 Rain Gauge, 200cm², 0.2mm, unheated

A Rain Gauge fully made of aluminium: accurate, robust, with a long service life. This Rain Gauge was built to last in rough environments and for agriculture and hydrological or meteorological purposes, with a universal design meets the need of most applications. Used in mast and floor mounting. The bucket has a steep angle which prevents residue (sand or dust) accumulations as well as facilitates water run of.

Figure 13 - A Rain Gauge Sensor (Measures precipitation)

Water is collected through a funnel with an orifice of 200 cm². Leaves and bird droppings are kept out of it by means of an aluminium filter with and easy cleaning mechanism. The funnel attaches to the body with a bayonet-style lock, as a prevention from harsh winds. All parts besides the buckets are made of aluminium, anodized, for extra protection and durability. (Adcon Telemetry).

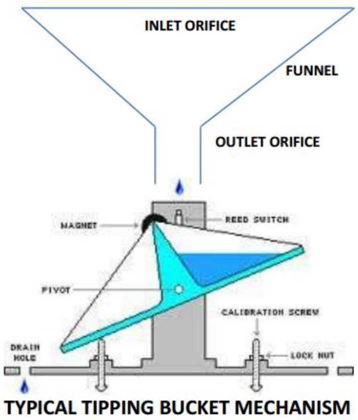

Figure 14 - The Tipping Bucket Mechanism

The Tiping Bucket Automated Precipitations Gauge, is an automated rain gauge, and has a simple working meachanism and is classified as an event measerment gauge.

The figure nº 12 illustrates the inside of an automated rain gauge and its basecally function. The rain fall into the inlet recipient and passes throw the funil into the outlet and falling in the pivoting bucket, as it fill u with water, equivalent of one-hundred of an inch of rain, the weight of the water cause it to tip and empty itself. The other bucket instantly moves under the outlet to catch water, and the movement repeats. Each time a bucket tips, an electric contact is made, giving up the total amount of rain in a certatin time period (Donald C. 2010).

The RG1 Rain Gauge, is unheated because there's no need. It has some special features such as a funnel lock to prevent from disassemble in windy days, and a poison box with an effective insect repellent. It also has a very easy way of cable replacement and on filed replacement (Adcon Telemetry).

Parameters of the RG1 Rain Gauge:

Weights 0.5 kg / 1.1 lb, with an operating temperature of freezing point to +75°C (+167°F), with an 0.2 mm resolution and orifice of 200 cm², with a capacity per hour up to 25mm @ + 1% and accuracy up to 50mm @ + 3% (Adcon Telemetry).

4.3 Radiation sensor (Pyranometer)

Pyranometer SP-LITE incl . amplifier Kipp & Zonen SP-Lite

This is a silicium-pyranometer, especially designed for agro-meteorology, with the special purpose to calculate evapotranspiration for precision irrigation purposes, to monitor solar panels in energy production, for air pollution dispersion calculations and similar application. It is comparable to ISO 9060-specified First Class Thermopile Pyranometers under clear and unobstructed natural daylight conditions. (Adcon Telemetry).

Figure 15 - A Pyranometer SP-Lite.

SP-Lite has a photo diode detector highly accurate and sensitive which creates a voltage output that is proportional to the incoming radiation (Adcon Telemetry). The solar radiation absorbed by the back coating on the thermopile sensor is transformed to heat which flows to the sensor to the pyrometer house. A voltage is created into the thermopile sensor, proportional to the radiation (Thuman C. and Schnitzer M., 2012)

The ISO-9060 Standard & Pyranometer Measurement Accuracy explains that "A thermopile is an electronic device which converts thermal heat energy to a voltage potential. Thermopiles generate an output voltage linearly proportional to the temperature differential (i.e. ΔT) between the thermopile hot junction receiver surface and cold junction pyranometer housing / heat-sink reference temperature" (Thuman C. and Schnitzer M., 2012)

The terms of maintenance were proven to track record of its original accuracy over long years. With the hardened crystal glass lense, that prevents from surface scratching and reflection of sunlight back to the atmosphere. Its dome-shape feature allows water and agro-chemicals from agriculture to simply run off, banning the formation of a layer of dust with obstructive outcomes. (Adcon Telemetry).

Parameters:

Properties	**SP-Lite**
Sensitivity	~75 µV/Wm²
Spectral Range	400 - 1100nm
Max. Irradiance	2000 W/m²
T.C. of Sensitivity	+/- 0.15% /°C
Operating Temperature	-30°C - 70°C
	-22°F - 158°F

Table 4 - Pyranometer Properties

4.4 Wind Speed Sensor (Anemometer)

Wind Speed Pro10/2 - 75m/s incl. arm and 2m cable

This professional wind speed sensor is made of robust, seawater resistant anodized aluminium, to stand severe conditions., and due to its aluminium cups, with considerable dimensions, the sensor has a very low starting point of less than 0.4m/s high accuracy and long durability is provided by the Low-friction ball bearings, besides requiring the easy and little maintenance parts replacement as well as keeping the its original specification for many years. The sensor will measure speeds of up to 270 km/h (Adcon Telemetry).

Figure 16 - Cup Anemometer

Properties:

The Wind Speed Pro10/2 has a magnetic measuring principle and a 3-arm Cup Anemometer measuring element, made of sea water resistant aluminium. With ranges from <0.4 – 75m/s (1.44– 270km/h) with a starting value <0.4m/s (1.44 km/h) and accuracy better than ± 0.5m/s and operating temperatures between -40°C ... +70°C (non-icing). Weights around 500g. and is complaint to standards VDI 3786, sheet 2 / WMO No.8. (Adcon Telemetry).

The installation of the sensor is made according to WMO requirements, on an Adcon pole with a diameter of 40mm it comes with a mounting arm 40cm long to provide proper distance to the pole. (Adcon Telemetry).

This is an equipment that measures the wind speed and gusts and has a very simple working system. It uses a magnetic system to measure the wind speed throw the rotation of the cups. It counts the rotation of the cup in each second, it moves past the magnetic detector or reed switch, which generates a brief pulse of electric current, this electric pulses have a rate proportional to wind speed, as explained by (Woodford C.2009).

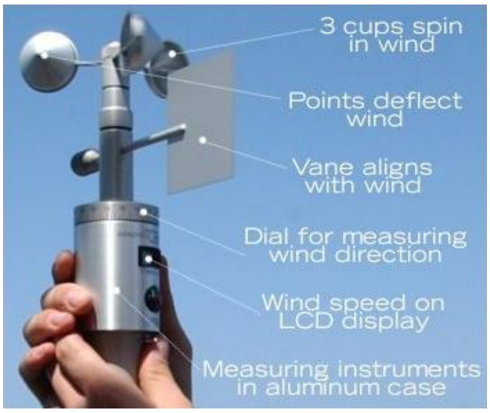

Figure 17 – Cup Anemometer description

4.5 Wind Direction Sensor (Wind Vane)

Wind Direction Pro10

This highly professional wind direction sensor is made of extremely robust, seawater resistant anodized aluminium, to stand severe conditions.

Figure 18 - Wind Vane

It has a very low starting threshold of less than 0.4m/s, and extremely low-friction bearings ensure high accuracy and a long service life. The Wind Vane is also made of aluminium and, like the wind cups, requiring easy and little maintenance parts replacement as well as keeping the its original specification for many years (Adcon Telemetry).

4.6 Atmospheric Pressure Sensor (Barometer)

Adcon BP1 Barometric Pressure 500 - 1500mbar, 0.1-2.5V, 3m

The piezoresistive sensor element is fully temperature compensated and with a accuracy performs better than 0,1%FS across the whole range. The sensor itself is encapsulated in a robust polycarbonate housing, as a WMO requirement, preventing errors in readings by protecting the sensor elements from heavy winds. With a high-capacity Goretex vent ensures that pressure inside the case equals outside pressure, and water infiltration. The sensor box is mounted to the pole of a weather station, made in Sweden (Adcon Telemetry).

"Piezoresistive pressure sensors are based on the resistivity dependence of materials under stress, similarly to strain gauges. Silicon is the most often used piezoeresistive transducer. Sensors are very strong, but very sensitive to changes in temperature, so they must be temperature compensated. Transducers are available in ranges from 1 kPa to more than 100 MPa, and have the widest dynamic range (they are used to measure air-blast pressure pulses in explosions), only approached by fibre-optic sensors." As said by Martinez, 2015.

Figure 19 - Barometric Pressure equipment

Properties of the BP1 Barometric Pressure 500 - 1500mbar, 0.1-2.5V, 3m:

The Pressure range is between 500 ... 1500mbar, with a IP67 protection and a sensing piezoresistive pressure element of a 1% FS accuracy. The operating temperature range from -40°C ... +100°C / -40°F ... +212°F and compensated temperature range around 0°C ... +80°C / 32°F ... +176°F. Has a singular 330g. of weight (Adcon Telemetry).

4.7 Maintenance, Calibration and Inspection

As this is a very knew installed equipment and the beginning of environment observations, some equipment maintenance programs are to be developed. For a near future the ISPT institute will develop a calibration office and regular inspections to be done by the INAMET, as it is the national entity responsible for this task. The ISPT and INAMET should be working together and sharing information and ideally the INAMET should give more support for the continuity of the meteorological observation process in order to create and keep and spread the collection of meteorological data for a wide range of future uses and benefits.

5 - The Installation Process

Here it is described the Installation process as well as guide lines followed.

The installation of the (10) ten AWS fallowed the INAMET, (O Instituto Nacional de Meteorologia e Geofísica de Angola) / (The National Institute of Meteorology and Geophysics of Angola). The process was at some point in conformity to the WMO recommendation however having in account the "developing Country state" and the expectation towards the accomplishment of international standard levels due to the internal problems of a typical developing country.

5.1 The Equipment and Sensors Installation

5.1.1 Rain Gauge

The Rain Gauge was installed in a second mast at 1.2 meters of distance of the first mast and with the mouth/ opening at 1m from the ground and towards SE direction.

Figure 20 - Rain Gauge in the mast during installation

5.1.2 Anemometer

The anemometer is at 3 m from the ground (having later expectation to go up to a 10m height as WMO guidelines for Weather and not agriculture purposes)

Figure 21 - The 3m height Anemometer, at the top of the mast

5.1.3 Hydrometer and Thermometer

The Humidity and temperature sensor is at 1.5 m height in accordance to WMO requirements.

Figure 22 - The Humidity and Temperature sensor in the installation process at 1.5m height

5.1.4 Pyranometer

The Pyranometer is facing north and at 1.5 m height.

Figure 23 - Pyranometer at 1.5 m height

Figure 24 - People involved in the installation process

6 - Measurements

6.1 Advantage Pro 6.4 website as data storage

The new data collected from the new AWS's can be seen in the site (www.isptundavala.dynalias.com) and with a key that enables access of the data in the site.

This pictures shows what can be seen in the site although not all of the option can be explained in this report.

In this site, it is possible to choose the automatic weather station, the sensor as well as the how to be displayed.

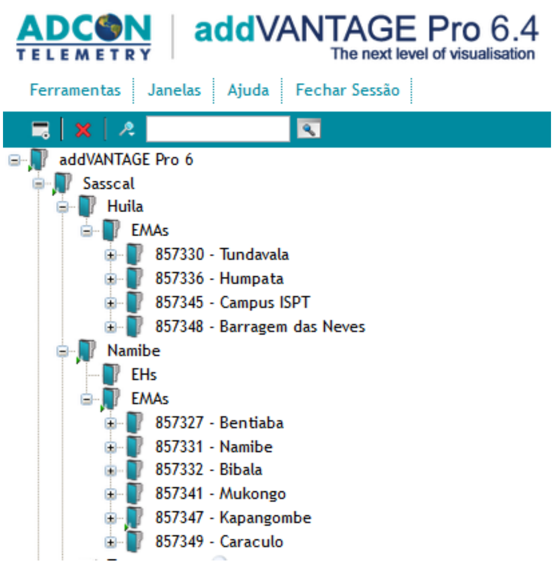

Figure 25 - Live data - The institute site for the weather stations observation.

It is possible to see in the image above the AWS (EMAs) and the sites belonging to each province.

In the next picture shows the different sensors in each AWS or site location.

From this site, it is possible to be displayed the different types of measures together or one by one. It is also possible to retrieve data as CSV files in a raw way or it is even possible to choose from properties the time, the maximum or minimum, different means and other properties as well.

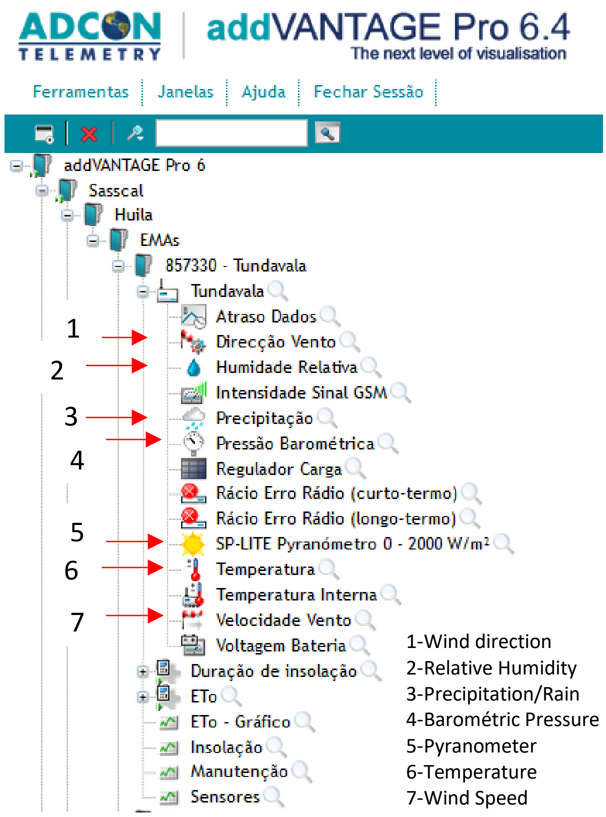

Figure 26 - The sensors in each site location or AWS. (This picture only shows for Tundavala AWS).

Image nº 24 shows the interface of the CSV files to retrieve. We have to choose the sensor or sensors and the dates and click on the CSV button that appears on screen. Other ways of retrieving data is also possible, it depends on what is needed and how we want the data, and the types of exportation are easy to learn from the manual present in the site for download.

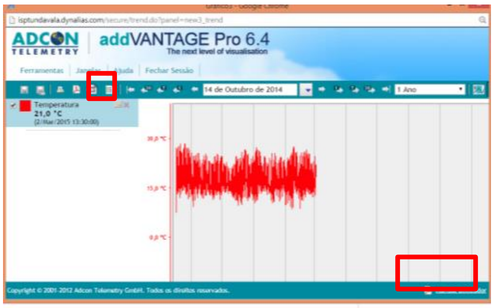

Figure 27 - Retrieving CSV files form the site and manual for user on the right

7- Recommendations

This part of the paper has the purpose of telling the guidelines, from the WMO (World Meteorological Organization), in order to achieve an international and standard reliable data for weather instruments so can be used for international and national meteorological institutes, research and other purposes.

Most of the recommendation in this paper are based on the non-conformity from the new AWS's installed in Angola due to the complexity of the WMO requirements documents. It is taking in account that the sensors were built in conformity with the WMO (Adcon Telemetry).

The advices on good practice for measurement and observations given by the WMO starts with the area where the instruments will be installed, for a typical synoptic or climatological station in a region or regional national network:

7.1 Siting Considerations

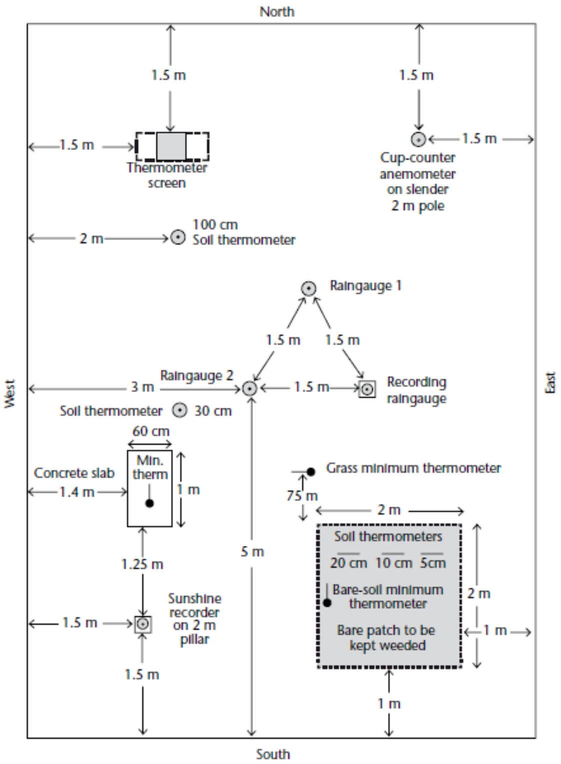

Figure 28 - Observation station showing the minimum distance between installations

The land station who makes surface synoptic observation should be localized in an area where the obtained meteorological data is representative of the atmosphere state which ranges between 2000 km² to 10000km ², and the area should have a plot of land designated to bear the meteorological observation usually with most favourable area around 1 ha. In order to prevent miss readings, the observation site should be apart from Industry as well as form constructions and threes, 10 to 20 times their heights, and greater than 100 m from any type of water bodies, besides if the site is in a coastal area. It is also to be aware of the direction of site due to some instruments which are affected by shadow. It is also advised security measures against lightning, flooding, theft and vandalism (WMO, 2007).

7.2 Coordinates of the AWS

As mentioned in the World Geodetic System (WGS-84) Earth Geodetic Model 1996 (EGM96), the stations position must be accurately known and recorded, latitude and longitude of 1 in 1000, as well as it's elevation, height of the station above mean sea level, to nearest meters. This is especially important as the pressure is related to its own elevation (WMO, 2008)

7.3 Sensors Heights

The Heights are especially important in wind speed measurements. It must be corrected for effective height or fallow standard reference level of 10 m for meteorological data (WMO, 2008), for agriculture purposes it is used at 2 m height from the ground (Battista P. at al, 2000). Some other sensors heights are also important, for that, table nº 3 shows the advises (Campbell Scientific, Inc., 2007)

SENSORS	HEIGTHS
Wind	10 m (WMO & EPA) 2 m ±0.1 m, 10 m ±0.5 m, optional (AASC)[2]
Air Temperature And Relative Humidity	1.25-2.00 m (WMO) 2.00 m for temperature only (EPA) 2 m & 10 m for temperature difference (EPA) 1.5 m ±1 m (AASC)
Precipitation	30 cm minimum (WMO) 1.0 m ±0.2 m (AASC)
Solar Radiation	3 m or less (WMO, EPA, AASC)

Table 5 – Table with sensor's heights recommended

[2] (AASC) - American Association of State Climatologists

7.4 Training

The presence of technical trained staff is required, skills for the different types of equipment's, electrical sensors, digital and microprocessor techniques or computers. (WMO, 2008)

7.5 Maintenance, Calibration and Inspection

The maintenance of the instruments and sensors have to follow the manufacturer prescribed procedures and the entity responsible for the stations should develop a maintenance programme adequate to the calibration and inspections of the AWSs.

As (WMO, 2008) requirements, all the land stations, synoptic and climatological especially should have inspections in less than two years' time. It is also advised that shorter interval of maintenance of the agriculture meteorological and special station to ensure the high standard of observations and the correct functioning of instrumentations as well. The maintenance of sites and instrumentation has the purpose, plus others, the following:

Non deterioration of the quality of observation between station inspections, which includes "housekeeping" at observing sites (e.g.: grass cutting and cleaning of exposed instruments and checks on automatic instruments by manufacturer's recommendations, in order to detect equipment faults at early stages and dependently the equipment is replaced or repaired.

Develop maintenance programmes and calibration support as well as reporting methods. For the AWSs it is also advised to check regularly the hardware components connections as well as cables connections in order to avoid failures and non-collecting of measurements. Rain Gauges and Pyranometers need more regularly cleaning as it gets cloth by leaves or dust, respectively.
Calibration and inspections should apply the same methods of maintenance, for AWSs the

field calibration is advised due to their, sometimes inhospitable location (WMO, 2008).

8 - The UCD Automatic Weather Station

The UCD AWS, has a 10m mast in order to record wind speed according to WMO requirements which gives credibility to report to the national and international standard of meteorology observation.

8.1- UCD AWS Location

It is located in Rosemount on UCD grounds, as shown in the figure nº19 as researched by Aisling, 2009 in (Creevey, A., 2009)

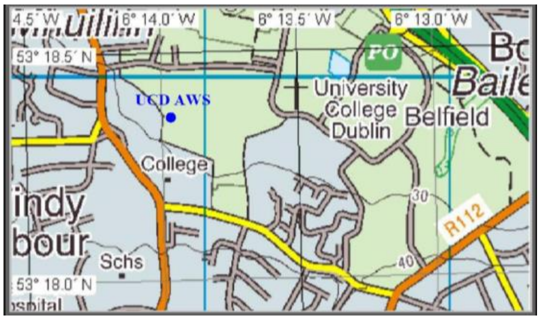

Figure 29 – UCD AWS Location in Rosemount on UCD grounds.

8.2 – UCD AWS Structure

The station and the measure instruments are shows in image nº 25. The mast has a very solid cement bases as well as adequate structure to suspend its height. It also have double sensors to measure each weather element according to WMO requirements as well, for the case of a failure of a sensor, there's always other one that keeps recording the atmospheric conditions. It also has a lightning rod to avoid damage of the tour and equipment due to height and metal constitution.

Figure 30 – The UCD Automatic Weather Station (10m height mast)

8.3 – UCD's AWS Measure Instruments

The AWS is composed by (11) measure instruments, when most are repeated. There are (4) four anemometers, (2) two cup anemometers at 2 m height and other two at 10 m height, together with wind direction sensors as well. In addition, an ultrasonic anemometer at around 2 m and also a sonic anemometer at 10 meters. The ultrasonic anemometer measures wind in three dimensions (Creevey, A., 2009)

Figure 31 - A sonic anemometer on the left and cup anemometer on the right and wind direction sensor at 2 meters' height

Figure 32 - The ultrasonic and a sonic anemometer at 10 m height

Figure 33 – A Humidity Sensor on the left at 2 m height and another at 10 m height on the right

There are two humidity sensors at 1.50 m and 2 m, this humidity sensors are compiled with thermometer, another Humidity sensor at around 5 m.

Figure 34 - Humidity sensor at around 5 m height

There are two by two solar radiation, two for the solar radiation and the other two other for the earth radiation or reflection radiation.

Figure 35 - A Pyranometer at 2 m height

Figure 36- Pyranometer for reflected radiation

The Rain gauges are placed one at 2 m height in the mast and one on the ground, around 30 cm height, as WMO recommendations (WMO, 2008). They are unheated and with 200 cm² area and collects 0, 01 mm per measurement as mentioned in (Creevey, A., 2009).

Figure 37 - The Rain Gauge at 2m height and on the ground at 30cm from the ground

Figure 38 – The 30 cm Rain Gauge and inside tipping bucket mechanism and protected net

There is also a soil temperature probe for soil temperature measurements.

Figure 39 - Cable that brings the information from the soil temperature probe

The atmospheric pressure sensor is protected by the box as well as a the RTU and

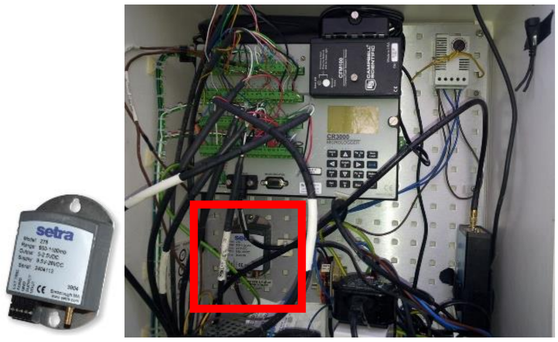

Figure 40 - The Atmospheric Pressure Sensor in the Campbell scientific enclosure (left figure belongs to Creevey, A. (2009).

The enclosure contains a cataloguer with rechargeable batteries, the atmospheric pressure sensor temperature and humidity probe, two thermocouples and two water reflectometers and a Spread Spectrum Radio. From the box, all the measurements are send by radio from the data logger (above pressure sensor on figure nº 40) to a computer in a nearby storehouse which works with Loggernet 3.4.1. Software, as explained in Creevey, A. (2009).

This weather station can be used as an example for the future 10 m height AWS to be installed back in Angola, with the purpose to record wind speeds that are representative of the area, as well as sonic and ultrasonic three-dimensional wind speed sensors and soil temperature probes.

The objective is to try the best to fallow and keep WMO requirements for standard meteorological reliable readings in order to build a good quality of atmospheric observations.

9 - Analysing data and Programing

For this section I had to learn how to retrieve data in the addVANTAGE pro 6.4 as mentioned above (in Measurements) in order to work in the Ostave program which I also had to learn to be able to run the Scripts developed by Dr. Conor. He developed two scripts, one for the New data from the New AWS, with data from middle October to Midle February and other for the Old data from 1961 to 1974 in order to be worked in my thesis in the end of this master course.

9.1 Octave

Octave is a free sofware, published by the Free Software foundation, it is being used by thousands worldwide for teaching, research and comercial perpuses as well. Uses a high-level language mostly compatible with matlab and "it is easily extensible and customizable via user-defined functions written in Octave's own language, or using dynamically loaded modules written in C++, C, Fortran, or other languages" as in (Eaton J., 2013). With a convinient command line interface. Has substencial tools to resolve common linear and non linear problems numeriacally and other numerical esperimets, integrating ordinary funtions, manipulating polynomials and integrating ordinary differential and differential-algebraic equations. (Eaton J., 2013)

9.2 Working Data in Octave

It was only possible to work with the 3.6.4 gcc 4.6.2 and not with the new version due to the incompatibility with windows. Nonetheless it was possible to work on the data in this version and also possible to add a special "package" in octave to be able to run Excel spread sheets (The Old data are in Excel spread sheets).

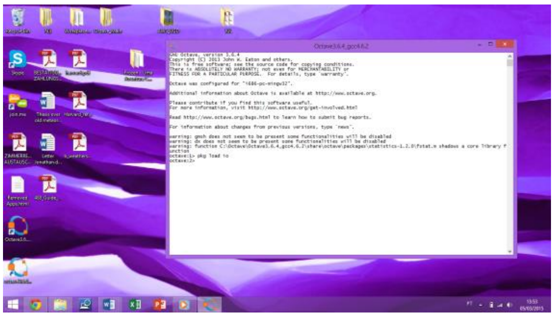

Figure 41- Octave command line interface in my Desktop

In this interface, it is possible to go throw the computer and enter any directories in the computer and run the scripts and plot results. I will show here a graph form the New data and the Old data.

In this report, will not be possible to compare both of them and get a conclusion of such analysis as the old data needs to be corrected and critically analysed as well as a whole year of New data need to be gathered in order to allow comparing, and this work will possible be done in my thesis.

The New data covers 10 different locations as shown in table nº 1, and seven types of measurements (Precipitation, wind speed and direction, atmospheric pressure, solar radiation and air humidity and temperature), the Old data only covers air temperature and Humidity and precipitation, which will narrow future comparing.

In octave, we run the script for temperature only, for both New and Old data, since I learn more about programing in Octave I will able to write a script for other measurements. So, for now I can only show a graph with the temperature readings from a New AWS and other from the old station. This is exclusively to show that I could run the data into octave as much work needs to be done on this data in order to be explained environment variables and the difference along the time.

9.3 Data from the New AWS

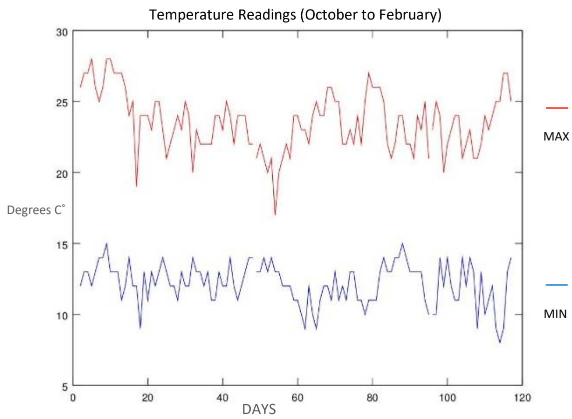

Figure 42 - Maximum and Minimum Temperature Readings from Tundavala (from 17/02/15 to 11/02/15)

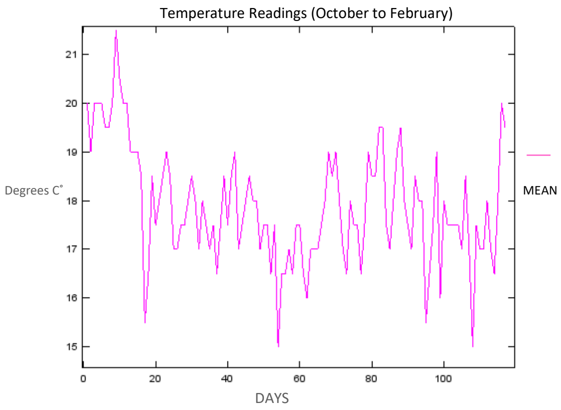

Figure 43 - Mean Temperature Readings from Tundavala (from 17/02/15 to 11/02/15)

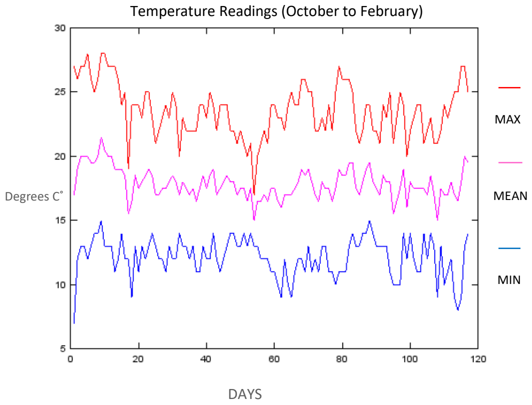

Figure 44 - Maximum, Minimum and Mean Temperature Readings from Tundavala (from 17/02/15 to 11/02/15)

9.4 <u>Data from the Old data (Meteorological data from Angola)</u>

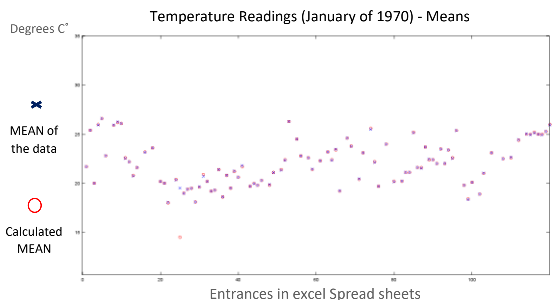

Figure 45 - Means of the Temperature from January 1970 in different location in the South of Angola

9.5 <u>The Old Data</u>

The Old data are in excel spread sheets as a true copy of the files which I have digitalized in 2014. This files have compiled data from more the (100) meteorological stations or collection stations in which only appears one reading for one station once a month, although reports the day of the highest and minimum temperature of that month. Since this data still have to go throw the correction process in octave we could only show the image above nº 45, which will enable digitalization correction. In the annex, figure j can be seen the Spread sheets in excel format and in the annex, figure h can be seen the scan of the real document. This data was collected by the Serviço Meteorológico de Angola - Luanda (1961-1974), by the time Portugal was still the colonizing Angola and copies were send to the Geophysics Institute of Coimbra's University in Portugal (Instituto Geofísico da Universidade de Coimbra - Portugal.), as the documents remained in Angola got to be lost or have uncertain fate due to the independence process and civil war in the country (Serviço Meteorológico de Angola - Luanda (1961-1974)).

10 - Future expectations

This work placement was widely profitable.
I have learned some critical thinking about meteorological variables, I have learned about meteorological and weather stations especially automatic ones and how data is collected and displayed. I have also worked in a new program, Octave, which allowed me to work with data and plot it, although I still have a long way to get used to the program, to be able to develop professional skills in order to analyse data on it.

For a near future I hope to work on the Old and New data and compare them in my master's thesis if possible, or afterwards.
This will turn the Old data available for research and as a beginning of the creation of a database, once lost by the independence process and civil war which my country passed throw. From this start it will be possible to get even older data and compile to this database from Portuguese's archives, but unfortunately not in a near future.

This work which I have developed for half of the country, the South, will be completed by a colleague, for the North of the country and when all completed can be used to correct some international reports such as IPCC's reports which uses simulations or even older data to build climate reports when no data is available or recorded. In other hand by correcting the IPPCC work will aloud the models producers to correct their models with true reliable data. Herewith, real scientific work is done which not only benefits the local and national services as it benefits the international scientific community.

11 – Conclusion

This work placement was in my opinion very helpful to the development of my skills in this Master's Course and for my work back in Angola as well.

It was possible to learn a wide amount of information during the 6 weeks which can be verified in this report.

The AWSs are good enough for a restart as it needs higher masts for proper wind speed readings as well as naming the sites as it should never have the same names as cities, towns or villages, something that should be corrected and not repeated in the future.

Some sites are not completely in agreement with the WMO siting advices, being another aspect to consider for this ten (10) AWS and for others as well for the future. Some aspects should now be taken in account if international reports are at aim of the project.

It is also advised that a full report should be developed for the record of all the procedures during the installation process as it was difficult to recover information to fill this report.

The maintenance program should be created and fallowed as scheduled in order to avoid misreading and errors.

All noncompliance with WMO advices from this New AWS rely on the initiation process which in time will get as requirements and as for the problems of a developing country.

Although some noncompliance, the AWSs are reporting New meteorological data which has been deactivated for the last 40 years, turning this small achievement into a great development and a benefit for the region and for the country as it will profit for a range of activities that rely on that information such as agriculture and civil constructions, as it will help prevent casualties from floods as well.

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Figure nº 1 ADCON livedata. Meteorology [Online] available at http://isptundavala.dynalias.com/livedata/map.jsf [Accessed 28 January 2015].

Figure nº 29 retrieved from Aisling, unpublished master thesis (Creevey, A. (2009))

Figure nº 4 - Angola _Huíla [Online] available at:http://cdn1.portalangop.co.ao/angola/pt_pt/files/dados/2013/1/5/imgmapa_data,0,8f32665c-e68c-4042-9016-619bbb41f199.png [Accessed 09 March 2015]

Figure nº 5 - Angola _ Namibe [Online] available at:https://encryptedtbn2.gstatic.com/images?q=tbn:ANd9GcQb3pzUXoGxOS9zFUtt_u4lV1_abvq3DztW1jxIlPc6wFZUGp0Hw[Accessed 09 March 2015]

Figure nº17. Anenometer [Online] available at: http://cdn4.explainthatstuff.com/anemometer2.jpg

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Annexes

Old and New data sitings from table 3. Marker Red belongs to New AWS and Marker Yellow to the old data.

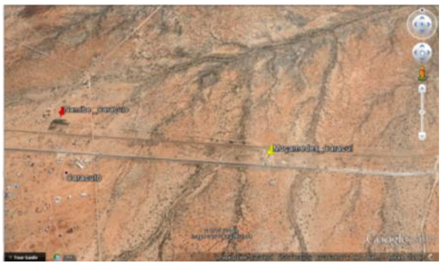

Figure a – Caraculo

Figure b – Bentiaba Figure

Figure C – Namibe

Figure d – Kapangombe

Figure e – Humpata

Figure f – Humpata inside Lubango (the white lines in the image follow the slops of Serra da Leba , as a border between Huíla and Namibe)

Files from the old data which was digitalized

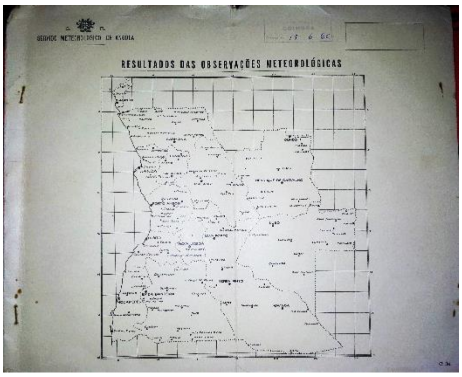

Figure g – Front cover of file

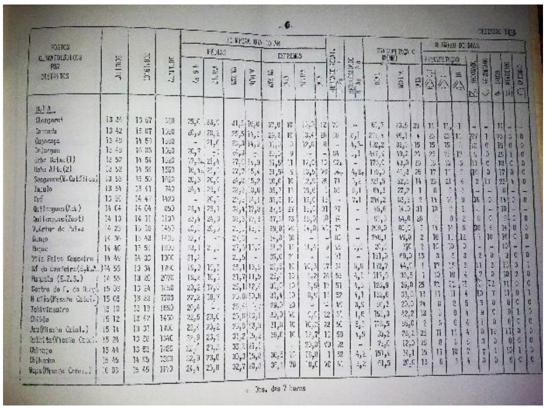

Figure h – Table with the data

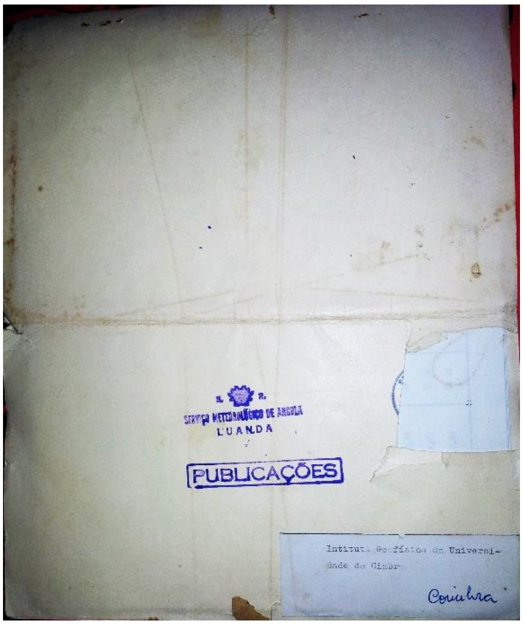

Figure i – Back cover

Mês de Setembro de 1970

Postos Climatológicos por Distritos	Latitude	Longitude	Altitude (m)	Temperatura do Ar – Médias – Às 9h	Temperatura do Ar – Médias – Diurna	Temperatura do Ar – Médias – Máxima	Temperatura do Ar – Médias – Mínima	Temperatura do Ar – Extremas – Máxima	Temperatura do Ar – Extremas – Data	Temperatura do Ar – Extremas – Mínima	Temperatura do Ar – Extremas – Data	Humidade Relativa U, às 9h	Nebulosidade N, às 9h	Precipitação R, (mm) – Total	Precipitação R, (mm) – Máxima	Precipitação R, (mm) – Data	Número de Dias de – Precipitação – R20,1	Número de Dias de – Precipitação – R21	Número de Dias de – Precipitação – R210	Número de Dias de – Trovoada	Número de Dias de – Relâmpago	Número de Dias de – Chuva	Número de Dias de – Nevoeiro	Número de Dias de – Cacimbo
Lobito (ou S.M.A.)	12 22	13 32	1	21.1	20.6	23.8	17.4	26.8	8	15.0	11	80	8.1	0.0	0.0	-	0	0	0	0	0	0	0	5
Monte Belo	12 25	14 24	1,260	20,,2	20.4	29.5	11.2	32.9	15	9.0	17	33	-	17.7	17.2	27	2	1	1	-	-	2	-	-
Cassequel	12 26	13 32	3	22.1	21.4	24.6	18.1	27.0	8	16.3	15?	74	8.1	0.0	0.0	-	0	0	0	-	-	0	-	-
Biópio	12 28	13 44	140	22.4	22.6	26.8	18.3	30.5	4	15.0	16	73	7.6	0.0	0.0	-	0	0	0	-	-	0	-	-
Bocoio (Sousa Laura)	12 28	14 08	960	21.4	19.6	26.9	12.2	30.5	16	9.1	2	84	-	0.0	0.0	-	0	0	0	-	-	0	-	-
Benguela (S.M.A.)	12 35	13 25	-	21.2	21.1	24.3	17.9	26.6	8	15.7	15	76	8.0	0.0	0.0	-	0	0	0	0	0	0	0	0
Benguela	13 35	14 25	5	21.8	21.0	26.4	15.7	29.0	VD	14.2	13	75	7.7	0.0	0.0	-	0	0	0	-	-	0	-	-
Cavaco (Cent. De Estudos)	12 35	13 37	30	22.0	21.2	25.1	17.3	27.5	4	13.9	15	81	8.2	0.0	0.0	-	0	0	0	-	-	0	-	-
Lomaum	12 43	14 24	1,020	19.7	22.0	30.0	13.9	32.5	20	12.4	2	68	3.8	0.0	0.0	-	0	0	0	0	0	0	0	2
Fazenda S.Francisco	12 57	13 05	43	22.9	-	-	15.7	-	-	12.3	6	74	5.3	0.0	0.0	-	0	0	0	-	-	0	-	-
Alto Capaça (C.Est.Ganda)	12 57	14 25	1,040	19.9	22.3	29.9	12.8	35.6	15	7.1	26	69	3.5	1.8	1.8	27	1	1	0	2	0	1	2	0
Ganda (Est. Zoot.)	12 57	14 38	1,370	21.0	22.1	30.2	14.0	32.0	VD	12.0	10	55	2.6	0.0	0.0	-	0	0	0	-	-	0	-	-
Alto Catumbela	12 58	14 46	1,260	21.8	21.8	32.1	11.5	35.0	VD	8.0	3	64	0.8	4.5	4.5	23	1	1	0	0	0	1	4	0
Vila Mariano Machado	13 00	14 36	1,300	21.2	-	29.3	-	-	-	-	-	64	-	0.0	0.0	-	0	0	0	0	0	0	2	0
Caimbambo	13 01	14 00	780	23.8	22.9	33.0	12.8	35.5	28	5.4	7	81	1.8	0.0	0.0	-	0	0	0	0	0	0	0	8
Catengue (C.F.B)	13 02	13 45	540	-	23.2	29.5	16.8	32.0	30	13.0	18	-	-	0.0	0.0	-	0	0	0	-	-	0	-	-
Cubal	13 02	14 15	930	19.8	21.6	31.1	12.0	36.0	16	6.0	27	76	-	0.0	0.0	-	0	0	0	-	-	0	-	-
Chicuma	13 26	14 52	1,550	21.8	21.2	30.4	12.5	32.5	3	9.0	VD	53	-	0.0	0.0	-	0	0	0	-	-	0	-	-
Est. Regional da Ganga	13 29	14 37	1,630	20.4	21.2	29.8	12.7	33.5	2	9.5	30	28	2.1	13.3	8.1	27	2	2	0	2	0	2	0	0

Resumo Climatológico | Postos Climatológicos Distritos | Postos Udométricos Distritos | Postos Climatológicos

Figure j _ Data in Excel spread sheets