AUTOMATIC WEATHER STATION DATA MANAGEMENT AT THE I.N.M. METEOROLOGICAL CENTER IN THE BALEARIC ISLANDS

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Abstract

Automatic weather stations yield a huge amount of useful data, that are not fully exploited by the software provided with the stations. Therefore, as new needs emerged, a set of computer programs has been developed, allowing us to: a) store the data in a more efficient way, keeping all records on line for different climatological applications; b) apply additional quality controls on the data, with tools to correct or delete the errors; c) automatically generate e-mail messages with warnings to the Civil Protection services or data summaries for different customers; d) Generate web pages with data summaries and graphic displays in real time; e) generate graphs, data listings and other climatological products for different purposes. As these programs have been developed locally, they can be easily modified to accomplish new tasks with quite a short response time.

Keywords: automatic weather station, data management, Balearic islands.

1. INTRODUCTION

The automatic weather stations (AWS from now on) of the Spanish *Instituto Nacional de Meteorología* provide data of wind, air temperature and humidity, precipitation and atmospheric pressure every ten minutes. These data are available to our regional forecasters in real time, as a monitoring tool to watch the weather evolution in the Balearic Islands, and past data (from a pair of years) can be retrieve from the workstation dedicated to the AWS data management, both as tables and as graphic presentations.

However, the provided climatological applications are limited to the mere printing of standard monthly summaries, with no other utilities implemented by default. Therefore, a set of computer programs and routine procedures had to be developed at our Meteorological Centre to be able to obtain a variety of products from the vast amount of useful data generated by the AWS.

The first task to undertake was to design new and better manageable data archives, since data are organized in the dialing computer in daily files, located in a monthly tree directory (with literal names!). These daily files are updated every hour through a dialing process, and then imported to yearly binary files located in another computer (which acts as a server for all our climatological processes), with a size of 37% of the original files. This storage efficiency is of little relevance today, but was crucial in the late eighties to allow all data to be kept in line in a single PC hard disk (of about 100 MB those days).

The programs were first developed in GW-BASIC, running on a PC-MsDOS, but advantage was taken from the need to adapt them to the 2000 year, and they were re-written in C. Therefore, they are now implemented in a SUN server running Solaris, and are also mirrored in a cheaper PC-Linux that acts as a supplementary and backup system. (Binary files are not fully compatible between these systems, due to the different byte order of their internal number representation, but this is easily solved through a conversion program).

Our experiences with this data and a brief description of the applications developed for them (both real-time and climatological) will be discussed in the following sections.

2. REAL-TIME APPLICATIONS

This section groups applications that are updated in real-time (hourly at present times), but may have either a meteorological or climatological character. Users of these products must be aware of the possible errors of the data, since their quality control is subject to a non real-time process.

2.1. Severe weather warnings to Civil Protection services

Civil Protection services are provided with heavy precipitation and/or strong wind gusts warnings through automatically generated e-mails, when prescribed thresholds of these elements are over-stepped. In addition, warnings of temperatures equal or under 0°C at the main town, Palma de Mallorca, are also included in the mails, allowing to take actions to provide shelter to eventual indigent people sleeping in open places.

Example of warning mail *(translated to English)**:***

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From:
Sent: Monday, November 25, 2002 7:20 PM

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25-November-2002, at 20:20.

Heavy precipitations (2.5 mm in 10 minutes, or more) in:

Port de Pollença B.A. at 19.50 (2.7 mm), 20.00 (2.6 mm)

Strong wind gusts (50 km/h or more) in:

Port de Pollença B.A. at 19.10 (53 km/h), 19.20 (57 km/h),
       19.40 (58 km/h), 19.50 (70 km/h)
Porreres at 19.40 (53 km/h), 20.00 (50 km/h)
Far de Portocolom at 19.30 (55 km/h)
Far de Capdepera at 19.10 (99 km/h), 19.20 (97 km/h),
       19.30 (90 km/h), 19.40 (90 km/h), 19.50 (86 km/h), 20.00 (91 km/h)
Aeroport de Menorca at 19.30 (55 km/h)

This information is not subject to quality control and may contain
errors.
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2.2. Real-time weather updates for internal use

Real-time AWS information is available only at two dedicated terminals, while many of our staff may be eventually interested in their data. Particularly, the spokesperson of our Met. Centre often needs an easy access to both past (recent) and real time meteorological data when providing information to local radio stations, newspapers and other media. The solution was to build an HTML page to our intranet Web server with AWS data summaries. This way,

anybody of the INM staff (not only in our Centre, but in the Central Services in Madrid or in any other regional Centre or airport) may instantly access the data in their computer with just a Web browser.

Example of HTML data summary:

Summary of AWS data from 26-11-2002

	Max. Wind gust			Temperatures				Humidity		Precipitation		
Station	**Dir**	**km/h**	**time**	**Max.**	**hora**	**Min.**	**time**	**Max.**	**Min.**	**Total**	**Max.**	**time**
Palma Portopí	NW	43	0120	17.3	1050	12.4	0700	82	58	0.4	0.1	0130
Palma Dic d.l'oest	WNW	44	1410	-	-	-	-	-	-	-	-	-
Serra d'Alfàbia	NNW	127	0000	7.7	1000	3.8	0000	95	94	-	-	-
Lluc	SE	45	0030	14.1	1100	7.8	0000	99	65	0.6	0.3	0120
Port de Pollença	N	67	0050	18.1	1110	12.0	0000	90	55	0.0	0.0	-
Porreres	SW	40	0030	18.3	1120	10.5	0710	91	51	0.0	0.0	-
Far de Portocolom	N	58	0000	18.8	1300	12.4	0000	96	45	0.0	0.0	-
Far de Capdepera	NNW	97	0200	17.2	1140	13.4	0210	94	47	0.2	0.1	0000
Aero. de Menorca	NNE	76	0120	-	-	-	-	-	-	6.5	0.9	0150
Aeroport d'Eivissa	WSW	32	1110	16.9	1040	11.8	0200	90	56	0.0	0.0	-

Latest AWS data from 26-11-2002 (At specified time or in the previous 10 minutes)

	Time	Average wind				Maximum wind				Temp.	Hum.	Prec.
Station	**UTC**	**Dir.**	**(m/s)**	**(kts)**	**(km/h)**	**Dir.**	**(m/s)**	**(kts)**	**(km/h)**	**(°C)**	**(%)**	**(mm)**
Palma Port.	1700	ESE	1.8	3	6	SE	3.9	8	14	14.3	69	0.0
Palma Dic	1700	SE	1.7	3	6	SSE	3.2	6	12	-	-	-
Serra d'Alf.	1700	NW	9.6	19	35	NW	12.3	24	44	6.7	94	0.0
Lluc	1700	S	0.8	2	3	SSE	3.1	6	11	8.3	85	0.0
Port Pollen	1700	NW	1.5	3	5	NNE	4.7	9	17	13.2	75	0.0
Porreres	1700	NW	1.8	3	6	NW	2.9	6	10	12.4	73	0.0
Portocolom	1700	WNW	1.9	4	7	WNW	3.5	7	13	13.3	80	0.0
Capdepera	1700	NNW	4.0	8	14	NNW	9.9	19	36	14.7	62	0.0
A.Menorca	1700	NNW	4.6	9	17	NNW	9.9	19	36	-	-	0.0
A.d'Eivissa	1700	WNW	1.3	3	5	W	3.0	6	11	14.1	64	0.0

2.3. Recent weather summaries for costumers

Some newspapers and other communication media, and other types of costumers such as insurance companies, are interested in receiving a daily summary of the weather of the past 24 hours. These are provided under contract through an automated procedure that compiles the summary with the AWS data and sends it by e-mail at scheduled times. This summaries include maximum wind gusts, extreme temperatures and total precipitation:

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Data summary from Automatic Weather Stations
Day 28-11-2002 at 21.00 official time.

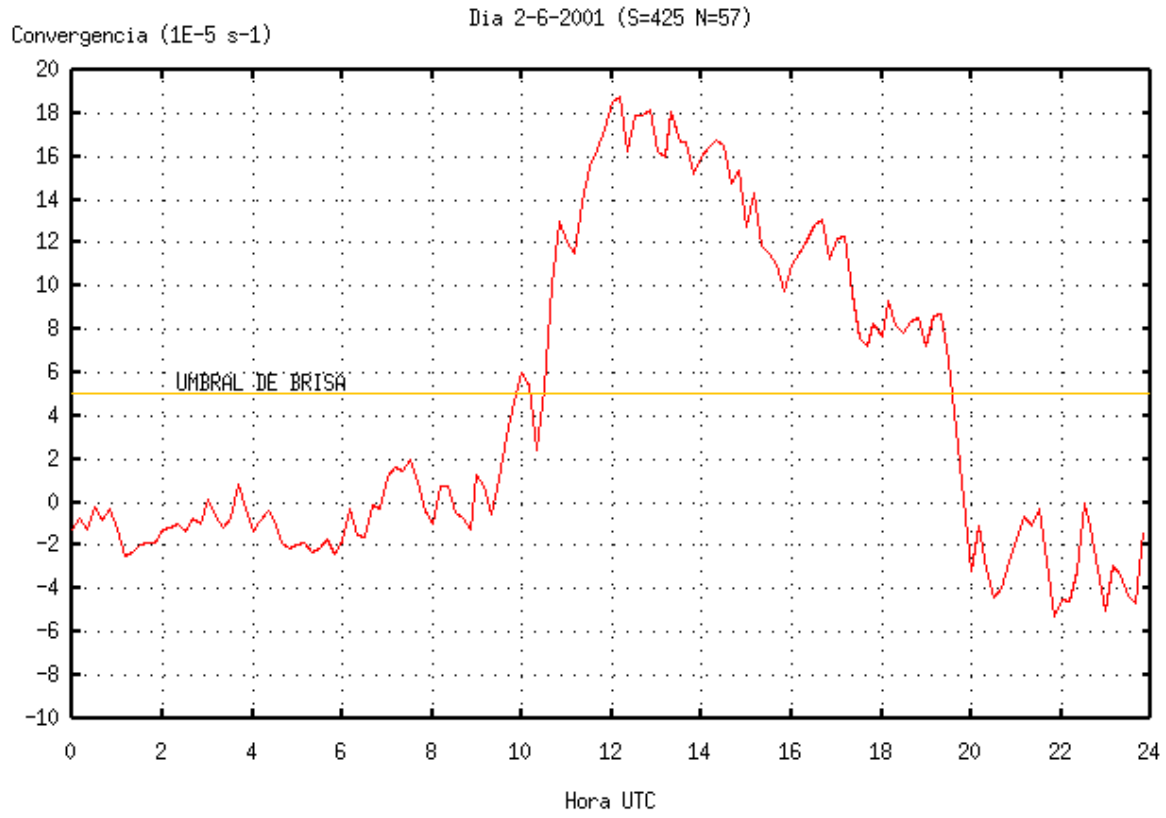
	Today temperatures (°C)			Precipit.(mm)		Max. gusts (km/h)	
Station	Now	Maxima	Minima	19-08	08-21	19-08	08-21
Palma Portopí	15.5	20.6	12.7	0.0	0.0	7	31
Palma Dic de l'oest	-	-	-	-	-	11	37
Aeroport de Palma	-	19.9	8.9	0.0	0.0	4	33
Serra d'Alfàbia	9.5	16.7	8.8	0.0	0.0	48	69
Lluc	11.5	20.8	2.5	0.0	0.0	30	30
Port de Pollença B.A.	16.0	21.2	8.7	0.0	0.0	11	32
Porreres	14.2	20.9	10.0	0.0	0.0	22	39
Far de Portocolom	16.5	19.9	14.5	0.1	0.0	23	35
Far de Capdepera	16.6	21.3	14.7	0.0	0.0	37	45
Aeroport de Menorca	14.9	17.9	12.1	0.0	1.4	30	37
Aeroport d'Eivissa	18.4	21.8	14.9	0.1	0.0	19	40

2.4. Sea breeze setting monitoring

Sea breeze circulations are a common feature of the Majorcan wind systems. (The other Balearic islands have also sea breeze circulations, but of a much more reduced scale). With a weak general pressure gradient the air at midday enters from sea to land through the two main bays, the Palma bay at the southwest and the Alcudia bay at the northeast, and converge to the centre of the island, where it rises, typically producing convective cumulus clouds. But many times there is a definite general wind that combines with the thermal effects, reinforcing the wind in one of the bays, restraining it in the other, and displacing the convergence zone wind-wards. In this situations diagnosing the sea breeze is not an easy task (not all the midday south-westerlies at the Palma bay are a sea breezes), yet it is of great importance because it affects the operational aviation procedures of the Palma international airport, located in the central coast of the bay.

This problem was addressed studying the convergence of the wind in Majorca, with the data of three AWS around the island depicting a triangle. The study showed that the sea breeze can be diagnosed when the wind convergence is greater than 5.10^{-5} s^{-1} (GONZÁLEZ *et al.*, 1998). Therefore, the graph of the wind convergence in Majorca (see example in figure 1) becomes a valuable tool for our regional forecasters. An intranet web page is then updated hourly with this graph, and the graphs of the previous two days are also presented, as an aid to forecasting the setting and ending times and the strength of the sea breeze.

Fig.1: Convergence of the wind at Mallorca in a typical sea breeze day



2.5. Daily updates of climatological summaries

Many communication media phone us inquiring thinks like: What have been the highest (lowest) temperatures in this month? Has any of them become a new record? Have the precipitations been much lower than usual? How strong is the drought we are suffering?

To answer these questions, climatological summaries of the current month are updated daily, based mainly on AWS data, though manually complemented with data from conventional observatories. This reports, presented also in a HTML web page, consist in tables with daily values of extreme temperatures, total precipitation and sunshine hours, plus the summary table of the month (from the first day to yesterday), that bears cumulated precipitation values for the month and from 1-January (*civil year*), 1-September (*hydrologic year*), and for the last 365 days (*moving year*), with departures from the normal values. Monthly and daily extreme temperatures are also related and compared with their averages.

The moving year precipitation and its relative anomaly (in percent) were implemented amidst the severe drought suffered from 1998 to 2001, which arose great concern in the water resource managers and the public in general. The inter-annual precipitation relative anomaly became a useful monitoring index of the state of the water resources, and a table with the values for Majorca (an average of the five more representative stations), Minorca and Ibiza (from their airports only) is updated daily and published in the Internet. The background colors of the table cells are computed in accordance with the values of the indexes.

Example of climatological advance from days 1 to 27, November 2002 (issued on 28-11-2002):

SUMMARY OF THE 27 FIRST DAYS OF NOVEMBER, 2002 (Provisional data, quality control pending)												
	Aerop. Menorca	**Capde- Pera**	**Port de Pollensa**	**Sant.de Lluc**	**Serra Alfàbia**	**S.Pobla Canova**	**Inca s. Esteràs**	**Porreres Poliesp.**	**Porto- colom**	**Aerop. Palma**	**Palma Port.**	**Aerop. Eivissa**
Total precip.	110.6	103.0	159.5	259.3	122.6	74.2	--	71.2	100.0	74.9	100.3	42.9
Anomaly	30.9	54.3	53.3	116.7	40.2	-6.6	--	24.5	60.7	38.5	59.6	-0.2
Max daily prec.	47.3	46.0	59.0	100.6	45.5	22.8	--	21.6	48.2	26.0	24.0	17.7
Day	25	25	25	25	14	25	--	25	25	25	15	25
Total from 1-Jan	620.0	509.7	1041.6	1756.5	--	657.5	--	574.6	547.8	502.4	630.2	442.4
Anomaly	101.4	142.2	337.4	698.8	--	103.9	--	147.6	195.4	138.3	267.6	87.4
Id. relative (%)	20	39	48	66	--	19	--	35	55	38	74	25
Total from 1-Sep	259.0	149.1	398.1	447.6	--	101.6	--	133.2	218.1	116.8	173.1	103.3
Anomaly	18.4	-13.3	104.9	27.3	--	-132.6	--	-38.6	73.6	-42.5	8.7	-49.0
Id. relative (%)	8	-8	36	6	--	-57	--	-22	51	-27	5	-32
Running annual	664.1	531.6	1176.3	2133.5	--	736.2	--	619.9	607.4	542.2	675.3	494.8
Anomaly	60.8	117.4	355.9	868.6	--	92.2	--	126.6	198.2	123.1	260.1	66.8
Id. Relative (%)	10	28	43	69	--	14	--	26	48	29	63	16
Maximum temp.	22.5	25.2	24.9	20.6	21.2	23.5	--	25.4	23.6	23.4	24.0	26.4
Day	3	11	10	2	11	10	--	10	11	10	10	10
Anomaly	0.8	3.5	2.0	-0.6	4.8	-0.5	--	1.7	-0.2	0.3	2.3	3.7
Minimum temp.	9.6	11.9	6.7	2.5	3.0	4.0	--	5.0	9.5	5.0	10.2	9.5
Day	26	6	20	5	6	26	--	26	26	26	21	20
Anomaly	4.1	6.4	2.6	3.4	3.7	0.9	--	1.6	5.7	3.6	3.8	3.9
Max. average	19.0	19.7	19.7	16.2	12.7	19.1	--	19.8	20.0	19.7	20.0	20.5
Anomaly	1.4	2.1	1.3	1.4	2.7	-0.2	--	0.9	1.0	0.9	0.7	1.5
Min. average	13.6	14.6	11.7	7.6	8.6	10.7	--	11.1	13.8	11.2	13.3	14.0
Anomaly	1.4	2.4	1.5	1.9	2.6	2.0	--	1.6	3.9	3.0	1.2	2.2
Average temp.	16.3	17.2	15.7	11.9	10.6	14.9	--	15.4	16.9	15.4	16.6	17.2
Anomaly	1.4	2.3	1.4	1.7	2.6	0.9	--	1.2	2.5	1.9	0.9	1.8
Sunshine hours	137.3	--	--	--	--	122.3	--	--	--	146.2	139.3	149.5
Number of data	27	24	27	27	27	27	20	27	27	27	27	27

In the following example they are green and blue, due to a precipitation surplus situation, but during the drought they were yellow to red:

Inter-annual relative precipitation anomaly (28-11-2002)	
Menorca	**+10 %**
Mallorca	**+37 %**
Ibiza	**+16 %**

3. CLIMATOLOGICAL APPLICATIONS

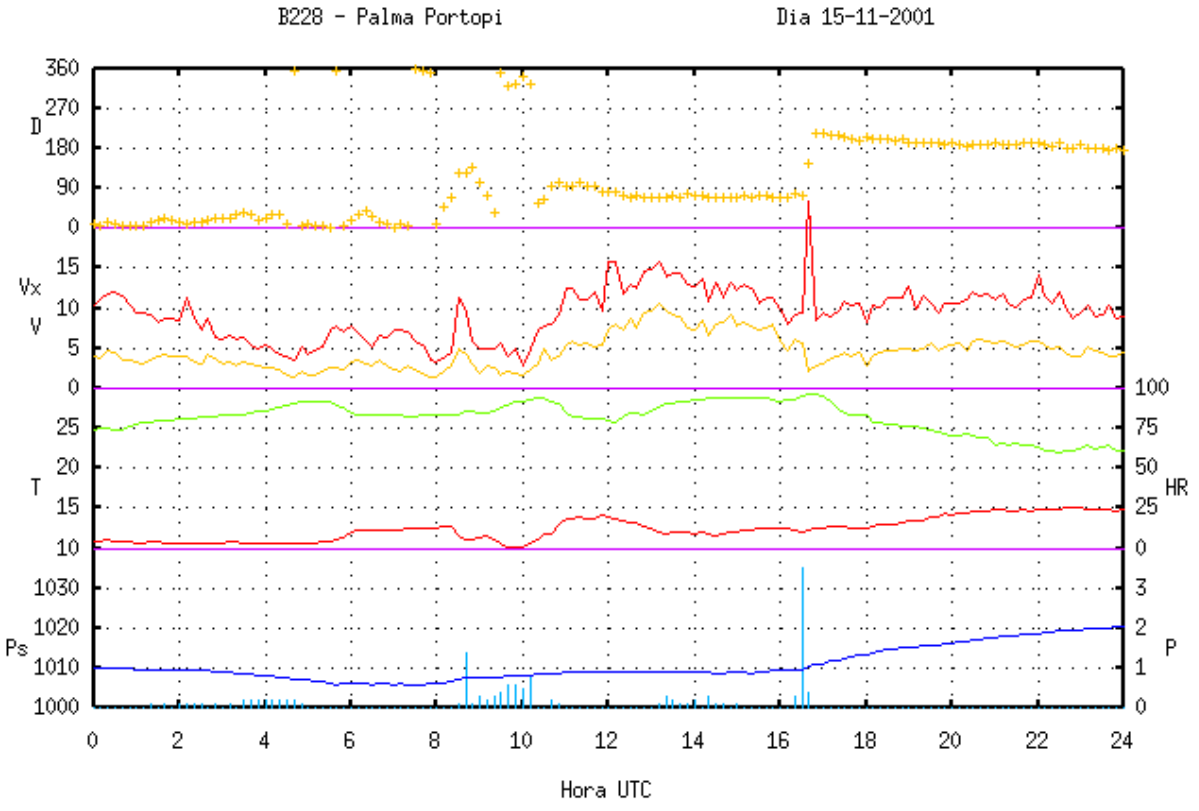
The applications presented in this section do not need real-time updates, since recent data are not the most relevant. Therefore, they apply to past data, and the first task to undertake is to perform a thorough quality control. Once corrected, the data files will be able to provide a variety of climatological products. This products are not disseminated as intranet web pages, but generated on demand through a telnet connection to the server. (For graphic outputs, the client machine will need to have an X server running).

3.1. Data quality control

To perform the data quality control, the first step is to obtain a listing with suspect values. These are values with impossible (relative humidity of more than 100%) or too extreme values (78°C temperature), or inconsistent with others (average wind higher than the gust value).

Afterwards, errors are corrected in an interactive process where visual inspection of the data plays a major role. All variables of one day are represented simultaneously (figure 2), allowing meteorological judgment on the plausibility of the displayed values. Point errors are replaced by the interpolated value between the previous and following 10' observations. Otherwise, the data are simply deleted. This method was developed to control the quality of the Spanish AWS data for the PYREX project (GUIJARRO, 1992 y 1998), with enhanced possibilities in the correction (point interpolation) and deletion of data (individual variables, all wind, all variables, ...)

Fig.2: Graph of the Palma AWS data from 15-11-2001. **D: wind direction (degrees); Vx and V: gust and average wind speed (m/s); T: temperature (ºC); HR: relative humidity (%); Ps: pressure (hPa); P: precipitation (mm).**



3.2. Access to historical data

Once corrected, historical AWS data may be accessed in different ways: listings of row data (every hour or every 10 minutes), maximum daily wind gusts (for insurance companies), etc. Historical graphs of the data or even the aforementioned wind convergence can also be retrieved.

3.3. Climatological products

More elaborate climatological products can also be generated from the historical, quality controlled data. Examples are monthly mean and extreme values of the measured variables, monthly, seasonal and annual bi-dimensional tables (by direction and velocity intervals) of frequencies of average or gust winds, or mean monthly/hourly values of temperature and humidity (GUIJARRO, 2003).

Monthly mean hourly t emperatures (°C) at B780-P. Pollença (1989-2002)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	9.5	9.6	10.6	12.2	15.6	19.1	21.9	23.5	20.3	16.7	13.2	10.6
2	9.3	9.4	10.5	12.0	15.2	18.7	21.5	23.0	20.0	16.6	13.1	10.5
3	9.2	9.3	10.3	11.9	15.0	18.4	21.2	22.7	19.8	16.4	13.1	10.4
4	9.0	9.2	10.2	11.7	14.8	18.2	20.9	22.4	19.6	16.3	13.0	10.3
5	8.9	9.1	10.1	11.6	14.5	18.0	20.7	22.1	19.5	16.1	12.9	10.3
6	8.8	9.0	9.9	11.3	14.5	18.1	20.7	21.9	19.4	16.0	12.7	10.2
7	8.8	8.9	9.8	11.6	15.8	19.8	22.0	22.4	19.4	15.9	12.7	10.2
8	8.7	9.0	10.7	13.6	17.7	21.7	24.2	24.7	21.0	16.7	12.7	10.1
9	9.4	10.5	13.0	15.3	19.2	23.1	25.6	26.5	23.0	18.8	14.3	11.0
10	11.6	12.4	14.7	16.7	20.4	24.1	26.8	27.7	24.3	20.3	16.0	12.9
11	13.1	13.9	16.0	17.6	21.0	24.8	27.4	28.6	25.3	21.5	17.1	14.3
12	14.3	15.0	16.8	18.2	21.4	25.0	27.6	28.9	25.8	22.1	17.9	15.2
13	14.9	15.6	17.2	18.4	21.6	25.3	27.8	29.1	25.9	22.4	18.3	15.6
14	15.1	15.9	17.3	18.5	21.7	25.4	28.0	29.3	26.0	22.5	18.3	15.9
15	15.0	15.9	17.3	18.4	21.7	25.4	28.0	29.2	25.8	22.3	18.1	15.8
16	14.6	15.6	17.0	18.2	21.5	25.2	27.8	29.0	25.5	22.0	17.6	15.3
17	13.8	15.0	16.4	17.8	21.2	24.9	27.6	28.5	25.0	21.4	16.8	14.4
18	12.5	13.9	15.6	17.1	20.7	24.4	27.1	28.0	24.2	20.3	15.7	13.1
19	11.7	12.5	14.3	15.9	19.5	23.4	26.0	26.9	23.3	19.3	15.0	12.3
20	11.0	11.7	13.2	14.9	18.6	22.4	25.0	26.1	22.6	18.6	14.4	11.8
21	10.5	11.0	12.4	14.2	17.8	21.7	24.3	25.5	22.0	18.0	14.0	11.5
22	10.1	10.5	11.8	13.5	17.2	21.0	23.7	24.9	21.4	17.5	13.6	11.2
23	9.9	10.1	11.3	13.0	16.6	20.4	23.2	24.4	21.0	17.1	13.4	10.9
24	9.7	9.8	10.9	12.6	16.0	19.7	22.5	23.9	20.5	16.8	13.2	10.7
Average	**11.2**	**11.8**	**13.2**	**14.8**	**18.3**	**22.0**	**24.6**	**25.8**	**22.5**	**18.8**	**14.9**	**12.3**

4. CONCLUSIONS

Data from AWS are an invaluable source for both real-time and climatological products. The logical developed at our Meteorological Centre has helped in serving the demands of a variety of customers, from insurance companies to Civil Protection services, and have also enhanced the internal use of the AWS data.

As the programs have been developed locally, they can be easily modified to accomplish new tasks in quite a short response time.

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