April 2017 Weather Summary

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Introduction to the MaREI weather station

Weather observations are fundamental to much of the research undertaken by MaREI, as observations of the atmosphere yield insights into availability, continuity and reliability of many renewable energy resources such as wind, solar and thermal energy. Additionally, weather information is critical for biophysical and chemical modelling of environmental conditions and system interactions and subsequent evaluation of such models.

Aside from research, weather forms part of our daily activities and decisions, such as what clothes to wear, what activities we might undertake and how we heat (and in some instances) cool our homes and workplaces.

Finally, early warning systems designed to warn the public of potentially adverse impacts arising from weather-climate related hazards also depend on reliable and near real time weather information.

In December 2016, an internal outreach proposal was accepted to instigate an observation program that can be used by MaREI for research, scientific and community outreach, comprised of two key elements:

1) A Weather Observation System (WOS)
2) A Live Video Stream System (VSS)

Here, the authors wish to highlight the WOS, which was deployed in mid-April 2017 for the MaREI community.

WOS Overview

The WOS is comprised of an integrated sensor suit (ISS) of instruments deployed at the mouth of Cork Harbour (51°50' N 8°18' W) on the grounds of the Beaufort Building at screen height (1.5 meters). The ISS combines a rain collector, temperature/humidity sensors, and anemometer/wind direction vane into a single UV-resistant ABS & ASA plastic unit for optimum performance and durability.

The ISS samples weather parameters and transmits observations via radio to a receiver unit / data logger located within the Beaufort Building, where the data are archived, time stamped and subsequently transmitted to the web.

Table 1 / Fig. 1 provides an overview of the instruments deployed within the ISS*.

Table 1 Overview of ISS instruments. The sampling frequency indicates the time between each observation of particular variables.

Variable	Sensor Type	Sampling Frequency
Temperature	PN Junction Silicon Diode	10-12 seconds
Relative Humidity	Film capacitor element	50-60 seconds
Wind Speed	Wind Cups with magnetic detection	2.5-3 seconds
Wind Direction	Wind Vane with magnetic encoder	2.5-3 seconds
Precipitation	Self-empting Tipping spoon	20-24 seconds
Pressure	Pressure transducer	50-60 seconds

*Barometer is located in the receiver

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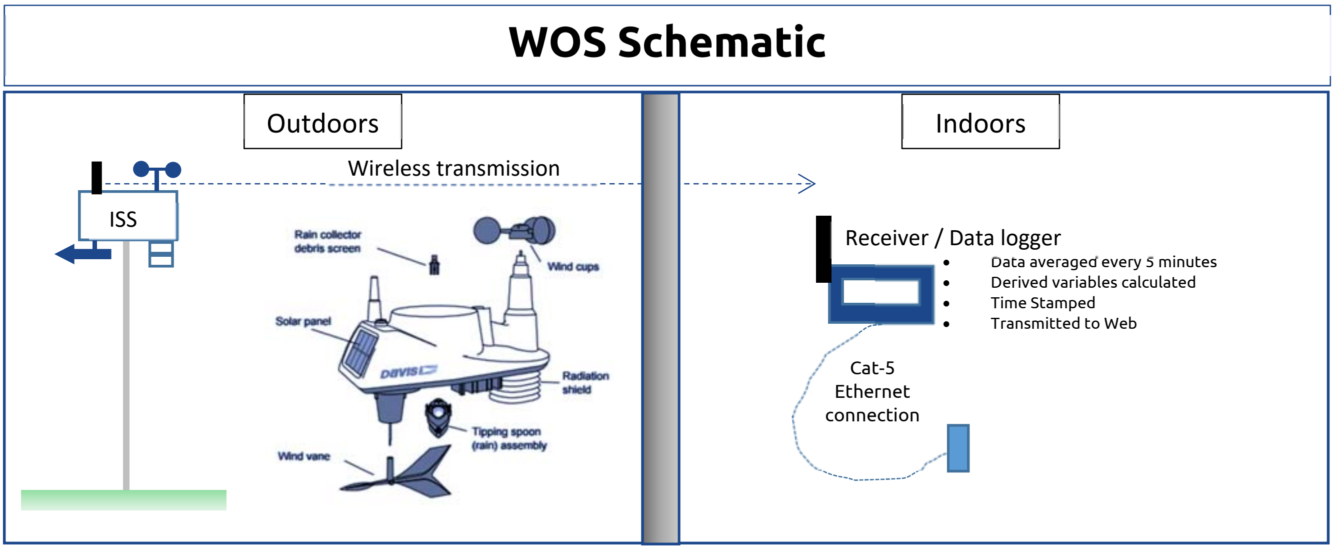


Fig. 1 Schematic of the WOS operation, the inset left provides a more detailed overview of the ISS assembly

The samples of each observation highlighted in Table 1 above are averaged over an **interval period**, originally this was set to 30 minutes but later this was decreased to 5 minutes. Effectively, this means observations are archived and available for analysis for each 5-minute period i.e. 288 observations per day.

In addition to these observations, the ISS automatically computes a number of derived variables including:

- Dew point temperature
- Heat Index and THW index
- Wind Chill
- Heating Degree Days
- Cooling Degree Days
- Equilibrium Moisture Content

The location of the ISS at screen height was chosen carefully based on the availability of site access, security and communication specifications. The deployment prioritised obtaining meteorological measurements that would be representative of conditions experienced by pedestrians at screen height.

The current deployment conforms to World Meteorological Organization technical guidance for instruments and observing methods (Report#81, Chapter 11) and will allow for regular maintenance and enable demonstrations for visitors to the site.

The WOS will have to be running for some time before biases due to the proximity of buildings and/or the adjacent water bodies can be quantified. Thereafter, corrections can be recommended based on the requirements of different applications.

However, to ensure observations are reasonable in the first instance, we carried out a ***tentative*** comparison between the MaREI Beaufort station and the synoptic station located at Roches Point (51°46'N 08°15'W) based on the first 21 days of operation (i.e. April 11th – April 30th 2017). Data for the synoptic station were obtained from Met Éireann (met.ie).

Comparison with other weather stations

Hourly Data from Roches Point (hereafter "MÉ-RP") were obtained for a contemporaneous period (April 12th 0000hrs – April 30th 2300hrs)[1]. Hourly data were obtained from this station for comparison due to its geographic proximity to the Beaufort station (hereafter "BMS"). Met Éireann reports observations at MÉ-RP are made at 40m A.S.L. Therefore, *a priori* it would be expected that relative to BMS:

- Air Temperatures would be systematically lower
- Wind speeds would be systematically higher
- Relative Humidity would be slightly higher

Thus, we carried out two levels of comparison, firstly, between the raw hourly values – if the observational system at BMS are correctly established, the three propositions above should be expected to hold true. Secondly, we applied simple corrections to the observational data at MÉ-RP to account for differences in elevation (~38.5m) between BMS and MÉ-RP (see Annex 1 for overview), and subsequently carried out a statistical comparison between the two datasets.

For temperature, WMO lapse rate for a standard atmosphere was applied:

$$\begin{gathered}\text{SLR: } 9.8°\text{C} / 1000\text{m} \\ = 0.0098 \text{ per meter} \\ \therefore 0.3773°\text{C added to each} \\ \text{observation}\end{gathered} \qquad [1]$$

For wind speed, the power law was applied as sufficient information on surface roughness and atmospheric stability were not readily available (which are needed for the log law):

$$u = u_r\left(\frac{z}{z_r}\right)^{a} \qquad [2]$$

Here, u is the corrected wind speed in m/s, u_r is the original observation in m/s, z is the desired height level (1.5m), z_r is the reference height level (40m) and α is an empirical exponent based on atmospheric stability, this was set to 0.143 i.e. for neutral atmospheric stability conditions.

Finally, Relative Humidity was corrected using a semi-empirical air density correction factor:

$$\psi = 2E\text{-}19x^6 - 1E\text{-}15x^5 + 2E\text{-}12x^4 - 1E\text{-}09x^3 + 3E\text{-}07x^2 - 0.0001x + 1.0002 \qquad [3]$$

Here, x = elevation in meters. For MÉ-RP x = 40 and ψ was calculated at 0.996.

We carried out a statistical comparison between hourly values recorded at BMS and MÉ-RP. We employed two principle metrics, namely the Root Mean Square Error (RMSE) and Mean Bias Error (MBE):

[1] Beaufort met station was down for a system update for 14 hours during the period: 26/04/17 1700hrs – 27/04/17 0600hrs (inclusive)

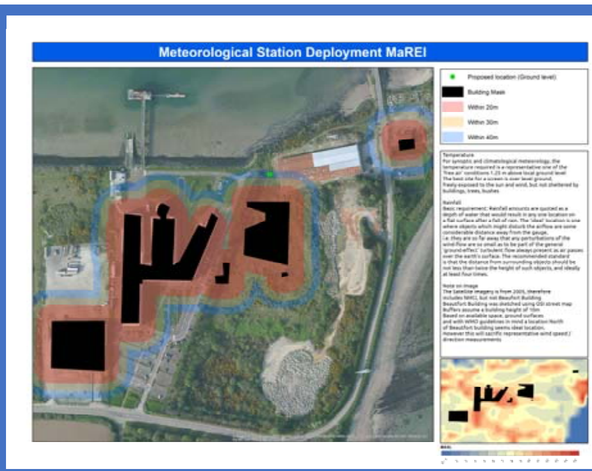
$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(p_i - a_i)^2}{n}} \qquad [4]$$

$$MBE = \frac{\sum_{i=1}^{n}(p_i - a_i)}{n} \qquad [5]$$

Where a = elevation corrected hourly observation at MÉ-RP and p = BMS hourly observation given in units of the variable of interest (i.e. in °C for temperature, ms^{-1} for wind speed etc.).

Equation [4] provides a measure of the absolute agreement (error) between BMS and values that would be expected at MÉ-RP provided both stations were deployed at the same elevation - however this metric eliminates the directionality of the error. Therefore, equation [5] provides a measure of the direction of the error (bias) which indicates if there is systematic over or under estimation of the variable of interest.

Below, we first highlight our comparison of hourly values, and subsequently summarise the daily meteorological situation for the second half of April 2017.



Hourly Temperature

Fig. 2 below shows a time-series for BMS and the uncorrected MÉ-RP air temperature observations. BMS is systematically warmer than the raw MÉ-RP observations by ~1°C (μ = 10.7°C, σ = 2.4°C | μ = 9.7°C, σ = 2.1°C | MBE = 0.8°C) as would be expected between near surface and higher elevation observations.

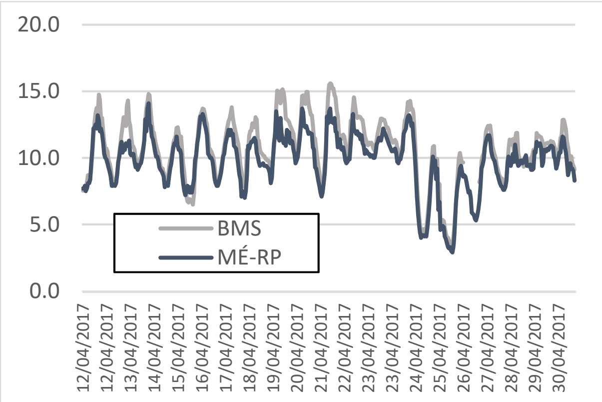


Fig. 2 Time series plot (April 12-30 2017) between Beaufort Met Station (BMS) and hourly observations made at Met Éireann's station Roches point (MÉ-RP). Note that BMS appears systematically warmer

Hourly observations from both stations follow logical diurnal patterns (minima prior to sunrise, maxima 1-2 hours after local midday) each day across the period. Moreover, both stations capture the introduction of a northerly airflow around the 25th of April, with a marked drop in air temperatures due to the introduction of this cooler air mass. Fig. 3 shows a time series between BMS and the elevation corrected MÉ-RP (Equation [1] above).

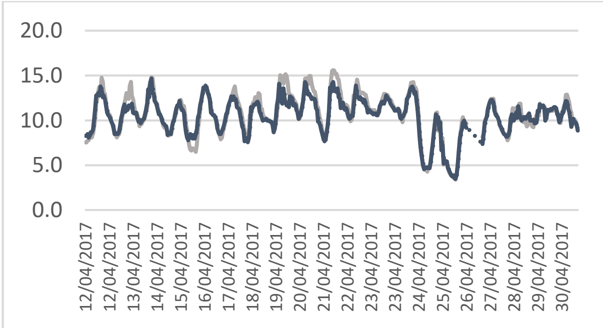


Fig. 3 Time series plot between Beaufort Met Station (BMS) and elevation corrected hourly observations made at Met Éireann's station Roches Point (MÉ-RP). Note that the magnitude of the warm bias appears reduced

The overall effect of the correction is to increase the temperature observed at MÉ-BP hence decrease the extent to which BMS observations are warmer (μ = 10.5°C, σ = 2.1°C). Overall, errors overall are low (RMSE 0.83°C and 0.25°C for uncorrected and corrected observations respectively). However, there still appears to be a slight warm bias between these stations (MBE = 0.2°C) as illustrated in Fig. 4 below.

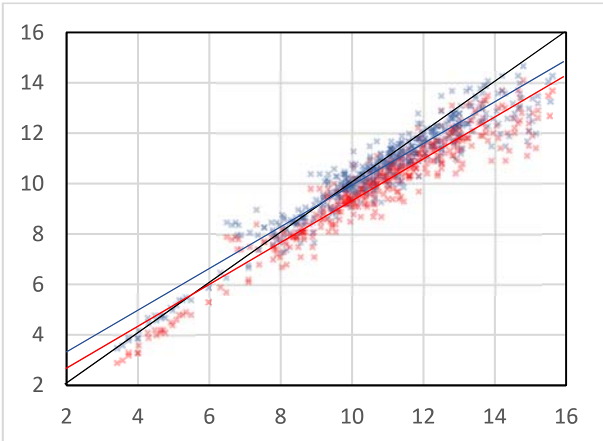


Fig. 4 Scatterplot of hourly observations at BMS v MÉ-BP uncorrected (RED) and v MÉ-BP corrected (BLUE). Black line shows 1:1 line ∴ points above = BMS < MÉ-BP points below = BMS > MÉ-BP

Hourly Relative Humidity

As a parcel of air rises into the atmosphere, the surrounding air pressure drops allowing the parcel to expand, this decreases its temperature hence (assuming the moisture content of the parcel remains unchanged) the relative humidity of the parcel will increase.

A time series of hourly relative humidity is presented below in Fig. 5 – as with air temperature, the relationship between BMS (μ = 75.7%, σ = 8.5%) and the uncorrected MÉ-RP data (μ = 77.5%, σ = 9.7%) follows what we might expect.

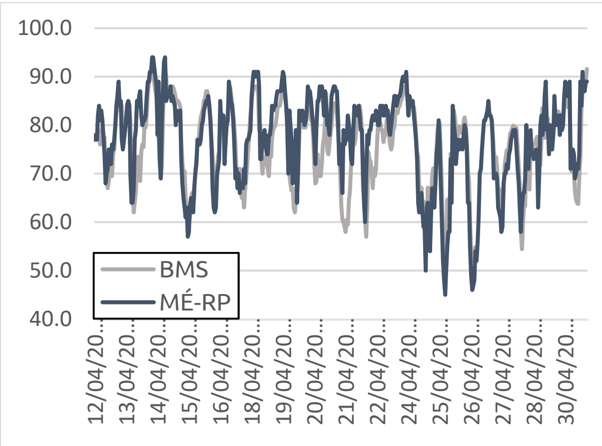


Fig. 5 Time series plot (April 12-30 2017) between Beaufort Met Station (BMS) and hourly observations made at Met Éireann's station Roches point (MÉ-RP).

As with temperature, the typical diurnal patters appear reasonable (with RH decreasing with temperature increasing). It is also interesting to note the characteristics of the air mass introduced around the 25th of April, which was rather dry, suggesting a Continental Artic air mass.

Fig. 6 highlights the time series with the corrected MÉ-RP data. The correction compares favourably with the BMS data (μ = 75.2%, σ = 9.2%) when corrected for elevation. While this should be interpreted with caution in light of a) the simplistic nature of the correction applied and b) the short period of comparison, it nevertheless suggests that BMS observations are representative of the wider synoptic conditions.

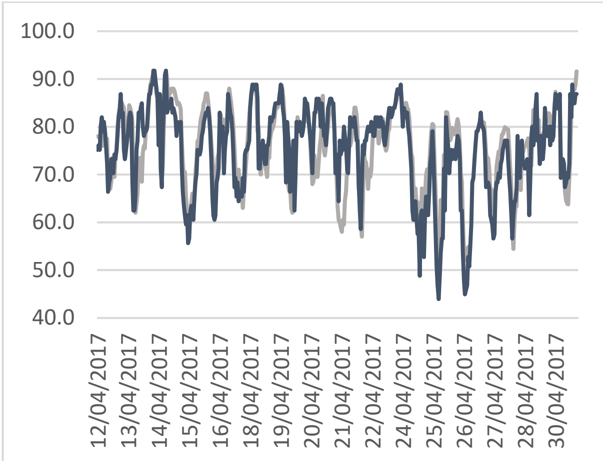


Fig. 6 Time series plot between Beaufort Met Station (BMS) and elevation corrected hourly observations made at Met Éireann's station Roches Point (MÉ-RP).

Statistically, the corrected data exhibited lower RMSE values (0.47%) compared to the uncorrected data (1.19%). The resulting correction also reverses the direction of the error: MBE for uncorrected data was -1.4% (i.e. hourly observations at BMS are on average higher) whereas MBE for corrected data was 0.5%.

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Hourly Wind Speed

The relationship between wind speed and elevation is rather straightforward (see Annex 1 for example). Due to the friction created when approaching the land surface, it is expected that wind speeds will increase with height as the distance to the source of friction is increased.

In light of this, it is unsurprising that wind speeds at MÉ-RP (μ = 5.1 ms^{-1}, σ = 2.8 ms^{-1}) are systematically higher than BMS (μ = 1.9 ms^{-1}, σ = 1.7 ms^{-1}) across the period, with a MBE of -3.2 ms^{-1}. However, relative differences across both stations show clear agreement. The time series of wind speeds between BMS and MÉ-RP is presented below in Fig. 7.

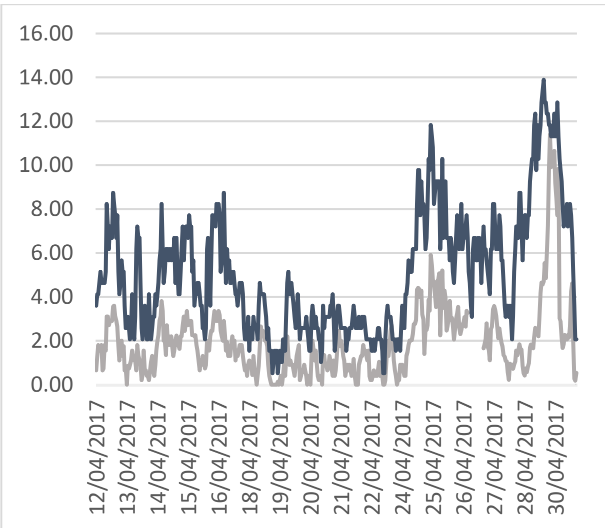

Fig. 7 Time series plot (April 12-30 2017) between Beaufort Met Station (BMS) and hourly observations made at Met Éireann's station Roches point (MÉ-RP).

Similar to temperature and relative humidity, it is striking to note the shift in synoptic regime is clearly visible around the 25th of April, with a shift from anti-cyclonic conditions (present during 17-24th April) to more typical low-pressure situation and resulting increase in hourly wind speeds.

The elevation correction (Equation [2] above) reduces the overall hourly wind speeds (μ = 3.1ms^{-1}, σ = 1.7 ms^{-1}) however there is still a low bias suggesting underestimation of wind speeds at BMS with a MBE of -1.2 ms^{-1} – see Fig. 8.

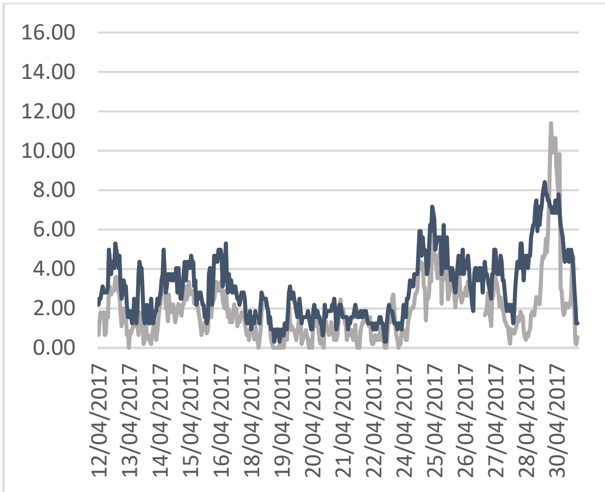

Fig. 8 Time series plot between Beaufort Met Station (BMS) and <u>elevation corrected hourly observations</u> made at Met Éireann's station Roches Point (MÉ-RP).

Until a longer time series is available for analysis, it is not possible to draw any definitive conclusions for the discrepancy between the stations (RMSE 3.18 and 1.17 ms^{-1} for uncorrected and corrected data respectively). Moreover, the correction method used (as with temperature and relative humidity) to account for elevation may lead to over-estimation of wind speeds for this height level.

Daily Temperature

Fig. 9 below shows the daily time series of mean temperature observations for BMS (μ = 10.7°C, σ = 1.64°C) against the uncorrected data from MÉ-RP (μ = 9.9°C, σ = 1.35°C). Temperatures are on average 0.8°C cooler at MÉ-RP than at Beaufort. As with the hourly observations, the difference in observed temperatures is to be expected between near surface and higher elevation weather observations, with the temperatures at BMS showing a higher bias.

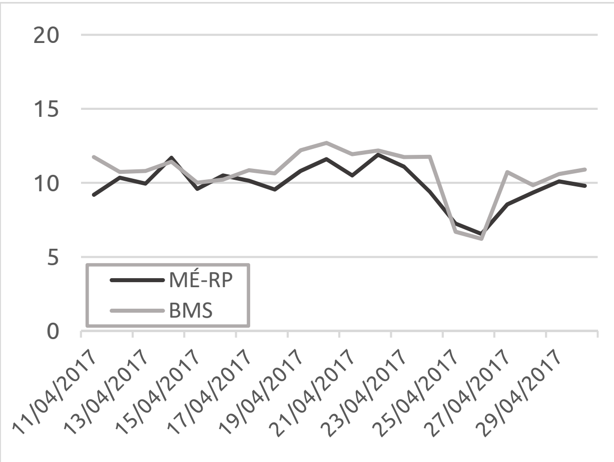

Fig. 9 Time series plot (Aril 11-30 2017) between Beaufort Met Station (BMS) and observations made at Met Éireann's station at Roches Point (MÉ-RP)

Difference in elevation between MÉ-RP and BMS evidently has a marked effect on the temperature observations, as with the hourly data. For this reason, as outlined previously, the Met Éireann data has been corrected to account for this difference by adding 0.3373°C to each measurement assuming a standard atmospheric lapse rate of 9.8°C/1 km. Fig. 10 below shows the same time series (as in Fig. 9) however the MÉ-RP data have been corrected for elevation.

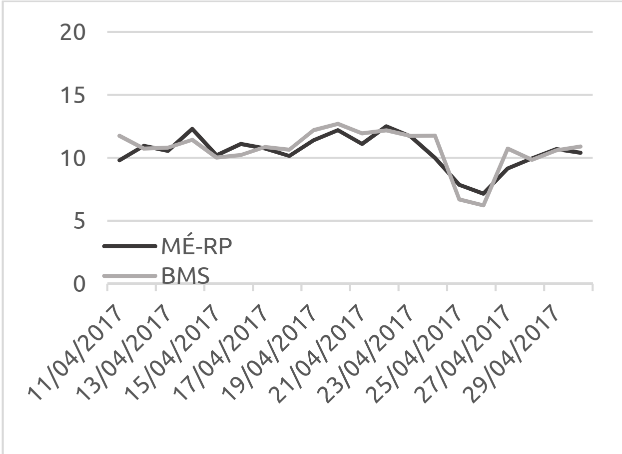

Fig. 10 Time series plot (Aril 11-30 2017) between Beaufort Met Station (BMS) and elevation corrected daily observations made at Met Éireann's station at Roches Point (MÉ-RP). Correction has reduced the magnitude of warm bias.

As with the hourly observations, the effect of correcting the data is to increase the temperature observations from MÉ-RP. However, temperatures still show a higher bias at BMS. A longer time-series will allow us to form more robust conclusions on the reasons for this warm bias.

The sudden change in temperature is also reflected in the daily data: note the drop in daily mean temperature from April 24th – this corresponds with a change to a northerly airflow and the arrival of a low pressure front, with the coldest date 26th, 4.5°C cooler than the average for the period.

April 2017 Weather Summary

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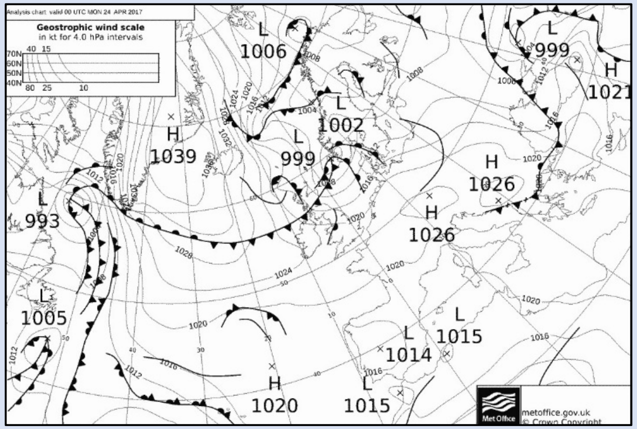
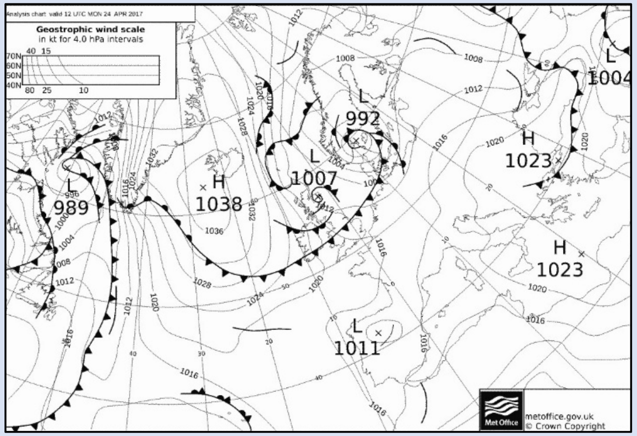
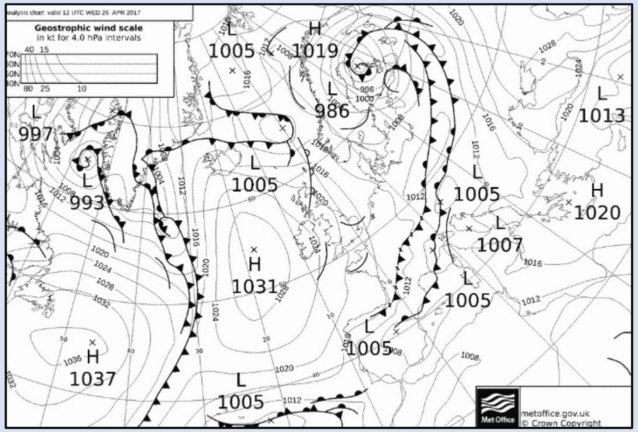
April 24th 0000hrs	April 24th 1200hrs	April 26th 1200hrs
		

What explains the drop in temperature on the 25th of April 2017?

As shown in the surface pressure charts above, a cold front (separates air masses of differing characteristics) moved over Ireland and the UK during the 24th of April, introducing colder drier air of Artic origin. By the 26th of April, the anti-cyclone (Area of High Pressure) shifted east blocking the northerly airflow and reinstating a south-westerly air flow

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Daily Relative Humidity

Relative humidity (RH) refers to the amount of moisture in the air when compared to what the air is capable of 'holding' at that temperature. When air reaches saturation point and can't hold any more moisture, it condenses into water droplets (e.g. dew on the surface, cloud droplets in the atmosphere), this would correspond to a relative humidity of 100%.

Fig. 11 shows the RH measurements using uncorrected data from MÉ-EP. The results follow what we would have expected looking at the hourly results, showing a higher bias for Roches Point (μ=77%, σ = 5.7 %) than for Beaufort (μ = 75%, σ = 4.6%), consistent with lower temperatures observed at the RP station.

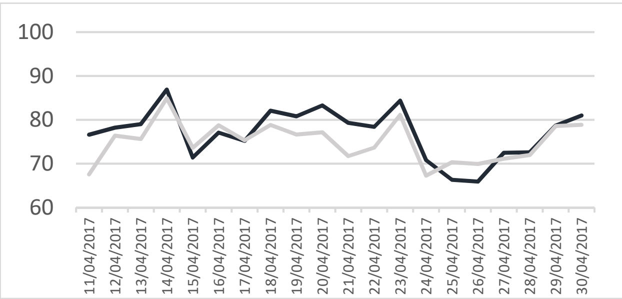


Fig. 11 Time series plot (Aril 11-30 2017) between Beaufort Met Station (BMS) non-corrected daily observations made at Met Éireann's station at Roches Point (MÉ-RP).

Fig. 12 shows the same parameter using the data that has been corrected using a semi-empirical air-density correction factor (BMS μ = 75%, σ = 4.6% | MÉ-RP μ=75.2%, σ = 5.6%). Correcting the data has the overall effect of reducing the relative humidity for MÉ-RP (previous average 77% corrected to 75.2%).

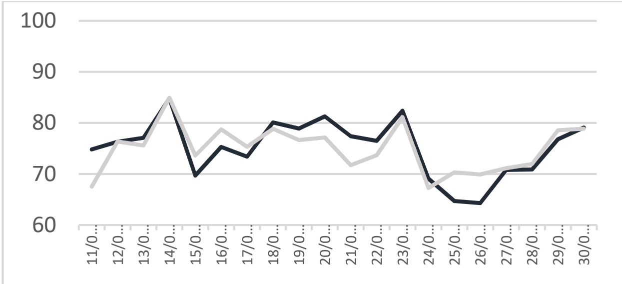
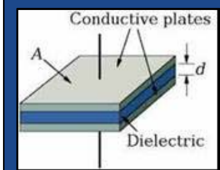


Fig. 12 Time series plot (Aril 11-30 2017) between Beaufort Met Station (BMS) and corrected daily observations made at Met Éireann's station at Roches Point (MÉ-RP). Note the higher bias remains at MÉ-RP.

Differences in the WOS between the sites may explain these differences. Met Éireann use a Vaisala Automatic Weather Station employing a HMP155 Humidity and Temperature Probe, whereas the Beaufort ISS employs a Sensirion SHT31 sensor for measuring RH.

How is relative humidity observed?



The Beaufort WOS uses to a **Film Capacitator** to measure humidity. This sensor consists of a glass substrate with a moisture sensitive layer, in between two metal layers. The absorption of water is proportional to the relative humidity and the dielectric constant, resulting in a change in the capacity of the element, giving us a measurement for RH.

Daily Wind Speed

Due to the reasons outlined previously, daily mean wind speeds were systematically higher at MÉ-RP ($\mu = 5.08ms^{-1}$, $\sigma = 2.34ms^{-1}$) than at BMP ($\mu = 2.34ms^{-1}$, $\sigma = 1.14ms^{-1}$). This is due to reduced ground friction at higher elevation and likely due to the more sheltered nature of the inner harbour as opposed to at the mouth of Cork Harbour. Despite this, the stations show broad agreement, following a similar pattern (see Fig. 13).

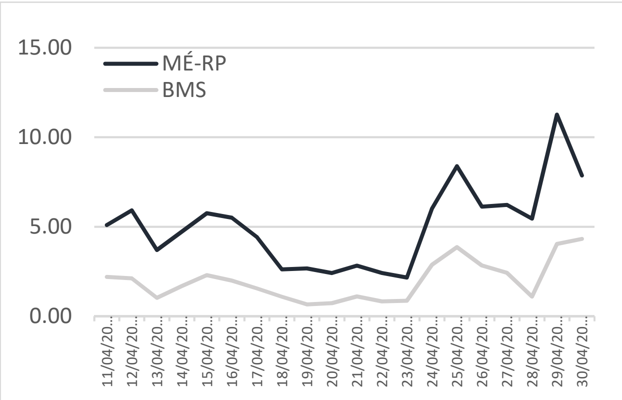


Fig. 13 Time series plot (April 11-30 2017) between Beaufort Met Station (BMS) and corrected daily observations made at MÉ-RP. Note the systematically higher wind speeds at Roches Point.

Fig. 14 shows the time series with the MÉ-RP data having been corrected for differences in elevation (accounting for the effect of land surface friction) using the power law.

Correcting the data reduces the overall daily wind speeds at MÉ-RP ($\mu = 3.08ms^{-1}$, $\sigma = 1.42ms^{-1}$). As with the hourly measurements, there is still a low bias at BMS, suggesting the underestimation of wind speeds. This is likely due to the fact that corrections carried out on the data only account for a single variable, where there are likely to be multiple variables causing differences between the data (e.g. the impact of the local environment/landscape).

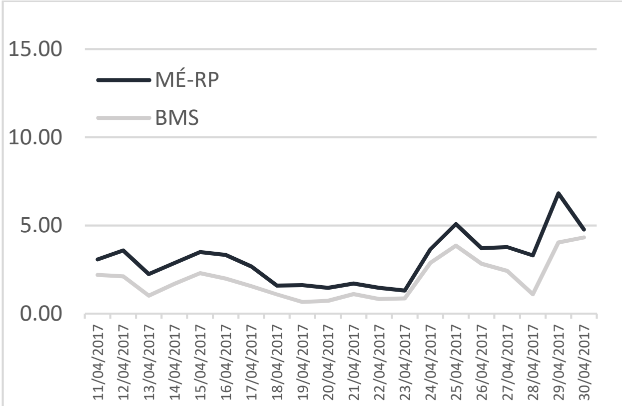


Fig. 14 Time series plot (April 11-30 2017) between Beaufort Met Station (BMS) and corrected daily observations made at MÉ-RP. Note that there are still systematically higher wind speeds at Roches Point, but the overall effect is the reduction in observed wind speeds.

A longer time series resulting from the continued observation and analysis of date from the Beaufort WOS will enable us to better understand these differences.

When comparing these results to temperature observations, the impact of synoptic conditions on several weather variables becomes evident. A marked increase in wind speeds around the 24th / 25th of April correspond with passage of a cold front associated with an area of low pressure. A second increase on the 28th corresponds with another low-pressure system crossing over Ireland during this period.

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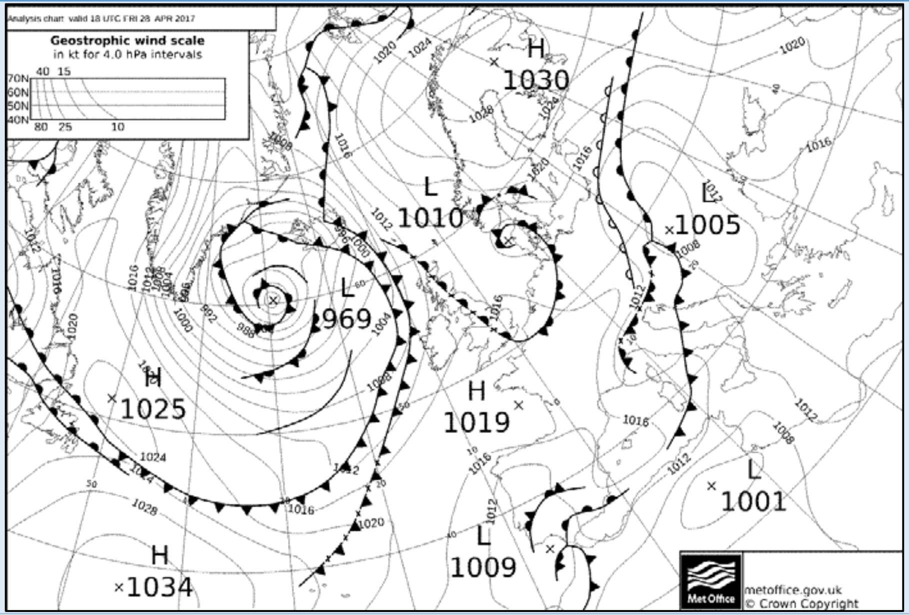
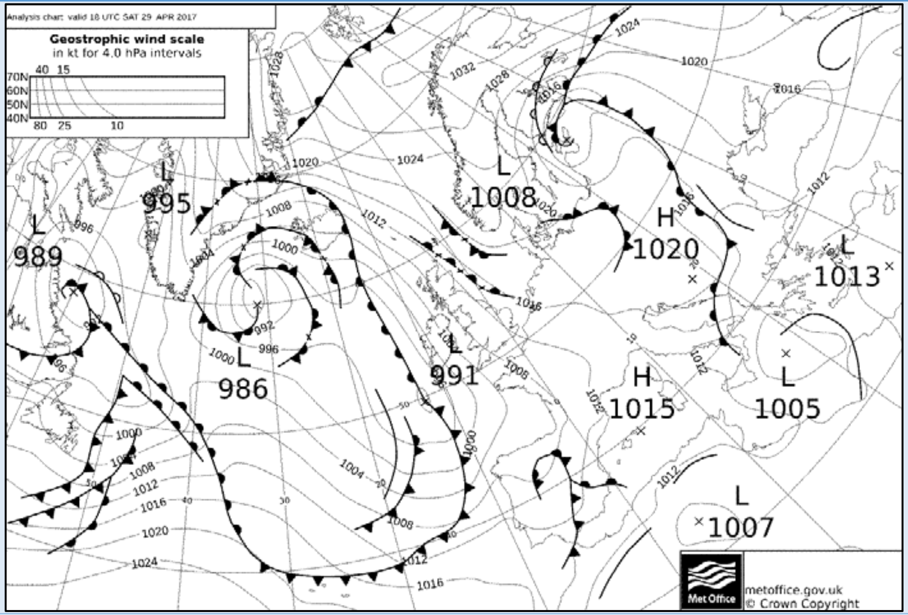
28th April 1800hrs



29th April 1800hrs



Here we can see the low pressure system approaching Ireland from the North East (left) and settling over Ireland (right), affecting weather conditions as observed by the MÉ-RP and BMS stations bringing increased wind and rain.

Daily Atmospheric Pressure

Atmospheric pressure is measured by the Beaufort WOS using a pressure transducer, with a sampling frequency of 2 Hz. This element convert applied pressure into an electrical signal that corresponds to the weight of the air column above the sensor.

This measurement shows near perfect correlation (0.998) between the daily measurements taken at BMS and MÉ-RP. Fig. 15 illustrates this, but there remains a lower pressure bias at MÉ-RP. Differences in elevation, surrounding landscape and instrumentation may explain this systematic bias.

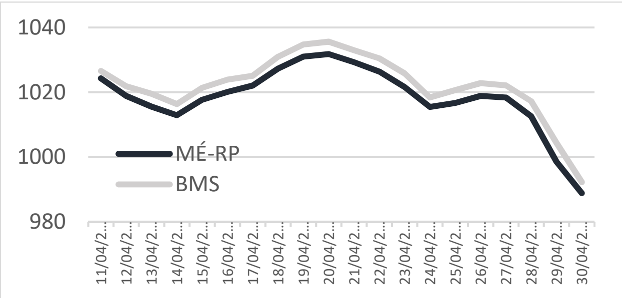


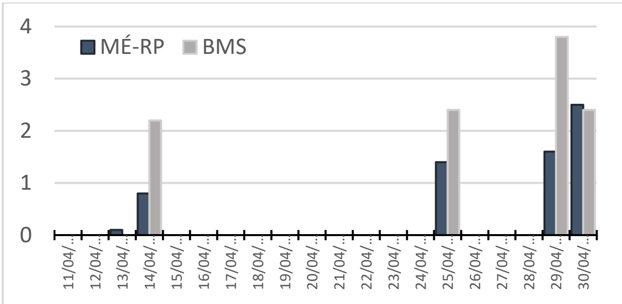
Fig. 15 Daily mean Pressure (Hpa) time series between Beaufort Met Station (BMS) and Met Éireann Roches Point station (MÉ-RP)

As is clear from the above graph, when considered alongside other parameters observed by the weather stations, the pressure drops off considerably following the 27th of April, in line with the low pressure system affecting the area at the time as outlined in figures 10 and 11. The archive of UKMO Weather Charts is a useful resource to help us link specific events to the measurements we are observing

Daily Rainfall

As with the atmospheric pressure, it is more practical to measure some parameters along a daily time series rather than hourly. Trends in rainfall, especially in extended periods of dry weather, can be easier to examine and interpret on a broader time scale.

The month of April was very dry, with only 5 days of rain recorded between April 11th and 30th. The recorded rainfall amounts were higher for the BMS (10.8mm in total) that for MÉ-RP (6.4mm). Differences in measuring equipment for rainfall could account for some of these differences. The MÉ station uses a rain gauge set into the ground, whilst the Beaufort WOS uses a self-emptying tipping spoon with a sample rate of between 20 and 24 Hz, it is important to note this is elevated off the ground housed within the main body of the ISS.



The highest daily accumulation of rainfall corresponds to the period of low pressure suggesting frontal rain but the timing differed between BMS (29th – 3.8mm) and MÉ-RP (30th – 2.4mm).

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NOAA Report

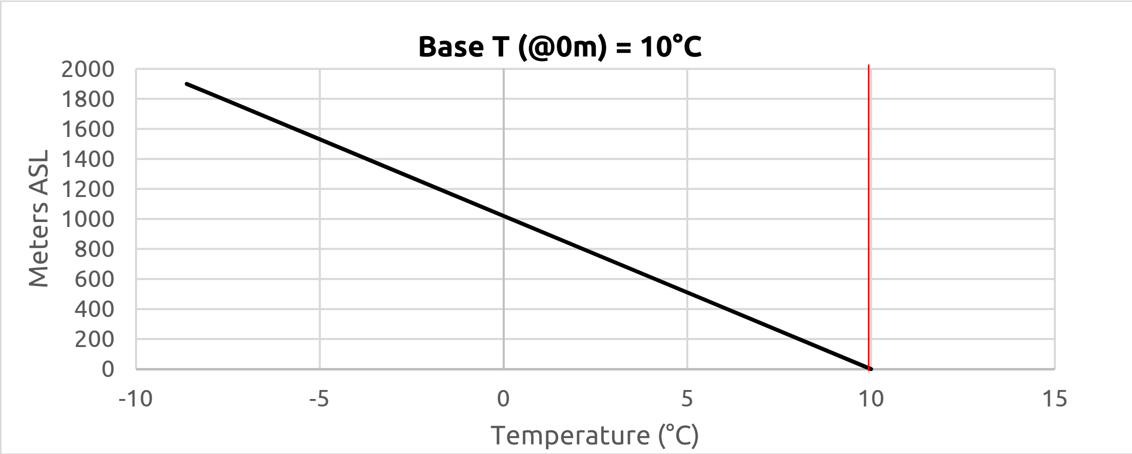
MONTHLY CLIMATOLOGICAL SUMMARY for APR. 2017
NAME: Beaufort Building CITY: Cork STATE: Munster, IRE
ELEV: 5 m LAT: 51° 50' 04" N LONG: 8° 18' 07" E

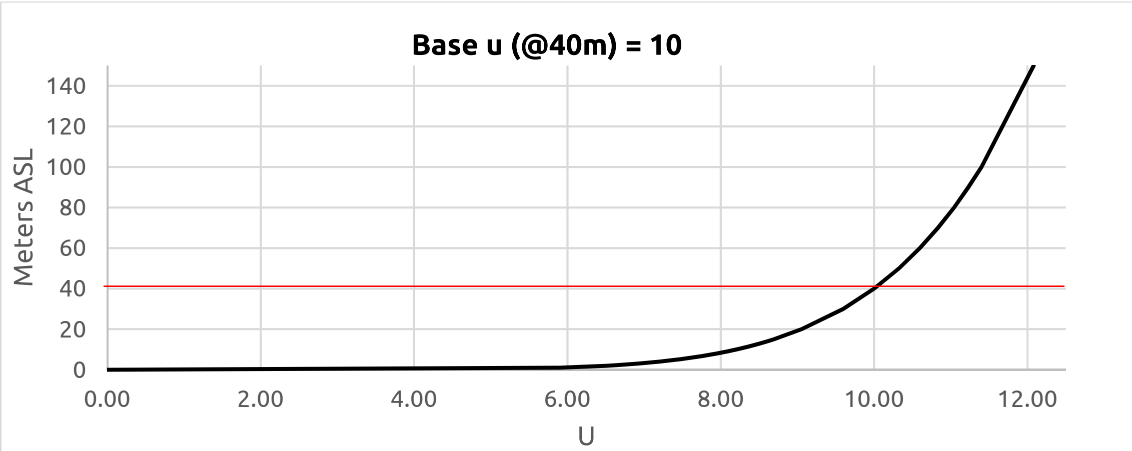
TEMPERATURE (°C), RAIN (mm), WIND SPEED (m/s)

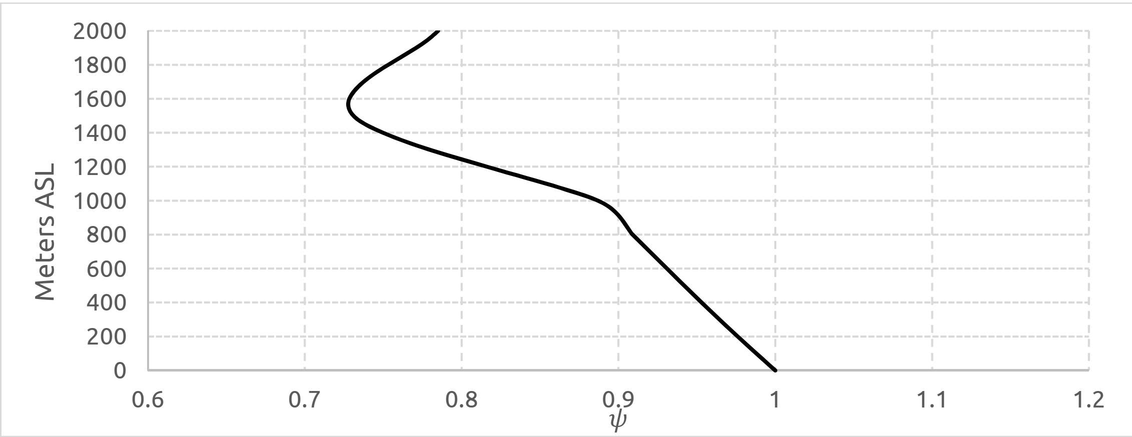
DAY	MEAN TEMP	HIGH	TIME	LOW	TIME	HEAT DEG DAYS	COOL DEG DAYS	RAIN	AVG WIND SPEED	HIGH	TIME	DOM DIR
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11	11.6	14.6	16:00	7.4	00:00	3.0	0.0	0.0	2.1	6.3	20:00	WNW
12	10.8	15.3	15:30	7.4	1:00	7.5	0.0	0.0	2.2	8.0	10:30	NW
13	10.8	14.6	18:00	8.0	6:00	7.5	0.0	0.0	1.0	5.4	15:00	NW
14	11.4	15.3	14:00	9.3	2:30	6.9	0.0	2.2	1.7	8.5	14:00	WNW
15	9.9	13.2	16:00	7.2	00:00	8.3	0.0	0.0	2.3	7.2	18:00	NW
16	10.3	14.1	15:30	6.3	6:30	8.0	0.0	0.0	2.0	7.2	15:30	WNW
17	10.9	14.4	18:00	7.9	5:30	7.4	0.0	0.0	1.6	5.8	1:00	NNW
18	10.6	13.6	17:30	7.3	6:30	7.7	0.0	0.0	1.1	5.4	13:00	SE
19	12.2	15.3	12:00	8.8	7:30	6.1	0.0	0.0	0.7	4.9	13:30	W
20	**12.7**	15.4	16:30	10.1	6:30	5.6	0.0	0.0	0.7	4.0	12:30	WNW
21	11.9	**16.2**	12:30	7.6	5:00	6.3	0.0	0.0	1.1	4.9	15:00	SSE
22	12.2	15.4	12:00	9.8	5:30	6.1	0.0	0.0	0.8	4.0	12:30	SSE
23	11.7	13.1	13:00	10.3	7:00	6.6	0.0	0.0	0.9	4.0	12:00	SSE
24	11.4	14.9	15:20	5.3	00:00	6.8	0.0	0.0	2.3	9.4	20:45	NNW
25	6.7	11.8	13:30	3.9	4:00	**11.6**	0.0	2.4	3.8	11.2	5:30	NNW
26	6.2	11.3	13:40	**3.3**	6:20	8.2	0.0	0.0	2.8	6.7	6:15	NNW
27	10.7	12.8	17:40	6.6	7:20	5.3	0.0	0.0	2.4	7.6	16:05	NNW
28	9.8	12.5	17:30	7.7	6:30	8.5	0.0	0.0	1.1	5.8	19:20	WNW
29	10.6	12.6	12:45	8.9	6:35	7.7	0.0	**3.8**	4.1	**16.5**	21:50	SSE
30	10.9	13.5	12:50	8.6	22:55	7.4	0.0	2.4	**4.3**	**16.5**	2:20	SSE
	10.7	16.2	21	3.3	26	142.4	0.0	10.8	2.0	16.5	29	WNW

Max >= 32.0: 0
Max <= 0.0: 0
Min <= 0.0: 0
Min <= -18.0: 0
Max Rain: 3.81 ON 29/04/17
Days of Rain: 4 (> .2 mm) 4 (> 2 mm) 0 (> 20 mm)
Heat Base: 18.3 Cool Base: 18.3 Method: Integration

Annex 1 – Corrections for elevation (Graphs)

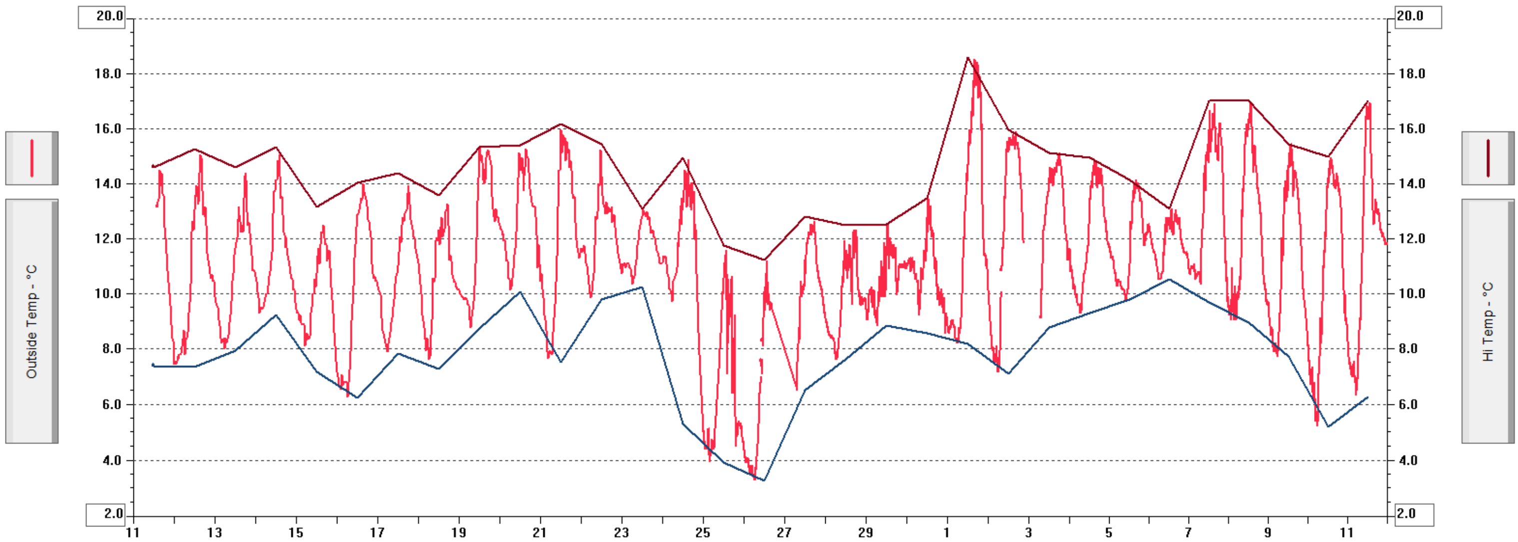


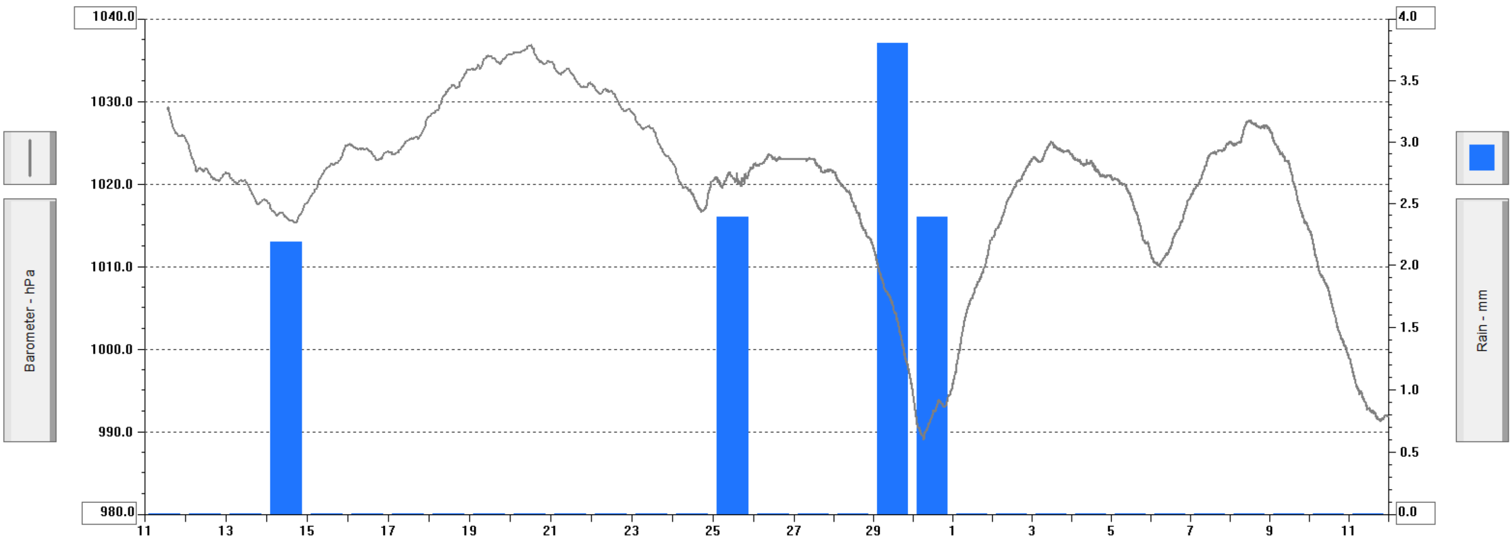




Annex 2 – Time Series for 11 April to 11 May 2017 for Min, Mean and Max Temperature (top) and Precipitation and Pressure (bottom)

These graphs are generated using Weatherlink Software using raw data collected by the WOS - [click here for more information](#)[2]





Real-time information from the station can be viewed at:

http://www.weatherlink.com/user/marei/index.php?view=main&headers=0

[2] http://www.davisnet.com/product_documents/weather/manuals/07395-210_GSG_06510_6555.pdf

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This report was untaken voluntarily please contact either of the authors directly for more information