Personal weather stations and sharing weather data via the Internet

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Introduction

In this article, we discuss several software packages that are designed to display and archive data from a personal weather station. We examine how these packages may be used to share weather data via the Internet. In particular, we look at uploading data to Weather Underground, the Met Office's Weather Observations Website (WOW) and the Citizen Weather Observer Program (CWOP) operated by NOAA (the National Oceanic and Atmospheric Administration).

Hardware

There are many different makes and models of personal weather station hardware on the market, ranging in price from around £50 up to around £1000. Typically, these will measure six weather variables: temperature, relative humidity, wind speed, wind direction, rainfall and barometric pressure. From these, other important weather variables may be calculated, including dew point, heat index, wind chill temperature, average wind speed, rain rate, and so on. When choosing between different models, factors to consider include accuracy, whether the sensors are wired or wireless, and how frequently weather data packets are sent from the sensors to the console. If sharing data via the Internet is envisaged, then the model chosen must have a connection to enable downloading of data to a PC or other device. This will usually be a USB port or, more rarely, a serial port. There are also models that connect directly to a home network router. There are many resources on the web offering comparisons of various models of weather station, for example Ambient Weather (2017). After some research the author purchased the Davis Vantage Vue model, and hence it is inevitable that this article is written from the perspective of a Vantage Vue user. However, most of the software packages discussed support a range of other models of weather station hardware.

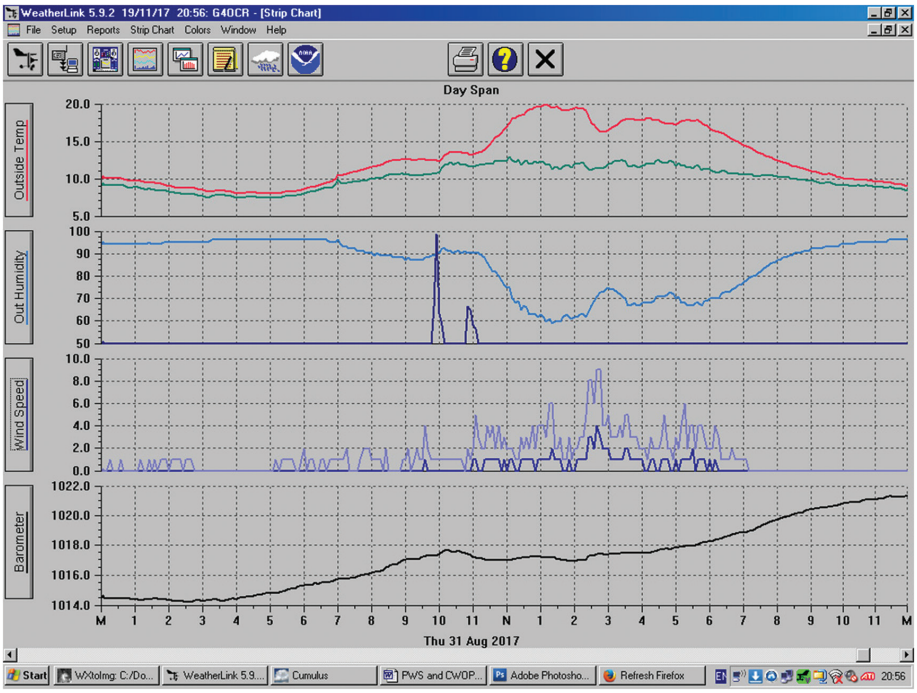

Figure 1. WeatherLink strip charts, showing temperature/dew point, humidity/precipitation rate, wind speed/gust, and barometric pressure.

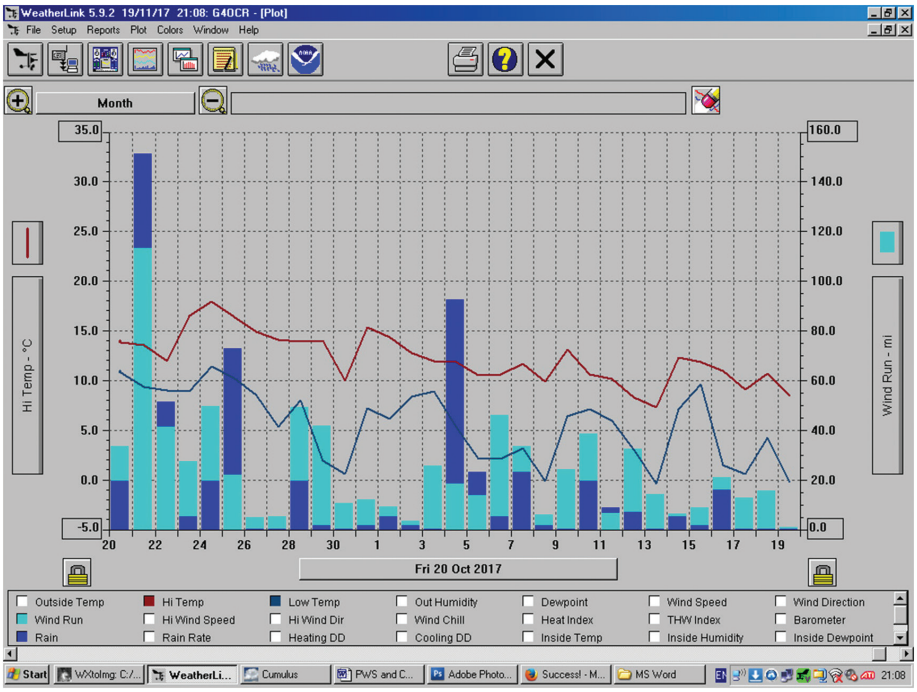

Figure 2. WeatherLink graphs, showing daily high temperature, low temperature, wind run and precipitation.

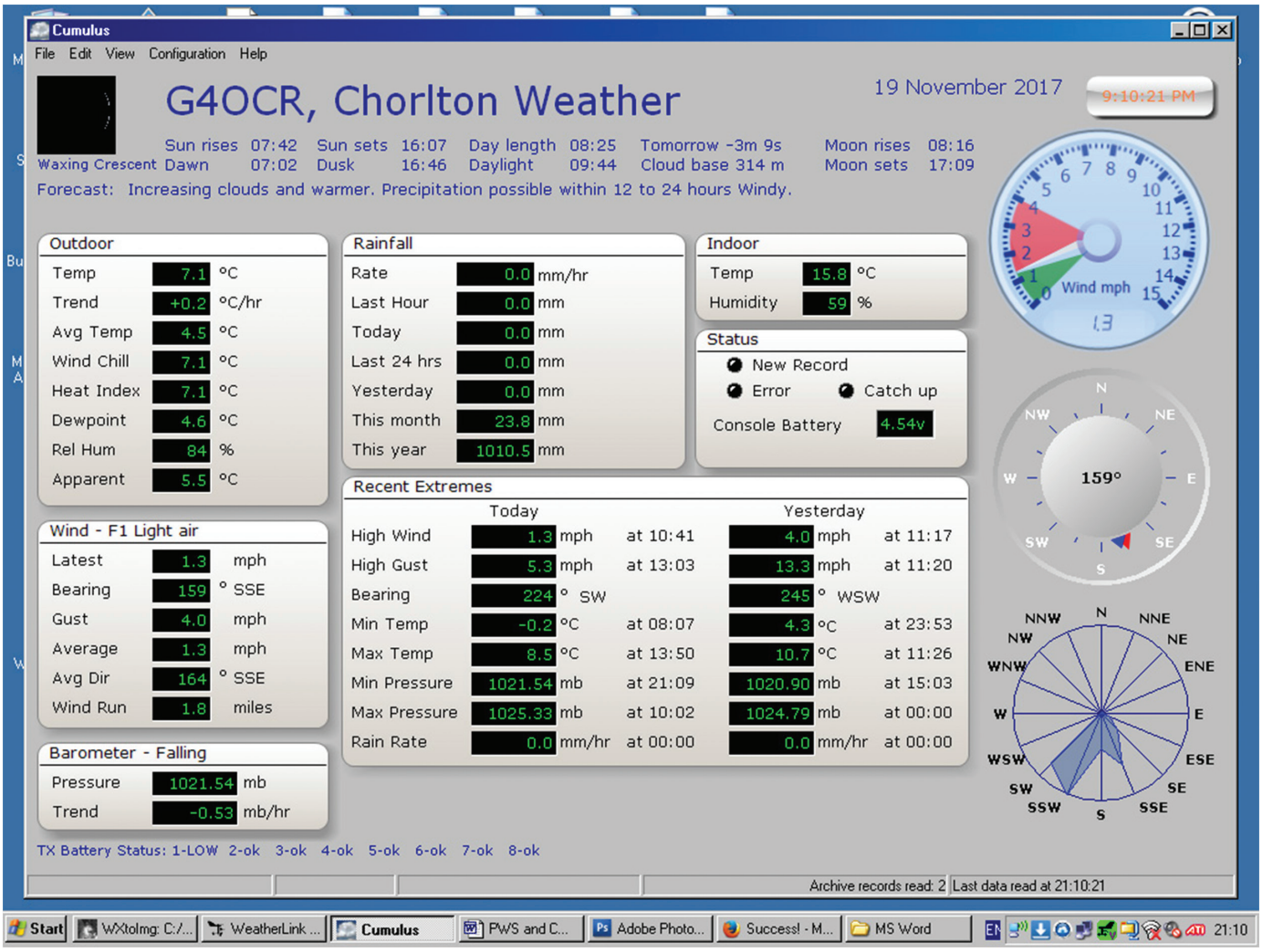

Figure 3. Cumulus real-time screen, including highs and lows for the current and previous day.

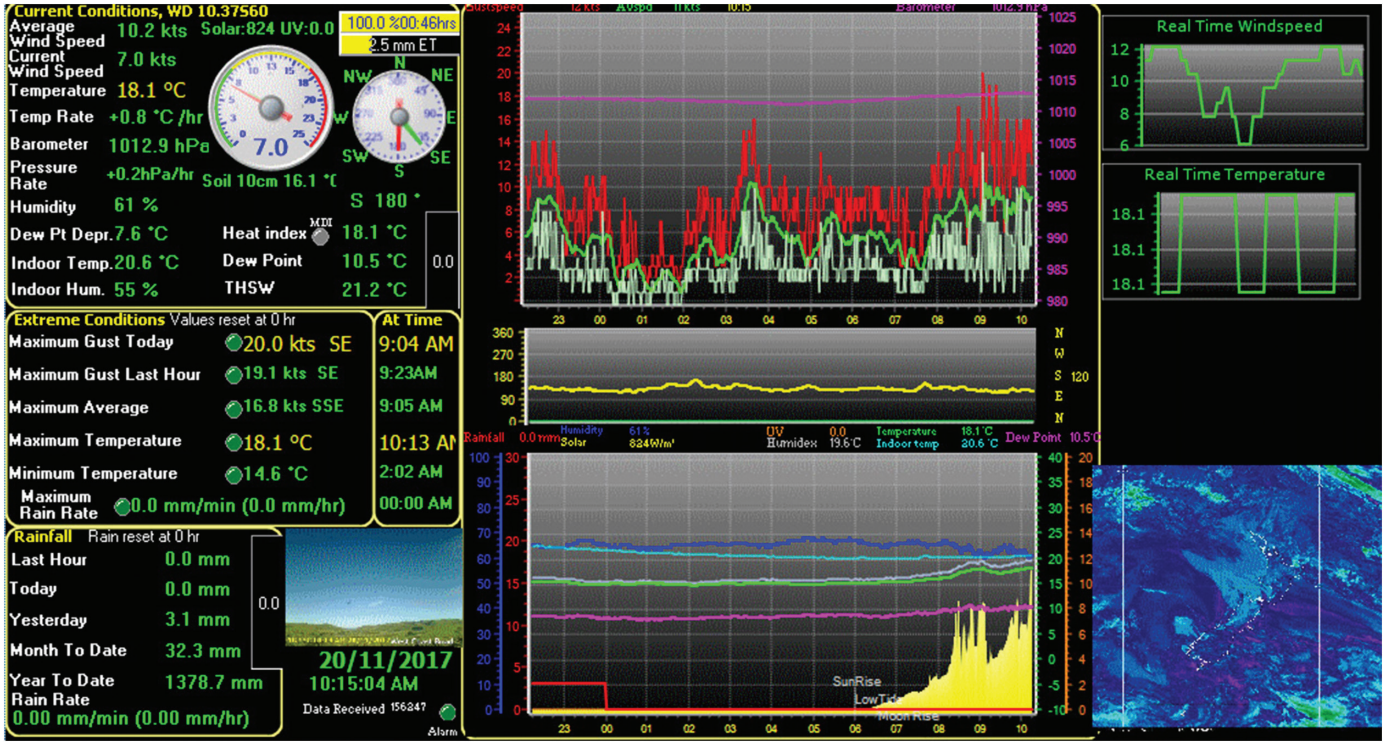

Figure 4. Weather Display real-time weather screen.

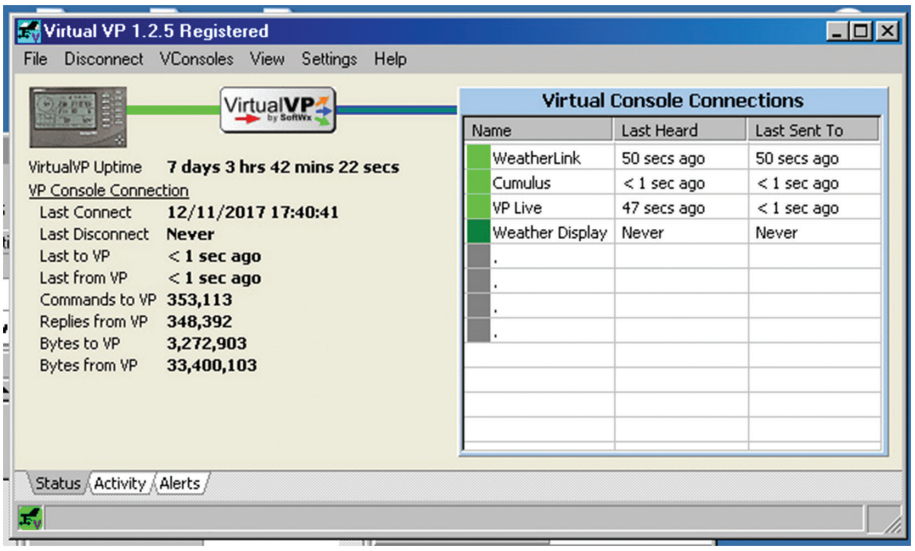

Figure 5. VirtualVP, showing virtual console connections to WeatherLink, Cumulus and VPLive.

As an example of the sort of comparison that may be made of different models of weather station, a study of one year's duration benchmarking the Davis Vantage Pro2 and Vantage Vue, the Oregon Scientific WMR200, the Fine Offset WH1080 and the La Crosse WS2350 against a professional Met Office Meteorological Monitoring System appeared in this journal (Bell *et al.*, 2015). The Davis Vantage Pro2 and Vantage Vue stations showed the closest agreement with the professional Met Office station on temperature, showing mean biases of less than 0.2 degC. However, the study also showed that the Pro 2 was prone to warm biases at night and that the Vue appeared to suffer from longwave radiation biases. For the other stations the mean temperature biases were well over 1 degC, and for the WMR200 and WS2350 could climb to over 4 degC in

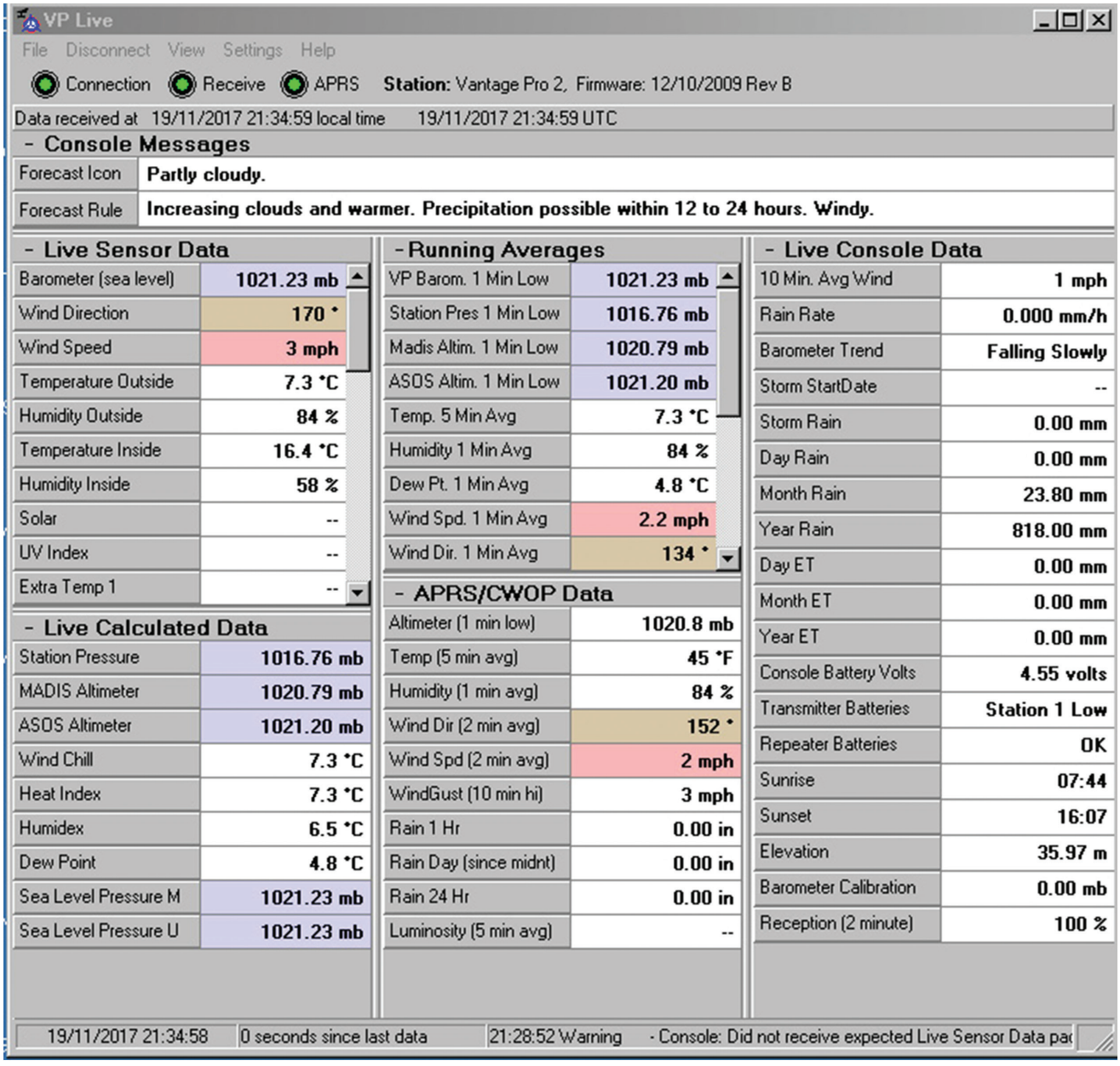

Figure 6. VPLive, showing live sensor data, live calculated data and a variety of running averages. Note that a red tint indicates that a variable is rising, and a blue tint indicates that it is falling.

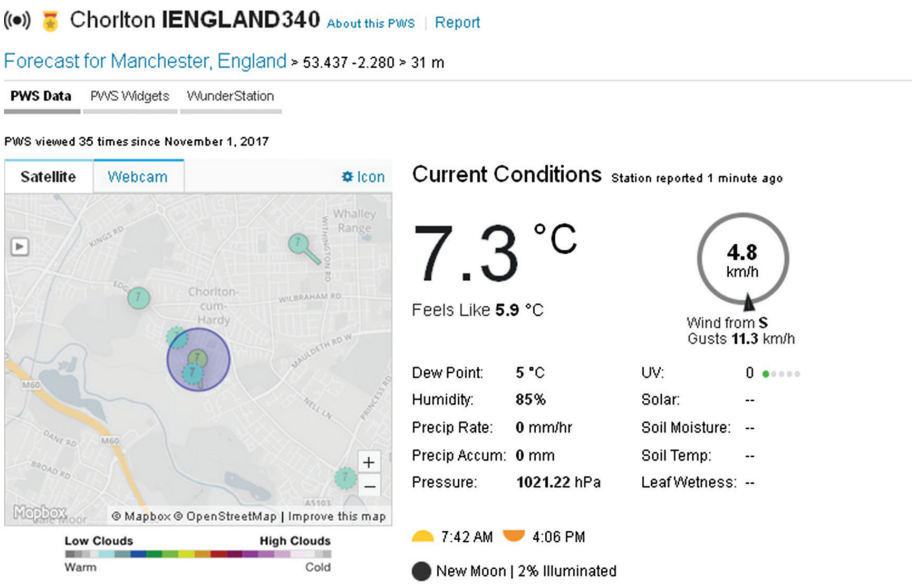

Figure 7. Current weather conditions displayed on a Weather Underground web page.

direct sunlight. Curiously, the rain gauges of the two Vantage Pro2 stations tested each differed from the professional gauge by around 10%, and in different directions. A comparison between two Vantage Pro2 and two Fine Offset WH1080 stations was also published in this journal (Jenkins, 2014) and showed that two examples of the same model of budget priced hardware can give significantly different readings.

To achieve optimal performance from any weather station it is important that the sensors are appropriately sited. The rain gauge needs to be sited away from rain shadows caused by trees and buildings, and the thermometer away from any heat sources such as air vents. The agreed standard for siting a thermometer is between 1.2 and 2.0m above ground level, whereas the agreed standard for siting an anemometer is 10m above ground level. For guidance on the correct siting of meteorological instruments, see World Meteorological Organization (2014). A more informal discussion of the siting of meteorological instruments can be found in Overton (2009), which may be downloaded from the RMetS website. Most personal weather stations have all sensors integrated into a single unit, and so compromise must be made. The author has sited his Vantage Vue sensor suite on a 1m-long aluminium mast which takes it just above the level of the eaves of the roof. Comparison with other nearby stations shows good agreement for temperature, humidity and rainfall, but somewhat poorer agreement for wind speed and direction. However, the advantage of siting the sensor suite above the eaves rather than on the chimney stack is that it allows easy access for maintenance. The rechargeable battery needs to be replaced every three years or so, and periodically cleaning the rain gauge and the radiation shield to remove debris is advisable. A discussion of wind measurements on rooftops is given by Wieringa (1996).

Software

There is a variety of software packages available that display and archive data from personal weather stations. Some packages are proprietary for a particular brand of hardware, whilst others support a range of stations from different manufacturers. Some software is available free, but most packages require a one-off payment. Typically, software will display the current values of various measured and calculated weather variables, and will also have features that enable graphical display of data accumulated over a period of time. Recent and all-time maxima and minima are often available. Many software packages also support the upload of data to a variety of websites.

Davis offer a proprietary software package, called *WeatherLink*. In order to connect the Vantage Vue console to a USB port on a laptop or PC, an additional component known as the data logger is required. This is sold packaged with *WeatherLink*. Although several alternative software packages may be used with Davis hardware, it is necessary to purchase *WeatherLink* in order to get the data logger. The Vantage Vue sensor suite and console plus the data logger and *WeatherLink* software may be purchased as a bundle. The data logger stores up to 2560 archive records. If records are being archived at 5-min intervals, then this equates to almost 9 days of data.

WeatherLink has many appealing features, including highly configurable strip charts (Figure 1) and the facility to build and customise graphs of one or more weather variables (Figure 2). It can also produce monthly or yearly weather reports in the standard NOAA format. However, the upload of weather data to the Internet requires expansion modules to be installed, and the author has found these to be somewhat unreliable. There are separate versions of *WeatherLink* for Windows and Mac OS X.

There are several software packages available that are each compatible with a range of personal weather stations. The *Cumulus* software supports a variety of weather stations including the Oregon Scientific WMR100, WMR200, WM-918 and WMR-928, the Fine Offset WH1080 and similar models, and the La Crosse WS2300, as well as Davis Vantage Pro2 and Vantage Vue stations. *Cumulus* is free, community-funded software available from Sandaysoft (2016) and is compatible with Windows XP and all later versions of Windows. However, it is not compatible with Mac OS X. *Cumulus* has a very attractive display of real-time sensor readings, calculated weather variables, and maxima and minima for the current and previous day (Figure 3). *Cumulus* is easily configured for the upload of weather data to Weather Underground, WOW and CWOP, and the author has found it to be extremely reliable. Both *WeatherLink* and *Cumulus* allow data to be downloaded from the console in real time and retrieval of data from the records stored in the data logger.

Weather View 32 currently retails at $49.99 for the basic home version and $99.99 for the more fully-featured professional version, and may be downloaded from Heider (2015). The home version of *Weather View 32* supports the Honeywell TE831W, TE923W and TN924W, the Oregon Scientific WMR-918/928N/968, Ultimeter weather stations, and the Davis Vantage Pro and Vantage Vue. *Weather View 32* features a highly configurable current weather screen. The professional version is required if one wishes to upload data to the Internet. It has a menu selection that downloads images of North and South America from the Geostationary Operational Environmental Satellites (GOES) in both the visible and infrared spectrum. Whilst this may be useful to users in the Americas, it is unfortunate that one cannot select images from the geostationary Meteosat satellites for coverage of Europe and Africa. A serious drawback of *Weather View 32* is that it only downloads live data from the console and does not retrieve records from the data logger. Thus, unlike *WeatherLink* and *Cumulus*, it needs to remain connected continuously to produce graphs of data, tabulate daily highs and lows, and so on. *Weather View 32* is compatible with the usual Windows operating systems; however, there is no version compatible with Mac OS X.

Weather Display retails at $60 (http://www.weather-display.com/). It supports a broad

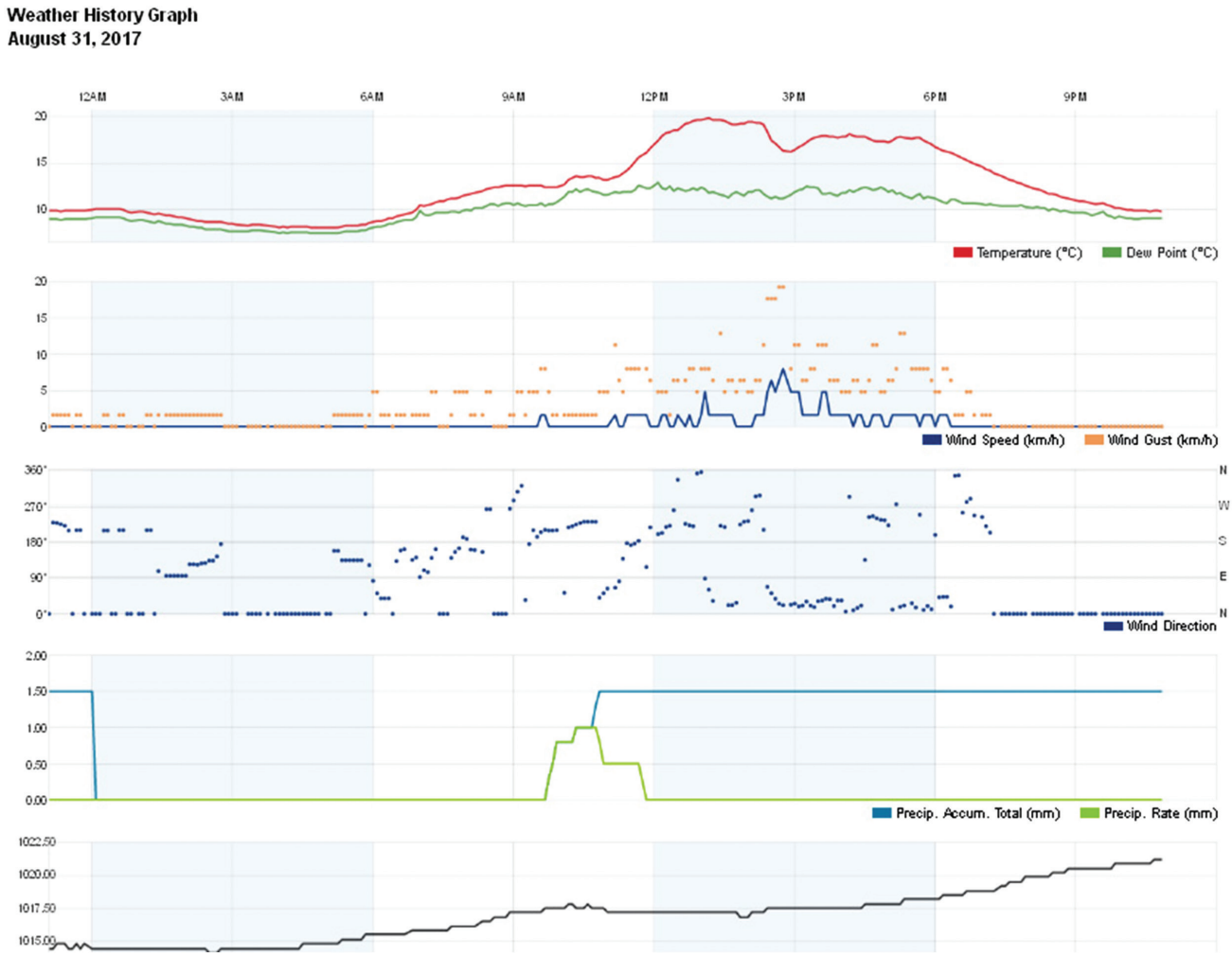

Figure 8. Graphs displayed on a Weather Underground web page: temperature/dew point, wind average speed/gust, wind direction, and barometric pressure.

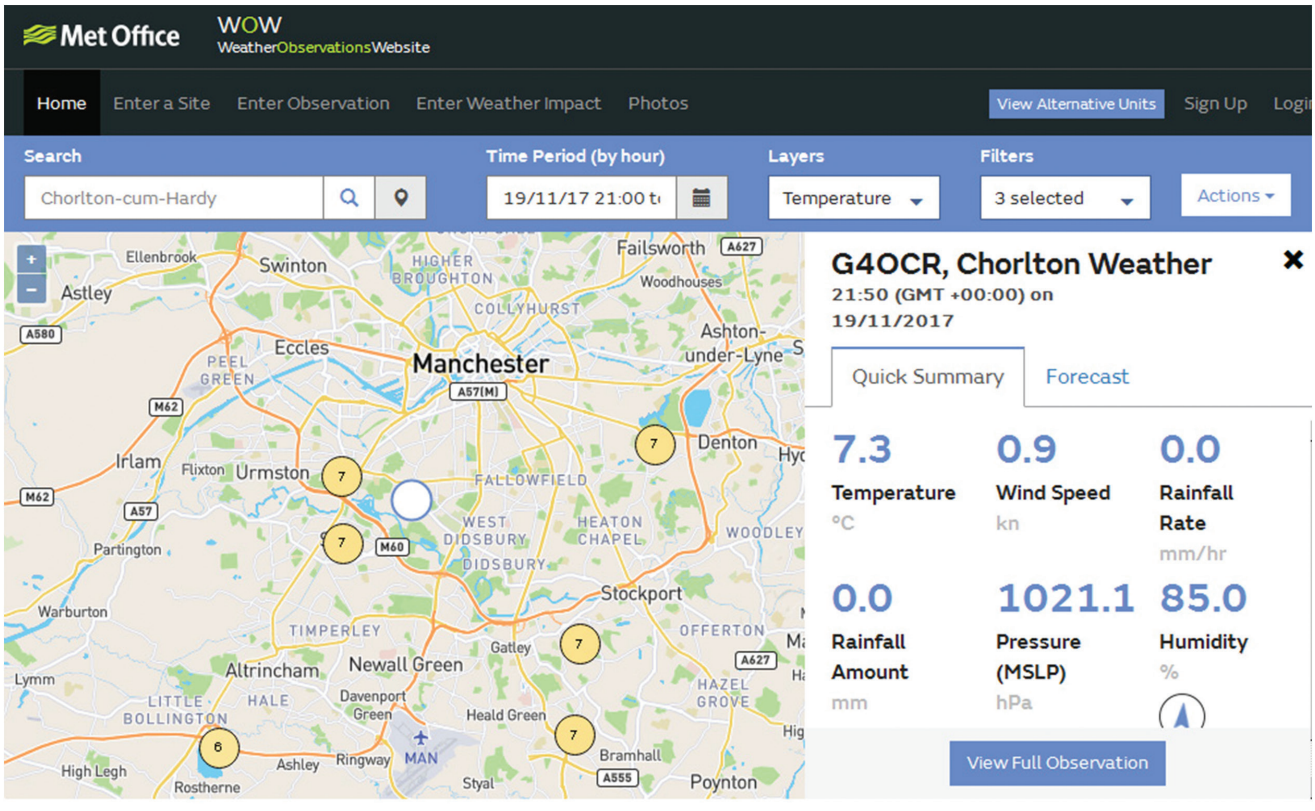

Figure 9. Home page on WOW, with map zoomed in to the region of the author's weather station.

range of personal weather station models, including the Oregon Scientific WM918, WMR-918, WMR-968, WMR-928N, WMR100, WMR200, WM-900H and WMR300, the Davis Vantage Pro and Vantage Vue, the La Crosse 2010, 2110, 2210, 2308, 2310, 2315, 2300, WS23XX, WS2350, 2500, 2510 and 3600, the Peet Bros Ultimeter 100, 500, 800, 2000 and 2100, the Honeywell TE923 and the Watson WS-1080, 1081, 2080 and WH3081. *Weather Display* features an attractive and colourful real-time weather screen (Figure 4) and is compatible with Windows operating systems and with Mac OS X.

WeatherSnoop has been developed specifically for Mac users by Tee-Boy. A trial version may be may downloaded from their website (Tee-Boy, 2017).

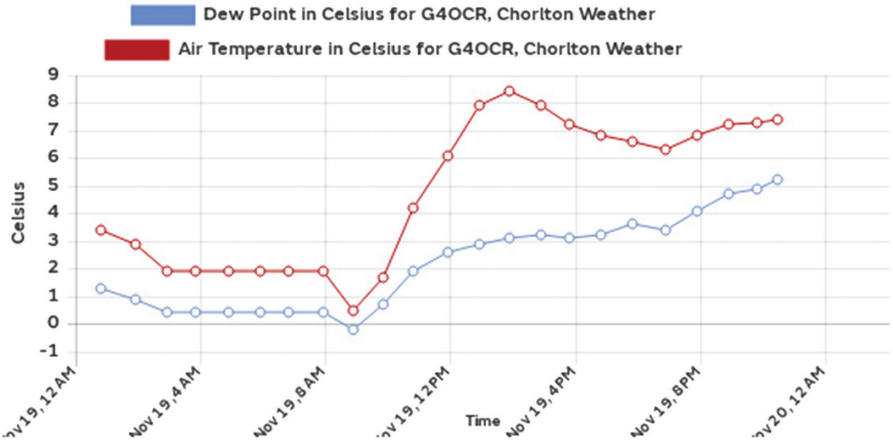

Figure 10. One-day graphs of temperature and dew point on WOW.

The user of Davis hardware may prefer not to be limited to just one software package and may wish to run two or more packages simultaneously. This is made possible by a piece of software called *VirtualVP*, which allows data from the Vantage Vue (or Vantage Pro 2) console to flow to up to four different weather programs (Figure 5). *VirtualVP* was available to download from SoftWX (2012) for a registration fee of $35, but the registration fee has been temporarily suspended due to compatibility problems of *VirtualVP* with the newest versions of *WeatherLink*. (See web links for further details.) Another useful piece of freeware for the Davis user is *VPLive*, also available from SoftWX (Figure 6). *VPLive* gives live calculated data and running averages that are not available via the other programs, including various subtly different ways of calculating sea level pressure and altimeter pressure. It may also be configured to run *WeatherLink* at specified intervals to ensure that weather records are downloaded before the buffer in the data logger becomes full.

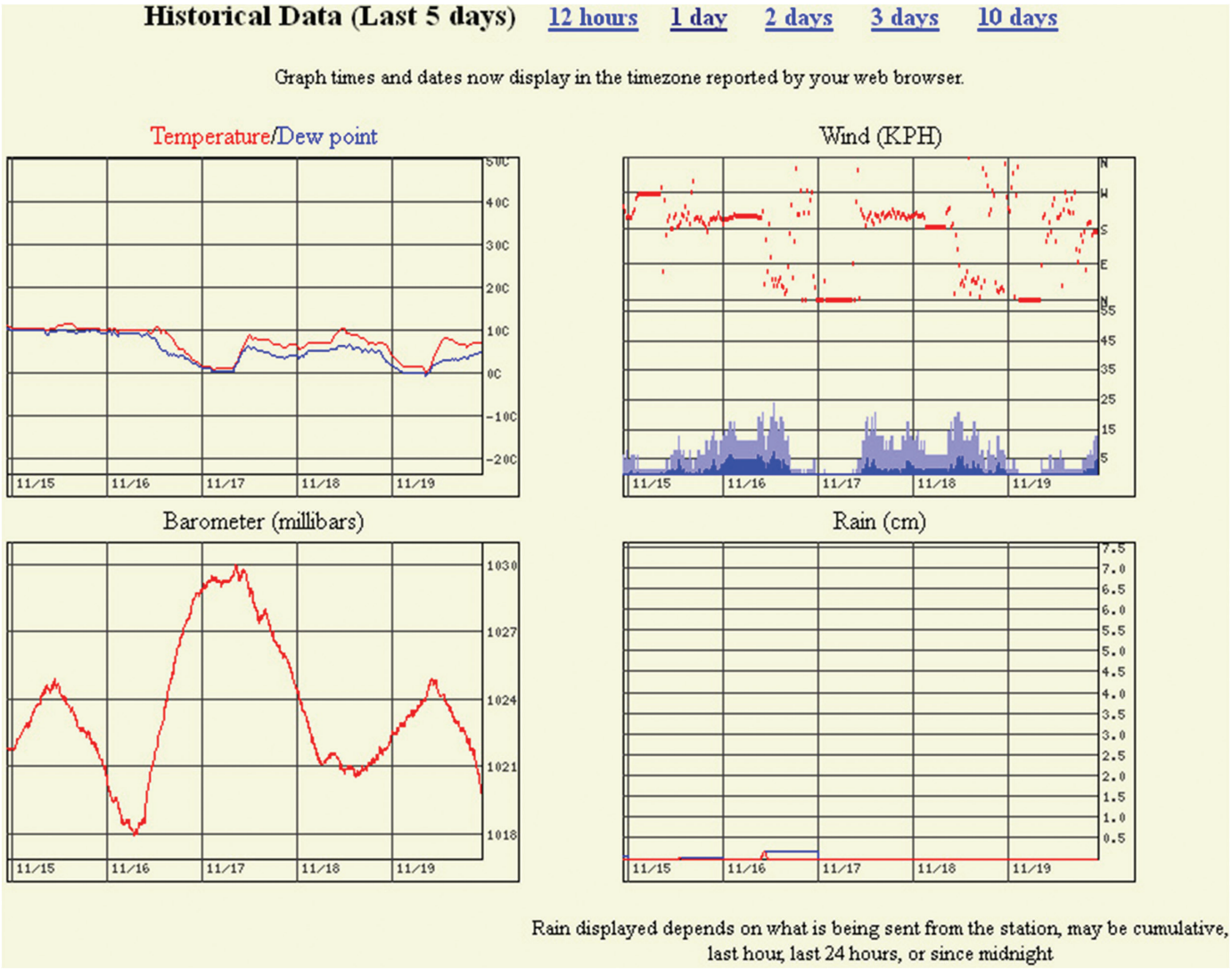

Figure 11. CWOP graphs on findu.com: temperature/dew point, wind direction/speed, barometric pressure, and precipitation accumulated/rate.

G4OCR Weather Reports

time (UTC)	temp C	wind direction	speed KPH	gust KPH	rain 1hr cm	rain 24hr cm	rain mn cm	humidity %	barometer mb
20171119223504	7	167	4.8	8.0	0.00	0.00	0.00	87	1019.8
20171119223004	7	174	4.8	12.9	0.00	0.00	0.00	86	1020.0
20171119222503	7	177	4.8	12.9	0.00	0.00	0.00	86	1020.0
20171119222005	7	168	4.8	12.9	0.00	0.00	0.00	86	1020.1
20171119221503	7	166	4.8	12.9	0.00	0.00	0.00	86	1020.1
20171119221003	7	160	4.8	12.9	0.00	0.00	0.00	85	1020.3
20171119220503	7	153	4.8	8.0	0.00	0.00	0.00	85	1020.4
20171119220012	7	175	4.8	8.0	0.00	0.00	0.00	85	1020.5
20171119215507	7	174	4.8	11.3	0.00	0.00	0.00	85	1020.7
20171119215023	7	185	1.6	11.3	0.00	0.00	0.00	85	1020.6
20171119214505	7	174	1.6	11.3	0.00	0.00	0.00	84	1020.7
20171119214032	7	155	1.6	6.4	0.00	0.00	0.00	84	1020.7
20171119213505	7	172	1.6	6.4	0.00	0.00	0.00	84	1020.8
20171119213003	7	182	1.6	6.4	0.00	0.00	0.00	84	1020.8
20171119212503	7	173	1.6	6.4	0.00	0.00	0.00	84	1021.0
20171119212012	7	163	1.6	6.4	0.00	0.00	0.00	84	1021.0
20171119211503	7	145	0.0	4.8	0.00	0.00	0.00	84	1021.0
20171119211003	7	166	1.6	6.4	0.00	0.00	0.00	84	1021.1
20171119210503	7	167	1.6	6.4	0.00	0.00	0.00	83	1021.2

Figure 12. CWOP tabular data on findu.com.

Temperature

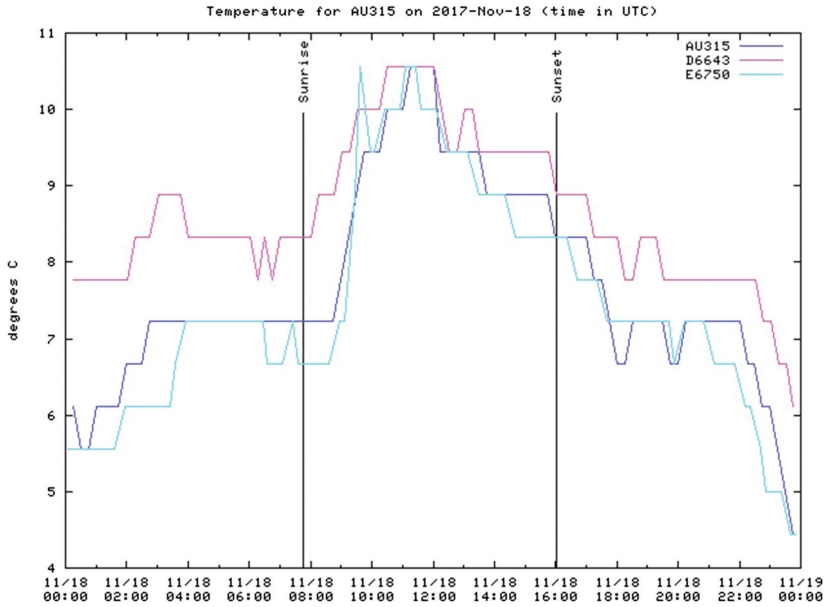

Figure 13. Temperature comparison with two nearby stations. The author's station is shown in blue, and the two nearby stations are shown in mauve and turquoise.

Uploading data to the Internet

Uploading weather data to the Internet enables others to benefit from operating a personal weather station and allows the operator to become part of the online community of operators of personal weather stations. Comparing notes and sharing experiences with others can be interesting and useful. There are several sites to which one can upload data at no charge.

Weather Underground (2017) was founded in 1993 and now boasts over 180 000 members world-wide. To become a member of Weather Underground, one needs to set up a user account with position and elevation information, and obtain a station ID and password. The Weather Underground site generates an aesthetically pleasing page for each Personal Weather Station (PWS), featuring current weather conditions, a map showing the locations of nearby weather stations, and graphs of temperature/dew point, wind speed/gust, wind direction, precipitation accumulated total/rate, and barometric pressure. The page refreshes at regular intervals and includes a counter for the number of visits during the current calendar month. Figures 7 and 8 show this. Weather Underground runs an algorithm to check the quality of data uploaded, and observation sites that pass the quality control check for five or more consecutive days are awarded 'goldstar' status. However, it is not revealed how the algorithm works.

A more recent resource is the Met Office's Weather Observations Website (Met Office, 2016). This was launched in June 2011, with the support of the Royal Meteorological Society and the Department for Education. The site receives and displays data from over two thousand observation sites, spanning over 150 countries. As might be expected, these are largely concentrated in the UK, although there are a significant number of sites in continental Europe, USA, Australia and New Zealand. As well as observations from amateur sites, official Met Office sites are also included. If these happen to be

Site	Distance	Location	Barometer	Temperature	Dewpoint
EW6750	8.6 kilometres East	Denton, UK (lat 53.4541°, long -2.1530°, altitude 84 metres)	-1.4mb	-0.6°C	0.2°C
EGCC	9.2 kilometres South	Manchester Airport, United Kingdom (lat 53.3537°, long -2.2750°, altitude 78 metres)	0.6mb	-0.1°C	1.2°C
DW8024	9.9 kilometres Southeast	Cheadle Hulme, UK (lat 53.3639°, long -2.1951°, altitude 79 metres)	0.8mb	-0.4°C	0.4°C
03351	10.9 kilometres Southwest	Rostherne No 2, United Kingdom Of Great Britain And Northern Ireland (lat 53.3600°, long -2.3820°, altitude 35 metres)	-0.3mb	0.3°C	1.1°C
DW9309	20.5 kilometres Northwest	Wigan, UK (lat 53.5239°, long -2.5531°, altitude 50 metres)	1.4mb	-0.4°C	1.6°C
FW0705	22.4 kilometres Southeast	Whaley Bridge, UK (lat 53.3330°, long -1.9914°, altitude 215 metres)	1.0mb	-0.7°C	1.1°C
DW6111	26.8 kilometres North	Rossendale, UK (lat 53.6682°, long -2.1703°, altitude 249 metres)	-0.8mb	0.1°C	1.7°C
EGGP	39.5 kilometres West	Liverpool Airport , United Kingdom (lat 53.3340°, long -2.8500°, altitude 26 metres)	0.6mb	-0.8°C	-0.3°C
03330	39.7 kilometres Southeast	Leek Thorncliffe, ENG, United Kingdom of Great Britain & N. Ireland (lat 53.1278°, long -1.9814°, altitude 298 metres)	-0.2mb	-0.4°C	2.2°C
03344	49.8 kilometres Northeast	Bingley, ENG, United Kingdom of Great Britain & N. Ireland (lat 53.8113°, long -1.8668°, altitude 262 metres)	1.2mb	-0.5°C	2.3°C

Figure 14. Eight-week comparison of the author's station with nearby stations.

nearby, then this gives opportunity for more precise calibration of sensors. The website can generate a map for a chosen region, showing all observation sites in the region, with 'layers' that can be selected to show temperature, humidity, wind direction, pressure, or rainfall at each site (Figure 9). Data from an individual site may be selected and displayed in either tabular or graphical form. Unlike Weather Underground, which features graphs for all weather variables, the Met Office's site allows a maximum of three variables to be graphed simultaneously. Also, the resolution of the graphs is much lower, with just one observation per hour plotted, as shown in Figure 10.

Another important Internet resource for sharing data is CWOP (Citizen Weather Observer Program, 2014) operated by NOAA. CWOP has over 22 000 active observation sites globally, concentrated primarily in North America, continental Europe and the UK. CWOP operates via APRS (Automatic Packet Reporting System; Bruninga, 2015). This was originally intended to be a system allowing mobile and fixed amateur radio stations to exchange position and status information via packet radio using the AX25 protocol. Weather data may also be exchanged via APRS, and data from individual stations may be retrieved via the findu.com website (Findu.com, 2014) in either graphical or tabular form (Figures 11 and 12). The graphs are relatively crude compared with those produced by Weather Underground, but more detailed than those produced by WOW. The precision of the various weather variables is lower than Weather Underground and WOW, with temperature being rounded to the nearest degree Fahrenheit and wind speeds to the nearest mile per hour. However, a very valuable feature of CWOP is the provision of very flexible tools for quality control of data, which enable the user to check sensors against those of nearby stations (Gladstone, 2012). One may generate a graphical comparison of data from one's own station with that of one or more chosen nearby stations for any chosen day (Figure 13). As well as amateur sites, official Met Office and airport observation sites are included. Graphs are available for temperature, dew point, relative humidity and barometric pressure. There are also wind vector charts over durations of one day and seven days. One may also compare longer term averages with neighbouring stations over periods ranging from three days up to a full year (Figure 14).

APRS was originally intended only for licensed radio amateurs. However, any operator of a personal weather station may feed weather data into the system, so long as this is only via the Internet rather than by radio. To upload data to the system one needs to register, and receive a unique identifier for one's station. These were originally 'CW' followed by a four-digit numeral, but have now progressed through 'DW' and on to 'EW' followed by a four-digit numeral. Licensed radio amateurs use their call sign as their identifier. To upload weather data via APRS, the server is http://cwop.aprs.net, port number 14580. A password is not required, and users should enter '–1' in the password field. A data packet should be uploaded at least once every 15 min, but to avoid excessive load on the APRS system not more than once every 5 min.

Weather data from CWOP is one of several data sources that feed into the Meteorological Assimilation Data Ingest System (MADIS, 2016) operated by NOAA. Other sources that feed into MADIS include data from a range of surface observations, data from geostationary and polar orbiting satellites, and observations from weather balloons and aircraft. From this wealth of data, MADIS makes available a range of products to the meteorological community. Users can request data from July of 2001, which is when MADIS was first available to the public, onwards up to the present. Thus, each personal weather station contributes to our evolving global understanding of weather and climate.

Weather observation remains incredibly popular, with ever increasing numbers of individuals contributing to various weather observation sites. It is hoped that this article will go some way to showing that this is neither expensive nor technically difficult and thereby encourage more people to get involved.

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