FIELD TEST

Kestrel 5500L portable AWS

Independent field trial and review

Introduction

I first came across the Nielsen-Kellermann range of portable AWS models in 2004, when I purchased a Kestrel 4000 model (on the left in **Figure 1**). This has served me well on numerous university fieldwork courses, walking and hillwalking trips and even two total eclipses since then. This review brings the picture up-to-date by examining the capability and accuracy of the latest iteration in the series, the Kestrel 5500L (on the right in **Figure 1**). Part of a Nielsen-Kellermann family of handheld instruments for various applications, these diminutive systems pack a wide range of meteorological sensors and capabilities into a small, light unit about the size of a mobile phone. Primary measurements include air temperature and humidity, barometric pressure and wind speed; from these are calculated or derived wet-bulb temperature, dew point, wind chill, heat index and altitude. The Kestrel 5500L model as reviewed can also be attached to an optional wind vane fitting and mounted on a tripod to provide continuous records of both wind speed and direction (**Figure 2**). The newer model also allows two barometric pressure records, one at station level and the other offset (to MSL, for example). The new model also has much larger memory and much easier data retrieval (via Bluetooth to a mobile phone app), making it a much more useful unit for fieldwork; these aspects are considered in more detail subsequently. The Kestrel 5500 is almost identical in size to its predecessor at 127 x 45 x 28 mm, slightly heavier at 124 g (Kestrel 4000 108 g), and is powered from a single 1.5 v Lithium AA battery, replacing the 2 x AAA required for the previous model. With reasonable use, battery life is from weeks to months. Both are waterproof (to IP67) and reasonably shockproof.

***Figure 1**. Side by side, the Kestrel 4000 (2004 model) and the latest iteration, the Kestrel 5500L.*

This review was conducted at the Stratfield Mortimer Observatory in south Berkshire, UK (**Figure 3**), against UK Met Office-standard equipment with recent thermometer calibrations. Laboratory wind tunnel tests on the anemometer calibration were undertaken in the Department of Meteorology at the University of Reading. Throughout the review period, weather conditions were dry, and often hot or very hot; there were thus no opportunities to examine performance in cold, wet or windy conditions.

The following sections summarise instrument performance, considering in turn air temperature, relative humidity, barometric pressure and wind speed. Usability aspects are then considered, including a comparison with my existing Kestrel 4000 unit, followed by summary conclusions. Except where comparisons are made with the Kestrel 4000 unit, review comparisons are necessarily based upon a single

Figure 2. *Kestrel 5500L with attached wind vane on standard tripod mount measuring outdoor wind speed and direction, in addition to other parameters*

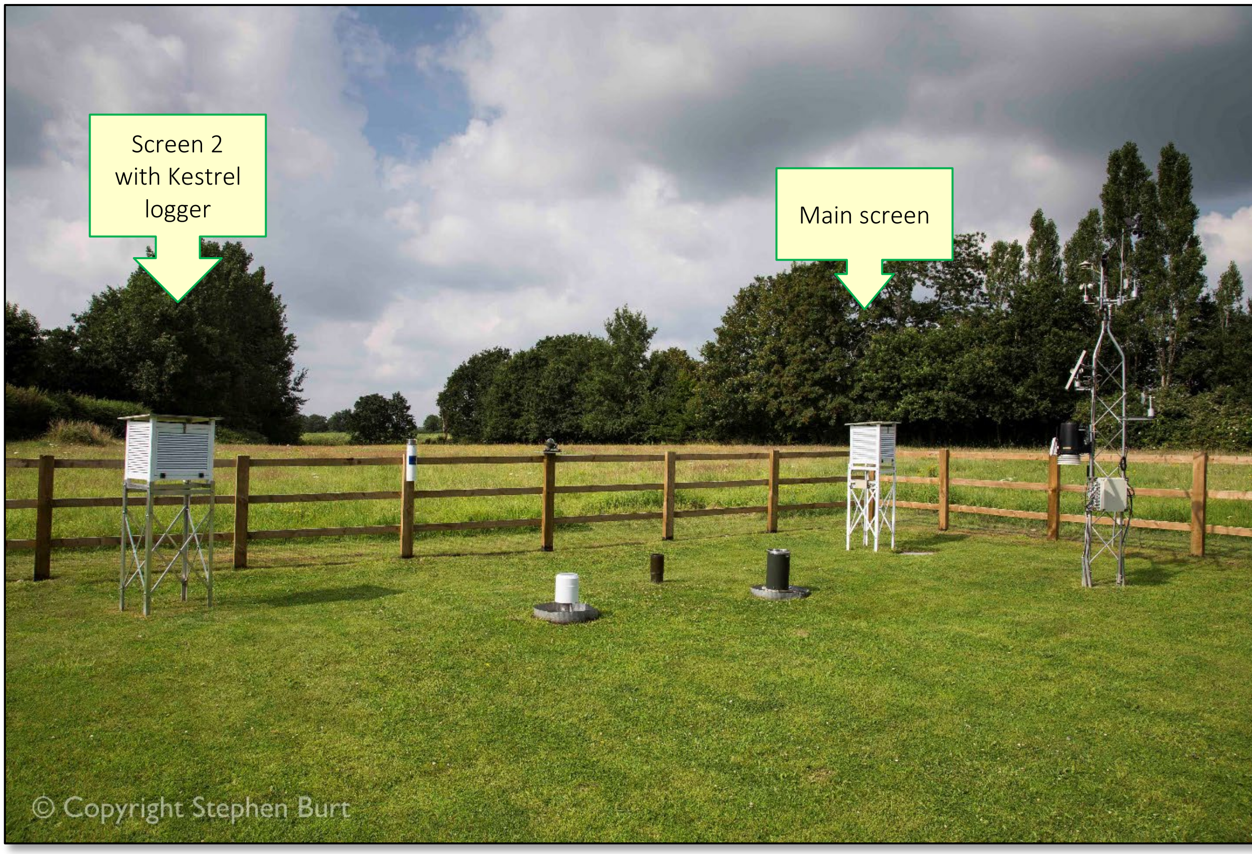

Figure 3*. The siting of the two Metspec Stevenson screens within the station enclosure at the Stratfield Mortimer Observatory in Berkshire, looking south-west*

Kestrel 5500L unit (serial no. 4316600) which has been assumed to be a fair and representative manufacturing sample of the model.

Methodology

For most of the review period, the Kestrel 5500L unit was housed within a UK Met Office standard Metspec Stevenson screen (double-louvred, with gloss-white exterior finish, the UK Met Office standard air temperature enclosure, **Figures 3 and 4**); exceptions to this are noted in the sections below as necessary. As set out in the individual sections below, logged readings from the instrument were compared with similarly-exposed instruments complying with World Meteorological Organisation guidelines. All comparison instruments possessed appropriate calibration certification or possessed calibrations specifically checked shortly before the review. For most comparative review measurements, the Kestrel 5500L was set to log 'spot measurements' at 5 minute intervals, in UTC, these records subsequently compared with the relevant parameter records logged at the same frequency and synced to the same logged time by two Campbell Scientific loggers sampling at 1 s or 10 s frequency (varying by element) and logging at 1 minute and 5 minutes resolution. Where appropriate for the test, some Kestrel 5500L records were logged at shorter sampling times as set out in the individual sections below.

Results - air temperature

Most of the air temperature comparisons were conducted with the Kestrel 5500L mounted at 1.25 m within a standard Metspec Stevenson screen, adjacent to two pre-calibrated 3 mm platinum resistance sensors (PRTs) logged by a Campbell Scientific logger (**Figure 4**); exceptions to this are noted in this section. **Figure 5** shows 5 minute logged temperature data from the Kestrel 5500L (red trace) on 19 July 2022, together with the 5 min logged records on the same day from one of the PRTs exposed within the same screen (blue trace) and a second PRT logged at the same interval in the main screen (green trace). This was 'Hot Tuesday', the day when several sites in the UK exceeded 40 °C for the first time on record. It can be seen that the Kestrel record lags the PRT record, by 15 or 20 minutes at times in the morning rise and the evening fall in temperature, while the detail of individual peaks and troughs during the day is significantly smoothed on the Kestrel record as a result of the latter's slower response time. Although the temperature sensor (a thermistor) on the Kestrel is itself quite responsive, the thermal inertia of the body of the instrument tends to damp out short-period fluctuations. As a result, the diurnal temperature range tends to be slightly under-recorded, especially so on days where temperatures are changing quickly, although the morning and evening lag tended (rather fortuitously) to more or less cancel out, reducing differences in 24 hour mean temperatures. On 19 July, the mean of the 288 x 5 min temperature samples for the Kestrel was 26.28 °C, compared with 26.24 °C for the PRT in the same screen, although individual samples during the day varied between 2.2 degrees Celsius warmer and 3.2 degrees Celsius cooler than the PRT value.

***Figure 4**. Kestrel 5500L mounted within the 'Screen 2' Metspec Stevenson screen at Stratfield Mortimer Observatory. Two of the calibrated platinum resistance sensors and one of the Campbell Scientific loggers are also visible within the screen*

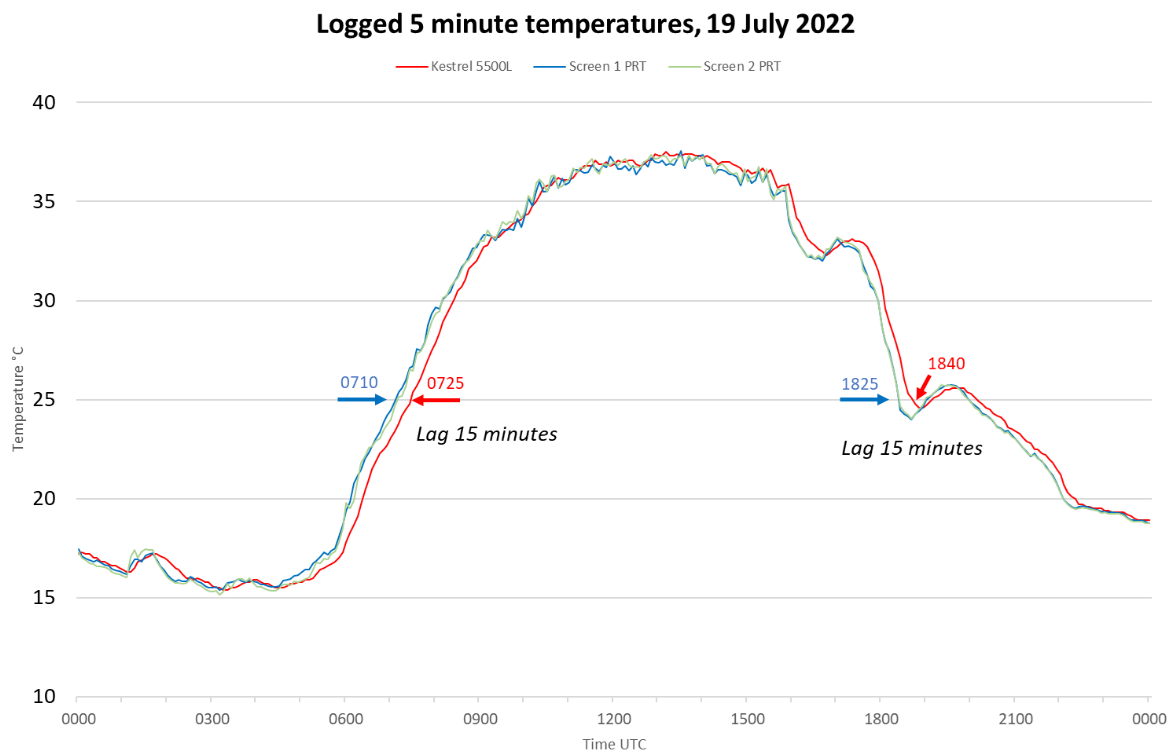

Figure 5. *Temperatures logged at 5 minute intervals on 19 July 2022 by Kestrel 5500L (red trace), a PRT in the same screen (blue trace) and another PRT located in the main screen 10 m distant (pale green trace). Based on 5 minute logged data, the maximum temperature logged by the Kestrel 5500L was 37.5 °C, by the PRT in the same screen 37.56 °C and in the main screen 37.37 °C.*

Table 1 shows the average daily maximum, minimum and mean daily temperatures (0000-2355 UTC daily) for a 37 day period during the review; values are included only where both sets of data were complete (288 x 5 minute logged samples). Over this period, daily maxima were under-recorded by an average 0.11 degrees Celsius, while daily minima were over-recorded by a similar amount. Mean daily temperatures were in excellent agreement, the Kestrel 5500L differing from the precision PRTs within the screen by an average of 0.03 degrees Celsius, with a standard deviation of 0.15 degrees. All but two days in this 37 day period recorded a mean temperature within 0.2 degrees Celsius of that recorded by a calibrated PRT in the same screen.

Table 1. *Daily maximum, minimum and mean temperatures 0000-2355 UTC for the Kestrel 5500L and a PRT exposed within the same screen for a 37 day period within 2 July - 16 August 2022. Note that for consistency these are the highest, lowest and mean of the 5 minute logged samples from each instrument (standard climatological maximum and minimum temperatures differ slightly, being defined as the highest/lowest of any running 60 s mean temperature).*

Mean maximum temperature °C			Mean minimum temperature °C			Daily mean temperature °C		
Kestrel	*Screen PRT*	*Diff*	*Kestrel*	*Screen PRT*	*Diff*	*Kestrel*	*Screen PRT*	*Diff*
25.98	26.09	-0.11	12.22	12.08	+0.14	19.29	19.26	+0.03

Not surprisingly, less good agreement with screen temperatures were obtained when the Kestrel unit was mounted outside the screen. **Figure 2** shows the unit mounted on its wind vane attachment only a few metres away from the thermometer screen, recording external wind speed *and* direction but therefore also exposed to full sunshine. Using the same format as **Figure 5**, **Figure 6** shows the corresponding 5 minute logged air temperatures within the screen and from the nearby Kestrel unit in the open air on 8 July 2022, a warm, sunny day followed by a clear night. While exposing the unit in this fashion is clearly necessary to sample wind direction *and* speed, the records of air temperature (and humidity) obtained are unlikely to be representative of true air temperature as measured within a Stevenson screen, owing to both solar radiation (warming), outgoing terrestrial radiation at night (cooling) and during precipitation (cooling). Note, however, that the response lag all but disappears with improved sensor ventilation.

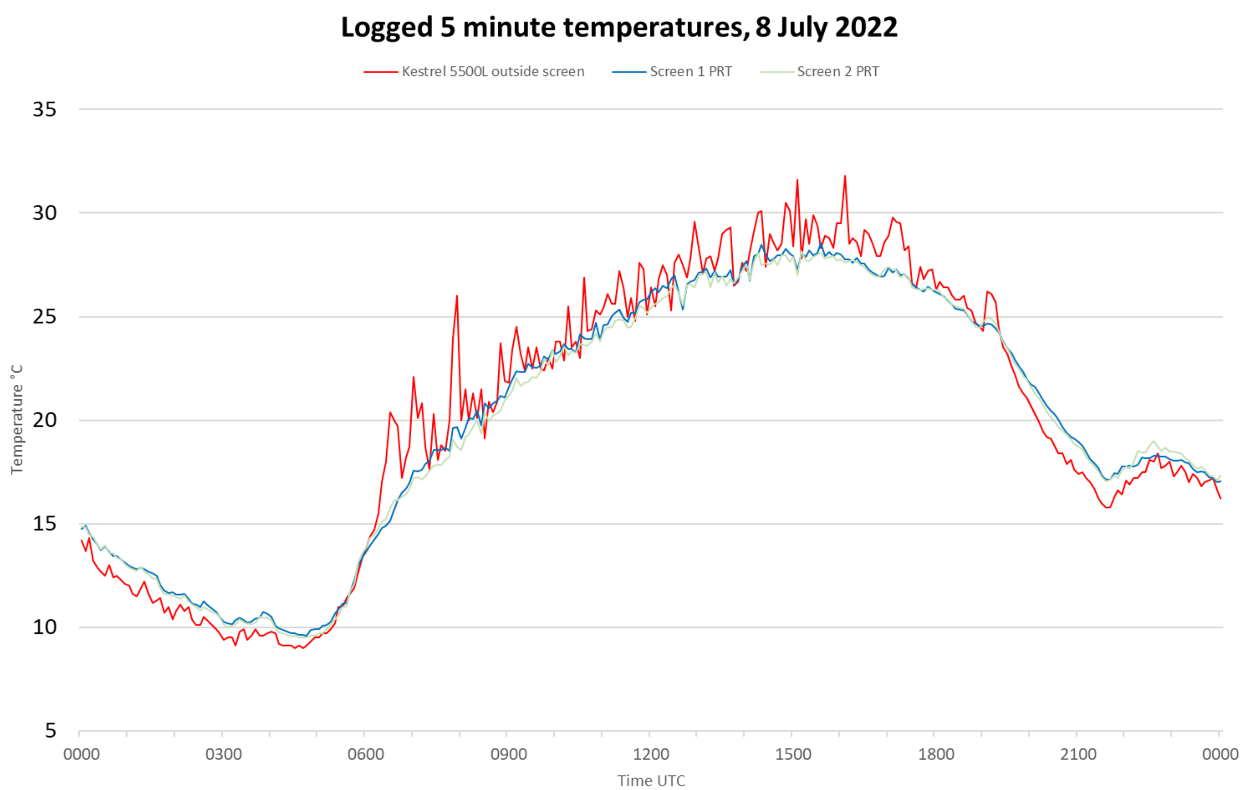

Figure 6*. As for Figure 5, but for 8 July 2022 and with the Kestrel 5500L (red trace) mounted outside the screen. Based on 5 minute logged data, the maximum temperature logged by the Kestrel 5500L was 31.8 °C, whereas the PRT in nearby screen recorded 28.14 °C and in the main screen 28.60 °C.*

The main drawback of the temperature records from the Kestrel 5500L is thus the unit's relatively slow response time. Whereas the small (3 x 50 mm) PRTs used within the two Stevenson screens can be expected to respond to a 63% change in air temperature within about 30 s at a ventilation speed of 1 m s^{-1}, as can be seen from **Figure 5** the Kestrel 5500L not infrequently lagged the PRT within the same screen by 10 minutes or more, as a result of which minor short-period fluctuations in temperature went unrecorded, particularly in light winds when ventilation through the screen will be almost non-existent.

To investigate whether this lag was due to sampling or averaging time, a similar comparison was made with 1 minute samples, shown in **Figure 7**, for 12 August 2022. In this case the 1 minute record is from the main screen located about 10 metres distant from the screen in which the Kestrel screen was located, as 1 minute records were not available from the latter. However, even at the shorter data interval the Kestrel 5500L record is clearly less responsive than the screen PRT record, although the maximum temperature recorded differs only slightly.

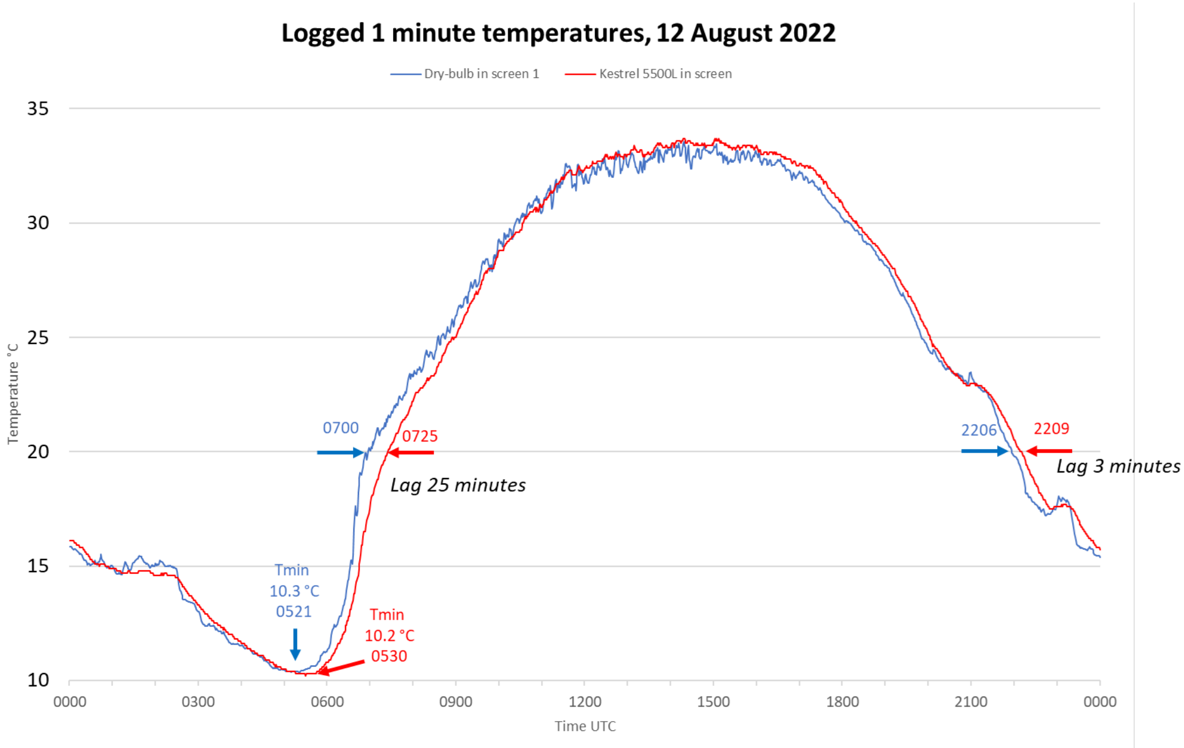

Figure 7. *As for Figure 5, but for 12 August 2022 and using 1 minute data points. Based on 1 minute logged data, the maximum temperature logged by the Kestrel 5500L was 33.7 °C, whereas the PRT in nearby screen1 (the main screen) recorded 33.56 °C*

The Kestrel 5500L's 'all-in-one' compact forma factor makes it difficult to design a laboratory test to isolate the response time of the small sensor from the thermal inertia of the unit's casing, but what limited lab tests were possible suggested that the 63% response time of the unit to a sudden 35 degree Celsius increase in temperature at 1 m s^{-1} airflow was about 3-4 minutes, and the 95% response time was a little over 10 minutes. In view of the design's form-factor and the intended usage of the device, this is probably a realistic compromise, but it does mean that temperature readings from the unit cannot be relied upon for some time following a sudden rise or fall in temperature, or a move from one location to another at a significantly different temperature, such as a warm building (or coat pocket) to an external location in winter.

One possible solution to reduce response time in a potential/optional instrument enhancement would be to provide the main temperature (and perhaps humidity) probe on a short lead, one which was connected into the unit's electronics replacing the existing in-body sensor. Removing the sensor from the main body of the unit, even if only by 20 cm or so, would significantly improve response time.

Results - Relative humidity

Dew point values on the unit are calculated from observed relative humidity, air temperature and barometric pressure. Relative humidity measurements from the Kestrel 5500L at 5 minute sampling intervals were compared with those from both a Rotronic capacitance-based humidity sensor (a similar technology to that used in the Kestrel instruments) and a dry- and wet-bulb psychrometer, the latter consisting of two matching (and recently calibrated) calibrated 3 x 50 mm PRTs housed in an identical screen about 10 m distant. For these PRTs, RH is calculated once per minute from 1 minute means of dry- and wet-bulb temperature by the Campbell Scientific logger. **Figure 8** shows a comparison of 5 minute sampled RH data for 19 July 2022, a direct comparison with **Figure 5**, and **Figure 9** shows 1 minute data for 14 August 2022. The latter date was chosen because of its large range in humidity.

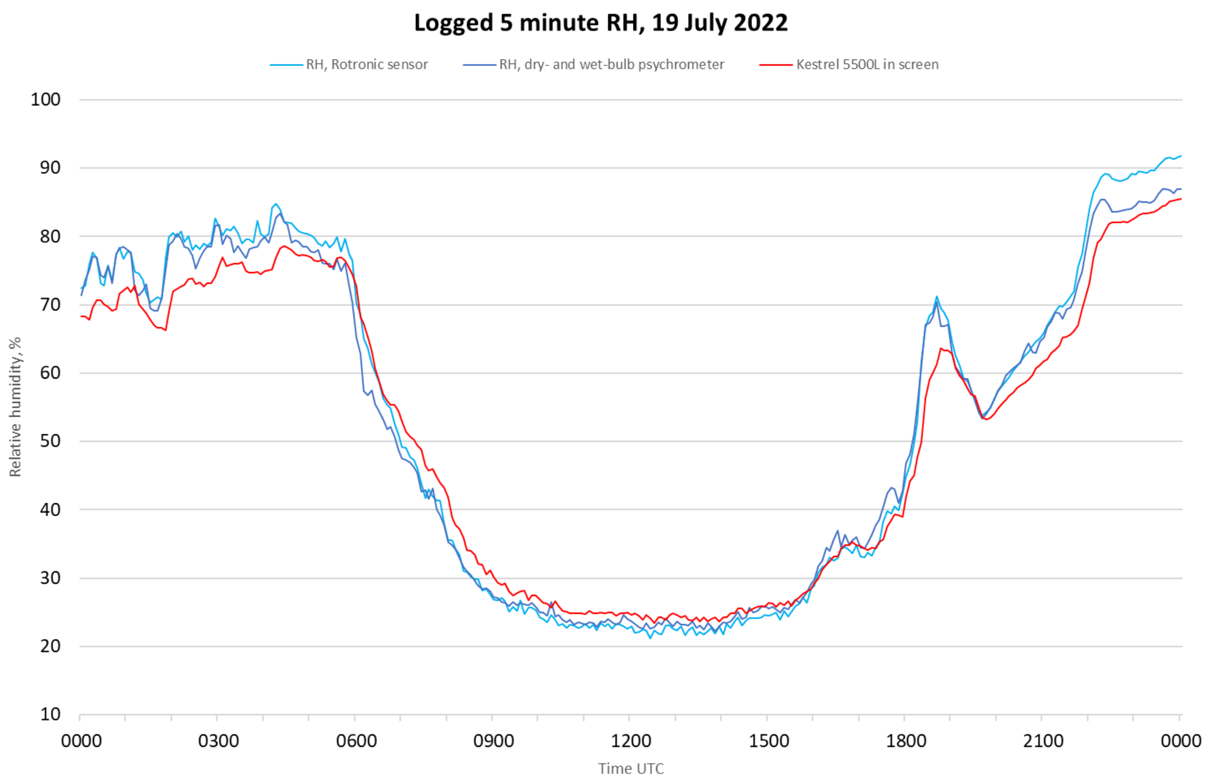

Figure 8. *Relative humidity logged at 5 minute intervals on 19 July 2022 by Kestrel 5500L (red trace), a dry- and wet-bulb PRT psychrometer (dark blue trace) and a Rotronic humidity sensor (pale blue trace), the latter two instruments located in the main screen 10 m distant. Based on 5 minute logged data, the mean (00-00h) relative humidity logged by the Kestrel 5500L was 51.5% (minimum 23%), by the psychrometer pair 52.5% (minimum 22%) and by the Rotronic sensor 53.0% (minimum 21%).*

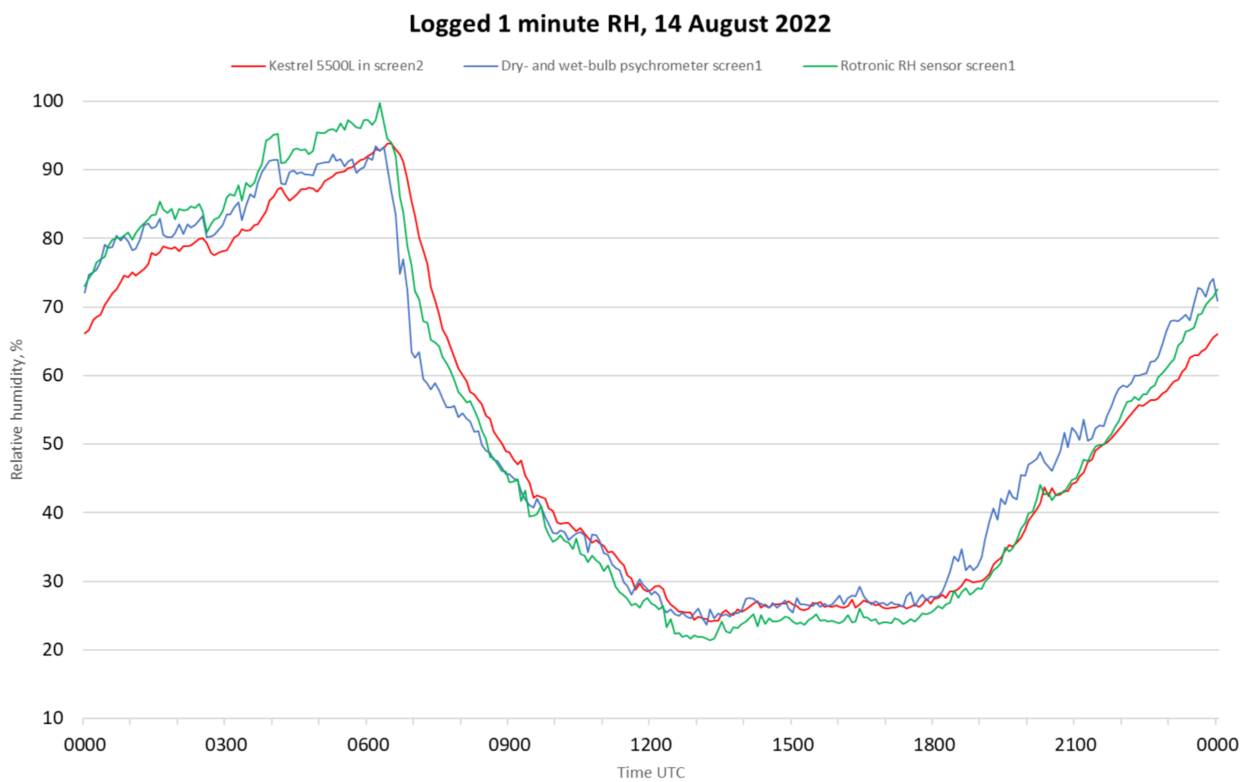

***Figure 9**. Relative humidity logged at 1 minute intervals on 14 August 2022 by Kestrel 5500L (red trace), a dry- and wet-bulb PRT psychrometer (dark blue trace) and a Rotronic humidity sensor (green trace), the latter two instruments located in the main screen 10 m distant. Based on 1 minute logged data, the mean (00-00h UTC) humidity logged by the Kestrel 5500L was 50.8% (minimum 24%), by the psychrometer pair 51.6% (minimum 23%) and by the Rotronic sensor 51.4% (minimum 21%).*

Similar conclusions regarding relatively slow response time for the humidity sensor can be drawn as for the temperature sensor as discussed above, but response times for humidity sensors are generally slower than for PRTs as they tend to be even more dependent upon ventilation speed; they are also much slower both to respond and to dry out again at high humidities (> 90%). The response time of the Kestrel 5500L unit was acceptable within the constraints of the unit, and would be further improved with greater ventilation.

Results - Barometric pressure

Over the period of the review, the 5 minute logged station level pressure from the Kestrel 5500L unit housed within the Metspec screen as stated above was compared with station level pressures measured by a calibrated Setra barometric pressure sensor located within a nearby building and logged by the Campbell Scientific logger at the same frequency. (The barometric pressure sensor within the Kestrel unit did not specifically require external exposure, but obviously when fitted as an integral component of the instrument no alternative was possible.) **Figure 10** shows the 5 min logged datapoints for the whole of July 2022 for both sensors, the Kestrel 5500L in red and the Setra sensor in blue. The difference between the two is shown in pale blue, right-hand scale. The average difference was 1.54 hPa, with a marked diurnal variation as a result of temperature changes. An offset of -1.54 hPa to the Kestrel's reported values would ensure the two readings remained in agreement within 0.5 hPa for 99.35% of the observation period. It should be noted, however, that the range in barometric pressure during July 2022 was not great, and different results may have been obtained in a winter month with a greater range in pressure.

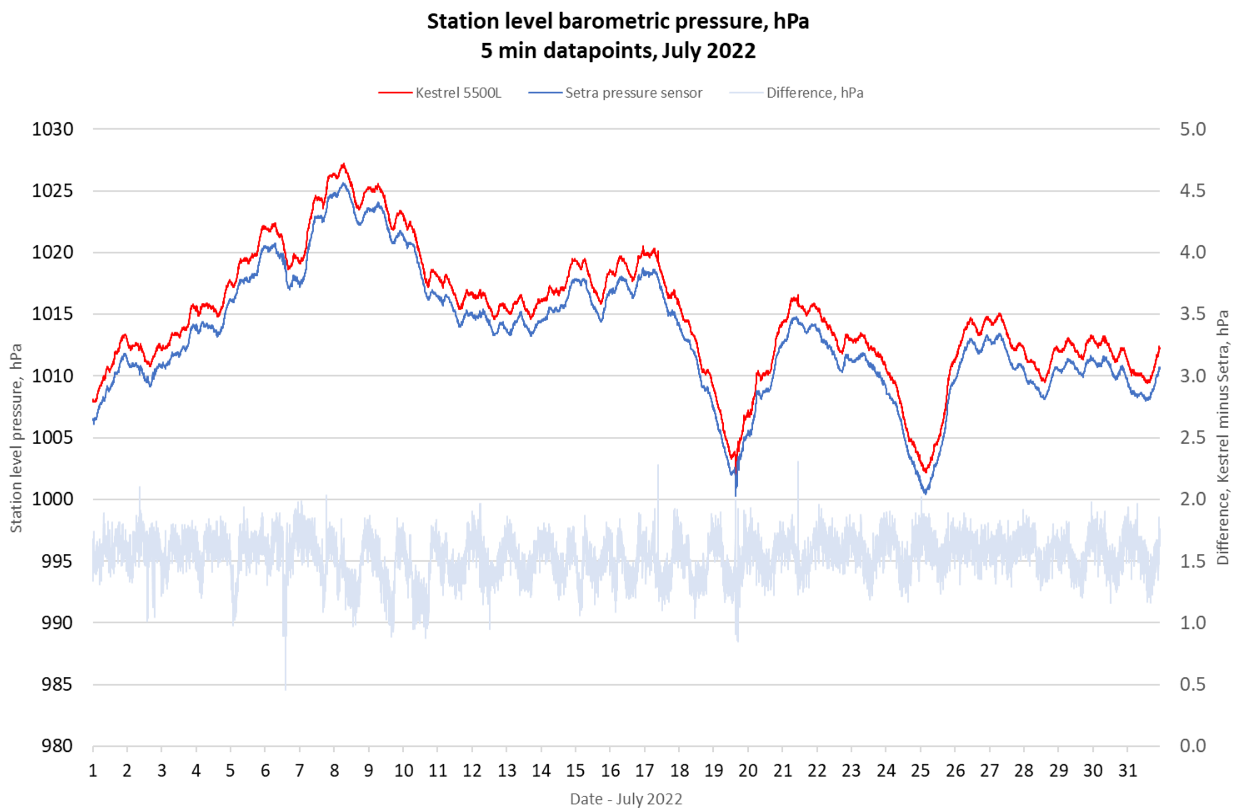

Figure 10. *Barometric pressure during July 2022, logged at 5 minute intervals by Kestrel 5500L (red trace), and a calibrated Setra pressure sensor (dark blue trace) located in an adjacent building. The average offset was +1.54 hPa and varied diurnally (pale blue trace, right-hand scale)*

Results - Wind speed

Making external comparisons of the Kestrel unit alongside an anemometer on a 10 m mast was unrealistic, and thus the unit was checked within the laboratory wind tunnel within the Department of Meteorology at the University of Reading. The Kestrel unit was set to log every 10 s while the wind tunnel was adjusted to cover a range of speeds from 0.5 to 10 m s^{-1}, each speed being maintained by the wind tunnel for 3 minute periods increasing from minimum to maximum wind speeds, and then reducing in steps from maximum to minimum once more. The average of all 10 s logged values over each 6 minute period, excluding periods when the wind tunnel speed was being adjusted, were compared with in-tunnel wind speeds measured by a calibrated Testo 425 Compact Thermal Anemometer (expected error within ± 5%). In all, 262 datapoints were obtained. The results are shown in **Figure 11**.

Perhaps surprisingly, the Kestrel wind speed was consistently over-estimated, by an average of a little over 15 per cent. Even allowing for possible errors in the wind tunnel anemometer, the unit appears to over-read by at least 10 per cent. However, in view of its likely usage profile (including exposure at heights well below the standard 10 m, frictional turbulence from surrounding objects and the like), such e

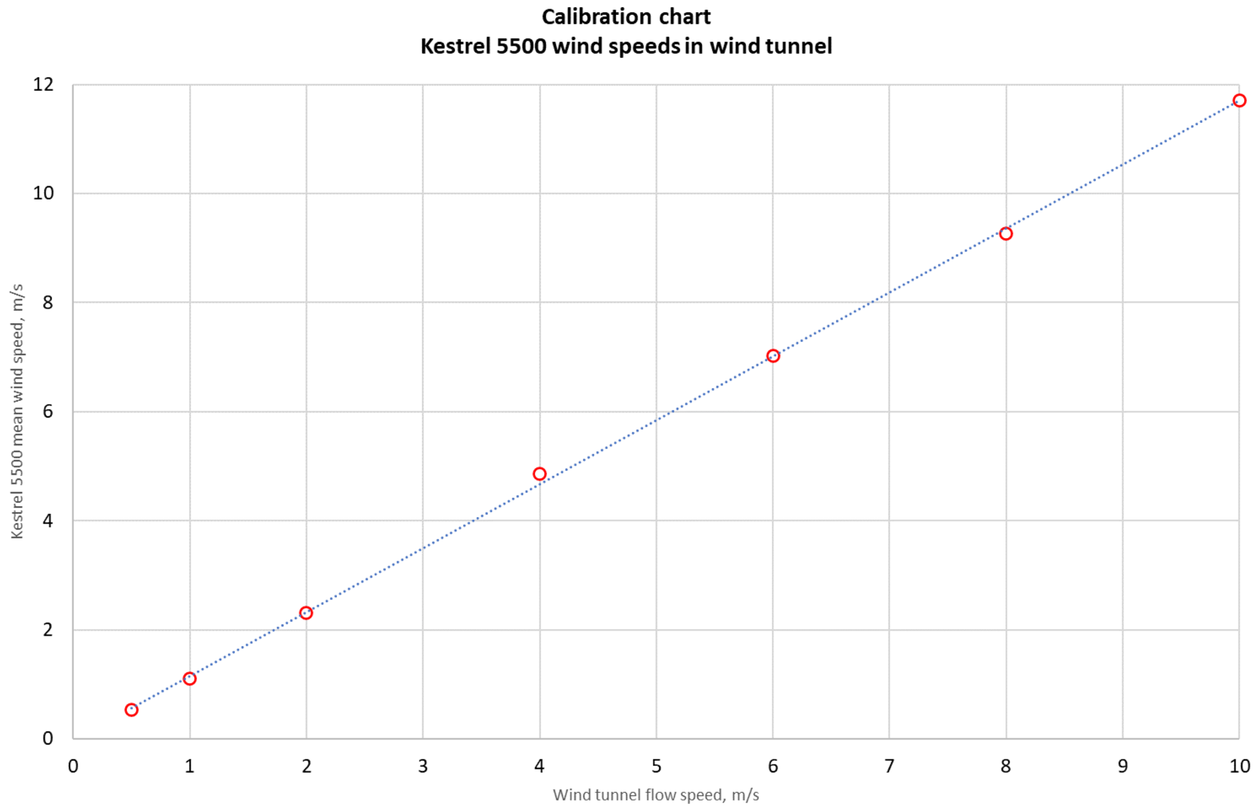

Figure 11. *Wind tunnel calibration results of the Kestrel 5500L. See text for methods.*

Usability aspects

The Kestrel 5500L retains the excellent ease of use of its predecessor Kestrel 4000 unit, with significant enhancements in several respects:

Much expanded memory. The Kestrel 4000's memory was sufficient for only about 20 hours worth of data at 5 min logging interval; the Kestrel 5500L will comfortably retain 6 weeks data at the same resolution, making it much more feasible to use for long periods (days to weeks) for field experiments or field courses.

Quicker and easier downloads. Data download from the 5500L via Bluetooth to the dedicated mobile phone app (Kestrel LiNK) is much quicker and more reliable than the previous cumbersome and slow USB cradle method on the Kestrel 4000, although the rather convoluted user interface required to connect, sync and download data would benefit from some thought in re-design.

Improved tripod fitting. The 5500L design now includes two recessed slots along part of the long axis of the unit. These slide into a small attachment fitted with a tripod screw, which is much quicker and very much more secure than the previous tripod attachment for the Kestrel range.

Ability to log wind direction as well as wind speed. The Kestrel 5500L has an optional wind vane fitting, which when mounted on a tripod or similar allows the unit to record both wind speed and direction. Note, however, that external exposure in sunshine or precipitation will result in gross errors in air temperature and probably humidity (see **Figure 6**).

Better backlight. The 5500L has both a brighter backlight than previous models, and the option of red or white colour – the red being more suitable for use with dark adapted eyesight.

Redesigned battery compartment. Only a minor thing, but the battery compartment cover on previous models was easily damaged and would render the unit unusable until a new cover could be obtained and fitted.

Kestrel units also come with a 5 year warranty as standard.

Drawbacks

The only major drawback found during the review was one that was a 'feature' presumably intended to be helpful, but which in fact turned out to be a major nuisance:

The Kestrel 5500L clock is reset to the time on the mobile phone during downloads.

Why is this a nuisance? Despite the Kestrel unit being deliberately set to UTC, and data downloads proceeding on that assumption, the clock was then reset to the mobile phone time (summer time BST, i.e. UTC+1) without warning during data download operations. This made it very difficult to be certain of the true time standard of the downloaded data. In a fieldwork environment, without comparable data from other instruments logged to a reliable time standard, there would be no way to determine the correct logged time and the data would be largely useless as a result. This drawback alone would make me hesitate to replace my existing Kestrel 4000, despite the many additional improvements in 20 years.

If there was a way to disable this auto-correction, I did not manage to find it in the menu settings.

My suggestion to Nielsen Kellermann would be to include a 'Disable Kestrel clock update from app' option in a future firmware systems setting. (Soon!)

Summary and conclusions

The Kestrel 5500L manages to squeeze a considerable environmental monitoring instrumental capability into a small, lightweight portable unit. Usability is helped by a logical user interface, a very substantial datalogging capacity and a straightforward and easy-to-use Bluetooth download function via the Kestrel LiNK app. Despite the constraints resulting from the small form factor, the performance of the sensor package is mostly good to very good, although response time can be slow for temperature and humidity measurements particularly where ventilation is limited, such as in a Stevenson screen in light winds: users must bear such limitations to logged measurements in mind. The accuracy of the sensors themselves was mostly excellent (although the wind speed measurements were about 15% too high when wind-tunnel tested), but it should be borne in mind that this review was based upon a single product sample necessarily assumed to be randomly representative of the standard manufactured product.

By comparison with my 20 year old Kestrel 4000, the Kestrel 5500L represents a significant step forward, and **I can wholeheartedly recommend its use in a fieldwork or field course environment**. However, due care and attention must be paid both to limitations in response time, and the automatic clock reset to mobile phone time on download 'feature': the latter can quickly and transparently render useless a set of measurements made to a pre-determined time standard such as UTC.

Website – UK distributor

https://r-p-r.co.uk/kestrel/kestrel.php

Nielsen-Kellermann website

https://nkhome.com/

This was an independent field test and review, free of inducements or payments by supplier or manufacturer.

Dr Stephen Burt FRMetS

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August 2022

www.measuringtheweather.com

The Weather Observer's Handbook (Cambridge University Press)