The Thies Precipitation Sensor.
A trial at Wokingham.

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1. Introduction.

In February 2011, a Thies Precipitation Sensor (TPS), Model 54103.20.041, was purchased and installed to undertake a comparison against data from the Wokingham Climatological Station.

It was decided for logistical purposes (to facilitate ease of connection to data logging/processing hardware) to install the sensor near my house, and depending on the outcome of the trial, to transfer it to the observing station at a later date. When looking at the results of this comparison, it should be noted that the TPS was located about 700 m from the site from which comparative readings were obtained. The TPS was also located at the most exposed point on top of a single storey flat roofed garage, at a height of 1 m above the roof and 5 m above the ground. A two storey dwelling was located to the Northwest of the TPS, and about 3 m distance at its closest, with another to the Southeast, about 5 m distant. The TPS had an open aspect for azimuths between 170 and 270 degrees, and between 030 and 090 degrees, but could be considered to be in the rain shadow of buildings in other directions, though the magnitude of any affect would depend on the strength and direction of the wind. There was also a possibility of rain splash from the garage roof and from the roofs of the adjacent buildings given rainfall of sufficient intensity.

2. The TPS

The Manufacturer claims the following attributes for the TPS, both on-line and in the 'Instruction for Use' sheets that were supplied with the sensor.

http://www.thiesclima.com/precipitation-sensor.html

1. A measuring instrument for the determination of the instantaneous precipitation intensity.
2. Integration of the precipitation intensity to calculate the precipitation quantity
3. The measuring signal is output as intensity-dependent analogue value.
4. It is possible to represent an intensity range from approx. 0.001 mm/min (0.06 mm/hr) up to 10 mm/min (600 mm/hr) with reasonable resolution.

The instrument consists of a horizontal line of IR phototransmission diodes facing a line of IR photodetector diodes across a 25 cm square sensing area. When an object (liquid or solid) falls through the area, the shadowing effect causes the detector output current to increase. The whole is encased in a waterproof plastic housing containing a regulated heater to prevent the build up of ice and snow. Power is obtained from a 24 volt AC PSU (not included). The unit is fitted with a bracket to facilitate clamping to a mast or pole. A free standing patio satellite dish mounding pole was purchased, and after bolting to a wooden base plate was placed in position on the flat roof and stabilised against wind movement using two roofing slates.

In order to obtain a continuous record of the TPS output, the output current of between 4 and 20 mA was taken through a 400 ohm load resistor and the resulting voltage stepped down to a maximum of 2000 mV to keep it within the limits of the ADC16, a Picolog analogue to digital converter for producing a suitable format for handing on to a PC.

http://www.picotech.com

The Picolog software provides both a graphical display and raw data in a spreadsheet format. By trial and error, I found that taking one reading per minute was sufficient to capture rainfall events, each reading comprising the average of at least 100 samples over that minute. The spreadsheet could easily be exported to other PCs on my network for post processing in Excel.

3. Ground Truth Instrumentation.

There are 3 types of rain gauge at the Wokingham climatological station. a) A standard 5 inch Met Office Mk2 gauge, which is read at 0900 GMT each day. b) An 8 inch tilting siphon gauge (TSR), which produces a continuous record on a paper chart affixed to a one rev/day drum. c) A tipping bucket gauge (TBR) (Young 52202) with a 200 sq cm collecting area, and a resolution of 0.1 mm. The latter gauge is connected to a Campbell Scientific CR10X data logger, and the time of each tip is logged to the nearest 0.5 seconds, allowing calculation of fairly precise rainfall rates up to approx. 500 mm/hr, although for brief falls that may be moderate/heavy but which may produce only 0.1 or 0.2 mm, the TSR gives a more accurate measure of the rate.

4. Setting up the TPS.

Having assembled and wired up the TPS, power was applied and a two day bench test was carried out. In this time, it was ascertained that the instrument was working, and produced an output within the manufacturer's specification. During this phase, the link to the ADC16 was set up and tested, and checks for stray 'pick-up' voltages which could affect the stability of the signal were made. Mechanical stress was applied to ascertain that there were not likely to be unexpected spurious signals caused by wind vibration. The operation of the internal heater was also checked.

At the end of this phase, the TPS was deployed on the garage roof, and logging commenced on the 29th January 2011. During that day, which was cold and with continuous low overcast but which appeared to be dry, the TPS indicated very slight precipitation on several occasions. My first thoughts were that this was spurious, but after dark, and using a powerful torch, it was possible to see a myriad of minute ice crystals in suspension in the air, an early encouraging indication of the sensitivity of the TPS. Having observed the operation of the 'exposed' TPS for a couple of days, it was time to commence the evaluation trial.

5. The Trial.

The trial commenced on the 1st February 2011, and was terminated on the 5th October 2011 when 3 days-worth of data was lost following a PC failure. By that time, it was decided that enough data had been collected to enable some conclusions concerning the operation of the TPS to be drawn. The one minute data from the TPS was analysed on a daily basis, and was compared with the data from the other local gauges. Rainfall amount was compared with the 5 inch official gauge and the TBR. Duration was compared with the TSR. Maximum rainfall rate was compared with the TBR and TSR. In this case, the maximum one minute rate in the 24 hour period from the TPS was compared with the maximum one minute rate from the TBR over the same period. Where possible, a measure of the maximum rate was obtained from the TSR, but for rates above about 50 mm/hr the inaccuracies inherent with this instrument lead to increasing uncertainty in the actual rate.

Using the calibration given in the TPS manufacturer's specification, indicating a log-linear relationship between the TPS output and precipitation rate, an equation satisfying the specification, with the TPS output configured as in this case, was found to be:

RR = EXP((V * 0.004797)-2.8134)

where RR = the rainfall rate in mm/hr

V = the indicated voltage (in mV) from the ADC16 after correcting for zero offset

Thus, a value of 0 mV equates to a rainfall rate of 0.06 mm/hr, 960 mV to a rate of 6 mm/hr, and one of 1920 mV to 600 mm/hr.

Note, the TPS produces a small current even with no precipitation is detected, and this results in a minimum voltage of 480 mV from the ADC16, indicating that the threshold precipitation rate that the TPC can detect is 0.06 mm/hr. The zero offset is set at 480 mV, giving a total span for the instrument and ADC16 from 0 to 1920 mV

Rainfall accumulation for the TPS can be calculated if the average rate over each minute is known, thus the accumulation from one minute at an average rate of 10 mm/hr would be 0.17 mm. The total accumulation over an hour would be the average of the individual one minute rainfall rates in that hour, and the daily accumulation the sum of the hourly values.

Rainfall duration for the TPS will be the sum of the minutes where the rainfall rate is not zero, though in practice, a rainfall rate of at least 0.1 mm/hr is required to assess duration from the TSR, so for the purpose of the trial the same criterion was adopted for the TPS.

The trial produced a total of 93 daily comparisons, each with a rainfall total, rainfall duration (for rate at least 0.1 mm/hr) and maximum rainfall rate for the 4 instruments, the TPS, the TBR, the TSR, and the 5 inch gauge, although duration for the TBR was not logged, and only 24 hour accumulation was known for the 5 inch gauge. Amount and duration are presented as monthly totals. Rainfall rate was ranked in terms of the TPS, and the average of 10 subsequent ranks is presented.

During the summer months, spurious signals from the TPS were noted. These usually occurred on sunny days, though also there were a few at night. These spurious signals were attributed to insects flying through the detector area, or walking on the face of the detector. On one occasion, a spurious signal which had the appearance of continuous slight precipitation for several hours during a night known to be dry was, on inspection of the sensor, found to be a spider's thread inside the sensor space moving about in the slight breeze. A tally of the number of days with insect effects each month and the total count (there could be 6 or more on some days) is given in Table 1.

6. Results.

Table 1. Monthly rainfall amount for TPS and 5 inch gauge, and duration for the TPS and TSR.

Month	Amount, TPS mm	5 inch gauge	Duration TPS hrs	TSR	Insects days with	count
Feb 2011	58.4	45.3	77.2	60.3	0	0
March	10.3	11.5	20.5	12.9	6	10
April	3.5	1.4	4.6	3.5	20	58
May	190.7	29.0	26.9	19.6	21	61
June	153.1	76.6	63.5	556	17	48
July	133.8	39.6	38.3	24.4	20	80
August	105.8	117.8	41.2	40.6	7	15
Sept	123.0	36.1	16.6	26.0	15	25
Total	778.7	357.4	288.9	243.3	106	297

Note: The amount registered by the TPS is based on the integration of the average one minute rainfall rates presented by the instrument, so that any error in the rate, or in the calibration values provided by the manufacturer, will lead to errors in this amount.

Table 2. Rainfall rate, average of blocks of 10 ranked TPS maximum daily values and the corresponding TBR and TSR values, all mm/hr-1

TPC rate rank	Average rate, mm/hr		
	TPS	TBR	TSR
1 to 10	210.4	39.4	38.5
11 to 20	90.1	41.0	33.5
21-30	30.7	18.8	15.7
31-40	11.2	19.8	16.7
41-50	7.5	13.3	12.4
51-60	3.6	6.2	7.4
61-70	1.5	2.5	4.0
71-80	1.0	3.1	3.1
81-90	0.7	0.5	1.8

Number of samples = 93
Number with TPS rate larger than TBR or TSR = 44
Number with TPS rate smaller then TBR or TSR = 49

The samples with the TPS rate larger than the TBR/TSR are skewed towards the high values. The highest daily max rate on the TPS was 339 mm/hr, with corresponding rates on the TBR of 52.8 and TSR of 65.0 for the same day. The highest TBR of 123.3 mm/hr had a TPS of 310 mm/hr on the same day. But there was also a daily TPS of 257 mm/hr with a TBR of 3.1 mm/hr and TSR of 3.6 mm/hr, also on another day, a TPS of 137 mm/hr with both TBR and TSR only giving 2.1 mm/hr.

The reason for these big discrepancies is not entirely clear. There is obviously scope for differences in rain rate due to the 700 m separating the sites when the precipitation is convective in nature. There were several occasions when the TPS recorded quite small rainfall rates when the TBR had quite high ones, notably 84.6 mm/hr on the TBR and 9.3 mm/hr on the TPS, and another example when the TBR recorded 64.3 mm/hr and the TPS 17.1 mm/hr. These are probably obvious examples of a genuine spatial variability of convective rain rates. This suggests that some of the difference, when the TPS recorded much higher rates than the TBR could also be genuine.

Also, the way that the TPS operates if the precipitation contains ice, either in the form of hail stones or of raindrops containing solid ice particles, is not known, but may explain some of the TPS apparently excessively high rates should a solid particle give a higher signal than a liquid one of the same size.

Another factor which could affect the TPS is its exposure. Under certain conditions of wind and high rainfall rates, ‘spray’ off the adjacent house roof, or splashing from the flat garage roof, cannot be ruled out. Both effects would serve to falsely elevate the TPS rainfall rate if detected by the sensor.

The monthly rainfall totals for the TPS in table 1 show that in 6 of the 8 months the TPS overestimated the amount, sometimes by quite a large measure (May and July). As stated earlier, over-inflated rainfall rates by the TPS will lead directly to this result.

The TPS monthly rainfall duration is a better match with the TSR, but still contains quite large monthly differences with the TSR. One obvious defect in the design of the TPS is the ability of driving rain to impinge on the detector faces, and the resulting droplets will produce a ‘raining’ signal after the rain has ceased and until the droplets evaporate. On some occasions this has been observed to be in the order of one hour, but the actual time taken to evaporate the droplets will depend on several factors, and may be quicker than this on other occasions. The presence of droplets on the detector will also falsely elevate the rainfall rate during actual precipitation.

Another problem affecting rainfall duration, though of less significance than the face wetting, is hysterisis in the instrument response to a cessation of rainfall. It was noticed during pre-deployment tests that there was a finite lag between the stopping of excitation of the sensor and return of the instrument output to a zero state. The time taken was variable, and depends on the instrument output immediately prior to cessation of precipitation, being longer for higher precipitation rates, but can be in the order of several minutes.

Finally, the problem with insects passing through the sensor space would seem to be insurmountable with this design. While the use of insect spray will, for a time, prevent spiders constructing their webs in front of the detector, moths, butterflies, bees, wasps and flies of all shapes and sizes are free to traverse the sensor space at will. While there is a correlation between the number of insect signals from the instrument, and sunshine/warmth and humidity, it has not been found feasible to attempt to filter out these signals automatically during post processing of the data, though once identified they can be removed manually.

7. Summary and Conclusions.

In summary, the Thies Precipitation Sensor under trial at Wokingham fails to reliably achieve the Range of Application claimed by the manufacturer. The TPS does produce a signal roughly proportional to precipitation intensity, but is not able to reach a standard of reproducibility required of an instrument for the determination of instantaneous precipitation intensities. As a result, the claim that by integrating the precipitation intensities, the precipitation quantity can be calculated is only true if it be understood that the quantity thus calculated may bear little resemblance to the actual amount of precipitation. Attempts to recalibrate the TPS using the latest comparison with the other gauges was not practicable due to the inconsistent behaviour of the TPS from one event to another.

The claim that it is possible to represent intensity ranges from approx. 0.06 mm/hr up to 600 mm/hr with reasonable resolution is again only true if an accurate measure of intensity is not required.

On the plus side, the instrument is well made and has operated reliably continuously for 18 months under both summer and winter conditions. It is possible that the results of the trial may have been more favourable had the TPS been located adjacent to the other measuring devices, and had it been given a more standard exposure.

Even though I am unable to use the TPS as a measuring instrument, it does have its uses, especially for detecting very slight precipitation, also the time of onset of any precipitation is fairly unambiguous, even if the time of cessation must be treated with caution, especially after heavy falls.

Appendix 1.
Example of TPS output.

Date 10 June 2011
Situation. Two slight rain showers near midday. Period of rain commenced near 1900z, and produced nearly 10 mm before midnight with some heavy bursts.
Maximum rain rate TPS 48.6 mm/hr TBR 24.0 mm/hr
Accumulation TPS 14.74 mm, 5 inch 9.9 mm, TBR 9.5 mm
Duration TPS 3.3 hr TSR 3.4 hr
Notes: TPS accumulation too high due to excessive rainfall rates. Duration good.

Fig 1. TPS raw data (time; output voltage) for 10th June 2011
Fig 2.   TBR accumulation for 10th June 2011, (time; rainfall accumulation mm)

Fig1.

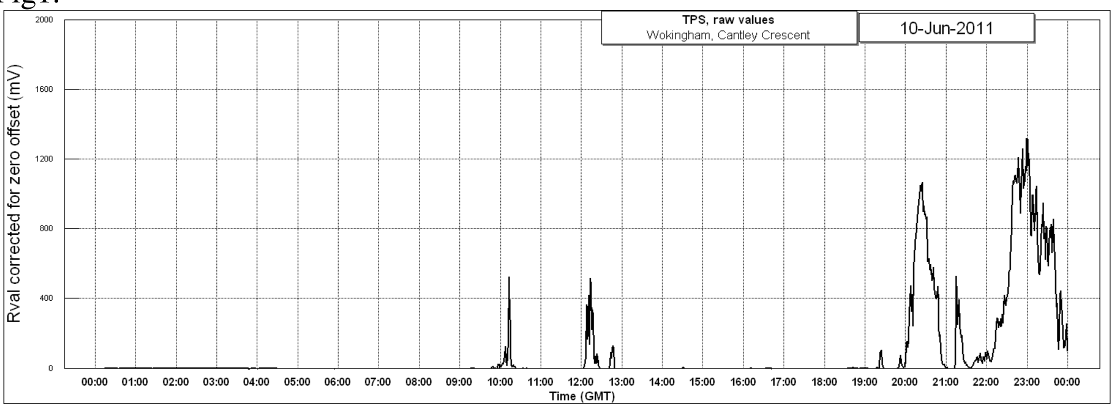

Fig2.