Hardware Information

This comparison was performed using the following radiation shields:

- Home-built fan aspirated shield (FARS)
- Davis #07714 naturally aspirated shield
- Ambient Weather LX100 naturally aspirated shield
- AcuRite VN1TX (aka 5n1) shield

The VN1TX unit is fan aspirated when there is enough solar energy on the solar cell to run the fan; at other times it is passive. This is the version that only has a single solar cell. It uses a Sensirion SHT21 temperature sensor which has a typical accuracy of +-0.3C (+-0.54F).

All other shields are fitted with custom-built sensors whose (NIST traceable) accuracy is +-0.08C (+-0.15F).

The test location is at approximately 38 degrees north latitude. Sensors are shaded by trees in the early morning so sun appears rather suddenly on them around 10:30Am local time.

Test Setup

As shown in the photograph, the passive shields and AcuRite sensor were mounted in one cluster while the FARS unit was separately mounted nine feet away from the passive cluster. The VN1TX was oriented approximately north as per AcuRite installation instructions. The FARS air inlet and passive shield temperature sensors were all 64-inches above ground level, and the bottom of the VNT1X (where the temperature sensor is located) was 78 inches above ground level.

All sensors are wireless, with the exception of a DC fan power connection to the FARS.

Data was recorded to a CSV log file using the WeatherStationDataLogger (WSDL) windows application.

Discussion

While in many cases it is desirable to locate a weather station's anemometer separate from temperature measurement, in this case having the anemometer integrated with the temperature sensor in the VN1TX is fortuitous. This allows for an examination of the effect of wind on solar shielding effectiveness.

The first six days of the test run were dominated by clear skies, day and night. There was a significant negative offset on VN1TX temperatures at night and I knew from past experience that some of this might be due to radiational cooling to the clear night sky. On the last night of the test run, a thick layer of low stratus moved in, eliminating the effect of cooling to a clear night sky. This provided a 3.6 hour period over which a calibration comparison between sensors was made.

Each of the sensors in this experiment has a different time lag in its response to temperature changes. This results in a difference between readings whenever the air temperature is changing (which is pretty much all the time). It is just a matter of how much and how fast the air temperature is changing. However, on average these differences will average out to zero if one is careful to avoid certain situations such as a time segment where the temperature is only increasing.

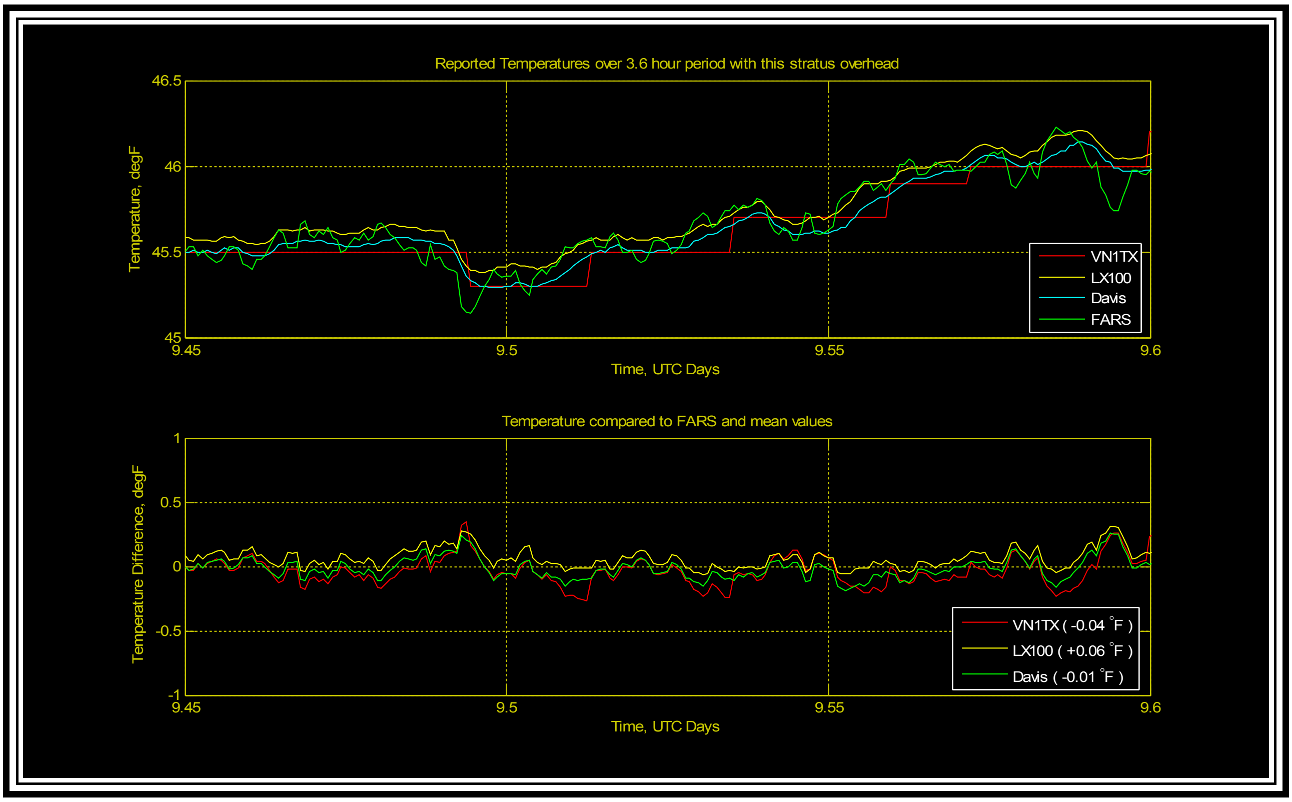
Several graphs of results are presented below. The time axis on each graph is in days, UTC relative to 00 UTC on the first day of the test run. The test location is in the Pacific time zone and daylight savings time was in effect, so midnight UTC occurs at 5PM local time. Temperatures are in degrees Farenheit and wind speed is in knots (MPH = knots * 1.15).

In analyzing overall effects (including that of wind), subsets of data are extracted and averaged for separate day and night periods. The morning and evening intervals where the lack of fan rotation in the VN1TX creates large errors is intentionally excluded from these averages. Obviously, including those times would result in a significant increase in average differences between the VN1TX and FARS readings.

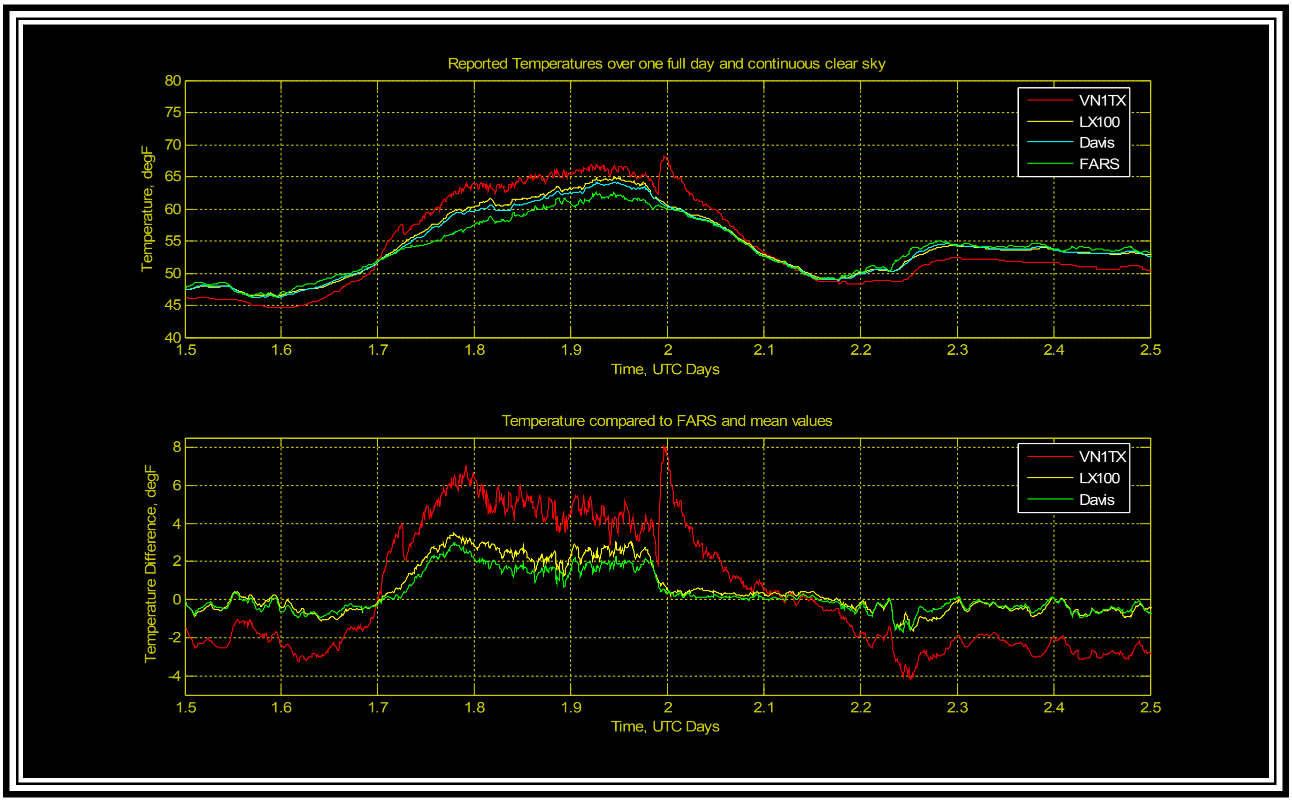
Data extracted for the night period runs from 11PM through 6AM and the day period is from 11AM to 4PM local daylight savings time.

Results

The first data graph image contains two sub-plots. This is the 3.6 hour calibration interval with a thick stratus layer overhead. The top graph shows the temperatures reported by the four sensors. The lower graph shows temperatures reported by the VN1TX, LX100 and Davis units relative to the FARS temperature. The mean differences are also shown in the graph legend. As luck would have it, this particular VN1TX unit has an SHT21 sensor with a very small temperature difference compared to FARS. With this difference being so small, no adjustments were made to the VN1TX temperatures for calibration purposes. The remaining graphs below are all showing raw temperatures from each sensor. It is also worth pointing out that a fair portion of the up-and-down variation seen in the lower graph is probably due to differing time lags in each sensors' response to changes.



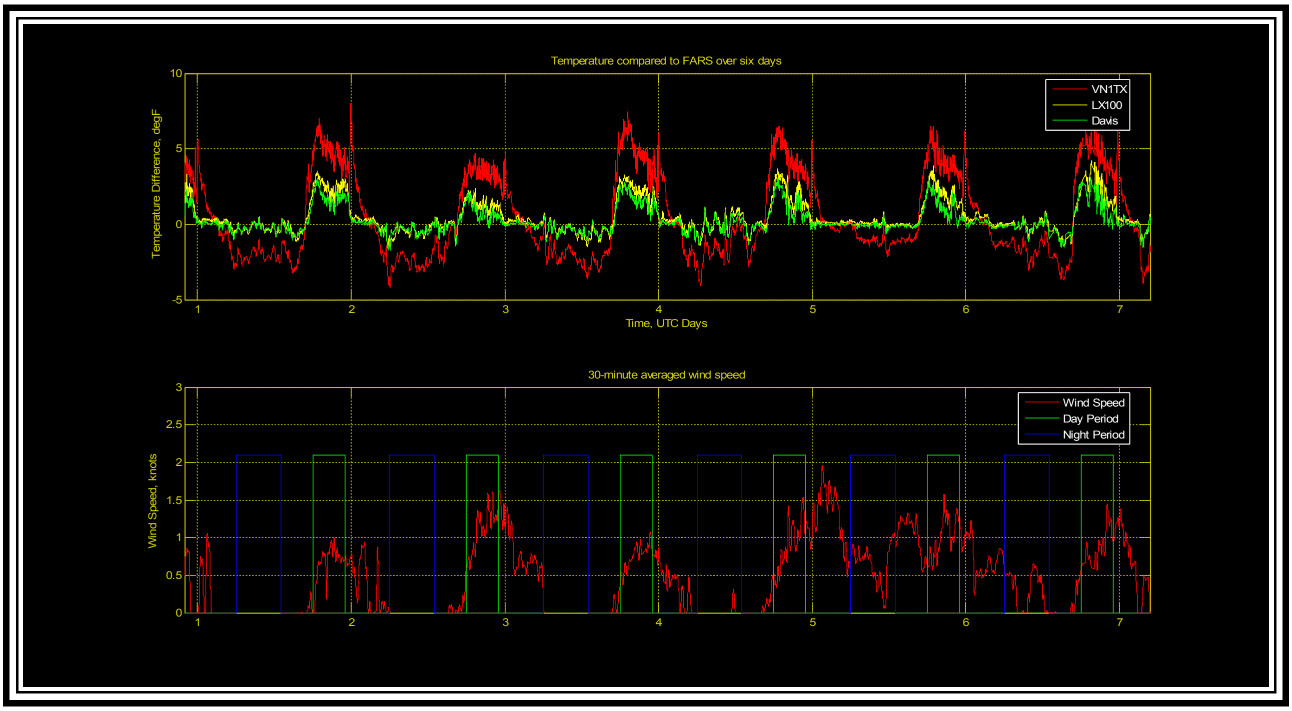
The next graph shows the test run over one full day with clear skies.



Most obvious in the VN1TX data are the "bat ears" at x-axis locations of about 1.73 and 2.0 where the aspirating fan turns off and on. Because morning sun is shaded by trees until about 10:30AM local time, the morning bat-ears are less pronounced -- when the sun finally hits the VN1TX sensor, it is already strong enough to start the fan running. Remember that this is the smaller 5n1 AcuRite sensor with a single solar cell -- the daytime performance of dual-solar cell unit is going to be different (hopefully better). Once the fan is running, solar heating bias is between 4 and 6 degrees F on average on this day. At night, there is somewhere between 2 or 2.5F of cooling bias due to the clear night sky.

The Davis and LX100 passive shields are very close in performance here, running between perhaps 1.7F and 3F of solar heating during the day. At night, these shields are exhibiting a minimal amount of cooling (less than 0.5F) to the clear night sky.

The next graph shows six consecutive days of the test run. Temperatures compared to the FARS and 30-minute averaged wind speed are the two sub-plots here. From this data, numerical averages of day and night temperature differences have been computed and are tabulated below. The day and night time intervals for which data is extracted for numerical averages are shown with green and blue boxes respectively on the graph.



Wind clearly (and not unexpectedly) has a significant effect here. For example compare the daytime performance of day 1 to day 2. Average wind is nearly double (1.10 on day 2 versus 0.65 on day 1) and the temperature difference between FARS and all othere sensors is much less on day 2 compared to day 1. The effect is especially noticeable with the VN1TX where the difference drops from 5F to 3.5F with the higher average wind.

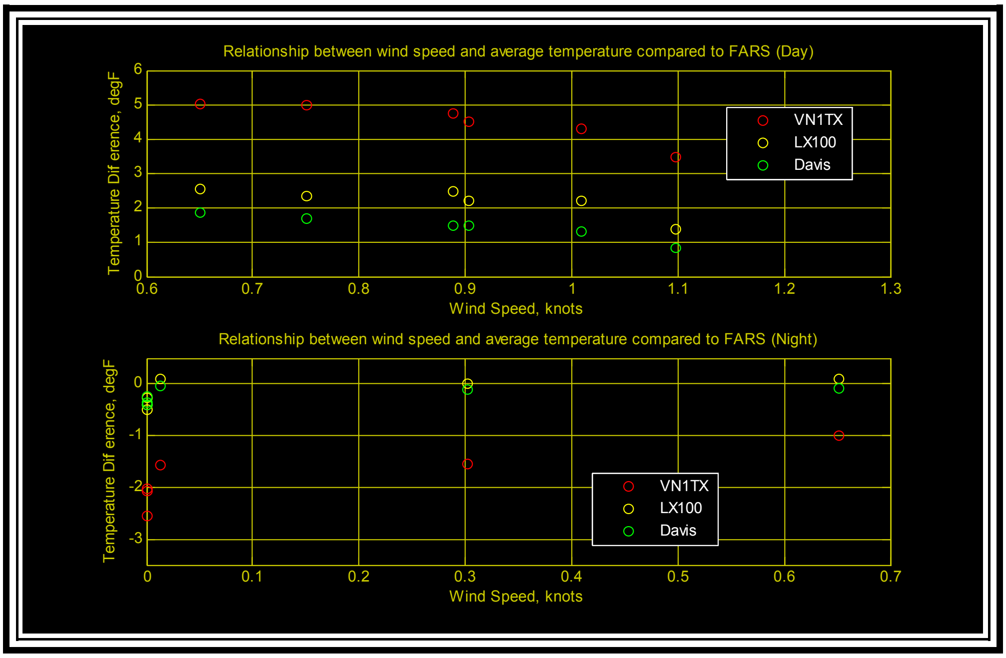
At night, wind is also well correlated with temperature differences in all sensors and is especially obvious with the VN1TX sensor. Differences are typically around 2 to 2.5F on calm nights and drop to 1F with only 0.65 knots of average wind.

Below are the tabulated average data extracted for day and night periods on each of the six days. The first table shows daytime averages, and the second is night.

To aid in visualizing the relationship between wind speed and the amount of temperature difference due to solar heating and radiational cooling, two scatter plots are also shown below in which the trends are clearly visible.

Daytime average differences (degF)				
Day	Wind (knots)	VN1TX	LX100	Davis
1	0.65	+5.02	+2.55	+1.85
2	1.10	+3.48	+1.38	+0.84
3	0.75	+4.98	+2.34	+1.71
4	0.90	+4.51	+2.22	+1.50
5	1.01	+4.30	+2.20	+1.31
6	0.89	+4.74	+2.49	+1.48

Nighttime average differences (degF)				
Day	Wind (knots)	VN1TX	LX100	Davis
1	0.00	-2.08	-0.28	-0.24
2	0.00	-2.55	-0.49	-0.40
3	0.00	-2.03	-0.40	-0.37
4	0.01	-1.57	+0.09	-0.04
5	0.65	-1.01	+0.08	-0.08
6	0.30	-1.55	-0.01	-0.10



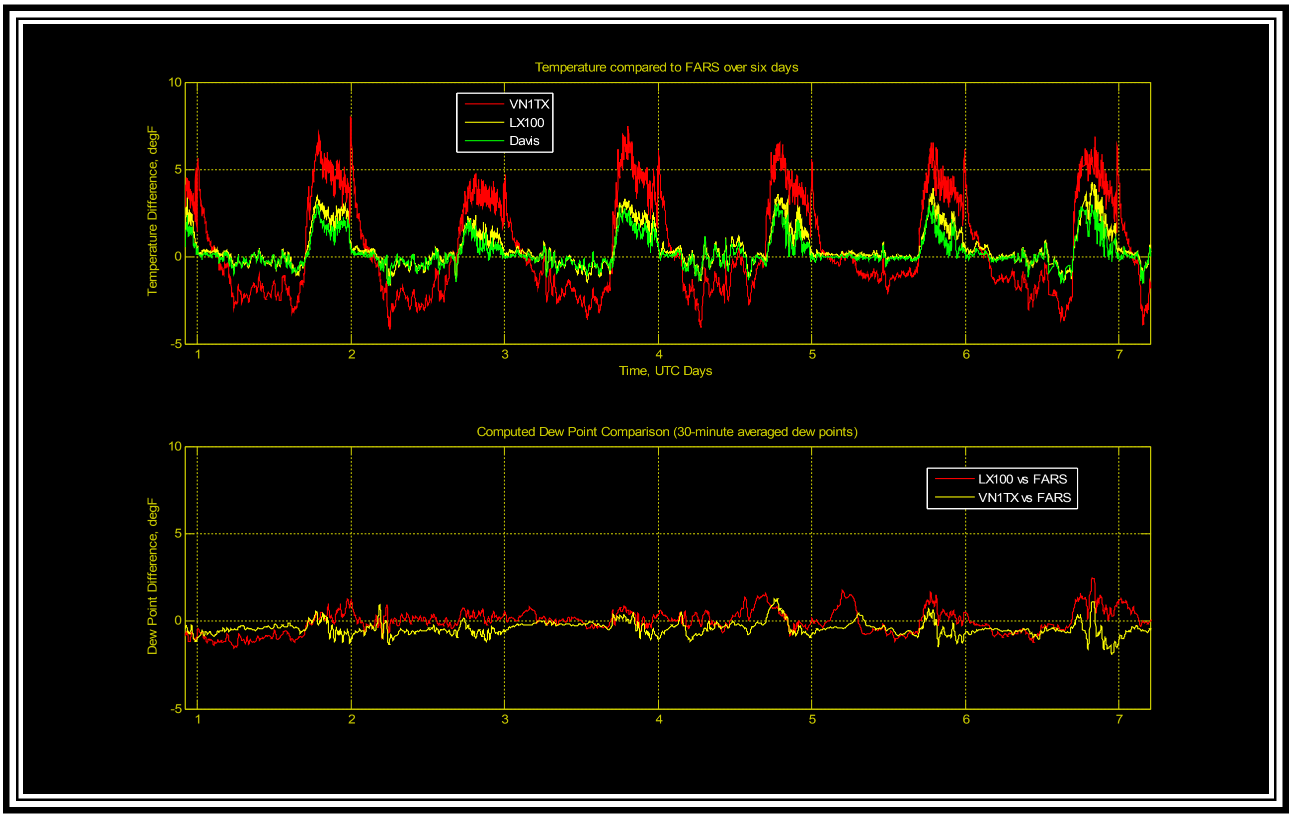
Dew Point Comparison

This report is about measuring temperature. However, the sensors used also measured relative humidity, and it is of perhaps passing interest to examine their performance in the presence of solar heating and radiational cooling.

Only three of the shield setups had humidity measurement capability; the FARS and LX100 shields used Sensirion SHT15 sensors and the VN1TX uses an SHT21 sensor (same manufacturer).

Since all humidity sensors are exposed to air with the same dew point it is interesting to compare computed dew points. The sensors only report relative humidity so it is necessary to compute dew point from the temperature and humidity reported by each sensor.

A properly functioning humidity sensor would be expected to measure the same dew poitn value, even if it is warmed by solar radiation compared to another sensor in the same parcel of air.



Computed RH data turns out to be very noisy and direct comparison of dew points is easier to comprehend if the dew point data is low-pass filtered. A 30-minute averaging filter was used to reduce the noise on this data before comparison. Such a filter introduces a 15-minute delay in the result, and that has been compensated by shifting the data by the amount of delay; thus it aligns properly with the temperature graph above it.The result graphed above shows that the dew points are indeed relatively insensitive to variations in temperature between sensors.

For the sake of completeness, below is the same graph, but with un-filtered dew point data.