Measurement and Uncertainty in Death Valley Temperatures

Dirk V. Baker[1], Todd Lericos[2], Richard Friese[3], Shannon Mazzei[3]

1. Campbell Scientific, Inc. Logan, UT USA
2. US National Weather Service*, Las Vegas, NV USA
3. US National Park Service*, Death Valley NP, CA USA

Background

- In August 2020 and again in July 2021, the official National Weather Service (NWS) weather station at Death Valley NP reported 130 °F (55.4 °C)
- If confirmed, this would set a record high temperature at the site for automated measurements
- The sensor model on this station is a Campbell Scientific CS215, which measures temperature and relative humidity, installed in a passive radiation shield
- In a collaboration between the NWS, National Park Service (NPS), and Campbell Scientific (CS), an additional station with several sensors was installed in May 2021 for comparison

Instrumentation

- The temperature sensors installed on the CS station (Figure 1) include:
  - Thermistor beads (3x)
  - 109 temperature sensor (thermistor)
  - HygroVUE™5 temperature & relative humidity sensor (2x)
- The beads and one HygroVUE™ 5 were installed in aspirated shields (Apogee TS-100), the 109 and second HygroVUE™ 5 were in passive shields
- Table 1 shows key specifications of the temperature sensors
- A pyranometer (CS320) and sonic anemometer (ClimaVUE™ 50) were also included
- The triplicate thermistor beads and 109 were compared with a high-accuracy standard in a liquid bath prior to deployment and showed agreement within a few hundredths °C [1]
- The NWS station (Figure 1) measures the sensors once per minute

Figure 1.

Figure 1 Key

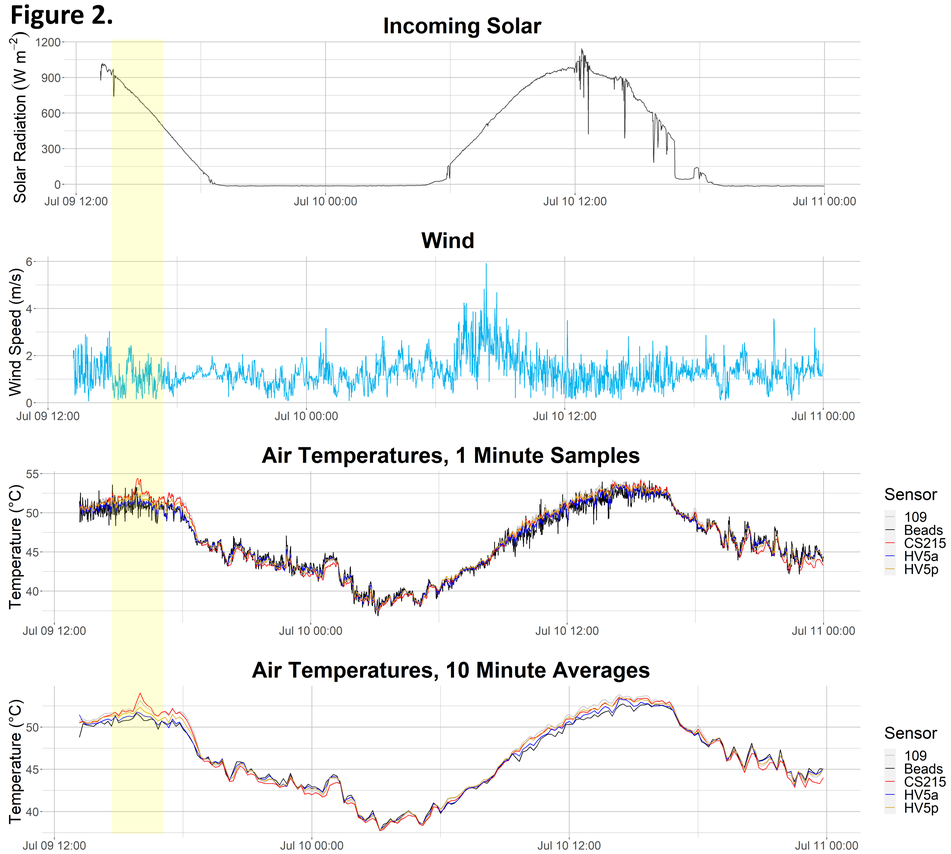
1. CS320 pyranometer
2. ClimaVUE™ 50 All-in-one
3. TS-100 aspirated shield with triplicate thermistor beads
4. Passive shield with 109 sensor
5. Passive shield with HygroVUE™ 5
6. TS-100 aspirated shield with HygroVUE™ 5
7. Passive shield with CS215
8. 05103 Wind Monitor

Table 1.

Sensor	Time Constant	Conditions	Uncertainty (at 50-60 °C)
CS215	<120 s	63%, 1 m/s	±0.9°C
HygroVUE™ 5	<130 s	63%, 1 m/s	±0.4°C
109	30 to 60 s	63%, 5 m/s	~±0.05°C [1]
Beads	7 s	63%, 1 m/s	~±0.05°C [1]

Key sensor specifications.

Figure 2.



Processing & Results

- The long time constants of the CS215 and HygroVUE™ 5 (Table 1) indicate that it would take 6 to 7 minutes to equilibrate to 95% of a step change
- 10-minute averages were used for numerical comparisons, but 1-minute comparisons are shown for reference (Table 2)
- A spike in air temperature on the afternoon of July 9, 2021 was shown by all sensors, but not as high as the CS215 (Figure 2)
- The CS215 and HygroVUE™ 5 in passive shields agreed well, though with discrepancies at night (Table 2)
- The two HygroVUE™ 5 sensors showed expected differences due to an aspirated shield (Table 2)
- The aspirated HygroVUE™ 5 agreed well with the thermistor beads (Table 2)

Table 2.

	Interval (minutes)	Mean CS215 vs $HV5_p$	SD CS215 vs $HV5_p$	Mean $HV5_p$ vs $HV5_a$	SD $HV5_p$ vs $HV5_a$	Mean $HV5_a$ vs Beads	SD $HV5_a$ vs Beads
Day	1	-0.0446	0.3432	0.3123	0.3515	0.1436	0.4790
Night	1	-0.2866	0.1866	0.0480	0.1598	-0.0445	0.3307
Day	10	-0.0441	0.3233	0.3130	0.3220	0.1439	0.1838
Night	10	-0.2877	0.1714	0.0476	0.1316	-0.0451	0.1523

Summary comparison statistics for the period from May through November, 2021. SD = standard deviation, HV5 = HygroVUE™ 5, p = passive shield, a = aspirated shield, Beads = average of three thermistor beads

Summary & Key Points

- July 2021 CS215 high not supported by other sensors
- Time constants should be considered in comparisons in general
- This focuses only on the differences between the sensors & shielding
  - Numerous other sources of uncertainty
- How should extremes be recorded?
  - There does not seem to be a standard for how extremes are recorded – single measurement vs smoothing or averaging
  - WMO[2] provides guidance on measurement intervals based on sensor time constant, but does not explicitly address extremes

***Note:** *This collaboration does not imply an endorsement of Campbell Scientific by either the U.S. National Weather Service nor the U.S. National Park Service.*

References

1. ***But it's a Dry Heat… like a Furnace.*** **Blog article.** https://www.campbellsci.com/blog/death-valley-collaboration
2. ***CIMO Guide 8.*** *https://community.wmo.int/activity-areas/imop/cimo-guide*