**Introduction**

- Early 1960s: silicon-cell pyranometers introduced
  - Much lower price, but less accurate than traditional thermopile pyranometers
  - Narrow spectral response (360-1120 nm) means they require a clear view of the sky and over-estimate solar radiation on cloudy days
  - Low price greatly increases their use in environmental research projects
- 2017: low-cost, digital thermopile pyranometers introduced by Campbell Scientific and Apogee Instruments (CS320)
  - Broad spectral response (385-2105 nm)
  - Correctly measure solar radiation on cloudy days
  - Affordable to environmental research and mesonets without sacrificing accuracy and flexibility
  - Not all pyranometers are of the same quality.
  - Three pyranometer categories established by the World Meteorological Organization (WMO) and the International Organization for Standardization (ISO)
  - The ISO categories named "secondary standard," "first class," and "second class" closely correspond to the WMO categories named "High quality," "Good quality," and "Moderate quality" (Jarraud 2014) (Table 1).

**Comparison Method**

- Solar radiation data were collected with a Campbell Scientific CR1000 datalogger with an AM16/32B multiplexer and the following co-located pyranometers:
  - CS320 digital thermopile pyranometers (n=10)
  - CS300 silicon-cell pyranometers (n=20)
  - SP Lite 2 silicon-cell pyranometers (n=5)
  - L200 silicon-cell pyranometers (n=5)
  - L200R silicon-cell pyranometers (n=5)
- 4 ISO secondary standard pyranometers:
  - Kipp & Zonen CM 11
  - Kipp & Zonen CMP 11
  - Hukseflux SR20
  - EKO MS-80

**Results**

- Overall, data from the recently introduced CS320 showed strong agreement with secondary standard pyranometers and a marked improvement over silicon-cell pyranometers (Figs. 1-3)
  - As expected, the greatest differences were during cloudy to partly-cloudy days where differences between silicon-cell and secondary standard pyranometers were often 20-20 whereas the CS320 data were most often within 2% (Figs. 1, 2)
  - The relatively large differences as expressed in percentages (Fig. 1b) at low solar angle (morning and evening) are of small absolute magnitude
- A good relationship between data from secondary standard versus the CS320 is virtually 1:1 with small variance (Fig. 3)

**Table 1.** ISO and WMO pyranometer standards compared to CS320 specifications

<table>
<thead>
<tr>
<th>ISO and WMO Standard</th>
<th>First Class</th>
<th>Second Class</th>
<th>CS320 Thermopile Pyranometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time (1%))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero Offset A</td>
<td>± 0.5 mW/m²</td>
<td>± 1.5 mW/m²</td>
<td>± 5 mW/m²</td>
</tr>
<tr>
<td>Zero Offset B</td>
<td>± 2 mW/m²</td>
<td>± 4 mW/m²</td>
<td>± 8 mW/m²</td>
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<tr>
<td>Uncertainty (up to 50%)</td>
<td>± 0.5 %</td>
<td>± 1.5 %</td>
<td>± 3 %</td>
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<tr>
<td>Mounting block</td>
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<tr>
<td>Tilt Response</td>
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<td>0°</td>
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<tr>
<td>Daily totals</td>
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<td>0%</td>
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<tr>
<td>Uncertainty (95% confidence level)</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
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<tr>
<td>Spectral range</td>
<td>300 to 3000</td>
<td>300 to 3000</td>
<td>385 to 2105 m²</td>
</tr>
<tr>
<td>Resolution</td>
<td>1 W/m²</td>
<td>5 W/m²</td>
<td>1 W/m²</td>
</tr>
</tbody>
</table>

**Summary and Additional Features**

- Data from the CS320 compare favorably with high-end pyranometers (Figs 1-3), offering a strong improvement in measurements over silicon-cell pyranometers
  - Priced similarly to silicon-cell (Table 2)
  - Internal heater to reduce errors from dew, frost, rain, and snow
  - Dome shape head allows sensor to shed dew and rain
  - SDI-12 digital output, compatible with all current Campbell Scientific dataloggers and other dataloggers compliant with the SDI-12 standard
  - Calibration data stored in sensor – no changes to program required after routine re-calibrations
  - Built-in tilt sensor that simplifies installation, diagnostics, and remote troubleshooting
  - Designed for long-term stability
  - Not intended for markets that require ISO certification

**References:**