Calibrating Space Radiometers to Ground based TSI Standards

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The World Radiometric Reference (WRR)

- The World Radiometric Reference (WRR) has been the conventional standard for ground based solar irradiance since 1977.
- The WRR is realized by a group of electrical substitution radiometers, the World Standard Group (WSG).
- The World Radiation Center (WRC) is mandated by WMO for maintaining and operating the WSG and for disseminating the WRR.
- The WSG will be replaced by the Cryogenic Solar Absolute Radiometer (CSAR).
- PMOD/WRC is a designated institute by METAS and WMO and currently holds eight CMC’s.
International Pyrheliometer Comparisons (IPC)
Stability of the WRR since 1980
WRR traceable TSI experiments

- SOVA/EURECA
- VIRGO/SOHO
- SOVIM/ISS
- PREMOS/PICARD (also SI traceable)
A cryogenic scale for solar irradiance measurements
Monitor for Integrated Transmittance

MITRA

Cryogenic Solar Absolute Radiometer

CSAR
Cryogenic Solar Absolute Radiometer (CSAR)

- Mechanical cooler
- Receiver cavity
- Quartz window 10 mm
- Reference block 20 K

METAS NPL
PMO2 represents the WRR

SI to WRR: \(-0.18\% \pm 0.053\% (k = 1)\)

PMO2 represents the WRR
Window Contamination Effect

<table>
<thead>
<tr>
<th>Item</th>
<th>Uncertainty (k = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MITRA</td>
<td>0.036%</td>
</tr>
<tr>
<td>Window contamination</td>
<td>0.035%</td>
</tr>
<tr>
<td>CSAR</td>
<td>0.014%</td>
</tr>
<tr>
<td>Repeatability (Statistical)</td>
<td>0.021%</td>
</tr>
<tr>
<td>WRR</td>
<td>0.030%</td>
</tr>
<tr>
<td>Overall SI-WRR intercomparison</td>
<td>0.064%</td>
</tr>
</tbody>
</table>

CSAR: 0.052% (Goal: 0.01%)

2015-06-30
SI to WRR: -0.22% ± 0.053% (k = 1)
2015-12-14
CSAR and MITRA windows switched
2016-03-22
windows cleaned in ultrasonic bath

IPC-XII

-0.3%

Walter et al. 2016
Dark Signal Compensation
(4-channel MITRA)

Simulated effect of dark compensation

Walter et al. 2016
The influence of atmospheric conditions on diffraction limits the achievable uncertainty!

Figure 3.21: Diffraction effect versus solar zenith angle for different model atmospheres for Davos (spectra calculated with LibRadtran). “Summer” and “Winter” are LibRadtran standard atmospheres, while the “Extreme” cases are based on the Davos water vapour climatology.

Figure 3.22: Seasonal influence on the diffraction correction, with 1σ uncertainties, based on Davos water vapour data.
Revised Target Uncertainty (k=1)

<table>
<thead>
<tr>
<th>Category</th>
<th>Uncertainty</th>
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</thead>
<tbody>
<tr>
<td>MITRA</td>
<td>0.015%</td>
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<tr>
<td>CSAR</td>
<td>0.010%</td>
</tr>
<tr>
<td>Equivalence of Windows</td>
<td>0.005%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.019%</strong></td>
</tr>
</tbody>
</table>
Figure 3.32: Distribution of temperatures in the cavity for the open and closed phase respectively in air and vacuum.
JTSIM Air-Vacuum Ratios for...

DARA

SIAR

+ ambient
+ vacuum

+ SIM #2
+ SIM #3

vacuum ambient pressure

Channel A

Channel B

Channel C
DARA/JTSIM calibration at Gemini Observatory, China
Pros and Cons of calibration against irradiance standard

- Full solar spectrum
- Diffraction, scattered light
- Standard mode of operation
- Closure experiment with component-level primary calibration
- Fairly simple infrastructure
- Low uncertainty

- Air-vacuum transfer
- Circumsolar component (field of view)
- “out in the wild” (wind, weather)
- Depends on sunshine
Status of VIRGO data

- Level 1 data are updated ~monthly on ftp://vdc.iac.es
- Level 2 data (corrected for degradation) have not been updated after Claus’ last data release
- A new method to determine instrument degradation is currently being developed using machine learning using exponential-linear, spline, monotonic regression, or a combination of the three methods
  - https://github.com/roksikonja/dslab_virgo_tsi
- It is not currently planned to continue work on the PMOD composite
Thank you for your attention!