2017 Pyrgeometer Inter-comparison in Darwin, Australia

Nozomu Ohkawara
Japan Meteorological Agency (JMA)
Contents

- Background
- 2017 Pyrgeometer Inter-comparison in Darwin, Australia
  - Outline
  - Instrument settings
  - Data used for the analysis
- Results
  - Offset under clear sky at night
  - Offset with cloud
- Summary
Background

- The infrared integrated sphere radiometer (IRIS) has been developed at PMOD as transfer standard of longwave radiation.
- The current standard of WISG consisting of 4 pyrgeometers has 4-5 W/m$^2$ offset against the IRIS from the results of inter-comparison at PMOD.
- The difference should also be confirmed at high total column water vapor (TCWV) so that the IRIS would serve as the world standard of longwave radiation.

**DL Difference (W/m$^2$)**

![Graph showing DL differences between WISG and IRIS at PMOD](Gröbner, 2014 BSRN meeting in Bologna)

**DL vs TCWV at Tateno station in Japan (Jan. 2013 – Jul. 2015)**
Outline

Collaboration campaign between Australian Bureau of Meteorology (BoM) and Japan Meteorological Agency (JMA) (special thanks to Mr. Michael Milner and Mr. Ian Dolley, Standards and Metrology Group, BoM)

- Venue: Darwin Airport (BSRN DWN station)  
  12.4239 S, 130.8925 E, 30.4m asl
  10 nights, 30 hours under clear sky
- Participating radiometers:  
  1 IRIS and 4 pyrgeometers
- Ancillary data  
  - Water vapor (GNSS, rawinsonde)  
  - Clouds (eye, satellite, sky camera)  
  - Others (air temp, press, …)
Instrument settings

IRIS

Pyrgeometers

Data logging system

Radiometer

Controller

DWN station building

75m

Pyrgometers

Data logging system
All 4 pyrgeometers are traceable to WISG and IRIS#3 is comparable to the other IRISs.

- Eppley PIR#34006F3 (YSI dome&body thermistor, participated in IPgC-II 2015, owner: BoM)
- K&Z CG4#060920 (YSI body thermistor, participated in IPgC-II 2015, owner: BoM)
- K&Z CG4#010567 (PT100 body thermistor, participated in IPgC-II 2015, owner: JMA)
- K&Z CGR4#070039 (PT100 body thermistor, calibrated at PMOD in 2016, owner: JMA)
- PMOD IRIS#3 (participated in IPgC-II 2015, owner: BoM)

1-minute averages are compared.
(pyrgeometer: average of 60 measurements, IRIS: average of 5-6 measurements)
- Average of 4 pyrgeometers are compared to IRIS#3

(The values of 1-min average of 4 pyrgeometers are very close with each other and stable throughout the inter-comparison)
Total column water vapor

- GNSS precipitable water vapor (PWV) (estimates from GNSS data using the free software “RTKLIB” (Takasu 2007))
- GNSS PWV was calibrated against rawinsonde PWV (12Z flights and 3 special flights at 15Z)

TCWV range during the inter-comparison: 35 - 62 (mm) → fit the purpose
**Clouds**

**Sky camera**

Data in clear sky at night (sun elevation < -6 deg.) are selected.

**Satellite images (Himawari 8)**

*four directions of north, south, east and west*

**Eye obs.**
Selection of clear sky at night during the inter-comparison

1) 20:00 16Oct - 22:30 16Oct
2) 20:30 17Oct - 00:40 18Oct
3) 19:00 18Oct - 20:30 18Oct
4) 22:30 19Oct - 04:00 20Oct
5) 19:00 21Oct - 03:50 22Oct
6) 19:30 23Oct - 03:45 24Oct
7) 20:00 24Oct - 21:30 24Oct

About 32 hours in total

Time series of DL and GNSS PWV during the inter-comparison
Results

Offset under clear sky at night

DL differences in clear sky at night
Right) 2017 inter-comparison in Darwin,
Left) Inter-comparison at PMOD (Gröbner 2014)

DL differences in each TCWV class

<table>
<thead>
<tr>
<th>Class</th>
<th>Ave.</th>
<th>Max.</th>
<th>Min.</th>
<th>Std dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCWV&lt;40</td>
<td>-5.69</td>
<td>-0.53</td>
<td>-8.76</td>
<td>1.69</td>
<td>341</td>
</tr>
<tr>
<td>40=&lt;TCWV&lt;45</td>
<td>-5.44</td>
<td>-1.71</td>
<td>-10.22</td>
<td>1.85</td>
<td>555</td>
</tr>
<tr>
<td>45=&lt;TCWV&lt;50</td>
<td>-4.99</td>
<td>-0.20</td>
<td>-10.18</td>
<td>2.52</td>
<td>676</td>
</tr>
<tr>
<td>50=&lt;TCWV</td>
<td>-4.81</td>
<td>-0.63</td>
<td>-6.93</td>
<td>0.95</td>
<td>235</td>
</tr>
</tbody>
</table>

Mean offset of 4 pyrgedimeters: -5.24 (W/m²)

Offset under clear sky at night

Mean offset of 4 pyrgedimeters: -5.24 (W/m²)

Frequency distribution of DL differences (W/m²)

average: -5.24
mode: 4.35
median: 4.75
Study on the large offset variation by RT calculations

- Air temp.
- Column water at each layer

5 Groups just after rawinsonde launch under clear sky

- 11Z 23 Oct
  - (mm)
  - (hPa) 0 5 10 15
  - 25.3
  - 28.8
  - 25.7
  - 25.3
  - 28.4

- 11Z 21 Oct
  - (mm)
  - (hPa) 0 5 10 15
  - 29.6
- The magnitude of the offset is largely affected by the air temperature in the lower atmosphere rather than by TCWV.

- The large variation of the offset seems to be possible at high TCWV.
Offset with clouds

- Cloud does not seem to affect much to the offset.

### Clear

**Mean offset : -5.24(W/m²)**

<table>
<thead>
<tr>
<th>Class</th>
<th>Ave.</th>
<th>Max.</th>
<th>Min.</th>
<th>Std dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCWV&lt;40</td>
<td>-5.69</td>
<td>-0.53</td>
<td>-8.76</td>
<td>1.69</td>
<td>341</td>
</tr>
<tr>
<td>40=&lt;TCWV&lt;45</td>
<td>-5.44</td>
<td>-1.71</td>
<td>-10.22</td>
<td>1.85</td>
<td>555</td>
</tr>
<tr>
<td>45=&lt;TCWV&lt;50</td>
<td>-4.99</td>
<td>-0.20</td>
<td>-10.18</td>
<td>2.52</td>
<td>676</td>
</tr>
<tr>
<td>50=&lt;TCWV</td>
<td>-4.81</td>
<td>-0.63</td>
<td>-6.93</td>
<td>0.95</td>
<td>235</td>
</tr>
</tbody>
</table>

### All data (Clear + Clouds)

**Mean offset : -4.72(W/m²)**

<table>
<thead>
<tr>
<th>Class</th>
<th>Ave.</th>
<th>Max.</th>
<th>Min.</th>
<th>Std dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCWV&lt;40</td>
<td>-5.03</td>
<td>-0.53</td>
<td>-8.76</td>
<td>1.68</td>
<td>527</td>
</tr>
<tr>
<td>40=&lt;TCWV&lt;45</td>
<td>-5.13</td>
<td>-1.69</td>
<td>-10.52</td>
<td>2.25</td>
<td>727</td>
</tr>
<tr>
<td>45=&lt;TCWV&lt;50</td>
<td>-4.29</td>
<td>3.26</td>
<td>-10.18</td>
<td>2.41</td>
<td>1179</td>
</tr>
<tr>
<td>50=&lt;TCWV</td>
<td>-4.89</td>
<td>-0.63</td>
<td>-6.93</td>
<td>0.97</td>
<td>252</td>
</tr>
</tbody>
</table>

Cloud does not seem to affect much to the offset.
Summary

- DL by the pyrgeometer is smaller than the IRIS by about 5W/m² (5.24 W/m² smaller in average for the TCWV range from 38.38 to 52.77mm) under clear sky at night.
- The results is very similar to those at PMOD in Davos when the TCWV is greater than 10mm. (WISG is smaller than the IRIS by 5.1 W/m² in average.)
- The magnitude of the offset is largely affected by the air temperature in the lower atmosphere, and large variation of the offset seems to be possible at high TCWV.
- Clouds does not seem to affect much to the offset at high TCWV.

Future work

- Further investigation about DL differences between the IRIS and the pyrgeometer under various conditions (TCWV, air temperature, clouds).
- Implementation of the offset correction in longwave radiation observations (adequate implementation of effects by TCWV, air temperature and spectral characteristics of the pyrgeometer silicon dome in the pyrgeometer equation).

$$E = \frac{U}{C} \left(1 + k_1 \sigma T_B^3\right) + k_2 \sigma T_B^4 - k_3 \sigma \left(T_D^4 - T_B^4\right)$$