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2017 Pyrgeometer Inter-comparison in Darwin, Australia

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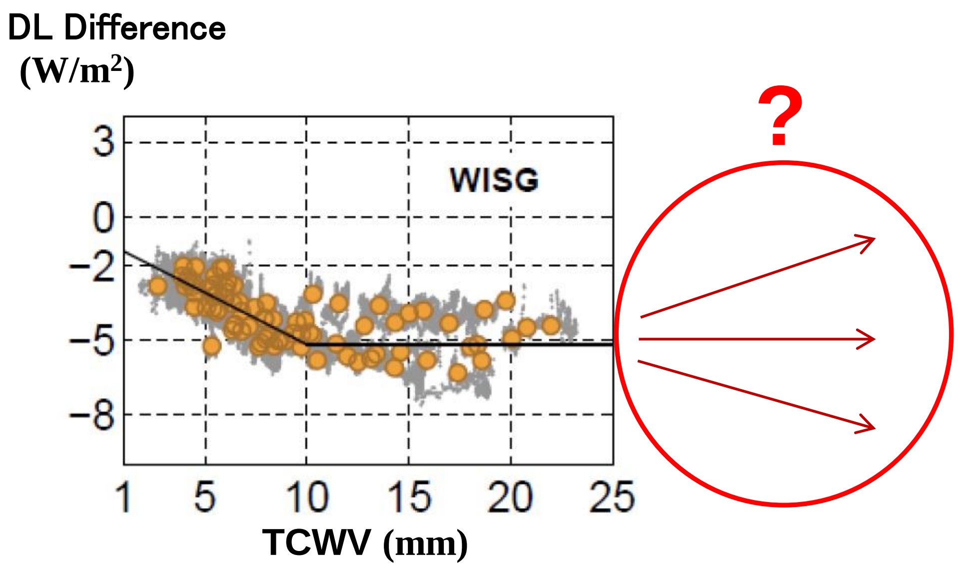
Contents

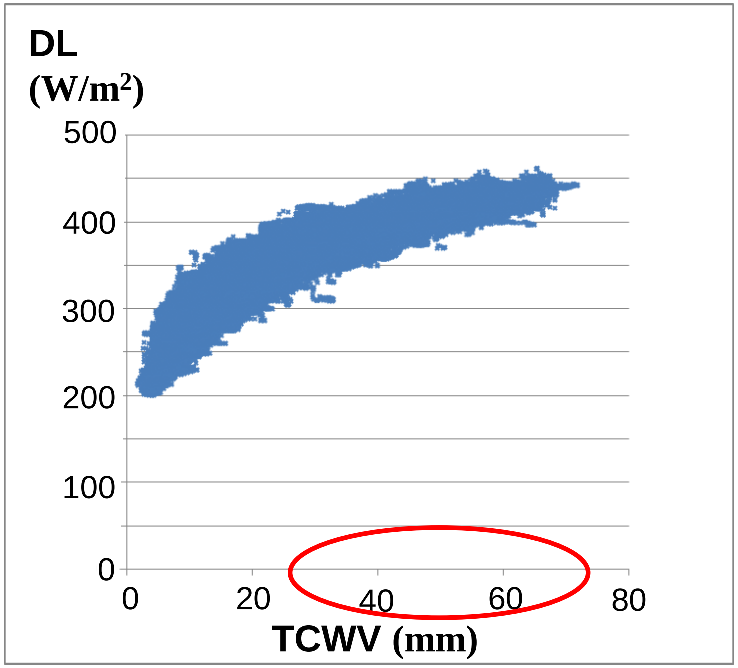
- ➢ Background
- ➢ 2017 Pyrgeometer Inter-comparison in Darwin, Australia
  - Outline
  - Instrument settings
  - Data used for the analysis
- ➢ Results
  - Offset under clear sky at night
  - Offset with cloud
- ➢ Summary

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 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)

2017 Pyrgeometer Inter-comparison in Darwin, Australia

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

- Period: 16Oct – 25Oct 2017

  10 nights, 30 hours under clear sky

- Participating radiometers:

  1 IRIS and 4 pyrgeometers

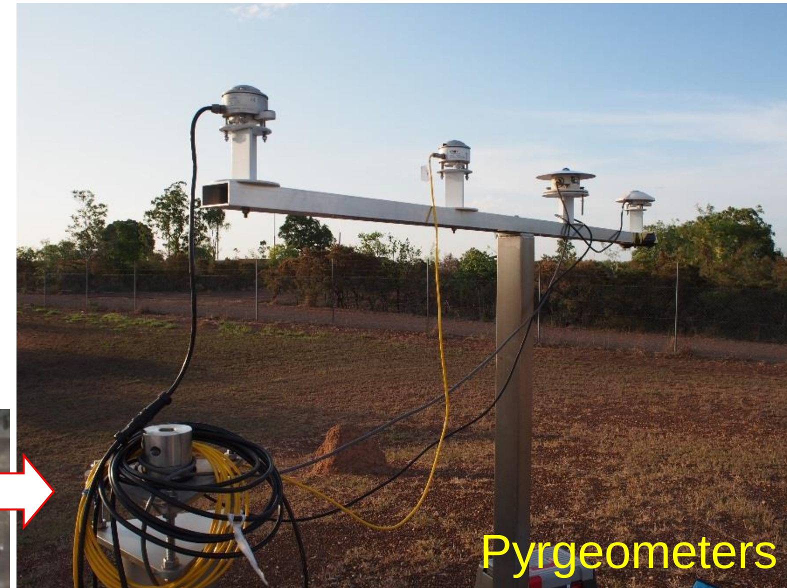
- Ancillary data
  - Water vapor (GNSS, rawinsonde)
  - Clouds (eye, satellite, sky camera)
  - Others (air temp, press, …)

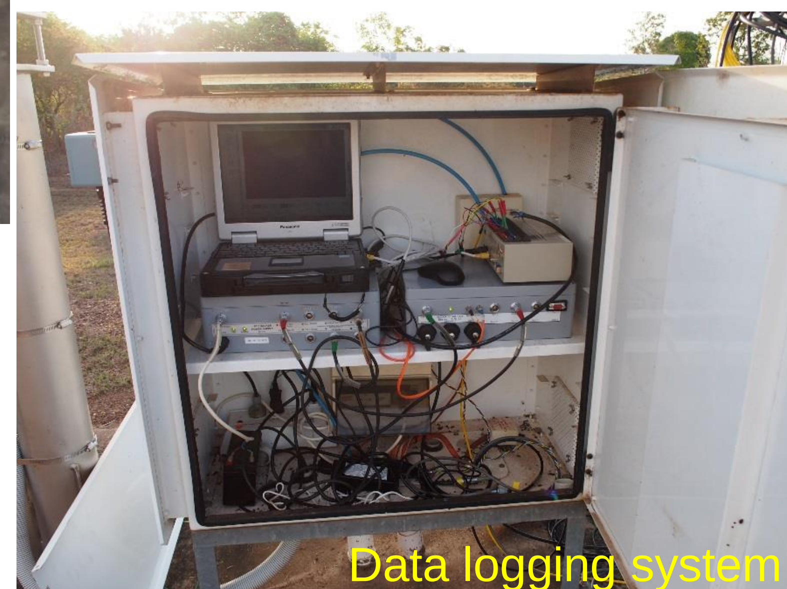
Instrument settings

IRIS

DWN station building

pyrgeometers





Data used for the analysis

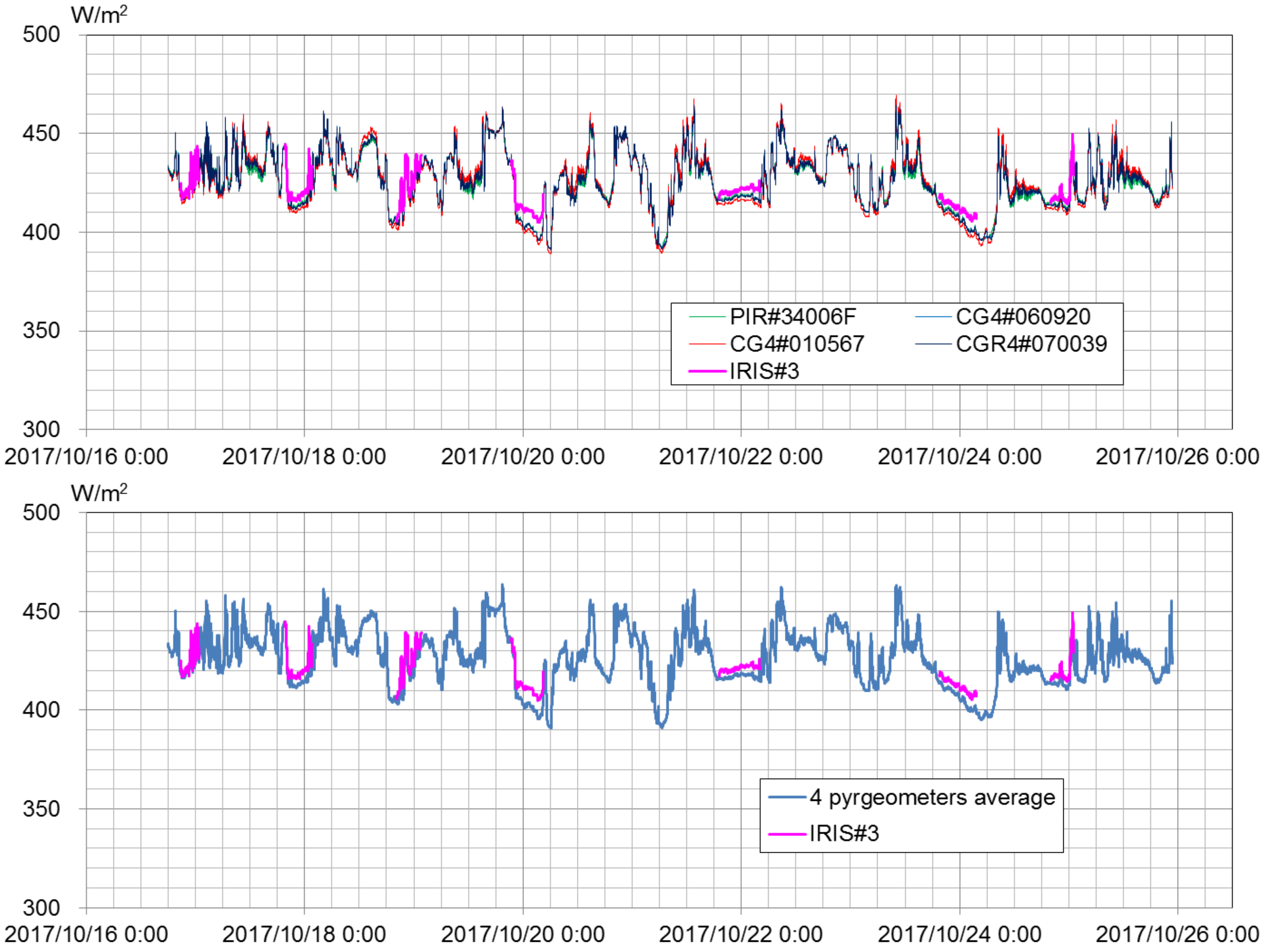
Downward longwave radiation

- 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

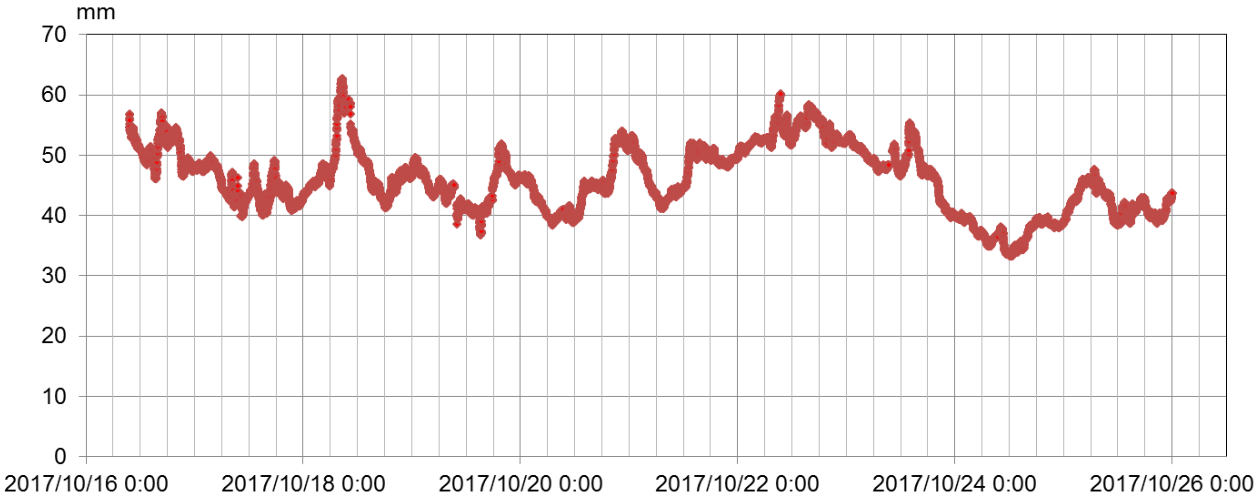
(The values of 1-min average of 4 pyrgeometers are very close with each other and stable throughout the inter-comparison)



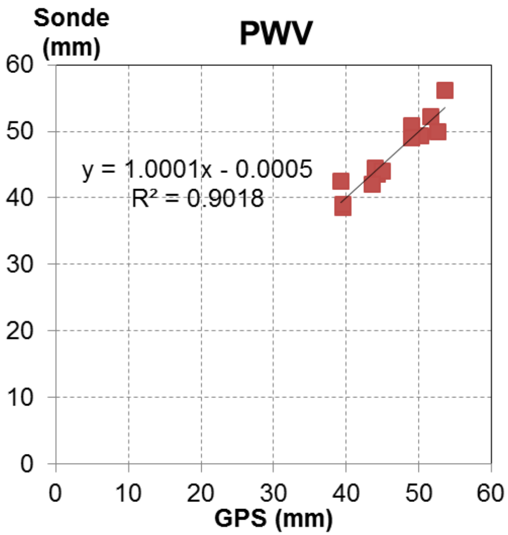
Time series of DL by pyrgeometers and IRIS during the inter-comparison

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)



Time series of GNSS PWV during the inter-comparison



rawinsonde PWV vs calibrated GNSS PWV

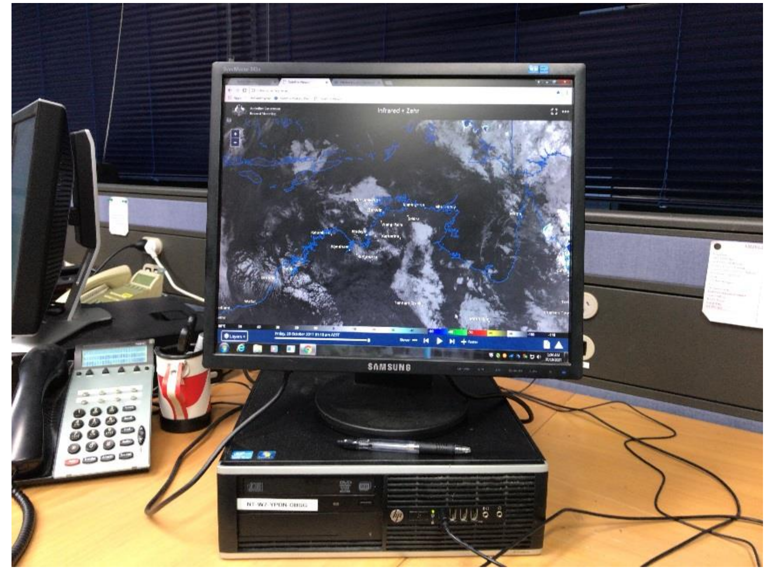
- TCWV range during the inter-comparison: 35 - 62 (mm) → fit the purpose

Clouds

Sky camera

four directions of north, south, east and west

Satellite images (Himawari 8)



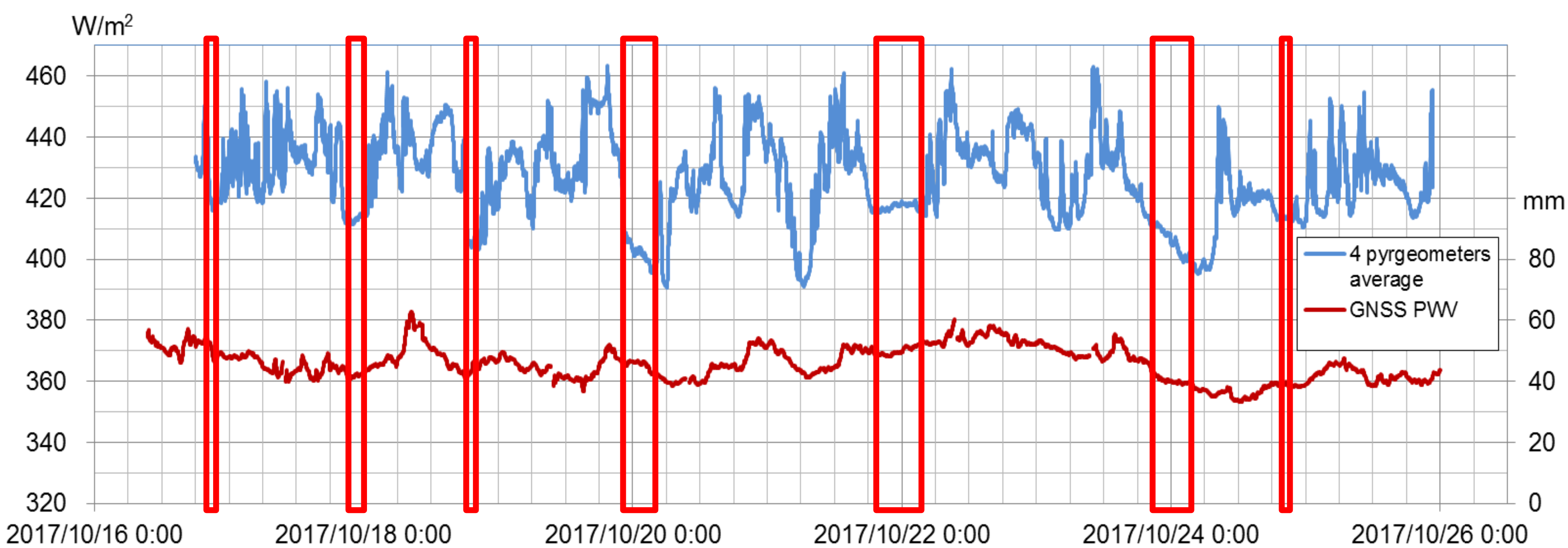
Eye obs.

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

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

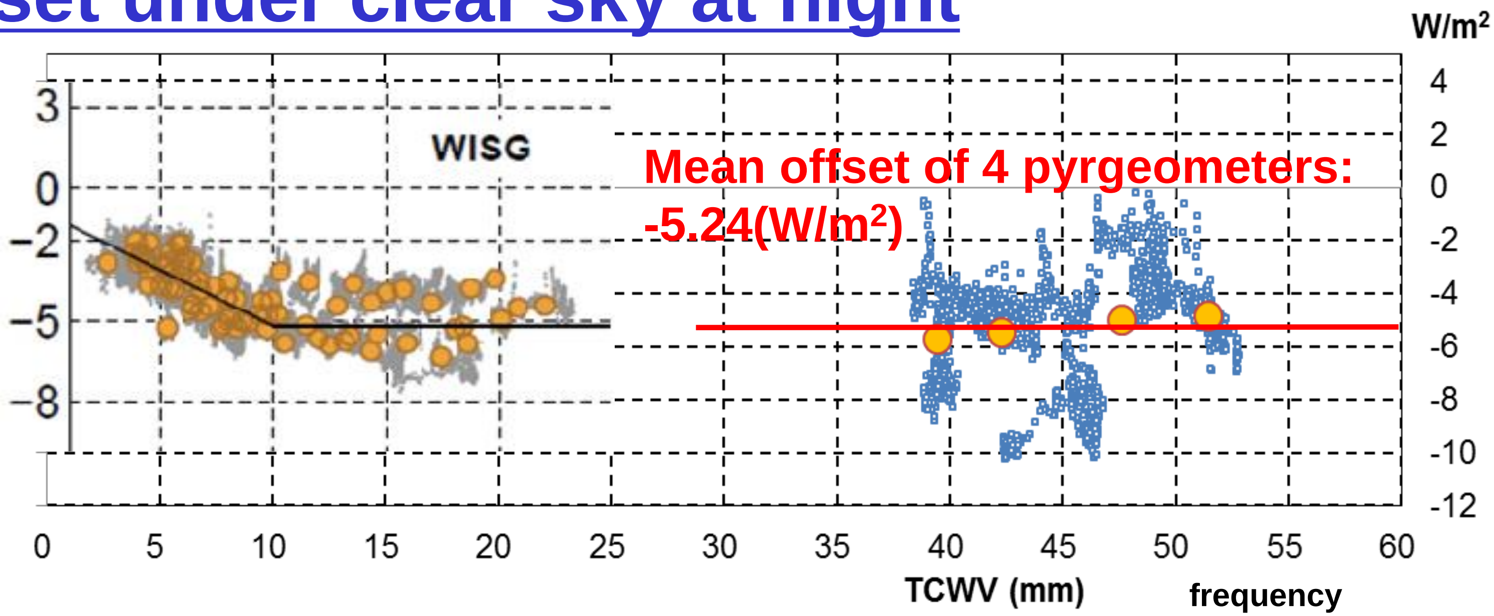
About 32 hours in total



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

Results

Offset under clear sky at night



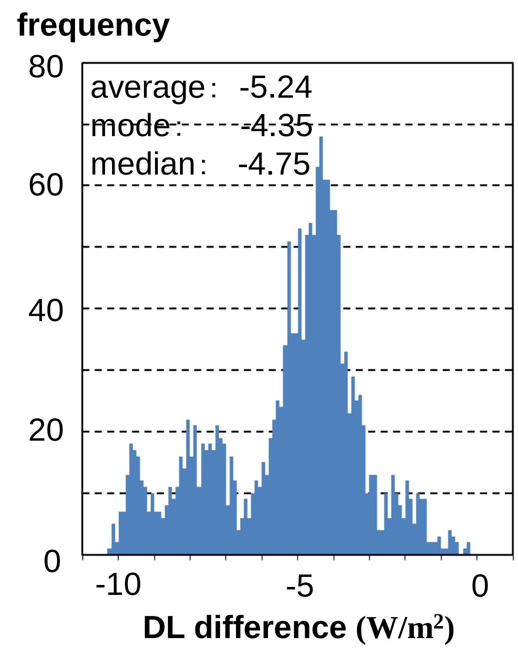
DL differences in clear sky at night

Right) 2017 inter-comparison in Darwin,

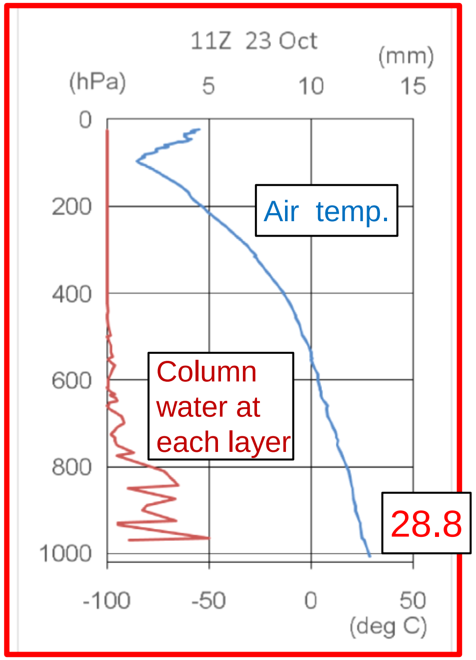
Left) Inter-comparison at PMOD (Gröbner 2014)

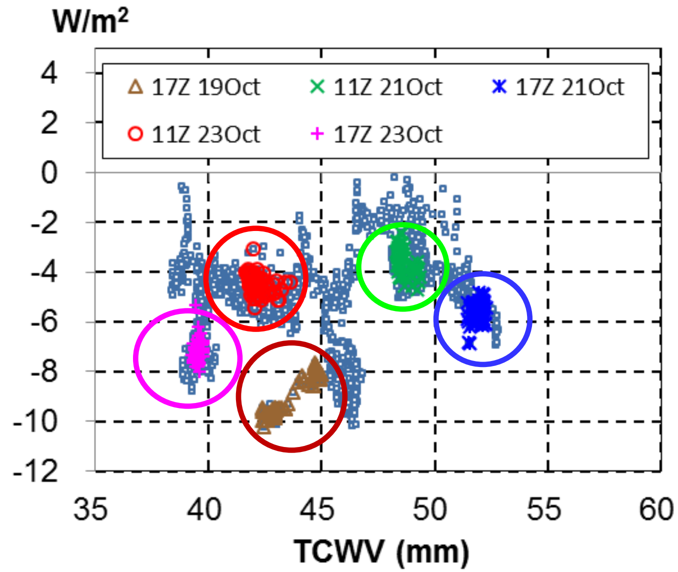
DL differences in each TCWV class

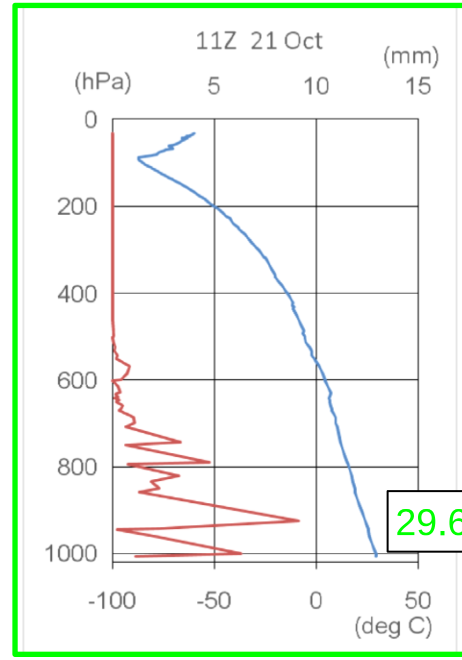
Class	Ave.	Max.	Min.	Std dev.	N
TCWV<40	-5.69	-0.53	-8.76	1.69	341
40=<TCWV<45	-5.44	-1.71	-10.22	1.85	555
45=<TCWV<50	-4.99	-0.20	-10.18	2.52	676
50=<TCWV	-4.81	-0.63	-6.93	0.95	235



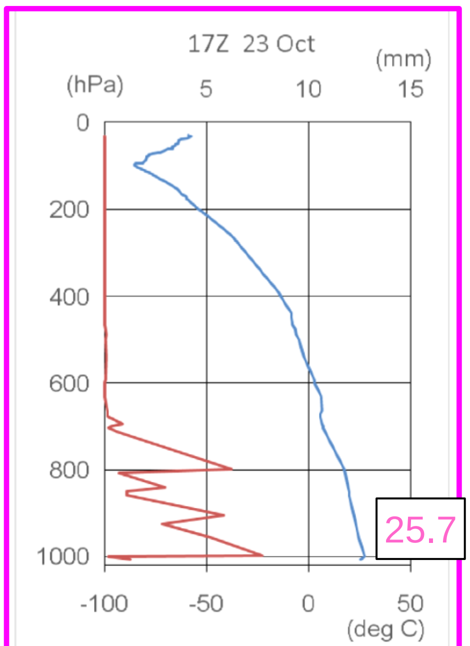
Study on the large offset variation by RT calculations

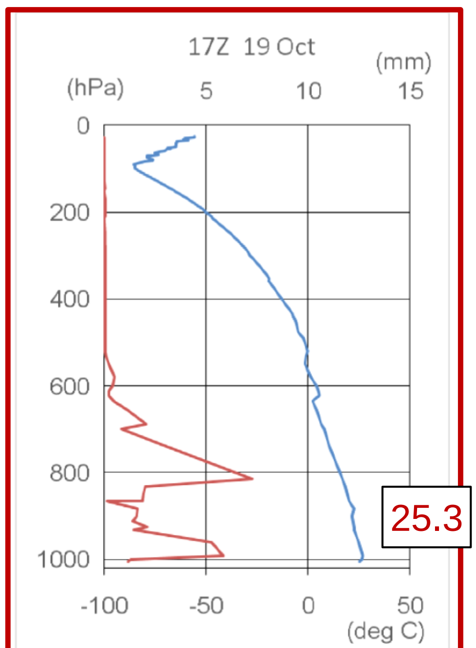


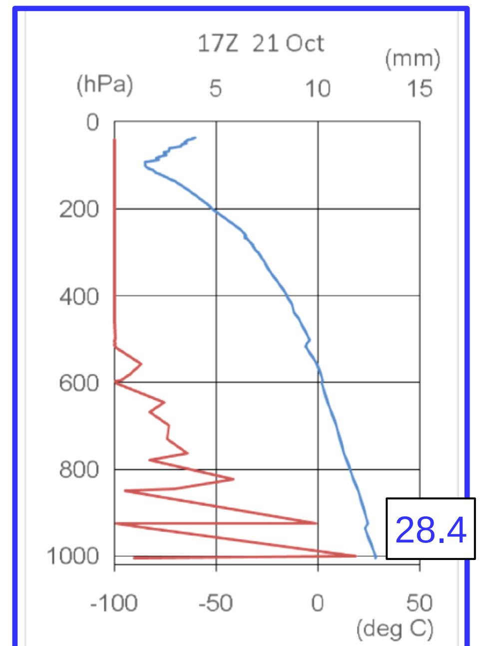




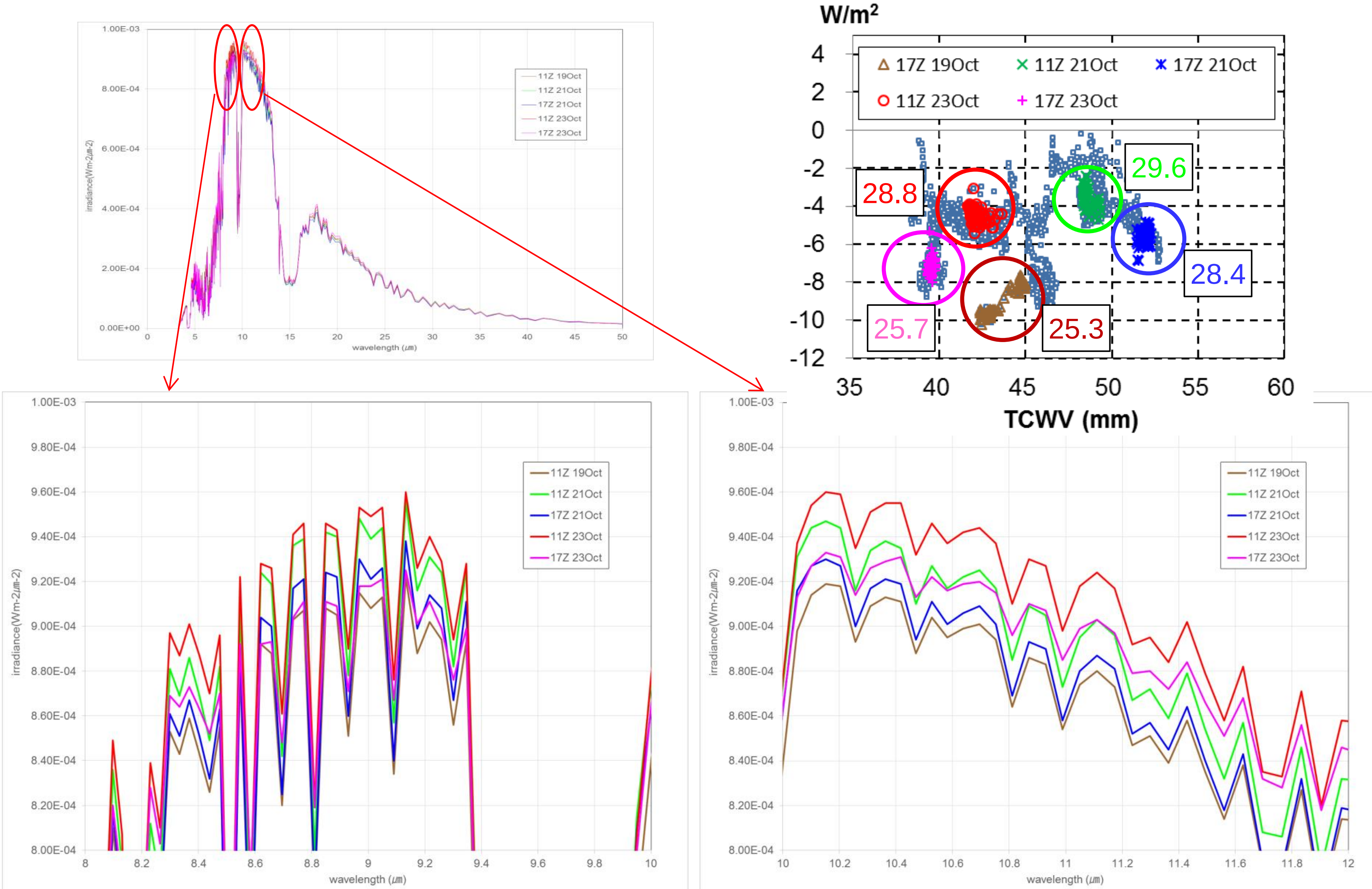
5 Groups just after rawinsonde launch under clear sky







- 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.

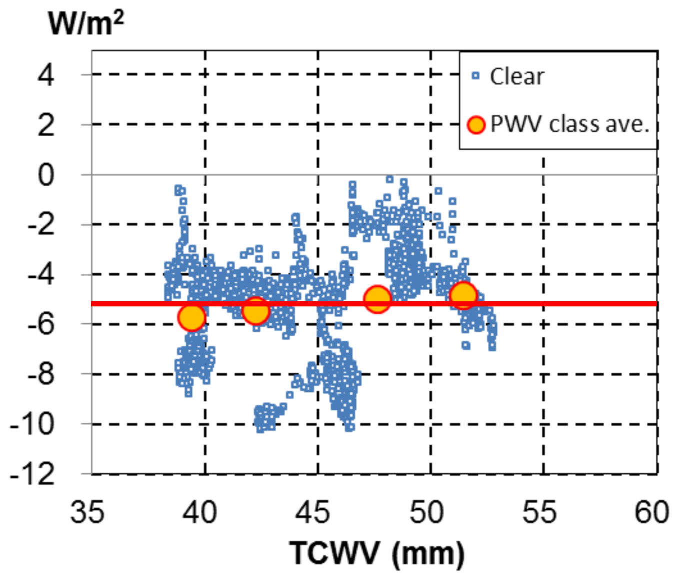


Offset with clouds

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

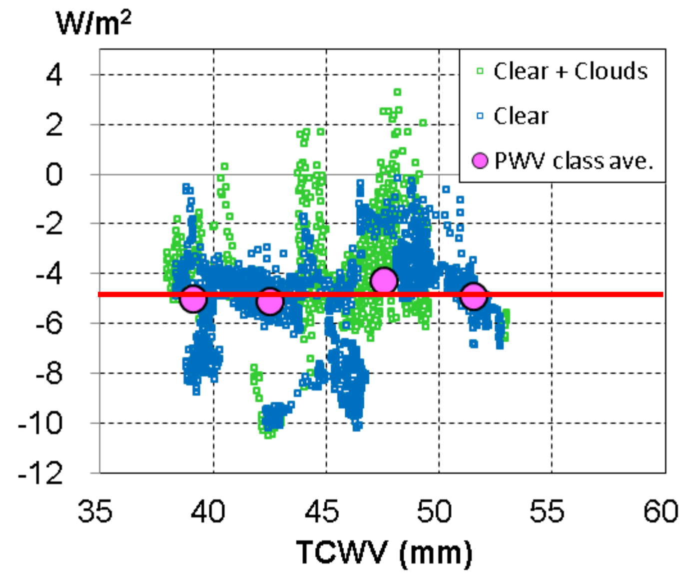
Clear

Mean offset : -5.24(W/m^2)



All data (Clear + Clouds)

Mean offset : -4.72(W/m^2)



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45=<TCWV<50	-4.99	-0.20	-10.18	2.52	676
50=<TCWV	-4.81	-0.63	-6.93	0.95	235

Class	Ave.	Max.	Min.	Std dev.	N
TCWV<40	-5.03	-0.53	-8.76	1.68	527
40=<TCWV<45	-5.13	-1.69	-10.52	2.25	727
45=<TCWV<50	-4.29	3.26	-10.18	2.41	1179
50=<TCWV	-4.89	-0.63	-6.93	0.97	252

Summary

- DL by the pyrgeometer is smaller than the IRIS by about 5W/m^2 (5.24 W/m^2 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/m^2 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 implamentation of effects by TCWV, air temperature and spectral characteristics of the pyrgeometer silicon dome in the pyrgeometer equation).

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