Measuring the HE/Co Relative Energy using FD background files

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Long Term Performance
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Calculating photon fluxes from background files (BG files record signal variances)

Phong Nguyen (PhD thesis)
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6.2.2 K_v Method

The K_v method reduces the reliance on some of the simplifying assumptions outlined in Section 6.2.1, providing a more reliable (on an individual pixel basis) conversion for the measured NSB variance into a photon flux. The following method was adapted from references [132–134].

Firstly, the variance scaling factor K_v is defined as follows

$$K_v = \frac{I_{ADC}}{\sigma^2_{ADC}} \quad (6.10)$$

[132] A. Segreto. Night sky background measurements by the Pierre Auger fluorescence detectors and comparison with simultaneous data from the UVscope instrument. In *Proceedings, 32nd International Cosmic Ray Conference (ICRC 2011): Beijing, China, August 11-18, 2011*, volume 3, page 129, 2011.

[133] M. Kleifges, A. Menshikov, et al. Statistical current monitor for the cosmic ray experiment pierre auger. *IEEE Transactions on Nuclear Science*, 50:1204–1207, August 2003.

[134] A. Menshikov, M. Kleifges, and H. Gemmeke. Fast gain calibration of photomultiplier and electronics. *IEEE Transactions on Nuclear Science*, 50:1208–1213, August 2003.

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the complete analogue signal chain [132]. Using information provided by K_v, the photon flux is given by

$$\Phi_\gamma = \frac{[\sigma^2_{ADC}]^{NSB} \times K_v \times C_{FD}}{A \times \Delta t} \qquad [\text{photons}/\text{m}^2/\text{deg}^2/\mu\text{s}] \qquad (6.12)$$

where definitions of $[\sigma^2_{ADC}]^{NSB}$, C_{FD}, A and Δt were provided in Section 6.2.1.

- C_{FD} is the calibration constant and can be thought of as the *inverse gain* of the pixel of interest (see Section 5.1). C_{FD} values are available through the FD Calibration database.
- A is the pixel aperture = $7.68\,\text{m}^2\,\text{deg}^2$ (the telescope aperture multiplied by the square of an FD pixel's angular size).
- Δt is chosen to be $100\,\text{ns}$.

Kv is not explicitly stored in the monitoring database.

Calculating photon fluxes from background files
(BG files record signal variances)

The software used to analyse the cal A data (and produce the relevant calibration parameters to be uploaded to the monitoring database) contains the following equation:

$$G = \frac{\sigma^2_{ADC}}{I_{ADC}} \Big/ F \times Sphe_{res} \Big/ 5 \Big/ range_{coeff} \tag{6.13}$$

where $Sphe_{res}$ and $range_{coeff}$ are predefined constants with values of 1.4 and 0.99893, respectively. By substituting in Equation 6.10, this can be rewritten as

$$G = \frac{1}{K_v} \Big/ F \times Sphe_{res} \Big/ 5 \Big/ Range_{coeff} \tag{6.14}$$

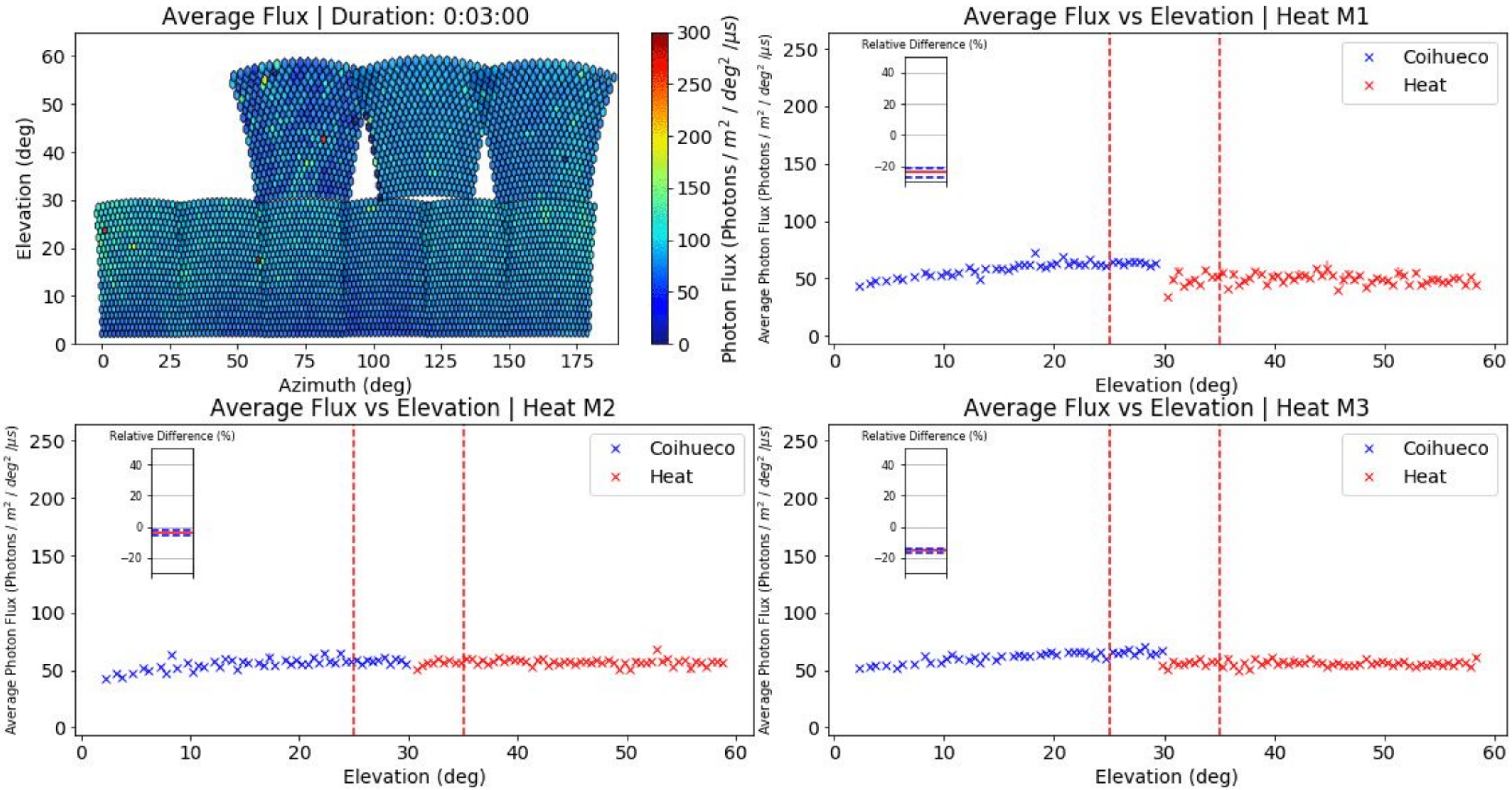
which can be rearranged to give

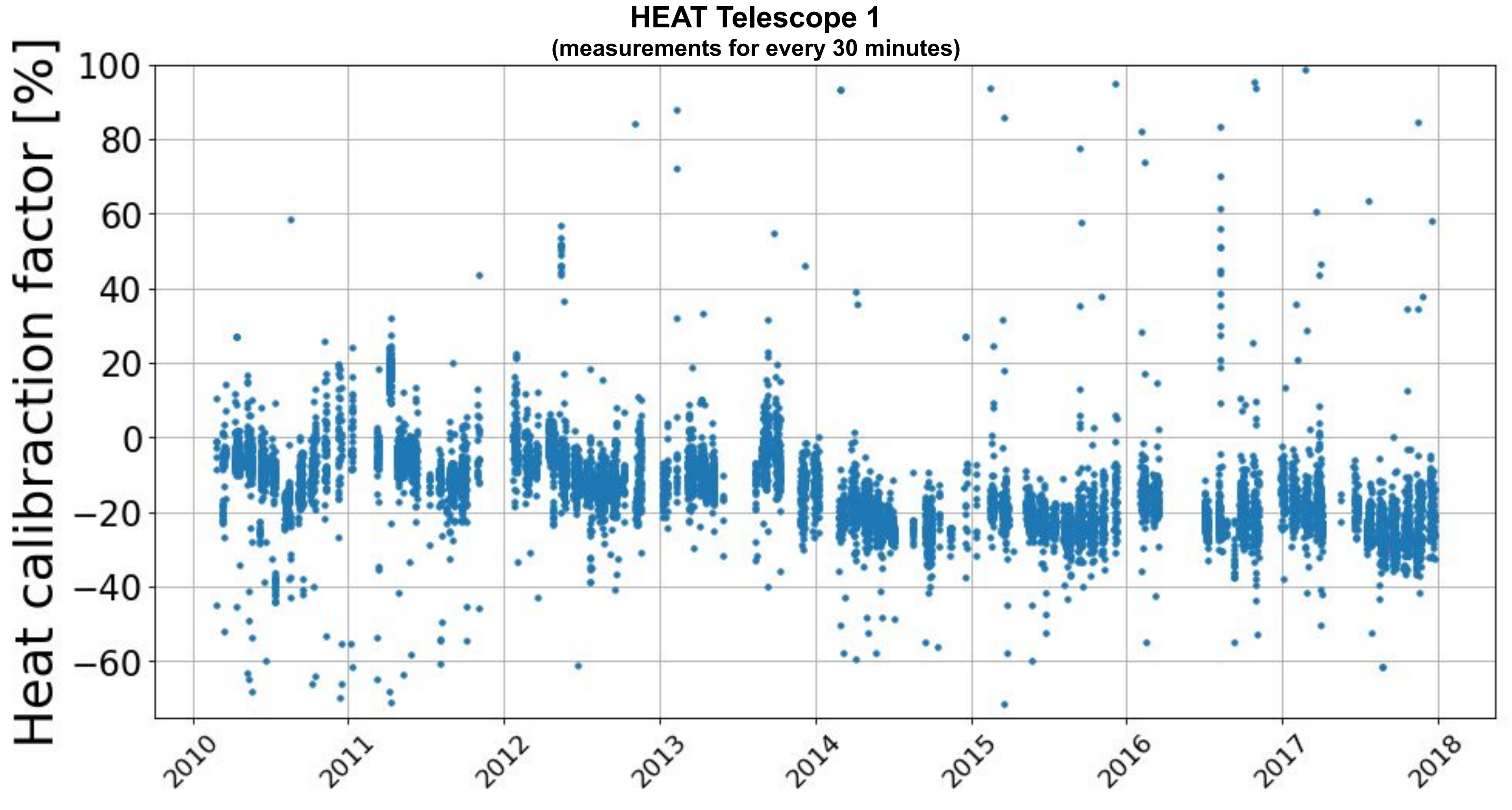
$$K_v = \frac{5}{G \times F \times Sphe_{res} \times range_{coeff}} \tag{6.15}$$

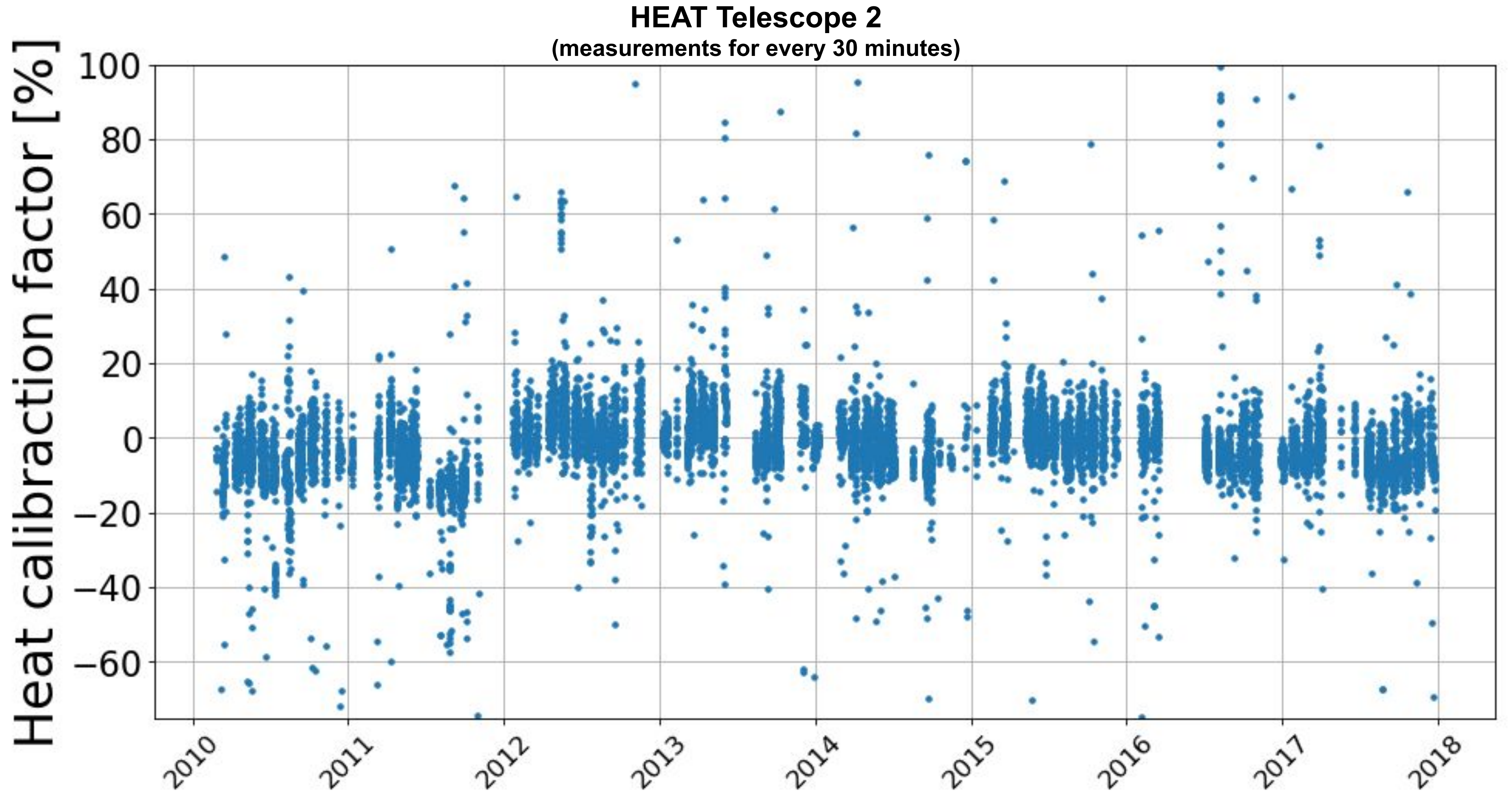
G is the PMT gain (ADC counts per photoelectron)
F is the noise equivalent bandwidth (MHz)

Kv is not explicitly stored in the monitoring database, but G and F are.

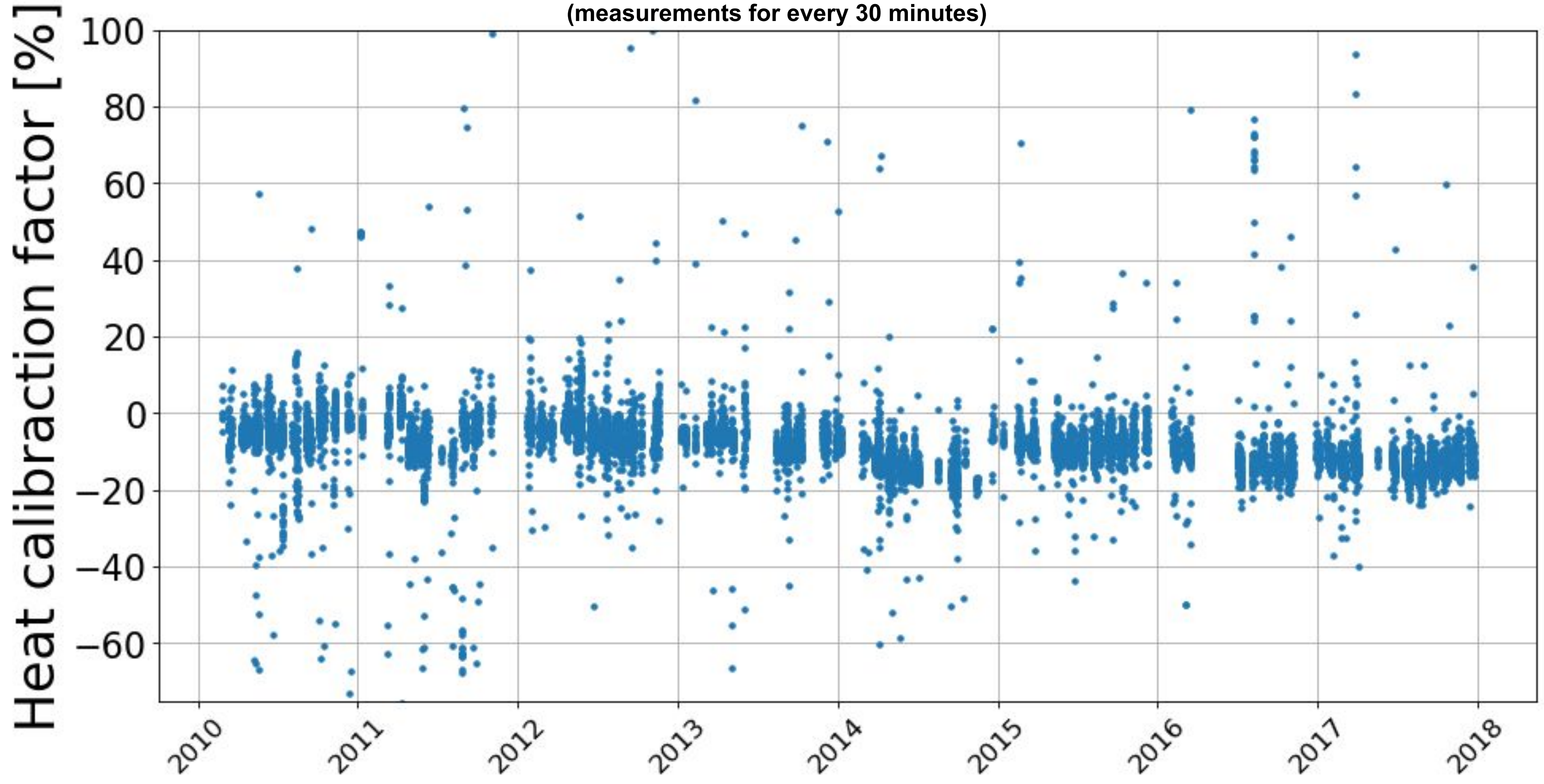
Time: 16/08/2014 01:00:00



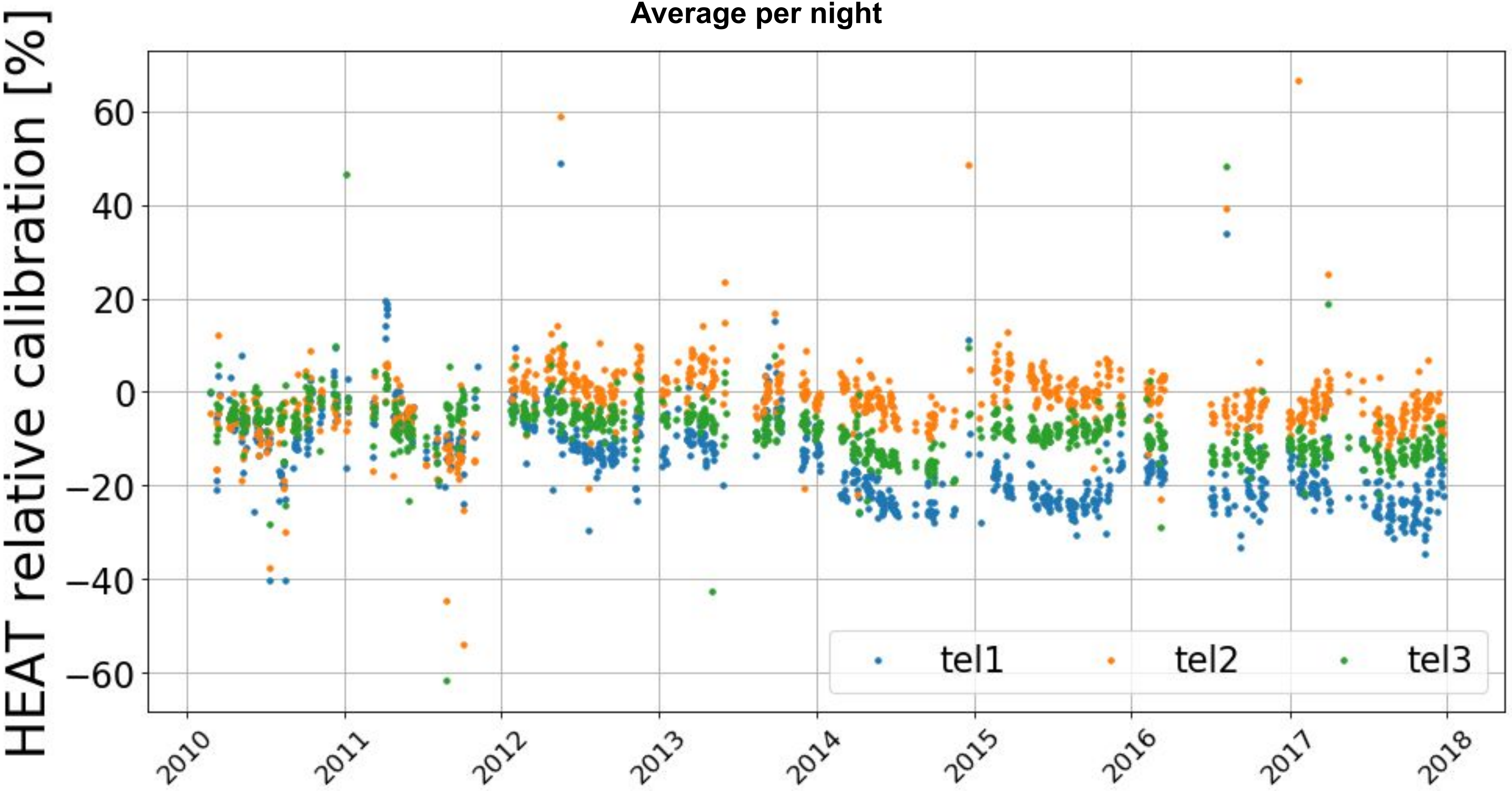

HEAT Telescope 1
(measurements for every 30 minutes)
Heat calibraction factor [%]
100
80
60
40
20
0
−20
−40
−60
2010
2011
2012
2013
2014
2015
2016
2017
2018


HEAT Telescope 2
(measurements for every 30 minutes)
Heat calibraction factor [%]
100
80
60
40
20
0
−20
−40
−60
2010
2011
2012
2013
2014
2015
2016
2017
2018

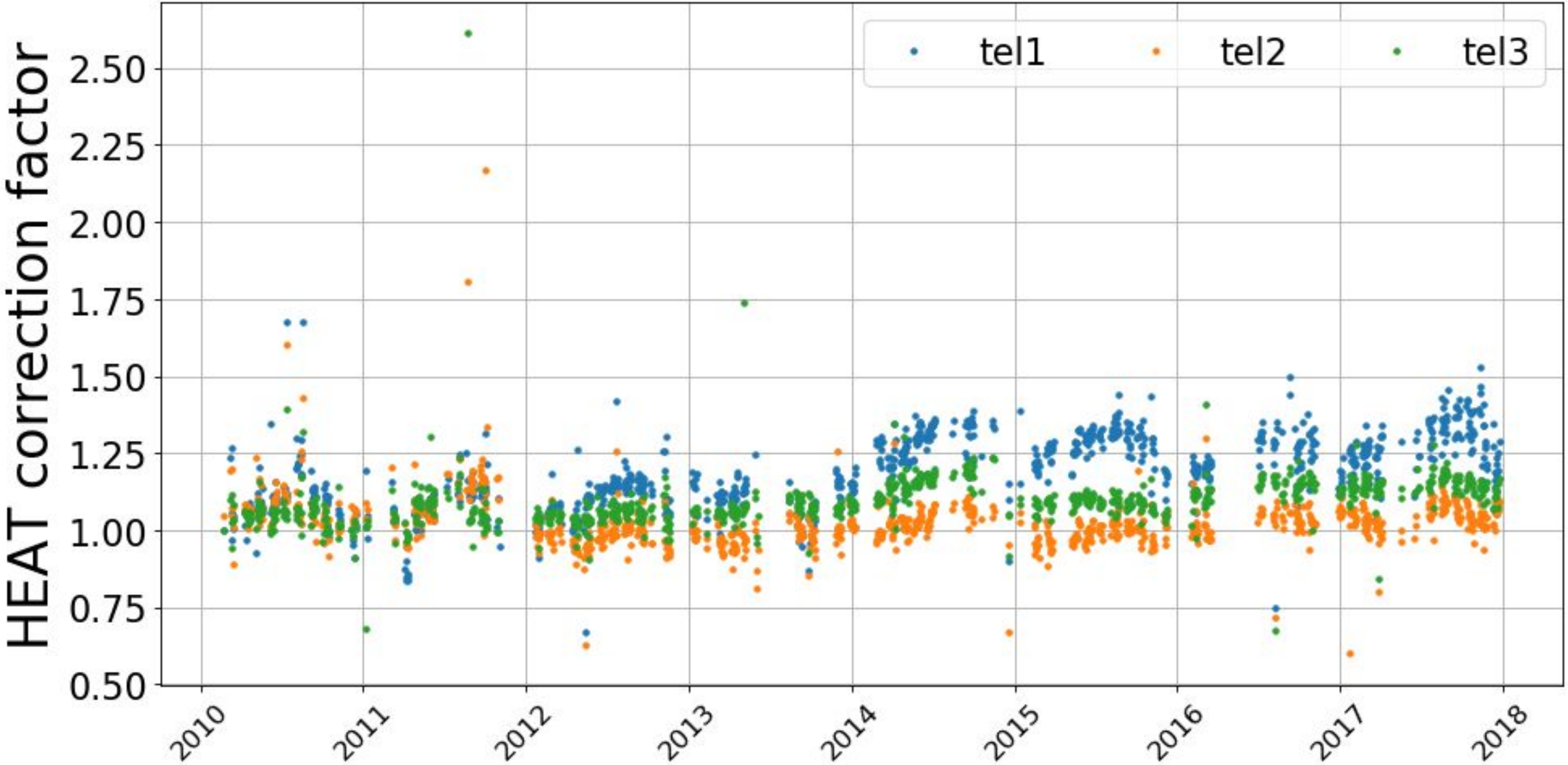
HEAT Telescope 3
(measurements for every 30 minutes)

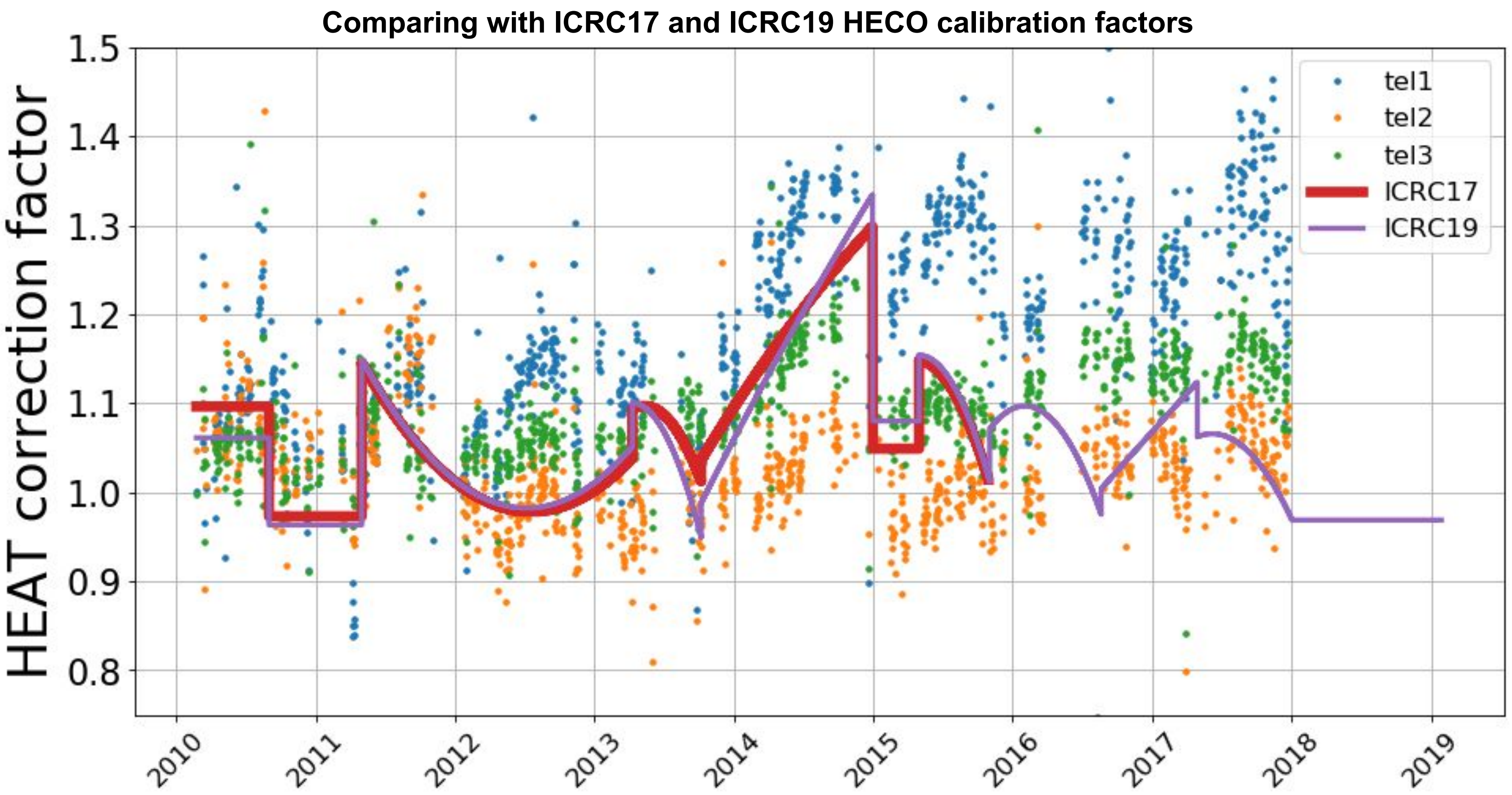


Average per night



Average per night




Comparing with ICRC17 and ICRC19 HECO calibration factors
HEAT correction factor
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
tel1
tel2
tel3
ICRC17
ICRC19

Data Table

GPSSecond tel1, tel2, …… tel25, tel26, tel27

950841600 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
950928000 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 NULL NULL NULL
951022016 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 1.001 1.047 0.998
952131648 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 NULL NULL NULL
952220544 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 1.234 1.196 1.1004
952304704 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 1.266 1.197 1.117

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Each raw correspond to the nightly average correction factor for each telescope (in four sites plus HEAT)
The last three columns correspond to HEAT telescopes
GPSSecond: Correspond to the GPS at the beginning of the night

Conclusion: HECO calibration data ready to be uploaded to DB.