Measuring the HE/Co Relative Energy using FD background files

Kenneth Jacks, Jose Bellido and Bruce Dawson

Long Term Performance Teleconference
Febrero 25, 2020

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

Phong Nguyen (PhD thesis)
GAP-2018-011

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

$$K_v = \frac{I_{ADC}}{\sigma^2_{ADC}} \tag{6.10}$$

[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.

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

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

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

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 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

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

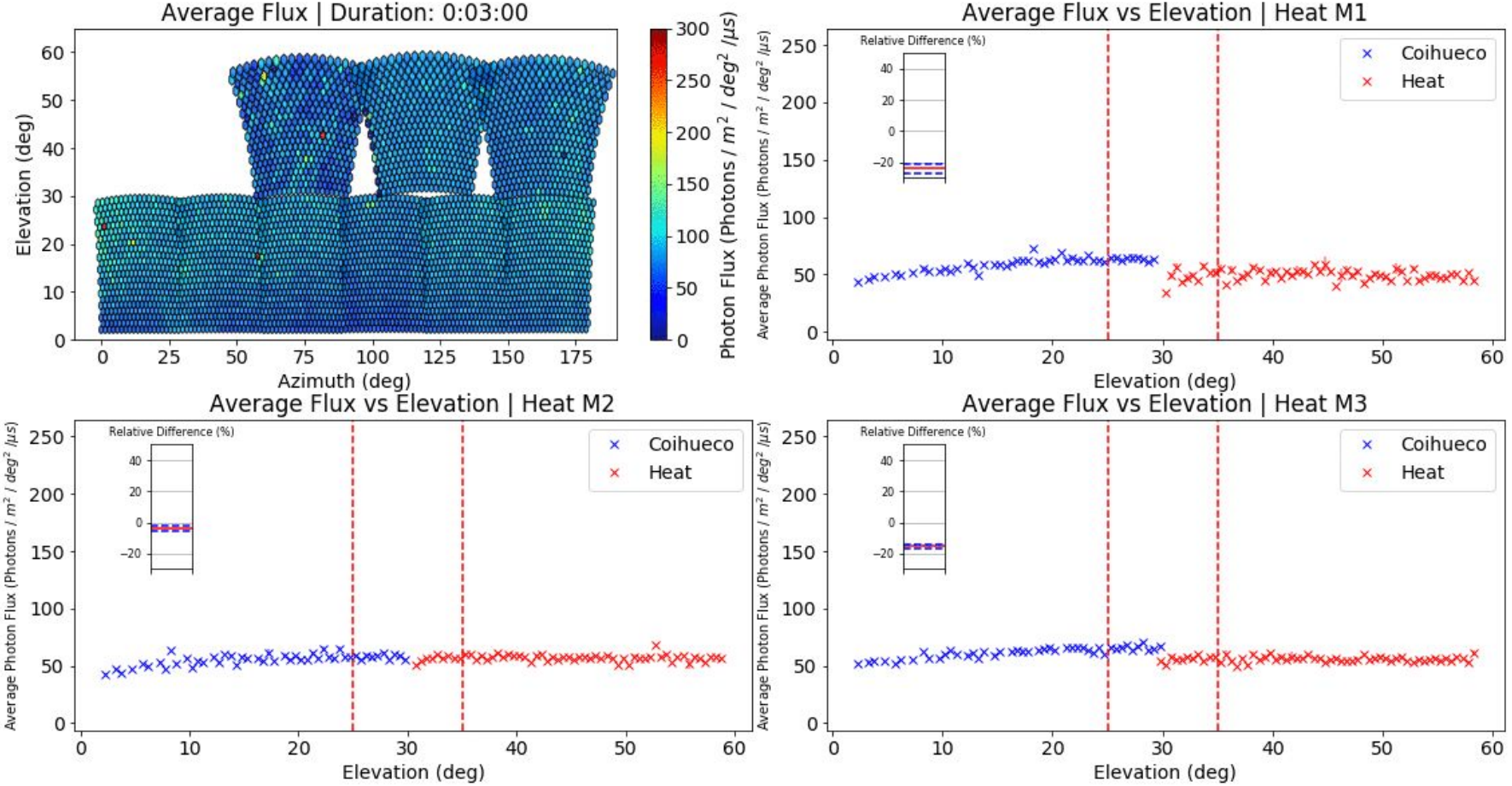
which can be rearranged to give

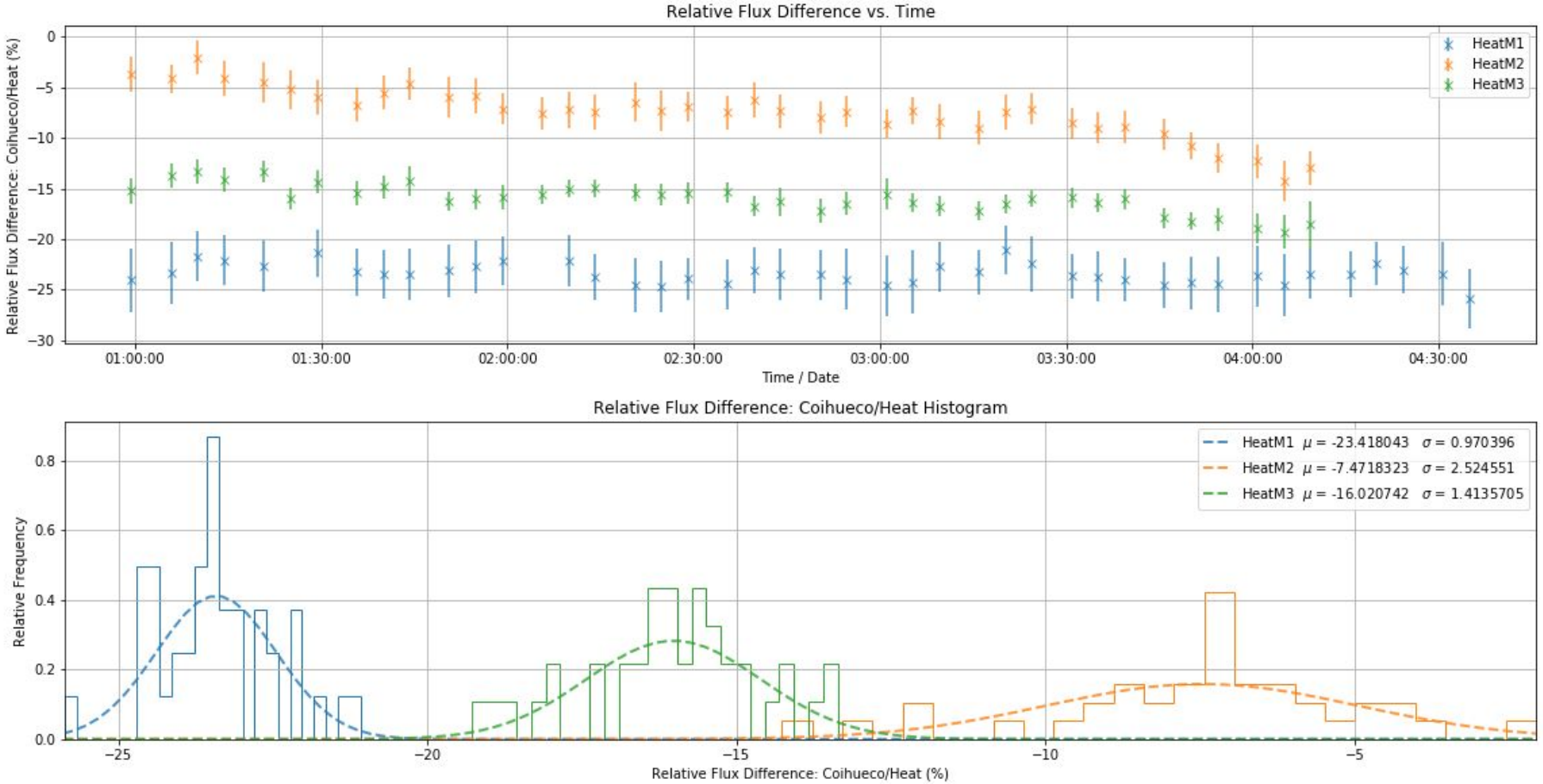
$$K_v = \frac{5}{G \times F \times Sphe_{res} \times range_{coeff}} \tag{6.15}$$

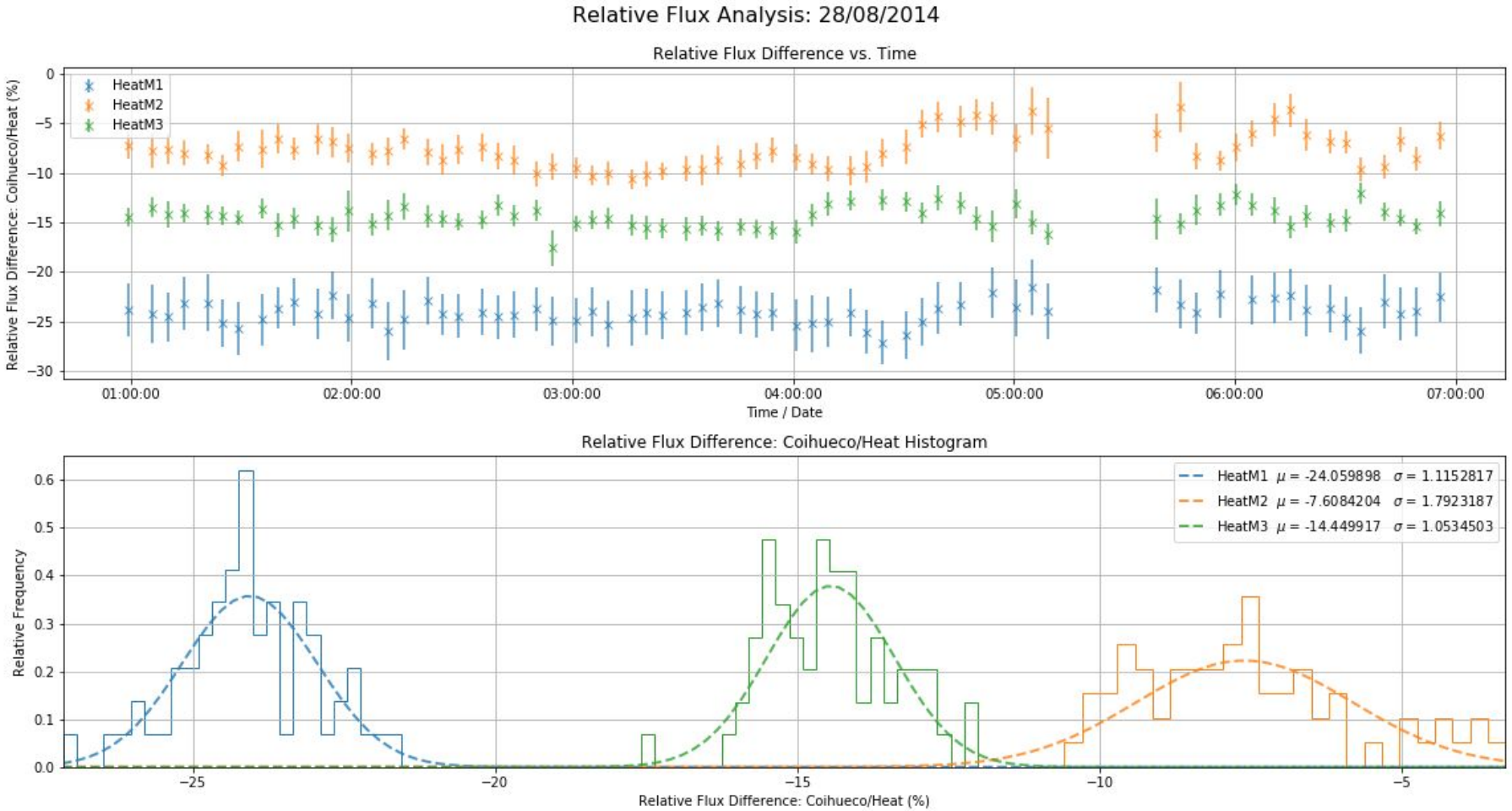
G is the PMT gain (ADC counts per photoelectron)
F is the noise equivalent bandwidth (MHz)

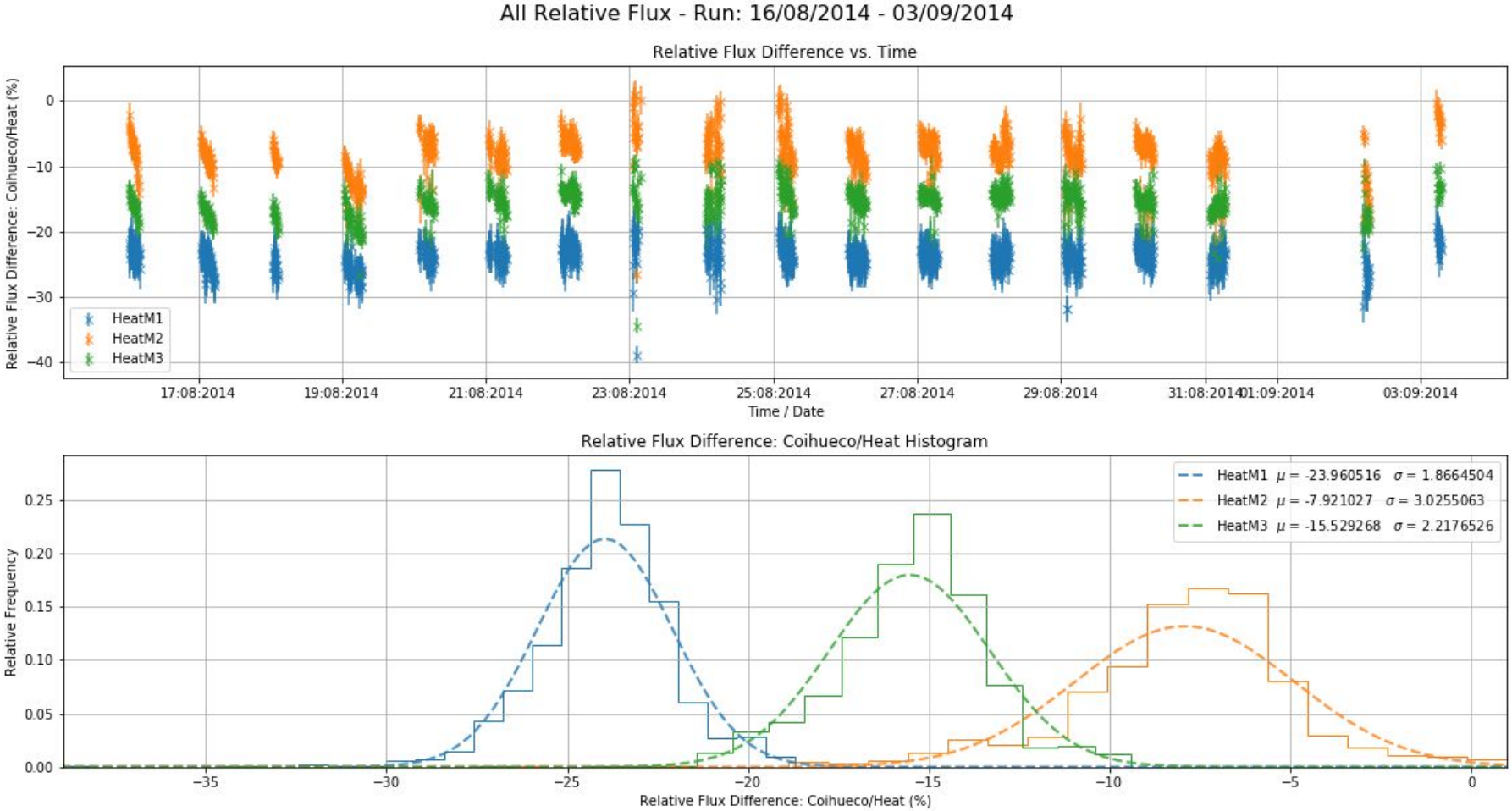
Kv is not explicitly stored in the monitoring database, but G and F are.

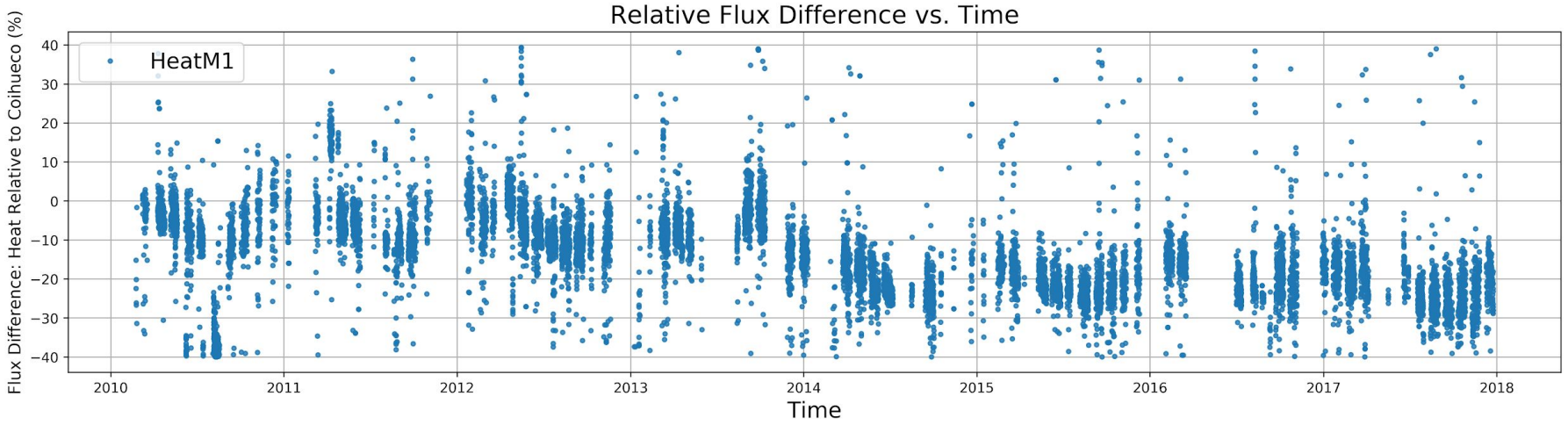
Time: 16/08/2014 01:00:00

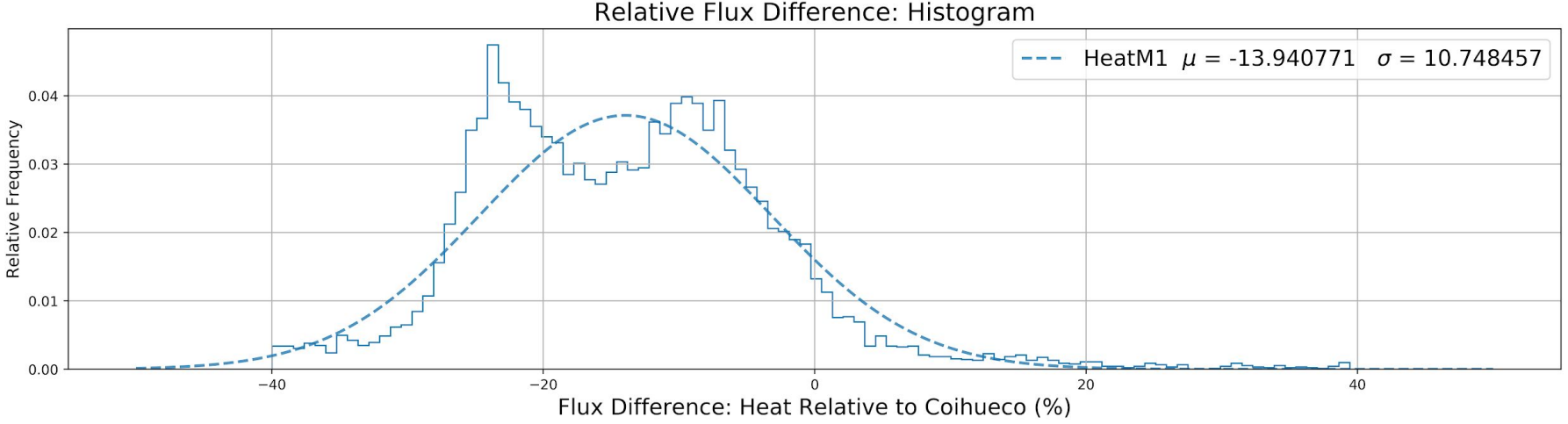


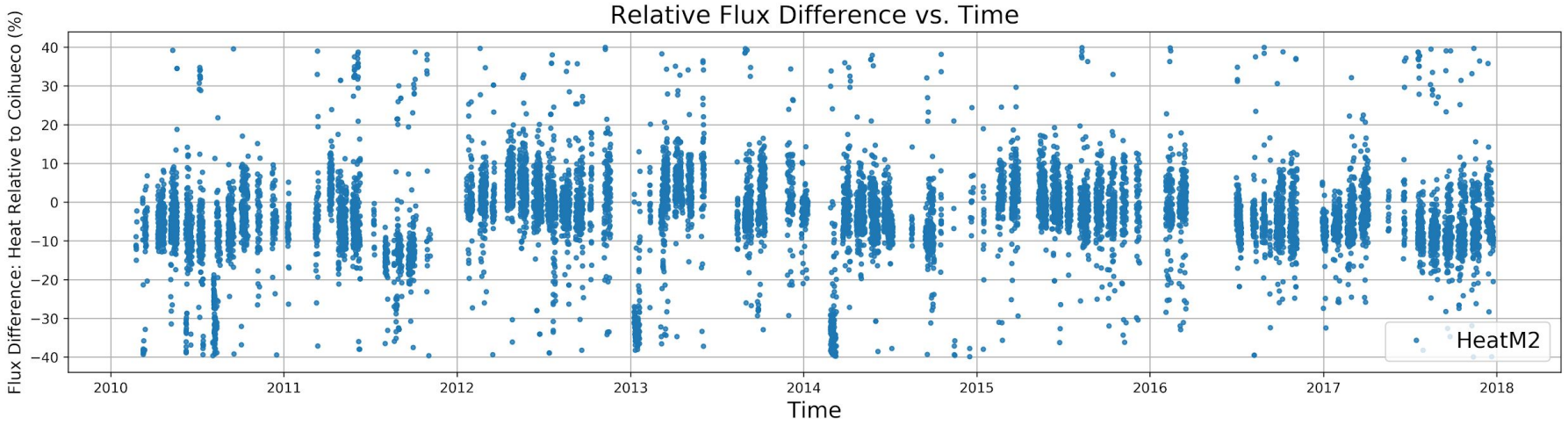

Relative Flux Analysis: 16/08/2014
Relative Flux Difference vs. Time
Relative Flux Difference: Coihueco/Heat (%)
Time / Date
HeatM1
HeatM2
HeatM3
Relative Flux Difference: Coihueco/Heat Histogram
Relative Frequency
Relative Flux Difference: Coihueco/Heat (%)
HeatM1 μ = -23.418043 σ = 0.970396
HeatM2 μ = -7.4718323 σ = 2.524551
HeatM3 μ = -16.020742 σ = 1.4135705

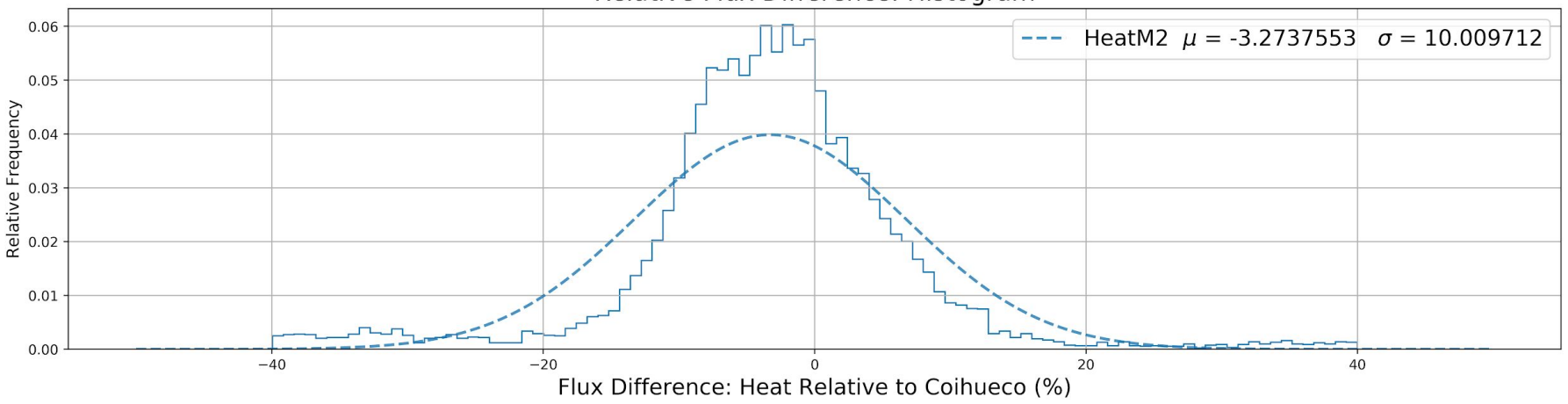

Relative Flux Analysis: 28/08/2014
Relative Flux Difference vs. Time
HeatM1
HeatM2
HeatM3
Relative Flux Difference: Coihueco/Heat (%)
0
−5
−10
−15
−20
−25
−30
01:00:00
02:00:00
03:00:00
04:00:00
05:00:00
06:00:00
07:00:00
Time / Date
Relative Flux Difference: Coihueco/Heat Histogram
HeatM1 μ = -24.059898 σ = 1.1152817
HeatM2 μ = -7.6084204 σ = 1.7923187
HeatM3 μ = -14.449917 σ = 1.0534503
Relative Frequency
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−25
−20
−15
−10
−5
Relative Flux Difference: Coihueco/Heat (%)

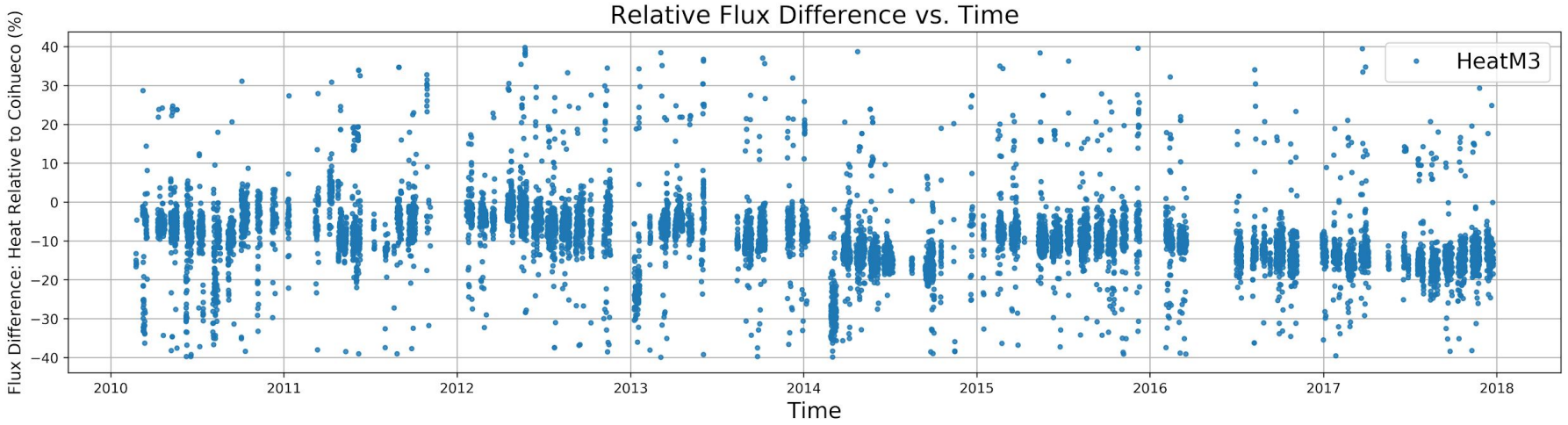

All Relative Flux - Run: 16/08/2014 - 03/09/2014
Relative Flux Difference vs. Time
Relative Flux Difference: Coihueco/Heat (%)
0
−10
−20
−30
−40
HeatM1
HeatM2
HeatM3
17:08:2014
19:08:2014
21:08:2014
23:08:2014
25:08:2014
27:08:2014
29:08:2014
31:08:2014
01:09:2014
03:09:2014
Time / Date
Relative Flux Difference: Coihueco/Heat Histogram
HeatM1 μ = -23.960516 σ = 1.8664504
HeatM2 μ = -7.921027 σ = 3.0255063
HeatM3 μ = -15.529268 σ = 2.2176526
Relative Frequency
0.25
0.20
0.15
0.10
0.05
0.00
−35
−30
−25
−20
−15
−10
−5
0
Relative Flux Difference: Coihueco/Heat (%)

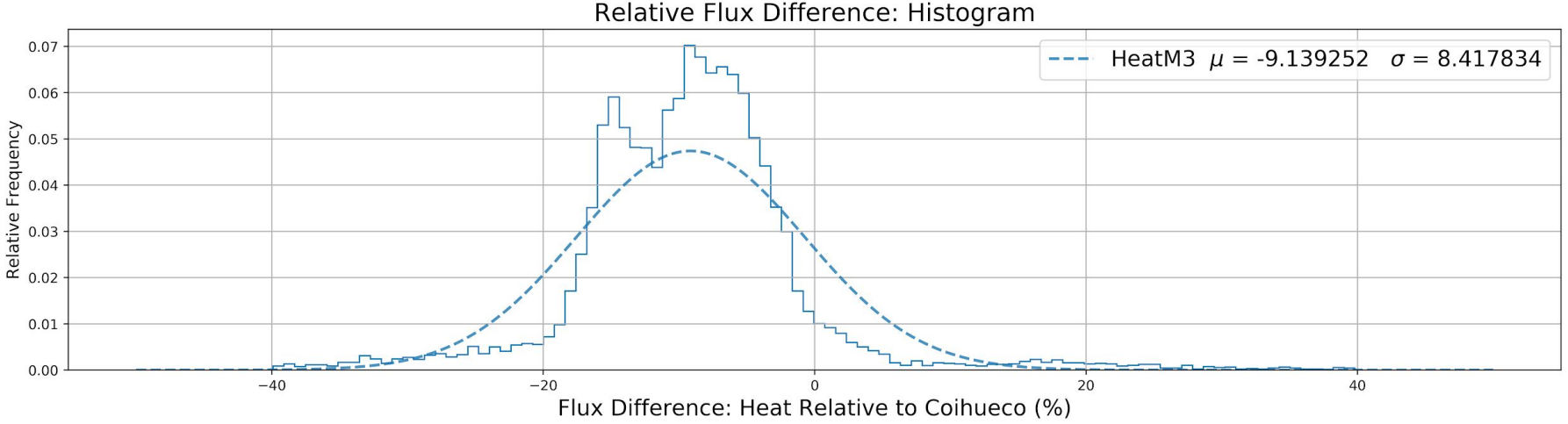

Relative Flux Difference vs. Time
HeatM1
Flux Difference: Heat Relative to Coihueco (%)
40
30
20
10
0
−10
−20
−30
−40
2010
2011
2012
2013
2014
2015
2016
2017
2018
Time

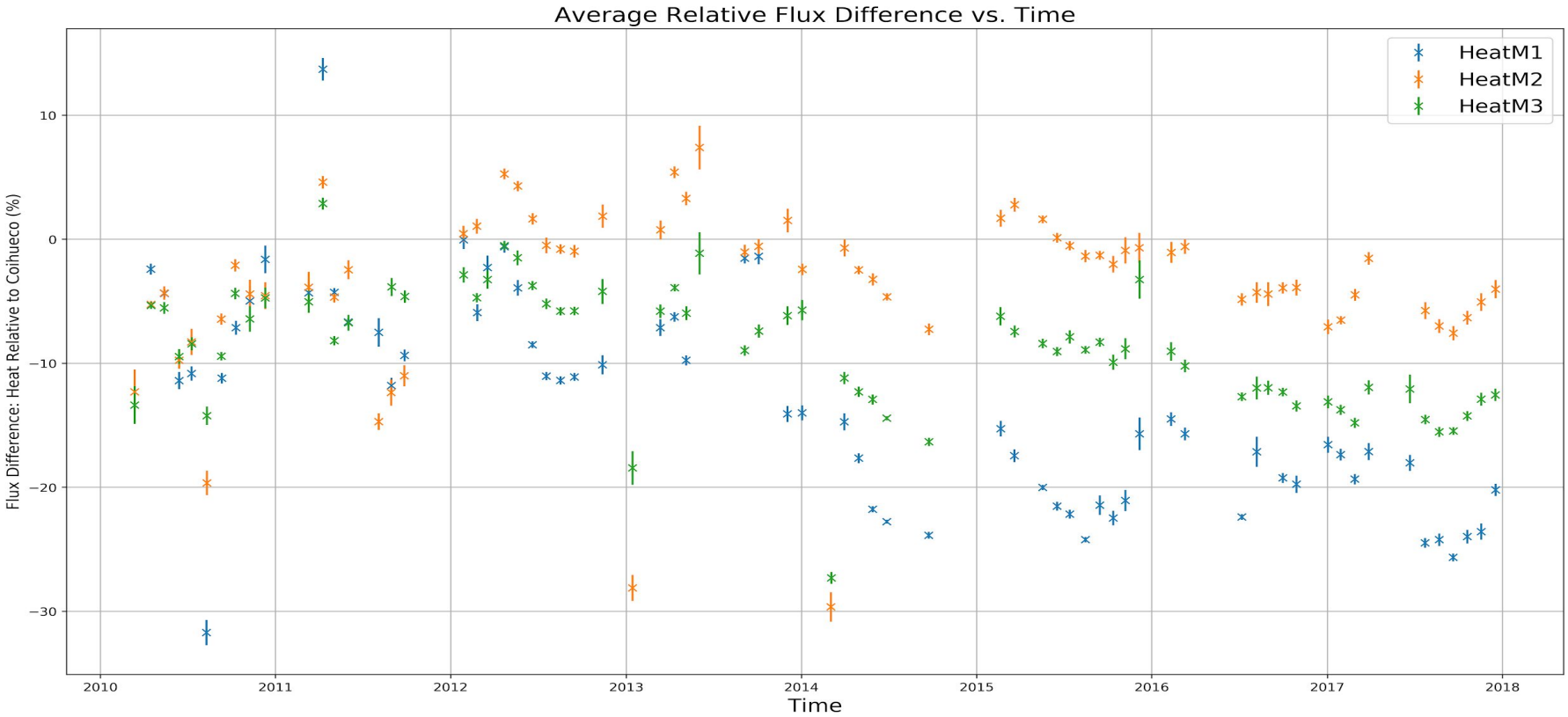

Relative Flux Difference: Histogram
HeatM1 μ = -13.940771 σ = 10.748457
Relative Frequency
0.04
0.03
0.02
0.01
0.00
−40
−20
0
20
40
Flux Difference: Heat Relative to Coihueco (%)


Relative Flux Difference vs. Time
Flux Difference: Heat Relative to Coihueco (%)
40
30
20
10
0
−10
−20
−30
−40
2010
2011
2012
2013
2014
2015
2016
2017
2018
Time
HeatM2


Relative Flux Difference: Histogram
HeatM2 μ = -3.2737553 σ = 10.009712
Relative Frequency
0.06
0.05
0.04
0.03
0.02
0.01
0.00
−40
−20
0
20
40
Flux Difference: Heat Relative to Coihueco (%)


Relative Flux Difference vs. Time
HeatM3
Flux Difference: Heat Relative to Coihueco (%)
Time
40
30
20
10
0
−10
−20
−30
−40
2010
2011
2012
2013
2014
2015
2016
2017
2018


Relative Flux Difference: Histogram
HeatM3 μ = -9.139252 σ = 8.417834
Relative Frequency
Flux Difference: Heat Relative to Coihueco (%)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
−40
−20
0
20
40


Average Relative Flux Difference vs. Time
HeatM1
HeatM2
HeatM3
Flux Difference: Heat Relative to Coihueco (%)
10
0
−10
−20
−30
2010
2011
2012
2013
2014
2015
2016
2017
2018
Time

Conclusions

- BG files have been used to monitor the Heat/Coihueco relative energy scale with a precision of about 2% (in each HEAT mirror!) for the period from 2010 to 2018.
- We need to create a relative calibration DB for each HEAT mirror to account for the variability.

Further applications of the BG files

- We have evaluated further applications of the BG files, such as:
    - Cloud detection,
    - Measuring the FD optical spot shape using bright stars.

  We will report at the next Collaboration meeting.