Accuracy of Ground-based Infrared Irradiance Measurements in the NOAA/BSRN Network

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- ~~Temperature measurements and equations in pyrgeometry~~
- Issues in the Atmospheric Radiation Measurement (ARM) program
- Calibration techniques and comparisons
- Field transfer of calibration

Albrecht & Cox (*J. Appl. Meteorol.* 1977)

$$E = \frac{U_{emf}}{C} + \sigma T_B^4 - k_3 \sigma (T_D^4 - T_B^4)$$

Philipona et al. (*Appl. Opt.* 1995)

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

Reda et al. (*J. Atmos. Sol. Terr. Phys.* 2002)

$$E = k_0 + \frac{U_{emf}}{C} + k_2 \sigma T_R^4 - k_3 \sigma (T_D^4 - T_R^4)$$

$$where \rightarrow T_R = T_B + 0.7044 U_{emf};\ [U] == mv$$

AERI - PIRs vs. surface temperature (2000)

Slopes
($W/m^2/K$)

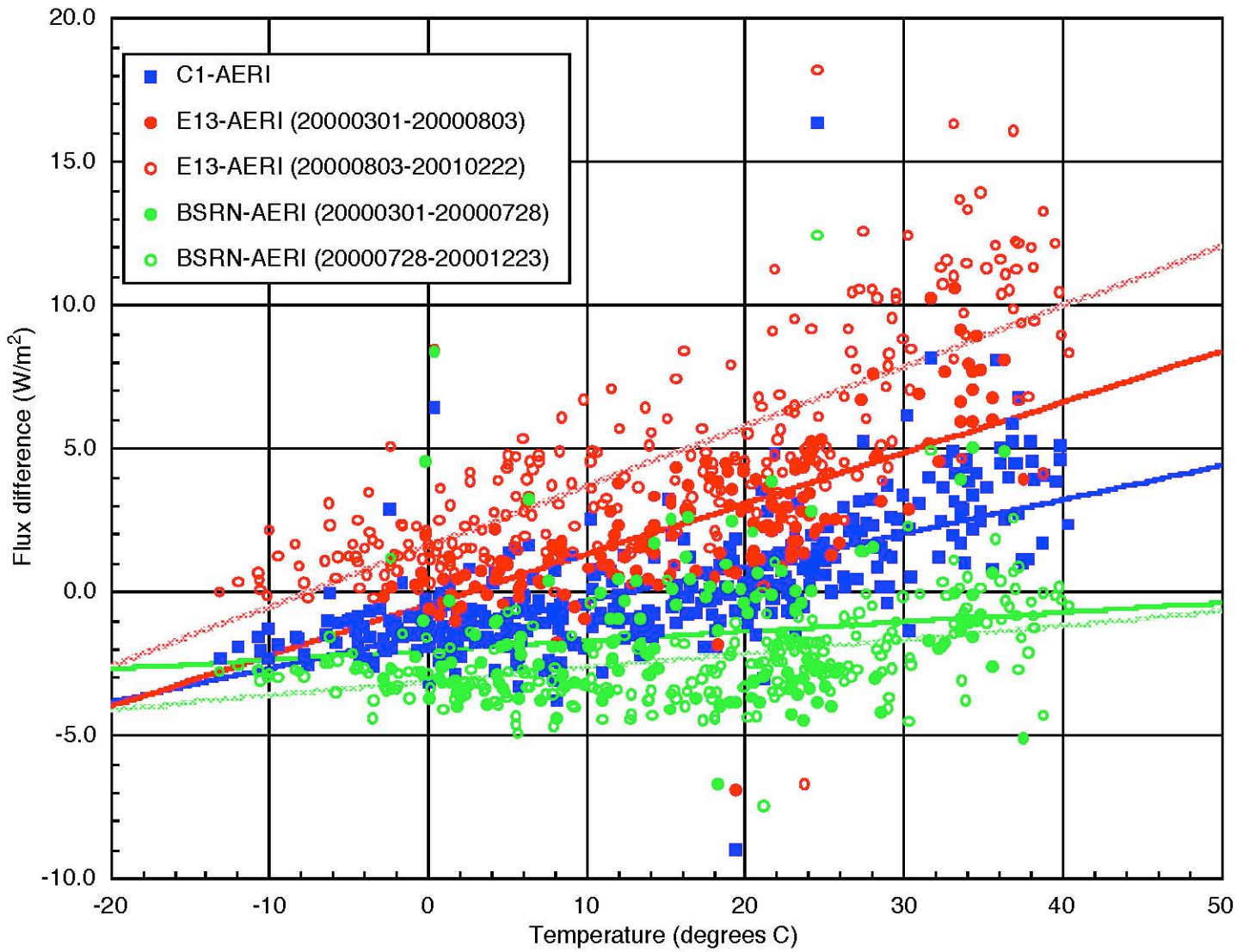
0.12

0.18(solid)

0.21(dotted)

0.03(solid)

0.05(dotted)



C1-BSRN	0.08
E13-C1	0.07
E13-BSRN	0.15

ARM PIR History

- First used Eppley C-values and 4.0 for k_3
- NREL/Eppley develop new blackbody
- Using Reda eqn and new BB resulted in ≈ 12 W/m^2 offset from AERI and RRTM
- Current process determines k_0 and k_3 in BB and k_2 outside when overcast and k_1 outside when clear

NREL Blackbody Calibration

$$W_{bb} = K_0 + K_1 * V + K_2 * \sigma T^4_r + K_3 * \sigma (T^4_d - T^4_r)$$

where,

W_{bb} = Blackbody radiation, in Watt/m^2

$K_{i=0-3}$ = PIR calibration coefficients

V = PIR thermopile output voltage, in μV

σ = $5.6697 * 10^{-8}$ Watt/(m^2.Kelvin^4)

T_d = PIR dome temperature, in Kelvin

T_r = PIR receiver temperature, in Kelvin,

$= T_c + \alpha * V$

where,

T_c = PIR case temperature, in Kelvin.

$1/\alpha = S * n * E$.

and,

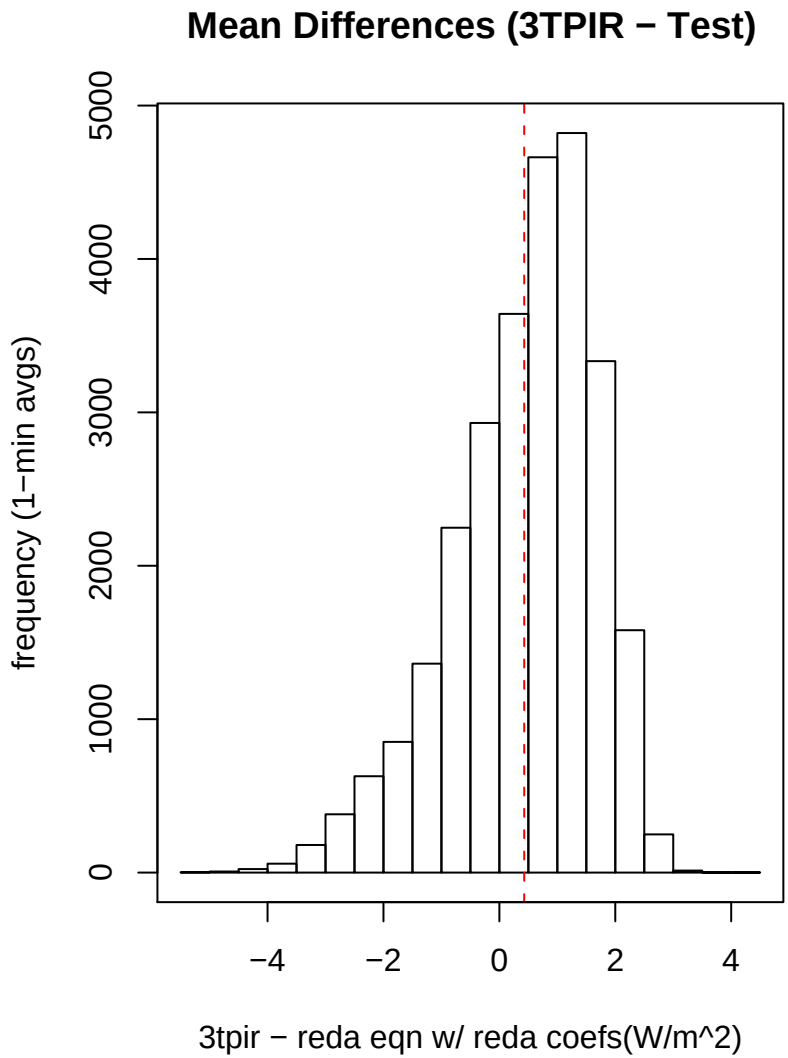
S = Seebeck coefficient = 39, in μV/K

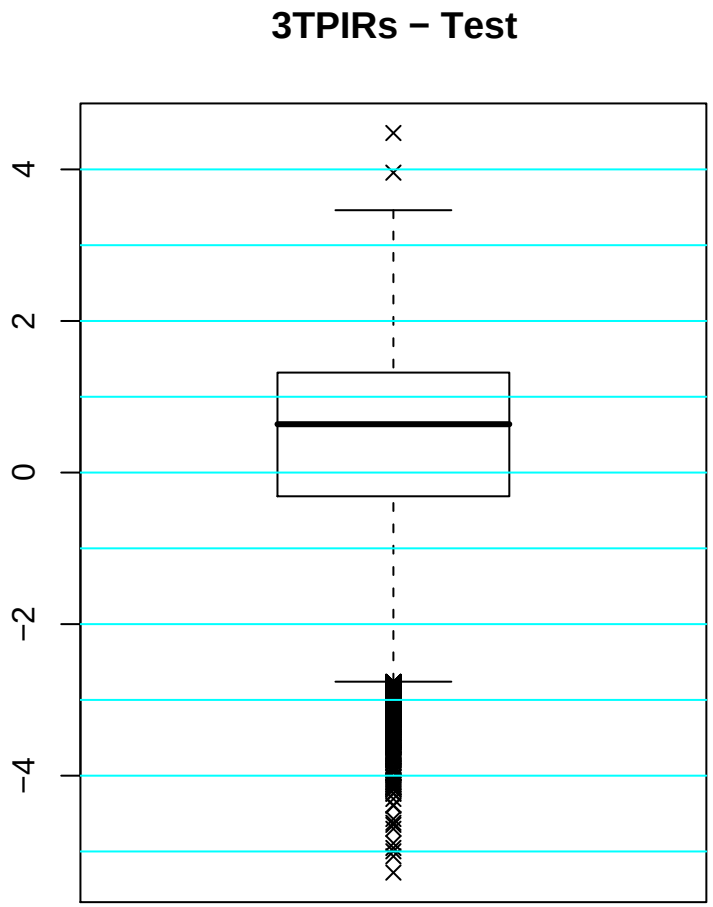
n = number of junctions = 56

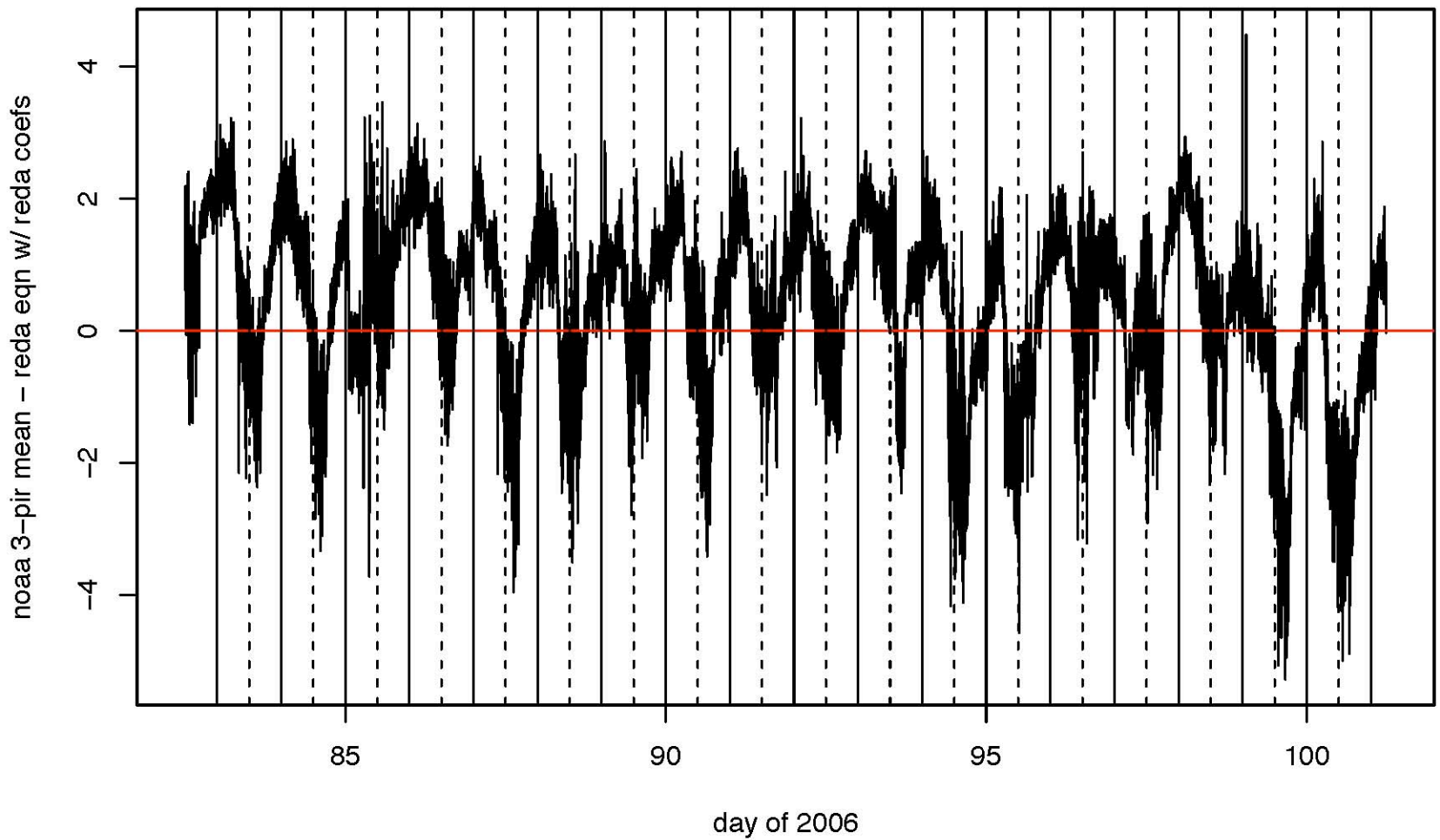
E = thermopile efficiency factor = 0.65

Then $T_r = T_c + 0.0007044 * V$.

The calibration is performed at 7 *pyrgeometer case* and *blackbody* temperature combinations, then a linear regression is used to calculate the calibration coefficients.


Mean Differences (3TPIR − Test)
frequency (1−min avgs)
0
1000
2000
3000
4000
5000
−4
−2
0
2
4
3tpir − reda eqn w/ reda coefs(W/m^2)

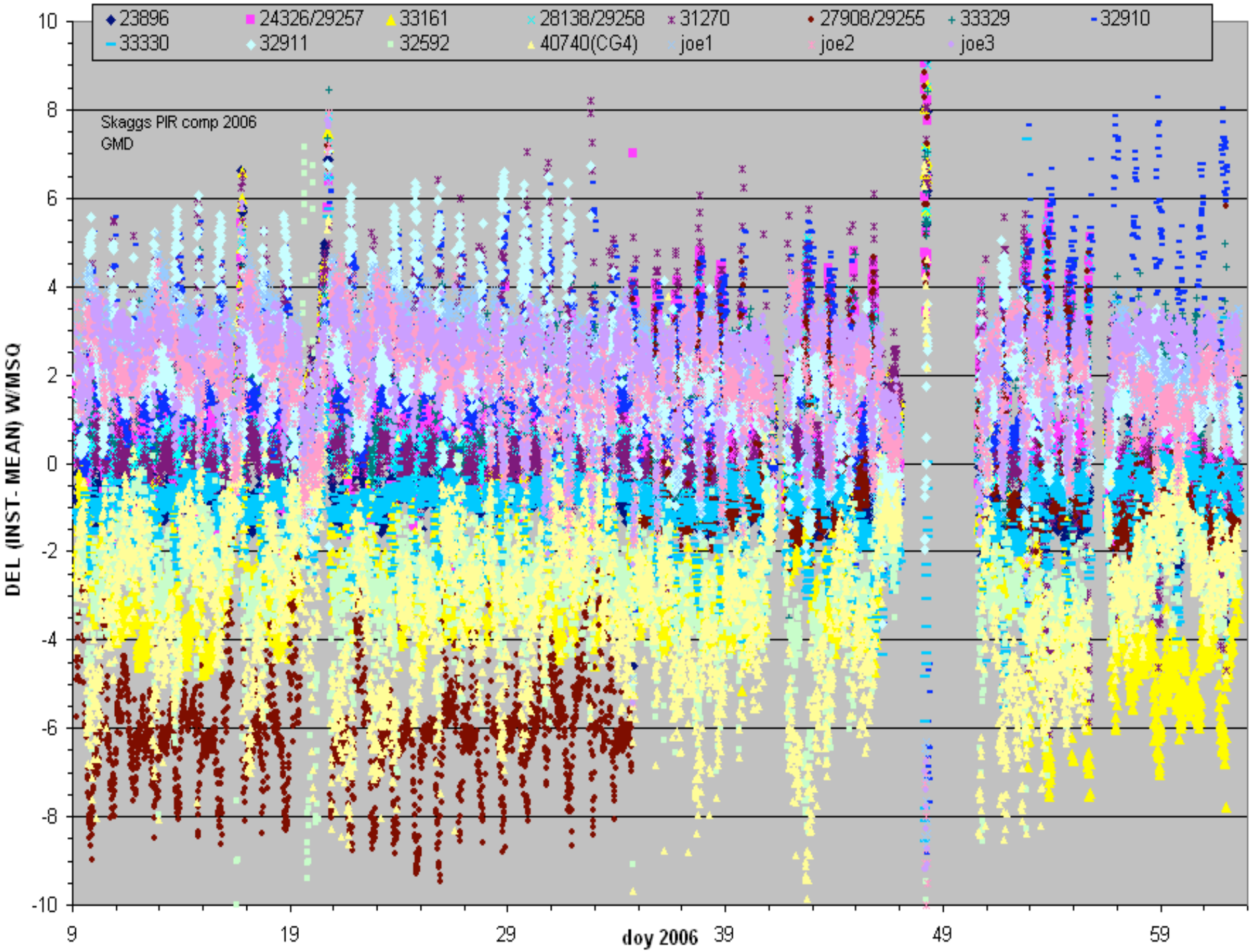

3TPIRs − Test
4
2
0
−2
−4

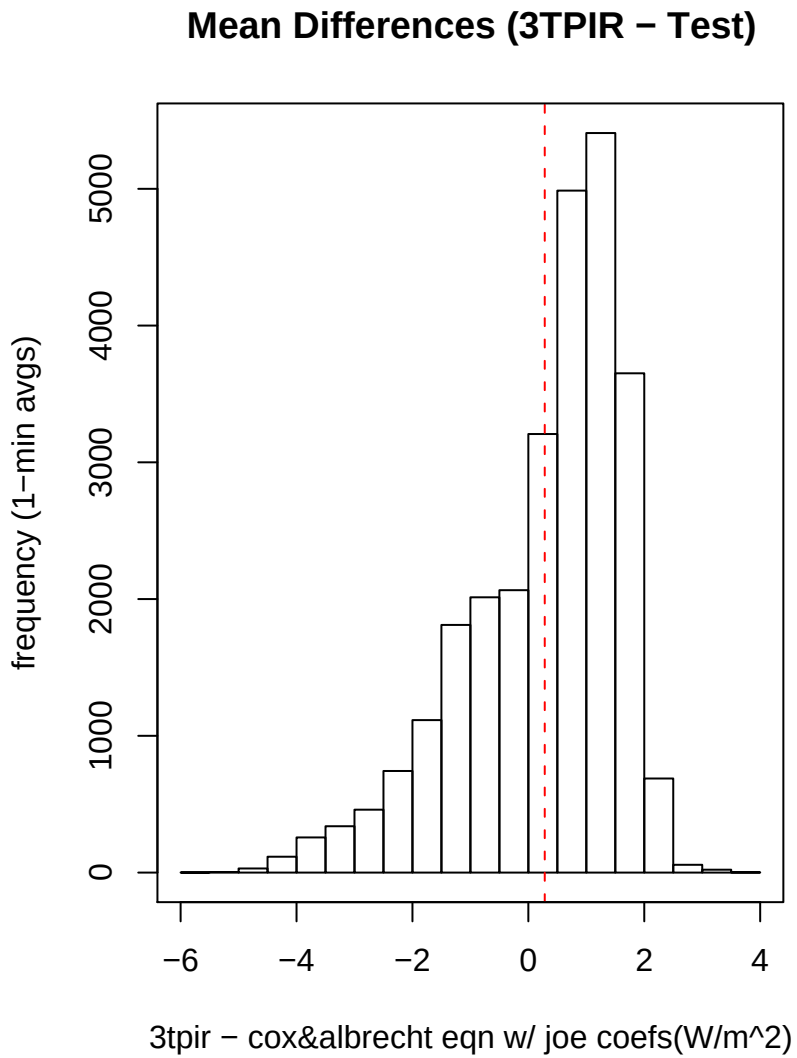

noaa 3−pir mean − reda eqn w/ reda coefs
4
2
0
−2
−4
85
90
95
100
day of 2006

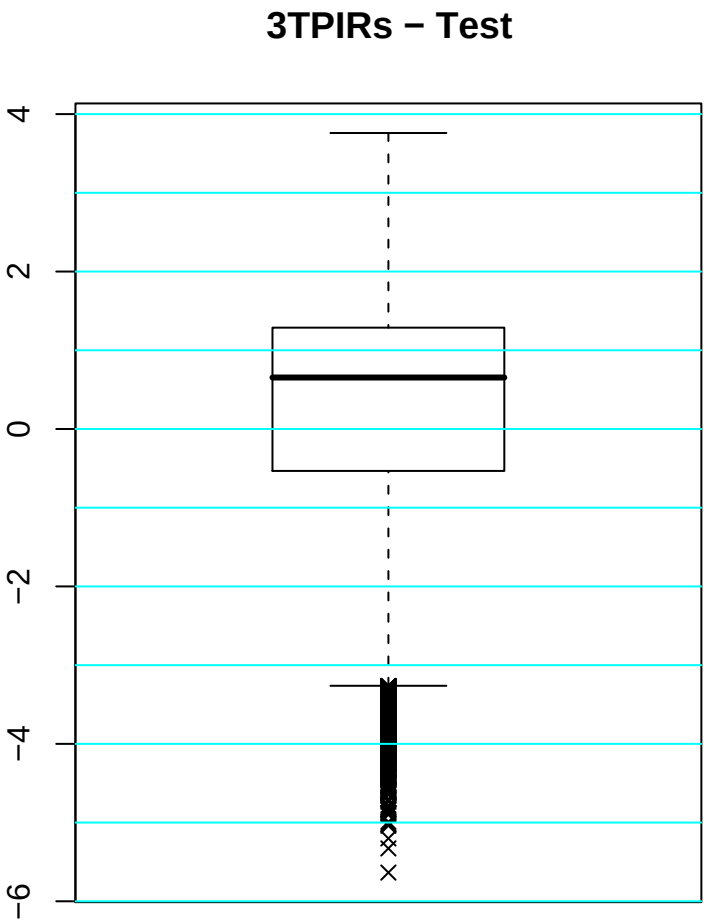
Calibration Methods

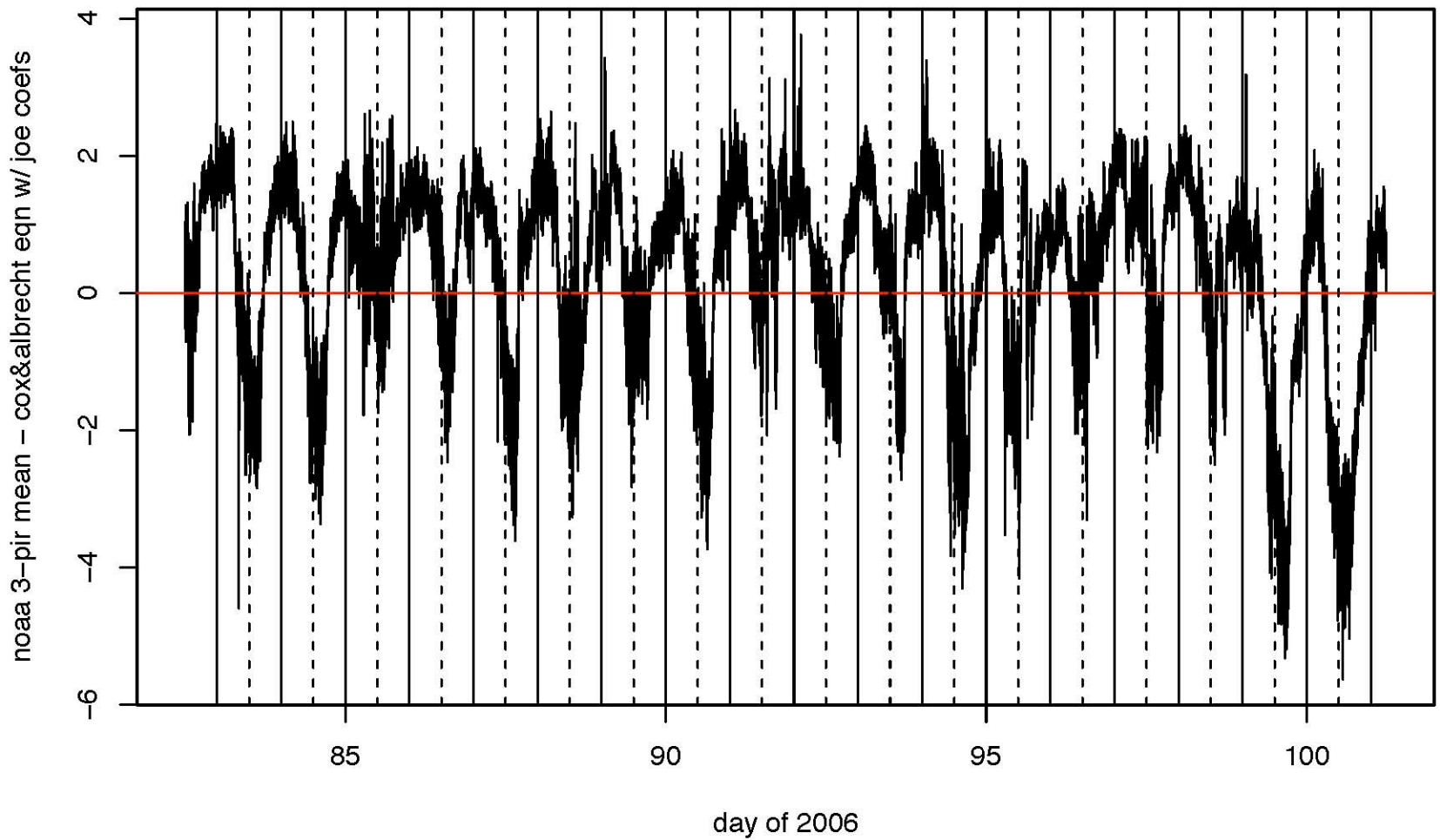
- GMD blackbody calibrations
- NREL blackbody and outdoor calibrations
- WMO blackbody calibrations

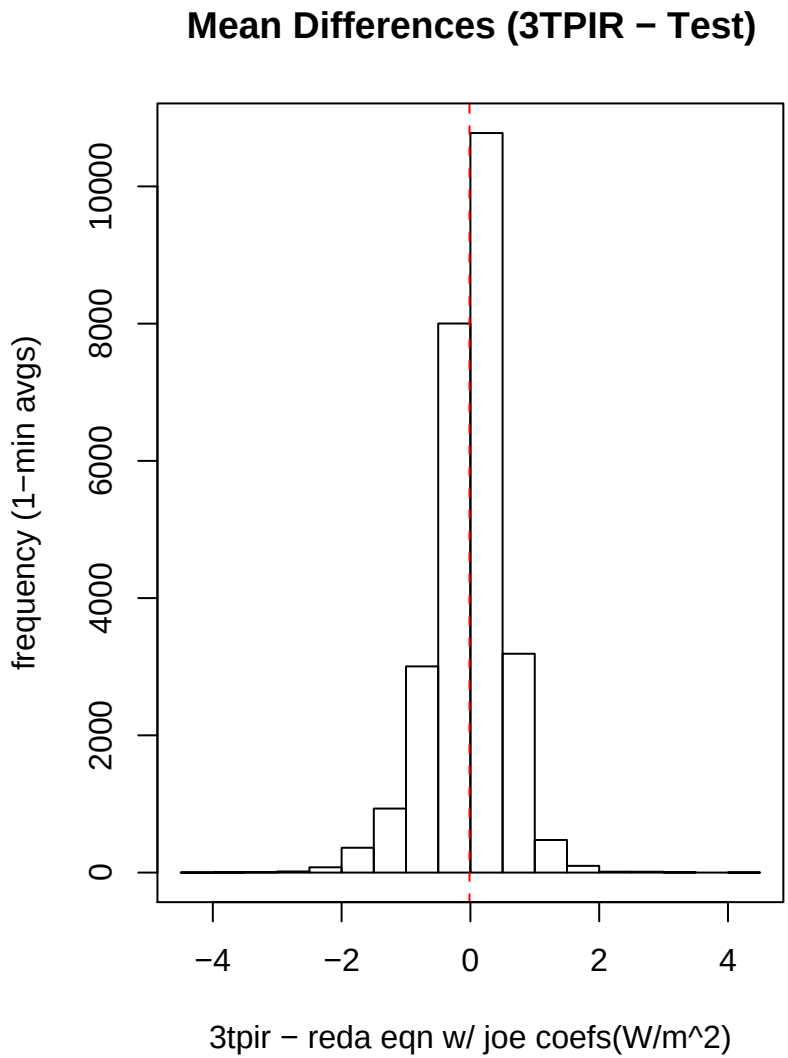
- Proposed outdoor calibrations

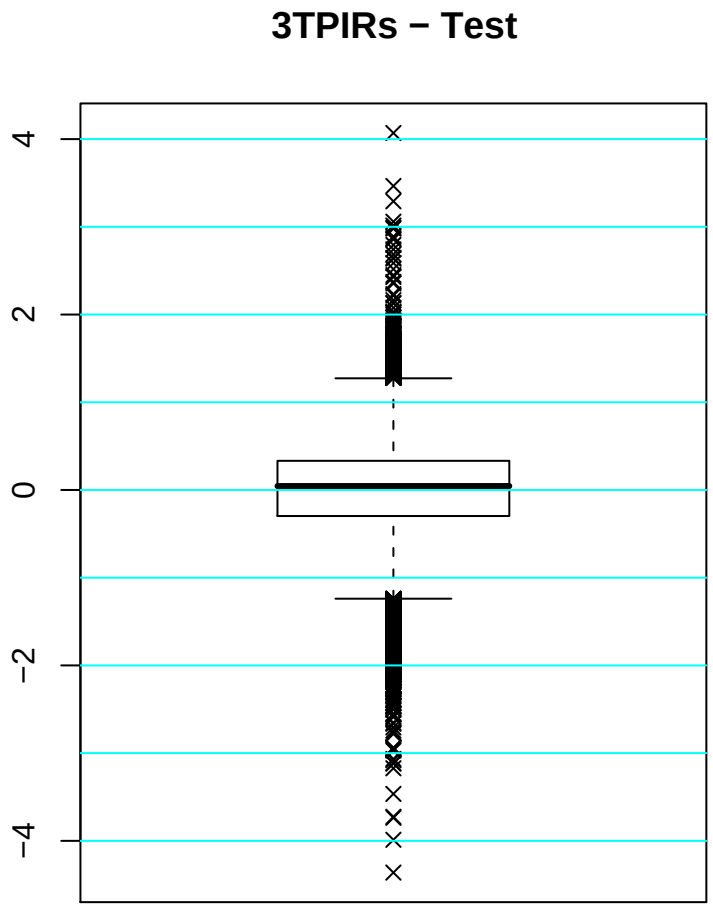

23896
24326/29257
33161
28138/29258
31270
27908/29255
33329
32910
33330
32911
32592
40740(CG4)
joe1
joe2
joe3
Skaggs PIR comp 2006
GMD
DEL (INST- MEAN) W/MSQ
doy 2006
10
8
6
4
2
0
-2
-4
-6
-8
-10
9
19
29
39
49
59

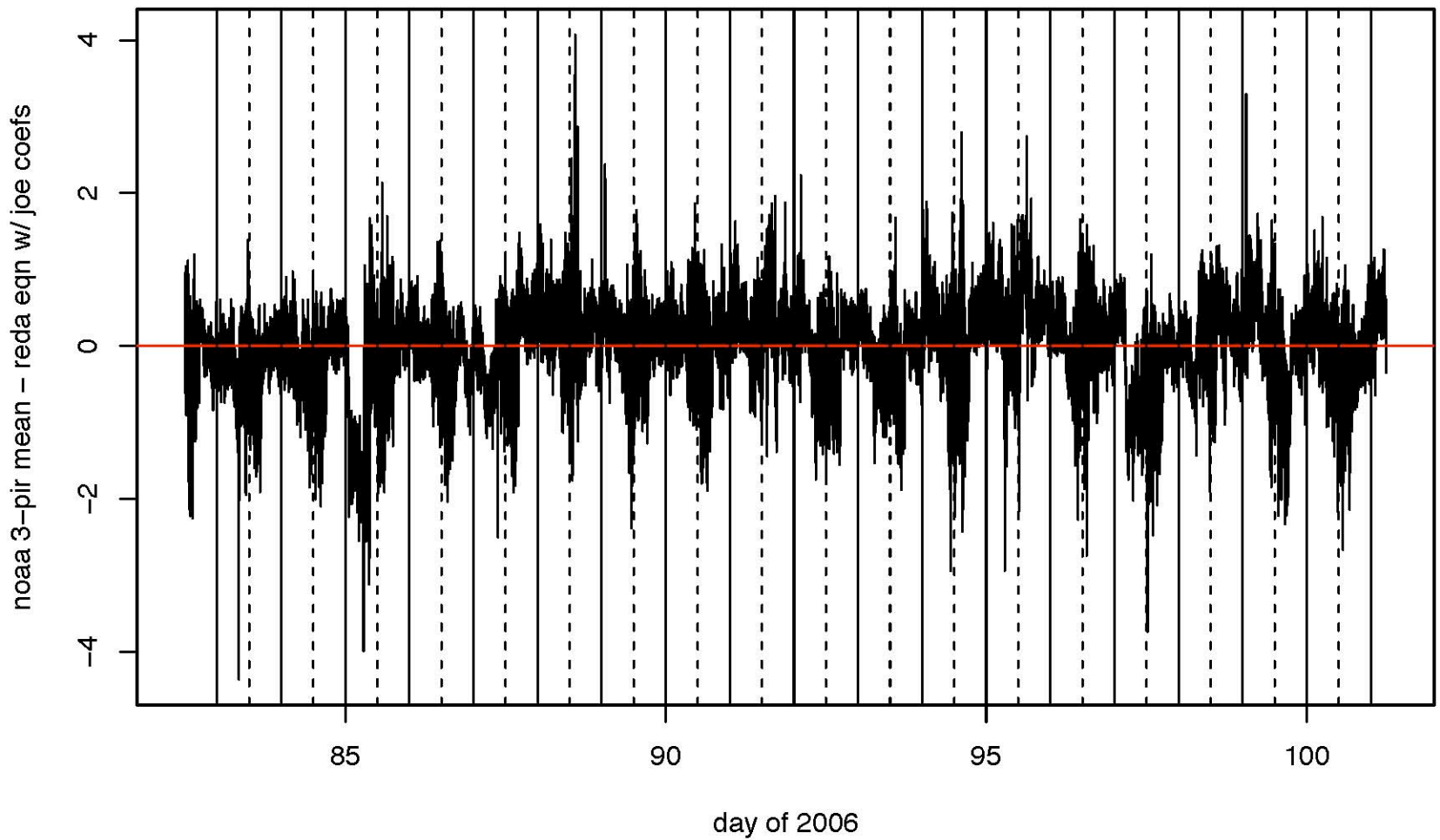

Mean Differences (3TPIR − Test)
frequency (1−min avgs)
0
1000
2000
3000
4000
5000
−6
−4
−2
0
2
4
3tpir − cox&albrecht eqn w/ joe coefs(W/m^2)

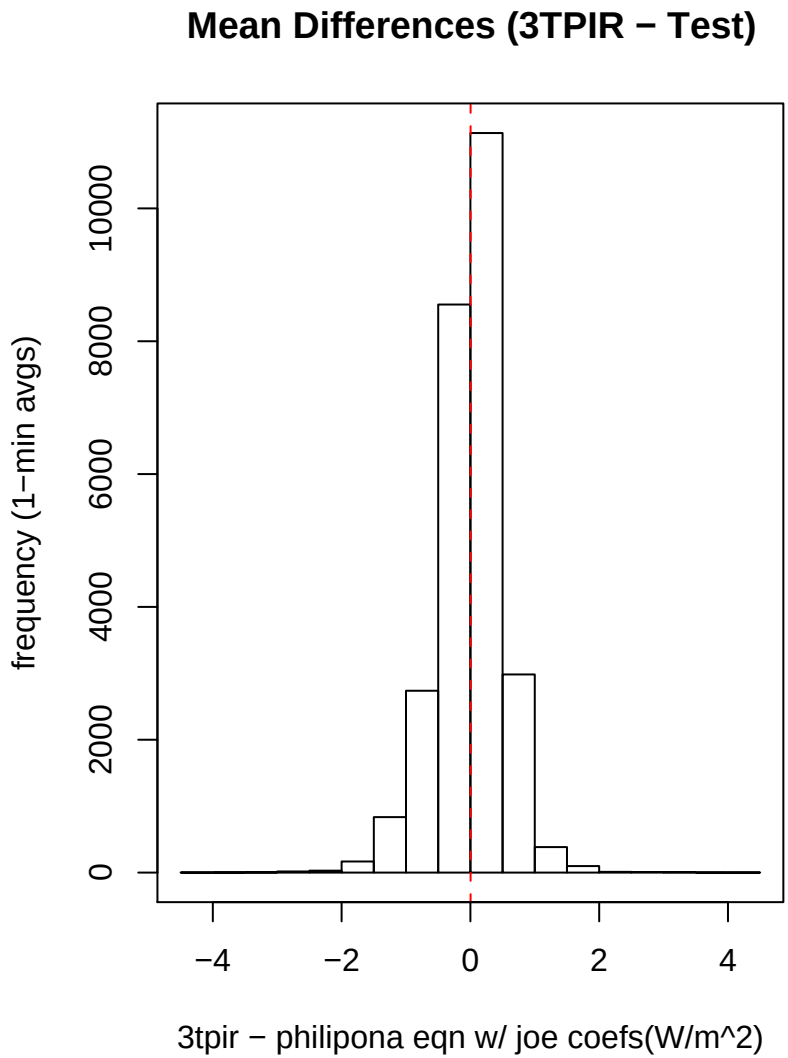

3TPIRs − Test
4
2
0
−2
−4
−6

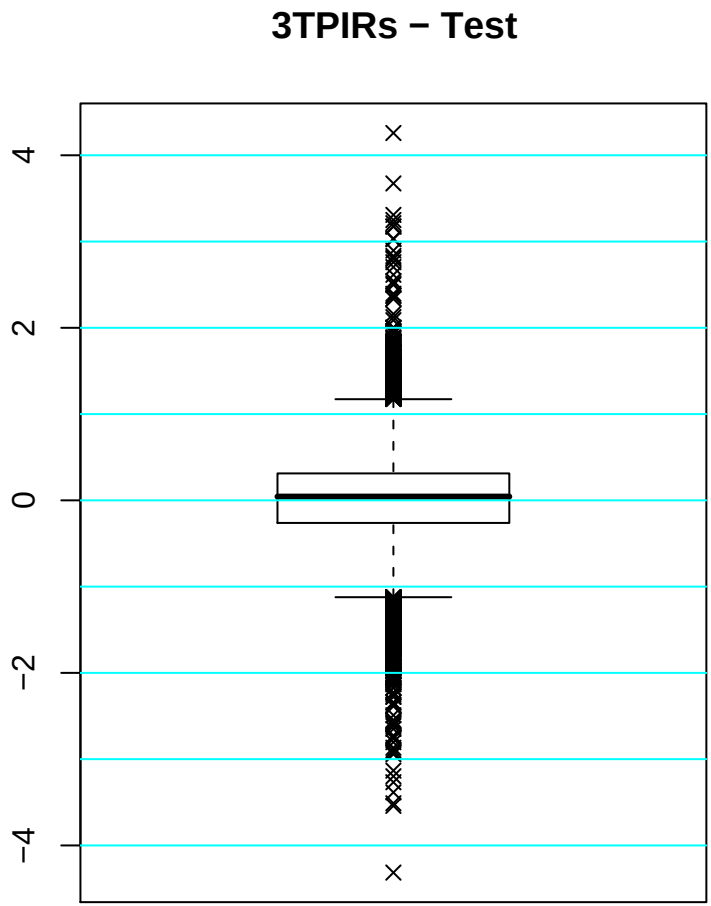

noaa 3−pir mean − cox&albrecht eqn w/ joe coefs
4
2
0
−2
−4
−6
85
90
95
100
day of 2006

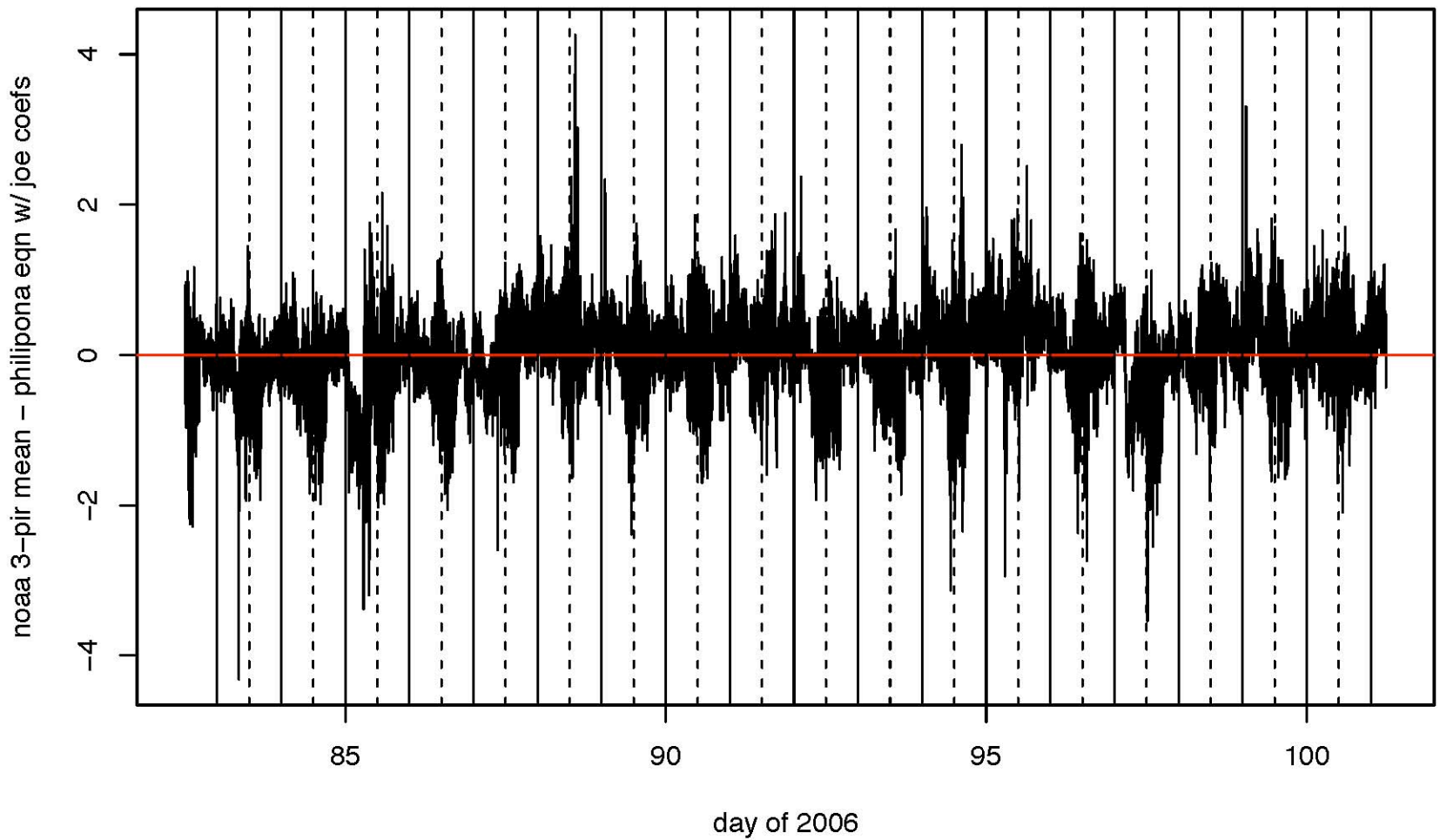

Mean Differences (3TPIR − Test)
frequency (1−min avgs)
0
2000
4000
6000
8000
10000
−4
−2
0
2
4
3tpir − reda eqn w/ joe coefs(W/m^2)


3TPIRs − Test
4
2
0
−2
−4


noaa 3–pir mean – reda eqn w/ joe coefs
4
2
0
−2
−4
85
90
95
100
day of 2006


Mean Differences (3TPIR − Test)
frequency (1−min avgs)
0
2000
4000
6000
8000
10000
−4
−2
0
2
4
3tpir − philipona eqn w/ joe coefs(W/m^2)


3TPIRs − Test
4
2
0
−2
−4

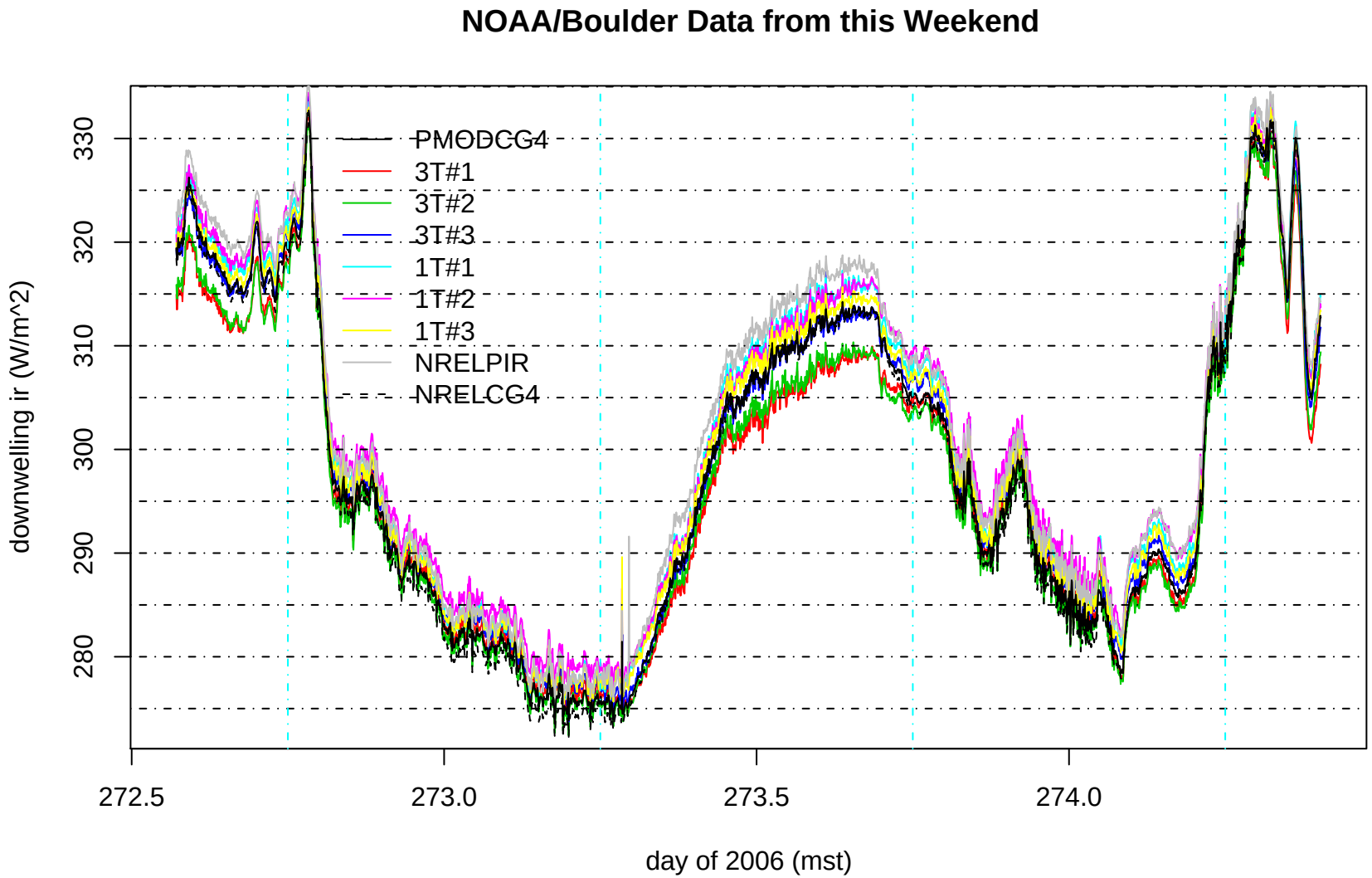

noaa 3−pir mean − philipona eqn w/ joe coefs
4
2
0
−2
−4
85
90
95
100
day of 2006

Conclusions

- Good blackbody calibrations with experimentally-determined dome/case correction term yields uncertainties of about 4 W/m^2; shading lowers this uncertainty
- Outdoor calibrations using either Reda or Philipona eqns produce uncertainties ~ 1 W/m^2
- This is predicated on the assumption of the standard in use being tied to an absolute standard

PMOD-Calibrated Pyrgeometer Comparison

- Three 3-thermistored PIRs calibrated in 2005
- Three 1-thermistored PIRs calibrated in 2005-06
- 1 CG4 from NREL calibrated in 2005
- 1 CG4 from PMOD calibrated in 2006
- 1PIR from NREL calibrated with their proposed method


NOAA/Boulder Data from this Weekend
PMODCG4
3T#1
3T#2
3T#3
1T#1
1T#2
1T#3
NRELPIR
NRELCG4
downwelling ir (W/m^2)
280
290
300
310
320
330
272.5
273.0
273.5
274.0
day of 2006 (mst)