Performance of Standard Radiometers on high-altitude platforms

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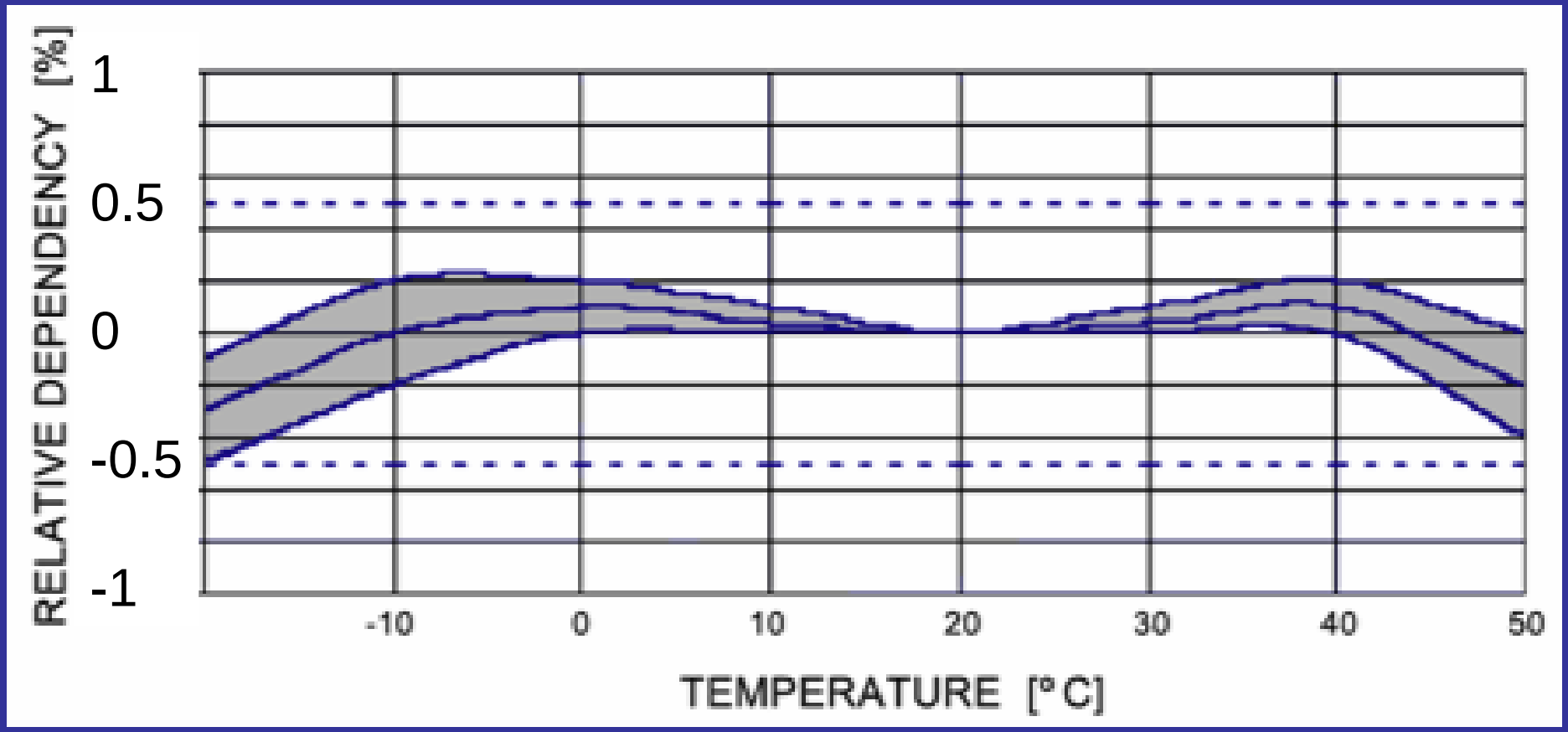
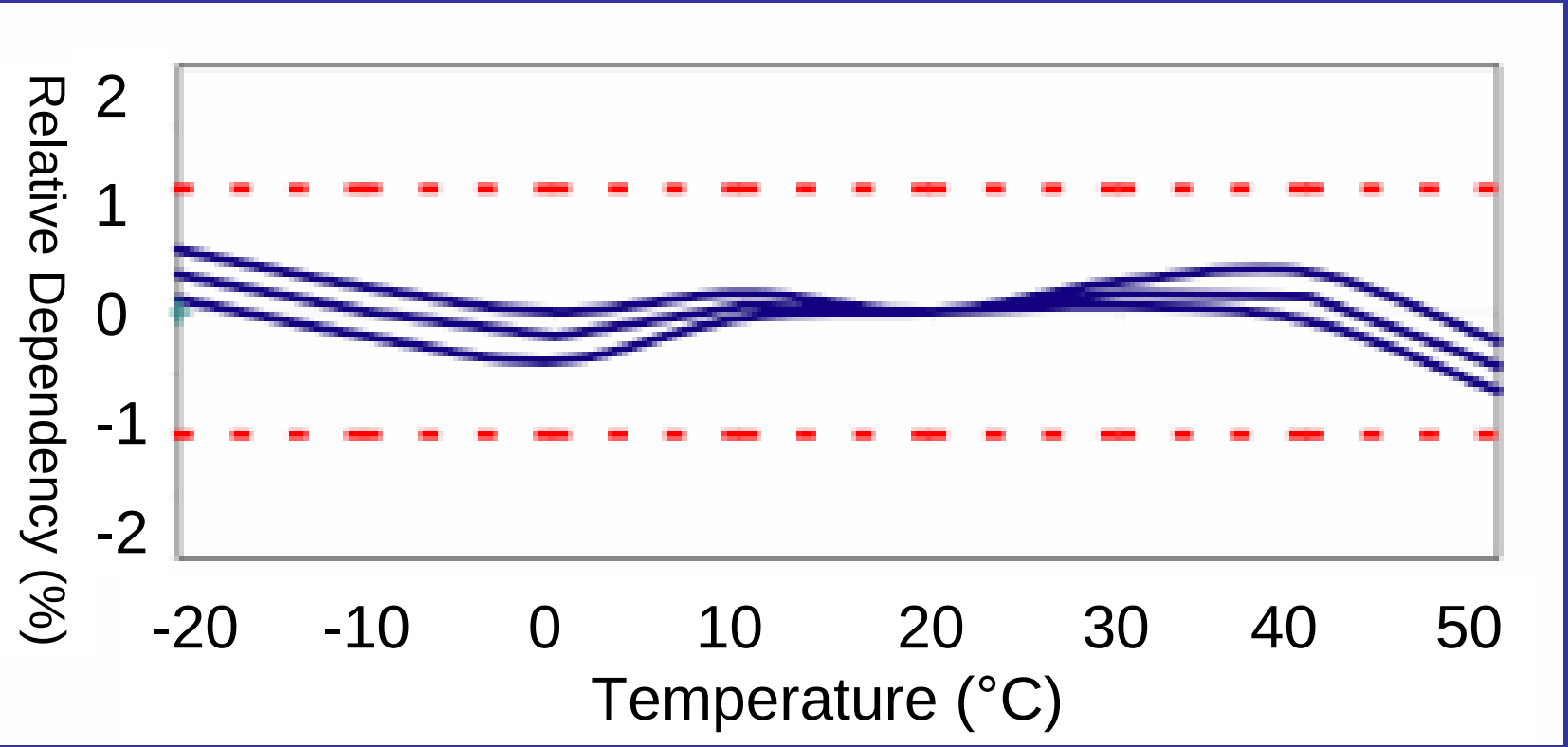
Sensitivity temperature dependency from manufacture: CM22



Sensitivity temperature dependency from manufacture: CG4

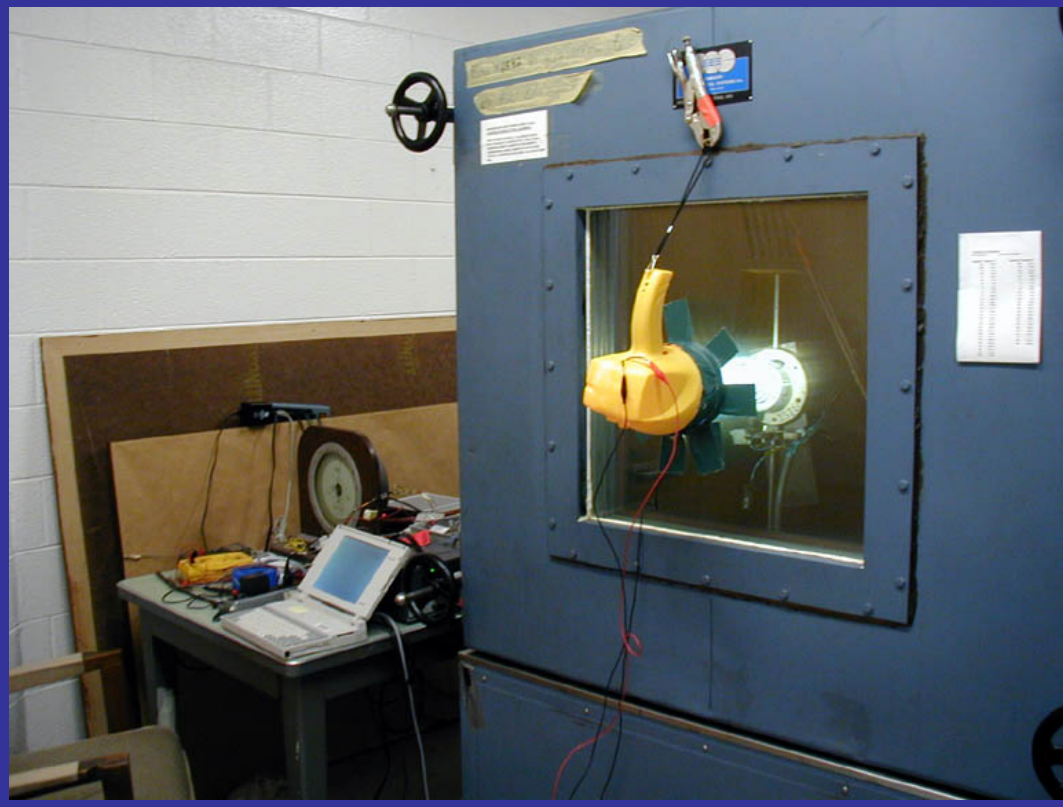


Applications

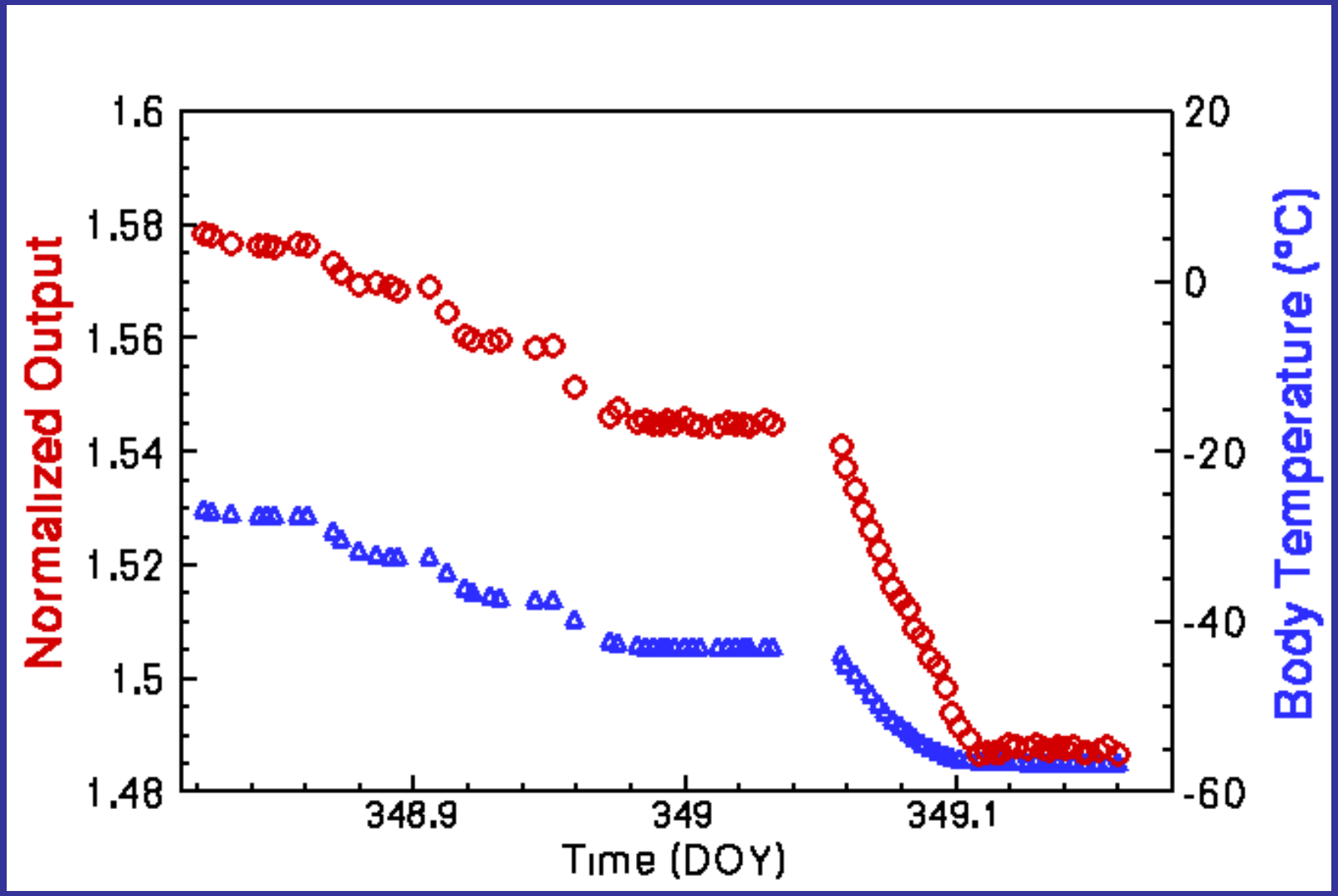
- Fly a high altitude platform (like a stratospheric balloon) carrying broadband flux radiometers over aircraft and over surface sites (ARM, BSRN,...) to measure radiative flux divergence;
- Polar radiation measurements.

Chamber Test Setup: Pyranometers

- Chamber temperature varies from 20 °C to -60 °C
- Chamber pressure varies from 830 hPa to 5 hPa
- External light source monitored by 2 LICOR Sensors;



Normalized CM22 Output vs. Body Temp.



Extending Sensitivity Temperature Dependency for pyranometer

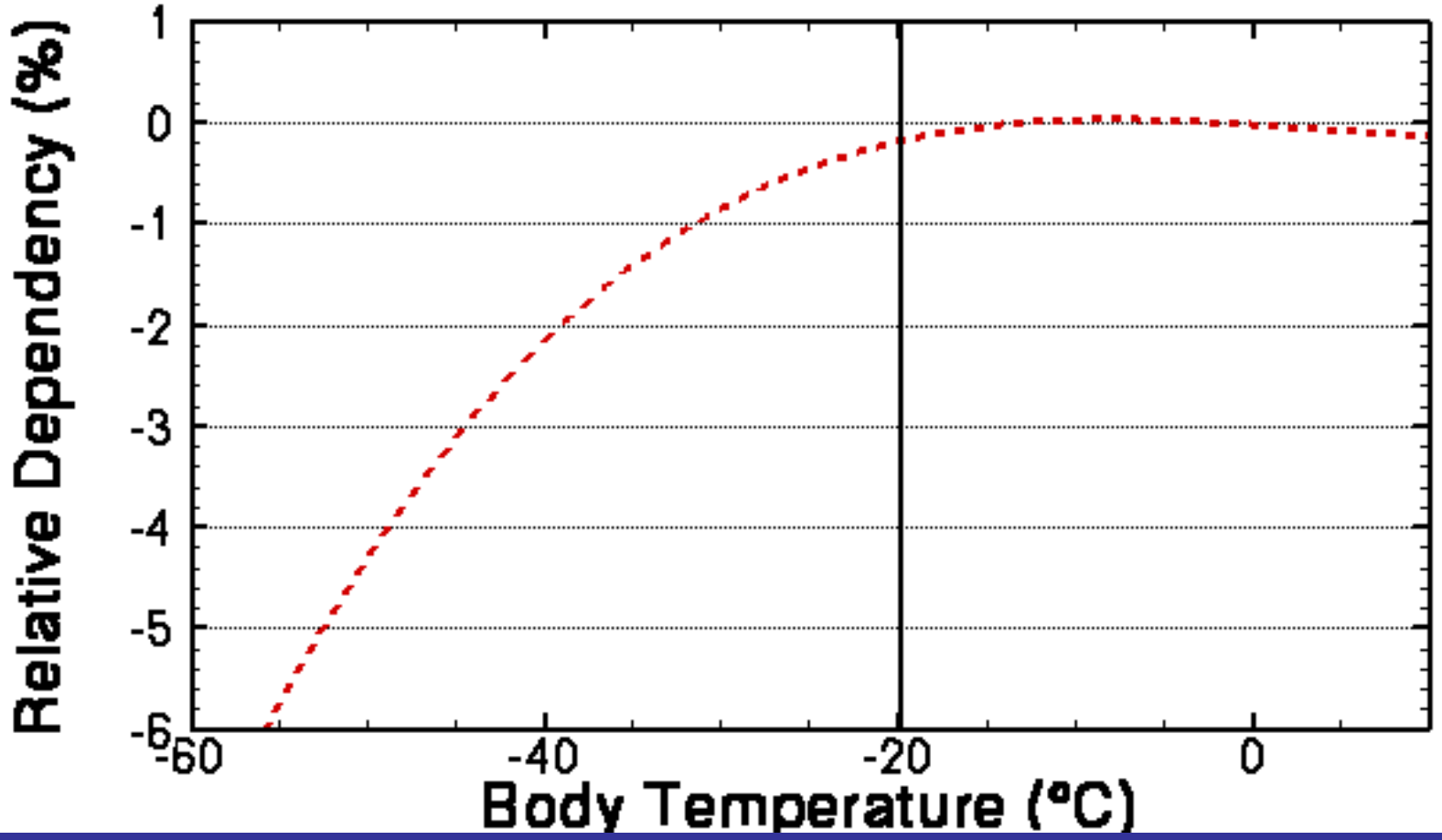
First, determine LICOR sensitivity using data taken at room temperature (~20°C):

$$S_{licor} = \frac{U_{licor}}{U_{cm}} \times S_{cm}^{fac}$$

Then, use LICOR to derive the pyranometer's sensitivity temperature dependency:

$$S_{cm}(T_B) = \frac{U_{cm}}{U_{licor}} \times S_{licor}$$

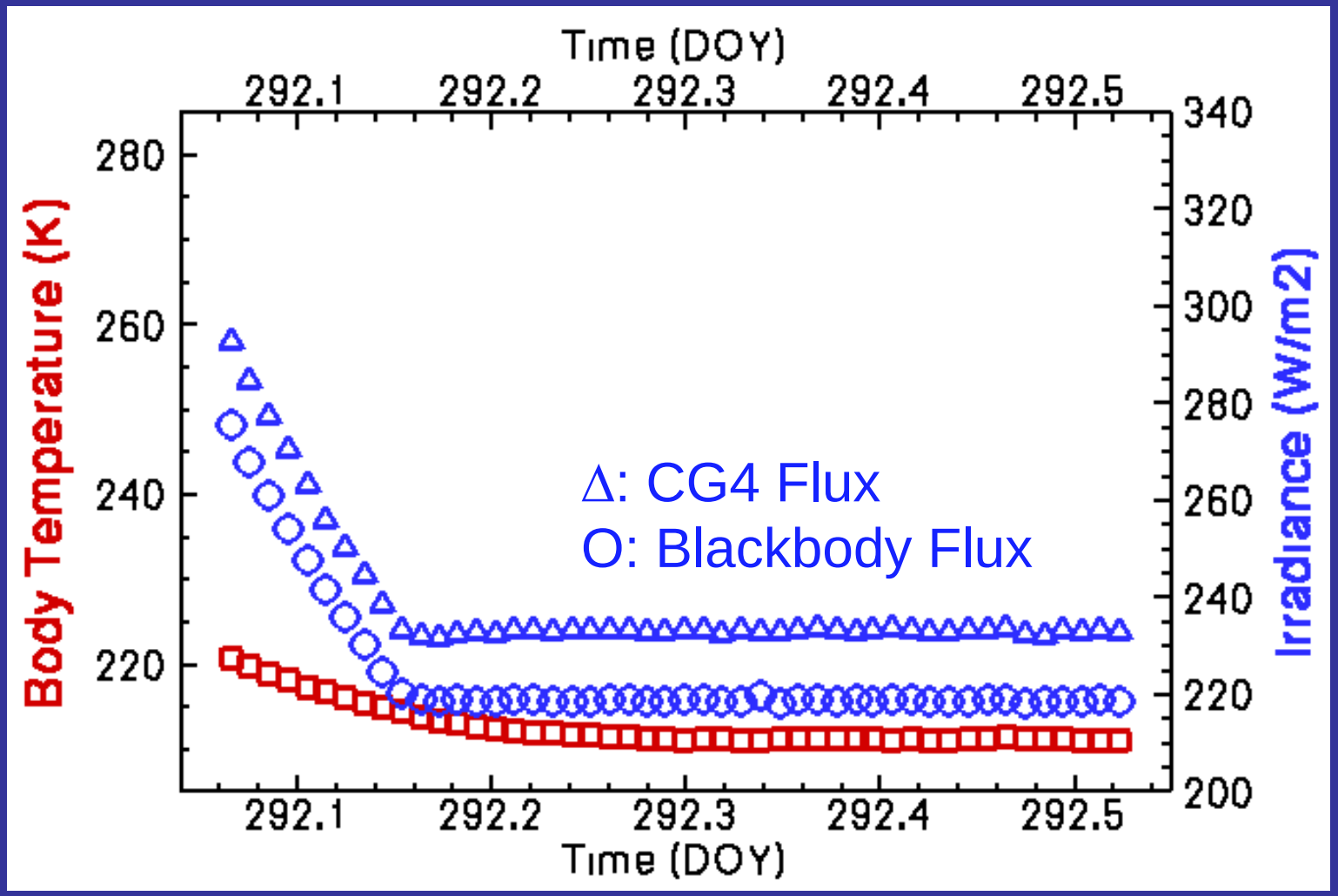
Extended Sensitivity Temp. Dependency: CM22 (CM21 similar)



Chamber Test Setup: Pyrgeometers

- Chamber temperature varies from 20 °C to -55 °C
- Chamber pressure varies from 830 hPa to 5 hPa
- Pyrgeometers exposed to different blackbody temperatures

CG4 and Blackbody Flux difference vs. Body Temperature

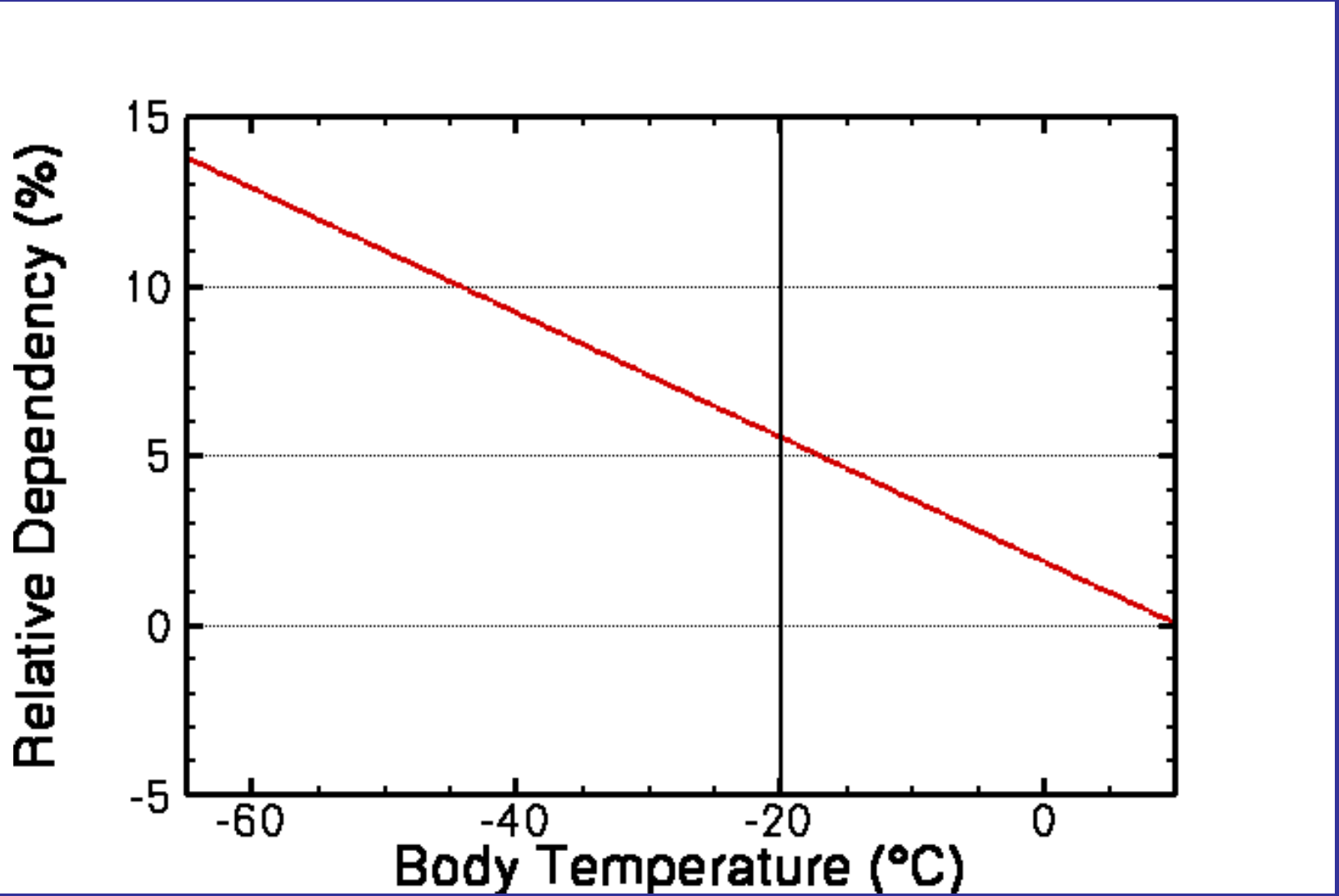


Extending Sensitivity Temperature Dependency for pyrgeometer

- For pyrgeometer, using blackbody to derived sensitivity temperature dependency:

$$S_{cg}(T_B) = \frac{U_{cg}}{F_{bb} - \sigma T_B^4 + k_3 \sigma (T_D^4 - T_B^4)}$$

Extended Sensitivity Temp. Dependency: CG4



Pressure Adjustment for Sensitivity

- For all vacuum chamber data, we introduce the pressure adjustment factor:

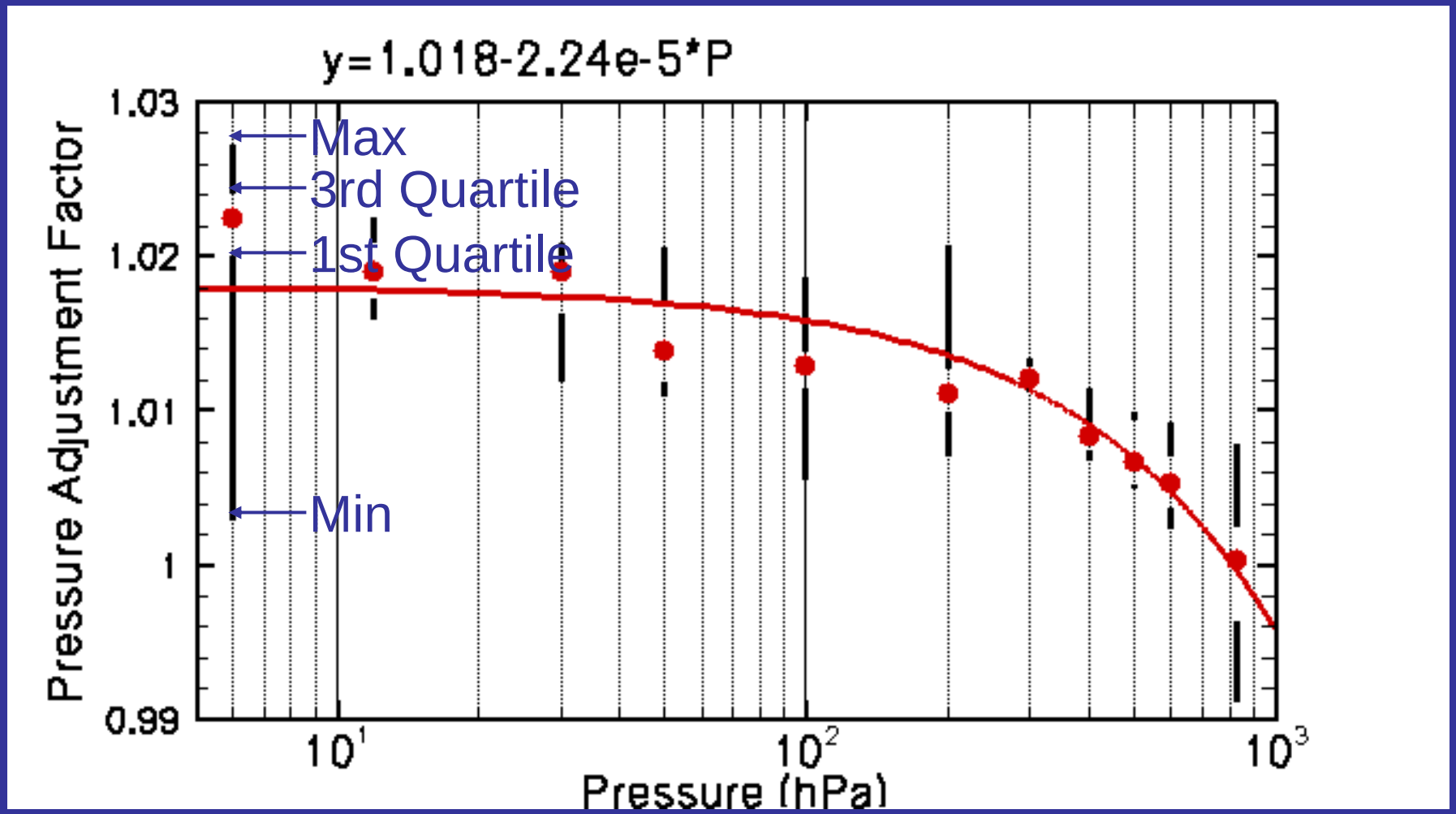
Pyranometer:

$$\frac{U_{cm}}{S_{cm}(T_B) \times \gamma_{cm}(P)} = \frac{U_{licor}}{S_{licor}}$$

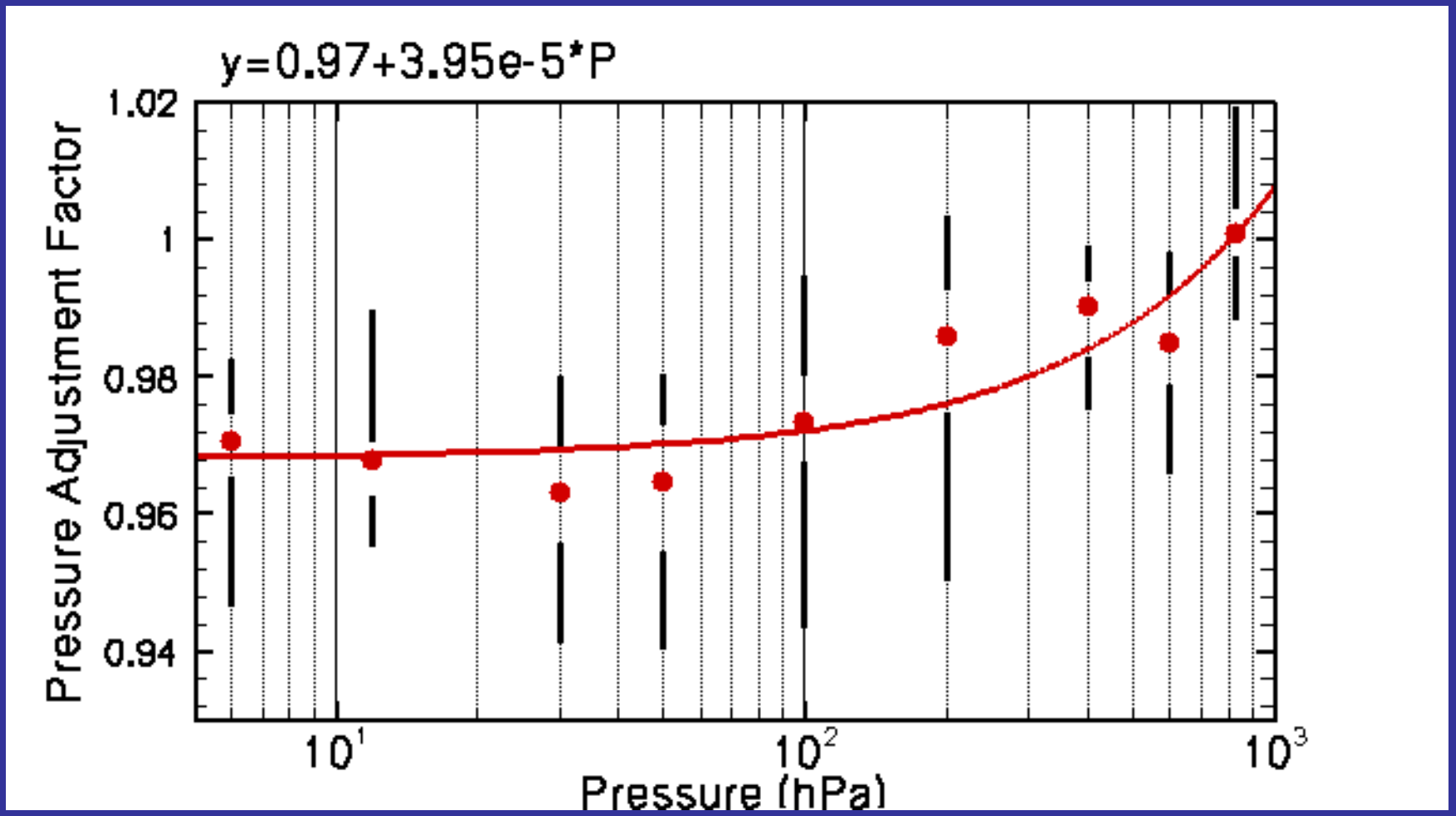
Pyrgeometer:

$$F_{bb} = \frac{U_{cg}}{S_{cg}(T_B) \times \gamma_{cg}(P)} + \sigma T_B^4 - k_3 \sigma (T_D^4 - T_B^4)$$

Pressure Adjustment Factor for CM22



Pressure Adjustment Factor for CG4



Temp. Dependent Sensitivity and Pressure Adjustment Factor improve agreement: CM22

	TB<-40°C	P<10 hPa
Number	249	415
Mean Licor output	649.5	265.3
Mean CM22 output	621.3	268.2 *
RMS	29.9	3.6
Bias	-28.2	2.9
Mean T(P)-Adjusted CM22 output	650.3	263.5
RMS	1.6	2.8
Bisa	0.8	-1.8

* The output is temperature adjusted

Temp. Dependent Sensitivity and Pressure Adjustment Factor improve agreement: CG4

	TB<-40°C	P<10 hPa
Number	818	180
Mean Blackbody output	235.0	353.1
Mean CG4 output	249.4	351.5 *
RMS	14.6	1.7
Bias	14.4	-1.6
Mean T(P)-Adjusted CG4 output	234.9	353.2
RMS	0.9	0.8
Bisa	-0.1	0.1

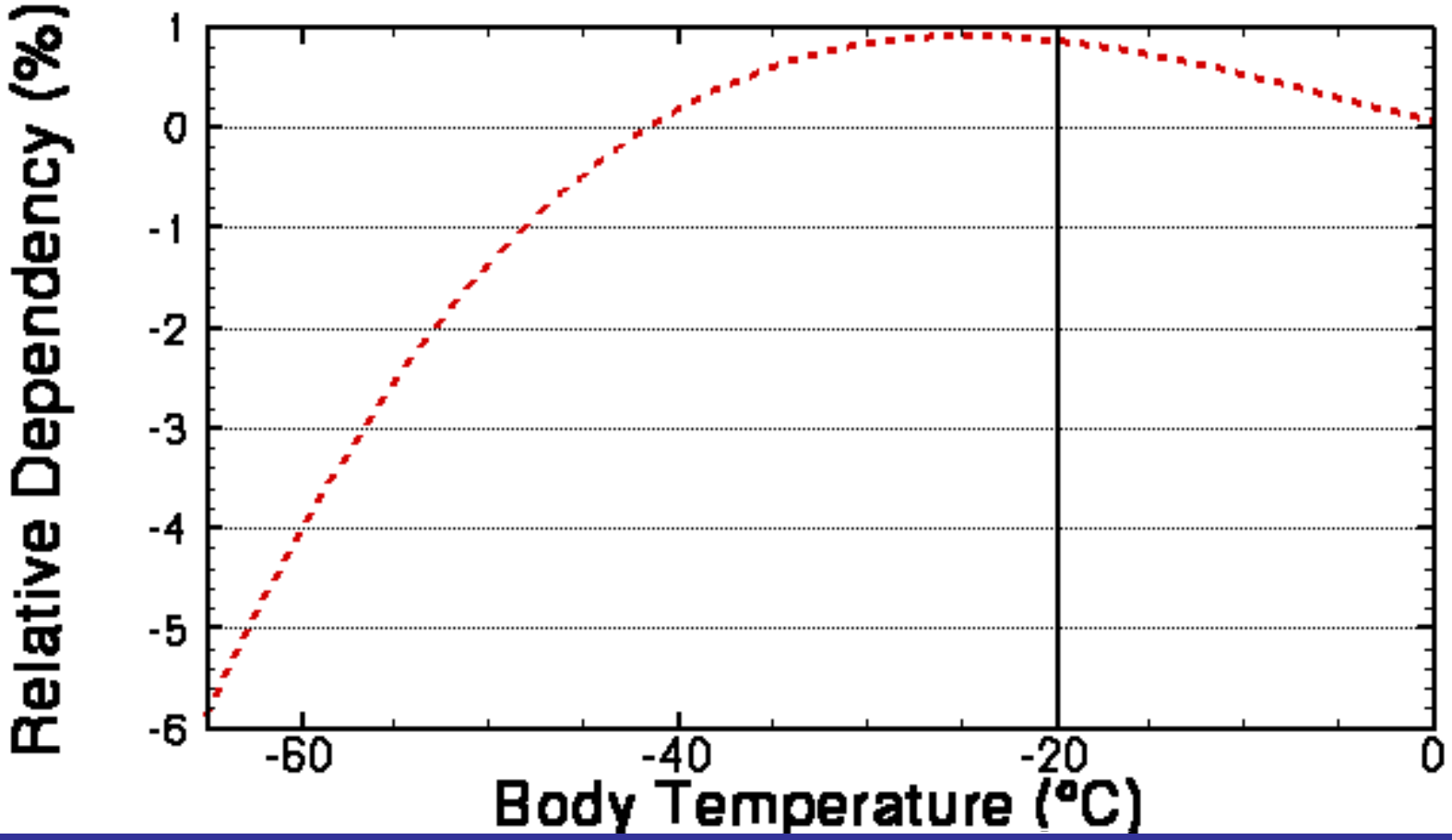
* The output is temperature adjusted

Conclusions

- Sensitivity of CM22 & CM21 pyranometers decreases by 4–6% as body temperature lowers to -60 °C.
- Sensitivity of CG4 pyrgeometer exhibits larger temperature dependency: it increases by 10% at body temperature of -45 °C.
- Sensitivity of CM22 and CG4 changes for about 2% from 5hPa to 830hPa.
- Thus…, to deploy standard radiometers on stratospheric platforms, they need to be characterized for their extended temp. dependency or put in temperature-controlled environment closure.

Backup Slides

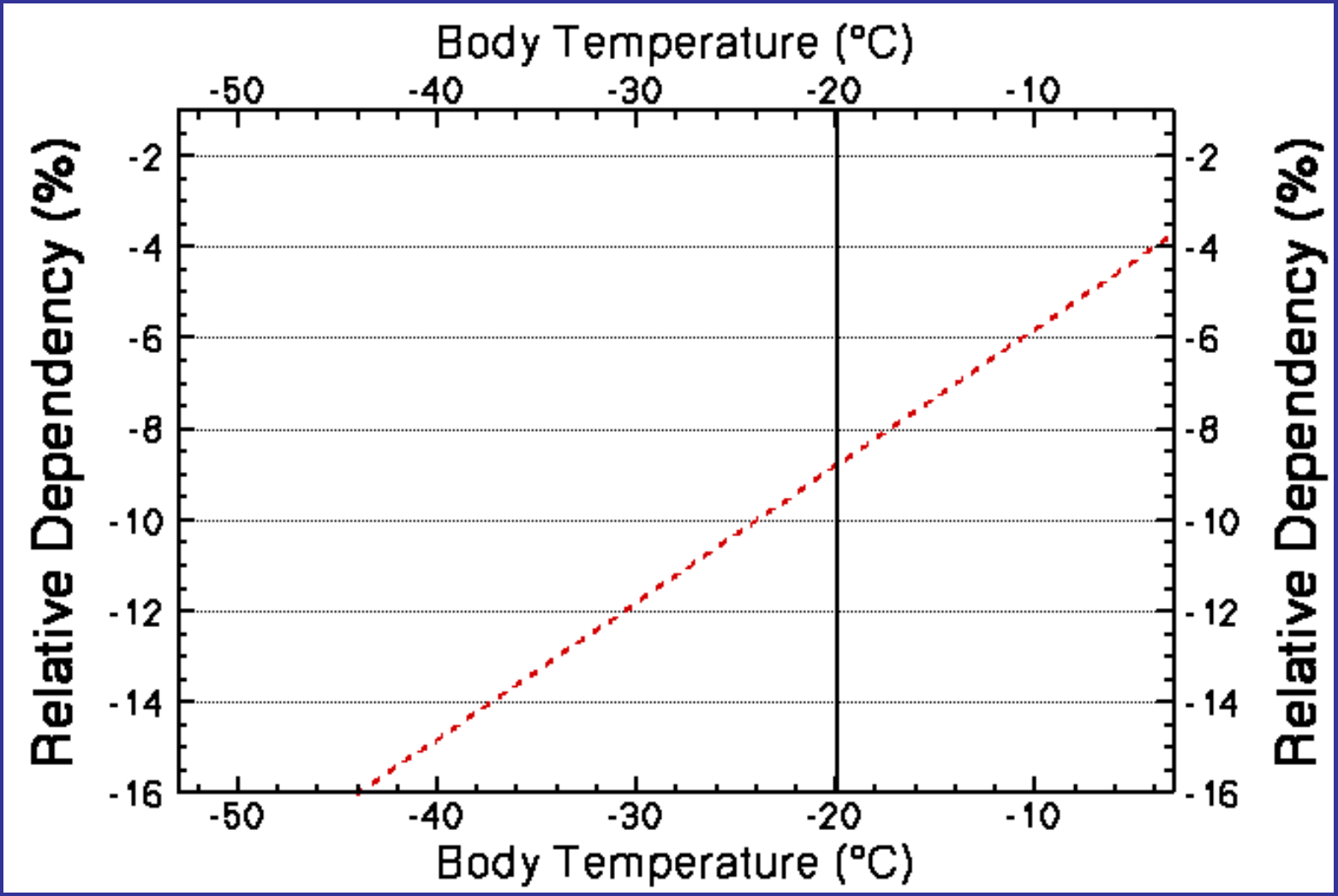
Extended Sensitivity Temp. Dependency : CM21



Temp. Dependent Sensitivity reduces the bias & RMS error at low temp.

- At body temp. less than -40 °C, Using temp. dependent sensitivity instead of the constant one:
  - Reduces the bias (RMS) between LICOR and CM22 output from 28 W/m2 to 1 W/m2, and RMS from 30 to 2 W/m2;
  - Reduces the bias between blackbody and CG4 output from 14 W/m2 to 1 W/m2, and RMS from 15 to 1 W/m2.

Pressure Adjustment Factor reduces the bias and RMS error further

- For chamber pressure less than 10 hPa, introducing pressure adjustment factor:
  - Reduces the bias between CM22 and LICOR from 3 W/m2 to 2 W/m2, and the RMS from 4 to 3 W/m2;
  - Reduces the bias between CG4 and blackbody from 2 to 0.1 W/m2, and RMS from 2 to 1 W/m2.

Extended Sensitivity Temp. Dependency: PIR