PIR – Precision Infrared Radiometer on Kilo Moana

Frank Bradley – frank.bradley@csiro.au

The Eppley PIR has 3 output signals; the thermopile (PIRc, mV), case temperature (PIR case, V), and dome temperature (PIR Hemis, V).

The 3 signals are combined in the Pyrgeometer Equation, which determines the thermal balance of the instrument and hence the contribution of downwelling longwave radiation (LW). The "Precise Method" given by Eppley is an approximation because it ignores the contribution of the dome temperature. The correct equation is given in Fairall et al. (1996), or Bradley and Fairall (2008). If the thermopile output is V, case and dome temperatures Tc and Td respectively (degrees Kelvin),

$$LW = V/s + \sigma Tc^4 + B\sigma(Tc^4 - Td^4)$$

where s is the PIR sensitivity, σ Boltzmann's constant (5.67×10^{-8}), and B a constant which depends slightly on the particular instrument but usually taken as 3.5. On the Kilo Moana cruise km0808, typical values of these 3 terms on the RHS were,

$-66.6+460.9+(-10.9) = 383.4$ Watts per m^2

Note that the first term, the only one involving the PIR sensitivity calibration, is not the most significant. That is due to the case temperature, so it's important that this be measured accurately. For this and the dome, Eppley have installed high quality thermistors, YSI 44031.

On Kilo Moana, the Campbell logger measures the resistance of these thermistors using what Campbell (section 7.3 of the manual) call a Half Bridge circuit, essentially the circuit shown on the Eppley PIR instruction sheet. The thermistor (resistance Rs) and a reference resistor (R_f = 10,000 ohms) form a divider across an accurate voltage Vx (5.000V) provided by the logger. If the voltage across Rs is V_1, the ratio $V_1/Vx=X=Rs/(Rs+R_f)$ and simple arithmetic gives $Rs=R_fX/(1-X)$. The logger outputs the voltages V_1 for both dome and case thermistors.

Calculating LW from data in MET file

For the example above, PIRc=-0.257mV, Case=2.393V, Hemis (Dome)=2.368V

First term: Thermopile sensitivity $s = 3.86 \times 10^{-6}$ volts/Wm^{-2} (calibration 15/2/2008) -0.257mV /1000 to convert to microvolts and divide by s gives -66.58

Second term: V_1 = 2.393V, Vx =5V so X=0.4786, R_f =10,000 so Rs =9179.1 ohms

The YSI 44031 equation is $T(K)= 1/[(C1+C2*ln(R)+C3*(ln(R))^3]$ with $C1$=0.0010295, $C2$=0.0002391, $C3$=0.0000001568, this gives 300.27 deg K. Converting to Celsius by subtracting 273.15 gives 27.12C , about 2C above ambient temperature which is typical for a sunny day. It's a useful check - if the calculated temperature of case or dome is much different from air temperature there's something wrong.

Third term: Calculate essentially as for 2nd. Dome resistance in this example was 8997.0 ohms, temperature 27.62C slightly higher than the case as you would expect

References

Bradley, E.F. and Fairall, C.W. , 2007 A guide to making climate quality meteorological and flux measurements at sea. NOAA Technical Memorandum OAR PSD-311, Earth System Research Laboratory, Boulder, CO.

Fairall, C. W., Persson, P. O. G., Bradley, E. F., Payne, R. E., and Anderson, S. , 1998 A new look at calibration and use of Eppley Precision Infrared Radiometers. Part I: Theory and application. *J. Atmos. Oceanic Tech.*, **15**, 1229-1242.