Zenith Angle Bias in Pyranometer Calibration

Michael Milner

Bureau of Meteorology

Australia

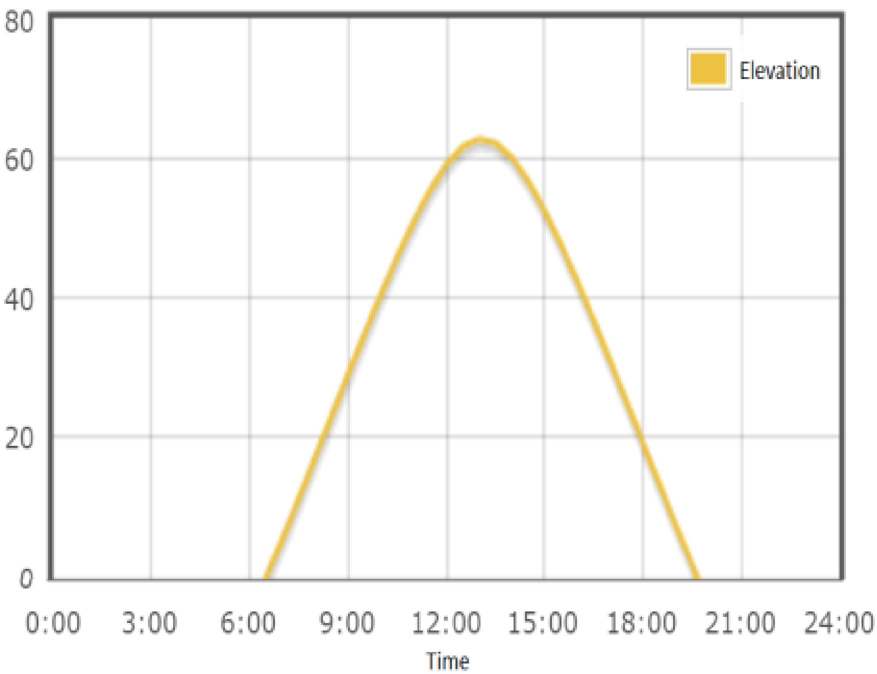
Intro - RAV Solar Calibration Facility

Overview

* Zenith Bias
* Pyranometer cosine response.
* Zenith Angle Binning.
* Case Study – Si pyranometer.

Zenith Bias – What is it?

Melbourne 28/2/16



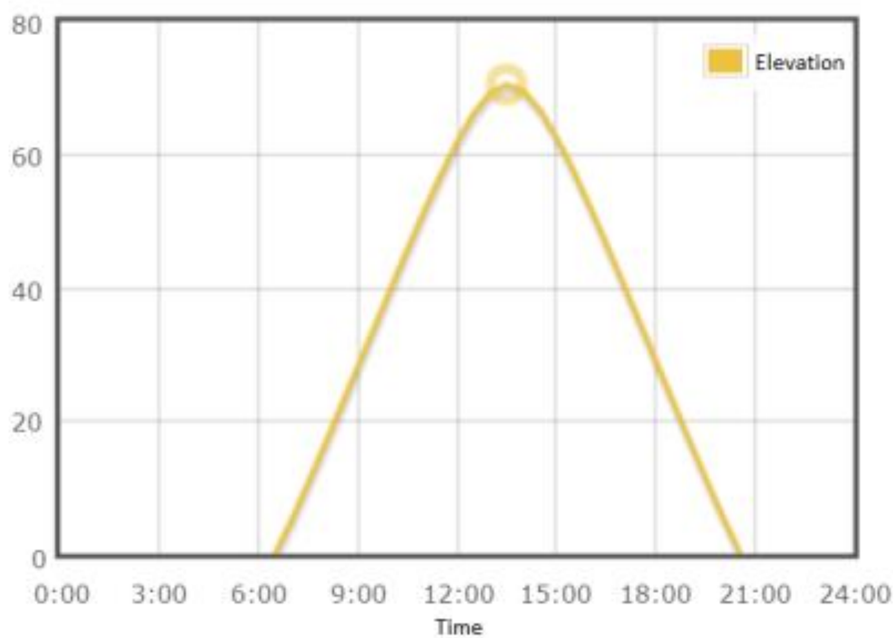
Measurements per degree

DAQ - 4 measurements/minute

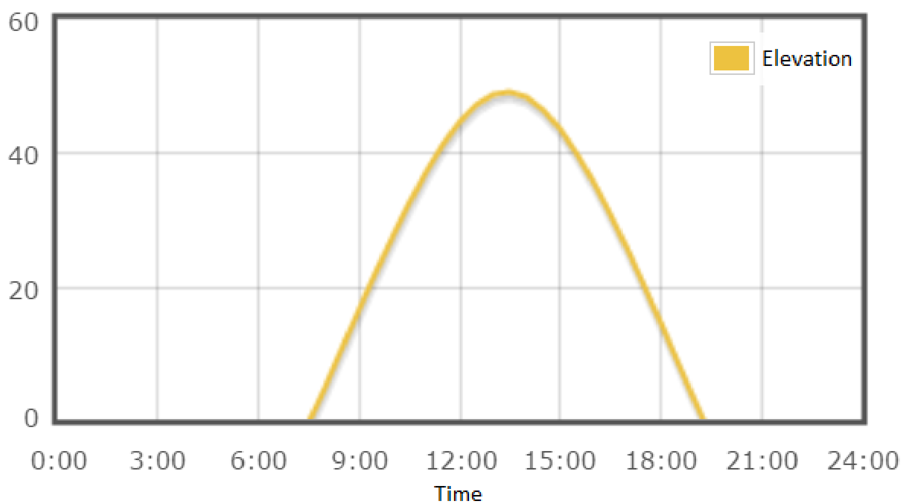
* 20° - 5 mins → 20 measurements
* 40° - 6.5 mins → 26
* 60° - 12 mins → 48
* 62° - 52 mins → 208

Zenith Bias – Why remove it

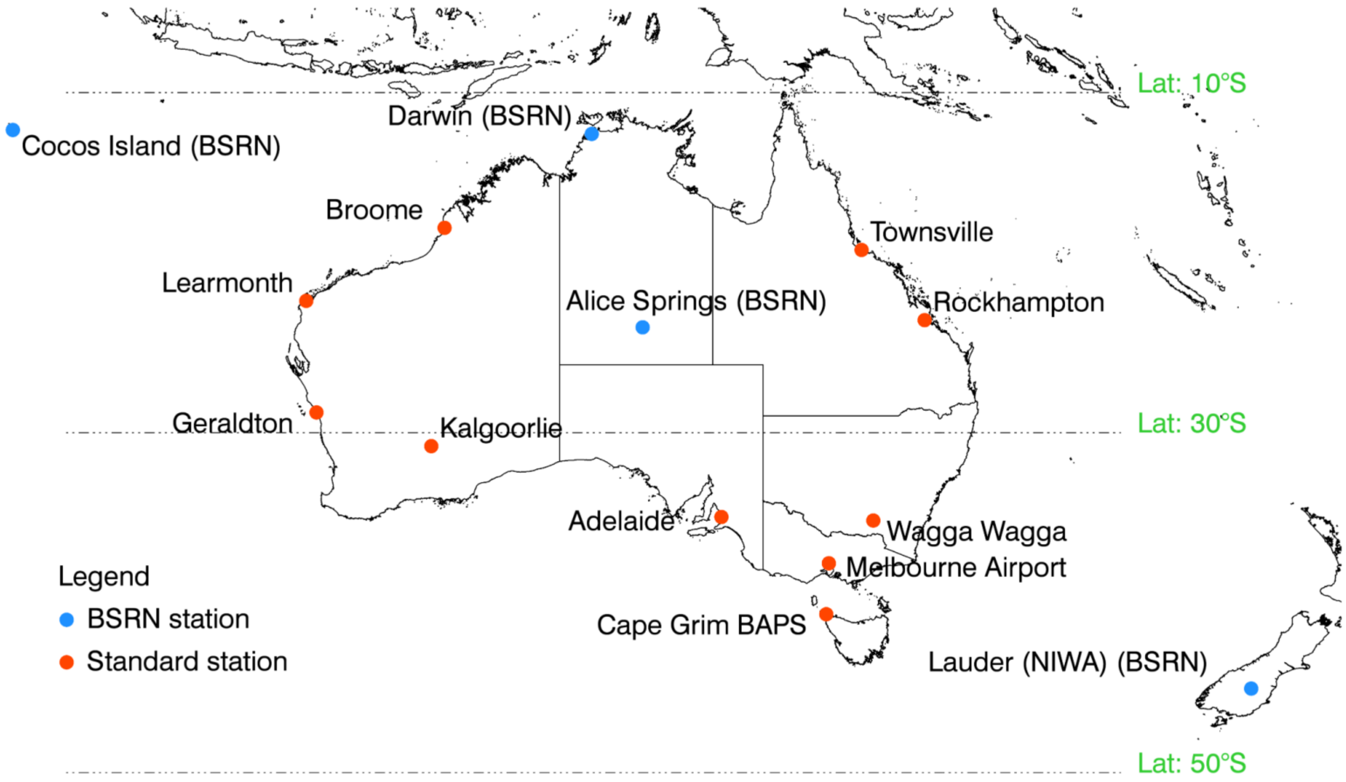
Melbourne 28/1/16



Melbourne 28/3/16

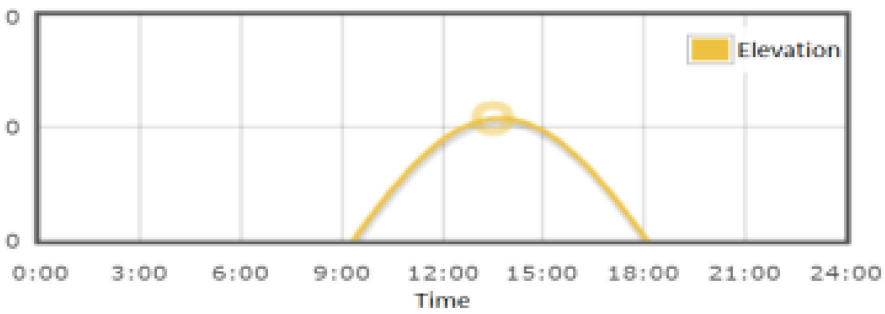


Zenith Bias – Why remove it?

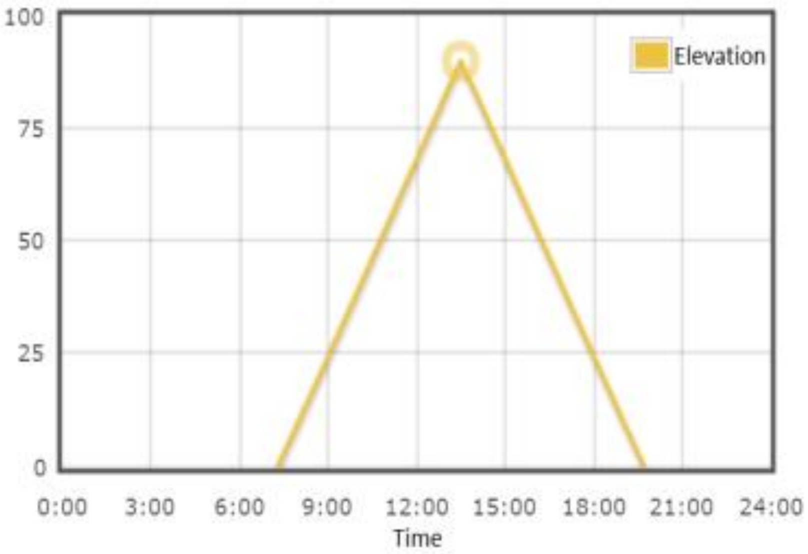


Zenith Bias – Why remove it

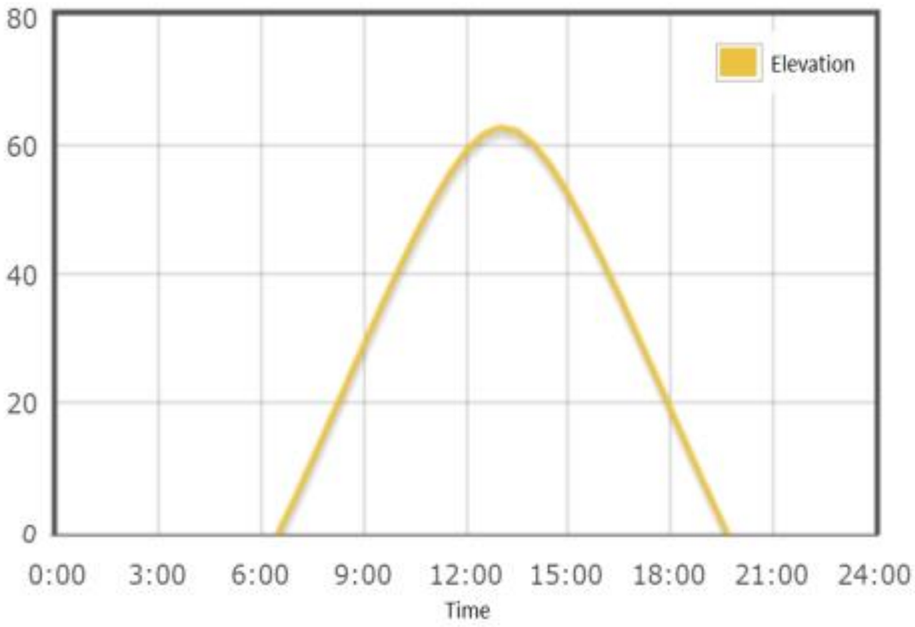
Lauder 21/6/15 - 21° Elevation



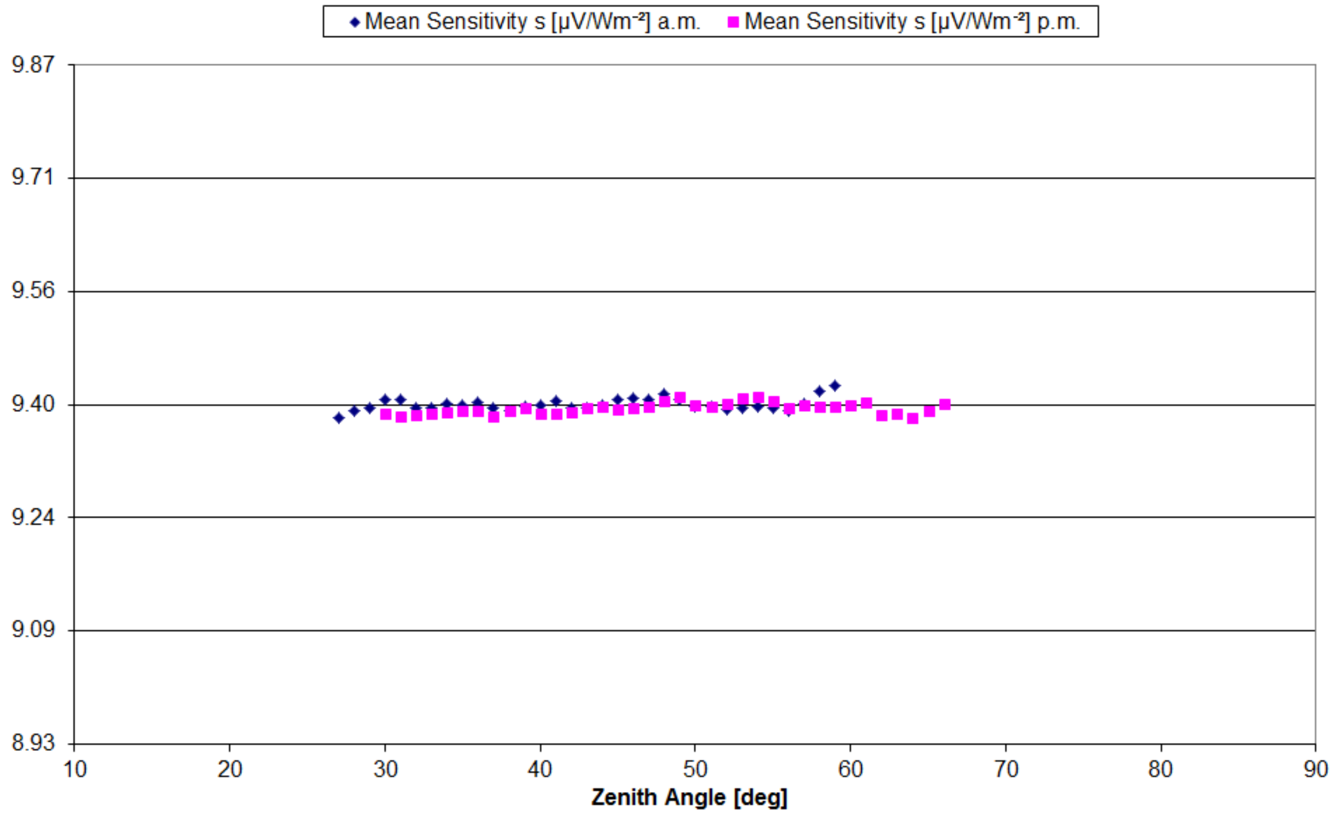
Darwin 26/10/15 - 0° Elevation



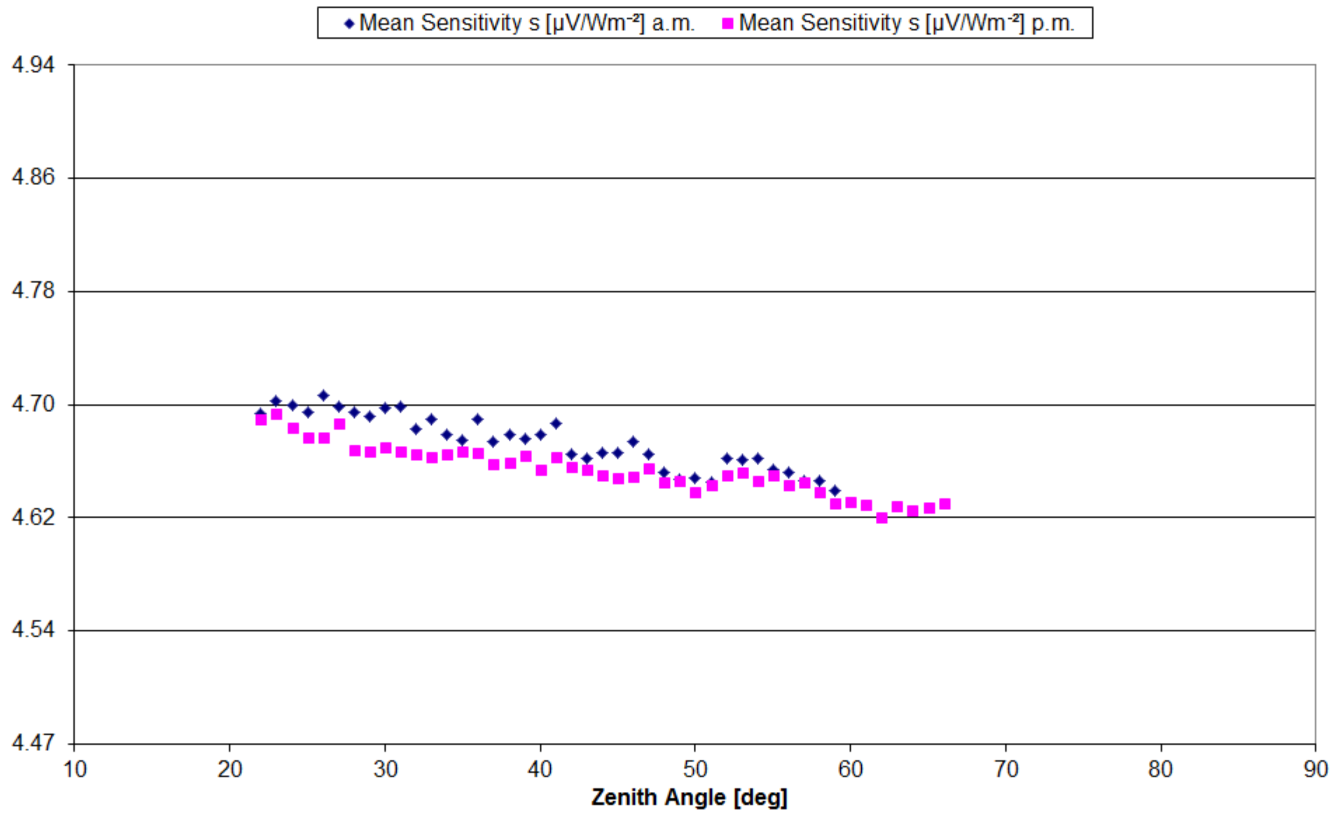
Pyranometer Cosine response



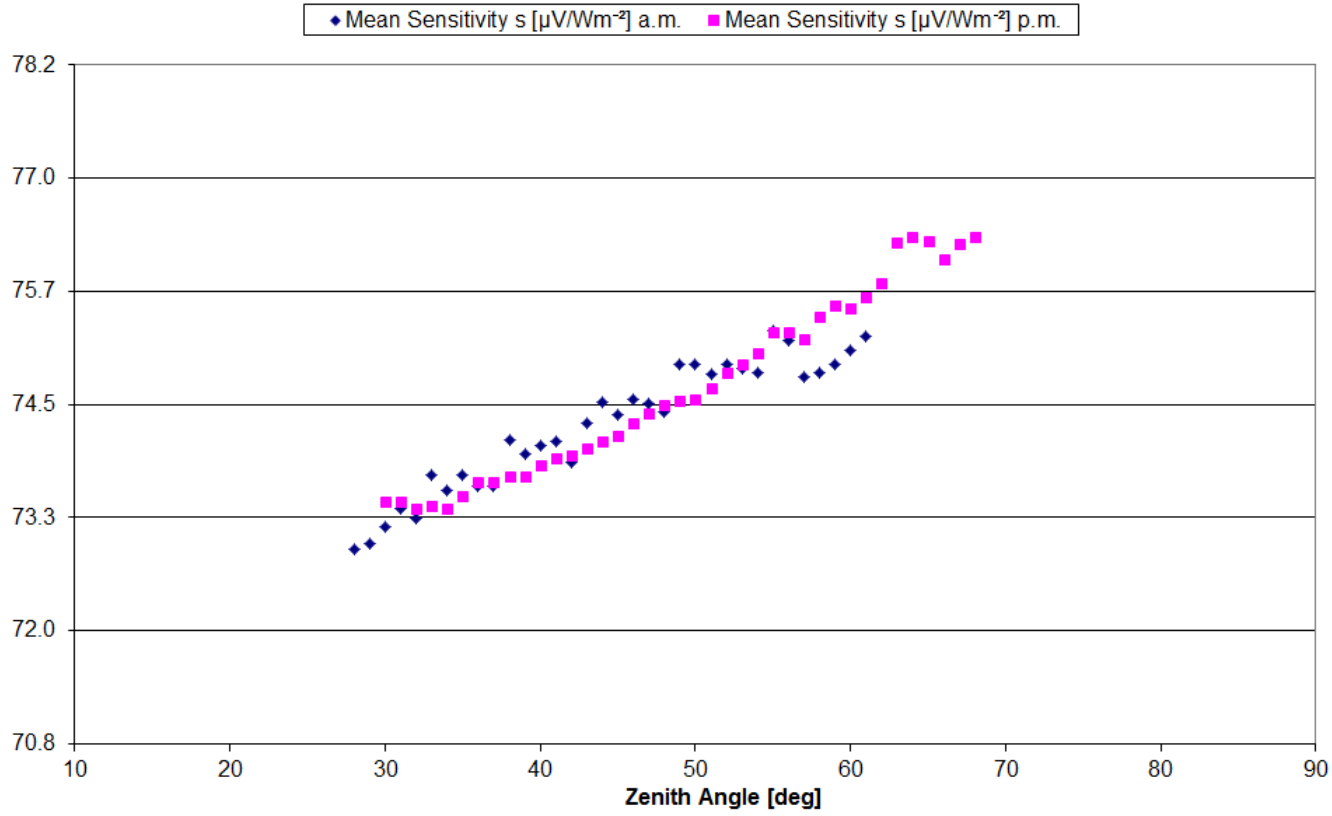
Pyranometer Cosine response RAV Standard



Pyranometer Cosine response BoM S&T Network



Pyranometer Cosine response Silicon Pyranometer



Simple Mean Sensitivity

$$\overline{Sens} = \frac{S_1 + S_2 + S_3 + \ldots\ldots + S_n}{n}$$

$$\overline{Sens} = \frac{\sum_{k=1}^{n} S(k)}{n}$$

* Sens – Mean sensitivity
* S – sample sensitivity
* K – integer 1 to n

Zenith Binning
1° Zenith Bin Mean Sensitivity

$$\overline{Sens(z)} = \frac{\sum_{k=1}^{n_z} S(k)}{n_z}$$

- Sens(z) - sensitivity of zenith bin z.
- S – sample sensitivity
- n_z – Number of samples in zenith bin z
- K – integer from 1 to n_z

Zenith Binning
Mean of Means

$$\overline{Sens} = \frac{\overline{Sens(z_1)} + \overline{Sens(z_2)} + \overline{Sens(z_3)} + \ldots\ldots + \overline{Sens(z_n)}}{n}$$

Zenith Binning
Mean of Means

$$\overline{Sens} = \frac{AM\left\{\overline{Sens(z_1)} + \overline{Sens(z_2)} + \overline{Sens(z_3)} + \ldots\ldots + \overline{Sens(z_a)}\right\}}{n}$$

$$+ \frac{PM\left\{\overline{Sens(z_1)} + \overline{Sens(z_2)} + \overline{Sens(z_3)} + \ldots\ldots + \overline{Sens(z_{n-a})}\right\}}{n}$$

Zenith Binning
Mean of Means

$$\overline{Sens} = \frac{AM\left\{\sum_{k=1}^{a}\overline{Sens(z_k)}\right\} + PM\left\{\sum_{k=1}^{n-a}\overline{Sens(z_k)}\right\}}{n}$$

Case Study: Silicon Pyranometer

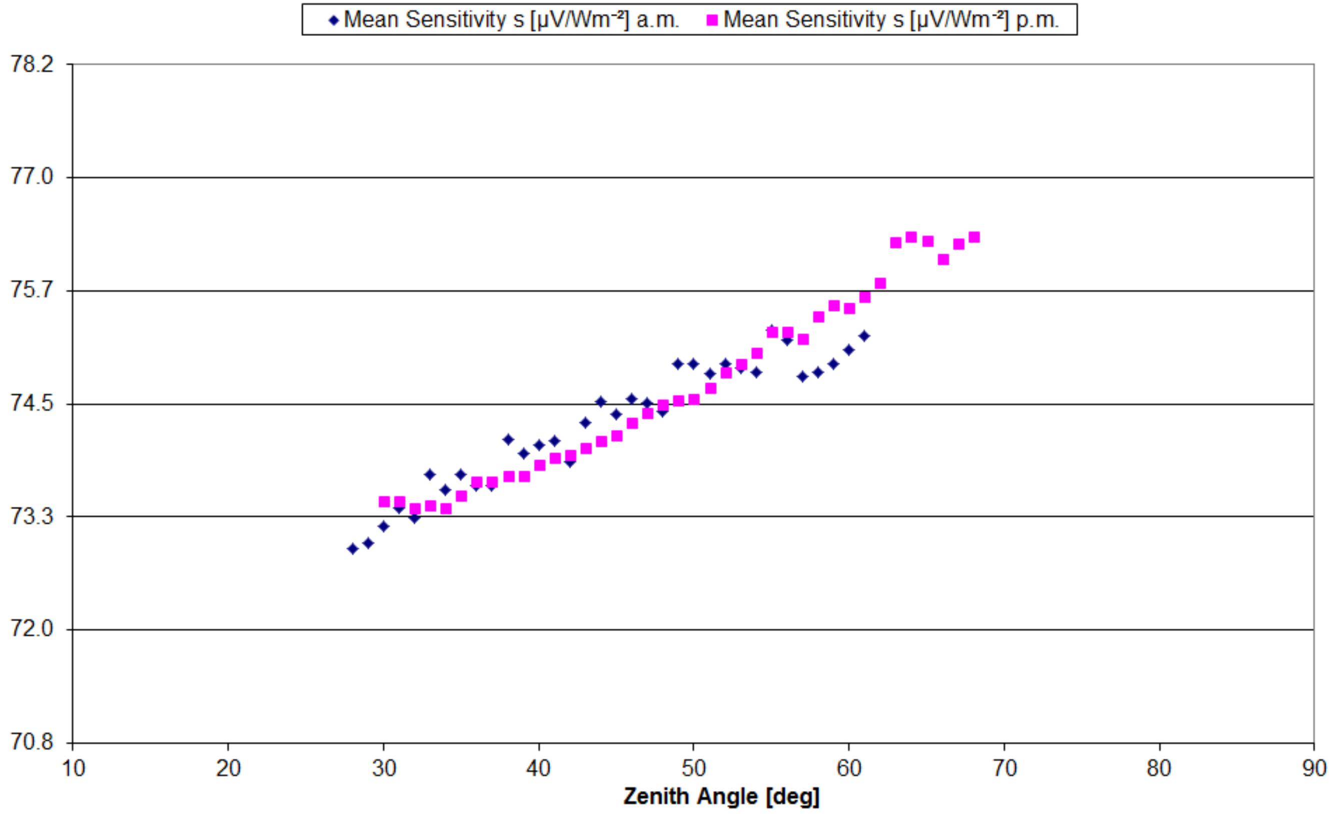
Sensitivity - Simple Mean

* Sens = 74.05μV/Wm²

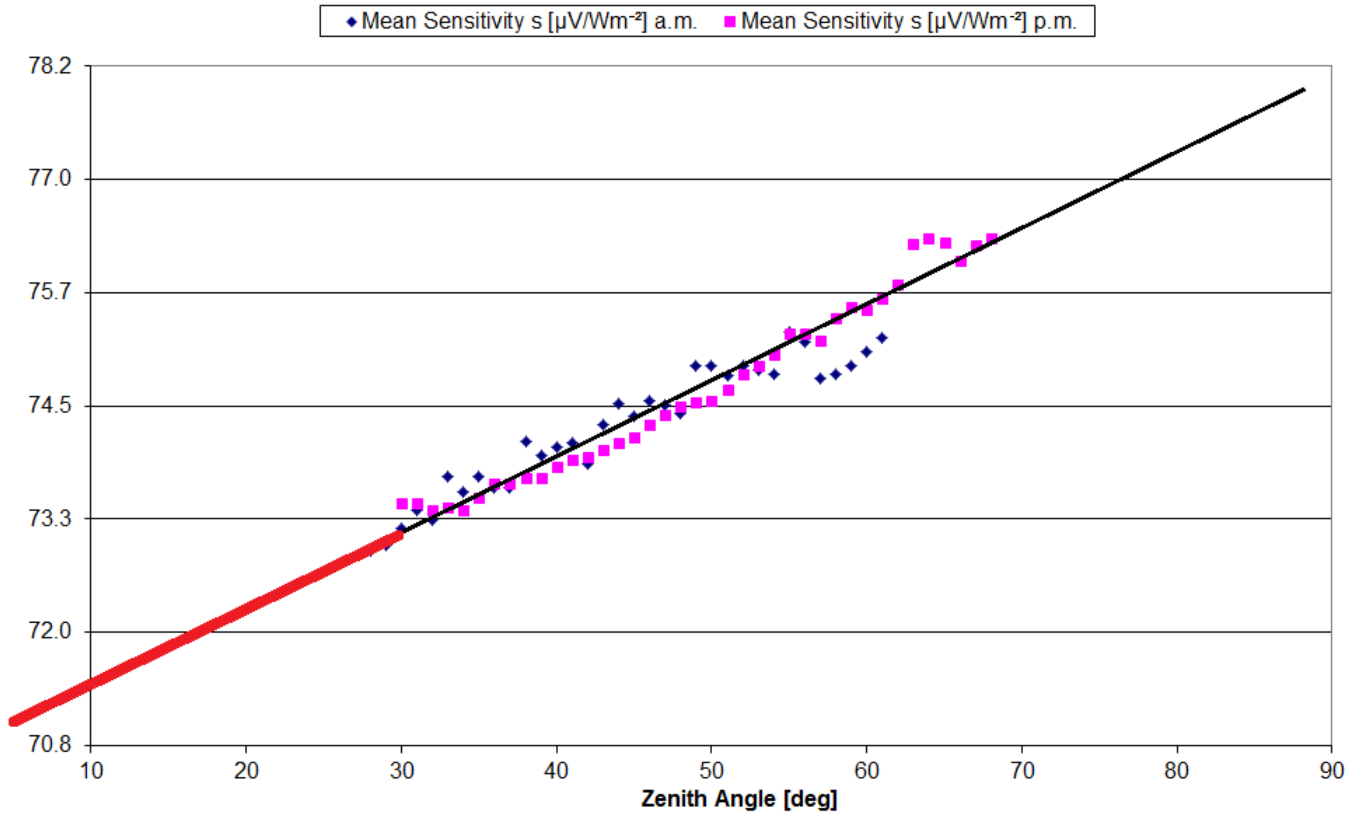
Sensitivity - Zenith bias removed

* Sens = 74.42μV/Wm²
* Approx 0.5%
* 5W in 1000W

Case Study: Silicon Pyranometer



Case Study: Silicon Pyranometer Installed at the Equator



Conclusions

* Zenith bias - more measurements at high elevation biasing the final sensitivity.
* Zenith binning - process gives each angle bin equal weight in determining final sensitivity.
* Pyranometers have variable cosine responses.
* Need to be mindful of geographic demands and constraints.

End.
Thank you.