Quantifying impacts of atmospheric and physical parameters on pyranometer calibration

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Background

Solar radiation is energy received from the sun in the form of near infrared radiation, visible light and a small amount of ultra-violet radiation. Solar radiation is an integral part of the surface energy budget and is the driving force behind biological and geophysical processes in our environment. Solar radiation data is used in climate modeling (GCM) and development of renewable energy technologies. Solar radiation can be measured by its components:

- Global – is a measure of total horizontal radiation, measured using a pyranometer
- Direct – does not get absorbed or scattered; measured using a pyrheliometer
- Diffuse – received after its direction has been changed by reflection and scattering; measured using a shaded pyranometer (excludes direct radiation)

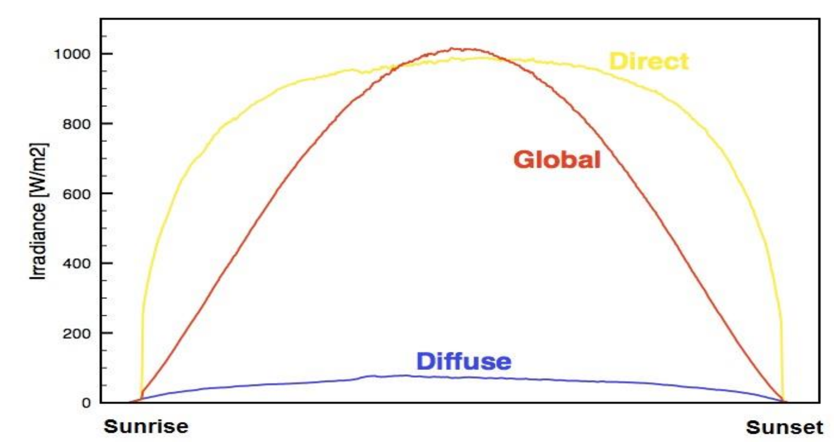

Figure 1. Graph depicting the components of global horizontal radiation

Calibration

Direct Normal Irradiance (DNI)
CHP1

Global Horizontal Radiation (GHI)

Diffuse Horizontal Irradiance (DHI)
Shaded CMP 22

GHI = DHI + DNI * COS(Θ)

Value from sensor undergoing calibration is compared to "true" value measured by reference sensors.

- Pyrheliometers are more accurate than pyranometers
- The diffuse component of short-wave radiation makes up a much smaller percentage of the global
- By measuring components independently, a lower degree of uncertainty will be translated into the reference measurements (ISO, 1993).

Study Objectives

Chose global short-wave radiation as a proxy

- Most radiation measurements by NEON are done by pyranometers
- Can likely translate to long-wave radiation

Variables Studied:

- Humidity
- Particle Matter 2.5 ($PM_{2.5}$)
- Sensor Leveling
- Visibility
- Zenith Angle

Uncertainty: NEON assessed uncertainty from reproducibility to be 0.613%

- The parameters under investigation affect the reproducibility of calibration.
- This Provides insight for ways to decrease uncertainty.

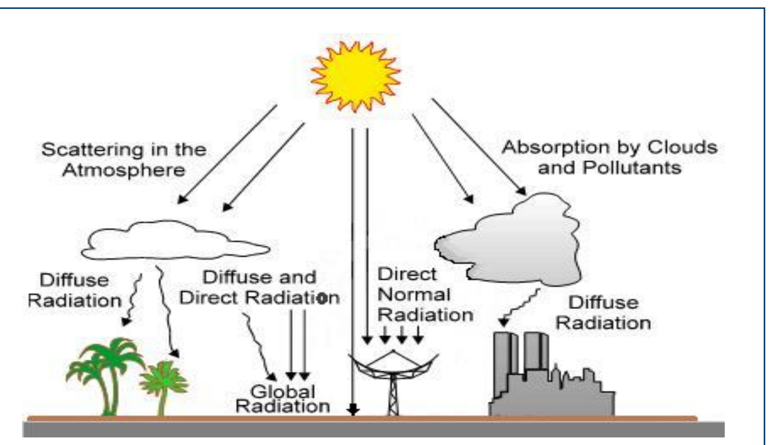

Figure 2. Solar radiation interactions

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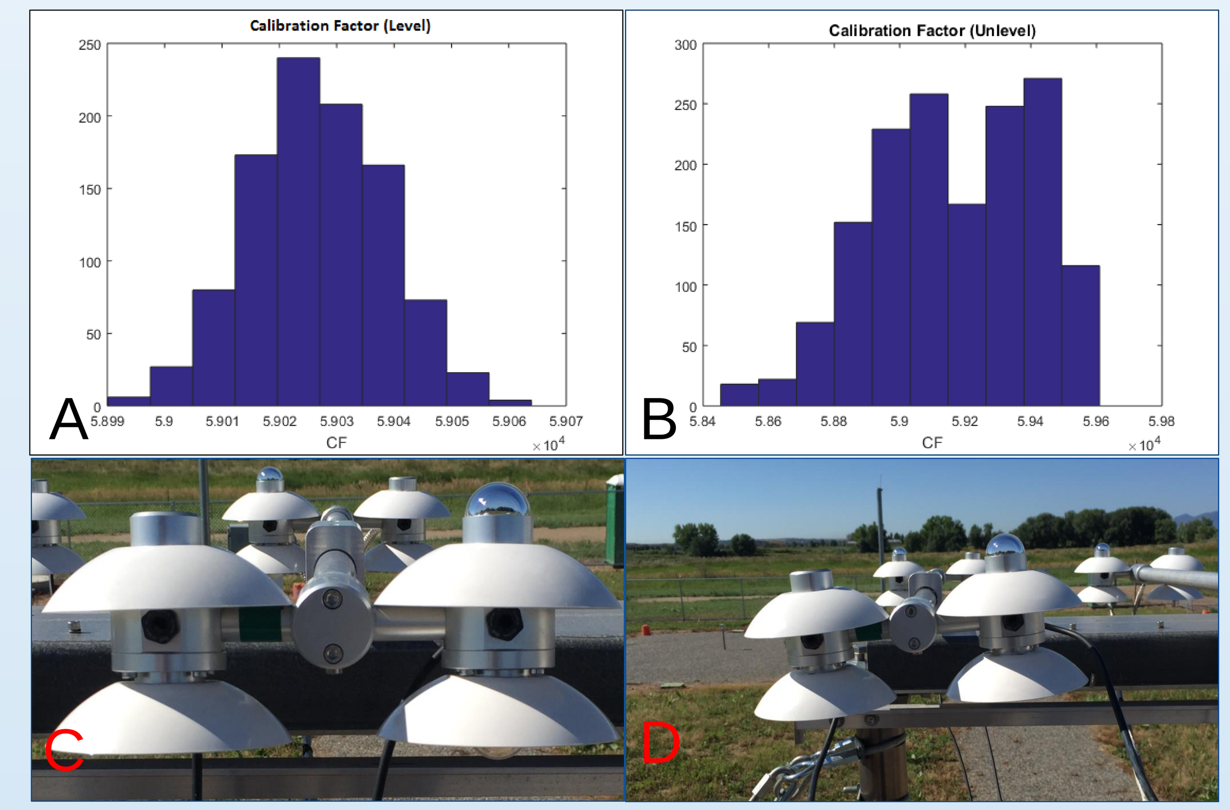
Results

Figure 5 a-d. The effect of improper leveling of the sensors is seen best through histograms (A & B). It is clear that under level conditions (visual in C) the calibration factor follows a normal distribution (A). On the other hand, if not leveled properly (visual in D), it often follows more of a bi-modal distribution (B). Unleveled sensors can be determined by data through this method for both the calibration and data acquired from the field.



Zenith angles were taken at 20 second resolution from clear sky data. Below is an example of one day (Figure 3A). Daily averages were computed for 11 days for VSI, PM2.5 and Humidity from CDPHE (2015) local area data and compared to calibration factor resulting from the clear sky portion of the day (Figure 3 B, C, and D, respectively).

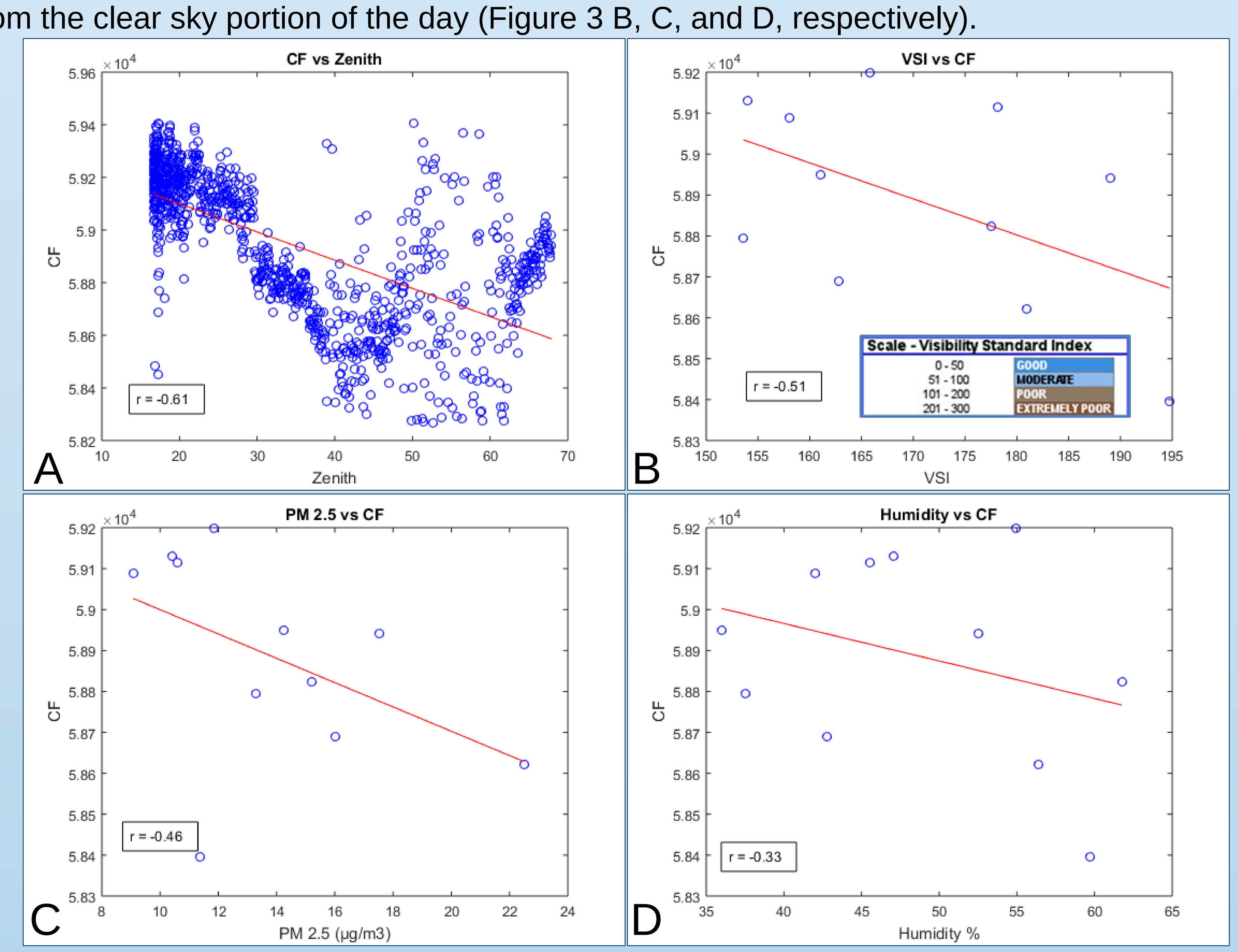


Figure 3 a-d. Linear approximation between calibration coefficient and variables for zenith angle: A and visibility (VSI), PM2.5, and humidity: B,C, and D, respectively.

The correlation coefficient (r) ranges from -1 (a perfect negative correlation) to 1 (a perfect positive correlation). In short, $-1 \leq r \leq 1$.

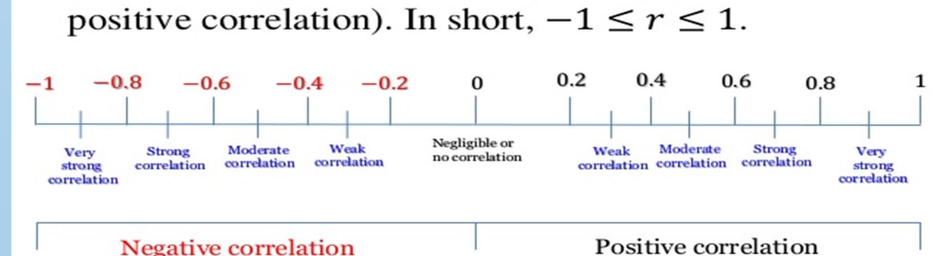


Figure 4. Relationship strength of Pearson correlation coefficient

Pearson correlation coefficient, uncertainty and linear relationships were examined to determine impact to pyranometer calibrations.

The Pearson correlation coefficient is a measure of the linear correlation (dependence) between two variables X and Y. It is widely used in the sciences as a measure of the degree of linear dependence between two variables (Figure 4.)

Conclusion

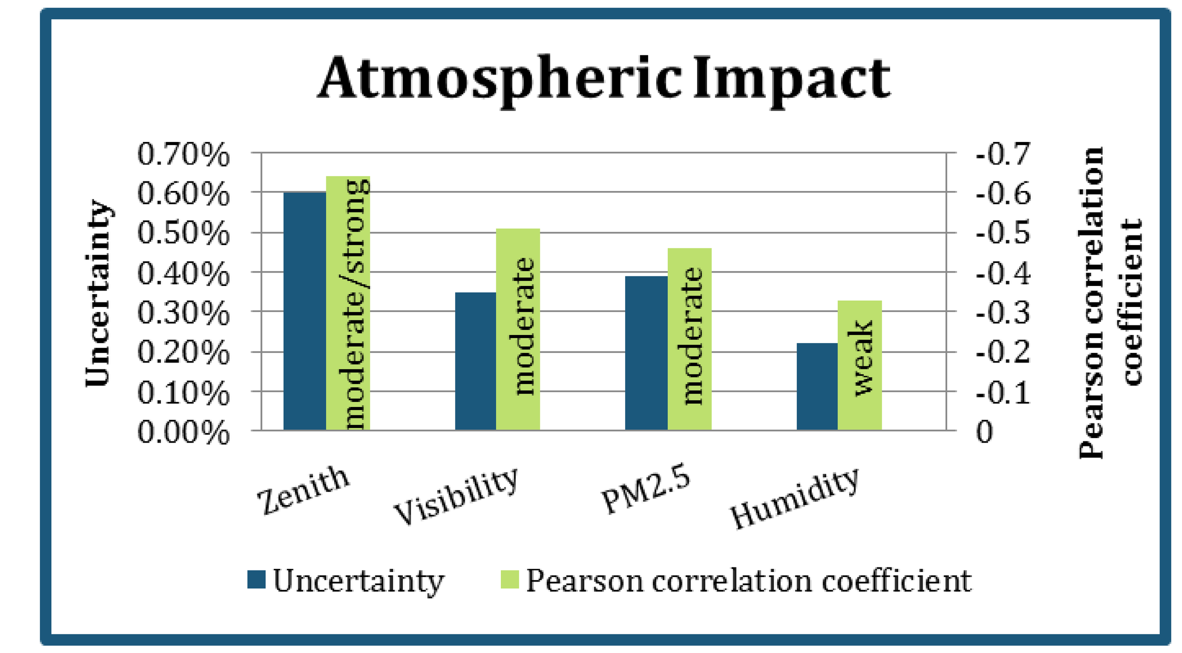


Figure 6. Summary of results for uncertainty contribution and correlation of studied variables on the calibration.

- Although several of the variables showed moderate correlations with the calibration factor, it is clear that the uncertainty attributed by the zenith angle is the largest contributor to the uncertainty associated with reproducibility and thus warrants further investigation
- Special attention must be taken when placing pyranometers on calibration deck as well as on towers for data collection to ensure proper leveling of solar radiation sensors

Future Work

- Conduct analysis with more sensors to confirm consistency of results.
- Perform experiment at different times of the year.
- After results are confirmed develop a correction algorithm as a function of zenith angle to reduce uncertainty in solar radiation measurements (can be done for sensor specific correction at calibration or general sensor type correction).
- Thresholds for the other variables may be looked into again after corrections for zenith angle have been applied

References

ISO. (1993) *Solar energy – Calibration of a pyranometer using a pyrheliometer ISO 9846.* Geneve, Switzerland: International Organization for Standardization.

Colorado Department of Public Health and Environment (CDPHE). (2015). *Air Quality Report*. http://www.colorado.gov/airquality/report.aspx. accessed July 27, 2015.

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