

Calibration and Analysis of TCS3400

Bobby Schulz - 10/18/2023

Executive Summary

After the previously discussed gain control problems were resolved, the data from the TCS3400 color sensor were once again compared to PAR readings. After finding an optimized conversion factor, it was found that the system performs very well ($R^2 = 0.84$) in diffuse light situations. However, in clear sky conditions the system does not perform as well (average of $R^2 = 0.62$ for all conditions). This seems to be due to discrepancy in the early morning and evening, likely due to responsiveness at extreme angles. Further investigation is to be done.

Introduction

After the previously discussed issues of gain correction in the TCS3400 were fixed the ongoing side by side comparison was continued. After about a week of data was accumulated another round of evaluation was performed.

Methods

Conversion Development

Since the goal is to determine PAR from a color sensor, it makes sense that only the red and blue channels would contribute to the conversion factor. After recursive testing it was found that the best fit (R^2) to PAR was made by simple use of the blue light channel.

After this, the desired multiple of the blue channel was found. This was done through exhaustive search within reasonable range of values.

Conversion equation simply ends up being

$$\text{PAR } [\mu\text{mol m}^{-2} \text{ s}^{-1}] = \text{TCS3400_BLUE} \times x$$

Data Cleaning/Conversion

Only very minor data cleaning was applied. The PAR readings (taken from an Apogee SQ-500) were made via analog measurements using a v3.0 Flight data logger. These raw millivolt readings were compensated for ADC offset by subtracting the zero floor from the readings. After this the millivolt readings were simply multiplied by the Apogee prescribed conversion factor (100 $\mu\text{mol m}^{-2} \text{s}^{-2}$ per mV) to obtain PAR values.

Any hour which did not have values for both sets of data was removed. Data was binned into hourly data intervals using an hourly mean.

Results

Conversion Factor

After searching for an optimized conversion value it was found that the optimal conversion factor for the entire data set was 2391

$$\text{PAR_EST } [\mu\text{mol m}^{-2} \text{s}^{-1}] = \text{TCS3400_BLUE} * 2391$$

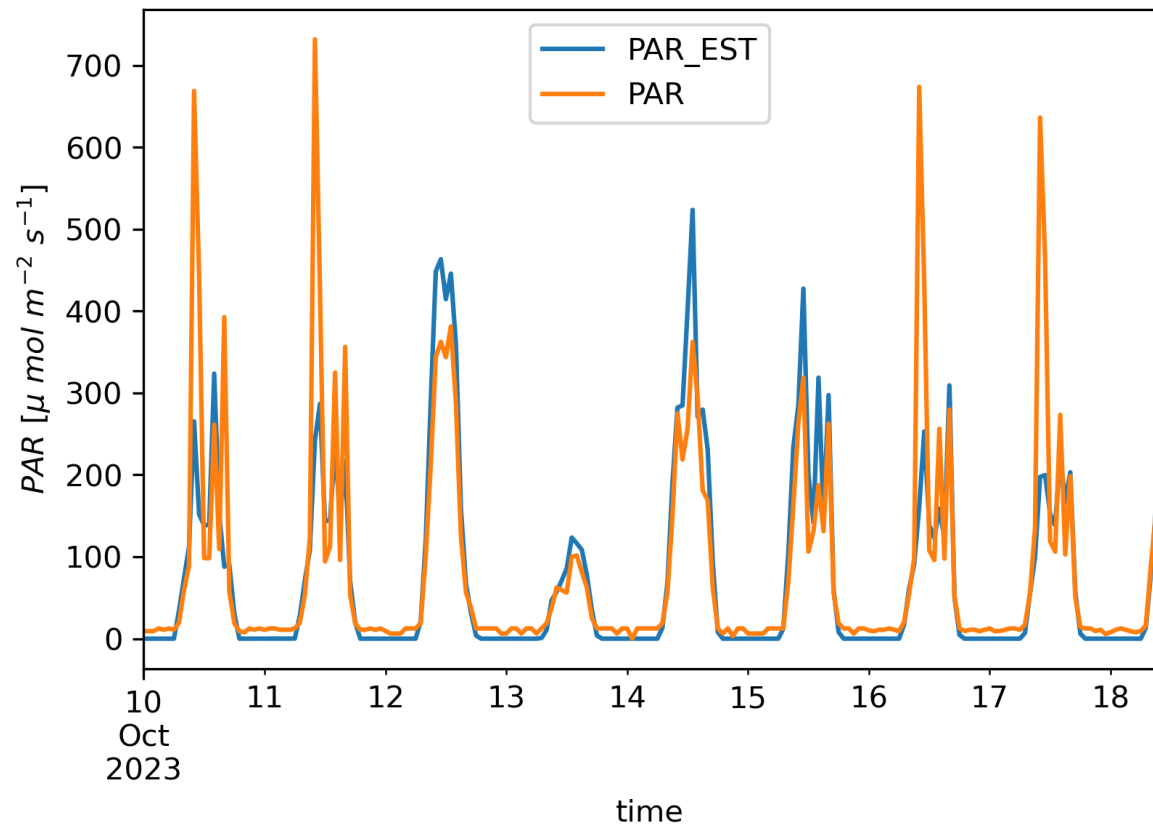
This conversion factor was used for the following evaluation

Diffuse vs Direct Sun

It was observed that there were notable differences between the diffuse light and direct light performance

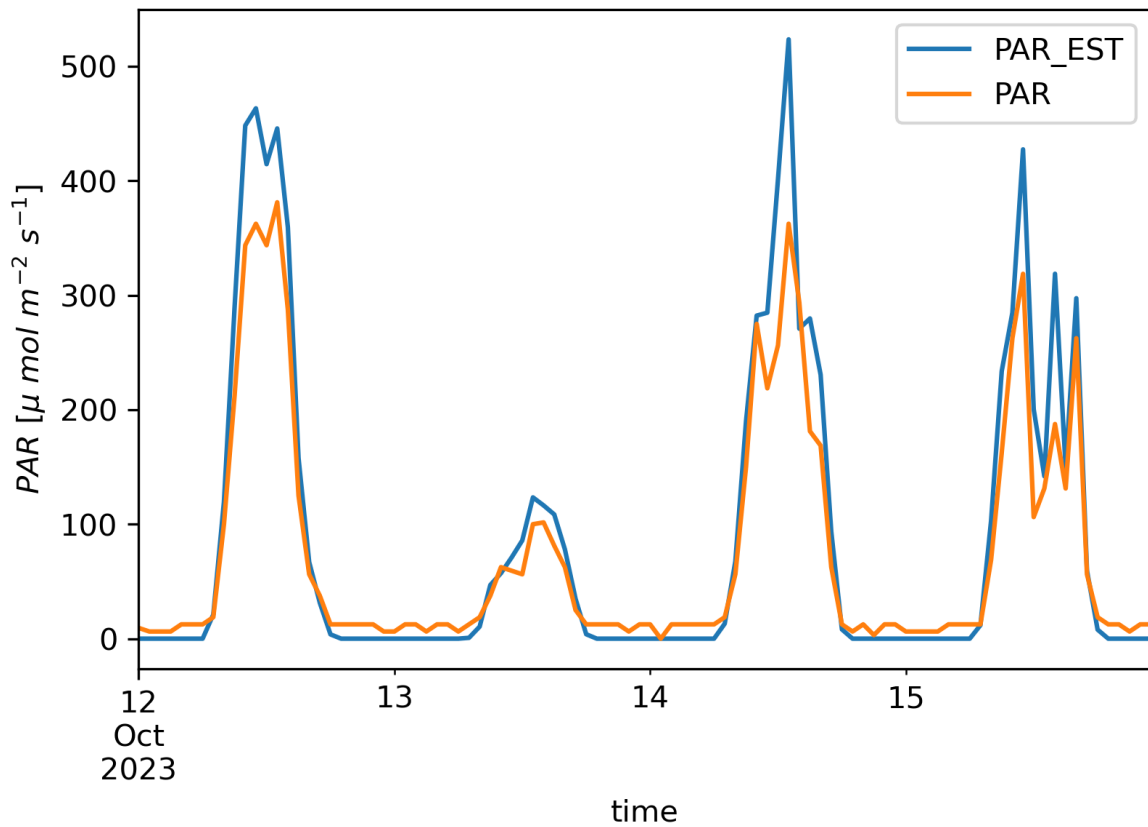
For the complete data set (4 days of direct sun, 4 days of diffuse sun), the results are as follows

Metric	R ²	ME	MAE	RMSE
Value	0.622	10.40	35.87	83.26



If we limit our analysis to just diffuse lighting days (October 12 - 15 reported between 'Partly Cloudy' and 'Mostly Cloudy') we achieve the following results using the same conversion factor.

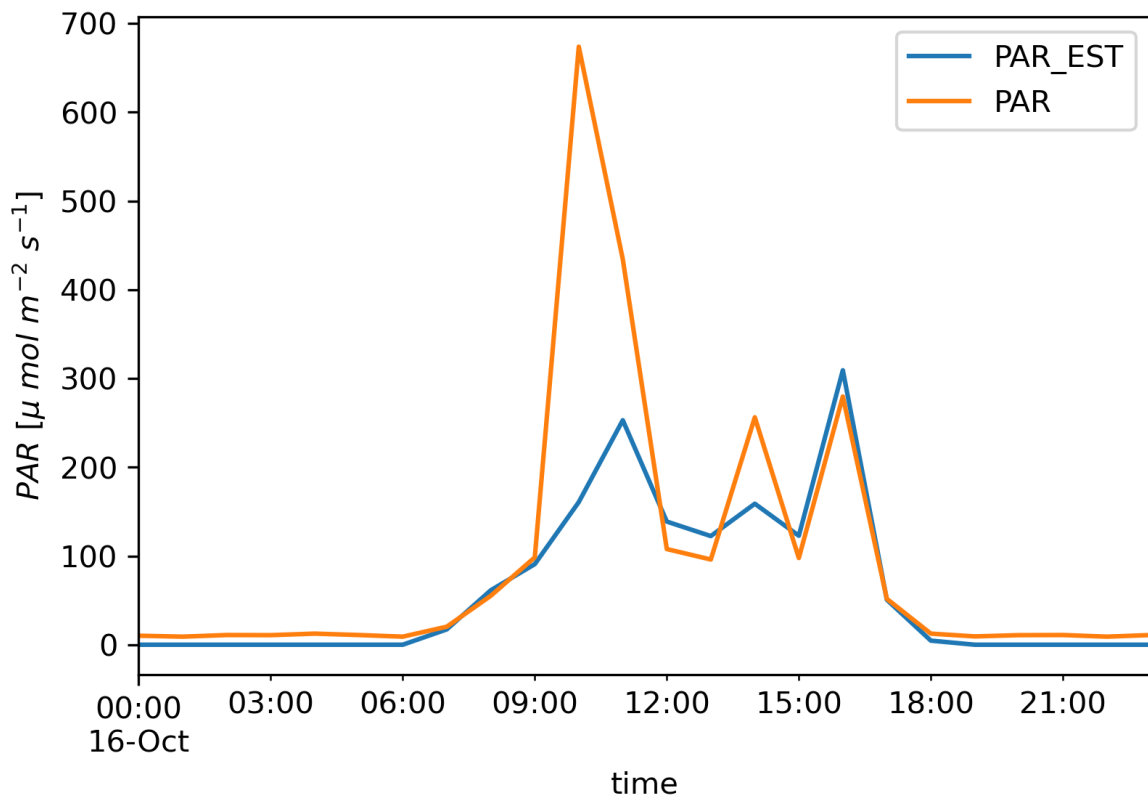
Metric	R ²	ME	MAE	RMSE
Value	0.839	-13.19	25.30	41.65



As we can see the performance is significantly improved for diffuse lighting situations.

We take a closer look at these direct light days, we see that consistently there is an error in the morning where we see a response of the Apogee PAR sensor which is not reflected in the TCS3400.

See detail example below.



Analysis

Performance in diffuse light situations is quite good, but overall performance is not as good as expected due to the discrepancy observed in the morning by the system.

Potential Explanations:

- Data is being taken in a representative environment, located in a back yard with surrounding tree cover. It is possible there is a differential shading occurring in low sun angles, especially since we see this only for morning and not evening.
- TCS3400 is not as responsive for low incidence angle. This seems unlikely since we see this aberration only in the morning, not the evening.
- Occlusion from part of the installation
- Box condensation/frost which eliminated by midday which is not experienced by the Apogee sensor

Further investigation will be performed to determine what the cause of this issue may be and to improve the overall conversion factor.