Improving Shipboard Light Data for Gradients 4 Cruise to Accurately Assess Picophytoplankton Growth

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Partnered in Research

Background

- Photosynthetically Active Radiation (PAR) is the wavelength range phytoplankton use to absorb sunlight to undergo photosynthesis
- Previous project of mine investigated the relationship between *Prochlorococcus* cell size and PAR in varying latitudes
- Only light data available in previous project was from Sensor 1 (ship radiometer) which is uncalibrated and measures surface PAR
- There is a need for accurate high resolution PAR data, especially at depth, because hourly data can capture changes in growth and size for these microscopic picophytoplankton
- In this project, light data I used is from Sensor 1 and Sensor 2 (LICOR radiometer) which is used to validate my model since it is calibrated but unavailable on research cruises at times
- This discrepancy in shipboard light data led me to create a computational model that takes improved PAR data and integrates it with depth regardless of sensor calibration and availability

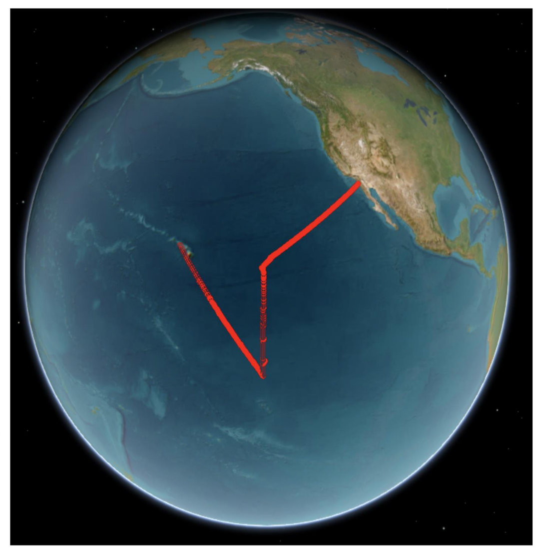


Figure 1: Gradients 4 cruise track

Abstract

Picophytoplankton are directly impacted by the amount of light they receive and closely follow the day-night cycle. To understand how picophytoplankton interacts with the diel cycle, accurate data for light is necessary to understand their biological rates.

Currently, shipboard instruments measure Photosynthetically Active Radiation (PAR) above the sea surface at high temporal frequencies. However, data collection is often prone to limitations in the field and can be uncalibrated. Furthermore, light attenuates with depth, which is currently not accounted.

Thus, we developed a data analysis pipeline and used existing models to accurately estimate hourly PAR below the sea surface. A variety of datasets, including satellite and other shipboard instruments, were used to compare and improve PAR data. Daily satellite data were first applied to the ship radiometer to smooth large outliers. Then, we compared the satellite smoothed PAR data against calibrated instruments that were available on select cruises. The calibrated PAR datasets were depth integrated using an algorithm that incorporates wind speed, chlorophyll, and the solar zenith angle to calculate light attenuation. The depth integrated values were validated against profile data. We found that the ship's data consistently overestimated PAR by a power law function.

Furthermore, there are over 100 cruises to be analyzed, and we expect to improve our understanding of daily picophytoplankton growth by using corrected light data. As these tiny cells play critical roles in managing global production, quantifying their relationship with the diel cycle allows us to anticipate shifts under future conditions.

Methods

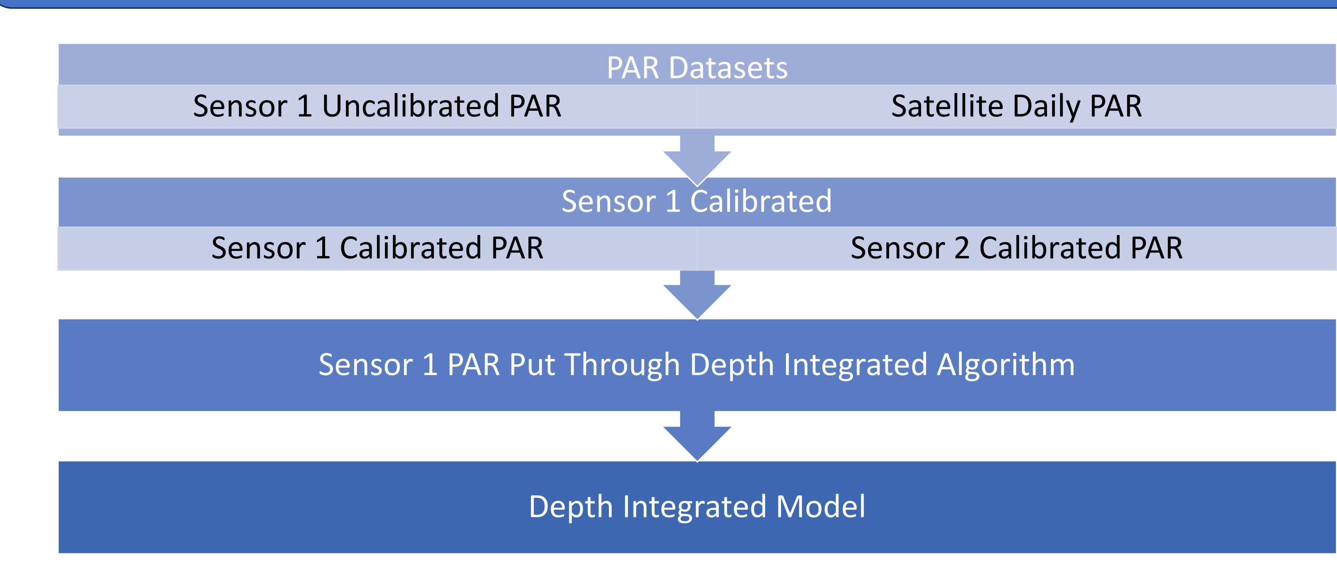


Figure 2: Concept map

- The data used in this study is from the Gradients 4 cruise (Figure 1), unless stated otherwise
- Python is the primary language used to sort and manipulate data
- RStudio was used to help translate script that calibrated the ship radiometer data using daily satellite resolution
- MATLAB was used to help translate the depth integration algorithm to create my model
- PAR datasets used for depth integrated model is from Simons CMAP which included Sensors 1 and 2, along with satellite data that helped smooth data down and get rid of any outliers
- Data necessary to create depth integrated model included chlorophyll, wind speed, sun zenith angle, and Sensor 1 calibrated PAR
- Chlorophyll data came from ECO fluorometer that was collected during the cruise
- Wind speed data came from Climate Data Store – Copernicus
- Sun zenith angle was calculated using a package called Astral based on longitude, latitude, and time
- The packages used to operate the data are pandas, numpy, matplotlib, datetime, plotly, scipy, and astral
- Most of the packages used were to index, plot, and convert data types.

Methods continued

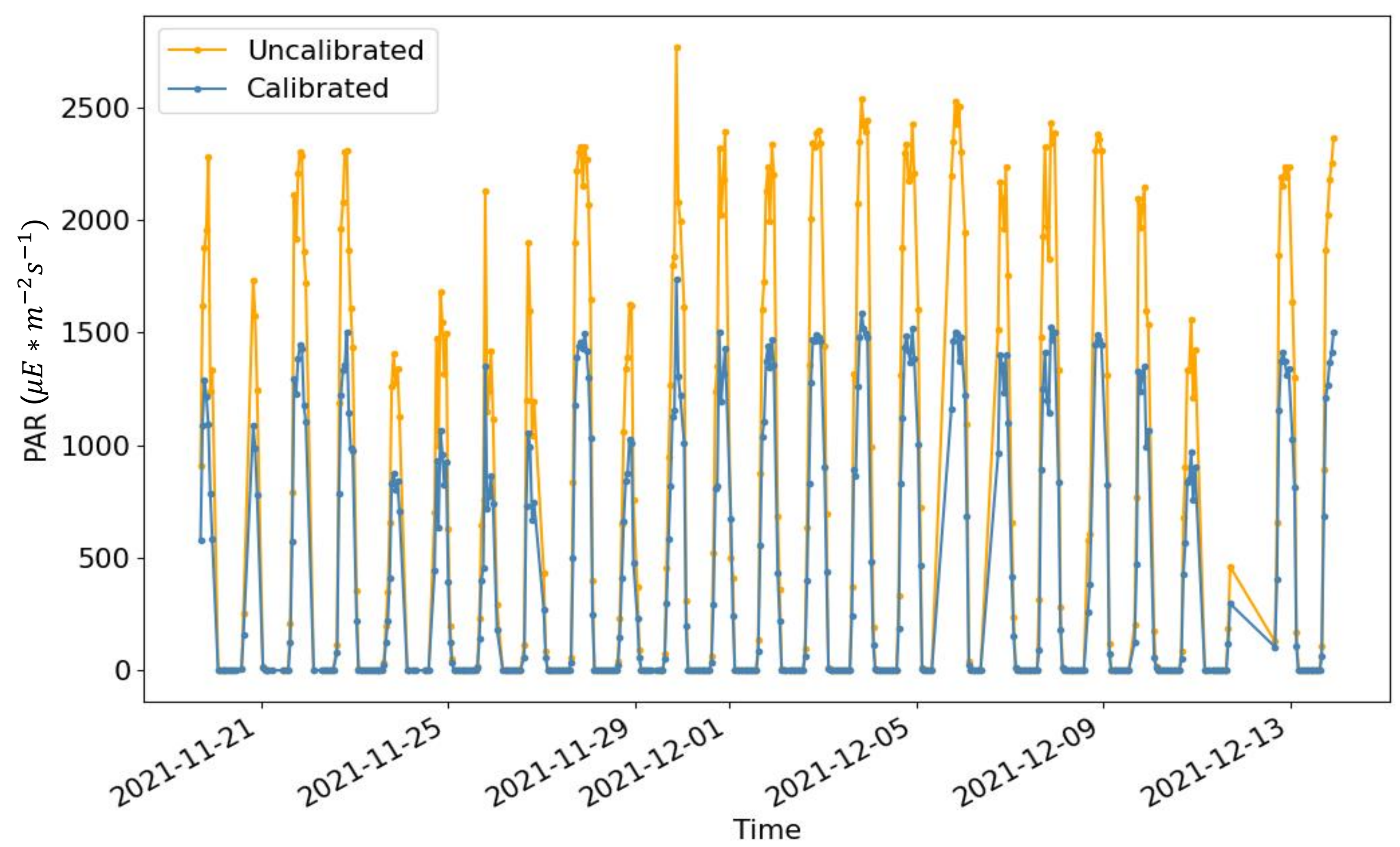


Figure 3: Sensor 1 calibration comparison over entire cruise

In Figure 2, the conceptual map represents the workflow of what PAR data I have collected and what I have done at each step of the process. I first collect my raw uncalibrated PAR data from Sensor 1 and then collect satellite PAR data in a daily resolution. After manipulating the Sensor 1 data from hourly to daily and applying a conversion factor to Sensor 1 by finding the difference between daily satellite PAR and Sensor 1 PAR, I have now calibrated Sensor 1. The product of Sensor 1 calibration using satellite data is shown in Figure 3. Each dot represents hourly data while the entire graph is in a daily resolution to better demonstrate how PAR changes throughout the entire cruise. The uncalibrated PAR in orange has outlier points, shown within the red circle, and has been lowered to where it should be within the daily pattern of calibrated PAR. The second red circle highlights gaps in data from both uncalibrated and calibrated PAR, meaning further improvement is needed. To get a better understanding how the two compare, Figure 4 below displays Sensor 1 and 2 against one another.

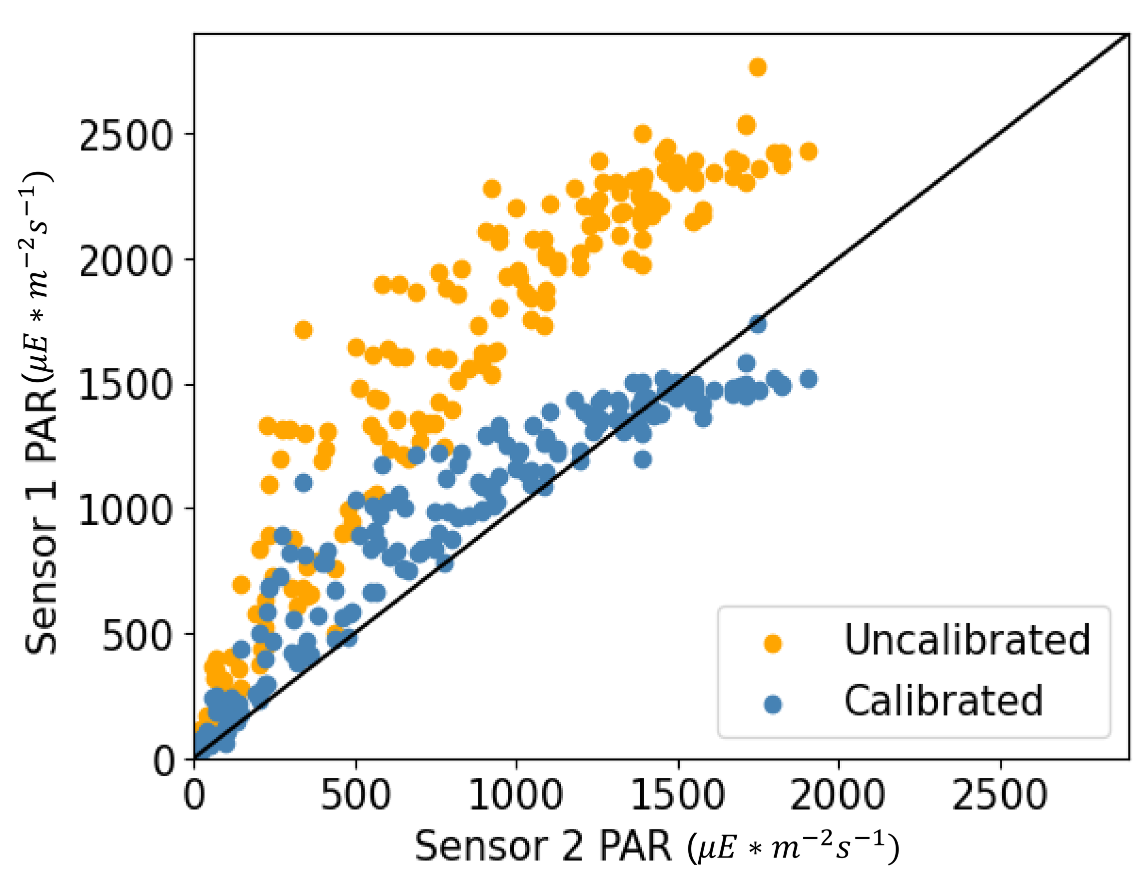
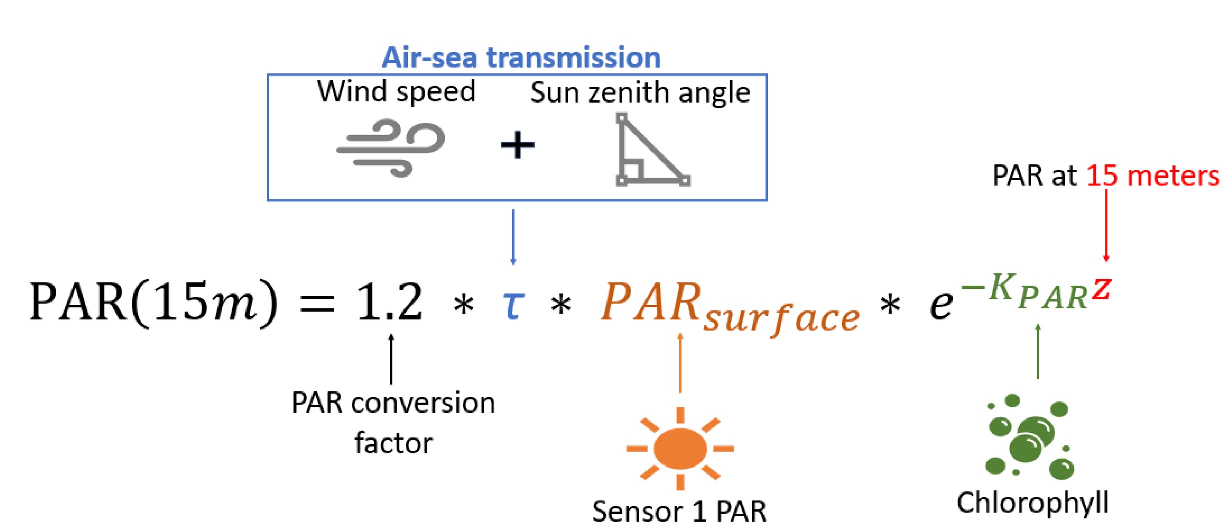


Figure 4: Sensor calibration improvement

In the second part of my conceptual map, I compared Sensors 1 and 2 against one another after calibration, which is shown in Figure 4. The orange dots represent hourly data and represents Sensor 1 before calibration. The blue dots represent Sensor 1 after calibration. The black line represents the identity line where the closer the dots are to the line; the more similar data is to Sensor 2. There is an improvement in PAR data for Sensor 1 as the calibrated points lie much closer to the identity line, but still does not match perfectly on the identity line.

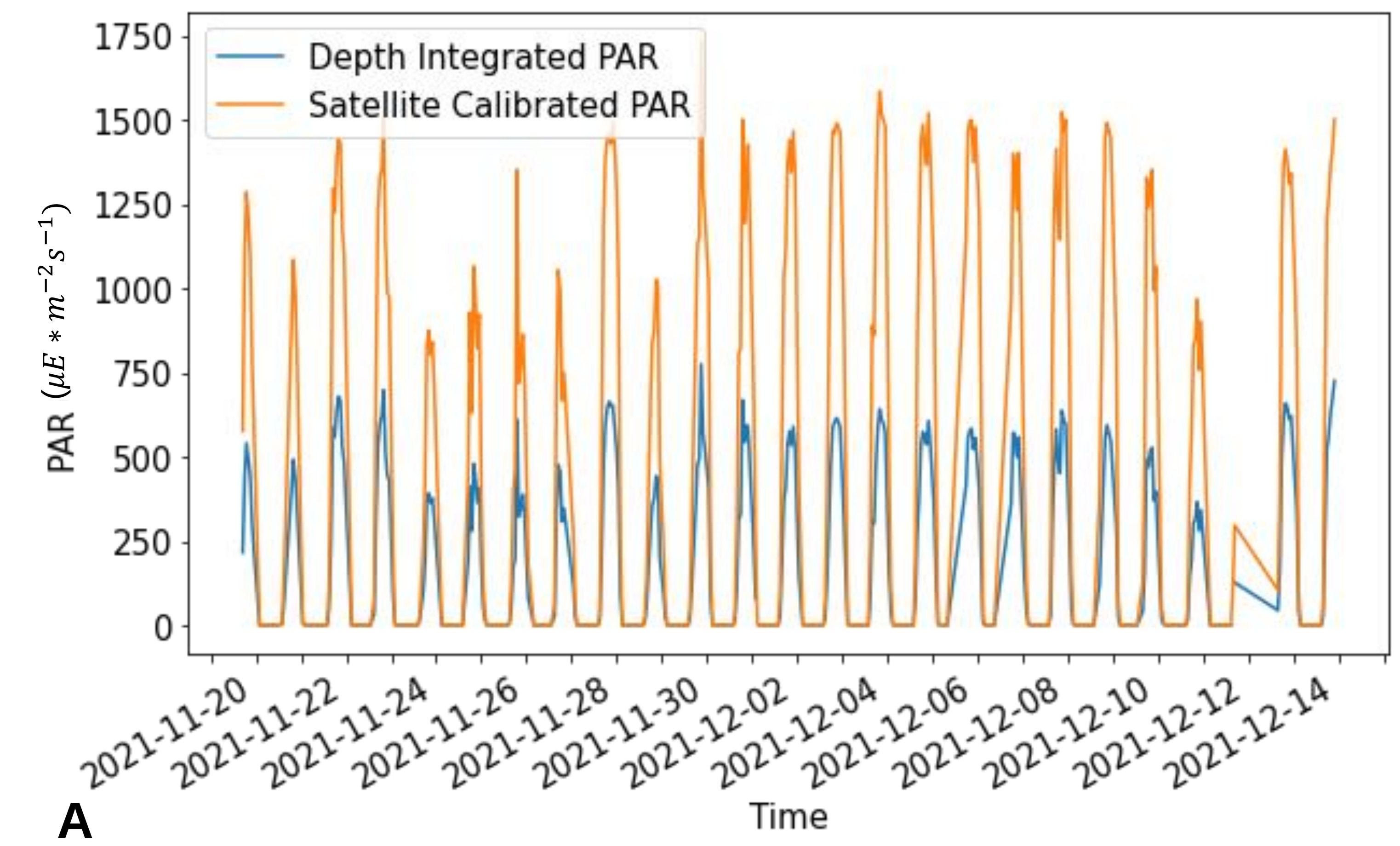


$$PAR(15m) = 1.2 * \tau * PAR_{surface} * e^{-K_{PAR} z}$$

Equation 1: Depth Integrated Algorithm

As we move onto the third step of the conceptual map, creating the depth integrated model needs two things. The newly calibrated PAR data from Sensor 1 and the depth integrated algorithm found in Equation 1 above. To integrate PAR at 15 meters below sea surface, a variety of parameters are needed. The PAR conversion factor is a given value by Allen et al. Air-sea transmission is found by calculating the wind speed and sun zenith angle. The PAR surface value is data from Sensor 1 and the reason why all this calibration was needed! For the PAR attenuation coefficient in green, I used chlorophyll data as opposed to Allen et al., which used the backscatter wavelength of chlorophyll at 490 nm. The depth at which we want to integrate PAR at, Z, is set at 15 meters.

Results



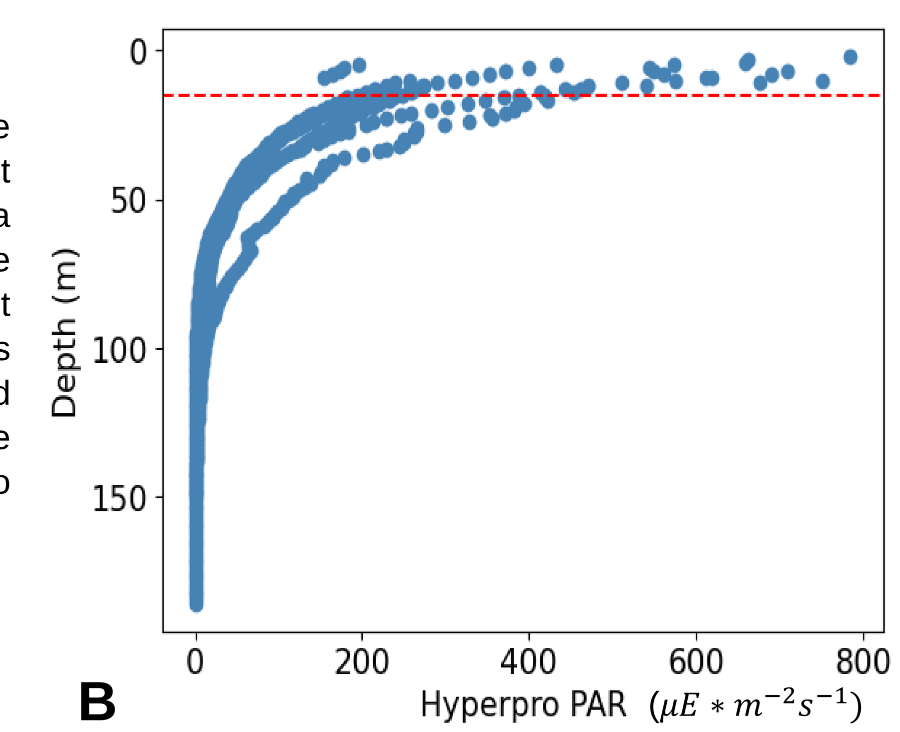


Figure 5: Depth integrated model and depth profile

Now that we are in the last step of the conceptual map, the depth integrated model is here, shown in Figure 5A! The orange line represents the calibrated data from Sensor 1 without integration. The blue line represents PAR data from Sensor 1 integrated at 15 meters. The values for the depth integrated PAR are much lower than Sensors 1 calibrated PAR data. This can be confirmed to be accurate as the depth profile in Figure 5B displays PAR attenuating rapidly within the surface water. The red dotted line represents the depth at 15 meters and values found at that line can be found in Figure 5A. Hyperpro, the device that collected PAR at depth, is used here only to confirm the range of values found in the depth integrated model

Discussion

After integrating PAR at 15 meters below the sea surface, I would like to investigate this further and try to integrate PAR for the entire mixed layer depth. Since the mixed layer depth is mixing light, nutrients, and picophytoplankton itself, having high resolution data on what PAR levels they are receiving can further our understanding of their importance in the biogeochemical cycle. In the future, I would like to also apply this model to all cruises found in SeaFlow, a flow cytometry device that counts picophytoplankton and abundance.

Experience

Before starting this project, I had no idea where to even find public datasets and how to use them. I could only work with one dataset at a time before getting frustrated at the amount of data I was working with. Now, I am capable of finding any sort of public dataset, along with merging multiple datasets together with different parameters to achieve what I want. I also know how to utilize GitHub and publish my data into my repository where you can check it out by scanning the QR code!

References

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Acknowledgements

I would like to thank Katherine Qi for the endless guidance she has provided me throughout my project. I would also like to thank François Ribalet and James G. Allen for their code that I utilized in my project. Finally, thank you to the Armbrust lab for their feedback and support! Supported by the UW Royalty Research Fund Award to Dr. José M. Guzmán.