A Comparison of Biogeochemical Argo Sensors, Remote Sensing Systems, and Shipborne Field Fluorometers to Measure Chlorophyll-a Concentrations in the Pacific Ocean off the Northern Coast of New Zealand

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Abstract

Accurately measuring chlorophyll-a concentrations within the world's oceans is an important part of building our understanding of its underlying processes and the human impact on it, and developing tools to do this is an area of active study. This study aims to quantify and document the trends in the discrepancies between three different chlorophyll-a measurement methods by analyzing data from a flow-through fluorometer, data from a Biogeochemical Argo float, and remote sensing data from the same region. The results from comparisons between each of these collection methods are presented.

Keywords: Chlorophyll-a measurement, remote sensing, Biogeochemical Argo, field fluorometers, VIIRS-SNPP, sensor comparison

Introduction

- Accurate chlorophyll-a concentration measurements are critical for studying a range of natural ocean processes (e.g. primary production, ocean circulation, harmful algal blooms) as well as monitoring the impact of human activities (e.g. surveying coastal water quality, mitigating effects from major oil spills) [1]
- The Biogeochemical (BGC) Argo floats help to increase the coverage of in-situ data by automating the data collection, but are known to suffer from sensor drift over time since their fluorometers cannot be serviced and calibrated regularly [2]
- Data from ocean color algorithms applied to remote sensing imagery has by far the greatest spatial and temporal coverage of the three methods, but is known to be significantly less accurate in certain regions and is limited to surface measurements [3]
- Regularly serviced in-situ fluorometers are the most precise of the three, but are limited in spatial and temporal coverage due to their dependence on expensive oceanographic research cruises [4]

Flow-through Data

Dataset source: Turner Designs 10AU Field and Laboratory Fluorometer on board the SSV *Robert C. Seamans*

Collection Dates: February 18th to March 12th, 2020

Data Preprocessing:

- Remove data from port stops
- Remove data points more than three standard deviations from the mean
- Filter out sensor noise with a 31-point median filter
- Calibrate the fluorometer's voltage-to -concentration relationship using vacuum-filtered hydrocast samples across 29 different stations

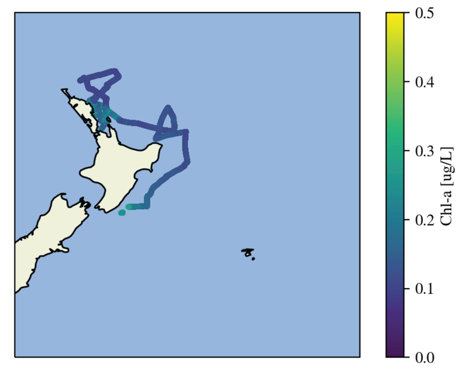

Fig 1: Locations and calibrated values of flow-through data points from the Seamans cruise track displayed on a map

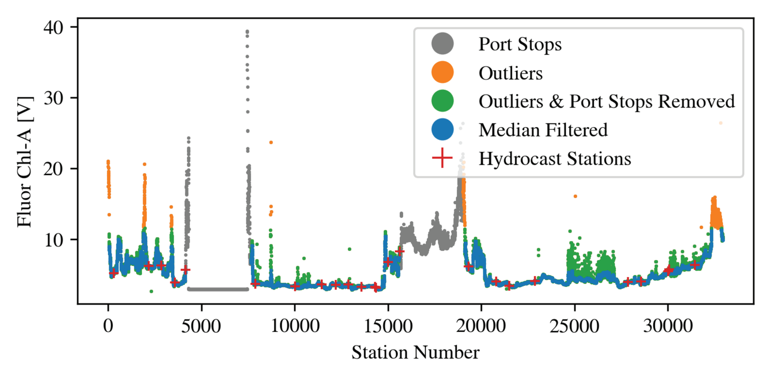

Fig 2: Flow-through data at various stages of preprocessing

Biogeochemical Argo Data

Dataset source: BGC Argo Float 5905108 (released by NOAA AOML). This float was selected because it was the only float equipped with a chlorophyll-a fluorometer that traveled within the area relevant to this study.

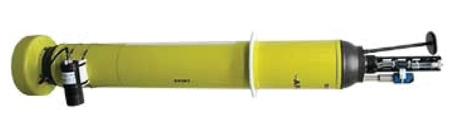

Fig 3: As of July 2020, 387 BGC Argo floats are used globally to take automated profiles of a variety of variables, including chlorophyll-a

(Image source: http://www.teledynemarine.com/apex-biogeochem?BrandID=23)

Collection Dates: July 29th, 2017 to February 3rd, 2020

Data Preprocessing:

- Reduce dimensionality by integrating chlorophyll measurements from the surface to the approximate mixed layer depth (20 meters)

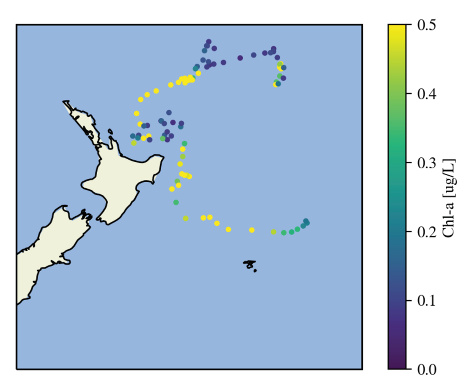

Fig 4: Locations and computed values of BGC Argo data points displayed on a map

Remote Sensing Data

Dataset source: VIIRS-SNPP dataset from NASA's OceanColor Web. The product data used was from the default chlorophyll algorithm applied over an 8-day period with a 4 kilometer resolution.

Collection Dates: July 4th 2017 to March 12th 2020

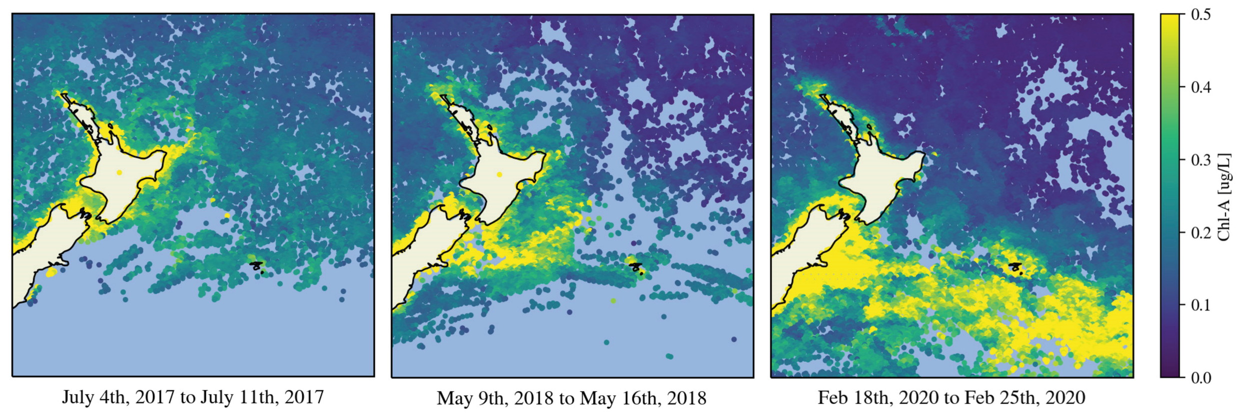

Fig 5: Chlorophyll-a values from VIIRS-SNPP dataset during three different time periods

Analysis

When graphing direct comparisons between the flow-through, BGC Argo, and remote sensing datasets, there is a distinct difference between the low and high-concentration data.

A Gaussian Mixture model was used to divide the data into low and high concentration clusters.

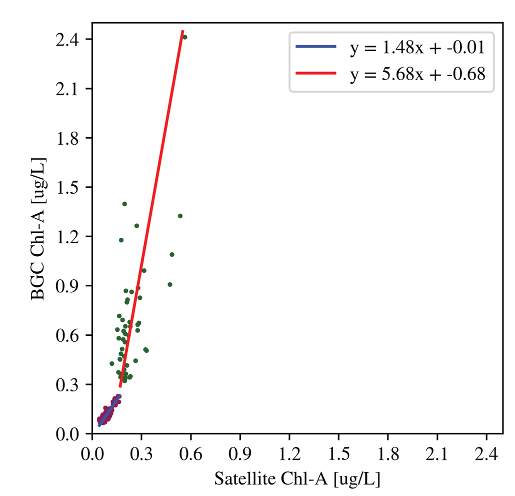

Fig 6: Chlorophyll-a data comparison between BGC Argo and remote sensing collection methods

A Total Least Squares model was used to quantify the relationship between each of the in-situ sensors with the satellite data.

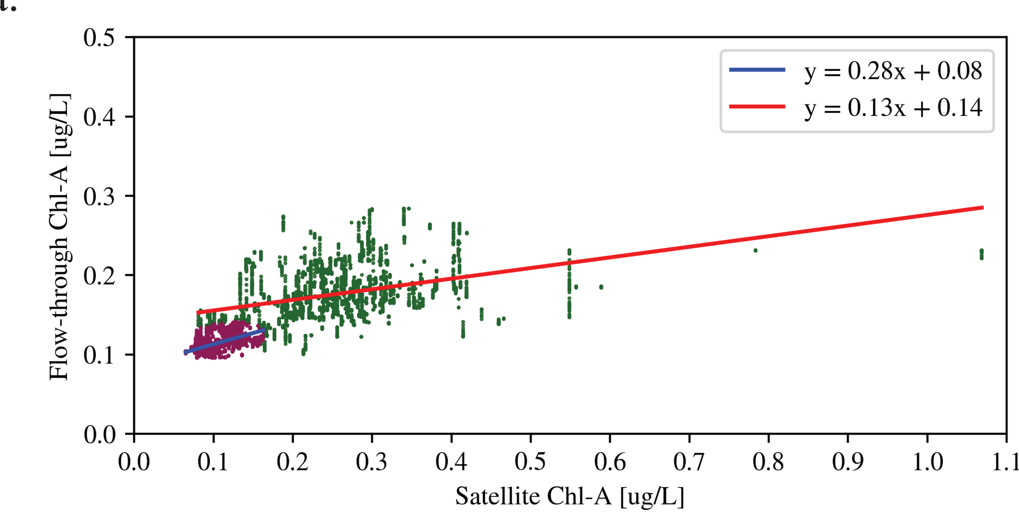

Fig 7: Chlorophyll-a data comparison between flow-through and remote sensing collection methods

Results

Dataset	% Difference
Flow-through/Satellite (Low concentrations)	10.10%
Flow-through/Satellite (High concentrations)	−30.60%
Flow-through/Satellite (Overall)	−6.06%
BGC Argo/Satellite (Low concentrations)	27.87%
BGC Argo/Satellite (High concentrations)	89.95%
BGC Argo/Satellite (Overall)	60.58%

Table 1: Average percent differences for different sub-sets of data

Conclusion

Across the three datasets, there was generally better agreement among recorded chlorophyll-a values in lower concentrations (<0.15-0.2μg/L) than in higher concentrations. In higher concentrations, the flow-through dataset generally reported lower chlorophyll-a values than the ocean color algorithm did while the BGC Argo dataset recorded much higher values.

It's worth noting that this may be an artifact of the ocean color algorithm. The default chlorophyll-a algorithm transitions between the OC3/OC4 (OCx) band ratio algorithm and the color index (CI) algorithm at $0.15 < CI < 0.2$ mg/m³, which is precisely where the trends between the datasets change.

Our results show that when using any chlorophyll-a measurement, the data collection method's impact on the results is non-trivial and should be taken into consideration, especially when analyzing data from different sensors.

References

[1] C. Hu and J. Campbell, Oceanic Chlorophyll-a Content. Berlin, Heidelberg: Springer Berlin Heidelberg, 2014, pp. 171–203

[2] G. C. Chang and R. W. Gould, "Comparisons of optical properties of the coastal ocean derived from satellite ocean color and in situ measurements," Opt. Express, vol. 14, no. 22, pp. 10 149–10 163, Oct 2006

[3] C. Hu, Z. Lee, and B. Franz, "Chlorophyll-a algorithms for oligotrophic oceans: A novel approach based on three-band reflectance difference," Journal of Geophysical Research: Oceans, vol. 117, no. C1.

[4] S. M. Glenn, T. D. Dickey, B. Parker, and W. Boicourt, "Long-term real-time coastal ocean observation networks," Oceanography, vol. 13, no. 1, pp. 24–34, 2000.

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