

# **HAWAII OCEAN COLOR: VALIDATION OF SATELLITE MEASUREMENTS OF CHLOROPHYLL IN HAWAIIAN OCEAN WATERS**

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## **ABSTRACT**

This project had two key goals. First, I made global ocean color and temperature data more relevant and accessible to those interested in the Hawaiian ocean ecosystem. I created a website, [www.higp.hawaii.edu/~raeannec/HawaiiOceanColor.html](http://www.higp.hawaii.edu/~raeannec/HawaiiOceanColor.html) which presents processed satellite imagery of the ocean surrounding the Hawaiian Islands, including the Northwest Hawaiian Islands. The measurements for the Kane'ohē Bay and Station ALOHA pixels are also given on the website. The global temperature and chlorophyll A images are taken from NASA's Ocean Color website. Second, I validated these satellite measurements by correlating with field measurements of chlorophyll A and temperature at Station ALOHA. I also investigated the magnitude and distribution of chlorophyll A concentration in the near-shore waters of Kane'ohē Bay with water samples obtained from kayak-based sampling and laboratory fluorometer measurements.

## **INTRODUCTION**

Ocean color refers to the color of light reflected off the ocean, thus we can determine the "color" of the ocean. Ocean color is strongly influenced by chlorophyll content, which is produced by microscopic ocean plants through photosynthesis, which is basically the process of a plant or organism using sunlight and carbon dioxide to produce sugars for its fuel and releasing oxygen. Nearly half of the world's oxygen is produced by phytoplankton, and much of the human produced carbon dioxide is used up by the phytoplankton. This consumption of carbon dioxide is a huge deal because many believe global climate change is caused by this over production of carbon dioxide by humans. The greenhouse effect occurs when certain 'greenhouse gases' (such as CO<sub>2</sub>) get trapped in the earth's atmosphere, letting heat from the sun in, but not letting the heat back out. It's important to remember that the Earth's atmosphere and oceans are really just one system. As the earth heats up due to the increasing CO<sub>2</sub> levels in the atmosphere, there is also an increase in the CO<sub>2</sub> levels in the ocean. As CO<sub>2</sub> dissolves in the ocean, it becomes carbonic acid, which causes the ocean to become more acidic (lower pH), a deadly change for many marine species. (Figure 1)

Thus, phytoplankton plays a key role in regulating the Earth's climate and the ocean's acidity. Phytoplanktons are also important because they are the base of the oceanic food web, and thus affect the productivity of the entire ocean. Thus ocean color mapping is an important tool to map chlorophyll, and therefore phytoplankton abundance. Since phytoplankton live in nutrient rich waters, mapping them can also show nutrient rich areas of the oceans.

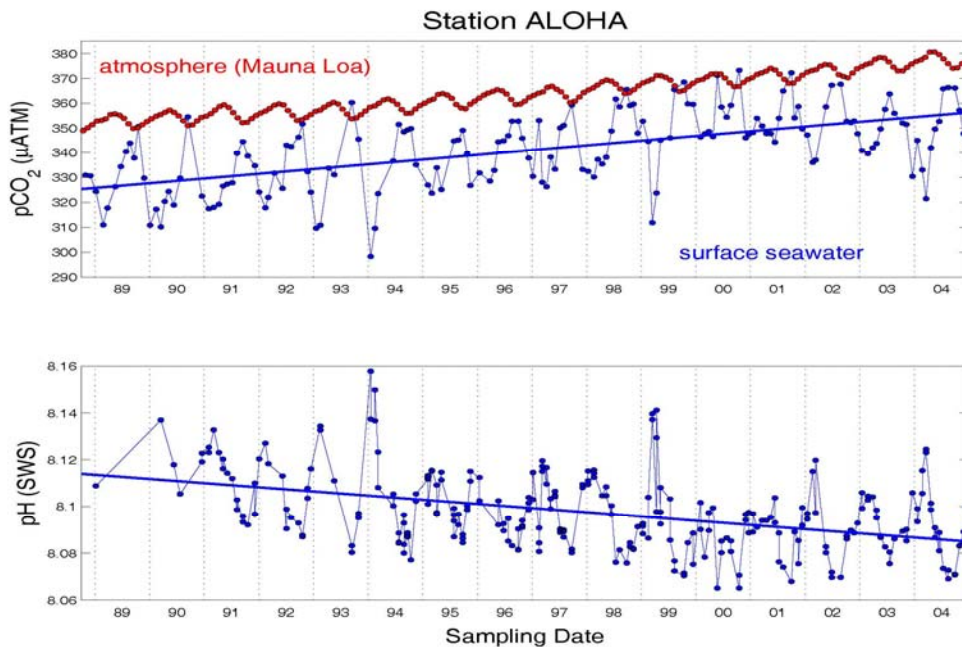


Figure 1: Data collected by the Hawaii Ocean Timeseries (HOT) program of a deep-water location called Station ALOHA (A Long-Term Oligotrophic Habitat Assessment). Station ALOHA is a site located about 100km North of Oahu where the water column has been monitored since 1988. The blue lines of the graphs show an increase in CO<sub>2</sub> levels in the ocean (upper graph) and the decreasing pH in the ocean (lower graph) with time. Image courtesy of Dave Karl, University of Hawaii.

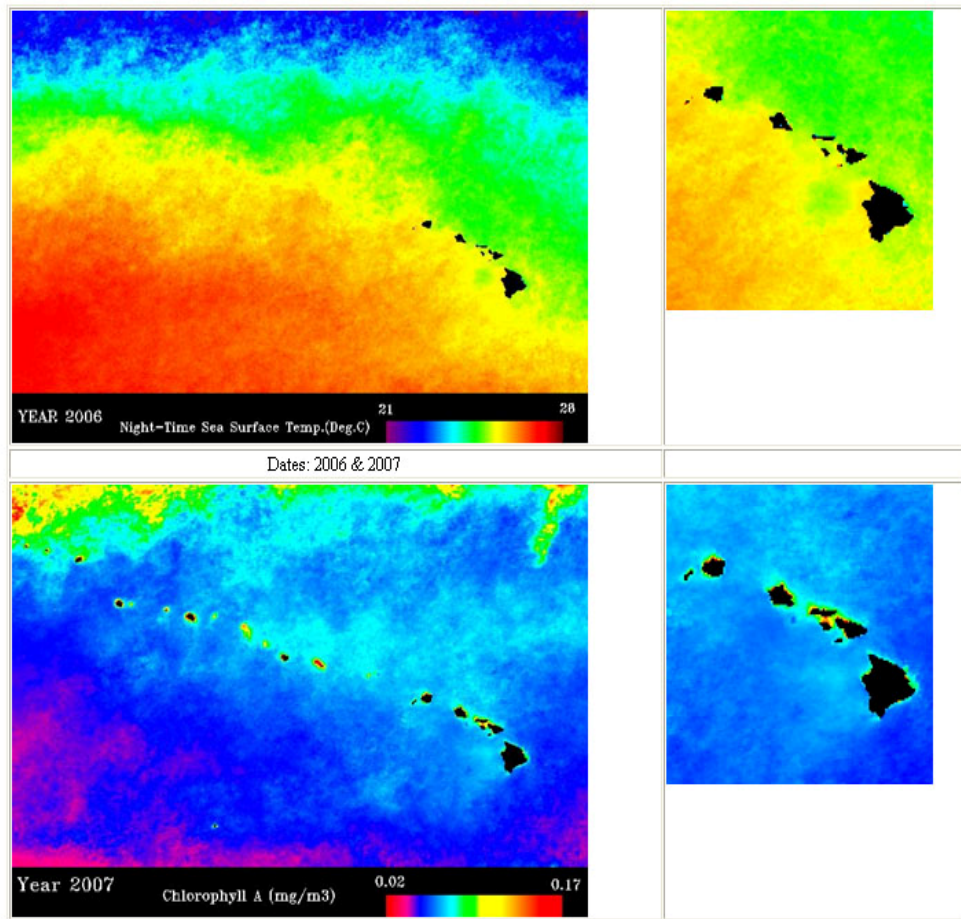
## METHODS

For the website development I downloaded global ocean color and night-time sea surface temperature images from NASA's ocean color website (<http://oceancolor.gsfc.nasa.gov/>). These images have a spatial resolution of 4km by 4km. To process the images, after downloading, I unzipped the image, then subscened it to include only the Hawaiian ocean waters, applied a color wedge, and lastly annotated the image. Each image is then placed on its respective page of Latest 8-Day, Latest Monthly, Latest Seasonal, and Latest Yearly images for Night-Time Sea Surface Temperature and Ocean Color. Also, included on each webpage are the latest satellite values for Station ALOHA and Kane'ohu Bay.

With the help of my mentors, I looked at two points of interest 1) Station ALOHA and 2) Kane'ohu Bay. I focused on the chlorophyll concentrations and night-time sea surface temperature for each point of interest. I investigated the Kane'ohu Bay chlorophyll A concentrations satellite data by going out in a kayak to various points in the Bay and collected water samples. While collecting water samples I also recorded the GPS positions of each of the points. The Station ALOHA satellite data was ground-truthed by using the HOT (Hawaii Ocean Time-Series) cruise data.

# Hawaii Ocean Color

Latest Year 2006 & 2007



Location	Ocean Color	Night-Time Sea Surface Temperature
Station Aloha	0.068378	24.536562
Kaneohe Bay	0.169673	24.822000

[Latest Seasonal](#)
[Latest 8 Day](#)
[Latest Month](#)

[Homepage](#)

Figure 2: Screen grab of a Latest Year page from my website, [www.higp.hawaii.edu/~raeannec/HawaiiOceanColor.html](http://www.higp.hawaii.edu/~raeannec/HawaiiOceanColor.html)

To investigate Kane’ohe Bay chlorophyll A concentrations, I with the help of my mentors, kayaked to various places in the Bay to collect water samples using brown plastic bottles. Samples were collected by filling the bottle with very near surface water. At each site, I collected to water samples for lab analysis. I kept the samples closest to their original environment temperature by towing the bottles in mesh bags. During transportation from the sample site to the lab, I placed the bottles in a cooler. Once back at the lab, I filtered the water samples using Glass Fiber Filters (GFF), a filtering apparatus, a vacuum pump, and tubing. I then

placed the filters in glass test tubes, covered the test tubes in foil, and placed them in a sub-zero freezer, until I was able to gather the supplies and set up the lab for analysis. The freezer helps to preserve the chlorophyll. Twenty-four hours before I was ready to analyze the samples, I prepared the samples by taking them out of the freezer, added 3 mL of acetone to each test tube with the frozen filter inside, and put them back in the freezer for an additional twenty-four hours. It is essential for the filters (which contained the chlorophyll-containing cells) to extract for 24 hours before being run through the fluorometer, to ensure the chlorophyll was released into the acetone. After 24 hours in the sub-zero freezer, I took the filters out of the freezer and removed the filters in each test tube, so only the acetone remains. It is the acetone that I then analyzed with the fluorometer for chlorophyll content. However, when I ran some of my first samples through the fluorometer, I found that the solutions were too concentrated and I needed to do 10-fold dilutions. The fluorometer could not accurately read the chlorophyll concentrations because it was calibrated for less concentration. Once diluted, the samples were wiped with Kimwipes to remove any condensation on the outside of the tube (the condensation could ruin the fluorometer) then run through the fluorometer to get chlorophyll concentration in  $\text{mg}/\text{m}^3$ .

To ground-truth the Station ALOHA satellite data I downloaded data from the HOT cruise website ([http://hahana.soest.hawaii.edu/hot/hot\\_jgofs.html](http://hahana.soest.hawaii.edu/hot/hot_jgofs.html)) for chlorophyll A. I compared this data from the monthly HOT cruises with the nearest 8-Day period and monthly period of the satellite data, and for the night-time sea surface temperature data I compared and correlated Station ALOHA's data with the monthly satellite measurement.

## RESULTS

I found that the Station ALOHA night-time sea surface temperature data correlated very well with the satellite data, as shown in Figure 3.

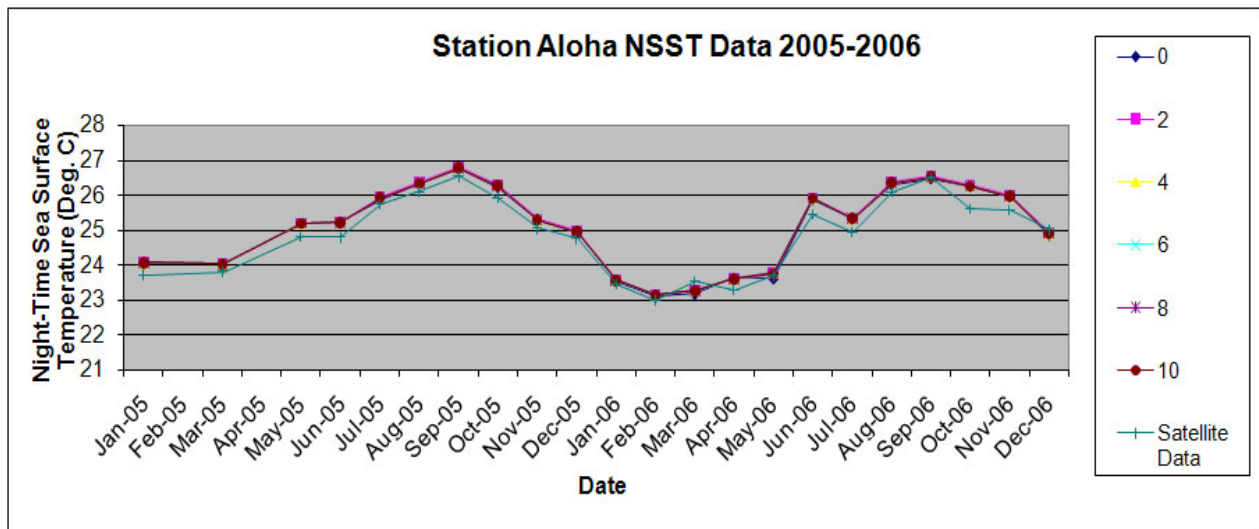
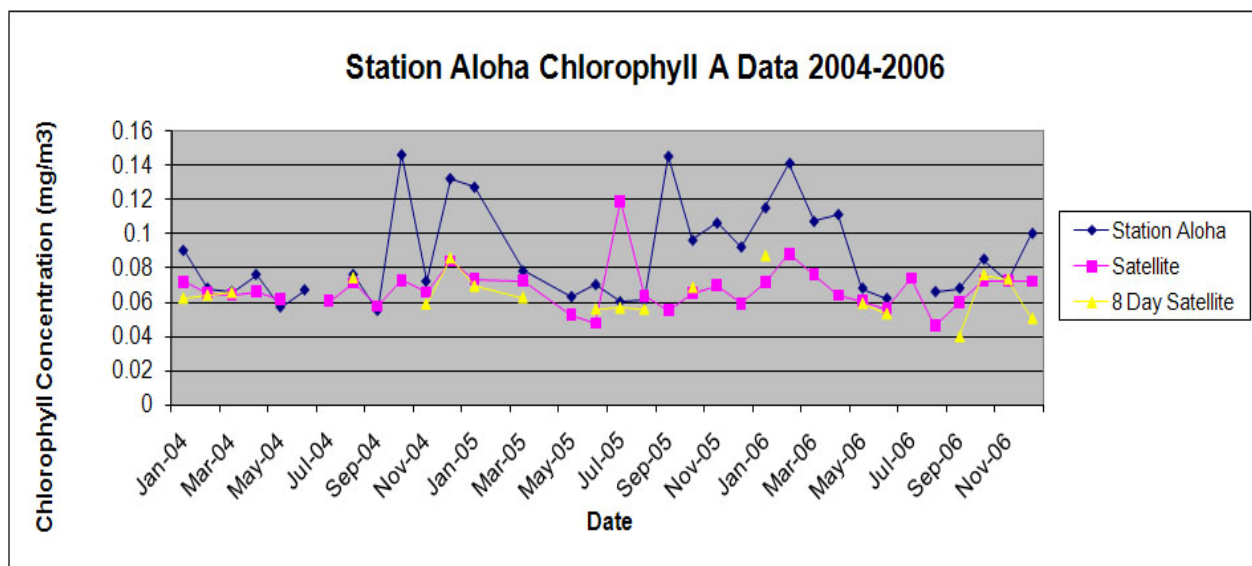


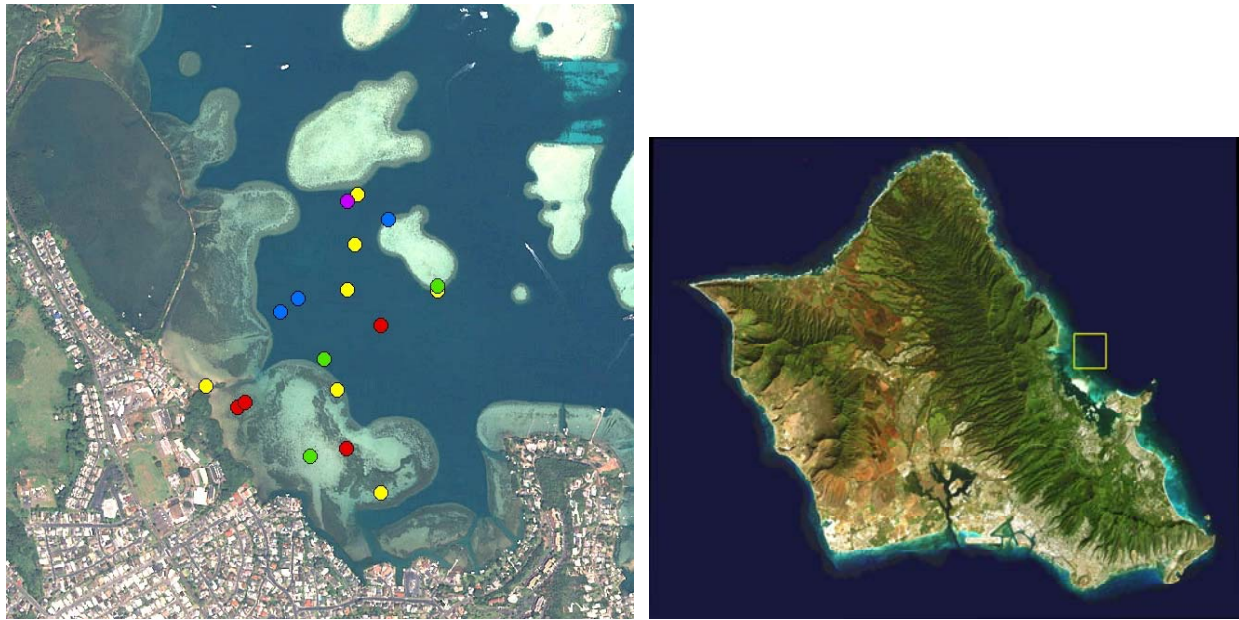
Figure 3: Graph comparing Station ALOHA night-time sea surface temperature data at various depths with the satellite data for Station ALOHA.

However, the Station ALOHA chlorophyll data did not correlate as well with the satellite data (Figure 4). Station Aloha cruise measurements show significantly higher in the 2004 to 2005 and 2005 to 2006 winter months. These elevated concentrations are not evident in the satellite measurements. One possibility is that the chlorophyll A algorithm employed by NASA Goddard Space Flight Center, used to produce the global datasets, is not well suited for this site. Another possibility is that within each pixel of the satellite data there may have been significant variations in chlorophyll content. Further research is required to understand the reason for the poor correlation.



Figures 4: Graph comparing Station ALOHA chlorophyll data with the satellite data for the nearest 8-Day period to the days the HOT cruise went out and the Monthly satellite data.

To investigate the levels and distribution of chlorophyll in Kane’ohe Bay we collected water samples at various sites on two different dates, March 12 and April 13. These sites are shown in Figure 6. At each site we collected two samples. Chlorophyll A concentrations ranged from 0.7 to 5.1 mg/m<sup>3</sup>. I averaged the two measurements at each site and plotted them with the color corresponding to the averaged value as shown in the Figure 5. The two measurements were generally 0.4 mg/m<sup>3</sup> of each other. More measurements at a single site are required to really assess the sampling and measurement error. For the first day, the mean and standard deviation of the concentrations was 2.5 and 0.805 respectively. The second day, the mean concentration was 2.63 with a standard deviation of 1.48. I also looked at the satellite chlorophyll A measurement for Kane’ohe Bay. The actual area where the Kane’ohe Bay satellite data was taken from is shown by the yellow box in Figure 6, this pixel is the closest to our field site that is regularly reported. The values for the nearest 8-Day period to the my two field visits were 0.15 mg/m<sup>3</sup> for March 12, and the April 13 data was 0.28 mg/m<sup>3</sup>.



Figures 5: Left image is of the various points of sample collection in Kane'ohe Bay. The colors in the image to the right are as follows, 1-1.45 mg/m<sup>3</sup>=Purple, 1.45-1.95 mg/m<sup>3</sup>=Blue, 1.95-2.10 mg/m<sup>3</sup>=Green, 2.10-2.95 mg/m<sup>3</sup>=Yellow, 2.95-4.95 mg/m<sup>3</sup>=Red.

Figure 6: Right image shows the actual satellite pixel location which was used to compare to field measurements.

## CONCLUSION

My website is at [www.higp.hawaii.edu/~raeanec/HawaiiOceanColor.html](http://www.higp.hawaii.edu/~raeanec/HawaiiOceanColor.html). This site consists of a home page describing the site, a page which discusses ocean color, and a page presenting the Station Aloha validation results. There are also links to the latest year, latest season, latest month, and latest 8 day satellite measurements. The "latest" pages present a color coded map of the sea surface temperature and chlorophyll A concentrations for the Hawaiian region. Satellite measurements of Kane'ohe Bay and Station Aloha site are listed for the time period and a time series for these two regions is listed.

The Station ALOHA data showed a very high correlation for sea surface temperature. However, the chlorophyll A satellite measurements do not show the pronounced peaks which were evident in the HOT cruise data. Some possible reasons for the lack of correlation for the Station ALOHA chlorophyll data could be that the HOT cruise might have gone out when there was an algal bloom and the satellite averaged the data and missed the values; perhaps the Station ALOHA pixel is slightly off from the actual Station ALOHA sampling site, which is much smaller than a 4km by 4km area of data.

The Kane'ohe Bay satellite data differed greatly from the actual data I collected. The satellite data values were much lower than the data values I recorded in my field visits. It is my guess that the satellite data does not accurately reflect the concentrations or variability of near-shore waters which we measured because the large pixels of the satellite data include the near-

shore with more off-shore waters. Higher spatial resolution measurements would likely improve this situation. More work on Kane'ohē Bay is needed to better understand the magnitude and variability of chlorophyll A concentrations in the bay.

### **ACKNOWLEDGEMENTS**

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