Temporal and spatial analysis of chlorophyll-a measurements within the Strait of Georgia, British Columbia: characterizing natural variability in relation to ocean colour images

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Abstract

Ocean colour satellite images are used to estimate chlorophyll concentration in ocean surface waters. The chlorophyll estimates provided by these images represent an average and provides no information regarding variations in concentrations that occur over space. This lack of correspondence can be more significant in coastal waters due to the more dynamic nature of these environments. This paper assesses the temporal and spatial variability of chlorophyll-a within a satellite pixel representation of the coastal water surface within the Strait of Georgia, on the west coast of Canada. This was accomplished by analyzing *in situ* flow-through fluorometer chlorophyll-a measurements continuously acquired aboard a ferryboat. The results from the temporal analysis showed that in the spring and summer the coefficient of variation was higher relative to the winter and fall months. The results from the spatial analysis identified no spatial trends (ie., variability was similar regardless of position in the Strait) in the summer and spring months, but in the winter and fall months, chlorophyll-a mean values nearer to land tended to have higher variability. These results will aid in defining *in situ* methods to validate chlorophyll-a ocean colour algorithms used to monitor the Strait of Georgia.

Background and Relevance

In the Strait of Georgia, British Columbia, chlorophyll-a (chl-a) is used as a proxy for primary productivity. As it is affected by a number of physical forces, concentrations varies spatially and temporally within a coastal setting, such as the Strait of Georgia (Masson, 2006). Generally, in these waters, phytoplankton growth is controlled by light in the winter and nutrient availability in the spring and summer (Harrison, 1983). The seasonal dynamics strongly influence the development of food webs, and consequently distinct fish migration patterns are observed in these waters (Harrison *et al.,* 1983; Mann, 1993). Satellite imagery provides a cost-effective tool to monitor the dynamics of these waters, such as surface chl-a, at large spatio-temporal scales (Gower *et al.,* 2005). However, to effectively use these images, the commonly used algorithms to determine chl-a estimates must be validated. A common approach for validation is to use ship-based punctual chl-a measurements, which are then compared to the estimated chl-a from a pixel resolution of the imagery (Robinson, 2004). The chl-a estimates within a pixel provided by the satellites does not necessarily represent the *in situ* natural variability of chl-a within the water surface. To address this issue, data from a high resolution flow-through fluorometer are used to determine the temporal and spatial variability of chl-a within a pixel representation on the coastal water surface.

Methods and Data

This project analyzed the spatial and temporal variability of *in situ* chl-a measurements within the Strait of Georgia, a highly productive, semi-enclosed coastal basin between the southern half of Vancouver Island and the British Columbia mainland (Harrison, 1983). Chl-a measurements from a flow-through fluorometer installed on a ferry running the BC Ferry route from Tsawwassen to Duke Point were utilized. The fluorometer measured chl-a concentrations in the engine water uptake of the ferry in 30 second intervals from January 1, 2005 to October 29, 2006. A temporal subset was created within a known ferry route time frame with departure from Tsawwassen at 12:45 pm (PST) and arrival at Duke Point at 3:15 pm (PST). This subset was created to maximize the comparability with ocean colour images, which provide near daily images acquired at approximately solar noon (IOCCG, 2007).

To spatially analyze the continuous point data, 10 stations were created at 5 km intervals along the ferry route. Each station was defined by a geographical filter with an area of 1100 m, which was set to be similar to the pixel size of satellite colour images for later comparison. The chl-a measurements for each station were grouped by their date / time to produce a dataset with multiple chl-a measurements for each station. Statistical measures including median, mean, standard deviation, and coefficient of variation were calculated for each station. Seasonal subsets were created to analyze the temporal variation.

Results

The results showed that within the winter / fall season, the middle of the Strait was found to show very little variability in chl-a concentrations within a satellite pixel representation on the water surface. On the eastern side of the Strait, near the Fraser River, 15% of all results were found to possess higher variability. Near the coast on the western side, approximately 7% of all results displayed higher variability. Within the summer / spring season, 12% of all results displayed higher variability, independent of space.

Conclusions

The high resolution fluorometer measurements provided valuable insight regarding the accuracy of ocean colour images used to monitor chl-a levels within the Strait of Georgia. For instance, chl-a estimates from a pixel resolution of an ocean colour image acquired in the middle of the Strait in the winter and fall seasons may accurately estimate the variability of chl-a. However, this is not true for waters closer to the coast or during the summer and spring months when the high dynamic of this system causes higher variability in the water. These results can be used alongside ocean colour satellite images to provide more information regarding the variability of mean chl-a values in a pixel.

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