SEAWIFS VALIDATION AT THE CARIBBEAN TIME SERIES STATION (CATS)

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INTRODUCTION

Ocean color images of the spatial distribution of surface chlorophyll generated from satellite sensors like the coastal zone color scanner (CZCS), Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Moderate-Resolution Imaging Spectroradiometer (MODIS) amongst others, has and will continue to greatly enhance our ability to understand geophysical processes on temporal and spatial scales with much more ease. The detailed spatial coverage provided by the satellite has provided data for analysis and for model comparisons that would never have been possible from the available ship data. This is of particular importance to areas such as the Eastern Caribbean which has traditionally been viewed as a nutrient poor oligotrophic sea where high phytoplankton biomass and productivity are limited to coastal upwelling regions and the immediate vicinity of river mouths (Corredor, 1979). Recent work has revealed the dynamic nature of the northeastern Caribbean, underscoring the significant effect of periodic intrusions of waters of continental origins (Corredor and Morell, 2001).

However to use remotely sensed data with confidence, ocean color algorithms need to be verified with *in situ* measurements. Many studies have shown inaccuracies in ocean color algorithms for particular regions. In this paper a large set of ship and satellite (SeaWIFS) data of chlorophyll-a from the Caribbean Time Series (CaTS) has been compiled and analyzed from October 1997 to November 2001. The data set allowed us to address the following questions for CaTS: (1) how do chlorophyll-a concentrations from SeaWIFS compare to ship data, (2) how the SeaWiFS and ship data compare to chlorophyll-a concentrations obtained from SeaWiFS algorithms ($OC2_{v4}$ and $OC4_{v4}$) using data obtained from a portable spectroradiometer (GER 1500), and (3) how do chlorophyll-a concentrations vary over temporal scale in CaTS.

MATERIALS AND METHODS

Water samples from the surface (~1m) were taken at monthly intervals at the Caribbean Time Series (CaTS) from October 1997 to November 2001 at the Caribbean Time Series (CaTS) station, located 26 nautical miles off the southwestern coast of Puerto Rico at 67^{o} W $17^{o}36'$ N (Fig. 1).

Fig. 1 Map of Puerto Rico and CaTS

Pigment Analysis

Total chlorophyll-a was obtained by filtering 500 ml of seawater directly on 0.7 μm glass fiber filters. To extract the pigments, the filters were covered with 10 ml of methanol and placed in a 15 ml centrifuge tube. The samples were kept in the dark at 4º C for at least 16 hours. Samples were centrifuged to remove the filter paper. Concentration of phytoplankton chlorophyll-a was obtained using the standard fluorometric method (Yentsch and Menzel 1963) measured in a Turner AU-10 Fluorometer.

Determination of chlorophyll-a concentration using different algorithms

Chlorophyll-a concentration were calculated using the algorithms used for SeaWiFS $OC2_{v4}$ and $OC4_{v4}$ algorithms, with the normalized water leaving radiance (nLw) and remote sensing reflectance (Rrs) being calculated by data obtained from a GER 1500 portable spectroradiometer.

Satellite Imagery

SeaWiFS Level 1 images were obtained from satellite receiving stations at the University of Puerto Rico-Mayagüez and the University of South Florida between October 1997 to November 2001 for the CaTS study area Some SeaWiFS images from the CaTS sampling date were unusable because of large cloud coverage; in which case the SeaWiFS image closest to the sampling date was used. Images were processed up to

Level 2 mapped (Level 3) using SeaDAS 4.1. (Fig. 2) The pixel that represented the exact location of CaTS was used as the center pixel for generating a 3 x 3 pixel block. The values for the nine pixels were averaged, and the standard deviation and confidence intervals (95%) were calculated. chlorophyll-a values obtained using the NASA $OC2_{V4}$ and $OC4_{V4}$ algorithms was compared to the experimental value, and to values obtained from calculating the different algorithms with data from the field spectroradiometer.

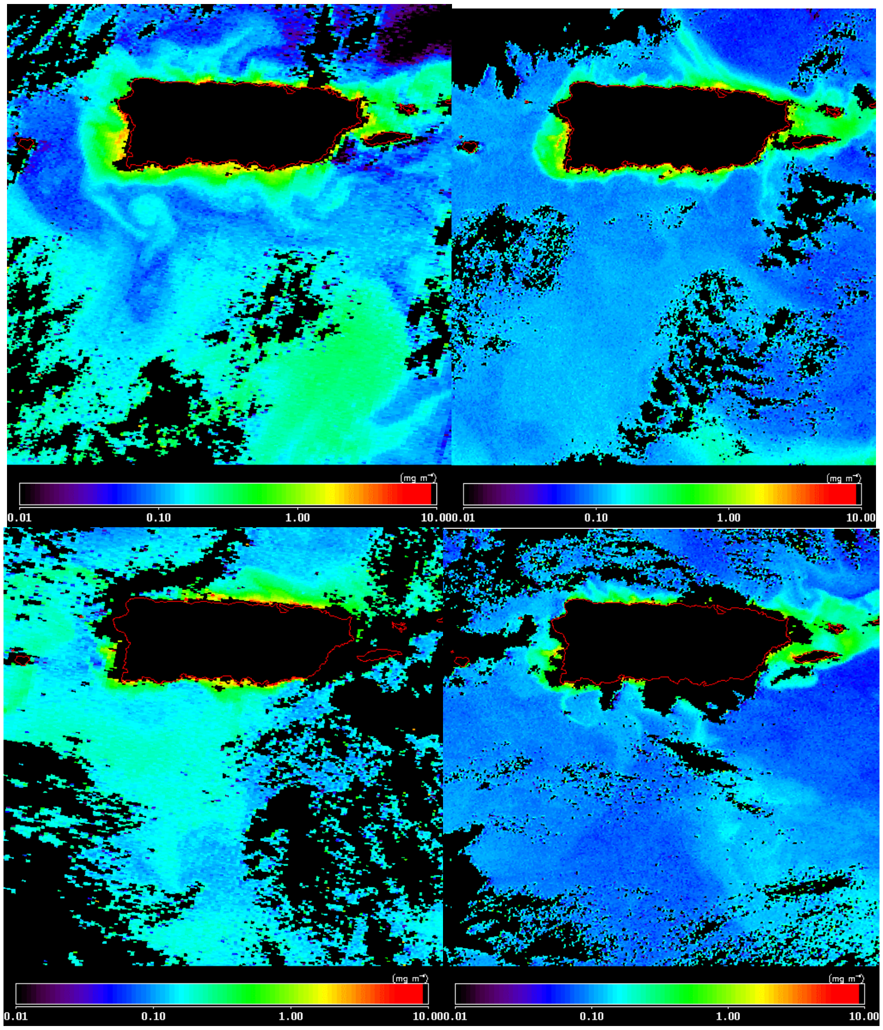

Fig. 2. SeaWiFS images of Puerto Rico and CaTS station

RESULTS AND CONCLUSIONS

Satellite Versus Ship Chorophyll-a

The correlation of chlorophyll-a concentration between satellite and calculated $OC4_{v4}$ algorithm was higher than the correlation for the $OC2_{v4}$ algorithm, r^2= 0.69 and 0.54 respectively (Fig. 3 a,b). The correlation between satellite and ship data was low (r^2= 0.42), while it became slightly higher (r^2=0.59) when ship data was compared to the chlorophyll-a concentration obtained with the $OC4_{v4}$ algorithm using the field spectroradiometer data (Fig. 3 c,d). The analysis of these data allowed us to compare ship chlorophyll-a concentration with the corresponding retrieved chlorophyll-a estimates using the SeaWiFS $OC4_{v4}$ algorithm. It was found that when the concentration of ship chlorophyll-a falls bellow 0.20 ug l^{-1}, SeaWiFs overestimates the chlorophyll-a value. If the concentration of ship chlorophyll-a was above 0.20 ug l^{-1}, SeaWiFS overestimated the value (Fig. 4). The differences observed could be attributed to: (1) variability in atmospheric conditions, (2) gradients in phytoplankton species composition (Chavez, 1995), and (3) the underestimation of phytoplankton resulting from the use of traditional (Lee-Borges et al., in review). Although we believe that all three contribute to the differences observed, we suggest that the underestimation of phytoplankton by 0.7 µm Whatman GF/F is an often overlooked and important factor in the equation. Based on our previous work in the Eastern Caribbean we estimate there is a 10-20% loss of chlorophyll-a through 0.7 µm GF/F filters compared to 0.2 µm membrane filters.

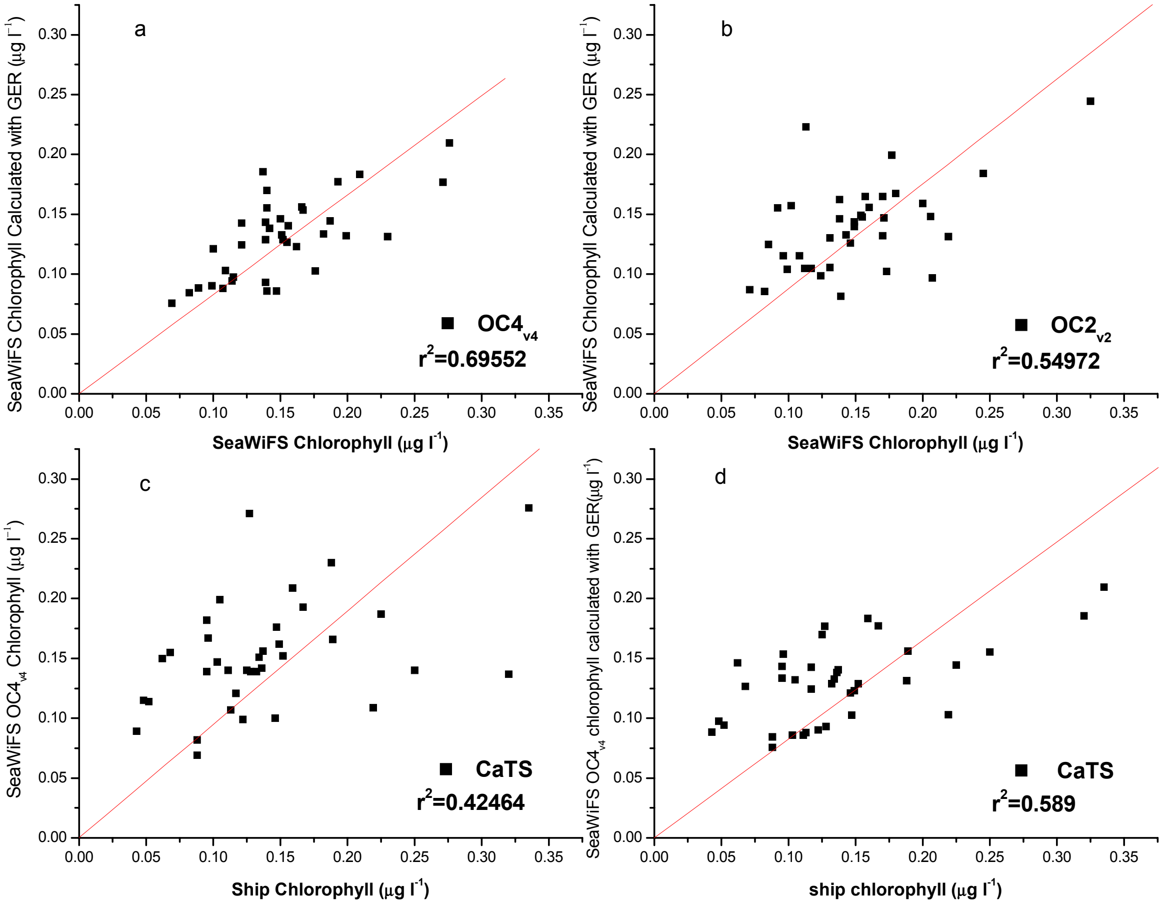

Fig. 3 Comparisons of chlorophyll-a concentrations obtained with (a) SeaWiFS $OC4_{v4}$ algorithm from satellite and calculated from GER data, (b) SeaWiFS $OC2_{v4}$ algorithm from satellite and calculated from GER data, (c) ship and SeaWiFS $OC4_{v4}$ algorithm, and (d) ship and $OC4_{v4}$ algorithm calculated form GER data.

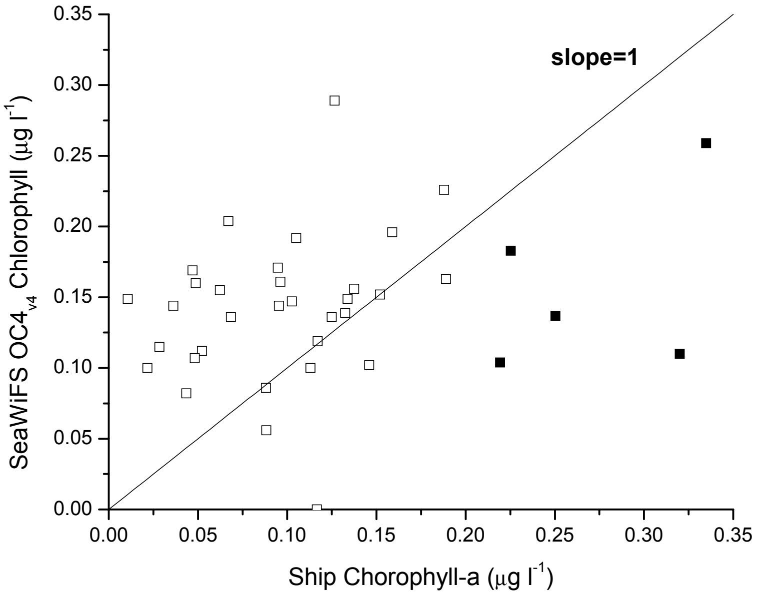

Fig. 4. Comparison of ship chlorophyll-a concentration with the corresponding chlorophyll-a concentration retrieved using the SeaWiFS OC4$_{v4}$ algorithm for where the ship chlorophyll-a concentration was >0.20 ug l^{-1} (open circles) and <0.20 ug l^{-1}(solid circles)

Seasonal Variability in Ship and Satellite Chlorophyll

There is an observed seasonal cycle in chlorophyll-a concentration for both, ship and satellite for CaTS, with peaks in May-July and October-January (Fig. 5). These observations are consistent with the fact that the Eastern Caribbean is under massive freshwater inputs from both direct precipitation and continental runoff (Corredor and Morell, 2001). Zonal trade winds cause seasonal displacement of the inter-tropical convergence zone (ICTZ) along a gradient from the Amazon River basin across the Orinoco River basin and into the Central Caribbean. These phenomena result in alternations of dry and rainy periods over the Caribbean and the northern portion of South America. During the dry period, normally centered on the month of April in northern South America, strong easterly winds enhance surface flow through the Caribbean and induce upwelling along the southern Caribbean (Morrison and Smith 1990) and erosion of the pycnocline in the central and northern portion of the basin (Margalef, 1965 Corredor, 1979). In the spring, high chlorophyll-a associated with the Amazon River plume can be seen far out in the Atlantic. At this time, high surface chlorophyll-a in the east-central Caribbean is maintained by upwelling processes not related to riverine flow. The NE Caribbean is deeply influenced by the oceanic waters of the Atlantic Ocean at this time. During the fall, flow from the Orinoco river spreads throughout the Eastern Caribbean Sea.

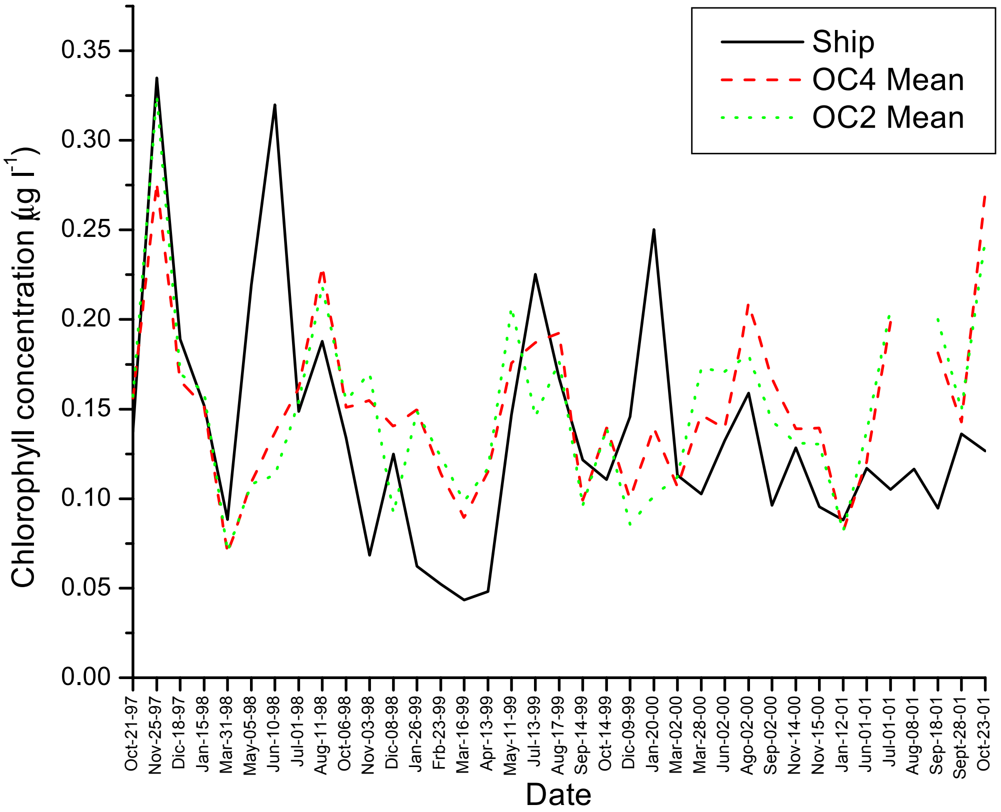

Figure 5. Comparison of the ship chl-a concentration with those retrieved with the OC2 and OC4 algorithms of SeaWiFS

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