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Phytoplankton dynamics in the eastern Caribbean Sea as detected with space remote sensing

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Abstract. The Space Information Laboratory (SIL) of the Tropical Center for Earth and Space Studies of the University of Puerto Rico at Mayagüez (UPRM) has been collecting and processing satellite data since December of 1996. Satellite imagery from the Advanced Very High Resolution Radiometer (AVHRR) and the Sea viewing Wide Field of view Sensor (SeaWiFS) provides us with a new understanding of phytoplankton dynamics in the Caribbean region. SeaWiFS shows the intrusion of waters into the eastern Caribbean Sea from the Orinoco River during fall and from the Amazon River during spring–summer. Strong coastal upwelling in Venezuela produced by the trade winds during winter–spring is detected with the AVHRR. The satellite data suggest that these seasonal events may play an important role in phytoplankton fertilization of the eastern Caribbean Sea. SeaWiFS and hydrological data are also combined to evaluate the impact of hurricanes on phytoplankton distribution. The development of models for estimation of ocean primary productivity using SeaWiFS and AVHRR data is now in progress.

1. Data collection and processing

The Space Information Laboratory (SIL) of the Tropical Center for Earth and Space Studies of the University of Puerto Rico at Mayagüez (UPRM) currently has a TeraScan High-Resolution Picture Transmission (HRPT) reception system from SeaSpace, which schedules, acquires and processes data from NOAA-12, NOAA-14 and Orbview-2 satellites. The antenna system consists of a 1.2 m-diameter parabolic antenna enclosed in a dome. It is located on the highest point of UPRM making possible the acquisition of data from the Mid-Atlantic Ocean to the Gulf of Mexico and from Brazil to the north-eastern United States. SeaWiFS raw images are saved in exabyte tapes. However, since these data are encrypted, a two-week delay period is required for further processing and analysis. After two weeks, the level 1A (L1A) files are generated using software from TeraScan and the National Aeronautics and Space Administration (NASA) and a ground processor key provided by NASA.

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The L1A files are processed with SeaDAS and chlorophyll-*a* (Chl-*a*) concentrations are obtained with the OC2 algorithm (O'Reilly *et al.* 1998). Advanced Very High Resolution Radiometer (AVHRR) images are processed with TeraScan software and Sea Surface Temperature (SST) is estimated with the algorithm of McClain *et al.* (1985). SST images are posted in real-time on the web (http://sil.uprm.edu/images.htm).

2. Results and discussion

The Caribbean Sea has traditionally been classified as oligotrophic. However, these satellite data analyses show that this region can be better defined as mesotrophic, depending on the time of the year. The intrusion of the Orinoco River during autumn generates large concentrations of Chl-*a* in the eastern Caribbean Sea that can be detected with SeaWiFS (figure 1(*a*)). Current sampling at the Caribbean Time Series (CaTS) station confirms that such intrusion can reach waters as close

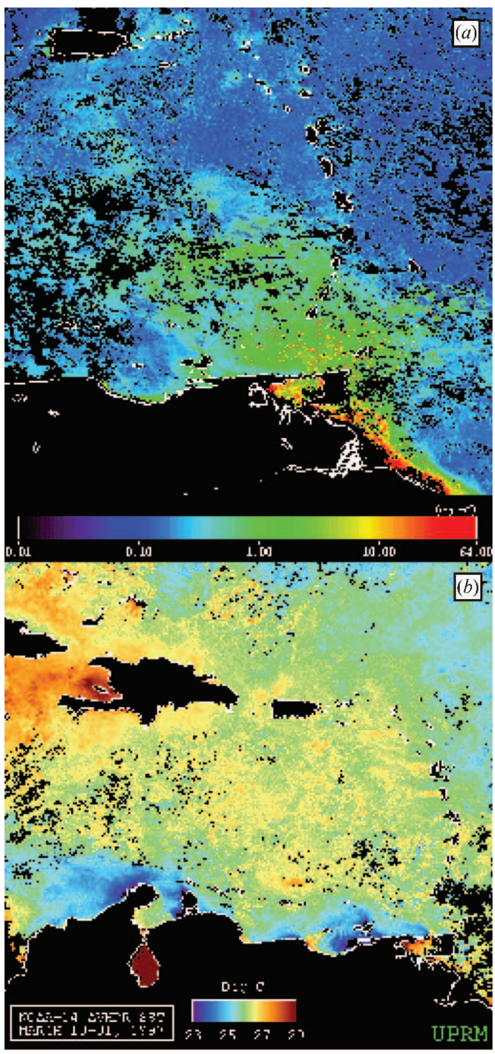

Figure 1. (*a*) SeaWiFS image showing the intrusion of the Orinoco River and (*b*) AVHRR image showing the coastal upwelling along the northern coast of South America.

as 26 nautical miles from Puerto Rico. Preliminary studies suggest that photodegradation of organic matter is responsible for regeneration of nutrients, which could help to maintain the phytoplankton populations for extended periods (Morell and Corredor 2001). Strong trade winds during winter and spring are responsible for coastal upwelling in northern Venezuela. SST derived from AVHRR data clearly show these colder waters (figure 1(*b*)). This process also brings nutrients to the surface, increasing the concentration of phytoplankton biomass. High Chl-*a* concentrations provide a good tracer for this water mass that can be detected with SeaWiFS. During spring and summer it is also possible to detect the intrusion of the Amazon River into the northern Lesser Antilles.

The impact of hurricanes on the phytoplankton dynamics of the Caribbean region can be assessed with a time-series of SeaWiFS images (Gilbes *et al.* 2001). Hurricane Georges was the second strongest hurricane of the 1998 season. Its eye made landfall on the eastern coast of Puerto Rico on September 21, 1998. At this time, the storm was classified as a category 3 hurricane on the Saffir–Simpson scale with sustained winds of $185\,\mathrm{km\,h^{-1}}$ and gusts of $241\,\mathrm{km\,h^{-1}}$. Hydrological data from Puerto Rico were used to evaluate the effects of run-off on ocean colour patterns in coastal waters and adjacent seas. Rivers and aquifers around the island delivered approximately one million metric tons of nitrogen (as nitrate) to coastal waters of Puerto Rico during and immediately after the storm (Gilbes *et al.* 2001). SeaWiFS imagery shows that river flooding associated with this hurricane led to dramatic changes in Chl-*a* patterns in coastal and oceanic waters around Puerto Rico and Hispaniola (figure 2).

Another study quantified Ocean Primary Productivity (OPP) rates within the eastern Caribbean Sea using SeaWiFS (Sastre 2000). The simplified Vertically Generalized Production Model (VGPM) was implemented to estimate OPP rates yielded by SeaWiFS-derived Chl-*a* and adjusted by AVHRR-derived SST. It was found that OPP rates derived from remote sensing data under the VGPM agreed well with *in situ* observations particularly at time-scales greater than one month

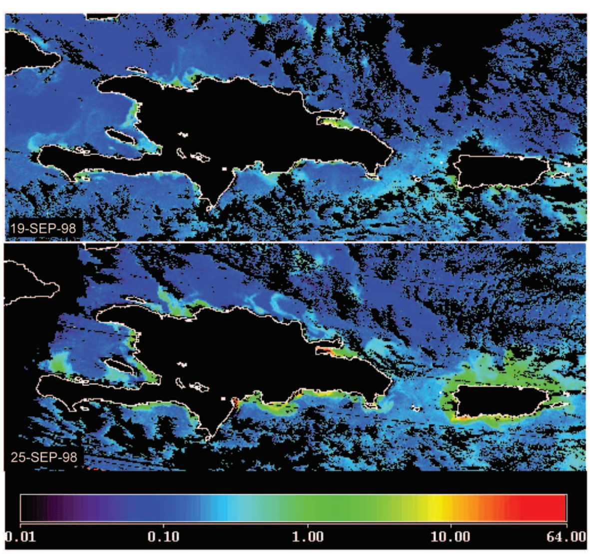

Figure 2. Chlorophyll-*a* as measured by SeaWiFS around Puerto Rico and Hispaniola before (top) and after (bottom) Hurricane Georges crossed the region.

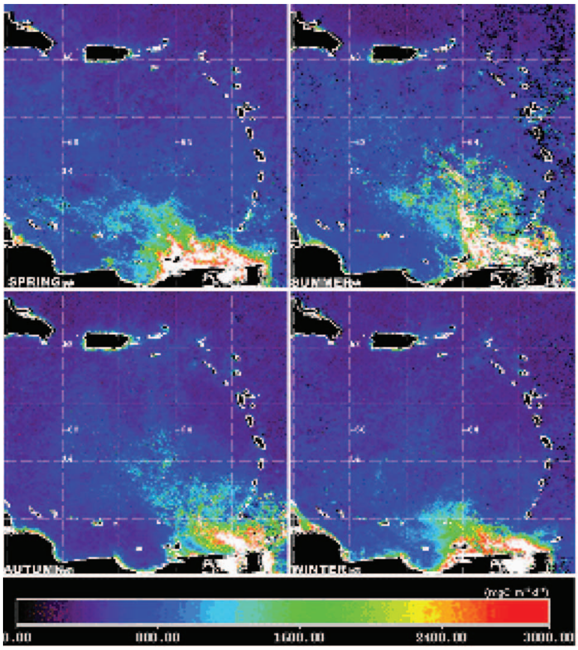

Figure 3. Seasonal primary productivity as estimated with SeaWiFS data and using the Vertically Generalized Production Model. The white mask corresponds to values greater than $3000\,mg\,C\,m^{-2}\,d^{-1}$ (after Sastre 2000).

(Sastre 2000). Seasonal composites of OPP images indicated that maximum rates occur between summer and autumn and remain low in spring and winter (figure 3). It is clear that the dispersal of the Orinoco and Amazon rivers plumes along with the influence of mesoscale eddies produce large variability of OPP distribution in the Caribbean Sea.

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