Using NASA's Giovanni System to Simulate Time-Series Stations In the Outflow Region of California's Eel River

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ABSTRACT

Oceanographic time-series stations provide vital data for the monitoring of oceanic processes, particularly those associated with trends over time and interannual variability. There are likely numerous locations where the establishment of a time-series station would be desirable, but for reasons of funding or logistics, such establishment may not be feasible. An alternative to an operational time-series station is monitoring of sites via remote sensing. In this study, the NASA Giovanni data system is employed to simulate the establishment of two time-series stations near the outflow region of California's Eel River, which carries a high sediment load. Previous time-series analysis of this location (Acker et al. 2009) indicated that remotely-sensed chl *a* exhibits a statistically significant increasing trend during summer (low flow) months, but no apparent trend during winter (high flow) months. Examination of several newly-available ocean data parameters in Giovanni, including 8-day resolution data, demonstrates the differences in ocean parameter trends at the two locations compared to regionally-averaged time-series. The hypothesis that the increased summer chl *a* values are related to increasing SST is evaluated, and the signature of the Eel River plume is defined with ocean optical parameters.

Introduction

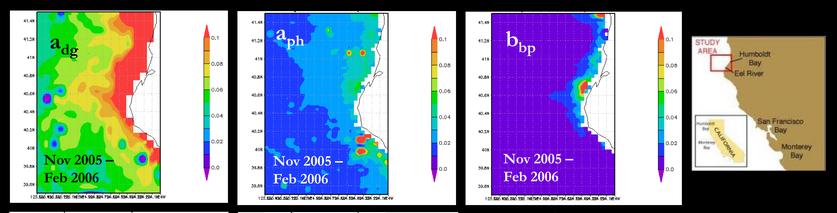
In order to investigate a multitude of oceanic processes with regional significance, the establishment of time-series stations at many different sites would be desirable. However, it is not feasible to maintain a research commitment to numerous sites of interest. An alternative, made feasible by the increased availability and ease-of-access to NASA remotely-sensed oceanographic data, is to use these data to simulate time-series stations. The NASA Giovanni system (**http://giovanni.gsfc.nasa.gov**) facilitates time-series investigations by providing monthly gridded Level 3 data for many different oceanic variables. Recently, ocean optical parameters have been added to Giovanni, providing enhanced research capability.

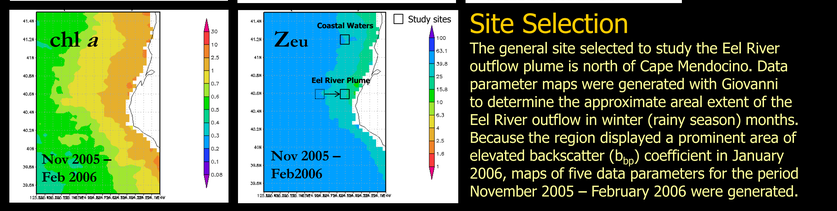
For this study, the influence of the outflow from California's Eel River was investigated. The Eel River, despite its relatively small flow, carries a high sediment load. The Eel River plume is thus discernible with ocean optical parameters. The study simulated the establishment of two time-series sites, one in a location influenced by the seasonal Variability of the Eel River outflow, and the second in a nearby location that is not influenced by the Eel River outflow. The goals of this study were: a) use remotely-sensed parameters to clearly distinguish the Eel River outflow plume; b) compare data trends for the two time-series sites, and c) evaluate increasing chl *a* trends that have been reported for this region in previous studies.

Methods

Time-series data for this study were processed by the NASA Ocean Biology Processing Group (OBPG). Level 2 geophysical data parameters are processed to Level 3 gridded products, which are ingested by the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) for use in the Giovanni system. Input data are from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua satellites; only sea surface temperature data from MODIS-Terra are used.

Giovanni was use to create maps of relevant data parameters for site selection (see below). Giovanni was also utilized to generate time-series plots and data output from Level 3 monthly data products. A 0.1 x 0.1 area centered on the simulated time-series site was used to generate the time-series. Data within each area was spatially averaged to produce each point in the time series. Both standard and evaluation data products in the Giovanni Water Quality data portal were analyzed in this study. The data output was imported into Excel, allowing linear regression and significance F -test analyses to determine trend significance. The Excel ternary diagram plotting spreadsheet *Tri-Plot* (Graham and Midgely 2000) was used for visualization of the ocean optical parameter classification scheme.

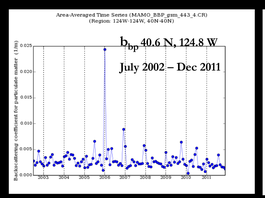


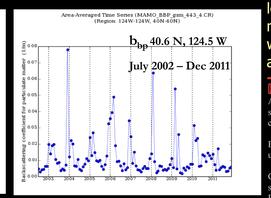


Site Selection

The general site selected to study the Eel River outflow plume is north of Cape Mendocino. Data parameter maps were generated with Giovanni to determine the approximate areal extent of the Eel River outflow in winter (rainy season) months. Because the region displayed a prominent area of elevated backscatter (b_{bp}) coefficient in January 2006, maps of five data parameters for the period November 2005 – February 2006 were generated.

The maps were used to select initial sites at 40.6 N, 124.8 W within the elevated b_{bp} region, and 41.2 N, 124.5 W outside the elevated b_{bp} region. Time series for the five parameters were examined. This examination revealed that the likely influence of the Eel River outflow was not clearly perceived for the initial "in plume" site, and it was moved to 40.6 N, 124.5 W. A b_{bp} time-series for this site showed several peaks in the winter, consistent with the high sediment load carried by the Eel River in winter months. The two sites used for this study were then termed the "Coastal Waters" site and the "Eel River Plume" site.





This presentation is dedicated to the memory of Gregory G. Leptoukh, *October 13, 1953 - January 12, 2012*

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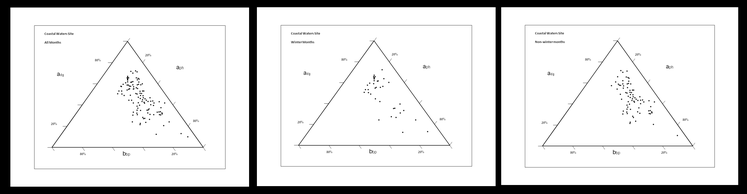
RESULTS

Observation of the Eel River plume optical signature

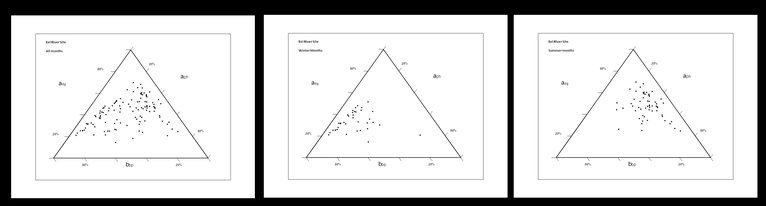
We devised a simple optical classification system using the three apparent optical property parameters now available in Giovanni, which are: a_{dg}, the absorption coefficient of dissolved and detrital matter; a_{ph}, the absorption coefficient of phytoplankton, and b_{bp}, the backscatter coefficient. In order to create a three-component classification system, b_{bp} was multiplied by a factor of 10. This classification system is not a true optical model; it is simply intended to show that the Eel River outflow plume can be distinguished with the available AOPs in Giovanni.

For the period July 2002 to December 2011, time-series were generated for several different data parameters in Giovanni for the two study sites. Results of the regression analysis (slope and significance F -test) are shown subsequently. For the optical classification system, a_{dg}, a_{ph}, and (b_{bp} x 10) were summed, and then the relative percentages of each parameter were calculated for each month. The results were then divided into winter months (December-March), non-winter months (April-November) and summer months (May-October). The relative percentages were then plotted in simple ternary diagrams using *Tri-Plot*.

The results demonstrate that the Eel River water is distinguishable during the winter months due to elevated b_{bp} Values. The elevated b_{bp} values are related to the high sediment load carried by the river in the winter, ascribed to increased scattering caused by inorganic mineral particles in the outflow plume. During the summer, the optical classification for the water at the Eel River Plume site is very similar to the optical classification at the Coastal Waters site.



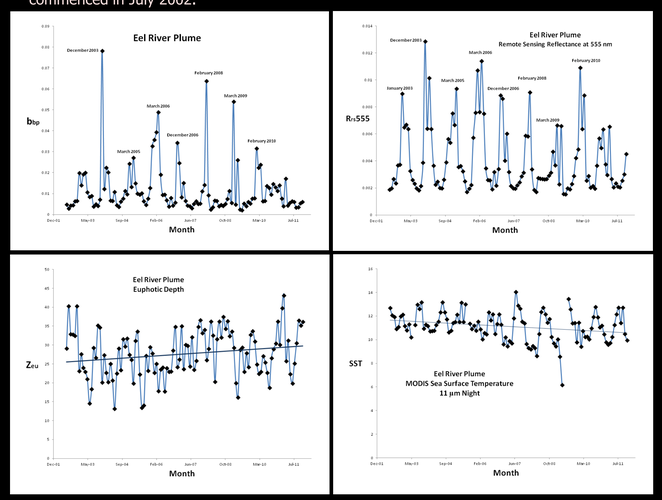
Optical water mass classification results for the Coastal Waters site. *Left*: All months. *Center*: Winter months. *Right*: Non-winter months. The winter month water is optically similar to the non-winter month water at the Coastal Waters site, indicating that the site is not influenced by the Eel River outflow.



Optical water mass classification results for the Eel River Plume site. *Left*: All months. *Center*: Winter months. *Right*: Summer months. Due to increased values of b_{bp} caused by increased scattering from inorganic mineral particles in the high sediment load carried by the Eel River during the rainy winter months, the Eel River water is distinguishable during the winter months at this site. Under the low flow summer conditions, the water at the Eel River Plume site is optically similar to the Coastal Waters site.

Time-series analyses

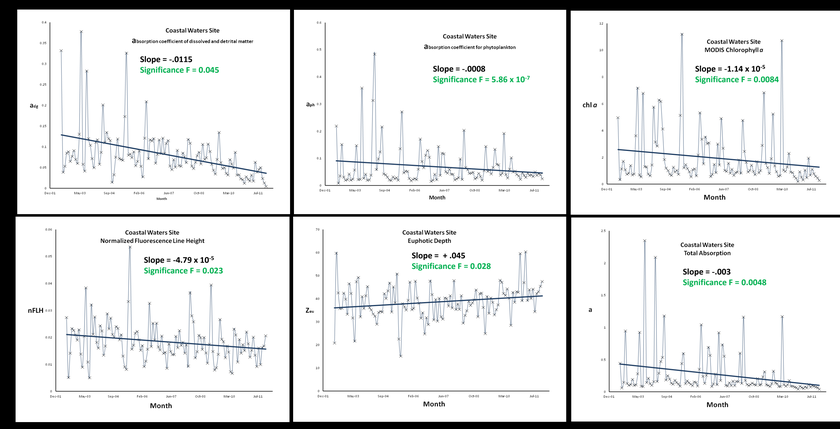
In the first step of the time-series analysis, the complete time-series for the Eel River Plume site were generated for the period July 2002 to December 2011. All of the data products are derived from MODIS-Aqua observations, which commenced in July 2002.



In the time series shown at left for the Eel River Plume site, the influence of the Eel River outflow is clearly discerned in the elevated values of b_{bp} and remote sensing reflectance at 555 nanometers (Rrs555), which occur during the winter rainy season. Surprisingly, euphotic depth minima do Not correspond to b_{bp} or Rrs555 maxima, indicating that absorption dominates over reflection with regard to water clarity. MODIS sea surface temperature displays a decreasing trend over the time-series period at the Eel River Plume site.

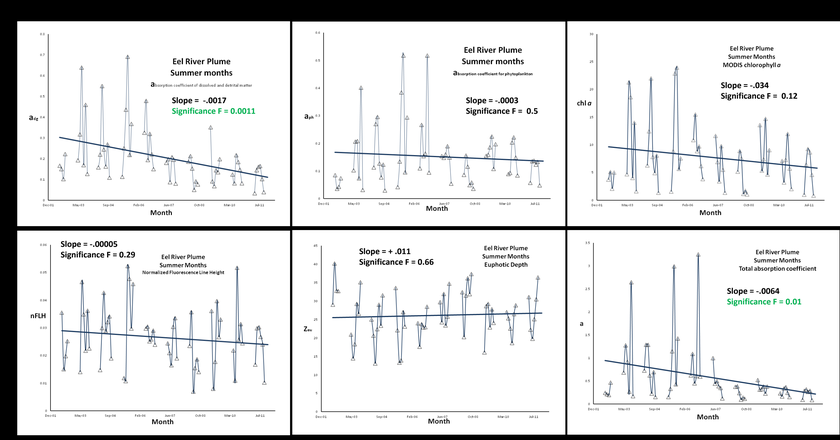
Time-series trends at the Coastal Waters site

Using the regression analysis function in Excel, the linear slope for the data parameter time series and the significance F value were calculated. The six parameters analyzed were a_{dg}, a_{ph}, chlorophyll *a* (chl *a*), normalized fluorescence line height (nFLH), euphotic depth (Z_{eu}) and total absorption (a). The slope and significance F value are shown below. A significance F value < .05 indicates a significant trend at the 95% confidence level.



Time-series trends at the Eel River Plume site

Using the regression analysis function in Excel, the linear slope for the data parameter time series and the significance F value were calculated for the summer months at the Eel River Plume site. This analysis was conducted to determine if trends in the summer at this site, when the influence of the Eel River water is low, were similar to the trends at the Coastal Waters site. This analysis extends the earlier work of Acker et al. (2009).



DISCUSSION

This simulation has provided highly interesting results worthy of further investigation. Two goals of the study, to identify the optical signature of the Eel River outflow and to compare trends at the two sites, have been demonstrated. The third goal is to evaluate these results in comparison to previous studies.

At both the Coastal Waters site and the Eel River Plume site, MODIS sea surface temperature exhibits a statistically significant negative trend (significance F = .008 and .01, respectively). Summer month SSTs in the Eel River plume site did not exhibit a statistically significant trend. The declining trend in SST can be attributed to an increased temperature difference between land and ocean temperatures, causing an increase in upwelling-favorable alongshore winds. These conditions would be expected to increasing oceanic upwelling and thus increase phytoplankton chlorophyll concentrations due to increased nutrient availability. (Bakun 1990; Snyder et al. 1993)

Unlike previous studies, however, this time-series site simulation showed decreasing chl *a* concentration trends and decreasing trends in related optical parameters, which is not consistent with the decreasing trend in SST, provided that upwelling has actually increased. The study sites are located in a "trap" region (Largier 2010), and are not in either the Cape Blanco or Cape Mendocino upwelling regions. It is possible that increased irradiance, possibly related to decreased cloud cover or coastal fog, is allowing enhanced photodegradation of organic matter in this region.

Acker et al. (2009) reported an increasing trend in SeaWiFS chl a for the Eel River outflow region, for an area slightly further offshore than the Coastal Water and Eel River plume sites. The figure above shows that SeaWiFS chl *a* shows an increasing trend in the Cape Mendocino upwelling region for the 1998-2007 time period studied by Acker et al., while MODIS chl *a* shows a decreasing trend from 2002 to present, concomitant with an increasing trend in Z_{eu}, which is based on MODIS data. Therefore, differences in spaceborne instrumentation and data processing must be considered as a possible explanation as well. In order to determine if the trends observed in this study are real, comparison to *in situ* data would be advisable, thus underscoring the need for sea-truth data to analyze trends observed in remotely-sensed data. The NOAA Central and Northern California Ocean Observation System (CeNCOOS) may be capable of providing such data.