Semi-Annual Progress Report

January 2001

Mark R. Abbott

College of Oceanic and Atmospheric Sciences

Oregon State University

MODIS Team Member, Contract # NAS5-31360

Task Objectives

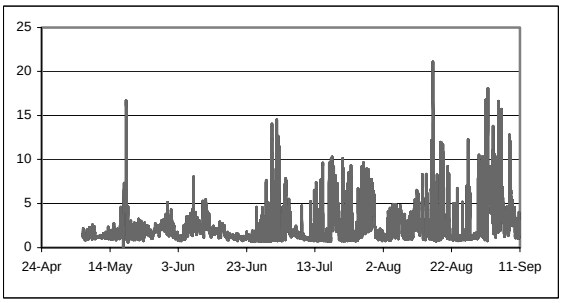
The objectives of the last six months were:

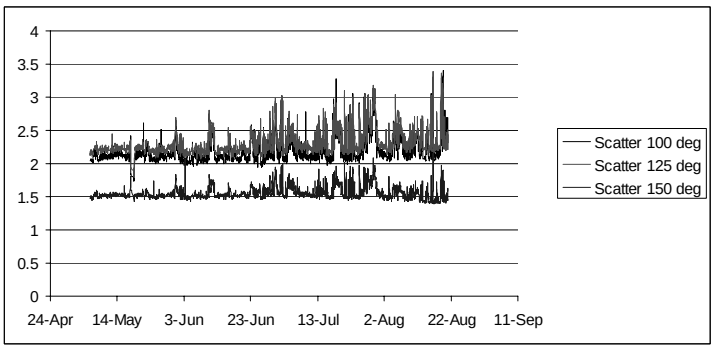
- Analyze data from MODIS validation cruises off Oregon
- Continue evaluation of MODIS imagery from several regions of the world ocean
- Complete chemostat experiments on the relationship of fluorescence quantum yield to environmental factors.
- Complete installation and test of MODIS Direct Broadcast facility
- Continue to develop and expand browser-based information system for in situ bio-optical data and MODIS imagery.

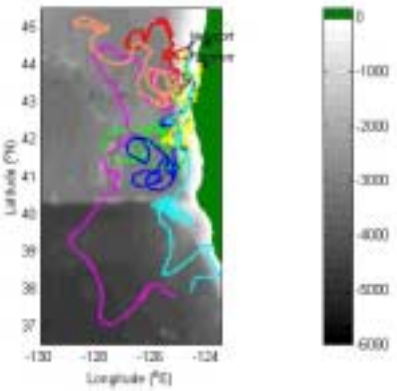
Work Accomplished

Validation Cruises and Early MODIS Imagery

We conducted two validation cruises as part of the NE Pacific Global Ecosystems Dynamics (GLOBEC) program, which is funded by the National Science Foundation. Our research is focused on the regulation of primary productivity by physical processes in the nearshore region off Oregon. We are using moored optical sensors, bio-optical drifters, and ship-based measurements of photosynthetic properties. We deployed four nearshore moorings in conjunction with physical moorings. The bio-optical package consisted of a WETLab ECO DFL fluorometer and ECO VSF Volume Scatter Function sensor. The moorings were located near Grays Harbor, WA, Newport, OR, Coos Bay, OR, and Gold Beach, OR. Although the optical sensors were active sensors and not directly comparable to the passive sensors such as MODIS and SeaWiFS, the data can be used to characterize the temporal and spatial variability of the optical properties of coastal waters. The moorings were deployed in spring 2000 and recovered last fall. Unfortunately, three of the moorings failed (leaking connecters, damaged cables, and leaking O-rings). The Newport mooring worked perfectly. Figure 1 shows the chlorophyll record estimated from the active fluorometer. There are clear "events" associated with coastal upwelling. Time series analysis shows that the time scale of these events is about 5 days. Figure 2 shows the volume scatter function (data collected at three angles). There is general correspondence between the chlorophyll and VSF time







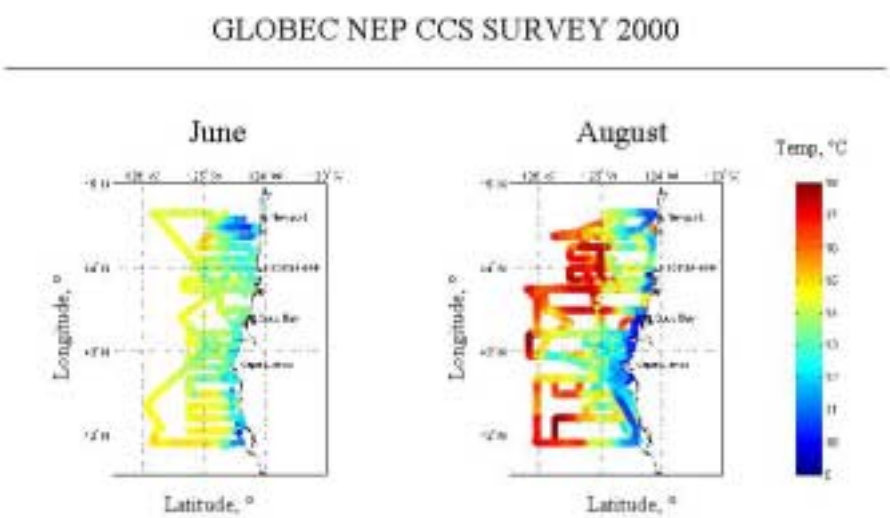
series, as expected. We will continue to examine these data in more detail as the VSF should vary as a function of particle type.

We deployed METOCEAN Data Systems bio-optical drifters during GLOBEC cruises in June and August 2000. The deployments in June were only a few days as the drifters were recovered. Seven drifters were deployed in August and allowed to remain in the California Current to examine longer time scale processes. All of the data can be viewed on our Web site at:

http://picasso.oce.orst.edu/ORSOO/oregon/drifters/

Rather than repeat this material, we direct the reader to this site. Maps of the August drifters are shown in Figure 3. The optical sensors provided useful data for about 6 weeks before becoming fouled. We are comparing the drifter measurements with the one MODIS image collected during the cruise (image from 2000 214). Unfortunately, the MODIS formatter failed during this period so there is only this one image.

We used our Fast Repetition Rate fluorometer to measure photosynthetic potential during the June and



August cruises. Measurements were made underway. At selected stations, the FRR was attached to a profiling system to collect vertical measurements.

Figure 4 shows the underway of sea surface temperature (SST) collected on the two cruises. Note the decreased SST values nearshore in the August cruise when upwelling-favorable winds were more intense. Variable fluorescence (F_V/F_M) and absorption cross-section (σ_{PSII}) from the FRR measurements are shown in Figure 5. Photosynthetic capacity is proportional to F_V/F_M; note that photosynthetic capacity is generally higher in cold, upwelled waters nearshore. Absorption cross-section is generally inversely-related to F_V/F_M. Figure 5 also shows these variables in relation to temperature/salinity values. There are clearly different water masses, especially in the May-June cruise.

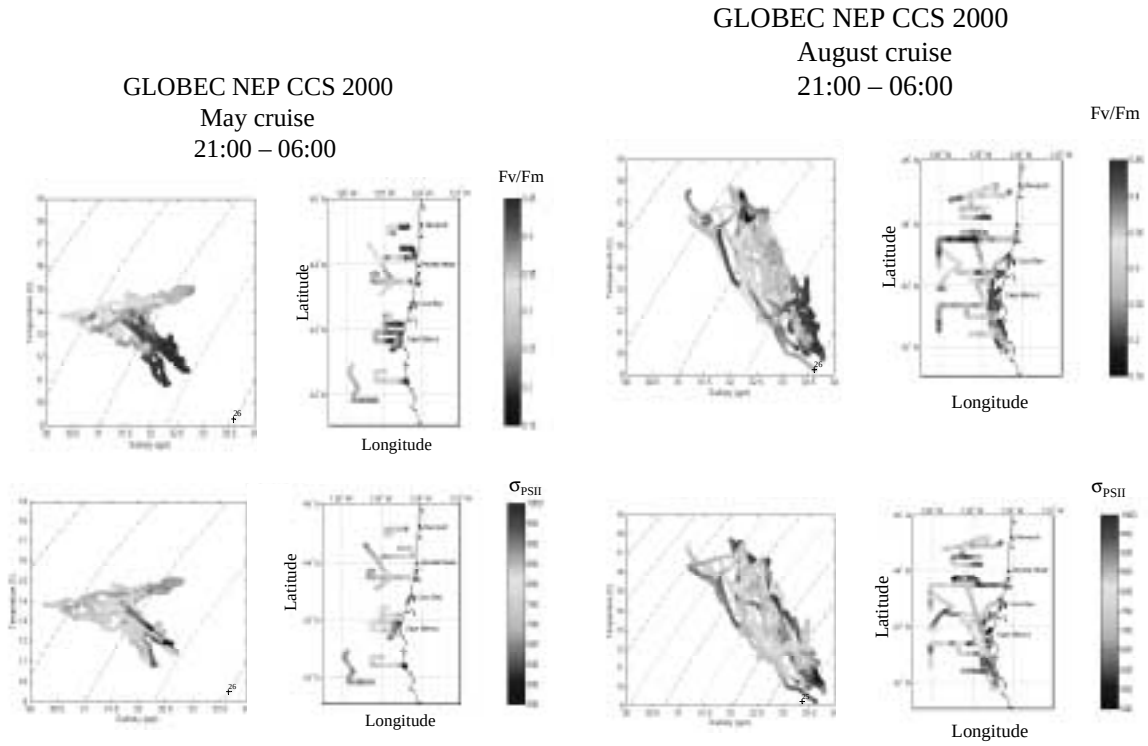


Figure 6 shows the MODIS-derived ratio of fluorescence line height (FLH) to chlorophyll. The spatial pattern of FLH/chl is similar to that of F_v/F_M from the August cruise; low FLH/chl nearshore with higher values offshore. We would expect that low FLH/chl would correspond with higher photosynthetic capacity. Within freshly-upwelled waters nearshore, nutrient levels should be higher, thus increasing photosynthetic capacity. We also note the area of low FLH/chl in the north part of the image, extending offshore. FRR measurements also show higher F_v/F_M. This pattern may be related to the plume of the Columbia River which enters the region from the north.

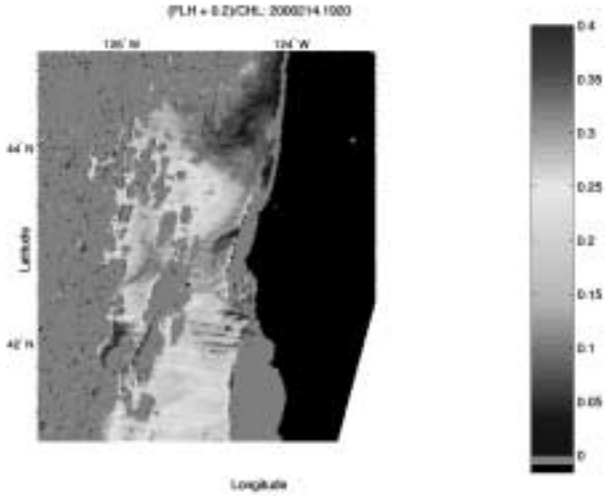
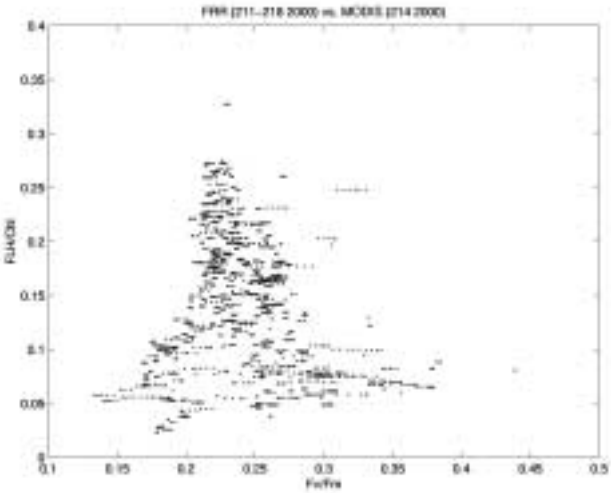


Figure 7 is scatterplot comparing the MODIS-derived FLH/chl and the FRR-measured F_v/F_M. Although there is in general an inverse relationship, there is considerable scatter. There are several explanations. First, we have included cruise measurements from several days before and after the sole MODIS image. Temporal evolution as well as advection will introduce significant scatter. Second, comparisons of MODIS-derived chlorophyll with SeaWiFS-derived chlorophyll show that although the spatial patterns are similar, MODIS appears to overestimate chlorophyll, especially nearshore. This would lead to errors in the FLH/chl patterns. Third, the relationship in the nearshore region between FLH and chlorophyll may differ significantly between freshly-upwelled populations, which have adapted to low light levels, and populations that have adapted to the higher light levels. Preliminary analyses (not shown here, but to be

presented at the MODIS Team meeting in January 2001) show that the nearshore region shows considerably more variability in the FLH-chlorophyll relationship than the offshore region where nutrients are low and light levels more uniform. This result is consistent with work reported by Abbott and Letelier in 1998 (and described in the July 1997 Semi-Annual report). We expect that MODIS FLH data will be useful in determining the photosynthetic state of phytoplankton, but that the appropriate "algorithm" will depend on oceanographic conditions.



Evaluation of MODIS Imagery

We have been evaluating MODIS FLH imagery globally and from the California Current and the Subtropical Gyre of the North Pacific. Unfortunately, the stability of the processing algorithms has not been adequate for quantitative analyses at this point. The NASA team is still developing appropriate software to account for the performance of the sensor. Masking algorithms are changing as well. We have concentrated on data collected since late September, when the Level 2 processing became more stable. At this point, we can state that there are intriguing patterns in the data and that the sensor appears to be able to detect FLH at much lower chlorophyll levels than we had anticipated.

Chemostat Experiments

As discussed in our July 2000 report, we have completed the first set of chemostat experiments. Samuel Laney successfully defended his MS thesis in August 2000. His first paper is now in press in the Journal of Atmospheric and Oceanographic Technology. In November 2000, Ricardo Letelier and Michael Behrenfeld (NASA/GSFC) collaborated with Ondrej Prasil, who is head of the Laboratory of photosynthesis, Institute of Microbiology of the Czech Republic, and Dr. Prasil's PhD student, Helena Dousova. The team examined the photosynthetic response of phytoplankton to a variable light field using the chemostat. Behrenfeld and Letelier recently submitted a NASA proposal to improve models of primary productivity using knowledge of the nutritional and light adapation state of the phytoplankton. MODIS FLH data will be evaluated as part of this proposed study.

Direct Broadcast

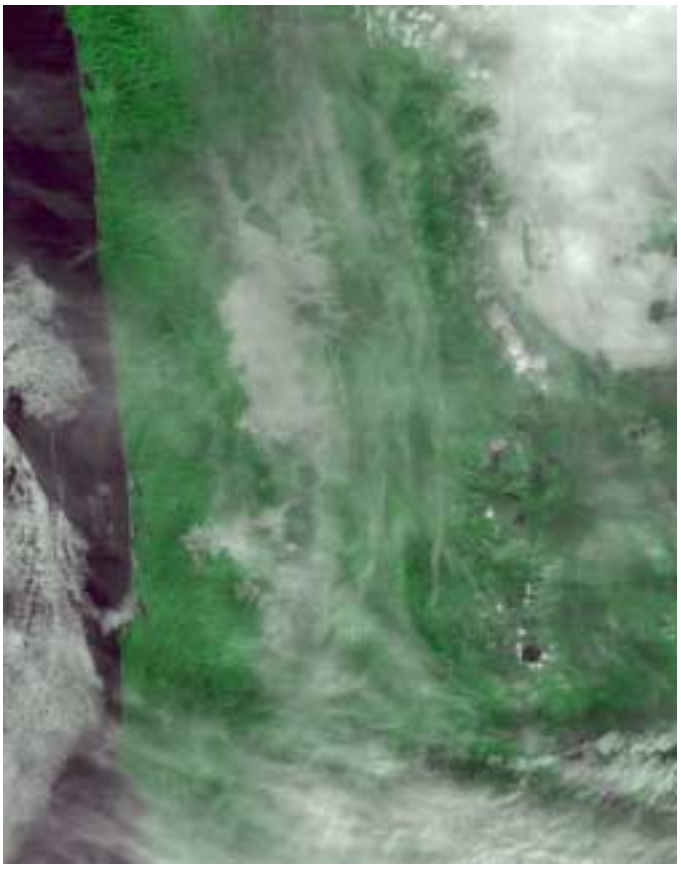
Our EOS Direct Broadcast facility was completed in December 2000. Figure 8 shows the X/Y mount being assembled by the team from the University of Dundee, Scotland. The next figure (Fig. 9) shows the four sections of the dish being assembled. Lastly, Figure 10 shows a false color composite of the 250 m bands collected on 7 December 2000. The image shows the western half of Oregon, from the confluence of the Willamette and Columbia Rivers at Portland (near the top, middle of the image) down to Crater Lake in Cascade Mountains (the large dark, nearly-circular lake at the bottom of the image). After some minor adjustments, we expect to begin software integration and tests in January 2001. We are installing the

NASA/GSFC "Sorcerer" software to handle the Level 0 conversion from L0 frames to L0 EOSDIS. The NASA software will be used to produce L1b. The data will then be run through the Miami ocean processing system to generate Level 2 and Level 3 products. The Level 1b data will be ftp'd to Steve Running at the University of Montana for production of MODIS land products. We have requests from other researchers for access to these data. A description of our DB site can be found at

http://picasso.oce.orst.edu/ORSOO/MODIS/DB/satdish.html

EOSDIS Plans

We have continued our work on distributed objects frameworks for EOS data retrieval and analysis. This work was supported through a contract with the Raytheon ECS prototyping activity. The Earth Science Explorer was enhanced to use asynchronous loading mechanisms that allow XML data islands to load data from a URL. This allows only the data islands to be reloaded without re-rendering the entire user interface. XML events are used to implement the asynchronous download and coordinate the mapping of the XML to HTML after the data has been downloaded completely. The entire architecture has been migrated to the Windows 2000 platform. Extensible Stylesheets (XSL) have been implemented throughout the Earth Science Explorer. The XML document object model (DOM) can be used to transfer data between stylesheets, ActiveX objects and the XML data island(s). XSL can be used to highlight data based on user specified conditions. The XSL document can be persisted to a file and reused. Boolean conditions and rendering parameters saved in the file can be reapplied to other instances of XML data. The use of Matlab as a server in other applications has also been demonstrated. In our demonstration application, the user can select a computer on the network to use as the Matlab server. However, Matlab must be installed on the selected remote computer. Once the remote computer is selected, commands can be passed to Matlab. The application uses the interface engine in order to interact with Matlab via DCOM. Matlab exports a set of functions to DCOM specifically for this purpose, and the interface engine makes use of these functions.



The Earth Science Explorer application encompasses front-end and back-end components and provides visualization capabilities on the client. Database access has also been built into the 3-tiered architecture for the Earth Science Explorer. Clients include XML and DHTML tools. An ActiveX component (OpenGL 3D control) has been implemented that supports surface plots. A static load-balancing system is under

development and COM objects that extract optical data values from an image for a bio-optical drifter track are under development.

Future activities will focus on using XML to detect patterns or features in newly arrived data to trigger alerts that can be delivered to a cell phone. We plan to use this approach to deliver updates on our drifters. Presently, drifter data is e-mailed every day from Service Argos, processed in Matlab for quality and generated as text files. Using an XML schema, we can associate type information with the drifter parameters and make it possible to generate an XSL stylesheet. The stylesheet serves the dual purposes of providing a rendering mechanism for the data to high-bandwidth browsers and the capability of sending e-mail alerts that contain one line descriptions of phenomena in the data to an Internet appliance/cell phone.

We are also looking at an alternate strategy using the COM+ event model at the database end. The system will allow monitoring of events and provide interested clients with notifications. The system will monitor the satellite data being received, as it enters the database. When it detects certain variations in the data, a message can be sent to a remote client. These variations could be simple changes in drifter locations or far more complex patterns involving multiple parameters.

Anticipated Future Actions

- Continue testing and evaluation of MODIS fluorescence algorithms with MODIS data
- Participate in MODIS validation cruise in 2001
- Bio-optical cruises and moorings off the Oregon coast in 2001
- Continue to develop and expand browser-based information system for in situ bio-optical data.

Problems and Solutions

The most significant concern now is access to consistently-processed time series of MODIS Level 2 and Level 3 data. The frequent processing changes makes it difficult to assess data quality or to identify failures in the processing algorithms. However, it is also apparent that MODIS is a fantastic sensor! Its ability to detect chlorophyll fluorescence is far greater than anticipated and preliminary comparisons with field measurements reveal important oceanographic processes.

The second concern regards the MODIS DB processing software. The University of Wisconsin software does not use EOS HDF, largely because of concerns regarding the reliance on the EOSDIS toolkits. However, the MODIS oceans code can only use EOS HDF Level 1b as input. Thus we have to rely on the GSFC L0 processing software, which only runs under Windows NT. This has led to a complicated processing system with a mix of Linux (production of L0 frames), NT (L0 frames to L0 EOSDIS), and Irix (L0 to L1b to L2/L3). Some coordination in software development would be appreciated.

Coordination of MODIS data collections and field programs has been problematic. Only a limited amount of MODIS data were collected off Oregon during our two cruises. This represents an enormous missed opportunity.