Semi-Annual Progress Report

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Task Objectives

The objectives of the last six months were:

- Complete sensitivity analysis of fluorescence line height algorithms
- Deliver fluorescence algorithm code and test data to the University of Miami for integration
- Complete analysis of bio-optical data from Southern Ocean cruise
- Conduct laboratory experiments based on analyses of field data
- Analyze data from bio-optical mooring off Hawaii.
- Develop calibration/validation plan for MODIS fluorescence data
- Respond to the Japanese Research Announcement for GLI
- Continue to review plans for EOSDIS and assist ECS contractor

Work Accomplished

Sensitivity Analysis of FLH Algorithms

A paper on the sensitivity of Fluorescence Line Height (FLH) to changes in MODIS band position, atmospheric turbidity, and fluorescence efficiency was accepted for publication in *Remote Sensing of the Environment.* This paper was described in the previous Semi-Annual report. We have recalculated some of the atmospheric transmission results using a new radiative transfer model, FASE, from the Phillips Laboratory. This model provides superior resolution of spectral absorption features in the atmosphere, such as oxygen. Thus far, our conclusions remain the same, and we will submit a revised version of the manuscript for final publication in the next few weeks.

Delivery of FLH Code

A "C" version of the FLH algorithm was delivered to Robert Evans at the University of Miami. Test data based on our measurements from near-surface ocean drifters was also delivered. The code included a full set of flags for error detection.

Southern Ocean Data Analysis

As discussed in previous reports, two bio-optical drifters were deployed in the Southern Ocean in late 1994. One drifter became trapped in a persistent eddy in Drake Passage for over forty days. Analysis of the bio-optical data showed that the quantum yield of fluorescence (as indicated by changes in the slope of the normalized fluorescence per unit incident light) changed consistently in response to changes in vertical velocity. As the drifter circulated around the eddy, it would alternately speed up and slow down, depending on whether it was on the poleward or the equatorward side of the eddy. To conserve vorticity, this would induce either an upwelling or a downwelling vertical velocity. In cases of upwelling, changes in quantum yield associated with changes in solar irradiance showed reduced nutrient limitation. We infer that upwelling was bringing nutrients to the surface, thus stimulating phytoplankton growth. This cycle was observed several times as the drifter circulated around the eddy. Increases in chlorophyll concentration over much longer time scales also showed the longer term response of primary productivity to the increased nutrient concentrations associated with the eddy. However, chlorophyll fluorescence showed a much more rapid response of the photosynthetic machinery, giving the promise of much higher temporal resolution estimates of primary productivity than simple biomass-based models. These results will be presented at the Ocean Sciences meeting in February 1996, and we are preparing a manuscript.

California Current Data Analysis

Decorrelation scales were calculated for various bio-optical and physical properties in the California Current. The data were derived from 24 bio-optical drifters that were deployed off northern California in 1993 and 1994. Within 100 km of the coast, the decorrelation time scales of velocity, temperature, chlorophyll and fluorescence were significantly shorter than offshore. In the nearshore region, the scales of temperature and biological properties were nearly identical, suggesting that the physical processes governing the statistics of ocean temperature (in this case, processes associated with upwelling) also govern the statistics of phytoplankton. Offshore, the time scales of temperature were much longer than the biological scales, implying that the processes affecting temperature were different than the processes affecting biological distributions.

This result is consistent with our understanding of upper ocean ecosystems. We expect that nearshore systems should be dominated by large, rapidly-growing species such as diatoms that can take advantage of favorable environmental conditions such as nutrient upwelling. These "boom and bust" systems are generally weakly coupled with zooplankton grazing and are associated with large downward fluxes of biogenic material. Offshore, we expect smaller, more slowly-growing phytoplankton that are tightly linked with small zooplankton. Downward fluxes tend to be smaller as well. New production (the ratio of nitrate-supported production to total production) should be higher nearshore and lower offshore. Thus we expect systems to be more physicallycontrolled where new production is high and more biologically-controlled where new production is low.

The results from the bio-optical drifters suggests that we can use statistical information on the relative time scales of physical and biological patterns to distinguish between these two types of phytoplankton ecosystems. Similar results have been suggested by Esaias and Iverson in their analysis of global primary productivity data. We will continue to pursue this approach to improve the performance of primary productivity models. These results will be discussed at the Ocean Sciences meeting.

Fluorescence Laboratory Experiments

Ricardo Letelier worked with Dr. Paul Falkowski (Brookhaven National Laboratory) in July on experiments in fluorescence and quantum yield. Letelier designed experiments with laboratory cultures to test this relationship. The experiments did support Letelier's hypothesis that parameters associated with the photosynthesis/irradiance function could be estimated from sun-stimulated fluorescence. These results were presented at the Tenth International Symposium on Primary Productivity. As mentioned in the previous report, this is an exciting result and we are preparing a publication. The previously described bio-optical drifter analysis confirmed the laboratory experiments.

Bio-Optical Mooring

We continued analysis of the bio-optical data from the Hawaii Ocean Time-series (HOT) mooring. Aside from the "blowover" due to higher-than-expected current speeds, the bio-optical data are of high quality. Estimates of chlorophyll from irradiance ratios provided concentrations that were similar to the climatological averages for this time of year. We are continuing to analyze the fluorescence measurements.

Dr. David Karl, who is the principal investigator of the HOT effort for JGOFS, has invited us to participate in a long-term mooring at the HOT location. We will provide two irradiance sensors each with an integrated data logger. This mooring will also have conventional bio-optical sensors as well as sediment traps, nutrient probes, and current meters. We plan to use the HOT site as one of our validation sites for MODIS algorithms. The complete biogeochemical sampling provided with the mooring as well as the monthly ship sampling will provide a cost-effective means to validate our MODIS fluorescence algorithms in an oligotrophic open ocean location.

Calibration/Validation Plan

We were requested by the EOS Project to deliver our calibration and validation plans for the MODIS oceans algorithms. These plans were discussed at the MODIS team meeting, and we delivered the fluorescence section to Esaias in December. We will participate in joint team activities, especially in the planned cruise off Northwest Africa shortly after launch of AM-1. However, most of our fluorescence algorithm work will require piggybacking with existing cruises in order to minimize costs. Our approach is to focus on three different regions of the world ocean: the oligotrophic Pacific at the HOT site, the high latitude Polar Front in the Southern Ocean, and the productive coastal ocean off Oregon.

We discussed the HOT sampling earlier. The Polar Front work will begin with our proposed JGOFS research in 1997/1998. Measurements of bio-optical properties as well as fluorescence and primary productivity will be collected through a combination of mooring, drifter, and ship measurements. We plan to continue these measurements in collaboration with John Parslow after the end of JGOFS. The Oregon coastal work will begin after the launch of AM-1 and will involve mooring and ship sampling. We will rely on lower cost, day trips on one of the smaller OSU research vessels.

GLI Proposal

The Japanese space agency, NASDA, released a Research Announcement soliciting proposals for algorithm development for GLI. This sensor is similar to MODIS and will launch in late 1999 on ADEOS-II. I was responsible for collecting input from the MODIS Oceans team for submission in response to the RA. The proposal consisted of a summary of team activities as well as copies of the Algorithm Theoretical Basis Documents. The Oceans team proposed to provide copies of the MODIS oceans algorithms to NASDA, although we will not provide actual code integration, etc. We proposed to compare the equivalent MODIS data products with those from GLI. We will also pursue techniques to blend these two data products together and to participate in join validation and calibration activities to support this data synthesis.

EOSDIS Plans

Advanced Networking

We continue to work with advanced networking in conjunction with HITC. This will include testing of satellite-based networking using Hughes communications satellites. Separately, we are testing ATM networks to desktop machines to deliver data from our SQL Server data base.

Information Systems Development

With the release of Windows 95 and Microsoft SQL Server 6.0, we have begun to use OLE capabilities to link our data base with desktop applications. Specifically, we are using Statistica, a statistics and graphics package, to develop custom OLE-based clients that can directly access the data base from within the application. We plan to develop real-time quality control tools to screen both the drifter and mooring data as it is transmitted to us from Service Argos and eventually will base our MODIS QA/QC tools on this system.

Earlier data management systems were based on a clear separation between the data base system and the analysis applications. Much as with the traditional library "stack" system, the actual data and information were separated from the user by a data location and retrieval process, in this case a card catalog and a librarian. This model is quite powerful, and it exploited the traditional separation between operating system and application. With the rapid growth of the Internet and changes in the way operating systems and applications are structured, there are now opportunities to move towards a system that is more flexible and distributed. The fundamental change involves the location where the application is executed.

A new model is emerging based on services and presentation. An immature form of this approach can be seen in network browsers that incorporate small applications ("applets") that are written in Java from Sun Microsystems. In such an environment, the user can customize his or her environment depending on the task. The specific location of either the software or where it is executed becomes immaterial. More of the functionality that once was the domain of the application is now embedded in the operating system.

Our data management system has been designed with this new model in mind. At present, we rely on Open Data Base Connectivity (ODBC), an industry-wide standard, to provide links between our relational data base and desktop applications. This approach provides a stronger connection between the data search and retrieval process and data analysis. In a sense, the researcher can now enter the library stacks directly.

We have now begun the next phase of our design, which relies more heavily on a World Wide Web metaphor for information management and data flow. In this context, the focus is on a "presentation" environment for a wide variety of customizable services. Links are available to a standalone data search and retrieval tool, but small analysis applets will be available as well. The user's environment is a compound document consisting of a wide variety of data types and embedded applications. With new distribution models such as the Internet and eventually cable television, this distributed compound document becomes a much richer (but more complicated to administer) environment.

Our approach is relying on both Java and OLE controls (OCX's) using Visual C++. These applets will be integrated with the data retrieval tool to produce specialized products (e.g., drifter tracks) as well as higher level analyses (e.g., chlorophyll concentrations derived from upwelled radiances). As ODBC evolves into OLE DB, the links between the data base and the operating system and applications will become stronger. Similar functionality will eventually be available through Java. These OCX applets can also be integrated into desktop applications (e.g., OLE-aware tools such as Microsoft Excel) that will be part of the Web browser. The net result will be a system where the user cannot not only enter the library but conduct analyses and publish new results.

This approach will allow the user to develop a customized environment by assembling small components as necessary to accomplish a particular task. As operating systems mature, these environments can be extended over both the local area network and the Internet so that the user can access both data and tools. This allow rapid development and the use of reusable objects. In the past, such comprehensive environments (such as All-In-One from Digital Equipment) were tightly bound within the operating system and were generally inflexible. Advances in the Web, operating systems, and object technology will foster the development of much more flexible and extensible systems.

These trends towards smaller, object-oriented applications, distributed file systems and components, and integrated presentation and services, are not yet clearly defined. Much of the technology is in its infancy, and it is not apparent which of the competing technologies will become standard. We expect that tools that are available today may fall by the wayside in the years to come. However, the overall approach is robust, and our design should be relatively isolated from changes in technology.

Hardware Configuration

Our present computer configuration is based on UNIX data server (100 GB disk array connected to an SGI PowerChallenge XL) which is linked to a Sun 690 running a Sybase client. This client talks to our Microsoft SQL Server data base engine which keeps track of the data files. We have a small parallel data base server linked to eight PC clients over an ATM network. We are working with Adaptec to test issues of scalability.

Future Directions

We will continue to pursue software tools using a component-based based approach, building on Web-like browsers (either Netscape or Internet Explorer). This will provide an integrated analysis/data base environment.

Anticipated Future Actions

We will complete our manuscripts on the bio-optical drifter data from the California Current and the Southern Ocean. We will also prepare a manuscript on our laboratory experiments on fluorescence and photosynthesis. Our main emphasis is to improve our understanding of the processes driving variability in fluorescence yield and how they might be related to productivity. We will deploy our bio-optical mooring at the HOT site this spring. We will participate in the EOS calibration/validation activities as well.

We will continue to develop our information system and to support the ECS contractor. We also anticipate that plans for an EOSDIS "federation" will mature, and that these plans may affect how our algorithm is implemented. We also plan to revise our ATBD. Lastly, we expect to support algorithm testing and integration by the University of Miami team.

Problems and Solutions

The most significant problem has again been unforeseen delays in receiving the Fast Repetition Rate fluorometer. The original manufacturer was unable to produce the system and has finally transferred all orders to a more experienced company, Chelsea Instruments. Discussions with Chelsea suggest that a "loaner" unit may be available for field and laboratory studies this summer, but our unit (which is still on order) may not be delivered until fall.

Continued budgetary problems in the Federal government has hampered our ability to plan and to carry out our tasks. We are concerned that allocations may be much lower than expected or may appear only in small increments. This makes it difficult to buy larger pieces of equipment necessary for field studies and for data processing and management.