Development of Algorithms and Strategies for Monitoring Chlorophyll and Primary Productivity in Coastal Ocean, Estuarine and Inland Water Ecosystems

Semi-Annual Technical Report: NAS5-96063
July 15, 2000

Janet W. Campbell
University of New Hampshire
Durham, New Hampshire 03824

Summary

This is the semi-annual technical report for the period January through June 2000 for the Execution Phase of my MODIS Instrument Team investigator project. The objectives of this work are:

- Establish a protocol for developing regional or site-specific bio-optical algorithms for coastal "case 2" waters.
- Prescribe a protocol for "stitching together" local or site-specific algorithms.
- Demonstrate these protocols in two coastal seas: the Gulf of Maine/Mid-Atlantic region, and the Yellow Sea/East China Sea region.
- Develop a strategy for monitoring coastal oceans, estuaries, and inland waters.

This report reflects the efforts of a research team consisting of myself, three staff scientists (Dr. Mark Dowell, Timothy Moore, and Ken Jacobs), and two Ph.D. students (Hui Feng and Seung-Hyun Son).

The following research papers have been completed and/or submitted this year:

Feng, H., J. W. Campbell, and T. S. Moore, The effect of uncertainty in optical property parameterization on chlorophyll retrieval from ocean color spectra: A simulation study. *J. Adv. Mar. Sci. Tech. Soci.*, **4**(2): 265-274

Moore, T. S., J. W. Campbell and H. Feng. "A fuzzy logic classification scheme for selecting and blending satellite ocean color algorithms" (submitted to the *IEEE Trans. in Geosciences and Remote Sensing*, Feb. 2000; currently being revised in response to reviewer comments).

Campbell, J.W., et al. (22 co-authors) "Comparison of algorithms for estimating ocean primary productivity from surface chlorophyll, temperature, and irradiance." (submitted to Global Biogeochemical Cycles, June 2000).

Presentations at international conferences and science team meetings:

Campbell, J. W. , T. Moore, and H. Feng. "Fuzzy logic applied to coastal ocean remote sensing." Presented at the Sixth International Conference on Coastal and Marine Remote Sensing, Charleston, SC, May 2000.

Campbell, J.W. "The primary productivity algorithm round robin experiments: progress report and future plans." Presented at the SeaWiFS Science Team Meeting, Durham NH, May 2000.

Campbell, J.W. "Selecting algorithms and blending retrievals in coastal waters." Presented at the MODIS Science Team Meeting, College Park, MD, June 2000.

Case 2 Algorithm Protocol Development

There are two areas of algorithm development that are addressed in this project. One is the bio-optical algorithm which retrieves chlorophyll and other optically-active constituent concentrations. The second area is the primary productivity algorithm.

Bio-optical algorithms The strategy for this work has been to promote the use of a standard semi-analytic remote-sensing reflectance model that relates remote-sensing reflectance to inherent optical properties (absorption and backscattering coefficients), and then to prescribe methods for parameterizing the IOPs as functions of the constituent concentrations of interest (chlorophyll, colored dissolved organic matter, and suspended sediment). This work requires complete in-situ data sets of the apparent and inherent optical properties, as well as the variables to be retrieved (chlorophyll, CDOM, suspended sediment). We are currently in the process of acquiring data for our demonstration areas (see next section) but the availability of such data is limited. We discuss this issue more in our work plan for the coming year (see Work Plan: 2000-2001).

Primary productivity algorithms A manuscript describing the Primary Productivity Algorithm Round Robin has been completed and submitted to Global Biogeochemical Cycles in June 2000. Following is the title, authors, and abstract of that paper:

COMPARISON OF ALGORITHMS FOR ESTIMATING OCEAN PRIMARY PRODUCTION FROM SURFACE CHLOROPHYLL, TEMPERATURE AND IRRADIANCE

Janet Campbell, David Antoine, Robert Armstrong, Kevin Arrigo, William Balch, Richard Barber, Michael Behrenfeld, Robert Bidigare, James Bishop, Mary-Elena Carr, Wayne Esaias, Paul Falkowski, Nicolas Hoepffner, Richard Iverson, Dale Kiefer, Steven Lohrenz, John Marra, Andre Morel, John Ryan, Vladimir Vedernikov, Kirk Waters, Charles Yentsch, and James Yoder

Abstract

Results of a single-blind round-robin comparison of satellite primary productivity algorithms are presented. Twelve algorithms, developed by 10 participant teams, were compared with daily depth-integrated primary production derived from ^{14}C measurements.

This in-situ data set was comprised of measurements made at 89 stations in 7 geographically diverse regions. Algorithms were applied to measurements of the surface chlorophyll, temperature and light to determine how well they could predict integral production from information amenable to remote sensing. Errors tended to be proportional to the production estimate, which varied by two orders of magnitude in the test data set. The best-performing algorithms yielded estimates that were generally within a factor of two of the ^{14}C-derived estimates. Many algorithms had systematic biases which can possibly be eliminated by reparameterizing the underlying relationships between productivity, light, and temperature. When biases were set to zero, ten of the algorithms agreed within a factor of two of the ^{14}C-based estimates. This level of accuracy, for any given station and any given day, is comparable to that reported for chlorophyll algorithms (O'Reilly et al., 1998). To the extent that errors are random and unbiased, spatially and temporally integrated production derived from satellite algorithms should have significantly better than factor-of-two accuracy.

Protocol for "Stitching Together" Algorithms

A manuscript was submitted to the *IEEE Transactions on Geoscience and Remote Sensing* in February 2000, and reviewer comments were returned in May. We have revised the manuscript in response to reviewer suggestions and are planning to return the revised manuscript by August 1. We believe we have satisfied the reviewers and that the paper will be accepted and in press within a month or two.

Demonstration in Gulf of Maine and Yellow Sea Regions

We are continuing to assemble a data base of bio-optical data for the two demonstration sites: Gulf of Maine and Yellow Sea. In June 2000, Seung-Hyun Son participated in a cruise to the Yellow Sea and East China Sea. He has brought back historical in-water optical data and remote sensing data to develop and demonstrate algorithm development strategies for this area.

Development of Monitoring Strategies

The Hong Kong University of Science and Technology is developing a plan to monitor the Pearl River Estuary using in-situ measurements and ocean remote sensing. In June, I was invited to participate in a two-day workshop at HKUST to advise them on the use of remote sensing measurements. They are proposing to establish an X-band ground-receiving station (in addition to the HRPT station they are now operating which supplies high-resolution SeaWiFS data to NASA) for receiving MODIS data. If they are successful in this pursuit, I see this as an avenue to begin developing and demonstrating monitoring strategies.

Support of MODIS Ocean Team Activities

At the June 9 meeting of the MODIS Oceans Team, it was decided that we would produce a quick paper (intended for publication in the *IEEE Transactions on Geoscience and Remote Sensing*) detailing the current status of the MODIS Ocean products. This paper would describe and characterize some of the existing problems (e.g., detector and mirror-side effects) and show how these affect the derived geophysical variables. Ken Carder and I agreed to take the lead in producing results for Case 2 waters. Tim Moore and I identified a granule covering the East Coast continental shelf region and portions of the Gulf of Mexico that was suitable for analysis of Case 2 products. Our results may be found at: http://modis-ocean.gsfc.nasa.gov/team/campbell.

Progress in Related Areas

In March 2000, I hired Dr. Mark Dowell to join my group as a staff scientist. Mark received a Ph.D. in oceanography from Southampton University in 1998, where his dissertation was on "Optical characterization and reflectance modeling in Case II water: quantitative tools for investigations of coastal environments." Mark has been active in bio-optical algorithm development in Europe, and he brought with him an extensive data set of measurements made in European coastal waters. Mark will be working on the primary productivity algorithm aspects of this MODIS contract. His primary focus will be in parameterizing the photosynthetically useable radiation (PUR) in Case 2 waters where substances other than phytoplankton absorb the photosynthetically available radiation (PAR).

The IOCCG report on the current status of Case 2 algorithms is near completion. The first author will be Shubha Sathyendranath, and there are chapters co-authored by John Kirk, Bob Bukata, John Parslow, Bob Arnone, Curt Daviss, Andreas Neumann, and Motoaki Kishino. I have contributed to the chapter on applications which was led by John Parslow.

I am in the process of establishing a Coastal Marine Bio-optics Laboratory. Ken Jacobs was hired to be responsible for designing and overseeing this laboratory. With this laboratory, we have undertaken a local field measurement program in the Great Bay Estuary, and plan to participate in cruises to the Gulf of Maine for obtaining bio-optical measurements, and to develop courses and summer workshops. This spring, I was awarded an internally-funded grant to purchase a fiber-optic spectrometer for measuring light absorption properties of coastal and estuarine waters. We will use this laboratory to test models relating remote sensing reflectance to the inherent optical properties of estuarine and coastal waters.