Semi-Annual Report for June-December, 1999

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Abstract

The algorithm development and validation activities of the second half of 1999 concentrated on field sampling in a variety of environments from a freshwater lake, to Case 1 oligotrophic, and to Case 2 coastal and estuarine waters using SeaWiFS, AVIRIS, AVIRIS LA, and PHILLS data. Three peer-reviewed publications appeared in print. A number of presentations and symposium papers were presented.

Tasks Accomplished Since June 1, 1999

1. Field experiments

a. Ecology of Harmful Algal Blooms (ECOHAB) cruises- July 5-8, September 7-10, and November 6-8, 1999

Jennifer Patch, Dan Otis, Jim Ivey and Joe Andrews collected remote-sensing reflectance and water samples for absorption during an ECOHAB Gulf of Mexico and West Florida shelf experiment. The data will be used to test and adapt the global chlorophyll and CDOM algorithms for presence of bottom-reflected radiance in SeaWiFS and MODIS data.

b. MODIS Algorithm Development/Process Experiment (MOCE5) – October 1-21, 1999

Z. Ping Lee collected remote-sensing reflectance and water samples for absorption during MODIS experiment. The data will be used to test and adapt the global chlorophyll and CDOM algorithms for turbid waters.

c. Calibration – October 7-11, 1999

Robert Steward and Chris Cattrall participated in a calibration experiment on Mt. Lemon, Arizona. Four Spectrix spectral radiometers were radiometrically calibrated on the 40" integrating sphere at the University of Arizona's Remote Sensing Group (RSG). The Spectralon reflectance panels owned by USF were resurfaced according to manufacture instructions. The directional reflectance factor of each was measured at 5 degree increments from 10^o to 85^o and at 9 wavelengths from 443 to 1043 nm. The reflectance factors were measured and directly compared to a NIST standard and a RSG standard made from Algoflon. The Spectrix were transported to the top of nearby Mt. Lemon (~3000m) where direct-diffuse solar-based calibrations were conducted and compared with those derived from the sphere.

d. COBOP99 - May 17 – June 8, 1999

In conjunction with Navy-sponsored COBOP Project, a two-week exercise was conducted on the Lee Stocking Island of the Bahamas. A state-of-the-art data set was collected of inherent and apparent optical properties by investigators from various institutions. Dan Otis collected reflectance and water samples for absorption for USF. The PHILLS was flown on several transects over the area with vicarious calibration measurements conducted by USF from the R/V Suncoaster. Aerosol optical thickness (AOT) at 10 channels was measured with an automated solar radiometer along with downwelling irradiance and meteorological parameters.

USF also supported the experiment with several daily sampling trips on the RV Subchaser including remote-sensing reflectance, diffuse attenuation profiles, bottom albedo, depth, and bottom imagery. The USF slow-drop package was deployed. Remote sensing reflectance and water samples were collected for absorption measurements. Several methods to characterize the PHILLS sensor were employed. These data will be used to modify MODIS algorithms for use in shallow waters.

2. Peer-reviewed Publications

a. Band-ratio or spectral-curvature algorithms for satellite remote sensing? by Z.P. Lee and Kendall Carder was submitted to Applied Optics for publication

For the retrieval of chlorophyll concentrations or the total absorption coefficients of oceanic waters based on water color, there are algorithms using either band ratios or spectral curvatures of remote-sensing reflectance or water-leaving radiance. In this short note, we show that band-ratio algorithms have the potential to be applied to wider dynamic range of oceanic waters than spectral-curvature algorithms.

b. Atmospheric correction of SeaWiFS imagery over turbid coastal waters: a practical method by C. Hu, K. L. Carder, and F. E. Muller-Karger was accepted by Remote Sensing of the Environment for publishing.

The current SeaWiFS algorithms frequently yield negative water-leaving radiance values in turbid Case II waters primarily because the water-column reflectance interferes with the atmospheric correction based on the 765 and 865 nm spectral bands. Here we present a simple, practical method to separate the water-column reflectance from the total reflectance at 765 and 865 nm. Assuming the type of aerosol does not vary much over relatively small spatial scales (~50-100 km), we first define the aerosol type over less turbid waters. We then transfer it to the turbid area by using a "nearest neighbor" method. While the aerosol type is fixed, the concentration can vary. This way, both the aerosol reflectance and the water-column reflectance at 765 and 865 nm may be derived. The default NASA atmospheric correction scheme is subsequently used to obtain the aerosol scattering components at shorter wavelengths. This simple method was tested under various atmospheric conditions over the Gulf of Mexico, and it proved effective in reducing the errors of both the water-leaving radiance and the chlorophyll concentration estimates. In addition, in areas where the default NASA algorithms created a mask due to atmospheric-correction failure, water-leaving radiance and chlorophyll concentrations were recovered. This method, in comparison with field data and other turbid-water algorithms, was tested for the Gulf of Maine and turbid, post-hurricane Gulf of Mexico waters. In the Gulf of Maine it provided more accurate retrievals with fewer failures of the atmospheric-correction algorithms. In the Gulf of Mexico it provided far fewer pixels with atmospheric-failure than the other methods, did not over-estimate chlorophyll as severely, and provided fewer negative water-leaving radiance values.

c. Atmospheric Correction of SeaWiFS Imagery: Assessment of Alternative Bands by C. Hu, K.L. Carder, and F.E. Muller-Karger was accepted for publication in Applied Optics.

d. Noise Reduction and Atmopsheric Correction for Coastal Applications of Landsat Thematic Mapper Imagery by M. Zhang, K.L. Carder, and F.E. Muller-Karger, Z. Lee, and D.B. Goldgof was published in Remote Sens. Environ. 70:167-180, 1999.

3. Presentations & Symposiums

a. Recalibration and Atmospheric Correction to the AVIRIS Low Altitude data for a Tampa Bay Transit Using Lowtran 7 by F. Robert Chen, Kendall L. Carder, and Z.P. Lee was presented at the 22nd Atmosphere transmission meeting in Hanscom AFB.

AVIRIS LA (Airborne Visible-Infrared Imaging Spectrometer, Low Altitude) has 10 nm spectral resolution from 400 nm to 2400 nm with a 4 m spatial resolution. AVIRIS LA data were collected from a Twin-Otter aircraft flying at 12,500 feet altitude over Tampa Bay, Florida on October 18, 1998 at 12 A.M. The AVIRIS LA preflight radiance calibration was adjusted vicariously using the method of Carder et al. (1993). The measured remote sensing reflectance spectra of Tampa Bay water taken at the time of the overflight using a field spectrometer was diffusely transmitted to 12,500 ft. and added to the path radiance calculated using Lowtran 7 with a winter marine aerosol type. The calculated and measured radiances at the aircraft matched closely for wavelengths longer than 470 nm, and a calibration adjustment was made for shorter wavelengths. Atmospheric radiance was then stripped from the entire scene. This imagery provides a measure of bottom-reflected radiance that will adversely affect SeaWiFS and MODIS data. Evaluation of those effects is continuing.

b. Bottom Reflectance of Various Benthic Types based on in-situ Multi-channel Imagery by Weilin Hou, Lisa Renadette, Andrew Farmer, Ken Carder, David Costello, Tom Peacock was submitted to AGU/ASLO meeting, San Antonio, TX for presentation.

Bottom reflectance is an important variable affecting remote sensing applications in coastal areas. It can be used to classify various bottom types and to estimate photon absorption for photosynthetic and heat budget studies, and is useful in monitoring ecosystem changes (e.g. coral bleaching, erosion and sedimentation effects). Direct in-situ measurements were carried out using intensified multi-spectral (6-channel) imagery (460, 520, 575, 620, 685 and 730nm) from a remotely operated vehicle (ROV), over different bottom types such as sea grass, coral, sand and mixtures. These efforts are part of the Coastal Benthic Optical Properties program (CoBOP) summer field campaign, May 20 – June 3, 1999, near Lee Stocking Island, the Bahamas. The imagery is calibrated by comparison to standard reflectors (~5% Spectralon). Results are compared to in-water remote sensing measurements acquired using hyperspectral (512-channel) spectrometers (Ed and Lu) onboard the ROV. Direct bottom albedos are calculated, and compare well with diver-deployed measurements at the same sites. End-members were mapped for extended areas by correcting for path radiance and attenuation effects and classifying each pixel of the bottom that was viewed.

c. Digitized Video in Oceanographic Research Project by Weilin Hou, Lisa Renadette, David Costello, Kendall Carder was presented at Digital Computational Video DCV99, December 10, 1999 TAMPA, FL

Optical approach represents the most intuitive research means known to human kind. Video, as our way of reproducing motion for further analysis, can be greatly beneficial to all research programs including oceanographic field studies. Some of the works that have been done in our research group, are good examples of such applications. The core of the approach is based on digitizing video taken underwater, in order to automatically process and extract large amounts of data. A first generation system, Image Control and Exam or ICE, is used to extract large particle size distribution and other optical properties, by frame capturing every single video frame from a recorded RS170 source (SVHS). To eliminate introduction of artificial noise, we now use a real-time disk system (RTD), which enables us to convert video frames in real-time on the fly. It also speeds up processing time. The system is currently used to study coastal environment such as coral reefs, sea grass beds and sandy bottom, and their optical properties such as reflectance and bathymetry, from a Remotely Operated Vehicle (ROV). In the near future, the system will be used to link to Autonomous Underwater Vehicle (AUV) via wireless transmission of analog video.

d. Database Structure of Current COBOP/HYCODE Project by Weilin Hou was presented at CoBOP Workshop 99, Lake Tahoe, California, October 3 - 7, 1999

Due to the requirement that CoBOP data should conform to future ONR data formats, we propose the following HyCODE format, which is a result of HyCODE Data Management Workshop held earlier this year. This structured ASCII data format will enable us to load all data into a relational database to view the results graphically. The results of this project will allow MODIS project data to be intercompared with ONR-funded field data.

e. MODIS CDOM and Chlorophyll: A First Look Using SeaWiFS and AVHRR Data by Steven Hawes, Kendall Carder, F. R. Chen, and Robert Evans was submitted to SPIE's 45th Annual meeting, July 30 – August 4, 2000, San Diego, Ca., for presentation.

MODIS algorithms for the concentration of chlorophyll a and the absorption coefficients of seawater constituents such as chromophoric dissolved organic matter (CDOM) were tested using SeaWiFS and AVHRR data, and global maps of these were generated for a 2-day composite. Chlorophyll a and CDOM are important components of the global carbon budget used in estimating carbon flux from the land to the ocean and carbon uptake by primary production in the sea. The first global map of CDOM was generated, and retrieved values of chlorophyll a were consistent with field measurements from time series off Hawaii and Bermuda. This data set provided a means of testing for quality assurance in derived MODIS products using numerical filters and comparisons against ocean-climatology data sets. Of special interest was the testing of a numerical filter to flag data suspected to be in error due to effects of absorbing aerosols on the atmospheric correction. Retrieval accuracies are compared for filtered and unfiltered data, and sensitivity analyses of numerical filters are discussed.

f. Bathymetry and Environmental Properties Observed From AVIRIS Data by Z. P. Lee, Kendall Carder, and F. R. Chen was submitted to the Sixth International Conference on Remote Sensing for Marine and Coastal Environments, Charleston, South Carolina, 1-3 May 2000 for presentation.

Using a newly developed process, environmental properties of Tampa Bay were derived from recent Airborne Visible-InfraRed Imaging Spectrometer (AVIRIS) data. The derived properties include bottom depth, bottom albedo, and water absorption coefficients. The derived bottom depths were compared with bathymetry charts and found to agree very well. Also, the derived image of bottom albedo shows distinct bottom patterns, with albedo end-members consistent with sand and seagrass. The image of absorption coefficients shows the waters of the study area to be horizontally well mixed. There was no significant co-variance between water absorption and bottom properties. These results suggest that environmental properties of a large shallow-water area can be adequately obtained just from hyperspectral imaging spectrometer data. This paper allows AVIRIS to be used to quantify the depths and albedo of coastal benthic features that can affect MODIS algorithms.

g. Spectral channels and their influence on remote-sensing retrieval: 1. Shallow waters by Z. P. Lee and Kendall Carder was submitted to AGU/ASLO meeting, San Antonio, TX for presentation.

Using a newly developed remote-sensing reflectance model and optimization approach, in-water properties of shallow-water environments were derived from the remote-sensing reflectance spectrum, which covered a spectral range from 400 to 800nm. These inversions used data of every 5nm, 10nm, and 20nm, as well as MERIS, SeaWiFS and MODIS channels, respectively. This investigation is aimed at evaluating the influence of the number of spectral and spacing channels on the accuracy of remote-sensing retrievals, providing guidance for future sensor designs. From this study, it was found for retrieving bathymetry, bottom albedo, and water absorption and scattering properties, that 1) 10nm to 20nm resolution can provide almost identical results to those using 5nm spectral resolution, 2) MERIS resolution provides very good results compared with those for 5nm, and 3) SeaWiFS or MODIS resolution can not provide accurate results regarding bottom depth, although it does provide fair accuracies for total absorption coefficients.

h. Bottoms Up! The Hemispherical-directional Reflectance of Sand, Corals, and Seagrass and the Effect on the Upwelling Light Field by David Costello and K. L. Carder was submitted to AGU/ASLO meeting, San Antonio, TX for presentation.

The spectral reflectivity of different bottom types is of primary interest for remote sensing purposes to the ONR-sponsored, Coastal Benthic Optical Properties Program (CoBOP). Understanding this process requires knowledge of the amplitude and directionality of the downwelling irradiance, the inherent optical properties (IOPs) of the water and/or the diffuse attenuation coefficients (Kd and Ku) for up and downwelling light, as well as the spectral bottom albedo. Additionally, some method (usually temporal or spatial averaging) often needs to be utilized to deal with wave-focusing of the downwelling light.

This contribution presents results obtained from in situ data acquired using the ROSEBUD ROV during the 1998 and 1999 CoBOP field campaign at Lee Stocking Island, Bahamas. The technique utilized minimizes the effects of wave-focusing without temporal or spatial averaging and allows you to compute local reflectivity at any depth with the water column and at the bottom. Local diffuse attenuation coefficients at any depth are also readily computed. The hyperspectral (512-channel) technique is fully described and results are presented for bright sand (R @ 550nm = 50%), coral (R @ 550nm = 4.5%), thick seagrass (R @ 550nm = 4%), and sparse seagrass (R @ 550nm = 15%).

4. Science Meetings

MODIS Science Team, November 16-18, 1999.