Semi-Annual Report for July-December, 2001

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NAS5-31716

Abstract

The activities of the second half of 2001 were concentrated on quality assurance (Q/A) for our products from the new MODIS data stream. We have updated our Case 2 chlorophyll a algorithms for MODIS using smooth functions for the transitions between different bio-domains and also have updated the quality and product thermally driven flags document. We also are collecting in situ data for cal/val of our products. Four peer-reviewed papers have been submitted for publication, and three papers have been published. A number symposium papers were presented at several conferences.

Tasks Accomplished Since July 1, 2001

1. Field experiments

a. Ecology of Harmful Algal Blooms (ECOHAB) cruises- June 31-July 3, Aug. 28-Aug. 31, Oct. 1-2, Nov. 17-20, and Dec. 11-14.

Jennifer Cannizzaro, Dan Otis, Harri Warrior collected remote-sensing reflectance and water samples for absorption during an ECOHAB West Florida shelf experiment and a recent red tide event. 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. The data will also be used for testing our red tide algorithm and for model comparison.

2. Presentations & Symposiums

a. A paper entitled "Light Absorption in the Sea: Remote Sensing Retrievals Needed for Light Distribution with Depth, Affecting Heat, Water, and Carbon Budgets" by K. Carder was presented at the MODIS science team meeting in December at Mariott hotel, in Baltimore.

b. A paper entitled "PHILLS Vicarious Calibration: a WFS experiment and guidance for LEO-15 calibration efforts" by K. Carder, F. Chen, P. Bissett, J. Ivey, Z. Lee and R. Steward was presented in HYCODE meeting in California.

On April 24, 2001, Florida Shelf Lagrangian Experiment (FSLE) cruises were accompanied by PHILLS hyperspectral overflights at 30,000 ft altitude. Robert Steward, and Jim Ivey collected remote sensing reflectance and water samples for absorption during two FSLE experiments. The PHILLS was flown on several transects over the area with vicarious calibration measurements conducted by USF from the R/V LINK. The USF slow-drop package was also deployed to collect inherent and apparent optical properties as a function of depth for an evaluation of effects of vertical structure on remote sensing spectra. The PHILLS imagery has been successfully calibrated. We show the procedures, results, derived bathymetry, and some noise effects with a 3 s period.

c. A paper entitled "An improved heat budget estimation including bottom effects for general ocean circulation models" by Kendall Carder, Hari Warrior, Daniel Otis and R. F. Chen was submitted to AGU/ASLO 2002 Ocean Science Meeting for presentation.

This paper studies the effects of the underwater light field on heat-budget calculations of general ocean circulation models for shallow waters. The presence of a bottom significantly alters the estimated heat budget in shallow waters, which affects the corresponding thermal stratification and hence modifies the circulation. Based on the data collected during the COBOP field experiment near the Bahamas, we have used a one-dimensional turbulence closure model to show the influence of the bottom reflection and absorption on the sea surface temperature field. The water depth has an almost one-to-one correlation with the temperature rise. Effects of varying the bottom albedo by replacing the sea grass bed with a coral sand bottom, also has an appreciable effect on the heat budget of the shallow regions. We believe that the differences in the heat budget for the shallow areas will have an influence on the local circulation processes and especially on the evaporative and long-wave heat losses for these areas. The ultimate effects on humidity and cloudiness of the region are expected to be significant as well.

d. A paper entitled "Interpretation of Observations of Trans-spectral Phenomena Acquired Using Hyperspectral Sensors Aboard a Remotely Operated Vehicle in Exuma Sound" by D. Costello, K. Carder, J. Ivey, D. English is submitted to AGU/ASLO 2002 Ocean Science Meeting for presentation.

Hyper-spectral (512-channel) optical data acquired during a relatively deep (102m) dive of our ROSEBUD Remotely Operated Vehicle (ROV) in the clear waters of Exuma Sound, Bahamas provided the opportunity to investigate the trans-spectral shift of photonic energy (inelastic scattering) as a function of water depth. Results show a convolution of several spectral processes (e.g. absorption, scattering) involving water molecules, dissolved material and particulates as well as trans-spectral (inelastic) processes involving fluorescence by water molecules (Raman), dissolved material and chlorophyll.
The spectral signatures of these convolved causes and effects allow deconvolution with a hyperspectral approach. Intrinsic to the convolution was the ability to position the vehicle at depths where Raman fluorescence dominated at red wavelengths. Results show that the calculated Raman absorption coefficients are generally consistent with historical values (i.e. 0.9x10^-4 at 525 nm excitation) and that an angstrum exponent of 5 is more appropriate than the often cited value of 4.

3. Peer-reviewed Publications

a. A paper entitled "Properties of the water column and bottom derived from AVIRIS data" by Zhongping Lee, Kendall. L. Carder, F. Robert Chen and Thomas G. Peacock is published in *J. Geophys. Res.*, Vol 106 (C6), 11639 - 11652 (2001).

Using AVIRIS data as an example, we show in this study that the optical properties of the water column and bottom of a large, shallow area can be adequately retrieved using a model-driven optimization technique. The simultaneously derived properties include bottom depth, bottom albedo, and water absorption and backscattering coefficients, which in turn could be used to derive concentrations of chlorophyll, dissolved organic matter, and suspended sediments. The derived bottom depths were compared with a bathymetry chart and a boat survey and were found to agree very well. Also, the derived bottom-albedo image shows clear spatial patterns, with end members consistent with sand and seagrass. The image of absorption and backscattering coefficients indicates that the water is quite horizontally mixed. These results suggest that the model and approach used work very well for the retrieval of sub-surface properties of shallow-water environments even for rather turbid environments like Tampa Bay, Florida.

b. A paper entitled "Solar-reflectance-based calibration of spectral radiometers" by Christopher Cattrall, Kendall L. Carder, Kurtis J. Thome and Howard R. Gordon is submitted to Geophysical Research Letters for publication**.**

A method by which to calibrate a spectral radiometer using the sun as the illumination source is discussed. Solar-based calibrations eliminate several uncertainties associated with applying a lamp-based calibration to field measurements. The procedure requires only a calibrated reflectance panel, relatively low aerosol optical depth, and measurements of atmospheric transmittance. Further, a solar-*reflectance*-based calibration (SRBC), by eliminating the need for extraterrestrial irradiance spectra, reduces calibration uncertainty to approximately 2.2% across the solar-reflective spectrum, significantly reducing uncertainty in measurements used to deduce the optical properties of a system illuminated by the sun (e.g., sky radiance). The procedure is very suitable for on-site calibration of long-term field instruments, thereby reducing the logistics and costs associated with transporting a radiometer to a calibration facility.

c. A paper entitled "Columnar aerosol single-scattering albedo and phase function retrieved from sky radiance over the ocean: Measurements of African dust" by Christopher Cattrall, Kendall L. Carder, and Howard R. Gordon is submitted to Journal of Geophysical Research for publication.

The single-scattering albedo and phase function of African mineral dust are retrieved from ground-based measurements of sky radiance collected in the Florida Keys. The retrieval algorithm employs the radiative transfer equation to solve by iteration for these

two properties which best reproduce the observed sky radiance using an assumed aerosol vertical structure and measured aerosol optical depth. Thus, no assumptions regarding particle size, shape, or composition are required. The single-scattering albedo, presented at fourteen wavelengths between 380 and 870 nm, displays a spectral shape expected of iron-bearing minerals but is much higher than current dust models allow. This indicates the absorption of light by mineral dust is significantly overestimated in climate studies. Uncertainty in the retrieved albedo is less than 0.02 due to the small uncertainty in the solar-reflectance-based calibration (±2.2%) method employed. The phase function retrieved at 860 nm is very robust under simulations of expected experimental errors, indicating retrieved phase functions at this wavelength may be confidently used to describe aerosol scattering characteristics. The phase function retrieved at 443 nm is very sensitive to expected experimental errors and should not be used to describe aerosol scattering.
Radiative forcing by aerosol is the greatest source of uncertainty in current climate models. These results will help reduce uncertainty in the absorption of light by mineral dust. Assessment of the radiative impact of aerosol species is a key component to NASA’s Earth System Enterprise.

d. A paper entitled “Ocean-Science Mission Needs: Real-Time AUV Data for Command, Control, and Model Inputs” by Carder, K. L., D. K. Costello, H. Warrior, L. C. Langebrake, W. Hou, J. T. Patten, and E. Kaltenbacher was published in *IEEE Jour. of Ocean. Eng. 26(4):* 742-751.

Predictive models for tides, hydrodynamics, and bio-optical properties affecting the visibility and buoyancy of coastal waters are needed to evaluate the safety of personnel and equipment engaged in maritime operations under potentially hazardous conditions. Predicted currents can be markedly different for two-layer systems affected by terrestrial runoff than for well-mixed conditions because the layering decouples the surface and bottom Ekman layers and rectifies the current response to oscillatory upwelling- and downwelling-favorable winds. Standard ocean models (e.g. Princeton Ocean Model) require initial- and boundary data on the physical and optical properties of the multi-layered water column to provide accurate simulations of heat budgets and circulation.

Two observational systems are designed to measure vertically structured conditions on the West Florida Shelf (WFS): a tethered buoy network and an autonomous underwater vehicle (AUV) observational system. The AUV system is described with a focus on the observational systems that challenge or limit the communications command and control network for various types of measurement programs. These include vertical oscillatory missions on shelf transects to observe the optical and hydrographic properties of the water column, and bottom-following missions for measuring the bottom albedo. Models of light propagation, absorption, and conversion to heat as well as determination of the buoyancy terms for physical models require these measurements. High data rates associated with video bottom imagery are the most challenging for the real-time, command and control communications system, but they are met through a combination of loss-less and lossy data-compression methods, depending upon the data-rate of the radio links.

e. A paper entitled “Atmospheric correction for airborne sensors: Comment on a scheme for CASI” by Hu, C. and K.L. Carder was published in *Remote Sens. Environ. 70*: 134-137, 2000.

f. A paper entitled “Remote-sensing reflectance and inherent optical properties for optically deep waters: a revisit” by Zhongping Lee, Kendall L. Carder, and Keping Du was submitted to Applied Optics for publication.

Remote-sensing reflectance (r_{rs}) is defined as the ratio of upwelling radiance to downwelling irradiance. Relationships between remote-sensing reflectance and inherent optical properties serve as the basis for ocean-color modeling, as well as for spectral deduction of oceanic constituents through analytical/semi-analytical models of ocean color. A decade ago, a simple and concise formula based on Monte Carlo simulations was developed by relating r_{rs} to a property u, the ratio of backscattering (b_b) to the sum of absorption (a) and backscattering ($u \equiv b_b/(a+b_b)$). This relationship generally ignored the shape differences in phase functions between molecular scattering and particle scattering. In this study, the relationship is updated with separate parameters for molecular and particle scattering, based on the Radiative Transfer Equation through use of Hydrolight numerical solutions. The new approach fits r_{rs} better than an earlier traditional formula, for both clear and turbid waters.

g. A paper entitled “A multi-band analytical algorithm for deriving absorption and backscattering coefficients from remote-sensing reflectance of optically deep waters” by Zhongping Lee, and Kendall L. Carder was submitted to Applied Optics for publication.

A multi-band analytical (MBA) algorithm is developed to retrieve absorption and backscattering coefficients for optically deep waters, which can be applied to data from past and current satellite sensors, as well as data from hyperspectral sensors. This MBA algorithm applies a remote-sensing reflectance model derived from the Radiative Transfer Equation, and values of absorption and backscattering coefficients are analytically calculated from values of remote-sensing reflectance. There are only limited empirical relationships involved in the algorithm, which implies that this MBA algorithm could be applied to a wide dynamic range of waters.
Applying the algorithm to a simulated non-"Case 1" data set, which has no relation to the development of the algorithm, the percentage error for the total absorption coefficient at 440 nm (a_{440}) is ~12% for a range of 0.012 - 2.1 m^{-1} (~6% for $a_{440} < \sim 0.3$ m^{-1}), while a traditional band-ratio approach returns a percentage error of ~30%. Applying it to a field data set ranging from 0.025 to 2.0 m^{-1}, the result for a_{440} is very close to that using a full-spectrum optimization technique (9.6% difference). Compared to the optimization approach, the MBA algorithm cuts the computation time dramatically with only a small sacrifice in accuracy, making it suitable for processing large data sets such as satellite images. Significant improvements over empirical algorithms have also been achieved in retrieving the optical properties of optically deep waters.

4. Science Meetings

MODIS Science Team, December 17-20, 2001 at Marriot hotel, Baltimore.