QUARTERLY REPORT

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OCEAN OBSERVATIONS WITH EOS/MODIS:
Algorithm Development and Post Launch Studies

by

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ABSTRACT

An algorithm for removal of the influence of the Oxygen "A" band absorption from atmospheric correction of SeaWiFS has been developed. This is important for MODIS as SeaWiFS will provide the test data set for the MODIS atmospheric correction algorithm.

REPORT

I shall describe developments (if any) in each of the major task categories.

1. Atmospheric Correction Algorithm Development.

a. Near-term Objectives:

(i) Investigate the effects of stratospheric aerosol on the behavior of the proposed atmospheric correction algorithm.

(ii) Investigate the effects of vertical structure in the aerosol concentration and type on the behavior of the proposed atmospheric correction algorithm.

(iii) Investigate the effects of polarization on the behavior of the proposed atmospheric correction algorithm.

(iv) Complete examination of ways to improve the accuracy and the speed of our implementation of the proposed algorithm.

(v) Complete a procedure to correct the 765 nm band on SeaWiFS for the effects of absorption by the Oxygen "A" Band.

b. Task Progress:

(i) We are continuing our effort to understand how to utilize the 1380 nm MODIS spectral band to atmospherically correct imagery for the effects of stratospheric aerosol. We have investigated simple to complex methods of correction. For example, in the most trivial, we assume that we know nothing about the optical properties of the stratospheric aerosol and simply subtract the reflectance at 1380 nm from the other bands. In contrast, in the most complex, we assume that all of the stratospheric aerosol's properties are know (using the 1380 nm band to estimate only its concentration) and then utilize a multiple scattering code to try to remove its effects from the other bands. To date, we have found no approach that we are satisfied with. The accuracy of the retrievals of water-leaving radiance are poorer than we believe they should be, and we shall continue to look for a satisfactory procedure to utilize the 1380 nm band.

(ii) Some preliminary computations (using our 50-layer Monte Carlo code) relating to the influence of vertical structure of the aerosol on atmospheric correction (the algorithm assumes that the aerosol is all in the surface boundary layer) have been carried out. These show an increased error in the retrievals in the presence of vertical structure; however, the error is not excessive.

(iii) We are now adding polarization to our 50-layer Monte Carlo radiative transfer code. We expect this to be complete during the next quarter.

(iv) In the implementation of our correction algorithm, extensive lookup tables are required for each aerosol model we employ. These give radiances for the various viewing directions and solar positions. The viewing and solar azimuths are incorporated via a Fourier transform (series). We have recast the algorithm by replacing the Fourier transform by an azimuthal interpolation. Also, we have improved the least-squares fits in the lookup tables by the addition of a quadratic term in the expansion series for each sun and viewing angle. This improves the algorithm's performance in situations in which the aerosol concentration is high. These enhancements have been provided to R. Evans for testing with the SeaWiFS processing code to understand their timing impact.

(v) We completed a procedure to correct the 765 nm band on SeaWiFS for the effects of absorption by the Oxygen "A" Band. A paper on this was submitted to Applied Optics.

c. Anticipated Activities During the Next Quarter:

(i) Continue examination of possible schemes for employing the 1380 nm band for correcting for stratospheric aerosols.

(ii) Upon completion of the Monte Carlo code including polarization we shall produce a complete set of pseudo data to test the effects of both vertical structure and polarization on the correction algorithm.

(iii) Finish adding polarization effects to the Monte Carlo code in (ii).

(iv) Work with R. Evans to incorporate improvements in our implementation procedure into the SeaWiFS processing code.

(v) None, task was completed.

2. Whitecap Correction Algorithm.

a. Near-term Objectives: As described in our last Semi-Annual Report, financial constraints prevent our carrying out a whitecap study of the scope originally proposed. Since our recent analysis suggested that it is neither possible nor important to have a precise prediction of the reflectance increase of the ocean due to whitecaps, i.e., errors of the order of 0.002--0.004 can be tolerated, we considered abandoning our experimental whitecap program completely. However, to assure acceptance of an atmospheric correction that utilizes the whitecap removal procedure as one component, we believed that some validation of the whitecap algorithm was necessary. Thus, we decided to limit our effort to trying to collect sufficient whitecap data to validate in a coarse manner the correction model that we developed based on a survey of the literature.

Our revised approach to the validation of the whitecap algorithm is to construct a ship-based radiometer for observing whitecaps while the ship is on station or underway. The radiometer, suspended from a boom off the bow of the ship, will continuously view a spot about 12 cm in diameter on the sea surface. A second radiometer on the deck of the ship will record the incident irradiance. The reflectance of the surface measured by the radiometer will be recorded as a function of time. This reflectance will consist of background reflectance (low) from whitecap-free areas (the predominant situation) and a much higher reflectance whenever a portion of a whitecap is in the field of view of the radiometer. After determining the reflectance of the whitecap-free areas (essentially the ``baseline'' of the reflectance) and subtracting it from the entire record, we will be left with the time-average reflectance due to the whitecaps. This is the average whitecap-leaving reflectance for a pixel.

The radiometer will be accompanied by a meteorological package which will provide the speed of the wind relative to the ship (and other, possibly relevant, parameters) and a GPS unit to provide the absolute speed of the ship. Combining these will yield the wind speed.

The whitecap radiometer will record in 10 nm bands centered at 6 wavelengths: 410, 510, 550, 670, 750, and 860 nm, and the downward surface irradiance will be measured in 5 bands, also 10 nm wide, centered at 410, 510, 550, 670, and 860 nm. Thus, we will be able to study the validity of the algorithm throughout the relevant spectral region.

Our plan is to deploy this radiometer on all SeaWiFS/MODIS cruises in which we participate, and from ``ships of opportunity'' when feasible.

b. Task Progress: We are well into construction of the radiometer itself. We have acquired the meterological package, and GPS. The data acquisition system computer is no longer available so we have started procurement of a new system. Our goal is to have a completed system ready for testing and deployment on D. Clark's October-November MODIS cruise.

c. Anticipated Activities During the Next Quarter: Finish the whitecap radiometer and test at sea in October-November.

3. In-water Radiance Distribution Schedule.

a. Near-term Objectives: None.

b. Task Progress: None.

c. Anticipated Activities During the Next Quarter: None.

4. Residual Instrument Polarization.

a. Near-term Objectives: None.

b. Task Progress: None.

c. Anticipated Activities During the Next Quarter: None.

5. Direct Sun Glint Correction.

a. Near-term Objectives: None.

b. Task Progress: None.

c. Anticipated Activities During the Next Quarter: None.

6. Prelaunch Atmospheric Correction Validation Schedule.

a. Near-term Objectives: The objectives of this task are two fold. First, we need to demonstrate that our atmospheric correction scheme will work to the required accuracy. To effect this we will apply the algorithm to compute the sky radiance in the blue from measurements in the near infrared. We should be able to do this to about the same accuracy as looking downward from space. Second, we need to study the aerosol phase function and its spectral variation in order to verify the applicability of the aerosol models. To effect these requires instrumentation for measuring the sky radiance and the optical thickness of the atmosphere. Such instrumentation is available in our laboratory and has been modified to operate with the relevant MODIS spectral bands. Our near-term objective is to learn how to invert sky radiance to obtain aerosol optical properties, to carry out such inversions, and to study the variation of the phase function with wavelength. We have collected a first data set at Key West, one day of which appears to be good enough to analyze.

Also, to obtain a long-term time series of the aerosol properties in a maritime environment, we are in the process of procuring a CIMEL sun/sky radiometer that can be operated in a remote environment and send data back to the laboratory via a satellite link. These are similar to the radiometers used by B. Holben and Y. Kaufman.

Finally, to obtain sky radiance data close to the sun, which we cannot do with our sky camera from a moving ship, we have designed a solar aureole camera and will start construction this quarter.

b. Task Progress: We have began analysis of the Key West data; however, for the only day with a clear enough sky the data were obtained at such a small solar zenith angle that inversion is only accurate for the forward part of the phase function. Our present inversions yield a value of single scatter albedo that is too low. We are trying to track down the source of the difficulty.

The CIMEL Electronique, Automatic Sun Tracking Photometer, a Vitel Inc. GOES Data Transmitter with accessories, and a set of Solar Power Panels are now on order.

Critical components of the aureole camera are now on order.

c. Anticipated Activities During the Next Quarter: Continue analysis of the Key west data, assemble and test the Automatic Sun Tracking Photometer, and assemble and test the aureole camera.

7. Detached Coccolith Algorithm and Post Launch Studies.

a. Near-term Objectives: re-analyze cruise data for the development of a coccolith algorithm and set up chemostats for laboratory measurements of coccolith-specific light scatter as a function of growth rate.

b. Task Progress: The optical data that we are analyzing was from a cruise to the central north Atlantic Ocean during a half-million square kilometer bloom of the coccolithophorid, Emiliania huxleyi. We have found that the chlorophyll-specific absorption was similar to previously reported laboratory culture measurements of the same species. Volume scatter measurements showed that the suspended coccoliths were responsible for about 80% of the total backscatter in the center of the bloom. Vertical profiles of backscatter showed that greatest calcite-dependent light scatter was observed just below the base of the mixed layer. Areal maps of calcite-dependent backscatter and reflectance (calculated from absorption and backscatter) were extremely similar, due to the dominance of backscatter over absorption. Calculated reflectance in this mesoscale feature reached as high as 21% at 440nm and 24%

at 550nm. Total scatter (b) was also calculated as the difference between beam attenuation and absorption. The ratio of backscatter to total scatter (B) was about 0.01-0.02 at 440nm and 550nm for scatter values of 1 to 3/m. As total scatter decreased from 1/m, B increased. The behavior of B was compared for coccolith-dominated versus chlorophyll-dominated waters. Definition of B is critical for the development of a "coccolith algorithm" for MODIS.

We are completing our first trials of our new chemostat reactors, verifying maximum growth rates of the coccolithophores in "batch mode"; this is critical for future interpretation of our light scatter results. One feature of the new chemostats is that we can control the hydrodynamic sheer that cells experience within the reactor. This is an important factor for coccolith detachment because the appearance of blooms in space is associated with increases in coccolith detachment. What we do not know (and our future experiments will answer this) is whether the changes in shape of coccoliths associated with changing growth rates also significantly impacts their light scatter properties.

c. Anticipated Activities During the Next Quarter: Continue trials with our new chemostat reactors.

8. Post Launch Vicarious Calibration/Initialization.

a. Near-term Objectives: None.

b. Task Progress: None.

c. Anticipated Activities During the Next Quarter: None.

9. Single Scattered Aerosol Radiance and PAR Algorithms.

a. Near-term Objectives: None.

b. Task Progress: None.

c. Anticipated Activities During the Next Quarter: None.

OTHER DEVELOPMENTS

The PI spent a significant portion of this reporting period completing the necessary requests to obtain government permission to procure several items of capital equipment.