Chapter 3

Adaptation of a Hyperspectral Atmospheric Correction Algorithm for Multi-spectral Ocean Color Data in Coastal Waters

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3.1 INTRODUCTION

This SIMBIOS contract supports several activities over its three-year time-span. These include certain computational aspects of atmospheric correction, including the modification of our hyperspectral atmospheric correction algorithm Tafkaa for various multi-spectral instruments, such as SeaWiFS, MODIS, and GLI. Additionally, since absorbing aerosols are becoming common in many coastal areas, we are making the model calculations to incorporate various absorbing aerosol models into tables used by our Tafkaa atmospheric correction algorithm. Finally, we have developed the algorithms to use MODIS data to characterize thin cirrus effects on aerosol retrieval.

3.2 RESEARCH ACTIVITIES

One of our accomplishments this year included further modifications of our hyperspectral atmospheric correction algorithm (Gao et al. 2000; Montes et al. 2001) suggested at the 2002 year-end review, as well as others that allow us flexibility in examining the results of different aerosol corrections applied to different scenes.

One of the inputs for Tafkaa is the wind speed. This is used to aid in correcting for the specular reflections from the ocean surface. Previously we had the ability to only read one wind speed value for the whole scene; this does not make much sense for typical MODIS and SeaWiFS scenes that span a reasonably large surface area. Tafkaa can now read an input data plane that has the wind speed, and it can use that information for each pixel. This does not tend to slow Tafkaa too much, although it does require more memory since the complete lookup tables for each wind speed need to be held in memory. Similar modifications were made for ozone amount, so Tafkaa may be run either for a single ozone value for the whole scene, or with an ozone input array provided.

Other modifications to Tafkaa include the ability to exclude certain classes of aerosol from consideration, the ability to force Tafkaa to use a certain aerosol model and optical depth, and the ability to solve only for aerosol optical depth when given a fixed aerosol model. Tafkaa now has the ability to ignore masked data, which makes it faster in areas where the clouds and land have been masked. Finally, an absorbing urban aerosol has been added to the lookup tables, which is useful in many areas, including off the east coast of both North America and Asia.

These modifications are on top of the previously reported modifications from the first two years of our report: making a fast, portable (the source code has been compiled on multiple architecture/OS/compiler platforms), modular version of Takfaa using the geometry on a pixel-to-pixel basis.

We participated in the field observations of Asian Dust events over the Monterey Bay in April 2003, along with many other researchers in the ADAM (Asian Dust Above Monterey) collaboration. We obtained some imagery with the PHILLS; unfortunately, it was not on the best days (in terms of the presence of Asian dust), and so we were not able to fly above, in, and below the dust layers, as was originally planned. Our collaborators did sample the Asian dust, where the layers were located, etc., and we anticipate being able to use the results of their research in the future to characterize the Asian dust that crosses the Pacific. This will allow us to build some aerosol lookup tables for similar events.

We are still in the process of calculating the Asian dust aerosol models, a project which has run behind schedule. We are in the process of writing papers about our research results. Of particular interest are the scenes at the time of the 2001 Leo-15 experiment.

3.3 RESEARCH RESULTS

During the first year of the SIMBIOS program we analyzed scenes from April, 2000, when AVIRIS flew under MODIS and SeaWiFS over the MOBY site (see Figures 3.1 & 3.2). We developed software to navigate the AVIRIS scene, and additional processing software to transfer the AVIRIS radiance measurements to space. We found that near 0.47 micron, the observed reflectance (corrected to the top of the atmosphere) for AVIRIS is 9% greater than that measured by MODIS; at 0.747 micron the difference is about 8%, with the MODIS values being greater than those of AVIRIS. Comparisons of water-leaving reflectance showed that MOBY agrees quite well with MODIS, but not with AVIRIS. This was, however, based on a single underflight, and the results needs to be revisited as all the instruments have different calibrations now than in the past.

The modifications to the base multi-spectral version of Tafkaa have continued. The modifications allow Tafkaa to execute more quickly, as well as increasing the types of aerosols available. As these modifications have occurred in the base version, it takes little more than recompiling the source code in order to propagate the modifications to the executables for the sensor-specific versions of Tafkaa.

We have processed several scenes from MODIS and SeaWiFS data with the pixel-to-pixel versions of the atmospheric correction code. For MODIS scenes, our algorithm and Gordon's algorithm return very similar results over areas of the open ocean. Our algorithm makes use of both the ocean channels of MODIS, as well as the land channels. Use of the land channels allows us to perform atmospheric corrections in certain turbid areas where the normal algorithms fail – for example, in areas with enough sediment so that there is measurable signal at 0.75 micron (see Figure 3.3). MODIS land channels also give us flexibility in presenting spectra when the ocean-color channels saturate, as can happen in certain circumstances as in some turbid waters as well as in some regions with coccolithophores (see Figures 3.4 & 3.5). For SeaWiFS scenes, our results tend to differ. First, the SeaWiFS correction uses the 0.765 mm band, a band that encompasses the O2 A-band absorption feature. Because of the presence of the strong absorption feature, it is difficult (impossible?) for our algorithm to use this band as the basis of atmospheric correction. Likewise, maps of the 0.665 mm band show that coastal ocean color features are still visible in that band, making it impossible to use that band for atmospheric correction.

Other areas of research include B.-C. Gao's collaborations to study methods of discriminating the effects of cirrus clouds and aerosols at longer wavelengths (Gao et al., 2002) and algorithms for masking sediment laden waters where it is necessary to use longer wavelengths to achieve any atmospheric correction (Li et al., 2003).

Products

We have shared previous versions of our algorithms with groups at GSFC and NRL-Stennis. Current source code, executables, look-up tables, and user guides for the atmospheric correction algorithms will be provided to the SIMBIOS office.

3.4 CONCLUSIONS

We have made progress in modifying our atmospheric correction algorithm to be used with multi-spectral data from MODIS and SeaWiFS. Our algorithm takes advantage of MODIS' long wavelength and land bands to provide atmospheric correction over brighter ocean scenes including sediments and coccolithophore blooms. These algorithms now use the complete geometry of each pixel, incorporate new aerosols, and allow for ozone and wind speed to vary on a pixel-by-pixel basis. Our results are promising, especially over turbid areas. We are in the process of refining our algorithms and are involved in testing with both groups working with the SIMBIOS program at GSFC and NRL-Stennis.

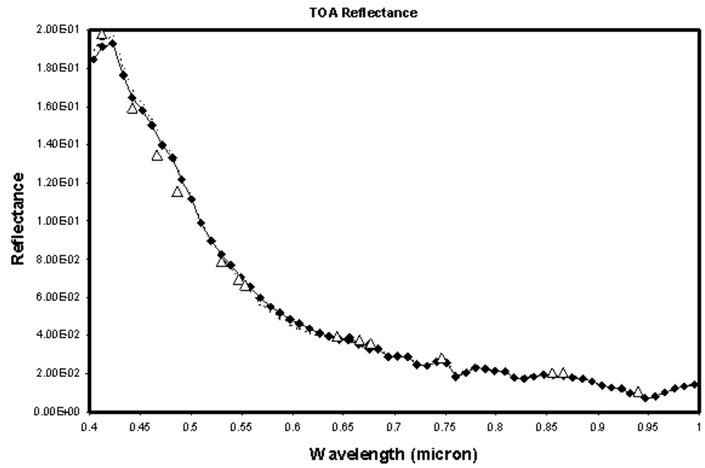

Figure 3.1: Top of the atmosphere reflectance observed near the MOBY site by AVIRIS (dashed line) and MODIS (open triangles). Note that while the radiance measurements are generally in good agreement, the AVIRIS radiance near 0.4 micron is significantly less than radiance observed by MODIS. The AVIRIS radiance at 0.747 micron is also about 10% less than that measured MODIS. The solid line with solid diamonds is the observed atmospheric reflectance before being transferred to the top of the atmosphere.

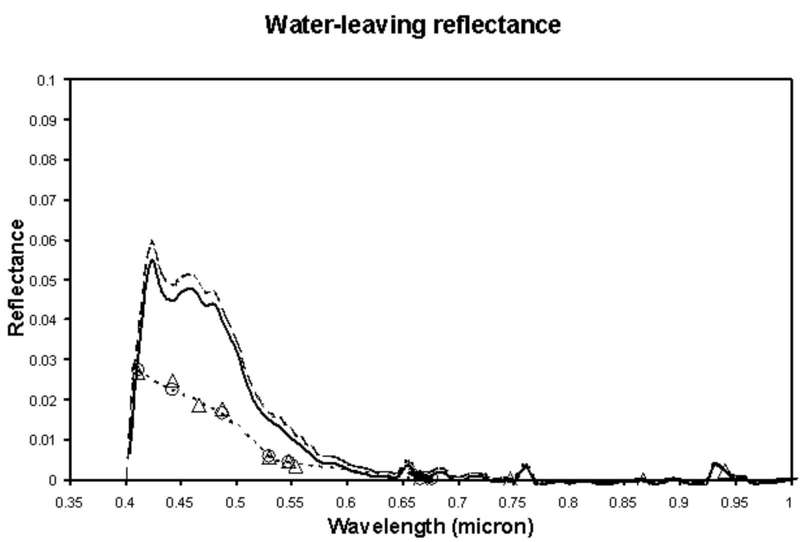

Figure 3.2: Derived water-leaving reflectance spectra from AVIRIS and MODIS (open triangles), compared to MOBY (open circles, small dashes) measurements. The solid line is AVIRIS corrected using the two MODIS bands near 0.75 micron and 0.865 micron to determine the atmospheric correction. The long-dashed line is the atmospheric correction derived using four window channels longer than 1 micron.

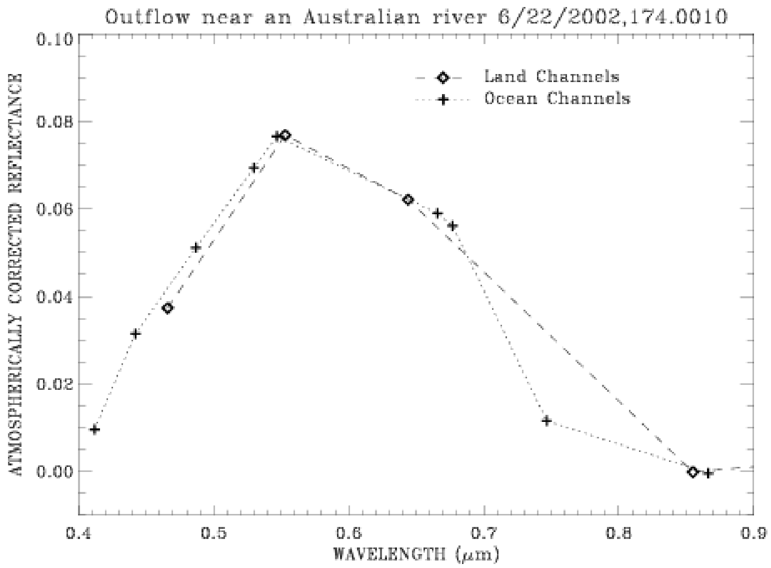

Figure 3.3: Atmospherically corrected reflectance from a MODIS image off the coast of Eastern Australia. The long dashes connect the sets of land channels (open diamonds), and the short dashes connect sets of ocean channels (plusses). These results were derived using some of the land channels and the pixel-to-pixel version of Tafkaa to determine an atmospheric correction. Note, in particular, that our results yield significant water leaving radiance at 0.75 micron. Water leaving reflectance cannot be retrieved for pixels like this one using Gordon's algorithm.

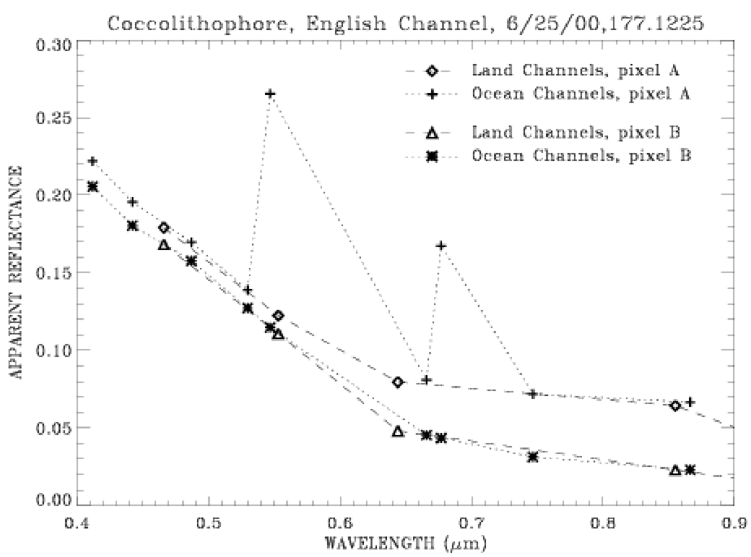

Figure 3.4: The at-sensor apparent reflectance from a MODIS image of the English Channel, 2000 June 25, comparing results from land and ocean channels from two different pixels in a coccolithophore bloom. The long dashes connect the land channels, and the short dashes connect ocean channels. The open diamonds (land channels) and plusses (ocean channels) are from pixel A, which is clearly saturated in the fifth and seventh ocean channels from the left. Spectra from nearby unsaturated pixel B are shown with open triangles (land channels) and asterisks (ocean channels).

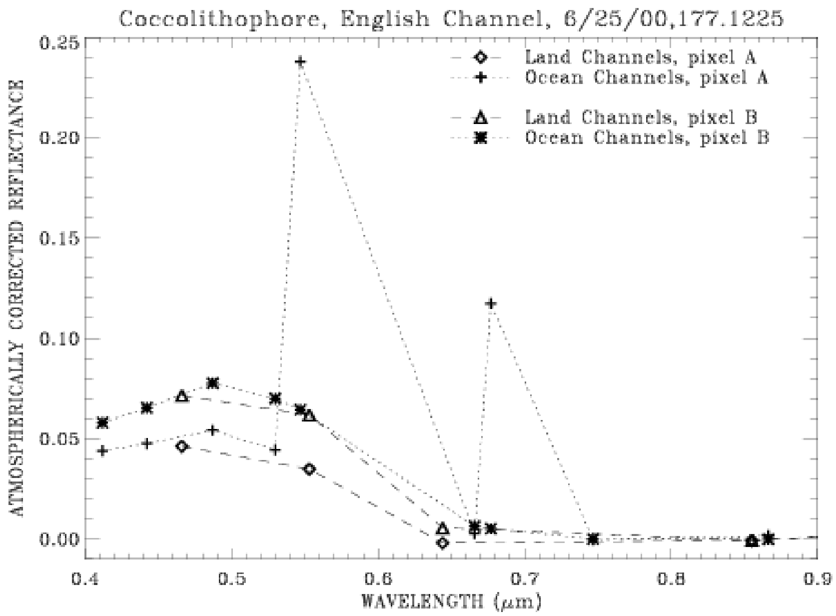

Figure 3.5: Atmospherically corrected reflectance from the same locations as in Figure 4. The symbols are the same as in Figure 4. Note the quite reasonable agreement between the atmospherically corrected land channels and ocean channels except for the two saturated channels.

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