Development of Water Correction Algorithm for Underwater Vegetation Signals

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The unique spectral characteristics of green vegetation, low reflectance in red and high reflectance in Near-Infrared (NIR), have been used to develop vegetation indices, such as Normalized Difference Vegetation Index (NDVI). Our preliminary studies suggest that NDVI was not a useful indicator for submerged aquatic vegetation (SAV), even in clear water, due to energy absorption by water in the NIR region. In order to improve the use of the vegetation indices, we modeled the depth-induced water absorption and scattering through a controlled indoor experiment. We used a GER 1500 spectroradiometer to collect spectral data over an experimental water tank (70cm tall, 50cm wide) that was deployed with a black panel or a white panel at a time; the panels were cut to fit the bottom of the tank. Our assumptions were: (1) the black bottom panel absorbs 100% incoming light; (2) the white bottom panel reflects 100% incoming light; and (3) the water volume scattering and absorption remains the same for the two conditions (black and white bottoms) at a given depth. The measured upwelling radiance was converted to % reflectance. We developed correctional algorithms for water scattering and absorption using the reflectance data. After finding the contribution of these features, we were able to remove the water effects from the measured data. The SAV reflectance that was corrected using the algorithm produced a spectral signature more closely resembling those of terrestrial vegetation. The application of the algorithm significantly improved the vegetation signals, especially in the NIR region. Our results suggest the conventional NDVI: (1) is not a good indicator for submerged plants even at shallow waters (0.3 m); and (2) the index values can significantly improve once the water effects are modeled and removed.

Key words: Methods, Models, Surface Water

Introduction

Over the past three decades, satellite/airborne sensors have been utilized to collect land cover information as well as to provide insight into the objects and processes that occur within water bodies. In order to collect information and data through remote sensing, a substantial amount of electromagnetic radiation (EMR), either reflected or emitted from a target under investigation, need to be detected and recorded by the sensor.

When your target is an underwater object, the process becomes more complicated as the light energy (EMR) is absorbed by pure water. The water absorption increases with wavelength, which makes it virtually hard to detect signals within the Near-Infrared (NIR) regions. In addition, EMR signals from a natural water body contain information on the pure water properties (i.e. water surface reflectance, water column scattering), suspended inorganic/organic solids, phytoplankton chlorophyll and other pigments, colored dissolved organic carbon, and water bottom backscattering.

The unique spectral characteristics of green vegetation, low reflectance in red and high NIR, have been used to develop vegetation indices, such as Normalized Difference Vegetation Index (NDVI). Our preliminary studies suggest that NDVI was not a useful indicator for submerged aquatic vegetation (SAV), even in clear water, due to energy absorption by water in the NIR region. In this study, we applied a water correction model that was developed using our experimental data in an image taken over seagrass beds to see if the algorithm application would improve the benthic signals.

Objective

The objective of this study was to test our water correction algorithm using a hyperspectral airborne image for its preliminary validation. The algorithm was developed based on experiment-driven water absorption and scattering coefficients.

Methods and Materials

Algorithm Description

Indoor controlled experiments were conducted to collect water depth-variant spectral information over an experimental water tank (70cm tall, 50cm wide) that was deployed with a black panel or a white panel at a time; the panels were cut to fit the bottom of the tank. The data were collected using a GER 1500 Spectroradiometer, made by Spectral Vista Corporation. The unit has a spectral range from 350 nm to 1050 nm, internal memory of 500 scans, and a field of view (FOV) of 4° and 23° option with fiber optic. Our assumptions were: (1) the black bottom panel absorbs 100% incoming light; (2) the white bottom panel reflects 100% incoming light; and (3) the water volume scattering and absorption remains the same for the two conditions (black and white bottoms) at a given depth. The measured upwelling radiance was converted to % reflectance. Water volumetric reflectance (%) was calculated using the data collected over the black panel (bottom reflectance = 0); and the water absorption (%) was calculated using the reflectance values measured over the white panel (measured reflectance = incident light – total water absorption + bottom panel reflectance + water volumetric reflectance). As a result, we obtained the absorption and volumetric reflectance correction coefficients (%) within a depth range from 0 to 70 cm and within a wavelength range from 400 to 900 nm (Cho and Lu, in press).

Algorithm Application

In order to apply the algorithm in an image, we selected an area of Mission-Aransas National Estuarine Research Reserve in Texas, where seagrass is abundant and water is generally shallow (< 2 m). The image data were obtained by AISA Eagle Hyperspectral Sensor and preprocessed and distributed by University of Nebraska at Lincoln Center of Advanced Land Management Information Technology (CALMIT) in the fall of 2008. After preprocessed for atmospheric and geographic corrections, the image data had 63 bands within a spectral range from 400 to 970 nm with a spectral resolution of 2.9 nm and a spatial resolution of approximately 1 m. The general coordinates for the image subset that we used are 685627.21 E and 3089698.35 N meters in the UTM Zone 14 North.

We conducted a spectral subset to include only the five hyperspectral bands that have been proven to contain critical vegetation information from our previous studies (Cho et al. 2008). The five bands are centered at 553.9, 694.6, 722.9, 741.7, 808.8 nm. In the ERDAS Imagine 9.1. Model Builder, we separated the five bands from the input (original) image, applied the correction algorithm using the appropriate coefficients for each of the wavelengths, then re-stacked the bands to create the output (water effect corrected) five-band image (Fig. 1). Using ENVI 4.1, the two images were opened and linked to compare the spectral profiles of the seagrass beds.

Results and Discussion

The original and the corrected images are shown in Fig. 2. The images are shown using the color infrared composite (Red: 722.9 nm; Green: 694.6 nm; Blue: 553.9 nm). The dominant color of the original image is blue (Fig. 2), indicating that the energy reflected at 553.9 nm much exceeded that at 722.9 nm or at 694.6 nm. The pink dominated colors of the corrected image indicated the relative reflectance of the bands have been changed. When spectral profiles of selected seagrass pixels were viewed (Fig. 3), it is evident that the application of the algorithm improved the vegetation signals, especially in the red and NIR regions. The digital number (DN) values for the original bands were % reflectance X 10 and the corrected image has the DN values representing % reflectance. Our results suggest the red and NIR signals from benthic features of a relatively clear, shallow water body can be improved significantly once the water effects are modeled and removed.

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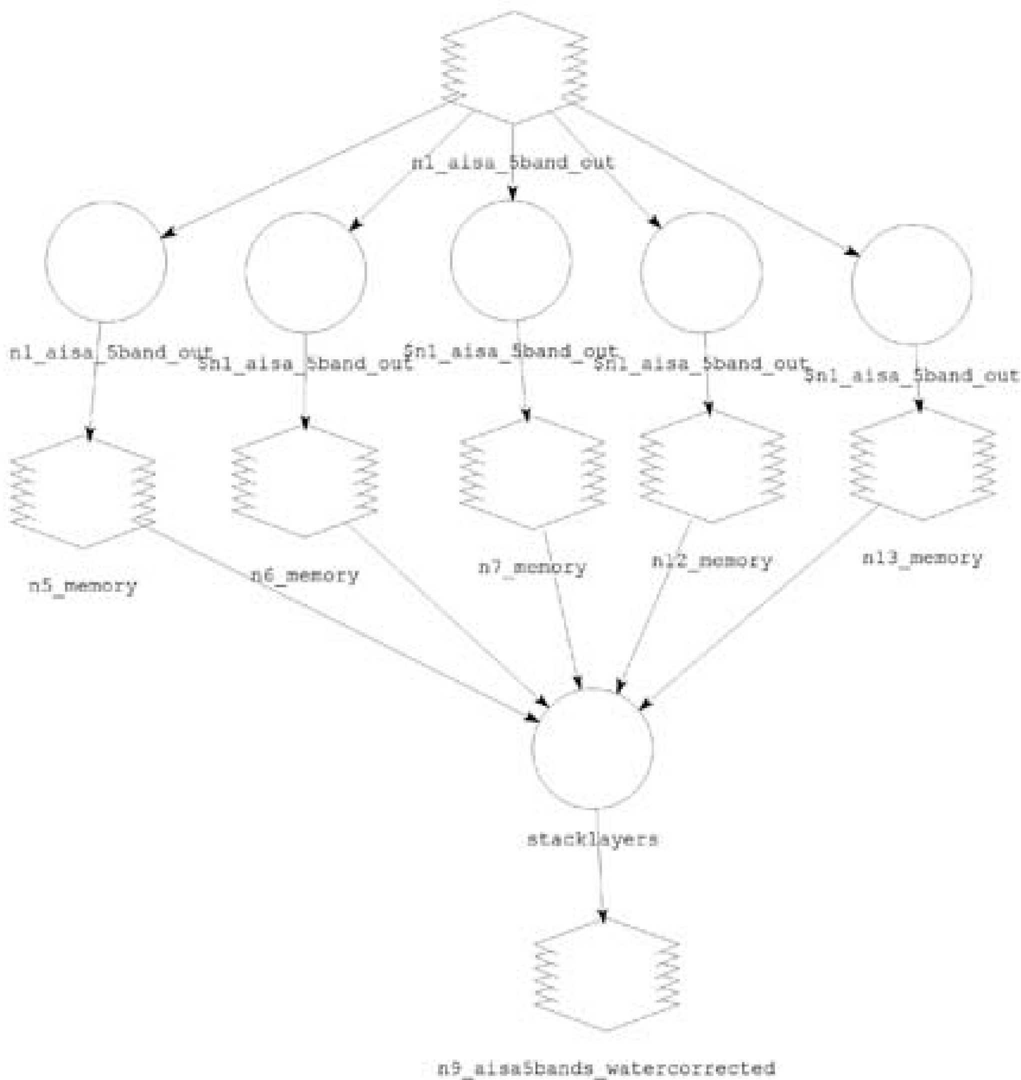

Figure 1. A schematic algorithm application using a five band image data in Model Builder of ERDAS Imagine 9.1.

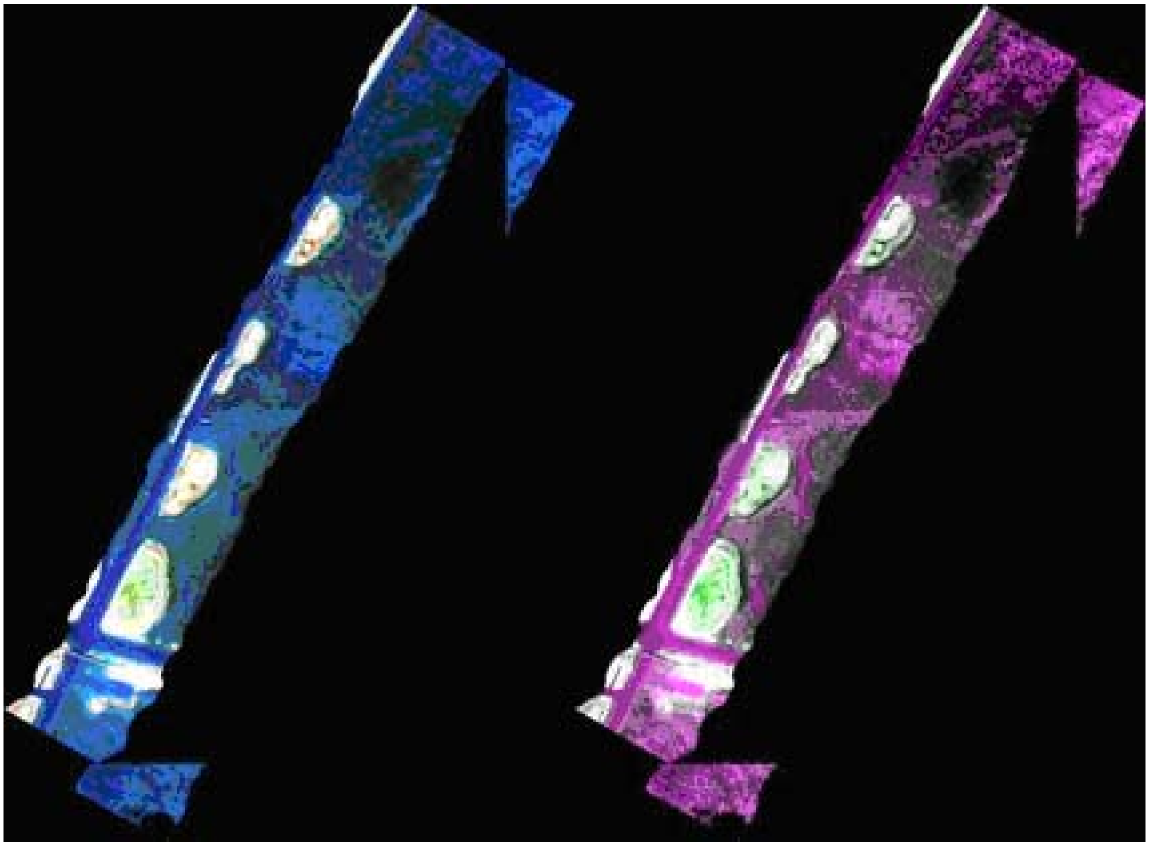

Figure 2. The original (left) and the corrected (right) subset image of airborne AISA data obtained over seagrass beds in Mission-Aransas National Estuarine Research Reserve, TX.

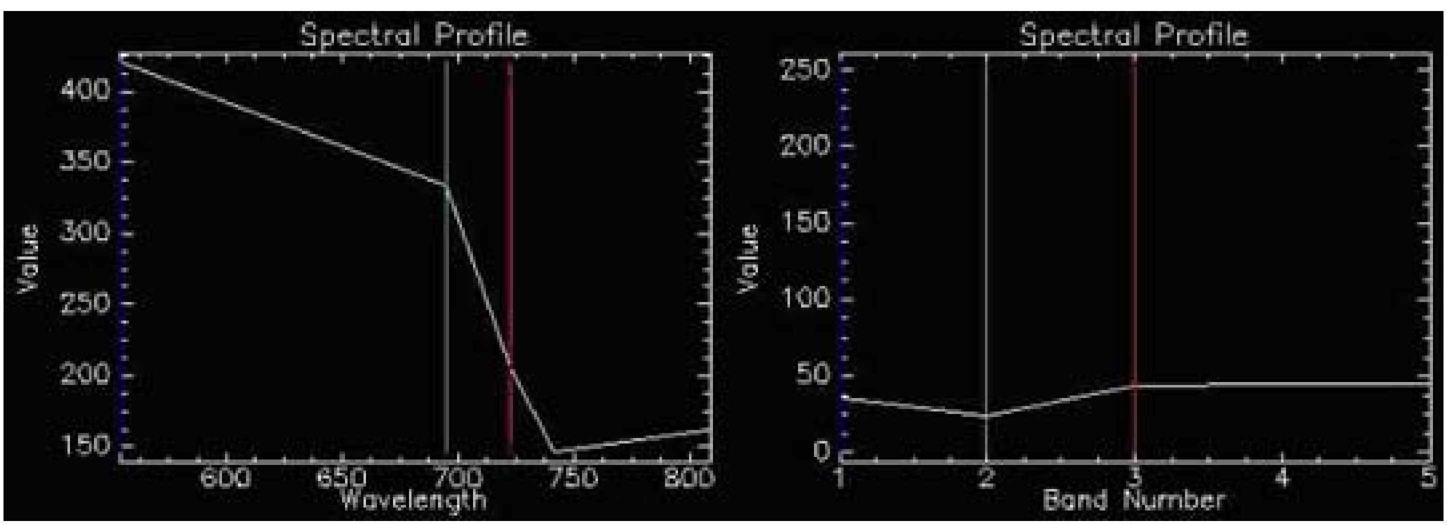

Figure 3. Spectra profiles of a selected seagrass pixel. The left is the original spectra profile and the right shows the profile after the correction using the algorithm.