**Measuring Coastal Marsh Vegetation Structure Using Multi-angular Remote Sensing**

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**ABSTRACT**

Radiative transfer can provide useful information about ground cover conditions, including vegetation structure parameters. It is hypothesized that remote sensing from multiple viewing angles could provide leaf area index (LAI) for coastal marshes. This paper introduces a study that focuses on possible methods of retrieving LAI using field measurements in the field and geographically referenced airborne remote sensing. Novel aspects of this study include:

- **Leaf area index (LAI)**, defined as the ratio of one-side leaf area to area of ground area, can be used to infer vegetation structure to photosynthesis and radiation absorption. To understand how LAI can be retrieved for coastal vegetation using multi-angular remote sensing, this study makes three main components: 1) ground data, 2) satellite data, and 3) retrieval methods.

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**INTRODUCTION**

Marshes play an important role in coastal hydrology, geophysical cycling, erosion control, and provide essential habitat for many coastal flora and fauna. However, coastal marshes are often disturbed by frequent erosions, flooding, fire, and other natural and anthropogenic disturbances. Efforts have been made to assess and monitor these landscapes to understand their vital processes and to aid in management. However, measuring marshes can be quite difficult, making large-scale, in situ evaluation challenging. Remote sensing techniques offer an efficient method to understand coastal marshes.

Leaf area index (LAI), defined as the ratio of one-side leaf area to area of ground area, can be used to infer vegetation structure to photosynthesis and radiation absorption. To understand how LAI can be retrieved for coastal vegetation using multi-angular remote sensing, this study makes three main components: 1) ground data, 2) satellite data, and 3) retrieval methods.

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**SATELLITE DATA**

This component of the study evaluates multi-angular imagery from spaceborne instruments with relatively high spatial resolution (15-20 m at nadir), specifically the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) aboard the NASA satellite Terra or the Compact High Resolution Imaging Spectrometer (CHRIS) aboard the Project For-Orbit-Arrayed Profiler (Proba) for applicability to LAI retrieval over coastal marshes.

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**2a. error ASTER**

The ASTER instrument was launched in 1999 aboard the NASA Terra spacecraft. ASTER has 14 bands covering the earth surface and atmosphere, multiangle data collection, and an ASTER scene. The image matches the gold rectangle in the map below. The ASTER scene was collected over the Blackwater Marsh National Wildlife Refuge on 4 September 2007. This will be used in this study primarily to validate retrieval methods (as a ground truth collection) and geocode the CHRIS data. However, because marsh landscapes are relatively flat, the stereographic bands might also provide valuable information about LAI. To test this hypothesis, the ASTER data will be compared to radiometric measurements made on the ground (within a few hours of the overpass) and LAI measurements that were made within two weeks of the same. The ground data was taken along Maple Dam Road (ground map above).

Additional work will be needed to reduce noise sources. Although the atmospheric reflectance is low in the NIR, some contribution to the vegetation bidirectional reflectance distribution function (BRDF) can be expected and so atmospheric effect should be removed. This can be done using the field data in a relative transferability model. In addition, spatial distribution of pools and other bodies of water in a grid could induce variations in the vegetation BRDF (see description for component 3 of this study).

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**2b CHRIS Proba**

The Compact High Resolution Imaging Spectrometer (CHRIS) aboard the Project For-Orbit-Arrayed Profiler (Proba) is a programmable spectrometer that has high spatial resolution (15-30 m at nadir) and spectral resolution (18 bands visible to NIR for 60 m at nadir), and is on the Blackwater Marsh National Wildlife Refuge a second time about 20 km from hex. Therefore, four would determine natural or in the study (three over the Blackwater Marsh study). Mode 3A was selected for these acquisitions because of the high gain settings would be useful for the lower reflectance common to marshland. The five nominal viewing angles are 45°, 55°, 65°, 75°, and 85°.

Atmospheric correction of the data is being done using algorithms developed by Lin-Guenter (Guenter et al. 2000). Guenter is being of the data is being done using in situ image measurements with the ASTER image described above. CHRIS photo-quad are also available to supplement geolocation is necessary. Data will be compared to ground measurements taken during September and October 2007.

Having samples of the vegetation BRDF sampled at multi viewing angles will allow more options to retrieve vegetation structure information. Although very few acquisitions fail the study area in one view, because of water, including drift, cloud, or interfering error, at least three views, close enough to ground measurements to be useful. The availability of prospectual data will allow other opportunities to explore external effects over the BRDF, especially in the presence of water.

Figure 2 shows also an increase in the vegetation BRDF at 80° in the same 2.5° view with increasing viewing angle. The image matches the region within the grid rectangle in the map above, line of the powder. For the CHRS Proba, the Southern Landscape of the USA, and in early August 2004, the USB2000 spectrometer was used. This instrument was configured with a 100 m aperture and 3.2 collection, line, and was set for a 2 m integration time and a 50 sample average. The USB2000 was equipped with a 15° aperture Goniometer tube to a 500-1 m multi-mode optical cable suspended 5.3 m from the roof with nontwisted, no-silphonated, no-silphonated. The vehicle again moved at about 60° north, while GIS happened continuously every second. For all, a Spectrum white reference was used to calibrate reflectance.

LAI measurements were taken every 1.9 m of a ridge, in one September and once in early October. USR 2000 used was with a 40° view and 16 second dwell time or right of the view. The measurements were taken in the late afternoon to avoid direct sunlight. LAI was scanned using the angle at the center of the sun (the horizon) so that any variation would be included. The scan for each LAI measurement included one reference measurement taken above the canopy, for every four scans taken below.

Data was co-registered using GIS data and matching features in the transect and performing a linear spline. Further refinement in positioning the data is essential from multi-band features from terrestrial reference system (STRS). From the ASTER satellite imagery, this registered data can be better georectified and associated with a relative azimuth angle. This data would be interpolated to the same georeferenced grid for comparison and model inversion.

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**3. RETRIEVAL METHODS**

This component of the study, a method to retrieve marsh LAI is developed from the multi-angular data collected. Initially, two approaches to retrieving LAI were developed, one from the compact BRDF (satellite and ground measurements) and LAI. However, it is more promising to invert a relatively flat marsh BRDF using the AER algorithm on LAI data (Ramsey et al. 1995). More recent work by Tan et al. (2007) produced LAI to an accuracy of 42% by integrating over a mean gap probability based on kernel models and a directional normalized difference vegetation index (NDVI). Given the relatively high reflectance of vegetation to water in the NIR, away from specular reflection, BRDFs of marsh vegetation are available, multiple views may be possible by assuming a black background (Ross 1984; Campbell and Norman 1998). Taking in ASD field-based measurements including models such as the Siegel’s, incremental reflectance Least-Squares (LSQ) model (Verhoef 1984) or the New Advanced Discrete Model (NADM) (Gaussian et al. 1993) has been shown to be effective for other types of land cover, and may also used for the marsh. The chosen approach is to run these models in the forward direction over many LAI values, given sun angle, leaf optical and orientation properties. These would be used to build look-up tables for the model. An inversion of the model is done by computing the lookup table that maximizes the square error of canopy reflectance.

Sensitivity analysis will also be done to identify key parameters and noise sources. The augmented methodology will then be parameterized using ground data available from this and other studies. Plan reflectance and transmittance for two dominant marsh species that can be used in the model parametric phase have been provided by the USGS (Ramsey and Randerson 2006). Soil and water samples were taken from the study site to obtain spectral properties needed. BRDF data of marsh vegetation taken by Mulder at 2004 will be used to validate reflectance estimates and verify the retrieved methodology. Given a low sun angle, the AER data that was used to validate the reflectance in the ground view with satellite (e.g., CHRIS and ground data in top).

When scaling up to the course-resolution spaceborne instruments, the presence of open water within a pixel must also be accounted for, in addition to the effect of water within the canopy. Sufficiency large bodies of water (i.e., several times the canopy height), could significantly alter the BRDF within apixel. When the BRDF is strongly influenced by open water, a spectral unmixing scheme off-axis might improve retrieval of LAI from the vegetation component of the signal. This step will require more band data and atmospheric correction.