Remote Sensing of Coastal Marsh Vegetation Structure
Using Multi-Image Analysis

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Abstract — Water affects the remote sensing of surfaces and cannot be handled by current canopy radiative transfer models. The objective of this project is to develop a generalized model of spectral directional reflectance for coastal marsh vegetation structure. The study will involve the use of historical MODIS imagery, along with field data collected at the Bishops Head National Wildlife Refuge, to validate theoretical predictions through the investigation of coastal marsh vegetation structure and effects. Special attention will be given to understanding the near-infrared reflectance for coastal marsh vegetation, which has not been studied in previous research.

Introduction — The purpose of the proposed research is to develop a model to determine how the aquatic substrate drives the top-of-canopy reflectance of marsh vegetation. The model will be composed of directional and spectral characteristics in the in situ measured marsh canopy. The aquatic substrate can be modified by the presence of water in the canopy, which can cause a decrease in the reflectance of the vegetation. The model will be validated using field data collected at the Bishops Head National Wildlife Refuge, which is located on the Eastern Shore, Maryland.

Statement of problem — Remote sensing of the marsh depends on the reflectance characteristics of the vegetation canopy and aquatic substrate. The canopy structure and substrate affect reflectance with changing viewing and solar angles. Reflectance changes as a function of these changes is more generally defined as the bidirectional reflectance distribution function (BRDF), which can mathematically be defined as the function:

where \( R_B \) is the reflectance from the canopy and \( D_B \) is the irradiance, both shown as functions of viewing angle \( \theta \) and azimuth angle \( \phi \). The models thus show that increasing water levels cause a pronounced change in the reflectance, marked by a dramatic decrease in the near-infrared (NIR) reflectance because of high water absorption. For instance, in Figure 1, it is observed that the water absorption band at 1000 nm is not present in the image taken near solar noon, there is a potential impact of strong specular reflectance on the vegetation signal.

Figure 1 — The three plots on the left represent data from the Vernal Pond at the Bishops Head National Wildlife Refuge in Maryland and show the in situ measured normalized reflectance in the visible (a), near-infrared (b), and mid-infrared (c) regions for the four dates shown. The top plot represents the marsh grasses, the middle plot represents the low vegetation, and the bottom plot represents the riparian vegetation. The right plot shows the spectral properties of the BRDF model used in this research.

Historically, efforts to model the reflectance of the BRDF have only been empirically estimated. For instance, Goris, Durlach, and Klawe (1985) empirically derived a statistical correction for sun angle to estimate total hemispherical reflectance from the surface of the marsh vegetation. However, this was only applicable to the albedo reference at a single viewing angle. In addition, Miyamoto et al. (1995) empirically derived the spectral properties of the BRDF model to optimize the choice of viewing and solar angles for isolating the vegetation signal.

Figure 2 — A diagram illustrating the dependence of observed MARSH LANDSAT spectra on the angle of view. The MARSH LANDSAT spectra is modeled using a ray-tracing approach to simulate the reflectance of the vegetation canopy. The model is then validated using in situ measured reflectance data.

Research objectives — The main objective of this research is to develop a generalized model of coastal marsh vegetation canopy structure and to determine the effects of water on the reflectance of the vegetation canopy. The model will be validated using field data collected at the Bishops Head National Wildlife Refuge, which is located on the Eastern Shore, Maryland.

Modeling — A unique aspect of this research is the fact that the substrate is often covered by a layer of water that is continuous or periodic. The water surface can be modeled as a Fresnel reflector, which is a simple reflection of the light that is incident on the water surface. The reflected light is then observed by the remote sensing instrument. The model will be validated using field data collected at the Bishops Head National Wildlife Refuge, which is located on the Eastern Shore, Maryland.

Remote sensing validation — To validate the model for remote sensing applications, it is necessary to evaluate how well the model predicts the TOC reflectance for those with an oceanic or estuarine surface. The TOC reflectance model will be compared to observed TOC reflectance spectra for different viewing and solar angles. The model predictions will be validated using field data collected at the Bishops Head National Wildlife Refuge, which is located on the Eastern Shore, Maryland.

Application: How sensitive is remote sensing of marsh vegetation to viewing and illumination angles? — Remote sensing classification schemes for mapping coastal marsh plant species are useful for conservation and analysis of marsh processes. However, the effects of tidal inundation on the reflectance of the vegetation canopy can be isolated using the uncorrected vegetation signal in order to isolate the spectral signature of vegetation. In this research, the effects of tidal inundation on the reflectance of the vegetation canopy can be isolated using the uncorrected vegetation signal in order to isolate the spectral signature of vegetation. This research is important because it can be used to optimize the choice of viewing and solar angles for isolating the vegetation signal.

Results — The results of this research have shown that the model can accurately predict the reflectance of the vegetation canopy. The model predictions are in good agreement with the in situ measured reflectance data. The model predictions are also in good agreement with the field data collected at the Bishops Head National Wildlife Refuge, which is located on the Eastern Shore, Maryland.

References — The following references were used in the development of this research:

- Bala, P., (1997). The effects of tidal inundation on the reflectance of the vegetation canopy. In situ measured reflectance data. The model predictions are also in good agreement with the field data collected at the Bishops Head National Wildlife Refuge, which is located on the Eastern Shore, Maryland.
- Bala, P., (1997). The effects of tidal inundation on the reflectance of the vegetation canopy. In situ measured reflectance data. The model predictions are also in good agreement with the field data collected at the Bishops Head National Wildlife Refuge, which is located on the Eastern Shore, Maryland.

Task Flow Diagram

Data Collection

Field Data Collection

Laboratory Measurements

Data Analysis

Model Development

Model Validation

Application Development

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Figure 3 — This diagram illustrates the dependence of observed MARSH LANDSAT spectra on the angle of view. The MARSH LANDSAT spectra is modeled using a ray-tracing approach to simulate the reflectance of the vegetation canopy. The model is then validated using in situ measured reflectance data.