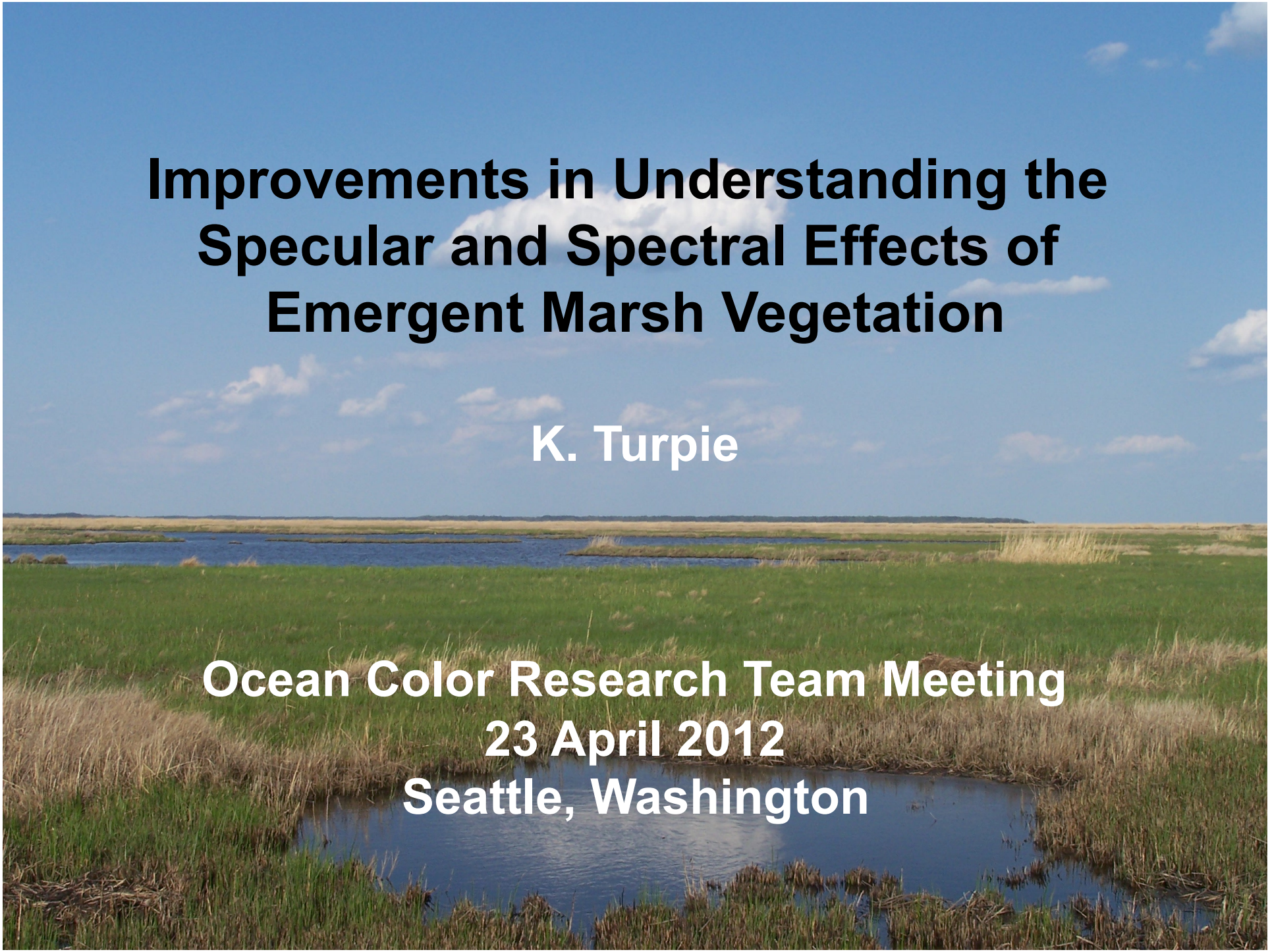


Improvements in Understanding the Specular and Spectral Effects of Emergent Marsh Vegetation

K. Turpie

Ocean Color Research Team Meeting
23 April 2012
Seattle, Washington


PROBLEM
2006/09/20

PROBLEM

- The study of emergent vegetation largely involves parameters familiar to the terrestrial researchers (e.g., LAI).
- However, water at the bottom of a marsh canopy produces **spectral** and **specular** reflectance properties not present in terrestrial canopies.
- These properties can affect and even hamper conventional remote sensing applications designed for terrestrial vegetation.
- **No model existed that describes the effects of an aquatic background marsh canopy reflectance.**

Leaf Area Index

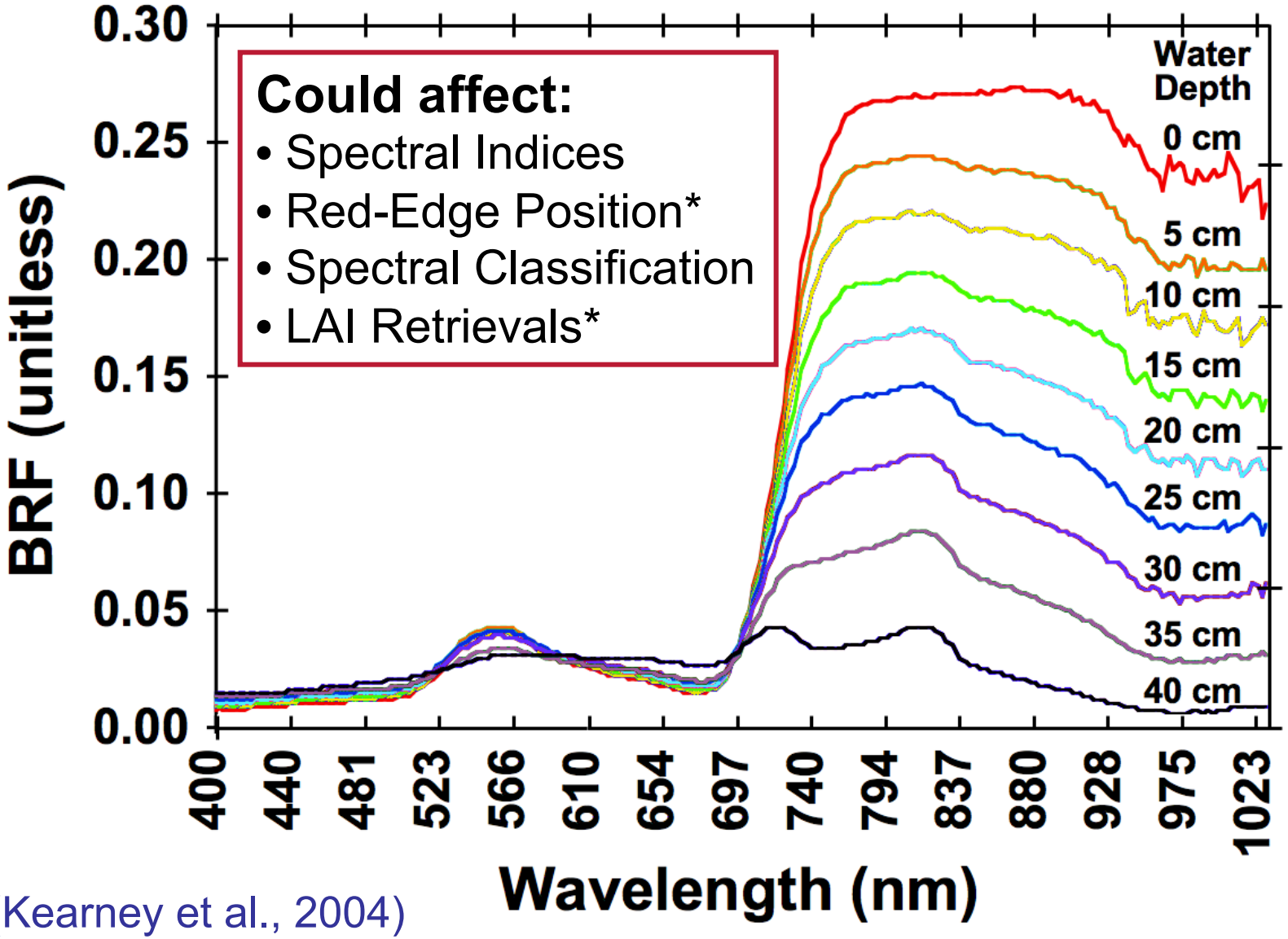
$$LAI = \frac{\text{single side leaf area}}{\text{horizontal ground area}}$$

Examples of applications :

- **Canopy Radiative Transfer**
- **fPAR**
- **Primary Production**
- **Energy Budget**
- **Total or Above Ground Biomass**

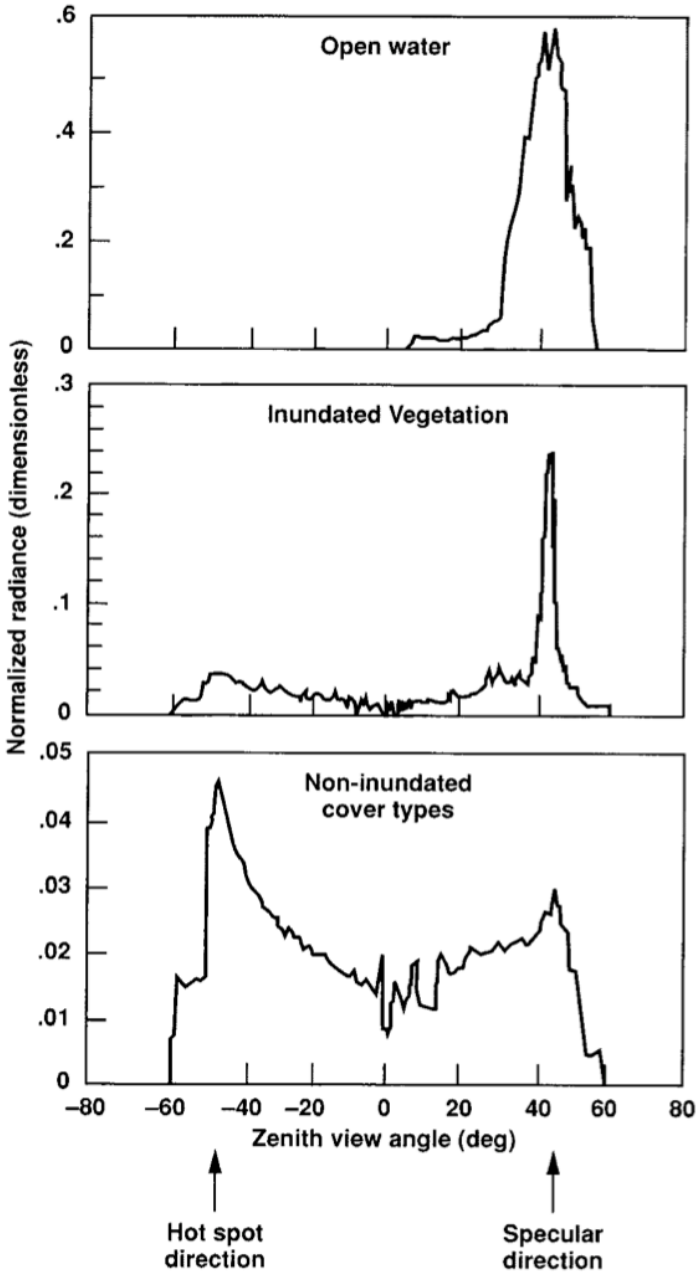
WETLAND SPECTRAL EFFECTS

Inundated Marsh Vegetation Spectrum



(Kearney et al., 2004)

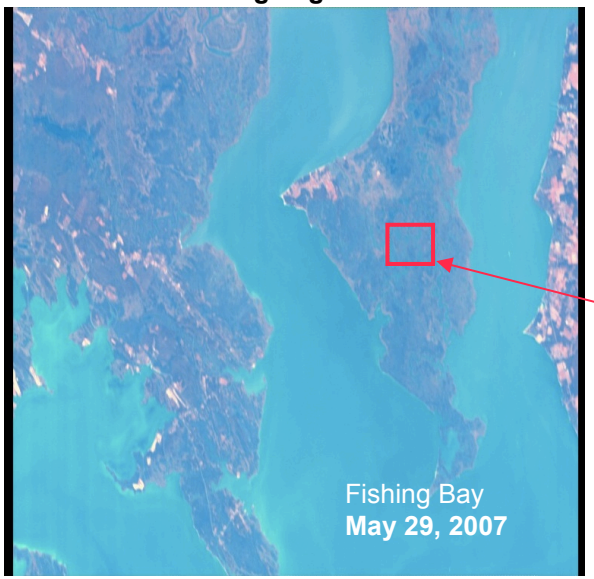
WETLAND SPECULAR EFFECTS

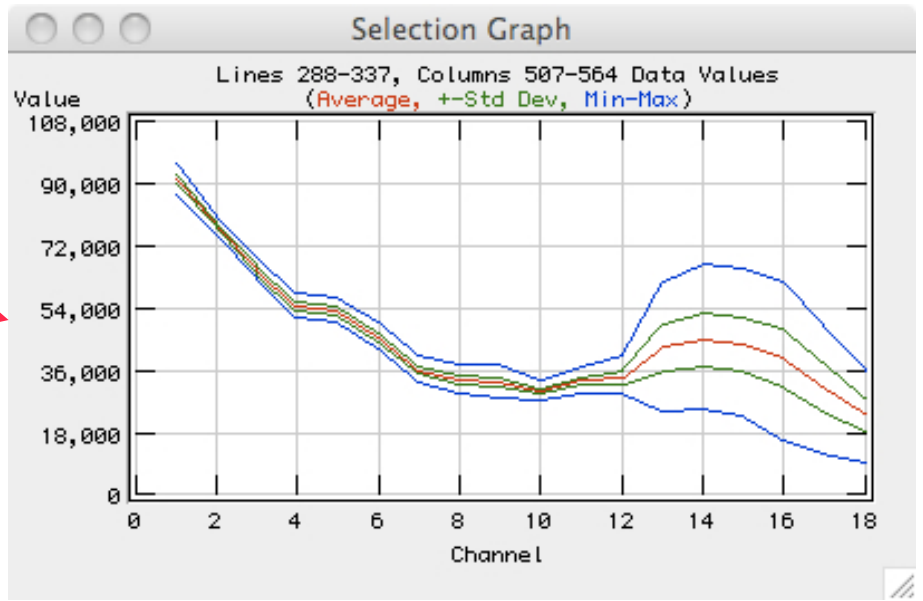


Airborne POLDER
Vanderbilt et al., 2002

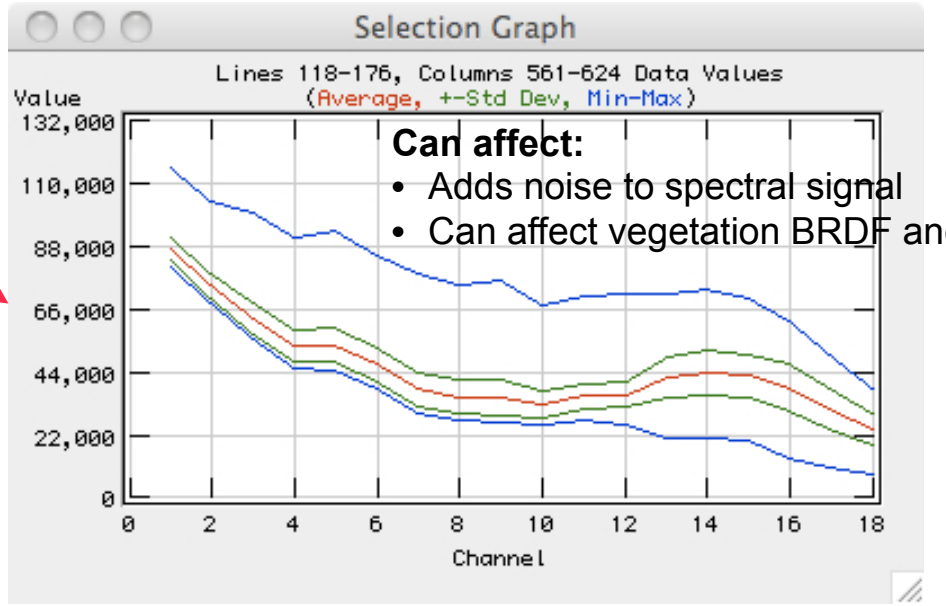
WETLAND SPECULAR EFFECTS

55º nominal viewing angle





0º nominal viewing angle



Can affect:

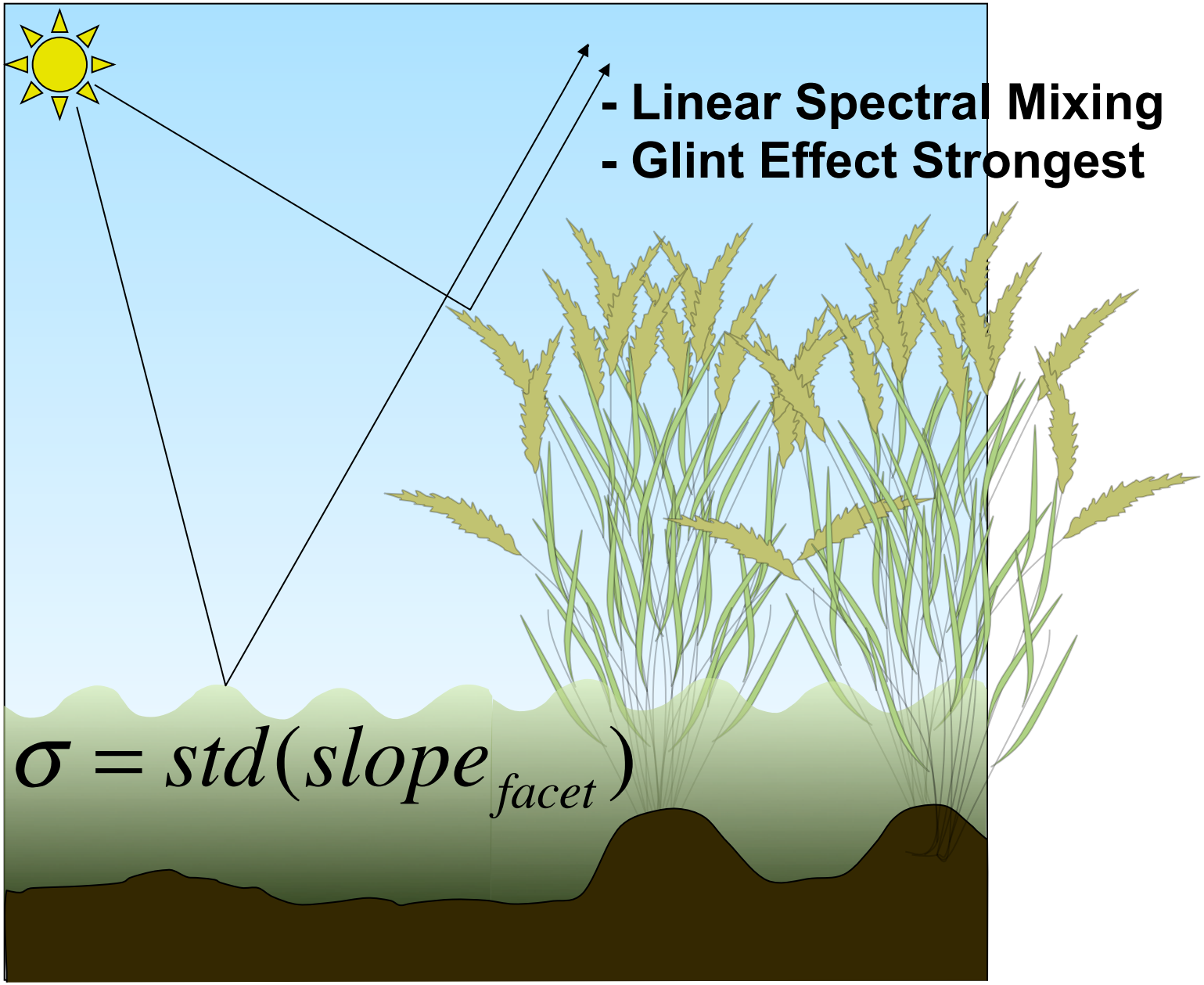
- Adds noise to spectral signal
- Can affect vegetation BRDF and spectrum.

CHRIS/Proba TOA reflectance

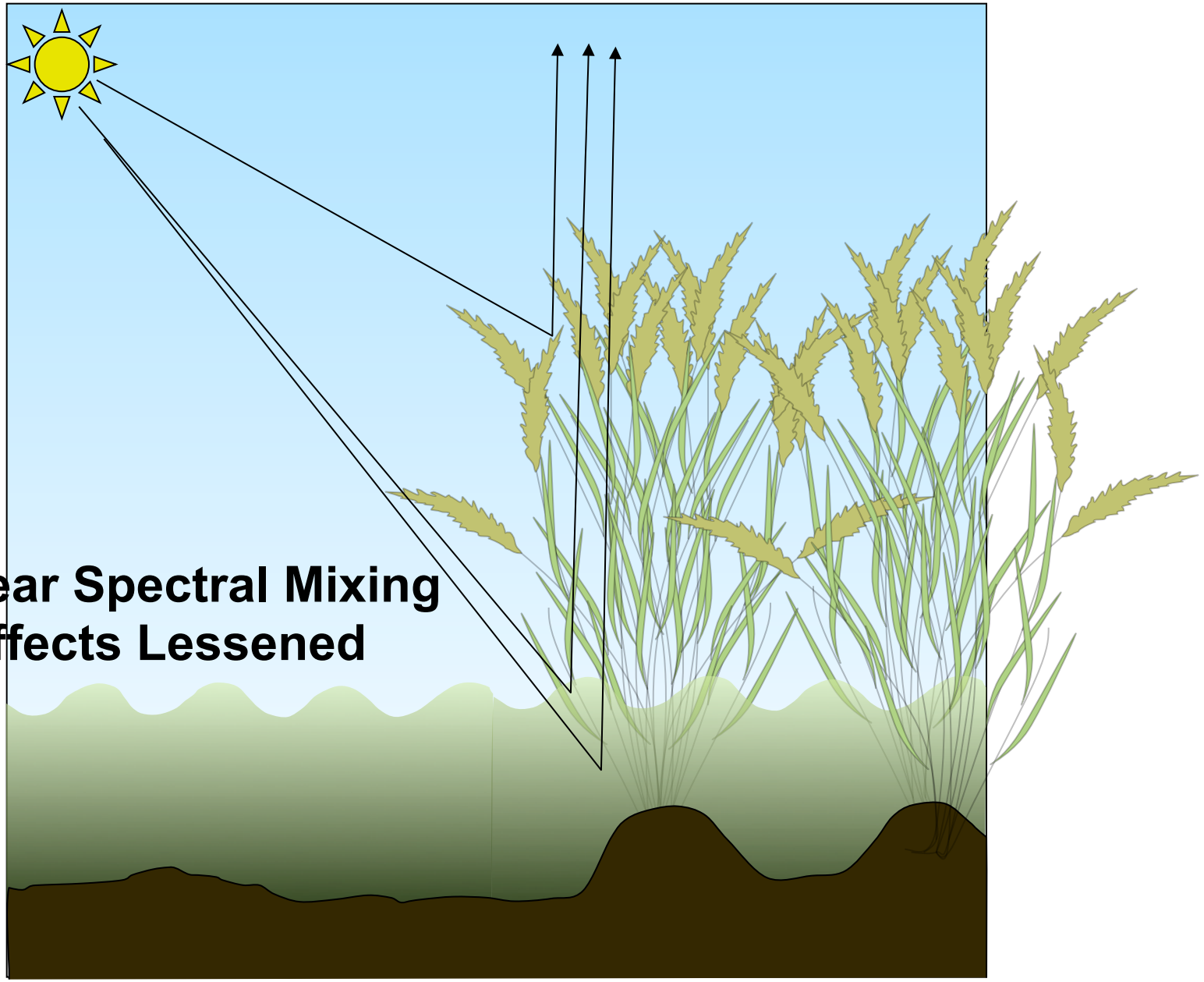
APPROACH

APPROACH

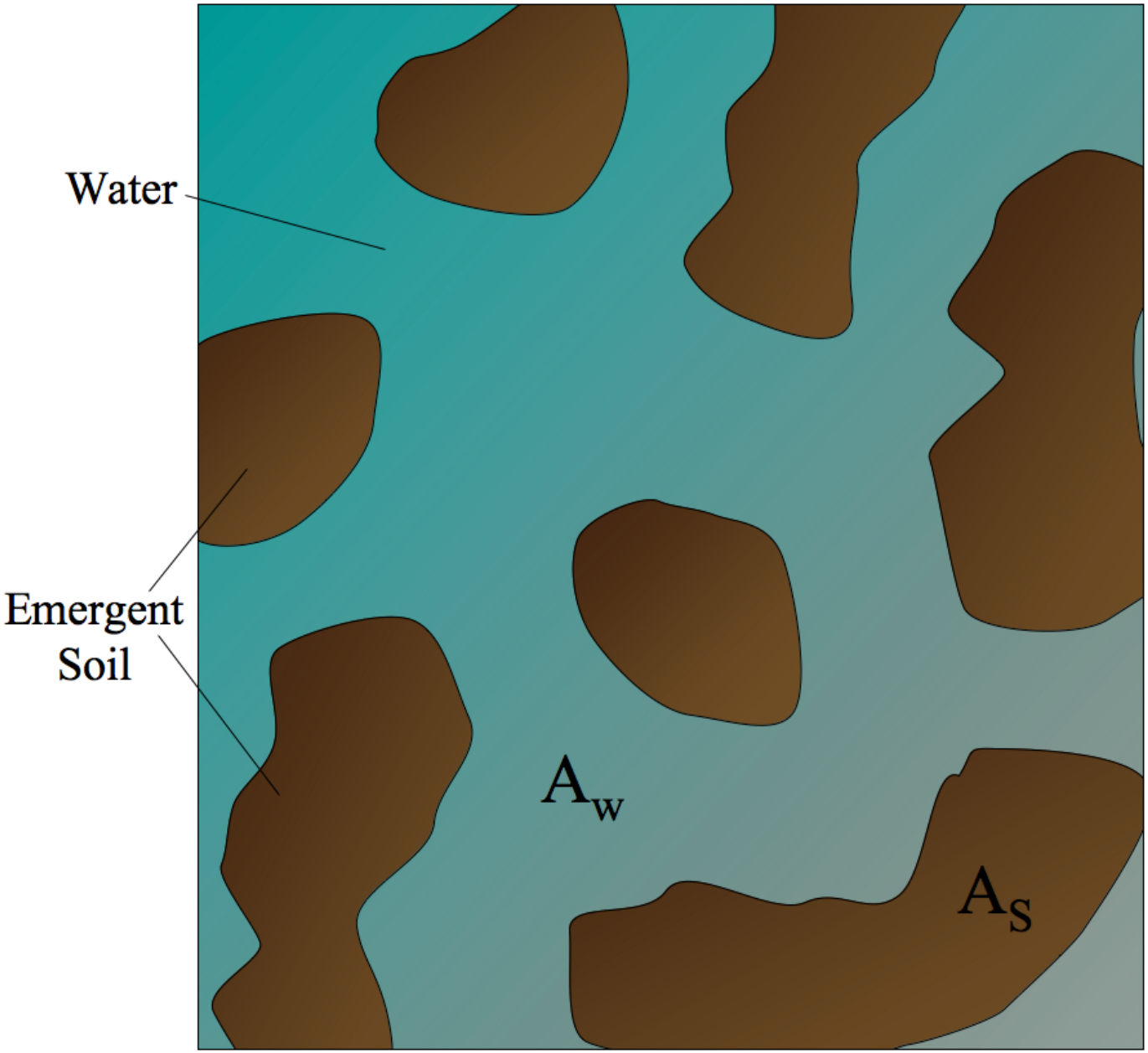
- Construct a model of marsh canopy reflectance to help understand these effects.
- Compare model predictions to data from three field experiments to explore specular and spectral effects.
- Consider how marsh aquatic background affects:
  - retrievals of Leaf Area Index (LAI),
  - vegetation reflectance anisoptropy, and
  - vegetation spectral characteristics, particularly the red-edge.
- This work initiates a bridge between terrestrial and aquatic remote sensing; one necessary where land and sea blend.


- Linear Spectral Mixing
- Glint Effect Strongest
$\sigma = std(slope_{facet})$

-Nonlinear Spectral Mixing
-Glint Effects Lessened



Case of Emergent Soil



$$\beta = \frac{A_w}{A_w + A_s}$$

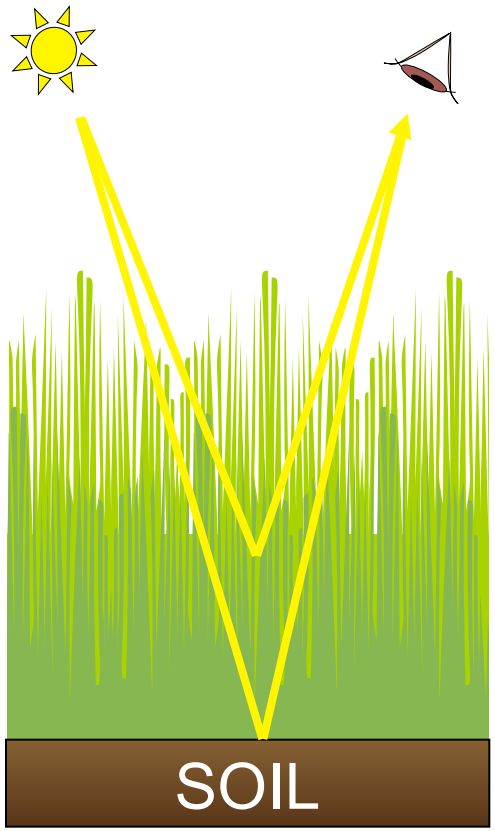
WCRM - Wetland Canopy Reflectance Model Modeling Approach

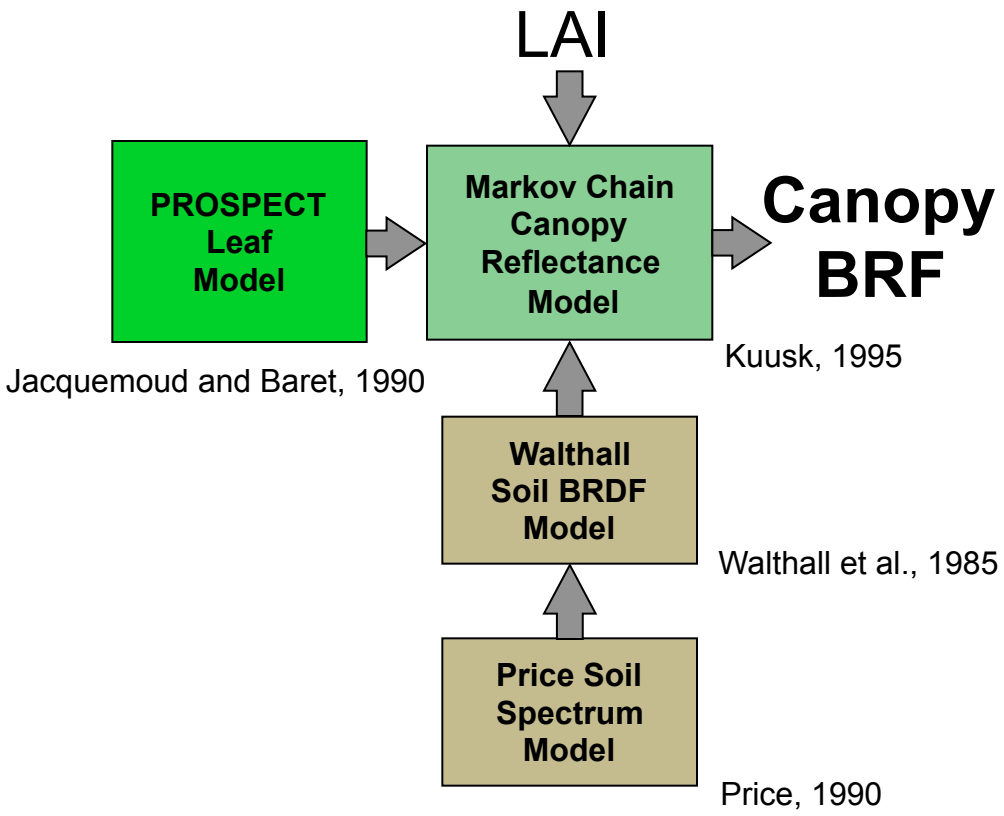
- Combine the **Soil BRDF model** (Walthall, 1985) in the **ACRM vegetation canopy reflectance model** (Kuusk, 1996) with an **aquatic background model**.

$$\rho_{aquatic} = (\beta\text{-}1)\,\rho_{soil} + \beta\,\rho_{water}$$

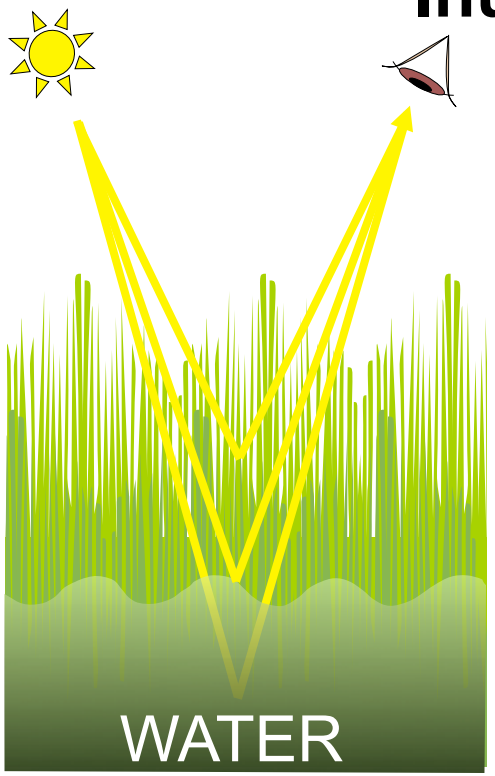
- **Aquatic background model** has a **specular** component and **diffuse** component.
- **Specular component**:
  - Water surface refectance from Fresnel equations.
  - Surface roughness (σ) based on Cox and Munk (1956).
  - Primarily affects **reflectance anisotropy**.
- **Diffuse component**:
  - Sub-surface reflectance using model by Lee et al. (1999).
  - Subsurface reflectance isotropy assumed.
  - Primarily affects canopy **spectral characteristics**.

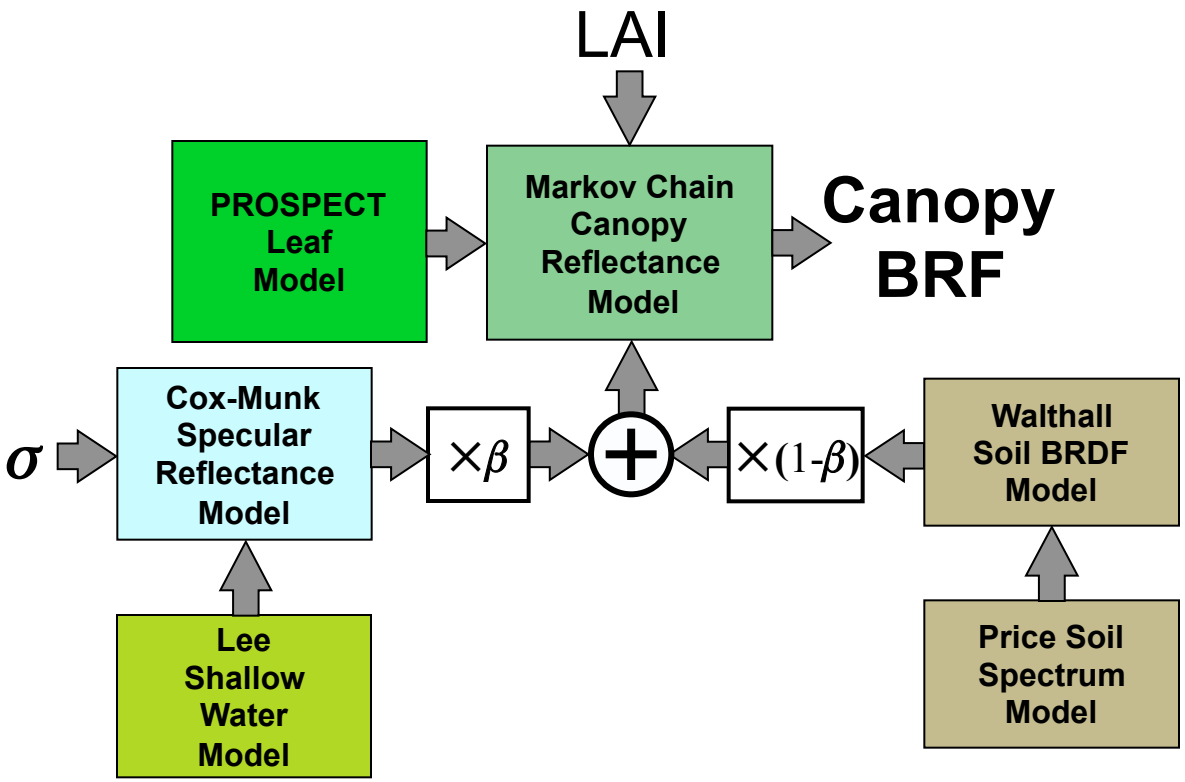
ACRM - Canopy Reflectance Model
Terrestrial Canopy



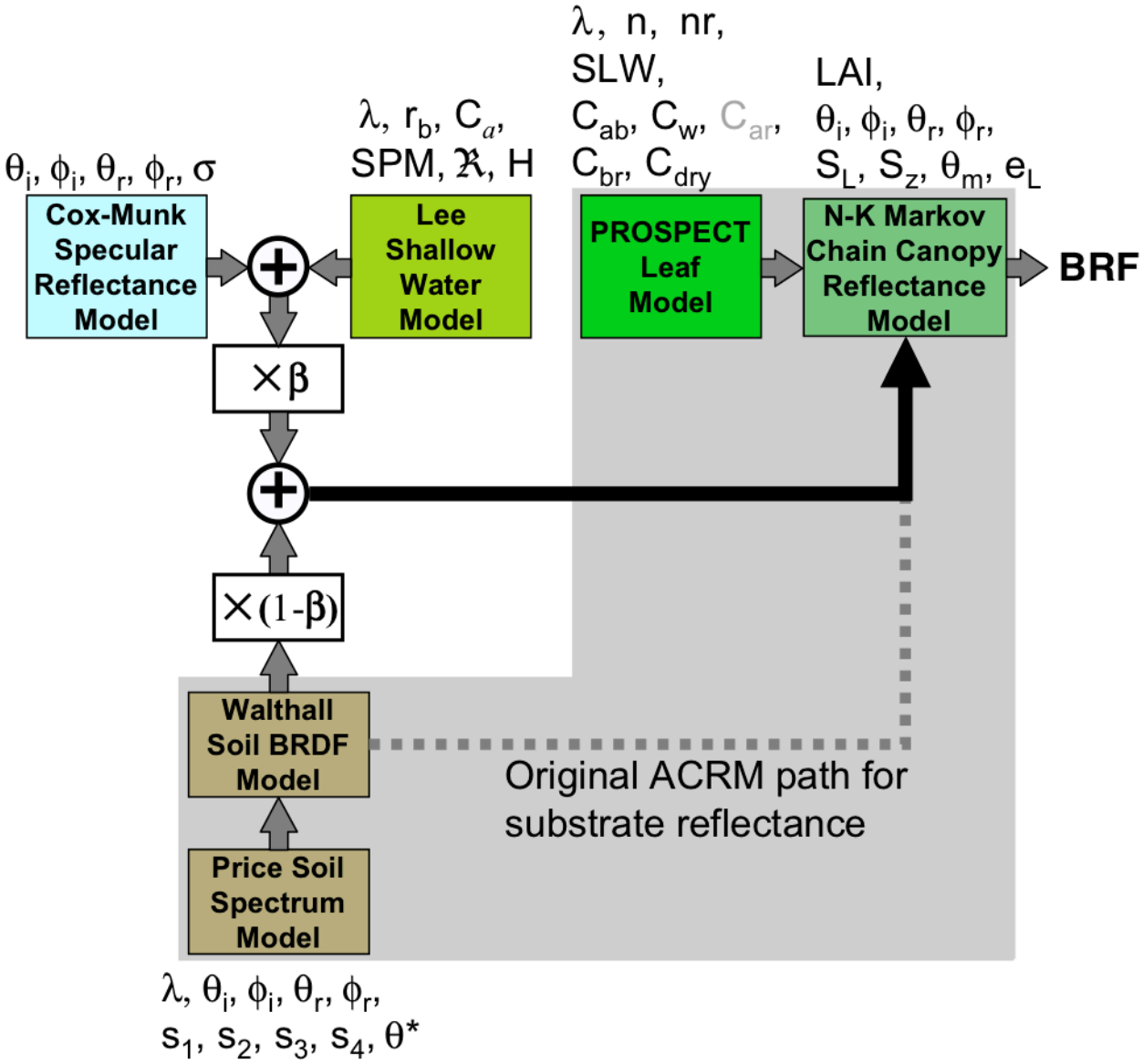


WCRM - Wetland Canopy Reflectance Model
Inundated Marsh Canopy





WCRM - Wetland Canopy Reflectance Model
Inundated Marsh Canopy




SPECULAR EFFECTS
2006/09/20

MARSH BRF EXPERIMENT

Data

Taken by Steven Schill in S. Carolina, 12 Oct 2000.

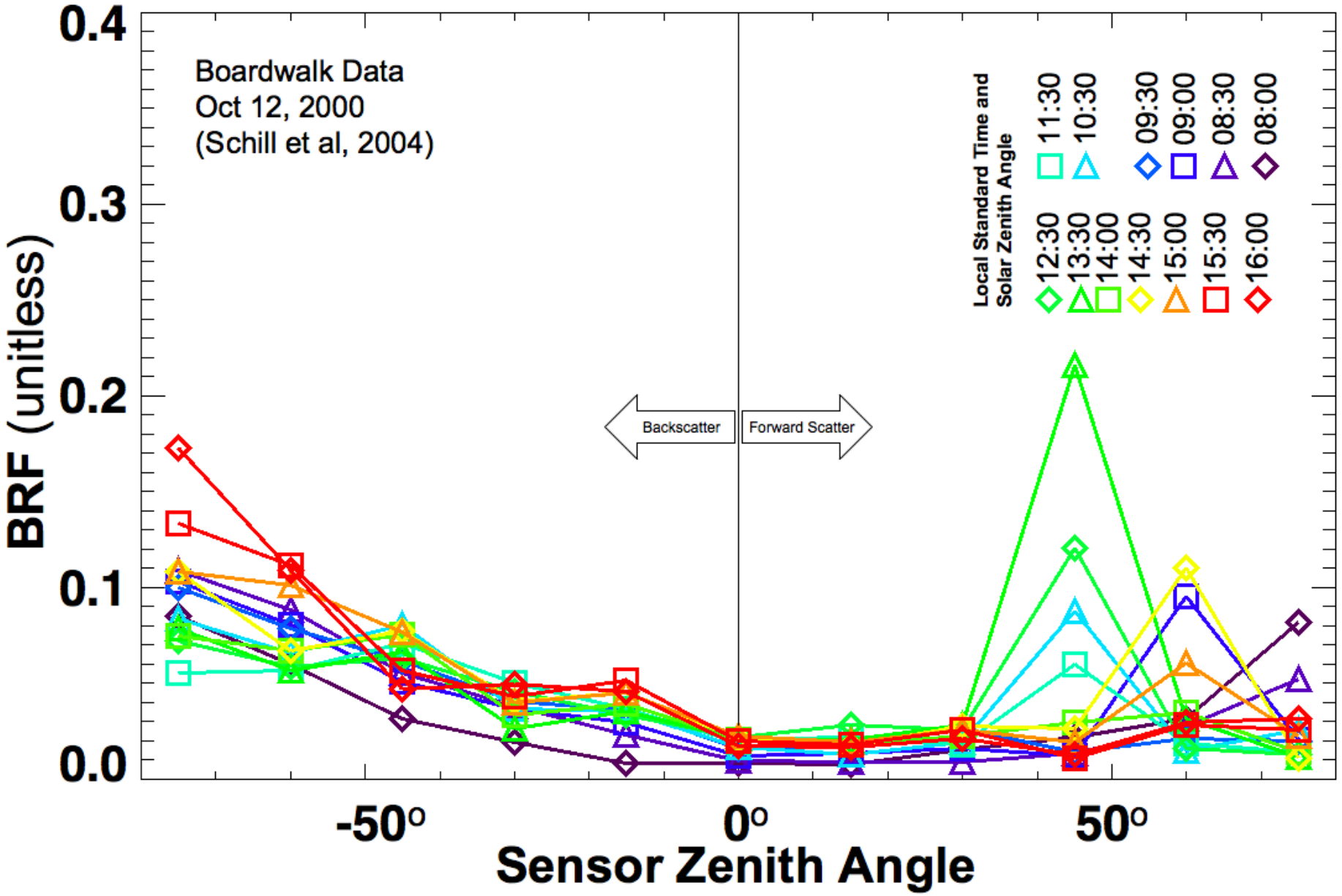
858 SFG canopy measurements of *S. alterniflora*:

- 11 zenith measurements.
- 6 azimithal planes.
- 13 times over a day.
- covers spectrum from 313 to 2403 nm.

(see Schill et al., 2004)

Sandmeier Field Goniometer (SFG)
(Photo courtesy of Steven Schill, 2000)

SFG Solar Principle Plane reflectance at 446nm



MARSH BRF EXPERIMENT

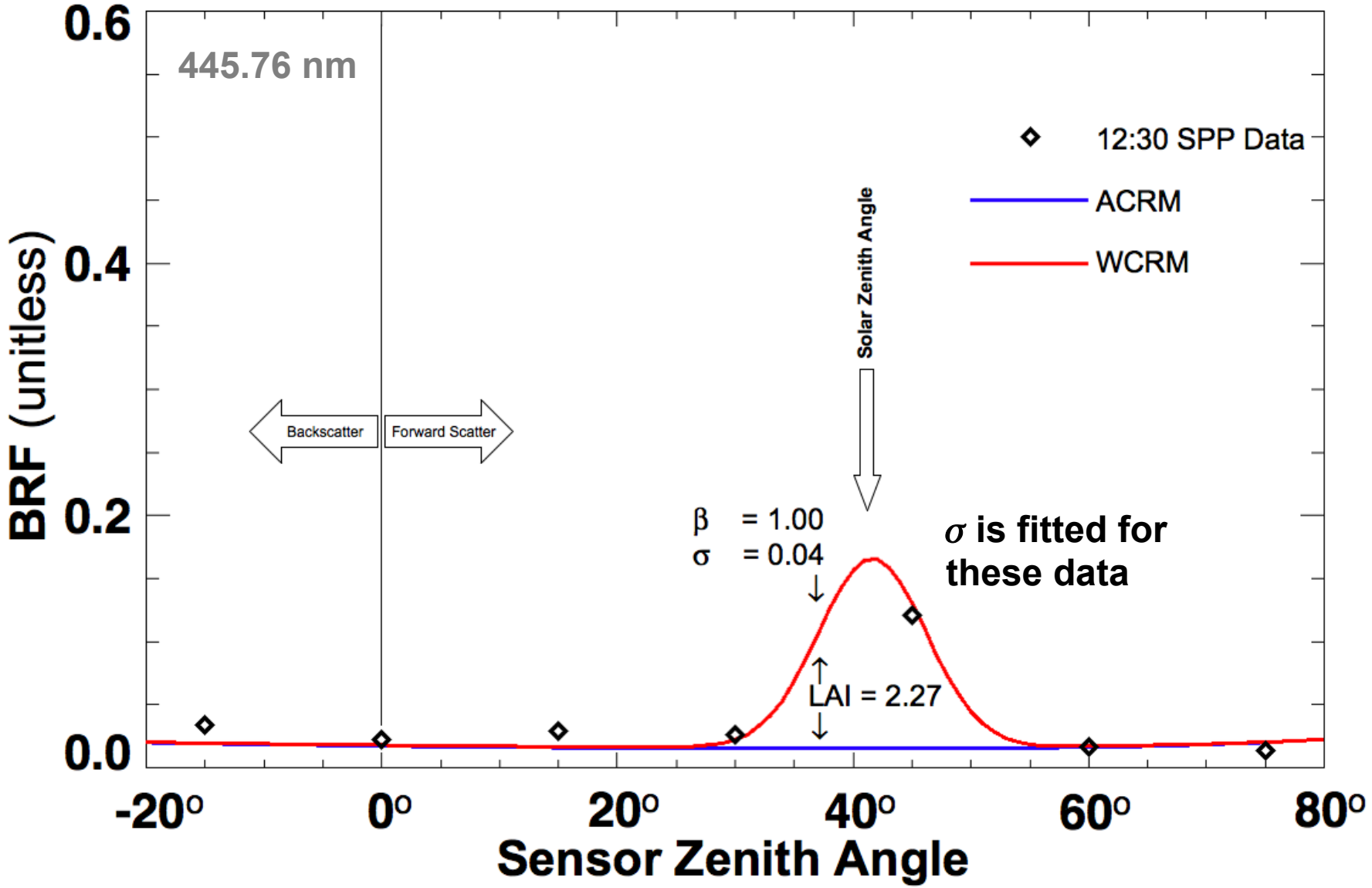
Objective:
Test whether WCRM reduces specular reflectance bias.

Method

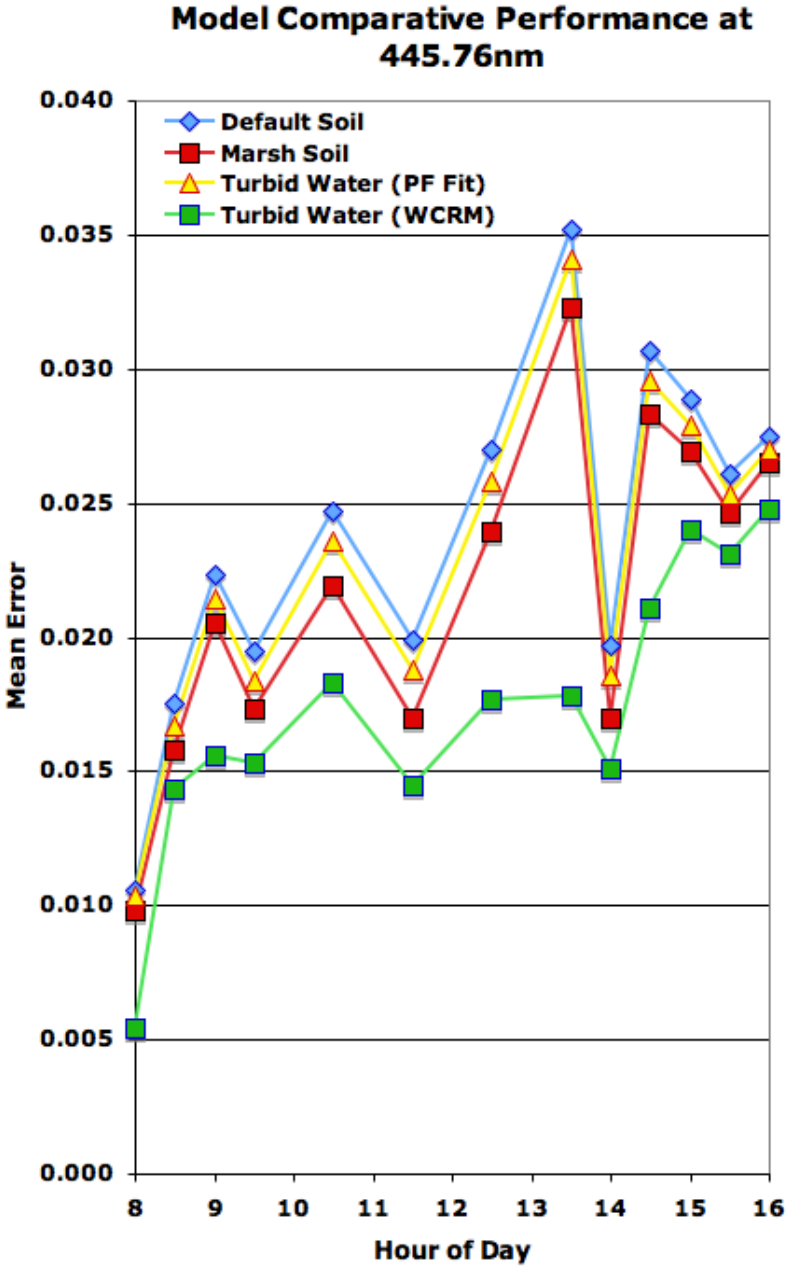
- Use modeling cases to predict reflectance measured by SFG data.
- 1 WCRM case.
- 4 ACRM cases (each with progressive improvements):
  - Default soil
  - Dry marsh soil
  - Wet marsh soil
  - Price function fit to WCRM shallow water spectrum.
- Compare differences between model predictions of reflectance and measurements.

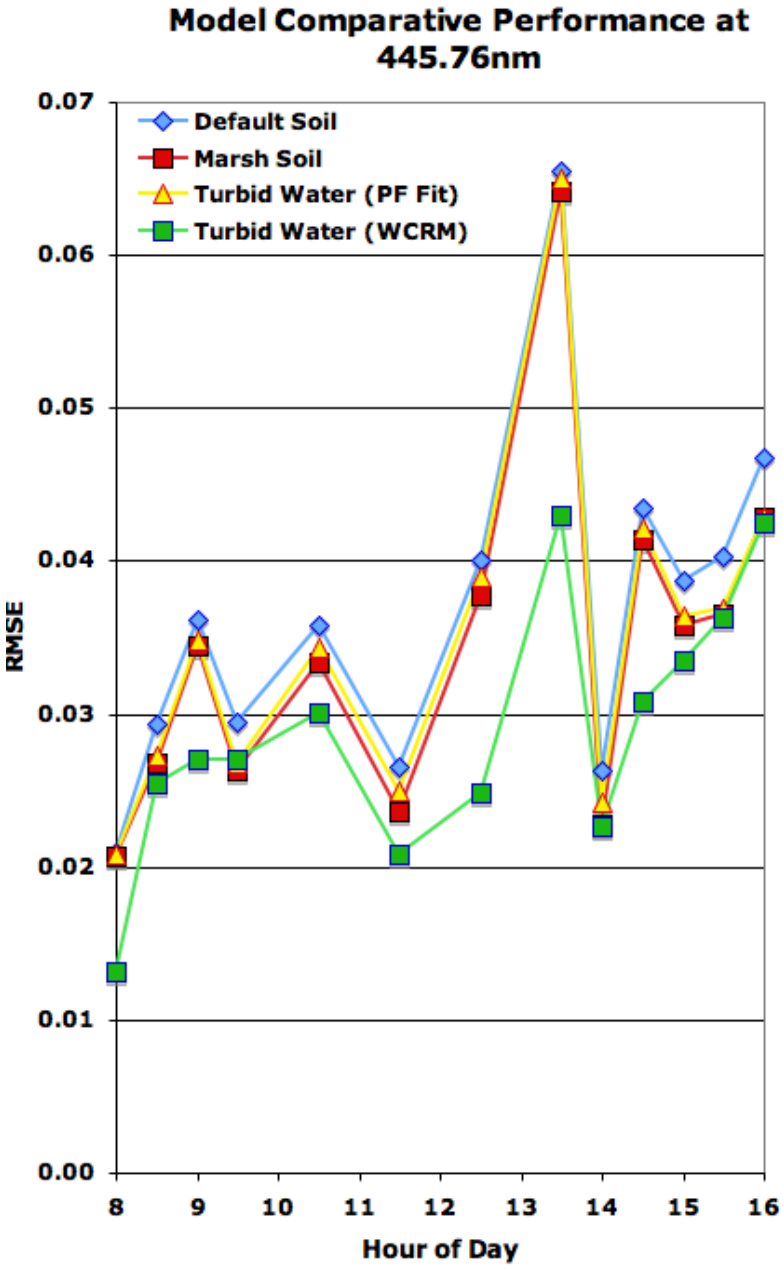
WCRM - Wetland Canopy Reflectance Model

Introduction of Specular Reflection

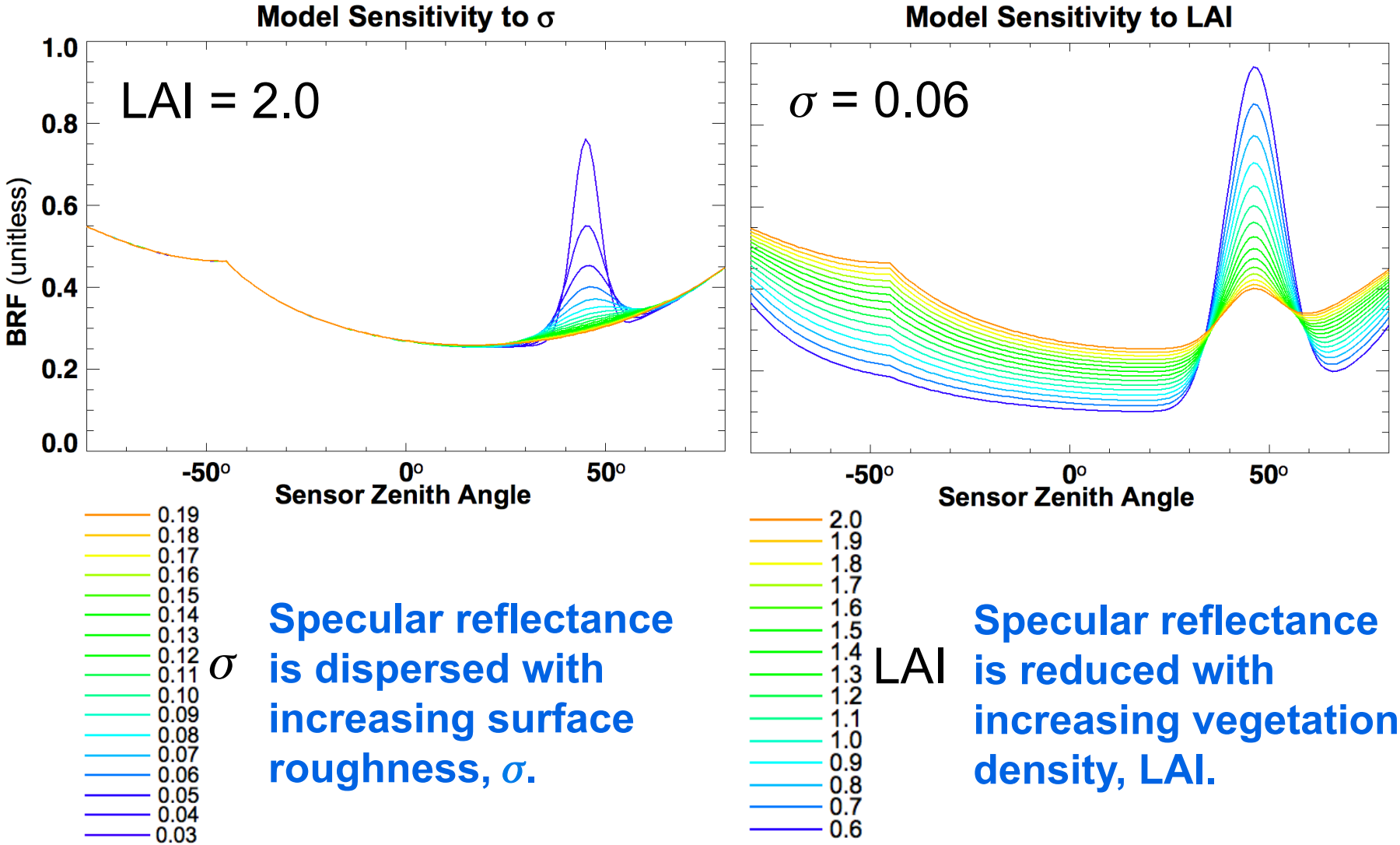


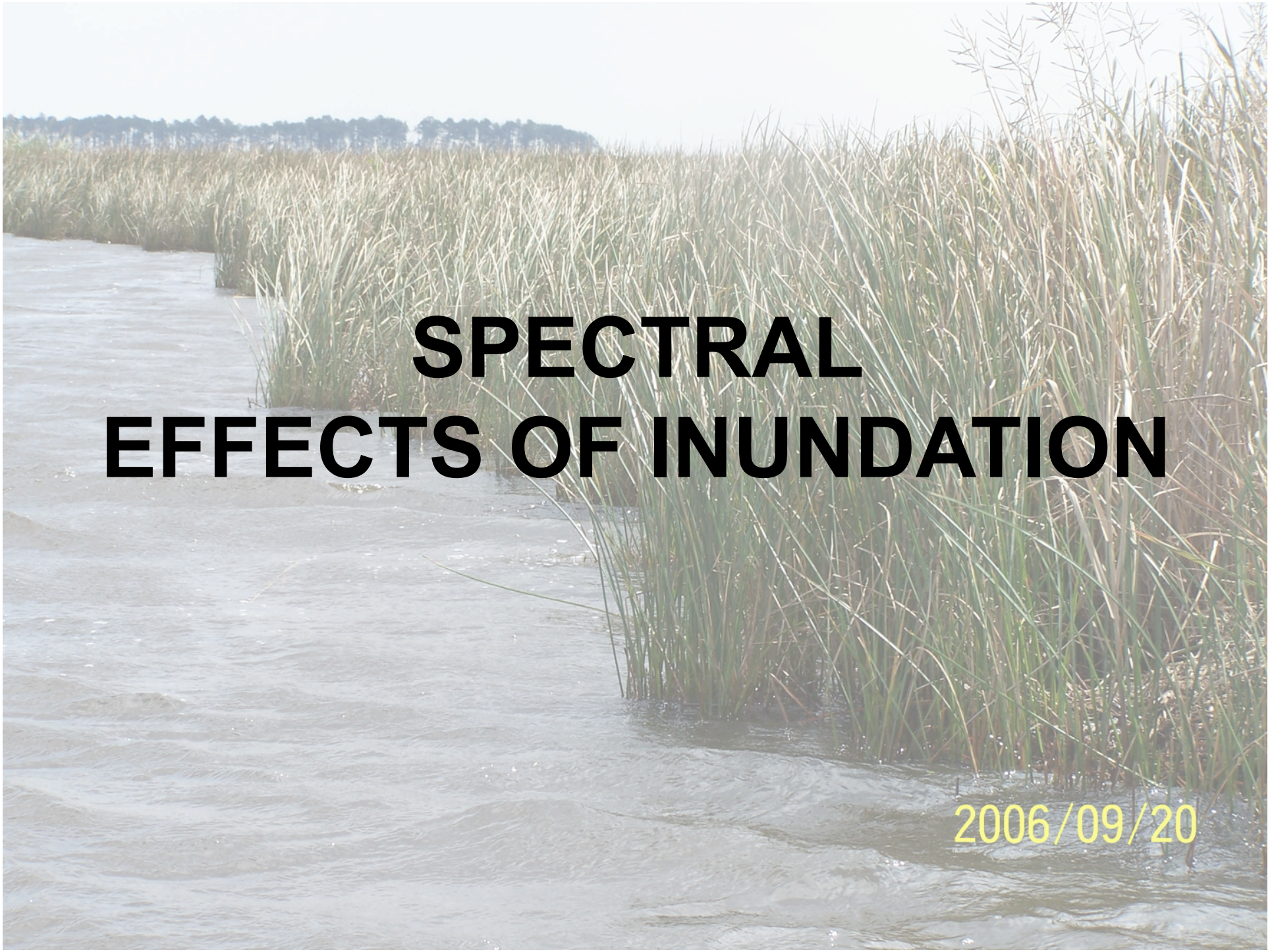
WCRM REDUCE BIAS CAUSE BY GLINT





WCRM - Wetland Canopy Reflectance Model
Model predicts that glint greatly reduced by vegetation



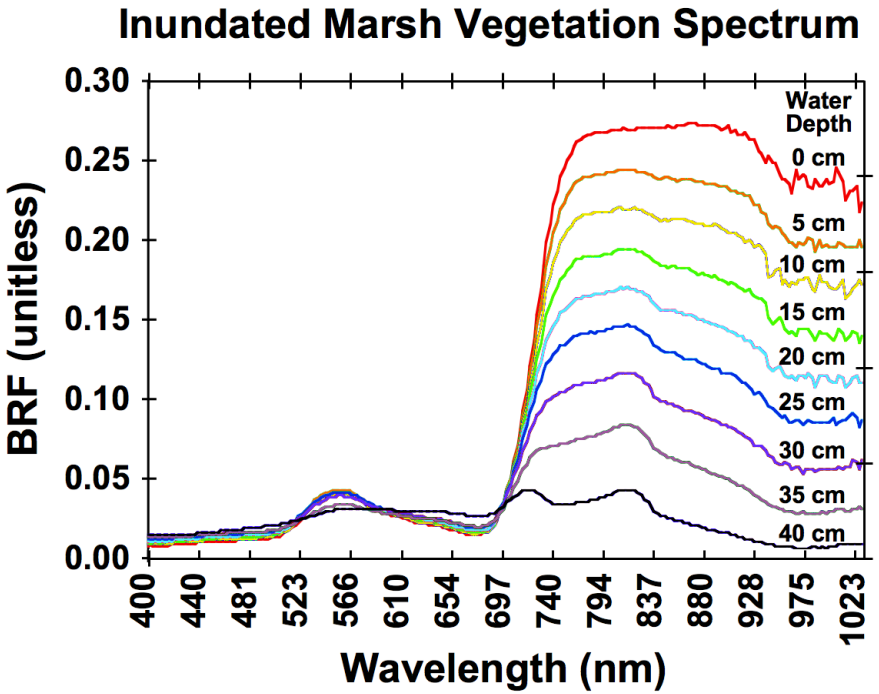

SPECTRAL
EFFECTS OF INUNDATION
2006/09/20

INUNDATION EXPERIMENT AND SIMULATION

Objective: Simulate marsh inundation experiment spectra; explain spectral features and red-edge effects.

Data

In 1995, David Stutzer measured the nadir canopy reflectance of *Spartina patens* as water level in enclosure was increased systematically.



Marsh inundation experiment apparatus (Kearney, Stutzer, Turpie, Stevenson, 2009)

INUNDATION EXPERIMENT AND SIMULATION

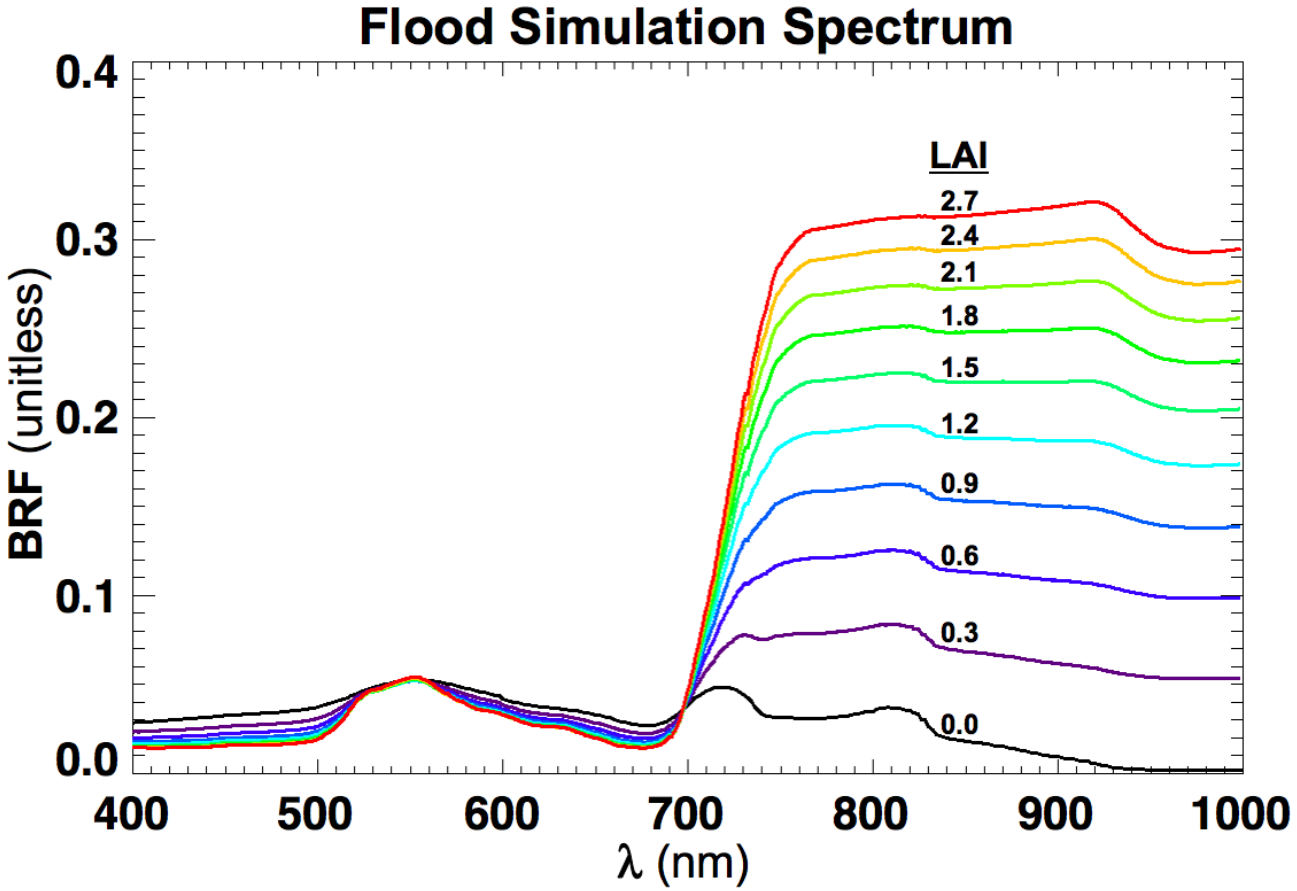
Method

- Run WCRM for linearly decreasing LAI values, simulating decreasing above-water biomass with rising water level.
- Quantatively compare results to data and use model first principles to explain features.
- Explore affects to red-edge with simulation.

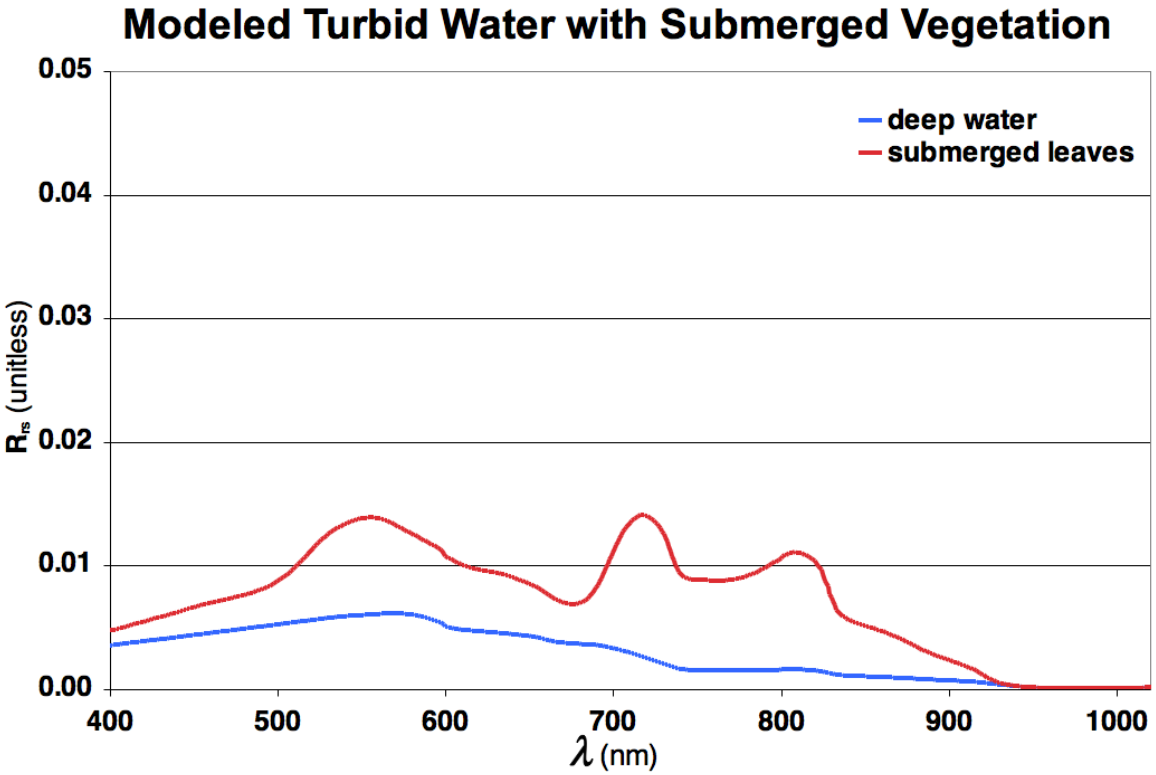
INUNDATION EXPERIMENT AND SIMULATION

Simulation

- Nadir canopy reflectance was modeled for linearily decreasing LAI.
- ACRM default parameters for leaf optics were used for PROSPECT.
- Leaf angle distribution set to erectophile (mode leaf angle = 90°).



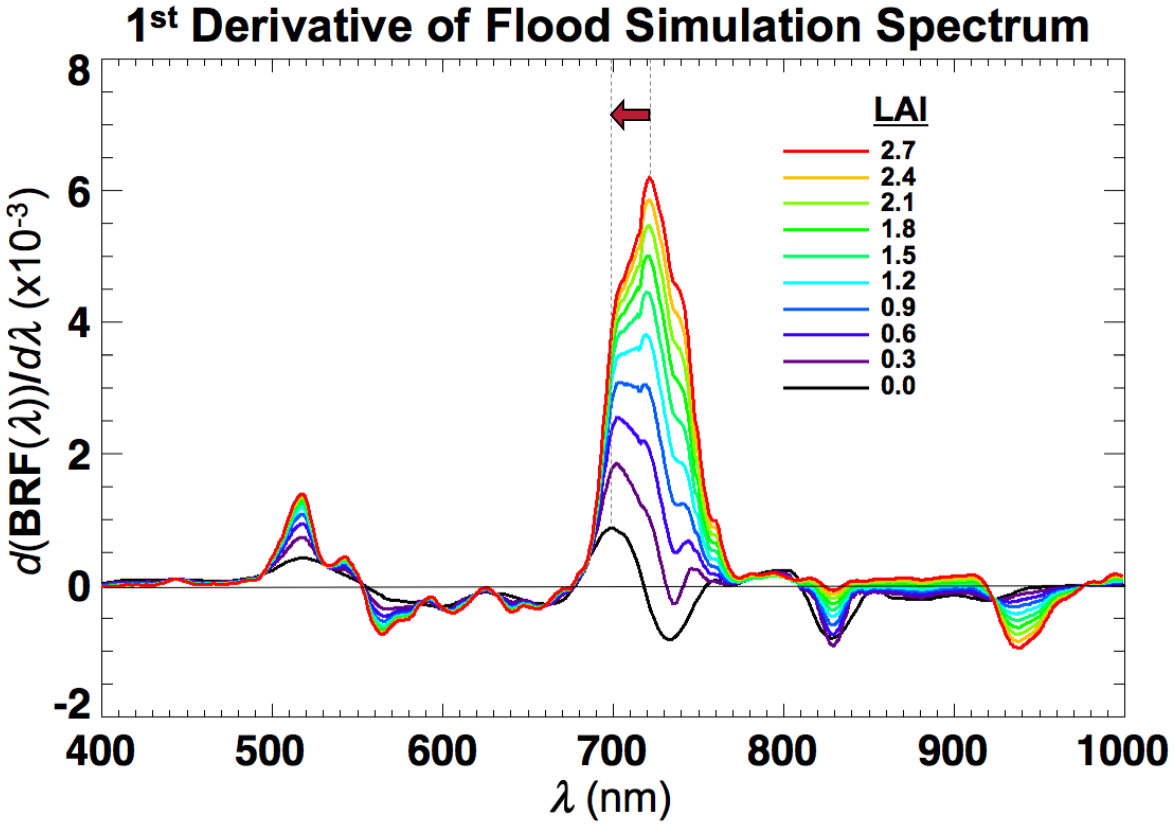
INUNDATION EXPERIMENT AND SIMULATION



Explanation (based on first principles built into model)

- The low reflectance of water in the NIR causes the vegetation reflectance to decrease with LAI.
- As more leaves are submerged, their high reflectance in the NIR highlights minima in the water and chlorophyll absorption just above 700 and 800 nm, causing peaks in reflectance.
- The peak at 550nm is from chlorophyll reflectance.

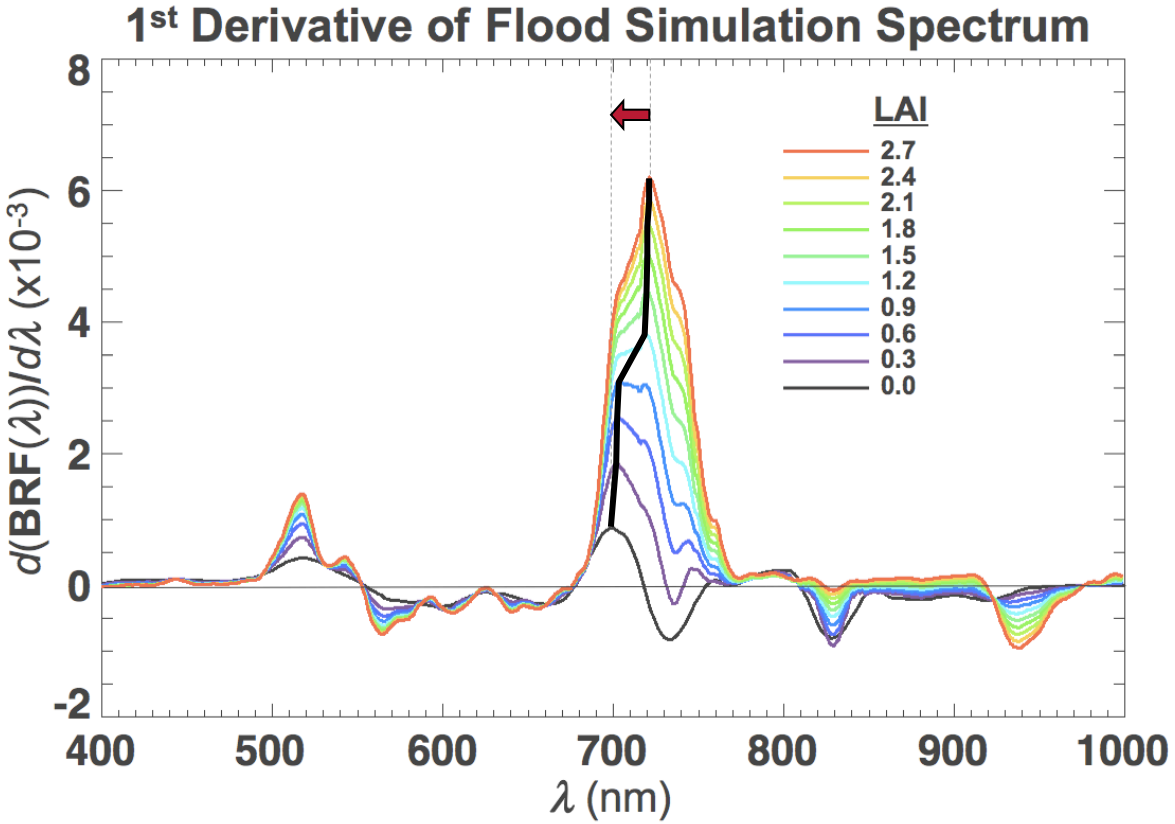
INUNDATION EXPERIMENT AND SIMULATION



Red-Edge Position Analysis

- 1st derivative shows changes in red-edge position.
- Red-edge position is observed to shift downward about 20nm as water goes from minimum to maximum level.

INUNDATION EXPERIMENT AND SIMULATION



Red-Edge Position Analysis

- 1st derivative shows changes in red-edge position.
- Red-edge position is observed to shift downward about 20nm as water goes from minimum to maximum level.

CONCLUSIONS

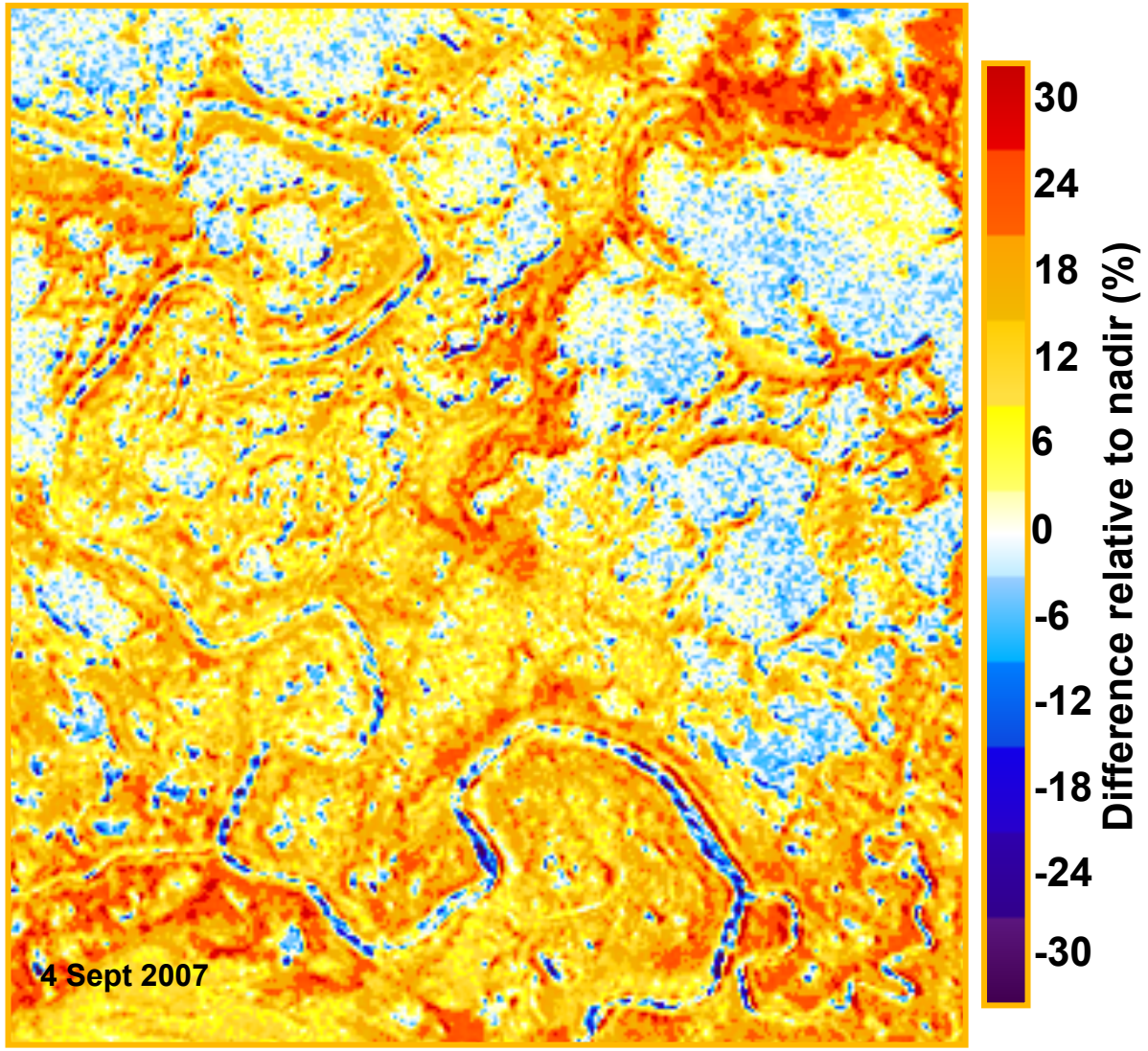
SUMMARY OF RESULTS

- The marsh canopy reflectance model, WCRM represents a first attempt to model reflectance of an inundated canopy.
- WCRM shown to reduce specular reflectance bias compared to four ACRM cases.
- WCRM could qualitatively simulate spectral effects of inundation; model first principles could explain the origin of spectral features.
- WCRM simulation demonstrated a 20nm shift in canopy red-edge as water went from minimum to maximum level.

FUTURE WORK

Modeling marsh canopies at remote sensing scale applications will require further work to understand the spectral mixing processes between adjacent open water and marsh vegetation.

Radiance difference between ASTER 3N and 3B



FUTURE WORK

Modeling marsh canopies at remote sensing scale applications will require further work to understand the spectral mixing processes between adjacent open water and marsh vegetation.

FUTURE WORK

- The surface roughness σ is unknown and needs further study.
- Partial water cover ($\beta < 1$) needs further study, including better modeling of wet organic soils.
- The vegetation component of the model may be challenged by the conditions found in marsh canopies (e.g., dark leaf reflectance, detritus, senescent leaves, and the persistence of standing dead stock in some species). Further work is needed to address this.
- The effects of spectral effects of inundation on spectral indices (e.g., NDVI) and spectral classification should be further explored.
- The effects of high concentrations of suspended sediment on canopy reflectance should be studied.
- There is a need for a protocol for taking field measurements in wetlands.


THANK YOU

Tidal marshes provide valuable ecological services. $14,397 USD per hectare per year globally*.

Are subject natural and anthropogenic threats; over half of marsh coverages lost since pre-industrial times.

Assessment and monitoring of coastal marshes support understanding and management of these resources.

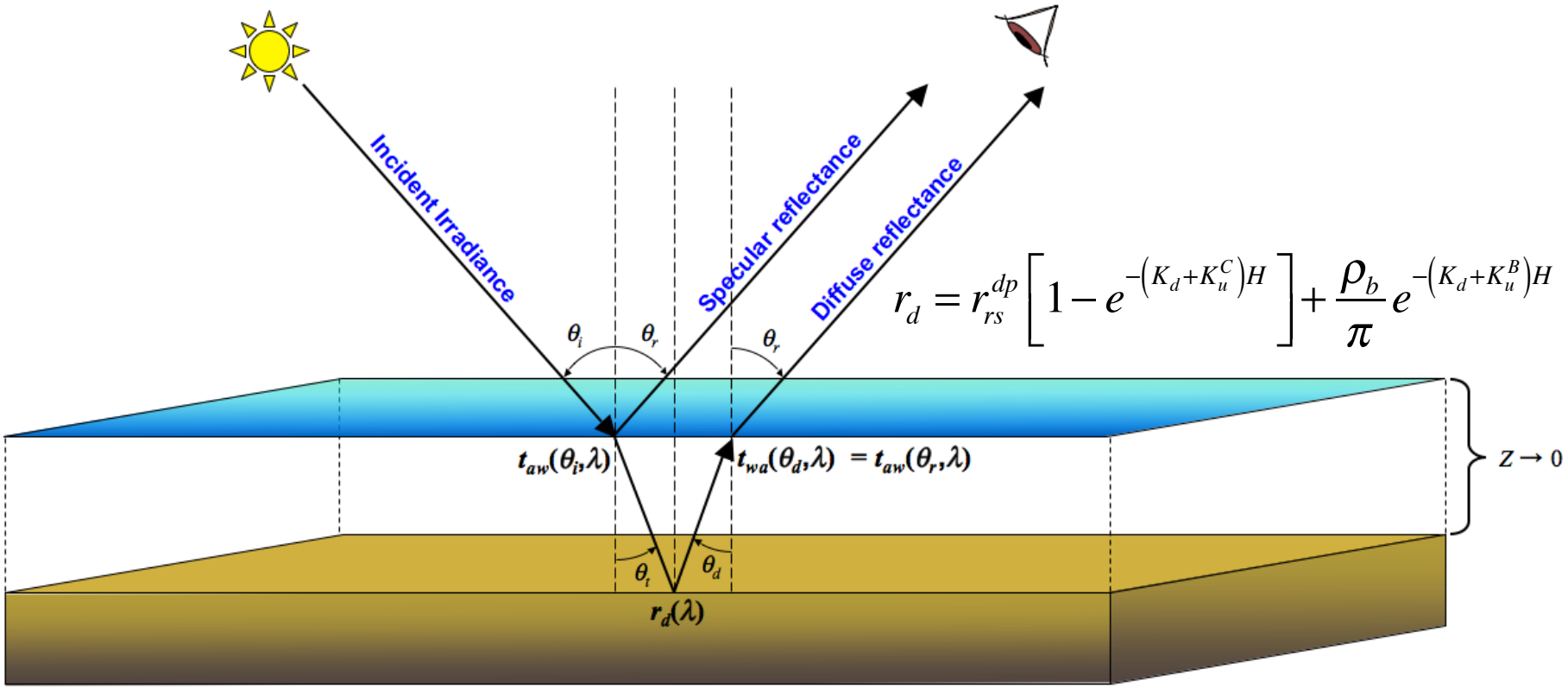
Remote sensing is an important tool to assess and monitor tidal marshes.

* 2009 inflation-adjusted value (Bromberg-Gedan 2009)

WCRM - Wetland Canopy Reflectance Model Calculations

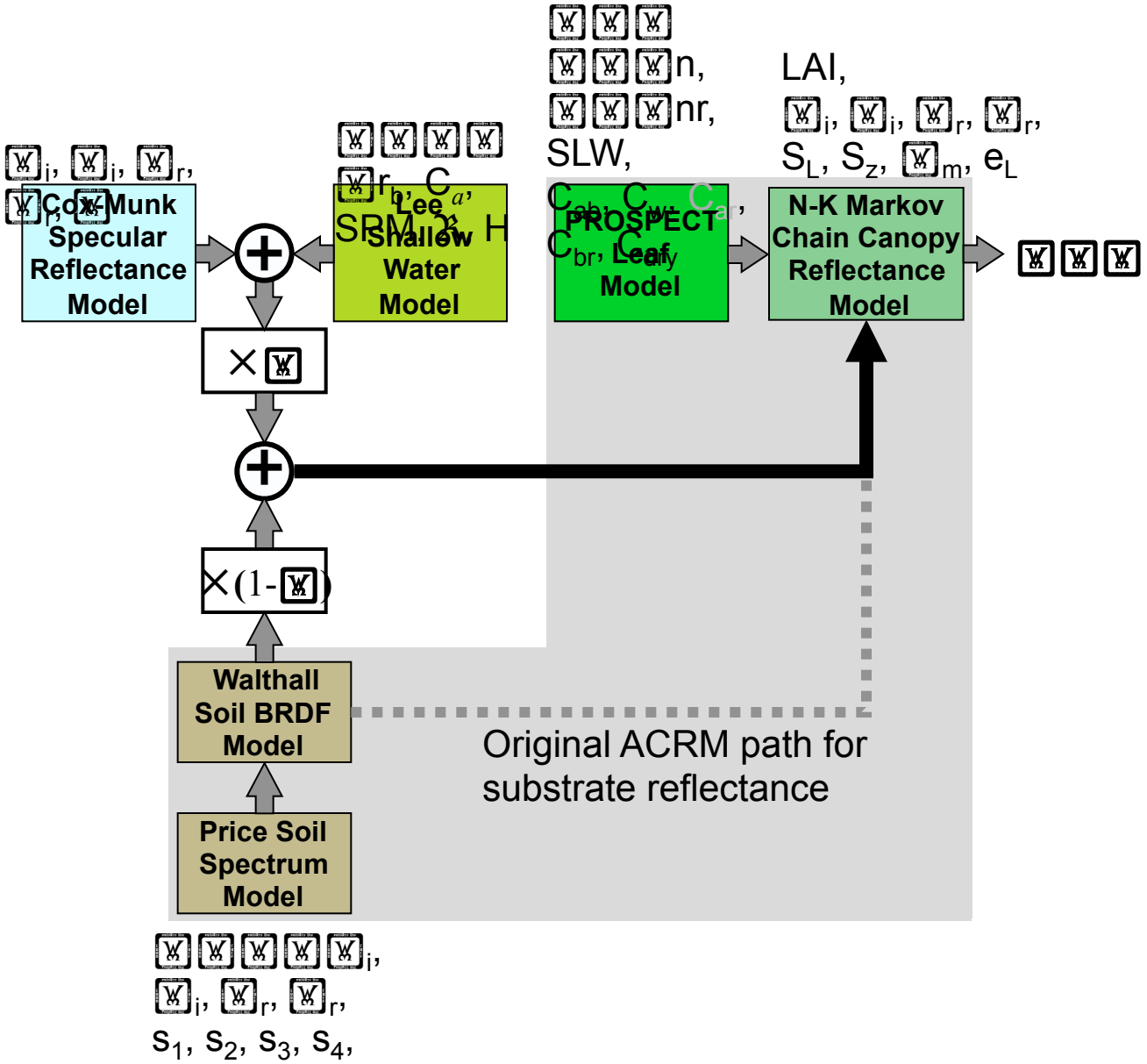
Diffuse Specular

$$f_{water}(\theta_i,\phi_i,\theta_r,\phi_r) = \frac{n_r^2 t_f(\theta_i) t_f(\theta_r) r_d}{\pi(1-\gamma r_d)} + \frac{r_f(\omega) p_\Omega}{4\mu_n^4 \mu_0 \mu}$$

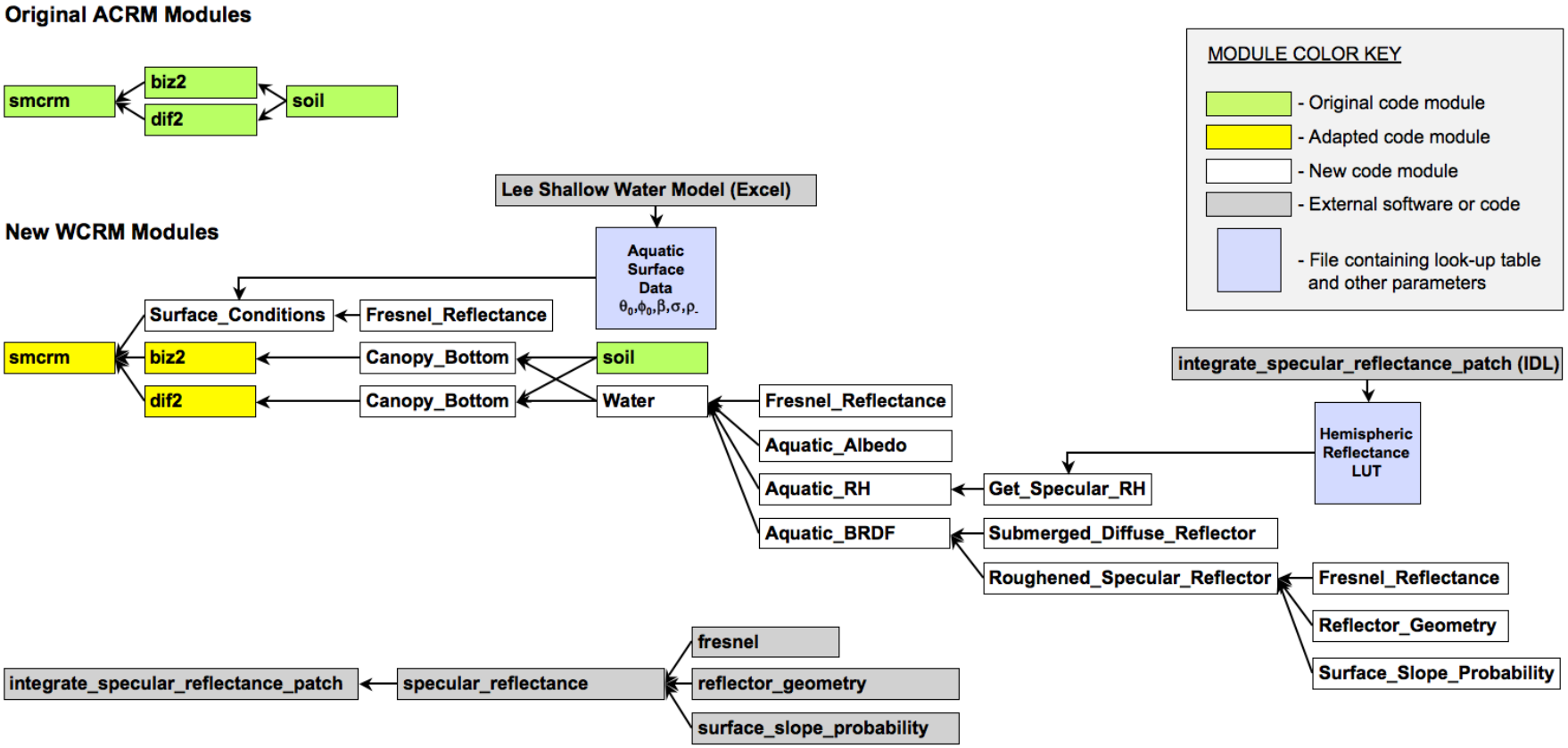


$$r_d = r_{rs}^{dp}\left[1 - e^{-\left(K_d + K_u^C\right)H}\right] + \frac{\rho_b}{\pi} e^{-\left(K_d + K_u^B\right)H}$$

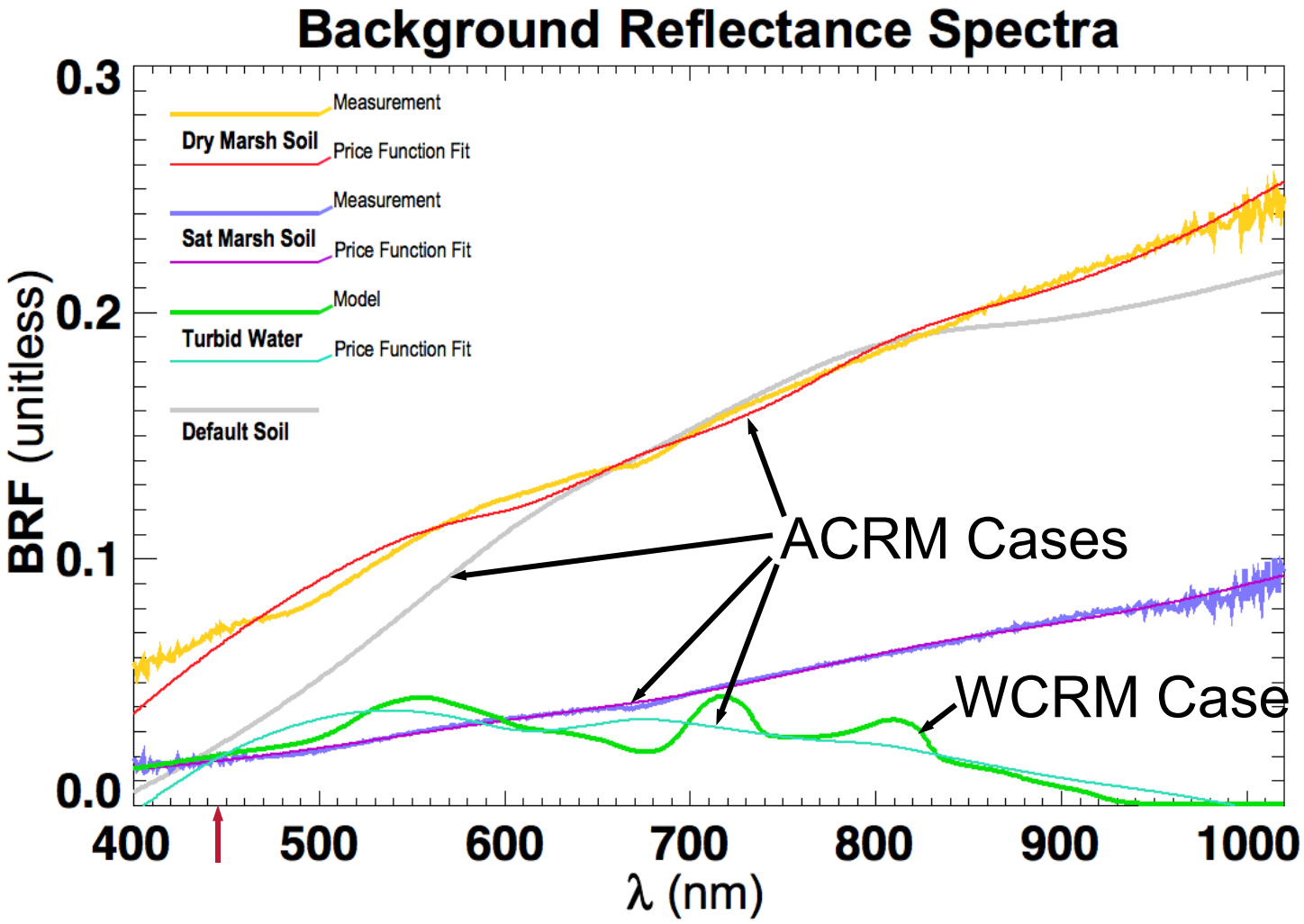
WCRM - Wetland Canopy Reflectance Model Algorithm



WCRM - Wetland Canopy Reflectance Model Implementation

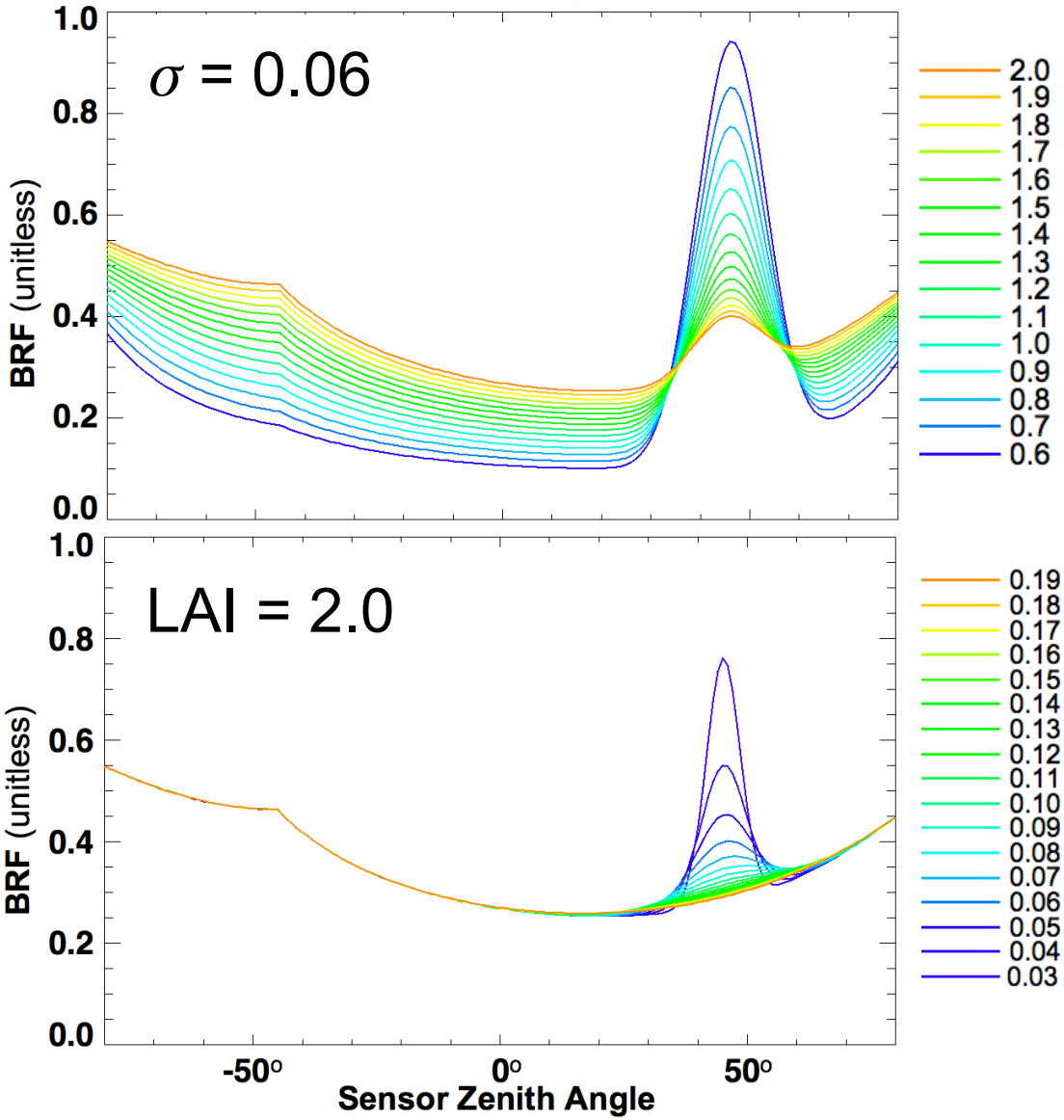


MARSH BRF EXPERIMENT



Measured and modeled background spectra for 5 model runs.

WCRM - Wetland Canopy Reflectance Model
Specular Effects



Specular reflectance is reduced with increasing vegetation density, LAI.

Specular reflectance is dispersed with increasing surface roughness, σ.


Water Surface Distortions
by Emergent Vegetation
2006/09/20