Uncoupling the optical signatures in coastal waters with ocean color sensors

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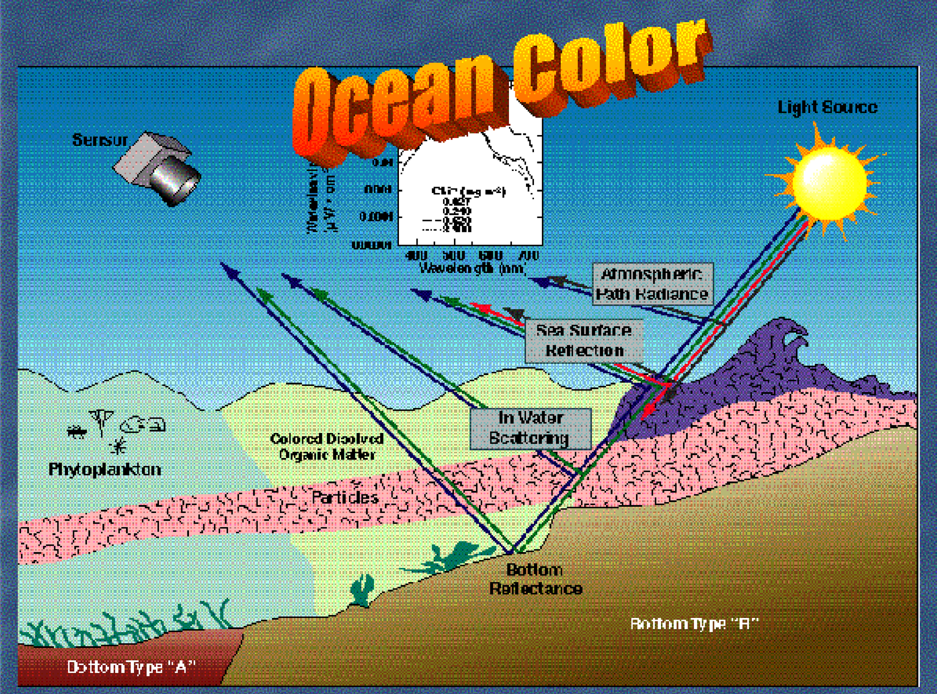
Abstract

Ocean color signatures are used to determine the changing coastal water properties and improve our understanding of physical and biological processes. Optimization methods were applied to spectral signatures from satellite and aircraft sensors to uncouple the water and bottom components for several different coastal environments representing river plumes and shallow water areas in turbid and clear waters. We determine the dissolved organic matter, backscattering coefficient and chlorophyll properties of the water, in addition to bottom albedo and water depth for these different areas. Optimization methods provide unique solutions based on the non-linear spectral decomposition. These methods were applied to multi- and hyperspectral imagery (SeaWIFS, MODIS and Phills) sensors and validated with in-situ measurements, to illustrate the changes in coastal optical properties and their inter-relationships

Objective:

- ➢Determine how coastal optical signatures are spatially distributed in coastal waters
- ➢Uncouple the spectral signature of ocean color
- ➢Separate the water optical components and water depth and bottom albedo



Semi-Analytical Approach

Not a constant in Case 2 waters ~VSF etc

Separation of Components–

0.051 typically

$$RRS = \left(\frac{F}{Q}\ \frac{T^2}{n^2}\right)\left(\frac{bb}{a+bb}\right)$$

+ Bottom reflectance + water depth

Currently Not Included

Backscattering $b_{b\lambda} \sim b_{bw\lambda} + b_b p_\lambda$

Absorption

$$a_{t\lambda} \sim a_{w\lambda} + a\phi_\lambda + a_{d\lambda} + a_{g\lambda}$$

water — phytoplankton — detritus — Chromophoric dissolved organic matter

Why Hyperspectral ?

PLUS:
Increased Spectral Channels Improved the accuracy of retrievals in coastal waters

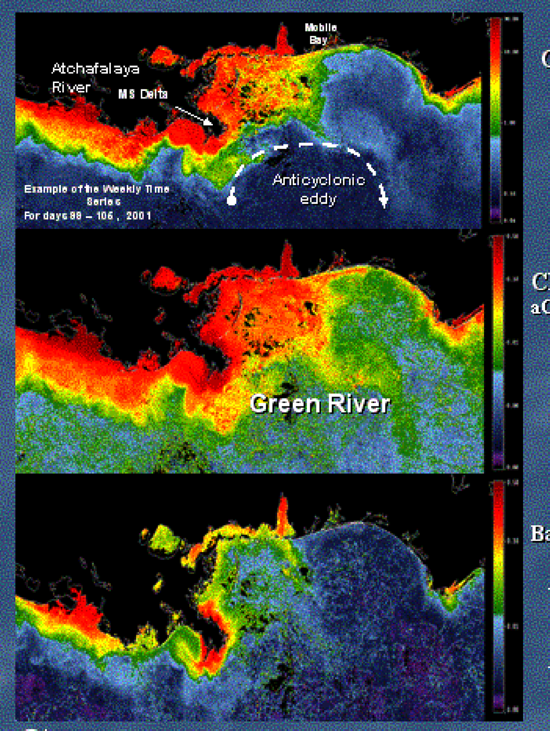
Spectroscopy from Space

The Ocean Color is Linked to the Ocean Optical Properties
- Absorption
- Scattering

Unravel the Color Spectrum into The Components
- Phytoplankton
- Colored Dissolved organic matter
- Particles (Size / type/ concentration)

Optical Properties used to monitor ocean processes
- River Plumes
- Rings and Eddies
- Filaments
- Upwelling

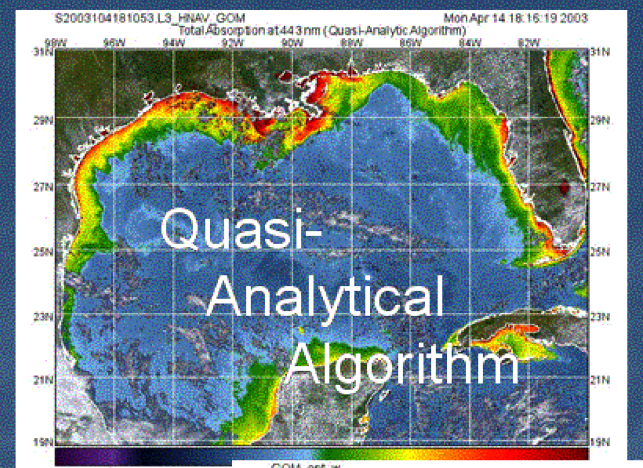
Monitoring Coastal Processes With Optical Signatures

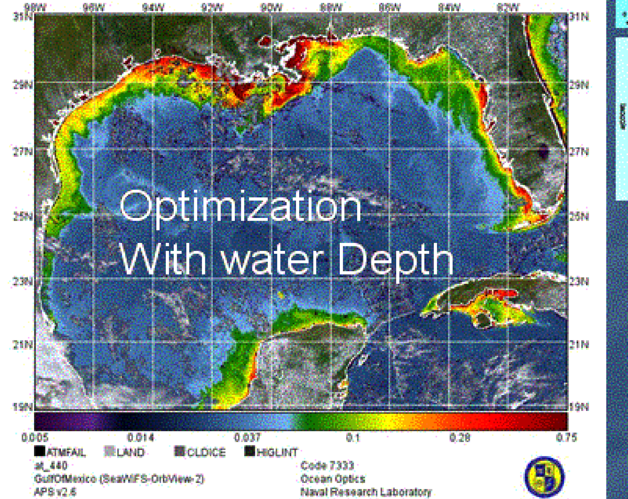


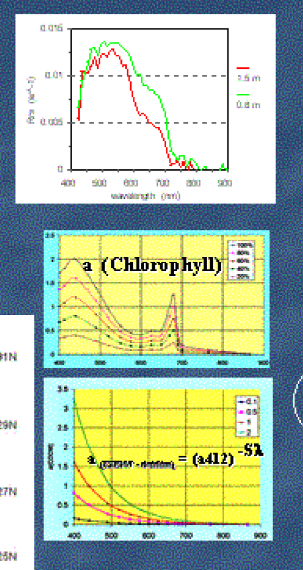
Chlorophyll (OC4)
- Maximum ratio
- Non-conservative property
- Timely response of terrestrial flux of nutrients
- Offshore Phytoplankton Blooms

CDOM – absorption aCDOM_400_g
- humic / fulvic acids - terrestrial sources
- photo-oxided at surface
- conservative tracer of coastal waters

Backscattering coefficient bb_555_a
- Total Suspended Sediments
- Size Distribution
- composition/ index of refraction
- Particle settling occurs offshore

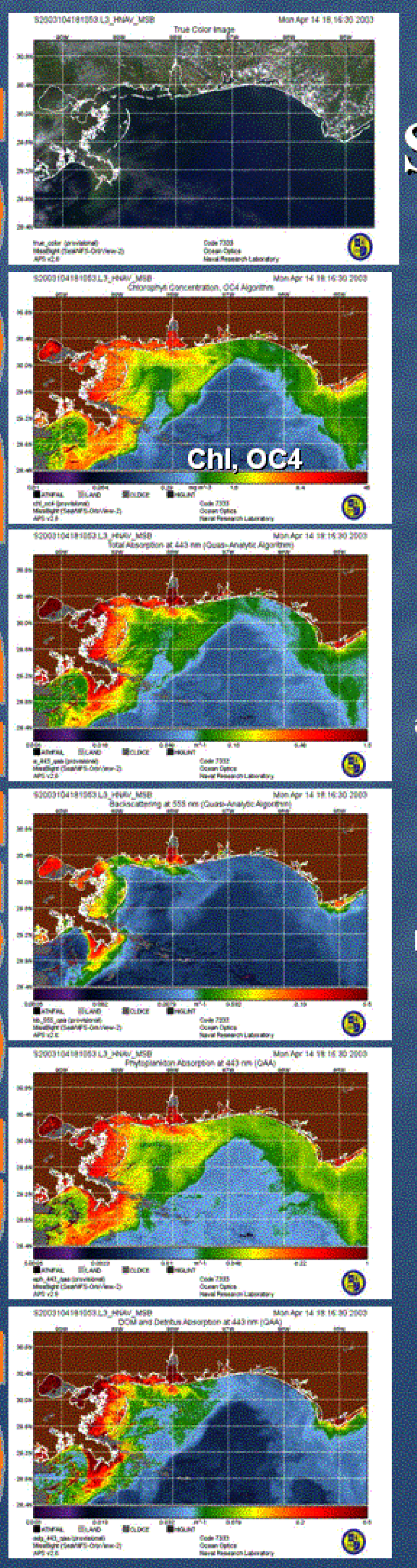






Optically Deep

SeaWIFS



Algorithms For Optically Deep Waters

In optically shallow waters the Bottom signature affects the retrievals

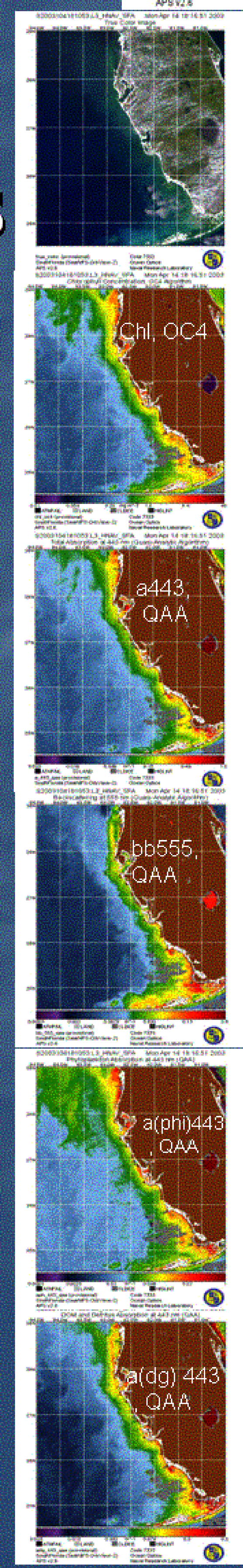
a443, QAA

bb555, QAA

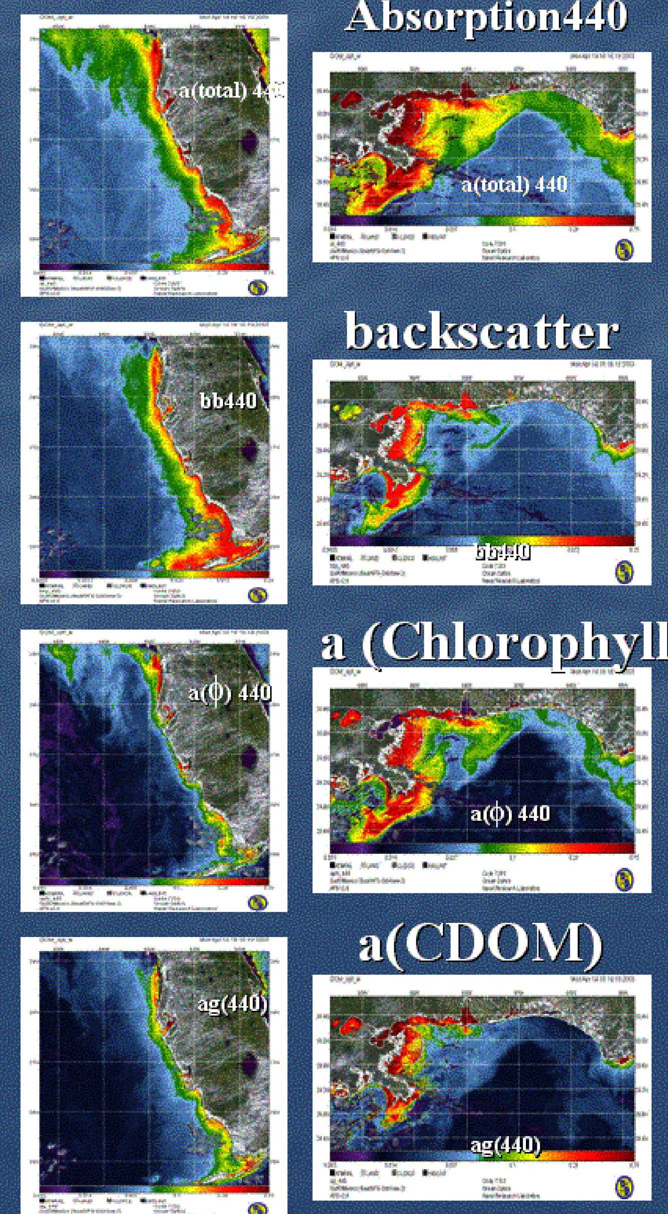
a(ϕ),QAA

a(dg),QAA

Optically Shallow



Problem- 6 Channels On SeaWIFS Inadequate to For shallow water solution



Absorption440

backscatter

a (Chlorophyll)

a(CDOM)

Spectral Unmixing using
Spectral Optimization Method

$$R_{rs}(\lambda) = f\,[a(\lambda),\ b_b(\lambda),\ \rho(\lambda),\ H,\ \theta_w,\ \theta_v,\ \varphi]$$

- a: absorption
- b_b: back-scattering
- ρ: bottom albedo

After optical/bio-optical models

Optimization

$$R_{rs}(\lambda_1) = F(a_w(\lambda_1), b_{bw}(\lambda_1), \boldsymbol{P,G,X,B,H})$$
$$R_{rs}(\lambda_2) = F(a_w(\lambda_2), b_{bw}(\lambda_2), \boldsymbol{P,G,X,B,H})$$
$$\vdots$$
$$R_{rs}(\lambda_n) = F(a_w(\lambda_n), b_{bw}(\lambda_n), \boldsymbol{P,G,X,B,H})$$

- P: Pigment
- G: Yellow substance
- X: suspended sediment
- B: Bottom
- H: Depth

a(ϕ)
a(dg)
bb
Btm Weight
Btm albedo

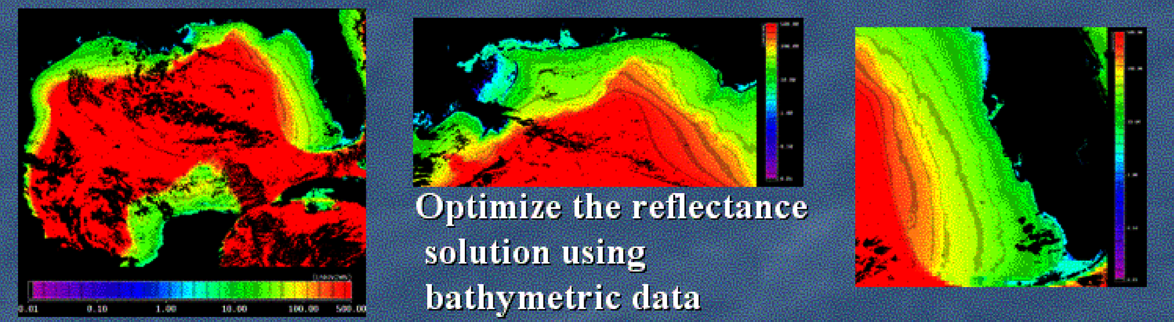
$R_{rs}(\lambda)$ from model ←→ $R_{rs}(\lambda)$ from sensor (spectrally matching)

Values of: P, G, X, B, and H.

Lee et al. 1999, 2001

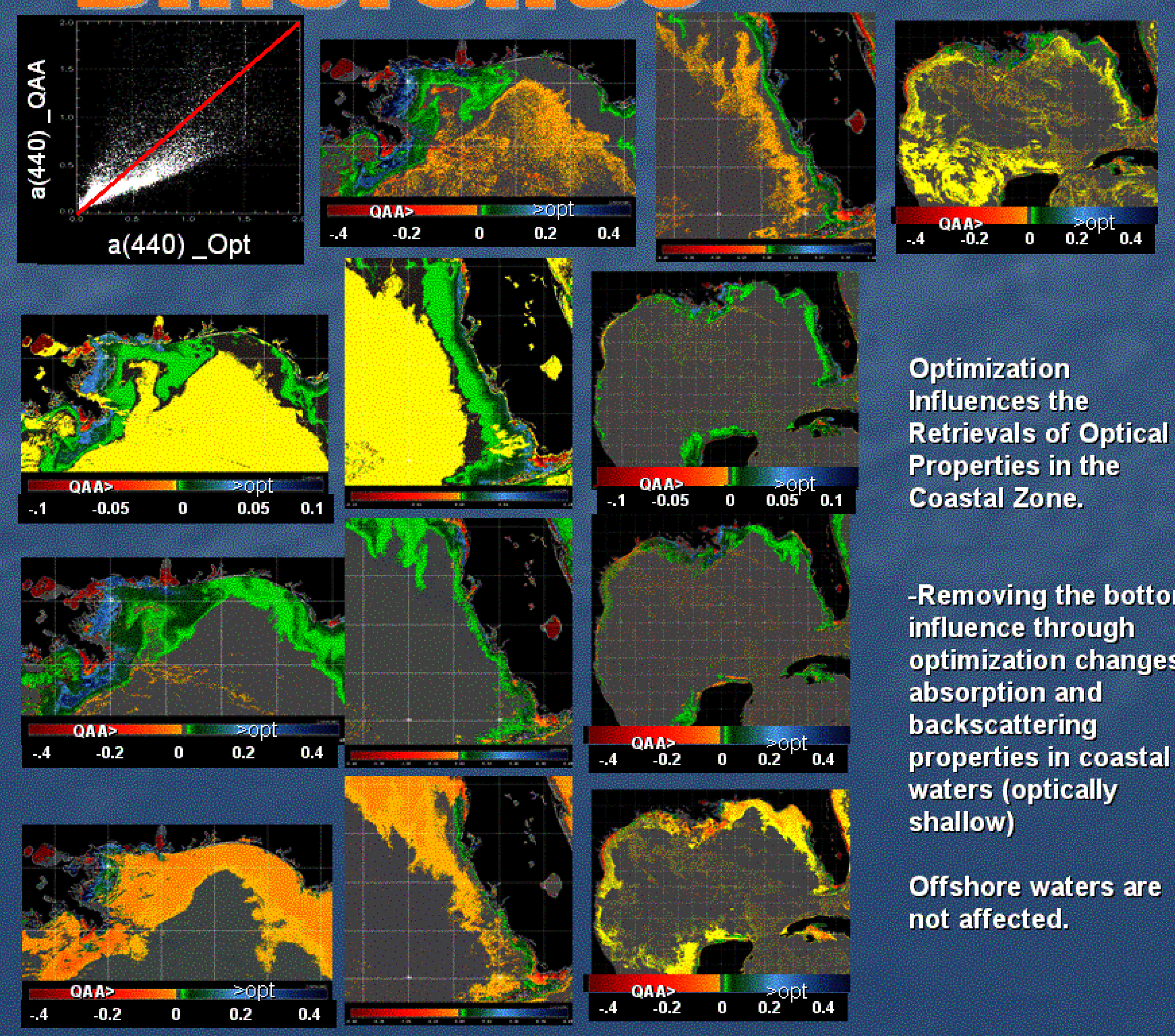
Extend Optimization to SeaWIFS

Constrained Optimization with Depth (1 km)



Optimize the reflectance solution using bathymetric data

Difference



Optimization Influences the Retrievals of Optical Properties in the Coastal Zone.

-Removing the bottom influence through optimization changes absorption and backscattering properties in coastal waters (optically shallow)

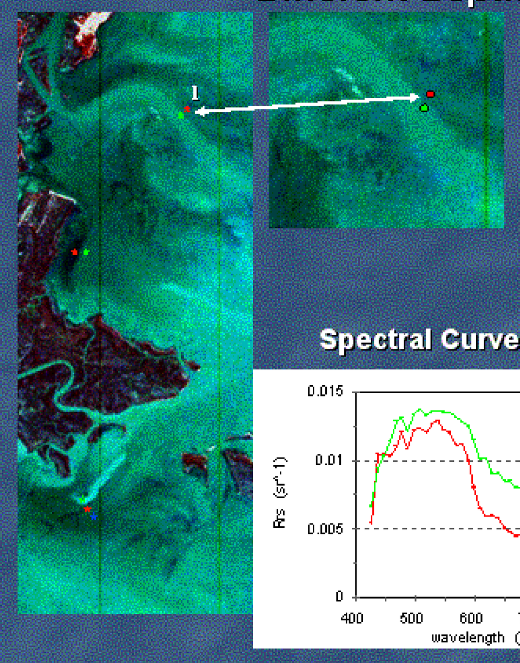
Offshore waters are not affected.

Uncoupling the Complete Solution using 128 Bands

Hyperion

Parameters	Landsat-7 ETM+	SeaWIFS	MODIS Terra/ Aqua	EO-1 ALI	EO-1 Hyperion
Spectral Range	0.4-2.4µm	0.412 - 0.865 µm	0.412 – 14.00 um	0.4-2.4 µm	0.4-2.5 µm
Spatial Resolution	30m	1km	250m, 500m, 1km	30m	30m
Swath Width	185 Km	1500 km	1500 km	37Km	7.7Km
Spectral Resolution	Variable	20 nm	~20 & >	Variable	10nm
Spectral Coverage	Discrete	Discrete	Discrete	Discrete	Continuous
Total # of Bands	7	8	32	10	220

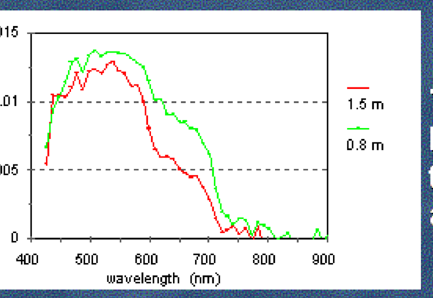
Different Depth, Same Bottom Type



Retrieved properties after dark water atm correction and optimization

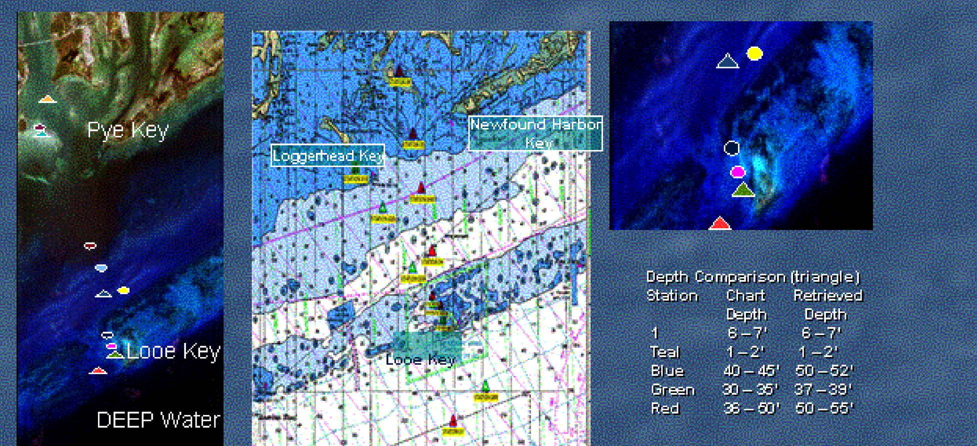
Absorption(440)	/ CHL mg/m3	Bottom Ref 550 nm	Depth (m)
0.12	2.0	0.07	1.5
0.15	2.5	0.07	0.8

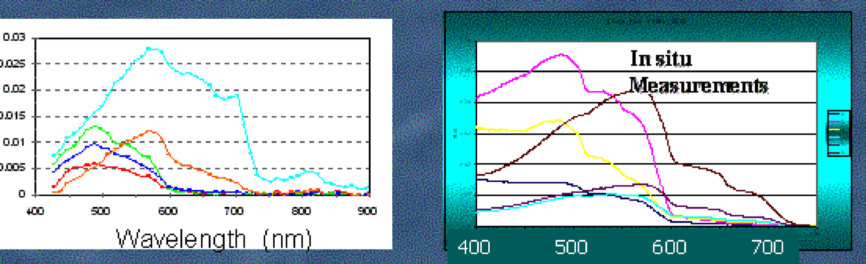
Spectral Curves



The added spectral bands enable uncoupling the depth and bottom albedo

Uncoupling the Depth Component in the Hyperspectral Signature





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Lee, Z. K Carder, K. Mobley, R. Stewart and J. Patch "Hyperspectral remote sensing for shallow water. Appl. Opt 38 331-3843 1999.

Conclusions

- Spectral signatures used to uncouple the water optical properties
- Optimization methods used to uncouple water and bottom properties in coastal areas. Applied to SeaWIFS
- SeaWIFS limited number of channels is inadequate for uncoupling bottom and water column properties
- Improved retrievals for coastal waters by constraining the optimization
  - Providing water depth improves retrievals in both optically shallow and optically deep waters
- Additional Hyperspectral channels (i.e. Hyperion) was used for uncoupling the bottom and water column properties in coastal waters