

Mapping optical parameters of coastal sea waters using the Hyperion imaging spectrometer — Intercomparison with MODIS

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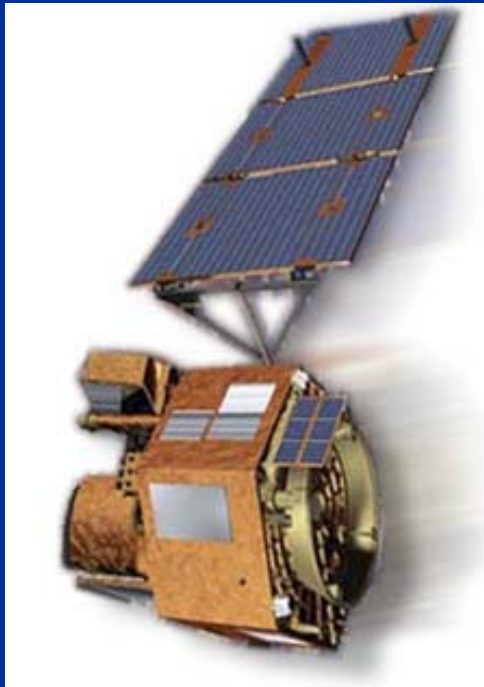
Current Ocean Color Satellite Sensors

- CZCS, OCTS, SeaWiFS, MODIS, MERIS, GLI
- Spatial resolution: typically 1 km
 - Not suitable for coastal region
 - (MERIS has a 300 m mode)
- Number of spectral bands: 6 – 12
 - OK for deep ocean
 - Insufficient for coastal waters

High Resolution Satellite Sensors

- Typically designed for land observation
- e.g. Landsat, SPOT, IKONOS
- High spatial resolution, 1 m to 30 m
- Limited no. of spectral bands
- Broad bandwidth
 - High SNR, but lack spectral specificity

Hyperspectral Satellite Sensor

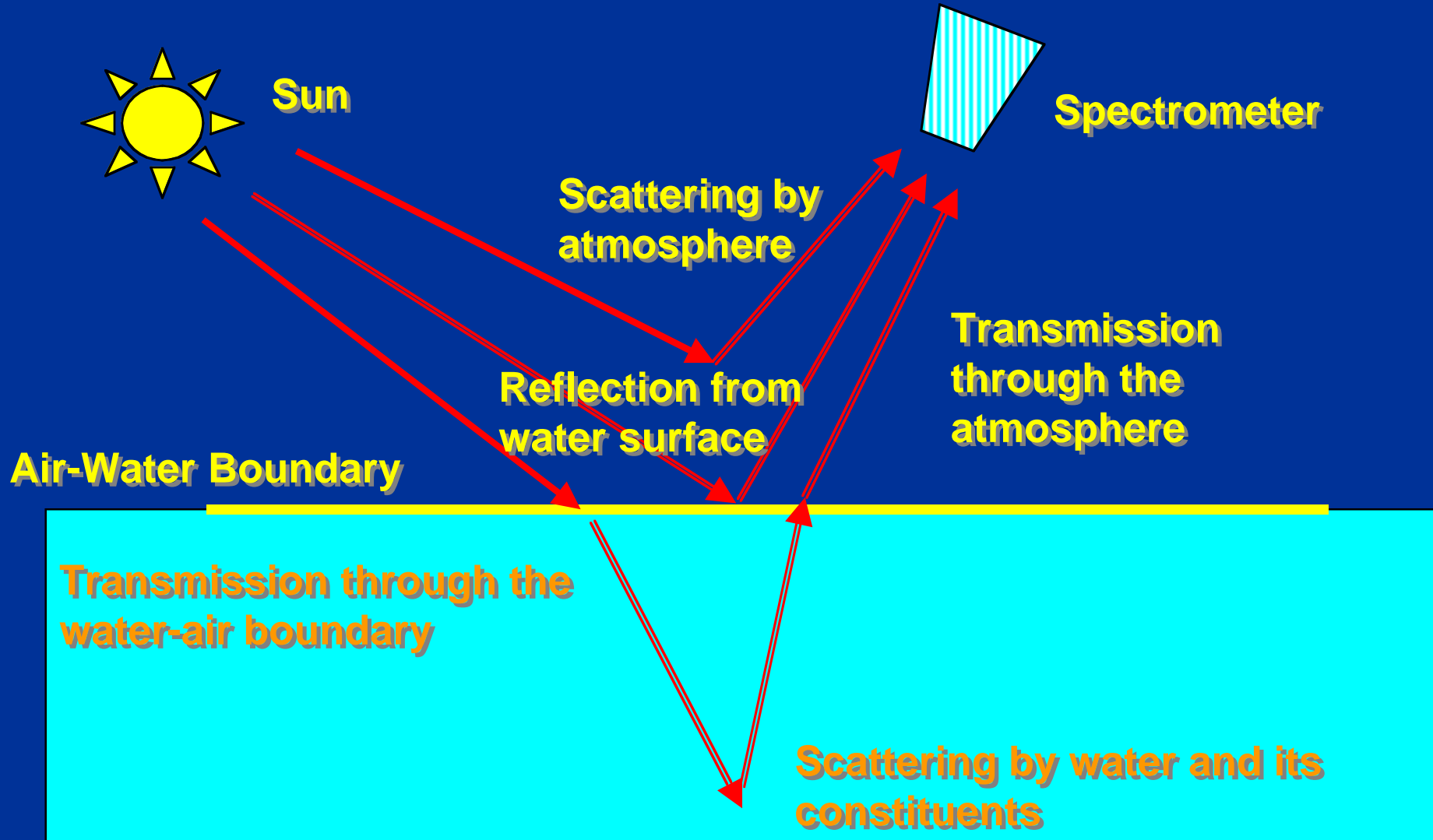


- EO-1 Satellite, launched Nov 2000, first satellite in NASA's New Millennium Program Earth Observing series
- Primary Aim: To develop and test a set of advanced technology land imaging instruments
- Hyperion : first space-borne hyperspectral instrument
 - Over 200 spectral bands, with high spatial resolution of 30 m

Hyperion Imaging Spectrometer

- No. of bands: 220
 - 200 bands selected for processing
- Spectral range: 357 to 2576 nm
 - 436 to 2406 nm selected for processing
- Bandwidth: 10 nm (nominal)
- Pixel size: 30 m
- Swath: 7.5 km across track
- SNR designed for land observation
 - SNR: 192 (550 nm), 140 (700 nm)
 - **Is it useful for coastal sea/ocean applications?**

Reflectance Measurement



Model of Hyperion Top-of-Atmosphere (TOA) Reflectance

$$R(\lambda) = T^{\uparrow} T^{\downarrow} \left[\frac{(1-r)^2}{n^2} R_w + r \right] + R_p$$

- ❖ n : water refractive index = 1.33
- ❖ r : water surface reflectance
- ❖ R_w : diffused water reflectance
- ❖ T^{\downarrow} : downward transmittance
- ❖ T^{\uparrow} : upward transmittance

Model of Diffused Water Reflectance

$$R_w(\lambda) = 0.33 \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)} + R_F(\lambda)$$

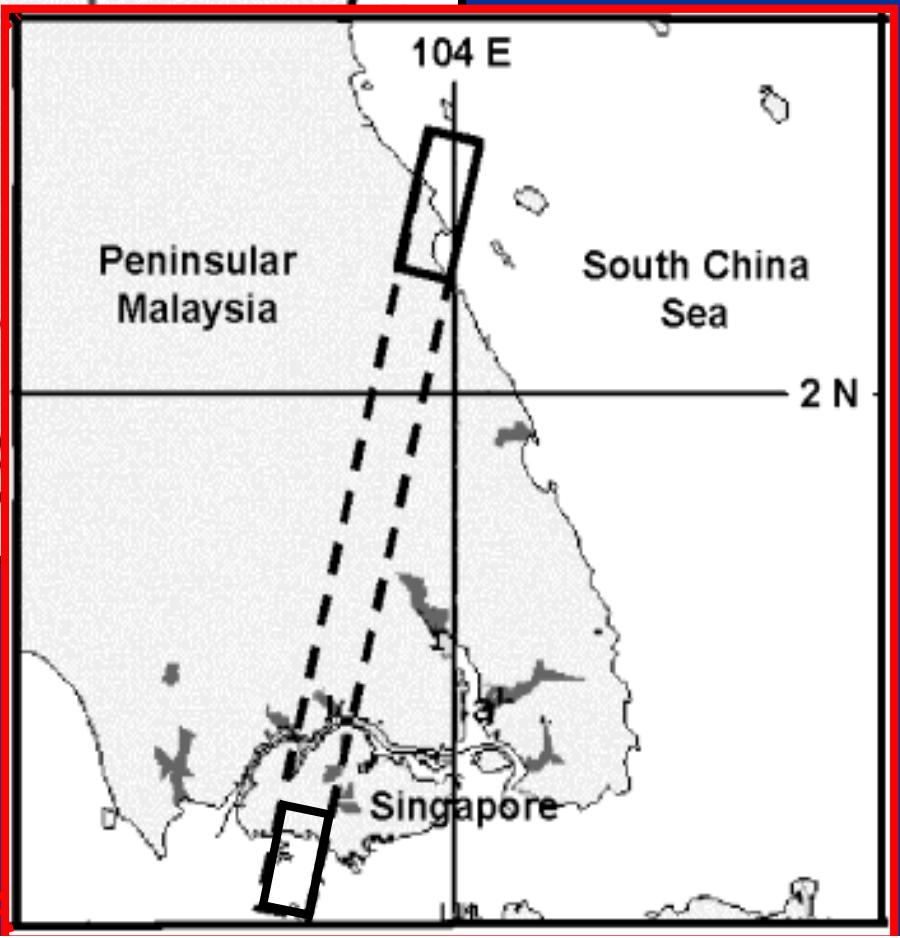
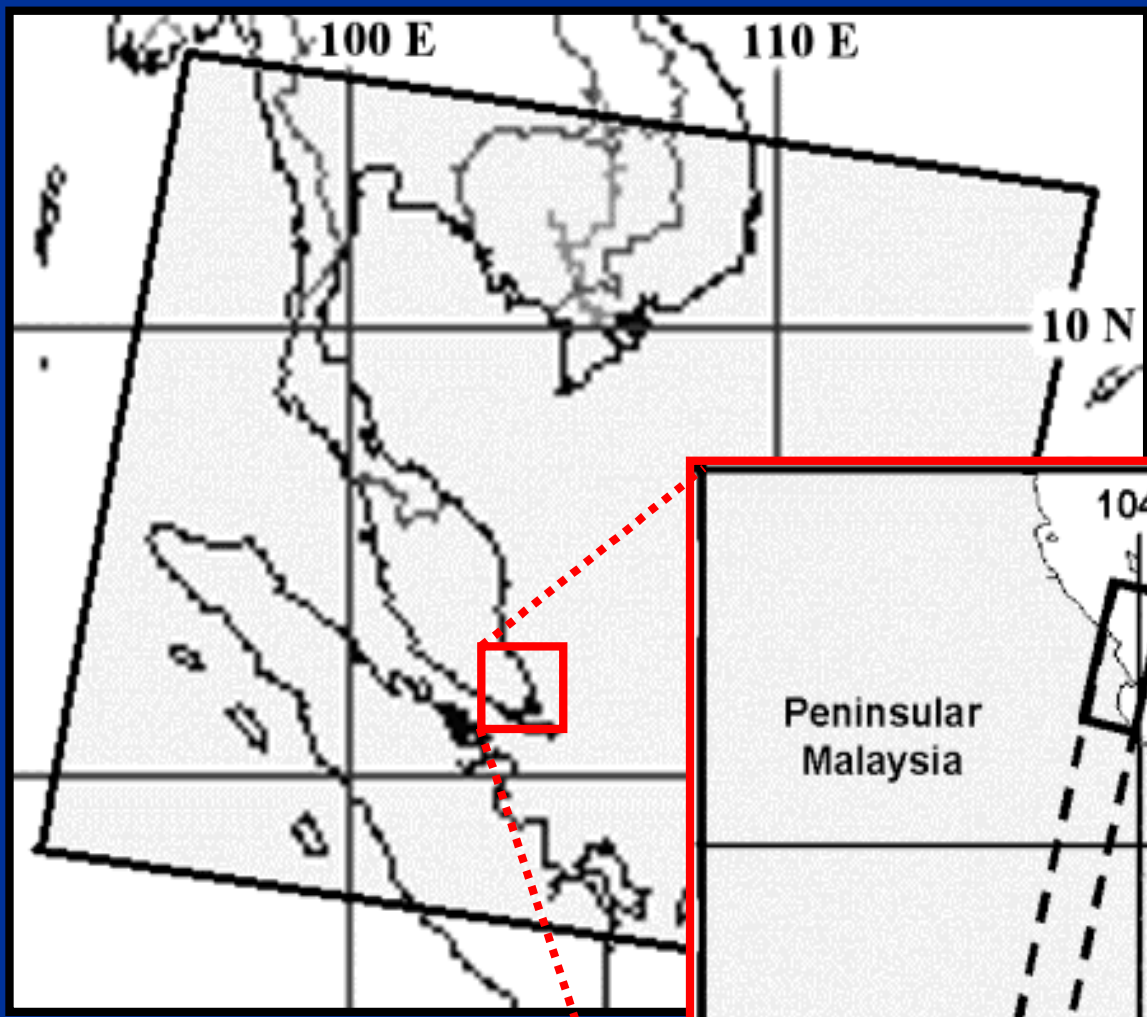
- ❖ $a(\lambda)$: absorption coefficient
- ❖ $b_b(\lambda)$: backscattering coefficient
- ❖ $R_F(\lambda)$: chlorophyll fluorescence

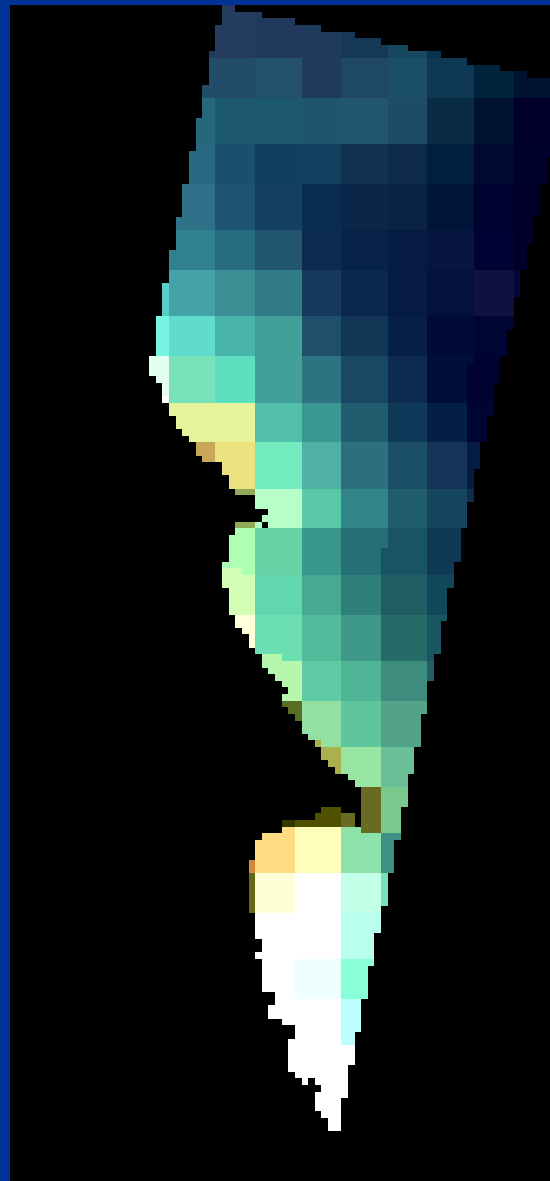
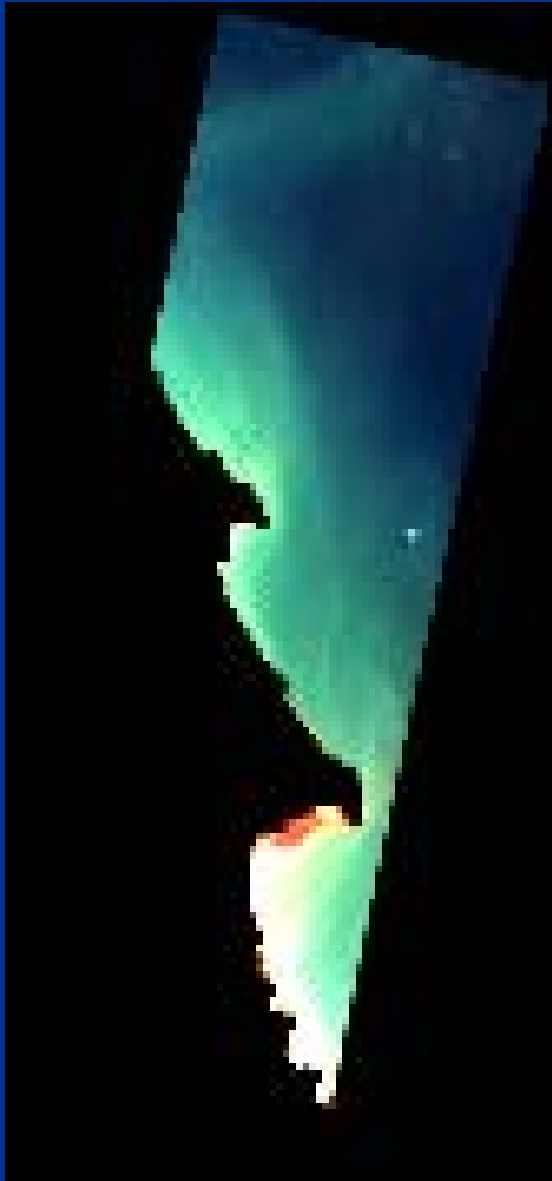
Retrieval of Parameters

- Altogether 10 parameters in the model
 - Environmental parameters: A , B , α , r
 - Water parameters: P_0 , G , X , F , S , y .
- Given a set of the parameter values, a reflectance spectrum can be calculated
- Find the set of best fit parameters that gives the smallest deviation between measured and calculated spectrum

Data Sets

- Hyperion
 - Day 137, 2001 - South China Sea, south-eastern coast of Peninsular Malaysia
 - Day 153, 2001 - Singapore Strait, south-west of the Singapore Island
- To improve SNR, apply low pass filter to Hyperion data cube, effectively reduce the resolution to about 300 m.





South China Sea

Day 137, 2001

Left: Hyperion
(start:03:07 UTC)

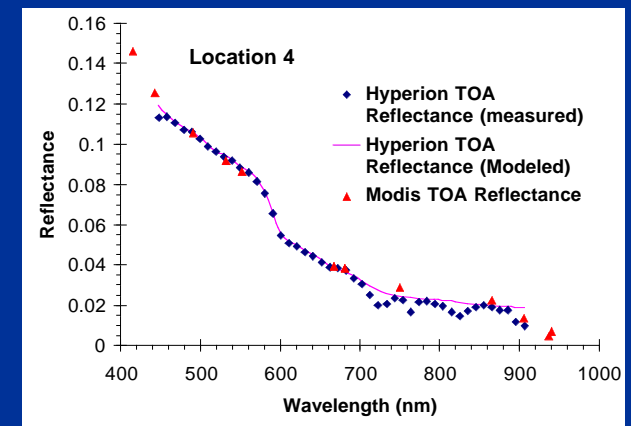
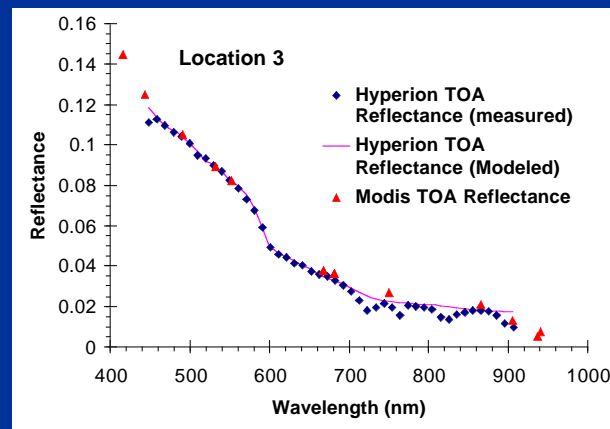
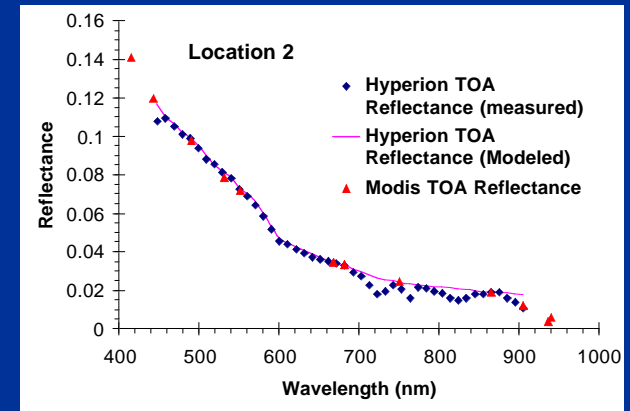
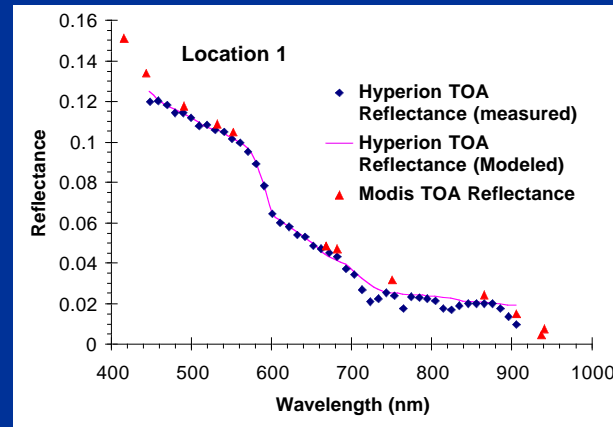
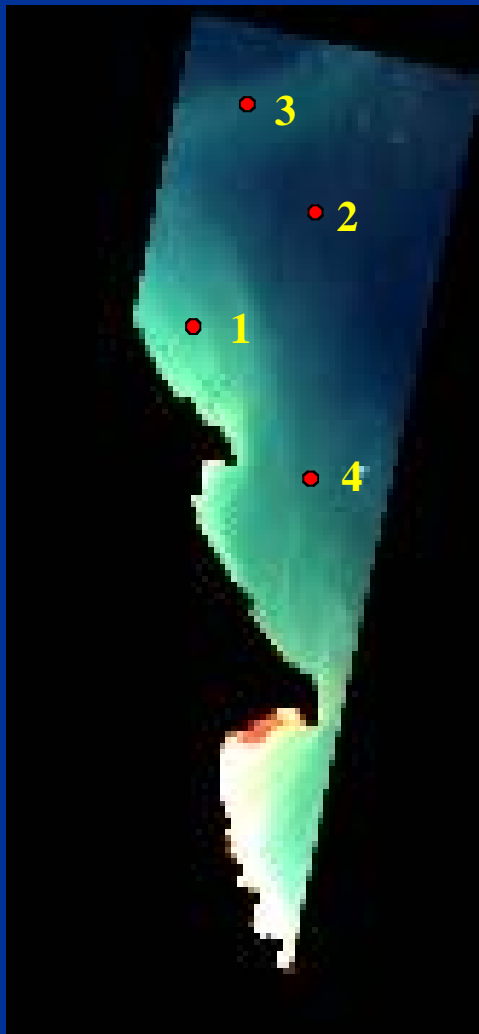
R=671nm,
G=550nm,
B=489nm.

Right: MODIS
(start:03:43 UTC)

R=667nm,
G=551nm,
B=490nm.

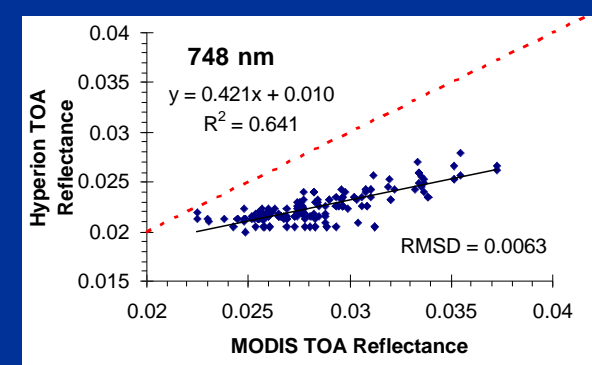
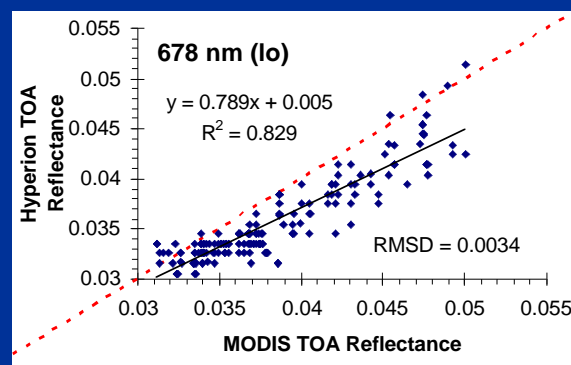
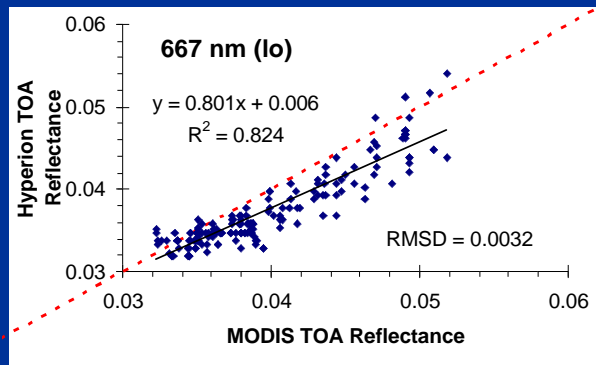
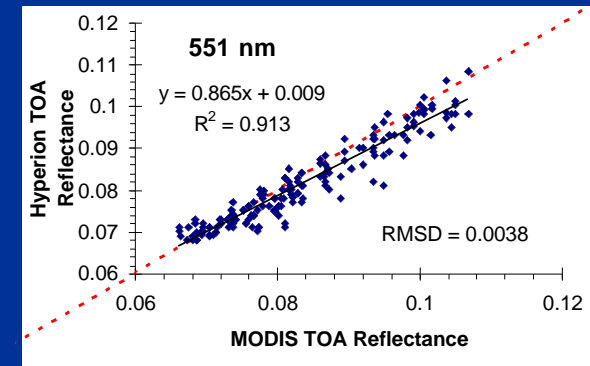
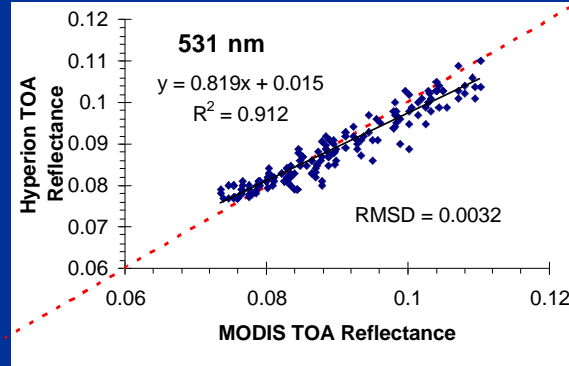
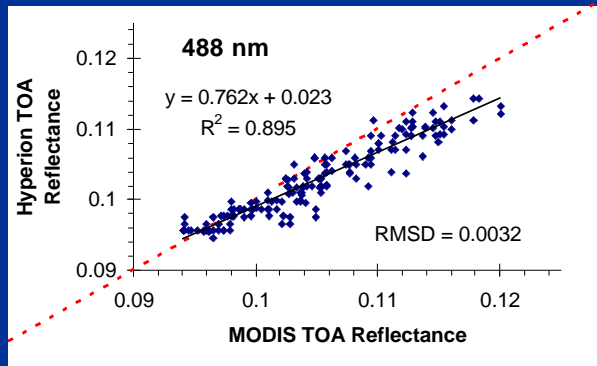
Both images are similarly stretched. The color and intensity features of both images are practically identical.

TOA reflectance



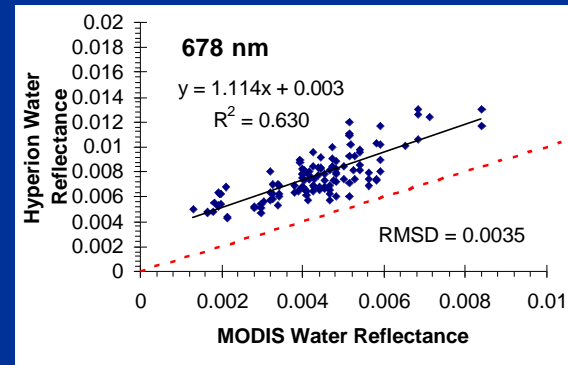
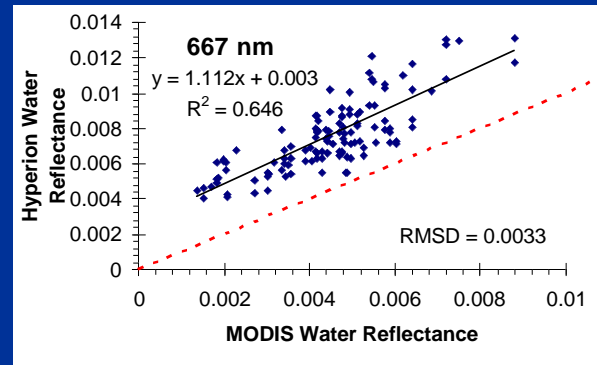
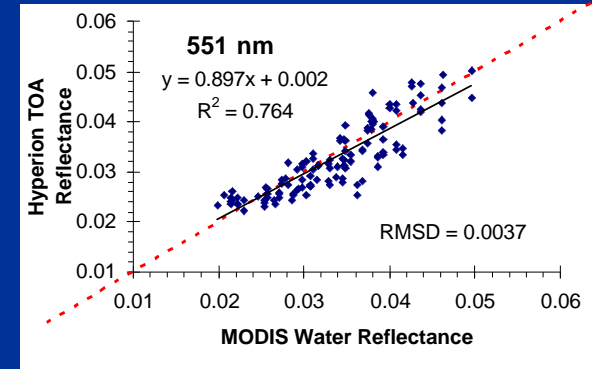
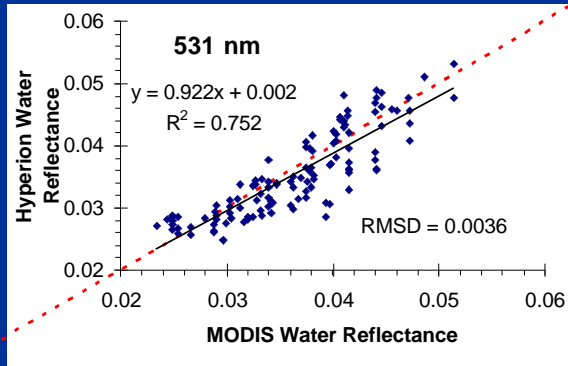
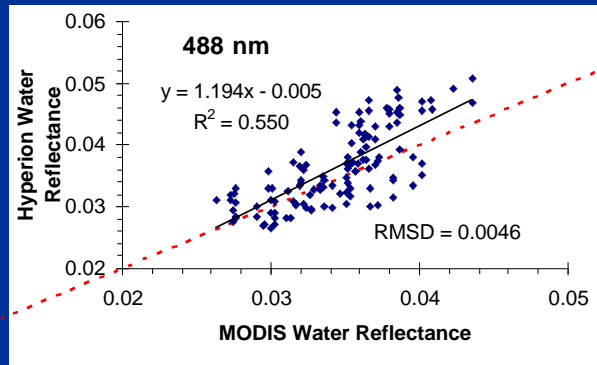
Hyperion TOA reflectance agrees very well with MODIS from 488nm to 668nm. At longer wavelengths, Hyperion reflectance is lower than MODIS

Comparison with MODIS Level 1 TOA Reflectance



Generally high correlation: Regression coeff. $R^2 > 0.8$,
RMS difference = 0.003 (Except NIR wavelengths)

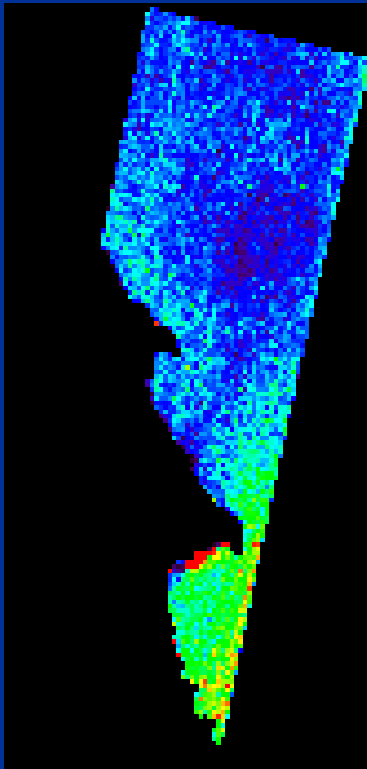
Comparison with MODIS Level 2 Water Leaving Reflectance




Water Leaving
Reflectance at 748nm not
available for MODIS
(Atmospheric Correction
Band)

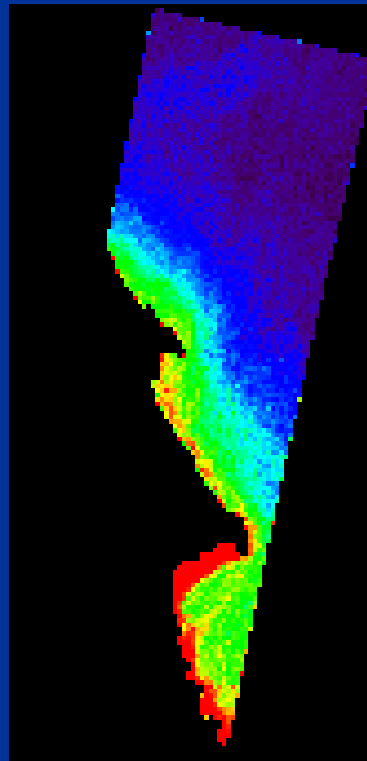
Correlation slightly degraded: Regression coeff. $R^2 > 0.6$,
RMS difference = 0.004

Maps of Seawater Optical Parameters Derived from Hyperion Data



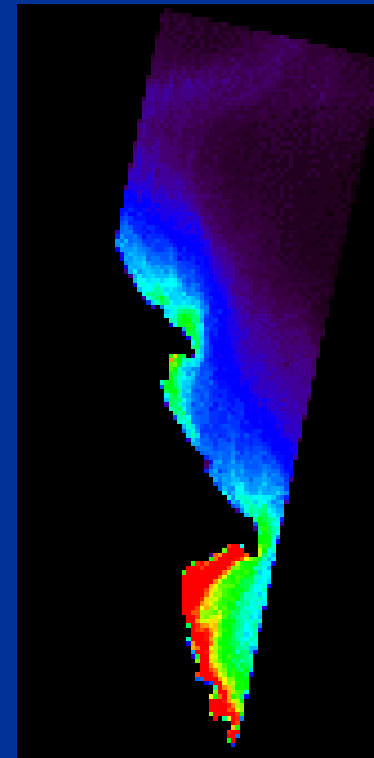
0  0.048


Chlorophyll Absorption
at 440 nm (m^{-1})



0  0.80

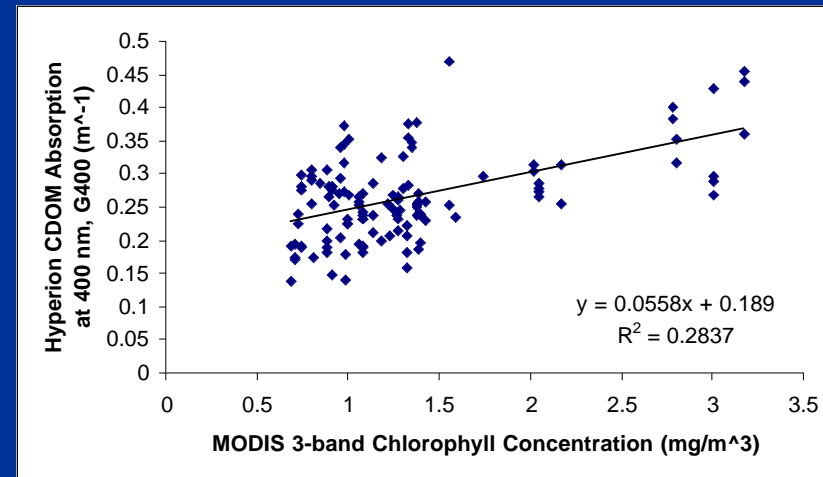
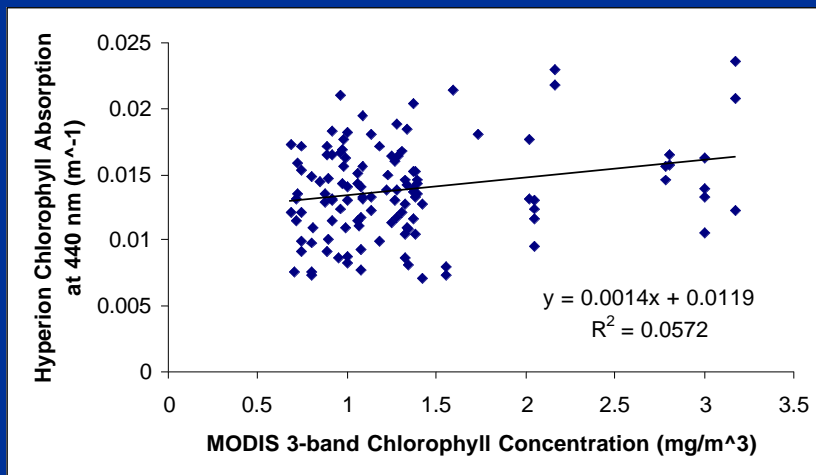
CDOM Absorption
at 440 nm (m^{-1})



0  0.20

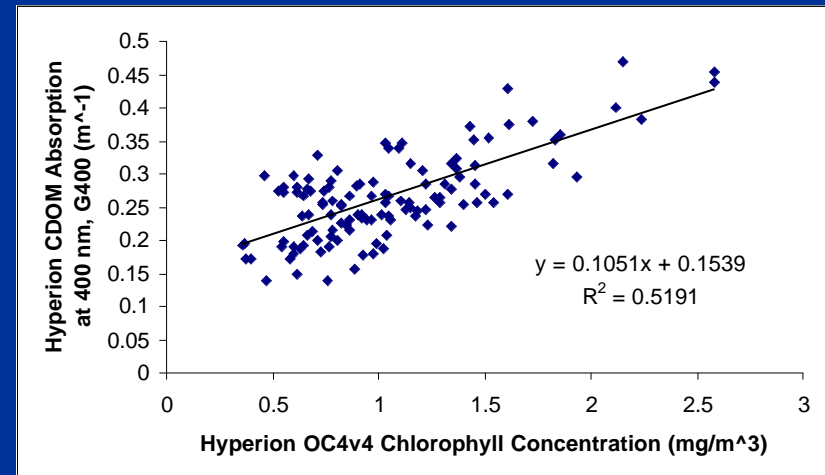
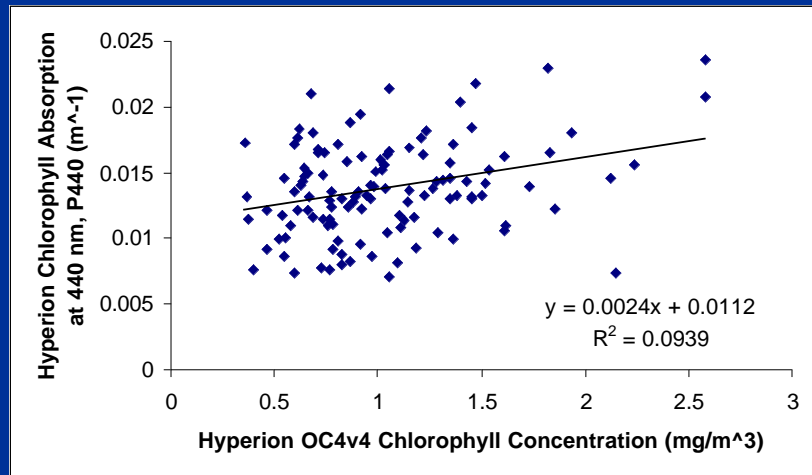
Sediment Scattering
at 551 nm (m^{-1})

Comparison with MODIS Chlorophyll Concentration



MODIS Chl-a concentration has low correlation with Chlorophyll absorption derived from Hyperion data. However, the correlation with CDOM absorption coefficient is significantly higher.


Comparison with Chlorophyll Concentration derived using SeaWiFS OC4v4 algorithm



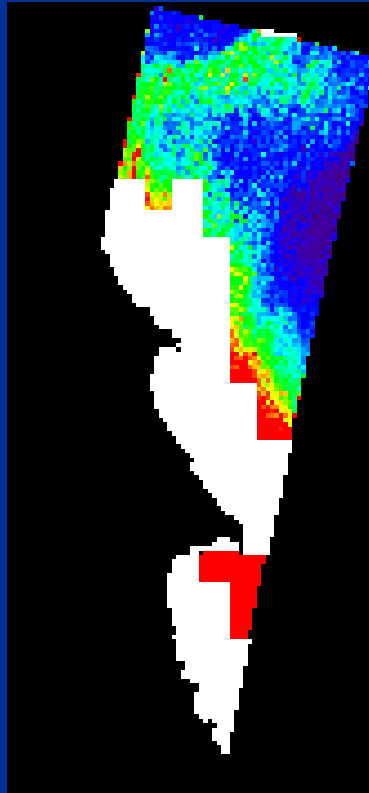
Similar trend as before: OC4v4 Chl-a concentration has low correlation with Chlorophyll absorption, but the correlation with CDOM absorption coefficient is significantly higher.

Maps of Seawater Optical Parameters Derived from Hyperion Data



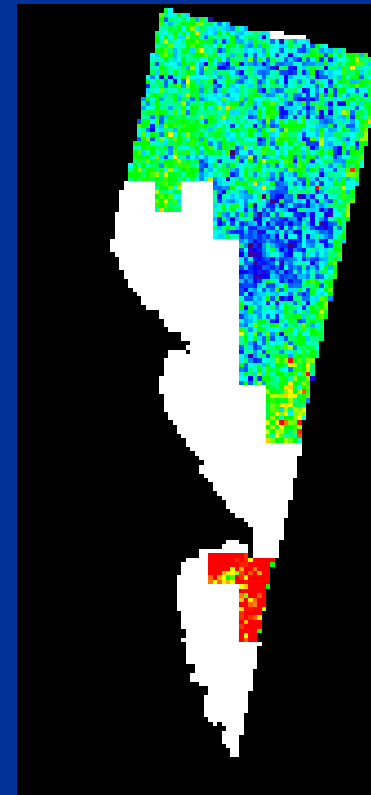
0  2.5


MODIS Chlorophyll
Concentration (mg/m^3)



0  2.5

OC4v4 Chlorophyll
Concentration (mg/m^3)



0  0.03

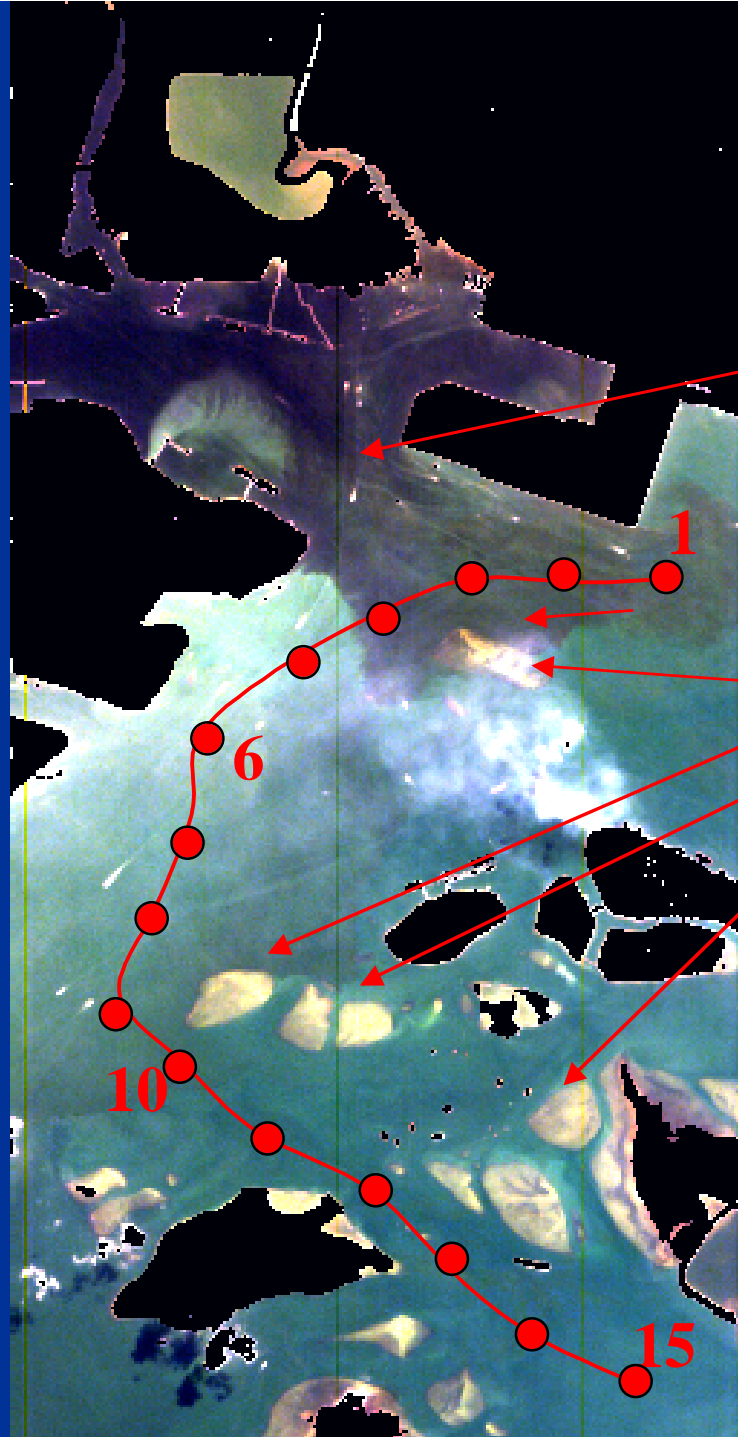
Hyperion Chlorophyll
Absorption at 440 nm (m^{-1})

Singapore Strait

Southern coast of
Singapore Island

Day 153, 2001

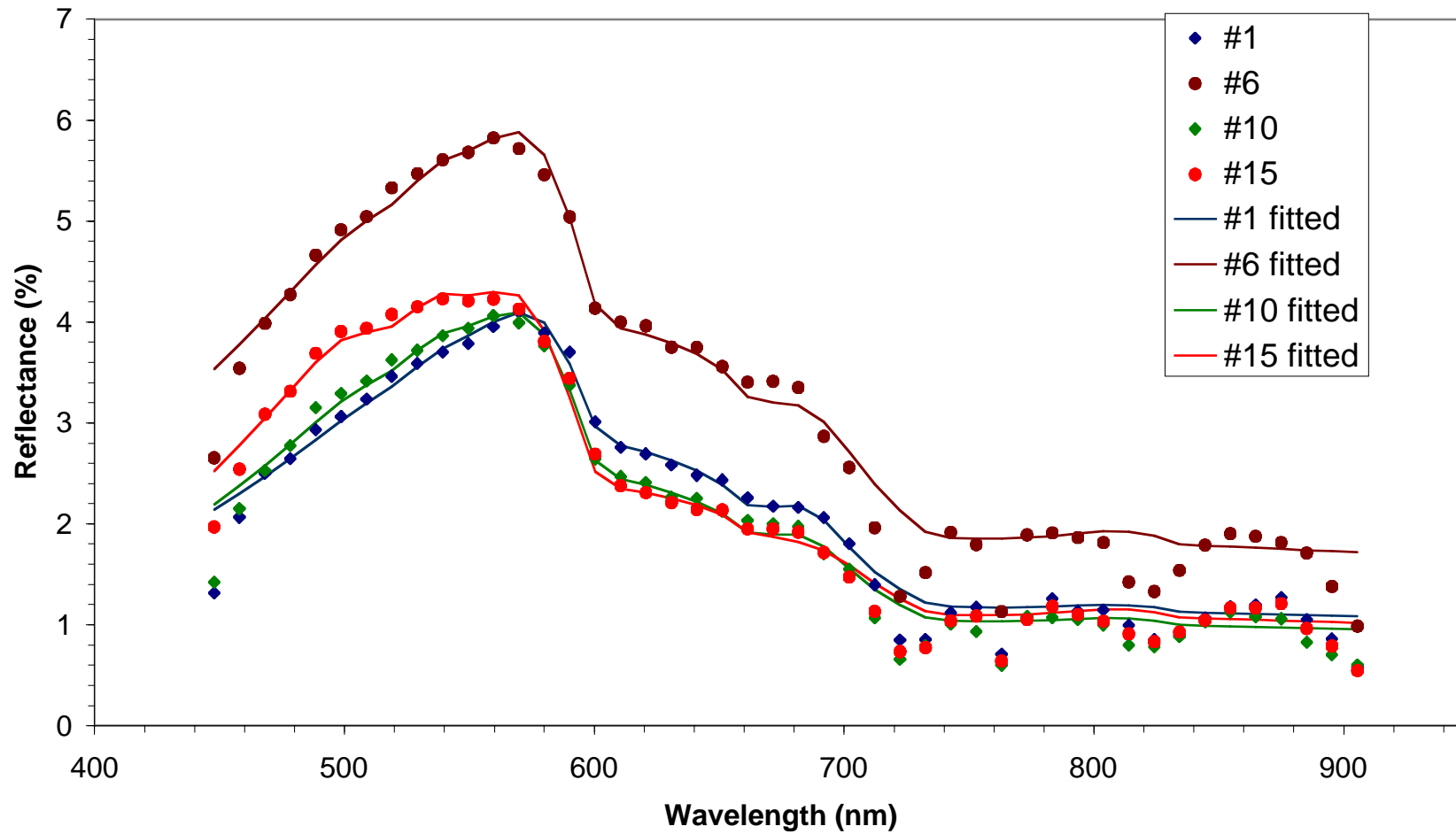
(MODIS Level 2
Ocean Color data
not available, too
close to land)



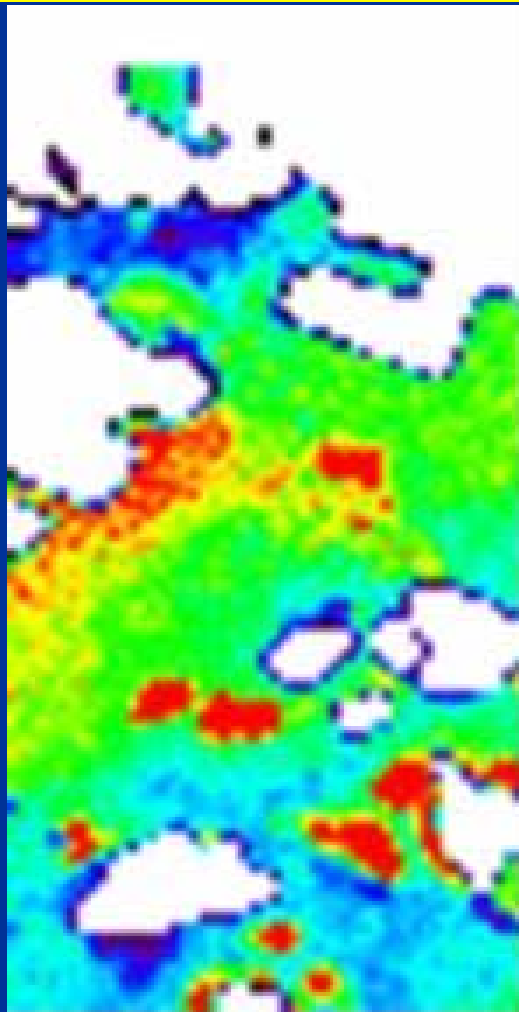
Dark
water

Submerged
Reefs

Rayleigh Subtracted Reflectance (Singapore Strait)

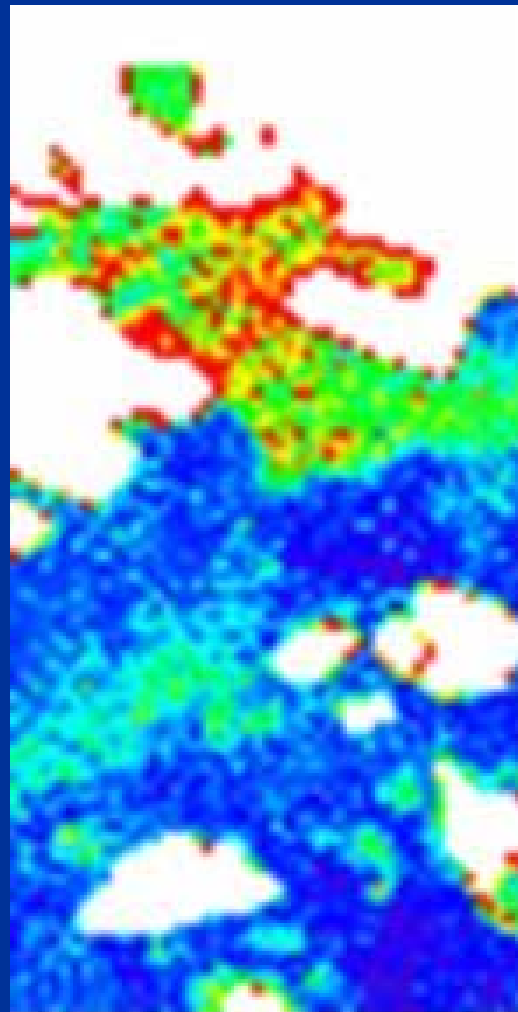


**Sediments Backscattering
at 550 nm**



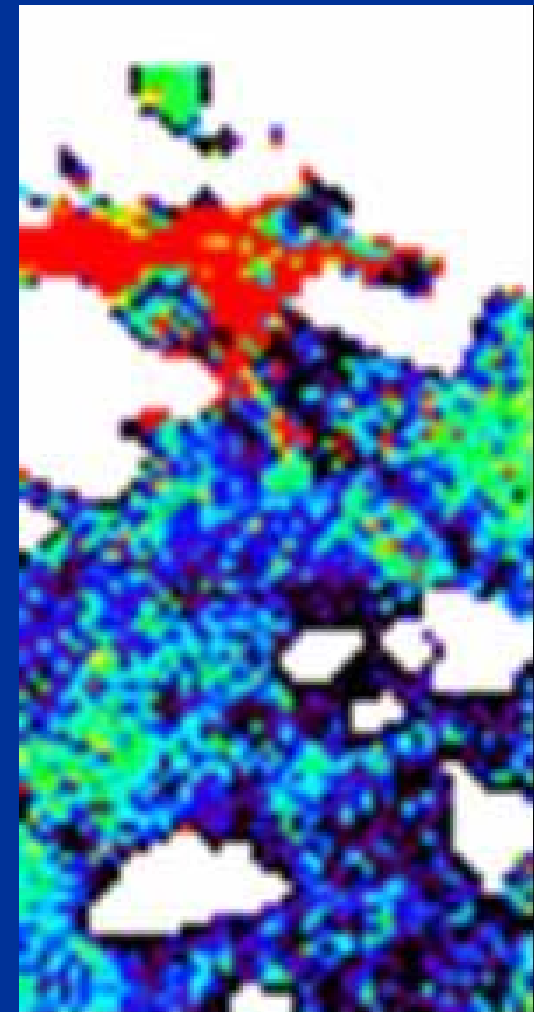
0 (m⁻¹) 0.65

CDOM Abs. at 440 nm



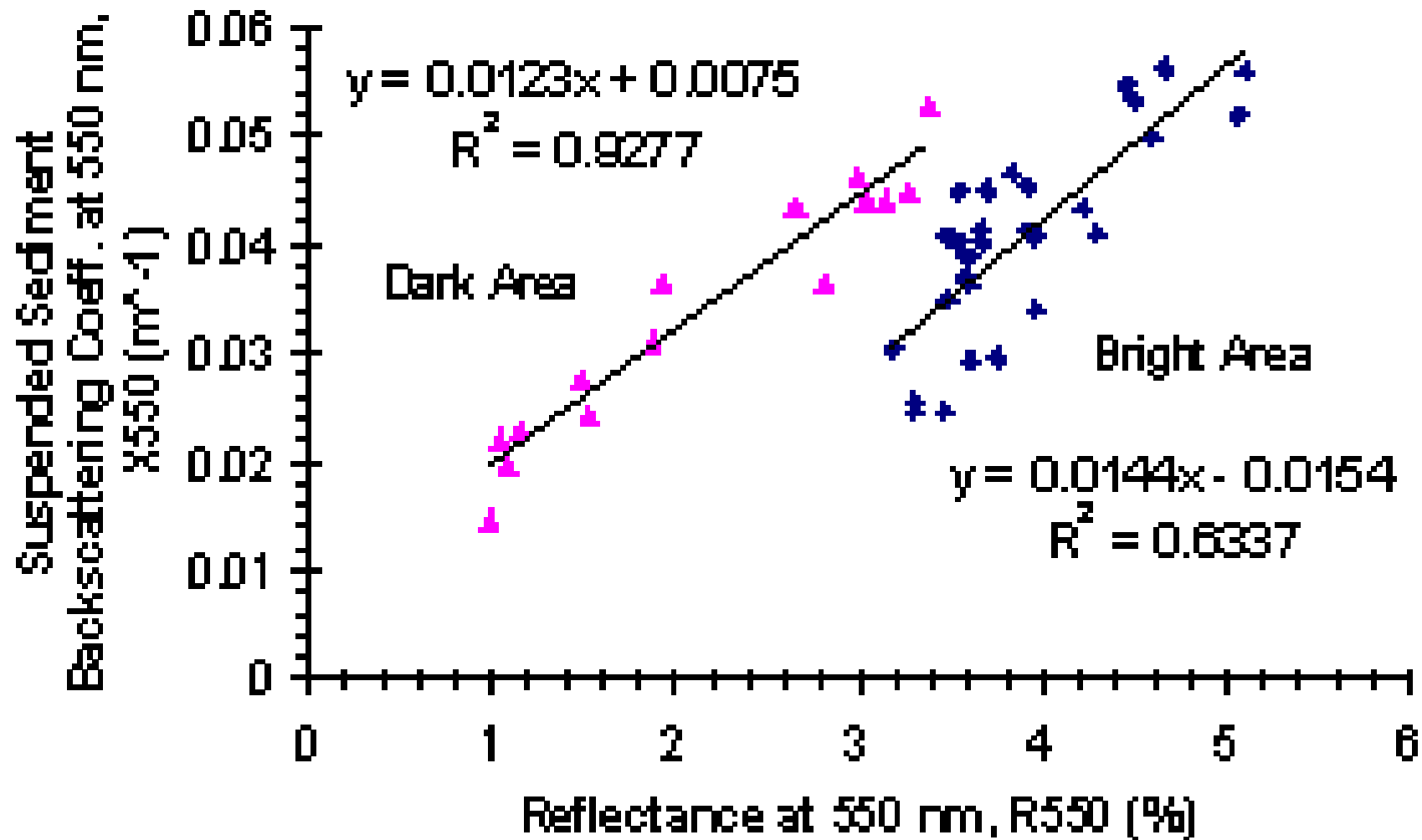
0 (m⁻¹) 1.2

Chlorophyll Abs. at 440 nm



0 (m⁻¹) 0.25

The dark water area is due to abundance of dissolved organic matter, not lack of sediments.



Conclusions

- Hyperion data can be used to derived coastal water optical parameters
- The problem of SNR can be overcome by averaging over a larger area (10 x 10 pixels) - OK for sea water.
- A technique has been developed to derive water optical parameters from Hyperion measured reflectance spectra, by using a coupled atmosphere-seawater reflectance model.
- There is good agreement between the Hyperion TOA reflectance and MODIS level 1 TOA reflectance

Conclusions

- There is good agreement between Hyperion derived water leaving reflectance and MODIS Level 2 water leaving reflectance
- Chlorophyll absorption coefficient at 440nm retrieved from Hyperion has a low correlation with MODIS Chlorophyll Concentration.
- However, MODIS chlorophyll concentration seems to correlate well with Hyperion derived CDOM absorption coefficient.
- In situations of high CDOM, low chlorophyll, MODIS chlorophyll product seems to be sensitive to CDOM, instead of chlorophyll.