NRL Remote Sensing: HICO Products & Results

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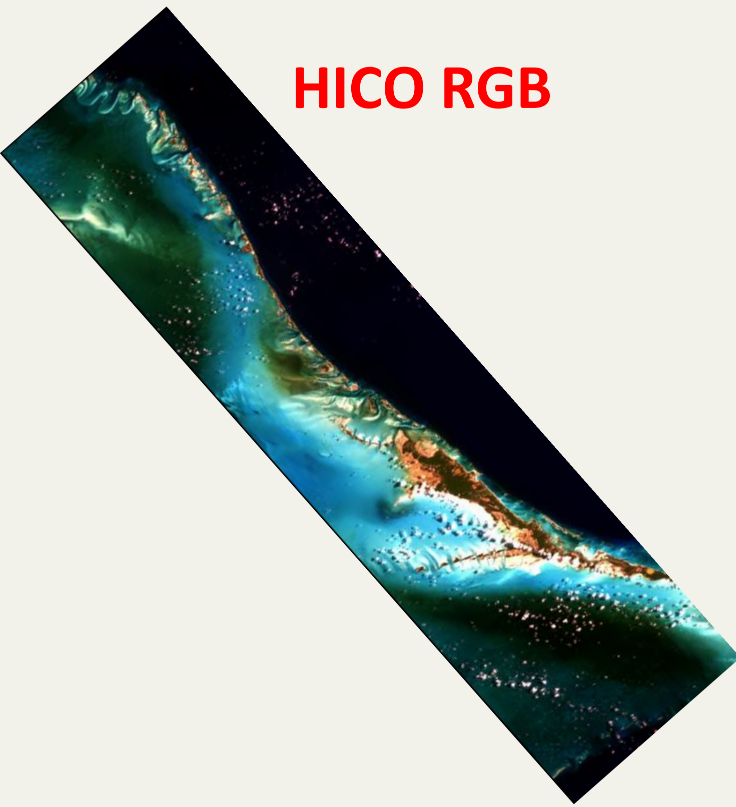
Outline

- Bathymetry/Bottom Type Retrieval
- Surface Velocity Retrieval
- Chlorophyll-*a* Retrieval
- Sensor Noise Effects
- Challenges
- Conclusion

Bathymetry/ Bottom Type

Lee Stocking Island, the Bahamas

- HICO image acquired on 16 June 2010
- Retrievals made using a LUT-based approach



HICO RGB

Coastal Waters Spectral Toolkit (CWST): Look-up Table Approach

Parameters:

Phytoplankton
Sediment
CDOM
Depth
Bottom Rrs

Input into Radiative Transfer Model

3 Component Radiative Transfer Model (EcoLight)→ Remote Sensing Reflectance Spectrum (R_{RS})

Database

Bottom	Reflectance

Pigment	Absorption

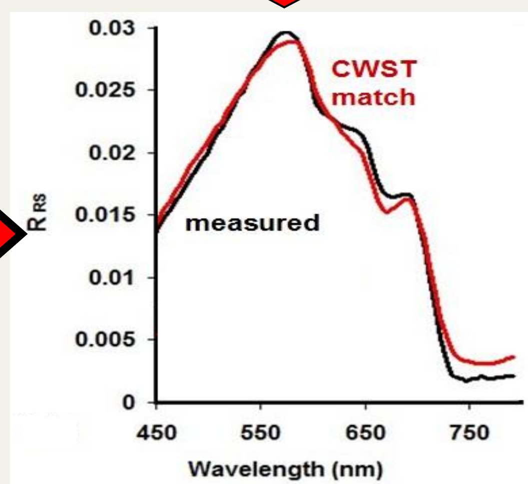
Index	Depth	Bottom	Pigment
111	0.0	14	1
112	0.5	3	1
113	1.0	14	4
114	2.0	14	2

Extract subset of parameters expected to be found in area [index, parameters, R_{RS} spectra]

Calibrated At Sensor Radiance

Lee Stocking Island, The Bahamas

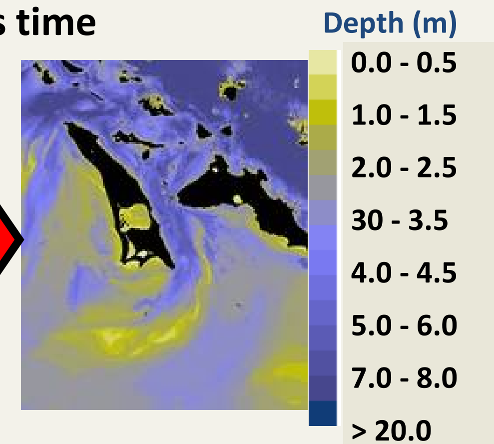
Atmospheric Correction



Metric is Euclidean Distance

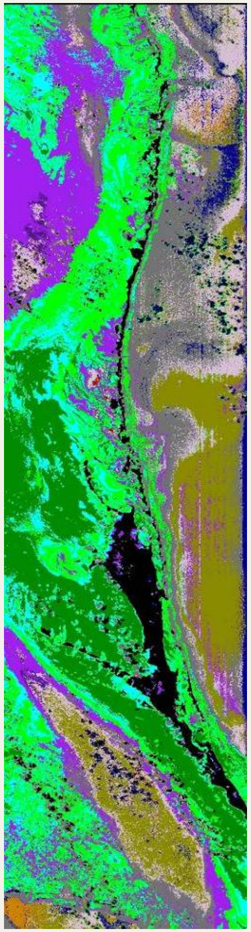
Compare measured spectrum to selected spectra to find best match - takes time

Phytoplankton Sediment CDOM, Depth Bottom Type

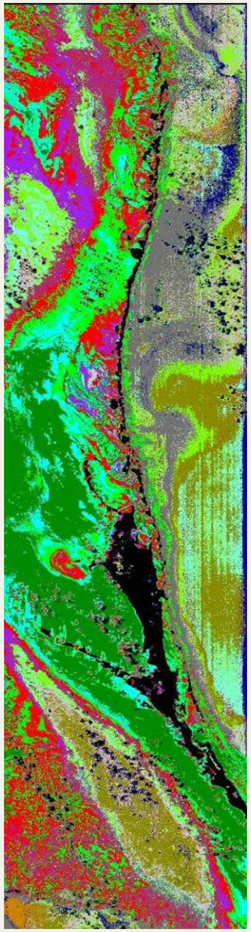


Courtesy: Jeffrey Bowles, NRL

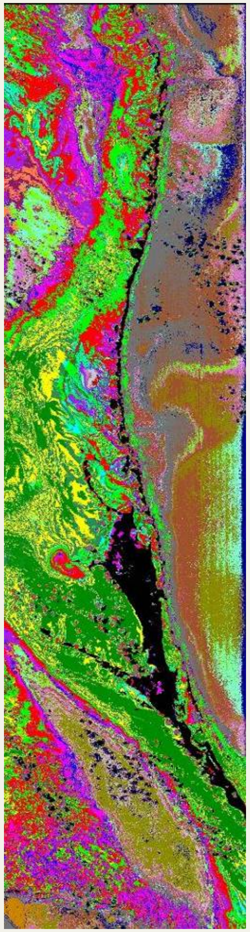
Bottom Type Retrieval



EL + LSI



EL + LSI + 50:50 mixes



EL + LSI + 50:50 + 25:75 mixes

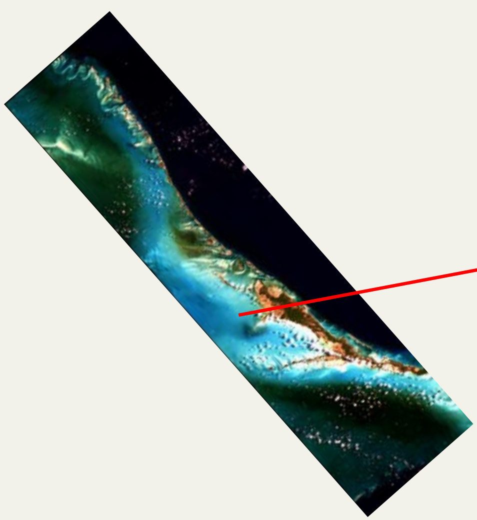
- masked pixel
- Ooid Sand (LSI)°50°Turf Algae (LSI)°50
- Biosand and grass (LSI)
- avg°ooid°sand°25°avg°seagrass°75
- Ooid Sand (LSI)°75°Turf Algae (LSI)°25
- Coral Sand (EL)
- Turf Algae (LSI)°75°Ooid Sand (LSI)°25
- avg°ooid°sand°50°avg°seagrass°50
- avg°ooid°sand°75°avg°seagrass°25
- Dark Sediment (LSI)
- Dark Sediment (LSI)°75°Turf Algae (LSI)°25
- 18% Gray
- avg°dark°sediment°50°avg°seagrass°50
- avg°dark°sediment°25°avg°seagrass°75
- Turf Algae (LSI)°75°Dark Sediment (LSI)°25
- Dark Sediment (LSI)°50°Turf Algae (LSI)°50
- Turf Algae (LSI)
- Ooid Sand (LSI)
- Red Algae (EL)
- Seagrass (LSI)
- avg°dark°sediment°75°avg°seagrass°25
- No match found (at all)
- Optically deep water
- Coral Dichocoenia (LSI)
- Green Algae (EL)
- Clean Seagrass (EL)
- Macrophyte (LSI)
- Brown Algae (EL)
- Coral Montastria (LSI)

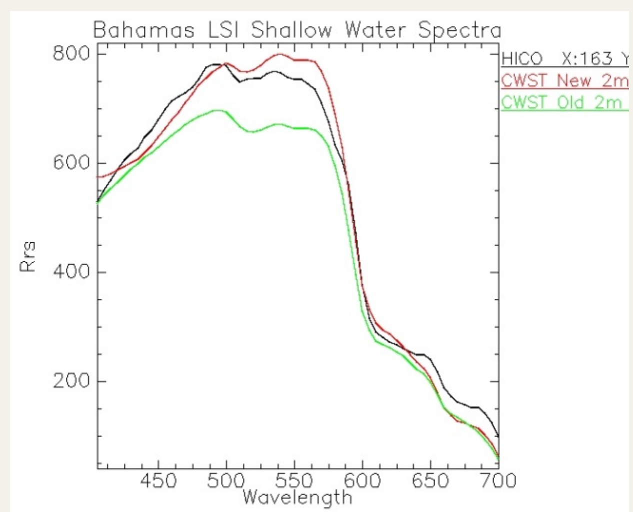
Courtesy: Gia Lamela, NRL

Effect of Adding Mixed Bottom Types

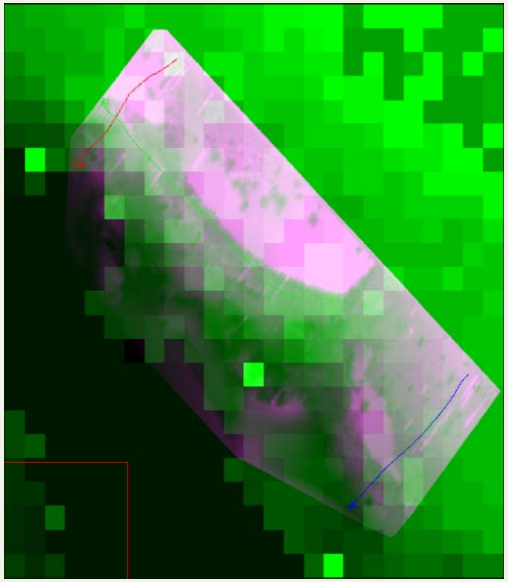
Euclidean Distance Statistics

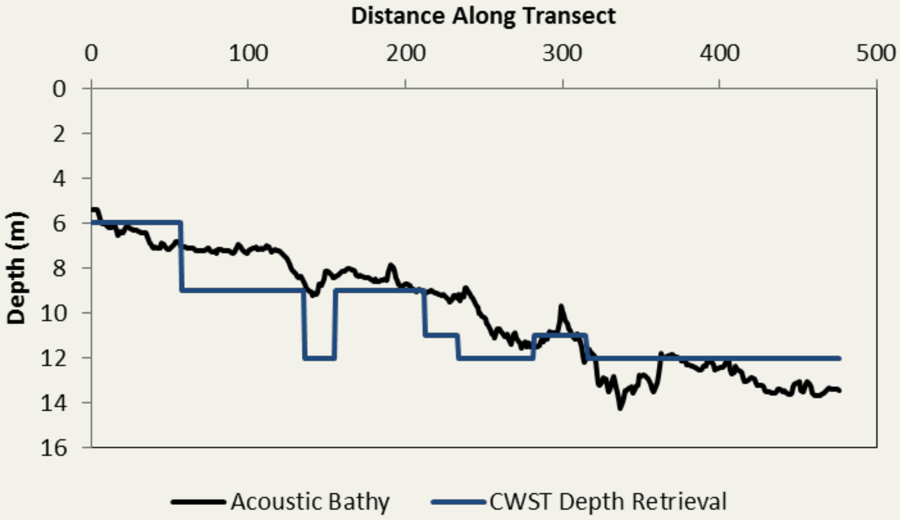
	Min	Max	Mean	StDev	Points
EL+LSI Bottoms	0.000503	11.95546	0.009726	0.076473	1,012,000
EL+LSI+50:50 Bottoms	0.000474	8.535275	0.009193	0.077433	1,012,000
EL+LSI+25:75 Bottoms	0.000373	8.695241	0.008164	0.078247	1,012,000



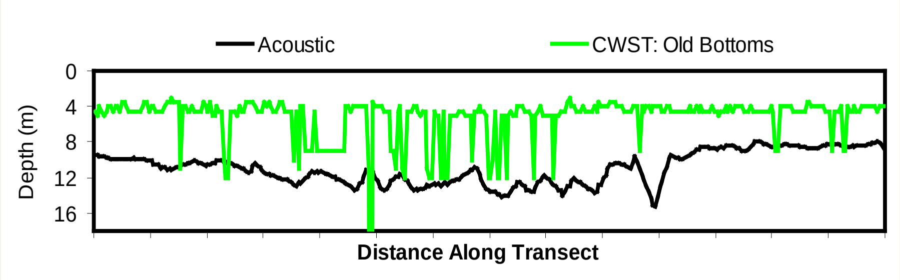


Bottom Depth Retrieval

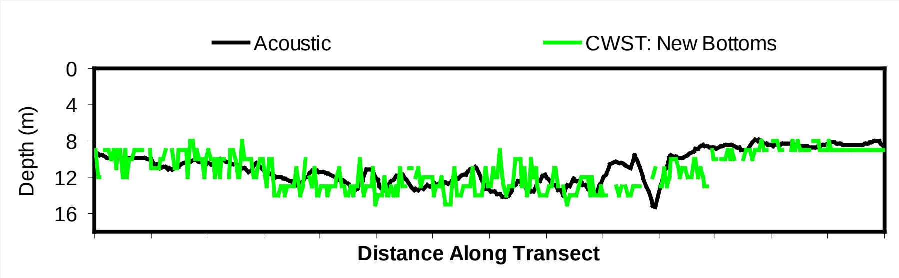




WITHOUT PROPER BOTTOMS



WITH PROPER BOTTOM TYPES



Courtesy: Gia Lamela, NRL

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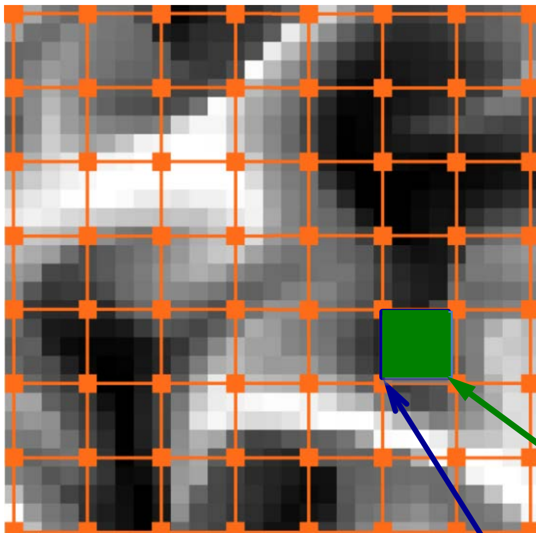
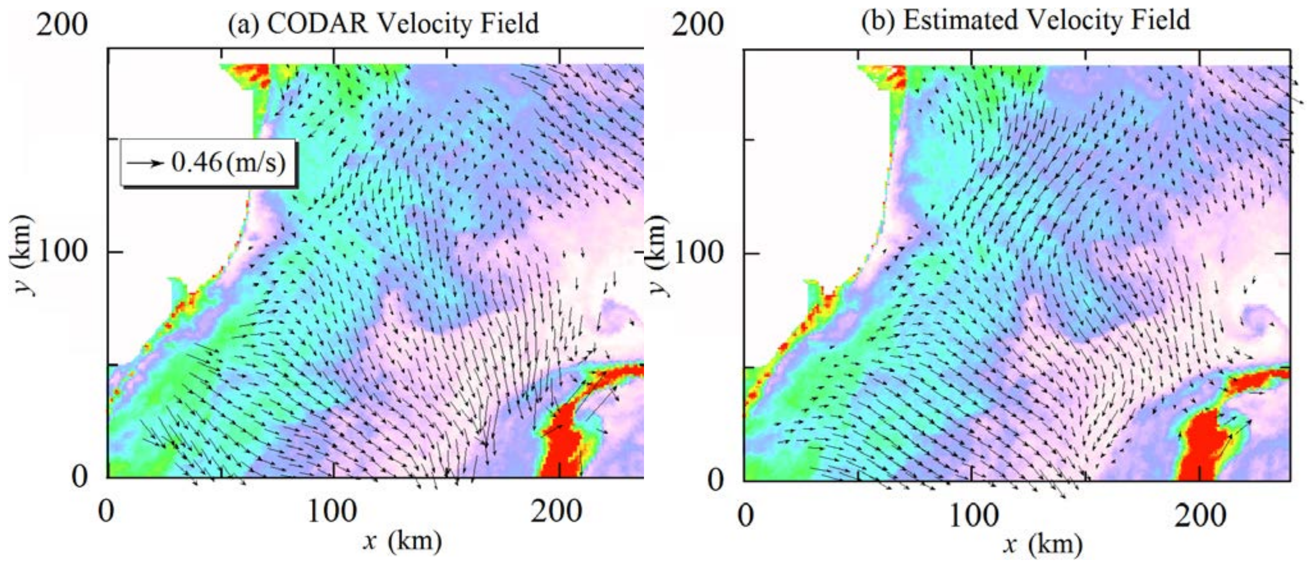
- Sensor Noise Effects
- Challenges
- Conclusion

Surface Velocity from Global Optimal Solution (GOS) - *Developed at NRL*

Tracks image features and requires only two images (e.g., May 5, 2007)

Model Grid for GOS



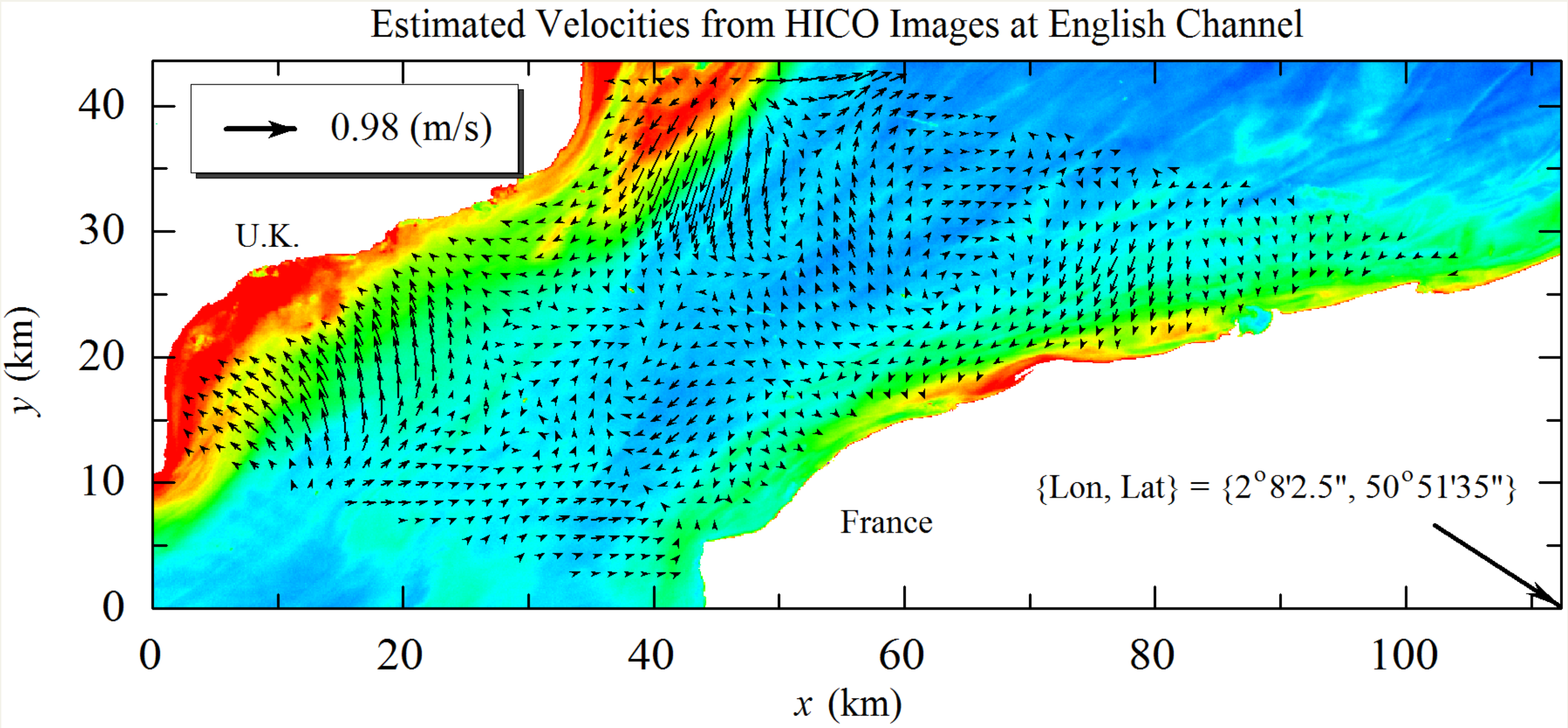


e.g., $v = a+bx+cy+dxy$

- Divides images into blocks & models velocity field in each block
- Optimize velocity in all blocks to satisfy tracer conservation equation over image
- Yields dense, differentiable velocity field—suitable for model initiation
- *Uniquely a*daptable to 2 or more tracers (e.g. IR & sediment) for improved accuracy

Surface Velocity from HICO

- Images taken at 10:05:46 UTC and 11:41:13 UTC on March 22, 2011
- Velocities determined using a three-tracer element (R_{606}, R_{674}, and R_{720})



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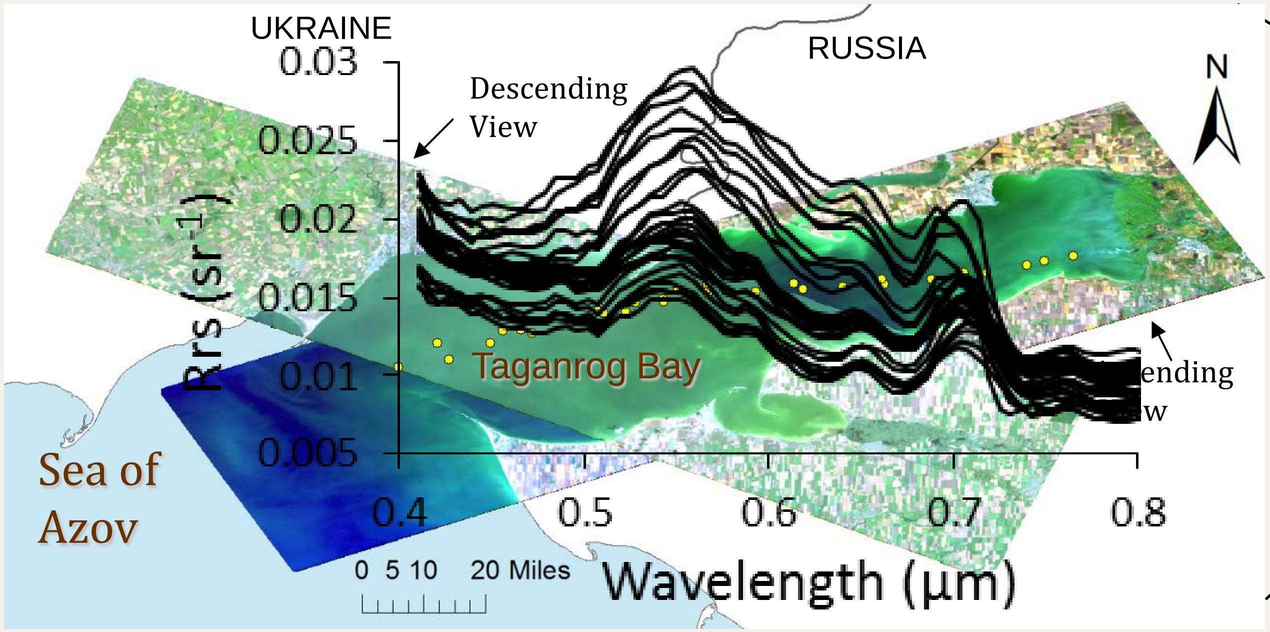
Chl-*a* Retrieval

- Test the potential of HICO as an operational tool for estimating chl-*a* concentration in coastal and estuarine waters
- Previous studies (e.g., Moses et al. 2012) using MERIS data demonstrated the reliability of NIR-red models for estimating chl-*a* concentration in productive coastal waters
- Current study using multi-temporal data collected after the demise of MERIS

Chl-*a* Retrieval – Taganrog Bay (Russia)



HICO and *in situ* data acquired: July – Sep in 2012 and Feb 2013

37 stations in 5 campaigns

Units	Min	Max	Median	Mean
mg m^{-3}	8.1	172.77	84.41	82.49

HICO data were atmospherically corrected using Tafkaa.

Chl-*a* Retrieval

Two-Band NIR-red Model

$$\text{Chl-}a \propto \left[\overline{R}_{665}^{-1} \times R_{708}\right]$$

(Gitelson 1992)

Three-Band NIR-red Model

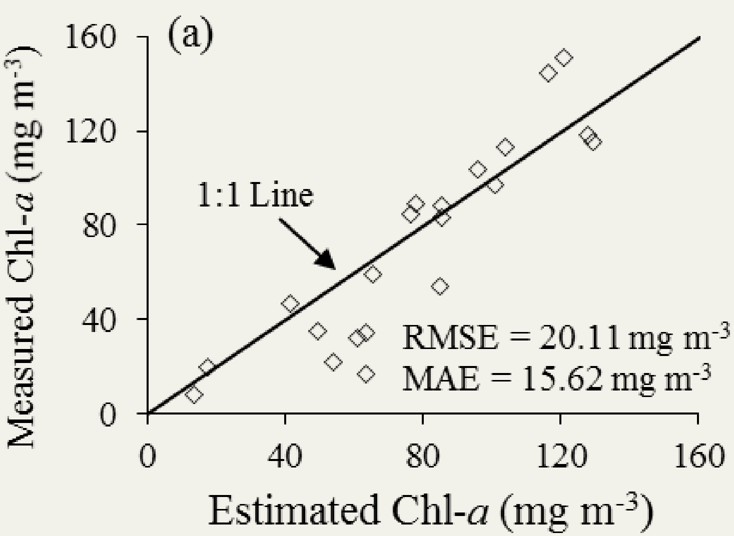
$$\text{Chl-}a \propto \left[\left(\overline{R}_{665}^{-1} - R_{708}^{-1}\right) \times R_{754}\right]$$

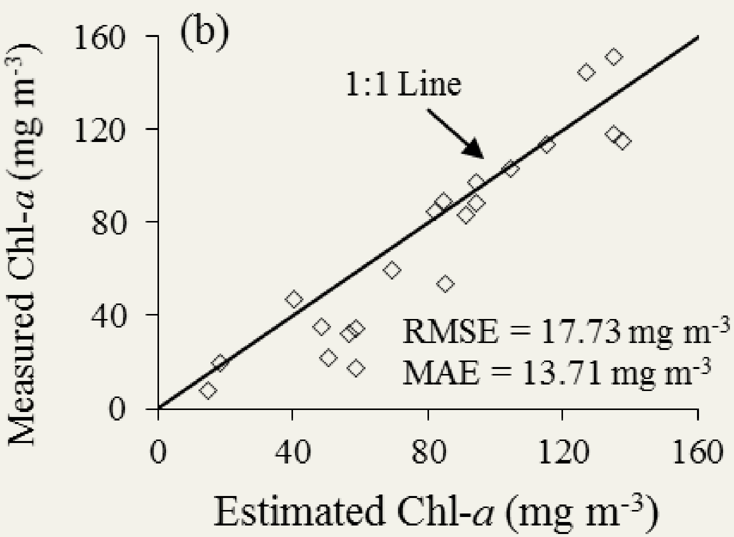
(Dall'Olmo and Gitelson 2005)

Note: $\overline{R}_{665}$ is the average of the reflectances at 662 nm and 668 nm

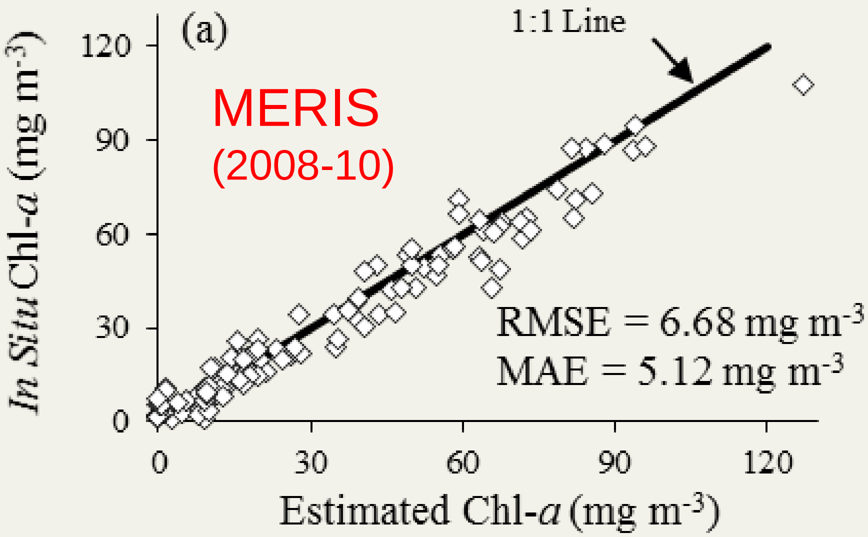
Chl-*a* = 318.33(2-Band) – 278.15

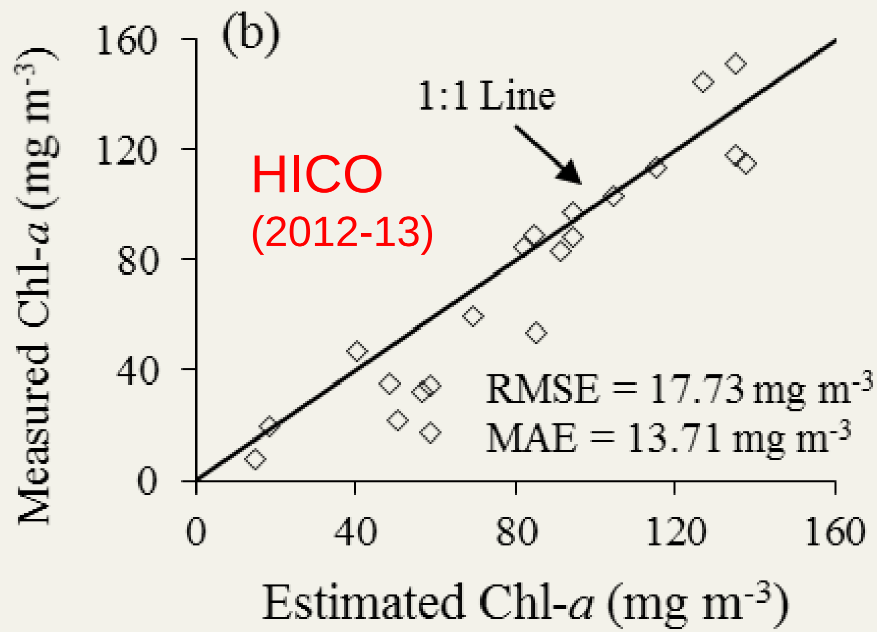
Chl-*a* = 505.05(3-Band) + 38.916





Comparison with MERIS

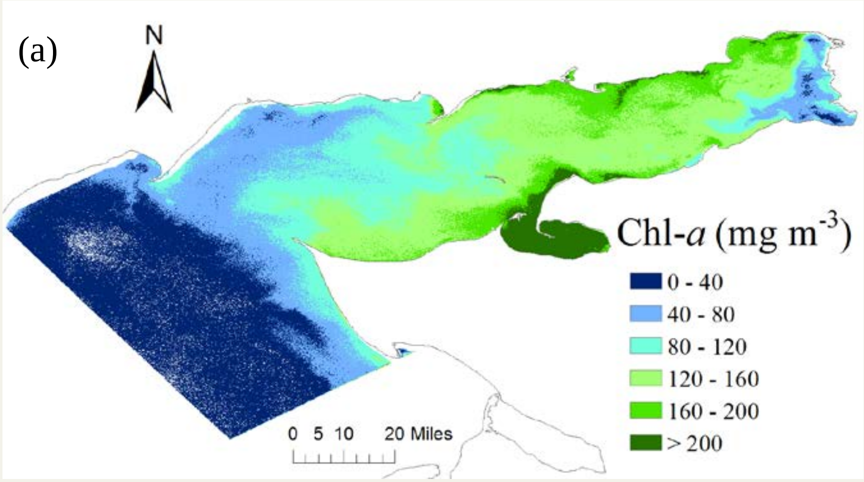


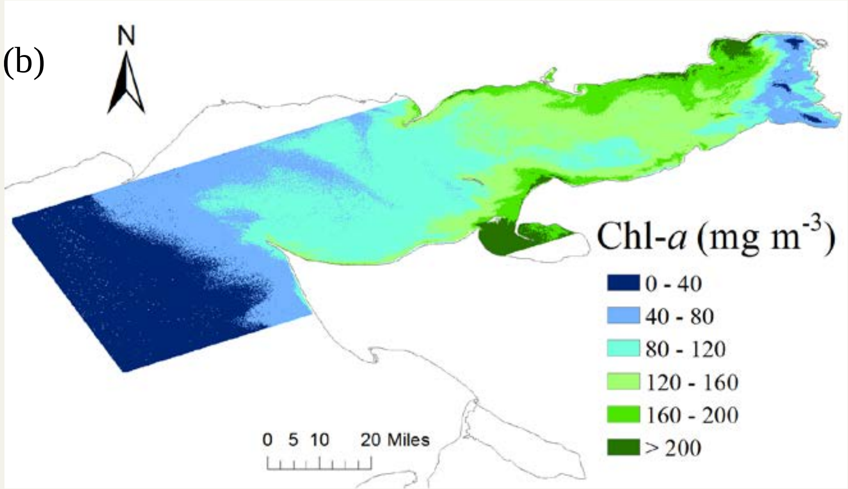


- Higher range of chl-*a* concentrations in the 2012-13 dataset
- Differences in the radiometric calibration and atmospheric correction
- Higher spatial and temporal variation in the 2012-13 dataset

Chl-*a* Maps

25 Aug 2012 | 27 Aug 2012

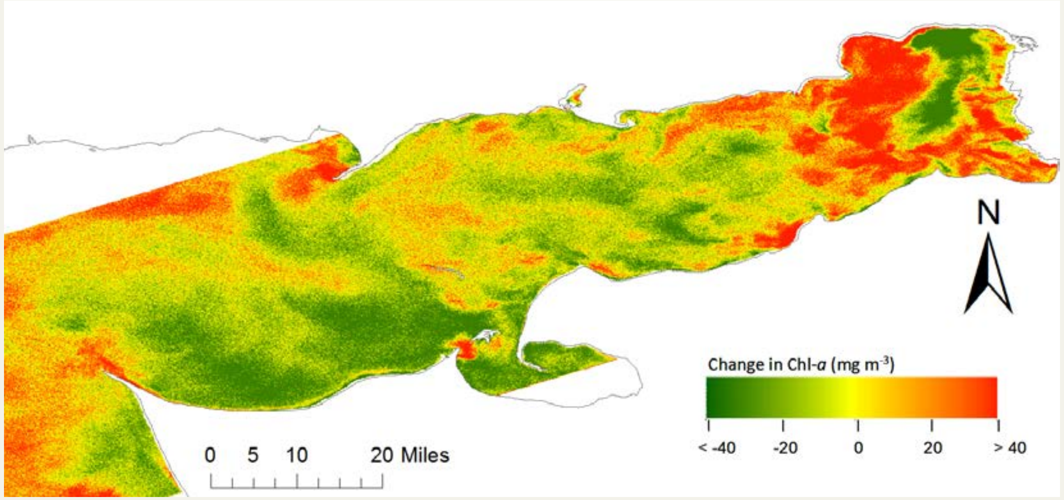




The chl-*a* estimates were quite accurate in spite of the high spatial and temporal variations of chl-*a* concentration in the bay

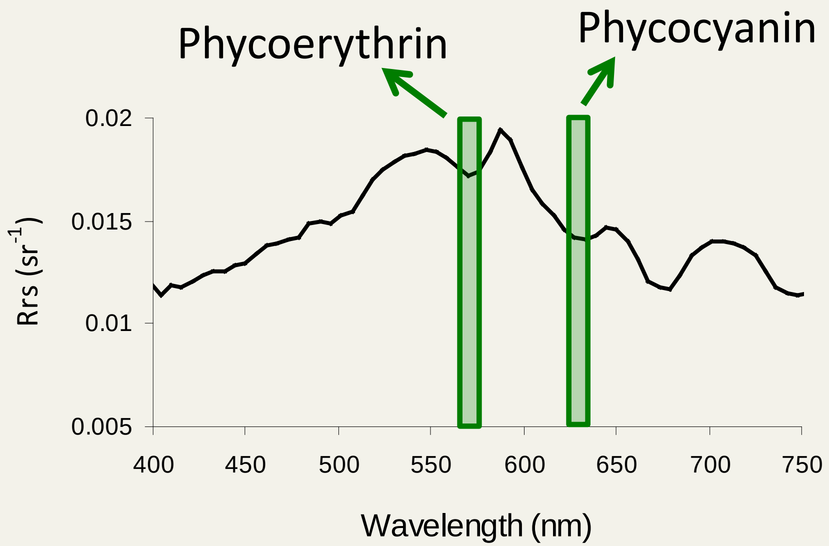
(Moses et al. 2013)

Changes in the chl-*a* concentration in the Taganrog Bay between 25 Aug and 27 Aug 2012.



Lake Kinneret (Israel)

11 March 2013



The presence of phycoerythrin and phycocyanin was confirmed by lab analysis of water samples

MODIS R645

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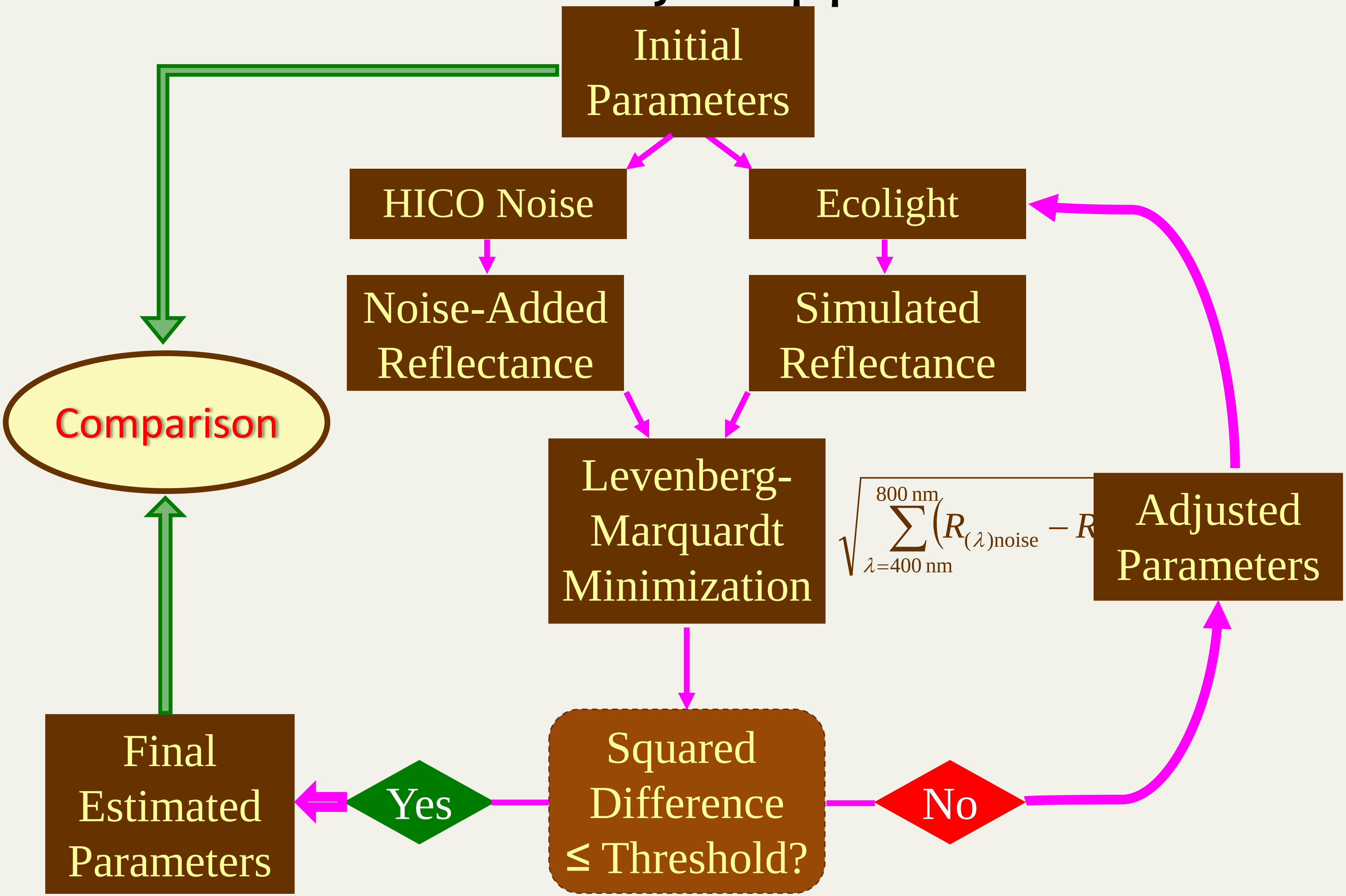
Sensor Noise Effects – Why Study?

- Inherent noise in the data affects everything retrieved from the data
- The Signal-to-Noise Ratio (**SNR**) is often specified as a single number (maximum based on a standard target)
- Prescribed SNR different from effective SNR
- Characterize the effect of HICO's SNR on the retrieval of biophysical parameters in typical coastal water conditions

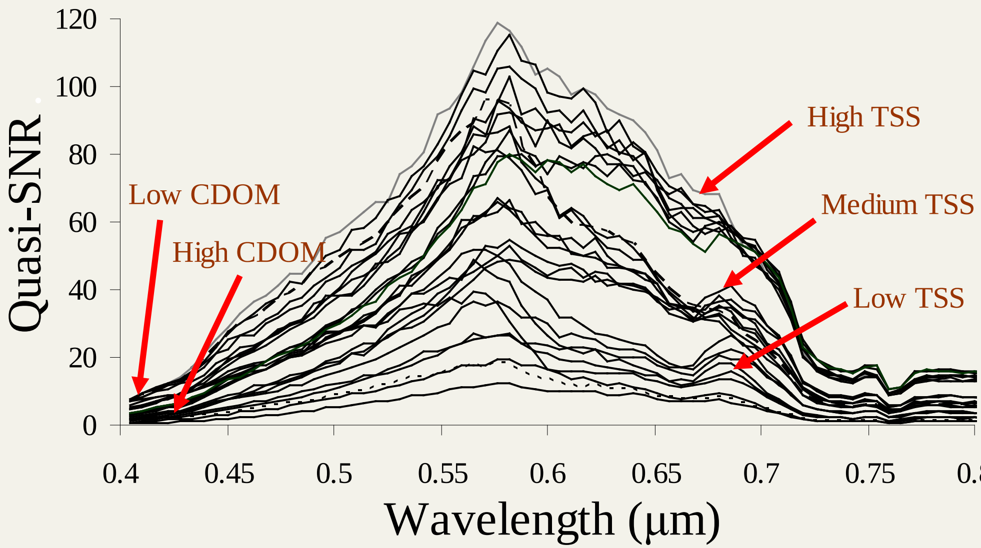
Noise Study - Approach

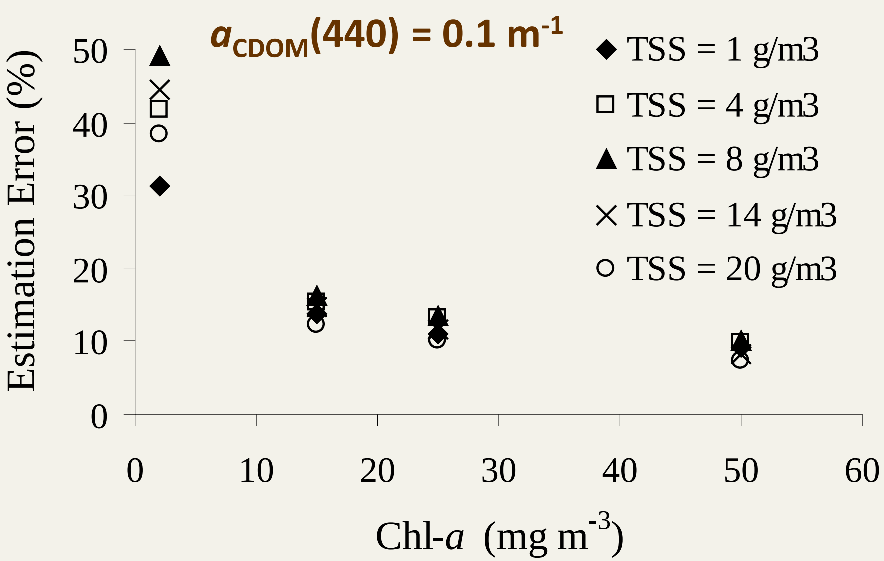
- Generate Rrs spectra using pre-defined bio-physical parameters
- Propagate the spectra through the atmosphere to generate at-sensor radiance
- Add noise to the at-sensor radiance
- Convert the noise-added at-sensor radiance to at-surface Rrs
- Retrieve parameters from noise-added Rrs and compare the results to the original parameters

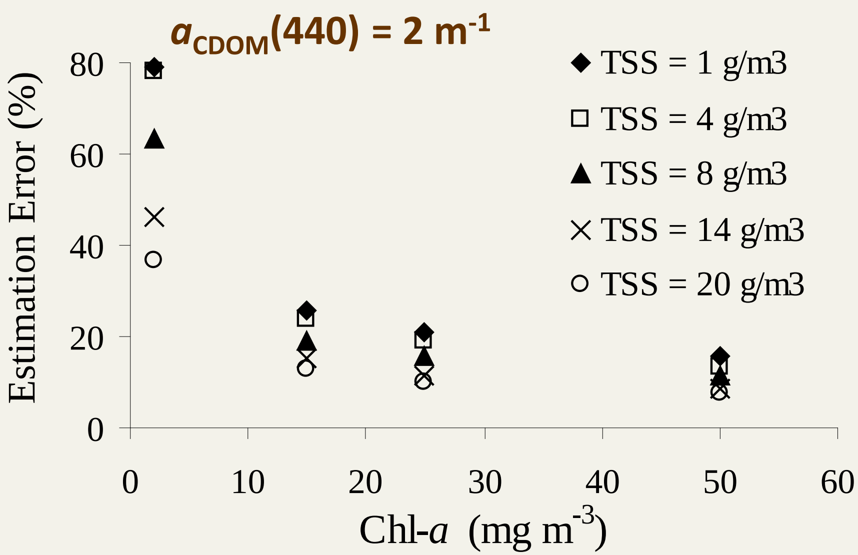
Noise Study – Approach



Noise Study - Results

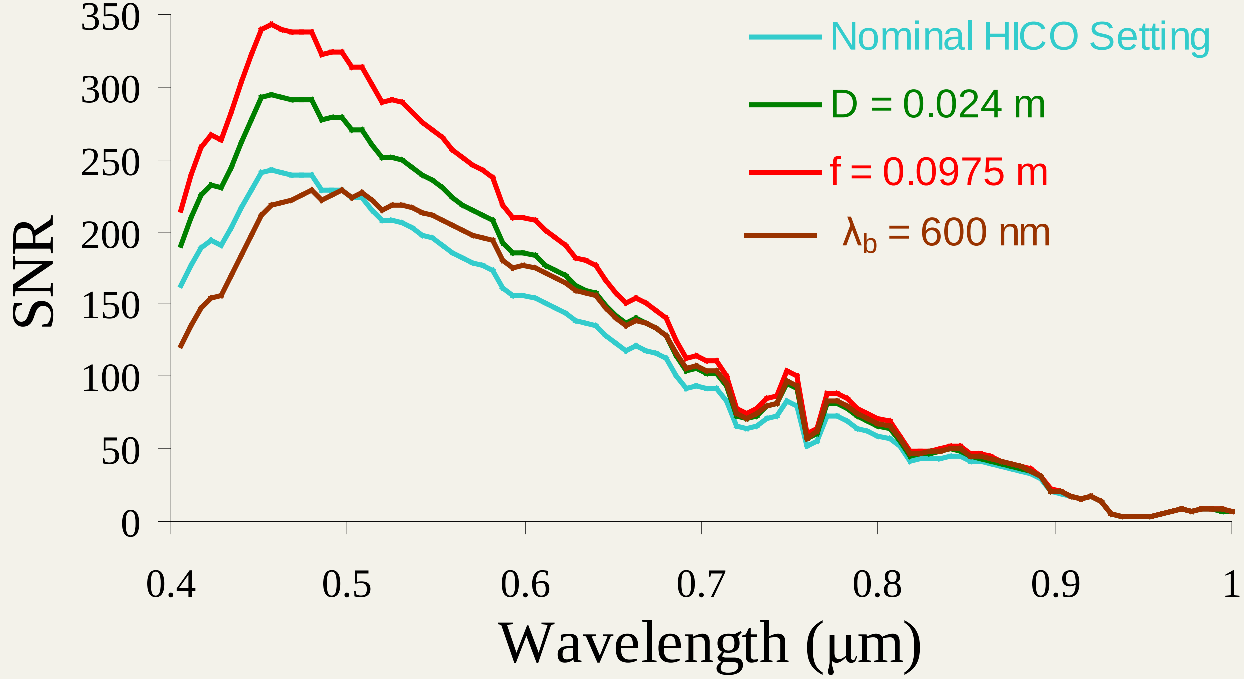






(Moses et al. 2012)

Improving SNR by Sensor Design

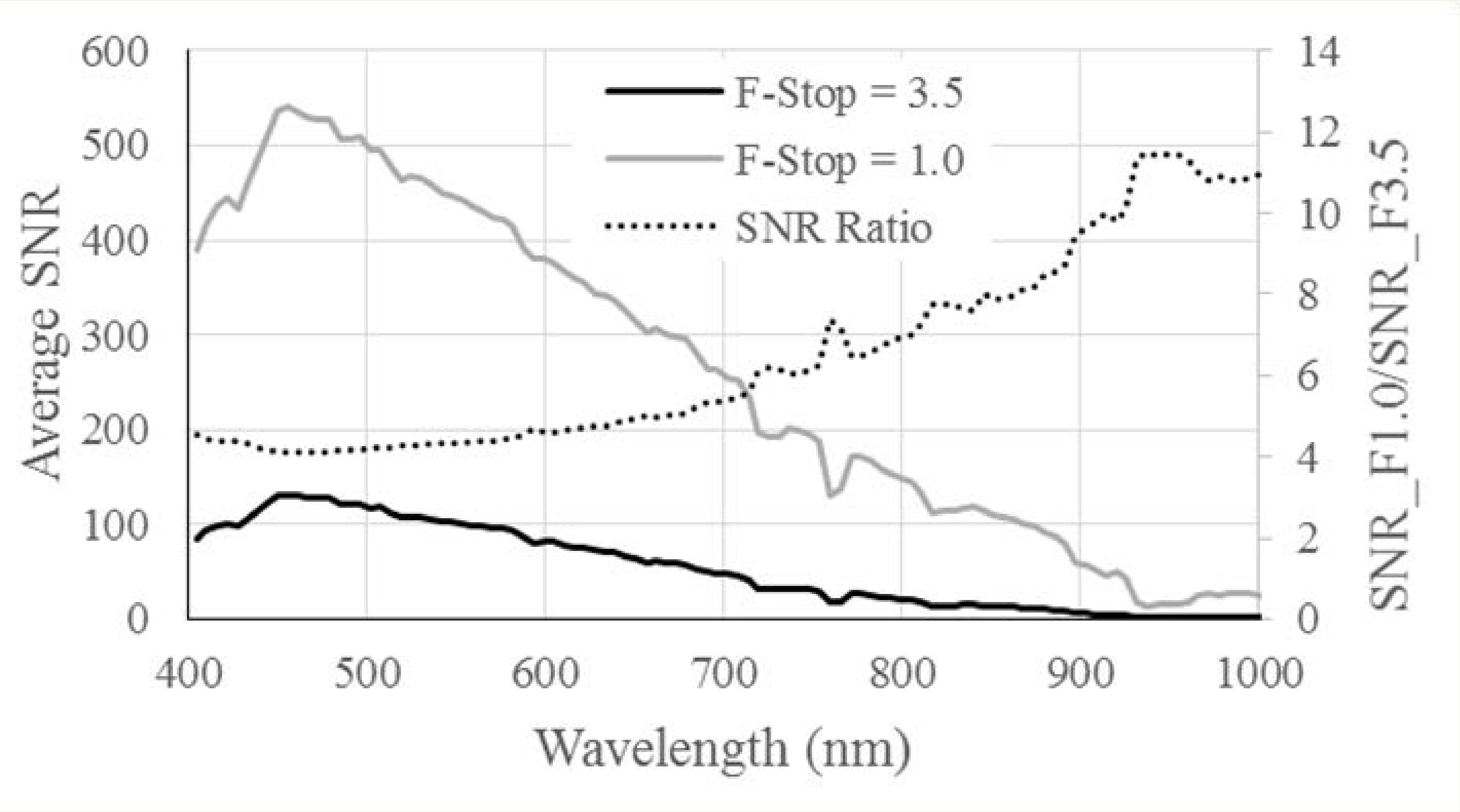


Note: D = diameter of the aperture; f = focal length; λ_b= blaze wavelength

Nominal HICO Setting: D = 0.019 m; f = 0.067 m; λ_b= 400 nm.

Improving SNR by Changing the Aperture Size

$$\text{F-Stop} = [\text{Focal length}/\text{Diameter of the aperture}]$$



SNR Impact on Retrievals

Retrieved Parameter	Avg. Percent Error		
	f/3.5	f/1.0	Improvement (%)
C_{wvap}	15.52	0.47	96.97
τ_{550}	15.1	6.83	54.77
Rrs_{blue}	181.46	9.76	94.62
Rrs_{green}	36.73	3.3	91.01
Rrs_{red}	21.38	1.87	91.21
Rrs_{NIR}	48.94	2.6	94.69

Parameter	Average Percent Error		
	f/3.5	f/1.0	Improvement (%)
Chl-*a*	53.27	26.22	50.78
$a_{CDOM}(440)$	62.18	16.93	72.77
SPM	25.93	9.14	64.75

$$\text{Improvement (\%)} = \left(\frac{[\text{Error}]_{\text{F-stop=3.5}} - [\text{Error}]_{\text{F-stop=1.0}}}{[\text{Error}]_{\text{F-stop=3.5}}} \right) \times 100$$

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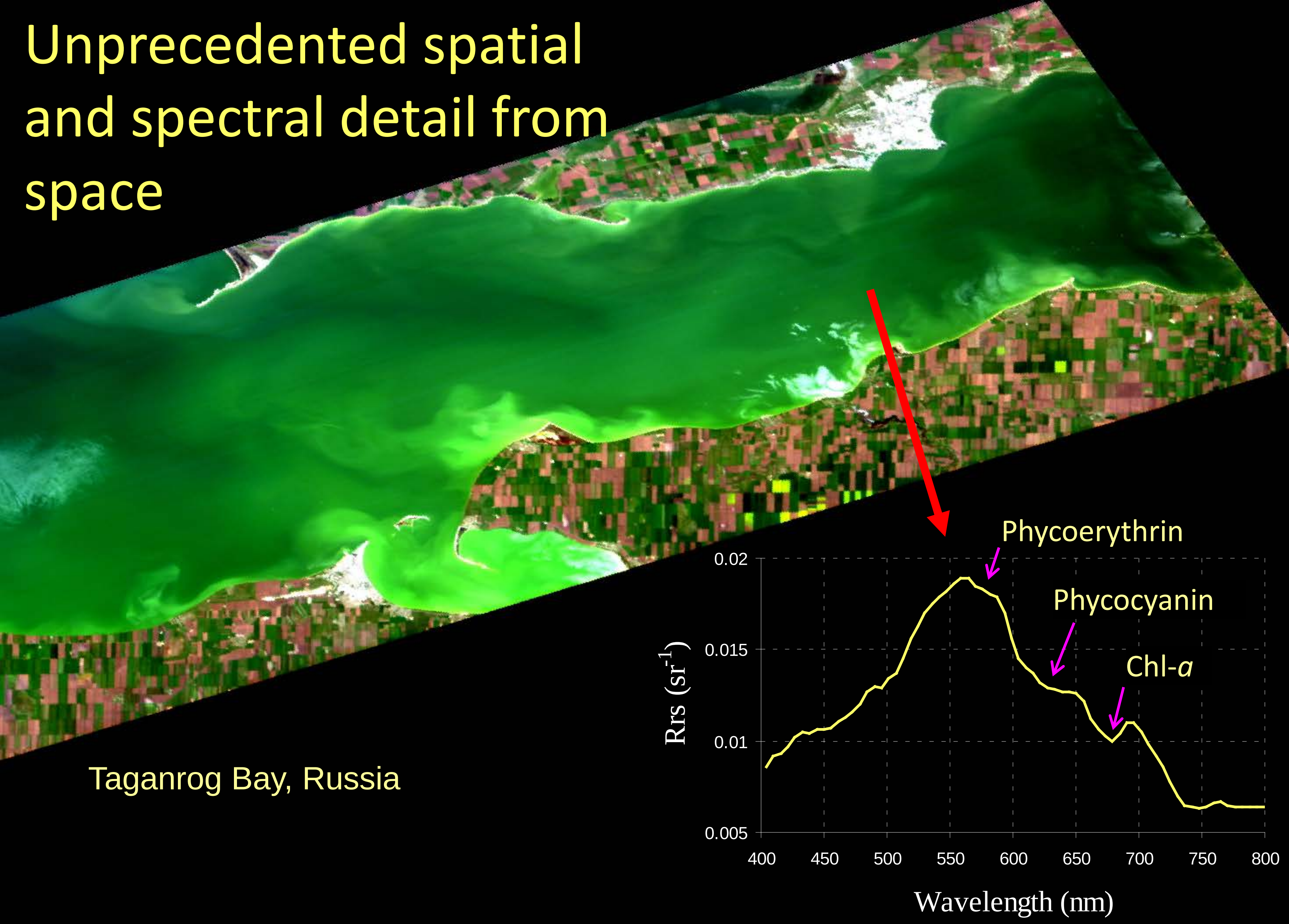
Challenges

- Second order light in the near infrared wavelengths
- No on-board calibration; vicarious techniques adopted
- Post-launch spectral shifts – shifts corrected for through continual comparison with concurrently acquired MODIS data
- Spectral etaloning – more in the NIR region; data are smoothed with a Gaussian filter to minimize etaloning effects
- Corrections to HICO data described by Gao et al. (2012)
- A maximum of only 16 images per day (capacity being increased)
- Only intermittent temporal coverage; but the pointing capability of HICO helps

Unprecedented spatial and spectral detail from space



Taganrog Bay, Russia

Thank You!

Contact:

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References

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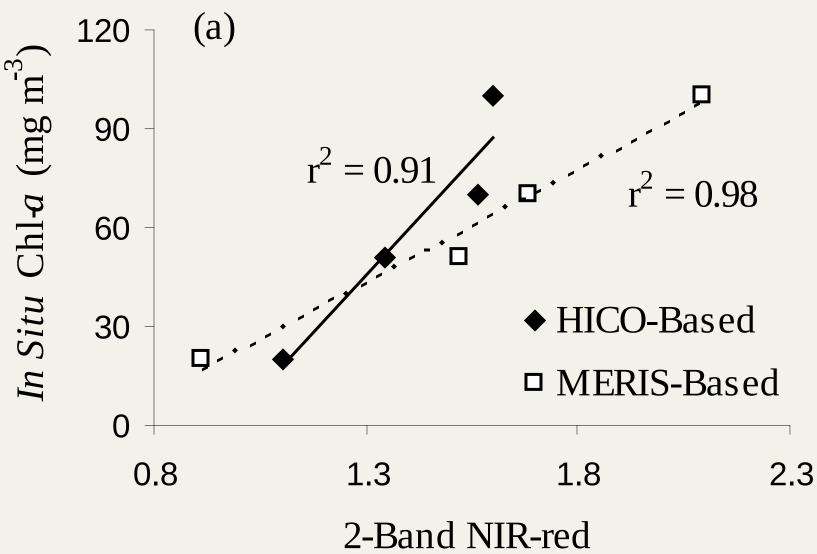
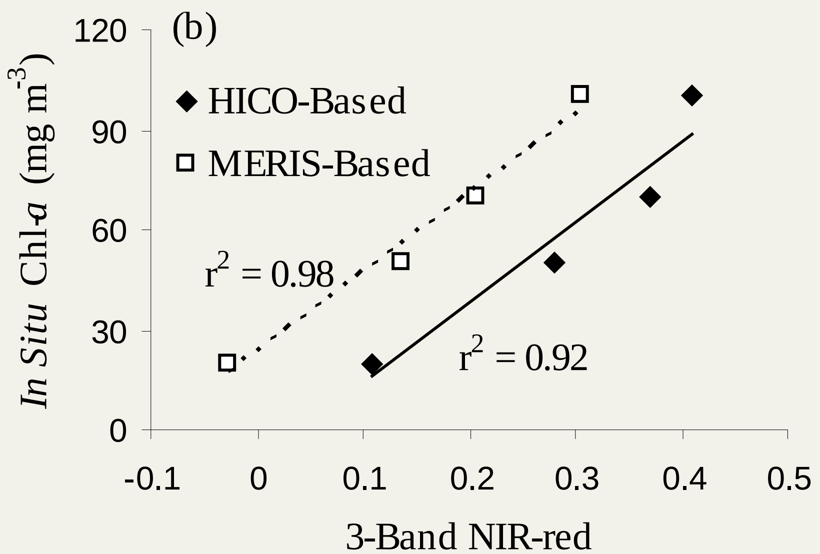
Comparison with MERIS Results

Images acquired over the Taganrog Bay on 13 July 2010





Difference in the slope of the regression is a function of, among other factors, the difference in the method used for atmospherically correcting the HICO and MERIS images.