MODIS Land Bands for Ocean Remote Sensing: Application to Chesapeake Bay

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NASA Ocean Biology Processing Group

MODIS Science Team Meeting, October 2006, College Park, MD

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- Why the land/cloud bands?
- Implementation & Sensor Characterization
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Some History

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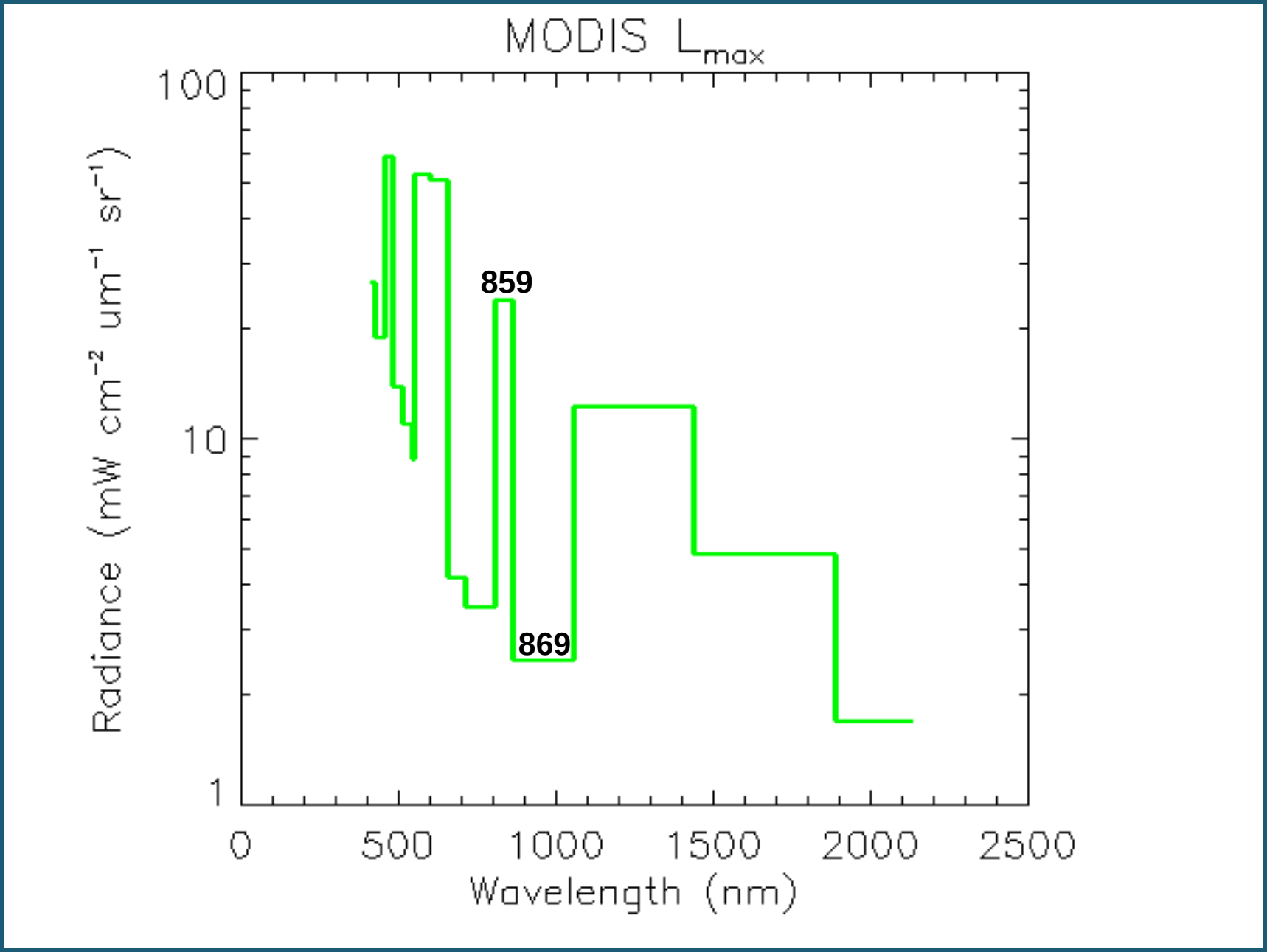
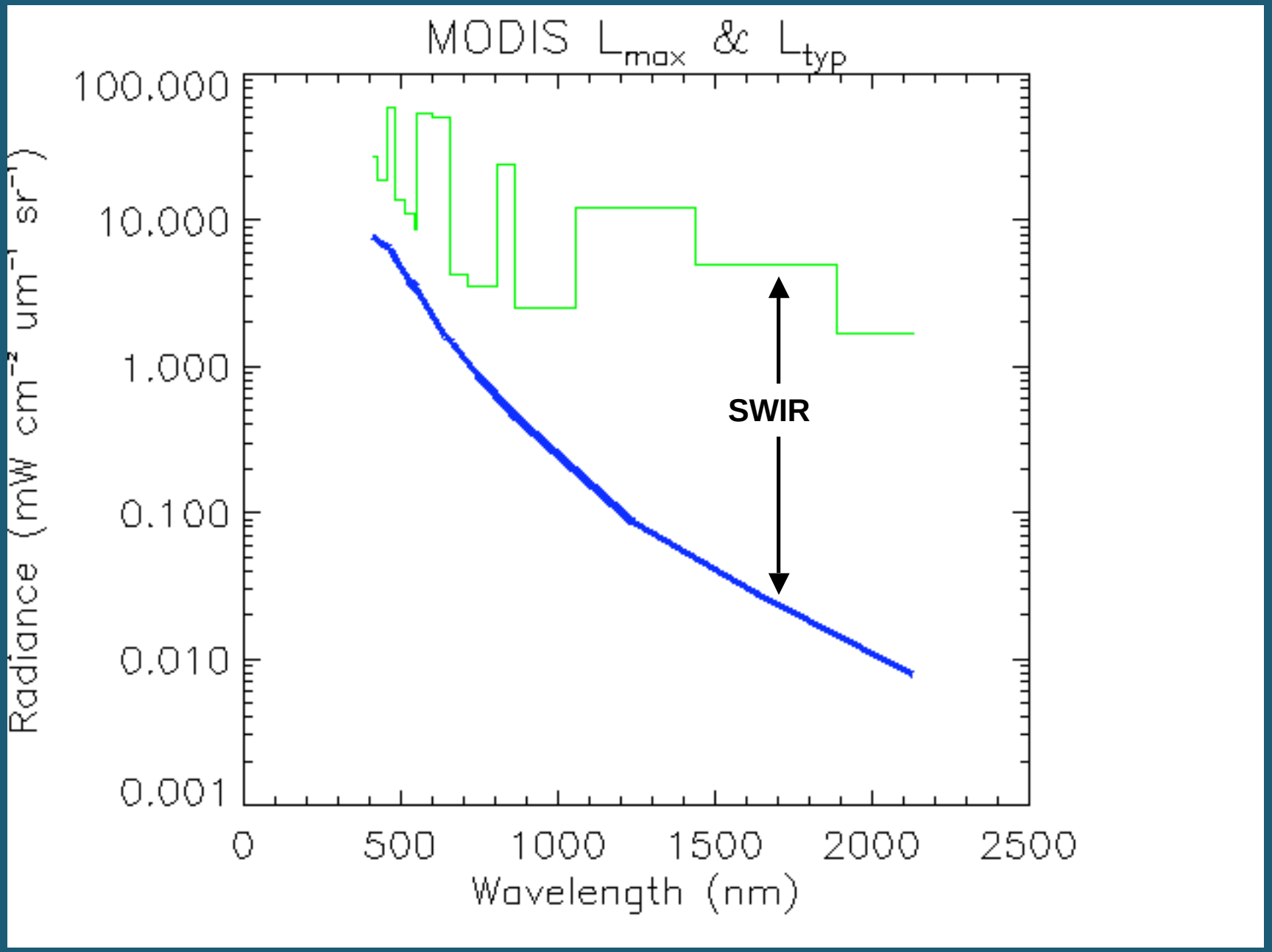
MODIS Land/Cloud Bands of Interest

Band	Wavelength	Resolution	Potential Use
1	645 nm	250 m	sediments, turbidity, IOPs
2	859	250	aerosols
3	469	500	C_a, IOPs, $CaCO_3$
4	555	500	C_a, IOPs, $CaCO_3$
5	1240	500	aerosols
6	1640	500	aerosols
7	2130	500	aerosols


MODIS L_{max}
100
10
1
Radiance (mW cm^{-2} um^{-1} sr^{-1})
859
869
0
500
1000
1500
2000
2500
Wavelength (nm)


MODIS L_{max} & L_{typ}
100.000
10.000
1.000
0.100
0.010
0.001
Radiance (mW cm^{-2} um^{-1} sr^{-1})
SWIR
0
500
1000
1500
2000
2500
Wavelength (nm)

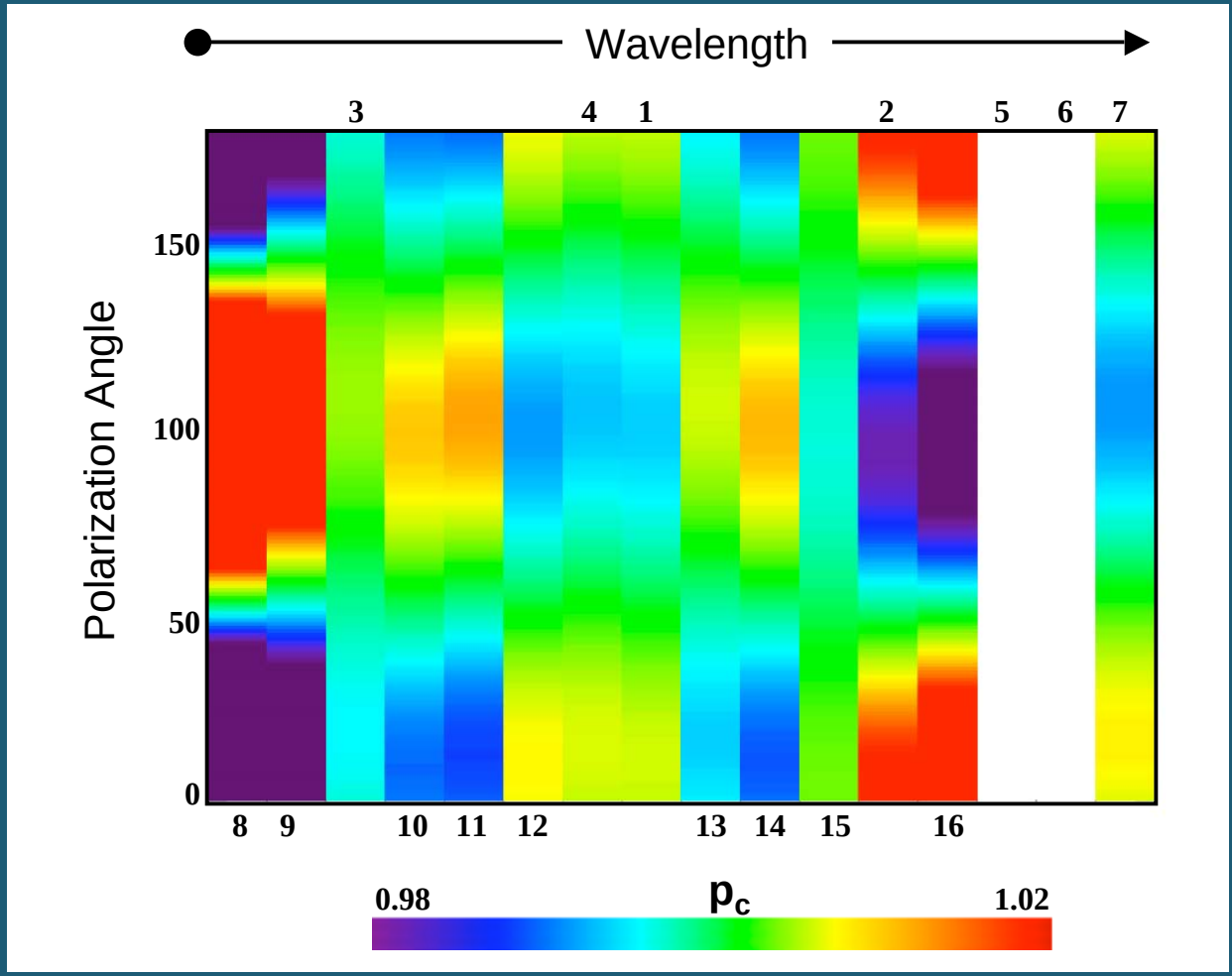
Expanded MODIS Ocean Band Suite

Band Number	Wavelength (nm)	Band Width (nm)	Spatial Resolution (m)	SNR at L_{typ}	L_{typ} mW cm^{-2} μm^{-1} sr^{-1}	L_{max} mW cm^{-2} μm^{-1} sr^{-1}
8	412	15	1000	1773	7.84	26.9
9	443	10	1000	2253	6.99	19.0
3	469	20	500	556	6.52	59.1
10	488	10	1000	2270	5.38	14.0
11	531	10	1000	2183	3.87	11.1
12	551	10	1000	2200	3.50	8.8
4	555	20	500	349	3.28	53.2
1	645	50	250	140	1.65	51.2
13	667	10	1000	1962	1.47	4.2
14	678	10	1000	2175	1.38	4.2
15	748	10	1000	1371	0.889	3.5
2	859	35	250	103	0.481	24.0
16	869	15	1000	1112	0.460	2.5
5	1240	20	500	25	0.089	12.3
6	1640	35	500	19	0.028	4.9
7	2130	50	500	12	0.008	1.7

Characterization & Calibration

- Relative spectral response functions: Rayleigh & aerosol tables
- Polarization sensitivities (reanalysis of pre-launch testing)

Polarization Sensitivity



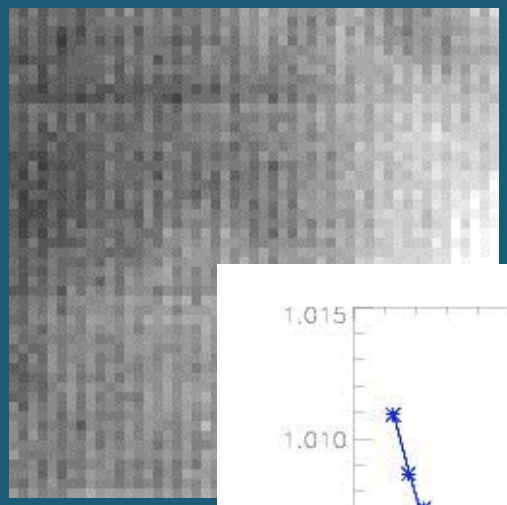
Meister, G., E.J. Kwiatkowska, and C.R. McClain (2006). Analysis of image striping due to polarization correction artifacts in remotely sensed ocean scenes. *Proc. SPIE Earth Observing Systems XI*, 6296.

Characterization & Calibration

- Relative spectral response functions: Rayleigh & aerosol tables
- Polarization sensitivities (reanalysis of pre-launch testing)
- Relative detector and sub-sampling corrections (striping)

Detector and Sub-sample Striping

TOA Radiance 469 nm



Ratio of Adjacent Samples Along Scan, 469 nm

Characterization & Calibration

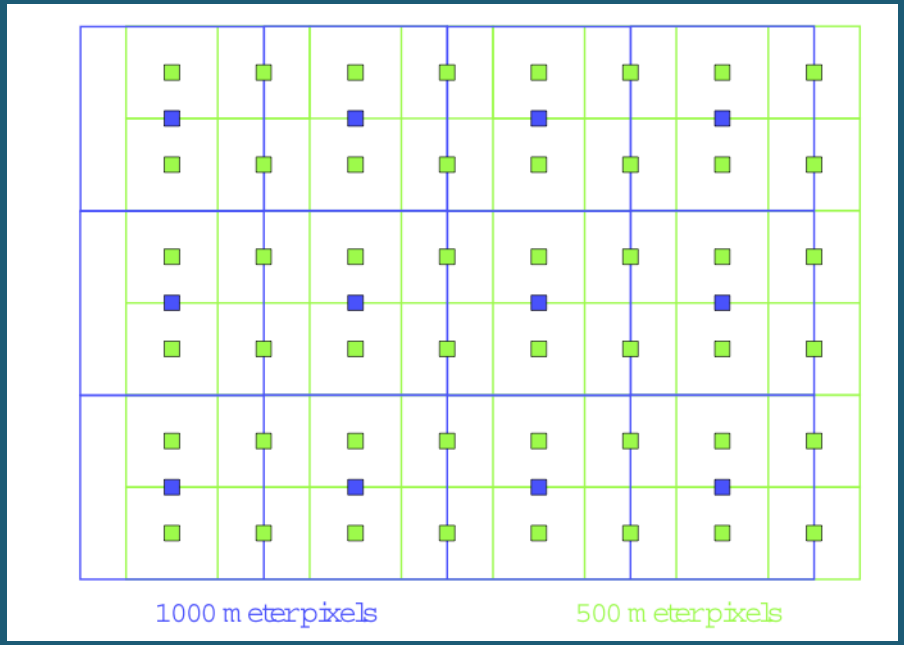
- Relative spectral response functions: Rayleigh & aerosol tables
- Polarization sensitivities (reanalysis of pre-launch testing)
- Relative detector and sub-sampling corrections (striping)
- Vicarious calibration to MOBY (preliminary)

Multi-Resolution Implementation

Aggregation

QKM	HKM		1KM	
645 nm	469 nm		412 nm	
859 nm	555 nm		443 nm	
	645 nm	1	469 nm	3
	859 nm	1	488 nm	
	1240 nm		531 nm	
	1640 nm		551 nm	
	2130 nm		555 nm	3
			645 nm	2
			667 nm	
			678 nm	
			748 nm	
			859 nm	2
			869 nm	
			1240 nm	3
			1640 nm	3
			2130 nm	3
			3.9 um	
			4.0 um	
			11 um	
			12 um	

Interpolation

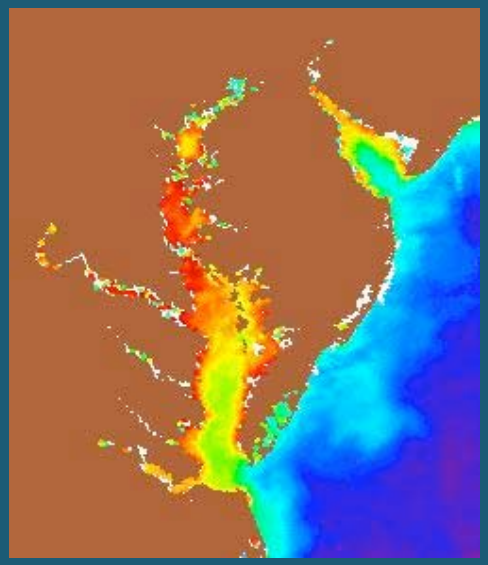


from Gumley, et al.

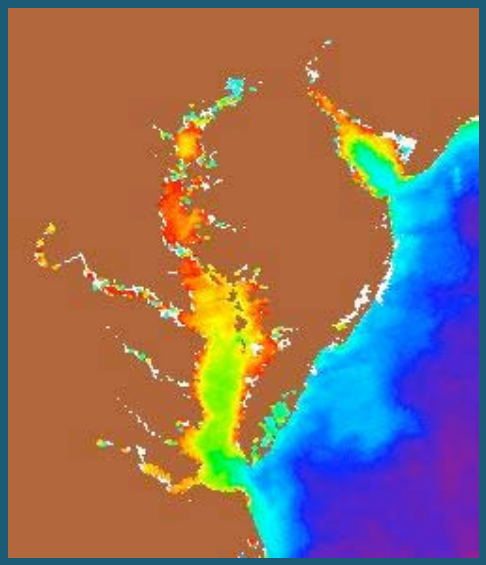
Observed (TOA) radiances, geolocation, radiant path geometries interpolated or aggregated to a com mon resolution at start.

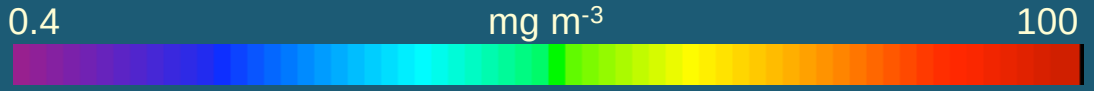
Chlorophyll: 1000-meter resolution

OC3 = f(443,488,551)



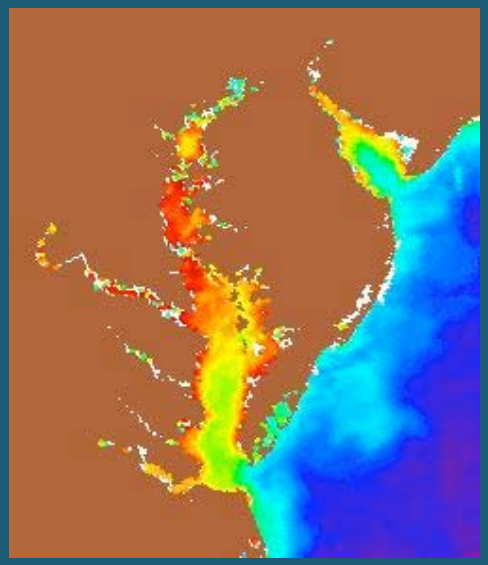
OC2 = f(469,555)



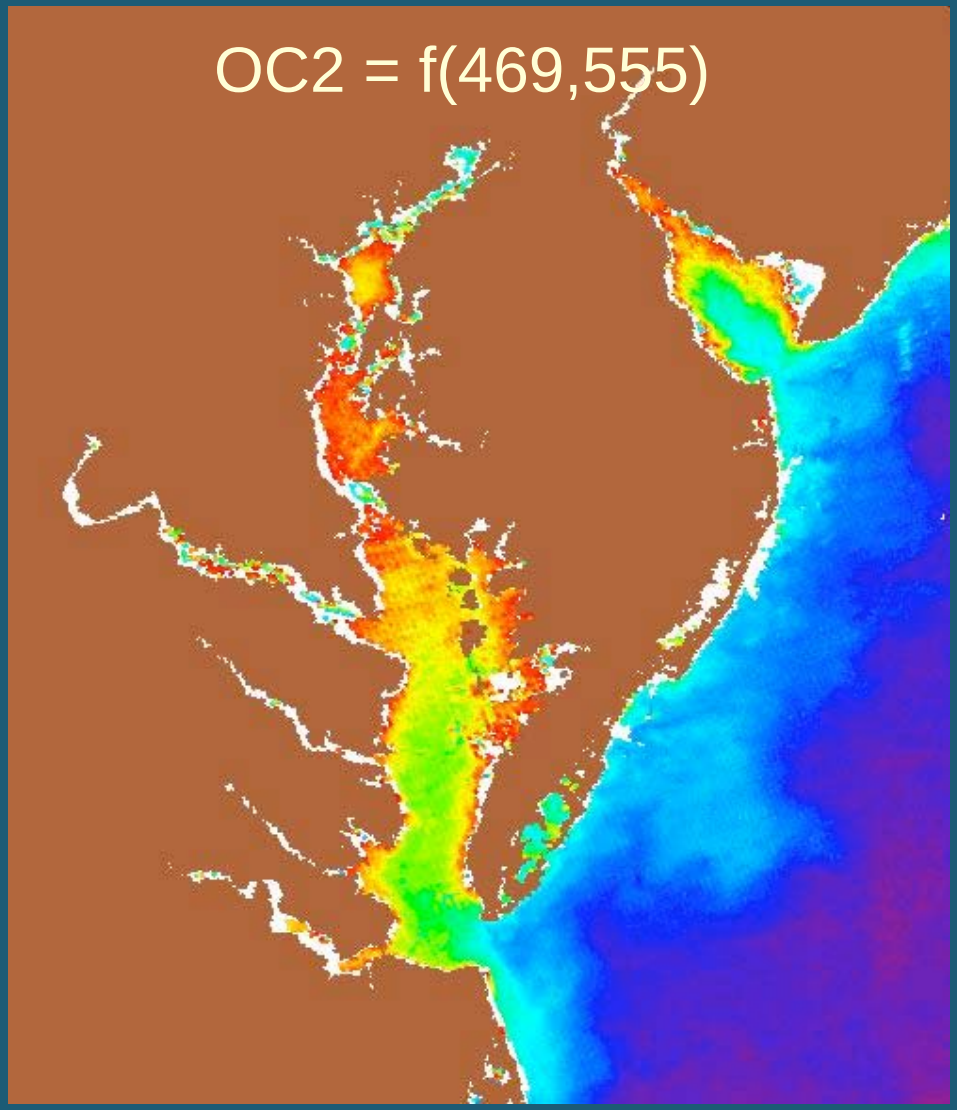


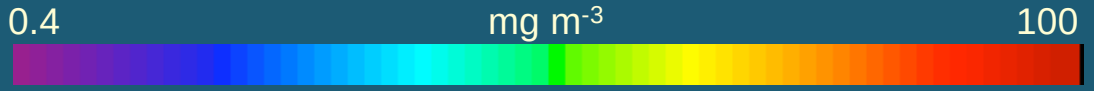
Chlorophyll: 1000 & 500-meter

OC3 = f(443,488,551)



OC2 = f(469,555)

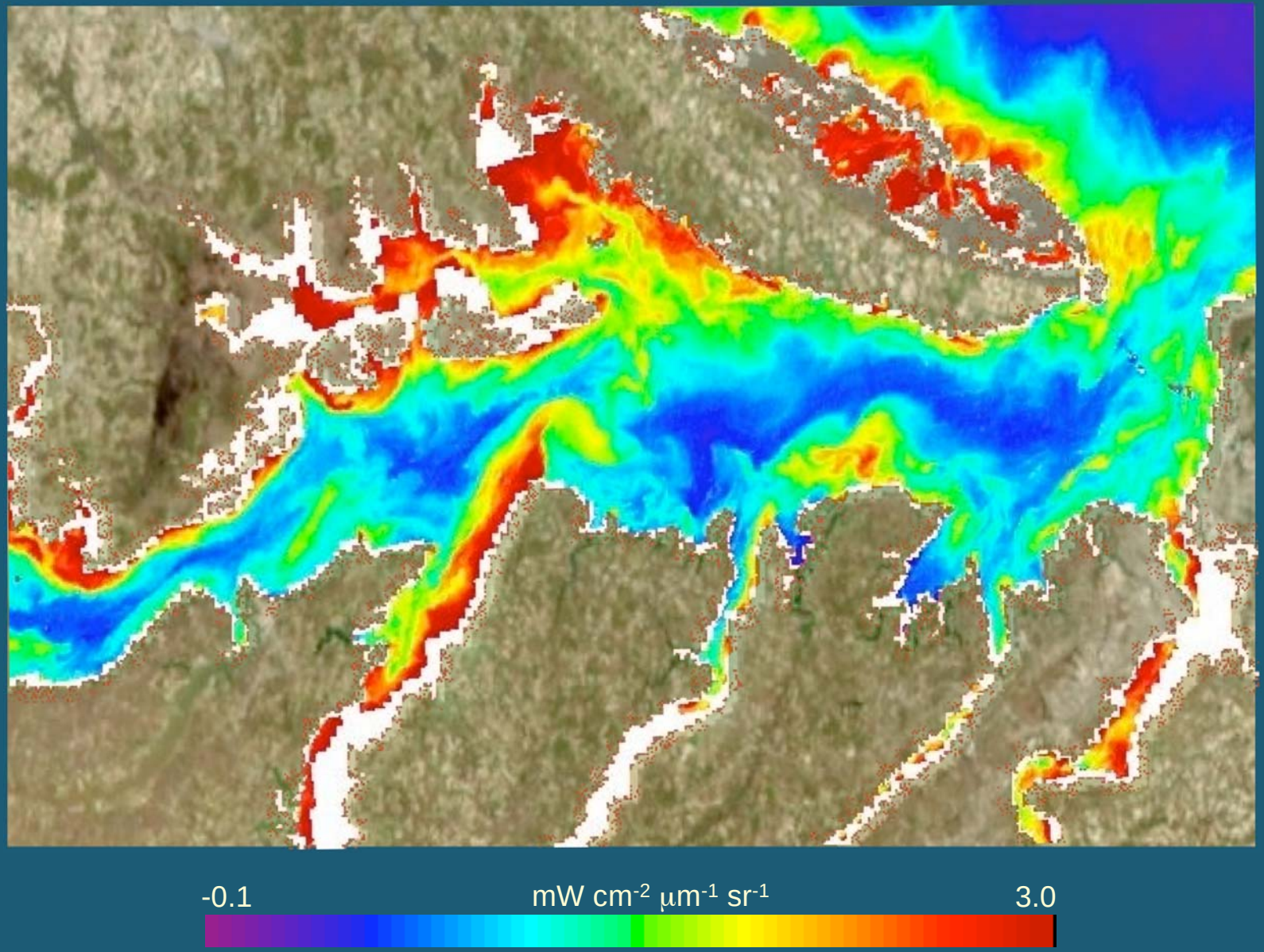




RGB Image: 250-meter Resolution

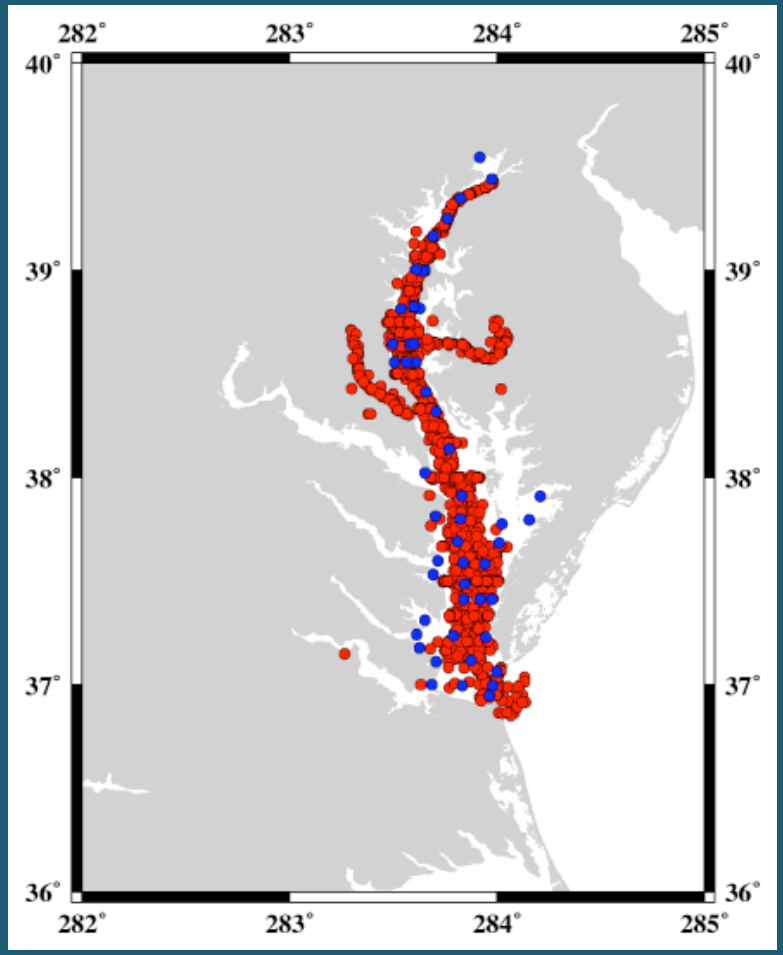
RGB Image: 250-meter Resolution

nLw(645): 250-meter resolution



In Situ Chlorophyll Data

~ 20 year record



SIMBIOS/Harding

3,000 stations

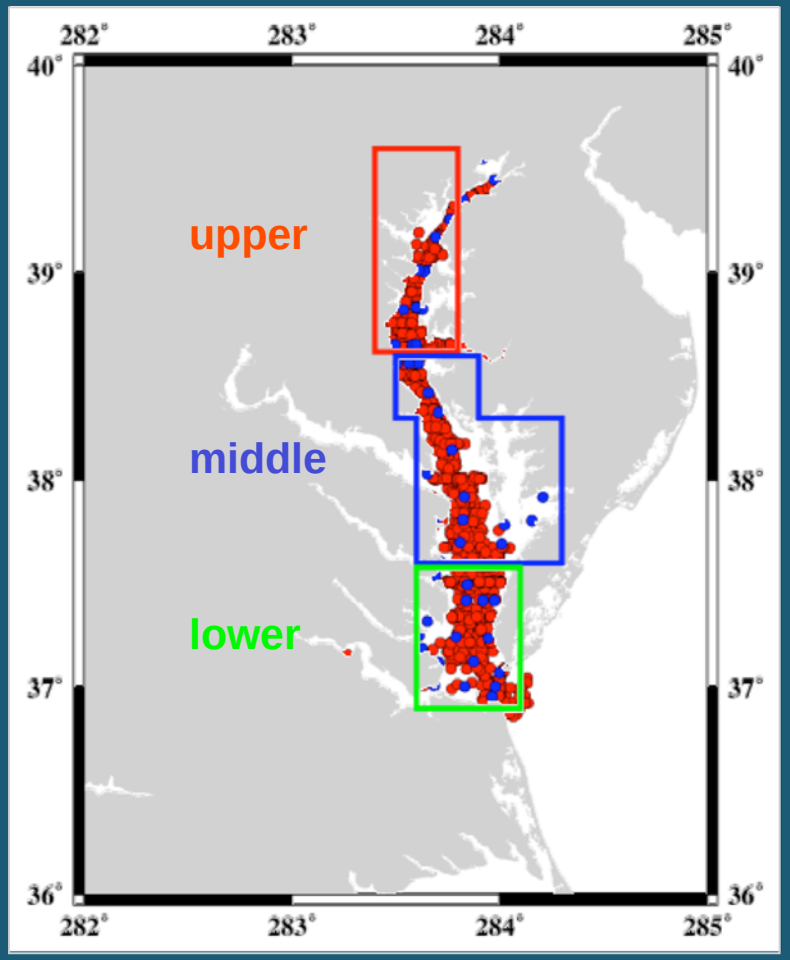
CBP

15,000 stations

(fluorometrically derived)

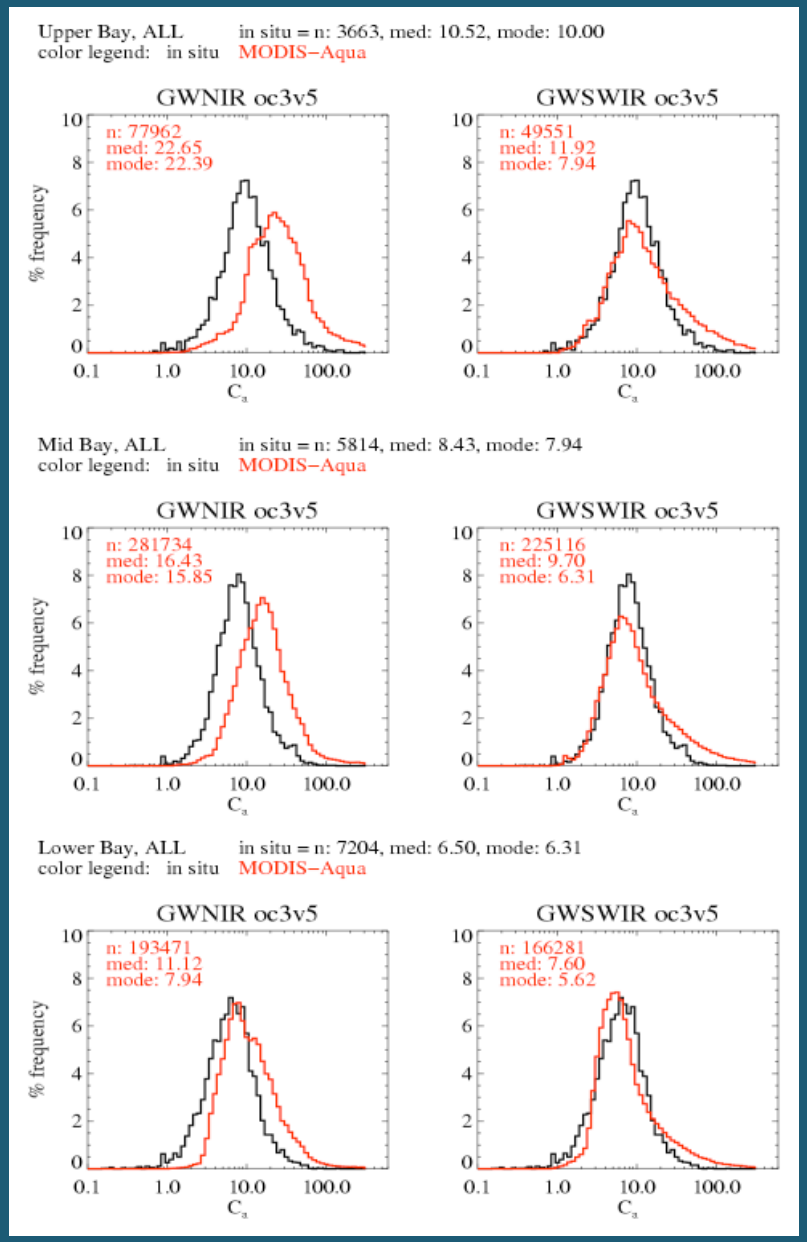
Spatial Stratification

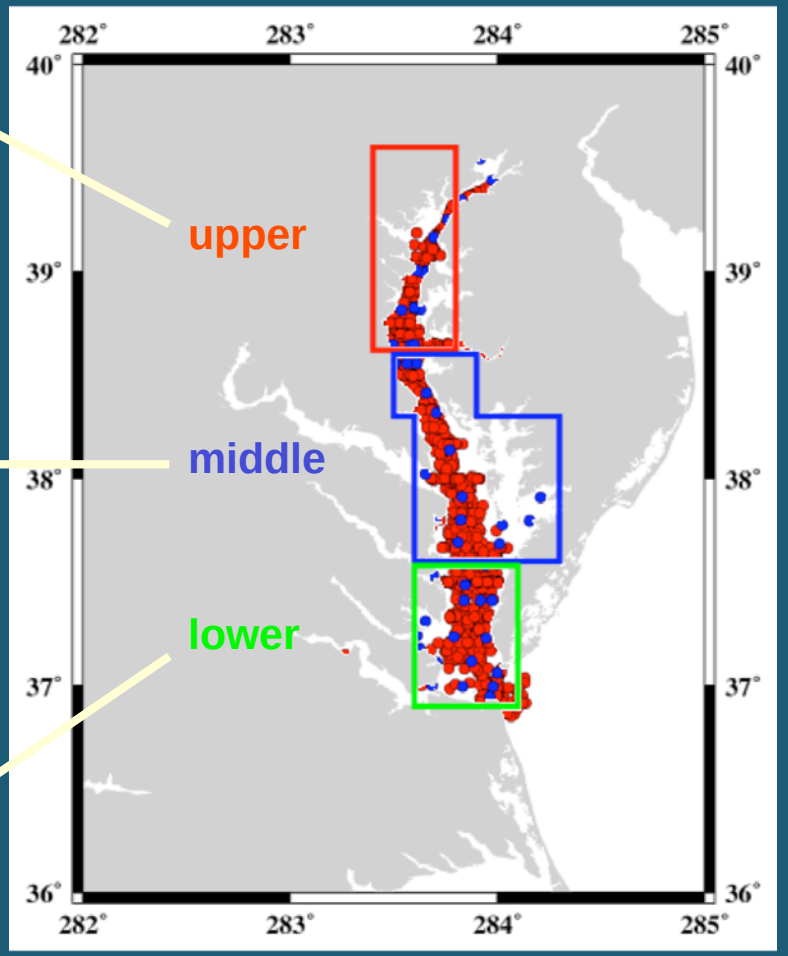
from *Magnuson et al. 2004*



Satellite vs In Situ

NIR SWIR





Median Percent Difference

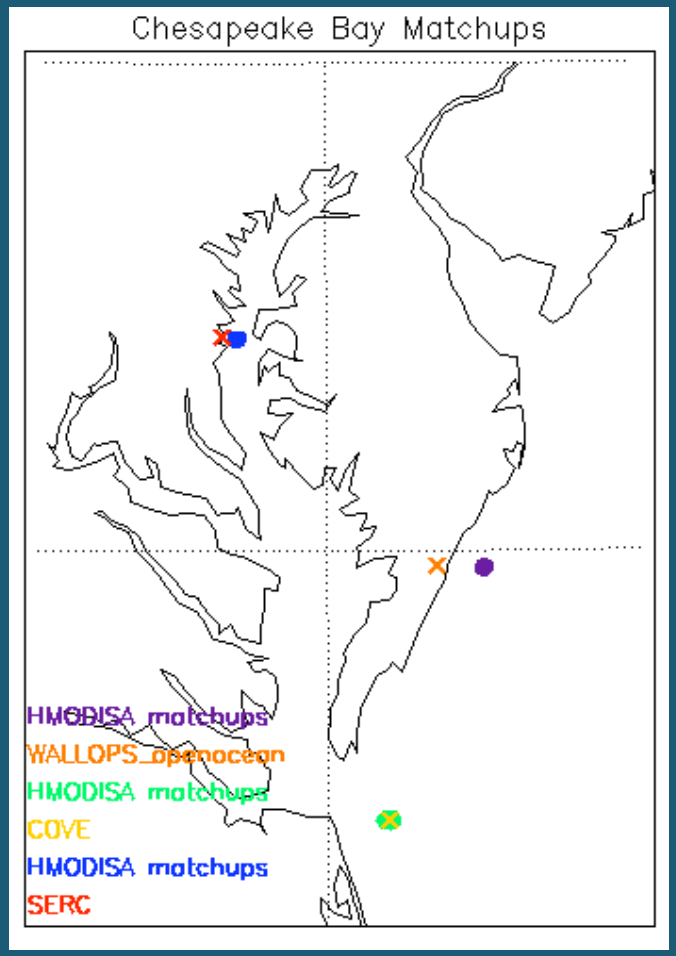
from *In Situ Chlorophyll*

Region	Method	All	Spring	Summer	Fall	Winter
Upper	NIR	115.3	141.5	104.7	185.8	151.2
	SWIR	13.3	25.2	20.5	48.6	35.8
Middle	NIR	94.9	87.7	122.2	113.9	148.4
	SWIR	15.1	-5.6	19.9	31.3	62.2
Lower	NIR	71.1	110.8	71.4	43.2	123.0
	SWIR	16.9	4.0	-4.6	13.5	72.0

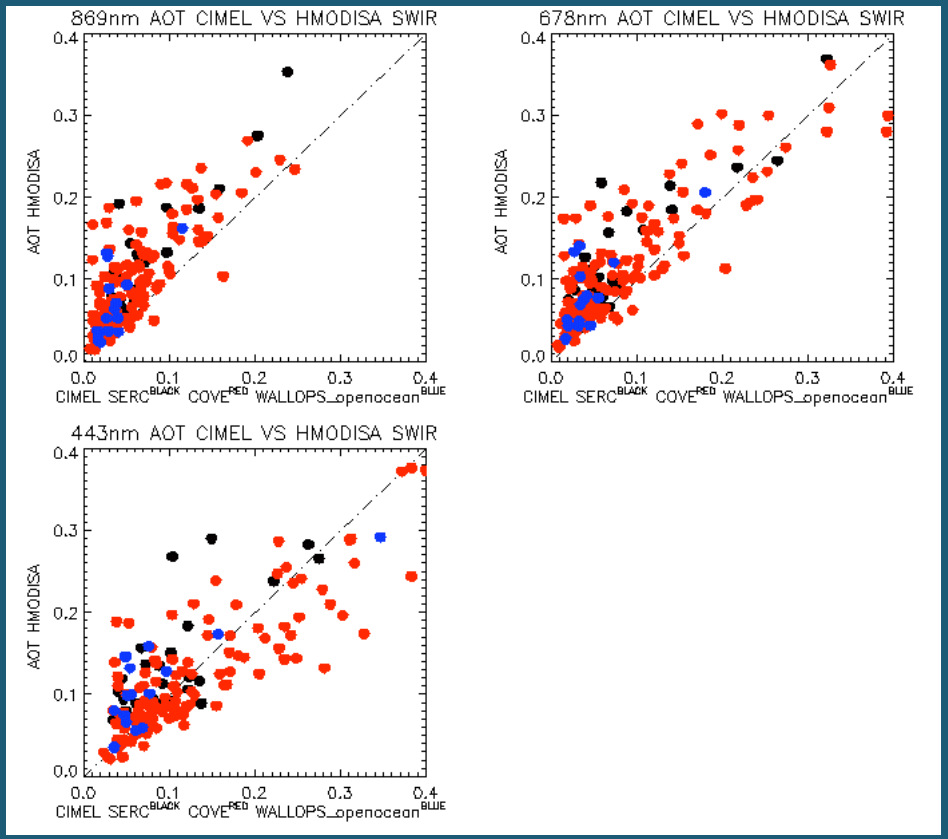
SWIR-based aerosol determination significantly reduces bias in C_a retrievals relative to historical record for all seasons.

Best improvement in Spring-Summer, where aerosol optical thickness (SWIR signal) is highest.

Match-up with AERONET



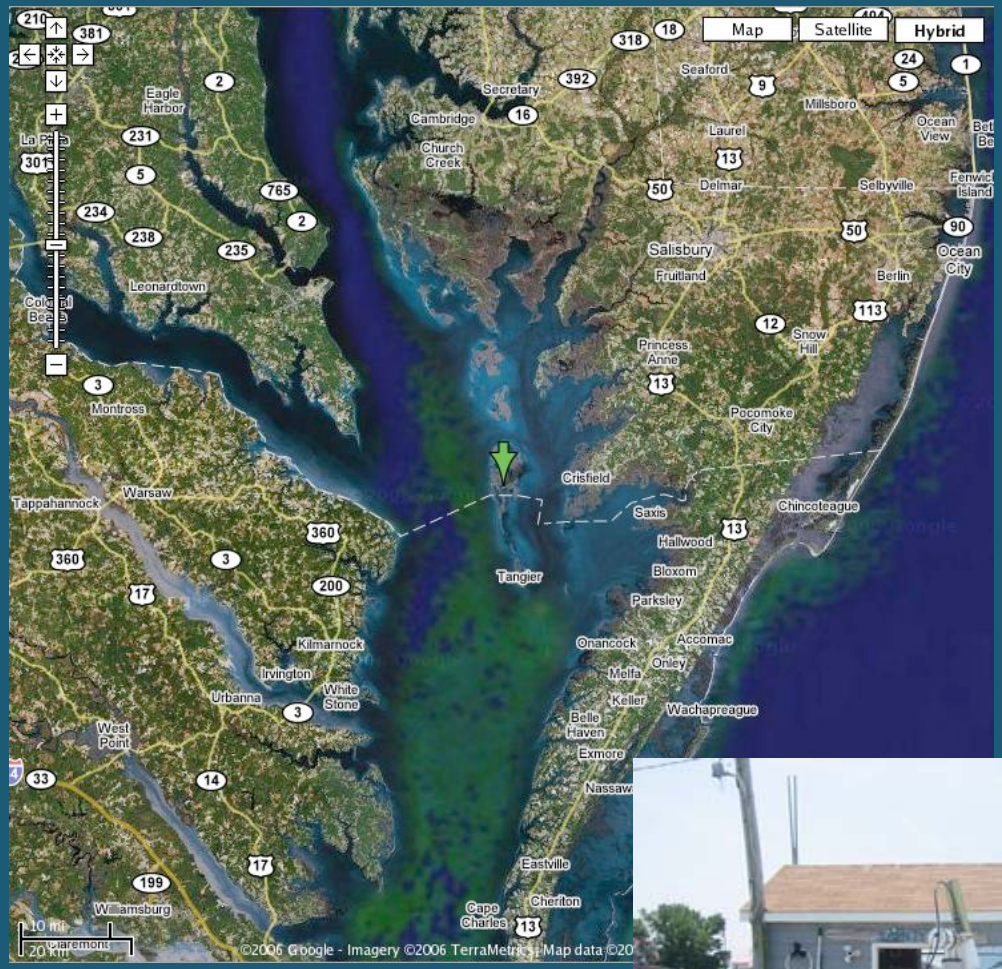
AOT Comparison



Development of regional aerosol models

See poster by E. Kwiatkowska

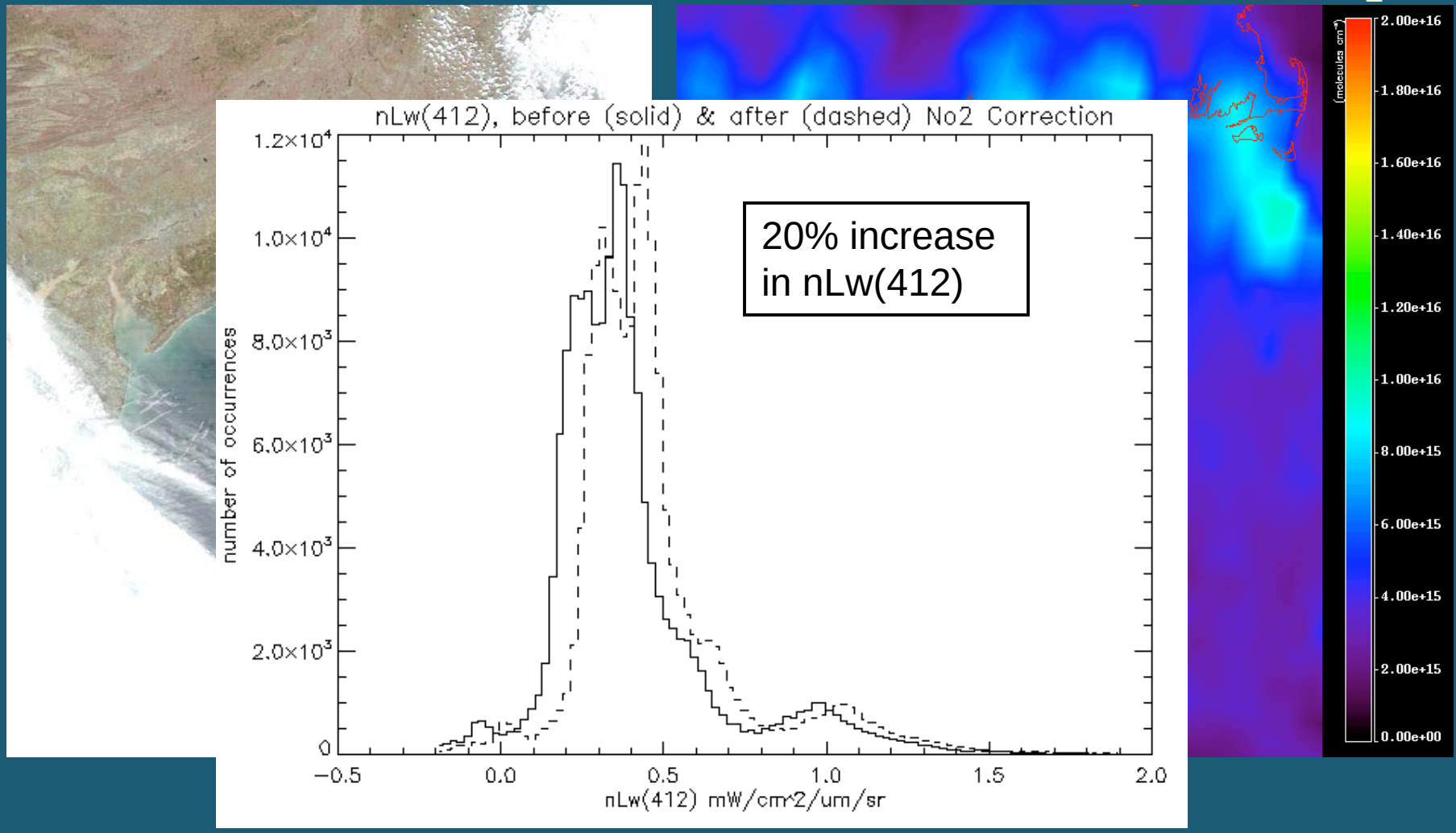
New AERONET CIMEL Site on Smith Island



Correction for NO_2 Absorption

MODIS/Aqua RGB

OMI/Aura Tropospheric NO_2



See poster by Z. Ahmad

Summary

- Developed processing capabilities to include higher resolution land/cloud bands in ocean remote sensing applications.
- Demonstrated some potential ocean products (500-meter chlorophyll, 250-meter nLw), and SWIR atmospheric correction.
- SWIR-based aerosol determination significantly reduced bias between retrieved and *in situ* chlorophyll.
- Software and tools distributed through SeaDAS, to encourage further evaluation and development by research community.
- More info: http://oceancolor.gsfc.nasa.gov/DOCS/modis_hires/

Future Plans

- Develop more applicable aerosol models based on local AERONET observations
- Incorporate MODIS-derived water-vapor concentrations for improved water-vapor correction (significant in SWIR)
- Assist NOAA Coast Watch to implement an operational Chesapeake Bay monitoring system using MODIS
- Develop “high-resolution” Level-3 products (binned/mapped)
  - Rolling 3-day, merged sensors for increased coverage
  - Pilot project in Great Barrier Reef, University of Queensland

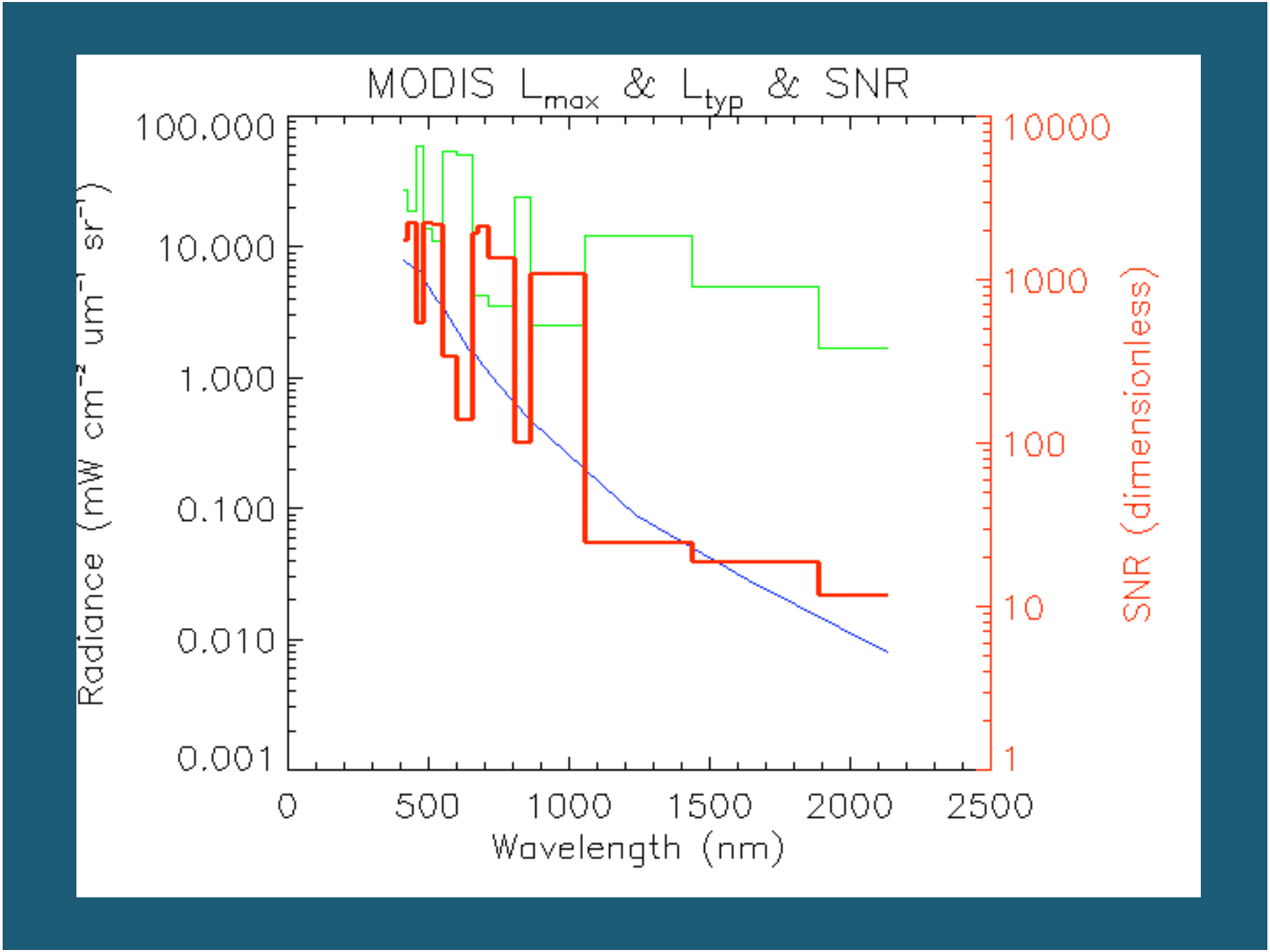

Thank You !

Expanded MODIS Ocean Band Suite

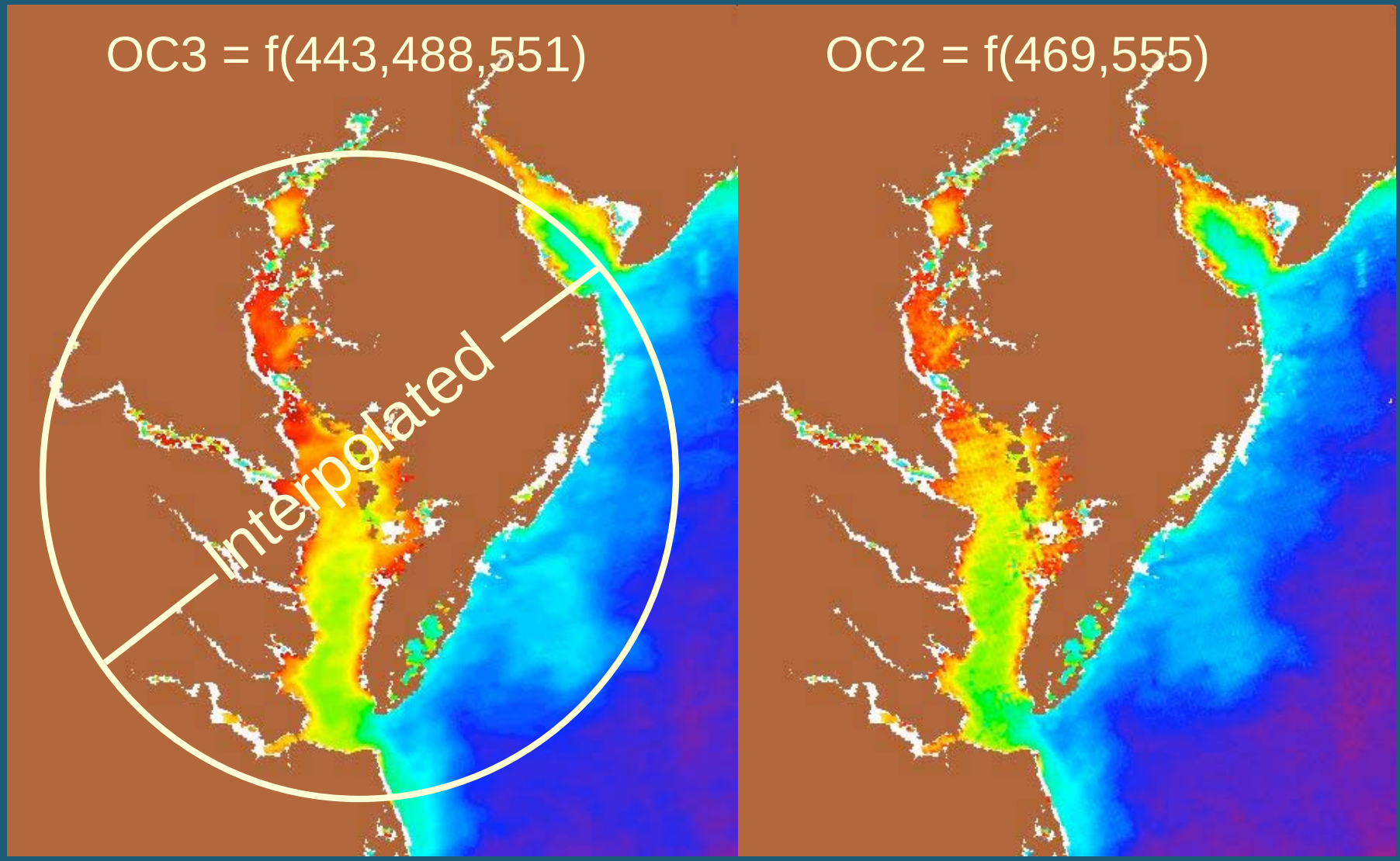
Band Number	Wavelength (nm)	Band Width (nm)	Spatial Resolution (m)
8	412	15	1000
9	443	10	1000
3	469	20	500
10	488	10	1000
11	531	10	1000
12	551	10	1000
4	555	20	500
1	645	50	250
13	667	10	1000
14	678	10	1000
15	748	10	1000
2	859	35	250
16	869	15	1000
5	1240	20	500
6	1640	35	500
7	2130	50	500

Expanded MODIS Ocean Band Suite

Band Number	Wavelength (nm)	Band Width (nm)	Spatial Resolution (m)	L_{max} mW cm^{-2} μm^{-1} sr^{-1}
8	412	15	1000	26.9
9	443	10	1000	19.0
3	469	20	500	59.1
10	488	10	1000	14.0
11	531	10	1000	11.1
12	551	10	1000	8.8
4	555	20	500	53.2
1	645	50	250	51.2
13	667	10	1000	4.2
14	678	10	1000	4.2
15	748	10	1000	3.5
2	859	35	250	24.0
16	869	15	1000	2.5
5	1240	20	500	12.3
6	1640	35	500	4.9
7	2130	50	500	1.7


MODIS L_{max} & L_{typ} & SNR
100.000
10.000
1.000
0.100
0.010
0.001
Radiance (mW cm^{-2} um^{-1} sr^{-1})
10000
1000
100
10
1
SNR (dimensionless)
0
500
1000
1500
2000
2500
Wavelength (nm)

Chlorophyll: 500-meter Resolution



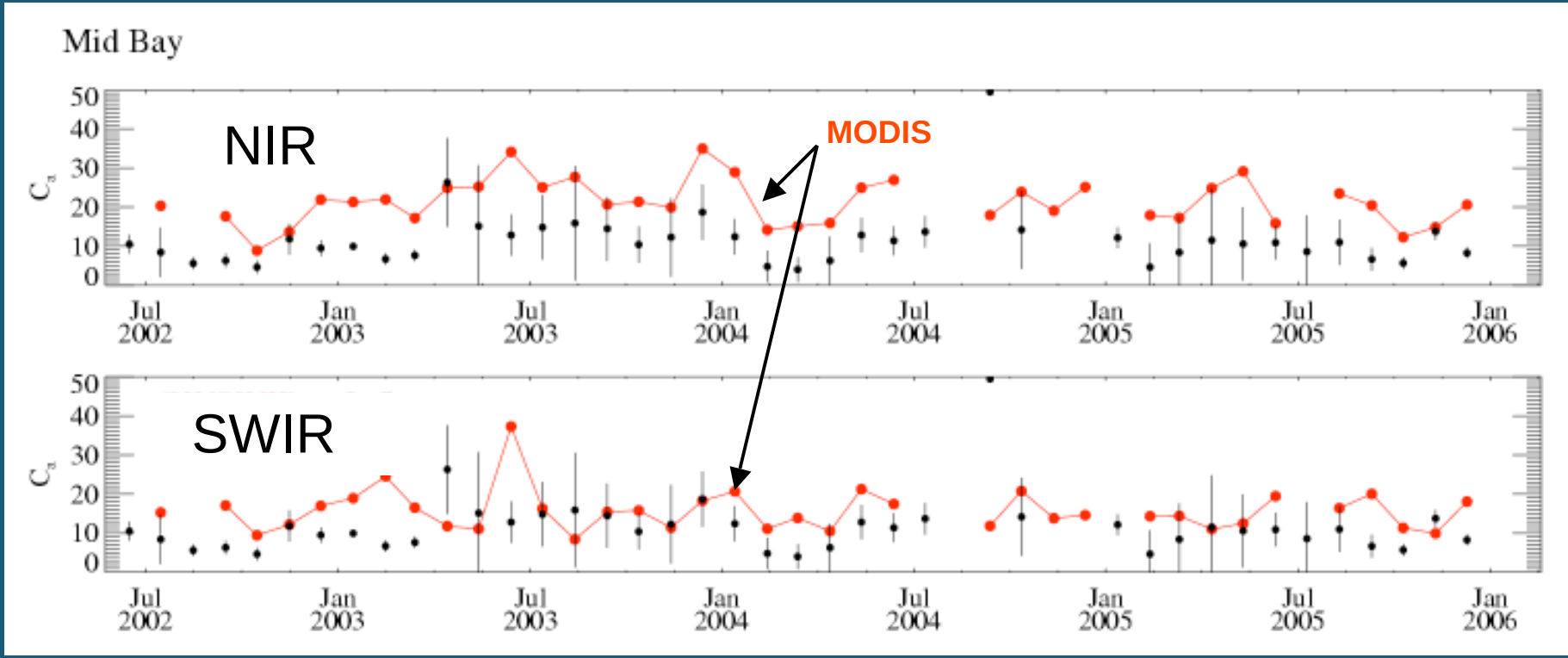
Aerosols from SWIR

- Evaluate standard and alternate aerosol determination
  1. aerosol determined via NIR at 748 and 869 nm
  2. aerosol determined via SWIR at 1240 and 2130 nm

- Processed 150 MODIS/Aqua scenes over Chesapeake Bay to retrieve OC3 Chlorophyll at 1km resolution.

- Compared with historical record of *in situ* C_a

Monthly Mean C_a Time-Series Comparison
Mid Bay



Chesapeake Bay Collaboration

- Chesapeake Bay Program (MD, VA, PA, DC, Federal EPA), University of Maryland, Old Dominion, NOAA Coast Watch, and NASA OBPG.
- CBP is an on-going program of *in situ* monitoring with a large historical data set spanning ~ 20 years.
- OBPG is assisting with use of remote sensing data to augment field campaign, and supporting operational implementation within NOAA Coast Watch.
- Utilizing local expertise and *in situ* measurements (in-water and atmospheric) to evaluate and improve performance of satellite retrievals on a regional scale (regional algorithms & atmospheric models).

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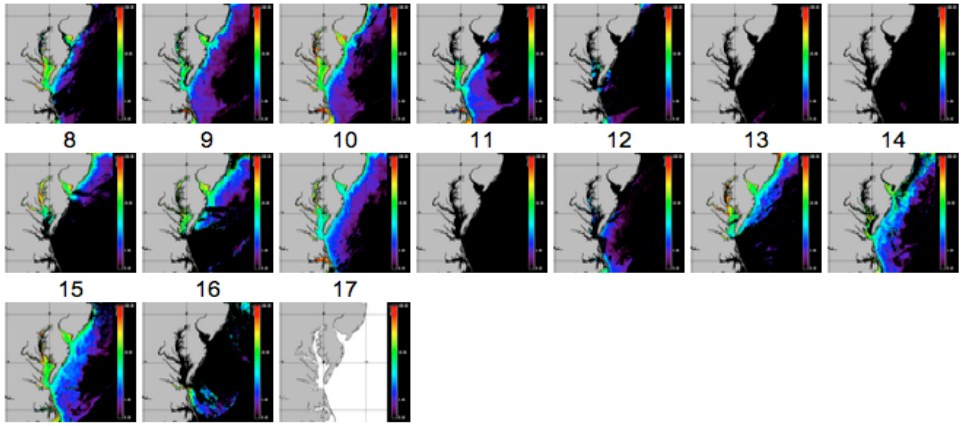
Chesapeake Bay SeaWiFS Chlorophyll -a

Following the Chesapeake Bay Remote Sensing Symposium in January 2006, NASA Ocean Biology Processing Group (OBPG) evaluated the performance of currently available remote sensing chlorophyll-a algorithms for the Bay. Details of the algorithms and their performance can be found at: http://seabass.gsfc.nasa.gov/eval/cbp_eval.cgi. As a result, the OC4v5 and OC3v5 algorithms are recommended for operational daily processing of SeaWiFS data at NOAA CoastWatch East Coast Node. SeaWiFS Level 1A data are processed using SeaDAS 5.0 software at East Coast Node, and Level 2 data and mapped Chl-a images are produced. Please note that Level 2 data are password protected, and questions regarding data access should be directed to Kent Hughes, CoastWatch Program Manager.

October 2006 Show Calendar

October 2006

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17				




Thank You !