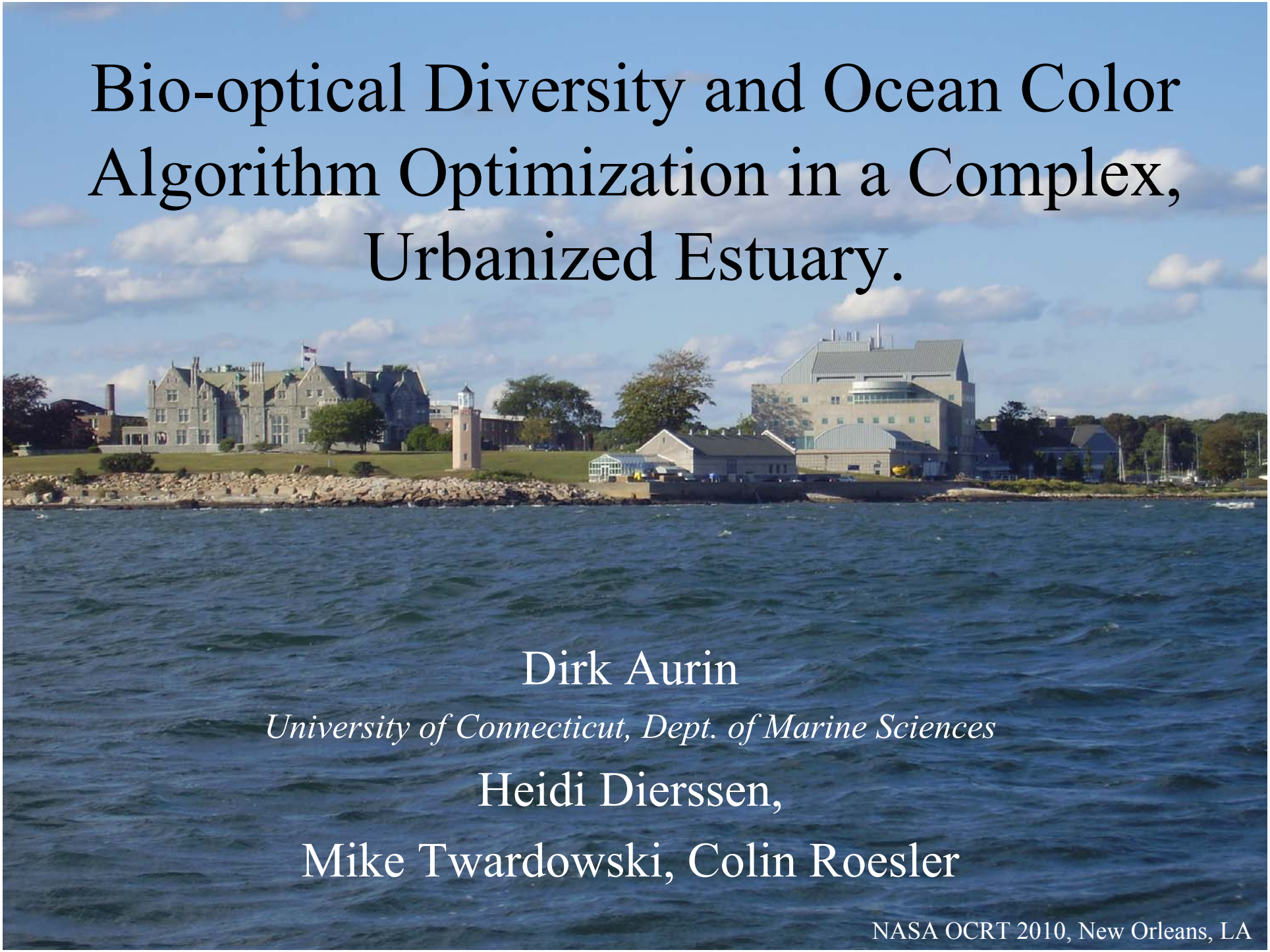
Bio-optical Diversity and Ocean Color Algorithm Optimization in a Complex, Urbanized Estuary.



Dirk Aurin

University of Connecticut, Dept. of Marine Sciences

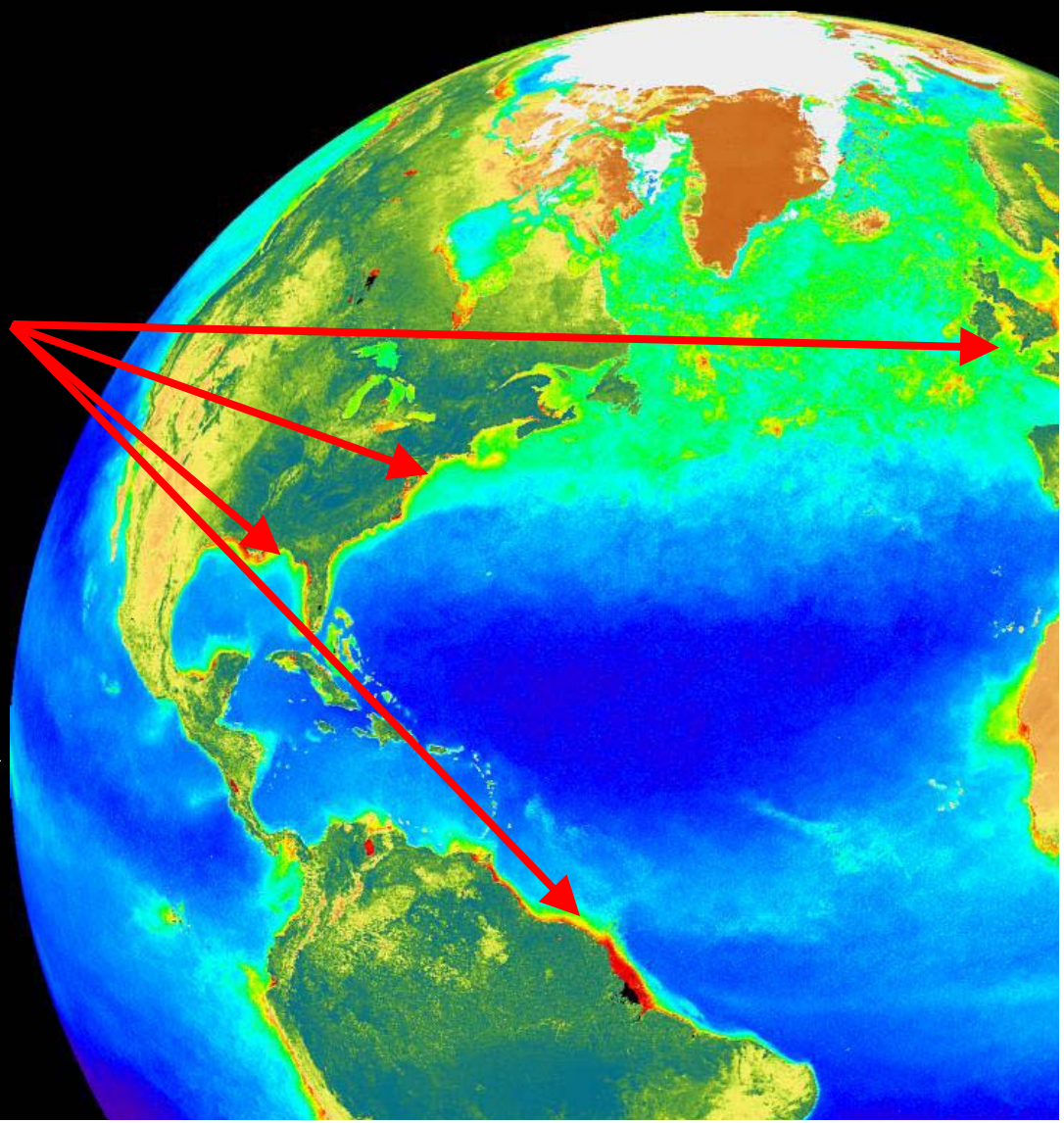
Heidi Dierssen,

Mike Twardowski, Colin Roesler

NASA OCRT 2010, New Orleans, LA

What is Optically Complex?

- Nearshore
  - –Dissolved (CDM)
  - –Non-algal (NAP)
  - –SAAs
    - –Problem: Spectral variability in optical properties



Developing SAAs for Complex, Dynamic Systems

- Characterize:
  - Inherent Optical Properties
  - Light field
  - Chl, TSM, etc.

•Are there distinct optical provinces within the region of interest?

For example...

Site

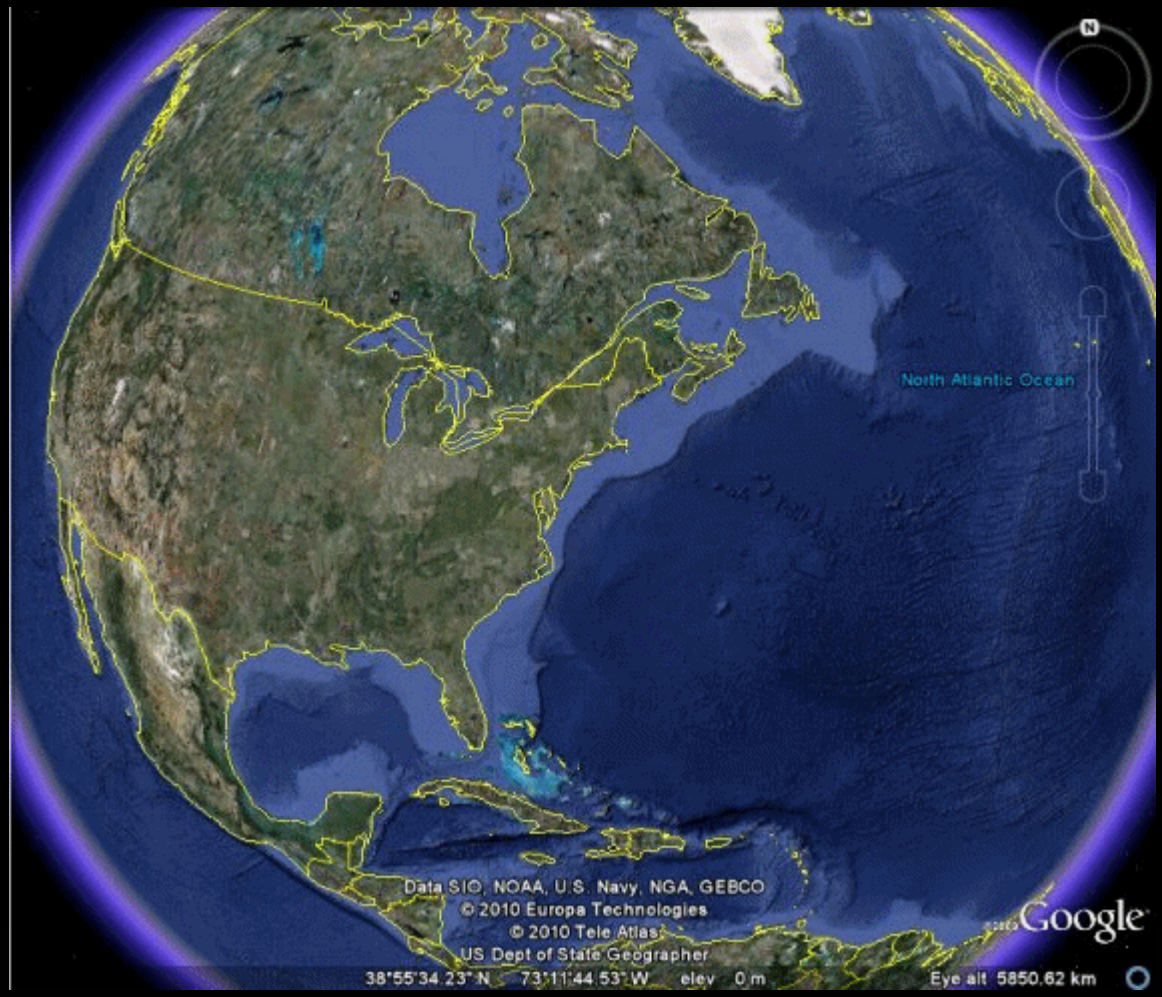
Optics

Selection

Optimization

Validation

Conclusion



Site

Optics

Selection

Optimization

Validation

Conclusion

Table 2. *Field cruises. Sub-regions are 1) Eastern LIS, 2) Central LIS, 3) Western LIS,4) CT River 5) NY Bight.*

Cruise	Date	Stations	Sub-regions				
			1	2	3	4	5
1) OGCO04	4-May	23	■	■	■	■	
2) LISICOS0305	5-Mar	9			■		
3) OGCO05	5-May	32	■	■	■	■	■
4) LISICOS0705	5-Jul	33			■		
5) LIS0106	6-Jan	2	■				
6) LISICOS0306	6-Mar	5			■		
7) LISICOS0406	6-Apr	3			■		
8) OCGO06	6-Jul	31	■	■	■	■	■
9) LISICOS0806	6-Aug	11			■		
10) LIS0507	7-Jun	3	■			■	
11) LIS0707	7-Jul	3	■			■	
12) LIS1207	7-Dec	3	■			■	

158 Stations between 2004 - 2007

Aurin, et. al., JGR, in press

Site

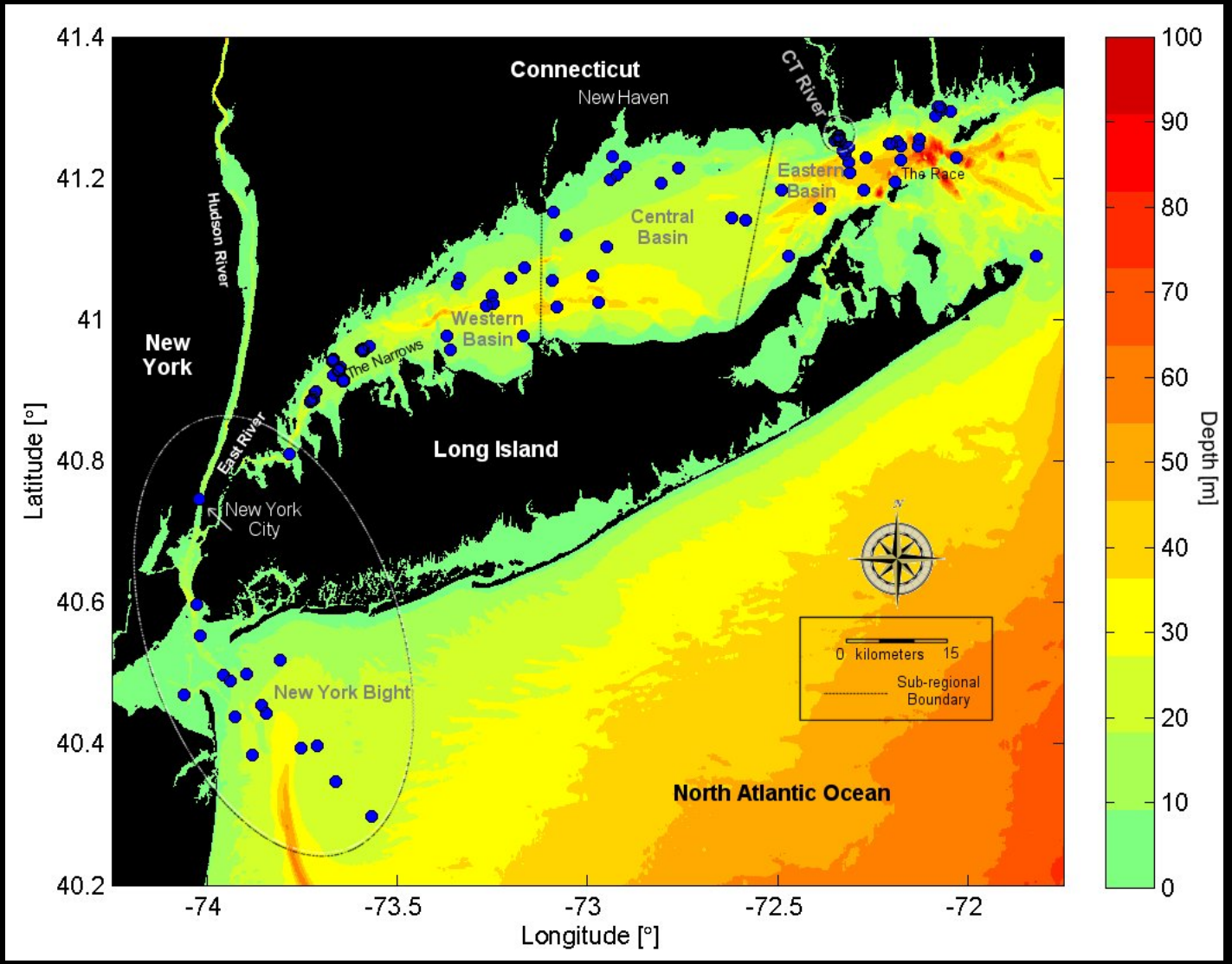
Optics

Selection

Optimization

Validation

Conclusion



Site

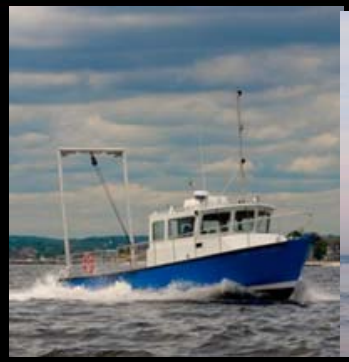
Optics

Selection

Optimization

Validation

Conclusion

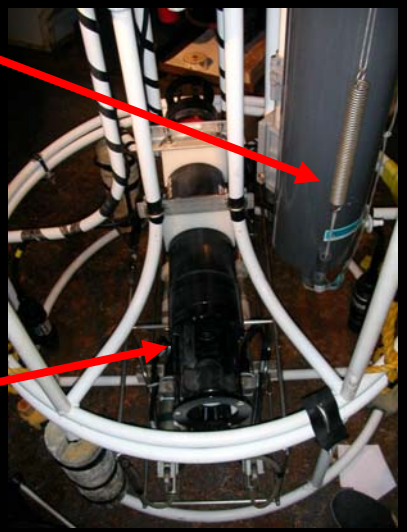


Radiometry:
Upwelling/Downwelling
radiance/irradiance, $R_{rs}(\lambda)$

absorption $a(\lambda)$
attenuation $c(\lambda)$
backscattering $b_b(\lambda)$
temperature
pressure
conductivity

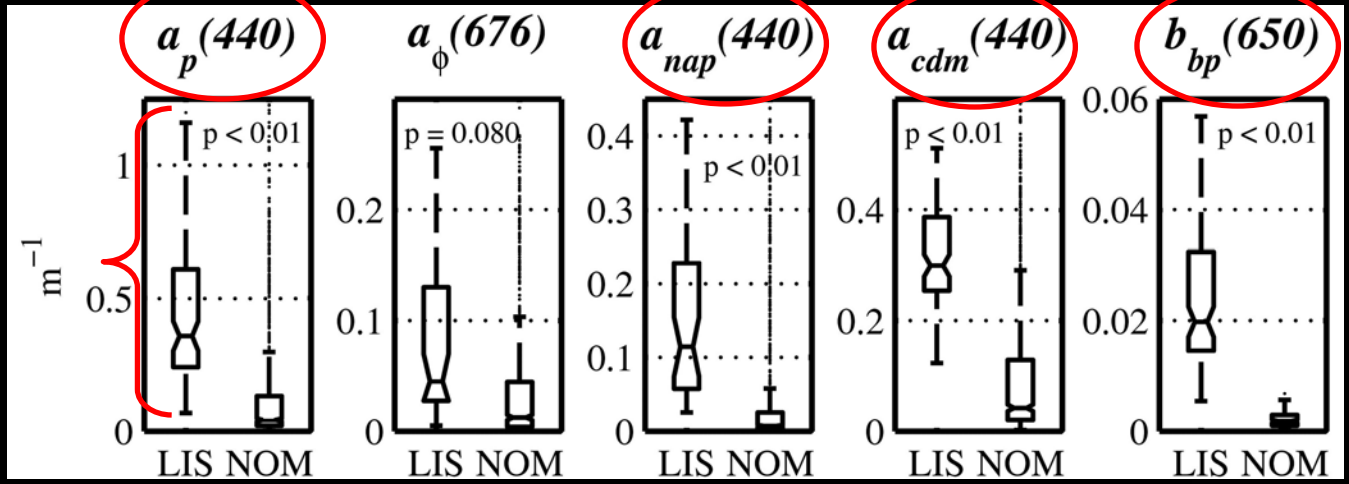
Chlorophyll
HPLC
TSM
QFT $a_{nap}(\lambda), a_{\varphi}(\lambda)$

Particle Size
Distribution



LIS vs. the World (NOMAD)

NASA bio-Optical Marine Algorithm Data set: 3,400 predominantly coastal stations worldwide.



Aurin, et. al., JGR, in press

LIS highly variable

LIS significantly higher than NOMAD

~Order of mag. higher

Remote Sensing Reflectance

Site

Optics

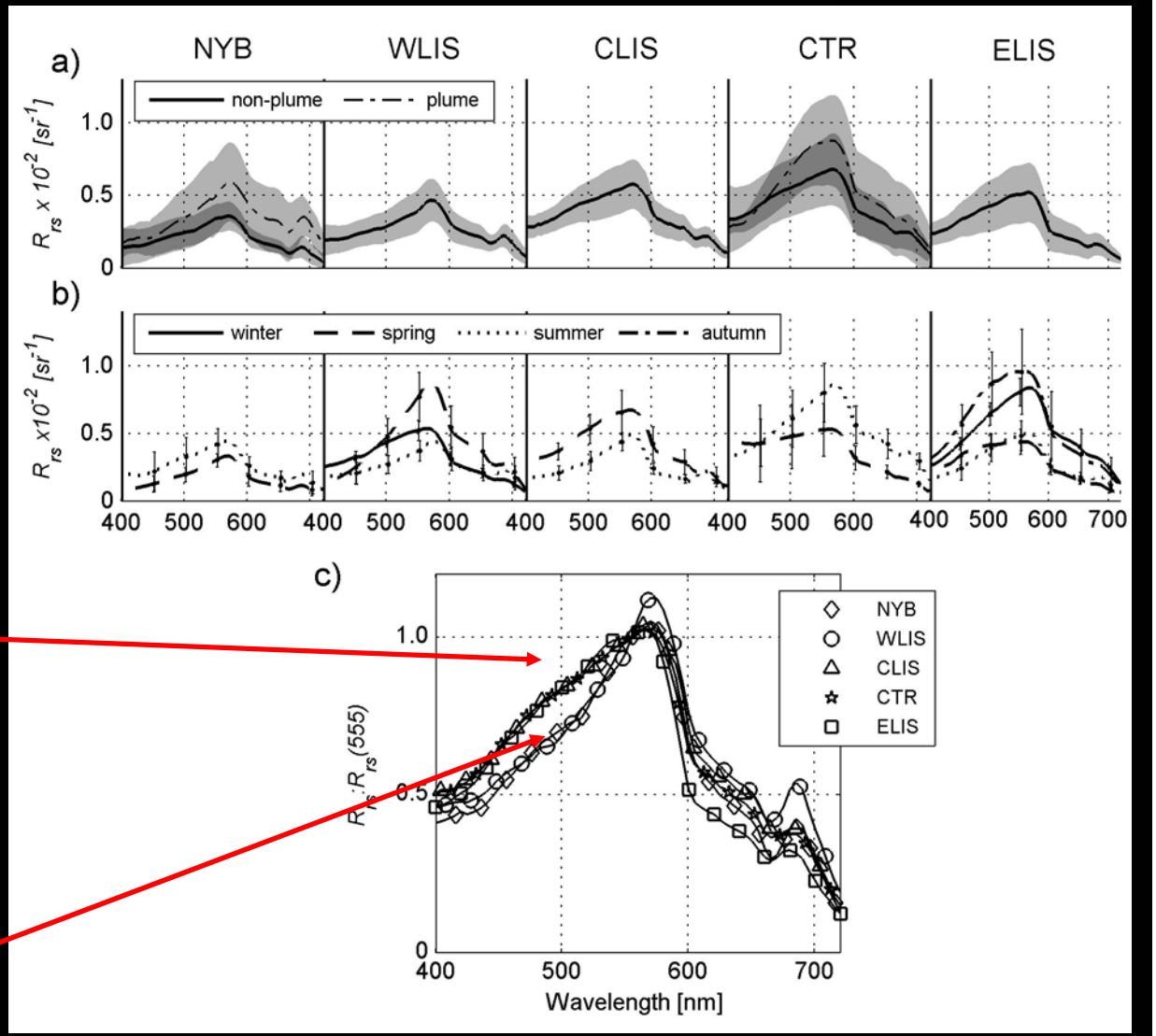
Selection

Optimization

Validation

Conclusion

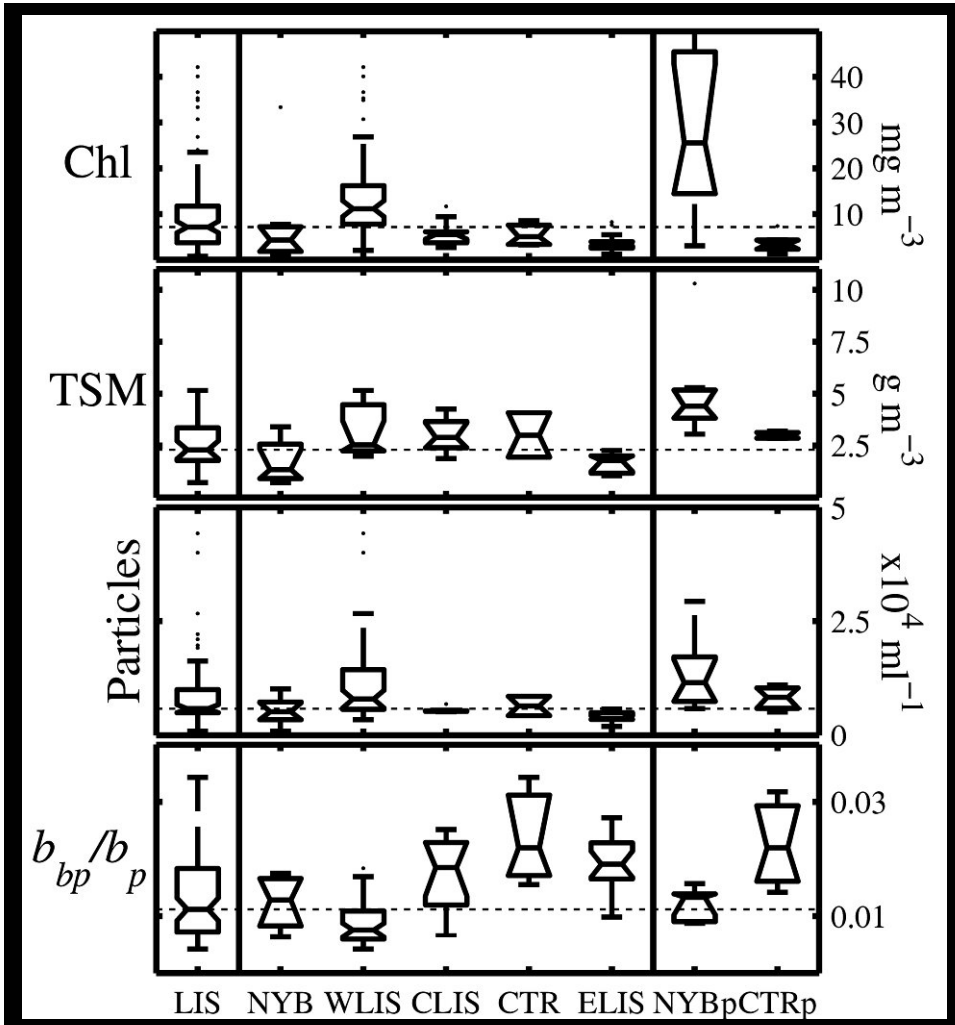
Variability between/within sub-regions, seasons in R_{rs}



Sediment dominated

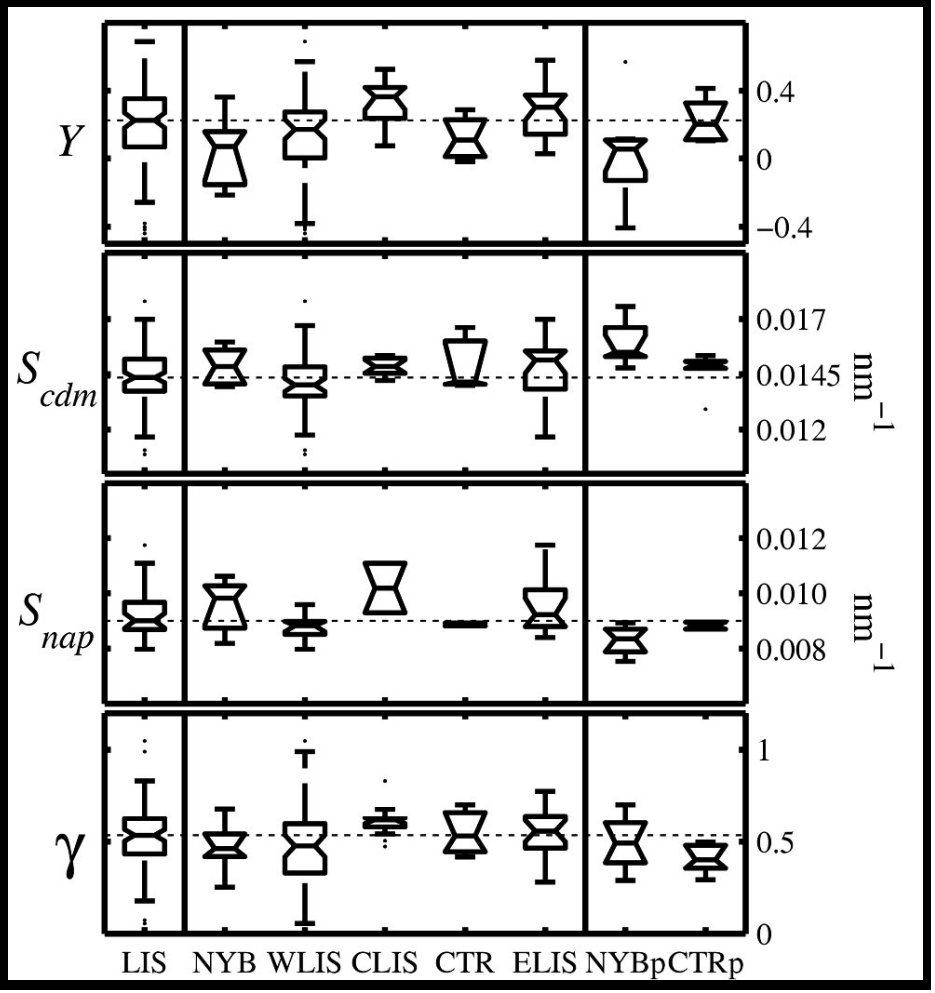
Phytoplankton dominated

Aurin, et. al., JGR, in press



Variability between sub-regions

Aurin, et. al., JGR, in press



IOP Spectral shape characteristics are fairly uniform across the region

Non-metric Multi-Dimensional Scaling (NMDS) – Cluster Map

Site

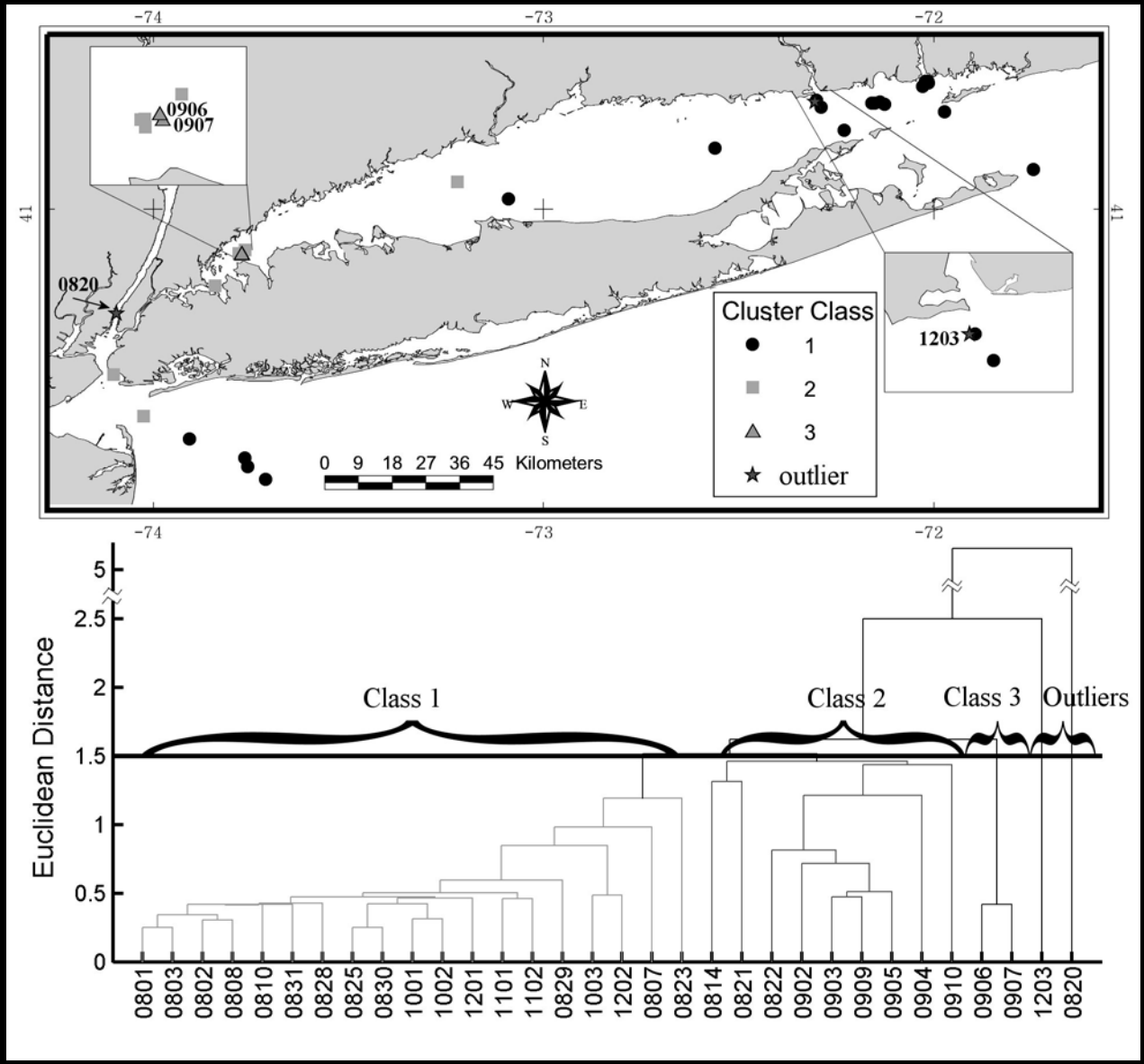
Optics

Selection

Optimization

Validation

Conclusion



Stations clustered into 3 groups based on constituent absorption and scattering (magnitude):

$a_p(440)$
$a_\varphi(676)$
$a_{nap}(440)$
$a_{cdm}(440)$
$b_p(440)$
$b_{bt}(650)$

Aurin, et. al., JGR, in press

Site

Optics

Selection

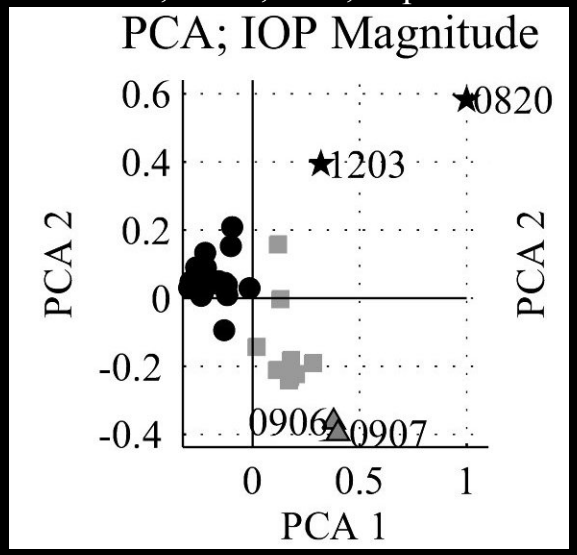
Optimization

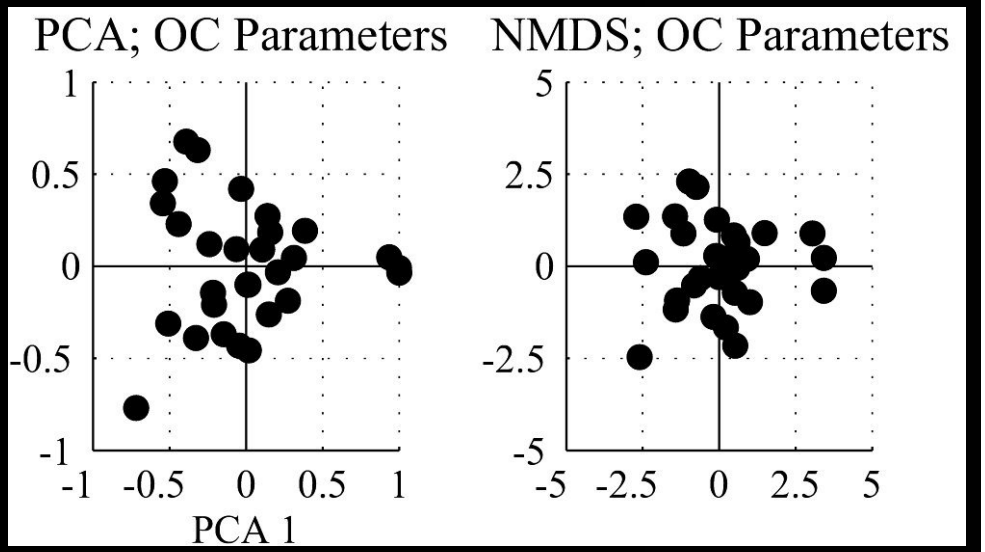
Validation

Conclusion

Non-metric Multi-Dimensional Scaling (NMDS) and Principal Component Analysis

Aurin, et. al., JGR, in press





Stations clustered based on IOP "quantity"

$a_p(440)$

$a_\varphi(676)$

$a_{nap}(440)$

$a_{cdm}(440)$

$b_p(440)$

$b_{bt}(650)$

Stations did not cluster based on IOP "quality"

Y

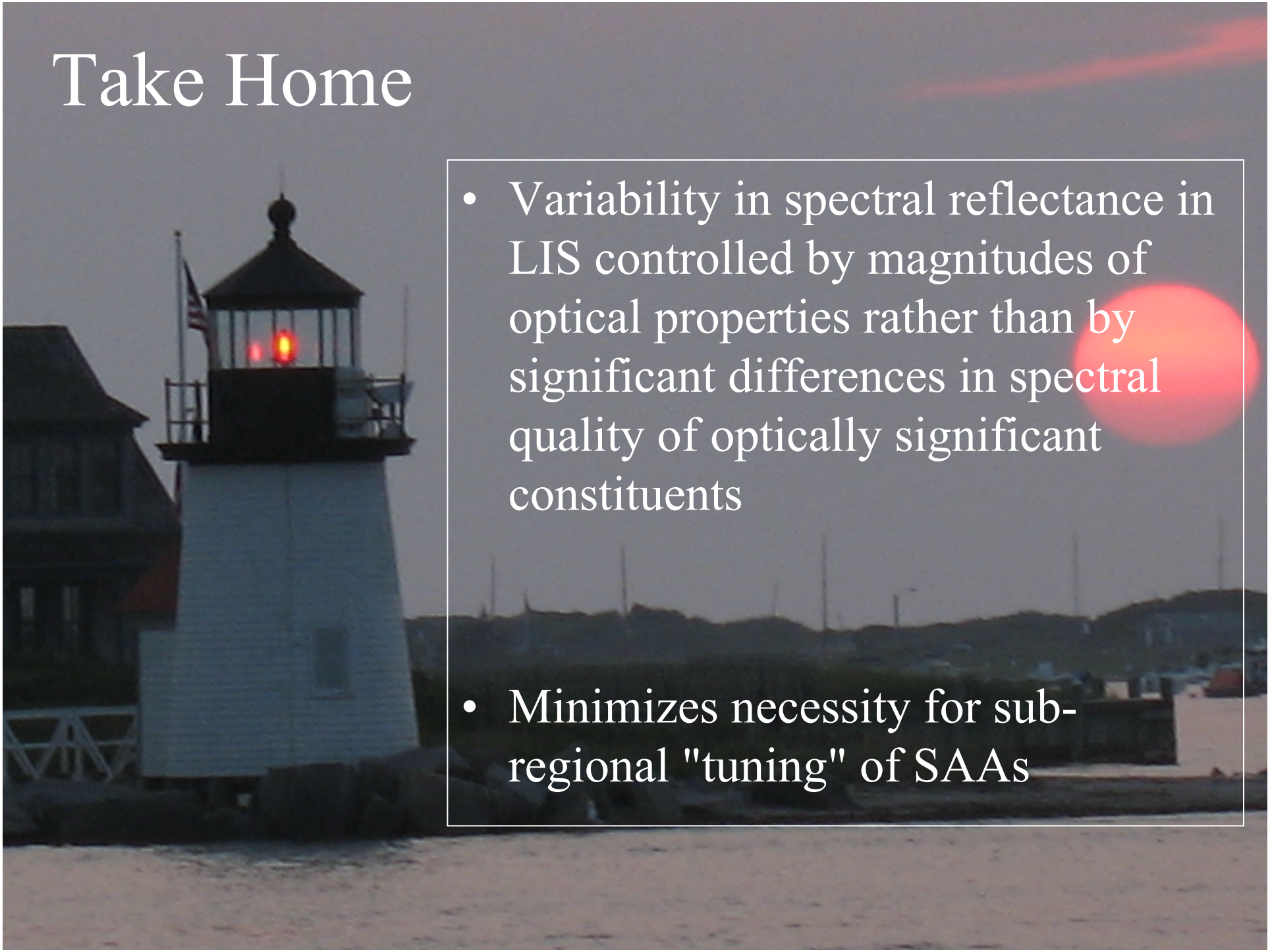
S_{cdm}

S_{nap}

Y

γ

Take Home



- Variability in spectral reflectance in LIS controlled by magnitudes of optical properties rather than by significant differences in spectral quality of optically significant constituents

- Minimizes necessity for sub-regional "tuning" of SAAs

Algorithm Selection

Site

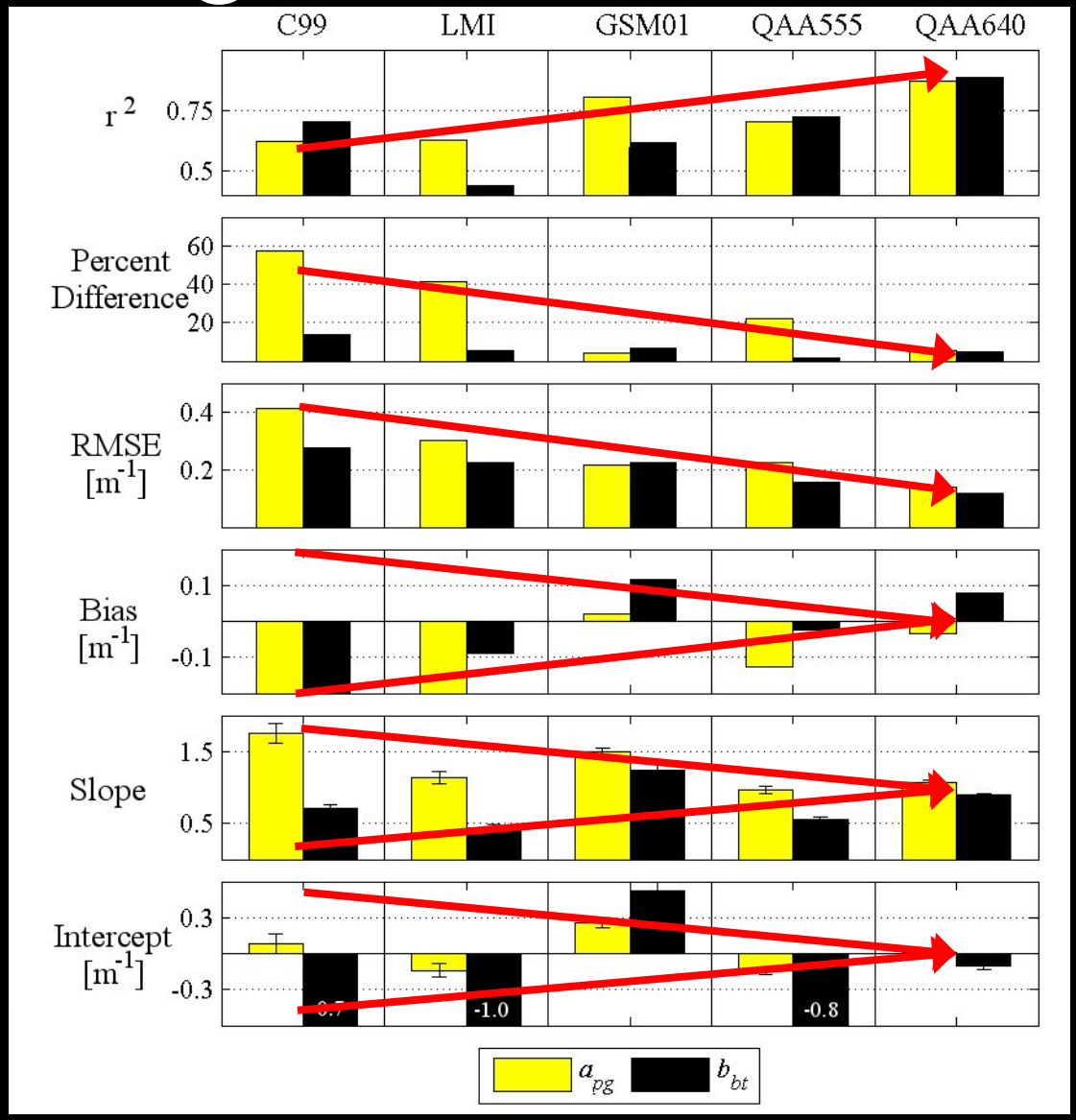
Optics

Selection

Optimization

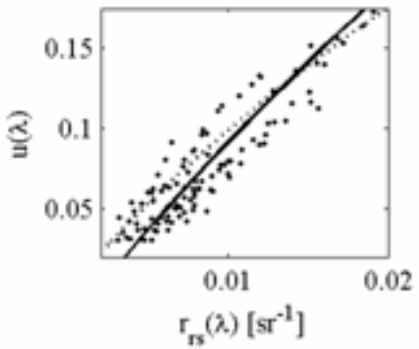
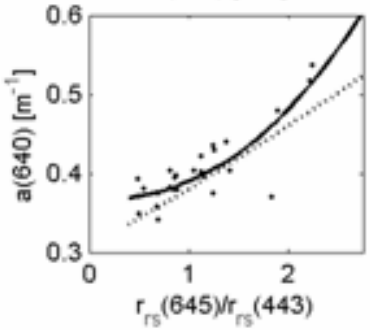
Validation

Conclusion



Aurin, et. al., AO, in prep.

Table 1. Empirical calibration of the QAALIS. Dots are LIS data, solid lines are tuned models (this study), dotted lines are models with original coefficients from Lee et al. [2004]. Stars indicate new models used in this study.

Mathmatical Model	Data versus Model	r^2	RMSE	n
$u(\lambda) = \frac{b_b(\lambda)}{a(\lambda)+b_b(\lambda)} = \frac{-g_0 + [(g_0)^2 + 4g_1 r_{rs}(\lambda)]^{1/2}}{2g_1}$; $g_0 = 0.121, g_1 = 0.006$		0.93	0.001	182
$a(640) = 0.37 + 0.023\,\rho_3^{2.3}$; $\rho_3 = \frac{r_{rs}(645)}{r_{rs}(443)}$		0.70	0.026	26

Aurin, et. al., AO, in prep.

•
•
•

- Tuned each of 7 empirical algorithm components (555 and 640) with data from LIS
- Some components required new models

Site

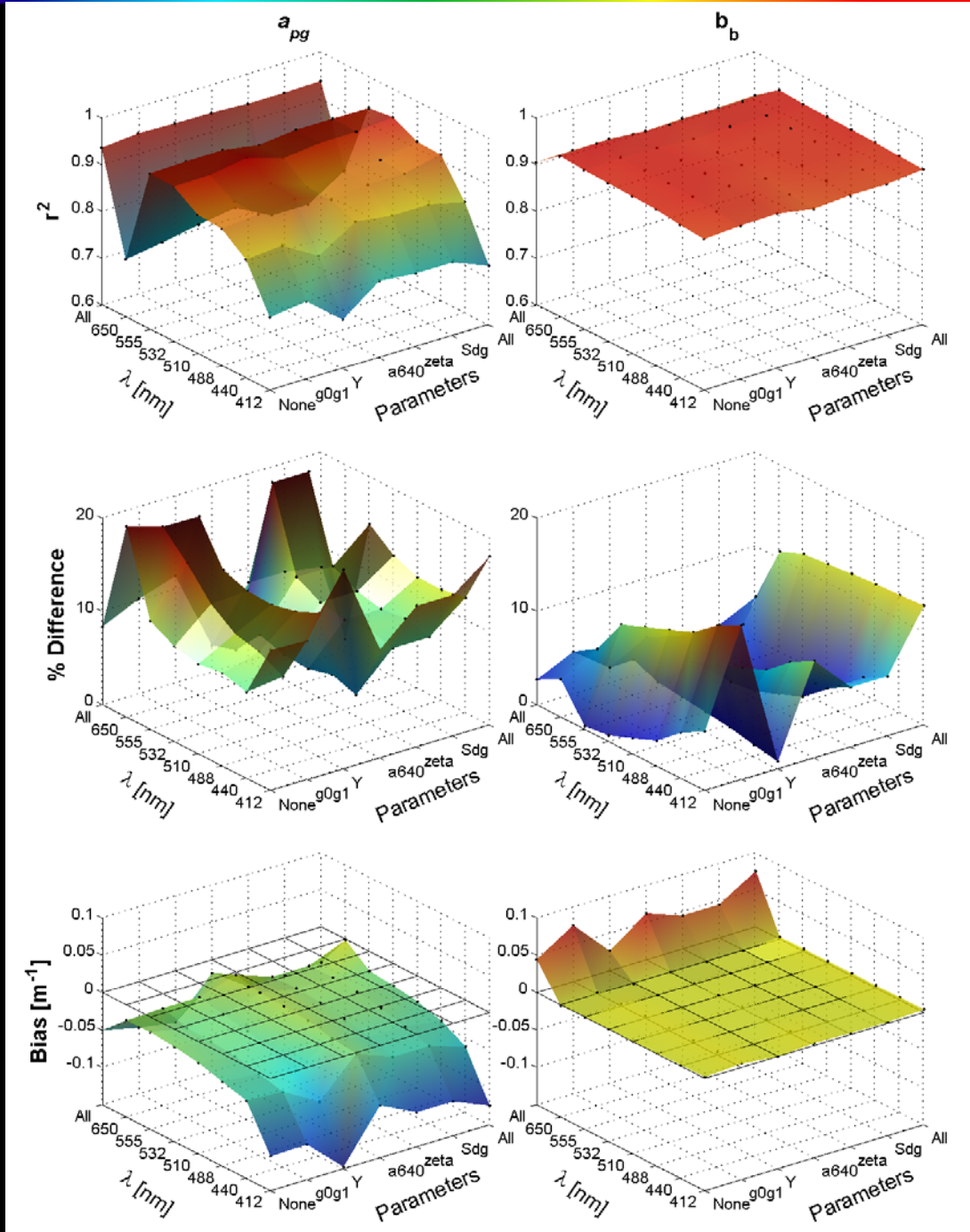
Optics

Selection

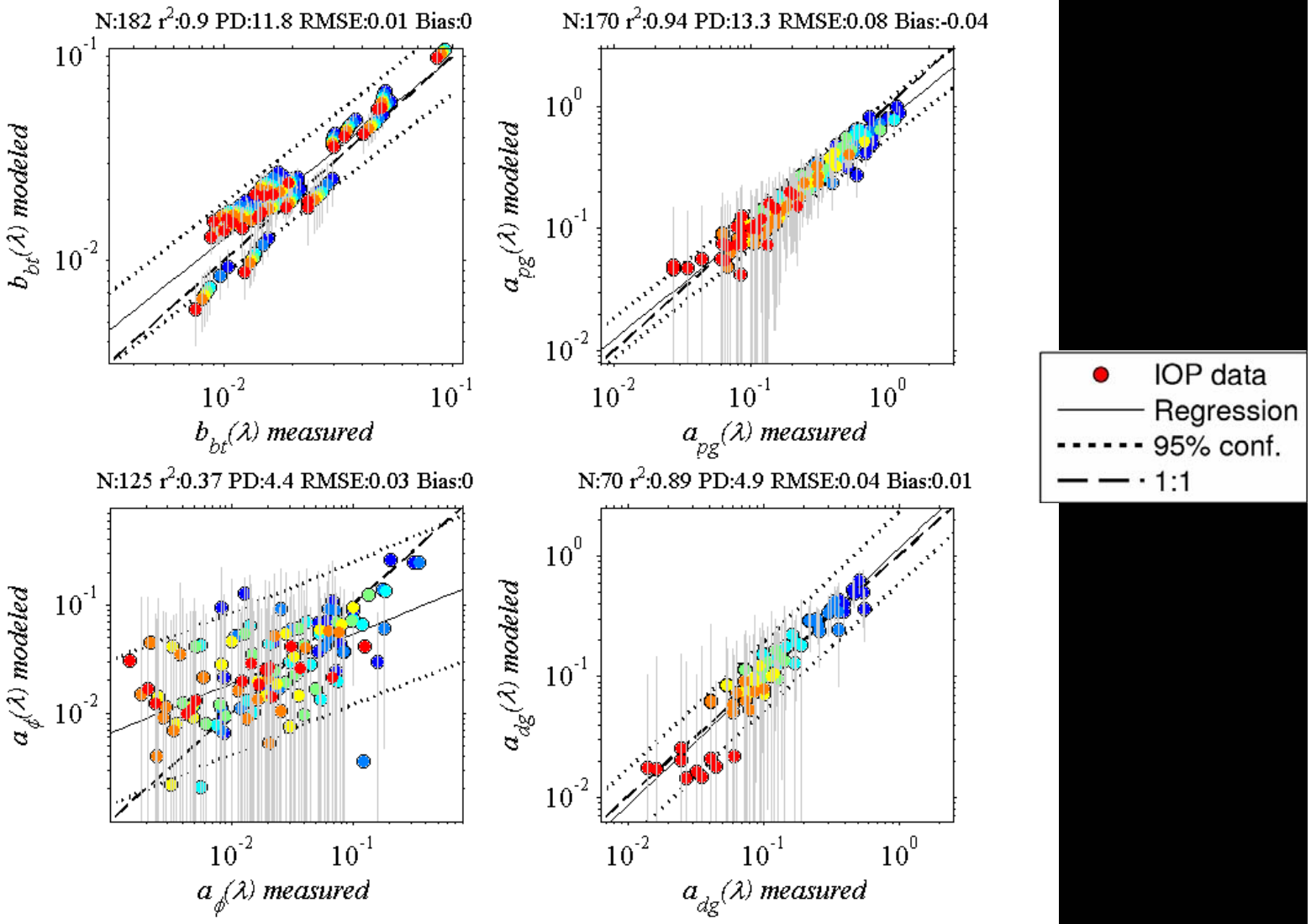
Optimization

Validation

Conclusion

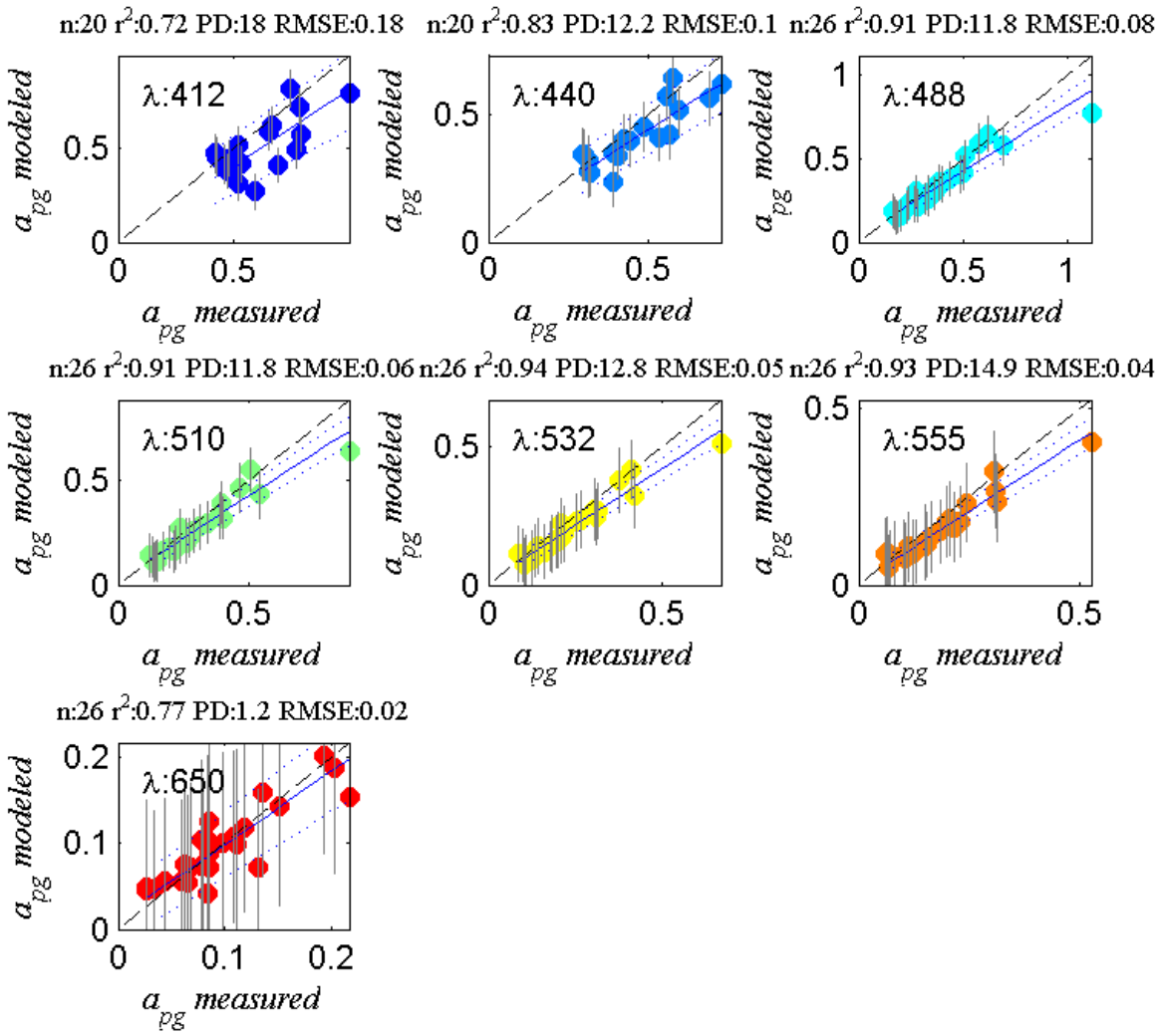


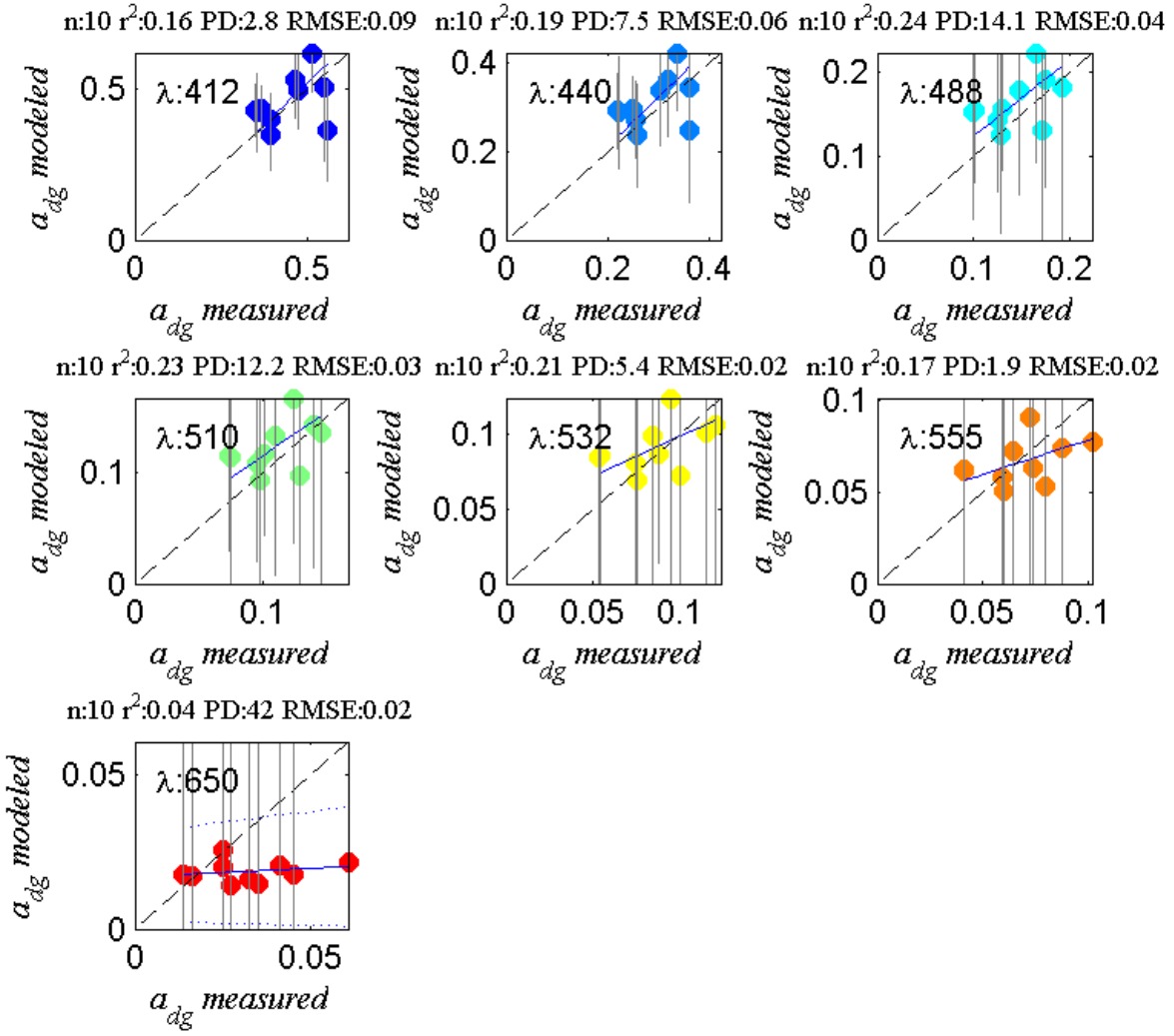
640 nm

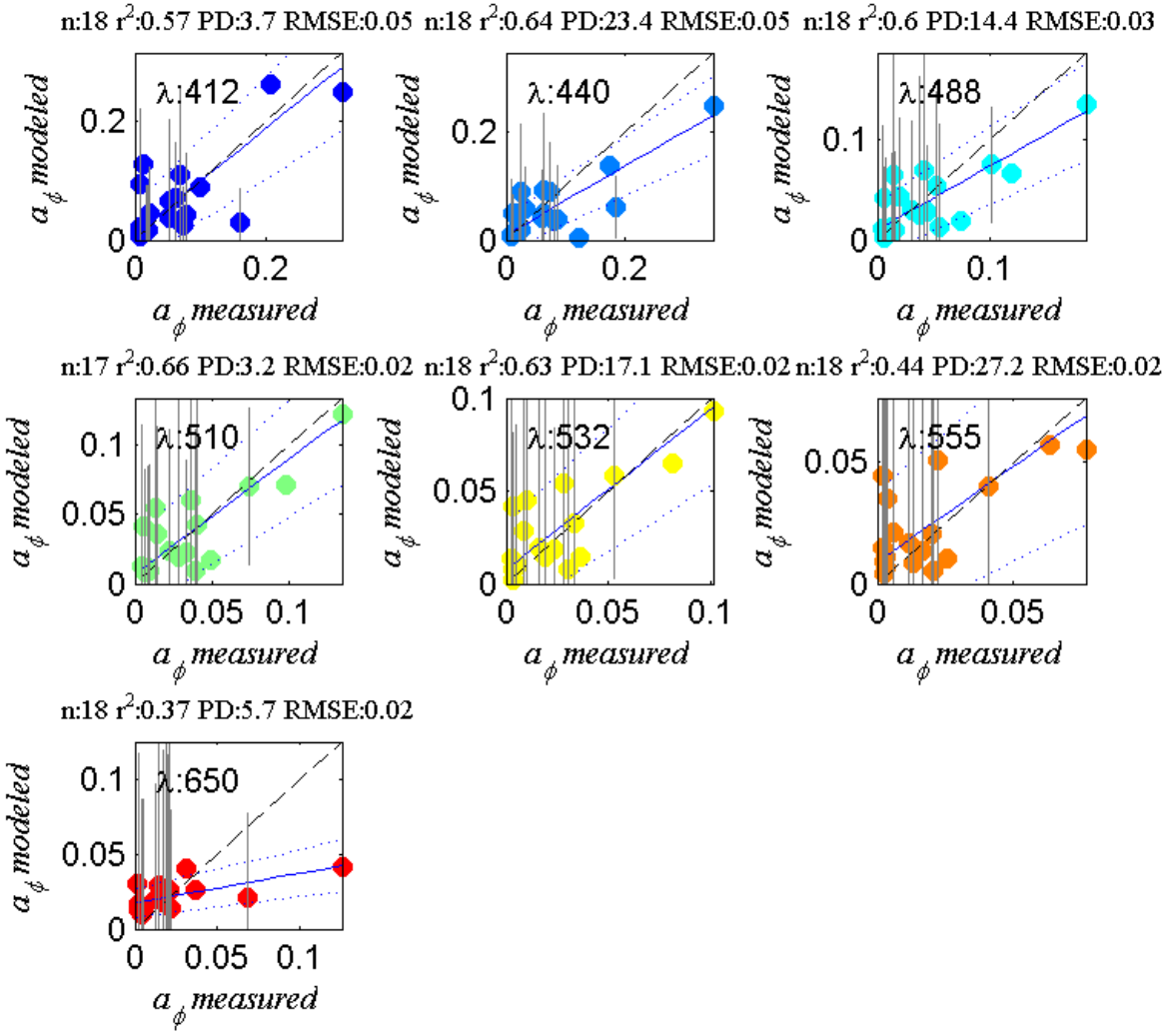


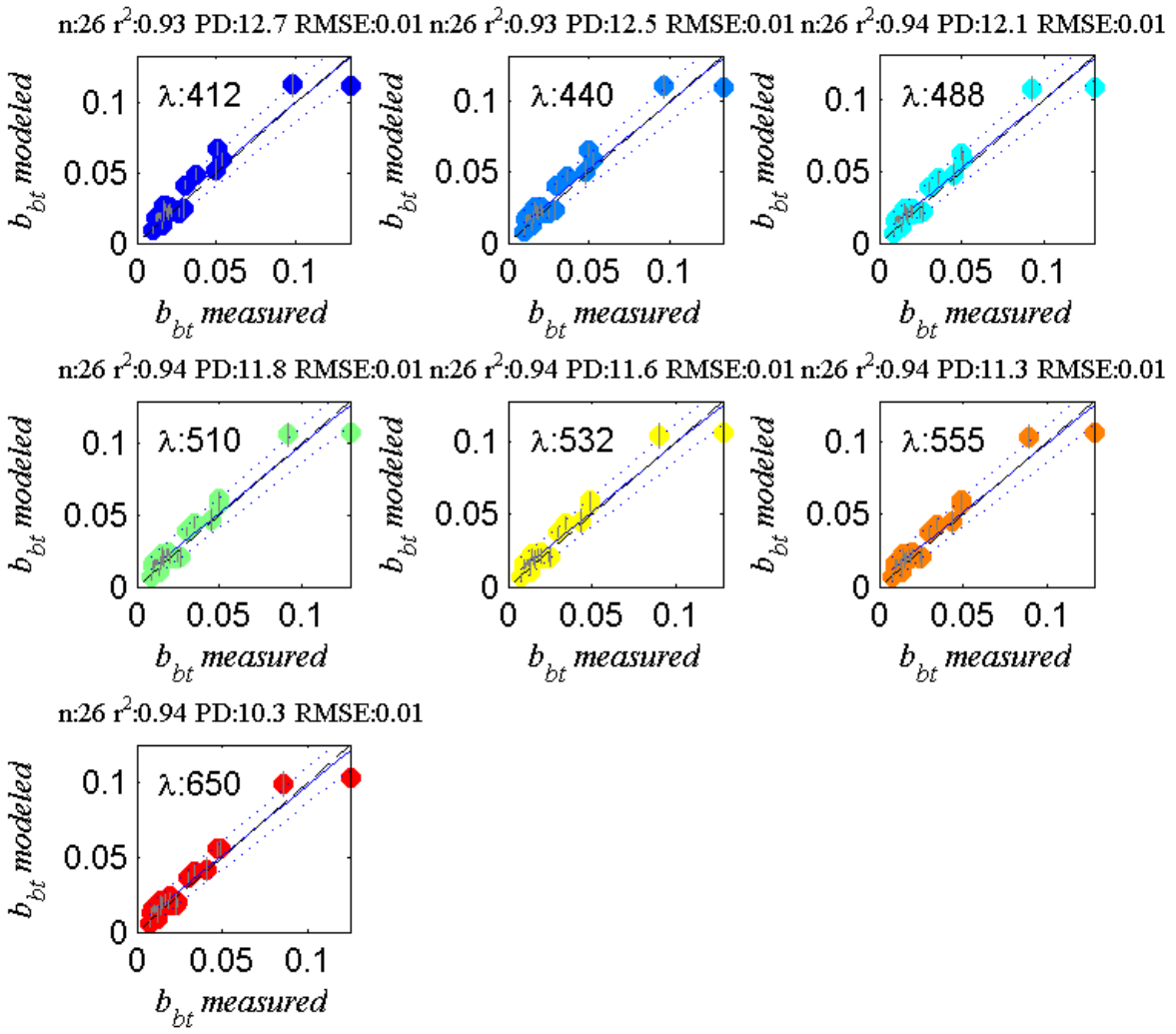
λ = 412 – 650 nm

Aurin, et. al., AO, in prep.


n:20 r²:0.72 PD:18 RMSE:0.18
λ:412
n:20 r²:0.83 PD:12.2 RMSE:0.1
λ:440
n:26 r²:0.91 PD:11.8 RMSE:0.08
λ:488
n:26 r²:0.91 PD:11.8 RMSE:0.06
λ:510
n:26 r²:0.94 PD:12.8 RMSE:0.05
λ:532
n:26 r²:0.93 PD:14.9 RMSE:0.04
λ:555
n:26 r²:0.77 PD:1.2 RMSE:0.02
λ:650
a_pg modeled
a_pg measured


n:10 r²:0.16 PD:2.8 RMSE:0.09
λ:412
n:10 r²:0.19 PD:7.5 RMSE:0.06
λ:440
n:10 r²:0.24 PD:14.1 RMSE:0.04
λ:488
n:10 r²:0.23 PD:12.2 RMSE:0.03
λ:510
n:10 r²:0.21 PD:5.4 RMSE:0.02
λ:532
n:10 r²:0.17 PD:1.9 RMSE:0.02
λ:555
n:10 r²:0.04 PD:42 RMSE:0.02
λ:650
a_dg modeled
a_dg measured


n:18 r²:0.57 PD:3.7 RMSE:0.05
λ:412
n:18 r²:0.64 PD:23.4 RMSE:0.05
λ:440
n:18 r²:0.6 PD:14.4 RMSE:0.03
λ:488
n:17 r²:0.66 PD:3.2 RMSE:0.02
λ:510
n:18 r²:0.63 PD:17.1 RMSE:0.02
λ:532
n:18 r²:0.44 PD:27.2 RMSE:0.02
λ:555
n:18 r²:0.37 PD:5.7 RMSE:0.02
λ:650
a_φ modeled
a_φ measured


n:26 r²:0.93 PD:12.7 RMSE:0.01
λ:412
n:26 r²:0.93 PD:12.5 RMSE:0.01
λ:440
n:26 r²:0.94 PD:12.1 RMSE:0.01
λ:488
n:26 r²:0.94 PD:11.8 RMSE:0.01
λ:510
n:26 r²:0.94 PD:11.6 RMSE:0.01
λ:532
n:26 r²:0.94 PD:11.3 RMSE:0.01
λ:555
n:26 r²:0.94 PD:10.3 RMSE:0.01
λ:650
b_bt modeled
b_bt measured
0
0.05
0.1

Biogeochemical Property Retrievals

Site

Optics

Selection

Optimization

Validation

Conclusion

- IOPs depend on particulate and dissolved property characteristics
- Isolate relationships between IOPs and biogeochemical properties
  - a_{φ} (440, 676) --> Chl (ideally)
  - b_b or R_{rs}(500-650) --> TSM

Biogeochemical Property Retrievals

Site

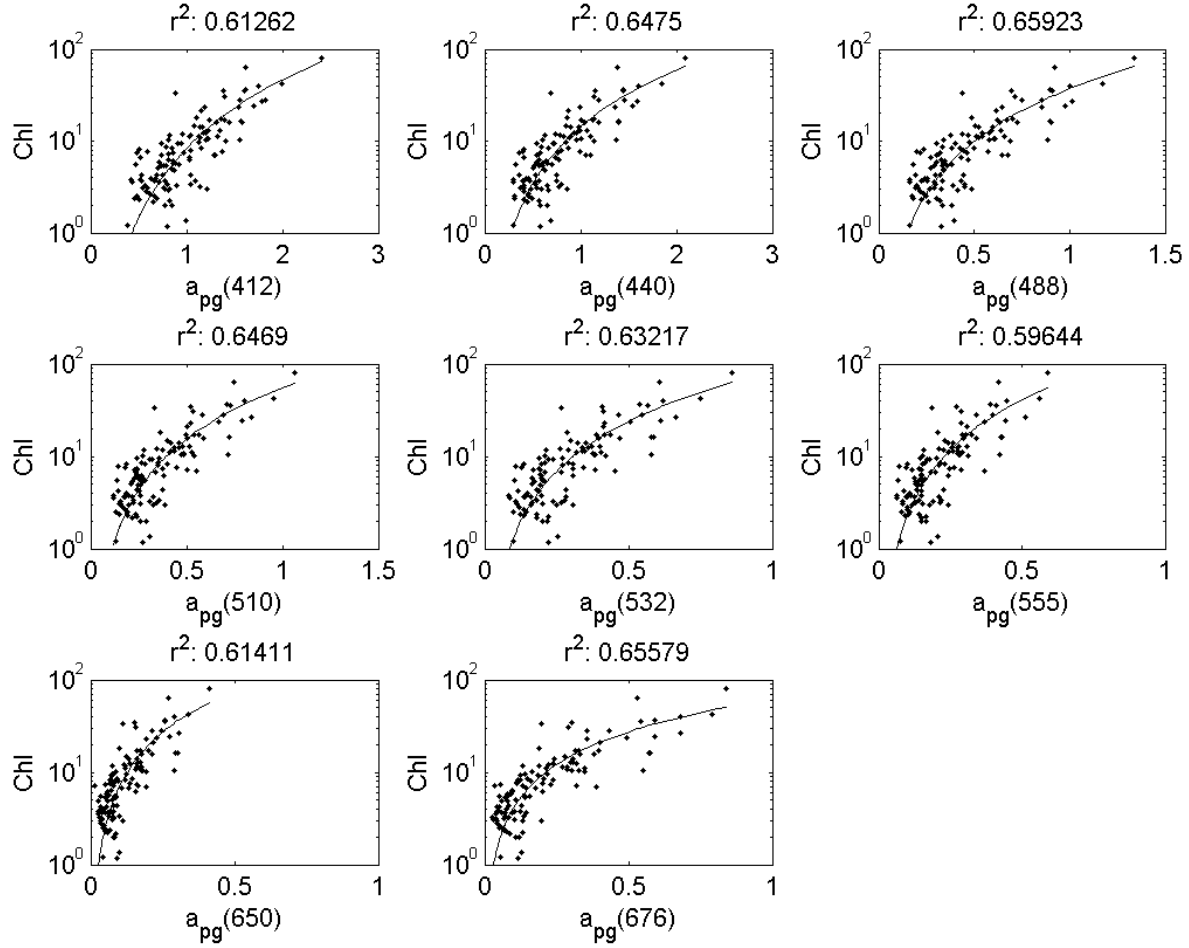
Optics

Selection

Optimization

Validation

Conclusion



Biogeochemical Property Retrievals

Site

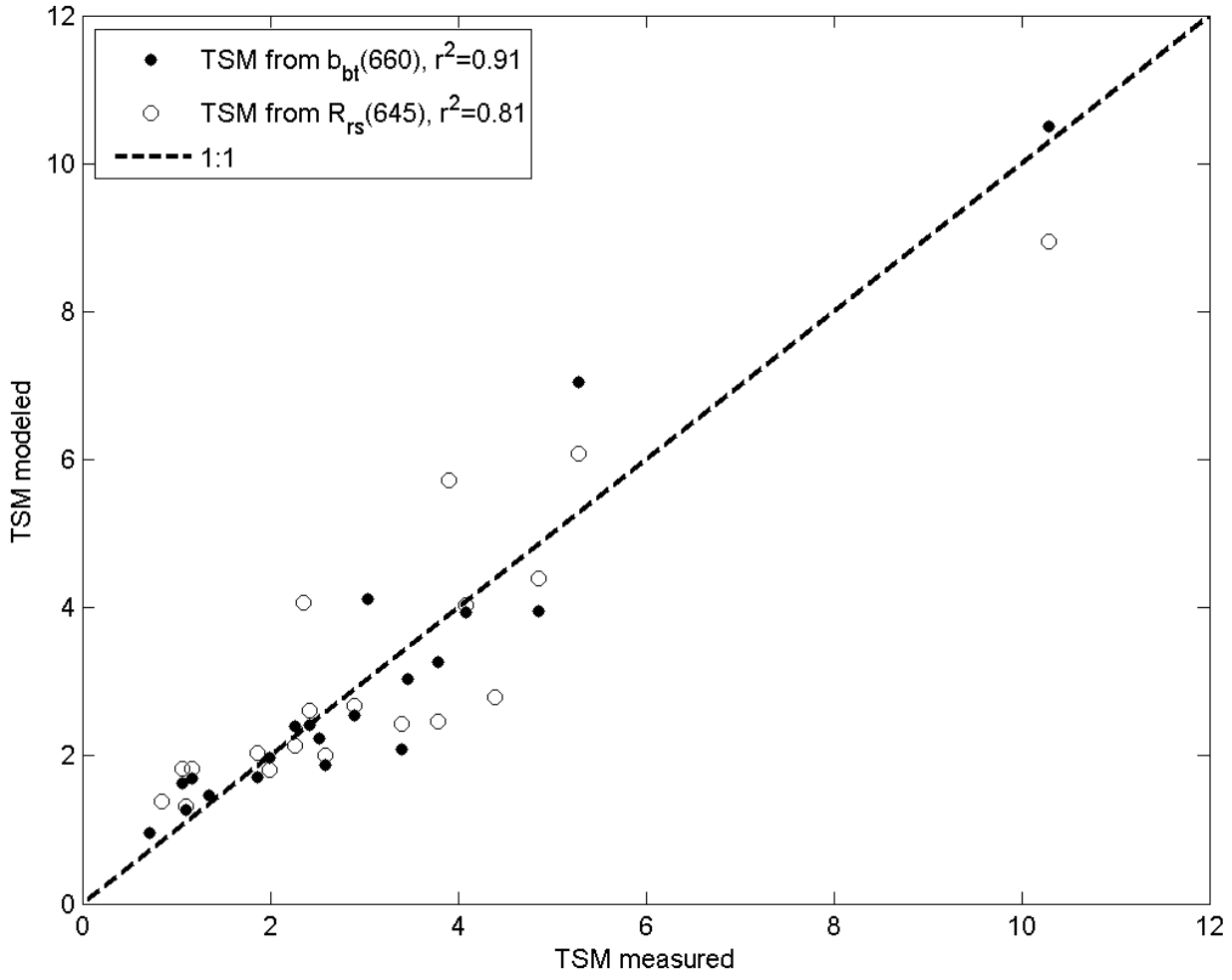
Optics

Selection

Optimization

Validation

Conclusion



Site

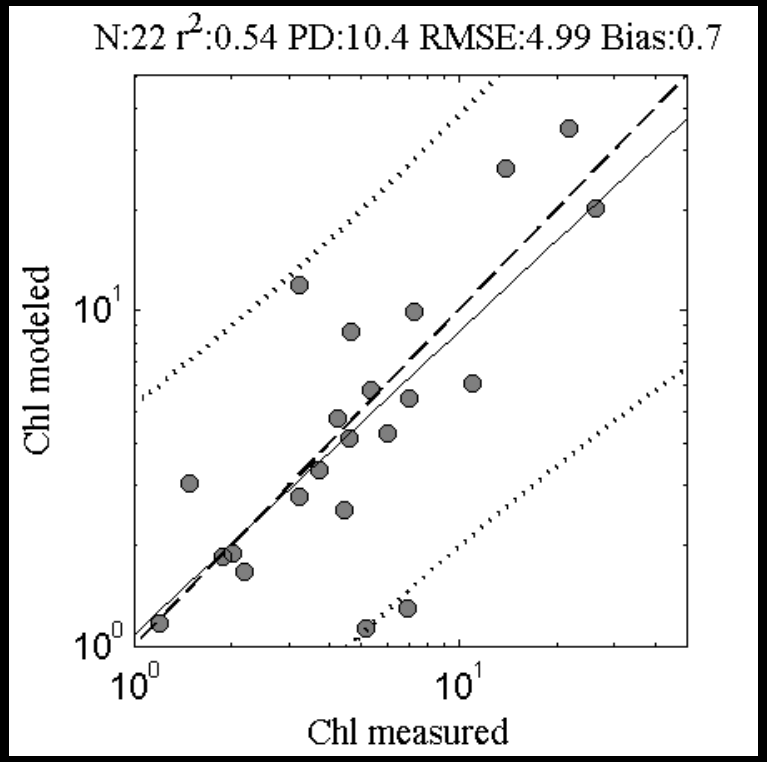
Optics

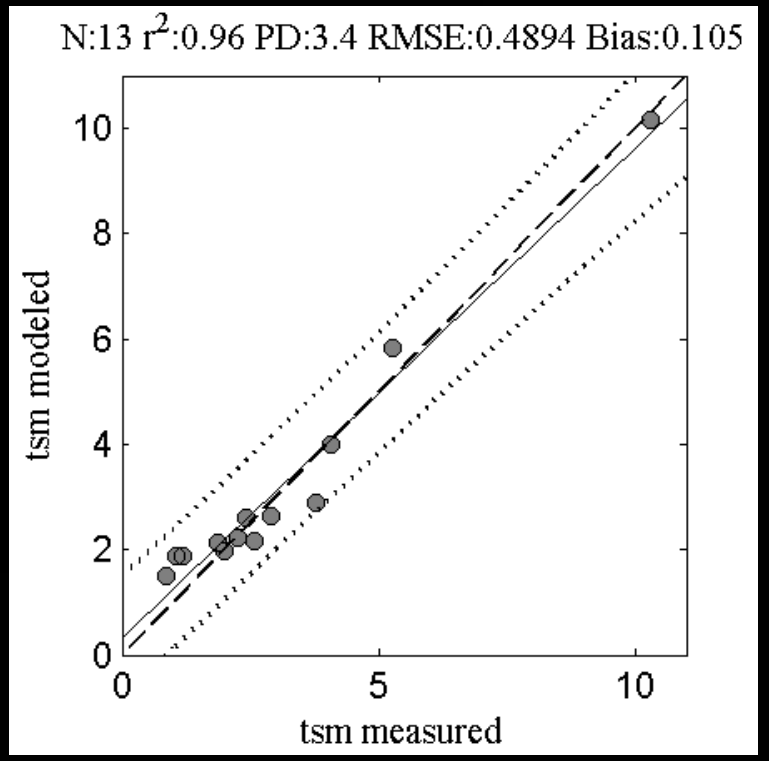
Selection

Optimization

Validation

Conclusion





Biogeochemical Property Retrievals

Site

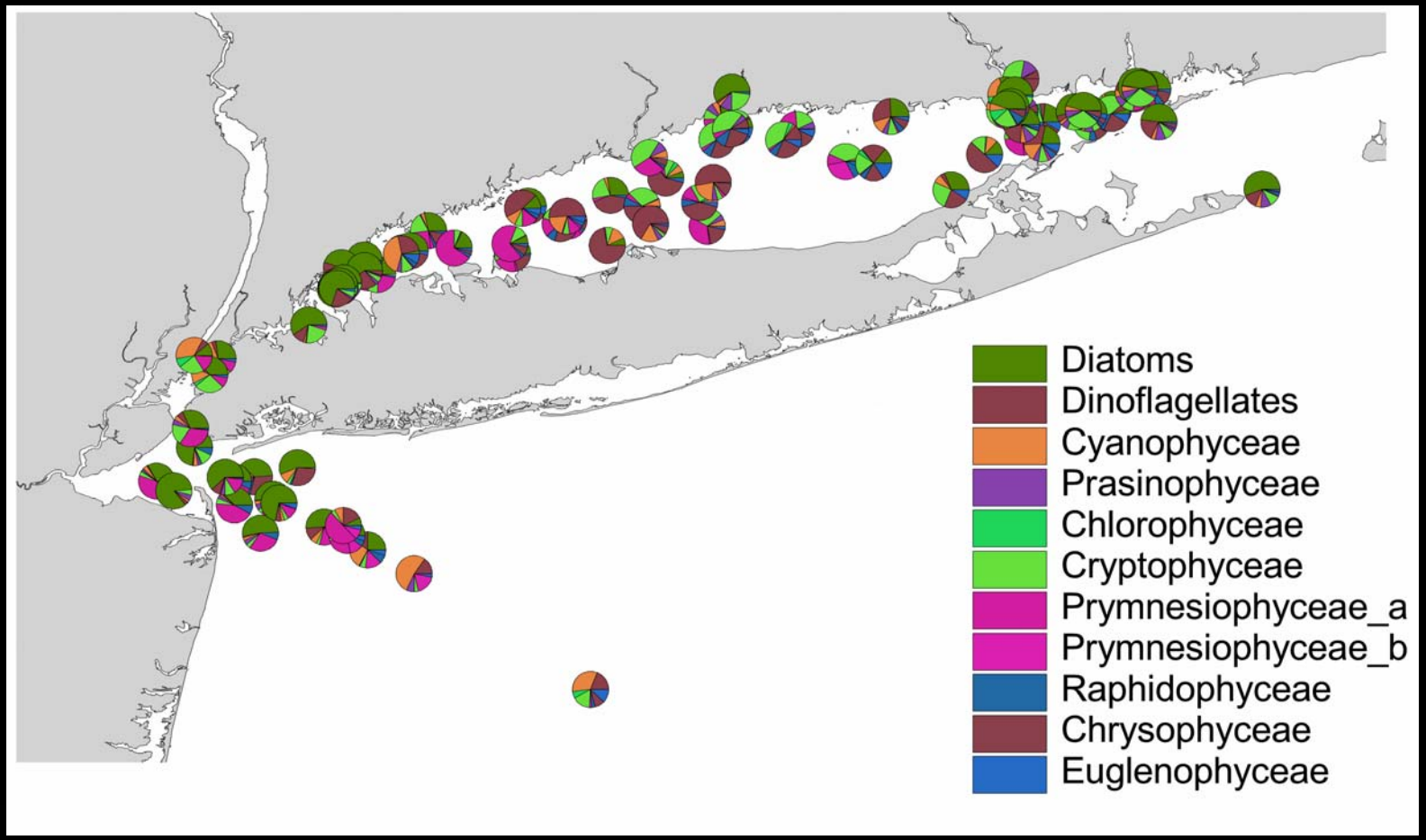
Optics

Selection

Optimization

Validation

Conclusion



Summary

- Characterization of optical variability important to SAA development in complex waters
- LIS highly complex and absorbs and scatters more strongly than most data in NOMAD
- Sub-regional heterogeneity in IOPs & R_{rs}
- IOP *spectral shape parameters* are generally homogeneous
- Regionally optimized QAA succeeds in retrieving IOPs from R_{rs}

New England Floods of 2010

Site

Optics

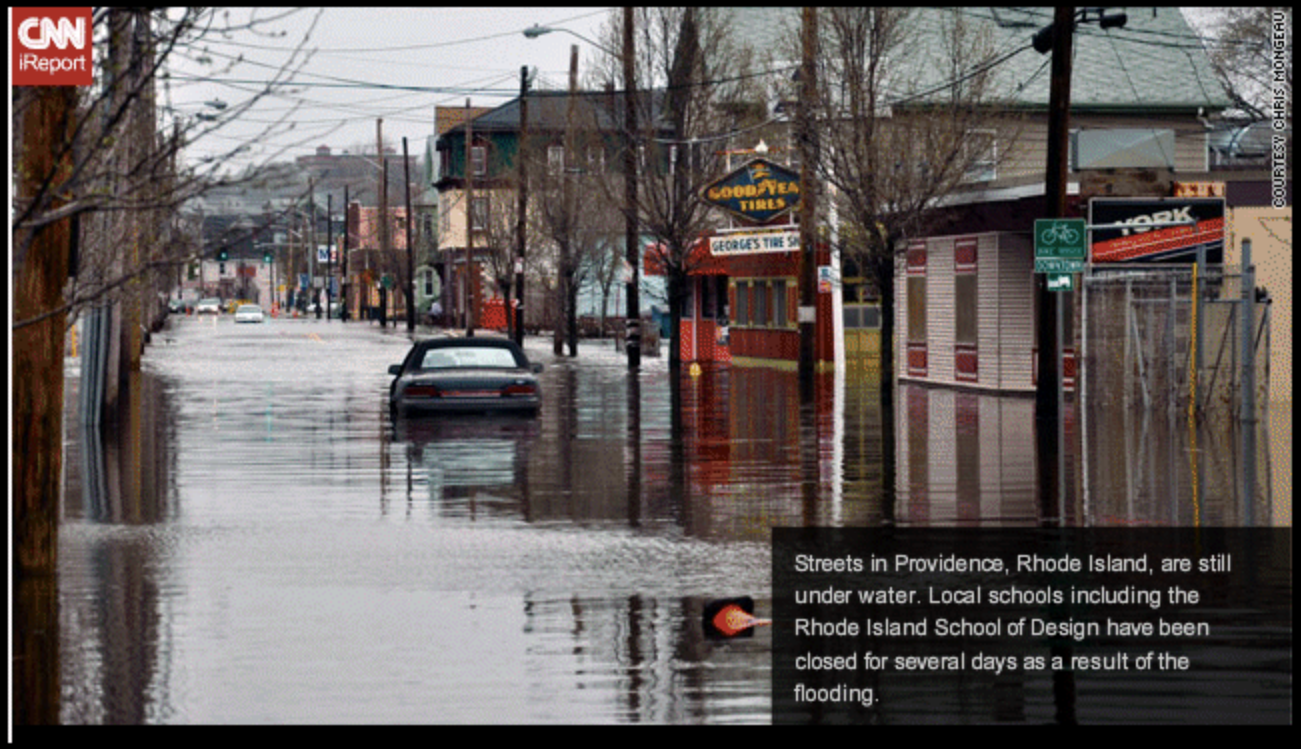
Selection

Optimization

Validation

Application

Conclusion



Streets in Providence, Rhode Island, are still under water. Local schools including the Rhode Island School of Design have been closed for several days as a result of the flooding.

New England Floods of 2010

- "Rhode Island experienced its worst flooding in more than 100 years." - AP
- "...unprecendented in our state's history." – Gov. Don Carcieri
- "Stonington, CT...largely cut off as two of its three bridges went out." - AP
- "...muddy earth beneath a Middletown [CT] apartment complex gave way, leaving two buildings teetering over the ravine," – AP
- "...detours around I-95, the main link between New York and Boston." -AP

Site

Optics

Selection

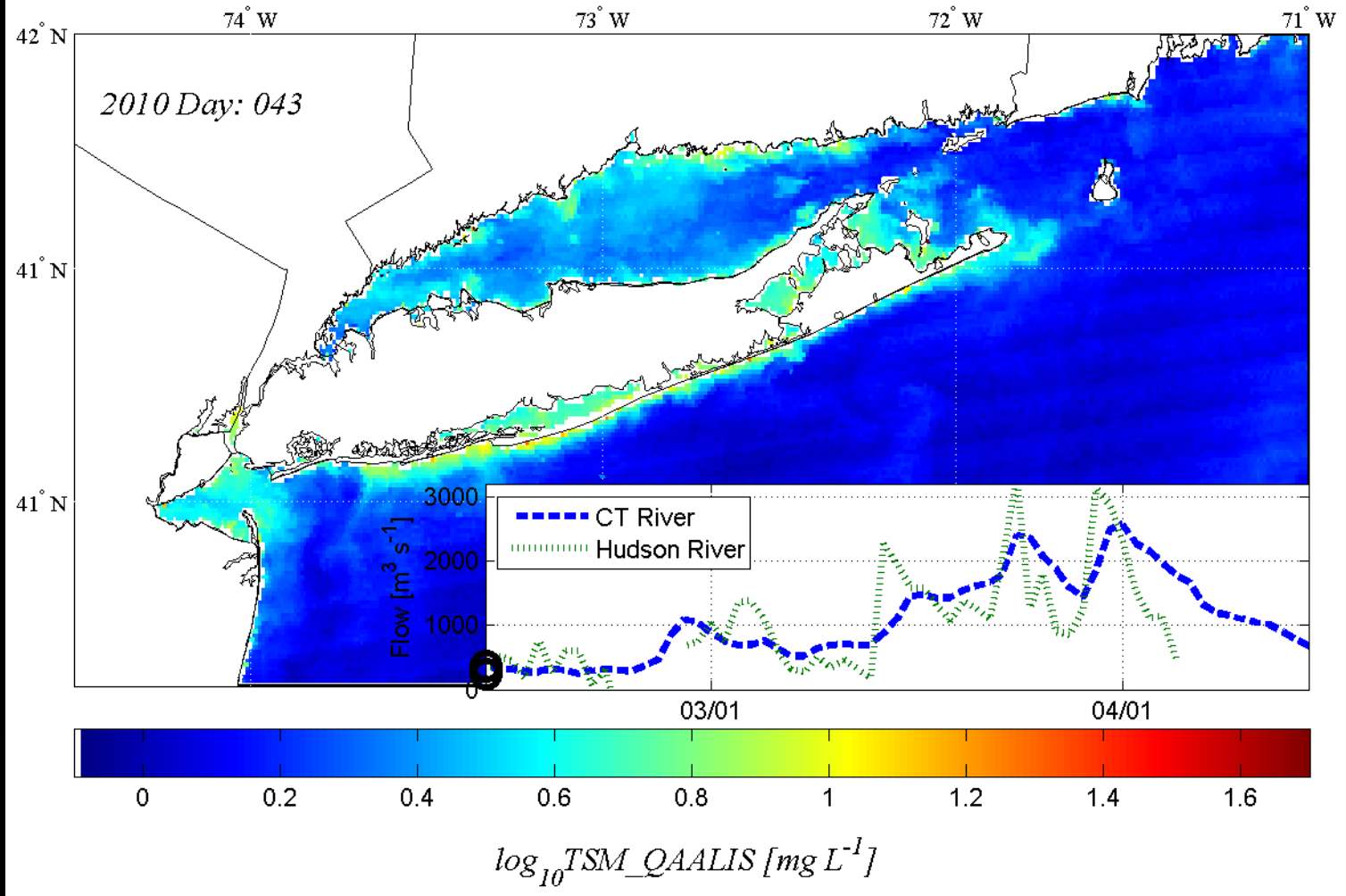
Optimization

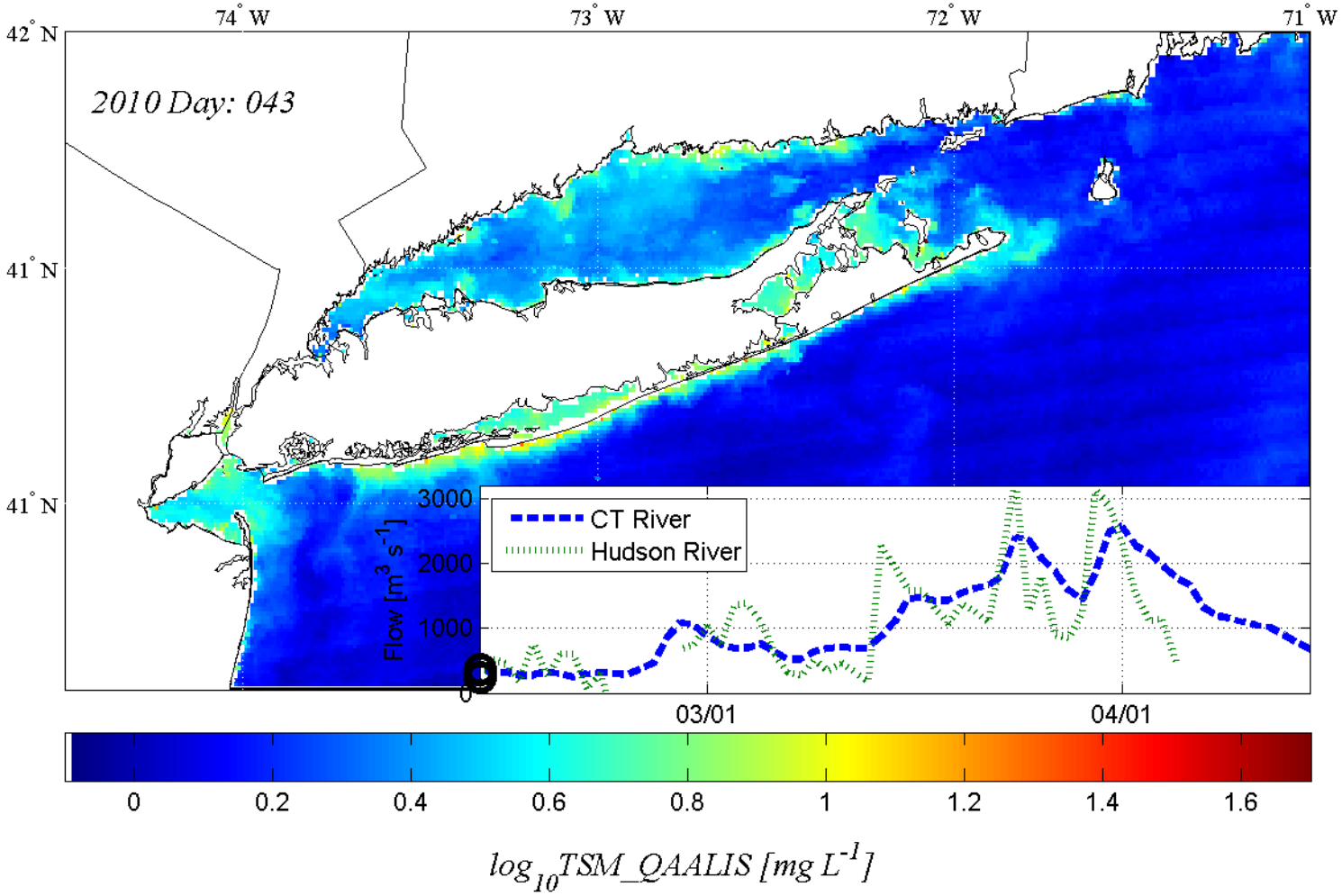
Validation

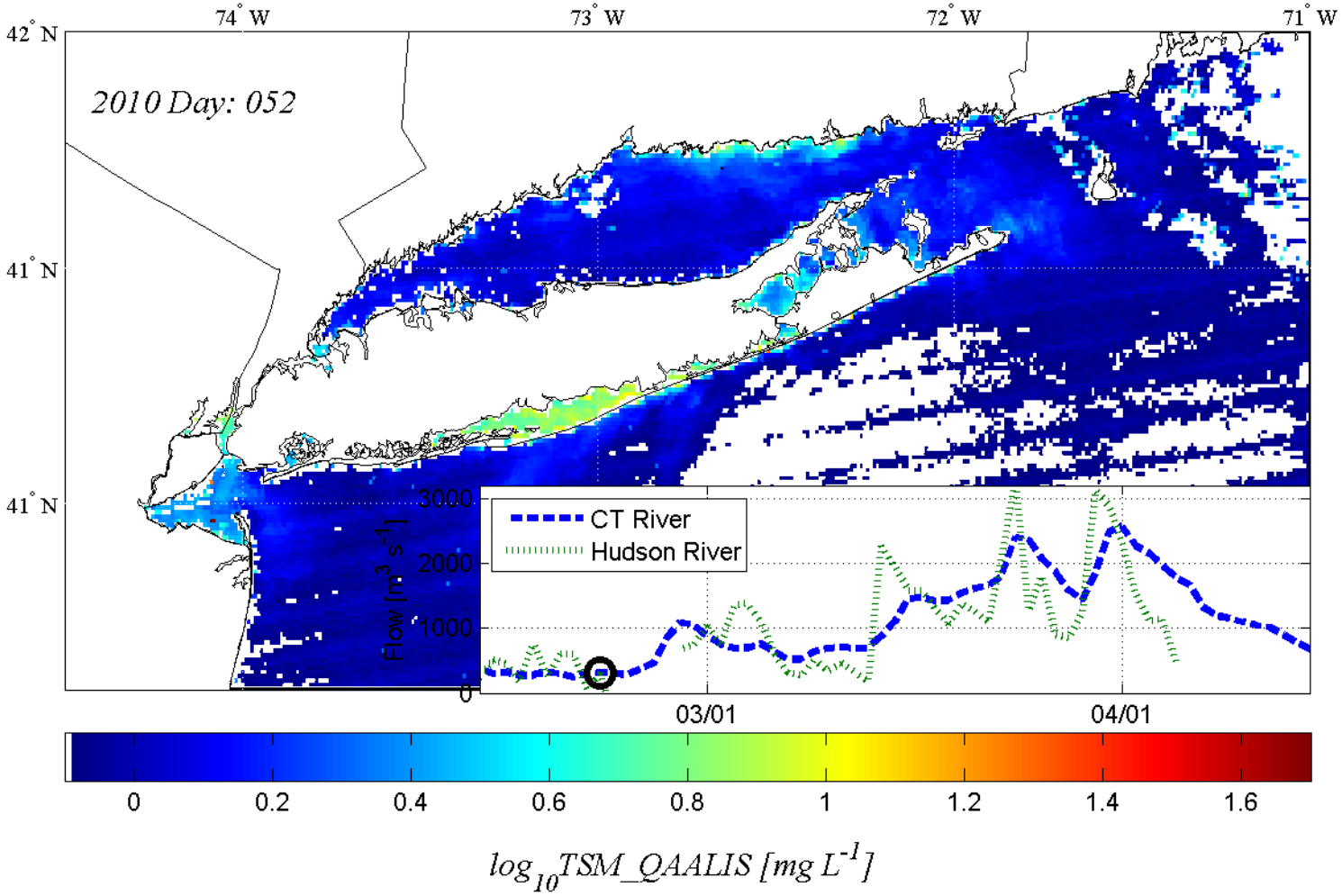
Application

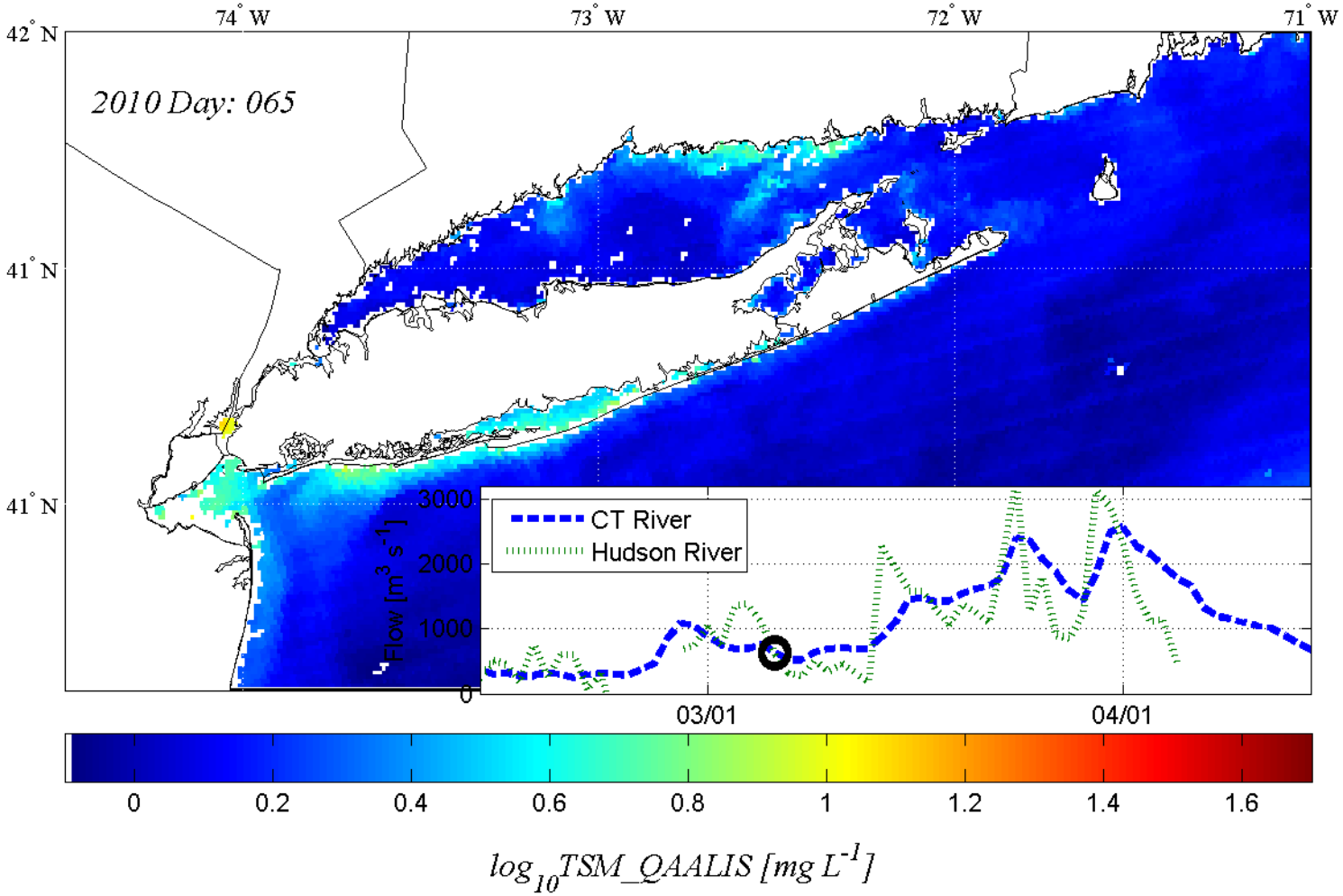
Conclusion

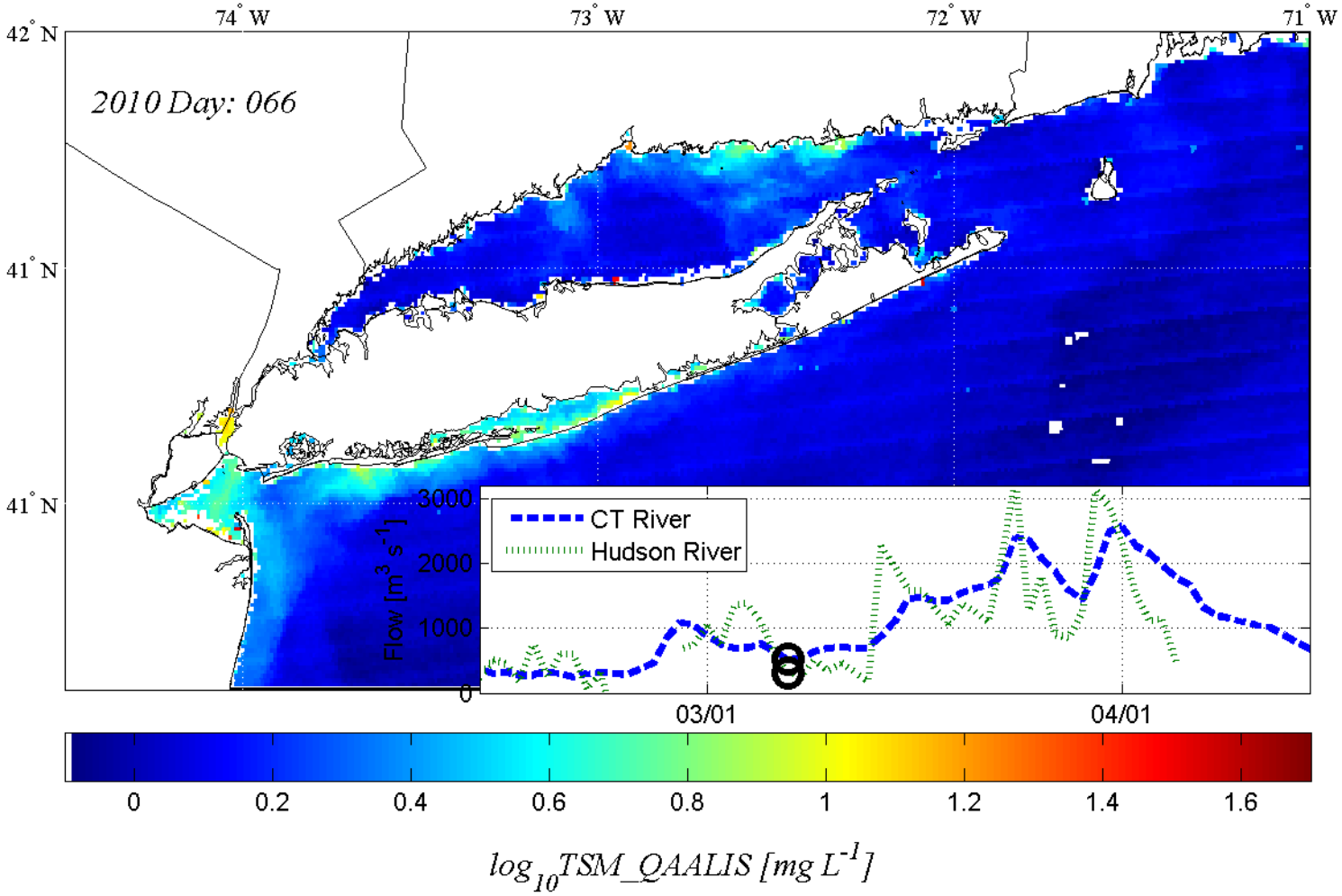
TSM delivery to coastal waters

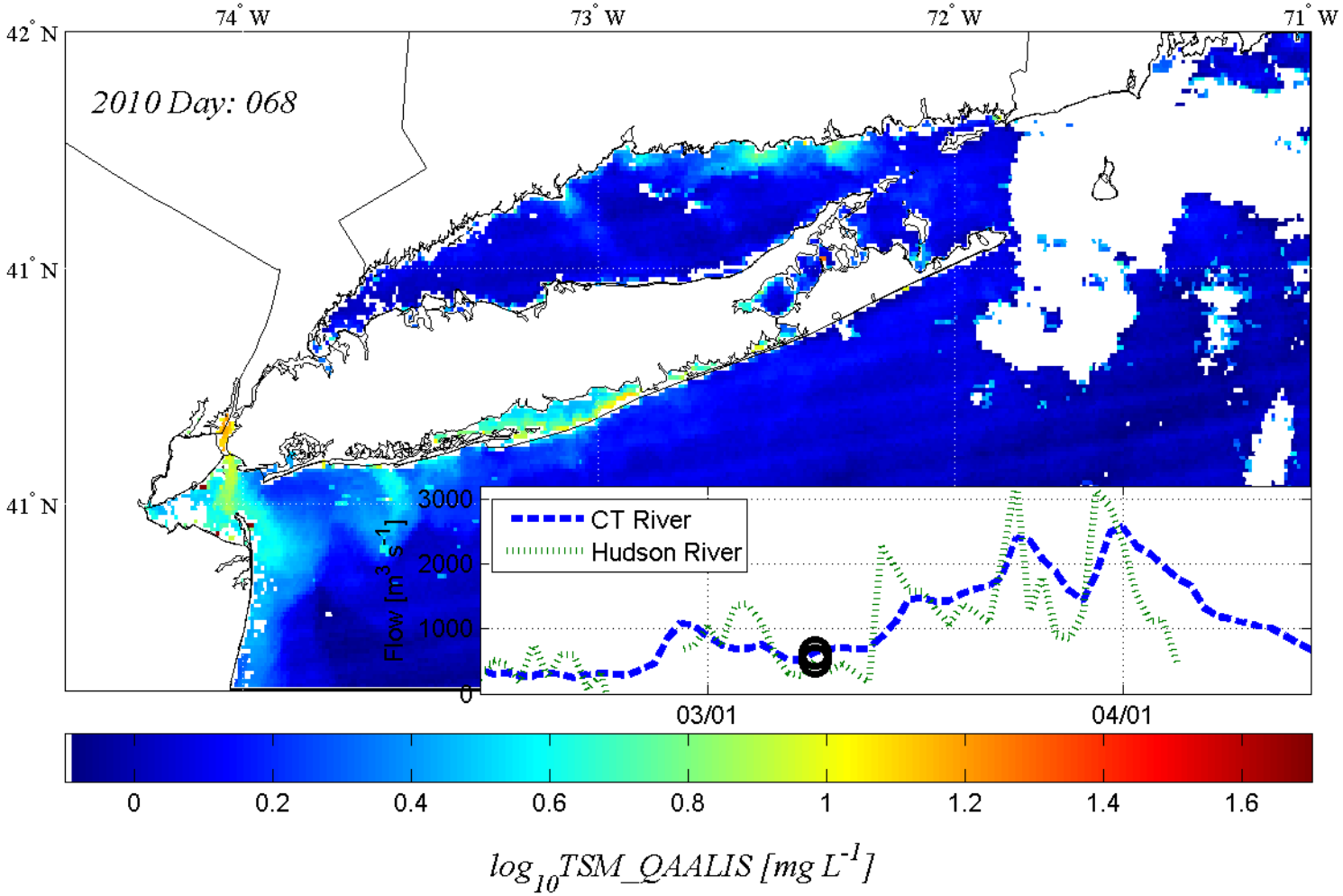


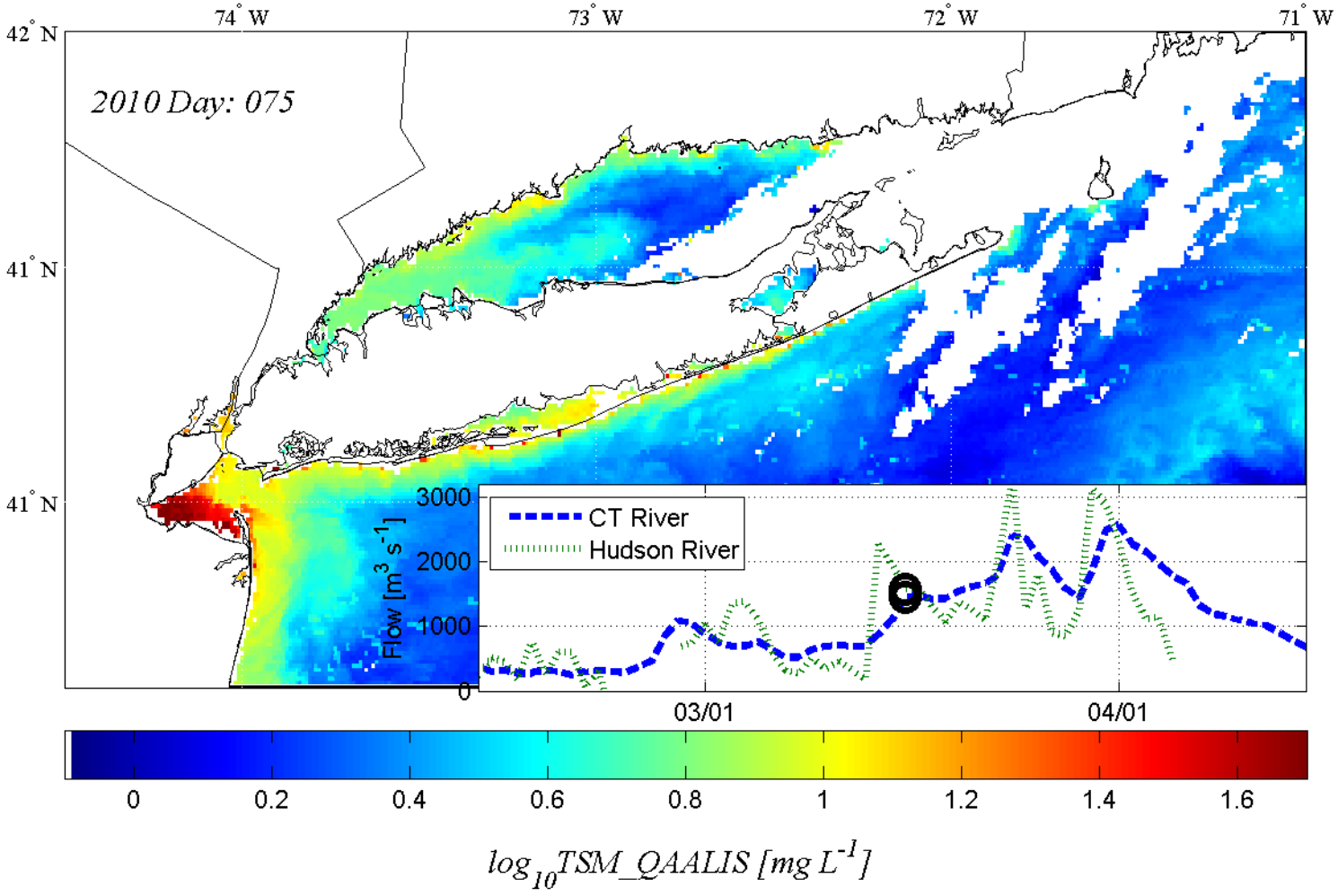

74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 043
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]

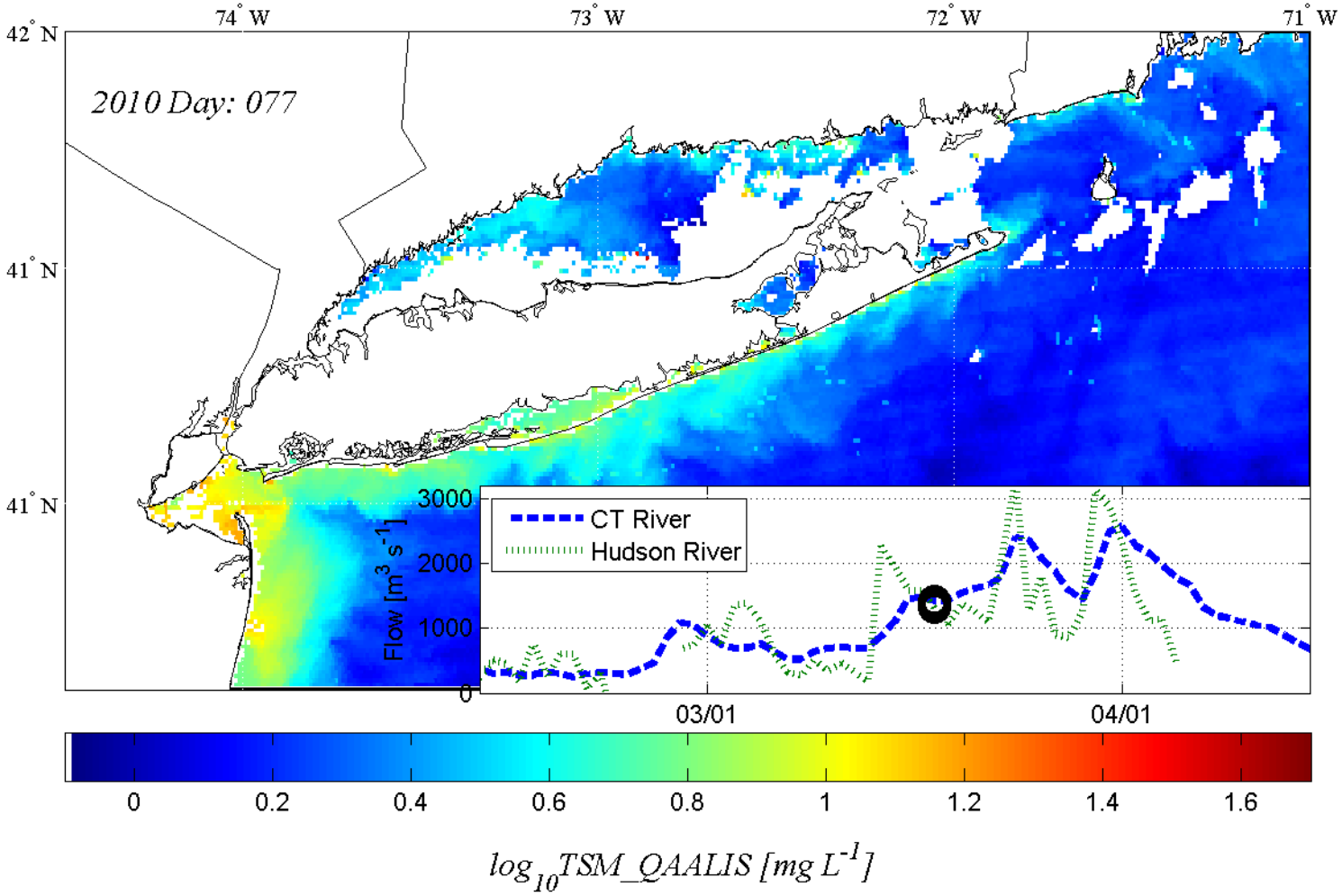

74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 052
CT River
Hudson River
Flow [m3 s-1]
3000
2000
1000
0
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]

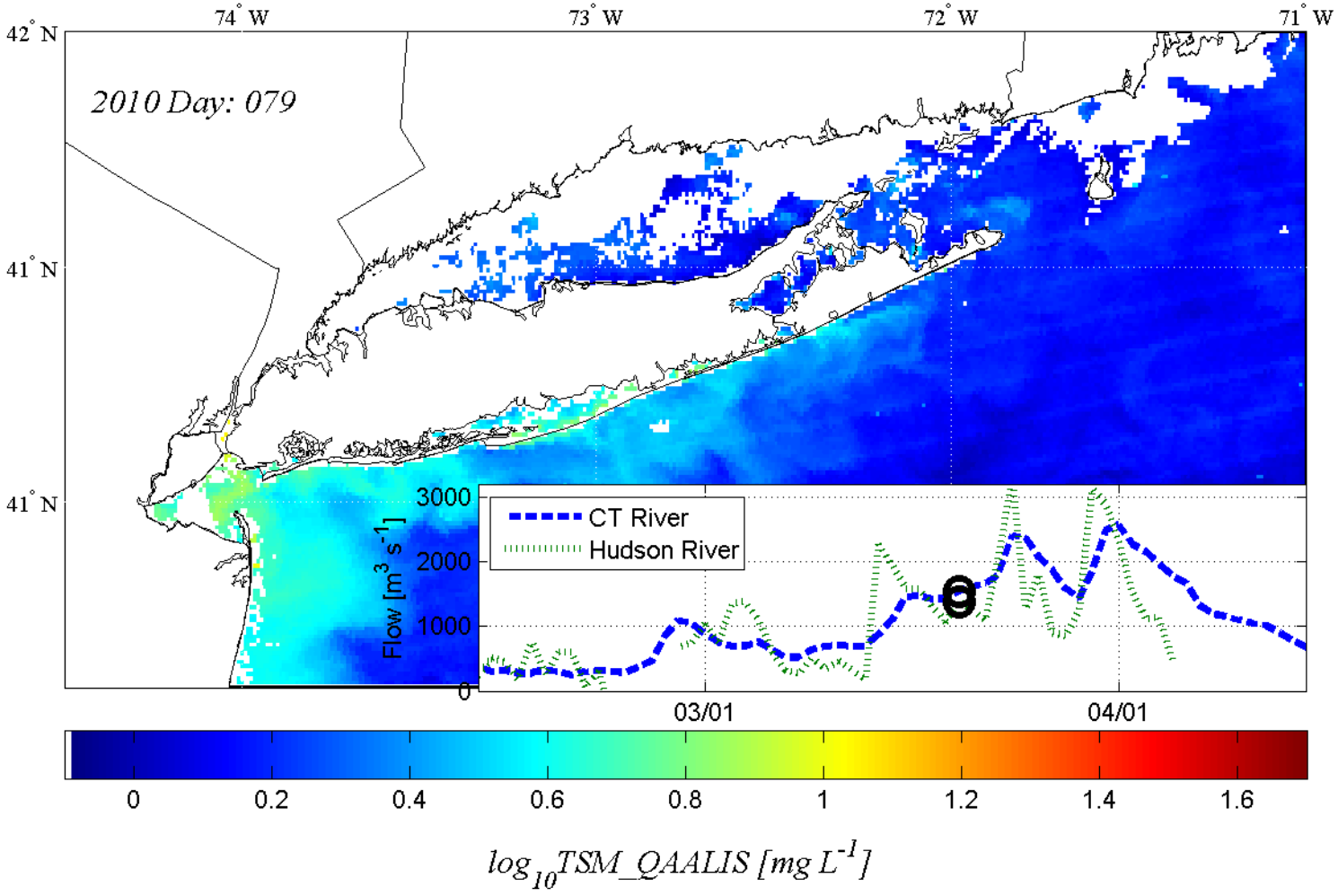

74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 065
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]

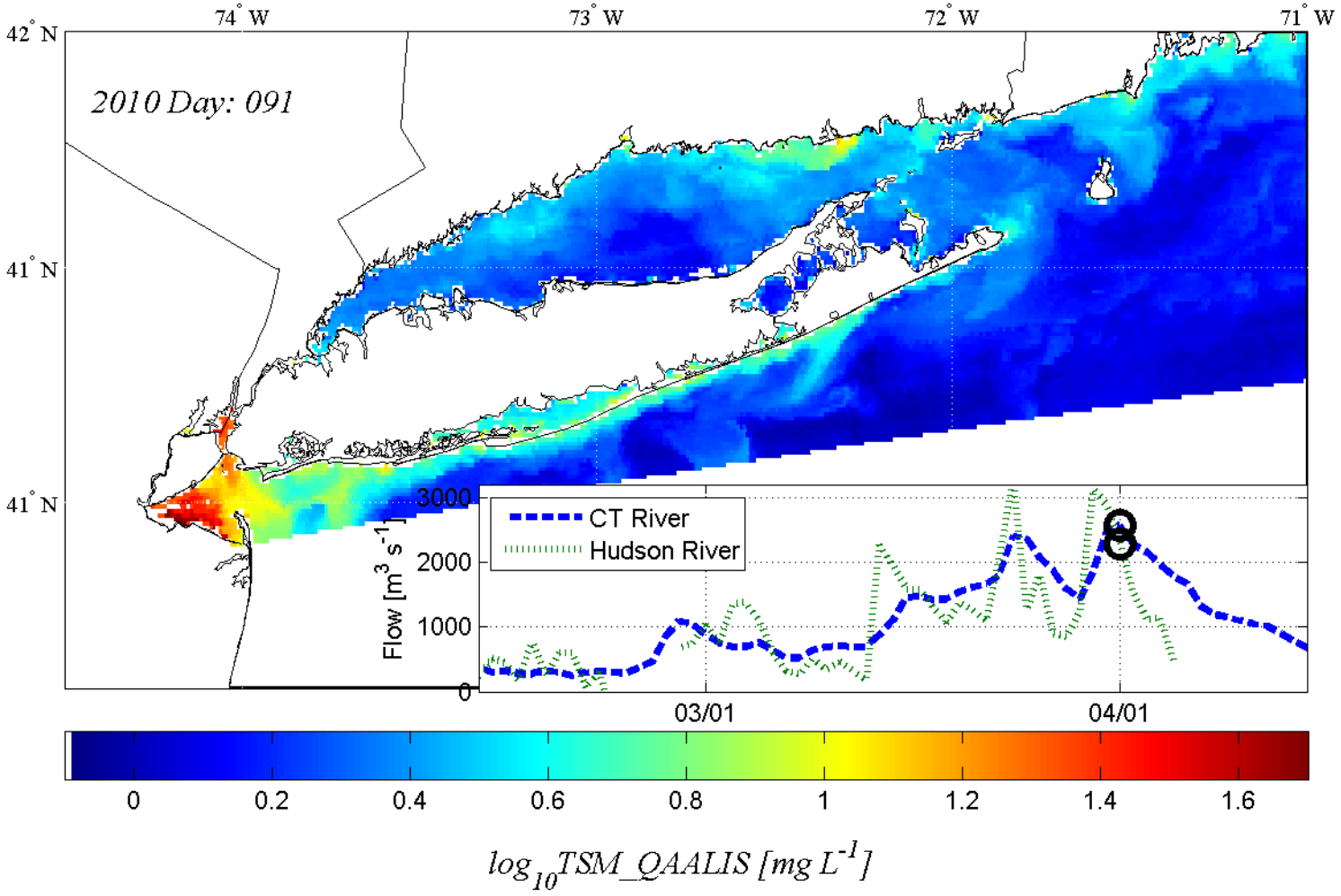

74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 066
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]

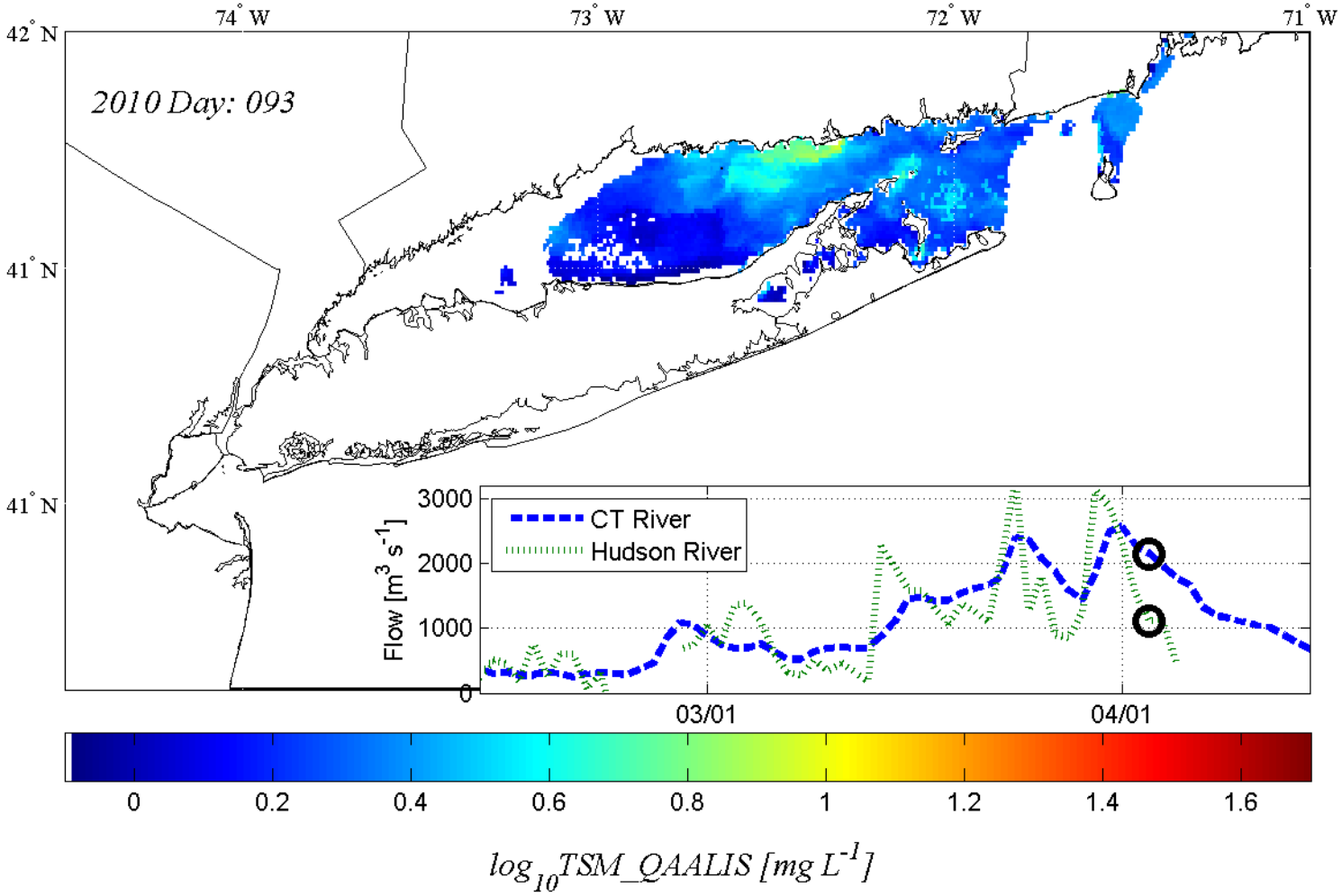

74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 068
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]

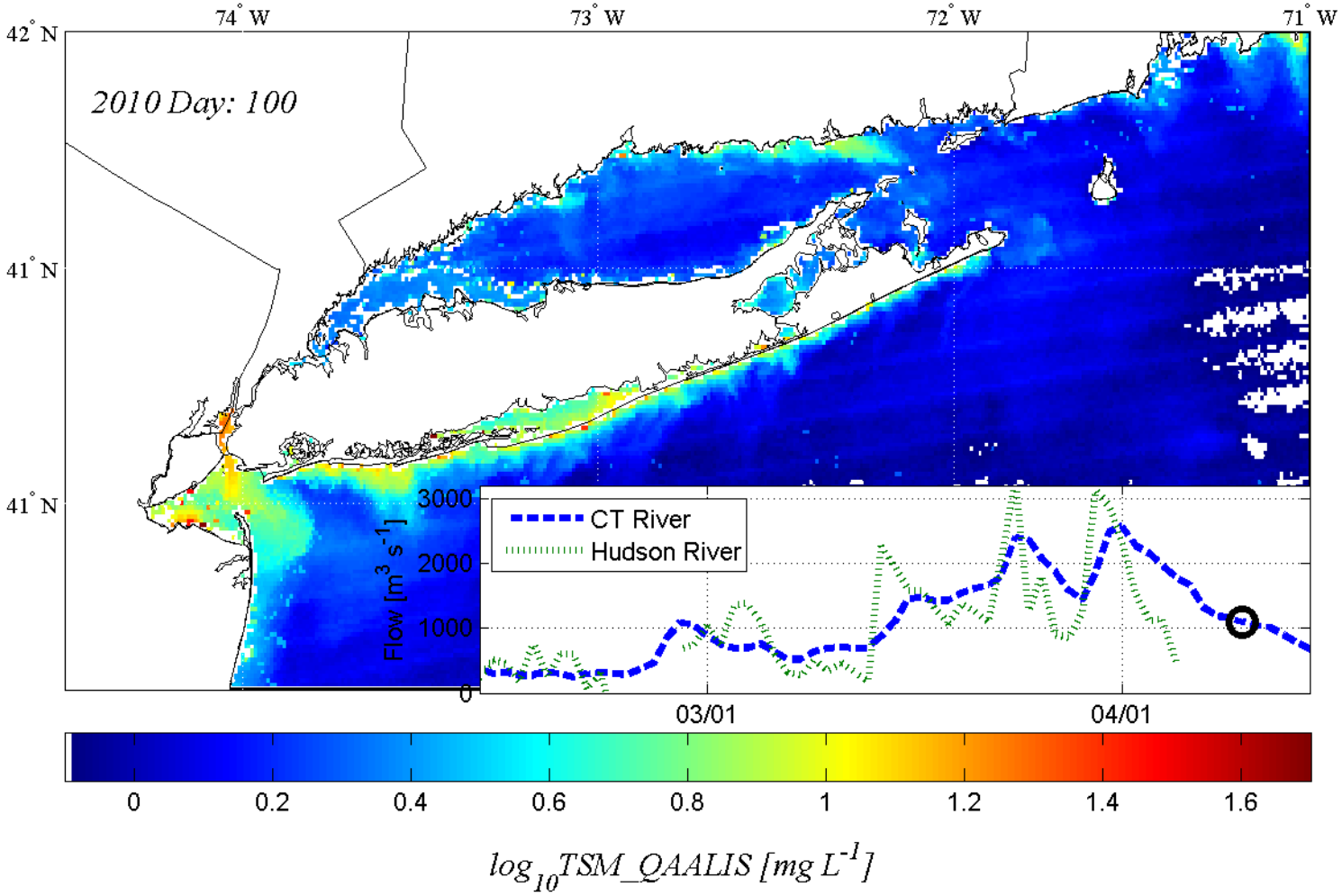

74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 075
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]


74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 077
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]


74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 079
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]


74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 091
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]


74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 093
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]


74° W
73° W
72° W
71° W
42° N
41° N
41° N
2010 Day: 100
3000
2000
1000
0
Flow [m3 s-1]
CT River
Hudson River
03/01
04/01
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
log10TSM_QAALIS [mg L-1]

New England Floods of 2010

	CT R.	Hudson R.	
TSM	16	40	mg/L
Vol.	2500	2500	m^3/s
Transport*	3,460	8,640	mton/day

*Assuming vertical homogeneity, no contribution to flow south of river guages, etc.

2.5 X higher

New England Floods of 2010

Site

Optics

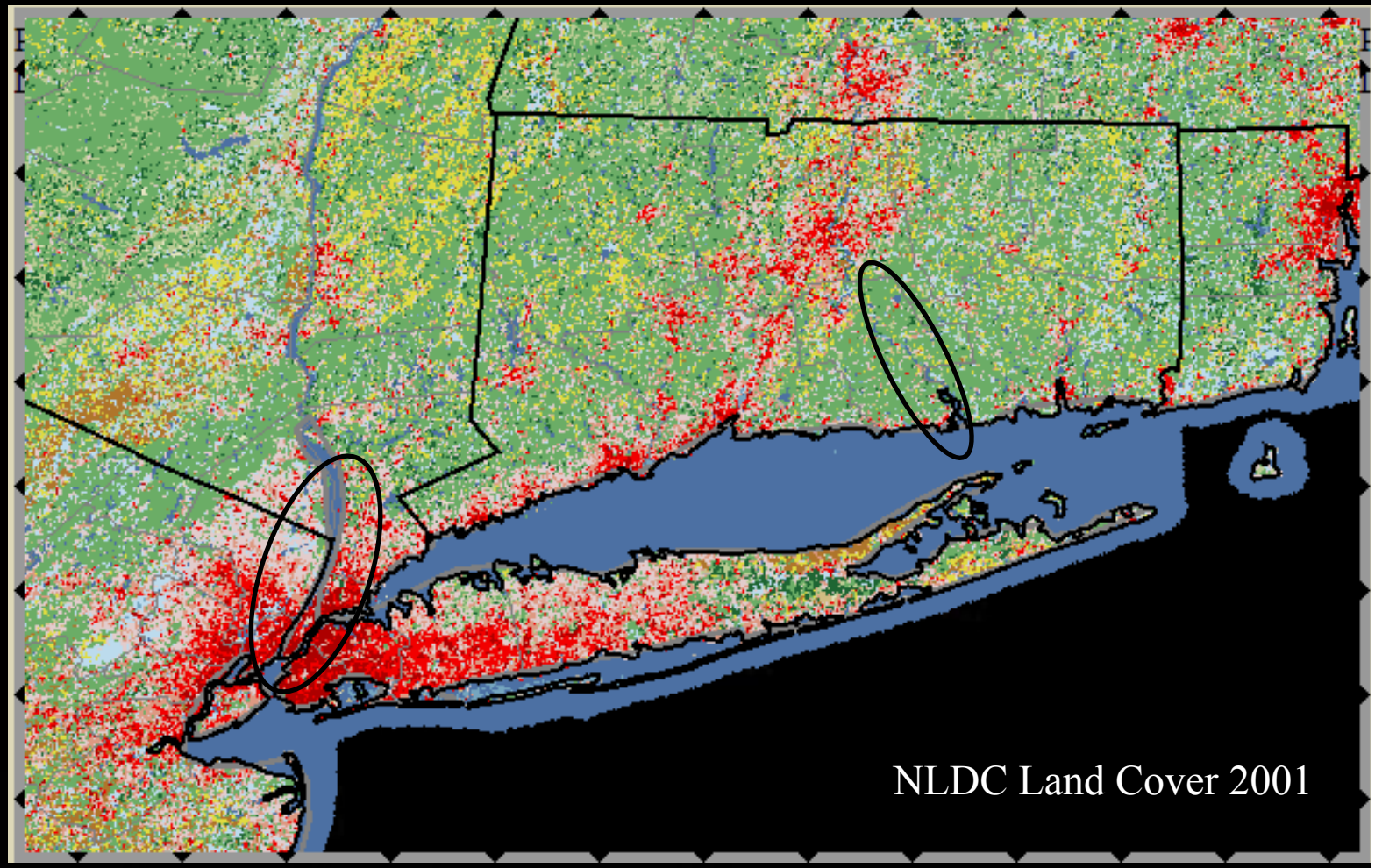
Selection

Optimization

Validation

Application

Conclusion



For more details...

- Aurin, Dierssen, Twardowski, Roesler, *Optical complexity in Long Island Sound and implications for ocean color remote sensing*, JGR, 2010, in press.
- Aurin, Dierssen, *Optimizing semi-analytical ocean color algorithms for the optically complex waters of Long Island Sound*, AO, 2010, in prep.

Site

Optics

Selection

Optimization

Validation

Conclusion

Acknowledgements

- University of Connecticut
  - LIS Integrated Coastal Observing System (LISICOS); ships of opportunity
- Office of Naval Research
  - National Defense Science and Engineering Fellowship
- NASA
  - OBB Funding
- Wet Labs, Inc.
  - Data acquisition and sharing