Development of Novel MODIS Global Ocean Data Products: CDOM and DOC

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Why study DOM?

- Major component of the global carbon pool
- Accounts for 12-50% of phytoplankton production
  - Underestimation of Ocean’s primary production
- Source of nutrients & energy for the microbial community
- Predominant flux of carbon from coast to ocean occurs through DOM

<u>Applications of Satellite-Derived CDOM</u>

- Retrieve coastal DOC and salinity
- Estimate photochemical production of CO_2 and CO
- Track water masses including river plumes; upwelling
- Measure of AOU (particle remineralization)*

*Swan et al. 2009; Nelson et al. 2010

Objectives

- Develop and validate global ocean satellite algorithms that will yield new MODIS ATBDs for:
  - Colored Dissolved Organic Matter (CDOM) absorption coefficient (a_{CDOM})
  - CDOM Spectral slope (S_{CDOM})
  - Dissolved Organic Carbon (DOC)

- Examine the seasonal, inter-annual and decadal-scale variability of global ocean surface layer DOC, a_{CDOM} & S_{CDOM} for SeaWiFS-MODIS time series.

Algorithm Development

- Extend and validate coastal ocean band-ratio algorithms for a_{CDOM} and S_{CDOM} to the global ocean.

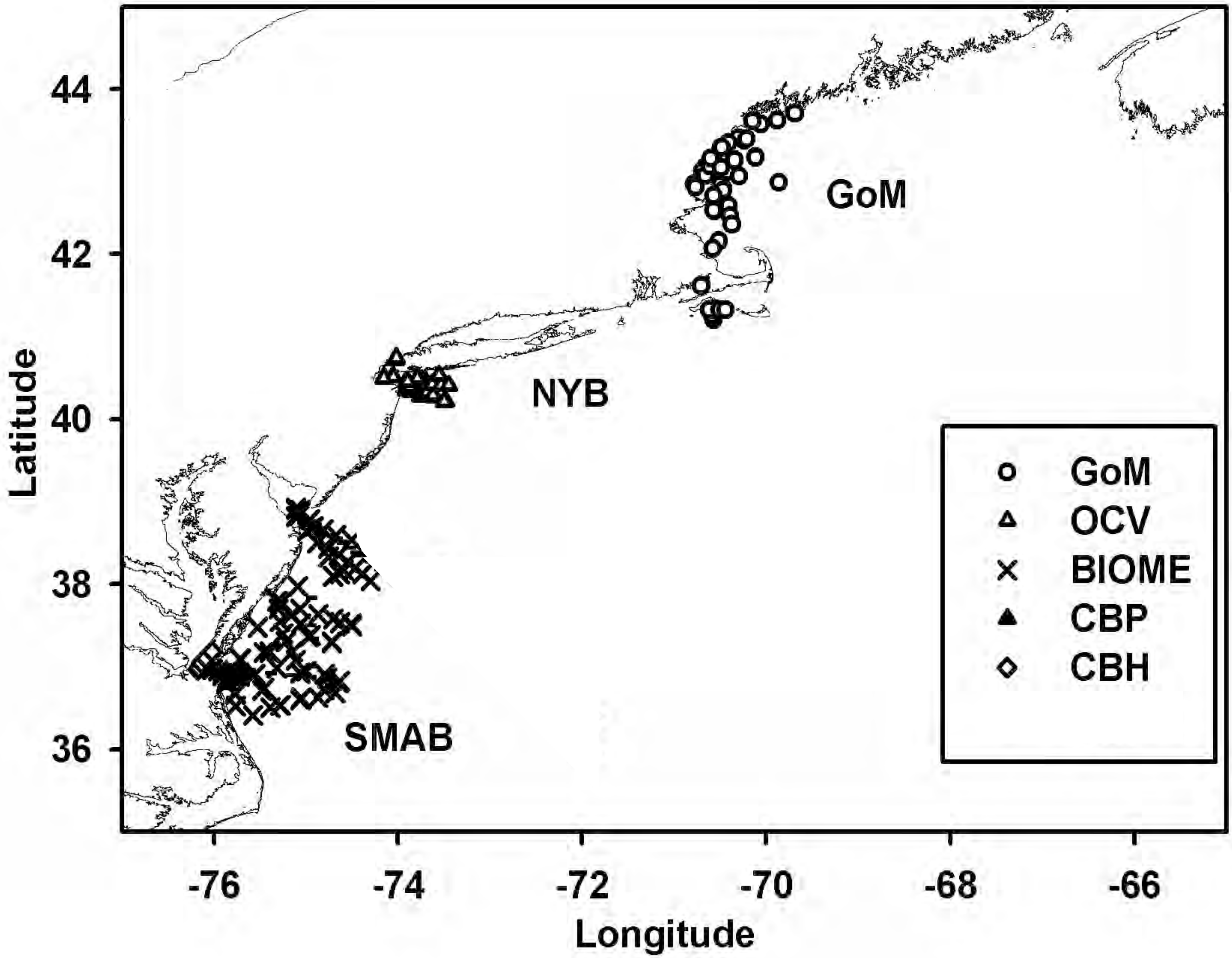
- Evaluate GIOP model with variable CDOM spectral slope

- Develop and validate multivariate machine learning algorithms including neural network and Gaussian Process models to retrieve DOC, a_{CDOM} and S_{CDOM}.

- Compare a_{CDOM} products with GSM and QAA products

- Select best performing algorithms using statistical plotting tools (Taylor and Target diagrams)

Field Stations for Coastal Algorithms



Gulf of Maine
April 26-30, 2007
May 26-28, 2007
June 6-8, 2007

New York Bight
May 5-9, 2007
Nov. 10-14, 2007
July 21-24, 2008
May 19-21,2009

SMAB
March 30-April 1, 2005
July 26-30, 2005
May 9-12, 2006
July 2-6, 2006

CB Plume
May 27, 2005
Nov. 3, 2005
Sep. 6, 2006
Nov. 28, 2006
March 19, 2007
April 23, 2007
July 3, 2007
Aug. 16, 2007

Lower CB: July 2004 to May 2006

Multi-regional CDOM Algorithms - in situ data

2.5
2
1.5
1
0.5
0

Rrs(412)/Rrs(547) (sr^{-1})

in situ observations
Model one-phase decay
Model 3rd Order Polynom.

$R^2 = 0.948$
Sy.x = 0.077

$R^2 = 0.939$
Sy.x = 0.084

N ~ 145

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

$a_{CDOM}(355)$ (m^{-1})

$a_{CDOM}(355) = \ln([Rrs412/Rrs547-0.272]/4.49)/(-5.78)$

$Rrs412/Rrs547 = 0.3 - 0.12X + 0.17X^2 - 0.19X^3$
$X = \ln[a_{CDOM}(355)]$

$a_{CDOM}(412) = \ln([Rrs412/Rrs555-0.257]/4.21)/-14.5$

$Rrs412/Rrs555 = 0.18 - 0.22X - 0.26X^2 - 0.16{*}X^3$
$X = \ln[a_{CDOM}(412)]$

2.5
2
1.5
1
0.5
0

Rrs(412)/Rrs(555) (sr^{-1})

in situ observations
Model one-phase decay
Model 3rd Order Polynom.

$R^2 = 0.950$
Sy.x = 0.085

$R^2 = 0.951$
Sy.x = 0.082

N ~ 145

0.0 0.3 0.6 0.9 1.2 1.5

$a_{CDOM}(412)$ (m^{-1})

Radiometry data from Stan Hooker

Regional & Seasonal DOC:a_{CDOM} Relationships

$R^2 = 0.96$

$R^2 = 0.92$

$R^2 = 0.88$

$R^2 = 0.90$

$R^2 = 0.91$

$R^2 = 0.92$

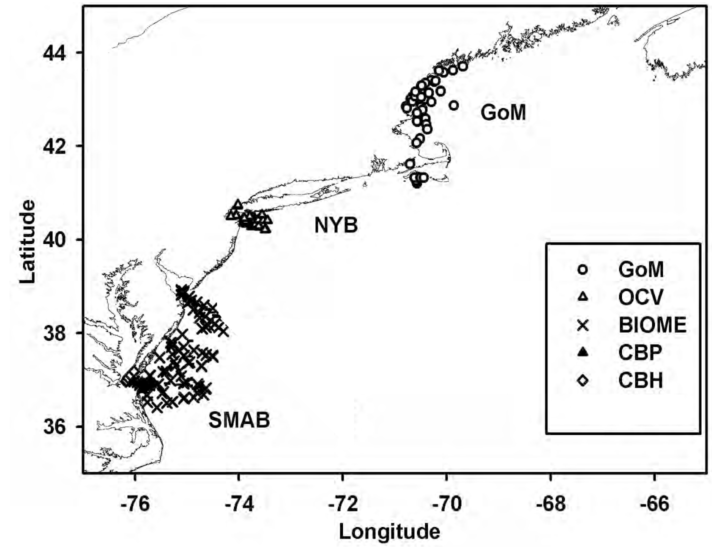
$R^2 = 0.97$

DOC (µM): 300, 250, 200, 150, 100, 50, 0

Southern MAB Summer
Southern MAB Fall, Winter & Spring
Hudson July 2008
Del Bay Summer 2005 & 2006
Hudson May & Nov 2007 & May 2009
GoM late May & early June 2007
GoM late April 2007

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

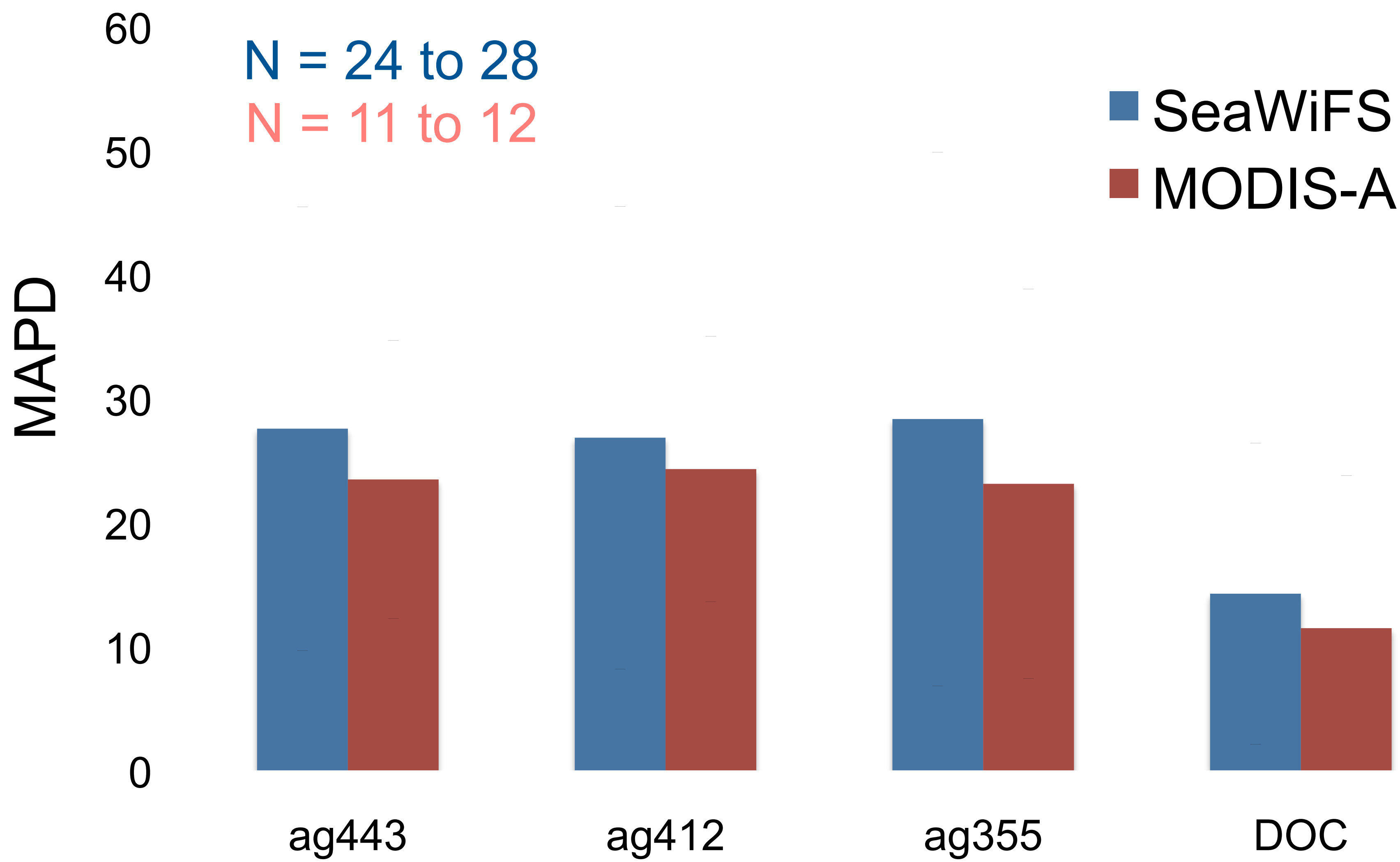
$a_{CDOM}(355)$ (m^{-1})



- DOC per unit a_{CDOM} increases from N to S: differences in source materials, such as more colored terrestrial DOM exported to the GoM due to the absence of large estuaries where the DOM can be degraded.
- Seasonal shift in DOC to a_{CDOM} relationships from accumulation of DOC from NCP and photooxidation of CDOM between spring and fall.

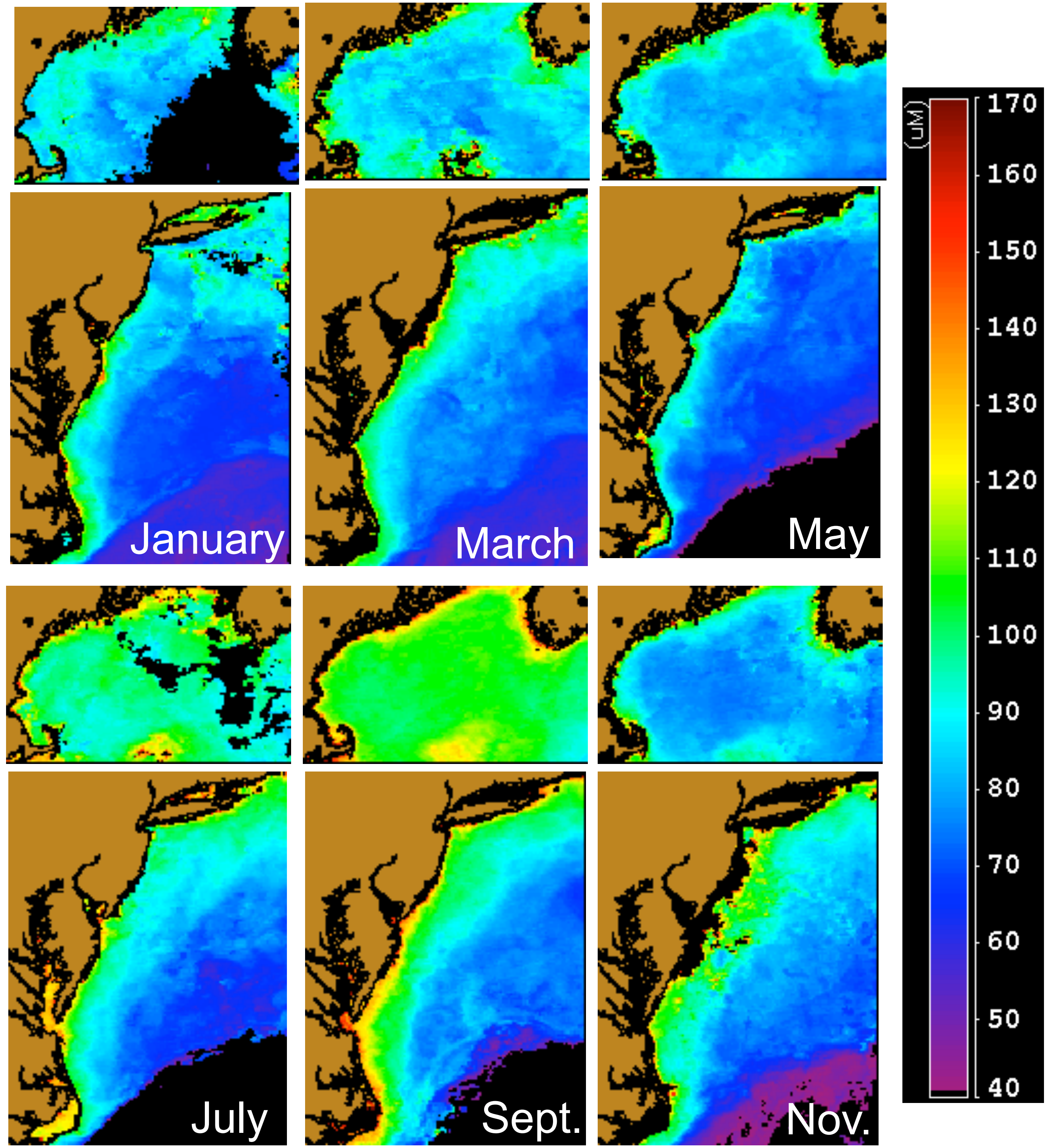
Preliminary Satellite Validation with Field Data

±8 hour between sample collection & satellite overpass



Recent sampling should increase N to ~100 match-ups

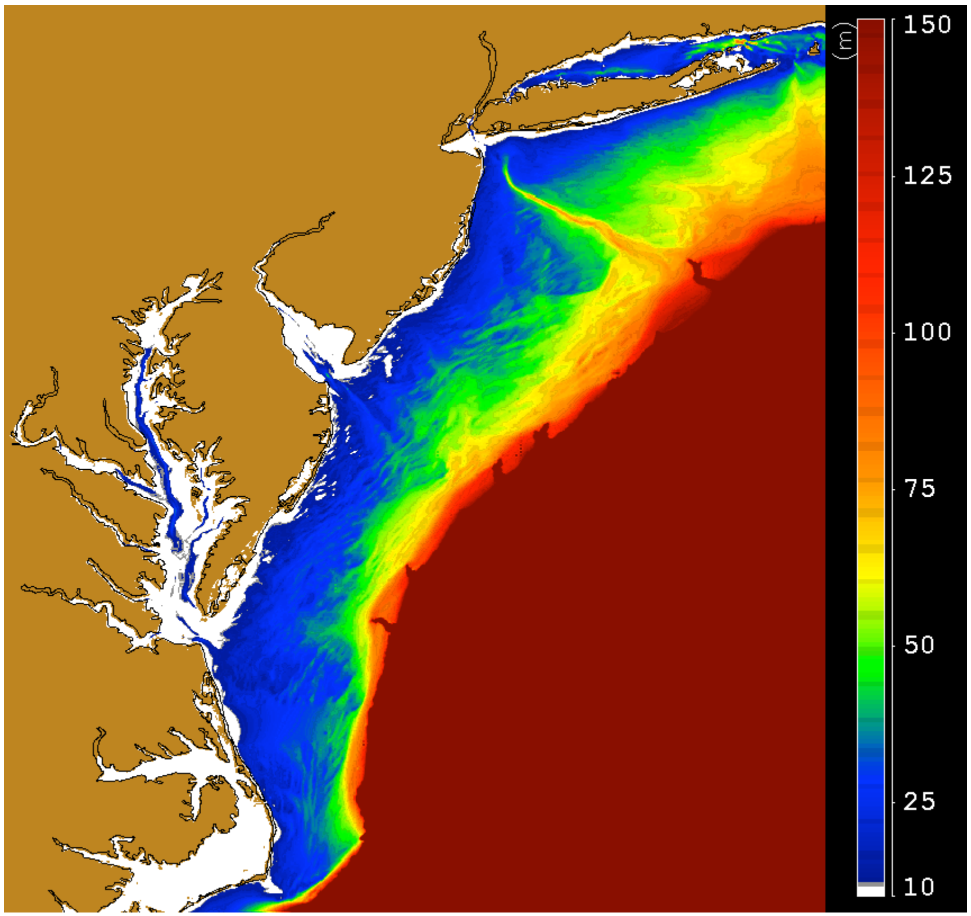
DOC 2004 Monthly Composites - MODIS-A 4km



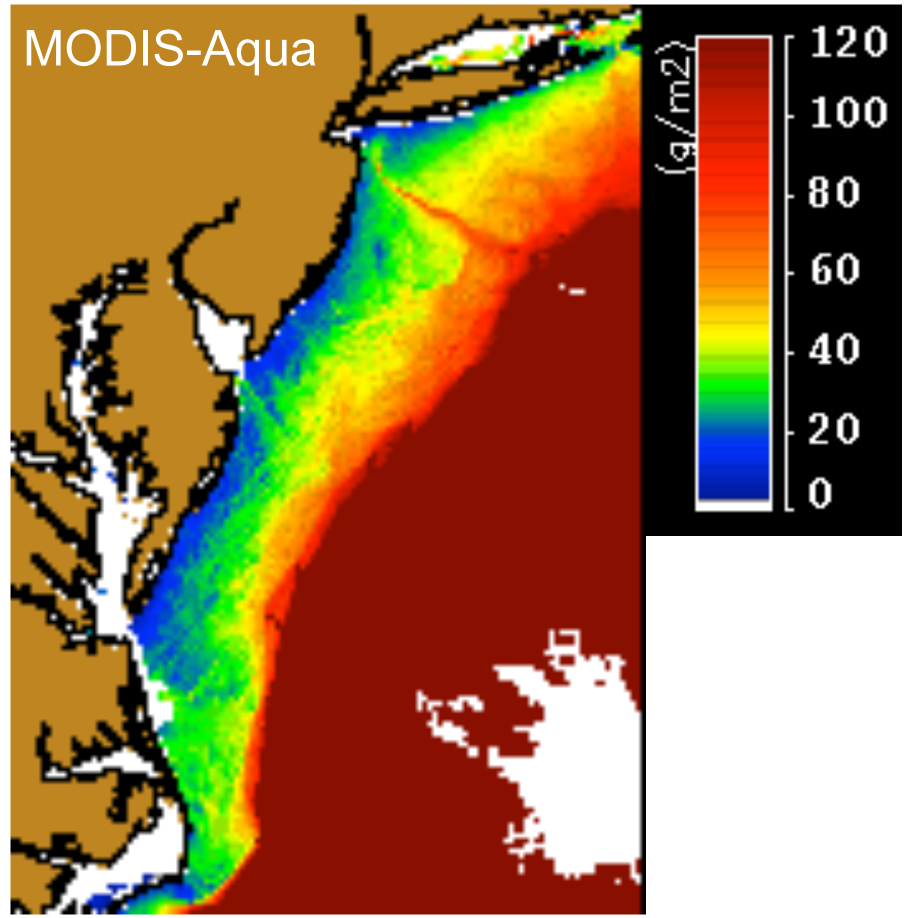
Seasonal increase in DOC from winter to summer

DOC inventory in the MAB for winter 2004

Bathymetry



Vertically integrated DOC February 2004

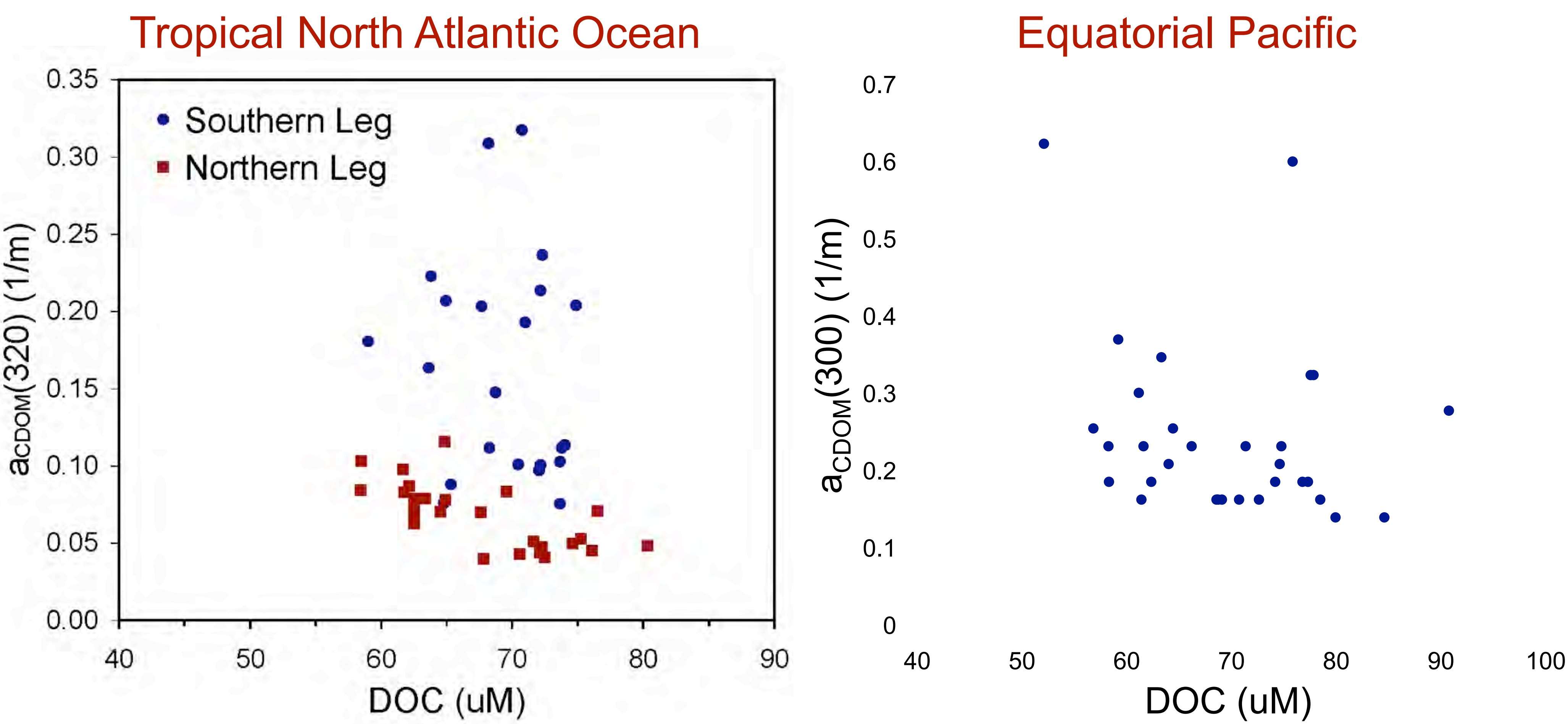


DOC inventory = ~3.4 x 10^{12} g C

Depth integrated over top 100m for bathymetry 10-100m

35° to 41.5°N, -77 to -71.5°W

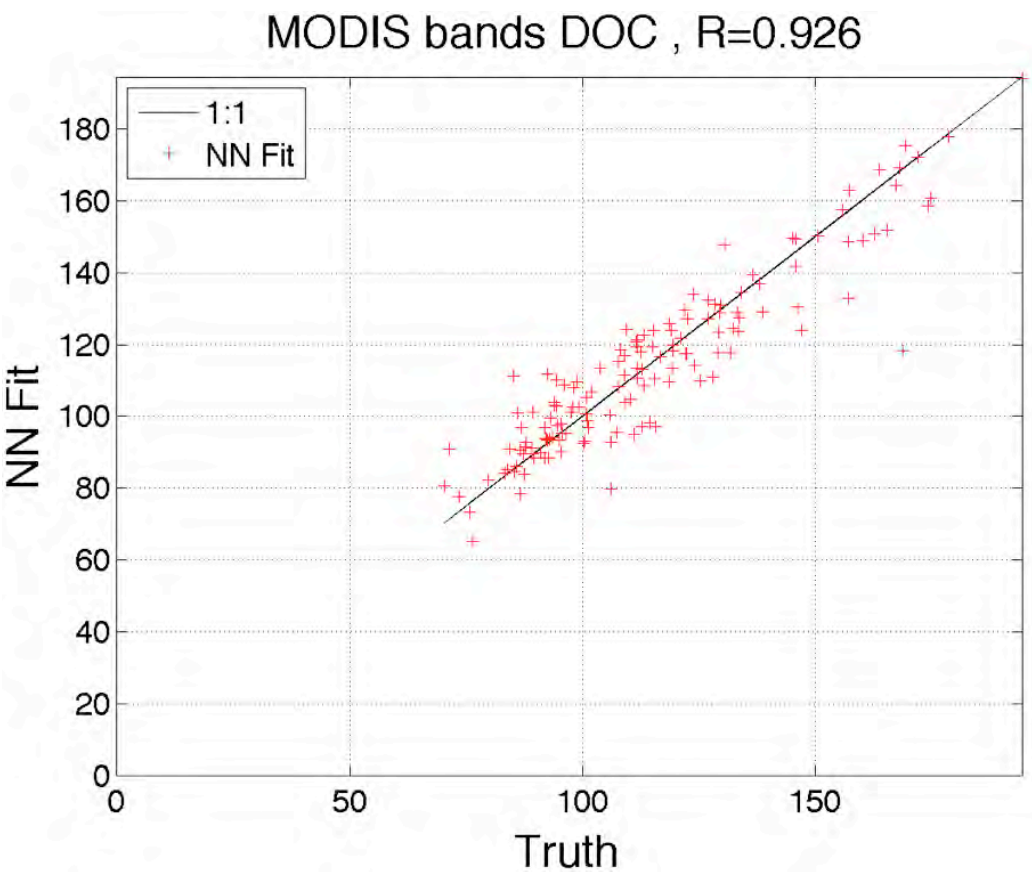
Open Ocean CDOM vs DOC



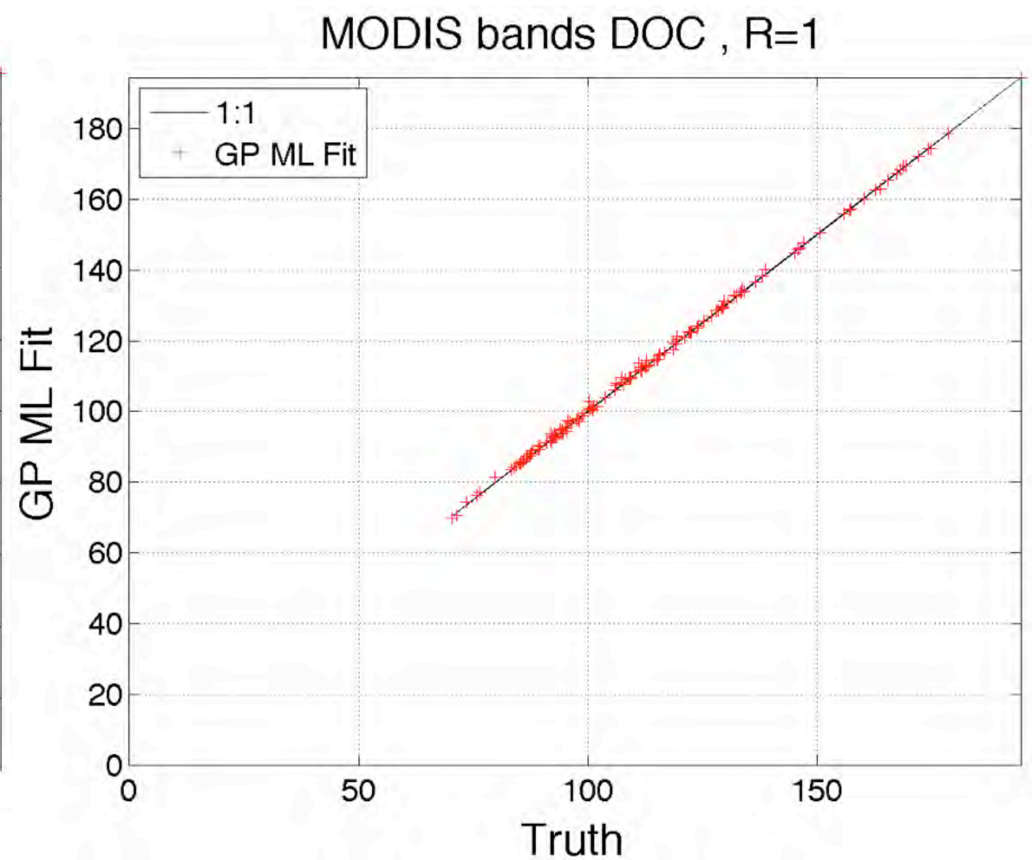
No trend between a_{CDOM} and DOC in ocean basins; positive trend between DOC and SST (Siegel et al. 2002)

Coastal ocean machine learning DOC algorithms

Neural Network (NN)



Gaussian Process Model (GP ML)

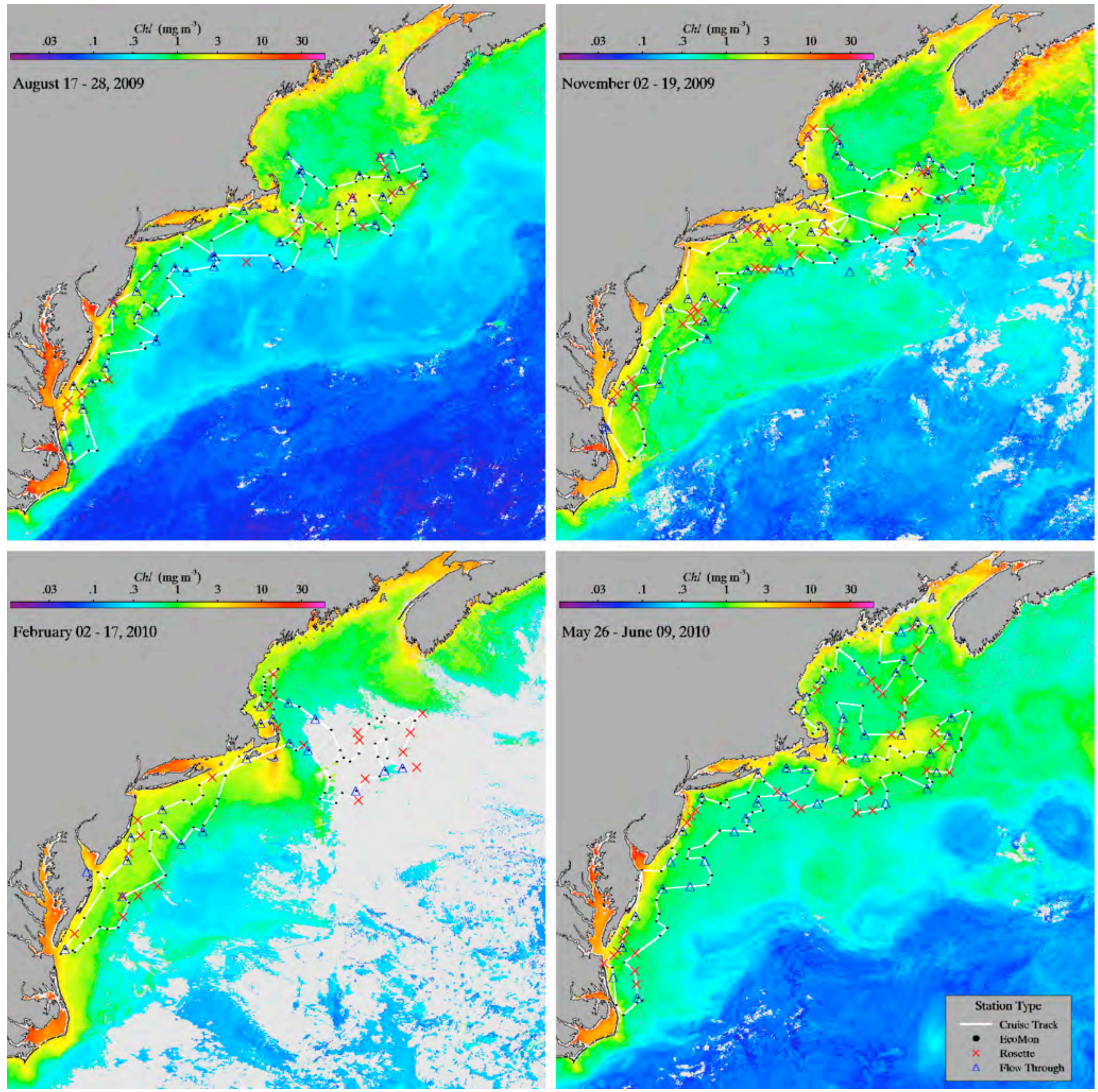


- Applied all Ocean MODIS-Aqua bands
- Randomized dataset: 80% to generate model; 10% to compute RMS; 10% for model validation
- Need ~1000 or more data points for more robust model

	Wavelength	Relative Importance
Most Important	Rrs490	0.00087123
	Rrs555	0.011976
	Rrs670	1.5876
	Rrs510	9.8423
	Rrs443	13.0898
Least Important	Rrs412	20.2553

The Impact of Climate Variability on Primary Productivity and Carbon Distributions in the Middle Atlantic Bight & Gulf of Maine (CliVEC)

- Field Observations
  - PP, pigments, POC/PN, DOC/TDN, DIC, alkalinity, a_{CDOM}, a_{ph}, a_d, N_2 fixation, nutrients, beam-c, FDOM, phyto cell counts, N uptake, respiration, ...
- PP model development
- Algorithm development and validation
- Satellite data processing
- Climate change impact analysis

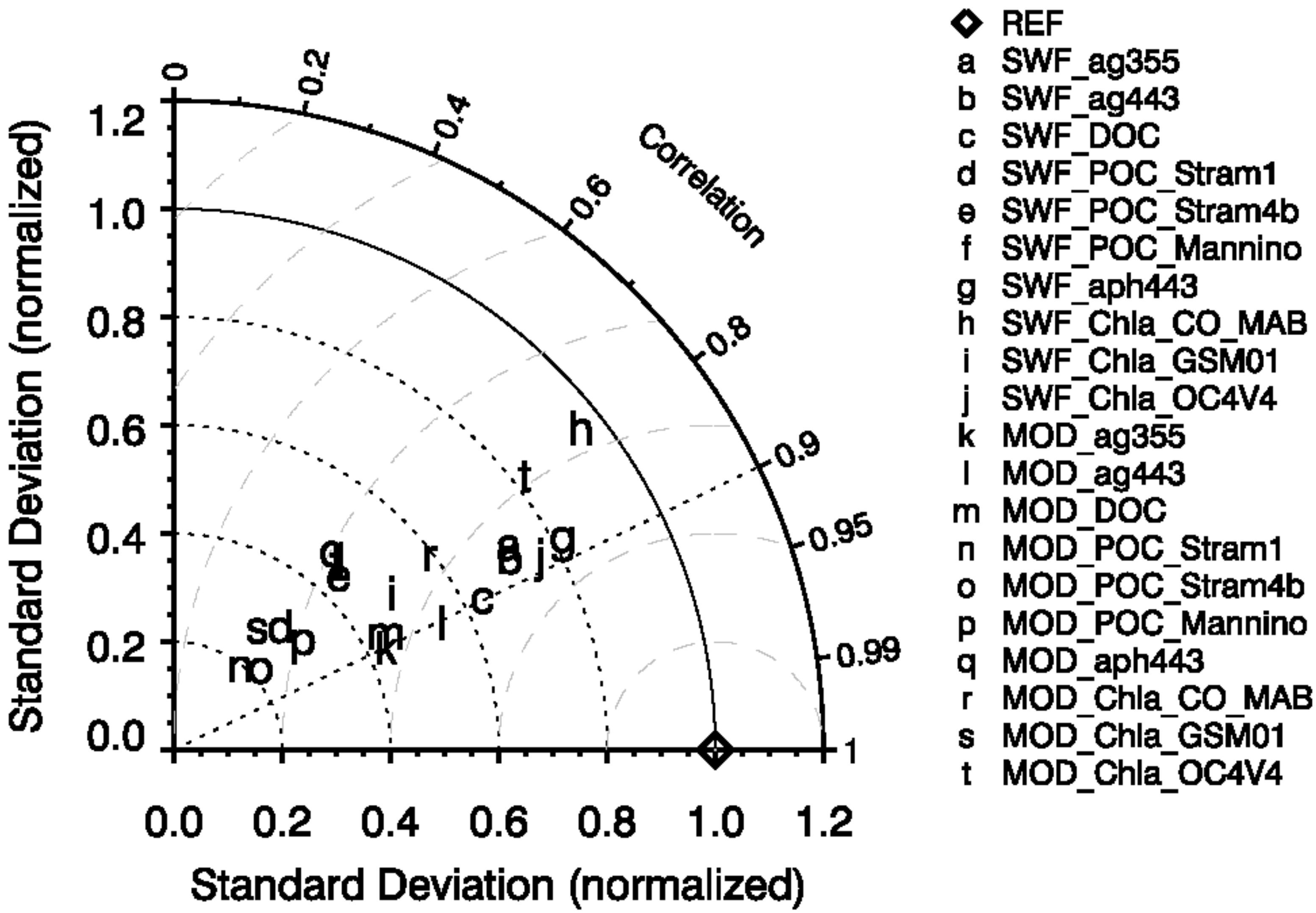


co-Is: M. Mulholland, K. Hyde & D. Lary

Other Field Data for Global Algorithms

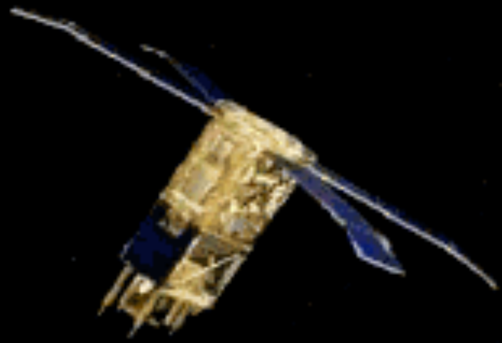
- NOMAD portion of SeaBASS
- Field datasets from Equatorial Pacific, Tropical North Atlantic, Southern Ocean and Patagonian shelf/slope waters.
- DOC from Hansell & Carlson public databases
- BCO-DMO database

Algorithms Comparison with Taylor Diagram



Taylor diagram quantitatively compares the centered-pattern root-mean-square difference, normalized standard deviation, correlation of satellite-derived and observed time series in a given dataset (e.g., by sensor, algorithm, region, season, etc.), and bias between satellite and field data.

Thanks



SeaWiFS

1 August 1997 - 11 December 2010