STAR JPSS 2016 Annual Science Team Meeting

VIIRS Ocean Color Breakout
Wednesday , 10 August 2016

Optical Measurements in Support of JPSS Cal/Val

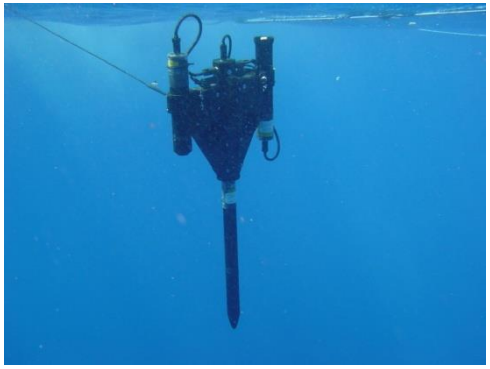
Michael Ondrusek, Eric Stengel and Charle Kovach
Bob Arnone, Zhongping Lee, Eric Stengel, Ryan Vandermeulen, Sherwin Ladner, Scott Freeman, Wesley Goode, Chuanmin Hu, David English, Jianwei Wei, Junfang Lin, Alex Gilerson, Sam Ahmed, Ahmed El-Habashi, Robert Foster, Nick Tufillaro, Curt Davis, Matteo Ottaviani, Carlos Carrizo, Guoqiang Wang, Veronica Lance, Menghua Wang.

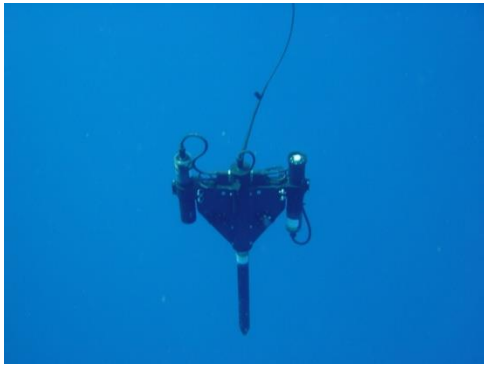
Primary Objectives:

- Provide in situ ocean color data to be used for calibration and validation of the JPSS Cal/Val effort.
- Define protocols and uncertainties in validation data collection.
- Coordinate ocean color validation cruises.

- **Validation of satellite ocean color sensors :**
  - Requires accurate and traceable in situ measurements
  - Hyperspectral to match all sensors
  - Many matchups and water types

- **Satlantic Profiler II (Hyperpro) in-water radiometer:**
  - Hyperspectral
  - Profiling
  - Lu, Ed, and Es

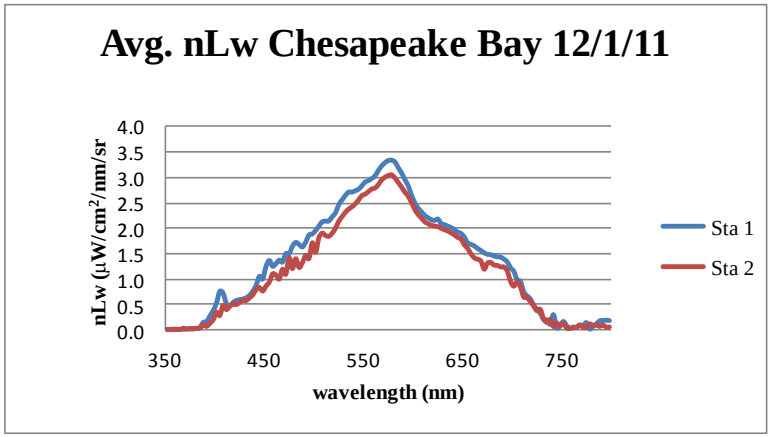


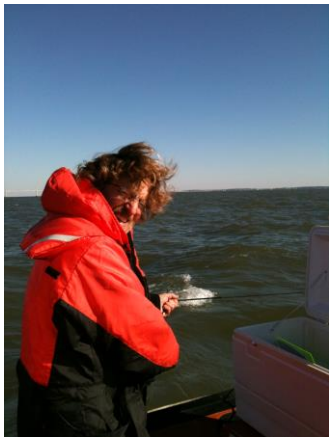


- **Validation capabilities**
  - Lwn/Rrs (in- and above-water)
  - Chlorophyll/pigments
  - Backscatter/Absorption
  - TSM
  - Aerosol Optical Depth

Validation Measurements since VIIRS launch

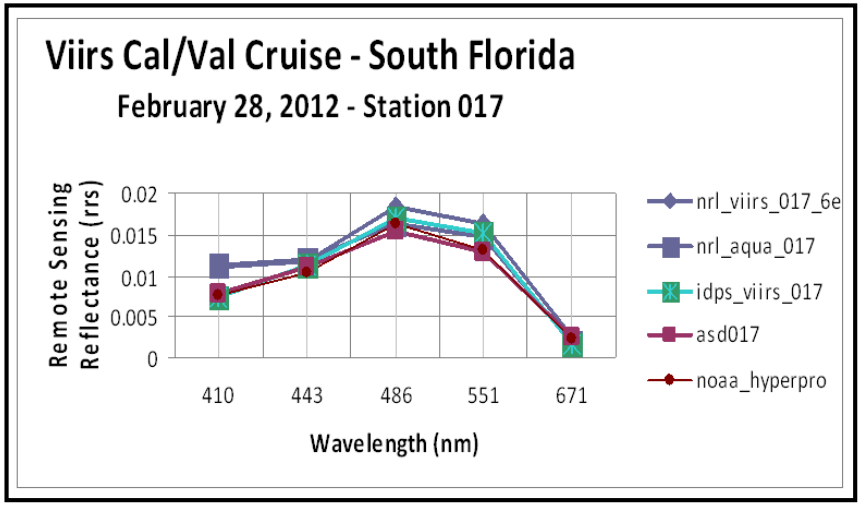
Dec. 1, 2011 VIIRS Intialization - Conducted Clear Sky Hyperpro ocean color validation measurements on the Chesapeake Bay.





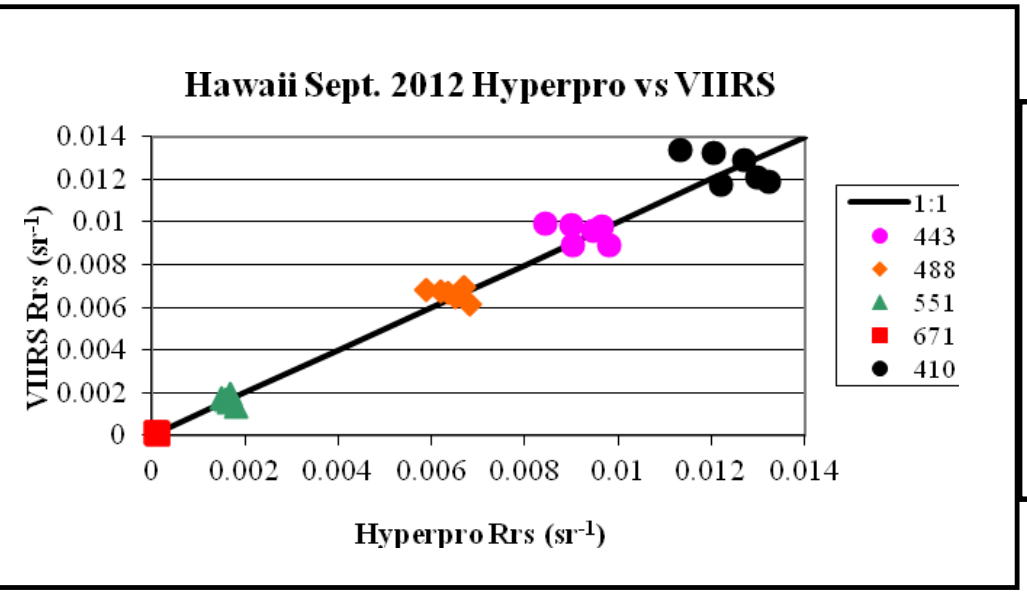
Chesapeake Bay VIIRS Ocean Color Validation: Conducted routine in-water Hyperpro and above-water ASD validation measurements in the Chesapeake Bay. Over 45 days with approximately 150 - 200 Stations in the Bay since Launch of VIIRS.

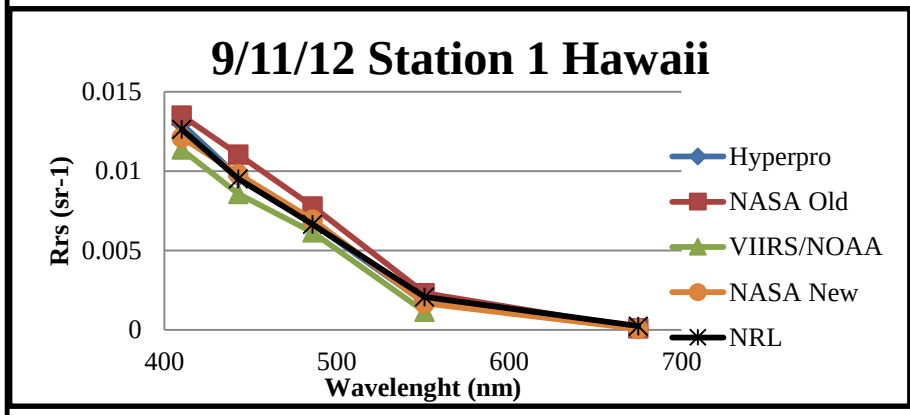
South Florida Cruise Feb. – Mar. 2012, 16 Hyperpro and ASD Validation Stations.



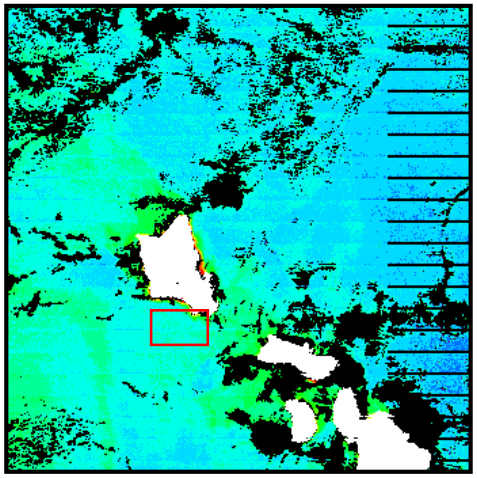
	Hypro vs IDPS		Hypro vs L2GEN		ASD vs L2gen		ASD vs IDPS		ASD vs Aqua		Hyperpro vsAqua	
ch	r2	slope	r2	slope	r2	slope	r2	slope	r2	slope	r2	slope
410	0.8628	0.8752	0.9071	1.0177	0.8414	0.9639	0.8364	0.7994	0.5753	1.2016	0.4575	1.2782
443	0.9848	0.9329	0.9848	0.9058	0.9468	0.9072	0.9766	0.9125	0.9202	0.9692	0.8922	0.9796
488	0.9981	0.9772	0.9964	0.9762	0.9735	1.0503	0.9912	0.9964	0.9888	0.9115	0.9914	0.8727
551	0.9895	0.9603	0.9850	0.9838	0.9635	1.1198	0.9759	1.0767	0.9804	0.9281	0.9779	0.873
671	0.9953	0.7362	0.9959	0.9368	0.8992	1.0056	0.9613	0.7327	0.9712	0.576	0.9792	0.6486

VIIRS validation using in situ Hyperpro measurements off Oahu, Hawaii collected in September, 2012 using NASA and NRL processings. The VIIRS data in the cross plot was processed using NASA data. 21 matchup stations

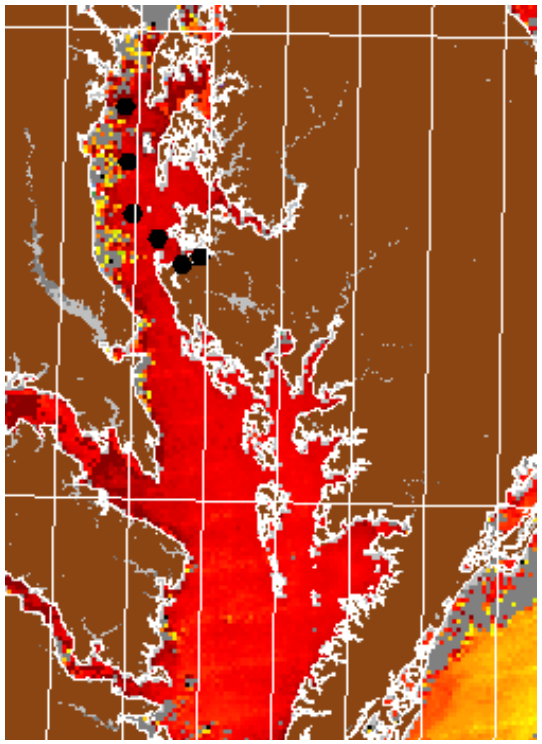


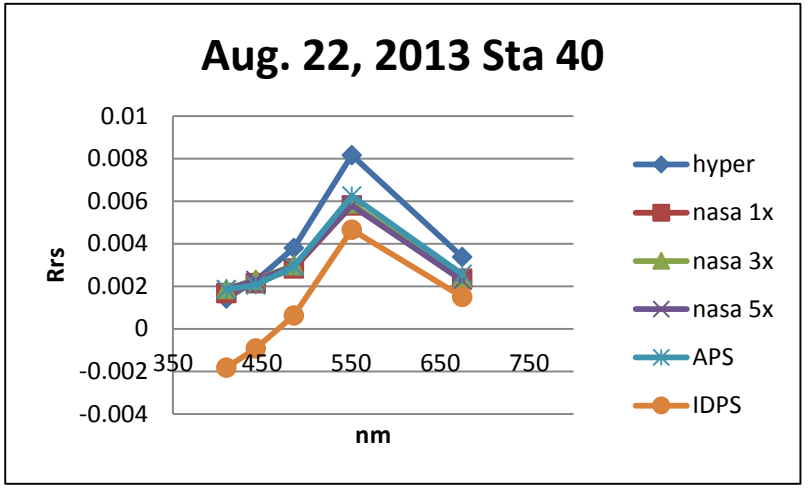


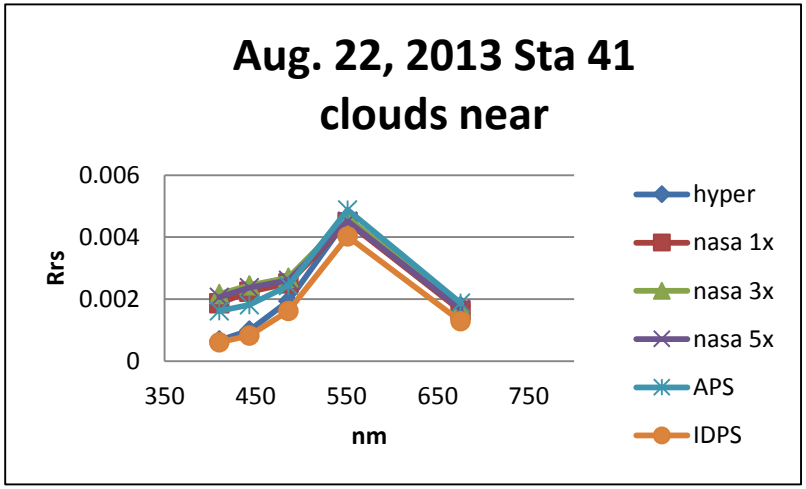
Band	% Diff Hyperpro – NASA	Std Dev of % Diff Hyperpro
410	1.50	3.48
443	3.18	1.05
488	3.93	3.38
551	1.40	36.27
671	-8.81	158.79
Average 410 to 551	2.50	11.05

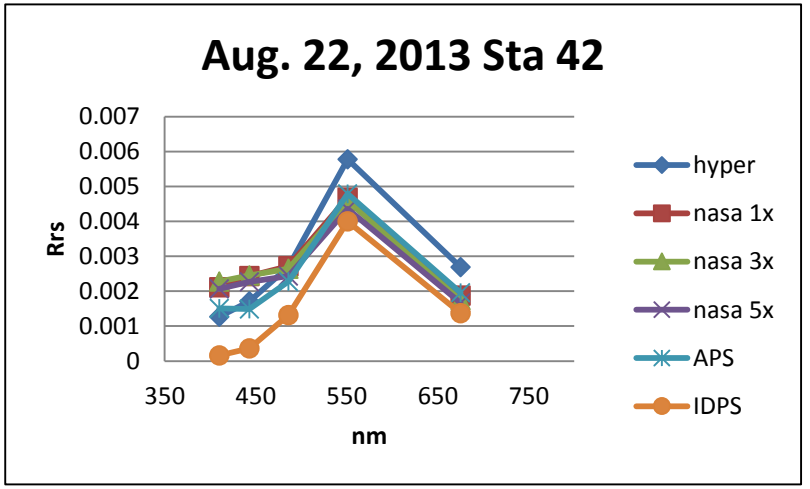


Two week, August 2013 Cruise with CUNY/CREST covering entire Chesapeake Bay. Shown, Day 234, transect up the bay. 42 Stations total

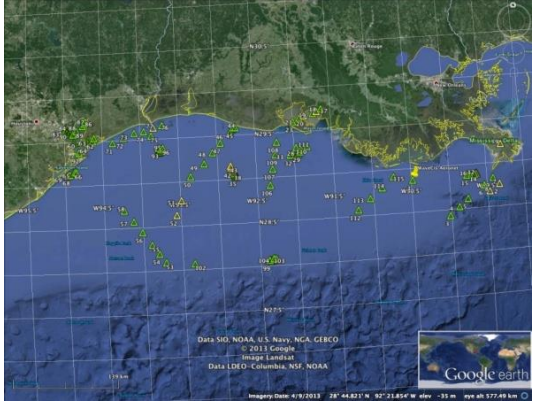


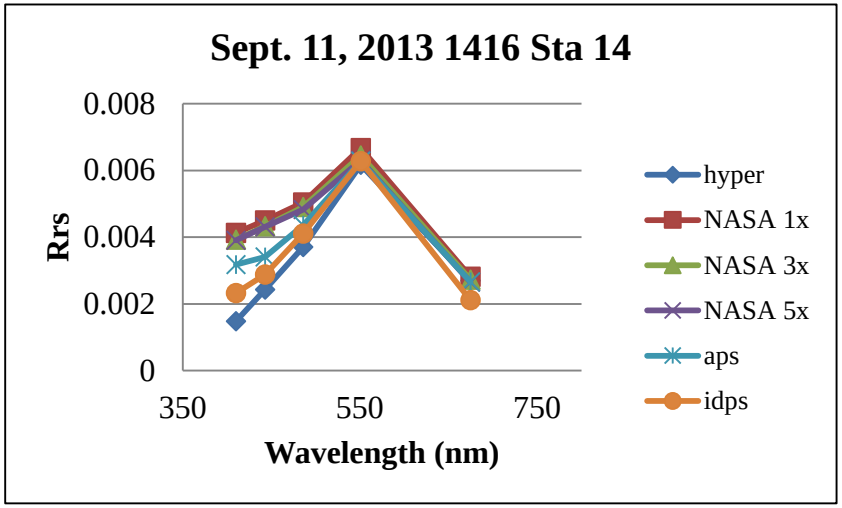


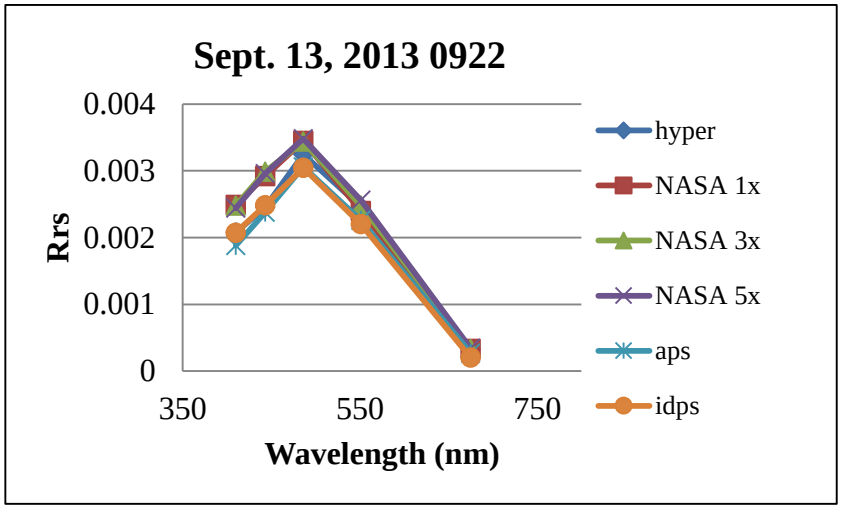


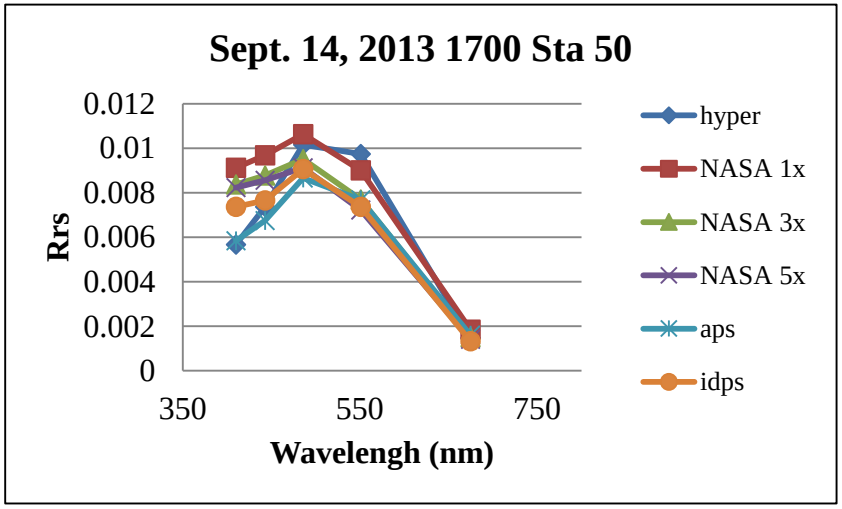


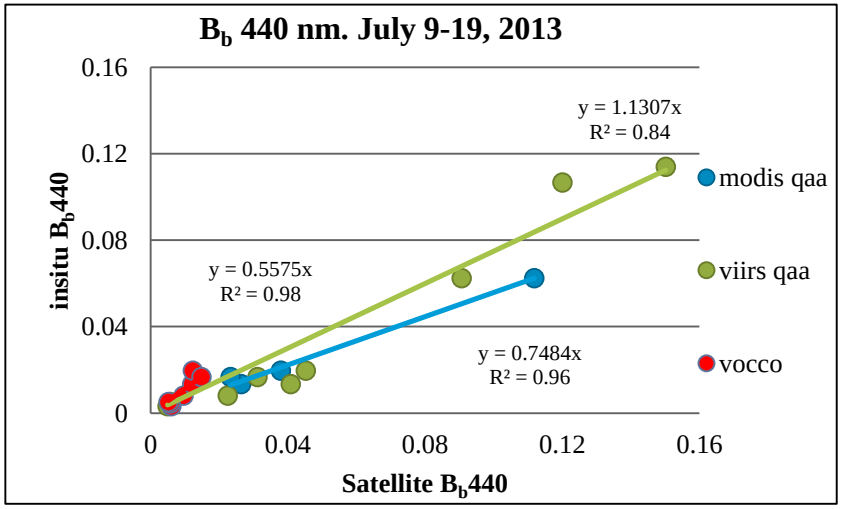
Sept. 2013 Geocape Cruise 112 Stations Rrs Data shown from 9/11, 13, and 14, 2013 and Ecopuc backscatter validations are show in bottom right



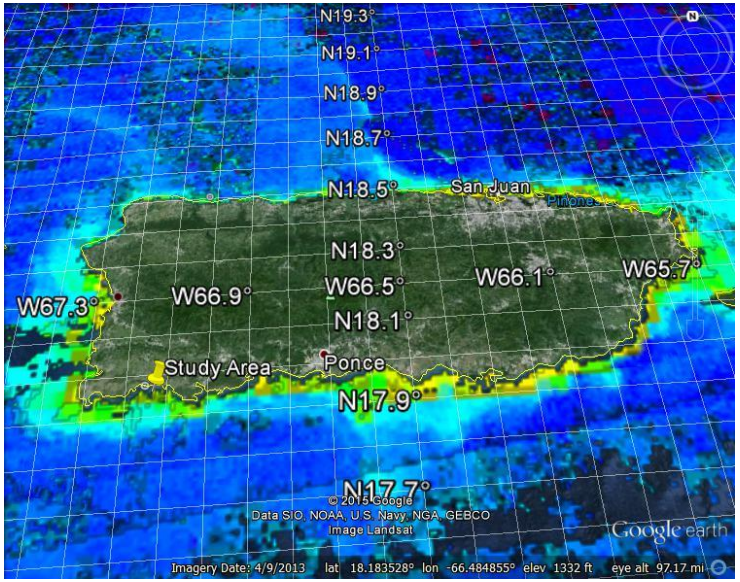




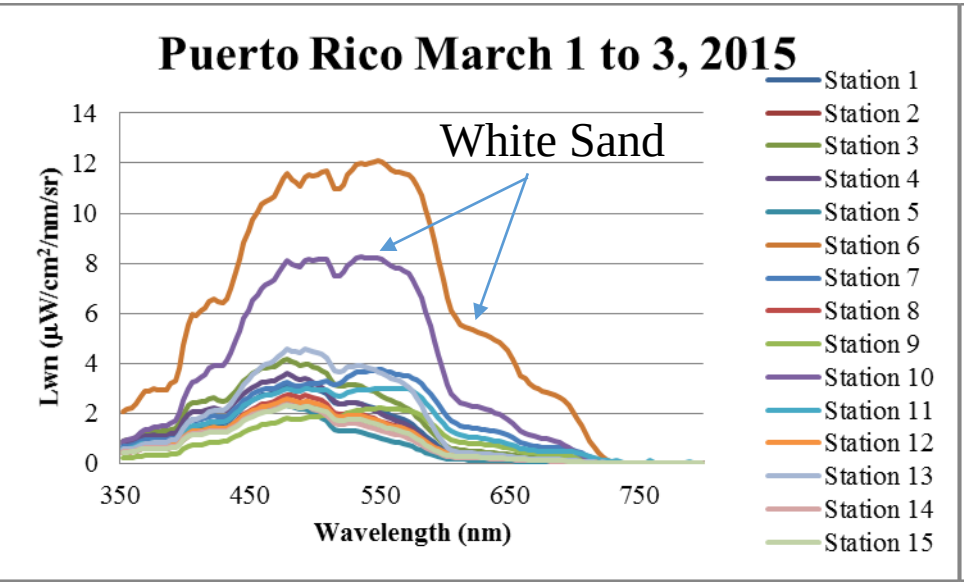


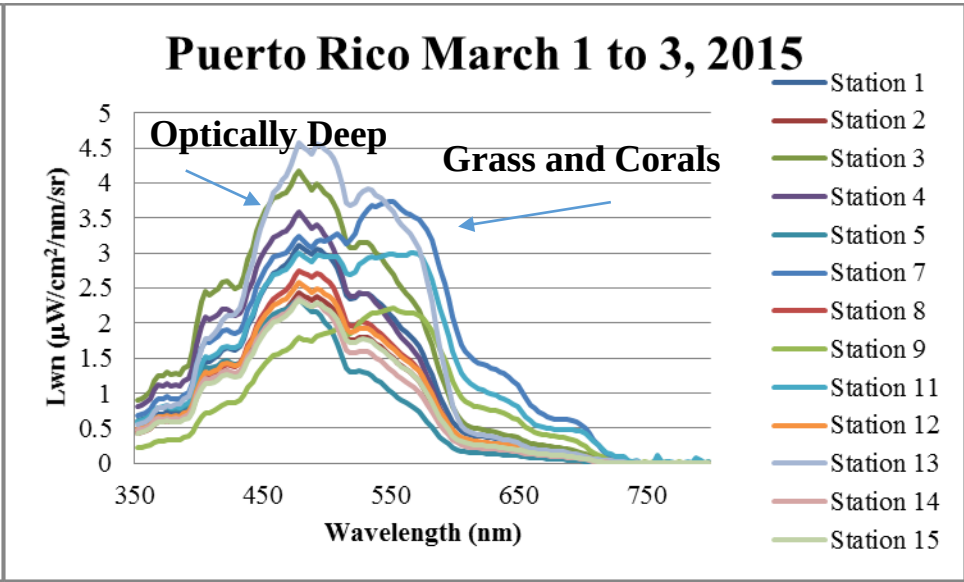


Conducted VIIRS Cal/Val cruises off Puerto Rico in May 2014 and March 2015 in collaboration with UMB, UPR, and EPA.. (image chl composite of March 1 to 6, 2015)



Occupied 15 stations each year in conditions ranging from shallow waters over sand and coral bottoms to optically deep waters





Dedicated VIIRS Cal/Val Cruise
NOAA Ship Nancy Foster
11-20 November 2014

International, Interagency and Academic Collaborations:

US Agencies

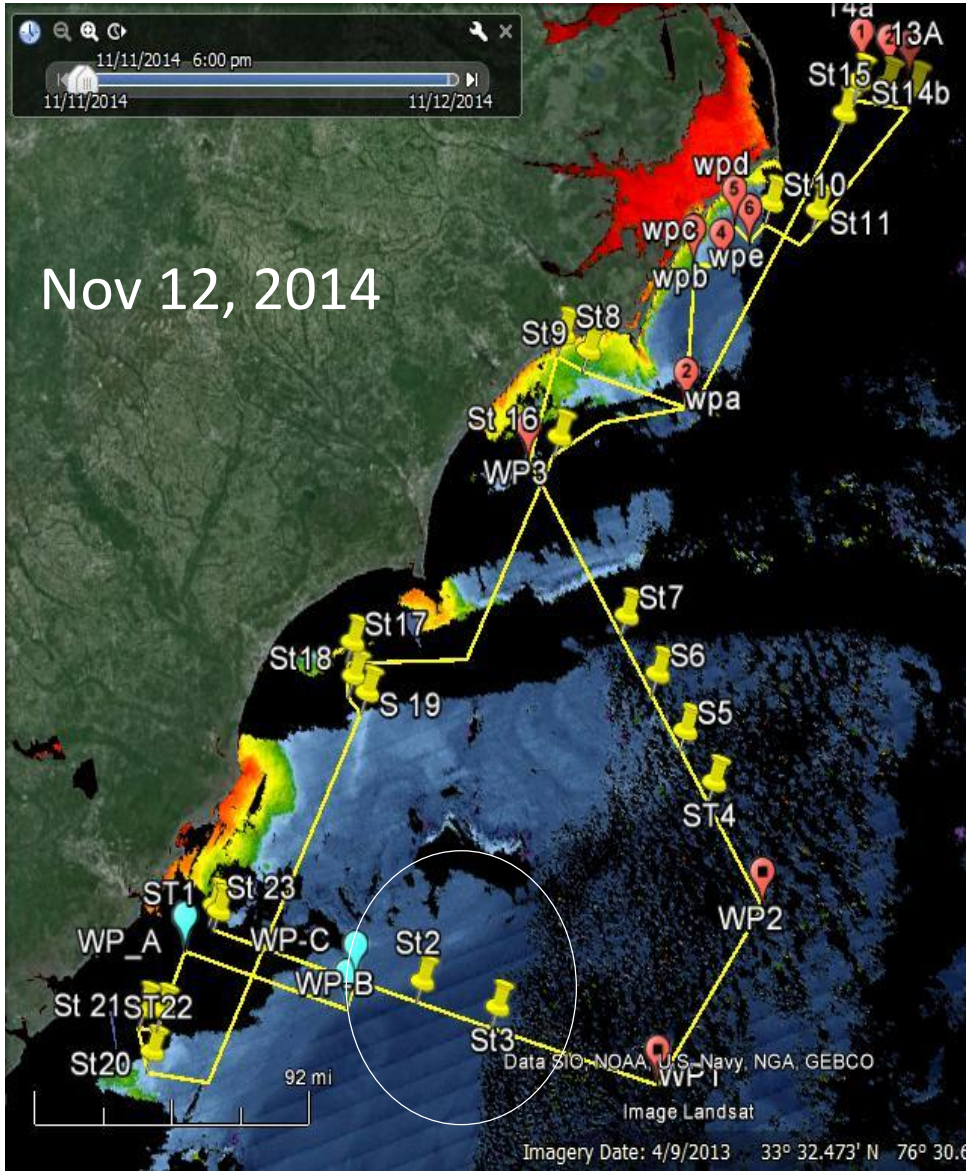
- **NOAA**/NESDIS/STAR (NOAA)
- Naval Research Laboratory, Stennis Space Center (**NRL**)
- NASA/Goddard Space Flight Center (**NASA**)
- National Institute of Standards and Technology (**NIST**)

European Union

- Joint Research Center of the European Commission (**JRC**)

Universities

- City University of New York, Long Island; CREST
- Lamont-Doherty Earth Observatory, Columbia University
- University of Massachusetts, Boston
- University of Miami
- University of South Florida
- University of Southern Mississippi



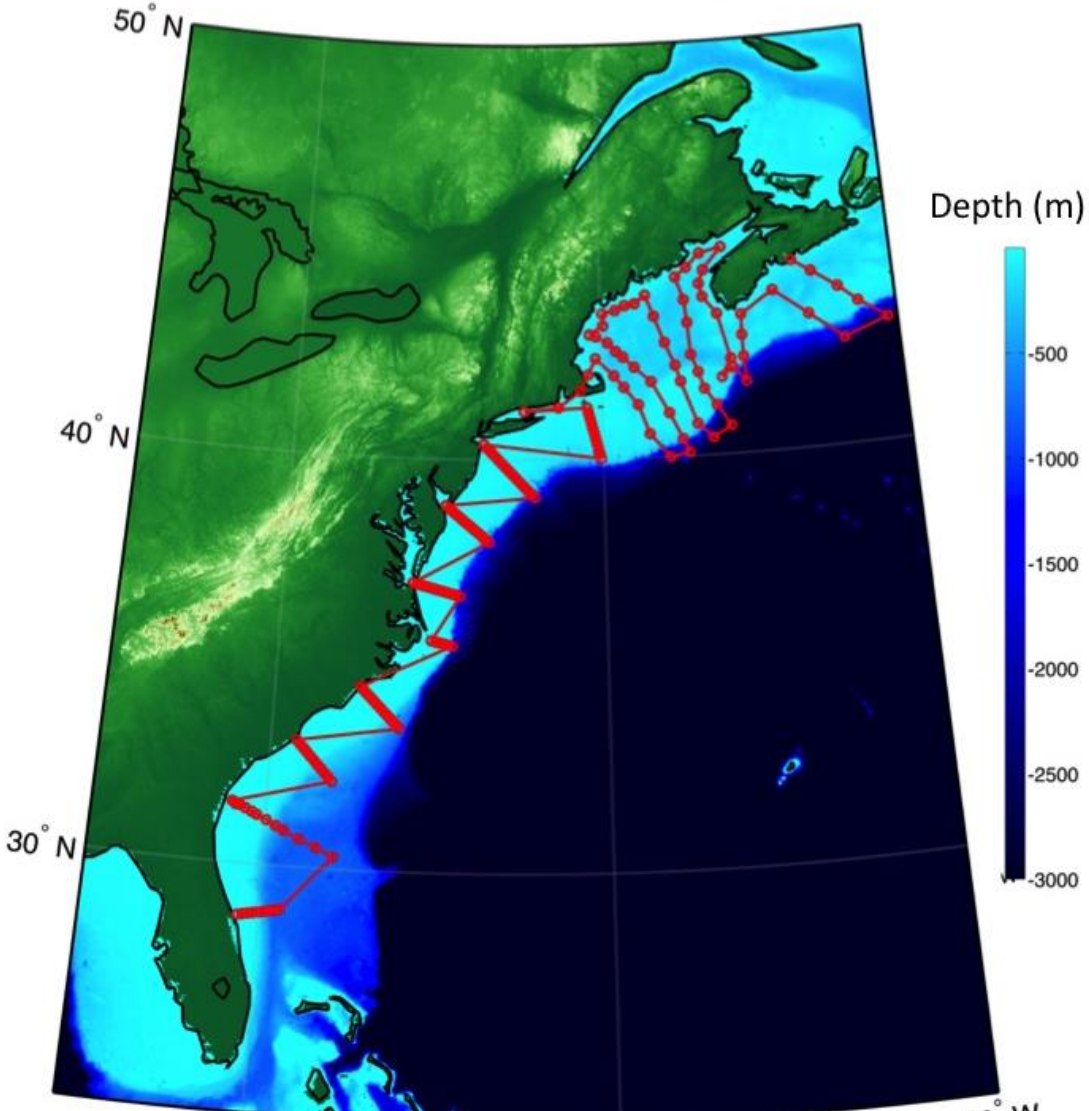
November 12, 2014 Blue water validations

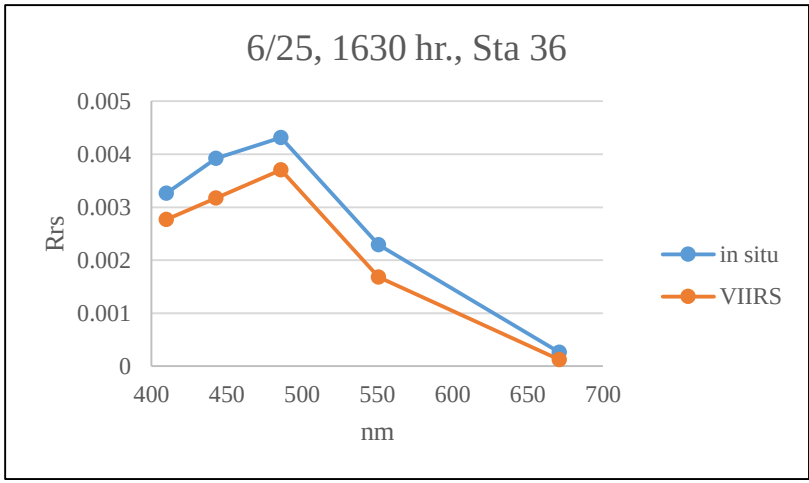
ECOA 1- The East Coast Ocean Acidification Cruise 2015

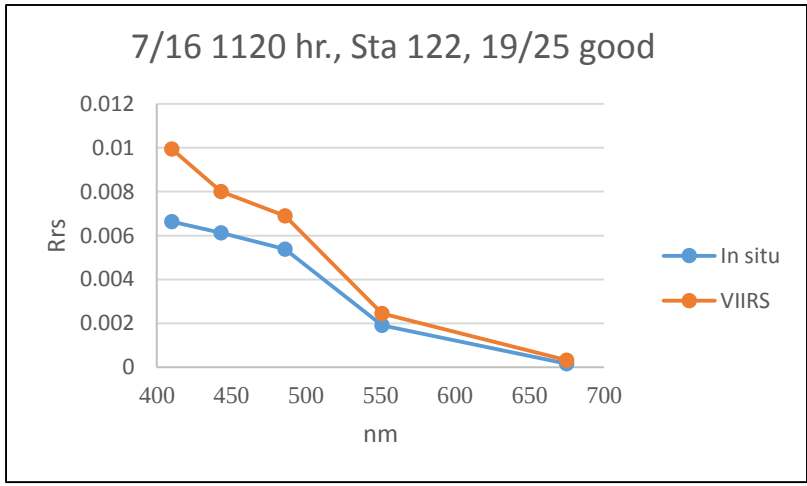
Leg 1 – June 17 to July 2, 2015 NNova Scotia to Norfolk, VA 21 optical stations

Leg 2 – July 8 to 24, 2015 53 optical stations from Chesapeake Bay to Miami

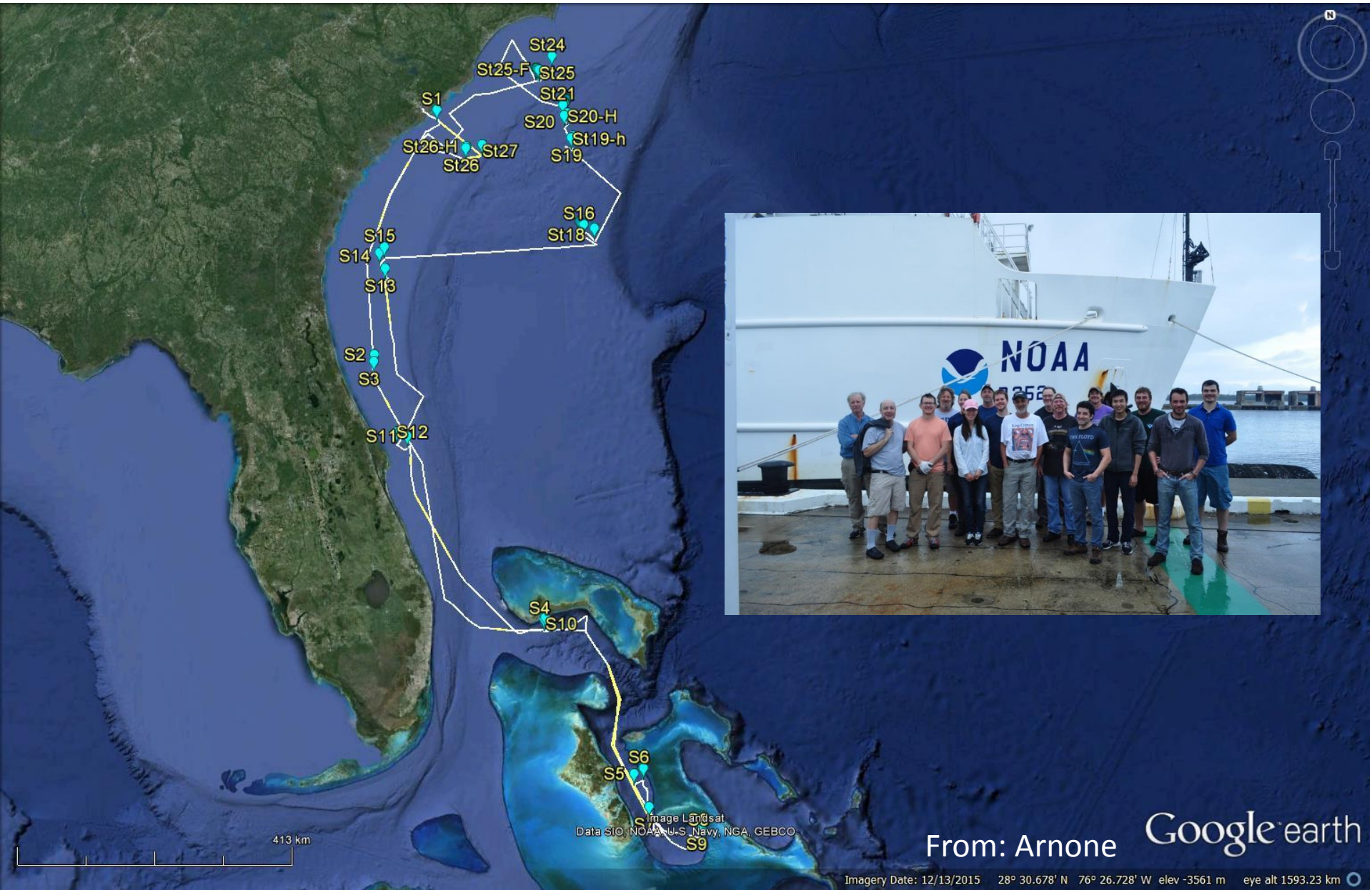
Figure 1. Tentative station plan





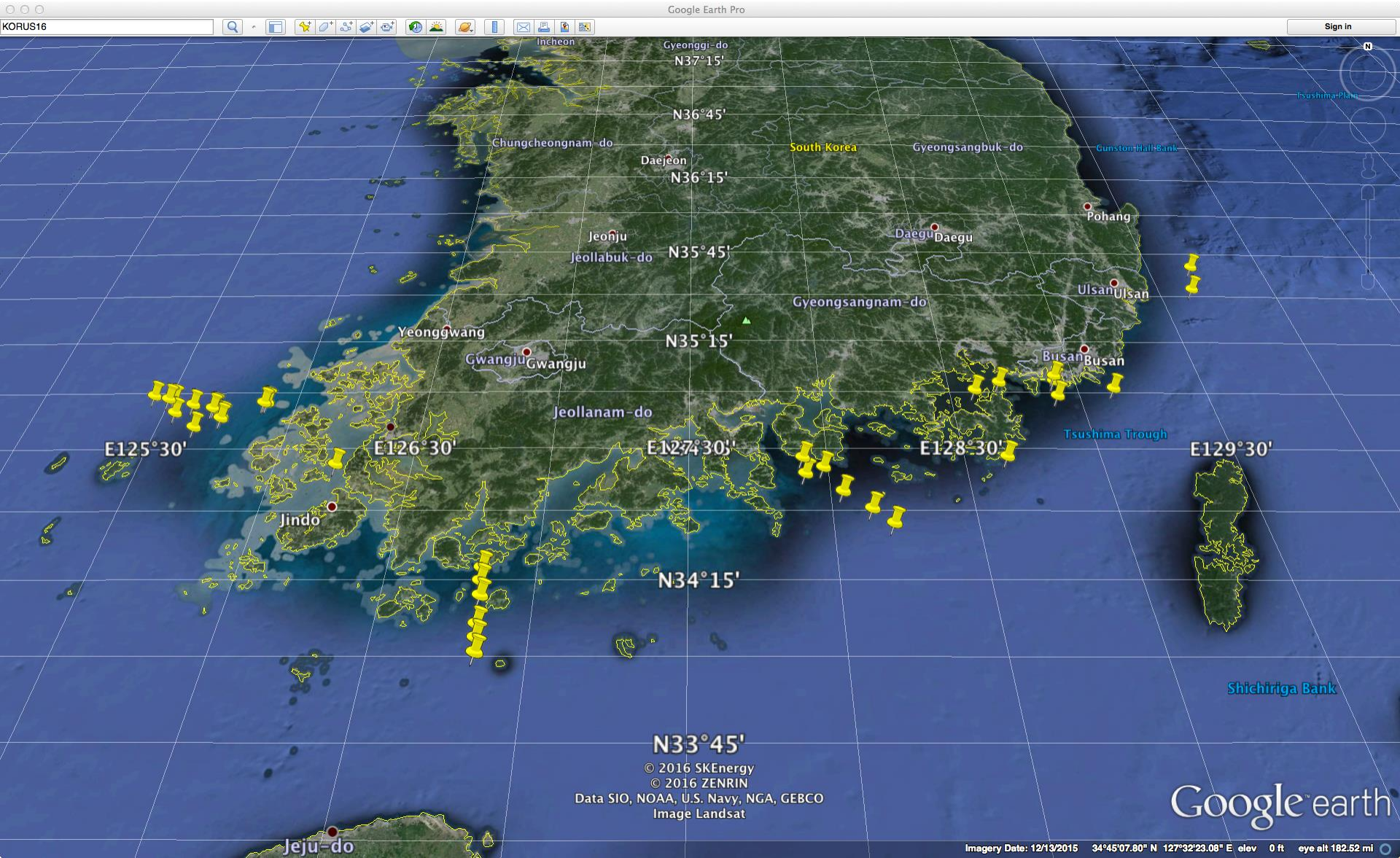


December 2015 Cal/Val Cruise

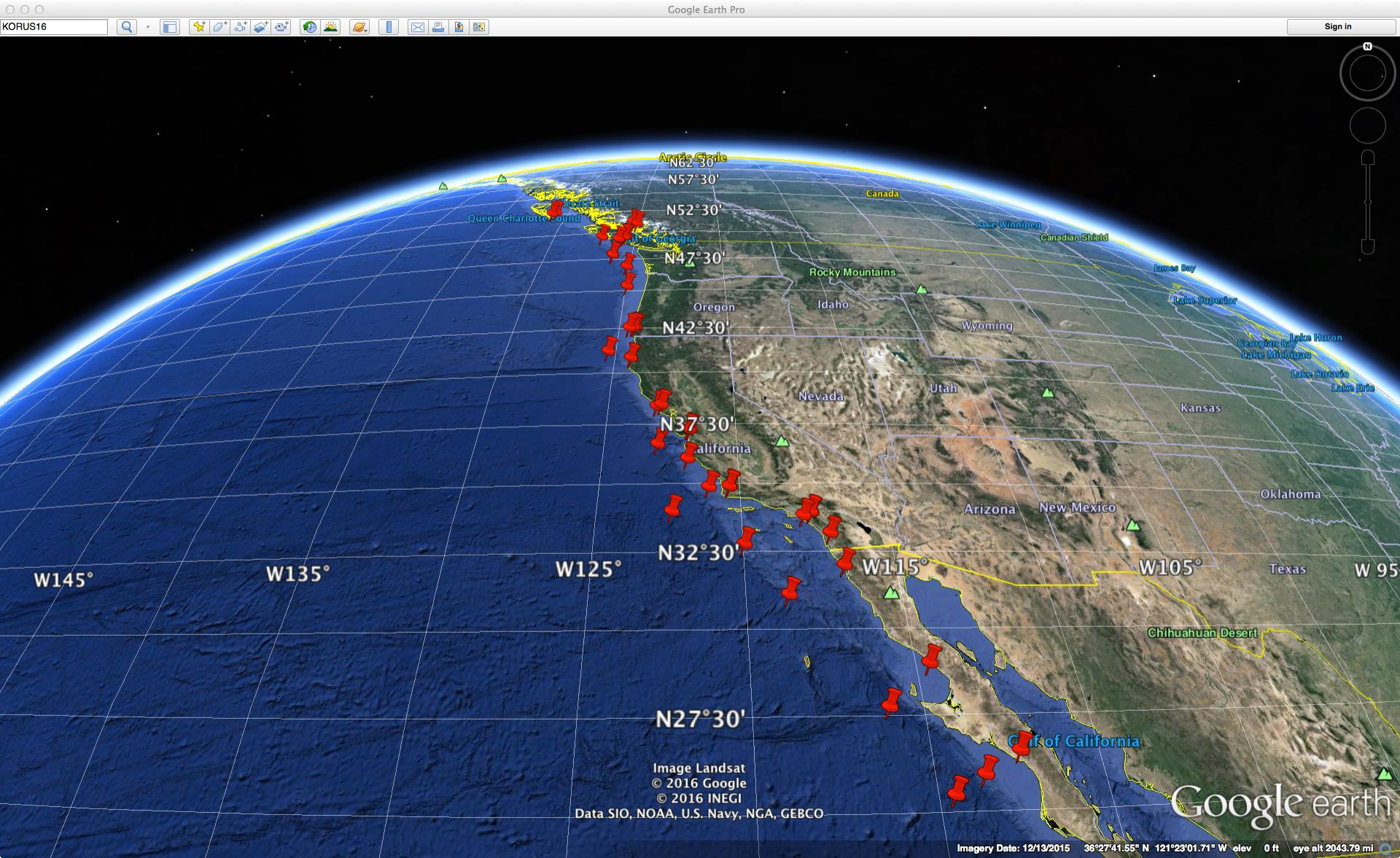


From: Arnone

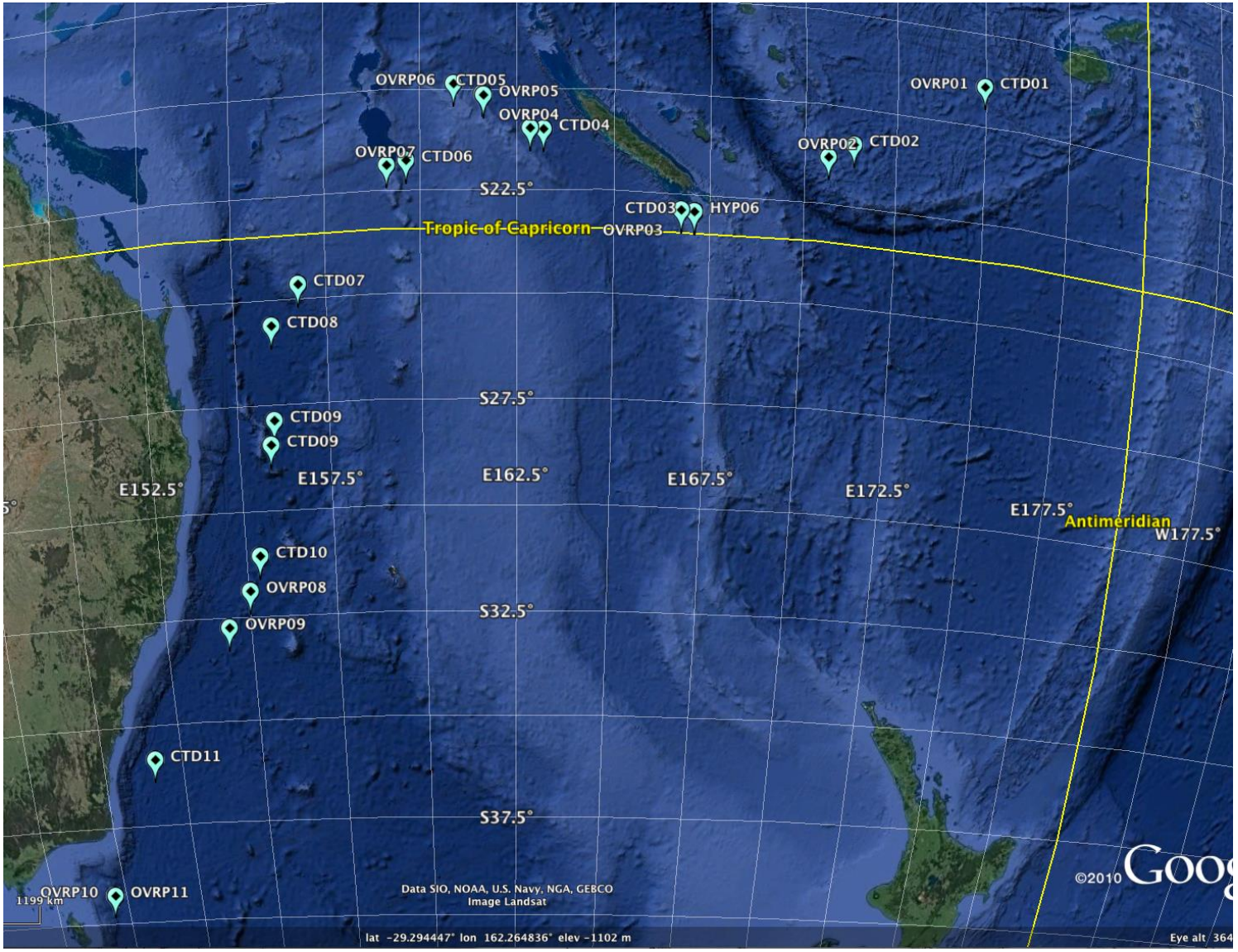
KORUS- off the coast of South Korea from May 20th to June 5th. Janmok conducted 35 stations. We measured Hyperpro, NURADS, Microtops, ASD Handheld II. Other groups measured pigments, IOPs and other relevant parameters.



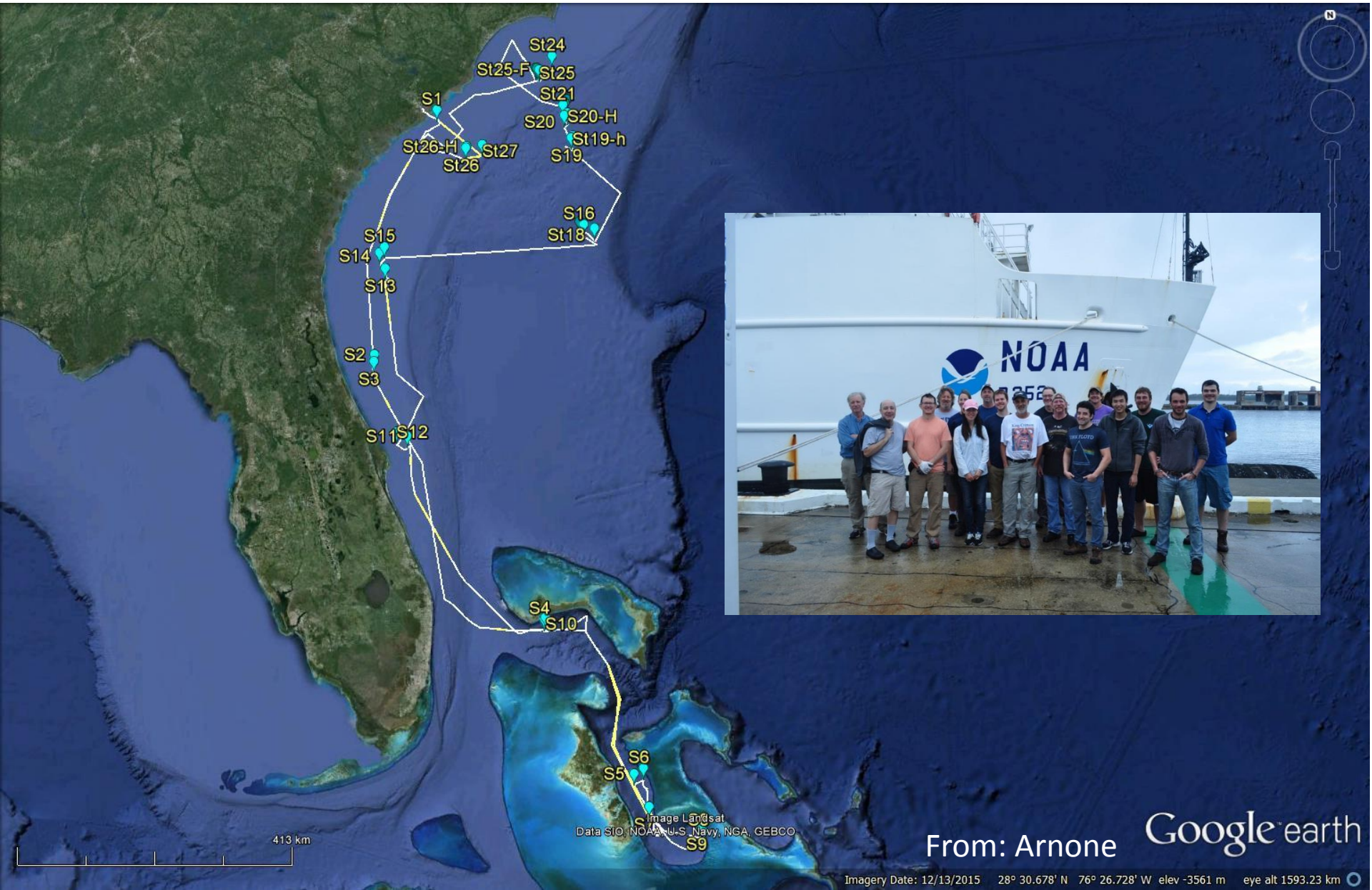
WCOA- From Baja, Mexico to Alaska from May 6th to June 5th. Aboard the NOAA Ship Ronald H. Brown. Measured Hyperpro, Microtops, pigments, Cdom, and particulate absorption. Other groups measured many other relevant parameters. 35 optical stations.



June – July 2016 CSIRO cruise – Fiji to Tasmania – 24 HyperPro II Stations with Microtops & ancillary chemistry & IOPs



December 2015 Cal/Val Cruise



From: Arnone

Science Objectives for the Cruise

Goals

1) Validation of VIIRS JPSS Satellite Ocean Color products

- **Occupied 27 Stations over 13 Days, 9 good station matchups with VIIRS**
- **Conducted pre- and post-cruise inter-cals**
- **Water-Leaving Radiance** - HyperPro, HyperTSRB, C-OPS, GER, SBA, HyperSAS, ASD Handheld 2
- **Aerosol Optical Depth** - Microtops
- **Bi-directional radiance distribution** - NURADS
- **Chlorophyll** - HPLC, Fluorometric, (in situ and extracted)
- **Absorption** - ACS, AC9, Spectrophotometric
- **Backscatter** - BB9, BB7, BB3, ECO Puck
- **Phytoplankton Physiology -** Imaging FlowCytobot
- **Carbon** - POC and DOC water analysis; plus CDOM
- **Total Suspended Matter** - Gravimetric

characterization of differences among the in situ ocean color measurements

Science Objectives for the Cruise

Goals (cont.)

2) Characterization of differences among the in situ ocean color measurements

a) replicate observations from multiple identical (same model) instruments deployed in parallel;
b) observations of the same in situ parameters but using different types of instruments;
c) different deployment protocols for sample collection;
d) different post-processing methods for the in situ data; and
e) spatial and temporal variability of the ocean waters.

3) Optical characterization of ocean variability (i.e. coastal, near-shore, cross-shelf, eddies, fronts, filaments, blue

-Can water mass characterization of the representing different bio-physical processes be defined using VIIRS bio-optical products in the a dynamic system such as the Gulf Stream?

Principal investigators (PIs), participating institutions and institution abbreviations.

PI Name (Last, First)	Participating Institutions	Research Group Abbreviation
Ondrusek, Michael*	NOAA/NESDIS Center for Satellite Applications and Research	NOAA/STAR
Ahmed, Sam	City College of New York	CCNY
Arnone, Robert	University of Southern Mississippi (USM) and Naval Research Center (NRL)	Stennis
Davis, Curtiss	Oregon State University	OSU
Gilerson, Alex	City College of New York	CCNY
Goes, Joaquim	Lamont-Doherty Earth Observatory at Columbia University	LDEO
Hu, Chuanmin	University of South Florida	USF
Johnson, B. Carol	National Institute of Standards and Technology	NIST
Lee, ZhongPing	University of Massachusetts, Boston	UMB
Mannino, Antonio	NASA Goddard Space Flight Center	NASA/GSFC
Voss, Kenneth	University of Miami	U. Miami

List of science party personnel aboard the NOAA Ship *Nancy Foster* (alphabetical order).

Name (Last, First)	Title	Research Group/Home Institution*
Arnone, Robert	Research Professor	Stennis/USM
Carrizo, Carlos	PhD Student	CCNY
Chavez, Joaquin	Staff Research Scientist	NASA/GSFC
Freeman, Scott	Staff Research Scientist	NASA/GSFC
el Habashi, Ahmed	PhD Student	CCNY
Kovach, Charles	Researcher	USF
Lin, Junfang	Postdoctoral Researcher	UMB
Ladner, Sherwin	Researcher	Stennis/NRL
Ondrusek, Michael	Chief Scientist	NOAA/STAR
Goode, Wesley	Researcher	Stennis/NRL
Ottaviani, Matteo	Researcher	CCNY
Stengel, Eric	Researcher	NOAA/STAR
Tufillaro, Nicholas	Researcher	OSU
Vandermeulen, Ryan	Remote Sensing Analyst	Stennis/USM
Wang, Guoqiang	PhD Student	UMB

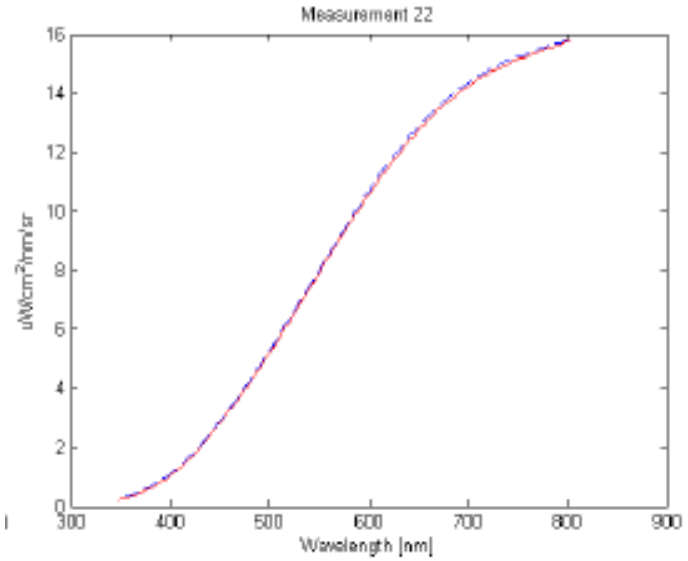
Pre-cruise calibrations done 11/19/15
Post-cruise calibrations done 1/5/16, 1/27/16 and 1/28/16

29 instrument calibrated
10 radiance
16 Irradiance
2 Par
1 ASD

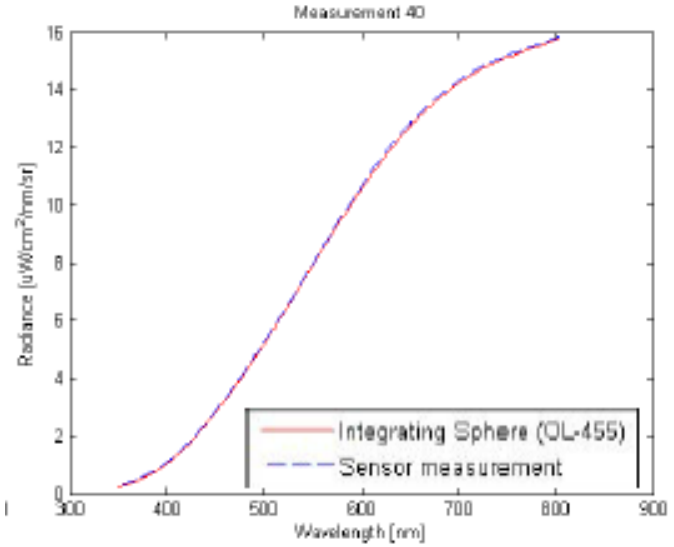
Radiance with plaque and integrating sphere
Irradiance directly with NIST Fel lamp

206 Lu Radiance

NEW CAL
(SLC)



BEFORE
CRUISE

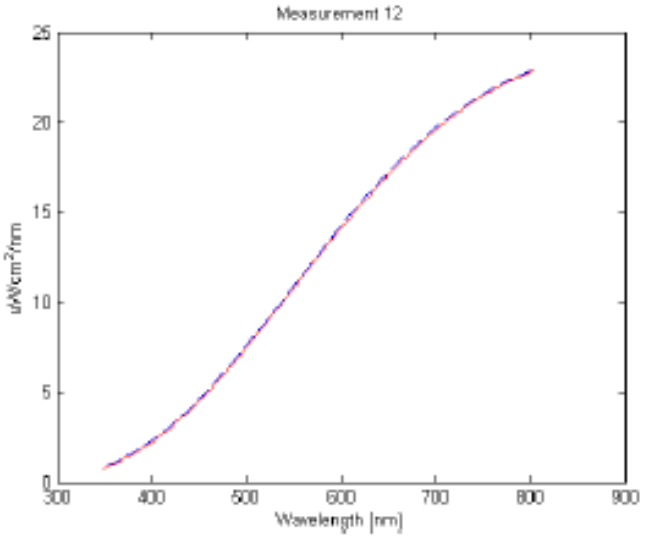


AFTER
CRUISE

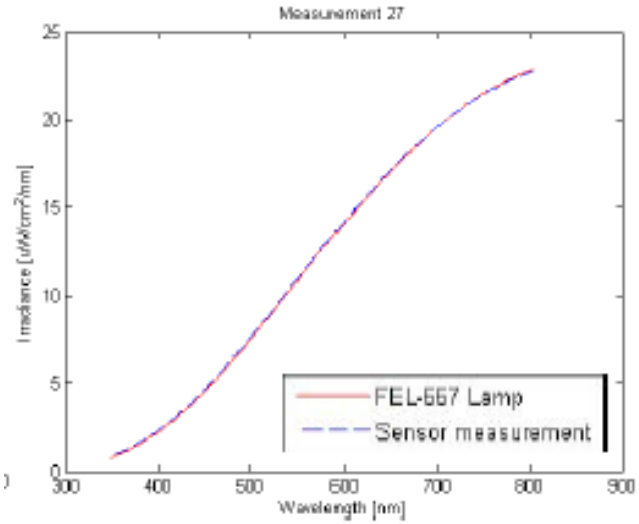
NEW CAL
(SLC)

233 Ed Irradiance

NEW CAL
(SLC)



BEFORE
CRUISE

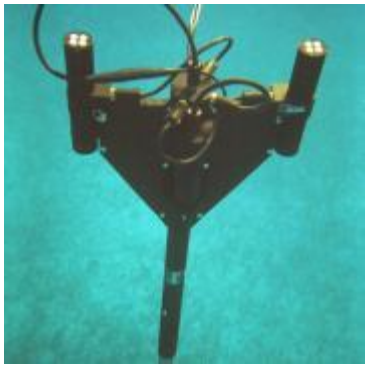


AFTER
CRUISE

NEW CAL
(SLC)

Instruments used to measure Remote Sensing Reflectance

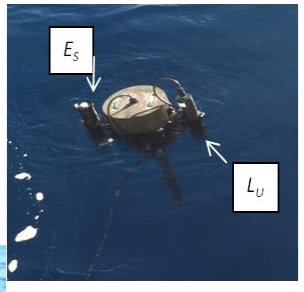
Profilers



3 HyperPro (Satlantic) – free-falling hyperspectral optical profiler. 10 nm bands sampled every 3 nm. Radiance FOV 8.5 degrees. Calibrated from 350 to 800 nm.

C-OPS (Biospherical Instruments, Inc.) – compact multispectral optical profiling system. a spectral range from 300 nm to 900 nm, with 19 wavebands wavelengths each: 305 nm, 320 nm, 340 nm, 380 nm, 395 nm, 412 nm, 443 nm, 465 nm, 490 nm, 510 nm, 532 nm, 555 nm, 565 nm, 625 nm, 665 nm, 683 nm, 710 nm, 780 nm, and 875 nm.

Instruments used to measure Remote Sensing Reflectance



Surface

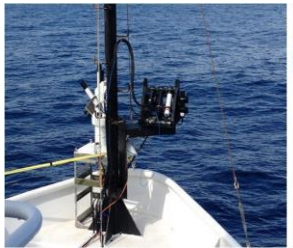
2 HyperTSRB (Satlantic) – Same instrument as hyperpro but collared to float at surface.

SBA (Satlantic) – Sky- Blocking Apparatus (SBA) radiometer package composed of one HyperOCR radiance sensor and one irradiance sensor. directly measures the water-leaving radiance Lw while blocking out sky-light (Lee et al., 2013).

Above-water

3 ASD Analytical Spectral Device (PANalytical) – Handheld 2 above-water spectrometer. Spectral range of 325 to 1075 nm. Spectral Resolution <3.0 nm, FOV 10 degrees. 2nd asd has 7 degrees FOV.

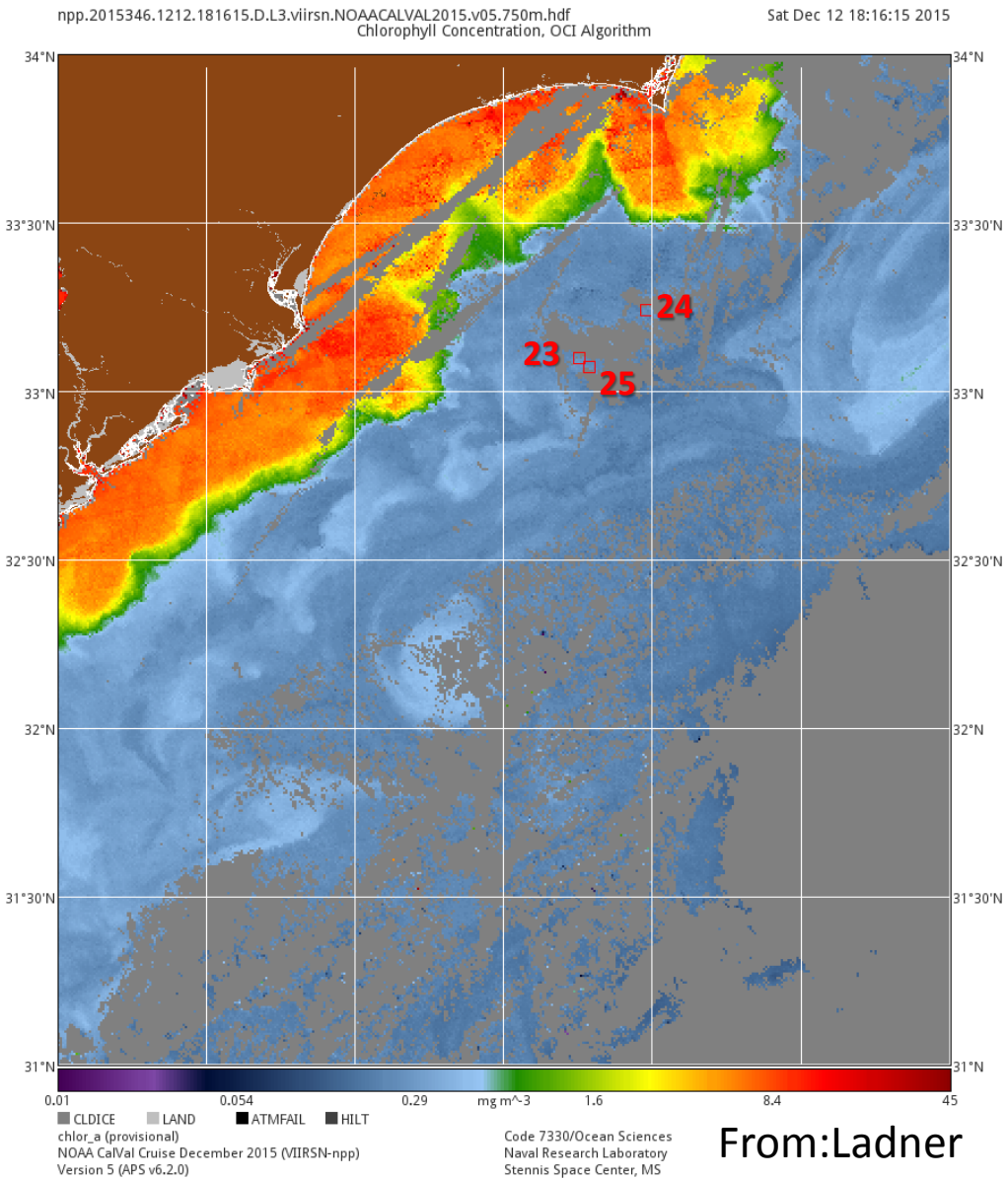
GER (Spectra Vista Corporation) – The GER 1500, Field Portable hand-held Spectroradiometer. Wavelengths from 350 nm to 1050 nm at 3 nm resolution with 4° nominal field of view (FOV).



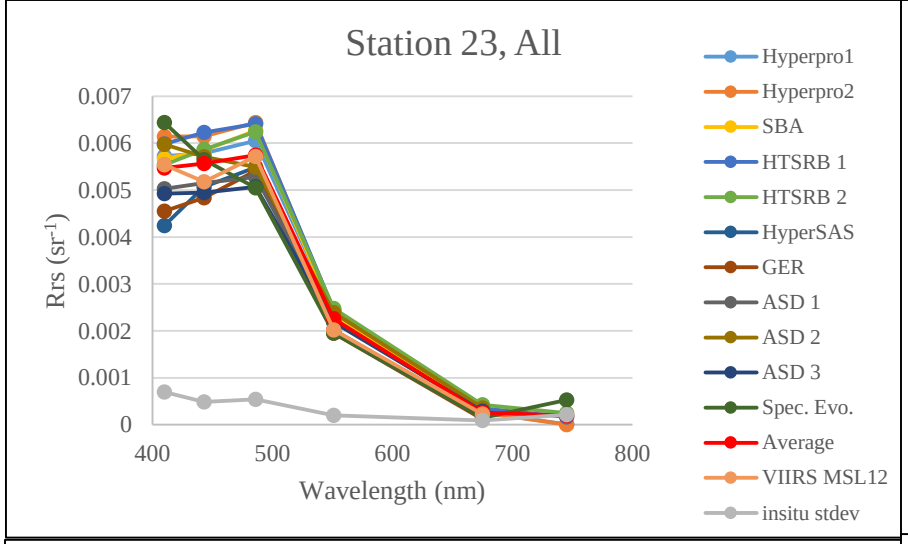
2 HyperSAS (Satlantic) – Autonomous above-water OCR's with narrow FOV of 3 degrees. Also set up to measure polarization

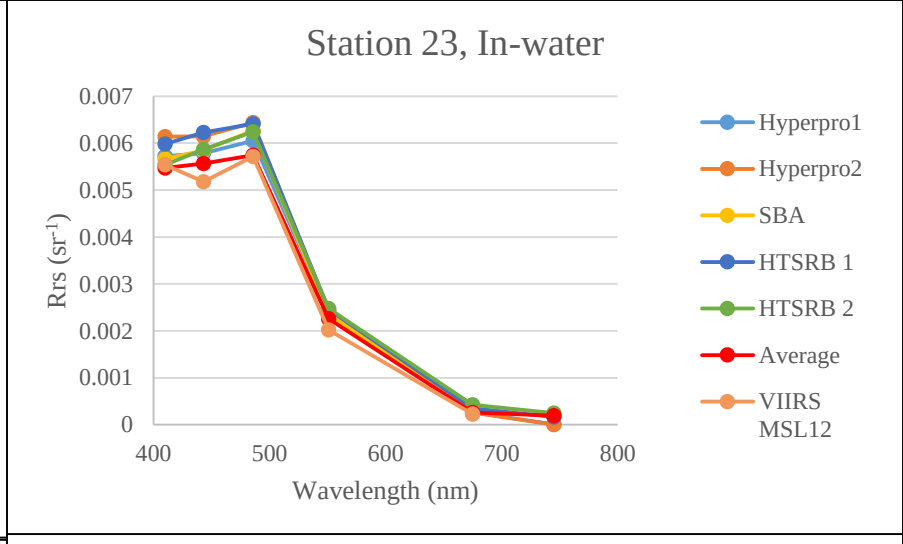
Spectral Evolution – 280 to 1900 nm handheld above water radiometer

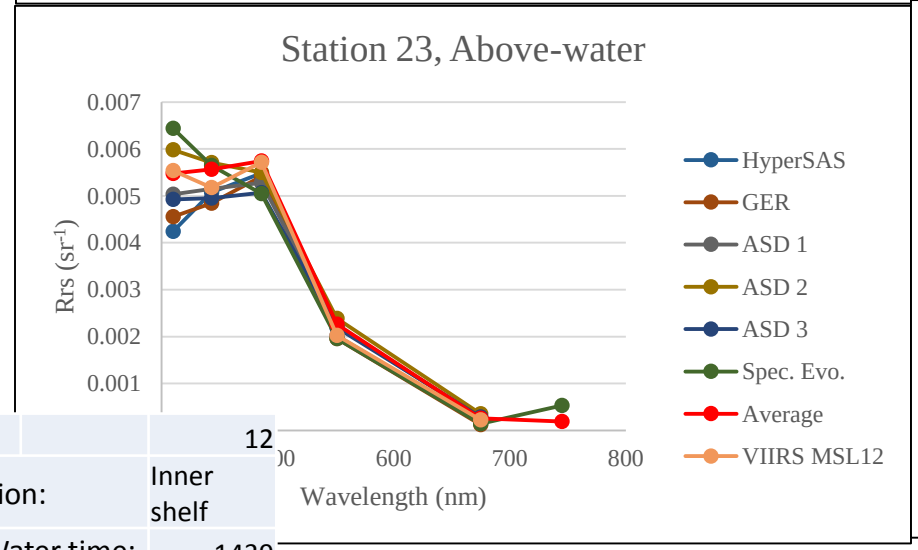
12/12/16 (1816 GMT)
St. 23,24,25

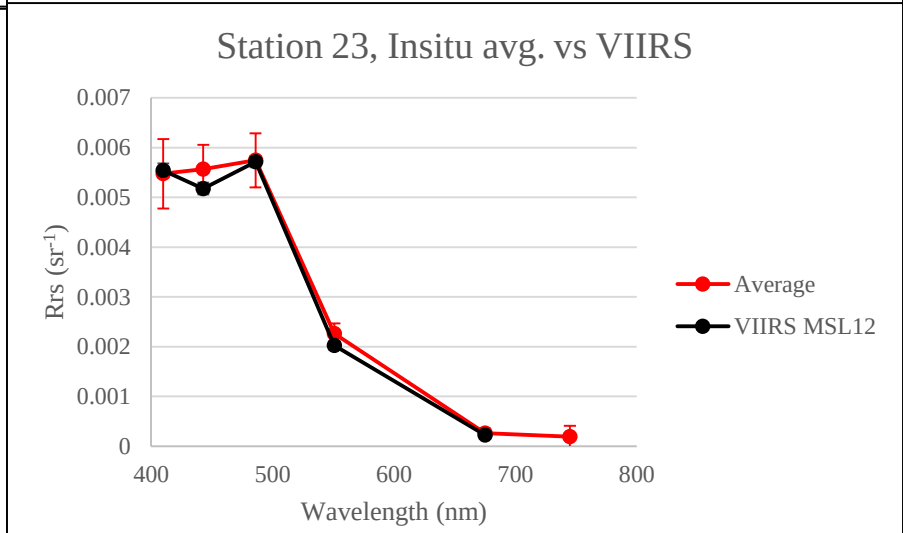


From:Ladner







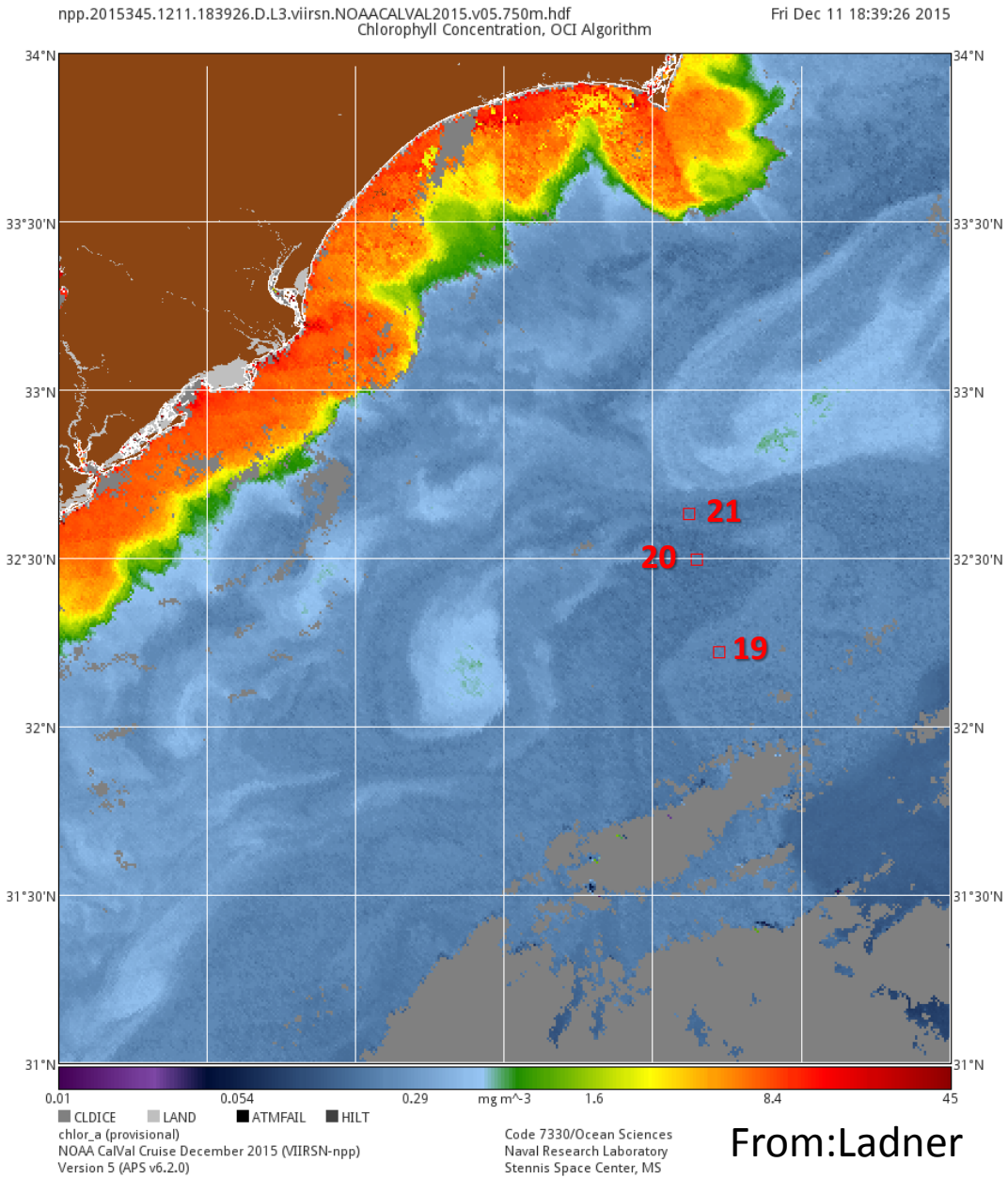


Date:	12
Description:	Inner shelf
Above-Water time:	1439
Surface time:	1345
Profile time:	1439
Depth:	50
Cloud cover:	0
Wind speed:	7
Seas (ft.):	2
Chl (mg/m3)	0.304
# pixels in 5 x 5	22

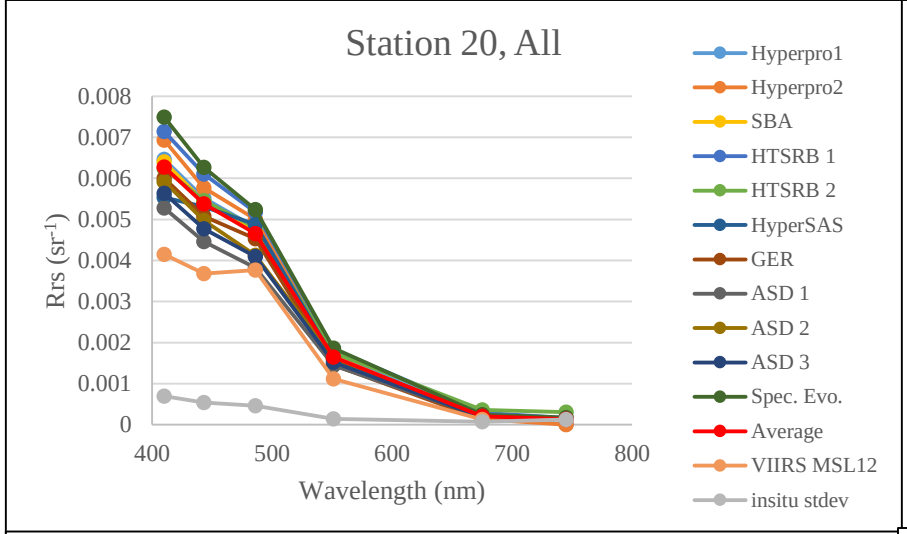
Percent Difference relative to Average

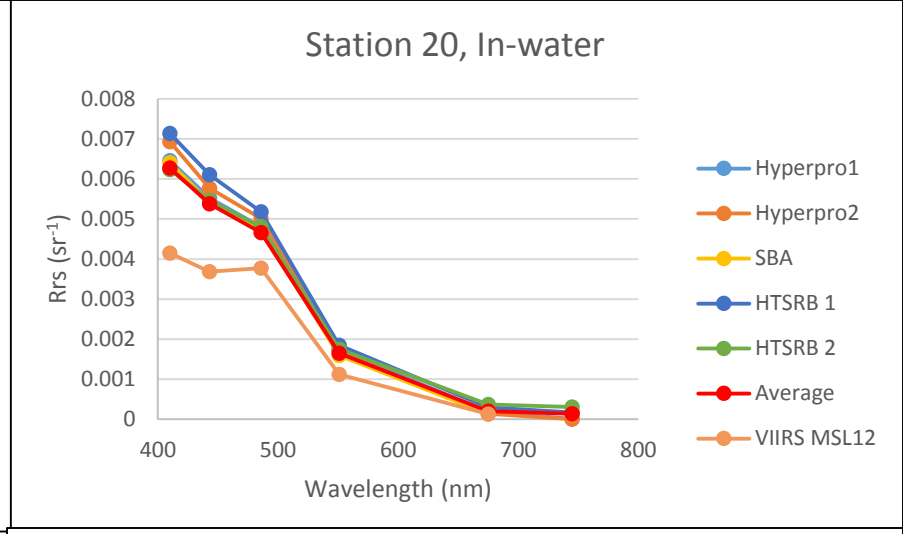
Band	Hyperpro1	Hyperpro2	SBA	HTSRB 1	HTSRB 2	HyperSAS	GER	ASD 1	ASD 2	ASD 3	Spec. Evo.
410	4.52	12.19	3.47	9.27	1.16	-22.51	-16.83	-8.10	9.20	-10.01	17.63
443	3.95	10.44	4.99	11.85	5.41	-8.92	-13.08	-7.52	2.55	-11.12	1.45
486	5.27	12.05	9.14	11.59	8.66	-4.54	-5.79	-8.13	-4.37	-11.78	-12.11
551	6.61	7.00	4.88	8.58	9.72	-10.75	-13.51	-1.39	5.60	-3.25	-13.50
675	-1.35	-0.17	-9.57	33.91	62.03	-33.80	-54.18	1.07	35.78	10.22	-43.94

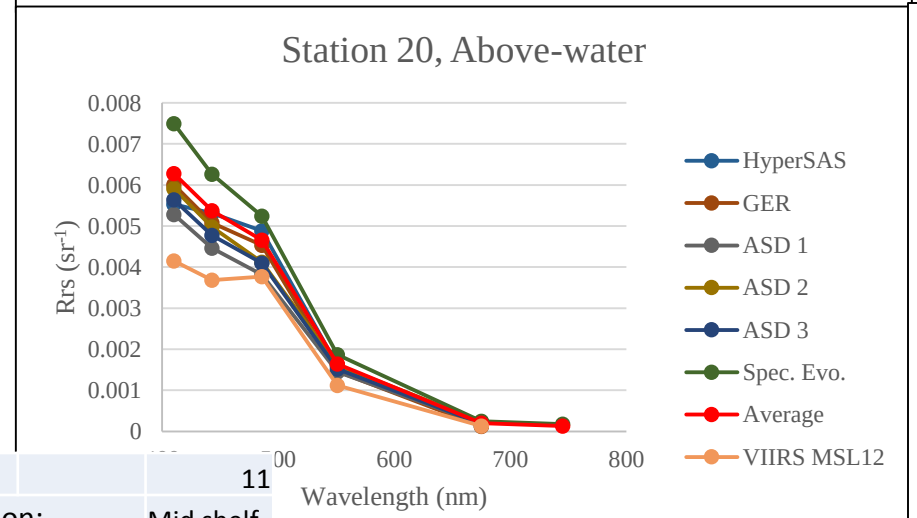
12/11/16 (1839 GMT)
St. 19,20,21

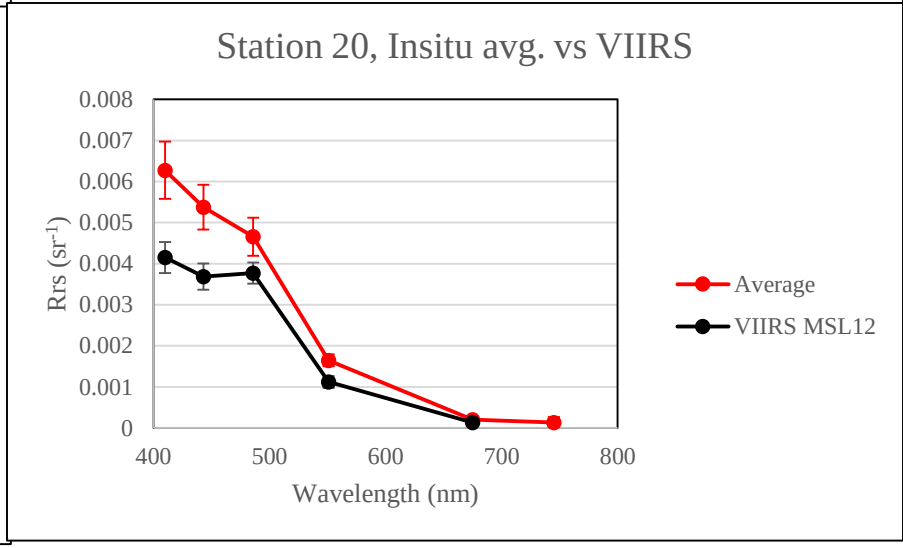


From:Ladner









Date:	11
Description:	Mid shelf
Above-Water time:	1643
Surface time:	1700
Profile time:	1731
Depth:	1000
Cloud cover:	0
Wind speed:	8.3
Seas (ft.):	2
Chl (mg/m3)	0.336
# pixels in 5 x 5	23

Percent Difference relative to Average

Band	Hyperpro1	Hyperpro2	SBA	HTSRB 1	HTSRB 2	HyperSAS	GER	ASD 1	ASD 2	ASD 3	Spec. Evo.
410	2.95	10.42	2.01	13.76	-0.65	-11.84	-4.36	-15.84	-5.73	-10.15	19.43
443	2.72	7.25	0.86	13.59	1.53	-1.21	-5.58	-16.99	-7.45	-11.21	16.50
486	3.18	7.56	1.61	11.17	3.20	4.84	-2.66	-17.96	-11.45	-12.04	12.55
551	5.01	1.83	-3.48	12.12	6.60	-2.36	-11.13	-12.09	-2.19	-7.63	13.30
675	-8.32	-31.58	-31.47	45.59	79.57	-35.50	-38.38	-7.68	16.27	-10.64	22.13

Instrument Percent difference relative to average of all instruments

2014 VIIRS Validation Cruise

Band	Hyperpro	Hyperpro	Micropro	C-OPS	SBA	HyperTSRB	ASD	ASD	GER	HyperSAS
410	4.83	-0.41	1.93	-1.49	-9.01	-4.29	6.47	-1.82	4.04	-0.75
443	6.84	3.12	-0.35	-4.21	-8.90	-0.28	1.34	-3.30	6.19	-1.31
486	4.83	3.81	-0.37	-2.19	-9.86	1.01	-4.71	-2.21	10.38	-0.75
551	5.22	4.14	-1.86	-7.24	-9.12	5.52	-0.11	-4.75	8.53	-1.16
675	-9.18	-14.02	-14.91	-17.22	-8.57	36.15	38.47	0.24	5.46	-11.25
All	2.51	-0.67	-3.11	-6.47	-9.09	7.62	8.29	-2.37	6.92	-3.04

2015 VIIRS Validation Cruise

Band	Hyperpro	Hyperpro	Spec Evo	SBA	HTSRB 1	HTSRB 2	ASD 1	ASD 2	ASD 3	GER	HyperSAS
410	3.88	13.32	14.46	-1.04	-0.97	-1.68	-6.04	2.29	-12.15	-7.30	-17.42
443	4.97	10.15	10.09	0.48	-1.31	0.41	-10.97	-3.32	-12.94	-4.97	-4.86
486	6.45	9.93	4.84	1.37	-2.34	3.36	-15.05	-8.95	-14.12	1.09	0.92
551	7.39	3.18	6.46	-2.70	-2.06	6.48	-10.68	-2.11	-8.75	-5.98	-3.61
675	-5.43	-17.26	-3.61	-33.49	50.99	72.27	-5.04	9.29	-7.03	-44.38	-35.22
Average	3.45	3.86	6.45	-7.08	8.86	16.17	-9.56	-0.56	-11.00	-12.31	-12.04

MSL12 VIIRS Percent difference relative to in situ

2014 VIIRS Cal/Val Cruise

Band	Hyperpro	Hyperpro	Micropro	C-OPS	SBA	HyperTSRB	ASD	ASD	GER	HyperSAS	Average
410	-6.73	-3.36	-5.39	-2.15	10.31	1.57	-8.17	-8.73	3.33	3.85	**-3.79**
443	-13.15	-10.87	-7.45	-3.93	4.15	-7.42	-8.53	-9.38	-8.44	-3.90	**-8.31**
486	-6.49	-5.70	-1.44	0.45	11.28	-2.84	3.67	-2.83	-8.83	0.35	**-2.30**
551	-3.58	-2.71	4.05	10.21	14.65	-2.89	2.89	3.18	-2.82	5.52	**1.17**
675	-10.37	-0.44	1.06	1.70	-3.34	-28.45	-25.91	-9.02	-22.89	-4.94	**-17.04**
All	-8.07	-4.62	-1.83	1.26	7.41	-8.01	-7.21	-5.36	-7.93	0.18	**-6.05**

2015 VIIRS Cal/Val Cruise

Band	Hyperpro	Hyperpro	Spec Evo	SBA	HTSRB	HTSRB	ASD 1	ASD 2	ASD 3	GER	HyperSAS	Average
410	-10.71	-33.17	-32.44	0.69	-17.95	-2.30	-5.63	-13.05	-6.59	11.00	33.56	**-6.96**
443	-18.16	-31.21	-29.54	-8.79	-22.38	-11.47	-4.18	-11.97	-8.68	-4.17	-4.42	**-14.09**
486	-10.39	-19.94	-14.26	-0.97	-12.37	-5.97	13.50	4.83	4.68	-2.64	-2.58	**-4.19**
551	-20.75	-24.85	-24.76	-7.82	-24.11	-18.53	-0.83	-12.52	-11.21	-6.12	-7.59	**-14.46**
675	-5.97	-7.69	1.95	82.36	-45.75	-40.02	0.21	-15.49	-9.78	82.26	56.15	**8.93**
Average	-13.20	-23.37	-19.81	13.09	-24.51	-15.66	0.62	-9.64	-6.32	16.07	15.02	**-6.16**

Going Forward:

- **Third Annual VIIRS Cal/Val cruise aboard the Nancy Foster out of Charleston, SC. Oct 5 to 19, 2016**

- **NASA/CSIRO CORAL cruise conducting optical characterizations over the Great Barrier Reef.**