Validation of Ocean Color Sensors Using a Profiling Hyperspectral Radiometer

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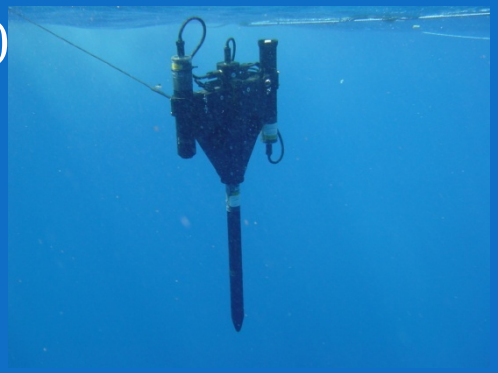
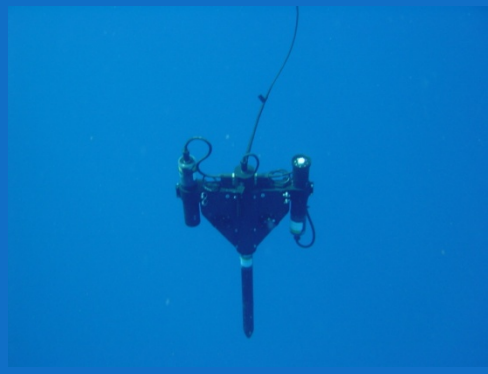
- **Validation of satellite ocean color sensors :**
  - Requires accurate and traceable in situ measurements
  - Hyperspectral to match all sensors
  - Many matchups and water types

- **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

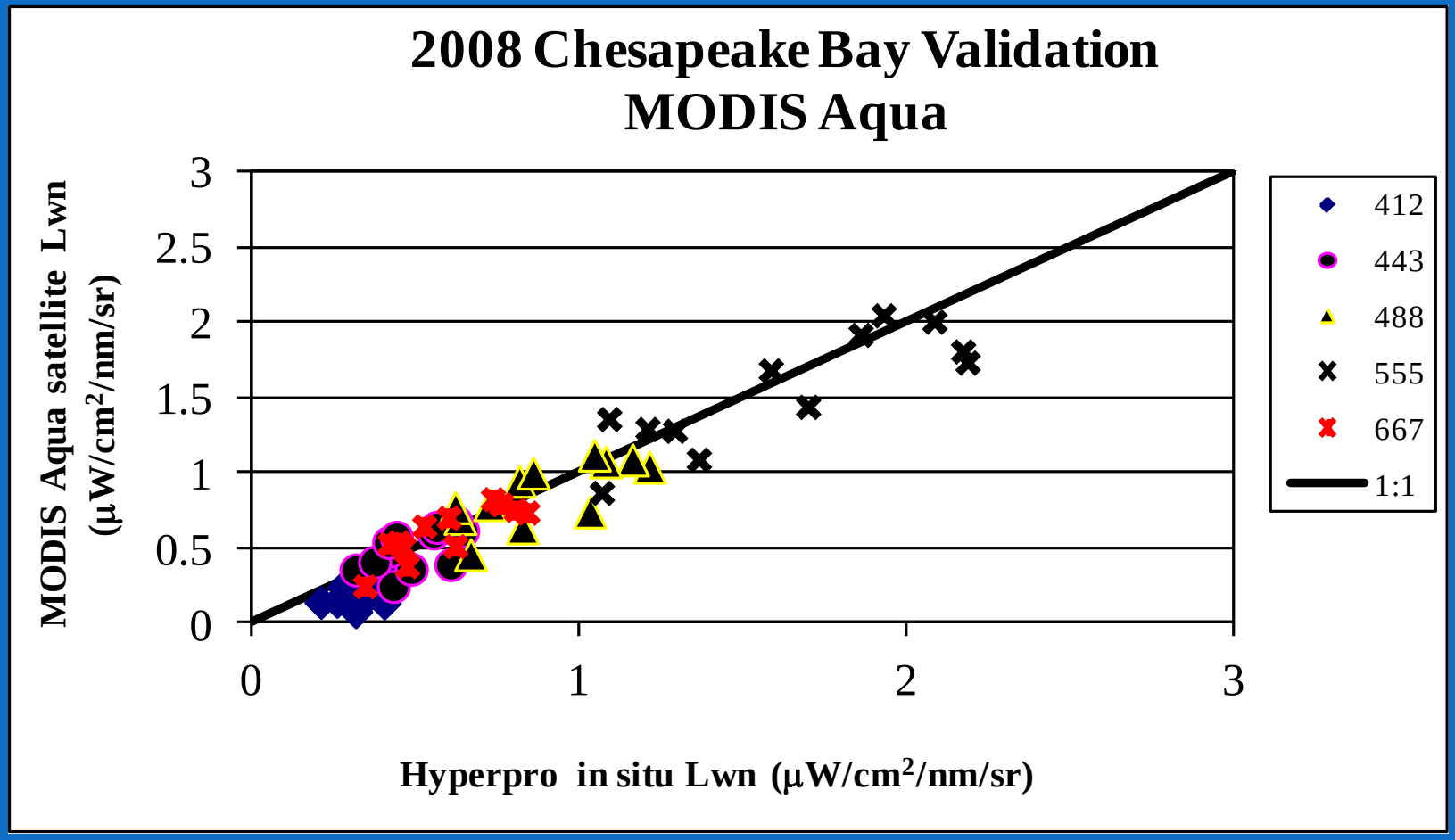




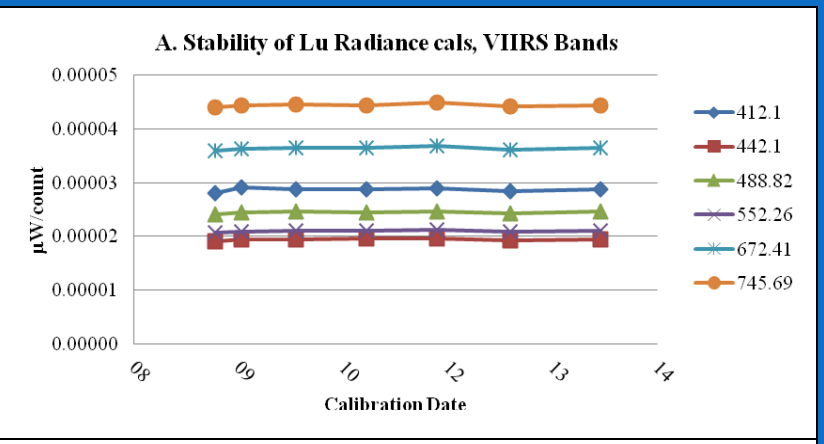
OUTLINE

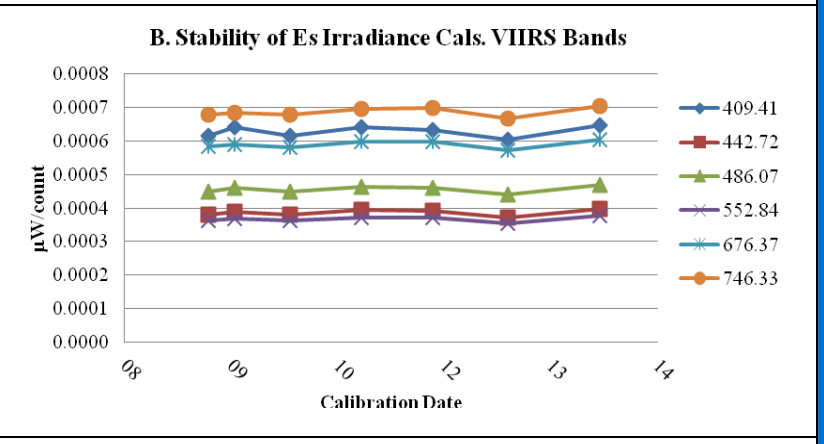
- Past validations
- Calibration stability
- Inter-calibrations
- Consistency between Hyperpros
- Matchups to MOBY and Boussole
- Comparison to above-water measurements
- Initialization and Validation of JPSS Suomi NPP VIIRS

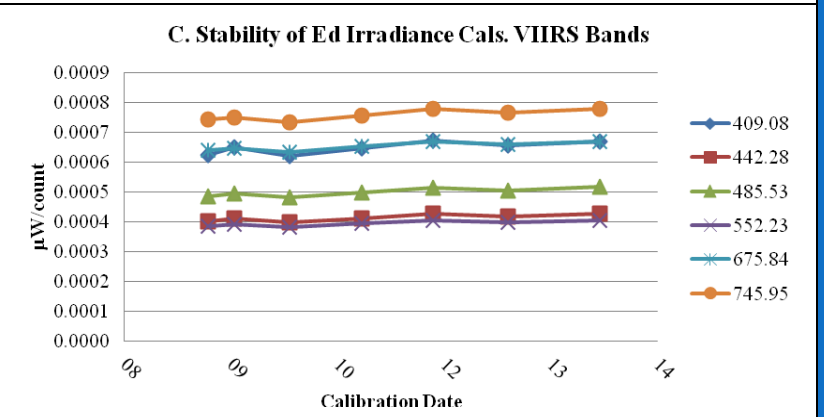
NOAA has been using a Hyperpro in-water radiometer to validate ocean color sensors and algorithm development since 2006



CALIBRATION STABILITY







nW/count

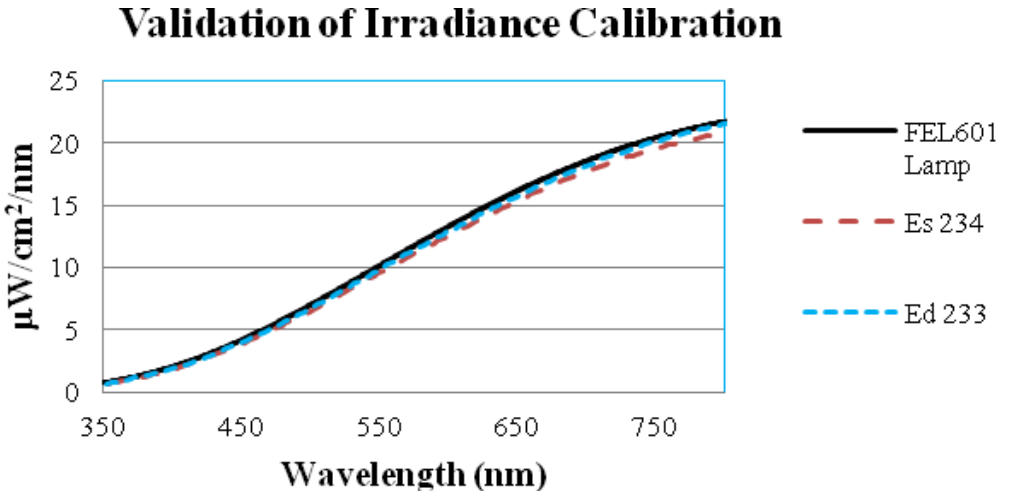
A. Lu	412.1	442.1	488.82	552.26	672.41	745.69
3/19/2009	0. 0281	0. 0191	0. 0240	0. 0207	0.0359	0. 0440
7/22/2009	0. 0291	0. 0195	0. 0245	0. 0209	0. 0363	0. 0443
4/7/2010	0. 0288	0. 0195	0. 0246	0. 0211	0. 0365	0. 0445
3/9/2011	0. 0289	0. 0196	0. 0246	0. 0210	0. 0364	0. 0443
2/9/2012	0. 0289	0. 0196	0. 0247	0. 0212	0. 0368	0. 0449
1/24/2013	0. 0284	0. 0193	0. 0242	0. 0208	0. 0361	0. 0441
3/31/2014	0. 0288	0. 0196	0. 0246	0. 0210	0. 0364	0. 0443
Average	0. 0287	0. 0194	0. 0245	0. 0210	0. 0364	0. 0443
Std Dev.	0. 0003	0. 0002	0. 0002	0. 0002	0. 0003	0. 0003

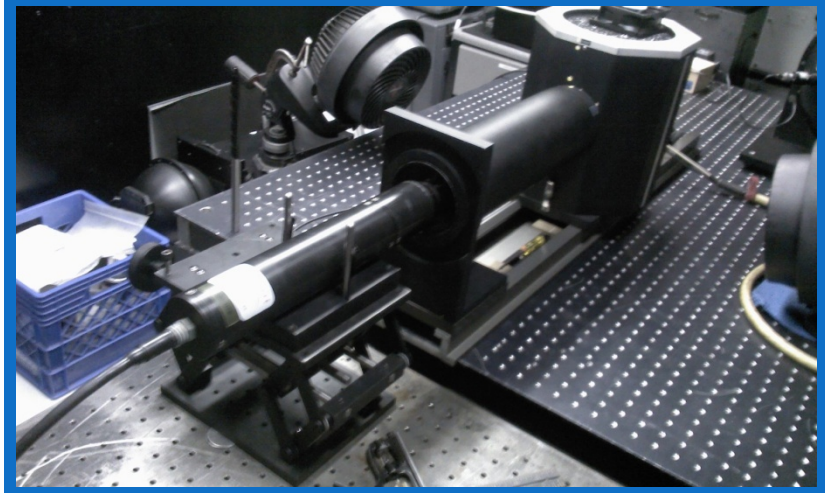
B. Es	409.41	442.72	486.07	552.84	676.37	746.33
3/19/2009	0. 616	0. 381	0. 450	0. 364	0. 583	0. 679
7/22/2009	0. 640	0. 390	0. 459	0. 368	0. 590	0. 685
4/7/2010	0. 614	0. 380	0. 450	0. 363	0. 581	0. 679
3/9/2011	0. 639	0. 393	0. 463	0. 372	0. 597	0. 694
2/9/2012	0. 632	0. 391	0. 461	0. 372	0. 598	0. 699
1/24/2013	0. 605	0. 373	0. 441	0. 355	0. 571	0. 667
3/31/2014	0. 647	0. 398	0.470	0. 377	0. 603	0. 703
Average	0. 628	0. 387	0. 456	0. 367	0. 589	0. 686
Std Dev.	0. 016	0. 009	0. 010	0. 007	0. 011	0. 013

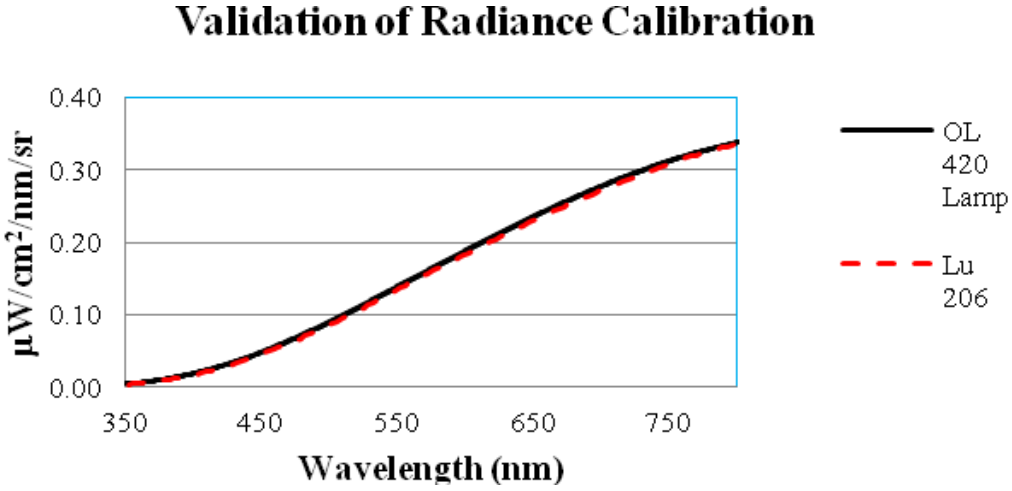
C. Ed	409.08	442.28	485.53	552.23	675.84	745.95
3/19/2009	0. 623	0. 400	0. 486	0. 386	0. 640	0. 744
7/22/2009	0. 649	0. 409	0. 496	0. 390	0. 647	0. 749
4/7/2010	0. 620	0. 397	0. 483	0. 383	0. 632	0. 735
3/9/2011	0. 646	0. 412	0. 499	0. 394	0. 653	0. 757
2/9/2012	0. 672	0. 426	0. 515	0. 405	0. 670	0. 779
1/24/2013	0. 655	0. 416	0. 504	0. 397	0. 659	0. 766
3/31/2014	0. 669	0. 426	0. 516	0. 405	0. 670	0. 777
Average	0. 644	0. 410	0. 497	0. 392	0. 648	0. 755
Std Dev.	0. 018	0. 010	0. 011	0. 008	0. 014	0. 016

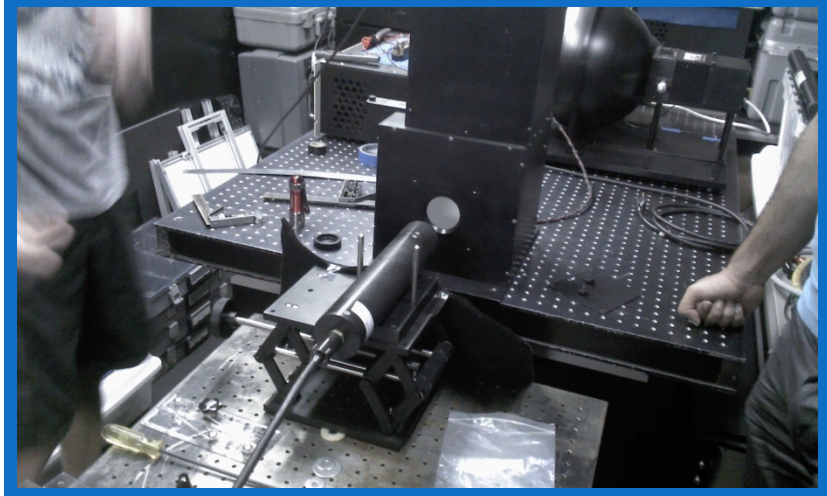
Validation of Calibration with MOBY Sources

MOBY CALIBRATION SOURCE 2/25/14



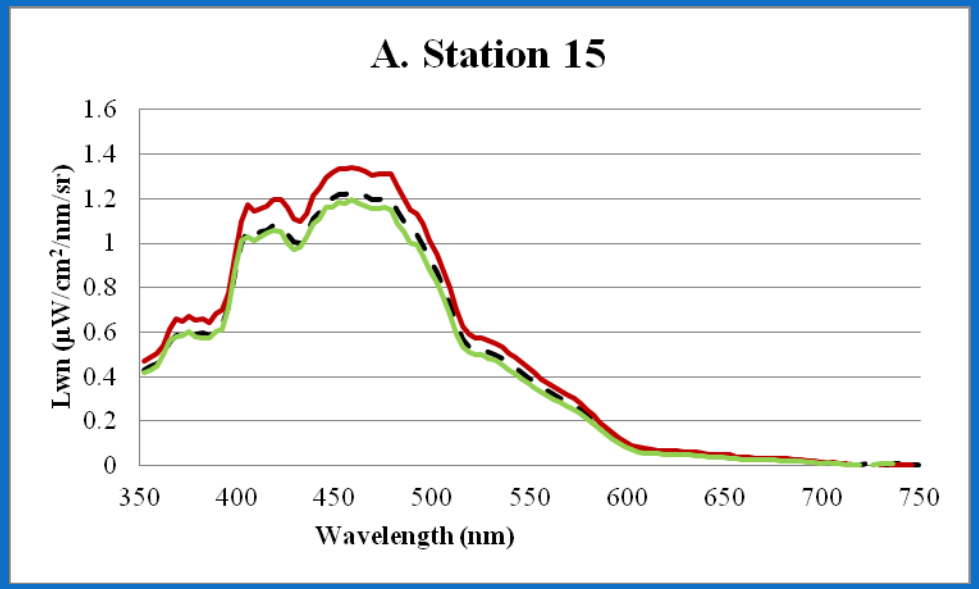




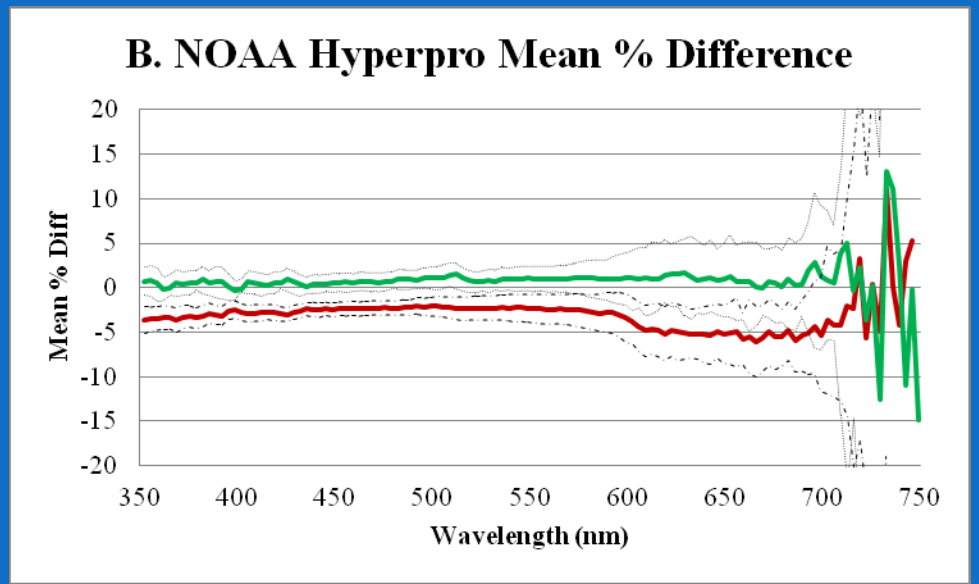


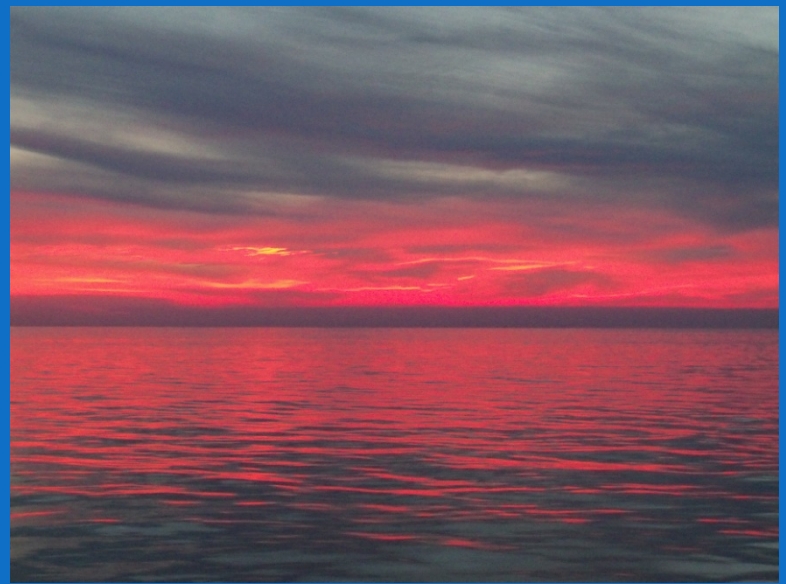
Consistency between Hyperpros, August, 2010 NATO Cruise, 41 Stations with 3 Simultaneous Hyperpro cast to assess variability between instruments.

Lwn plots from different Hyperpro profilers (NOAA dashed line)



Mean Percent Difference to NOAA Hyperpro

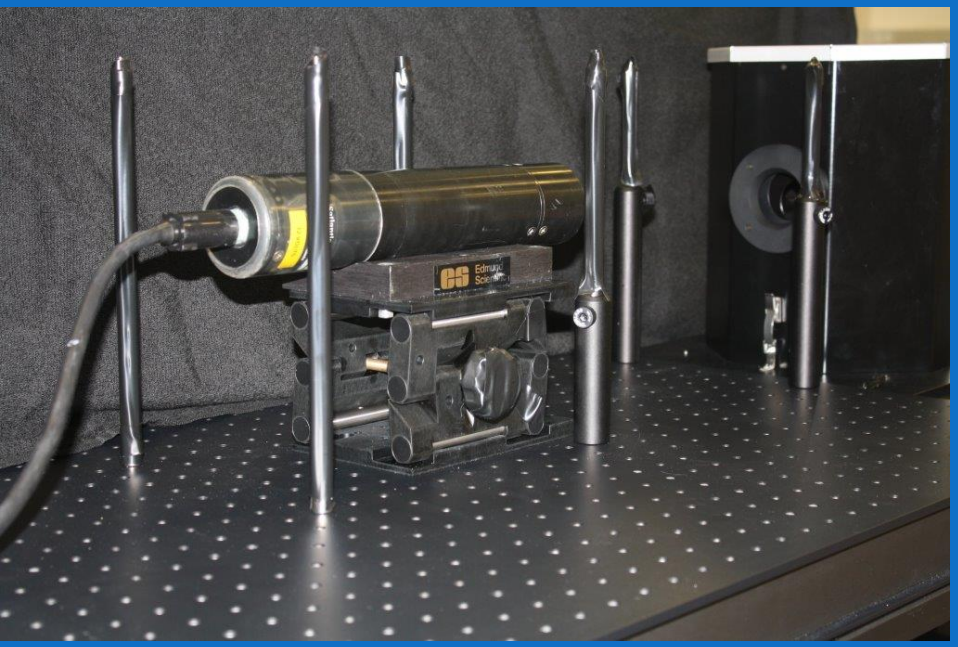




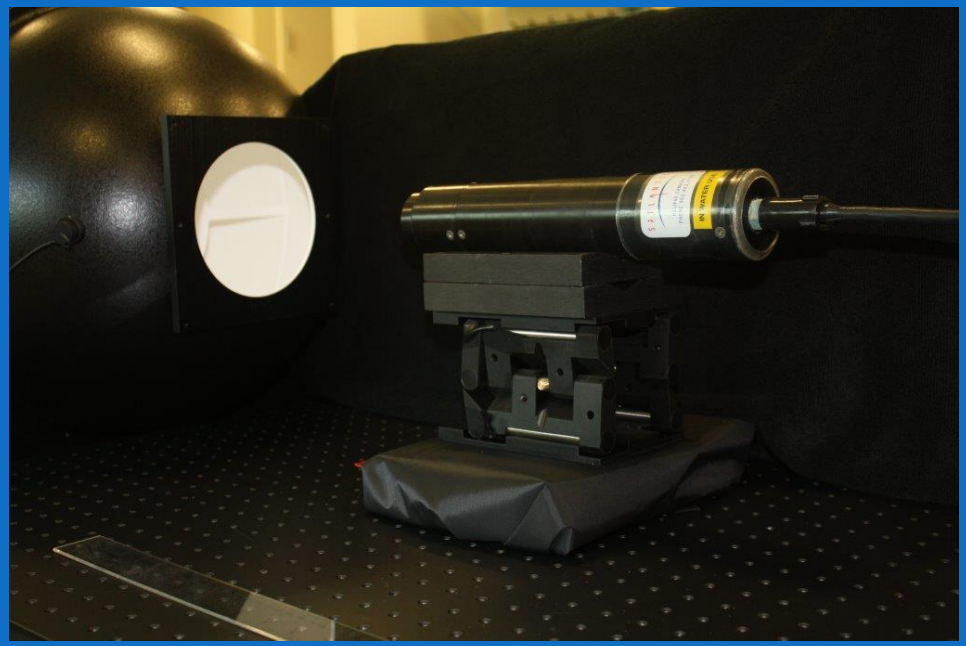
New calibration facility at NCWCP for optical calibrations.

- more frequent calibrations
- inter-calibration of team members.

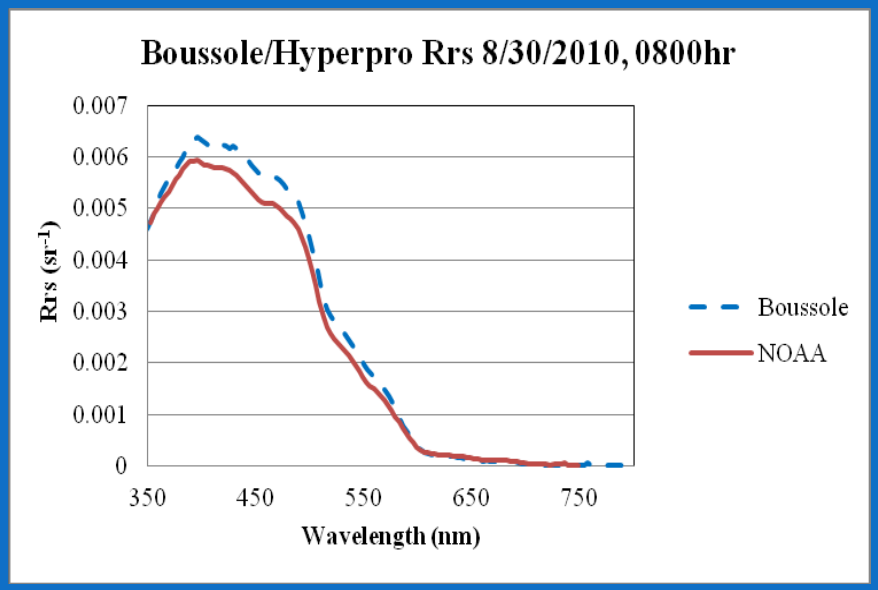
NIST Spectral Irradiance Standard with Gamma Sci. 5000 Housing

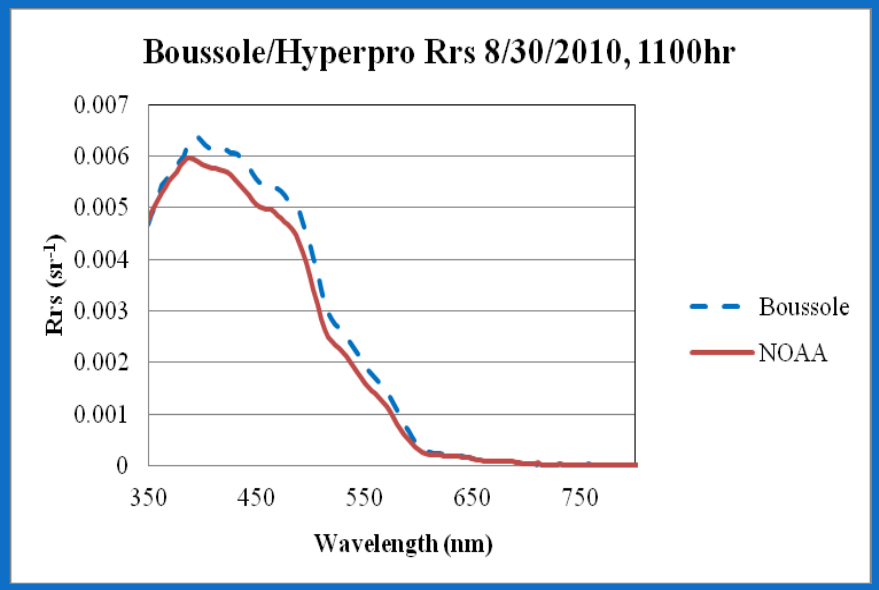


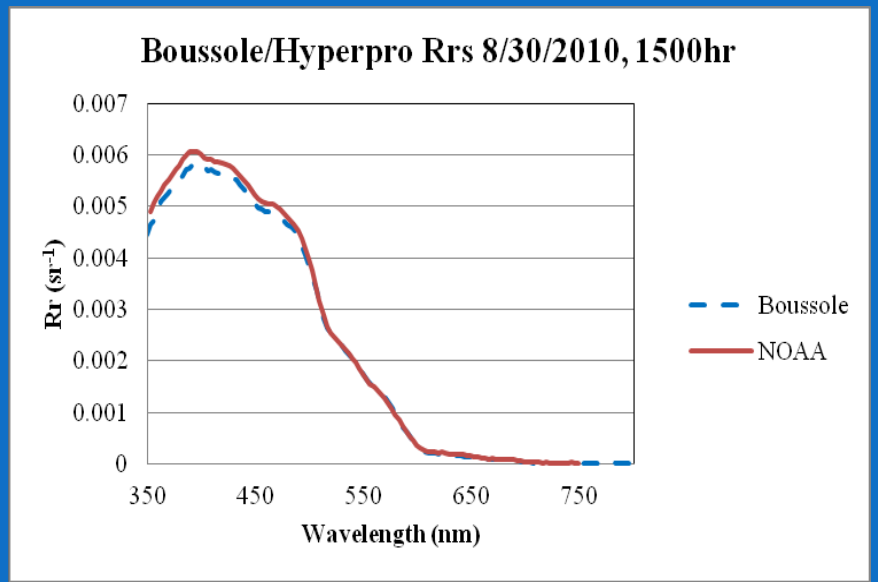
Gooch & Housego OL455 Integrating Sphere Radiance Calibration Source

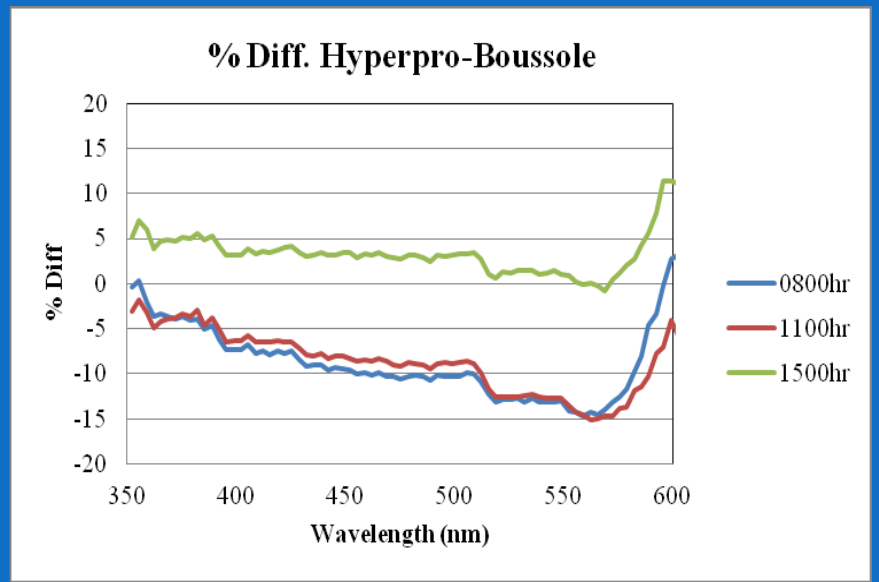


Remote Sensing Reflectances from simultaneous NOAA Hyperpro and Boussole Buoy measured during NATO Cruise, August 30, 2010

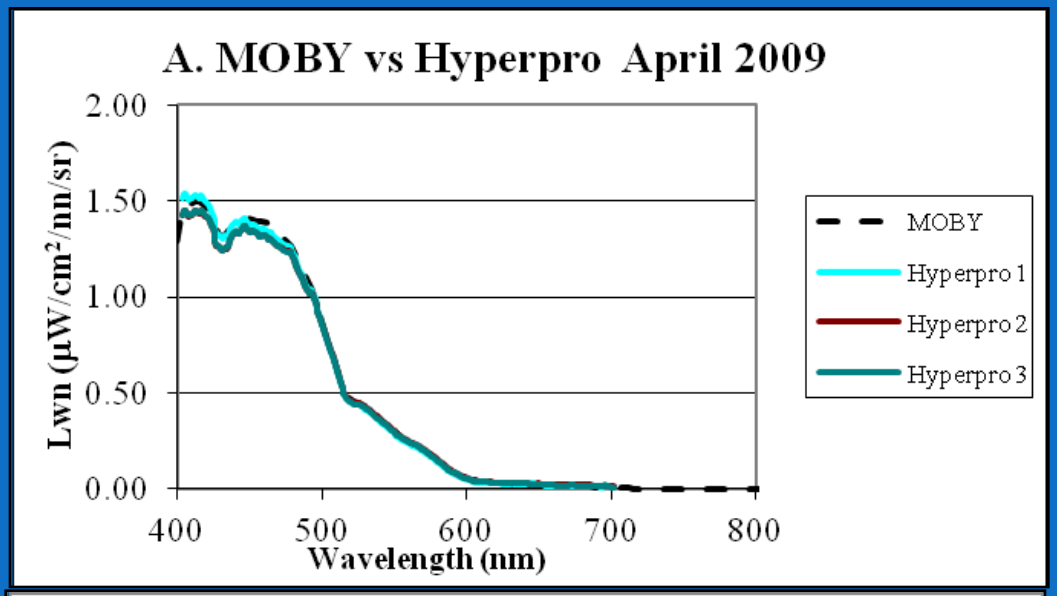


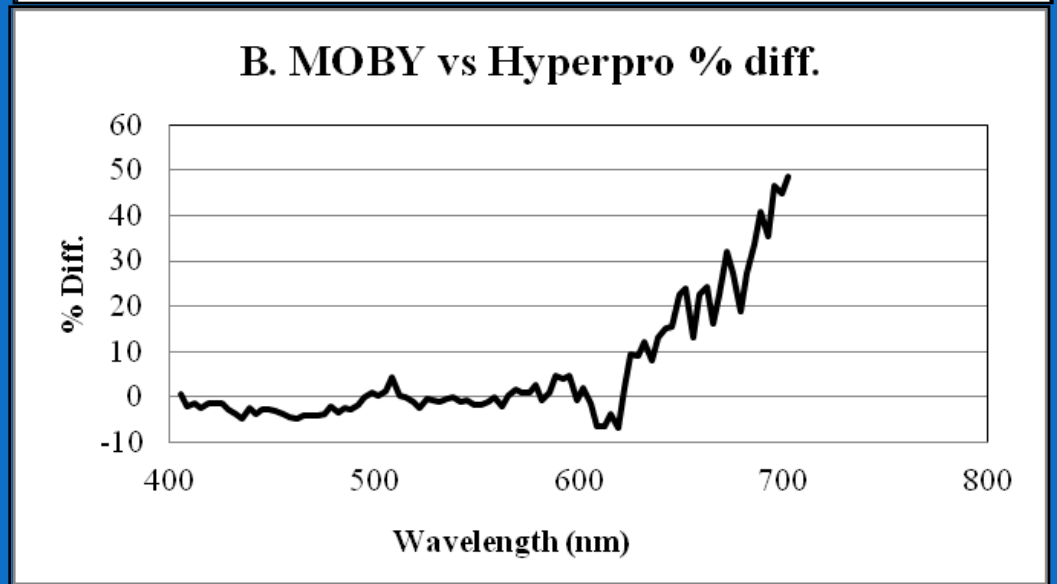


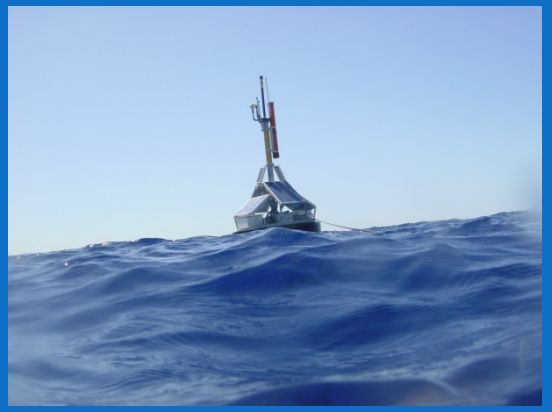




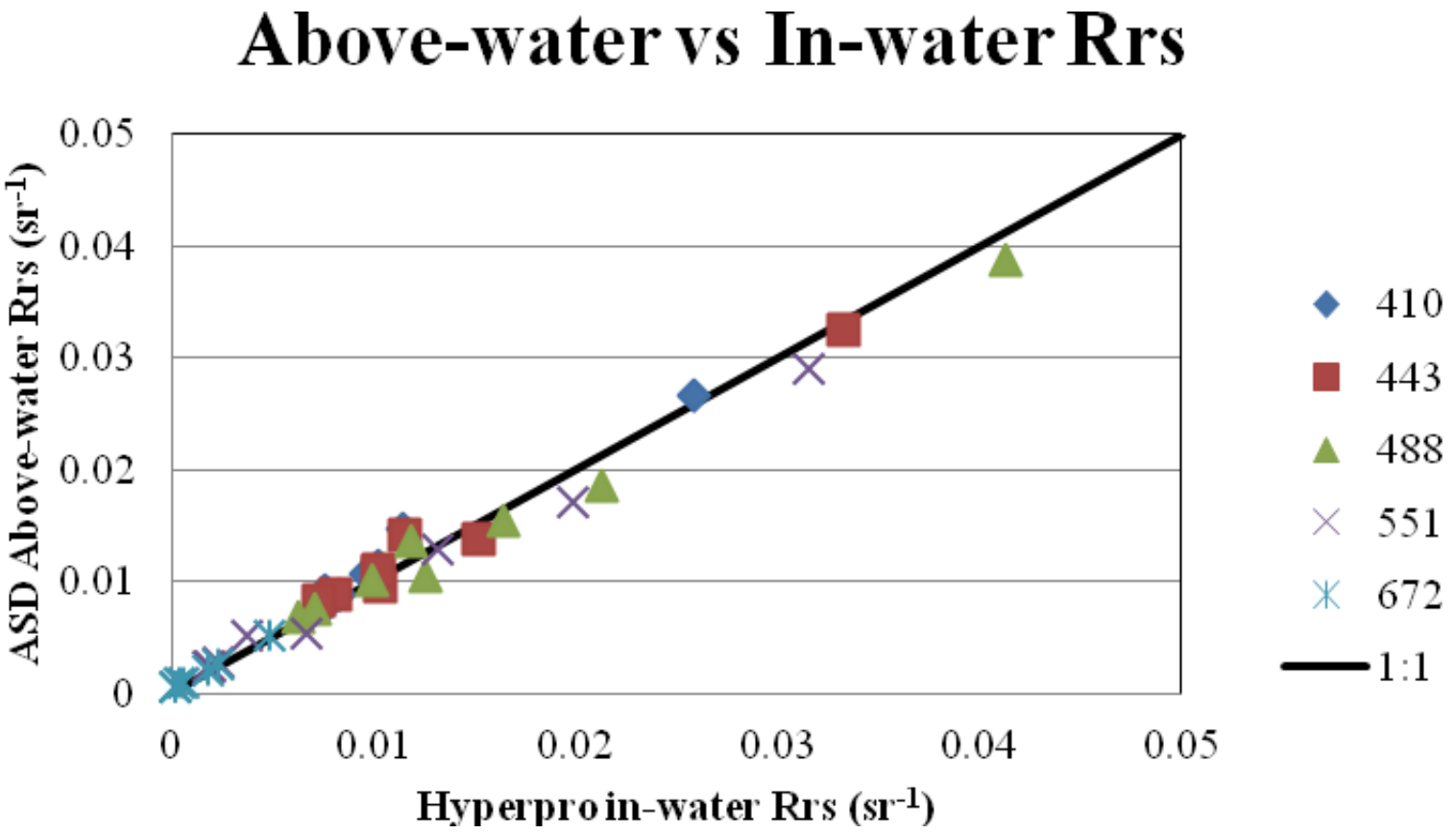
Normalized Water-Leaving Radiances and percent differences from simultaneous NOAA Hyperpro and MOBY Buoy measured during an April 2009 MOBY swapout cruise.



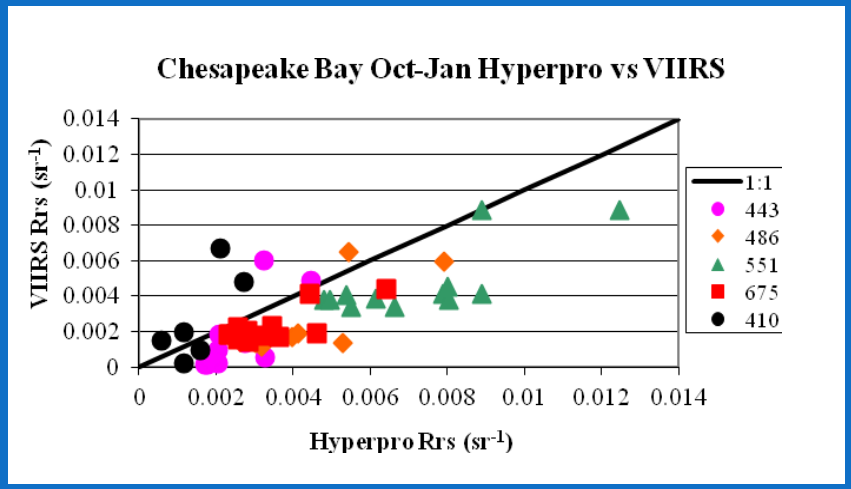




Remote Sensing Reflectance Comparison Between NOAA Hyperpro Profiler and ASD Handheld II above-water radiometer during March 2012 Florida Cruise

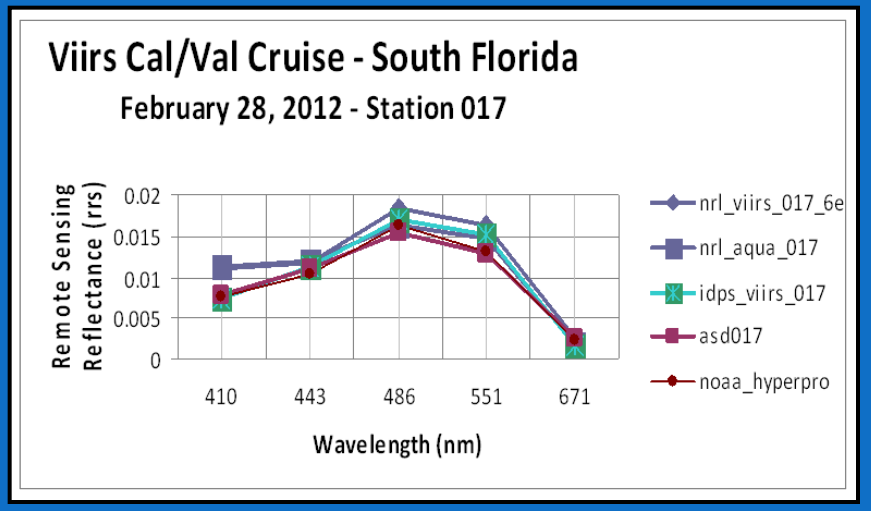


Chesapeake Bay VIIRS Ocean Color Validation: Conducted routine in-water Hyperpro and above-water ASD validation measurements in the Chesapeake Bay 12/1/11, 2/3/12, 3/27/12, 5/11/12, 7/3/12, 10/11/12, 11/2/12, 1/7/13, 1/10/13, 2/14/13, 2/15/13, 4/11/13, 5/1/13, 5/2/13, 5/3/13, 5/30/13, and 5/31/13, 6/21/13 , 7/30/13, 8/12/13, 8/13/13, 8/14/13, 8/15/13, 8/16/13, 8/19/13, 8/20/13, 8/21/13, 8/22/13, 9/25/13 on 10/11/13, 10/21/13, and 12/11/13
Total of 107 Stations in the Bay since Launch of VIIRS.



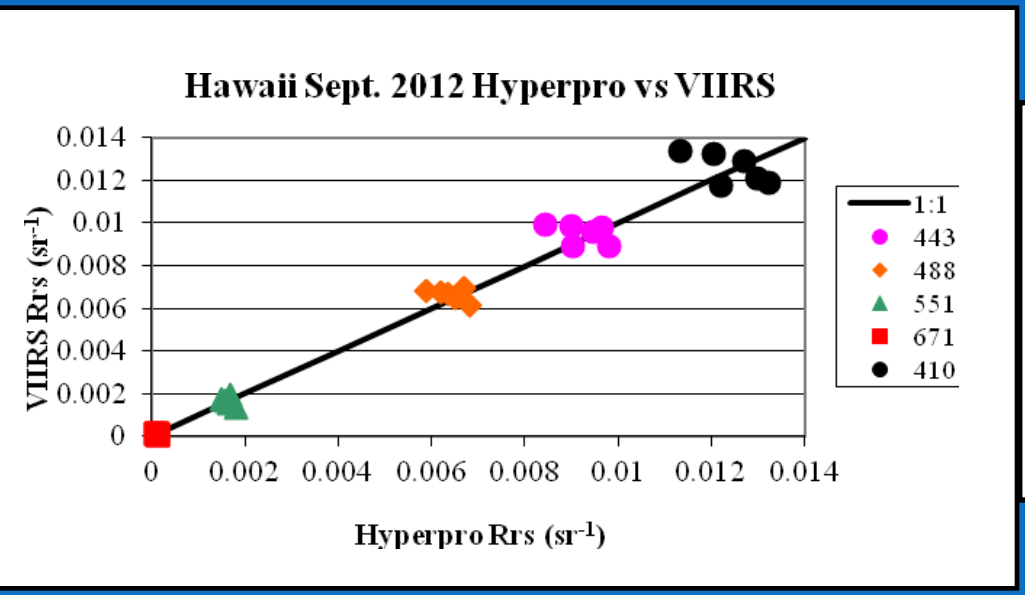
Band (nm)	Avg. % diff. Hyperpro – VIIRS Oct 12-Jan 13	Avg. % diff. Hyperpro – VIIRS Jun 13 - present
410	66	36
443	-50	-24
488	-46	-36
551	-35	-22
671	-33	-28
Average 443 to 671 nm	-41	-27

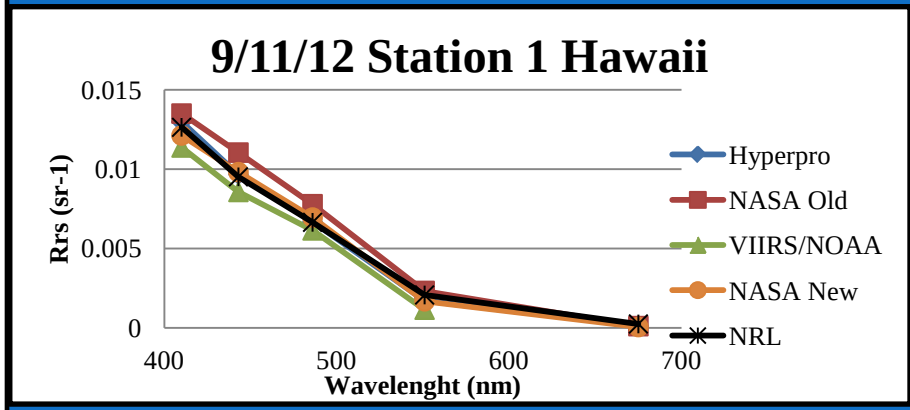
South Florida Cruise Feb. – Mar. 2012, 16 Hyperpro and ASD Validation Stations.



	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

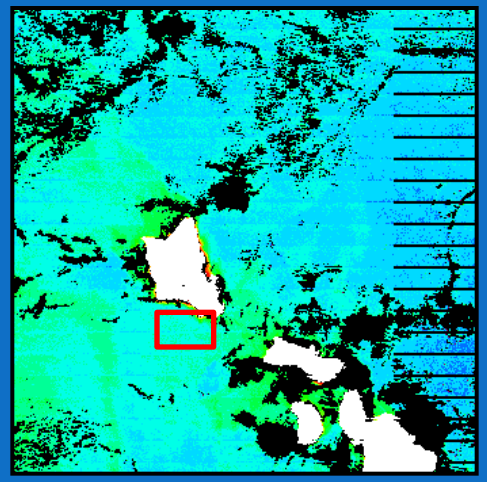
VIIRS validation using in situ Hyperpro measurements off Oahu, Hawaii collected in September, 2012 using NASA and NRL processings. The VIIRS data in the cross plot was processed using NASA data. 21 matchup stations.



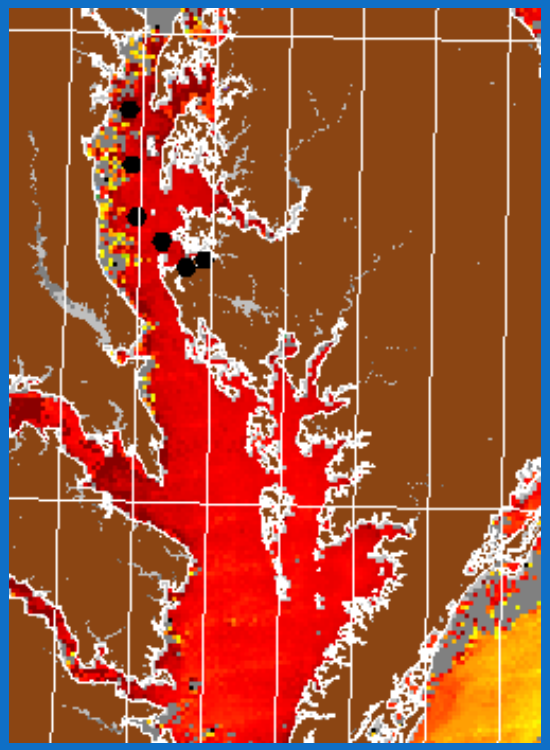


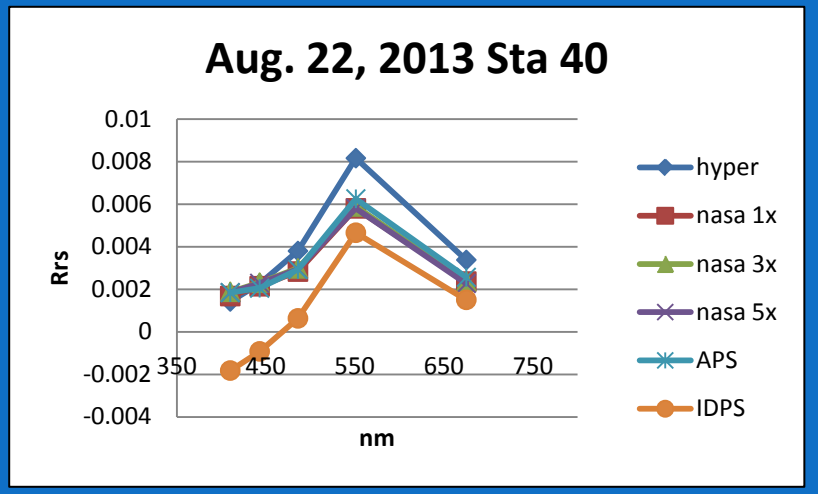
Band	% Diff Hyperpro – NASA	Std Dev of % Diff Hyperpro
410	1.50	3.48
443	3.18	1.05
488	3.93	3.38
551	1.40	36.27
671	-8.81	158.79
Average 410 to 551	2.50	11.05

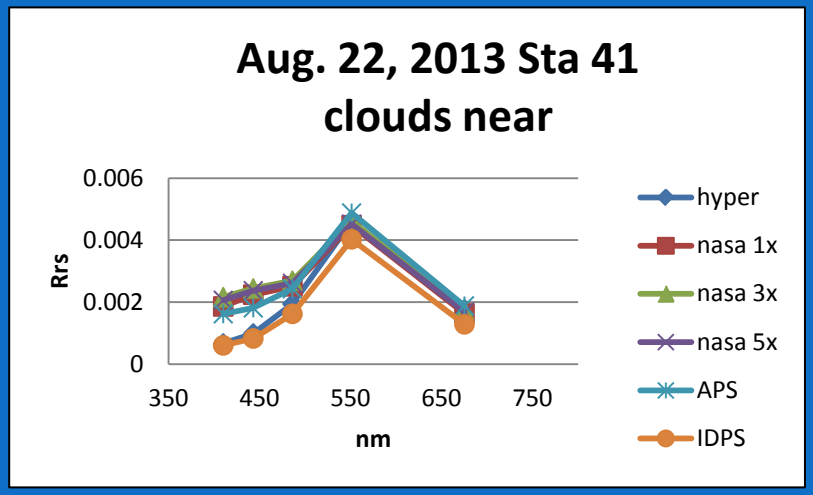
V2012256235456_chlor_a

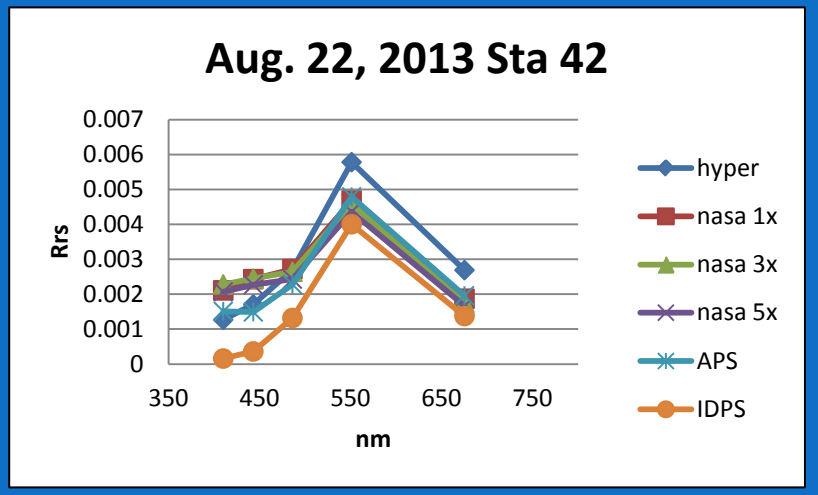


Two week, August 2013 Cruise with CUNY/CREST covering entire Chesapeake Bay. Shown, Day 234, transect up the bay. 42 Stations total

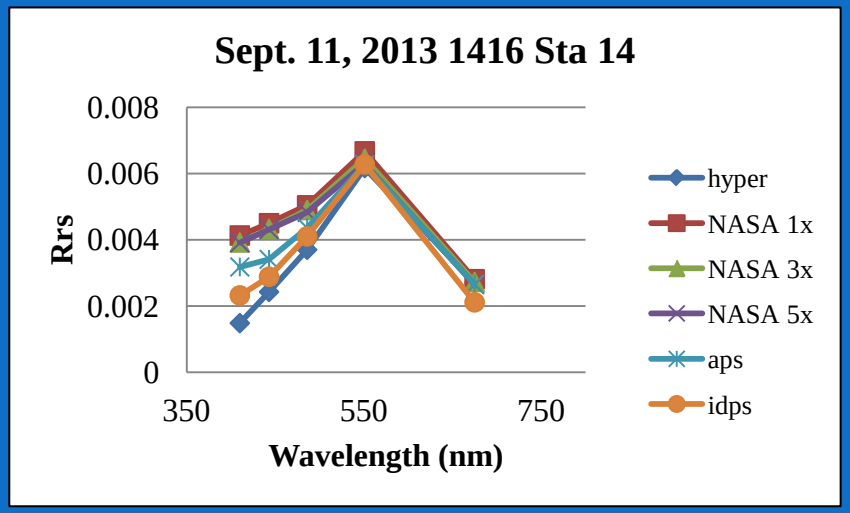


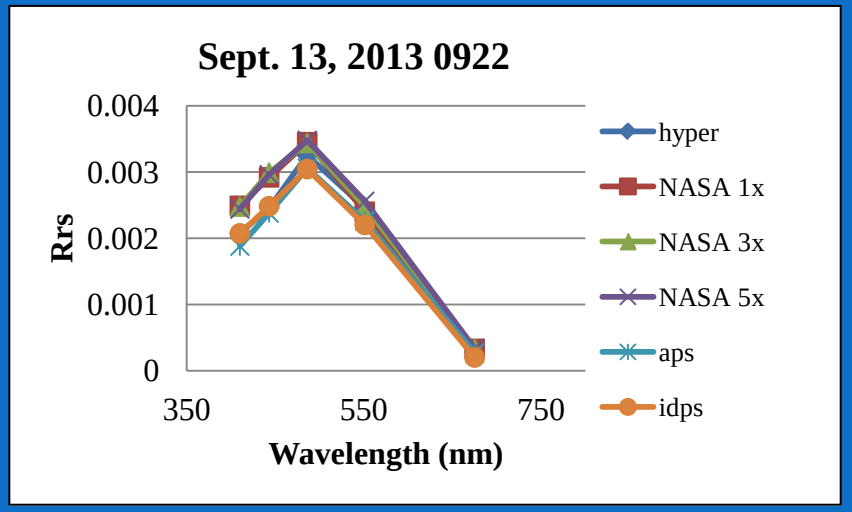


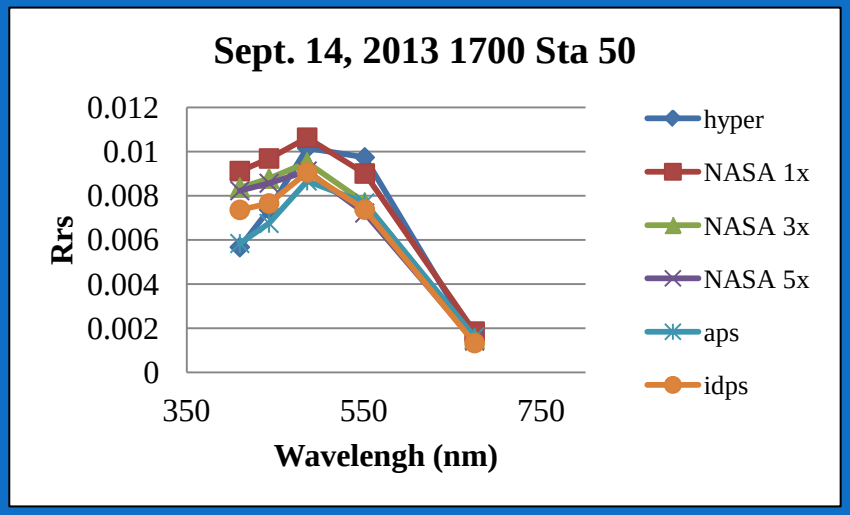


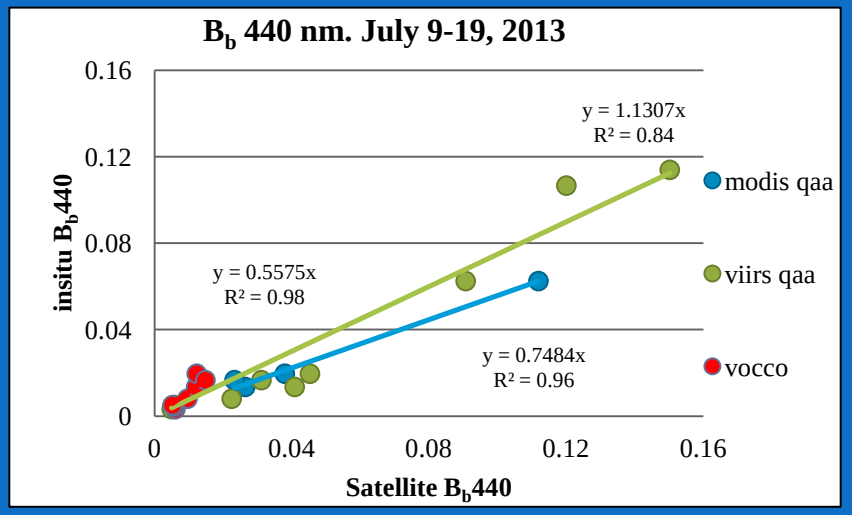


Sept. 2013 Geocape Cruise 112 Stations Rrs Data shown from 9/11, 13, and 14, 2013 and Ecopuc backscatter validations are show in bottom right.



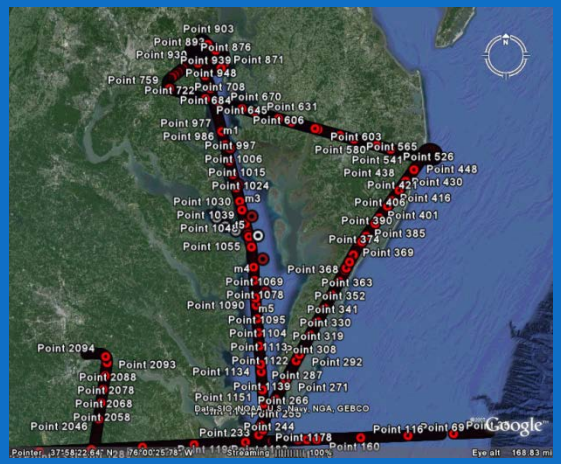




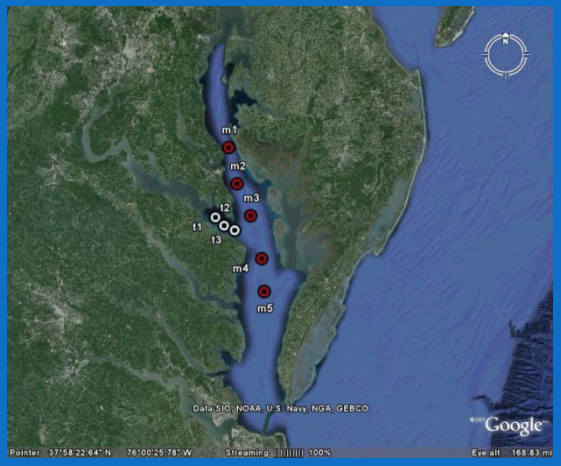


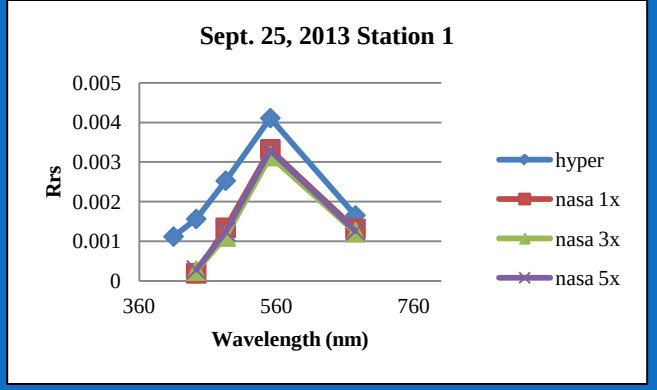
Sept. 25, 2013 VIIRS and *Multiple Altimeter Beam Experimental Lidar* (*MABEL*) Flyover Validations Locations, 5 Stations

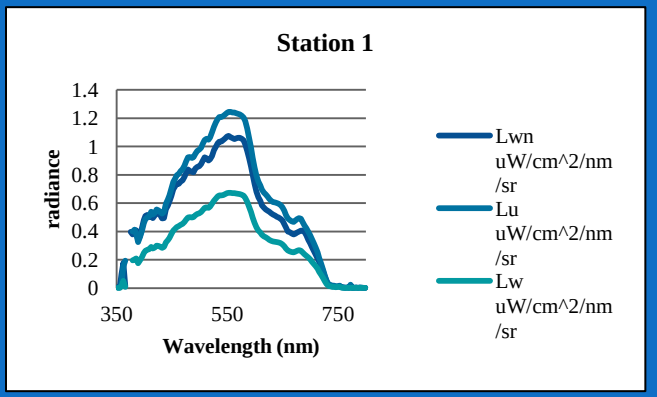
MABEL Track



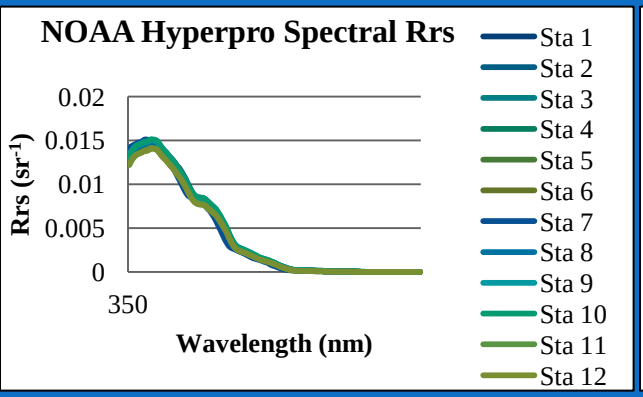
Validation Stations

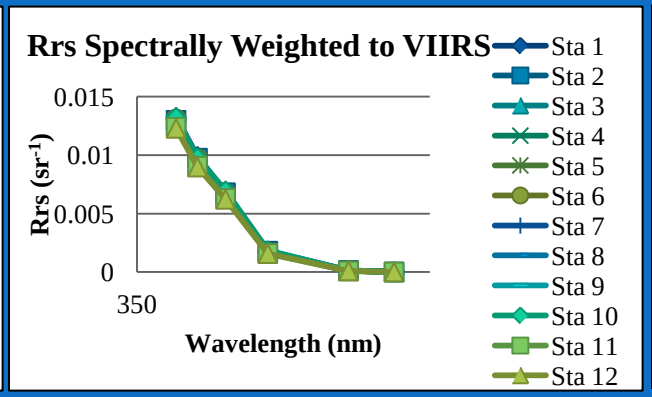


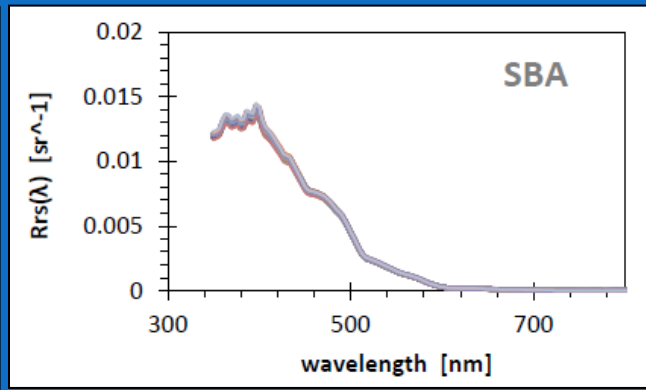




Blue water **VIIRS ocean color validation at MOBY** site in Hawaii. March 2 – 4, 2014: Conducted measurement comparisons between our Hyperpro, MOBY and Dr. Lee's (U. Mass) new skylight blocking radiometer at 12 stations.







VIIRS/Landsat 8/SBA validation cruise South of Puerto Rico May 3-5, 2014. 15 Stations

CONCLUSIONS

- With good calibration techniques and careful attention to protocols, Hyperpros can provide accurate traceable validation measurements for ocean color sensors
- Calibrations can be stable for years
- Repeatability and consistency between Hyperpros are very good
- Hyperpros matched MOBY and Boussole well
- Hyperpros compared well to above-water instrument
- Recommend frequent calibrations and inter-calibrations
- Recommend using new multi-cast method and Prosoft Version 8 for collecting and processing data