Temporal Assessment of the Calibration and Accuracy of VIIRS Radiometric (SDR) and Ocean Color Products (EDR) at MOBY (Standard Cal/Val Site) and WavCIS (Aeronet-OC)

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Sherwin D. Ladner[1], Robert Arnone[2], Paul Marinolich[3], Jennifer Bowers[3], Ryan Vandermeulen[2], Adam Lawson[1], Richard Crout[1]

(1) Naval Research Laboratory, Code 7330, Stennis Space Center, MS 39529 (USA), (228) 688-5754, Sherwin.Ladner@nrlssc.navy.mil (2) University of Southern Mississippi, Stennis Space Center, MS 39529 (USA) (3) Vencore, Inc., Stennis Space Center, MS 39529

I. Abstract

As part of the Joint Polar Satellite System (JPSS) Ocean Color Cal/Val Team, the group at Stennis Space Center (NRL/USM/Vencore Inc.) has been working to facilitate calibration and validation of the SUOMI NPP Visible Infrared Imaging Radiometer Suite (VIIRS) ocean color products at various *in situ* sites in coastal (Aeronet-OC/WavCIS) and offshore (Standard Cal/Val Site/MOBY) waters. In order to derive water leaving radiance (nLw) at operational processing centers, such as those of NOAA and Navy, the sensor must be well characterized and calibrated and the processing should adequately address the system atmospheric correction. The team has established matchup and vicarious calibration methods and procedures to adjust and monitor the accuracy of the retrieved ocean satellite products and to provide methods to improve product algorithms while characterizing uncertainty. Additionally, we look at recent changes in SDR calibration due to the delta-c implementation which occurred in May 2014. Vicarious calibration gains show that a Pre- and Post-delta-c calibration change exists at both cal/val sites. Results show that SNPP VIIRS radiometric calibration (SDR/unity gains) has improved over time but has not yet stabilized requiring continued calibration updates. We investigate temporal differences between VIIRS top-of-atmosphere (vicarious calibration), normalized water leaving radiance (nLw) and chlorophyll products as compared to the measured *in situ* response at both cal/val sites. Evaluations to date indicate that using the NOAA SDR with vicarious calibration provides high quality ocean optical products ready for operational use.

II. Objectives

- Establish matchup and vicarious calibration procedures to adjust, monitor and improve the accuracy of SNPP VIIRS retrieved ocean color properties at cal/val sites (MOBY-blue, WavCIS-coastal).
- Evaluate the temporal stability and trends of the SNPP VIIRS real-time SDR radiometric calibration (unity gains) at the MOBY blue water site.
- Investigate time series differences between SNPP VIIRS retrieved ocean color products versus measured at MOBY (blue water) and WavCIS (green water/coastal).
- Assess recent changes (May 2014) in SDR calibration due to delta-c implementation (pre and post) at MOBY and WavCIS.

III. Matchup and Vicarious Calibration Procedures

Matchup Criteria:

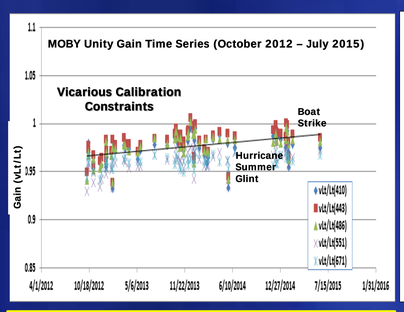
- Time constraint: within 3 hours of in situ measurement.
- Satellite was selected as a single pixel unless specifically noted otherwise.
- Removed satellite viewing angles above 56 degrees.
- Removed solar zenith angles above 70 degrees.
- Level 2 quality flags: ATMFAIL, NAVFAIL, CLDICE, LAND, HIGLINT, MODGLINT.

Vicarious Calibration Criteria:

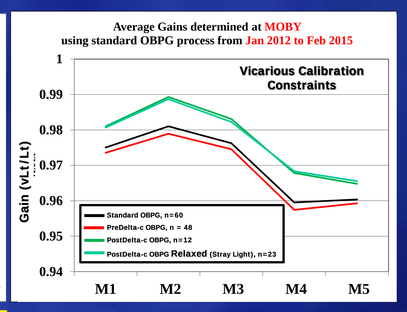
We employ a strict calibration quality screening, allowing only the ocean flag and restricting angles, etc. as defined by NASA OBPG methodology (Baliey et al 2008, Franz et al, 2007):

- The time window set to define coincident ± 3 hours
- *In situ* data are typically screened as follows:
  - exclude wind speeds > 8 m/s
  - set a maximum Aerosol Optical Thickness (AOT) = 0.2
  - set the minimum nLw value = 0
  - set the maximum nLw value = 3
- Satellite data can be screened as follows:
  - set the maximum Coefficient of Variance = 0.15
  - set the minimum percent valid pixel requirement to 100
  - set the satellite box size = single pixel, 9 km (3 km x3km AOI) or 25km (5 km x5 km AOI); MOBY=5x5, WavCIS=3x3
  - set the satellite zenith angle minimum = 0 and maximum = 56
  - set the solar zenith angle minimum = 0 and maximum = 70
  - set the satellite azimuthal angle minimum = -180 and maximum = 180
  - set the solar azimuthal angle minimum = -180 and maximum = 180
  - Omit satellite if Level 2 quality flags set: ATMFAIL, HILT(saturation), CLDICE, LOWNLW, LAND, HISATZEN, HISOLZEN, NAVFAIL, HIGLINT, STRAYLIGHT, MAXAERITER(NIR), HIPOL, and MODGLINT.

IV. Real-time SDR Temporal Radiometric Gain Trend & Delta-c Calibration Change (May 2014) Effect on Vicarious Calibration Gains

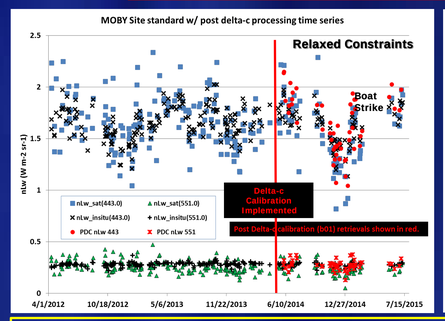


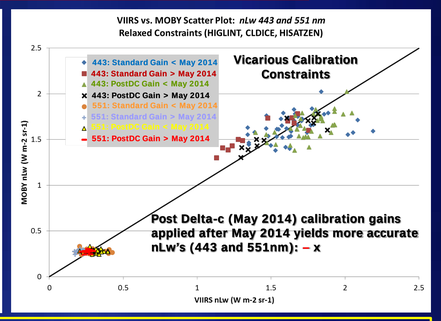
Trend in gains shows real-time SDR improvement over time and sensor calibration/drift is not stable over this time period. Continued monitoring and vicarious calibration needed if used for near-real-time operations. Seems that post delta-c SDR is stabilizing, under continuous evaluation.



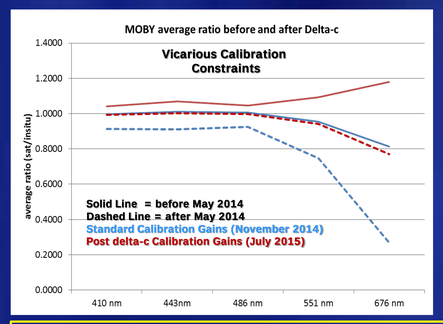
Vicarious calibration spectral gains derived using real-time SDR at MOBY shows that a pre and post delta-c (May 2014) calibration change exist. Will continue to monitoring and evaluation.

V. MOBY & WavCIS Time Series Uncertainty SDR Calibration Effect : Delta-c Assessment (May 2014 +)



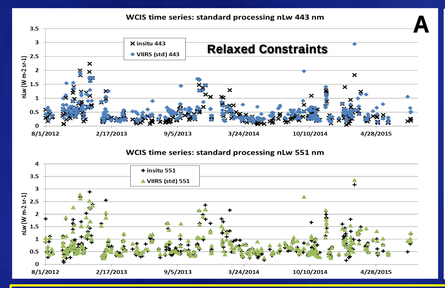


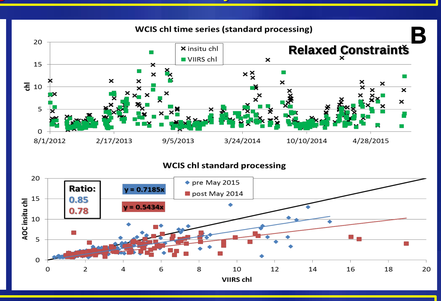
MOBY Matchups (Blue Water Site): Standard coefficients provide best nLw retrievals prior to delta-c implementation for both 443 & 551nm. Post Delta-c coefficients provide best retrieval after the real-time SDR Delta-c was implemented for both 443 and 551nm.



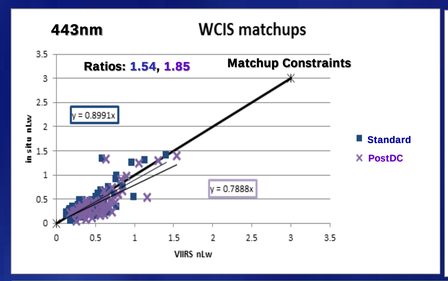
	MOBY nLw ratio (sat/insitu)	410 nm	443nm	486 nm	551 nm	676 nm
pre May 2014	Standard avg ratio	***0.9957***	***1.0108***	***1.0061***	***0.9541***	***0.8142***
	Standard avg ratio std	0.1262	0.1215	0.1185	0.2189	0.6737
	PostDC avg ratio	1.0409	1.0695	1.0449	1.0917	1.1792
	PostDC avg ratio stdev	0.0909	0.0834	0.0786	0.1551	0.5721
post May 2014	Standard avg ratio	0.9132	0.9104	0.9256	0.7476	0.2667
	Standard avg ratio stdev	0.0948	0.0754	0.0569	0.0864	0.3393
	PostDC avg ratio	***0.9928***	***1.0016***	***0.9965***	***0.9411***	***0.7703***
	PostDC ratio stdev	0.0870	0.0699	0.0579	0.0945	0.3972

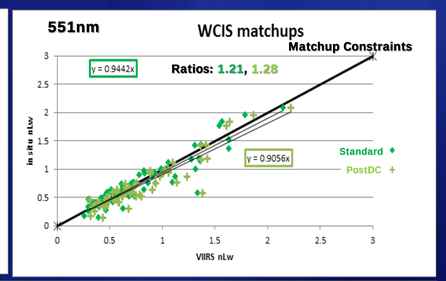
MOBY Stats (Blue Water Site: Standard calibration gain set works best prior to May 2014 (Delta-c Implementation) – Solid Line. Post Delta-c calibration gain set works better after May 2014 - Dashed Line.





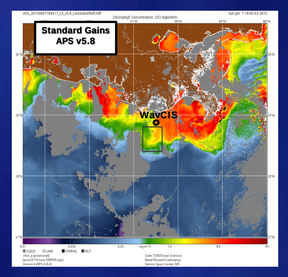
WavCIS Matchups (Green Water Site): (A) Figure shows time series matchups between WavCIS nLw 443 and 551nm and VIIRS standard gain processing. NLw's agree very well with more natural variability (coastal) and higher uncertainty and post delta-c (after May 2014) differences and improvements are inconclusive - see scatter plots below. (B) CHL time series matchup between WavCIS and VIIRS standard gain processing. Evaluation using standard gains (slopes: preDC: 0.72, postDC: 0.54) shows that VIIRS Chlorophyll estimates are worse/higher after May 2014 (post Delta-c implementation) compared to pre delta-c timeframe.

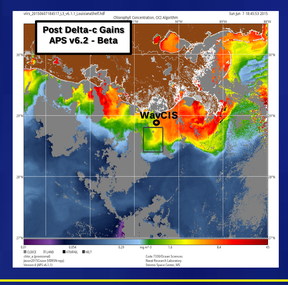


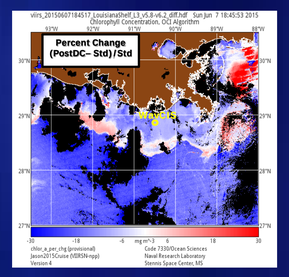


WavCIS Matchups (Green Water Site): Results for post delta-c analysis are preliminary and inconclusive. Greater natural variability in coastal waters seems to obscure/complicate this type (average ratio) of analysis. Comparisons between standard and post delta-c gain sets are very similar at WavCIS and post delta-c slopes (443nm & 551nm) are slightly lower and ratios are slightly higher. It is hard to say that post delta-c gains do not effect/improve nLw matchups. These matchups are unconstrained due to inadequate number of constrained matchups. Further evaluation is needed and will continue.

VIIRS Chlorophyll June 7, 2015 – Post Delta-c Calibration Effect

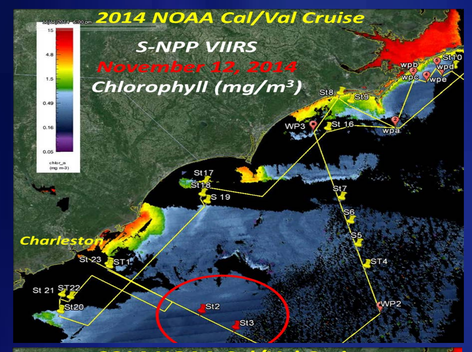


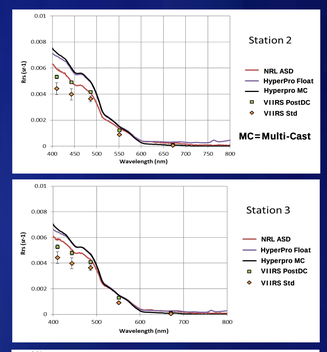


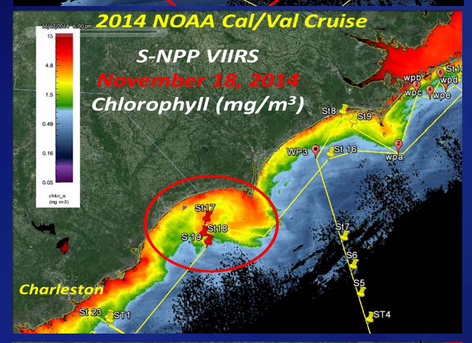


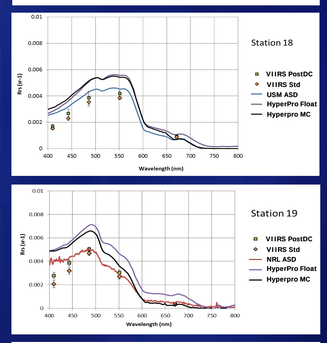
CHL image comparison and difference for VIIRS in Louisiana Bight / North Central Gulf of Mexico between standard and post delta-c gains show that the post delta c gains : (1) lower offshore CHL values up to 30%, (2) increase intermediate coastal/offshore plume boundary CHL values up to 15% and (3) lower coastal CHL values up to 10%.

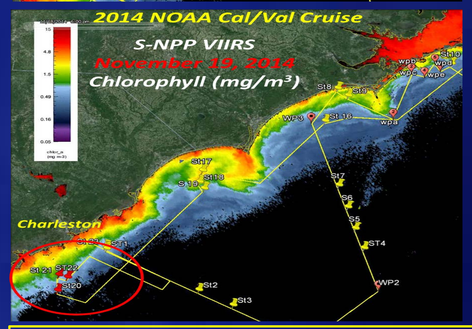
VI. Standard/Post Delta-c Gains Comparisons - Cruise Matchups

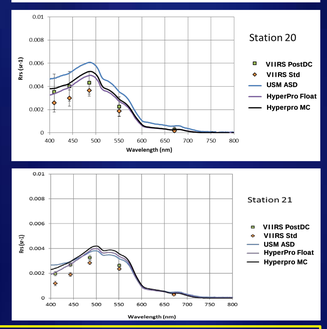






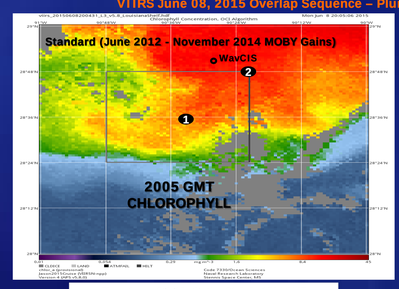


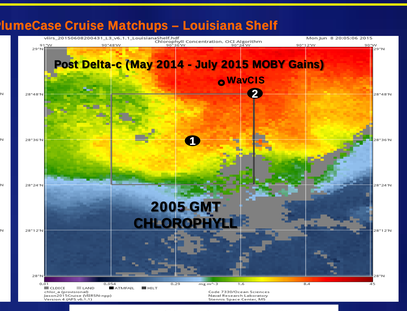


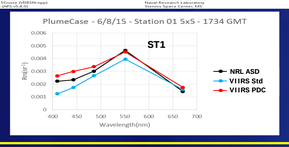


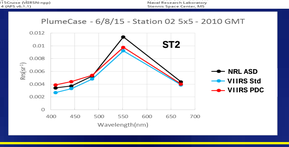
Figures show comparisons during the 2014 NOAA Cal/Val Cruise off the U.S. East Coast between VIIRS and *in situ* Rrs for the standard gain set (including pre and post delta-c vicarious calibration at MOBY – April 2012 to November 2014) and a post-delta-c gain set (May 2014 thru July 2015 at MOBY only). Initial results show that for multiple Rrs stations compared to VIIRS that delta-c gains improves spectral matchups in both offshore and nearshore waters off the U.S East Coast.

VIIRS June 08, 2015 Overlap Sequence – PlumeCase Cruise Matchups – Louisiana Shelf









Figures show comparisons during the 2015 ONR Basic Research "PlumeCase" Cruise off the Louisiana Coast in the North Central Gulf of Mexico between VIIRS and *in situ* Rrs for a standard gain set (pre and post delta-c matchups at MOBY) and a post-delta-c gain set (May 2014 thru July 2015). Initial results show matchups for multiple Rrs stations w/ VIIRS using delta-c gains improves matchups for most wavelengths in coastal waters (turbidity plume / high sediment).

VII. Summary

- Matchup and vicarious calibration criteria and procedures to adjust and monitor the accuracy of SNPP VIIRS retrieved ocean color properties at cal/val sites (MOBY-blue, WavCIS-coastal) were established (similar to NASA OBPG) and presented.
- NOAA Real-time SDR calibration has improved over time spectrally at standard cal/val site MOBY (gain closer to 1) and it seems that the sensor is stabilizing since SDR delta-c implementation. Need several (10+) more calibration quality matchups at MOBY to verify.
- SNPP VIIRS ocean color products match up very well at both blue (MOBY) and green/coastal water (WavCIS) and cal/val cruise sites indicating that using NOAA real-time SDR with continued vicarious calibration provides high quality operational ocean color products.
- Vicarious calibration gains and evaluation at MOBY indicate that a pre and post delta–c calibration change exist and using post delta-c calibration after May 2014 improves matchups. Post delta-c analysis at WavCIS is inconclusive and requires further evaluation with more high quality matchups due to higher coastal variability. Evaluation shows VIIRS chlorophyll estimates at WavCIS using standard gains are worse (higher) after post delta-c implementation.