OCEAN COLOR PRODUCTS VALIDATION AT NOAA COASTWATCH

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ABSTRACT

We discuss the validation activities of Ocean Color products Chlorophyll Concentration (Chlor_a) and water leaving radiances (nLw) using NPP-VIIRS data at NOAA CoastWatch. The current analysis is for the EDR products. Further, Level4 products like the daily Chlorophyll Anomaly is used by operational users for Harmful Algal Bloom monitoring. CoastWatch's role is to ensure that good quality VIIRS products comparable to heritage ocean color sensor products from MODIS and SeaWiFS are produced to meet the users' data continuity needs.

INTRODUCTION

Following the launch of the Suomi NPP satellite, CoastWatch has routinely processed the VIIRS NPP data in near real time [1] for two possible choices of the ocean color algorithms available to us initially, to produce Ocean Color products. One of them is the IDPS OC3V empirical algorithm and the other is CoastWatch's implementation of NASA Ocean Biology Processing Group (OBPG) L2gen algorithm, which is also currently being used for our heritage products from MODIS on Aqua and Terra and in the past for SeaWiFS and MERIS data streams. A third choice (NOAA-MSL12) has been recently made available for comparison and the results from this are presented here. For different algorithm streams, current experimental products (Chlor_a, nLw, Chlorophyll Anomaly) are produced for all CoastWatch regions for the Continental U.S. (CONUS) at full resolution, and additional Level-3 (L3) and Level-4 (L4) products are created for daily Global coverage at a reduced spatial resolution of 4km. In addition, global data at full native resolution, divided into 24 sectors, is being made available via a THREDDS server. The L3 and L4 global reduced resolution experimental products are distributed via our experimental data web server initially and later from the CoastWatch and OceanWatch web servers familiar to our current operational users when the products are declared operational.

VALIDATION METHOD

The QA approach includes comparison of VIIRS data with NASA MODIS climatology (2002-2010) as well as with NASA science quality delayed products from VIIRS. A user-driven stratification scheme bins Chlorophyll values into 3 ranges, 0.01 to 1.0 mg/L, 1.0 to 10.0 mg/L and 10.0 to 100.0 mg/L to demarcate coastal, near-coastal and open ocean waters. A second separate stratification method bins the Chlorophyll retrievals and water leaving radiances (nLw) by bathymetry into four bins with ranges between 0 to 50 meters, 50 to 100 meters, 100 to 500 meters and greater than 500 meters in depth. The comparison statistics for each of these classes as well as daily maps of comparisons for CoastWatch regions were created for visual inspection of algorithm discrepancies if any. The statistics from the daily analysis for each of the regions are then plotted using freely available JavaScript based dynamic web tools as a time series to look for trends and changes correlated with calibration updates made both at the sensor data record level (SDR) and environmental data record level (EDR), both upstream of CoastWatch processing. The primary CoastWatch regions under this study are the Gulf of Mexico and Hawaii region at the satellite's native resolution of 750m and a mapped Global product for Chlorophyll at 4km resolution. Ancillary analysis products use the daily Chlorophyll Anomaly (difference of daily values to seasonal values) to create a running 15-day composite to monitor the stability of the product in less productive waters like Hawaii. Daily scatter plots of inter-sensor comparisons for Chlorophyll are created routinely as well. The QA products also include histograms of the daily composites for Chlorophyll with corresponding statistics and a time

series of the statistical measures like mean, median and standard deviation for all pixels in each of the CoastWatch regions for the various algorithms [4].

RESULTS

We present results from the preliminary Quality Assessment of the L3 Ocean Color products (Chlor_a only) from VIIRS NPP addressing our operational end user requirements.

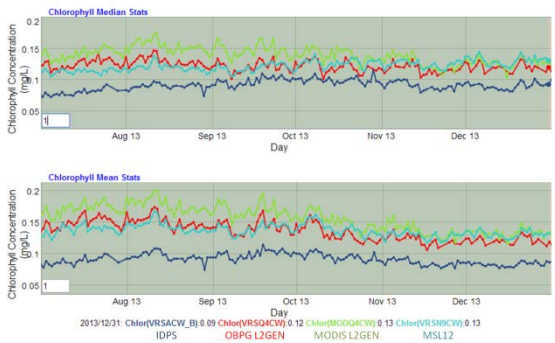

Figure 1 Inter-sensor plot of the median (top) and mean (bottom) values of the Daily Global composite at 4km resolution, Chlorophyll Concentration for various VIIRS algorithms and heritage MODIS Aqua.

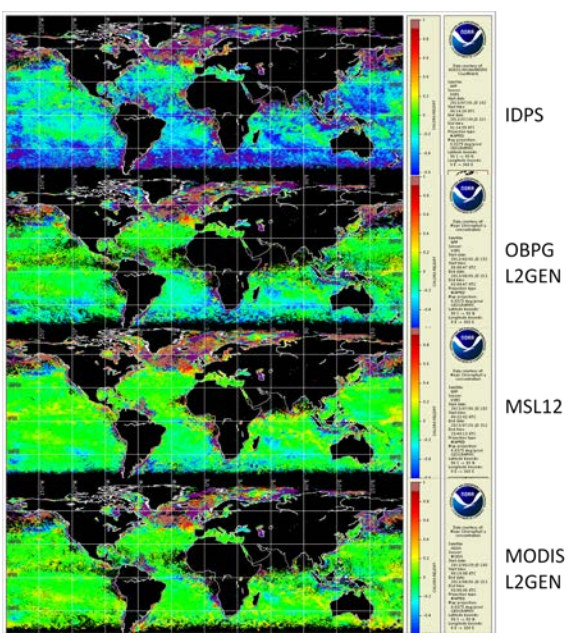

Figure 2 VIIRS Chlorophyll Monthly Relative Difference with MODIS Climatology (July 2013) shows that IDPS is severely undervalued for Global ocean latitudes 60^0 N-S. High latitudes pixels show larger differences in all cases.

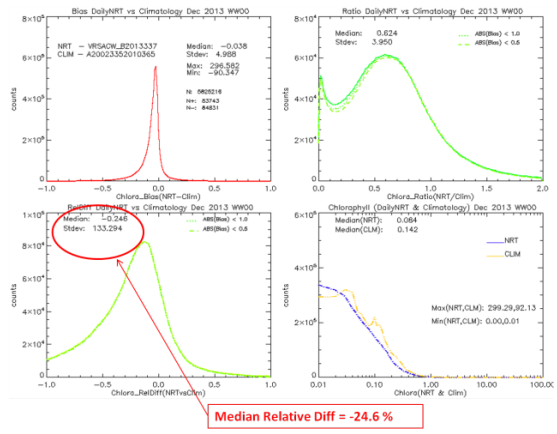

Figure 3 IDPS VIIRS Daily (12/03/2013) vs. Climatology Statistics (Bias, Ratio, Relative Difference histograms)

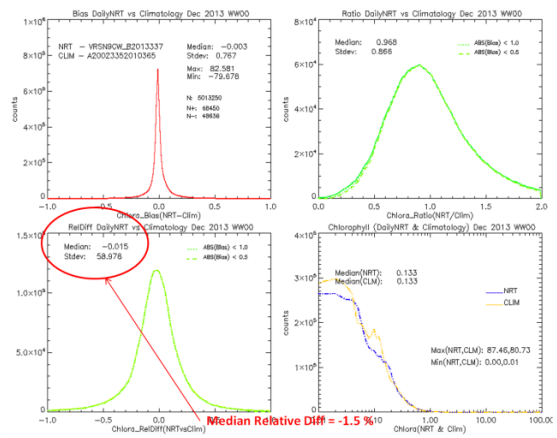

Figure 4 NOAA MSL12 VIIRS Daily (12/03/2013) vs. Climatology Statistics (Bias, Ratio, Relative Difference histograms). Note the relative difference is less at -1.5 %

Table 1 Monthly Median Relative Difference (%) with Climatology for Global (WW00)

Sensor Product	July	Aug	Sep	Oct	Nov	Dec
VRSACW(IDPS)	-33.7 %	-30.9 %	-28.0 %	-25.0 %	-25.0 %	-27.1 %
VRSQ4CW(NASA L2GEN)	-10.40 %	-11.10 %	-11.0 %	-9.20 %	-10.2 %	-10.1 %
VRSN9CW(MSL12)	-4.10 %	-3.10 %	-1.80 %	0.01 %	-0.10 %	-0.90 %
MODQ4CW(NASA)	-0.30 %	0.30 %	0.50 %	0.30 %	-1.3 %	-2.50 %

As part of the preliminary VIIRS inter-sensor comparison results, the time series plot (Figure 5) shows the Global, 7-day average, median chlorophyll relative difference (on a scale where 1 corresponds to 100%) for (1) VIIRS IDPS (VRSACW) EDR versus NASA VIIRS Science Quality (light green), and VIIRS IDPS EDR versus MODIS Climatology (deep blue), (2) NOAA MSL12 (VRSN9CW) versus NASA L2gen (dark green) and MODIS Climatology (purple), and (3) MODIS NASA (MODQ4CW)

versus Climatology (red) from July to December of 2013. After the vicarious calibration gains were applied, IDPS values for coastal pixels (water depth 0-50m) are 20% higher than NASA's VIIRS retrievals. IDPS retrieval values for Open Ocean (water depth > 500m) are 10% lower than NASA VIIRS for the time period studied. The difference with MODIS Climatology however is even more at –30%. NOAA MSL12 algorithm is within ~ 1-5 % of Climatology and does the best for all water depths. The summary statistics for all pixels by month is given in table 1 for the various choices of VIIRS algorithms and stratified by water depth. The average for the six months is given in table 2.

Table 2 Median Relative Difference (%) with Climatology for Global (WW00) stratified by water depth

Sensor Product	< 50m	50m to 100m	100m to 500m	>500m
VRSACW(IDPS)	-16.6%	-38.4%	-45.4%	-28.0%
VRSQ4CW(NASA)	-22.6%	-26.3%	-27.5%	-11.8%
VRSN9CW(MSL12)	**-0.05%**	**5.3%**	**2.30%**	**-2.0%**
MODQ4CW(NASA)	-17.5%	-17.5%	-14.0%	-0.80%

From the above Relative Difference statistics for Global Ocean stratified by water depth, shows that the NOAA MSL12 does much better than IDPS Chlorophyll when both are compared with MODIS Climatology as a common baseline. Even in shallow waters of depth less than a 100m, NOAA MSL12 is within a few percent whereas the IDPS Chlorophyll product is much lower for all water depths.

In addition to the Global 4km resolution products, we also compared the 750m CONUS products for two CoastWatch regions, Gulf of Mexico and Hawaii (GM05 & HI05) and the results of the analysis are summarized in the two tables (3 & 4) for the six months of data from July to December of 2013. They are consistent with what we already see for the Global analysis. From the time series plots in Fig. 6, NOAA MSL12 (VRSZ9CW) has the smallest relative error when compared to MODIS climatology values. The IDPS VIIRS product (in blue) has the largest deviation from climatology values for water depths greater than 500m. Even for shallow waters, the time series shows that NOAA MSL12 does better than other alternatives for VIIRS and is comparable to the MODIS SWIR (MODWCW) product currently in operations.

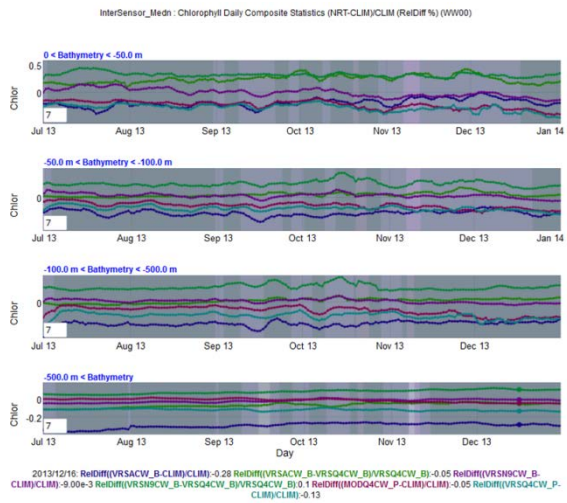

Figure 5 Median Relative Difference (%) for Global (WW00) Chlorophyll stratified by water depth. The relative difference is calculated both with MODIS Climatology as well as NASA OBPG science quality products

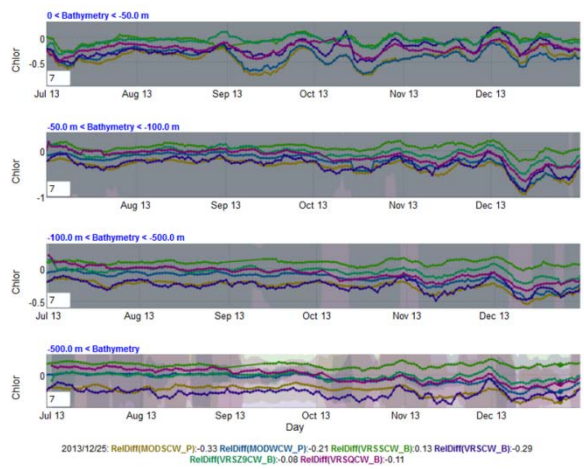

Figure 6 CONUS region (GM05) Median Relative Difference (%) of Chlorophyll stratified for four different water depths.

Table 3 Median Relative Difference (%) with Climatology for CONUS (Gulf of Mexico) Stratified by water depth

Sensor Product	< 50m	50m to 100m	100m to 500m	>500m
VRSCW(IDPS)	-22.00%	-27.00%	-24.70%	-21.10%
VRSSCW (NOAA)	-2.35%	7.45%	10.20%	13.40%
VRSQCW(NASA)	-21.20%	-6.60%	-5.00%	1.55%
VRSZ9CW(MSL12)	**-5.05%**	**-3.90%**	**-2.40%**	**-0.80%**
MODSCW(NOAA)	-37.30%	-29.70%	-23.90%	-17.90%
MODWCW(NOAA)	-35.70%	-15.50%	-11.90%	2.10%

The operational MODIS NOAA L2gen (MODSCW) product has a slightly higher relative error due to a well known issue, collection5 L1B calibration being out of sync with the L2gen processing software. For the CONUS region (GM05) stratified by Chlorophyll values as shown in Fig 7, the relative difference is the least in the case of the NOAA MSL12 Chlorophyll product when compared to climatology for values within the range [0.01, 1.0] mg/L.

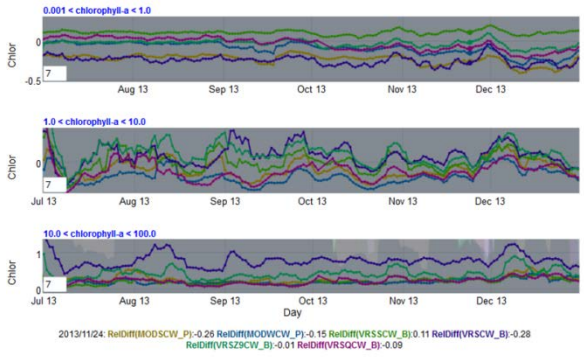

Figure 7 Median Relative Difference (%) of Chlorophyll with MODIS Climatology for CONUS region GM05 for three different Chlorophyll ranges. Product legends are ***[VIIRS: IDPS (VRSCW-blue), NOAA l2gen (VRSSCW-light green) NOAA-MSL12 (VRSZ9CW-dark green), NASA-L2gen (VRSQCW-purple); MODIS: NOAA L2gen (MODSCW-Yellow); NOAA MSL12-SWIR (MODWCW-cyan)]***

For the high values range, IDPS product does poorly and is > 50% for the relative difference. For this high range all products are around 20% or more than the climatology values as seen in the summary table 4 for the six months of data analyzed so far. The NOAA MSL12 algorithm does relatively well (~3% difference) even in the moderate chlorophyll regime for the Gulf of Mexico, even with a relaxed masking (only HIGLINT, CLDICE, HISATZEN) applied to ocean pixels compared to the NASA L2gen product.

Table 4 Median Relative Difference (%) compared with MODIS Climatology for CONUS (Gulf of Mexico) stratified by Chlorophyll values

Sensor Product	0.01 < chlor < 1.0	1.0 < chlor < 10.0	10.0 < chlor < 100
VRSCW(IDPS)	-23.00%	2.00%	74.00%
VRSSCW (NOAA)	11.00%	-5.50%	19.00%
VRSQCW(NASA)	-1.00%	-18.00%	20.50%
VRSZ9CW(MSL12)	**-2.00%**	**3.00%**	**35.00%**
MODSCW(NOAA)	-22.00%	-15.0%	22.00%
MODWCW(NOAA)	-7.00%	-22.0%	19.00%

SUMMARY

The goals set for this analysis were to provide a final recommendation from NOAA CoastWatch to implement the best algorithm choice to run in operations at NOAA following the inclusion of the third choice of algorithms (NOAA MSL12) to this comparison set. The results from the six month study period from 2013, suggest that the NOAA-MSL12 product performs better and is within acceptable uncertainties [2, 3] for operational use than the other alternatives considered here, the IDPS and l2gen for Open Ocean as well as coastal waters, and hence has been selected by JPSS to be promoted to operations at NOAA.

ACKNOWLEDGEMENT

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REFERENCES:

[1] K. Hughes, H. Gu, P. Keegstra, Y. S. Kim, S. Ramachandran, M. Soracco, R. Vogel (2013), "VIIRS NPP Ocean Color Products at NOAA CoastWatch - A First Look", *NOAA 2013 Satellite Conference, College Park, MD*.

[2] S. Ramachandran, M. Wang (2011), "Near-Real-Time Ocean Color Data Processing Using Ancillary Data from the Global Forecast System Model", *IEEE Trans. Geosci. Remote Sens.*, vol. 49, no. 4, DOI:10.1109/TGRS.2010.2078825

[3] Joint Polar Satellite System (JPSS) Program L1 Requirements document, JPSS-REQ-1002, Version 2.9, Jun 27, 2013

[4] CoastWatch Ocean Color Quality Assessment webpage, http://www.star.nesdis.noaa.gov/sod/mecb/coastwatch/NRT-QA/OC-QA-CW.html