The Importance of FRM in Ocean Color Satellite Data Validation for NOAA

Menghua Wang & Ocean Color EDR and Cal/Val Teams

NOAA/NESDIS Center for Satellite Applications and Research (STAR)
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College Park, MD 20740, USA

The FRM4SOC Workshop
National Physical Laboratory, London, UK, October 4-5, 2018

Website for VIIRS ocean color images and Cal/Val:
http://www.star.nesdis.noaa.gov/sod/mecb/color/

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## VIIRS Ocean Color EDR & Cal/Val Teams

<table>
<thead>
<tr>
<th>EDR</th>
<th>Name</th>
<th>Organization</th>
<th>Funding Agency</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean Color</td>
<td>Robert Arnone, Sherwin Ladner, Adam Lawson, Jen Bowers</td>
<td>U. Southern MS, NRL, QinetiQ Corp., SDSU</td>
<td>JPSS/NJO</td>
<td>Satellite matchup tool (SAVANT) – Golden Regions, Cruise participation and support WAVE_CIS (AERONET-OC site) operation</td>
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<tr>
<td></td>
<td>Carol Johnson</td>
<td>NIST</td>
<td>JPSS/NJO</td>
<td>Traceability, AERONET Uncertainty</td>
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<tr>
<td></td>
<td>Nicholas Tufillaro, Curt Davis</td>
<td>OSU</td>
<td>JPSS/NJO</td>
<td>Ocean color validation, Cruise data matchup West Coast</td>
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<tr>
<td></td>
<td>Burt Jones, Matthew Ragan</td>
<td>USC</td>
<td>JPSS/NJO</td>
<td>Eureka (AERONET Site)</td>
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<td></td>
<td>Alex Gilerson, Sam Ahmed</td>
<td>CUNY</td>
<td>JPSS/NJO</td>
<td>LISCO (AERONET site), Cruise data and matchup</td>
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<tr>
<td></td>
<td>Chuanmin Hu</td>
<td>USF</td>
<td>JPSS/NJO</td>
<td>NOAA data continuity, OC data validation</td>
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<tr>
<td></td>
<td>Ken Voss &amp; MOBY team</td>
<td>Miami</td>
<td>JPSS/NJO</td>
<td>Marine Optical Buoy (MOBY)</td>
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<tr>
<td></td>
<td>Zhongping Lee, Jianwei Wei</td>
<td>UMB</td>
<td>JPSS/NJO</td>
<td>Ocean color IOP data validation and evaluation Ocean color optics matchup</td>
</tr>
</tbody>
</table>

Working with: NOAA CoastWatch, VIIRS SDR team, DPA/DPE, Raytheon, NOAA OC Working Group, NOAA various line-office reps, NOAA NCEI, NOAA OCPOP, IOCCG, NASA, ESA, EUMETSAT, etc.

Collaborators: D. Antoine (BOUSSOLE), B. Holben (NASA-GSFC), G. Zibordi (JRC-Italy), R. Frouin (for PAR), and many others.
Summary of VIIRS Ocean Color EDR Products (Updates)

• Inputs:
  – VIIRS M1-M7, I1, and the **SWIR** M8, M10, and M11 bands SDR data
  – Terrain-corrected geo-location file
  – Ancillary meteorology and ozone data

• Operational (Standard) Products (**10**):
  – Normalized water-leaving radiance \((nL_w)'s\) at VIIRS visible bands M1-M5, and **I1 (638 nm)**
  – Chlorophyll-a (Chl-a) concentration
  – Diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, \(K_d(490)\)
  – Diffuse attenuation coefficient of the downwelling photosynthetically available radiation (PAR), \(K_d(PAR)\)
  – **QA Score** for data quality \((nL_w(\lambda)\) spectra) (Wei et al., 2016)
  – Level-2 quality flags

• Experimental Products (**29**):
  – Inherent Optical Properties (IOP-a, IOP-a\(_{ph}\), IOP-a\(_{dg}\), IOP-b\(_b\), IOP-b\(_{bp}\)) at VIIRS M2 or other visible bands (M1-M5) from the Quasi-Analytical Algorithm (QAA) (Lee et al., 2002)
  – Photosynthetically Available Radiation (PAR) (**R. Frouin**)
  – Chl-a from ocean color index (OCI) method (Hu et al., 2012, Wang and Son, 2016)
  – Others, e.g., user specific products (e.g., **Chl-a anomaly** and **Chl-a anomaly ratio**)

- Data quality of ocean color EDR are extremely sensitive to the SDR quality. It requires \(~0.1\%\) data accuracy (degradation, band-to-band accuracy…)!
MSL12 with the NIR-SWIR data processing system is used for VIIRS

Menghua Wang, NOAA/NESDIS/STAR
VIIRS Climatology Ocean Color Product: $K_d(490)$
SNPP (2012–2018)

MSL12 with the NIR-SWIR data processing system is used for VIIRS

Menghua Wang, NOAA/NESDIS/STAR
VIIRS Climatology Ocean Color Product: $nL_w(443)$
SNPP (2012–2018)

MSL12 with the NIR-SWIR data processing system is used for VIIRS

Menghua Wang, NOAA/NESDIS/STAR
VIIRS Climatology Ocean Color Product: $nL_w(551)$

SNPP (2012–2018)

MSL12 with the NIR-SWIR data processing system is used for VIIRS

Menghua Wang, NOAA/NESDIS/STAR
Global daily NRT Chl-a anomaly and anomaly ratio are Routinely produced

Menghua Wang, NOAA/NESDIS/STAR
High Chl-a Anomaly Linked to HAB in the West Coast of Florida (July 26, 2018)

Global NRT Chl-a anomaly and anomaly ratio are routinely produced

Menghua Wang, NOAA/NESDIS/STAR
VIIRS-SNPP and NOAA-20 Chl-a Images
(January 6, 2018)
VIIRS-SNPP and NOAA-20 Chl-a Images
(January 6, 2018)
To meet requirements from **All** users (operational, research, modeling, etc.), we have been routinely producing VIIRS global ocean color products in **two data streams**: Near-Real-Time (NRT) and Delayed Science-Quality data.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Near-Real Time (NRT)</th>
<th>Delayed Science-Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency:</td>
<td>Best effort, as soon as possible (~12-24h)</td>
<td>Best effort, on 1-2-week delay</td>
</tr>
<tr>
<td>Processing System:</td>
<td>MSL12</td>
<td>MSL12</td>
</tr>
<tr>
<td>SDR:</td>
<td>IDPS Operational SDR</td>
<td>OC-Improved SDR</td>
</tr>
<tr>
<td>Ancillary Data:</td>
<td>Global Forecast System (GFS) Model</td>
<td>Science quality (assimilated; GDAS) from NCEP</td>
</tr>
<tr>
<td>Coverage:</td>
<td>May have gaps due to various issues</td>
<td>Complete global coverage</td>
</tr>
<tr>
<td>Processed by:</td>
<td>NOAA CoastWatch, transferring to OSPO (operational)</td>
<td>NOAA/STAR</td>
</tr>
<tr>
<td>Distributed by:</td>
<td>NOAA CoastWatch, OSPO</td>
<td>NOAA CoastWatch, NCEI</td>
</tr>
<tr>
<td>Archive Plans:</td>
<td>Yes, from OSPO to NCEI</td>
<td>Yes, from CoastWatch to NCEI</td>
</tr>
<tr>
<td>Full Mission Reprocessing:</td>
<td>No</td>
<td>Yes, every ~2-3 years or as needed</td>
</tr>
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</table>
NOAA Capability: End-to-End Ocean Color Data Processing

- NOAA Ocean Color Team has been developing/building the capability for the **End-to-End** satellite ocean color data processing including:
  - Level-0 (or Raw Data Records (RDR)) to Level-1B (or Sensor Data Records (SDR)).
  - Level-1B (SDR) to ocean color Level-2 (Environmental Data Records (EDR) using the Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing.
  - Level-2 to global Level-3 (routine daily, 8-day, monthly, and climatology data/images).
  - Validation of satellite ocean color products (in situ data and data analysis capability).
- Support of in situ data collections for VIIRS Cal/Val activities, e.g., MOBY, AERONET-OC sites (3 sites operation, added Lake Erie site), NOAA dedicated Cal/Val cruises (2014, 2015, 2016, 2018, 2019 ...).
- **On-orbit instrument calibration (solar and lunar)** for ocean color data processing:
- **On-orbit vicarious calibration using MOBY in situ data:**
- **RDR (Level-0) to SDR (Level-1B) data processing** (efficient RDR to SDR processing):
- **Ocean Color Viewer (OCView)**—Online display and monitoring of ocean color product imagery.
- **Ocean Color Data Analysis and Processing System (OCDAPS)**—IDL-based VIIRS ocean color data visualization and processing package
- Work with users to meet their requirements.
Report for the 2014 NOAA dedicated Cal/Val cruise has been published!

NOAA Technical Report NESDIS 146

DOI 10.7289/V52B8W0Z

Report for
Dedicated JPSS VIIRS Ocean Color Calibration/Validation Cruise

http://dx.doi.org/10.7289/V52B8W0Z
Report for the 2015 NOAA dedicated Cal/Val cruise has been published!

NOAA Technical Report NESDIS 148


Report for
Dedicated JPSS VIIRS Ocean Color
Calibration/Validation Cruise
December 2015

Dedicated VIIRS Cal/Val Cruise IV
NOAA Ship Okeanos Explorer
9-18 May 2018

Cal/Val cruise report will be published early next year!
The three secondary lamps and the Gamma Scientific 5000 housing were shipped to the NPL in April 2017. One lamp was damaged during transit.

Measurements conducted by NPL personnel.

NOAA lamp measurements agree well with the NPL scale and other systems.

Ratio to NPL measurements
Verify the Performance of Reference Radiance Sources used by Fiducial Reference Measurement (FRM) Ocean Color Radiometers for Satellite Validation

- Data supplied to NPL on September 10, 2018. Inter-comparison results pending.
- Measurements of NPL supplied radiometers conducted using same Gamma Scientific 5000 lamp holder and same Gamma Scientific lamp utilized in irradiance calibration exercise.
High quality in situ measurements, e.g., MOBY in situ optics data, are crucial to derive reliable vicarious gains for satellite ocean color products.
High quality MOBY daily in situ data are also important/useful for on-orbit sensor performance monitoring!
High quality MOBY daily in situ data are also important/useful for on-orbit sensor performance monitoring!
Matchup of MOBY In Situ & VIIRS-SNPP (NIR-SWIR)
VIIRS vs. In Situ Data

In Situ Data Sources:
- R. Arnone (U. South Miss.)
- C. Davis (Oregon State U.)
- C. Hu (U. South Florida)
- Z. Lee (U. Mass. Boston)
- M. Ondrusek (NOAA/STAR)
- G. Zibordi (JRC)

- Three dedicated Cal/Val cruises (2014-2016) and
- Various in situ measurement opportunities

Very significant amount of work!
## Statistics of VIIRS vs. In Situ Data

<table>
<thead>
<tr>
<th>Product</th>
<th>RATIO (VIIRS/In Situ)</th>
<th>DIFFERENCE (VIIRS-In Situ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVG</td>
<td>MED</td>
</tr>
<tr>
<td>$nL_w(410)$</td>
<td>1.2192</td>
<td>0.9658</td>
</tr>
<tr>
<td>$nL_w(443)$</td>
<td>0.9776</td>
<td>0.9202</td>
</tr>
<tr>
<td>$nL_w(486)$</td>
<td>0.9466</td>
<td>0.9298</td>
</tr>
<tr>
<td>$nL_w(551)$</td>
<td>0.9773</td>
<td>0.9316</td>
</tr>
<tr>
<td>$nL_w(671)$</td>
<td>1.0698</td>
<td>0.9768</td>
</tr>
<tr>
<td>All</td>
<td>1.0375</td>
<td>0.9383</td>
</tr>
</tbody>
</table>

**In Situ Data Locations**

- **Red**: The three NOAA dedicated Cal/Val cruises
- **Blue**: Various in situ measurement opportunities
Conclusions

- VIIRS-SNPP and VIIRS-NOAA-20 global ocean color products have been routinely produced, providing necessary satellite data for various applications in open oceans, coastal and inland waters, as well as for further improving data quality.

- Our evaluation results (using various in situ data) show that VIIRS-SNPP can produce high quality ocean color data over global open oceans and reasonable data quality over coastal and inland waters.

- FRM data (i.e., MOBY in situ optics data) have been used for VIIRS on-orbit vicarious calibration, and routine sensor performance monitoring. Therefore, FRM data are required to be available to the community in near-real-time.

- We have successfully carried out four dedicated ocean color Cal/Val cruises with three cruise reports published. In addition, NOAA has been supporting four AERONET-OC sites for providing routine in situ data.

- We welcome collaborations for improving satellite ocean color products, e.g., Cal/Val activities using FRM data and other in situ data for satellite product validation.

VIIRS Images and Cal/Val: https://www.star.nesdis.noaa.gov/sod/mecb/color/

VIIRS Ocean Color Data: https://coastwatch.noaa.gov/

Thank You!