VIIRS Ocean Color Products and Updates

Menghua Wang &
Ocean Color EDR and Cal/Val Teams

NOAA/NESDIS Center for Satellite Applications and Research (STAR)
E/RA3, 5830 University Research Ct.
College Park, MD 20740, USA

STAR JPSS 2017 Annual Science Team Meeting
NCWCP, College Park, Maryland, August 27-29, 2018

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

Acknowledgements: This work has been supported by JPSS/VIIRS funding. We thank MOBY team for in situ optics data, VIIRS Cal/Val PIs and their collaborators in support of VIIRS Cal/Val activities.
<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>
</tr>
<tr>
<td></td>
<td>Carol Johnson</td>
<td>NIST</td>
<td>JPSS/NJO</td>
<td>Traceability, AERONET Uncertainty</td>
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<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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<td></td>
<td>Burt Jones, Matthew Ragan</td>
<td>USC</td>
<td>JPSS/NJO</td>
<td>Eureka (AERONET Site)</td>
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<tr>
<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>
</tr>
<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 $\sim$0.1% data accuracy (degradation, band-to-band accuracy…)!
VIIRS Climatology Ocean Color Product Image
SNPP (2012–2018)

MSL12 with the NIR-SWIR data processing system is used for VIIRS
Experimental Ocean Color Product Image (Selected)
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)

Chl-a Anomaly

Chl-a Anomaly Ratio

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

Menghua Wang, NOAA/NESDIS/STAR
Example:
Algae Bloom in the Baltic Sea on August 14, 2015

One can see differences between two images for bloom size < ~500 m, showing high spatial resolution data providing more details for bloom spatial distribution/features

More Detailed Algae Bloom Information Provided by VIIRS High Spatial Resolution (375 m) $nL_w(638)$ Data

VIIRS data acquired on Aug. 14, 2015 over Baltic Sea

Plot for line $L$ in Figs. 2a & 2b
Increased spectral coverage with VIIRS new $nL_w(638)$ data, providing important spectral information.
Two Data Streams for VIIRS Ocean Color EDR

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>
</tbody>
</table>
NOAA Capability of **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.**
Measurements done just after Hurricane Matthew in the region 13-18 October 2016.


Published other Cal/Val cruise reports (2014 and 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!
VIIRS-SNPP and NOAA-20 Chl-a Images
(January 6, 2018)
Global VIIRS merged Chl-a from SNPP/NOAA-20 are routinely produced

Menghua Wang, NOAA/NESDIS/STAR
VIIRS SNPP, NOAA-20, Sentinel-3A OLCI Merged Global Chl-a (August 14, 2018)

Ocean color data from the THREE sensors are all derived using the same MSL12!

Menghua Wang, NOAA/NESDIS/STAR
Matchup of MOBY In Situ & VIIRS-SNPP (NIR-SWIR)
Validation Effort

VIIRS-SNPP 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
VIIRS Global Chl-a Comparisons of NOAA-20 vs. SNPP (June 1, 2018)

All

Oligotrophic

Deep-water

Coastal/Inland water
# VIIRS Ocean Color Side Meeting

**Tuesday, 28 August 2018,**

NCWCP 1st Floor Conference Room (A+B)

<table>
<thead>
<tr>
<th>Time</th>
<th>Duration (min)</th>
<th>Speaker(s)</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0915</td>
<td>30</td>
<td>Wang, Menghua</td>
<td>Welcome and Overview of MSL12 and Ocean Color EDR Team activities</td>
</tr>
<tr>
<td>0945</td>
<td>15</td>
<td>Sun, Junqiang</td>
<td>VIIRS OC calibration update</td>
</tr>
<tr>
<td>1000</td>
<td>15</td>
<td>Liu, Xiaoming</td>
<td>New merged products</td>
</tr>
<tr>
<td>1015</td>
<td>15</td>
<td>Mikelsons, K.</td>
<td>New capabilities of OCV-Online display and monitoring of ocean color product imagery</td>
</tr>
<tr>
<td>1030</td>
<td>15</td>
<td>Zhaohui Cheng</td>
<td>Operational (near real-time) OC update</td>
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<tr>
<td>1045</td>
<td>15</td>
<td>BREAK (15 min)</td>
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<tr>
<td>1100</td>
<td>120</td>
<td>Voss, K. (U. Miami)</td>
<td>Update on MOBY-Refresh and MOBY products</td>
</tr>
<tr>
<td>1115</td>
<td>15</td>
<td>Ondrushek, M. (NOAA Cruise(s) Overview and Optical in situ Validation</td>
<td>Evaluation of VIIRS ocean color products and development of enhanced ocean products and applications</td>
</tr>
<tr>
<td>1130</td>
<td>15</td>
<td>Arnone, R. (Stennis)</td>
<td></td>
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<tr>
<td>1145</td>
<td>15</td>
<td>Gilerson, A. (CCNY)</td>
<td>CCNY VIIRS validations at the Long</td>
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<tr>
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<td>Island Sound Coastal Observatory (LISCO) and on cruises</td>
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<tr>
<td>1200</td>
<td>1311</td>
<td>LUNCH (75 min)</td>
<td></td>
</tr>
<tr>
<td>1315</td>
<td>15</td>
<td>Hu, C. (USF)</td>
<td>Evaluation of VIIRS performance in coastal waters and in its capacity to detect dark water and harmful algal blooms</td>
</tr>
<tr>
<td>1330</td>
<td>15</td>
<td>Lee, Z. (UMB)</td>
<td>Towards consistent VIIRS AOP and IOP products</td>
</tr>
<tr>
<td>1345</td>
<td>15</td>
<td>Tufillaro, N. (OSU); Jones, B./Ragan, M. (USC)</td>
<td>Validation of VIIRS ocean color products for the US West Coast</td>
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<tr>
<td>1400</td>
<td>15</td>
<td>Carol Johnson (NIST)</td>
<td>NIST update</td>
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<tr>
<td>1445</td>
<td>15</td>
<td>Joaquim Goes (LDEO)</td>
<td>Phytoplankton physiology/functional types</td>
</tr>
<tr>
<td>1430</td>
<td>20</td>
<td>Lance, V. Facilitator: Ondrushek, M. (NOAA/STAR)</td>
<td>Cruise reports, Cruise data sharing policy at NOAA; NCEI archiving of cruise data (by cruise); in situ Ocean Color Optical Database at NOAA</td>
</tr>
<tr>
<td>1450</td>
<td>25</td>
<td></td>
<td>Group Discussion: May 2019 (FY19) cruise planning/lessons learned from previous cruises.</td>
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<tr>
<td>1515</td>
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<td>BREAK (15 min)</td>
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<tr>
<td>1530</td>
<td>171</td>
<td>Daniel Tong, OAR/ARL</td>
<td>Isoprene emissions from VIIRS ocean color informs air quality forecasts</td>
</tr>
<tr>
<td>1545</td>
<td>15</td>
<td>Eric Geiger, Coral</td>
<td>Coral Reef Watch use and applications for ocean color data products</td>
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<tr>
<td>1600</td>
<td>15</td>
<td>Yongsheng Zheng Lance, V.</td>
<td>NCEI Scientific Stewardship on NOAA MSL12 Ocean Color EDR Products</td>
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<tr>
<td>1615</td>
<td>15</td>
<td>(CoastWatch)</td>
<td>Ocean Color Data distribution through NOAA CoastWatch/OceanWatch and NCEI</td>
</tr>
<tr>
<td>1630</td>
<td>30</td>
<td>Menghua Wang</td>
<td>Questions, discussion, plans for next year</td>
</tr>
<tr>
<td>1700</td>
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<td>ADJOURN SIASM</td>
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</tbody>
</table>
Conclusions

- VIIRS-SNPP and VIIRS-NOAA-20 global ocean color products have been routinely produced using the NIR-, SWIR-, and NIR-SWIR-based atmospheric correction algorithms, 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 show that VIIRS-SNPP can produce high quality ocean color data over global open oceans and reasonable data quality over coastal and inland waters.

- VIIRS-NOAA-20 can also produce reasonable ocean color data quality, and ocean color results are generally comparable to those from VIIRS-SNPP.

- However, there are still some issues/problems, including NOAA-20 SDR calibration problems that significantly impact VIIRS ocean color data quality.

- VIIRS-NOAA-20 mission-long ocean color data reprocessing is current underway due to IDPS SDR calibration errors and error in early polarization correction.

- Significant effort is still needed for improving ocean color data quality over turbid coastal and inland waters.

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

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

Thank You!