VIIRS Ocean Color Products

Menghua Wang &
Ocean Color EDR & Cal/Val Teams
Date: August 25, 2015

STAR JPSS 2015 Annual Science Team Meeting
College Park, MD, August 24-28, 2015

Ocean Color Teams contributed 21 posters (Thursday)
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<tr>
<th>EDR</th>
<th>Name</th>
<th>Organization</th>
<th>Funding Agency</th>
<th>Task</th>
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<tbody>
<tr>
<td>Lead</td>
<td>**Menghua Wang (OC EDR &amp; Cal/Val Lead), L. Jiang, X. Liu, W. Shi, S. Son, L. Tan, X. Wang, J. Sun, K. Mikelsons, V. Lance, **M. Ondrusek, **E. Stengel</td>
<td>NOAA/NESDIS/STAR</td>
<td>JPSS/NJO</td>
<td>Leads – Ocean Color EDR Team &amp; Cal/Val Team OC products, algorithms, SDR, EDR, Cal/Val, vicarious cal., refinements, data processing, algorithm improvements, software updates, data validations and analyses</td>
</tr>
<tr>
<td>Ocean Color</td>
<td><strong>Robert Arnone</strong>&lt;br&gt; Sherwin Ladner, Ryan Vandermeulen&lt;br&gt; Adam Lawson, Paul Martinolich, Jen Bowers</td>
<td>U. Southern MS&lt;br&gt; NRL&lt;br&gt; QinetiQ Corp.&lt;br&gt; SDSU</td>
<td>JPSS/NJO</td>
<td>Satellite data evaluation, in situ data Look Up Tables – SDR-EDR impacts, vicarious calibration 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-OC Uncertainty</td>
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<td></td>
<td><strong>Curt Davis, Nicholas Tufillaro</strong></td>
<td>OSU</td>
<td>JPSS/NJO</td>
<td>Ocean color validation, Cruise data matchup West Coast</td>
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<td><strong>Burt Jones, Matthew Ragan</strong></td>
<td>USC</td>
<td>JPSS/NJO</td>
<td>Eureka (AERONET-OC Site)</td>
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<td><strong>Sam Ahmed, Alex Gilerson</strong></td>
<td>CUNY</td>
<td>JPSS/NJO</td>
<td>LISCO (AERONET-OC Site) Cruise data and matchup</td>
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<td><strong>Chuanmin Hu</strong></td>
<td>USF</td>
<td>JPSS/NJO</td>
<td>NOAA data continuity, cruise participation/support</td>
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<td><strong>Ken Voss &amp; MOBY team</strong></td>
<td>RSMAS –Miami</td>
<td>JPSS/NJO</td>
<td>Marine Optical Buoy (MOBY)</td>
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<td><strong>Zhongping Lee, Jianwei Wei</strong></td>
<td>UMB</td>
<td>JPSS/NJO</td>
<td>Ocean color IOP data validation and evaluation Ocean color optics matchup, cruise participation</td>
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Working with: NOAA **CoastWatch**, VIIRS **SDR team**, DPA/DPE, Raytheon, NOAA OC Working Group, NOAA Coral Reef Watch, NOAA various line-office reps, NASA OBPG, NOAA OCPOP, etc.

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

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

• Operational (Standard) Products (8):
  – Normalized water-leaving radiance ($nL_w$’s) at VIIRS visible bands M1-M5
  – Chlorophyll-a (Chl-a) concentration
  – Diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, $K_d(490)$ (New)
  – Diffuse attenuation coefficient of the downwelling photosynthetically available radiation (PAR), $K_d(PAR)$ (New)
  – Level-2 quality flags

• Experimental Products:
  – 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)
  – Chlorophyll-a from ocean color index (OCI) method (Hu et al., 2012)
  – Others from users requests

➤ Data quality of ocean color EDR are extremely sensitive to the SDR quality. It requires ~0.1% data accuracy (degradation, band-to-band accuracy…)!
Multi-Sensor Level-1 to Level-2 (MSL12)

- **MSL12 is the official VIIRS ocean color data processing system.**
- MSL12 was developed for the purpose of using a consistent and common data processing system to produce ocean color products from multiple satellite ocean color sensors (Wang, 1999; Wang and Franz, 2000; Wang et al., 2002), i.e., it is measurement-based ocean color data processing system.
- It has been used for producing ocean color products from various satellite ocean color sensors, e.g., SeaWiFS, MOS, OCTS, POLDER, MODIS, GOCI, etc.

MSL12 Ocean Color Data Processing

- MSL12 is based on SeaDAS version 4.6.
- Some significant improvements: (1) the SWIR-based data processing, (2) Rayleigh (new) and aerosol LUTs, (3) algorithms for detecting absorbing aerosols and turbid waters, (4) ice detection algorithm, (5) improved straylight/cloud shadow algorithm, & others.
- In 2014, some new algorithms (BMW–new NIR reflectance correction, Destriping, $K_d$(PAR), etc.)

MSL12 for VIIRS (and others) Ocean Color Data Processing

- Routine ocean color data processing (daily, 8-day, monthly) since VIIRS launch.
- Coastal turbid and inland waters from other approaches, e.g., the SWIR approach, results in the US east coastal, China’s east coastal, Lake Taihu, Lake Okeechobee, Aral Sea, etc.
- Capability for multi-sensor ocean color data processing, e.g., MODIS-Aqua, VIIRS, GOCI, and will also add J1, OLCI/Stentinel-3, and SGLI/GCOM-C data processing 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)).
  - 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, **NOAA dedicated cruise**, etc.

- **On-orbit instrument calibration (solar and lunar)** for ocean color data processing (Cal effort is needed to meet ocean color requirement):

- **RDR (Level-0) to SDR (Level-1B) data processing** (**needed for quick data reprocessing**):
To meet requirements from All users (operational, research, modeling, etc.), we plan to produce VIIRS ocean color products in two data streams:

- **Near-Real-Time (NRT) Ocean Color Data Processing (12-24 hours):**
  - Quick turn around with ~12-24 hours latency (operational)
  - Using standard IDPS SDR data
  - Ancillary data using the Global Forecast System (GFS) model
  - Data may not be completed due to various issues (SDR missing, computer, etc.)
  - Data will be processed in NOAA CoastWatch and OSPO

- **Science Quality Ocean Color Data Processing (One-two weeks delay):**
  - About one-two weeks delay
  - Reprocessed mission-long ocean color data and continue-forward data stream
  - Using improved SDR (based on IDPS SDR data)
  - Science quality (assimilated) NCEP ancillary data
  - Complete global coverage
  - May expand to more experimental products & test with improved algorithms
  - Ocean color EDR will be reprocessed (mission-long) about every two-three years (or as needed, e.g., short-term data reprocessing, error fixing, etc.)
  - Data will be processed in NOAA/STAR and transferred to CoastWatch for distributions
Generated using MSL12 for VIIRS ocean color data processing

VIIRS Climatology $K_d(490)$ Image
(March 2012 to February 2015)

Generated using MSL12 for VIIRS ocean color data processing


http://dx.doi.org/10.1002/2009JC005286

The BMW Algorithm for Ocean Color Data Processing

1. Inputs of the TOA L1B data, geolocation data, and ancillary data

2. **The NIR atm. corr. with *Bailey* et al. (2010) algorithm**
   - Yes
     - $nL_w(\lambda_{NIR}) < 0.005$?
     - No: Turbid Water Pixel
   - No: Turbid Water Pixel

3. Clear water pixel: use the derived $\varepsilon^{(m)}$ value
   - Do all pixels in the entire scene have $\varepsilon^{(m)}$ values?
     - Yes
       - The **MUMM atm. corr. with *Wang* et al. (2012) NIR relationship**
     - No

Comparisons of MODIS and VIIRS-derived $nL_w(\lambda)$ images at four selected bands.

Comparison of NOAA VIIRS ocean color products with Marine Optical Buoy (MOBY) in situ data.

Note: Vicarious calibration gains applied since May 2012.

Vicarious gains were derived using MOBY in situ data.

MOBY in situ optics data have been providing critical data set in support of VIIRS calibration and validation activities, including VIIRS Level-1B (SDR) data monitoring for sensor on-orbit calibration.
MOBY Matchup
with
VIIRS OC-SDR/EDR Processing
(BMW-nc4)

MOBY (MSL12 Global)

nLw_410

AVG: 1.00548
STD: 0.0066999

nLw_443

AVG: 1.00416
STD: 0.00256848

nLw_486

AVG: 1.00209
STD: 0.0056916

nLw_551

AVG: 1.00250
STD: 0.0134125

nLw_671

AVG: 1.10062
STD: 0.024550

CHL

AVG: 0.998037
STD: 0.161090

(2012-01-01 ~ 2014-05-31)
Q1+Q2, ±3hr

Use OC-SDR with New MSL12

Menghua Wang, NOAA/NES.
# Statistics of VIIRS MSL12 vs. In-Situ (MOBY)

## Current Data Processing
(2012-01-01 ~ 2014-05-31)

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<td>0.101</td>
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Global Oligotrophic Water OC Product Time Series

**OC-SDR:** Generated by the OC Team with OC calibration approach

**IDPS-SDR:** From operational IDPS-generated SDR

Reprocessed both mission-long SDR data using the same new MSL12

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Dedicated VIIRS Cal/Val Cruise
NOAA Ship Nancy Foster
11-21 November 2014

International, Interagency, and Academic Collaborations:
4 US Agencies, EU-JRC, 6 Universities

Validation Measurements
Water-leaving radiance; Chlorophyll-a; Absorption and backscattering coefficients; Bi-directional radiance distribution; Phytoplankton physiology; Carbon; Total suspended matter; Aerosol optical depth, etc.

Cruise Track

Viirs Chlorophyll-a

Validation Results
- Occupied 23 stations over 10 days
- Simultaneous measurements at each station for:
  - 4 profiling radiometers
  - 2 floating radiometers
  - 6 above-water radiometers
- Conducted pre- and post-cruise inter-calibrations

11 potential station matchups with VIIRS

Pre-cruise inter-calibration results for 5 radiance sensors

The cruise report is completed!
Conclusions/Path Forward (1)

- With improved SDR (calibration) and EDR (data processing algorithms), VIIRS ocean color products are now comparable to or better than those from MODIS-Aqua.
- We have completed mission-long OC data reprocessing using IDPS-SDR with new MSL12.
- We have started VIIRS mission-long science quality ocean color data reprocessing (including SDR and EDR), and will finish that in late 2015, & the data stream will go forward. **Two data streams will be produced: near-real-time and science quality ocean color data.**
- Calibration from both solar and lunar is necessary. We need lunar model data!
  - VIIRS ocean color products have been improved after the implementation of some important updates, new algorithms, and with vicarious calibrations.
  - In general, VIIRS normalize water-leaving radiance spectra show reasonable agreements with in situ measurements at MOBY, AERONET-OC sites, and various other ocean regions.
  - The new NIR ocean reflectance correction algorithm (BMW) improves ocean color data over coastal and inland waters. The destriping algorithm significantly improves VIIRS-derived ocean color imageries.
  - New $K_d$(PAR) product has been developed and routinely produced to meet users requirements.
  - NOAA dedicated Cal/Val cruise in Nov. 2014, and plan to have it in late 2015. The report for the 2014 Cal/Val cruise has been completed.
  - There will be many applications using VIIRS ocean color products.
  - We have developed VIIRS instrument calibration capability, and with new calibration LUTs, VIIRS ocean color products are significantly improved.
  - Our evaluation results show that VIIRS-SNPP is capable of providing high-quality global ocean color products in support of science research and operational applications.
  - We have been actively working with other current and future ocean color sensors, e.g., MODIS-Aqua, Korean GOCI, EUMETSAT for Sentinel-3 (launch late 2015), JAXA GCOM-C (launch early 2017), and VIIRS on J1 (launch 2017).
• Complete VIIRS mission-long ocean color data reprocessing (science quality, i.e., improved SDR, algorithms, and science quality ancillary data).
• VIIRS reprocessed data stream will go forward (about one-two weeks delay). VIIRS science quality data will be distributed through CoastWatch and other means (e.g., NODC effort).
• Cal/Val team will finish the 2014 VIIRS dedicated cruise report and in situ data analyses (e.g., improve in situ data quality).
• More in situ data are needed for validation and improvement of VIIRS ocean color products.
• In situ data quality (instrument calibration, measurement protocols, data processing methodology, etc.)
• Dedicated VIIRS ocean color Cal/Val cruise in December 2015, and establishing annual Cal/Val cruises.
• Continue work on sensor on-orbit calibration (solar and lunar), algorithms improvements, etc.
• We have been working on J1 instrument. Need more efforts for J1 VIIRS pre-launch data analyses as J1 close to launch (access to J1 sensor data).
• Algorithms improvements for both open oceans and coastal/inland waters. In particular, significant efforts are needed for coastal/inland waters.

Details: Ocean color breakout session and the Team 21 posters on Thursday!