VIIRS Ocean Color Team Activities in 2017

Menghua Wang &
Ocean Color EDR Team

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College Park, MD 20740, USA

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.
## 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>
</tr>
<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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<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>
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<td>Zhongping Lee, Jianwei Wei</td>
<td>UMB</td>
<td>JPSS/NJO</td>
<td>Ocean color IOP data validation and evaluation</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>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.

*Menghua Wang, NOAA/NESDIS/STAR*
### VIIRS Spectral Bands for Ocean Color

**VIIRS** (Visible Infrared Imaging Radiometer Suite) on Suomi National Polar-orbiting Partnership (SNPP)


<table>
<thead>
<tr>
<th>VIIRS†</th>
<th>MODIS</th>
<th>SeaWiFS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ocean Bands</strong> (nm)</td>
<td><strong>Other Bands</strong> (nm)</td>
<td><strong>Ocean Bands</strong> (nm)</td>
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<tr>
<td>410 (M1)</td>
<td>638 (I1)</td>
<td>412</td>
</tr>
<tr>
<td>443 (M2)</td>
<td>862 (I2)</td>
<td>443</td>
</tr>
<tr>
<td>486 (M3)</td>
<td>1600 (I3)</td>
<td>488</td>
</tr>
<tr>
<td>—</td>
<td></td>
<td>531</td>
</tr>
<tr>
<td>551 (M4)</td>
<td><strong>SWIR Bands</strong></td>
<td>551</td>
</tr>
<tr>
<td>671 (M5)</td>
<td>1238 (M8)</td>
<td>667</td>
</tr>
<tr>
<td>745 (M6)</td>
<td>1601 (M10)</td>
<td>748</td>
</tr>
<tr>
<td>862 (M7)</td>
<td>2257 (M11)</td>
<td>869</td>
</tr>
</tbody>
</table>

†VIIRS-SNPP nominal center wavelength

**Spatial resolution for VIIRS M-band:** 750 m, **I-band:** 375 m
Summary of VIIRS Ocean Color EDR Products

**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 (9):**
- 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), $K_d(PAR)$

**New added global products: $nL_w(638)$ (I-band with 375 m), QA Score, and Chl-a anomaly and Chl-a anomaly ratio**
- 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**)
- OA Score for data quality ($nL_w(\lambda)$ spectra) (**Wei et al., 2016**)

We are open for adding new VIIRS global products

Data quality of ocean color EDR are extremely sensitive to the SDR quality. It requires $\sim0.1\%$ data accuracy (degradation, band-to-band accuracy…)!
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---measurement-based data processing system.
  - 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, ...).

- 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.
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 a 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>Spatial Coverage:</td>
<td>May be gaps due to various issues</td>
<td>Complete global coverage</td>
</tr>
<tr>
<td>Processed by:</td>
<td>CoastWatch, transferring to OSPO (operational) FY16</td>
<td>NOAA/STAR</td>
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<tr>
<td>Distributed by:</td>
<td>CoastWatch, OSPO</td>
<td>CoastWatch, NCEI</td>
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<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>
We have recently reprocessed VIIRS mission-long ocean color data products for the Science Quality data stream in April 2017. This is the second data reprocessing due to some significant improvements (algorithms and SDR). The first VIIRS mission-long OC data reprocessing was completed in May 2016. The science quality data stream has been going forward routinely.

The Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing system has been significantly improved (warrant for the second mission-long data reprocessing).

For the Science Quality data stream, VIIRS mission-long SDR has been reprocessed using significantly improved on-orbit calibration (both solar and lunar approaches).

VIIRS ocean color data are available through CoastWatch. In particular, the Science Quality data stream will also be distributed through CoastWatch and NCEI.

The reprocessed VIIRS mission-long Science Quality ocean color data have been significantly improved, providing accurate and consistent ocean color data for science research and applications. It shows the importance of the lunar data for calibration, particularly in recent years (and forwarding).

VIIRS chlorophyll-a (Chl-a), $K_d$(490), $K_d$(PAR), $nL_w$(410), $nL_w$(443), $nL_w$(486), $nL_w$(551), and $nL_w$(671), as well as 1-band $nL_w$(638) data are routinely produced now using the MSL12 ocean color data processing system.

We show VIIRS global climatology ocean color product images, as well as some evaluation/validation results.
High quality MOBY daily in situ data are also important/useful for on-orbit sensor performance monitoring!
# Statistics of VIIRS versus In-Situ (MOBY)

<table>
<thead>
<tr>
<th>VIIRS</th>
<th>OC-SDR NIR (Gain in 2017-03-26)</th>
<th>OC-SDR NIR (Gain in 2017-03-26)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RATIO (SAT/ENV)</td>
<td>DIFFERENCE (SAT-ENV)</td>
</tr>
<tr>
<td>Product</td>
<td>AVG</td>
<td>MED</td>
</tr>
<tr>
<td>$nL_w(410)$</td>
<td>1.0179</td>
<td>1.0153</td>
</tr>
<tr>
<td>$nL_w(443)$</td>
<td>1.0159</td>
<td>1.0119</td>
</tr>
<tr>
<td>$nL_w(486)$</td>
<td>1.0164</td>
<td>1.0124</td>
</tr>
<tr>
<td>$nL_w(551)$</td>
<td>1.0276</td>
<td>1.0098</td>
</tr>
<tr>
<td>$nL_w(671)$</td>
<td>1.1219</td>
<td>1.0045</td>
</tr>
<tr>
<td>$nL_w(638)$</td>
<td>1.0656</td>
<td>0.9366</td>
</tr>
</tbody>
</table>

_Menghua Wang, NOAA/NESDIS/STAR_
VIIRS Climatology Chlorophyll-a Image (2012–2016)

Most coastal regions and inland lakes are in the northern hemisphere!

Global Oligotrophic Waters

Log scale: 0.01 to 64 mg/m³
VIIRS Mission-long QA Score (global 8-day mean value)

**Mean = 0.93**

**Mean = 0.90**

**Mean = 0.80**

Excellent data quality ($nL_w(\lambda)$ data) over open oceans, and OC data over coastal/inland waters are reasonable (need to be improved)

**Higher score in winter**

**Lower score in summer**

**Blue:** Global Oligotrophic Waters

**Green:** Global Deep Waters (depth > 1km)

**Red:** Regions with depth ≤ 1km, e.g., coastal & inland waters

VIIRS science quality OC data are processed using the MSL12!
VIIRS-derived Daily Chl-a

Green: Global Deep Waters (depth > 1km)

Blue: Global Oligotrophic Waters

Slightly Chl-a drop over oligotrophic waters

VIIRS science quality OC data are processed using the MSL12!

Menghua Wang, NOAA/NESDIS/STAR
VIIRS-derived 8-day $nL_w(443)$

Blue: Global Oligotrophic Waters

Green: Global Deep Waters (depth $>1$km)

Water getting Bluer recently?

VIIRS science quality OC data are processed using the MSL12!
VIIRS-derived 8-day $nL_w(551)$

Green: Global Deep Waters (depth > 1km)

Blue: Global Oligotrophic Waters

Quite stable in VIIRS-derived $nL_w(551)$!

VIIRS science quality OC data are processed using the MSL12!

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Global Oligotrophic Water $nL_w(443)$

Mean & STD (2012-2017)

Continued in 2017

Out of family in late 2016

Mean & STD (2012-2015)

Highly consistent $nL_w(443)$

2012-2015

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Global Oligotrophic Water

\( nL_w(443) \) STD Values

STD \(~0.05\) for 2012-2017

STD \(~0.03\) for 2012-2015
Global Oligotrophic Water $nL_w(551)$

Early mission in 2012

Mean & STD (2012-2017)

Mean & STD (2012-2015)
Global Oligotrophic Water

$nL_w(551)$ STD Values

Similar STD ~ 0.005-0.007

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New VIIRS $nL_w(638)$ with Imaging Bands
(Resolution at 375 m)

Example:
Algae Bloom in the Baltic Sea on August 14, 2015

One can see differences between two images for bloom size $< \sim 500$ 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

$\frac{nL_w}{cm^2 \mu m^{-1} sr^{-1}}$ (mW cm$^{-2}$ $\mu m^{-1}$ sr$^{-1}$)

Latitude (Deg.)

58.6 58.7 58.8 58.9 59 59.1 59.2 59.3
Increased spectral coverage with VIIRS new $nL_w(638)$ data, providing important spectral information.
VIIRS-derived $nL_w(638)$ Climatology Image

February 2012–May 2017

Land

$nL_w(638)$ (mW cm$^{-2}$ μm$^{-1}$ sr$^{-1}$)

0.03 0.1 0.3 1.0 3.0

No Data
Eddies near Amazon River
January 1-31, 2014

Examples of Reconstructed Chl-a Images (1)

January 15, 2014

We can now see eddy movement in the reconstructed Chl-a images.
Report for the 2014 NOAA dedicated Cal/Val cruise has been published!


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

Measurements done just after Hurricane Matthew in the region 13–18 October 2016.

Report will be published soon (this year)!
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>VIIRS 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>
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<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>
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<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
Matchup of AERONET-OC In Situ versus VIIRS OC-SDR NIR
### Statistics of VIIRS OC (NIR) vs. In-Situ (AERONET-OC)

<table>
<thead>
<tr>
<th><em>fm</em></th>
<th>RATIO (SAT/ENV)</th>
<th>DIFFERENCE (SAT-ENV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVG</td>
<td>MED</td>
</tr>
<tr>
<td>( nL_w(410) )</td>
<td>1.0924</td>
<td>1.0213</td>
</tr>
<tr>
<td>( nL_w(443) )</td>
<td>1.0417</td>
<td>0.9988</td>
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<tr>
<td>( nL_w(486) )</td>
<td>0.9792</td>
<td>0.9645</td>
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<tr>
<td>( nL_w(551) )</td>
<td>0.9246</td>
<td>0.9091</td>
</tr>
<tr>
<td>( nL_w(671) )</td>
<td>0.6399</td>
<td>0.5777</td>
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<tr>
<td>( nL_w ) All</td>
<td>0.9360</td>
<td>0.9406</td>
</tr>
</tbody>
</table>

Menghua Wang, NOAA/NESDIS/STAR
Conclusions

• VIIRS 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 is now capable of providing high quality global ocean color products in support of science research and operational applications.

• We will prepare for the OC data processing for VIIRS-J1 in FY18, which will provide more complete global coverage with VIIRS-SNPP.

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

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

Thank You!
VIIRS SDR Calibration for Improvement of Ocean Color Products

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\(^2\)Global Science and Technology, 7855 Walker Drive, Maryland, USA

8/16/2017 8:xx-8:xx AM
Outline

• Introduction
• Solar Diffusor Stability Monitor (SDSM) Calibration
• Solar Diffusor (SD) Calibration
• Lunar Calibration
• Hybrid Approach
• Inter-sensor and In-situ Comparison
• Ocean Color Products Performance
• Summary
VIIRS Background

- 22 spectral bands - 410 nm to 12.013 µm spectral range
- 14 Reflective Solar Bands (RSB) : 3 image bands, I1-I3, and 11 moderate bands, M1-M11
- The VIIRS RSB are calibrated on orbit by SD/SDSM calibration
- Monthly lunar observation through its space view (SV) since launch.
- For VIIRS, the angle of incidence (AOI) of the SV is exactly the same as that of the SD. Lunar observations should provide identical on-orbit gain change for VIIRS RSB as SD/SDSM calibration.

VIIRS RSB uncertainty specification is 2%, but ocean color EDRs (using M1-M7, NIR; also M8, M10, and M11, NIR-SWIR; recently I1) need to achieve ~0.2%. This has been achieved.
SD/SDSM Calibration Overview

- **SD and SDSM sun view screens:**
  - Prevent RSB and SDSM saturation
  - Vignetting functions (VFs)
  - VFs measured prelaunch and validated by yaw measurements
  - SD bidirectional reflectance factors (BRFs)

- **BRFs measured prelaunch and validated by yaw measurements**
  - SD on-orbit degradation is tracked by the SDSM measurements at 8 wavelengths from 412 nm to 935 nm

- **RSB**
  - Key assumption: SD degrades uniformly with respect to both incident and outgoing directions


  - SDSM measures H-factors
  - F-factors, or RSB calibration coefficients, are the final calibration product
SDSM Calibration Algorithm

- SDSM is a ratio radiometer, which views SD, Sun, and an internal dark scene successively in three-scan cycles.

- SD BRF for SDSM view direction

\[
BRF_{SD,SDSM}(\lambda,t) = \rho_{SD,SDSM}(\lambda)H(\lambda,t)
\]

  - \(\rho_{SD,SDSM}(\lambda)\): Prelaunch BRF for SDSM view direction
  - \(H(\lambda)\) is solar diffuser degradation since launch

- SD degradation, H factors, for SDSM view direction at the wavelength of the SDSM detector D

\[
H(\lambda_D) = \left( \frac{dc_{SD,D}}{\rho_{SD,SDSM}(\lambda_D)\tau_{SD} \cos(\theta_{SD})} \right)_{Scan} \left( \frac{dc_{SV,D}}{\tau_{SV}} \right)_{Scan}
\]

- **Improvements**
  - Robust and accurate VFIs and BRFs from yaw measurements
  - Ratio of the averages
  - Sweet spots selection

SDSM operations: Every orbit first few months, then once per day for about two years, and once per two days since May, 2014.

SDSM Calibration Performance

SD Degradation (H-Factors)

- Very stable
- SDSM is very accurate!
- Results are all actual measurements
  - No averaging over orbits, no smoothing, NO FANCY TRICKS

SD Degradation – First 70 days

- First 25 days behaved differently.
- But H-factor is in different direction from RSB view direction – KEY ISSUE
- Unexpected but real degradation features (Nov 2014)
SD Calibration Algorithm

• SD is made of Spectralon®, near Lambertian property

• Solar radinace reflected by the SD

\[ L_{SD}(\lambda) = I_{Sun}(\lambda) \cdot \tau_{SDS} \cdot \cos(\theta_{SD}) \cdot \rho_{SD,RTA}(\lambda) \cdot h(\lambda) / d_{VS}^2 \]

- \( \rho_{SD,RTA}(\lambda) \): Prelaunch BRF for RTA view direction
- \( h(\lambda) \): SD degradation for SDSM view direction is used as the SD degradation for the RTA direction

• RSB calibration coefficients, F factors

\[ F(B, D, M, G) = \frac{RV_{S,SD} \cdot \int RSR_B(\lambda) \cdot L_{SD}(\lambda) \cdot d\lambda}{\sum_i c_i(B, D, M, G) \cdot d\lambda \cdot \int RSR_B(\lambda) \cdot d\lambda} \]

- \( B, D, M, G \): Band, Detector, HAM side, and gain status

SD Calibration: Every orbit

• Improvements
  - Robust VFs and BRFs from yaw measurements
  - Improved H factors
  - Sweet spot selection
  - Time-dependent RSR

**SD Calibration Performance**

**RSB Calibration Coefficients (SD F-Factors)**

- **Band M1 HAM 1 HG F-factors**

  - Very stable and smooth
  - Different from MODIS: Much less degradation of the scan mirror
  - But the input H-factor measured by the SDSM is for the SDSM view direction – KEY ISSUE

- **Band-averaged HAM 1 HG F-factors**
Lunar Calibration Algorithm

- Moon is very stable in its reflectance
- RSB calibration coefficients, F factors, from lunar observations

\[
F(B,M) = \frac{g(B)N_{t,M}}{\sum_{D,S,N} L_{pl}(B,D,S,N)\delta(M,M_N)},
\]

- \( g(B) \): View geometric effect correction (ROLO lunar model and extra correction)

SNPP VIIRS is scheduled to view the Moon approximately monthly (about nine months every year)

- Advantages
  - Lunar surface reflectance has no observable degradation
  - Can be used for inter-comparison

**Lunar Calibration Performance**

**RSB Calibration Coefficients (Lunar F-Factors)**

- **Lunar and SD F Factors Lunar and SD F factors (M1-M4)**
  - Symbols: Moon
  - Lines: SD

- **Lunar and SD F factors (M1-M4)**
  - Symbols: Moon
  - Lines: SD

**Calibration coefficients Ratios**

- **Own Lunar model and correction beyond ROLO model**
- **New Lunar results much improved – smooth, no oscillation - 0.2% stability**
- **SD F-factors and lunar F-factors diverge, especially for short wavelength RSBs.**
- **SD F-factors have error**
It was discovered by 2014 that SD degradation is not uniform.

Standard SD calibration brings non-negligible error into RSB characterization.

Slopes of H-factors in each individual event with respect to solar declination.

Hybrid Approach

- **SD Calibration**
  - SD degrades non-uniformly, resulting long-term drifts
  - Results are stable and smooth
  - Observation in every orbit

- **Lunar Calibration**
  - No degradation issue
  - Infrequent and no observation in three months every year

- **Hybrid Approach**

  \[ F(B, D, M, G) = R(B, t) \cdot F(B, D, M, G) \]

  \[ R(B, t) = \langle f(B, M, t) \rangle_M / \langle F(B, D, M, 0, t) \rangle_{D, t-15 < t_i < t+15, M} \]

  - Lunar calibration provides long-term baseline
  - SD calibration provides smoothness and frequency

F-Factors Ratios are fitted to quadratic polynomials of time

Hybrid Calibration Performance

- Hybrid calibration coefficients (Hybrid F-factors) achieves long-term accuracy but also with short-term stability achieving ~0.2% level.
- Earth-based SDR studies show that Hybrid-method indeed mitigated the long-term defect and give stable time-series.

Inter-sensor and In-situ Comparison

Aqua MODIS and VIIRS Radiance SNO Ratio

Water Leaving Radiance: nLw(551), M4

Ocean Color Products Performance

Global Deep Water (Depth > 1km)

nLw(443), M2

Red: VIIRS IDPS
Green: VIIRS Hybrid

Chl-a

Red: VIIRS IDPS
Green: VIIRS Hybrid

nLw(551), M4

Red: VIIRS IDPS
Green: VIIRS Hybrid

Kd(490)

Red: VIIRS IDPS
Green: VIIRS Hybrid


Charts were produced by X. Liu and S. Son.
• Very rigorous RSB calibration has been achieved and demonstrated.
• “Hybrid-method” mitigation is the primarily important correction that removes the long-term worsening bias coming from within SD calibration at the SDR level.
• With our hybrid F-factor look-up-tables (LUTs), both the reprocessed mission-long and forward real-time VIIRS Ocean Color EDR products demonstrate very high quality performance.
• Forward delivery of publicly accessible science quality EDR with the hybrid F-factor LUTs has been implemented since May 2016.
• Our hybrid F-factor LUTs for all RSB have been adopted for the official operational VIIRS SDR reprocessing (as an option for high quality science quality EDRs).
• Per request, our hybrid F-factor LUTs have also been sent to NASA Ocean Biology and Biogeochemistry Program Group (OBPG) for their testing and processing.
Table 1. Specification for SNPP VIIRS RSBs and SDSM detectors.

<table>
<thead>
<tr>
<th>VIIRS Band</th>
<th>CW* (nm)</th>
<th>Band Gain</th>
<th>Detectors</th>
<th>Resolution*</th>
<th>SDSD Detector</th>
<th>CW* (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>410</td>
<td>DG</td>
<td>16</td>
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<td>D1</td>
<td>412</td>
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<tr>
<td>M2</td>
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<td>DG</td>
<td>16</td>
<td>742m x 776m</td>
<td>D2</td>
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<tr>
<td>M3</td>
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<td>16</td>
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<td>D3</td>
<td>488</td>
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<td>M4</td>
<td>551</td>
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<td>16</td>
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<td>M11</td>
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<td>16</td>
<td>742m x 776m</td>
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<td>NA</td>
</tr>
</tbody>
</table>

*CW: Center Wavelength; DG: Dual Gain; SG: Single Gain; Resolution: Track x Scan at Nadir after aggregation
Yaw carefully planned, cover all solar angle range for SD/SDSM calibration.
- Carefully derive BRFs and VFs from the yaw measurements is the crucial 1st step.
- Need to do it right just one time from yaw data.

RSB On-Orbit Calibration

- 22 spectral bands - 410 nm to 12.013 μm spectral range
- 14 Reflective Solar Bands (RSB) : 3 image bands, I1-I3, and 11 moderate bands, M1-M11
- The VIIRS RSB are calibrated on orbit by SD/SDSM calibration
- Monthly lunar observation through its space view (SV) since launch.
- For VIIRS, the angle of incidence (AOI) of the SV is exactly the same as that of the SD. Lunar observations should provide identical on-orbit gain change for VIIRS RSB as SD/SDSM calibration.

VIIRS RSB uncertainty specification is 2%, but ocean color EDRs (using M1-M7, NIR; also M8, M10, and M11, NIR-SWIR; recently I1) need to achieve ~0.2%. This has been achieved.
Reconstruction of Missing Data in the VIIRS Global Ocean Color Images Using the DINEOF Method

Xiaoming Liu and Menghua Wang

VIIRS Ocean Color EDR Team
NOAA/NESDIS Center for Satellite Applications and Research (STAR)

JPSS Annual Science Team Meeting, College Park, MD, August 14-18, 2017
Introduction

• Visible Infrared Imaging Radiometer Suite (VIIRS) ocean color images, such as normalized water-leaving radiances $nL_w(\lambda)$, chlorophyll-a (Chl-a) concentrations, and the water diffuse attenuation coefficient at the wavelength of 490 nm ($K_d(490)$) (Wang et al., 2013), are very useful for monitoring and understanding coastal biological and ecological processes and phenomena. However, there are lots of missing pixels in the ocean color images due to clouds and various other reasons.

• The Data Interpolating Empirical Orthogonal Function (DINEOF) is a method to reconstruct missing data in geophysical datasets based on Empirical Orthogonal Function (EOF). It utilizes both temporal and spatial coherencies of data to infer a solution at the missing locations (Alvera-Azcarate et al., 2005). In this study, the DINEOF is used to fill up gap pixels in the VIIRS global daily, 8-day, and monthly composite ocean color images.
Original VIIRS daily Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15 and (d) Oct. 15, 2014, generated from VIIRS global daily Level-3 binned file.
Reconstruct Global Daily Data Using DINEOF

• Input: Global daily Level-3 binned data file in Jan, Apr, Jul and Oct 2014.

• To increase DINEOF performance, global data are divided into 16 zonal sections: 80°S-70°S, 70°S-60°S, ... 10°S-Equator, Equator-10°N, 10°-20°N, ... 60°-70°N, 70°-80°N.

• Replace pixels that are missing for the whole month with climatology value.

• Apply DINEOF on each of the 16 zonal sections, fully reconstruct all pixels, including non-missing pixels.

• Output: Fully reconstructed global daily Level-3 binned data.
Fully reconstructed daily Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15, and (d) Oct. 15, 2014.
Examples of Reconstructed Chl-a Images (1)

Eddies near Amazon River
January 1-31, 2014

We can now see eddy movement in the reconstructed Chl-a images.
Examples of Reconstructed Chl-a Images (2)

South Pacific Gyre
Oct. 1-31, 2014

We can now see Gyre coverage variation in the reconstructed Chl-a images.
Validation with 5% valid pixels

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean</th>
<th>Median</th>
<th>STD</th>
</tr>
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<tbody>
<tr>
<td>Jan</td>
<td>1.022</td>
<td>0.996</td>
<td>0.261</td>
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<tr>
<td>Apr</td>
<td>1.033</td>
<td>0.996</td>
<td>0.319</td>
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<tr>
<td>Jul</td>
<td>1.015</td>
<td>0.986</td>
<td>0.246</td>
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<tr>
<td>Oct</td>
<td>1.021</td>
<td>0.985</td>
<td>0.354</td>
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</table>
Reconstruct Global 8-Day Data Using DINEOF

Reconstructed 8-day Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15, and (d) Oct. 15, 2014.
Validations and Evaluations

Scatter plot of reconstructed vs. original 8-day Chl-a for (a) Jan. 9-16, (b) Apr. 15-22, (c) Jul. 12-19, and (d) Oct. 8-15, 2014
Reconstruct Global Monthly Data Using DINEOF

Reconstructed monthly Chl-a for (a) Jan., (b) Apr., (c) Jul., and (d) Oct. 2014.
Validations and Evaluations

Monthly scatter plot for (a) Jan., (b) Apr., (c) Jul., and (d) Oct. 2014
Reconstructed daily, 8-day, monthly $K_d(490)$ for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19 8-day, and (d) Oct monthly in 2014.
Reconstruct Global $nL_w(443)$ Data Using DINEOF

Reconstructed daily, 8-day, monthly $nL_w(443)$ for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19, and (d) Oct. monthly in 2014.
Reconstruct Global $nL_w(551)$ Data Using DINEOF

Reconstructed daily, 8-day, monthly $nL_w(551)$ for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19 8-day, and (d) Oct. monthly in 2014.
<table>
<thead>
<tr>
<th>Date</th>
<th>Mean</th>
<th>STD</th>
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</thead>
<tbody>
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<td>V201401_test_L3.nc</td>
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<tr>
<td>V201404_test_L3.nc</td>
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<td>0.124521</td>
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<tr>
<td>V201407_test_L3.nc</td>
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<td>0.115728</td>
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<tr>
<td>V201410_test_L3.nc</td>
<td>0.979550</td>
<td>0.137193</td>
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</table>

Table 1. Recon/original Chl-a mean and STD for 8-day and monthly

<table>
<thead>
<tr>
<th>Date</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>V20140092014016_test_L3.nc</td>
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<td>0.125919</td>
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<tr>
<td>V201401_test_L3.nc</td>
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<td>V201404_test_L3.nc</td>
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<tr>
<td>V201407_test_L3.nc</td>
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<tr>
<td>V201410_test_L3.nc</td>
<td>1.00713</td>
<td>0.110283</td>
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</table>

Table 2. Recon/original $K_d(490)$ mean and STD for 8-day and monthly
Summary and Conclusions

• DINEOF is used to fill gap pixels in VIIRS global Level-3 data for Chl-a, $K_d(490)$ and $nL_w(\lambda)$.

• In the reconstructed daily Level-3 images, variations of both large-scale and small-scale dynamic features are captured.

• The reconstructed pixels are validated with 5% of good pixels that are artificially treated as mixing pixels.

• 8-day and monthly data are also reconstructed by binning the non-gap daily global Level-3 data, and results are quite reasonable.
NOAA CoastWatch/OceanWatch Ocean Color Data Dissemination

Veronica P. Lance* and Paul M. DiGiacomo and the NOAA CoastWatch/OceanWatch Team

*Global Science & Technology, Inc.

2016 STAR/JPSS Annual Science Meeting
College Park, MD, 14-18 August 2017
NOAA CoastWatch/OceanWatch Team

Paul DiGiacomo – Program Manager

<table>
<thead>
<tr>
<th>Full Time “CW Central” Technical Team</th>
<th>With Support From</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heng Gu</td>
<td>Veronica Lance</td>
</tr>
<tr>
<td>Phil Keegstra</td>
<td>Emily Smail</td>
</tr>
<tr>
<td>Sathya Ramachandran</td>
<td>Sheekela Baker-Yeboah</td>
</tr>
<tr>
<td>Michael Soracco</td>
<td>Ryan Wattam</td>
</tr>
</tbody>
</table>

And PolarWatch and 5 Regional Nodes
Role of NOAA CoastWatch/OceanWatch

NOAA CoastWatch/OceanWatch

NESSDIS/STAR
(Oceans/SOCD)

- Science research
- Algorithm/product development
- Cal/Val
- Quality assessment and monitoring
- Reanalysis, reprocessing
- Satellite application development & support

NESSDIS/OSPO

- Cross-NOAA program and data framework
- Interface between development, users of all levels and applications
- Measurement (vice) mission-based approach to multi-sensor satellite data
- Processing and customization of pre-and/or post-operational products; “value-added” for CoastWatch users
- NRT & science quality time-series data service
- Global and user regions of interest
- Quality monitoring
- Multiple pathways to data discovery
- Intermediate repository
- Help desk, project assistance, public outreach
- Best effort, 8/5 support

NESSDIS/NCEI

- Data stewardship
- Determine archive-worthiness; identify storage requirements
- Ensure robust metadata
- Data archive; long term storage
- Discovery of and access to archived data
- Support for users

• USERS

2017 STAR/JPSS Annual Science Meeting,
College Park, MD, 14-18 August 2017
Suomi NPP VIIRS OC Data Products

- Near Real Time (Days 1-14)
  - Global
  - Regional

- Science Quality (Day 15 – 2 Jan 2012*)
  - Global
  - Regional

Also: Now Operational at OSPO

* Data from early mission (since launch Nov. 2011 to 2 Jan 2012) are available only upon special request and will be provided with a quality warning.
# NRT & Science Quality Data

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Near-Real Time</th>
<th>Delayed-Mode/Science-Quality</th>
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</thead>
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<tr>
<td>Latency:</td>
<td>Best effort, as soon as possible (~12-24h)</td>
<td>Best effort, on a 2-week delay</td>
</tr>
<tr>
<td>Processing System:</td>
<td>MSL12 (v1.01; will transition to v1.2x)</td>
<td>MSL12 (v1.2x)</td>
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<tr>
<td>SDR:</td>
<td>IDPS Operational SDR</td>
<td>OC-improved SDR</td>
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<td>Ancillary Data:</td>
<td>Global Forecast System (GFS) Model</td>
<td>Science quality (assimilated; GDAS) from NCEP</td>
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<td>Spatial Coverage:</td>
<td>May be gaps due to various issues</td>
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<td>Processed by:</td>
<td>OSPO (operational)</td>
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<td>Archive Plans:</td>
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<tr>
<td>Full Mission Reprocessing:</td>
<td>No</td>
<td>Yes, every ~2-3 years or as needed</td>
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</table>
*Early mission data are not publically distributed due to quality issues. They can be specially requested but will come with a quality warning.
L2 & L3 Global Products

- Standard:
  - Chlorophyll-a
  - $K_d(490)$
  - $K_d$(PAR)
  - $nL_w$ 5 M-Bands
    - 412
    - 445
    - 488
    - 555
    - 672
  - $nL_w$(638) I-Band
  - QA Score

- Experimental:
  - L2_flags
  - Latitude
  - Longitude
  - IOPs
  - PAR
    - Future inclusion as released by MECB
L2 & L3 Sector and Regional Products

- **Standard:**
  - Chlorophyll-a
  - $K_d(490)$
  - $K_d$(PAR)
  - $nL_w$ 5 M-Bands
    - 412
    - 445
    - 488
    - 555
    - 672
  - $nL_w$(638) I-Band
  - QA Score

- **Experimental:**
  - L2_flags
  - Latitude
  - Longitude
  - Edgemask
  - IOPs
  - PAR
  - Future inclusion as released by MECB

- **User Driven ("Customized" routine production; considered upon request):**
  - HAB anomaly product
  - $R_{rs}$
  - Special projections
  - Etc.
L3 Global 750m Sectors

UZ  VZ  WZ  XZ  YZ  ZZ
UY  VY  WY  XY  YY  ZY
UX  VX  WX  XX  YX  ZX
UW  VW  WU  XW  YW  ZW
# CW Distribution of NRT

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Processing Level</th>
<th>Nominal Spatial Resolution</th>
<th>Chl-a</th>
<th>nLws</th>
<th>KdPAR</th>
<th>Kd490</th>
<th>Rrs (672)</th>
<th>Chlorophyll Fronts</th>
<th>True Color</th>
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<tbody>
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<td>X</td>
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<tr>
<td>Daily merged mapped CW regions***</td>
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<td>Daily merged global single file</td>
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<tr>
<td>Daily merged global sectorized***</td>
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<tr>
<td>True monthly merged global sectorized***</td>
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</table>
### CW Distribution of Science Quality

<table>
<thead>
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<th>Product Description</th>
<th>Processing Level</th>
<th>Nominal Spatial Resolution</th>
<th>Chl-a</th>
<th>nLws</th>
<th>(K_a) (PAR)</th>
<th>(K_a) (490)</th>
<th>QA Score</th>
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<tbody>
<tr>
<td>Daily granule global swath @ 750 m</td>
<td>L2</td>
<td>750 m</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Daily merged global sectorized</td>
<td>L3</td>
<td>750 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>in progress at CW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-day merged global sectorized</td>
<td>L3</td>
<td>750 m</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>in progress at CW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>True monthly merged global sectorized</td>
<td>L3</td>
<td>750 m</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>in progress at CW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily merged global single file</td>
<td>L3</td>
<td>4 km</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>7-day merged global single file</td>
<td>L3</td>
<td>4 km</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Monthly merged global single file</td>
<td>L3</td>
<td>4 km</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Data Formats

- Global and Sector:
  - NetCDF v4 CF
  - GeoTIFF & PNG

- Tailored and CONUS Regional:
  - NetCDF v4 CF
  - GeoTIFF & PNG
  - HDF (v4 with CoastWatch metadata; to be phased out)
Pictured is daily NRT Chlorophyll-a [mg m$^{-3}$];
NRT Regional

- “CONUS” 750m regions: Hawaii, West Coast, Great Lakes, Northeast, Southeast, Gulf of Mexico, Caribbean

Granule

Daily Merge for Caribbean Region
International Partners (1)

- **EUMETSAT**
  - Processing and staging of L2 750m Mediterranean datasets
  - EUMETcast (Copernicus Service) broadcasts VIIRS data to EU

Shown: L3 Daily merge, mapped, $k_{d\text{PAR}}$ [m$^{-1}$]
International Partners (2)

- **CSIRO**

- Processing and staging of L3 Australia 750m datasets

Daily Merge, mapped, $k_d$PAR [m$^{-1}$]
Website Revamp v.1.2 in Progress
OC Product Pages

NOAA CoastWatch • OceanWatch
Ocean Color - Science Quality - VIIRS SNPP

Data are available through the following servers:

<table>
<thead>
<tr>
<th>Service</th>
<th>Resource Locator</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTTPS</td>
<td><a href="https://coastwatch.noaa.gov/cw_html/cw_granule_selector.html">https://coastwatch.noaa.gov/cw_html/cw_granule_selector.html</a></td>
</tr>
<tr>
<td>THREDDS</td>
<td><a href="https://www.star.nesdis.noaa.gov/thredds/socd/coastwatch/catalog_MECB_viirs_lom_global.html">https://www.star.nesdis.noaa.gov/thredds/socd/coastwatch/catalog_MECB_viirs_lom_global.html</a></td>
</tr>
</tbody>
</table>

Updated: 22 February 2017

8/24/2017

2017 STAR/JPSS Annual Science Meeting,
College Park, MD, 14-18 August 2017
L2 Granule Selector

NOAA CoastWatch • OceanWatch
Level-1 / Level-2 Ocean Data

The NOAA CoastWatch granule selector enables a user to select a Level-1 or Level-2 dataset by selecting a date and clicking on the granule that covers the user’s area of interest. For VIIRS near real-time data is available for the last 15 days and science quality data is available from 2012 up to near real-time coverage. Clicking a granule will open an information window containing a link to the preview image and/or data file. If multiple files are desired (each file can be 38 to 550 MB), clicking on the download icon (●) will add the selected granule to a list that can be downloaded and used to retrieve files using local software.

https://coastwatch.noaa.gov/cwn/cw_granule_selector.html
L2 Spatial Search Tool

NOAA CoastWatch • OceanWatch
Level-2 VIIRS Ocean Color Science Quality

https://coastwatch.noaa.gov/cw_html/cw_polygon_search.html#searchbox
Data Stewardship and Long-Term Archive by NCEI

- NOAA CoastWatch/OceanWatch is delivering MSL12 full mission science quality data (L2 and L3) for data stewardship and long-term archiving by NCEI.
- Data will be stored at CLASS but easily accessible via CoastWatch and through NCEI spinning disk.
- Spinning disk access page in progress, *waiting on me to edit the content description.*
Sentinel-3A OLCI

- A Cooperative Arrangement between the United States and the European Commission and technical arrangements between NOAA and EUMETSAT (and NOAA and ESA for S1 and S2) are all complete.
- NOAA is primary outlet in US for Sentinel 3 marine data.
- EUMETSAT data transfer via terrestrial multicast to NOAA/STAR is now routine. L1 and L2 marine data products are now available through CW.
- NOAA CoastWatch/OceanWatch provides near real-time access to global OLCI (L1b and L2 full and reduced resolution)
- SLSTR data products from EUMETSAT and SRAL data are coming into STAR and will be redistributed through CoastWatch.
- OLCI data complements existing JPSS sensors:
  - 300m spatial resolution
  - Spectral bands meeting NOAA NOS HAB requirements
  - Morning vs. afternoon orbits
  - Relieves single point-of-failure for HAB forecasting
Sentinel-3A OLCI
Both NRT and Science Quality VIIRS-SNPP Ocean Color data are available through NOAA CoastWatch/OceanWatch.

Science Quality
L2 global, granules:
FTP:
THREDDS:
https://www.star.nesdis.noaa.gov/thredds/catalog/swathNPPVIIRSSCIENCEL2WW00/catalog.html
Or, you can interactively select and download data (or get your file list for automated commands) using the Granule Selector Tool here:
https://coastwatch.noaa.gov/cwn/cw_granule_selector.html
L3 global 4 km mapped:
FTP:
Summary (2)

Both NRT and Science Quality VIIRS-SNPP Ocean Color data are available through NOAA CoastWatch/OceanWatch.

Near Real Time

THREDDS OC NRT main page:
https://www.star.nesdis.noaa.gov/thredds/socd/coastwatch/catalog_coastwatch_viirs_global.html
Includes: L2 global granules (swath); L3 global 4km mapped, daily, weekly, monthly merged

Or, you can interactively select and download data (or get your file list for automated commands) using the Granule Selector Tool here:
https://coastwatch.noaa.gov/cwn/cw_granule_selector.html
Thank You

Web Site:  CoastWatch.NOAA.gov

Help Desk:  Coastwatch.info@NOAA.gov

Me:  VeronicaLance@NOAA.gov
“Current Status of MOBY Data Products”

Kenneth Voss, Physics Dept., Univ of Miami

Co-Authors: Mark Yarbrough (MLML), Carol Johnson (NIST), Stephanie Flora (MLML), Mike Feinholz (MLML), Art Gleason (UM), Howard Gordon (UM), and Terry Houlihan (MLML)

8/17, STAR JPSS 2017 annual meeting, College Park, Md.
1) Brief statement on current status of MOBY Operation and Refresh

2) Explanation of M261 post calibrated data posting

3) Description of corrections we are working on implementing in the data stream.
Currently have a 20 yr. time series of vicarious calibration data at the MOBY site thanks to NASA, NOAA, Dennis Clark, and the rest of the MOBY team (many of whom have been in the project since the beginning).
Current status

• Deployment M263 started approximately 8/2.
• Currently working through controller issues, but the data is looking good. Getting 22 hr and 00 hr (or 23hr) files each day, but not 20 hr file, working on understanding why.
• We are on our third deployment of the new Blue spectrometer system. We are learning and testing for the optimal acquisition and data reduction procedures for this new system.
As might be recalled, M261 was a deployment that had several issues. At the beginning the pre-calibration for the mid arm was suspect, so we did not use the midarm measurement and only produced and posted the product Lw2 which uses the top arm and the bottom arm.

Mid deployment the top arm was broken off, and we were then forced to make a new product which used the lower arm measurement, and an empirical, seasonal KL to propagate this to the surface. This product was called Lw14.

With the post-calibrations we found that we could recover the midarm measurement after the arm had been damaged, but this did not propagate backwards beyond this point (other calibrations must have been effected when the collision that broke the arm occurred).

Taking all of this into account, we have replaced the data on the data directory with the post calibrated data.
This post calibrated data has two “epochs”:
1) the time period before the top arm was broken off uses the top and bottom arm, with the precalibrations to produce Lw2 and Lwn2. (and associated Lw22 and Lwn22 for wavelengths greater than 575 nm).

2) the time period after the top arm was broken off will use post calibrated mid arm and lower arm data to produce the Lw7 and Lwn7 product (and associated Lw27 and Lwn27 for red wavelengths).

IMPORTANT: Note that with the post cal, we have taken down data the Lw14 product that was produced during the deployment to give “real time” data. Also, now that we have midarm and lower arm data, thus a real KL measurement to evaluate, some days have changed their quality designation (good, bad or questionable).
We are working on ways to improve the accuracy of the MOBY data product, along with doing a better assessment of the environmental induced uncertainties in the data products.

Some of the factors, that we can model, include tilting of the Es collector, the BRDF effect and tilting the radiance collector, tilt of the buoy changing the Lu measurement depth, and possibly the biggest, instrument self-shadowing.

We can evaluate each of these individually and look on the effect on the data. To investigate an apparent optical property, rather than a radiometric property, we will look at the remote sensing reflectance, \( RRS = \frac{Lw}{Es} \) during two deployments in 2012/2013.
I will select RRS 520 nm, as it should be fairly stable.
MOBY

RRS (520 nm) for the two deployments in 2012-2013

Mean is 0.0024, while the COV is 6%
The correction for irradiance collector tilt (and actual cosine response) is shown below. As can be seen, this correction (for the most part less than 1) can be a significant effect, although it is also generally less than 2%.
Other corrections include accounting for solar zenith angle, BRDF effects, and small arm depth corrections. These are typically less than 1% effects. So the data with and without these corrections looks like:

In this, the mean is slightly lower (<2% change) and COV is slightly better (5.4% vs. 6/2%).
Corrections

So far this is without a shadowing correction. The graph below shows the corrected RRS vs. relative sun-arm azimuth. 180 degrees is when the arm and buoy are lined up such that the sun is on the opposite side of the buoy from the arm, maximum shading. As can be seen the lowest points are occurring when the buoy is oriented in this manner, hence these lowest points, while not many in number, need the shadowing correction which we are still working on (about 10% effect at 180 deg).
Time series is on-going, now 20 years long.

New deployment has just started, with 3rd deployment of blue spectrograph

M261 post calibrated data has been posted to the Coastwatch site

We are working on various modeling efforts which could help with both improving the data set and documenting the measurement uncertainty
STAR JPSS 2017
Annual Science Team Meeting

VIIRS Ocean Color Breakout
Wednesday, 16 August 2017

Optical Measurements in Support of JPSS Cal/Val

Michael Ondrusek, Eric Stengel and Charle Kovach
<table>
<thead>
<tr>
<th>Location</th>
<th>Season</th>
<th>Year</th>
<th>Stations</th>
<th>Status</th>
<th>To Menghua</th>
<th>Seabass Format</th>
<th>Notes</th>
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<tbody>
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<td>Ches. Bay GEOCAPE</td>
<td>July</td>
<td>2012</td>
<td>57</td>
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<td>NASA GEOCAPE</td>
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<td>Chesapeake Bay 2012</td>
<td>Dec</td>
<td>2011</td>
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<td>Processed</td>
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<td>South Florida</td>
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<td>2012</td>
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<td>Oahu, HI</td>
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<td>2012</td>
<td>21</td>
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<td>2013</td>
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<td>CUNY Ches. Bay Exp.</td>
<td>Aug</td>
<td>2013</td>
<td>42</td>
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<td>GOM GEOCAPE</td>
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<td>2013</td>
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<td>Processed</td>
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<td>Puerto Rico</td>
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<td>2014</td>
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<td>2014</td>
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<td>VIIRS Cal/Val</td>
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<td>Yes</td>
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<tr>
<td>Puerto Rico</td>
<td>Mar</td>
<td>2015</td>
<td>15</td>
<td>Processed</td>
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<td>Yes</td>
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</tr>
<tr>
<td>East Coast Ocean Acidification</td>
<td>Jun/July</td>
<td>2015</td>
<td>74</td>
<td>Processed</td>
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<td>Yes</td>
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<tr>
<td>VIIRS Cal/Val</td>
<td>Dec</td>
<td>2015</td>
<td>27</td>
<td>Processed</td>
<td>Yes</td>
<td>Yes</td>
<td>Many good matchups</td>
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<tr>
<td>Chesapeake Bay 2016</td>
<td>All Year</td>
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<td>6+</td>
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<td>No</td>
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<td>KORUS OC</td>
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<td>2016</td>
<td>35</td>
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<td>Yes</td>
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<td>West Coast Ocean Acidification</td>
<td>May/June</td>
<td>2016</td>
<td>35</td>
<td>Processed</td>
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<td>Yes</td>
<td>lots of clouds some good matches</td>
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<td>Fiji to Australia</td>
<td>Jun/July</td>
<td>2016</td>
<td>24</td>
<td>Processed</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>CORAL PRISM</td>
<td>Oct</td>
<td>2016</td>
<td>37</td>
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<td>Hurricane Matthew</td>
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<td>VIIRS Cal/Val</td>
<td>Oct</td>
<td>2016</td>
<td>12</td>
<td>Processed</td>
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<td>No</td>
<td>Several Matchups</td>
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<tr>
<td>P18 South Pacific</td>
<td>Jan/Feb</td>
<td>2017</td>
<td>45</td>
<td>Processed</td>
<td>No</td>
<td>Yes</td>
<td>includes south pacific gyre low chl H2O</td>
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<tr>
<td>JOEYS</td>
<td>March</td>
<td>2017</td>
<td>12</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Chesapeake Bay 2017</td>
<td>All Year</td>
<td>2017</td>
<td>17</td>
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<td>No</td>
<td>No</td>
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<tr>
<td>Total since VIIRS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>
Primary Objectives:

• Provide in situ ocean color data to be used for calibration and validation of the JPSS Cal/Val effort.

• Define uncertainties in validation data collection.

• Outline best protocols to address validation and collection issues.
December 2015 Cal/Val Cruise
VIIRS Cal/Val Cruise III (NF-16-08), October 5 to 18, 2016 aboard the NOAA Vessel Nancy Foster
May 2018
Cal/Val Cruise

range 477 nm.
<table>
<thead>
<tr>
<th>Instrument Shorthand</th>
<th>Full Identification/Purpose</th>
<th>Manufacturer or Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ac-9</td>
<td>In situ spectrophotometer - 9 channel resolution</td>
<td>WET Labs</td>
</tr>
<tr>
<td>ac-s</td>
<td>In situ spectrophotometer – high spectral resolution</td>
<td>WET Labs</td>
</tr>
<tr>
<td>ADCP</td>
<td>Acoustic Doppler Current Profiler</td>
<td>Teledyne RD Instruments</td>
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<tr>
<td>ASD</td>
<td>Analytical Spectral Device; HandHeld2-Pro visible and near infrared spectrophotometer</td>
<td>PANalytical</td>
</tr>
<tr>
<td>BB-3</td>
<td>Backscatter – 3 channels</td>
<td></td>
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<tr>
<td>BB7FL2</td>
<td>Backscatter – 7 channels, Fluorescence – 2 channels</td>
<td>WET Labs</td>
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<tr>
<td>C-OOPS</td>
<td>compact hyperspectral optical profiling system</td>
<td>Biospherical Instruments, Inc.</td>
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<td>CTD</td>
<td>Conductivity, Temperature, Depth</td>
<td>Generic, various manufacturers</td>
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<tr>
<td>ECO-Puck Triplet Fluorometer</td>
<td>Fluorescence at 3 channels for determining chlorophyll, CDOM and phycoerythrin</td>
<td>WET Labs</td>
</tr>
<tr>
<td>ECO-Puck Triplet Scatterometer</td>
<td>Scatter – 3 channels (443, 550, 860)</td>
<td>WET Labs</td>
</tr>
<tr>
<td>GER</td>
<td>Field portable spectroradiometer</td>
<td>Spectra Vista Corporation</td>
</tr>
<tr>
<td>FlowCam</td>
<td>Dynamic imaging particle analysis for species composition and size measurements</td>
<td>Fluid Imaging Technologies, Inc.</td>
</tr>
<tr>
<td>HyperOCI</td>
<td>Hyperspectral irradiance sensor</td>
<td>Satlantic LP</td>
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<tr>
<td>HyperOCR</td>
<td>Hyperspectral radiance sensor</td>
<td>Satlantic LP</td>
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<td>HyperPro, HyperPro-II</td>
<td>Free-falling hyperspectral optical profiler</td>
<td>Satlantic LP</td>
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<tr>
<td>HyperSAS</td>
<td>Above water optical system</td>
<td>Satlantic LP</td>
</tr>
<tr>
<td>HyperSAS-POL</td>
<td>Above water optical system with sky polarimeter</td>
<td>Satlantic LP with modifications by CCNY</td>
</tr>
<tr>
<td>HyperTSRB</td>
<td>Hyperspectral radiometer configured to float on the sea surface</td>
<td>Satlantic LP</td>
</tr>
<tr>
<td>Imaging Flow CytoBot (IFCB)</td>
<td>Automated microscopic imaging instrument</td>
<td>McLane Research Labs</td>
</tr>
<tr>
<td>Microtops</td>
<td>Handheld sun photometer (atmospheric aerosols and optical depth)</td>
<td>Solar Light Company</td>
</tr>
<tr>
<td>NURADS</td>
<td>Upwelling Radiance Distribution Camera System</td>
<td>Voss and Chapin, 2005</td>
</tr>
<tr>
<td>Sartorius CPA 2250</td>
<td>Balance</td>
<td>Sartorius</td>
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<tr>
<td>RISBA</td>
<td>Radiometer Incorporating the Sky Blocking Approach</td>
<td>Lee et al. 2013</td>
</tr>
<tr>
<td>SBE 49</td>
<td>Conductivity, Temperature, Depth</td>
<td>SeaBird Scientific</td>
</tr>
<tr>
<td>VSF-9</td>
<td>Volume scattering function – 9 channels</td>
<td>WET Labs</td>
</tr>
<tr>
<td>SR1900 (Spectral Evolution)</td>
<td>Spectroradiometer, handheld</td>
<td>Spectral Evolution, Inc.</td>
</tr>
</tbody>
</table>
Instruments used to measure Remote Sensing Reflectance

Profilers

**Hyp** (Satlantic) – Hyperpro free-falling hyperspectral optical profiler. 10 nm bands sampled every 3 nm. Radiance FOV 8.5 degrees. Calibrated from 350 to 800 nm.

**C-OPS** (Biospherical Instruments, Inc.) – compact multispectral optical profiling system. A spectral range from 300 nm to 900 nm, with 19 wavebands wavelengths each: 305 nm, 320 nm, 340 nm, 380 nm, 395 nm, 412 nm, 443 nm, 465 nm, 490 nm, 510 nm, 532 nm, 555 nm, 565 nm, 625 nm, 665 nm, 683 nm, 710 nm, 780 nm, and 875 nm.
Instruments used to measure Remote Sensing Reflectance

Surface

**Float** (Satlantic) – HyperTSRB. Same instrument as hyperpro but collared to float at surface.

**SBA** (Satlantic) – Sky-Blocking Apparatus (SBA) radiometer package composed of one HyperOCR radiance sensor and one irradiance sensor. Directly measures the water-leaving radiance $L_w$ while blocking out sky-light (Lee et al., 2013).

Above-water

**ASD** Analytical Spectral Device (PANalytical) – Handheld above-water spectrometer. Spectral range of 325 to 1075 nm. Spectral Resolution <3.0 nm, FOV 10 degrees. 2nd ASD has 7 degrees FOV.

**GER** (Spectra Vista Corporation) – The GER 1500, Field Portable hand-held Spectroradiometer. Wavelengths from 350 nm to 1050 nm at 3 nm resolution with 4° nominal field of view (FOV).

**HyperSAS** (Satlantic) – Autonomous above-water OCR’s with narrow FOV of 3 degrees. Also set up to measure polarization

**Spec-Evo** – Spectral Evolution above water radiometer.
Date: 10/13, 287
Description: Just off Charleston
Overpass time: 1740
Above time: 1843
Surf. Time: 1743
Profile time: 1720
Depth (m): 17
Cloud cover (%): 0
Wind speed (kts): 10
Seas (ft): 3
Meas. Chl (mg/m³): 1.39
VIIRS Chl (mg/m³): 2.02
# pixels in 5 x 5: 21
Current (m/s): 0.5
Current source direction: 45°
Pixel travel OP - sta: 0

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Date: 10/13, 287
Description: 8 km away
Overpass time: 1740
Above time: 2018
Surf. Time: 2046
Profile time: 2010
Depth (m): 17
Cloud cover (%): 0
Wind speed (kts): 9
Seas (ft): 3

Meas. Chl (mg/m³): 1.81
VIIRS Chl (mg/m³): 2.24

# pixels in 5 x 5: 21
Current (m/s): 0.5
Current source direction: 45
Pixel travel OP - sta: 5
Station 3

Date: 10/14, 288
Description: 17 miles off Savannah
Overpass time: 1901
Above time: 1600
Surf. Time: 1535
Profile time: 1531
Depth (m): 18
Cloud cover (%): 15
Wind speed (kts): 9
Seas (ft): 3
Meas. Chl (mg/m$^3$): 1.846
VIIRS Chl (mg/m$^3$): 2.18
# pixels in 5 x 5: 22
Current (m/s): 0.2
Current source direction: 100
Pixel travel OP - sta 4

Percent difference relative to Average

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Station 4

Date: 10/14, 288
Description: Nurads Prob.
Overpass time: 1901
Above time: 1753
Surf. Time: 1840
Profile time: 1753
Depth (m): 9
Cloud cover (%): 50
Wind speed (kts): 15
Seas (ft): 5
Meas. Chl (mg/m³): 1.84
VIIRS Chl (mg/m³): N/A
# pixels in 5 x 5: N/A
Current (m/s): N/A
Current source direction: N/A
Pixel travel OP - sta: N/A

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Wavelength (nm)

Date: 10/14, 288
Description: Nurads Prob.
Overpass time: 1901
Above time: 1753
Surf. Time: 1840
Profile time: 1753
Depth (m): 9
Cloud cover (%): 50
Wind speed (kts): 15
Seas (ft): 5
Meas. Chl (mg/m³): 1.84
VIIRS Chl (mg/m³): N/A
# pixels in 5 x 5: N/A
Current (m/s): N/A
Current source direction: N/A
Pixel travel OP - sta: N/A

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Wavelength (nm)
### Station 5

**Date:** 10/15, 289  
**Description:** Windy, above only  
**Overpass time:** 1842  
**Above time:** 1843  
**Surf. Time:** none  
**Profile time:** none  
**Depth (m):** 15  
**Cloud cover (%):** 40  
**Wind speed (kts):** 20  
**Seas (ft):** 5  
**Meas. Chl (mg/m³):** 5.466  
**VIIRS Chl (mg/m³):** 4.81  
**# pixels in 5 x 5:** 22  
**Current (m/s):** 0.2  
**Current source direction:** 225  
**Pixel travel OP - sta:** 0

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**Percent difference relative to Average**

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### Station 6

**Wavelength (nm)**

400 500 600 700 800

**Rrs (sr⁻¹)**

- **In situ**
- **Viirs**

**Percent difference relative to Average**

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**Date:** 10/16, 290  
**Description:** Windy,  
**Overpass time:** 1823  
**Above time:** 1343  
**Surf. Time:** none  
**Profile time:** 1352  
**Depth (m):** 14  
**Cloud cover (%):** 50  
**Wind speed (kts):** 17  
**Seas (ft):** 5  
**Measure Chl (mg/m³):** 2.62  
**VIIRS Chl (mg/m³):** 3.24  
**# pixels in 5 x 5:** 17  
**Current (m/s):** 0.5  
**Current source direction:** 315  
**Pixel travel OP-sta:** 10
Percent difference relative to Average

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### Station 9

- **Date:** 10/16, 290
- **Description:** Off Savannah
- **Overpass time:** 1823
- **Above time:** 2054
- **Surf. Time:** none
- **Profile time:** 2015
- **Depth (m):** 18.7
- **Cloud cover (%):** 20
- **Wind speed (kts):** 5
- **Seas (ft):** 5
- **Meas. Chl (mg/m³):** 1.34
- **VIIRS Chl (mg/m³):** 1.78
- **# pixels in 5 x 5:** 18
- **Current (m/s):** 0.7
- **Current source direction:** 100
- **Pixel travel OP - sta:** 4

---

**Graphs:**
- **Wavelength (nm) vs. Rs (sr⁻¹):**
  - Station 9
  - Data from various sources (Hyp 1, Hyp 3, Spec. Evo, GER, ASD 1, ASD 2, ASD 3, ASD 4, Average, VIIRS)
- **chlor_a** (mg/m³) color bar:
  - Chlorophyll-a concentration ranges from 0.01 to 20.00 mg/m³
- **Time Series:**
  - eC1 (1/m) vs. Time (hr)
  - Data from NOAA/Val CRUISE 2016/2017: BOPEX: 2016/2017
  - MAPE = 22.52, MAPE = 24.61
Station 10

Date: 10/17, 291
Description: Good offshore conditions
Overpass time: 1806
Above time: 1340
Surf. Time: 1420
Profile time: 1341
Depth (m): 92
Cloud cover (%): 5
Wind speed (kts): 10
Seas (ft): 3
Meas. Chl (mg/m³): 2.15
VIIRS Chl (mg/m³): 0.26
# pixels in 5 x 5: 22
Current (m/s): 0.2
Current source direction: 210
Pixel travel OP - sta 4

Percent difference relative to Average

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### Station 12

**Date:** 10/17, 291  
**Description:** Good offshore conditions  
**Overpass time:** 1806  
**Above time:** 2015  
**Surf. Time:** 2045  
**Profile time:** 2015  
**Depth (m):** 35  
**Cloud cover (%):** 0  
**Wind speed (kts):** 8  
**Seas (ft):** 2  
**Meas. Chl (mg/m³):** 0.591  
**VIIRS Chl (mg/m³):** 1.23  
**# pixels in 5 x 5:** 22  
**Current (m/s):** 0.2  
**Current source direction:** 100  
**Pixel travel OP - sta** 2

### Percent difference relative to Average

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**Wavelength (nm):** 400, 450, 500, 550, 600, 650, 700

**Rrs (sr⁻¹):**

- **In situ**
- **Viirs**

**Pixel travel OP - sta:**

- ** chlor_a (mg m⁻³)**
- **0.01** to **20.00**

**MAPE:**

- **13.85**
- **13.38**
Percent difference relative to Average

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### MSL12 VIIRS Percent difference relative to in situ

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#### 2015 VIIRS Cal/Val Cruise

<table>
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<tr>
<th>Band</th>
<th>Hyperpro</th>
<th>Hyperpro</th>
<th>Spec Evo</th>
<th>SBA</th>
<th>HTSRB</th>
<th>HTSRB</th>
<th>ASD 1</th>
<th>ASD 2</th>
<th>ASD 3</th>
<th>GER</th>
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#### 2016 VIIRS Cal/Val Cruise

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<th>Hyp 2</th>
<th>Hyp 3</th>
<th>Float 1</th>
<th>Float 2</th>
<th>SBA</th>
<th>Spec. Evo</th>
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<th>HyperSA</th>
<th>ASD 1</th>
<th>ASD 2</th>
<th>ASD 3</th>
<th>ASD 4</th>
<th>Average</th>
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Summary:

Despite Hurricane, we were able to conduct several good validation stations while optically characterizing the aftermath of a hurricane path.

Variability between in situ measurements in coastal waters is dominated by inter-pixel variability despite some biases between measurements.

10 to 20% variation between independent in situ measurements in coastal waters. Simultaneous measurements with identical, inter-calibrated instruments and identical processing greatly reduces the variability.

VIIRS is slightly under-estimating radiances in coastal water relative to shipboard measurements.
Evaluation of VIIRS Ocean Color products and development of enhanced ocean products and applications

Robert Arnone¹, Sherwin Ladner², Bill Gibson³, Wes Goode²,
1. University of Southern MS  2. Naval Research Laboratory  3. La State University

Topics:
1. Cal Val  Foster Cruise – 2016 Mathew – Summary
   - Matchups, HyperPro / ASD
   - Protocols
   - Flowthrough  ➔ also Poster- Ladner, Arnone, Goode, Anderson
2. Diurnal VIIRS Paper - VIIRS products using difference fields
   - Importance of matchup time for cal–validation - )Seasonal changes in color
3. Anomaly products (VIIRS and Models) - Events - Hotspots  SPIE paper
   - Applied to Blue Fin Tuna Foster ➔ Poster –Arnone, Jones, Soto
4. WavCIS Aeronet Status
5. Invitation SPIE -Ocean Sensing and Monitoring April 15-19

Stennis - Cal val Team
Annual Summary
Foster Oct 2016 Cruise
1. Chl Extended offshore
2. Movement of the Gulf Stream onto the coast areas
   SST didn’t detect Stream with uniform Temperature.
3. Exchange of Coast waters offshore Discharge
4. Cruise departed 5 days following Passage of Mathew
Cal Val cruise 2016 - Foster - Flowthrough – IOP

VIIRS Daily Coverage with Stations

Oct 13

Oct 14

Oct 15

Oct 16

Oct 17

Oct 18

Day 291

Stations 10,11,12

St 11

Cloud Free
FOSTER 2016 Cal Val cruise

Oct 13, 2016
- 2 Floating Hyperpros
- Hyperpro – NOAA
- VIIRS Matchup- revised
- 1x1 APS (5x5)

Trichodesmium Bloom side of Ship
Oct 13, 2016
Off Charleston entrance

VIIRS - Orbit 1 17:41 and Orbit 2 19:18

RSIS - Orbit 1 17:41 and Orbit 2 19:18
- Floating Hyperpros (USM- NRL)
- Hyperpro – NOAA
- MSL 3flag-20% - HP-APS

VIIRS Overpass – 17:18

Station 3- 16:00

Station 4- 18:00
FOSTER 2016 Cal Val cruise
Oct 17, 2017
- Floating Hyperpros (USM- NRL
- Hyperpro – NOAA
- St 11 is Closest Matchup
  at time of Orbit – 18:02
  MSL 3 flag-20% - HP APS
  Plus 4 ASD

Flows through Matchup

Station 10- 13:40

Station 11- 17:30
Closest to Time of ORBIT
Flowthrough Matchup

Station 12- 20:30
FOSTER  2016 Cal Val cruise

Foster Oct 18-- Orbit at 17:45

The surface Waters were scattered *Trichodesmium* Bloom Off side of Ship.

Coastal waters  surface Patches

MSL 3 flag-20% - HP APS

: Established Floating HyperPro
Protocols for using Prosoft software for processing.

Plus 4 ASD

3 Hyperpros agreed at Stations

Station 13- 13:40

4 hour before over pass 17:45
Floating Hyperpro Protocols for Post Processing - Prosoft 8.1.4.

1. Measurements were made over 10 minute time period.
2. Processing using Prosoft v8.1.3-4 and data were averaged over the deployment interval and tilts greater than 2 degrees was omitted.
3. Use the Es rather that ED (tested both)
4. Did a consistency of ALL ES sensors on Foster!
5. Fresnel reflectance \( (\rho) = 0.025 \) and refractive index of sea water \( (n) = 1.34 \) (Prosoft Defaults). \( \text{factor} = (1-0.021)/(1.345^2) \); \( \text{Rrs} = L_u \times \text{factor}/E_d \).

\[
L_w(\lambda) = \frac{1 - \rho}{n^2} \cdot L_u(0^- , \lambda)
\]

\( \rho = 0.025 \) is the Fresnel reflectance of the air sea interface,
\( n = 1.34 \) is the refractive index of seawater.

Remote sensing reflectance
\[
R_{R_S}(\lambda) = \frac{L_w(\lambda)}{E_s(\lambda)}
\]
Addressing ASD protocols

ASD –
St – 1,2,3,4
5,6,7,8a,b,9
10,11,12,13,

- 2 blue tile stations for 2 NRL ASDs (1,2) for 2 stations (5a,11b).
  #2 - Consistent at both
  #1 - Changed
A. Validate VIIRS Inherent Optical Properties Spectral total absorption → at 410, 443, 486, 551, 671

B. Continuous underwater measurements from flowthrough defined the spatial optical variability at stations.

C. How did the optics change within a VIIRS Pixel? Needed for pixel calibration!

D. Identified the Spatial variability at the time of Overpass

E. Established protocols for acs – Scattering Comparison of Scatter Correction: using Rudiger RR -

F. VIIRS Validation Matchup done for the 24 hour Day and ± 30 minutes of overpass.

Poster - Evaluation of SNPP VIIRS Inherent Optical Properties during the 2016 NOAA Cal/Val Cruise – Ladner, Arnone, Goode, Anderson
Mar 17, 2016 Flowthrough Total Absorption

Matchup 24 hours
C = Station 11

Matchup +- 30 minutes
Sub-Pixel Variability
"Spatially Homogenous"

Correlation
At 551-r2
.99969
.99973

Station 11 - Excellent Matchup - Spatially Consistent

+- 30 minutes

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<th>MSL12</th>
<th>APS</th>
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<tbody>
<tr>
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<td>443</td>
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<td>551</td>
<td>.99969</td>
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<tr>
<td>671</td>
<td>.99992</td>
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</table>
Foster 2016  Matchup Flowthrough IOP absorption

Day 288 - Oct 14, 2017

Day 289 - Oct 15, 2017

Day 290 - Oct 16, 2017

Total Absorption 551 St4
Day 288 St 4 Oct 14
APS R2
17:04  19:01
410 .99744 .99829
443 .99883 .999
486 .99987 .9994
551 .99985 .99963
671 .99995 .99997

Matchup
+– 30 minute

Station 4

Linear Correlation- R2

Total Absorption 551 – St 5
Day 289  18:42  Oct 15 R2
MSL12  APS 17:06
410  NA .98689
443  NA .98587
486  NA .98526
551  NA .98458
671  NA .99497

Matchup
+– 30 minute

Total Absorption 551 – St 9
Day 290  - Oct 16 R2
APS 19:01  MSL12
410 .99568  clouds
443 .99614
486 .99602
551 .99729
671 .99979
**Total Absorption 551 R2**
Day 287 St 1, 2 Oct 13

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</table>

**Matchup**

+/- 30 minutes

**Foster 2016 Matchup Flowthrough IOP absorption**

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<th>Oct 13 , Day 287   First</th>
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<tr>
<td>Ac (551)</td>
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<table>
<thead>
<tr>
<th>Oct 18 , Day 292   Last</th>
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</thead>
<tbody>
<tr>
<td>Ac (551)</td>
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</table>

No matchup at Time of Orbit

14 hour Matchup

**Total Absorption 551 R2**
Day 292 Oct 18 17:47 total 14 hours prior

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<td>551</td>
<td>.94141</td>
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<tr>
<td>671</td>
<td>.94235</td>
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</table>

NOAA NRL
Enhanced Potential VIIRS

New VIIRS – Orbital Overlap
Valid Data
Diurnal Changes in ocean color
~ 100 minutes

Can affect the Matchup time
What Can Cause Diurnal Color change?

1. Advection of Water masses - Estimate the surface “currents” \((\text{Max Cross Correlation})\)
2. Biological Bloom or Decay, Particle Resuspension
3. Vertical Movement of optical layers - Upwelling and Downwelling
   - Phytoplankton Migration (HAB detection during the day)

**Enhanced Products**

**Diurnal Changes from VIIRS Orbital Overlap**

**New - VIIRS Difference Products**

- VIIRS imagery for April 3, 2016

**Bloom Increase**

**Decrease Decay**

Second Orbit Higher

Backscattering at 551 nm

Changes in the Particles in the Mobile Bay Plume—Note the Difference product is identifying Spatial Ocean Features. The Plume has both Vertical Layers and Physical Convergence and Divergence Zone.

VIIRS Difference Products

1. Backscatter 551: Particles
2. Satellite Penetration Depth

Diurnal Changes VIIRS Orbital Overlap

Orbit 1
Orbit 2

Difference H17:56-19:38
Difference H17:57-H19:38

Optical Depth (meters)

Penetration Depth
Within 100 minutes
Mobile Plume
The diurnal difference (orbit 1- orbit2) VIIRS nLW spectral channels (A410, B 443, C551, D671) month 2014

Water Regions
A- Open  1
B - Shelf  2
C - Coastal -3

Orbit 1 greater

Orbit 2 greater

How does the Difference Products change Seasonally? Timing of VIIRS Overpass can affect the Ocean Color

~17:00

Orbit 1

White - M1 410
Red      - M2 443
Green - M3 486
Blue     - M5 551
Yellow - M6 671

~19:00

Orbit 2

The trend line in open waters (Blue) suggests the higher Solar elevation in summer months makes the second orbit greater color.

→ Time of the Overlap affects the Ocean Color. Same for SNPP and J1?

The diurnal difference (orbit 1- orbit2) VIIRS nLW spectral channels (A410, B 443, C551, D671) month 2014
How Abnormal was this event in last few months?
What regions were affected? Define Level of Uncertainty?

Daily Chlorophyll and Surface Currents and Salinity Contours?
Defining Dynamic Anomalies Properties –DAP

Where are the abnormal Hotspots in 8-21-2015

Chlorophyll Hotspots

8-21-2015 Weekly Chl

2 week lag 8 Week mean

Plume to Key West

Higher

Normal

Lower

Difference

Need to determine the Level of the Anomaly - by a mask of the Standard Deviation

4.0 Standard Deviation Mask

Hotspot location Greater than 4 SD 2mg/m² Higher

Level of Anomaly
How Abnormal Condition affect the Ecosystem

VIIRS Products and America Seas Model

Anomaly Products

Plume to Key West Event
Sept 21 - 2015

Coupling Satellite and Ocean Models

Absorption 443
Euphotic Depth
Current Magnitude

One St-Dev

Weekly 8 Week Avg Anomaly Stand Deviation

Backscatter
SSTemperature
Temperature

Chlorophyll
SSSalinity
Salinity

Animation
Oregon & Foster Cruise  Fishers -- Tuna

How is the Ecosystem responding to the present Nowcast? Have changes taken place? Are there areas that are abnormal? How are Fisheries responding the Abnormal HotSpots?

Water Clarity – Euphotic depth

VIIRS Water Clarity May 27

VIIRS Water Clarity Anomaly May 17-24

NOWCAST

Abnormal Patches of more clearer and turbid waters.

Is this typical? What is Different / Changed?
Oregon & Foster Cruise
May 2017 Salinity

Nowcast Surface Currents

Surface Salinity May 27

NOWCAST

High Salinity

Oregon May 29

B17

High Salinity

Foster 5/29/17 19:14

Is this typical? What is Different / Changed

Anomaly May 17-24 SD MSK1

Average Weekly Currents

Higher

Low Salinity

Higher

Low

CC

Lower

High

Lower Anomaly salinity regions - B176, B185-B082

MS plume to EAST
MS - Plume at B176
LA - Coast has high Salinity region

Nowcast Surface Currents

5/29/17 19:14

B17

B176
Chlorophyll May 27

NOWCAST

Chlorophyll May 27

Anomaly May 24-17 SD MSK1

Is this typical? What is Different / Changed →

Chl- Extending Offshore! Anomaly Chlorophyll - Lower along LA coast - Higher along MS coast
Instrument Update and Present Status:

A. New Owners of ST52B purchased this platform in November of 2016, new boarding agreement in place by end of March, 2017.
B. SN610 - Operational to Sept 2016 and replaced with SN638 Loaner.

1. April 10th, platform generators down, replaced both battery chargers, main batteries and computer power supply. Site repaired and running.
3. May 26th- SeaPrism time data was not being updated. Corrected problem by installing latest HTTP CIMEL program.
5. Presently, main battery might be dead (last replaced in 2013), delays due to bad weather. Sn 638 will be reinstalled ASAP and SN 610 will be returned to NASA. Check Filter Wheel motor.
WaveCIS – CSI “nLw” Operational FULL Time Series

July 2017 – July 2017

CSI Site Matchups this Year
262 points for WaveCIS (4-6 readings/day)
102 for Navy APS VIIRS,
77 for MSL12 VIIRS

Constraints: Valid
50% of 5x5 box centered around in-situ sensor
Center pixel valid (WaveCIS Site Location)
nLw between 0-4
Flagged for CLDICE, HIgLINT, ATMFAIL, PRODFAIL

Note Differences in WavCIS matchup (MSL12, NRL)

Summary

1. Oct 2016 Foster cruise
   Match up with Hyperpros, ASD and Flowthrough
   Coastal waters – *Trichodesmium*
   Protocols for Floating Hyperpro, and IOP-acs

2. Diurnal ocean color using VIIRS Orbital Overlaps - J1/NPP Compare
   New VIIRS Difference products. Vertical optical layers, Bloom etc
   VIIRS overlaps support for a Geostationary Sensor!

3. Dynamic Abnormal properties - “Hotspots” using VIIRS and Physical models

4. WavCis – Aeronet Operational and Calibrated at NASA

Thank You

Stennis - Cal val Team
Annual Summary
Conference Chairs: Weilin “Will” Hou, Naval Research Lab), Robert A. Arnone, Univ. Southern Mississippi  
Program Committee: Sam Ahmed, City College of New York Linda Mullen, Naval Air Systems Command Brandon Cochenour, Naval Air Systems Command; Fraser Dalgleish, Florida Atlantic University); Chuanmin Hu, University of South Florida) ; James Sullivan, Florida Atlantic University ; Michael Twardowski, Florida Atlantic University

Sessions:

A. Ocean Remote Sensing: Lidar, Ocean Color, SST, SAR  
- active and passive remote sensing of the ocean and atmosphere (visible, IR/SST, microwave/SAR)  
- inversion techniques for active and passive measurements  
- calibration and characterization of satellite sensors  
- cloud screening and effect of ambient/residual cloud on retrievals  
- Cal/Val, quality control and consistency checks of satellite products, inter-sensor comparisons  
- uncertainty evaluation  
- radiative transfer in the ocean and atmosphere

B. In Situ Sensing and Monitoring

C. Extreme Events: Oil Spill & Harmful Algal Bloom (HAB) Sensing and Monitoring

D. Unmanned Systems, Sensors, Measurements

E. Imaging Sensors, Systems and Signal Processing Techniques: Optical & Acoustical

F. Characterization and Forecasting of Oceanic, and Coastal Environments

G. Bioluminescence

Thank You
END
Evaluation of VIIRS performance in coastal waters and in its capacity to detect dark water and harmful algal blooms

Chuanmin Hu, David English, Jennifer Cannizzaro, Brian Barnes, Lin Qi
Optical Oceanography Laboratory,
College of Marine Science,
University of South Florida
1. Performance for open-ocean and coastal waters
2. Performance for estuaries
3. Application for harmful algal blooms
4. Application for floating macroalgae blooms
1. Performance for open-ocean and coastal waters
<table>
<thead>
<tr>
<th>Region</th>
<th>Project</th>
<th>Cruise</th>
<th>Start Date</th>
<th>End Date</th>
<th>Field R$_{rs}$(λ)</th>
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Total # of field R$_{rs}$(λ) = 184
Summary of USF Field Experiments in oceanic/coastal waters (2012-2016)

Northern/Central GOM
- Oligotrophic GOM/
  Mississippi R. plume

Northeast GOM
- CDOM-rich, coastal Big
  Bend;
  Red tide (8/2014)

SAB/Gulf Stream/Bahamas
- Oligotrophic Gulf Stream; Turbid post-
  H. Matthew-(10/2016)

Above-water:
- Instrument = ASD
- Instrument = SPECTRIX

NE GOM
- Field \( R_{rs}(\lambda) \)
- Valid VIIRS same day match-ups
'Old' VIIRS MSL12

Rrs_410
- Slope: 1.02
- y-int: -0.0004
- r²: 0.93
- N: 26
- Med. ratio: 0.89
- APD: 15.1
- RMSE: 0.0011

Rrs_443
- Slope: 1.04
- y-int: -0.0004
- r²: 0.93
- N: 26
- Med. ratio: 0.94
- APD: 13.4
- RMSE: 0.0010

Rrs_486
- Slope: 1.12
- y-int: -0.0007
- r²: 0.85
- N: 29
- Med. ratio: 0.99
- APD: 14.5
- RMSE: 0.0010

Rrs_551
- Slope: 0.96
- y-int: -0.0000
- r²: 0.93
- N: 29
- Med. ratio: 0.97
- APD: 13.5
- RMSE: 0.0008

Rrs_671
- Slope: 0.92
- y-int: 0.0001
- r²: 0.92
- N: 16
- Med. ratio: 1.11
- APD: 16.6
- RMSE: 0.0003

Rrs_all
- Slope: 1.01
- y-int: -0.0002
- r²: 0.92
- N: 126
- Med. ratio: 0.98
- APD: 14.5
- RMSE: 0.0009

'SNew' VIIRS MSL12

Rrs_410
- Slope: 1.03
- y-int: 0.0005
- r²: 0.93
- N: 32
- Med. ratio: 1.10
- APD: 10.8
- RMSE: 0.0012

Rrs_443
- Slope: 1.07
- y-int: 0.0000
- r²: 0.90
- N: 32
- Med. ratio: 1.09
- APD: 15.5
- RMSE: 0.0009

Rrs_486
- Slope: 0.96
- y-int: 0.0000
- r²: 0.90
- N: 31
- Med. ratio: 1.05
- APD: 15.1
- RMSE: 0.0008

Rrs_551
- Slope: 1.15
- y-int: -0.0004
- r²: 0.88
- N: 31
- Med. ratio: 1.01
- APD: 14.5
- RMSE: 0.0010

Rrs_671
- Slope: 0.92
- y-int: 0.0002
- r²: 0.91
- N: 143
- Med. ratio: 1.05
- APD: 14.8
- RMSE: 0.0009

Rrs_all
- Slope: 1.05
- y-int: 0.0000
- r²: 0.92
- N: 143
- Med. ratio: 1.08
- APD: 14.8
- RMSE: 0.0009
2. Performance for estuaries
# Summary of USF Field Experiments in estuarine waters (2012-2016)

## Table: Field Experiments

<table>
<thead>
<tr>
<th>Start Date</th>
<th>End Date</th>
<th>Project</th>
<th>Cruise_ID</th>
<th>Region</th>
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<td>07/12/16</td>
<td>NASA-Tampa Bay</td>
<td>pan1512</td>
<td>Old Tampa Bay/MTB</td>
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<tr>
<td>05/23/16</td>
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<td>Old Tampa Bay/MTB</td>
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<td>05/24/16</td>
<td>07/25/16</td>
<td>NASA-Tampa Bay</td>
<td>pan1512</td>
<td>Old Tampa Bay/MTB</td>
</tr>
</tbody>
</table>

## Figures:

- **Figure 1**: Overview of Florida Panhandle estuaries
- **Figure 2**: Map of Tampa Bay, FL with Old Tampa Bay (OTB) and Middle Tampa Bay (MTB) highlighted.
Field $R_{rs}(\lambda)$:

Florida Panhandle estuaries (n=59)

Chl-a: 0.91 – 11.9 mg m$^{-3}$
4.9 ± 2.8 mg m$^{-3}$

$a_{CDOM}(443)$: 0.05-1.7 m$^{-1}$
0.91 ± 0.40 m$^{-1}$

Tampa Bay, FL (n=57)

Chl-a: 3.0 – 53.6 mg m$^{-3}$
12.6 ± 10.2 mg m$^{-3}$

$a_{CDOM}(443)$: 0.36 – 11.0 m$^{-1}$
1.4 ± 1.7 m$^{-1}$
Observations:

• **Important:** cannot directly compare processing schemes using data shown here! Why? Because the dates and locations of match-up pairs differed greatly amongst processing schemes. For example: only 4 match-up pairs were available when field and VIIRS Rrs(551) using all three processing schemes were valid.

• Relaxation of spatial homogeneity filter led to increased # of match-up pairs, but poorer match-up quality.

• Agreement between field and VIIRS Rrs(λ) weakest at 410nm.
3. Application for harmful algal blooms
VIIRS captures phytoplankton vertical migration in the NE Gulf of Mexico

14:00 hour  15:41 hour   Difference

Chl =>

Karenia brevis bloom (red tide), from Qi et al. (2017, Harmful Algae)
VIIRS captures phytoplankton vertical migration in the NE Gulf of Mexico

Rrs spectral changes in 100 minutes (left) agree with previous field measurement (right)

From VIIRS measurements, July 30, 2014

From Schofield et al. (2006, JGR)
VIIRS captures phytoplankton vertical migration in the NE Gulf of Mexico

Glider measurement from the same bloom shows thinner surface layer at 15:41 than at 14:00 within a diel cycle of *K. brevis* vertical migration (Hu et al., 2016)

Blue: 14:00; red: 15:41
4. Application for floating macroalgae blooms
VIIRS continuity in monitoring floating macroalgae in the Atlantic

Algae coverage from simultaneous image pairs

\[ \text{VIIRS derived algae area coverage (km}^2\) ]

- Slope = 0.94
- Intercept = -2.27
- \(R^2 = 0.95\)

From Wang and Hu (submitted)

---

Algae coverage from monthly composites

\[ \text{VIIRS derived monthly mean algae coverage (km}^2\) ]

- Slope = 0.94
- Intercept = -35.60
- \(R^2 = 0.98\)

\[ \text{MODIS derived monthly mean algae coverage (km}^2\) ]

\[ F=573.02 \]

\[ P<<0.001 \]
VIIRS continuity in monitoring floating macroalgae in the Atlantic

Color represent mean surface density during 2016 for 0 – 22N, 63 – 38W

From Wang and Hu (submitted). 0.1 on the color scale means 0.1% instead of 10%
CONCLUSIONS

- Considering that ~40% of the open ocean and coastal match-ups pairs for the Gulf of Mexico were collected in shallow (z=3-8m), optically complex coastal waters with variable bottom types, the overall agreement between field and satellite $R_{rs}(\lambda)$ was impressive!
- For the Panhandle and Old Tampa Bay estuaries, performance degraded, but was still reasonable except for the 410-nm band.
- VIIRS observations of macroalgae slicks in global oceans were consistent with the MODIS data product.
- VIIRS also showed unique capability to study short-term changes in surface harmful algal blooms.
- The Rrs validation work is being summarized in a manuscript (Cannizzaro et al.), while other works have been published (Hu et al., 2016; Qi et al., 2017) or submitted (Wang and Hu).
Towards consistent VIIRS AOP and IOP products

ZhongPing Lee, JunFang Lin, Laura Zoffoli, Jianwei Wei

University of Massachusetts Boston
Acknowledgements:

NOAA/STAR
UMB activities:

1. Evaluation of VIIRS Rrs products
2. Evaluation of VIIRS IOPs products
3. Some applications
1. Evaluation of VIIRS Rrs products

Data:
VIIRS CoastWatch L2, SBA Rrs

Measurements in Mass Bay:
Aug. 30, 2016 (1 match-up station);
Sep. 13, 2016 (2 match-up stations);
Sep. 15, 2016 (2 match-up stations);
Sep. 22, 2016 (5 match-up stations);
Feb. 2, 2017 (4 match-up stations);

VIIRS cal/val cruise:
SBA system to obtain accurate “ground truth” of Lw (Rrs)

(Lee et al 2013)
Comparison of Satellite Rrs data with Measurements in Mass Bay

\[ \lambda = 410 \text{ nm} \]
\[ y = -0.14 x + 0.001 \]
\( (R^2 = 0 \text{ MAPD} = 59.54\%) \)

\[ \lambda = 443 \text{ nm} \]
\[ y = 0.08 x + 0.001 \]
\( (R^2 = 0 \text{ MAPD} = 47.4\%) \)

\[ \lambda = 486 \text{ nm} \]
\[ y = 0.17 x + 0.002 \]
\( (R^2 = 0.03 \text{ MAPD} = 19.56\%) \)

\[ \lambda = 551 \text{ nm} \]
\[ y = 0.15 x + 0.002 \]
\( (R^2 = 0.13 \text{ MAPD} = 17.76\%) \)

\[ \lambda = 671 \text{ nm} \]
\[ y = 0.28 x + 0.0003 \]
\( (R^2 = 0.22 \text{ MAPD} = 37.1\%) \)
Examples of Rrs spectra

Station 1: SBA Rrs, VIIRS Rrs
Score: 0.6

Station 2: SBA Rrs, VIIRS Rrs
Score: 0.8

Station 3: SBA Rrs, VIIRS Rrs
Score: 1

Station 4: SBA Rrs, VIIRS Rrs
Score: 1

Station 5: SBA Rrs, VIIRS Rrs
Score: 0.8
Examples of Rrs spectra  
(Feb. 2, 2017)
Examples of Rrs spectra (VIIRS cal/val cruise)

2016 Oct. 13 (Chla (mg/m³))
Part 1: Summary

1. For Massachusetts Bay, VIIRS Rrs data at shorter wavelengths (e.g. 410 nm) are always lower than field measurements.
2. QA score is a good indicator of the quality of satellite Rrs data. Satellite Rrs data with higher scores agree better with field measurements.
3. For most matchup stations during the 2016 VIIRS cruise, NOAA VIIRS Rrs data agree well with field measurements.
2. Evaluation of VIIRS IOPs products

Commonly, measurements from ACS (or AC9) and BB9 (HS6) are considered the “ground truth” of IOPs in field.

How good are the “ground truth” of IOPs?
An example of uncertainties of ACS measurements from the 2014 VIIRS cruise (two ACSs for each station)

(a) $\lambda = 411$ nm

MeanCV = 0.08

(b) $\lambda = 443$ nm

MeanCV = 0.09

(c) $\lambda = 490$ nm

MeanCV = 0.07

(d) $\lambda = 530$ nm

MeanCV = 0.03
A scheme to obtain reliable IOPs in situ: $R_{rs} & K_d$

\[
R_{rs} (\Omega) = \left( G_0^w (\Omega) + G_1^w (\Omega) \cdot \frac{b_{bw}}{a + b_b} \right) \frac{b_{bw}}{a + b_b} + \left( G_0^p (\Omega) + G_1^p (\Omega) \cdot \frac{b_{bp}}{a + b_b} \right) \frac{b_{bp}}{a + b_b}
\]

\[
K_d = (1 + m_0 \cdot \theta_s) \cdot a + \left( 1 - \gamma \cdot \frac{b_{bw}}{b_b} \right) \cdot m_1 \cdot (1 - m_2 \cdot e^{-m_3 \cdot a}) \cdot b_b
\]

Advantages:
(1). We can obtain hyperspectral absorption and backscattering coefficients;
(2). With more casts (~5-15 casts for each station) of HyperPro, we can obtain more reliable absorption and backscattering coefficients of water.
Comparison of uncertainties of absorption from Rrs&Kd and ACSs

(a) $\lambda = 411$ nm

MeanCV = 0.03
MeanCV = 0.08

(b) $\lambda = 443$ nm

MeanCV = 0.03
MeanCV = 0.09

(c) $\lambda = 490$ nm

MeanCV = 0.03
MeanCV = 0.07

(d) $\lambda = 530$ nm

MeanCV = 0.02
MeanCV = 0.03

(e) $\lambda = 555$ nm

MeanCV = 0.02
MeanCV = 0.02

(f) $\lambda = 665$ nm

MeanCV = 0.02
MeanCV = 0.01
Examples of IOPs spectra
Validation of VIIRS IOPs products (VIIRS 2015 cruise)

Examples of IOPs spectra
$R_{rs}$ & $K_d$ IOPs vs VIIRS IOPs (VIIRS cruises 2014 & 2015)

(a) $\alpha(\lambda)$

\[ y = x - 0.01 \]
\[ (R^2 = 0.96 \text{ MAPD} = 13.2\%) \]

(b) $b_b(\lambda)$

\[ y = 0.75x + 0.001 \]
\[ (R^2 = 0.97 \text{ MAPD} = 15.6\%) \]
Part 2: Summary

(1). With multiple casts of ACS and HyperPro measurements, it is found that the derived hyperspectral $a$ and $b_b$ from $R_{rs}$ & $K_d$ are with lower uncertainties when compared with those from the presently used ACS system.

(2). Validation of IOPs during the VIIRS cruises (2014 and 2015) shows that the VIIRS IOPs by QAA are generally consistent with in-situ IOPs.
1) Submersible

2) Taking photos of phytoplankton cells

3) Sensible size range: <10 to 100 μm (~1 μm resolution)
Different species recorded by IFCB for two dominant phytoplankton groups:
A: diatoms,
B: dinoflagellates,
C: others
3. Some applications

A. How good is solar transmission estimated from remote sensing?

B. How big is the impact of modeled solar transmission based on remote sensing on upper column T and MLD?
A. How good is solar transmission estimated from remote sensing?
B. How big is the impact of modeled solar transmission based on remote sensing on upper column T and MLD?

(see Liu’s poster)
Thank you!
USC-OSU VIIRS Cal/Val 2017

STAR JPSS Annual Science Meeting
14-18 August 2017, College Park, MD

Matthew Ragan, USC
Ivan Lalovic, Nick Tufillaro, OSU
Outline

- Platform Eureka Operation
- Side by Side SeaPRISM Comparisons
- NOAA Cruise
  - Spectral Evolution Rrs automation with uncertainties
  - Plaque Comparisons
- Current Work: Eureka Cruise Fall 2017
Infrastructure Upgrades at Platform Eureka
RJ-12 Coupler with self vulcanizing putty and electrical tape
NMEA Box with RJ-12 Keystone connector and cable gland
Side-by-side SeaPRISM Comparison

1 September —> 31 December 2016
119 Matches

SeaPrism_2 Removed 5 December 2017

Outlier Rejection

Remove 10% (12 points out of 119) of data with largest difference from initial linear regression

SeaPrism 1: Instrument 612
SeaPrism 2: Instrument 058
Sky Radiance Sensor Comparisons (Regression on All Bands)

![Graph showing Li Bands comparison](image)

- **Slope**: 1.0129
- **Intercept**: 0.012139

The graph plots sensor readings across different wavelengths, with points representing various sensor responses. The linear relationship is indicated by the slope and intercept values.
Normalized Water Leaving Radiance Sensor Comparisons  
(Regression on All Bands)
Notes

Outlier rejection effect is minimal (but still good practice)

Sky Radiance provides (rough) estimate of ‘instrument’ noise and bias.

Water leaving radiance provides (rough) estimate of ‘processing’ noise and bias.

Sensors show a ‘difference’ of ~10% in field, but ‘stable’ (a stable bias over time) that is easily corrected with a ‘vicarious’ — field based, band-by-band — adjustment.

Working on paper comparing ‘field’ variances to 'lab' cal variances.
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<th>STATION</th>
<th>Date and UTC Time</th>
<th>LAT / LONG</th>
<th>Decimal Degrees</th>
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Automated processing application to compute Remote Sensing Reflectance from Spectral Evolution above water radiance measurements. Statistical procedures are used to remove outliers and data is resampled and binned to a standard grid. Data from Nancy Foster Cruise is shown.
PLAQUE DIFFERENCES

OSU_white

NRL_gray
courtesy S. Ladner

STPECTRALON

All Stations

NIST_blue

Schematic

Stations 05 and 11 only
NRL_g and OSU_w PLAQUE DIFFERENCES 10/13/2016
— Spectral Evolution CONSECUTIVE MEASUREMENTS, STATION 01 & 02

**STATION 01**

**Directory:** ...omparisons/01_pcomp/

%Error<sub>SR</sub> = 2.1033

---

**STATION 02**

**Directory:** ...omparisons/02_pcomp/

%Error<sub>SR</sub> = 3.1946
SUMMARY AND OBSERVATIONS

- \( R_{RS} \) obtained for all stations from measured spectra \( S_{ref}, S_{w+s}, S_{sky} \); \( R_{RS} = (S_{w+s} - S_{sky}M)/(\pi S_{ref}/0.99) \), where \( M \) is Mobley correction
  - Qualitatively matches HyperPro results for most stations

- Quantified differences between reference plaques measured consecutively for OSU SEV instrument: \( \text{OSU}_{white}, \text{NRL}_{grey}, \text{NIST}_{blue} \)
  - Typical contribution to spectral error: 2~5%

- Experimental uncertainty needs better quantification
  - Challenges due to varying reflections from nearby surfaces (hull, bridge, etc.) on-board the Nancy Foster
    => Comprehensive error-budget needed (instruments, plaques, FOV, angular and temporal acquisition differences)
    => Define error component analysis & quantification methods

- Experimental uncertainty due to sea-state (winds \( \gg 16 \)kts for 40% of the stations)
  => Implementing new baseline reconstruction algorithms for OSU data processing of above water measurements
Working on new data products by ‘fusing’ data from VIIRS with Sentinel-2, GOES-R that builds on NOAA’s ‘Variational’ methods.

Figure 7. Panel (a) shows the cropped region shown in Fig. 6 and the graph (b) shows the $S$ curve with the threshold and the image piece (columns 137 to 148) that we used compute the values of $S$ curve. The panels (c), (d) and (e) represent the destriped images of (a) with $\alpha = 1$ with unweighted regularization term and $\alpha = 10^{-5}$ and $\alpha = 10^{-2}$ with weighted regularization term, respectively. Panel (e) provides the best solution for the destriped image. Panel (e) is over regularized whereas panel (d) is not sufficiently regularized. Panel (f) represents the percentage error between panels (a) and (e).
Current Work

- Fall Eureka Cruise
- Side by Side Field Cal/Variance SeaPRISM paper
- Working on new products using data fusion with VIIRS and other sensors (Sentinel-2, Landsat-8, GOES-R, …)
- Working on protocols for both hand-held spectrometers as well as HyperPROs with NOAA.
VIIRS Ocean Color Science Meeting

NPR, NII, and VXR Time Series

Carol Johnson
NPR and NII Integration
Sphere Spectral Radiance Source Standards

VXR Portable Filter Radiometer, 6 channels at SeaWiFS type bands
Three Applications

• The Nxx spectral radiance $L(\lambda)$ and the VXR relative spectral responsivities (RSRs) are known: **Calibrate VXR with the Nxx spheres**

• The Nxx $L(\lambda)$ is unknown but the absolute spectral responsivities (ASRs) of the VXR bands are known: **Calibrate the Nxx spheres at the 6 VXR wavelengths**

• Both $L(\lambda)$ and the ASRs are known: **Validate the Nxx and VXR values**, as well as the veracity of the VXR to transfer between source and detector – based facilities (e.g. FASCAL and SIRCUS at NIST)
Interpolations are Required

\[ S_b = \int L(\lambda) F_b r_b(\lambda) d\lambda \]

\[ \lambda_{b,m} = \frac{\int L(\lambda) F_b r_b(\lambda) d\lambda}{\int L(\lambda) F_b r_b(\lambda) d\lambda} = \frac{\int L(\lambda) r_b(\lambda) d\lambda}{\int L(\lambda) r_b(\lambda) d\lambda} \]

\[ \Delta \lambda_{b,m} = \frac{\int L(\lambda) F_b r_b(\lambda) d\lambda}{L(\lambda_{b,m}) F_b r_b(\lambda_{b,m})} = \frac{\int L(\lambda) r_b(\lambda) d\lambda}{L(\lambda_{b,m}) r_b(\lambda_{b,m})} \]

\[ F_b r_b(\lambda_{b,m}) = \frac{S_b}{L(\lambda_{b,m}) \Delta \lambda_{b,m}} \]

\[ L(\lambda_{b,m}) = \frac{S_b}{F_b r_b(\lambda_{b,m}) \Delta \lambda_{b,m}} \]

\[ \text{Calibrate the VXR} \]

\[ \text{Calibrate the Nxx} \]

\[ \text{Validate FASCAL, SIRCUS,} \]
\[ \& VXR \text{ efficacy} \]

The moment wavelengths and the bandpasses are the same for ASR or RSR values, but vary with the spectral distribution of the source – by how much depends on the spectral out of band in the filters.

\[ \text{Does } S_b = L(\lambda_{b,m}) F_b r_b(\lambda_{b,m}) \Delta \lambda_{b,m} ? \]

Or, does \( S_b = \int L(\lambda) F_b r_b(\lambda) d\lambda \)?

NPR FASCAL history, four lamp sets, multiple calibrations on each lamp set. Data not uniform in spectral coverage or density of values. 18 Years of use.
NII FASCAL history, two lamp sets, multiple calibrations on each lamp set.
Data not uniform in spectral coverage or density of values. 13 Years of use.
First Approach: Analytical function (physical basis, consistent interpretation of data, identification of outliers, estimates of uncertainty at interpolated points).

Regions of atmospheric features were excluded: 760 nm, 915 to 985 nm, 1100 to 1150 nm, 1300 to 1500 nm, & 1730 to 1980 nm (use of integrating sphere increases the path length).

The 1973 NBS Spectral Irradiance method was explored (region subdivided spectrally)

\[
\ln(\lambda^5 L(\lambda)) = a + \frac{b}{\lambda}
\]

\[
L(\lambda) = \left[ \sum_{i=0}^{n} c_i \lambda^i \right] \exp \left( \frac{b}{\lambda} \right)
\]
FEL Irradiance standard (wavelength is in micrometers)

N = 1, full range, unweighted
SSE = 0.026, ADRS = 1

N = 4, 300 nm to 1100 nm, unweighted
SSE = 0.004, ADRS = 1

Note: I’m fitting in one step – did not linearize the blackbody term
NPR April 2014 FASCAL data (wavelength is in micrometers)

N = 0, full range, unweighted
SSE = 2.6E4, ADRS = 0.940

N = 4, 300 nm to 1100 nm, unweighted
SSE = 15.2, ADRS = 0.9999

Note: Residuals fall outside the FASCAL uncertainties; fit is sensitive to starting parameters; residuals have structure
Second approach: Interpolate with smoothing splines (new grid is every 0.1 nm)

Smoothing spline, weak smoothing (p = 0.02)

Smoothing spline, strong smoothing (p = 0.007)
FASCAL Cal Sphere ID = 201

Final Choice:
Smoothing spline, $p = 0.005$, unweighted fits

2017 VIIRS OC Breakout Session, C. Johnson, NIST
VXR RSRs

Composite of 6 SIRCUS ASR calibrations – 1999 to 2011
VXR
RSRs

Composite of 6 SIRCUS ASR calibrations – 1999 to 2011

Band 6 at 870 nm

200 300 400 502 600 610

200 600 800 1000 1200

0.97 0.975 0.98 0.985 0.99 0.995 1.005

10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10}

10^{0} 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7}
Blue: Band average FASCAL w VXR RSRs;
Red: VXR net signals; Lines = poly fits;
Cyan line = difference

$L(\lambda_{b,m},t)$ and $S_b(t)$ were normalized to the FASCAL time with the minimum difference to a VXR signal file

FASCAL: $N = 2$
VXR: $N = 8$
NII Sphere Lamp
Set 2

Blue: Band average FASCAL w VXR RSRs;
Red: VXR net signals;
Lines = poly fits;
Cyan line = difference

$L(\lambda_{b,m},t)$ and $S_b(t)$ were normalized to the FASCAL time with the minimum
difference to a VXR signal file

FASCAL: N = 2
VXR: N = 3
Observations & To Do

• Lamps operated de-rated last beyond the rated lifetime
• Repeated calibrations on one lamp set necessary
• Change in blue for NPR LS4 attributed to poorly seasoned lamps
• VXR and FASCAL agree to within 1%, indicates VXR stable over this time frame if we assume FASCAL is reproducible
• Four other lamp sets, with data back to 1999, remain
• Can use these results to assign ASRs and compare to the SIRCUS results for the VXR (six different calibrations, 1999 to 2011).
• Integrating spheres more difficult to model than FELs or FELs/plaque
Backup
Expanded uncertainties over the full range
FASCAL Cal Sphere ID = 301

Smoothing spline, fix smoothing parameter not specified, unweighted fits
Smoothing spline, fix smoothing parameter = 0.01, unweighted fits
Final Choice: Smoothing spline, fix smoothing parameter = 0.005, unweighted fits
<table>
<thead>
<tr>
<th>Residuals %</th>
<th>Wavelength nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.4</td>
<td>200</td>
</tr>
<tr>
<td>-0.2</td>
<td>400</td>
</tr>
<tr>
<td>0</td>
<td>600</td>
</tr>
<tr>
<td>0.2</td>
<td>800</td>
</tr>
<tr>
<td>0.4</td>
<td>1000</td>
</tr>
<tr>
<td>0.6</td>
<td>1200</td>
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</table>

**FASCAL Cal Data Sphere ID = 301**

- **NPR radiance 1999MayJul.mat**
- **NPR radiance 2000Jan.mat**
- **NPR radiance 2000Aug.mat**
- **NPR radiance 2001Mar.mat**
- **NPR radiance 2001Apr.mat**
- **NPR radiance 2001Dec.mat**
- **NPR radiance 2002May.mat**
- **NPR radiance 2003Mar.mat**
- **NPR radiance 2003Jun.mat**
- **NPR radiance 2003Sep.mat**
- **NPR radiance 2004JulCor.mat**
- **NPR radiance 2005Apr.mat**
- **NPR radiance 2006Sep.mat**
- **NPR radiance 2009Jun.mat**
- **NPR radiance 2011Apr.mat**
- **NPR radiance 2012Mar.mat**
- **NPR radiance 2013Mar.mat**
- **NPR radiance 2014Apr.mat**
P floats, use weights
I would still like a physics based model
NII Lamp Set 1
Better to have more fascal wavelengths here every 25
Here every 10 nm
Lamp set 4
Phytoplankton functional types, biomass and photosynthetic competency in the mid-Atlantic Bight following hurricane Matthew

Esther Kang, Kali McKee, Helga do R. Gomes, Joaquim I. Goes
Lamont-Doherty Earth Observatory
Columbia University | Earth Institute

Zhongping Lee & Jianwei Wei
UNIVERSITY OF MASSACHUSETTS
BOSTON

Chuanmin Hu, Shaojie Sun David English
UNIVERSITY OF SOUTH FLORIDA
BROAD OBJECTIVES

Examine the distribution and photo-physiology of phytoplankton functional types (PFTs) in the Mid-Atlantic Bight shelf region using high resolution flow through measurements

Examine the potential of flow through measurements for enhancing the utility of satellite ocean color for PFT biomass and productivity estimates
FLOW-THROUGH SETUP

- Automated Laser Fluorometer (Chl a, CDOM, PE-1, PE-2, PE-3, Fv/Fm, NPQ, PQ)
- Satlantic FIRe (Chl a, Fv/Fm, sPSII)
- bbe-Moldaenke (Chl a - Diatoms, Cryptophytes, Green Algae, Cyanobacteria)
- FlowCAM (Phytoplankton imaging, taxonomy and size classification)

WATER COLUMN MEASUREMENTS

- Automated Laser Fluorometer (Chl a, CDOM, PE-1, PE-2, PE-3, Fv/Fm, sPSI)
- Satlantic FIRe (Chl a, Fv/Fm, sPSII, Electron Transport Reactions)
- FlowCAM (Phytoplankton imaging, taxonomy and size classification)
- Phycobilipigment estimates in seawater
Flow through set up
Distribution of Chl a, blue water cyanobacteria, coastal water cyanobacteria, Cryptophytes along cruise track
Distance plots of CDOM, Chl a and Diatoms

- CDOM
- Chl a (mg m⁻³)
- Coastal Cyanobacteria
Distance plots of CDOM, Chl a and Diatoms
Phytoplankton Community Composition

- Diatoms
- DDAs
- Dinoflagellates
- Diazotrophs
- Other
- Beads

Distribution of major PFTs at stations 1 & 2
Distribution of major PFTs at stations 3 & 4
Phytoplankton Community Composition

- Orange: Diatoms
- Gray: DDAs
- Dark Blue: Dinoflagellates
- Light Green: Diazotrophs
- Pink: Other
- Black: Beads

Distribution of major PFTs at station 5
Distribution of major PFTs at stations 6, 7, 8, 9

Phytoplankton Community Composition

- Diatoms
- DDAs
- Dinoflagellates
- Diazotrophs
- Other
- Beads

Distribution of major PFTs at stations 6, 7, 8, 9
Distribution of major PFTs at stations 10, 11 & 12
Composition of PFTs at discrete stations

- **Diatoms**
- **Dinoflagellates**
- **Diazotrophs**
Variability of phytoplankton specific absorption coefficient (Oct. 2016)
Diversity of PFTs during cruise 2016
Distribution of major PFTs during 2014 and 2016 cruises
Blue water cyanobacteria

T-S plots showing PFTs associated with different water types

Coastal water cyanobacteria

Cryptophytes
Green Algae  Cryptophytes  Diatoms

T-S plots showing PFTs associated with different water types
Comparison of MODIS-A and VIIRS derived Chl a with in-situ Chl a along the cruise track.
FUTURE PLANS

• Distribution patterns of PFTs in relation to microscale features and frontal zones

• Estimation of net primary productivity using measurements of phytoplankton absorption cross section and quantum yield

\[ NPP(z) = \int \phi(z) \times a_{ph} \times E(z, \lambda) \, d\lambda \]

• Validation with deck incubation based measurements of net primary productivity

• Utilize O-BGC provinces of Wei-Lee (2016) for scaling shipboard measurements to regional, basin and global scales

• Compare with sea surface nitrate and new production measurements from NPP-VIIRS
Comparison of phytoplankton specific absorption coefficient during cruises of 2014 and 2016
a) Chl distributions southwest of Sargasso Sea (November 2014); (b) O-BGC provinces derived for the cruise area, with each province denoted by different colors. Two eddies associated with the Gulf Stream are visible in the new O-BGC provinces. Overlaid pie charts denote the percentages of PFTs and the total cell abundance showing differences in PFTs and cell numbers with each province.
NASA-KORUS Cruise Track (May-June 2016) and variable fluorescence ($F_v/F_m$) values shown in inset super-imposed on Aqua-MODIS Chl for waters around Korean Peninsula. (b) O-BGC provinces (May-2016) derived using Wei et al (2016) approach with each province denoted by different colors. Superimposed on O-BGC provinces are fluorescence values showing high/low phytoplankton biomass areas indicated by higher/lower fluorescence. Also shown PFTs associated with O-BGC province.
Interannual variability in sea surface nitrate for Sept. from MODIS-Aqua
Monthly maps of sea surface nitrate showing changes in nitrate inputs and drawdown
Interannual variation in nitrate based new production measurements in the North Pacific Ocean from MODIS-Aqua
THANK YOU
NOAA/NESDIS Technical Reports on Dedicated VIIRS Cal/Val Cruises

Veronica P. Lance*
and VIIRS Cal/Val Cruise Team Members

*Global Science & Technology, Inc.

NOAA Ship Nancy Foster
2014, 2015, and 2016

NOAA Ship Okeanos Explorer – April/May 2018

2016 STAR/JPSS Annual Science Meeting
College Park, MD, 14-18 August 2017
Acknowledgements

- NOAA/JPSS Ocean Color Cal/Val team
- Officers and crew of the NOAA Ship Nancy Foster
- NOAA OMAO
- NOAA JPSS program
- NOAA STAR Ocean Color EDR team
- NOAA CoastWatch/OceanWatch Central
Outline

• NOAA dedicated to VIIRS Cal/Val cruises (Annual each fiscal year):
  • Participating groups
  • Objectives
  • Observations
  • Reports Published
    • 2014 (NF-14-09) – NESDIS #146
      http://dx.doi.org/10.7289/V52B8W0Z
    • 2015 (NF-15-13) – NESDIS #148
      http://doi.org/10.7289/V5/TR-NESDIS-148
  • Report currently in progress for 2016 (NF-16-08)
  • Future: April/May 2018 – TBD
  • Data submission and archiving status and next steps
Participating Institutions

**US Agencies:**
- NOAA/STAR
- National Institute of Standards and Technology (NIST)
- Naval Research Lab (Stennis)

**Universities:**
- U. Southern Mississippi
- U. Miami
- U. South Florida
- U. Massachusetts – Boston
- City College of NY
- LDEO at Columbia
- HBOI at Florida Atlantic U.
- (2016)

**International:**
- Joint Research Centre of the European Commission (2014)
Cruise Objectives:

1) Validate VIIRS ocean color satellite remote sensing

2) Characterize and quantify sources of uncertainty associated with in situ ocean color measurements

3) Characterize the optical properties of dynamic ocean processes
Representative Measurements

In water profiling, surface floating and above water ocean radiometry

Apparent Optical Properties (AOPs) – Remote sensing reflectance - Simultaneous profiles with several instruments (e.g. HyperPro; MicroPro (2014 only); C-OPS; also several handheld and deck-mounted instruments)
Representative Measurements
In water profiling, surface floating and above water ocean radiometry
Representative Measurements
In water profiling, surface floating and above water ocean radiometry

Inherent Optical Properties (IOPs) - Total absorption; CDOM absorption; scatter and backscatter; fluorometry (chlorophyll, CDOM, phycoerythrin)
VIIRS Cal/Val Cruises

Representative Measurements
Flow-through continuous measurements

- IOPs - Beam attenuation/scattering; backscatter; CDOM and chlorophyll fluorescence
- Phytoplankton characterization - Dynamic imaging particle analysis (FlowCam); phytoplankton functional groups; chlorophyll and phycobilipigments; photosynthetic efficiency
Representative Measurements

Discrete water sampling and analyses
Filter pad spectral absorption
HPLC phytoplankton pigment analyses
CDOM absorption
Dissolved organic carbon
Particulate organic carbon and particulate nitrogen
Fluorometric extracted chlorophyll
Suspended particulate material
Particle fluorescence and digital imaging (FlowCam)
Variable fluorescence (2014 only)
Advanced Laser Fluorometer (ALF; 2014 only)
Phycobilipigment concentration (2014 only)
VIIRS Cal/Val Cruises

NESDIS Technical Reports

• NOAA dedicated to VIIRS Cal/Val cruises (Annual each fiscal year):
  • Completed
    • **2014** (NF-14-09) – NESDIS #146 published
      [Link](http://dx.doi.org/10.7289/V52B8W0Z)
    • **2015** (NF-15-13) – NESDIS #148 published
      [Link](http://doi.org/10.7289/V5/TR-NESDIS-148)
  • In Progress
    • **2016** (NF-16-08) – Report *in progress*
      • Draft of content and Tables A1-A7 sent out last week
      • Please discuss at workshop tomorrow:
        • proposed “Above Water Group” chapter
        • Review Tables A1-A7
      • Next draft before Labor Day
Next Cruise
April/May 2018
Depart: Florida Keys
Return:

NOAA Ship Okeanos Explorer
Data Submission and Archiving

- **Dr. Sheekela Baker-Yeboah**, Physical Oceanographer from NCEI has joined STAR/SOCD and will be working on in situ archiving.
- **2014 (NF-14-09) Data**– Initiated archive with NCEI with data on hand. Ascension number and DOI are TBD. Please submit outstanding datasets.
- **2015 (NF-15-13) and 2016 (NF-16-08) Data**– Assembling datasets now – please submit your data.
- **Data Submission Log on Google Drive:** [https://docs.google.com/spreadsheets/d/1p2zbFR0pVrxknHOKoE8EC5yDfTh9sfscpcsxyx9IOH8/edit#gid=1730912765](https://docs.google.com/spreadsheets/d/1p2zbFR0pVrxknHOKoE8EC5yDfTh9sfscpcsxyx9IOH8/edit#gid=1730912765)
Summary

3 Successful dedicated cruises:
- 2014: http://dx.doi.org/10.7289/V52B8W0Z
- 2016 Report: In progress

Next cruise, NOAA Ship Okeanus Explorer, April/May 2018

Message for participants:
- Please submit outstanding datasets for 2014, 2015 and 2016
- Please work with Sheekela for preparing or updating your datasets for archiving
Data Submission Log on Google Drive:
https://docs.google.com/spreadsheets/d/1p2zbFR0pVrxknHOkoE8EC5yDfTh9sfscpcsx9I0H8/edit#gid=1730912765
## Accounting of Cruise Data Submissions NF-14-09

<table>
<thead>
<tr>
<th>Group</th>
<th>Dataset</th>
<th>Status (VL)</th>
<th>Mike O. has?</th>
<th>Menghua has?</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>Hyperpro profiling (Rrs, etc.)</td>
<td>only matchup stations (n=9)</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>ECO Pucks on Hyperpro 2x triplets</td>
<td>no - reprocessing required; not highest priority; completion date expected: TBD</td>
<td>no</td>
<td>-</td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>chl-a fluorometric (method?)</td>
<td></td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>Microtops</td>
<td><a href="https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_14.html">https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_14.html</a></td>
<td>online</td>
<td>-</td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>ASD (Rrs - above water)</td>
<td></td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>NOAA/STAR (Eric)</td>
<td>TSM</td>
<td>not available, samples melted</td>
<td>n/a data not available</td>
<td>n/a</td>
</tr>
<tr>
<td>Stennis (Ryan - USM)</td>
<td>ASD (Rrs - above water)</td>
<td>only matchup stations (n=9 this might be everything for handheld)</td>
<td>yes; Mike says 9 stations is complete</td>
<td>yes</td>
</tr>
<tr>
<td>Stennis (NRL)</td>
<td>ASD (Rrs - above water)</td>
<td></td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>Stennis (Ryan)</td>
<td>Hyperpro (Rrs - floating)</td>
<td>only matchup stations (n=9; check on whether more stations for floating)</td>
<td>yes; Mike says 9 stations is complete</td>
<td>yes</td>
</tr>
<tr>
<td>Stennis (Bob)</td>
<td>Flowthrough ac9 unfiltered (a, b, c)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Stennis (Bob)</td>
<td>Flowthrough ac9 filtered (ag, ap,</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Stennis (Bob)</td>
<td>(bb)</td>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Stennis (?)</td>
<td>Microtops</td>
<td>available online?</td>
<td>Not found at aeronet site?</td>
<td>-</td>
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### Accounting of Cruise Data Submissions NF-14-09

<table>
<thead>
<tr>
<th>Group</th>
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<th>Status (VL)</th>
<th>Mike O. has?</th>
<th>Menghua has?</th>
</tr>
</thead>
<tbody>
<tr>
<td>UMB (Jianwei)</td>
<td>SBA floating hyperpro (Rrs)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>UMB (Jianwei)</td>
<td>IOP BB9 (bb)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>UMB (Jianwei)</td>
<td>IOP ACS180 filtered and unfiltered (apg, cpg)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>UMB (Junfang)</td>
<td>Spectral Evolution Handheld</td>
<td>not available because of incorrect setup.</td>
<td>n/a data not available</td>
<td></td>
</tr>
<tr>
<td>USF (David)</td>
<td>Filter Pad Absorption (ap, ad, aph)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>USF (David)</td>
<td>Chlorophyll (Welschmeyer)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>USF (David)</td>
<td>Chlorophyll (Acidification)</td>
<td>x</td>
<td>yes</td>
<td></td>
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<tr>
<td>USF (David)</td>
<td>ASD HandHeld above water (Rrs)</td>
<td>7 stations - (this is probably everything they have?)</td>
<td>yes; Mike says 7 stations is complete</td>
<td>yes</td>
</tr>
<tr>
<td>USF (?)</td>
<td>Microtops</td>
<td>available online?</td>
<td>Not found at aeronet site?</td>
<td></td>
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<tr>
<td>USF (?)</td>
<td>Hyperpro</td>
<td></td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>CCNY</td>
<td>Hypersas-POL</td>
<td></td>
<td>yes</td>
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<tr>
<td>CCNY</td>
<td>GER</td>
<td></td>
<td>yes</td>
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<tr>
<td>CCNY</td>
<td>Microtops</td>
<td>available online?</td>
<td>Not found at aeronet site?</td>
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</tr>
<tr>
<td>JRC (Giuseppe)</td>
<td>Micropro (profiling; Es, Ed, Lu, KI?, Kd, Eu, Ku, R, Q, Rrs nLw)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>JRC (Giuseppe)</td>
<td>IOPs in same file, maybe calculated??</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>JRC (Giuseppe)</td>
<td>TRLoS- he says most data no good - good at 5 stations</td>
<td>x</td>
<td>yes; 5 stations</td>
<td>yes</td>
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# Accounting of Cruise Data Submissions NF-14-09

<table>
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<tr>
<th>Group</th>
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<th>Status (VL)</th>
<th>Mike O. has?</th>
<th>Menghua has?</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA(Scott)</td>
<td>C-OPS (profiling Rrs: Ed, Lu, Es, )</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>IOPS (acs, unfiltered: cg, agp, ag, )</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>IOPS (ac9, filtered: ag)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>IOPS (bb3: bbp)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>IOPS (VSF-9: VSF)</td>
<td>x</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>HyperSAS</td>
<td></td>
<td></td>
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<tr>
<td>NASA (Aimee)</td>
<td>POC</td>
<td>x</td>
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<td>NASA (Aimee)</td>
<td>DOC</td>
<td>x</td>
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<td>NASA (Aimee)</td>
<td>CDOM</td>
<td>x</td>
<td></td>
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<tr>
<td>NASA (Aimee/Crystal)</td>
<td>HPLC</td>
<td>x</td>
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<td>yes</td>
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<tr>
<td>LDEO (Joaquim)</td>
<td>ALF</td>
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<tr>
<td>LDEO (Joaquim)</td>
<td>FiRe</td>
<td></td>
<td></td>
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<tr>
<td>LDEO (Joaquim)</td>
<td>bbe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO (Joaquim)</td>
<td>phyocobilipigments</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>LDEO (Joaquim)</td>
<td>Flow Cam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO (Joaquim)</td>
<td>microscopy</td>
<td></td>
<td></td>
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<tr>
<td>U. Miami (Ken)</td>
<td>NURADS (8 stations)</td>
<td>x</td>
<td>y</td>
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<tr>
<td>NIST</td>
<td>n/a</td>
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### Accounting of Cruise Data Submissions NF-15-13

<table>
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<tr>
<th>Group</th>
<th>Dec-15 Description</th>
<th>Mike O. has?</th>
<th>Menghua has?</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>Hyperpro profiling (Rrs) x only values for VIIRS matchups</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>ECO Pucks on Hyperpro 2x triplets (Chl, CDOM, phycoerythrin, bb at 443, 450, 860)</td>
<td>no - reprocessing required; not highest priority; completion date expected: TBD</td>
<td></td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>chl-a fluorometric (Welschmeyer)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>ASD (Rrs - above water) check for completeness</td>
<td>MO checking</td>
<td></td>
</tr>
<tr>
<td>Stennis (Ryan - USM)</td>
<td>TSM</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASD (Rrs - above water) check for completeness</td>
<td>MO checking</td>
<td></td>
</tr>
<tr>
<td>Stennis (NRL)</td>
<td>ASD (Rrs - above water) check for completeness</td>
<td>MO checking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hyperpro (Rrs - floating)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stennis (Bob)</td>
<td>Flowthrough ac9 unfiltered (a, b, c)</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Stennis (Bob)</td>
<td>Flowthrough ac9 filtered (ag, ap, bb)</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Stennis (Bob)</td>
<td>Flowthrough (bb)</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>UMB (Jianwei)</td>
<td>RISBA (was SBA) floating hyperpro (Rrs)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IOP BB7FL2 (bb at 412, 440, 488, 532, 595, 695, 715; CDOM fl; Chl fl)</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>UMB (Jianwei)</td>
<td>IOP ACS180 filtered and unfiltered (apg, cpg)</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>UMB (Guoqing)</td>
<td>Flow Cytobot</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>UMB (Jianfang)</td>
<td>Spectral Evolution Handheld</td>
<td>MO checking</td>
<td></td>
</tr>
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</table>
### Accounting of Cruise Data Submissions NF-15-13

<table>
<thead>
<tr>
<th>Group</th>
<th>Data Type</th>
<th>Dec-15</th>
<th>Mike O. has?</th>
<th>Menghua has?</th>
</tr>
</thead>
<tbody>
<tr>
<td>USF (David)</td>
<td>Filter Pad Absorption (ap, ad, aph)</td>
<td>x (rec'd but trouble unzipping)</td>
<td>MO checking</td>
<td></td>
</tr>
<tr>
<td>USF (David)</td>
<td>Chlorophyll (Welschmeyer)</td>
<td>x (rec'd but trouble unzipping)</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>USF (David)</td>
<td>Chlorophyll (Acidification)</td>
<td>x (rec'd but trouble unzipping)</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>USF (David)</td>
<td>CDOM absorption (new for 2015 from ap sampling)</td>
<td>x (rec'd but trouble unzipping)</td>
<td>MO checking</td>
<td></td>
</tr>
<tr>
<td>USF (David)</td>
<td>ASD HandHeld above water (Rrs)</td>
<td>check for completeness</td>
<td>MO checking</td>
<td></td>
</tr>
<tr>
<td>USF</td>
<td>Microtops</td>
<td><a href="https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_15.html">https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_15.html</a></td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>USF (?)</td>
<td>Hyperpro - profiling</td>
<td>x (rec'd but trouble unzipping)</td>
<td>yes - Mike has good files</td>
<td>yes</td>
</tr>
<tr>
<td>CCNY</td>
<td>Hypersas-POL</td>
<td>only for matchup stations; only at VIIRS channels</td>
<td>yes; MO has all photos</td>
<td></td>
</tr>
<tr>
<td>CCNY</td>
<td>ASD</td>
<td>only for matchup stations; only at VIIRS channels</td>
<td>MO checking</td>
<td></td>
</tr>
<tr>
<td>CCNY</td>
<td>GER</td>
<td>only for matchup stations; only at VIIRS channels</td>
<td>yes; MO has all</td>
<td></td>
</tr>
<tr>
<td>OSU (Nick)</td>
<td>Hyperpro - profiling</td>
<td>only for matchup stations; only at VIIRS channels</td>
<td>yes, but all directories (need to arrange for matchup)</td>
<td></td>
</tr>
<tr>
<td>OSU (Nick)</td>
<td>Spectral Evolution Handheld</td>
<td>check for completeness</td>
<td>MO checking</td>
<td></td>
</tr>
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### Accounting of Cruise Data Submissions NF-15-13

<table>
<thead>
<tr>
<th>Group</th>
<th>Data Type</th>
<th>Dec-15</th>
<th>Mike O. has?</th>
<th>Menghua has?</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA(Scott)</td>
<td>C-OPS (profiling Rrs: Ed, Lu, Es,</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>C-OPS (profiling Rrs: Ed, Lu, Es,</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>IOPS (acs, unfiltered: cgp, agp, ag,</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>IOPS (ac9, filtered: ag)</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>IOPS (bb3: bbp)</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>IOPS (VSF-9: VSF)</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>NASA(Scott)</td>
<td>HyperSAS</td>
<td>yes</td>
<td>pulled from</td>
<td>NASA SeaBASS</td>
</tr>
<tr>
<td>NASA (Joaquin C.)</td>
<td>POC</td>
<td>yes</td>
<td>pulled from</td>
<td>NASA SeaBASS</td>
</tr>
<tr>
<td>NASA (Joaquin C.)</td>
<td>DOC</td>
<td>yes</td>
<td>pulled from</td>
<td>NASA SeaBASS</td>
</tr>
<tr>
<td>NASA (Joaquin C.)</td>
<td>CDOM</td>
<td>yes</td>
<td>pulled from</td>
<td>NASA SeaBASS</td>
</tr>
<tr>
<td>NASA (Joaquin C.)</td>
<td>HPLC</td>
<td>X</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>LDEO (Joaquim G.)</td>
<td>Nutrients (which?)</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO (Joaquim G.)</td>
<td>Flow Cam</td>
<td>no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U. Miami (Ken)</td>
<td>NURADS (8 stations)</td>
<td>X</td>
<td>yes</td>
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## Accounting of Cruise Data Submissions NF-16-08

<table>
<thead>
<tr>
<th>Group</th>
<th>Data Type</th>
<th>Oct-16</th>
<th>Mike O. has?</th>
<th>Menghua has?</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>Hyperpro profiling (Rrs)</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>ASD</td>
<td>Rrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>operated NASA C-OPS</td>
<td>nlw, Rrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOAA/STAR (Mike)</td>
<td>water samples to be analyzed by NASA</td>
<td>HPLC, POC, DOC, CDOM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOAA/STAR (Eric)</td>
<td>SPM (TSS)</td>
<td>SPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>USF</strong></td>
<td>Microtops</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>USF</td>
<td>Extracted Chl-a</td>
<td>Chl-a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USF</td>
<td>Filter Pad Absorption</td>
<td>a, ad, ag</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CCNY_Gilerson</strong></td>
<td>HyperSAS</td>
<td>RRS for stations only (no underway)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CCNY_Gilerson</strong></td>
<td>GER</td>
<td>RRS for stations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO_Goes</td>
<td>Nutrients</td>
<td>N02+N03, Si, P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO_Goes</td>
<td>Phycobilipigments</td>
<td>concentrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO_Goes</td>
<td>microscopy</td>
<td>phyttoplankton counts, ID</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO_Goes</td>
<td>Fire</td>
<td>fv/fm, sigma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO_Goes</td>
<td>ALF</td>
<td>several</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDEO_Goes</td>
<td>FlowCAM</td>
<td>phyttoplankton types</td>
<td></td>
<td></td>
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</tbody>
</table>

*USF Extracted Chl-a can be found at [https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_16.html](https://aeronet.gsfc.nasa.gov/new_web/cruises_new/Nancy_Foster_16.html)*
<table>
<thead>
<tr>
<th>Group</th>
<th>Oct-16</th>
<th>Mike O. has?</th>
<th>Menghua has?</th>
</tr>
</thead>
<tbody>
<tr>
<td>UMB</td>
<td>SBA HyperPro (floating)</td>
<td>nlw, Rrs</td>
<td></td>
</tr>
<tr>
<td>UMB</td>
<td>Profiling IOP package</td>
<td>various IOPs</td>
<td></td>
</tr>
<tr>
<td>UMB</td>
<td>Spectral Evolution Handheld</td>
<td>Rrs</td>
<td></td>
</tr>
<tr>
<td>UMB</td>
<td>IFCB flowcytobot</td>
<td>DATA NO GOOD - WILL NOT DELIVER</td>
<td>NO</td>
</tr>
<tr>
<td>HBOI_Twardowski</td>
<td>MASCOT IOP profiling package</td>
<td>many parameters</td>
<td></td>
</tr>
<tr>
<td>Stennis/USM &amp; NRL</td>
<td>Underway IOPS</td>
<td>bb, c, ap, ag, etc.</td>
<td></td>
</tr>
<tr>
<td>Stennis/USM &amp; NRL</td>
<td>Handheld ASD</td>
<td>Rrs</td>
<td></td>
</tr>
<tr>
<td>Stennis/USM &amp; NRL</td>
<td>Floating Hyperpro</td>
<td>nlw, Rrs, other parameters on package</td>
<td></td>
</tr>
<tr>
<td>Stennis/USM &amp; NRL</td>
<td>Secchi Disk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U. Miami</td>
<td>NURADS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OSU</td>
<td>HyperPro profiling</td>
<td>nlw, Rrs, etc. on package</td>
<td></td>
</tr>
<tr>
<td>OSU</td>
<td>Spectral Evolution Handheld</td>
<td>Rrs</td>
<td></td>
</tr>
<tr>
<td>NIST</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>
VIIRS/OLCI Cooperation

Bojan R. Bojkov

and the Marine Applications team
The Current EUMETSAT satellite fleet

**METOP -A and -B**
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

**JASON-2, -3**
(LOW-EARTH, 63° INCL. NON SYNCHRONOUS ORBIT)

OCEAN SURFACE TOPOGRAPHY MISSION

**Sentinel -3a**
(LOW-EARTH, SUN-SYNCHRONOUS ORBIT)

Copernicus Global Marine and Land Environment Mission
Operated by EUMETSAT

**METEOSAT SECOND GENERATION -9, -10, -11**
(GEOSTATIONARY ORBIT)

TWO-SATELLITE SYSTEM:
- METEOSAT-11: IN-ORBIT BACKUP
- METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)
- METEOSAT-9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)

**METEOSAT-8 (2nd GENERATION)**
(GEOSTATIONARY ORBIT)

INDIAN OCEAN DATA COVERAGE MISSION
AT 40° E (TBD June 2016)
Copernicus Sentinel-3

Launched: 16 February 2016
10:00 local, desc. orbit (98.6°)

Instruments:
1. OLCI
   Ocean and Land Colour Instrument
2. SLSTR
   Sea and Land Surface Temperature Radiometer
3. SRAL
   SAR Radar Altimeter
4. MWR
   Microwave Radiometer
Ocean Colour Radiometry @ EUMETSAT

• **Context**
  - Ocean Colour is a new user community for EUMETSAT
  - EUMETSAT delegation for Copernicus S3 marine data services by the European Commission (EC)
  - The main customer is the Copernicus Marine Environment Monitoring Services (CMEMS)

• **Priority Objectives**
  - Deliver fully characterized operational products from the OLCI-A-B (and C-D in the future) constellation
  - Evolution of S3 OLCI operational products
  - Establishment of a European Vicarious Calibration infrastructure
  - Development of an Ocean Colour Products Portfolio
Ocean Colour – applications and user requirements

- CMEMS – primary user in the Copernicus framework
- Large and diverse user base

EU legislation
- Water Framework Directive

Water quality
- Harmful algal bloom forecast

Diversity of regional water habitats, processes and constituents =
High variability of optical water properties =
Broad range of applications and users

Users request
- relevant products of known high quality
- harmonization, consistency and stability across missions
- focus on coastal and inland waters (in addition to open sea)
- new products

CMEMS, S3VT-OC, IOCS, S3 MAG, GMES-PURE, Copernicus Marine Expert Exchange, Sentinel-3 Mission Documentation (S3 Mission Requirements Traceability Document, S3 Calibration and Validation Plan)
Institutions and community interfaces

Ocean Colour is global and very regional → diverse community

- Program partner
- Developer of GS and IPFs
- L1B responsibility
- Cal/Val, fixes, monitoring

ESA / MPC

• Major user in the Copernicus framework

CMEMS

S3VT-OC

• Validation user
• Representative of global “expert” users

IOCCG / CEOS OCR-VC

• Agency coordination bodies

IOCS

• Team developing into the international science team

OLCI Level-1B and Level-2 ocean colour products

Institutions / Science / Commercial users worldwide

- Regional and global applications
  - e.g. EU legislation reporting obligations
  - e.g. water quality, fisheries, aquaculture, ecosystems, sediments, carbon cycle, climate

EC

C3S

- Future climate service user
Ongoing tasks at EUMETSAT

Sentinel-3 \{A,B,C, D\} / OLCI:

**Cal/Val tasks** based on Joint ESA/EUM S3 Cal/Val Plan
- Solar diffuser in-flight characterization, completed for S3A
- Operational scheduling of radiometric calibrations
- Radiometric stability validations at L3
- Geometric validation at ground control points
- Ad hoc in situ FRM validations (MOBY)
- Validations with L3 (multi-mission/climatology)
- Product quality verifications (flags, artifacts)

**Product maintenance** to achieve useable products
- Fixes for major issues (biases, flags, old MERIS to OLCI,..)
- REF product validations for new PB releases
- Test reprocessings/product validations to define new PBs

**System Vicarious Calibration** (SVC) – development of Copernicus FRM capability required for ocean colour missions to meet user product quality requirements
- Study 1: Requirements for Copernicus SVC capability
Sentinel-3: OLCI Level 2 products operational

Zoomed in OLCI imagery of algae bloom in the Baltic Sea, 20 July 2016 03:00 UTC,
Source: EUMETSAT
Use of VIIRS NOAA OC data/tools for intercomparisons

- NOAA VIIRS products used extensively to ‘debug’ the initial versions of the L1 and L2 processors and “system” gains provided by ESA

- Tremendous help from the NOAA OC team

- Integration of OLCI into NOAA OC Cal/Val pages – a very special thanks to Menghua Wang
Sentinel-3A OLCI Level-2 products operational

Sentinel-3A OLCI algal pigment concentration
14-27 June 2017, 14-day composite, OC4ME clear water algorithm
Sentinel-3 SLSTR and OLCI L2 operational as of 5 July

Cloud masking still needs work on Sentinel-3
VIIRS/OLCI cooperation: Ocean Colour Processor

• User Needs
  • Ocean colour users need products with the same characteristics regardless of the scene observed. This applies to the water-leaving radiances as well as the optical and bio-geo-chemical properties;
  • The atmospheric correction process shall have open ocean, coastal and inland water competency, ensuring consistent correction above clear as well as turbid waters;
  • The in-water product shall be multi-water consistent across clear and turbid;
  • The L2 product shall include directly usable quality information and expression of parameter uncertainties.

• Approach
  • A new independent development, implementing the state of the art, IPR-free such as for example the ESA CCI legacy;
  • Open source and active involvement of the global expert community, via community code and independent peer reviews;
  • Flexible framework easing transition from prototype to operational processor, supporting expansion of products portfolio → agile development
  • Design with applicability to other missions e.g. geostationary
VIIRS/OLCI cooperation: OC FRM Infrastructure

OC Fiducial Reference Measurement (FRM) = “European MOBY”

• For OC missions, the system vicarious adjustment is critical to meeting the mission accuracy requirements;

• Vicarious adjustment capability is critical for the long-term operational Copernicus and JPSS Programmes to provide quality Ocean Colour products and services;

• Sustained European infrastructure(s) are essential for the long term and complimentary to the NOAA MOBY activities.

• Key requirements include: high accuracies and SI-traceability of the optical radiometer system, minimal environmental uncertainties -marine and atmospheric- at the deployment site, and operational performance to support calibrated time-series over a few decades.
Approach for the OC FRM:

Step 1: Community driven requirements/specifications
Has been implemented by a EUMETSAT-led Copernicus study establishing the highest level applicable scientific, technical and operational requirements that form the basis for the development of a Copernicus Infrastructure for Ocean Colour Vicarious adjustment. This study was run in liaison with the ESA study ”QA4EO FRM4SOC” focusing on the development of best practises for these FRMs for satellite ocean colour validation, and the international OC community (reviews)

Step 2: Preliminary design
Three studies will run in parallel in order to compare thoroughly the possible approaches/designs in the 2017-2018 time frame. Again, international review of the preliminary design will be undertaken.

Step 3: Final design and deployment
The concept selected at the conclusion of Phase 2 will be developed into a detailed technical design specification in the 2019 time frame, with a deployment in 2021 timeframe pending final budgetary approval by the European Commission.
Summary

• NOAA OC team critical to OLCI OC gaining operational status at EUMETSAT, through intercomparisons, Cal/Val, personnel exchanges, etc.

• Future EUMETSAT-NOAA cooperation on OC:
  • Continue on-going L1 and L2 activities
  • Start work together on the community OC processor (*and the related Cal/Val tools*)
  • Help define future European OC FRM infrastructure
  • To be formalised by year end
Ocean Color in Operational Ocean Forecast Systems

Avichal Mehra\textsuperscript{1}, Sudhir Nadiga\textsuperscript{1}, Hae-Cheol Kim\textsuperscript{1}, Vladimir Krasnopolsky\textsuperscript{1}, and Eric Bayler\textsuperscript{2}

\textsuperscript{1}NOAA / NWS / NCEP / EMC

\textsuperscript{2}NOAA / NESDIS / STAR

JPSS/PGRR Meeting, August 16, 2017
Outline

• Background

• Overall objectives

• Interesting results

• Operational Plans

• Ongoing Work
Operational configuration of RTOFS

- Hybrid Coordinate Ocean Model (HYCOM) with 1/12° horizontal resolution and 41 hybrid layers
- Iso- pycnal (deep ocean), z-levels (surface), σ (coasts)
- NAVOCEANO daily initialization with MVOI (now 3DVAR) data assimilation from NCODA (Navy’s Coupled Ocean Data Assimilation)
- Daily 2-day nowcast (GDAS) and 8-day forecasts (GFS)

Graphics by Todd Spindler
Current Ocean Color Projects (funded by JPSS-PGRR program)

Titles:

- Using Neural Networks for gap-filling and preliminary short-range (1-2 weeks) to medium-range (3-4 weeks) predictions of satellite-derived ocean color fields (Chl-a, Kd$_{490}$ and Kd$_{PAR}$)
- Initial biogeochemical modeling at NOAA/NCEP: Using VIIRS ocean color data for validation and data assimilation

Main priorities:

- Update OC fields for Ocean Data Assimilation (NCODA)
- Predict OC fields for feedback during forecast cycle
Ocean Color & NN/BGC

Ocean Processes

OC (Chlorophyll-a)
OC is signature of Ocean Biology

Ocean Chemistry

Ocean Biology

Upper-ocean Physics: SST, Salinity, SSH, Currents, ...

NN/BGC emulation

OC (Chlorophyll-a)
OC comes from ecological model

NN/BGC

Ecological Model

Upper-ocean Physics: SST, Salinity, SSH, Currents, ...
(satellite & in situ measurements)

FEEDBACK FROM OCEAN BIOLOGY (COLOR) TO UPPER-OCEAN HEATING IS IMPORTANT FOR OCEAN/COUPLED FORECASTING
1. **Ocean Color (OC) integration in operational ocean and coupled modeling**
   - Ingest NRT and Science quality data: OC data in ocean models for physical and biological processes
     
     **Application:** Improve short-term Operational Ocean Forecasts
   - Consistent Gap-Filled OC values across multiple satellite missions for use in long ocean reanalysis efforts
     
     **Application:** Neural Network (NN)-based consistent gap-filled Ocean Color

2. **Make Short-Term (1-2 weeks) to Medium-Term (3-4 weeks) Ocean Color Predictions**
   
   **Application:** Short-term to Medium-term Operational Ocean Forecasts

3. **Bio-Geo-Chemical Modeling with Ocean Color inputs**
   
   **Application:** Use Ocean Color Fields for estimating 3D Ocean BGC ocean states
   
   **Application:** Boundary and initial conditions for Coastal OFS (inputs for NOS, NMFS)
NESDIS Science-quality Chlorophyll-a significantly outperforms NRT and BASE in ocean model simulations; GODAS analyses used as observations;
BASE is model run with SeaWiFS 4-yr monthly climatology; SCI is run with VIIRS science-quality OC; NRT is run with VIIRS NRT OC
(all based on 4 year experiments 2012-2015)
SST Verification against GODAS for NINO 3.4 (170W-120W; 5S-5N)

- Algorithmic impact (Chl vs Kpar) is not as big as expected (e.g., SeaWiFS case) when daily-averaged forcings were used.

- When diurnal variation is resolved (hourly forcings used) both Kpar and Chl algorithm yielded different results from the others.

(www.climate.gov/)
NN is able to capture OC variability reasonably well over most of the global oceans for training period > 2 years.
Operational Plans with Ocean Color

Integrating Ocean Color in RTOFS:

(1) Use Statistical (NN) Model

Blend of mean, low-frequency variability, high-frequency variability
Advantage: Being tested for next operational RTOFS upgrade/impacts

(2) Use Biogeochemical Model

Use BGC model with NCODA/RTOFS.
Advantage: Provides full 3-d ocean biological state
**Statistical OC Model in RTOFS**

**Schematic View**

- **DAY N-1**: RTOFS (Daily Averages)
- **DAY N**: RTOFS, NN (Inter), ENRT OC
- **DAY N+1**: RTOFS

**GFS FORCING**

**BLEND**

- VSCI_CLIM
- NN_INTER
- ENRT_MESO

**BLENDS**

- MIXES MEAN (VSCI_CLIM), LOW-FREQUENCY (NN_INTER)
- AND HIGH-FREQUENCY (ENRT_MESO) OC VARIABILITY
Biogeochemical OC Model in RTOFS Schematic View

DAY N-1
RTOFS-BGC

GDAS FORCING

DAY N
RTOFS-BGC

VIIRS
4km L3 OC

NCODA Analysis

Bio-ARGO data

CORRECTION
(incremental update)

DAY N+1
RTOFS-BGC

Data Assimilative Mode

Forecast Mode
Objective: Ocean Color for Operational Ocean Forecast Systems:

(1): Preliminary assessment of NESDIS NRT and science-quality OC in ocean models (completed).
(2): Testing NN model for coupling to RTOFS (on-going).

FY 18 Targets:

(1): Testing for operational upgrade of RTOFS with embedded NN (on-target)
(2): Role of ocean color in SST predictions over weather time scales (on-going).
Objective: Ocean Color for Operational Ocean Forecast Systems:

(1): Science quality VIIRS products and thermal structure effects on BGC variables (completed)
(2): In-line coupling of NPZD-type ecosystem model in HYCOM/RTOFS (completed)

FY 18 Targets:

(1): Ocean color (VIIRS science quality) data assimilation (2DVAR) in RTOFS-BGC-NCODA (on-going)
(2): Implementation of physical/biogeochemical variables (3DVAR) in RTOFS-BGC-NCODA (on-target)
(3): Exploring added complexities (e.g., 9-component BGC model which includes carbon and dissolved oxygen sub-modules) (TBD)
Thank You!
Satellite-based Ocean Color Tools for Coral Reef Management

Erick Geiger, William Hernandez, Brianna Craig, Rob Warner, Alan E. Strong, C. Mark Eakin, Menghua Wang, Jacqueline L. De La Cour, Gang Liu, Kyle Tirak, Scott F. Heron, William J. Skirving

STAR JPSS Annual Team Meeting
August 16, 2017 - NCWCP, College Park, MD
Ocean Color
How can it help coral reef managers?

The color of coastal water is related to water quality.

Satellite ocean color data provide a synoptic view of water quality.

Of the many satellite ocean color products, two are most commonly used for monitoring water quality:

**Chlorophyll-a**
Represents phytoplankton biomass and nutrient status (productivity) as an index of water quality.

**$K_d(490)$**
The diffuse attenuation coefficient at 490nm (or light blue in the visible spectrum).

Total organic and inorganic matter held in solution and suspension (turbidity) within the water column.
Goal:
Provide satellite products for monitoring land-based sources of pollution over coral reef environments tailored to managers’ feedback.

FY13/14:
NOAA NESDIS STAR’s Ocean Color Team and NOAA Coral Reef Watch conduct “proof of concept” pilot effort using daily ocean color data from the Visible Infrared Imaging Radiometer Suite (VIIRS) matched with large rainfall events. Study areas include Southern Puerto Rico (Guánica) and West Maui (Ka’anapali) watersheds.

FY15/16:
VIIRS data updated to “science quality” and spatial resolution of products enhanced. Begin creating virtual monitoring areas and experimental anomaly products. Cal/Val efforts are advanced with Puerto Rico partners and initiated with West Maui partners.
Review

FY16/17: 
Held workshop in West Maui for local watershed manager feedback and to expand user group. Provided student intern with lab equipment for collecting in situ water quality data. VIIRS MLS12 v1.21 reprocessing.

Ongoing: 
Continue development of virtual monitoring areas. Develop multi-sensor approach with Landsat 8, Sentinel-2. Expand managers’ workstation and populate with new VIIRS data, including 375m resolution data.
Study Area

U.S. Coral Reef Task Force priority watershed sites:
• Ka’anapali (West Maui, Hawai’i)
• Faga'alu (American Samoa)
• Guánica Bay (Puerto Rico).
Study Site
West Maui – Five Watersheds

- Three distinct management zones: Urban, Agricultural, Conservation
- Anticipating land use change in the next decade
West Maui North Runoff Example - Mid January 2016

Photo credit: Multicopter Maui
West Maui Airport Watershed (Central)
Role for Ocean Color Project

• Which drainages are the biggest source of stressors (nutrient and sediment)?
• How long does sediment persist?
• What are the circulation patterns?
• Which drainages are triggered at what rainfall intensity?
• Can we observe improvements after mitigation on land?
Visible Infrared Imaging Radiometer Suite (VIIRS)

Provides ocean color data at ~750m resolution.

Daily, afternoon pass. One pass a day (no ocean color at night).

Science quality data delayed 2 weeks. Near real-time data is delayed 1 day.

Geophysical data:

Chlorophyll-a (mg/m³)
$K_d(490)$ (m⁻¹)
$K_d(PAR)$ (m⁻¹)
Normalized water-leaving radiance at:
410, 443, 486, 551, 671nm (mW/cm²/μm/sr)
Visible Infrared Imaging Radiometer Suite (VIIRS) Chlorophyll-a prototype 2km resolution

August 6, 2014
Visible Infrared Imaging Radiometer Suite (VIIRS) Chlorophyll-a prototype 750m resolution

August 6, 2014
Proof of Concept
Matching with Precipitation Events

Top left and right: VIIRS Kd(490) images for February 27 and March 15, 2012. Black circles indicate the West Maui watershed.

Bottom left: Daily rainfall amounts in Mahinahina from February 27 to March 31, 2012. Black circles indicate the West Maui watershed.

Bottom right: Kd(490) values near West Maui watershed for the same time period. The large rainfall event is associated with a local rise in Kd(490) or turbidity.
VIIRS Monthly Mean $K_d(490)$ for West Maui Region (2012 – mid 2017)
Coral Reef Watch Tools
Daily Mapped Ocean Color Images – 750m

January 23, 2014 – Chlorophyll-α
Coral Reef Watch Tools
3- and 8-Day Average Ocean Color Images – 750m

September 23, 2016 – Previous 8-day Average $K_d(490)$

September 22-30, 2016: Brown water events captured by drones
Coral Reef Watch Tools
Climatological Means and Minimums

Mean November $K_d(490)$

Monthly Minimum $K_d(490)$
March 5, 2014 – $K_d(490)$ Anomaly

March, 2014: Large rainfall events
Coral Reef Watch Tools
Virtual Monitoring Areas

Mean January Chlorophyll-α
Coral Reef Watch Tools
Virtual Monitoring Areas

Mean January Chlorophyll-a

1. Honokohau Bay
2. Honolua, Mokuleia, Honokahua Bay
Coral Reef Watch Tools
Virtual Monitoring Areas

3. Oneloa Bay

Mean January Chlorophyll-a
Coral Reef Watch Tools
Virtual Monitoring Areas

1. Honokohau Bay
2. Honolua, mokuleia, Honokahua Bay
3. Oneloa Bay
4. Namalu Bay
5. Napili, Honokeana Bay
6. Airport North
7. Airport South
8. Kaanapali North
9. Kaanapali South
10. Lahaina North
11. Lahaina South
12. Maalaea Bay
13. Kahului
14. West Maui Total Area
15. ...
Coral Reef Watch Tools
Virtual Monitoring Areas

2. Honolua, Mokuleia, Honokahua Bay

Monthly Maximum $K_d(490)$
Coral Reef Watch Tools
Virtual Monitoring Areas

Monthly Maximum $K_d(490)$

Daily Maximum $K_d(490)$
Coral Reef Watch Tools
Alert Products

August 6, 2014

K_d(490)

<0.03

0.03-0.035

0.035-0.045

0.045-0.055

>0.055
Coral Reef Watch Tools
Alert Products

March 5, 2014

K_d(490)

<0.03

0.03-0.035

0.035-0.045

0.045-0.055

>0.055
Coral Reef Watch Tools
Manager’s Portal

West Maui Ocean Color Monitoring

Product: Chl-α, Kₖ(490), Anomaly, Alert

Map Extent: Maui
Aggregation: Daily
Virtual Area: Namalu Bay
Time Series: Max Kₖ(490)

Daily Maximum Kₖ(490)

High Resolution True Color: Sentinel-2, Landsat
Proposed information platform using GIS for HI and PR.

Information can be compiled in a web mapping application for watershed managers that can include:

- Watershed layers
- Benthic habitat/land cover maps.
- Water quality from satellites (VIIRS, Landsat/Sentinel).
- *In situ* water samples results.
- Layers from watershed managers.

http://arcg.is/1QpyIL7
Satellite Ocean Color Product Development

Preliminary Results (event-driven variations in $K_d(490)$ and Chl-a):
- Click here for preliminary time series results for Puerto Rico.
- Click here for preliminary time series results for West Maui.

Presentations:
- Click here for a poster presented at the 2015 NOAA Satellite Conference.
- Click here for a poster presented at the 2016 Ocean Sciences Meeting in New Orleans.

NOAA Coral Reef Watch and NOAA/NESDIS' Ocean Color Team are working closely with partners in the U.S. Coral Reef Task Force (USCRFT) Watershed Working Group (WWG) to develop pilot satellite ocean color products using data from the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite operated by the NOAA Joint Polar Satellite System (JPSS).

The pilot satellite ocean color products are designed to help coral reef ecosystem managers monitor variable water quality and measure bleaching across spatial and temporal scales.
Bio-Optical Oceanography Laboratory
Team Members

- Dr. Roy Armstrong - Director
- Dr. Yasmin Detres - Researcher
- Suhey Ortiz, Maria Cardona, Myrna Santiago, Jenniffer Perez, Omar Lopez - Graduate Students
- Luis Lugo - Staff
Thank you from the
NOAA Coral Reef Watch Team!!

Mark Eakin
Jacquie De La Cour (GST)
Gang Liu (GST)
Erick Geiger (GST)
Ben Marsh (GST & ReefSense)
Kyle Tirak (GST)
Andrea Gomez (CCNY & NOAA-CREST)
William Hernandez Lopez (CCNY & NOAA-CREST)
William Skirving (GST & ReefSense)
Scott Heron (GST & ReefSense)
Rob Warner (NOAA/NOS)
Al Strong (GST & SR)
The Watershed Perspective on Ocean Color: Possible Application and Needs in Puerto Rico

Paul Sturm
Ridge to Reefs
Roberto Viqueira Ríos
Protectores de Cuencas
Guánica Watershed Coordinator
STAR JPSS Meeting
Annual Science Team Meeting
August, 2017
The Guanica Bay Watershed Management Plan: A Pilot Project for Watershed Planning in Puerto Rico

- The Guanica Bay Watershed Management Plan was Completed in 2008.
- Coordination Efforts 2010-Present
- Implementation 2012-Present
- Update 2015-Present

**UPDATE:**

- Address the EPA's nine elements of a watershed management plan
- To date, 65% of the updated document has been drafted.
- Updating a watershed characterization based on new develop land use information provided by the Puerto Rico Planning Board (2015)
- Updates from the restoration activities that has been developed.
- Update estimated pollutant loads applying the Watershed Treatment Model.
- Final updated draft of the Plan is expected to be completed by August of 2017.
Guánica Lagoon

• From 2010-2013 major improvements had been achieved.
  • Strong Commitment from the Puerto Rico Government in General
  • Soil Salinity Study
  • H & H Study
  • Farm Inventory
  • Socioeconomic Study
  • 65% engineering Design
  • Enviromental compliance
• An important drawback in the restoration efforts raised (2013)
  • Intentions of the DA to regain farming activities inside the historic footprint of the Guanica Lagoon.
  • PRLA started clearing wetland areas for farming without any environmental compliance process and public engagement.
  • Most of our efforts where dedicated to protect the Lagoon
  • Legal action was taken with the USACE and EPA
• PRLA was fined and a precedent was established for wetland protection
• No clearings for the past 3 years
• Current Administration stepping back
• NRCS has approved funding to implement conservation practices in the subwatershed of the Lajas Valley.

Next Steps:

• A series of meetings are being coordinated that will take place in the following months with new Government officials to present the project and gain support from the new Government administration.
• Another set of meetings will be coordinated with the farming community to ensure their participation in the process and to reopen the possibility of an agreement of the difference in public policy towards the land in the Lagoon area.
• An outreach and education campaign
Río Loco River Restoration

- NRCS implementation of 3 major restoration projects on the Río Loco river to restore river banks with bioengineering strategies that included the implementation of a collaborative effort to apply hydroseeding on the restored areas by Protectores de Cuencas, Inc.
- During this process, most of the old abandoned irrigation infrastructure inside the river that was identified in the Watershed Management Plan as priority to be removed were taken out of the river.
- 2 sites remaining that we have secure funding from the DNER to remove them in the following year.

**Next Steps:**

- Currently working on Environmental Compliance
- Debris removal for next year
GUÁNICA TREATMENT WETLANDS

- 100% engineering designed
- 100% of permit process completed
- Close to final MOU with PRASA
- NPDS Permit Issue Resolved

**Next Steps:**

- Coordinate with community and Municipality
- Start Construction
REDUCING SEDIMENT TRANSPORT/ UPPER AREA

Shade Coffee Roundtable Initiative

• Instigated by Protectores de Cuencas in March 2011.
• Farmers, Academia, NGO’s, State and Federal Agencies.
• To develop criteria for shade coffee certification for Puerto Rico
• Identify incentives for motivating coffee producers to continue to use historical agricultural practices that are sustainable and environmentally friendly
• Help create economic niches for the coffee produced in the shade that can be marketed separately and that results in greater profits for producers.
• Continue working towards the institutionalization of these practices and programs
• PDC identified and enrolled 10 farmers interested in obtaining the shade coffee certification.

Next Steps:

• Finalize Certification Process.
• Foundation of a Certification Entity.
• Certify 10 farmers and include Certification Logo in 3 Coffee Brands.

Expanding Conservation/Sediment Control Practices

• Implementation of Hydroseeding Techniques
• Collaboration on a sedimentation assessment Dr. Ramos.
• 95% of sediments come out from dirt roads in coffee farms
• NOAA Domestic Grant
• 3 Farms engaged
• 8 Different BMP implemented, tested and evaluated for effectiveness
• New Proposal submitted to expand Efforts to Sea Grant Program

Next Steps:

• New Proposals submitted to expand Efforts to NFWF and NRCS
• Certified conservation practices on NRCS programs
**Source Area Pollution**

**Pollution Tracking IDDE**
- Proposal to NFWF for IDDE and Demonstrative Project in the Río Loco Main Tributaries
- First round in pollution targeting

**Next Steps:**
- Data analysis and projection
- Next round of samplings
- Submit Interim report
- Design of Pilot SWP project
- Implement Demonstrative project
- Conduct Additional EDDE in other areas of the coastal communities in Guánica
- Meeting and field visit with EPA and PRASA

**Monitoring**
- Meeting with all partners conducting Monitoring
- Identification of Monitoring sites
- Proposal submitted to NOAA Domestic (UPR and NASA) for Baseline Remote Sensing Water Quality Assessment and characterization
- Proposal submitted to Sea Grant to continue with NASA monitoring.

**Next Steps:**
- Identify additional funding sources to continue monitoring
- Monitor Implementation SWP project in Malecón area
POSSIBLE APPLICATION AND NEEDS FOR PUERTO RICO AND BEYOND

1. Helping to demonstrate the benefits of restoration efforts (land/boat based water quality measurements are limited by time and funding) – Guánica WWTP
2. Helping to reinforce the identification of significant pollution sources
3. Further resolving nearshore and shallow site measurements
4. Ability to report parameter measurements with estimated error
5. Efforts in Lakes
6. Support for higher resolution DEMs or Lidar type products
7. Encouraged by user-friendly products in development
8. Cognizant of challenges with sediment and limited magnitude of change
Sustained Watershed Management

- Building Sustainable sources of Funding
- Co-management Guánica Dry Forest
- Ecotourism
- Puerto Rico Tourism Company

Next Steps:

- Coordination Efforts Summarized Report
- List of all funding sources and partners
- WMP Update
- Private Funders
- Conversations with Puerto Rico Government and NOAA for long term coordination efforts funding
INSTITUTIONAL CAPACITY BUILDING

Native Plants Nursery

- NFWF Funds
- More than 60,000 plants produced
- Restoration Projects across the Island
- Expected to produce over 100,000 plants by the end of the year
- Additional 2 acres of land from Yauco Municipality to expand maturing area

Monitoring Equipment

- HACH 2100Q Portable Turbidimeter
- HACH SL1000 Portable Nutrient Multiparameter
- YSI Multiparameter
- HANA Ammonia Medium Range Portable Photometer - HI96715
- IDEXX Quanti-Tray System for bacteria

Restoration Equipment

- 5 4x4 Pick up trucks
- 1 6m Dump Truck
- 1 Backhoe
- 1 Bulldozer
- 1 Compacting Roller
- 1 Skid Steer
- 3 water truck
- 6 trailers
- Hydromulcher

Staff:

- 5 Technical Personnel
- 20 General Labor experts in BMP and Green Infrastructure Implementation
THANK YOU!

Paul Sturm
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Roberto Viqueira
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VIIRS retrievals of \textit{Karenia brevis} harmful algal blooms in the West Florida Shelf using Neural Networks.

Sam Ahmed$^1$, Ahmed El-Habashi$^1$ and Vincent Lovko$^2$.

NOAA Collaborators Drs. Richard P. Stumpf$^3$ and Michelle C. Tomlinson$^3$

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Outline

- Background of Harmful Algal blooms (HABs) in West Florida Shelf (WFS)
- Neural Networks (NN) algorithm architecture
- *Karenia Brevis* Harmful Algal bloom (*KB*-HABs) retrieval approach
- Comparison of in-situ measurements vs. retrieval algorithms
- Consecutive satellite images showing variations
- Field measurements
- Conclusion
Harmful algal blooms, occur when colonies of phytoplankton grow out of control while producing toxic or harmful effects on people, fish, shellfish, marine mammals and birds.

In United States it has been estimated that $30-$70 million is lost annually as a result of HABs (Fisher et al.). Recent July 4th 2016 bloom had a major effect on economy and health.
MODIS & VIIRS satellite capability for KB HABs detections

- MODIS retrieval of KB uses fluorescence line height technique (nFLH) which requires 678nm chlorophyll fluorescence band

- 678 nm band not available on VIIRS providing impetus for development of NN technique, which uses as inputs 486, 551 and 671 nm available in VIIRS.
Neural Networks (NN) Algorithm Architecture.

- A multilayer perceptron neural network (NN) was developed based on a 4 component bio-optical (pure water, phytoplankton, CDOM and NAP): 20,000 simulated dataset generated as a random variables, based on a wide range of coastal and oceanic NOMAD IOPs, used in a forward bio-optical model based on radiative transfer, to generate 20,000 sets of Rrs at 486,551 and 671 nm (VIIRS bands)/

- NN was trained on 10,000 and tested and validated on remaining 10,000 simulated dataset and field measurements.

- Note: NN uses Rrs from VIIRS as inputs at 486, 551 & 671 nm, all relatively long wavelengths which are not greatly impacted by atmospheric correction inadequacies.

- Output of IOPs (aph etc) all at 443 which at the peak of aph and thus exhibit most variation (We are only interested at aph443)
Example of VIIRS NN retrievals of $a_{ph443}$, and its conversion to equivalent $[Chla]$. 

- Reflectance data obtained from the NASA Level 2, L2gen data processing system.

- Any individual pixel is excluded from the image if it has been flagged land, cloud, failure in atmospheric correction, bad navigation quality, both high and moderate glint, negative Rayleigh-corrected radiance $aph443$. 

$a_{ph443}$: phytoplankton absorption at 443 nm. 

$[Chla]$: Chlorophyll-a concentrations
First we relate VIIRS Rrs (486,551,671) to $a_{ph443}$ using NN for estimation of $a_{ph443}$ which is approximately proportional to [Chla].

Then, in a second critical step, we evolve limiting criteria which make use of two facts (Cannizzaro, 2009)

I. low backscatter $bb_{p551} \leq$ max specific value.  
   &Equiv. $Rrs_{551} \leq 0.006$ sr$^{-1}$ Filter F1

II. $a_{ph443}$  
    $a_{ph443} \geq 0.061$ m$^{-1}$ Filter F2

These limiting criteria are applied to retrieved VIIRS retrievals of $a_{ph443}$ & $Rrs_{551}$ to effectively delineate and quantify KB.
Successive applications of backscatter filter F1, and minimum absorption filter F2 (light grey) to NN VIIRS and MODIS retrievals so residual images show KB HABs on 10/09/2012.

KB in-situ measurements:

- Cell Counts/L Classification:
  - x Not Observed
  - ○ Very Low (1-10,000)
  - ○ Low (10,000-100,000)
  - ○ Medium (100,000-1,000,000)
  - ○ High (1,000,000+)

Successive applications of backscatter filter F1, and minimum absorption filter F2 (light grey) to NN VIIRS and MODIS retrievals so residual images show KB HABs.
NN VIIRS retrievals compared against near-coincident in-situ Karenia Brevis (KB) cell counts (2012-2016)

• To obtain sufficient numbers of points for statistically meaningful comparisons all Karenia Brevis cell counts collected by Florida Fish and Wildlife Conservation Commission (FWC) over 2012-16 period were compared to all valid near coincident VIIRs retrievals. Comparisons of retrievals V in-situ shown in the coming slides for following algorithms:
  
  NN (Neural Network) 
  (Ocx) Ocean Color product for chlorophyll-a (NASA). 
  (GIOP) Generalized Inherent Optical Property model 
  (QAA_5) Quasi-Analytical Algorithm version 5 
  (RGCI) Red Green chlorophyll-a Index [Chla] retrievals for WFS [L. Qi, C. Hu 2015]:

In-situ Cell Counts (Cell L⁻¹) 
Classification of Values:
- Low (10,000-100,000)
- Medium (100,000-1,000,000)
- High (1,000,000+)
Retrieval comparisons using NN and other retrieval algorithms against in-situ cell counts

To determine $R^2$ and error ($\epsilon$) the orthogonal linear regression approach was used (L. Leng et al 2007).

Showing in-situ comparison for the 93 available match-ups points for 100 minutes overlap windows with in-situ observations obtained using the different algorithms (NN, OCx, GIOP, RGCI, and QAA$_{v5}$).
Data distribution comparison for **KB cell counts** in-situ measurements and equivalent their [Chla] retrieval algorithms

<table>
<thead>
<tr>
<th>KB in-situ &amp; retrievals algorithms</th>
<th>[Chla] data values (µg·L$^{-1}$)</th>
<th>mean</th>
<th>median</th>
<th>mode</th>
<th>STD</th>
<th>min</th>
<th>max</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-situ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NN</td>
<td></td>
<td>4.1</td>
<td>1.4</td>
<td>0.8</td>
<td>9</td>
<td>0.1</td>
<td>62</td>
<td>68</td>
</tr>
<tr>
<td>OCx</td>
<td></td>
<td>7.4</td>
<td>3.9</td>
<td>1.9</td>
<td>12</td>
<td>0.99</td>
<td>71</td>
<td>68</td>
</tr>
<tr>
<td>GIOp</td>
<td></td>
<td>9</td>
<td>4.4</td>
<td>2.9</td>
<td>20</td>
<td>1.19</td>
<td>122</td>
<td>68</td>
</tr>
<tr>
<td>RGCI</td>
<td></td>
<td>50</td>
<td>10.6</td>
<td>3.1</td>
<td>118</td>
<td>0.04</td>
<td>597</td>
<td>68</td>
</tr>
<tr>
<td>QAA$_{v5}$</td>
<td></td>
<td>13.7</td>
<td>2.7</td>
<td>0.6</td>
<td>56</td>
<td>0.24</td>
<td>461</td>
<td>68</td>
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<tr>
<td>VIIRS 100 minutes window</td>
<td></td>
<td>13.7</td>
<td>6.2</td>
<td>3.2</td>
<td>28</td>
<td>0.05</td>
<td>163</td>
<td>68</td>
</tr>
</tbody>
</table>

To determine $R^2$ and error (ɛ) the orthogonal linear regression approach was used (L. Leng et al 2007), where errors are assumed to exist for both variables. The error (ɛ) is calculated as the sum of orthogonal distances. Results are shown in the next slide.
<table>
<thead>
<tr>
<th>y-axis [Chla] (µg·L⁻¹)</th>
<th>x-axis KB Cell Counts (cells L⁻¹)</th>
<th>R²</th>
<th>ε</th>
<th>Slope &amp; Intercept</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>NN</td>
<td>VIIRS 100 minutes window</td>
<td>0.42</td>
<td>5.01</td>
<td>y =0.52 x −2.04</td>
<td>68</td>
</tr>
<tr>
<td>OCx</td>
<td></td>
<td>0.34</td>
<td>5.24</td>
<td>y =0.43 x −1.54</td>
<td>68</td>
</tr>
<tr>
<td>GIOP</td>
<td></td>
<td>0.37</td>
<td>12.64</td>
<td>y =1.60 x −7.28</td>
<td>68</td>
</tr>
<tr>
<td>RGCI</td>
<td></td>
<td>0.19</td>
<td>15.46</td>
<td>y =1.14 x −5.39</td>
<td>68</td>
</tr>
<tr>
<td>QAA</td>
<td></td>
<td>0.23</td>
<td>15.13</td>
<td>y =1.31 x −6.09</td>
<td>68</td>
</tr>
<tr>
<td>NN</td>
<td>VIIRS 15 minutes window</td>
<td>0.79</td>
<td>0.42</td>
<td>y =0.47 x −1.83</td>
<td>18</td>
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<tr>
<td>OCx</td>
<td></td>
<td>0.55</td>
<td>0.72</td>
<td>y =0.34 x −1.13</td>
<td>18</td>
</tr>
<tr>
<td>GIOP</td>
<td></td>
<td>0.45</td>
<td>3.57</td>
<td>y =1.20 x −5.25</td>
<td>18</td>
</tr>
<tr>
<td>RGCI</td>
<td></td>
<td>0.50</td>
<td>2.28</td>
<td>y =0.75 x −3.55</td>
<td>18</td>
</tr>
<tr>
<td>QAA</td>
<td></td>
<td>0.34</td>
<td>3.82</td>
<td>y =0.90 x −3.88</td>
<td>18</td>
</tr>
</tbody>
</table>

**Table:** Statistics of comparison for retrieval algorithms and their successful retrievals against in-situ observations (2012-2016)
Consecutive satellite images on Nov. 3rd 2014

Showing variation in bloom.
Changes in bloom for consecutive satellite images of region 1 using retrieved OC3 \([\text{Chla}]\).

- The bloom, as delineated by the \([\text{Chla}]\) color contour in the images, appears, qualitatively, to increase in concentration and expand in the southwest direction over the 96 minute interval between the consecutive overlapping VIIRS-MODIS-VIIRS images.
region 1 using NN retrieved [Chla].
NN retrievals from Tampa Bay, Region 2.

Figure shows VIIRS and MODIS-A sequential retrievals from Tampa Bay, where a bloom seems to shrink in [Chla] densities opposite to the wind and current direction, implying that there are a complexity of factors at work, possibly including downwelling.
Results of field measurements showing temporal variability on 1/19/2017

<table>
<thead>
<tr>
<th>Station</th>
<th>Depth (m)</th>
<th>Lat. (°)</th>
<th>Long. (°)</th>
<th>Start Time (GMT)</th>
<th>End Time (GMT)</th>
<th>K. brevis (cells L⁻¹)</th>
<th>Time diff (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV1701</td>
<td>0.7</td>
<td>27.31836</td>
<td>-82.59587</td>
<td>17:20</td>
<td>17:25</td>
<td>7,280,000</td>
<td>120</td>
</tr>
<tr>
<td>CV1713</td>
<td>0.7</td>
<td>27.31713</td>
<td>-82.59606</td>
<td>19:21</td>
<td>19:25</td>
<td>1,552,000</td>
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</tr>
<tr>
<td>CV1702</td>
<td>0.7</td>
<td>27.31500</td>
<td>-82.59831</td>
<td>17:48</td>
<td>17:52</td>
<td>1,776,000</td>
<td>87</td>
</tr>
<tr>
<td>CV1712</td>
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<td>27.31480</td>
<td>-82.59846</td>
<td>19:15</td>
<td>19:19</td>
<td>1,326,000</td>
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<tr>
<td>CV1703</td>
<td>0.7</td>
<td>27.31467</td>
<td>-82.60061</td>
<td>18:00</td>
<td>18:04</td>
<td>1,024,000</td>
<td>68</td>
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<td>CV1711</td>
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These results illustrate both the intra pixel variations that can typically occur (as well as inter pixel variations) and also confirm the temporal variations that can be expected. The relative contributions of drift or upwelling/downwelling to the results are not known.
Conclusion

- The use of NN retrievals of $a_{ph}443$ from VIIRS show promise as a viable algorithm for the Florida coastal regions with complex water conditions.

- Comparisons against in-situ measurements show that VIIRS [Chl$\alpha$] data retrievals are significantly improved for all algorithms for shorter overlap time windows.

- Show important impact of temporal variations on retrieval accuracies.

- Further detailed comparisons with in-shore in-situ measurements are planned and considerations of subpixel variability addressed.
Acknowledgment

We thank NOAA JPSS and NOAA-Crest for the support to continue this work.

Thank you