Overview of Ocean Color EDR Team Activities

Menghua Wang
& VIIRS Ocean Color EDR Team

VIIRS Ocean Color Breakout Session
August 27, 2015
<table>
<thead>
<tr>
<th>EDR</th>
<th>Name</th>
<th>Organization</th>
<th>Funding Agency</th>
<th>Task</th>
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<tbody>
<tr>
<td>Ocean Color</td>
<td>Robert Arnone, Sherwin Ladner, Ryan Vandermeulen, Adam Lawson, Paul Martinolich, Jen Bowers</td>
<td>U. Southern MS NRL QinetiQ Corp. SDSU</td>
<td>JPSS/NJO</td>
<td>Satellite data evaluation, in situ data Look UpTables – SDR-EDR impacts, vicarious calibration 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-OC Uncertainty</td>
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<td>Curt Davis, Nicholas Tufillaro</td>
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<td>JPSS/NJO</td>
<td>Ocean color validation, Cruise data matchup West Coast</td>
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<td>Burt Jones, Matthew Ragan</td>
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<td>JPSS/NJO</td>
<td>Eureka (AERONET-OC Site)</td>
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<td>Sam Ahmed, Alex Gilerson</td>
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<td>JPSS/NJO</td>
<td>LISCO (AERONET-OC Site) Cruise data and matchup</td>
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<td>JPSS/NJO</td>
<td>NOAA data continuity, cruise participation/support</td>
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<td>Ken Voss &amp; MOBY team</td>
<td>RSMAS –Miami</td>
<td>JPSS/NJO</td>
<td>Marine Optical Buoy (MOBY)</td>
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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 Ocean color optics matchup, cruise participation</td>
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</tbody>
</table>

Working with: NOAA CoastWatch, VIIRS SDR team, DPA/DPE, Raytheon, NOAA OC Working Group, NOAA Coral Reef Watch, NOAA various line-office reps, NASA OBPG, NOAA OCPOP, etc.

Collaborators: D. Antoine (BOUSSOLE), B. Holben (NASA-GSFC), G. Zibordi (JRC-Italy), R. Frouin (for PAR), and others.
## VIIRS Spectral Bands for Ocean Color

VIIRS on Suomi NPP has Ocean and SWIR spectral bands similar to MODIS

<table>
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<tr>
<th>VIIRS$^+$</th>
<th>MODIS</th>
<th>SeaWiFS</th>
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<td>Ocean Bands (nm)</td>
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<td>865 (I2)</td>
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<td>1610 (I3)</td>
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<td>555</td>
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<td>SWIR Bands</td>
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<td>1238 (M8)</td>
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<tr>
<td>1610 (M10)</td>
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<tr>
<td>2250 (M11)</td>
<td>2130</td>
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</table>

$^+$VIIRS 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 and the SWIR M8, M10, and M11 bands SDR data
  – Terrain-corrected geo-location file
  – Ancillary meteorology and ozone data

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

• Experimental Products:
  – Inherent Optical Properties (IOP-a, IOP-a_ph, IOP-a_dg, IOP-b_b, IOP-b_bp) at VIIRS M2 or other visible bands (M1-M5) from the Quasi-Analytical Algorithm (QAA) (Lee et al., 2002)
  – Photosynthetically Available Radiation (PAR) (R. Frouin)
  – Chlorophyll-a from ocean color index (OCI) method (Hu et al., 2012)
  – Others from users requests

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

- **Multi-Sensor Level-1 to Level-2 (MSL12)**
  - MSL12 was developed for the purpose of using a consistent and common data processing system to produce ocean color products from multiple satellite ocean color sensors (Wang, 1999; Wang and Franz, 2000; Wang et al., 2002), i.e., it is **measurement-based** ocean color data processing system.
  - It has been used for producing ocean color products from various satellite ocean color sensors, e.g., SeaWiFS, MOS, OCTS, POLDER, MODIS, GOCI, etc.
  - MSL12 is the official VIIRS ocean color data processing system.

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

- **NOAA-MSL12 for VIIRS (and others) Ocean Color Data Processing**
  - Routine ocean color data processing (daily, 8-day, monthly) since VIIRS launch.
  - Coastal turbid and inland waters from other approaches, e.g., the **SWIR approach**, results in the US east coastal, China’s east coastal, Lake Taihu, Lake Okeechobee, Aral Sea, etc.
  - Capability for multi-sensor ocean color data processing, e.g., MODIS-Aqua, VIIRS, GOCI, and will also add J1, OLCI/Stentinel-3, and SGLI/GCOM-C data processing capability.
New Rayleigh Lookup Tables

- **Developed Hyperspectral Rayleigh Lookup Tables (LUTs)**
  - Developed new Rayleigh lookup tables including polarization effects for the entire solar reflective spectrum (335-2555 nm) for satellite ocean color remote sensing.
  - The new Rayleigh LUTs cover solar-zenith angles of 0-88 Deg., sensor-zenith angles of 0-84 Deg., all azimuth angles, and wind speeds of 0-30 m/s.
  - The same Rayleigh LUTs can be applied to any satellite sensors (multi-spectral and hyperspectral).
  - The same LUTs can be applied for **High Altitude Lakes**.
  - The LUTs can be used to account for the effect of sensor spectral response function.
  - **Consistent Rayleigh radiance computations for all satellite sensors.**

- **New Rayleigh LUTs for Ocean Color Data Processing (MSL12)**
  - VIIRS **detector-based** exact Rayleigh radiance computations.
  - Exact Rayleigh radiance computation with atmospheric pressure variation.
  - More accurately account for the effect of VIIRS sensor spectral response function, particularly for large solar-zenith angles.
  - More accurate Rayleigh radiance computations and improved ocean color products.
  - The same Rayleigh LUTs for J1, J2, J3, J4, ……., as well as for satellite sensors from Sentinel-3, GCOM-C, etc.
Developed new NIR ocean reflectance correction algorithm: BMW (Bailey (2010), MUMM (2000), and Wang (2012))

The BMW Algorithm for Ocean Color Data Processing

- Inputs of the TOA L1B data, geolocation data, and ancillary data
- The NIR atm. corr. with Bailey et al. (2010) algorithm
- $nL_w(\lambda_{NIR2}) < 0.005$?
  - Yes
  - Turbid Water Pixel
  - Compute $\varepsilon^{(m)}(\lambda_{NIR2}, \lambda_{NIR2})$ using distance-weighted mean $\varepsilon^{(m)}$ from either clear or turbid water pixels for a given scene
  - Clear water pixel: use the derived $\varepsilon^{(m)}$ value
  - Do all pixels in the entire scene have $\varepsilon^{(m)}$ values? 
    - Yes
      - The MUMM atm. corr. with Wang et al. (2012) NIR relationship
      - Output Results
  - No

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

Destriping of VIIRS Ocean Color Products
(Examples)

\( nL_w(412) \)

\( K_d(490) \)

Polarization Correction (1)

Case Study: 04/14/2014 00:43 UTC

$nL_w(412)$ without polarization correction

$nL_w(412)$ with old polarization correction

VIIRS Granule at 55°S and 155°W in South Pacific Ocean
Polarization Correction (2)

Case Study: 04/14/2014 00:43 UTC

$nL_w(412)$ without polarization correction  

$nL_w(412)$ with **new** polarization correction

VIIRS Granule at 55°S and 155°W in South Pacific Ocean
End-to-End Ocean Color Data Processing

- NOAA Ocean Color Team has been developing/building the capability for the End-to-End satellite ocean color data processing including:
  - Level-0 (or Raw Data Records (RDR)) to Level-1B (or Sensor Data Records (SDR)).
  - Level-1B (SDR) to ocean color Level-2 (Environmental Data Records (EDR)).
  - Level-2 to global Level-3 (routine daily, 8-day, monthly, and climatology data/images).
  - Validation of satellite ocean color products (in situ data and data analysis capability).

- Support of in situ data collections for VIIRS Cal/Val activities, e.g., MOBY, AERONET-OC sites, NOAA dedicated cruise, etc.

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

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

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

- **Science Quality Ocean Color Data Processing (One-two weeks delay):**
  - About one-two weeks delay
  - Reprocessed mission-long ocean color data and continue-forward data stream
  - Using improved SDR (based on IDPS SDR data)
  - Science quality (assimilated) NCEP ancillary data
  - Complete global coverage
  - May expand to more experimental products & test with improved algorithms
  - Ocean color EDR will be reprocessed (mission-long) about every two-three years (or as needed, e.g., short-term data reprocessing, error fixing, etc.)
  - Data will be processed in NOAA/STAR and transferred to CoastWatch for distributions
VIIRS Climatology Chlorophyll-a Image
(April 2012 to October 2014)

Log scale: 0.01 to 64 mg/m³
Climatology from 2012/04 to 2014/10

Generated using MSL12 for VIIRS ocean color data processing

http://dx.doi.org/10.1002/jgrd.50793
Generated using **MSL12** for VIIRS ocean color data processing

http://dx.doi.org/10.1002/2009JC005286
Generated using MSL12 for VIIRS ocean color data processing


http://dx.doi.org/10.1016/j.rse.2014.12.011
VIIRS Chl-$\alpha$ and $K_d(490)$ Images in Mediterranean Sea
(October 2014 to January 2015)

Chl-$\alpha$: Log scale: 0.01 to 64 mg m$^{-3}$

NOAA CoastWatch has been providing VIIRS OC data to EUMETSAT

$K_d(490)$: Log scale: 0.01 to 2 m$^{-1}$
Global Oligotrophic Water OC Product Time Series

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

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

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

Global Deep Water (> 1km depth) OC Product Time Series

Hawaii

VIIRS Ocean Color EDR Monitoring Sites

1. MOBY Site; 2. South Pacific Gyre; 3. Chesapeake Bay; 4. US East Coast; 5. AERONET-OC CSI Site; 6. AERONET-OC LISCO Site; 7. AERONET-OC USC Site.

Website:
http://www.star.nesdis.noaa.gov/sod/mecb/color/
Matchup comparison of MOBY In Situ (with VIIRS MSL12)

We thank MOBY team (PI: Ken Voss) for in situ MOBY radiance data.
Comparison of NOAA VIIRS ocean color products with Marine Optical Buoy (MOBY) in situ data.

Note: Vicarious calibration gains applied since May 2012.

Vicarious gains were derived using MOBY in situ data.

MOBY in situ optics data have been providing critical data set in support of VIIRS calibration and validation activities, including VIIRS Level-1B (SDR) data monitoring for sensor on-orbit calibration.
MOBY Matchup with VIIRS Current Data Processing (2012-01-01 ~ 2014-05-31) Q1+Q2, ±3hr

Use IDPS-SDR with Old MSL12
MOBY Matchup
with
VIIRS New EDR Processing
(BMW-hdf)

Use IDPS-SDR
with
New MSL12

(2012-01-01 ~ 2014-05-31)
Q1+Q2, ±3hr
MOBY Matchup with VIIRS OC-SDR/EDR Processing (BMW-netCDF4)

Use OC-SDR with New MSL12

MOBY (2012-01-01 ~ 2014-05-31) Q1+Q2, ±3hr
# Statistics of VIIRS MSL12 vs. In-Situ (MOBY)

<table>
<thead>
<tr>
<th></th>
<th>Current Data Processing</th>
<th>New EDR Processing (BMW-hdf)</th>
<th>OC-SDR/EDR Processing (BMW-netCDF4)</th>
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<td><strong>AVG</strong></td>
<td><strong>MED</strong></td>
<td><strong>STD</strong></td>
<td><strong>No</strong></td>
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<td>( nL_w(410) )</td>
<td>1.0426</td>
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<td>( nL_w(443) )</td>
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<td>( nL_w(486) )</td>
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<td>( nL_w(551) )</td>
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<td>( nL_w(671) )</td>
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<td>( K_d(490) )</td>
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Statistics of VIIRS MSL12 vs. In-Situ (MOBY)

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<tr>
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<td>AVG</td>
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<tr>
<td>nL(_w)(410)</td>
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<td>Chl-a</td>
<td>0.8956</td>
<td>0.9034</td>
<td>0.279</td>
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</table>

“same STRAYLIGHT_FLAG (from OC-SDR/EDR processing) applied..”
& “same Geolocation information (since 2012-02-28)”
Matchup comparison of Aeronet-OC In Situ (with VIIRS MSL12)

AERONET-OC data were obtained at:
http://aeronet.gsfc.nasa.gov/new_web/ocean_color.html
We thank AERONET-OC PIs for contributing useful ocean color radiance data.

Aeronet-OC CSI with VIIRS New EDR Processing (BMW-hdf)

Use IDPS-SDR with New MSL12

CSI (2012-01-01 ~ 2014-05-31)
Aeronet-OC CSI with VIIRS OC-SDR/EDR Processing (BMW-netCDF4)

(2012-01-01 ~ 2014-05-31)

Use OC-SDR with New MSL12
Statistics of **VIIRS MSL12** vs. **Aeronet-OC**

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**CSI**
Statistics of **VIIRS MSL12** vs. **Aeronet-OC**

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<tr>
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<tr>
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<tr>
<td>$nL_w_{All}$</td>
<td>1.3314</td>
<td>1.0393</td>
<td>1.104</td>
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“same STRAYLIGHT_FLAG (from OC-SDR/EDR processing) applied..”
Aeronet-OC USC
with
VIIRS OC-SDR/EDR
Processing
(BMW-netCDF4)

Use OC-SDR
with
New MSL12
### Statistics of VIIRS MSL12 vs. Aeronet-OC

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<td>0.6621</td>
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<tr>
<td>$nL_{w, All}$</td>
<td>0.800</td>
<td>0.7563</td>
<td>0.597</td>
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</table>
Conclusions/Path Forward (1)

- With improved SDR (calibration) and EDR (processing algorithms), VIIRS ocean color products are now comparable to or better than those from MODIS-Aqua.
- We have completed mission-long OC data reprocessing using IDPS-SDR with new MSL12.
- We have started VIIRS mission-long science quality ocean color data reprocessing (including SDR and EDR), and will finish that in late 2015, & the data stream will go forward. **Two data streams will be produced: near-real-time and science quality ocean color data.**
- Calibration from both solar and lunar is necessary. We need lunar model data!
  - VIIRS ocean color products have been improved after the implementation of some important updates, new algorithms, and with vicarious calibrations.
  - In general, VIIRS **normalize water-leaving radiance** spectra show reasonable agreements with in situ measurements at MOBY, AERONET-OC sites, and various other ocean regions.
  - The new NIR ocean reflectance correction algorithm (BMW) improves ocean color data over coastal and inland waters. The destriping algorithm significantly improves VIIRS-derived ocean color imageries.
  - New $K_d$(PAR) product has been developed and routinely produced to meet users requirements.
  - NOAA dedicated Cal/Val cruise in Nov. 2014, and plan to have it in late 2015. The report for the 2014 Cal/Val cruise has been completed.
  - There will be many applications using VIIRS ocean color products.
  - We have developed VIIRS instrument calibration capability, and with new calibration LUTs, VIIRS ocean color products are significantly improved.
  - Our evaluation results show that VIIRS-SNPP is capable of providing high-quality global ocean color products in support of science research and operational applications.
  - We have been actively working with other current and future ocean color sensors, e.g., MODIS-Aqua, Korean GOCI, EUMETSAT for Sentinel-3 (launch late 2015), JAXA GCOM-C (launch early 2017), and **VIIRS on J1** (launch 2017).
Conclusions/Path Forward (2)

• Complete VIIRS mission-long ocean color data reprocessing (science quality, i.e., improved SDR, algorithms, and science quality ancillary data).
• VIIRS reprocessed data stream will go forward (about one-two weeks delay). VIIRS science quality data will be distributed through CoastWatch and other means (e.g., NODC effort).
• Cal/Val team will finish the 2014 VIIRS dedicated cruise report and in situ data analyses (e.g., improve in situ data quality).
• More in situ data are needed for validation and improvement of VIIRS ocean color products.
• In situ data quality (instrument calibration, measurement protocols, data processing methodology, etc.)
• Dedicated VIIRS ocean color Cal/Val cruise in December 2015, and establishing annual Cal/Val cruises.
• Continue work on sensor on-orbit calibration (solar and lunar), algorithms improvements, etc.
• We have been working on J1 instrument. Need more efforts for J1 VIIRS pre-launch data analyses as J1 close to launch (access to J1 sensor data).
• Algorithms improvements for both open oceans and coastal/inland waters. In particular, significant efforts are needed for coastal/inland waters.
Questions?
Aeronet-OC LISCO with VIIRS OC-SDR/EDR Processing (BMW-netCDF4)

Use OC-SDR with New MSL12
## Statistics of VIIRS MSL12 vs. Aeronet-OC

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<td>STD</td>
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SNPP VIIRS SDR Calibration for Improvement of Ocean Color Products

Junqiang Sun¹,² and Menghua Wang¹

¹NOAA/NESDIS Center for Satellite Applications and Research
E/RA3, 5830 University Research Ct., College Park, MD 20740, USA
²Global Science and Technology, 7855 Walker Drive, Maryland, USA

8/27/2015 9:00-9:15 AM
Key Points

- Ocean color products are highly sensitive to details in processing algorithms and calibration.
- VIIRS RSB uncertainty specification is 2%; For ocean color EDR products, the ocean bands (M1-M7) are required to be calibrated with an uncertainty of ~0.1-0.3%.
- Solar diffuser (SD) degrades non-uniformly, resulting in long-term bias in calibration results, especially for short wavelength bands.
- A hybrid approach properly combining the SD and lunar calibration coefficients restores the accuracy of the calibration coefficients from the non-uniformity issue and other various effects:
  - Lunar calibration provides long-term baseline
  - SD calibration provides smoothness and frequency
- Every component must itself be accurately characterized!
  - SDSM calibration/SD calibration; Lunar calibration; Hybrid approach
- Challenges and potential issues
Solar Illumination and Sweet Spot

Illumination of SD and SDSM Aperture

Solar angles

SDSM response

Band M1 Detector 1 response

Good selections stabilizes results, reduce noise – Different from ATBD
Prelaunch BRFs of the SD and the VFs of SD and SDSM Screens

- 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 wavelength from 412 nm to 935 nm

The author carefully made yaw planning in 2012 with NASA colleagues for on-orbit validation of BRDF and VF.

We have carefully re-derived BRFs and VFs from the yaw measurements (removes seasonal variation artifacts and noises)

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

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

  - \( \rho_{SD,SDSM}(\lambda) \): 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

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

- Improvements

  - Carefully re-derived the VFs and BRFs from yaw measurements
  - Ratio of the averages (different from ATBD!)
  - 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 Results

Sun view response trending

SDSM can accurately track the SD degradation for SDSM direction

SD degradation

Unexpected but real degradation (Nov., 2014)

SDSM can accurately track the SD degradation for SDSM direction
• SD is made of Spectralon®, near Lambertian property

• Solar radinace reflected by the SD

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

- \( \rho_{RSD,RTA}(\lambda) \): 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

\[ F(B, D, M, G, t) = \frac{RVS_{B,SD} \cdot \int RSR_B(\lambda,t) \cdot L_{SD}(\lambda) \cdot d\lambda}{\sum_i c_i(B, D, M, G) \cdot dn' \cdot \int RSR_B(\lambda,t) \cdot d\lambda} \]

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

SD Calibration Algorithm

- Improvements
  - Carefully rederived the VFVs and BRFs from yaw measurements
  - Improved H factors
  - Sweet spot selection
  - Time-dependent RSR

SD Calibration Results

Band M1 HAM 1 HG F-factors

Time-dependent RSR

Impact of RSR on F-factors

Band Averaged HAM1 HG F-factors

HG = High Gain
LG = Low Gain

SD can accurately track the RSB gain change as long as SD degradation for the RTA view can be approximated as that for the SDSM view.

OOB 2.83%, prelaunch
OOB 2.24%, 2014
Lunar Calibration Algorithm

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

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

- \( g(B) \): 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 Planning and Calibration Results

Roll maneuver

Lunar image (M6 in April, 2012)

- View geometry dependence
- **Planning is important starting point** – made lunar planning tool and planned lunar observations in early mission
- However, the phase angle range change from [-56°, -55°] to [-50.5°, 51.5°]
- Size of the moon
- Oversampling effect
- Scans seeing full lunar image

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

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

\[
R(B, t) = \left\{ f(B, M, t) \right\}_M / \left\{ F(B, D, M, 0, t) \right\}_{D, t-15 < t_1 < t+15, M}
\]

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

\[J. \text{ Sun and M. Wang, “Radiometric Calibration of the VIIRS Reflective Solar Bands with Robust Characterizations and Hybrid Calibration Coefficients,” submitted to Applied Optics.}\]
Hybrid Calibration Coefficients

Calibration coefficients Ratios

Symbols: Measured
Lines: Fitted

Calibration Coefficients (M1)

Symbols: Hybrid
Lines: SD

Calibration Coefficients (M4)

Symbols: Hybrid
Lines: SD

Calibration Coefficients

Symbols: Hybrid
Lines: SD
Improvements in Ocean Color Products

- VIIRS data were reprocessed using MSL12 with SDR generated with updated hybrid calibration coefficients.
- NOAA ocean color products produced with the hybrid calibration coefficients have met validated maturity in March 2015.
- Hybrid results agree with MOBY in situ!

Green: VIIRS IDPS; Red: VIIRS Hybrid; Blue: Moby in Situ

Some Other Challenges

- SD degrades abnormally
- RVS may change on-orbit
  - Aqua and Terra MODIS RVS have changed more than 20% and 40%, respectively, at small AOI.

- S-NPP orbit drift

- Polarization sensitivity may change on-orbit
  - Terra MODIS polarization sensitivity changed dramatically on-orbit
Summary

• Robust characterizations of essential calibration components have been completed
• A hybrid approach combining the SD and lunar calibration coefficients, along with robust inputs, achieves the highest accuracy up to date
• Hybrid calibration approach, using both solar and lunar calibrations, has significantly improved VIIRS ocean color products
• “Solar diffuser degradation uniformity condition” will be a key issue for all instruments such as VIIRS J1, VIIRS J2, etc, that use SD/SDSM for reflective solar bands calibration - Lunar calibration is necessary as a solution.
• There will be more challenge issues/problems when the instrument begins to age. Thus, more effort for instrument on-orbit calibration will be needed.
Backup
Non-Uniformity of the SD Degradation

- SD degrades non-uniformly with respect to the incident angle for SDSM view direction.
- SD degrades non-uniformly with respect to the incident angle for rotating telescope assembly (RTA, RSB) view direction.
- According to optical reciprocity, then SD also degrades non-uniformly with respect to the outgoing direction.
- The different signs of the variation slopes of the H-Factors and F-Factors with respect to solar declination confirm that SD degrades non-uniformly with respect to outgoing direction.

- 0.1% per degree; 1% per 10 degrees for 412 nm (D1 and M1).
- Angle between SDSM view direction and RTA view direction is larger than 100 degree?
- SD calibration is not accurate enough for ocean color data 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>
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<tr>
<td>M1</td>
<td>410</td>
<td>DG</td>
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<td>742m x 776m</td>
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</table>

*CW: Center Wavelength; DG: Dual Gain; SG: Single Gain; Resolution: Track x Scan at Nadir after aggregation
Statistical Evaluation of VIIRS Ocean Color Data Retrievals

Karlis Mikelsons, Lide Jiang, Menghua Wang
STAR VIIRS Ocean Color Team

STAR JPSS
2015 Annual Science Team Meeting
August 27, 2015
Methodology

• Analyze SNPP-VIIRS ocean color data granules from two regions, from time period 2012 - 2014, processed with the most recent MSL12 (BMW algorithm)
• Exclude all $nL_w$ data flagged as land, clouds, high sun-glint, and atmospheric correction failure, as well as all masked or out-of range $nL_w$ data
• Subtract lat-lon binned and time averaged $nL_w$ over 31 days (day-15…day+15) from $nL_w$ data in each granule: $\Delta nL_w = nL_w - \text{time\_averaged(binned}(nL_w))$
• Collect statistics in VIIRS bands M1-M5 for $\Delta nL_w$ (410, 443, 486, 551, 671 nm) dependence on solar-zenith angle, sensor-zenith angle, glint coefficient, wind speed, atmospheric pressure, and other retrieval and auxiliary parameters
• Also collect number of data points dependence on retrieval parameters
• Plot $\Delta nL_w$ vs. retrieval parameters and look for deviations from average and other artifacts
Region 1: North Atlantic

region of study: 50-62.5N, 15-40W box

binned $nL_w$: $(0.5^{\circ}\text{lat} \times 1^{\circ}\text{lon} \approx 50 \times 50\text{km})$
Region 2: South Pacific
region of study: 10-60S, 90-140W box
binned $nL_w: (0.5^\circ\text{lat} \times 0.5^\circ\text{lon})$
$nL_w$ dependence on sensor-zenith angle
$nL_w$ dependence on solar-zenith angle
$nL_w$ dependence on pixel number along the scan
North Atlantic (OC-SDR)
2012 - 2014

\[ \Delta n \times \Delta L_w(412, 445, 488, 555), 5 \times \Delta L_w(672) \]

Pixel along scan
Number of data points

\[ 10^0 \, \, 10^1 \, \, 10^2 \, \, 10^3 \, \, 10^4 \, \, 10^5 \, \, 10^6 \, \, 10^7 \]
$nL_w$ dependence on detector number
$nL_w$ dependence on sun glint coefficient
North Atlantic (OC-SDR)
2012 - 2014

\Delta \text{L} \text{w}(412, 445, 488, 555), 5 \times \Delta \text{L} \text{w}(672)

\text{Glint coefficient}

\text{Number of data points}
South Pacific (OC-SDR)
2012 - 2014

\( \Delta nLw(412, 445, 488, 555), 5\times \Delta nLw(672) \)

number of data points

\( \text{glint coefficient} \)
$nL_w$ dependence on atmospheric pressure
\( nL_w \) dependence on wind speed
$nL_w$ dependence on water vapor concentration
nL_w dependence on ozone concentration
South Pacific (OC-SDR)
2012 - 2014

\[ \Delta n L_w(412, 445, 488, 555), 5 \times \Delta n L_w(672) \]

ozone concentration (cm)

number of data points
Summary

1. Better calibration in OC-SDR significantly improves retrieval consistency for 2012
2. Statistical dependence of $nL_w$ on most retrieval parameters is nearly flat, signifying consistency of the new MSL12 ocean color data processing system in various conditions
3. In all cases, no significant year-to-year changes in statistics were observed
4. Good $nL_w$ retrievals for satellite zenith angle up to 50° (North Atlantic) and nearly 70° (South Pacific)
5. $nL_w$ underestimated for solar zenith angles > ~67° in both regions
6. Significantly decreased $nL_w$ for low values of solar zenith angle (<25°) in South Pacific (likely due to seasonal effects/variations in the region)
7. Noticeable dependence on pixel along the scan in North Atlantic
8. Slightly increased $nL_w$ with higher wind speed (whitecaps?) and higher water vapor concentration
VIIRS Ocean Color Breakout
Thursday, 27 August 2015

Overview of VIIRS Cal/Val Nov. 2014 Cruise & Cruise Objectives

Michael Ondrusek
Dedicated VIIRS Cal/Val Cruise
NOAA Ship Nancy Foster
11-20 November 2014

International, Interagency and Academic Collaborations:

US Agencies
• NOAA/NESDIS/STAR (NOAA)
• Naval Research Laboratory, Stennis Space Center (NRL)
• NASA/Goddard Space Flight Center (NASA)
• National Institute of Standards and Technology (NIST)

European Union
• Joint Research Center of the European Commission (JRC)

Universities
• City University of New York, Long Island; CREST
• Lamont-Doherty Earth Observatory, Columbia University
• University of Massachusetts, Boston
• University of Miami
• University of South Florida
• University of Southern Mississippi
### Principal investigators (PIs)

<table>
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<tr>
<th>PI Name (Last, First)</th>
<th>Participating Institutions</th>
<th>Research Group Abbreviation</th>
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<tr>
<td>Ondrusek, Michael*</td>
<td>NOAA/NESDIS Center for Science, Technology and Research</td>
<td>NOAA/STAR</td>
</tr>
<tr>
<td>Ahmed, Sam</td>
<td>City College of New York</td>
<td>CCNY</td>
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<tr>
<td>Arnone, Robert</td>
<td>University of Southern Mississippi (USM) and Naval Research Center (NRL)</td>
<td>Stennis</td>
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<td>NASA Goddard Space Flight Center</td>
<td>NASA/GSFC</td>
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<td>Gilerson, Alex</td>
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<td>Hu, Chuanmin</td>
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<td>USF</td>
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<td>UMB</td>
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<td>Voss, Kenneth</td>
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<td>U. Miami</td>
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<td>Zibordi, Giuseppe</td>
<td>Joint Research Centre of the European Commission</td>
<td>JRC</td>
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### List of science party personnel aboard the *Nancy Foster*

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<tr>
<th>Name (Last, First)</th>
<th>Title</th>
<th>Research Group/Home Institution*</th>
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<tr>
<td>Arnone, Robert</td>
<td>Research Professor</td>
<td>Stennis/USM</td>
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<td>Freeman, Scott</td>
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<tr>
<td>Zibordi, Giuseppe</td>
<td>Researcher</td>
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Science Objectives for the Cruise

Goals

1) Validation of VIIRS JPSS Satellite Ocean Color products

- Occupied 23 Stations over 10 Days, 9 station matchups with VIIRS
- Conducted pre- and post-cruise inter-cals
- Water-Leaving Radiance - HyperPro, MicroPro, HyperTSRB, C-OPS, GER, SBA, TRIOS, HyperSAS, ASD Handheld 2
- Aerosol Optical Depth - Microtops
- Bi-directional radiance distribution - NURADS
- Chlorophyll - HPLC, Fluorometric, (in situ and extracted)
- Absorption - ACS, AC9, Spectrophotometric
- Backscatter - BB9, BB7, BB3, ECO Puck
- Phytoplankton Physiology - Flowcam, FIRe, Alf
- Carbon - POC and DOC water analysis; plus CDOM
- Total Suspended Matter - Gravimetric
Science Objectives for the Cruise

Goals (cont.)

2) Characterization of differences among the in situ ocean color measurements

a) replicate observations from multiple identical (same model) instruments deployed in parallel;
b) observations of the same in situ parameters but using different types of instruments;
c) different deployment protocols for sample collection;
d) different post-processing methods for the in situ data; and
e) spatial and temporal variability of the ocean waters.
Science Objectives for the Cruise

Goals (cont.)

3) Optical characterization of ocean variability (i.e. coastal, near-shore, cross-shelf, eddies, fronts, filaments, blue

   - Can water mass characterization of the representing different bio-physical processes be defined using VIIRS bio-optical products in the a dynamic system such as the Gulf Stream?
Evaluation of VIIRS ocean color products and development of enhanced ocean products and applications

Robert Arnone\textsuperscript{1}, Ryan. Vandermuelen\textsuperscript{1}, Sherwin. Ladner\textsuperscript{2}

- Maintain WavCis – Aeronet Site
- Cal Val Cruises
1) Ocean Color product stability using VIIRS orbital overlaps to track monthly trends

2) VIIRS validation of Gulf Stream water masses Foster Cruise

3) Characterizing the diurnal changes in coastal bio-optical properties in coastal waters

4) Temporal Assessment of the Calibration and Accuracy of VIIRS Radiometric (SDR) and Ocean Color Products (EDR) at MOBY and WavCIS

5) Using the VIIRS I 1-band to enhance bio-optical monitoring of coastal waters

6) Applications of VIIRS ocean color for real time adaptive sampling
1) Ocean Color product stability using VIIRS orbital overlaps to track monthly trends

VIIRS 100 minute Overlap

How do the differences in the color products within 100 minute change with season?

Example of Open ocean waters ROI

Table: Chlorophyll concentration change

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<th>Chlor_a difference mg/m³</th>
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<td>T175147</td>
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VIIRS Product Difference Mean and Variance of the M CHANNELS
1) Ocean Color product stability using VIIRS orbital overlaps to track monthly trends

VIIRS - Seasonal Overlap Difference

410 nm M1
1700-1900 Overlap

First orbit minus Second orbit.

Which orbit has higher reflectance?

Changes in winter to Summer
- Solar Angle

Largest in M1 Minimal in M5
- Strongest in Open ocean water!
- Similar trend in Coastal waters

Summary:
1. Overlap nLw differences provides very sensitive ability to track the trends in both the Sensor response and processing.
   - Dependent on diurnal changes! Next..

2. Enables internal consistency within the sensor across the orbital swath.

3. Can be applied on a global basis.
2) VIIRS validation of Gulf Stream water masses Foster Cruise

Characterized multiple instruments for Spectral radiance .. Above and in water etc.

VIIRS – Validation crossing Dynamics Gulf Stream Fronts . -
1) Shingle
2) Cape Hatteras.
3) Charleston
Upwelling - Bio-optical response.

Calibration - Matchup requires Defining the VIIRS pixel variability
2) VIIRS validation of Gulf Stream water masses Foster Cruise

Summary -- see poster !!

1. Unique data sets for instrument protocols
2. OC Spatial variability on Station
3. OC response to ocean processes!
4. Agreement of VIIRS and Flowthrough optics
5. New Questions to address → accuracy of instruments vs temporal and spatial variability.
6. Bio-optical Water Mass classification -
3) Characterizing the diurnal changes in bio-optical properties in coastal waters

How fast can Ocean Color change in ~ 100 minutes?

Diurnal Variability of Chlorophyll and nLw at WavCis

Oct 22, 2014 day295 Chlorophyll

VIIRS nLw validated
The diurnal changes!
Poster includes MOBY
3) Characterizing the diurnal changes in bio-optical properties in coastal waters

Summary;
1. VIIRS – Overlap products was able to capture hourly changes in ocean color!!
2. Calibration and validation in coastal areas requires short time for matchup!
3. New product capability from VIIRS! See poster!

Diurnal Changes identifies new ocean processes product. Bloom occurring!

Chlorophyll Difference
Orbit 1 minus 2

Second Pass Greater

Bloom
Decay

Frontal Movement

4) Temporal Assessment of the Calibration and Accuracy of VIIRS Radiometric (SDR) and Ocean Color Products (EDR) at MOBY and WavCIS (Aeronet-OC)

**SDR (Real time) Gains Trend @ MOBY**

**Effect of SDR Calibration Change May 2014 (Delta-c) on Vicarious Calibration Gain Sets**

Trend (unity gains) shows:
- NOAA real-time SDR improvement over time (not stabilized).
- Need continuous vicarious calibration for operations.

Effect of SDR Calibration Change May 2014 (Delta-c) on Vicarious Calibration Gain Sets

A pre and post delta-c (May 2014) calibration change exist. Needs further evaluation w/ more matchups highly constrained matchups. Evaluation at green water AERONET site (WavCIS) underway.
4) Temporal Assessment of the Calibration and Accuracy of VIIRS Radiometric (SDR) and Ocean Color Products (EDR) at MOBY and WavCIS (Aeronet-OC)

MOBY and WavCIS Time Series Analysis and SDR Calibration Effect (Delta-c May 2014)
(See poster for more results including post delta-c green water analysis at WavCIS, cruise matchups, etc.)

**VIIRS vs. MOBY Time Series – April 2012 – July 2015**

- **443nm**
  - VIIRS agrees very well with MOBY
  - Post Delta-c (May 2014) calibration gains applied after May 2014 yields more accurate nLw's (443 nm)

- **551nm**
  - Percent change (standard vs post delta-c gains) yields up to 30% differences in chlorophyll offshore and nearshore

**VIIRS Chlorophyll June 7, 2015 – Post Delta-c Calibration Effect**

- Standard Gains APS v5.8
- Post Delta-c Gains APS v6.2 - Beta

**Percent Change (PostDC– Std)/Std**

- -17%
- 16%
- -20%
- 8%

% decrease / increase in CHL
Spatially improved ocean color products are obtained by combining the 750-m \(M(\lambda)\) bands with the 375-m I1-band.

Algorithm based on covariance of each \(M(\lambda)\) band with I1-band.

For each pixel and \(\lambda\), the sharpening is weighted as a direct function of \(M(\lambda)\) covariance with the high resolution (I-1) band in a 5x5 subarray. Maps of “sharpening confidence” are created.

44 coastal matchups show that sharpened nLw have improved R-values, RMSE, and NMB!
5) Using the VIIRS I-band to enhance bio-optical monitoring of coastal waters


**Summary**

1. New product and coastal applications for VIIRS sensor in ocean color.
2. Enhance resolutions for VIIRS ocean color can be achieved by combining the I bands with the M bands.
3. New VIIRS Coastal ocean product derived at 375m for coastal waters!
4. Spatial Covariance used to spectrally weight Band sharpening.
5. Results are confirmed in coastal waters and demonstrate improved VIIRS validation.

**Sharpened (375) nLw M bands** are linked into processing to produce high resolution Ocean Color Products.

**Validation**

New VIIRS use of I BANDS.
6) Applications of VIIRS ocean color for real time adaptive sampling

Using Circulation Models and VIIRS Ocean Color to direct sampling locations in Fronts, River Plumes, and validating Ocean Models

Real time Animated VIIRS Color and models to validate coastal plumes.

Enabled Glider Deployments Adaptive Sampling.

Define Model Uncertainty

Stations for Validation of VIIRS Models

--See Poster
6) Applications of VIIRS ocean color for real time adaptive sampling

Management Decisions for Near Real-time Adaptive Sampling

STEP1: Gather data into google Earth

VIIRS Ocean Data
- Chlorophyll-a,
- backscattering,
- absorption, euphotic depth, sea surface temperature

Physical circulation models
- SST, currents, salinity,
- mixed layer depth, sea surface height

Ancillary data
- Real-time data from buoys or moorings,
- weather data,
- meteorological models (wind data)

How to optimally apply VIIRS data for sampling! “Plume”

Poster details 4 Steps on how VIIRS is used in steps for adaptive sampling!

Summary:
1. Fusing Satellite color and SST with circulation models defines uncertainty.
2. VIIRS Color data used for Model Validation
3. Glider deployment is dependent on density Requires accurate location of Plumes!
4. Adaptive sampling used to optimize samples for VIIRS validation

VIIRS ocean color provides a critical component in defining River Plumes ecosystems!

AUV Jubilee activities in Gulf

JPSS- Meeting
Summary: See 6 Posters for details.

1. VIIRS Orbital Overlaps – tracks the trends are stable
   - Validated the diurnal response – 100 minutes of VIIRS color
   - Spatial and temporal response of ocean color is required for cal val procedures.
2. Foster Cruises validated VIIRS ocean color transects
3. VIIRS cal val:
   - VIIRS real-time SDR improving over time @ MOBY
   - VIIRS/insitu matchups indicate high quality operational OC products.
   - Cal/val @ MOBY indicates a pre and post delta-c (May 2014) calibration change.
4. VIIRS new products:
   - Enhanced spatial resolution - I and M band Sharpening
   - Diurnal changes in Color -- Blooms and Currents
   - Tested the cal val protocols.
5. VIIRS color Applications for Adaptive sampling and models validation
6. WavCIS Platform – maintained and updated with calibrated Seaprism Aug. 2015!

Plans:
Cruises - a) Cal Val Foster Gulf Stream, b) Gulf of Mexico Cruise – Plumes
Monitor Diurnal Changes.
Maintain - Operational WavCIS – Aeronet
Comparisons of Optical Validation Measurements from the November 2014 VIIRS Cal/Val Cruise

**Instruments used to measure Remote Sensing Reflectance**

**Profilers**

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

**MicroPro** (Satlantic) - free-falling multispectral optical profiler. Seven spectral bands with 10 nm bandwidth centered at nominal wavelengths of 412 nm, 443 nm, 490 nm, 510 nm, 555 nm, 665 nm, and 683 nm. 18 degree FOV.

**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**

**HyperTSRB** (Satlantic) – 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.
Pre- and Post-cruise inter-calibration of Satlantic irradiance Ed sensors used in Nov. 2014 Cal/Val cruise

Ed 233

Ed 290

Ed 375

Ed 473
Pre- and Post-cruise inter-calibration of Satlantic radiance Lu sensors used in Nov. 2014 Cal/Val cruise.
Pre- and Post-cruise inter-calibration of Satlantic irradiance Es sensors used in Nov. 2014 Cal/Val cruise
November 12, 2014   Blue water validations
Date (Nov): 18th
Description: offshore shelf, Just west of Stream
Above-Water time: 1000
Surface time: 1030
Profile time: 1200
Depth (m): 103
Cloud cover (%): 15
Wind speed (kts): 10
Seas (ft.): 2-4
Chl (mg/m3) 0.24

Percent difference relative to Average

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<th>Hyperpro</th>
<th>Micropro</th>
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Date: 12
Description: Offshore, East of stream front
Above-Water time: 1435
Surface time: 1450
Profile time: 1445
Depth: 120
Cloud cover: 10
Wind speed: 10
Chl (mg/m³): 0.23

Percent difference relative to Average

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Locations of stations and track from 18 November with the VIIRS-NRL chlorophyll imagery
Date: 18
Description: Coastal, in bloom
Above-Water time: 1047
Surface time: 920
Profile time: 1005
Depth: 18
Cloud cover: 5
Wind speed: 18.5
Seas (ft.): 2-4
Chl (mg/m3): 6-8

Percent difference relative to Average

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Date: 18
Description: Coastal, in bloom near front
Above-Water time: 1315
Surface time: 1240
Profile time: 1328
Depth: 22
Cloud cover: 5
Wind speed: 15
Seas (ft.): 2-4
Chl (mg/m3): 2.2

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Date: 18
Description: Coastal, Clear side of front
Above-Water time: 1610
Surface time: 1645
Profile time: 1600
Depth: 26
Cloud cover: 35
Wind speed: 10
Seas (ft.): 2-3
Chl (mg/m3): 0.59

Percent difference relative to Average

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Locations of Stations 20, 21 and 22 on 19 November showing the transect of the shelf fronts with respect to chlorophyll image.

### Date:  19
### Description:  South of Charleston, shelf
### Above-Water time: 1026
### Surface time: 930
### Profile time: 1008
### Depth:  24
### Cloud cover: 40
### Wind speed: 10.5
### Seas (ft.): 1-2
### Chl (mg/m³)  0.54

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Date: 19
Description: South of Charleston, shelf
Above-Water time: 1301
Surface time: 1255
Profile time: 1305
Depth: 18
Cloud cover: 0
Wind speed: 9
Seas (ft.): 1
Chl (mg/m3) 0.95

Percent difference relative to Average

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Date: 19
Description: South of Charleston, shelf
Above-Water time: 1520
Surface time: 1555
Profile time: 1520
Depth: 26
Cloud cover: 0
Wind speed: 4
Seas (ft.): 1
Chl (mg/m³) 0.62

Percent difference relative to Average

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Station 23, All

Station 23, Profilers

Station 23, Surface

Station 23, Above-water

Date: 20
Description: Charleston Sea Buoy
Above-Water time: 950
Surface time: 825
Profile time: 900
Depth: 19
Cloud cover: 0
Wind speed: 16
Seas (ft.): 1-2
Chl (mg/m3): 0.5

Percent difference relative to Average

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### MSL12 VIIRS Percent difference relative to in situ (with Sta 23)

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### MSL12 VIIRS Percent difference relative to in situ without (Sta. 23)

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MSL12 VIIRS 5x5 avg vs avg of all Rrs measurements

Sta. 2 in situ average versus MSL12 VIIRS

Sta. 3 in situ average vs MSL12 VIIRS

Sta. 17 in situ average vs MSL12 VIIRS

Sta. 19 in situ average vs MSL12 VIIRS

Sta. 20 in situ average vs MSL12 VIIRS

Sta. 21 in situ average vs MSL12 VIIRS

Sta. 22 in situ average vs MSL12 VIIRS

Sta. 23 in situ average vs MSL12 VIIRS
### Chlorophyll validation for clear stations

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### Graphs:

- **Nov. 14, VIIRS Cal/Val Cruise Chl.**
- **Chlorophyll validation for clear stations**
Conclusions:

Consistency between 10 independent measurements of water leaving radiance is within 10%.

Differences between in situ measurements is most likely dominated by variability in water masses.

VIIRS matchups to in-water validation measurements are promising.
CCNY VIIRS validations at the Long Island Sound Coastal Observatory (LISCO) and on cruises, algorithm development

Sam Ahmed, Alex Gilerson
The City College of New York

Scientists: Matteo Ottaviani, Amir Ibrahim (now at GSFC)
Students: Robert Foster, Ahmed El-Habashi, Carlos Carrizo, Eder Herrera, Anna McGilloway
Outline

• Validation on the LISCO site
• Validation on SABOR and VIIRS cruises
• VIIRS algorithms development
• Radiative transfer vicarious calibration/validation
• Sky glint correction in polarization mode
Validation from Long Island Sound Coastal Observatory (LISCO)

Mult-spectral SeaPRISM instrument. Transmits data to NASA AERONET every hour.

HyperSAS-POL with polarimetric sensors. Transmits data to CCNY server every hour.
Match-up plots show fairly high correlation for 491, 551, and 668nm for all sensors. Much lower correlation is observed for violet (413nm) and blue (442nm), which is independent of the processing scheme or the sensor.
Ship-Airborne Bio-Optical Research (SABOR)
NASA Cruise  July 17- August 7, 2014

R/V Endeavor owned by NSF operated by University of Rhode Island, 185 feet, crew -12, scientists -15

NASA GISS, NASA Langley CCNY, U. of Maine, Oregon State University, Sequoia Scientific, WET Labs

CCNY team: A. Gilerson, PhD students R. Foster, C. Carrizo

Rhode Island – Bermuda – Norfolk, VA - Rhode Island

Research Scanning Polarimeter (RSP) and lidar were installed on the aircraft

Included satellite validation component
NOAA VIIRS Cal/Val Cruise, November 2014

Update on cruise report

Objectives:
- Uncertainty of products
- In-situ protocols assessments
- Characterizing the spatial uncertainty of VIIRS Products

Overall Goals

Gulf Stream Station Transects
A. Nov 12 – Stations 2 and 3
B. Nov 13 – Stations 4, 5, 6, 7
C. Nov 15 – Stations 10, 11
D. Nov 16 - Stations 12, 13, 14

Night time transect flowthrough
A. Nov 11 - 12 – West front of GS
B. Nov 12 – 13 - East front and Offshore waters
C. Nov 19-20 - 2 parallel crossings

Shelf and Coastal waters sampling
Nov 14 – Station 8.9
Nov 15 - 10, 11
Nov 18 – Station 17, 18, 19
Nov 19 – Station 20, 21, 22
Nov 20 – Station 23

Night time transects
Nov 14 – 15 – Zig zag pattern
Nov 18 – 19 - southern transects water fronts

From R. Arnone, 02/12/15

Participants: NOAA/NESDIS, NASA – Goddard, NRL, U. Southern Mississippi, U. of Massachusetts, U. of South Florida, CCNY, Columbia U., JRC (Italy)
HyperSAS-POL, Handheld spectroradiometers

HyperSAS had 2 radiometers in unpolarized mode and 4 with polarization sensitivity.

HyperSAS integration time was 2000ms for water and 128-250 ms for sky measurements, 6-4000ms for ASD and 160 ms for GER.
Remote Sensing Reflectance comparison between GER, HyperSAS, HyperPRO, MODIS and VIIRS on July 26th and on July 31st (SABOR cruise)

VIIRS and MODIS
- Grid size: 3x3
- Pixels flagged: 0%
- Flags not checked: high and moderate sun glint contamination and stray light contamination.

Several other instruments from other groups (above and below water) were deployed, comparison is in progress
Spectral Remote Sensing Reflectance comparison between GER, HyperSAS, HyperPRO, MODIS and VIIRS (VIIRS cruise)

November 12, 2014
Blue water

Station 03

November 20, 2014
Blue water
Turbid water on the way into port

Station 23

From M. Ondrusek Dec 18, 2014
Algorithm Developments - Neural Network (NN) algorithm for VIIRS KB Harmful Algal Bloom (HABS) retrievals in WFS

**Fig. 1a** Shows the Bio-Optical model and the Radiative Transfer simulations. of 20000 random IOP data sets within NOMAD prescribed ranges and resulting related Rrs values generated by Hydrologht

**Fig. 1b** Architecture of NNVIIRS, one-hidden layer multilayer perceptron (MLP) with 6 neurons at the hidden layer, trained with 10,000 set of Rrs and related IOPs, NN trained on 10,000 data sets to model relationship of Rrs values to IOPs at 443 nm
NN KB HABS retrieval comparisons site 1 on 9/2/2014-major HAB occurrence
NN KB HABS retrieval comparisons site 2 on 9/16/2014 much nearer coast
Development of Algorithms for Retrieval of Chlorophyll-a in the Chesapeake Bay and other Coastal Waters Based on JPSS-VIIRS Bands

Evaluation on the field data, Chesapeake Bay, 2013

OC3V

[[Chl]] = (35.75 * (Rrs708/Rrs665) - 19.30) * 1.124

Gilerson et al 2010 very high data consistency; no 708nm band on VIIRS

Algorithms which include 745nm band

\[ \text{chl1} = 10^{(a1 + a2 \cdot \frac{Rrs488}{Rrs550} + a3 \cdot \frac{Rrs671}{Rrs745})} \]

Similar results \[ \text{chl2} = ((2.459 \cdot t1 \cdot \frac{Rrs745}{Rrs671} - 0.439 + t2)/(0.022))^1.124 \]
Performance of the algorithms based on the satellite data

Evaluation on the satellite data VIIRS 2012-15, strict filtering, matchups with the in situ data of the Chesapeake Bay Program

OC3V

\[ \text{chl1} = 10^{(a1 + a2 \frac{\text{Rrs488}}{\text{Rrs550}} + a3 \frac{\text{Rrs671}}{\text{Rrs745}})} \]

\[ \text{chl2} = \frac{(2.459 \times (t1 \frac{\text{Rrs745}}{\text{Rrs671}}) - 0.439 + t2)}{0.022} \] \times 1.124

- Relatively good performance of OC3V on VIIRS in comparison with MODIS probably due to the better VIIRS spatial resolution.
- Algorithms based on 745nm band show performance similar to OC3V. That means that statistics of retrieval is determined by the spatial and temporal characteristics of matchups.
A Radiometric Approach for Calibration of Current and Future Ocean Color Satellite Sensors using AERONET-OC data

- To demonstrate a Radiative Transfer (RT) based radiometric vicarious calibration methodology for current and future satellite OC sensors.

- We envision our methodology as being capable of carrying out OC sensor validation of SDR independently of the atmospheric correction process.

Optics Express, 2014
RT-satellite matchups and estimated gain factors

Estimated gain factors based on WaveCIS, Venise and USC
Scalar Sky Glint Correction Methods

For scalar reflectance:

$$\overline{Rrs} = \frac{(\overline{I}_t - \rho \cdot \overline{I}_s)}{\overline{E}_d}$$

$$\rho$$ estimates how much incident light is reflected from the surface.

$$\rho = f \left( \theta_s, \phi_s, \theta_v, \phi_v, n(\lambda), \Omega_{\text{FOV}}, \text{windspeed}, \text{sky illumination} \right)$$

C. Mobley, Appl. Optics, 1999

How do we estimate polarized Remote Sensing Reflectance?

How much polarized light is reflected from a sea surface?
Stokes Vector Rotation

\[
\vec{R}_s(\theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(2\theta) & -\sin(2\theta) & 0 \\ 0 & \sin(2\theta) & \cos(2\theta) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}
\]

polarized \( \rho \)

\[
\vec{S}_{Refr} = [\vec{R}_s(\beta) \cdot \vec{F} \cdot \vec{R}_s(\alpha)] \cdot \vec{S}_{Sky}
\]

Fresnel matrix for facet.

Effective Fresnel Matrices (\( \rho \)) For Glint Correction

vs. Detector Zenith, 440 nm, 40° Solar Zenith, 90° relative azimuth

Reflection of light from surface

Transmission from below to above
Comparison with Underwater Polarimeter

16:37 UTC, July 30th, 2014.
80 km South-East of Norfolk, VA.
Evaluation of VIIRS performance over coastal waters and its capacity to detect dark water and harmful algal blooms

Chuanmin Hu, Lin Qi, Jennifer Cannizzaro, David English, Brian Barnes, and Alina A Corcoran

Univ. South Florida, huc@usf.edu

NOAA JPSS/VIIRS Team Meeting, August 24 – 28, 2015
Objectives

- Evaluate/Validate VIIRS ocean color data products
- Demonstrate VIIRS capacity in studying coastal oceans (water quality, harmful algal blooms, oil spills)
- Share data and results with community to advance science and mission planning

How?

- Field measurements following community-accepted protocols
- Satellite data analysis and comparison with field measurements
- Communication with science team and the community
- Technical reports and publications
Field Measurements
Conducted by USF Optical Oceanography Lab in collaboration with other groups.
All measurements have filter-pads absorptions and CDOM absorptions. Most measurements also have scattering and reflectance IOPs. Some have taxonomy and profiling data.
Field Measurements

An example from the DEEPEND02 cruise (Aug 8 – 22, 2015)

MODIS 5-day composite ending Aug 12, overlaid with cruise stations and glider track to Aug 12

MODIS 3-day composite showing glider track up to Aug 18
Field Measurements

Protocols follow community standards to assure high quality

Southwest Florida Shelf (Feb. 2012) (n=57)

\[ y = 1.0257x^{1.0776} \]

\[ R^2 = 0.9831 \]

Old Tampa Bay (Jun.-Dec. 2013) (n=166)

\[ y = 0.9957x^{0.987} \]

\[ R^2 = 0.9655 \]
VIIRS data processing

Three data sources

- IDPS processing – during early stage of validation
- NOAA/NESDIS MSL12 processing – limited availability
- NASA/GSFC L2GEN processing – for cross-sensor comparison
VIIRS data product evaluation

Evaluation during initial phase (IDPS processing)

N = 80

VIIRS IDPS WFS 2012 - 2013
Data downloaded in November 2013

QF Flags not applied

QF Flags applied
VIIRS over dark water and HABs

Demonstration of difficiency and temporal solution
VIIRS over dark water and HABs
Most pixels agree well between MODIS and VIIRS, for all bands

(a) VIIRS $R_{\text{vis}}(443)$ vs. MODIS $R_{\text{vis}}(443)$
- $R^2 = 0.89$
- Slope = 0.960
- Intercept = 0.00014
- URMS = 24.7%
- Mean ratio = 0.998

(b) VIIRS $R_{\text{vis}}(488)$ vs. MODIS $R_{\text{vis}}(488)$
- $R^2 = 0.94$
- Slope = 0.926
- Intercept = 0.00030
- URMS = 15.7%
- Mean ratio = 1.008

(c) VIIRS $R_{\text{vis}}(551)$ vs. MODIS $R_{\text{vis}}(547)$
- $R^2 = 0.97$
- Slope = 0.883
- Intercept = 0.00012
- URMS = 15.7%
- Mean ratio = 0.922

(d) VIIRS $R_{\text{vis}}(671)$ vs. MODIS $R_{\text{vis}}(667)$
- $R^2 = 0.94$
- Slope = 0.825
- Intercept = 0.00008
- URMS = 32.2%
- Mean ratio = 0.960
VIIRS over dark water and HABs

However, bloom patterns can only be revealed by MODIS FLH (Hu et al., 2015)

FWC has been using MODIS FLH to track HABs in near real-time for years
VIIRS over dark water and HABs
A Red-Green-Chlorophyll-Index (RGCI) performs better than OC3
VIIRS over dark water and HABs

VIIRS RGCI reveals similar patterns as MODIS FLH (Qi et al., in press)
VIIRS over dark water and HABs

Why? CDOM dominates light absorption in the blue so blue bands cannot be used. VIIRS red band (662 – 682 nm) encompasses the MODIS red band (662 – 672) and FLH band (672 – 682).
RGCI for other coastal regions?

Test over the South Atlantic Bight using NOAA/VIIRS Nov 2014 cruise data

23 stations in total, each with about 3 depths measured. Only 6 found same day (± 12 hours) VIIRS data.
**RGCI for other coastal regions?**

Test over the South Atlantic Bight using NOAA/VIIRS Nov 2014 cruise data

RGCI is not applicable in very low (< 0.2) or very high (> 10) chl waters

These results were derived from NOAA MSL12 processing
Cross-sensor comparison

SeaWiFS, MODIS, VIIRS products as a function of viewing angle, Gulf of Mexico

From Barnes and Hu (submitted, also see poster)
Summary

- Collected, processed, and shared field data through several dedicated cruises and cruises of opportunity
- Evaluated of VIIRS data from different processings (IDPS, NASA GSFC, NOAA MSL12)
- Demonstrated VIIRS capacity in detecting and monitoring dark water and HAB events

Publications


Barnes, B. B., and C. Hu (submitted). Dependence of satellite ocean color data products on viewing angles: A comparison between SeaWiFS, MODIS, and VIIRS. RSE.

What’s Next?

- Continue field and laboratory experiments to support VIIRS cal/val and science applications
  - Finish processing data from past cruises
  - Participate in new cruises

- Continue evaluation of VIIRS products, especially from MSL12 processing
  - Use data collected by the Cal/Val team
  - Extend to data collected by other groups

- Improve algorithms and data products to have better absolute accuracy and relative consistency
  - Biooptical properties
  - Blooms and other image features

- Publish results in journal articles and promote VIIRS II
Backup slide: relax to 12-day matchup instead of 1-day matchup for SAB cruise
Towards consistent VIIRS AOP and IOP products

ZhongPing Lee, JunFang Lin, JianWei Wei, Lin Qi

University of Massachusetts Boston
UMB activities:

1. Evaluation of VIIRS Rrs products
   1a. Compare VIIRS Rrs with climatological Rrs of gyre waters
   1b. Compare VIIRS Rrs with in situ measurements
   1c. Compare VIIRS Rrs with concurrent MODIS Rrs
   1d. Compare Rrs from fixed platform

2. Measurement and processing of in situ IOPs
   2a. Participate NOAA Cal/Val cruise
   2b. Scattering correction of the ac-s system

3. Application of in situ measurements
   Hyperspectral absorption coefficient of “pure” seawater derived from in situ Rrs
1a. Compare VIIRS Rrs with climatological Rrs of gyre waters

**Location:** South Pacific Gyre (SPG) and North Atlantic Gyre (NAG)

**Data:** VIIRS (from CLASS), 5/2013-2/2014
- MODIS_Aqua (from OBPG; daily-climatology)
  - all are area average

<table>
<thead>
<tr>
<th>Band characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VIIRS</strong></td>
</tr>
<tr>
<td>M1</td>
</tr>
<tr>
<td>M2</td>
</tr>
<tr>
<td>M3</td>
</tr>
<tr>
<td>M4</td>
</tr>
</tbody>
</table>
South Pacific Gyre (SPG)

Ocean color comparisons between CoastWatch <1-year data and MODIS Aqua 10-year climatology

8-day climatology

8-day moving average

Note the wave difference: 547 vs 555 nm
North Atlantic Gyre (NAG)
Ocean color comparisons between CoastWatch <1-year data and MODIS Aqua 10-year climatology

CoastWatch VIIRS Rrs at subtropic gyres are generally consistent with MODIS-A climatology; but occasionally display unexpected values.
1b. Compare VIIRS Rrs with in situ measurements
SBA-VIIRS Data Comparison

VIIRS data was averaged over 9 pixels.
Caribbean Sea (Puerto Rico) Experiments
Dec-13-2014

20141213, VIIRS overpass at 17:00pm
Clear sky; 1.5 m waves;
Time difference: ~1 hrs

6 miles from the shore
Comparison of in-situ Rrs, CLASS VIIRS and CoastWatch VIIRS products

CoastWatch VIIRS products show much better results in this region.
The VIIRS ocean color EDR data is used as is, without further quality control. (Considering ATMWARN flag, all data in Massachusetts Bay can be questionable)
Rrs spectra comparison

STA1

STA2

STA3

STA4
CLASS VIIRS products VS in situ measurements

VIIRS EDR data [sr\(^{-1}\)] vs SBA measurements [sr\(^{-1}\)]

Rrs

a

ACS [m\(^{-1}\)]

bb

CLASS VIIRS EDR [m\(^{-1}\)] vs BB7 [m\(^{-1}\)]
1c. Compare VIIRS Rrs with concurrent MODIS Rrs
1c. Compare VIIRS Rrs with concurrent MODIS Rrs

MSL12 VIIRS
07/25/2015
18:47 (GMT)

GSFC MODISA
07/25/2015
18:25 (GMT)
1d. Compare Rrs from fixed platform
### 2a. Participate NOAA Cal/Val cruise


<table>
<thead>
<tr>
<th>VIRRS</th>
<th>Days</th>
<th>ACSs</th>
<th>BB9</th>
<th>SBA</th>
<th>Spectral Evolution (SR1900)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>10</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>11</td>
</tr>
</tbody>
</table>

**ECOA Cruise Leg1 (6/17/2015 - 7/3/2015)**

<table>
<thead>
<tr>
<th>ECOA</th>
<th>Days</th>
<th>ACS</th>
<th>HS6</th>
<th>Hyper-Pro</th>
<th>ASD</th>
<th>Micro-TOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>17</td>
<td>26</td>
<td>26</td>
<td>20</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>
Station 21

VIIRS Rrs

SBA Rrs

$\Delta h \approx 1 \text{ h}$

Station 23

VIIRS Rrs

SBA Rrs

$\Delta h \approx 4 \text{ h}$
A value of ~0.18 has been suggested for $\varepsilon$ when sediments dominate the scattering (Kirk, 1993).
3. Application of in situ measurements

Hyperspectral absorption coefficient of “pure” seawater derived from in situ Rrs

Plan of FY15

Continue ...

1a. Compare VIIRS Rrs with climatological Rrs of gyre waters

1b. Compare VIIRS Rrs with concurrent MODIS Rrs

1c. Compare VIIRS Rrs with in situ measurements (Puerto Rico, Mass Bay, other opportunities)

2a. Participate NOAA Cal/Val cruise to collect AOP/IOP
Acknowledgements:

NOAA/STAR
Thank you!
"Present Status of MOBY and MOBY-Refresh"

Kenneth Voss, Physics Dept., Univ of Miami

Collaborators: Carol Johnson (NIST), Mark Yarbrough (and others at MLML), Art Gleason (UM), Yong Sung Kim and Paul DiGiacomo (NOAA/NESDIS/STAR)

8/15, STAR JPSS 2015 annual meeting, College Park, Md.
The current MOBY site is off of Lanai, Hawaii.

Tent constructed on UHMC site

Ships available
Currently have a 17 yr + time series

Primary ocean color vicarious calibration site for VIIRS.
Current status

• Next deployment will be in mid September.
• Currently an issue with top battery in MOBY dating back to mid August.
• Trying to get out to fix, but there are currently 3 hurricanes in the vicinity of the Hawaiian islands (they are up to the letter “I” out there)...so going out to fix the instrument has been an issue. Maybe fixed yesterday (Wednesday).
Instruments are getting old, so we are now in the middle of a “refresh” of the optical system and onboard control system.

Changes include upgraded and new control computers and new optical system.
In-line Volume Phase Holographic grating

From
http://www.bayspec.com/technical-support/definitions/vpg/
Currently testing Blue spectrometer and components of new system

Wavelength calibration...approximately 0.3 nm/pixel
Currently testing Blue spectrometer and components of new system

Zoom in on the 450 nm data, shows good stray light characteristics, and a Full Width at Half Maximum of approx. 1 nm.
Preliminary results from the blue spectrometer prototype

White light illumination

Showing spatial resolution

We will be doing spectral resolution, stray light analysis on the system in Hawaii.
Some data showing more detail on cross track imaging
Testing new components to be used in new system, such as a fiber optic splitter instead of dichroic beam splitter:

Splitting ratio could be effected by how the light is put into the fiber at the collector. We tested by varying the incident angle of light on the cosine collector (worse case), no change in ratio. Tests also help us learn more about the spectrometer systems operating parameters as we go along.
In the process we are cleaning up other issues we find with MOBY: slight polarization sensitivity

Before, +-3% (effectively 1.0% in field)

NOTE: SCALE CHANGE, LEFT +-4%
Bottom +-0.8%

After, no polarization dependence evident signal within +- 0.2%, no cos(2*theta) dependence.
Refresh schedule

• The September deployment will have the new controller.

• We are working towards having the first deployment of the Blue spectroradiometer on the January deployment (along side the current system). We are aiming for at least a one year cross over experiment.

• We have been able to order the long lead time items for the red spectrometer.

• We expect that we will be able to start ordering the rest of the parts needed for complete refresh in late spring 2016.

• The goal is to be completely done with Refresh by Sept 2018.
To evaluate VIIRS Ocean color products we compare them with *in situ* data and other satellite data. Examples using data from the Ocean Color AERONET site `Platform Eureka,’ in the Southern California Bight, and cruises as part of the Hawaiian Ocean Time Series (HOT).

**Data Sources:**

**VIIRS data sources:**
- NASA VIIRS
- NOAA STAR VIIRS (MSL12)
- NOAA CLASS

**In situ**
- HyperPRO (Hawaii from OSU)
- SeaPRISM (Platform Eureka from NASA Ocean Color AERONET)
- HyperPRO and above water Rrs with Spectral Evolution PSR-1100

**Satellite**
- MODIS-AQUA (from NASA Ocean Color Website)
- Landsat-8
Above and in-water light field measurements are routinely made at Station ALOHA, 100 km north of Oahu, Hawaii (22.75 °N, -158.00 °E) as part of the Hawaiian Ocean Time Series (HOT) program. Spectral matches at Station ALOHA of VIIRS data with HyperPRO cruise data collected one minute apart (23:43 and 23:44 GMT).

VIIRS image over Hawaii from 17 August 2012 (23:43 GMT). The star marks Station ALOHA.
Use of the SeaPRISM hourly optical data at the Ocean Color AERONET site ‘Platform Eureka’ aboard an oil platform in the Southern California Bight.

Spectral matchups at Platform Eureka between the in situ data (blue), HICO hyperspectral measurements (red), and VIIRS measurements (green). Data are from September 6, 2012.
Above and in water validations
Cruise October 2014

Spectral Evolution above water Spectral Reflectance with fiber optic.

SKY Measurement

WATER Measurement

Reflectance REFERENCE Measurement

Example SPECTRA

Satlantic HyperPRO in water Spectrometer
**Spectral Evolution PSR-1100**
Using ‘empirical’ correction (0.75) to get matches for new instrument.

Current Processing with HyperPro showing good correlations.
Landsat and VIIRS OC3 on 7 October 2014

Landsat OC3: 18:28 GMT (11:28 PDT)

VIIRS OC3: 21:26 GMT (01:26 PDT); Landsat +2HRs

Linear Scale from 0 - 3 mg/L. Each image, though, has been individually contrasted adjusted to try to highlight features. Water was very clear this day.
Monitoring coastal ‘Mesoscale’ events

Monitoring Coastal Blooms during March

2015-03-01 21:04
Time series of chlorophyll-a data from VIIRS shows Bloom/Eddie passing by Platform Eureka during March 6-8, 2015.
Example Time Series and Regressions: Jan-March 2015
Chlorophyll Time Series 2015 at Platform Eureka

**eureka Chlorophyll (box size 3x3)**

- **SeaPRISM 1.5**
- **NOAA CLASS VIIRS**
- **NASA VIIRS**
- **NOAA STAR VIIRS**

**eureka NASA VIIRS - SEAPRISM CHL Matches**

- **Window Time (hrs): 3**
- **Box size: 3x3**
- **High Chlorophyll Cut Off: 3 mg m⁻³**
- **Number of matches: 106**
- **Slope: 0.8351**
- **RMSE: 0.1278**

**eureka VIIRS NOAA STAR - SEAPRISM CHL Matches**

- **Window Time (hrs): 2**
- **Box size: 3x3**
- **High Chlorophyll Cut Off: 3 mg m⁻³**
- **Number of matches: 73**
- **Slope: 0.84127**
- **RMSE: 0.1062**

**eureka VIIRS NOAA STAR - SEAPRISM CHL Matches**

- **Window Time (hrs): 2**
- **Box size: 3x3**
- **High Chlorophyll Cut Off: 3 mg m⁻³**
- **Number of matches: 8**
- **Slope: 1.0456**
- **RMSE: 0.027781**
Platform Eureka Data Collection

Challenges

Platform Eureka SeaPRISM site is excellent and data is key for our work, however:

- Data flow has been intermittent; *New radio system installed.*
- Calibration issues: *Installed TWO SeaPRISMSs to cross-check.*
- Some NOAA STAR (MSL12) swaths not processed: *Will be picked up on reprocessing.*
- Protocols/Processing for New Spectrometer

---

Example Data Gaps in MSL12: Year 2013

<table>
<thead>
<tr>
<th>Date Range</th>
<th>File Names</th>
</tr>
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<tbody>
<tr>
<td>Days 131-138, 140-146</td>
<td>VRSVCH.B2015028.001735.nc</td>
</tr>
<tr>
<td>Days 139, 147, 148</td>
<td>VRSVCH.B2015028.002026.nc, VRSVCH.B2015028.002151.nc, VRSVCH.B2015028.002317.nc</td>
</tr>
<tr>
<td>Days 149</td>
<td>VRSVCH.B2015028.002442.nc, VRSVCH.B2015028.002858.nc</td>
</tr>
<tr>
<td>Day 028</td>
<td>VRSVCH.B2015028.120851.nc (Day 028 is missing some granules)</td>
</tr>
</tbody>
</table>

NOAA STAR (MSL12) Data Catalog

http://www.star.nesdis.noaa.gov/thredds/catalog/swathNPPVIIRSL2WW00/2015/catalog.html
Experimental Products

Research and development using ‘optical flow’ to interpolate and (short time) extrapolation of product fields — helps us to track ‘mesoscale’ events.

Steps:

1. **Destriping** building on NOAA’s* variational methods
   - added optimization over spectra and time
   - automating optimization (does not require user to pick threshold)
   - ‘in-painting’ experiments to handle lost data due to cloud cover

2. Image sequence ‘**equalization**’
   - this is integrated into the destriping step

3. ‘**Optical flow**’: variational functional is used to estimate **vector fields**
   - integration providing a dynamic model of the product fields evolution

**Destriping References**

Erik Boltt and Ranil Basnayake, Clarkson University
Theory/numerics is part of NGA funded project to Clarkson University:
NGA 2013-15: *Impacts of Remote Multi-Attribute Spatiotemporal Dynamical Systems Analysis*, Erik Boltt, Clarkson University, PI.


Example of Striping in VIIRS Image

- Subsampled image near the Santa Monica region in Southern California on November 6th.
Example of destriping in VIIRS Image

- Subsampled image near the Santa Monica region in Southern California on November 6th
Example of a Destriped NASA image
(*.nc from NASA Ocean Color Site; NASA uses a vicarious destriping method based on a historic image and calibration database for VIIRS)
Example of a destriped image by applying two steps: First, Vicarious destriping from NASA; Second, a ‘Variational’ scene based destriping.
Optical Flow Example:
Chlorophyll flow map around Catalina and Platform Eureka,
Work in progress

References:
E. Boltt, N. Tufillaro, R. Basnayake, J. Sin, and M. Gierach, Variational destriping on ocean color products with a simple numerical scheme, draft 2015.

Plans for July 2015-June 2016

- Participate in and present results at NOAA telecons and the NOAA STAR/JPSS Annual Meeting in August 2015.
- Participate in NOAA VIIRS science cruise for cross calibration of instruments and methods for:
  - Above Water Rrs
  - HyperPRO optical profiles
- Analysis of a two-year time series of NOAA STAR and NASA VIIRS data products at Platform Eureka.
- Publication on the Platform Eureka time series including comparisons with other SeaPRISM sites.
- Publication of statistical comparison of destriping methods on accuracy of final ocean color product fields.
- Research application of optical flow for dynamic ocean color product flow maps
USC SeaPRISM

Burt Jones and Matthew Ragan
STAR/JPSS
27 August 2015
ACCOMPLISHMENTS

-Performed CAL/VAL Cruise with OSU

-Updated Communications at Platform Eureka and Santa Catalina Island

-Installed Second CIMEL Sun Photometer for Data Comparison/Validation
SIGNIFICANCE

- Urban Coastal Site:
  - located off the shelf
  - deep water (~200m)
  - easily accessible

- Range of Different Characteristic Waters:
  - urban runoff
  - coastal upwelling
  - offshore oligotrophic
SIGNIFICANCE

- Located in an Area of Important:
  - economic
  - societal
  - ecological

- Only Site in Eastern Pacific
RESULTS

- Fewer data interruptions with updated communications and new computer
- Collected in-situ measurements with OSU
- Analysis of data presented by OSU
Calibration Support for VIIRS Ocean Earth Data Records Products by NIST

Carol Johnson
Sensor Science Division, NIST
August 27, 2015
cjohnson@nist.gov
SeaPRISM080 is part of AERONET-OC

VIIRS measures the Earth for routine data collection

VIIRS measures the Moon – for mission drift corrections

MOBY provides the in situ $L_w(\lambda)$ for vicarious calibration
https://moby.mlml.calstate.edu/

AERONET-OC: serves as a global validation network

aeronet.gsfc.nasa.gov/new_web/ocean_levels_versions.html

Image Credit: SeaWiFS Project, NASA/GSFC, and GeoEye (oceancolor.gsfc.nasa.gov)
The agreement between GSFC and JRC for 080 for the radiance calibration is within +/- 1%. We wanted to know how these source-based calibration coefficients compared to SIRCUS.
GSFC provided spectral responsivities derived from the vendor-supplied filter transmittance data. We wanted to compare these to the system level radiance responsivities measured on SIRCUS. Inaccuracies will impact the GSFC or JRC broadband calibration factors and the derived ocean color products.
SeaPRISM at the Gustaf Dalen Lighthouse Tower in the northern Baltic. Credit: G. Zibordi, Joint Research Centre, Italy

SeaPRISMs operate autonomously. For SIRCUS, we needed to control the foreoptic selection, filter selection, and gain using RS232 interface and the instrument’s command set.
SeaPRISM Program vs RS232 Commands

Normalized by the SIRCUS sphere monitor photodiode, SeaPRISM signals from 364k DN to 1.2k DN demonstrated a 20% nonlinearity – something never observed during GSFC or JRC characterizations.

SIRCUS laser blocked gave an offset; laser open gave signals that decreased to zero and then increased; hence nets were negative – not physical behavior. The PRS mode on a broadband source gave 0 DN with the source blocked.

Correction Model

• What if
  – There is an internal offset $B_{\text{int}}$, a positive value in units of DN, that is always subtracted prior to outputting the measurement result; and
  – if the result of this internal subtraction is negative, the sign is reversed so that only positive values are output.

• Identifying $S_{\text{closed}}$ with $B_{\text{int}}$ allowed us to correct the SIRCUS data
Ambiguity Exists for Low DN Output

The ambiguity affects the spectral characterization: example: $B_{\text{int}} = 138$ DN, then an output of 2 DN means the signal was either 140 DN or 136 DN due to the internal subtraction and sign reversal. The relative error depends on the signal level – worse case is for zero or $2B_{\text{int}}$. This limits the dynamic range, and measurements of the out-of-band at the system level are not possible.
Corrected Linearity

Apparent 20% at a laser wavelength of 868 nm for the 870 band is actually ±0.1%
Calibration Factor Comparison

The uncertainties are estimates for the GSFC or JRC calibration factors. A wavelength shift has been included for clarity. The agreement is excellent.
Question: Can we develop a faux reflectance target that mimics the water’s spectral distribution, is Lambertian, and stable in time? Then, how well do all radiometers on a cruise agree with the faux target?

Prototype: ground blue glass, used in Long Island Workshop and Nov 2014 Nancy Foster cruise
The NIST STARR facility measured the blue tile before and after the Nov 2014 cruise. The results agree within the uncertainties, so we can say the tile was stable. The largest uncertainty component is from the lack of spatial uniformity.
Validation for NESDIS/STAR Lab

Is being modeled after the MOBY validation program (Jan 2015 most recent trip), except we will bring the sources to NIST’s RSL facility.

Cal Van, MOBY facility - radiance

Tent, MOBY facility – irradiance NIST (top), MOBY (bottom)
Upcoming Work

• Measure SeaPRISM representative filters for out-of-band (component level test)
• Finish SeaPRISM080 archival paper (90% complete)
• Report on blue tile results for Nov cruise
• Continue investigation of best choice for colored “faux water” reflectance standards
• NESDIS/STAR irradiance and radiance source validation at NIST
• Colored radiance source for cruise validation at NESDIS
Community composition, biomass and photosynthetic competency of phytoplankton associated with microscale features and frontal zones of the Gulf Stream

Christy Jenkins, Joaquim I. Goes, Helga do R. Gomes, Alex Chekalyuk

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

Robert A. Arnone

THE UNIVERSITY OF SOUTHERN MISSISSIPPI
BROAD OBJECTIVES

Examine the distribution and photo-physiology of phytoplankton functional types (PFTs) associated with microscale features and frontal zones 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, sPSII)
- Satlantic FIRe (Chl a, Fv/Fm, sPSII, Electron Transport Reactions)
- FlowCAM (Phytoplankton imaging, taxonomy and size classification)
- Phycobilipigment estimates in seawater
R/V Nancy Foster cruise track overlaid on VIIRS Chl data binned for the 1st week of Nov. 2014
Flow through set up
Distribution of CDOM, Chl a, variable fluorescence and σPSII along the cruise track as measured with the flow through system.
Distribution of biomass of PFTs along cruise track measured by bbe Molaedankanke
Distribution of major PFTs along the cruise track using FlowCAM
Distribution of CDOM, temperature and salinity along the cruise track
Distribution of Chl a (measured by three different instruments) temperature along the cruise track
Variations in major PFTs with temperature along the cruise track (measured by bbe)
Variations in major phycobilipigment containing PFTs with temperature along the cruise track (measured by bbe)
Variations in diatom biomass and photosynthetic competency of phytoplankton populations
T-S plots showing CDOM concentrations and total Chl a associated with different water types
Blue water cyanobacteria

Coastal water cyanobacteria

Cryptophytes

T-S plots showing PFTs associated with different water types
Green Algae
Cryptophytes
Diatoms

T-S plots showing PFTs associated with different water types
T-S plots showing photosynthetic performance of PFTs different water types
Cruise track showing N-S section from which seawater samples were drawn from different depths
Comparison of MODIS-A and VIIRS derived Chl a with in-situ Chl a along the cruise track.
FUTURE PLANS

• Development of PFT and phytoplankton size distribution algorithms using a combination of in-situ optical and hydrography measurements

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

• Estimation of primary productivity using measurements of phytoplankton biomass and photo-physiology
THANK YOU
An experimental evaluation of sea surface reflectance factors relevant to AERONET-OC above-water radiometry

Giuseppe Zibordi

Institute for Environment and Sustainability
AERONET - Ocean Color is a sub-network of the Aerosol Robotic Network (AERONET), supporting ocean color validation activities with highly consistent time-series of $L_W(\lambda)$ & $\tau_a(\lambda)$.

- NASA manages the network infrastructure (i.e., handles the instruments calibration and, data collection, processing and distribution within AERONET).
- JRC has the scientific responsibility of the processing algorithms and performs the quality assurance of data products (in addition to the management of 5 out of 15 sites).
- PIs establish and maintain individual AERONET-OC sites.

Application of GLR AERONET-OC $L_{WN}$ to VIIRS data products validation

Above-Water Radiometry

\[
E_s(\lambda, \theta_0, \phi_0) \quad L_s(\lambda, \theta', \varphi) \quad E_s(\lambda, \theta_0, \phi_0) \quad L_s(\lambda, \theta', \varphi)
\]

Side view \quad Top view

\[\theta, \theta', \varphi, \nu, \lambda, \phi, \varphi_0\]

Sky-radiance: \(L_i\) \quad Sea-radiance: \(L_T\)

**Removal of sky-glint contribution**

\[
L_W(\varphi, \theta, \lambda) = L_T(\varphi, \theta, \lambda) + \rho(\varphi, \theta, \theta_0, W)L_i(\varphi, \theta', \lambda)
\]

with \(L_T\) and \(L_i\) passing strict QA/QC tests, and \(L_T\) determined from the mean of relative minima

**Correction for off-nadir view**

\[
L_W(\lambda) = L_W(\varphi, \theta, \lambda)C_{\lambda Q}(\lambda, \theta, \varphi, \theta_0, \tau_a, IOP, W)
\]

**Transformation to exact normalized water-leaving radiance**

\[
L_{WN}(\lambda) = L_W(\lambda)(D^2t_d(\lambda)\cos\theta_0)^{-1}C_{f/Q}(\lambda, \theta_0, \tau_a, IOP)
\]

Values of $\rho^U$ and $\rho^P$ for the AERONET-OC measurement geometry

**Unpolarized case**
Rayleigh sky
Cox-Munk surfaces


**Polarized case**
Rayleigh sky
FFT surfaces

Matchup spectra and measurement conditions

From above-water (AERONET-OC)

From in-water profiling

Acqua Alta Oceanographic Tower
Distributions of $\rho^U$ and $\rho^P$ for matchups

(a) $\rho^U$ vs. Sun Zenith

(b) $\rho^P$ vs. Sun Zenith

AAOT

N=185

m = 2.6

$\sigma$ = 0.1

N=185

m = 2.6

$\sigma$ = 0.5
Assessment AERONET-OC $L_W$ from $\rho^U$
Assessment AERONET-OC $L_W$ from $\rho^p$
Conclusions

The experimental assessment of the sea surface reflectance factors $\rho^U$ and $\rho^P$ (proposed by C. Mobley on 1999 and 2015, respectively) applied for the generation of AERONET-OC $L_W$ data, beyond

a. limitations due to a restricted range of measurement conditions (e.g., low wind speeds which are however an intrinsic feature of AERONET-OC data products),

b. constrains (but also advantages) due to the applied technology and measurement methodology,

c. and the strict QA/QC criteria embedded in the AERONET-OC processing scheme designed to ensure the highest accuracy to data products at the expenses of their number:

1. indicates a generic better performance of $\rho^U$ factors;

2. but it also indicates that most appropriate sea surface reflectance factors would vary between the ideal values of $\rho^U$ and $\rho^P$, likely because of depolarization effects not accounted for in the computation of $\rho^P$ (e.g., like those due to aerosols).

The previous findings do not presently suggest to revert the use of current $\rho^U$ to $\rho^P$ factors, nor any significant revision of the uncertainty budget for AERONET-OC data products determined with wind speed tentatively lower than 5 m s$^{-1}$. 
Incorporating Ocean Color Remote Sensing in Ecosystem Based Fisheries Management

Kimberly Hyde & Michael Fogarty
NOAA/NMFS/NEFSC

STAR JPSS Annual Science Team Meeting
Ecosystem Based Management

- Within NOAA there is a strong focus on Integrated Ecosystem Assessments and Ecosystem-Based Approaches to Management, with an increasing emphasis on ecological forecasting.

- There is also an emphasis to monitor changes in the oceans and how climate changes impact phytoplankton species composition and the marine food web.

- In this context, there is a need for accurate, timely, consistent and fit for purpose ocean color data/products to support NOAA (NMFS, NOS, OAR) and related users with ongoing coastal, ocean and inland water applications, especially fisheries and broader living marine resource management.
Ocean color remote sensing

- Documenting, monitoring and forecasting the response of marine ecosystems to environmental variability and climate change
- Assessing biodiversity
- Biogeochemical cycling
- Connections between seasonal blooms (phenology) and recruitment
- Examining variations in functional groups/size class abundance and distribution patterns (temporally and spatially)
- Food-web structure and secondary/tertiary production
Ecosystem Production Potential

Goal: Use a **bottom-up** approach to determine fisheries production potential and exploitation for various ecosystem components.

- Benthos
- Benthivores
- Planktivores
- Piscivores

Question: How efficiently is primary production transferred to higher trophic levels?
Ecosystem Production Potential - Historical

\[ EPP = PP \cdot T^{TL-1} \]

Where \( EPP \) is Ecosystem Production Potential, \( T \) is the ecological transfer efficiency, \( TL \) is the mean trophic level of the catch.

Historically, an exploitation rate of 50% was assumed to be sustainable.

(Pauly, 1995 – Fisheries Research)
Ecosystem Production Potential - Model

\[ P_i = T \cdot P_j + A_i - F_i \]

Where \( P_i \) is Production at the \( i^{th} \) node, \( T \) is the matrix of ecological transfer efficiencies, \( A_i \) is a vector of external inputs to the \( i^{th} \) node, and \( F_i \) is a vector of losses from the \( i^{th} \) node.
Ecosystem Production Potential - Model

Proposed Ecosystem Limit Reference Point:

The total Exploitation Rate should not exceed the fraction of Microplankton Production in the System.
Proposed Ecosystem Limit Reference Point:

The total Exploitation Rate should not exceed the fraction of Microplankton Production in the System.

Use ocean color remote sensing to estimate the fraction of Microplankton Production.
Phytoplankton size classes

Pan et al. 2008 & 2010
Phytoplankton size classes

JANUARY

TOTAL

MICROPLANKTON

NANO + PICOPLANKTON

Chlorophyll $a$ (mg m$^{-3}$)

Pan et al. 2008 & 2010
Phytoplankton size classes
Size Fractionated Primary Production
Size Fractionated Primary Production

TOTAL

MICROPLANKTON

NANO + PICOPLANKTON

Chlorophyll a (mg m$^{-3}$)

Percent Microplankton (%)

Percent Nano+Picoplankton (%)
Size Fractionated Primary Production

TOTAL

MICROPLANKTON

NANO + PICOPLANKTON

Primary Production (gC m\(^{-2}\) d\(^{-1}\))

Percent Microplankton (%)

Percent Nano + Picoplankton (%)

NOAA FISHERIES
Size Fractionated Primary Production

TOTAL

MICROPLANKTON

NANO + PICOPLANKTON

Primary Production (gC m\(^{-2}\) d\(^{-1}\))

.01

.1

1

10
Size Fractionated Primary Production

**JANUARY**

**TOTAL**

**MICROPLANKTON**

**NANO + PICOPLANKTON**

**Primary Production (gC m^{-2} d^{-1})**

![Image of geographical distribution of primary production for different size fractions in January.](image-url)
Size Fractionated Primary Production
Ecosystem Production Potential - Model

Upper Trophic Levels

- Planktivores
  - MesoZooplankton
    - MicroZooplankton
      - Nano/picoplankton
      - Nanoflagellates
        - Bacteria
    - Microplankton
      - Suspension-Feeding Benthos
      - Deposit-Feeding Benthos
      - Benthivores
The proposed ecosystem limit reference point is that the exploitation rate should not exceed the fraction of microplankton production in the system (\(\sim 20-30\%\)), which equates to \(\sim 825,000 \text{ t} \) of harvestable production.
Summary

- Fishery removals exceeded recommended levels (~825,000 t) in the past, but are now close to estimates of sustainable extraction rates for the ecosystem as a whole.
Directed targeting of some species means that some functional groups are still at risk.
Summary

- A diversified catch will be necessary to create a more balanced harvesting policy.
Summary

- Changes in the phytoplankton community composition and/or rates of primary production will affect the community production and the overall fisheries yield of the system. Thus, there is an ongoing need for:

  - Climatological quality (preferably hyper-spectral) ocean color remote sensing data (RRSs, PAR, CHL, IOPs, Kd) to monitor changes in the phytoplankton community.
  - Improved algorithms for measuring phytoplankton functional groups/size classes on the continental shelf.
  - *In situ* validation data of phytoplankton pigments, primary production, and other related parameters.
Predicting Phytoplankton Functional Types with Remote Sensing Data

Tim Moore
University of New Hampshire

Chris Brown
NESDIS STAR

8/27/15
Ocean color approaches for discerning phytoplankton communities from remote sensing

- **Functional type** (biogeochemical function)
  - Spectral approach – PHYSAT, PhytoDOAS
- **Phytoplankton size** (governs many traits)
  - Spectral approaches (absorption, backscattering properties)
  - Chlorophyll approaches

Table 1. Summary of the algorithms, contact person, PFT represented.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Contact Person</th>
<th>PFTs</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewin et al. (2010)</td>
<td>R.J.W. Brewin</td>
<td>Micro, Nano, Pico</td>
<td>Abundance-based</td>
</tr>
<tr>
<td>Devred et al. (2006)</td>
<td>E. Devred</td>
<td>Micro, Nano+Pico</td>
<td>Abundance-based</td>
</tr>
<tr>
<td>OC-PFT</td>
<td>T. Hirata</td>
<td>Micro, Nano, Pico, Diatom, Haptophyte, Prokaryotes, Chlorophyte, Pico-Eukaryotes, Prochlorococcus</td>
<td>Abundance-based</td>
</tr>
<tr>
<td>Uitz et al. (2006)</td>
<td>J. Uitz</td>
<td>Micro, Nano, Pico</td>
<td>Abundance-based</td>
</tr>
<tr>
<td>PHYSAT</td>
<td>S. Alvain</td>
<td>Diatom, Nanoeukaryote, Prochlorococcus, Synchococcus-like, Phaeocystis</td>
<td>Optics-based</td>
</tr>
<tr>
<td>PhytoDOAS</td>
<td>A. Bracher</td>
<td>Diatom, Coccolithophore, Cyanobacteria</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Ciotti and Bricaud (2002)</td>
<td>A. Bricaud</td>
<td>Micro, Pico</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Fujiwara et al. (2011)</td>
<td>T. Hirawake</td>
<td>Micro, Nano, Pico</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Kostadinov et al. (2009)</td>
<td>T. Kostadinov</td>
<td>Micro, Nano, Pico</td>
<td>Optics-based</td>
</tr>
<tr>
<td>Mouw et al. (2010)</td>
<td>C. Mouw</td>
<td>Micro, Pico</td>
<td>Optics-based</td>
</tr>
</tbody>
</table>

http://pft.ees.hokudai.ac.jp/satellite/index.shtml
Niche Concept

- Widely accepted that PFT groups have distinct biogeography.
- Margalef Mandala is a useful construct to understand phytoplankton distributions across a varied environmental landscape.
- Niche models widely used in ecology to describe species distributions.
- Statistical in nature, and depends on assumptions regarding species presence/absence.

from Balch, 2004
SeaWiFS coccolithophore bloom patterns

Moore et al, 2011 RSE
A Coccolithophore ‘bloom’ niche model

- Using OC data, bloom pixels used as mask to select co-located environmental data
- Niche was characterized by statistical distribution of environmental data (SST, MLD, PAR, Winds).
AMT in situ data (HPLC, nutrient, CTD) 1998-2010

HPLC-based functional groups

Functional Groups (CHEMTAX)

Satellite Data
- SST (NOAA AVHRR)
- Wind (NOAA CFSR)
- PAR (SeaWiFS)
- PSD (SeaWiFS)
- MLD (HYCOM)
- Nutrients

Habitat/niche model (environmental + ocean color)

Evaluation

PFT Probabilities

Ocean Color Particle Size (SeaWiFS)

Match-up data set sorted by PFT

Development
PFT Training Data Set

Atlantic Ocean HPLC Data

AMT SeaBASS CLIVEC Pangea

N ~ 2500

CHEMTAX (based on ‘known’ pigment ratios)

% Phytoplankton of Chla

Diatoms Dinoflagellates Prochlorococcus Prymnesiophytes Chlorophytes Chrysophytes Cryptophytes Synechococcus Prasinophytes

PFT groups

• 4 PFT groups created
• Dominant PFT identified as fraction of biomass > 0.45
• Coccolithophores added from existing model
Atlantic matchup data set

- ~800 matchup points between HPLC in situ and satellite variables.
- 340 points had a ‘dominant’ PFT present (~50%).
- Nanoflagellates dominated PFTs (~70%).
- Synechococcus dominant least abundant (5%).
\[
Z^2 = (V_{rs} - y_j)^t \Sigma_j^{-1} (V_{rs} - y_j)
\]

\(V_{rs}\) – Environmental vector
\(y_j\) – \(j\)th PFT mean vector
\(\Sigma_j\) – \(j\)th PFT covariance matrix
### Performance matrix – 5 PFT types

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Training* % correct</th>
<th>Eval** % correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43.9</td>
<td>40.6</td>
</tr>
<tr>
<td>2</td>
<td>58.8</td>
<td>50.7</td>
</tr>
<tr>
<td>3</td>
<td>70.7</td>
<td>55.6</td>
</tr>
<tr>
<td>4</td>
<td>72.3</td>
<td>55.7</td>
</tr>
<tr>
<td>5</td>
<td>79.3</td>
<td>63.9</td>
</tr>
<tr>
<td>6</td>
<td>88.7</td>
<td>72.6</td>
</tr>
</tbody>
</table>

- Best performance with all variables combining OC & env data.
- Systematic additions of variables improved performance.

*Training Data used from ‘dominant’ points in pool of data (N=370)

**Data not used but ‘not dominant’ from remaining pool of data (N=421)

---

Scenario 1: PSD only  
Scenario 2: Sc1 + SST  
Scenario 3: Sc2 + PAR  
Scenario 4: Sc3 + MLD  
Scenario 5: Sc4 + wind  
Scenario 6: Sc5 + nutrients
Summary

• A model was developed to predict dominant PFT groups at the oceans *surface* using particle size information from ocean color imagery combined with environmental data.

• The model was based on a ‘habitat/niche’ concept formed by observed relationships between identified PFT groups (from in situ HPLC) and co-located satellite variables (e.g., PAR, MLD, wind, SST and nutrients).

• Model is driven by assumptions on 1) initial Chemtax-derived phytoplankton group accuracy, 2) partitioning of these groups into PFTs, and 3) niche concept applying to broad phytoplankton groups.

• 5 PFTs were characterized in this model: Nanoflagellates, Diatoms, Coccolithophores, Prochlorococcus and Synechococcus.
Summary (continued)

• The model currently works predicts correct PFT 86-90% based on training set, and about 70% accuracy with a separate data set that is not totally appropriate for the model since there are no ‘Dominant’ points in that data set.

• Despite the large matchup data set, only 1/3 of the points were ‘dominant’, and more data would be beneficial for both further training, and evaluation.

• The output maps look reasonable, but its difficult to assess without other metrics to validate.
Future Work

• Explore alternative PFT groupings.
• Utilize upcoming PSD imagery for Aqua and VIIRS (Kostadinov).
• Assess model with an appropriate validation data set.
• Utilize monthly nitrate product for Atlantic (J. Goes).
Backup Slides
Building the capacity of monitoring water quality in coastal waters: Pilot studies in the Chesapeake Bay

Guangming Zheng\textsuperscript{1,2}, Paul M. DiGiacomo\textsuperscript{1}, Marilyn Y. Murphy\textsuperscript{1}

\textsuperscript{1}NOAA/NESDIS/STAR

\textsuperscript{2}Global Science & Technology, Inc.
Water quality remote sensing in the Chesapeake Bay

Nutrients and sediments (pathogen + pollutants)
Phytoplankton blooms
Hypoxia
Fish and shellfish kills
Seagrass habitat loss
Collapse of fishery harvests
Reduced biodiversity
Aquaculture failures

Satellite
Algorithms
Field sampling

Product → Information → Knowledge → Decisions

River discharge

River Transect of Chesapeake Bay main stem

Ocean
Evolution of sediment plumes in the Chesapeake Bay

[Zheng et al., 2015a]
Short-term evolution of sediment plumes after discharge events

<table>
<thead>
<tr>
<th>Types</th>
<th>Injection</th>
<th>Transport</th>
<th>Temporary Turbidity Max</th>
<th>Persistent Turbidity Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial shape of SPM</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
</tr>
<tr>
<td>Timing (days)</td>
<td>0–5</td>
<td>3–10</td>
<td>5–30</td>
<td>&gt;13</td>
</tr>
</tbody>
</table>

Long-term regime shift of typology
Hurricane Ivan (2004) triggered a discharge of sediments equivalent to the total amount discharged over the preceding 10 years.

The shift in typology occurred in an abrupt manner after Hurricane Ivan.

The regime shift is likely associated with Hurricane Ivan (2004).
Another important detail:

- Chlorophyll transect is decoupled from suspended sediment transect

- Higher algal biomass is located downstream of the Turbidity Max
Satellite Remote-sensing of water quality parameters: Current and future approaches

Normalized water-leaving radiance

Total Inherent Optical Properties

Optical Properties of Individual Components

Water quality parameters (examples):
- Phytoplankton
- Suspended Particles
- Colored Dissolved Organic Matter
Solve for $A_{i,j,k}$ and $B_{i,j,k}$

Identify feasible solutions

Input: $a_{nw} (\lambda)$

Output: $a_d (\lambda), a_g (\lambda), a_{ph} (\lambda)$

Optimal Solution

Range of Feasible Solutions

Matrix $C_{26 \times 30}$

$C_{i,j} = (x_i, y_j)$

$\{x_i\} = \{0.75, 0.76, \ldots 1\}$

$\{y_j\} = \{0.48, 0.49, \ldots 0.77\}$

Step 1

Solve for $A_{i,j,k}$ and $B_{i,j,k}$

Step 1

Matrix $D_{26 \times 30 \times 315}$

$D_{i,j,k} = (A_{i,j,k}, B_{i,j,k})$

Step 2

Solve for $a_d (\lambda)_{i,j,k}, a_g (\lambda)_{i,j,k}, a_{ph} (\lambda)_{i,j,k}$

Step 2

Matrix $E_{26 \times 30 \times 315}$

$E_{i,j,k} = (a_d (\lambda)_{i,j,k}, a_g (\lambda)_{i,j,k}, a_{ph} (\lambda)_{i,j,k})$

Step 3

Satisfy constraints #3–#5

Identify feasible solutions

Feasible Solutions

Step 4

Matrix $E_{26 \times 30 \times 315}$

Inequality Constraints

Step 2

9 weights, $w$

Step 2

$\hat{a}_d (\lambda)_{p}$

Step 1

315 combined $\hat{a}_{dg} (\lambda)$ spectra

$\hat{a}_{dg} (\lambda)_{k}$

Step 1

Step 1

$\hat{a}_g (\lambda)_{q}$

7 basic $\hat{a}_d (\lambda)$ spectra

Library of representative spectra

Derive speculative solutions

$\hat{a}_g (\lambda)_{q}$

5 basic $\hat{a}_g (\lambda)$ spectra

[Zheng et al., 2015b]
Advantages of GSCM

- Representative spectra determined from hierarchical cluster analysis using field data.

- The inequality constraints allows spectral shape of $a_{ph}(\lambda)$ to vary widely

<table>
<thead>
<tr>
<th>Inequality Constraints</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>$0.75 &lt; \frac{a_{ph}(412)}{a_{ph}(443)} &lt; 1$</td>
</tr>
<tr>
<td>#2</td>
<td>$0.48 &lt; \frac{a_{ph}(490)}{a_{ph}(443)} &lt; 0.77$</td>
</tr>
<tr>
<td>#3</td>
<td>$0.76 &lt; \frac{a_{ph}(469)}{a_{ph}(412)} &lt; 1.13$</td>
</tr>
<tr>
<td>#4</td>
<td>$0.19 &lt; \frac{a_{ph}(555)}{a_{ph}(490)} &lt; 0.50$</td>
</tr>
<tr>
<td>#5</td>
<td>$0 &lt; \frac{a_{d}(750)}{a_{d}(443)} &lt; 0.3$</td>
</tr>
</tbody>
</table>
The model-derived $a_d$, $a_g$, and $a_{ph}$ agree reasonably well with measurements:

- Small systematic error (e.g., $MR$ differs within ±10% from 1 @443 nm)

- Small random error (e.g., $MPD$ ranges between 11 and 17%, and $RMSD$ between 0.07 and 0.14 m$^{-1}$ @443 nm)
Application of GSCM to MODIS data

**Input:**
- MODIS-Aqua $R_{rs}(\lambda)$ (SWIR atmospheric correction)

**QAA-GSCM Output:**
- $a_d(\lambda)$: NAP
- $a_{ph}(\lambda)$: Phytoplankton
- $a_g(\lambda)$: CDOM

**QAA Output:**
- $a_{ph}(\lambda)$: Phytoplankton
- $a_{dg}(\lambda)$: NAP + CDOM
- $a_{nw}(\lambda)$: Total particulate matter

**GSCM:**
- Generalized Stacked-Constraints Model (GSCM)

**Output:**
- $NAP$ Phytoplankton $CDOM$

References:
- [Zheng et al., in prep]
- [Wang, 2007; Wang & Shi, 2007]
- [Lee et al., 2010]
- [Lee et al., 2009]
- [Zheng et al., 2015b]
- [Lee et al., 2010]
Optical identification of water mass

Fall 2002

- Water mass A:
  - Potomac River plume
  - CDOM and NAP dominated
  - $b_{bp}(443):a_d(443) = 1.8 \pm 0.2 \%$
  - CDOM-NAP mixed plume

- Water mass B:
  - Rappahannock River plume
  - CDOM dominated
  - $b_{bp}(443):a_d(443) = 1.5 \pm 0.2 \%$
  - “Tea-colored” plume

- Water mass C:
  - York River plume
  - CDOM and NAP dominated
  - $b_{bp}(443):a_d(443) = 2.2 \pm 0.3 \%$
  - CDOM-NAP mixed plume

- Water mass D:
  - James River plume
  - NAP dominated
  - $b_{bp}(443):a_d(443) = 2.5 \pm 0.2 \%$
  - “Turbid” plume
Conclusions

• Combining satellite-derived suspended sediments data and field-measured streamflow data allows us to elucidate short- and long-term trends of sediment distribution.

• The GSCM-type approach which allows the extraction of mathematically dissociated absorption coefficients of phytoplankton, nonalgal particles, and CDOM is a promising new tool for water quality research and applications.

Future research

• Improve the spectral shape of satellite-derived $R_{rs}(\lambda)$ in the blue spectral region

• Identify potential links between optical properties and water quality parameters such as toxins, harmful algal cell counts, dissolved oxygen, oxygen demands, priority pollutants, and etc.
Publications


Projects presented here are funded by the NOAA Ocean Remote Sensing (ORS) Program.

We appreciate NOAA/NOS/CO-OPS, USGS, and NASA/GSFC/OBPG, for providing the wind, streamflow, and ocean color radiometric data. We thank Lide Jiang for providing the simulated tidal current data.

We thank all scientists and personnel who contributed to the collection and processing of field data of absorption coefficients used in this study. In particular, we thank L. W. Jr. Harding, C. Hu, and A. Mannino who made the data available through the NASA's SeaWiFS Bio-Optical Archive and Storage System (SeaBASS).

We are grateful to Menghua Wang and Seung-Hyun Son for providing MODIS Aqua reflectance data.
HOW SATELLITE OCEAN COLOR CAN AID OUR UNDERSTANDING OF OCEAN ACIDIFICATION

National Oceanic & Atmospheric Association (NOAA)

Ocean Acidification Program Office

Dwight Gledhill, NOAA OAP Deputy Director

http://www.oceanacidification.noaa.gov/
Ocean Acidification

120 GT
≈ 1/2 of fossil-fuel & cement-manufacturing emissions

CO₂

Ocean Acidification

\[ \text{CO}_2, \text{gas} + \text{H}_2\text{O} \rightarrow H^+ + \text{HCO}_3^- \]

\[ H^+ + \text{CO}_3^{2-} \rightarrow \text{HCO}_3^- \]
How significant are these changes?

Idealized diversity trajectories of selected calcareous and organic fossil lineages.

- Organic-walled dinocysts
- Calcareous nannofossils
- Planktic foraminifera
- Benthic foraminifera
- Shallow reef builders

**2.4 PgC/year**

Clarkson et al., 2015

Current fossil fuel emission rates
8.3 PgC/year

Source: Honisch et al. 2012
The NOAA Ocean Acidification Program (OAP) was established under SEC. 12406. of the Federal Ocean Acidification and Monitoring Act (FOARAM) to oversee and coordinate research, monitoring, and other activities consistent with the strategic research and implementation plan developed by the interagency working group on ocean acidification.

The program is to foster and direct …the establishment of a long-term monitoring program of ocean acidification utilizing existing global and national ocean observing assets, and adding instrumentation and sampling stations as appropriate to the aims of the research program…
Species Response to Ocean Acidification

**Organisms and Animals Affected by Ocean Acidification**

- Thalassiosira rotula
- Thalassiosira weissflogii
- Chlorella autotrophica
- Thalassiosira pseudonana
- Dunaliella salina
- Winter flounder
- Black sea bass
- Walleye pollock
- Thalassiosira oceanica
- Atlantic surf clams
- Bay scallop
- Hard clam
- Pterepod
- Krill
- Copepods
- Red king crab
- Tanner crab
- Blue king crab
- Dungeness crab
- Rock sole
- Summer flounder
- Herring
- Ling cod
- Surf smelt
- Sea scallop
- Geoduck
- Olympia oysters
- Golden crab
- Snow crab
- Pygmy rock crab
- American lobster
- Pacific cod
- Atlantic tomcod
- Atlantic silverside
- Mummichog
Ocean Acidification v2.0

Coastal Carbon Dynamics

What role do coasts play in controlling ocean carbon?
Ocean Acidification v2.0

Corrosive plume off Casco Bay, Maine:
Salisbury et al., UHN
NOAA Ocean Acidification Monitoring

Monitoring AC OA Survey

Monitoring WCOA Survey

Monitoring ECOA Survey

Monitoring GOMECC Survey
Remotely Sensing Ocean Acidification

CDIAC CO2 System Program
Remotely Sensing Ocean Acidification

\[ A_T = a + b(SSS - 35) + c(SSS - 35)^2 + d(SST - 20) + e(SST - 20)^2 \]


\[ pCO_{2,sw} = y_0 + A e^{(-K_0/B)} + pCO_{2,air} \]


http://www.coral.noaa.gov/accrete/oaps.html
Remote Sensing Ocean Acidification

pCO₂ based on Signorini et al., 2013

Sea Surface Temperature Application to OA

Application: temperature, solubility of carbon dioxide, mineral solubility

Salinity Sensors Application to OA

Application: salinity, total alkalinity, solubility of carbon dioxide, mineral solubility, mixing

Atmospheric CO$_2$ Application to OA

Application: air-sea gas disequilibrium, secular changes in OA

Satellite Ocean Color Application to OA

Application: chlorophyll, particulate & dissolved colored carbon, particulate inorganic carbon, primary & net community productivity, classification

Coastal Mapping Application to OA

Application: coral reef area, coral reef health, shallow water resuspension, near coastal processes

Soil Moisture/Water Budgets Application to OA

Application: water cycle studies, freshwater flux to the ocean

Altimetry Application to OA

Application: ocean currents, mixing

User Community and Stakeholders of OA Data

An Oysters Tale...

The J-SCOPE forecast system for Washington and Oregon coastal waters
User Community and Stakeholders of OA Data

## Applications, Tools, Products

<table>
<thead>
<tr>
<th>Name</th>
<th>Frequency</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>LME 20xx Ecosystem Report Card</td>
<td>Annual</td>
<td>Alaska Fishery Management &amp; Industries</td>
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<tr>
<td>Long-term bio-economic forecast</td>
<td>5-yr</td>
<td>Alaska Fishery Management &amp; Industries</td>
</tr>
<tr>
<td>Regional Vulnerability Assessment</td>
<td>5-yr</td>
<td>Alaska Fishery Management &amp; Industries</td>
</tr>
<tr>
<td>Regional OA Forecast &amp; Scenario Projection</td>
<td>On-demand</td>
<td>New England and Mid-Atlantic Marine Fisheries Commission</td>
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<tr>
<td>Large Marine Ecosystem IEA</td>
<td>ND</td>
<td>Greater Atlantic Regional Fisheries Office</td>
</tr>
<tr>
<td>National Coral Reef Status &amp; Trends Report Card</td>
<td>TBD</td>
<td>Regional Fishery Management Councils</td>
</tr>
<tr>
<td>Etc.</td>
<td></td>
<td>Coral Reef Management Community</td>
</tr>
</tbody>
</table>
Concluding Thoughts

- The vulnerability of society to the impacts of ocean acidification differs regionally due to local chemistry, biology, and economic dependence. This heterogeneity creates an opportunity for information product needs.

- Most of the user needs for OA data products emerge from the marine resource management and industry community in the form of synthesis assessments. Not necessarily nRT.

- Satellite Ocean Color products are particularly of aid in improving synoptic mapping of OA with the coastal domain where biological forcing imparts a first-order effect to carbonate system dynamics.

- Applications range from classification of water types for improved empirical relations to direct determination of relevant processes (e.g. NPP).

- Opportunities exist to further improve coastal/shelf algorithms by furthering joint OAR-NESDIS geochemical surveys (i.e. ECOA)
Thank you

http://oceanacidification.noaa.gov/
NOAA CoastWatch Ocean Color Data Dissemination

Paul M. DiGiacomo
NOAA/NESDIS/STAR
NOAA CoastWatch Program
# NRT & Science Quality Data

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Near-Real Time</th>
<th>Delayed-Mode/Science-Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency:</td>
<td>Best effort, as soon as possible (~12-24h)</td>
<td>Best effort, ~1-2 weeks 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</td>
<td>CoastWatch, NCEI</td>
</tr>
<tr>
<td>Archive Plans:</td>
<td>TBD (but not through STAR)</td>
<td>Yes, from CoastWatch to NCEI</td>
</tr>
<tr>
<td>Full Mission Reprocessing:</td>
<td>No</td>
<td>Yes, ~2-3 years or as needed</td>
</tr>
</tbody>
</table>
Suomi NPP VIIRS OC Data Products

- **Near Real Time** (Jan 21, 2015 – Present; 2/2012 – Present in November)
  - Global
  - Regional
Suomi NPP VIIRS OC Data Products

- Near Real Time (Days 1-8)
  - Global
  - Regional
  Available Now
- Science Quality (Days 8 – n)
  - Global
  - Regional
  Available Early 2016
- Reprocessed (Mission)
  - Global
L3 Global 4km

Daily  Weekly  Monthly
# L3 Global 750m Sectors

<table>
<thead>
<tr>
<th>U</th>
<th>V</th>
<th>W</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
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<td>VW</td>
<td>WU</td>
<td>XW</td>
<td>YW</td>
<td>ZW</td>
</tr>
</tbody>
</table>

9/2/2015
NOAA/NESDIS/STAR
L3 Regional

- “CONUS” 75m regions: Hawaii, West Coast, Great Lakes, Northeast, Southeast, Gulf of Mexico, Caribbean

Daily Merge

Granule
Regional Partners (1)

- **EUMETSAT**
  - Processing and staging of 750m Mediterranean datasets (L3 available through CoastWatch)
  - EUMETcast (Copernicus Service) broadcasts L2 VIIRS
Regional Partners (2)

- CSIRO
  - Processing and staging of L3 Australia 750m datasets
L2 & L3 Global Products

- **Standard:**
  - Chlorophyll-a
  - Kd490
  - KdPAR
  - nLw_412
  - nLw_445
  - nLw_488
  - nLw_555
  - nLw_672

- **L2_flags**
- **Latitude**
- **Longitude**

- **Experimental:**
  - IOPs
  - PAR

- Future Inclusion
L2 & L3 Regional Products

- **Standard:**
  - Chlorophyll-a
  - Kd490
  - KdPAR
  - nLw_412
  - nLw_445
  - nLw_488
  - nLw_555
  - nLw_672

- **Experimental:**
  - IOPs
  - PAR

- **L2 flags**
- **User Driven:**
  - HAB anomaly product
  - Rrs
  - Others TBD

Future Inclusion
Data Formats

- Global / Sector:
  - NetCDF (v4 CF)
  - GeoTIFF & PNG

- Regional:
  - NetCDF (v4 CF)
  - HDF (v4 with CoastWatch metadata)
  - GeoTIFF & PNG
Access & Protocols (1)

- HTTP
- FTP
- THREDDS
  - OPENDAP
  - NetcdfSubset
- WCS
- WMS
- NCML
- ISO
- UDDC
Access & Protocols (2)

- **HTTP:**
  - [http://coastwatch.noaa.gov](http://coastwatch.noaa.gov)

- **FTP:**

- **THREDDS:**
  - [http://coastwatch.noaa.gov/thredds](http://coastwatch.noaa.gov/thredds)
L2 Granule Selector

The NOAA CoastWatch S-NPP VIIRS granule selector enables a user to select a Level-2 VIIRS ocean color dataset by selecting a date and clicking on the granule that covers the user’s area of interest. The background data will change to show the chlorophyll-a product for the selected day and clicking on a granule will open an information window containing a true color image and various access points to retrieve the data.

Date: 2015-08-25 Time: 2052
Download Data:
True Color Image (PNG)
VIIRS L2 Ocean Color Data (CW NetCDF)
VIIRS Ocean Color Channel Data (CW HDF)
THREDDS access
Planned Enhancements

- Data Portal
  - Facilitate the discovery and access to Ocean Data
  - Present a variety of search options
    - Locate the single or handful of datasets (Granule Selector/CW web search)
    - Locate a small to intermediate collection of data meeting user-driven criteria (in development)
  - Locate bulk collections of data (science data on FTP/THREDDS)
Sentinel-3A

- A Cooperative Arrangement between the United States and the European Commission is nearing ratification
- NOAA (NESDIS/)/STAR plans to provide near real-time access to global OLCI and SLSTR data products from EUMETSAT
- EUMETSAT data transferred via terrestrial multicast to NOAA – initial tests promising
- OLCI data complements existing JPSS sensors:
  - 300m spatial resolution
  - Spectral bands meeting NOAA NOS HAB requirements
  - Relieves single point-of-failure for HAB forecasting
NOAA CoastWatch Ocean Color Data Dissemination

Paul M. DiGiacomo
NOAA/NESDIS/STAR
NOAA CoastWatch Program
Backup Slides
Example “Snapshot” 9/2016

- Reprocessing V1 (MSL12 v1.0.3)
- 1 Week
- 9/1/2016
- Reprocessing
- Sci-Qual

Science-Quality Data replaces 8-day old NRT data

MSL v1.0.2

IDPS SDR GFS Model

OC SDR GDAS

“forward science processing”

NRT

Science Quality
Example “Snapshot”

Science-Quality Data replaces 8-day old NRT data

Reprocessing/Science 1  Science 2  NRT

GFS Model

OC SDR

GDAS

“forward science processing”

Reprocessing V1

Science 1  Science 2

1 Week

1 Week

2012  2015  2016  Today

9/2/2015 NOAA/NESDIS/STAR