# Ocean Break-out Agenda

## May 20

<table>
<thead>
<tr>
<th>Time</th>
<th>Overview and Status</th>
<th>Details</th>
</tr>
</thead>
</table>
| 1:30  | Bryan Franz, Gene Feldman, Gene Eplee, Gerhard Meister, Fred Patt | Overview of Science Team & Ocean SIPS  
\[ Status of MODIS and VIIRS OC & SST production \]  
\[ Status of instruments and calibration \]  
\[- VIIRS calibration update (GE) \]  
\[- MODIS calibration update (GM) \]  
\[- SeaWiFS calibration update (FP) \]  
\[ Questions/Discussion \] |
| 3:00  | Break                                                   |                                                                         |

## Data Product Quality

<table>
<thead>
<tr>
<th>Time</th>
<th>Organizer</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>3:20</td>
<td>Brian Barnes</td>
<td>Cross-sensor continuity between SeaWiFS, MODIS/Aqua, and VIIRS over the Gulf of Mexico</td>
</tr>
<tr>
<td>3:40</td>
<td>Lian Feng and Chuanmin Hu</td>
<td>Effects of bright-target adjacency on TOA radiance and ocean color products: A statistical assessment</td>
</tr>
</tbody>
</table>

## Data Product Applications

<table>
<thead>
<tr>
<th>Time</th>
<th>Organizer</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:00</td>
<td>Watson Gregg</td>
<td>Using S-NPP VIIRS ocean chlorophyll in a global model</td>
</tr>
<tr>
<td>4:20</td>
<td>Greg Silsbe</td>
<td>Net Primary Production modeling from satellite</td>
</tr>
<tr>
<td>4:40</td>
<td>Chuanmin Hu</td>
<td>Comparison of MODIS and VIIRS in detecting harmful Karenia brevis blooms in the NE Gulf of Mexico: A case study</td>
</tr>
</tbody>
</table>

## Standard Product Updates

<table>
<thead>
<tr>
<th>Time</th>
<th>Organizer</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00</td>
<td>Barney Balch</td>
<td>Updates to PIC algorithm</td>
</tr>
<tr>
<td>5:20</td>
<td></td>
<td>Discussion</td>
</tr>
</tbody>
</table>
## Ocean Break-out Agenda

### May 21

<table>
<thead>
<tr>
<th>Time</th>
<th>Name</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:30</td>
<td>Zhongping Lee</td>
<td>Discussion of Ocean Color products, what should we produce</td>
</tr>
<tr>
<td>2:30</td>
<td></td>
<td>Break</td>
</tr>
<tr>
<td>2:40</td>
<td>Prabhat Koner</td>
<td>Predicted vs observed results for different channel combinations, information content and operational error for multi-sensors SST retrievals</td>
</tr>
</tbody>
</table>
| 3:00  | Peter Minnett | Discussion of SST products and algorithms, what should we produce, what is the algorithm status, how can proposed approaches complement.  
  Peter Minnett - MODIS continuity algorithm  
  Andy Harris - deterministic inverse method for SST retrieval  
  Kyle Hilburn - analysis and mitigation of atmospheric crosstalk |
| 4:00  |               | Discussion                                                            |
MODIS & VIIRS Ocean Processing Status
2014.0 Multi-Mission Ocean Reprocessing

Scope
• OC from CZCS, OCTS, SeaWiFS, MERIS, MODIS(A/T), and VIIRS
• SST from MODIS

Motivation
1. improve interoperability and sustainability of the product suite by adopting modern data formats, standards, and conventions
2. incorporate algorithm updates and advances from community and last MODIS Science Team developed since 2010 (last alg. update).
3. incorporate knowledge gained in instrument-specific radiometric calibration and updates to vicarious calibration

Status
• OC from OCTS & VIIRS done, MODISA in progress
• SST from MODISA and MODIST done (not yet released)
Product Development and Documentation
Standard, Evaluation, and Test Products

- a **standard product** is one that the SIPS is committed to maintain, and the DAAC is committed to archive and distribute, at the ultimate discretion of Program Management.

- an **evaluation product** is one that the SIPS/DAAC may produce and distribute, if resources allow, to support community assessment of a new product or alternative product algorithm.

- a **test product** is one that the SIPS may produce to support the algorithm PI in implementation verification and product testing.

*In practice, OC standard products are made at Level-2 and Level-3, while eval products are made only at Level-3 (usually from Level-3 Rrs dailies).*
OC Implementation
NASA Standard Processing Code

SeaWiFS L1A
MODIS L1B
MODIST L1B
OCTS L1A
MOS L1B
OSMI L1A
CZCS L1A
MERIS L1B
OCM-1 L1B
OCM-2 L1B
VIIRS L1A
GOCI L1B
OLI L1T

Level-1 to Level-2
(common algorithms)

ancillary data

sensor-specific tables: Rayleigh, aerosol, etc.

observed radiances

water-leaving reflectances & derived prods

predicted at-sensor radiances

in situ water-leaving radiances (MOBY)

Level-2 Scene

Level-2 to Level-3

Level-3 Global Product
SST Implementation
NASA Standard Processing Code

MODISA L1B
MODIST L1B
VIIRS L1A

Level-1 to Level-2
(common algorithms)

ancillary data

observed radiances

brightness temps & derived SST prods

Level-2 Scene

Level-2 to Level-3

Level-3 Global Product

sensor-specific tables: radiance/temperature
Product Documentation

• MODIS has historically required that every standard product have associated with it an Algorithm Theoretical Basis Document (ATBD)

• The original MODIS ATBDs are extremely out of date and in many cases they are not relevant to current standard products

• This is largely due to the fact that the MODIS processing was awarded to the NASA OBPG in 2004 with the mandate to adopt the SeaWiFS heritage processing, as documented in SeaWiFS TMs

• It is also the case that the ocean algorithms are predominantly sensor-independent, evolved from broad community contributions

• To satisfy NASA Program Management and better serve the research community, we need to establish a new set of product documentation for the current standard product suite of MODIS & VIIRS, and maintain that level of documentation going forward

• To that end, Ocean SIPS is developing a set of online documents that can be easily updated and will include dynamic links to ensure that implementation and validation information remains current
Product and Algorithm Description Document
standardized elements

- **Product Summary**
  - defines what it is and what it’s for

- **Algorithm Description**
  - as detailed as necessary to ensure full traceability to algorithm basis and heritage (e.g., links to published literature)
  - if applicable to multiple sensors, include any sensor-specific modifications required (e.g., adjustments for band passes)
  - algorithm failure conditions and associated product flags

- **Implementation**
  - how is the product distributed (product suite, file-types, encoding)
  - direct links to source code and/or software flow charts
Product and Algorithm Description Document
standardized elements

• Assessment
  – validation analyses (e.g., direct link to dynamic match-ups)
  – uncertainties

• References
  – links to previous ATBD(s) or TM(s), if relevant
  – links to published literature (DOIs)

• Product History
  – document version (date)
  – product change log
Particulate Inorganic Carbon (PIC)

Table of Contents

1. Product Summary
2. Algorithm Description
3. Implementation
4. Assessment
5. References

1 - Product Summary

This algorithm derives the concentration of particulate inorganic carbon (PIC) in mol m\(^{-3}\), calculated using observed in situ relationships between water-leaving radiances, spectral backscattering coefficients, and concentrations of PIC (i.e., calcium carbonate or calcite). Algorithm implementation is contingent on the availability of sensor bands near 443 and 555 nm. The algorithm is applicable to all current ocean color sensors. The PIC product is included as part of the standard Level-2 OC product suite and the Level-3 PIC product suite.

MODIS Aqua PIC seasonal composite for Spring 2014
Algorithm Description

The PIC algorithm is a hybrid of two independent approaches, defined here as the 2-band approach (Balch et al. 2002) and the 3-band approach (Gordon et al. 2001). The 2-band approach is used when the 3-band approach fails.

Input:
2-band approach
Normalized water-leaving radiance in two bands near 443 and 555 nm.

3-band approach
Spectral top-of-atmosphere reflectances at three wavelengths near 670, 765, and 865 nm.

Output:
PIC: the concentration of particulate inorganic carbon in mol m\(^{-3}\)

The 2-Band Approach:
The algorithm makes use of a precomputed look-up table, derived from in situ measurements, that contains the total backscattering coefficient for calcite at 546 nm, \(b_{sc}(546)\) in m\(^{-2}\), as a function of nLW(443) and nLW(555). The concentration of calcite (PIC) is computed by dividing \(b_{sc}(546)\) by a calcite-specific backscattering coefficient (1.628 m\(^2\) mol\(^{-1}\)), as also derived from in situ measurements.

In cases where nLW(555) is not available (OCIS, MODIS, MERIS, etc.), it is estimated from the closest native green wavelength (557, 550, and 565 nm, etc.) using the empirical relationships described here.

The 2-band algorithm may fail to retrieve PIC for two primary reasons: 1) the normalized water-leaving radiance could not be retrieved due to atmospheric correction failures or other masking conditions (e.g., clouds or land), and 2) the retrieved water-leaving radiance may be outside the range of values in the precomputed LUT. A common reason for either of these conditions is that the PIC concentration is very high, which can result in large water-leaving radiance signals in the near infrared channels that lead to poor or failed atmospheric correction. In some cases the signal is so strong in the near infrared that the observation is flagged and masked as a cloud. When these failures occur, the algorithm will attempt a retrieval using the 3-band approach, which uses a simple atmospheric correction that is more robust over bright waters.

The 3-Band Approach:
Observed TOA reflectances, \(r(\lambda)\), at three spectral bands near 670, 765, and 865 nm are converted to reflectance and then related to the components of the radiative path reflectance through:

\[ r(\lambda) = (r(\lambda) + t(\lambda) \times r(\lambda) \times t(\lambda) \times r(\lambda) + r(\lambda)) \times r(\lambda) \]

where:
- \(r(\lambda)\) is top-of-atmosphere reflectance (measured),
- \(r(\lambda)\) is reflectance due to Rayleigh scattering in the absence of aerosols (calculated),
- \(r(\lambda)\) is reflectance due to whitecaps and fog (calculated),
- \(t(\lambda)\) is diffuse transmission of the atmosphere from surface to sensor (calculated),
- \(t(\lambda)\) is atmospheric gas transmission Sun to surface (calculated),
- \(r(\lambda)\) is water-leaving reflectance (unknown), and
- \(r(\lambda)\) is aerosol reflectance (unknown).

Aerosol and water-leaving reflectances can be expressed roughly as:

\[ r(\lambda) \approx r(\lambda) \times \exp(-a(\lambda) - \lambda) \]

and

\[ r(\lambda) \approx \exp(-a(\lambda) - \lambda) \]

where:
- \(a(\lambda)\) is the absorption coefficient of seawater,
- \(b(\lambda)\) is the total backscattering coefficient, and
- \(\lambda_0 = 865\) nm.

Backscattering by calcite and seawater can be roughly expressed as:

\[ b_{sc}(\lambda) \approx b_{sc}(546) \times \left(\frac{\lambda}{\lambda_0}\right)^{1.18} + b_{se}(\lambda) \]

Through an iterative procedure, seeded by setting the backscattering coefficients to their pure seawater values, values for \(r(\lambda)\) and \(r(\lambda)\) can be retrieved, and ultimately the backscattering coefficient for calcite at 546 nm, \(b_{sc}(546)\) can be derived. The concentration of calcite (PIC) is then computed by dividing \(b_{sc}(546)\) by a calcite-specific backscattering coefficient (1.628 m\(^2\) mol\(^{-1}\)).

Sensor-specific details:
As noted, the 2-band algorithm uses a common look-up table defined for nLW(443) and nLW(555), and adjusts the satellite nLW retrievals as needed to account for sensor-specific differences in center wavelength relative to the look-up table indices. For the 3-band approach, the atmospheric properties and water optical properties are computed at the sensor-specific band passes in the red and near-infrared, and thus the sensor differences are inherent in the implementation. The actual wavelengths used for the various sensors are shown in the table below, with the 3-band algorithm center wavelengths in parentheses.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>443</th>
<th>555</th>
<th>670</th>
<th>765</th>
<th>865</th>
</tr>
</thead>
<tbody>
<tr>
<td>SeaWiFS</td>
<td>443</td>
<td>555</td>
<td>(557, 560, 565 nm)</td>
<td>(557, 560, 565 nm)</td>
<td>(557, 560, 565 nm)</td>
</tr>
<tr>
<td>MODIS</td>
<td>443</td>
<td>547</td>
<td>(510, 523, 532 nm)</td>
<td>(510, 523, 532 nm)</td>
<td>(510, 523, 532 nm)</td>
</tr>
<tr>
<td>MERIS</td>
<td>443</td>
<td>560</td>
<td>(620, 670, 770 nm)</td>
<td>(620, 670, 770 nm)</td>
<td>(620, 670, 770 nm)</td>
</tr>
<tr>
<td>VIIRS</td>
<td>443</td>
<td>551</td>
<td>(671, 751, 862 nm)</td>
<td>(671, 751, 862 nm)</td>
<td>(671, 751, 862 nm)</td>
</tr>
</tbody>
</table>

Failure conditions:
The PIC product is not computed if the Level-2 flags indicate LAND, HIQLINT or CLOUDS. A failure condition is indicated in Level-2 by setting the PIC value for that pixel to the _FILLVALUE and setting the Level-2 flags to indicate PRIOFAIL.
Implementation Details

3 - Implementation

Product Short Name: pic
Level-2 Product Suite: OC
Level-3 Product Suite: PIG
Level-3 Mapping: ATMFLS, LISATEN, STRAYLIGHT, CLOC, LOWLV, NAVWAV, MATYARN, VISLIDEN, NAVWAV, FILTER, GLINT

For further details on the implementation, go to the algorithm source code or the graphical description of the algorithm implementation in the NASA ocean color processing code (l2gen).
4 - Assessment

A limited set of Level-2 satellite-to-in-situ match-up validation results are available as a validation tool of the SeaWiFS Bio-Optical Archive and Storage System (SeaBASS) and are provided below.

- SeaWiFS
- MODIS Aqua
- MODIS Terra
- VIIRS
- OCTS
- CZCS
- MERIS

MODIS Aqua vs. In situ

<table>
<thead>
<tr>
<th>Dates</th>
<th>2000-01-01 to 2015-05-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Archived</td>
<td>2000-01-01 to 2015-05-08</td>
</tr>
<tr>
<td>North</td>
<td>90</td>
</tr>
<tr>
<td>South</td>
<td>-80</td>
</tr>
<tr>
<td>West</td>
<td>-180</td>
</tr>
<tr>
<td>East</td>
<td>180</td>
</tr>
<tr>
<td>Depth</td>
<td>0 to 10000</td>
</tr>
<tr>
<td>Output products</td>
<td>pic</td>
</tr>
<tr>
<td>Investigator/Experiment/Cruise</td>
<td>ALL</td>
</tr>
<tr>
<td>Data Source</td>
<td>oostbias</td>
</tr>
<tr>
<td>Minimum valid satellite pixels</td>
<td>50</td>
</tr>
<tr>
<td>Maximum solar zenith angle</td>
<td>70</td>
</tr>
<tr>
<td>Maximum solar zenith angle</td>
<td>55</td>
</tr>
<tr>
<td>Maximum difference between satellite and in situ</td>
<td>3</td>
</tr>
<tr>
<td>Maximum coefficient of variation of satellite pixels</td>
<td>0.15</td>
</tr>
<tr>
<td>Maximum Irradiance difference between measured and modeled</td>
<td>20</td>
</tr>
<tr>
<td>Maximum windspeed</td>
<td>35</td>
</tr>
<tr>
<td>Satellite version</td>
<td>R2013.1</td>
</tr>
<tr>
<td>Most Recent Data Update</td>
<td>2014-11-07 18:20:27</td>
</tr>
</tbody>
</table>

Search Results

Total number of matchups: 17

Data format is YYYY-MM-DD, time format is HH:MM:SS, and times are GMT. Only products with matchups will be displayed.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Name</td>
<td>MODIS Aqua Range</td>
</tr>
<tr>
<td>pic</td>
<td>0.00004, 0.00130</td>
</tr>
</tbody>
</table>

The linear regression algorithm has been changed to reduced major axis.
1. PI develops new algorithm or modification, demonstrates feasibility, perhaps publishes results.

2. If PI and Ocean Team Leader agree, PI works with SIPS to implement in NASA processing code and to develop a test plan for verification and large-scale testing.

3. If PI is satisfied with implementation tests, and SIPS confirms that required computing resources are available, evaluation products and documentation will be produced and distributed, and the algorithm will be incorporated into SeaDAS.
   a. PI works with SIPS to develop or update the Product Description Document (to be hosted under “evaluation products”).
   b. SIPS/DAAC begins production and distribution of product
   c. PI performs assessment of results (validation, global dist., trends)

4. Before the next mission reprocessing opportunity, PI/SIPS/DAAC and Program Management review the performance evaluation, documentation, and appropriateness for standard production.
Ocean Color Products Discussion
# R2014.0 Changes to OC Standard Product Suite

<table>
<thead>
<tr>
<th>Level-2 OC Product</th>
<th>Algorithm Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $R_{rs}(\lambda)$</td>
<td>calibration updates, ancillary data updates, improved land/water masking, terrain height, other minor fixes</td>
</tr>
<tr>
<td>2. Ångstrom</td>
<td>$\lambda = 412, 443, 469, 488, 531, 547, 555, 645, 667, 678$</td>
</tr>
<tr>
<td>3. AOT</td>
<td>new algorithm (Hu et al. 2012)</td>
</tr>
<tr>
<td>4. Chlorophyll $a$</td>
<td>coefficient update</td>
</tr>
<tr>
<td>5. $K_d(490)$</td>
<td>no change</td>
</tr>
<tr>
<td>6. POC</td>
<td>updated algorithm and LUT</td>
</tr>
<tr>
<td>7. PIC</td>
<td>remove product (redundant with new IOP suite)</td>
</tr>
<tr>
<td>8. CDOM_index</td>
<td>consolidated algorithm, minor fixes</td>
</tr>
<tr>
<td>9. PAR</td>
<td>MODIS-only, no change</td>
</tr>
<tr>
<td>10. iPAR</td>
<td>MODIS-only, flagging changes (allow negatives)</td>
</tr>
<tr>
<td>11. nFLH</td>
<td>added suite of inherent optical property products (Werdell et al. 2013)</td>
</tr>
<tr>
<td>12. IOPs</td>
<td></td>
</tr>
<tr>
<td>Level-2 OC Product</td>
<td>Algorithm Reference</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>1. $R_{rs}(\lambda)$</td>
<td><em>Spectral water-leaving reflectance and derived aerosol optical properties</em></td>
</tr>
<tr>
<td>2. Ångstrom</td>
<td></td>
</tr>
<tr>
<td>3. AOT</td>
<td>$\lambda = 410, 443, 486, 551, 671$</td>
</tr>
<tr>
<td>4. Chlorophyll $a$</td>
<td>* Phytoplankton chlorophyll concentration*</td>
</tr>
<tr>
<td>5. $K_d(490)$</td>
<td><em>Marine diffuse attenuation at 490nm</em></td>
</tr>
<tr>
<td>6. POC</td>
<td><em>Particulate organic carbon concentration</em></td>
</tr>
<tr>
<td>7. PIC</td>
<td><em>Particulate inorganic carbon concentration</em></td>
</tr>
<tr>
<td>8.</td>
<td></td>
</tr>
<tr>
<td>9. PAR</td>
<td><em>Daily mean photosynthetically available radiation</em></td>
</tr>
<tr>
<td>10.</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td></td>
</tr>
<tr>
<td>12. IOPs</td>
<td><em>Suite of inherent optical property products (Werdell et al. 2013)</em></td>
</tr>
</tbody>
</table>
Expanded Product Suite - IOPs

proposed IOP product suite

- \( a(\lambda) \)  
  total absorption at all visible wavelengths
- \( b_b(\lambda) \)  
  total backscatter at all visible wavelengths
- \( a_{ph}(\lambda) \)  
  phytoplankton absorption at all vis. wavelengths
- \( a_{dg}(443) \)  
  absorption due to colored-detritus at 443nm
- \( S_{dg} \)  
  exponential spectral slope for \( a_{dg} \)
- \( b_{bp}(443) \)  
  particle backscattering at 443nm
- \( S_{bp} \)  
  power-law spectral slope for \( b_{bp} \)
- uncertainties  
  uncertainties in \( a_{dg}, a_{ph}, b_{bp} \) at 443nm

rationale

- provides total \( a \) and \( b_b \) for input to IOP-based derived product algorithms (e.g., Lee et al. spectral \( K_d \), euphotic depth)
- provides sufficient information to compute full spectral component absorption and scattering coefficients and uncertainties

| VIIRS | \( \lambda = 410, 443, 486, 551, 671 \) |
| MODIS | \( \lambda = 412, 443, 469, 488, 531, 547, 555, 645, 667, 678 \) |
## Current Evaluation Products

<table>
<thead>
<tr>
<th>Products</th>
<th>Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chl, $a_{dg}(443)$, $b_{bp}(443)$</td>
<td>Maritorena (GSM)</td>
</tr>
<tr>
<td>IOPs ($a(443)$, $a_{ph}(443)$, $a_{dg}(443)$, $b_{bp}(443)$)</td>
<td>Lee (QAA)</td>
</tr>
<tr>
<td>$K_d(412), K_d(443), K_d(490)$</td>
<td>Lee</td>
</tr>
<tr>
<td>Zeu</td>
<td>Lee</td>
</tr>
<tr>
<td>Zeu</td>
<td>Morel</td>
</tr>
<tr>
<td>$K_{PAR}$</td>
<td>Morel</td>
</tr>
</tbody>
</table>

Produced at Level-3 only (from daily binned Rrs)
Stop producing $K_d$(PAR)

$K_d$(PAR) [m$^{-1}$]

$K_d$(USR) [m$^{-1}$]

PAR: 400-700 nm
USR: 400-560 nm

(Lee et al 2013)
SST Coordination Discussion
SST Discussion

Three SST PIs selected for VIIRS:

1. Andy Harris: A Deterministic Inverse Method for SST Retrieval from VIIRS
2. Frank Wentz: Analysis and Mitigation of Atmospheric Crosstalk (using AMSR-2 microwave measurements)
3. Peter Minnett: Sea-Surface Temperature from VIIRS-Extending the MODIS Time Series For Climate Data Records.

All are directed to deriving accurate SST from VIIRS; three very different approaches to achieve the same goal.

Good progress has been made by all groups in the first months of the projects.
Next steps

• All projects require independent in situ measurements to validate the different approaches to correct for the effects of the intervening atmosphere.
• Subsurface measurements provided by drifting and moored buoys provide the most numerous validating measurements.
• A provisional set of matchups between VIIRS brightness temperatures (from NOAA CLASS) has been developed at RSMAS.
  – This will be shared with the other groups.
• Ocean SIPS plans to generate NASA VIIRS BT’s; and a more comprehensive match-up data base will be generated.
• Additional variables in the new match-up data base will be included to enhance its utility.
  – SST groups will coordinate with Ocean SIPS for contents of new database

The breakout session was a very useful way of each group sharing ideas and reporting progress. A dialogue with the Ocean SIPS has begun.
Questions?