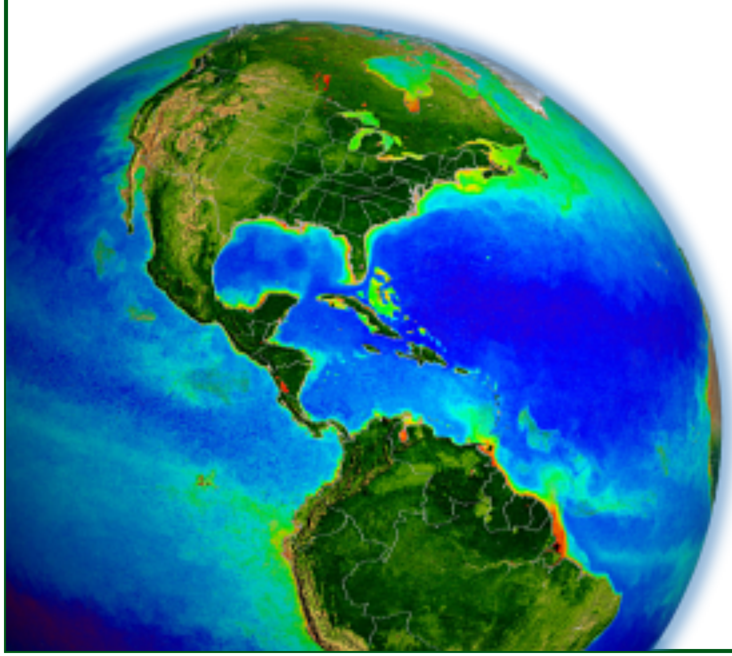
MODIS & VIIRS Ocean Science Team Break-out Report



MODIS Science Team Meeting

19-22 May 2015, Silver Spring, MD

Ocean Break-out Agenda

May 20

Overview and Status		
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		
3:20	Brian Barnes	*Cross-sensor continuity between SeaWiFS, MODIS/Aqua, and VIIRS over the Gulf of Mexico*
3:40	Lian Feng and Chuanmin Hu	*Effects of bright-target adjacency on TOA radiance and ocean color products: A statistical assessment*
Data Product Applications		
4:00	Watson Gregg	*Using S-NPP VIIRS ocean chlorophyll in a global model*
4:20	Greg Silsbe	*Net Primary Production modeling from satellite*
4:40	Chuanmin Hu	*Comparison of MODIS and VIIRS in detecting harmful Karenia brevis blooms in the NE Gulf of Mexico: A case study*
Standard Product Updates		
5:00	Barney Balch	*Updates to PIC algorithm*
5:20	*Discussion*	

Ocean Break-out Agenda

May 21

Ocean Color Product Discussion		
1:30	Zhongping Lee	*Discussion of Ocean Color products, what should we produce*
2:30	*Break*	
SST Discussion		
2:40	Prabhat Koner	*Predicted vs observed results for different channel combinations, information content and operational error for multi-sensors SST retrievals*
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

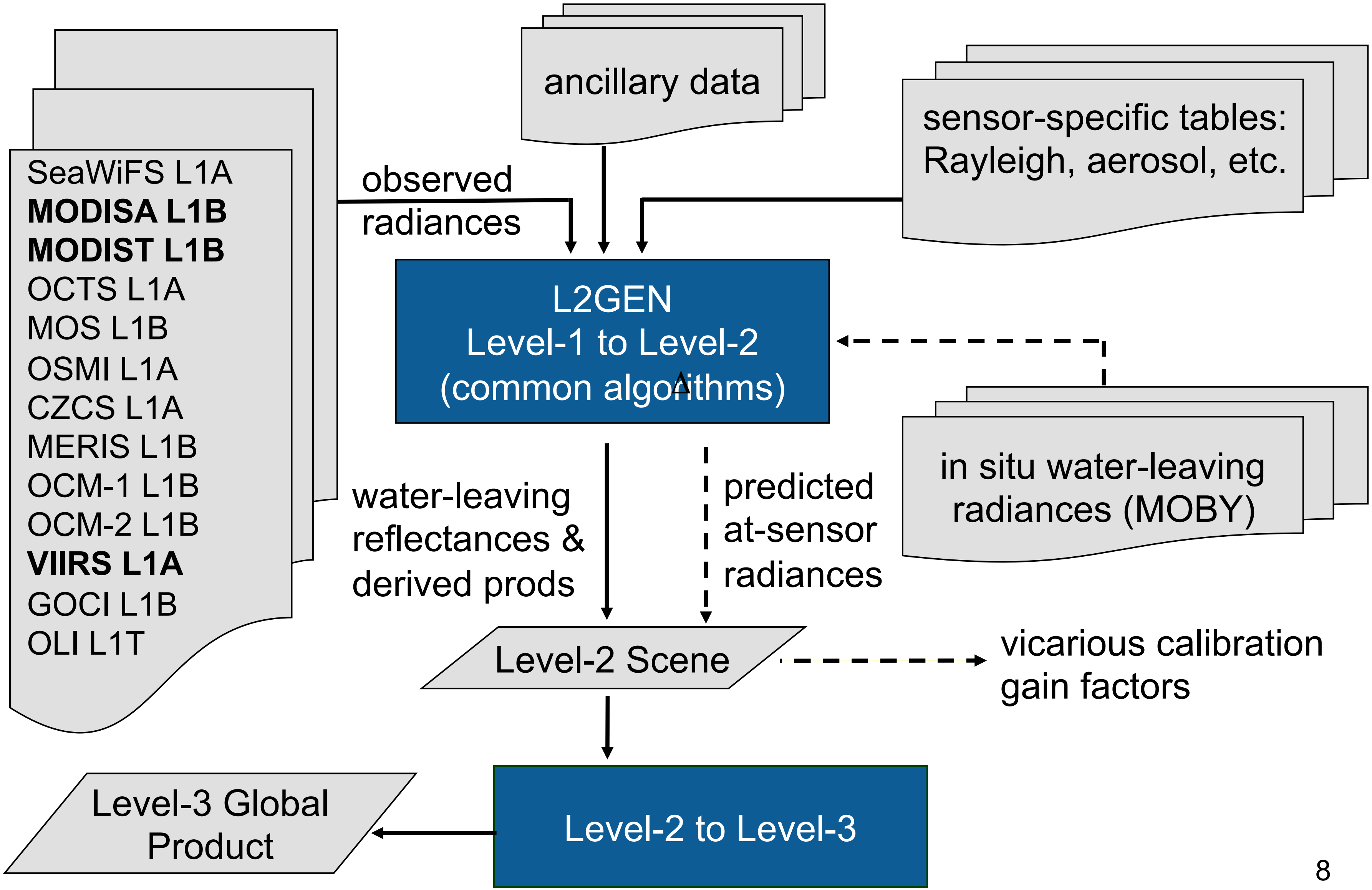
- a **standard product** is one that the SIPS is committed to maintain, and the DAAC is committed to archive and distribute, at the ultimate discretion of Program Management

- 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

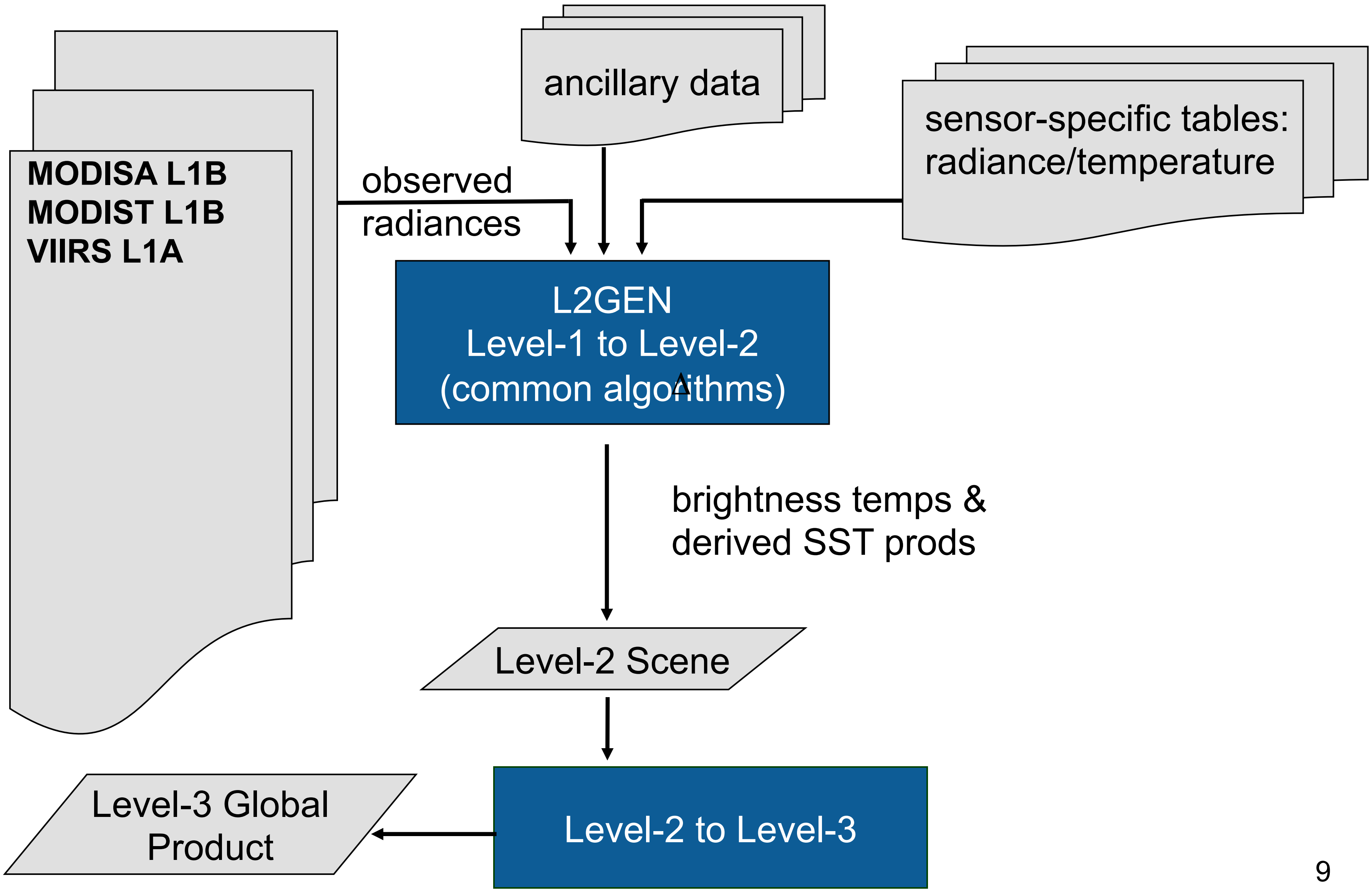
- a **test product** is one that the SIPS may produce to support the algorithm PI in implementation verification and product testing

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



SST Implementation
NASA Standard Processing Code



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

Product and Algorithm Description Documents

EARTHDATA Data Discovery - DAACs - Community - Science Disciplines -

OceanColor WEB

- Home
- Data Access
- Missions & Sensors
- OceanColor Forum
- Support Services
- Documentation
- Quality Assessment
- Software & Tools
- External Partners
- About Us

View the Legacy Website

Algorithm Descriptions

The Ocean Biology Processing Group (OBPG) produces and distributes a standard suite products for all compatible sensors at Level-2 and Level-3, plus sea surface temperatur MODIS. The OBPG also produces a suite of Level-3 evaluation products. Descriptions these standard and evaluation products are provided below.

Standard Ocean Color Products

Chlorophyll *a* (chlor_a; mg m^{-3})

The concentration of the photosynthetic pigment chlorophyll *a*.

Diffuse attenuation coefficient for downwelling irradiance at 490 nm (Kd_

The diffuse attenuation coefficient for downwelling irradiance over the first optical atte

Inherent Optical Properties (IOPs; m^{-1})

The spectral marine absorption and backscattering coefficients of water column constit

Particulate Organic Carbon (POC; mg m^{-3})

The concentration of particulate organic carbon.

Particulate Inorganic Carbon (PIC; mol m^{-3})

The concentration of particulate inorganic carbon.

Photosynthetically Available Radiation (PAR; Einstein m^{-2} d^{-1})

Daily mean photosynthetically available radiation (PAR) at the ocean surface.

Instantaneous Photosynthetically Available Radiation (iPAR; Einstein m^{-2}

PAR the ocean surface at the time of the satellite observation. MODIS only.

Normalized Fluorescence Line Height (nFLH; mW cm^{-2} µm^{-1} sr^{-1})

Relative measure of water-leaving radiance associated with chlorophyll fluorescence. M

Remote Sensing Reflectance (Rrs; sr^{-1})

The at-surface spectral remote-sensing reflectances observed by the satellite instrumen correction. The aerosol optical thickness and Ångstrom data products are also describe

Standard Sea Surface Temperature Products

11 µm Sea Surface Temperature (SST; °C)

Sea surface temperature derived from long-wave (11-12 µm) thermal radiation. MODIS only.

4 µm Sea Surface Temperature (SST4; °C)

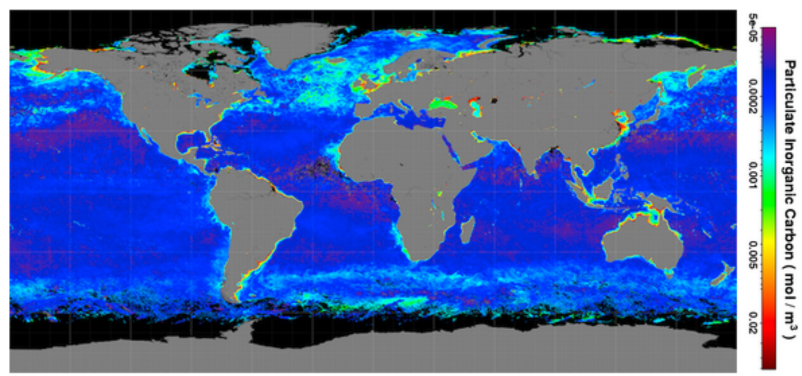
Sea surface temperature derived from short-wave (3-4 µm) thermal radiation. MODIS only.

Particulate Inorganic Carbon (PIC)

Table of Contents

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 555nm. 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

2 - Algorithm Description

The PIC algorithm is a hybrid of two independent approaches, defined here as the 2-band approach (Balch et al. 2005) and the 3-band approach (Gordon et al. 2001). The 3-band approach is used when the 2-band approach fails.

Input:

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

3-band approach
Spectral top-of-atmosphere reflectances at three wavelengths near 670, 750, and 870 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, $b_{bc}(546)$ in m^{-1}, as a function of nLw(443) and nLw (555). The concentration of calcite (PIC) is computed by dividing $b_{bc}(546)$ 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 (OCTS, MODIS, MERIS, etc.), it is estimated from the closest native green wavelength (547, 560, 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 radiances could not be retrieved due to atmospheric correction failures or other masking conditions (e.g., clouds or land), and 2) the retrieved water-leaving radiances 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 radiances, Lt(λ) , at three spectral bands near 670, 765, and 865 nm are converted to reflectance and then elated to the components of the radiant path reflectance through:

$$\rho_t(\lambda) = (\rho_r(\lambda) + t_s(\lambda) \times \rho_f(\lambda) \times t_s(\lambda) \times \rho_w(\lambda) + \rho_a(\lambda))t_g(\lambda)$$

where:
$\rho_t(\lambda)$ is top-of-atmosphere reflectance (measured), $\rho_r(\lambda)$ is reflectance due to Rayleigh scattering in the absence of aerosols (calculated), $\rho_f(\lambda)$ is reflectance due to whitecaps and foam (calculated), $t_s(\lambda)$ is diffuse transmittance of the atmosphere from surface to sensor (calculated), $t_g(\lambda)$ is atmospheric gas transmittance Sun to surface to sensor (calculated), $\rho_w(\lambda)$ is water-leaving reflectance (unknown), and $\rho_a(\lambda)$ is aerosol reflectance (unknown).

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

$$\rho_a(\lambda) \approx \rho_a(\lambda_0) \times \exp(a \times (\lambda_0 - \lambda))$$

and

$$\rho_w(\lambda) \approx \frac{b_b(\lambda)}{6.179 \times (a_w(\lambda) + b_b(\lambda))}$$

where:
a_w is the absorption coefficient of seawater, b_b is the total backscattering coefficient, and λ_0 = 865 nm.
Backscattering by calcite and seawater can be roughly expressed as:

$$b_b(\lambda) \approx b_{bc}(546) \times \left(\frac{546}{\lambda}\right)^{1.35} + b_{bw}(\lambda)$$

Through an iterative procedure, seeded by setting the backscattering coefficients to their pure seawater values, values for $\rho_a(865)$ and a can be retrieved, and ultimately the backscattering coefficient for calcite at 546 nm, $b_{bc}(546)$ can be derived. The concentration of calcite (PIC) is then computed by dividing $b_{bc}(546)$ by an *a priori* 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 define 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.

SeaWiFS	443, 555 (670, 765, 865)
MODIS	443, 547 (667,748,869)
MERIS	443, 560 (665, 779, 865)
VIIRS	443, 551, (671, 751, 862)

Failure conditions:
The PIC product is not computed if the Level-2 flags indicate LAND, HIGLINT 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 PRODFAIL.

Implementation Details

3 - Implementation

Product Short Name	pic
Level-2 Product Suite	OC
Level-3 Product Suite	PIC
Level-3 Masking	ATMFAIL,LAND,HISATZEN,STRAYLIGHT,CLDICE,LOWLW, NAVWARN,ATMWARN, HISOLZEN,NAVFAIL,FILTER,HIGLINT

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).

Main Page | Related Pages | Modules | Namespaces | Classes | Files

File List | File Members

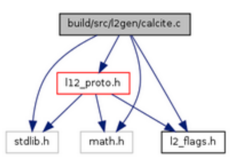
Defines | Functions

build/src/l2gen/calcite.c File Reference

(r11331/r10609)

```
#include <stdlib.h>
#include <math.h>
#include "l12_proto.h"
#include "l2_flags.h"
```

Include dependency graph for calcite.c:



Go to the source code of this file.

Defines

#define	BAD_CACO3 BAD_FLT
#define	N443 490
#define	N550 456

Functions

float	get_bbstar (float lat)
float	calcite_3b (l2str *l2rec, int32_t ip)
float	calcite_2b (l2str *l2rec, int32_t ip)
float	calcite_c (l2str *l2rec, int32_t ip)
void	calcite (l2str *l2rec, l2prodstr *p, float prod[])

Main Page | Related Pages | Modules | Namespaces | Classes | Files

File List | File Members

build/src/l2gen/calcite.c (r11331/r10609)

Go to the documentation of this file.

```
/*-----------------------------------------------------------------------*/
/* calcite.c -  get calcium carbonate concentration.                     */
/*                                                                       */
/* Inputs:                                                               */
/*     l2rec - level-2 structure containing one complete scan after      */
/*             atmospheric correction.                                   */
/* Outputs:                                                              */
/*     caco3 - calcium carbonate concentration, per pixel          .     */
/*                                                                       */
/* Written by: W. Robinson, GSC, 7 Jun 2000.                             */
/*             S. Bailey, OCDPG, July 2004, conversion to C.             */
/*             B. Franz, OCDPG, Sep 2004, sensor generalization and      */
/*                implementation of 2-Band algorithm.                    */
/*                                                                       */
/*-----------------------------------------------------------------------*/

#include <stdlib.h>
#include <math.h>
#include "l12_proto.h"
#include "l2_flags.h"


#define BAD_CACO3 BAD_FLT

static float pi       = PI;
static float radeg    = RADEG;
static int32_t  caco3_msk = LAND | HIGLINT | CLOUD;
static float caco3min  = 1.18e-5;     /* bcb */
static float bbstar = 4.0;            /* bcb */

/* --------------------------------------------------------------------- */
/* calcite_3b() - calcium carbonate concentration from 3-Band algorith.. */
/*                                                                       */
/* Gordon, H.R. Boynton, G.C., Balch, W.M., Groom, S.B., Harbour, D.S.,  */
/* Smyth, T.J., Retrieval of Coccolithophore Calcite Concentration from  */
/* SeaWiFS Imagery, GRL, 28, 8, 1587-1590.                               */
/*                                                                       */
/* --------------------------------------------------------------------- */

float get_bbstar(float lat) {
    static float c[] = {8.701E-01,1.200E-01,-5.999E-04,-6.606E-04,
           4.202E-05,-1.150E-06,1.614E-08,-1.138E-10,3.196E-13};
```

Assessment

4 - Assessment

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

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

SeaBASS

SeaBASS Search

Home | Data Users | Data Contributors | Data Search | NOMAD | Data Archive | Wiki | Lists | Contact Us

MODIS Aqua vs. In situ

Dates	1930-01-01 to 2015-05-08
Date Archived	2000-01-01 to 2015-05-08
North	90
South	-90
West	-180
East	180
Depth	0 to 10000
Output products	pic
Investigator/Experiment/Cruise	ALL
Data Source	seabass
Minimum valid satellite pixels	50
Maximum solar zenith angle	70
Maximum satellite zenith angle	56
Maximum time difference between satellite and in situ	3
Maximum coefficient of variation of satellite pixels	0.15
Maximum irradiance difference between measured and modeled	20
Maximum windspeed	35
Satellite version	R2013.1
Most Recent Data Update	2014-11-07 16:20:27

Permalink | Back to Validation Search

Search Results

Total number of matchups: 17

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

pic | Download Stats/Plots | Generate Data File (.csv) | Download Data File

Statistics | Data

Product Name	MODIS Aqua Range	In situ Range	#	Best Fit Slope	Best Fit Intercept	R^2	Median Ratio	Abs % Difference	RMSE
pic	0.00004, 0.00130	0.00003, 0.00065	17	1.92308	-0.00003	0.52004	1.70518	70.51802	0.00027

The linear regression algorithm has been changed to reduced major axis.

Product Lifecycle

from concept to standard product

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

Level-2 OC Product	Algorithm Changes
1. $R_{rs}(\lambda)$ 2. Ångstrom 3. AOT	*calibration updates, ancillary data updates, improved land/water masking, terrain height, other minor fixes* λ = 412, 443, 469, 488, 531, 547, 555, 645, 667, 678
4. Chlorophyll *a*	*new algorithm (Hu et al. 2012)*
5. $K_d(490)$	*coefficient update*
6. POC	*no change*
7. PIC	*updated algorithm and LUT*
8. CDOM_index	*remove product (redundant with new IOP suite)*
9. PAR	*consolidated algorithm, minor fixes*
10. iPAR	*MODIS-only, no change*
11. nFLH	*MODIS-only, flagging changes (allow negatives)*
12. IOPs	*added suite of inherent optical property products (Werdell et al. 2013)*

R2014.0 VIIRS OC Standard Product Suite

Level-2 OC Product	Algorithm Reference
1. $R_{rs}(\lambda)$	*Spectral water-leaving reflectance and derived*
2. Ångstrom	*aerosol optical properties*
3. AOT	λ = 410, 443, 486, 551, 671
4. Chlorophyll *a*	*Phytoplankton chlorophyll concentration*
5. $K_d(490)$	*Marine diffuse attenuation at 490nm*
6. POC	*Particulate organic carbon concentration*
7. PIC	*Particulate inorganic carbon concentration*
8.	
9. PAR	*Daily mean photosynthetically available radiation*
10.	
11.	
12. IOPs	*Suite of inherent optical property products (Werdell et al. 2013)*

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*

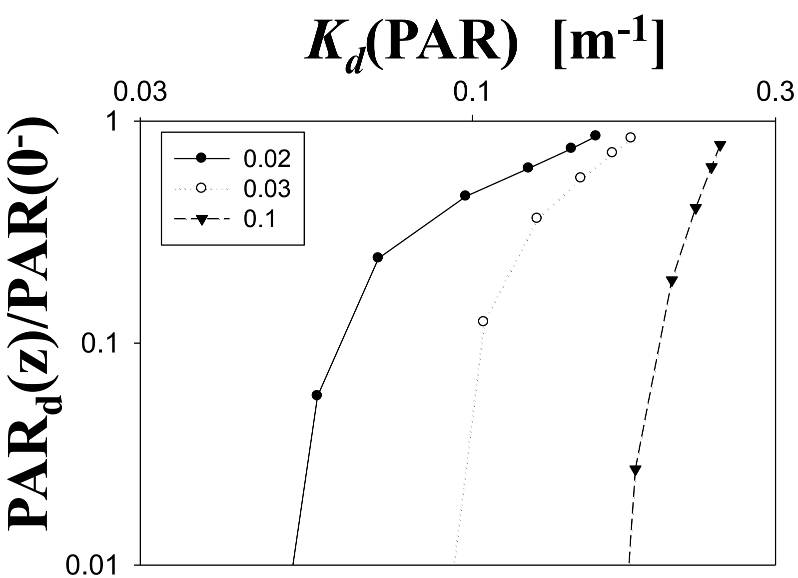
VIIRS	λ = 410, 443, 486, 551, 671
MODIS	λ = 412, 443, 469, 488, 531, 547, 555, 645, 667, 678

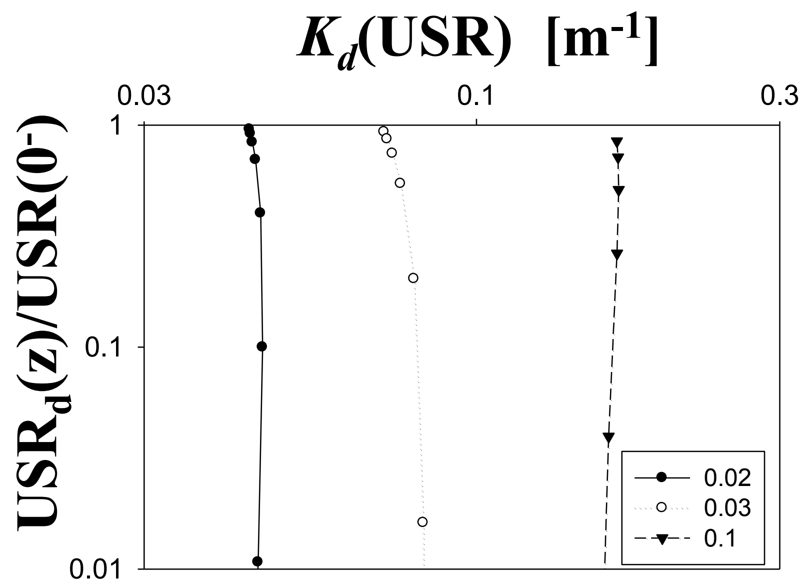
Current Evaluation Products

Products	Algorithm
Chl, $a_{dg}(443)$, $b_{bp}(443)$	Maritorena (GSM)
IOPs ($a(443)$, $a_{ph}(443)$, $a_{dg}(443)$, $b_{bp}(443)$)	Lee (QAA)
$K_d(412)$,$K_d(443)$,$K_d(490)$	Lee
Zeu	Lee
Zeu	Morel
K_{PAR}	Morel

Produced at Level-3 only (from daily binned Rrs)

Stop producing K_d(PAR)





(Lee et al 2013)

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

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?