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Chapter 1

SeaWiFS Postlaunch Calibration and Validation Overview

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Abstract

Since launch in August 1997, The SeaWiFS Project Office has worked diligently to improve all aspects of the mission, including refinements in mission operations, navigation accuracy, data processing efficiency, user and field operations support, and data product quality. Data product quality is the responsibility of the Calibration and Validation Team (CVT). The work of the CVT prior to launch is largely documented in the prelaunch *SeaWiFS Technical Report Series*, and other published documents and journal articles. Once operational SeaWiFS data processing began in September 1997, the CVT has made many improvements in the prelaunch processing algorithms as a result of innumerable analyses and evaluations. This two-volume set in the *SeaWiFS Postlaunch Technical Report Series* documents the major improvements and analyses that have been completed up to the third reprocessing in May 2000. These improvements have been incremental and have previously spawned reprocessings in January and August 1998. This chapter provides a review of the CVT activities and procedures.

1.1 INTRODUCTION

The SeaWiFS calibration and validation program has four basic areas of responsibility that include:

1) Providing the processing algorithms;
2) Verifying and documenting the level conversion processing code, i.e., level-0 through level-3;
3) Tracking sensor performance and calibration from fabrication through the lifetime of the mission; and
4) Verifying the quality of the data products.

These responsibilities encompass a broad range of science and technology. Given the original 28 month launch schedule, the SeaWiFS Project was hard pressed to define and implement a viable capability for mission operations, data capture, calibration and validation, and data processing. For the Calibration and Validation Team (CVT), the principal group originally identified by NASA management to assist the SeaWiFS Project was the Moderate Resolution Imaging Spectroradiometer (MODIS) Oceans Team. The SeaWiFS Project directly funded members of that team (H. Gordon, R. Evans, D. Clark, and K. Carder) to accelerate their respective activities and to assist the SeaWiFS Project prepare for launch.

The CVT also sought the participation and assistance of the ocean color community, fully recognizing that successful fulfillment of its objectives required the participation of a broader community. In many cases, this assistance was funded under grants and contracts, but most often, it was provided by individual researchers on a voluntary basis. As part of this process, CVT identified areas where the community infrastructure and capability was lacking or nonexistent for supporting global ocean color missions. To address these deficiencies, the CVT and the SeaWiFS Project Office initiated or accelerated a number of efforts:

1) Measurement protocols;
2) Calibration round-robins [SeaWiFS Intercalibration Round-Robin Experiments, (SIRREXs)];
3) Bio-optical Data Archive [SeaWiFS Bio-optical Archive Storage System, (SeaBASS)];
4) Prelaunch Bio-optical Algorithm Working Group†;
5) Advanced laboratory and *in situ* measurement technology;
6) *SeaWiFS Technical Report Series*‡ and;
7) The SeaWiFS Data Analysis System (SeaDAS)§

† After launch, the SIMBIOS program assumed many of the responsibilities related to algorithm development.

‡ The *SeaWiFS Technical Report Series* (pre- and postlaunch) are funded by the SeaWiFS Project Office. The majority of volumes are authored by members of the CVT and its collaborators.

§ The SeaDAS interative image processing software currently supports processing from the Coastal Zone Color Scanner (CZCS), SeaWiFS, the Ocean Color and Temperature Scanner (OCTS), and the Marine Optical Spectroradiometer (MOS). It also supports the display of MODIS ocean products.

Over the course of the extended prelaunch- and operational phases of the project, the CVT conducted and participated in many activities which are summarized in Table 1 and are reviewed in Hooker and McClain (2000).

The revised set (reprocessing #3) of archive geophysical data parameters and the quality control masks and flags are listed in Table 2. Level-1a data is in sensor counts and is navigated, but requires a separate transformation provided by the CVT to convert counts to radiance. The level-2 and -3 products are in geophysical units, e.g., milligrams per cubic meter ($\mathrm{mg\,m^{-3}}$). It is expected that the archive product list will grow as the ocean community defines new products and algorithms and as other Earth science disciplines begin using SeaWiFS data for atmospheric and terrestrial applications. Indeed, the SeaWiFS Project is actively encouraging the development of new products and applications and has worked with other groups to generate non-archive evaluation products, such as the normalized difference vegetation index (NDVI) over land. The SeaWiFS Project, however, does not have the expertise nor the resources to verify non-oceanic products.

1.2 DATA PROCESSING ALGORITHMS

Data processing algorithms include those for sensor calibration, stray light, atmospheric correction, bio-optical properties, masks, flags, and level-3 binning. There is a substantial amount of literature available on these topics for which Table 1 provides many of the references. It is not sufficient to simply verify and document individual algorithms, but the organization, links, and sequence of the data manipulations within the data processing system must also be described (Darzi 1998). A major component of all this is the creation of the file specifications and input–output routines. Much of this was undertaken by the CVT. In fact, SeaWiFS was one of the first NASA projects to adopt the hierarchical data format (HDF) and worked with the National Center for Supercomputing Applications (NCSA) during the HDF development.

The prelaunch verification of the processing was greatly facilitated by creating simulated data (Gregg et al. 1993 and 1994) by the Mission Operations Element and routine end-to-end processing coordinated by the Data Processing Element. The CVT worked closely with the algorithm providers, especially the University of Miami collaborators (H. Gordon, R. Evans, J. Brown, and others), who provided much of the level-2 and -3 processing code. As a result of the extensive prelaunch testing, data flowed through the processing system and to the GSFC Distributed Active Archive Center (DAAC) within hours of the first OrbView-II transmission to the receiving station at the NASA Wallops Flight Facility.

During the 120 day postlaunch data acceptance period, the CVT performed extensive analyses to verify that the acceptance criteria (Hooker and McClain 2000) were satisfied and presented its findings at a miniworkshop with members of the MODIS Oceans Team. Corrections to the operational algorithms during the first four months culminated in the first reprocessing in January–February 1998. More substantial changes, including incorporating time-dependent adjustments to the sensor calibration, necessitated the second (August–September 1998) and third (May 2000) reprocessings. Robinson et al. (2000, Vol. 10) summarize the primary changes for each reprocessing. Preparations for the third reprocessing included two miniworkshops where algorithm issues were reviewed and evaluation strategies were defined. The results of analyses conducted in preparation for the second and third reprocessings were posted on project web sites for consideration by the user community. Finally, for reprocessing #3, all level-1, -2, and -3 processing codes were rewritten and streamlined.

1.3 SENSOR CALIBRATION

Table 1 is a list of the various activities and accomplishments of the CVT including documents dealing with the SeaWiFS calibration and characterization and processing algorithms. In the postlaunch phase, the CVT has pursued a variety of analyses for tracking the on-orbit behavior of the instrument, which are included in the following list.

A. Prelaunch
   1. Laboratory sensor characterization and calibration
   2. Solar calibration for "transfer-to-orbit" comparison

B. Postlaunch
   1. Operational Adjustments
      a. Lunar calibration (monthly): Time dependence correction
      b. Solar calibration (daily): Time dependence (bands 7 and 8)
         i. Fine resolution check of lunar correction
      c. Open ocean $\epsilon(765, 865)$ analysis: Vicarious calibration (band 7)
      d. MOBY L_{WN} time series: Vicarious calibration (bands 1–6)

C. Product Evaluations
   1. Global clear-water time series (8-day binned data)
      a. L_{WN} (bands 1–6) $\epsilon(765, 865)$, $\tau_a(865)$, chlorophyll *a*, number of clear water bins
   2. $L_t - L_r < 0$ and negative L_W analyses (statistics and global distributions)
   3. $\tau_a(865)$ comparisons (AERONET versus SeaWiFS)
   4. L_W and L_{WN} comparisons (*in situ* versus SeaWiFS)
   5. Chlorophyll *a* and $K(490)$ comparisons (*in situ* versus SeaWiFS)
   6. E_s (surface irradiance) comparisons (*in situ* versus theoretical clear sky values)
   7. Global time series of mean cloud albedo at 865 nm (inconclusive and discontinued)

Table 1. Specific activities and accomplishments of the SeaWiFS CVT and collaborators. The term "Vol." indicates a *SeaWiFS Technical Report Series* volume; an underlined volume number indicates a volume in the *Postlaunch* Series). The CVT web site is located at `http://seawifs.gsfc.nasa.gov/~grey/calval.html`.

Activity or Accomplishment	*Reference*
Round-Robins and Measurement Protocols	
Six calibration round-robins	Vols. 14, 16, 34, 37, and 7
Joint US–Japan SeaWiFS–OCTS	Johnson et al., 1997
prelaunch cross-calibration	Johnson et al., 1997
Data collection protocols	Vols. 5 and 25 (revision)
Data analysis round-robin	Vol. 26
Tower shading effects experiment	Zibordi et al. 1999
Two measurement protocol experiments	Zibordi: Vol. 3
Calibration Instrumentation and Community Support	
SeaWiFS SWG *in situ* radiometer calibration support	CHORS, 1992–1995
SeaWiFS Transfer Radiometer (SXR)	Johnson: Vol. 1
SeaWiFS Quality Monitor (SQM)	Johnson et al. 1998 and Hooker and Aiken 1998
SeaWiFS Sensor Calibration and Characterization	
Two prelaunch solar-based calibration experiments	Vols. 19 and 27
Prelaunch acceptance report	Vol. 22
Prelaunch calibration, first report	Vol. 23
Prelaunch calibration, second report	Vol. 4
Stray light description	Vol. 31
Solar diffuser design	Vol. 39
Calibration temperature dependence	Vol. 40
Postlaunch data acceptance evaluation	December 1997
Science quality data certification	McClain et al. 1998
Lunar and solar data analysis procedures	Barnes et al. 1999
Prelaunch solar calibration transfer to orbit analysis	Vol. 5
Co-funded MODIS Oceans Team Activities	
Atmospheric corrections	Gordon
Semi-analytical chlorophyll algorithm	Carder
In situ vicarious calibration	Clark
Three operational Marine Optical Buoys (MOBY)	Clark et al. 1997
Support facility in Honolulu, Hawaii	
One shipboard spectrometer	
Routine deployments	July 1997–present
Two Marine Optical Characterization Experiments (MOCE)	Clark
Postlaunch data acceptance workshop	
SeaWiFS postlaunch initialization cruise	Clark and Gordon
Additional Supported Investigations	
Atmospheric correction studies	Fraser: Vols. 13, 19, and 27
Bermuda Atlantic Time Series (BATS) observations	Siegel
CalCOFI optical observations	Mitchell
Plymouth Marine Bio-Optical Data buoy (PlyMBODy)	Aiken: Vol. 33
Atlantic Meridional Transect (AMT) with PML[a]	Aiken: Vols. 35 and 2
Nine cruises	
Portable shipboard laboratory	
CTD and Niskin bottle rosette	
Bio-optical algorithm development and evaluation	O'Reilly
French cruise off NW Africa	Morel

Table 1. (cont.) Specific activities and accomplishments of the SeaWiFS CVT and collaborators. The term "Vol." indicates a *SeaWiFS Technical Report Series* volume; an underlined volume number indicates a volume in the *Postlaunch* Series). The CVT web site is located at `http://seawifs.gsfc.nasa.gov/~grey/calval.html`.

Activity or Accomplishment	*Reference*
Algorithm Development	
Workshops (Meeting summaries published)	Vols. 18, 24, 36, and 43
Seven prelaunch bio-optical algorithm and protocols workshops	
Absorption measurement workshop at SIO[b]	Mitchell
One calibration workshop	
Two atmospheric correction workshops (One was a joint meeting with MODIS Project)	
SeaWiFS Bio-optical Algorithm Mini-workshop (SeaBAM)	
SeaWiFS postlaunch data acceptance workshop	
Two SeaWiFS algorithm evaluation mini-workshops	
Atmospheric correction algorithm	Gordon and Wang 1994, and Gordon 1995
Bio-optical data archive (SeaBASS)	Vol. 20
Data quality masks and flag algorithms	Vol. 28
Out-of-band effects and correction scheme	Vols. 28, 39, 40, and 41
Initial level-3 binning algorithm	Vol. 32
$K(490)$ algorithm	Vols. 41 and <u>10</u>
SeaWiFS stray-light correction algorithm	Vol. 41
CZCS pigment and chlorophyll a algorithms	O'Reilly et al. 1998 and Vol. <u>10</u>
CVT image gallery	`http://calval-2.gsfc.nasa.gov/calval/`
Quality Control (QC) Software	
Operational QC Software	Vol. 38
Level-1, -2, and -3 quality assurance	
Ancillary data quality assurance (winds, pressure, ozone)	
Derived product evaluation	
Sensor engineering telemetry data tracking (Presently handled by Mission Operations)	
Calibration evaluation (lunar, solar, vicarious)	
Operational Processing Software	
Format specifications and code for all products	`http://seawifs.gsfc.nasa.gov/SEAWIFS/SOFTWARE/SOFTWARE.html#Product Specifications`
Documentation on final processing flow completed	Darzi 1998
Level-1, -2 and -3 code verification (At-launch and reprocessings No. 1–3)	
SeaWiFS Data Analysis System[c] (SeaDAS)	
Three training classes	Summer 1994
Preliminary version	Summer 1994
IDL licenses (45 total)	Distributed to the Science Working Group
One training class	May 1995
Version 1	Summer 1995
Sun workstation delivered to Shirshov Institute (Moscow)	1995
One training class	April 1996
Version 2	May 1996
Version 3	September 1997
Seven training classes	November 1997

Table 1. (cont.) Specific activities and accomplishments of the SeaWiFS CVT and collaborators. The term "Vol." indicates a *SeaWiFS Technical Report Series* volume; an underlined volume number indicates a volume in the *Postlaunch* Series). The CVT web site is located at `http://seawifs.gsfc.nasa.gov/~grey/calval.html`.

Activity or Accomplishment	*Reference*
SeaWiFS Data Analysis System[c] *(SeaDAS) (cont.)*	
Version 3.1	February 1998
Two training classes	July 1998
Version 3.2	October 1998
Version 3.3	April 1999
Linux version	May 1999
Version 4	May 2000

a. PML is the Plymouth Marine Laboratory.
b. SIO is the Scripps Institution of Oceanography.
c. SeaDAS is primarily funded by the NASA Oceanography Program, however, the SeaWiFS Project is presently providing the funding needed for equipment upgrades and system administration assistance. The SeaDAS staff rely largely on the CVT for processing code.

Table 2. SeaWiFS archived atmospheric and ocean surface products for Reprocessing #3. The quality control (QC) masks and flags are listed as well because some are used as exclusion criteria for the level-3 binning. The Tilt and Sensor Engineering Limits flags are applied line-by-line and are not represented in the level-2 products as graphic overlays.

Level	*Product Type*	*Product Name*
Level-1	Geolocated sensor counts†	
Level-2	Ocean Products	L_{WN}: 412, 443, 490, 510, 555, and 670 nm; Accuracy Goal: ±5%
		Chlorophyll *a*; Accuracy Goal: ±35% in Case-1 water
		$K(490)$
	Atmospheric Products	$\gamma(510,865)$ (Ångström exponent)
		$\tau_a(865)$
		$\epsilon(765,865)$
	QC Masks	Land‡
		Cloud and ice‡
		Sun glint‡
		Atmospheric correction failure or invalid data‡
		High L_t‡
		Chlorophyll algorithm failure‡
	QC Flags	Large solar zenith angle (increased to 75°) ‡
		Large satellite zenith angle‡
		Negative L_W (bands 1–5)§
		Stray light‡
		Coccolithophore‡
		Low $L_{WN}(555)$‡
		Outside chlorophyll *a* algorithm range (0–64.0)
		Missing ancillary data
		Turbid Case-2 water
		Shallow water
		High $\tau_a(865)$
		Tilt underway‡
		Absorbing aerosol‡
		Trichodesmium
		Maximum number of NIR iterations exceeded‡

† CVT provides calibration tables to convert counts to radiance separately.
‡ Masks and flags used as exclusion criteria in the generation of level-3 binned products.
§ Values set to 0 for binning.

Table 2. (cont.) SeaWiFS archived atmospheric and ocean surface products for Reprocessing #3. The quality control (QC) masks and flags are listed as well because some are used as exclusion criteria for the level-3 binning. The Tilt and Sensor Engineering Limits flags are applied line-by-line and are not represented in the level-2 products as graphic overlays.

Level	*Product Type*	*Product Name*
Level-2	QC Flags	
		Sun glint correction $L_r > L_t$‡ Outside ϵ range Sensor engineering limits exceeded
Level-3	Binned Products	All level-2 fields Chlorophyll $a/K(490)$

† CVT provides calibration tables to convert counts to radiance separately.
‡ Masks and flags used as exclusion criteria in the generation of level-3 binned products.
§ Values set to 0 for binning.

8. Earth curvature effects on L_r estimates
9. f/Q corrections (bidirectional reflectance) to L_W values (Morel and Gentili 1996)
10. Effects of alternative solar spectra, $F_0(\lambda)$, on vicarious calibrations and derived products
11. Band 8 calibration evaluation using clear sky, low chlorophyll region along Antarctic coast

Of the postlaunch analyses, all are described in detail in various chapters of this volume with the exception of the cloud albedo time series. The cloud albedo time series proved to be very noisy and was dropped after the lunar and solar calibrations were shown to be very robust for tracking sensor degradation.

The overall scheme for sensor calibration is shown in Fig. 1; it illustrates how the various prelaunch and postlaunch calibrations are connected. The lunar calibration is used to remove any time dependence in the sensitivity (Eplee and Barnes 2000, this Vol./lunar data analyses); the solar calibration is used as a cross check of the lunar measurements for bands 7 and 8 (Eplee and Barnes 2000, this Vol./solar data analyses). Because there is no accurate method for vicariously calibrating band 8 at this time, the prelaunch calibration is assumed. This assumption is verified to within ±2% by the solar calibration transfer-to-orbit results (Barnes et al. 1999). These results are supported by an analysis of clear sky (cloud albedo threshold set at 0.35), low chlorophyll waters, i.e., no NIR reflectance, along the Antarctic coast near 60°S,25°E during November 1997 through January 1998. Under these conditions, $L_t(865)$ always exceeded $L_r(865)$, i.e., band 8 is not undercalibrated, and the average $\tau_a(865)$ value was around 0.01, similar to minimum values observed at McMurdo during the same time, i.e., band 8 is not significantly overcalibrated.

Once the time dependencies are removed, the prelaunch calibration coefficients (Johnson et al. 1999) of bands 1–6 are adjusted using the Marine Optical Buoy (MOBY) matchups to minimize the average difference between the buoy and SeaWiFS normalized water-leaving radiances (Eplee and McClain 2000 this Vol./MOBY data analyses). The band 7 (765 nm) calibration is adjusted so that the $\epsilon(765, 865)$ values are near the values expected at the MOBY site (Robinson and Wang 2000, this Vol./band 7 calibration). Checks of the results of this process include analyses of the eight day global binned products to verify that no unexpected trends are occurring. For example, the second global reprocessing was initiated when it was realized that bands 7 and 8 were degrading. This degradation resulted in a steady increase in the $\epsilon(765, 865)$ values with a commensurate gradual decrease in the global mean clear water radiances.

Matchup analyses using independent *in situ* data sources are also used for verification (Bailey et al. 2000, Vol. 10). These analyses show that the SeaWiFS clear water radiances after the second reprocessing compare very well with the *in situ* values suggesting that the sensor calibration is correct. The comparisons, however, over regions of high chlorophyll and turbid water show that the SeaWiFS water-leaving radiances are low, particularly at 412 and 443 nm, which has been attributed to the assumption of zero water-leaving radiance at 765 and 865 nm in the atmospheric correction algorithm. One of the primary reasons for initiating global reprocessing #3 is to address this problem. Below is an outline of the entire calibration verification procedure.

A. Determine temporal degradation lunar calibration data
   1. Degradations in bands 1, 2, 5, 6, 7, and 8 observed
B. Determine nominal L_{WN} values from MOBY
   1. Use the same values as used in MOBY–SeaWiFS matchup data set
C. Set band 7 calibration correction factor
   1. Assume band 8 prelaunch calibration
      a. Calibration correction factor = 1.0

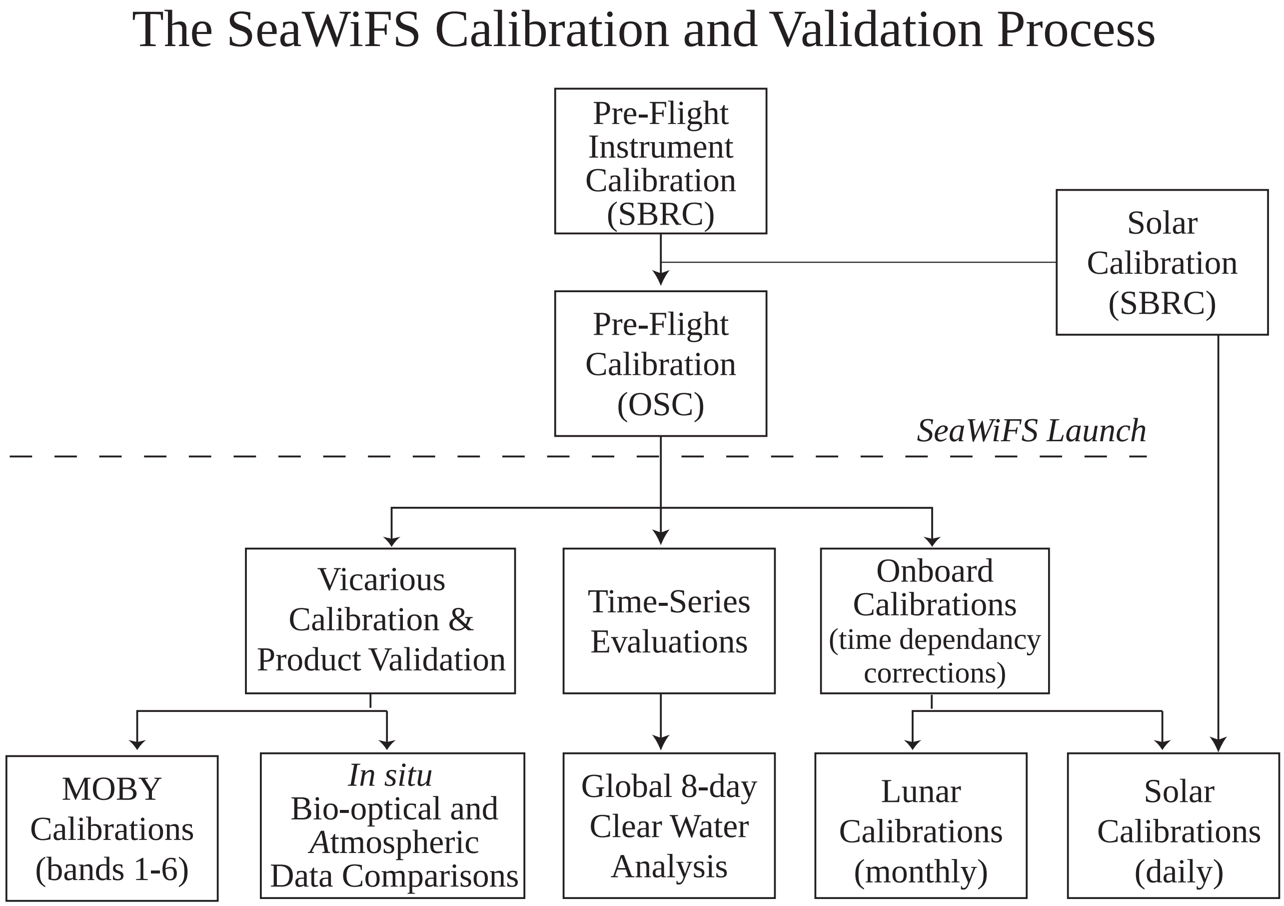

Fig. 1. Schematic of SeaWiFS calibration chronology and methods.

   b. Time-dependent degradation correction from lunar data
2. Adjust band 7 calibration factor to get appropriate mean $\epsilon(765, 865)$ value
   a. Time-dependent degradation correction from lunar data
   b. Use MOBY LAC time series

D. Analyze MOBY L_{WN} data for bands 1–6
1. Use theoretical E_s values
2. Check for trends in time series
3. Use MOBY LAC time series
4. Apply exclusion criteria to matchup data set
5. Adjust calibrations to minimize SeaWiFS–MOBY L_{WN} differences for valid matchup data
   a. Compute geometric mean of match-up ratios
   b. Generate final calibration adjustment factors

E. Check global clear-water L_{WN} values from eight-day composite time series and compare with nominal MOBY clear water values

F. Evaluate mask and flag performance (e.g., cloud and coccolithophore)

G. Run match-up analyses on other ship and buoy data for verification of clear water L_{WN} values

1.4 PRODUCT VALIDATION

Product validation consists of matchup analyses and real-time quality control. McClain et al. (1996) outline the various analyses that were envisioned prior to launch. Since launch, these analyses have been substantially expanded and refined as is outlined in this volume. All global area coverage (GAC) and local area coverage (LAC), including high resolution picture transmission (HRPT) station, data products are passed through automated checks and visual inspections before being approved for archiving at the GSFC DAAC. Not every file can be reviewed visually, but those that trigger a flag from the automated checks are inspected.

Another aid in diagnosing problems is the routine generation of quality control products which are not archived and are automatically purged after a certain period of time. The list of qualtiy control products up to reprocessing #3 was:

a) Zonal wind;
b) Ozone;
c) Sensor azimuth angle;

d) $L_r(443)$;
e) Aerosol model #2;
f) Merdional wind;
g) Solar zenith angle;
h) $L_{WN}(670)$;
i) $L_g(865)$;
j) Surface pressure;
k) Albedo at 865 nm;
l) $L_a(765)$;
m) $L_f(865)$;
n) Precipitable water;
o) Sensor zenith angle;
p) $L_t(443)$;
q) Aerosol model #1; and
r) $\epsilon(765, 865)$ flag (pixels having values outside the range of valid $\epsilon(765, 865)$ values.

These products were discontinued once reprocessing #3 commenced, as their routine generation was no longer necessary for product evaluation. The other aspect of quality control is the definition of quality control masks and flags. These are listed in Table 2 along with the level-3 exclusion criteria. Pixels that are masked are not processed to level-2. Pixels that are flagged are processed, but are not necessarily included in the level-3 products. Beginning with reprocessing #3, suites of quality control products and masks and flags will be refined at each reprocessing. It should be noted that the present suit of masks and flags are designed to optimize the accuracy of the chlorophyll *a* product. In the future, as suites of products for atmospheric, terrestrial, and other ocean parameters are defined, each will need its own set of masks and flags.

Finally, the CVT works closely with the Sensor Intercomparison and Merger for Biological and Interdisciplinary Ocean Studies (SIMBIOS) Project (co-located with the SeaWiFS Project; McClain and Fargion 1999) to provide cruise support so as to optimize the collection of *in situ* data with respect to the SeaWiFS coverage. This support includes overpass predictions in advance to assist researchers planning ship tracks and station times. The project provides real-time data products which can be tailored to the researchers needs via the SIMBIOS website (`http://simbios.gsfc.nasa.gov`). These products can be electronically mailed to the ship or point of contact. In addition, if the ship locations are known a week or more in advance of the satellite overpass, onboard LAC data can be scheduled to ensure that high resolution data over the ship will be available for matchup analyses.

During the first two years of operations, the project supported 125 field studies. In addition, LAC data is routinely scheduled over time series sites, such as MOBY; the *Acqua Alta* Oceanographic Tower (AAOT) in Venice, Italy; the Bermuda Atlantic Time-series Study (BATS) site; the Hawaii Ocean Time-series (HOT) site; certain Tropical Ocean Global Atmosphere (TOGA) program Tropical Atmosphere Ocean (TAO) moorings; and others. LAC recorder space that is not used to cover validation targets is used over default regions of interest, such as the Galapagos Islands. Figure 2 provides a typical LAC data collection summary. The SIMBIOS program supports a number of *in situ* data collection activities including cruise and mooring bio-optical data and aerosol optical thickness from a number of Aerosol Robotic Network (AERONET) sites. The matchup methodology for atmospheric parameters is outlined in Wang et al. (2000, this Vol./aerosol matchup analyses).

1.5 SUMMARY

Since the inception of the SeaWiFS Project in the early 1990s, the CVT has labored diligently to ensure that a comprehensive and effective calibration and validation program was in place by launch. The four-year launch delay allowed time for many capabilities to be realized in time for launch. The overall philosophy of the CVT has been to involve the research community as partners and to initiate activities which develop community infrastructure. In order to gain a better appreciation for the challenges of field data collection, the CVT has developed its own field program dedicated to improving measurement accuracy and collecting high quality bio-optical data. Dr. Stanford Hooker leads this effort and has been actively involved in the British Atlantic Meridional Transect (AMT) program (Robins et al. 1996 and Aiken et al. 1998) and a number of measurement protocol experiments on the Venice platform (Hooker et al. 1999).

With each reprocessing, significant improvements in the data products have been achieved. After the second reprocessing, problems with low or negative water-leaving radiances persisted in certain situations. As a result, improvements have been made in a number of algorithms in preparation for reprocessing #3:

1) Sensor degradation correction (Eplee 2000, this Vol./ lunar calibration)
2) Bilinear gain knee offset adjustments (Eplee 2000, this Vol./calibration knee offsets)
3) Improved ozone interpolation scheme (Ainsworth and Patt 2000 this Vol./)
4) Sun glint correction algorithm (Wang and Bailey 2000, this Vol./sun glint correction)
5) Surface whitecap correction (Robinson et al. 2000 second Vol./diagnostic analyses)
6) Various atmospheric correction algorithm improvements (Wang 2000, this Vol./atmos. correction updates; Siegel et al. 1999)
7) Absorbing aerosol detection (Hsu 2000/ Vol./ 10 absorbing aerosol flag)
8) Out-of-band corrections to L_W values (Wang et al. 2000 Vol./ 10 SeaWiFS spectral bandpass effects)
9) $K(490)$ algorithm (Mueller 2000/ Vol. 10, $K(490)$ algorithm revision),
11) Improved chlorophyll *a* algorithm (O'Reilly et al. 2000 second Vol./chl-a algorithm revision).

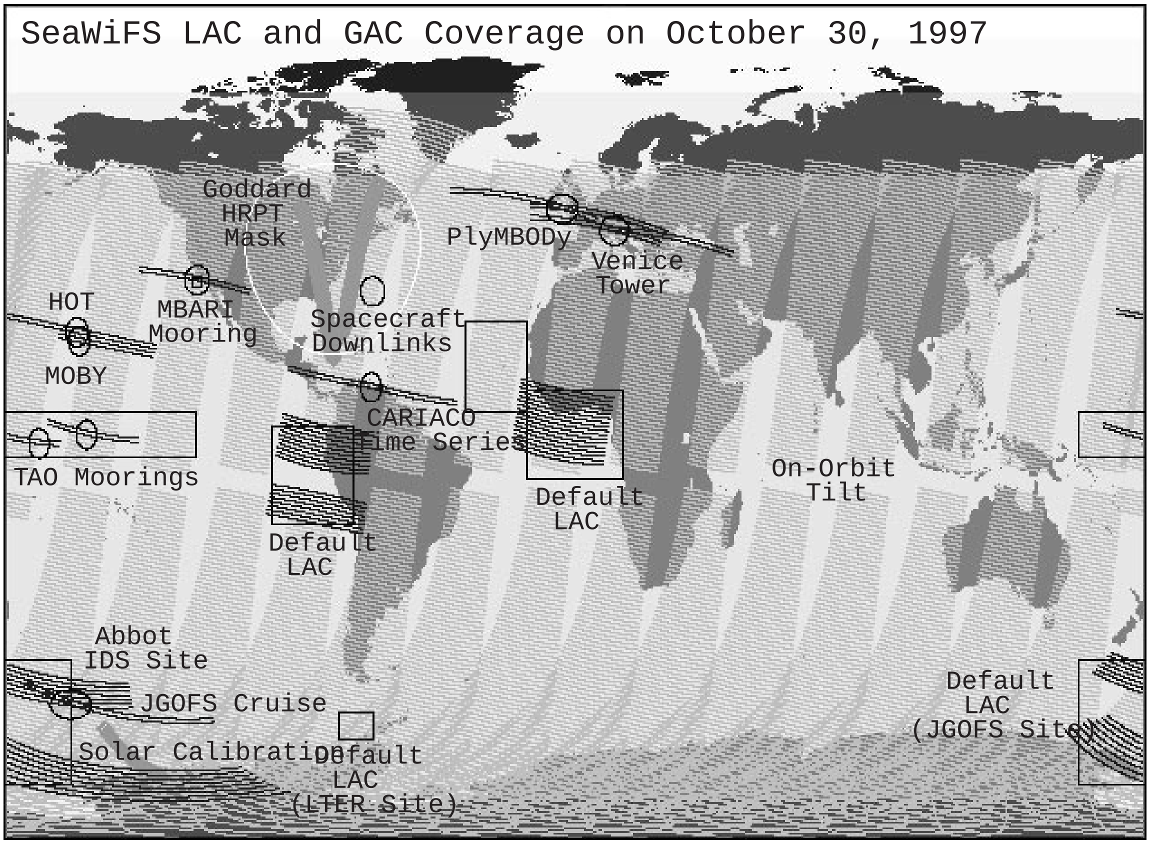

Fig. 2. A typical daily SeaWiFS onboard LAC data collection schedule.

These have been incorporated in the third reprocessing.

Other potential improvements were evaluated, but not incorporated. For instance, the Rayleigh radiance model was compared to other models, some with Earth curvature effects included. No significant differences were found for solar zenith angles less than 70°. Also, the bidirectional reflectance algorithm of Morel and Gentili (1996) was tested, but use of the algorithm was deferred until certain improvements could be implemented. Finally, a different solar spectrum was tried, but yielded almost identical results as the current spectrum, because the vicarious calibration compensates for the differences.

As further improvements and new products are defined, annual reprocessings are anticipated; the CVT will continue to work with the Data Processing Element on how processing efficiency can be maximized as the SeaWiFS data set grows.

Glossary

- AERONET Aerosol Robotic Network
- BATS Bermuda Atlantic Time-series Study
- CVT Calibration and Validation Team
- DAAC Distributed Active Archive Center
- GAC Global Area Coverage
- HDF Hierarchical Data Format
- HOT Hawaii Ocean Time-series
- HRPT High Resolution Picture Transmission
- LAC Local Area Coverage
- MOBY Marine Optical Buoy
- MODIS Moderate Resolution Imaging Spectroradiometer
- NCSA National Center for Supercomputing Applications
- NDVI Normalized Difference Vegetation Index
- PlyMBODy Plymouth Marine Bio-Optical Data Buoy
- SIMBIOS Sensor Intercomparison and Merger for Biological and Interdisciplinary Ocean Studies
- TAO Tropical Atmosphere–Ocean
- TOGA Tropical Ocean Global Atmosphere

References *** include:

Eplee 2000 this Vol./lunar calibration)

Hsu 2000 next Vol./absorbing aerosol flag)

Mueller 2000: next Vol./K(490) algo. revision)

O'Reilly and Maritorena 2000 second Vol./chl-a algorithm revision

Robinson et al. 2000: the surface whitecap correction (this Vol./diagnostic analyses)

Wang 2000: this Vol./atmos. correction updates

Wang and Bailey 2000, this Vol./sun glint correction

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