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# SeaWiFS Technical Report Series

**Stanford B. Hooker, Editor**
*Goddard Space Flight Center*
*Greenbelt, Maryland*

**Elaine R. Firestone, Technical Editor**
*General Sciences Corporation*
*Laurel, Maryland*

# Volume 18, SeaWiFS Technical Report Series Cumulative Index: Volumes 1–17

**Elaine R. Firestone**
*General Sciences Corporation*
*Laurel, Maryland*

**Stanford B. Hooker**
*Goddard Space Flight Center*
*Greenbelt, Maryland*

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
Greenbelt, Maryland 20771

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Abstract

The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) is the follow-on ocean color instrument to the Coastal Zone Color Scanner (CZCS), which ceased operations in 1986 after an eight-year mission. SeaWiFS is expected to be launched in 1995 on the SeaStar satellite, being built by Orbital Sciences Corporation (OSC). The SeaWiFS Project at the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC), has undertaken the responsibility of documenting all aspects of this mission, which is critical to the ocean color and marine science communities. This documentation, entitled the *SeaWiFS Technical Report Series,* is in the form of NASA Technical Memorandum Number 104566. All reports published are volumes within the series. This particular volume serves as a reference, or guidebook, to the previous 17 volumes and consists of 6 sections including: an errata, an addendum (summaries of various SeaWiFS Working Group Bio-optical Algorithm and Protocols Subgroups Workshops, and other auxiliary information), an index to key words and phrases, a list of all references cited, and lists of acronyms and symbols used. It is the editors' intention to publish a cumulative index of this type after every five volumes in the series. Each index covers the topics published in all previous editions, that is, each new index includes all of the information contained in the preceeding indices.


# 1. INTRODUCTION

This is the third in a series of indices, published as a separate volume in the Sea-viewing Wide Field-of-view (SeaWiFS) Technical Report Series, and covers information found in the first 17 volumes of the series. The Report Series is written under the National Aeronautics and Space Administration's (NASA) Technical Memorandum (TM) Number 104566. The volume numbers, authors, and titles are as follows:

Vol. 1: S.B. Hooker, W.E. Esaias, G.C. Feldman, W.W. Gregg, and C.R. McClain, *An Overview of SeaWiFS and Ocean Color.*

Vol. 2: W.W. Gregg, *Analysis of Orbit Selection for SeaWiFS: Ascending vs. Descending Node.*

Vol. 3: C.R. McClain, W.E. Esaias, W. Barnes, B. Guenther, D. Endres, S.B. Hooker, B.G. Mitchell, and R. Barnes, *SeaWiFS Calibration and Validation Plan.*

Vol. 4: C.R. McClain, E. Yeh, and G. Fu, *An Analysis of GAC Sampling Algorithms: A Case Study.*

Vol. 5: J.L. Mueller and R.W. Austin, *Ocean Optics Protocols for SeaWiFS Validation.*

Vol. 6: E.R. Firestone and S.B. Hooker, *SeaWiFS Technical Report Series Cumulative Index: Volumes 1–5.*

Vol. 7: M. Darzi, *Cloud Screening for Polar Orbiting Visible and IR Satellite Sensors.*

Vol. 8: S.B. Hooker, W.E. Esaias, and L.A. Rexrode, *Proceedings of the First SeaWiFS Science Team Meeting.*

Vol. 9: W.W. Gregg, F. Chen, A. Mezaache, J. Chen, and J. Whiting, *The Simulated SeaWiFS Data Set.*

Vol. 10: R.H. Woodward, R.A. Barnes, W.E. Esaias, W.L. Barnes, A.T. Mecherikunnel, *Modeling of the SeaWiFS Solar and Lunar Observations.*

Vol. 11: F.S. Patt, C.M. Hoisington, W.W. Gregg, and P.L. Coronado, *Analysis of Selected Orbit Propagation Models.*

Vol. 12: E.R. Firestone and S.B. Hooker, *SeaWiFS Technical Report Series Cumulative Index: Volumes 1–11.*

Vol. 13: C.R. McClain, J.C. Comiso, R.S. Fraser, J.K. Firestone, B.D. Schieber, E-n. Yeh, K.R. Arrigo, and C.W. Sullivan, *Case Studies for SeaWiFS Calibration and Validation, Part 1.*

Vol. 14: J.L. Mueller, *The First SeaWiFS Intercalibration Round-Robin Experiment, SIRREX-1, July 1992.*

Vol. 15: W.W. Gregg, F.S. Patt, and R.H. Woodward, *The Simulated SeaWiFS Data Set, Version 2.*

Vol. 16: Mueller, J.L., B.C. Johnson, C.L. Cromer, J.W. Cooper, J.T. McLean, S.B. Hooker, and T.L. Westphal, *The Second SeaWiFS Intercalibration Round-Robin Experiment, SIRREX-2, June 1993.*

Vol. 17: Abbott, M.R., O.B. Brown, H.R. Gordon, K.L. Carder, R.E. Evans, F.E. Muller-Karger, and W.E. Esaias, *Ocean Color in the 21st Century: A Strategy for a 20-Year Time Series.*

This volume within the series serves as a reference, or guidebook, to the aforementioned volumes. It consists of the four main sections included with the first two indices published, Volumes 6 and 12, in the series: a cumulative index to key words and phrases, a glossary of acronyms, a list of symbols used, and a bibliography of all references cited in the series. In addition, as in Volume 12, errata and addenda sections have been added to address issues and needed corrections that have come to the editors' attention since the volumes were first published.

The nomenclature of the index is a familiar one, in the sense that it is a sequence of alphabetical entries, but it utilizes a unique format since multiple volumes are involved. Unless indicated otherwise, the index entries refer to some aspect of the SeaWiFS instrument or project, for example, the *mission overview* index entry refers to an overview of the SeaWiFS mission. An index entry is composed of a keyword or phrase followed by an entry field which directs the reader to the possible locations where a discussion of the keyword can be found. The entry field is normally made up of a volume identifier shown in bold face, followed by a pages identifier, which is always enclosed in parentheses:

keyword, **volume**(pages).

If an entry is the subject of an entire volume, the volume field is shown in slanted type without a page field:

keyword, *Vol. #*.

For the first time in the series of indices, an entry can be the subject of a complete chapter, as in the chapters found in Volume 13. In this instance, both the volume number and chapter number appear without a page field:

keyword, *Vol. # ch. #*.

Figures or tables that provide particularly important summary information are also indicated as separate entries in the pages field. In this case, the figure or table number is given with the page number on which it appears.

## 2. ERRATA

1. Note: It had been expected that SeaWiFS would utilize the ozone measurement data obtained from the NIMBUS Total Ozone Mapping Spectrometer (TOMS). In May 1993, however, this instrument ceased operations. As of this writing, the alternative sensor that will provide equivalent or similar data for the SeaWiFS mission will either be the Earth Probe-Total Ozone Mapping Spectrometer (EP-TOMS) or the Television and Infrared Satellite (TIROS) Operational and Vertical Sounder (TOVS).
2. Note: The name of the Moderate Resolution Imaging Spectrometer (MODIS) has been changed to the *Moderate Resolution Imaging Spectroradiometer*; the acronym has stayed the same.
3. Note: Previously in the *SeaWiFS Technical Report Series,* mention was made of the *tilt* and *nadir* versions of the MODIS instrument—the so-called MODIS-T and MODIS-N variations, respectively. As of this writing, only the MODIS-N instrument will be developed and launched. In this, and all subsequent volumes of this series of technical memoranda, *MODIS* refers to this nadir version of the instrument.
4. In Volume 13 of the *SeaWiFS Technical Report Series,* "Case Studies for SeaWiFS Calibration and Validation, Part 1," Equation 19 was printed as:

$$A = \frac{I_0 - I_2}{I_0}, \qquad = 1 - \exp\left[\frac{-\tau_{ox}}{\mu_0 + \mu}\right]. \tag{19}$$

The correct equation should read:

$$A = \frac{I_0 - I_2}{I_0}, \qquad = 1 - \exp\left[-\tau_{ox}\left(\frac{1}{\mu_0} + \frac{1}{\mu}\right)\right]. \tag{19}$$

5. In Volume 3, page 34, under Section 3.5, the list of eight assumptions should read:
   1) For a given scene, the aerosol type, as characterized by the Ångström exponents, are constant. In the global CZCS processing, the Ångström exponents for all scenes were 0.1, 0, and 0 for 443, 520, and 550 nm, respectively. These values imply almost no wavelength dependence in aerosol scattering, which is approximately true for marine atmospheres.
   2) $L_W(670)$ was assumed to be zero everywhere.
   3) The Ångström exponent at 443 nm was assumed to be the average of those estimated at 520 nm in clear water regions.
   4) The second order interaction between Rayleigh and aerosol scattering was assumed to be zero.
   5) The sun glint mask algorithm assumed constant 6 m $s^{-1}$ wind speeds. No radiometric correction was made for sun glint or sea foam.
   6) The correction geometry assumed a flat Earth.
   7) The Rayleigh optical thickness was assumed to be constant. (In the global processing, the ozone optical thicknesses have been derived from Total Ozone Mapping Spectrometer (TOMS) Dobson units.)
   8) The water-leaving radiances were assumed to be independent of scan angle.
6. Also in Volume 3, a reference was incorrectly made to "Table 9." The reference should have read "Table 1, Volume 5" [of the *SeaWiFS Technical Report Series*].

7. Note: Since the issuance of previous volumes, a number of the references cited have changed their publication status, e.g., they have gone from "submitted" or "in press" to printed matter. In other instances, some part (or parts) of the citation has changed, for example, the title or year of publication. Listed below are the references in question as they were originally cited in one or more of the first 17 volumes in the series, along with how they now appear in the references section of this volume.

*Original Citation*

Gordon, H.R., and K. Ding, 1991: Self shading of in-water optical instruments. *Limnol. Oceanogr.*, **37,** 491–500.

*Revised Citation*

Gordon, H.R., and K. Ding, 1992: Self shading of in-water optical instruments. *Limnol. Oceanogr.*, **37,** 491–500.

*Original Citation*

Gregg, W.W., and F.S. Patt, 1993: Assessment of tilt capability for spaceborne global ocean color sensors. *IEEE Trans. Geosci. Remote Sens.*, (submitted).

*Revised Citation*

Gregg, W.W., and F.S. Patt, 1994: Assessment of tilt capability for spaceborne global ocean color sensors. *IEEE Trans. Geosci. Remote Sens.*, **32,** 866–877.

*Original Citation*

McClain, C.R., G. Feldman, and W. Esaias, 1993: Oceanic primary production, *Global Change Atlas*, C. Parkinson, J. Foster, and R. Gurney, Eds., Cambridge University Press, (in press).

*Revised Citation*

McClain, C.R., G. Feldman, and W. Esaias, 1993: Oceanic primary production, *Global Change Atlas*, C. Parkinson, J. Foster, and R. Gurney, Eds., Cambridge University Press, 251–263.

*Original Citation*

Patt, F.S., and W.W. Gregg, 1993: Exact closed-form geolocation algorithm for Earth survey sensors. *Int. J. Remote Sens.*, (submitted).

*Revised Citation*

Patt, F.S., and W.W. Gregg, 1994: Exact closed-form geolocation algorithm for Earth survey sensors. *Int. J. Remote Sens.*, (accepted).

# 3. ADDENDA

This section presents summaries of the following meetings which were held at the NASA Goddard Space Flight Center (GSFC):

a) the Second SeaWiFS Working Group (SWG) Bio-optical Algorithm and Optical Protocols Workshop (BAOPW-2) (Section 3.1) 8–10 November 1993; written by C. McClain, J. Mueller, and J. Acker;

b) the end-to-end software review of the Marine Optical Buoy (MOBY), 7–8 April 1994; written by S. Hooker (Section 3.2);

c) the SeaWiFS Calibration Subgroup Meeting, 12 April 1994; written by C. McClain (Section 3.3);

d) the SeaWiFS Atmospheric Correction Subgroup Meeting, 3 May 1994; written by C. McClain (Section 3.4);

e) the Third SWG Bio-Optical Algorithm and Optical Protocols Workshops (BAOPW-3), 12–13 May 1994; written by C. McClain (Section 3.5); and

f) the Fourth SWG Bio-Optical Algorithm and Optical Protocols Workshops (BAOPW-4), 9–10 November 1994; written by C. McClain (Section 3.6).

In addition, this section contains the SeaWiFS Baseline Product List, revised 26 April 1994—written by W. Esaias and C. McClain (Section 3.7)—and the names and addresses of all attendees of the aforementioned workshops and meetings (Section 3.8).

## 3.1 Bio-Optical Algorithms and Protocols

The following is a summary of the Second SeaWiFS Bio-optical Algorithm and Optical Protocols Workshop (BAOPW-2), which was held at GSFC on November 8–10, 1993. The primary workshop objectives were to: 1) define the initial SeaWiFS pigment and chlorophyll *a* algorithms, 2) complete a draft of the measurement protocols for Case-2 waters, and 3) draft recommendations for near- and long-term round-robin calibration program. Due to the way the workshop was conducted, the summary is arranged according to subject matter, and not in the session sequence. The team members and invited guests are listed in Table 1.

**Table 1.** Team members and invited guests to the BAOPW-2, held 8–10 November, 1993 at GSFC. The subgroup memberships are as listed in Hooker et al. (1993). Attendees are identified with a checkmark (✓).

| *Team Members* | *Present* | *Team Members* | *Present* |
|---|---|---|---|
| J. Aiken | ✓ | A. Morel | ✓ |
| W. Balch | ✓ | J. Morrison | ✓ |
| K. Carder | ✓ | J. Mueller | ✓ |
| D. Clark | | F. Muller-Karger | ✓ |
| C. Davis | | D. Siegel | |
| W. Esaias | ✓ | R. Smith | |
| H. Gordon | ✓ | P. Stegman | ✓ |
| F. Hoge | | C. Trees | ✓ |
| S. Hooker | ✓ | C. Yentsch | |
| M. Kishino | | | |
| G. Mitchell | ✓ | | |

### 3.1.1 Bio-optical Algorithm Sessions

1. *Introduction:* (C. McClain)
   - A. Workshop Objectives and Agenda
   - B. Review of Action Items from the First Workshop

#### *3.1.1.1 Bio-optical Algorithm Development*

The item numbers below follow the Workshop Charter stated for the first bio-optical algorithm and optical protocols workshop—BAOPW-1 (Firestone and Hooker 1993).

*Item 3A.*

*Bio-optical data sets:* The data sets to be provided to the SeaWiFS Project are shown in Table 2 along with their respective status.

Following the discussion on data set status, R. Doerffer agreed to provide North Sea data. Also, A. Morel commented that he has three classes of data: historical, intermediate, and recent. The historical data would be difficult to retrieve because of the media. Retrieving the intermediate data would require a substantial effort. The recent data, which was collected within the past two years, can be made available.

*Item 3B.*

*The SeaWiFS Project bio-optical data archive and distribution system* (C.R. McClain): The database structure and implementation plan for both the historical pigment database and bio-optical database have been defined and implemented. Documents describing both were distributed at the workshop and will become volumes in the *SeaWiFS Technical Report Series.* To date, both types of Coastal Zone Color Scanner (CZCS) Nimbus Experiment Team (NET) data, station and along-track, have been ingested into the bio-optical database.

Other bio-optical data sets that have been received and are being processed include optics-only data from the Joint Global Ocean Flux Study (JGOFS) North Atlantic Bloom Experiment (NABE) and the JGOFS Equatorial Pacific Process Study (EqPac), provided by C. Trees; and optics-only data from the World Ocean Circulation Experiment (WOCE), provided by J. Marra. Several historical pigment data sets have been ingested, including data from A. Longhurst (North Atlantic); G. Mitchell [Research on Antarctic Coastal Ecosystem Rates (RACER)]; and JGOFS EqPac station data. In addition, the data from the first two calibration round-robins (SeaWiFS Intercalibration Round-Robin Experiments, SIRREX-1 and SIRREX-2) have been ingested, and the prelaunch calibration and characterization data for the SeaWiFS instrument from Hughes/Santa Barbara Research Center (SBRC) is also being ingested.

*SeaWiFS Bio-optical Database* (S.B. Hooker): The SeaWiFS Calibration and Validation Program implemented an on-line database for round-robin, SeaWiFS prelaunch calibration, and bio-optical data. The system and present holdings were described. The data distribution policy and plans related to expanding the holdings were discussed.

*Item 3C.*

*Semi-analytical algorithm development* (H. Gordon, K. Carder, A. Morel, and R. Doerffer): K. Carder assumed the lead in the chlorophyll pigment algorithm development.

*Strawman Operational Pigment and Chlorophyll a Algorithms* (K. Carder): Per the recommendation from the first bio-optical algorithm workshop, the pigment and chlorophyll algorithms should be semi-analytical, encompass both Case-1 and Case-2 waters, and should allow for *seamless* space-time variability in key parameters as the bio-optical database becomes more global in coverage. K. Carder has assumed the responsibility of developing the methodology and presented his initial approach.

The chlorophyll algorithm requires estimates of remote sensing reflectance at 412, 443, 555, and 670 nm, and knowledge of both the $Q$ factor and backscatter and absorption coefficients for water, Gelbstoff, and phytoplankton at 412, 443, and 555 nm. A number of issues were discussed, including:

- a) the availability of data sets containing suitable measurements of the free parameters;
- b) the estimation of specific absorption coefficients for phytoplankton;
- c) test criteria for branch points in the algorithm logic; and
- d) the incorporation of relationships based on inherent optical properties (IOP) into the algorithm.

One major concern is the present lack of suitable measurements over a wide variety of water masses.

*Strawman Operational Pigment and Chlorophyll a Algorithms Continued* (K. Carder): Further discussion on the strawman algorithm was concluded. K. Carder will incorporate several suggestions into a revised version of the algorithm which he will provide to the SeaWiFS Project by early January 1994.

*Item 4.*

*Quality Control (QC) Flags and Masks*

*Cloud mask* (C.R. McClain, R. Evans, S. Gallegos, K. Arrigo, and R. Stumpf): C. McClain examined an albedo threshold approach using the CZCS 750 nm band. K. Arrigo presented results for CZCS scenes having low sun elevations, ice, and coccolithophore blooms. S. Gallegos presented some results from the work she had done on a statistical approach for a cloud and ice mask.

*Coccolithophore flag* (H. Gordon, W. Balch, F. Hoge, and C. Brown): C. Brown presented an algorithm for flagging coccolithophore blooms in CZCS imagery.

*Sea ice flag* (G. Cota, J. Aiken, K. Arrigo, R. Zaneveld, and G. Moore): It is generally felt that insufficient data is available to develop an ice flag separate from a cloud flag.

*Trichodesmium flag* (A. Morel and A. Subramaniam): A. Subramaniam presented some observations and analyses of *in situ* data from *Trichodesmium* blooms. He also

**Table 2.** Bio-optical data sets to be provided to the SeaWiFS Project.

| *Team Members* | *Source* | *Status* |
|---|---|---|
| K. Carder | North Atlantic<br>Gulf of Mexico | Not received<br>Not received |
| J. Mueller<br>C. Trees | North Pacific | Not received (permission needed from the Navy) |
| D. Clark | CZCS NET Data [1]<br>MOCE-I [2]<br>MOCE-II | Received<br>Being processed<br>Being processed |
| C. Davis | Equatorial Pacific<br>North Atlantic<br>U.S. West Coast | Not received<br>Not received<br>Not received |
| M. Kishino | Tokyo Bay<br>Sea of Japan | Not received<br>Not received |
| G. Mitchell | RACER | Pigments received<br>Optics not received |
| | CalCoFI 1 [3]<br>CalCoFI 2 | Not received<br>Not received |
| R. Arnone<br>A. Weidemann<br>J. Mueller | Gulf of Mexico | Not received |
| D. Siegel | Bermuda | Not received |

[1] Coastal Zone Color Scanner NIMBUS Experiment Team
[2] Marine Optical Characterization Experiment
[3] California Cooperative Fisheries Institute

submitted a recommendation on an approach to developing a flag algorithm.

*Bottom reflectance flag* (K. Carder, C. Davis, W. Esaias, and R. Arnone): The SeaWiFS Project decided to use a bathymetry database to flag shallow water areas, rather than rely on a radiometric algorithm.

*Land mask* (R. Evans and C.R. McClain): A combination of geographic and radiometric algorithms will be used. Implementation is underway.

*Item 5.*

1. *Bio-optical Field Program Update* (S. Hooker): This session was meant to provide an update of recent field activities relevant to algorithm development with brief presentations of the results, if available. The session concluded with a discussion of bio-optical cruises planned by the community in order to evaluate overall program deficiencies and strategies.

   A. Report on MOCE-II (S. Hooker): The SeaWiFS Project's Calibration and Validation Group maintains a schedule of bio-optical cruises (Fig. 1). Additions or changes to that schedule included the following (also in Fig. 1):

      1) Oligotrophy in the Pacific (OLIPAC) Ocean, A. Morel, June 1994;
      2) (Geochemical) Fluxes in the Pacific (FLUPAC) Ocean, A. Morel, August 1994;
      3) Arabian Sea, J. Aiken, August–October 1994;
      4) North Sea, J. Aiken, November 1994;
      5) JGOFS Arabian Sea Bio-optics, November 1994;
      6) Yellow Sea, C. Trees, July 1994;
      7) U.S. Mid-Atlantic Bight, D. Kamykowski, late 1994;
      8) Chesapeake Bay, F. Muller-Karger, annual, 1993–1995;
      9) Gulf of California, J. Mueller and *Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)* Principal Investigators, (November 1994, March, June, and November 1995); and
      10) Naval Research Laboratory (NRL) Arabian Sea, A. Weidemann, June–July 1995.

*Item 6.*

*Alternative bio-optical data collection strategies* (J. Mueller, K. Carder, C. Davis, G. Mitchell, and R. Arnone): Little progress has been made. K. Carder and C. Davis will provide a draft protocol in the January–February 1994 time frame.

| Location | Contact | Brief Description of Activities | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Calendar Year 1991* | | | | | | | | | | | | | | |
| Monterey Bay | D. Clark | MOBY test deployment. | | | | | | | | ■ | | | | |
| Moss Landing | D. Clark | Submersible *in situ* radiometer test. | | | | | | | | | | ■ | | |
| *Calendar Year 1992* | | | | | | | | | | | | | | |
| Bermuda | D. Siegel | JGOFS pigments and optical time series. | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Lake Pend Oreille | R. Zaneveld | ONR Optical Closure Experiment. | | | | ■ | ■ | | | | | | | |
| Monterey Bay | D. Clark | MOCE-1 instrumentation shake-down. | | | | | | ■ | ■ | | | | | |
| Monterey Bay | D. Clark | MOBY at-sea test. | | | | | | | | | | ■ | | |
| *Calendar Year 1993* | | | | | | | | | | | | | | |
| Bermuda | D. Siegel | JGOFS pigments and optical time series. | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| S. California Bight | G. Mitchell | CalCoFI bio-optical algorithm validation. | ■ | | | ■ | | | ■ | | | ■ | | |
| Gulf of California | D. Clark | MOCE-2 final integration of instruments. | | | ■ | ■ | | | | | | | | |
| Gulf of Mexico | R. Arnone | Navy optical instruments shake-down. | | | | ■ | | | | | | | | |
| Lanai, Hawaii | D. Clark | Deep sea mooring (for MOBY) deployment. | | | | | | | | | | ■ | | |
| Monterey Bay | D. Clark | Final test of prototype MOBY. | | | | | | | | | | | ■ | |
| Weddell Sea | J. Torres | Phytoplankton production and biomass. | | | | | | | | | | | ■ | ■ |
| *Calendar Year 1994* | | | | | | | | | | | | | | |
| Bermuda | D. Siegel | JGOFS pigments and optical time series. | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| S. California Bight | G. Mitchell | CalCoFI bio-optical algorithm validation. | ■ | | | ■ | | | ■ | | | ■ | | |
| Lanai, Hawaii | D. Clark | MOBY prototype deployment. | | ■ | | | | | | | | | | |
| Gulf of Mexico | A. Weidemann | Navy regional Case 2 algorithms cruise. | | | ■ | ■ | ■ | | | | | | | |
| Mid-Atlantic Bight | D. Kamykowski | Case 1 and Case 2 pigments. | | | | ■ | | | | | | | | |
| Lanai, Hawaii | D. Clark | MOBY refurbishment. | | | | | ■ | | | ■ | | | ■ | |
| Lanai, Hawaii | D. Clark | MOCE-3 initialization and certification. | | | | | | | | ■ | ■ | | | |
| Sargasso Sea | A. Weidemann | Navy Case 1 and 2 algorithms cruise. | | | | | | | | | ■ | | | |
| Arabian Sea | R. Arnone | Navy Case 1 and 2 pigments cruise. | | | | | | | | | ■ | ■ | ■ | |
| Arabian Sea | W. Balch | JGOFS mini-process study cruise. | | | | | | | | | | ■ | | |
| Gulf of California | D. Clark | MOCE-4 calibration and validation cruise. | | | | | | | | | | | ■ | |
| *Calendar Year 1995* | | | | | | | | | | | | | | |
| Bermuda | D. Siegel | JGOFS pigments and optical time series. | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Lanai, Hawaii | D. Clark | MOBY refurbishment. | | ■ | | | ■ | | | ■ | | | ■ | |
| Gulf of Mexico | D. Clark | MOCE-5 calibration and validation cruise. | | | | ■ | ■ | | | | | | | |
| Arabian Sea | R. Arnone | Navy Case 1 and 2 pigments cruise. | | | | | | ■ | ■ | | | | | |
| Canary Islands | D. Clark | MOCE-6 calibration and validation cruise. | | | | | | | | ■ | ■ | ■ | | |
| *Calendar Year 1996* | | | | | | | | | | | | | | |
| Bermuda | D. Siegel | JGOFS pigments and optical time series. | ■ | ■ | ■ | ■ | ■ | | | | | | | |
| Arabian Sea | R. Arnone | Navy Case 1 and 2 pigments cruise. | ■ | | | | | | | | | | | |
| Lanai, Hawaii | D. Clark | MOBY refurbishment. | | ■ | | | ■ | | | ■ | | | ■ | |
| Eastern Pacific | D. Clark | MOCE-7 calibration and validation cruise. | | | | | | ■ | ■ | | | | | |

**Fig. 1.** Field deployment schedule for SeaWiFS, as of late 1993.

#### *3.1.1.2 Special Topics*

This session, led by C. McClain, was for discussing topics of interest relevant to algorithm development, SeaWiFS QC, and ocean color missions. The topics discussed were:

a) SeaWiFS sensor status update, W. Esaias;
b) Regression analyses for bio-optical algorithms, J. Campbell;
c) Remote sensing reflectance from inherent optical properties, R. Zaneveld;
d) $K(490)$ algorithms, Case-1 Water, C. Trees;
e) $K(490)$ algorithms, Case-2 Water, R. Arnone;
f) Coccolithophore detection, C. Brown;
g) *Trichodesmium* detection, A. Subramaniam;
h) Cloud and ice detection, S. Gallegos;
i) Cloud and ice detection, K. Arrigo; and
j) Marine Optical Spectroradiometer (MOS) and *Priroda*, A. Neumann.

During the presentations on $K(490)$, the point was made that the baseline Austin-Petzold algorithm is robust over a broader range of Case-1 waters than the original data set encompassed. It was also shown, however, that the algorithm is not accurate in turbid Case-2 waters.

The Austin-Petzold relationship remains the baseline for $K(490)$. This algorithm, however, is not accurate in very turbid Case-2 waters. K. Carder will continue to refine his chlorophyll *a* algorithm and will provide an update to the Project by the end of the year. J. Aiken volunteered to examine the existing CZCS pigment algorithm and assess its performance using additional data sets. He will provide those results to the Project by the March 1994 SWG meeting.

Questions were raised regarding the SeaWiFS distributed products (W. Esaias) about whether or not the current level-2 and level-3 products are the most useful for the user community. For instance, it is not clear that binned normalized water leaving radiances at wavelengths other than 550 nm have any applications. Also, the bio-optical algorithms may use reflectance and $E_0$. Should adjustments in the present product list be recommended? A lengthy discussion resulted with a decision to continue the deliberations later in the workshop. When discussions resumed, they focused primarily on the definition and usefulness of the CZCS pigment product. It was agreed that the most accurate estimates of water-leaving or normalized water-leaving radiance should be used to compute the pigment product, rather than to employ values derived using a method identical to the CZCS atmospheric correction. The final recommendations were synthesized and are listed in the tables found in Section 3.7. These recommendations will be distributed to the SWG for comment and will be formally addressed at the March SWG meeting.

### 3.1.2 Optical Protocols

Attendees and invited guests to the Round-Robin and Optical Protocols Working Group are found in Table 3.

#### *3.1.2.1 Workshop Objectives and Agenda*

J. Mueller lead the summary and status action items from the first workshop, again using the item numbers from the BAOPW-1 meeting (Firestone and Hooker 1993).

**Table 3.** Round-Robin and Optical Protocols Working Group attendees. The subgroup memberships are as listed in Hooker et al. (1993).

| *Team Members* | *Present* | *Team Members* | *Present* |
|---|---|---|---|
| D. Clark | | M. Lewis | |
| C. Davis | | C. McClain | ✓ |
| R. Doerffer | ✓ | G. Mitchell | |
| W. Esaias | ✓ | A. Morel | ✓ |
| H. Gordon | ✓ | J. Mueller | ✓ |
| F. Hoge | | D. Siegel | |
| M. Kishino | | R. Smith | |
| O. Kopelevich | | R. Zaneveld | ✓ |
| *Other Attendees* | | | |
| R. Arnone | | S. Gallegos | |
| K. Arrigo | | J. Morrow | |
| C. Brown | | A. Neumann | |
| J. Campbell | | A. Subramaniam | |
| R. Evans | | G. Zimmerman | |

*Item 1A.*

*Ship shadowing* (D. Siegel and J. Mueller): No progress to report.

*Item 1B.* Not discussed

*Item 1C.*

*Bio-optical algorithm instrumentation specifications* (J. Mueller): No progress to report. J. Mueller has obtained the CZCS NET data and will be performing correlation analyses to see what corrections can be made to observations at wavelengths near to, but not coincident with, the SeaWiFS bands.

*Item 1D.*

*Case-2 water protocols* (K. Carder, C. Yentsch, R. Doerffer, F. Muller-Karger, C. Davis, W. Esaias, A. Weidemann, R. Arnone, and R. Stumpf): No progress to report. R. Doerffer will provide data to assist in the development of these protocols.

*Item 1E.*

*Data quality control* (J. Mueller, D. Siegel, C. Davis, A. Weidemann, G. Mitchell, and H. Gordon): J. Mueller will present some initial comparisons later in the workshop. More comprehensive analyses need to be completed.

*Item 1F.*

*Aircraft data collection protocols* (C. Davis, F. Hoge, K. Carder, M. Lewis, and P. Slater): No progress to report.

*Item 1G.* Not discussed

#### 3.1.2.2 Case-2 Protocols

The group, lead by J. Mueller, discussed the areas in which new protocols must be drafted to reflect:

a) well-known difficulties associated with making accurate radiometric and optical measurements in turbid Case-2 waters, and
b) the increased need for accurate measurements of IOP to develop and validate semi-analytic algorithms of the form recommended by the Algorithm Working Group.

This recommendation is for algorithms based, in any of several forms, on the interrelationships between the ratio $b_b/a$, chlorophyll concentration, and remote sensing reflectance. Physically, remote sensing reflectance ($R_{rs}$) may be accurately modelled as a function of the ratio of backscattering to absorption, where absorption is strongly dependent, and scattering is somewhat dependent, on pigment concentrations. Pigment concentrations are often expressed using chlorophyll *a* concentration as a proxy index for a *typical* oceanic phytopigment assemblage.

The *classical* ratio algorithm simply assumes the following: other absorbing substances are either constant or covariant with chlorophyll *a*; and the log of a ratio of two radiometric quantities, e.g., upwelling radiances, can be approximated by a linear function. The classical type algorithm will calculate least-squares coefficients for the apparent functional relationship between the radiometric quantities.

A semi-analytic algorithm, of the type proposed for SeaWiFS, expresses some (or all) IOP explicitly in terms of chlorophyll, theoretical relationships, or constants, then combines equations for two or more wavelengths and inverts the result to solve for chlorophyll. In several models, reflectance is expressed as a function of the ratio of backscattering to absorption, which in turn is then empirically linked to chlorophyll *a* concentration.

To date, most observational algorithm development has been limited to finding direct correlations between chlorophyll and spectral combinations of remote sensing reflectance. This emphasis is reflected in the brevity with which IOP measurement and analysis protocols are presented in the SeaWiFS Optical Protocols (Mueller and Austin 1992), even though they are specified as *required* variables for bio-optical algorithm development. Given the explicit appearance of IOP in the proposed baseline algorithm and recent advances in instrumentation to measure spectral absorption, beam attenuation, and segments of the volume scattering function, the majority of the working group members seem to favor revising the protocols to emphasize IOP measurements more prominently (albeit an explicit vote was not taken on that issue).

The workshop discussions identified three general areas where new, or strengthened protocols are necessary. These are:

1) Experiment design and sampling methods for algorithm development in Case-2 waters (R. Doerffer);
2) Protocols and related database for measuring absorption (R. Zaneveld); and
3) Protocols and related database for measuring scattering (R. Zaneveld).

Individuals identified in parentheses will orchestrate the development of protocols for each area. A detailed outline of the specific subtopics identified in each area is given below, together with the names of potential contributors (those on the working group agreed to provide input, and contributions from the others will be solicited).

It was agreed to pull each topic area together as a *loose-leaf notebook* containing individual working reports, etc., from the identified contributors, with a brief overview and summary recommendation for new protocols written by the topic leader (identified in parentheses above). J. Mueller will coordinate the overall effort, and will draft recommended protocol additions, or revisions, based on the material presented. The intent is to assemble this material by early February 1994 for distribution to all SeaWiFS Science Team members. The protocol numbers refer back to the same numbered sections in Mueller and Austin (1992).

*Outline*
*(contributors identified in parentheses)*

I. Experiment Design and Sampling Methods for Algorithm Development in Case-2 Waters
   A. Overview of Case-2 Sampling Methods and Experiment Design (R. Doerffer)
   B. Instrument Self-Shadow Effects [Gordon and Ding model].
      1. Near-IR tank experiments (R. Doerffer and J. Mueller)
         a. Wave and platform effects (R. Doerffer and J. Mueller)
         b. Above-water remote sensing reflectance measurements, including Gulf of Mexico Experiment (GOMEX) results (K. Carder, C. Davis, R. Arnone, and J. Mueller).

II. Absorption: Measurement Protocols and Database
   A. Overview and Absorption Protocol Recommendations (R. Zaneveld)
   B. Absorption Measurement Methods
      1. Filter Method vs. Reflecting Tube Absorption Comparisons (C. Roesler, R. Zaneveld)
      2. "$\beta$-Factor" Comparisons in Filter Particle Absorption Measurements (J. Cleveland)
      3. Benchtop Absorption Meter for Dissolved Organics (K. Carder)
      4. Methods for Separating Constituent Components of Absorption (K. Carder and R. Zaneveld)
      5. Filter Specifications [Protocol 5.4.3] (C. Trees)

B. Database: Absorption, Chlorophyll, and other variables.
   1. Overview, summary, and coordination of data base assembly (J. Campbell)
   2. Filter Absorption and Pigment data sets (G. Mitchell, K. Carder, M. Kishino, C. Roesler, and others who will be determined at a later date).
   3. Filter Absorption, Pigments, and Radiometry Data Sets (K. Carder; M. Wernand; R. Doerffer; J. Cleveland, C. Trees, and J. Mueller; K. Voss, and B. Balch, and others who will be determined at a later date).
   4. Absorption, other IOP, Pigments, and Radiometric Profiles (R. Zaneveld, Pend Orielle Closure Experiment, and East Puget Sound)
   5. Protocol 5.4.2 and 5.2.4.3 Review and Revision (K. Carder, R. Zaneveld, R. Doerffer, and C. McClain)

III. Scattering: Measurement Protocols and Database
   A. Overview of Scattering Measurement Methods, Prognosis for Improved Instruments and Methods, Protocol Recommendations (R. Zaneveld)
   B. Backscattering Measurement:
      1. Single-Wavelength $\beta(170°)$ (R. Maffione)
      2. Intermediate and large angle scattering meter development [5 angles at 9 wavelengths] (R. Zaneveld)
      3. General Angle Scattering Meter (GASM) (K. Voss)

#### *3.1.2.3 Data QC and Analysis Round-Robin*

J. Mueller lead this discussion on a follow-up of an activity initiated during the protocols workshop in May 1993 (Firestone and Hooker 1993). He presented some initial comparisons between his analysis technique and that used by C. Davis of diffuse attenuation coefficients and derived water-leaving radiances, which indicated some large discrepancies for some optical profiles. Further analysis, and the participation of others, is required.

#### *3.1.2.4 Calibration Round-Robin*

Results from SIRREX-2 (J. Mueller): The results obtained from SIRREX-2 indicate a significant improvement over SIRREX-1 in terms of the sphere comparisons, etc. The final report will be submitted to the Project by December 1994 for publication in the *SeaWiFS Technical Report Series* (see Mueller 1994).

*Recommendations for SIRREX in 1994*

1. SIRREX-3 (Group Experiments):
   a. Continue the sphere characterizations and radiance scale transfers with emphasis on spatial and angular uniformity and temporal stability.
   b. Verify stability and stray light rejection for all transfer radiometers.
   c. Examine the bidirectional diffuse reflectance of the plaques.
2. Radiometer Round-Robins:
   a. Calibrate selected sets of radiometers at several laboratories within 3–4 week intervals, and test comparability of *blind test* results.
   b. Follow up on discrepancies as appropriate.
3. FEL lamp irradiance standards
   a. Schedule FEL lamps for transfers at GSFC on an annual basis.
4. Error budget analyses
   a. Document overall calibration error budget illustrating goals, SIRREX accomplishments to date, and schedule for meeting goals.

#### *3.1.2.5 The Long-Term Round-Robin Program*

The SeaWiFS Project is supporting the present round-robin program, which has a limited duration and scope (C. McClain). Questions that need to be addressed include:

1. How will the activity be expanded and supported in the future within the US?
2. How will it be managed?
3. How will an international program be coordinated? It was also recommended that an approach for quantifying the overall impact of the round-robin comparison program on the quality of *in situ* optical measurements be defined.

## 3.2 MOBY Review Summary

An end-to-end software review of the MOBY was held 7–8 April 1994 at GSFC, the attendees of which are listed in Table 4. The review was triggered by an inability of the buoy to properly multi-task during its February 1994 deployment off the coast of Lanai, Hawaii. More specifically, the buoy cannot collect data reliably if the cellular telephone communications task is running while the MOBY data acquisition task is executing. It is important to note, however, that the buoy is collecting data successfully, but in a more simplistic serial mode; that is, the buoy collects *in situ* data once per day, does nothing else during that acquisition event, and then stops acquisition before attempting the next scheduled activity.

A review panel comprised of GSFC Forth (an interactive and interpretive language used in small computers) experts, autonomous system experts, and Project personnel was assembled to meet with the MOBY Team to assist in determining the source of the multi-tasking problem. The Project representatives also reviewed the MOBY data processing and distribution plan.

### 3.2.1 Agenda

The following is the agenda followed for this review.

**7 April 1994**

| | | |
|---|---|---|
| 0800 | Introductory Remarks | C. McClain |
| 0810 | MOBY System Overview | D. Clark |
| 0830 | End-to-end Communications Overview | W. Broenkow |
| 0850 | Hardware (as it relates to software) Overview | M. Yarbrough |
| 0910 | MOBY Software Overview | W. Broenkow |
| 0930 | MOBY Operating System | R. Reeves |
| 1000 | *Break* | |
| 1010 | Resume Review | |
| 1200 | *Adjourn* | |
| 1330 | *Afternoon Session* | |
| 1500 | Meeting with Nancy Farnan | |
| 1530 | Review of Contract Deliverables | D. Clark |
| 1700 | *Adjourn* | |

**8 April 1994**

| | | |
|---|---|---|
| 0800 | Introductory Remarks and Morning Agenda | C. McClain |
| 1000 | *Break* | |
| 1010 | Resume Review | |
| 1200 | *Adjourn* | |
| 1330 | *Afternoon Session* | |
| 1340 | Post-processing Software Overview | D. Clark |
| 1400 | Individual Post-processing Elements | W. Broenkow |
| 1500 | *Adjourn* | |

**Table 4.** MOBY review attendees.

| *Attendee* | *Level of Participation* |
|---|---|
| Samuel Bergeson-Willis | Participant |
| William Broenkow | MOBY Team |
| Robert Caffrey | Review Panel |
| Dennis Clark | MOBY Team |
| Mary Cleave | Participant |
| Michael Darzi | Participant |
| Wayne Esaias | Participant |
| Stanford Hooker | Review Panel |
| Charles McClain | Review Panel |
| Todd Miller | Review Panel |
| Richard Reaves | MOBY Team |
| Thomas Riley | Review Panel |
| Shane Hynes | Review Panel |
| Mark Yarbrough | MOBY Team |

### 3.2.2 Review Panel Comments

The MOBY Review Panel had a number of comments based on the information presented.

1. The panel members were impressed with the operating system and the people who built it. They feel it is based on a sound architecture and should work. It appears to be a multi-tasking Forth system with each task operating in a non-preemptive round-robin fashion. The system is a hybrid Forth modeled after a particular commercial package (probably polyForth) but patterned after several others.
2. The execution problem is probably due to a programming bug in the Forth code. Stack overflow, which could be caused by improper clean-up of the stack when a task completes and exits, is the most likely source of difficulty .
3. Richard Reaves is the only person who understands the MOBY operating system, so he is a single point of failure. Another person needs to be brought on to ensure Richard's knowledge is duplicated and retained by the Team.
4. The MOBY Team is needlessly isolated and should investigate a wider participation in the Forth community. The Special Interest Group (SIG) Forth and Forth Interest Groups are user groups that can provide an opportunity for the Team to meet other Forth programmers. There is a user community in Monterey (near the Team's locale in Salinas, California).
5. Another opportunity for interaction in the Monterey area is Everett "Skip" Carter who has developed a buoy using Forth (408-899-0336 and on the Internet: skip@taygeta.oc.nps.navy.mil).
6. The MOBY Team should investigate the use of version control software (VCS) or a public domain program.
7. The MOBY Team should schedule code walk-throughs at a frequency in keeping with the level of elapsed development and the importance of the version being created, i.e., major revisions requiring substantial effort need reviews.
8. Once the MOBY Team has implemented many of the recommendations, particularly the data simulator, one of the panel members should probably visit Moss Landing Marine Laboratory (MLML) and review the progress made.
9. The present data processing system requires manual intervention to handle all calibration and formatting.
10. No QC is currently in place, although some parts of such a system are under consideration or rudimentary design.

### 3.2.3 Action Items for the MOBY Team

Action items to be completed by the Team include:

a. Overview details need to be agreed upon. This begins with a highest-level sketch of what the system looks like and is followed by a diagram of the basic functional units, each of which performs a well-specified task. This diagram includes the pathways and interfaces between the various components and must be supported by lists of requirements and specifications. The lists detail what each basic unit does by itself and in relation to the other units, via the data pathways and interfaces, which means the interfaces must also be completely described. Once an overview of the buoy is completed, the entire system is largely defined and the requirements for the operating system, which will control its execution, can then be specified (or in this case, completely evaluated).

b. A list of tasks and a description of what each task does needs to be created. This should also include what activates and deactivates a particular task.

c. The time it takes to execute one loop in the round-robin should be determined and monitored.

d. Timing diagrams need to be produced, in part, to establish whether or not the hardware can support what the software is required to do, and also to aid the debugging effort.

e. A watchdog timer should be implemented.

f. The stack depth is a good indicator of system health and should be monitored. The current stack depth is frequently at 30 and should usually be less than 8 and never above 20 (as a rule of thumb).

g. An interactive programming environment should be created. Right now the program cannot be debugged when it runs. This will require the implementation of a `TALKER` task.

h. A simulator for each data source should be created, probably using personal computers (PCs) or local area transport (LAT) interfaces on a VAX (if the proper data rates can be simulated). This will allow for testing and debugging even when the buoy is unavailable.

i. The `GET` and `RELEASE` Forth commands should be looked at. There may be a requirement associated with their use for certain functions to be locked out when tasks exit.

j. An automated processing capability should be developed prior to the launch of SeaWiFS.

k. MLML should itemize the tasking, milestones, and resource requirements for near-real time data analysis. In particular, the QC modules, both in terms of how the data is collected and processed, need to be clearly presented.

## 3.3 Calibration Subgroup Meeting

The SeaWiFS Calibration Subgroup Meeting was held on 12 April 1994. The purpose of the meeting was to review the results of analyses on the prelaunch calibration and characterization data provided by Hughes/SBRC. These data are being archived within the SeaWiFS Calibration and Validation database. The archived data will be described in a separate technical memorandum within the *SeaWiFS Technical Report Series* (Volume 23).

| | | |
|---|---|---|
| 0830 | *Introduction* | C. McClain |
| 0845 | Prelaunch Sensor Calibration Data and Data Analyses | |
| | Calibration Equation† | R. Barnes |
| | Sensor Certification Matrix† | |
| | Out-of-Band Radiance Corrections† | |
| | Stray Light Corrections† | R. Barnes |
| 1100 | Prelaunch Ground-based Solar Calibration† | Biggar/Slater |
| 1130 | SeaWiFS Transfer Radiometer† | C. Johnson |
| 1200 | *Lunch* | |
| 1330 | GSFC Sphere Status and SeaWiFS Scale Maintenance | J. McLean |
| 1400 | SeaWiFS Calibration Plans During Thermal Vacuum Testing Period at GSFC | R. Barnes |
| 1500 | Post-launch Vicarious Calibration Plans | Biggar/Slater |
| 1530 | Post-launch Vicarious Calibration at Hawaii Optical Mooring Site | C. McClain |
| 1600 | General Discussions | |

## 3.4 Atmospheric Correction Subgroup

The meeting of the SeaWiFS Atmospheric Correction Subgroup was held at GSFC on 3 May 1994. The purpose of the meeting was a comprehensive discussion regarding both the current status of the SeaWiFS algorithm and further required improvements to the algorithm. In addition, the ongoing problem of the oxygen absorption band was discussed.

| | | |
|---|---|---|
| 0830 | Introduction | C. McClain |
| 0845 | Status Report on the Operational SeaWiFS Atmospheric Correction Scheme | H. Gordon |
| 1000 | *Break* | |
| 1015 | Aircraft Measurement of Reflectance off the Antarctic Peninsula Using an Airborne Polarization and Directionality of Earth's Reflectances (POLDER) Simulator | R. Frouin |
| 1115 | CZCS Atmospheric Corrections Using Look-up Tables† | R. Fraser |
| 1200 | *Lunch* | |
| 1330 | Preparations for the Advanced Earth Observation Satellite (ADEOS) or POLDER Mission as Related to SeaWiFS | P. Deschamps |
| 1415 | Oxygen Absorption at 765 nm† | R. Fraser |

† Topics slated for publication within the Series.

| | | |
|---|---|---|
| 1430 | Investigations of Oxygen Absorption Effects at 765 nm on the Operational SeaWiFS Algorithm | H. Gordon |
| 1445 | A Proposed Out-of-Band Correction Scheme† | R. Barnes |
| 1515 | Current Implementation of the Operational Atmospheric Correction Algorithm | H. Gordon |
| 1530 | *Discussion* | |

The meeting was small, but very informative and constructive. H. Gordon's work on the operational algorithm has progressed substantially since the previous atmospheric correction workshop in May 1993. The initial description of the algorithm has been published by Gordon and Wang (1994), and other augmentations to the algorithm, including the glint flag, the whitecap correction, and the 765 nm oxygen absorption correction have been either completed or are well underway.

Gordon has also analyzed the limitations of the plane parallel assumption and found that the assumption introduces negligible errors for SeaWiFS geometries. Primary concerns at present are corrections in the presence of absorbing aerosols, e.g., Saharan and Asian dust, and the effects of stratospheric aerosols.

## 3.5 Bio-Optical Algorithm and Protocols

This section summarizes BAOPW-3, held at GSFC on 12–13 May 1994. The attendees and invited guests to BAOPW-3 appear in Table 5.

The purposes of the workshops were to 1) finalize the initial operational SeaWiFS pigment and chlorophyll *a* algorithms, and 2) complete the measurement protocols for Case-2 waters.

### 3.5.1 Bio-Optical Algorithm Development

1. *Introduction* (C. McClain):
   A. Workshop Objectives and Agenda
   B. SeaStar/SeaWiFS update
2. *Operational Chlorophyll a Algorithm* (K. Carder): Since the last bio-optical algorithm meeting, there has been considerable discussion between K. Carder, R. Zaneveld, J. Mueller, and D. Siegel on the form of the chlorophyll *a* algorithm. All agree on the basic structure of the algorithm, and that the algorithm should be modular so that specific components can be isolated and replaced as improved parameterizations are developed. Of primary concern is the temporal and spatial variability in phytoplankton absorption coefficients.
3. *Band Ratio Algorithms for SeaWiFS and CZCS* (J. Aiken): J. Aiken described a variety of multiple band ratio algorithms for a number of geophysical parameters. One issue is whether the CZCS pigment product should utilize bands other than those that are similar to the CZCS bands. The Project's present position is it should not unless it can be demonstrated that other band ratio algorithms produce a significant improvement in the pigment retrievals. Also, assuming the CZCS data will eventually be reprocessed using improved atmospheric and cloud masking algorithms, an attempt to develop a more geographically robust algorithm using only the CZCS bands should be undertaken.

**Table 5.** Team members and invited guests to the SWG Bio-optical Algorithm and Protocols Workshops, held 12–13 May 1994 at GSFC. Attendees are identified with a checkmark (✓).

| *Team Members* | *Present* | *Team Members* | *Present* |
|---|---|---|---|
| J. Aiken | ✓ | C. McClain | ✓ |
| W. Balch | | G. Mitchell | ✓ |
| K. Carder | ✓ | A. Morel | |
| D. Clark | ✓ | J. Mueller | ✓ |
| C. Davis | ✓ | F. Muller-Karger | ✓ |
| R. Doerffer | ✓ | D. Siegel | ✓ |
| W. Esaias | ✓ | R. Smith | |
| H. Gordon | ✓ | C. Trees | ✓ |
| F. Hoge | | C. Yentsch | ✓ |
| S. Hooker | | J. Yoder | ✓ |
| D. Kamykowski | ✓ | R. Zaneveld | ✓ |
| M. Kishino | ✓ | | |
| O. Kopelevich | | | |
| *Other Attendees* | | | |
| S. Ackleson | | L. Harding | |
| M. Behrenfeld | | S. Hawes | |
| C. Brown | | J. Morrow | |
| J. Campbell | | H. Schiller | |
| H. Fukushima | | | |

The point was also made that the SeaWiFS Project plans to periodically reprocess the entire SeaWiFS data set as improvements to the atmospheric, bio-optical, and calibration algorithms are developed, and the suite of derived products can be modified with each reprocessing as the Science Team recommends. The only limitation at present is the data volume and number of data granules passed to the GSFC Distributed Active Archive Center (DAAC).

### 3.5.2 Optical Protocols

1. *Workshop Objectives* (J. Mueller)
2. *Case-2 Protocols:*
   A. Overview and Strawman Outline (J. Mueller)
   B. Status of the Absorption Database Development (J. Campbell)
   C. Case-1 and Case-2 Discrimination (R. Doerffer)
   D. Absorption Protocols (C. Trees and R. Zaneveld)

E. Scattering Protocols (R. Zaneveld): Drafts of sections of the Case-2 protocols were written in advance and distributed. J. Campbell has been soliciting absorption spectra data from the community and some data and preprints of data analyses have been provided. As a result of R. Doerffer's presentation, the terms "Case-1" and "Case-2," as originally defined by Prieur and Morel, may not be appropriate for the purposes of measurement protocols.

3. *Data QC and Analysis Round-Robin* (D. Siegel): D. Siegel will organize and host a small data analysis round-robin at UCSB this summer. The purpose is to quantify the differences among various algorithms for estimating surface upwelling radiance, irradiance, and diffuse attenuation coefficient. The participants will draft a publication based on their results.
4. *An Atmospheric Correction Scheme for Turbid Waters* (J. Aiken): J. Aiken described a *brightest* pixel method for the atmospheric correction of turbid water using aircraft data.
5. *An Instrument Self-Shading Experiment* (R. Doerffer): R. Doerffer described a laboratory experiment designed to quantify instrument self-shading effects. It was recommended that he test the Gordon and Ding (1992) correction scheme.
6. *An Update on the Chlorophyll Measurement Protocols* (C. Trees): C. Trees discussed recent revisions of the JGOFS protocols based on information provided by R. Bidigare and his own work.
7. *Wavelength Interpolation Analyses* (J. Mueller): J. Mueller presented initial empirical orthogonal function (EOF) analyses of the CZCS NET radiometer data. The objective is to quantify how well the observed upwelling water radiance and irradiance spectra, and the downwelling irradiance spectra, can be determined from radiometric observations at a limited number of wavelengths. If sufficient accuracy can be achieved, observations at wavelengths near, but not identical to, the SeaWiFS bands can be used for algorithm development. Suggestions offered included separating the different radiometric parameters and performing separate analyses on each and partitioning the data into unique water types.

### 3.5.3 Bio-Optical Algorithm Development

1. *The MODIS Document Archive (MODARCH),* (D. Herring): D. Herring presented a brief description of the MODARCH system which the EOS/MODIS program is using to archive documents and presentation materials. The system can be accessed through the Internet.
2. *Operational Chlorophyll a Algorithm Continued* (K. Carder): Discussions on the chlorophyll *a* algorithm were continued based on previous deliberations.
3. *Field Program Reports*
   A. Bermuda Bio-optical Time Series (D. Siegel)
   B. CalCoFI Bio-optical Data Set (G. Mitchell)
   C. MOCE and MOBY Update (D. Clark)
   D. GOMEX Data Update (J. Mueller)
   E. Navy Field Program Update (C. Davis)
   F. United Kingdom (UK) Field Program Update (J. Aiken)
   G. Japanese Field Program Update (M. Kishino)
   H. German Field Program Update (R. Doerffer)

The intent was not to present results, but activities and data set development status. D. Siegel is routinely feeding data into the SeaWiFS bio-optical database. G. Mitchell has several hundred high latitude historical bio-optical stations ready for submission to the database pending the outcome of the data analysis round-robin. He has also participated in six CalCoFI cruises. The GOMEX data is nearly ready for submission by J. Mueller and C. Trees (most of the pigment data has been received already). D. Clark described the first and second MOCE cruises in Monterey Bay, the Gulf of California, and Baja regions. The initial processing of these data is about 90% complete. He described recent progress with the MOBY deployment and support facility development in Hawaii. The buoy was deployed in February and will be retrieved in June 1994.

C. Davis discussed the optical observations to be collected on six Navy and NSF sponsored cruises in the Arabian Sea during 1994 and 1995. J. Aiken, M. Kishino, and R. Doerffer provided updates on British, Japanese, and German bio-optical cruise plans over the next year, respectively. The SeaWiFS launch slip is having a serious impact on some of these programs as most were either designed as post-launch validation cruises or were counting on SeaWiFS coverage to meet their scientific objectives.

### 3.5.4 Calibration Round-Robin

1. *Calibration Round-Robin* (J. Mueller)
   A. Hawaii Intercomparison Study: J. Mueller and C. Cromer described a mini-round-robin conducted at the MOBY support facility in Hawaii. As a result of the experiment, several modifications to the calibration sphere configuration are being recommended.
   B. Immersion Coefficient Study: J. Mueller discussed laboratory measurements of the immersion coefficients required for the calibration of irradiance measurements. Some concerns have been raised regarding the historical values applied to marine environmental radiometers (MERs).
   C. SIRREX-3 Activities: J. Mueller briefly outlined the activities to be conducted during the next round-robin at CHORS. Several participants suggested the event be slipped beyond the present July schedule.

2. *Neural Network Applications* (H. Schiller): H. Schiller described an application of neural network methodologies to the inversion of CZCS water-leaving radiance data for estimation of chlorophyll *a* and other quantities in Case-2 water. The approach results in substantially reduced processing times.

### 3.5.5 Workshop Wrap-Ups

*Summaries, Action Items, Final Discussions, etc.*

Tthe topics for discussion in this segment were: the operational chlorophyll *a* algorithm (D. Siegel), and protocols and round-robin (J. Mueller).

The Action Items included the following:

1. K. Carder, working with R. Zaneveld, D. Siegel, and J. Mueller, will generate a draft document describing the chlorophyll *a* algorithm, implementation, and rationale which will be submitted to the SeaWiFS Project by mid-June.
2. J. Aiken, D. Clark, and C. Trees will generate a draft document on the rationale and form of CZCS and SeaWiFS band ratio algorithms which will be submitted to the SeaWiFS Project by mid-June.
3. J. Mueller has several action items including the following:
   A. Collate the Case-2 protocol documents and modifications to the existing protocols, and submit these to the SeaWiFS Project;
   B. Finalize the comparison of his MER with the MOBY radiometer, which he conducted in Hawaii;
   C. Notify the SIRREX-3 participants of the agenda and work that must be completed in advance (one item is the mapping of sphere apertures and a recommended measurement scheme must be defined);
   D. Complete the processing of the GOMEX optical measurements and provide them to the SeaWiFS Project;
   E. Complete the immersion coefficient study in collaboration with Biospherics, Inc. and refine the protocols section on immersion coefficients as required; and
   F. Work with C. Davis on the completion of the analysis of their initial study on reflectance measurements.
4. K. Carder, C. Davis, J. Mueller, and R. Doerffer are to collaborate on the remote sensing reflectance protocol. R. Doerffer will be executing a 10-day field study during July 1994 in the North Sea which should provide additional data for the verification of the technique.

## 3.6 BAOPW-4

This summary is of the Fourth SeaWiFS Bio-optical Algorithm Optical Protocols Workshop (BAOPW-4), held at GSFC on 9–10 November, 1994. The primary workshop objectives were to: 1) finalize the initial operational CZCS pigment, chlorophyll *a*, and $K(490)$ algorithms and 2) complete the update of the *in situ* measurement protocols. Due to the way the workshop was conducted, the summary is arranged according to subject matter, not the session sequence. Attendees and invited guests are listed in Table 6.

### 3.6.1 Bio-optical Algorithm Sessions

1. *Introduction* (C. McClain)
   A. Workshop objectives and agenda
   B. Review of Action Items from the third workshop
   C. SeaStar/SeaWiFS update

**Table 6.** Team members and invited guests to the BAOPW-4, held 9–10 November 1994 at GSFC. Attendees are identified with a checkmark (✓). Those people who came in members' places are indicated with their names in parentheses and are listed directly below the member's name.

| *Team Members* | *Present* | *Team Members* | *Present* |
|---|---|---|---|
| J. Aiken | | O. Kopelevich | |
| (G. Moore) | ✓ | M. Lewis | ✓ |
| W. Balch | | C. McClain | ✓ |
| K. Carder | ✓ | G. Mitchell | ✓ |
| D. Clark | | A. Morel | |
| G. Cota | ✓ | J. Mueller | ✓ |
| C. Davis | ✓ | F. Muller-Karger | |
| R. Doerffer | | | |
| W. Esaias | ✓ | D. Siegel | ✓ |
| H. Gordon | | R. Smith | |
| F. Hoge | ✓ | C. Trees | |
| S. Hooker | | C. Yentsch | ✓ |
| D. Kamykowski | | J. Yoder | |
| (G. Kirkpatrick) | ✓ | (A. Bernard) | ✓ |
| M. Kishino | ✓ | R. Zaneveld | |
| *Other Attendees* | | | |
| J. Campbell | | D. Phinney | |
| G. Fargion | | A. Webb | |
| R. Frouin | | J. Zaitzeff | |
| S. Hawes | | | |

2. *The NASA/HQ Perspective* (R. Frouin)
3. *The Operational Chlorophyll a Algorithm* (K. Carder): Based on comments received during and since the last bio-optical algorithm workshop, K. Carder has restructured the algorithm and rewritten the algorithm description. That document was distributed to the Science Working Group Bio-optical Algorithm Subgroup in August for comment. The subgroup is now generally satisfied with the algorithm structure. The primary concern is that the algorithm has been developed using

a small data set from the Gulf of Mexico, the North Pacific, and the North Atlantic. There are also some concerns about the particulate backscattering coefficient parameterization. To address the issue of general applicability, an independent validation effort is being undertaken. The validation will seek to test not only the algorithm as a whole, but also specific components of the algorithm. The specific components include the following:

A. Remote sensing reflectance as a function of absorption and backscattering coefficients;
B. Particulate backscatter coefficient as a function of reflectance at 443, 490, and 555 nm;
C. Gelbstoff absorption as a function of absorption at 400 nm;
D. Phytoplankton absorption spectrum as a function of the phytoplankton absorption at 675 nm; and
E. Chlorophyll *a* concentration as a function of phytoplankton absorption at 675 nm.
    1) J. Campbell, working with the SeaWiFS Project, will solicit and distribute contributed data sets for this purpose. One recurring comment voiced by several attendees was the concern that the absorption coefficients for water being used by the marine optics community may be too large. K. Carder will provide the algorithm code to anyone who wishes to participate.
    2) If the semi-analytic chlorophyll algorithm fails to return a value, a reflectance ratio algorithm is used. K. Carder and G. Moore will examine the ratio defined in the draft document† and also examine alternative empirical algorithms (see discussion in next section).

4. *CZCS Pigment Algorithms—both Empirical and Semi-analytic* (G. Moore): G. Moore presented results of studies on empirical and simulated ratio algorithms and provided an initial draft of a paper‡ for comment. The paper also examines relative concentrations of different pigments. The group suggested that an algorithm using two 2-band reflectance ratios be used for the operational CZCS pigment product. The options, however, are available from the presentation included only ratios with 412 and 443 nm reflectances in the numerator. In high concentration waters, these reflectances are small and are subject to errors due to the atmospheric correction, instrument noise, and instrument calibration. It was suggested that G. Moore examine algorithms which incorporate a 490–555 nm reflectance ratio rather than a ratio using the 412 nm band. It was also decided that the best band ratios available should be used and not just those compatible with the CZCS band. He should also incorporate K. Carder's data into the analysis.
5. *SeaWiFS $K(490)$ Algorithm* (J. Mueller): The question is whether or not the differences between the CZCS bands and SeaWiFS bands, i.e., 550 nm versus 555 nm, cause a significant change in the Austin-Petzold $K(490)$ algorithm constants. J. Mueller did not have time to examine this issue in detail and will follow up with a report.
6. *Field Program Reports*: The intent here was not to present results, but activities. In the cases where investigators are being funded by the SeaWiFS Project (Siegel, Mitchell, Clark, and Mueller), the updates should review past and future cruise plans, numbers of stations, data collected, status of analysis, data delivery to SeaWiFS Project, etc. Each presentation was to be no longer than 15 minutes.
    A. Bermuda Bio-optical Time Series (D. Siegel)
    B. CalCoFI Bio-optical Time Series (G. Mitchell)
    C. Japanese Field Program Update (M. Kishino)
    D. MODIS Case-2 Field Studies (K. Carder)
    E. Arabian Sea Bio-optical Program (D. Phinney and C. Davis)
7. Operational Chlorophyll *a* Algorithm Continued (K. Carder)
8. CZCS Pigment Algorithm Continued (G. Moore)

### 3.6.2 Optical Protocols

1. *Workshop Objectives and the Action Items Resulting from BAOPW-3* (J. Mueller)
2. *Data QC and Analysis of the Round-Robin Results* (D. Siegel): The Data Analysis Round-Robin (DARR) did show that different analysis techniques can lead to substantial differences in derived products, especially at wavelengths longer than 600 nm and for upwelling radiance. The report is due from D. Siegel and will be published in the *SeaWiFS Technical Report Series.*
3. *Status and Discussion of the Protocols Update* (J. Mueller):
    a) Outline of Revised and Added Protocols—the revised or added section numbers from the original protocols TM (Volume 5) appear in parentheses.
        1) Absorption Profiles (*in situ*; Sections 5.2.4 and 6.8.2)
        2) Absorption Samples (spectrophotometric; Sections 5.4.2 and 6.8.2)
        3) Backscattering Profiles (Section 5.2.5)
        4) Instrument Self-Shading Corrections to $L_u$ and $E_u$ at the surface ($z = 0^-$, Sections 5.1.6 and 6.1.7)

† *Reference:* Carder, K.L., S.K. Hawes, and Z. Lee, 1994: SeaWiFS algorithm for chlorophyll *a* and colored dissolved organic matter in a subtropical environment (in preparation).

‡ *Reference:* Aiken, J., G. Moore, D. Clark, and C. Trees, 1994: SeaWiFS strawman pigment algorithm: introduction, rationale and methodological approaches (in preparation).

5) Above-Water $L_W$ from Ships and Low-Altitude Aircraft (Sections 3.3, 5.1.7, 5.1.8, and 6.2)
6) Case-1 and Case-2 Sampling Protocols (Sections 5.8 and 5.8.3)
7) Draft hardcopies of the revised protocols TM (Volume 25, Revision 1 of the protocols) were distributed and discussed in detail. Final revisions were completed by the end of the second day and were handed to the SeaWiFS Project for publication.

4. *SIRREX-3 Results* (J. Mueller): SIRREX-3 went reasonably well. All data were documented in near-real time and have been ingested into the SeaWiFS Bio-optical Archive and Storage System (SeaBASS). One problem that arose was the primary FEL lamp used as the *standard* lamp is deteriorating. J. Mueller will be submitting the round-robin report for publication in the SeaWiFS TM Series.
5. *Protocols Update Continued* (J. Mueller)
   A. Final edits, as well as editorial improvements, will be made of the protocol revisions to reconcile any outstanding issues which surface in the discussion.
   B. An outline identifying unresolved protocol areas in which significant progress is expected, to be included in Revision 2, will be developed.

### 3.6.3 Workshop Wrap-Ups

1. Action Items
   A. K. Carder and G. Moore: refine the empirical reflectance ratio algorithm used in the chlorophyll *a* algorithm.
   B. G. Moore: examine empirical CZCS pigment algorithms that incorporate a 490/555 nm reflectance ratio. Collect comments on the draft Aiken et al. paper and assist co-authors in getting the manuscript submitted to the SeaWiFS Project for publication.
   C. J. Campbell and C. McClain: collect, organize, and distribute data sets suitable for testing the chlorophyll *a* algorithm (overall algorithm and specific components).
   D. D. Siegel: finalize the DARR report.
   E. J. Mueller: complete the accuracy analysis of the Austin-Petzold algorithm for the SeaWiFS bands. Submit the SIRREX-3 results to the SeaWiFS Project for publication.
   F. W. Balch, J. Campbell, K. Carder, G. Cota, G. Mitchell, G. Moore, and D. Siegel: conduct the chlorophyll *a* algorithm studies over the next 2–3 months and distribute their results to the SeaWiFS Project and the Bio-optical Algorithm Subgroup by the end of February.

## 3.7 Revised Baseline Product List

The listings of standard products recommended by the Project Scientists, as of April 1994, are given in Tables 7–9. (These products may be revised in the future and will be reported in subsequent volumes of the *SeaWiFS Technical Report Series.*) There are a few changes from the original recommendations of the Bio-Optical Working Group. These changes have been made as a result of input from the Science Team and subsequent discussions within the SeaWiFS Project, in order to provide the most useful information at launch.

Changes in the level-2 products include:

a) saving the aerosol radiance ($L_a$) at 670 nm rather than the water-leaving radiance at $L_{WN}(670)$, since the water-leaving radiance at 670 nm is very small; and
b) at launch, the atmospheric correction will assume that $L_{WN}(670)$ equals zero.

The single scattering epsilon will be reported for the 670/865 combination, along with the aerosol optical depth at 865 nm.

The level-3 binned products follow the level-2 product listing. It is important to note that binning must be optimized for a single product, in this case chlorophyll *a*, since only a single set of statistics for sample numbers will be accumulated. Accordingly, the high aerosol optical depth values, where the atmospheric correction may have unacceptably high errors, will not be included in the binned aerosol products. The flags planned for use at launch are also defined, and have undergone some revision.

The approach taken is to attempt to process all ocean data to level-2 and provide flags for certain conditions. Threshold values need to be set for several of the flags, and evaluated after launch. Where atmospheric correction is impossible, and over land, ice, and clouds, the total at-satellite radiance will be reported. The current defaults for producing level-3 fields according to how flags are set are also given. The present listing should serve well through the instrument check-out period.

It is important to note that, if necessary, the products list can be revised with each reprocessing. For example, at some point, it might make sense to report water-leaving radiance at 670 nm for reflective waters, report values for 765 nm corrections and aerosol parameters, and to have multiple level-3 products optimized for different geophysical fields, e.g., aerosols and coccolith concentration. The usefulness of the present binned water-leaving radiances can also be evaluated at that time.

The final algorithms for some of the masks and flags are still being defined, e.g., the stray light flag. Once this initial suite of operational mask and flag algorithms is finalized, a separate summary description will be published in the *SeaWiFS Technical Report Series.*

**Table 7.** SeaWiFS level-2 products.

| *Product* | *Original Baseline* | *Bytes* | *Revised Baseline* | *Bytes* |
|---|---|---|---|---|
| $L_{WN}(412)$ | Yes | 2 | Yes | 2 |
| $L_{WN}(443)$ | Yes | 2 | Yes | 2 |
| $L_{WN}(490)$ | Yes | 2 | Yes | 2 |
| $L_{WN}(510)$ | Yes | 2 | Yes | 2 |
| $L_{WN}(555)$ | Yes | 2 | Yes | 2 |
| $L_a(670)$ | Yes | 2 | Yes | 2 |
| $L_a(765)$ | Yes | 2 | No | |
| $L_a(865)$ | Yes | 2 | Yes | 2 |
| $\epsilon(670, 865)$ | No | | Yes | 1 |
| $\tau_a(865)$ | No | | Yes | 1 |
| CZCS Pigment | Yes | 2 | Yes | 2 |
| Chlorophyll *a* | Yes | 2 | Yes | 2 |
| $K(490)$ | Yes | 2 | Yes | 2 |
| Masks/Flags | Yes | 2 | Yes | 2 |
| *Total* | 12 | 24 bytes/pixel | 13 | 24 bytes/pixel |
| Scaling | All Linear | | All Linear | |
| Masked Pixels | Values = 0 | | Values = Level-1 radiances for $L_{WN}$ and $L_a$ products, 0 for other products | |

*Definitions:*

a) $L_{WN}$= normalized water-leaving radiance;
b) $L_a$ = aerosol radiance;
c) $\tau_a$ = aerosol optical thickness;
d) Masks/Flags = bit plane overlays of QC parameters, e.g., cloud and ice mask, 0–30 m isobath; and
e) $L_a$ and $\epsilon$ values are single scattering parameters.

**Table 8.** SeaWiFS level-3 binned products.

| *Product* | *Original Baseline* | *Revised Baseline* |
|---|---|---|
| $L_{WN}(412)$ | Yes | Yes |
| $L_{WN}(443)$ | Yes | Yes |
| $L_{WN}(490)$ | Yes | Yes |
| $L_{WN}(510)$ | Yes | Yes |
| $L_{WN}(555)$ | Yes | Yes |
| $L_a(670)$ | Yes | Yes |
| $L_a(765)$ | Yes | No |
| $L_a(865)$ | Yes | No |
| $\epsilon(670, 865)$ | No | Yes |
| $\tau_a(865)$ | No | Yes |
| CZCS Pigment | Yes | Yes |
| Chlorophyll *a* | Yes | Yes |
| $K(490)$ | Yes | Yes |
| Chlorophyll $a/K(490)$ | Yes | Yes |
| *Total* | 12 | 12 |

The SeaWiFS level-3 standard mapped images are: CZCS pigment, chlorophyll *a*, $K(490)$, $L_{WN}(550)$, and $\tau_a(865)$.

**Table 9.** SeaWiFS level-2 masks and flags.

| *Parameter* | *Bits* | *Mask or Flag* | *Bin* |
|---|---|---|---|
| Engineering Tolerance: can be displayed line by line | | | Yes |
| Tilt: can be displayed line by line | | | No |
| Solar Zenith Angle | 1 | Flag | No |
| S/C Zenith Angle | 1 | Flag | No |
| High $L_t$ | 1 | Flag | No |
| Stray Light | 1 | Flag | No |
| Land | 1 | Mask | No |
| Bathymetry | 1 | Flag | Yes |
| Cloud/Ice/Land | 1 | Mask | No |
| Missing Ancillary Data | 1 | Flag | Yes |
| Glint | 1 | Flag | No |
| Atmospheric Correction Algorithm Failure | 1 | Flag† | No |
| High $L_a(865)$ | 1 | Flag | No |
| Negative $L_W$ | 1 | Flag | No |
| Coccolithophore | 1 | Flag | No |
| Turbid Case-2 | 1 | Flag | Yes |
| Low $L_W(555)$ | 1 | Flag | No |
| Level-3 Binning | 1 | Flag | No |
| *Total* | 16 | Available | 0 |

*Definitions:*

1. Flag: a bit plane is switched on, but data is still processed to level-2. Level-3 processing will exclude pixels flagged for tilt, stray light, land mask, cloud/ice, glint, and coccolithophores.
2. †: level-2 processing is attempted, but atmospheric correction procedures failed to return parametric values with unacceptable ranges. Level-1 $L_t$ is assigned to the pixel values.
3. Mask: a bit plane is switched on, the pixel is assigned its level-1 count value and is not processed to level-2. Masked pixels are excluded from level-3 processing.
4. Scan Line Flags Engineering Tolerance: a bit-per-scan line is reserved within the level-2 file for each of 32 sensor engineering parameters to indicate if any of the parameters are outside normal operating range.
5. Tilt: the scan line ranges for each tilt state ($-20°$, $+20°$, $0°$, and tilting) are provided in the header of each file. Also, the tilt angle is stored with every scan line as a real number. Scan line ranges for the *tilting* state will be excluded from binning.
6. Pixel Flag and Mask Descriptions Solar Zenith Angle: all pixels with solar zenith angles greater than 70° will be flagged.
7. Spacecraft (S/C) Zenith Angle: all pixels with pixel-to-spacecraft zenith angles greater than the absolute value of 45° will be flagged.
8. High $L_t$: all pixels having counts (radiances) greater than the knee value (760 counts) in one or more bands will be flagged.
9. Stray Light: a fixed number of GAC pixels in the vicinity of a pixel whose count level exceeds a specified value will be flagged as being contaminated by stray light. The flag will be generated using both bands 7 and 8 because of the even-odd band asymmetry in the stray light and because the effects are most pronounced in these bands.
10. Land: pixels over land, as determined using an external database, will be masked.
11. Bathymetry: pixels over water with depths less than or equal to 30 m, as determined using an external database, will be flagged.
12. Cloud/Ice/Land: pixels having an albedo at 865 nm greater than a fixed value, e.g., 0.9%, will be flagged.
13. Missing Ancillary Data: if a gap in the ancillary data exists, the monthly climatological value is used and the pixel will be flagged.
14. Glint: pixels having a $L_g(865)$ greater than a fixed fraction of $L_t(865)$ will be masked.
15. Atmospheric Correction Algorithm Failure: pixels where the atmospheric correction algorithm fails to return epsilon values within a specified range will be flagged and assigned the level-1 total radiance values.
16. High $L_a$: pixels having a $L_a(865)$ greater than a fixed fraction of $L_t(865)$ will be flagged.
17. Negative $L_W$: any pixel having a computed $L_W$ greater than zero will be flagged and the value will be set to zero.
18. Coccolithophore: using a modified version of the method of Brown and Yoder (1994), pixels selected as being contaminated by coccolithophores will be flagged. The primary modification will be to delete the $L_a(670)$ test.
19. Turbid Case-2: The reflectance algorithm recommended in Bricaud and Morel (1987) for discriminating between Case-1 and Case-2 waters will be used to flag Case-2 water.
20. Low $L_W(555)$: Pixels where the water-leaving radiance at 555 nm is below a predefined level, e.g., 10 times the noise equivalent radiance (NE$\Delta$L), will be flagged.

### 3.8 Colleagues' Addresses

Following are the names and addresses of attendees of the various workshops and reviews presented in Sections 3.1–3.7. Members of the various teams and panels are identified with their team name(s) shown in *slanted* type face.


James Aiken *SeaWiFS Science Team*
Plymouth Marine Laboratory
Prospect Place
West Hoe
Plymouth, PL1 3DH
UNITED KINGDOM
Telephone: 44–752–222772
Fax: 44–752–670637
Internet: j.aiken@pml.ac.uk

Steven Ackleson
Ocean Optics Program, Code 3233
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217
Telephone: 703–696–4732
Fax: 703–696–4884
Inernet: ackless@onrhq.onr.navy.mil

Robert Arnone
NRL/Code 7240
Stennis Space Center, MS 39527
Telephone: 601–688–5268
Fax: 601–688–4149
Internet: arnone@csips2.nrlssc.navy.mil

Kevin Arrigo
NASA/GSFC/USRA/Code 971
Greenbelt, MD 20771
Telephone: 301–286–9634
Fax: 301–286–0240
Internet: kevin@shark.gsfc.nasa.gov

William Balch *SeaWiFS Science Team*
MBF/RSMAS/U. of Miami
4600 Rickenbacker Causeway
Miami, FL 33149–1098
Telephone: 305–361–4653
Fax: 305–361–4600
Internet: balch@rcf.rsmas.miami.edu

Michael Behrenfeld
Brookhaven National Laboratory
Upton, NY 11973
Telephone: 516–828–2123
Fax: 515–828–3000
Internet: behrenfe@bnlux1.bnl.gov

Samuel Bergeson-Willis
NASA/GSFC/Code 704
Greenbelt, MD 20771
Telephone: 301–286–5344
Fax: 301–286–1718
Internet: sam_bergeson-willis@ccmail.gsfc.nasa.gov

William Broenkow
Moss Landing Marine Laboratory
PO Box 450
Moss Landing, CA 95039
Telephone: 408–633–3304
Internet: broenkow@mlml.calstate.edu

Christopher Brown
NASA/GSFC/NRC/Code 971
Greenbelt, MD 20771
Telephone: 301–286–0946
Fax: 301–286–0240
Internet: chrisb@puffin.gsfc.nasa.gov

Robert Caffrey *MOBY Review Panel*
NASA/GSFC/Code 735
Greenbelt, MD 20771
Telephone: 301–286–4766
Internet: r.caffrey@baloo.gsfc.nasa.gov

Janet Campbell
OPAL/Morse Hall
Univ. of New Hampshire
Durham, NH 03824
Telephone: 813–893–9148
Fax: 813–893–9189
Internet: campbell@kelvin.unh.edu

Kendall Carder *SeaWiFS Science Team*
Dept. of Marine Science *MODIS Science Team*
Univ. of South Florida
140 Seventh Avenue, South
St. Petersburg, FL 33701–5016
Telephone: 813–893–9148
Fax: 813–893–9189
Internet: kcarder@monty.marine.usf.edu

Francisco Chavez
Associate Scientist
Monterey Bay Aquarium Research Institute
160 Central Avenue
Pacific Grove, CA 93950
Telephone: 408–647–3709
Fax: 408–649–8587
Internet: chfr@mbari.org

Dennis Clark *SeaWiFS Science Team*
NOAA/NESDIS *MODIS Science Team*
E/RA 28, WWB, Rm. 104 *MOBY Team*
Washington, DC 20233
Telephone: 301–763–8102
Fax: 301–763–8020
Internet: dclark@orbit.nesdis.noaa.gov

Mary Cleave *SeaWiFS Project*
NASA/GSFC/Code 970.2
Greenbelt, MD 20771
Telephone: 301–286-1404
Fax: 301–286–1775
Internet: mary@ardbeg.gsfc.nasa.gov

Glen Cota
Ecology Program
University of Tennessee
Knoxville, TN 37996
Telephone: 615–974–3065
Fax: 615–974–3067
Internet: cota@utkvx.utcc.utk.edu

Michael Darzi — *SeaWiFS Project*
NASA/GSFC/GSC/Code 970.2
Greenbelt, MD 20771
Telephone: 301–286–9150
Fax: 301–286–1775
Internet: darzi@calval.gsfc.nasa.gov

Curtiss Davis
Code 7212/NRL
4555 Overlook Avenue
Washington, DC 20375
Telephone: 202–767–9296
Fax: 202–404–7453
Internet: davis.@rira.nrl.navy.mil

Roland Doerffer — *SeaWiFS Science Team*
GKSS Forschungszentrum Geesthacht
Max-Planck-Strasse
D-2054 Geesthacht
GERMANY
Telephone: 49–4152–87–2480
Fax: 49–4152–87–2444
Telex: 0218712
Internet: doerffer@dvmc10.gkss.de
Internet: doerffer@pfsun1.gkss.de

Wayne Esaias — *SeaWiFS Science Team*, *MODIS Science Team*
NASA/GSFC/Code 971
Greenbelt, MD 20771
Telephone: 301–286–5465
Fax: 301–286–0240
Internet: wayne@petrel.gsfc.nasa.gov

Robert Evans — *SeaWiFS Science Team*, *MODIS Science Team*
MPO/RSMAS/U. of Miami
4600 Rickenbacker Causeway
Miami, FL 33149
Telephone: 305–361–4799
Fax: 305–361–4622
Internet: bob@rsmas.miami.edu

Guiletta Fargion
Dept. of Marine Biology
Texas A&M Galveston
Box 1675
Galveston, TX 77553
Telephone: 409–740–4529
Internet: g-fargion@tamu.edu

Robert Frouin
NASA Headquarters
Code YS
Washington, DC 20546
Telephone: 202–554–6479
Fax: 202–554–6499
Internet: rfrouin@ucsd.edu

Hajime Fukushima — *SeaWiFS Science Team*
Tokai University
317 Nishino
Numazu, 410–03
JAPAN
Telephone: 81–559–68–1211 ext. 4425
Fax: 81–559–68–1155
Internet: hajime@numazugw.cc.u-tokai.ac.jp

Sonia Gallegos
Naval Research Laboratory
Code 7240–Remote Sensing
Stennis Space Center, MS 39529
Telephone: 601–688–4867
Fax: 601–688–4149
Internet: gallegos@snaps.nrlssc.navy.mil

Howard Gordon — *SeaWiFS Science Team*, *MODIS Science Team*
UM/Dept. of Physics
Coral Gables, FL 33124
Telephone: 305–284–2323
Fax: 305–284–4222
Internet: gordon@phyvax.ir.miami.edu

Lawrence Harding
0112 Skinner Hall
Univ. of Maryland
College Park, MD 20742
Telephone: 301–405–6372
Fax: 301–314–9581
Internet: hardingl@mbimail.umd.edu

Steven Hawes
Dept. of Marine Science
Univ. of South Florida
140 Seventh Ave., South
St. Petersburg, FL 33701
Telephone: 813–893–9503
Fax: 813–893–9189
Internet: ska@monty.marine.usf.edu

Frank Hoge — *SeaWiFS Science Team*, *MODIS Science Team*
NASA/GSFC/WFF
Wallops Island, VA 23337
Telephone: 804–824–1567
Fax: 804–824–2343
Fax: 804–824–1036
Internet: hoge@osb1.wff.nasa.gov

Stanford Hooker — *SeaWiFS Project*, *MOBY Review Panel*
NASA/GSFC/Code 970.2
Greenbelt, MD 20771
Telephone: 301–286–9503
Fax: 301–286–1775
Internet: stan@ardbeg.gsfc.nasa.gov

Shane Hynes — *MOBY Review Panel*
Swales Associates
5050 Powder Mill Road
Beltsville, MD 20705
Telephone: 301–572–1220
Internet: s_hynes@swales.com

Daniel Kamykowski *SeaWiFS Science Team*
NCSU/MEAS/Box 8208
Raleigh, NC 27695
Telephone: 919–515–7894
Fax: 919–515–7802
Internet: dan_kamykowski@ncsu.edu

Motoaki Kishino *SeaWiFS Science Team*
Inst. of Phys. & Chem. Res.
Hirosawa 2–1
Wako-shi, Saitama, 351–01
JAPAN
Telephone: 81–48–462–1111 ext. 3635
Fax: 81–48–462–1449
Internet: kishino@rkna50.riken.go.jp
Span: rik835::in%"kishino@rkna50.riken.go.jp"

Oleg Kopelevich *SeaWiFS Science Team*
P.P. Shirshov Inst. of Oceanology
23 Krasikova St.
Moscow, 117218
RUSSIA
Telephone: 7–095–124–7583
Fax: 7–095–292–6511
Telex: 411968 Okean SU
Internet: lomi@lobelc.msk.su

Marlon Lewis *SeaWiFS Science Team*
Department of Oceanography
Dalhousie University
Halifax, Nova Scotia B3H 4J1
Telephone: 902–492–4780
Fax: 902–492–4781
Internet: marlon@predator.ocean.dal.ca

Charles McClain *SeaWiFS Science Team*
NASA/GSFC/Code 971 *SeaWiFS Project*
Greenbelt, MD 20771 *MOBY Review Panel*
Telephone: 301–286–5377
Fax: 301–286–2717
Internet: mcclain@calval.gsfc.nasa.gov

Todd Miller *MOBY Review Panel*
NASA/GSFC/Code 735
Greenbelt, MD 20771
Telephone: 301–286–3112
Fax: 301–286–1643
Internet: nnjtm@vx730.gsfc.nasa.gov

B. Greg Mitchell *SeaWiFS Science Team*
UCSD/MRD 0218
La Jolla, CA 92093–0218
Telephone: 619–534–2687
Fax: 619–534–2997
Internet: bgmitchell@ucsd.edu

Gerald Moore
Plymouth Marine Laboratory
Prospect Place
West Hoe
Plymouth, PL1 3DH
UNITED KINGDOM
Telephone: 44–752–222772
Fax: 44–752–670637
Internet: g.moore@pml.ac.uk

André Morel *SeaWiFS Science Team*
Lab de Physique et Chimie Marines
Université Pierre et Marie Curie
BP 08, 06230 Villefranche Sur Mer
FRANCE
Telephone: 33–93–76–37–11
Fax: 33–93–76–37–39
Internet: morel@ccrv.obs-vlfr.fr

John Morrison
North Carolina State University
Dept. of Marine, Earth, and Atmospheric Sciences
Jordan Hall, Room 1125
Box 8208
Raleigh, NC 27695-8208
Telephone: 919–515–7449
Fax: 919–515–7802
Internet: john_morrison@ncsu.edu

John Morrow
Biospherical Instruments, Inc.
5340 Riley Street
San Diego, CA 92110
Telephone: 619–686–1888
Fax: 619–686–1887
Internet: morrow@biospherical.com

James Mueller *SeaWiFS Science Team*
SDSU/CHORS
6505 Alvarado Road, Suite 206
San Diego, CA 92120–5005
Telephone: 619–594–2230
Fax: 619–594–4570
Internet: j.mueller@chors.sdsu.edu

Frank Muller-Karger *SeaWiFS Science Team*
Dept. of Marine Science
Univ. of South Florida
140 Seventh St., South
St. Petersburg, FL 33701
Telephone: 813–893–9186
Fax: 813–893–9189
Internet: carib@carbon.marine.usf.edu

Andreas Neumann
DLR, Institute for Space Sensing Applications
German Aerospace Research Establishment
Rudower Chaussee 5
0-1199 Berlin, GERMANY
Telephone: 49–30–69545–640
Fax: 49–30–69545–642
Internet: neumann@dvi.ws.ba.dlr.de

David Phinney
Bigelow Laboratory
McKown Point
W. Boothbay Harbor, ME 04575
Telephone: 207–633–9600
Fax: 207–633–9641

Richard Reaves *MOBY Team*
Moss Landing Marine Laboratory
PO Box 450
Moss Landing, CA 95039
Telephone: 408–755–8675
Fax: 408–755–8686
Internet: reaves@mlml.calstate.edu

Thomas Riley
NASA/GSFC/Code 916
Greenbelt, MD 20771
Telephone: 301–286–6807
Internet: riley@chapman.gsfc.nasa.gov

David Siegel *SeaWiFS Science Team*
UCSB/CRSEO
Santa Barbara, CA 93106–3060
Telephone: 805–893–4547
Fax: 805–893–2578
Internet: davey@crseo.ucsb.edu

Raymond Smith *SeaWiFS Science Team*
CRSEO/UCSB
Santa Barbara, CA 93106
Telephone: 805–893–4709
Fax: 805–893–2578
Internet: ray@crseo.ucsb.edu

Petra Stegman
Graduate School of Oceanography
Univ. of Rhode Island
South Ferry Road
Narragansett, RI 02882
Telephone: 401–792–6863
Fax: 401–792–6728
Internet: petra@uri.gso.uri.edu

Richard Stumpf
Center for Coastal Geology
US Geological Survey
600 4th Street
St. Petersburg, FL 33701
Telephone: 813–893–3100 ext. 3024
Fax: 813–893–3333
Internet: rstumpf@wayback.er.usgs.gov

Ajit Subramaniam
Brookhaven National Laboratory
Upton, NY 11973
Telephone: 516–828–2123
Fax: 515–828–3000
Internet: ajit@bnlcl6.bnl.gov

Charles Trees *SeaWiFS Science Team*
SDSU/CHORS
6505 Alvarado Road, Suite 206
San Diego, CA 92120–5005
Telephone: 619–594–2241
Fax: 619–594–4570
Internet: chuck@chors.sdsu.edu

Alan Webb
NASA Headquarters
Code YD
Washington, DC 20456
Telephone: 202–554–6482
Fax: 202–554–6499
Internet: awebb@mtpe.hq.nasa.gov

Alan Weidemann
NOARL/Code 331
Stennis Space Center, MS 39529
Telephone: 601–688–5253
Fax: 601–688–5997

Mark Yarbrough *MOBY Team*
Moss Landing Marine Laboratory
PO Box 450
Moss Landing, CA 95039
Telephone: 408–755–8685
Fax: 408–755–8686
Internet: yarbrough@mlml.calstate.edu

Charles Yentsch *SeaWiFS Science Team*
Bigelow Laboratory
McKown Point
W. Boothbay Harbor, ME 04575
Telephone: 207–633–9600
Fax: 207–633–9641

James Yoder *SeaWiFS Science Team*
URI/GSO
Narragansett, RI 02882
Telephone: 401–792–6864
Fax: 401–792–8098
Internet: yoder@uri.gso.uri.edu

J. Ronald Zaneveld *SeaWiFS Science Team*
Oregon State University
Ocean. Admin. Bldg. 104
Corvallis, OR 97331–5503
Telephone: 503–737–3571
Fax: 503–737–2064
Internet: zaneveld@oce.orst.edu

James Zaitzeff
NOAA/NESDIS
Oceanic Sciences Branch, Code E/RA13
World Weather Bldg., Rm. 102
Washington, DC 20233
Telephone: 301–763–8231
Fax: 301–763–8020
Internet: jzaitzeff@orbit.nesdis.noaa.gov

Gerhard Zimmerman
DLR, Institute for Space Sensing Applications
German Aerospace Research Establishment
Rudower Chaussee 5
0-1199 Berlin, GERMANY
Telephone: 49–30–69545–669
Fax: 49–30–69545– 642

## Cumulative Index

Unless indicated otherwise, the index entries that follow refer to some aspect of the SeaWiFS instrument or project, for example, the *mission overview* index entry refers to an overview of the SeaWiFS mission.

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–V, W, X, Y–



–Z–

## Glossary

### – A –

AC Alternating Current
ACC Antarctic Circumpolar Current
ACRIM Active Cavity Radiometer Irradiance Monitor
ACS Attitude Control System
A/D Analog-to-Digital
ADEOS Advanced Earth Observation Satellite (Japan)
AE Ångström Exponent
ALSCAT ALPHA and Scattering Meter (Note: the symbol $\alpha$ corresponds to $c(\lambda)$, the beam attenuation coefficient, in present usage).
AM-1 Not an acronym, used to designate the morning platform of EOS.
AMC Angular Momentum Compensation
AOCI Airborne Ocean Color Imager
AOL Airborne Oceanographic Lidar
AOP Apparent Optical Property
AOS/LOS Acquisition of Signal/Loss of Signal
ARGOS Not an acronym, but the name given to the data collection and location system on the NOAA Operational Satellites.
ARI Accelerated Research Initiative
ASCII American Standard Code for Information Interchange
ASI Italian Space Agency
AT Along-Track
AVHRR Advanced Very High Resolution Radiometer
AVIRIS Advanced Visible and Infrared Imaging Spectrometer
AXBT Airborne Expendable Bathythermograph

### – B –

BAOPW-1 First Bio-optical Algorithm and Optical Protocols Workshop
BAOPW-2 Second Bio-optical Algorithm and Optical Protocols Workshop
BAOPW-3 Third Bio-optical Algorithm and Optical Protocols Workshop
BAOPW-4 Fourth Bio-optical Algorithm and Optical Protocols Workshop
BAS British Antarctic Survey
BATS Bermuda Atlantic Time-Series Station
BBOP Bermuda Bio-Optical Profiler
BBR Band-to-Band Registration
BCRS Dutch Remote Sensing Board
BEP Benguela Ecology Programme
BER Bit Error Rate
BMFT Minister for Research and Technology (Germany)
BOMS Bio-Optical Moored Systems
bpi bits per inch
BRDF Bidirectional Reflectance Distribution Function
BSI Biospherical Instruments, Incorporated
BSIXR BSI's Transfer Radiometer
BTR Bright Target Recovery
BUV Backscatter Ultraviolet Spectrometer
BWI Baltimore-Washington International (airport)

### – C –

CalCoFI California Cooperative Fisheries Institute
Cal/Val Calibration and Validation
CALVAL Calibration and Validation
Case-1 Water whose reflectance is determined solely by absorption.
Case-2 Water whose reflectance is significantly influenced by scattering.
CCPO Center for Coastal Physical Oceanography (Old Dominion University)
CDF (NASA) Common Data Format
CD-ROM Compact Disk-Read Only Memory
CDOM Colored Dissolved Organic Material
CDR Critical Design Review
CEC Commission of the European Communities
CENR Committee on Environment and Natural Resources
CHORS Center for Hydro-Optics and Remote Sensing (San Diego State University)
CICESE *Centro de Investigación Científica y de Educación Superior de Ensenada* (Mexico)
CIRES Cooperative Institute for Research in Environmental Sciences
COADS Comprehensive Ocean-Atmosphere Data Set
COOP Coastal Ocean Optics Program
COTS Commercial Off-The-Shelf (software)
CPR Continuous Plankton Recorder
cpu Central Processing Unit
CRM Contrast Reduction Meter
CRN Italian Research Council
CRSEO Center for Remote Sensing and Environmental Optics (University of California at Santa Barbara)
CRT Calibrated Radiance Tapes; or Cathode Ray Tube.
CSIRO Commonwealth Scientific and Industrial Research Organization (of Australia)
CSL Computer Systems Laboratory
CT Cross-Track
CTD Conductivity, Temperature, and Depth
CVT Calibration and Validation Team
CW Continuous Wave
CZCS Coastal Zone Color Scanner

### – D –

DAAC Distributed Active Archive Center
DARR Data Analysis Round-Robin
DAT Digital Audio Tape
DC Direct Current
DCF Data Capture Facility
DCOM Dissolved Colored Organic Material
DCP Data Collection Platform
DEC Digital Equipment Corporation
DMS dimethyl sulfide
DOC Dissolved Organic Carbon
DOM Dissolved Organic Matter
DOS Disk Operating System
DSP Not an acronym, but an image display and analysis package developed at RSMAS University of Miami.
DXW Not an acronym, but a lamp designator.

– E –

EAFB Edwards Air Force Base
ECEF Earth-Centered Earth-Fixed
ECMWF European Centre for Medium Range Weather Forecasts
ECT Equator Crossing Time
EEZ Exclusive Economic Zone
EOF Empirical Orthogonal Function
ENSO El Niño Southern Oscillation
ENVISAT Environmental Satellite
EOS Earth Observing System
EOSAT Earth Observation Satellite Company
EOSDIS EOS Data Information System
EqPac Equatorial Pacific (Process Study)
EP-TOMS Earth Probe-Total Ozone Mapping Spectrometer
EPA Environmental Protection Agency
ER-2 Earth Resources-2
ERBE Earth Radiation Budget Experiment
ERBS Earth Radiation Budget Sensor
ERL (NOAA) Environmental Research Laboratories
ERS Earth Resources Satellite
ESA European Space Agency
EUVE Extreme Ultraviolet Explorer

– F –

FASCAL Fast Calibration (Facility)
FDDI Fiber Data Distribution Interface
FEL Not an acronym, but a lamp designator.
FGGE First GARP Global Experiment
FLUPAC (Geochemical) Fluxes in the Pacific (Ocean)
FNOC Fleet Numerical Oceanography Center
FORTRAN Formula Translation (computer language)
FOV Field-of-View
FPA Focal Point Assembly
FRD Federal Republic of Deutschland (Germany)
FTP File Transfer Protocol
FWHM Full-Width at Half-Maximum

– G –

GAC Global Area Coverage, coarse resolution satellite data with a nominal ground resolution at nadir of approximately 4 km.
GARP Global Atmospheric Research Program
GASM General Angle Scattering Meter
GF/F Not an acronym, a specific type of glass fiber filter made by Whatman.
GIN Greenland, Iceland, and Norwegian Seas
GISS Goddard Institute for Space Studies
GLI Global Imager
GLOBEC Global Ocean Ecosystems dynamics
GMT Greenwich Mean Time
GOES Geostationary Operational Environmental Satellite
GOFS Global Ocean Flux Study
GOMEX Gulf of Mexico Experiment
GP Global Processing (algorithm)
GPM General Perturbations Model
GPS Global Positioning System
GRGS *Groupe de Recherche de Geodesie Spatial*
GRIDTOMS Gridded TOMS (data set)
GSFC Goddard Space Flight Center
GSO Graduate School of Oceanography (University of Rhode Island)
G/T System Gain/Total System Noise Temperature
GUI Graphical User Interface

– H –

HDF Hierarchical Data Format
HEI Hoffman Engineering, Incorporated
HeNe Helium-Neon
HIRIS High Resolution Imaging Spectrometer
HOTS Hawaiian Optical Time Series
HP Hewlett Packard
HPLC High Performance Liquid Chromatography
HQ Headquarters
HRPT High Resolution Picture Transmission
HYDRA Hydrographic Data Reduction and Analysis

– I –

IAPSO International Association for the Physical Sciences of the Ocean
IAU International Astrophysical Union
IBM International Business Machines
ICD Interface Control Document
ICES International Council on Exploration of the Seas
IDL Interactive Data Language
IFOV Instantaneous Field-of-View
IMS Information Management System
I/O Input/Output
IOP Inherent Optical Property
IR Infrared
ISCCP International Satellite Cloud Climatology Project
ISIC Integrating Sphere Irradiance Collector
IUE International Ultraviolet Explorer

– J, K –

JAM JYACC Application Manager
JGOFS Joint Global Ocean Flux Study
JOI Joint Oceanographic Institute
JPL Jet Propulsion Laboratory
JRC Joint Research Center

– L –

LAC Local Area Coverage, fine resolution satellite data with a nominal ground resolution at nadir of approximately 1 km.
LANDSAT Land Resources Satellite
LDGO Lamon-Doherty Geological Observatory (Columbia University)
LDTNLR Local Dynamic Threshold Nonlinear Raleigh
Level-0 Raw data.
Level-1 Calibrated radiances.
Level-2 Derived products.
Level-3 Gridded and averaged derived products.
LMCE *Laboratoire de Modelisation du climat et de l'Environment* (France)
L&N Leeds & Northrup
LODYC *Laboratoire d'Océanographie et de Dynamique du climat* (France)
LOICZ Land Ocean Interaction in the Coastal Zone
LPCM *Laboratoire de Physique et Chimie Marines* (France)
LRER Long-Range Ecological Research
LSB Least Significant Bits

– M –

MAREX Marine Resources Experiment Program
MARS Multispectral Airborne Radiometer System
MASSS Multi-Agency Ship-Scheduling for SeaWiFS
MBARI Monterey Bay Aquarium Research Institute
MEM Maximum Entropy Method
MER Marine Environmental Radiometer
MERIS Medium Resolution Imaging Spectrometer
METEOSAT Meteorological Satellite
mF Minor Frame
MF Major Frame
MIPS Millions of Instructions Per Second
MIZ Marginal Ice Zone
MLE Maximum Likelihood Estimator
MLML Moss Landing Marine Laboratory (San Jose State University)
MOBY Marine Optical Buoy
MOCE Marine Optical Characterization Experiment
MODARCH MODIS Document Archive
MODIS Moderate Resolution Imaging Spectroradiometer
MODIS-N Nadir-viewing MODIS instrument
MODIS-T Tilted MODIS instrument (to minimize sun glint)
MOS Marine Optical Spectroradiometer
MOU Memorandum of Understanding
MSB Most Significant Bits
MS/DOS MicroSoft/Disk Operating System
MTF Modulation Transfer Function

– N –

NABE North Atlantic Bloom Experiment
NAS National Academy of Science
NASA National Aeronautics and Space Administration
NASCOM NASA Communications
NASDA National Space Development Agency (Japan)
NASIC NASA Aircraft/Satellite Instrument Calibration
NAVSPASUR Naval Space Surface Surveillance
NCAR National Center for Atmospheric Research
NCCOSC Navy Command, Control, and Ocean Surveillance Center
NCDC (NOAA) National Climatic Data Center
NCDS NASA Climate Data System
NCSA National Center for Supercomputing Applications
NCSU North Carolina State University
NDVI Normalized Difference Vegetation Index
NE$\Delta$T Noise Equivalent Delta Temperature
NE$\delta$L Noise Equivalent delta Radiance
NER Noise Equivalent Radiance
NERC Natural Environment Research Council
NESDIS National Environmental Satellite Data Information Service
NET NIMBUS Experiment Team
NGDC National Geophysical Data Center
NIMBUS Not an acronym, but a series of NASA experimental weather satellites containing a wide variety of atmosphere, ice, and ocean sensors.
NIST National Institute of Standards and Technology
NMC National Meteorological Center
NMFS National Marine Fisheries Service
NOAA National Oceanic and Atmospheric Administration
NOARL Naval Oceanographic and Atmospheric Research Laboratory
NORAD North American Air Defense (Command)
NOS National Ocean Service
NRA NASA Research Announcement
NRaD Naval Research and Development
NRIFSF National Research Institute of Far Seas Fisheries (Japan)
NRL Naval Research Laboratory
NSCAT NASA Scatterometer
NSF National Science Foundation
NSSDC National Space Science Data Center

– O –

OAM Optically Active Materials
OCEAN Ocean Colour European Archive Network
OCTS Ocean Color Temperature Sensor (Japan)
ODAS Ocean Data Acquisition System
ODU Old Dominion University
OFFI Optical Free-Fall Instrument
OI Original Irradiance
OLIPAC Oligotrophy in the Pacific (Ocean)
OMEX Ocean Marine Exchange
ONR Office of Naval Research
OPT Ozone Processing Team
OS Operating System
OSC Orbital Sciences Corporation
OSFI Optical Surface Floating Instrument
OSSA Office of Space Science and Applications
OSU Oregon State University

– P –

PAR Photosynthetically Available Radiation
PC (IBM) Personal Computer
PDR Preliminary Design Review
PDT Pacific Daylight Time
PFF Programmable Frame Formatter
PI Principal Investigator
PIKE Phased Illuminated Knife Edge
PM-1 Not an acronym, used to designate the afternoon EOS platform.
PML Plymouth Marine Laboratory
POC Particulate Organic Carbon
POLDER Polarization and Directionality of the Earth's Reflectances (France)
PON Particulate Organic Nitrogen
PR Photo Research
PRIME Plankton Reactivity in the Marine Environment
PST Pacific Standard Time
PSU Practical Salinity Units
PTFE Polytetrafluoroethylene
PUR Photosynthetically Usable Radiation

– Q –

QC Quality Control
QED Quantum Efficient Device

– R –

R&A Research and Applications
R&D Research and Development
RACER Research on Antarctic Coastal Ecosystem Rates
RF Radio Frequency
RFP Request for Proposals
RISC Reduced Instruction Set Computer
rms root mean squared
ROSIS Remote Sensing Imaging Spectrometer, also known as the Reflective Optics System Imaging Spectrometer (Germany)
RR Round-Robin
RSMAS Rosenstiel School for Marine and Atmospheric Sciences (University of Miami)
RTOP Research and Technology Operation Plan

– S –

SAC Satellite Applications Centre
SARSAT Search and Rescue Satellite
SBRC (Hughes) Santa Barbara Research Center
SBUV Solar Backscatter Ultraviolet Radiometer
SBUV-2 Solar Backscatter Ultraviolet Radiometer–2
S/C Spacecraft
SCOR Scientific Committee on Oceanographic Research
SDPS SeaWiFS Data Processing System
SDS Scientific Data Set
SDSU San Diego State University
SeaBASS SeaWiFS Bio-optical Archive and Storage System
SEAPAK Not an acronym, but an image display and analysis package developed at GSFC.
SeaSCOPE SeaWiFS Study of Climate, Ocean Productivity, and Environmental Change
SeaWiFS Sea-viewing Wide Field-of-view Sensor
SES Shelf Edge Study
SGI Silicon Graphics, Incorporated
SI *Système International d' Unitès* or International System of Units
SIG Special Interest Group
SIO Scripps Institution of Oceanography
SIO/MPL Scripps Institution of Oceanography/Marine Physical Laboratory
SIRREX SeaWiFS Intercalibration Round-Robin Experiment
SIRREX-1 The First SIRREX (July 1992)
SIRREX-2 The Second SIRREX (June 1993)
SIRREX-3 The Third SIRREX (September 1994)
SIS Spherical Integrating Source
SISSR Submerged *In Situ* Spectral Radiometer
SJSU San Jose State University
SMM Solar Maximum Mission
S/N Serial Number
SNR Signal-to-Noise Ratio
SO Southern Ocean (algorithm)
SOC Simulation Operations Center
SOGS SeaStar Operations Ground Subsystem
SOH State of Health
SOW Statement of Work
SPM Suspended Particulate Material or Special Perturbations Model (depending on usage).
SPO SeaWiFS Project Office
SPOT *Satellite Pour l'Observation de la Terre* (France)
SPSWG SeaWiFS Prelaunch Science Working Group
SQL Sequential Query Language
SRC Satellite Receiving Station (NERC)
SRT Sigma Research Technology, Incorporated
SST Sea Surface Temperature or SeaWiFS Science Team (depending on usage).
ST Science Team
SUN Sun Microsystems
SWAP Sylter Wattenmeer Austausch-prozesse
SWG Science Working Group
SXR SeaWiFS Transfer Radiometer

– T –

T-S Temperature-Salinity
TBD To Be Determined
TBUS Not an acronym, but a NOAA orbit prediction
TDI Time-Delay and Integration
TDRSS Tracking and Data Relay Satellite System
TIROS Television and Infrared Observation Satellite
TLM Telemetry
TM Technical Memorandum
TOGA Tropical Ocean Global Atmosphere program
TOMS Total Ozone Mapping Spectrometer
TOPEX Topography Experiment
TOVS TIROS Operational Vertical Sounder
TSM Total Suspended Material
TV Thermal Vacuum

– U –

UA University of Arizona
UARS Upper Atmosphere Research Satellite
UAXR University of Arizona's Transfer Radiometer
UCMBO University of California Marine Bio-Optics
UCSB University of California at Santa Barbara
UCSD University of California at San Diego
UH University of Hawaii
UIM/X User Interface Management/X-Windows
UM University of Miami
UNESCO United Nations Educational, Scientific, and Cultural Organizations
UPS Uninterruptable Power System
URI University of Rhode Island
USC University of Southern California
USF University of South Florida
UTM Universal Transverse Mercator (projection)
UV Ultraviolet
UVB Ultraviolet-B
UWG User Working Group

– V –

V0 Version 0
V1 Version 1
VAX Virtual Address Extension
VCS Version Control Software
VDC Volts Direct Current
VHF Very High Frequency
VI Virtual Instrument
VISLAB Visibility Laboratory (Scripps Institution of Oceanography)
VISNIR Visible and Near Infrared
VMS Virtual Memory System

### –W, X, Y, Z–

WFF Wallops Flight Facility
WHOI Woods Hole Oceanographic Institute
WMO World Meteorological Organization
WOCE World Ocean Circulation Experiment
WORM Write Once Read Many (times)
WVS World Vector Shoreline

## Symbols

### – A –

- $a$ The semi-major axis of the Earth's orbit, a formulation constant, a constant equal to 0.983, or a constant equal to $-20/\tanh(2)$ (depending on usage).
- $a(z,\lambda)$ Spectral absorption coefficient.
- $a_{\leq}$ Oxygen absorption coefficient.
- $a_{\text{ox}}$ Coefficient for oxygen absorption.
- $a_{\text{oz}}$ Coefficient for ozone absorption.
- $a_{\text{wv}}$ Coefficient for water vapor absorption.
- $A(k)$ Absorptivity.
- $A(\lambda)$ Coefficient for calculating $b_b(\lambda)$.
- $A_i$ The intersection area.

### – B –

- $b$ Formulation coefficient or a constant equal to 1/3 (depending on usage).
- $b(z,\lambda)$ Total scattering coefficient.
- $b(\theta,z,\lambda_0)$ Volume scattering coefficient.
- $b_b(z,\lambda)$ Spectral backscattering coefficient.
- $b_{bc}(\lambda)$ Spectral backscattering coefficient for phytoplankton.
- $b_r(\lambda)$ Total Raman scattering coefficient.
- $b_w(\lambda)$ Total scattering coefficient for pure seawater.
- $B$ Excess target radiance.
- $B(\lambda)$ Coefficient for calculating $b_b(\lambda)$.

### – C –

- $c(z,\lambda)$ Spectral beam attenuation coefficient .
- $c(z,660)$ Red beam attenuation (at 660 nm).
- $[chl.\ a]/K$ Concentration of chlorophyll $a$ over $K$, the diffuse attenuation coefficient.
- $C$ Chlorophyll $a$ pigment, or just pigment concentration.
- $C_{13}$ Pigment concentration derived using CZCS bands 1 and 3.
- $C_{23}$ Pigment concentration derived using CZCS bands 2 and 3.
- $C_{\text{ref}}$ Reference chlorophyll value (0.5).
- $[C+P]$ Pigment concentration defined as mg chlorophyll $a$ plus phaeopigments $\text{m}^{-3}$.

### – D –

- $d$ The distance between source and detector apertures.
- $d_i$ Distance from the $i$th observation point to the point of interest.
- $d_j$ Distance from the $j$th observation point to the point of interest.
- $D$ Sequential day of the year.
- $\vec{D}$ Orbit position difference vector.
- $D_{\text{at}}$ Along-track position difference.
- $D_{\text{ct}}$ Cross-track position difference.
- $D_{\text{rad}}$ Radial position difference.
- $DC$ Digital count (value) or direct current (depending on usage).
- $DC_{10}$ Digital counts at 10-bit digitization.

### – E –

- $e$ Orbit eccentricity of the Earth.
- $E(\lambda)$ Spectral irradiance.
- $E_a(\lambda)$ Irradiance in air.
- $E_{\text{beg}}$ Beginning irradiance value.
- $E_{\text{cal}}$ Calibration source irradiance.
- $E_d$ Incident downwelling irradiance.
- $E_d(0^-,\lambda)$ Incident spectral irradiance.
- $E_d(z,\lambda)$ Downwelled spectral irradiance.
- $E_{\text{end}}$ Ending irradiance value.
- $E_{\text{meas}}(\lambda)$ Measured radiance.
- $E_{\text{ref}}(\lambda)$ Reference radiance.
- $E_s(\lambda)$ Surface irradiance.
- $E_{\text{rem}}$ Percentage of energy removed from a wavelength band.
- $E_{\text{sky}}(\lambda)$ Spectral sky irradiance distribution.
- $E_{\text{sun}}(\lambda)$ Spectral sun irradiance distribution.
- $E_u(z,\lambda)$ Upwelled spectral irradiance.
- $E_w(z,\lambda)$ Irradiance in water.

### – F –

- $f_i$ Filter number, $i$=0–11.
- $f$-ratio The ratio of new to total production.
- $\bar{F}$ Arithmetic average.
- $\overline{F}(\lambda)$ A mean conversion factor.
- $F(\lambda)$ Calibration factor.
- $F(\lambda)$ A conversion factor to convert PR714 readings to the GSFC sphere radiance scale.
- $\bar{F}(\lambda)$ Average of calibration factors.
- $F_0$ Extraterrestrial irradiance corrected for Earth-sun distance.
- $\overline{F}_0$ Mean solar irradiance.
- $F_0'$ Extraterrestrial irradiance corrected for the atmosphere.
- $\overline{F}_0(\lambda)$ Mean extraterrestrial spectral irradiance.
- $\overline{F}_0(\lambda)$ Mean extraterrestrial irradiance.
- $F_a$ Forward scattering probability of the aerosol.
- $F_i$ A correction factor.

### – G –

- $g_1$ A constant equal to 0.82.
- $g_2$ A constant equal to $-0.55$.
- $G$ Gain factor.
- $G(\lambda)$ $\hat{R}_a(\lambda_i)/\hat{R}_a(670) = (670/\lambda)^{\gamma}\, T_{2r}(670)/T_{2r}(\lambda_i)$.
- $G_e$ Gravitational constant of the Earth (398,600.5 $\text{km}^3\ \text{s}^{-2}$).

### – H –

- $H_{\text{GMT}}$ GMT in hours.
- $H_s$ Altitude of the spacecraft (for SeaStar 705 km).

### – I –

- $i$ Inclination angle or interval index (depending on usage).
- $i'$ Inclination angle minus 90°.
- $I$ Rayleigh intensity.
- $I_0$ Surface downwelling irradiance.
- $I_1$ Radiant intensity after traversing through an absorbing medium.
- $I_2$ Reflected radiant energy received by the satellite sensor.

– J –

$j$ Interval index.
$J2$ The $J2$ gravity field term (0.0010863).
$J3$ The $J3$ gravity field term (−0.0000254).
$J4$ The $J4$ gravity field term (−0.0000161).
$J5$ The $J5$ gravity field term.

– K –

$k$ Wavenumber of light ($1/\lambda$).
$k_1$ Beginning wavenumber.
$k_2$ Ending wavenumber.
$k_c(\lambda)$ Spectral fit coefficient weighted over the SeaWiFS bands; $k_c'(\lambda)$ also used.
$K(z,\lambda)$ Diffuse attenuation coefficient.
$K_0(\lambda)$ Diffuse attenuation coefficient at $z = 0$.
$K_c(\lambda)$ Attenuation coefficients for phytoplankton.
$K_E(\lambda)$ Attenuation coefficient downwelled irradiance.
$K_g(\lambda)$ Attenuation coefficients for Gelbstoff.
$K_L(z,\lambda)$ Attenuation coefficient upwelled radiance.
$K_w(\lambda)$ Attenuation coefficients for pure seawater.

– L –

$L(\lambda)$ Spectral radiance.
$L(z,\theta,\phi)$ Submerged upwelled radiance distribution.
$L_a$ Aerosol radiance.
$L_c(\lambda)$ Cloud radiance threshold.
$L_{cal}$ Calibration source radiance.
$L_g(\lambda)$ Sun glint radiance.
$L_i(\lambda)$ Spectral radiance for run number $i$.
$L_{NER}\lambda)$ Noise equivalent radiance.
$L_r(\lambda)$ Rayleigh radiance.
$L_{r0}(\lambda)$ Rayleigh radiance at standard atmospheric pressure, $P_0$.
$L_s(\lambda)$ Subsurface water radiance.
$L_{sat}(\lambda)$ Saturation radiance for the sensor.
$L_{sky}(\lambda)$ Spectral sky radiance distribution.
$L_t(\lambda)$ Total radiance at the sensor.
$L_u(z,\lambda)$ Upwelled spectral radiance.
$L_W(\lambda)$ Water-leaving radiance.
$L_{WN}(\lambda)$ Normalized water-leaving radiance.

– M –

$m$ Index of refraction.
$M$ Path length through the atmosphere.
$M_m'$ The corrected mean orbit anomaly of the Earth, which is a function of date, and refers to an imaginary moon in a circular orbit.
$M_{oz}$ Path length for ozone transmittance.

– N –

$n$ Index of refraction or mean orbital motion in revolutions per day (depending on usage).
$n(\lambda)$ An exponent conceptually similar to the Ångström exponent.
$n_w(\lambda)$ Index of refraction of water.
$N$ The total number of something.

– O –

$\vec{O}$ $\vec{P} \times \vec{V}$.

– P –

$p_a$ A factor to account for the probability of scattering to the spacecraft for three different paths from the sun.
$p_w$ The probability of seeing sun glitter in the direction $\theta, \Phi$ given the sun in position $\theta_0, \Phi_0$ as a function of wind speed ($W$).
$P$ Nodal period, phaeopigment concentration or local surface pressure (depending on usage).
$\vec{P}$ Orbit position vector.
$P(\theta^+)$ Phase function for forward scattering.
$P(\theta^-)$ Phase function for backward scattering.
$P_0$ Standard atmospheric pressure (1,013.25 mb).
$P_a$ Probability of scattering to the spacecraft.
$P_i$ PR714 raw radiance.
$P_\sigma$ Phaeopigment concentration.

– Q –

$q$ Water transmittance factor.
$Q(\lambda)$ $L_u(0^-,\lambda)$ to $E_u(0^-,\lambda)$ relation factor (theoretically equal to $\pi$).

– R –

$r$ Water-air reflectance for totally diffuse irradiance.
$r_1$ The radius of circle one or source aperture (depending on usage).
$r_2$ The radius of circle two or detector aperture (depending on usage).
$R$ Reflectance.
$R(0^-,\lambda)$ Irradiance reflectance just below the sea surface.
$R_a$ Aerosol reflectance.
$\acute{R}_a$ $R_a/(qT_{2r})$.
$R_e$ Mean Earth radius (6,378.137 km).
$R_L(z,\lambda)$ Spectral reflectance.
$R_r$ Rayleigh reflectance.
$R_{rs}$ Remote sensing reflectance.
$R_s$ Subsurface reflectance.
$R_t$ Total reflectance at the sensor.
$\acute{R}_t$ $(R_t - R_r)/(qT_{2r})$.
$R_z$ Sunspot number.

– S –

$s(\lambda)$ Slope for the range 0–1,023.
$S$ Solar constant.
$S(\lambda)$ $L_a(\lambda)/L_a(670)$.

– T, U –

$t$ Time variable.
$t(k)$ Spectral transmission as a function of wavenumber.
$t(\lambda)$ Diffuse transmittance of the atmosphere.
$t_1$ First observation time.
$t_2$ Second observation time.
$t_0$ Initial time.
$t_{aa}$ Aerosol transmittance after absorption.
$t_{as}$ Aerosol transmittance after scattering.
$t_d$ Direct component of transmittance after absorption by the gaseous components of the atmosphere, scattering and absorption by aerosols, and scattering by Rayleigh.
$t_e$ Time difference in hours between present position and most recent equator crossing.
$t_{EC}$ Equator crossing time.

$t_{oz}$ Transmittance after absorption by ozone.
$t_r$ Transmittance after Rayleigh scattering.
$t_s$ Diffuse component of transmittance after absorption by the gaseous components of the atmosphere, scattering and absorption by aerosols, and scattering by Rayleigh.
$t_{wv}$ Transmittance after absorption by water vapor.
$T_s(\lambda)$ Transmittance through the surface.
$T$ Tilt position.
$T(\lambda,\theta)$ Total transmittance (direct plus diffuse) from the ocean through the atmosphere to the spacecraft along the path determined by the spacecraft zenith angle $\theta$.
$T_{2r}$ Two-way diffuse transmittance for Rayleigh attenuation.
$T_0(\lambda,\theta_0)$ Total downward transmittance of irradiance.
$T_e$ Equation of time.
$T_{ox}$ Transmittance of oxygen ($O_2$).
$T_{oz}$ Transmittance of ozone ($O_3$).
$T_s(\lambda)$ Transmittance through the surface.
$T_w(\lambda)$ Transmittance through a water path.
$T_{wv}$ Transmittance of water vapor ($H_2O$).

– V –

$\vec{V}$ Orbit velocity vector.
$V_i(t_j)$ The $i$th spatial location at observation time $t_j$.

– W –

$W$ Wind speed.
$W_d$ Direct irradiance divided by the total irradiance at the surface.
$W_s$ Diffuse irradiance divided by the total irradiance.

– X –

$x$ Abscissa or longitudinal coordinate, or the pixel number within a scan line (depending on usage).
$X$ ECEF $x$ component of orbit position.
$\dot{X}$ ECEF $X$ component of orbit velocity.

– Y –

$y$ Ordinate or meridional coordinate.
$Y$ ECEF $y$ component of orbit position.
$\dot{Y}$ ECEF $Y$ component of orbit velocity.

– Z –

$Z$ ECEF $z$ component of orbit position.
$\dot{Z}$ ECEF $Z$ component of orbit velocity.

– Greek –

$\alpha$ Percent albedo, tilt angle, formulation coefficient (intercept), or the power constant in the Ångström formulation (depending on usage).

$\beta$ A formulation coefficent (slope) or a constant in the Ångström formulation (depending on usage).
$\beta(z,\lambda,\theta)$ Spectral volume scattering function.

$\gamma$ The Ångström exponent.

$\delta$ Great circle distance from $\Psi_s(t_0)$ to $\Psi_s(t-t_0)$, the departure of each individual conversion factor from the mean, or a relative difference (depending on usage).
$\Delta k$ Equivalent bandwidth.
$\Delta p CO_2$ Partial pressure difference of $CO_2$ between air and sea water.
$\Delta P$ The difference in successive pixels or the pressure deviation from standard pressure, $P_0$ (depending on usage).
$\Delta t$ Time difference.
$\Delta\lambda$ An interval in wavelength.
$\Delta\omega$ The longitude difference from the sub-satellite point to the pixel.
$\Delta\omega_s$ Longitude difference.

$\eta$ Bearing from the sub-satellite point to the pixel along the direction of motion of the satellite.

$\theta$ Spacecraft zenith angle or pitch (depending on usage).
$\dot{\theta}$ Pitch rate.
$\theta_1$ The intersection angle of circle one.
$\theta_2$ The intersection angle of circle two.
$\theta_0$ Solar zenith angle.
$\theta_n$ The zenith angle of the vector normal to the surface vector for which glint will be observed.
$\theta_N$ The angle with respect to nadir that the sea surface slopes to produce a reflection angle to the spacecraft.
$\theta_s$ Scan angle of sensor.
$\theta'_s$ Scan angle of sensor adjusted for tilt.

$\lambda$ Wavelength of light.

$\mu$ Mean value or cosine of the satellite zenith angle (depending on usage).
$\mu_0$ Cosine of the solar zenith angle.
$\overline{\mu}_d(0^+,\lambda)$ Spectral mean cosine for downwelling radiance at the sea surface.

$\nu_j$ The $j$th temporal weighting factor.

$\xi_{EM}$ The distance between the Earth and the moon.

$\rho$ Fresnel reflectivity or the weighted direct plus diffuse reflectance.
$\rho(\theta)$ Fresnel reflectance for viewing geometry.
$\rho(\theta_0)$ Fresnel reflectance for solar geometry.
$\rho_{c,i}$ Reflectance of clouds and ice.
$\rho_n$ Sea surface reflectance for direct irradiance at normal incidence for a flat sea.
$\rho_N$ Reflectance for diffuse irradiance.

$\sigma$ Standard deviation of a set of data values.
$\sigma^2$ The mean square surface slope distribution.

$\tau(z,\lambda)$ Spectral optical depth.
$\tau_a$ Aerosol optical thickness.
$\tau_{ox}$ Oxygen optical thickness at 750 nm.
$\tau_r$ Rayleigh optical thickness.
$\tau'_r$ Pressure corrected Rayleigh optical thickness.
$\tau_{r0}$ Rayleigh optical thickness at standard atmospheric pressure, $P_0$.
$\tau_{ro}$ Rayleigh optical thickness weighted by the SeaWiFS spectral response.
$\tau_s(\lambda)$ Spectral solar atmospheric transmission.

$\Phi$ Spacecraft azimuth angle or roll (depending on usage).

$\dot{\Phi}$ Roll rate.

$\Phi_0$ Solar azimuth angle.

$\Psi$ Pixel latitude or yaw (depending on usage).

$\dot{\Psi}$ Yaw rate.

$\Psi_d$ Solar declination latitude.

$\Psi_s(t)$ Sub-satellite latitude as a function of time.

$\omega$ Longitude variable or the surface reflection angle (depending on usage).

$\omega_0$ Old longitude value.

$\omega_a$ Single scattering albedo of the aerosol.

$\omega_e$ Equator crossing longitude.

$\omega_i$ Spatial weighting factor.

$\omega_s$ Longitude variable.

$\Omega$ Solar hour angle.

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**13. ABSTRACT** *(Maximum 200 words)*

The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) is the follow-on ocean color instrument to the Coastal Zone Color Scanner (CZCS), which ceased operations in 1986 after an eight-year mission. SeaWiFS is expected to be launched in 1995 on the SeaStar satellite, being built by Orbital Sciences Corporation (OSC). The SeaWiFS Project at the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC), has undertaken the responsibility of documenting all aspects of this mission, which is critical to the ocean color and marine science communities. This documentation, entitled the *SeaWiFS Technical Report Series*, is in the form of NASA Technical Memorandum Number 104566. All reports published are volumes within the series. This particular volume serves as a reference, or guidebook, to the previous 17 volumes and consists of 6 sections including: an errata, an addendum (summaries of various SeaWiFS Working Group Bio-optical Algorithm and Protocols Subgroups Workshops, and other auxiliary information), an index to key words and phrases, a list of all references cited, and lists of acronyms and symbols used. It is the editors' intention to publish a cumulative index of this type after every five volumes in the series. Each index covers the topics published in all previous editions, that is, each new index includes all of the information contained in the preceeding indices.

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