Optical Oceanography
From the Single Particle to the Ecosystem:
A Summer Class and a Web Book

Submitted to

Dr. Paula Bontempi
Manager, Ocean Biology and Biogeochemistry Programs
Office of Earth Science, Code YS
NASA Headquarters
300 E St. SW
Washington, DC 29546

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Emmanuel Boss
University of Maine
School of Marine Sciences, 5741 Libby Hall
Orono, ME 04469-4388
207-581-4378 emmanuel.boss@maine.edu

Curtis D. Mobley
Sequoia Scientific, Inc.
2700 Richards Road, Suite 109
Bellevue, WA 98005
425-641-0944 x 109 curtis.mobley@sequoiasci.com

Collin Roesler
Bigelow Laboratory for Ocean Sciences
West Boothbay Harbor, ME 04575
207-633-9600 croesler@bigelow.org

Mary Jane Perry
University of Maine
Darling Marine Center
193 Clarks Cove Road
Walpole, ME 04573
207-563-3146 ext. 245 perrymj@maine.edu

Brian Rahill
RainStorm Consulting, Inc.
48 Forest Avenue
Orono, ME 04473
207-866-3908 brian@rainstormconsulting.com

CONTENTS

INTRODUCTION

Optical oceanography—including bio-geo-optics, ocean color remote sensing, radiative transfer theory, underwater visibility, instrument design, and other subdisciplines—is fundamental to basic oceanographic research and earth remote sensing. Airborne hyperspectral sensors are increasingly being used for monitoring and mapping coastal ecosystems such as sea grass beds and coral reefs, and for littoral zone military operations. In spite of their importance to science, the optical aspects of oceanography are infrequently taught in university oceanography departments. We as educators and scientists have long pondered the best way to educate the next generation of scientists in optical oceanography and ocean color remote sensing and to address the needs of the research community.

During the last two decades we have on occasion been able to teach small numbers of students in summer courses. Our intensive, hands-on curriculum is well proven, and over 100 graduates of our courses have gone on to influential careers. Demand for our summer course remains high, and this educational mechanism should be continued. However, there is also need for a broad-based and permanent repository of information on optical oceanography, which should be available to all. The most recent textbooks (e.g., Mobley, 1994; Kirk, 1994; Spinrad, Carder and Perry, 1994) are all somewhat out of date and limited in their subject matter. No text covers the many developments of the last decade or presents the numerous "tricks of the trade."

We therefore propose a dual approach to education in all aspects of optical oceanography. We will develop a web-based, dynamically growing, on-line "web book" that addresses both the education and reference needs of the broad optical oceanography and ocean color remote sensing communities and which will be freely accessible to all. The presentation will span single particles to ecosystems at user-selectable levels of detail. We will also continue to teach eclectic summer courses using our proven pedagogical methodologies. Each summer course can be tailored to particular needs. In 2007 we will concentrate on NASA-specific needs for education in ocean-color remote sensing.

This proposal thus requests funding to develop a web-based "text book" as a two-year effort and to teach a three-week intensive summer course in 2007, which will emphasize ocean-color remote sensing. The summer course will be used to beta test the initial version of the web book as a teaching tool. The web book will then be completed during year two, incorporating features as suggested by the students in the summer course.

We next describe the web book, and then the summer course.

THE WEB-BASED TEXTBOOK

The guiding idea of this work is to create a web-based, dynamically growing, on-line "web book" that addresses both the education and reference needs of the broad optical oceanography and ocean color remote sensing communities and which will be freely accessible to all. The presentation will span single particles to ecosystems at user-selectable levels of detail.

This book both addresses the educational needs of all levels of students in optical oceanography and serves as a repository of reference information on the underlying theory as well as on the "tricks of the trade." This book thus goes far beyond the previous NASA-, NSF- and Navy-sponsored summer courses, which can be attended by only a few students. **This web book is a new paradigm for education.**

Why a web-based book as opposed to a hardcover book? A web-based book:

1) **Makes the material freely available to all.** University professors and commercial publishers are experimenting with electronic and on-line text books. However, those on-line resources are generally either limited in scope (such as lecture notes on a particular topic; see, for example, www.es.flinders.edu.au/~mattom/IntroOc/ or www.tpdsci.com/) or have unacceptable license restrictions, such as being able to view a given page only a few times or being able to view the book only on one computer. We will avoid these limitations by making our comprehensive web book freely available to everyone.

2) **Allows for on-going updates of the material.** As new peer-reviewed results (observations, theory, techniques, and instrument designs) become available, they can be readily incorporated into the web book, so that the material does not go out of date.

3) **Allows for community input.** This web book can become a community learning center with other people contributing additional material after the "first edition" comes out, á la the open source LINUX software world. We (or others as time passes) would then fill the role of editors of material submitted by others for incorporation into the website.

4) **Goes beyond static black and white.** A web book can make extensive use of color figures, PowerPoint files, film loops (e.g. showing what happens to a radiance distribution as a function of depth, how water color changes during an algal bloom, or showing a time series of an ecosystem simulation), Java applets, and executable codes that a user could run to illustrate certain concepts or investigate selected problems.

The proposed web book will have three levels of presentation:

Level 1: Introduction to Optical Oceanography. This level presents the basic definitions, concepts, example data, and accepted facts of optical oceanography, at about the level of our previous summer course lectures. The intended audience is people new to the field, and those who want just a summary presentation of the subject matter.

Level 2: In-depth examination of the material of Level 1. This level goes into the details [at the level of *Light and Water* (Mobley, 1994) and similar books cited above] of the various level 1 topics so as to bring the reader up to the level of current research. The intended audience is people who plan to do, or are doing, research in optical oceanography, and researchers who are expert in one area and desire to learn the details of another area. For example, level 1 would present basic information on phytoplankton absorption spectra, and level 2 would then go into the details of absorption by different pigments, the roles the pigments play in cell physiology, the differences in pigments and absorption spectra among different kinds of phytoplankton, etc. Similarly, level 1 would derive the radiative transfer equation, and level 2 would discuss solution methods (Monte Carlo simulations, the single-scattering approximation, etc.) and present simulation results to illustrate various concepts such as Monte Carlo noise; or relative influences of absorption, scattering, and phase functions on light fields.

Level 3: Ancillary material. Here we will discuss design, calibration, and data processing for various instruments, or link to websites with such info (e.g., to WETLabs for ac-9 user info, or to NASA protocol documents). This would be like the information in the summer course labs. We would also have pdf's of selected papers (copyrights permitting), of *Light and Water* and *Hydrologic Optics* (Preisendorfer, 1976) or of technical reports (e.g., Petzold's classic technical reports, which are generally unavailable but still useful today). (Note: After *Light and Water* went out of print, Academic Press returned the copyright to Curtis Mobley. Thus all parts of this text can be placed on line. *Hydrologic Optics* by Preisendorfer (1977) is an uncopyrighted U. S. Government document in the public domain, as are many useful government-sponsored technical reports.) We can tabulate numerical data as needed for research or as used to generate some of the figures in Levels 1 and 2. We will also link to available software, such as the SCATTERLIB website of scattering codes (Flatau, 1997; http://atol.ucsd.edu/scatlib/index.htm), and to data sources such as the World-wide Ocean Optics Database (WOOD; Smart, 2000; http://wood.jhuapl.edu/).

Appendix A gives a chapter outline for the web book.

WEB SITE SPECIFICATIONS

Optimal usability is a critical goal for a web-based learning tool such as this web book. To that end, both the public-facing and administration areas of the web book will be built using standards-compliant, accessible XHTML and CSS. Developing the web book using this approach will ensure that it meets the highest standards of accessibility and reaches the widest audience possible according to Section 508 as well as W3C (World Wide Web Consortium) standards. This approach further provides for rapid development, ease-of-update, and faster loading pages.

The web site will be designed and constructed by RainStorm Consulting (http://www.rainstormconsulting.com/) under direction of the B. Rahill, one of the co-principal investigators on this proposal. Rainstorm is committed to this standards-compliant, accessible approach for each and every project it undertakes. Rainstorms' experience developing sites in this manner spans more than fifty projects, many for educational, non-profit, and governmental sectors that require the highest levels of accessibility and usability.

The application logic will be developed using PHP, an open-source development language. The data for the site will reside in a MySQL database, an open-source, enterprise-level database which also powers the NASA Acquisition Internet Service (NAIS) (http://nais.nasa.gov/) website. Nightly, weekly and monthly data backups will be performed on the database and all site files.

The site will reside on a Linux-based server running dual processors, 6 gigabytes of RAM, mirrored hard drives and redundant power supply and Internet connections. Statistics available on the number of visitors, page views, most active pages, top entry and exit pages- as well as referring websites- will be processed nightly and available to the administrators via secure web-based login. These statistics will enable us to gauge the effectiveness and reach of the web book and help to make critical decisions to increase visitors after the site launch.

Content materials for the web book are in a variety of disparate formats including PowerPoint, executable (.exe), PDF, and other file formats. RainStorm will deliver a completed web book that combines each of these unique components in a seamless manner that will ensure all aspects of the web book are accessible and usable across the widest possible platform. When necessary, we will convert existing technologies into simpler formats while maintaining the content and functionality of the tool.

To create and edit the sections of the web book, group staff will login to a secure website administration area and from there select from available components to "build out" the educational modules and their associated assessments. Sample components include sections multiple choice, true/false, and Likert scales. Customized replies and even follow-up components can be assigned based on participant response and/or choice.

While there is additional upfront work needed to make the application this flexible, this approach will allow for the optimal level of control and customization by group staff. It will also provide for the completed application to be easily and quickly converted for other uses, including additional books or revised editions with minimal modification to the underlying code.

Rainstorm has developed similar tools to post books and training manuals online including a 12-chapter, 600-page desk guide for the Bureau of Navy Medicine. In addition, Rainstorm is currently using this technology to develop a semester-long course for college students in nutrition and healthy eating funded by the USDA (#2005-35215-15412) and in conjunction with eight research universities including Michigan State

University, Pennsylvania State University, The University of Rhode Island, and five others.

THE 2007 SUMMER COURSE

This course will be a three-week graduate-level course in optical oceanography and remote-sensing, which will be held at the University of Maine's Darling Marine Center in summer 2007.

The course is a continuation of the tradition started by Mary Jane Perry in 1985 as the Friday Harbor Optical Oceanography course and that was offered in Maine in 2001 and 2004. The course is an intensive, hands-on experience for 16 students and combines theory, modeling, and in-water and above-water measurement in the unique coastal and estuarine settings of the coastal Gulf of Maine.

The course creates an opportunity for graduate students from diverse disciplines to learn the fundamentals of optical oceanography and remote sensing in a coastal/estuarine environment and familiarize them with the state-of-the-art instrumentation. Our objective is to provide a learning and collaborative environment in which graduate students can integrate optics, remote sensing, and oceanography. Our long-term goal is to educate a cadre of students who will have synthesized a perspective of the field and make a difference (as individuals and as a collaborative community) in the field of oceanography in general and ocean optics in particular. The course has been taught seven times: five time at Friday Harbor (in 1985, 1987, 1989, 1995, and 1998) and twice at the Darling Marine Center (in 2001 and 2004). Since 1985 over 100 students from a number of disciplines in oceanography and related fields have benefited from the course. The subsequent successful and influential research and management careers of these students proves that this course is a wise expenditure of effort, time and money for developing the next generation of oceanographers.

The main components of the course will be: (1) lectures; (2) formal (i.e., instructor-directed) laboratory, field sampling and modeling exercises with an emphasis on integration of measurements with models and theory; (3) team-focused field experiments; (4) guest lectures; and (5) student projects in which the students use data from the field experiments to investigate a specific, focused question and conclude with written and oral reports.

In the class the students will learn to calibrate and operate state of the art optical instrumentation (ac-s, LISST floc and LISST b, bb-9, Eco-VSF, fluorometers, hyperspectral radiometers, ISUS, bench-top spectrophotometers), learn methods to measure biogeochemical parameters such as suspended matter and phytoplankton biomass, and to quality control through practices such as calibration and optical closure with different measurements. In addition the students will learn to use Mie codes to compute the optical properties of different types of particles and run HydroLight (http://www.hydrolight.info) the state-of-the-art radiative transfer model provided at no charge by C. Mobley for use during the course. HydroLight allows the students to simulate light fields based on their measurements and compare them to radiometric parameters they measure, as well as simulate "what if" scenarios. The student will learn to process data using Matlab, a powerful tool for analysis of large data sets such as those collected from remote sensing and in-situ sensor systems.

The Darling Marine Center has well-equipped laboratories and classrooms that have been found to be very suitable for the class. We have the computer infrastructure required for the class (laptops for every student, courtesy of the NSF-funded summer 2003 optics and geo-statistics class, with wireless cards installed with funds from the 2004 ocean optics class, and U-Maine supported student Matlab licenses). A 44-foot vessel and a variety of other smaller boats are available. A residence and dining hall will house and feed the students. On-campus housing is available for the faculty and visiting scientists that require it.

INVESTIGATOR ROLES

The various investigators on this proposal each have their own areas of expertise and roles to play in the web site development and summer course teaching, which we outline below (investigator CVs follow the appendices below). Perry was the pioneer in developing the nation's first summer course in Bio-Optical Oceanography, a course that has evolved since 1985 following the needs of the community and still draws more applicants than spaces available internationally. Mobley, Boss, and Roesler, and Perry have all taught intensive courses in optical oceanography and related topics, and are well acquainted with the needs of both students and researchers. They will each participate as a lecturer and a mentor in the Ocean Optics class in the summer of 2007.

C. Mobley is an authority on radiative transfer theory as applied to oceanography and hyperspectral remote sensing. He is the author of the *Light and Water* textbook and the developer of the widely used HydroLight commercial radiative transfer code, which he brings to the course at no charge. He will provide material from *Light and Water* (updated and revised as needed) and his summer course lecture notes, which will be the starting points for various chapters. He will use his various models (HydroLight, Monte Carlo, etc.) to generate example outputs illustrating various features of oceanic light fields. He will take the lead science role in overseeing the design, content, and testing of the entire web site.

E. Boss specializes in understanding scattering and the influence of particles on oceanic light fields. He is also an expert in combining different optical measurements to better constrain size and compositional information of the underlying optically reactive materials. He will contribute content from his lecture, notes, data sets and numerical codes for scattering by spherical and nonspherical particles. Boss will be the lead coordinator the Ocean Optics class. His role on the book will be greater in year 2 than year 1, as level 2 and 3 content is added to the web site.

C. Roesler, an expert on inherent optical properties, and in particular absorption and in bio-optical modeling of IOPs and reflectance to retrieve ocean constituents. She is a principal investigator for the Gulf of Maine Ocean Observing System (GoMOOS), in charge of the optical observing program. She will provide not only modeling code but also observing system data sets with associated analysis tools. She will provide material from her lecture notes, summer course laboratories and cruise activities (including pertinent data). She will also provide Matlab code for instrument-specific data processing (e.g. raw to calibrated ac-9 data) and optical modeling (e.g. peer-reviewed IOP and AOP models of her own and from others) as well as ocean observing optical data sets with data analysis tools.

M. J. Perry will provide her extensive knowledge of bio-optics and particular expertise on phytoplankton physiology and fluorescence. She established the first course in Bio-Optical Oceanography in 1985 and has continued as a leader in education. She will contribute lecture notes and calibration protocols for fluorometers, and will also provide optical data examples from autonomous underwater gliders. Her role will be greater in year 2 than year 1, as level 2 and 3 content is added to the web site.

B. Rahill is the President and founder of RainStorm, Inc. He and other RainStorm personnel have extensive experience in designing websites for government and academic clients as well as developing online, interactive tools. Mr. Rahill will be responsible for overall website project management and direction, server administration, and communication with the team science members. His expertise will insure that the web site is both user friendly and expandable as time goes on. His role is greatest at the start of the project, and less during the second year after the site is designed and the addition of content is the primary task. Other Rainstorm personnel who will contribute to the actual software development are listed in Appendix B.

WORK SCHEDULE

Year 1.

Web site design. The first step of our work is to decide on the layout of the site as regards issues of "useabilty" and ease of maintenance and future upgrades. This design work will be led by B. Rahill, who has extensive experience with sophisticated web sites and on-line publishing (see examples at http://www.rainstormconsulting.com). Guidance as to user needs will be provided by Mobley, Boss, Roesler, and Perry.

Web site construction: The website will be constructed by Rainstorm Consulting under supervision of B. Rahill using content material provied by Mobley, Boss, Roesler, and Perry. Our initial goal is go get Version 1.0 of the web book up and running for use during the summer course. We will populate Version 1.0 with the Level 1 material for Chapters 1 to 8.

Summer course. We will use the Version 1.0 web book as a teaching and reference tool during the 2007 summer course in optical oceanography at the University of Maine. The students in that course will serve as beta testers for the Version 1.0 web site, and their feedback will guide the remaining development of the book

Milestones: The Version 1.0 web book with Level 1 material is locally available at the University of Maine for use during the summer course. This local version, further modified according to the beta-test results from the course, will go on-line for all users at the end of the year. Solicit further user feedback.

Year 2.

During the second year of work, we will continue populating the webbook with Level 2 and 3 material. We will add Chapters 9 and 10 and advanced features, such as interactive codes or applets. During year two, we expect to continue to maintain the site and adjust it as needed based on user feedback and statistics as well as respond in a timely manner with any programming updates and bug fixes.

Milestone: The Version 2.0 web book with all chapters, all level 2 material, and all or most level 3 material goes online at the end of the year.

REFERENCES

Bissett, W. P., K. L. Carder, J. J. Walsh, and D. A. Dieterle, 1999. Carbon cycling of the Sargasso Sea: II. Numerical simulation of apparent and inherent optical properties. *Deep-Sea Res. I* 46, 271-317.

Flatau, P., 1977. SCATTERLIB—Light scattering codes library. In *Ocean Optics XIII*, S. Ackleson and R. Frouin, Editors, Proc. SPIE 2963, 414-416.

Kirk, J. T. O., 1994. *Light and Photosynthesis in Aquatic Ecosystems, Second Edition*. Cambridge Univ. Press.

Mobley, C. D., 1994. *Light and Water—Radiative Transfer in Natural Waters*. Academic Press (out of print as hardcover but now available on CD as searchable pdf files).

Preisendorfer, R. W., 1976. *Hydrologic Optics*. Six volumes published by NOAA Environmental Research Laboratories (out of print as hardcover but now available on CD as searchable pdf files).

Smart, J. H., 2000. World-wide ocean optics database (WOOD). *Oceanography* 13(3), 70-74.

Spinrad, R. W., K. L. Carder, and M. J. Perry, 1994. *Ocean Optics*. Oxford Univ. Press.

Walker, R. W., 1994. *Marine Light Field Statistics*. John Wiley and Sons, 675 pages.

CURTIS D. MOBLEY

Vice President and Senior Scientist
Sequoia Scientific, Inc.
2700 Richards Road, Suite 107
Bellevue, WA 98005
425-641-0944 ext. 109
curtis.mobley@sequoiasci.com

Education and Academic Honors

University of Maryland at College Park. Ph.D. in Meteorology, 1977. Physics minor.
Fulbright Scholar to the Federal Republic of Germany, 1969-70
Woodrow Wilson Fellow, 1969-70
University of Texas at Austin. B.S. in Physics with Highest Honors, 1969

Primary Career Interest

Research in optical oceanography and radiative transfer, especially numerical modeling and remote sensing applications

Employment

Vice President and Senior Scientist, Sequoia Scientific, Inc., 1996-present
Affiliate Professor, School of Oceanography, Univ. of Washington, 1997-present.
Senior Research Engineer, SRI International, 1994-1996
National Research Council Resident Research Associate (Senior), Jet Propulsion Laboratory, 1991-1993
Manager, Oceanic Optics Program, Office of Naval Research, 1989-1991
Joint Institute for the Study of the Atmosphere and Ocean, Univ. of Washington, 1979-1989

Publications:

Light and Water: Radiative Transfer in Natural Waters by C.D. Mobley, Academic Press, San Diego, 592 pages, 1994.

Principal Component Analysis in Meteorology and Oceanography by R.W. Preisendorfer (posthumously), compiled and edited by C.D. Mobley. Elsevier Science Publishers, Amsterdam, 425 pages, 1988.

Seven Invited Book Chapters

Over fifty refereed journal articles in optical oceanography and radiative transfer

Mary Jane Perry
Professor, School of Marine Sciences and Ira C. Darling Center, University of Maine
Affiliate Professor, School of Oceanography, University of Washington
perrymj@maine.edu, (207) 563-3146 ext. 245

A. Professional Preparation:

Ph.D. –1974	Scripps Institution of Oceanography, University of California, San Diego
1974 – 1976	Lecturer, Washington University Medical School, St. Louis, Missouri

B. Appointments:

1999 – present	Professor of Oceanography, University of Maine, Orono, Maine
1999 – present	Affiliate Professor, University of Washington, Seattle, Washington
1980 – 1982	Assistant and Associate Program Officer positions at NSF
1976 – 1999	Progression of professorial ranks at University of Washington, Seattle
1976	Assistant Professor, University of Georgia, Athens, Georgia

C. Publications:

(i) A list of up to 5 publications most closely related to the proposed project.

Sackmann, B., and M. J. Perry. (In press, accepted Nov. 2005). Ocean color observations of a surface water transport event: Implications for Pseudo-nitzschia on the Washington coast. *Harmful Algae.*

Sackmann, B., L. Mack, M. Logsdon, and M. J. Perry. 2004. Seasonal and inter-annual variability of SeaWiFS-derived chlorophyll a concentrations in waters off the Washington and Vancouver Island coasts, 1998-2001. *Deep-Sea Res.* II 51: 945-965.

Daly, K.L, R.H. Byrne, A.G. Dickson, S.M. Gallager, M.J. Perry, and M.K. Tivey. 2004. Chemical and Biological Sensors for Time-Series Research; Current Status and New Directions. *J. Mar. Tech. Soc.* 38:121-141.

Rudnick, D.L., R.E. Davis, C.C. Eriksen, D.M. Fratantoni, and M.J. Perry. 2004. Underwater gliders for ocean research. *J. Mar. Tech. Soc.* 38:73-84.

Eisner, L.B., M.S. Twardowski, T.J. Cowles, and M.J. Perry. 2003. Resolving phytoplankton photoprotective: Photosynthetic carotenoid ratios on fine scales using in situ spectral absorption measurements. *Limnology and Oceanography* 48: 632-646.

(ii) A list of up to 5 other significant publications

McManus, M.A., {others}… M.J. Perry, et al. 2003. Changes in Characteristics, Distribution and Persistence of Thin Layers Over a 48-Hour Period. *Mar. Ecol. Prog. Ser.* 261: 1-19.

Perry, M. J., and D. L. Rudnick. 2003. Observing the ocean with autonomous and Lagrangian platforms and sensors (ALPS): the role of ALPS in sustained ocean observing systems. *Oceanography* 16: 31-36.

Culver, M. E., and M. J. Perry. 1997. Calculation of solar-induced fluorescence from surface and subsurface waters. Journal of Geophysical Research 102: 10,563-10,572.

Roesler, C., S., and M. J. Perry. 1995. Reflectance modeling: a method for determining phytoplankton absorption coefficients and fluorescence from reflectance spectra. Journal of *Geophysical Research* 100: 13,279-13,294.

Perry, M.J. 1986. Assessing marine primary production from space. *BioScience* **36:** 461- 467.

D. Synergistic Activities

2005–present, Observing Steering Committee (formerly ORION Executive Steering Committee)

2005–present, The Oceanography Society, Councilor for Biological Oceanography
2005–present, ACT (Alliance for Coastal Technology) fluorometry Advisory Committee
2004 Co-Chair of NSF Committee of Visitors' review of "Biocomplexity in the Environment"
2004 Member of Office of Naval Research Board of Visitors' review of Ocean Sciences
2004 Speaker at EPSCoR workshop on "Environmental Observing Systems"
2004 Alliance for Coastal Technologies workshop on AUVs and gliders, invited speaker
2003 Co-Chair of workshop on "Autonomous and Langrangian Platforms and Sensors"
2003 Speaker at workshop on "Next Generation of Biological and Chemical Sensors"
2002 NRL Shallow Water Analysis Meeting, participant
2000–2002, Member of NSF Advisory Committee / Geosciences
2000–2002, Member of NSF Advisory Committee / Environmental Research & Education

Innovative Teaching: In 1980, optical and biological oceanography were distinct communities with different languages and cultures. In 1985 I developed an interdisciplinary, team-taught, intensive summer course in bio-optical oceanography that has been taught many times since; this course has played a significant role in bridging the chasm between communities and in creating a new one.

Research: My long-term goal is to understand the mechanisms responsible for controlling the abundance, distribution, and productivity of marine phytoplankton in the ocean. My current research focuses on the interpretation of optical data in a physiological context and on the incorporation of optical sensors into under-water, autonomous platforms for long-term ocean observations.

E. Collaborators & Other Affiliations.

(i) *Collaborators*

Alice Allredge (UCSB), Robert Byrne (USF), Paula Coble (USF), William Cochlan (SFSU), Tim Cowles (OSU), Mary Culver (NOAA), Kendra Daly (USF), Russ Davis (SIO), Margaret Dekshenieks (UH), Russell Desiderio (OSU), Andrew Dickson (SIO), Percy Donaghay (URI), David Fratantoni (WHOI), Scott Gallager (WHOI), Louis Goodman (UmassD), Van Holliday (BAE), Curt Mobley (Sequoia), Monica Orellana (IBS), Dan Rudnick (SIO), Collin Roesler (Bigelow), Margaret Tivey (WHOI), Charles Trick (WOU), Bess Ward (Princeton). All University of Washington faculty and WET Labs personnel.

(ii) *Graduate and Post Doctoral Advisors*

Doctoral advisor: R. W. Eppley (retired)
Postdoctoral advisor: O. H. Lowry, deceased.

(iii) *Thesis Advisor and Postgraduate-Scholar Sponsor*

Postgraduate scholars: Emmanuel Boss (UMaine), Paula Coble (USF), Rick Reynolds (Scripps)
Ph.D. students: Bess Ward (Princeton), Joan Cleveland (ONR), Monica Orellana (UW), David Martin (UW), Collin Roesler (Bigelow Labs), Mary Culver (NOAA)
M.S. students: J. Bolger, N. Navaluna, Boh-Yen Bang, J. Coleman
Present graduate students: Brandon Sackmann, Brian Thompson, Andrea Drzewianowski, Caleb Carter

Collin S. Roesler
Bigelow Laboratory for Ocean Sciences
180 McKown Point Road
West Boothbay Harbor, ME 04575
Tel.: (207) 633-9654
Fax: (207) 633-9641
Email: croesler@bigelow.org

EDUCATION

1985 B. S. Brown University, Geology and Aquatic Biology (double major, with honors)
1987 M. S. Oregon State University, Oceanography (Physical)
1992 Ph. D. University of Washington, Oceanography (Biological)

EMPLOYMENT

1999 - present	Senior Research Scientist, Bigelow Laboratory for Ocean Sciences
2003 - 2004	Visiting Professor, Geology Dept., Bowdoin College
1999 - 2003	Adjunct Professor, Department of Marine Sciences, University of Connecticut
1994 - 1999	Assistant Professor, Department of Marine Sciences, University of Connecticut
1993 - 1994	Postdoctoral Fellow, College Ocean. Atmos. Sci., Oregon State University

PEER-REVIEWED PUBLICATIONS APPLICABLE TO PROJECT

*Student or post-doc first author

Roesler, C. S. and D. B. Chelton. 1987. Zooplankton variability in the California Current, 1951-1982. CalCOFI Rep. 28: 59-96.

Roesler, C. S., M. J. Perry, and K. L. Carder. 1989. Modeling *in situ* phytoplankton absorption from total absorption spectra. Limnol. Oceanogr. 34: 1512-1525.

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Schofield, O., J. Grzymski, W. P. Bissett, G. Kirkpatrick, D. F. Millie, M. Moline, and **C. S. Roesler.** 2000. Optical monitoring and forecasting systems for harmful algal bloom: possibility or pipe dream? J. Phycol. 35: 1477-1496.

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Brian M. Rahill

48 Forest Avenue
Orono, Maine
(207) 866-0197
(207) 866-3908

EDUCATION

M.A., The Ohio State University, Columbus Ohio, 1999, Cultural Studies in Education

B.S. Biochemistry and Microbiology, Dual Major, University of New Hampshire, 1994 Summa Cum Laude

PROFESSIONAL EXPERIENCE

President 1999-present

RainStorm Consulting
www.rainstormconsulting.com

Laboratory Manager / Research Associate 1994-2000

Department of Pathology
The Ohio State University

PUBLICATIONS

Randolph-Habecker JR, **Rahill B**, Torok-Storb B, Vieira J, Kolattukudy PE, Rovin BH, Sedmak DD. The expression of the cytomegalovirus chemokine receptor homolog US28 sequesters biologically active CC chemokines and alters IL-8 production. *Cytokine*. 2002 Jul 7;19(1):37-46.

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Shaw JE, Knisley S, Severson L, **Rahill B**, Lang RW. Establishment of AIDS-related primary-effusion lymphoma (PEL) cell lines that proliferate continuously without serum. *J Virol Methods*. 2001 May;94(1-2):137-46.

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PATENT

Daniel D. Sedmak, Dan M. Miller, Brian M. Rahill, Yingxue Zhang: Methods for Disrupting IFN Signal Transduction. Patent #US6103531.

Emmanuel Boss
School of Marine Sciences
University of Maine, 5741 Libby Hall
Orono, ME 04469
Tel.: (207) 581-4378
Fax: (207) 581-4388
Email: emmanuel.boss@maine.edu URL: http://misclab.umeoce.maine.edu/

a. Professional Preparation.

1990 B. S.	Hebrew Univ., Math, Physics, Honors
1991 M. S.	Hebrew Univ., Oceanography, Highest honors, (advisor Nathan Paldor)
1996 Ph. D.	Univ. of Washington, Oceanography (advisor Luanne Thompson)
1997	Postdoc, Univ. of Washington., Oceanography (advisor MJ Perry)
1998	Postdoc, Oregon State Univ., Oceanography (advisor JRV Zaneveld)

b. Appointments.

1999-2002	Assistant Professor (Sr Res), Oregon State Univ., Oceanography
2002-2005	Assistant Professor, School of Marine Sciences, Univ. of Maine
2005-present	Associate Professor, School of Marine Sciences, Univ. of Maine

B. 5 Pertinent publications.

Peng, W., E. Boss, and C. Roelser, 2005. Uncertainties of inherent optical properties obtained from semi-analytical inversions of ocean color. Applied Optics, 44, 4074-4085.

Boss E., W. S. Pegau, M. Lee, M. S. Twardowski, E. Shybanov, G. Korotaev, and F. Baratange. 2004. The particulate backscattering ratio at LEO 15 and its use to study particles composition and distribution. J. Geophys. Res., 109, C0101410.1029/ 2002JC001514.

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Five other significant publications:

Behrenfeld, M. J., E. Boss, D. A. Siegel, and D. M. Shea, 2005. Carbon-based ocean productivity and phytoplankton physiology from space. Global Biogeochemical Cycles, 19(1), GB100610.1029/2004GB002299.

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C. Collaborators

Y. Agrawal (Sequoia Sci.), M. Behrenfeld (NASA Goddard), B. Bergamaschi (USGS, Sacramento), F. Chai (U. Maine), T. Dickey (UC, Santa Barbara), W. Gardner (Texas A&M), P. Hill (Dalhousie), B. Jones (USC), P. Jumars (U Maine), L. Karp-Boss (U. Maine), C. Lee (U. Washington), C. Mobley (Sequoia Sci.), M. J. Perry (U. Maine), C. Roesler (Bigelow), J. Trowbridge (WHOI), M. S. Twardowski (WetLabs), R. J. V. Zaneveld (WetLabs).

D. Advisors and advisees

N. Paldor, L. Thompson, M. J. Perry and R. J. V. Zaneveld
S. Hearing, P. Wang, W. Salde, M. Estapa, C. Russo, T. Bergman.

APPENDIX A: WEB BOOK CHAPTER OUTLINES

Chapter 1. Introduction.

Level 1. A qualitative overview of optical oceanography showing why optics is an important subdiscipline of oceanography. Present a few specific examples showing optics as crucial to primary production, ocean color remote sensing, and ecosystem management (e.g., remote sensing of coral reefs or sea grass beds for mapping and monitoring) and prediction (via coupled physical-biological-optical models).

Level 2. Glossary of terms. This will include not just inherent and apparent optical properties (IOPs and AOPs), etc., but also terms applicable to the technology, like LED and PMT, in which we not only describe what it is but also how it is used in instrumentation and what its capabilities and weaknesses are. This would be very useful, for example, when someone buys a bench-top spectrophotometer and has to choose between a diode array and PMT detector–it makes a huge difference for suspensions.

Chapter 2. Light

Level 1. Basic Radiometry. Light and how it's measured; similar to Chapter 1 of *Light and Water*.

Level 1. Descriptive overview of various commercial instruments (Satlantic, Biospherical, etc) for measuring E_d, L_u, etc.

Level 2. The solar spectrum and atmospheric effects on sunlight at the sea surface.

Level 2. Polarization. Stokes and Mueller formulations. When can you get by with an unpolarized description of light, and when do you need to account for polarization.

Level 3. Photometry. Show what happens to radiometry when you use the human eye as an instrument. Although not central to optical oceanography, photometry is important for Secchi disk observations and visibility by humans and fish, and for understanding the human perception of ocean color (what we see versus what we measure).

Level 3. Design of radiometers. Calibration. More detailed discussion of particular instruments. Links to company websites.

Level 3. Selected advanced results from radiometry, optics, and optical engineering that are used in instrument design.

Chapter 3. Overview of Optical Oceanography

Level 1. Definitions of IOPs and AOPs; similar to parts of *Light and Water* Chapter 3.

Level 1. Examples of measured IOPs and AOPs (e.g., as a function of chlorophyll concentration for case 1 water, or of sediment load for Case 2, or show bottom effects on R_{rs} for shallow water).

Level 1. Derive the radiative transfer equation (RTE), Gershun's law, and a few other basic formulas. Discuss connections between radiative transfer theory and IOPs and AOPs to show the theoretical structure of optical oceanography.

Level 2. Case 1 vs Case 2 waters: utility of and problems with this classification scheme.

Level 2. The Jerlov classification of ocean water types.

Level 3. Pdfs of selected papers.

Level 3. Links to websites with optical oceanography info (e.g., ONR, NRL, NASA, WOOD and NODC databases)

Chapter 4. Optical Constituents of the Ocean

Level 1. What is a particle; what is a dissolved substance? What is a phytoplankton? Like M. J. Perry's summer course lecture on phytoplankton and how you can view them in various ways, with emphasis on scale and structure. Link to Phytopia to view phytoplankton, review properties.

Level 1. Optical properties of various constituents. Example phytoplankton, colored dissolved material (CDM),and mineral particle absorption and scattering spectra.

Level 2. Partitioning of particle and dissolved constituents into their sub-classifications (CDM, particulate organic and inorganic components, etc)

Level 2. Commonly used models for IOPs and AOPs.

Level 2. Particle size distributions, and how the size distribution affects IOPs.

Level 2. Going from single particle optical properties to bulk IOPs.

Level 3. Overview of Mie theory.

Level 3. On-line executable Mie code and examples.

Level 3. Pdfs of selected papers.

Chapter 5. Absorption

Level 1. Review of the definitions of absorbance, absorbtance, and absorption coefficient.

Level 1. Measurement of absorption by various instruments (ac-9, spetrophotometers, integrating cavities, etc).

Level 1. Examples of absorption spectra for various constituents (phytoplankton, CDM, minerals, etc).

Level 2. Compare strengths & weaknesses of various instruments for measuring absorption. For example, when and why would you use an ac-9 vs. a spectrophotometer?

Level 2. Absorption by pure water: a simple problem that is not so simple.

Level 2. Detailed discussion of absorption spectra of various constituents, phytoplankton pigments. Pigment packaging effects on absorption spectra.

Level 2. Overview of the biological roles played by different phyto pigments (phytosynthetic vs photoprotective, etc.)

Level 2. Absorption of light and re-emission as fluorescence and other loss terms (heat and photochemistry).

Level 3. Mie theory again, as pertains to absorption.

Level 3. Discuss how to use and calibrate various instruments, e.g., scattering correction for ac-9 absorption measurments. Like some of the summer course labs.

Level 3. Links to WETLabs for ac9 user info, etc.

Chapter 6. Scattering

Level 1. Review of the definitions of the volume scattering functin (VSF), phase function, scattering coefficient b, backscatter coefficient b_b, etc.

Level 1. Measurement of scattering by various instruments (ac-9 for b, Hydroscat and EcoVSF for b_b, historical and current instruments for VSF, LISST for small-angle VSF. Also discuss benchtop laboratory instruments for VSF measurement.).

Level 1. Examples of scattering spectra for for b and b_b and the backscattering ratio

Level 1. Examples of VSF measurments. Petzold's and recent data.

Level 2. Historical models for the VSF (Henyey-Greenstein, etc).

Level 2. Recent models for the VSF (Fournier-Forand in particular).

Level 2. Scattering by pure water and salt water.

Level 3. Mie theory again, as pertains to scattering.

Level 3. Discuss how to use and calibrate various instruments, e.g., Hydroscat and EcoVSF. Like some of the summer course labs.

Level 3. Links to WETLabs for ac9 user info, HOBILabs for HydroScat, etc.

Level 3. Interactive Mie simulations with public software.

Level 3. Scattering by inhomogeneous and nonspherical particles.

Level 3. Salinity and temperature effects on scattering.

Chapter 7. Radiative Transfer Theory

Level 1. Review of the RTE. Similar to parts of *Light and Water*, Chapter 5.

Level 1. Simple solutions of the RTE. A few cases such as no absorption or isotropic scattering.

Level 1. Examples of measured or modeled radiance distributions to show behavior with depth/wavelength/albedo of single scattering, etc.

Level 2. Boundary conditions at the air-water surface. Fresnel equations, Cox-Munk wave slope-wind speed law, gravity-capillary wave spectra, etc.

Level 2. Boundary conditions at the sea bottom. Bidirectional Reflectance Distribution Function (BRDF) definition. Lambertian bottoms. Example bottom reflectances for different materials.

Level 2. The asymptotic radiance distribution.

Level 2. The two-flow equations and their weaknesses.

Level 2. Incorporation of Raman scatter into the RTE.

Level 2. Incorporation of chl fluorescence into the RTE.

Level 2. Solving the RTE: The single-scattering approximation. Like Mobley's summer course lecture.

Level 2. Solving the RTE: Monte Carlo methods. Like *Light and Water* Chapter 6, but with examples.

Level 3. Incorporation of CDOM fluorescence into the RTE.

Level 3. Solving the RTE: The second-order scattering analytical solution of Walker (1994). Used in the applied community.

Level 3. Solving the RTE: Diffusion theory. Not often useful in optical oceanography, but sometimes used for sea ice.

Level 3. Solving the RTE: Invariant imbedding theory. What Hydrolight uses. Like *Light and Water* Chapter 8.

Level 3. Solving the RTE: Discrete ordinates. Widely used in atmospheric optics; occasionally used in optical oceanography.

Level 3. Solving the RTE: How to model wind-blown sea surfaces with full gravity-capillary wave spectra and Monte Carlo ray tracing.

Level 3. If time permits, we will develop an executable version of EcoLight (a specialized and extremely fast version of HydroLight) that the user could run on-line to solve a selected class of problems, similar to the SBDART website (http://arm.mrcsb.com/sbdart/) for atmospheric radiative transfer calculations.

Chapter 8. Remote Sensing

Level 1. Definition of the remote sensing reflectance R_{rs} and related quantities.

Level 1. Remote sensing as an inverse problem.

Level 1. Different kinds of remote sensing: multispectral vs hyperspectral, active vs. passive, etc.

Level 1. Overview of ocean color imagers (SeaWiFS, MODIS, PHILLS, CASI, etc.)

Level 1. Examples of multispectral (e.g., SeaWiFS) imagery, hyperspectral (e.g., PHILLS) imagery, LIDAR, etc.

Level 1. Overview of operational and planned ocean color remote sensing satellites and airborne systems.

Level 1. Measurment of R_{rs} from above the surface (removal of sky reflectance).

Level 1. Measurement of R_{rs} from below the surface (extrapolating L_u upward).

Level 1. Example R_{rs} spectra. As functions of chlorophyll concentration in case 1 waters, coastal waters with high sediment loads, shallow waters with bottom effects, etc.

Level 2. Band-ratio algorithms for extraction of environmental information from remote-sensing data (CZCS to MODIS)

Level 2. Semi-analytic models for extraction of environmental info from remote-sensing data.

Level 2. Analytic models….

Level 2. Shape-function models….

Level 2. Neural network models….

Level 2. Spectrum-matching and look-up-table methods….

Level 2. Different types of LIDAR systems: search light vs flood light, range gated vs synchronous scanning, etc.

Level 2. LIDAR bathymetric remote sensing. Overview of LIDAR bathymetry and operational LIDAR systems (e.g., SHOALS)

Level 3. Codes for inversion of R_{rs}.

Level 3. Derivation of the LIDAR equation.

Level 3. Links to remote sensing web sites (SeaWiFS, etc).

Chapter 9. Ecosystem Optical Modeling

Level 1. Historical models for primary production (PP); the exp($-K_{PAR} \bullet z$) level of incorporating light into biological PP models

Level 1. Problems with using PAR rather than spectral scalar irradiance $E_o(\lambda)$ in PP models. Problems with using E_d as a proxy for E_o.

Level 1. Improved light calculations: e.g., use of Morel's spectral model of $K_d(\lambda)$ (as a function of chlorophyll for Case 1 waters) for computing in-water light for PP models (as done, for example, in the EcoSim model of Bissett et al., 1999).

Level 1. Overview of current ecosystem models (ROMS-EcoSym-EcoLight and similar models)

Level 1. Monitoring and understanding ecosystems: overview of ocean observatories and optics in observatories. Science vs operational issues. Data collection and archiving issues.

Level 2. Partitioning ecosystem components into functional groups, each with its own optical properties (as is done in EcoSym).

Level 2. Improved light computations for ecosystem models: EcoLight.

Level 2. Coupled physical-biological-optical models, e.g., the ROMS-EcoSym-EcoLight model now under development by Mobley.

Level 2. Use of remote sensing for validation of ecosystem model predictions.

Level 3. Film loops of ecosystem model predictions of spring blooms, episodic events, etc.

Level 3. Detailed descriptions of ROMS, EcoSim, EcoLight, and other models used in coupled ecosystem models.

Level 3. Links to ocean observatories (GoMOOS, BATS, HOTS, COOL, etc.)

Chapter 10. Visibility and Imaging

Level 1. Environmental effects on visibility: particle scattering vs absorption vs turbulence; backscatter vs forward scattered light.

Level 1. Overview of oceanographic imaging systems.

Level 1. Definition and equivalence of point spread (PSF) and beam spread (BSF) functions.

Level 1. The PSF as the fundamental quantity governing visibilty.

Level 1. Example PSFs as functions of particle types, VSF, distance.

Level 2. Radiative transfer and photometry of the Secchi disk.

Level 2. Visibility as a convolution of the image at zero distance with the PSF.

Level 2. How the convolution integral leads to the use of Fourier transforms and MTFs in image analysis and prediction.

Level 2. Underwater photography. Overview of the basics.

Level 2. Using polarization to improve images.

Level 3. Imaging though the sea surface.

Level 3. Fluorescence imaging (e.g., FILLS)

Level 3. Historical imaging systems (e.g., Magic Lantern)

Level 3. Recent imaging systems (e.g., Streak-tube imaging LIDAR)

Chapter 11. Special Topics

This chapter will discuss various topics of current interest, for example:

Level 2. The detection and monitoring of harmful algal blooms.

Level 3. Specifics of data analysis and interpretation for observing on various platforms (i.e. moorings, floats, and gliders). This is a very timely and important issue, as the data issues are different depending upon what is being measured (i.e. fluorescence versus absorption based chlorophyll on any platform; radiance versus k on a mobile platform, etc.)

We will sometimes want to present the same information in more than one chapter. For example, IOP models could be presented in the "Overview of Optical Oceanography" chapter, and then the absorption models could be included again in the absorption chapter, and the scattering models could be included again in the scattering chapter. Ditto for Mie theory, which in important for understanding both absorption and scattering. This can be easily done via linking the same material to various chapters.

APPENDIX B: WEB BOOK DESIGN PERSONNEL

In addition to Brian Rahill, the principal investigator for the web aspects of the on-line book, other RainStorm personnel (included in the RainStorm budget), whose expertise will contribute to the web site development are

Ron Adams, B.A. - Senior Web Developer
Mr. Adams has experience has extensive skills and experience in the areas of web-based and database programming. His recent work includes online tools for The Ohio State University, The University of Maine, The Surgeon General of the United States and the Bureau of Navy Medicine. Ron will be responsible for writing the underlying application logic that will drive the interactive features of the website and contribute to its ease of maintenance.

Alexandra Roberts, B.A. - Web Developer
A 2005 graduate of the University of Maine with a degree in New Media, Alexandra builds and manages standards-compliant, CSS-based websites for RainStorm. Her skills in Flash, video production, and software training are also essential components of RainStorm's offerings.

Jason Clarke - Web Developer
A web developer and writer, Jason works on project management, client relations, and web development for RainStorm. He also helps RainStorm clients navigate more recent web-based opportunities including blogging, online advertising, and community-building strategies.

Jeremy Knope, B.A. - Programmer

A programmer fluent in many languages including PHP, Ruby, Python, and several others, Jeremy is architect and developer for RainStorm's many dynamic, web-based applications and services. His attention to new technologies combined with his deep-rooted understanding of programming helps ensure RainStorm is continually improving its suite of customized online tools.

Sean P.O. MacCath-Moran, B.S. - Programmer
A skilled PHP/MySQL programmer with superb attention to detail, Sean P.O. MacCath-Moran has more than 10 years professional experience as a developer across a wide variety of platforms. He holds a BS in computer science from the University of Maine, Orono as well as two other degrees. His numerous awards and honors include a Navy Achievement Medal.