First Workshop report for the Office of Naval Research (ONR)
Radiance in a Dynamic Ocean (RaDyO) Program

University of Rhode Island, Narragansett, Rhode Island

November 14-16, 2005

Workshop Report compiled by Tommy Dickey and Grace Chang (UCSB)

Introduction

The Office of Naval Research (ONR) has initiated a new 5-year research initiative, entitled Radiance in a Dynamic Ocean (RaDyO). The program officially began October 1, 2005 and its first workshop was held at the University of Rhode Island (URI) in Narragansett, Rhode Island November 14-16, 2005. The overarching research objective of RaDyO is to investigate the time-dependent distribution of radiance within the upper ocean. The primary goals of the program are: 1) to examine the time-dependent distribution of radiance in relation to a dynamic ocean surface boundary layer, 2) to combine a radiance-based transfer model with models of surface boundary layer processes including surface waves and bubble production, and 3) to investigate the feasibility of inverting coupled models to determine key conditions within the surface boundary layer. RaDyO will utilize a combination of field observations and models to meet its research objectives. It is anticipated that major field activities will take place in 2007 and 2008. Some preliminary fieldwork is expected to precede these two principal field years. Theoretical and modeling activities will be conducted throughout the duration of RaDyO and it is anticipated that these approaches will be closely tied to the planning of field experiments and the analyses and simulations of field observations.

The program manager for RaDyO is Steve Ackleson of ONR, the lead-scientist is Tommy Dickey, and the co-lead-scientist is Grace Chang (both of the University of California, Santa Barbara (UCSB)). Contact information for RaDyO investigators (along with their primary research objectives) and relevant ONR program managers are found on the RaDyO website, http://www.opl.ucsb.edu/radyo/. The RaDyO website is also used to inform the public about RaDyO activities, to disseminate research information among RaDyO investigators, and to facilitate the sharing and optimal utilization of RaDyO data and models.

Workshop Goals and Summary of Workshop Activities

The first RaDyO Workshop was organized by program manager Steve Ackleson with the assistance of Sarah Kolesar. The local host for the meeting was David Farmer, Dean of the Graduate School of Oceanography of the University of Rhode Island.

There were several goals for the inaugural meeting of RaDyO investigators and associated ONR program managers. Some of the major accomplishments of the workshop follow:

1. The workshop provided the first opportunity for investigators, who had been selected for inclusion in RaDyO, to meet each other, share ideas, and begin dialogues and planning of field and modeling studies.

2. Steve Ackleson outlined ONR's major motivations for initiating RaDyO and its expectations.

3. Each participating group provided key information concerning its proposed RaDyO research activity during 15-minute formal presentations followed by brief question and answer periods. In particular, the groups:
   a. Summarized their specific research goals and explained how these goals would contribute to the overarching RADyO program objectives
   b. Provided lists of specific observations (i.e., properties and variables to be measured) and/or modeling strategies
   c. Described observational, platform, and logistical needs
   d. Listed areas of needed complementary observations and/or modeling (i.e., gaps)
   e. Identified potential redundancies

Each group's powerpoint presentation is available on RaDyO's website (password protected).

4. The discussion portion of the workshop was organized by subdividing the RaDyO investigators into three separate groups with a leader/rappateur, who was responsible for summarizing the deliberations and discussions of the subgroup. The subgroups included representatives of each of the major subdisciplines in order to facilitate the discussion of cross-cutting issues. The three major topical areas addressed independently by each subgroup were:

Topic #1: RaDyO objectives & logistical requirements
Topic #2: Approach & schedule
Topic #3: Data management and reporting

At the end of each breakout session of the subgroups, a plenary session was used to summarize and synthesize the discussions bringing closure to the topics.

5. The final plenary session included discussions of
a. short term funding issues (FY06) led by Steve Ackleson,
b. action items and responsibilities,
c. project science leadership, and
d. schedule for the next meeting date and location

The remainder of the report focuses on summaries of the discussions devoted to Topics #1, 2, and 3 (based on point 4. above) and includes a concluding section (based on point 5. above).

Summaries of Discussions of Topics #1, 2, and 3
The leaders of the subgroups for these discussions were Tommy Dickey (Subgroup 1), Russel Morison, (Subgroup 2), and Marlon Lewis (Subgroup 3). Notes for the individual groups may be obtained from each of these leaders. Here, we have attempted to synthesize and summarize the major points derived from the collective discussions.

<u>Topic #1: RaDyO objectives & logistical requirements</u>
Purpose: to identify the overarching goals of RaDyO. We were asked to answer the question "What new fundamental understanding do we expect to emerge from this project?" and to identify the primary observational and modeling requirements necessary to achieve those goals.

An overarching goal of RaDyO is to learn how time-dependent radiance distribution is influenced by the sea surface, the surface boundary layer (SBL), and the atmosphere. Fundamental understanding of coupling and interactions of surface physical and optical processes is a project objective.

It is anticipated that fundamental understanding will be advanced in several areas. For example,

1. We will find out what real, sea-surface topography is like and how it varies as a function of time and over a range of spatial scales.
    a. Undulating, but unbroken surface
    b. Higher sea-states (whitecaps and more)
2. We will discover the wave group contribution to breaking and its contribution to bubble injection
3. We will better understand the dynamics of the evolution of the resulting bubble field (concentration, size, depth (x,y), time) following a breaking event as a function of a) local turbulence, b) hydrodynamics of breaking events (and hydrodynamic feedback), c) buoyancy (collective/individual), d) advection, e) dissolution, f) stabilization, and g) background circulation patterns (Langmuir)
4. We will reach a better understanding of the modification of the underwater radiance field as a result of real sea-surface topography.
5. We will better understand the relative role of bubbles, including organic coatings and the particle-bubble interactions, in the space and time-dependent variation in the scattering of light in the upper ocean.
6. We will be able to make several physical inferences based on optical measurments

The research activity will necessarily entail use of both forward and inverse models and observations and models must encompass a broad range of scales of processes in space and time.

General observational requirements will include measurements of:
1. visible radiation distribution (up and down, above and below ocean surface)
2. surface and internal gravity waves
3. physical processes with scales down to microscales at and near the surface and upper ocean dynamics and structure including turbulence – for example, this will include identification and measurements of Langmuir cells, fronts, eddies, coastal runoff
4. inherent optical properties (IOPs) in water column and relevant biological constituents
5. optics to measure surface waves and breaking and bubbles and their properties
6. acoustics to measure bubbles and their properties and distributions
7. meteorological variables (i.e., for spectral solar radiation, heat and momentum fluxes, etc.)
8. surfactants

Some examples of specific observational requirements are outlined below to provide a more detailed starting point for planning:

1. Meteorology (Sufficient for Q_n estimation)
    a. Wind speed/direction
    b. Humidity
    c. Air Temperature
    d. Solar irradiance downwelling (SW)
    e. Solar irradiance upwelling (SW and LW)
    f. "Sky" radiance distribution (polarized, unpolarized)
    g. Upwelling radiance distribution (polarized, unpolarized)
    h. Sonic anemometer
    i. Surface skin temp
2. Sea-surface roughness
    a. Surface slope field (polarometric camera; resolution cm scales capillary waves)
    b. Stereophoto (longer than 50 cm)
    c. Side-scan Doppler sonar (300 m range, 1.5 m resolution)
    d. Laser altimeter 1 cm height resolution 3 desired; incremental funds needed.
    e. Directional wave buoy? Probably not.
    f. Surfactants (surface only) skimmer & incremental funds needed. Skimmer –what to do with data? Important for capillary waves and bubbles
    g. Video (Vis/IR) for whitecaps
    h. Microscale breakers (Video, Vis/IR)
3. Upper ocean boundary layer (50 meters, some deeper)
    a. Turbulence (Coherent Doppler/shear probes)
    b. Bubble size distribution (<5 – 600 μm)
    c. Bubble size distribution (VSF inversion – potentially small)
    d. Hyperspectral a and c, E_D
    e. Vertical sonar to get penetration depth of bubble clouds /vertical velocity
    f. Radiance distributions, upward/downward; unpolarized and polarized, fixed angles f(t)
    g. Co-location highly desirable – with platform to be determined
    h. CTD
4. Sub-surface (>50 meters) –various physical measurements such as CTD, currents etc.

Similar outlines will be developed by investigators for other aspects of the project. Note that time and space synchronization using GPS will be necessary.

Modeling requirements will include:
1. surface wave fields
2. turbulence and large eddy simulations
3. boundary layer models of several scales from mm to Langmuir cells
4. near surface and upper ocean dynamics and thermodynamics (including penetration of spectral solar radiation)
5. radiative transfer above and within the upper ocean
6. interfacial models for transmission coefficient across sea surface (i.e., optical MTF of surface)

7. bubbles and turbulence

Topic #2: Approach & Schedule

Purpose: to outline an approach and schedule that will realize the project goals and, at the same time, permit the individual research to follow personal research interests. Given that there are limited funds and a prescribed funding profile, it was deemed important to specify responsibilities, identify potential observational or modeling gaps, and indicate potential redundancies (e.g. several groups measuring the same thing). We were asked to suggest and justify one or more study sites.

The group consensus was that two major field experiments should be conducted – likely in two different oceanographic settings – the first in FY 2008 and the second in FY 2009. It was felt that instrument development and testing as well as some fundamental science goals could be accomplished in laboratories in FY 2006 and by using a well-equipped pier in FY 2007. The Scripps pier was suggested as a good possibility for the latter work and this will be discussed in detail at the next RaDyO workshop to be held in San Diego. It is anticipated that a visit to the Scripps pier will be made as part of that meeting. FY 2010 will be used for analyses, modeling, and publication development.

Consideration of all aspects of the program revealed no major redundancies. The apparent overlaps were in fact deemed to be quite advantageous for the project. For example, some duplication of instrumentation and measurements is desirable because of possible instrument failures and for verification of measurements.

There are several important factors that investigators deem to be important in regard to field sites and observational platforms. Below, we outline some of the major points of these discussions.

Sites

Overall, the experiments should encompass a broad range of wave and optical conditions. The water depths of interest for the program appear to be greater than 100-200 m so as to obviate bottom influences. Relatively clear waters ($<0.5\ m^{-1}$) were desired. Some of the measurements and anticipated platforms will require relatively benign oceanic conditions. For example, deployments of AUVs and even some mooring operations cannot be accomplished in high wind and wave state conditions. Those interested in small-scale wave, bubble, and optical measurements also need relatively benign conditions (e.g., 7-12 m/sec winds or less). On the other hand, some of the wave-oriented investigators desire moderate to intense wind (but less than hurricane force) and wave conditions (e.g., well-developed sea states). Some investigators prefer a full range of solar radiation and cloud conditions, while others will be limited in this regard. Sites that have been offered as candidates by RaDyO investigators include: off Hawaii (i.e., the HALE-ALOHA/HOT site north of Oahu), Southern California Bight, Santa Barbara Channel (and/or outside the channel as well), and central to northern California. The seasonal climatologies of weather and waves for these will be examined in detail in the coming months. Because of the rather bimodal needs of RaDyO investigators in terms of sea state, it is likely that separate sites will be needed for the two major field programs in order to satisfy the group's collective research needs and meet the overall program objectives. One suggestion was to do the first field year in a more benign environment, which reduce risk in loss or damage to instrumentation and allow shakedown of problems during moderate conditions. The following year could be done in a more dynamic, challenging weather and sea-state. It was emphasized that the program must remain interdisciplinary and that multiple observations of suites of variables be made in common waters. Likewise, the collaborations of modelers and observationalists are seen as essential to the program.

Some of the detailed items concerning site selection follow:

1. Occurrence of Phenomena of Interest

Variable winds (but not hurricanes) and atmos. conditions
  Winds up to 20 m/sec, reasonably clear water, $0.5 m^{-1}$
Variable skies – either sunny or full overcast preferred
Rain events
Internal waves
Langmuir cells
Variable sea states

Variable optical properties but biased toward clear water
Variable water masses
Fronts and eddies
Blooms
Runoff
Variable bubble conditions (incl. coatings)
Minimal bottom effects (relatively deep waters)

2. Access to site
Near ports for exchange of personnel and equipment and instruments
Maximize ship/platform sampling time – longer time series – more variable conditions sampling
Launching of AUVs and gliders

Suggested ports included: Santa Barbara, San Francisco, San Diego, Monterey, and Honolulu

3. Complementary Observations
Satellite observations (i.e., SPOT plus others – winds, waves, surface features, color, SAR, altimetery, etc.)
Ship sampling (i.e., CAlCOFI, NOPP CHARM MOSEAN, NOAA moorings for waves and winds, LTERs, PISCO, Plumes and Blooms, other Navy projects; HALE-ALOHA/HOT site, etc.)
High frequency radar for currents and waves (must be relatively near coasts or islands)
High resolution weather prediction and analyses
Data from oil platforms
Historical observations
Glider measurements off California coast/CalCOFI
Monterey Bay experiments

4. Periods of observations (Season)
See 1 above for several criteria
Upwelling seasonal effects
Eddies
Rainy or dry season
Wind conditions
Length of day
Zenith angle of Sun

Platforms
A multi-platform approach that would include ships (including SWATHs), R/P FLIP, moorings (devoted to RaDyO and nearby complementary wave or weather buoys), and AUVs as complemented with satellite and aircraft was deemed desirable. A variety of deployment techniques will likely be used. These will include instruments deployed from booms (above and below water), pop-up profilers deployed away from the mother vessel, AUVs, and ROVs. For several investigators, a very stable observational platform is a necessity. R/P FLIP was discussed at length in that it is an ultra-stable platform and has been used successfully for wave and optical measurements in the past. Some of the drawbacks for R/P FLIP include: large shadowing of optics and wave field, waste materials flushed in vicinity of measurement gear, high distance of booms above waterline (this may be an advantage for some measurements), limited berthing of scientists (likely maximum of 10), very small laboratory space, difficulty in transferring equipment to or from R/P FLIP while at sea, and cost would be directly from RaDyO funds at expense of science funding. Some discussion of the use of SWATH vessels including the University of Hawaii's Kilo Moana has transpired following the workshop. The Kilo Moana is relatively stable as compared with conventional monohulls, but not as stable as R/P FLIP. Like R/P FLIP ship shadowing would be an issue, but ROVs and AUVs could be deployed quite easily. No waste materials are discharged at sea so relatively pristine surfactants could be sampled. However, it has excellent and spacious laboratory facilities, can berth X(?) scientists, transfer of personnel and equipment would be possible under moderate sea and weather conditions, and it would not cost the RaDyO program any funds as it is a UNOLS vessel. The use of booms and any other special structures for RaDyO would have to be deemed possible and approved. The R/P FLIP will likely be toured and discussed at the next RaDyO meeting in San Diego and we intend to tour and discuss the possible use of the Kilo Moana during the AGU/ASLO/TOS Ocean Sciences Meeting in Honolulu in February 2006.

Again, it is likely that moorings, AUVs and perhaps even other ships of opportunity will complement the central RaDyO ocean platform. There were some discussions of other stable platforms such as oil drilling rigs or other man-made open ocean platforms. Most of these appeared to have severe disadvantages and are not presently being seriously considered. We are encouraging discussions of both the topics of site selection and platforms through our web-based forum.

Responsibilities
The abstracts of proposals and individual powerpoint presentations will all be available on the RaDyO website. During the meeting, we broke into topical groups to develop coordinated plans for RaDyO. The groups were: 1) IOP and radiation group, 2) surface and bubble group, and 3) modeling group. These subgroups were quite effective in coordinating plans and measurements. It is anticipated that these subgroups will continue discussions via eamil and at future RaDyO meetings. An important logistical consideration will concern the actual makeup of scientific parties for the selected vessels for the major field experiments. This will evolve.

A breakdown of some of the specific responsibilities follows:

Waves – Ken Melville, Mike Banner, Hemantha Wijesekera, David Farmer, Tommy Dickey, Grace Chang

Optics – Mike Banner, Ken Voss, Scott Pegau, Ron Zaneveld, Tommy Dickey, Grace Chang, Ken Melville, Marlon Lewis

Meteorology – Ken Melville, Tommy Dickey, Grace Chang, Mike Banner, Hemantha Wijesekera

Turbulence – Ken Melville, Hemantha Wijesekera, David Farmer

Hydrography – Tommy Dickey, Grace Chang, Scott Pegau, Hemantha Wijesekera, Mike Banner

Currents – Ken Melville, Tommy Dickey, Grace Chang, Hemantha Wijesekera, David Farmer

Bubbles – Marlon Lewis, Mike Banner, Ron Zaneveld, Dave Farmer, Ken Melville, Hemantha Wijesekera

Modeling – George Kattawar, Dick Yue, Lian Shen, Mike Banner, Russel Morison

<u>Topic #3: Data management and reporting</u>
Purpose: to outline the interaction of modeling and field observations, including schedules for distributing results (e.g., simulations and observations) between RaDyO participants as well as reporting project results to the greater oceanographic community (e.g., target meetings and journal publications). Establish how data (sensor and model) will be shared between RaDyO participants?

The group discussed several aspects of data management and reporting. These were more exploratory in nature, but some consensus appears to have been suggested:
1. Data and metadata will be held by PIs. The RaDyO website will be used to direct investigators to desired data sets. The data system will thus be distributed rather than centralized.
2. Some common units and formatting of data will be followed. Examples such as those of JGOFS will be evaluated for adoption.
3. Data will be shared freely among PIs and their students and postdoctoral fellows.
4. Data of common interest and requiring minimal processing (e.g., CTD, ADCP currents, Mets, etc.) will likely be shared amongst the group as soon as possible following processing to facilitate processing and interpretation of the more specialized data sets.
5. Special consideration will be given for data obtained form proto-type and emerging instrumentation. Publication considerations will be evaluated to protect student theses in particular. However, it will be important for all PIs to be good citizens and share key data that are needed to meet the goals and objectives of the RaDyO program as a whole.

6. A nominal 1-year period of data latency (following end of data retrieval for a given experiment) should suffice for most situations. Special needs would be considered by the RaDyO investigators and Steve Ackleson on behalf of ONR.
7. Modelers are expected to share credit with observationalists when their data are used in modeling publications. This should follow from offers of co-authorship or acknowledgements based on contributions and efforts. Access to models may also be requested by observationalists to facilitate planning of experiments and for enhancing data value – in this case, observationalists would offer co-authorship or acknowledgements for any resulting publications.

These topics will be revisited and discussed at all future RaDyO workshops.

The group consensus that future workshops should discuss various publication and meeting presentation opportunities. Some indicated that The Oceanography Magazine had done well for previous comparable programs and might be a good community-wide venue for a volume of RaDyO results. Ocean Science and Ocean Optics Meetings will likely be excellent outlets for RaDyO presentations. All suggestions for potential publications and meetings are welcome and will be posted on the RaDyO website.

Concluding Items
Steve Ackleson reviewed the budgetary aspects of RaDyO and the needs for short-term funding of individual groups. Several action items were discussed. These included the development of a RaDyO website that the UCSB Ocean Physics Laboratory (OPL –namely Grace Chang) is already hosting and maintaining, the promotion of discussions concerning the various advantages and disadvantages of specific observing platforms and field sites. The group endorsed Marlon Lewis' nomination of Tommy Dickey to serve as RaDyO's lead-scientist. He accepted and Grace Chang, who has developed and will maintain the RaDyO website, will act his co-lead-scientist for the project. It was agreed that the next RaDyO Workshop will be held in San Diego roughly April 3-5, 2006 and will be hosted by Ken Melville. Group will tour R/V Kilo Moana during Ocean Sciences in Honolulu in February.

Some action items follow:
1. PIs are to prepare budgets for latter part of this FY (special needs) and extend to end of DRI – state how much money needed between now and 30 September 2010. Plan for length of cruises to be about 1 month in two major field years
2. DURIP – next meeting, folks should find out who gets them this round and then plan for new submittals for RaDyO out year field experiments
3. Pier testing program to be fleshed out in near term (Ken Melville for Scripps pier)
4. At next RaDyO Workshop in Sna Diego, tour FLIP and bunk down for an evening!
5. Meet with Kilo Moana (SWATH vessel) crew and discuss its possible use. To be arranged by Tommy for Ocean Sciences Meeting in Honolulu February 2005.
6. Surfactant leader? Marlon – check w/ SOLAS
7. Grace - Establish RaDyO website/coordination activity (done)
8. RaDyO LOGO – Ron Z!!!!