RaDyO Highlights and Firsts

Tommy Dickey:
General RaDyO program firsts:

1. Observations and modeling of variability of near surface and upper ocean optical variability on unprecedented time and space programs enabling detailed analyses and interpretation of physically forced high frequency and wavenumber variations in optical quantities bearing on a host of applied problems including imaging, visibility, animal vision and camouflage, phytoplankton responses to fast changing light fields, near surface heating via wave focusing
2. Exploration of the role of bubble populations and their distributions on light propagation using simultaneous acoustical and optical measurements
3. Use of optical and infrared imagers (including polarimetric methods) to 1) quantify wave dynamics on short time and space scales, 2) quantify wavebreaking and whitecapping
4. Characterization of underwater light field using high temporal, multi-angle spectrometers and cameras (some polarimetric)in surface microlayer and upper ocean – high intensity light flashes observed.

Mike Banner, Johannes Gemmrich, Russel Morison, Howard Schultz and Chris Zappa:
1. First two-dimensional slope field measurements of capillary-gravity wind waves in the open ocean made using an imaging polarimeter
2. First infrared analysis of microscale breaking in the open ocean
3. First analysis of open ocean breaking waves from the dominant wind sea whitecaps to microscale breakers shows an unanticipated strong attenuation of the small scale breakers.
4. First detailed response of the underwater radiance to the surface wave field including breaking of all scales.

Helen Czerski, Svein Vagle, and David Farmer:
1. Making detailed and accurate acoustic measurements of bubble populations which include bubbles down to 5 microns in radius. Previously the limit was around 16 microns, and those measurements were far less accurate.
2. Combining acoustical and optical data to make collocated simultaneous measurements of the bubble populations which are consistent with each other.

Dariusz Stramski et al.:
Highlights/breakthroughs from the project on wave-induced fluctuations in underwater light field:
(1) We achieved significant technological advancements in radiometric measurements of wave-induced fluctuations in underwater light field, which allow accurate resolving the fluctuations down to very short temporal scales of the order of 1 millisecond.
(2) Our measurements showed, for the first time, that the intensity of flashes of focused light at near-surface depths in the ocean can exceed the time-average irradiance by a factor greater than 10. For the first time the wave focusing effects were measured at different wavelengths within the visible spectral region which show that the intensity of

fluctuations relative to time-average light levels is higher in the red compared with the blue spectral region. We determined that the highest transient concentrations of solar energy integrated over visible spectral region under a wind-disturbed sea surface can reach about 3000 W m^{-2} or 13000 μmol quanta m^{-2} s^{-1}. These findings can have broad impact on marine photochemistry and biology.
(3) For the first time we quantified the enhancement of particle concentration as a function of particle size and the associated increases in particulate absorption and scattering within the sea surface microlayer relative to underlying surface layer of bulk seawater. We found that the surface microlayer enhances to different extent the particle concentrations at different sizes, for example the enhancement is consistently greatest for particles in the size range from about 10 to 20 μm in both marine environment examines, the costal Santa Barbara Channel and the open ocean off Hawaii. We discovered that in contrast to bulk surface seawater, the particle assemblages trapped within the surface microlayer exhibit significant absorption within the infrared spectral regions which suggest that microlayer most likely effectively retains the black carbon-like particles originating from atmospheric deposition.

Mike Twardowski et al:
1) First substantive and comprehensive measurements of the optical volume scattering function from several diverse regions throughout the world's oceans
2) First in-situ measurement of the theorized mid-angle enhancement in the volume scattering function due to bubbles
3) Resolution of bubbles less than about 20 um for the first time from inversion of the volume scattering function
4) Measured bubble plumes under breaking waves at the time scales required to resolve their dynamics and evolution (20 Hz sample rate)
5) First in-situ measurement of the linear polarization elements of the volume scattering function

Ken Voss:
First simultaneous measurements of full downwelling polarized spectral radiance distribution above and below the surface. Illustrates variation in sources of polarized light going from skylight to scattering from water and particles as the depth increases.

George Kattawar and Yu You:
1. Developed the first numerical 3D model that gives fast and accurate polarized light fields in a coupled atmosphere-ocean system, capable of emulating the dynamic light field beneath a roughened air-sea interface.
2. Developed the first computer code to compute the wave-induced light fluctuations in near-surface downwelling irradiance, with sufficient temporal and spatial resolution, and including multiple scattering; to be in good agreement with field measurements.
3. Made first calculations to make use of instantaneous wave slope measurements to simulate the complete underwater polarized light field.

Marlon Lewis:

1. Successful design, development and deployment of a high dynamic range camera (10^6 scene dynamic range) to resolve the full radiance distribution at high frequency, including the solar disk.
2. First measurement of the vertical profile of the full radiance distribution (both hemispheres) with vertical resolution ~0.25 m, and with simultaneous measurement of the sky radiance distribution.

Grace Chang:

1. First critical analysis of platform effects on measurements and analysis of optical and physical properties, with respect to the use of R/P FLIP in moored configuration.

2. Direct computations of imaging modulation parameters using field-measured data, including small-angle VSFs.

3. Comprehensive data set to allow the investigation of physical and hydrographic effects on image modulation in relatively clear and turbid environments.