Thursday, October 11
Oral Session 9
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CONTINUOUS INTEGRATING CAVITY MEASUREMENTS OF ABSORPTION SPECTRA AND THEIR EVALUATION WITH RESPECT TO PHYTOPLANKTON DISTRIBUTION

The absorption properties of natural waters can vary considerably due to differences in the concentration and composition of their optically active constituents (phytoplankton, CDOM, and non-algal particles). Due to this dependence, absorption coefficient measurements can provide information about these parameters. Of special interest is the investigation of phytoplankton by this means, because different groups can be characterized by their absorption signature. Furthermore, absorption coefficient spectra are important as input for models calculating the underwater light field and for the validation of remote sensing observations. Integrating cavity approaches have been shown to be very suitable to obtain accurate absorption coefficient measurements, as they overcome problems like the often low concentration of absorbing material and errors introduced by light scattering on particles. However, these instruments require frequent calibration, because their optical path length changes with the reflectivity of the integrating cavity, which is subject to contamination and aging. While feasible for lab application, this is a major obstacle for the long-term deployment of flow-through integrating cavity instruments. In this contribution, we describe the development and current status of a completely automated integrating cavity instrument designed for flow-through operation. The Hyperspectral Absorption Sensor (HyAbS) is based on a point-source integrating cavity absorption meter (PSICAM), and the challenges and potential solutions with respect to its long-term automated operation are highlighted. Example data from field deployments is shown, and a special focus is put on the approach used to evaluate the obtained absorption spectra in real time for phytoplankton biomass and taxonomy.

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ABSORPTION COEFFICIENTS DERIVED FROM IN SITU RADIOMETRY USING GERSHUN'S LAW

Absorption is a fundamental process influencing the shape and magnitude of the light field underwater. However, in situ absorption coefficients are difficult to measure accurately with currently available instruments due to the presence of scattering material. An alternative technique to determine in situ absorption spectra uses Gershun's equation to derive absorption coefficients from in situ radiometry measurements of Ed, Eu, and Eo. The number of studies using this technique in the past 20 year is extremely limited. Given significant developments in radiometric sensor technology during this time, it is timely to re-assess the quality of Gershun absorption data. Practical advantages of the Gershun method compared to established instruments are reduced bias associated with sample collection (pumping or discrete) and that absorption is determined from much larger sample volumes. This difference in sample volume might be significant when comparing field data to data from satellites which detect large surface areas. Here, two contrasting datasets of in situ radiometry were used to calculate spectral absorption coefficients. Resulting absorption spectra were highly sensitive to data quality control and number of depth bins included in the calculations. Comparison with PSICAM absorption data showed a tendency to overestimate PSICAM values by up to 30% (400–625 nm), with expected maximum deviation >100% in the red region, where inelastic processes (ignored in the classic Gershun equation) have a significant effect. Potential sources of systematic errors in Gershun's and PSICAM data are explored, taking into account inelastic scattering effects and potential impact of large, relatively sparse coloured particles.

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A REVISED MODEL FOR DERIVING THE BULK REFRACTIVE INDEX FROM THE BACKSCATTERING RATIO CONSIDERING THE DIFFERENT SUBPOPULATIONS OF MARINE PARTICLES AND THE INTERNAL STRUCTURE OF PHYTOPLANKTON CELLS

In 2001, M. Twardowski and coworkers proposed a model based on Mie theory to estimate the bulk refractive index from the backscattering ratio and the hyperbolic slope of the particle size distribution (PSD). In the present study, we propose to re-examine Twardowski et al.'s model considering the different sub-populations of marine particles and the heterogeneity of phytoplankton cells. For that purpose, the scattering is modeled considering particles from the submicrometer viruses and heterotrophic bacteria to micrometer phytoplankton species. In addition, organic non living particles (detritus) and sediments are considered. The size ranges of the different compartments are defined from literature (Stramski et al., 2001 ; Stramski et al., 2004). Concerning the internal structure of phytoplankton cells, an exhaustive review was performed by Bernard et al., 2009. They showed that a chloroplast layer surrounding the cytoplasm was an optimal morphology to simulate optical properties of algal cells. The open access radiative transfer code named ScattnLay (Yang et al., 2003) was used for computing the scattering two-layered spheres. Results show that even if the relative abundance of the phytoplankton is weak (less than 1 %), the impact of the two-layered phytoplankton cells on the bulk backscattering is significant enough to modify the analytical model between the backscattering ratio and the PSD slope.

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LOW-COST SPECTRORADIOMETER SYSTEMS FOR IMPROVED SPATIAL AND TEMPORAL WATER QUALITY MONITORING

Spectroradiometric measurements of surface water can provide valuable information about the bio-geochemical composition including phytoplankton type and abundance, sediment concentration, carbon stocks, water clarity, and presence of harmful algae. While satellite oceancolor remote sensing has shown great utility to provide global water quality information, limitations exist for optically complex inland waters. Spectroradiometers deployed in the field offer the capability to resolve small scale spatial features such as cyanobacteria blooms that orbiting platforms may not. Historically, in-situ radiometric devices are expensive and require significant user expertise and therefore often prohibit measurements at the spatial and temporal scales needed to fully characterize the water quality phenomena of interest. The Michigan Tech Research Institute (MTRI) has developed several new low-cost high-fidelity radiometric instruments that can be used to better monitor water quality in challenging environments. The first instrument package is designed for deployment on fixed structures with the intent of measuring water-leaving radiance at sub-minute time-scales. This high temporal frequency radiometric data is shown to resolve the size and biomass of cyanobacteria surface mats undergoing advection from prevailing water currents. The second instrument is a handheld radiometer system which uses an off-the-shelf NoIR webcam detector and 3D printed optical housing. A controlling application for smartphones or tablets has also been created to guide non-experts through the measurement process to ensure quality data is collected. The low cost nature of this solution allows for the potential distribution of many radiometers to citizen scientists and water managers toward the formation of a distributed sensor network.

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FLUOSIEVE: TOWARDS FIELD APPLICATION OF A HIGH-THROUGHPUT FLUORESCENCE IMAGING FLOW CYTOMETER FOR MARINE PHYTOPLANKTON ANALYSIS

High-throughput quantitation and characterization of phytoplankton in natural seawater is of fundamental significance for ocean ecology and environment study. Imaging flow cytometry (IFC) can extract statistical information by analyzing numerous phytoplankton images captured while they flow through an optical interrogation area, thanks to its high-throughput capability in acquiring phytoplankton images with cellular resolution. However, taking fast yet accurate measurement of diverse natural phytoplankton with extreme heterogeneity remains challenging for current IFC instruments. Some fundamental issues such as lack of sensitivity and resolution for detecting picophytoplankton, compromises between imaging throughput and imaging quality due to motion/defocusing blurring for analyzing larger microphytoplankton, still limited their practical application in terms of measurement accuracy and throughput. Combining laser-sheet excitation with "flow-through" detection, a new light-sheet fluorescence IFC (LSF-IFC) has been devised recently. This new IFC has demonstrated several advantages in laboratory experiments over shortcomings associated with traditional IFCs for phytoplankton analysis. Its universal usage of single objective lens, out-of-focus noise suppression, excitation power density concentration and more in-focus photons integration all together facilitate great enhancement in phytoplankton image resolution, signal-to-noise and throughput. Based on previous progress achieved indoors, the technology is further developed into field instrument, named FluoSieve, recently. Besides routine usage in laboratory setting, FluoSieve was exclusively designed to work for field environments such as coastal station, onboard research vessel, and et al. We will report the development and preliminary measurements of this new instrument. It is expected FluoSieve can be promoted towards more field applications that demand automated phytoplankton analysis.

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LIDAR MEASUREMENTS OF OCEAN OPTICAL PROPERTIES MADE DURING THE NORTH ATLANTIC AEROSOL AND MARINE ECOSYSTEMS STUDY (NAAMES) USING NASA'S HIGH SPECTRAL RESOLUTION LIDAR

The NASA Langley Research Center's High Spectral Resolution lidar (HSRL) was deployed from an aircraft on NAAMES missions in 2015, 2016, and 2017. This lidar is optimized for both ocean and atmospheric profiling and, in particular, has the ability to provide depth-resolved ocean optical properties that complement ocean color measurements. The HSRL calibrated measurements of ocean particulate backscatter, diffuse attenuation, and depolarization were measured simultaneously during NAAMES. We present correlations between this unique set of optical properties and provide comparisons with in situ measurements acquired on the NAAMES research vessel and Bio-Argo floats and remote sensing retrievals from the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite instrument. Specifically, lidar depolarization profiles measured during the NAAMES campaigns provide a unique dataset to evaluate the dependence on particle shapes and the observed correlation to both the measured backscatter and attenuation. Moreover, the HSRL airborne depolarization data is used to assess the CALIOP (Cloud-aerosol Lidar with Orthogonal Polarization) depth integrated depolarization measurements which have been used to derive global distributions of ocean backscatter. Overall, the NAAMES results provide a means to assess current and future satellite observing strategies involving lidar as a natural complement to current ocean color retrievals.

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Plenary Session 4
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NEXT-GENERATION SENSING TECHNOLOGIES FOR EXPLORING OCEAN WORLDS

Dr. Ved Chirayath's plenary presentation will highlight two instrument technologies he invented at NASA including Fluid Lensing, the first remote sensing technology capable of imaging through ocean waves in 3D at sub-cm resolutions, and MiDAR, a next-generation active hyperspectral remote sensing and optical communications instrument. Fluid Lensing has been used to provide the first 3D multispectral imagery of shallow marine systems from unmanned aerial vehicles (UAVs, or drones), including coral reefs in American Samoa and stromatolite reefs in Hamelin Pool, Western Australia. MiDAR is being deployed on aircraft, and underwater remotely operated vehicles (ROVs) as a new method to remotely sense living and nonliving structures in extreme environments. MiDAR images targets with high-intensity narrowband structured optical radiation to measure an object's non-linear spectral reflectance, image through fluid interfaces such as ocean waves with active fluid lensing, and simultaneously transmit high-bandwidth data. As an active instrument, MiDAR is capable of remotely sensing reflectance at the centimeter (cm) spatial scale with a signal-to-noise ratio (SNR) multiple orders of magnitude higher than passive airborne and spaceborne remote sensing systems with significantly reduced integration time. This allows for rapid video-frame-rate hyperspectral sensing into the far ultraviolet and VNIR wavelengths. Finally, Chirayath will present preliminary results from NASA NeMO-Net, the first neural network for global coral reef classification using fluid lensing and MiDAR.

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