Use of the Polarized Radiance Distribution Camera system in the RADYO program

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LONG-TERM GOALS

My work involves experimentally investigating the interrelationships and variability of optical properties in the ocean and atmosphere. My goal is to define the variability of the optical properties, particularly those dealing with light scattering, and to improve the prediction capabilities of image and radiative transfer models used in the ocean. My near term ocean optics objectives have been: 1) to improve the measurement capability of measuring the in-water and above-water spectral radiance distribution and extending this capability to polarization, 2) to investigate the variability of the Point Spread Function (PSF) as it relates to the imaging properties of the ocean, and 3) to improve the characterization of the Bi-directional Reflectance Distribution Function (BRDF) of benthic surfaces in the ocean, and 4) to understand the capabilities and limitations of using radiative transfer to model the BRDF of particulate surfaces.

OBJECTIVES

The major objective of this research is to understand the downwelling spectral polarized radiance distribution, in the near surface of the ocean.

APPROACH

We have built, with ONR support (through the DURIP program) a camera system capable of measuring the polarization state of the downwelling radiance distribution. This instrument follows in the footsteps of other instruments we have developed (Voss and Liu, 1997) and uses a combination of 3-4 images of the radiance distribution to form this polarized radiance distribution. Because the downwelling radiance distribution is very dynamic, we need to have a system that will quickly make these images as matched as possible, so this required a completely new design.

The system we have designed uses 4 fisheye camera lenses with coherent fiber bundles behind each image. Each fisheye will have a polarizer in a different orientation. After the image is in the coherent fiber bundle, these bundles will be brought together and imaged on a CCD array camera, through a filter changer (for spectral information). Thus in a single image we will have 4 separate fisheye images of the scene, each with different polarization information. The work in this proposal is to characterize this instrument, and use it in the RadYO program.

WORK COMPLETED

During the past year we have reduced the data from the first real field campaign of the RADYO project in the Santa Barbara Channel, worked on improving the DPOL instrument, and participated in the second RADYO field experiment off of the island of Hawaii. Both of these field trips were done on the research platform R/P Flip in collaboration with other researchers doing both optical measurements and surface wave field measurements. While working on the data from the first field experiment we found that we needed to improve the rigidity of the optical system, as a limiting error was how well we could "flat field" the images to reverse the effects of fiber inhomogeneity. The mechanical structure of the system was reworked between these two experiments. We also found in our characterization experiments that our lens relay system did not work well in a large enough wavelength band. We thus reworked the lens relay system using upgraded multi-lens elements. Thus we had to completely recharacterize the system. Finally we worked on calibrating and characterizing the fourth lens of our system, which allows the determination of the 4^{th} stokes vector, dealing with circular polarization. While on the research cruises we measured downwelling spectral polarized radiance distribution, both in the water (using DPOL) and above the surface (with our sky camera system, developed for this project), upwelling spectral polarized radiance distribution (with DPOL), and the aerosol optical depth (using Microtops sunphotometers).

RESULTS

First for the easy part, all of the aerosol optical depth measurements, in both cruises have been reduced and are available both from our lab and also from the NASA Marine Aerosol Network
(http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html).
We have also reduced the polarized sky radiance distribution data and the in-water data from the Santa Barbaba Channel experiment and are working to find the best way to present this data on our website and distribute this data to collaborators in the RADYO program. We have just finished the Hawaii experiment, and we are currently doing the post-calibrations of the instrumentation.

To give examples of some of the data, we have show two downwelling distributions, both at 520nm. Figure 1 shows the downwelling polarized radiance distribution for 2m, while Figure 2 shows the downwelling polarized radiance distribution for 40m.

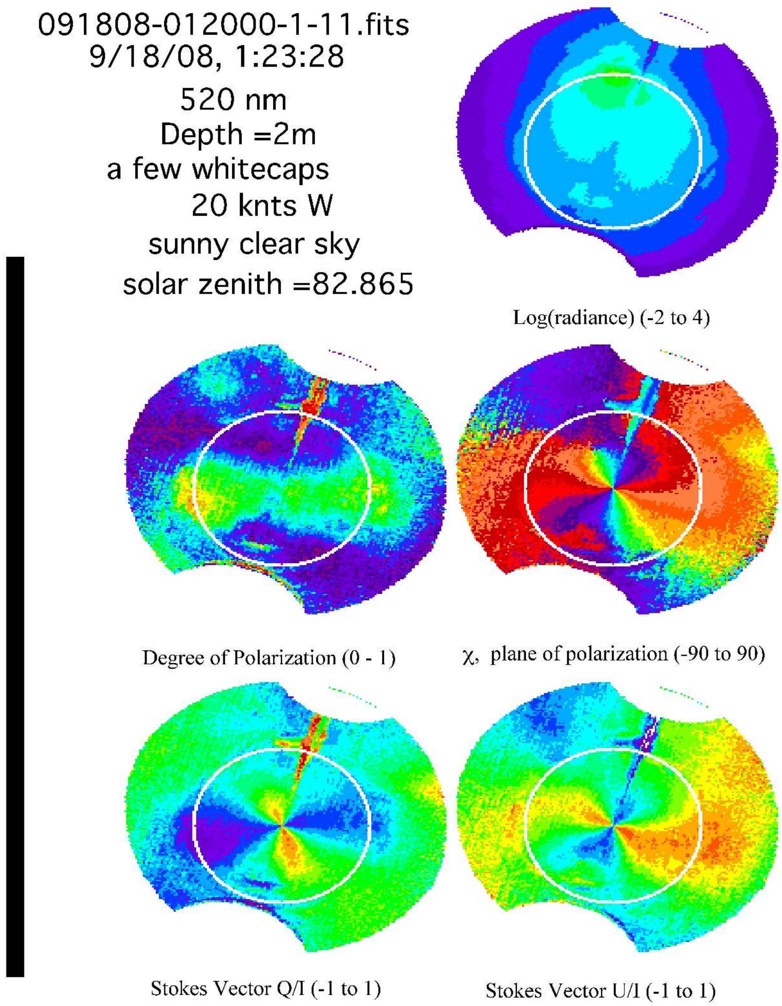

Figure 1. Data products from a downwelling spectral polarized radiance distribution image taken at 2 m depth, at 01:23 UTC on 9/18/08. The solar zenith angle for this image was 82 degrees, as the sun was almost setting. The image is a fisheye projection, where the edge of the image is at approximately 90 degrees in water, the center of the image is pointed directly up, the zenith angle is proportional to the distnace from the center of the image. Colors in each picture run from purple (lowest value) through green (mid range) to red (highest value). The white circle illustrates the edge of the snell's cone (approximately 48 degrees). We show log of the radiance (upper right) values ranging from -2 to 4, -2 would be deep purple while 4 would be orange. The next line shows the degree of polarization and plane of polarization. The degree of polarization shows that the maximum degree of polarization occurs at 90 degrees (in air) to the sun, and is just a transmittal of the above water polarization pattern, as are the plane of polarization and stokes vectors Q and U shown below.

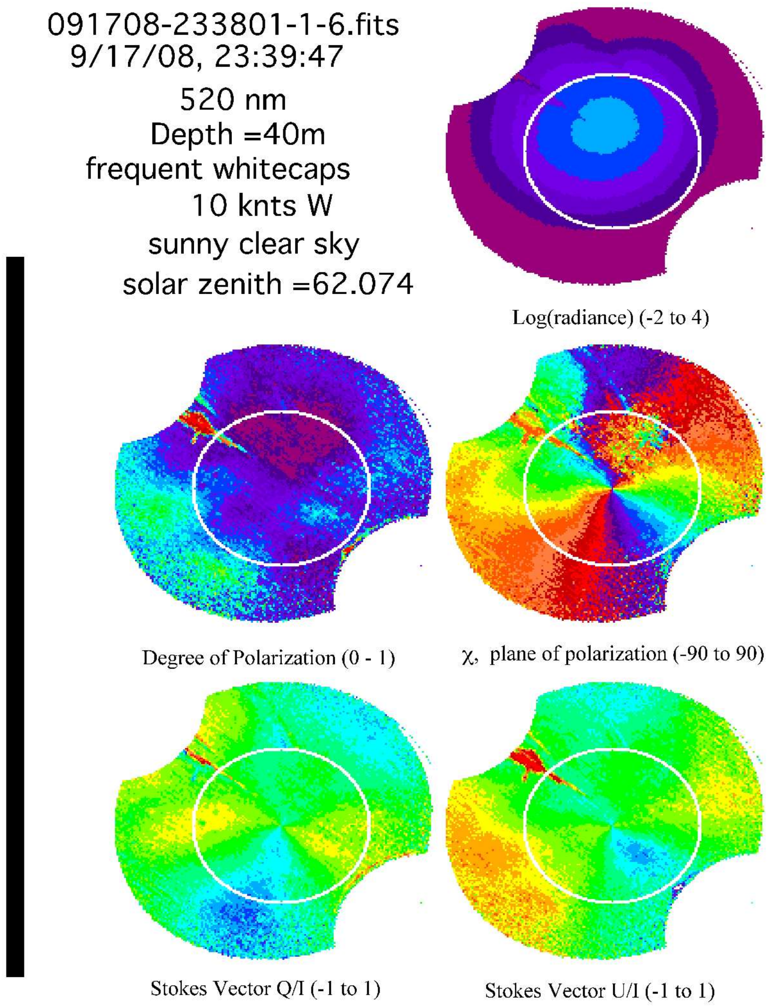

Figure 2. Data products from a downwelling spectral polarized radiance distribution image taken at 40 m depth, at 23:40 UTC on 9/17/08. The solar zenith angle for this image was 62 degrees, this was taken just before the image in Figure 1. The image is a fisheye projection, where the edge of the image is at approximately 90 degrees in water, the center of the image is pointed directly up, the zenith angle is proportional to the distnace from the center of the image. The white circle illustrateds the edge of the snell's cone (approximately 48 degrees). We show log of the radiance (upper right) values ranging from -2 to 4, -2 would be deep purple while 4 would be orange. The next line shows the degree of polarization and plane of polarization. In contrast to Figure 1, the degree of polarization shows that the maximum degree of polarization occurs at 90 degrees in water to the refracted position of the sun. In this case the maximum degree of polarization is due to scattering effects in the water, rather than the atmosphere as in Fig. 1. In addition Q and U are determined by these in-water effects.

IMPACT/APPLICATIONS

This system will provide a brand new measurement capability. In the RaDYO program this instrument will be used in combination with other measuremetns of the sea surface and optical parameters. The goal of the overall RadYO program is to understand how the radiance distribution is modified in the near surface, and what factors are important to this modification.

RELATED PROJECTS

This project is part of the overall ONR RadYO program. We also have DURIP support to build the instrument, fundamental to this work. Our work on the polarized radiance distribution is also related to our efforts with NASA funding to look at both the upwelling radiance distribution and the polarized upwelling radiance distribution.

REFERENCES

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PUBLICATIONS

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