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.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**
4. TITLE AND SUBTITLE **Use of the Polarized Radiance Distribution Camera System in the RADYO Program**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Miami,Physics Department,Coral Gables,FL,33124**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

During the last year we fielded the instrument in two field campaigns. The first was the RADYO pier test, off of Scripps Pier through most of January 2008. The second field campaign, which ended today (September 30, 2008) took place in Santa Barbara Channel. Our equipment was deployed from the R/P Flip. Most of the year was spent modifying the instrument with the lessons we learned from the Scripps Pier experiment (mainly lightening the instrument), performing instrument characterizations and calibrations, and finally looking at data from these two campaigns (very briefly for the second campaign.

Figure 1. Sample image from Polarization camera system. There are 4 separate fisheye images shown in this one camera image, the result of our quadfricated fiber bundle. Each small fisheye image carries different polarization information. Three of the images have linear polarizers in line with the image optical path. The remaining image contains a circular polarization analyzer. By combining these images, the 4 stokes vectors can be determined.

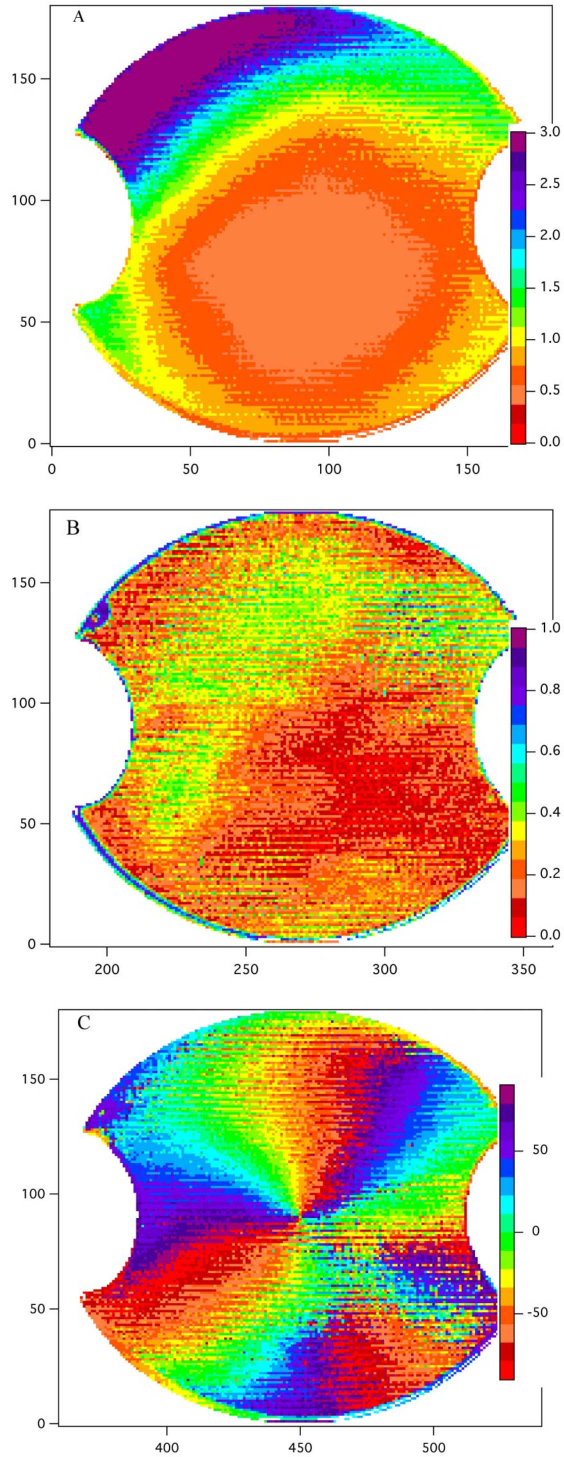

Figure 2. This is an example upwelling image showing first intensity (relative units, Fig. A), Degree of polarization (1 = 100% polarized, Fig. B), and angle of polarization plane, C (zero corresponds to a plane of polarization perpendicular to the plane containing the view direction and nadir.

RESULTS

We have only just now started to get field data with this instrument so there are no significant results to report at this time. The results during the Pier test mainly pointed out areas we needed to improve. The proximity of the pier, and the shallow water, made most of the data difficult or impossible to interpret. However Fig. 1 shows an example image, taken in the laboratory, with the system, while Fig. 2 shows an example data set from the most recent cruise in the Santa Barbara Channel. This is an upwelling radiance distribution image, showing the intensity, degree of polarization and angle of the polarization plane. The image is shown in the fisheye projection, where the center of the circle is the nadir direction and angle from nadir is linearly proportional to the distance from the center of the image to the edge (which corresponds to 90 degree Nadir angle). The halfmoon shape out of each side corresponds to the image area for which the camara would be able to see a neighboring dome, so there is no data there.

From the intensity image one can see that the solar direction is towards the upper left of the images. The minimum upwelling radiance in this distribution is towards the anti-solar direction. Often in clear water this minimum is on the solar side of nadir, but with this higher Chl water, this isn't the case. The degree of polarization image shows a degree of polarization which ranges from 0 to almost 50%. The maximum degree of polarization is in the region of 90 degree scattering. The angle of the polarization plane, chi, varies in a reasonable fashion around the azimuthal direction. The common definition has the reference plane containing the view direction and the nadir direction. 0 degrees in this coordinate system corresponds to a polarization plane perpendicular to this reference plane, and chi is 0 in the solar direction.

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

K. J. Voss and Y. Liu, "Polarized radiance distribution measurements of skylight: I. system description and characterization", 1997, Applied Optics, **36** :6083-6094.