REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*

2. REPORT TYPE
Conference Proceeding

3. DATES COVERED *(From - To)*
18-22 Nov 2002

4. TITLE AND SUBTITLE
Seasonal Variations in Optical Conditions Associated with the Mobile Bay Outflow Plume

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
602435N

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Research Laboratory
Oceanography Division
Stennis Space Center, MS 39529-5004

8. PERFORMING ORGANIZATION REPORT NUMBER
NRL/PP/7330/02/0063

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217-5660

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
River and estuarine outflow waters contain high loads of colored dissolved organic material (CDOM or gelbstoff), sediments, and biological matter with strong optical signatures. In regions with large, single point sources, interactions with ambient shelf waters are fairly simple. The buoyant outflow plumes tend to remain cohesive and become trapped against the contra solem coast. These plumes can extend for distances of more than 100 km along coast with characteristic widths of 5-15 km (internal Rossby radius of deformation) and thickness' of a few 10's of meters. When winds turn to upwelling favorable, the plume waters are rapidly dispersed, mixing their optically important constituents across the shelf. Wind relaxation or a turn to downwelling favorable wind initiates a new along-coast plume. Such strong dynamic/optical interactions drive high variability in coastal optical character. The objective of this study is to examine this high dynamic variability in relationship to seasonal variations in forcing and constituent loading fields.

15. SUBJECT TERMS
Mobile Bay, plume, contra solem

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Don Johnson
Unclassified	Unclassified	Unclassified	SAR	7	19b. TELEPHONE NUMBER *(Include area code)* 228-688-4691

SEASONAL VARIATIONS IN OPTICAL CONDITIONS ASSOCIATED WITH THE MOBILE BAY OUTFLOW PLUME

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INTRODUCTION

River and estuarine outflow waters contain high loads of colored dissolved organic material (CDOM or gelbstoff), sediments, and biological matter with strong optical signatures. In regions with large, single point sources, interactions with ambient shelf waters are fairly simple. The buoyant outflow plumes tend to remain cohesive and become trapped against the *contra solem* coast. These plumes can extend for distances of more than 100 km along coast with characteristic widths of 5-15 km (internal Rossby radius of deformation) and thickness' of a few 10's of meters. When winds turn to upwelling favorable, the plume waters are rapidly dispersed, mixing their optically important constituents across the shelf. Wind relaxation or a turn to downwelling favorable wind initiates a new along-coast plume. Such strong dynamic/optical interactions drive high variability in coastal optical character. The objective of this study is to examine this high dynamic variability in relationship to seasonal variations in forcing and constituent loading fields.

In previous studies, we have examined the dynamic/optical interactions of the Chesapeake Bay (Johnson et al., 2001) and Hudson River plumes (Johnson et al., 2002), both large, nearly single-point sources. In the present study, we focus on a multiple source region - the Mobile Bay and Mississippi Sound outflows. These fresh water sources contribute to the western Mississippi Bight, between the DeSoto Canyon and the Mississippi Delta. Figure 1 shows the area with its high concentration of chlorophyll-a. In this area, the Mobile Bay outflow is dominant, containing over twice the river transport as that flowing into the Mississippi Sound. But the Mississippi Sound is an estuary, itself, with multiple passes to the continental shelf, and fairly strong tidal current exchange between the sound and the inner shelf. In addition to the optical variability caused by wind/current interactions, variations in seasonal outflow and seasonal optical loading play important roles in variability of the optical character of ambient shelf waters.

METHOD

Our approach to the problem has been to make quarterly surveys over the area of interest, from Mobile Bay westward along the barrier islands of Mississippi Sound.

Figure 2 shows the pattern of these surveys which were conducted during May 01, September 01, December 01, March 02 and May 02. Each of the surveys was repeated several times over about one week. At night, the ship ran the pattern as rapidly as possible with only the shipboard flow-through system in operation. Flow-through water was taken from a depth of 2.9 meters. Instrumentation consisted of temperature, salinity and fluorometer sensors, and an ac-9 optical spectrum sensor (WetLabs) which measured the 9-channel spectra of optical absorption, $\mathbf{a}_{t\text{-}w}$, and total optical attenuation, $\mathbf{c}_{t\text{-}w}$ (both minus the contribution from pure water). Center wavelengths of each channel were located at 412, 440, 488, 510, 532, 555, 650, 676 and 715 nanometers. Optical scattering spectra, $\mathbf{b}_{t\text{-}w}$, is calculated as the difference between $\mathbf{c}_{t\text{-}w}$ and $\mathbf{a}_{t\text{-}w}$. At 20-30 minute intervals during the rapid survey, a 0.45 micron filter was placed in line with the ac-9 flow. Since this removed most of the particles, the resulting absorption, $\mathbf{a}_g$, is from dissolved organics. Subtracting this value from $\mathbf{a}_{t\text{-}w}$, obtained immediately after the filter was removed, gives an estimate of particulate absorption, $\mathbf{a}_p = \mathbf{a}_{t\text{-}w} - \mathbf{a}_g$. The separation in time between measurements was about one minute, and considered negligible. Filtering was successful in all surveys except for the May 01 cruise.

A surrogate for Chlorophyll-a was obtained from the $\mathbf{a}_{t\text{-}w}(676)$ peak (i.e., 676 minus average of 650 +715), and a surrogate for CDOM was taken as the difference between $\mathbf{a}_{t\text{-}w}(412)$ and $\mathbf{a}_{t\text{-}w}(440)$. CDOM from the filtering process correlated well with the CDOM surrogate calculated in this fashion from the flow-through samples. This is valid since, near the surface, CDOM dominated over particulates. However, at depth, where particulates dominated, the surrogate measure did not work.

During daylight hours, profiling stations were made along the rapid survey tracks. This was done with a slightly negatively buoyant package consisting of a CTD with an ac-9 and a variety of scattering sensors, including a hydroscatt during both May cruises. This package dropped slowly through the water column, eliminating vertical ship motion interference from the sensitive optical measurements.

Winds were obtained from the NDBC station at Dauphin Island, Alabama, just west of the entrance to Mobile Bay. River transport was obtained from USGS gauge data on the Mobile River (flow into Mobile Bay), and the Pearl, Pascagoula and Biloxi Rivers, which flow into Mississippi Sound.

RESULTS

Figure 3 provides a synopsis of the rapid surveys in a time sequence. This figure shows seasonal variations as well as variations within the monthly survey patterns. By comparing May 2001 and May 2002, it also gives some indication of inter-annual variations.

- Temperature: seasonal changes are readily indicated, with maximum temperature in September and minimum temperature in March. The seasonal changes dominated over both monthly survey pattern variations (spread of the points in each month) and inter-annual variations (comparison of May 01 with May 02).

- Salinity: monthly survey pattern changes were dominant, followed by inter-annual variations and a weak seasonal change. The large monthly survey pattern variations can be readily explained by the outflow plume variations in both space and time (wind variations on storm scales of 2-6 days). The large inter-annual variation can be explained by inter-annual variations in river transport (Figure 4). From figure 4, it is clear that the late winter/early spring runoff was about 70% greater in 2001 compared to 2002, contributing to the much lower salinity found in the pattern of May 01.

- Chlorophyll-a and CDOM surrogates: although there is a clear seasonal pattern in chlorophyll-a, the inter-annual variation is heavily dominant, consistent with the higher run-off in 2001 compared to 2002. However, CDOM was actually lower and with less variability during the strong outflow in 2001.

- Scattering: Optical scattering, $\mathbf{b}_{t\text{-}w}$, measured by the ac-9 is dominated by forward scattering which, in turn, is dominated more by plankton than by sediments. It should be no surprise then that the $\mathbf{b}_{t\text{-}w}$ series matches the surrogate chlorophyll-a curve.

To examine the scattering response in more detail, figure 5 shows depth profiles of the ratio of backscatter (bb), taken from the Hydroscatt, to scatter (b), taken from the ac9. These profiles were taken near the middle of the survey area (Fig. 2) in May, 2001 and May, 2002. Since backscatter is sensitive to hard mineral components in the water column and scatter from the ac9 is sensitive to forward scatter from soft plankton, the ratio provides a relative measure of non-organic to organic particles for the two years. In May, 2001, this ratio in the mid- to upper-water column was about ½ of that for May, 2002, suggesting that the large chlorophyll-a contribution in May, 2001, was not accompanied by an equally large amount of minerals. Since CDOM (Fig. 3) was also not particularly high in May, 2001, compared to May, 2002, this further suggests that the large run-off was dominated by nutrient rich, clear water which then contributed strongly to a larger than normal chlorophyll bloom offshore. In May, 2001, the profile shows a 4-meter thick nephloid layer at the bottom to which minerals contributed strongly.

SUMMARY

From May, 2001, through May, 2002, quarterly surveys were made along a box-shaped pattern just offshore of Mobile Bay and the Mississippi Sound Barrier Islands. The purpose of the study was to determine the optical variability in a multiple-source river outflow region and its linkage to dynamic forcing. Although seasonal patterns were clearly seen, and spatial variability during each cruise was large, the inter-annual variations, as expressed in the differences between May 01 and May 02, were surprisingly high. The response to large outflow in the late winter/early spring of 2001 gives rise to an hypothesis that high river flushing produced relatively low amounts of CDOM, but provided the nutrient basis for a strong offshore chlorophyll bloom. This means, then, that inter-annual variability is dependent not only on quantity of runoff, but also on its timing.

ACKNOWLEDGEMENTS

This study was conducted as a collaboration of several programs. The "Hyperspectral characterization of the coastal ocean" project, program element 0601153N, and the "Prediction of Coastal Buoyancy Jets (COJET)" project, program element 0602453N, were sponsored by the Office of Naval Research and administered by the Naval Research Laboratory. We are grateful to the captains and crews of the R/V Pelican, the R/V Edwind Link and the R/V Longhorn for their considerable support in the field efforts.

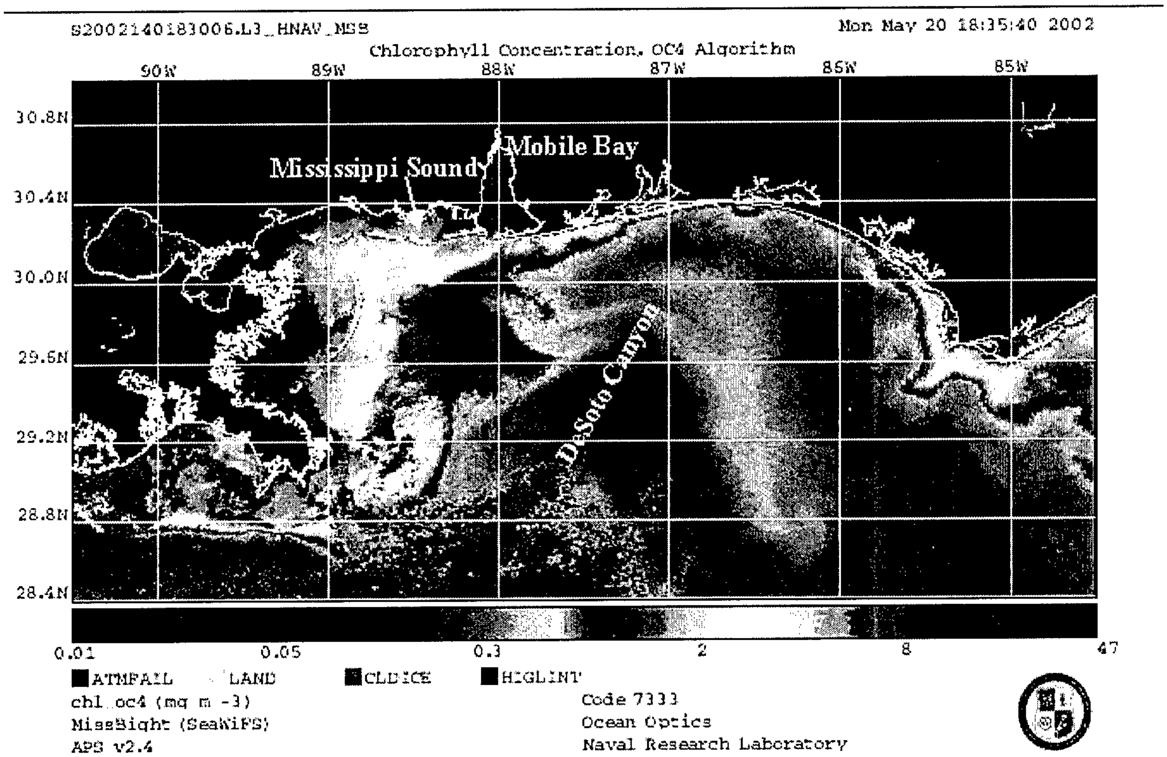


Figure 1: SeaWifs chl-a image of working area in the western Mississippi Bight during the May 02 cruise.

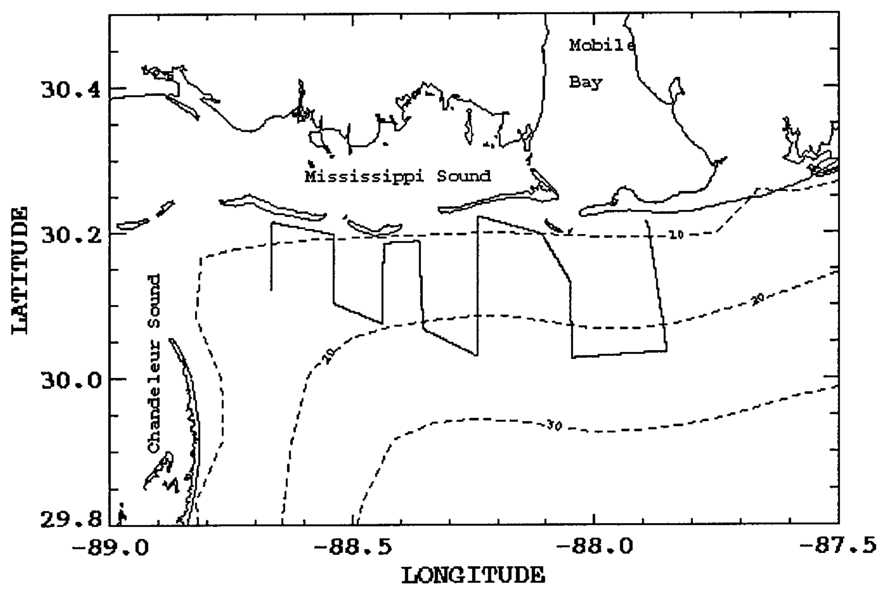


Figure 2: Survey track lines.

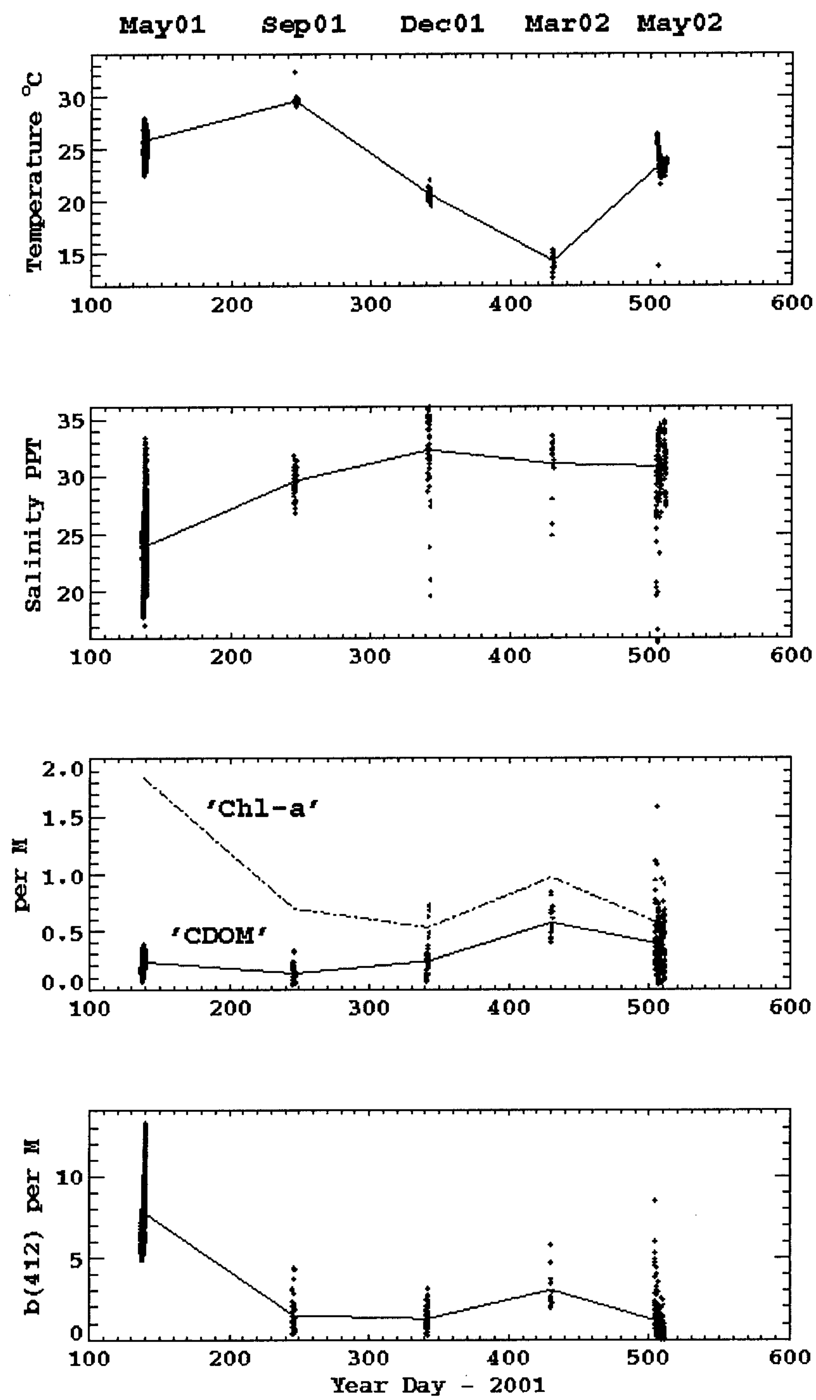


Figure 3: Time series of rapid survey pattern for each month. Dots represent all observations. Lines connect monthly averages.

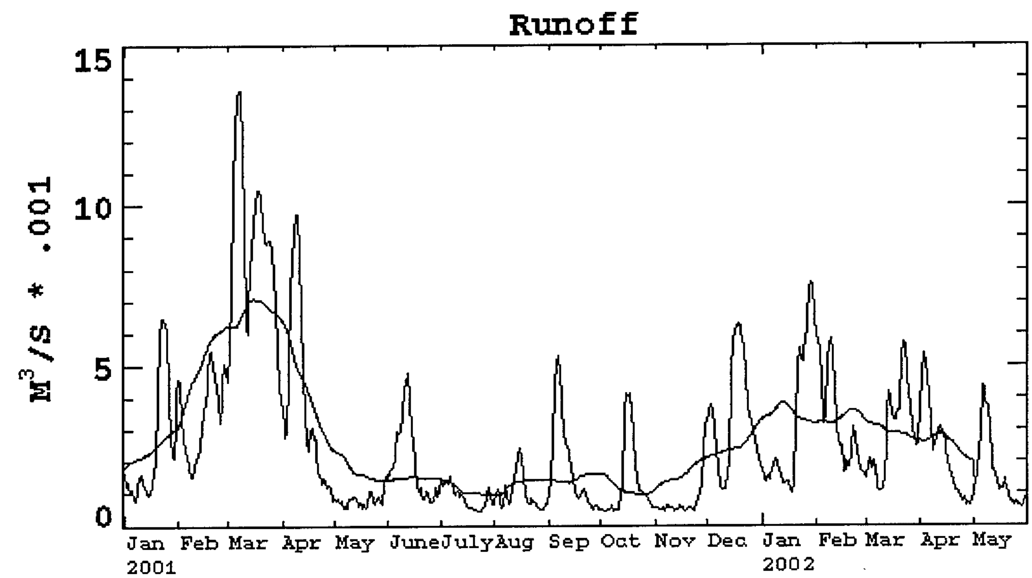


Figure 4: Combined runoff into Mobile Bay and Mississippi Sound. Overplot with 60 day smoothing.

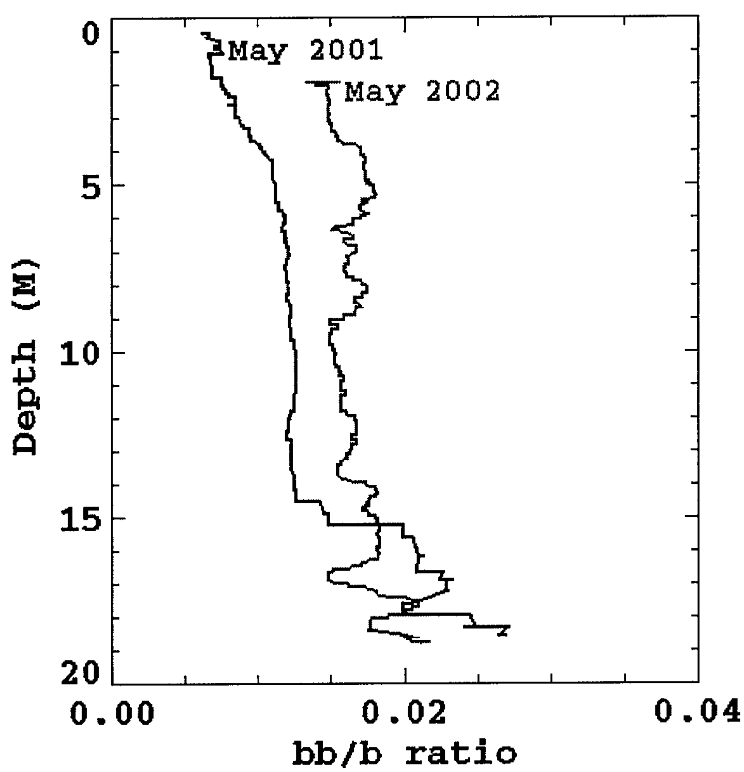
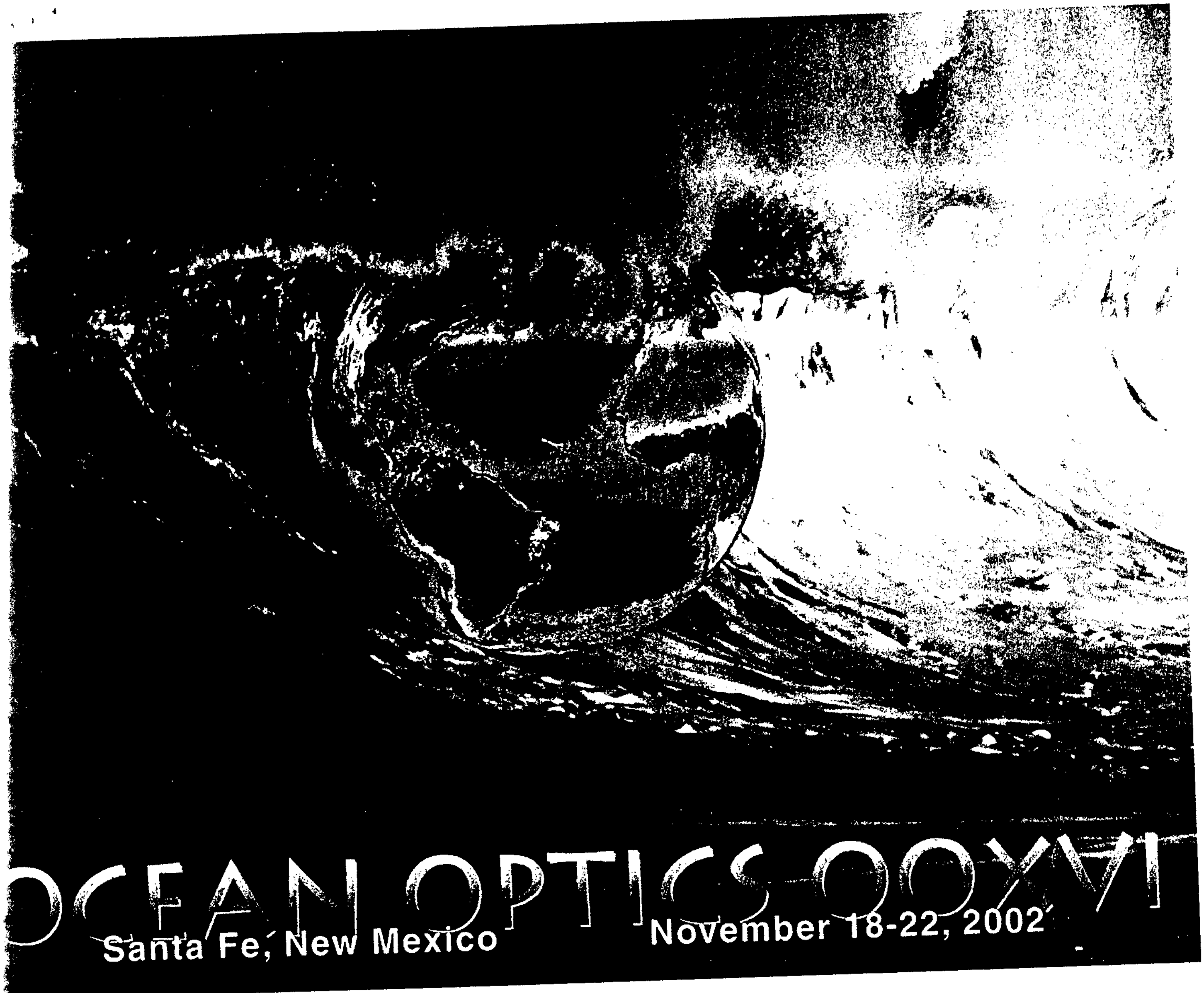


Figure 5: Ratio of hydroscatt backscatter (bb) to ac9 scatter (b) at 532 nanometers



Program and Abstracts

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