THE FLORIDA STATE UNIVERSITY
DEPARTMENT OF OCEANOGRAPHY

FINAL REPORT
FOR THE CONTRACT PERIOD
1 APRIL 1982 - 31 MARCH 1988

TO
OFFICE OF NAVAL RESEARCH

CONTRACT NUMBER N00014-82-C-0404
AUGUST 1988
THE FLORIDA STATE UNIVERSITY
DEPARTMENT OF OCEANOGRAPHY

FINAL REPORT
FOR THE CONTRACT PERIOD
1 APRIL 1982 - 31 MARCH 1988

to
OFFICE OF NAVAL RESEARCH

PRINCIPAL INVESTIGATORS:
BENOIT CUSHMAN-ROISIN
DORON NOF
JAMES J. O'BRIEN
DAVID THISTLE
GEORGES WEATHERLY
D.C. WHITE and D. THISTLE

for

CONTRACT NUMBER N00014-82-C-0404

AUGUST 1988
TABLE OF CONTENTS

SECTION I
Final Report
Dr. Benoit Cushman-Roisin ...................................... 1

SECTION II
Final Report
Mesoscale Processes in the Ocean ............................ 3
Dr. Doron Nof

SECTION III
Annual Progress Report
Research in Upper Ocean Predictability ................... 5
Dr. James J. O'Brien

SECTION IV
Final Report
Dr. David Thistle ................................................ 10

SECTION V
Final Report
Bottom Boundary Studies as Part of HEBBLE ............. 13
Dr. Georges Weatherly

SECTION VI
Final Report
The Role of Exopolymer in Adhesion of the Initial Microfouling Community and in Biofilm Stability ........ 16
Dr. D.C. White and Dr. D. Thistle
During the contract period of April 1, 1986 to March 31, 1988, my ongoing research program has been the investigation, by analytical and numerical models, of mesoscale fronts (including frontal eddies) and, to a lesser extent, of the large-scale circulation. My two doctoral students have concentrated their studies on their respective numerical models, adhering to an established timetable. Graduate student Edgar Pavia has applied his particle-method model to frontal systems; applications in progress include eddy merging and axisymmetrization under various conditions. Having developed a highly accurate spectral code, student B. Tang has investigated geostrophic turbulence at the deformation-radius scale and beyond, from quasi-geostrophic to frontal amplitudes. Both models are highly original and provide the community with solutions to problems never previously addressed.

In 1987, under the auspices of the ONR contract, the 3rd Annual Colloquium on Oceanic Vortices was held at Florida State University and was well attended by scientists from the physical oceanography community. The number of participants was 50 (40 from North America and 10 from Western Europe). A report and abstracts from this meeting were compiled and widely distributed.

Attached is a listing of the publications produced during the contract period. This was the first contract between ONR and Cushman-Roisin, P.I.
PUBLICATIONS BY B. CUSHMAN-ROISIN
PERIOD OF ONR CONTRACT N00014-82-C-0404

Refereed Publications

1986

1987
"Large-scale ocean dynamics," Climatology and Space Observations, Cepadues-Editions, France, 631-642.

1987

1987
"Wind and buoyancy driven ocean circulation," Climatology and Space Observations, Cepadues-Editions, France, 655-663.

1987
"Exact analytical solutions for elliptical vortices of the shallow-water equations," Tellus, 39A, 235-244.

1987

1987

1988

1988

1988
(with E.G. Pavia and V. Tverberg) "A relaxation technique for the solution of internal waves in fjords and on shelves," to be submitted to J. Mar. Res.

1988
(with B. Tang) "Eddies and geostrophic turbulence beyond the radius of deformation," in preparation.

Other Publications

1987

1987

Book Review

1988
Analytical studies of eddy-environment interactions and polar eddies were conducted. The studies were motivated by observations which suggest that ring evolution in the world ocean is dominated by a series of strong interactions. Eddies interact vertically with the atmosphere or deep fluid, and horizontally with surrounding fluids or walls. The studies depart significantly from past theoretical efforts, which have concentrated on the evolution of isolated eddies on a beta plane.

Specifically, we examined: (1) the dynamics of ventilating warm rings, (2) the interactions of warm rings with western boundary currents, (3) the interactions of rings and neighboring mesoscale phenomena, (4) warm ring interactions with western meridional boundaries, (5) the structure and dynamics of “thick” eddies, and (6) the influence of the quadratic variation of the Coriolis parameter with (high) latitude on mesoscale processes. Observations documenting each of these interactions were reviewed and descriptions of their effects are discussed.

Preliminary calculations suggest that the above interactions are characterized by novel dynamics. It is hoped that our work will help to clarify the dynamical link between eddies and the large scale circulation.

PUBLICATIONS


* Preparation of these papers began prior to April 1986.


Annual Progress Report

Research in Upper Ocean Predictability
Secretary of the Navy Research Chair in Oceanography

Chair Incumbent and P.I.: Dr. James J. O'Brien
Florida State University
Tallahassee, Florida 32306
904-644-4581

Technical Progress Report for 1 October 1986 - 31 March 1988
1. Papers submitted to refereed journals


2. Papers published in refereed journals


3. Papers published in non-refereed journals

None.

4. Books or chapters submitted for publication

None.

5. Books or chapters published


6. Patents field (inventor, title, filing date)

None.

7. Patents granted (inventor, title, number, date)

None.
8. Invited presentations at conferences


9. Contributed presentations at conferences

None.

10. Honors

Dr. James J. O’Brien was awarded the 13th Sverdrup Gold Medal in Air-Sea Interaction by the American Meteorological Society.

Dr. James J. O’Brien was elected President, IAPSO, August 1987 for 4 years.

Dr. James J. O’Brien was elected Fellow, AGU, January 1988.

Dr. James J. O’Brien was elected Fellow, AAAS, January 1988.
11. **Professional personnel associated with ONR Contract**

**Principal Investigator:** Dr. James J. O'Brien  
Secretary of the Navy Professor  
Meteorology and Oceanography  
Director, Mesoscale Air-Sea Interaction Group

**Research Associate:** Dr. Mark Luther

**Meteorologist:** Mr. David Legler

**Computer Research Specialist:** Mr. Jim Merritt

**Grants Specialist:** Mrs. Ruth Pryor

**Word Processor:** Mrs. Rita Kuyper

12. **Graduate Students**

1. Mr. Tommy Jensen (Denmark)  
   Topic: Indian Ocean Model  
   Degree: Ph.D., Physical Oceanography  
   Date: 1988

2. Mr. John McCalpin (USA)  
   Topic: Indian Ocean Eddies  
   Degree: Ph.D., Physical Oceanography  
   Date: 1988

3. Lt. Ray Simmons (USA-USN)  
   Topic: Verification of Arabian Sea Model  
   Degree: M.S., Physical Oceanography  
   Date: 1987

4. Mr. Ole Martin Smedstad (Norway)  
   Topic: Data Assimilation of Sea Level  
   Degree: Ph.D., Geophysical Fluid Dynamics  
   Date: 1987

13. **Principal Investigator**

Dr. James J. O'Brien  
The Florida State University  
Meteorology Annex  
Tallahassee, Florida 32306-3041  
(904) 644-4581  

Contract Number: N00014-85-G-0240  
Contract Title: Upper Ocean Forecasting  
Telex Number: 509525  
Telemail: J.OBRIEN/OCEAN
Under this contract, I participated in the High Energy Benthic Boundary Layer Experiment (C.D. Hollister and A. R. M. Nowell, scientific directors). The HEBBLE project required an assessment of the likely impact of biological effects on parameters of an emerging sediment-transport model. In outline, the approach of the HEBBLE biologists to such an assessment was to determine the abundance and distribution of organisms at the HEBBLE site. From these data and a knowledge of the natural history and probable fluid-dynamic consequences of the organisms (or their shallow-water relatives), we identified taxa or functional groups of organisms that seemed most likely to influence sediment motion. These organisms were nominated for study in laboratory flumes or with SEADUCT to quantify their effects on sediment transport.

The approach was implemented as follows. In July 1982, sixteen navigated box cores were taken at the HEBBLE site in a stratified random manner. From each, the central nine subcores were processed for macrofauna, and two of these subcores were also processed for meiofauna. The polychaetes from the two subcores per core were sent to K. Fauchald for identification. The remaining noncrustacean taxa from these subcores were sent to Josie (Yingst) Aller. In my laboratory, we have worked up the tanaids, isopods, harpacticoid copepods, and nematodes.

The most dramatic result is that the major macrofaunal taxa (polychaetes, bivalves, isopods, and tanaids) are conspicuously more abundant than elsewhere in the deep sea at comparable depths (Thistle et al., 1985). Also, more than 60% of the polychaetes make tubes, as do a substantial number of the crustaceans. Because of the potential impact of small-scale roughness on sediment transport, this information has been conveyed to the experimentalists. Other likely effects of the organisms on sediment transport are less clear. Two polychaete species are very abundant and appear likely to dominate the budget of sediment processing by deposit feeders, focusing this aspect of the investigation of potential biological effects.

Although the primary mandate for HEBBLE biology was the determination of its importance in sediment transport, coordinated studies of deep-sea biological questions have had a legitimate, if secondary, role. Using the data from two preliminary samples, Thistle et al. (1985) presented an overview of the ecology of the area, noting strong contrasts with that of more tranquil deep-sea areas. In particular, the fauna seemed to be modified by the risk of erosion posed by the strong bottom currents while benefiting from the increased food flux. Using the data from the main HEBBLE samples, I was able to confirm that tanaids (Reidenauer and Thistle, 1985) and isopods (Thistle and Wilson, 1987) were unusually abundant for the depth and that epifaunal forms were rare. My student Kevin Sherman put a heroic effort into working up the nematodes (260 species), which allowed us to describe the composition and some of the ecology of this important component of the fauna (Thistle and Sherman, 1985; Carman et al., 1987). I also
showed that benthic storms displace harpacticoid copepods from site and thus participate in the organization of the community there (Thistle, in press).

HEBBLE Publications from a previous contract


HEBBLE Publications under N00014-82-C-0404


Other Publications in which N00014-82-C-0404 is acknowledged


FINAL REPORT TO THE OFFICE OF NAVAL RESEARCH

For work under contract N0014-82-C-0404

April 1, 1982 - March 31, 1988

BOTTOM BOUNDARY STUDIES AS PART OF HEBBLE
(High Energy Benthic Boundary Layer Experiments)

Georges Weatherly
Department of Oceanography
Florida State University
Tallahassee, FL 32306

My objectives in HEBBLE were (1) to obtain and to analyze long-term abyssal current meter records from the HEBBLE area, (2) to obtain and to analyze current meter records completely spanning the HEBBLE site bottom boundary layer, and (3) to obtain a better understanding of the bottom boundary layer and its importance in the general ocean circulation.

PUBLICATIONS


SUBMITTED PUBLICATIONS


REPORTS


THESES
FINAL REPORT TO THE OFFICE OF NAVAL RESEARCH
For work under Contract N00014-82-C-0404

THE ROLE OF EXOPOLYMER IN ADHESION OF THE INITIAL MICROFOULING COMMUNITY AND IN BIOFILM STABILITY

D. C. White
Institute for Applied Microbiology
University of Tennessee
Knoxville, TN  37932-2567

and

D. Thistle
Department of Oceanography
Florida State University
Tallahassee, FL  32306-3048

OBJECTIVES

The long-term objective of the work performed under this contract has been to define the role of the microbial film in initiating the biofouling sequence and to determine the role of exopolymers in irreversible attachments in biofilms and in stabilizing sediments.

ABSTRACT

The community structure of the biofouling film can be determined by examination of the patterns of polar lipid ester-linked fatty acids (PLFA). By examining the shifts in cyclopropane and trans/cis monoenoic proportions, as well as the accumulation of the exogenous storage polymer poly-beta-hydroxy alkanoate, the nutritional status of the microbes can be determined. The extraordinary resolution of the capillary gas chromatograph (GC) coupled with the diversity of bacterial fatty acids provides a means of quantitatively measuring microbial community structure. The creation of electron-withdrawing derivatives of the PLFA followed by GC analysis with chemical-ionization mass spectrometry and negative-ion detection has increased the sensitivity to femtomolar levels (hundreds of bacterial cells). The specificity of the analysis has been increased by a new derivatization with dimethyldisulfide that provides clear separation of trans/cis isomers and specific fragmentation that defines the position of the unsaturation in monoenoic fatty acids. This new technique has allowed identification of monocultures from the initial phases of microfouling.

With these new methods and the use of the GC/CINIMS at Lund Sweden, we were able to show that there appears to be an initial microfouling community consisting of typical gram-negative, "Vibrio-like" bacteria that attaches to Teflon surfaces in hours and that community did not change significantly in the first week of exposure. A specific portion of that community was removable with gentle washing. The accumulation of high proportions of trans-monoenoic and cyclopropane fatty acids accompanying the starvation sequence of V. cholerae was also shown. This change is associated with changes in the adhesive properties of the organisms. The source of the initial microbial microfouling community was examined by fractionating the inlet waters of the microfouling test beds with Nucleopore filters and then using a newly developed method.
for quantitatively recovering the PLFA from them. Studies have shown that the community structure of the initial microbial microfouling community most closely resembles the microbiota associated with particulate material in the estuarine source waters. The free bacteria (retained by 0.4-um filter) and the particulates retained on a 10-um filter are much more like the initial microbial microfouling community than the microbes retained on a 3.0-um filter.

CURRENT REPORTS AND PUBLICATIONS


