Marine Physical Laboratory

Ocean Dynamics

R. Pinkel and M. Merrifield

Supported by the
Chief of Naval Research
Grant N00014-90-J-1099

Final Report

MPL-U-5/97
March 1997

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University of California, San Diego
Scripps Institution of Oceanography

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. Agency Use Only (Leave Blank).	2. Report Date.	3. Report Type and Dates Covered.
	March 1997	Final Report

4. Title and Subtitle.
Ocean Dynamics

5. Funding Numbers.
Grant N00014-90-J-1099

Project No.
Task No.

6. Author(s).
R. Pinkel and M. Merrifield

7. Performing Monitoring Agency Names(s) and Address(es).
University of California, San Diego
Marine Physical Laboratory
Scripps Institution of Oceanography
San Diego, California 92152

8. Performing Organization Report Number.
MPL-U-5/97

9. Sponsoring/Monitoring Agency Name(s) and Address(es).
Office of Naval Research
Ballston Centre Tower One
800 North Quincy Street
Arlington, VA 22217-5660
Lois Goodman, Code 322PO

10. Sponsoring/Monitoring Agency Report Number.

11. Supplementary Notes.

12a. Distribution/Availability Statement.

Approved for public release; distribution is unlimited.

12b. Distribution Code.

13. Abstract (Maximum 200 words).

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14. Subject Terms.
internal wavefield, wavenumber frequency spectrum, Doppler sonar

15. Number of Pages.
7

16. Price Code.

17. Security Classification of Report.	18. Security Classification of This Page.	19. Security Classification of Abstract..	20. Limitation of Abstract.
Unclassified	Unclassified	Unclassified	None

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-10

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for the Period 10-1-89 - 6-30-96

Abstract

Efforts in the MPL Ocean Dynamics program during 1993-96 focused in three areas. First was the study of fine scale shear and strain as measured by profiling CDT's and Doppler sonar during the SWAPP experiment. A second effort fielded an oceanographic contribution to the 1993-94 SIMI experiment in the Beaufort Sea. Analysis of these data are presently in an advanced state. Finally, we are completing analysis of wavenumber-frequency spectra of fine scale shear from geographic sites around the world. The goal is to quantify variation of spectral form as a function of overall energy level and latitude. Each of these efforts is reviewed below.

Research Summary

The Statistics of Fine Scale Shear and Strain

Gregg (1989) has provided observational evidence that averaged estimates of dissipation, ξ , vary approximately as the square of the internal wavefield energy level $\xi - E^2$. Gregg notes that the finding is consistent with a specific model for energy transfer in the internal wavefield proposed by Henyey et al., (1986). If it is also consistent with a purely statistical breaking model, based on the random superposition of independent waves, support for any particular dynamic scenario vanishes.

However, most previous statistical models of the wave breaking process have demonstrated an extreme sensitivity of dissipation to energy level. Doubling E results in an increase of dissipation by a factor of 2×10^5 in the early model of Garrett and Munk (1972b) and by 10^3 in the later model of Desaubies and Smith (1982).

As an aspect of the Ocean Dynamics Program we reexamined these mixing models, attempting to reconcile their predictions with the observations of Gregg. An extensive Doppler sonar (5.5 m vertical resolution) and CTD (5400 profiles to 420 m) data set, obtained from the Research Platform FLIP during the SWAPP experiment, was applied to the problem. A model for the probability density function (pdf) of Richardson number was developed, accounting for both shear and strain variability. This pdf is an explicit function of the vertical differencing scale, $\overline{\Delta z}$, over which shear and strain are estimated. From this pdf, a related probability density of overturning can be derived, as a function of overturn scale and internal wavefield energy level. The third moment of this pdf is proportional to the buoyancy flux, which can be related to dissipation, assuming a fixed flux Richardson number.

When this finite difference approach is pursued, dissipation levels are found to vary nearly as E^2 for a variety of contrasting internal wave spectral models. Gregg's constant of proportionality is recovered, provided independent realizations of the Richardson number process are said to occur every 10-14 hours.

Beaufort Sea Internal Wave Climatology

As an aspect of the SIMI ice dynamics experiment, a 150 kHz self-contained Doppler sonar was used to monitor currents in the upper Arctic ocean through the winter months of 1993-94. This winter record complemented numerous spring observations associated with conventional ONR ice-camps. The spring observations have shown the Beaufort Sea internal wavefield to be 10-50 times less energetic than its mid-latitude counterpart. Our hypothesis was that the winter ice-cover isolated the ocean from wind forcing, resulting in the low observed energy levels in spring.

However, the ocean is substantially open to the atmosphere during the summer months. If atmospheric forcing is indeed a dominant factor, fall observations should show the Arctic wavefield to be as energetic as mid-latitude wavefields. Over the winter the wavefield presumably decays to the low energy state seen in the spring. In monitoring this decay, details of both non-linear processes within the wavefield and dissipation processes might be inferred.

A high resolution Scripps designed sonar was deployed during the manned phase of the SIMI site, in November 1993. This was replaced by a battery operated device which ran through the winter, being recovered in April 1994. The surprise of SIMI is that the internal wave energy levels initially observed in the fall are as low as typical spring values. Indeed, energy levels appeared to increase over the winter, in several distinct isolated events (Fig. 1). The initial conclusion from SIMI is that the ice cover of the Beaufort Sea is not responsible for the low observed wavefield energy level. Some other factor, perhaps the low energy in the Arctic mesoscale field, is key.

The Wavenumber Frequency Spectrum of Shear

Our understanding of energy flow through the internal wave spectrum, from forcing scales to dissipation scales, is observationally limited. Except at exceptional sites, like the Beaufort Sea or the Equatorial ocean, the internal wave spectrum always seems to look the same. As an aspect of the Ocean Dynamics program we have developed coded pulse Doppler sonars with resolution capable of detecting small differences in the wavefield spectrum. We have operated these systems at a variety of sites around the world, from 83° N (CEAREX, 1989) to 2 °S (TOGA COARE, 1992-93). Energy levels varied from 50 times less than the GM standard (SIMI, LEADEX) to 10 times more (TOGA COARE, CEAREX, Fig. 2). The interesting preliminary result is that the shear spectral forms appear to progress from lowest to highest variance levels in a systematic manner. The progression of forms is significantly different from the Garrett Munk model, which has been used as the basis for numerous theoretical studies. It also differs from a recent model suggested by Muller et al. 1991 based on atmospheric observations. When published in final form, the set of spectra will provide useful clues for theoreticians modeling the internal wavefield. A manuscript will be submitted to J. Phys. Oceanogr. in the next several months.

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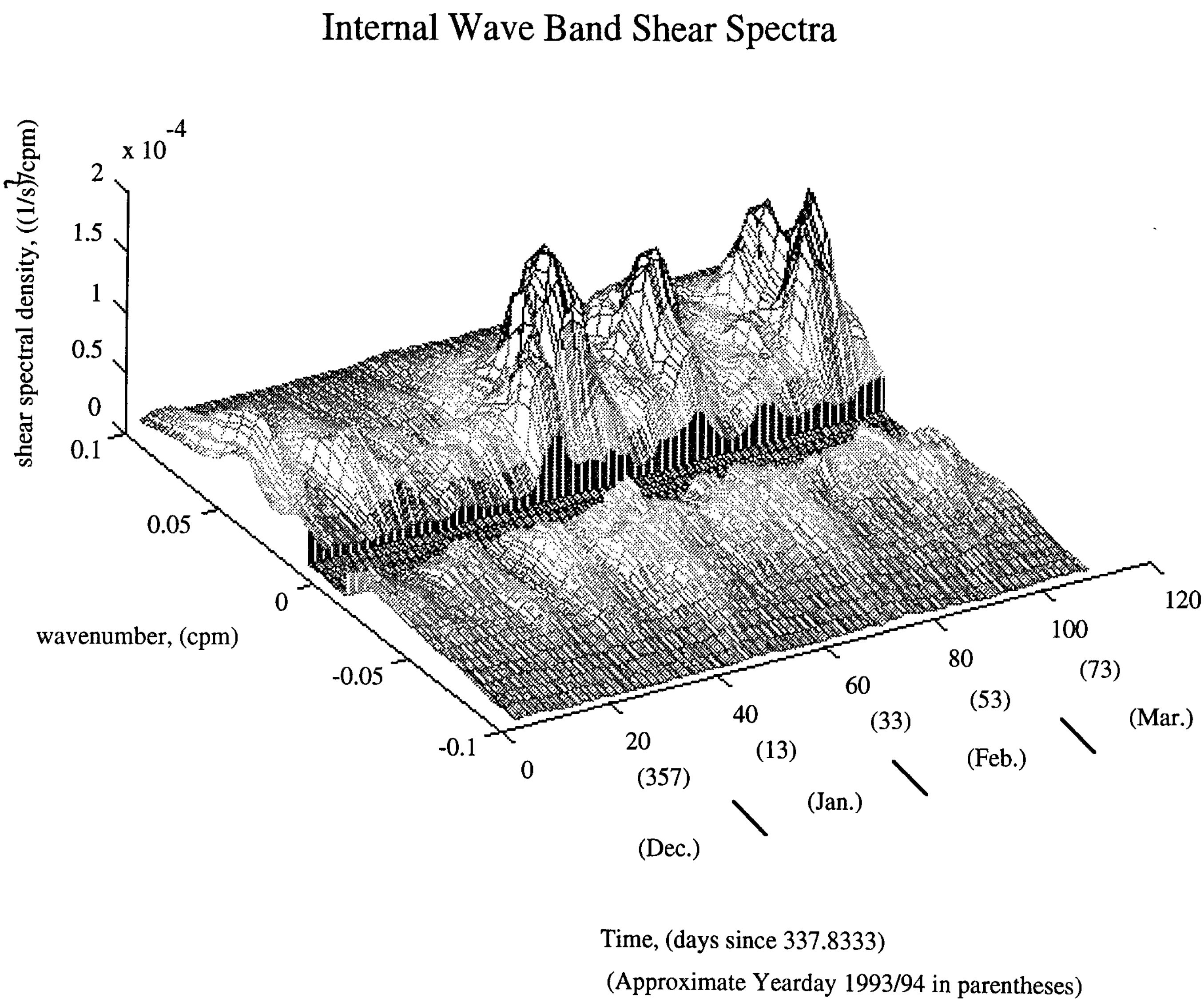

Figure 1. Vertical wavenumber spectra of horizontal velocity in the upper Beaufort Sea vary through the winter of 1993-94. Major increases in downward propagating energy are seen in late winter associated with wind/ice motion events.

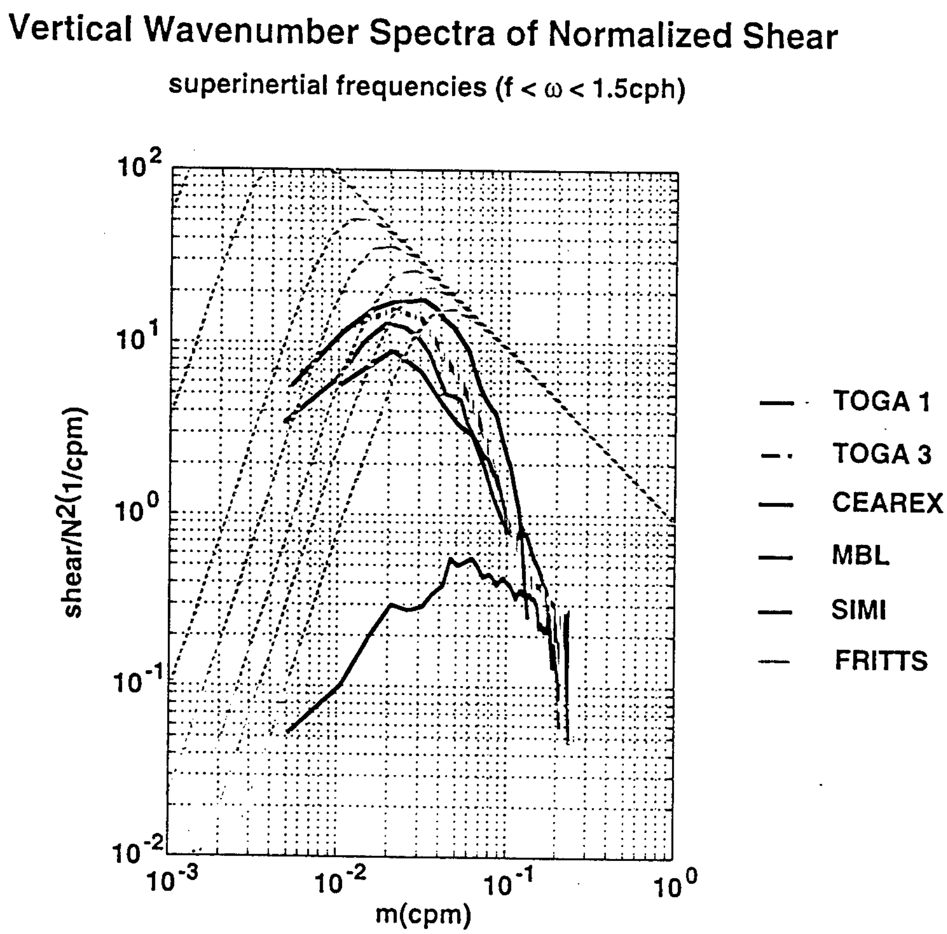

Figure 2. A global collection of spectra of horizontal velocity shear as obtained by coded pulse Doppler sonar. Shear variance levels vary by a factor of 30. Energy levels vary by a far greater amount (a factor of 100). This is only weakly reflected in the shear levels as the spectrum apparently shifts to higher wavenumber as energy decreases.

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