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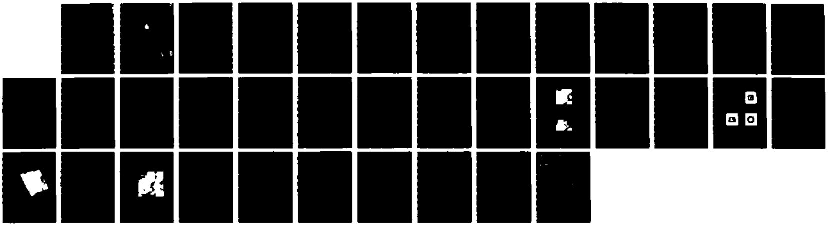

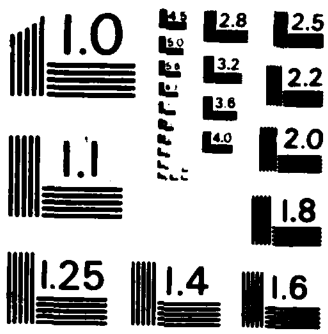

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Woods Hole Oceanographic Institution

Dynamic Presentation of Long Term Upper Ocean Study (LOTUS) Data Using Videotape

by

Ellyn T. Montgomery

September 1986

Technical Report

Funding was provided by the Office of Naval Research under contract Nos. N00014-76-C-0197, NR 083-400, and N00014-84-C-0134, NR 083-400.

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Robert C Beardsley

Robert C. Beardsley, Chairman
Department of Physical Oceanography

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ABSTRACT

In order to show efficiently the large amount of data obtained during the Long Term Upper Ocean Study (LOTUS), a new method of data presentation was developed. Three data variables can be included in a simple color contour plot, but if successive color contour plots are recorded on videotape, a fourth variable, time, can also be shown.

This report documents the process of making a videotape presenting scientific data in this way, from raw data to finished videotape. The videotape shows internal wave kinetic energy versus frequency and depth; the time variation of the videotape displays real time variation in the ratio of 14/30 second to one week, or about 1 month of data every 2 seconds.

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ACKNOWLEDGEMENTS

I wish to thank Mel Briscoe for providing the concept of using a videotape, and for giving advice and editorial assistance. Also, I am very grateful to Roger Goldsmith, whose help in understanding the subtleties of the UNIRAS software was invaluable, and to Bill Lange for his patience and technical expertise in making and editing the videotape. Peter Wiebe and the Center for Analysis of Marine Systems kindly lent me their color graphics terminal and printer, which expedited the process immensely.

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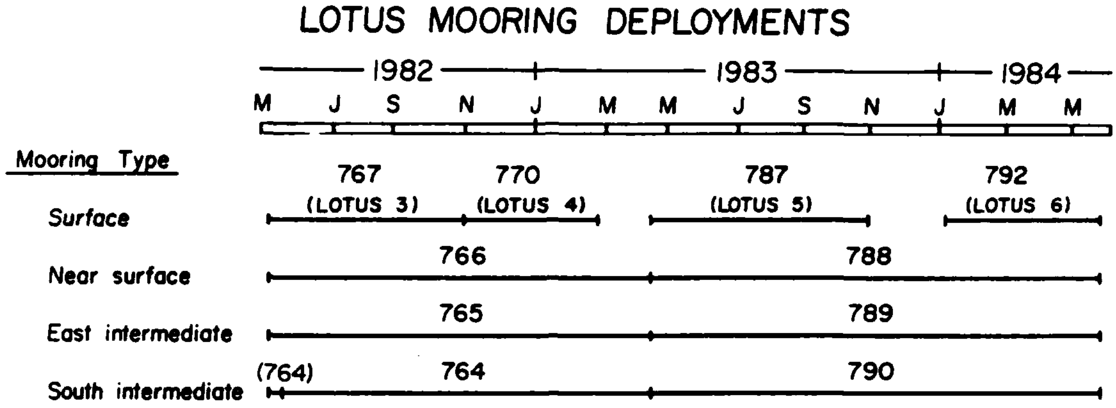
INTRODUCTION

The need to consider a dynamic method of data presentation, such as videotape, was generated by the large data set collected during the Long Term Upper Ocean Study (LOTUS). LOTUS was a two year experiment (Briscoe and Weller, 1984), designed to acquire and analyze a continuous set of data, sampled primarily from the upper ocean, but covering the entire range of depths. LOTUS took place between May 1982, and May 1984. The mooring arrays were deployed at 34°N, 70°W (the old Woods Hole Site L), on the Hatteras Abyssal Plain. Figures 1a and 1b show the duration and relative position of each of the moorings used during the two years of LOTUS.

A listing of all LOTUS-related Woods Hole Oceanographic Institution technical reports is provided in the Appendix to furnish details about the experiment that are not described here.

A maximum of two years of current meter data exists for depths between 5 and 4000 meters. Most conventional methods of data presentation would show the data at each depth separately; the goal in this case was to show all the data together. Three variables (e.g., kinetic energy versus frequency and depth) can be shown in a two-dimensional color contour plot, but in order to show the fourth variable, time, some dynamic form of presentation, such as videotape, must be used.

This report documents the process used to make a videotape presenting LOTUS data. All stages of the work are included: data selection and manipulation; use of UNIRAS software to create individual plots; and the actual videotaping of the plots.



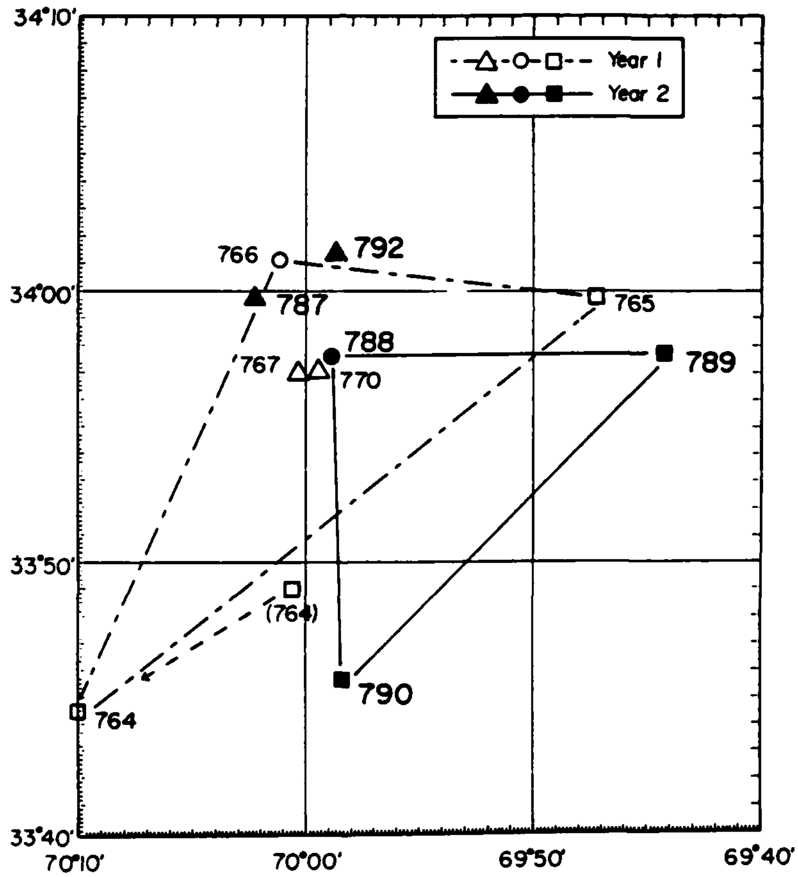


Figure 1a. The durations of moorings used during LOTUS.

Figure 1b. Locations of each mooring used during LOTUS.
Year 1 mooring array: surface (767, 770 △); near surface (766 ○); intermediate (764, 765 □).
Year 2 mooring array: surface (787, 792 ▲); near surface (788 ●); intermediate (789, 790 ■).

METHODS DISCUSSION

Although a wide variety of possible methods of creating a time display of horizontal kinetic energy spectral density versus depth and frequency were available at the outset of this project, it soon became obvious that many fewer were actually feasible. For example, the animation of the time display could have been done by computer, but this would have required a more sophisticated computer graphics system than we have, so the less automated method of generating individual color contour plots and filming them sequentially was used. Even with the general method chosen, there were still many decisions to be made. Several of the options considered are discussed below.

In order to have the project completed by the deadline of mid-January 1986, the use of in-house equipment and existing software was necessary. This limitation made videotaping individual plots generated using PROSPECT (for the spectral analysis) and UNIRAS (for the graphics) the most reasonable option. The data and software needed were both on one of the Woods Hole Oceanographic Institution (WHOI) computers, a Digital Equipment Corporation VAX 11/780, designated the Red VAX, so this system was used to carry out all of the processing. WHOI has a videotape studio, and display devices (VCR's) are readily available for general use, so videotape was chosen as the film medium over 16 mm or film loops. This left only the choice of which hardcopy device to use.

Three color hardcopy options were available on the Red VAX: slides from the Matrix QRC camera; paper hardcopy from the Applicon color printer; and paper hardcopy from the Tektronix 4695 color ink jet printer. Slides were not used due to anticipated problems with registration of the overlaid plots during the videotaping. The possibility of using the Applicon was eliminated due to cost, though it would have produced consistently sized hardcopies of better quality than the other available hardcopy devices. Applicon plots cost $40 per page, including magnetic tape mount charges. Even if six figures were plotted per Applicon page, the cost of making hardcopies of all of the plots would have been approximately $1400. This left the Tektronix 4695 as the hardcopy device, which produced good quality color plots. It is a pinch roller device, though, so the plots did not come out exactly the same size (to the mm), which caused minor problems with overlaying the plots during the videotaping. The cost of making all the hard copies on the Tektronix was less than $400.

Some of the methods considered but not used were: using an image encoder to convert the image generated by the computer directly to videotape; videotaping images from the computer terminal's screen; and using another WHOI computer, the Remote Sensing VAX Processor (RSVP), to do all the processing and using a 16-mm movie camera to film the images.

An image encoder was not available at WHOI at the time, and due to the project deadline, it would have been impossible to get one to use, set it up, test the system, and then make the videotape. Unfortunately, this probably would have been the best way available to transfer computer generated images onto videotape. There is now an encoder at WHOI, so the procedures described herein should be modified to allow its use.

Videotaping directly from the screen was not used because of mediocre image quality on the videotape, individual plot generation time, and the large amount of disk space required to keep enough plots available to make a videotaping session worthwhile. This method would have been a more viable option, if WHOI had available in software a method of bring plots to the monitor rapidly enough in succession to allow 'real time' filming of the series of images displayed on the screen.

The RSVP system's image processing capabilities were attractive, but too much time would have been spent developing a program to produce equivalent contour plots on that system. Also hardcopy was a problem: still photographs were available, but expensive; and the 16 mm camera had no way to control the number of frames shot for each plot, so the time base of the film would be irregular.

All of the above mentioned considerations made using PROSPECT and UNIRAS software on the Red VAX, generating hardcopies of the plots on the Tektronix 4695, and videotaping the individual plots in sequence the best method for completing this project. As computer graphics and videotape technology improve, and become more affordable, there will be other "best methods", but at the time, the method described herein was the best.

COLOR CONTOUR PLOTS AND VIDEOTAPE

The videotape was made from a series of color contour plots, each showing the same depth and frequency ranges over different time periods. Frequency was the x variable, water depth was the y variable, and horizontal kinetic energy spectral density was the z variable; the values of z were contoured. The plots were created using 11 spectra calculated over the same time period, each for a different depth.

Each plot shows 7 days 3 hours of data. This duration was chosen because the inertial and tidal periods (about 21.5 and 12.4 hours respectively) then both fall near spectral frequencies. The start times of all plots are 3 days 13 hours 30 minutes (one half of the total time) later than the start time of the preceding plot. Each plot therefore overlaps by half the preceding and succeeding plots, and every other plot is adjacent in time.

The completed videotape used 206 color contour plots to show the time variation of kinetic energy spectral density for frequencies between .012 and 2 cycles per hour, versus depth. Two years of data are displayed in about 50 seconds of videotape. The plots blend into each other so that trends over time can be observed.

DATA PROCESSING

A) Set up

The first task was examination of the LOTUS data set, to decide which instrument depths should be used for the plots. The data were collected by current meters on surface or subsurface moorings, sampling every 3.75 or 7.5 minutes. All the records were reduced to a common 15 minute time base by vector-averaging 2 or 4 points together; this gave 684 data points in each 1-week time series. The data were stored in Buoy Format data files. Buoy Format is the standard format developed and used at WHOI for storing the large time series that come from current meter moorings. The current meter data reports (Tarbell *et al.*, 1984 and 1985) and the Buoy Group data processing report (Spencer et al., in preparation) are good sources of further information on Buoy Format and the LOTUS current meter data.

The objective was to select instruments that had at least 50% data return over the two year period and that were representative of the whole depth range. The same depths were used as much as possible throughout, to minimize the number of parameters that had to be changed at each step of the processing. When data from a given depth were unavailable, but data from an adjacent depth were available, the data from the nearby depth were used (i.e., if data from 100 m were missing and the next instrument on any mooring was at 127 m, data from 127 m would then be used instead of from 100 m). Figure 2 shows the overall current meter data return from the centrally located surface and near-surface moorings used in LOTUS. The 4 intermediate moorings used over the two years of LOTUS are not shown, because data were used from them in only one instance, to supply data for the first year at 500 m.

Most of the instruments were at depths less than 500 meters, so to distribute the existing data evenly over the full 4000 meter depth range, a logarithmic Y axis was used. The nominal depths chosen were the following: 15 m, 25 m, 75 m, 100 m, 200 m, 300 m, 500 m, 750 m, 1000 m, 1500 m and 4000 m. Unfortunately, there were no data available for the first year at 2500 m, so this depth was not used in the plots, though it would have improved the depth distribution. Instruments shallower than 100 m were from surface moorings, those deeper than 100 m were from near surface moorings (except for the first year 500 m data, which came from an intermediate mooring), and data from 100 m came primarily from surface moorings, but sometimes from the near surface moorings. Figure 3 shows a schematic of the moorings with instruments at the depths chosen for use in the videotape. The Y axis is log to the base 10 scale, as is the y axis of the contour plots.

B) Start Time Determination

The next step was determination of the start time of each of the planned plots. Since the spectra were to be calculated over 7 day 3 hour intervals and overlapped by one half, the start time for each time series

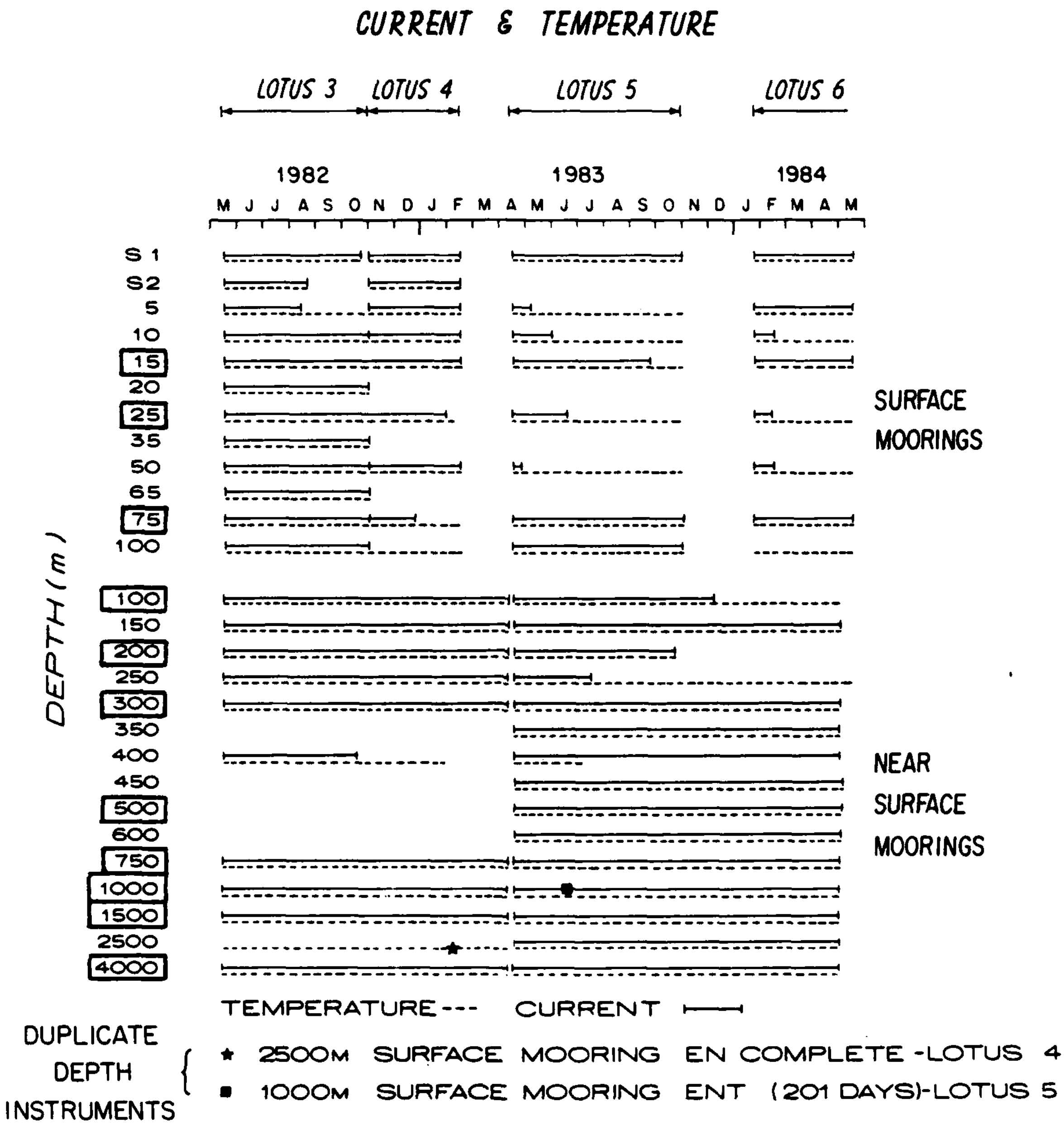


Figure 2. Chart showing current meter data availability during LOTUS. The selected depths are boxed.

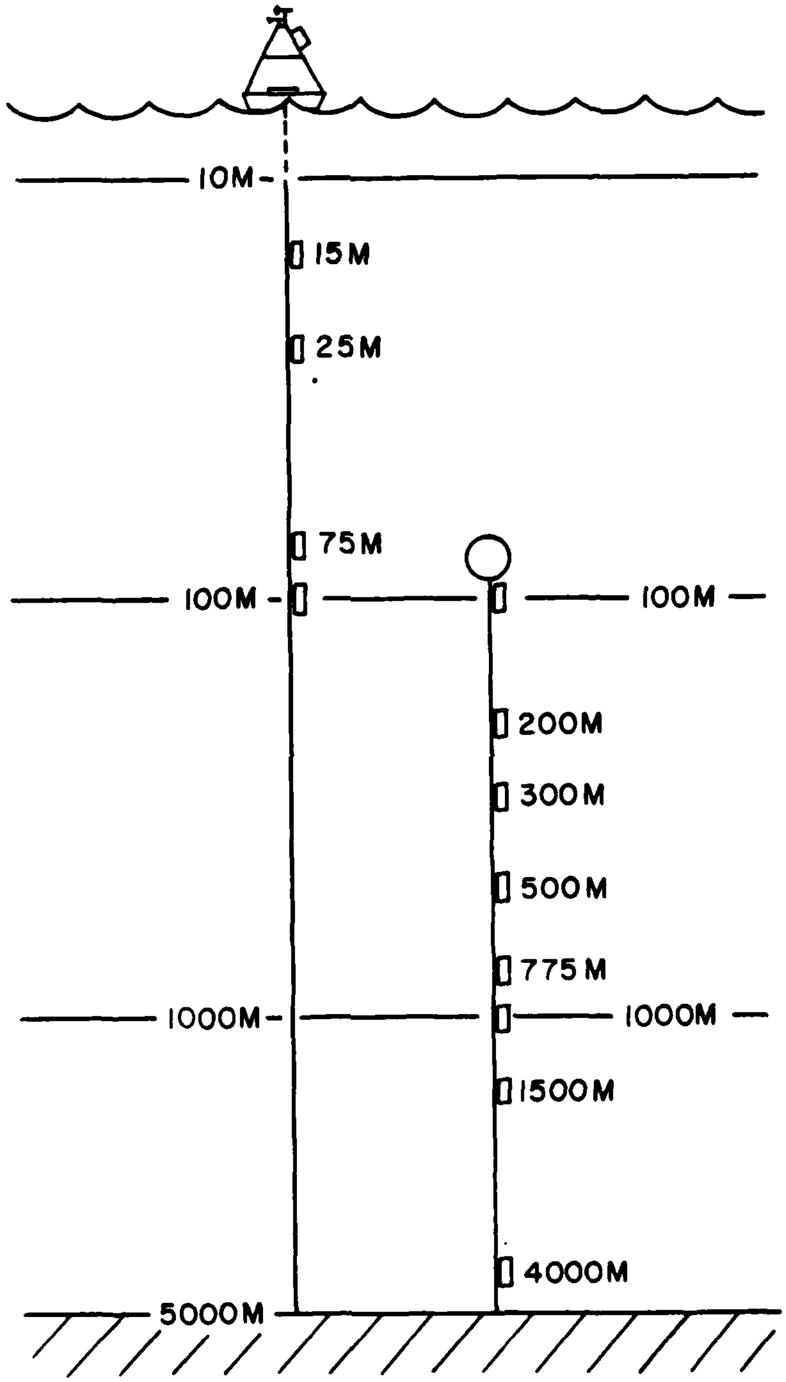


Figure 3. Schematic showing a surface and a near surface mooring typical of those used in LOTUS with instruments at the depths chosen for use in the videotape. Note that depth is presented on a $\log_{10}$ axis to more evenly distribute the data.

had to be obtained. To achieve this end, a short program was written to take start and stop time of the entire series, the desired delta time and overlap, and calculate the start times of all the possible plots within the defined time period. The listing of computed start times became the source for subsequent processing. Since the data set spanned two years, a total of 206 plots was needed to present all the data. The start time of the plot was subsequently put in the lower right hand corner of each plot, so the time could be more easily identified during the videotape.

C) Spectral Analysis

Spectra of the 15 minute averaged data were computed using PROSPECT (a WHOI spectral analysis program; Hunt, 1982) for each depth for each 1 week time period. In this case, calculating the auto spectra of the data allowed the frequency components contributing to the variance of a fluctuating process to be displayed.

Each 684 point, 1 week time series was broken into 2 adjacent 342 point pieces with a third 342 point piece overlapped 50% with the other two. The least squares linear trends were removed from each piece, and each piece was cosine windowed ("Hanning") and normalized by $\sqrt{8/3}$ to account for variance lost in the windowing. A fast Fourier transformation was then done on each piece and a raw spectrum calculated. The average spectrum of the 3 pieces was then smoothed. The average spectrum had 171 points (1/2 the number of points in the piece) which were grouped to reduce their number and obtain more statistical stability. The grouping was 9 single, 15 with 5 averaged together, and 8 with 10 averaged together; the last 7 points were discarded.

Each smoothed, averaged spectrum therefore had 32 points (9 + 15 + 8). The periods represented were between 85.5 and .536 hours.

The output of the PROSPECT routine SPECACR comes as an unformatted ASCII file for subsequent plotting, and as a formatted file for listing. The formatted file was used as the data source for subsequent processing, and will be referred to as the A*.DAT file (* = instrument ID and code).

All the depths for a given time interval were processed together, and were assigned a two letter identifying code, starting at "NA", and ending at "VS". The codes were necessary to simplify retrieval of the data files for specific plots. For instance, all 11 A*.DAT files for start time 06/18/82 had the code NJ, so these files were quickly accessible as A*NJ.DAT (* = instrument ID only here).

Because of the large number of spectral computations to be completed (11 depths x 206 start times = 2266 smoothed, averaged spectra), command files were used to control the processing. These command files passed variables to the command file that ran PROSPECT, and allowed many runs to be done together in one overnight batch job. Usually 10-20 of the time periods were done in one night. The command files were large and cumbersome to edit, but were worth the effort in run time saved.

D) Array Manipulation

The A*.DAT files for each time period had to be combined to create one file for input to UNIRAS (the graphics software package used to generate the plots). Along with reading 11 A*.DAT files and writing one output file, several other modifications had to be made to allow the plots to be created. The following steps were repeated 11 times (once for each depth) for each 7 day 3 hour time series, to obtain the needed data for one color contour plot.

The squared values of the East and North components of the spectra (columns 1 and 2, labeled A1 and A2 respectively) and the accompanying period (last column) were read from the A*.DAT file. East and North were used to calculate the Horizontal Kinetic Energy spectral density (HKE). The units of HKE spectra are (erg/gm) / (cycle per hour), or $cm^2\ s^2$/(cycle per hour). The Horizontal Kinetic Energy spectral density varies from approximately 0 to 30 (erg/gm) / cycle per 85.5 hours, so the logarithm to the base 10 of Horizontal Kinetic Energy spectral density was calculated to distribute the data evenly among the contour levels. The $\log_{10}$ transformed Horizontal Kinetic Energy spectral density was called LH and used as the Z variable in the plots.

$$LH = \log_{10} [(A1 + A2)/2]$$

Period was used as the X variable, and was log transformed to make the spacing as it would have been if frequency were plotted in the usual way for spectra. Since the maximum and minimum values of period were 85.5 hours and 0.536 hours, the $\log_{10}$ values were 1.932 and -0.2708, respectively. For ease in the plotting stage, one was added to the $\log_{10}$ value to make both the axis maximum and minimum positive.

The convention of displaying the auto spectra of current meter data with frequency plotted on a log X axis, with the lowest value at the left and the highest value at the right, was followed in these plots. Instead of converting periods to frequency every time, period was plotted, but the axis was labeled with the equivalent frequency. For example, 85.5 hours corresponds to a frequency of 0.0117 cycles per hour, so $1 + \log_{10}(85.5)$ was assigned to X minimum, and $1 + \log_{10}(0.536)$ was assigned to X maximum. Details of the tick mark calculation process will be described in Part C of the UNIRAS processing section.

The value of depth for each spectrum was input by the user. In order not to have all the data bunched at the surface, as it would appear on a linear scale plot, the log of the value of depth was used. Also, so that the plot resembled the "real" ocean, 15 meters became the top Y axis value, and 4000 meters became the bottom. This organization required that the value of Y maximum be 15 m, and Y minimum be 4000 m. UNIRAS sometimes incorrectly dimensions the plots, if the assigned value for the axis maximum is not actually greater than the value assigned to the minimum. To avoid this problem, the log to the base ten of the depth was multiplied by -1, so 15 m became -1.1761, and 4000 m became -3.6021, and thus, the value of Y maximum was made greater than the value of Y minimum.

The data arrays after processing had 352 points, 32 for each of 11 depths. The first 32 points were the 15 meter spectrum, modified as described above, the next 32 were the modified 25 meter spectrum, followed by subsequent depths till the end of the file. The X and Y arrays were the same from one plot file to the next, with the changes occurring in the Z values (except when a substitute depth was used in place of the original depth). A missing data depth was treated by inserting values of 99.9999 into the Z array for each of the 32 periods for the depth. Values of depth and period were processed in the usual manner, so the output data files always had the same number of points. For instance, if 15 m data were missing, the first 32 values of Z would be 99.9999, the first 32 values of Y (depth) would be -1.1761 $\left(-\log_{10}(15)\right)$, and the first 32 values of X (period) would be those read from the A*.DAT file; thus the number of points is not changed by missing data.

The files resulting from these manipulations were named EN*AR.DAT (* = start date of time series analyzed), and were used as the input files for UNIRAS. The format used was: Z, X, Y, (1X,F10.4,2X,F6.4,2X,F6.4), but as long as the format from the processing is the same as the format read by the plot generation program, it does not matter specifically what the format is.

UNIRAS PROCESSING

UNIRAS is a versatile raster-based software package that has good color contouring capabilities. It consists of a library of Fortran callable subroutines that do virtually everything from simple vector drawing to three-dimensional plot rotations. The UNIRAS Raspac and Geopac software contain all the routines needed to make color contour plots. The images generated by UNIRAS are stored in plot-deferred files called UNIWORK.DAT and UNIINFO.DAT. These plot files can be displayed or hard-copied on the device selected in the program. A Tektronix 4107 terminal and 4695 color ink jet printer were used for this project. Both devices functioned well, except for the problems inherent to ink jet printers, namely jet clogging.

The program created to generate each of the 206 different color contour plots can be separated into 5 main parts: parameter setting, missing data handling, axis drawing, reading data arrays, and data interpolation and contouring. Command files were again used to pass parameters to the program, control the file assignments and runs, and rename the output files for identification.

A new version of UNIRAS was released in the time between the completion of the videotape and the publication of this report. The videotape was completed using the old version (84.1), therefore the processes described herein are for the old version. Many of the subroutines are the same, but information given here will not necessarily function in the new version as it did in the old version. The following discussion of UNIRAS processing is intended only to document how plots were created for use in the videotape, not to serve as a guide to using UNIRAS subroutines. For information on UNIRAS, the reader is referred to the UNIRAS Raspac and Geopac guides (European Software Contractors).

A) Parameter Setting

Most of the routines used in generating UNIRAS plots require some of the following parameters to be supplied to the program: array names, scaling factors, maximum and minimum values of axes, axis lengths, number of grid units, line widths, and text fonts. Though these parameters could be written into the program, in this application they were assigned to variables. The default values of the variables were those for the case when all data depths were present. The default values were assigned to the variables in data statements, and were modified when any data depth was determined to be missing. Some of the default values used were the following: X axis length = 100 mm, Y axis length = 100 mm, grid onto which data points were placed = 16x24 (16 grids in the X direction and 24 grids in the Y direction), and number of points = 352.

Colors for the contours were also defined using variables. A default color scheme was available, but the separation between adjacent colors was not enough to allow the reds and oranges to be distinguished once the plot was filmed. There are 256 colors available concurrently in UNIRAS, so plenty of shades were available to choose from. Percentages of cyan, magenta, and yellow were chosen to define each color, and then the colors were assigned to the given contour levels. The printer had to be used instead of the terminal for the color testing because it could print the defined colors, and the terminal could not. Each contour level in these plots represents a factor of 3 change in the value of z. The color assigned to the lowest level is very dark blue and is used for values less than 0.00316 (erg/gm)/cph. The color assigned to the highest level, for values greater than 31.6 (erg/gm)/cph is bright yellow. The green-red boundary occurs at 0.316 (erg/gm)/cph.

B) Treatment Of Missing Values

In cases of one or more sporadically missing data depths, part of the plot representing the missing data had to be blanked out. The program could find which data depths were missing by checking for 99.9999's in the Z values, or by interactive input of availability of data at Y meters. Once the missing depths were established, the default values were changed to modify the plot size accordingly.

If the contouring routine was called over the whole area, including the 99.9999's indicating missing data, artificial, steep contour gradients were created as a result of the 99's being adjacent to real data values of a much lower magnitude. To avoid this problem, the contouring routine was only used on areas of real data. When there was a data depth missing, the Y length of the plot was reduced so that it agreed exactly with the extent of data coverage. Effectively, one or two subplots with depth ranges of less than the default 15-4000 m (eg., 100-4000 m) were made within the axes designed to contain all data depths. Since the smaller plot(s) could not entirely fill the area, the missing data were represented by the band of white paper with no printing on it left inside the axes.

If the surface depths were missing sequentially, (15 meters; 15 and 25 meters; 15, 25, and 75 meters; or 15, 25, 75 and 100 meters) the only parameters that needed modification were the axis lengths, upper limits, and number of grid units. For instance, if data from 15 and 25 meters were missing, the next available data depth was 75 meters, so the plot was drawn using 75 meters as Y maximum instead of 15 meters, and the Y length and number of grids in the Y direction were decreased proportionally.

When data were missing from a depth between two depths with data, the situation was a little more complicated. The two areas of existing data had to be treated completely separately, as two subplots. When no 25 m data were available, a subplot showing the 15 meter data band had to be made, as well as a subplot showing the 75 to 4000 meter data. Therefore, when missing data depths existed, in most cases the whole area between adjacent depths with data was blanked out. When a subplot with just 15 m data had to be made, a width of 15-18 m was chosen to allow this data to be visible (a line representing the 15 m data would be useless). This slight expansion of depth coverage was also used when 75 m was missing, the lower boundary of the top subplot was at 30 m not 25 m. The procedure for making subplots was essentially the same as for making one plot, except both the minimum and the maximum values of Y had to be changed, and two subplots were made to fit within the axes each time, instead of one. Figures 4a and b compare the parameters needed to make a plot with all depths present and the parameters that are needed when a data depth is missing from the middle of the plot.

C) Axis Drawing

UNIRAS has several automatic axis drawing and labeling routines, but none worked in this application having two logarithmic axes. The axes of the plots therefore were created using simple vector drawing routines. The axes were the same for all plots generated for the videotape, and served to frame the plots and subplots.

Use of the vectors entailed doing the calculations to determine where to put the tick marks. Linear interpolation was the method used to determine the tick positions on the axes. The total length of an axis (in mm) was known, as was the range of values it represented (-3.6021 to -1.1761 for the Y axis, depth), and the desired value of each tick mark. For example, to determine where to put the 1000 m tick on a 100 mm Y axis going from 15 to 4000 m (-1.761 to -3.6021), this equation could be used:

$$\left[\frac{(-3.6021) - \left(-\log_{10}(1000)\right)}{(-3.6021) - (-1.1761)}\right]100 = 24.79 \text{ mm.}$$

So the 1000 m tick mark would be placed 24.79 mm above the plot origin.

For the X axis (frequency), the standard log scale intervals were chosen: .02, .05, .1, .2, .5, 1.0 and 2.0 cph. The corresponding period of each was calculated and log transformed (remember, the data were in terms of period not frequency), then linear interpolations were done as described above to determine the tick positions on the X axis.

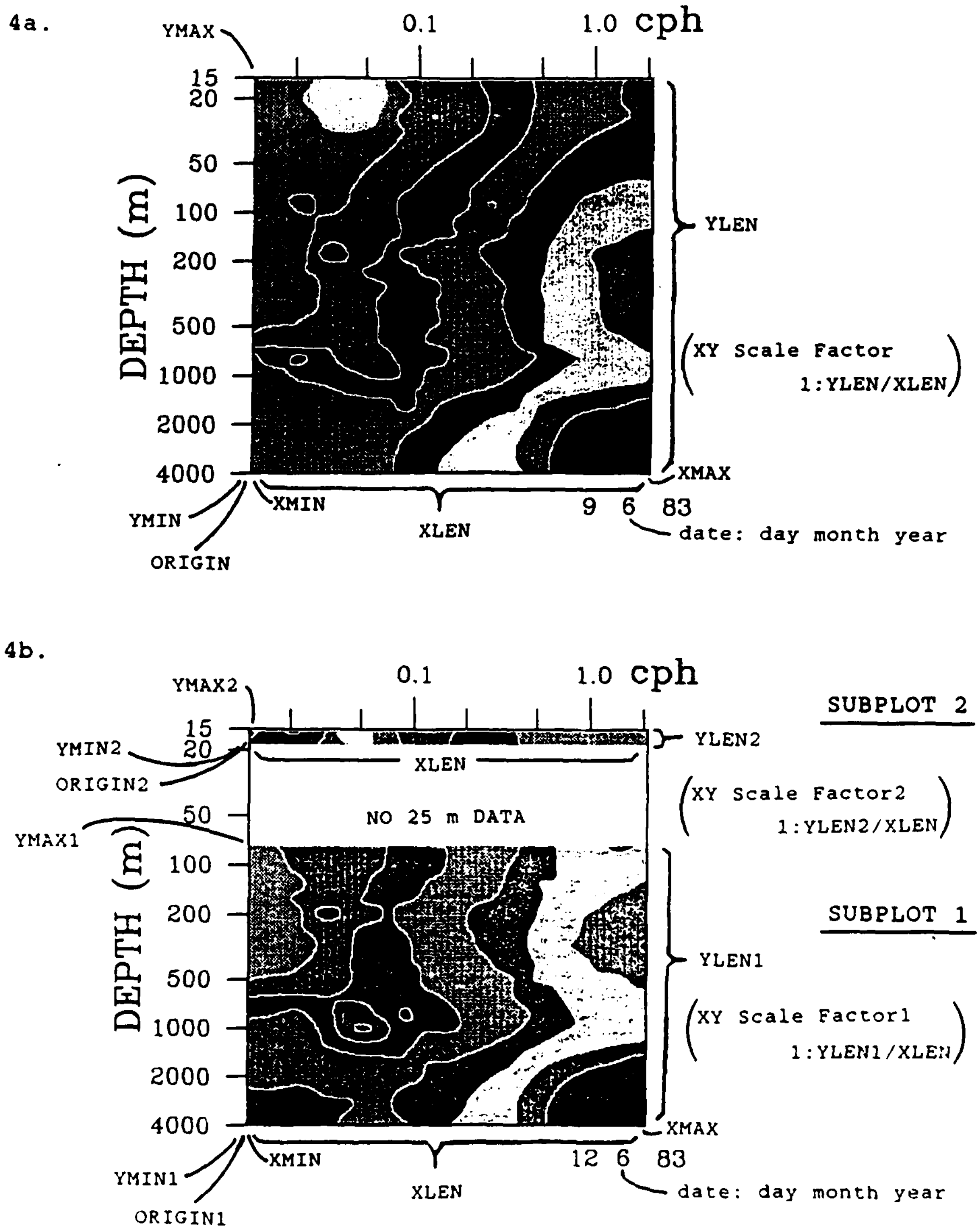


Figure 4. Examples showing the parameters needed to make a plot (a) when all depths are present, and (b) when 25 m data are missing.

When all the desired tick mark locations had been calculated, the values were put into the vector-drawing routines, and the axes drawn. The text used for labels was entered, and positioned using the tick mark locations as reference.

D) Reading Data

As long as the format of the data arrays agreed with the format read by the UNIRAS program, no problems were encountered. Some care was taken to insure that the data were actually put were expected, but otherwise, this process was quite simple. The only complication occurred when doing two subplots for the case of data missing from an intermediate depth; the array counters had to be reset when the second part of the data was read.

E) Data Interpolation and Contouring

The input data arrays were two-dimensional (11x32) and were irregularly spaced due to the $\log_{10}$ transformations. For the UNIRAS contouring routine to work, the data had to be evenly spaced so that a regular matrix could be formed. The simplest UNIRAS interpolation routine, GINTP1, was used to create regular data arrays from the irregularly spaced data. GINTP1 used a combination of linear, quadratic, and distance weighting methods of interpolation. No additional smoothing was done during the interpolation process.

The contouring routine, GCONR2, used a regular matrix, of size X grid, Y grid (see Parameter Setting), to fit a smooth surface to the points. To do this, it averaged the values in each box created by the grid lines, and used the values of adjacent grid boxes to calculate the values for empty boxes. A more detailed explanation of how GINTP1 and GCONR2 work can be found in the UNIRAS Geopac Interpolation Users' Guide (European Software Contractors).

The interpolation and contouring subroutines used to create the plots were both changed in the new version of UNIRAS. GCONR2 was replaced by GCONR2S, and the new Geopac Interpolation manual is called the GEOINT manual. The changes made improve the quality of the contour plot, but do not alter the basic shapes drastically.

An example of the basic plot resolution is shown in Figures 5a, b, c and d. Figure 5a shows a segment of a regularly spaced data array. All the points had the same value, except one point near the left side was 3 times greater than the rest, which for this example corresponded to 8 color contour levels. The effect of contouring using an even number of grids in the X and Y directions (20x20) is shown in Figure 5b. The symmetric nature of contouring over equal X and Y grids is obvious, especially compared to Figure 5c, which shows the same data contoured using the 16x24 matrix actually used for the videotape plots. Figure 5d shows the same data treatment as Figure 5b, but was created using the new version of UNIRAS. This is obviously a better contouring routine, but it was not available when the videotape was made.

In all cases, the effect of one point different from the surrounding ones was fairly large. If the number of grids in each direction was doubled, the size of the area affected by the "odd" point would be smaller, but there would also be more "empty" grid boxes between points, which with irregular data is undesirable. In choosing grid size, a balance had to be achieved between high resolution, with many grid boxes, most of which were empty, and lower resolution, with fewer empty grid boxes.

The irregularly spaced input data points for the two year average plot, represented by dots of the appropriate color class for their magnitude, and the regular grid over which they were contoured (16x24), are shown in Figure 6. The X and Y arrays of the input data points were the same in all plots, and only the magnitude of Z varied, except in cases where a nearby data depth was substituted for the original, then the Y arrays were also different. The logarithmic distribution is obvious in this presentation. Figure 6 also shows how the logarithmic scale allowed depth coverage to be fairly complete for this data, and how the 16x24 grid matrix fits the data, as described in the previous paragraph. The depth distribution of data would have been better if there were enough data at 50 and 2500 meters to use.

An intermediate stage of the process that was not plotted for the videotape, but that shows how the individual spectra become contoured, is presented in Figure 7. The darkened lines represent the depths at which spec-

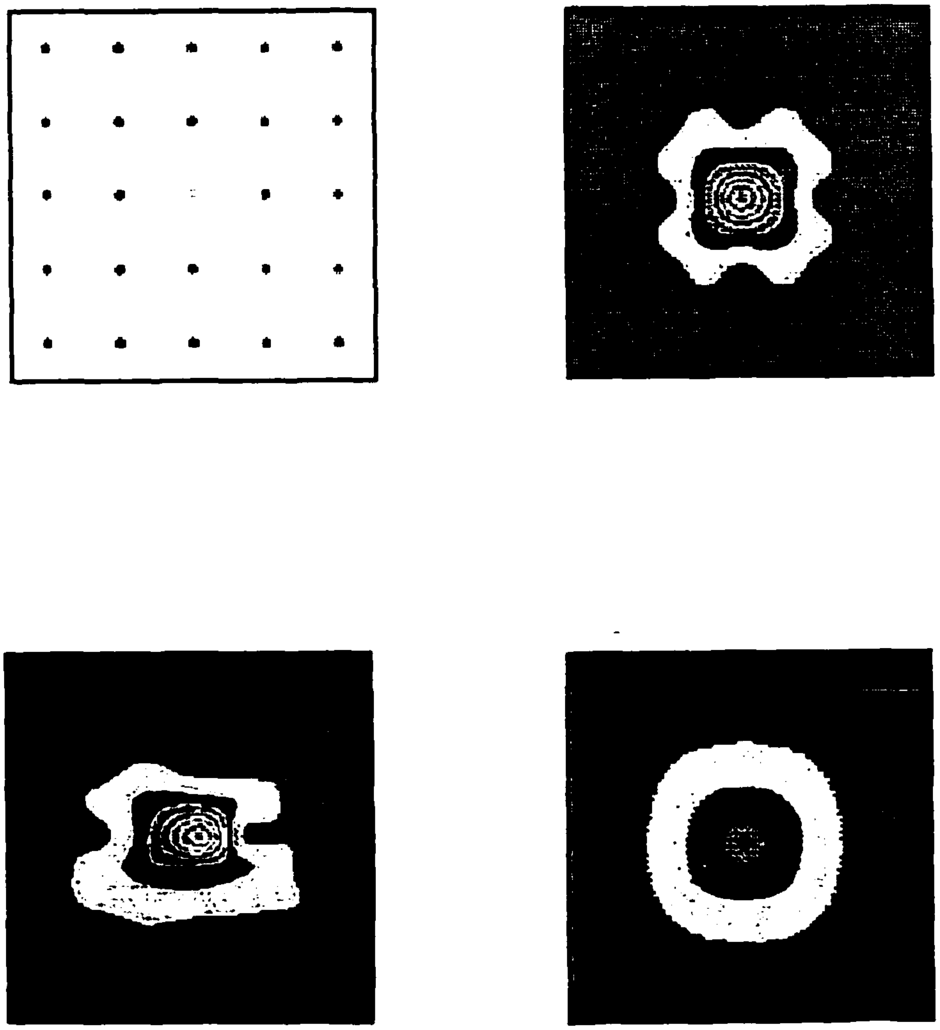


Figure 5a. Dot plot showing regularly spaced data points to be contoured.
b. The points in Figure 5a, contoured using GCONR2, with a 20x20 grid (even X and Y values).
c. The points in Figure 5a, contoured using GCONR2, with the 16x24 grid used in the plots for the videotape.
d. The points in Figure 5a, contoured using the new version of GCONR2S with a 20x20 grid.

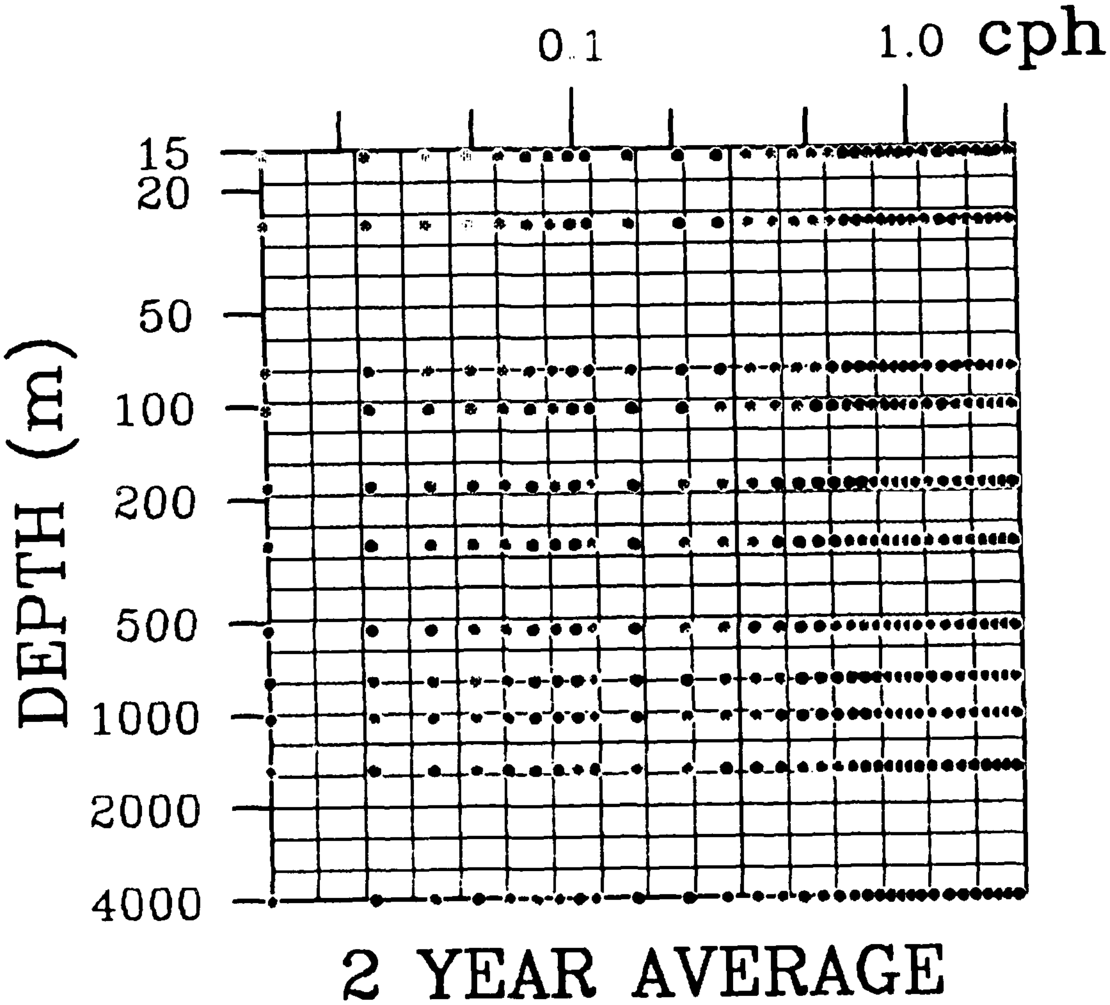


Figure 6. Input data points (for 2-year average) with color representing the magnitude of Z and the grid onto which they were interpolated.

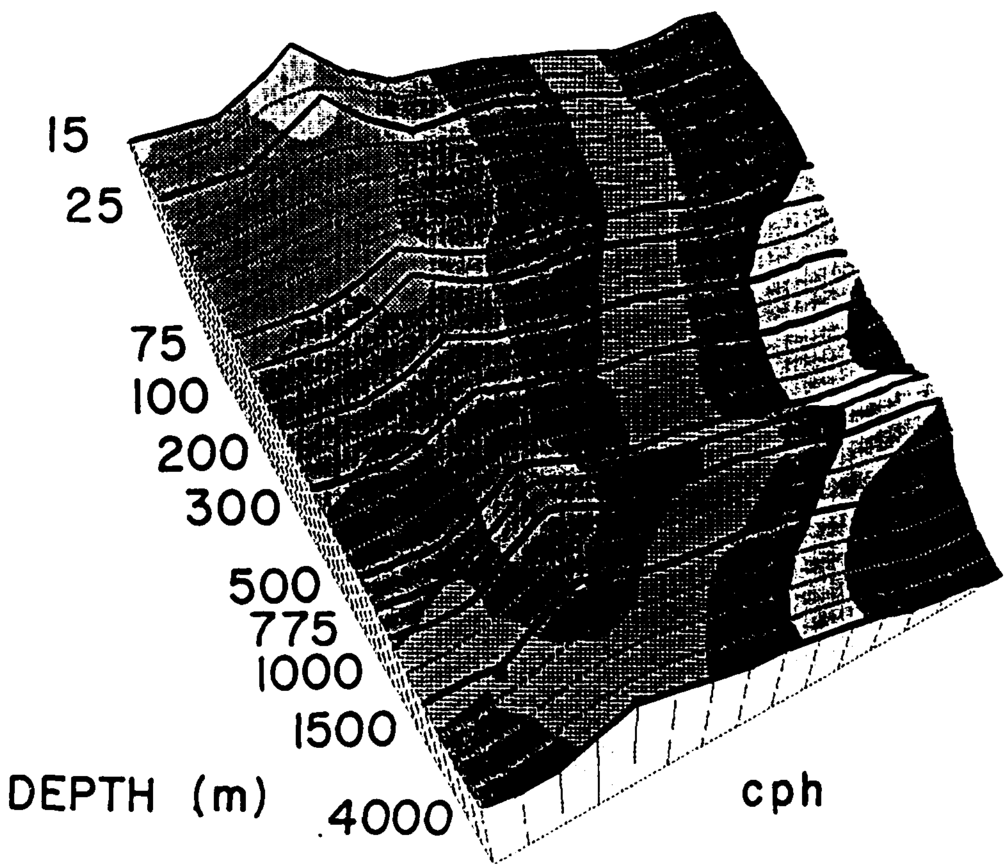


Figure 7. Contoured surface plot, showing how spectra from each of the 11 data depths were oriented with respect to the rest of the plot.

tra were calculated. The amplitudes of the spectra are shown, with colors used to represent the defined contour levels. The last step in creating a two-dimensional color contour plot was mapping the surface plot (Figure 7) onto a base page. The final result used in the videotape is shown in Figure 8. The data represented here are the two year averaged spectra from each of the standard 11 depths, after interpolation, contouring, and axis tick and label addition.

VIDEOTAPING

The process of videotaping was commenced when hardcopies of the 206 plots were completed. The master copy was made on 3/4 inch videotape, using the studio and equipment available at WHOI. The camera was fixed looking downward with the lens parallel to a horizontal surface on which the plots were placed, and not moved until the whole process was completed. Three flood lights were placed around the surface to light the plots.

The rate of 4 plots per second displayed on a videotape seemed to be approximately the rate that would allow the viewer to just differentiate between the plots, while seeing primarily the flow of one plot to the next. The videotape apparatus works at 30 frames per second, so an initial test was done filming each plot for 7 frames. A series of 15 plots was filmed for this test, to check the actual appearance of a videotape shot at this speed. Getting the speed right was important because it was not a trivial thing to change the speed of a completed videotape with the equipment at WHOI. The rate of 7 frames per plot looked fine in the test, so that speed was used for the rest of the filming. After seeing the completed videotape, 7 frames per plot seemed a little too fast, so a slightly slower speed would have been preferable to use (10-12 frames per plot).

The first plot was centered in the videotape frame, and a non-reflective glass sheet was placed over it to decrease glare from the lights. This plot was filmed and stored in system memory, then projected onto a color monitor and used as a reference for registration of subsequent plots. Using the mixer and the monitor, the plot with the next start time was placed

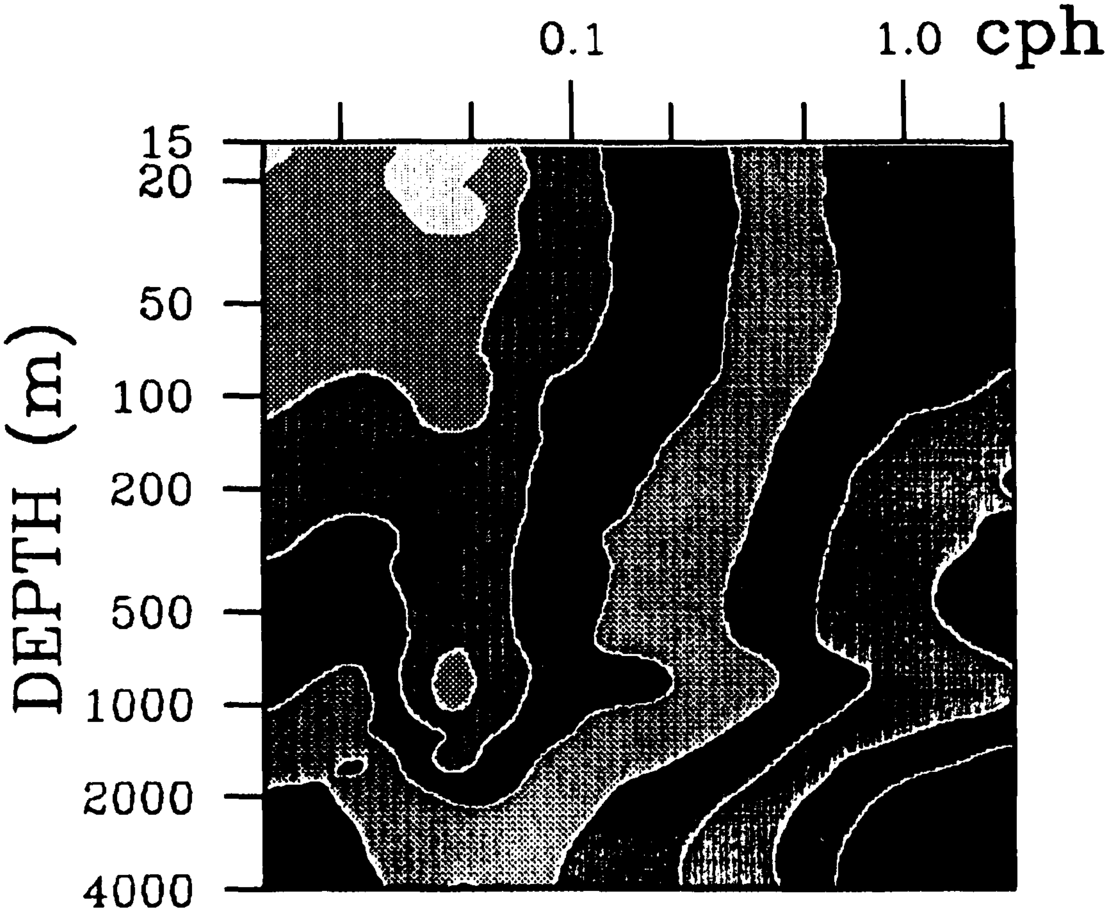


Figure 8. Color contour plot showing horizontal kinetic energy spectral density averaged over two years, versus depth. Each contour level corresponds to a factor of three in energy; the green-red boundary occurs at 0.316 (erg/gm)/cph.

under the glass sheet and positioned to exactly overlay the original plot. After it was positioned, the second plot was filmed, and then the next plot was positioned and filmed, and so on until all the plots were on videotape.

It took two days to film the 206 plots. Much of the second morning was taken trying to exactly match the shade of white that was the previous day's background color. The colors recorded on the videotape shifted over time, so optimally all filming should be done in one session, unless very advanced videotape equipment is available.

The title pages were edited into the beginning of the videotape after the complete time series was filmed. Adding to either end of the videotape was much easier than replacing a missed or bad plot in the middle. The editing apparatus used for this project was not good at inserting frames at exact locations. Fortunately, new editing equipment has been obtained, so many of the problems encountered during this project should not occur in the future.

An audio track, with the months read aloud to denote the passage of time, was added to the videotape last. The source was changed from camera to microphone, and as the videotape was displayed on a monitor, the months were recited into the microphone.

SUMMARY

A videotape was made of current meter data collected during LOTUS. 206 color contour plots generated by PROSPECT and UNIRAS were filmed sequentially to show the variation of kinetic energy spectra over depth and time.

The processing began with examination of the data set to choose the best instruments to present the most complete data. Eleven depths were used to represent the entire water column. Start times 3 days 13 hours 30 minutes apart were calculated for the time between May 1982 and May 1984, when LOTUS data were available. Spectra were then computed for each start time, over a 7 day 3 hour period, for each of the data depths available for that time. The 11 A*.DAT files were used to create one EN*AR.DAT file for each time period, which was used as input to the UNIRAS plotting program. Color contour plots were made for each time period using UNIRAS Geopac software, and plotted using a Tektronix 4695. When all the hardcopies were completed, each one was filmed in temporal order, for 7 frames. After the time series was filmed, the videotape was edited to add the voice track and the title frames. With all this completed, the videotape was ready to present. It was first shown by Melbourne G. Briscoe at the Ocean Sciences meeting of the American Geophysical Union in New Orleans, on 16 January 1986.

If this project were to be done again, the following changes in this procedure should be considered:

(a) use as much data as are available even though the construction of the EN*AR.DAT files would be much more complicated;

(b) use 7 plots to get through a week, that is, overlap 7 one-week plots by one day each instead of 2 plots by half a week; this would give much more smoothness and time resolution in the final videotape but would require 700 plots instead of just 200;

(c) contour to a regular grid (e.g., 20x20 instead of 16x24);

(d) slow the display from 14/30 second per week to perhaps 20/30 - 1 second per week;

(e) use a computer system that can display color contour plots sequentially in real time, and use a video encoder. With this equipment, hard copies of the plots would be unnecessary, and filming would be much easier.

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APPENDIX: LOTUS-related WHOI Technical Reports

Title	WHOI No.	Date
Long-Term Upper Ocean Study (LOTUS): A Summary of the Historical Data and Engineering Test Data.	82-53	Dec 82
The Long-Term Upper Ocean Study (LOTUS) Cruise Summary and Hydrographic Data Report, OCEANUS 119 - May 1982.	83-7	Feb 83
The Long-Term Upper Ocean Study (LOTUS) Cruise Summary and Hydrographic Data Report, OCEANUS 129, Oct 1982.	83-29	Aug 83
Long-Term Upper Ocean Study (LOTUS) at 34°N, 70°W Meteorological Sensors, Data, and Heat Fluxes for May-October 1982 (LOTUS-3 and LOTUS-4).	83-32	Sept 83
The Long-Term Upper Ocean Study (LOTUS) Cruise Summary and Hydrographic Data Report, ENDEAVOR 97, April 1983.	83-33	Oct 83
The Long-Term Upper Ocean Study (LOTUS): Cruise Summary and Hydrographic Data Report, OCEANUS 141, November 1983, and OCEANUS 145, January 1984.	84-26	June 84
Compilation of Moored Current Meter and Wind Recorder Data, Volume XXXV, Long-Term Upper Ocean Study (LOTUS) (Moorings 764, 765, 766, 767, 770) May 1982-April 1983.	84-36	Aug 84
The Long-Term Upper Ocean Study (LOTUS): Cruise Summary and Hydrographic Data Report, OCEANUS 154, May 1984.	84-39	Sept 84
Compilation of Moored Current Meter and Wind Recorder Data, Volume XXXVIII, Long-Term Upper Ocean Study (LOTUS) (Moorings 787, 788, 789, 790, 792) April 1983-May 1984.	85-39	Dec 85
Data Tabulations and Analysis of Diurnal Sea Surface Variability Observed at LOTUS.	86-5	Feb 86

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16. Abstract (Limit: 200 words)

In order to show efficiently the large amount of data obtained during the Long Term Upper Ocean Study (LOTUS), a new method of data presentation was developed. Three data variables can be included in a simple color contour plot, but if successive color contour plots are recorded on videotape, a fourth variable, time, can also be shown.

This report documents the process of making a videotape presenting scientific data in this way, from raw data to finished videotape. The videotape shows internal wave kinetic energy versus frequency and depth; the time variation of the videotape displays real time variation in the ratio of 14/30 second to one week, or about 1 month of data very 2 seconds.

17. Document Analysis a. Descriptors

1. LOTUS
2. moored instruments

b. Identifiers/Open-Ended Terms

1. scientific videotapes
2. dynamic data presentation

c. COSATI Field/Group

18. Availability Statement:	19. Security Class (This Report)	21. No. of Pages
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