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OBSERVATIONS OF TEMPERATURE, SALINITY AND SOUND VELOCITY MICROSTRUCTURE ON THE UK CONTINENTAL SHELF

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INTRODUCTION

Over the past two decades, a considerable amount of effort by a number of researchers (eg [1,2]) has been devoted to the measurement of the random temperature structure of the oceans. Except for special cases [3] however, such measurements have generally been carried out in the open ocean. The observations to be described here were made as part of a continuing programme of studies to investigate the effects of fluctuations on sonar performance at high frequencies in shallow continental shelf waters.

Surveys, comprising vertical profiles of temperature, salinity, sound speed and current velocity and horizontal profiles of temperature, salinity and sound speed, were conducted in three cruises during the summer of 1986. The locations, all on the continental shelf, were the area 5 - 40km south-east of Portland (April 28th - May 1st), the Firth of Clyde and some adjacent lochs (June 29th - July 15th) and the general area of the Channel Islands and the Hurd Deep (August 18th - 29th). The positions of all survey sites are shown in Fig.1. Those discussed in this paper are circled and their locations given in Table 1.

Table 1. Locations of survey sites.

SITE	LATITUDE	LONGITUDE	WATER DEPTH
PORTLAND 1	50°17.9'N	2°13.2'W	53m
CLYDE 1	55°57.6'N	4°53.2'W	43m
CHANNEL 1	49°17.7'N	2°33.7'W	57m
CHANNEL 2	49°37.6'N	3°19.2'W	67m

It should be borne in mind through the following discussion of the results that each survey represents a specific place at a particular time. The Portland cruise was essentially an equipment handling and proving trial, and the survey sites were chosen arbitrarily. The Clyde cruise was characterised by unusually calm weather with winds rarely exceeding 10 - 15 knots and sea-states generally 1 - 2. The Channel Islands cruise started with 15 - 20 knot winds and a large westerly swell building up during the first week. Work was stopped by a violent storm (Hurricane Charlie) August 26th - 27th and this was followed by continuous 25 knot winds and sea-state 5.

There has not yet been time for detailed analysis of the data, and this paper presents preliminary results. Examples of typical vertical and horizontal profiles are given.

INSTRUMENTATION

The data were collected using an environmental measurement system consisting principally of:

i) Vertical profiling underwater unit (Fig. 2), carrying sensors as detailed

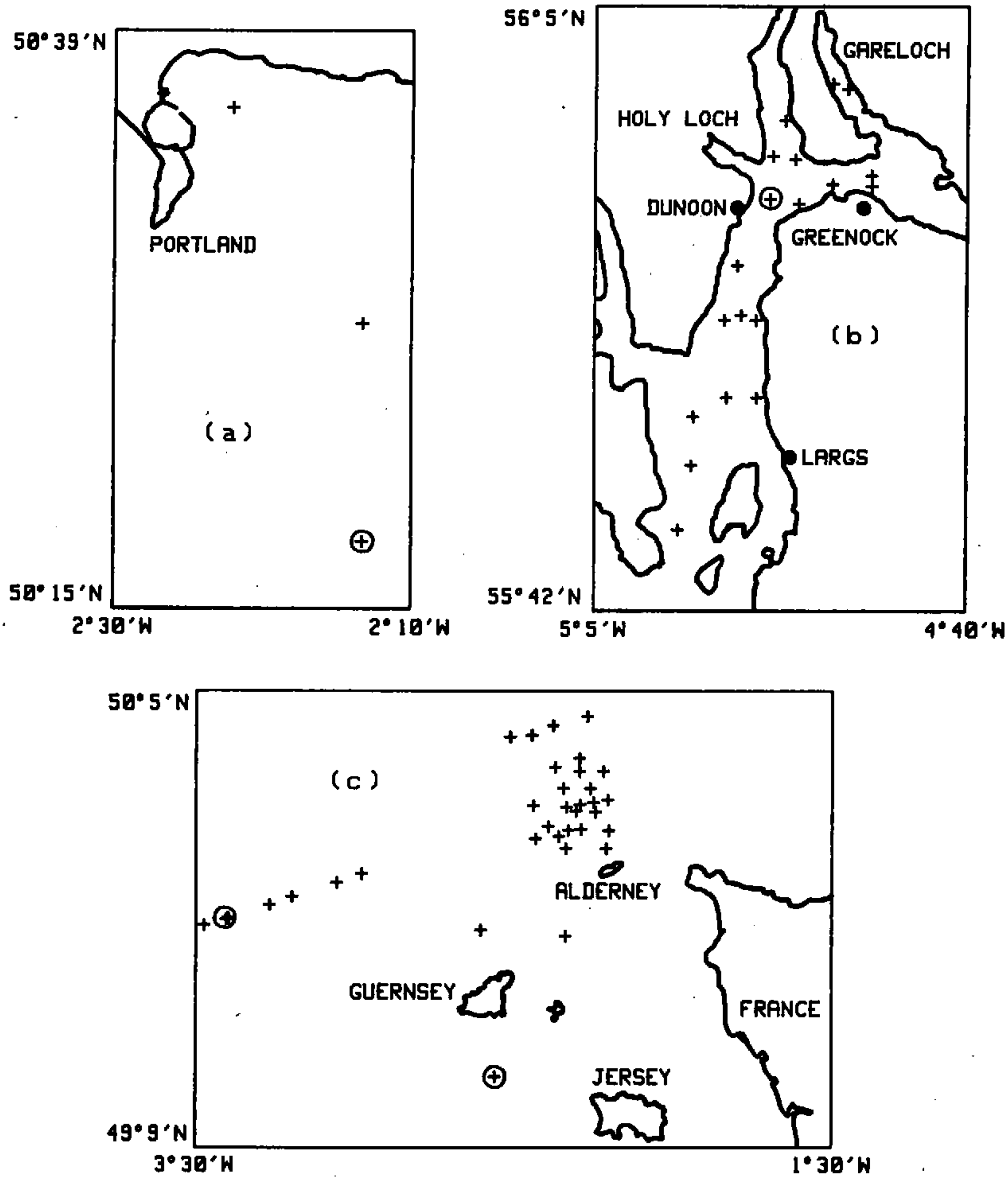

Fig. 1 Locations of the sites surveyed during (a) the Portland cruise, (b) the Clyde cruise and (c) the Channel Islands cruise. Survey sites discussed in the text are circled.

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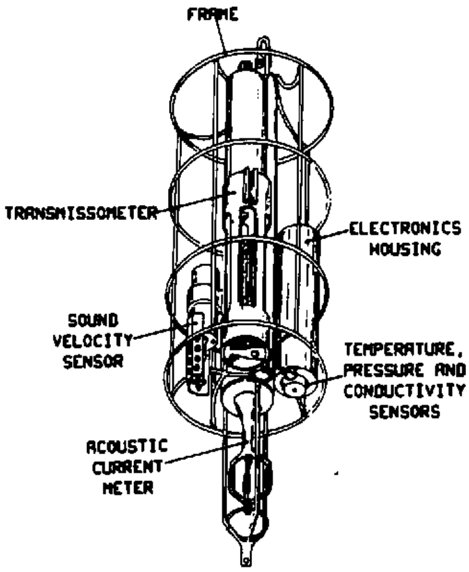

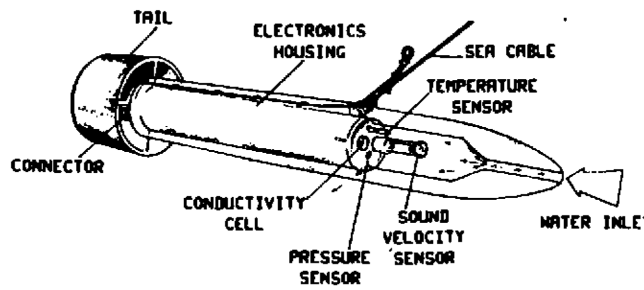

Fig. 3 Sketch of Tow Fish

Fig. 2 Sketch of Vertical Profiler

in Table 2. The various sea water parameters were measured concurrently and electronics within the underwater unit were provided to condition the raw data and encode them for transmission to the deck unit.

ii) Horizontal profiling Tow Fish (Fig. 3), carrying sensors as in Table 2, and data conditioning/encoding electronics as in the vertical profiler.

iii) A deck unit which was used to supply power to the underwater units and decode the data for passing to the computer via an RS232 interface.

iv) On board computer (Hewlett Packard 9826), which was used to store and subsequently display the data. Additionally, the software calculated values of depth, salinity and sound velocity from the measured data and monitored the health of the underwater units.

The data were recorded on disc as each sample was taken, and the time taken for these transfers limited the sampling rate to 2 Hz. The system is currently being modified to increase the sampling rate, but with the existing set-up the best spatial resolution is 0.05m for vertical profiles and 0.5m (relative to the water) for horizontal profiles, at a tow speed of 2 knots.

SURVEY PROCEDURE

Surveys were generally conducted as follows:

A series of 5 vertical profiles were taken at 125m intervals along a straight line. Plots of the temperature and current profiles were then examined to identify the depths with a high level of microstructure and the depths of interfaces between strata. The horizontal profiler was then towed along the line at each of these depths. If it was suspected that the large scale structure of the area was anisotropic horizontally, the procedure would be repeated along a line orthogonal to the first.

Table 2. Summary of sensor specifications.

PARAMETER	PROFILER	TOW FISH
Depth:		
Range	0 to 300m	0 to 200m
Accuracy	±0.5% fsd	±0.5% fsd
Resolution	10cm	10cm
Temperature:		
Range	0 to 30°C	0 to 30°C
Accuracy	±0.05°C	±0.1°C
Resolution		0.01°C
Salinity (Calculated from conductivity):		
Range	5 to 35 ppt	5 to 35 ppt
Accuracy	±0.02 ppt	±0.02 ppt
Optical Transmission Coefficient:		
Range	0 to 90% attenuation	N/A
Accuracy	±5% fsd	N/A
Sound Velocity:		
Range	1400 to 1600 ms^{-1}	1400 to 1600 ms^{-1}
Accuracy	±0.5%	±0.5%
Water Current Magnitude:		
Range	0 to 2.5 ms^{-1}	N/A
Accuracy	±5%	N/A
Water Current Direction:		
Range	0 to 360°	N/A
Accuracy	±2.5°	N/A

Depending upon the wind and sea state, the series of 5 vertical profiles took between 2 and 3 hours and the horizontal tows took 15 to 20 minutes each. A survey could thus be comfortably completed between changes of tidal direction.

EXAMPLE RESULTS

Portland

Fig. 4 shows typical vertical profiles of temperature (solid line) and salinity (dashed line) from the Portland 1 site. A distinct surface layer is visible, with some stratification down to about 20 metres. The water is well mixed below this depth. This profile was taken at 1500 hours, and at this location no surface layer was present at the start of the day, but developed during the morning. Microstructure on a sub-metre scale is seen in both profiles, albeit of low amplitude.

Sound speed calculated from temperature and salinity is shown as the solid line in Fig. 5, and the measured sound speed, with a slight offset for clarity, is

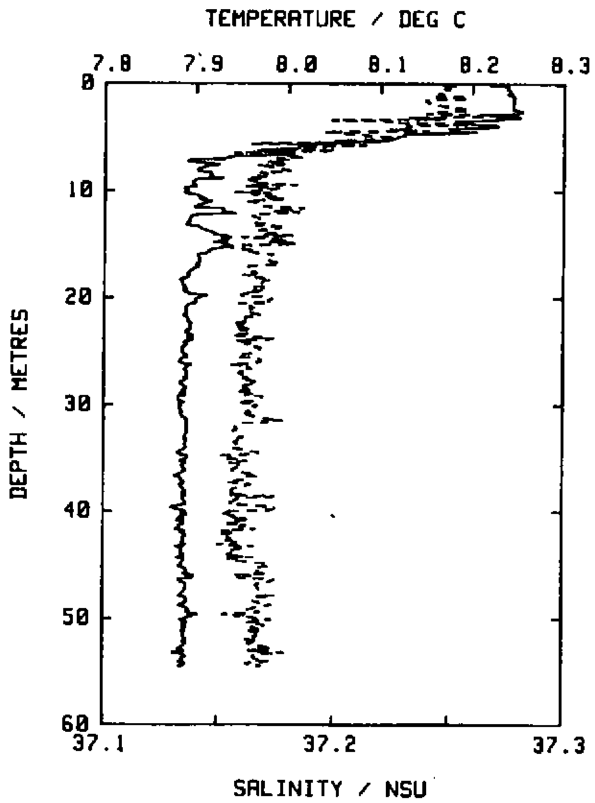

Fig. 4 Temperature (solid line) and salinity (dashed line) vertical profiles at Portland 1 site.

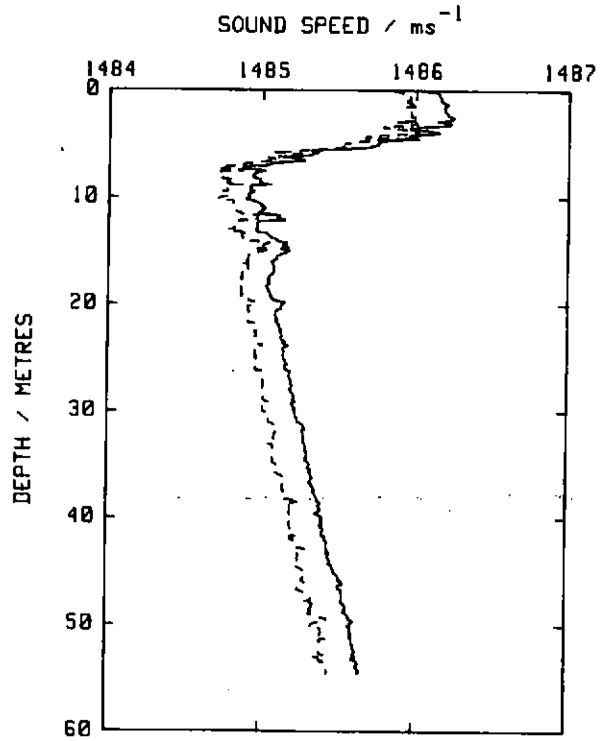

Fig. 5 Calculated (solid line) and measured (dashed line) sound speed vertical profiles at Portland 1 site.

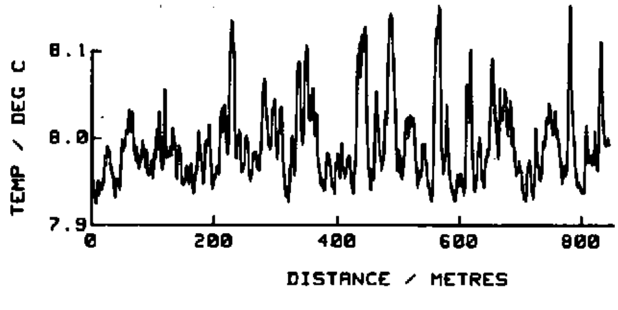

Fig. 6 Horizontal temperature profile, depth 15m, at Portland 1 site, plotted against distance travelled over sea bed by tow fish.

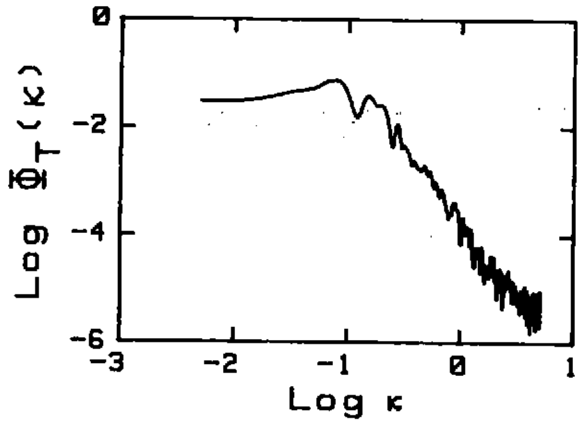

Fig. 7 Wavenumber power spectrum computed from the temperature series of Fig. 6.

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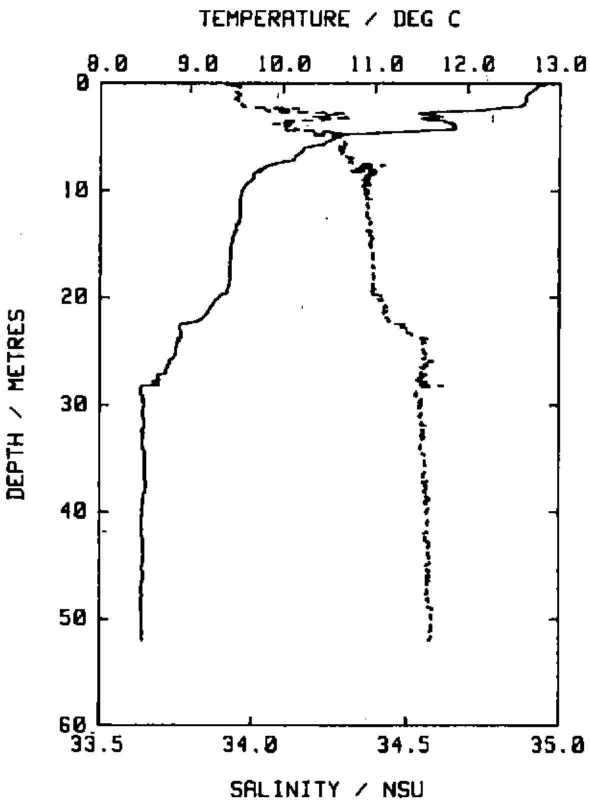

Fig. 8 Temperature (solid line) and salinity (dashed line) vertical profiles at Clyde 1 site.

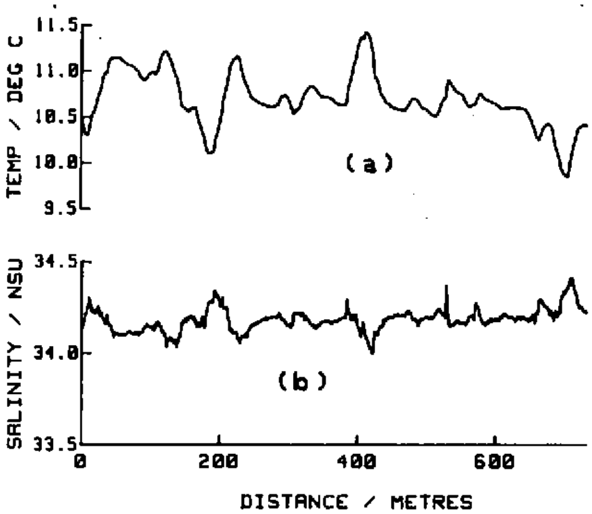

Fig. 9 Horizontal profiles of (a) temperature and (b) salinity, depth 10m, at Clyde 1 site, plotted against distance over sea bed.

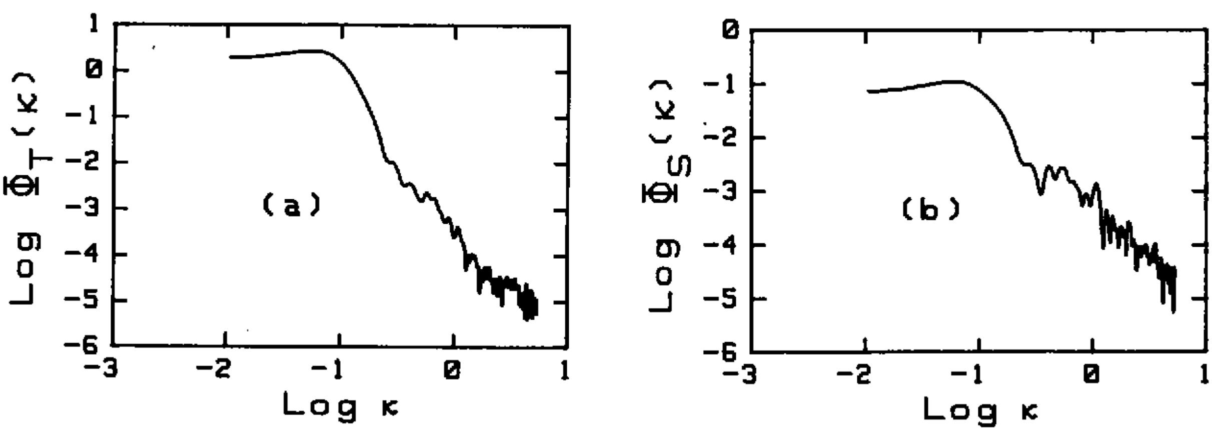

Fig. 10 Wavenumber power spectra computed from the (a) temperature and (b) salinity series of Fig. 9.

shown as the dashed line. Both profiles are similar in their large scale form, but do not agree in the fine scale details. This is probably due to the sound speed sensor being separated horizontally by about 50cm from the temperature and conductivity probes.

A horizontal profile at a depth of 15m is shown in Fig. 6. This shows fluctuations with a range of scale sizes and an rms value of 0.05°C. The power spectrum, computed from this temperature data after compensating for variations in fish depth and removing any linear trend, is shown in Fig. 7, plotted against spatial wavenumber (2π/distance) on log-log axes. Following a short level portion, the spectrum falls more or less linearly with increasing wavenumber, with a slope initially about -3 then reducing to approximately -1.8. For isotropic homogeneous turbulence a slope of -5/3 (-1.67) is expected [4].

Clyde

Fig. 8 shows typical vertical profiles of temperature (solid line) and salinity (dashed line) from the Clyde 1 site. Again, a distinct surface layer is visible, and in this case stratification extends down to 30m. The temperature range is much greater than at the Portland site and here the salinity profile is a mirror image of the temperature, rather than being of similar form as at Portland. Very little microstructure is seen in these profiles.

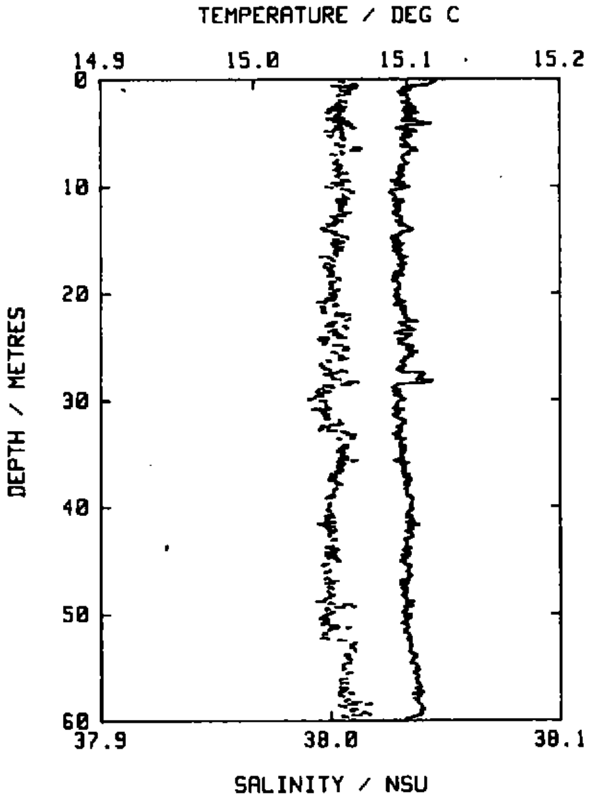

Fig. 11 Temperature (solid line) and salinity (dashed line) vertical profiles at Channel 1 site.

Horizontal profiles, at a depth of 10m, of temperature and salinity are shown in Figs. 9(a) and 9(b) respectively. These show temperature fluctuations with a negligible fine-scale component and an rms value of 0.3°C, and salinity fluctuations with a degree of negative correlation with the temperature, but having a stronger fine-scale component and an rms value of 0.06 ppt. The temperature and salinity spectra, Figs. 10(a) and 10(b) respectively, are similar in form to those from Portland, but here both have a steep initial fall, slope about -5, followed by slopes of -2.9 for temperature and -1.9 for salinity.

Channel Islands

Fig. 11 shows typical vertical profiles of temperature (solid line) and salinity (dashed line) from the Channel 1 site before the passage of Hurricane Charlie. The water column appears to be completely mixed and although fine-scale fluctuations are visible, their amplitude is very small. Horizontal profiles taken at the same time are similar in character.

Fig. 12 shows typical vertical profiles of temperature (solid line) and

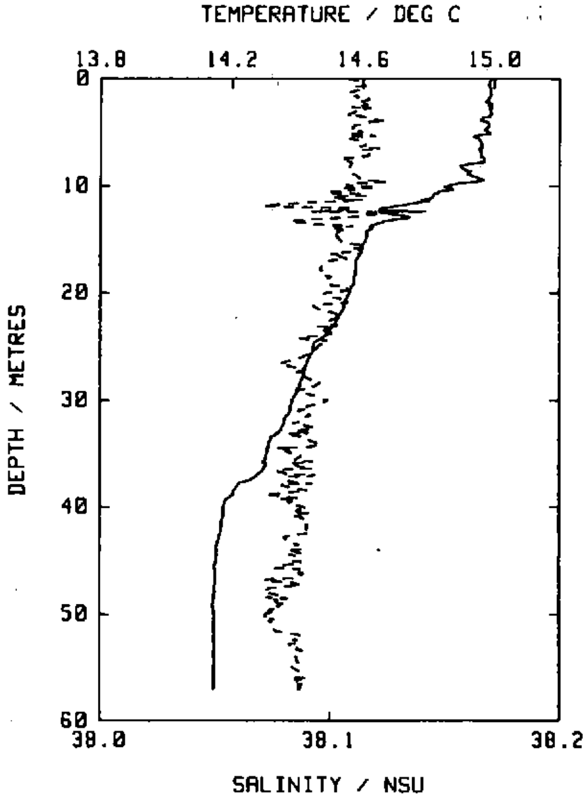

Fig. 12 Temperature (solid line) and salinity (dashed line) vertical profiles at Channel 2 site.

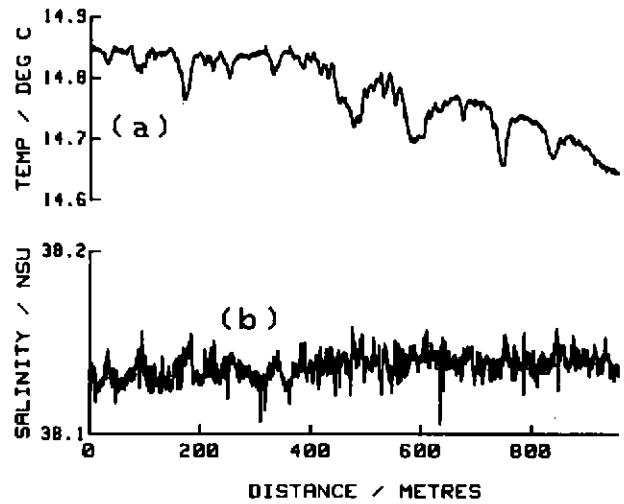

Fig. 13 Horizontal profiles of (a) temperature and (b) salinity, depth 10m, at Channel 2 site, plotted against distance over sea bed.

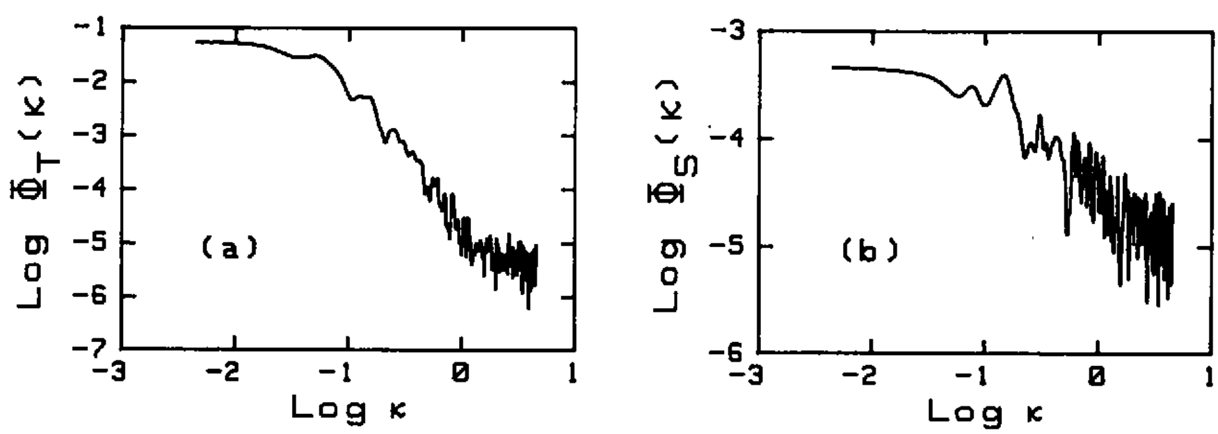

Fig. 14 Wavenumber power spectra computed from the (a) temperature and (b) salinity series of Fig. 13.

salinity (dashed line) from the Channel 2 site shortly after the passage of Hurricane Charlie. The temperature profile shows a 10m deep mixed surface layer, with stratification down to 40m, but there is little large scale structure in the salinity profile. Fine-scale structure is visible near the surface in the temperature plot and throughout the salinity profile, with a layer of stronger activity between 10 and 15 metres.

Horizontal profiles, at a depth of 10m, are shown in Figs. 13(a) and 13(b) for temperature and salinity respectively. The temperature record is similar in nature to that from Clyde 1, but contains a slightly stronger fine-scale component and has an rms value of only 0.07°C. The salinity profile consists entirely of fine-scale fluctuations and has an rms value of 0.007 ppt. The temperature and salinity spectra are shown in Figs. 14(a) and 14(b) respectively. Their form is again similar to the previous examples, the initial fall in the temperature plot having a slope of -3.5, followed by a much shallower slope of -1, whilst the slope of the falling region in the salinity spectrum is -1.1.

DISCUSSION

Although these examples of data from three areas on the continental shelf could hardly be more different, a few comments may be made about the generality (or lack of it) of the results. Depite the profiles for each area being described as 'typical', continental shelf waters cannot be considered stationary in terms of the time scale between profiles. Significant changes were seen from one hour to the next and over distances of only a few hundred metres, but it is not possible from these data to separate the temporal from the spatial effects. This observation, coupled with the gross differences between the profiles from the three widely separated areas, would suggest that a general model for fluctuations in shallow continental shelf waters is not feasible, at least on the range of scale sizes 10^{-1} to 10^2 metres considered here. The spectra computed from the fluctuations, however, are remarkably similar in form.

The concept that temperature fluctuations in the upper ocean could be modelled by a one dimensional wavenumber spectrum composed of a series of power law segments (giving straight lines on a log-log plot) was proposed by Medwin [5]. His spectrum consisted principally of an inertial range dominated by homogeneous isotropic turbulence (-5/3 slope) bounded at low wavenumbers by the physical restriction of the water depth and at high wavenumbers by viscous losses and diffusion. It is obvious from the present results and earlier reports (eg [6]) that, even if an inertial range exists, there is a lower wavenumber region with a slope of around -3.

Mosely and Del Balzo [7] referred to this as a buoyancy range, and suggested that the transition from a -3 power law to -5/3 occurred at a buoyancy wavenumber, κ_b, given by

$$\kappa_b = C^{3/4} N^{3/2} \varepsilon^{-1/2} \qquad (1)$$

where C is a positive constant of order unity, N is the Brunt Vaisala frequency and ε is the rate of kinetic energy dissipation.

The values of κ_b for the measurements discussed here have not yet been computed, but internal waves were observed at the Clyde 1 location with periods of around 20 minutes. Assuming that this corresponds to the Brunt Vaisala frequency and estimating the energy dissipation rate to be in the range 10^{-8} to 10^{-7} m^2s^{-3} gives values for κ_b between 1 and 5 m^{-1}, with logarithms between 0 and 0.7. Examination of Figs. 7, 10 and 14 confirms that this is consistent with the spectra shown there.

CONCLUSIONS

1. Shallow continental shelf waters are highly complex and variable and both vertical and horizontal profiles can change significantly within hours and over distances of a few hundred metres.

2. There is generally a region of strong fine-scale fluctuation associated with the surface layer and any stratification immediately below it. The lower mixed portion of the water column is relatively quiet.

3. Fluctuation spectra over the wavenumber range 0.01 to $10m^{-1}$ are similar in form and may be modelled as a sequence of power law regions represented as straight lines on a log-log plot.

4. Over these wavenumbers the spectra seem to be dominated by a buoyancy range with a -3 power law below κ_b, and by an inertial range with a -5/3 power law above.

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