Celtic Sea

Overview

The Celtic Sea is located in the North Atlantic Ocean between southern Ireland and southwest England (Figure 1). The Sea's western edge covers a continental shelf region characterized by rough and irregular edge. Both upwelling and internal wave activity have been noted along the continental shelf edge.

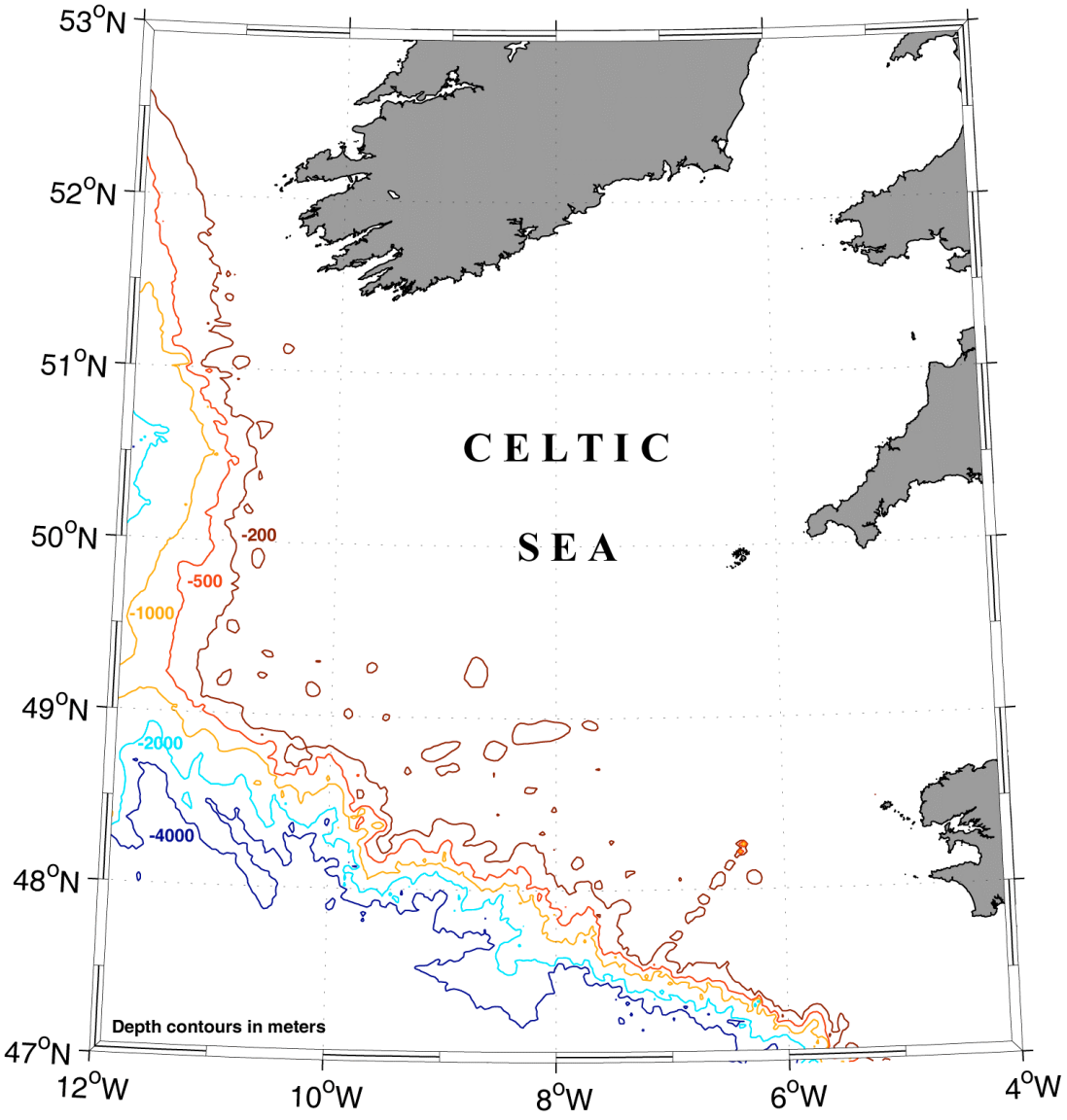


Figure 1. Bathymetry of the Celtic Sea [Smith and Sandwell, 1997]

Observations

Studies on the internal waves in the Celtic Sea have been carried out by Pingree and Mardell [1981, 1985] and Holt and Thorpe [1997]. Each report internal waves originating near the shelf break during the summer months (July to September) when a well developed thermocline is present (Table 1).

Table 1 - Months when internal waves have been observed in the Celtic Sea.
(Numbers indicate unique dates in that month when waves have been noted)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
					2	7	2	4			

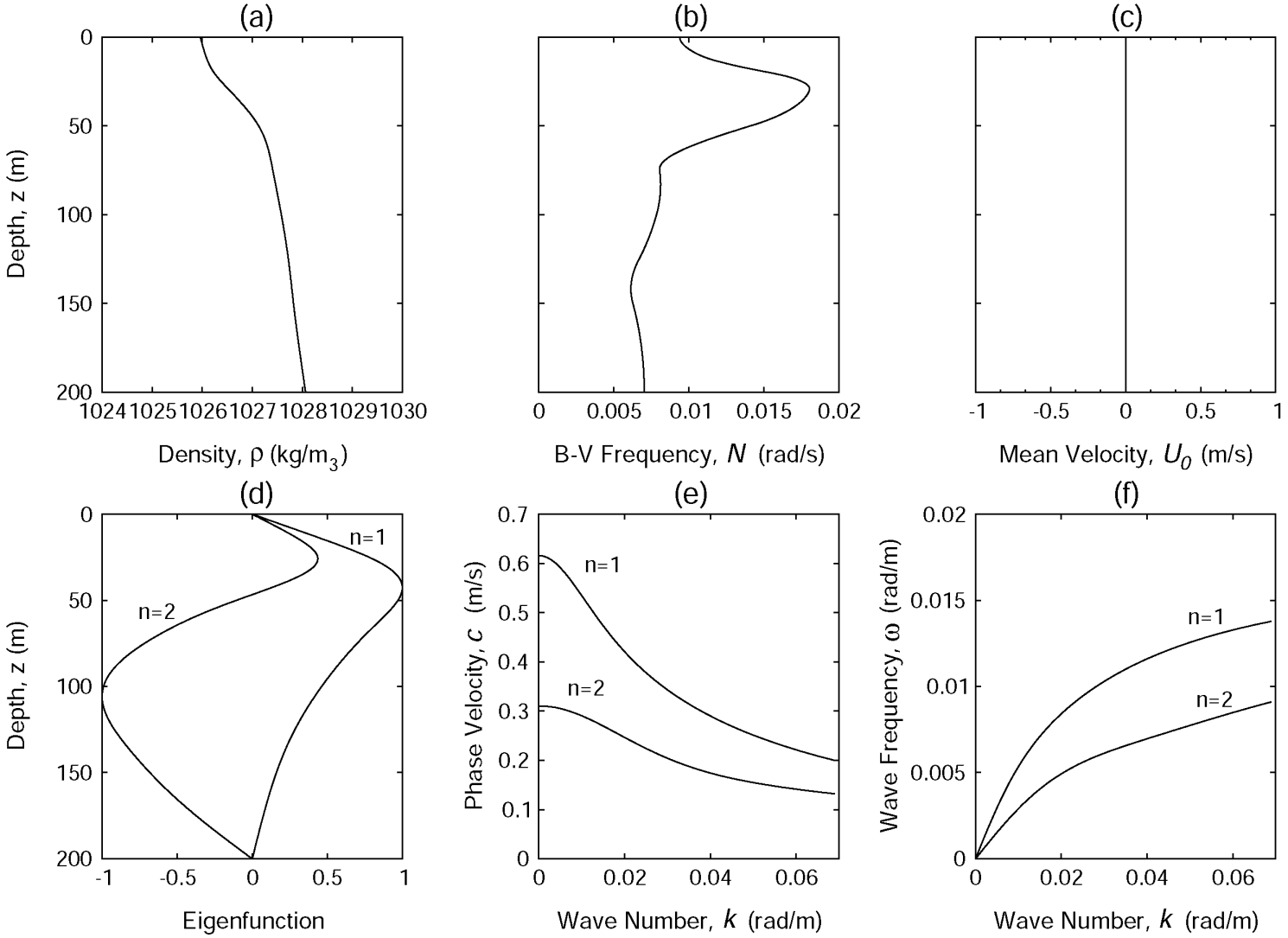
Figure 2 shows a typical density profile for the Celtic Sea derived from temperature and salinity data taken from the NODC World Ocean Atlas 1998 at 48°N, 9°W for July. The normalized Mode 1 and Mode 2 eigenfunctions have been evaluated for $\lambda = \frac{2\pi}{k_0} = 250m$, with H = 200 m. For long waves ($k \to 0$) the maximum first mode wave speed (c_0) is computed to be 0.62 m/s without the effect of current shear. Figures 2e and 2f give the phase velocity and dispersion relations for the data. The figure also presents the environmental coefficients and KDV parameters evaluated at k_0.

The Russian Almaz S-Band SAR acquired imagery over the continental shelf break on 5 July 1991 (Figure 4 [Apel 1995, Evans 1995]). Internal wave signatures are visible and extend from the lower left to the upper right hand portion of the image. The dark regions in the right hand side of the image are believed to be a cool stable area of upwelled water. Upwelling may serve to excite internal waves in areas of high bathymetric relief [Apel 1995]. Figure 3 shows the Almaz image overlaid with the local bathymetry. The internal waves appear inside the 500-m isobath with their overall pattern roughly aligned with the bathymetry.

Holt and Thorpe [1997] noted that only a fraction (20% to 30%) of the internal waves they observed had orientations consistent with across slope tidal generation (Figure 5). This is the result of a complex topography along the shelf edge producing many regions of internal wave generation. The studies sampling rate were on the order of the internal wave periods, which limited the derivation of other wave characteristics.

Pingree and Mardell [1981] report the thermocline on the shelf break of the Celtic Sea was broader in vertical extent then on either the shelf or the adjacent ocean. In this study two moorings were deployed normal to the shelf edge and separated by 13.5 km. Data collected during September 1973 (Figure 6) showed internal waves passing mooring 001 between 1-2 hours after tide started streaming on shelf and then passing mooring 002 around 3.2 hours later. The waves were propagating with an orientation of 20° to 40° to line between moorings. Taking into account a 6.5 km on shelf tidal movement, they calculate a 0.6 m/s wave speed with 30 to 40 minute periods.

Pingree and Mardell [1985] reported that internal waves in July 1983 were observed on the surface as parallel "walls of white water" separated by approximately 1 km. In situ measurements indicated wave periods of (15 min to 1 hour) with speeds of 0.7 m/s, interpacket separations of 30 km and peak to trough amplitudes were noted to exceed 50 meters.



KDV Parameters Mode 1	
Wave Speed (k = 0) c_0 (m/s)	0.62
Nonlinear coefficient $1/\alpha$ (m)	-54.77
Dispersion Factor $\gamma^{1/2}$ (m)	41.66
Amplitude (KDV theory) η_0 (m)	-24.3
Non-Linear Phase Velocity V (m/s) for (s^2=1)	0.94

Figure 2. a) Density Profile derived from NODC World Ocean Atlas Monthly (July) temperature and salinity data at 48^0N. 9^0E. depth = 200 m b) derived Brunt-Väisälä frequency *N*(z) c) zero flow current profile d) Normalized vertical eigenfunctions (mode 1 & 2) for $2\pi/k_0$ = 250m, H = 200 m for density and velocity profiles shown e) phase velocity f) dispersion relations

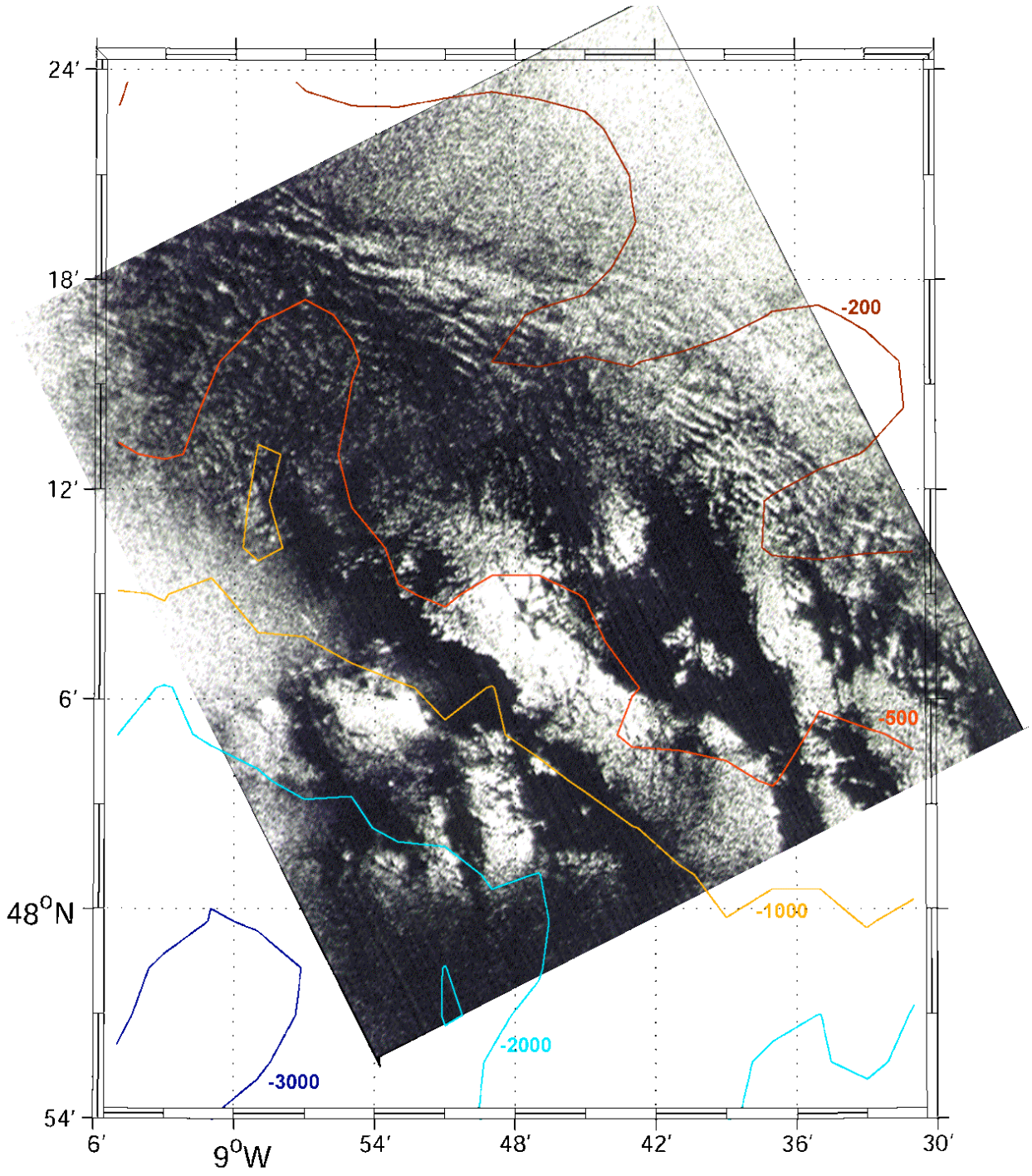


Figure 3. Almaz image from 5 July 1991 shown with the local bathymetry. [Smith and Sandwell, 1997]

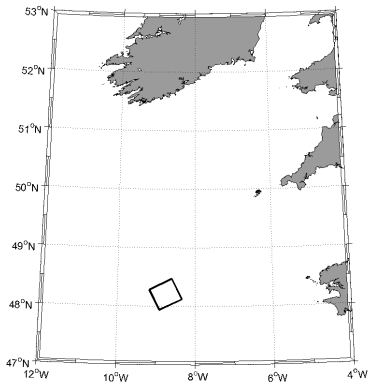
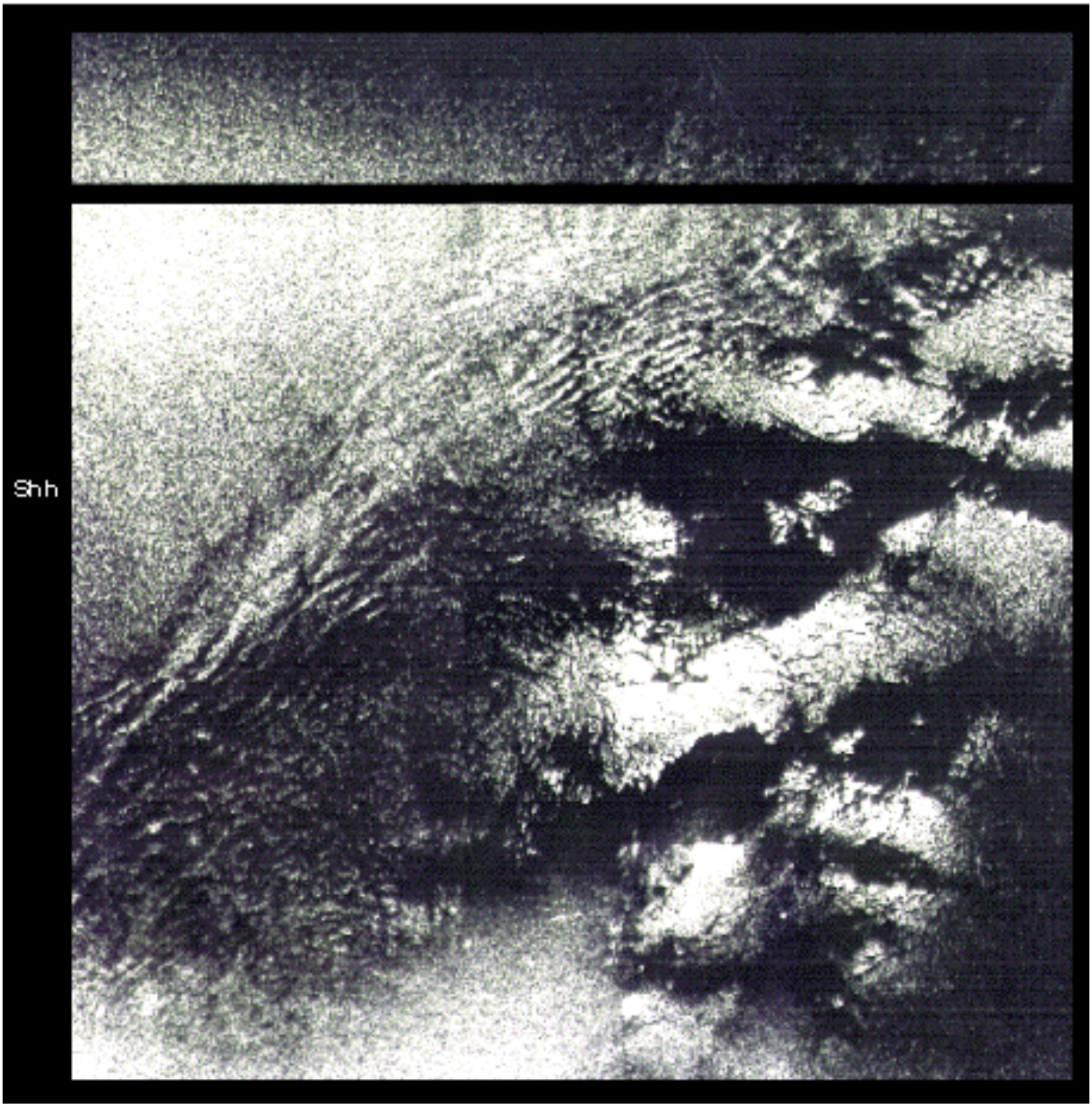


Figure 4. Russian Almaz (S-Band, HH) SAR image of the Celtic Sea acquired on 5 July 1991. The image shows a region of tidally induced upwelling and internal wave generation at the edge of the continental shelf. Imaged area is approximately 40 km x 35 km. [Data courtesy V. S. Etkin and A. L. Smirnov] [After Apel, 1995; Evans, 1995].



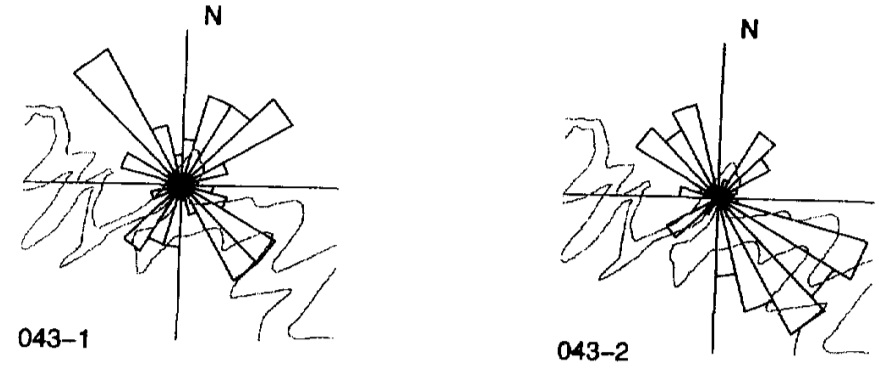
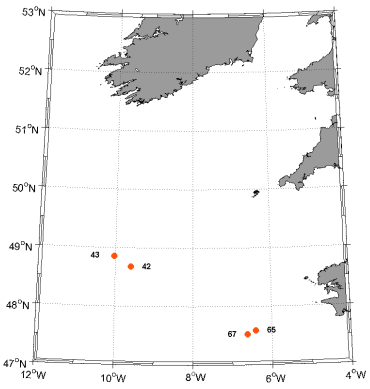


Figure 5. The distribution of internal wave packet propagation direction of propagation, produced from moorings observations at the shelf-break. The phase relationship between the velocity and temperature record has been used to remove the 180-degree ambiguity in direction. The data have been divided in to 15 degree bins. The outline of the 200 m and 300 m isobaths within 30 km of the mooring are also shown. [After Holt and Thorpe, 1997]



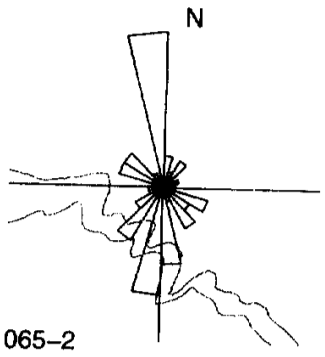
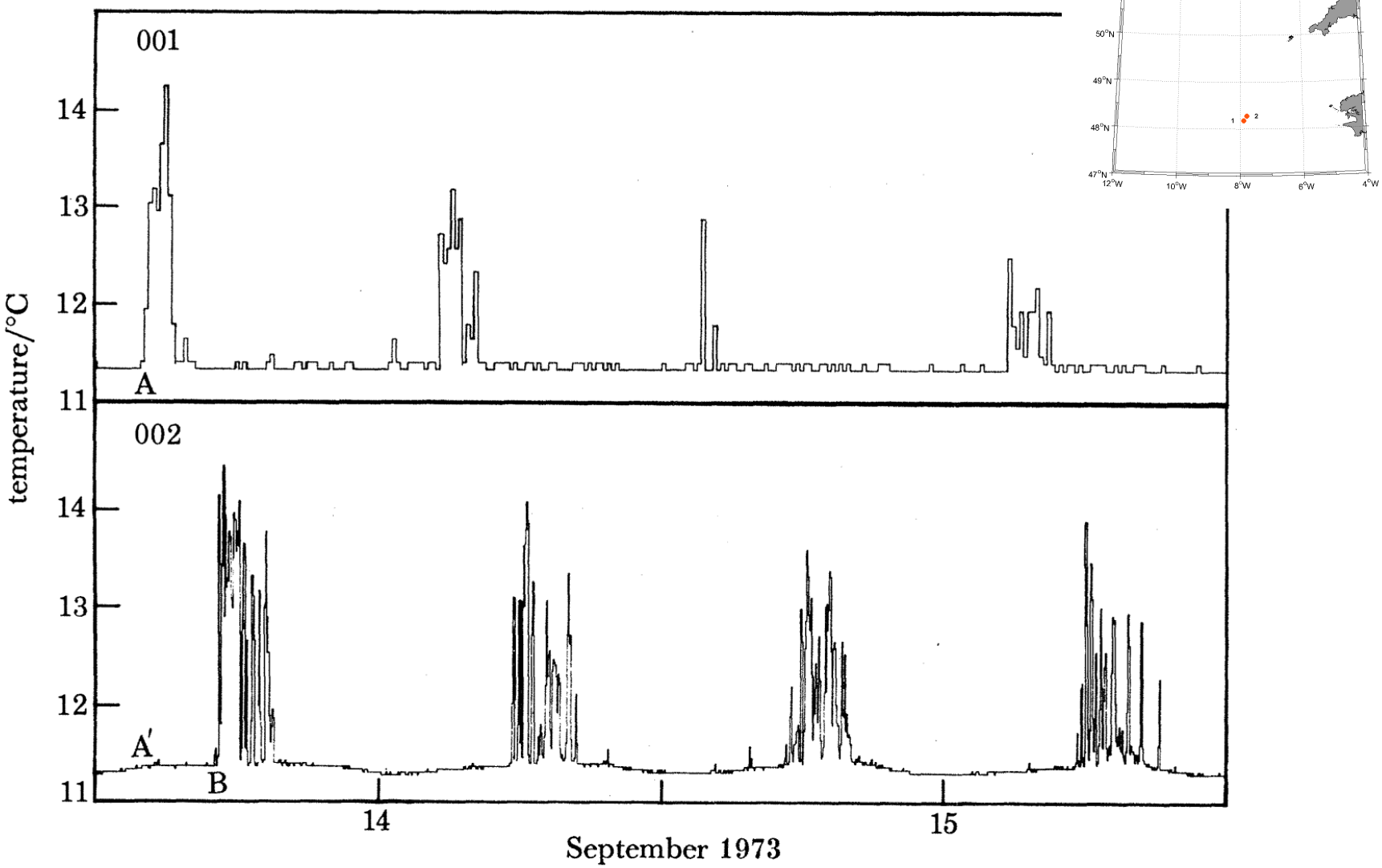


Figure 6. Temperature traces acquired in September 1973 for current meters 98 m off the bottom at mooring 001 (48.185°N, 7.90°E, depth 188 meters) and 002 (48.28°N, 7.78°E, depth 184 m). Internal waves first recorded at mooring 001 were observed at mooring 002 about 3.2 hours later. [After Pingree and Mardell, 1981]



References

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Smith, W. H. F., and D. T. Sandwell, Global seafloor topography from satellite altimetry and ship depth soundings, Science, v. 277, p. 1957-1962, 26 Sept., 1997. http://topex.ucsd.edu/marine_topo/mar_topo.html

Related Publications

Pingree, R.D., D.K. Griffiths, and G.T. Mardell, 1983: The structure of the internal tide at the Celtic Sea shelf break. *J. Mar. Biol. Assoc. U.*K., **6**4, 99-113.

Pingree, R.D., and A.L. New, 1995: Structure, seasonal development and sunglint spatial coherence of the internal tide on the Celtic and Armorican shelves and in the Bay of Biscay. *Deep-Sea Re*s., **4**2, 245-283.