The Mid-Atlantic (New York) Bight

Overview

Continental shelf internal waves have been observed along the East Coast of the United States (between approximately 37^o to 41^o N. latitude and 71^o to 75^o W. longitude); in the Mid-Atlantic (New York) Bight. Figure 1 presents a bathymetry map of the continental shelf in this area.

The area is a prodigious source of internal solitons. Apel et al. [1975] reported the existence of solitons in the New York Bight based on ERTS (Earth Resource Technology Satellite) imagery collected in August 1972, May 1973, and July 1973. The analyses laid down the basic characteristics of the internal waves in this area of the U.S. East Coast. Since 1973, several field programs[‡] and a large amount of satellite imagery have helped to characterize the internal waves of the region. The waves are typically observed between May and October when summer heating of the upper layers in coastal waters enhances the stratification necessary for internal wave occurrences. The solitons are generated by tidal flow near the edge of the continental shelf and occur in groups separated by some 20 to 35 km, depending on their speeds of propagation, which are typically 0.5 to 1 m/s. Soliton amplitudes of 5 to 25 m have been measured, and wavelengths from 200 to over 1000 m.

Table 1 presents a summary of internal wave characteristics for New York Bight. The values have been reported in the literature and derived from remote sensing data sources. Table 2 shows the months of the year during when internal waves have been observed in these areas

Table 1. Characteristic Scales for the New York Bight Solitons

Packet Length L (km)	Along Crest Length C_r (km)	Maximum Wavelength λ_{MAX} (km)	Internal Packet Distance D (km)
1 - 10	10 - 30	1 - 1.5	15 - 40
Amplitude $2h_0$ (m)	Long Wave Speed c_0 (m/s)	Wave Period (min)	Surface Width l_1(m)
-6 to -20	0.5 to 1.0	8 - 25	100

Table 2 - Months when Internal Waves have been observed in the New York Bight.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
				X	X	X	X	X	X		

‡ SAR Internal wave Signature Experiment (SARSEX)-1984, [Gasparovic et al., 1988]; Joint US/Russian Internal wave Remote Sensing Experiment (JUSREX)-1992, [Gasparovic and Etkin 1994]; Shallow Water Acoustics in Random Media (SWARM)-1995, [Apel et al., 1997]

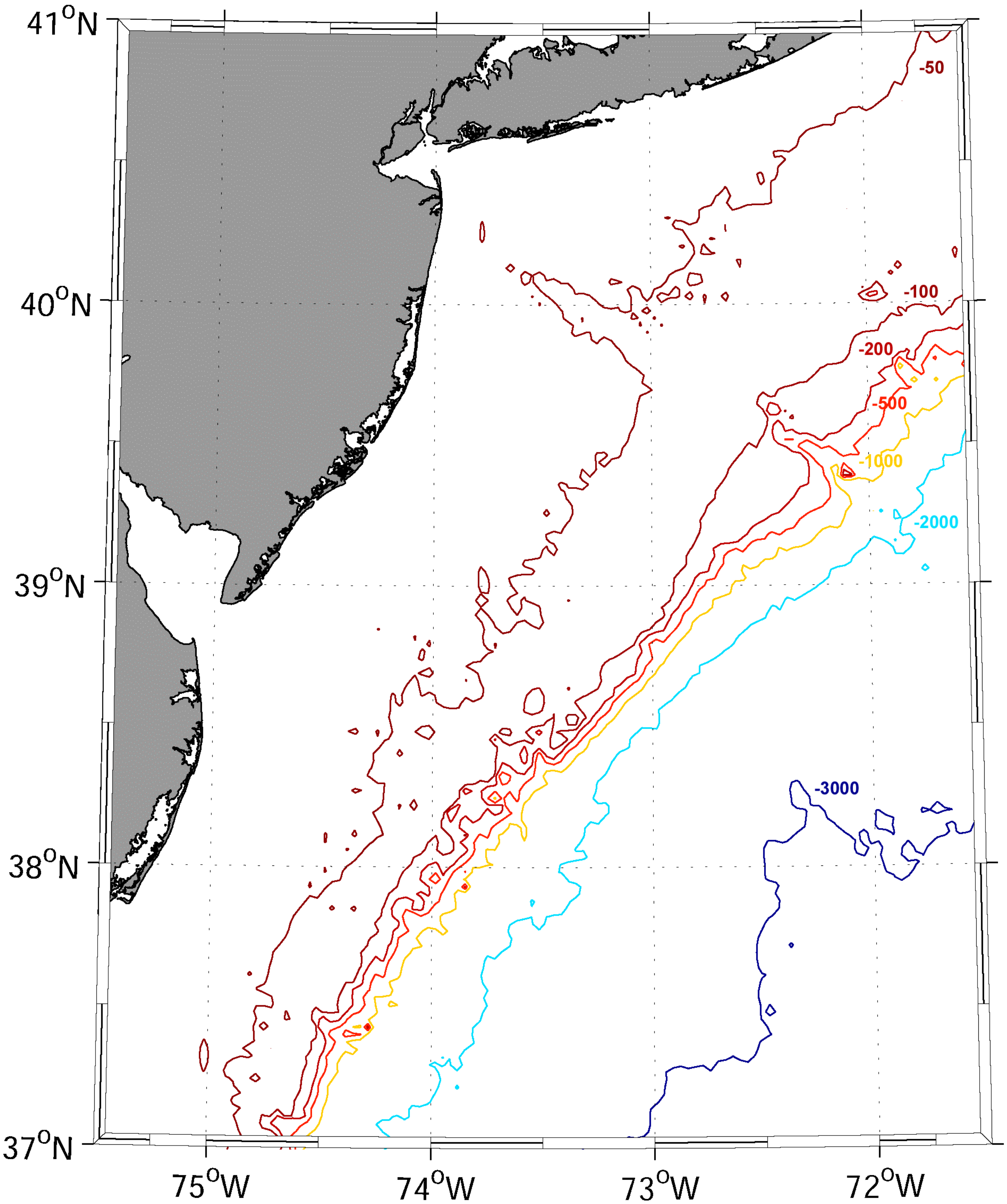


Figure 1. Bathymetry of the Mid-Atlantic Bight. (Derived from Smith and Sandwell version. 8.2)

Imagery

Internal wave signatures in the New York Bight have been observed in astronaut photographs, and Landsat optical images as well as synthetic aperture radars Seasat, SIR-B, ERS 1/2 Radarsat-1 and NASA AirSAR.

Figures 2 and 3 show typical internal solitary wave packets in the New York Bight. Four packets are visible in figure 2, and represent waves excited during the last four semidiurnal tidal cycles. Interpacket separations are approximately 24 to 35 km. In-situ observations collected as part of SWARM [Apel et. al 1997] has shown double amplitudes of 5 to 25 m, nonlinear phase speeds of order 0.65 m/s, and wavelengths from 200 to over 1000 m. Considerable in-water data exist to support the SAR imagery. Figure 3 is an ERS-1 SAR images of the New York Bight region, superimposed on GEBCO bathymetric chart. North of the Hudson Canyon, the crests are strongly oriented along isobaths, with crest lengths in excess of 120 km. South of the Canyon, seven packets are visible, with interpacket separations near 15 km, suggesting possible generation on both ebb and flood semidiurnal tides. The packets disappear as they approach shallow water, typically near 25-40 m –approximately the upper layer depth, because of strong bottom attenuation. Just a few broken crests can be seen inside the 50-meter isobath on figure 3. Additionally, their phase velocities are reduced by both the shoaling and (usually) by the decreasing pycnocline depth towards shore. The result is that the distance between packets is reduced; in Fig. 2, the spacing between the last two packets in the image is only about 25 km, as contrasted with the other two, which are nearer to 35 km.

Fig. 4 shows an enlargement of a segment of Figure 3 south of the Hudson Canyon. A nascent packet with one or two oscillations is seen forming at the southeast end of the image; its position is very close to the shelf break, slightly inshore of the 200-m isobath. This demonstrates that the generation process takes place quite close to the shelf break.

Figure 5 is a Seasat L-Band SAR image of the Mid-Atlantic Bight collected on 31 August 1978 [Fu and Holt 1982]. The image shows a large number of shoreward propagating internal waves packets long its entire 200-km length. Like the ERS data in figure 4, the wave crests are strongly oriented along isobaths. The maximum wavelengths are approximately 1.3 km. Individual packets contain as many as 30 waves. The large number of wave packets is a testament to the large number of internal wave sources that exist along the continental shelf in the New York Bight. A few internal wave packets can be seen radiating perpendicular to the shoreward propagating wave fronts. The most likely source is the submarine canyons in the area that are oriented perpendicular to the shelf break.

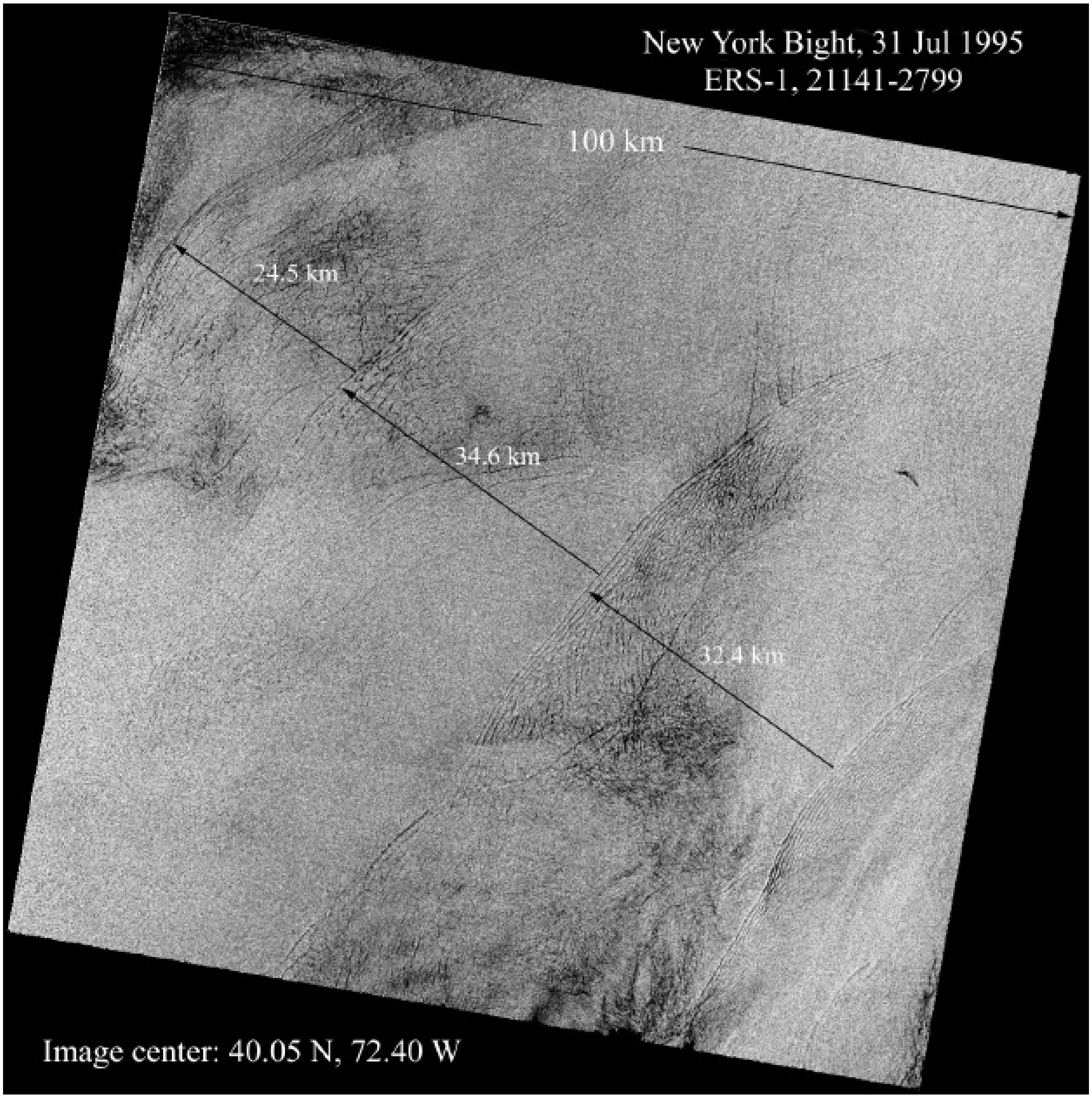
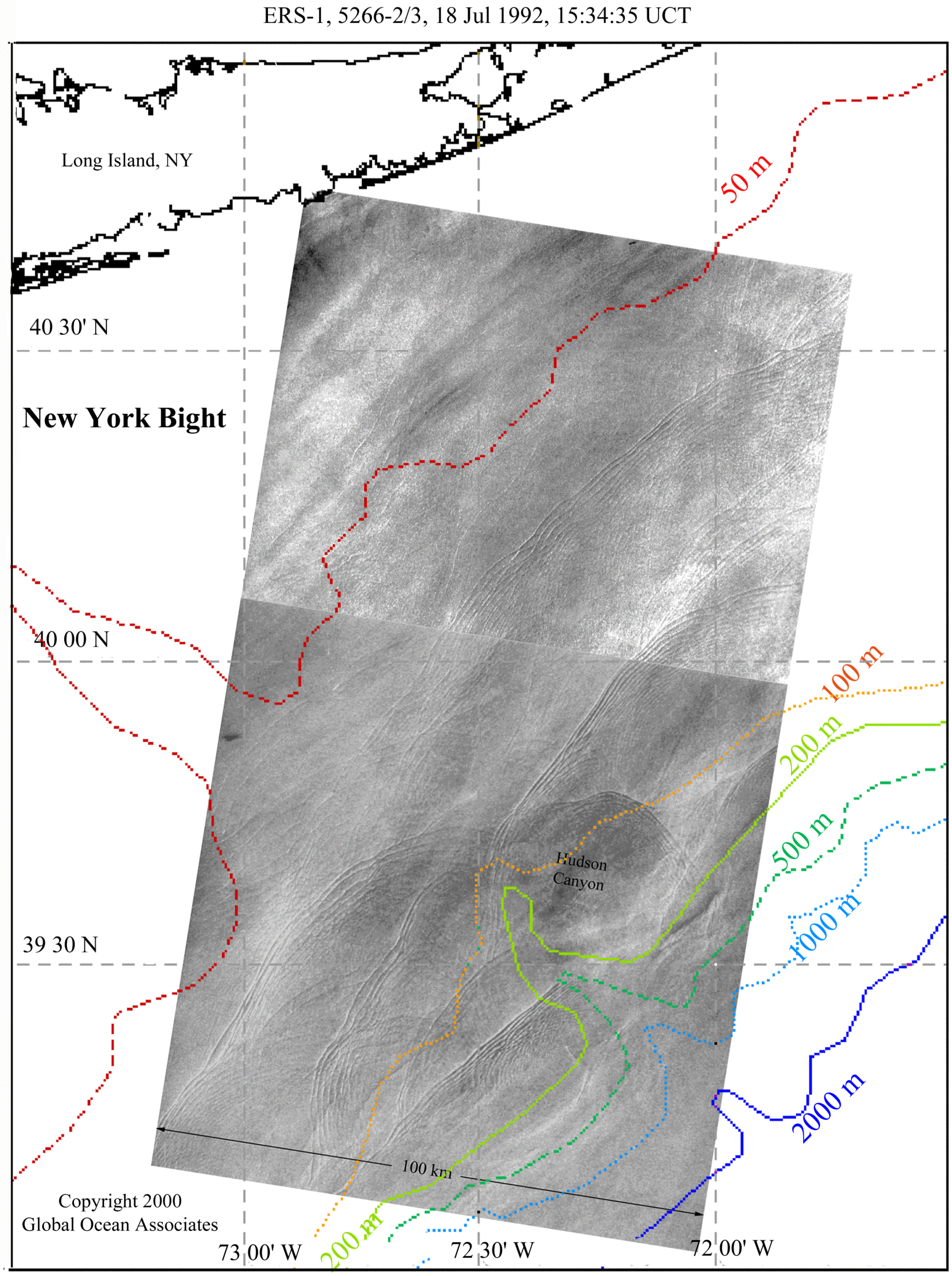


Figure 2. ERS-1 SAR C-band VV image of the New York Bight taken on July 31, 1995. Image is approximately 100 km x 100 km. Four packets of tidally generated internal waves are visible north of the Hudson Canyon, which lies near the bottom center of the image. Distance between packets is set by 12 ½-h semidiurnal tidal period. ©Copyright European Space Agency, 1995



Original Image Copyright European Space Agency, 1992

Figure 3. ERS-1 C-Band VV SAR images of the NY Bight shown with the local bathymetry. Bathymetry derived from GEBCO Digital Atlas 97..

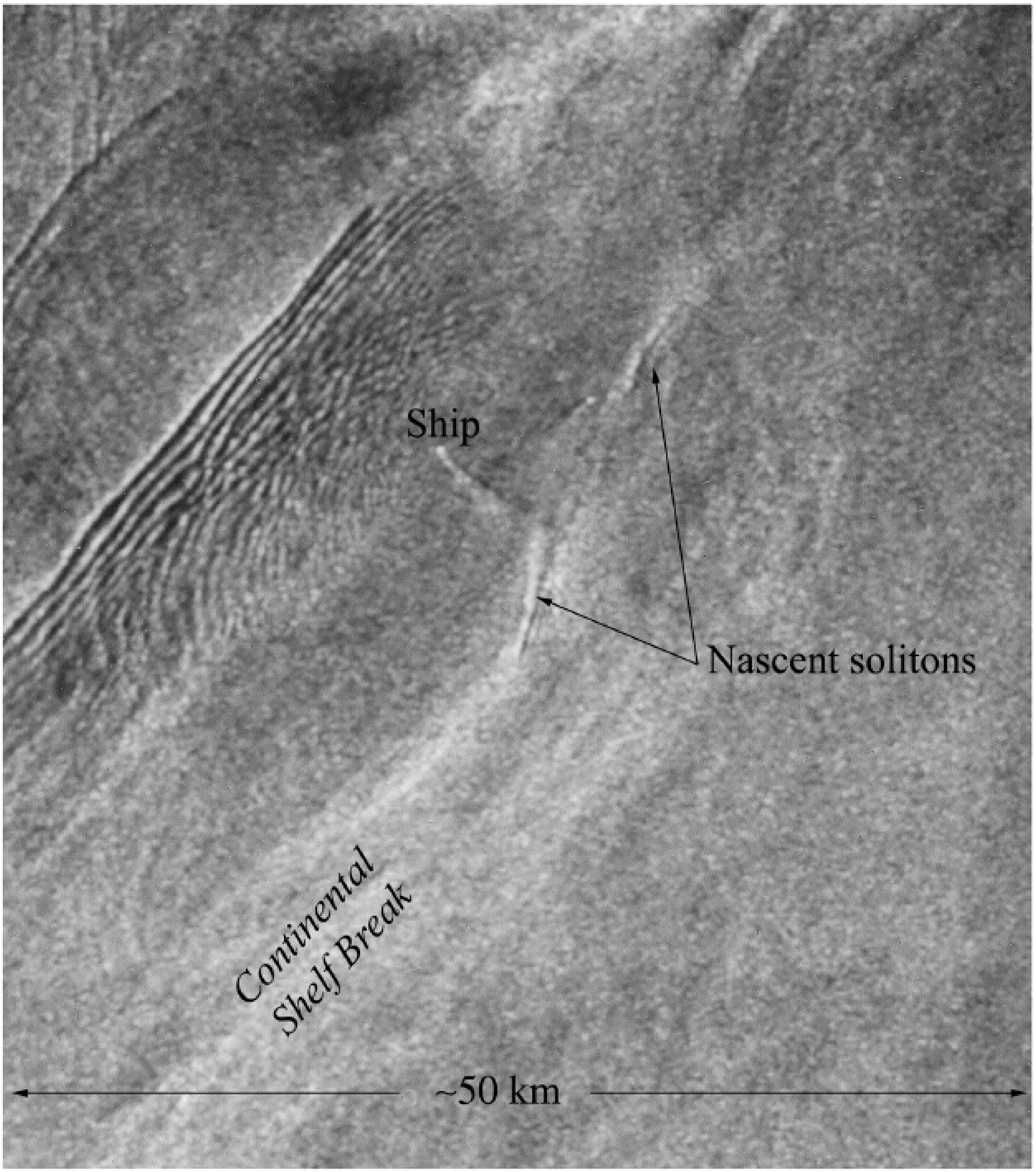


Figure 4. Enlarged segment of figure 3, showing solitons SW of Hudson Canyon in the New York Bight, July 18, 1992. Nascent solitons are just being formed very near to the 200-m shelf break (cf. Fig. 3.) and will propagate toward the northwest. Original image © European Space Agency, 1992.

Figure 5. Seasat L-band HH SAR image of the Mid-Atlantic taken on August 31, 1978. (Rev 0931 0240 GMT) Image dimension 200 km x 100 km centered near at $38^{0}04'$ N. $73^{0}55'$ W. [Fu and Holt, 1982]

KDV Parameters

Figure 6 shows a typical undisturbed density profile for the NY Bight collected via CTD cast in July 1995, during the SWARM experiment. The normalized Mode 1 and Mode 2 eignefunctions have been evaluated for $l = \frac{2}{pk_0} = 500m$, with H = 300 m. For long waves ($k \to 0$) the maximum first mode wave speed (c_0) is computed to be 1.01 m/s without the effect of current shear. Figures 6e and 6f give the phase velocity and dispersion relations for the data. Table 3 presents the environmental coefficients and KDV parameters evaluated at k_0 for U_0= 0.

Table 3. Environmental Coefficients and KDV parameters (λ_0=500) NY Bight (SWARM) Solitons

Long Wave Speed c_0 (m/s)	Nonlinear coefficient $1/\alpha$ (m)	Dispersion Factor $\gamma^{1/2}$ (m)	Amplitude (KDV theory) h_0 (m)	Non-Linear Phase Velocity V (m/s) for (s^2=1)
1.01	-13.49	30.49	-2.97.	1.19

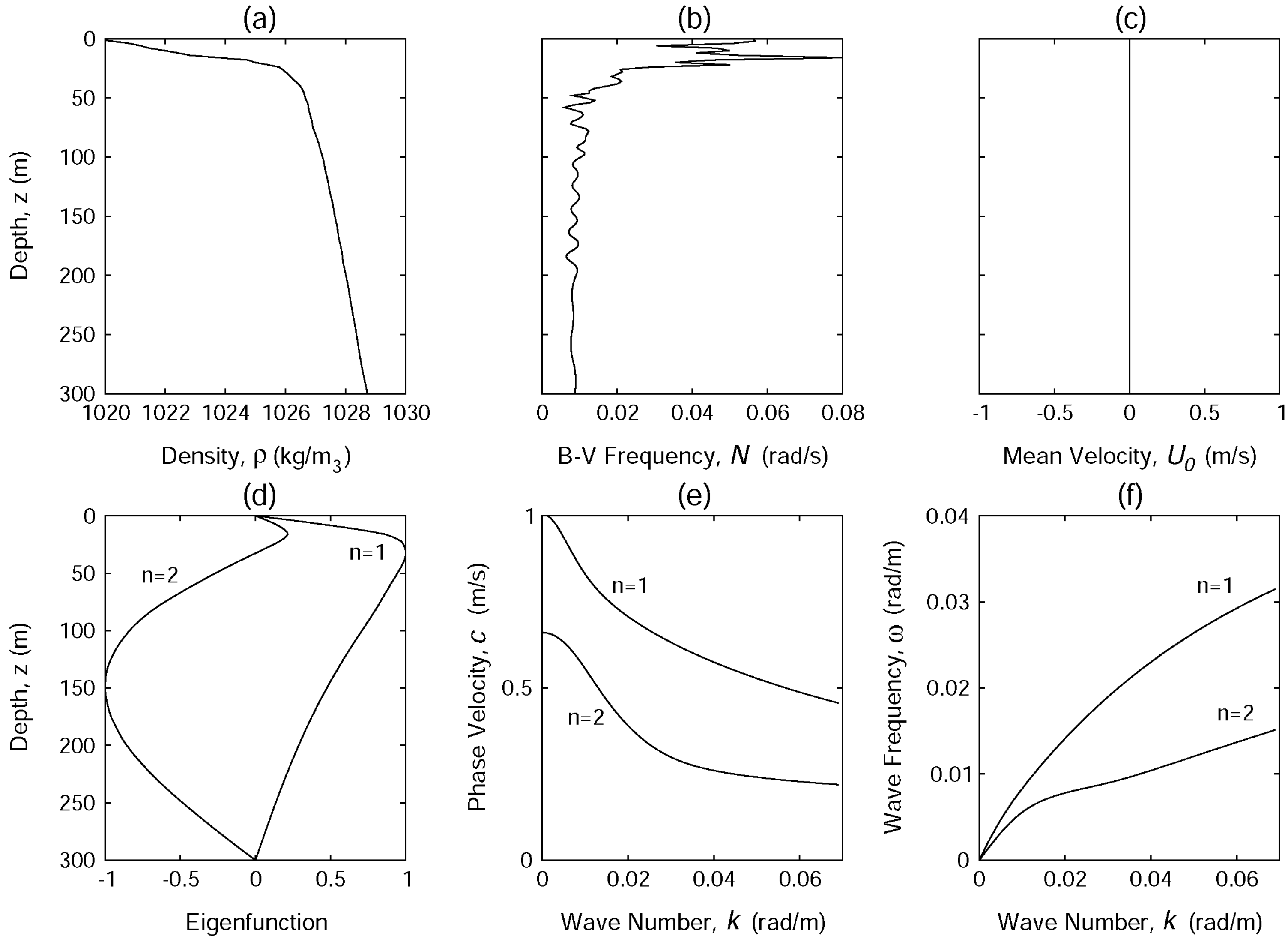


Figure 6. a) Undisturbed Density Profile for NY Bight collected during SWARM (CTD 214 - July 1995) b) derived Brunt-Väisälä frequency N(z) c) current flow profile d) Normalized vertical eigenfunctions (mode 1 & 2) for $2\pi/k_0$ = 500 m, H = 300 m for density and velocity profiles shown e) Phase Velocity f) Dispersion relations. .

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