New York (Mid-Atlantic) Bight

Overview

The New York Bight is located along the East Coast of the United States between the entrance to the Chesapeake Bay and Long Island (Figure 1). The area has a significant continental shelf extending up to 250 km from shore and is influenced by the Gulf Stream circulation as well as short duration wind driven upwelling and estuarine exchanges.

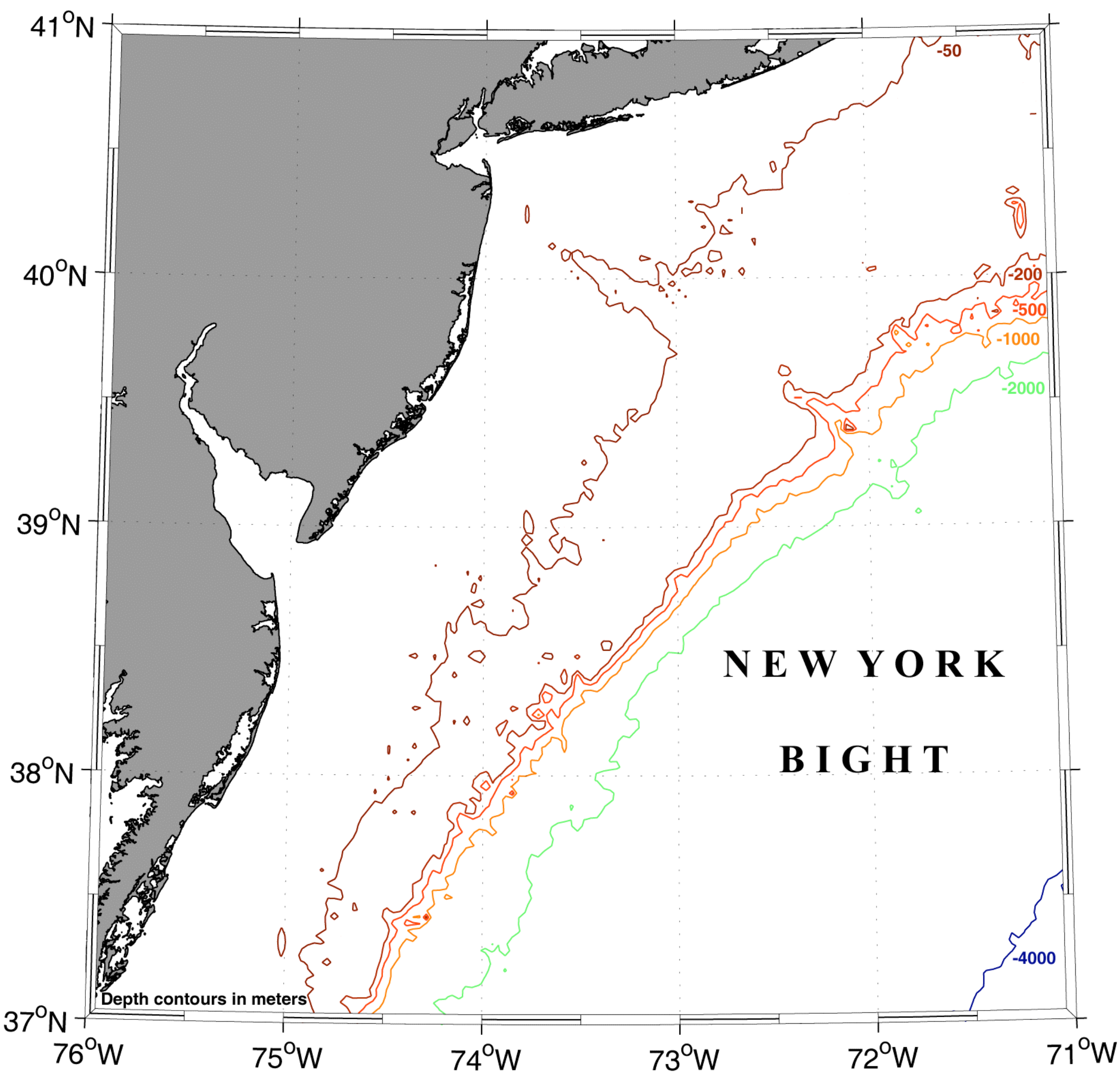


Figure 1. Bathymetry of the New York Bight [Smith and Sandwell, 1997].

Observations

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. Since 1973, several field programs[+] and a large amount of satellite imagery have helped to characterize the internal waves of the region. The internal waves are typically observed in imagery between May and October when summer heating of the upper layers in coastal waters enhances the stratification necessary for internal wave occurrences.

In situ measurements taken during the winter months also show the presence of internal waves [M. Orr, personal communication, 2004]. In winter the mix layer occupies the majority of the water column height. These "winter" internal waves manifest themselves as waves of elevation propagating along the pycnocline close to the bottom. Table 1 shows the months of the year during when internal waves have been observed in these areas.

Table 1 - Months when internal waves have been observed in the New York Bight.*
(Numbers indicate unique dates in that month when waves have been noted)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
3				4	10	18	14	7	1	4	

(This table represents only a small number of observation that have been made since 1973 and is biased towards the summer months due to data collected in experiments conducted between July to September)

The New York Bight 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 2 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.

Figure 2 shows a typical undisturbed density profile for the NY Bight collected via CTD cast on 4 August 1995, during ONR's SWARM experiment. The normalized Mode 1 and Mode 2 eigenfunctions have been evaluated for $\lambda = \frac{2\pi}{k_0} = 500m$, with H = 300 m. For long waves ($k \to 0$) the maximum first mode wave

Table 2. Characteristic Scales for continental shelf solitons in the New York (Mid-Atlantic) Bight

Characteristic	**Scale**
Amplitude Factor	-6 to –25 (m)
Long Wave Speed	0.5 to 1.0 (m s^{-1})
Maximum Wavelength	1 to 1.5 (km)
Wave Period	8 to 25 (min)
Surface Width	100 (m)
Packet Length	1 to 10 (km)
Along Crest Length	10 to 30 (km)
Packet Separation	15 to 40 (km)

[+]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]

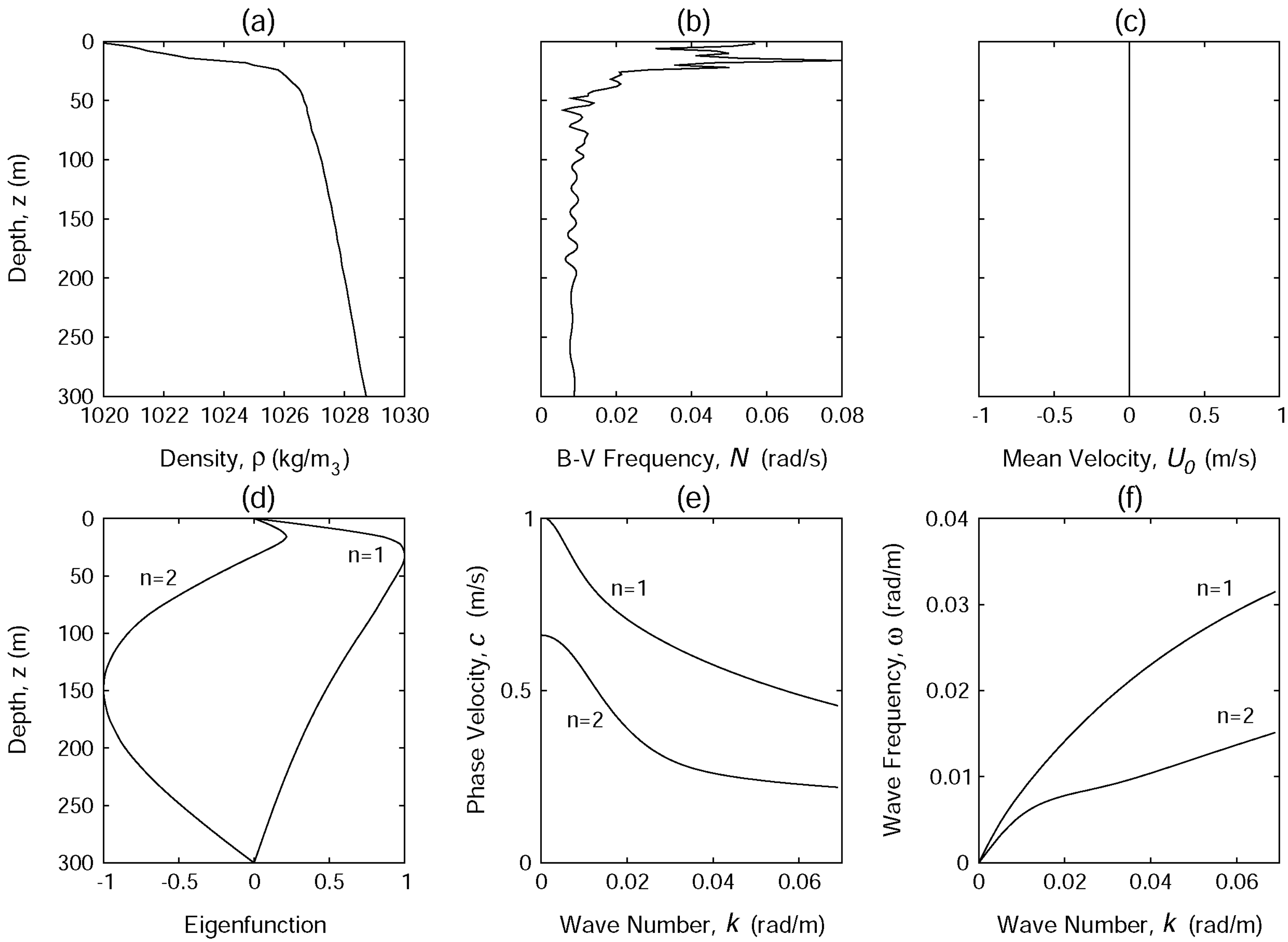


Table 3
KDV Parameters
Mode 1

Wave Speed (k = 0) c_0 (m/s) 1.01
Nonlinear coefficient $1/\alpha$ (m) -13.49
Dispersion Factor $\gamma^{1/2}$ (m) 30.49
Amplitude (KDV theory) η_0 (m) -2.97
Non-Linear Phase Velocity V (m/s) for (s^2=1) 1.19

Figure 2. 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.

speed (c_0) is computed to be 1.01 m/s without the effect of current shear. Figures 2e and 2f 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.

Figure 3 is an ERS-1 (C-band, VV) SAR image acquired in July 1995 during the SWARM experiment and shows typical internal solitary wave packets in the New York Bight. Four packets are visible and represent waves excited during the last four semidiurnal tidal cycles. Interpacket separations range from 24 to 35 km. In-situ observations collected as part of SWARM [Apel et. al 1997] has shown peak-to-trough amplitudes of 5 to 25 m, nonlinear phase speeds of order 0.65 m/s, and wavelengths from 200 to over 1000 m. Figure 4 shows a temperature history collected via a thermistor string during SWARM. The semi-diurnal tidal modulation can be seen at a 12.42 hour interval with solitons appearing as spikes on top of the tidal modulation.

Internal waves in the area around Hudson Canyon are shown in Figures 5 to 7. Figure 5 is an echo sounder profile acquired on 15 June 1976 that shows a lee-wave formation near the shelf break north of the Canyon. One theory of internal wave generation suggests that the operative process is the formation of a lee wave sown-current of a sharp change in bathymetry (See section 4.2 of Background and Theory). Figures 6 and 7 are ERS-1 SAR images of the New York Bight region collected in July 1992. 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 4. 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 Figure 3, 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. 8 shows an enlargement of a segment of Figure 7 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 9 is a SEASAT L-Band SAR image of the Mid-Atlantic Bight collected on 31 August 1978 [Fu and Holt 1982]. Throughout the image the signature of a large number of shoreward propagating internal waves packets are visible. Like the ERS data in Figure 7, 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 10 is a false-color ASTER infrared image acquired 8 June 2001 off the Delmarva Peninsula. The image shows internal wave packets propagating shoreward from a number of directions.

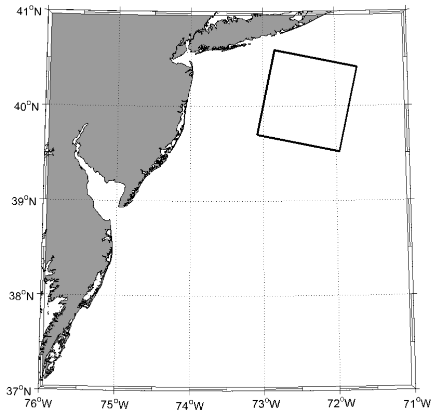
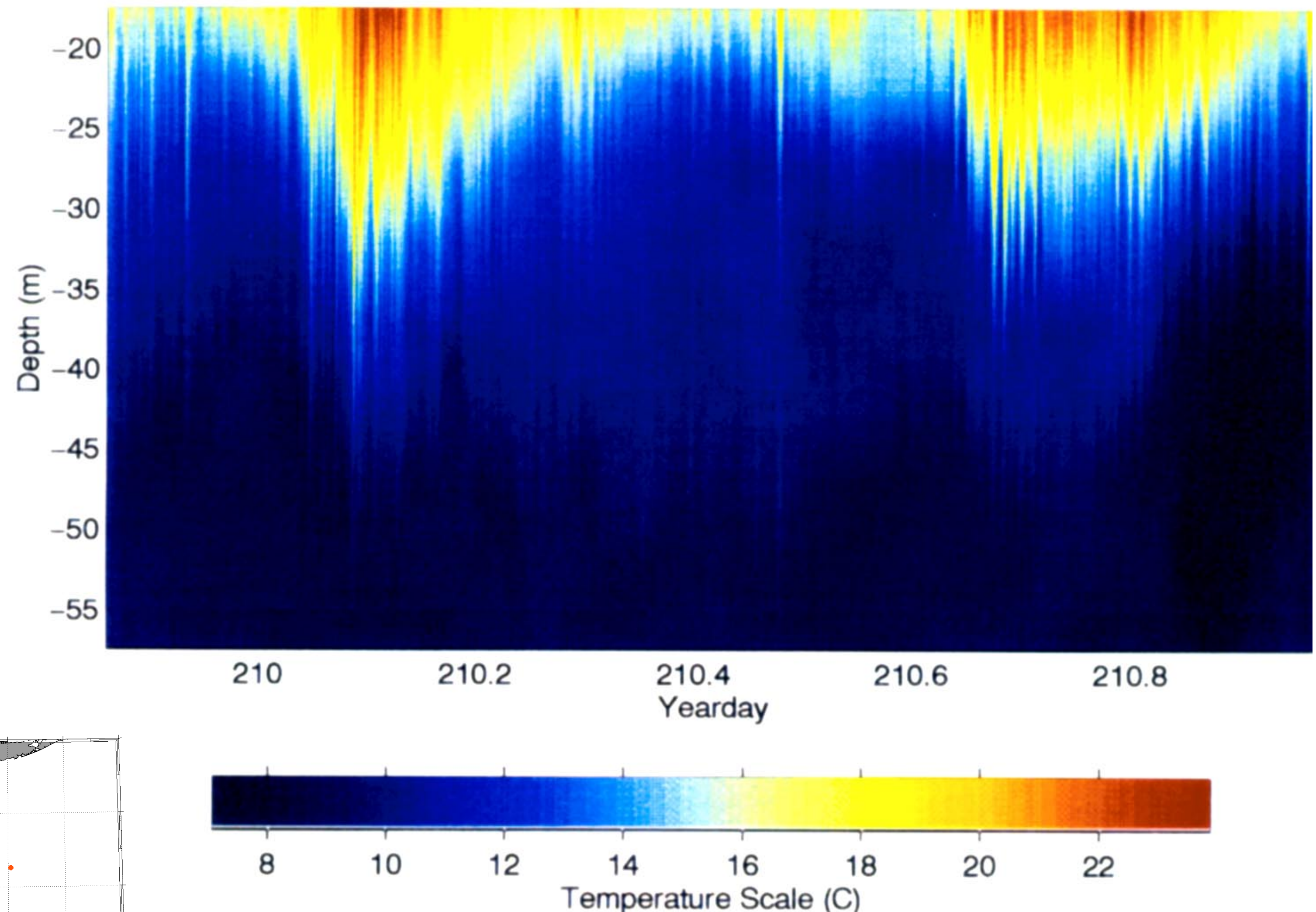


Figure 3. ERS-1 (C-band VV) SAR image of the New York Bight during SWARM acquired on 31 July 1995 at 1535 UTC (orbit 21141, frame 2799). Four packets of tidally generated internal waves are visible north of the Hudson Canyon, which lies near the bottom center of the image. Distance between packets (32.4, 34.6 and 24.5 km, right to left) is set by 12 ½-h semidiurnal tidal period. Imaged area is approximately 100 km x 100 km. ©ESA 1995.



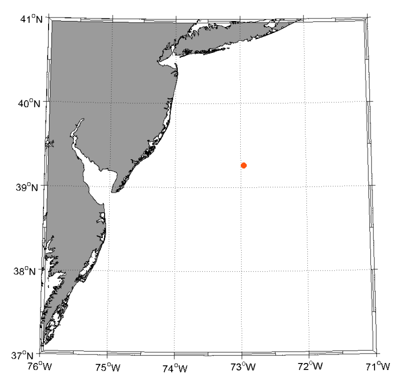
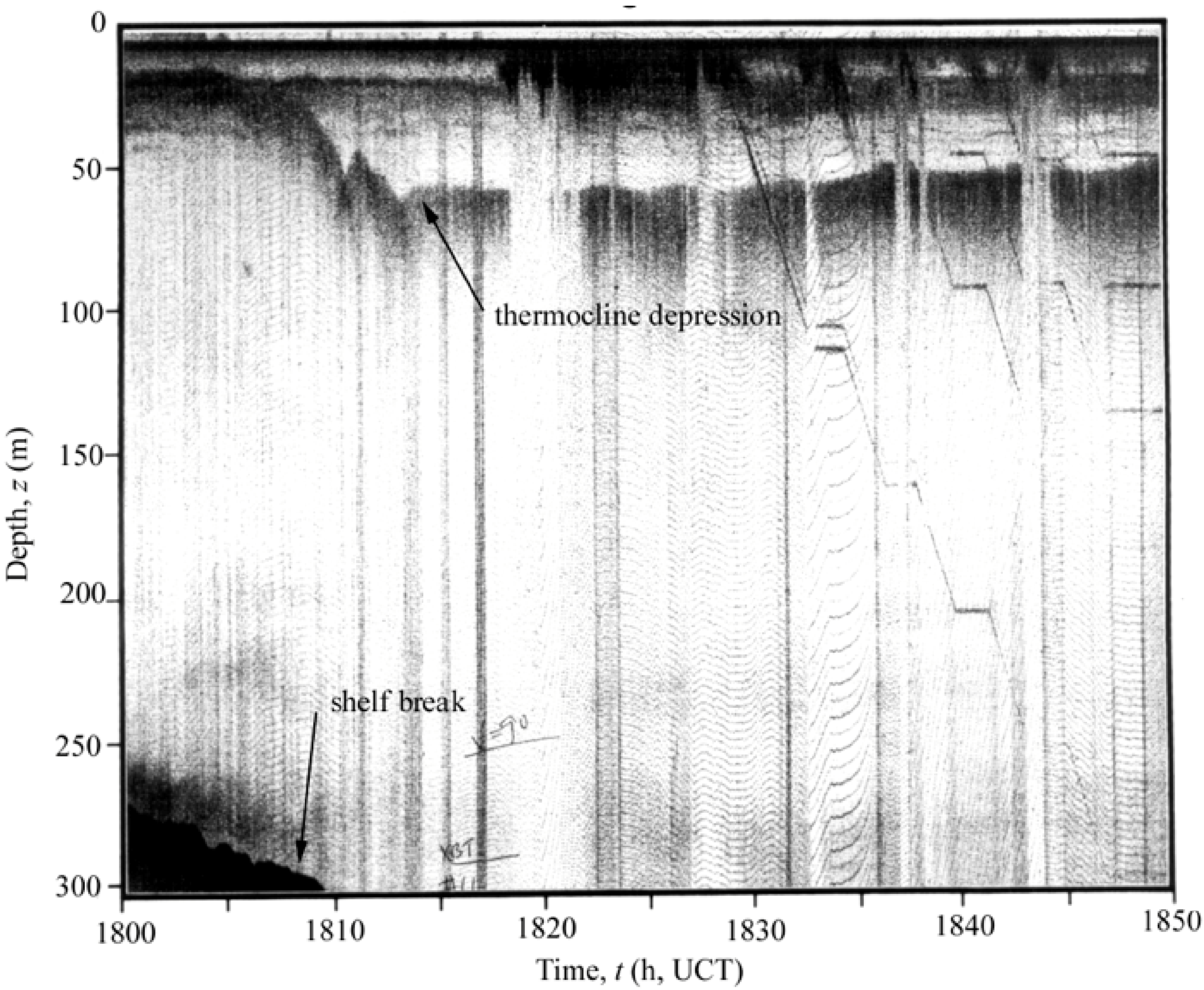


Figure 4. Temperature record from thermistor string T598 (located at 39.19°N., 72.83°W) acquired on 27 July 1995,as part of SWARM. The data show the long wavelength (12.42 hour) tide with solitons "riding on top of it" [After Apel et al. 1997]



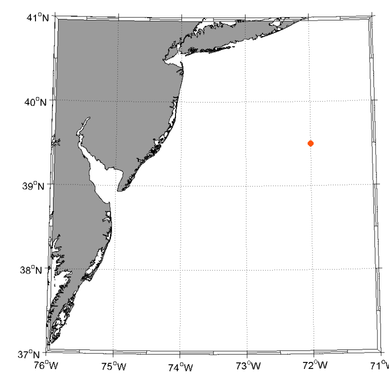


Figure 5. Twenty (20) kHz echo-sounder profile of a lee wave northeast of Hudson Canyon in the New York Bight just off the shelf break, acquired on 15 June 1976. XBT and CTD casts confirmed the pycnocline depression.

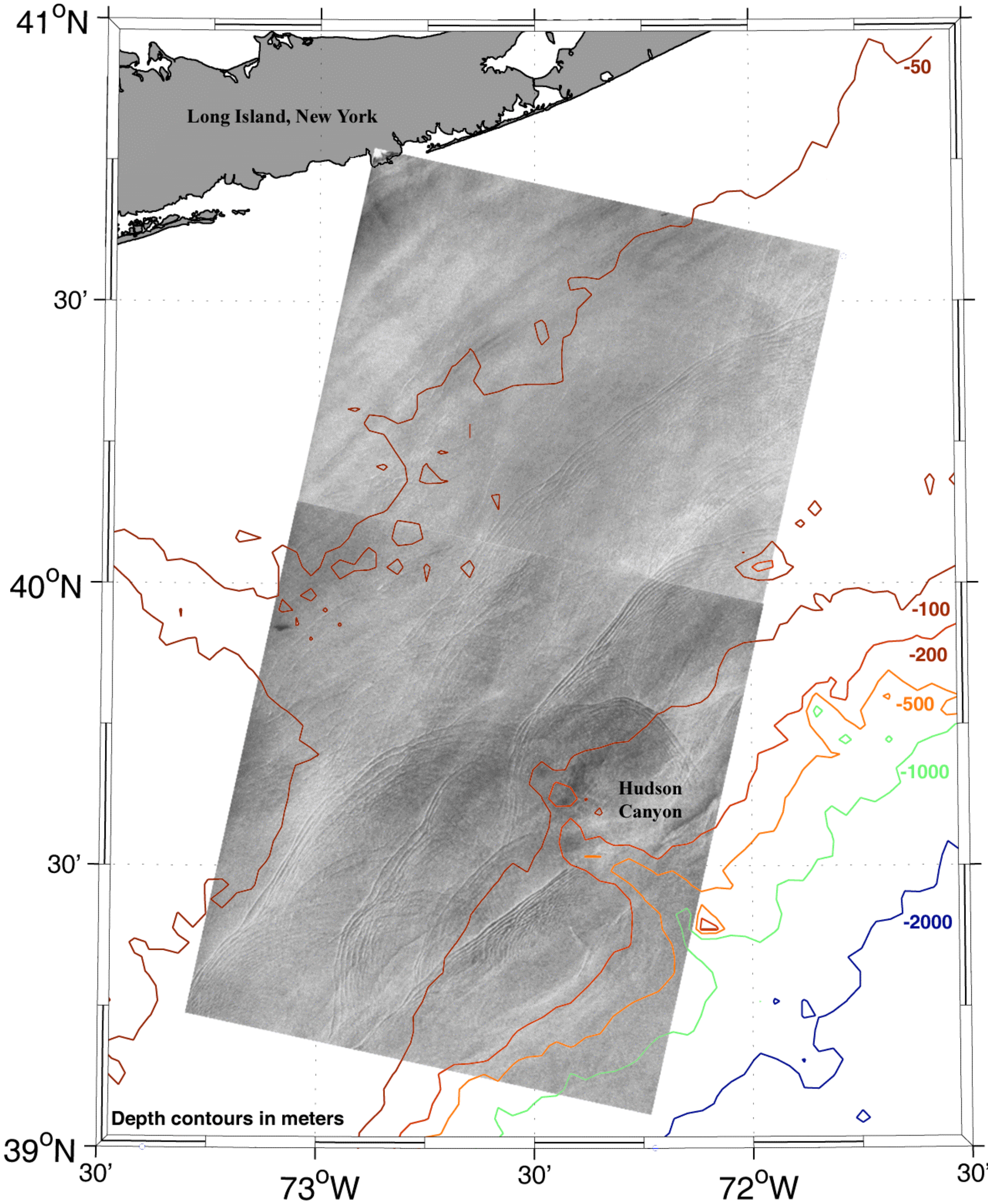
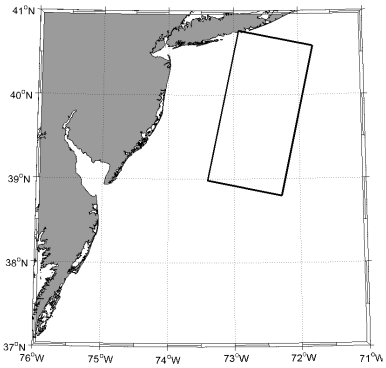


Figure 6. ERS-1 (C-band VV) SAR image of the New York Bight acquired on 18 July 1992 at 1535 UTC (orbit 5266, frames 2799, 2817) shown with the local bathymetry [Smith and Sandwell, 1997]. The internal waves form seaward of the 200 meter isobath at a number of location along the continental shelf break.



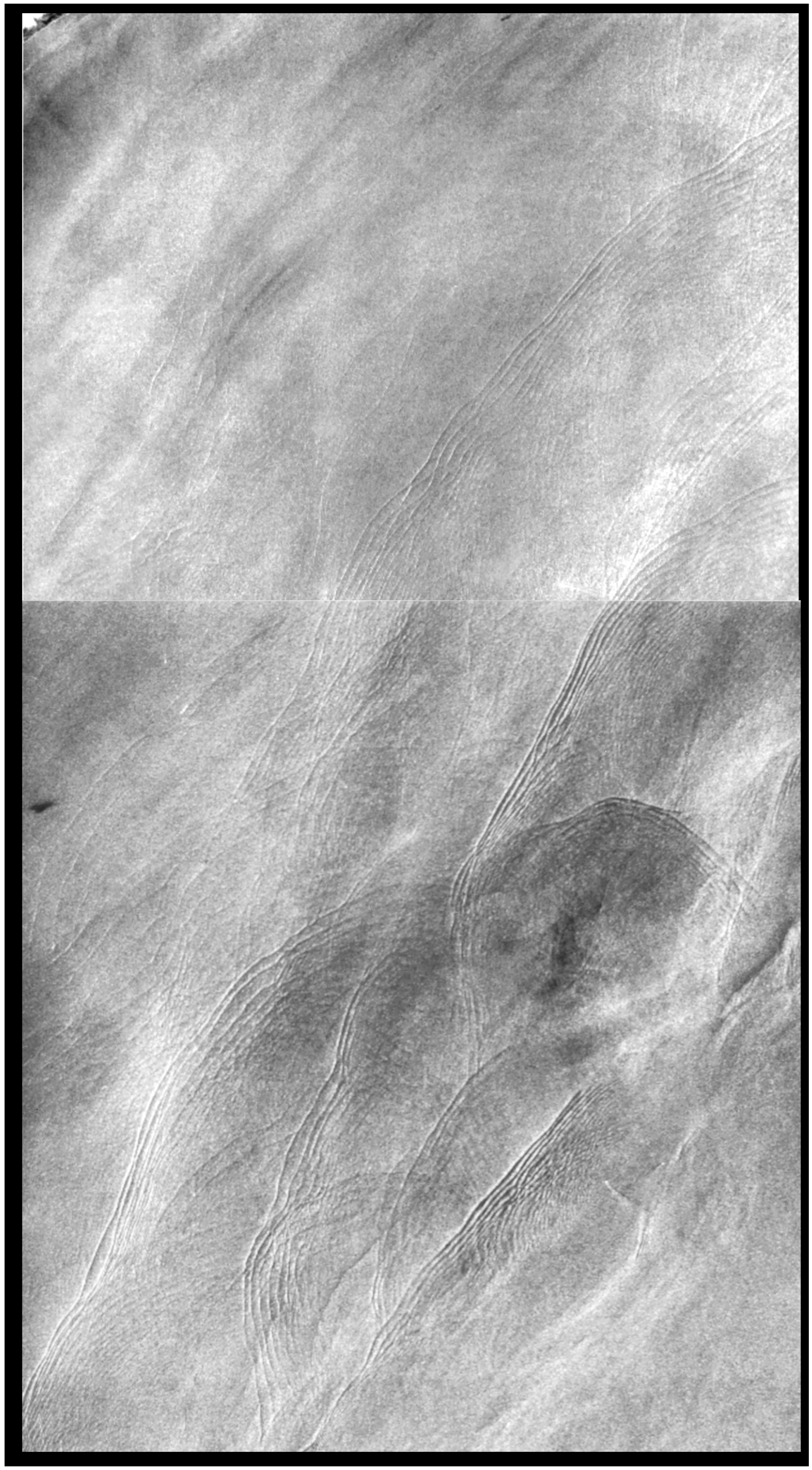


Figure 7. ERS-1 (C-band, VV) SAR image of the New York Bight acquired on 18 July 1992 at 1535 UTC (orbit 5266, frames 2799, 2817). The image shows the influence of Hudson Canyon [see Figure 5] in the generation of internal waves along the continental shelf break. Imaged area is approximately 180 km x 100 km. ©ESA 1992

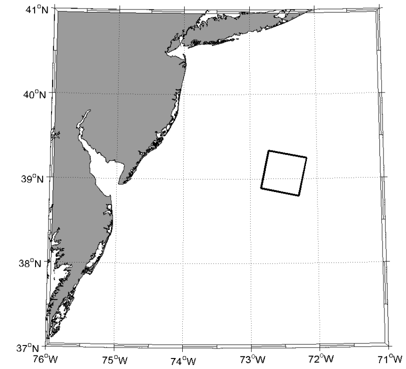
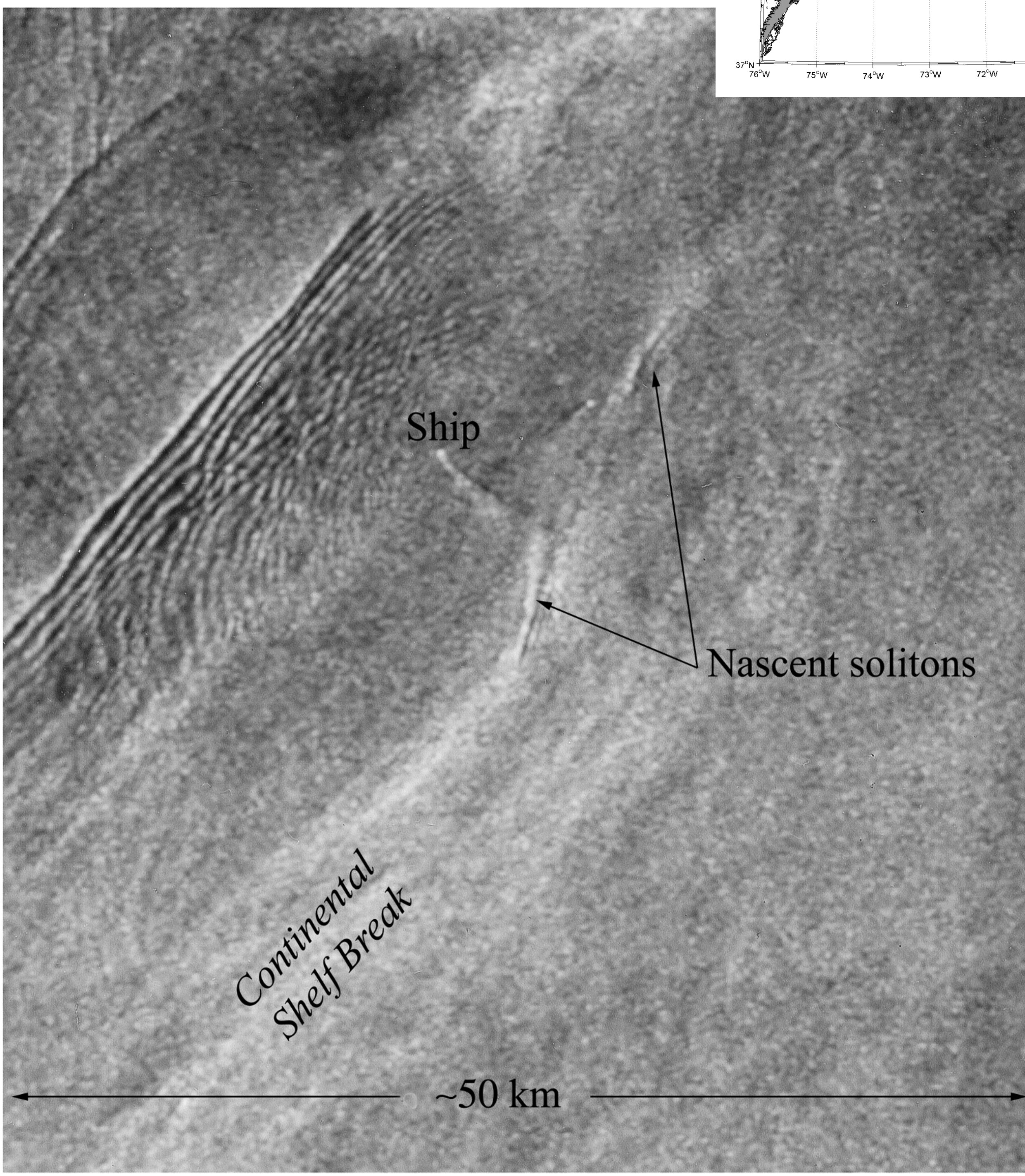


Figure 8. Enlarged segment of the ERS-1 (C-Band, VV) SAR image acquired on 18 July 1992 at 1535 UTC (orbit 5266, frame 2817) showing solitons southwest of Hudson Canyon in the New York Bight. Nascent solitons are just being formed very near to the 200-m shelf break that will propagate toward the northwest. Imaged area approximately 56.5 km x 50 km. Original ERS-1 image ©ESA 1992.



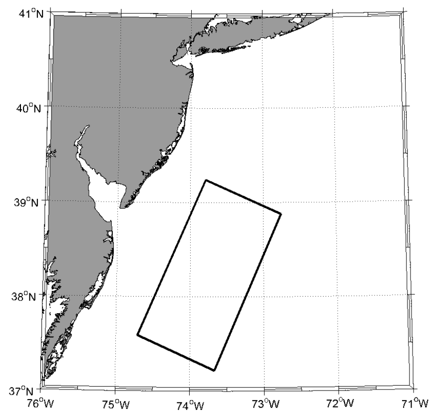
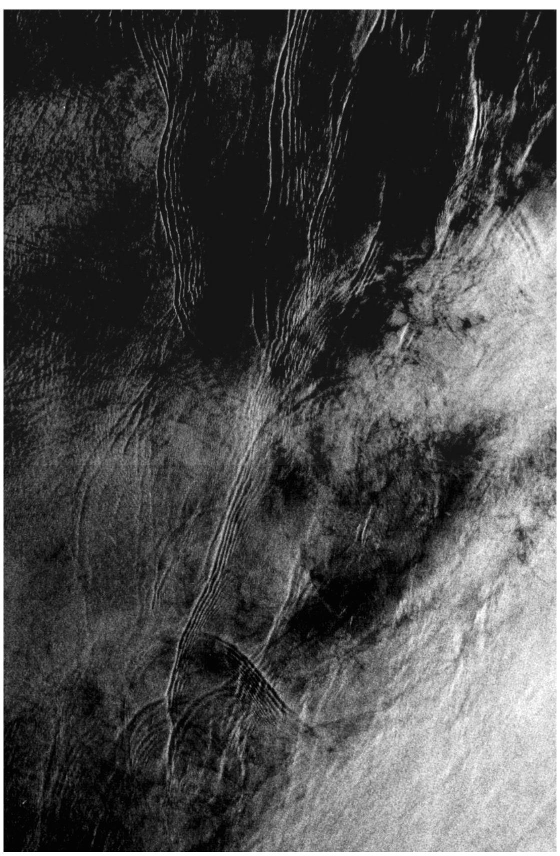
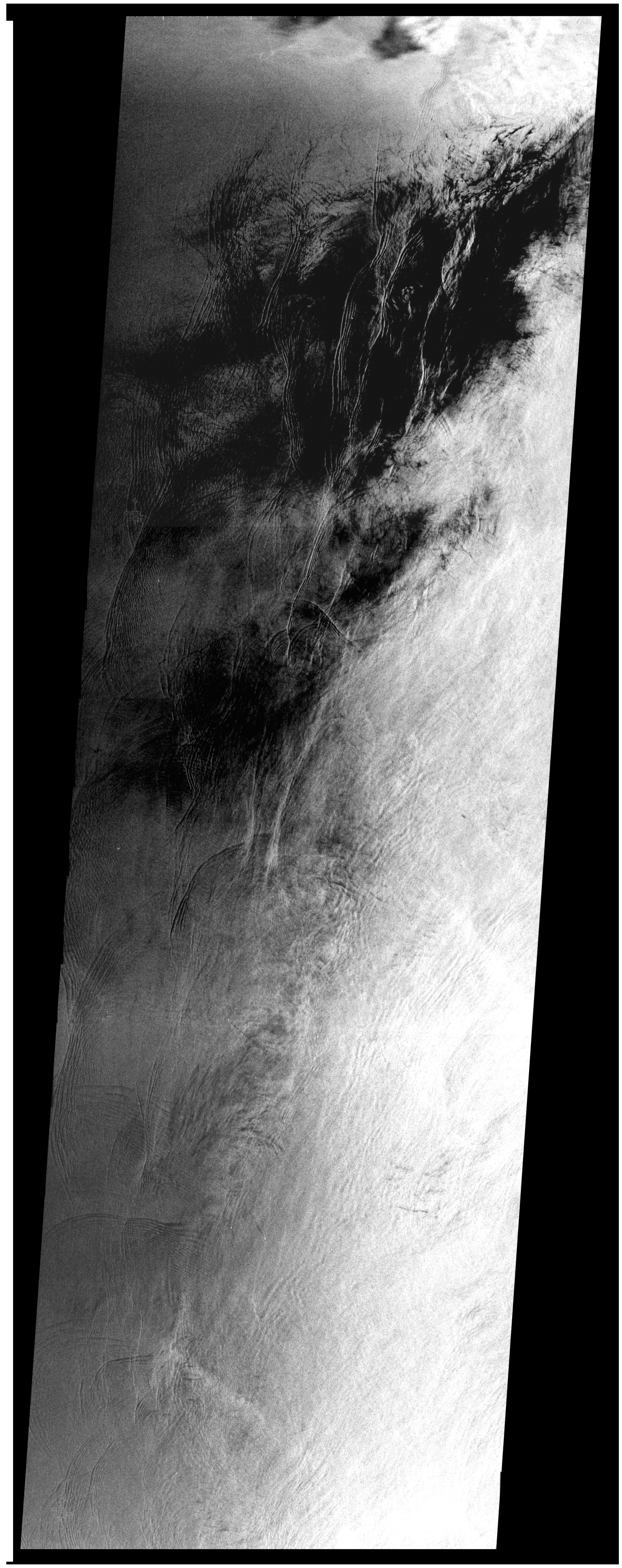
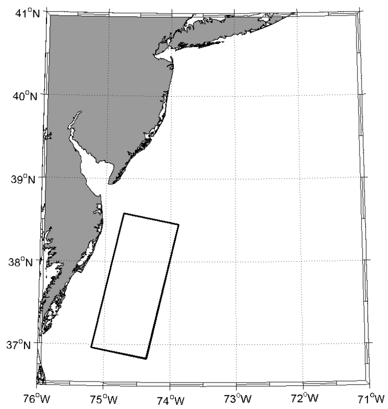


Figure 9. (Right) SEASAT (L-band, HH) SAR image of the New York Bight acquired on 31 August 1978 at 0240 UTC (Rev 0931) Imaged area is approximately 320 km x 100 km. [After Fu and Holt, 1982] (Below) An enlargement highlighting the wave signatures. Imaged area is approximately 55 km x 75 km. [Image courtesy NASA JPL]







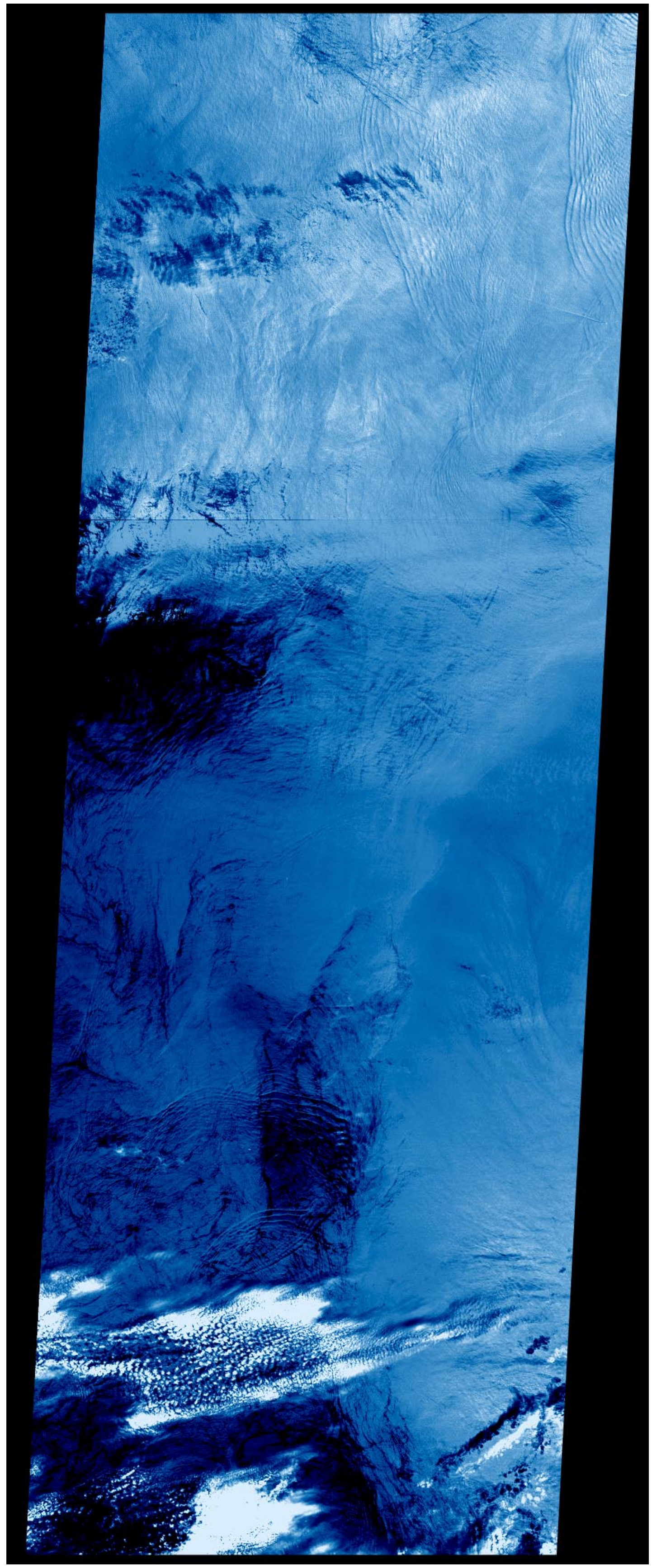


Figure 10. ASTER false color VNIR image of the southern end of the New York Bight acquired on 8 June 2001 at 1607 UTC. The image shows a variety of internal wave signatures in the area off the Delmarva Peninsula. Imaged area is 60 km x 180 km.

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