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National Oceanic and Atmospheric Administration
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Woods Hole, Massachusetts
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Merton C. Ingham[1] and James Eberwine[2]

[1]*Atlantic Environmental Group, National Marine Fisheries Service, Narragansett, RI 02882*
[2]*National Weather Service Office, Atlantic City, NJ 08405*

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldridge, Secretary
National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries
Northeast Fisheries Center
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ABSTRACT

Analysis of nearshore ocean temperature data collected in the floatwell of a tide gauge on Steel Pier and wind data collected at the Atlantic City, New Jersey, weather station during summer months of 1981 shows a strong correlation between major cooling or warming events in the water and the strength of upwelling or downwelling wind components one day earlier.

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One of the tenets of classical theory of coastal upwelling dynamics (Defant 1961, p. 652) holds that the most effective wind direction for transporting surface waters offshore, thereby bringing cooler water up into the surface layer, is one which is parallel to the coastline (with the land on the left in the northern hemisphere). Assuming that this is applicable to the waters over the continental shelf in the Middle Atlantic Bight, upwelling should occur along the Virginia - New Jersey coastline during the summer months when winds from the southwestern quadrant are common (Williams and Godshall 1977; Lettau et al. 1976).

Hicks and Miller (1980) reported indications of summer upwelling in response to southerly winds, bringing cold bottom water into the surf zone near Monterey Beach, New Jersey (about 80 km northeast of Atlantic City, New Jersey). They found upwelling in July 1976 to be vigorous enough, following two days of strong southerly winds, to bring waters of the "cold cell" into the surf zone, causing a drop of 9.3°C (from 18.3° to 9.0°C) in surf temperature. Their analysis of 1973 and 1974 data also showed large decreases of surf temperature during July, August, and September, each preceded one or two days earlier by strong winds from the south and southwest.

Recreational surf fishermen along the New Jersey shore also have frequently observed the upwelling effects of strong south winds, but haven't used the term "upwelling" or the concept in describing their experiences. Wilson (1983), for example, speaks of "cold currents" and "cold waters" being brought in by southerly winds, and describes the effects of the cooler water on the behavior of several species of gamefish.

An unusual opportunity to gather evidence of wind-driven coastal upwelling exists in the area of Atlantic City, New Jersey, as the consequence of the availability of accurate wind data taken at the weather station (a first-order station of the National Weather Service at the Aviation Facilities Experimental Center) and water temperature data logged four times a day at the tide gauge station on the Steel Pier. Although the weather station is about 16 km inland from the pier, wind data collected there and reduced to daily averages realistically portray general wind field conditions along the coast and in the vicinity of the pier.

The trend of the local coastline is about WSW to ENE in the vicinity of the pier (Fig. 1), which means that a wind from about 250° would have the maximum upwelling effect, and one from 70° would produce the maximum convergence and "downwelling". During the summer months, the monthly mean resultant wind directions (based on 1941-70 data) observed at the weather station are: June - 140°, July - 260°, August - 200°, and September - 270°. (U.S. Department of Commerce 1975).

The wind data used in this study were daily mean vector resultant velocities taken from Local Climatological Data summaries for the Atlantic City weather station published monthly by the National Climatic Data Center.(1) Upwelling wind components are computed from these data

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(1) National Climatic Data Center, National Environmental Satellite, Data, and Information Service, NOAA, Asheville, North Carolina 28801.

by multiplying them by the cosine of the angle between the published daily resultant and the 250°-70° line and assigning the appropriate sign, positive for upwelling or negative for downwelling.

The seawater temperature data were obtained from manuscript records of 6-hourly observations recorded at the Atlantic City weather station by telephone link with a thermistor installed in the floatwell of the National Ocean Service tide station on Steel Pier. The average depth of the thermistor beneath the surface is 2.4 m, ranging from about 3.2 m at high tide to 1.9 m at low tide. The 6-hourly data were converted to daily averages, and daily changes in water temperature were calculated by subtracting each day's average from the next day's.

Visual comparison of time-series plots of daily water temperature and wind component data for summer 1981 (Fig. 2) was inconclusive, though there seemed to be some correspondence between major wind events and rapid changes in temperature. Linear regression analysis of daily water temperature changes and the upwelling wind component the day before yielded correlation coefficients which were too low to imply a functional relationship. It appeared that random small-amplitude noise in the water temperature data might be responsible for the poor correlation. Accordingly, we re-ran the linear regression analysis using just those water temperature changes which were at least one standard deviation above or below monthly means (high-pass filter). The results of this analysis were far more conclusive (Fig. 3), yielding correlation coefficients (R) of -0.777, -0.855, and -0.752 for June, July, and August, respectively. The coefficients are negative because upwelling wind components (+) produce decreases in water temperature and downwelling components (-) produce increases in water temperature.

Best-fit linear equations for the three months of high-pass data are: June, Y = 4.18 - 0.89 X; July, Y = 2.27 - 1.16 X; and August, Y = 2.51 - 0.91 X, where Y = the one-day change in water temperature (°F) and X = upwelling wind component (mi/hr). These equations have quite similar slopes but different intercepts (Fig. 3), which suggests that changes in upwelling/downwelling wind strength produce comparable changes in water temperature in each of the three months, but that the wind strength required for a given change is greater in June than in July and August, probably because of smaller differences between the temperature of upwelled bottom water and surface water in June.

In an attempt to document and verify the upwelling events, a search of a file of infrared imagery from the GOES satellite for summer 1981 was conducted. It revealed that there was clear sky in the Atlantic City area both before and after just one of the upwelling events, the one which began about 13 July. Imagery from the Advanced Very High Resolution Radiometer on the NOAA 6 satellite revealed a narrow band of cooler water in the Atlantic City area on the 15th that wasn't present on the 11th (Figs. 4 and 5).

The results of this study of wind and water temperature data from just one summer suggest that wind-driven upwelling does occur along the central New Jersey coast. More sophisticated analyses of summertime conditions in other years should be conducted before more extensive quantification or modeling is undertaken, however. Specifically, it would be important to test the assumption that 250° winds are the most effective for upwelling and to determine more accurately the lag time between wind conditions and water temperature changes.

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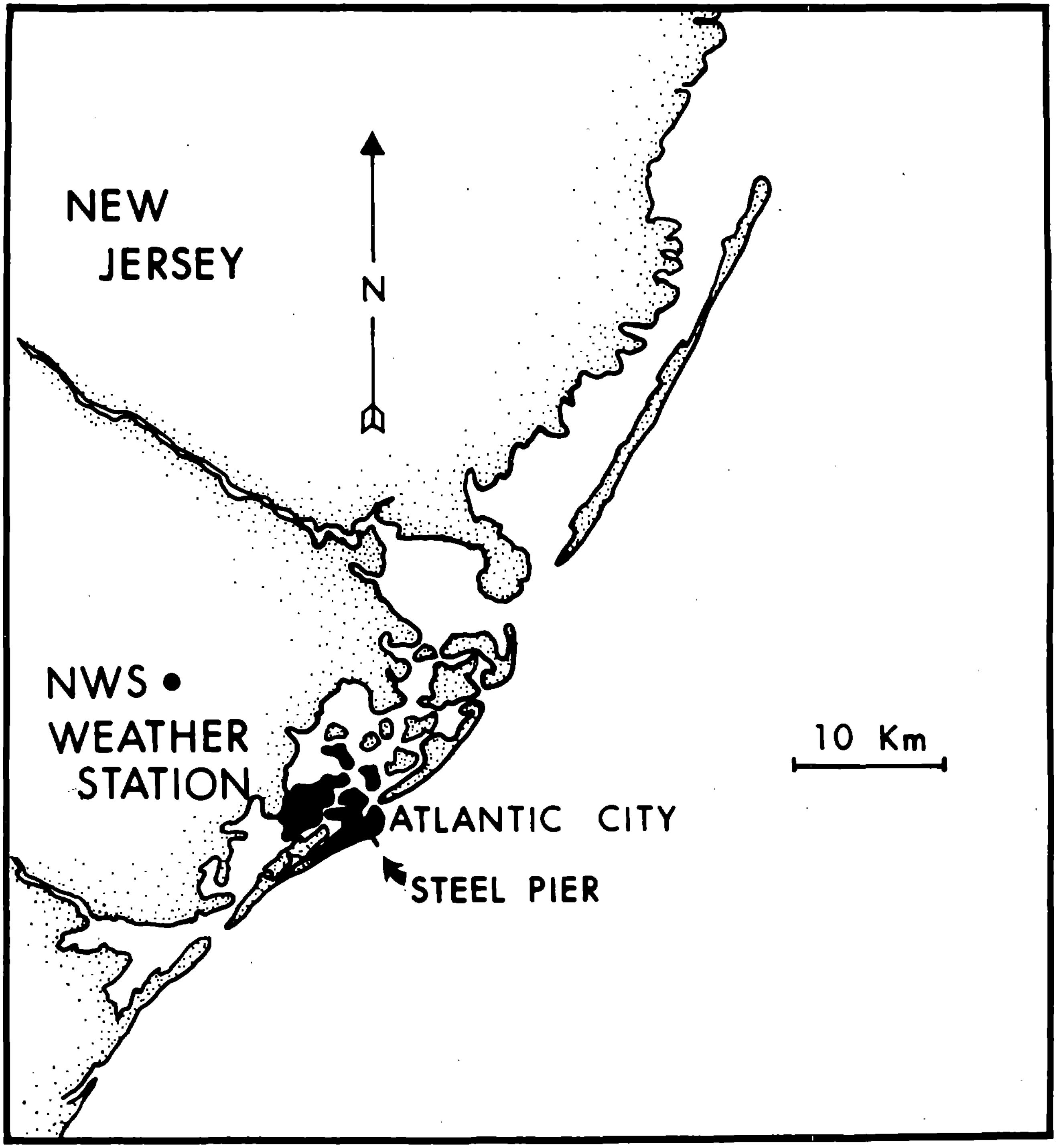

FIGURE 1. Location of the study area and points at which water temperature and wind velocity data were collected.

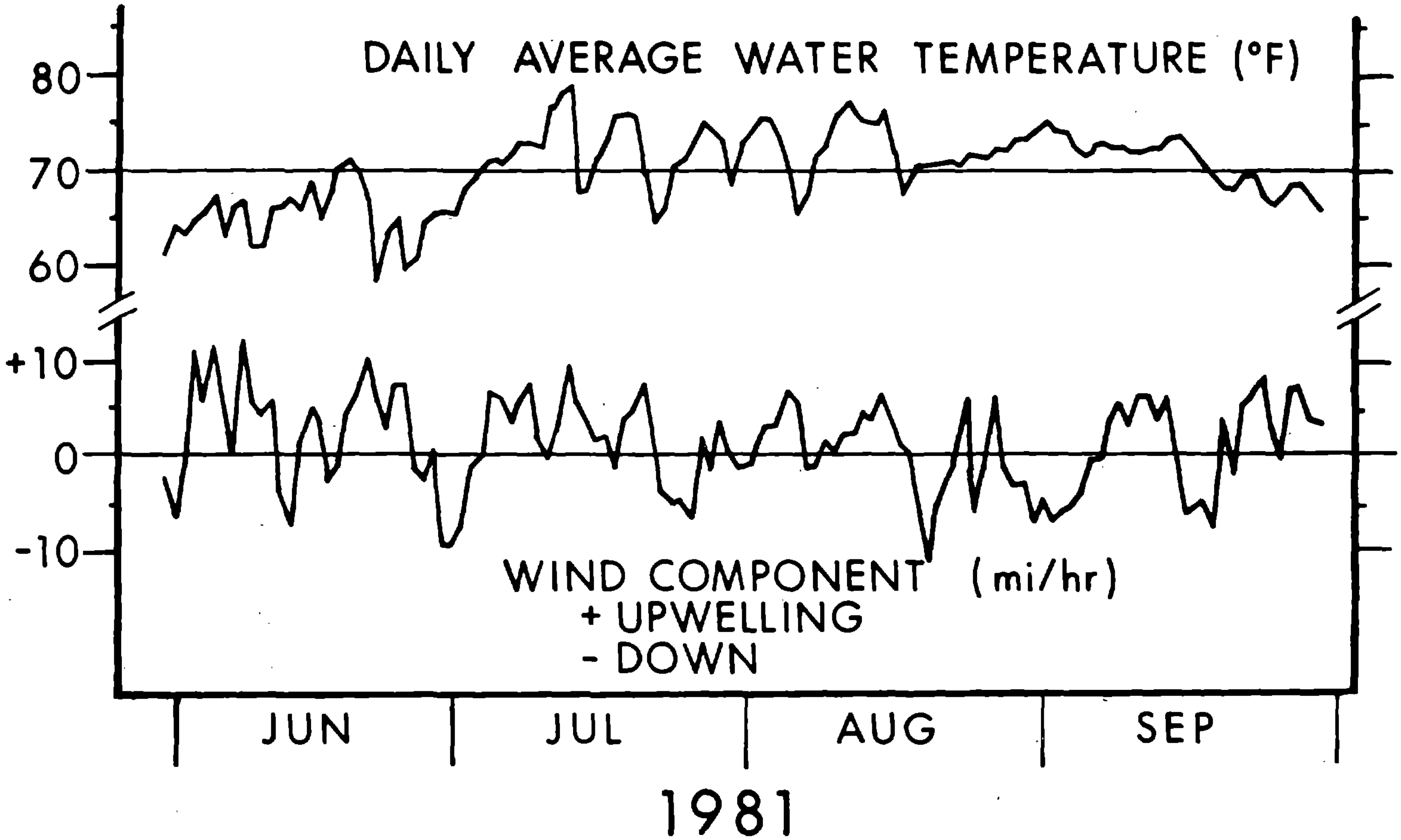

FIGURE 2. Trends in daily average water temperature (°F) measured at the Steel Pier and upwelling/downwelling wind component (mi/hr) from wind velocity measurements made at the Atlantic City weather station in 1981.

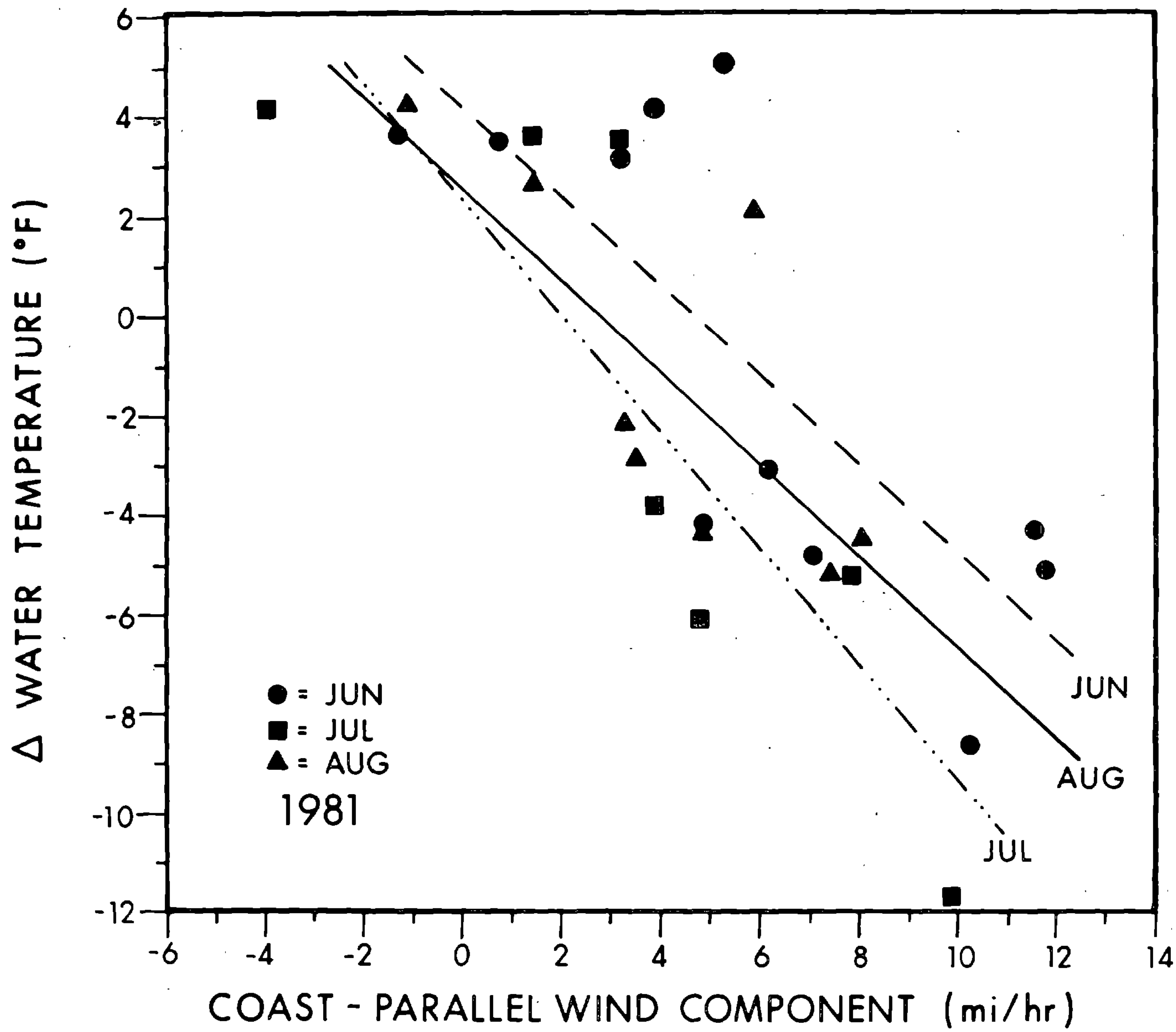

FIGURE 3. Best-fit linear regressions of water temperature change (°F) and upwelling (+)/downwelling (-) wind components (mi/hr) for high-pass filtered data (Δ water temperatures greater than 1 standard deviation from monthly mean).

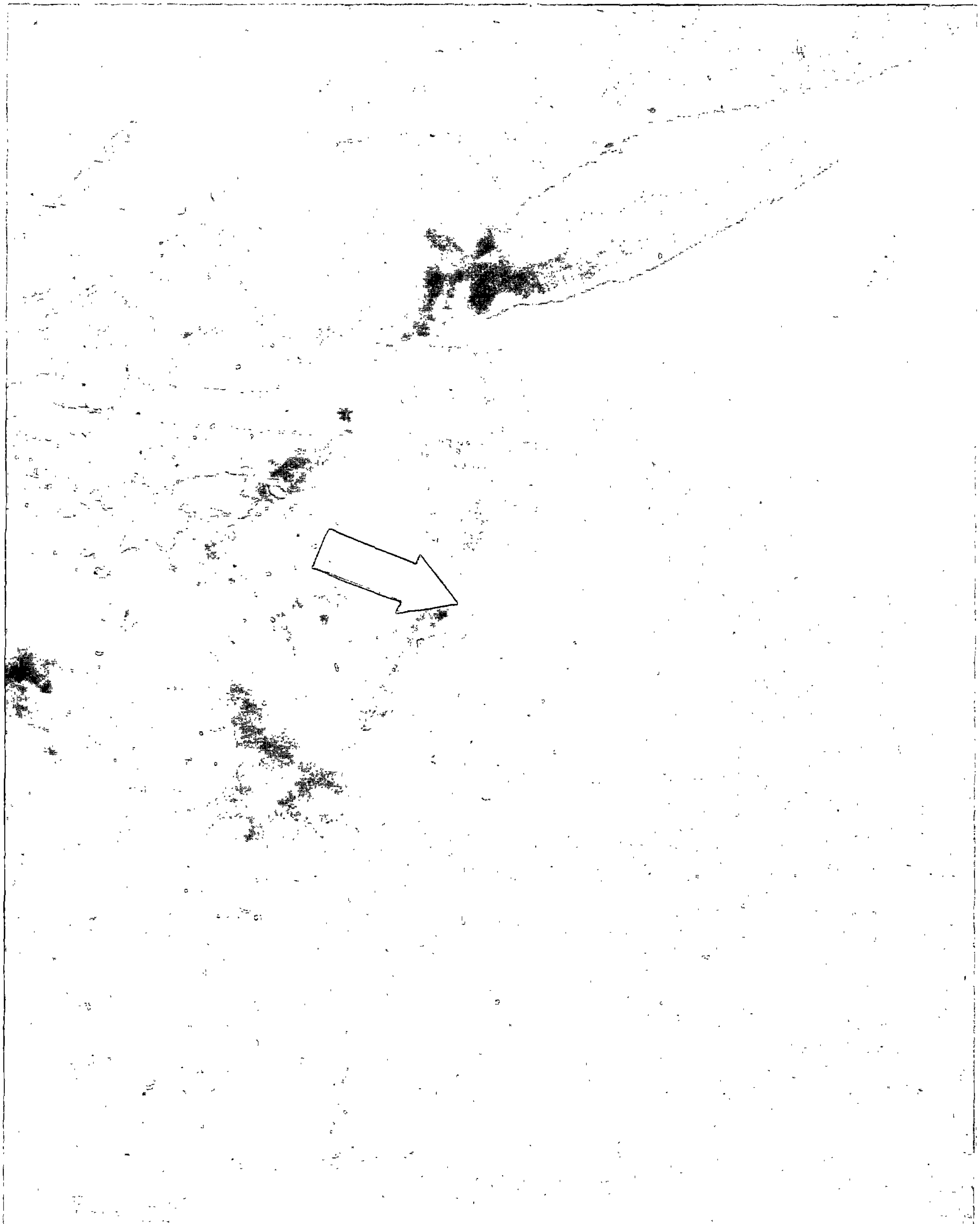

FIGURE 4. Infrared imagery from the NOAA 6 satellite for 11 July 1981. Arrow shows location of Atlantic City, New Jersey.

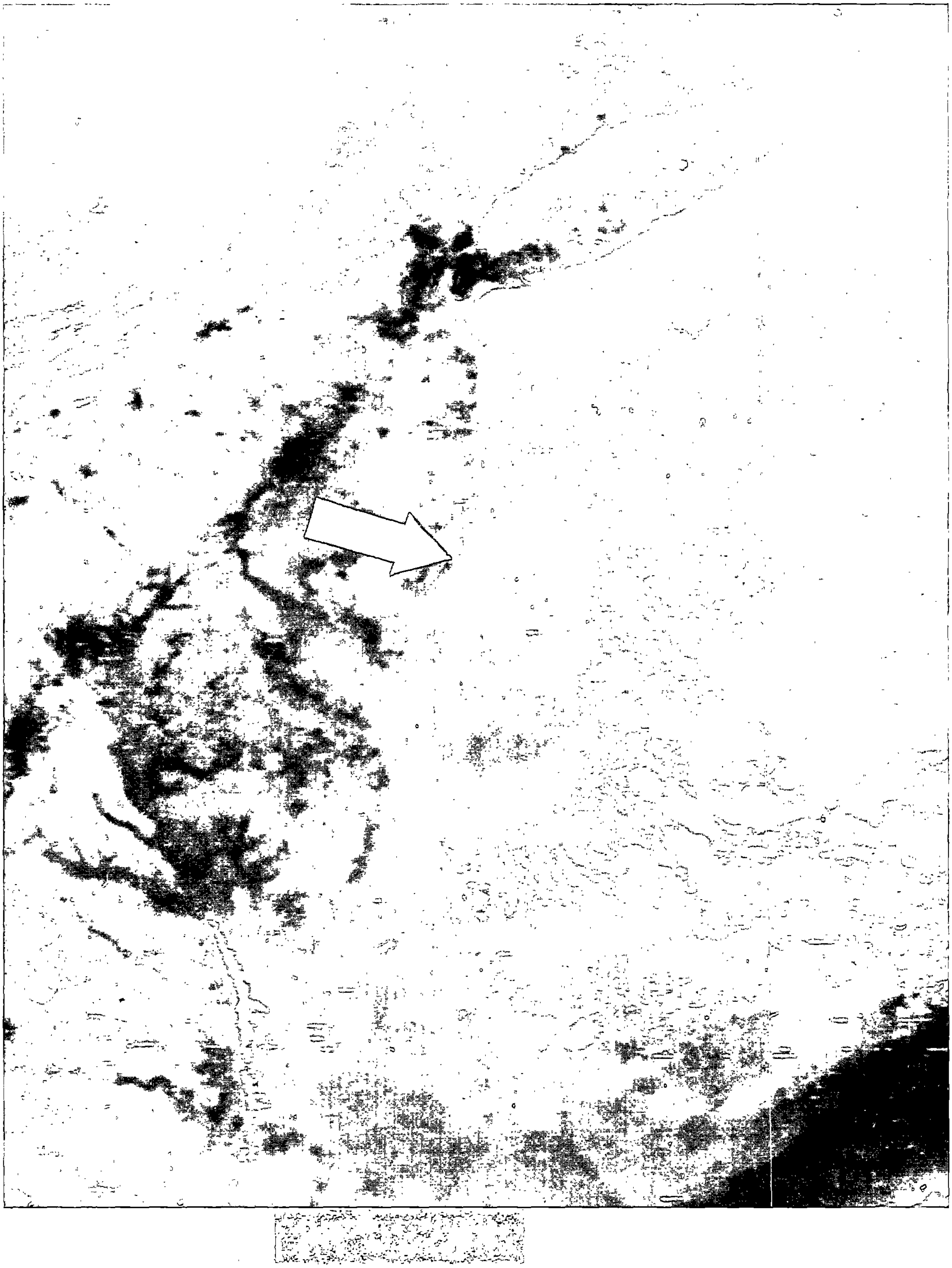

FIGURE 5. Infrared imagery from the NOAA 6 satellite for 15 July 1981. Arrow shows location of Atlantic City, New Jersey.