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Marine Climatology

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The offshore water in the bend of the Atlantic coastline from Long Island on one side to New Jersey on the other is known as New York Bight. This 15,000 square miles of the Atlantic coastal ocean reaches seaward to the edge of the continental shelf, 80 to 120 miles offshore. It's the front doorstep of New York City, one of the world's most intensively used coastal areas—for recreation, shipping, fishing and shellfishing, and for dumping sewage sludge, construction rubble, and industrial wastes. Its potential is being closely eyed for resources like sand and gravel—and oil and gas.

This is one of a series of technical monographs on the Bight, summarizing what is known and identifying what is unknown. Those making critical management decisions affecting the Bight region are acutely aware that they need more data than are now available on the complex interplay among processes in the Bight, and about the human impact on those processes. The monographs provide a jumping-off place for further research.

The series is a cooperative effort between the National Oceanic and Atmospheric Administration (NOAA) and the New York Sea Grant Institute. NOAA's Marine EcoSystems Analysis (MESA) program is responsible for identifying and measuring the impact of man on the marine environment and its resources. The Sea Grant Institute (of State University of New York and Cornell University, and an affiliate of NOAA's Sea Grant program) conducts a variety of research and educational activities on the sea and Great Lakes. Together, Sea Grant and MESA are preparing an atlas of New York Bight that will supply urgently needed environmental information to policy-makers, industries, educational institutions, and to interested people. The monographs, listed inside the back cover, are being integrated into this *Atlas of New York Bight*.

ATLAS MONOGRAPH 7 presents what we know about the climate of New York Bight in two ways: first, selected data illustrate the seasonal variation of meteorological parameters; second, isopleth maps and statistical graphs give a detailed climatic profile. The Bight coasts have a temperate, rainy climate with warm summers, no dry season, and rapid changes in weather from season to season, at times from day to day. Unique to the Atlantic coast between New England and North Carolina, says Lettau, is the major cyclonic storm track that passes through the outer Bight, following the New Jersey coastline. Because such storms intensify and move very rapidly, they present distinct weather forecasting problems for Bight coastal areas, especially since not all conditions favorable for storm formation actually produce a storm. According to Brower and Quayle, the atlas data provide the best possible climatological picture of the Bight's near-coastal zone, a region of sharp gradients and complex climates.

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16. ABSTRACT

The marine climatology of New York Bight is presented both as summaries of available data on those meteorological variables that make up the climate and as interactive processes among land, sea, and air that influence the meteorological variables and produce the distinctive marine climate. The data summaries consist of monthly averages of temperature, temperature anomalies, heating degree days, relative humidity, precipitation, wind, fog, and haze over the eastern, central, and southern portions of the Bight. The climate-forming processes active over the Bight include the effect of the heat reservoir on the sea surface, the sea breeze, and the effect of coastal geography on storms. The maps and graphs in the atlas present a detailed climatic profile of the Bight. Statistics include means, extremes, and percent frequency of occurrence of threshold values for these parameters: wind, visibility, present weather, sea level pressure, temperature, clouds and waves. (Author modified)

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MESA NEW YORK BIGHT ATLAS MONOGRAPH 7

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原书缺页

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The National Weather Service (NOAA) and the US Coast Guard provided the coastal station observations, which are routinely sent to NCC for archiving. Summarization of the data was made possible through programs designed at NCC and funded primarily by the Naval Weather Service Command in support of the marine atlas revision program. The Naval Weather Service also provided major support for acquisition of basic marine data.

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Abstract

The marine climatology of New York Bight is presented both as summaries of available data on those meteorological variables that make up the climate and as interactive processes among land, sea, and air that influence the meteorological variables and produce the distinctive marine climate. The data summaries consist of monthly averages of temperature, temperature anomalies, heating degree days, relative humidity, precipitation, wind, fog, and haze over the eastern, central, and southern portions of the Bight. The climate-forming processes active over the Bight include the effect of the heat reservoir on the sea surface, the sea breeze, and the effect of coastal geography on storms.

The maps and graphs in the atlas present a detailed climatic profile of the Bight. Statistics include means, extremes, and percent frequency of occurrence of threshold values for these parameters: wind, visibility, present weather, sea level pressure, temperature, clouds, and waves. The National Climatic Center (Asheville, NC) processed and analyzed data from 130,000 surface marine observations, 500,000 observations for six coastal land stations, and 50,000 observations at two light stations for the general period 1949 to 1974. These data provide the best possible climatological picture of the Bight's data-sparse, near-coastal zone, an area of sharp gradients and complex climates.

Introduction

The primary aim of this monograph is to give the reader an appreciation of the climate of a circumscribed area—New York Bight—in the northwestern region of the Atlantic Ocean and the adjacent North American continent. To do this, we must initially summarize and order the available meteorological and oceanographic data, then interpret the resulting mean conditions of the physical processes of the triple interface formed by the air, the sea, and the land. The ordering of the data leads to a description of the climate and may be called a *climatographical process;* it can be limited to the study area—in this case, the Bight. The interpretation of the data leads to an understanding of the climate and may be called a *climatogenetical process;* it has a wider domain because local processes act on, and are themselves the result of, characteristics acquired by the fluid atmosphere and ocean in their previous trajectories.

The climatography of the Bight is presented on two levels. First, the narrative section utilizes selected data as examples and illustrations of the seasonal variation of meteorological parameters. It is intended as an overview indicating the range and scope of the climatic variation. Second, a comprehensive summary of marine climatic data and climatic data for adjacent coastal stations is provided as a reference for specific values of climatological variables as a function of space and time over the Bight.

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Marine Climatology

Bernhard Lettau

The ultimate objective of marine climatology is to explain the time variation of the atmosphere's structure. This can be done by studying the energy exchange mechanisms at the air-sea interface, the physical parameters of the atmosphere and the sea, and, in a coastal environment such as New York Bight, the sharp discontinuity in the surface parameters at the shoreline. Though we can list the relevant factors easily enough, understanding each of the individual processes on the list is not so easy; our actual information about them is limited and sometimes nonexistent. For example, the heat capacities of air and seawater are known quite accurately. But how energy is divided between water evaporation and warming the air and the seawater at the interface can only be estimated from experiments limited in space and time; and the long-term atmospheric effect of a slow change in temperature of much of the ocean can only be guessed at. The Bight's marine climatology is a mosaic of schematic processes put together from limited observations–limited because of the high cost of maintaining permanent stations at sea.

A popular analogue to the atmosphere is a heat engine driven by solar radiation absorption. Although most of the absorbed energy is expended in maintaining the global radiation balance, a small fraction maintains the general atmospheric circulation, which in turn redistributes atmospheric energy. The important surface energy exchange processes involved are water evaporation at the sea surface *(latent heat flux)* and heat exchange between the ocean and atmosphere due to temperature differences *(sensible heat flux)*. Since the sea surface temperature is generally somewhat higher than the air temperature, sensible heat flux usually proceeds from the ocean to the atmosphere.

The typical structure of the atmosphere over the ocean–the marine climate–results from the relative magnitude of the latent and sensible heat fluxes. The ratio of energy used in heating the air to energy expended in evaporation is called the Bowen ratio. If water availability at the sea surface is limited, the ratio increases rapidly. A characteristic ocean value is 0.10, with some latitudinal variation (Sellers 1965). Since 10 times more energy is used in evaporation than in warming the air, the marine atmosphere typically has a high humidity.

A second reason marine temperatures are l extreme than temperatures over land is turbule mixing of the ocean's surface layer by the wind. Tl mixing distributes an energy gain or loss at the s surface through approximately 100 m (300 ft) water; consequently the ocean can give up or acce sizable amounts of energy without changing average temperature by very much.

Since the amount of energy available at the s surface decreases rapidly from the subtropics to t poles, oceanic evaporation also falls off rapid Rainfall reaches a maximum in mid-latitude a subpolar regions. Thus, the subtropical regions are t sources of atmospheric moisture, and the subpo regions are the sinks (receptors).

Within this broad framework of northwa transport of sensible and latent heat by the atm phere and of sensible heat by the oceans, the speci situation in the Bight is influenced by gene eastward atmospheric motions, which produce cert systematic differences between the climates of t west coasts and the east coasts of the northe hemisphere.

Mid-latitude weather systems move eastw because of a combination of the earth's sphericity, rotation, and the angle between its axis of rotati and the ecliptic plane. Small systems move eastw more rapidly than large systems, carrying typi marine effects inland along continental west coa but away from continental east coasts. One p nounced consequence of the east coast-west co difference is that along the Pacific coast August the highest average temperature, whereas along Atlantic coast July has the highest. Along the No American west coast the marine effects are limited a narrow strip by the coastal mountains, wh modify the air as it moves eastward; along European west coast nothing hinders the mar effects, which can occasionally be found thousand miles inland.

East of the Rocky Mountain barrier lies semi-permanent boundary between dry, polar, co nental air and moist, tropical maritime air. T boundary moves southward in winter and northw in summer (Bryson and Hare 1974), increasing seasonal temperature and humidity contrast c comparable latitudes along the west coast. Bry and Hare estimate that air of Arctic origin dominates the Bight intermittently for one or two months during the year; maritime air originating from the tropical Atlantic or the Gulf of Mexico dominates the Bight for nine to ten months. Occasional intrusions of mild and dry air originating over the Pacific dominate the area for the remaining month.

New York Bight's climatic setting is therefore governed by a series of energy exchange processes between the sea surface and the atmosphere—the latter an amalgam of air masses with different temperature and moisture characteristics influencing both the intensity and direction of the energy exchanges. The climatological statistics form a descriptive outline of the average structure of the atmosphere but are inadequate to reveal many of the details of the day-to-day interaction between the sea and the atmosphere.

Climatological Data

The most comprehensive source of marine meteorological data is the US Naval Weather Command Tape Data Family 11 or TDF-11 (US Naval Weather Command 1970). The TFD-11 areas that relate to New York Bight are shown on Map 1: Area 5, designated Quonset Point, extending from 40°N to 42°N and 69°W to 72°W; Area 6, designated New York, extending from 40°N and 72°W northward to the Connecticut coast and westward to the New Jersey coast; and Area 7, designated Atlantic City, extending from 38°N to 40°N and from 72°W to the coast. These areas correspond to sections of Marsden squares 151, 152, and 116, respectively.

Observations in TDF-11 were taken by ships of various registry traveling through these areas. The meteorological records, spanning roughly 100 years, do not form a homogeneous series because differences in observation techniques, variations in the accuracy and precision of instruments, and systematic biases (directly from a general tendency toward daytime observation and indirectly from a tendency toward fair-weather routing) introduce deviations from true climatological values. The integrated effect of these deviations cannot be estimated very well but may be assumed small in relation to the seasonal variation of the meteorological parameters.

Map 1 also shows nine climatic stations that have histories of accurate recordings. Five of the nine are National Weather Service offices. Although Seabrook is located outside the New Jersey coastal region, it was used as a solar energy data point, along with Central Park Observatory in New York City.

Air temperature is the most basic and familiar meteorological parameter and the most variable over space and time. It is affected by differences in the nature of the underlying surface, by variations in the radiant energy fluxes, and, for a given location, by temporal alterations of air masses of different origin. In the coastal zone the first two effects combine to produce higher daytime and summer maximum temperatures and lower nighttime and winter minimum temperatures over land than over sea.

Most important to the surface layers of the marine atmosphere—that is, those layers closest to the water—is the modification of temperature and humidity when continental air moves out over the ocean. Air at the surface rapidly warms if the continental air is colder than the sea surface because surface air density is decreased and vertical overturning and turbulent mixing are enhanced. The warming extends through a deep layer of the atmosphere and can sometimes reach altitudes of 10,000 ft (3,000 m) within a few hundred miles of the coast. The simultaneous increase in the moisture content characteristically leads to convective (cumulus) clouds.

If the continental air is warmer than the sea surface, surface cooling forms a temperature inversion (temperature increasing with height), which tends to stabilize the air by increasing its surface density. Turbulent mixing is suppressed, and modification is limited to the lowest atmospheric layers. If the sea surface temperature is below the air's dew point temperature (temperature at which condensation occurs if the air is externally cooled), water vapor may condense to form an advection fog (Jiusto 1964). With weak winds, the fog will extend from the sea surface to the level at which the dew point temperature falls below the air temperature; with strong winds, wind-generated turbulence will lift the fog layer above the sea surface to produce a low, dense, stratus cloud cover.

Turning now to mean monthly air temperatures over the Bight, we see that in the New York sector (Figure 1, top) values range from a minimum of 36°F (2°C) in February to a maximum of just above 72°F (22°C) in August. The annual range is about 36°F and half of all observations fall within about 8°F, increasing to roughly 10°F in winter and decreasing to 6°F in summer. The winter maximum results from extremely cold outbreaks of continental air that

Map 1. General locator

Climatic Data Stations

Cape May, 38°57'N, 74°56'W
elev 17 ft; individual observer

Atlantic City, 39°27'N, 74°34'W
elev 64 ft; observer—National Weather Service

Seabrook, 39°30'N, 75°14'W
elev 90 ft; observer—Seabrook Farms Company

Long Branch, 40°42'N, 74°10'W
elev 15 ft; individual observer

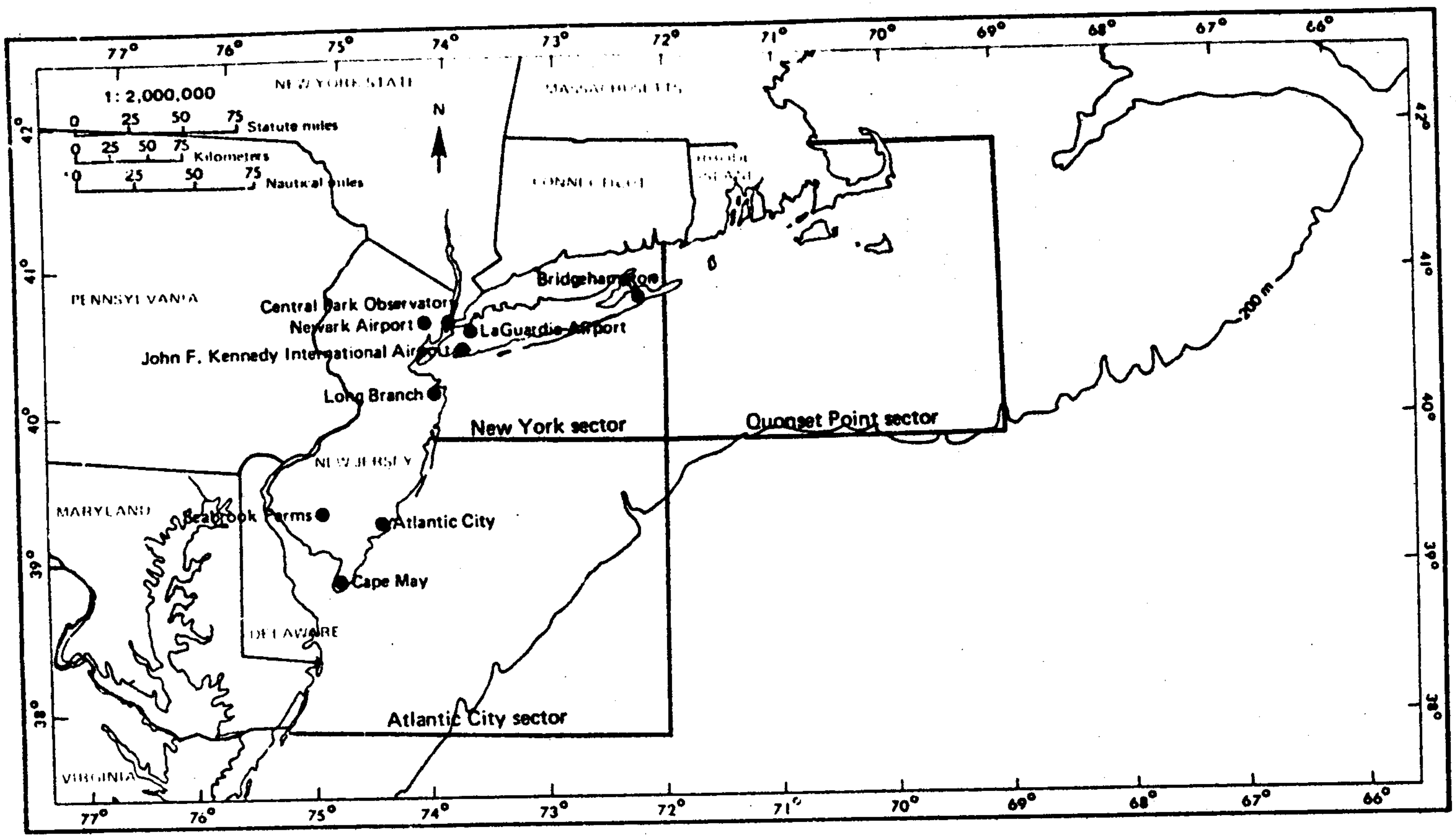
John F. Kennedy International Airport, 40°39'N, 73°47'W
elev 13 ft; observer—National Weather Service

LaGuardia Airport, 40°46'N, 73°54'N
elev 11 ft; observer—National Weather Service

Central Park Observatory, 40°47'N, 73°58'W
elev 131 ft; observer—National Weather Service

Newark Airport, 40°42'N, 74°10'W
elev 11 ft; observer—National Weather Service

Bridgehampton, 40°57'N, 72°18'W
elev 61 ft; individual observer



Lambert Conformal Conic Projection

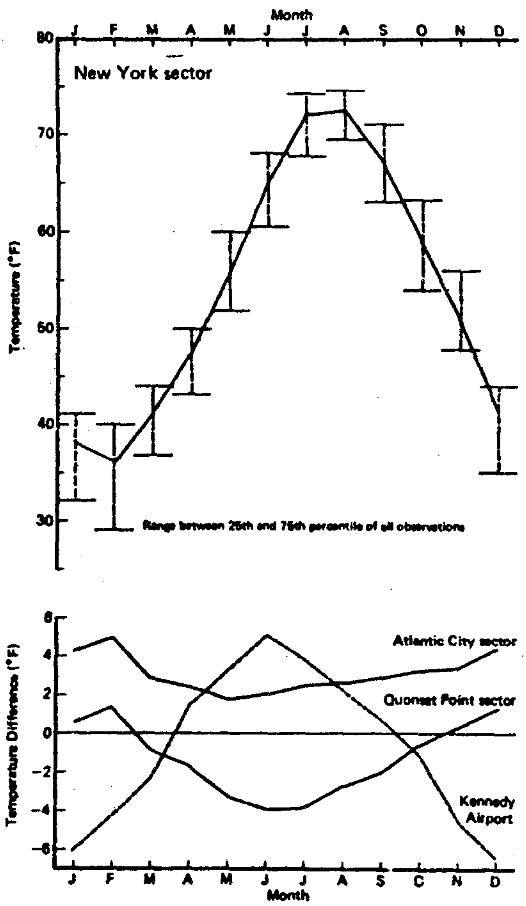


Figure 1. Air temperature variation and differences

retain low temperatures in spite of the rapid surface warming and turbulent mixing produced by the large air-sea temperature differences.

The monthly temperature deviations in the Quonset Point sector (Figure 1, bottom) are positive in winter (temperatures higher than in the New York sector) and negative in summer, ranging from +1.4°F (+0.8°C) in February to −3.8°F (−2.1°C) in June and −3.9°F (−2.2°C) in July. The annual range is therefore lower than in the New York sector, indicating that the New York sector has a more continental character. This is because the Quonset Point sector extends much farther seaward than the New York sector, and observations there on the average represent a more nearly complete adjustment of air temperature to sea surface temperature.

The monthly temperature deviations in the Atlantic City sector (Figure 1, bottom) show the same tendency as those in Quonset Point; however, they are positive throughout the year, ranging from a maximum of +5.1°F (+2.8°C) in February to a minimum of +1.9°F (+1.0°C) in May. Since the winter temperature deviation is greater than the average summer deviation, the annual range is less than in the New York sector, again emphasizing the continental nature of that sector.

The reversed trend of the Kennedy Airport line (Figure 1, bottom), which shows that this station is warmer in summer and colder in winter than the Bight, indicates that continental characteristics extend very close to the shore.

Figure 1 also suggests a seasonal shift in the trend of the *isotherms* (lines of equal temperature) over the sea. In winter the east-west temperature gradient in the Bight is relatively small (the New York and Quonset Point sector temperatures are more nearly the same), but the gradient southward is relatively high. In summer the east-west temperature difference is high and the north-south temperature difference is low (the New York and Atlantic City sector temperatures are more nearly the same). This implies a generally east-west trend of winter isotherms with high temperatures to the south and a generally north-south trend of summer isotherms with low temperatures to the east.

The distribution of the air-sea temperature difference is a measure of the degree of adjustment of an air mass to the underlying sea surface; it may be used to estimate the direction and magnitude of the sensible heat exchange between the air and the sea.

Air-sea temperature distributions in the New York, Quonset Point, and Atlantic City sectors do not differ significantly from one another but do vary seasonally (Figure 2). The January distribution has the greatest range, is skewed to the negative side (air colder than sea surface), and has a low but broad maximum. In the Quonset Point sector, no single modal value is evident; differences of −2°F to −8°F occur roughly 5% of the time. The distribution falls off relatively slowly on both the positive and negative sides, with values exceeding +5°F (+2.8°C) and −21°F (−11.7°C) approximately 5% of the time. In the New York sector there is a tendency toward a bimodal distribution in January, with peaks at temperature differences of −9°F (−5°C) and +1°F (+0.6°C); however, the intermediate minimum may be a spurious result of the small number of observations in this sector. The falloff toward higher and lower values is similar to that in the Quonset Point sector. In the Atlantic City sector January tends toward a rounded peak with maximum temperature differences between −5°F and −6°F (−3°C); in all other respects the distribution is virtually the same as that in the other two sectors.

The April distributions have a smaller range than those in January, reach a sharp and well-defined peak, and more nearly resemble normal distributions displaced toward the positive side of the scale. In the Quonset Point sector the maximum is at temperature differences of 1°F and 2°F, each occurring more than 9% of the time. The values +10.8°F (+6.0°C) and −5°F (−2.8°C) are exceeded 5% of the time.

The major difference between the April and January distributions in all sectors is the much greater frequency of positive temperature differences—a result of the contrast between the rapid warming of the atmosphere in spring, particularly over the continents, and the much slower warming of the sea surface.

The April distribution in the New York sector is nearly the same as in the Quonset Point sector. Although the modal value falls at +3°F (+1.7°C), its frequency of occurrence is only slightly higher than +1°F (+0.6°C) and +2°F (+1.1°C). The tendency toward a greater occurrence of high positive values may be because this sector does not extend so far seaward as the other two sectors.

The April distribution of the Atlantic City sector shows a lower maximum and a relatively greater frequency of large negative temperature differences than the other two sectors. Since the prevailing wind at Atlantic City is from the west, this is very likely the long-term effect of occasional cold air outbreaks over the somewhat warmer sea surface in this sector.

The July distribution of temperature differences in the Quonset Point sector is about the same as the April distribution. In the New York sector, large positive temperature differences occur less frequently in July than in April. In the Atlantic City sector, the July distribution is more sharply peaked than in the April distribution and also has lower frequency of occurrence of moderate and large positive temperature differences; increased frequency in this sector occurs near zero rather than at the moderate negative differences of the New York sector.

The October distribution of temperature difference strongly reflects the contrast between the still relatively warm ocean surface layers and the already occasionally cold atmosphere. In all three sectors the

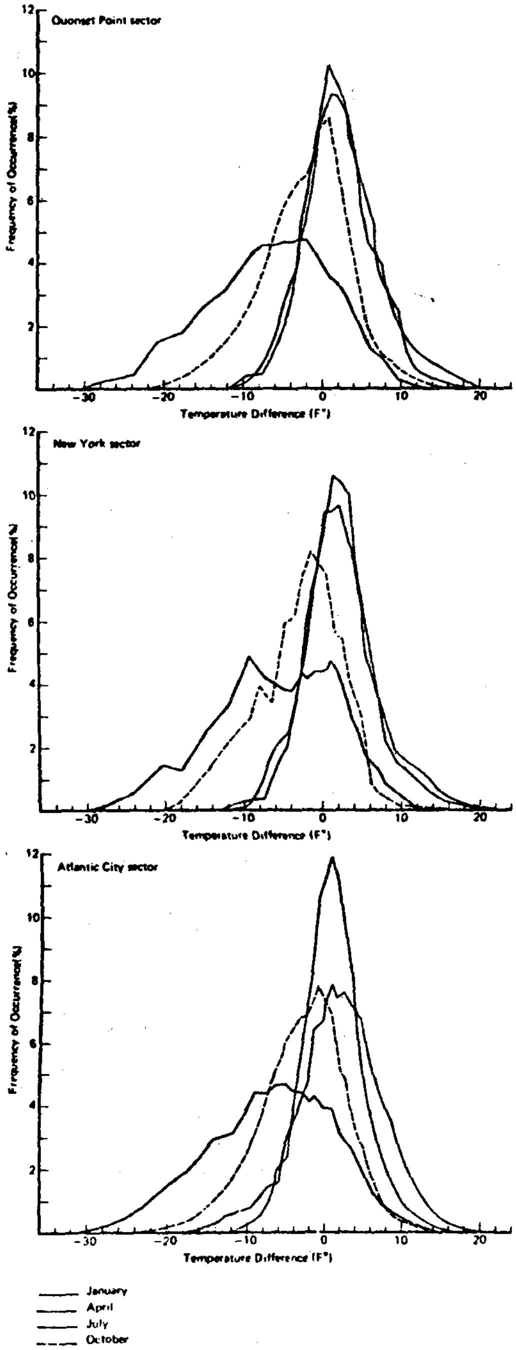


Figure 2. Distribution of air-sea temperature differences