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Weather Conditions and Trends in the Maine-Virginia Coastal and Offshore Areas During 1970-79

Merton C. Ingham
National Marine Fisheries Service, Atlantic Oceanographic Group
Narragansett, Rhode Island, 02882, USA

Abstract

Time series of monthly average values of air temperature, precipitation, and percentage sunlight, collected at six coastal weather stations during 1970-79 from Portland, Maine, to Norfolk, Virginia, were analyzed and interpreted. Wind stress data were computed from surface pressure measurements made on board ships and at coastal weather stations, and trends in average annual streamflow data for three areas in the region of interest are noted. Extreme conditions and trends showed rather extensive geographic continuity in the weather data. The most extreme occurrence during the decade of the 1970's was the record succession of three unusually cold and windy winters in 1976-77, 1977-78 and 1978-79. Other less extreme departures from average conditions are evident in the time series of data.

Introduction

The area covered in this review includes the coastal and offshore waters along the Atlantic coast of the United States from Maine to Virginia, oceanographically comprised of the Gulf of Maine, Georges Bank and the Middle Atlantic Bight. The last two are primarily areas of shallow water over the continental shelf, but the first includes a large area of deep water.

Summaries of long-term mean weather conditions have been prepared by Williams *et al*. (1977) and Godshall *et al*. (1980) for the Georges Bank (including Gulf of Maine) and Middle Atlantic Bight areas. Together, these summaries cover the geographical area of concern to this study rather well in terms of surface wind, visibility, air temperature (Georges Bank) and superstructure icing. Earlier atlases for the North Atlantic (Meserve, 1974; Naval Oceanographic Office, 1963; Naval Weather Service Detachment, 1976) include the area of interest in the broader portrayal of mean monthly or seasonal conditions.

According to Godshall *et al*. (1980), the northern part of the area of interest lies between the normal summer and winter locations of the Polar Front, yielding two distinctly different wind regimes in the two seasons. Summer (May-August) is characterized by southwesterly winds associated with large-scale circulation of subtropical anticyclones. Winter (October-March) winds are northwesterly or westerly, stronger than summer winds, and associated with smaller-scale circulation systems. For the southern part of the area of interest (Middle Atlantic Bight), Williams *et al*. (1977) attributed the northwesterly wind field of winter to the dominance of the Icelandic Low, yielding a seasonal mean of 7-9 knot (3.5-4.5 m/sec) winds from the west-northwest and northwest. The summer field is dominated by the Bermuda Subtropical High, characterized by southwest winds of 3.5-4.5 knots (1.8-2.2 m/sec).

In their discussion of estuarine and continental shelf circulation in the Middle Atlantic Bight, Beardsley and Boicourt (1981) summarized what was known about atmospheric forcing over the continental shelf. They pointed out that synoptic scale (>2 days, >500 km) disturbances are responsible for most of the surface wind variance over the continental shelf and open ocean. This is manifested in the Middle Atlantic Bight as frequent intense cyclones, averaging 2.5 per month in summer and 5 per month in winter, the latter being more intense. The cyclones are produced by the interaction between warm moist air offshore and cooler drier air over the continent. They characteristically move northeastward along the coast toward Georges Bank and Nova Scotia, intensifying as they move. The mean surface wind stress is eastward to southeastward except in summer when it is northeastward, and the mean stress is generally stronger offshore (2-8 times at the shelf edge) and veers cyclonically (up to 30°) with increasing distance offshore.

Air temperature in winter over the coastal waters from Maine to Virginia is strongly influenced by the cold continental air masses moving over the ocean during episodes of strong westerly and northwesterly winds. During the summer, however, sea-surface temperature has the strongest influence on air temperature during the period of southwesterly winds. Average monthly air temperatures along the New York and New Jersey coasts (Lettau *et al*., 1976) show a minimum of about 2°C in January-February and a maximum of about 25°C in July-August, with autumn cooling occurring more rapidly than spring warming

(-4.4° C/month versus +4.0° C/month). Seaward from the coast, the magnitudes of the minimum and maximum would be moderated, but the profile of the annual cycle would be similar. About 100 km off the New Jersey coast, the January-February minimum is about 4° C and the July-August maximum about 25° C. Southward in the vicinity of Norfolk, Virginia, for the same distance offshore, the minimum is about 7° C and the maximum about 26° C. In the Gulf of Maine, the minimum average air temperature is about 0° C and the maximum about 18° C (Naval Weather Service Detachment, 1976).

Year-to-year and short-term (one or two decades) variations in wind condition and air temperatures can be considerable and mask longer-term trends. For example, the mean annual air temperature at New Haven, Connecticut (Fig. 1) show interannual variations greater than 2° F (1.1° C), short-term trends up to about 4° F (2.2° C), and longer-term trends generally more than 2° F. If this temperature record is considered diagnostic, the decade of the 1970's was a period of rapid warming (about 4° F) with interannual changes up to 2° F, following warming in the 1960's and rapid cooling in the 1950's, superimposed on a 50-year warming trend of about 2° F and a century-long warming trend of about 4° F.

Data Sources and Processing

Meteorological data covering the Maine-Virginia coastal and offshore waters are not abundant. The highest quality data spanning the 1970-79 decade are those collected at weather stations located near the coastline: Portland, Maine; Boston, Massachusetts; Providence, Rhode Island; New York City, New York; Atlantic City, New Jersey; and Norfolk, Virginia (Fig. 2). Data and departures from long-term means are published regularly for these stations in the form of monthly and annual summaries called "Local Climatological Data" (LCD) sheets by the Climate Center of NOAA (National Oceanic and Atmospheric Administration), located at Asheville, North Carolina. The following data were selected from the LCD sheets for portrayal and interpretation in this review:

1. Monthly average air temperature departures for the 1970's were prepared by subtracting the long-term monthly mean station air temperature (1941-60 for Atlantic City, 1931-60 for other stations) from the mean air temperature recorded for each station in each month.
2. Monthly total precipitation departures for the 1970's were obtained by subtracting the long-term monthly mean measurements of precipitation from the monthly totals recorded for each station in each month.
3. Percent possible sunlight was calculated by dividing the cumulative period of measured effective sunlight each month by the calculated total possible period of sunlight for each station in each month. Since 1953, all sunlight duration data recorded at weather stations in the United States have been collected with a photoelectric "sunshine switch". It is activated by sunlight bright enough to permit an object exposed in the sun to cast a shadow and record the amount of time each day that the sunlight was this bright or brighter.

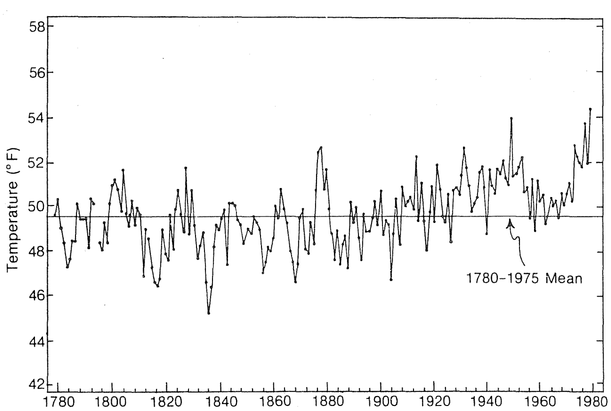

Fig. 1. Variation in mean annual air temperature at New Haven, Connecticut, 1780-1979. (Plot and mean for 1780-1975 prepared by National Climate Center, Asheville, North Carolina; extension to 1979 added with data furnished by National Climate Center.)

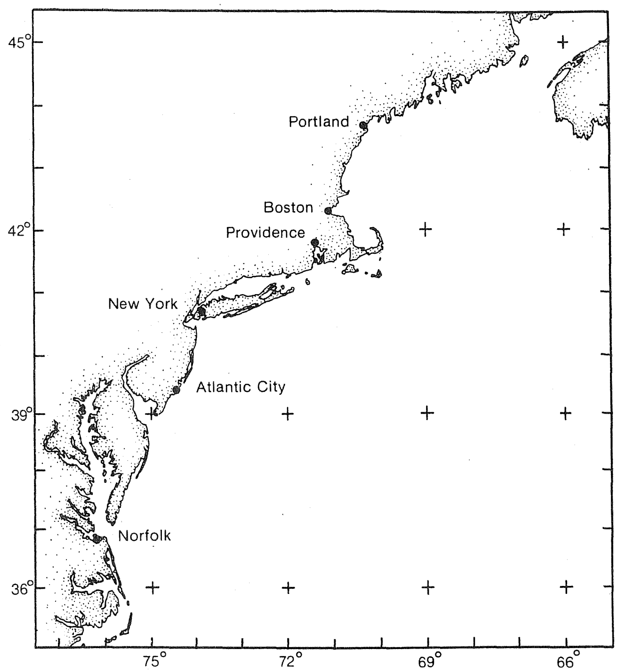

Fig. 2. Locations of six coastal weather stations whose data were used in this paper. The crosses indicate eleven grid points from which computed wind stress data were pooled.

Wind field conditions over coastal and offshore waters were portrayed by utilizing wind stress indices collected from ships and coastal weather stations by the Pacific Environmental Group of the U. S. National Marine Fisheries Service, using a method described by Bakun (1973). Eleven grid points were selected as being reasonably representative of the area of interest, and average monthly meridianal and zonal indices of wind stress were computed for the 11 data points for each month of the 10-year period.

Results and Discussion

Air temperature departures (Fig. 3) recorded at coastal weather stations are most meaningful oceanographically in the October-March period when winds are predominantly from northwest or west-northwest, driving cool dry continental air seaward over coastal and offshore waters, cooling and mixing them. During the other months of the year, the coastal air temperatures are strongly influenced by warm moist southerly winds. The most outstanding departures during 1970-79 occurred in the winters of 1976/77, 1977/78 and 1978/79. Negative departures showed at each of the weather stations and were generally stronger south of Providence.

These three winters were truly anomalous over a much broader area than that covered by the data presented in Fig. 3. Diaz and Quayle (1980) analyzed temperature and precipitation records for these winter periods in the United States and found that the occurrence of three consecutive severe winters was unprecedented in weather records since the 1890's, with January 1979 being the coldest on record for the country and January 1977 being the second coldest. The five winters preceding that of 1976/77 (Fig. 3) showed major positive air temperature departures up to 10° F (5.6° C) generally lasting 2-4 months, but up to 8 months in the case of Norfolk during 1973-74.

Patterns of variation in precipitation at the coastal weather stations (Fig. 4) are not as informative as the

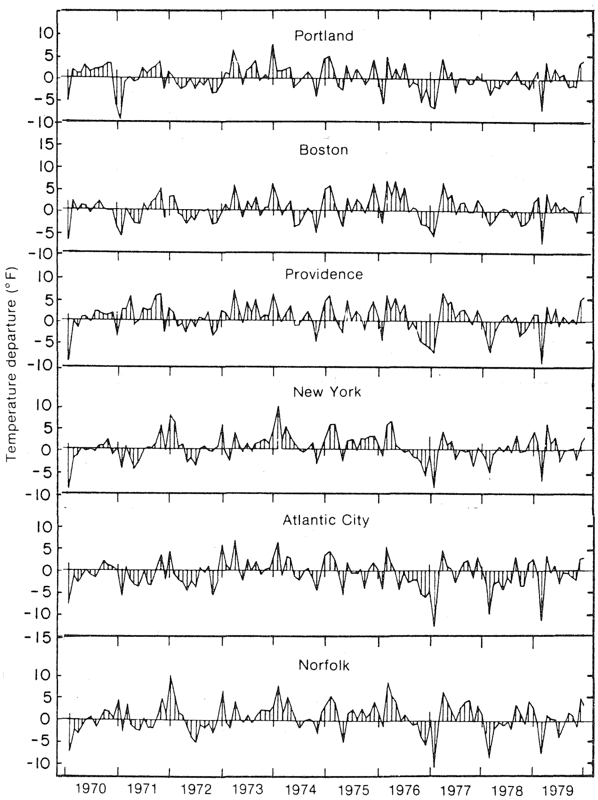

Fig. 3. Monthly average air temperature departures for 1970-79 from means for 1931-60 at coastal weather stations (1941-70 at Atlantic City).

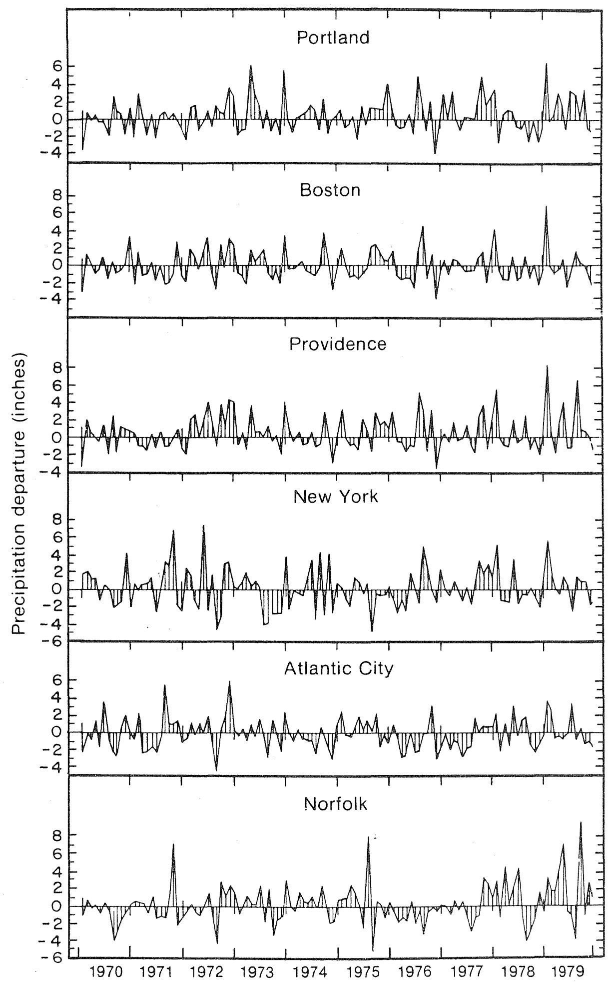

Fig. 4. Monthly average precipitation departures for 1970-79 from means for 1931-60 at coastal weather stations (1941-70 at Atlantic City (1 inch = 2.54 cm).

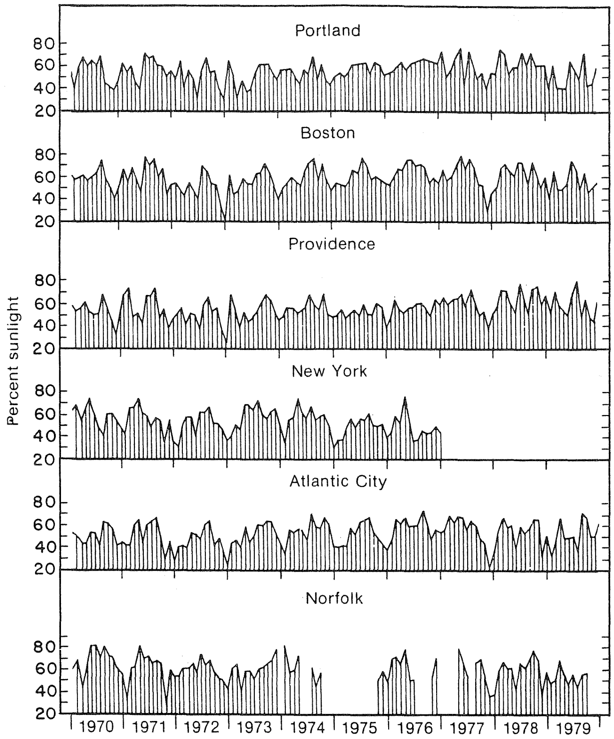

Fig. 5. Monthly percentage effective sunlight recorded at coastal weather stations, 1970–79.

air temperature patterns, nor is geographical continuity as extensive, extreme departures being repeated at only three or four of the stations. The winters which were anomalous in regard to air temperature were not correspondingly anomalous with respect to precipitation.

Since stream discharge into coastal waters may be more informative and more significant with respect to the marine environment than precipitation records, annual mean values of streamflow into Chesapeake Bay and Long Island Sound and the flow of the Merrimack River for two decades (1960–79) were obtained from reports of the U. S. Geological Survey (Fig. 5). The most apparent conclusion from these data is that there was greater streamflow into the coastal environment during the 1970's than in the 1960's, the increase averaging about 40% in each area.

Monthly percentage values of effective sunlight at the coastal weather stations (Fig. 6) show remarkable geographical continuity for extreme events. The relatively high values of November 1976 and the unusually low values of November 1977 are clearly shown for all stations south of Portland. Also, the unusually high values during February-March ("spring-bloom" months for phytoplankton) of 1978 show at all reporting stations (New York record incomplete). During 1973–78, there appears to have been a gradual increase in effective sunlight (about 10–15%) in winter and early

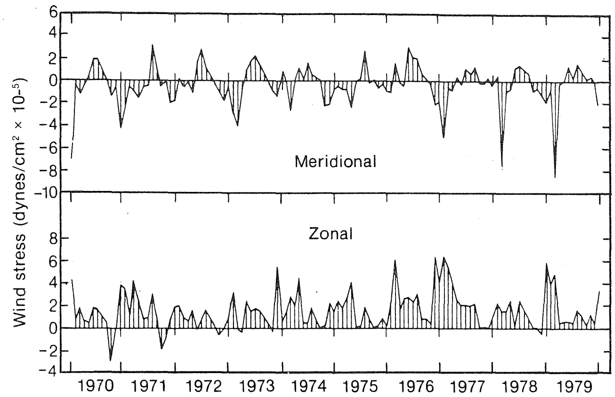

Fig. 6. Computed indices of monthly wind stress components in 1970–79 for 11 grid points indicated in Fig. 2. (Positive values northward for meridianal component and eastward for zonal component.)

spring at all except the New York and Norfolk Stations. The geographical continuity shown in these records implicates differences in air mass conditions on a synoptic scale (>500 km) possibly significant to phytoplankton productivity throughout the area.

Monthly average wind stress indices (Fig. 7) for the area of interest show striking year-to-year and multiyear differences. The most apparent of these are the early months of 1977, 1978 and 1979 when the southward (meridianal) stress (northerly wind) was greater than in any other year of the decade. These values are characteristics of the three consecutive record-cold winters experienced in the region. During 1977 and 1979, the eastward (zonal) stress was also comparatively high, implying that these two winters experienced unusually strong or persistent northwesterly winds.

The minimum eastward stress usually occurred each year in September or October. However, during the first 4 years of the decade, westward stresses were recorded for September or October, and this did not occur again until October 1978. Maximum eastward stresses usually occurred in the January-April period. The largest northward wind stresses usually occurred each year in late spring and summer, the years 1972, 1973 and 1976 being prominent in this regard. During the spring and summer period of 1976, anoxic or near-anoxic bottom water developed in a large area off New Jersey, which led to an extensive kill of benthic and epibenthic organisms, and the persistent southerly winds (northward stress) during that period have been hypothetized as one of the contributing factors.

Possible Effect on Marine Environment

The most outstanding meteorological event in the 1970–79 decade was the succession of three unusually

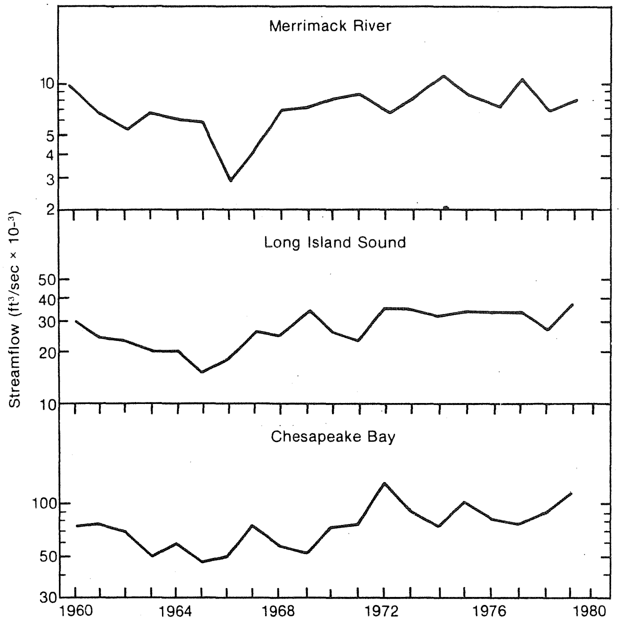

Fig. 7. Average annual streamflow for 1960-79 into Chesapeake Bay and Long Island Sound, and in the Merrimack River (Massachusetts) which is used as an "index stream" by the U. S. Geological Survey.

severe winters: 1976/77, 1977/78 and 1978/79. They left a strong signature throughout the region from Maine to Virginia. During the months of December to March, larvae of several species (e.g. cod, pollock and sand lance) are present in the water column on Georges Bank and in adjacent areas. The impact on larvae of strong northwesterly winds, especially in 1976/77 and 1978/79, and of the unusually low air temperatures is a matter of conjecture. Certainly, vertical mixing of the water would be maximized by the cold windy conditions. Also wind-driven surface-layer transport to the south or southeast should have been strong, possibly carrying significant numbers of the larvae off the Bank and adversely affecting the year-class strength of one or more of the species. On the other hand, the unusually vigorous vertical mixing should have increased the concentration of nutrients in the photic zone, perhaps leading to increased phytoplankton productivity and providing better forage for fish larvae in the water column in the spring. Fishery biologists and oceanographers should examine time series of relevant biological and chemical data for possible variations resulting from the anomalous weather conditions described in this paper.

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