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

by

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

INTRODUCTION

The area covered by this summary includes the coastal and offshore waters of the middle Atlantic and New England states of the U.S.A., oceanographically comprised of the Middle Atlantic Bight, Georges Bank, and the Gulf of Maine. The first two are primarily areas of shallow water over the continental shelf, but the latter includes major areas of deeper water.

Summaries of long-term mean weather conditions have been prepared for the Middle Atlantic Bight and Georges Bank (includes Gulf of Maine) by Williams, et al. (1977) and Godshall, et al. (1980). Together, the two summaries cover the geographic 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 (U.S. Navy Weather Service Command, 1974, U.S. Naval Oceanographic Office, 1963, and U.S. Naval Weather Service Command, 1976) include our area of interest in their broader portrayal of mean monthly or seasonal conditions.

According to Godshall, et al. (1980) the northern part of our area of interest falls between the normal summer and winter locations of the Polar Front, yielding two distinctly different wind regimes in the two seasons. Summer (actually May-August) is characterized by southwesterly winds associated with large-scale circulation of subtropical anticyclones. Winter

(October-March) winds are northwesterly or westerly, stronger, and associated with smaller-scale circulation systems.

For the Middle Atlantic Bight, the southern part of our area of interest, Williams et al. (1977) attribute the northwesterly wind field of winter to the dominance of the Icelandic Low, yielding a seasonal mean of 7-9 knots (3.5-4.5 m/s) from the WNW-NW. The summer wind field is dominated by the Bermuda Subtropical High, characterized by SW winds of 3.5-4.5 knots (1.8-2.2 m/s).

In their discussion of estuarine and continental shelf circulation in the Middle Atlantic Bight, Beardsley and Boicourt (1981) summarize what is known about atmospheric forcing over the continental shelf. They point out that synoptic scale (>2 days, >500 km) disturbances are responsible for most of the surface wind variance over the shelf and open ocean. This is manifested in the Middle Atlantic Bight as frequent, intense cyclones; 2.5 per month in summer, 5 per month in winter and more intense in winter than in summer. The cyclones are produced by the interaction between warm, moist, maritime air offshore and cooler, drier, continental air, and characteristically move northeastward along the shelf toward Georges Bank and Nova Scotia, intensifying as they move. The mean surface wind stress is eastward-southeastward except in summer, when it is northeastward, and the mean stress is generally stronger offshore (2 to 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 W-NW winds. During the summer period, however, sea surface temperature has the strongest influence on air temperature, during the period of southwesterly winds. Lettau et al. (1976) prepared a plot of monthly average air temperatures along the New York and New Jersey coasts which shows a minimum of about 2°C in January-February and a maximum of about 25°C in July-August. According to the plot, fall cooling occurs more rapidly than spring warming, -4.4°C/month vs. +4.0°C/month. Farther seaward the magnitudes of the minimum and maximum would be moderated, but the profile of the annual cycle would be very similar. About 100 km off the New Jersey coast, the January-February minimum is about 4°C and the July-August maximum is about 25°C. Southward, in the vicinity of Norfolk, the same distance offshore, the minimum is about 7°C and the maximum is about 26°C. In the northern portion of our area of interest, in the Gulf of Maine, minimum average air temperatures are about 0°C and the maximum is about 18°C (Naval Weather Service Detachment, 1976).

Year-to-year and short-term trend (one or two decades) variations in wind and air temperature conditions can be considerable and tend to mask long-term trends. For example, the mean annual air temperature at New Haven, Connecticut (fig. 1) for 1780-1979 shows inter-annual variations greater than 2°F, short-term trends up to about 4°F and longer term trends generally more than 2°F. If we treat this temperature record as diagnostic, the decade of the 70's could be considered as one of rapid warming (about 4°F), with inter-annual changes of up to about 2°F, following warming in the 60's and cooling in the 50'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

Time series meteorological data covering the decade of the 70's in the Maine-Virginia coastal and offshore area aren't abundant. The highest quality data sets spanning the whole time period are those collected at the first-order weather stations located near the coastline: Portland, Maine; Boston, Massachusetts; Providence, Rhode Island; JFK International Airport, 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 National Climatic Center of the National Oceanic and Atmospheric Administration, located in Asheville, North Carolina. The following data were selected from those on the LCD's for portrayal and interpretation in this summary:

Monthly average air-temperature departures prepared by subtracting the long-term monthly mean station air temperatures (1931-1960 period, except 1941-1970 for Atlantic City) from the monthly average air temperature recorded for each station each month.

Monthly total precipitation departures obtained by subtracting the long-term monthly mean station measurements of precipitation from the monthly totals recorded for each station each month.

Percent possible sunlight calculated by dividing the cumulative period of measured effective sunlight each month by the calculated total possible period of sunlight for each station each month.

Since 1953 all sunlight duration data recorded at weather stations (about 160) in the United States have been obtained with a photo-electric "sunshine switch". The instrument is activated by sunlight bright enough "-- to permit an object exposed in the sun to cast a shadow", and it records the amount of time each day that the sunlight was this bright or brighter.[(1)]

Wind field conditions over coastal and offshore waters were portrayed by utilizing wind stress indices routinely computed on a 3° grid (fig. 2) from atmospheric pressure data collected from ships and coastal weather stations by the Pacific Environmental Group of the National Marine Fisheries Service, using a method described by Bakun (1973). Eleven grid points were selected as being reasonably representative of our area of interest, and average monthly meridional and zonal indices of wind stress were computed for the eleven data points for each month of the 10-year period.

TIME SERIES PORTRAYALS OF METEOROLOGICAL DATA

The meteorological variables introduced in the preceding narrative are portrayed in time series graphs with 120-month bases in figures 3-6. The variables derived from coastal weather station data are segregated so that each figure (3, 4, 5) deals with a single variable, with six graphical bands, one for each coastal station. Portrayal of the variables in this way makes it relatively simple to identify events which had rather broad geographic continuity by scanning the bands for repetition of graphical features.

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 the WNW-NW, driving cool, dry continental air over coastal and offshore waters, cooling and mixing them. During the other months of the year the coastal air temperature record would be strongly influenced by marine air carried by southerly winds, thus approximately

(1) From "A History of Sunshine Data in the United States 1891-1980. Unpub. Rep. by Fred Doehring, National Climate Center, NOAA, Asheville, NC.

reflecting coastal water temperatures, whenever southerly winds prevail.

Accordingly, the most outstanding and significant departures in the 1970-79 air temperature record occurred in the winters of 1976-77, 1977-78 and 1978-79. Negative departures showed at each of the weather stations, and generally were stronger south of Providence. The longest time period covered by the departures occurred in late 1976 and early 1977, when negative values were recorded for periods ranging from 5 to 7 months, peaking in January 1977.

These three winter periods were truly anomalous over a much broader area than our area of interest. Diaz and Quayle (1980) analyzed temperature and precipitation records for these winter periods and found that the occurrence of three consecutive severe winters in the continental United States was unprecedented in weather records since the 1890's. January 1979 was the coldest on record for the country and January 1977 was the second coldest.

The five winters preceding that of 1976-77 showed major positive air temperature departures of up to 10°F (5.6°C), generally lasting 2-4 months, but up to 8 months in one case (Norfolk, 1973-74). Perhaps this series of mild winters is part of the reason the succeeding three cold winters were so striking to us.

Patterns of variation of precipitation at the coastal weather stations (fig. 4) are not as regular or as informative as the air temperature patterns. Geographic continuity is not as extensive either; extreme departures may be repeated at just 3 or 4 of the stations. The winters which were anomalous in regard to temperature did not appear to be correspondingly anomalous in precipitation.

Records of stream discharge into the coastal zone may be more informative and more significant for the marine environment. Figure 7 shows annual mean streamflow into Chesapeake Bay and Long Island Sound re-plotted from reports of regional offices of the U.S. Geological survey and flow of the Merrimack River plotted from data furnished by a local office of the U.S. Geological Survey(2). The most apparent conclusion to be drawn from these plots is that the decade of the 70's witnessed considerably greater streamflow into the coastal environment than the decade of the 60's, with each area receiving about 40% more in the 70's.

(2) U.S. Dept. of Interior, Geological Survey, Water Resources Division, Room 224, Pastore Federal Bldg., Providence, RI 02903. H. E. Johnston, Chief, Subdistrict Office.

Monthly values of percent possible sunlight at the coastal weather stations (fig. 5) show remarkable geographic continuity for extreme events. For example, the relatively high values of November 1976 and the unusually low values of November 1977 are clearly shown in each of the records south of Portland, Maine. Also, the unusually high values during February and March ("spring bloom" months for phytoplankton) of 1978 show in all records from all the stations reporting (New York record incomplete). During 1973-1978 there appears to be a gradual increase in effective sunlight (about 10-15%) in winter and early spring, showing in the Portland, Boston, Providence, and Atlantic City records. The geographic continuity shown in these records implicates synoptic scale (>500 km) differences in air mass conditions on a scale possibly significant to phytoplankton productivity throughout the area.

Monthly average wind stress indices (fig. 6) for the area of interest show some striking year-to-year and multiyear differences. Perhaps the most apparent of these are in the early months of 1976, 77, 78 and 79, when the southward stress (northerly wind) went from the lowest value of the decade to the highest. The 1977, 78 and 79 values are characteristics of the three consecutive record cold winters experienced off the Middle Atlantic and New England states. During 1977 and 79 the eastward stresses also were comparatively high, which means that these two winters experienced unusually strong or persistent northwesterly winds.

The minimum eastward wind stress generally occurred each year in September or October. In the first four years of the decade, however, westward stresses were computed for September or October; this did not occur again in that season until October 1978. Maximum eastward wind stress values generally occurred in the January-April period. The largest values for this period occurred in 1976 and 1977.

Late spring and summer showed the largest northward wind stresses each year. The years 1972, 73 and 76 stand out in this regard, with relatively large stresses over a five-month period. Spring and summer of 1976 was the period during which a large area of anoxic or near-anoxic bottom water developed off New Jersey, leading to an extensive kill of benthic and epibenthic organisms, and the persistent southerly winds (northward stress) during that period have hypothesized to be one of the contributing factors.

SUMMARY

The most outstanding meteorological event in the decade of the 70's as revealed by the variables treated here was the succession of three unusually severe winters: 1976-77, 1977-78 and 1978-79. They left a strong signature in the air temperature and wind stress records, throughout the area of interest. During the December-March periods involved, larvae of several species, including cod, pollock and sand lance, are present in the water column on Georges Bank. The impact of the strong northwesterly winds, especially in 1976-77 and 1978-79, and the unusually cold air temperatures is at this time a matter of conjecture. Certainly, vertical mixing of the waters would be maximized by the cold windy conditions. Also, wind-driven surface layer transport to the S-SE should have been strong, possibly carrying a significant number of larvae off the Bank into the much deeper slope water environment, perhaps adversely affecting the year-class 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.

We hope that fishery biologists and oceanographers with relevant biological and chemical data will scan them for variations possibly resulting from the anomalous weather conditions described.

REFERENCES

Bakun, Andrew. 1973. Coastal Upwelling Indices, West Coast of North America, 1946-71. NOAA Technical Report NMFS SSRF-671. U.S. Department of Comm., NOAA, Wash., DC, 103 pp.

Beardsley, Robert C. and William C. Boicourt. 1981. On Estuarine and Continental Shelf Circulation in the Middle Atlantic Bight. Chapter 7. In: Evolution of Physical Oceanography, B. A. Warren and C. Wunsch, eds., MIT Press, Cambridge, MA, 198-233.

Diaz, Henry F. and Robert G. Quayle. 1980. An analysis of the recent extreme winters in the contiguous United States. Monthly Weather Review, 108(6):687-99.

Godshall, Frederic A., Robert G. Williams, Joseph M. Bishop, Fred Everdale and Steven W. Fehler. 1980. A climatologic and oceanographic analysis of the Georges Bank region of the outer Continental Shelf. U.S. Department of Comm., NOAA, Wash., DC, 289 pp.

Lettau, Bernhard, William A. Brower, Jr. and Robert G. Quayle. 1976. Marine climatology. MESA New York Bight Atlas Monograph 7. New York Sea Grant Institute, Albany, NY, 239 pp.

Meserve, J. M. 1974. U.S. Navy marine climatic Atlas of the world. Vol. 1 - North Atlantic Ocean. Naval Weather Service Detachment, U.S. Naval Weather Service Command, Washington, DC 371 pp.

Naval Weather Service Detachment. 1976. Climatic study of the near coastal zone - east coast of the United States. Published by Director, Naval Oceanography and Meteorology. Washington, DC, 133 p.

U.S. Naval Oceanographic Office. 1963. Oceanographic Atlas of the North Atlantic Ocean - Pub. No. 700, Section IV, Sea and Swell. Washington, DC, 227 pp.

Williams, Robert G., and Frederic A. Godshall. 1977 Summarization and interpretation of historical physical oceanographic and meteorological information for the Mid-Atlantic region. U.S. Department of Commerce, NOAA, Washington, DC, Final report to the Bureau of Land Management, U.S. Department of the Interior, Interagency Agreement AA550-IA6-12, 295 pp.

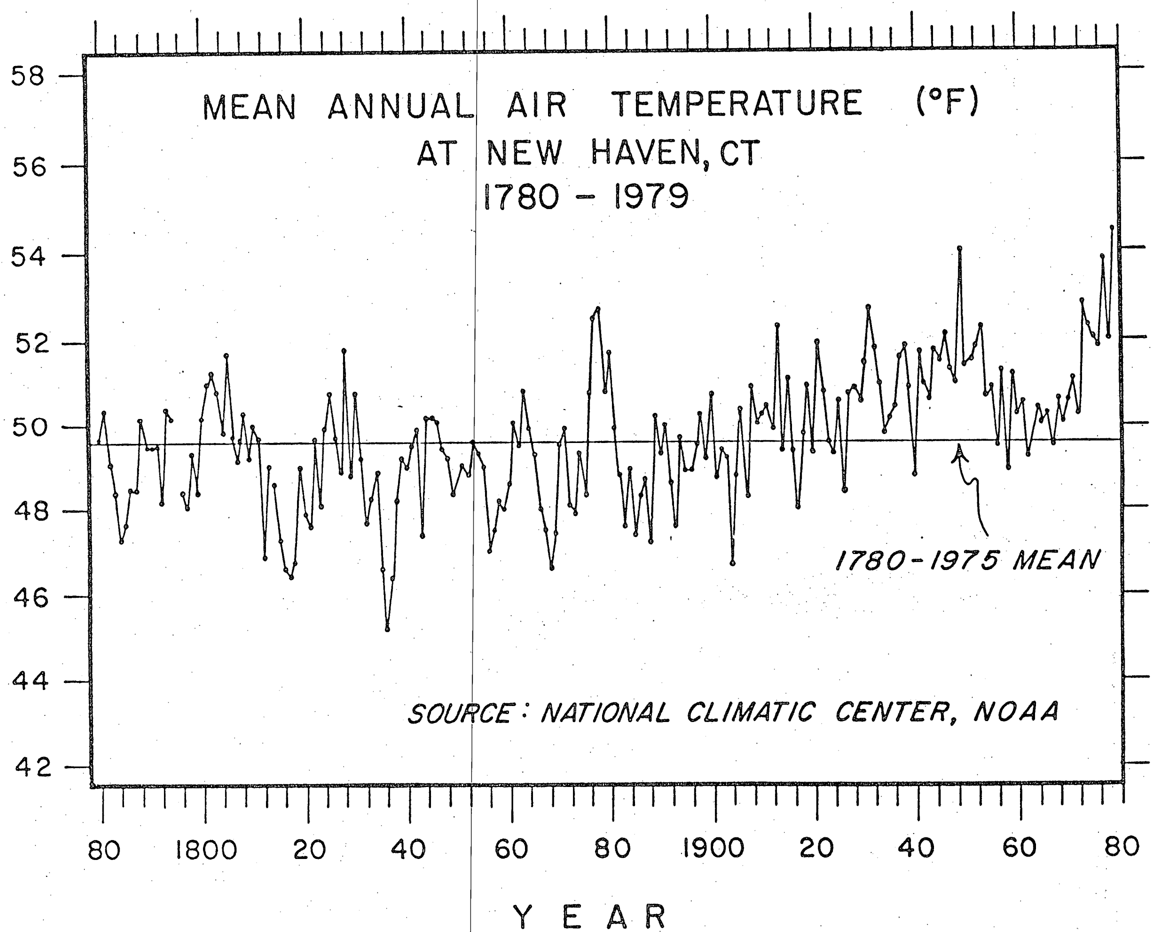

Figure 1. Mean annual air temperature (°F) at New Haven, Connecticut 1780-1979. Plot and mean for 1780-1975 prepared by National Climatic Center, Asheville, North Carolina. Extension of plot for 1976-1979 added with data furnished by National Climatic Center.

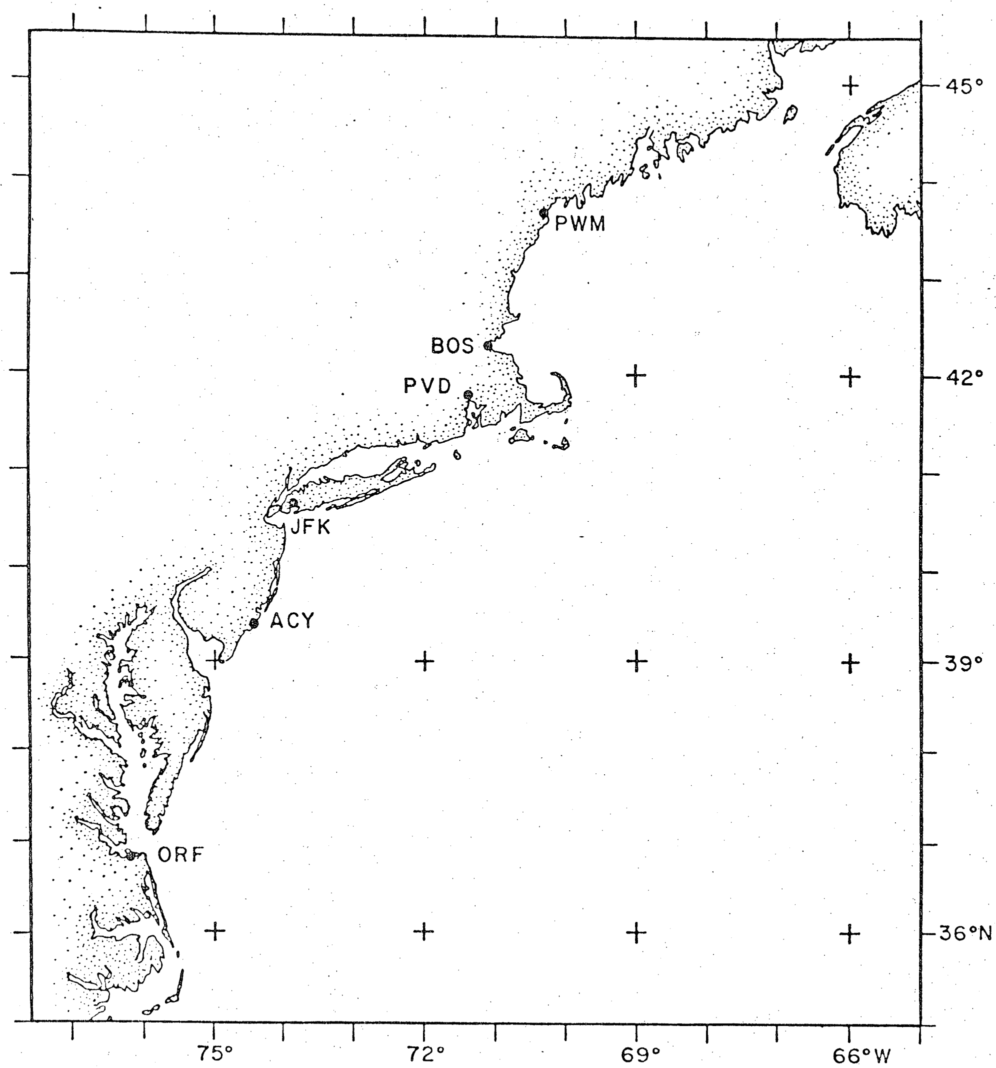

Figure 2. Location of coastal weather stations whose data were used: Portland, Maine (PWM), Boston, Massachusetts (BOS), Providence, Rhode Island (PVD), John F. Kennedy International Airport, New York, NY (JFK), Atlantic City, New Jersey (ACY), and Norfolk, Virginia (ORF). Crosses indicate eleven grid points from which computed wind stress data were pooled.

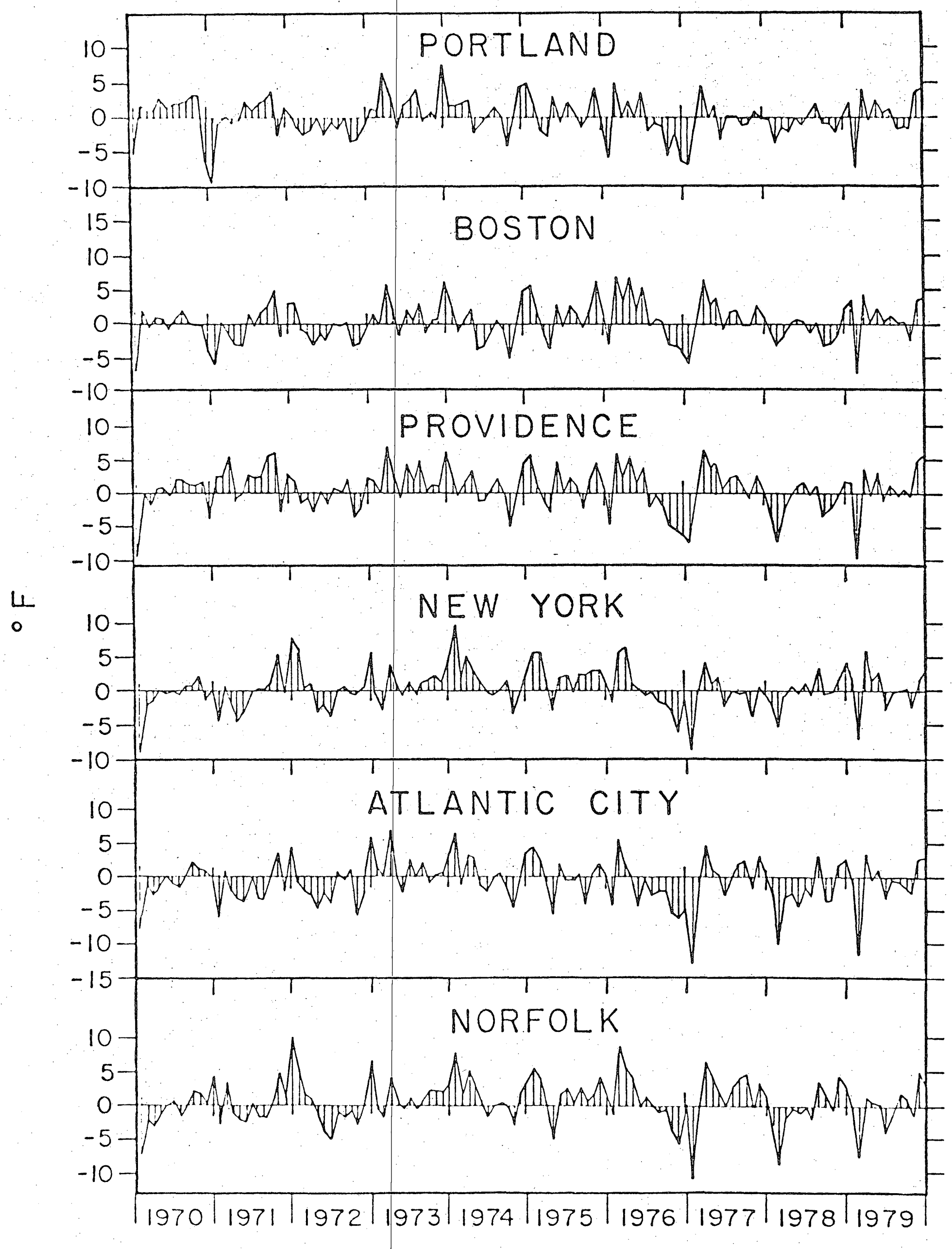

Figure 3: Monthly average air temperature departures (°F) for 1970-79 from six coastal weather stations. Departures computed from 1931-60 means, except for Atlantic City's, which was 1941-70. Tic marks on horizontal axes indicate December values.

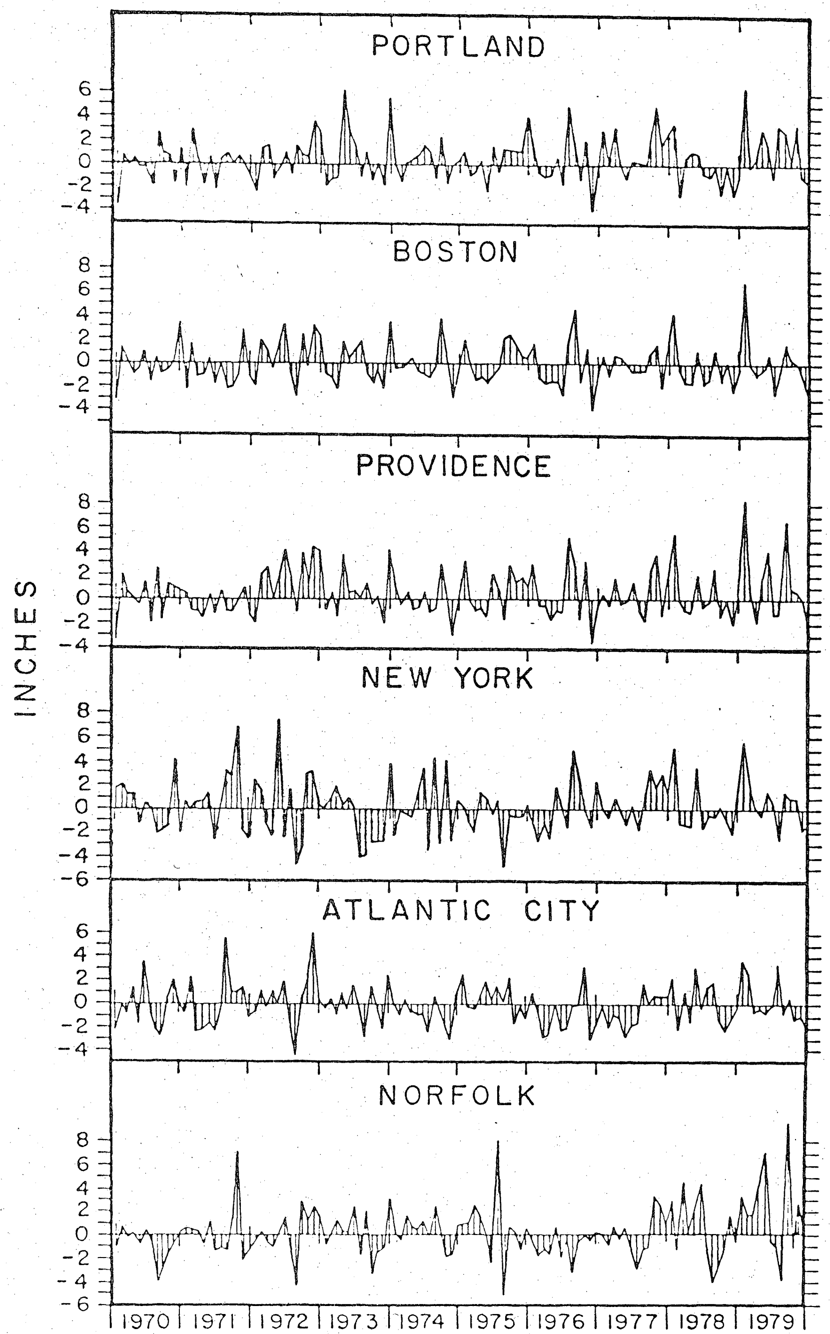

Figure 4. Monthly average precipitation departures (inches) for six coastal weather stations. Departures computed from 1931-60 means except Atlantic City's, which was 1941-70. Tic marks on horizontal axes indicate December values.

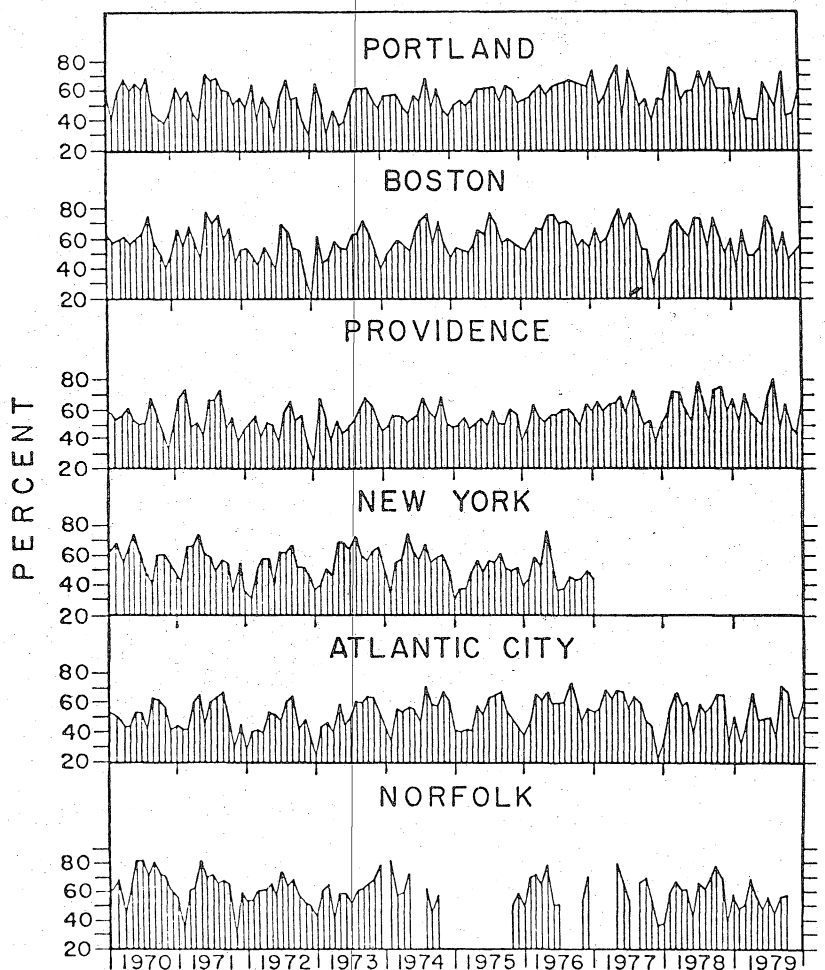

Figure 5. Monthly percent possible effective sunlight recorded at six coastal weather stations. Tic marks on horizontal axes indicate December values.

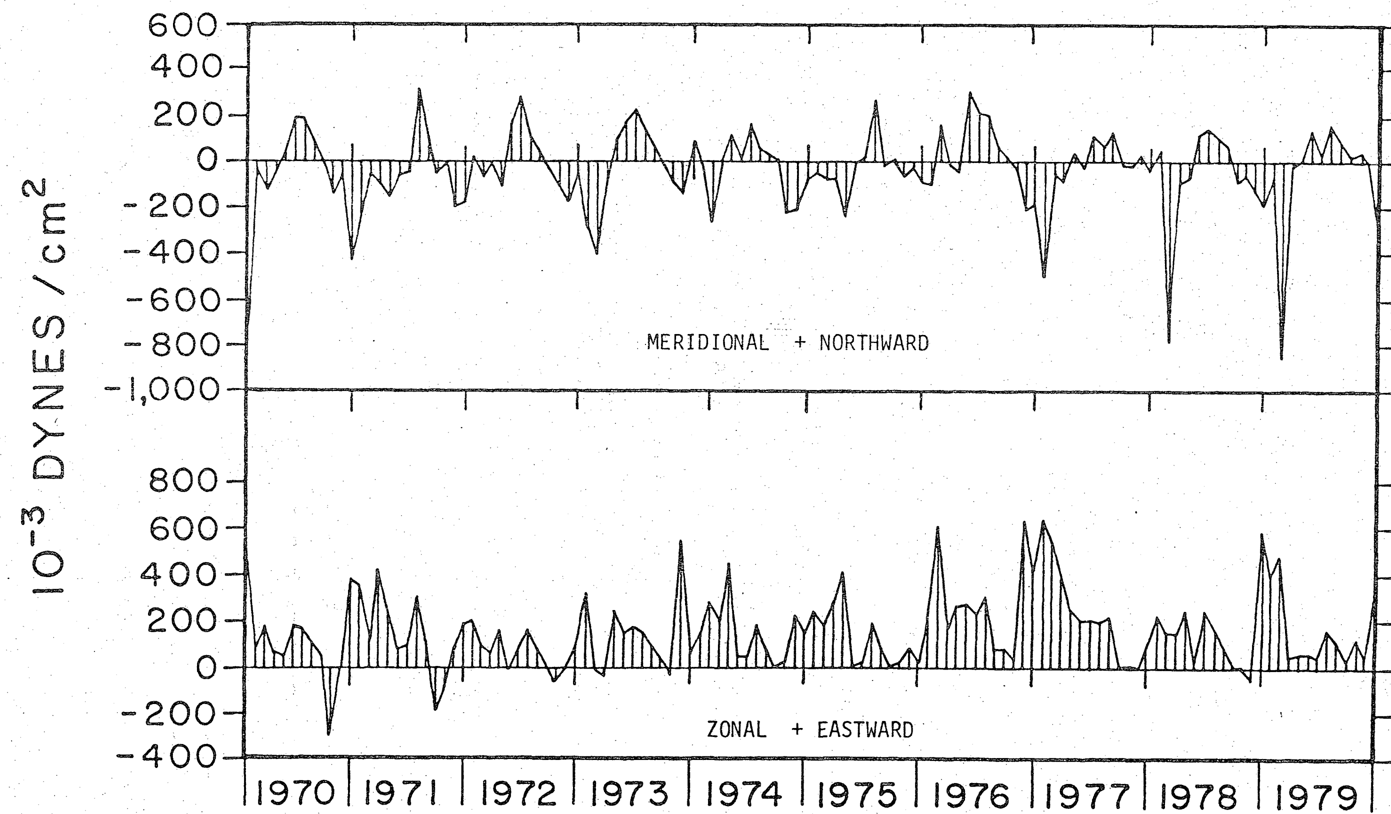

Figure 6. Computed indices of monthly mean wind stress components (10^{-3} dyne · cm^{-2}). Positive values northward or eastward. Tic marks on horizontal axes indicate December values.

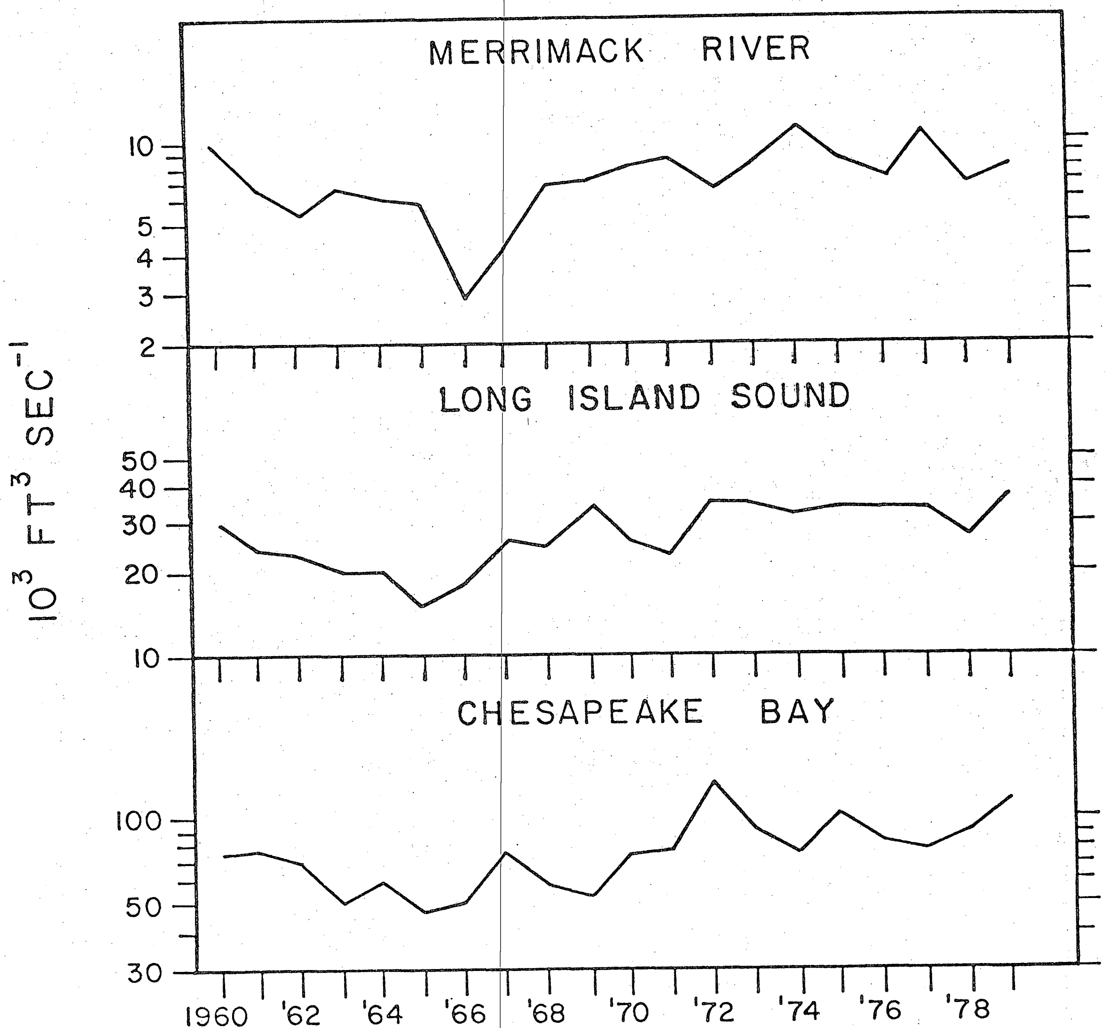

Figure 7. Annual average streamflow (10^3 ft^3 sec^{-1}) into Chesapeake Bay, Long Island Sound and in the Merrimack River (near Lowell, Massachusetts), a tributary to the Gulf of Maine used as an "index" stream by the U.S. Geological Survey.