Effects of the Winter of 1976–1977 on the Northwestern Sargasso Sea

Abstract. *A survey was conducted in the northwestern Sargasso Sea during the spring to assess the effect and extent of the winter cooling of 1976 to 1977 on the ocean. Newly formed, well-mixed layers of 18°C water as deep as 550 meters were observed. The main thermocline south of the Gulf Stream was 100 to 150 meters deeper than it is on the average, which implies significant changes in the baroclinic transports.*

Charts of the energy exchanges between the ocean and the atmosphere show that major heat losses to the atmosphere occur in the vicinity of the Gulf Stream, east and north of Cape Hatteras (*1*). Most of the oceanic cooling occurs during the winter, and by early spring large areas south of the Gulf Stream have mixed layers as deep as 350 m with temperatures close to 18°C. During the summer a shallow, seasonal thermocline develops over this area. However, a large pool of this relatively homogeneous water continues to occupy the upper part of the water column. Because of its temperature, this water mass has become known as 18°C water (*2*). Its temperature and salinity have remained remarkably constant for decades (*3*).

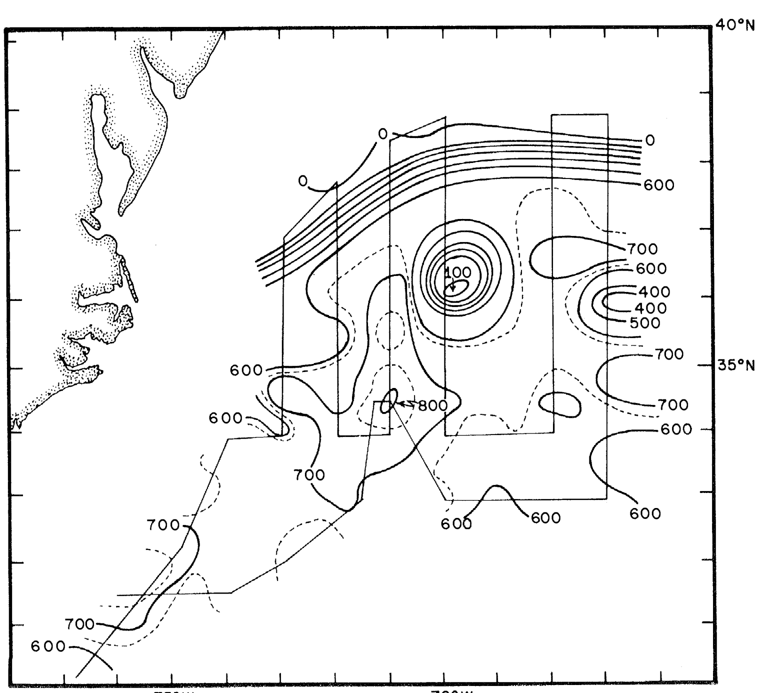
The winter of 1976 to 1977 along the eastern seaboard was notably severe. Consequently, early in 1977 a survey of the northwestern Sargasso Sea was conducted, using the R.V. *Researcher* of the National Oceanic and Atmospheric Administration, to assess the effects of this severe cooling on the ocean.

The area surveyed is shown in Fig. 1. Along the track line, expendable bathythermographs (XBT's) were dropped approximately every 24 km (13 nautical miles). Hydrographic casts, with oxygen measurements, were taken approximately 110 km (60 nautical miles) apart. These were initially taken to a depth of 1200 m, and later to 2100 m. Several were taken to the bottom. Salinity-temperature-depth casts were taken to 1200 m with almost every hydrographic cast. The depth of the 15°C isotherm from the XBT's is displayed in Fig. 1. This isotherm lies at the top of the main thermocline underlying the 18°C water, and its vertical displacement illustrates the extent to which the depth of the thermocline may have been influenced by the winter's storm activity.

The deepest regions of the thermocline lay south of the Gulf Stream, the position of which is indicated by the steep slope of the 15°C isotherm at the northern edge of the surveyed area. The deepest depression was found near 34°N, 71°W, where the 15°C isotherm reached a depth of about 800 m. The shoal areas at 36°N, 70°W and 36°N, 67°W are Gulf Stream rings. Examination of individual temperature transects taken through this region from 1969 to 1974 indicates that, on the average, the depth of the 15°C isotherm fluctuates between 600 and 700 m (*4*). Deepest values tended to occur during the spring. Occasionally these observations showed the 15°C isotherm deeper than 750 m. Thus, the thermocline this spring was as deep as or deeper than that in an average spring.

The great depth of the thermocline implies that Gulf Stream transports are higher than average. However, part of this increased transport lies to the south of the main axis of the Gulf Stream and occurs in an anticyclonic eddy surrounding the deepest depression of the thermocline. A detailed comparison between the transports this year and those previously measured is being prepared by Worthington (*5*).

The great depth of the thermocline at the end of this winter is a result of deep layers of 18°C water. Nearly homogeneous layers as deep as 550 m were observed. An example of an XBT trace that shows this is curve c in Fig. 2. Shown also for comparison are previously observed examples of deep layers of 18°C water (*2*). The mixed layer in curve c is 60 percent deeper than that in curve a. Curve c is from the region near 34°N, 71°W where the thermocline is deepest. In other areas where the 15°C isotherm was deeper than 700 m, the mixed-layer depths were comparable to that shown by curve c. In regions where the 15°C isotherm lay between 600 and 700 m, the



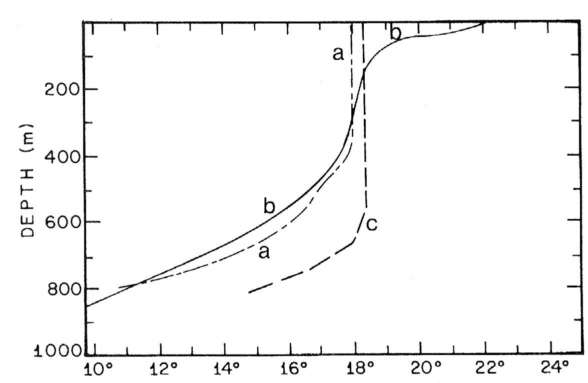


Fig. 1 (left). Depth of the 15°C isotherm in meters between 28 March and 15 April 1977. Fig. 2 (right). Temperature-depth curves: (a) R.V. *Atlantis*, hydrographic cast 1153, 28 February 1932, 34°02′N, 54°05′W; (b) R.V. *Atlantis*, hydrographic cast 5306, 11 June 1955, 34°53′N, 70°16′W; (c) R.V. *Researcher*, XBT 83, 4 April 1977, 34°39′N, 71°01′W.

traces were similar to curve a with mixed layers about 400 m deep. The temperatures of these mixed layers varied from 18.0° to 18.7°C. The coldest layers were found to the east, and the warmest layers were found near 31.5°N, 75°W. Salinities ranged from 36.47 to 36.51° per mil, and oxygen values were between 4.9 and 5.4 ml/liter. These are close to saturation values and indicate that most of these layers formed this winter.

These observations indicate that the atmosphere can, in the course of one winter, significantly change the topography of the main thermocline in the northwestern Sargasso Sea. This implies that the baroclinic volume transports in and near the Gulf Stream are also strongly affected. Worthington (*6*) has postulated that the Gulf Stream system, at least in part, is maintained by the thermodynamic processes that produce 18°C water. He suggested that outbreaks of polar continental air in winter cause deep vertical mixing of 18°C water south of the Gulf Stream and somehow deepen the main thermocline in this region. At present, the process that creates the deep mixed layers and deepens the main thermocline is unknown. Whether it is a convergence somehow caused by the cooling of the upper part of the water column, a convergence due to the winter wind stress distribution, or a result of some other factor needs to be clarified.

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3 June 1977; revised 22 August 1977

Holocene Woodlands in the Southwestern Deserts

Abstract. *Twenty-nine radiocarbon-dated pack rat middens document woodland communities in the deserts of the southwestern United States less than 10,000 years ago. A synchronous change from woodland to desert or grassland occurred about 8000 years ago in the Chihuahuan, Sonoran, and Mohave deserts. A shift of the Aleutian low and the winter storm track to the north, which resulted in drastically reduced winter precipitation in these areas, is inferred. The shift to nonpluvial climates in the Southwest lagged behind the beginning of nonglacial climates in the North because the melting continental glaciers contined to affect general circulation patterns.*

The southwestern United States is presently arid or semiarid and includes four deserts that differ in climate and biota. Aridity in the Southwest is presumably a late Tertiary development that favored the evolution and immigration of desert-adapted plants and animals and the formation of desert biotic communities (*1*). However, late Pleistocene pollen and plant macrofossils from the Southwest have consistently recorded woodland or forest. The formation of the present desert communities occurred during the Holocene or postglacial period that followed the last glaciopluvial period. The Holocene-Pleistocene boundary for the Southwest was placed at 12,000 years ago based on pollen records in Arizona and Nevada (*2*). However, the existence of woodland plant communities for thousands of years later than 12,000 years ago is documented by well-preserved fossils in ancient pack rat (*Neotoma*) middens in the deserts themselves. In this report I reexamine the early Holocene vegetational and inferred climatic transitions for the southwestern deserts.

Pack rat middens with radiocarbon dates from 11,000 to more than 40,000 radiocarbon years before present (B.P.) contain records of late Wisconsin vegetation in many areas of the southwestern United States. Most of these records are of woodland plants in areas that are now desert. In these areas, the environmental gradients are elevational gradients, where temperature decreases and precipitation increases with elevation. Desert communities are in the lowest, hottest, driest areas, with juniper and piñon-juniper woodlands in the higher, more mesic areas.

In the northern Chihuahuan Desert of Trans-Pecos Texas, piñon-juniper woodland extended from an elevation of 1495 m in the Guadalupe Mountains to 600 m near the Rio Grande in the Big Bend (*3*). In the Sonoran Desert of Arizona and adjacent California, single-needle piñon (*Pinus monophylla*) grew as low as 510 m, while more xeric juniper woodland grew as low as 260 m (*4, 10*). In the Mohave Desert of Nevada, a xeric juniper woodland with scant piñon occurred at 1100 to 1830 m (*5*). In southern Nevada and northeastern California, single-needle piñon was recorded as low as 730 m (*5, 6*). There are additional records of juniper woodland and piñon-juniper woodland from the western Mohave Desert (*7*).

Many desert species are associated with the woodland plants in the fossil midden assemblages. Extralocal taxa that no longer grow near the midden sites usually comprise 25 to 35 percent of the macrofossils. Many plants in the assemblages still grow at the site (*4, 8*). Many of the desert taxa in middens collected in the Sonoran Desert are dominants in the present Mohave Desert communities 150 to 395 km to the north. Joshua tree (*Yucca brevifolia*) and big sagebrush (*Artemisia tridentata*) were recently found in midden samples from Montezuma's Head in the Ajo Mountains of Organ Pipe Cactus National Monument, Arizona. The site is about 395 km south of the nearest big sagebrush locality in Arizona, and only about 35 km north of the Mexican border. These samples also contained single-needle piñon, juniper, and shrub live oak (*Quercus turbinella ajoensis*). The assemblages have been radiocarbon dated at 13,500 ± 390 B.P. (laboratory number A-1698, *Juniperus*), 17,830 ± 870 B.P. (A-1697, *Pinus monophylla–Juniperus* mix), 20,490 ± 510 B.P. (A-1695, *Juniperus*), and 21,840 ± 650 B.P. (A-1696, *Pinus monophylla*). The midden records of Mohave Desert species farther south than their present range suggest that the Mohave Desert occupied a relatively greater area in the late Pleistocene.

The only midden record of a late Pleistocene desert community without woodland associates is that of Wellton Hills No. 1 at an elevation of 160 m in Yuma County, Arizona, dated at 10,580 ± 550 B.P. (A-1407, *Larrea divaricata*). It contained creosote bush (*Larrea divaricata*) and white bur-sage (*Ambrosia dumosa*), which still grow in the area today (*4*). Creosote bush and white bur-sage are widespread codominants in both Sonoran and Mohave Desert low-elevation communities. Late Wisconsin macrofossils of characteristic Sonoran Desert species, such as paloverde (*Cercidium microphyllum* and *C. floridum*) and saguaro (*Cereus giganteus*), have not