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A Volumetric Temperature/Salinity Census for the Middle Atlantic Bight

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Abstract

Two seasonal volumetric temperature/salinity diagrams have been prepared for the waters of the Middle Atlantic Bight from Nantucket Shoals to Cape Hatteras, to a depth of 200 m and extending as much as 130 km beyond the edge of the continental shelf. Total volume included is 23,146.6 km^3, of which about half is fresher than 35‰ and can be considered of coastal origin. There is very little change from winter to summer in the total volume of this fresher water but its distribution varies seasonally, showing the effects of spring runoff and suggesting a summer influx of Slope Water in the northern portion of the bight.

I. Introduction

Since its introduction in the papers of Montgomery, Pollak and Cochrane (1958), the volumetric temperature/salinity census has proved useful in describing both open ocean and coastal waters. Volumetric diagrams help to identify important water masses, their limits, and their relative abundances, and to show seasonal variation and in some cases to evaluate the effects of environmental influences such as advection, evaporation, and precipitation, or coastal runoff.

The diagrams presented here are for the winter and summer in the Middle Atlantic Bight. The Bight (Fig. 1) is one of the principal oceanographic regimes of the eastern North American coast and one which is important from the point of view of shipping, fishing, development of resources and pollution prevention. The purpose of the diagrams is to show the distribution of Shelf Water within the Bight in the two seasons, with some emphasis on geographical differences within the region.

The diagrams also complement those of Barinov and Bryantsev (1972), who presented winter and summer diagrams for the waters of the Scotian Shelf, Georges Bank, and the Gulf of Maine. One difference between this work and that of Barinov and Bryantsev is that they included only water inside the 200-meter curve, whereas we have extended our region as far as 130 km seaward of the edge of the shelf, although we do not include any water more than 200 meters deep. These limits were chosen because the main body of Shelf Water extends seaward well beyond the 200-m curve and we wished to include that extension in our accounting. The lower limit of 200 m was chosen because Shelf Water is not found below that depth.

The region of investigation thus includes an area of about 206,400 km^2 whereas the area of the shelf shallower than 200 m is about 120,000 km^2.

The total volume of the region is 23,145.6 km^3 including 7,785.6 km^3 of water inshore of the 200-meter curve and 15,360 km^3 seaward of that line. By way of contrast, the volume in the region studied by Barinov and Bryantsev (1972) is about 37,000 km^3, and that of the entire North Atlantic Ocean is 137,222,000 km^3.

The diagrams (Figs. 2 and 3) are based on 180 hydrographic stations (87 in winter and 93 in summer) from the files of the Woods Hole Oceanographic Institution and The National Oceanographic Data Center. The object was to achieve broad distribution of the stations in space and good representation over the last forty years but the actual coverage was somewhat uneven in both respects. Similarly, it was intended to confine the winter diagram to observations made in February and March and the summer diagram to August and September, but that was not always possible.

In the diagrams, the number in each box represents the volume of water, in km^3, in that particular T/S class. Totals by 1° temperature intervals are printed to the right of the diagram, and by 0.2 °/₀₀ of salinity along the bottom. Classes containing the greatest volumes were summed to give the 50 percent (stippled) and 75 percent (hatched) boundaries. Density is indicated by Sigma-t curves.

II. Description of Diagrams

A. Winter

In the winter diagram (Fig. 2) the 75 percent outline incorporates two principal water masses. The mode running from 3°, 32.6‰, 26.0 σ_t to about 11°, 35.0‰, 26.8 σ_t is Shelf Water, sometimes identified as Coastal Water, the dominant water mass on the continental shelf northeast of Cape Hatteras.

The mode running from 14°, 35.2‰, 26.6 σ_t to 5°, 35.0‰, 27.6 σ_t is Slope Water. The Slope Water temperature/salinity curve lies almost parallel to the curve for Western North Atlantic Water (Wright and Worthington, 1970) but is somewhat fresher at all temperatures (Colton, 1968).

The juncture of these two water masses--the region from 10°, 35‰ to 13°, 35.6‰--is where the greatest volumes of water are found. The seven hatched squares contain 8812.8 km^3--38 percent of the total. Water of these characteristics occupies a layer as much as 100 m thick, centered at about 100-120 m, and is widespread throughout the Slope Water. In the winter it forms a temperature and salinity maximum between the slightly colder and fresher Slope Water underneath and the much colder and fresher Shelf Water above. In the summer it appears as a region of small temperature gradient between the seasonal thermocline and the deeper Slope Water.

This water represents the extent of penetration of seasonal influence of the atmosphere. It is renewed annually when autumn gales and cooling break down the summer thermocline. It is the Slope Water analog of the 18-degree water in the Sargasso Sea (Worthington, 1959) and deserves a name of its own. Miller (1950) refers to water of these temperature-salinity characteristics as Mid-Depth Slope Water; and Chamberlin (1975) calls it "the warm band." As a more specific name, we suggest "Upper Slope Water Thermostad," using terminology suggested by Seitz (1967).

The water warmer than 15° C in the winter was found in only two stations, both located south of 36° N and east of 75° W, in the Cape Hatteras region where the Gulf Stream is found close to shore. One of the stations was entirely warmer than 15° and more saline than 36.0‰ in the upper 200 m and thus is clearly Gulf Stream water. The other is both colder and fresher, running from 19°, 36.18‰ to 9°, 35‰ and is representative of the southwest extremity of the Slope Water.

The values enclosed in ellipses near the bottom of the diagram are all associated with a single station--Albatross IV, Station 66-72, occupied at 39° 30' N, 69° 30' W on March 12, 1966. Those which are starred are the only classes where that station overlapped other observations. Station 66-72 is representative of observations made during the National Fish and Wildlife Surveys of 1964-1966 (Colton et al., 1968) which were the three coldest years recorded at the Nantucket weather station from 1931 to 1969. It may thus indicate simply a colder than usual year. On the other hand, its temperature-salinity character is like that of coastal water usually found much further east, and Colton (1968) has suggested that it represents an influx from that direction.

B. Summer

The summer diagram (Fig. 3) covers a greater range of both salinity and temperature than the winter diagram and the water masses are not so clearly identifiable by temperature/salinity characteristics, except that the Slope Water remains strong.

There is no water colder than 5° C in the summer diagram, as opposed to a lower limit of 2° in winter. There is a diffuse mode of hatched and stippled squares, which parallels the winter Shelf Water mode and is the slightly warmed remnant of winter water described by Bigelow (1933) and by Ketchum and Corwin (1964).

The effects of spring runoff are reflected in the left side of the summer diagram, which includes three times as much water between 31 and 32‰ than does the winter diagram, and 90 km^3 of water fresher than 31‰ which does not appear at all in the winter. The freshening is more pronounced in the southern half of the region, where most of the runoff is concentrated.

C. Seasonal Effects

One reason for undertaking the census was to ascertain what seasonal changes, if any, occur in the volume of Shelf Water in the Middle Atlantic Bight. For that purpose 35‰ has been taken as the dividing line between Shelf Water and Slope Water, except that cold Slope Water lying underneath the "upper Slope Water Thermostad" may drop below that salinity and is excluded from the Shelf Water totals. The criterion seems reasonable because temperature is clearly not a reliable index in the upper 200 m and oceanic water in the Western North Atlantic Ocean at those depths is all more saline than 35% except in the Labrador Sea.

The winter volume of Shelf Water, thus defined, is 11,472 km^3 and the summer volume is 11,175 km^3. The difference is 297 km^3, less than 3 percent, so that for practical purposes the Shelf Water volume of the Middle Atlantic Bight can be considered constant.

This result was somewhat surprising because it was thought that the seasonal variation in runoff whould create more Shelf Water in the summer, and because the Shelf Water/ Slope Water boundary extends further seaward at the surface in the summer while remaining nearly stationary at the bottom (Wright, 1975).

Nearly half of the Shelf Water was found beyond the edge of the continental shelf in water deeper than 200 m. Conversely, 182.4 km^3 of Slope Water are found on the continental shelf in winter and 286.2 km^3 in summer, representing 2.9 and 4.5 percent, respectively, of the volume over the shelf. This Slope Water is found along the bottom, underlying the prism of Shelf Water extending seaward. Its summer increase, though small, is probably real. It occurs almost entirely north of 39° N, which may indicate an increased exchange of surface Shelf Water and deeper Slope Water at the shelf edge south of New England in the summer time, as suggested also by bottom drifters (Bumpus, 1965).

In Figure 4 the T/S ranges for the Middle Atlantic Bight (using only values fresher than 35‰) are compared with those shown by Barinov and Bryantsev (1972) for the waters of Georges Bank, the Gulf of Maine and the Scotian Shelf. The Middle Atlantic Bight is both warmer and saltier, in both seasons, as expected. Nevertheless, the 50 percent outlines have some overlap in both winter and summer. In the winter the two modes lie along the same axis; in summer the overlap is only in the salinity range of 32-33‰. We note also that the anomalously cold station in the Middle Atlantic Bight winter mentioned above has the same T/S pattern as the mean of the Barinov-Bryantsev diagram, another indication of its possible eastern origin.

III. Summary

Despite uncertainties arising from irregular space and time distribution of data and those inherent in the method, some conclusions can be drawn from this volumetric temperature/salinity tabulation for the Middle Atlantic Bight:

1. The volume of Shelf Water in the Bight is virtually unchanged, winter to summer.

2. Nearly half of the Shelf Water in the Bight is located in surface layers well beyond the edge of the continental shelf.

3. A prominent and permanent feature of the region is the Upper Slope Water Thermostad, analogous to the 18° water in the Sargasso Sea.

4. Seasonal effects in the New England portion of the Middle Atlantic Bight differ from those further south. North of 39° N there are indications of more near-bottom intrusion of Slope Water in summer whereas south of that latitutde the effects of runoff are more pronounced.

5. Although there are clear similarities between the waters of the Bight and those on the shelf to the east of Nantucket Shoals, there is little overlap of the 50 percent modes for the two regions and little evidence that water from the east reaches the Middle Atlantic Bight unmodified.

Acknowledgement

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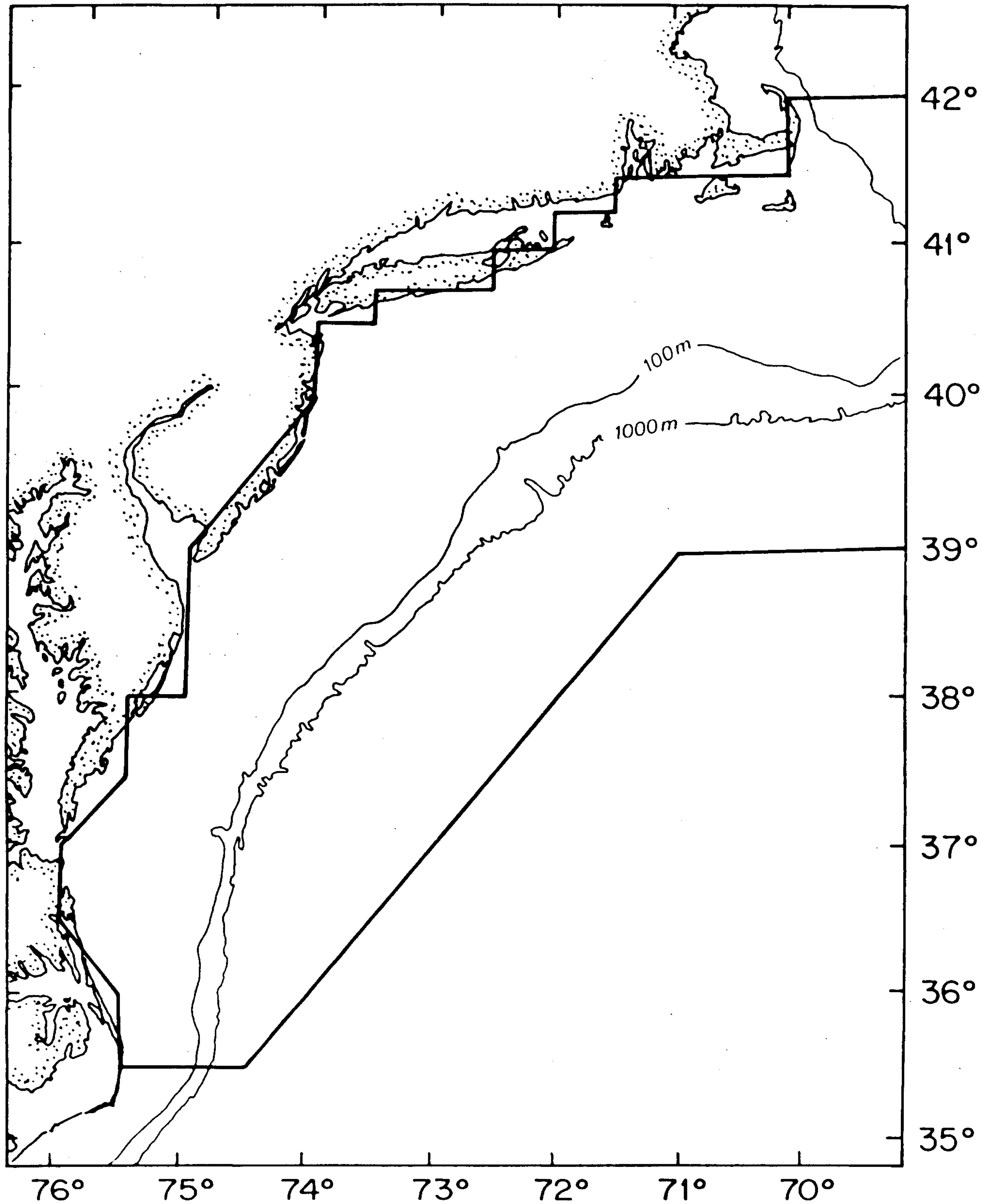


Figure 1

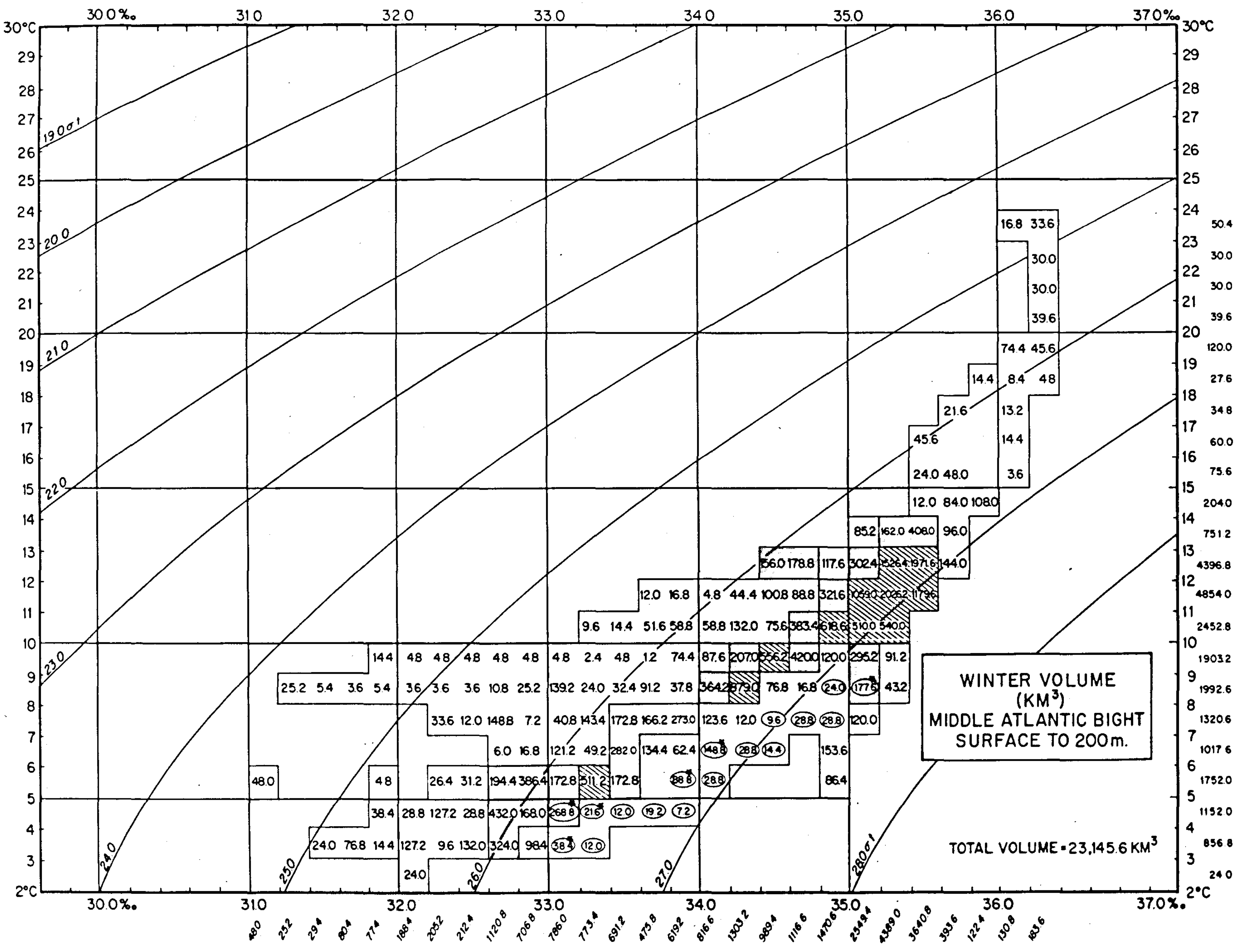
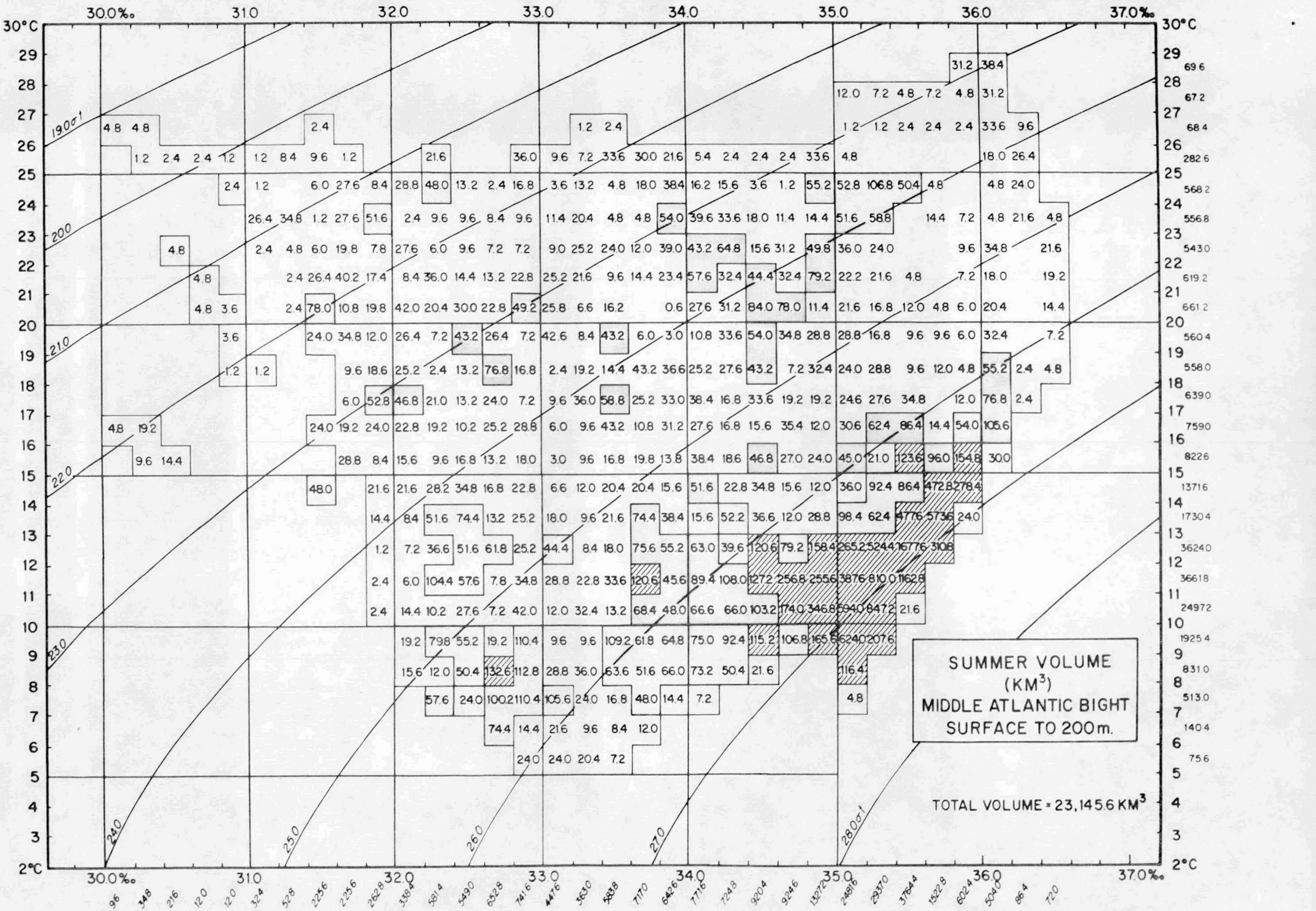

WINTER VOLUME
(KM³)
MIDDLE ATLANTIC BIGHT
SURFACE TO 200m.
TOTAL VOLUME = 23,145.6 KM³
30.0‰
31.0
32.0
33.0
34.0
35.0
36.0
37.0‰
30°C
2°C
19.0σt
20.0
21.0
22.0
23.0
24.0
25.0
26.0
27.0
28.0σt

Figure 2



SUMMER VOLUME
(KM^3)
MIDDLE ATLANTIC BIGHT
SURFACE TO 200m.
TOTAL VOLUME = 23,145.6 KM^3
30.0‰
31.0
32.0
33.0
34.0
35.0
36.0
37.0‰
30°C
2°C
19.0σt
20.0
21.0
22.0
23.0
24.0
25.0
26.0
27.0
28.0σt

Figure 3

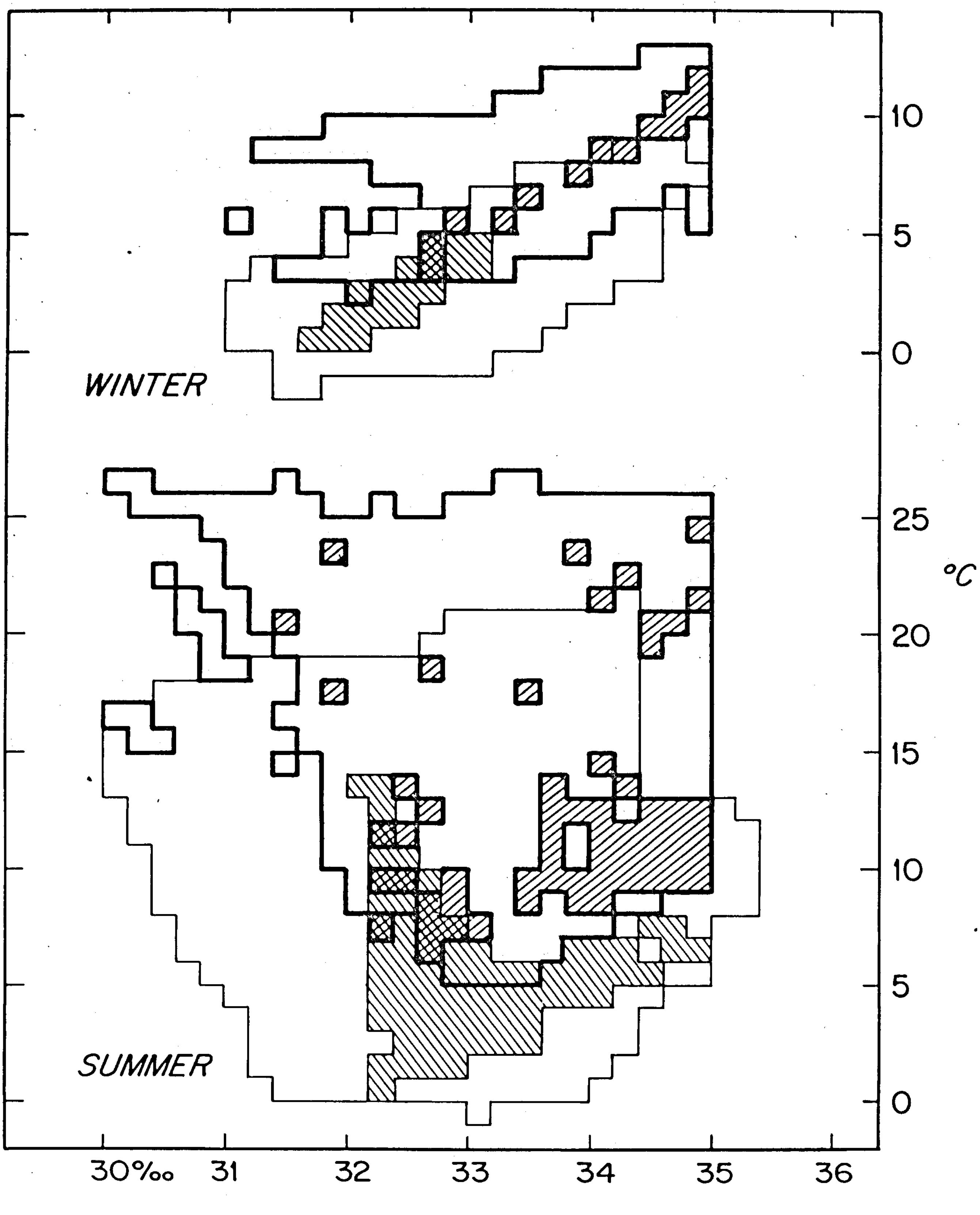


Figure 4