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Estimating salinity to complement observed temperature: 2. Northwestern Atlantic

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Abstract

This paper addresses the problem of estimating salinity for a large region in the Atlantic Ocean containing the Gulf Stream and its recirculation. Together with Part 1 [Thacker, W.C., 2007-this issue. Estimating salinity to complement observed temperature: 1. Gulf of Mexico. Journal of Marine Systems. doi:10.1016/j.jmarsys.2005.06.008.] dealing with the Gulf of Mexico, this reports on the first efforts of a project for developing world-wide capability for estimating salinity to complement expendable-bathythermograph (XBT) data. Such estimates are particularly important for this region, where the strong frontal contrasts render the task of assimilating XBT data into numerical models more sensitive to the treatment of salinity.

Differences in salinity's co-variability with temperature and with longitude, latitude, and day-of-year from the northwestern part of the region with the Gulf Stream to the southeastern part more characteristic of the Sargasso sea suggested that the region be partitioned to achieve more accurate salinity estimates. In general, accuracies were better in the southeastern sub-region than in the more highly variable northwestern sub-region with root-mean-square estimation errors of 0.15 psu at 25 dbar and 0.02 psu at 300 dbar as compared with 0.35 psu and 0.50 psu, respectively, but in the southeast there was an unexpected error maximum around 1000 dbar where estimates were slightly less accurate than in the northwest. For pressures greater than 1400 dbar root-mean-square errors in both sub-regions were less than 0.02 psu.

Keywords: XBT; CTD; Regression; Data assimilation; HYCOM

1. Introduction

The companion paper (Thacker, 2007-this issue) introduces a project for developing the capability of estimating salinity from observations of temperature, so that salinity can be corrected when expendable-bathythermograph (XBT) data are assimilated into numerical models of oceanic circulation. The success reported there for estimating salinity for the Gulf of Mexico with its Loop Current suggested that the next step should be to investigate a large, highly variable region in the North Atlantic Ocean containing the Gulf Stream. Similar success for this region would indicate that relatively large and complicated regions might be addressed without having to deal with more, smaller regions that would slow the progress of the project.

As the project is still in an exploratory stage, the exact boundaries of the region to study were quite arbitrary, so the 30° longitude by 20° latitude region for this study shown on the map in Fig. 1 was chosen with the thought that experience here might provide guidance for the

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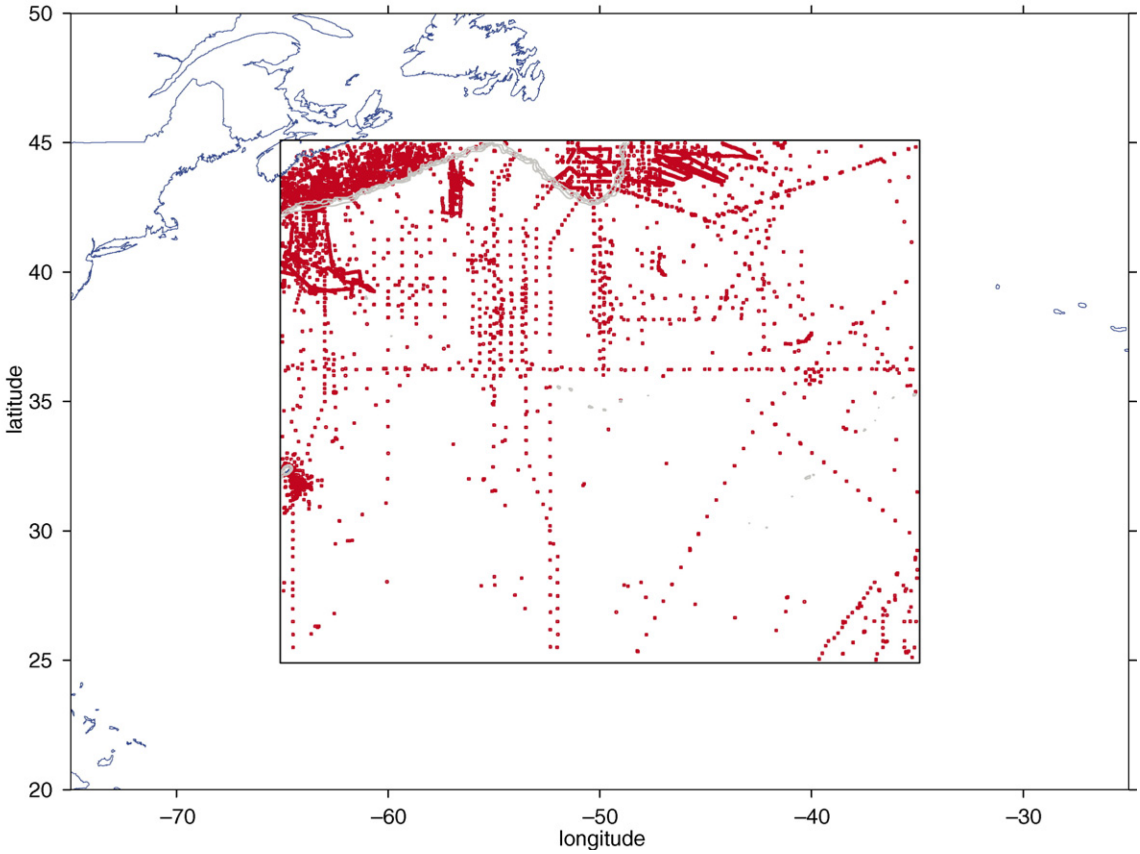

Fig. 1. Map of the North Atlantic Ocean showing the area addressed in this study. Red dots represent the 11,644 CTD stations from the World Ocean Database 2001 for the rectangular region. Bathymetric contours at 500, 1000, 1200, and 2000 m are indicated in gray.

choice of other regions as the study progresses. Nova Scotia can be seen at its northwest corner, the Bahamas to the southwest, and the Azores to the east; Bermuda is on its western boundary. Except for the Scotian Shelf and the Grand Banks, most of the region is very deep.[1] Both temperature and salinity exhibit a wide range of variability across this large region. In particular, they change abruptly across the fronts associated with the meandering Gulf Stream (Watts, 1983) and with the drifting warm-core eddies to its north and cold-core eddies to its south (Richardson, 1983). Moreover, the region is open with nothing preventing water from crossing its arbitrary boundaries. While the primary external influence is that of the Gulf Stream entering from the west, water from the Labrador Current impinges from the north (Loder et al., 1998), and there are less pronounced exchanges across the southern and eastern boundaries.

In spite of this region's size and complexity and the wide ranges over which its salinity and temperature vary, throughout the region salinity exhibits a pronounced co-variability with temperature. Scatter plots of temperature vs. salinity at fixed pressure show data throughout the region cluster along relatively well-defined curves.[2] While this co-variability is relatively weak near the ocean's surface, it is stronger in and below the thermocline, allowing knowledge of temperature to restrict the range of salinity by more than an order of magnitude. Still, the various water types encountered in this region contribute to the spread of salinity values. If they could be identified and treated separately, accuracy might be improved. Unfortunately, identifying the water type from temperature and location is difficult and deserves a separate study. The challenges of the continental shelf are finessed by basing the salinity

[1] Thanks are extended to Dong-Shan Ko of the Naval Research Laboratory for providing the DBDB2 bathymetric data. The contours in Fig. 1 are not labelled, but the shelf can be identified from the closely spaced contours in the north.

[2] To study water-mass anomalies Armi and Bray (1982) describe the TS curve over a wide pressure range using a cubic-spline function. Their fit was not to the measurements but to curves from two previous analyses (Iselin, 1936; Worthington and Metcalf, 1961).