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## SPATIAL TEMPERATURE AND SALINITY FIELDS OVER THE SHELVES OF NEWFOUNDLAND AND LABRADOR

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## TABLE OF CONTENTS

Abstract/Résumé.....	v
Introduction.....	1
Data Sources.....	2
Data Analysis.....	3
Data Products.....	5
Acknowledgements.....	5
References.....	5
Fig. 1. The total number of temperature profiles (a) by year and (b) by month available in the Labrador region and the total number of salinity profiles available in the Labrador region (c) by year and (d) by month.....	8
Fig. 2. The total number of temperature profiles (a) by year and (b) by month available in the Newfoundland region and the total number of salinity profiles available in the Newfoundland region (c) by year and (d) by month.....	9
Fig. 3a. Location map showing the number of temperature observations in the Newfoundland region for January to April from 1910 to 1992. The bathymetry lines are 300 and 1000 m.....	10
Fig. 3b. Location map showing the number of temperature observations in the Newfoundland region for May to August from 1910 to 1992. The bathymetry lines are 300 and 1000 m.....	11
Fig. 3c. Location map showing the number of temperature observations in the Newfoundland region for September to December from 1910 to 1992. The bathymetry lines are 300 and 1000 m.....	12

Fig. 3d.	Location map showing the number of temperature observations in the Labrador region for January to April from 1910 to 1992. The bathymetry lines are 300 and 1000 m.....	13
Fig. 3e.	Location map showing the number of temperature observations in the Labrador region for May to August from 1910 to 1992. The bathymetry lines are 300 and 1000 m.....	14
Fig. 3f.	Location map showing the number of temperature observations in the Labrador region for September to December from 1910 to 1992. The bathymetry lines are 300 and 1000 m.....	15
APPENDIX A.	Horizontal maps of monthly average temperatures and salinity at standard oceanographic depths for the Newfoundland and Labrador regions.....	17
APPENDIX B.	Horizontal maps of monthly average bottom temperature and salinity for the Newfoundland and Labrador regions.....	115

## ABSTRACT

Colbourne, E. B. and D. Foote. 1994. Horizontal temperature and salinity fields over the shelves of Newfoundland and Labrador. Can. Tech. Rep. Hydrogr. Ocean Sci. No. 160: v + 128 p.

A review of the temporal and spatial distribution of the historical temperature and salinity data in the Newfoundland region bounded by 42° N to 55° N latitude and 40° W to 60° W longitude, excluding the Gulf of St. Lawrence and in the Labrador region bounded by 52° N to 64° N latitude and from 51° W to 67° W longitude is presented. Horizontal contour maps of the monthly averaged temperature and salinity fields are presented at standard oceanographic depths based on all available CTD, bottle and bathythermograph data collected from 1910 to 1992. In addition contour maps of the monthly averaged bottom temperature and salinity fields are presented for the Newfoundland and Labrador continental shelf areas.

## RÉSUMÉ

Colbourne, E. B. and K. D. Foote. 1994. Température horizontale et salinité des plateaux de Terre-Neuve et du Labrador. Can. Tech. Rep. Hydrogr. Ocean Sci. No. 160: v + 128 p.

On donne une vue d'ensemble de la distribution temporelle et spatiale des données historiques de température et de salinité de le région de Terre-Neuve, délimitée par 42° N à 55° N de latitude et 40° à 60° de longitude, excluant la région du Golfe St-Laurent délimitée par 52° N à 64° N de latitude et 51° à 67° de longitude. Des cartes de contour horizontales, des températures mensuelles moyennes et de salinité sont présentées pour des profondeurs océanographiques standards, basées sur les CTD disponibles ainsi que les données de bouteilles et données bathythermographiques amassées depuis 1910 à 1992. De plus, des cartes de contour des moyennes mensuelles de température et de salinité sont présentées pour les régions du plateau continental de Terre-Neuve et du Labrador.

## 1. INTRODUCTION

With the recent increase in environmental research in Atlantic Canada and its possible linkage to changing patterns in the ecosystem, there is an immediate need for increased baseline knowledge of the physical oceanography of the Newfoundland and Labrador areas. A first step in this process is to make available all historical data in the region in a form where it can be easily used by the scientific community without having to deal with large quantities of raw data.

Previous studies of the oceanography off the east coast of Newfoundland have included analyses of temperature and salinity data at Station 27 located about 8.0 km east of St. John's Newfoundland (Keeley, 1981a, Bailey, 1966, Huyer and Verney, 1975, Colbourne and Fitzpatrick, 1994) and along the ICNAF standard Flemish Cap transect (Keeley, 1981b) and Bonavista transect (Colbourne and Senciali, 1993). The International Ice Patrol of the U.S. Coast Guard has also conducted studies concentrated mainly in the offshore branch of the Labrador current along the southeast slopes of the Grand Bank (Kollmeyer et al., 1965). Additional studies have included extensive analysis of temperature and salinity variability along the east and northeast Newfoundland shelves (Petrie et al. 1991, Petrie et al., 1992, Petrie et al. 1986, Templeman, 1975). Drinkwater and Trites (1986) have compiled monthly averaged temperature and salinity for standard areas over the entire Grand Bank and most of the northeast Newfoundland shelf up to 1982. DeYoung et al. have presented an analysis of the historical temperature and salinity data over a wide area of the Northwest Atlantic at seasonal time scales.

The data products presented in this report complement and up-date the earlier similar studies by Drinkwater and Trites (1986) by extending the data analyses to include data from 1910 to 1992 from all available data sources. The report includes a brief summary of these data sources, the temporal and spatial distribution of the data, analysis, and a presentation of horizontal temperature and salinity maps in the Newfoundland and Labrador regions at standard oceanographic depths and near the bottom. The analysis is presented at spatial scales of the order of the major banks and continental shelves in the regions and at monthly time scales.

## 2. DATA SOURCES

The results presented here are based on an analysis of all available bottle, mechanical bathythermograph (MBT), expendable bathythermograph (XBT) and conductivity-temperature-depth recorder (CTD) data collected in the Newfoundland region in the area from 42° N to 55° N latitude and from 40° W to 60° W longitude, excluding the Gulf of St. Lawrence and in the Labrador region from 52° N to 64° N latitude and from 51° N to 67° W longitude, from 1910 to 1992.

A considerable amount of oceanographic data dating back to 1910 is available for this particular area, including data from standard oceanographic stations along transects (adopted in 1976 by the International Commission for the Northwest Atlantic Fisheries) in the Northwest Atlantic ocean from Cape Cod (USA) to Egedesminde (West Greenland) (Anon. 1978). In addition, data from Canadian fisheries assessment surveys from the southern Grand Bank to Labrador together with data from the US Coast Guard and Russian hydrographic surveys are included in the analysis. Most of these data were available from the Marine Environmental Data Service (MEDS) in Ottawa, Canada and from archives at the Northwest Atlantic Fisheries Center (NAFC) in St. John's, Newfoundland.

Approximately 30 % of the data, mainly before the late 1970s, were collected at standard oceanographic depths (0,10,20,30,50,75, 100,125,150,200,250,300 and 400 m) using water sampling bottles fitted with reversing thermometers. Since the 1960s and up to the present a considerable amount of data were collected using mechanical and electronic bathythermographs (approximately 55 %) and since the late 1970s conductivity-temperature-depth (CTD) recorders have become commonplace (approximately 15 %). The data collected by these instruments have expected accuracies ranging from  $\pm 0.2$  °C in temperature for bathythermographs to  $\pm 0.02$  °C for reversing thermometers and  $\pm 0.005$  °C for CTDs. Accuracies in salinities range from  $\pm 0.02$  from bottle titrations to  $\pm 0.005$  from CTD measurements.

### 3. DATA ANALYSIS

Temporal biasing in the calculation of monthly averages is likely when there are variations in the amount of data collected from year to year and when the data for a particular month are not distributed evenly throughout the month.

The distributions of temperature and salinity data collected among years for the Labrador and Newfoundland regions are shown in Fig. 1 and 2. In the Newfoundland region 6 % of the temperature data were collected from 1910 to 1950, 15 % from 1951 to 1960, 16 % from 1961 to 1970, 21 % from 1971 to 1980 and 42 % from 1981 to 1992. Very few observations were made before the 1930s and a large gap in the historical record is apparent during the early 1940s corresponding to the second world war. Similarly, 10 % of the salinity data were collected from 1910 to 1950, 15 % from 1951 to 1960, 17 % from 1961 to 1970, 22 % from 1971 to 1980 and 36 % from 1981 to 1992. There has been a large increase in both temperature and salinity data collected in the area since the 1980s, however the total number of salinity profiles is only about half the number of temperature profiles indicating the high usage of bathythermographs, particularly during the 1970s and 1980s. As a result the means calculated here will be biased towards later years.

The distribution of temperature and salinity data in the Labrador region over years shows a somewhat different pattern with 5 % of the temperature data collected between 1921 to 1950, 18 % from 1951 to 1960, 20 % from 1961 to 1970, 21 % from 1971 to 1980 and 36 % from 1981 to 1992. Similarly, 8 % of the salinity data were collected from 1921 to 1950, 11 % from 1951 to 1960, 29 % from 1961 to 1970, 24 % from 1971 to 1980 and 28 % from 1981 to 1992. While there have been a significant increase in the temperature data collected since 1980 there was no significant increase in salinity data collection on the Labrador Shelf.

A strong seasonal bias in the historical temperature data for the Newfoundland region is apparent with only 13 % of the data collected during the winter (January, February and March), 40 % in the spring (April, May and June), 28 % in the summer (July, August and September) and 19 % in the fall (October, November and December). In the Labrador region 8 % of the temperature data were collected during the winter, 12 % in spring, 48 % in

summer and 32 % in the fall. The number of salinity profiles shows a similar distribution. The shift in the data collection towards summer and fall in the Labrador region is clearly related to ice cover in northern regions during the winter and spring months.

Spatial biasing of the monthly averages also occur when there is a significant amount of data confined to a particular area of the region under consideration, for example along standard transect lines or at fixed oceanographic monitoring stations. Figures 3a to 3f show the spatial distribution of temperature profiles on a monthly basis in a  $1.0^{\circ}$  latitude by  $1.5^{\circ}$  longitude square projection in the Newfoundland and Labrador regions. The number of temperature profiles range from less than 10 in offshore regions to over 500 in some areas in the inshore regions of the Grand Bank. In the Labrador regions the number of profiles were considerably lower with virtually no coverage in northern areas in the winter months to reasonable coverage in August with the number of profiles ranging from over 100 in the inshore areas in southern areas to fewer than 10 in northern and offshore areas.

The data were quality controlled for obvious spikes and linearly interpolated or decimated if necessary to the standard depth intervals referred to above. The profiles were not extrapolated beyond their depth range. The profiles were restricted in the range of -1.86 to 20.0 °C for temperature and from 29.0 to 36.0 psu for salinity. Data profiles collected with the same instrument within one minute of latitude and within a 30 minute time interval were considered duplicates and only one was retained. In addition, in cases where a particular cast was repeated on the same station as described above with a different instrument the duplicate data were discarded, keeping CTD and bottle data over BTs.

To prepare for computer contouring the data were subsampled at the standard depths and averaged into a  $0.25^{\circ}$  latitude by  $0.38^{\circ}$  longitude grid and a simple arithmetic mean computed for all profiles in the grid on a monthly basis. As mentioned above this average consists of up to 500 profiles on the Grand Bank near the coast to as low as 1 profile in the offshore and northern regions. No attempts were made to adjust these monthly averages for temporal or spatial biasing arising from the sample distribution discussed above. The plotting package used this averaged data as input to a finite difference Laplacian interpolation contouring scheme. Contour lines were generally not extrapolated beyond 2 grid points into areas with missing data.

#### 4. DATA PRODUCTS

Appendix A contains horizontal contour maps of the monthly averages of temperature and salinity at standard oceanographic depths of 0, 10, 20, 30, 50, 75, 100, 150, 200 m for the Newfoundland and Labrador regions. Similarly appendix B contains horizontal maps of the monthly averaged bottom temperature and salinity for the Newfoundland and Labrador regions.

These plots show the seasonal variations in the temperature, and salinity fields at various depths from the surface to 200 m depth and near the bottom in the Northwest Atlantic mainly over the continental shelves of the Canadian Atlantic coast from south of the Grand Bank and north to Baffin Bay. Areas on some maps with missing or broken isolines correspond to areas with limited data as indicated by the spatial distribution maps in Figs. 3a to 3f. The contour maps for the Labrador and Newfoundland region were done separately, this may cause differences in the detail of the contour lines in the regions of overlap due to the interpolation scheme use to draw the contours.

#### *Acknowledgements*

This work has been supported through the Government of Canada's Atlantic Fisheries Adjustment Program (Northern Cod Science Program). We thank Drs. G. Mertz and G. R. Lilly for their helpful reviews and comments. We also thank the many scientists and technicians who have contributed to the Northwest Atlantic data base over the years.

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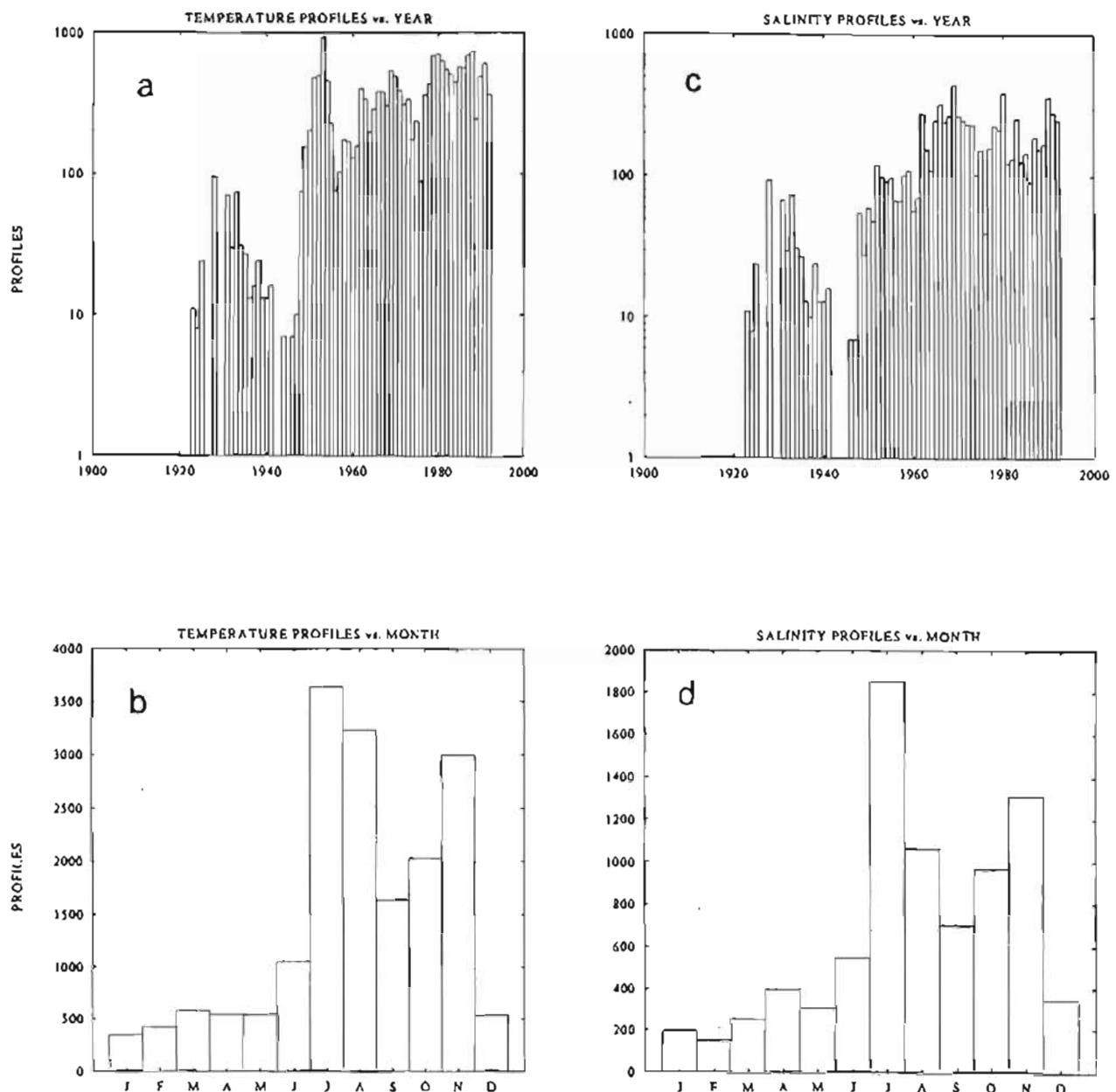


Fig. 1. The total number of temperature profiles (a) by year and (b) by month available in the Labrador region and the total number of salinity profiles available in the Labrador region (c) by year and (d) by month.

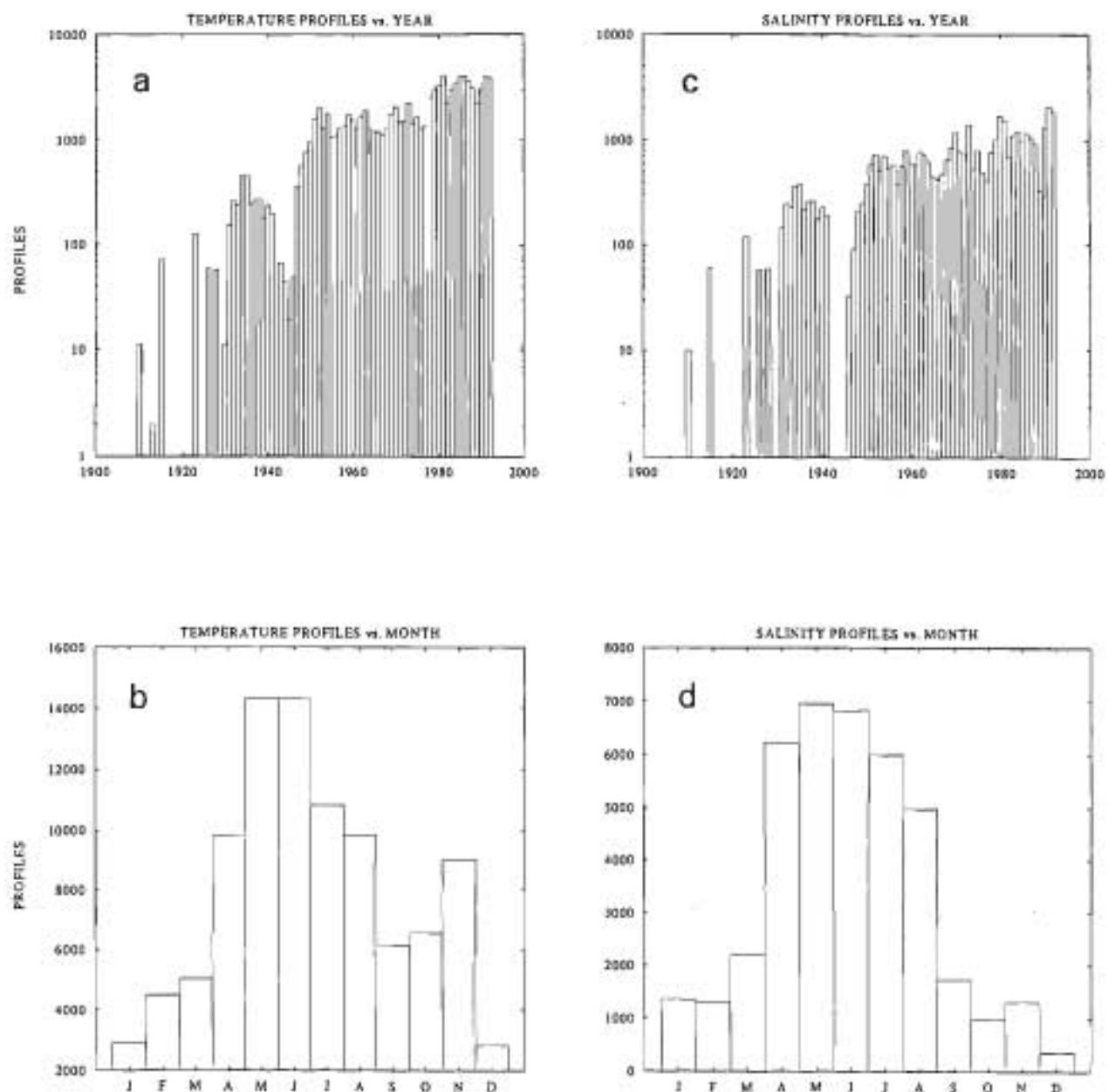


Fig. 2. The total number of temperature profiles (a) by year and (b) by month available in the Newfoundland region and the total number of salinity profiles available in the Newfoundland region (c) by year and (d) by month.

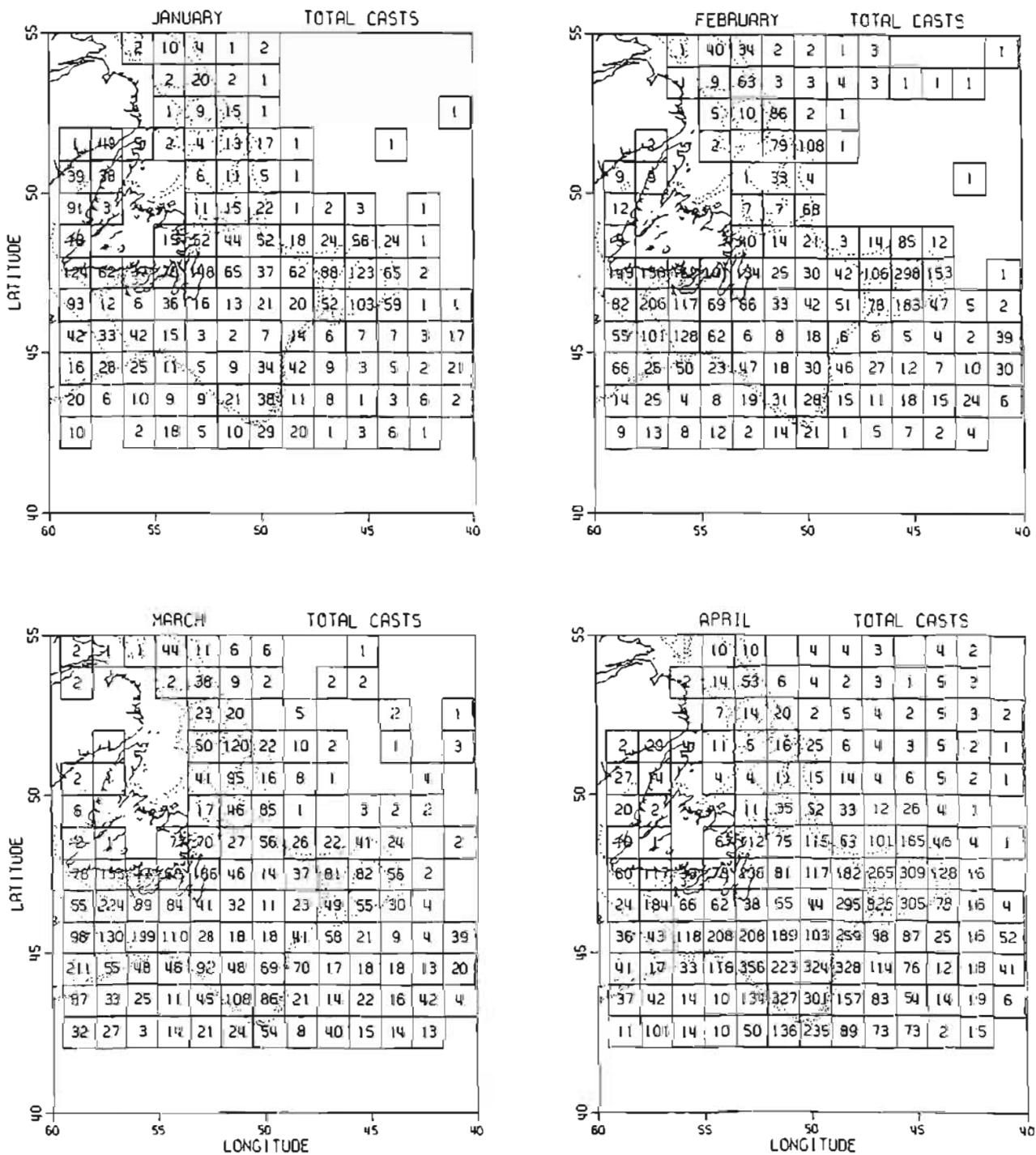


Fig. 3a. Location map showing the number of temperature observations in the Newfoundland region for January to April from 1910 to 1992. The bathymetry lines are 300 and 1000 m.

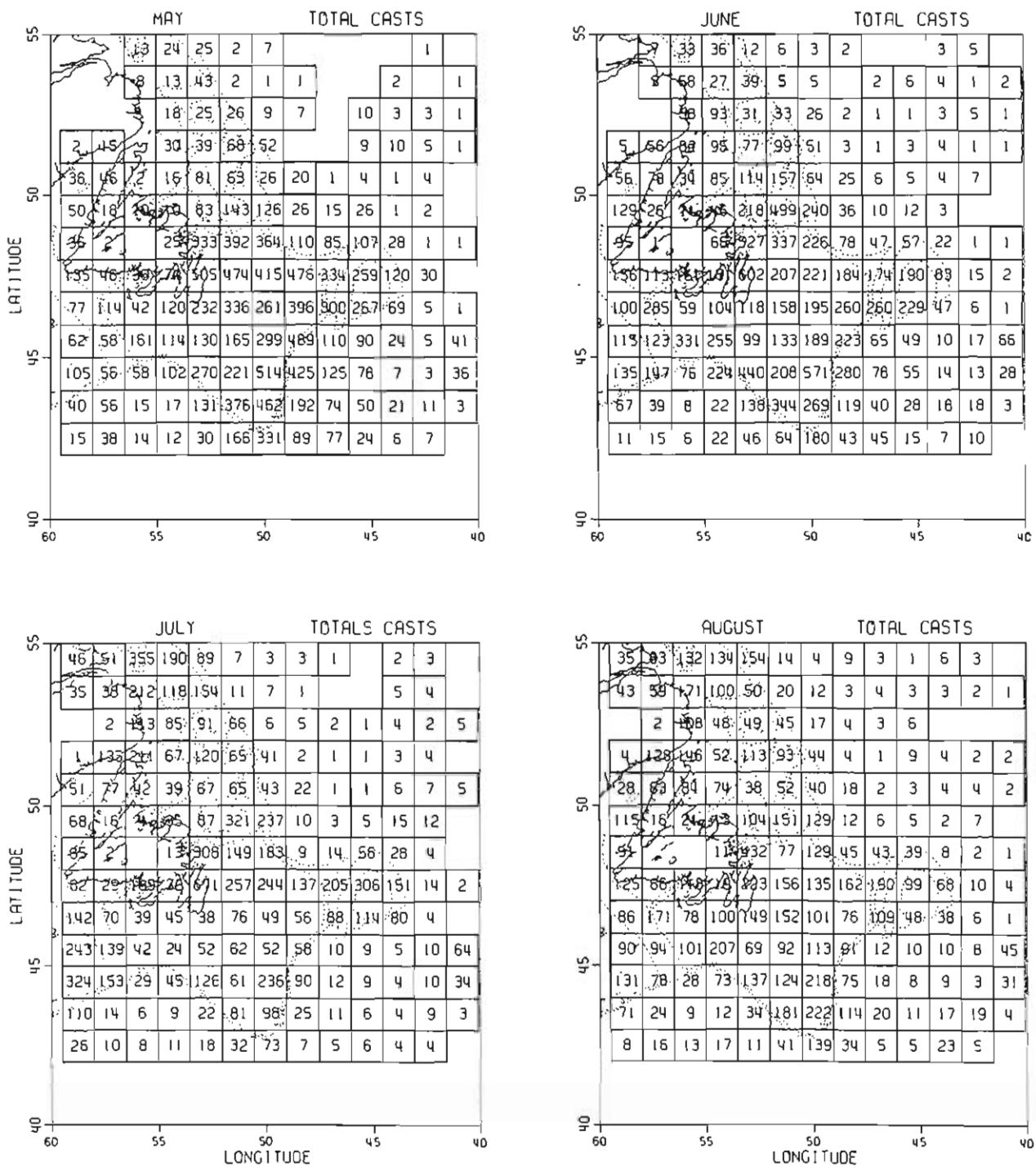


Fig. 3b. Location map showing the number of temperature observations in the Newfoundland region for May to August from 1910 to 1992. The bathymetry lines are 300 and 1000 m.

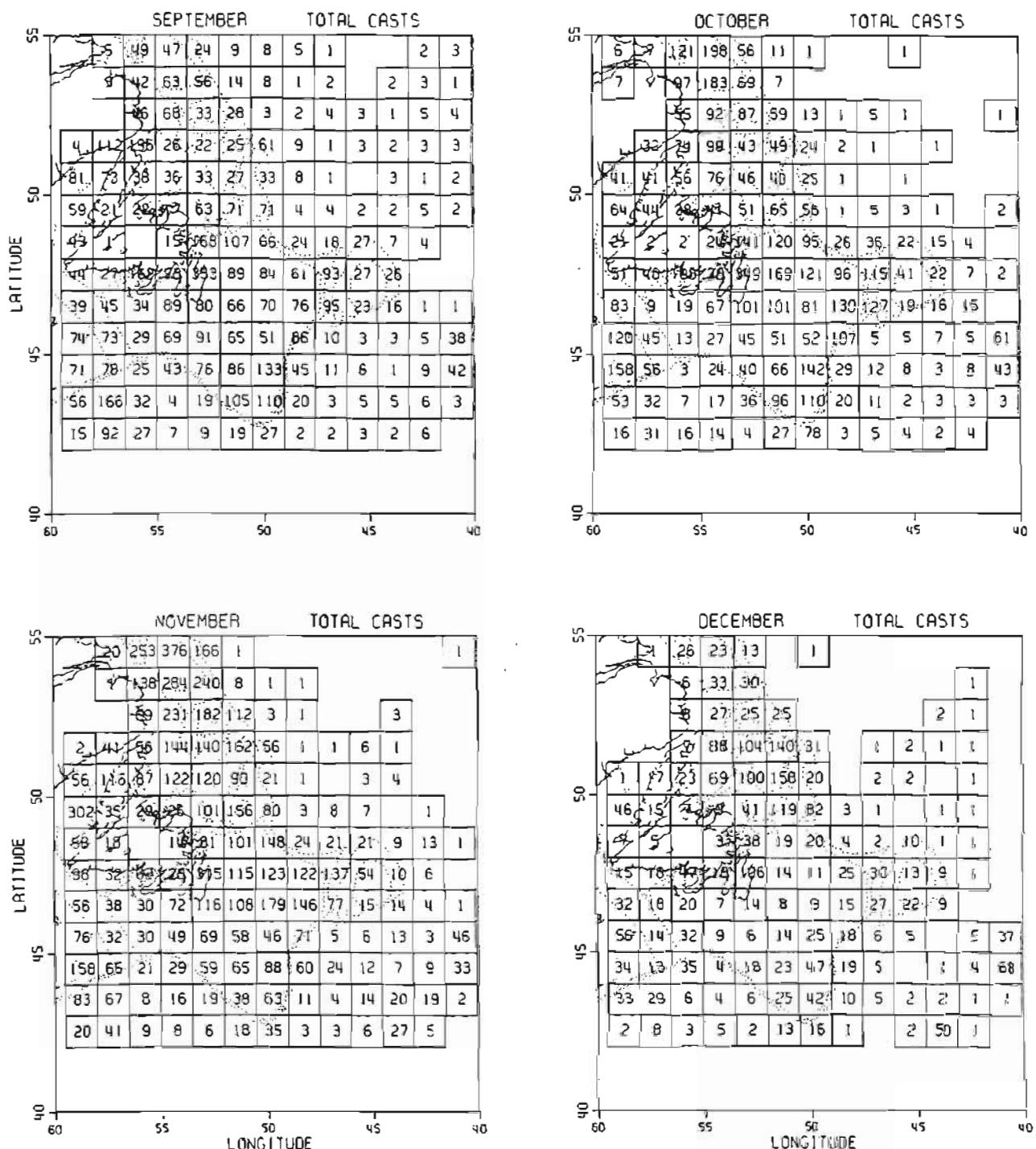


Fig. 3c. Location map showing the number of temperature observations in the Newfoundland region for September to December from 1910 to 1992. The bathymetry lines are 300 and 1000 m.

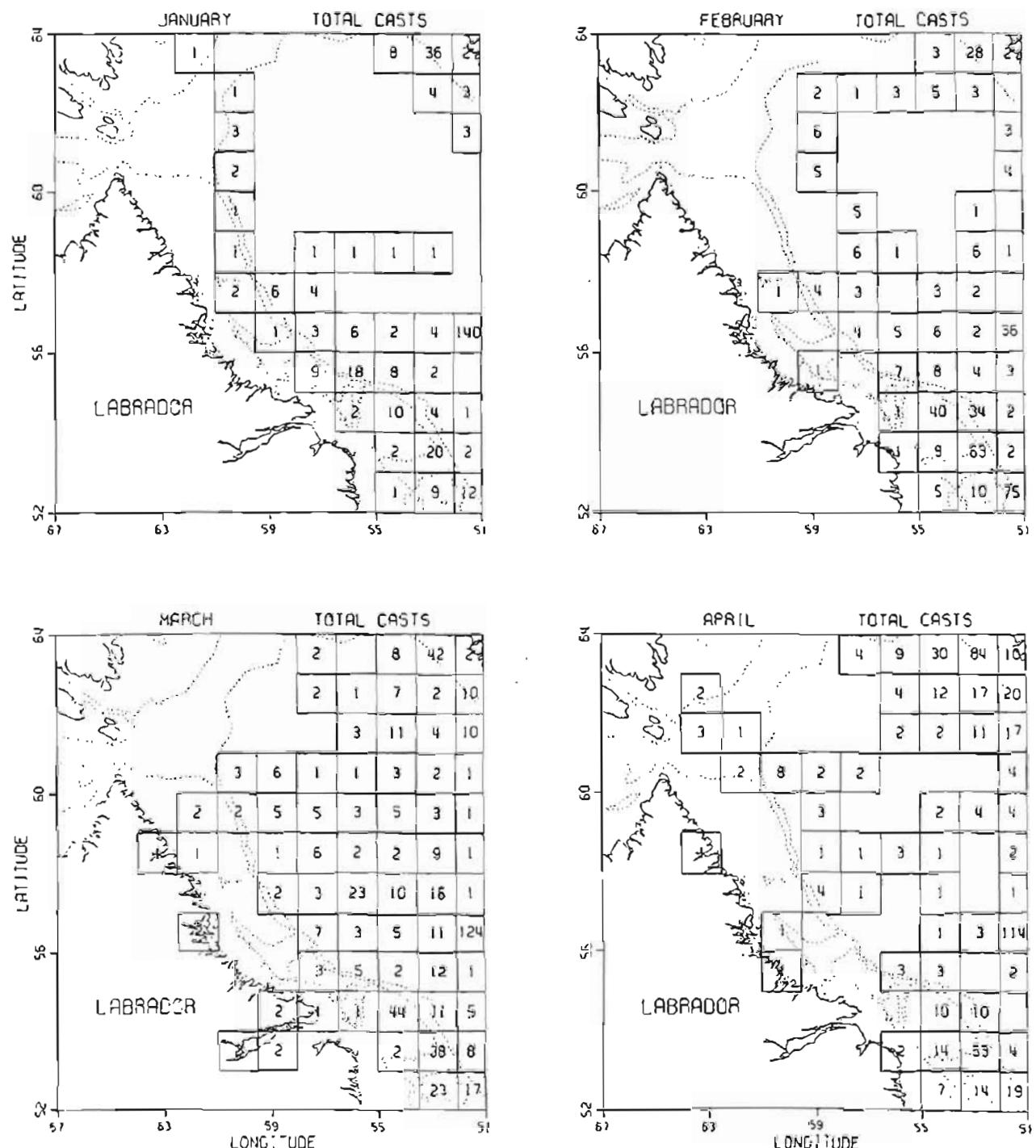


Fig. 3d. Location map showing the number of temperature observations in the Labrador region for January to April from 1910 to 1992. The bathymetry lines are 300 and 1000 m.

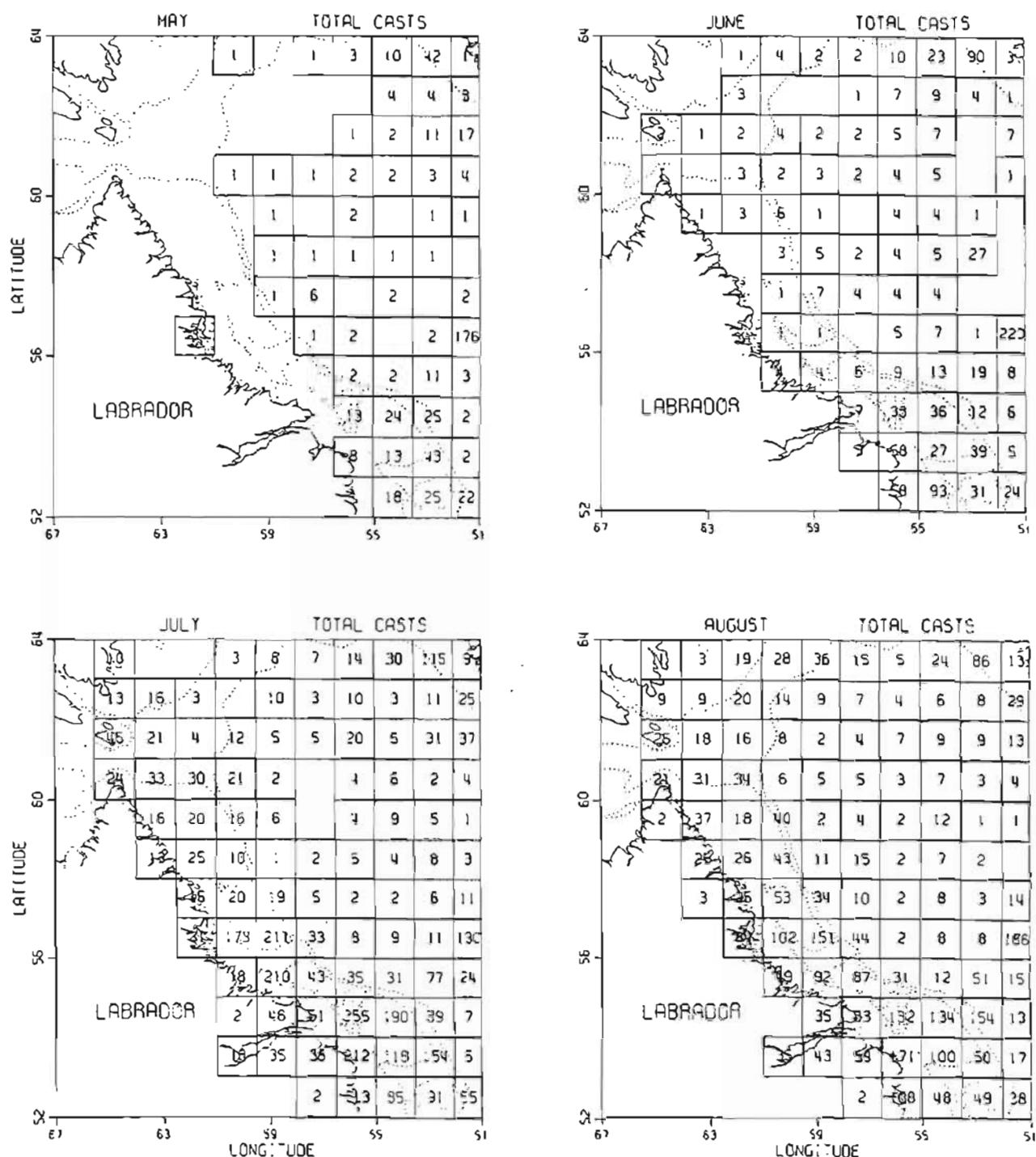


Fig. 3e. Location map showing the number of temperature observations in the Labrador region for May to August from 1910 to 1992. The bathymetry lines are 300 and 1000 m.

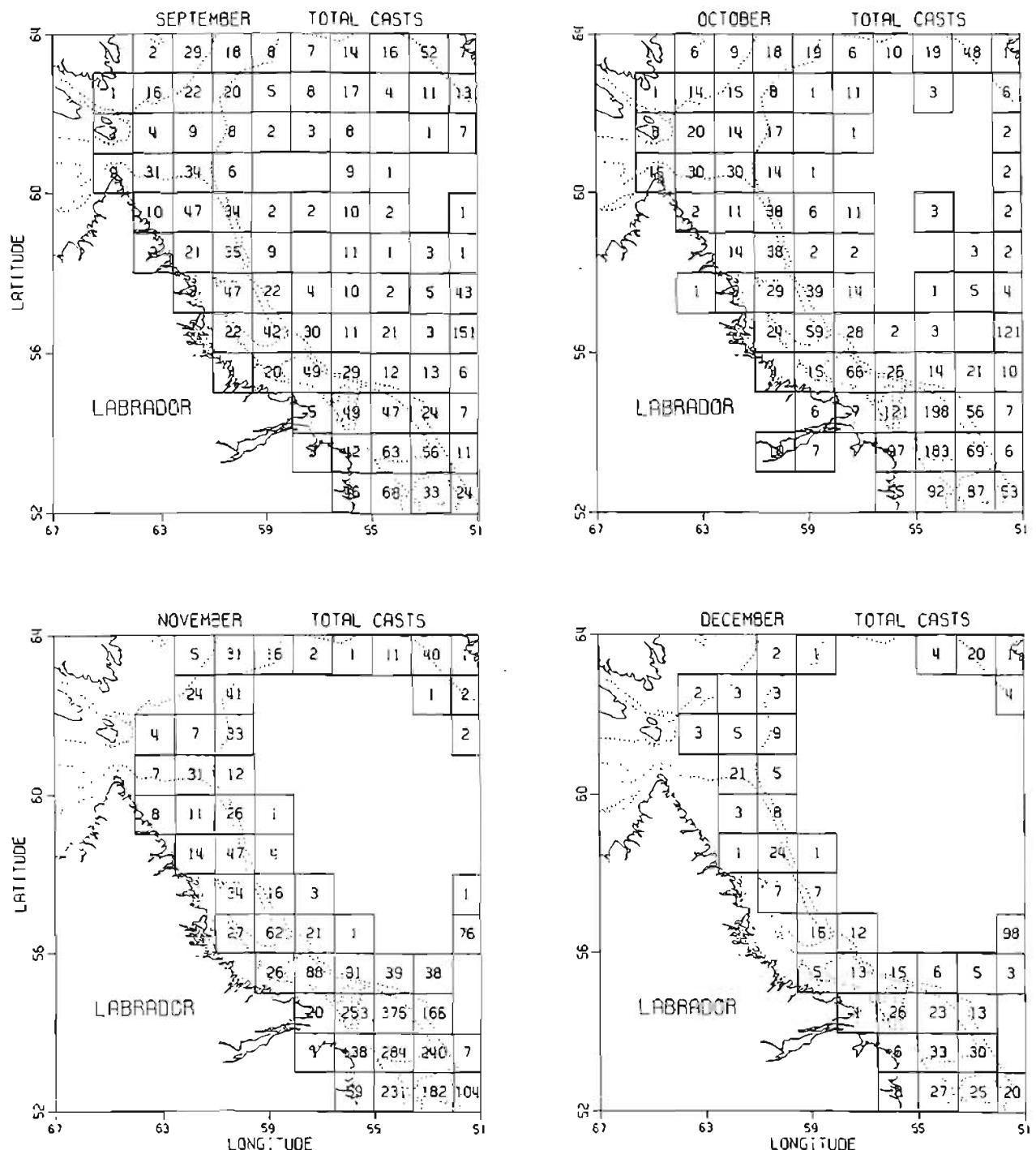
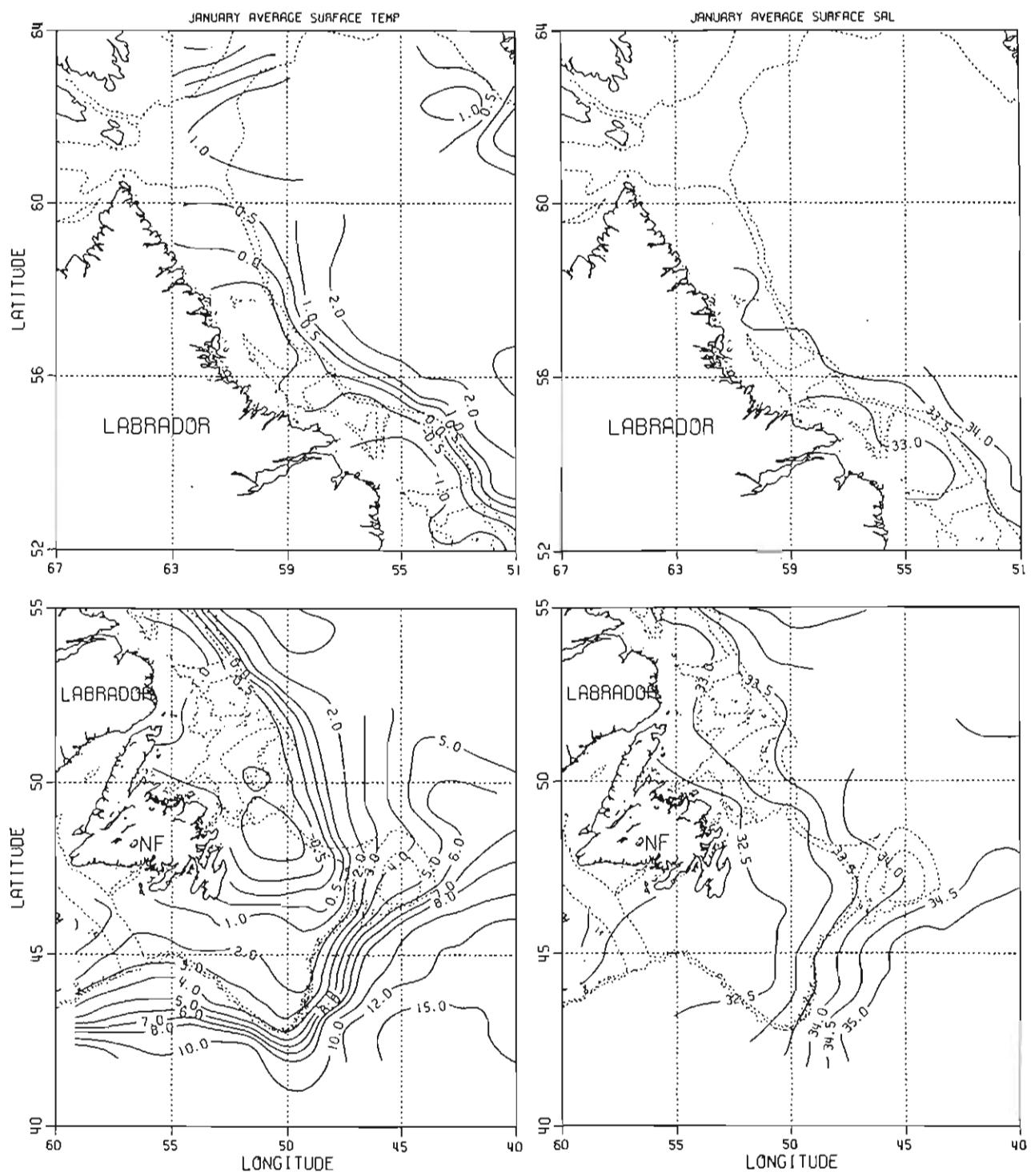
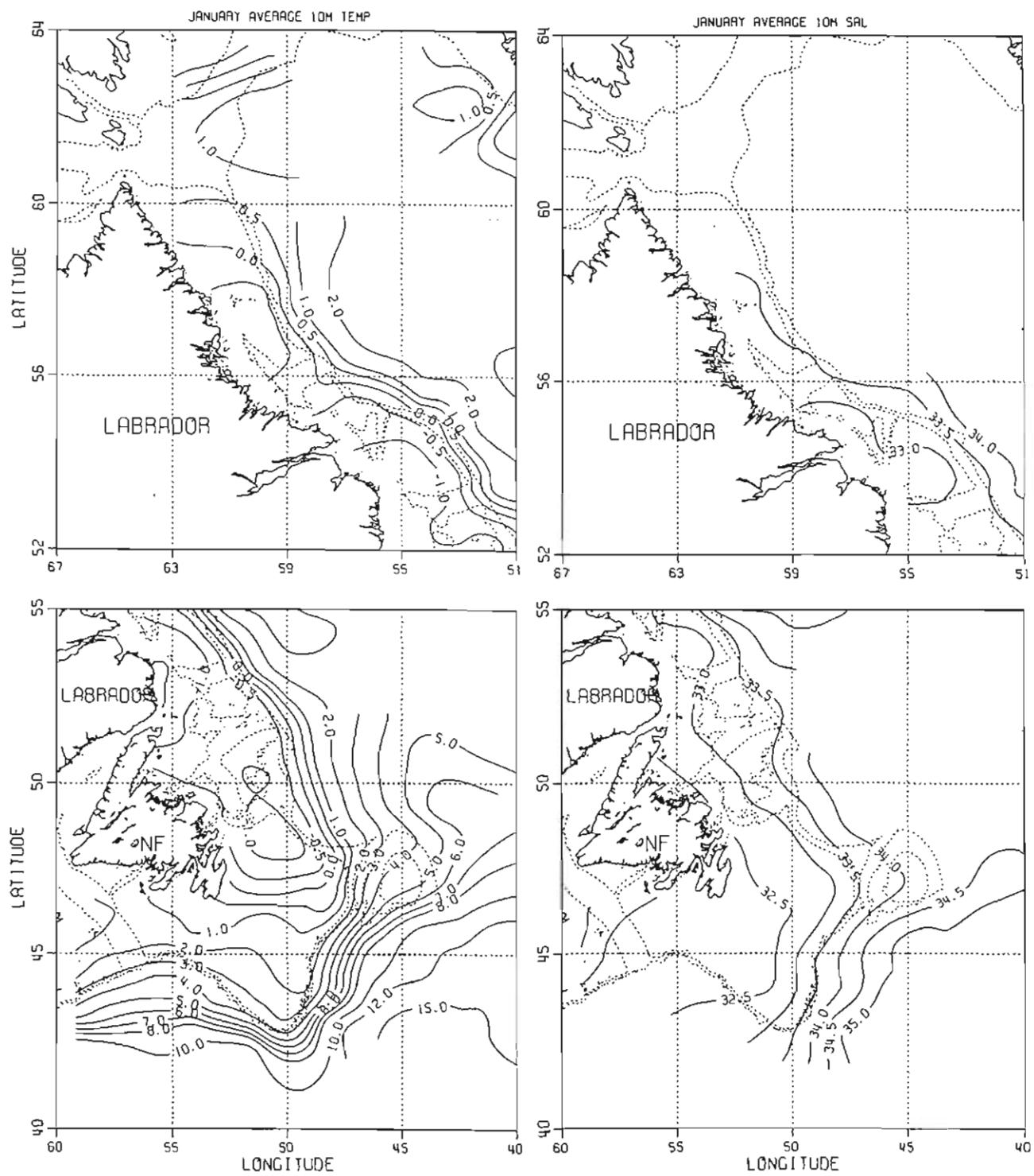
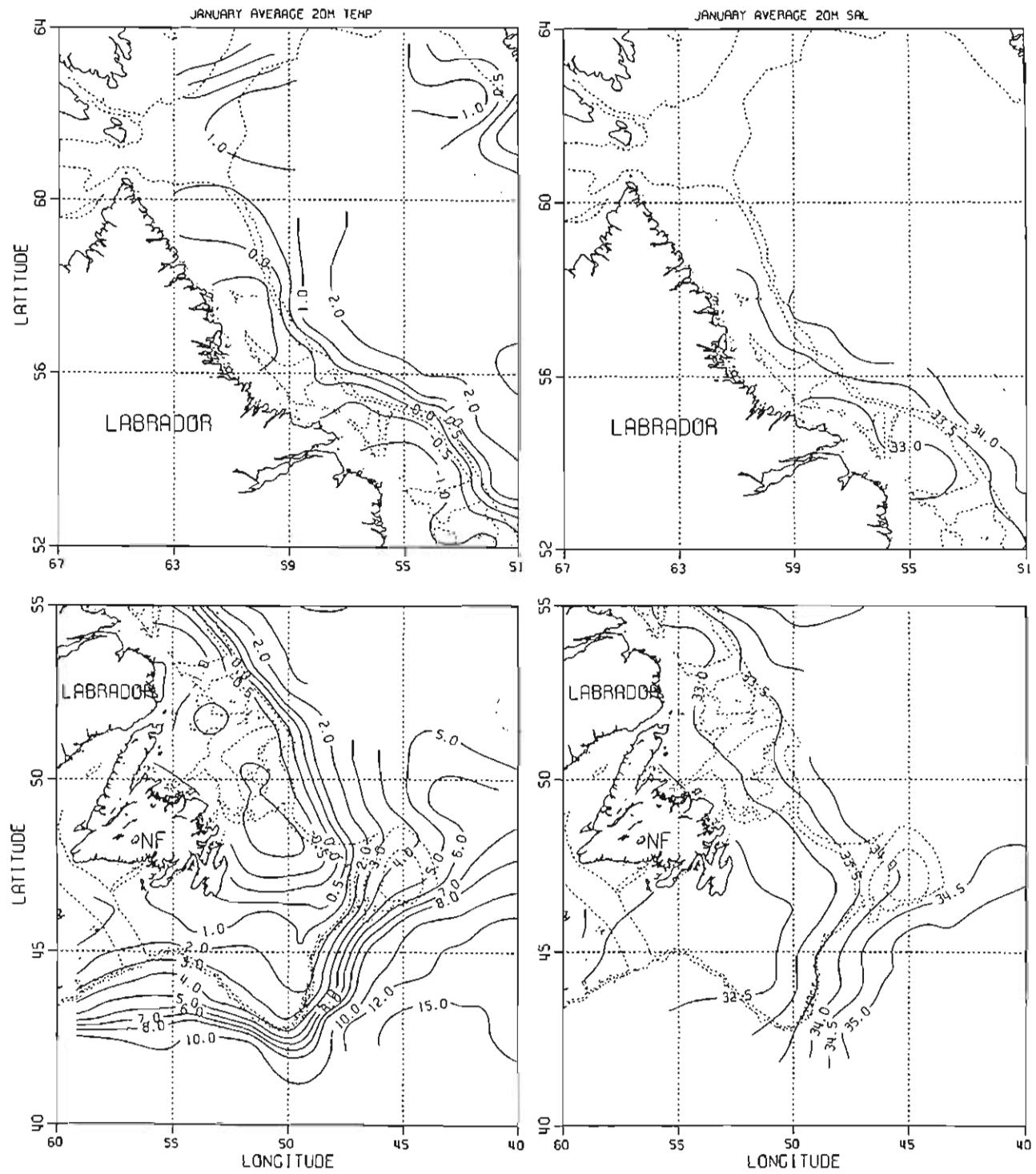


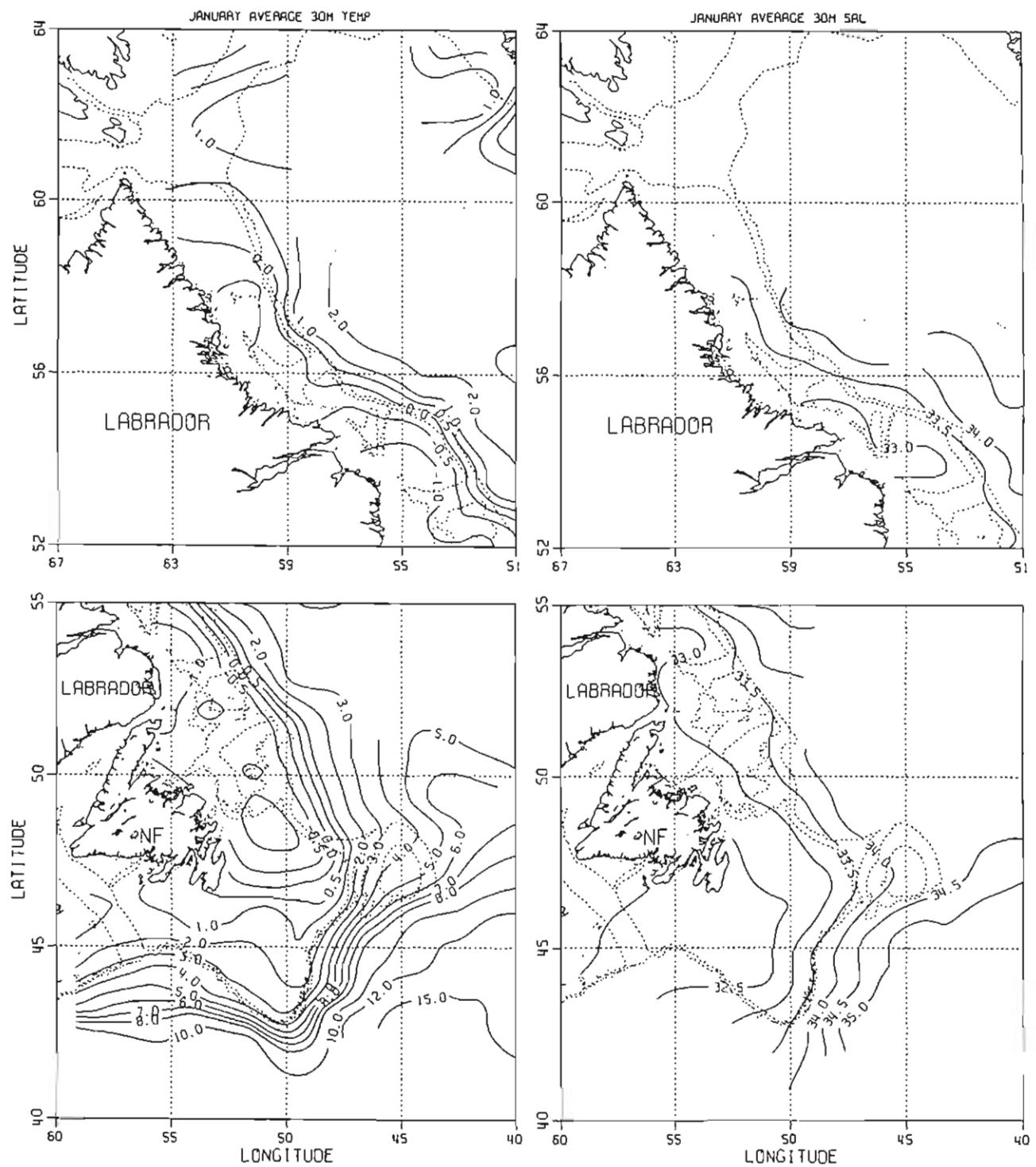
Fig. 3f. Location map showing the number of temperature observations in the Labrador region for September to December from 1910 to 1992. The bathymetry lines are 300 and 1000 m.

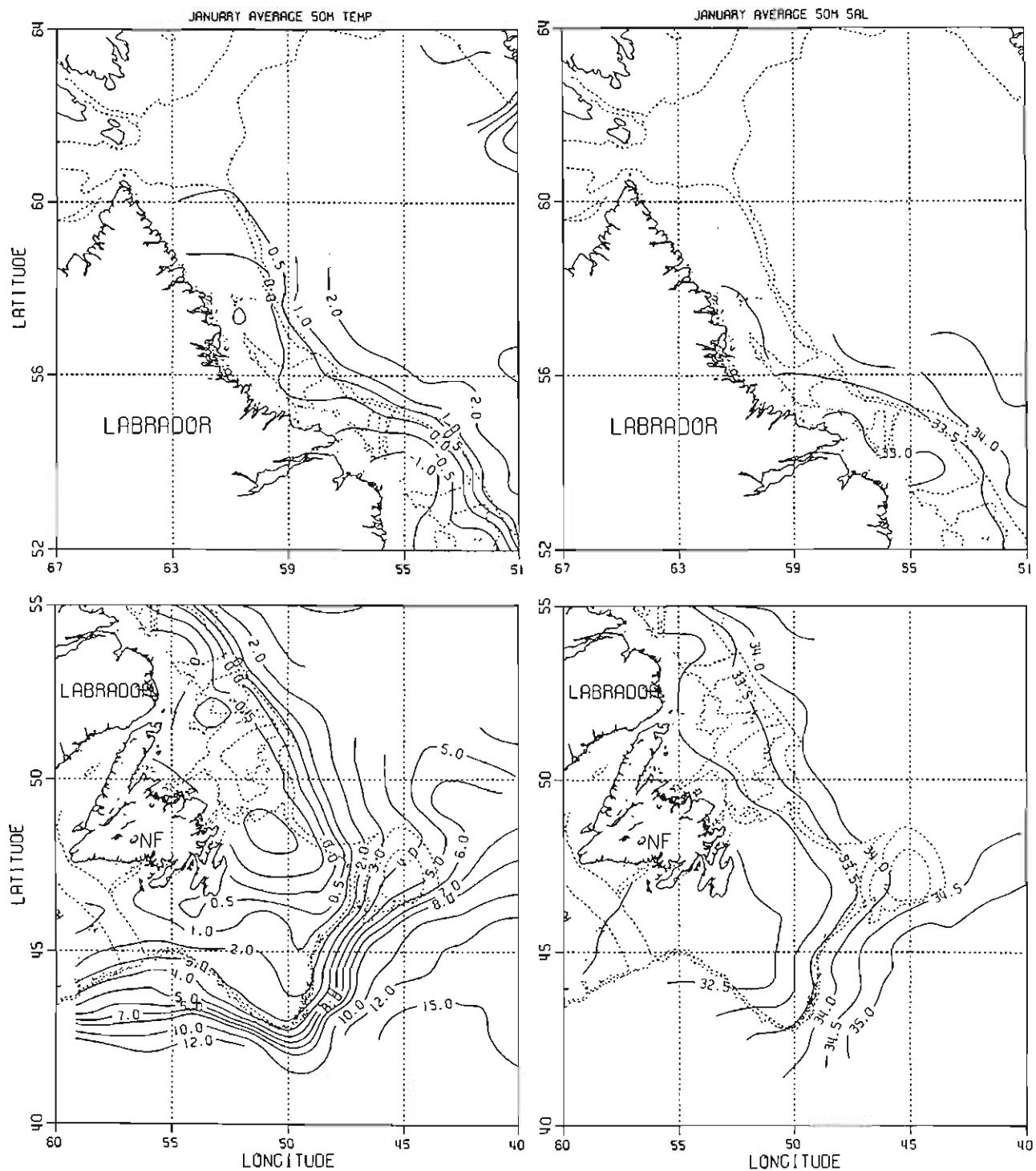
APPENDIX A. Horizontal maps of monthly averaged temperature and salinity at standard oceanographic depths for the Newfoundland and Labrador regions.

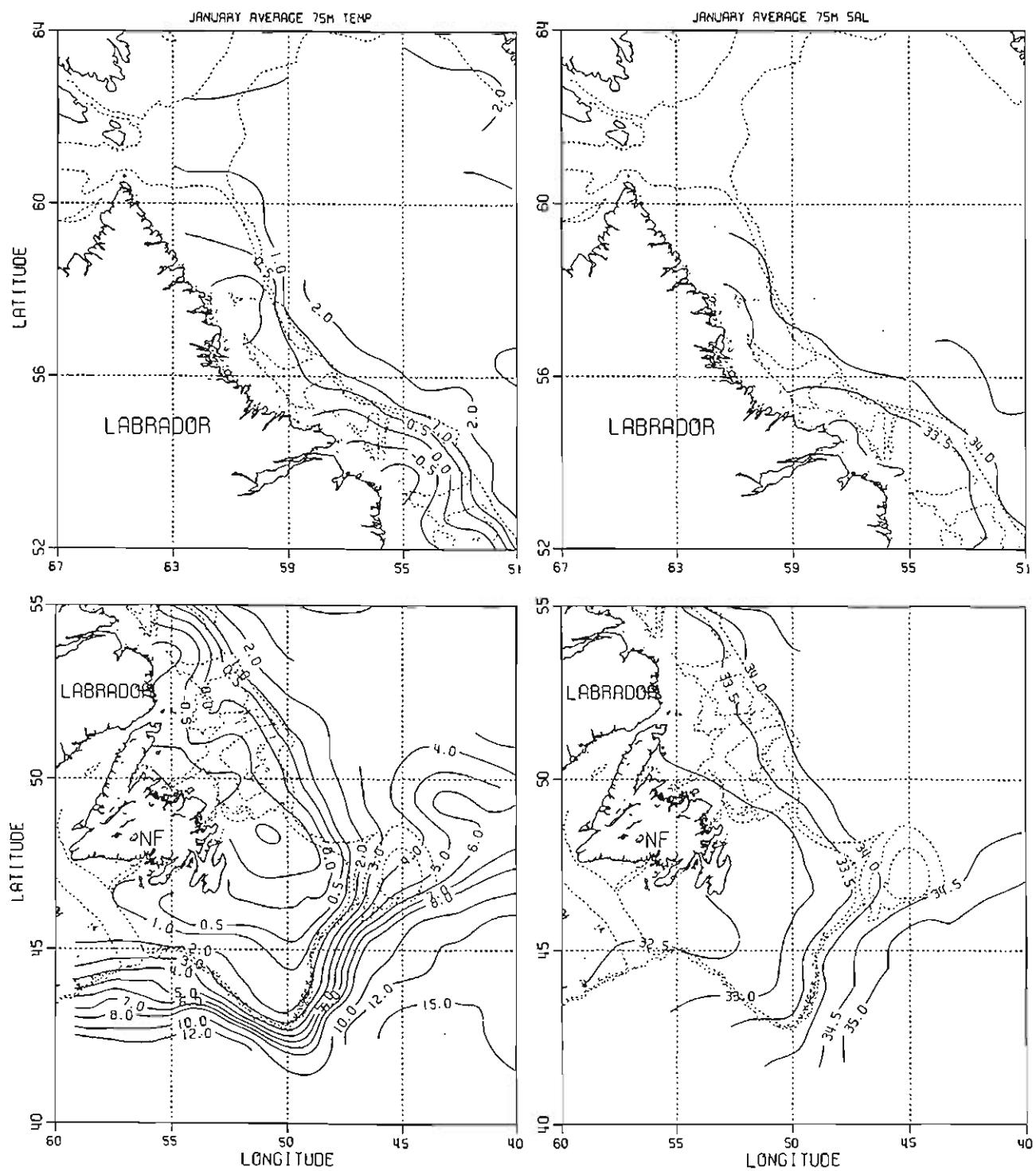


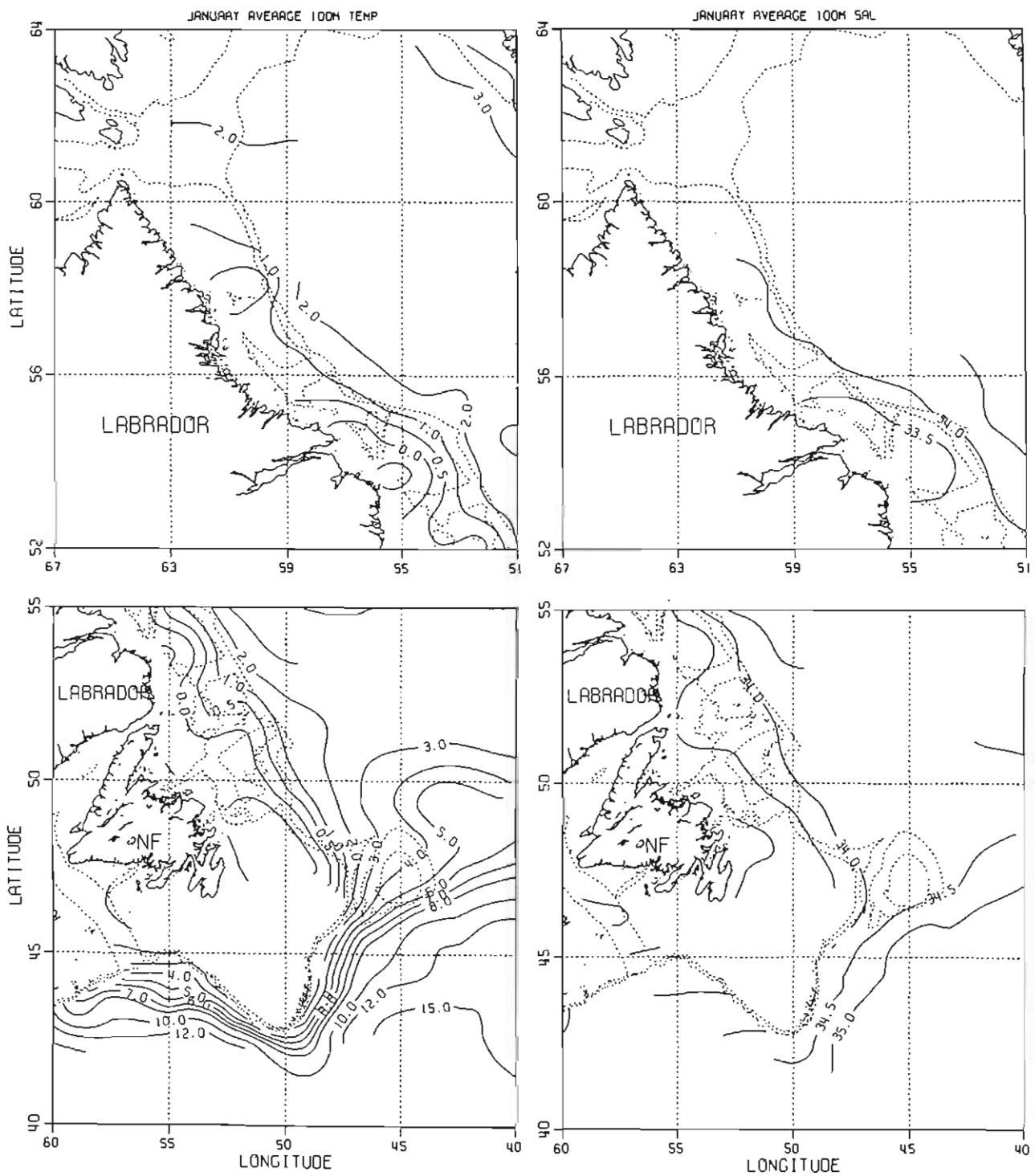


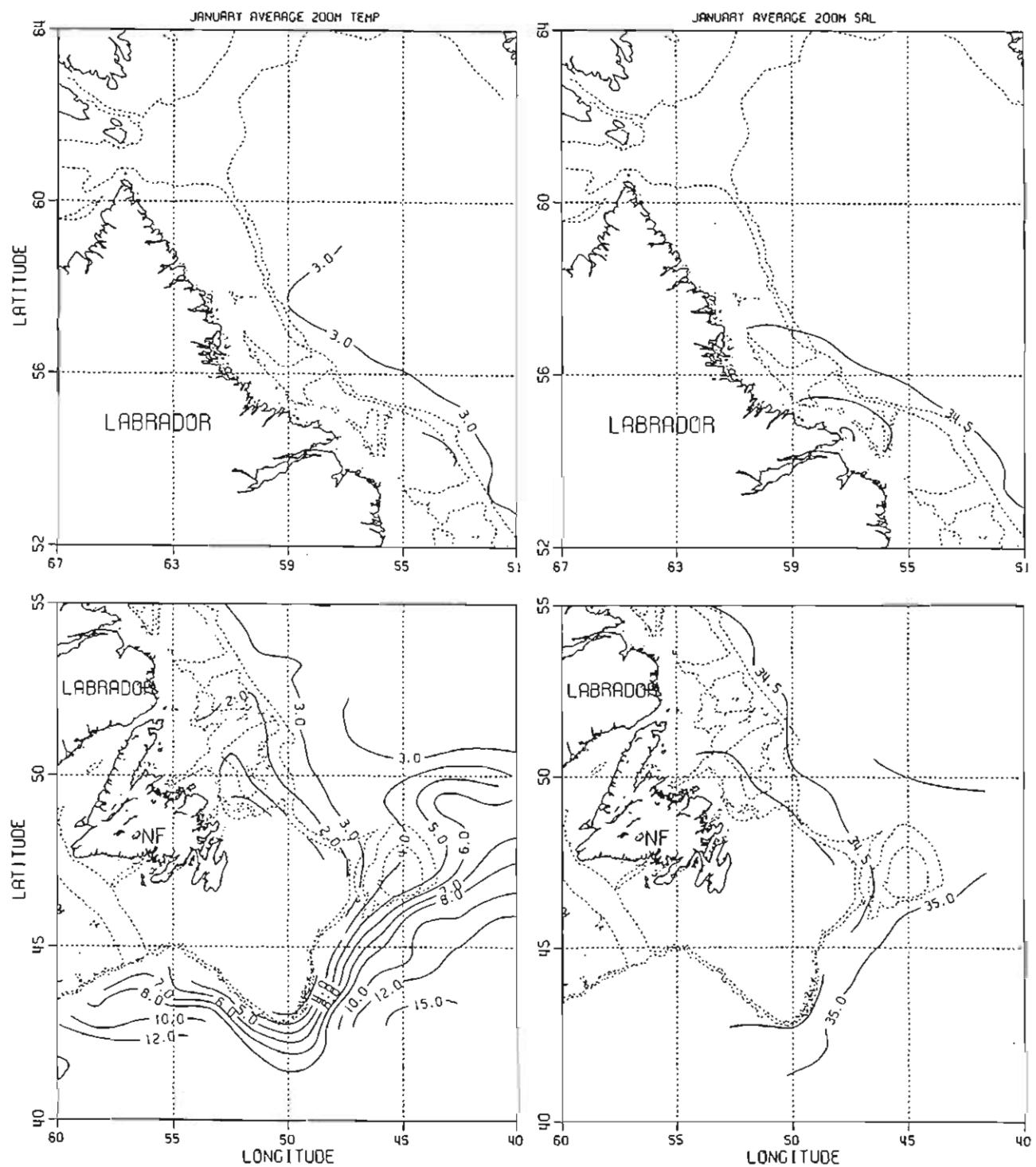


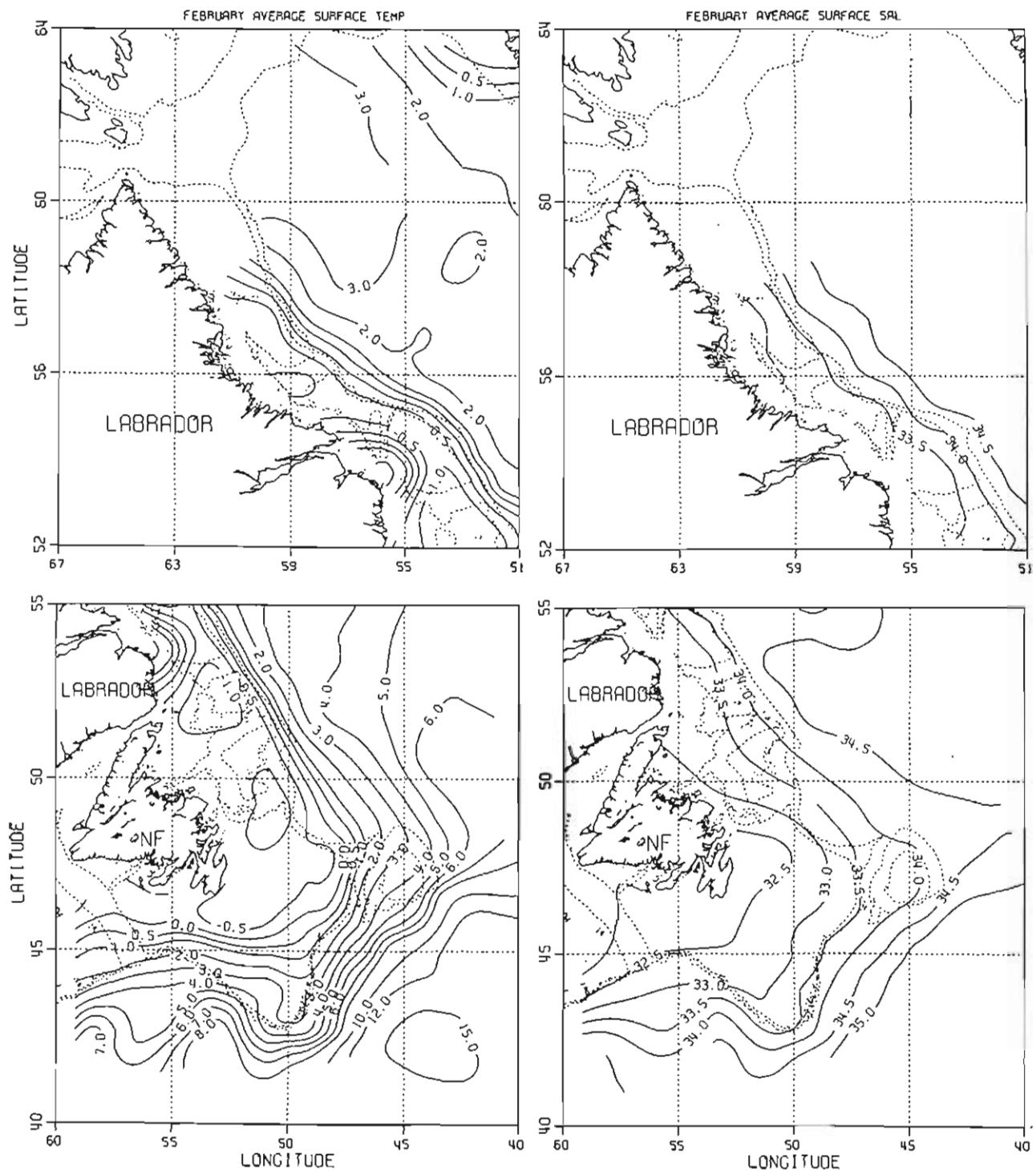


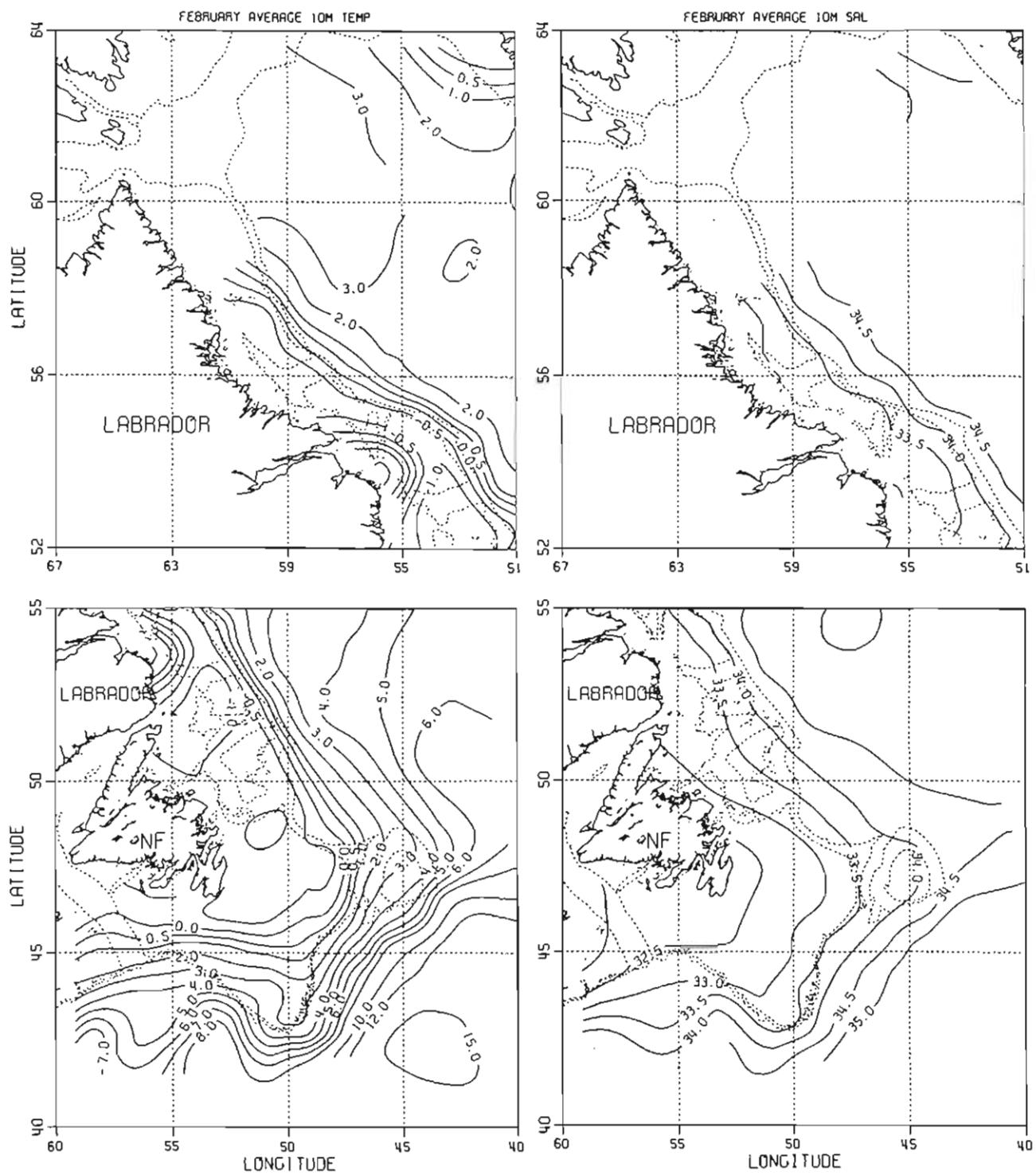


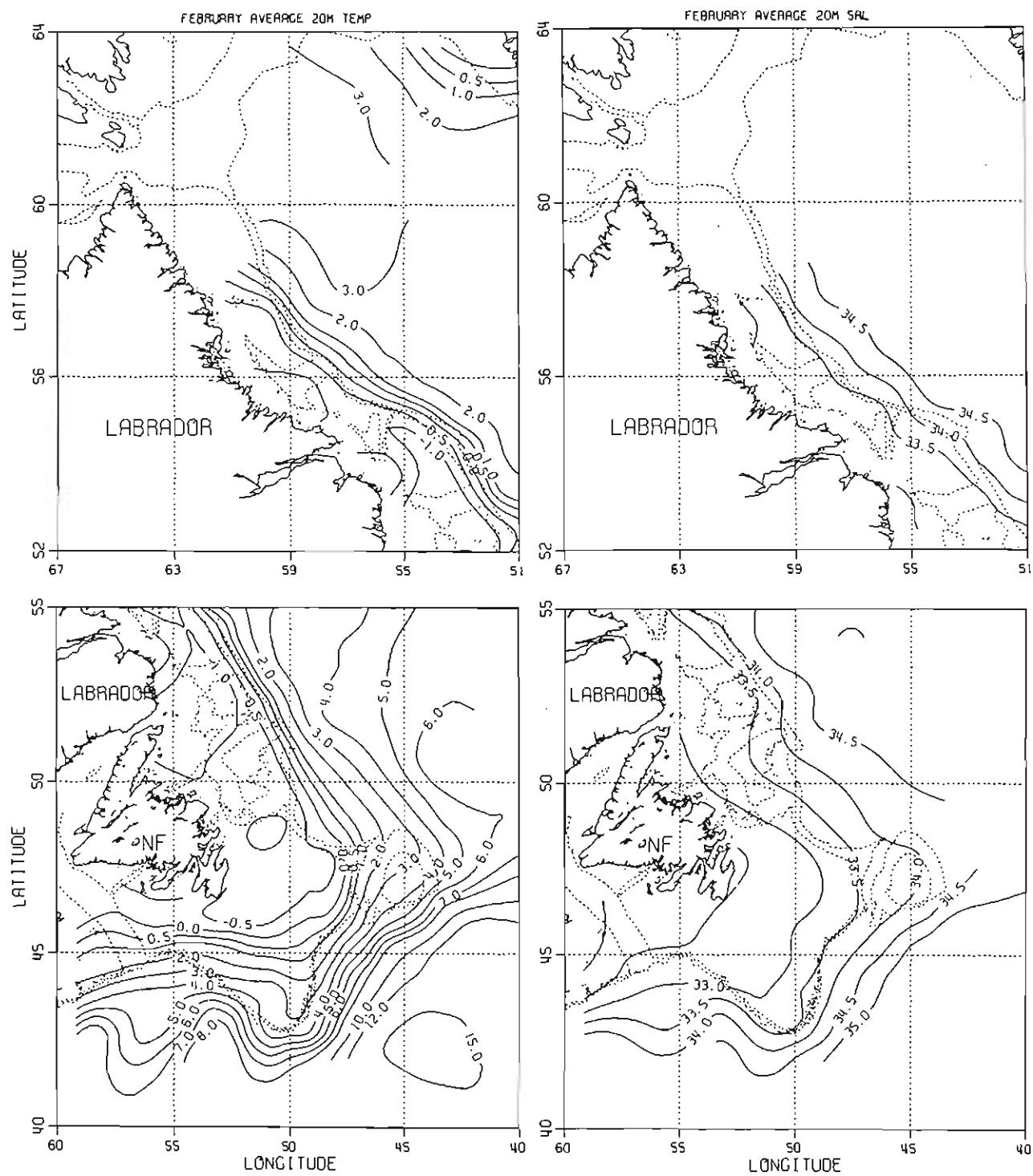


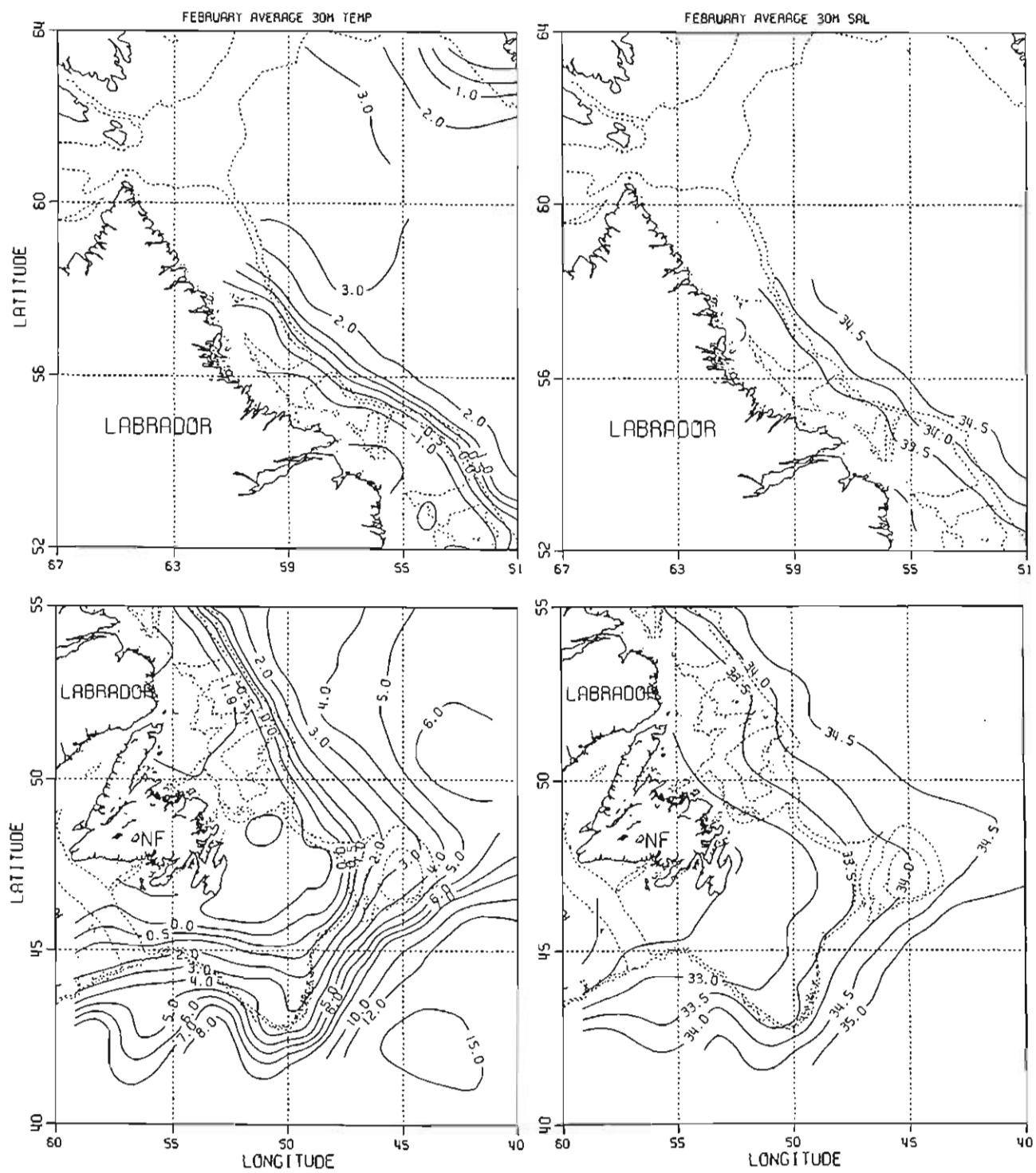


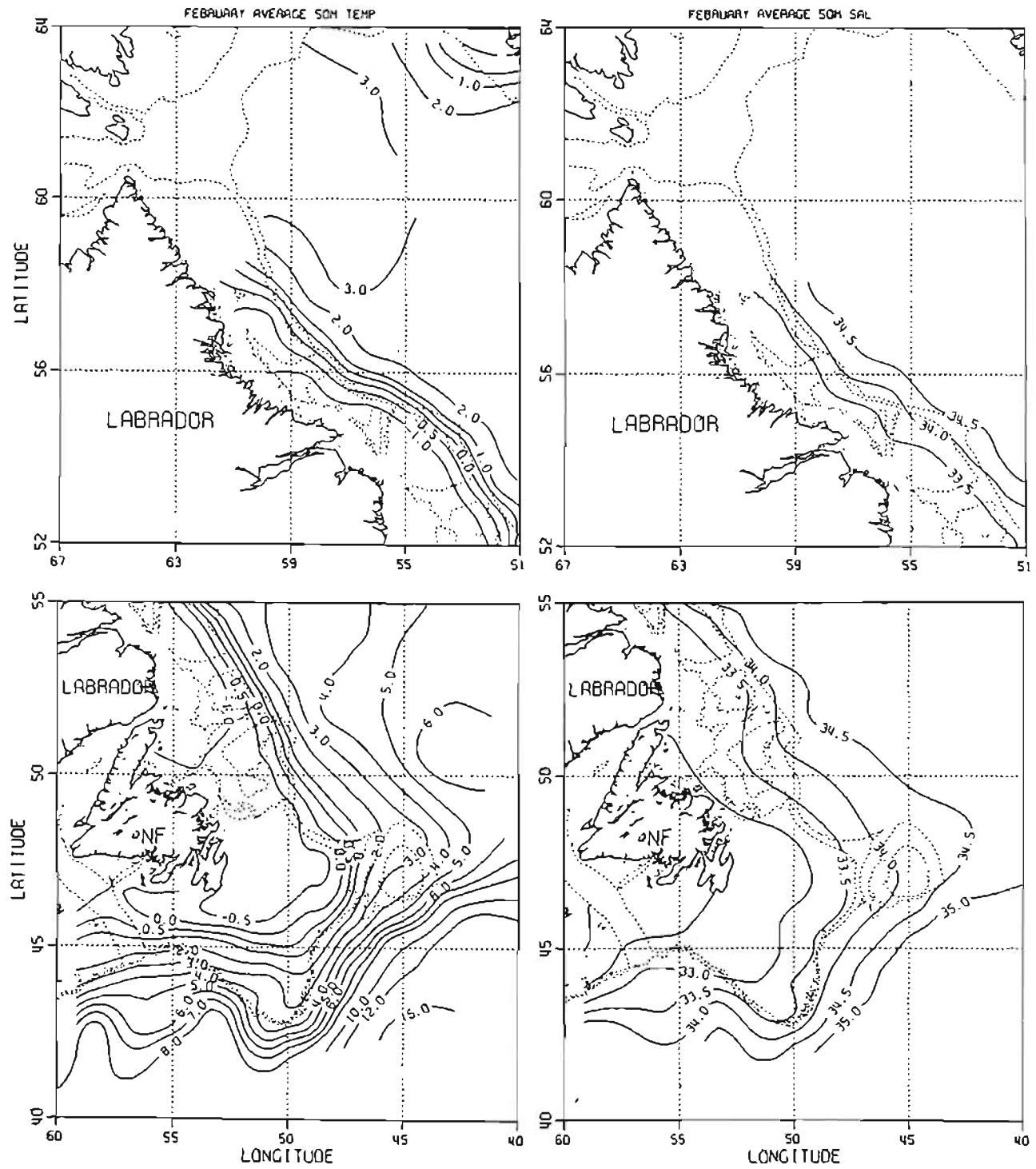


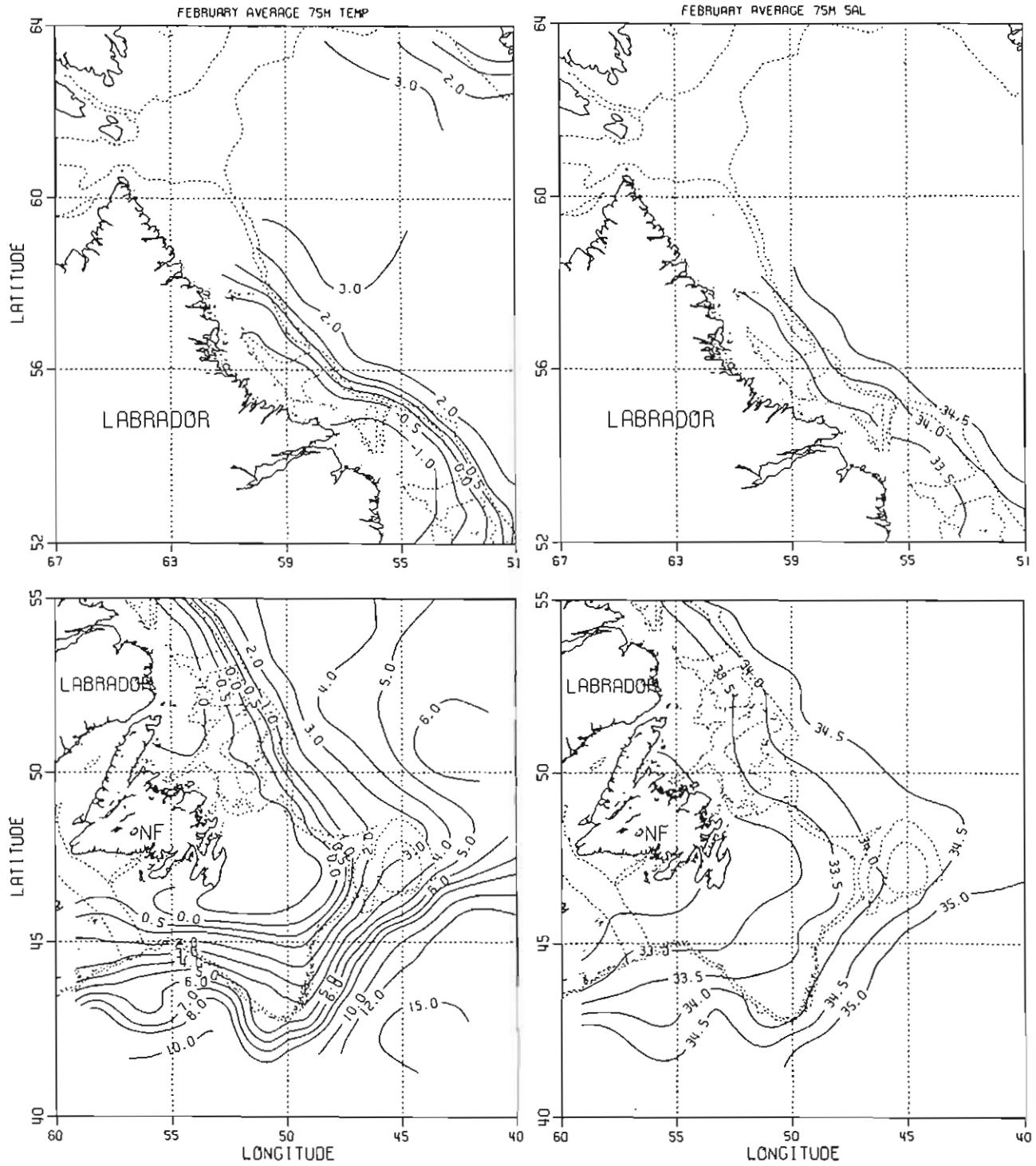


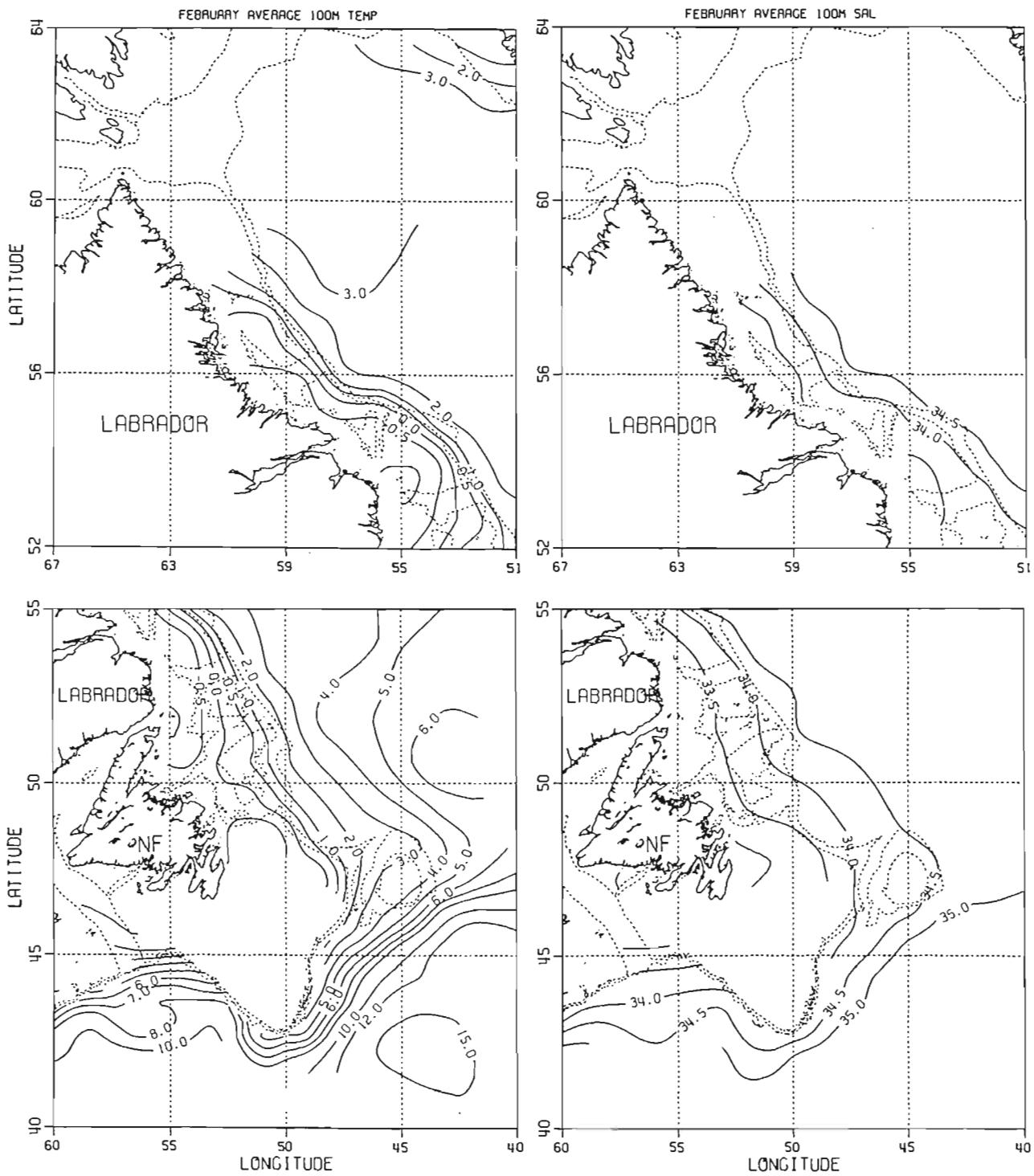


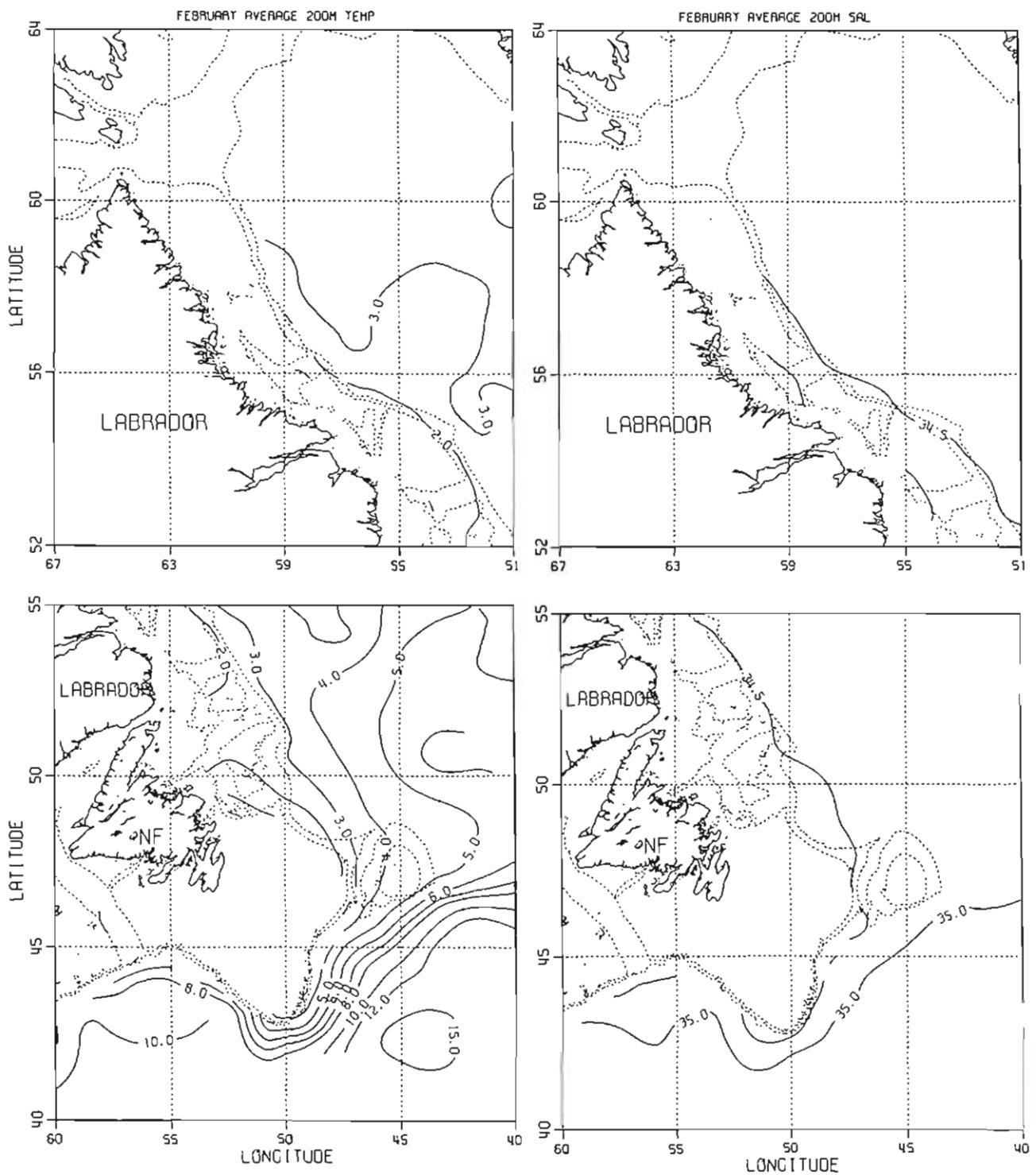


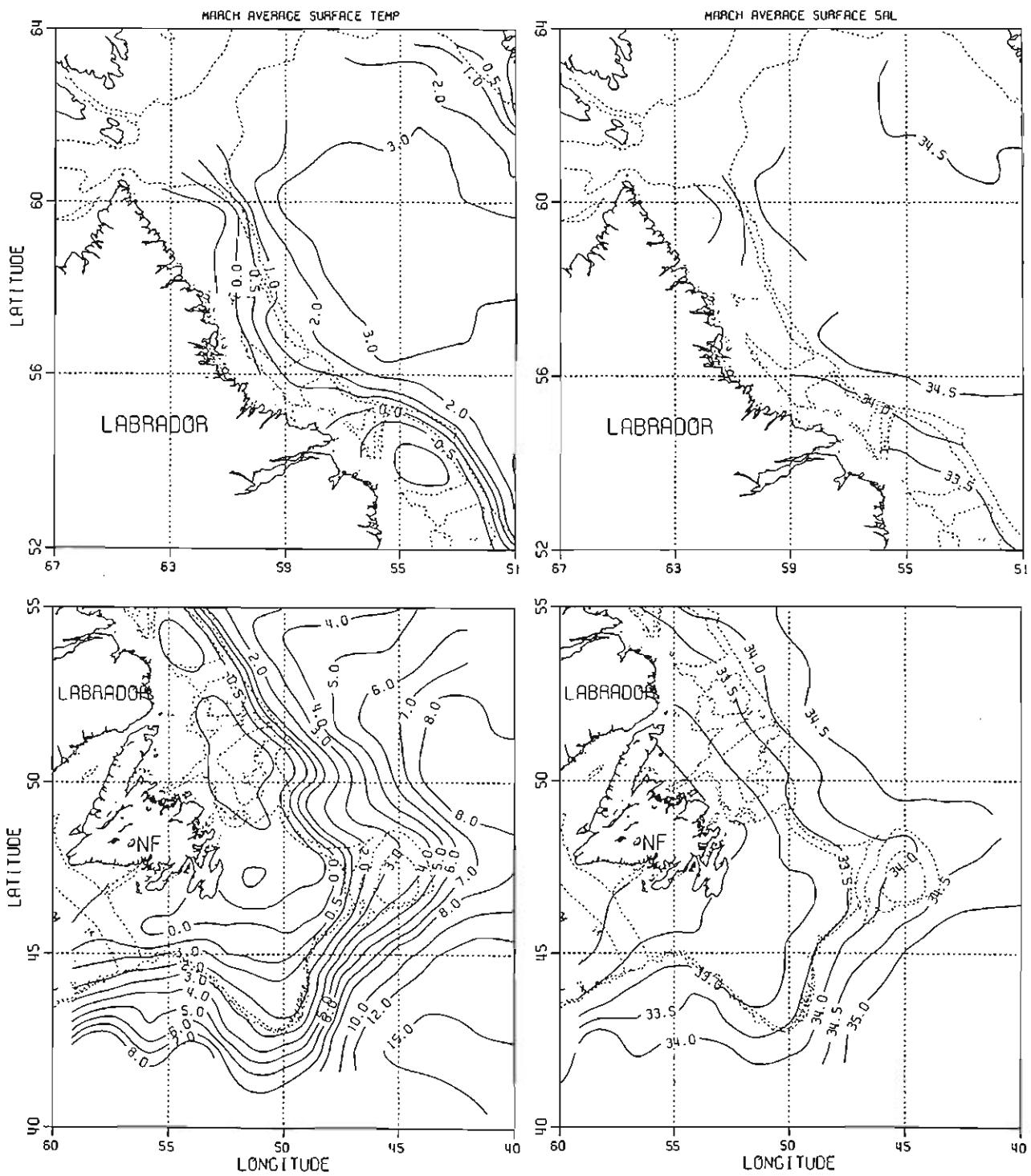


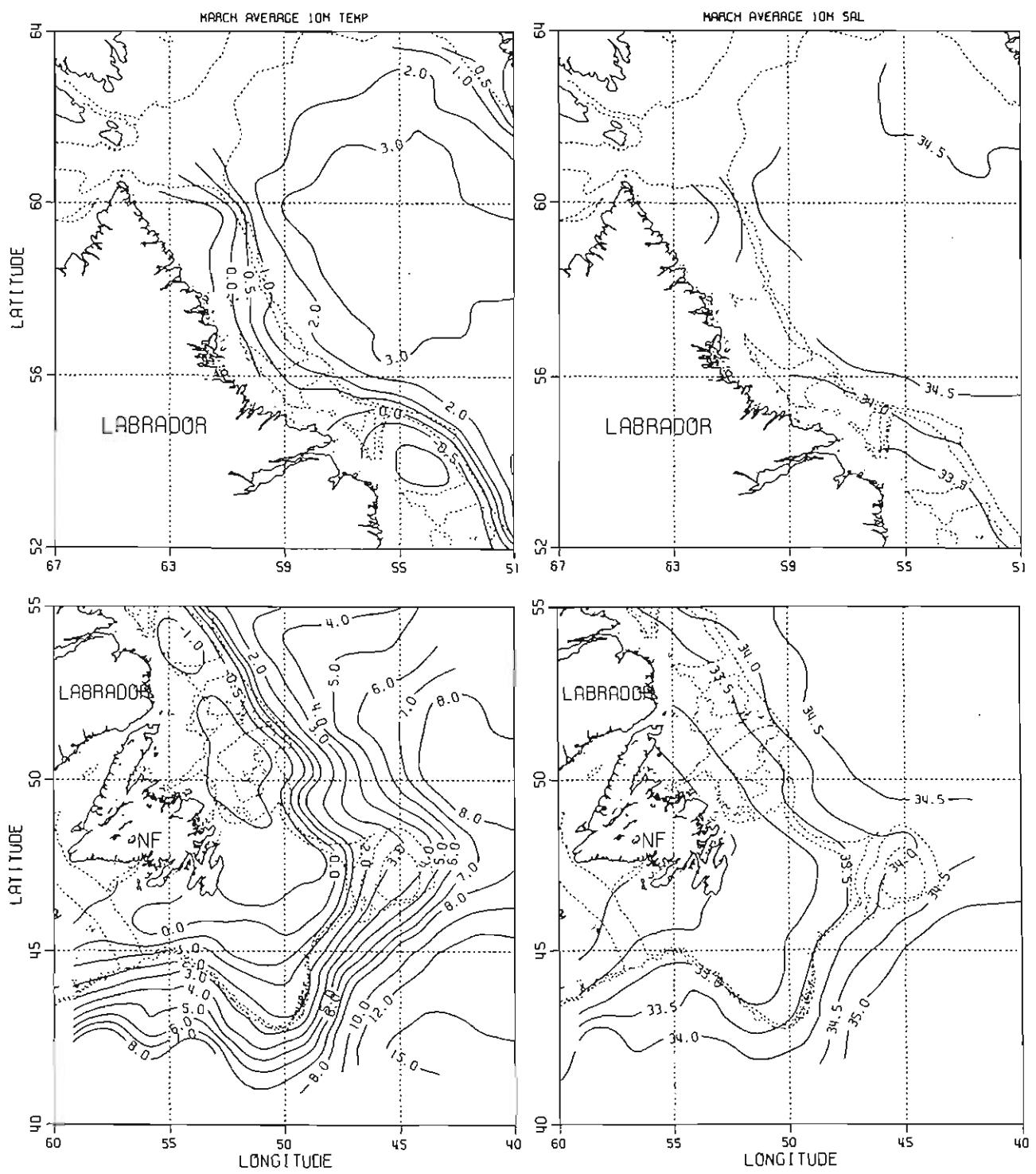


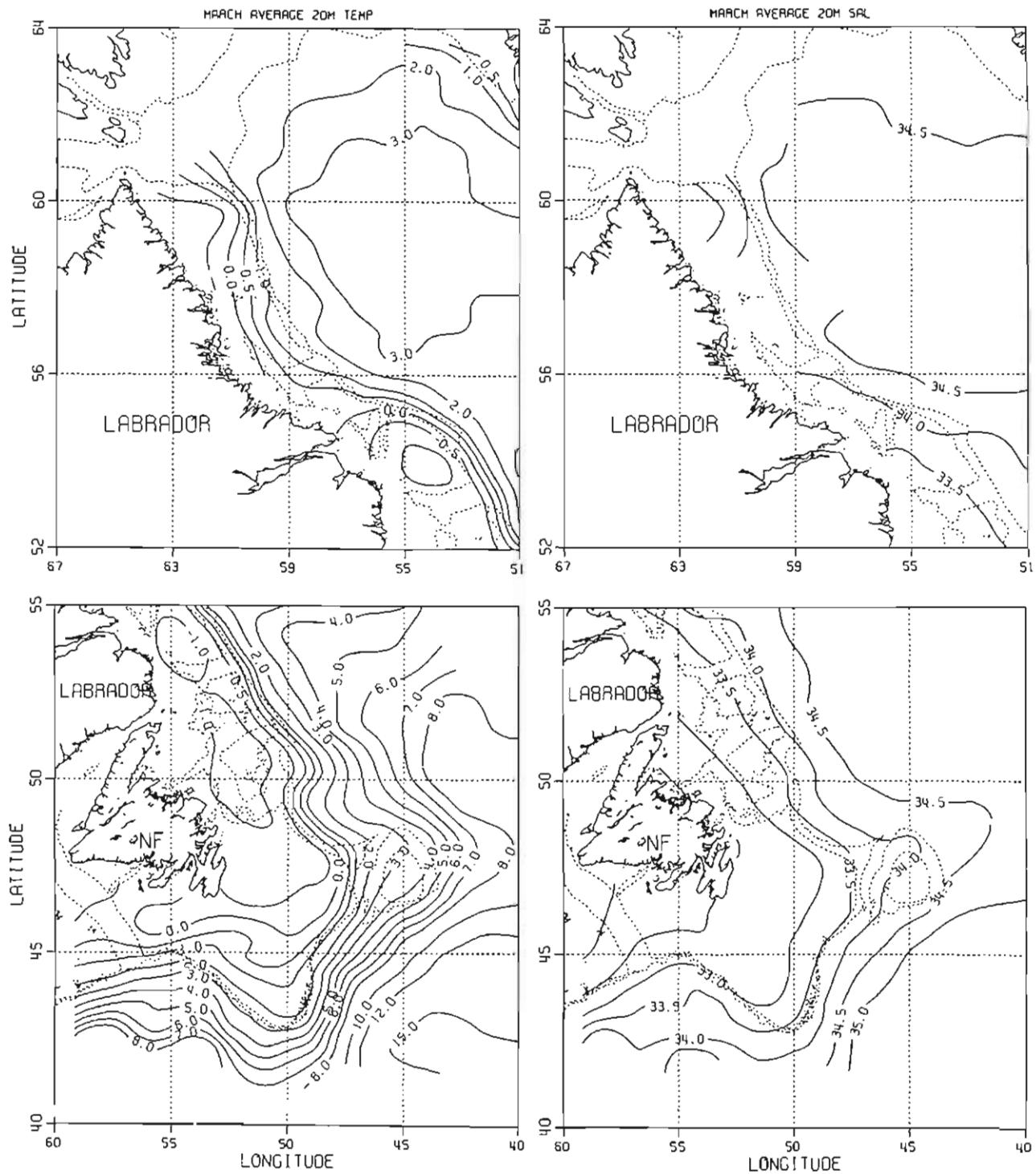


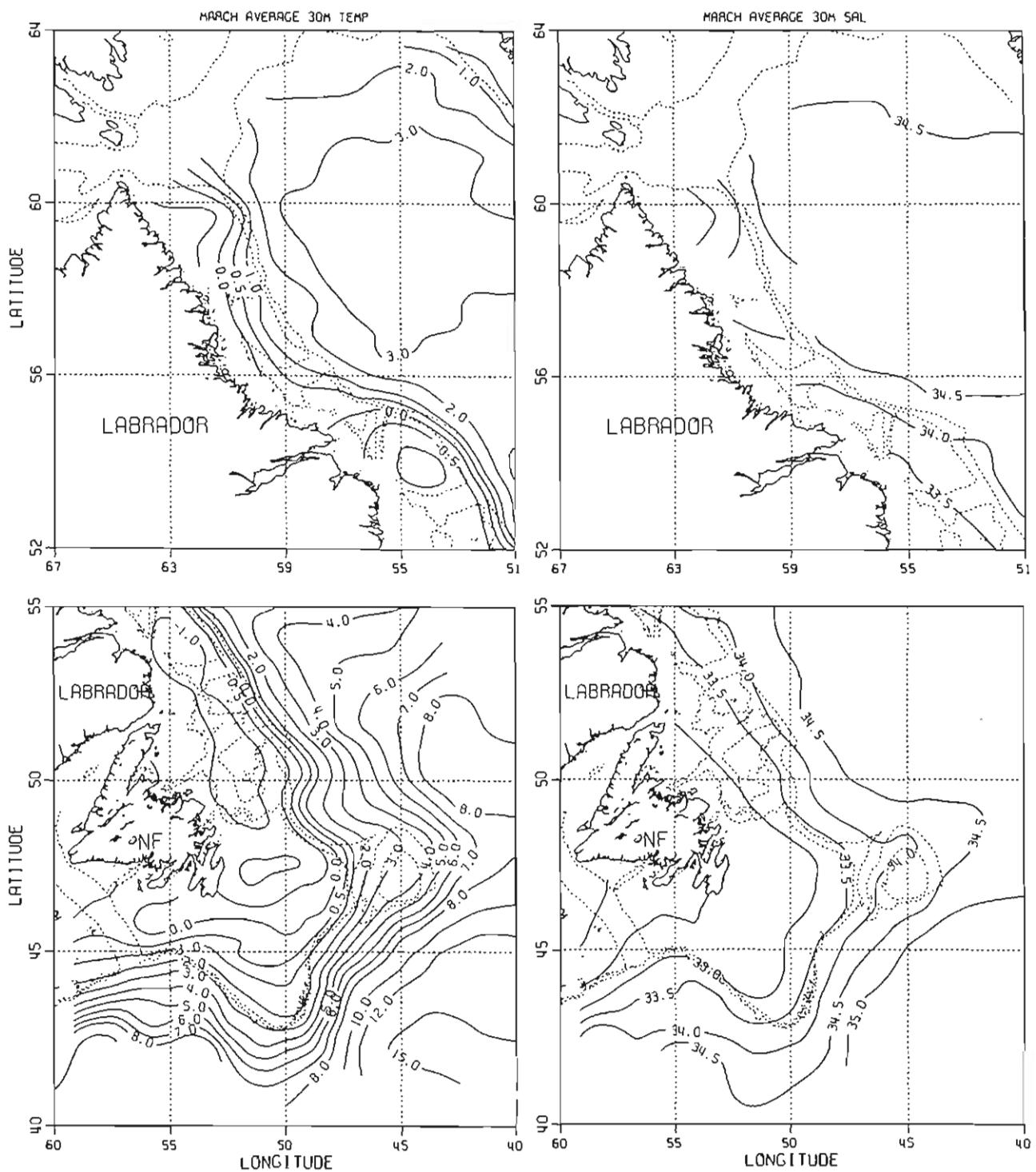


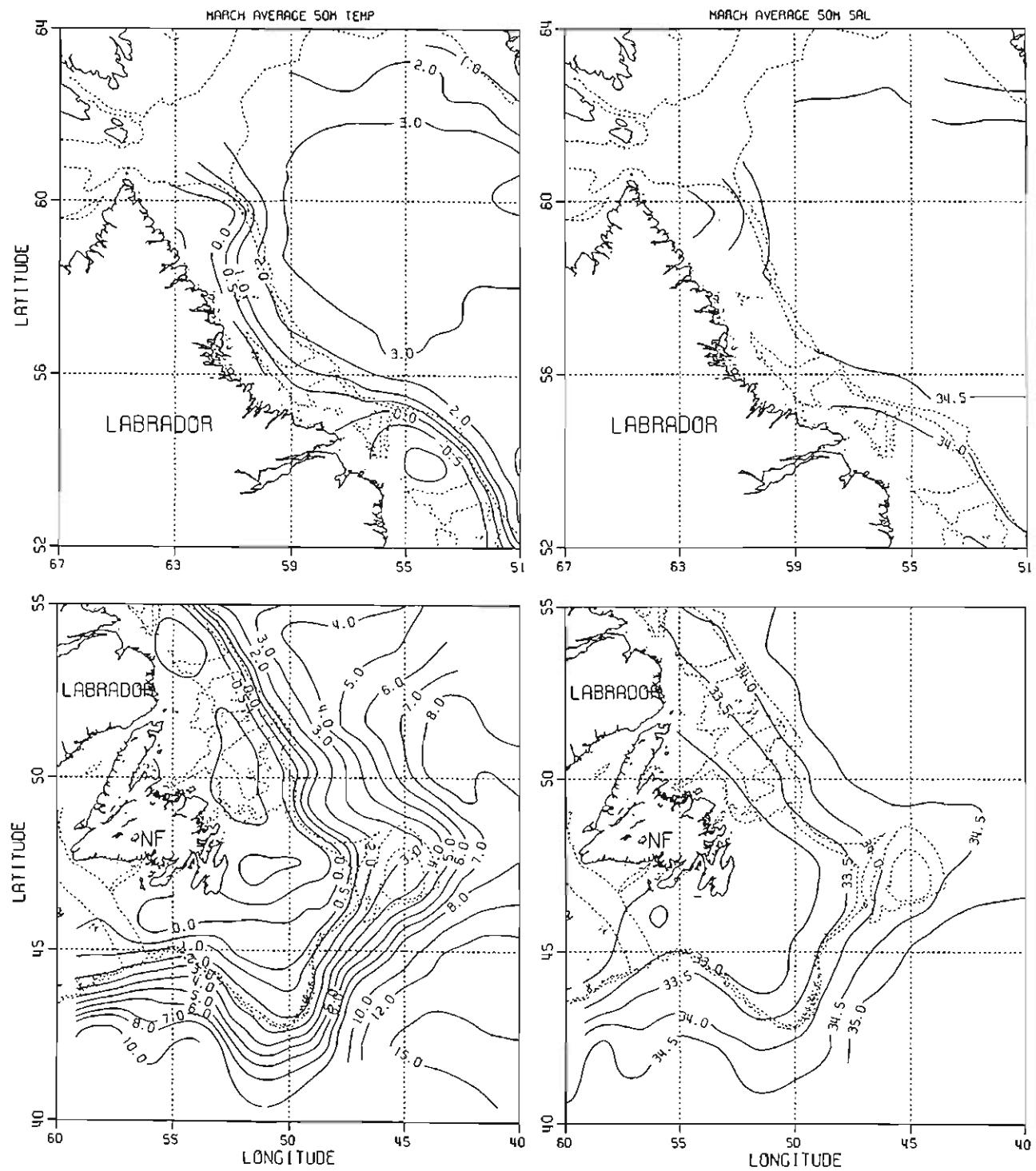


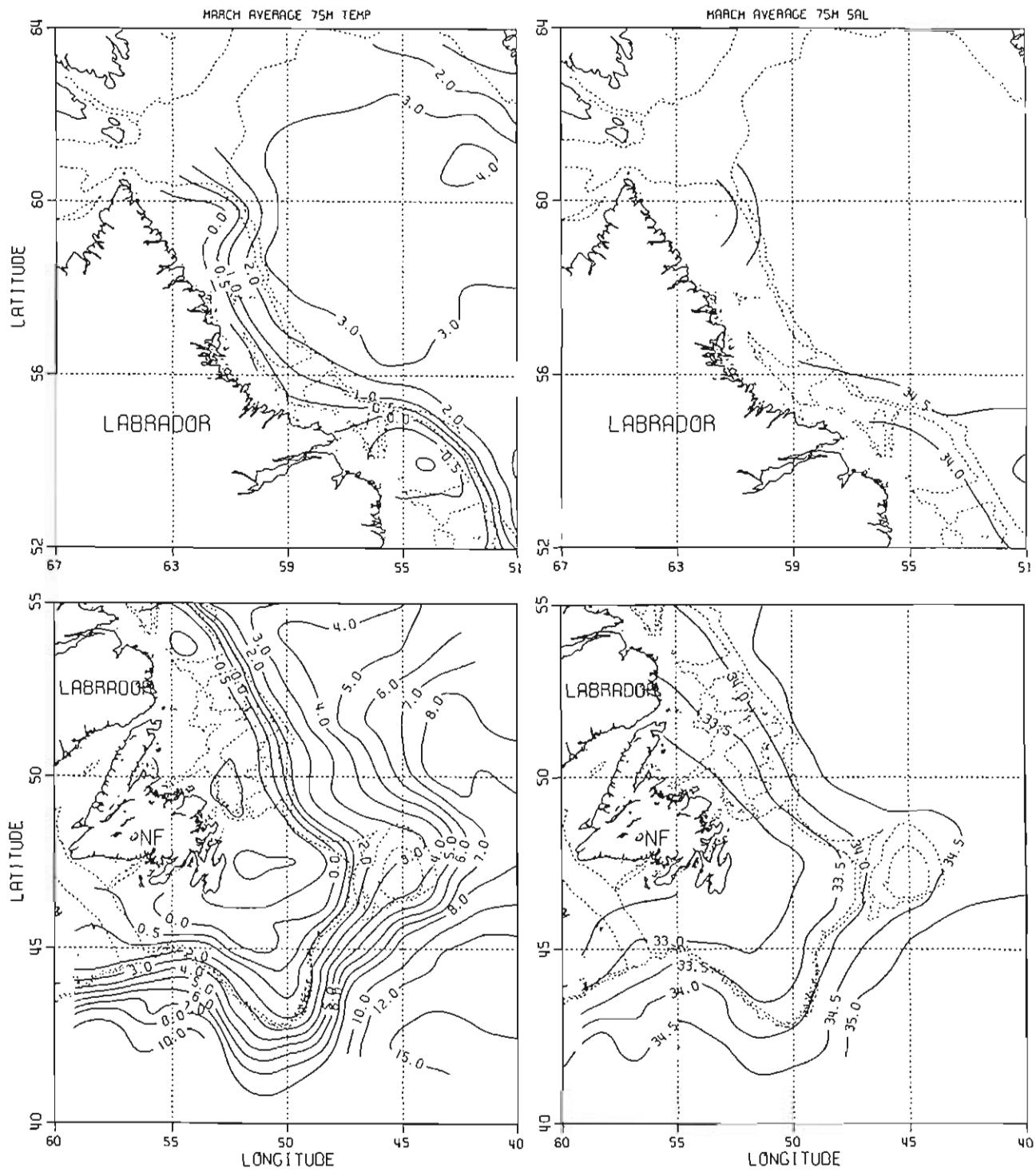


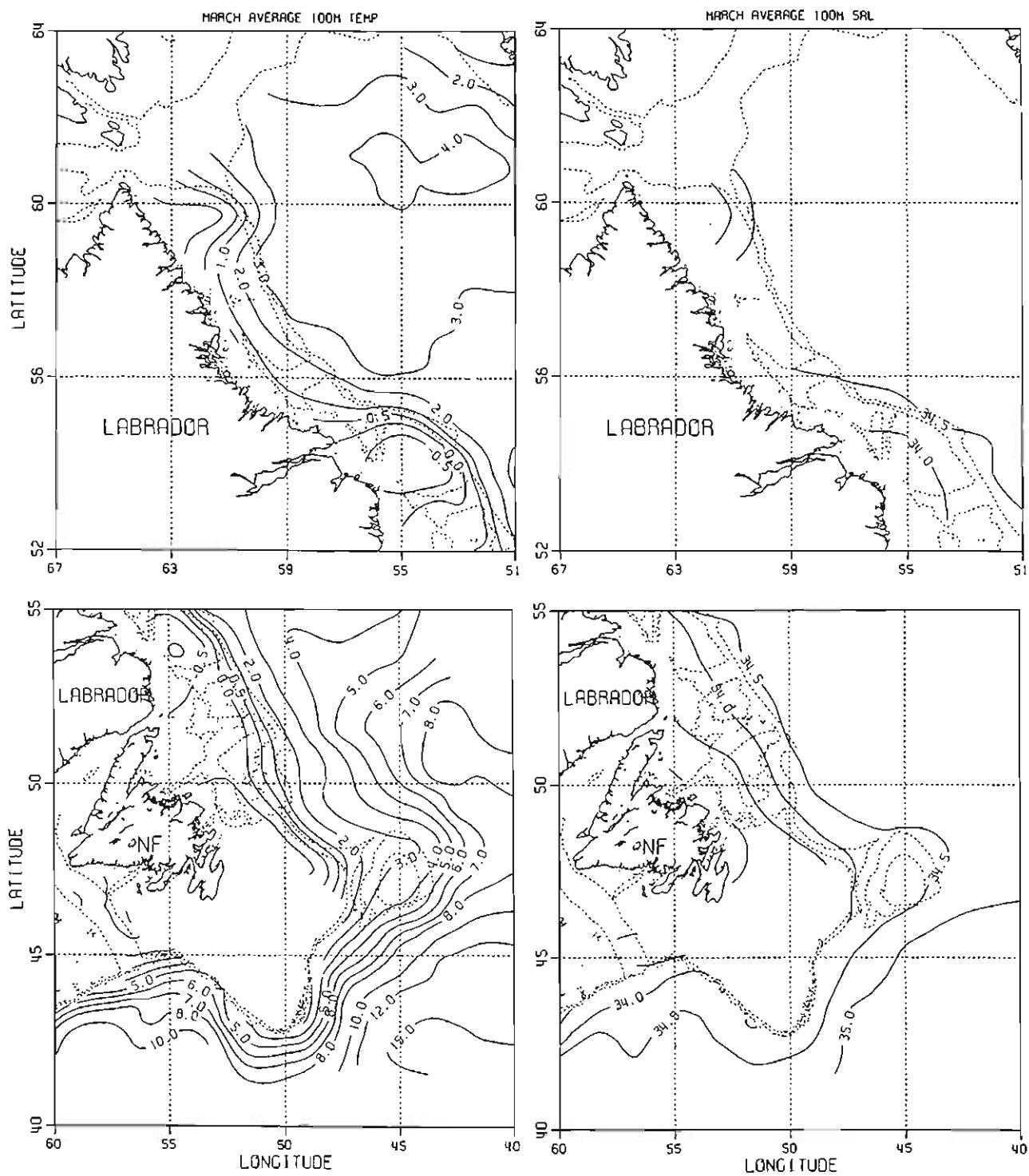


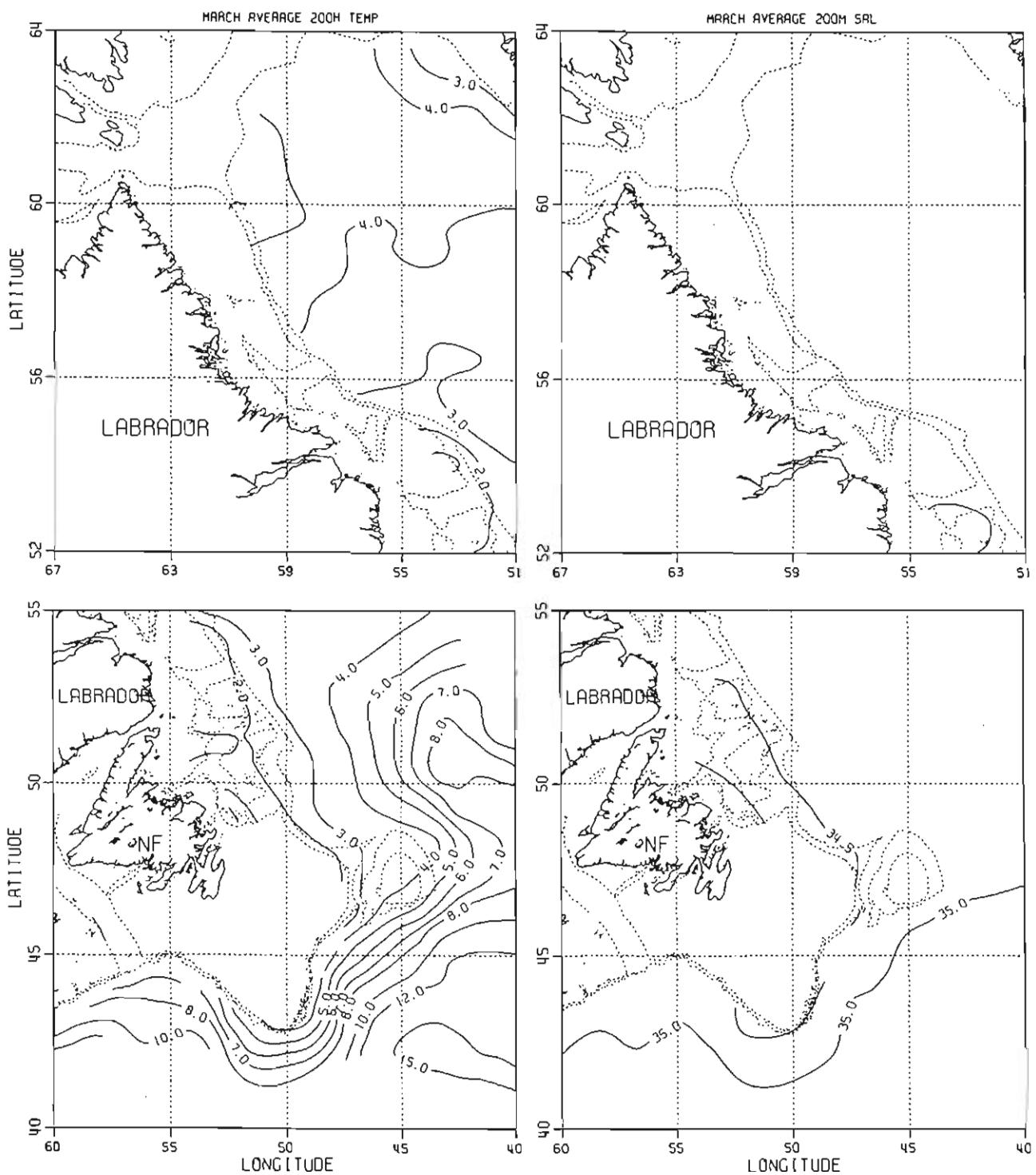


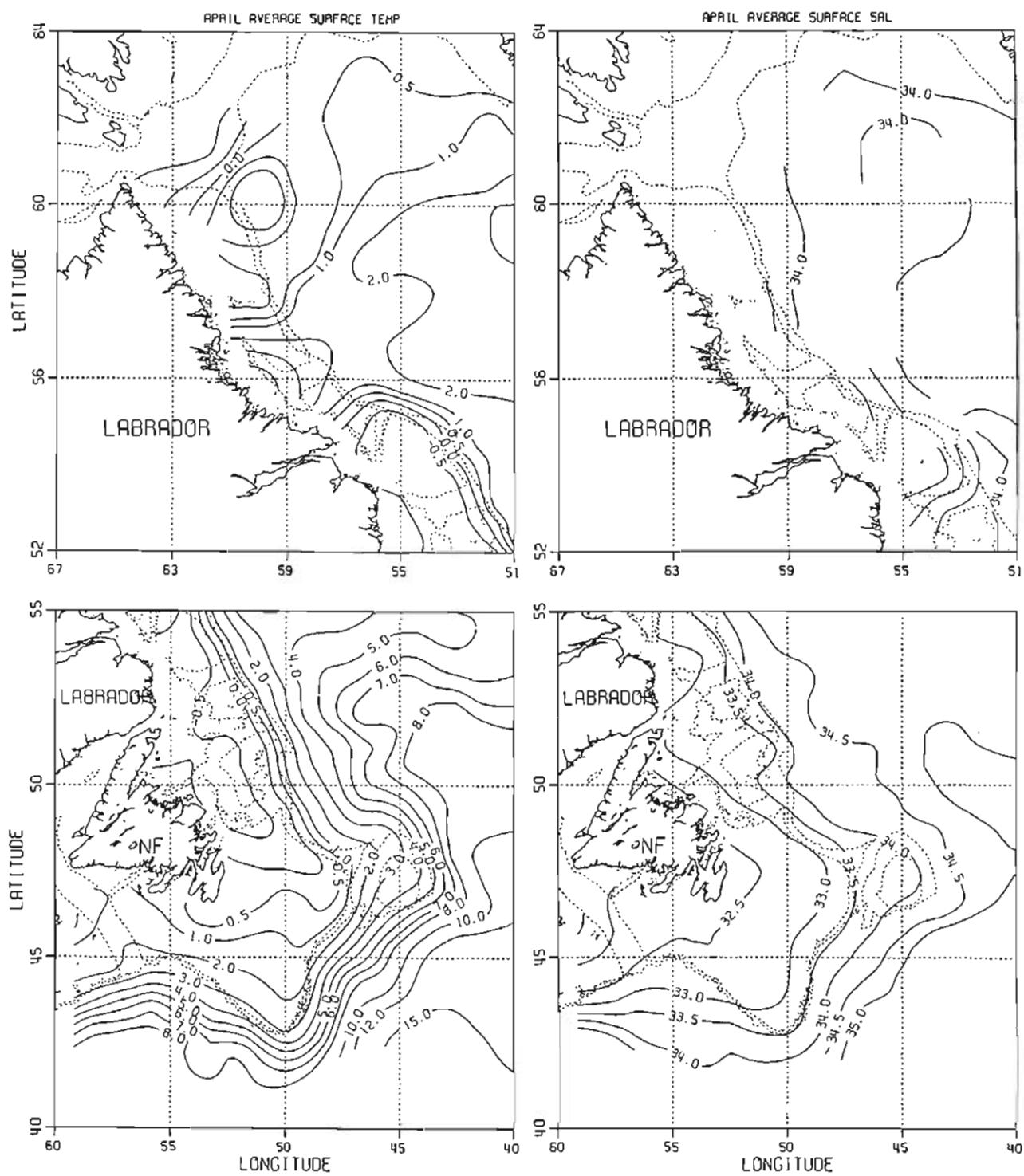


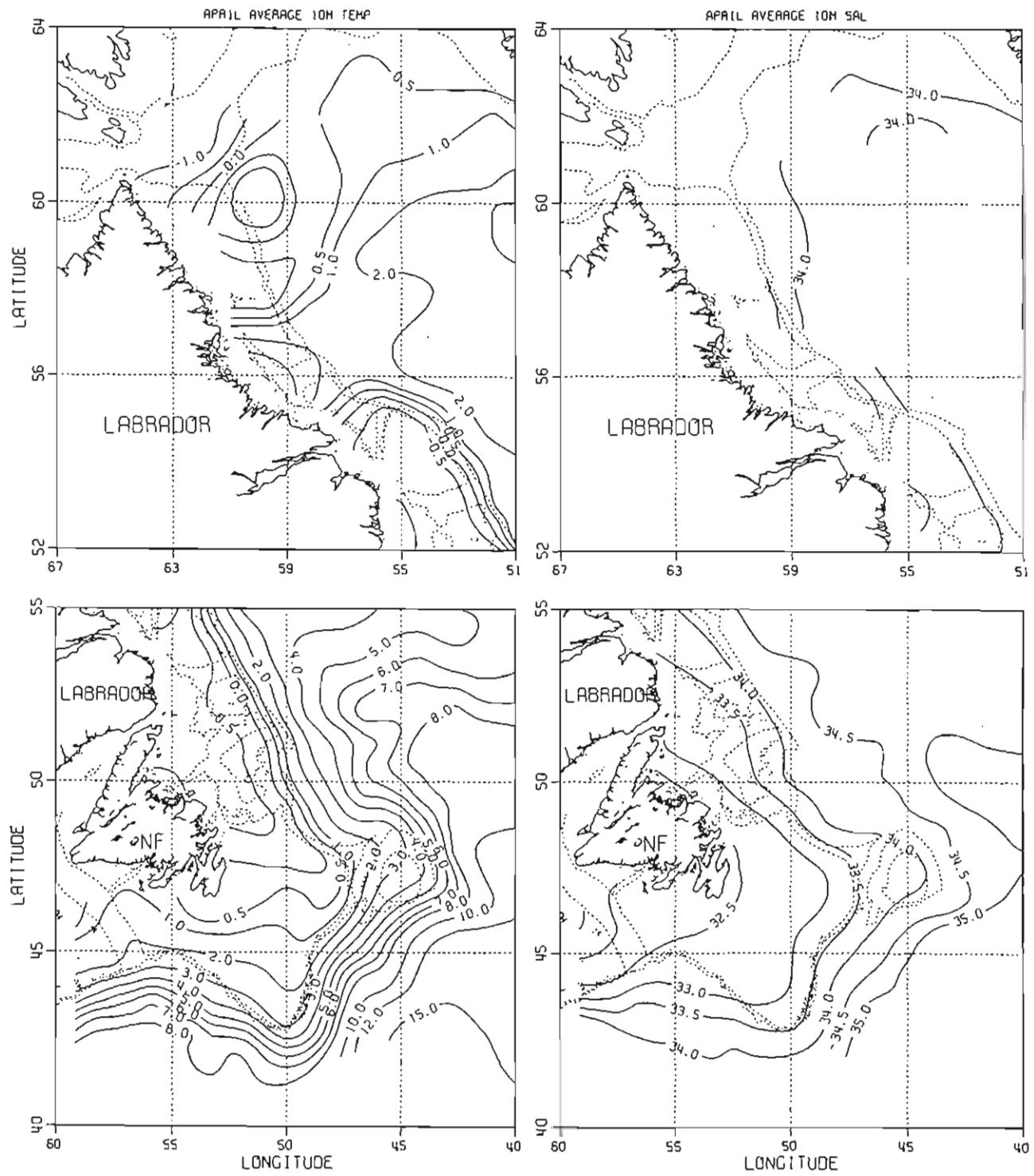


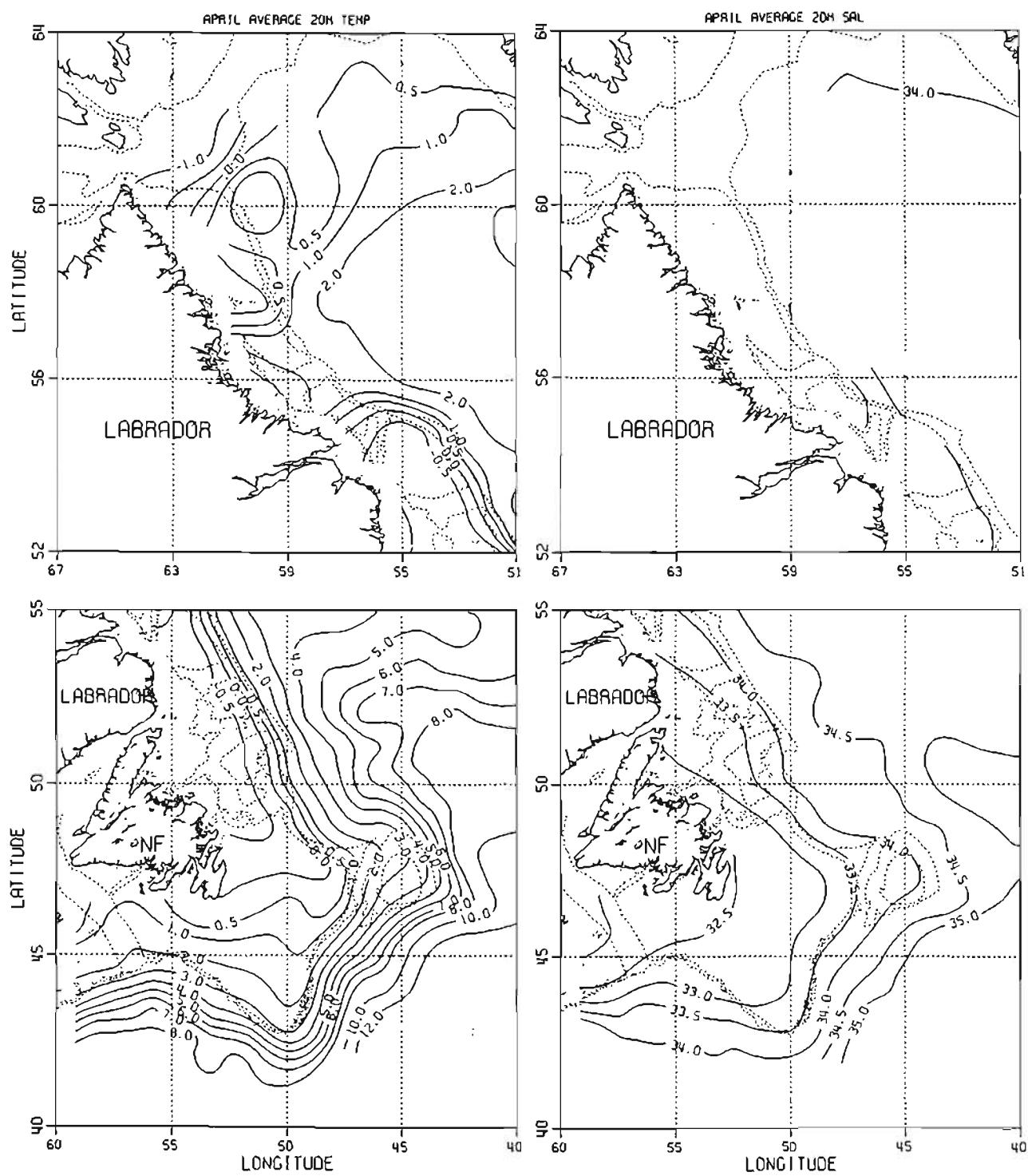


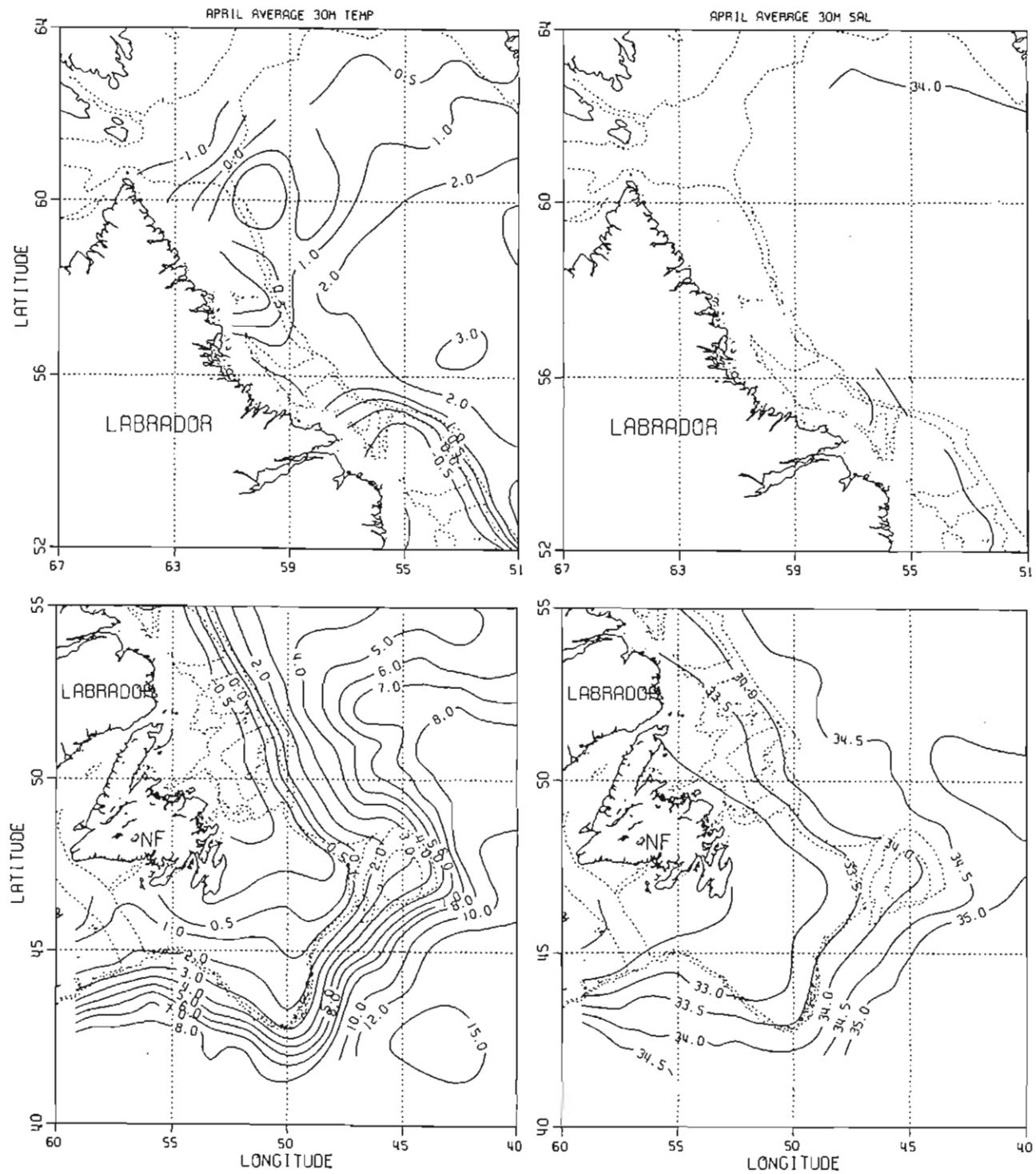


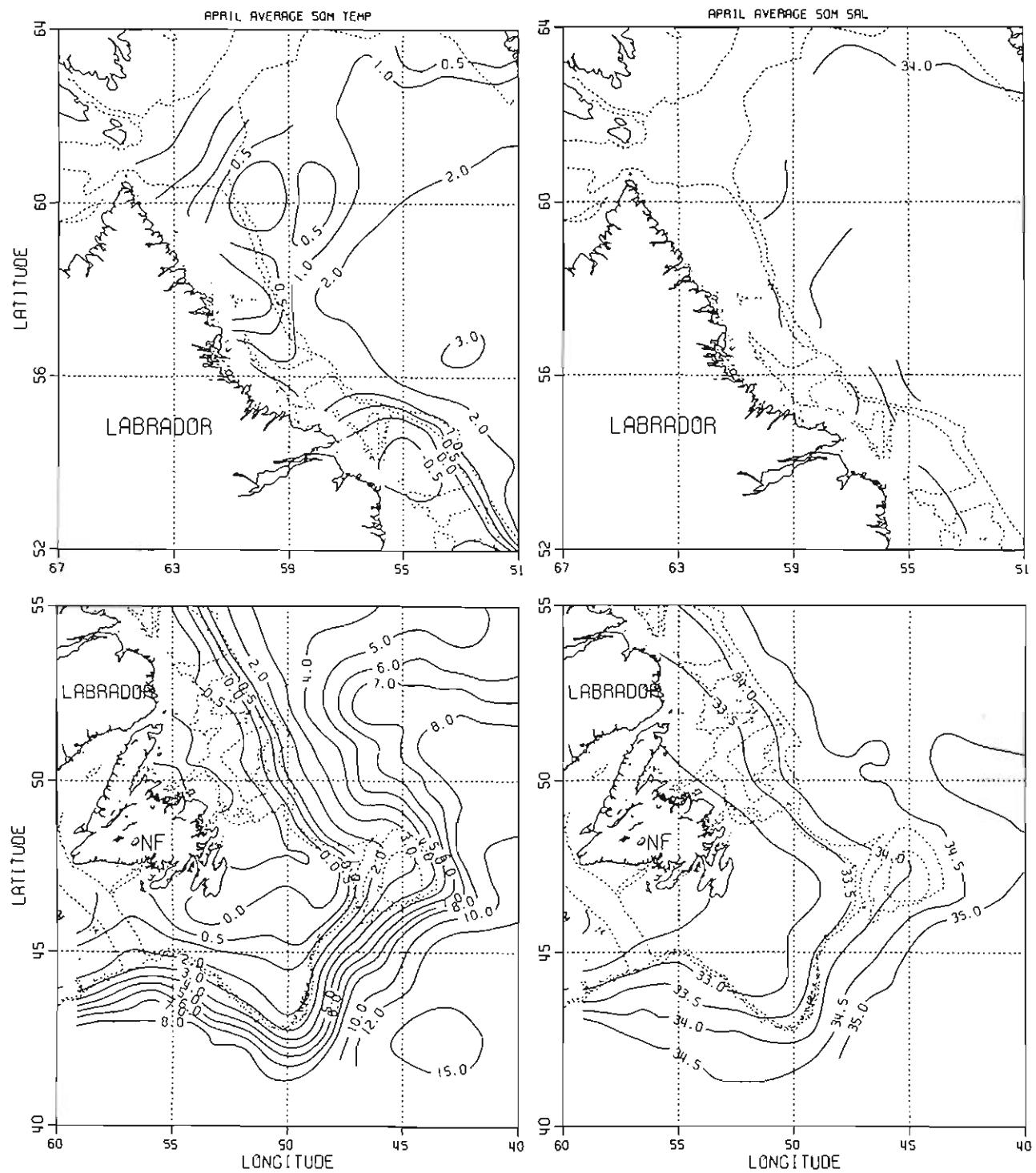


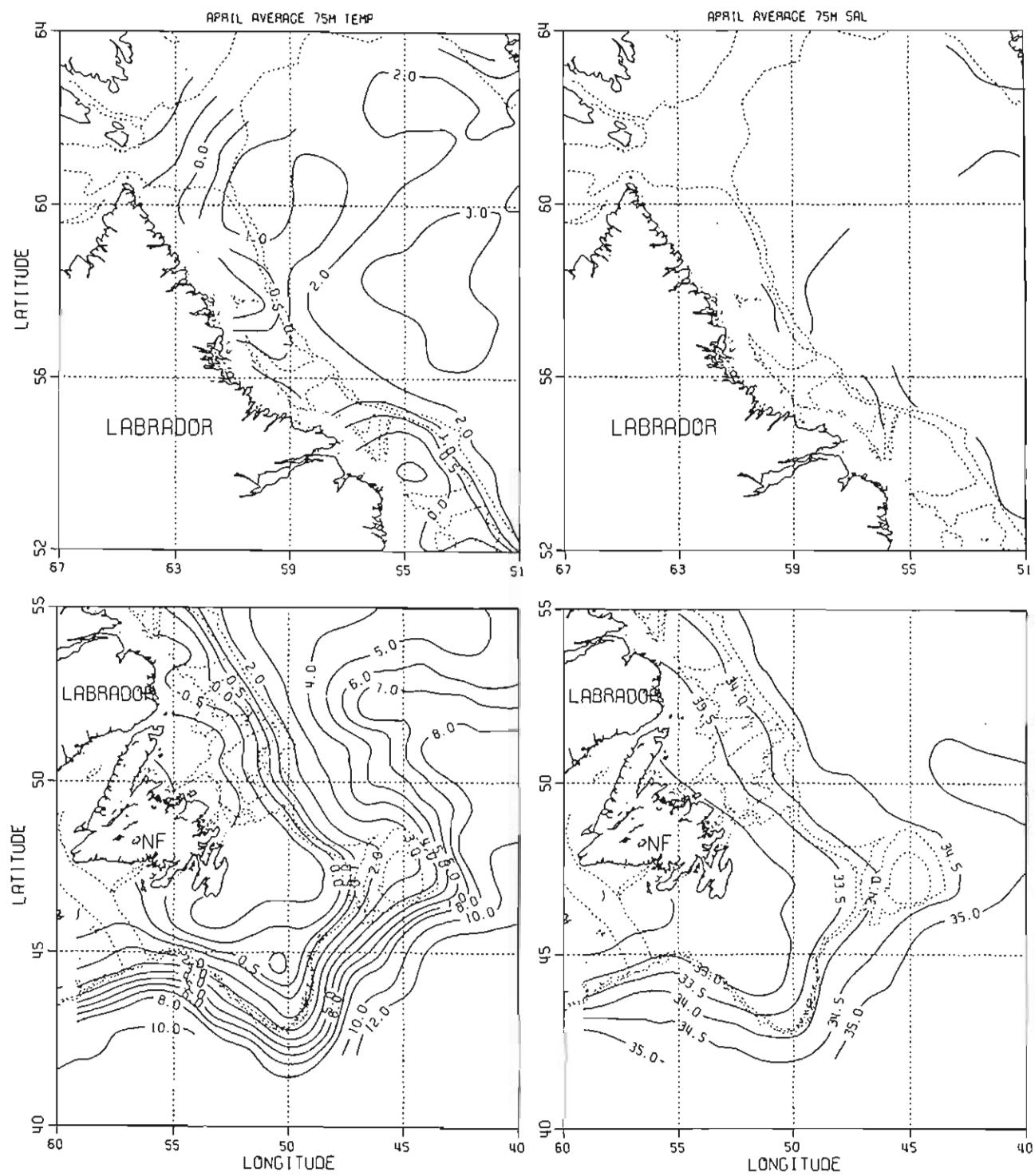


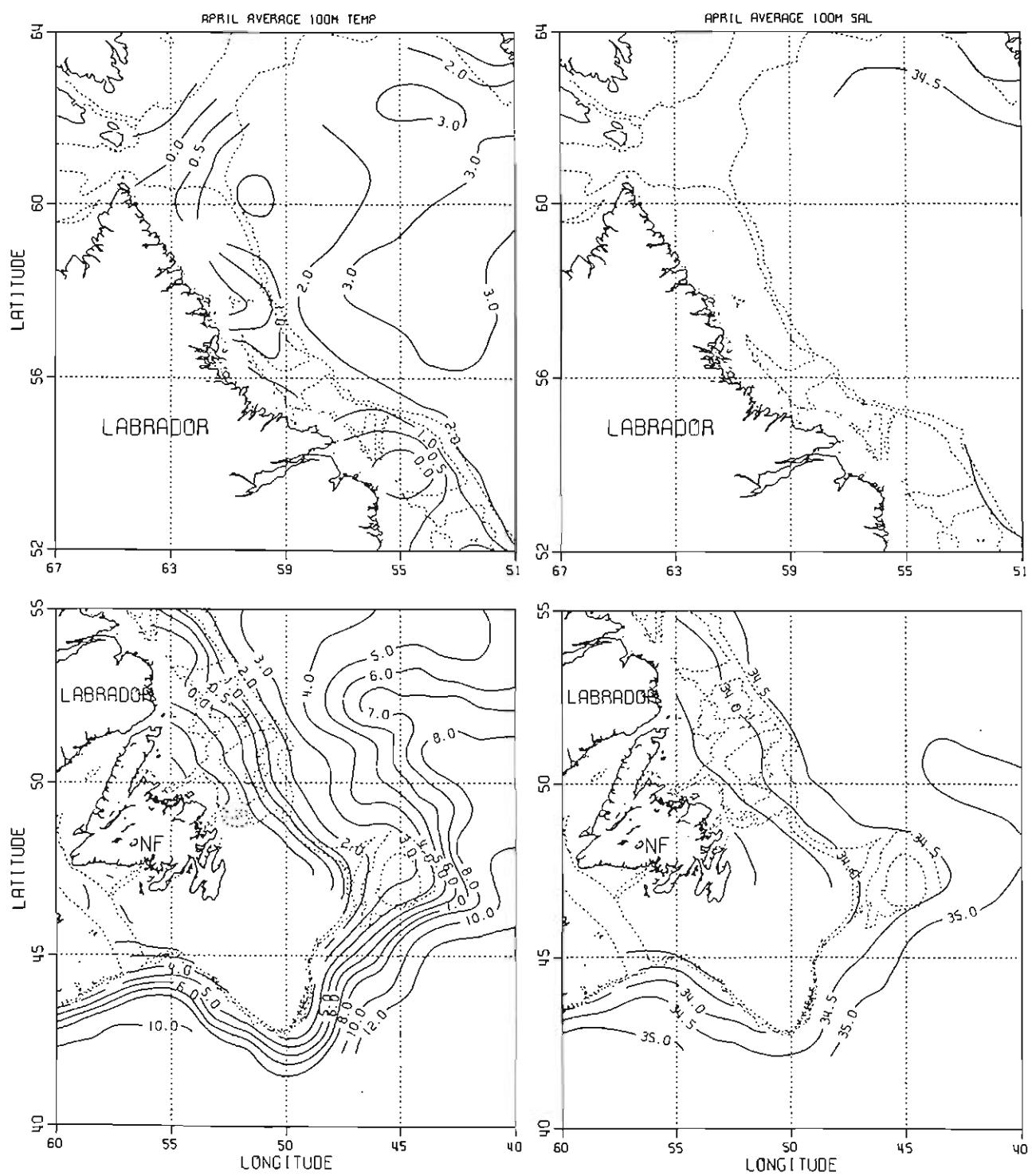


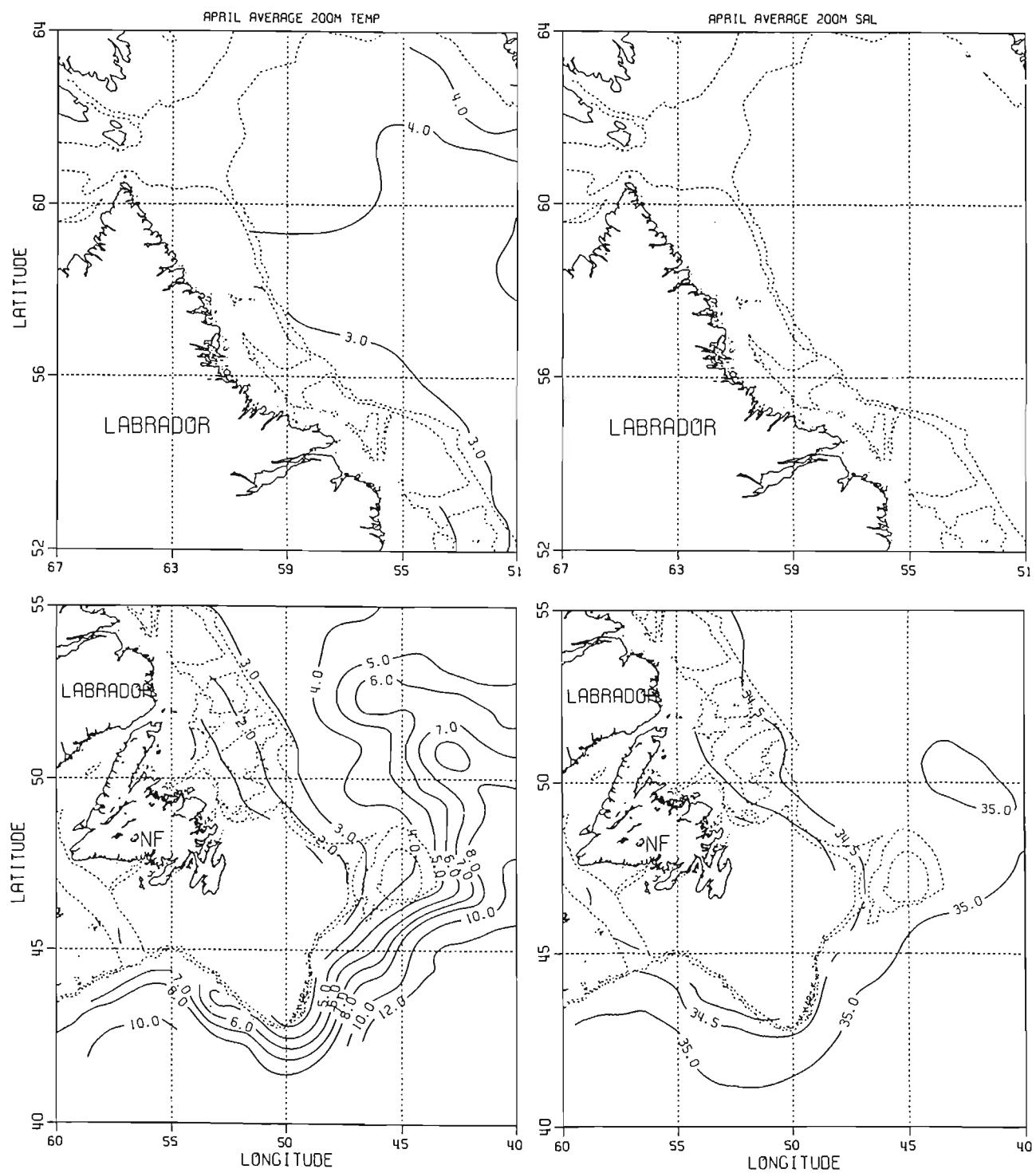


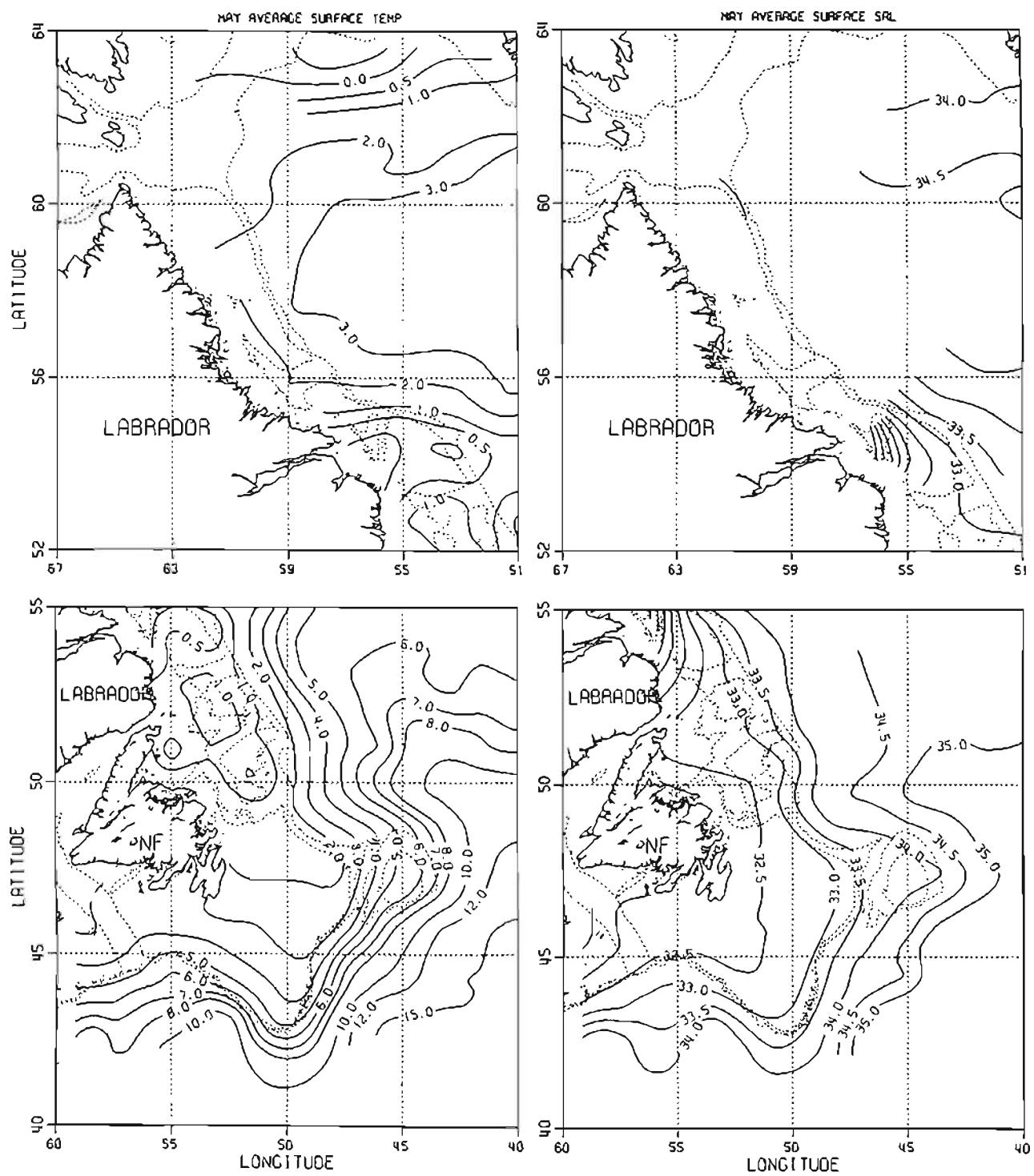


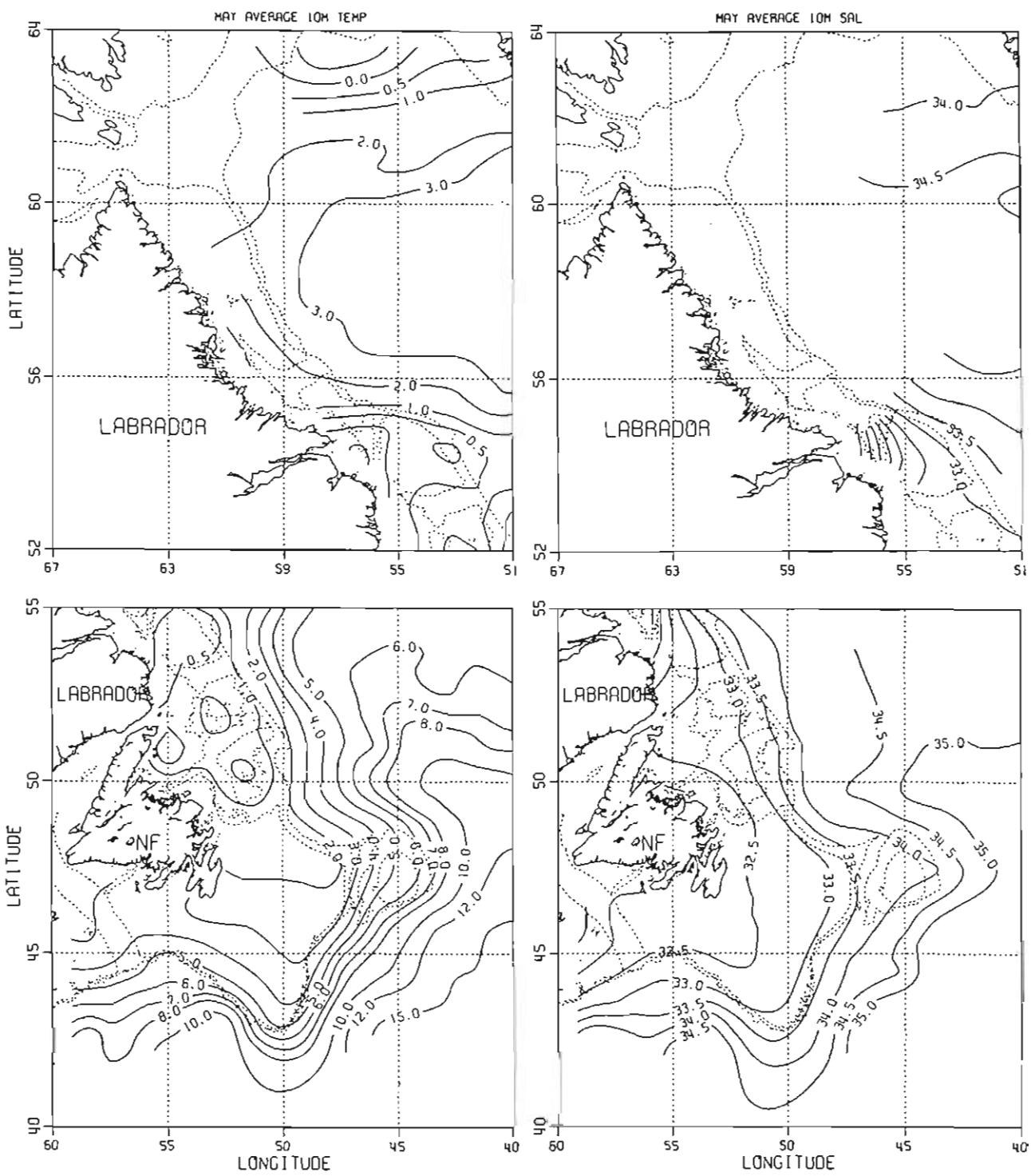


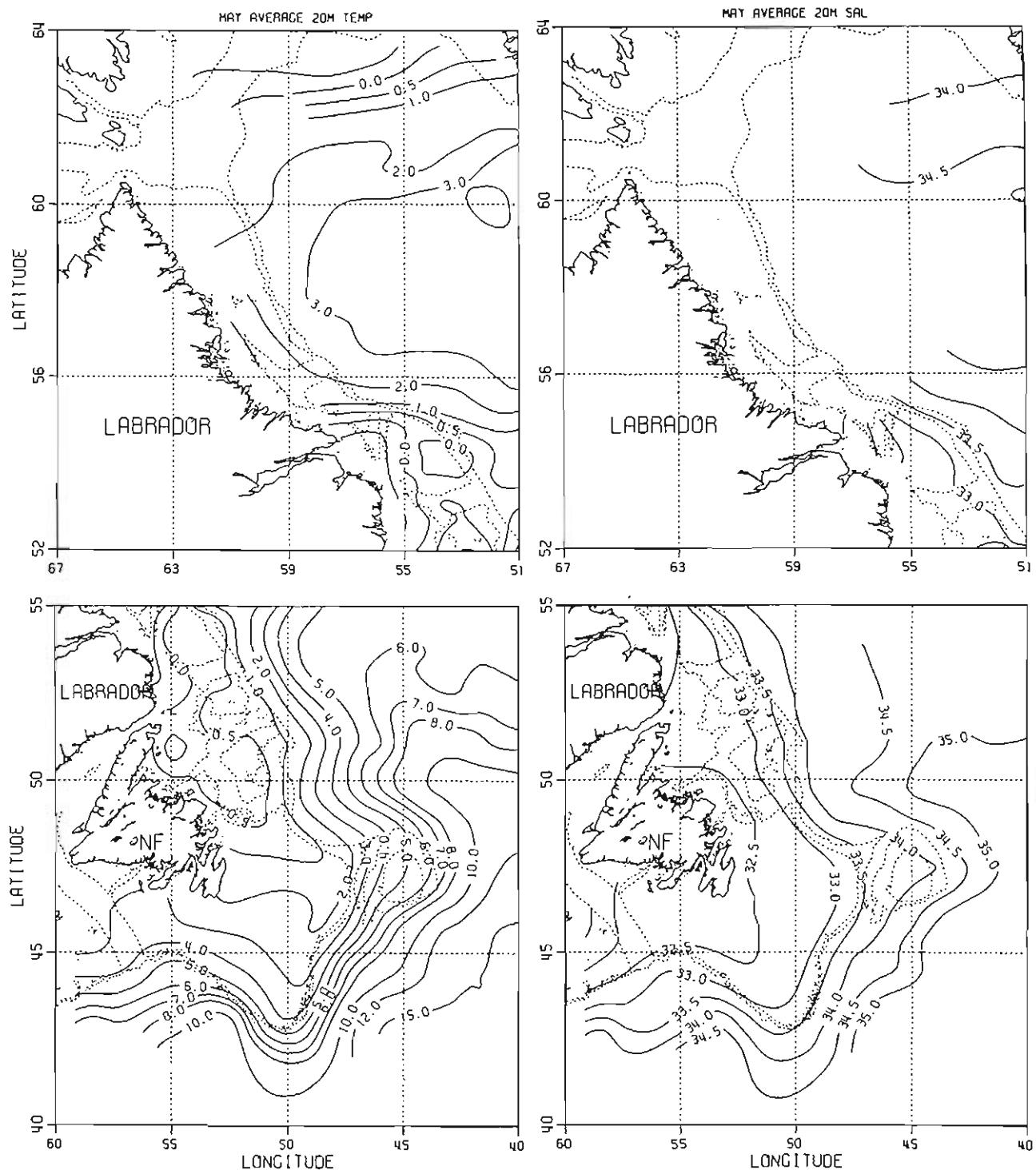


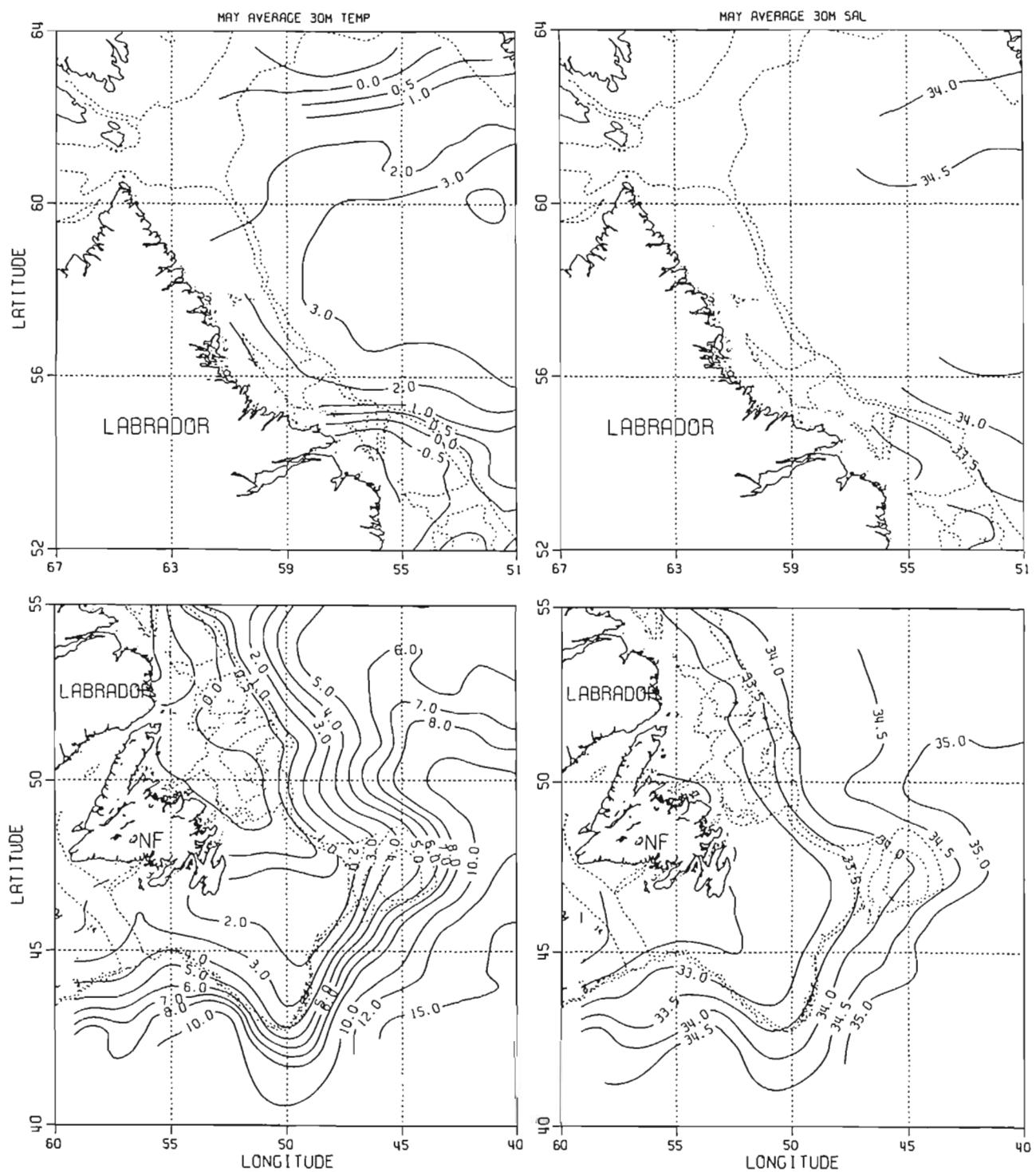


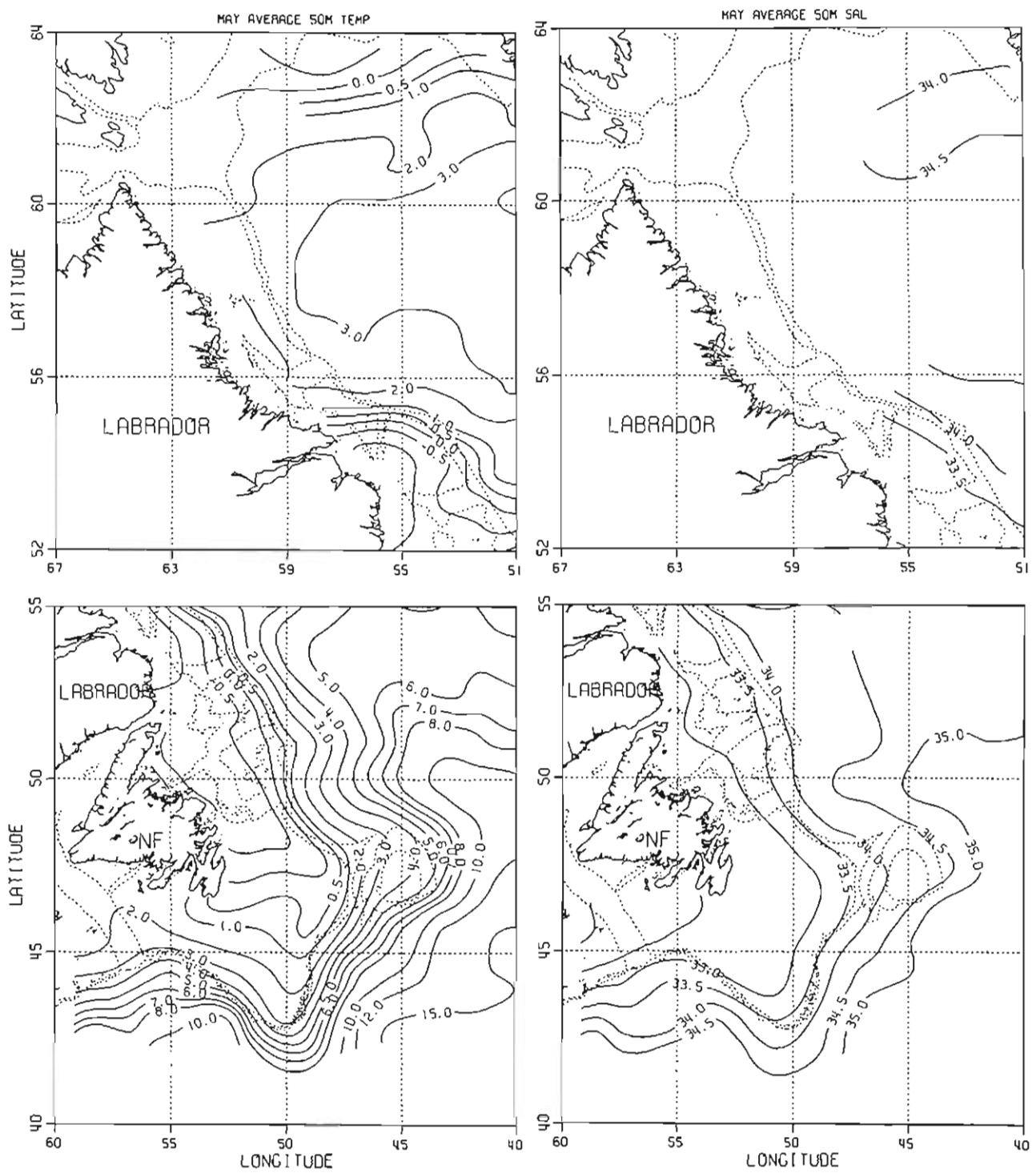


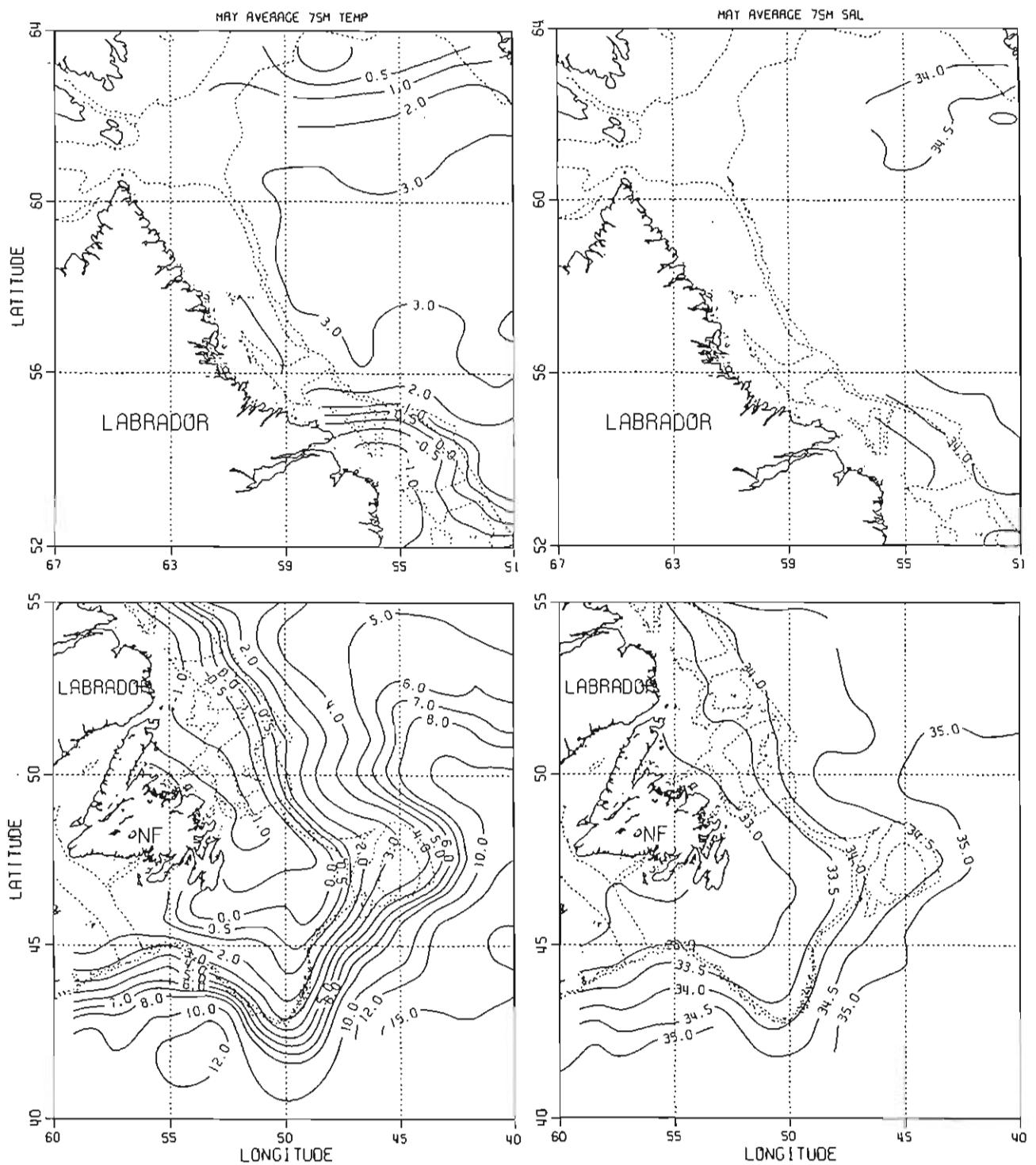


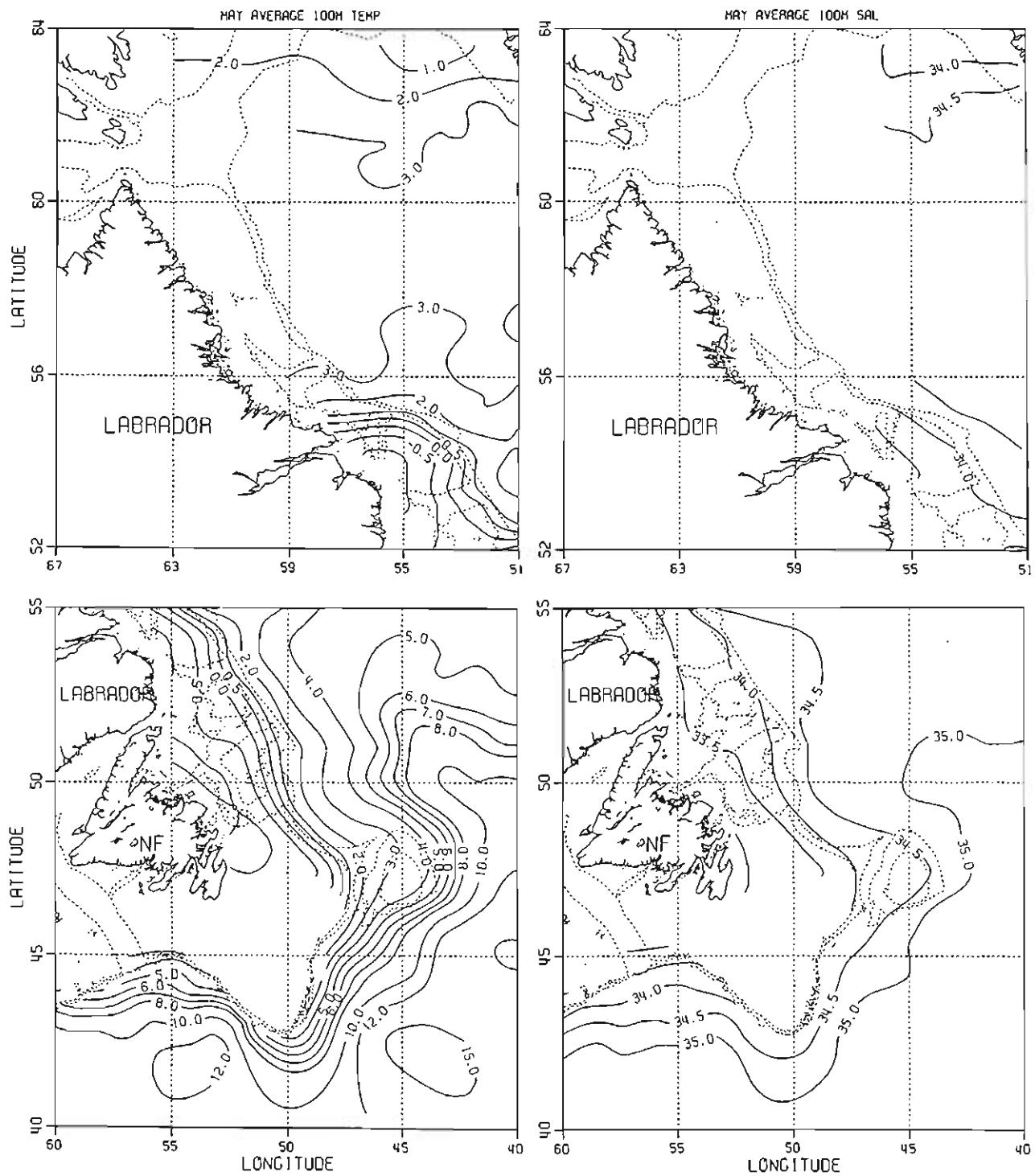


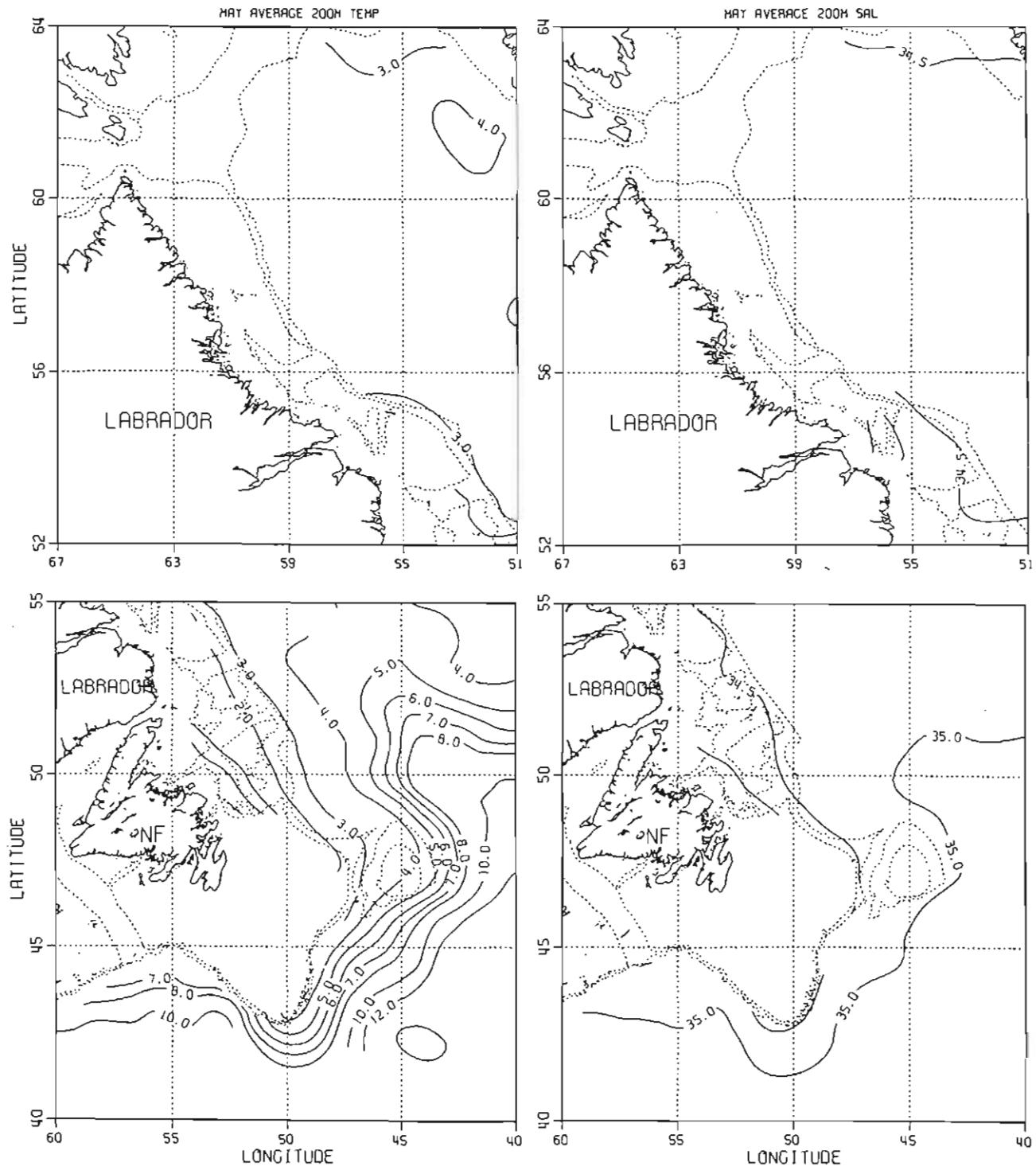


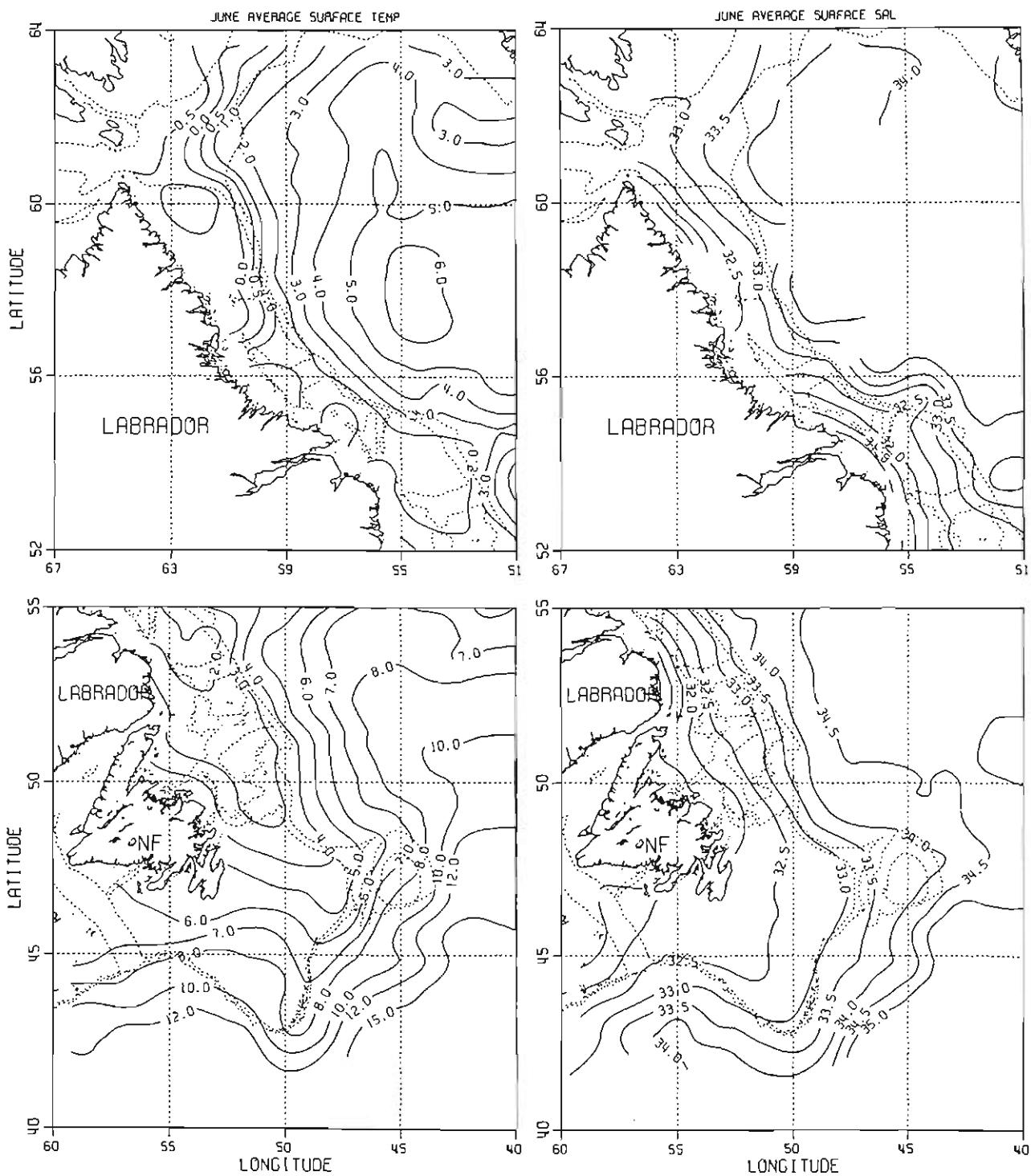


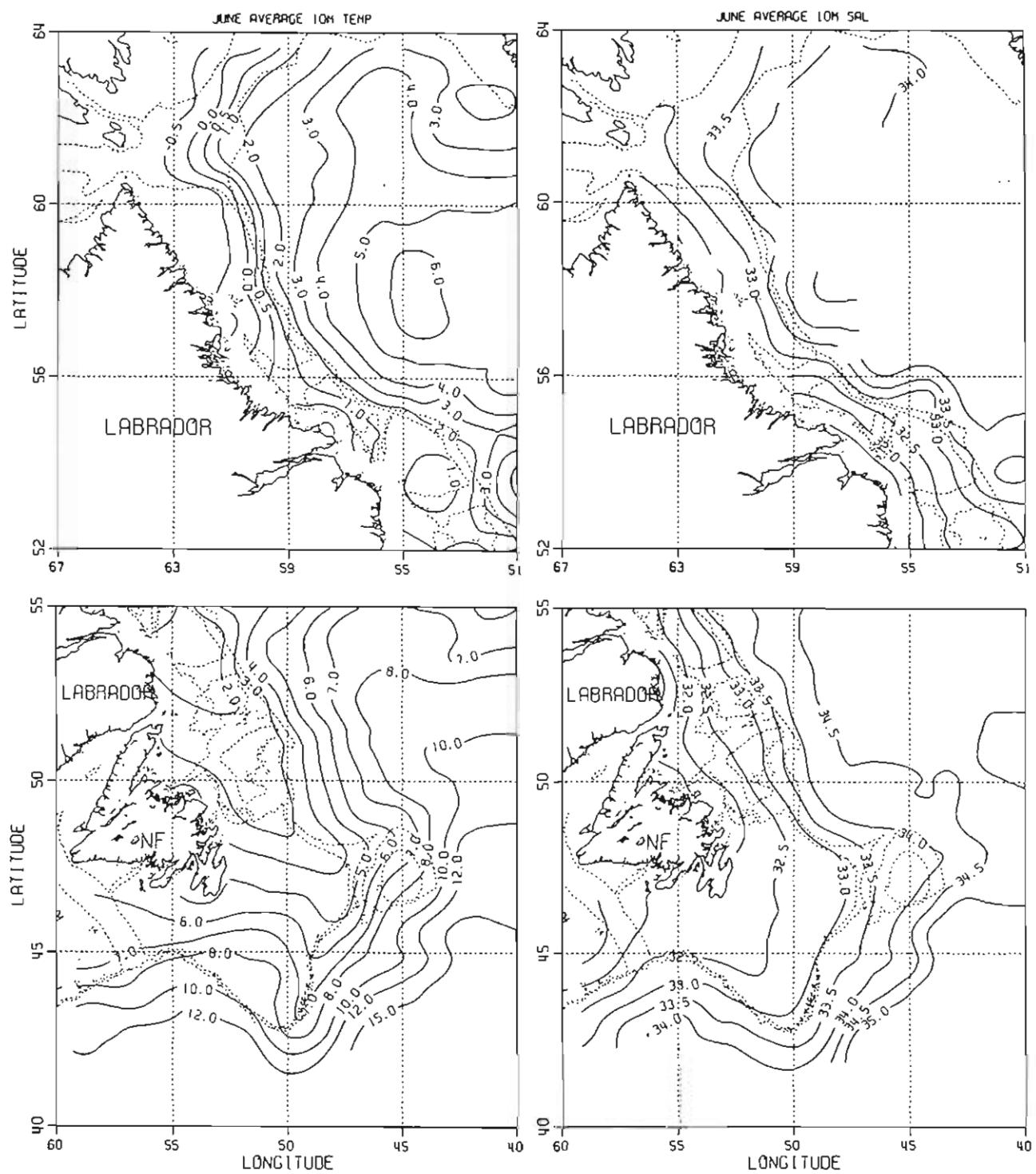


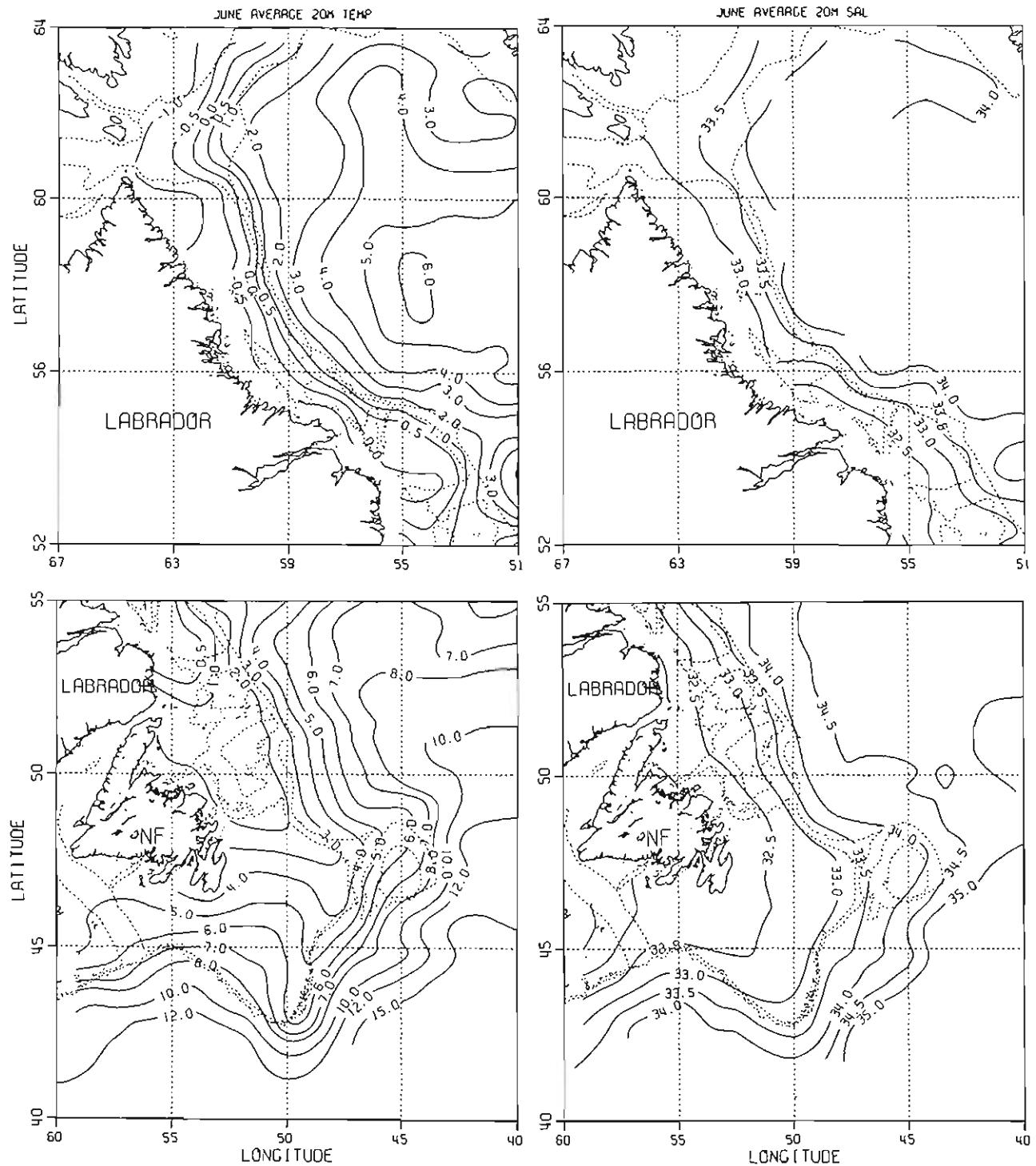


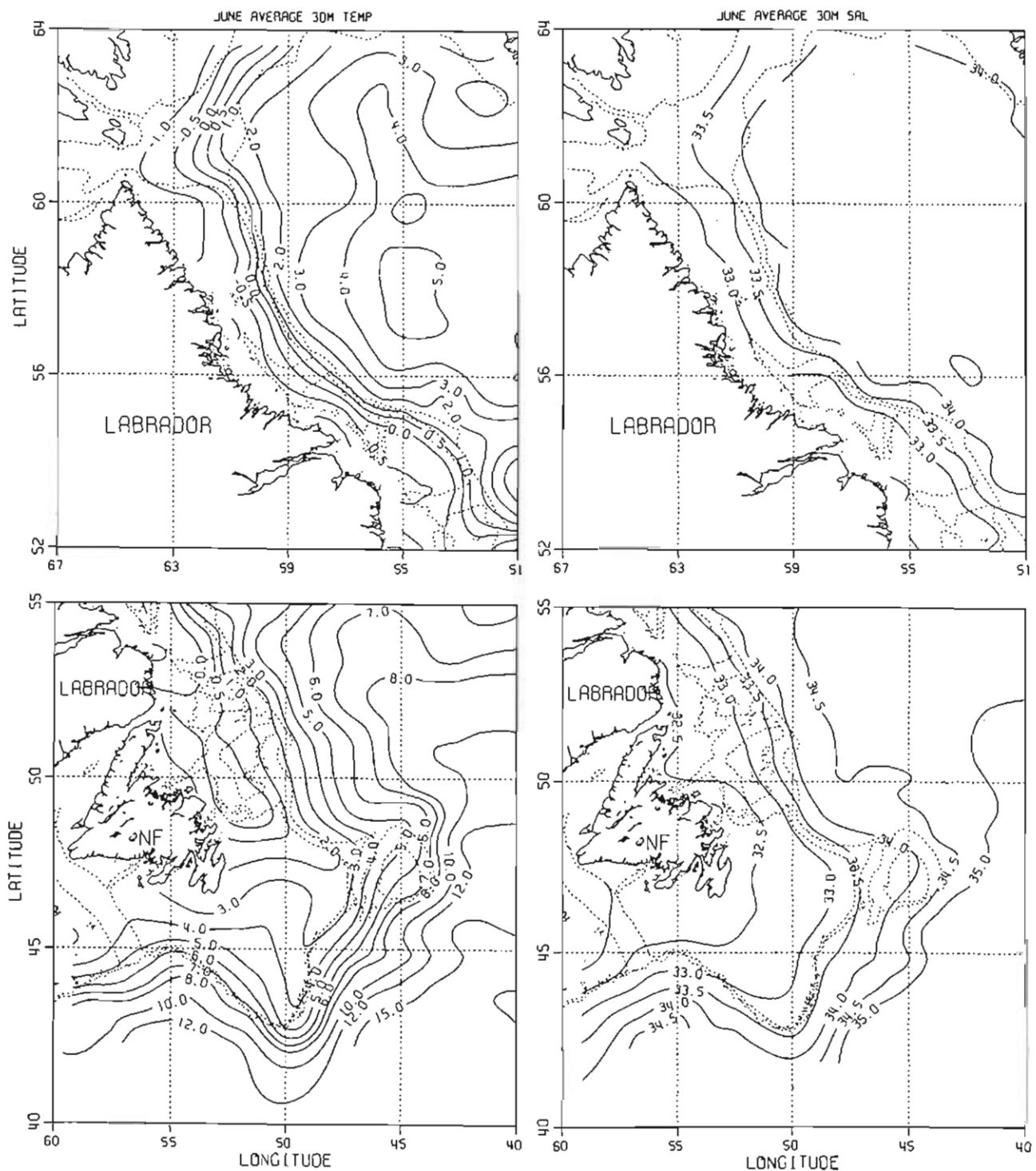


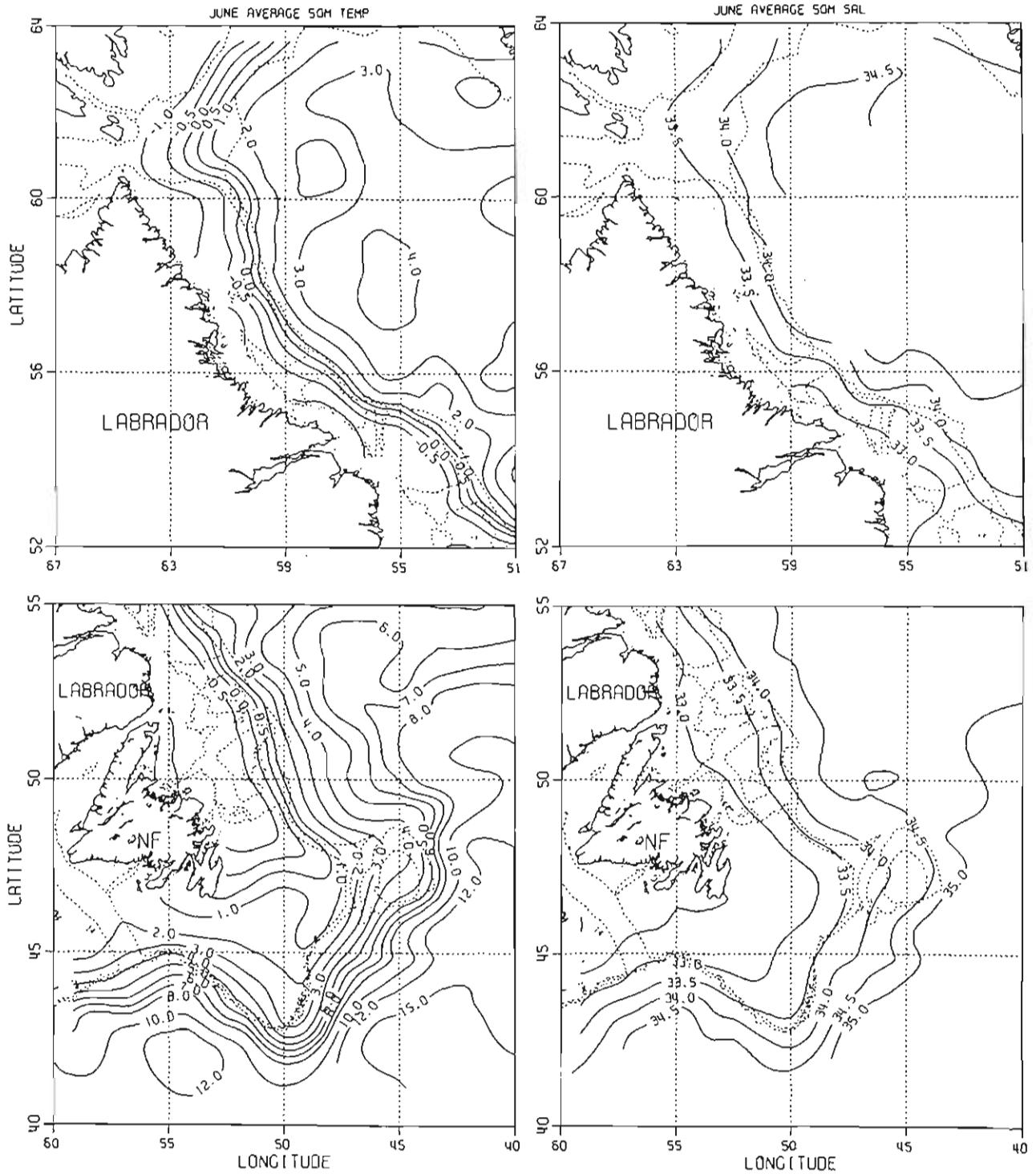


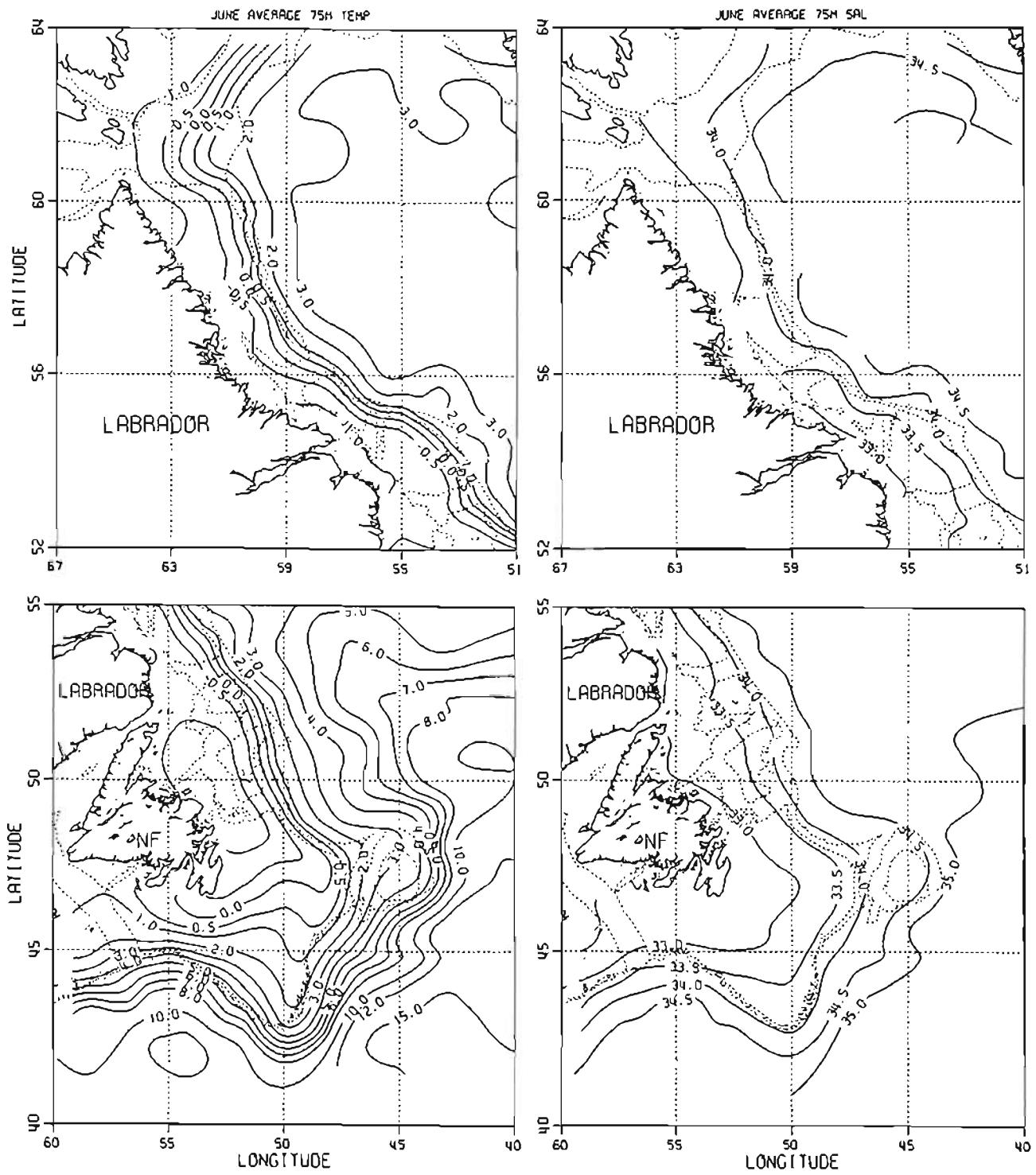


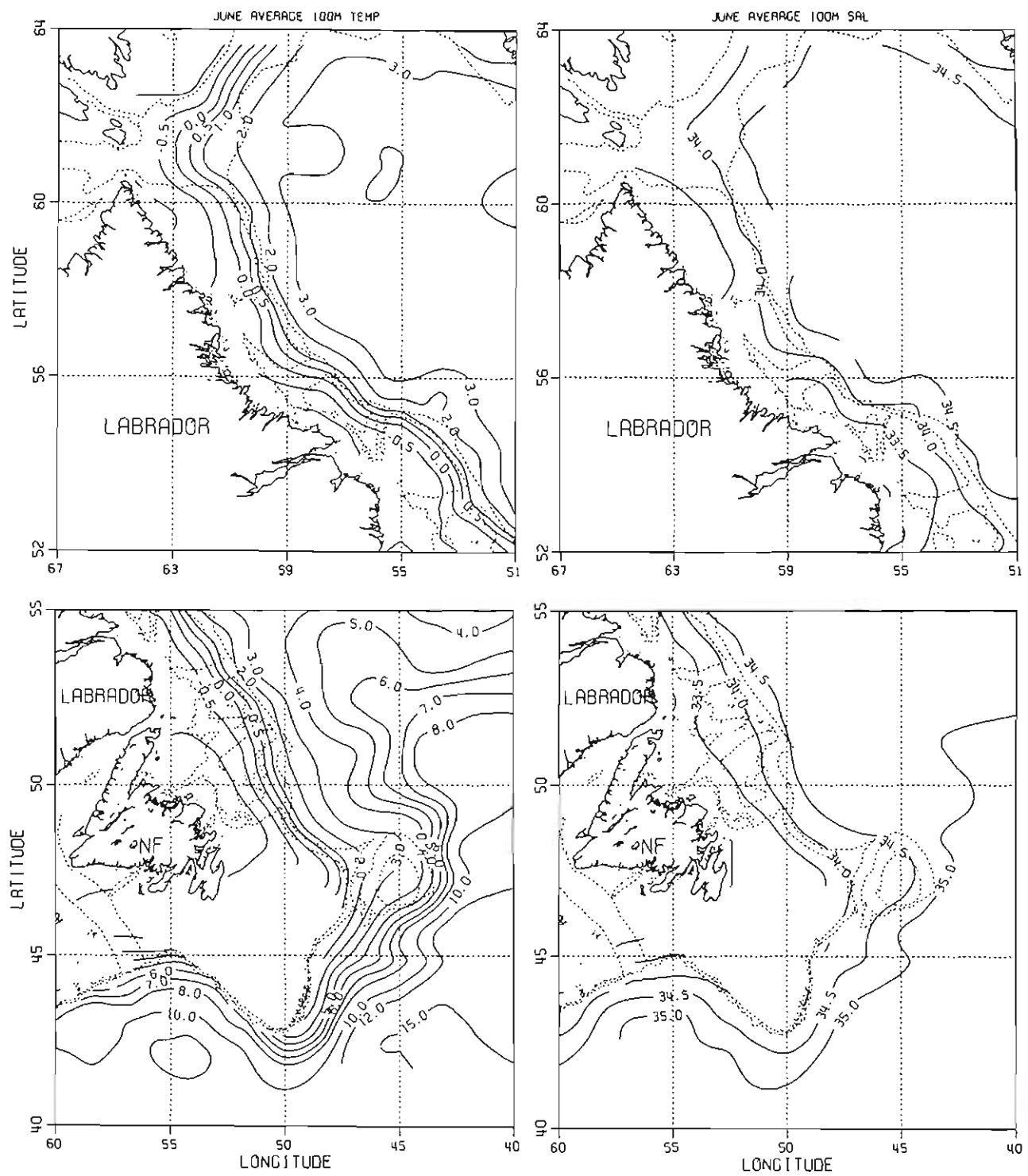


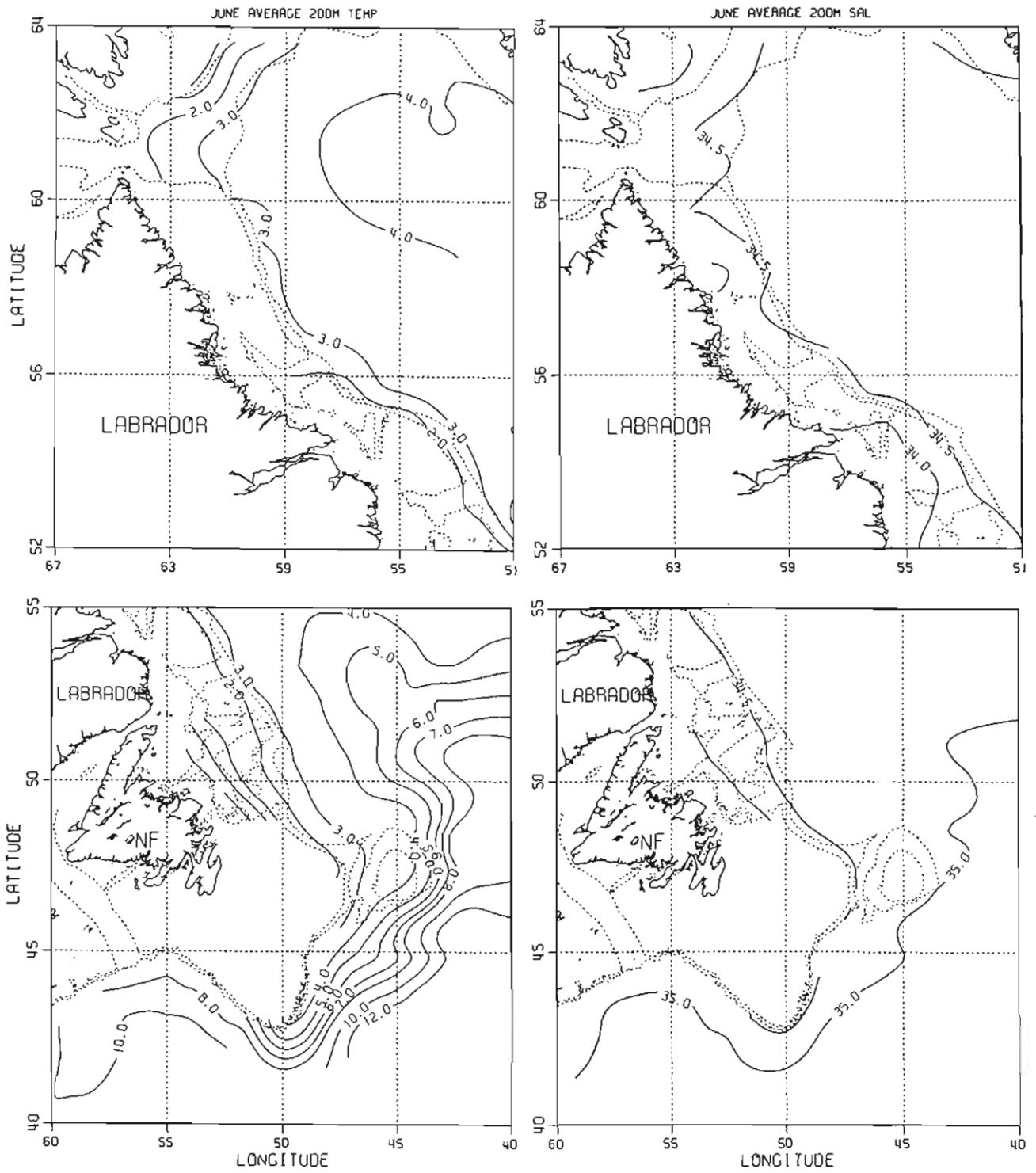


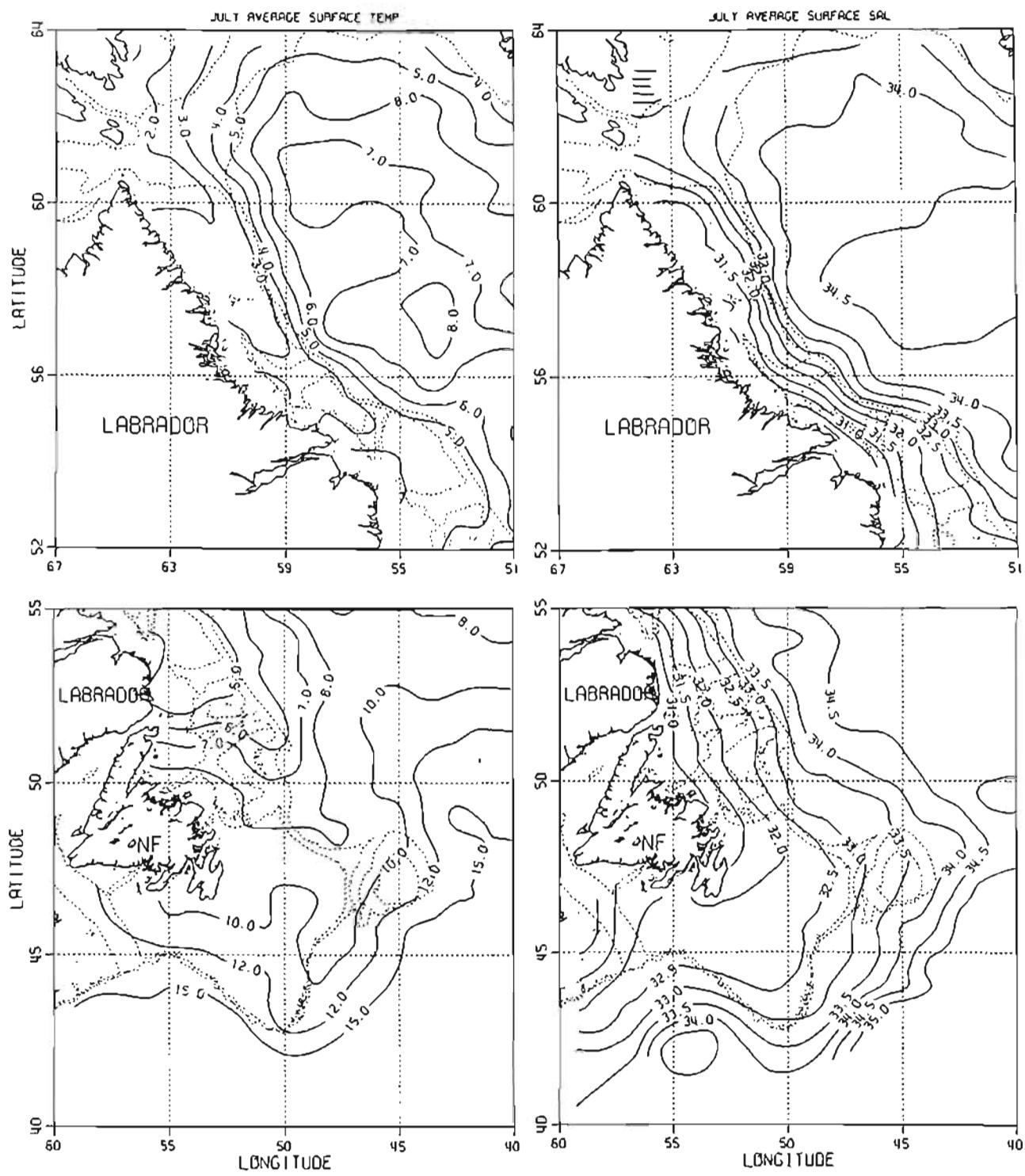


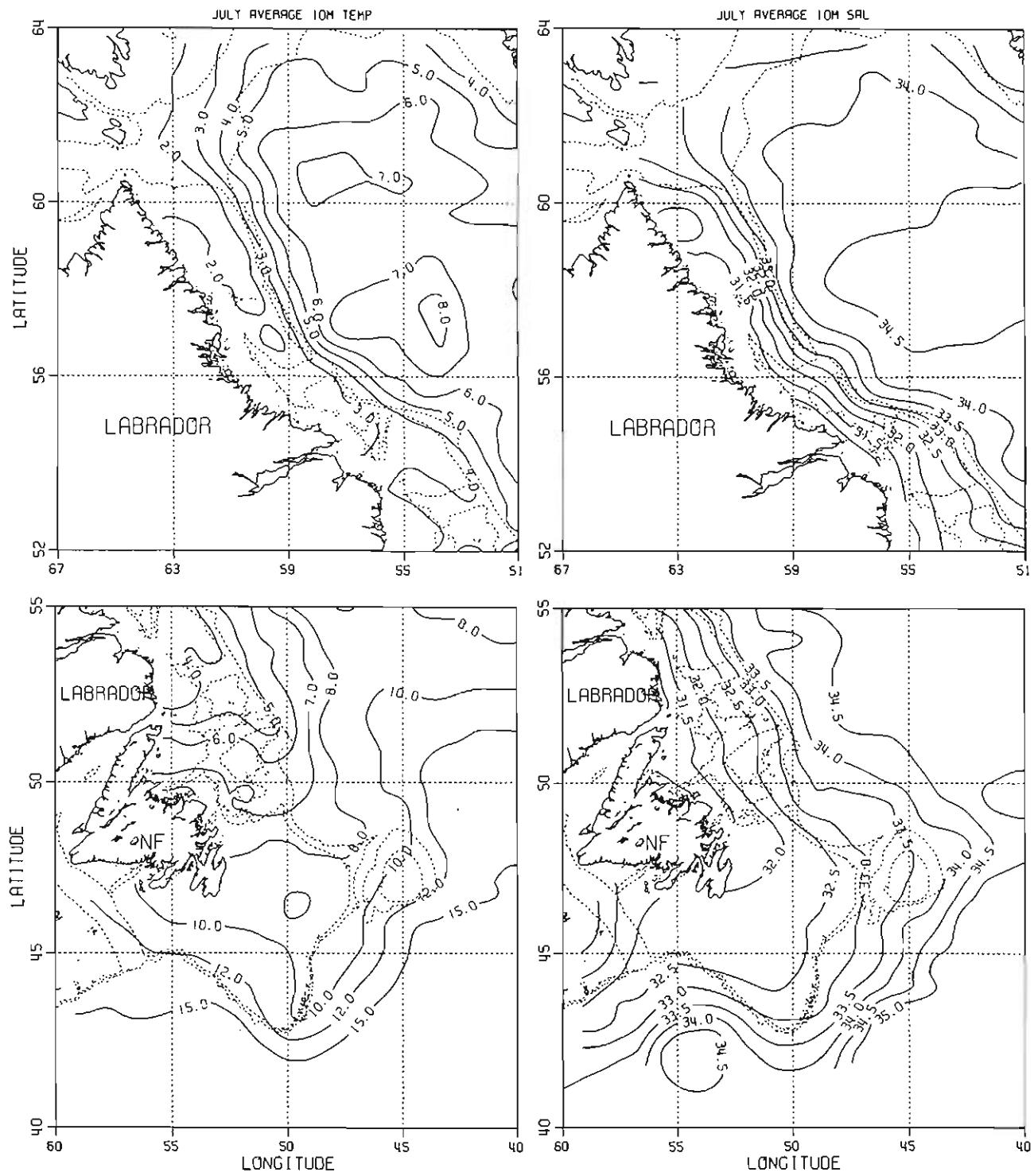


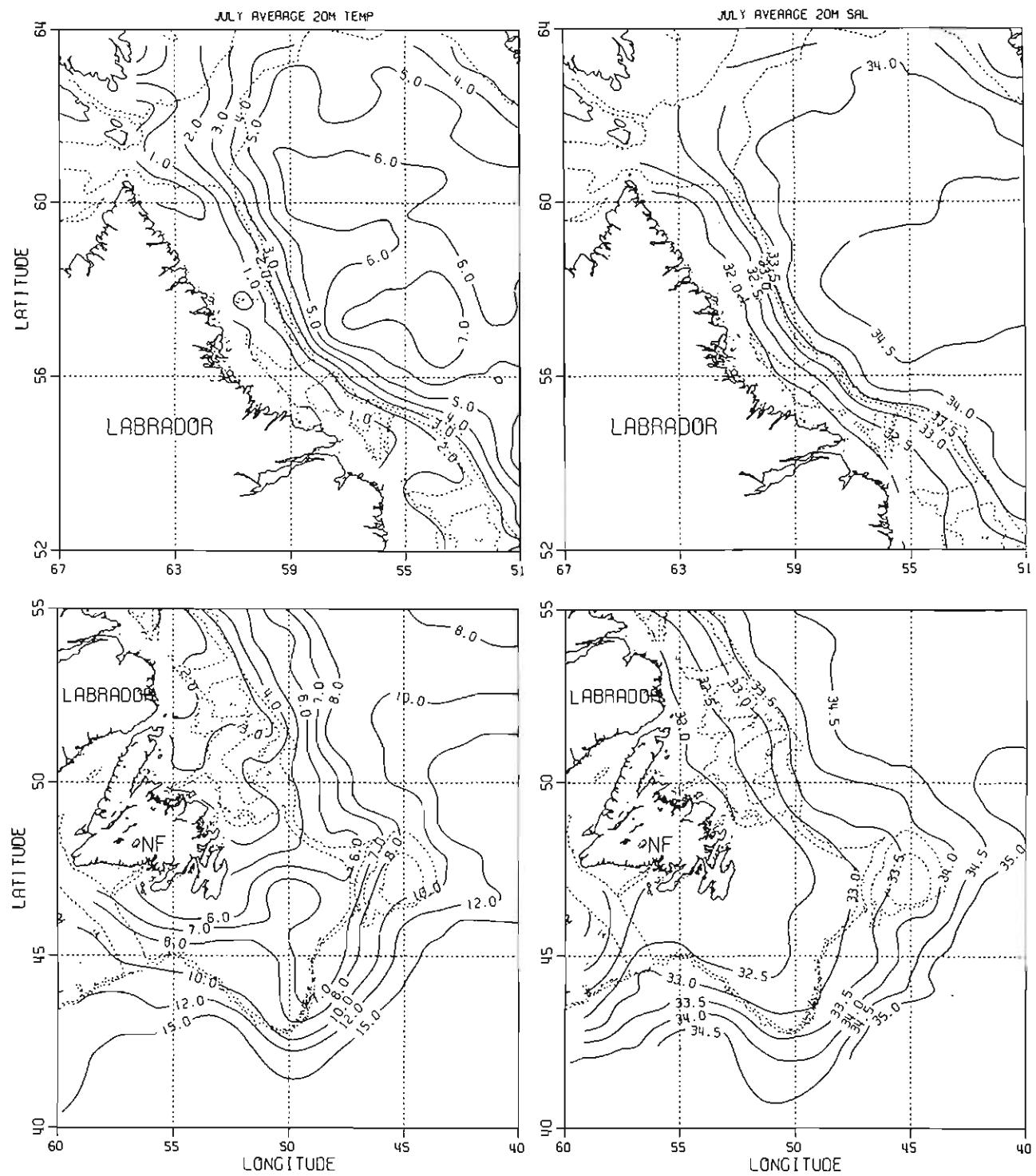


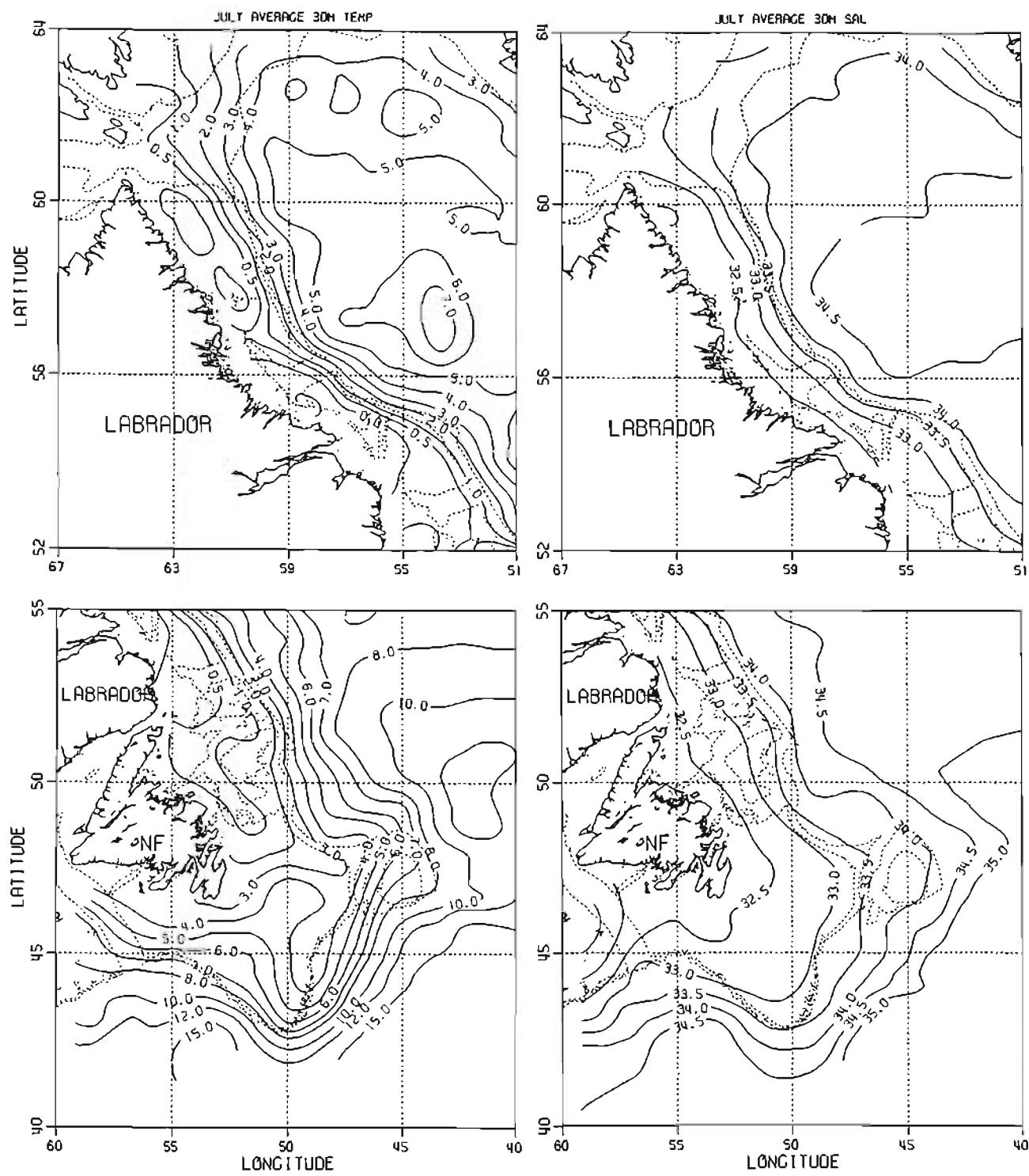


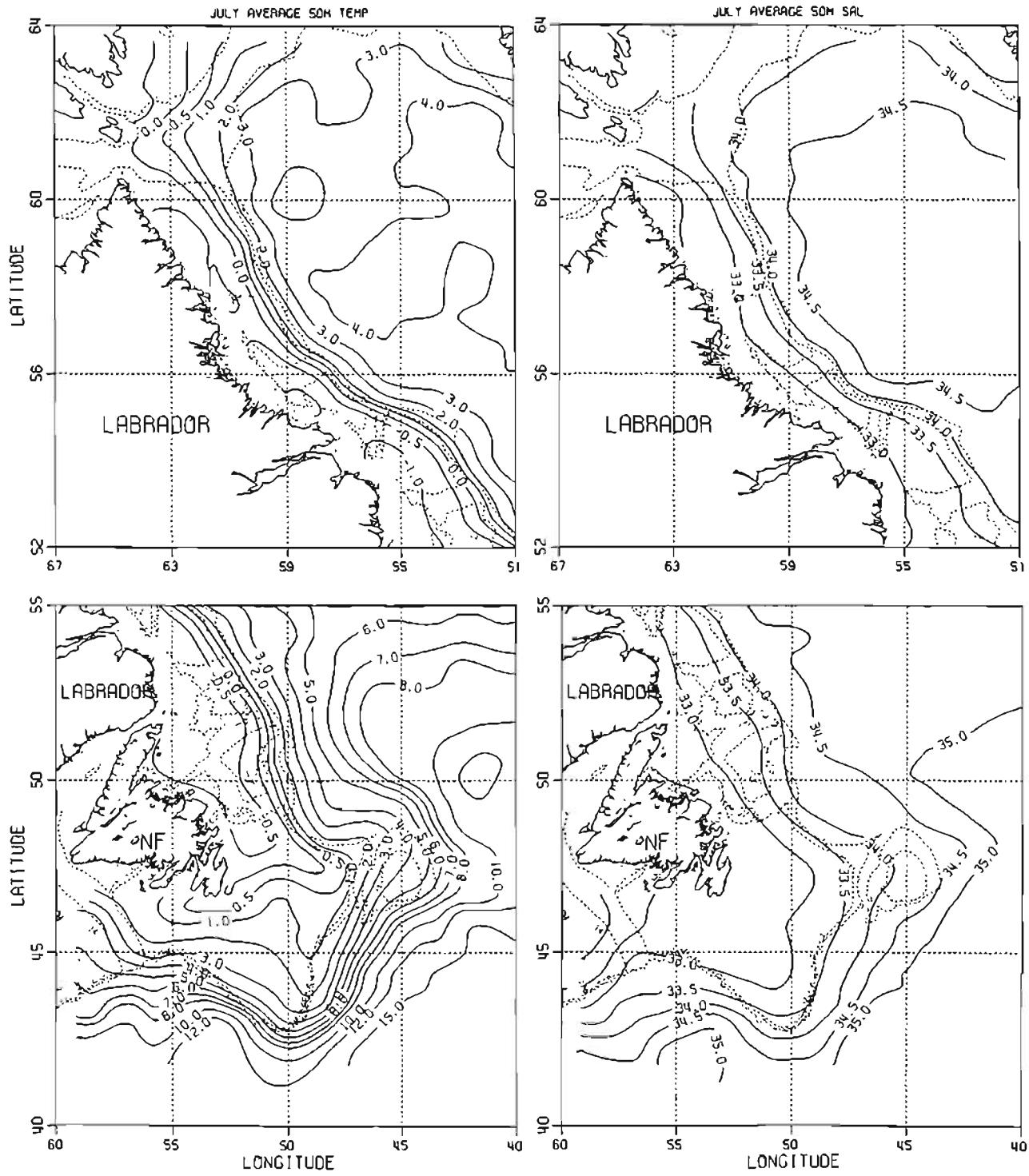


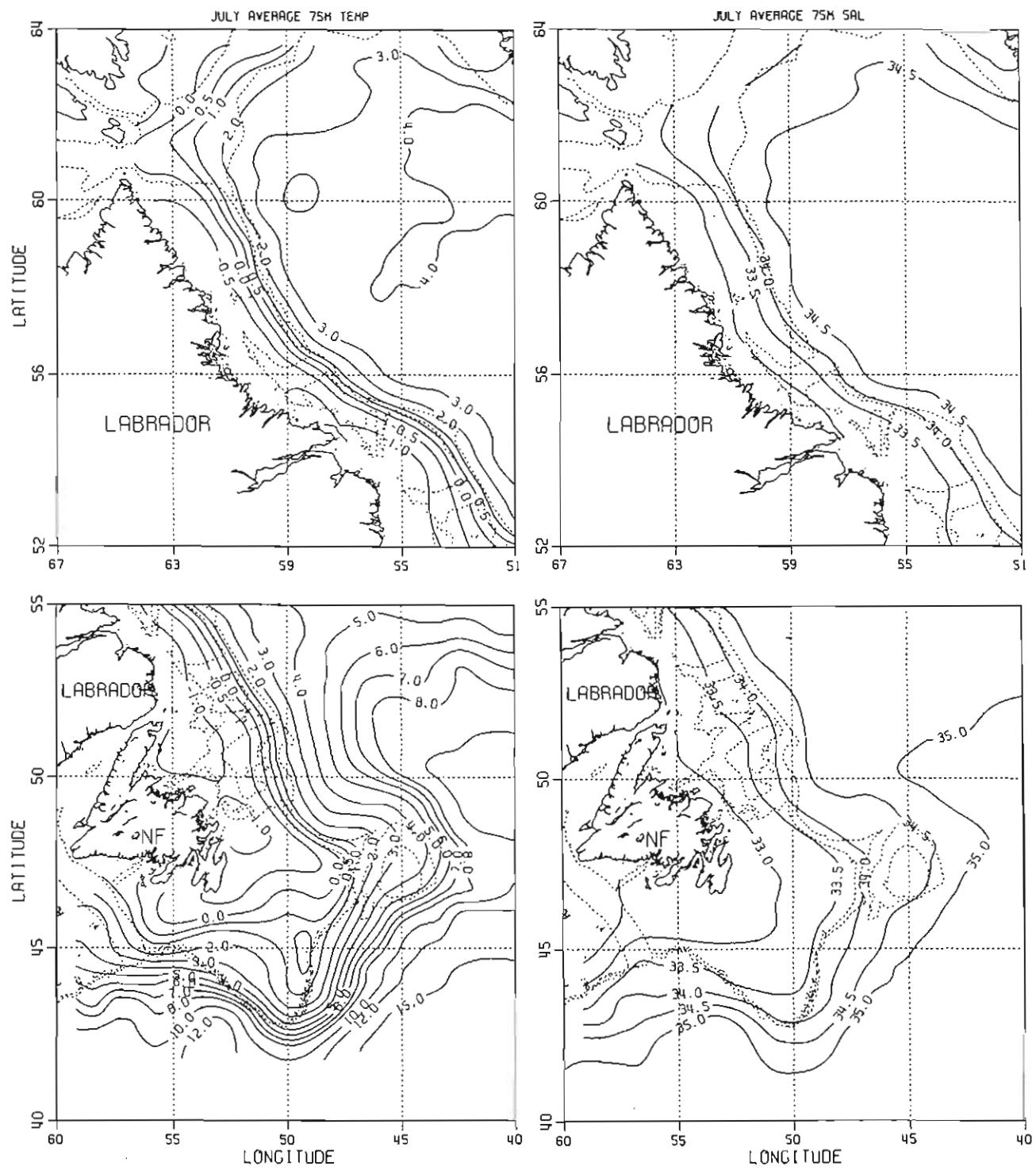


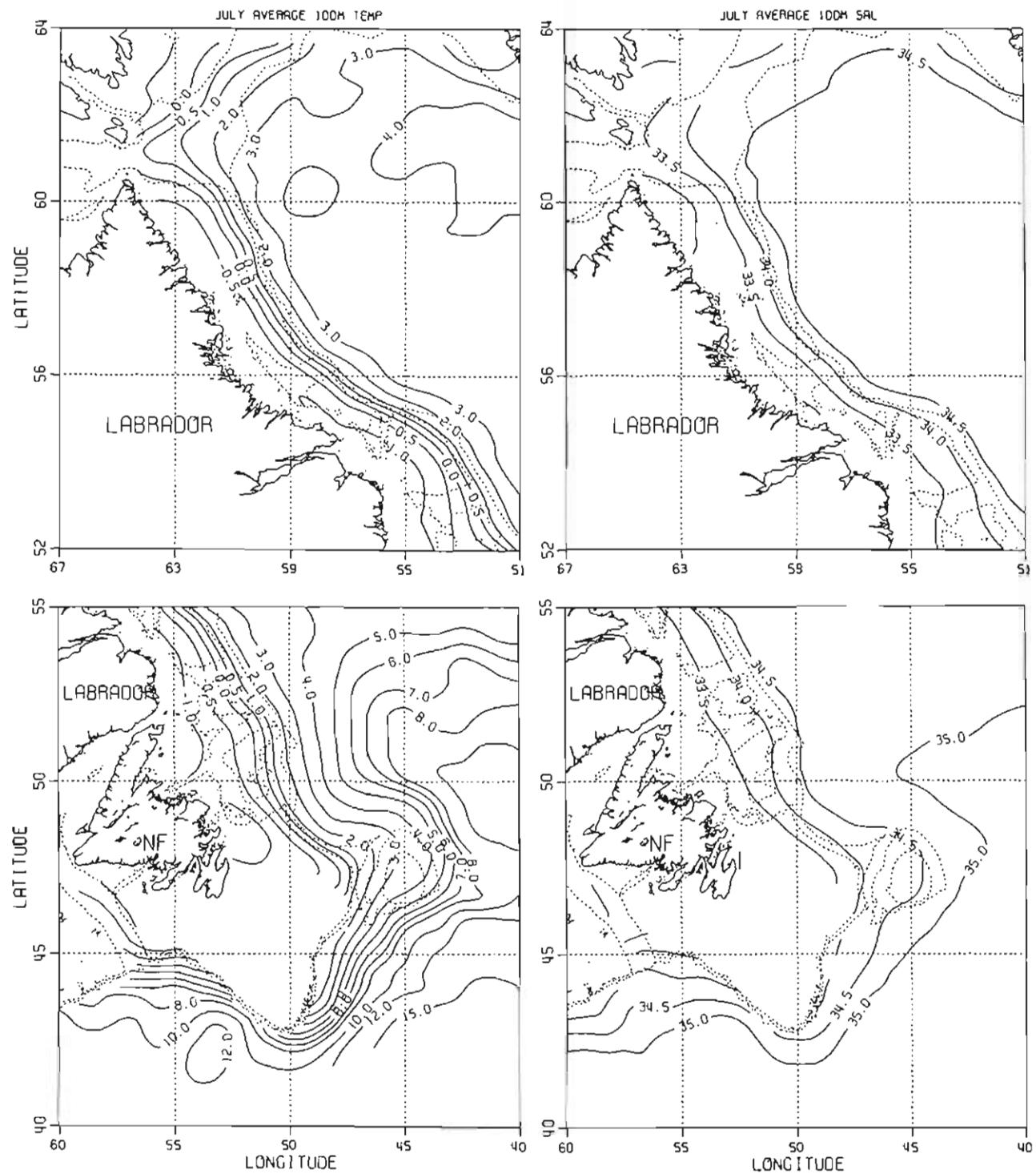


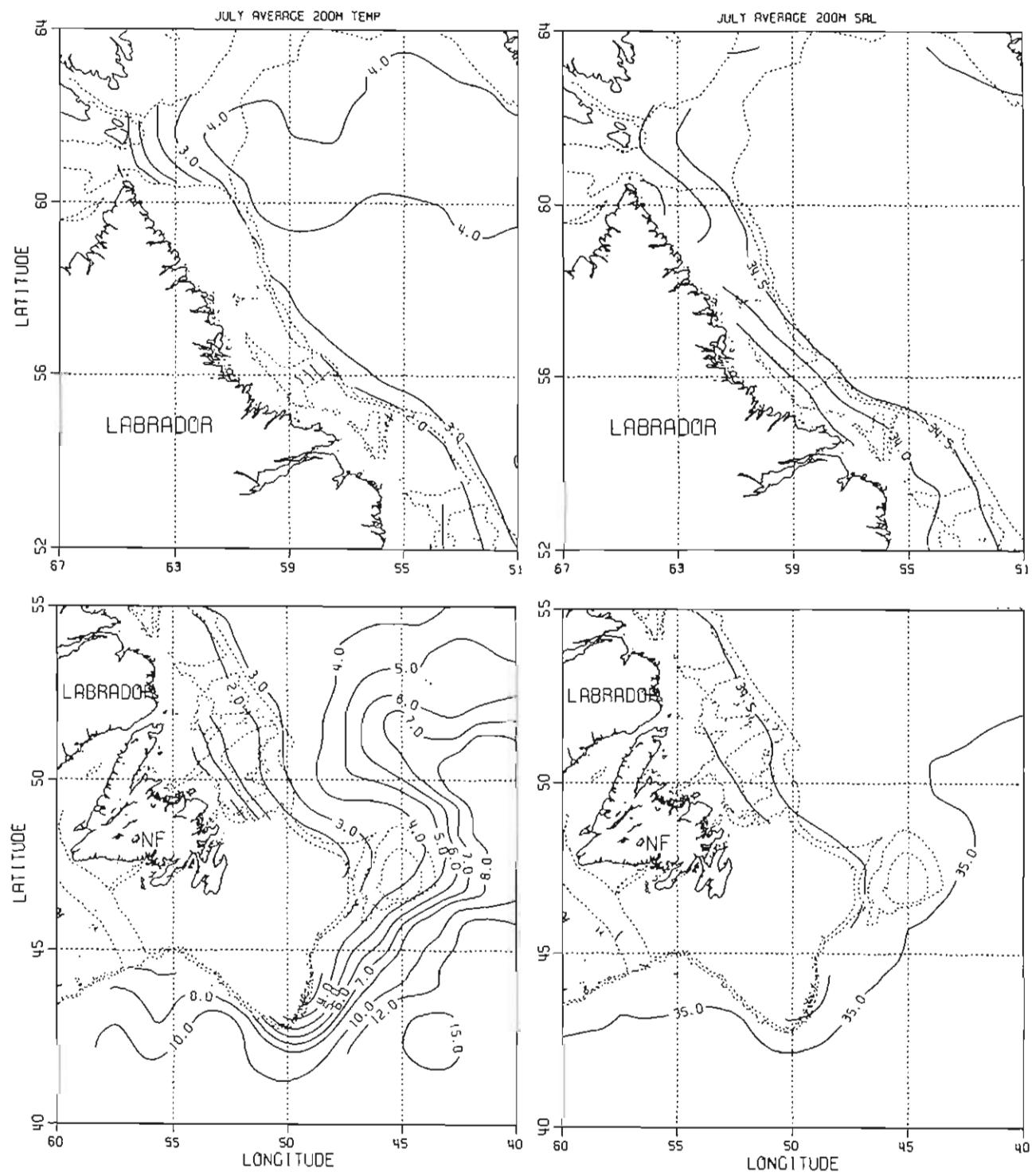


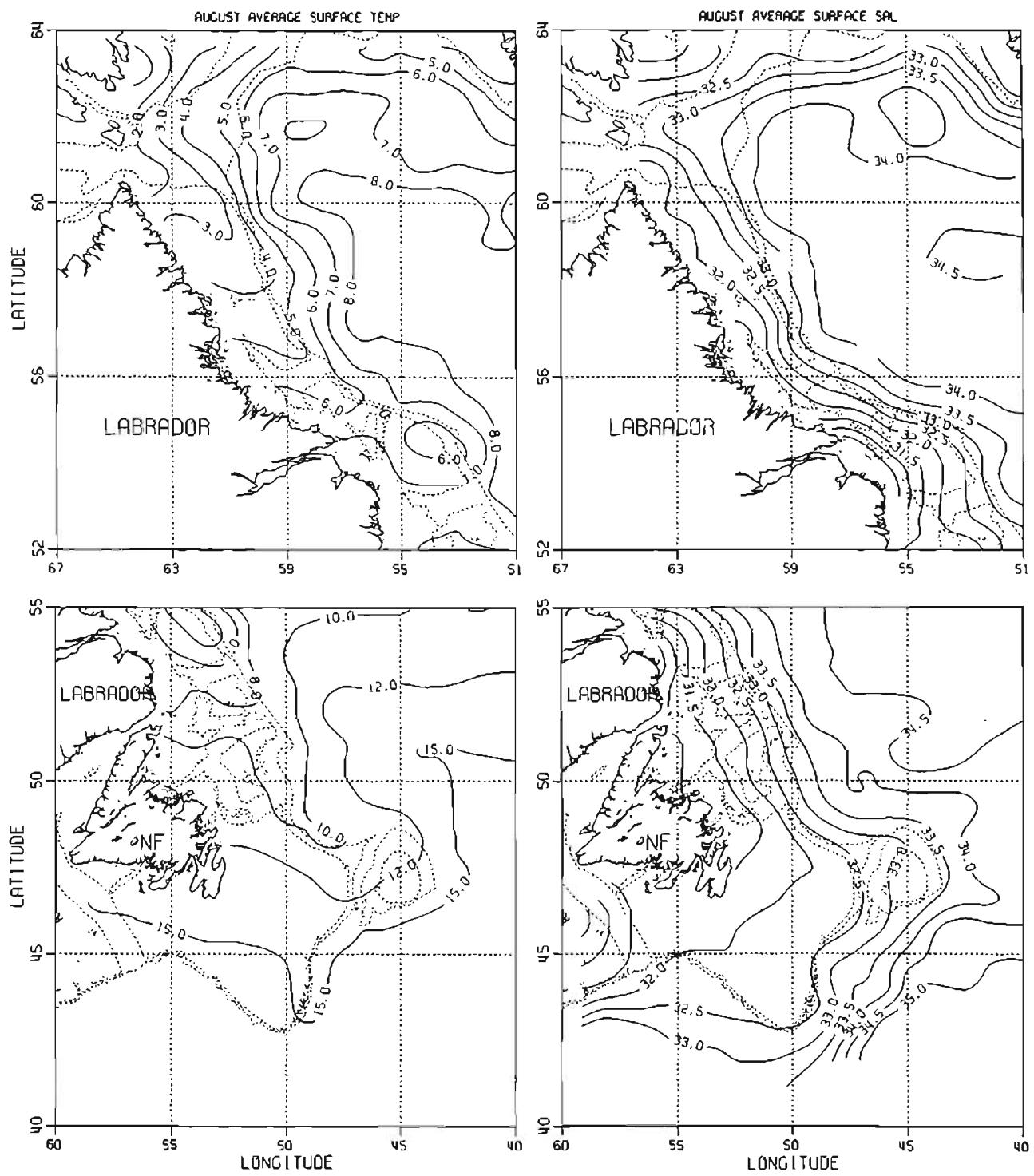


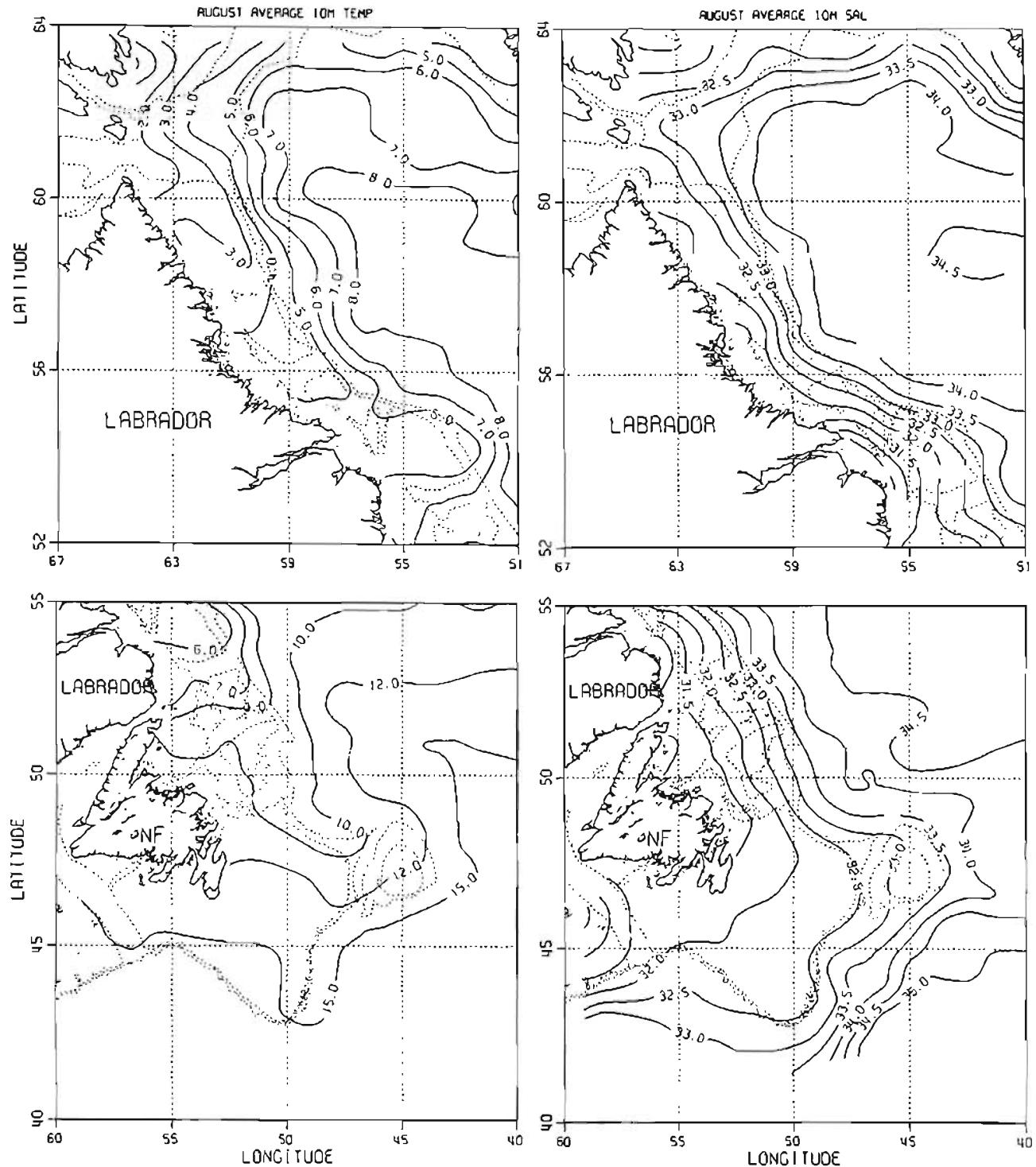


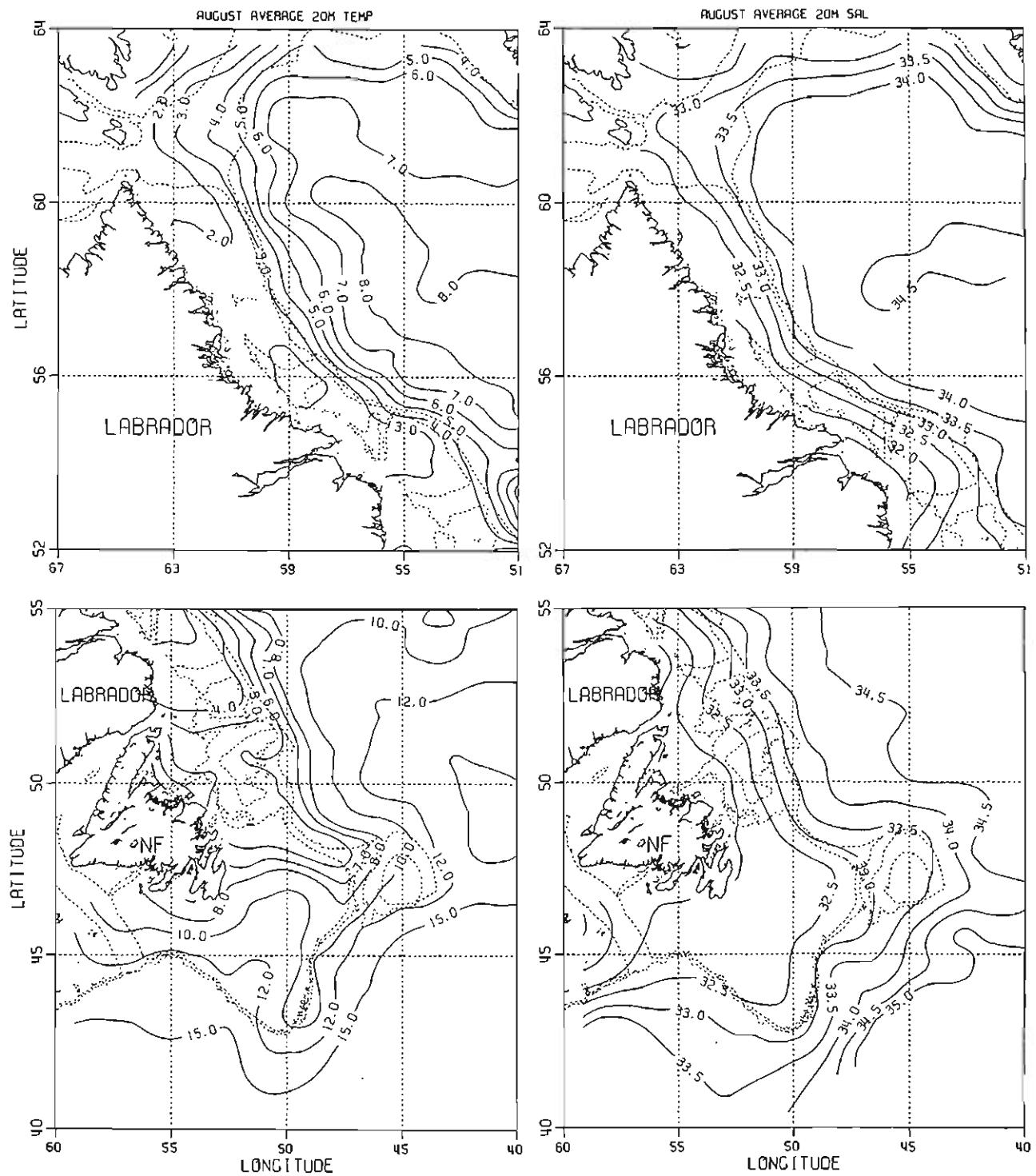


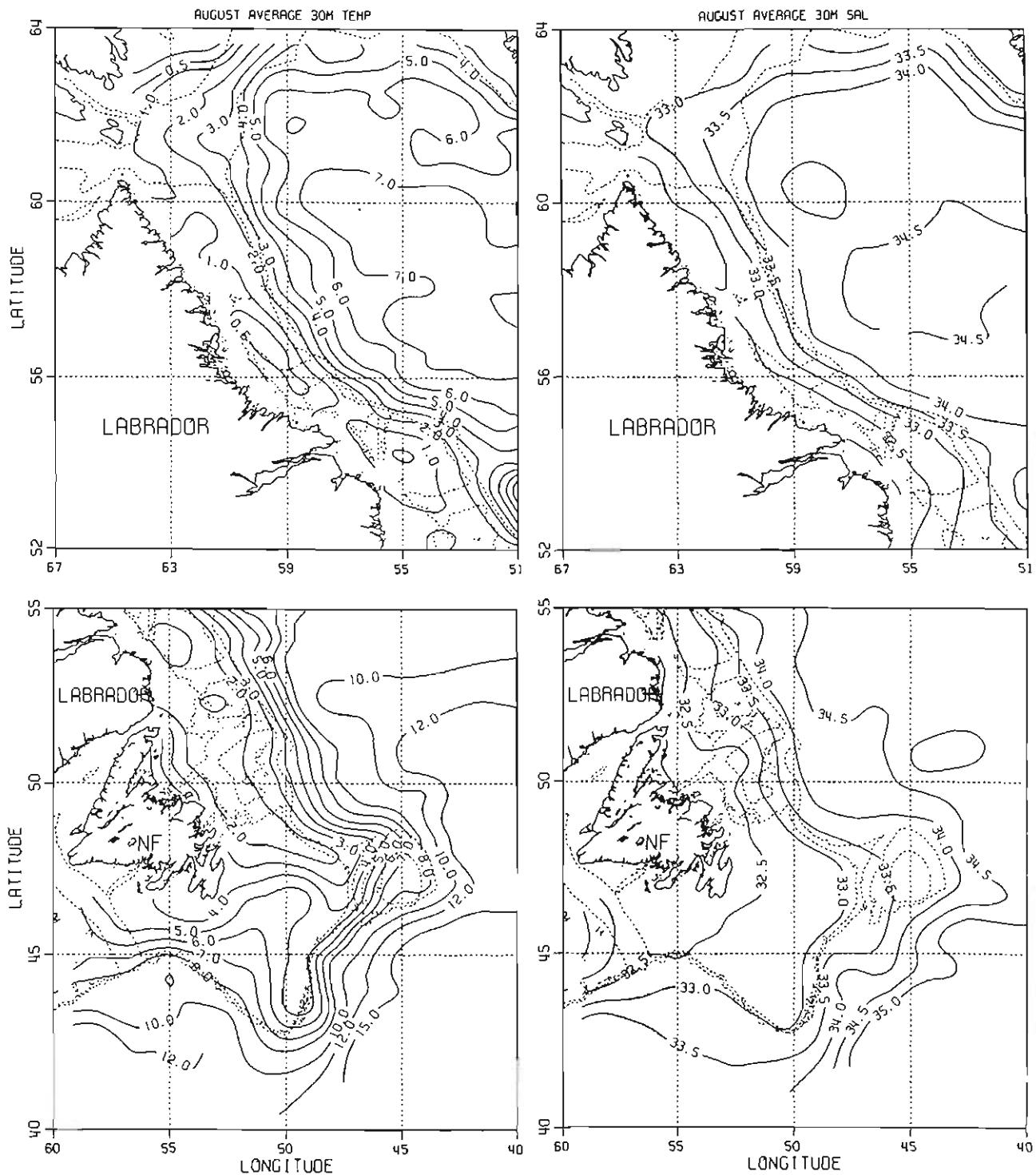


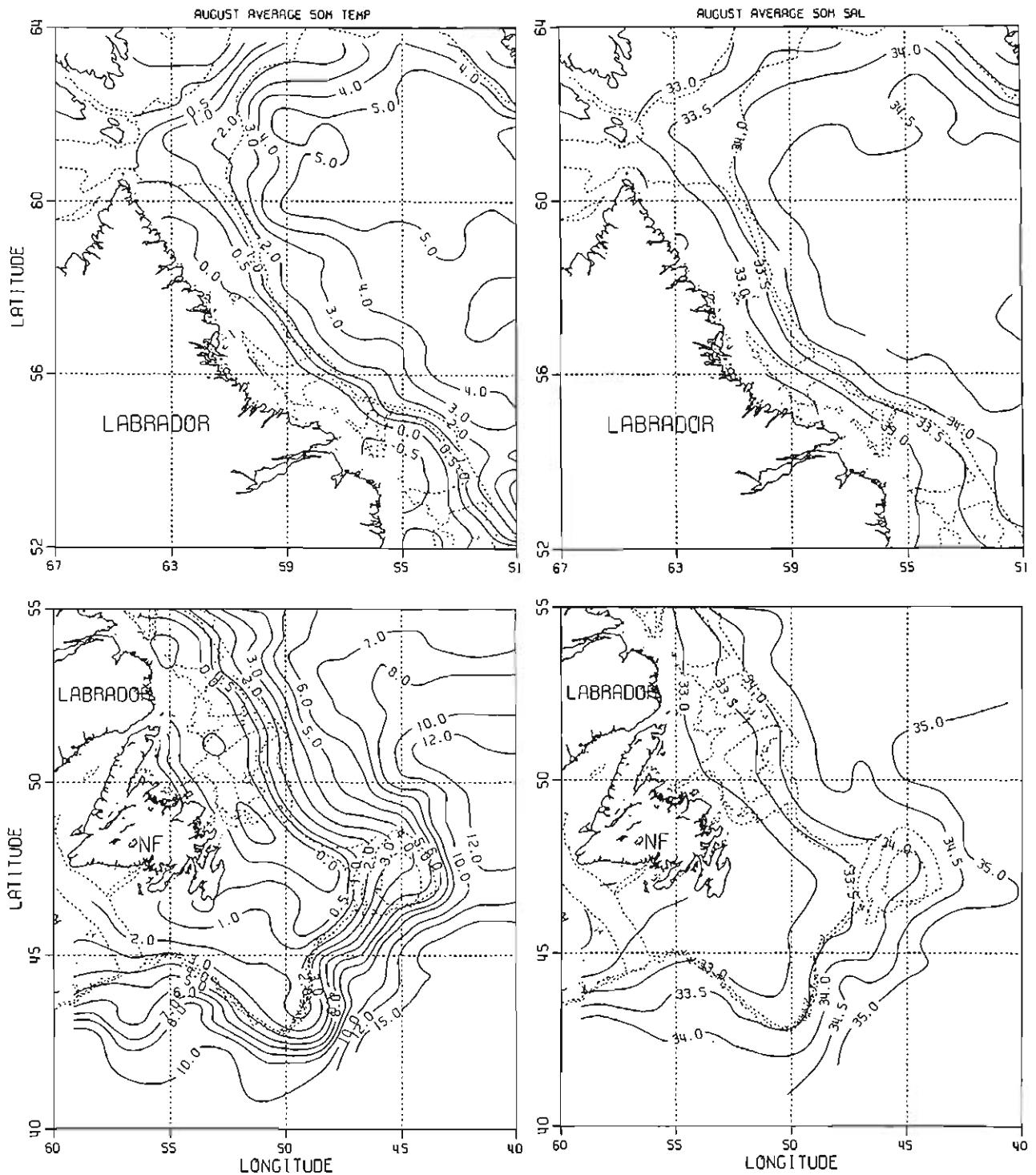


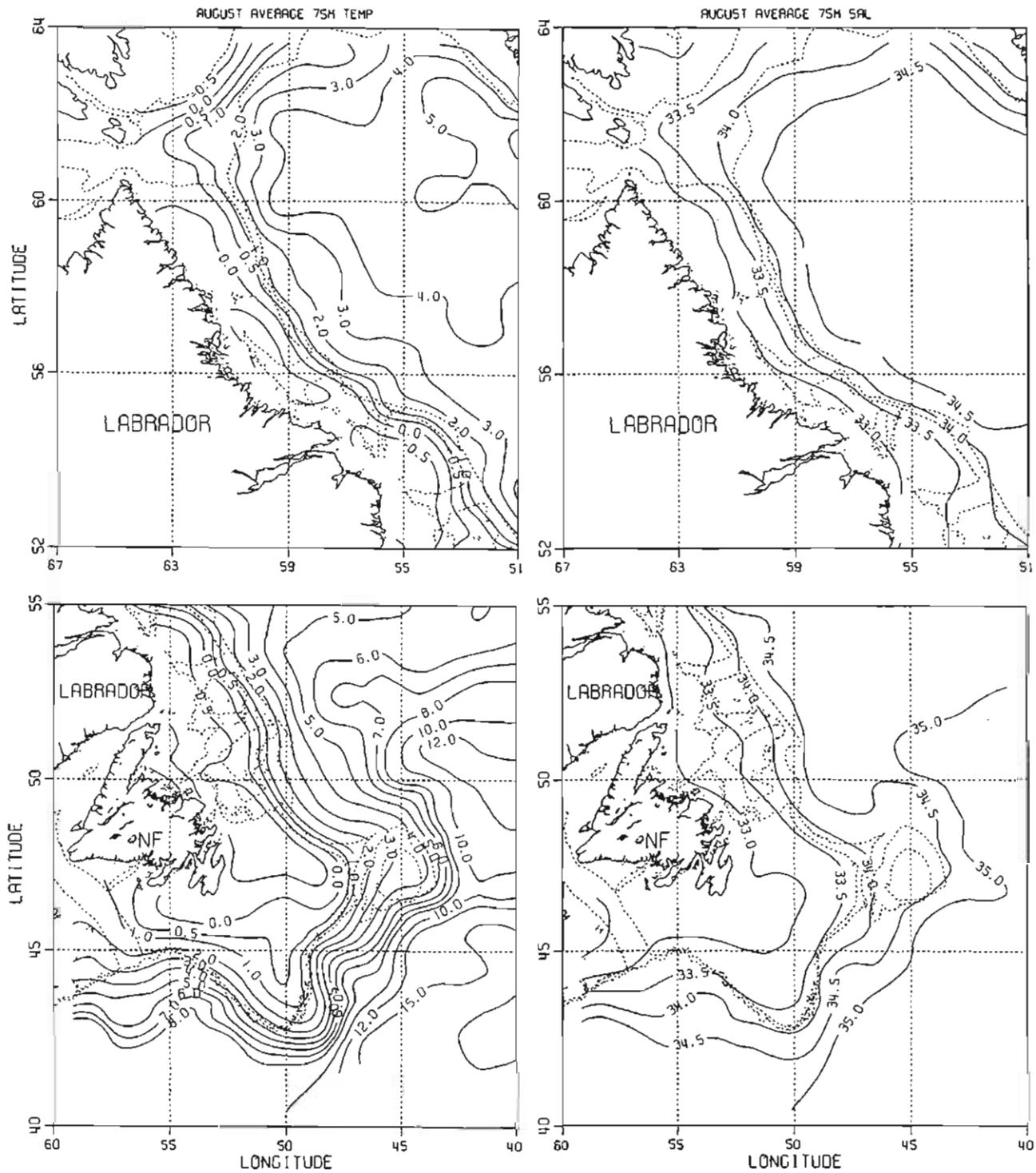


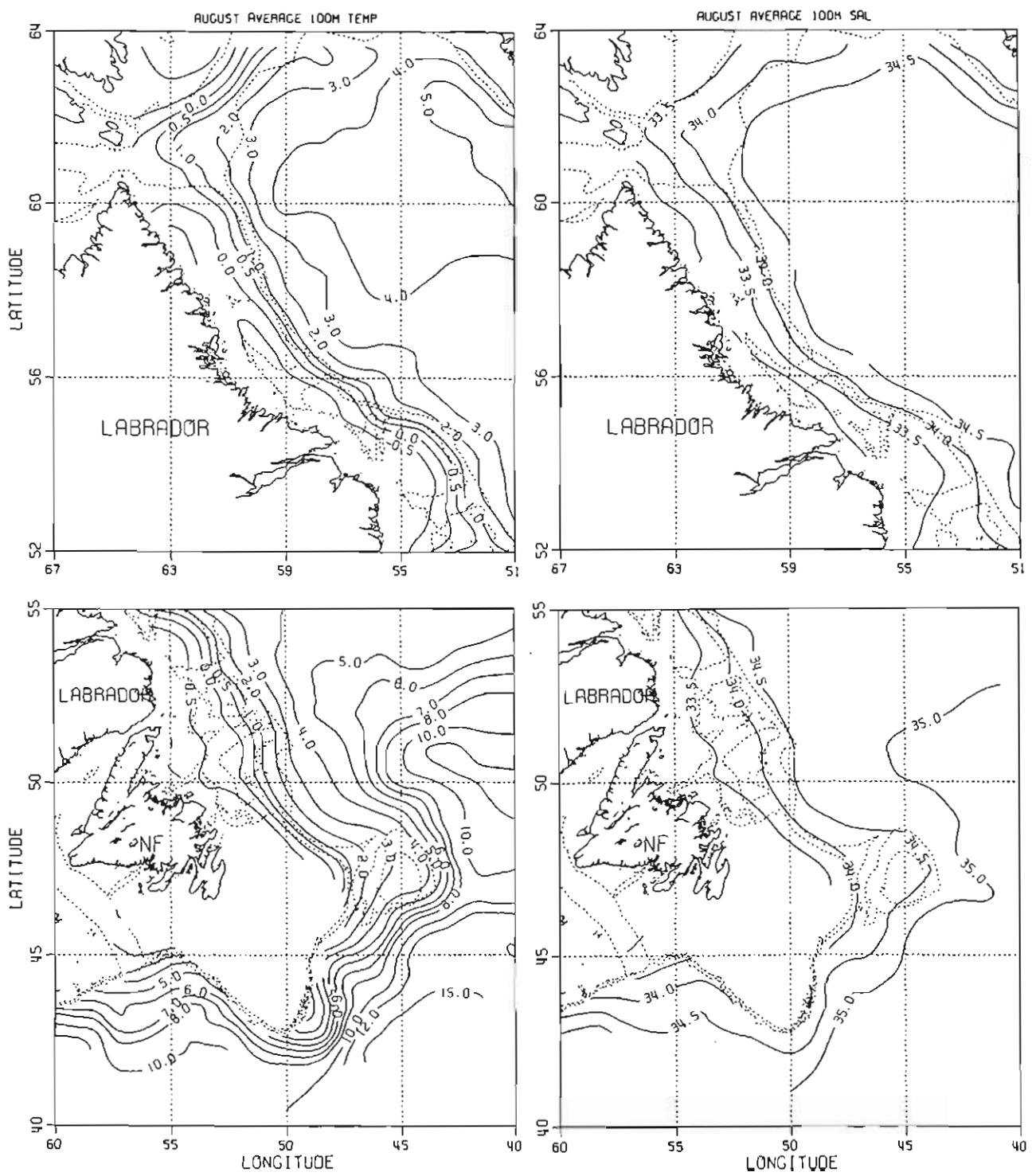


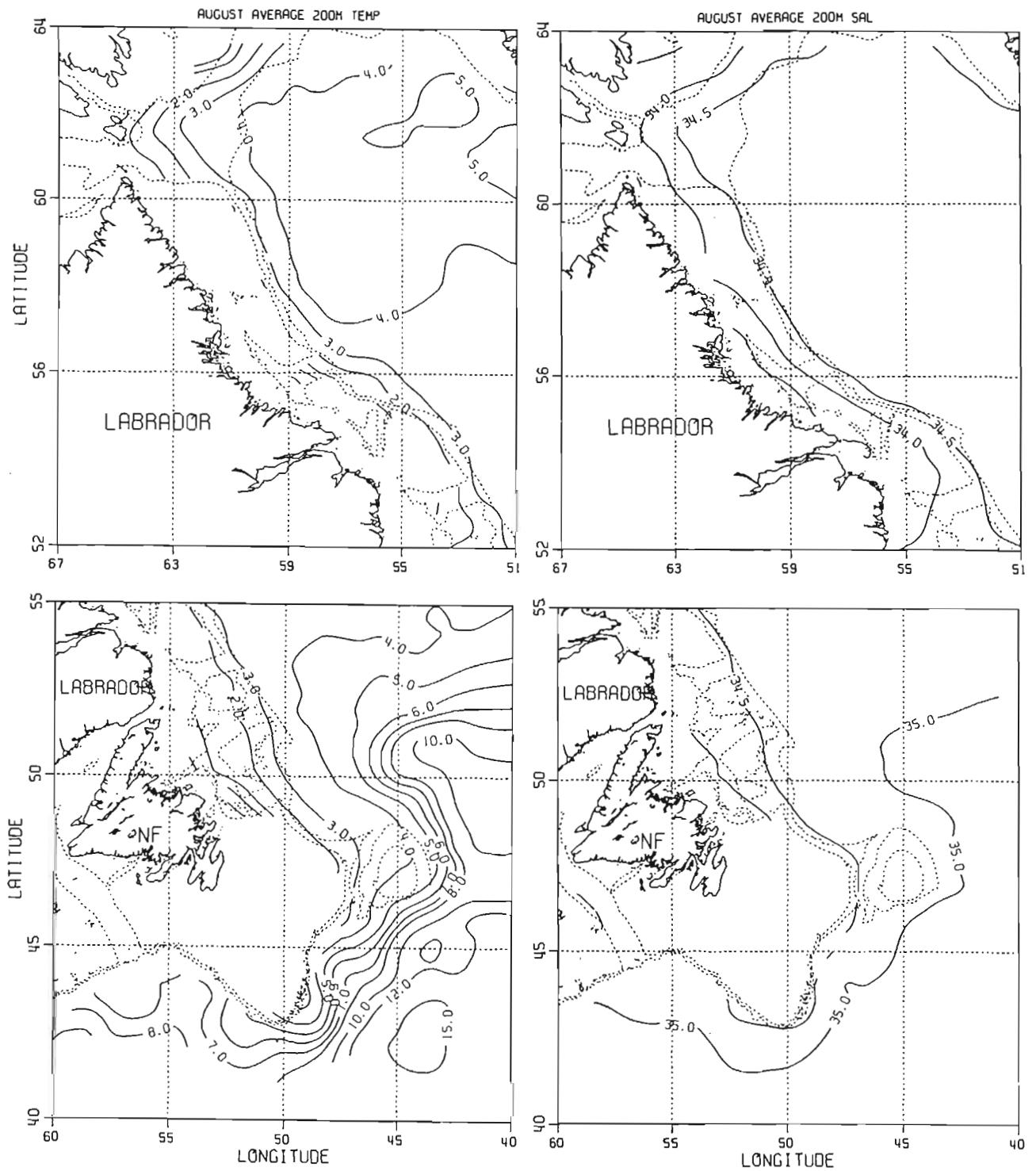


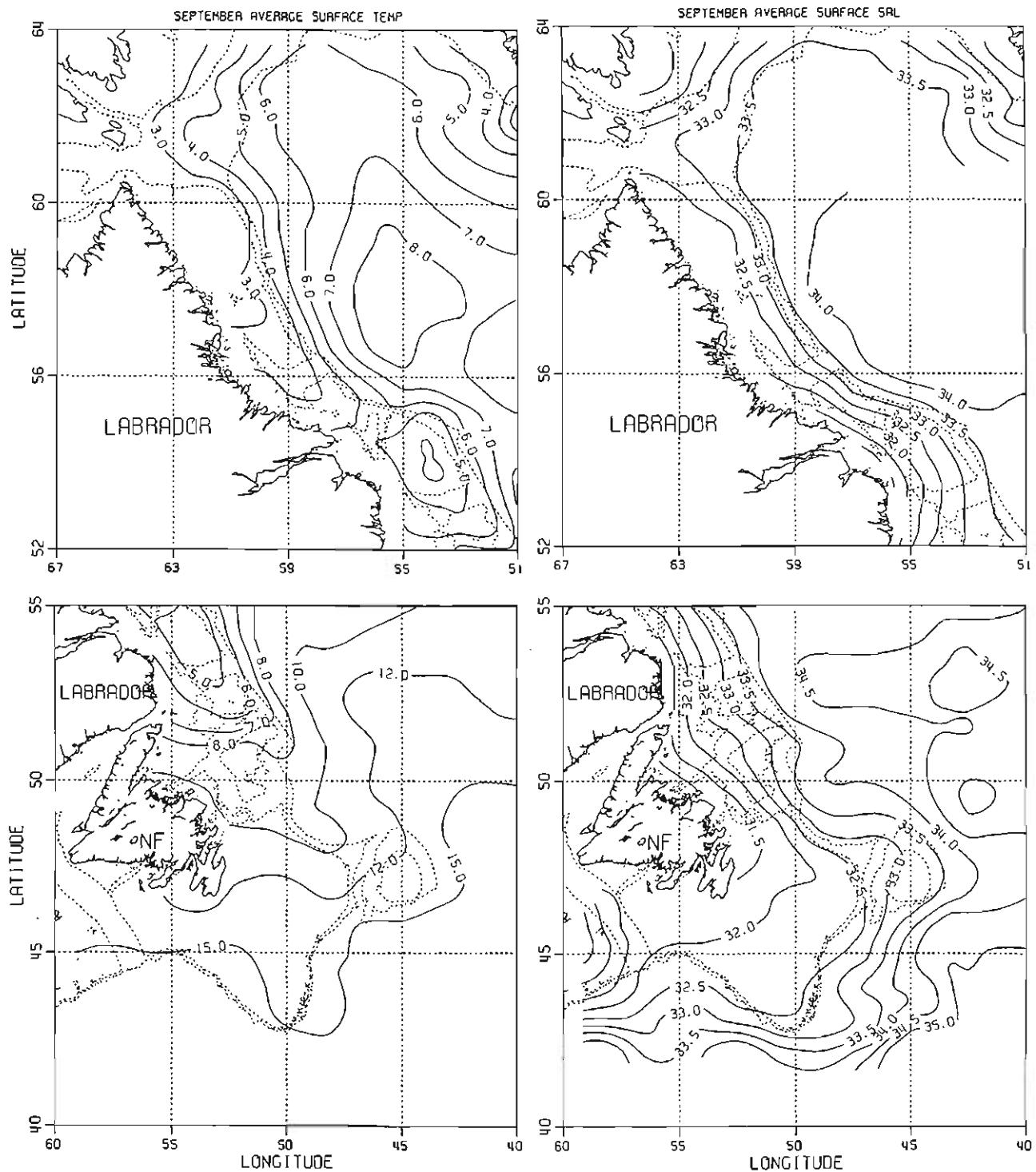


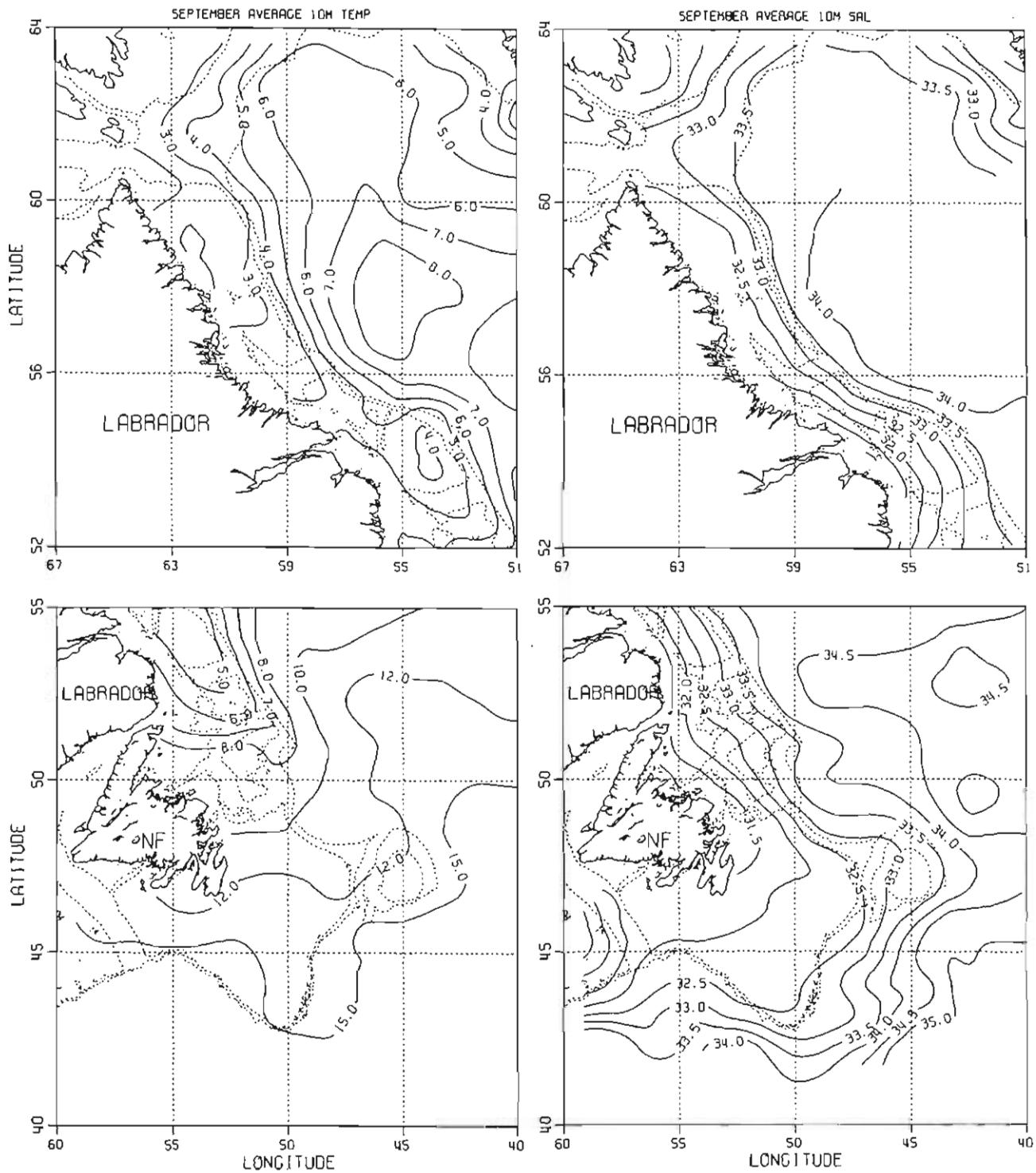


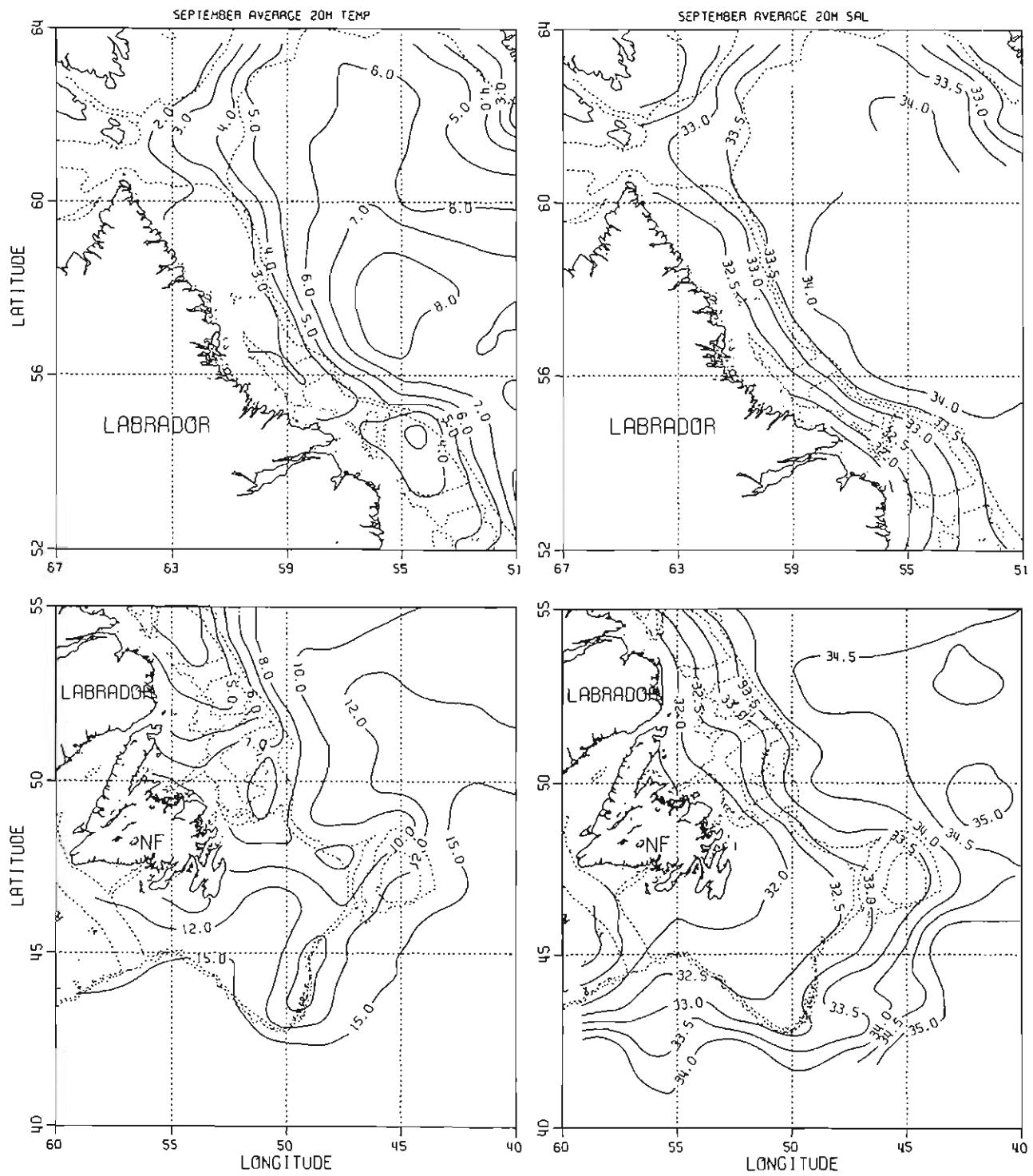


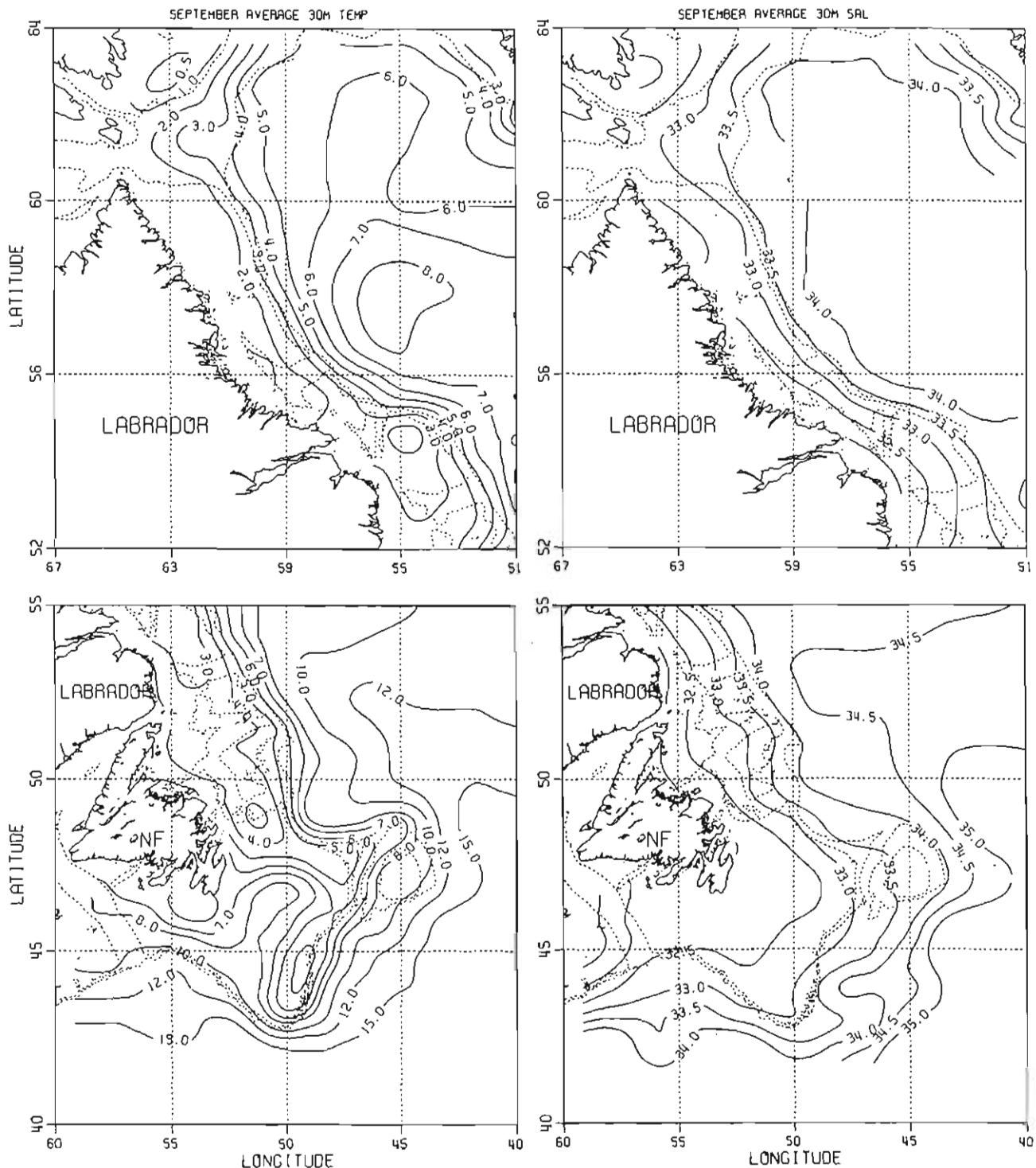


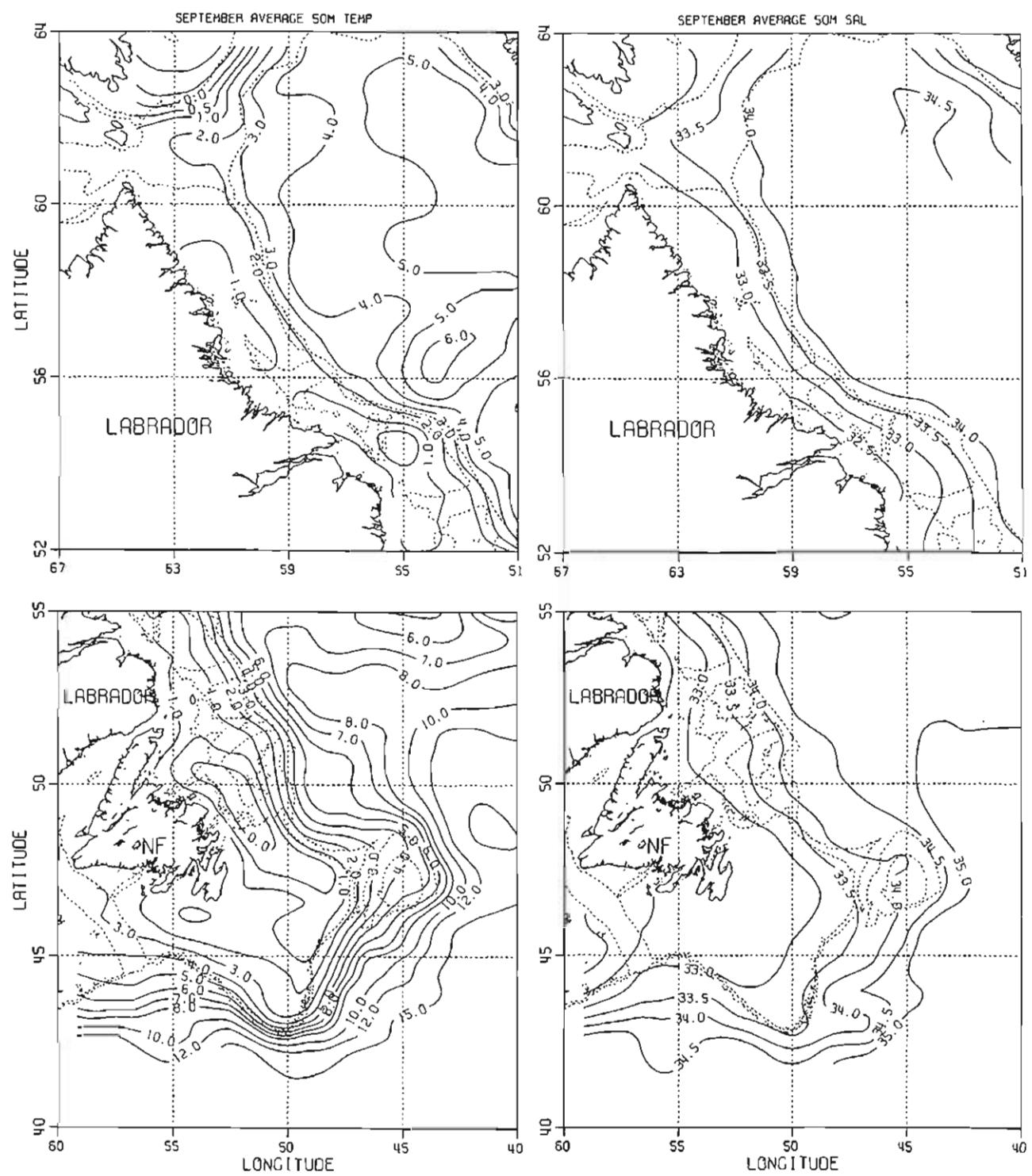


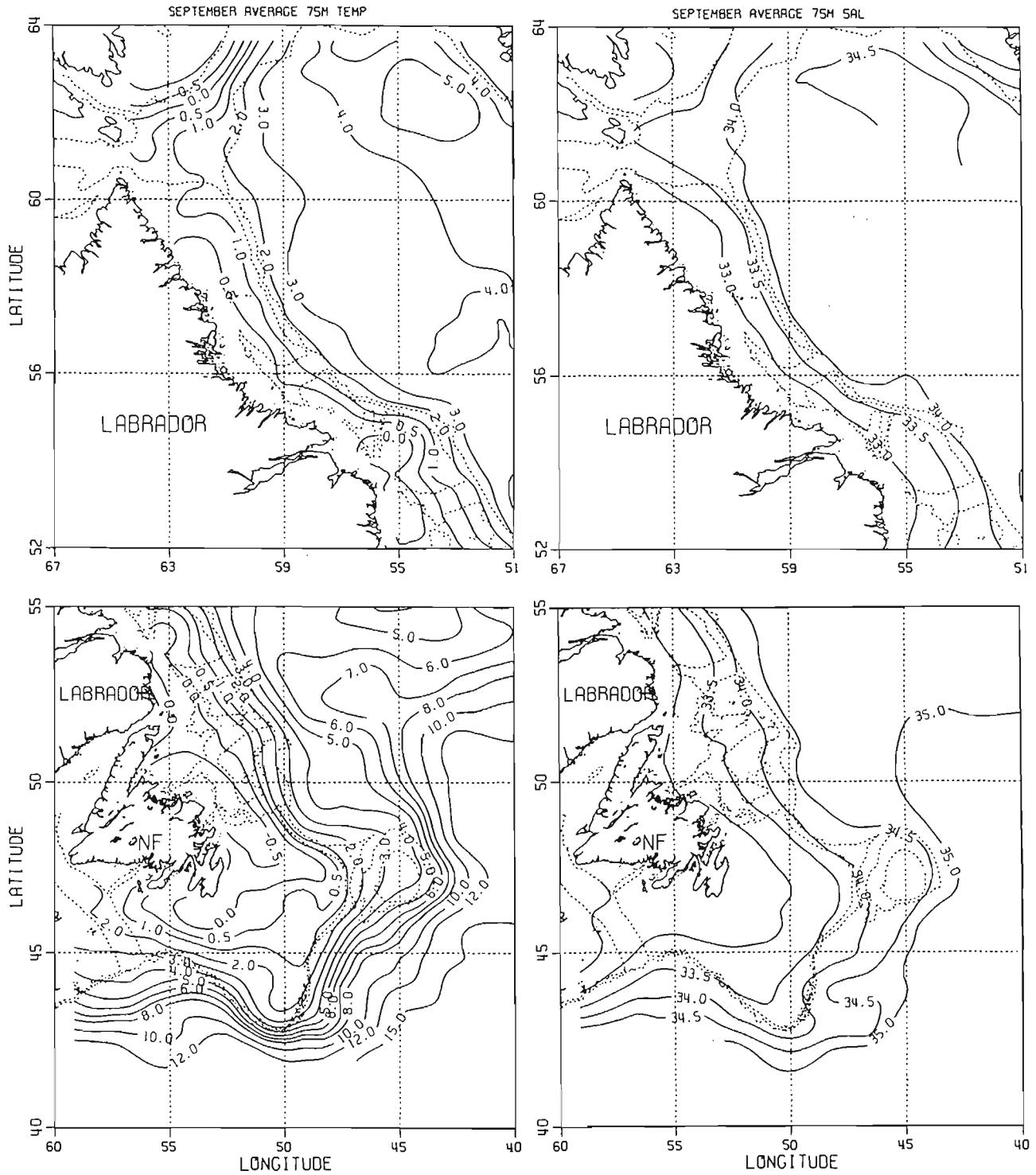


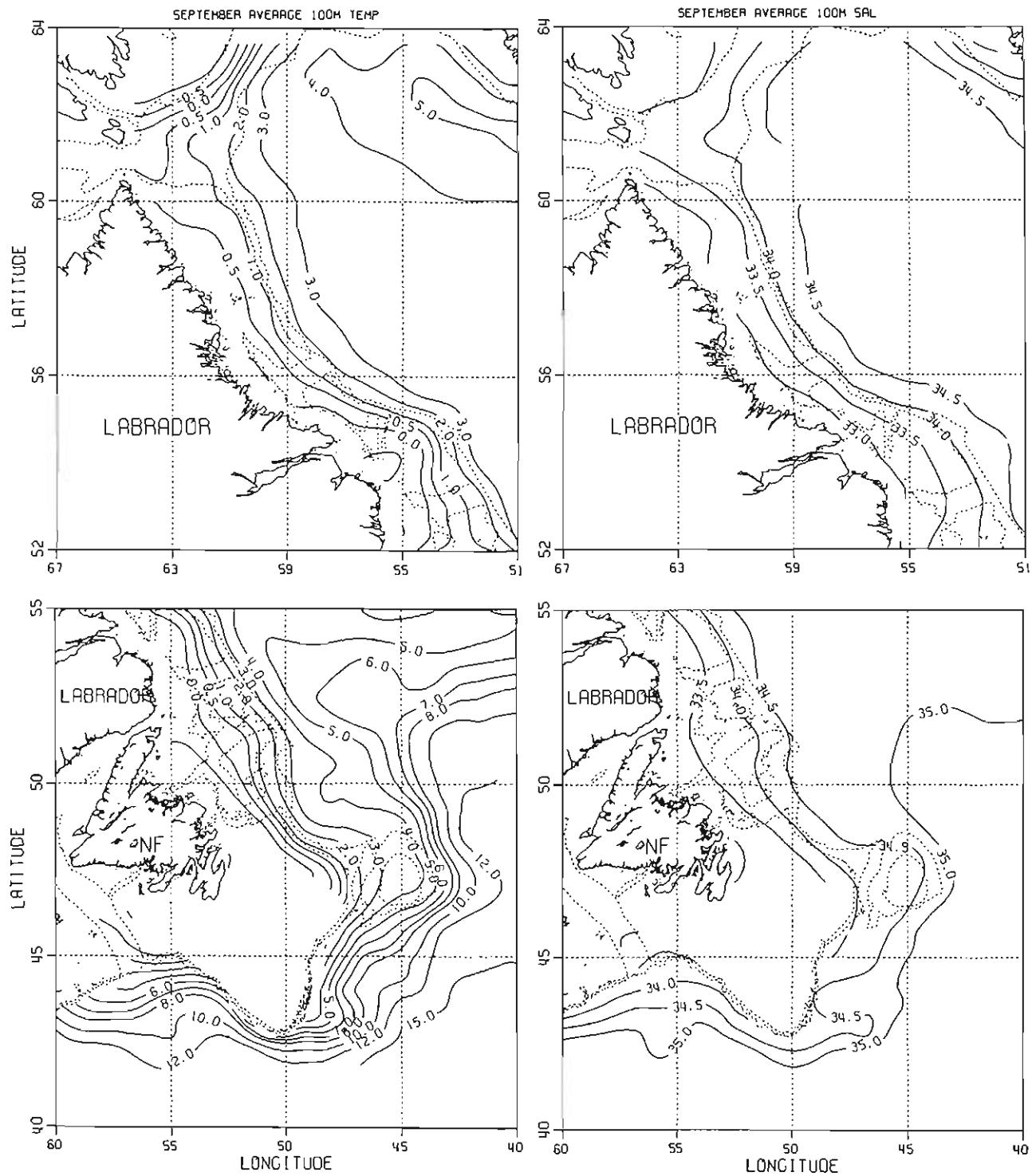


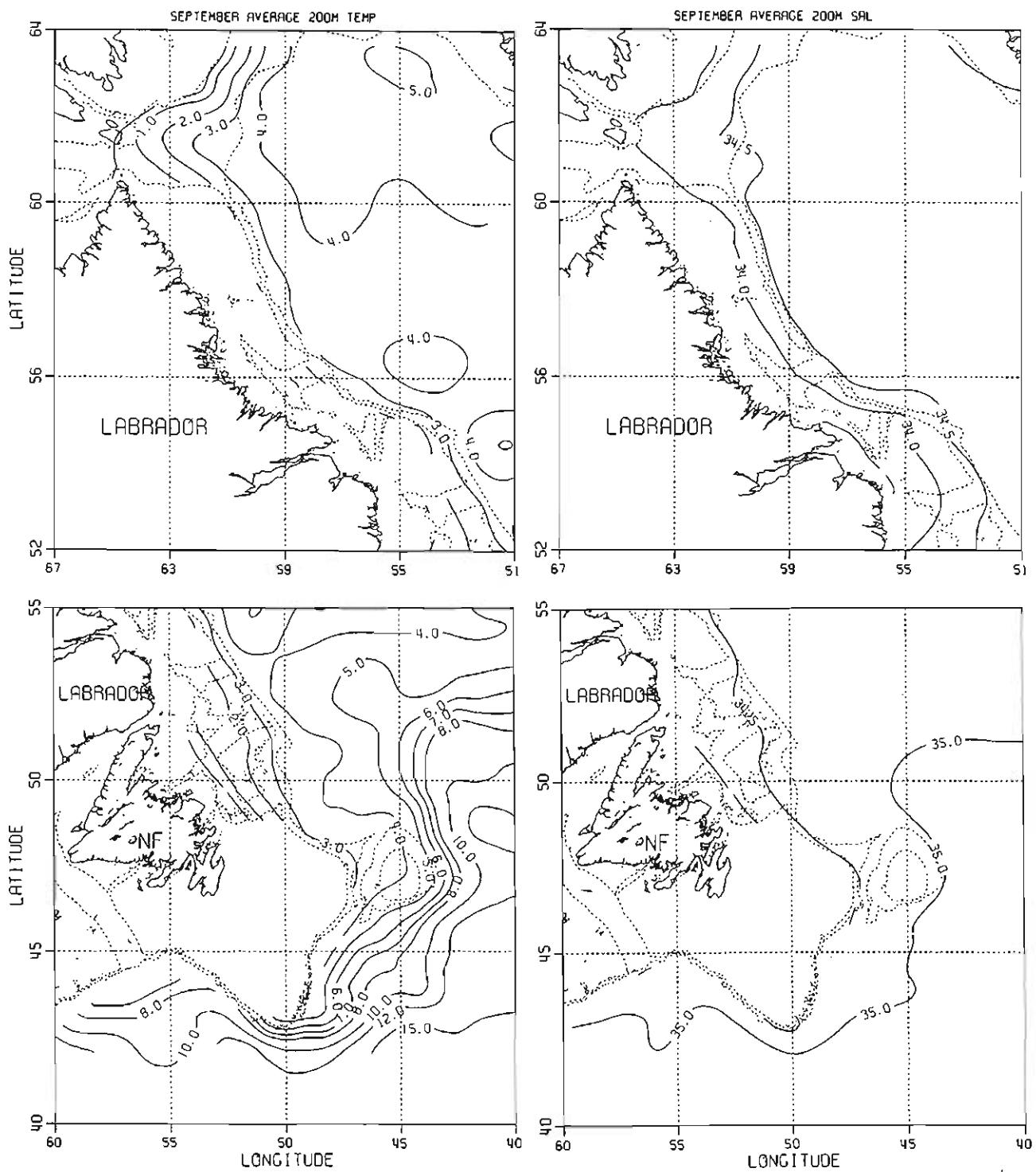


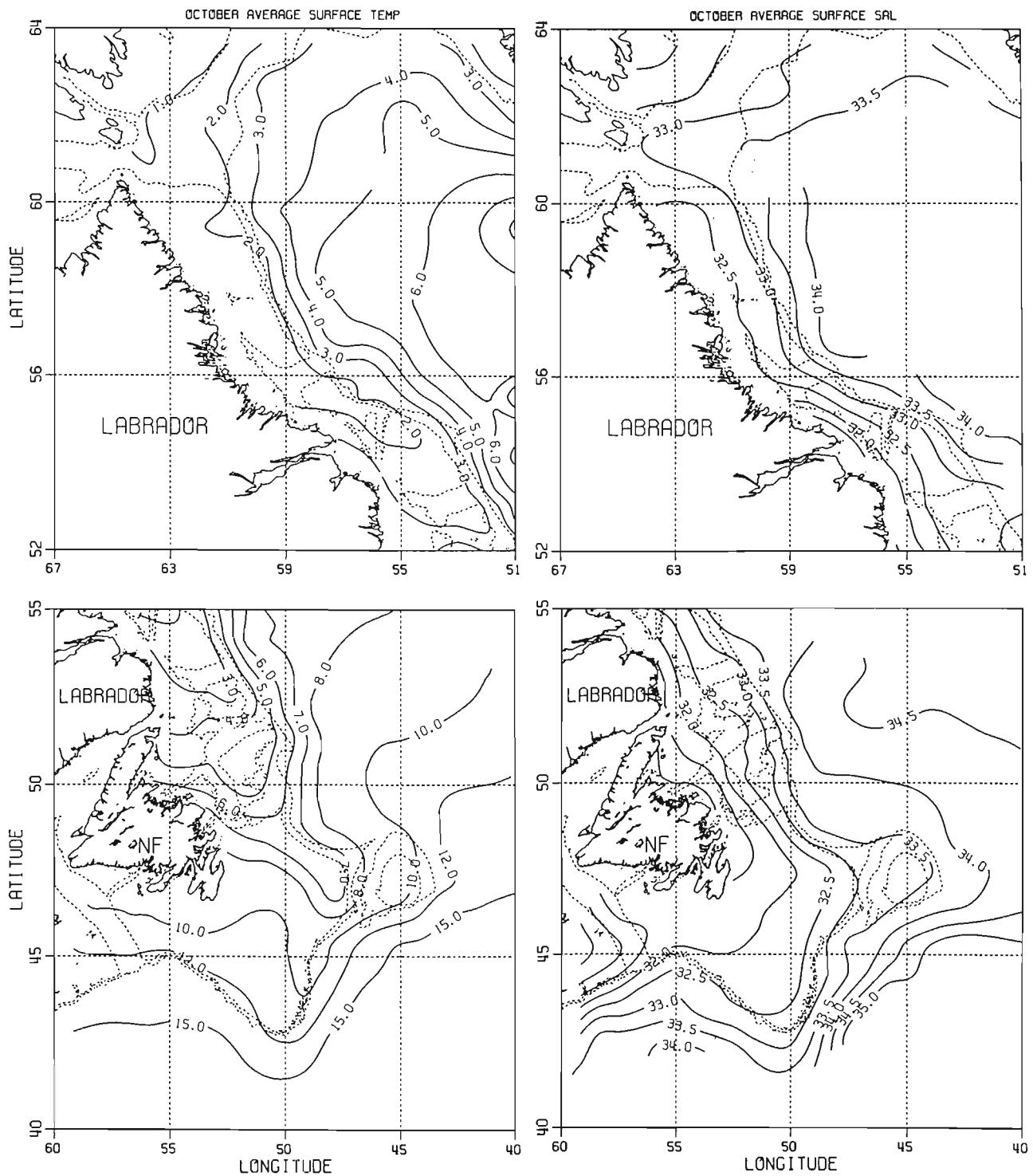


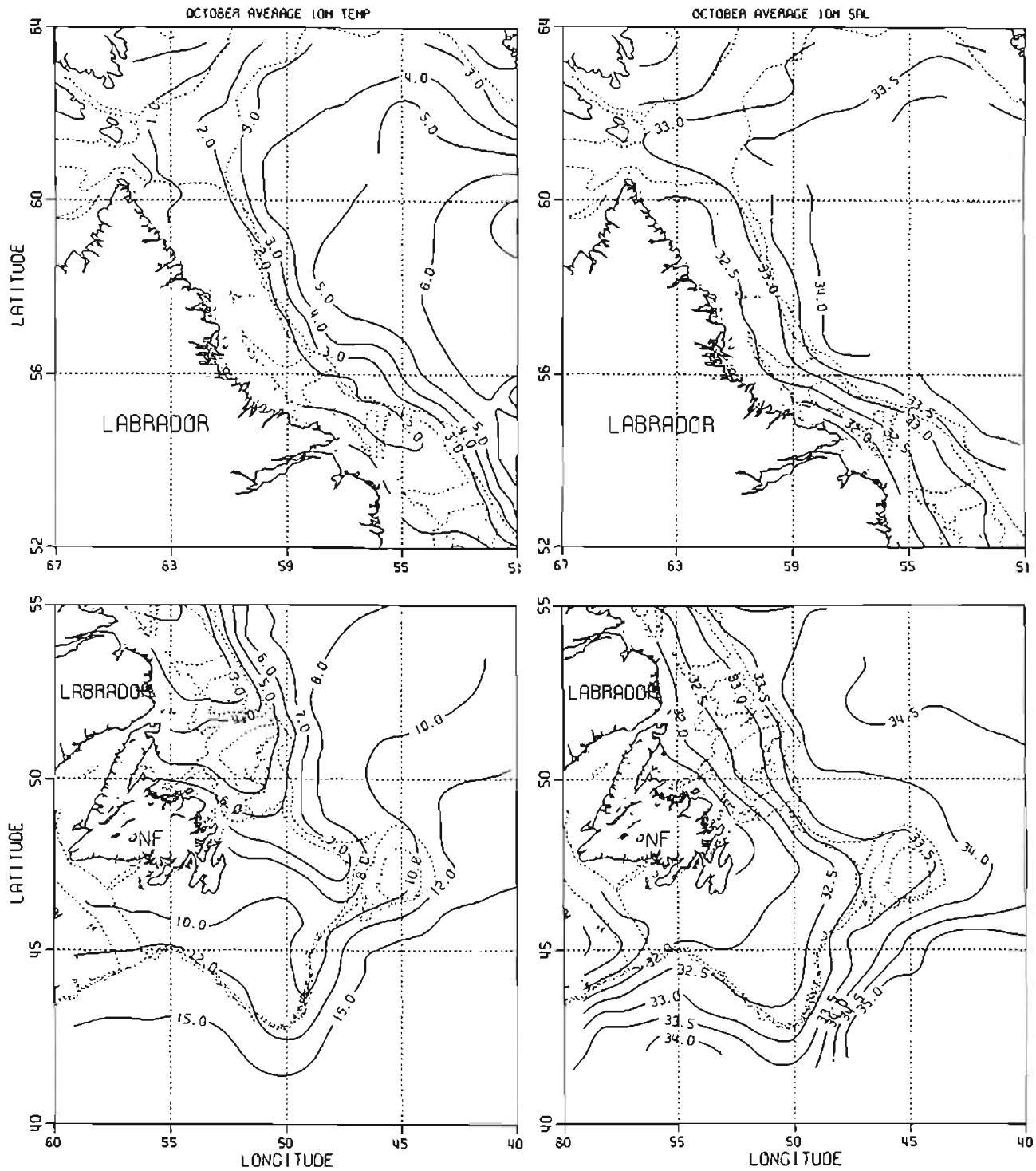


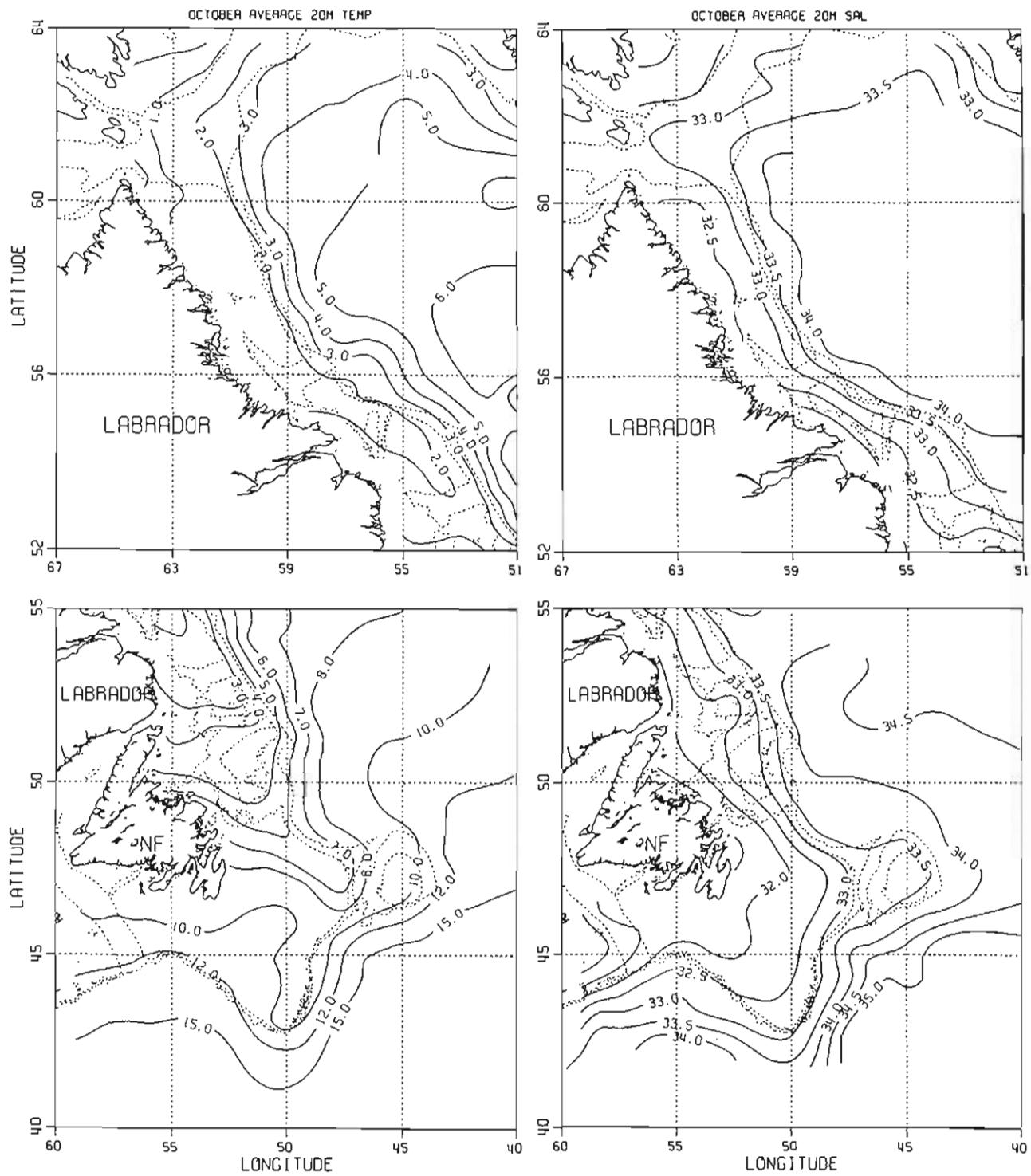


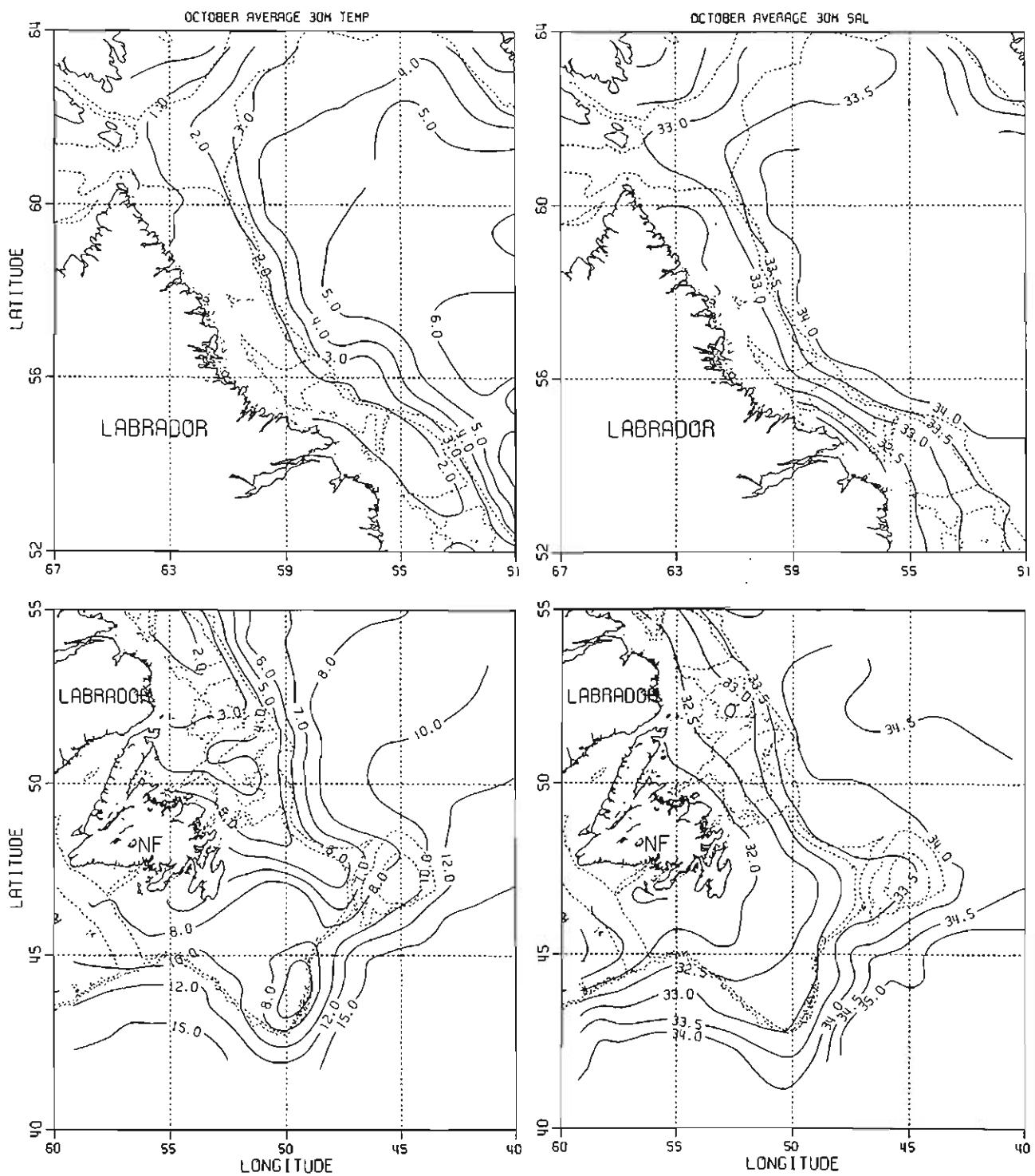


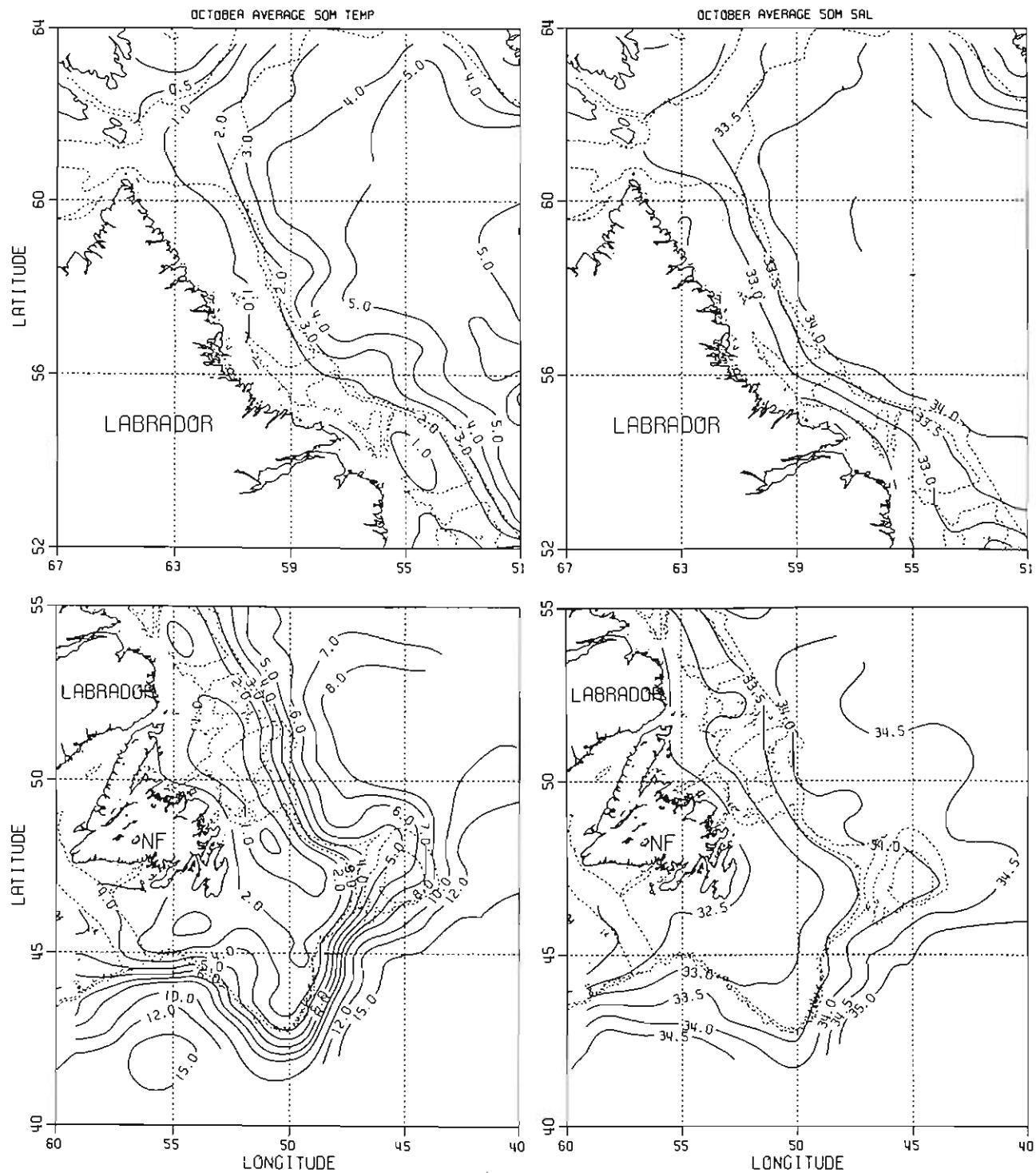


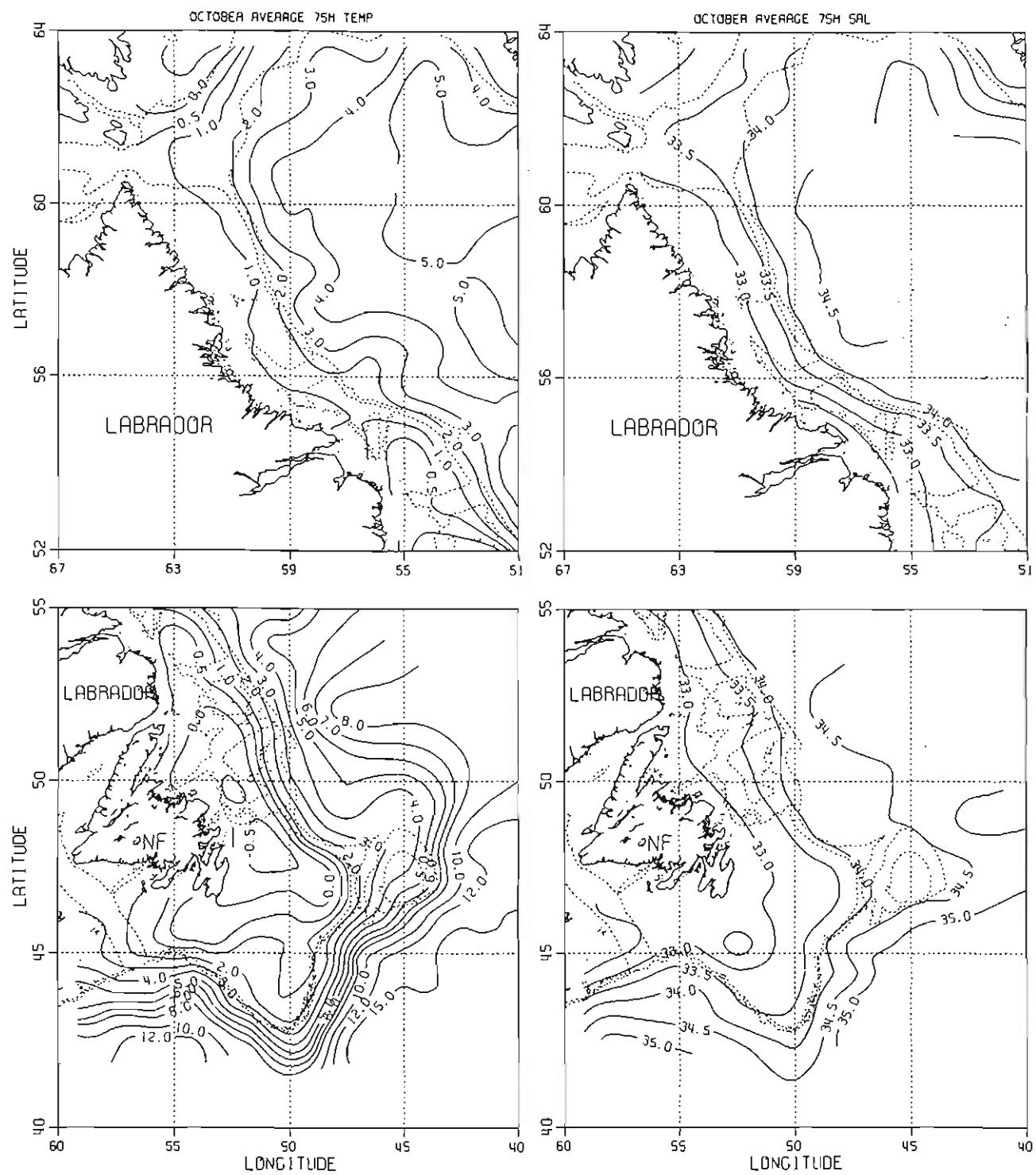


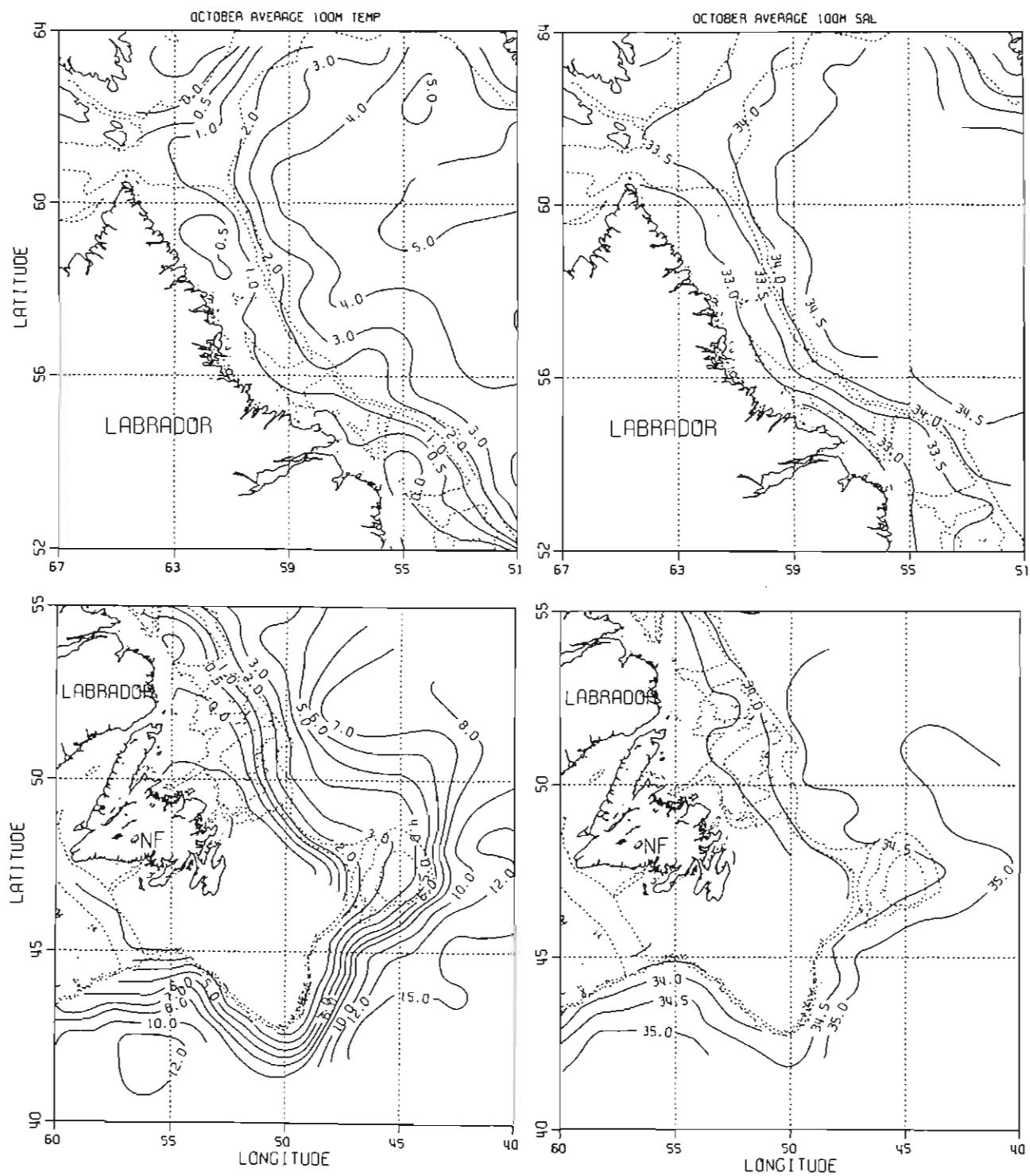


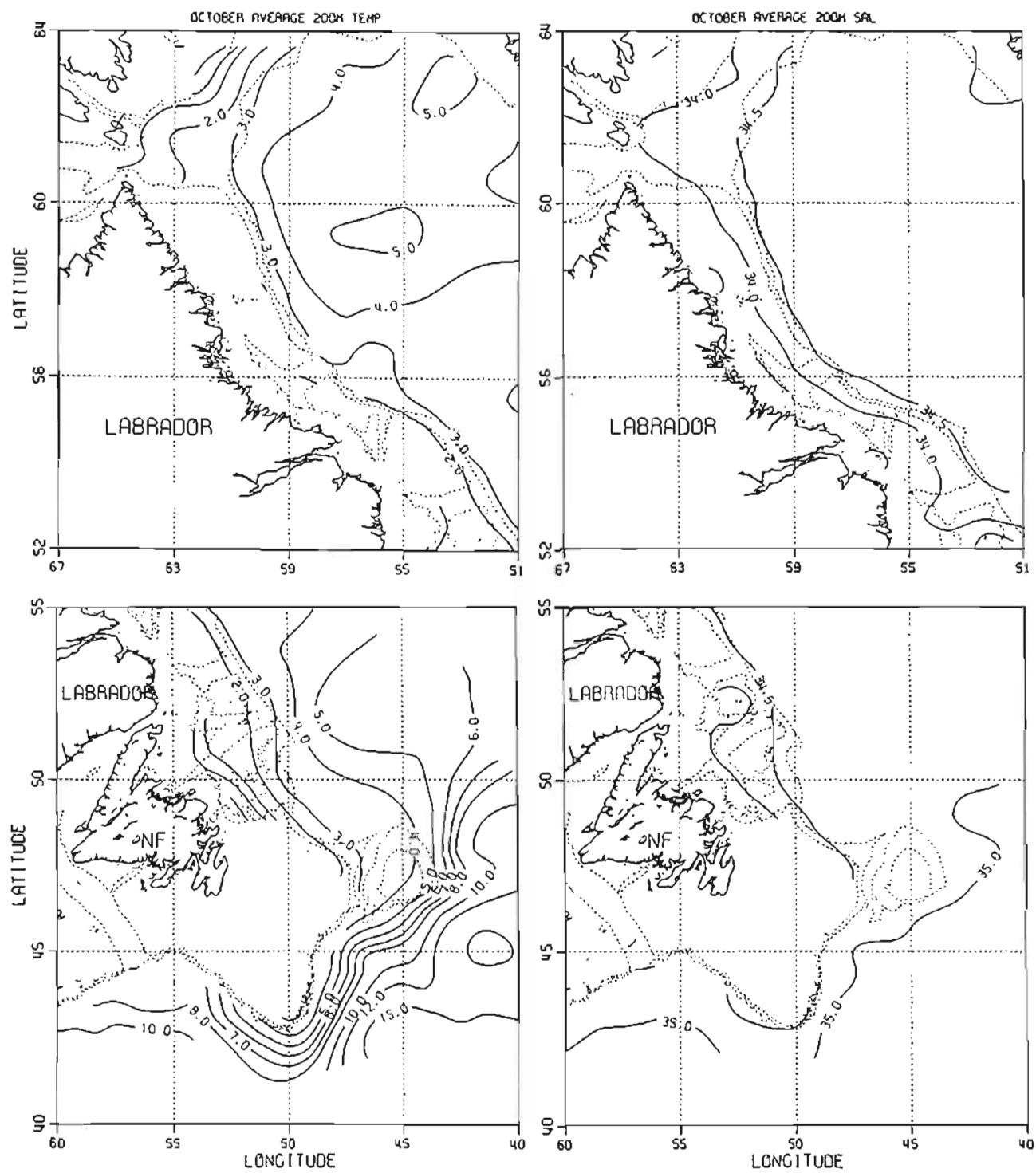


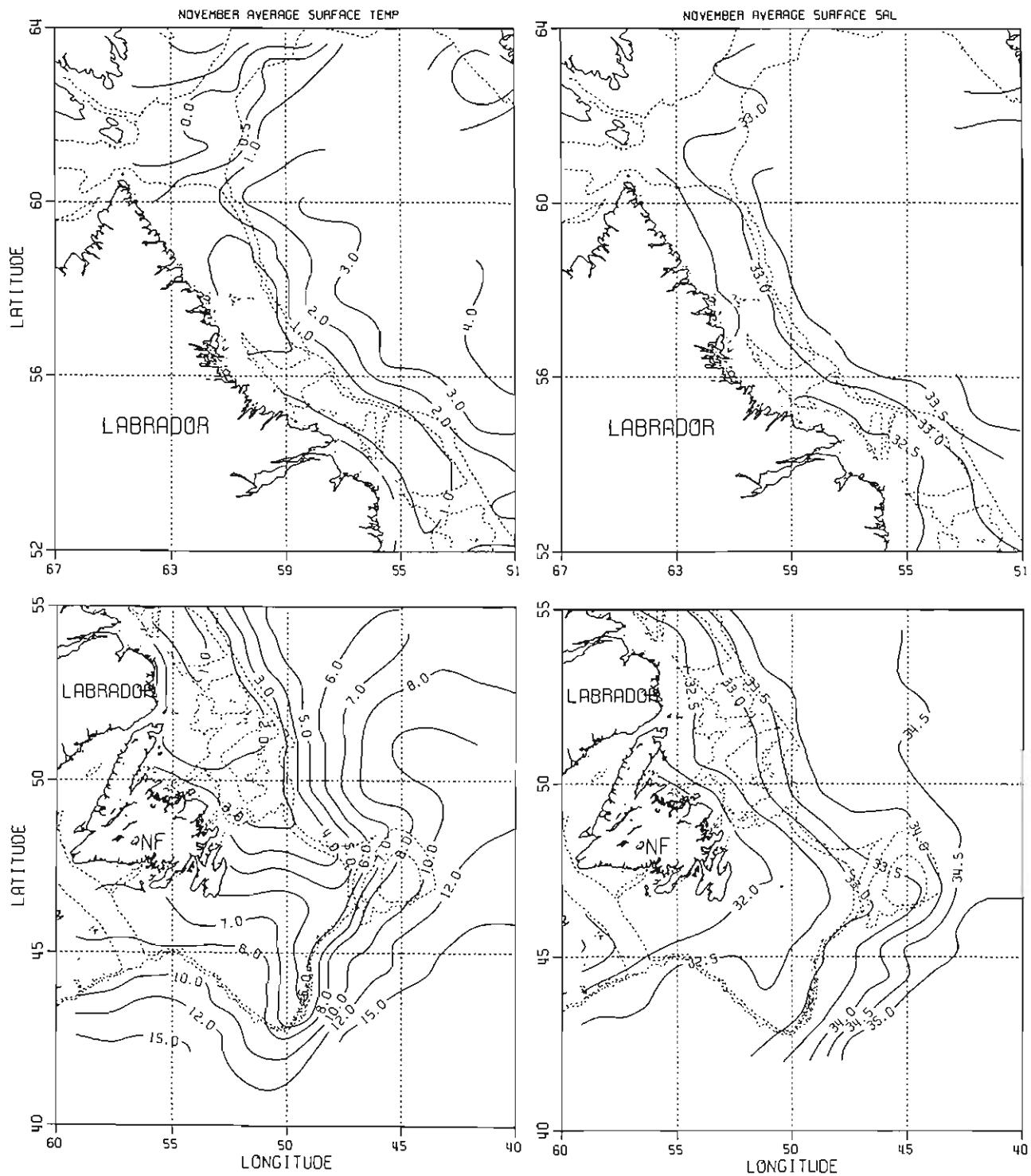


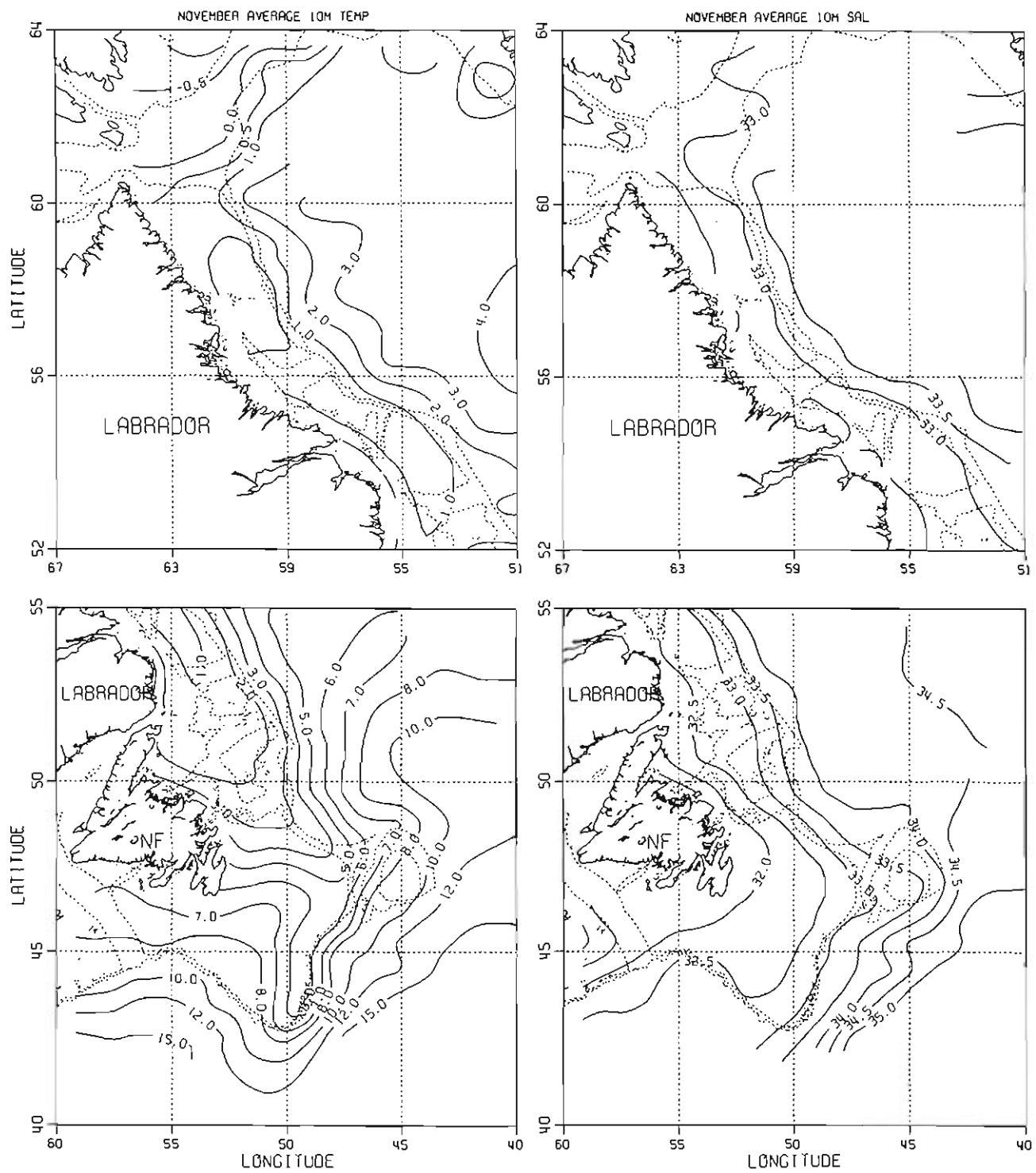


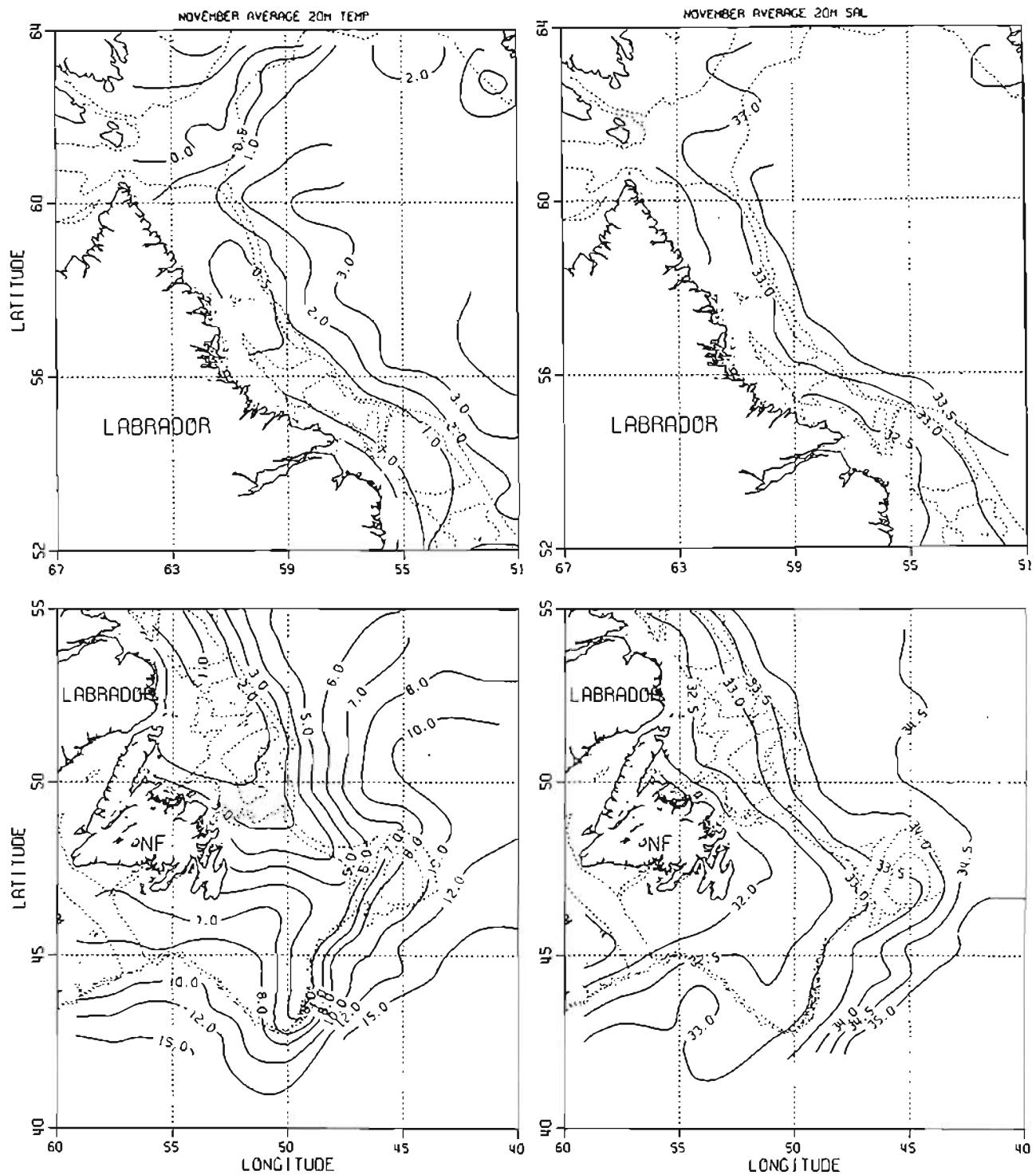


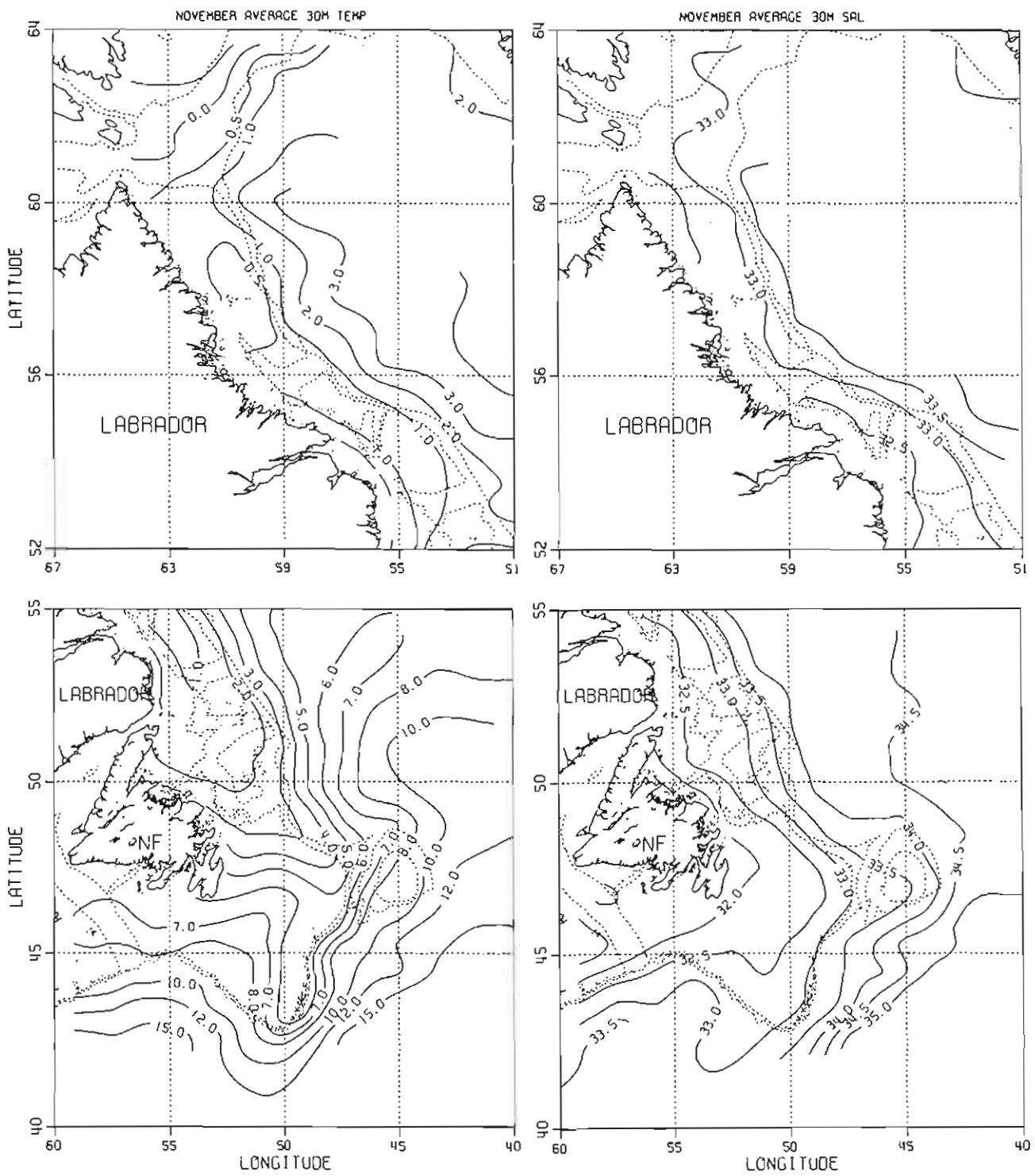


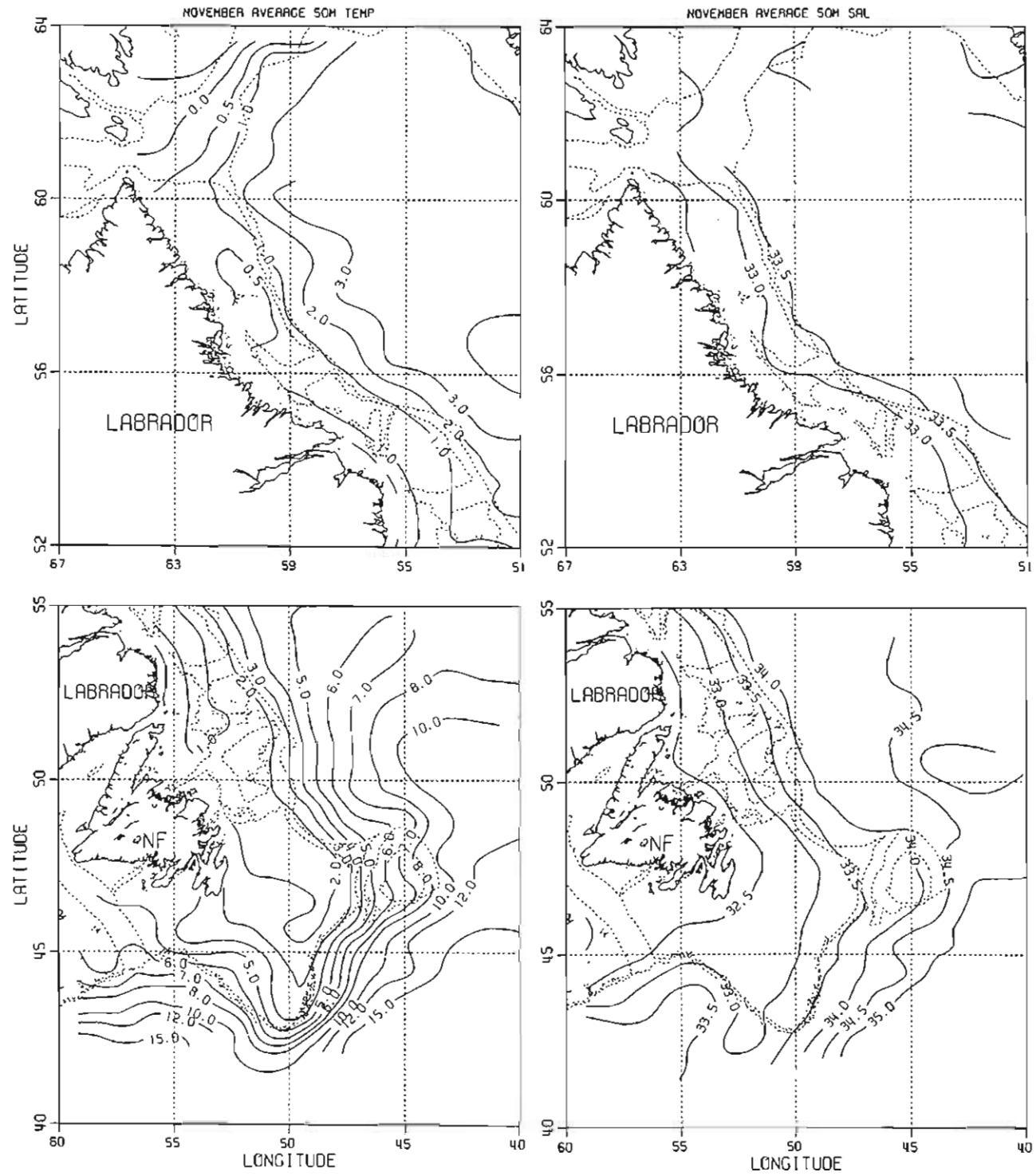


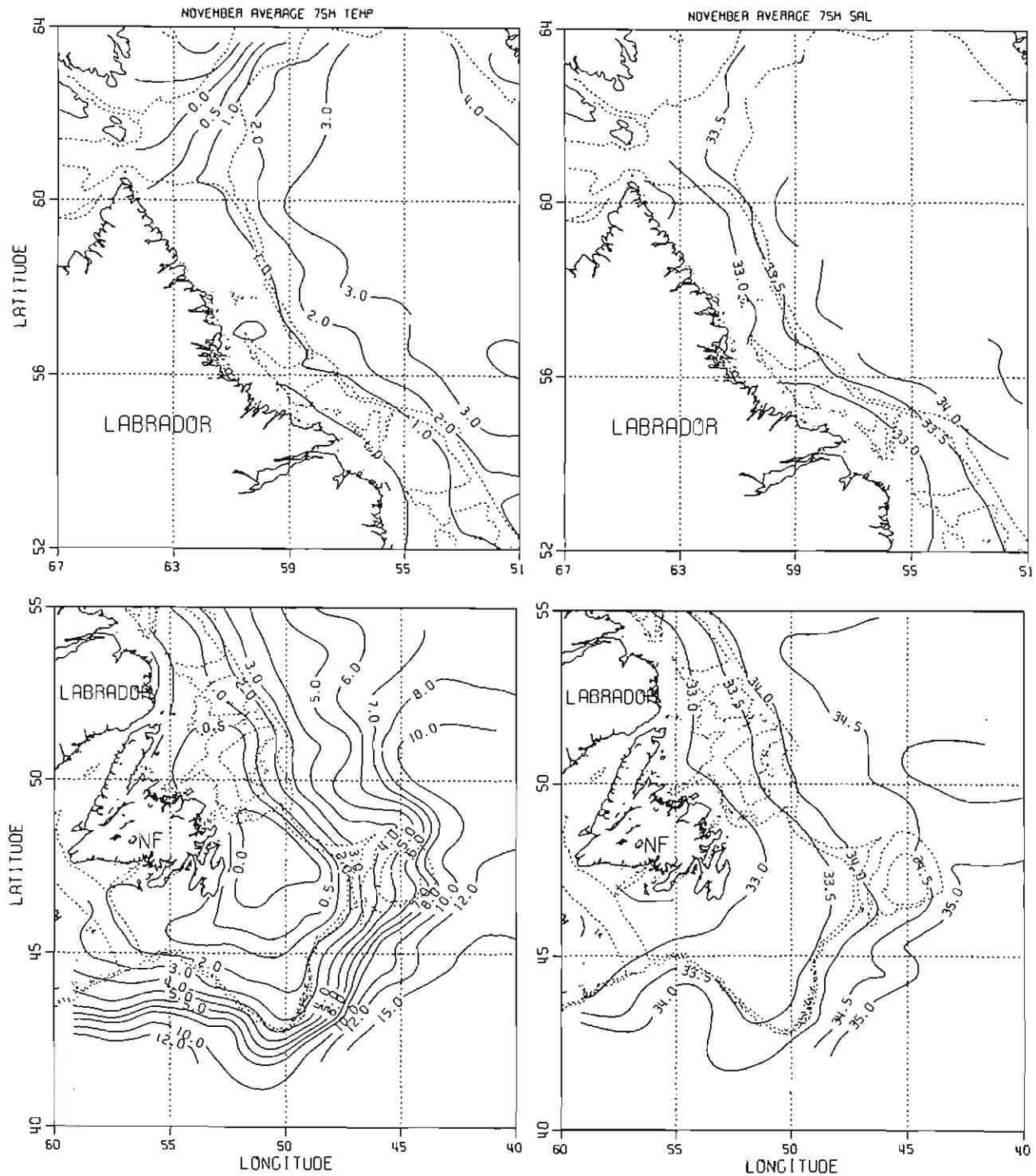


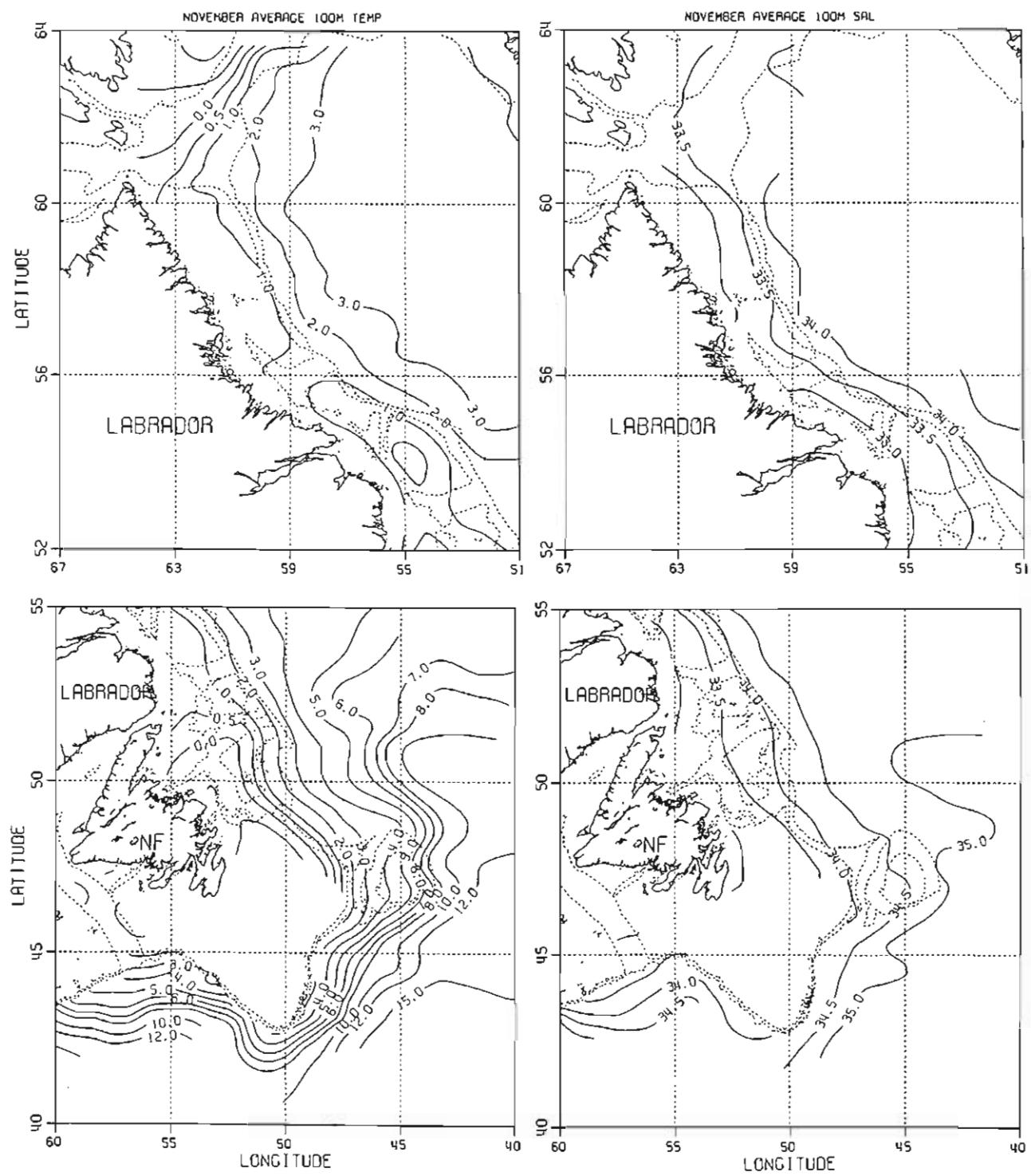


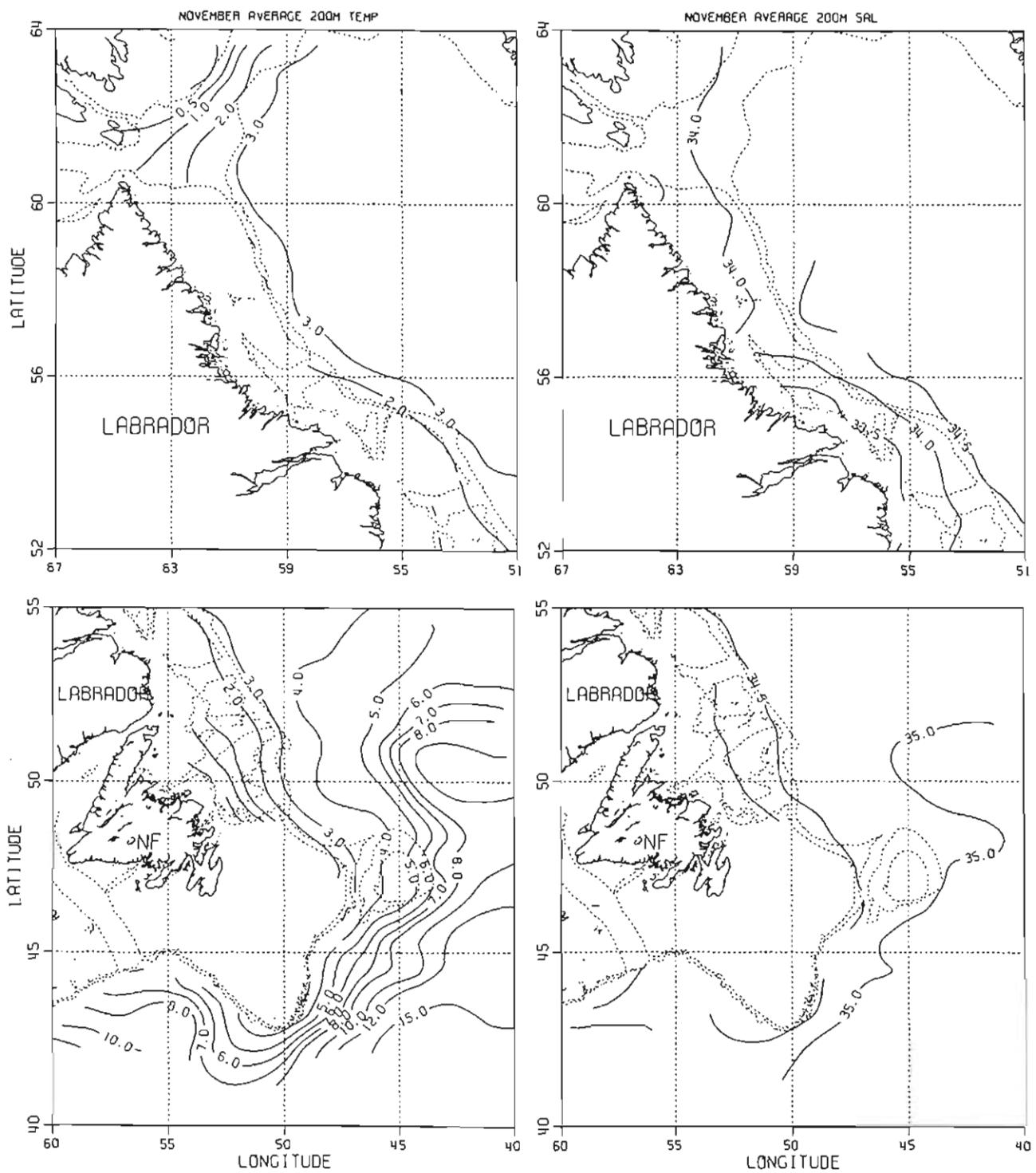


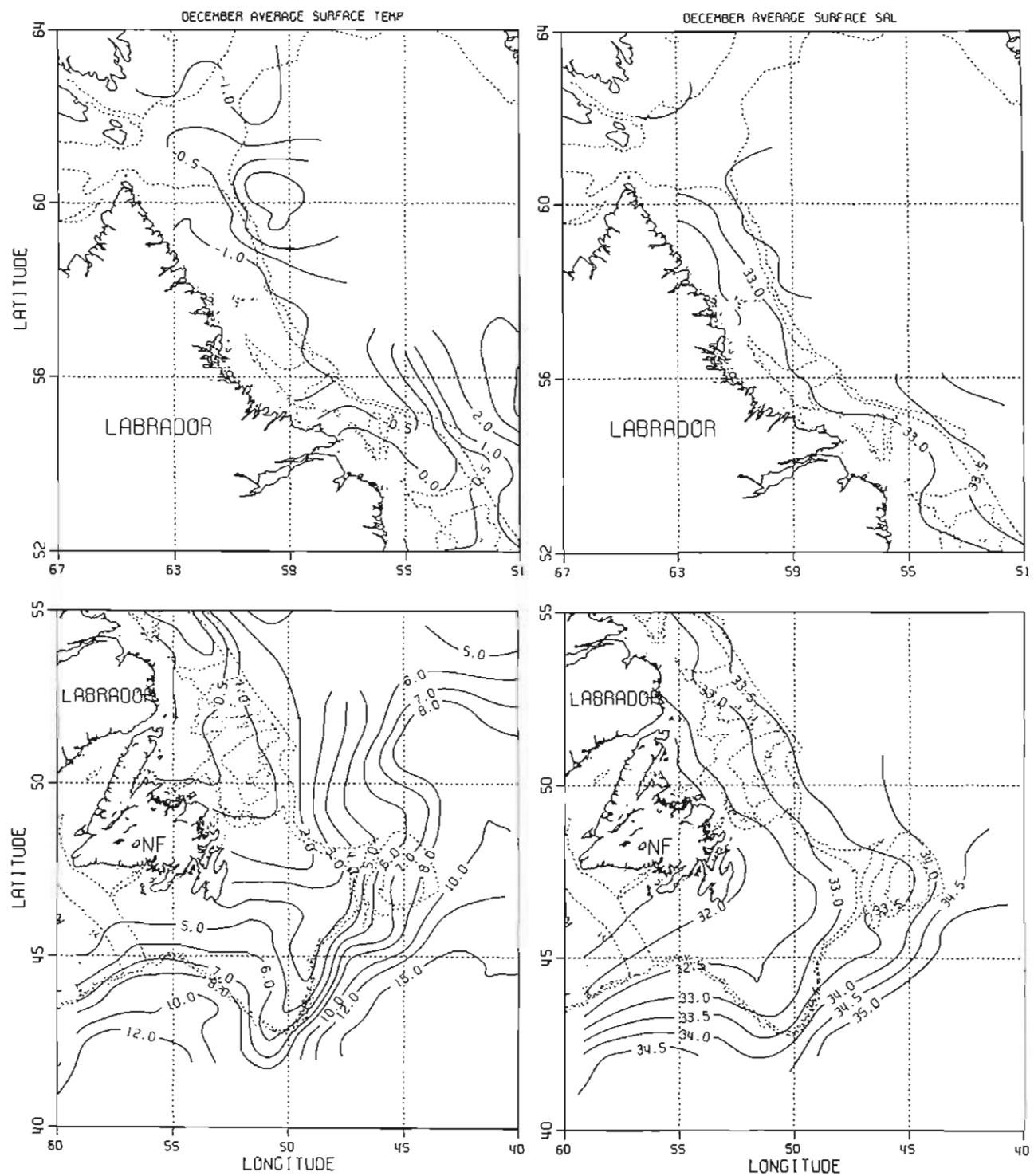


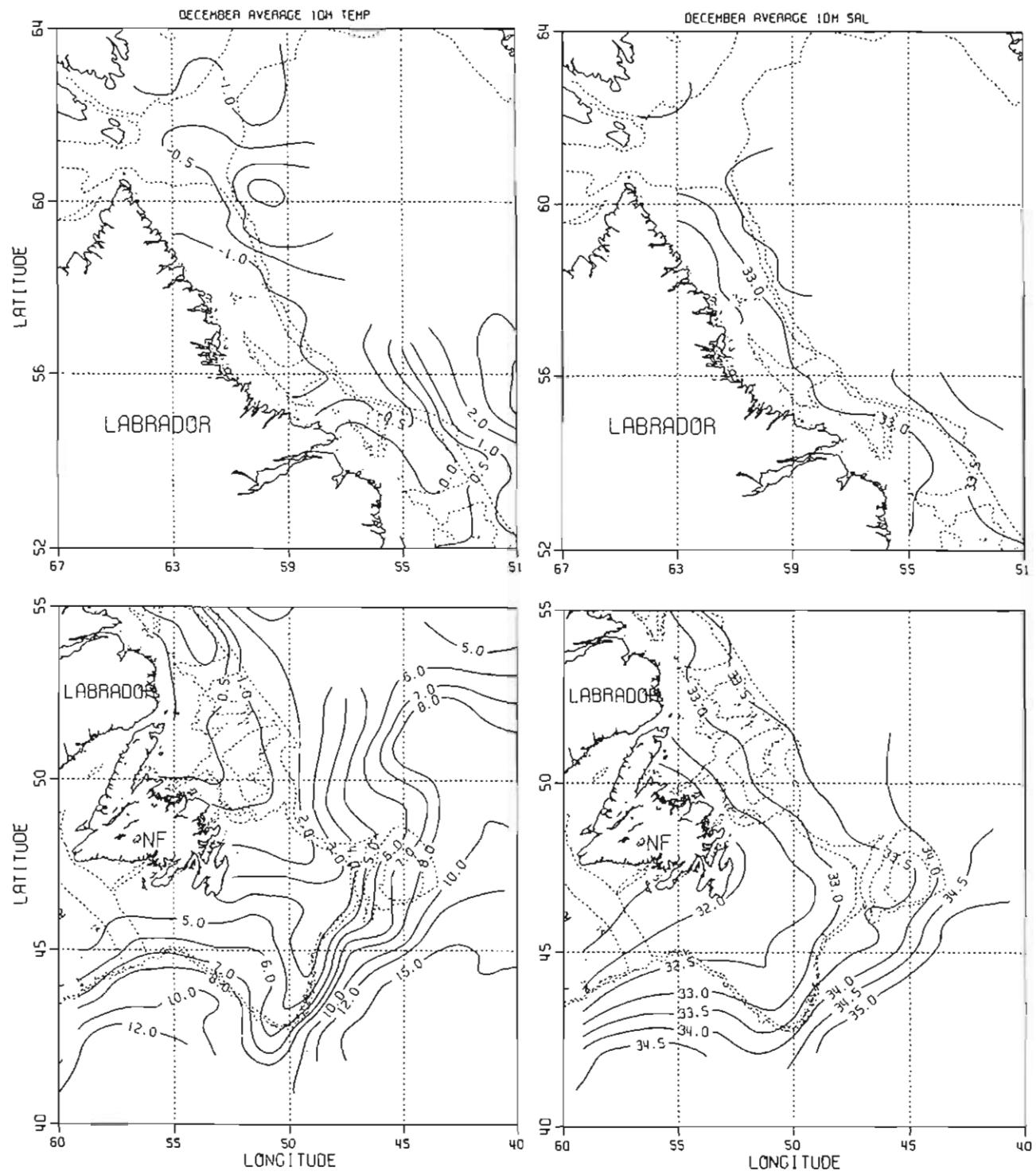


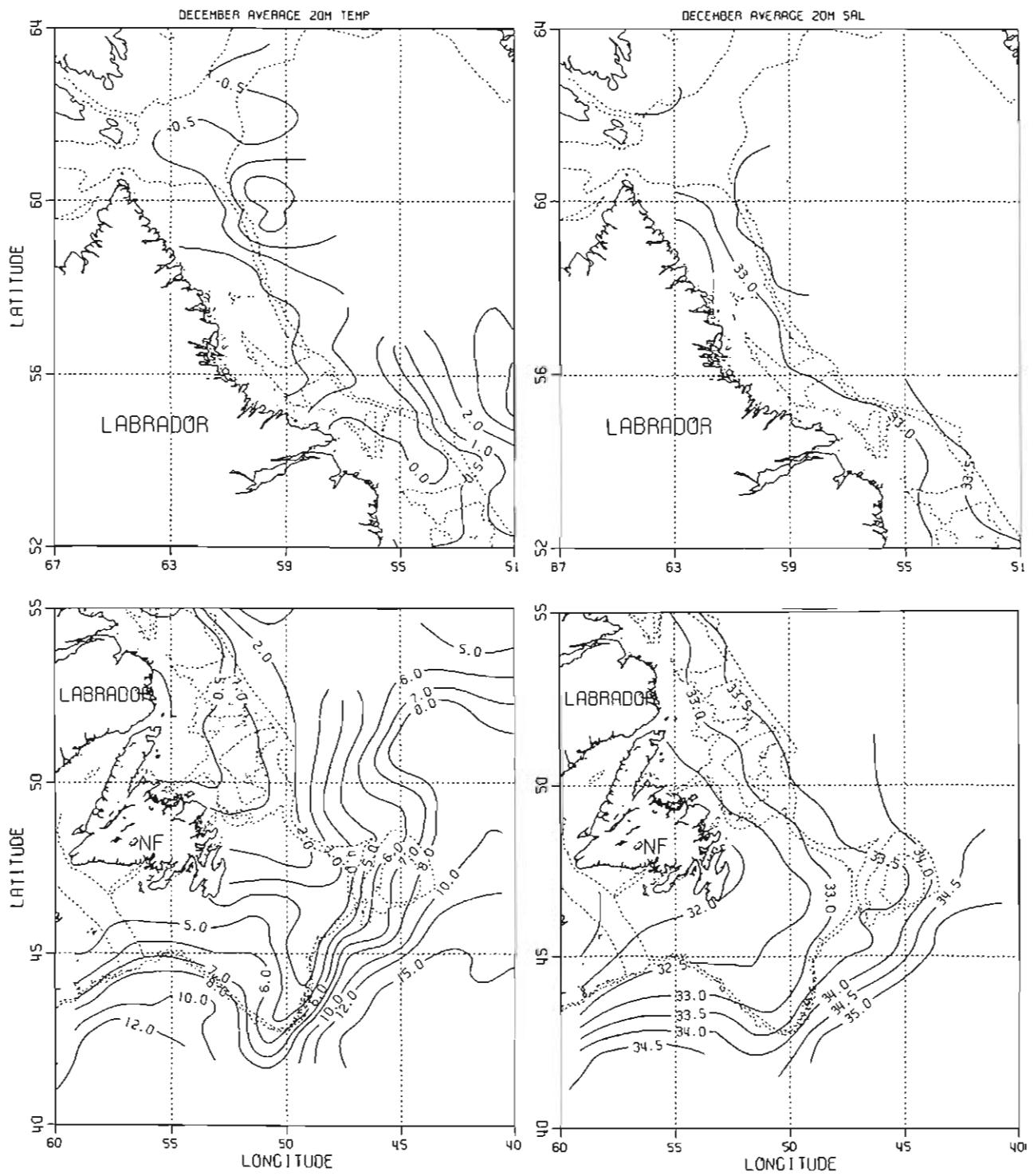


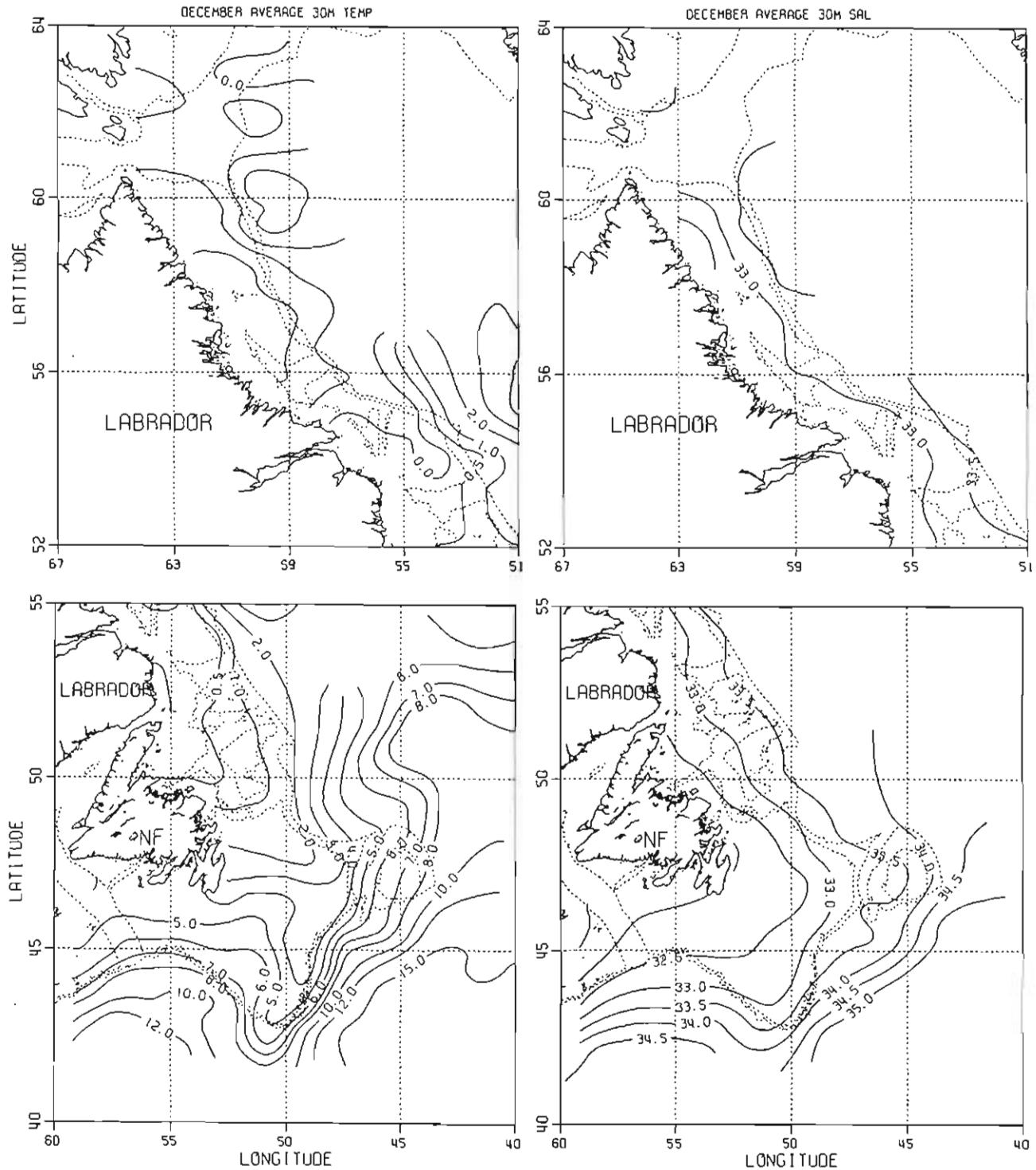


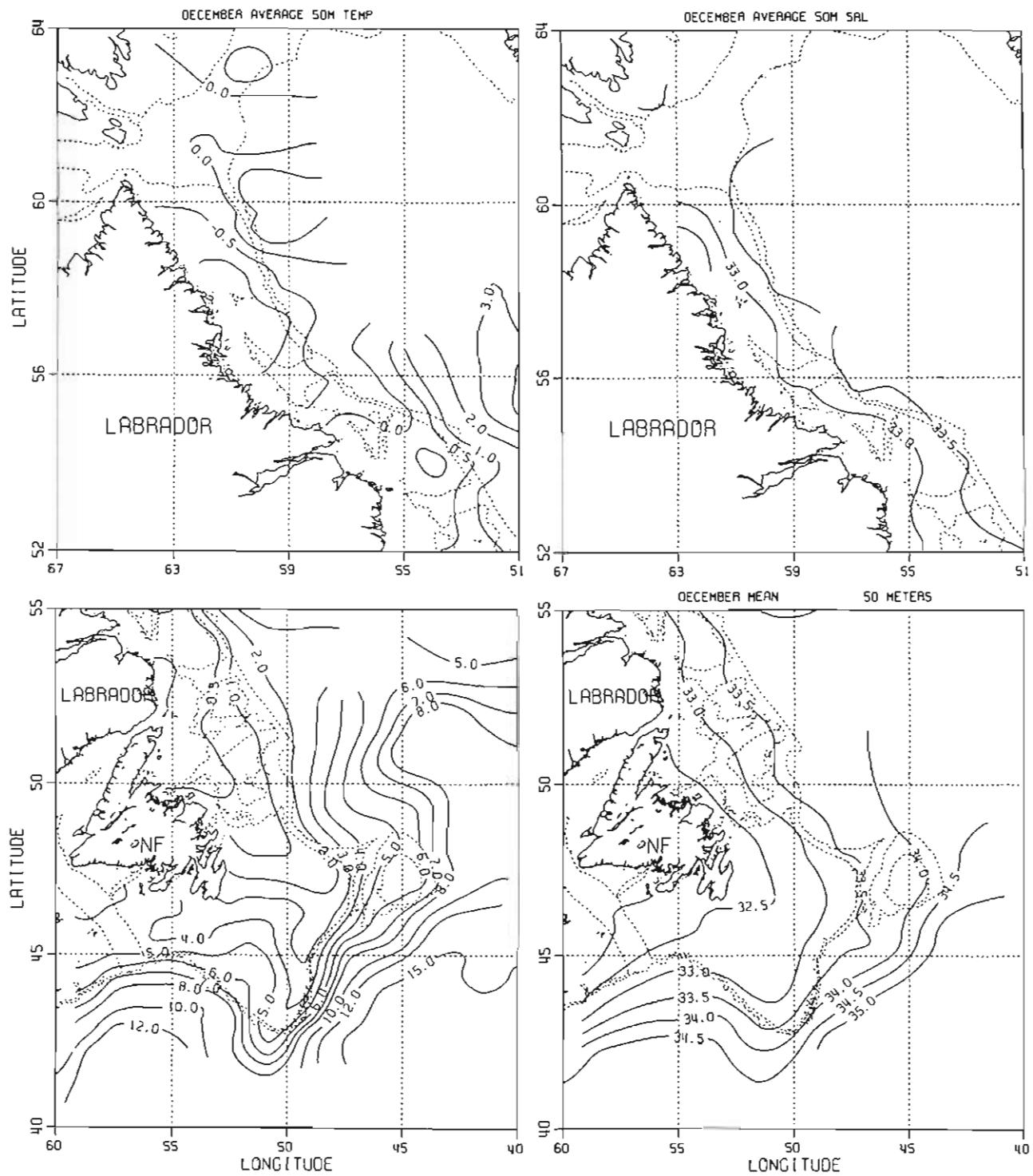


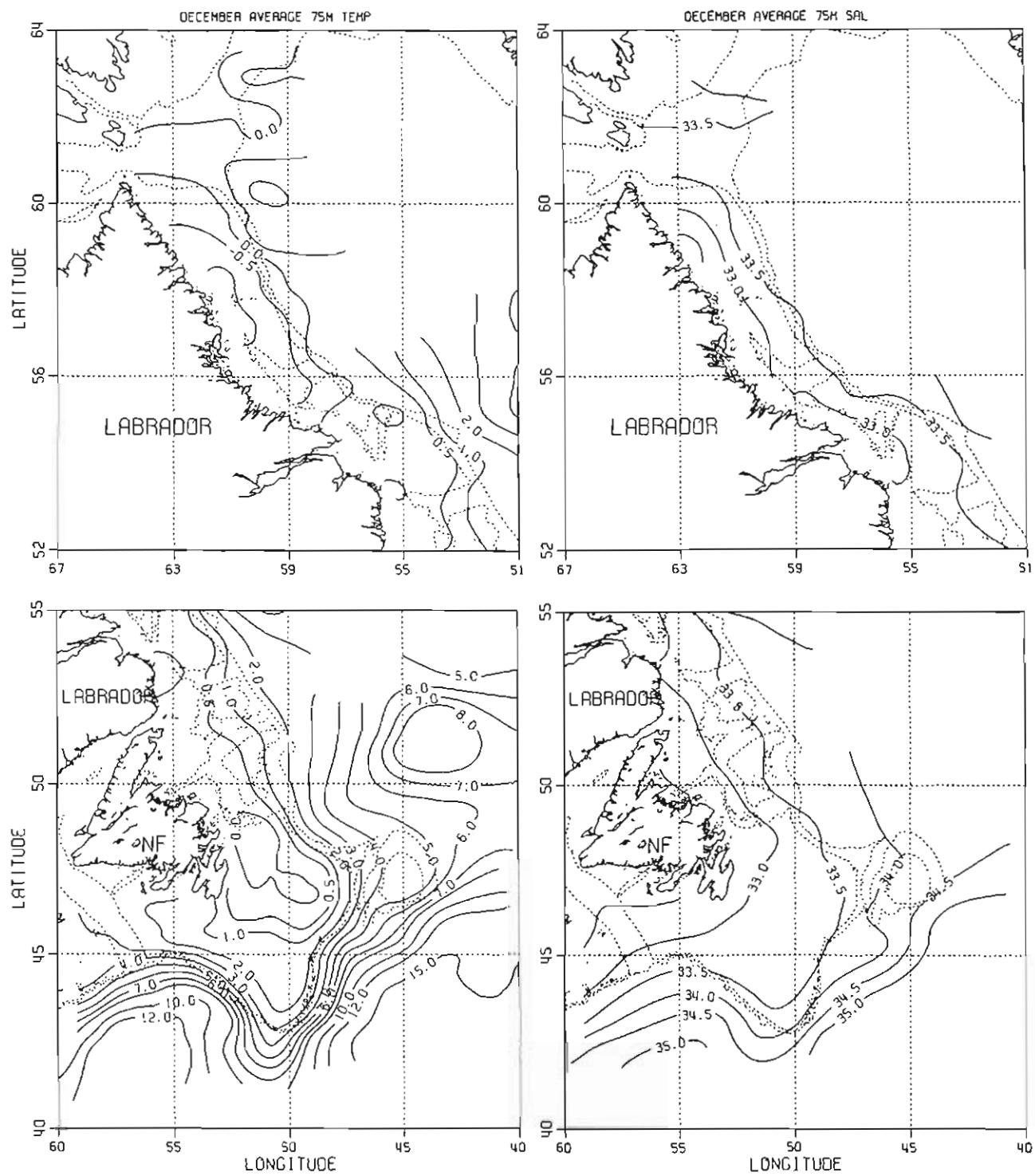


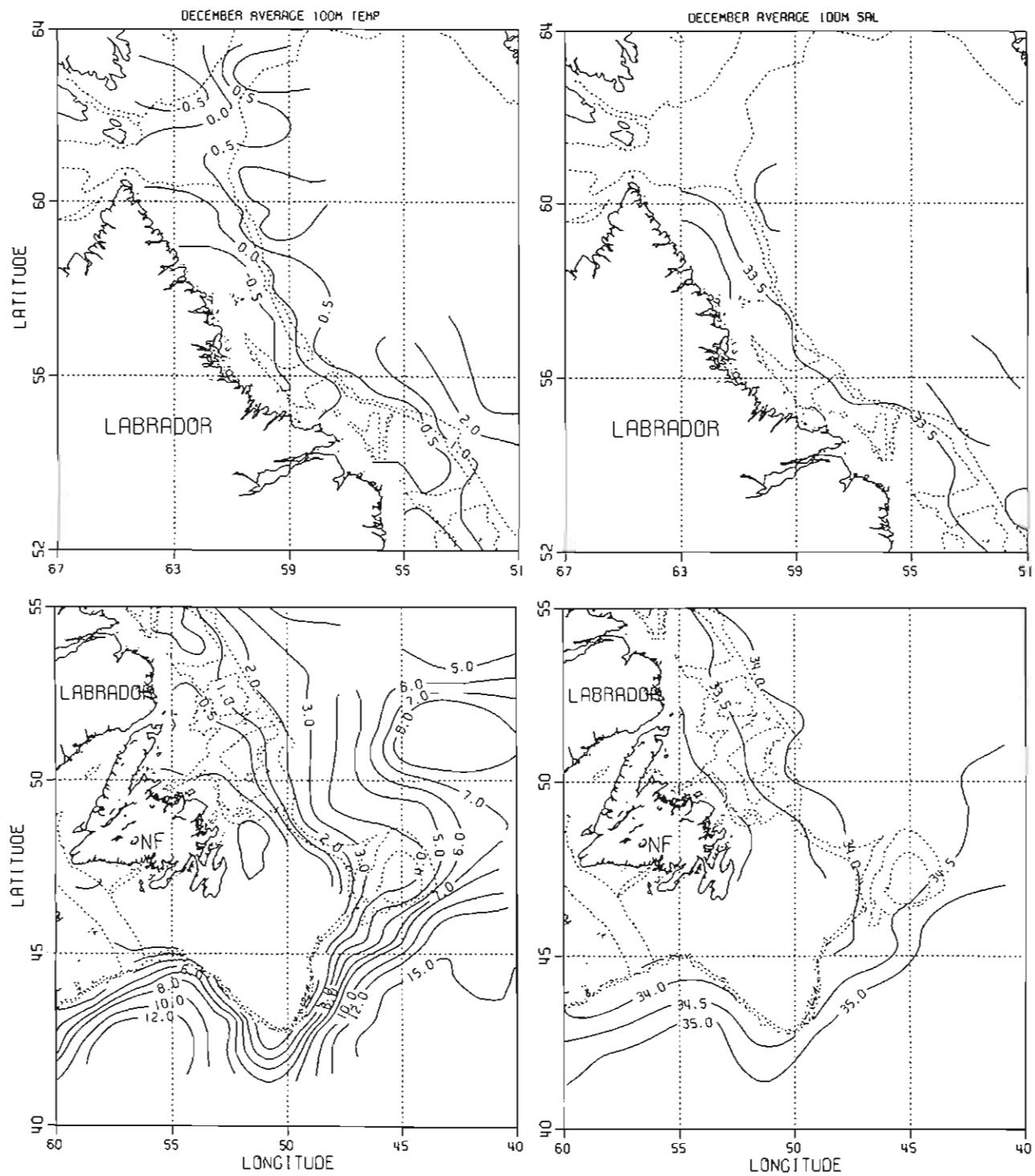


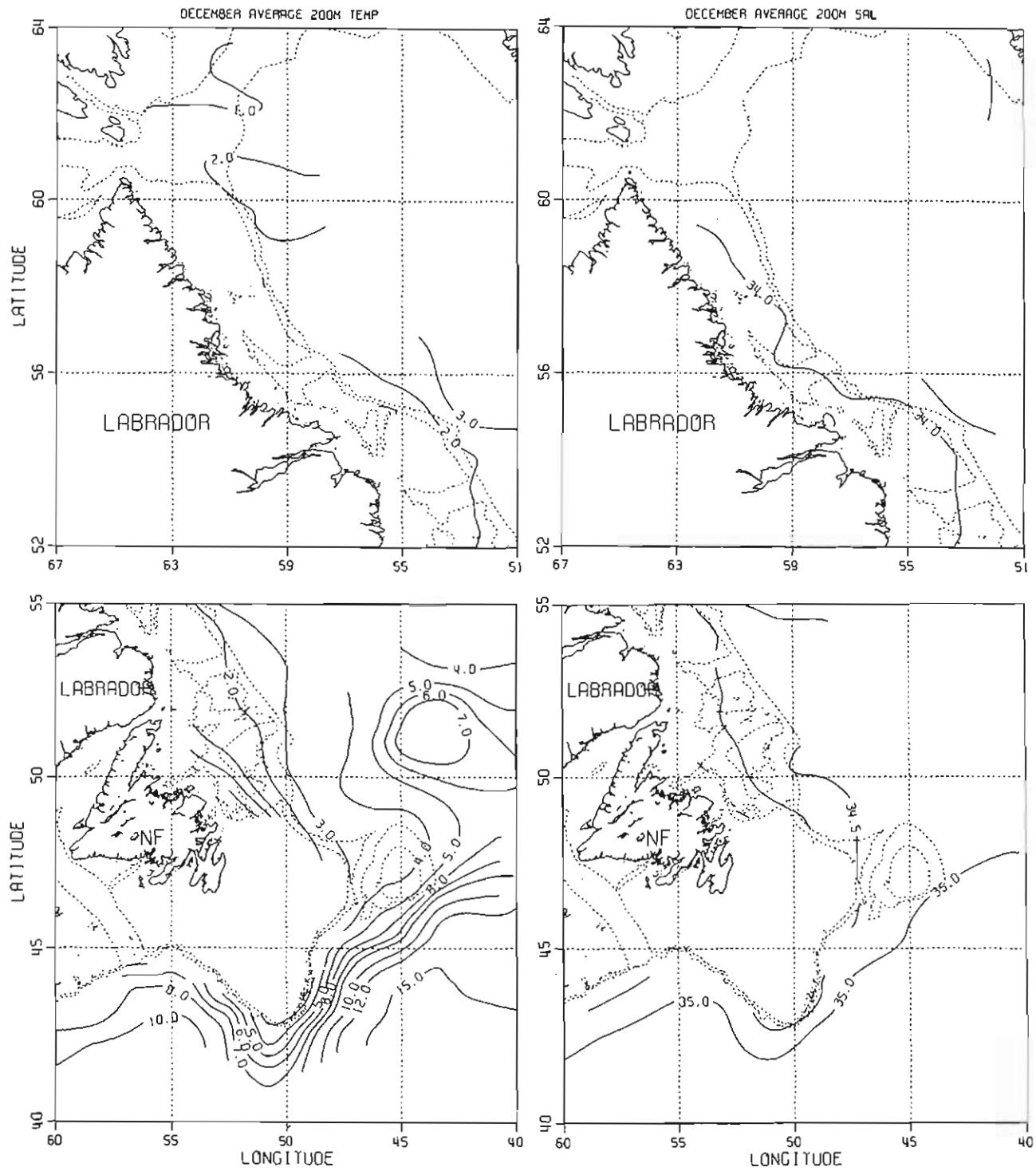












APPENDIX B. Horizontal maps of monthly averaged bottom temperature and salinity for the Newfoundland and Labrador regions.

