2003

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Citation/Publisher Attribution

Krahmann, G., et al. (2003), The Labrador Sea Deep Convection Experiment data collection, *Geochem. Geophys. Geosyst.*, 4, 1091, doi: 10.1029/2003GC000536, 10.
Available at: https://doi.org/10.1029/2003GC000536

Geochemistry Geophysics Geosystems G3
AN ELECTRONIC JOURNAL OF THE EARTH SCIENCES
Published by AGU and the Geochemical Society

Data Brief
Volume 4, Number 10
31 October 2003
1091, doi:10.1029/2003GC000536
ISSN: 1525-2027

The Labrador Sea Deep Convection Experiment data collection

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[1] Between 1996 and 1998, a concerted effort was made to study the deep open ocean convection in the Labrador Sea. Both in situ observations and numerical models were employed with close collaboration between the researchers in the fields of physical oceanography, boundary layer meteorology, and climate. A multitude of different methods were used to observe the state of ocean and atmosphere and determine the exchange between them over the experiment's period. The Labrador Sea Deep Convection Experiment data collection aims to assemble the observational data sets in order to facilitate the exchange and collaboration between the various projects and new projects for an overall synthesis. A common file format and a browsable inventory have been used so as to simplify the access to the data.

Components: 2872 words, 6 figures.

Keywords: Deep convection; Labrador Sea.

Index Terms: 4223 Oceanography: General: Descriptive and regional oceanography; 4536 Oceanography: Physical: Hydrography; 4520 Oceanography: Physical: Eddies and mesoscale processes.

Received 28 February 2003; **Revised** 20 August 2003; **Accepted** 9 September 2003; **Published** 31 October 2003.

Krahmann, G., et al., The Labrador Sea Deep Convection Experiment data collection, *Geochem. Geophys. Geosyst.*, *4*(10), 1091, doi:10.1029/2003GC000536, 2003.

1. Introduction

[2] Open ocean deep convection has long been recognized to be one of the important processes to form water masses in the world oceans. Successful modeling of the large- and meso-scale ocean circulation thus requires high quality parametrizations for the typically subgrid scale process of deep ocean convection.

[3] Open ocean deep convection takes place only in a very limited number of locations. In most cases it involves harsh climatic conditions making it difficult to observe in situ. The Labrador Sea is one of these unwelcoming places. Compared to the other locations it has, however, the advantages of being reasonably accessible and having a good historical record of data. It was thus decided to perform a concerted study of open ocean convection in the Labrador Sea.

[4] Under the framework of an Accelerated Research Initiative sponsored by the Office of Naval Research, a group of scientists [*LabSea Group*, 1998] started a series of well integrated research projects to advance our understanding of open ocean convection in the Labrador Sea (see Figure 1). The program began in 1996 and focused primarily on the oceanic convection process and its interaction with geostrophic eddies and the basin-scale circulation. Secondary goals were concerned with: air-sea interaction, coupling between deep convection and atmospheric/sea ice conditions, the surface ocean fresh water balance, export pathways of newly formed well ventilated deep waters, and the relation between the vigor of convection and decadal climate

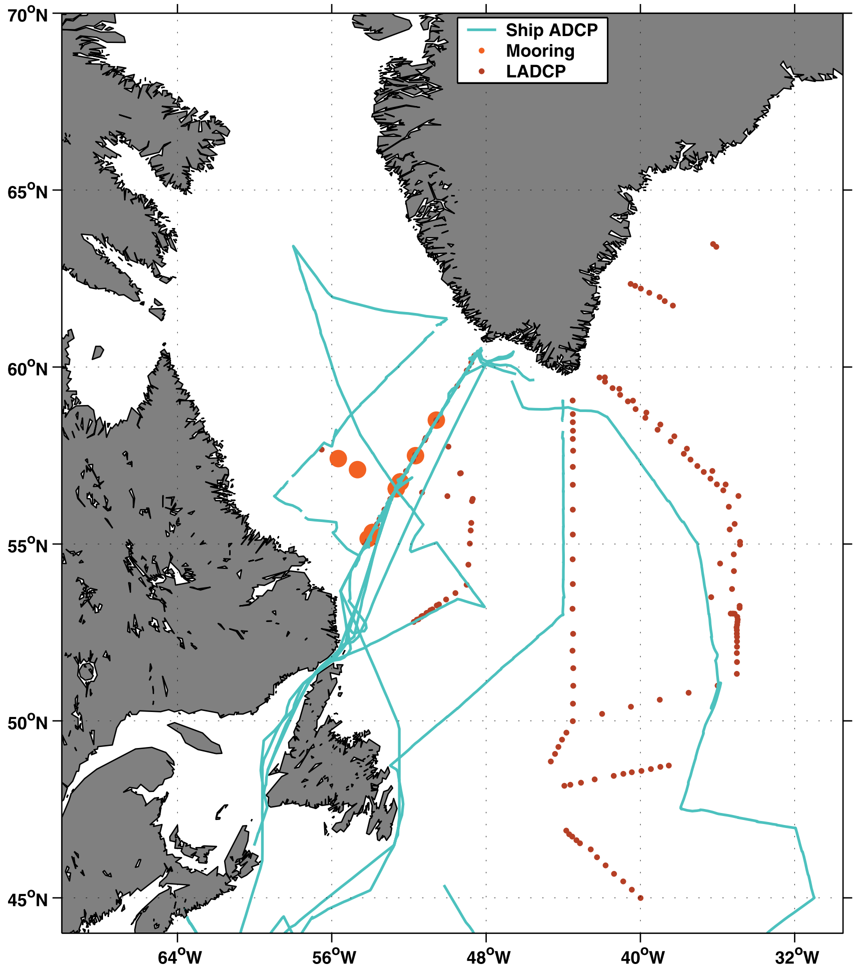

Figure 1. Experimental area of the Labrador Sea Deep Convection Experiment. Locations of ocean current measurements assembled in the data collection are shown as lines and markers.

variability. The program included a large range of standard to cutting edge oceanographic measurements, the development and deployment of dedicated new instruments, measurements from aircrafts, and remote sensing as well as theoretical work and numerical modeling at various resolutions.

[5] Already in the planning phase emphasis was placed on close collaboration within the group to obtain a wide range of input in order to best design the observational part of the project. Diagnostics of the historical record as well as model results were used to determine the layout and locations of moorings and float deployments. The first analysis of the data has resulted in a significant number of publications covering various aspects of convection in the Labrador Sea, most of which were published in a special issue of the *Journal of Physical Oceanography* (Vol. 32, No. 2, 2002).

[6] The purpose of the data collection we present here is to facilitate and enhance further exchange of the observational data between the various projects as well as the community at large. This will enable interested scientists to perform further analyses On the basis of the comprehensive range of data collected during the Labrador Sea Deep Convection Experiment.

2. Database Information

[7] The different data sets of the collection have been contributed directly by a large number of

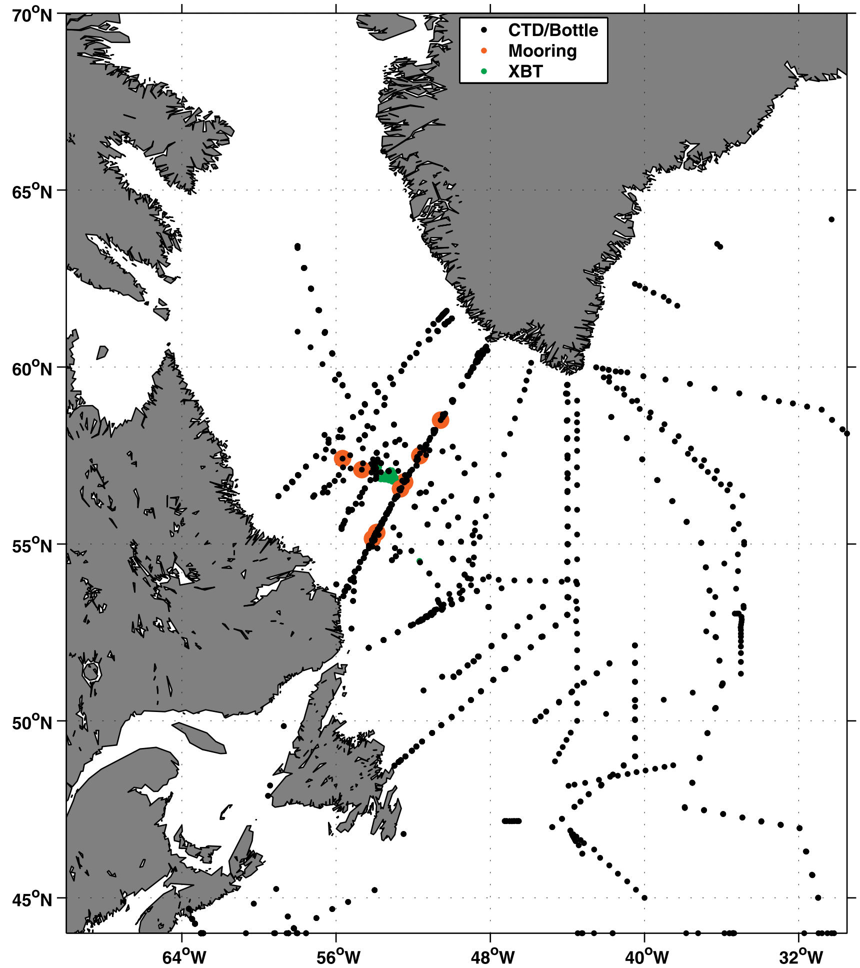

Figure 2. Experimental area of the Labrador Sea Deep Convection Experiment. Locations of temperature and salinity measurements assembled in the data collection are shown as markers.

principal investigators or have been obtained from the World Ocean Circulation Experiment (WOCE) hydrographic program office (http://whpo.ucsd.edu/). As these data sets are usually stored in the format of choice by the different groups, exchange of data nearly always includes the conversion of one format to another. In recent years the computer system independent Network Common Data Form (NetCDF, http://www.unidata.ucar.edu/packages/netcdf/) has made inroads in the oceanographic community. To facilitate the exchange and the usage of the data collection we have converted all data sets to NetCDF format. In addition we have created a browsable inventory of the data collection containing ancillary information for each data set.

[8] The data have been quality controlled by the providing parties. However, we strongly suggest that users of the data collection contact the principal investigators to verify the highest quality of the data. Contact addresses are provided in the NetCDF data files as well as in the html-formatted descriptions.

[9] The data is available in form of a CD-ROM from the corresponding author or can be accessed directly over the internet at http://www.ldeo.columbia.edu/labseacd/labseahome.html. This web site is also the location where we will publish future updates and possible errata.

3. Data Description

[10] The field work of the experiment consisted of a number of closely coordinated components. In Figures 1 to 5 we show the locations of all

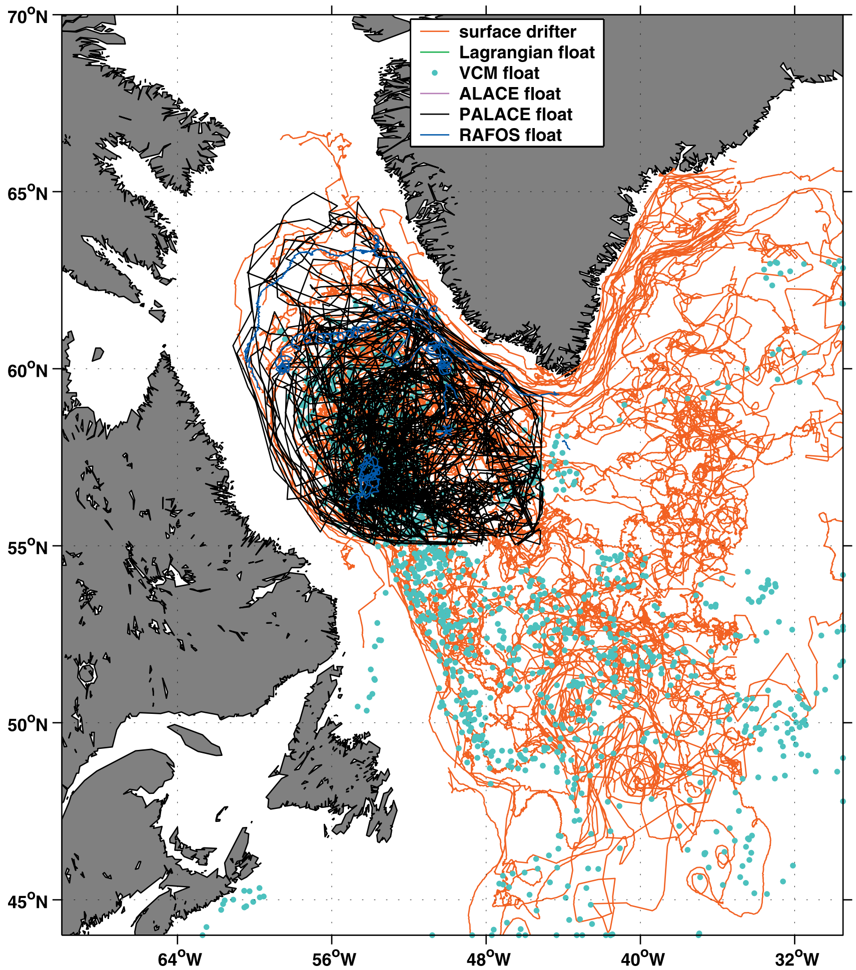

Figure 3. Experimental area of the Labrador Sea Deep Convection Experiment. Float and drifter trajectories contained in the data collection are shown as lines and markers.

measurements assembled in the data collection. Basic types of the data are distinguished by color. Figure 6 displays a graphical time table indicating the periods which the individual data sets cover. Overall a good temporal and spatial coverage was established and maintained throughout the experiment period.

[11] In the following list we introduce the data collected in the different projects and refer to relevant publications.

3.1. P-ALACE Floats (R. Davis, B. Owens)

[12] Within the WOCE Atlantic Circulation and Climate Experiment (ACCE), Scripps Institution of Oceanography (SIO) and the Woods Hole Oceanographic Institution (WHOI) deployed over 150 Profiling Autonomous Lagrangian Circulation Explorer (P-ALACE [*Davis et al.*, 2001]) floats in the subpolar gyre of the North Atlantic to quantitatively map the pathways of transport in the upper 1500 m. These floats track currents at depth for about 15 days and measure a Conductivity-Temperature-Depth (CTD) profile at the end of each current tracking interval. Many of those floats were set in the Labrador Sea. *Lavender et al.* [2000] present circulation maps based on that data including countercurrent found offshore of the deep West Greenland and Labrador Currents.

3.2. VCM Floats (R. Davis)

[13] For the ONR Labrador Sea Convection Experiment, SIO [*Davis et al.*, 2001] developed a

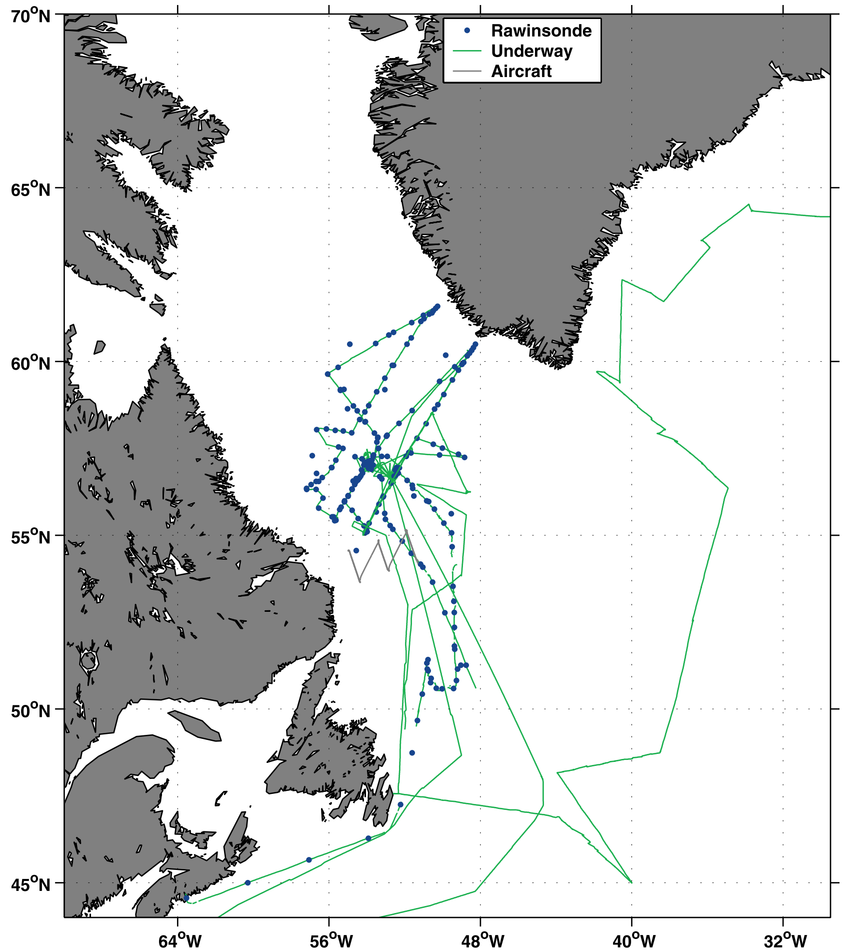

Figure 4. Experimental area of the Labrador Sea Deep Convection Experiment. Locations of meteorological measurements contributed to the data collection are shown as lines and markers.

Vertical Current Meter float [see *Voorhis*, 1970] based on the P-ALACE float (above) in order to measure vertical currents associated with wintertime convection. These measure currents and T/S profiles just like P-ALACEs but during their current following intervals time series of vertical velocity are gathered. *Lavender et al.* [2002] decribe these data.

3.3. Profiling RAFOS Floats (M. Prater)

[14] The data from 14 floats was collected. The floats were parked at depths from 150 to 400 m, and most made vertical temperature profiles over the top 1000 m of the water column approximately once per week. Each float measured temperature and pressure at high (every two to five minutes in three 5-hour bursts per day), and/or low (every two to eight hours) sampling rates. Float positions were determined three times per day. *Prater et al.* [1999] gives the details of the float operation and data, while *Prater* [2002] used the float data to study eddies in the Labrador Sea.

3.4. Surface Drifters

[15] Over 100 surface drifters were deployed during the Labrador Sea Deep Convection Experiment. Positions of the drifters were typically obtained several times a day.

3.5. Lagrangian Floats (E. D'Asaro)

[16] These data give the depth, temperature and horizontal positions of Lagrangian floats deployed

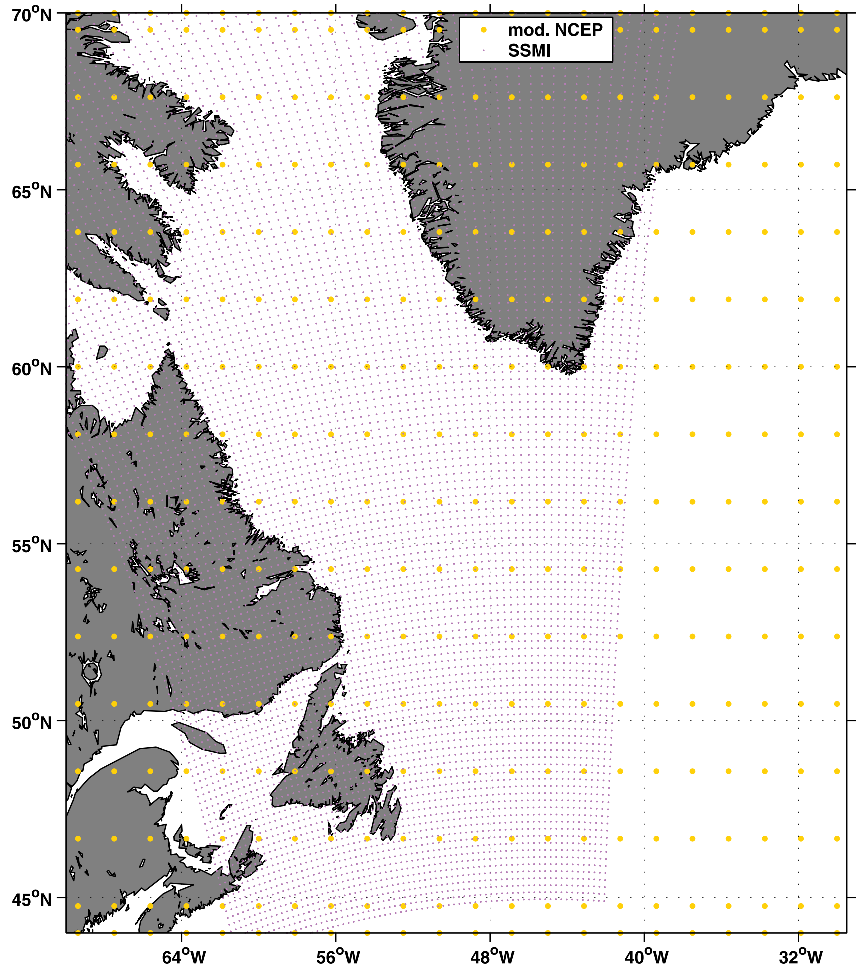

Figure 5. Experimental area of the Labrador Sea Deep Convection Experiment. Grid points of satellite ice concentration data and of the modified NCEP/NCAR reanalysis data assembled in the data collection are denoted by dots.

in the winters of 1997 and 1998 in the central Labrador Sea during active convection [*Harcourt et al.*, 2002; *Steffen and D'Asaro*, 2002]. The drifters are water-following in both the vertical and horizontal and can therefore map out the structure of the convective turbulence.

3.6. CTD

[17] CTD profiles were obtained on several cruises in the experiment area. On most cruises the WOCE line AR07W crossing the central Labrador Sea was covered at least partially.

3.7. Ship ADCP

[18] Ship based Acoustic Doppler Current Profiler (ADCP) data has been recorded on a number of cruises. The data, obtained from the WOCE data center, has been averaged over one hour intervals.

3.8. XBT

[19] Expendable Bathythermograph (XBT) data has been obtained for one cruise in the experiment area.

3.9. Radio Sonde

[20] Radio sonde ascent meteorological data has been observed on one cruise in winter 1997.

3.10. Meteorological Underway

[21] Ship based meteorological data has been observed during several cruises. When original

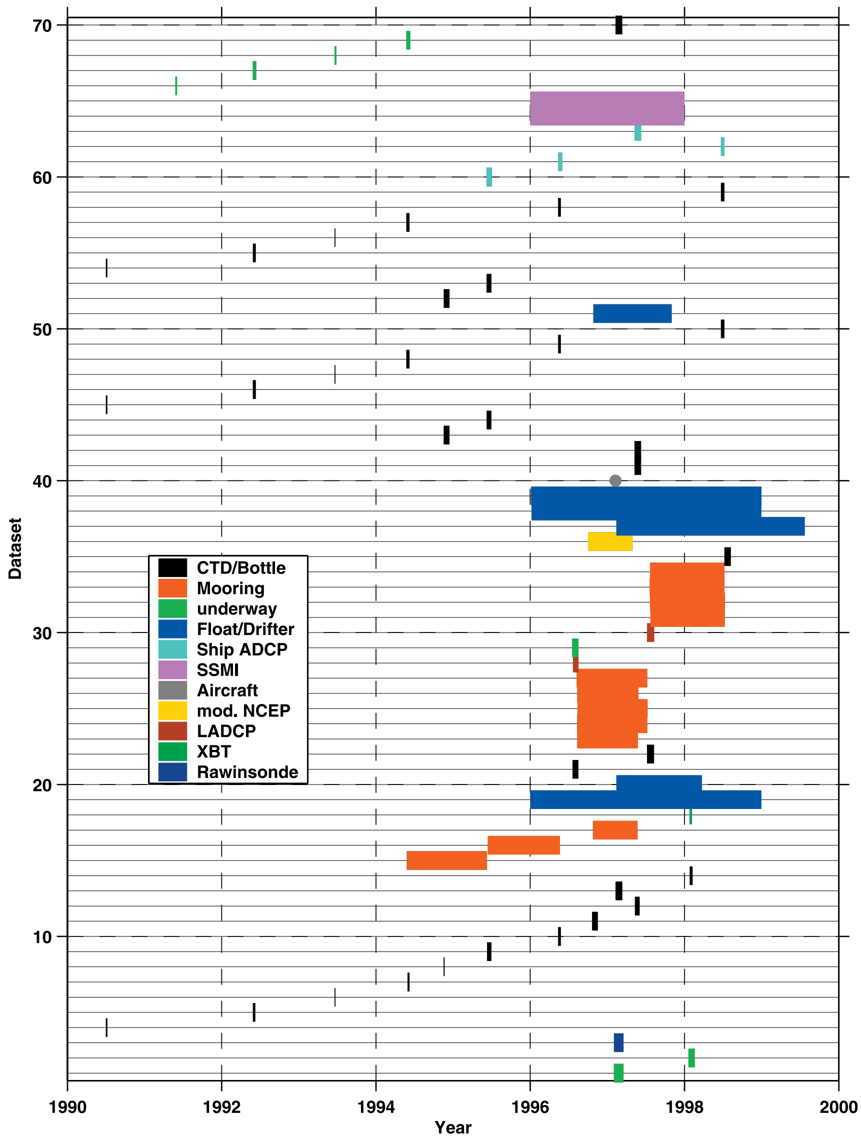

Figure 6. Time coverage of the individual data sets. Different colors denote different types of data.

high temporal resolution data was available it has been included in the data collection. For a few cruises low temperal resolution data from the Comprehensive Ocean Atmosphere Data Set (COADS) has been in included consisting of bridge observations several times per day.

3.11. Aircraft Section (I. Renfrew)

[22] In January and February 1997 instrumented aircraft operated by the U. S. Air Force Weather Reserve were available to the LabSea Experiment for a small number of meteorological research flights. The C-130 aircraft were equipped with basic flight-level instrumentation and the capability to release dropsondes. Detailed observations of boundary-layer roll vortices and air-sea turbulent heat fluxes during a cold-air outbreak on the 8th February 1997 are available and are described in *Renfrew and Moore* [1999]. A mesoscale modelling study of this case is described in *Pagowski and Moore* [2001]. Note that flight and ship-operations planning during this period were improved by tailored real-time weather forecasts for the Labrador Sea area carried out by the Naval Research Laboratory and the Department of Physics at the University of Toronto [*Renfrew et al.*, 1999].

3.12. Modified NCEP/NCAR Reanalysis Turbulent Heat Fluxes (K. Moore and I. Renfrew)

[23] A comparison of surface-layer meteorological variables and surface turbulent heat fluxes from the R/V Knorr and atmospheric reanalysis products from NCEP/NCAR [*Kalnay et al.*, 1996] and the ECMWF highlighted a serious problem with the formulation of the scalar roughness length in the NCEP/NCAR model [*Renfrew et al.*, 2002]. This poor formulation leads to overestimates in the turbulent air-sea heat fluxes during unstable conditions, and especially during high wind speeds; for example, during cold-air outbreaks such as those that occur over the Labrador Sea and over the western boundary currents [*Renfrew et al.*, 2002; *Moore and Renfrew*, 2002]. A set of revised NCEP/NCAR turbulent heat fluxes is provided, where the surface-layer meteorological variables from the reanalysis are used as input to a validated, commonly-used bulk-flux algorithm based on that of *Smith* [1988]. The algorithm is detailed in *Renfrew et al.* [2002] and the revised turbulent heat flux fields are discussed in *Moore and Renfrew* [2002].

3.13. Niskin Bottle Data

[24] Concentrations of various tracers, such as oxygen content, alkalinity, phosphate content, and others have been measured from Niskin bottle water samples. Bottle data released to the WOCE data center has been included in the data collection.

3.14. CFC (W. Smethie)

[25] CFCs 11, 12 and 113 were measured on the winter Labrador Sea cruise, Knorr 147, in February and March, 1997, to WOCE standards. In addition to being available here, these data are also part of the WOCE Global Data Archive. These data have been used with CFC data from other cruises to the subpolar North Atlantic to determine the CFC-11 inventory for Labrador Sea Water and from this inventory, the rate of formation of Labrador Sea Water [*Rhein et al.*, 2002]. The collection and processing of these data was supported by ONR Grant 0014-96-0612 and NSF Grant OCE98-11034.

3.15. SSM/I

[26] Sea ice concentration data for the Labrador Sea has been obtained from the National Snow and Ice Data Center (NSIDC). NSIDC SSM/I sea ice products are in polar stereographic projection at a resolution of 25 by 25 km. The data in the collection covers the years 1996 to 1998. Two sets of SSM/I sea ice concentration grids have been formulated. The first data set was generated using the NASA Team algorithm [*Cavalieri et al.*, 2002] and the second using the Bootstrap algorithm [*Comiso*, 2002]. Both are included in the data collection.

Acknowledgments

[27] G. Krahmann and M. Visbeck acknowledge support for the data collection from ONR under grant N00014-98-1-0302. The different projects received support from ONR, NOAA, NSF, NASA, and BMBF. We of course want to thank the numerous scientists and support personel who collected and contributed the data. Thanks also to Felix Tubiana who helped to prepare the manuscript. This is Lamont contribution LDEO 6505.

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