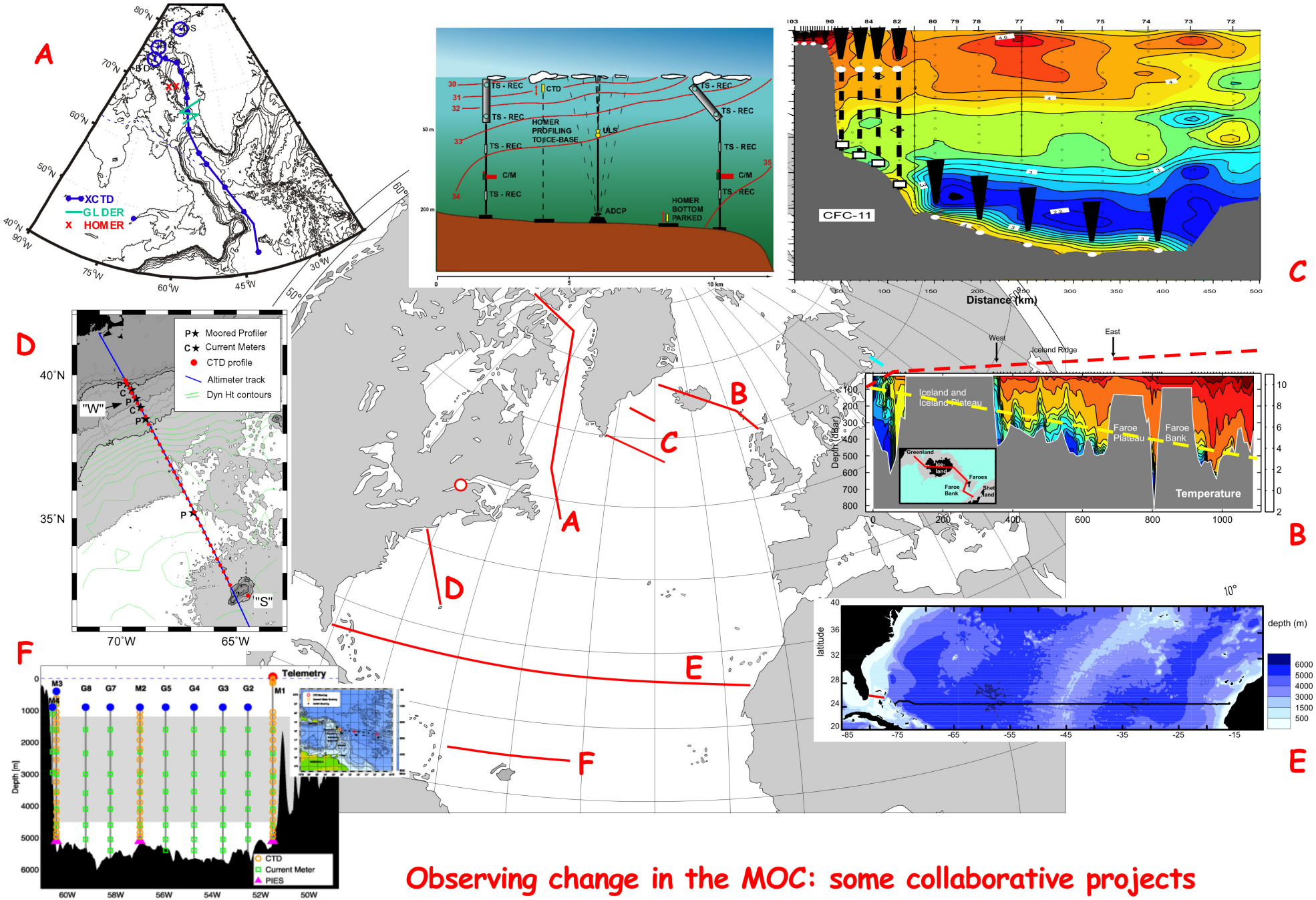
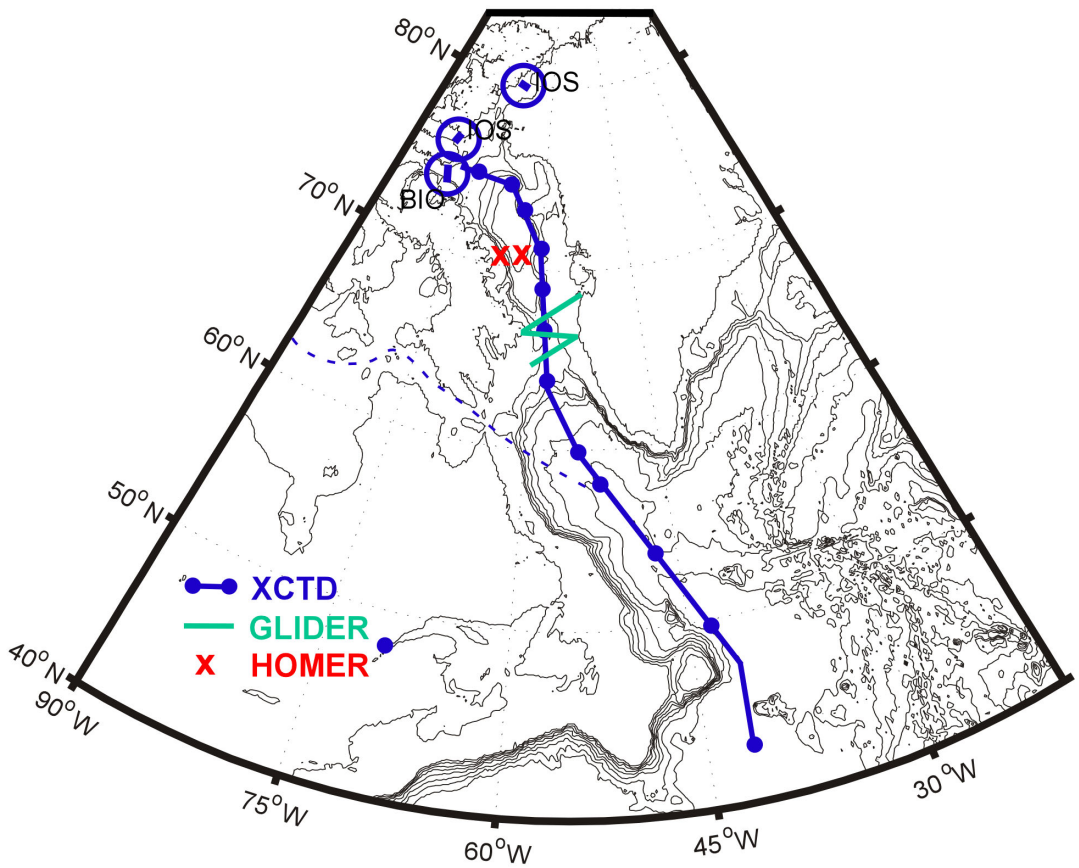
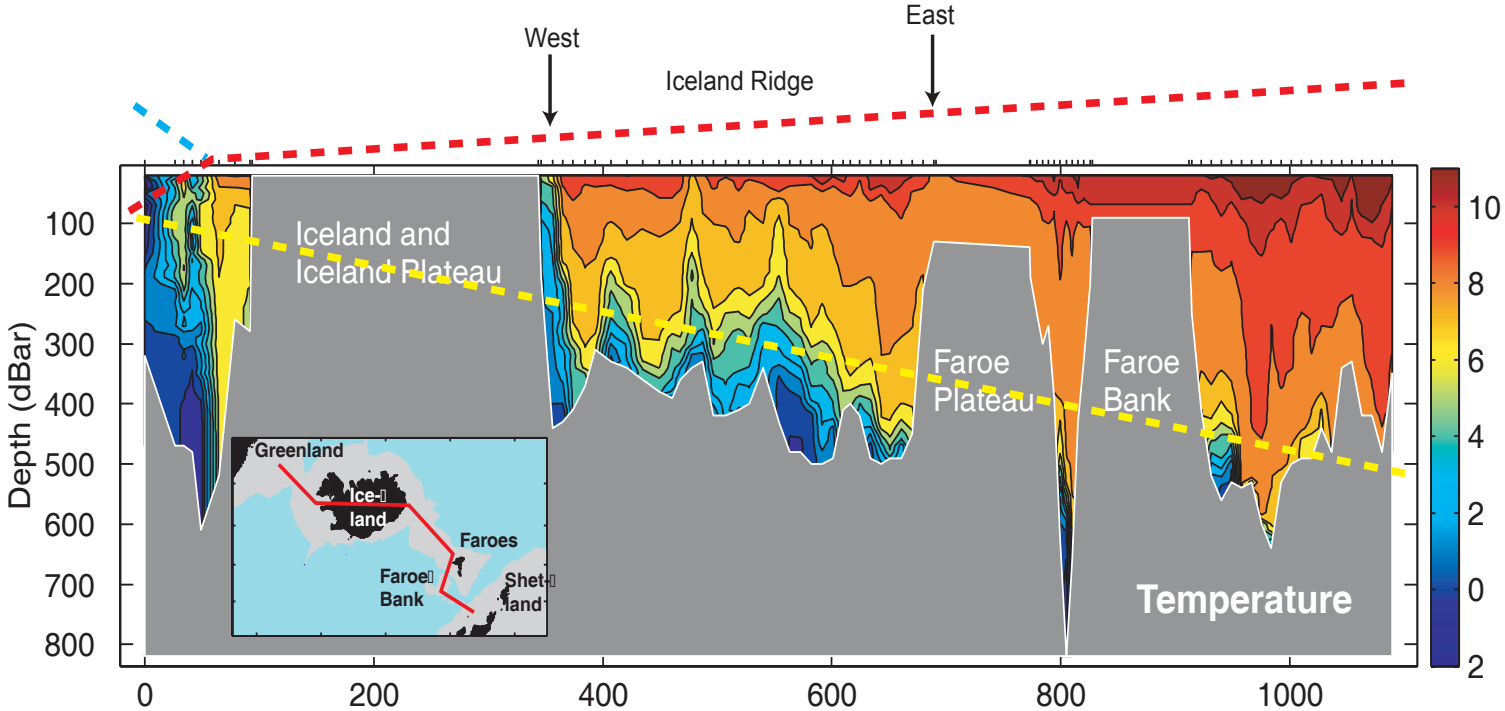


Observing change in the MOC: some collaborative projects

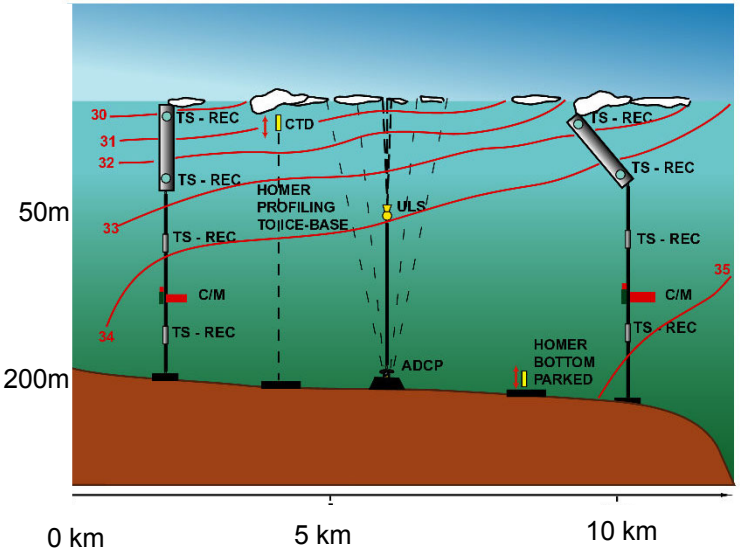


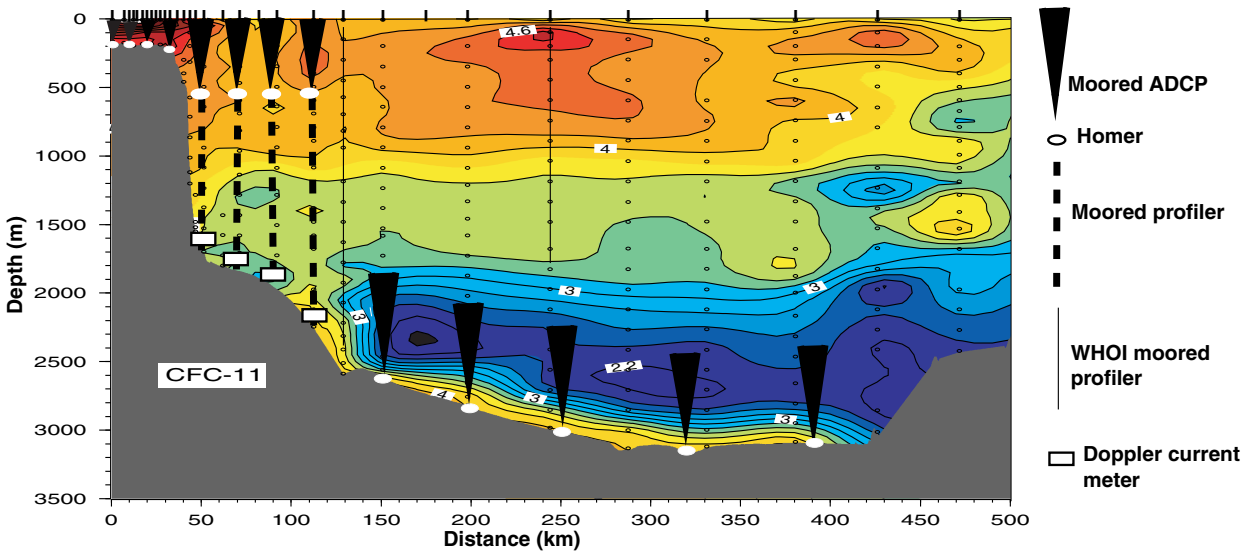
A. Beginning the task of tying the Canadian Arctic Archipelago throughflow to changes in the ìstorage basinî of the Labrador Sea.

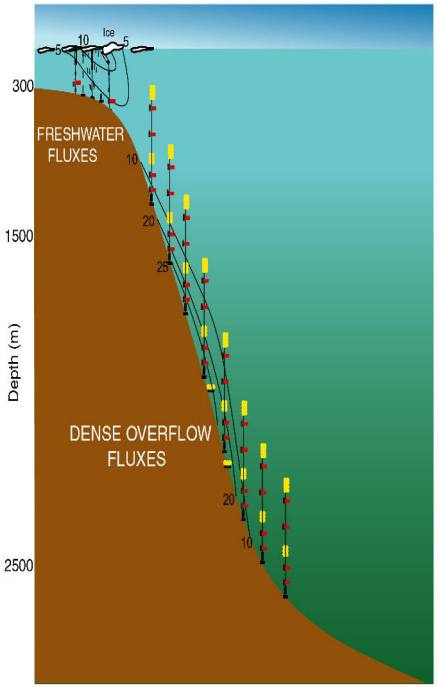
Elements shown include the continuation and perhaps expansion of the BIO Moorings program in Barrow Strait (begun 1998; S. Prinsenberg, BIO, N.S. Canada), deployments of IOS (Sidney B.C.Canada) current meter moorings in two northern passages (now in the 4th year of a 6-year program; H Melling, IOS Sidney), deployments of the Eriksen Seaglider west of Greenland (proposed to begin summer 2002; P Rhines U. Washington, Seattle), deployment of two HOMER profilers to monitor change in the Pacific Water wedge sub-ice in western Baffin Bay (profilers now on trial prior to 1st deployment; I. Vassie, DML Scotland) and a XCTD repeat transect from the Gulf Stream through Davis Strait to Lancaster Sound (first transects due to begin on 15 July and 1 November 2002; E Carmack, IOS Sidney). These efforts aim to measure the CAA throughflow and its changes through to the Davis Strait. In the Labrador Sea itself, the capture of novel tracers (e.g. SF_6 & ^{129}I) using moored pre-programmable samplers is the subject of a current proposal to the UK-NERC RAPID thematic programme (Co-investigators A. Watson, UEA, UK; TWN Haine, JHU, Baltimore; T Johannessen U. i. Bergen; WR Smethie, LDEO; GM Raisbeck/F Yiou, Gif-s-Yvette Fr; and J-C. Gascard LODYC Paris Fr) and would add vital information on the retention or throughflow of deep and abyssal waters to the DWBC.



B. Greenland-Scotland Ridge Exchanges:
Most of the overflows which cross the Greenland Scotland Ridge have been measured during the EC-VEINS project (1997-2000) using a mix of conventional current meter moorings and novel bottom-mounted systems, and have already begun to provide evidence of long term variability. The pre-existing VEINS arrays will continue in the recently funded ASOF-EC Project. However a quite new and unifying task will be to monitor the net balance of all exchanges across the Ridge using satellite altimetry and hydrography. The hydrographic and current structure over the Greenland-Scotland Ridge can with some simplification be viewed as three layer system: deep overflows, inflows of Atlantic Water and outflow of Polar surface water. In a novel experiment as part of the ASOF-EC programme of EC FP-V, Detlef Quadfasel of IFM Hamburg (currently with the Niels Bohr Institute of the University of Copenhagen) proposes to determine the fluxes of these different layers crossing the Ridge by measuring two variables:- the slope of the sea surface along the Ridge crest, and the slope of the mutual interface between the surface watermasses and the cold, dense overflow water (above). The former can be obtained from satellite altimetry, such as from the TOPEX/Poseidon and ERS missions, and when the sea level difference between Iceland and the Faroese shelf is plotted there is seen to be strong variability on timescales of months to years and also a trend. The mean interface height over, and north and south of the respective sills can be determined with a seasonal resolution from the standard hydrographic sections worked by Iceland, the Faroe Islands and Scotland, with higher resolution from inverted echo sounders moored in the eastern part of the section. The collaborative funding for this ASOF Task is thus a mix of ASOF-EC (W), ASOF-EC (E) plus a pending bid to the Danish National Science Foundation for the satellite work.

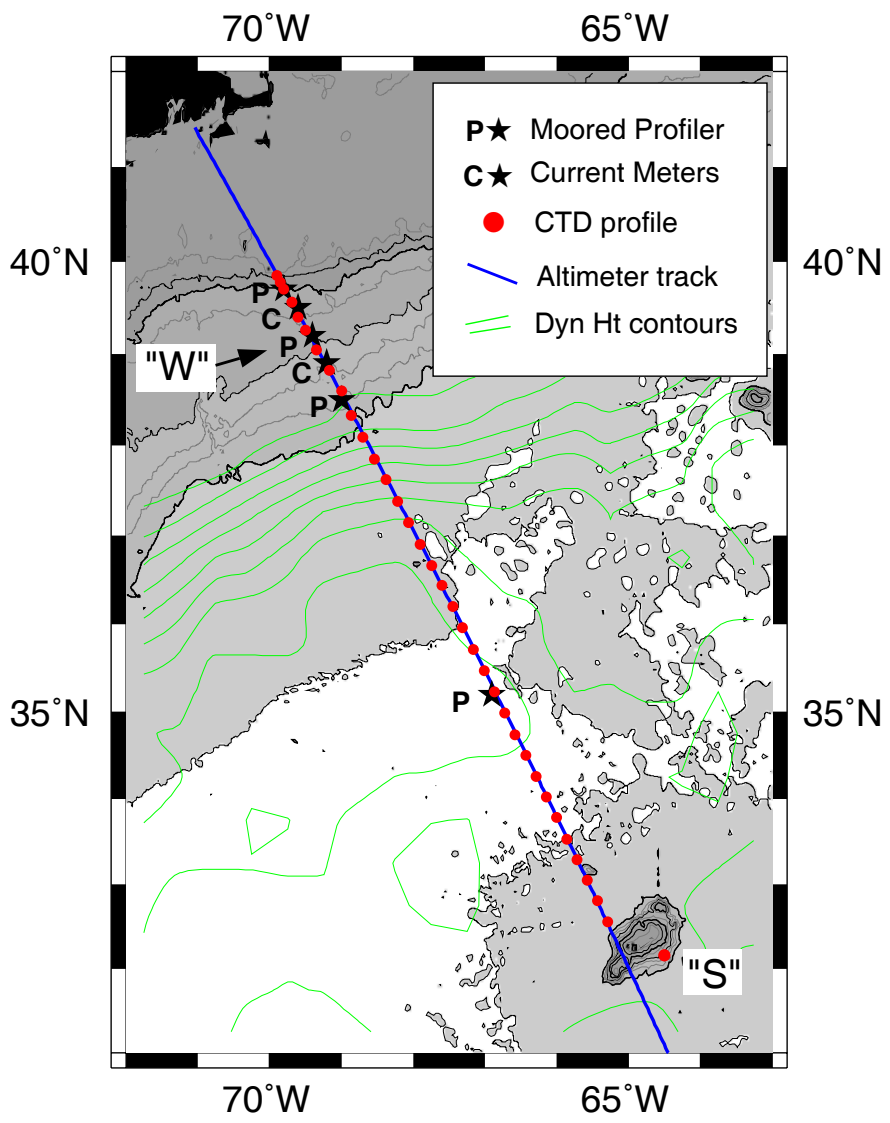






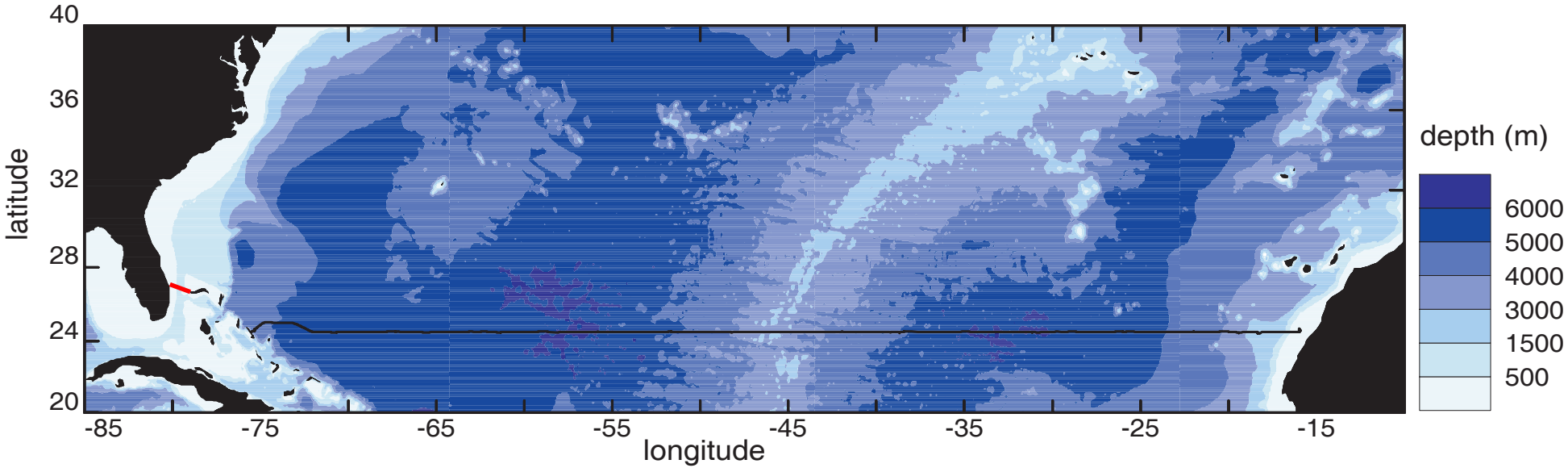
C. Flux measurements off SE Greenland.

Most projections of greenhouse gas induced climate change anticipate a weakened THC in the North Atlantic due to increased freshening and warming in subpolar seas. However, as yet, we have not a single measurement of the freshwater flux passing south to the Atlantic under the ice of the East Greenland shelf or through the Canadian Archipelago. These Figures document current international attempts to address the problem off East Greenland. Figures 1a,b (left and above left) describe the twin ASOF arrays off Angmaggssalik SE Greenland designed both to continue the measurement of the dense Denmark Strait Overflow where it descends the east Greenland Slope, and to begin the task of measuring the salinity profile under the ice on the adjacent shelf, initially using ìpipeî moorings, later using bottom-parked HOMER profilers which will rise to the ice base twice per day for a year. These UK-German-Finnish arrays with Icelandic hydrography are now funded as part of the ASOF-EC bid under the EC-FPV programme, with additional support from the NOAA SIO-LDEO Consortium on the Oceanís Role in Climate: Abrupt Climate Change Studies (CORC-ARCHES). A current bid to the UK-NERC RAPID Thematic by Karen Heywood, UEA, UK seeks to deploy a further large freshwater flux and boundary current array (ìMINKEî) on the old WOCE A1E line from Cape Farewell. This array is co-linear and collaborative with an existing hydrography/tracer repeat section by Bob Pickart WHOI, featuring two moored CTD profilers (Figure 2 above), and would lie close to the line of a French ìOVIDEî trans-ocean hydrographic Section (led by Herle Mercier, LPO/IFREMER) which will be occupied by IFREMER biennially from 2002.

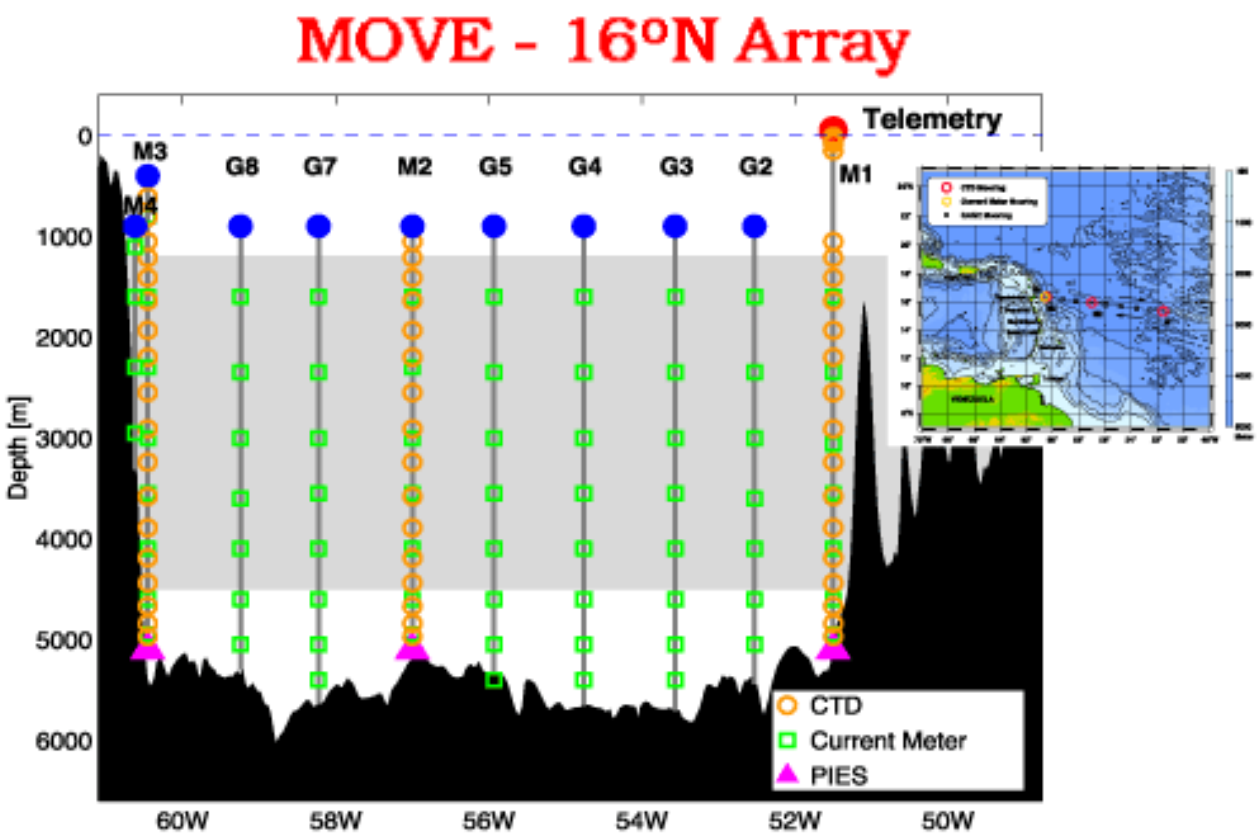


D. Measuring The Deep Western Boundary Current.

The influence of Northern Seas on the Meridional Overturning Circulation of the north Atlantic may derive both from the Arctic Ocean and Nordic Seas via the overflows of the Greenland-Scotland Ridge, or be transferred through the passageways of the Canadian Arctic Archipelago. Recirculation within the Labrador Sea will retain and transform these watermasses to some (unknown) extent before they are discharged into the Deep Western Boundary Current which flows equatorward through the Western Basin. This observing array between Woods Hole and Bermuda is the subject of a current proposal to NSF by a WHOI group led by John Toole, and is designed to characterise the changing hydrography, tracer chemistry and flow of the DWBC after all of these northern influences have come together. In detail, it is chosen to underlie a Jason satellite altimeter track, is intended to be in place initially for a period of 5 years, and will resolve the hydrography with sufficient frequency (300+ CTD sections per year) to resolve tidal, diurnal, seasonal and annual changes. A UK proposal to the NERC RAPID Thematic Programme by Chris Hughes (POL), David Marshall (U. Reading) and Ric Williams (U. Liverpool) would both add and gain value by contributing up to 18 Bottom Pressure Gauges (BPG) /Inverted Echo Sounders (IES) and 18 HOMER profiling CTDs to the WHOI array for a period of 3-4 years, with the equipment set in three clusters between the 3 and 5 km depth contours. Both proposals will have a particular focus on the boundary waves which act to remove unsupported boundary pressure anomalies and thus rapidly and efficiently communicate meridional overturning circulation anomalies from high to low latitudes.



E. A trans-ocean MOC array at the latitude of maximum heat flux.
A number of zonal observing arrays are in place or are in prospect, aimed at finding out how the rate and hydrographic character of the oceanís thermohaline circulation might change, and what might be the causes of such change. These arrays make the fundamental assumption that changes in the THC are coherent across a broad latitude range and that climatic ìsignalsî may pass between them, for example in the DWBC. Only one proposal, by Marotzke, Bryden and Cunningham of SOC, attempts full-ocean span, with groups of instruments set along 25N to cover the DWBC in the west, the Mid Atlantic ridge and the eastern boundary off Africa. They point out that the ocean heat transport is mainly accomplished by the MOCóóóthe zonally integrated meridional flow as a function of time and depth. Since fluctuations in heat transport are expected to be dominated by the velocity field and only to a lesser extent by changes in heat content, they reason that it makes sense to measure the MOC near the latitude of maximum ocean heat transport in the N. Atlantic. And since mass transport between any two points depends only on the pressure difference between these points, they reason that continuous observation of density at the western and eastern boundaries is required to provide a measure of the MOC. Hence a trans-ocean array near 25N. In fact 25N has three advantages:- it lies at or near the heat transport maximum, has four modern hydrographic occupations for comparison, and already has a long series of western boundary current observations (cable observations of flow through the Florida Straits by the Miami Group) not available anywhere else. Thus this array is the subject of a dual proposal, to NSF by Bill Johns (RSMAS) and Molly Baringer (AOML) for augmented Florida Straits transport measurements and augmented monitoring of the DWBC, and by Marotzkeís Group at SOC to the NERC RAPID Thematic Programme for a trans-ocean distribution of moored current meters, BPGs and CTD profilers together with occasional repeat trans-ocean hydrographic sections.



F. Western Basin MOVE array at 16N.
A further zonal array monitors the MOC further south in the tropics at 16N and at present completes the observing system that enables us to track the propagation of ocean-climate signals moving equatorward along the deep western boundary of the N. Atlantic. Observations have been carried out since January 2000 and represent a collaborative effort between Uwe Send of IFM Kiel (a contribution to the German CLIVAR Program) and a group from Woods Hole Oceanographic Institution (Toole, McCartney, Curry). The site was selected to exploit the narrowness of the western basin at this latitude, which means that the entire basin can be spanned to the Mid Atlantic Ridge with relatively few instruments, and was also selected as a site of a (modelled) minimum in eddy kinetic energy, where mesoscale noise on the observations might be correspondingly slight. In this long-term experiment, the integrated geostrophic transport field is determined by a combination of hydrographic and pressure measurements, and complemented by a picket fence array of current meters.

In US, a sub-project of the Study of Environmental Arctic Change (SEARCH)
In Europe, a project of EC Framework Programme V

The present potential for international collaboration in observing the Meridional Overturning Circulation (MOC) of the N. Atlantic and its long-term variability.

Prepared for the Meeting ìNorth Atlantic Science Connectionsî held May 24, 2002 in Reykjavik, Iceland. [Note: though some of the examples shown below are from existing and funded programs, many are still at the proposal stage. These are included to illustrate the potential that currently exists to observe the thermohaline circulation of the North Atlantic as a complete system, and are shown with the permission of their originators. Any text errors are due to RRD].

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