OBSERVED CHANGES IN ARCTIC OCEAN TEMPERATURE DURING 1995-1999

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Introduction

Vertical temperature (*T)* profiles were acquired on an annual basis during 1995-1999 from the Arctic Ocean using the German vessel *Polarstern* and U.S. Navy fleet submarines. A subset of these data, along transects that were occupied sequentially in different years (Figure 1), is used here to assess *T* changes in the Atlantic Water (AW) layer in the northern Makarov, Amundsen and Nansen basins during 1995-1999. Geographical near-coincidence of the transects within each area means that changes between different transects in a given area can reasonably be taken to indicate temporal rather than spatial changes.

The first three of selected areas 1-4 cross the Lomonosov Ridge and encompass portions of the Amundsen and Makarov basins adjacent to the Ridge. The northernmost, fourth area traverses the northern Makarov and Amundsen basins and much of the Nansen Basin (Figure 1). The northward flowing boundary current that overlies the steep western (Amundsen Basin) flank of the Lomonosov Ridge is a primary pathway for flow of AW to the central Arctic Ocean. Data from areas 1-3 therefore provide information on *T* change along a primary advective route for propagation of changes from the ocean margins into the interior basins. Data from area 4, which includes three basins and three ridges, is well situated for detecting widespread changes in the central Arctic Ocean. Area 4 data from a 1991 *Oden* cruise provide a reference for gauging the overall extent of the changes that occurred during the 1990s.

Interannual changes in the AW layer (defined by $T>0$ºC) from 1995-99 were evaluated using layer mean and maximum temperatures computed from the profile data. The mean and maximum temperatures tracked each other closely. Only the maximum temperatures T_{max} , which show changes more clearly than the mean temperatures, are shown (Figures 2 and 3).

Discussion

The AW in the northern Makarov, Amundsen and Nansen basins warmed through most of the 1990s, apparently ceasing by 1998-1999 (Figure 3). Overall magnitude of the warming was similar in each basin, and comparison with the 1991 *Oden* data suggests that this magnitude was about 0.5°C. Phasing of the warming differed by region. Most of the 0.5°C warming in the Amundsen and Nansen basins had occurred, based on comparison with the 1991 *Oden* data, prior to 1995. The Makarov Basin underwent a similar amount of warming, but over the 1995-1998 period.

Northward currents along the western flanks of the Alpha-Mendeleyev and Lomonosov ridges and the AMOR provide mechanisms for advection of water from the Eurasian margins to the interior basins. These currents originate from the eastward flow that overlies the Eurasian continental slope. This eastward flow originates in the North Atlantic Current via Fram Strait and the Barents Sea and contains the highest AW temperatures in the Arctic Ocean. A year-long *T* time series measured at 274 m depth along the offshelf edge of this flow during 1995-96 (site

LM2 on Figure 1) shows that *T* can vary, if we neglect the warm eddy events during which T can approach 2.5°C, from about 1.25 -1.85°C (Figure 4). Source waters for the northward ridge-associated currents therefore vary over a range of T sufficient that encompasses the variations observed farther north. Northward flow along the Amundsen flank of the Lomonosov Ridge has in fact been measured, as the results from a current meter at site LM2 show a year-long northward mean current speed of 1.3 cm s^{-1} at a depth of 274 m. Consistent with this scenario, the 1995-96 cooling along the southern Amundsen Basin flank of the Lomonosov Ridge (Figure 2, Area 1) reflects the passage through mooring site LM2 of a pronounced cooling event during April 1996 (Figure 4).

Northward flow along the ridge flanks can account for the *T* variations at the eastern basin margins. Warming in the Makarov Basin adjacent to the Alpha-Mendeleyev Ridge was, in particular, greater than farther west into the basin. There is, however, no documented mechanism for advection of these changes from the ridge flanks into the central basins. Significant lateral heat transport may be associated with diffusive processes, as evidenced by the widespread interleaving and thermohaline inversion structures that occur throughout much of the central Arctic Ocean. Mesoscale eddies are present along the Eurasian margins and may transport some heat basinward. It is also possible that intrabasin currents, such as permanent sub-basin scale gyres or transient cores or filaments, exist but have not been documented in the field data.

The breakdown over the crest of the Lomonosov Ridge of the central basin pattern of interannual *T* variability probably reflects the high latitude constraint for flow along isobaths and a lack of cross-isobath flow that might otherwise advect *T* changes from the flanking currents onto the Ridge crest. Spatial variability over the ridge crest probably reflects topographically trapped mesoscale circulation features. Variability on similar scales has been reported in zooplankton distributions spanning the Lomonosov Ridge farther south and may also reflect such ridge-trapped circulations. The data are, however, insufficient for more than speculation on this issue.

Conditions over the AMOR, sampled only in Area 4 (Figure 3), appeared like those over the Lomonosov Ridge to vary differently than in the adjacent basins. Early cooling (1995-98) over the Amundsen Basin side of the inner rift valley was followed by later warming (1998-99), similar to the pattern associated with the Lomonosov Ridge. The Nansen Basin side of the AMOR was overlain by early cooling followed by later warming. In the absence of time change information elsewhere along the AMOR, speculation on the sources of change seem premature. The AMOR becomes discontinuous farther south toward the Eurasian margins, diminishing the likelihood that a northward current would retain its identity between the margins and the area sampled.

The data reported here suggest that the AW warming that was pronounced early in the 1990s had tapered off by 1998-99. Persistence of warming at least through 1997 would be consistent with the observed continuation of the large-scale atmospheric forcing regime whose onset roughly coincided with the initial warming sometime around 1990. Cessation of the warming in the late 1990s would be consistent with the cyclical nature of the atmospheric forcing. Determining whether in fact this persists is contingent on acquisition of ocean data from the central basins during and beyond the year 2000

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