Arctic sea ice thickness variability observed over a decade in the Fram Strait

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Introduction

In the beginning of the 1990s, thinning of Arctic sea ice north of Greenland was reported (Wadhams 1990). When further evidence of widespread Arctic sea ice thinning was published (e.g. Rothrock et al. 1999, Wadhams and Davis 2000), the topic received much attention within the scientific community and media in general. The views were slightly moderated after new data suggested that the ice thickness remained constant during the 1990's (Winsor 2001). In addition, models suggest that the observed reduction in ice thickness is not as much a reduction of ice volume through thinning as it is a redistribution of ice from the sampling area to other regions within the Arctic (Holloway and Sou 2002).
With the recent controversy on Arctic sea ice thinning as a background, the aim of this study is to use a decade of ice thickness measurements by upward looking sonars (ULS) in the Fram Strait to answer the following questions: 1. How do the measurements in the Fram Strait reflect the changes of sea ice in the Arctic Ocean, and 2. What are the main features of the sea ice thickness variability over the decade?

The data

The conclusions on widespread Arctic sea ice thinning are based on data from submarine sonar surveys. The chief advantage of submarine sonars is that they allow basin-scale surveys to be carried out on a single cruise, giving the geographical variation in ice thickness characteristics. However, a submarine can not, unlike moored upward looking sonars (ULS), generate systematic time series of ice thickness at a fixed geographical point. Using simultaneous measurements with advanced doppler current meters, one can derive continuous sea ice mass balance data for the investigated location.
The Fram Strait is the main gateway for sea ice leaving the Arctic. This relatively narrow strait is therefore a natural location for the task of establishing the measurement of a systematic time series of Arctic ice thickness at a fixed point in space. The Norwegian Polar Institute (NPI) has maintained an array of ULS' across the East Greenland Current at 79°N since 1990 (Fig. 1).
Two to four instruments has covered the ice drift in the past thirteen years. Details about the NPI moorings, instruments, data, and processing methods can be found in Kvambekk and Vinje (1992); Vinje et al. (1998), Vinje et al. (2002), Widell et al. (2003) and Kwok et al. (2004).

Preliminary results

The project is still in an early phase, with focus mainly on reanalysis and verification of the existing data. The time series presented here, 1990-1999, is hence only 3-5 years longer than the time series presented by Vinje et al (1998). New data will subsequently be processed. The ice drafts are derived from echo sounding, hydrostatic pressure and temperature measurements. A climatology of T and S between the instrument and surface is used to estimate the speed of sound in order to get a distance and draft from the instrument recordings. Statistical methods are then used on the time series to classify each individual ice draft as open water or ice, i.e. a sort of refinement through statistical processes. Fig. 2 shows the monthly averaged sea ice thickness, calculated from the ice draft time series. The black curve shows the result when open water is included.

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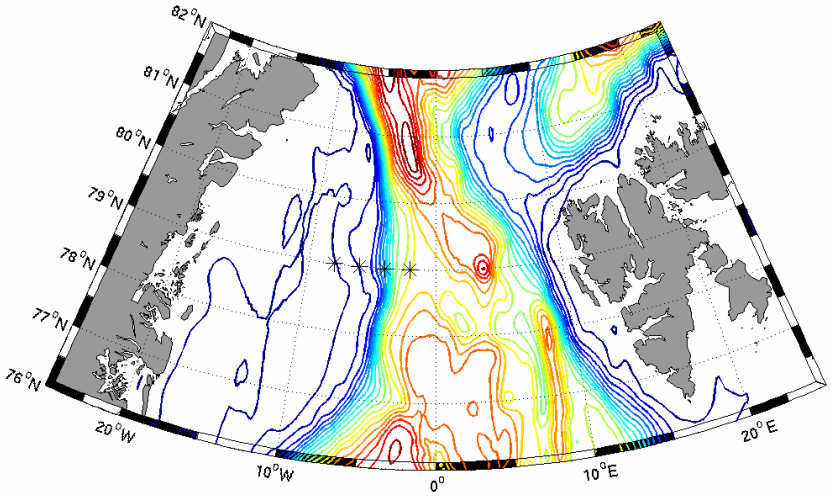

Fig. 1: Map of the Fram Strait with ULS positions (stars) and seafloor topography indicated with 200 m equidistant contour lines.

Excluding open water gives higher estimates (red curve), but otherwise both results are similar. A large interannual variability is observed.

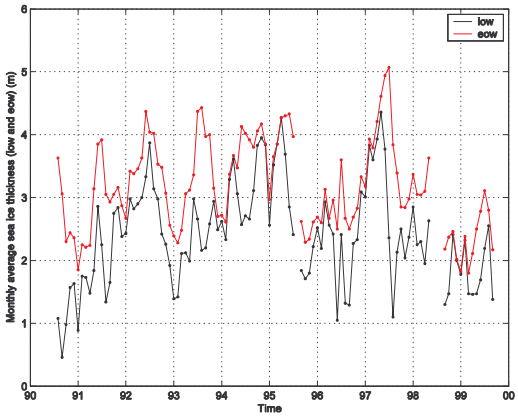

Fig. 2: Monthly averaged sea ice thickness, including (black), and excluding open water (red).

Further studies will aim at quantifying and explaining the cause of this variability. The development of the frequency distribution during winter (March) over the years is shown in Fig. 3 a. There is a tendency of more thick ice in the distribution until 1998, when the peak of the distribution is shifted toward thinner ice. The time series of the frequency distribution during summer (July) is more stationary (Fig. 3 b). There is a weak tendency of thinner ice in the distribution in the last part of the time series.

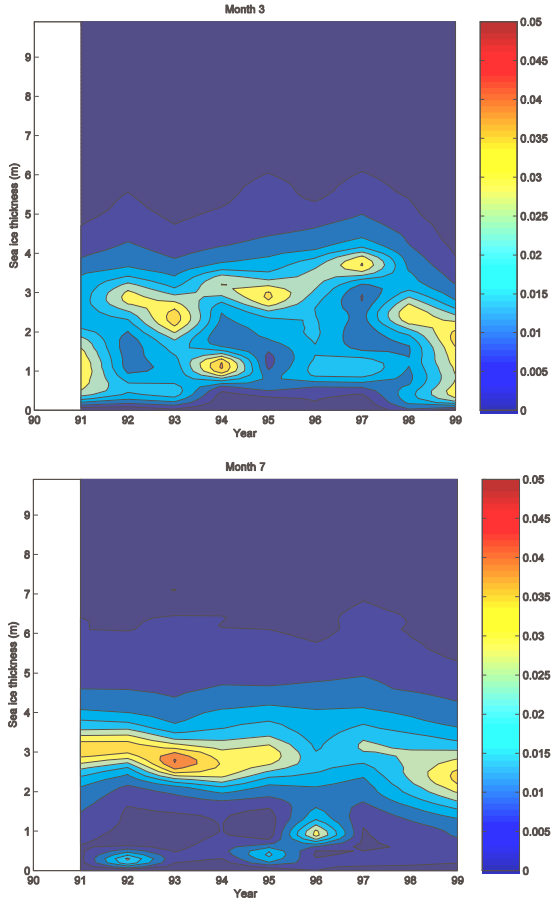

Fig. 3: Ice thickness frequency distributions for March (a, upper graph) and July (b, lower graph).

***In situ* ice measurements**

As a part of the NPI project " *Surface properties and thickness of multi-year sea ice in the Fram Strait for calibration/validation of CRYOSAT*", in situ ice measurements and observations were applied in direct connection with the ULS observations in the Western Fram Strait during a cruise with the RV "Lance" in September 2003. The results from this work package are ment to 1) support the processing of ULS data from the same area, 2) ease sea ice related interpretations from remote sensing products, 3) support the CALibration and VALidation process of the ESA CryoSat satellite mission, and 4) function as a base for more detailed studies over the following years. The measurements included: (a) Direct snow and ice thickness measurements (stake and drill), (b) direct freeboard measurements (drillholes and ice edge), (c) indirect total ice thickness measurements (electromagnetic sounding), (d) snow type characterization, (5) surface water salinity measurements and (e) regular ice observations and log (from the bridge of RV "Lance").

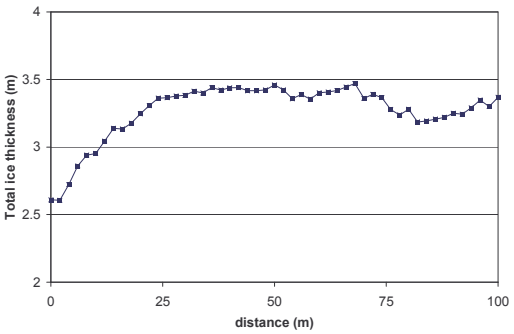

Fig. 4: Ice thickness profile from electromagnetic measurements with a Geonics EM31 ICE instrument from the Western Fram Strait, obtained 11 September 2003.

On 6 ice stations, multi-year ice floes being rather small (range 50 m diameter) were met, and in total 14 thickness drillings gave direct measured ice thicknesses between 1.90 and >11 m. These measurements were used adjusting an empirical relation between apparent electrical conductivity and ice thickness, which is necessary for the processing of the electromagnetic profile measurements (see {Haas et al. 1997). 6 profiles were measured, covering a total length of 365 m (see example in Fig. 4).
The snow cover was always less or equal 4 cm thick (usually between 0 and 1.5 cm), consisting of snow with rounded grains/faceted crystals usually 0.5-1 mm (max. 2 mm) large. The freeboard measured was between 17 and 43 cm, with a mean of 28 cm (13 measurements). Surface water salinity was measured next to the ice floe edges 27.0-30.8 ppt, showing the influence by ice melting.

Conclusions and Outlook

We emphasise that this publication is presenting an ongoing study, and only preliminary results are shown. So far, there is no clear trend toward a general thinning in the time series at the present state of the processing. However, a large interannual variability is observed.
The work for the coming years will include comparisons of overlapping time series from different instruments to verify the instrument performance and validate estimates. The complete time series will be reprocessed with new open water detection algorithms implemented. With the help of backtracking sea ice from the point of thickness measurement to its origin within the Arctic, time series of thickness of sea ice from the same origin (eastern/western Arctic, Siberian shelves, North of Greenland) will be developed and analysed. More extensive in situ sea ice thickness measurements from the ice surface by means of electromagnetic sounding is planned for September 2004. Those data will be integrated with measurements from the 2003 campaign and earlier expeditions to the same area. The entire dataset will then support the data processing/interpretation of the available ULS time series of ice draft, and support the the CryoSat Mission sea ice investigations. The ULS measurements in the Fram Strait itself will be continued.

Acknowledgements

We thank Kristen Fossan (NPI) and many other helpers which supported the NPI-ULS and in situ measurements in the Fram Strait. We are further grateful to the captain and crew of the RV "Lance" for their help and support during the research and maintenaince cruises to the Fram Strait. This work is funded by the

project ASOF-N and the Norwegian Polar Institute. ASOF-N is a project funded by the European Commission and a contribution to the EU 5th Framework Programme.

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