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Sea Ice Thickness Changes in Fram Strait and the Arctic Basin during 1990–2013 from Moored Sonars with Emphasize on Sea Ice Minimum Years 2007 & 2012

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1. Introduction

Arctic sea ice has become significantly thinner during the first decade of the 21st century [e.g., Haas et al., 2008; Kwok and Rothrock, 2009; Vaughan et al., 2013], with concurrent changes in age composition toward more first-year ice (sea ice of not more than one winter growth) at the expense of old ice (sea ice that has survived at least one summer melt season) [e.g., Comiso, 2012; Vaughan et al., 2013].

We examine 24 years (1990–2013) of monthly ice thickness distributions from the Transpolar Drift in Fram Strait, as observed by upward looking sonars (ULS) moored on the seabed. An extensive discussion of this time series for 1990–2011 can be found in Hansen et al. (2013) and the reader is referred to that manuscript for more detailed information. The update presented here now also covers the two record low summer Arctic sea ice extend years 2007 and 2012.

Fram Strait, located between northeast Greenland and Svalbard, is the only deep connection between the Arctic Basin and other oceans and is the main export gate for sea ice. The mooring location in Fram Strait is well suited for long-term monitoring of Arctic sea ice thickness, due to the steady advection of ice through the strait from many sites across the Arctic Ocean. Ice thickness observed here represents an integrated signal of the time varying state of the ice cover in the mayor part of the Arctic Ocean that deliver ice to the Transpolar Drift and Fram Strait.

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2. Results

The ULS time series of sea ice thickness in Fram Strait show significant thinning during the 1990–2012 period. Figure 1 shows the monthly time series of the modal ice thickness on the left and the mean ice thickness on the right. If the monthly ice thickness probability density function has two modes the second mode, representing the level multiyear ice was selected for the modal ice thickness time series. The thickness of this old level ice (modal thickness) declined at a rate of 21% per decade (−53±4 cm per decade) and the mean ice thickness by 15% per decade (−43±7 cm per decade). The mean ice thickness reduced from an annual average of 3.0 m during the 1990s to 2.2 m at the end of the record. Back-trajectories of ice drift show that the observed ice originates mainly from the Eurasian shelf seas and drifted across the central Arctic Ocean following the Transpolar Drift. The observed ice thinning in Fram Strait therefore is representative for a large part of the Arctic Ocean, however, with time lags of up to several years (typical about three years for ice origin in the Eurasian marginal seas).

The level (modal) ice thickness time series (Figure 1, left) shows a relative steady decline with no signs of recovery, which is qualitatively similar to the development of the sea ice volume in the Arctic Basin as seen from satellite observations and models. The thickness of old level ice is approaching values more typical for seasonal ice. During the periods 1996–1998 and 2003–2004 the modal ice thickness time series has local maxima with monthly mean modal ice thicknesses of up to 3.5 m, which can be related to different source regions. The modal ice thickness time series, representing mainly level, undeformed ice, has local minima in 2008 and 2012. Assuming a time lag of several months to years these minima are likely related to the strong melt events in 2007 and 2012 causing the record sea ice extend minima during those years. That the 2012 melt signal seems to be faster transported to Fram Strait is in line with the minima sea ice extend patterns. In 2007 most of the anomalous melting took place in the Beaufort and Chukchi Seas, i.e. far away from Fram Strait, while in Fram Strait sea ice extend conditions in 2007 were pretty average for recent decades. The 2012 summer sea ice extend minimum also was expressed in reduced sea ice area in Fram Strait and northeast of it, which can explain the more direct, faster response of reduced ice thicknesses in 2012 compared to 2007.

The time series of the mean ice thickness (Figure 1, right) shows higher variability than the modal ice thickness and even a slight recovery in 2012. The mean ice thickness in Fram Strait is strongly dependent and co-varies with the amount of thick, ridged sea ice (the long tail of the ice thickness distribution). The fraction of this thick, ridged ice also got significantly reduced (by 50% during the time series, equaling 21% per decade). The mean ice thickness time series therefore is more closely related to the reduction of old deformed ice, also expressed in the younger ice age in the Arctic Basin (e.g. Maslanik et al., 2011), as to anomalous thermodynamic melting events contributing to reduced level ice thickness and reduced summer sea ice area. Therefore we likely find little correspondence between the mean ice thickness and sea ice extent minimum years 2007 and 2012. The year 2007 shows comparable high mean ice thicknesses with a decline in 2008 but no local minimum until beginning 2012. During 2012 the mean ice thickness increases again. Processed 2013 data is not available for analysis at the time of writing.

The month to month variability of modal, but especially mean sea ice thickness is high (black dots in Figure 1). There is no clean seasonal cycle and pronounced inter-annual variability. The modal thickness seems to show some 3–4 year cyclical variations (blue line in Figure 1, left), which awaits further analysis.

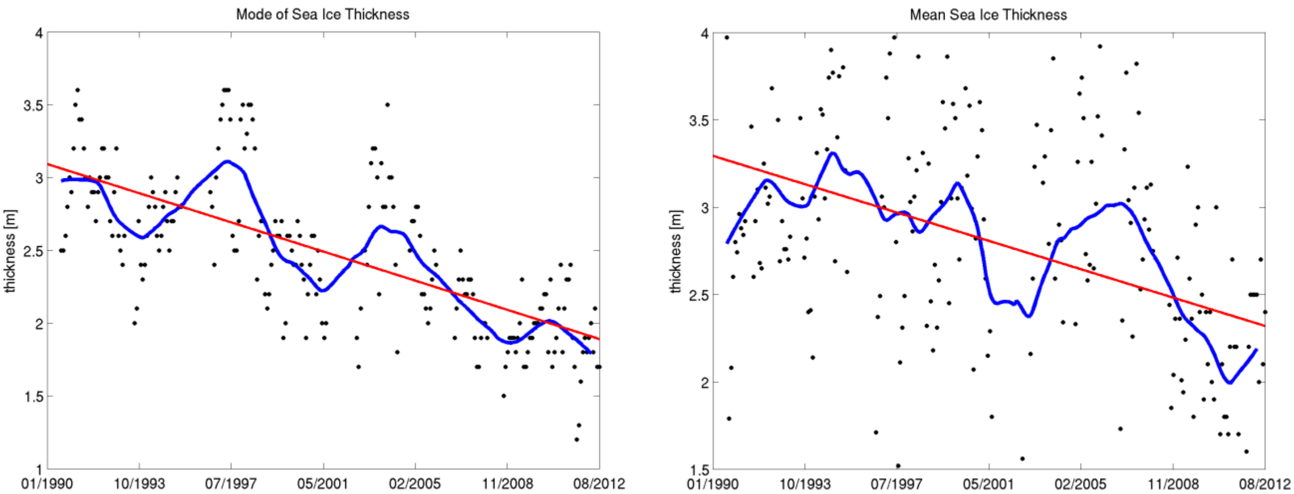

Figure 1. Monthly time series (black dots) of modal (left) and mean (right) sea ice thickness in Fram Strait at 79°N, 5°W. Blue lines show 36 month moving averages and red lines show linear trends. Currently the time series covers January 1990 to August 2012.

3. Discussion and Conclusions

In a more general view, low ice thicknesses, however, as prevailing during recent years, will cause an increase in amplitude of the sea ice extend seasonal cycle and the likelihood of record low sea ice extents during summer. If weather conditions (temperature, wind) are favorable larger parts of the now thinner ice cover can melt during one melting season. It is an important implication that the sea ice extent then depends more on the actual weather each melt season than previously. Because of that, for the near future we also can expect increased inter-annual variability of ice composition and thickness in the region. The ice extent in Fram Strait itself shows low correlation with ice thickness as it is mainly related to sea ice dynamics, i.e., local winds.

The now thinner ice cover and the larger year to year variability in sea ice extent can influence human activity in the Arctic. Some area of the Arctic Ocean might become easier accessible. However, due to the increased, more weather dependent, variability of the ice cover also the needs for better sea ice prediction might increase. In addition to climate monitoring applications the ULS Fram Strait sea ice thickness observations are of particular relevance for shipping and offshore petroleum activities: from this data set the full sea ice thickness distribution can be obtained and most relevant parameters can be deduced, such as level ice thickness and frequency and depth of pressure ridges.

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