Ice thickness in the Beaufort Sea and Northwest Passage in April 2016, and comparison with April 2015

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Abstract

Three long airborne ice thickness surveys were carried out in the Northwest Passage and Canadian Beaufort Sea by York University in early April 2016, and compared to similar surveys performed in late April 2015. Results show that ice thicknesses in the Northwest Passage were similar in both years, although there was less multiyear ice (MYI) in 2016 (Section 2.2). In the Beaufort Sea, the thickness of MYI was similar to 2016 (Section 2.1). However, due to strong divergence and export, first-year ice (FYI) was much thinner than in 2015, giving rise to expectations of earlier FYI melt and disappearance in 2016 than in 2015. However, multiyear ice may survive as long as in 2015, and may thus retard the overall retreat of the ice edge as it did in 2015, thus somewhat mitigating the effects due to the thin FYI. Data are available for collaborations with other observationalists and modelers for initialization and validation of sea ice models and remote sensing data to improve sea ice forecasts for the 2016 summer season (e.g. Lindsay, 2012).

Figure 1: York University's Airborne Sea Ice Observatory (ASIO) with tethered AEM ice thickness sensor (white torpedo near left/central lower margin). Note shadows of aircraft and sensor. Photo courtesy Mark Drinkwater, ESA@CryoVEx 2014.

1. Measurements

York University's Airborne Sea Ice Observatory (ASIO) has performed extensive ice thickness surveys in the Beaufort Sea and Northwest Passage in April 2015 and 2016. Measurements were carried out with an airborne electromagnetic (AEM) sensor towed with a DC3-T aircraft (Figure 1). Total (ice plus snow) thickness retrievals are accurate within +/- 0.1 over level pack ice and +/-0.2 m over level fast ice. More information about the measurements and related objectives can be found in Haas (2012) and Haas & Howell (2015).

In both 2015 and 2016, two surveys were carried out each, one in the eastern and one in the western Canadian Beaufort Sea (Figures 2 and 4).

In addition, 5 drifting buoys were deployed on MYI in 2015, and one in 2016, giving further insights into ice drift trajectories and the fate of MYI during the summer.

2. Results and implications for 2016 sea ice summer season

2.1 Beaufort Sea

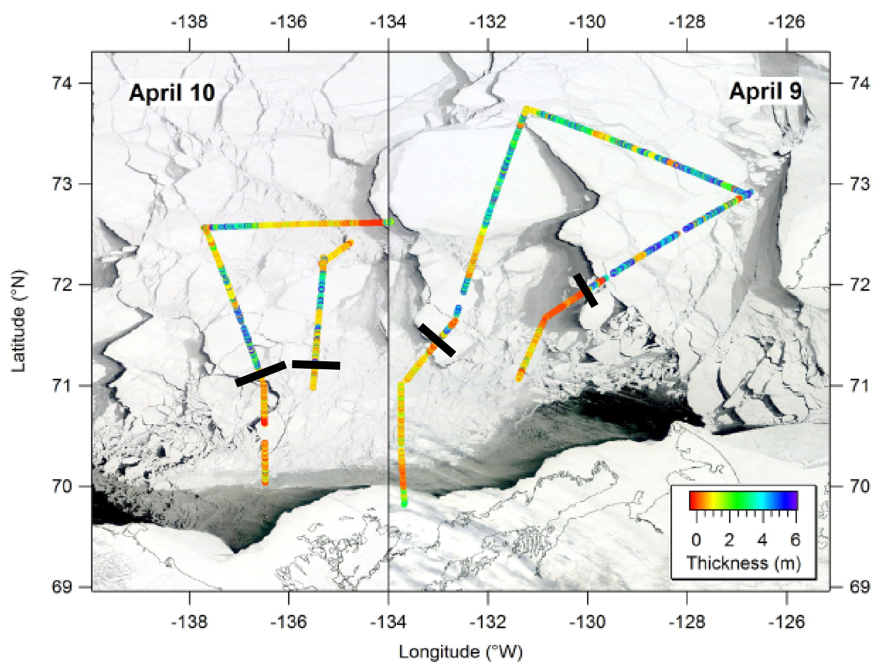

Figure 2: Ice thickness measurements in the Beaufort Sea on April 9 and 10, 2016, superimposed on concurrent MODIS imagery. Short black lines demarcate the boundary between FYI (south) and MYI (north) regimes.

Figure 2 shows the results of both thickness surveys overlaid on a MODIS optical image. It can be seen that the ice cover was strongly fragmented, due to strong wind-driven ice divergence commenced in February and March. FYI can be distinguished from MYI mostly by their different thicknesses, the former being ≤ 2 m thick, the latter ≥ 2 m. The FYI regime was identified with Canadian Ice Service (CIS) ice charts, and is the region south of the southernmost occurrence of MYI along each flight path (i.e. ice south of approximately 71°N; see Figure 2). A similar classification was carried out for the measurements in 2015 (Figure 4). Figure 3 shows derived thickness distributions, distinguishing roughly between FYI and MYI regimes. Note that the heights of individual peaks of the distributions and mean thicknesses over this heterogeneous region strongly depend on the actual locations of survey lines, and therefore bear relatively little information. Therefore, the following discussion focusses mostly on the location of individual peaks only, i.e. the dominant modes of the thickness distributions.

The 2016 FYI thickness distributions (Figure 3 bottom) are characterized by strong modes at 0-0.1 m and 0.6-0.7 m. There was less open water and thin ice in the western study region, which may result from the fact that the ice in that region is older and may have grown thicker and more deformed since its initial formation further east. However, most importantly, the 2016 FYI thickness distributions show an

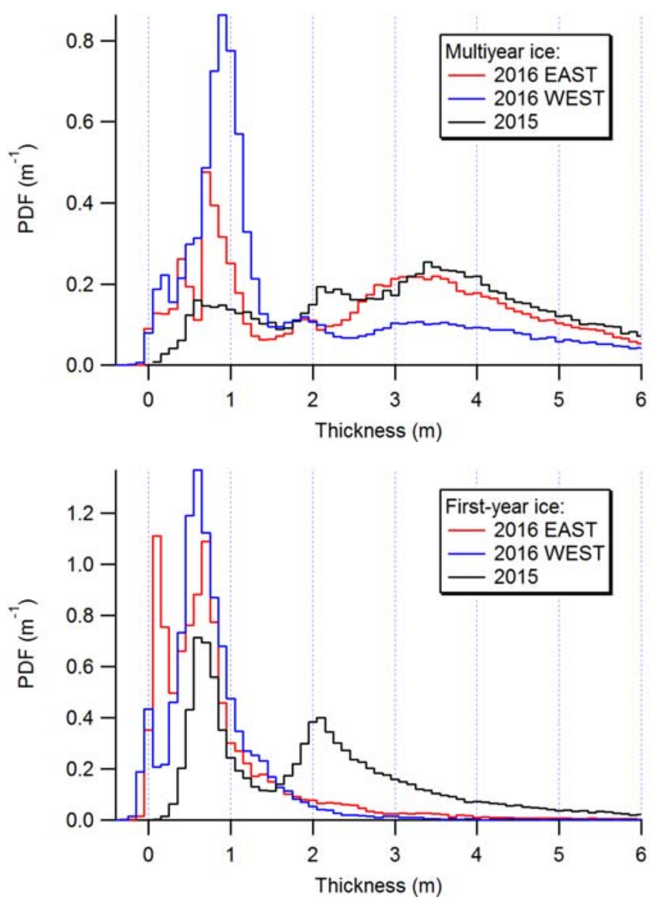

Figure 3: Ice thickness histograms (probability density functions, PDF; bin width 0.1 m) of the MYI (top) and FYI regimes (bottom) in the Beaufort Sea. Graphs show histograms for the individual, eastern and western surveys in 2016, and combined histograms for both flights in 2015 (cf. Figure 4).

almost complete absence of the mode at 2.1 m, which in 2015 and before is representative of old FYI formed since the onset of ice formation in the previous fall (Haas, 2012). It is the absence of this thick FYI which makes the FYI region of the Beaufort Sea very vulnerable to early melt and decay this summer, and which will lead to a rapid retreat of the ice edge to the FYI/MYI ice regime boundary. However, we assume that the thick FYI initially formed in the Canadian Beaufort Sea had already drifted further west during the summer, and must now be located north of Alaska and in the Chukchi Sea.

The 2016 MYI regime thickness distributions are also dominated by strong modes of thin ice resulting from newly formed ice interspersed between large regions of MYI floes (Figure 3 top). Those modes are at 0.7 m in the East, and 0.9 m in the West, again suggesting ice growth while the ice moved from East to West. Both eastern and western surveys show a small peak at a thickness of 1.9 m, which represents old FYI formed since freeze up as discussed above, or second year ice. However, that mode is somewhat thinner than the mode at 2.1 m found in 2015, indicating that old FYI in 2016 is ≈20 cm thinner than in 2015.

Both 2016 MYI regime thickness distributions show broad modes thicker than 3 m (Figure 3, top), representative of actual MYI floes. It appears that the MYI was somewhat thinner in 2016 (modes between approximately 3 and 3.5 m) than in 2015 (broad mode at 3.4 m). This similarity suggests that the MYI in the region has the same or slightly smaller chances of survival in the coming summer than it had in 2015.

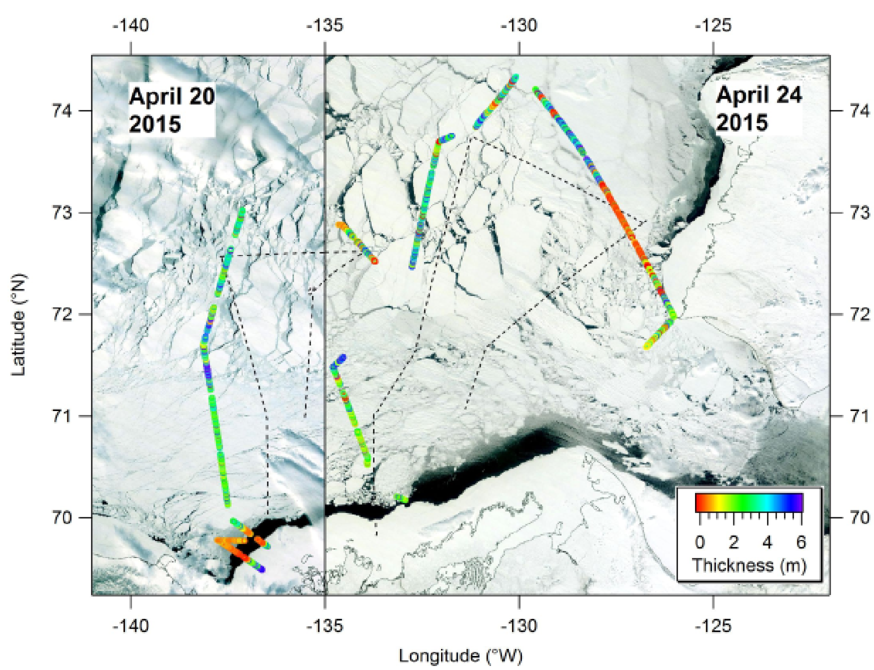

Figure 4: Ice thickness measurements in the Beaufort Sea on April 20 and 24, 2015, superimposed on concurrent MODIS imagery. Same color scale as in Figure 1.

In the summer of 2015, a band of MYI survived throughout most of the summer in the southern Beaufort Sea (Figure 5). By means of a drifting buoy air-dropped onto a MYI floe during our survey, we were able to show that that MYI band originated from the 3-4 m thick MYI surveyed in April 2015 in the Eastern Beaufort Sea. It is thus an example for the survivability of MYI, and we expect that the MYI surveyed by us in April 2016 will have similar chances for survival as in 2015, provided all other components of the energy and mass balance are of similar magnitude. However, as the MYI regime in 2016 seems more fragmented and interspersed with thinner FYI than in 2015 (see Figures 2, 3, and 4), 2016 may see an earlier disappearance of FYI and therefore more open water within the MYI regime, with the potential to thus accelerate MYI decay by accelerated ice-lead albedo feedback processes.

In order to aid forecasting and interpretation of 2016 summer season MYI decay, we have again air-dropped a drifting buoy on a MYI floe this April. Its drift trajectory from April 9 to May 16 can be seen in Figure 6, and real-time data are available at http://justinbeckers.com/autonomous-stations/buoy-300234062442620

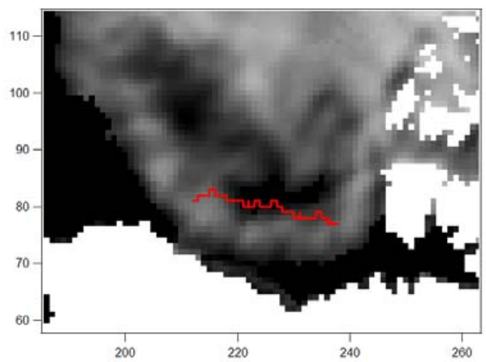

Figure 5: Map of the Beaufort Sea, showing land (white), water (black), and ice concentration (grey tones; bright: high ice concentration) on August 6, 2015, derived from SSMI passive microwave observations (NASA team algorithm, downloaded from NSIDC). Red line shows trajectory of drifting buoy from deployment on April 20, 2015 until failure on August 6, 2015. The buoy was air dropped on a MYI floe in the MYI regime.

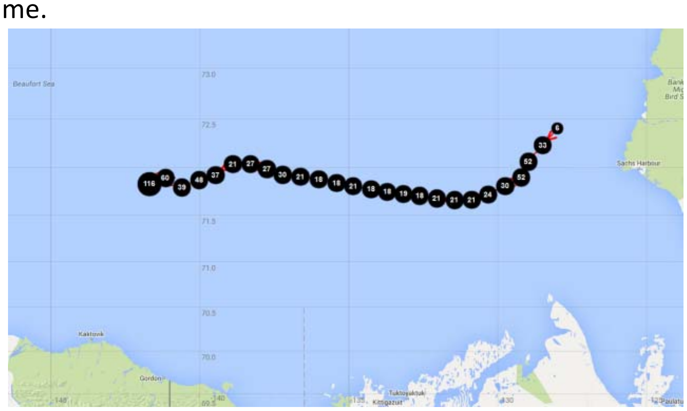

Figure 6: Map of the Beaufort Sea, showing the drift track of a buoy deployed on a MYI floe on April 9, 2016, until May 16, 2016. Real-time data from this buoy can be downloaded from http://justinbeckers.com/autonomous-stations/buoy-300234062442620

2.2 Northwest Passage (NWP)

Figure 7 shows a map of ice thicknesses in the NWP. For further analysis, we distinguish between the ice in M'Clintock Channel (MCC) and Victoria Strait (VS). Note that in contrast to April 2015, and due to the low sea ice concentrations during the summer of 2015, there was hardly any MYI in and south of Victoria Strait.

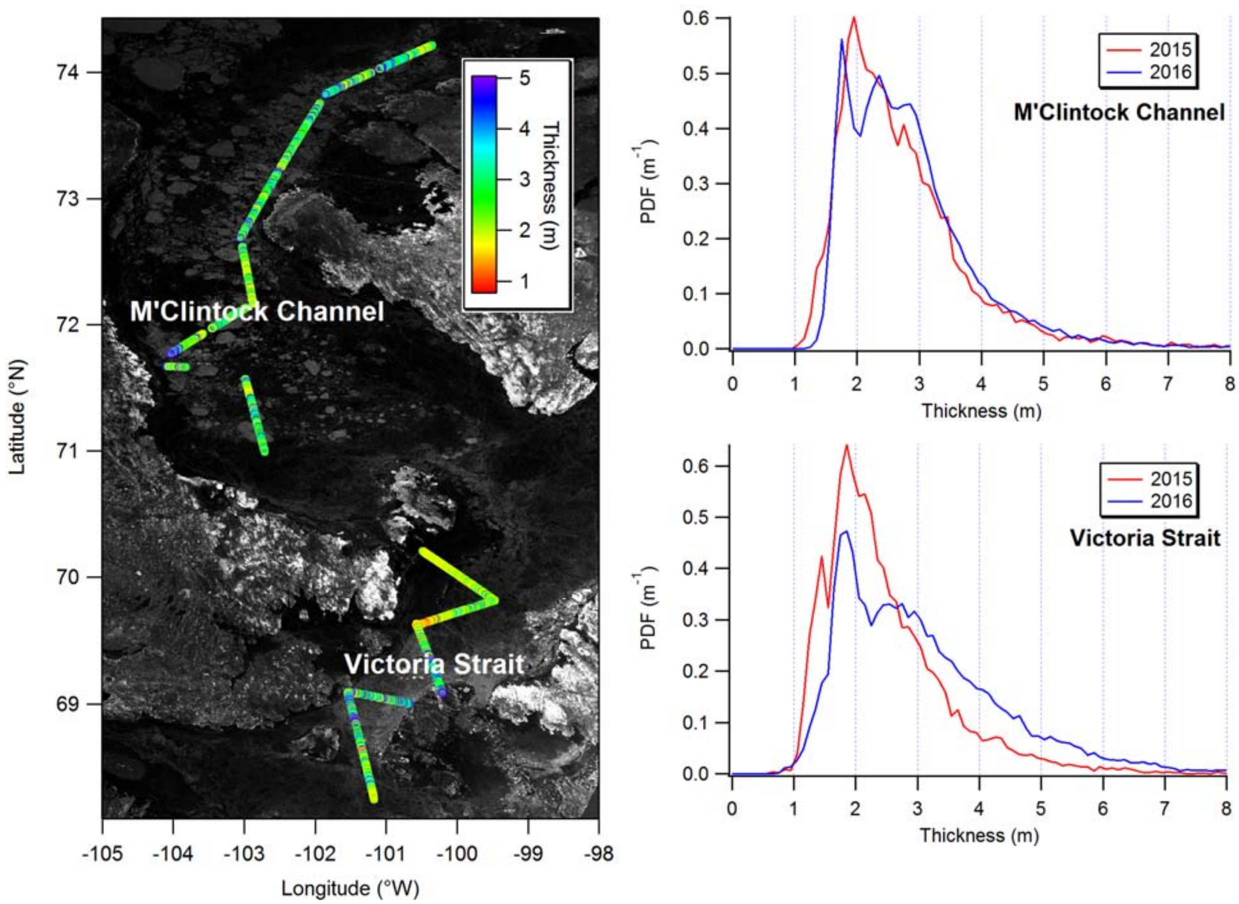

Figure 7: Sentinel 1 radar image of M"Clintock Channel and Victoria Strait, with 2016 ice thickness data overlaid (left). Right column shows thickness distributions obtained in both regions in 2015 (red) and 2016 (blue).

The thickness distributions of MCC (Figure 7, top right) show very similar FYI and MYI thicknesses for 2015 and 2016. FYI modes range between 1.8 m in 2016 and 2 m in 2015 (region 7 of Haas & Howell, 2015), while most MYI had thicknesses between 2 and 3 m. Ice thickness in VS was likewise very similar in 2015 and 2016 (Figure 7, bottom right). Old, level FYI had thicknesses of around 1.9 m in both years (region 10 of Haas & Howell, 2015). In addition, there are large amounts of highly deformed FYI, 2-3 m thick. In 2016, that deformed ice also contributed to a stronger tail of ice thicknesses > 4-5 m. However differences in the thickness and amount of deformed ice are biased by different flight tracks in 2015 and

2016, with the 2016 surveys including more nearshore ice which was also more strongly deformed.

Assuming similar weather conditions as in 2015, the similar ice thickness distributions in 2016 suggest similar ice conditions in the summer of 2016. However, the results presented here also show that winter ice conditions in the NWP remain largely unchanged, with widespread presence of thick MYI and highly deformed, thick FYI in certain key regions. Therefore, with less favorable weather conditions during spring and summer of 2016, there are likewise chances for a more severe ice season than in the summer of 2015.

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