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MORPHOLOGIES OF RIDGES SURVEYED OFF SVALBARD AND IN FRAM STRAIT, 2011 AND 2012 FIELD EXPEDITIONS

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ABSTRACT

Three first-year ice ridges were examined in the landfast ice of Svalbard, in the Barents Sea, and in the Fram Strait. The first ridge (R1-2011) was located in Woodfjorden, while the second one (R2-2011), was located in the Western part of the Barents Sea between Svalbard and Hopen Island. These surveys were conducted in March 2011 and one cross section for each ridge is presented. The third ridge (R2-2012) was located near the Fram Strait pack ice edge, and the survey took place in March 2012. Measurements of vertical profiles along the slightly curved spine of the ridge, and two transects perpendicular to the spine are presented for this ridge. The sail height, keel depth, consolidated layer thickness, rubble block sizes and porosities are examined for each ridge. The ice drift history of ridge R2-2012 is reconstructed from met.no ice drift vectors, showing that the ice followed a drift path south from the Atlantic Sector near the North Pole.

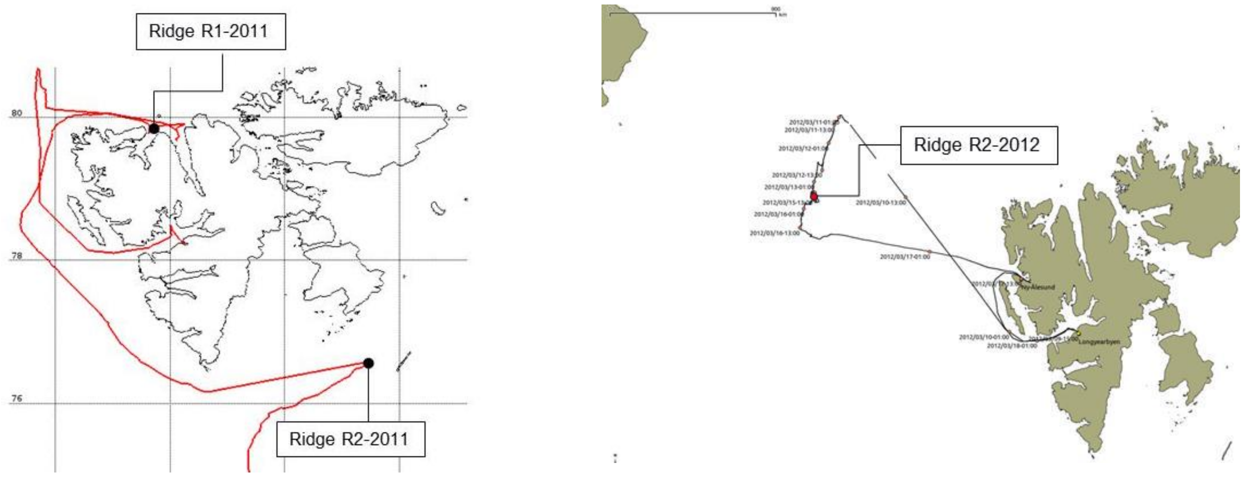
INTRODUCTION

First-year ice ridges are often a key consideration from an engineering perspective. In many cases first-year ridges control the design of offshore structures. Ridges also impede significantly the navigation in ice-infested regions and can scour the sea floor in shallow waters, which has significant consequences for the design of pipelines and other sub-sea installations. Ridges are complex structures with a wide variability in shape and size. Newly formed first-year ridges are made of poorly bonded individual ice pieces forming the sail above water line and a keel below. The blocks that initially pile up underwater form cavities which fill up with water. As the season progresses, the water freezes in these voids, and forms a consolidated layer of ice. The rubble, which is under the consolidated layer, consists of loose or partially consolidated blocks, with water trapped in between.

Strub-Klein and Sudom (2012) carried out a comprehensive analysis of the morphology of first-year ice ridges and gathered all available data and previous analyses on floating first-year sea ice ridges in one paper. The aim was to present a catalogue that is as complete as possible and to improve the existing relationships and statistical models for ridge geometry and morphology. Most of the data sources gathered by Strub-Klein and Sudom (2012) have earlier been used by Timco and Burden (1997), Sudom et al. (2011) or Strub-Klein (2011), with the addition of some data that was newly available or newly discovered by the authors. Data from surveys of the two ridges in Svalbard waters presented in this paper is also included in the catalogue, but the data for the ridge investigated in Fram Strait is not included. The results presented in this paper contribute to more data and knowledge in terms of geometry, morphology and consolidation of first-year ridges off Svalbard and in Fram Strait.

SITE AND EXPERIMENTAL METHOD

The first ridge (R1-2011) was located in Woodfjorden, while the second one (R2-2011), was located in the Barents Sea between Svalbard and Hopen Island, see Figure 1a. The surveys were conducted in the period from 20 – 30 March 2011. The third ridge (R2-2012) was located in the Fram Strait and was surveyed on 14 March 2012; see Figure 1b.



a) Expedition route for “ColdTech-2011”. b) Expedition route for “ColdTech-2012”.

Figure 1 Map of the tracks for the ColdTech expeditions and show the locations for the investigated ridges.

Measurements of geometry, porosity, morphology and physical-mechanical properties were made. Only one cross section was made for each of the ridges surveyed in Woodfjorden and Barents Sea by using 2″ Kovacs augers. A section along the spine and two perpendicular cross sections were drilled for the ridge located in the Fram Strait. In this manner the sail height, keel depth, the consolidated layer thickness, level ice thickness and even the porosity were measured. We are using the same definitions of ridge geometry and morphology as described by Strub-Klein and Sudom (2012) as shown in Figure 2.

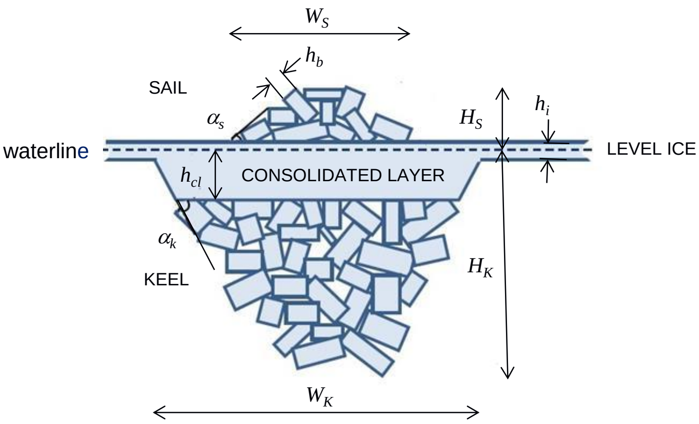


Figure 2 Typical model of a first-year ice ridge, after Strub-Klein and Sudom (2012).

The bottom of the consolidated layer is defined when the ice feels softer, when the auger reaches a gap or when water or slush is brought up by the auger. The porosity is defined by recording the vertical extension of each gap felt while drilling. However, this technique is subjective and operator dependent, so the consolidated layer thickness and morphology may be determined in an approximate way. A levelling telescope was used to measure the surface elevation and the thickness of the ice blocks in the sail was measured.

RIDGE GEOMETRY AND MORPHOLOGY

Ridge R1 -2011 surveyed in Woodfjorden

When the survey started on the ridge in Woodfjorden (R1-2011), the weather conditions were mild and probably due to rain prior to the survey, there was a mixture of water, wet snow and slush on the top of the level ice, which refroze quickly as the temperature decreased rapidly during the following night. The drilled cross section of the ridge R1-2011 is shown in Figure 3, which is based on 29 boreholes with 2 m spacing. The ridge was covered by a 0.39 m (average) thick snow layer on top of the ice. The cross section shows a classic shape with a triangular sail and keel, but the cross section is not symmetric as the top of the sail and bottom of the keel are skewed relative to each other.

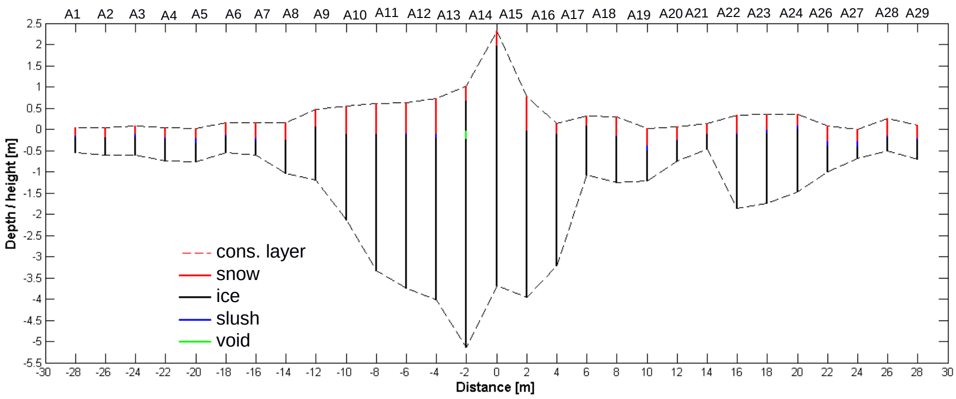


Figure 3 The drilled cross section for ridge R1-2011 located in Woodfjorden.

A summary of geometric properties of this ridge is given in Table 1 and compared with properties of typical or average ridges in Svalbard waters and Barents Sea as reported by Strub-Klein and Sudom (2012). Compared to a typical ridge in Svalbard waters, this ridge is larger and it is characterized by higher and wider sail and has a slack sail angle. The sail width and keel width are among the widest ridges included in the review made by Strub-Klein and Sudom (2012) for Svalbard waters. A wide keel, and a keel depth which is almost the same as a typical ridge in Svalbard region, results in a slack keel angle. The average level ice thickness near the ridge is 0.37 m and the average block thickness in the sail is 0.26 m. As shown in Figure 3, it was difficult to assess the difference in ice consistency between ice and slush, and a consolidated layer could not be determined. The mixture of water and slush on top of the ice added to this issue. The high block size to ice thickness ratio indicates that the ridge was probably formed fairly recently. The ridge was covered in a relatively thick, isolating snow layer and a mixture of water and slush on top of the level ice.

Table 1 Summary of geometric properties of the investigated ridges compared with mean values (max. values in parentheses) reported by Strub-Klein and Sudom (2012).

Ridge		H_s [m]	H_k [m]	W_s [m]	W_k [m]	A_s [m^2]	A_k [m^2]	a_s [deg.]	a_k [deg.]
R1-2011, Woodfjorden		2.3	5.1	18.0	37.4	20	96	14	15
R2-2011, Barents Sea		2.4	6.8	5.0	37.1	14	126	41	20
R2-2012, Fram Strait		2.0	6.7	8.0	24.4	11	65	23	24
Strub-Klein and Sudom (2012)	Svalbard	1.2(4.5)	4.8(10.8)	6.6(8)	13.8(37.4)	4(24)	33(202)	20	35
	Barents	2.1(4.7)	8.5(15)	10.2	37.0	11(35)	157(518)	22	25

Ridge R2 -2011 surveyed between Svalbard and Hopen Island

The drilled cross section of the ridge R2-2011 (located between Svalbard and Hopen Island) is shown in Figure 4 and it is established based on 18 boreholes at spacing of 2-2.5 m. The cross section has a triangular sail, and a keel with an almost flat bottom. The geometric properties are summarized in Table 1. The sail height of this ridge is almost the same as for a typical ridge in Barents Sea, but the sail width is narrow and sail angle is steep. The ridge has a shallow keel, but the keel width is almost the same as a typical for ridge in this area. The shallow keel results in a relatively slack keel angle. The consolidated layer thickness is estimated based on drillings and plotted in Figure 4. Maximum and minimum consolidated thickness is 6.1 m and 0.35 m, respectively, with an average of 1.48 m. The average level ice thickness near the ridge is 0.8 m, and average ice block thickness in the sail is 0.78 m. The high ice block to ice thickness ratio indicates that the ridge was probably formed only some few weeks prior to the investigations. The ridge was almost free of snow and it was difficult to observe any erosion of the ice blocks. Based on observations using underwater camera, a large portion of the keel seems to consist of long ice blocks that are stacked horizontally on top of each other and rotated approximately 45^o relative to the horizontal plane during formation of the ridge. Therefore, we suspect the holes drilled at the centre of the sail, i.e. holes (A9) and (A10), follows the long axis of the ice blocks which are stacked together. It is therefore believed that the estimated thickness of the consolidated layer is overestimated in this part of the keel.

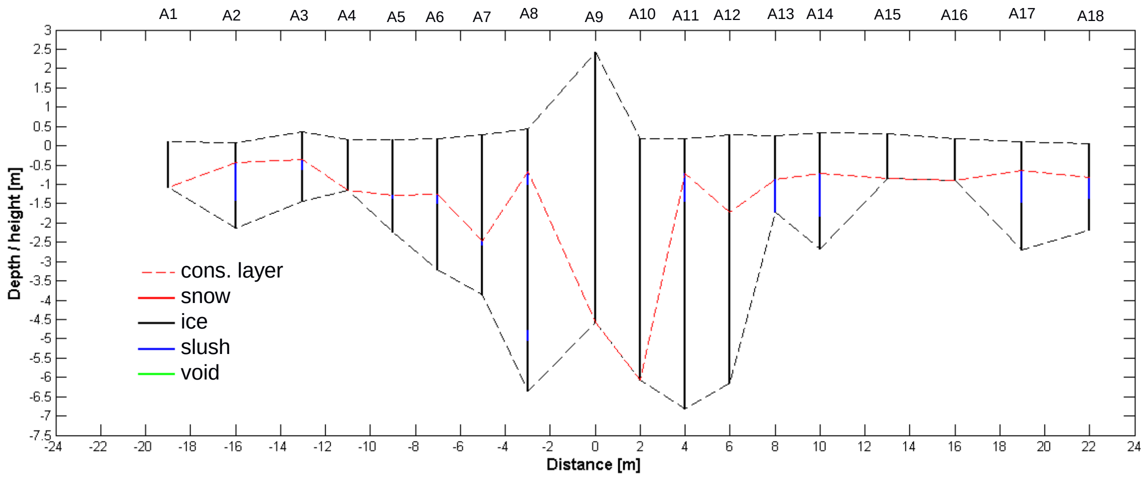


Figure 4 The drilled cross section for ridge R2-2011 located between Svalbard and Hopen Island.

Ridge R2-2012 surveyed in Fram Strait

In 2012 an ice floe about 200 m x 200 m with a number of irregular pressure ridges was chosen for investigation. The geometry of ridge R2-2012 was investigated through drilling vertical profiles along the slightly curved spine of the ridge, and two transects perpendicular to the spine as shown in Figure 5. The drilled sections are marked as line A (6 holes drilled at 5 m spacing) along the spine and lines B and C across the spine (20 holes drilled at 2 m spacing for each section) as indicated in Figure 5. The drilled profile along the spine of the ridge is shown in Figure 6, while the profiles along transect B and C are shown in Figure 7 and Figure 8, respectively.This ridge broke up due to heavy weather the day after it was investigated.

Figure 5 Photo of the ridge R2-2012 and illustrates the lines established for drilling of holes along the spine A and cross sections B and C.

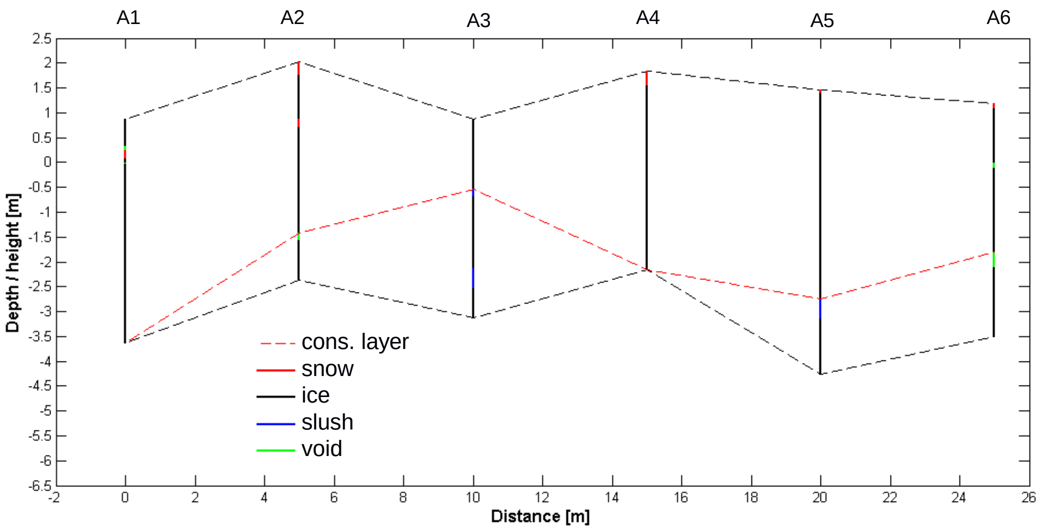


Figure 6 Drilled cross section along the spine of ridge R2-2012 located in the Fram strait.

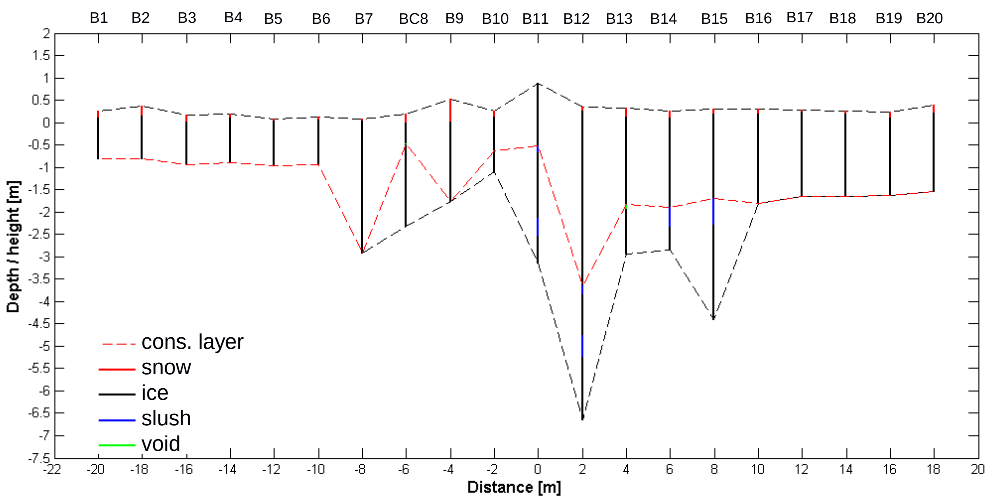


Figure 7 Drilled cross section along transect B of ridge R2-2012 located in the Fram strait.

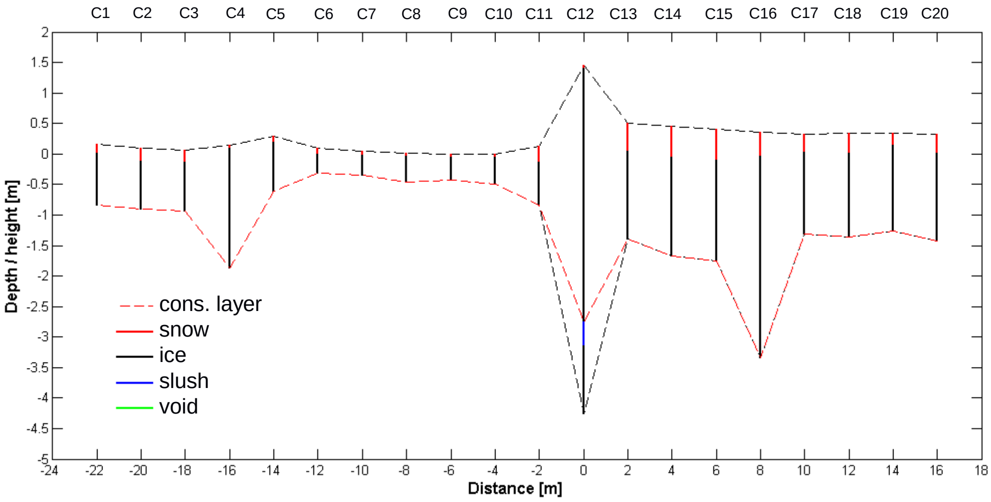


Figure 8 Drilled cross section along transect C of ridge R2-2012 located in the Fram strait.

The sail height varies from 0.87 m to 2.0 m along the spine and the average height was 1.2 m, while the variation of keel depth is in the range of 2.2 m to 4.3 m with an average value of 3.2 m. The maximum keel depth is 6.7 m as shown for transect B. The sail width varied between 5.5 m to 8.0 m with an average of 6.8 m and the keel width was fairly constant, i.e. between 23.2 m and 24.4 m. The ridge was probably formed as two ice floes of different thickness were compressed together. The average ice thickness of the thinner ice is 0.94 m, while the thickness of the thicker ice floe is 1.62 m. Maximum sail height for this ridge is approximately the same as a typical ridge in Barents Sea, but the the sail is more narrow. The sail angle is between 16^{o} for transect B, and 29^{o} for transect C, with an average of 23^{o}, which is in line with the typical sail angle of 22^{o}. The sail is built up of quite large blocks, as shown in Figure 5. The ice block thickness varies between 0.75 m and 1.0 m with an average thickness of 0.87 m. For the rectangular blocks, the ice block length to thickness ratio is in the range of 1.0 to 2.3.

The consolidated layer estimated by drilling are plotted on the cross sections in Figure 6 to Figure 8. Maximum and minimum consolidated layer thicknesses are 3.63 m and 0.53 m along the spine with an average thickness of 2.05 m. The average consolidated layer thickness for the entire ridge is 1.86 m. The highest gap/void for the entire ridge is at point B8 shown in Figure 7, i.e. consolidated thickness at this borehole is 0.48 m measured from the water line. As shown in Figure 8, there was a refrozen lead between boreholes C6 to C10. There is a relatively large distance between boreholes (2 m for transects B and C, 5 m along the spine). In addition, the sail is built up of quite large blocks. Due to large distance between the boreholes and relatively large ice blocks, we could easily have missed some voids between ice blocks. This is also a matter of how the blocks in the keel are stacked together.

ICE DRIFT

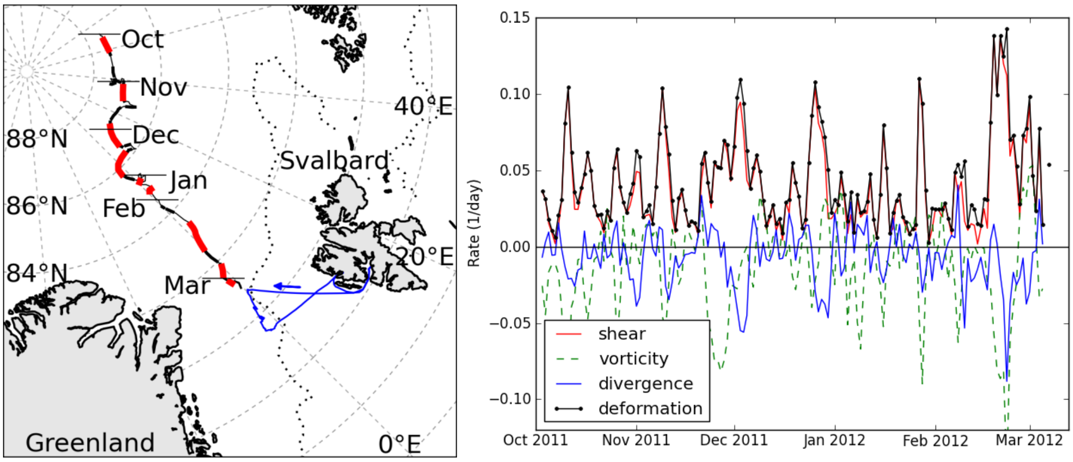
The drift path of the ice investigated and associated deformation of ice pack were evaluated to estimate the likely time of formation of ridge R2-2012. The drift path was derived from met.no sea ice drift vector fields (Lavergne et al., 2010). For every day from 1 October until May, the Low Resolution sea ice drift product of met.no provides the translation of an ensemble of grid points over the course of 2 days. The grid spacing is 62.5 km. From this a likely drift trajectory was estimated for the ice encountered on 11 March. First, the approximate position on 1 October was determined for this ice by tracing ice drift backward in time. Following this, forward drift trajectories were calculated for starting points within a radius of 500 km, separated by as little as 5 km. The trajectory with the smallest distance to the ship position on 11 March was chosen to represent the ice drift trajectory. Sea ice deformation along the drift track was determined from the same sea ice drift vector fields. Following Kwok (2006), the invariants of the drift field, i.e. divergence, vorticity, and shear, are defined as:

$$DIV = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}, CURL = \frac{\partial u}{\partial y} - \frac{\partial v}{\partial x}, SHEAR = \left[\left(\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y} \right)^2 + \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \right)^2 \right]^{1/2} \qquad (1)$$

were u and v are the drift components in East and North direction, respectively. The differentials were evaluated over ±100 km (i.e, 1.5 grid cell sizes) around the drift trajectory for every day. Deformation is due to the combination of divergence and shear,

$$DEF = \left[DIV^2 + SHEAR^2 \right]^{1/2} \qquad (2)$$

The derived drift track for ice encountered on 11 March 2012 is shown in Figure 9a. It is expected that ice encountered followed a trajectory in the Arctic Basin on 1 October 2011 (72.4° E, 87.57° N). Drifting to the west and to the south, the ice reached 0° E, 86° N in December when it changed course due south until 11 March. The proposed origin is consistent with previous assessments of ice drift. Pfirman et al. (1997), based on wind and buoy drift data from 1979 to 1994, concluded that ice in this area typically leaves the Arctic within one year. This assessment extends to more recent years as drift rates increased since (Rampal et al., 2009). The invariants of the drift field along the track are shown in Figure 10b. Deformation is dominated by shear, and notable deformation events at a scale of 100 km or larger occurred every 3 to 4 weeks. The last significant period of deformation was at the end of February, with a tail extending to the end of the record.



a) b)

Figure 9 (a) Overview map of reconstructed ice drift track shown from 1 October 2011 until 11 March 2012. Positions are marked on the first of each month (horizontal lines). Periods of deformation (>0.05 day^{-1}, thick black line) and heavy deformation (>0.075 day^{-1}, thick red line) are indicated. Ship track (blue solid line) and ice edge on 11 March 2012 (dotted line) are shown for illustration. (b) Total deformation, shear, vorticity, and divergence of the ice field along the drift path.

We conclude that pressure ridge R2-2012 most likely formed at the end of February or early March 2012, i.e. approximately 10 to 30 days prior to the investigation. The ice pack underwent an extended period of deformation at that time. Further, comparing block size and level ice thickness of 0.87 m and 0.94 m, respectively, it is entirely plausible that 0.07 m of ice formed during the 10 to 30 days between deformation and characterization (cf. ice thickness development at other Arctic locations, e.g. Barrow, Alaska, (Petrich et al., 2013).

ANALYSIS AND DISCUSSION

Ridge geometry

Parametric relationships for the investigated ridges are given in Table 2 and compared with similar data reported by Strub-Klein and Sudom (2012) for Svalbard waters and Barents Sea.

Table 2 Parametric relationships for the investigated ridges compared with key ratios reported by Strub-Klein and Sudom (2012).

Ridge	Comment	H_k/H_s	W_k/H_k	W_k/H_s	W_s/H_s	W_k/W_s	A_k/A_s
R1-2011	trans. A	2.2	7.3	16.1	7.8	2.1	4.8
R2-2011	trans. A	2.8	5.5	15.3	2.1	7.4	9.3
R2-2012	total	3.3	3.6	11.7	3.3	3.5	6.1
Strub-Klein and Sudom (2012)	mean	5 (4.4)	4.9	20.9	3.8	6.8	8.4 (14.7)
	max	11.8 (13.2)	16.7	86.7	9.6	35.9	8.3 (14.7)
The same values apply for Svalbard waters and the Barents Sea, (values for Barents Sea are given in parentheses).							

Ridge R1-2011

The ridge located in Woodfjorden (R1-2011) is characterized by a low keel depth to sail height ratio. This ridge is among the widest ridges included in the review made by Strub-Klein and Sudom (2012) for Svalbard waters, which is indicated by a very low keel width to sail width ratio and low sail width to sail height ratio. A wide keel results in high keel width to keel depth ratio. The keel area to sail area ratio for this ridge is considerably lower than the ratio reported by Strub-Klein and Sudom (2012) for this region.

Ridge R2-2011

Compared to a typical ridge in Barents Sea, the ridge R2-2011 is characterized by low sail width to sail height ratio, i.e. it has a narrow sail width. The shallowness of the keel is indicated by the low keel depth to sail height ratio, low keel width to sail height ratio and somewhat higher keel width to sail height ratio. The ridge has a considerably lower keel area to sail area ratio compared to the typical ratio for Barents Sea.

Ridge R2-2012

The ridge R2-2012 is characterized by low sail width to sail height ratio, keel width to keel depth ratio, keel width to sail height ratio, and keel width to sail width ratio. This means that this ridge has a sail height which is typical for Barents Sea, but the sail width is narrow and it has a shallow and narrow keel. The keel area to sail area ratio for this ridge is also lower than typical for Barents Sea.

Ridge morphology and porosity

The dynamics around ridges can be such that the surrounding ice thickness changes with time; more rafting events can occur, or the existing surrounding ice can grow, melt or even disappear. Therefore, the size of the blocks are considered to be a better representation of the original level ice thickness than the actual ice surrounding the ridge at the time the measurements were done. The average level ice thickness and average block sizes in the sail for the investigated ridges are summarized and compared with typical values reported by Strub-Klein and Sudom (2012) for Svalbard waters and Barents Sea in Table 3. A measure for the degree of consolidation of first year ridges can be related to the geometric ridge properties, i.e., the consolidated layer thickness to level ice thickness ratio, consolidated layer thickness to sail height ratio and consolidated layer thickness to keel depth ratio as given in Table 3.

Table 3 Key morphological values of investigated ridges compared with data reported by Strub-Klein and Sudom (2012).

Ridge		h_i [m]	h_b [m]	h_{cl} [m]			h_{cl}/h_i		h_b/h_i	h_{cl}/H_s		h_{cl}/H_k	
				Min.	Avg.	Max.	Min.	Avg.		Min.	Avg.	Min.	Avg.
R1-2011		0.37	0.26	-	-	-	-		0.70	-	-	-	-
R2-2011		0.80	0.78	0.35	1.48	6.06	0.44	1.85	0.98	0.15	0.62	0.05	0.22
R2-2012		0.94	0.87	0.48	1.86	3.65	0.51	1.98	0.93	0.24	0.93	0.07	0.28
Strub-Klein and Sudom (2012)	Svalbard	1.05	0.31	-	1.37	5.41	-	1.30	0.30	-	1.14	-	0.29
	Barents	0.76	0.67	-	1.47	4.53	-	1.93	0.88	-	0.70	-	0.17

Ridge R1-2011

The ice thickness near ridge R1-2011 is 0.37 m, which is only 45% of the average ice thickness measured near ridges for Svalbard waters, but the ice block thickness is in the same range. The low ice block to level ice ratio indicates that the ice growth is low between ridge formation and when the survey took place, which supports the assumption that the consolidation of this ridge is low. As pointed out earlier, we could not discover any consolidation of ridge R1-2011 by drilling. According to Strub-Klein and Sudom (2012), the consolidated layer thickness to level ice thickness ratio for a typical ridge in Svalbard region is 1.3. Based on the level ice level ice thickness of 0.37 m, the consolidated layer is estimated to be approximately 0.5 m. Macro porosity of ice rubble is defined as $\eta=V_c/V=1-V_i/V$, where V_c is the volume of cavities between the solid ice blocks (water, slush, snow and air) and V_i is the volume of solid ice blocks. As described earlier, the ridge in Woodfjorden (R1-2011) was covered with a 0.39 m thick snow layer on top of the ice, which results in very high macroscopic porosity of the sail, i.e. 73%, and a relatively high macroscopic keel porosity (11%). However, the macroscopic ridge porosity of the entire ridge is 21%, which is more or less in line with the ridge porosity for Svalbard waters. According to Strub-Klein and Sudom (2012), typical values for the sail, keel and ridge porosities in Svalbard waters are 14%, 7% and 23%, respectively.

Ridge R2-2011

The ice block to level ice thickness ratio for ridge R2-2011 is high, i.e. the ice growth is small after ridge formation. If the consolidated layer thickness is defined as the highest gap or void of the entire drilled profile, the minimum consolidated thickness is 0.35 m and therefore, the consolidated layer to level ice ratio, consolidated layer to sail height ratio and consolidated layer to keel depth ratio are considerable lower than the typical ratios for Barents Sea ridges. Based on the average consolidated layer thickness of 1.48 m, the consolidated layer to level ice ratio, consolidated layer to sail height ratio and consolidated layer to keel depth ratio, are in the same range as a typical ridge in Barents Sea, see Table 3. The sail of the ridge R2-2011 was virtually free of ice, and sail consisted of ice blocks with an average thickness of 0.78 m, while keel was made up of large part of rafted ice. The macroscopic porosity of the sail is 0%, keel porosity of 13%, and macroscopic ridge porosity of 12%, are considerable lower than typical ridge in Barents Sea, i.e. sail porosity of 19%, keel porosity of 27% and total ridge porosity of 27%, as reported by Strub-Klein and Sudom (2012).

Ridge R2-2011

We already concluded that ridge R2-2012 most likely is formed approximately 10 to 30 days prior to the investigation, which is also supported by the high ice block thickness to level ice thickness ratio. Based on the minimum consolidated thickness of 0.48 m, the consolidated layer to level ice thickness ratio, consolidated layer thickness to sail height ratio and consolidated layer thickness to keel depth ratio are considerable lower than the ratios reported by Strub-Klein and Sudom (2012) for Barents Sea. Based on the average consolidated layer thickness of 1.86 m, the resulting ratios defining the degree of consolidation as summarized in Table 3, are in the same range as a typical ridge in Barents Sea. The macroscopic sail porosity of the ridge R2-2012 in Fram Strait is 54% and is very high, which may be due a high degree of snow in the sail. The keel porosity of 6% and total ridge porosity of 12% are considerably lower than a typical ridge in Barents Sea. As described earlier, the ridge R2-2011 consists of a large part of rafted ice stacked together, while the ridge R2-2012 is built up of quite large blocks. Due to large distance between the boreholes and relatively large ice blocks, we could easily have missed some voids between ice blocks. This is probably the reason for the low macroscopic porosities obtained for these ridges.

Bonnemaire et al. (2003) assumed a consolidated layer to level ice ratio is between 1.3 and 1.6 in the ridge they investigated in the Barents Sea, based on previous estimations of the level ice thickness in the same area and assuming that the level ice is undisturbed. Høyland (2007) reported a ratio of 2.0 for three ridges in the Barents Sea, but also identified the difficulty of measuring an undisturbed level ice close the ridges. This is only slightly higher than the ratio between 1.85 and1.98 found for the investigated ridges presented herein. The ISO Codes (ISO 19906, 2010) recommend that in the absence of field data, to assume the consolidated layer is twice as thick as the surrounding level ice which has grown under the same conditions as the ridge.

SUMMARY

Three first-year ice ridges were examined in the landfast ice of Svalbard, in the Barents Sea, and in the Fram Strait. The ridge located in Woodfjorden is characterized by a high and wide sail, but the keel width and keel depth is almost the same as a typical ridge in Svalbard region. Maximum sail height of this ridge was 2.3 m, while the keel depth was 5.1 m. The keel depth to sail height ratio, keel width to sail width ratio and sail width to sail height ratio are low. A wide keel results in high keel width to keel depth ratio. The keel area to sail area ratio is also low. The high block size to ice thickness ratio indicates that the ridge was probably formed only some few weeks prior to the investigations. A consolidated layer could not be detected by drilling through the ridge. The relatively thick, isolating snow layer and the mixture of water and slush on top of the level ice, in combination with relative mild weather conditions also support this assumption of little consolidation of the ridge.

The ridge located between Svalbard and Hopen Island, is characterized by low sail width to sail height ratio, i.e. it has a narrow sail width and sail height of 2.4 m, which is typical for Barents Sea. The ridge has a shallow keel with maximum keel depth of 6.8 m, and the keel width is almost the same typical for this region. The shallow keel is indicated by the low keel depth to sail height ratio, low keel width to sail height ratio, and somewhat higher keel width to sail height ratio. The keel area to sail area ratio is low for this ridge. The average level ice thickness of 0.8 m and average ice block thickness is 0.78 m. Based on the average consolidated layer thickness 1.48 m, the consolidated layer to level ice thickness ratio, and consolidated layer to sail height ratio are in the same range as a typical ridge in Barents Sea.

Based on the environmental history, reconstructed from ice drift and reanalysis products, we concluded that pressure ridge R2-2012 located in Fram Strait, most likely was formed approximately 10 to 30 days prior to the investigation. The ridge was probably formed as two ice floes of different thickness were compressed together. The average ice thickness of the thinner ice is 0.94 m, while the thickness of the thicker ice floe is 1.62 m. This ridge is characterized by low sail width to sail height ratio, keel width to keel depth ratio, keel width to sail height ratio and keel width to sail width ratio. This ridge has a maximum sail height of 2.0 m, which is typical for Barents Sea, but the sail width is narrow and it has a shallow keel, and narrow keel, maximum keel depth of this ridge was 6.7 m. The keel area to sail area ratio is also lower than typical for Barents Sea. The average thickness of the consolidated layer is 1.86 m. The consolidated layer thickness to level ice thickness ratio, and consolidated layer thickness to sail height ratio and consolidated layer thickness to keel depth ratio is in the same range as a typical ridge in Barents Sea.

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