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Relationship between transpolar flights over the Arctic and the upper atmospheric circulation

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Abstract

International flights from North America to Asia usually take tracks across the Arctic region for reducing fuel and operating costs. For example, the track of United Airlines flight 895 (UAL895) traveling from Chicago to Hong Kong via the Arctic region usually uses the following three routes: the Atlantic, central Arctic, and Pacific routes. Using a reanalysis product, we show that flight routes depend on the location and strength of the upper flow over the Arctic Ocean, which has a seasonal variation. During summer, when anticyclonic flow associated with blocking occurs over the Pacific Arctic region, UAL895 flights choose the Pacific and Atlantic routes to avoid a strong head wind. In addition, when the jet stream is strong over the Atlantic–Arctic region (the northern parts of Greenland and Barents Seas), the Atlantic route is selected to take advantage of strong tail winds resulting from the blocking over this region. During winter and, especially, years with less sea ice in the Bering Sea, the frequency of Alaskan blocking has increased, indicating that the prediction of the sea-ice extent over the Bering Sea would provide useful information for aircraft operation over the Arctic region.

Key words: Arctic flight track, sea-ice extent, blocking events

1. Introduction

Aircrafts contribute to the emissions of carbon dioxide (CO₂), water vapor (H₂O) and oxides of nitrogen, leading to global climate change (Lee and others 2009; 2010). Aircraft CO₂ emissions have increased to 2.5% of the total anthropogenic emitted CO₂ over the previous 50 years (Lee and others 2009). The strengthened column-averaged, north–south temperature-gradient response to the increase in CO₂ has caused an increased level of upper-level clear-air turbulence, which is a major cause of aviation incidents (e.g., injured passengers, structural damage, flight delays) (Sharman and others 2006). Previous studies have reported an increase in the frequency and intensity of turbulence at upper levels for a doubling of the CO₂ concentration (Williams and Joshi 2013, Williams and others 2017, Storer and others 2017). A reduction in fuel usage would, therefore, help to reduce operating costs and minimize climate impacts.

Two approaches to reduce aircraft emissions are the development of technologies (e.g., efficient engines, clean fuels, body and wing forms) and the improvement of air-traffic management (e.g., shortening flight times), which may be optimized by monitoring the upper atmospheric circulation, because aircraft routes and flight lengths mainly depend on the horizontal wind speed at upper levels (Palopo and others 2010).

Therefore, avoiding headwinds and enhancing the probability of tailwinds would reduce aircraft fuel consumption. Previous studies have reported that the change in the phase of atmospheric circulation over the Atlantic sector causes changes in the position and strength of the jet stream, and thereby influences aircraft routes (Irvine and others 2013; Kim and others 2016; Williams 2016). Kim and others (2016) indicated certain links between the route and travel time of a flight from New York to London and the phase of the North Atlantic Oscillation (NAO). In the positive phase (NAO+), when the jet stream tends to shift northward over the northern Atlantic Ocean, flight times become shorter than during the negative phase (NAO-). In addition, the number and timing of the route varies with the season because of differences in the strength and location of the jet stream in summer and winter (Irvine and others 2013). In contrast, over the Pacific Ocean, changes in atmospheric circulation over high and low latitudes (e.g., resulting from the Arctic and El Niño Southern Oscillations) affect the flight time of aircraft at mid-latitudes (Karnauskas and others 2015). Therefore, the route and season are strongly influenced by atmospheric circulation patterns over the Northern Hemisphere.

Polar routes exist to minimize the total travel time and fuel consumption of aircraft travelling from one

continent to another. The commencement of cross-polar flight began in 1998 when entry into Russian airspace was permitted by the Russian Government (Jacobson and others 2011). The number of international flights that use the Arctic route has been increasing in recent decades, with several companies currently using the cross-polar flight track throughout the year.

The United Airlines (UAL) flight 895 travels from Chicago (ORD) to Hong Kong (HKG) almost every day, which, to minimize the distance and time of flight, passes over the Arctic region (Fig. 1a). However, flight UAL895 does not always travel the shortest route from ORD to HKG, suggesting the dependence of the Arctic route on the upper level flow over the Arctic Ocean. We investigate here the relationship between the flight track and the upper-level atmospheric circulation, particularly during the summer and winter seasons.

2. Data and methodology

2.1 Meteorological data

We use 6-h ERA-Interim reanalysis data from January 1979 to December 2016 on a $0.75^\circ \times 0.75^\circ$ latitude/longitude grid produced by the European Centre for Medium-Range Weather Forecasts (Dee and others 2011) for determination of the geopotential height, wind speed, sea-surface temperature, and sea-ice concentration. We mainly focus on the atmospheric circulations during summer (from May to August, hereafter MJJA) and winter (from December to March, hereafter DJFM). To calculate the frequency of blocking events over the Northern Hemisphere, we apply a blocking index defined by D'Andrea and others (1998). At each longitude, the meridional gradient of geopotential height at 250 hPa (Z_{250}) between the southern and northern parts of Z_{250} ($GHGS$ and $GHGN$) are calculated as

$$GHGS = Z(\psi_0) - Z(\psi_s) / (\psi_0 - \psi_s) \quad (1)$$

and

$$GHGN = Z(\psi_n) - Z(\psi_0) / (\psi_n - \psi_0) \quad (2)$$

respectively, where

$$\begin{aligned} \psi_n &= 76.5^\circ \pm \Delta \\ \psi_0 &= 60.0^\circ \pm \Delta \\ \psi_s &= 43.5^\circ \pm \Delta \end{aligned} \quad (3)$$

for $\Delta = 0^\circ, 0.75^\circ, 1.5^\circ, 2.25^\circ, 3.0^\circ, 3.75^\circ, 4.5^\circ$.

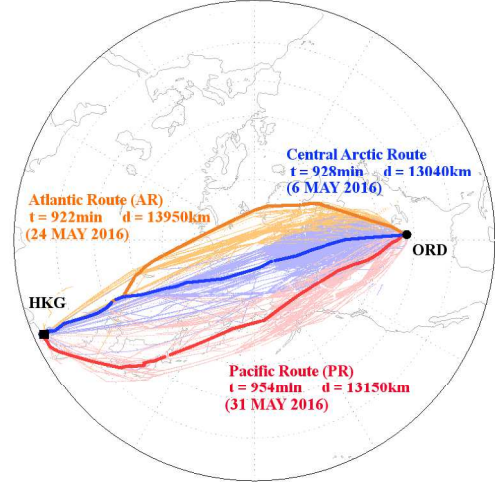
A specific longitude on a given day is locally defined as being blocked if both of the following conditions are satisfied (for at least one value of Δ):

$$GHGS > 0 \quad (4)$$

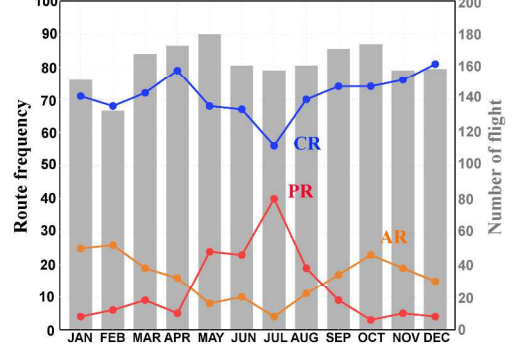
and

$$GHGN < -5 \text{ m/}(\text{degrees latitude}) \quad (5)$$

(a) UAL 895 flight routes



(b) Route frequency [2011–2016]



(c) Bering Sea Ice Cover [60–70°N, 180–210°E] (DJFM)

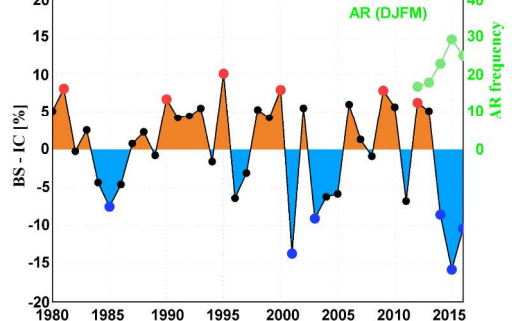


Fig. 1 (a) All flight tracks (thin lines) and the representative track (thick lines) for the Atlantic (AR, orange), central Arctic (CR, blue) and Pacific routes (PR, red) for May 2016. The time and distance for the representative tracks are shown.

(b) Monthly average frequency of each route from 2011–2016. Gray bars show the number of flights from Chicago (ORD) to Hong Kong (HKG) via the Arctic region from 2011–2016.

(c) Ice-cover anomaly during December and March from the climatology over the Bering Sea (60–70°N, 180–210°E) from ERA-Interim. The green line shows the frequency of flights taking the Atlantic route.

2.2 Flight track data

Flight information is obtained from the flightaware website (<https://flightaware.com>), which provides the location, height and total flight time of commercial flights all over the world. We focus on flight UAL895

from ORD to HKG over the Arctic region (Fig. 1a), whose average total flight time is about 16 h depending on the flight track. Flight information is available since 2011, which is a relatively long time period compared with other flights for this route.

We use the northernmost position of aircraft over the Atlantic (15°W – 15°E) and Pacific (165°E – 165°W) Arctic regions to classify UAL895 flight tracks, resulting in three routes: the Atlantic route (northward of 75°N over the Atlantic–Arctic region or northward of 87°N over the Pacific–Arctic region), the central Arctic route (from 72°N to 87°N over the Pacific–Arctic region) and the Pacific route (southward of 72°N over the Pacific–Arctic region). Examples of flight tracks for each route in May 2016 are shown in Fig. 1(a). As the central Arctic route is the most efficient and shortest route between ORD and HKG, it is the most common of the three routes throughout the year (Fig. 1(b)). Both the Atlantic and Pacific routes have a longer distance compared with the central Arctic route, however, flight UAL895 sometimes chooses them at a frequency depending on the season. While the Pacific route has a higher frequency during MJJA, the Atlantic route has a higher frequency during DJFM, indicating that the aircraft routing over the Arctic region depends on the atmospheric circulation and season.

3. Relationship between the Arctic flight route and upper-atmospheric circulation

3.1 Summer

During summer, flight UAL895 chooses the central Arctic or Pacific routes almost exclusively (Fig. 1(b)). To understand the difference in upper atmospheric circulation patterns between the central Arctic and Pacific routes, we constructed maps of geopotential height and wind speed at 250 hPa (Z250 and W250) by subtracting the composites of central-Arctic-route days from those of Pacific-route days during summer. Figure 2(a) shows the differences in Z250 and W250 between the Pacific- and central-Arctic-route days during summer, with positive anomalies of Z250 found over the Pacific–Arctic sector. The head-wind anomalies from far eastern Eurasia to the Canadian Arctic Archipelago are consistent with an anticyclone flow associated with positive Z250 anomalies. In contrast, the tail-wind anomalies associated with positive Z250 anomalies are seen from eastern Asia to Canada. Therefore, the Pacific route is very favorable for flight UAL895 when the head wind over the Pacific–Arctic region is strengthened, and the tail-wind anomaly is strong from Alaska to eastern Asia.

The positive anomalies of Z250 suggest the increase in the frequency of summer blocking over eastern Asia and the Beaufort Sea during Pacific-route days. The peak blocking events over the European–Atlantic and Pacific regions are significant weather events according

to previous studies (Matsueda 2009, Matsueda and Endo 2017, Hoffman and others 2014). We show the difference in the frequency of summer blocking events between the central-Arctic-route and Pacific-route days in Fig. 3(a), where, over the Pacific region (around 150°E and 130°W), two peaks of the difference in the frequency of blocking are clearly seen. The increases in the blocking frequency are consistent with a positive Z250 anomaly over eastern Asia and Alaska/northern Canada (Fig. 2(a)). When the blocking dominates over the Pacific–Arctic region, flight UAL895 takes the Pacific route to avoid the strong head wind associated with this blocking pattern. This result suggests that the blocking events over the Pacific–Arctic regions and eastern Asia are the fundamental phenomena governing flight routes during summer.

3.2 Winter

We focus on the difference in atmospheric circulation between the central Arctic and Atlantic routes, where the latter is more frequent during winter (Fig. 1(b)). Using the same composite maps as in Fig. 2(a), but focusing on the winter case (Fig. 2(b)), we see that for Atlantic-route days, positive Z250 anomalies appear over Alaska and western Canada, causing head-wind anomalies from the central Arctic to the Canadian Arctic Archipelago. In contrast, tail-wind anomalies exist from northern Greenland to central Siberia. The positive Z250 anomaly dominates over the Barents Sea, enhancing anticyclonic flow at the upper level. For Pacific-route days, positive Z250 anomalies are found over Alaska and western Canada, however, a positive W250 anomaly is not clearly seen over the Barents Sea (not shown).

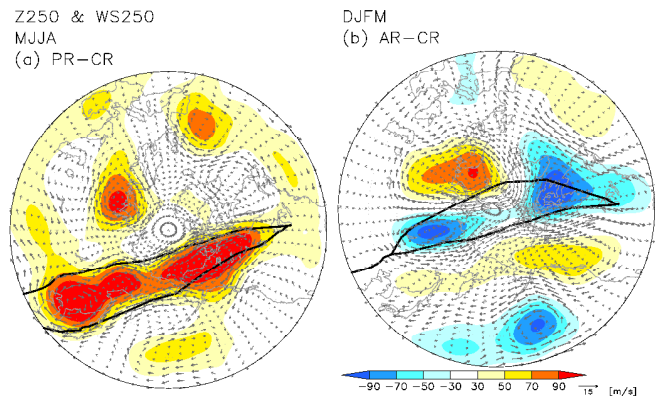


Fig. 2 (a) Difference maps in geopotential height (Z250 [m]: shading) and air velocity (vectors [m/s]) at 250 hPa between the Pacific (PR) and central Arctic (CR) routes for summer (MJJA).

(b) Difference maps in geopotential height (shading [m]) and velocity (vectors [m/s]) at 250 hPa between the Atlantic (AR) and central Arctic routes for winter (DJFM). Black contours show the representative tracks as shown in Fig. 1a.

During winter, relatively higher blocking frequencies are found over the European–Atlantic and Pacific sectors for Atlantic-route and central-Arctic days. There is a difference in blocking frequencies over the European–Atlantic sector (between 20°E and 50°E) and the Pacific region (between 150°E and 130°W) in winter (Fig. 3b), although the amplitude of difference is smaller than that in summer. The peak European–Atlantic (Pacific) blocking difference results from a positive anomaly of Z250 over the Barents Sea (from Alaska to western Canada), suggesting that the winter blocking over the Pacific and European–Atlantic sectors impacts the aircraft route over the Arctic Ocean.

3.3 Atmospheric response to change in Arctic sea ice

The decline in Arctic winter sea ice promotes turbulent heat release into the atmosphere, resulting in a geopotential height anomaly over the Arctic region (Rinke and others 2013). To understand the atmospheric response to sea-ice decline over the Arctic, we focus on years with low and high sea-ice extent in the Bering Sea (Fig. 1(c)), and investigate the difference in the atmospheric circulation in Z250 fields during winter (Fig. 4(a)). The Z250 anomaly pattern is similar that for Atlantic-route days as shown in Fig. 2(b), particularly for the Western Hemisphere, indicating that this anomaly pattern may be a response to the decline in Bering Sea ice. In fact, the frequency of Atlantic-route days during winter was relatively high during years of low ice extent (the winters of 2015 and 2016), while in years with a high ice extent (the winters of 2012 and 2013), the frequency was relatively low compared with other years. To investigate the relationship between the sea-ice extent over the Bering Sea and the atmospheric circulation over the Northern Hemisphere, we performed regression analyses between Z250 and the sea-ice concentration over the Bering Sea (Fig. 4(b)), giving a positive correlation over western Canada and a negative correlation over the North Pacific. This pattern of Z250 is similar to patterns of the Z250 anomaly during years with a low ice extent (Fig. 4(a)) and Atlantic-route days (Fig. 2(b)), although the amplitude of Z250 is smaller than for Z250 anomalies in Figs. 2(b) and 4(a), indicating that the increased Alaskan blocking frequency during years with a low ice extent influences flight operations.

For composite maps as in Fig. 4(a), but focusing on the summer case, the Z250 anomaly pattern is different from the winter case in terms of the atmospheric response to sea-ice decline over the Bering Sea (not shown), because anomalous snow melting in northern Eurasia leads to summer atmospheric circulation anomalies (Matsumura and others 2010). Matsumura and Yamazaki (2012) found that large surface heating associated with early snow melting in northern Eurasia

forms an anticyclonic circulation anomaly over eastern Siberia. In addition, the El Niño–Southern Oscillation and the development of the Okhotsk High determine the degree of summer blocking over the eastern Asia region (Park and Ahn 2014).

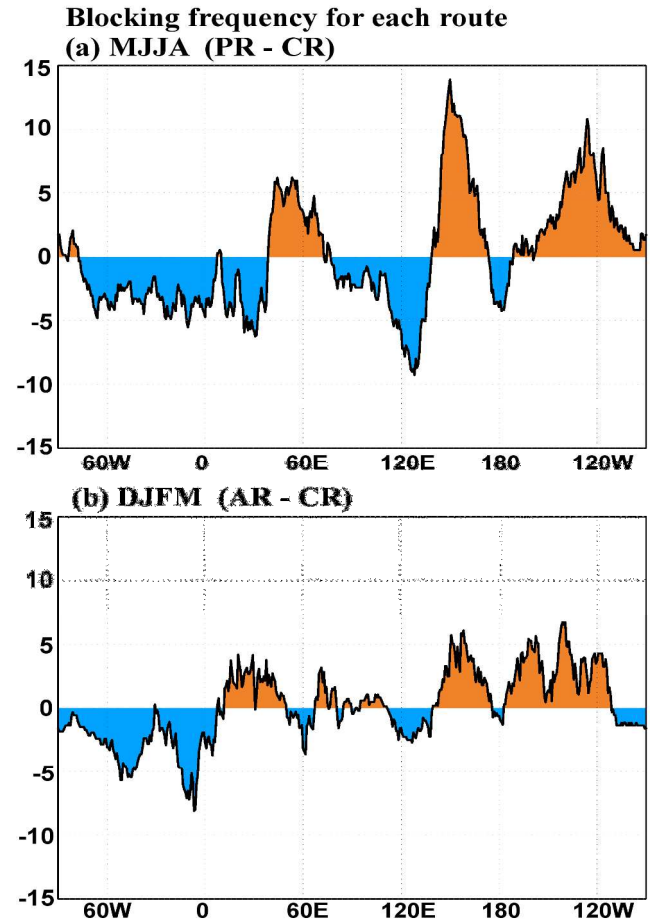


Fig. 3 (a) Difference in frequency of blocking [%] between the Pacific (PR) and central Arctic (CR) routes (PR-CR) in summer (MJJA) as a function of longitude.

(b) Difference in frequency of blocking [%] between the Atlantic (AR) and central Arctic (CR) routes (AR-CR) in winter (DJFM) as a function of longitude.

4. Summary and discussion

We have investigated the relationship between the upper level flow over the Northern Hemisphere and flight tracks over the Arctic region. The tail wind anomaly from northern Greenland to western Siberia is induced by European–Atlantic blocking, which influences flight operations during winter. Alaskan blocking events during summer, which result in a head-wind anomaly from eastern Siberia to the Canadian Arctic Archipelago, impede aircraft from crossing the central Arctic route, while the tail wind anomaly from Alaska to eastern Asia is favorable for the Pacific route. Our composite analysis demonstrates the impact of blocking events on aircraft routes.

However, operational and fuel costs must be discussed before the beneficial operation of flights can be considered. Operational costs not discussed here include the cost of entering another country's airspace, which differs for each country. Previous studies have reported that the increased probability of a tail wind minimizes the total flight time, and reduces the fuel and operational costs (Williams 2016, Karauskas and others 2016, Kim and others 2016). Based on results of these studies, using the tail wind anomaly from northern Greenland to western Siberia and over the Pacific Ocean, while avoiding the head wind anomaly area from eastern Siberia to the Canadian Arctic Archipelago, would reduce operational and fuel costs. Hence, the accurate forecast of blocking events is important for aircraft operation over the Arctic region.

The frequency of summer Pacific blocking events from 2051 and 2110 is expected to increase slightly (Matsueda and Endo 2017). In addition, Pacific blocking events lasting 15–29 days are predicted to increase in the future, suggesting that planning would be simplified because once a blocking situation develops, the atmospheric pattern likely persists for weeks, which favors the Pacific route. In contrast, winter blocking events lasting 9 days or less are expected to increase in the future. Our results show that the frequency of the Alaskan blocking event is related to the sea-ice concentration over the Bering Sea, and would be the determining factor during years with a low sea-ice extent in the Bering Sea. An accelerated decline in the Arctic sea ice would lead to an increase in the frequency of Alaskan blocking events, which would continue to influence aircraft operation over the Arctic region in the future.

As the sea-ice retreat in the Bering Sea is predictable through the 3-month leading Z500 (Nakanowatari and others 2015), the forecasting of sea-ice variability would provide an efficient guide for aircraft operations over the Arctic Ocean. However, the amplitude of the Z250 anomaly associated with sea-ice decline is smaller than that of the difference in Z250 between years with a low and high ice extent, implying that the Z250 anomaly is not entirely explained by the decline in Arctic sea ice. For example, the change in sea-surface temperature over the mid-latitudes has a large impact on storm tracks in the Northern Hemisphere, resulting in a wind-speed anomaly over the Arctic region (Sato and others 2014, Ok and others 2017). Screen and Francis (2014) suggested that the atmospheric response to the variability of sea-surface temperature over tropical ocean causes the wind-speed and temperature anomalies at higher latitudes. Therefore, sensitivity experiments must be performed to investigate the atmospheric response to a change in the sea-surface temperature over mid-latitudes and the tropics in the near future.

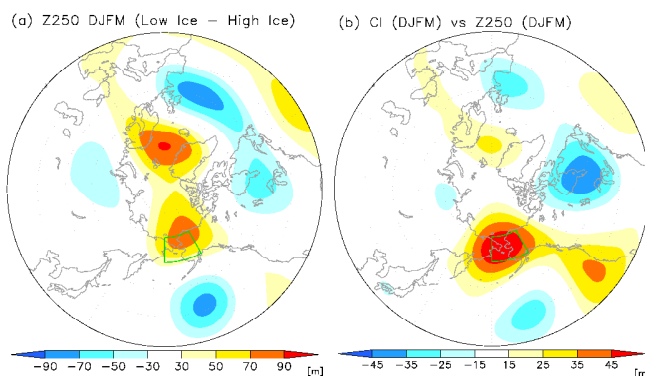


Fig. 4 (a) Difference maps in Z250 between years with low and high sea-ice extent in the Bering Sea for winter (DJFM).
(b) Regression field of Z250 with Bering Sea ice cover in winter.

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Summary in Japanese

和文要約

北極海空路と北半球の大気循環場との関係

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北アメリカ-アジア間で運行されている国際線は、エネルギー消費や飛行時間を抑えるため、距離の短くなる北極海の上空を通過する。シカゴ-香港間で運行されているユナイテッド航空 895 便 (UAL895) は、北極海の上空を通過する航空機の 1 つだが、北極海上を通過する空路は主に 3 つ (太平洋側ルート、中央北極海ルート、大西洋側ルート) に分類することができる。これは、飛行機は上空の追い風を受けることで、飛行時間を短縮できるためである。そこで本研究では、再解析データを用いて、北半球のブロッキングに伴う風の強さや位置の変化と UAL895 が北極海上を飛行するルートに関係があることを明らかにした。北半球では、ブロッキングに伴い北極海太平洋側で高気圧性の循環が強まると、北極海中央で向かい風が強くなるため、航空機が北極海の大西洋側や太平洋を通過する傾向にある。一方、大西洋側北極海でブロッキングに伴い上空の風が強まると、グリーンランド上空で追い風が強くなるため、大西洋側北極海を通過する傾向にあった。北極海の上空の大気循環は、熱帯の海面水温やベーリング海の海氷分布と関係性が見られており、数ヶ月前から予報可能であることが示唆され、北極海ルートを通過する航空会社に有益な情報を提供できる可能性がある。

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Utilization of discarded and unused woody materials for biomass heating and power plant

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Abstract

The global warming due to increases of warming gases in the atmosphere has well been recognized in the world. Reducing the emission of CO₂ is crucial now for every nation together with its regional governments. As biomass energy resources, discarded and unused woody materials from local forests will be one of the solutions, as the trees have consumed a great amount of CO₂ through the lifetime and they will emit nearly equal amount of CO₂ when burning, and the CO₂ liberated from their burning might be able to be isolated from the atmosphere into storage. The economic aspects are always key issue in biomass energy. Putting stress on the economic aspects of biomass energy, the author studied the biomass fuels for heating units and power plants on its present state and future prospective, in a local city in Hokkaido, northern island of Japan, where cold and frequent heavy snowing are typical in winter.

Key words: biomass energy, discarded wood, unused wood, heating, power plant

1. Background

Energy shortage such as oil and gas has featured Japan, where the society and industry have long covered it by import from rich countries in natural energy. Coal, abundantly reserved in Japan, is only an exception. However, unfortunately, most of coal found in deep under-ground layers has been defeated in its market by overseas cheap ones produced from opencast mines, and even coal has been imported.

Mountainous nature with few long and magnificent rivers and narrow continental shelves, has impeded development of water, tidal and wind forces as typical renewable energy. Contrary to the U.S. and other large countries, mountainous country does not directly mean rich in usable biomass reserves, particularly in wood, since the steep mountains often bring about relatively high market prices of those woody products, in particular, of discarded wood in forests.

The global warming due to increases of warming gases in the atmosphere has well been recognized in the world. Reducing the emission of CO₂ is crucial now for every nation together with its regional governments, through overcoming any hindrance and negative background. As biomass energy resources, discarded and unused woody materials from local forests will be one of the solutions, as the trees have consumed a large amount of CO₂ through the lifetime and they will emit nearly equal amount of CO₂ when burning, and the CO₂ liberated from their burning might be able to be isolated from the atmosphere into storage. As an alternative fuel from local forests will be one of the solutions, as the

forest has consumed a great amount of CO₂ through its lifetime and it will emit the equal amount of CO₂ when burning and the CO₂ liberated from its burning might be able to be isolated from the atmosphere in storage. It will have an opportunity to bring great benefits to the environment with some measures to reduce the amount of the emission greatly. The energy stored in wood is able to be converted into useful energy by transferring heat from combustion to hot water, where boilers play key role. Biomass boilers have been developed in the world as alternative heating source generators to coal boilers (Saidur and others, 2011, for an instance).

Biomass boilers are used for heating buildings; industrial premises, central and municipal heating plants, farm building, hotels, operating facilities, etc. In Hokkaido, biomass boilers have widely been in use (Kuboyama, and others, 2004; Official Website of Hokkaido Prefecture 2018a, 2018b; Niseko's Towns efforts as an Eco Model city).

Eventually, the forest should be properly managed to keep it well in order to sustainable use of biomass woody materials, and to prevent illegal deforestations and any harmful activity, certificate systems should be requested for forest enterprises and performing parties and persons, together with related regulations (Yamamoto and others, 2014). The Sustainable Green Ecosystem Council (SGEC) established in 2003 provides a unique certificate system for forest sustainability, which is oriented toward the peculiar situation in Japan, where afforestation prevails and a number of small size forest owners holds a majority in

its society. SGEC has controlled the amount of logging activity per year and area, ordered forestations after logging, and set up forestation plans and their road maps to future.

In the wider definitions, biomass includes agricultural and food processing wastes as well as sewage sludge and animal manure. The paper does not take considerations about them. Two clear reasons exist. One of them is that the amount of those fuel sources could not be available in cities of relatively small size in populations. The other is that the total amount of discarded wood over Hokkaido is about 110mil.m³, of which 40 mil. m³ is utilized as biomass energy source at the present. There remains considerable amount of discarded woods to be able to alter to active energy.

There are a few kinds of biomass fuels that come from local forests. They are wood pellets, precision dry wood chips, green wood chips, and general discarded wood chips. The main differences between them will be moisture content, calorific value, bark percentage, the amount of processing each one goes through, and the price as a consequence. The wood pellets, most energy dense one, usually contain a moisture between 5% and 8%, and they are the driest and easiest to manage. However, the pellets need large forest resources and slightly big consumer markets. Discarded wood chips will include the byproduct pieces and chips of lumbering, which are slightly different from the discarded ones in forests.

In the local city the present paper discusses, for the moment at least, the consumer market is not large enough for the pellets to be appropriate for purposes of heating and/or power generation. In the discarded wood, the bigger ones are the more useful as fuels. When the marketable timbers are taken away from the forest, the bigger ones are usually left in the forest, due to the cost to remove them, and as a consequence, they remain as obstacles for afforestation in the forest.

The biomass fuel resources are found abundant in regional forests in Hokkaido. For instance, the Official Website of Hokkaido Prefecture(2018b) noted the amount 1,110,000 m³/year of them was left in the Hokkaido prefecture. Such large amount of discarded wood left in the forests aroused the interest of the regional researchers, to generate energy for heat through boilers for the regional societies. They soon found the transport cost of the discarded wood from the forests to boilers caused a main hindrance in this renewable energy usage, which included secure of transport measures, including preparing devices to transport them. The transport measures are often expensive. Both national and regional governments support the project by purchasing main particular devices and/or granting subsidies to the enterprises. Up to the present, the society of Japan has relied on imported fossil fuels to large extent.

Although fossil fuels have higher calorific value per kg. and easy to manage, their prices have been unstable and fossil fuel resources are of limited amount of resources.

A previous study investigated the economic aspects of biomass related ecosystems (Bateman and others, 2011). However, the society and the market discussed in it are different from those of the present study. The economic aspects are always key issue in biomass energy. On the economic point of view of energy, the author studied the biomass fuels for heating units and power plants on its present state and future prospective, in a local city in Hokkaido, northern island of Japan, where cold and frequent heavy snowing are typical in winter.

2. Government policies for biomass utilization in Japan

To promote the renewable energy production and biomass utilization for heat and power generation, Japan has established a number of policies and incentives. Basic Act for the promotion of biomass utilization in 2009, its Amendment(2016) and Basic Plan for the promotion of biomass utilization in 2010 were aimed to set basic policies on the development of technologies for biomass utilization. The most critical policy was “Feed-in Tariff Scheme for Renewable Energy (Ministry of Economy, Trade and Industry:METI) which has been implemented since July 2012, soon after the tragic Tohoku Earthquake and Fukushima nuclear power plant accident. Since then, wood pellet consumption in Japan has grown up.

According to FAOSAT in 2016, the domestic production of wood pellets in the last five years was only 90t, most of which were exported to the market of China, and relatively high quality pellets, which covered a larger consumption of pellets in Japan, have been imported from Canada, China, Vietnam and the others.

To prevent illegal logging for wood pellets on the sustainable forest principle, the Basic Act for the Promotion of Biomass Utilization has a number of requirements for wood pellets and the other biomass use. Some of them are noted as follows:

- Mitigation of global warming,
- Revitalization of rural areas,
- Full utilization of different types of biomass,
- Considerations of environment preservation.

Under the Ministry of Agriculture, Forestry and Fisheries’ (MAFF) slogan, “illegal harvested timber should not be used”, the Clean Wood Act went into force in 2017, since illegal imports of wood products through complex trade routes had not been blocked.

As to wood chips, the standardizations are still at the

development stage, probably due to no notable trading market in Japan for the moment.

3. Methodology

3.1 Calorific values of wood chips

Among a variety of kinds of tree, Japanese larch, abundant in Hokkaido, was focused. Japanese larch timber is mainly processed for general timber market and for paper industry as pulp. Pictures of a forest and discarded wood conditions of Japanese larch are shown in Fig. 1. They were taken in Engaru, local town in Hokkaido, at the time when the National and Private Forests Meeting was held in this area.

The Stylus TG-630 camera (Olympus Tokyo, Japan) was used. Analyses were carried out, using the Image J and IrfanView.

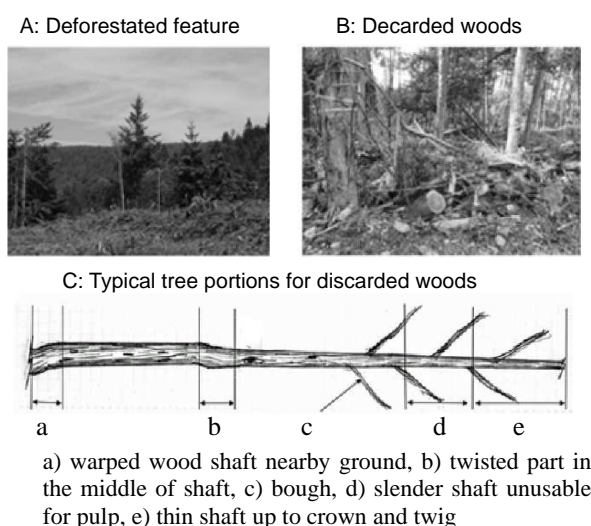


Fig. 1 Japanese larch in Hokkaido (modified illustrations via Official Website of Hokkaido Prefecture, 2018c)

Calorific assessment is crucial for each available wood chip for boilers. There remain a variety of arguments on standardization of calorific assessment of wood chips for even wood-burning stoves. Actual calories of burning wood fuels are dependent on the moisture content of them, and on various factors, such as wood materials themselves, boilers and structures of power plants, including the storage conditions.

In this paper, the author decided to choose the calculation method available at the web site of Japan Woodchip Manufacture's Association 2018. The calculation scheme, originally for cone calorimeter, is on the base of perfectly dry wood conditions, although the moisture contains in actual wood fuels even at the furnace to some extent.

The fraction of the evaporable moisture /water

content of the wood fuels designated by U_w , is simply given by

$$U_w = (W - W_0) / W \times 100 \quad \text{in \%} \quad (1)$$

where W_0 is the mass of the wood fuel in perfectly dried conditions and W is the mass of the one in actual conditions. Heat potential estimations were carried out for actually available wood chips, applying the simple formula (1).

3.2 Market prices of timber and fuel oil

Monthly average timber prices are available on the Min-yurin Shimbun, timber market newspaper in Japan. As to the both of fuel prices, the actually paid prices by the City of Mombetsu were adopted in this study.

These prices are key factors on this theme. There had been a few discussion papers published on the prices before (Yoda and others, 2010, 2011, 2012a and 2012b; Vesergaard, and others, 2011a and 2011b; Chahal and others, 2011; Phan and others, 2013; Yoda and others, 2017). The experience led to adopt the abovementioned price system.

4. Results and Discussion

The trees in Hokkaido have reportedly around 4,000 - 5,000 kcal/kg. The heat potentials of several kinds of wood are available in various reports. Fig. 2 shows one of them (Official Website of Japan Woodchip Manufacturers' Association, 2018). Those data were obtained by use of a cone calorie meter in completely dry conditions.

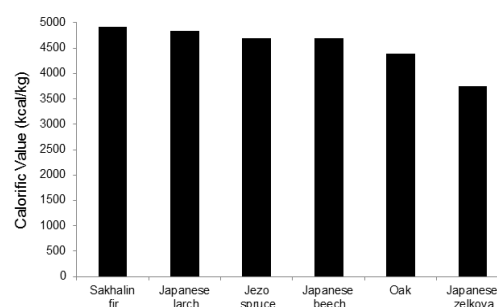


Fig. 2 Calorific values of several kinds of tree

The calorific values of trees in the ideal moisture conditions were found of a little difference among the kinds of tree.

It has been empirically well known that the heat potentials of wood or wood chips are dependent on the moisture or water content in them. The traditional data tell the woods of 20% water content has as much as double calorific value to those of 100% content ones, and the woods within 10-20% water content are ideal for burning for heat generation, while in reality, most of woods for heating have around 30% water content, except for extreme cases.

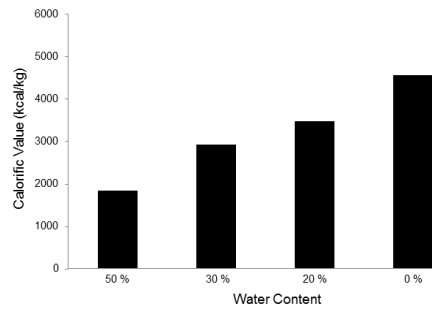


Fig. 3 Calorific values of a wood in different water content conditions

Calorific values in the different moisture conditions were obtained by collecting and analyzing those open web data, as shown in Fig.3.

There has been no reliable data about the water/moisture contents of each portion of discarded wood which is kept in the same natural conditions. Boughs and twigs would have rapid responses to the change of ambient moisture content, that is to say, in rainy days or in dry and windy days. Together with this, heat mass volume of boughs and twigs is minor in biomass heating and wood chips are usually stored in open enclosures.

Taking account of these, in practice, the heat potential of biomass wood chips would be assumed to be the value of the market timber approximately, probably without choice, particularly in the case of feasibility study of wood chips for biomass heating. Fig. 3 suggests that the wood chips could have the heat potential of 3,000 kcal/kg, while fuel oil has 9,600 kcal/kg in the EU industry.

The price trends of biomass wood and the price of fuel oil, as a strong competitor in energy market, form the staple of the total cost. Monthly timber price trends are available in the Min-yurin Shimbun in 2015.

The wood chip price market was found stable through the year. The wood chips of broad-leaf trees have the highest price, and a notable difference exists in the prices between the wood chips of broad-leaf and the others.

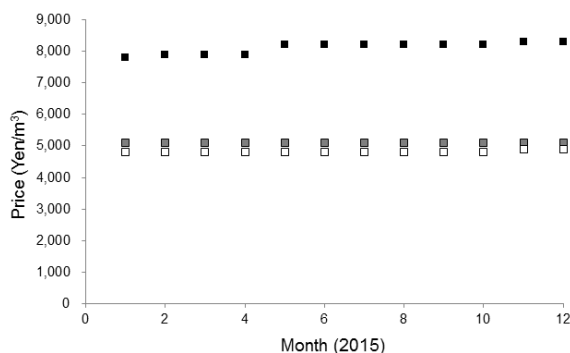


Fig. 4 Monthly price trends of discarded woods. Broad-leaf trees (back squares in the figure), Yezo spruce and Sakhalin fir (grey squares), and Japanese larch (white squares).

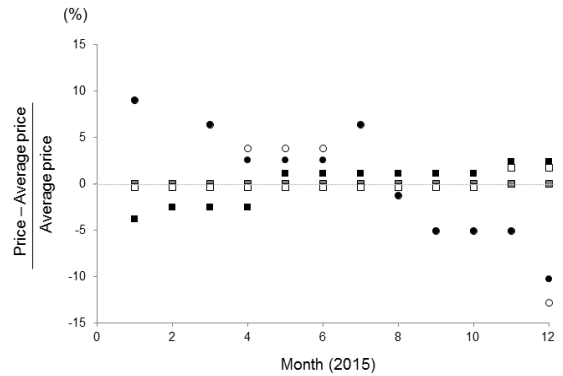


Fig. 5 Monthly oil and wood chips price deviations. Deviations in price of heating oil (black circles), those of fuel oil (white circles), and those of wood chips. Squares are as same as in Fig.4.

Monthly fuel oil price and wood chip price deviations are shown in Fig.5. The oil price varied throughout the year and its trend was of typical ones in the regions cold in winter and warm in summer. However, it should note that the recent oil price trends have been affected by the global markets and international political policies.

As far as the timber market concerns, the price of broad-leaf timber was the highest among these three kinds through the year. The Japanese larch was the cheapest. The prices of both Sakhalin fir and Japanese larch had similar trends.

Discarded wood for power plants has advantages in cost and emission, although another advantage, which will accrue to much better circumstances for reforestation, has been never recognized in those prices.

The disadvantages of the discarded wood chips lie with their thermal qualities, in particular, water contents; depending on the portions of trees while discarded, and natural conditions during the storage.

Especially in Hokkaido, winter season with snowing lasts six or seven months. The discarded wood chips are kept in wet conditions for a long time.

Drying discarded wood chips will be technically easy, but it requires the energy for drying and closed storage rooms, likely bunkers. Such additional, relatively high, expenditures of energy, equipment and facility do not meet the market principle.

The combustion of wood fuels in boilers requires the invariance of the thermal quality of them to generate the maximum efficiency in combustion by easy control. Conversely, boilers need a high capability where fuels of various thermal qualities are stoked up at random into the furnaces, and shall meet the safety regulations at the same time. Eventually, such boilers are slightly more expensive than pellet fueling boilers, where burning dry and nearly homogeneous wood fuels and being easily controlled, and much more expensive than oil fueling boilers.

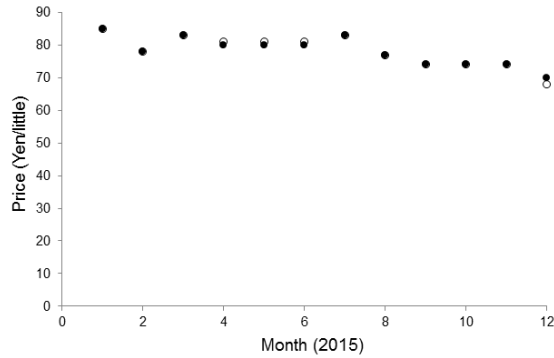


Fig. 6 Price trends of wood and oil fuel. These are actual prices for both heating oil (black dots) and fuel oil (white dots).

The prices in Fig.6 are those of actually paid by the city of Mombetsu. Fig. 6 suggests, to protect biomass industry, the city had controlled the price of biomass wood.

The price of 300kW biomass boiler is around 30 – 40 million yen in Hokkaido, while in Europe the similar boilers are available at the price of about 5 million yen.

The other disadvantage lies with the process of discarded wood chips from forest to power plant. The high processing cost of them consequent the wood chips had been discarded in forest until the time of reforestation.

The author obtained the data as high as 10,000 yen/m³ for the processing cost estimations from several companies. The cost should be added to the total cost of biomass power plant. Biomass power plant using wood chips as basic fuels would hardly survive under such high cost structure.

To find and examine another relatively cheap wood material had naturally been carried out to solve this cost problem. They were by-products and residues from wood processing industry (BPS in brief). The author obtained the market price of those wood materials around 1,000 – 3,500 yen/m³.

A previous study derived the conclusion by cost simulations: when the price of BPS in market hovers around or goes over 3,605 yen/m³, the profit of biomass power plant would be likely to accrue (Nakama and others, 2011). The study also estimated the possible highest price about 6,800 yen/m³.

The price of BPS materials were lower than those of discarded wood. In case of the unusable timber chips as the base fuel materials for boilers, the total cost for generation of heat or energy would be considerably reduced. However, a question arises; whether the timber industry could provide the amount of such materials enough to stable use for the boilers as its base fuel. In practice, the wood fuels for power plant would be blends and mixtures of discarded wood and BPS chips. Another problem still remains; the cost of boilers for them, in comparison to oil fueling boilers.

If wood fueling boilers are working well for a long time, without serious slagging and fouling problems, the difference at initial investment could be collected through the operations over 15 years due to low price of fueling wood.

As beforementioned, under the new government energy policy to reduce carbon emission, local governments have been demanded to use the discarded wood for heating units and power plants, where those biomass materials could be available. Local governments such as the city of Mombetsu had established the subsidy scheme for the discarded wood, mainly for its processing expenditures. The city of Mombetsu, for instance, has granted 300yen/m³ subsidy to utilizations of unusable timber materials for the biomass power plant.

The Hokkaido Prefecture grant the subsidies for the acquisition of boilers burning unusable wood materials and other necessary facilities (Official Website of Hokkaido Prefecture, 2018d). The similar subsidies afforded the city of Mombetsu to support a hospital management where biomass boilers are working for heating system.

Enlargement efforts of the local consumer's market would contribute further reduction of the cost as well as total amount of carbon emission, where the role of proximity dimensions in facilitating biomass power plants should be demanded.

5.Conclusion

The economic aspects are always key issues in biomass energy. Putting stress on it, the author studied the biomass fuels for heating units and power plants, discussing their present state and future prospective, in a local city in Hokkaido. There are several problems left in the effective use of biomass materials. To solve them, the local governments together with the local communities will have to assume the executive responsibilities on the biomass issues.

Since we can no longer leave the nature to manage itself under our onslaught, changing the discarded or wasted materials to be useful energy resources could be one step forward to realize the healthy nature again as well as sustainable human society.

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Turning features of an icebreaker during ramming operations: a case study

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Abstract

Syowa Station, Japan's main Antarctic research base, is located in Lützow–Holm Bay (LHB). This bay is often covered with very thick multiyear landfast ice. The Japanese Antarctic research icebreaker *Shirase II* conducts “ramming” icebreaking operations comprising repeating backing and ramming, sometimes thousands of times, in one cruise. In this study, we analyzed data for turning in ice while ramming, which is a rare occurrence. The turning angle per ramming procedure and the turning radius are correlated with the ramming penetration distance. Thus, the required time and ice area width for one turn can be estimated from the data of the first several ramming trials. In addition, shortening the approach run length decreases the time required per ramming procedure and the turning trajectory and increases the required number of ramming procedures. To balance these effects, we attempted to reduce the total required time by controlling the approach run length. It was concluded that the best operation to reduce the turning time is to use an approach run length that is sufficient to achieve high impact velocity, unless the brash ice in the broken channel significantly prevents the ship's astern movement.

Key words: icebreaker, ramming, turning, maneuverability, navigation support

1. Introduction

Syowa Station, Japan's main Antarctic research base, is located in Lützow–Holm Bay (LHB). This bay is often covered with very thick multiyear landfast ice. While icebreakers can usually navigate with continuous icebreaking, the ramming operations (i.e., backing and ramming) are required in areas where the ice thickness exceeds a certain level. In this operation, an icebreaker repeats the following procedure:

1. Move astern for an approach run
2. Accelerate using a channel (made by the previous ramming operation) and impact on ice at high speed
3. Penetrate using kinetic energy and propulsion thrust

This procedure requires significant time and fuel. In LHB, the Japanese Antarctic research icebreaker *Shirase II* (hereafter called *Shirase*) sometimes conducts thousands of ramming operations in one cruise.

During navigation under very heavy ice conditions, icebreakers sometimes need to turn during ramming operations. *Shirase* has made 180° turns during ramming operations in both the 2012/2013 and 2017/2018 cruises. Turning by 180° during ramming operations can require half a day or more, so its efficient execution is important.

Many studies (e.g., Daley and Riska, 1990) have

investigated straightforward ramming performance. By contrast, only some studies (e.g., Nozawa, 2006) have investigated turning performance with continuous icebreaking, and little is known about turning ramming performance because this operation occurs rarely.

Owing to the low frequency of turning ramming operations, valuable data can be obtained from multiple turns with ramming by the same icebreaker. In this study, we investigate the turning of *Shirase* to determine principles for conducting more efficient turning and to provide information for navigation planning.

2. Method

Table 1 lists the main dimensions of *Shirase* (for other specifications, refer to Yamauchi and Mizuno, 2009). *Shirase*'s navigation data is recorded using a ship-monitoring system (SMS) that records basic navigation information including GPS location (accuracy: < 10 m), ship motion, steering angle, and engine power (Yamauchi et al., 2011). Navigation data of four turns from the last nine years are extracted for analysis (Table 2). The ice thickness values (h) observed during the turns are shown in the table only as guides; they are roughly estimated by image analysis of photos taken with a compact digital camera (2012/2013) and by unaided visual observation (2017/2018). Slash-delimited numbers indicate

observed samples. Image analysis is conducted based on the same principle as the video method conducted since 1988 (Shimoda et al., 1997). However, it is considered less accurate than the video method because the compact camera was not fixed, which may have caused large variations in observed values. Although the ice thickness may vary during a turn, we did not consider this in this study because of the lack of high-precision data with high sampling density.

The inner part of LHB contains “landfast level ice” (Turns 1–3) of high and stable thickness. Furthermore, “Hummock ice” of variable thickness develops on the ice edge.

Table 1. Main dimensions of *Shirase* (Yamauchi and Mizuno, 2009)

Overall length	138.0 m
Length of water line	126.0 m
Maximum breadth	28.0 m
Depth	15.9 m

Table 2. General descriptions of analyzed turns

	Season	Ice feature	Ice thickness (m)
Turn 1	January, 2013	Landfast level ice	2.6 / 4.0
Turn 2	February, 2013	Landfast level ice	4.2 / 4.4 / 5.2
Turn 3	January, 2018	Landfast level ice	1.7 / 2.1
Turn 4	February, 2018	Hummock ice near ice edge	2.1 / 2.2

The navigation data is analyzed through the three steps described below.

1) Ramming section extraction and characteristic parameter calculation for each ramming procedure

In this study, one ramming procedure is defined from starting astern movement to stopping the ship body after penetrating the ice. Fig. 1 shows an example of a ramming procedure extracted from SMS data. The shaft speed and rudder angle are the average of two values. A ramming procedure is decomposed into three phases:

A) Astern

This phase is defined from stopping the previous ramming procedure to starting the next approach run, including a few minutes for reversing the engine rotation. The ship speed is controlled carefully to avoid collisions with the ice, typically by changing the shaft speed at a rate <120 rpm to maintain a velocity of <1.5 m/s. The rudder is kept neutral during astern movement to avoid damage, and the traveling direction is controlled by changing the balance of the left–right thruster output. For typical ramming navigation of *Shirase*, the astern distance (identical to the approach run length discussed below) is ideally 300 m. The actual astern distance must sometimes be shorter mainly because brash ice fills the channel and reduces the efficiency of astern movement. The astern distance can also be reduced intentionally when ramming partially weak or cracked ice. Such operations are often used with hummock ice.

B) Approach run

After the astern movement phase, the ship accelerates

with high engine power through the channel. In the present analysis, *Shirase*’s regular operational speed of 137 rpm was used for all but two cases. The rudder angle is controlled to follow the channel shape and then strongly turned in the direction of turning so that the ship collides with the side of the previous ramming print, which has a curvilinear triangular shape.

C) Penetration

After colliding with the ice edge, the ship penetrates the ice under high engine power. The rudder is kept neutral or at a small angle to reduce water resistance. This phase is defined as ended when the ship is at a complete stop for 5 s.

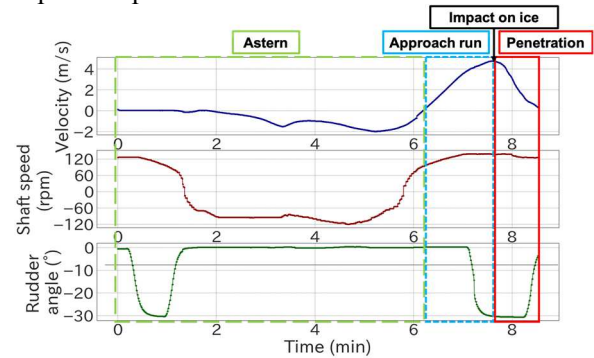


Fig. 1 Typical change of velocity, engine power, and rudder angle during ramming

First, we define the impact velocity (V). Because the exact time at which the ship impacts ice is difficult to identify, in this study, we assume that the velocity is maximized when the ship impacts ice. Thus, the impact velocity is defined as the maximum speed during each ramming procedure. Vance (1980) noted that the impact velocity increases with the approach run length (L) although it reaches a specific impact velocity with a sufficient approach run length. Through field experiments with the *USCGC Katmai Bay* icebreaker, Vance (1980) also suggested that the impact velocity converged to its maximum after accelerating for 2.5–3.0 ship lengths. For *Shirase*, the impact velocity is controlled at <5 – 6 m/s to maintain sufficiently low ice pressure on the ship hull. The approach run length needed to achieve this impact velocity is 300–400 m, that is, 2.5–3.0 ship lengths.

Second, we define the penetration distance (D) as the distance between the impact point and the ship stopping point. This variable is often used to indicate ramming progress on site. The penetration distance varies with the ice condition and impact velocity.

The turning angle (Θ) is defined as the difference in heading between the first and the last ramming procedure during a turn. It represents the total displacement angle of the turn; it varies between cases because the selected turns do not necessarily reach 180° . N denotes the required number of ramming procedures, and the turning angle per ramming procedure (θ) is calculated as Θ/N .

2) Projection of ramming positions to X-Y plane

The GPS position of the ship stopping point for each ramming procedure is extracted from the above ramming datasets and projected to the X-Y plane. The longitude and latitude are taken as the X- and Y-axis directions, respectively, with north and east being positive.

3) Calculation of turning circle and its radius

The turning circle is approximated by nonlinear least-squares fitting as the trajectory of each turn. Its radius is calculated and defined as the turning radius (r). Although the trajectory of a continuous icebreaking turn is rarely a geometrical circle, we assume it to be a geometrical circle for ramming turns.

3. Results and discussion

3.1 Turning features

Table 3 shows the statistics of each turn. The ramming positions and fitted circles are plotted concentrically in Fig. 2. The subscript av denotes the averaged values for the turn.

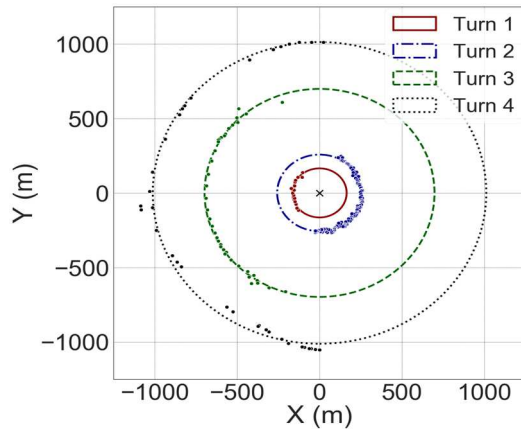


Fig. 2 Concentric plot of ramming endpoints and fitted circles for four turns

Table 3. Statistics of four ramming turns

	N	r (m)	V_{av} (m/s)	D_{av} (m)	L_{av} (m)	Θ (deg)	θ (deg)	h (m)
Turn 1	15	164.7	7.3	104	264	52	3.4	2.6 / 4.0
Turn 2	143	257.2	6.6	52	158	158	1.1	4.2 / 4.4 / 5.2
Turn 3	39	697.9	9.0	118	292	142	3.6	1.7 / 2.1
Turn 4	35	1012.3	6.6	143	201	179	5.1	2.1 / 2.2

Table 4 Maneuverability test results with continuous icebreaking (analyzed by the University of Tokyo, not published)

	Season	Estimated radius (m)	Ice / snow thickness (m)	Velocity (m/s)	Engine power (rpm)	Rudder angle (deg)
Exp. 1	December, 2009	560	0.7~1.0 / 0.3	4~4.5	137	30 (partially 15)
Exp. 2	February, 2010	760	0.3~0.5 / 0	2~4	95	30

The turning radii clearly vary. For two experiments conducted in 2009/2010, the turning radii during continuous icebreaking were 560 and 760 m, respectively (Table 4). The present study shows that the

turning radius during ramming sometimes becomes smaller than that during continuous icebreaking.

Fig. 3 shows the quantitative relation between D and r . The turning radius increases with the penetration distance. The figure shows the regression formula and its correlation coefficient R . Despite the low number of samples, it is expected that the turning radius for an area can be roughly estimated by conducting several ramming procedures and calculating their penetration distances.

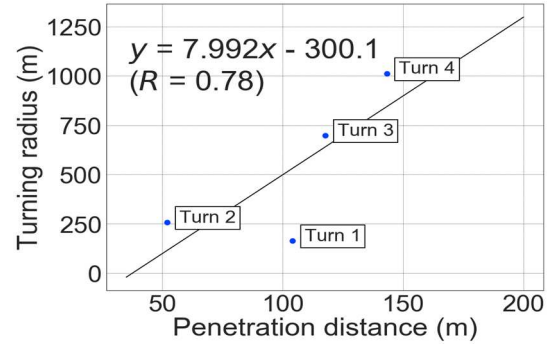


Fig. 3 Relation between penetration distance (D) and turning radius (r)

Because thicker ice reduces the penetration distance, the turning radius decreases with increasing ice thickness. However, Nozawa (2006) noted that the turning radius with continuous icebreaking increases as a function of ice thickness. The results of the present study are not consistent with this previous report. Here, we discuss the reason for this inconsistency by focusing on the unique features of ramming.

All ramming tracks of Turns 2 and 3 are plotted in Fig. 4 in different colors. The GPS data during penetration only are plotted. This shows that each ramming track is a nearly straight line throughout the turn. In particular, 20 and 10 consecutive ramming examples are extracted from Turns 2 and 3, respectively, and plotted in Fig. 5. This shows that during penetration, the tracks are like straight lines with slight changes in heading angle, although slightly curved tracks are seen in Turn 3.

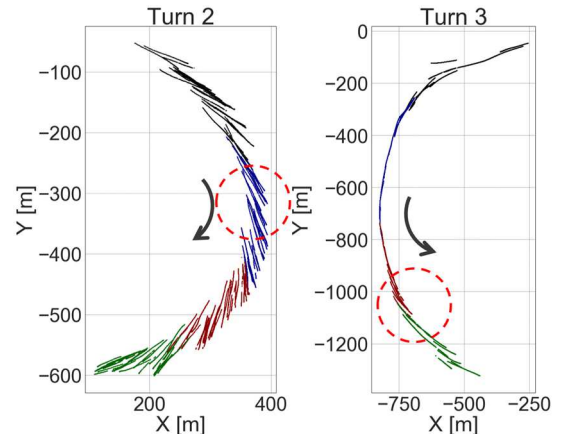


Fig. 4 Tracks during penetration. Red dashed-line circles denote extracted areas shown in Fig. 5.

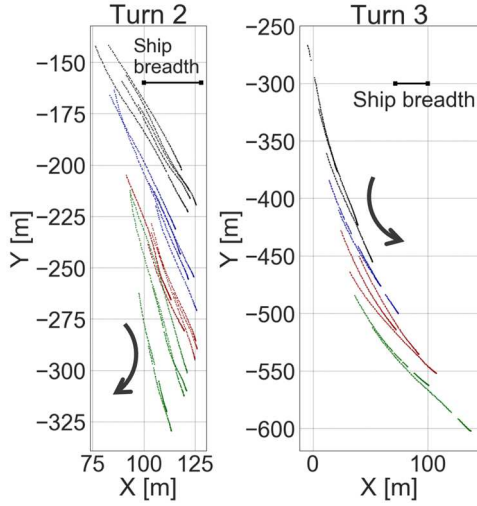


Fig. 5 Tracks during penetration (20 and 10 consecutive ramming procedures from Fig. 4 extracted for magnification.)

The relationship shown in Fig. 3 can be explained as follows. The turning angle is mainly achieved during the approach run and less so, if at all, during penetration. Therefore, longer penetration distances expand the tracks outward, thereby lengthening the turning radius compared to that in gradual (short penetration distance) ramming.

If this holds under all conditions, it is possible that the longer penetration distance does not contribute to the efficiency of a ramming turn. In fact, gradual ramming with shorter penetration distances may be more efficient because of the shorter trajectory. It is critical to determine whether the turning angle is achieved to any extent during penetration.

To discuss this more quantitatively, the time series data of the ship's yaw rate and velocity are shown in Fig. 6. Each line represents each turn, as obtained by averaging each ramming procedure after aligning the procedures such that the impact timing on the ice is 0 s. The turning direction is considered positive for the yaw rate plot of each turn. The yaw rate is clearly maximized during the approach run, and it decreases rapidly after impact. This is attributed to the ship bouncing from the ice edge. The yaw rates of Turns 3 and 4, which have long penetration distances, remain positive for a while. Although the yaw rate does not necessarily coincide with the angle of the navigation track, it implies that some of the turning angle can be achieved during the penetration phase. However, the amount is smaller than that during acceleration, such that the turning radius is increased, as in the discussion following Fig. 5.

For greater clarity, the turning angle per ramming procedure θ is calculated for each turn by dividing the total change in angle by the number of ramming procedures. The result is shown in Fig. 7, with the penetration distance plotted on the horizontal axis.

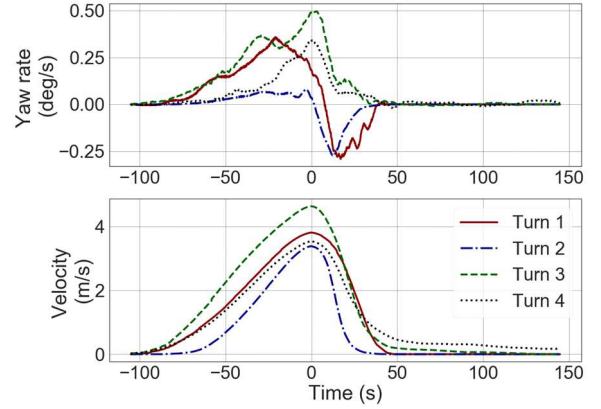


Fig. 6 Averaged yaw rate change and velocity change during ramming for each turn

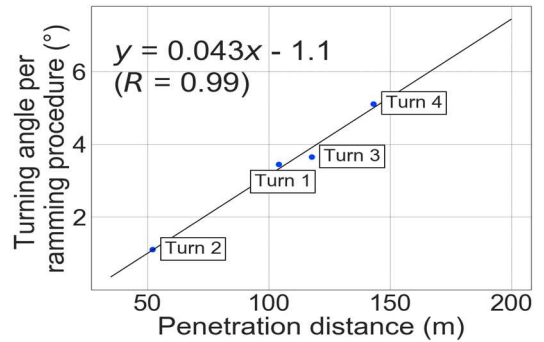


Fig. 7 Relation between penetration distance (D) and turning radius per ramming procedure (θ)

The result shows a clear positive near-linear correlation between the penetration distance and the turning angle per ramming procedure. It can be expected that the required number of ramming procedures to achieve a certain change in angle can be estimated from the penetration distances of several ramming trials, thus yielding the total time required for turning. Because the penetration distance can be observed and calculated easily on site and in real time, this is considered useful for navigation planning.

3.2 Discussions on efficient turning

Next, we attempted to improve the efficiency of the turning operation based on the above results. The conceptual diagram is shown in Fig. 8.

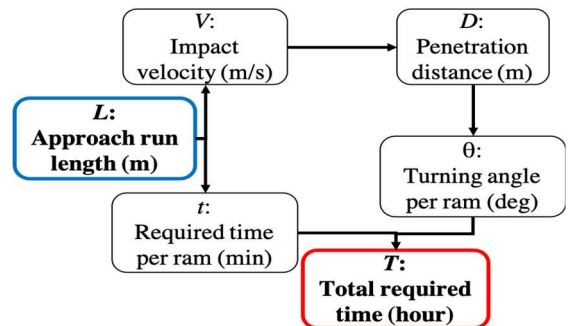


Fig. 8 Conceptual diagram of calculation

The approach run length (L) is chosen as the predictor variable. The navigation officer can control this easily by changing the timing to stop the astern movement. The total required time (T) is defined as the total time required for turning by a certain angle, which is the objective variable to reduce. When we consider a turn of Θ , T can be decomposed into the following equations:

$$T = (\Theta/\theta) \cdot t \quad (1)$$

$$\theta = a_\theta \cdot D + b_\theta \quad (2)$$

$$D = a_D \cdot V + b_D \quad (3)$$

$$V = a_V \cdot L + b_V \quad (4)$$

$$t = a_t \cdot L + b_t \quad (5)$$

Therefore, T can be expressed as an equation of only one variable L :

$$T = \frac{\Theta \cdot (a_t \cdot L + b_t)}{a_\theta \cdot (a_D \cdot (a_V \cdot L + b_V) + b_D) + b_\theta} \quad (6)$$

Here, a and b with subscripts denote constants, and t is the time required per ramming procedure during the turn. Tatinclaux (1992) noted that the penetration distance D is a linear function of the impact velocity V , although the relational expression varies for different ice conditions. The coefficients of the relational expression are calculated for the four areas of turning, as shown in Fig. 9. At this time, it is difficult to identify a tendency between the ice conditions and the features of the regression lines.

We assumed that the dependency of θ on V can be calculated from the relations shown in Fig. 7 and Fig. 9. Though the above discussion indicates that changes in V affect D and thus θ , it is also possible that this effect is small and that the relation shown in Fig. 7 is largely due to the effects of ice condition differences on both D and θ separately. For an accurate calculation, the contribution of V to θ should be quantified without ice condition differences. Because of the shortage of data for such quantification, we assumed that the regression formula shown in Fig. 7 is applicable to the change in D accompanying the change in V . Considering this uncertainty, we calculated seven scenarios: relational expression of the original regression line, 20% raised/inclined, 10% (of average of four turns) parallel upward/downward shifted, and 20% increased/decreased uniformly (Fig. 12).

V and t change depending on L . The relation among V , t , and L is calculated in the same manner as above. Preceding icebreaking tests of Shirase (2010/2011, result not published) suggested that the relation between L and V was linear and that the relational expression did not vary significantly for different ice conditions. This is justified because the icebreaker passes an open water channel during the approach run. The results of the present analysis agree with this report, as shown in Fig. 10. However, the correlation between

L and t varies for the four turns (Fig. 11). This is attributed to effects on the relation by brash ice coverage in the channel generated by the icebreaker itself. The quantity of produced brash ice is greater in thicker ice areas (i.e., Turns 1 and 2). If the brash ice in the channel is increased, the ice resistance is increased, and thus, the required time per unit length astern distance is longer. Therefore, it is reasonable that the regression lines of Turns 1 and 2 (thicker ice areas) are steeper than those of Turns 3 and 4 (thinner ice areas).

In the regression analyses, some irregular ramming procedures are removed:

- 1) Extreme penetration distances despite low impact velocities

Two ramming procedures with penetration distances >200 m are removed from Turn 3. Such ramming procedures can be caused by partially thin ice, though the actual cause has not been identified.

- 2) Low engine power

Two ramming procedures are performed at low velocity because low engine power is used.

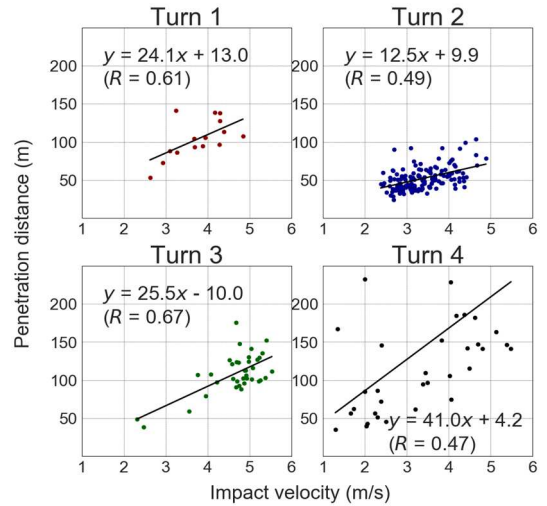


Fig. 9 Regression analysis between impact velocity (V) and penetration distance (D)

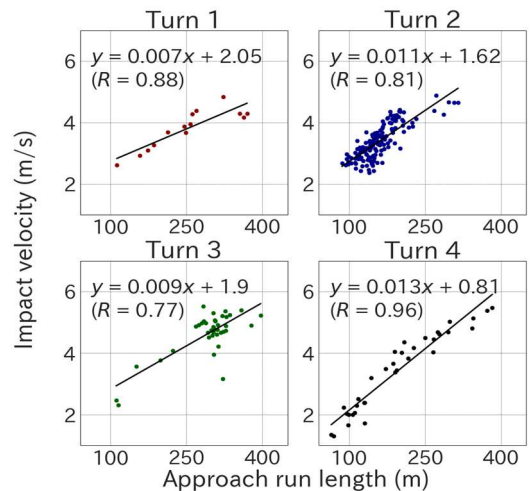


Fig. 10 Regression analysis between approach run length (L) and impact velocity (V)

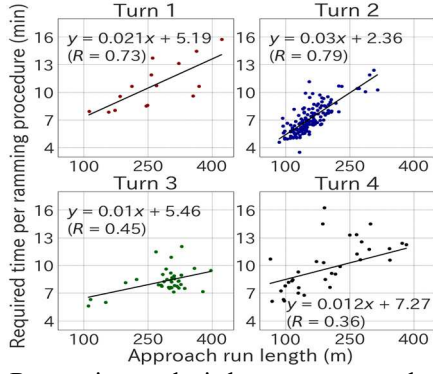


Fig. 11 Regression analysis between approach run length (L) and required time per ramming procedure (t)

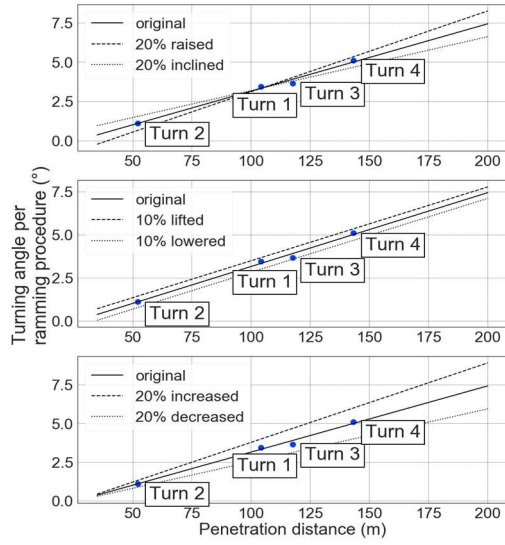


Fig. 12 Relational expressions of seven scenarios between penetration distance (D) and turning angle per ramming procedure (θ)

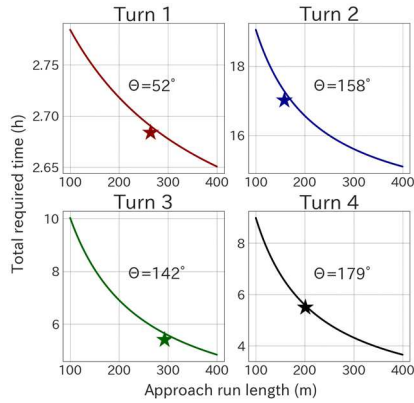


Fig. 13 Estimated total required time (T) and its dependency on approach run length (L). Actual time–length point for each turn is indicated by a star.

By using the relational expressions mentioned above, T is calculated for various L values in the feasible range of 100–400 m. The results are shown in Fig. 13 and Fig. 14. These estimations are compared to the actual required times and averaged approach run lengths.

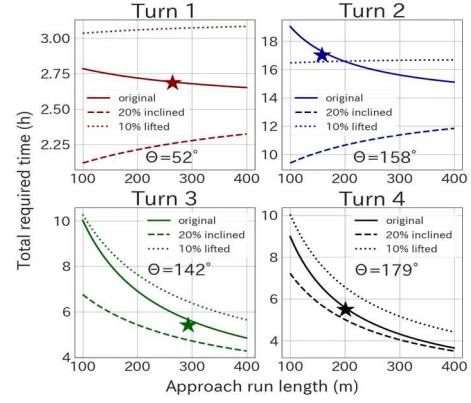


Fig. 14 Estimated total required time (T) and its dependency on approach run length (L) – scenarios of 20% inclined/10% lifted (parallel upward shift) from the original D – θ equation. Actual L – T values are indicated using stars.

In the scenario with the original D – θ regression lines (Fig. 13), T decreases monotonically with L for all four cases. The actual data lies almost on the lines, indicating the reliability of the calculation scheme. The result implies that the approach run length should be increased for a time-efficient turn.

However, Fig. 14 shows that the L – T correlations for Turns 1 and 2 change from negative to positive in two scenarios whereas for Turns 3 and 4, they are negative for all three scenarios. The scenarios not plotted in this figure are all decreasing functions. The reason for this is explained below.

The conditional expression for T as a decreasing function of L is

$$\frac{dT}{dL} \leq 0 \quad (7.1)$$

By calculating this using equation (6), we obtain:

$$-a_D a_V a_\theta b_t + a_t b_\theta + a_D a_t a_\theta b_V + a_t a_\theta b_D \leq 0 \quad (7.2)$$

Here, we conducted a sensitivity study as follows:

- 1) The average and standard deviation of each coefficient were calculated for the four turns. For a_θ and b_θ , the value itself is used for the mean value and 50% of its value is substituted for the standard deviation as a guide.
- 2) The standard value is calculated by substituting the averaged coefficients into the left-hand side of (7.2).
- 3) Each coefficient is increased by its standard deviation while holding the others constant, and the difference from the standard value is calculated for each coefficient (hereafter defined as sensitivity).

The results are shown in Table 5. It shows that b_t has the greatest influence compared to the other coefficients. This suggests that the L – t relation has the greatest contribution to the shape of the L – T curve. Here, we must consider that b_t changes depending on

a_t in the process of regression analysis. This complication arises because the linear model assumption is not applicable for small values of L (< 100). Theoretically, t at $L = 0$ should be constant regardless of ice conditions.

Based on the above discussion, the results shown in Fig. 14 can be explained as follows. In Turns 1 and 2, heavy ice conditions yield regression lines with larger a_t and smaller b_t (see discussion on page 17), thus making dT/dL positive.

Table 5 Sensitivity of dT/dL to each coefficient

a_t	b_t	a_v	b_v	a_D	b_D	a_θ	b_θ
0.01	-11.36	0.00	-0.28	-0.13	0.21	0.00	-0.02

These results suggest that the approach run length should be lengthened for time-efficient turns, especially when brash ice coverage in the channel is low and the approach run length can be increased relatively freely. However, this does not always apply if brash ice fills the channel.

For predicting the total required time, Fig. 13 and Fig. 14 show that the total time changes by up to 50% depending on the approach run length. Again, if the brash ice prevents a long approach run, the turn may require more time than that predicted using the relation shown in Fig. 7. Further studies are required for the practical prediction of the total required time for turning while ramming.

4. Conclusions

The turning performance under ramming operation is investigated by analyzing data from four turns conducted in actual ice-covered sea. As a result, the following features of ramming turns are obtained:

- The turning radius increases almost linearly with penetration distance.
- The turning angle per ramming procedure increases with the penetration distance despite the longer trajectory.
- The total required time for turning decreases with increasing approach run length for 100–400 m runs, unless brash ice significantly prevents the ship's astern movement.

Based on these results, the following navigation guidelines for ramming turns are suggested:

- To reduce the turning time, the approach run length should be increased unless brash ice significantly fills the channel.
- For an icebreaker that is forced to turn in a narrow area, it may be effective to shorten the penetration distance to achieve small turns.
- It is expected that the total required time for turning can be estimated using the penetration

distances of the first several ramming procedures during a turn, although this method has low reliability based on the results of the present study.

To confirm the validity of the analysis, a field experiment of two turns in one area with varying approach run lengths is desired. In addition, turns performed by other icebreakers must be investigated to generalize the results. It has already been suggested that the turning performance during continuous icebreaking varies depending on the shape of the ship (Nozawa, 2006; Sazonov, 2011).

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[Appendix]

**PROGRAM of
The 34th International Symposium
on Okhotsk Sea and Polar Oceans, 2019**

Date: 18-20 February 2019

**Place: Mombetsu Citizens' Public Hall,
Mombetsu Arts & Culture Center,
Mombetsu Municipal Museum,
at Mombetsu, Hokkaido, Japan**

**Okhotsk Sea and Polar Oceans Research Association
(OSPORA)**

9:00	【Opening Address】 Shuhei Takahashi Chair of the Symposium Committee 【A : Keynote Address】 Chair, Shuhei Takahashi (Sea Ice Museum)
9:20	A-1 The meteorological observations in the far-east by Jean Barthe, physician on the French frigates <i>La Virginie</i> and <i>La Sibylle</i> ◇Gaston R. Demarée (Royal Meteorological Inst. Belgium, Belgium), Takehiko Mikami (Tokyo Metropolitan Univ.), Patrick Beillevaire (French National Center Sci. Res., France), Yoshio Tagami (Univ. Toyama), Masumi Zaiki (Seikei Univ.), Togo Tsukahara (Kobe Univ.) and Junpei Hirano (Teikyo Univ.)
9:50	Break
10:00	【A : Keynote Address】 Chair, Shuhei Takahashi (Sea Ice Museum) A-2 Multidecadal variability of Atlantic meridional overturning circulation and its impact on global and Arctic climate ◇Xian Yao Chen (Ocean Univ. China, China)
10:30	A-3 Trends in supply of DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid) -a novel source- ◇Koretaro Takahashi (Kitami Inst. Tech.) 【A : Special Lecture】 Chair, Yoshio Tagami Univ. Toyama)
11:00	A-4 Dynamics of precipitation and temperature in the Baikal region (on the example of the cities of Baikalsk, Irkutsk, Bratsk) ◇Natalia Ianchenko (Irkutsk National Res. Tech. Univ., Russia)
11:30	A-5 The climate of Hakodate (Hokkaido) in 1850-60s and the global warming ◇Takehiko Mikami (Tokyo Metropolitan Univ.) and Masumi Zaiki (Seikei Univ.)
12:00	Lunch
13:00	【B : Snow, Ice and Human Life】 Chair, Kanichiro Matsumura (Tokyo Univ. Agriculture) 《Keynote Address》 B-1 Meteorological observations of the French warship at the end of the Tokugawa period and summer climate conditions around Hokkaido ◇Yoshio Tagami (Univ. Toyama), Gaston R. Demarée (Royal Meteorological Inst. Belgium, Belgium), Takehiko Mikami (Teikyo Univ.), Patrick Beillevaire (French National Center Sci. Res., France), Masumi Zaiki (Seikei Univ.), Togo Tsukahara (Kobe Univ.) and Junpei Hirano (Teikyo Univ.)
13:30	B-2 Utilization of discarded and unused woody materials for biomass heating and power plant ◇Tsuyoshi Yoda (City of Mombetsu/Aomori Pref. Ind. Tech. Res. Center)
13:50	B-3 Technical issues on undergrounding of utility cables to improve the rural landscape in Hokkaido ◇Hiroshi Ota, Tetsuo Takahashi, Madoka Ohtake, Keisuke Iwata and Yasuaki Matsuda (Civil Eng. Res. Inst. Cold Region)
14:10	B-4 Snow load on the ground on the Sakhalin. Damage, calculation, mapping ◇Valentina A. Lobkina (Far East Geological Inst., Russia)
14:30	Break
14:40	Chair, Toshihiro Ozeki (Hokkaido Univ. Edu.) B-5 Marine litter in the World Heritage “Shiretoko”: Estimations of the volume and the sources ◇☆A Yu Sugita, Yusuke Kobayashi and Takayuki Shiraiwa (Hokkaido Univ.)
15:00	B-6 The MONODUKURI PBL in cold area basis research to prevent smartphone electrical discharge ◇☆A Saki Iwadate, Kazuki Osanai, Muhammad Haziq Aiman, Kazutaka Yokota and Kei Horio (Utsunomiya Univ.)
15:20	B-7 The MONODUKURI PBL in cold area -Basis research on protection against cold and preservation of body temperature- ◇☆A Asahi Sawasato, Yuri Abe, Mohammad Alif Aimullah, Kazutaka Yokota and Kei Horio (Utsunomiya Univ.)
15:40	B-8 Preparing a handmade fixed wing UAV for drift ice observation ◇Kanichiro Matsumura (Tokyo Univ. Agriculture), Stanley Anak Suab and Ram Avtar (Hokkaido Univ.)
16:00	Break

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Place: 1F Main Hall

	【C : Climate Change】 Chair, Takayuki Shiraiwa (Hokkaido Univ.)
16:10	C-1 Changes in terminus positions, ice speed and surface elevation of marine-terminating glaciers in northwestern Greenland during the last 30 years ◇☆A Daiki Sakakibara, Shin Sugiyama (Hokkaido Univ.) and Anders Anker Bjørk (Univ. Copenhagen, Denmark)
16:30	C-2 Rapid retreat of Bowdoin Glacier in northwestern Greenland controlled by the ocean and glacier bed geometries ◇☆A Izumi Asaji, Daiki Sakakibara (Hokkaido Univ.), Shintaro Yamasaki (Kyoto Univ.) and Shin Sugiyama (Hokkaido Univ.)
16:50	C-3 Analysis and modeling of some characteristics of climate change in Central Siberia ◇Igor A. Ognev and Natalia I. Ianchenko (Irkutsk National Res. Tech. Univ., Russia)
17:10	C-4 El Niño Thermodynamics -Unusual weather is made in the surface mixed layer (200m) in Pacific equator east ◇Takao Nakajin (Tokai Univ.)
18:30	White Concert 『Okhotsk Sea Ice Museum』

☆A The Aota Masaaki Award Candidate

Monday 18 Feb. 2019 Mombetsu Arts & Culture Center Place: 3F Special Conference Room

10:00	【M1 : Public Program, Forum of oil Pollution Measures and Environmental Protection】 <i>(in Japanese language only)</i> Chair, Go Saito (OEPN, Okhotsk Environment Protection Net) Introduction, Masato Ito (OEPN, Okhotsk Environment Protection Net) M1-1 On the history of OEPN and the current situation surrounding us ◇Masato Ito (OEPN, Okhotsk Environment Protection Net) M1-2 About new information of Sakhalin II project ◇Andrey Klepikov and Natalia Gonchar (Sakhalin Energy, Russia) M1-3 Recent oil spill incidents and preparedness for oil spill incident ◇Kazumi Konno (Mombetsu Coast Guard Office) M1-4 Disaster relief volunteer activities in Hokkaido ◇Yutaka Sakamoto (Hokkaido Council of Social welfare) M1-5 Red list of birds of Lake Komuke -We take heavy responsibility for the future of birds ◇Kazuhiro Oodate (Mombetsu-Kaihatsu Club)
12:00	Lunch

	【D : Workshop, Polar Prediction Project -From Observations to Predictions-】	
13:00	Introduction, Jun Inoue (NIPR)	Chair, Jun Inoue (NIPR)
13:05	D-1 Real-time forecasts over the Arctic region during 2017/2018 Arctic expedition of the KOPRI IBRV Araon ◇Yonghan Choi, Joo-Hong Kim (Korea Polar Res. Inst., Korea), Baek-Min Kim (Pukyong National Univ., Korea), Chang-Kyu Lim (Korea Polar Res. Inst., Korea), Shin-Woo Kim, Nam-Kyu Noh (Pukyong National Univ., Korea) and Xiangdong Zhang (Univ. Alaska, USA)	
13:25	D-2 Developing insights into the Arctic researches during early winter using RV Mirai ◇Jun Inoue (NIPR)	
13:45	D-3 Application of cloud particle sensor sondes to monitoring cloud evolution under off-ice flow condition over the Arctic Ocean ◇Kazutoshi Sato (Kitami Inst. Tech.) and Jun Inoue (NIPR/SOKENDAI)	
14:05	D-4 Operational sea ice prediction for the Japanese research vessel MIRAI's expedition cruise in 2018 ◇Liyanarachchi Waruna Arampath De Silva (Univ. Tokyo), Takeshi Terui (NIPR), Hajime Yamaguchi (Univ. Tokyo) and Jun Inoue (NIPR)	
14:25	Break	
		Chair, Takuji Waseda (Univ. Tokyo)
14:35	D-5 Sea ice observations along a fixed marginal ice zone transect in the refreezing eastern Chukchi Sea ◇☆A Takehiko Nose, Takuji Waseda and Tsubasa Kodaira (Univ. Tokyo) and Jun Inoue (NIPR)	
14:55	D-6 Observed waves in the refreezing eastern Chukchi Sea during 2018 Mirai Cruise ◇Takuji Waseda, Takehiko Nose, Tsubasa Kodaira (Univ. Tokyo), Alison Kohout (Univ. Victoria, Canada), Johannes Gemmrich (National Inst. Water Atmospheric Res., New Zealand), Hui Shen (Bedford Inst. Oceanogr., Canada) and Jun Inoue (NIPR)	
15:15	D-7 Oceanographic observation of refreezing warm Chukchi Sea during 2018 Mirai Cruise ◇☆A Tsubasa Kodaira, Takehiko Nose, Takuji Waseda (Univ. Tokyo) and Jun Inoue (NIPR)	
15:35	D-8 Influence of autumn ocean heat flux on sea ice advance in the Chukchi Sea ◇Takuya Nakanowatari, Jun Inoue (NIPR) and Jinlun Zhang (Univ. Washington, USA)	
15:55	Break	
		Chair, Jun Ono (JAMSTEC)
16:05	D-9 Impact of sea ice thickness on the predictability of the Arctic environmental variability ◇Jun Ono, Yoshiki Komuro and Hiroaki Tatebe (JAMSTEC)	
16:25	D-10 Incorporation of satellite-derived thin ice data into a global OGCM simulation ◇Takahiro Toyoda (Meteorological Res. Inst.), Katsushi Iwamoto (NIPR/Niigata Univ. /Mombetsu City), L. Shogo Urakawa, Hiroyuki Tsujino, Hideyuki Nakano, Kei Sakamoto, Goro Yamanaka (Meteorological Res. Inst.), Yoshiki Komuro, Shigeto Nishino (JAMSTEC) and Jinro Ukita (Niigata Univ.)	
16:45	D-11 Development of TOPAZ5 for the Arctic Ocean-Ice-Biogeochemistry-Wave forecast and reanalysis ◇Tsuyoshi Wakamatsu, Annette Samuelsen (Nansen Center, Norway/Bjerknes Center for Climate Res., Norway), Jiping Xie (Nansen Center, Norway), Çağlar Yumruktepe, Mostafa Bakhoday-Paskyabi (Nansen Center, Norway/Bjerknes Center for Climate Res., Norway), Alfati Ali (Norwegian Meteorological Inst., Norway) and Laurent Bertino (Nansen Center, Norway/Bjerknes Center for Climate Res., Norway)	
17:05	D-12 Information retrieval for Northern Sea Route (NSR) navigation: a statistical approach using the TOPAZ4 and AIS data ◇Tomoko Koyama, Jun Inoue and Takuya Nakanowatari (NIPR)	
17:25	D-13 Sea ice conditions in the Beaufort Sea in autumn 2018 ◇Kazutaka Tateyama, Kazutoshi Sato (Kitami Inst. Tech.), Noriaki Kimura (Univ. Tokyo) and Hayato Okuda (Kitami Inst. Tech.)	
17:45	Break	
17:55 18:30	【Kickoff Meeting for Making a New Arctic Research Icebreaker】 (in Japanese language only) Chair, Hajime Yamaguchi (Univ. Tokyo)	
18:30	White Concert 『Okhotsk Sea Ice Museum』	

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Mombetsu Arts & Culture Center

Place: 3F Meeting Room

	【E : Cold Region Engineering】 Chair, Kuk-Jin Kang (Korea Res. Inst. Ships Ocean Eng., Korea)
13:00	E-1 Turning features of an icebreaker during ramming operations: a case study ◇☆A Yuto Takahashi, Hajime Yamaguchi (Univ. Tokyo), Shuki Ushio (NIPR), Yutaka Yamauchi and Shigeya Mizuno (Japan Mar. United Corp.)
13:20	E-2 Experimental evaluation of ice load acting on an Arctic offshore structure with different ice drifting angle ◇☆A Cheolhee Kim, Young-Shik Kim, Hyung-Do Song, Kuk-Jin Kang and Jinho Jang (Korea Res. Inst. Ships Ocean Eng., Korea)
13:40	E-3 Systematic literature study for important factors of station-keeping in Arctic condition ◇Byungmo Kim and Seunghyun Ha (Korea Mar. Ocean Univ., Korea)
14:00	E-4 An experimental investigation on the mooring performance of a turret moored Arctic offshore vessel ◇☆A Hyungdo Song, Young-Shik Kim, Cheolhee Kim, Young-Uk Won and Kuk-Jin Kang (Korea Res. Inst. Ships Ocean Eng., Korea)
14:20	Break
	Chair, Koh Izumiyama (Hokkaido Univ.)
14:30	E-5 An experimental validation of an icevaning control algorithm for an Arctic offshore vessel in managed ice condition ◇Young-Shik Kim, Hyung-Do Song, In-Bo Park and Kuk-Jin Kang (Korea Res. Inst. Ships Ocean Eng., Korea)
14:50	E-6 Influence of initial arrangement of ice floes on ice loads in non-smooth discrete element method simulation ◇☆A Kenta Hasegawa, Shotaro Uto, Haruhito Shimoda, Daisuke Wako and Takatoshi Matsuzawa (Natl. Mar. Res. Inst.)
15:10	E-7 Modification of local ice load prediction based on IBRV ARAON's 2016 Arctic field data ◇Sungrok Cho and Kyungsik Choi (Korea Mar. Ocean Univ., Korea)
15:30	E-8 On interfacial wave making resistance of a ship ◇Hiromitsu Kitagawa and Eiji Sakai (Ocean Policy Res. Inst.)
16:50	E-9 Exploration of the parameter space for ice floe drift Luuk Blaauw (Univ. Twente, Netherlands), Grant Skidmore (Univ. Melbourne, Australia), ◇Amin Chabchoub (Univ. Sydney, Australia) and Jason Monty (Univ. Melbourne, Australia)
16:10	Break
18:30	White Concert 『Okhotsk Sea Ice Museum』

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Monday 18 Feb. 2019

Mombetsu Municipal Museum

Place: Museum Lecture Room

	【M2 : Public Program: Our Home Okhotsk Sea】 <i>(in Japanese language only)</i> Chair, Masaki Fujiwara (City of Mombetsu)
13:00	M2-1 The current state of Mombetsu fisheries ◇Hiroaki Iida (Mombetsu Fish. Corp. Assoc.)
13:40	M2-2 Recent topics on chum salmon in Hokkaido ◇Hayato Saneyoshi (Salmon & Freshwater Fish. Res. Inst.)
14:20	Break
14:30	M2-3 Effective utilization of scallop mantle ~New snack food development and use as a functional material~ ◇Hirofumi Takeda (Abashiri Fish. Res. Inst.)
15:10	M2-4 Visualization of fish behaviour using bio-logging technology ◇Kazushi Miyashita (Hokkaido Univ.)
15:50	Break
16:00 17:00	「Discussion」 Chair, Tsuneo Nishiyama (Tokai Univ.)
18:30	White Concert 『Okhotsk Sea Ice Museum』

	【 F : Workshop, Utilization of the Northern Sea Route and the Arctic Ocean ~ Update and New Concept 】 <p style="text-align: right;">Chair, Natsuhiko Otsuka (Hokkaido Univ.)</p>
9:00	Introduction, Natsuhiko Otsuka (Hokkaido Univ.) 《Keynote Address》
9:05	F-1 Future opportunities and challenges for Russia's Northern Sea Route ◇Lawson W. Brigham (Univ. Alaska, USA)
9:35	F-2 How the "Arctic League" views the use of the Arctic Ocean under climate change? Fujio Ohnishi, ◇Juha Saunavaara and Natsuhiko Otsuka (Hokkaido Univ.)
9:55	F-3 Improving connectivity between East Asia and Europe through the Arctic: Submarine fiber-optic cable projects current status ◇Juha Saunavaara (Hokkaido Univ.)
10:15	F-4 Framework of NSR gateway evaluation: A preliminary discussion ◇Motohisa Abe (Hokkaido Univ.)
10:35	Break
10:45	F-5 Investigation of ship speed along the Northern Sea Route by satellite AIS ◇Natsuhiko Otsuka, Xiaoyang Li (Hokkaido Univ.) and Kazutaka Tateyama (Kitami Inst. Tech.)
11:05	F-6 Characteristics of recent NSR shipping activities by destination and objective ◇Xiaoyang Li and Natsuhiko Otsuka (Hokkaido Univ.)
11:25	F-7 Desktop study of Northern Sea Route trial shipping ◇Natsuhiko Otsuka (Hokkaido Univ.), Eisaku Nakamura (Hokkaido Res. Inst. Twenty-First Century Co., Ltd.), Juha Saunavaara and Fujio Ohnishi (Hokkaido Univ.)
11:45	F-8 Scientific diplomacy in the Arctic - Japan's commitment to the Arctic Council - ◇Julie Babin (Laval Univ., Canada)
12:05	Lunch
	【 G : Workshop, Activities Industry-Government-Academia Collaborative Research on the Arctic Region Supported by J-ARC Net 】 <p style="text-align: right;">Chair, Masato Tanaka (Hokkaido Univ.)</p>
13:00	G-1 Activities to promote industry-government-academia collaborative research on the Arctic region supported by Japan Arctic Research Network Center (J-ARC Net) ◇Masato Tanaka, Shingo Tanaka, Yasushi Fukamachi and Sei-ichi Saito (Hokkaido Univ.) Study on marine ecosystem during sea-ice season in the seasonal sea-ice region ◇Kohei Matsuno (Hokkaido Univ.), Seiji Katakura (City of Mombetsu), Hiromi Kasai (Hokkaido Natl. Fish. Res. Inst.) and Katsunori Kimoto (JAMSTEC)
13:30	G-2 Arctic technology research forum to consolidate opinions from industry ◇Takashi Kikuchi (JAMSTEC), Hajime Yamaguchi (Univ. Tokyo), Hiroshi Yoshinaga (Mitsubishi Heavy Industries Ltd.), Satoru Fukuba (Japan Marine United Corp.), Masahiro Miwa (INPEX CORPORATION), Takao Kashiwagi (Mitsui O.S.K. Lines, Ltd.), Hajime Yoshida (Zeni Lite Buoy, Ltd.), Kay I. Ohshima, Yasushi Fukamachi (Hokkaido Univ.), Hironori Yabuki and Yuji Kodama (NIPR)
13:50	G-3 LNG transportation from the Arctic Ocean - YAMAL LNG Project - ◇Shiro Izumi, Yuta Orito and Takao Kashiwagi (Mitsui O.S.K. Lines, Ltd.)
14:10	G-4 The feasibility study for ice navigation support system for the Northern Sea Route ◇Eisuke Akane (JAMSTEC), Hajime Yamaguchi (Univ. Tokyo), Akihisa Konno (Kogakuin Univ.), Kazutaka Tateyama (Kitami Inst. Tech.), Takatoshi Matsuzawa (Natl. Mar. Res. Inst.), Misako Kachi, Masahiro Hori (JAXA), Genki Sagawa (Weathernews Inc.), Shiro Izumi (Mitsui O.S.K. Lines, Ltd.), Toshiro Arima, Akira Teshima (Nippon Kaiji Kyokai), Hironori Yabuki, Tetsuo Sueyoshi (NIPR), Noriaki Kimura (Univ. Tokyo), Takashi Kikuchi and Takeshi Kawano (JAMSTEC)
14:30	Break

	【 G : Workshop, Activities Industry-Government-Academia Collaborative Research on the Arctic Region Supported by J-ARC Net 】 Chair, Masato Tanaka (Hokkaido Univ.)	
14:40	G-5 Recent activity and possibility of the Northern Sea Route ◇Natsuhiko Otsuka (Hokkaido Univ.), Eisaku Nakamura, (Hokkaido Res. Inst. Twenty-first Century Co., Ltd.), Juha Saunavaara and Fujio Ohnishi (Hokkaido Univ.)	
15:00	G-6 The utilization marine bunker for ships in the Arctic zone ◇Hiroyuki Goda (Tokai Univ.)	
15:20	G-7 Study on oil spill response technology in cold water condition - Lessons learned from Exxon Valdes and Deepwater Horizon - ◇Naoki Nakazawa (Syst. Eng. Assoc., Inc.), Hajime Yamaguchi (Univ. Tokyo), Akira Kurokawa (Eng. Adv. Assoc. Japan), Jun Ono (JAMSTEC), Takashi Terashima (Kumashiro Syst. Frontier Co., Ltd.), Genki Sagawa (Weathernews Inc.), Shuho Yano (Japan Workvessel Assoc.), Yasushi Fukamachi and Kay I. Ohshima (Hokkaido Univ.)	
15:40	G-8 Assessing and mediating damages on infrastructure and changes in ground surface due to permafrost thaw ◇Takahiro Abe (JAXA), Go Iwahana (Univ. Alaska, USA), Takumi Kawamura (IWATA CHIZAKI Inc.), Syunji Kanie (Hokkaido Univ.), Takeo Tadono (JAXA), Masato Furuya (Hokkaido Univ.), Yoshihiro Iijima (Mie Univ.), Alexander Fedorov (Yakutsk Permafrost Inst., Russia), Yuri Zhegusov (Inst. Humanities & Indigenous People North, Russia), Anastasia Tseeva (Yakut State Design & Res. Inst. Constr., Russia), Petr Efremov (Yakutsk Permafrost Inst., Russia) and Alexey Desyatkin (Inst. Biological Problems Cryolithozone, Russia)	
16:00	G-9 An indispensable condition to secure the continuity of sea ice and permafrost engineers in Japan ◇Satoshi Akagawa (Cryosphere Eng. Lab.), Shunji Kanie (Hokkaido Univ.), Takahiro Takeuchi (Hachinohe Inst. Eng.), Toshio Sone (Hokkaido Univ.), Yuji Kodama (NIPR), Akira Kurokawa (Eng. Adv. Assoc. Japan), Naoki Nakazawa (Syst. Eng. Assoc., Inc.) and Takashi Terashima (Kumashiro Syst. Frontier Co., Ltd.)	
16:20	Break	
	【 M3 : Prevention and Mitigation of Disasters in the Okhotsk Region of Hokkaido, Japan 】 <i>(in Japanese language only)</i>	
16:30	Introduction, Kazuhiro Takahashi (Abashiri Develop. Constr. Dept.)	
16:35	M3-1 Disaster prevention education promoting by a meteorological observatory ◇Kazuhiro Taniuchi (Abashiri Local Meteorological Office)	
16:55	M3-2 Activity of one-day school for disaster prevention ◇Kazuaki Taki (Okhotsk General Subprefectural Bureau)	
17:05	Break	
17:15 18:30	Panel Discussion 『Action When Disaster Happened - Toward Disaster Mitigation』 Masahiro Nemoto (Japan Red Cross Hokkaido College of Nursing) Kazuhiro Taniuchi (Abashiri Local Meteorological Office) Kazuaki Taki (Okhotsk General Subprefectural Bureau) Yasuyuki Ohara (City of Mombetsu) Takashi Sato (Mombetsu Shiomi Junior High School) Teruo Yamamoto (City of Mombetsu)	Coordinator, Kazuhiro Takahashi (Abashiri Develop. Constr. Dept.)
19:00	Dinner Party for Friendship between Scientists & Volunteers 『Mombetsu Central Hotel』	

	【H : Workshop, Subarctic Climate System and Land-Ocean Linkage】 Chair, Humio Mitsudera (Hokkaido Univ.)
9:00	Introduction, Humio Mitsudera (Hokkaido Univ.)
9:05	H-1 Formation of bottom water off Peter the Great Bay in the Sea of Japan ◇Kiyoshi Tanaka (Univ. Tokyo)
9:25	H-2 Marine environment in Kamaishi Bay ◇☆A Yanmei Sun, Kiyoshi Tanaka, Yutaka Michida and Daigo Yanagimoto (Univ. Tokyo)
9:45	H-3 An analysis of hydrological characteristics in the tidal zone of Bekanbeushi River ◇☆A Manhui Ding and Takayuki Shiraiwa (Hokkaido Univ.)
10:05	H-4 Numerical simulation of typhoon storm surge in the Luoyuan Bay ◇☆A Yuan Nan (Ocean Univ. China, China), Xiping Chen (National Mar. Hazard Mitigation Service, China), Xueen Chen (Ocean Univ. China, China) and Jinrui Chen (FuJian Marine Forecasts, China)
10:25	Break
	Chair, Tomohiro Nakamura (Hokkaido Univ.)
10:40	H-5 Estimation of freshwater discharge from the Kamchatka Peninsula to its surrounding oceans ◇☆A Shi Muqing and Takayuki Shiraiwa (Hokkaido Univ.)
11:00	H-6 Role of river discharges from Kamchatka Peninsula in the Okhotsk Sea ◇Toru Miyama (JAMSTEC) and Humio Mitsudera (Hokkaido Univ.)
11:20	H-7 On global distribution and interannual variability of wintertime halocline Masato Oda, Hiromichi Ueno and ◇Humio Mitsudera (Hokkaido Univ.)
11:40	H-8 Distribution, variation and statistics of the index of mixing due to interaction of a vortex and internal waves in the North Pacific ◇Kaoru Ito and Tomohiro Nakamura (Hokkaido Univ.)
12:00	Lunch
	Chair, Hiroaki Ueda (Univ. Tsukuba)
13:00	H-9 Future projection of day-to-day temperature cooling in East Asia ◇Masamitsu Hayasaki (Japan Automobile Res. Inst.), Seiji Sugata (National Inst. Environ. Studies) and Hiroaki Ueda (Univ. Tsukuba/Hokkaido Univ.)
13:20	H-10 Modulation of snowfall, cyclogenesis and tropical cyclone in the East Asia relevant to the combined effect of the Indian and Pacific Ocean SSTs ◇Hiroaki Ueda (Univ. Tsukuba/Hokkaido Univ.)
13:40	H-11 Atmospheric circulation field regulating sea ice change and long-term trend in the Sea of Okhotsk ◇☆A Kaede Maesaki (Univ. Tsukuba)
14:00	H-12 Far-reaching effects of sea ice extent in the Sea of Okhotsk on sea-surface turbulent heat flux and their possible influence ◇Tomohiro Nakamura, Yusuke Takahashi (Hokkaido Univ.) and Takuya Nakanowatari (NIPR)
14:20	H-13 A study of predictability of environment for a heavy snowfall - A case study in Sapporo during 22-23 December 2016 - ◇Hiroaki Asai (SOKENDAI/Japan Meteorological Agency) and Jun Inoue (SOKENDAI/NIPR)
14:40	Discussion
15:00	Break
	【I : Meteorology and Oceanography in Polar Regions】 Chair, Toru Miyama (JAMSTEC)
15:10	I-1 Grease ice observations in the southern Sea of Okhotsk with P/V Soya ◇Masato Ito, Takenobu Toyota, Jun Nishioka, Daiki Nomura, Naoya Kanna, Kan Murakami and Kay I. Ohshima (Hokkaido Univ.)
15:30	I-2 Variations of sea ice band in the northern Chukchi Sea associated with sea ice rafting ◇☆A Jumpei Yamamoto and Koji Shimada (Tokyo Univ. Mar. Sci. Tech.)
15:50	I-3 Ocean measurements near the fronts of marine-terminating glaciers in northwestern Greenland ◇☆A Naoya Kanna, Shin Sugiyama, Takuto Ando, Izumi Asaji and Yoshiki Fujishi (Hokkaido Univ.)
16:10	Break

Tuesday 19 Feb. 2019 Mombetsu Arts & Culture Center Place: 3F Special Conference Room

	【J : Arctic Sea Routes】	Chair, Noriaki Kimura (Univ. Tokyo)
16:20	J-1 Sea spray observation and analysis on R/V Mirai ◇☆A Shuichi Fushimi (Univ. Tokyo), Toshihiro Ozeki (Hokkaido Univ. Edu.), Hajime Yamaguchi (Univ. Tokyo), Masaki Katsumata (JAMSTEC) and Jun Inoue (NIPR)	
16:40	J-2 Trial demonstration of Fluid-Ice-Ship interactive simulations by particle method ◇☆A Takahito Iida and Takefumi Higaki (Osaka Univ.)	
17:00	J-3 Evaluation of the Northern Sea Route feasibility by optimum route search ◇☆A Kengo Okada, Hajime Yamaguchi (Univ. Tokyo), Jun Ono (JAMSTEC) and Takatoshi Matsuzawa (Natl. Mar. Res. Inst.)	
19:00	Dinner Party for Friendship between Scientists & Volunteers 『Mombetsu Central Hotel』	

Tuesday 19 Feb. 2019 Mombetsu Arts & Culture Center Place: 3F Meeting Room

	【K : Remote Sensing】	Chair, Toshiyuki Takagi (Natl. Inst. Tech., Kushiro Coll.)
10:00	K-1 Application of ALOS-2/PALSAR-2 for detecting deformed sea ice area in the Sea of Okhotsk - Toward understanding ice deformation processes - ◇Takenobu Toyota (Hokkaido Univ.) and Junno Ishiyama (Toma Town Office)	
10:20	K-2 Observation of multi-year ice distribution using the satellite microwave data ◇Noriaki Kimura (Univ. Tokyo), Kazutaka Tateyama (Kitami Inst. Tech.), Hajime Yamaguchi and Hiroyasu Hasumi (Univ. Tokyo)	
10:40	K-3 Ship-based television complex STK – The program for remote sea ice thickness measurements ◇Sergey Serovetnikov, Sergey Frolov and Tatiana Alekseeva (Arctic & Antarctic Res. Inst., Russia)	
11:00	K-4 The system of video registration and visualization of the results of laboratory experiments Andrey Kurkin, ◇☆A Vitaly Kuzin, Dmitry Tyugin and Oxana Kurkina (Nizhny Novgorod State Tech. Univ. n.a. R.E. Alekseev, Russia)	
11:20	K-5 High resolution sea ice motion analysis with MODIS data in the western Arctic region ◇☆A Shungo Yaguchi, Noriaki Kimura (Univ. Tokyo), Motoyo Itoh (JAMSTEC), Yasushi Fukamachi (Hokkaido Univ.), Takashi Kikuchi (JAMSTEC) and Hajime Yamaguchi (Univ. Tokyo)	
12:00	Lunch	

Tuesday 19 Feb. 2019 Mombetsu Municipal Museum Place: Museum Lecture Room

	【L : Marine Biology and Fisheries】	Chair, Hiroshi Sasaki (Ishinomaki Senshu Univ.)
9:00	L-1 Characteristics in variability of primary production environments in the Okhotsk Sea waters off Hokkaido using satellite remote sensing ◇Hiromi Kasai (Hokkaido National Fish. Res. Inst.) and Takahiko Kameda (National Res. Inst. Fish. Sci.)	
9:20	L-2 Nitrogen fixation and diazotroph community structure in the high latitude region around Hokkaido, northern Japan ◇☆A Takuya Sato (Univ. Tokyo), Takuhei Shiozaki (JAMSTEC), Yukiko Taniuchi, Hiromi Kasai (Hokkaido Natl. Fish. Res. Inst.) and Kazutaka Takahashi (Univ. Tokyo)	
9:40	L-3 Time series monitoring of environmental DNA in Okhotsk Sea ◇Satoshi Nagai (National Res. Inst. fish. Sci.), Yoko Kawakami, Noriko Nishi (AXIOHELIX Co. Ltd), Sirje Sildever, Nanako Kanno (National Res. Inst. fish. Sci.), Akihiro Shiimoto (Tokyo Univ. Agriculture) and Seiji Katakura (City of Mombetsu)	
10:00	L-4 The effects of multiple stressors on the distribution of coastal benthic foraminifera: A case study from the Skagerrak-Baltic Sea region - Zombie foraminifera reveal impacts of ocean acidification in the Baltic Sea - ◇☆A Laurie M. Charrieau, Helena L. Filipsson, Karl Ljung (Lund Univ., Sweden), Melissa Chierici (Univ. Göteborg, Sweden/Inst. Mar. Res., Norway), Karen Luise Knudsen (Aarhus Univ., Denmark) and Emma Kritzberg (Lund Univ., Sweden)	
10:20	Break	

☆A The Aota Masaaki Award Candidate

	<p>【L : Marine Biology and Fisheries】 Chair, Hiromi Kasai (Hokkaido Natl. Fish. Res. Inst.)</p>
10:30	<p>L-5 Shell morphology/density variations of thecosomatous pteropod <i>Limacina helicina</i> recovered from off Mombetsu, Sea of Okhotsk: A result from 2017 to 2018 ◇Katsunori Kimoto (JAMSTEC), Keisuke Shimizu (Univ. Exeter, UK), Erina Shima, Hiroshi Sasaki (Ishinomaki Senshu Univ.), Hiromi Kasai (Hokkaido Natl. Fish. Res. Inst.) and Seiji Katakura (City of Mombetsu)</p>
10:50	<p>L-6 Variability of shell density of thecosomatous pteropod <i>Limacina sp.</i> ◇☆A Erina Shima, Hiroshi Sasaki (Ishinomaki Senshu Univ.) and Katsunori Kimoto (JAMSTEC)</p>
11:10	<p>L-7 Genetic differences in spatially and temporally isolated populations: Winter and spring populations of pelagic mollusk <i>Clione</i> (Gymnosomata), southern Okhotsk Sea, Japan ◇☆A Tomoyasu Yamazaki (Shellfish Museum of Rankoshi), Takashi Kuwahara (Sea Ice Museum) and Kunio T. Takahashi (NIPR/SOKENDAI)</p>
11:30	<p>L-8 Ocean acidification driven biological vulnerability in the high latitudes: Comparison between the Gulf of Alaska, Bering Sea and Beaufort Sea ◇☆A Nina Bednarsek (Southern California Coastal Waters Res. Project, USA), Richard Feely (NOAA Pacific Mar. Environ. Lab., USA), Kerry Naish (Univ. Washington, USA), Katsunori Kimoto (JAMSTEC), Andrea Niemi (Fish. Ocean, Canada), Albert Hermann (NOAA Pacific Mar. Environ. Lab., USA), Lorenz Hauser, Isadora Jimenez (Univ. Washington, USA) and Phyllis Stabenro (NOAA Pacific Mar. Environ. Lab., USA)</p>
12:00	Lunch
	<p>Chair, Ikutaro Shimizu (Hokkaido Natl. Fish. Res. Inst.)</p>
13:00	<p>L-9 Lipid composition and autolytic activity of the northern North Pacific krill (<i>Thysanoessa inermis</i>) that was washed ashore in Shiretoko Peninsula Hokkaido, Japan ◇Koretaro Takahashi (Kitami Inst. Tech.), Daiki Yasunaka and Shingo Inoue (Hokkaido Univ.)</p>
13:20	<p>L-10 Study on homing of black rockfish (<i>Sebastes schlegelii</i>) by biotelemetry ◇☆A Yoshinori Tatsu, Makoto Tomiyasu, Hokuto Shirakawa and Kazushi Miyashita (Hokkaido Univ.)</p>
13:40	<p>L-11 Visualization of spawning migration of pacific herring <i>Clupea pallasii</i> - Three-dimensional change of the migration and its factors - ◇☆A Makoto Tomiyasu, Hokuto Shirakawa, Masahiro Ogawa, Daichi Oshiyama and Kazushi Miyashita (Hokkaido Univ.)</p>
14:00	<p>L-12 Diet and weaning period of Dall's porpoise around Hokkaido, Japan ◇☆A Ayaka Matsuda (Hokkaido Univ./JPN Society Promo. Sci.) and Takashi Fritz Matsuishi (Hokkaido Univ.)</p>
14:20	<p>L-13 Outline of the second expedition of whale scientific permit survey off coast of the Okhotsk Sea under the NEWREP-NP program ◇Hideyoshi Yoshida, Hikari Maeda (Natl. Res. Inst. Far Seas Fish.), Gen Nakamura (Tokyo Univ. Mar. Sci.), Tsutomu Tamura and Hidehiro Kato (Inst. Cetacean Res.)</p>
14:40	Break
	<p>【L : Workshop, Recent Progress in Salmon Researches: Perspectives to the Sustainable Use of Salmon Resources in the Okhotsk Area】</p> <p>《Keynote Address》 Chair, Yoshitaka Sasaki (Abashiri Fish. Res. Inst.)</p>
15:00	<p>L-14 Mystery of homing in Pacific salmon - Sensory mechanisms of natal stream imprinting and homing - ◇Hiroshi Ueda (Hokkaido Univ./Hokkaido Aquaculture Promo. Corp.)</p>
15:30	<p>L-15 Recent status of chum salmon stocks in Hokkaido ◇Yasuyuki Miyakoshi, Makoto Fujiwara, Hayato Saneyoshi (Salmon & Freshwater Fish. Res. Inst.) and Yoshitaka Sasaki (Abashiri Fish. Res. Inst.)</p>
15:50	<p>L-16 Migration period of juvenile chum salmon into and out of the littoral zone in the Nemuro region ◇Kiyoshi Kasugai (Salmon & Freshwater Fish. Res. Inst.)</p>
16:10	Break

Tuesday 19 Feb. 2019 Mombetsu Municipal Museum Place: Museum Lecture Room

	【L : Workshop, Recent Progress in Salmon Researches: Perspectives to the Sustainable Use of Salmon Resources in the Okhotsk Area】 Chair, Yasuyuki Miyakoshi (Salmon & Freshwater Fish. Res. Inst.)
16:20	L-17 Migration and homing behavior of chum salmon tagged in the Okhotsk Sea, eastern Hokkaido ◇Hayato Saneyoshi, Makoto Fujiwara (Salmon & Freshwater Fish. Res. Inst.), Itsuki Tatsuoka, Satoki Ohba, Hokuto Shirakawa (Hokkaido Univ.), Yasuyuki Miyakoshi (Salmon & Freshwater Fish. Res. Inst.) and Kazushi Miyashita (Hokkaido Univ.)
16:40	L-18 Effects of terrestrial animals on carcass removal from salmon spawning streams in eastern Hokkaido ◇Kei Matsumoto and Katsuaki Komai (Kitami Inst. Tech.)
17:00	L-19 Balance between human economic activities and impacts on ecosystem by Atlantic salmon escape and Pacific salmon invasion ◇Ikutaro Shimizu (Hokkaido Natl. Fish. Res. Inst.)
17:20	Discussion 『The Future Salmon Research in the Okhotsk Region』
19:00	Dinner Party for Friendship between Scientists & Volunteers 『Mombetsu Central Hotel』

Wednesday 20 Feb. 2019 Mombetsu Arts & Culture Center Place: 1F Main Hall

	【J : Arctic Sea Routes】 Chair, Hajime Yamaguchi (Univ. Tokyo)
9:30	J-4 Arctic & Security -from the Security View Point- ◇Takahiro Ishihara (Japan Mar. Self Defense Force /Keio Univ.)
9:50	J-5 Navigation Support by ADS in R/V MIRAI Arctic cruise 2018 ◇Hironori Yabuki, Takeshi Sugimura, Takeshi Terui, Jun Inoue (NIPR), Hajime Yamaguchi, Waruna Arampath (Univ. Tokyo) and Souichiro Sueyoshi (Nippon Marine Enterprises)
10:10	J-6 Development of ship speed prediction method in the ice-covered waters along the Northern Sea Route ◇Hayato Okuda Kazutaka Tateyama (Kitami Inst. Tech.) and Natsuhiko Otsuka (Hokkaido Univ.)
10:30	J-7 Introduction of KRISO Arctic safe routing system (KARS) ◇Kuk-Jin Kang, Seong-Yeob Jeong, Jeong-Joong Kim (Korea Res. Inst. Ships & Ocean Eng., Korea), Hyun-Soo Kim (Inha Tech. College, Korea), Chan-Su Yang (Korea Inst. Ocean Sci. & Tech., Korea), Seong-Heon Jeong (Dong-Kang M-Tech, Korea) and Myung-Il Roh (Seoul National Univ., Korea)
10:50	Break
11:00 11:30	【Closing Session】 Chair, Seiji Katakura (City of Mombetsu) <ul style="list-style-type: none"> •Symposium Declaration: •A Review of the Symposium: •Prize-awarding Ceremony of the Aota Masaaki Award: •Closing Remarks: Shuhei Takahashi (Chair of the Symposium Committee)
12:00	Lunch
13:30 16:00	【M4: Public Program, Symposium on the Forest-Ocean Linkage】 <i>(in Japanese language only)</i> 『Importance of the Forest -To Promote the Public Interest Function of the Forest and to Make the Forestry to Growing Industry』 Introduction, Akihisa Ishida (Mombetsu City) Presenter, Norie Tamura (Res. Inst. Humanity & Nature)

13:30 17:30	<p>【M5 : Public Program : The Okhotsk Terroir Symposium 2019 in Mombetsu】 (in Japanese language only)</p> <p>『Dispatch and Development of New Okhotsk Tourism』</p> <p>Part 1 : Offer of Information and Topics</p> <p>Part 2 : Practice Examples, Proposal and Suggestion</p> <p>Part 3 : Panel Discussion</p>
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9:00 11:00	<p>【P : Poster Session】</p> <p>P-1 The relationship between phytoplankton bloom and sea ice melt in the Sea of Okhotsk, revealed from the profiling floats ◇Sachiko Kishi, Kay I. Ohshima, Noriaki Isshiki (Hokkaido Univ.), Sohey Nihashi (Natl. Inst. Tech., Tomakomai Coll.) and Stephen C. Riser (Univ. Washington, USA)</p> <p>P-2 Variability in abundance and shell size of the pteropods <i>Limacina</i> spp. in the seasonal ice zone of the Antarctic Ocean ◇Kunio T. Takahashi (NIPR/SOKENDAI), Haruko Umeda (Kaizansenri Inc.) and Tsuneo Odate (NIPR/SOKENDAI)</p> <p>P-3 Reaction behaviors of fish for LED light with different wavelength ◇Yoko Tanouchi, Yasuzumi Fujimori, Susumu Shimizu, Hiroki Yasuma, Naoto Matsubara, Takuma Hayashi (Hokkaido Univ.) and Seiji Katakura (City of Mombetsu)</p> <p>P-4 Abundance of eggs and larvae of Walleye Pollock in the Pacific area of Japan ◇Tomonori Hamatsu (Hokkaido Natl. Fish. Res. Inst.)</p> <p>P-5 Searching for male-dominantly expressed genes in undifferentiated gonad of Amur sturgeon ◇Ken Kitagawa, Shigeo Ijiri and Shinji Adachi (Hokkaido Univ.)</p> <p>P-6 Ovarian development in hybrid sturgeons ◇Takayuki Otomo, Yosuke Aizawa, Hikaru Takayanagi, Kazuki Mukai, Shigeo Ijiri and Shinji Adachi (Hokkaido Univ.)</p> <p>P-7 Measurement and modeling of underwater acoustic propagation in Mombetsu port area ◇Shun Sakamoto, Shingo Yoshizawa (Kitami Inst. Tech.), Tomotaka Niibo, Tomoya Tsukui (IHI Corp.), Takashi Saito (Mitsubishi Electric TOKKI Sys. Corp.)</p> <p>P-8 Relationship between transpolar flights over the Arctic and the upper atmospheric circulation ◇Kazutoshi Sato (Kitami Inst. Tech.) and Jun Inoue (NIPR)</p> <p>P-9 Verification of AMSR-2 sea ice concentration and utilization of ship navigation in the Arctic Ocean ◇Nodoka Ono (JAXA)</p> <p>P-10 Radar image segmentation for sea ice navigation using deep learning ◇Toshiyuki Takagi (Natl. Inst. Tech., Kushiro Coll.) and Kazutaka Tateyama (Kitami Inst. Tech.)</p> <p>P-11 Use of unmanned aerial vehicles (UAV) for surveys of anthropogenic snow patches ◇Alexandra A. Muzychenko, Valentina A. Lobkina and Leonid E. Muzychenko (Far East Geological Inst., Russia)</p> <p>P-12 Features of the elemental composition of snow cover in the Baikal region ◇Natalia Ianchenko (Irkutsk National Res. Tech. Univ. Russia)</p> <p>P-13 Arctic exploration history and climate change ◇Shuhei Takahashi (Sea Ice Museum)</p> <p>P-14 Transport of fresh fish before World War II ◇Masaya Yamada (Hokkaido Industrial Archaeology Society/Hokkaido Cultural Property Protection Assoc./City of Mombetsu)</p>
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【P : Poster Session 「Exhibition」】

- P-15** Migration of eelpout dipline *Lycodes soldatovi* (Perciformes: Zoarcidae)
Oleg Z. Badaev (TINRO Center, Russia)
- P-16** Geoeological information-modeling system and its implication for the biocomplexity and survivability assessment of the Okhotsk Sea ecosystem
Vladimir F. Krapivin (Kotelnikov Inst. Radioengin. & Electronics, Russia) and
Costas. A. Varotsos (National & Kapodistrian Univ., Greece)
- P-17** An adaptive optical technology for monitoring marine ecosystems
Ferdenant Mkrtchyan, Vladimir Krapivin and Vladimir Klimov (Kotelnikov Inst. Radioengin. & Electronics, Russia)
- P-18** Arctic latitudes environmental pollution effects
Costas. A. Varotsos (National & Kapodistrian Univ., Greece), Vladimir F. Krapivin and
Vladimir Yu. Soldatov (Kotelnikov Inst. Radioengin. & Electronics, Russia)
- P-19** Remote monitoring of water surface and ice cover of the Arctic
Ferdenant Mkrtchyan (Kotelnikov Inst. Radioengin. & Electronics, Russia) and
Sergey Shapovalov (Inst. Oceanology, Russia)
- P-20** Oceanologic condition in the waters of South Primorye (Sea of Japan) in 2018
Boris S. Dyakov (TINRO-Center, Russia)
- P-21** The Primorskoe Current on standard sections and satellite images of the Japan sea surface
Boris S. Dyakov (TINRO-Center, Russia)
- P-22** Hydrological characteristics of the Amur Bay (Japan Sea) in February 2018
Vladimir I. Matveev and Alexander L. Figurkin (TINRO-Centre, Russia)
- P-23** The recent temperature changes in the Okhotsk Sea mesothermal waters core
Alexander L. Figurkin (TINRO-Center, Russia)

9:30 11:00	<p>【Public Program : Symposium for Public Education】 <i>(in Japanese language only)</i> Chair, Takashi Kuwahara (Okhotsk Sea Ice Museum)</p> <p>Presentations by Junior-High School Students</p> <p>I . Presentation of the General Learning -Mombetsu Junior High School</p> <p>II . Presentation of the International Understanding Learning -Shokotsu Junior High School</p> <p>III . Presentation of the Local Disaster Prevention Learning -Shiomi Junior High School</p> <p>Review, Shinya Otomo (Mombatsu Shiomi Elementary School)</p>
12:00	Lunch
13:10 14:30	<p>【Public Program : Symposium on Sea Ice for Children and Parents】 <i>(in Japanese language only)</i> Introduction, Fusao Saito (City of Mombetsu) Chair, Takashi Suzue (City of Mombetsu)</p> <p>I . Wonder of drift ice in Okhotsk Sea Shuhei Takahashi (Okhotsk Sea Ice Museum)</p> <p>II . What kind of country is Belgium? Gaston Demarée (Royal Meteorological Inst. Belgium)</p> <p>III . Quiz about drift ice and Belgium Shuhei Takahashi (Okhotsk Sea Ice Museum) and Gaston Demarée (Royal Meteorological Inst. Belgium)</p>

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