8-24-2014

Research on the application of sea ice information in the Arctic North West Passage

Yuanhui Yang

WORLD MARITIME UNIVERSITY

Dalian, China

RESEARCH ON THE APPLIACTION OF SEA ICE INFORMATION IN THE ARCTIC NORTH WEST PASSAGE

By

YANG YUANHUI

The People's Republic of China

A research paper submitted to the World Maritime University in partial fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE

(MARITIME SAFETY AND ENVIRONMENTAL MANAGEMENT)

2014

DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): Yang Yuanhui

(Date): July 19, 2014

Supervised by:

Liu Dagang

Professor

Dalian Maritime University

Assessor:

Co-assessor:

ACKNOWLEDGEMENTS

This paper is developed as part of my studies to apply for the master's degree of Maritime Safety and Environmental Management (MSEM) at WMU and DMU. I am profoundly grateful to all people who have supported and helped me in various ways during my studies.

First and foremost, I would like to express my most sincere gratitude to my supervisor Professor Liu Dagang for his patience and encouragement and for guiding me through the process of this project. His help is indeed valuable.

I must give my heartfelt thanks to all professors attending the MSEM 2014 program. Their professional knowledge broadened my eyesight and instilled in me new ideas and methodologies without which, the study would not have been completed. My gratitude also goes to the administrative staff at the International Convention Research Center of DMU, for providing me with support during my study.

I remain very grateful to all classmates of MSEM 2014. I thank them for their company and for sharing their views and experiences. Together we experienced a nice time of life in DMU.

I also want to express my sincere thanks to my colleagues at Dalian MSA. My absence from work for MSEM program increased their workload and the research itself would not have been possible without their contribution.

Last but not the least, my deepest gratitude goes to my parents and wife for their

encouragement and support throughout the study.

ABSTRACT

Title of Research Paper: **Research on the Application of Sea Ice Information in the Arctic Northwest Passage**

Degree: **Msc**

Arctic Ocean is the culmination of Europe, Asia and North America. The Arctic Route is the shortcut throughout Europe, North America and East Asia in terms of maritime transportation. Easy navigation, resource development and strategic position will make the Arctic Route become a major part of the international shipping course. The integration of the world economy is becoming faster and faster; therefore, shipping industry will take a major position in international trade. In recent years, as the global climate is becoming warmer year by year, the temperature of Arctic is rising up, ice is melting down, the scope of ice is becoming narrowed down, and the opening of the Arctic Route will be possible. Sea ice in the Arctic is one of the main factors that influence the safety of voyage and the opening of the Arctic Route. When sailing in the Arctic Route, it seems very important to the driver to master some ice information throughout the route.

In order to make the drivers get more quick and effective ice information and make it more secure when sailing in the Northwest Passage, this paper makes a detailed introduction of the Arctic Northwest Passage according to the existing data and related research findings and analyzes seven concrete Northwest Passage characteristics and the general situation of the sea area. By collecting and organizing the research results that experts in China and abroad had made about the legal changes of Arctic sea ice in the Northwest Passage, the author gives an overall change trend about the Arctic sea ice.

Then by tracking, searching and screening the main source of ice information along the Northwest Passage on the Internet, this paper provides several main web sites such as Canada Ice Service, National Data Center and IPY Ice Logistics Portal. Through the analysis and arrangement of the websites, this paper gives an identification method about ice information in the Arctic Northwest Passage online, that is, through the identification of the Egg Code in the graph to understand the ice information of specific sea areas.

Finally, this paper makes a comprehensive analysis and comparison about the websites that can provide ice information, and determines make Canadian Ice Service as the most important part of this paper's research. On this foundation, it gives an application method of the available ice information while sailing in the Northwest Passage. Based on case studies, it gives the usage of the ice information online that can be used when sailing in the Northwest Passage, and in addition, it gives a method to understand the ice information through the Canadian Ice Service when sailing along the Northwest Passage.

This study can help the officer know ice information more quickly and effectively when sailing in Northwest Passage, and it can make them master the ice conditions wherever they are at any time so it can achieve the purpose that guarantee the safety of voyage in Northwest Passage.

Keywords: the Northwest Passage; Ice information; Ice chart; Egg Code

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LIST OF ABBREVIATIONS

IPY	International Polar Year
CIS	Canadian Ice service center
NIC	National Center for Ice

Chapter 1 Introduction

1.1 Research Significance of this Subject

Arctic Ocean is the culmination of Europe, Asia and North America, due to the separation from the mainland, the arctic route a shortcut maritime transport between Europe, North America and East Asia, once the arctic route is open to navigation, it will have a great influence on the layout of the global route. (Bai & Li, 2009, pp. 7-9)

Using high-resolution satellite and a variety of data analysis we can know, due to the global climate warming year by year in recent years, rising temperatures, melting ice, arctic ice shrinking happened in the arctic region, the opening of the arctic route would be possible (Liu, 2008, pp. 254-255).

In August 2007, according to NASA satellite photos, since at least 120000 years, "the Northeast Passage" and "the Northwest Passage" opened at the same time for the first time (Liu, 2009), sea ice researchers described it as "historic event". This shows that humans can have commercial navigation through the arctic waters.

With the developing trend of global economic integration, commercial intercourse is becoming more and more frequent all over the world, and all kinds of factors of production are accelerating the configuration and spread around the world (Zhang, 2009, pp. 34-41). This changes the world trade pattern, as well as the international economic, political and cultural configuration. (Fang, 2010, pp. 63-65)

International commercial trade is mainly done through shipping (Shi, 2010, pp. 7-9), and shipping route has become the major way in the international transport of goods, especially in East Asia, Northern Europe and North America. Among these main parts of world trade in goods, the arctic route navigation appears to be especially important. For China, since the access entry into the WTO, China's foreign trade grows rapidly year by year, and trade volume had reached $2.1738 trillion in 2007, which covers about sixty percent of GDP, and among which more than ninety percent of international trade transportation is done by sea. After the opening of the arctic route, it would greatly shorten international shipping route between China, Europe and North America. Maritime transport costs will greatly reduce. In addition, after the opening of the arctic route, China can also open up new channels for energy procurement overseas which can reduce possible political problems brought by going through politically sensitive waters such as the Strait of Malacca and the Suez Canal, Panama Canal and the Somali coast these (Pan, 2005, pp. 35-40). Obviously, if the arctic route opens, it will have far-reaching effects for China's foreign trade (Li & Tian, 2009, pp. 97-101).

Convenient navigation, resource development and strategic position will make the arctic route a major part of the international ocean shipping routes (Yu, 2009, pp. 227-228). At present, countries such as Norway, Iceland and Canada are positive in the development and utilization of the arctic route (Lei, 2007, p. 16). The arctic

route will be the most efficient seaway between North America, Europe and East Asia (Chen & Zhao, 2003, pp. 284-298).

Because the Northwest Passage is located in the Arctic Circle, special geographical environment factors lead to the Northwest Passage in the frozen state all the year round. Only few months will meet the navigation demand. Be that as it may, harsh environment, numerous islands, thousands of iceberg, the scarcity of shipping facilities and lack of experiences in the Arctic navigation make it very difficult for ship sailing in the Northwest Passage (Xie, 2010, pp. 24-26). According to incomplete statistics of AMSA2009, 293 maritime accidents occurred in the arctic waters during 1995 to 2004. Maritime accidents not only destroy the Arctic environment, but also cause huge economic loss. It is not conducive to business development and utilization of the arctic route (Yan, 2011).

Taking all these factors into consideration, when the ship is sailing in the Arctic route, officers must keep track of current and future ice condition. As is known to us all, the study of sea ice condition specifically for the Northwest Passage is not enough. For this reason, this article will focus on introducing the method of understanding the ice condition by ice chart, and make the ship drivers quickly and effectively master the sea ice, so that they can guarantee navigation safety of Northwest Passage in the Arctic more effectively.

1.2 Background Information of the Topic

With global warming, the Arctic Sea ice is melting, the chance of the arctic route

navigation is bigger and bigger, the world is paying more and more attention to the arctic route (Zhang, 2009, pp. 345-349). A large amount of sea ice along the arctic route is one of the key factors affecting the navigation safety. In view of this, international professors have done a lot of researches on the arctic navigation and sea ice changes.

Many countries and international organizations have launched investigations and researches on the arctic route. They have published many books, a lot of conference reports and research papers. Experts have made some studies on the arctic route profile, business feasibility, legal status, the geopolitics and strategic elements, etc.

Eight-nation Arctic Council was established in 1996 in Ottawa, with the assessment of the Arctic shipping a major responsibility of this organization (Stewart, Howell & Draper, 2007, pp. 370-380). In AMSA2009, the status of the arctic shipping climate, supervision and geographic factors are introduced, and the prospects of the development are forecast before 2020.

In December 2002, seven countries including Russia, Norway, Germany, Britain, the Netherlands, Italy and Finland held a three-year Arctic research managers forum. The forum mainly focuses on the means of ice information collection and forecast in the arctic route: in addition, there are also some studies on Marine traffic regulations and insurance, and the evaluation of its impact on environmental and the measures for emergency response (Jamey, 2007, p. 9).

In addition to some common large projects, many scholars' study on arctic route was carried out in different fields. J.E.Walsh and M.S Timlin made a simulation

analysis on the sea ice in the northern hemisphere (Frank, 2000, p. 8). S.E.L.Howell and J.J.Yaekel analyzed the Northwest Passage's sea ice changes impact on shipping from 1969 to 2002 (Howell & Yackel, 2004, PP. 205-215). L.Burg introduced the environmental conditions in the Arctic route in Arctic Offshore Workability report, and carried on a case study to the Beaufort Sea, Chukchi Sea and the Bering Strait. China carried out three scientific expeditions in the Arctic in 1999, 2003 and 2008 respectively, obtained a large number of field observation data and samples, and established the arctic station in Norway - "the Yellow River Station" in 2004, to strengthen the study of arctic region.

Overall, the current study of arctic route almost focuses on the long-term changes and interannual variability of sea ice, climate changes, the legal status of the arctic route and the environment of navigation, etc. However, little research has been done as to the application of ice information after shipping.

1.3 The Research Objective of This Article

This paper collects and organizes the experts' achievement in the modification of law of the sea ice along the Northwest Passage in recent years, and the overall trend of arctic sea ice is given.

This paper also analyzes the main source of sea ice information of the Northwest Passage; make analysis to some related websites on which the Northwest Passage sea ice information is provided, and finally gives several comprehensive sea ice information web sites and their main contents.

This article provides some online identification methods of the arctic ice along the Northwest Passage information, emphasizing the on identification method of the ice chart especially the oval chart

This article puts forward available application of sea ice information online while sailing in the Northwest Passage, combined with oval charts in the ice chart to understand the sea ice information. In the end, the basic process on the application of information is presented.

Chapter 2 Research Overview of the Arctic Northwest Passage and the Sea Ice Change Rule along the Northwest Passage

2.1 Introduction to the Arctic Northwest Passage

The Northwest Passage is a sea route passing through the Arctic Ocean, along the northern coast of North America via waterways amidst the Canadian Arctic Archipelago, connecting the Atlantic and the Pacific Oceans. The various islands of the archipelago are separated from one another and the Canadian mainland is separated by a series of Arctic waterways collectively known as the Northwest Passages. Its total length is about 800 n miles and the depth of the main channel water is 305 m. It is the shortest route between the Atlantic and the Pacific Ocean. If the Northwest Passage was once used for the commercial navigation, it would bring about significant economic benefits.

Thousands of islands are available in the sea along the Northwest Passage, and awful weather and complex environment make it as one of the most dangerous routes in the world. Its biggest drawback is the short duration of navigable period, huge ice cover, Iceland, ice off the coast and fixed ice, hinder the voyage of the ship.

Although the Bering Strait is navigable all year round, only a couple of months are navigable within one year in the northern coast of the United States and Canada. (Xu, 1989)

Through continuous exploration by human beings, people divide the Arctic Northwest Passage into seven specific Arctic routes generally. The biggest difference is the division in the intermediate sea area of every route, and different routes go through different channels, as is shown in figure 2.1.

Figure 2.1 Arctic Northwest Passage

Source: http://en.wikipedia.org/wiki/Northwest_Passage, June 10, 2014

Specific routes are listed as follows:

(1) The north route of the Northwest Passage, which passes through the Bering Strait and Chukchi Sea, the Beaufort Sea, McClure Strait, Melville Viscount Strait, Barrow Strait, Lancaster Strait, Baffin Bay, Davis Strait, Labrador Sea;

(2) The Prince of Wales Strait route, which passes through the sea area is that similar

to line 1, only from the Amundsen Bay in the south of Banks Island via the Prince of Wales Strait merge into route 1, thereby it surrounds McClure Channel;

(3) Peel Sound route, which passes through the Bering Sea and Chukchi Sea, the Beaufort Sea, Amundsen bay, Dove Joint Channel and Cory West Bay, Arthur Strait, Queen Maud Land Bay, Victoria Strait, Larson Strait, Franklin Strait, Peel Sound, Barrow Strait, Lancaster Strait, route 3 merges with the line 1 eventually, the difference lies in the first half of the routes;

(4) Peel Sound adjustment route, which changes based on route 3, through the east side of the Prince William island rather than the west. This route is standby channel in order to avoid the heavy ice serious interference when the Victoria Channel is in the freeze period in the route 3;

(5) Rakem Prince Strait route, which is basically the same as route 3. The difference is that route 5 passes through Rakem Prince Bay in the east side of the Somerset island, rather than the west, and it also passes through the Bylot Channel;

(6) Adjustment route 1 of Rakem Prince Channel, which passes the Bering Sea and Chukchi Sea, the Beaufort Sea, Amundsen Bay, Dove Joint Channel and west bay of Cory, Arthur Strait, Queen Maud Land Bay, Simpson Strait, Rasmussen Bay, Ray channel, James Ross Strait, Bylot Strait and Rakem Prince Bay, Barrow Strait, Lancaster Channel one by one;

(7) Adjustment route 2 of Rakem Prince Channel, which is actually changed to line 4, takes the place of the route from the Bylot Strait to the Lancaster Channel by the route in the southern and western areas of Baffin Island. It passes the Bylot

Strait and then heads to Frick Carat Strait, Foxe Channel, Hudson channel and Labrador Sea.

In addition to the seven routes mentioned above, some people also divided arctic routes into six routes based on international convention. It is based on the route 7, and combines the adjustment route of peel channel and Rakem Prince Channel route. We call it the adjustment of Rakem Prince Channel route 1. The two kinds of views are not conflicting. In general, the theory is consistent on the international Northwest Passage division. The officers shall decide the specific route according to the size of the ship, the ice condition and climate of the area in navigation.

2.2 Research Conclusion on Arctic Sea Ice Trends

Compared with other parts of the earth, more significant changes have taken place in terms of the arctic climate, and many scientists and researchers concerned from different countries have done some systemic studies in the arctic climate, especially regarding the change of sea ice during the past 30 years.

(1) The area of Arctic sea ice has decreased during the past 40 years. Since the late 1970s, the Arctic sea ice coverage area is always falling in summer, and the decrease speed is becoming faster and faster in recent years. Particularly in September 2007, sea ice's coverage area is in the minimum value according to the satellite observations. The average Arctic sea ice area fluctuated around 12.5 million km^2 from the early 1970s to the mid 1980s; the northern sea ice area was rapidly lowering since the late 1980s, remaining only about 11.6 million km^2 in the mid 1990 s. (K.,

L.E., & E.C., 1996, PP. 209-213)

(2) Changes are very inconsistent in different waters. (O.M.E., E., & M., 1999, PP. 1937-1939)

(3) The biggest reduction is in summer, while the change can be ignored in the winter. (Zhu & Chen, 2003, pp. 23-29)

(4) The thickness of sea ice is decreasing. The Arctic sea ice's average thickness reduced from 3.7 m to 2.6 m between 1987 and 2007. The average thickness of the Arctic perennial sea ice has decreased from 3.3 m to 2.8 m during 2007 to 2008, and average thickness of one-year sea ice has reduced from 1.8 m to 1.6 m. (Franckx, 1993, p. 315)

Chapter 3 Main Websites Information for the Arctic Ice Northwest Passage

Sea ice information is the data of ice condition. Sea ice information contains some text data, different forms and ice charts. The general ways to obtain high latitudes sea ice information is mainly through historical statistics, ice fax figure and online information.

Sailing directions and ocean route sailing auxiliary information can provide some historical data which belong to the average year, and can be used as a reference for making voyage decisions. Ice condition fax charts are available to users in the related institutions in some countries, but there is a scope limitation, the reception range is not wide enough, and aging is not guaranteed. As for the online information, some information on the high latitudes ice condition could be found in some related websites.

With the development of science and technology and the application of network, online high latitudes ice condition information has become much more perfect, and the application of the information is playing an increasingly important role in ship sailing in high latitude areas.

Through a comprehensive comparison among various online sea ice information, the author thinks that the websites which provide comprehensive information on the Arctic sea ice in the Northwest Passage mainly include in the Canadian Ice service station, the National Ice Center and IPY Ice Logistics Portal, etc.

3.1 The Canadian Ice Service Station

The Canadian ice service station is committed to providing the Canadian surrounding waters with the most accurate and real-time ice condition service organizations. The website is http://ice-glaces.ec.gc.ca/, with two language versions (English and French) for users to choose according to their need.

The Canadian ice service station is established in order to promote the safety and efficient maritime operations, and also help to protect the Canadian environmental organization. It is authoritative in providing ice information of the Canadian surrounding waters. The home page of English version is shown in Figure 3-1.

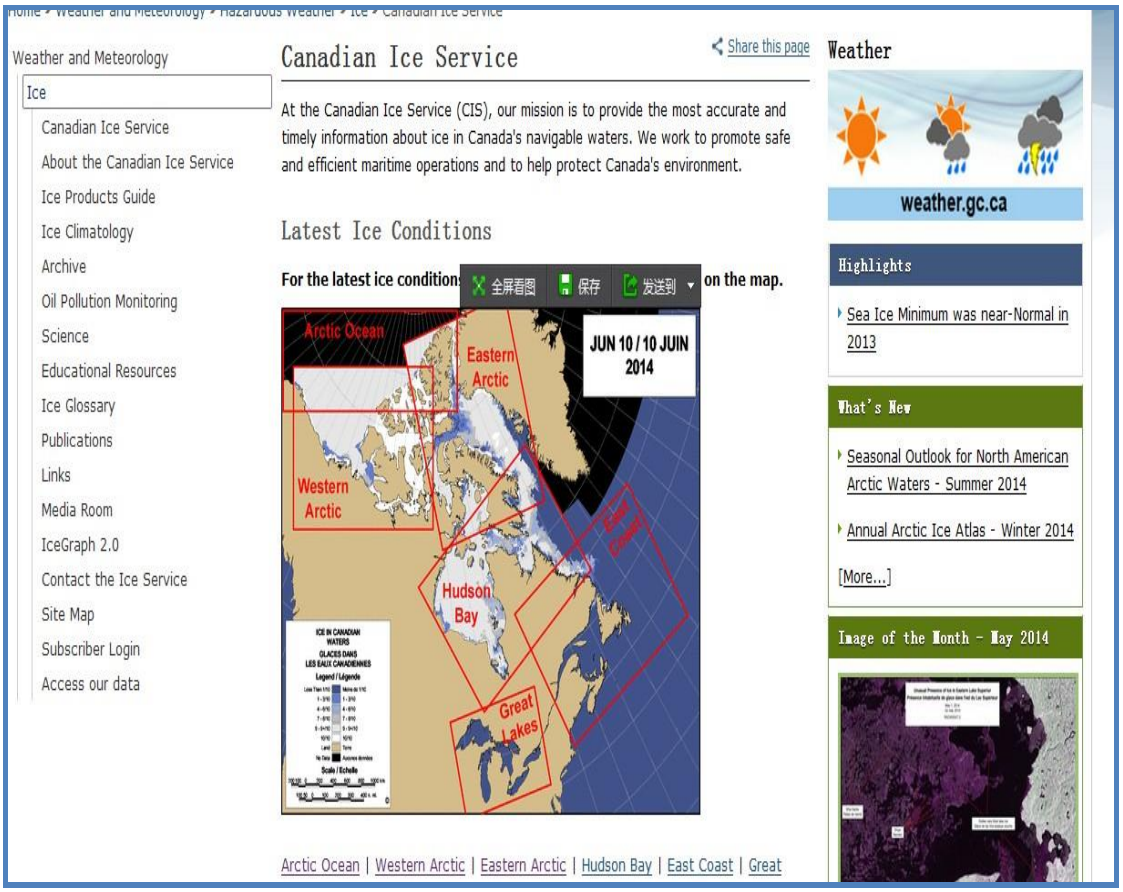


Figure 3-1 English homepage of Canadian Ice Service

Source: http://www.ec.gc.ca/glaces-ice/?lang=En, June 10, 2014

On top of the homepage, there are respectively the Canadian government website, services and departments, etc. There are also columns of Weather, Highlights, What's New and Image at the right side of the home page. The main content of the website home page is presented on the left, including the column of Canadian Ice Service, About the Canadian Ice Service, Ice Products Guide, Ice Climatology, Archives, Oil Pollution Monitoring, Science, Education Resources, Ice Glossary, Publications, Links, Media Room, Ice graph 2.0, Contact the Ice Service, Site Map, Subscriber Login and Access our data. On top of the middle part is the purpose of

the Canadian ice service station, the lower figure is five partitions around the Canada's waters, and in order to understand the corresponding sea ice information, you can click to enter.

There are many different forms of ice in the waters around Canada, including sea ice, lake ice, river ice and iceberg, etc. These influence the safety of navigation in the Canadian waters. The Canadian ice service is mainly established to provide customers with Canadian ice and iceberg information, introduce the formation and change of ice and iceberg in detail, etc. There are a lot of information about the ice code and online access to the Canadian ice-service center files.

Among them, it is an important part of the site about ice chart and introduction of the oval chart in the ice chart, later in the article we will give a detailed introduction. Five areas of the Arctic Ocean are shown in the figure 3-1, click to enter and get some ice diagrams of each part, such as the Eastern Arctic part in figure 3-2.

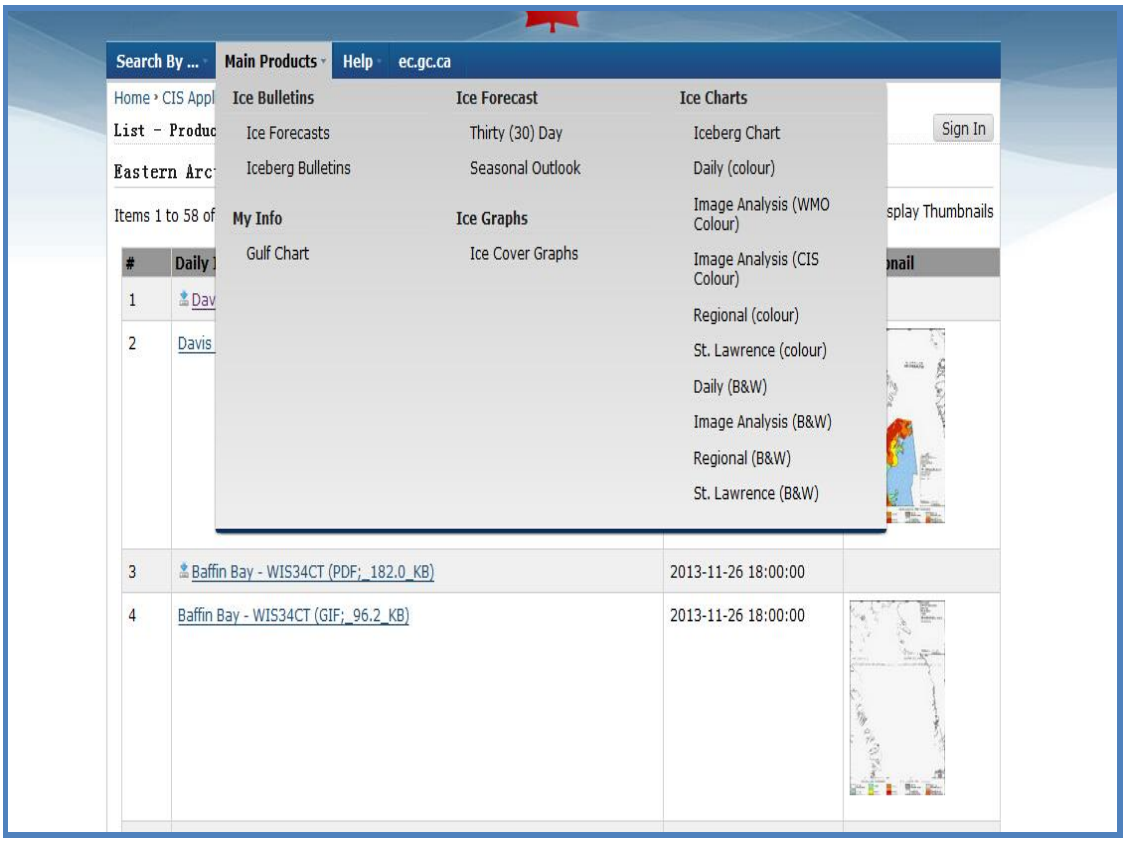


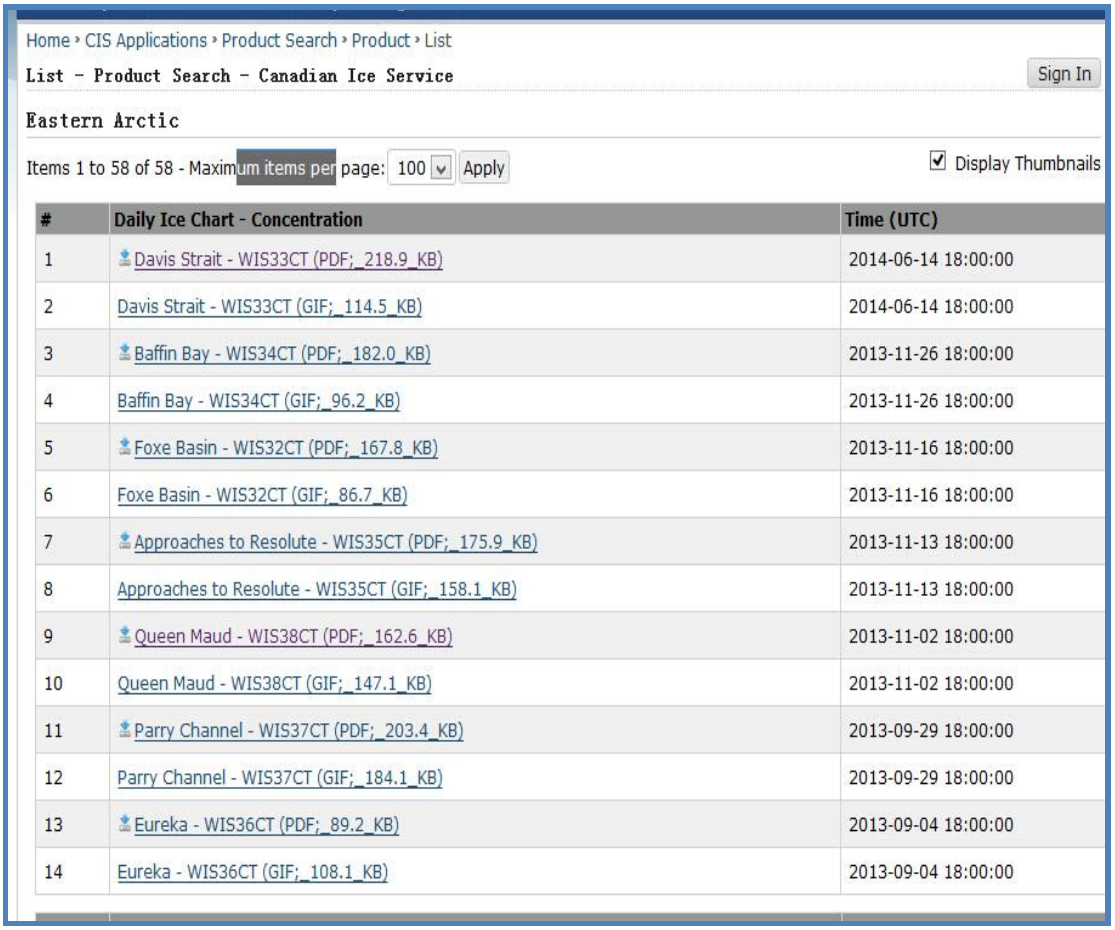
Figure 3-2 Regional ice charts of Eastern Arctic

Source: http://iceweb1.cis.ec.gc.ca/Prod20/page2.xhtml?CanID=11090&lang=en, June 10, 2014

As is shown in figure 3-2, there are five sections, Ice Bulletins, Ice Graphs, Ice Forecast, My info and Ice Charts, respectively. Among them, the key point to be introduced in this paper is ice chart.

There are ten categories in the ice chart: Daily chart(B & W), Daily chart (color), Regional(B & W), Regional (color), St. Lawrence(B & W), St. Lawrence (color), Image Analysis(B & W), Image Analysis (CIS color), Image Analysis (WMO color)and Iceberg. The image has GIF and PDF formats. The oval chart denoting color and B & W in these ten categories is the same in the chart. You can choose a detailed introduction for the daily chart as an example.

Click on the daily chart, can get the page as is shown in figure 3-3, which includes the Parry Channel, the Davis Strait, Baffin Bay, Foxe Basin, Eureka and Queen Maud sea ice daily chart and so on.



Home › CIS Applications › Product Search › Product › List

List - Product Search - Canadian Ice Service

Sign In

Eastern Arctic

Items 1 to 58 of 58 - Maximum items per page: 100 Apply

Display Thumbnails

#	Daily Ice Chart - Concentration	Time (UTC)
1	Davis Strait - WIS33CT (PDF; 218.9 KB)	2014-06-14 18:00:00
2	Davis Strait - WIS33CT (GIF; 114.5 KB)	2014-06-14 18:00:00
3	Baffin Bay - WIS34CT (PDF; 182.0 KB)	2013-11-26 18:00:00
4	Baffin Bay - WIS34CT (GIF; 96.2 KB)	2013-11-26 18:00:00
5	Foxe Basin - WIS32CT (PDF; 167.8 KB)	2013-11-16 18:00:00
6	Foxe Basin - WIS32CT (GIF; 86.7 KB)	2013-11-16 18:00:00
7	Approaches to Resolute - WIS35CT (PDF; 175.9 KB)	2013-11-13 18:00:00
8	Approaches to Resolute - WIS35CT (GIF; 158.1 KB)	2013-11-13 18:00:00
9	Queen Maud - WIS38CT (PDF; 162.6 KB)	2013-11-02 18:00:00
10	Queen Maud - WIS38CT (GIF; 147.1 KB)	2013-11-02 18:00:00
11	Parry Channel - WIS37CT (PDF; 203.4 KB)	2013-09-29 18:00:00
12	Parry Channel - WIS37CT (GIF; 184.1 KB)	2013-09-29 18:00:00
13	Eureka - WIS36CT (PDF; 89.2 KB)	2013-09-04 18:00:00
14	Eureka - WIS36CT (GIF; 108.1 KB)	2013-09-04 18:00:00

Figure 3-3 Page of daily ice charts

Source: http://iceweb1.cis.ec.gc.ca/Prod20/page2.xhtml?subID=2001&grp=&lang=en, June 10, 2014

Click on the links among the page can get daily ice conditions in every region of the map. For example, by clicking the Davis Strait's link, you can get the page shown in figure 3-4.

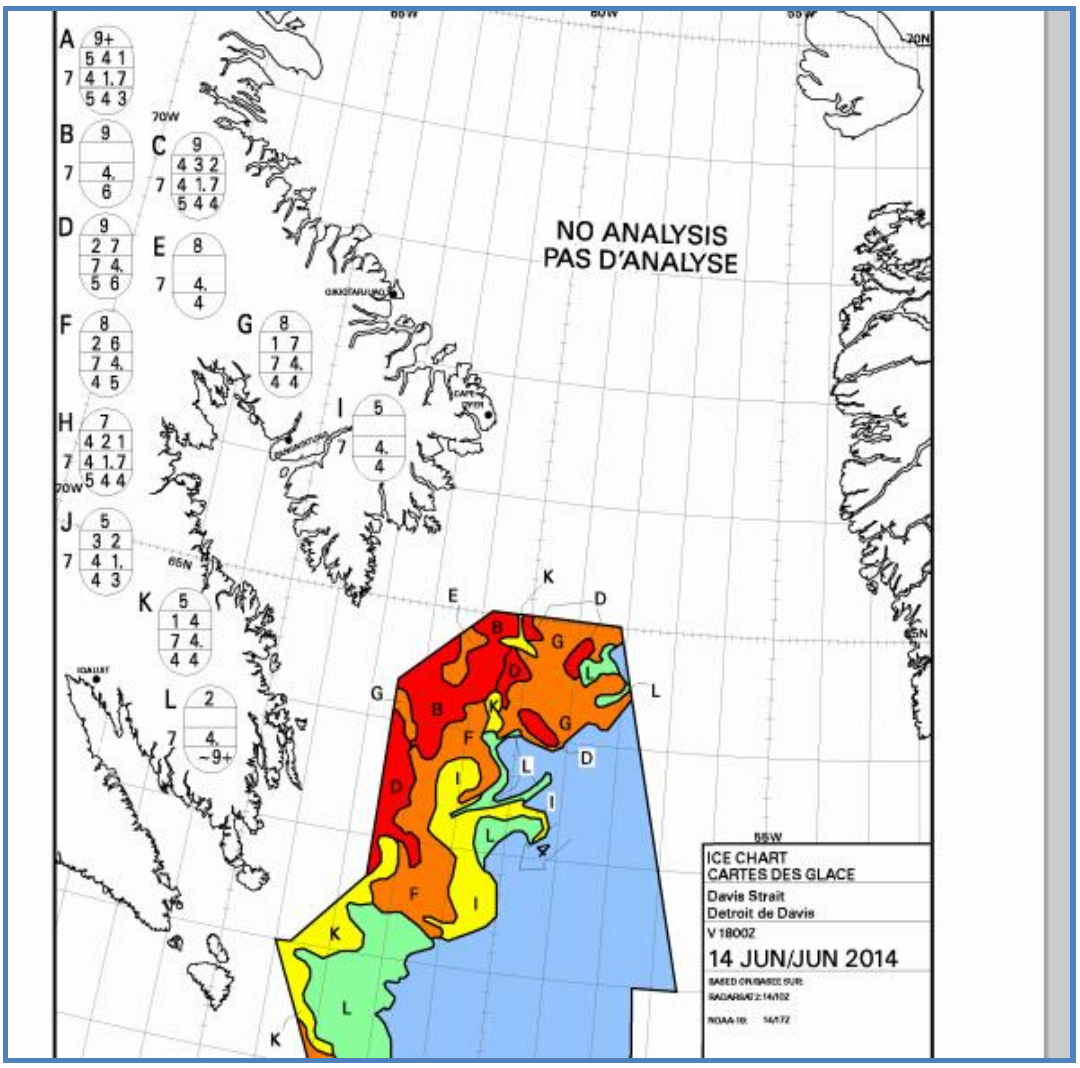


Figure 3-4 Daily ice chart of Davis Strait

Source: http://iceweb1.cis.ec.gc.ca/Prod20/page3.xhtml, June 10, 2014

Figure 3-4 is a diagram for Davis Strait daily ice analysis, each area of the chart has different ovate chart marks, and the meaning of specific oval chart should be introduced in the article. Information of the region ice conditions can be obtained through the identification of ice ovate chart in this picture.

3.2 The National Ice Center

National ice center is a comprehensive operation center founded by the USN, the national oceanic and atmospheric administration and the US coast guards. Its website is http://www.natice.noaa.gov/. The center's main task is to provide the high-quality, timely and accurate products related to the snow and ice, and it also provides services that can protect the interests of the United States in the global area of strategic, operational and tactical requirements. The home page is shown in figure 3-5.

Figure 3-5 Homepage of National Ice Center

Source: http://www.natice.noaa.gov/, June 10, 2014

The center is mainly used to provide some products with ice and snow and other services. The section related to this article is “products” in figure 3-5 marked in arrows, and you can click to get the page shown in figure 3-6.

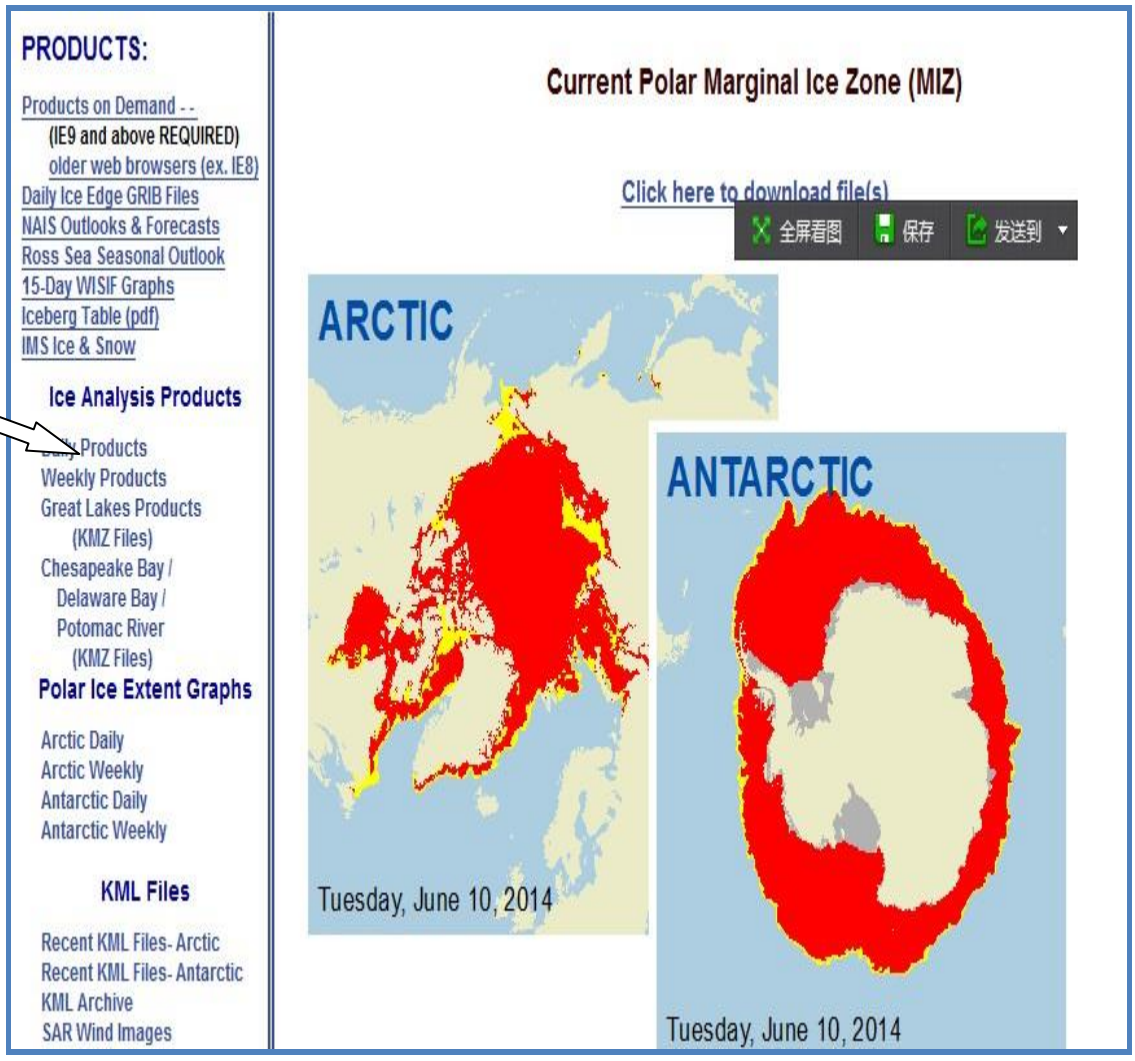


Figure 3-6 Page of National Ice Center

Source: http://www.natice.noaa.gov/Main_Products.htm, June 10, 2014

In figure 3-6 page, there are many products for users to choose according to their

needs. Choose the part indicated by the arrows in the figure, and you can get a page shown in figure 3-7.

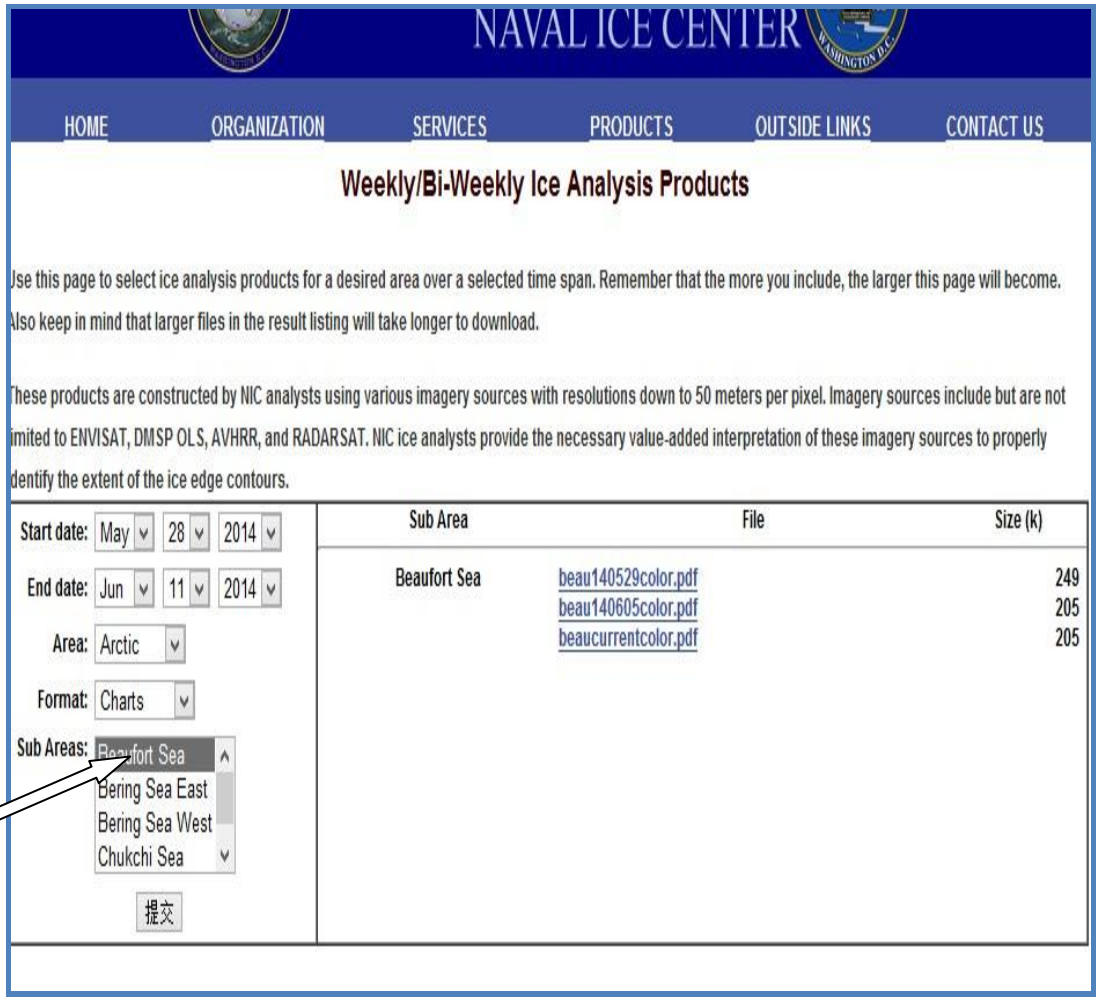


Figure 3-7 Weekly ice analysis products

Source: http://www.natice.noaa.gov/products/weekly_products.html, June 10, 2014

In figure 3-7, you can choose whatever you want according to your needs, including the date, region and format, etc. Just as the arrow indicating in Baffin Sea, you can click the right link to get the required ice figure.

3.3 IPY Ice Logistics portal

IPY (international polar year) Ice Logistics Portal is made up of oceanography and Marine climatology joint sea ice expert group of technical committee and the polar view. The purpose of this website is to create a link, which people can obtain information of sea Ice provided by the Canadian Ice service center (CIS) and the National Center for Ice (NIC). Its website is http://www.bsis-ice.de/IcePortal/index.html, with the homepage shown in figure 3-8.

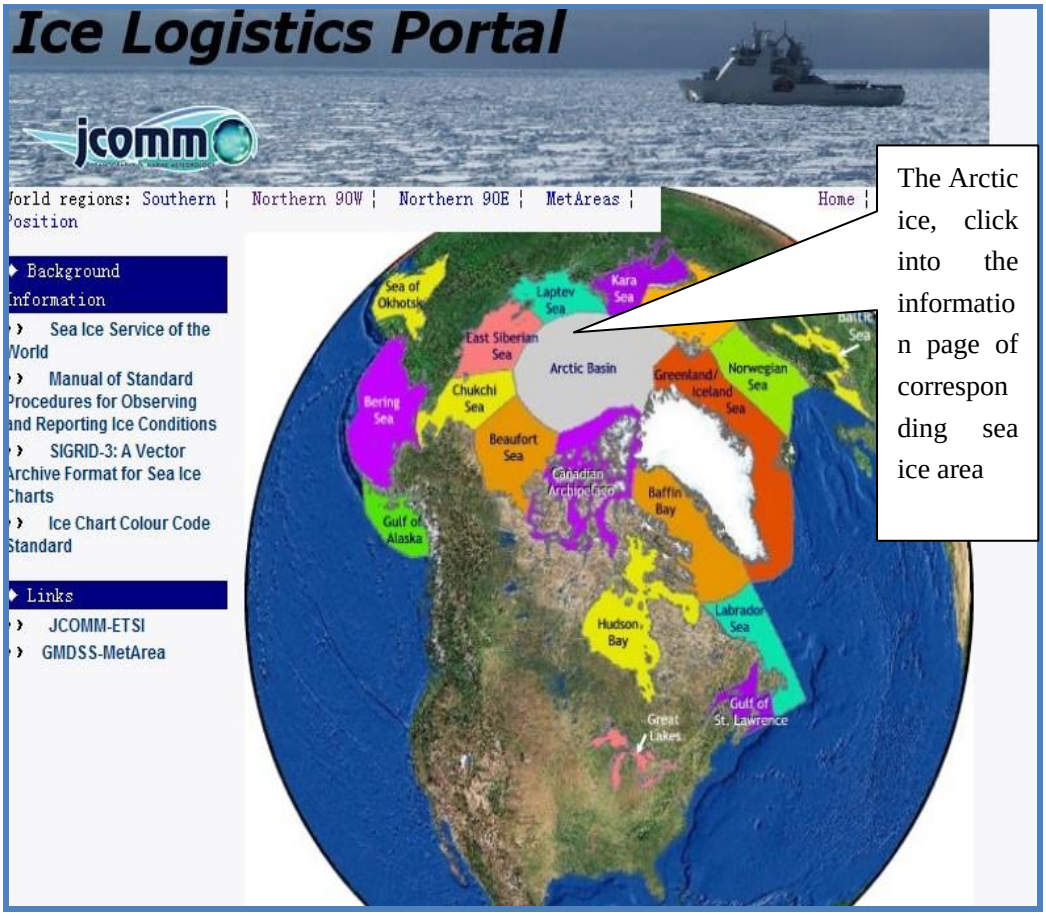


Figure 3.8 Homepage of IPY ice logistics portal

Source: http://www.bsis-ice.de/IcePortal/displayNorthernMap90W.html, June 10, 2014

Click on the position corresponding to the area of figure 3-8, and then you can enter the page of the required area, just as clicking the Beaufort Sea area to get the page shown in figure 3-9.

Figure 3-9 Homepage of Beaufort Sea

Source: http://www.bsis-ice.de/IcePortal/BeaufortSea.html, June 10, 2014

There are representative ice charts in different periods and with different meanings in figure 3-9. Users can choose according to their needs. For example, click the picture (ice chart indicated by the arrows in figure 3-9) and figure 3-10 is available.

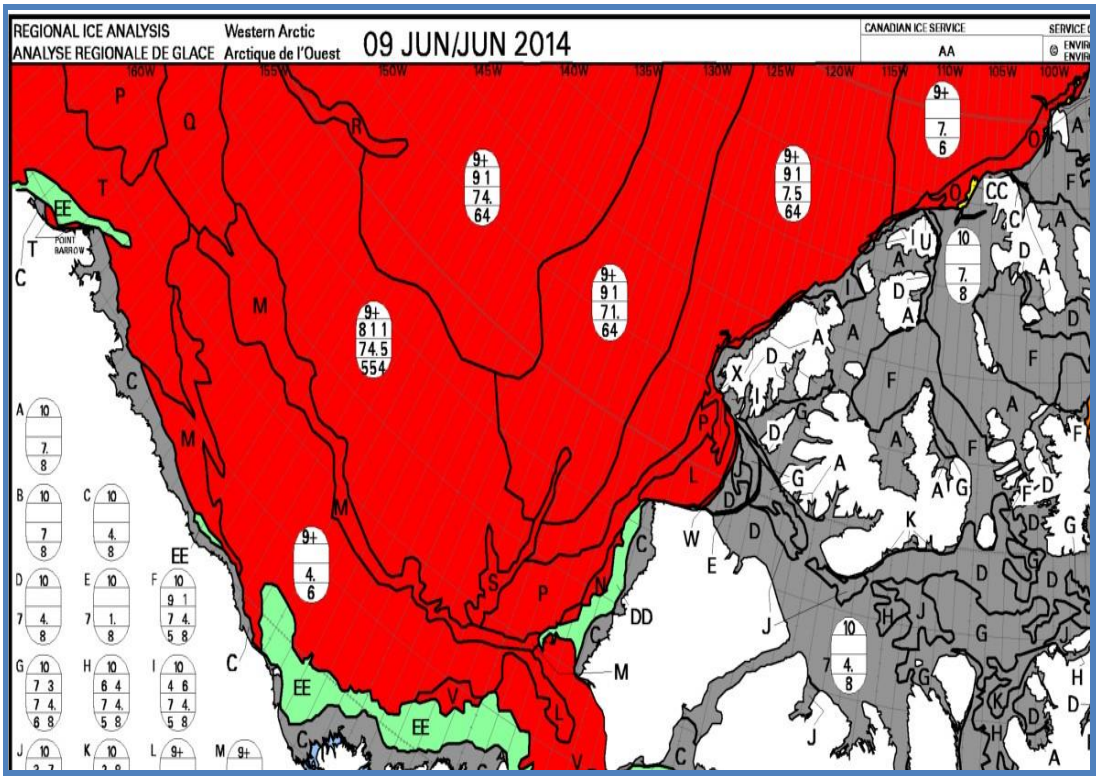


Figure 3-10 The ice image of Beaufort Sea on Jun 9th 2014

Source: http://www.bsis-ice.de/IcePortal/CIS/20140630180000_WIS56CT_0007742321.pdf, Jun 9, 2014

In the ice chart shown in figure 3-10, with different colors representing the regional ice intensity, there is an oval chart in each region, through which readers can get ice information of various regions.

3.4 Other Websites

In addition, ice information is available in other sites. Such as the Arctic ROOS (http://arctic-roos.org/), Polar Meteorology Group (http://polarmet.osu.edu/) and the national snow and ice data center (http://nsidc.org/). Information in these websites

are an overall introduction of Arctic ice. With no specific information on ice in the Arctic Northwest Passage, this article does not make a detailed introduction.

Chapter 4 Identification of Online Ice Information in the Northwest Passage

Through the previous discussions of this article, the main ice information online is ice chart in the website. There are many ovate charts in the ice chart, with intensity of sea ice, development stage (the number of ice more than 3 years age), and the basic data of the ice mode contained in an oval in the ice chart. Identification of ovate chart in ice chart becomes the key to understanding specific ice information.

4.1 The Form of Oval Figure and the Main Content

Format and the meaning of the oval chart are explained by the example. The ice chart in figure 4-1 is provided by the Canadian ice service center, which represents the live ice chart (color ice chart) of Hudson Strait on June 13, 2014.

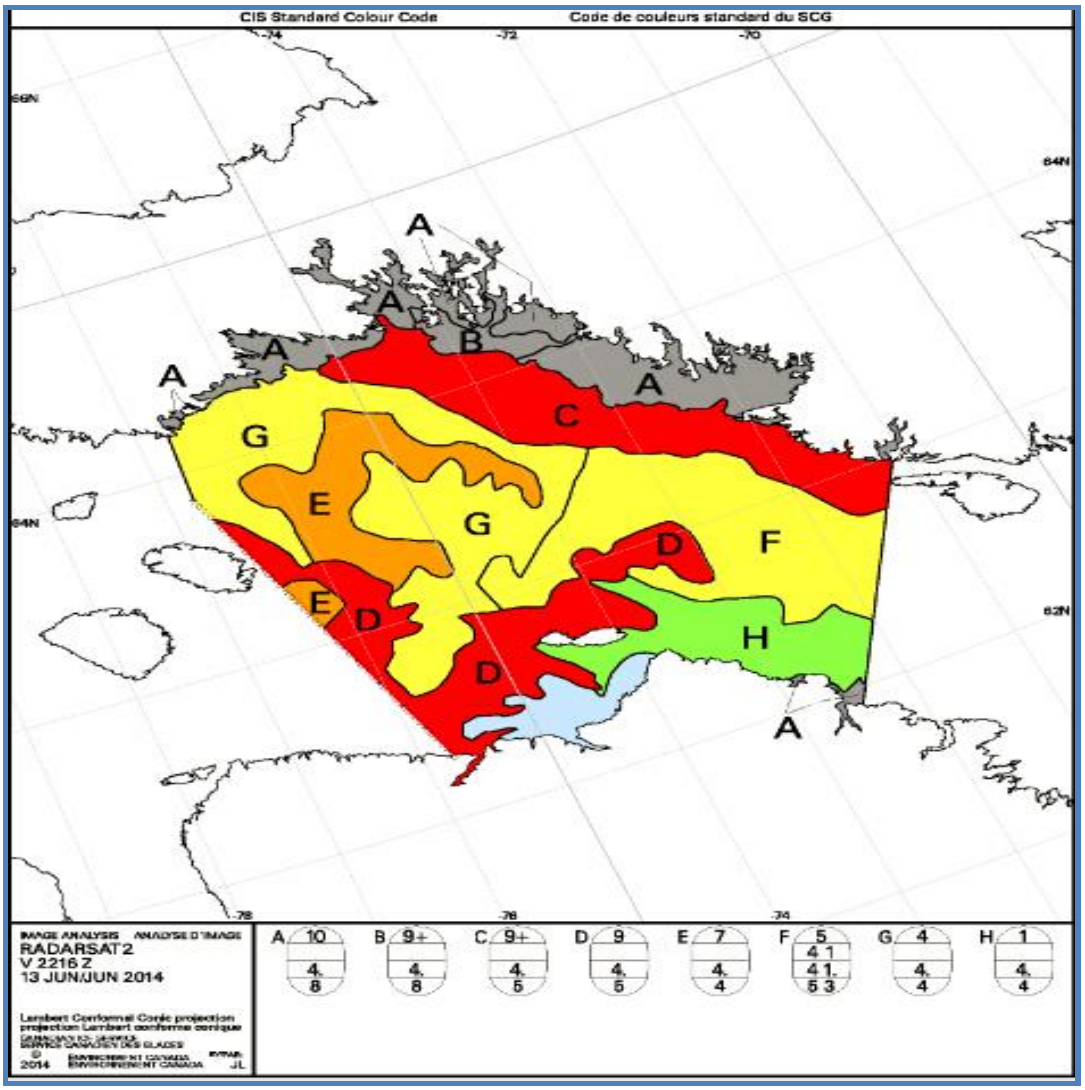


Figure 4-1 Color ice image of Hudson Strait

Source: http://ice-glaces.ec.gc.ca/prods/WIS29CT/20140708180000_WIS29CT_0007752761.pdf, June 13, 2014

As can be seen in the above example, Hudson Strait was divided into different areas, and specific ice condition with different letters can be read at the bottom of the corresponding letter on the oval chart.

Different Numbers and symbols make up the oval chart. There are numbers inside

and outside the ovate chart, totally divided into four lines, the column number is not necessary, and the number outside oval figure in left and right side represent different meanings. In usual international ice chart, the oval figure number or symbol is used to show the corresponding detailed ice area, as is shown in figure 4.2.

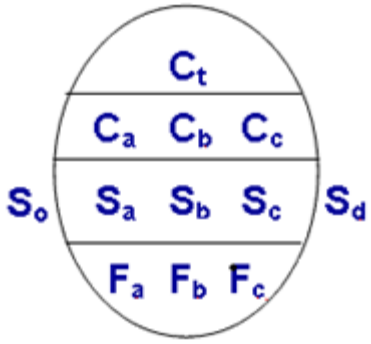


Figure 4-2 Egg code

Source: compiled by author, 2014

C is on behalf of the total intensity within the scope, in 1/10.

Ca, Cb and Cc show division intensity related to different thickness of sea ice, with unit of 1/10 (table 4.1). Ca is the most thick sea ice code, and the Cc is the thinnest code. There is no report if it is less than 1/10. Report C, Sa, Fa if a stage of development of sea ice is 10/10.

Sa, Sb and Sc are on behalf of development stage of sea ice, with 1/10 as the unit (table 4.2). The thickest development is Sa, Sb with the second thickest, and Sc the third thickest. General Sa, Sb and Sc should respectively be prepared to formulate and submit three biggest intensity stages. Another development stage can be preparing for Sd. If there is a sea ice at the stage thicker than offered by Sa, and the intensity is less than 1/10, the formulation is So.

Table 4.1 Coding for ice concentration

code	intensity	code	intensity
0	< 1/10	6	6/10
1	1/10	7	7/10
2	2/10	8	8/10
3	3/10	9	9/10
4	4/10	10	10/10
5	5/10		

Source: compiled by author, 2014

Table 4.2 Coding for sea ice stages of development

Code	Development phase of the ice	thickness	Code	Development phase of the ice	thickness
1	frazil ice，grease ice，slush，flake ice	<10 cm	9	Thin one year ice，second phase	50-70 cm
2	Sun crust，dark ice shell，ice shell	<10 cm	1 ·	Medium one year ice	—
3	First ice	10-30 cm	4 ·	Thick one year ice	—
4	Grey ice	10-15 cm	7 ·	Old ice	—
5	Grey-white ice	15-30 cm	8 ·	Two years ice	—
6	One year ice	>=30 cm	9 ·	Mult-year ice	—
7	Thin one year ice	30-70 cm	▲ ·	Land origin ice	—
8	Thin one year ice，first phase	30-50 cm	X ·	Unknown ice	—

Source: compiled by author, 2014

F shows ice type, Fa, Fb, Fc respectively corresponding to the development phase of the coding (Sa, Sb, Sc), the form of ice (size of float ice) (table 4-3). If this set of coding is lacking in any kind of material, all of them will be represent by (/) in the corresponding positions. If there is a huge number of ice bergs, their intensity cannot be ignored, the Fa code is (9).

Table 4-3 Code forms of ice

Code	Ice shape	Ice breadth
0	pancake ice	<2 m
1	Small pieces of ice，crushed ice	2-20 m
2	The massive ice	20-100 m
3	Glacon	100-500 m
4	Medium floating ice	500-2000 m
5	Big floating ice	2000-10000 m
6	Huge floating ice	>10000 m
7	Tremendous floating ice	
8	Fixed ice, iceberg fragments or floating iceberg	
9	Iceberg	
/	Unknown	

Source: compiled by author, 2014

3）The application of symbol "∾" in the special case

Symbol "∾" is in the fourth row of the oval figure, which shows ice in the banding area.

When the ice is in the banding area and the type of the floating ice is medium-sized or larger, ice forms could be shown in two oval figures. The second symbol "∾" of the oval chart is at the side of the amount of ice in the band area.

When there is a thick ice inset in band area, with two oval figures, the total amount of ice is expressed in the first oval chart, and the amount of ice in the band area is shown in the second oval chart.

4.2 Illustration of Color Ice Chart

Ice chart can be black and white chart or a color chart, which represent different ice conditions with a variety of colors and symbols.

Color ice chart is to let a person get the region ice information from the ice chart more quickly, thus to determine whether the ship passing through the region should slow down or even stop. Overall, the meanings of the color ice chart are like traffic lights: green meaning the vessel can get through, yellow meaning the vessel should pay attention to safety, red meaning danger.

When the area ice content is 1/10 or more, the type of ice is divided into two categories: less than 15 cm and greater than or equal to 15 cm.

The color of the specified ice area is determined by the quality of the thickness of ice which is greater than 15 cm, and the specific meaning is shown in table 4-4.

Table 4-4 The Symbols of Ice Type that Thicker than 15cm

Legend	Color	Meaning
	Blue	Open waters
	Green	Ice quality is 1/10-3/10
	Yellow	Ice quality is 4/10-6/10
	Orange	Ice quality is 7/10-8/10
	Red	Ice quality is 9/10-1

Source: compiled by author, 2014

According to its specific content, white (with oblique broken line) and light purple are used respectively to represent the firn ice; usually, the fast ice regardless of the thickness is black or gray, with specific meaning are shown in table 4-5.

Table 4-5 Symbols of Firn Ice and Fast Ice

Legend	Color	Meaning
	White	Firn ice content is 1/10 - 4/10
	Lilac	Firn ice content is 5/10 or more
	Black	New ice ignore the thickness
	Dark grey	New ice ignore the thickness

Source: compiled by author, 2014

During the ice type thickness of less than 15 cm, the main types of ice are grey ice and new ice, which is shown in the color chart with no background color star patterns of different colors. And the subordinate part of the content of the ice shows a background color of the star pattern, with specific meanings shown in table 5.

Table 4-6 Symbols of Ice Type that Thin than 15cm

Legend	Color	Meaning
	White light blue symbol	The main content of the ice thickness is less than 10 cm
	White blue symbol	The main content of the ice thickness is between 10 to 15 cm
	Yellow light blue symbol	Subordination part of ice thickness is less than 10 cm
	Green orange symbol	Subordination part of ice thickness is between 10 to 15 cm

Source: compiled by author, 2014

In order to provide further convenience for understanding, now we give an example to introduce the ice figure identification. Figure 4-3 is the Baffin Bay ice chart on July 31, 2011, and each of the letters on the drawing of the oval chart shows the specific ice condition corresponding to the position of letters in the sea area.

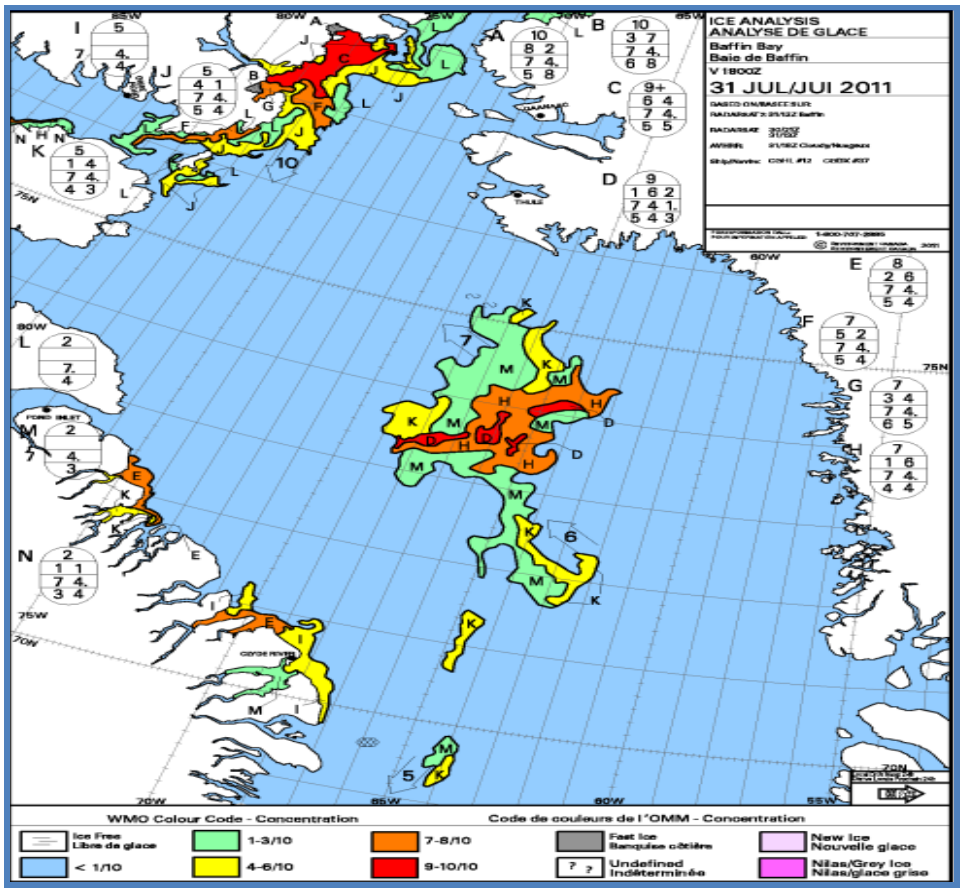


Figure 4-3 Color ice chart of Gulf of Baffin Bay

Source: http://ice-glaces.ec.gc.ca/prods/WIS34CT/20140708180000_WIS34CT_0007752803.pdf, July 31, 2011

Take the oval chart B as an example (in figure 4-3), which represents the meaning as follows: the total quality of sea ice is 10/10, containing 3/10 of the one year thin ice in the huge floating ice state, and 7/10 of the one year thick ice in the state of the floating iceberg. In addition, the number seven on the left side of the oval chart I show the one year thin ice is available in this area, but the content is less than 1/10.

Chapter 5 Application of Online Sea Ice Information in the Arctic Northwest Passage

5.1 Online Information Available On Arctic Sea Ice in the Northwest Passage

From the study of the arctic sea ice changes, with the intensity of the greenhouse effect, the global temperature is gradually rising, the arctic sea ice melting, the sea ice coverage reducing year by year; therefore, the opening of the arctic route is possible. If the ship navigates along the arctic Northwest Passage, timely and accurate information about the sea ice is the indispensable basic guarantee for the safety of navigation. In the Northwest Passage, navigators need to master the information of sea ice area in the region between the Bering Strait and the Greenland

Through the introduction of chapter 3 in this paper, we can find the information of sea ice that the Canadian ice service provides is more comprehensive, with a timely update and a great reference value. Information provided by National Ice Center is not very comprehensive, only introduce part of the Arctic area, and it is not updated timely. Information provided by Ice IPY Ice Logistics Portal mostly comes from the Canadian Ice service center; as for the other websites which can provide sea ice

information, they provide basic sea ice information of the overall Arctic ice, with no specific sea ice information for the Arctic Northwest Passage.

After a comprehensive comparison, we can know that most of the websites are not user-friendly. Some ice information they give is not updated in time, some has plenty of reference to other web sites, and some just provides general ice cover area and the trend of change within the scope of the arctic, with no provide a specific area information of sea ice. Therefore, it cannot provide navigation vessel with effective information at the Northwest Passage. This article is based on data collection, data classification, comparison and induction to practical web sites which primarily refers to with the Canadian ice service center (http://ice-glaces.ec.gc.ca/).

In accordance with the information provided by the Canadian ice service center, the Arctic Northwest Passage is divided into several regions for convenience: they are mainly the western Arctic, East North and Hudson's Bay. On the other hand, the Canadian ice service station also provides information on the East Coast and the Great Lakes. A specific division diagram is shown in figure 5-1.

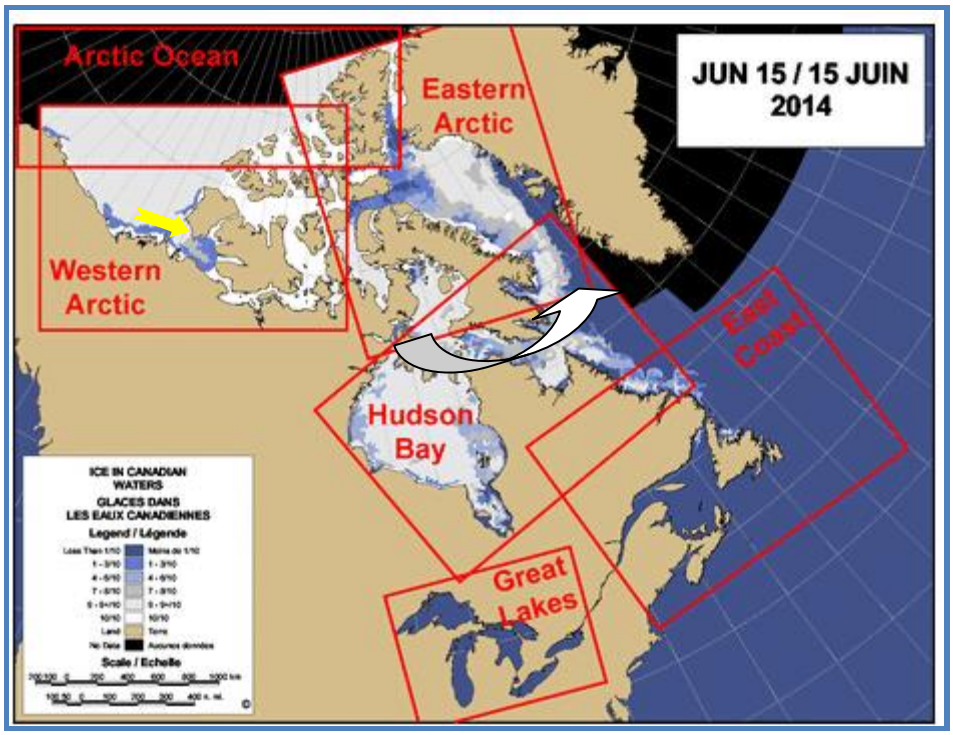


Figure 5-1 Divided chart of Northwest Passage

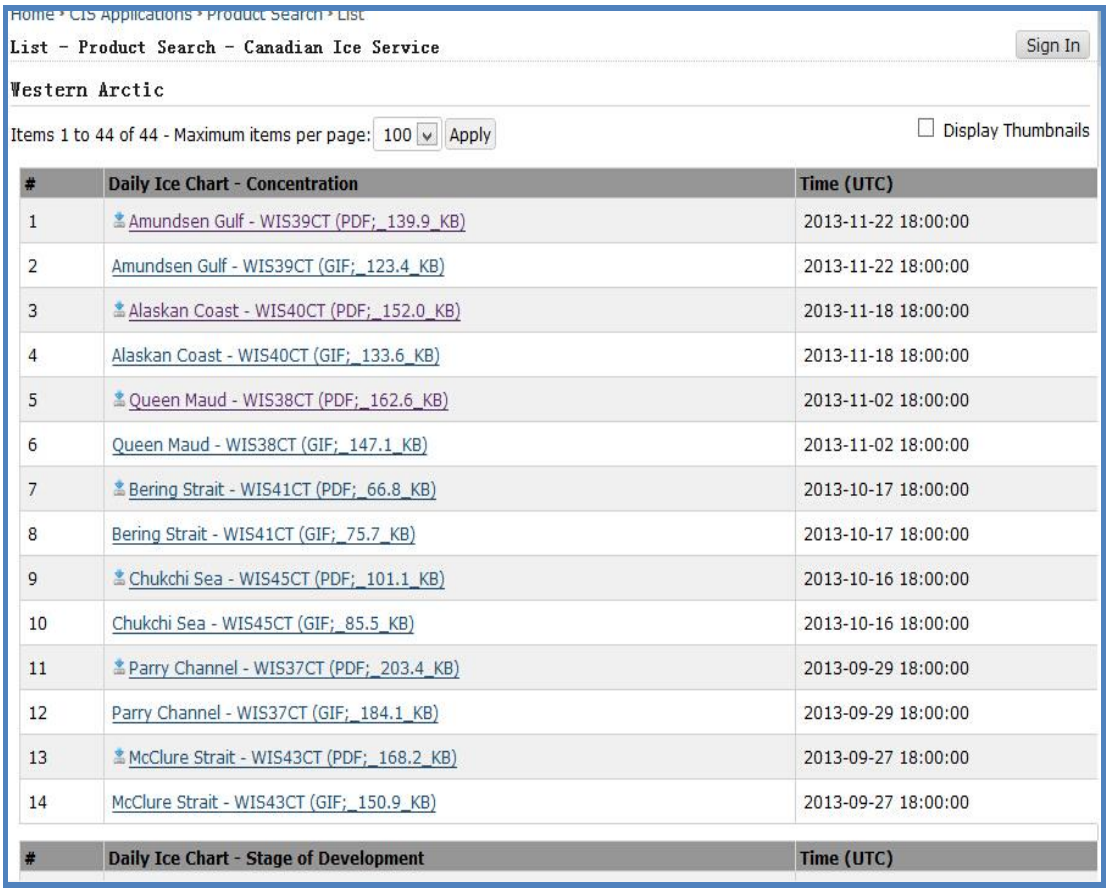
Source: http://www.ec.gc.ca/glaces-ice/?lang=En, June 15, 2014

The Western Arctic is mainly composed of the part of east of Chukchi Sea, and west of Barrow Strait. Eastern Arctic is mainly from the east of Franklin Channel to the west of Greenland, as well as part of the north of Hudson's Bay. Hudson's bay, East Coast and Great Lakes are their adjacent waters. As the chart shows, divided areas will be a little bit overlapping. Click in the overlapping area, and you can get the sea ice.

5.2 A Case Study on Information Application of the Ship Navigation in the Arctic Northwest Passage

If the ship plans to access the Atlantic Ocean through the Northwest Passage, after it sails into the Bering Sea, it can choose south passage of the Northwest Passage. The ship will pass the Western Arctic, Eastern Arctic in turn, and then enter into the Hudson's Bay or the East Coast. Sailing direction is shown in figure 5-1 arrow sign.

Ship navigates out of the Bering Sea, firstly it enters the Chukchi Sea, then into the Western Arctic waters. Click on the part of the link, and you can get the page shown in figure 5-2, all parts of specific sea ice charts in the Western Arctic are available in the page.



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List - Product Search - Canadian Ice Service

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Western Arctic

Items 1 to 44 of 44 - Maximum items per page: 100 Apply

Display Thumbnails

#	Daily Ice Chart - Concentration	Time (UTC)
1	Amundsen Gulf - WIS39CT (PDF; 139.9 KB)	2013-11-22 18:00:00
2	Amundsen Gulf - WIS39CT (GIF; 123.4 KB)	2013-11-22 18:00:00
3	Alaskan Coast - WIS40CT (PDF; 152.0 KB)	2013-11-18 18:00:00
4	Alaskan Coast - WIS40CT (GIF; 133.6 KB)	2013-11-18 18:00:00
5	Queen Maud - WIS38CT (PDF; 162.6 KB)	2013-11-02 18:00:00
6	Queen Maud - WIS38CT (GIF; 147.1 KB)	2013-11-02 18:00:00
7	Bering Strait - WIS41CT (PDF; 66.8 KB)	2013-10-17 18:00:00
8	Bering Strait - WIS41CT (GIF; 75.7 KB)	2013-10-17 18:00:00
9	Chukchi Sea - WIS45CT (PDF; 101.1 KB)	2013-10-16 18:00:00
10	Chukchi Sea - WIS45CT (GIF; 85.5 KB)	2013-10-16 18:00:00
11	Parry Channel - WIS37CT (PDF; 203.4 KB)	2013-09-29 18:00:00
12	Parry Channel - WIS37CT (GIF; 184.1 KB)	2013-09-29 18:00:00
13	McClure Strait - WIS43CT (PDF; 168.2 KB)	2013-09-27 18:00:00
14	McClure Strait - WIS43CT (GIF; 150.9 KB)	2013-09-27 18:00:00

#	Daily Ice Chart - Stage of Development	Time (UTC)

Figure 5-2 Homepage of Western Arctic

Source: http://iceweb1.cis.ec.gc.ca/Prod20/page2.xhtml?CanID=11081&lang=en, June 15, 2014

Each link of Figure 5-2 is the part of specific waters ice chart links, and you can click to get ice figure. Such as ships into the Chukchi Sea, click on the marked part of the figure, the ice chart is available as is shown in figure 5-3. Many small areas specifically marked with different letters are divided again in ice chart, and every color of the small area is also different, each letter representing different ice ovate chart. In the above, we have made detailed introduction, read the oval figure and regional color meaning which can help us get the information of sea ice.

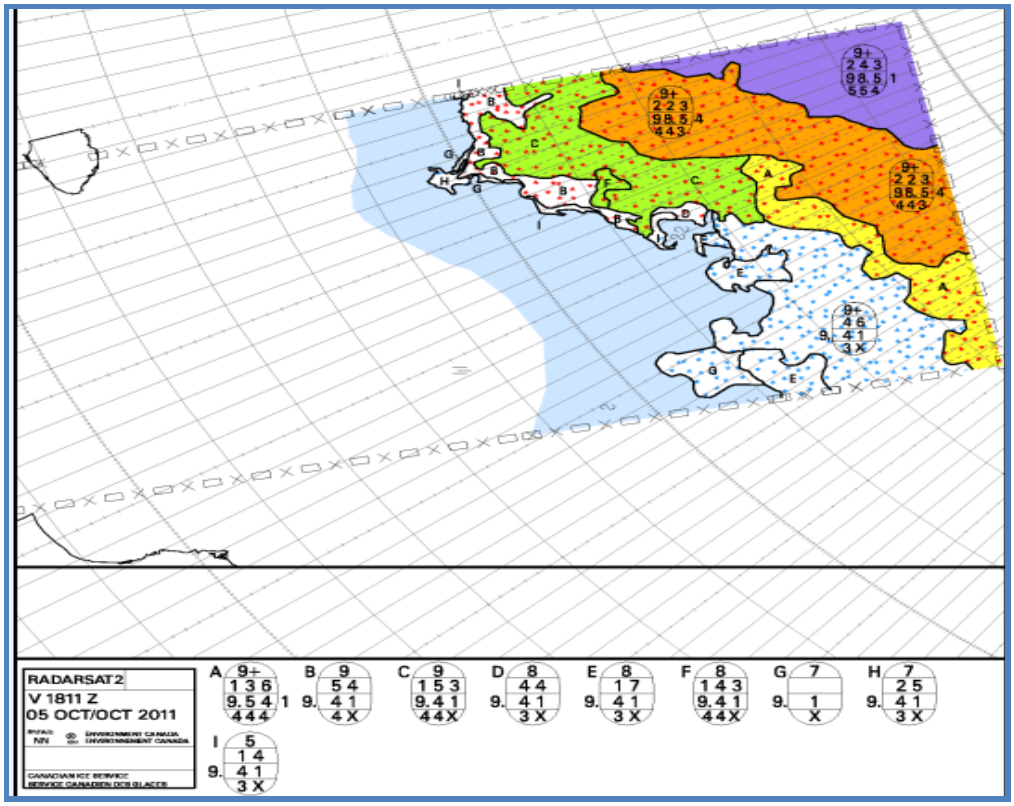

Figure 5-3 Ice Chart of Chukchi Sea

Source: http://iceweb1.cis.ec.gc.ca/Prod20/page3.xhtml, June 15, 2014

Take the oval figure C of 5-3 as an example, in figure 5-4.

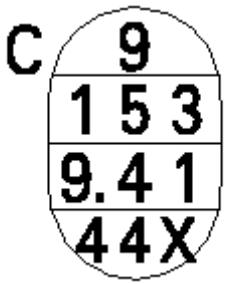

Figure 5-4 Oval Figure C

Source: figure 5-3

The regional color marked in oval figure C is green orange, meaning its peripheral part of ice thickness between 10 to 15 cm. Oval figure denotes that: the region sea ice intensity is 9/10, of which 1/10 is in the state of the multiyear ice, 5/10 of the ice grey in a floating state and 3/10 of the ice flake. In this way, we can get the Chukchi Sea ice chart from the Western Arctic chart and specific sea ice information can be obtained from the ice chart.

When the ship is navigating in the Queen Maud Land Bay, it enters the common area of the Eastern Arctic and the Western Arctic. In this area, the ice chart you want can be obtained by clicking on the Western or Eastern Arctic. When the ship proceeds and then enters the Eastern Arctic area, click the connection of the region, and then you can get the page shown in figure 5-5.

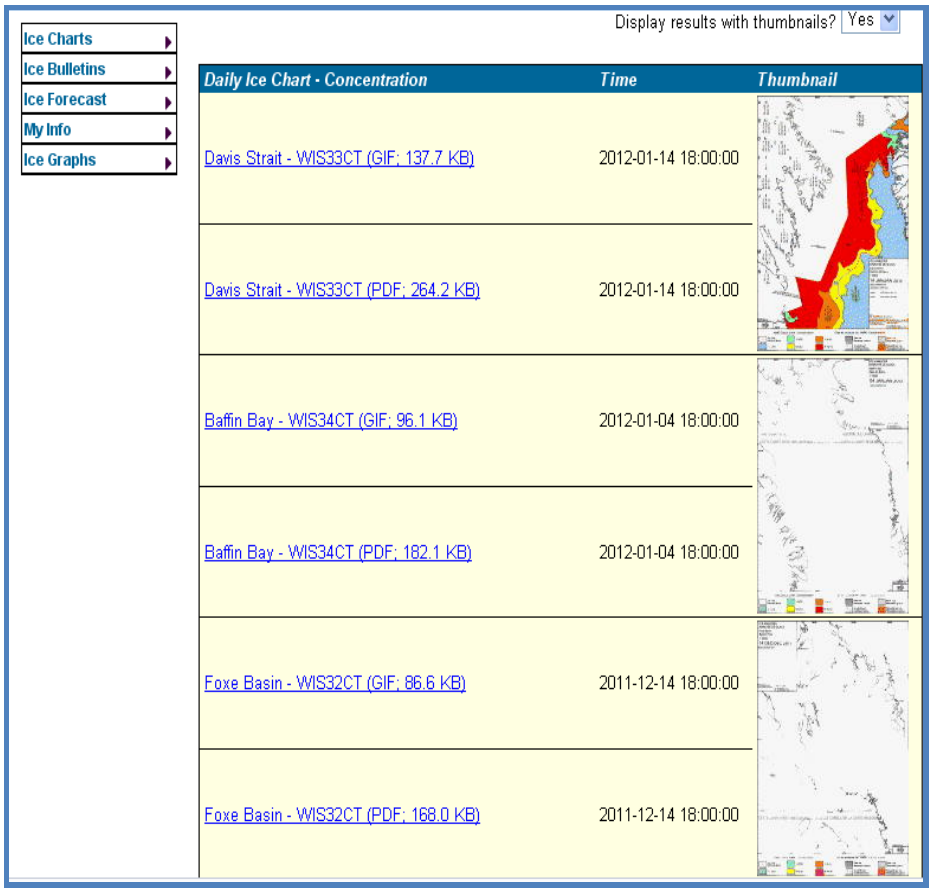

Figure 5-5 Homepage of Eastern Arctic

Source: http://iceweb1.cis.ec.gc.ca/Prod20/page2.xhtml?CanID=11090&lang=en, Jan 15, 2012

In this area, specific sea ice chart can be obtained according to the above-mentioned method, and the ice information is obtained. After ship leaves Queen Maud Land Bay, continues to sail, goes through Barrow Strait, it will pass Baffin Bay and Davis Strait in turn, for example, click on the corresponding link of Davis Strait, we can also get an ice chart shown in figure 5-6.

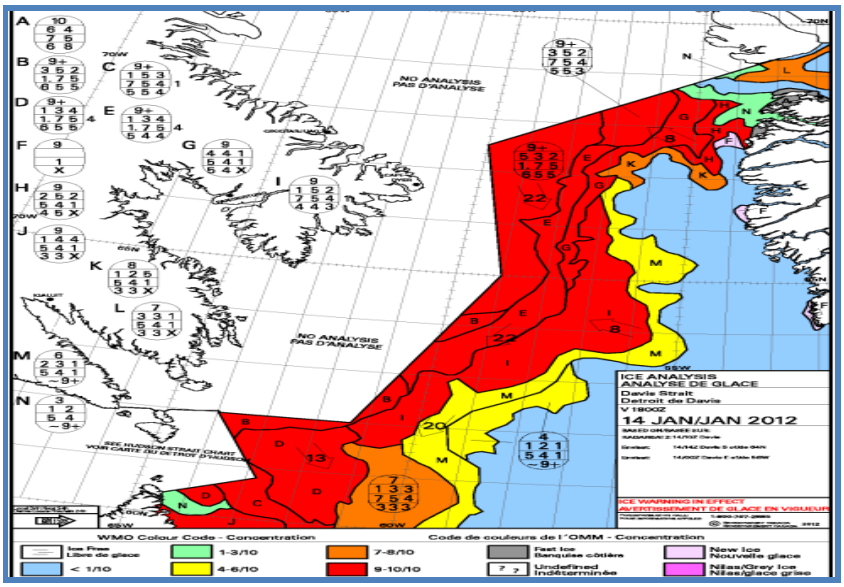

Figure 5-6 Ice chart of Davis Strait

Source:

http://ice-glaces.ec.gc.ca/prods/WIS33CT/20140708180000_WIS33CT_0007752797.pdf, Jan 15, 2012

The ice chart shown in figure 5-6, can help us analyze the specific ovate chart in accordance with the method introduced in the above article, and therefore get specific ice information.

Out of Davis Strait, the ship continues to navigate in this area. It will enter the Hudson's Bay, as is shown in figure 5-7. In the same way, at this time you can click on the link of Hudson's bay area to get a specific chart of ice and ice information is thus obtained.

Figure 5.7 Homepage of Hudson Bay

Source: http://iceweb1.cis.ec.gc.ca/Prod20/page2.xhtml?CanID=11092&lang=en, Jan 15, 2012

After entry into Hudson Bay, if you continue to sail, the ship will be out of the Northwest Passage and arrive at the destination.

Chapter 6 Conclusion

6.1 Conclusion

The Northwest Passage located in the Arctic Ocean is the shortest route which covers three continents-Asia, Europe and America in potential. The Northwest Passage has great advantage in range compared with other existing routes. Although there are many unfavourable environmental factors in the Northwest Passage, such as the sea ice, it can shorten the sailing schedule, reduce the cost and the energy consumption of shipping accordingly. With the global climate warming, especially in the summer, the arctic sea ice is melting faster; therefore sailing through the Northwest Passage will save the extra fees caused by sailing schedule delay, sea ice block and icebreaking cost, thus making the passing by vessel time, energy and money-saving.

After the Arctic route is formally open to navigation, there will be more and more ships navigating in the passage. Therefore, how to safely navigate is well worth studying. In order to ensure the voyage in the Northwest Passage, this paper studied the meteorological and hydrological conditions in the Northwest Passage, combined with some meteorological website analyses and sorted out various kinds of

information sources to provide the drivers with a quick and effective method of obtaining the Northwest Passage information. It can ensure the safety of ship sailing through the Northwest Passage in the Arctic and improve the navigation safety level of the arctic Northwest Passage, thus minimizing unnecessary loss and improving the economic benefits. In addition, you can make a more reasonable choice to specific routes.

There is much hydrometeorological data that introduce the arctic route and many websites available, but from the view of practical application, the specific ice information data and the website can be used is very little. In this paper, the author selected several important ones with a detailed analysis. The Canadian ice service center is one of the main sources of sea ice information, and the website provides some information on the Northwest Passage of the Arctic sea ice which can help ensure officer's safe navigation.

6.2 Limitations

Through this study we can see, the number of major sites introducing the Arctic ice information along the Northwest Passage is rather few and information on some other websites is incomplete. It is wrong to determine the sea ice only by a single source so we can consider a combination of image data from high satellite and the navigation service provided by the national department concerned in this area to understand the state of the sea ice.

Additionally, the ice information updated in the website is not stable. The website

did not do an in-depth research on how to send the ice information to the ship, and even if it has been sent to the ship, it also cannot guarantee that everyone can accurately interpret this ice information.

Because the information in this study is relatively less, and the author's level and time is limited, further studies on the application of the Arctic ice information in future work is still needed in order to have a more profound understanding of the part of the application of Arctic ice along the Northwest Passage.

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