CHAPTER 2

Ice Observations

- ☐ Aerial Ice Observations
- ☐ Shipboard Ice Observations
- ☐ Iceberg Observations
- ☐ Ice Thickness Observations

Simon Prinsenberg (DFO)

Photo 2.1: Bifurcated grey-white and thin first-year ice, medium floes, moving under the Confederation Bridge

This chapter deals with ice-observing methodology.

Ice observations are made using electronic aids such as radar, by visual observation or from a combination of both methods. These methods vary as functions of the platform from which the ice observations are made as well as what electronic aid equipment is available.

The emphasis in this chapter is on visual ice observations made from aerial- and surface-based platforms. References are made to the use of airborne radar imagery; however, the reader is referred to documents related to the interpretation of radar imagery. (cf. 4 and 5)

Ice observations are dependant on the perspective from which the ice is viewed. Ice can be observed from the aerial perspective using an aircraft or helicopter or from the surface perspective using a vessel or from shore. Each perspective has limitations on the nature and detail of ice observations which can be made and in turn drawn on an ice chart. It is important that the Ice Services Specialist (ISS) understand these limitations and what aspects of the ice can and cannot be observed from each perspective.

2.1 Aerial Ice Observations

Using aircraft as platforms from which to conduct ice reconnaissance, a nearly synoptic description of ice conditions can be obtained. Large areas of ice can be covered in a relatively short time, using the latest state-of-the-art electronic aids combined with visual observations, where weather conditions and daylight make it possible to see the ice surface.

However the limitations must be realized. As the observing distance from the aircraft increases, it becomes progressively more difficult to detect changes in the ice surface. Therefore it is necessary to determine the visibility limit, which is the maximum distance from the aircraft at which the ISS can confidently identify and locate ice features. Under normal circumstances, the visibility limit should not exceed 15nm (25 km) on each side of the aircraft. Ice observations made in the early morning or late afternoon under sunny skies allow for much easier identification of surface features away from the aircraft. In an overcast situation with snow-covered ice, a condition known as flat light will often exist. This condition eliminates shadows and causes ice-surface features to appear insignificant or even invisible. Observing limits will change as a function of altitude and the prevailing horizontal and vertical visibility.

In order to successfully perform ice-reconnaissance duties, the ISS must be able to recognize, identify and record the different characteristics and features which distinguish one ice type from another. Training and experience in ice recognition allows the ISS to identify ice types, concentrations, floe sizes and significant surface features.

Aerial observing platforms are usually stable relative to their intended track, but ground speed varies considerably with wind. For this reason, the aircraft position should be plotted on the ice chart with a dot every few minutes.

In the conduct of aerial ice reconnaissance, the ISS employs standard techniques and procedures which are designed to provide the maximum amount of useful, quality-controlled information. Discussion with the participating air crew as to the extent of flight, general area of reconnaissance, close-tactical support requirements and other particulars are routine for each flight. Attendance at pre-flight weather briefings is also normal.

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Photo 2.2: A ship's track through fast ice, with open water in the background

2.1.1 Use of Electronic Aids: The ISS has available on board the reconnaissance aircraft several useful electronic aids that can be combined, where appropriate, with visual observations. These aids may include an airborne imaging radar and an airborne radiation thermometer (ART).

Airborne Imaging Radar: An imaging radar is the most valuable ice-observing tool. It is presently the only operational source of mapped ice information when the surface becomes obscured by fog or cloud. An ISS who is fully familiar with the operation and the limitations of the radar system can effectively delineate ice edges and large leads, estimate the total ice concentrations and when used in combination with other sources of information, identify and distinguish many ice types. There are two types of imaging radars that are used for ice reconnaissance. The first type is the **Side-Looking Airborne Radar (SLAR)**, which is a real-aperture system. It differs from most other airborne radars in that the antenna is rigidly fixed to the aircraft and the energy is directed towards either side of the aircraft ground track. Scanning of the area to either side of the ground track is accomplished by the movement of the aircraft in flight. The radar returns are then processed and converted into intensity-modulated traces on cathode ray tubes. This light is used to expose film thus producing a photo radar map of the ground. The signal is also digitized and processed by on-board computers and is transmitted to ships and ground stations in digital format. It then is relayed to the Canadian Ice Service and Canadian Coast Guard Ice Operation Centres.

Imagery may be acquired at 25, 50 or 100 km swath widths on both sides of the aircraft. Generally speaking, the 100 km swath is used when wide aerial coverage is desired. If more detail is needed or the width of a channel being imaged is narrow, a 50 km swath may be specified. Unless otherwise specified, the SLAR is operated at the 100 km swath.

The second type of airborne imaging radar is the **Synthetic Aperture Radar (SAR)**. This radar forms an image by a different process. It uses a relatively short antenna to produce a wide beam. The image is built up by successive scans but the radar also makes use of the Doppler history of the surface being scanned as the aircraft moves forward. As the beam of the radar moves across the surface, changes in position are calculated and this information is used in creating the radar image. The effect is to synthesize a much longer antenna than is physically possible on the SLAR, achieving a constant resolution across the image. This factor, along with a finer resolution, distinguishes the SAR from the SLAR.

The radar image is mainly a function of the return microwave energy which is dependent on the radar system parameters and the surface characteristics. Through practice and experience, radar imagery can be interpreted by studying changes in texture, pattern and tone.

Airborne Radiation Thermometer: The ART provides a linear trace of the surface temperature along the flight track directly below the aircraft. Due to the effect of atmospheric moisture on the accuracy of the temperature reading, the system is routinely calibrated over known temperature reference targets, such as melting ice or frazil ice. Its prime application is in monitoring surface temperatures of open water bodies for determining the growth and decay of ice.

2.1.2 Ice Type Identification:

The first tool the ISS should use during any visual observation is the local ice climatology. Although some ice types will look virtually identical at different times of the year, a knowledge of what ice types and features are possible in any given location will greatly simplify the identification process. The ISS should be aware of all ice information for the area from ships, shore stations and scientific parties to further support the ice types under consideration. Previous ice charts and observations should also be referred to in order to maintain the consistency of observations between flights.

Accurate aerial observations require careful examination of the ice surface for subtle features. Although some conditions are very easy to interpret, such as old ice floes in a matrix of grey ice, other conditions require more attention to details. An example of a more complicated ice condition to observe is small floes and ice cakes of old ice within a heavily ridged snow-covered area of thin first-year ice.

Surface topography is one indicator of ice type that can be used in most observing situations. For example, the surface topography of first-year ice is generally rougher than old ice. Old ice floes tend to stand out as smooth rounded areas encased by ridged and rubbled first-year ice in mixed ice-type conditions. Determining whether the ice surface is ridged or rafted will also help determine ice type, since thinner ice will tend to raft rather than ridge. Old ice floes have a higher freeboard than first-year ice and hence will appear to "stick out" of the general ice surface.

Ice colour is another indicator of ice type that can be used when lighting conditions permit and the ice surface is free of snow. Since thin ice types are more transparent, they show the darkness of the water beneath them. As the ice thickens it becomes greyer in appearance.

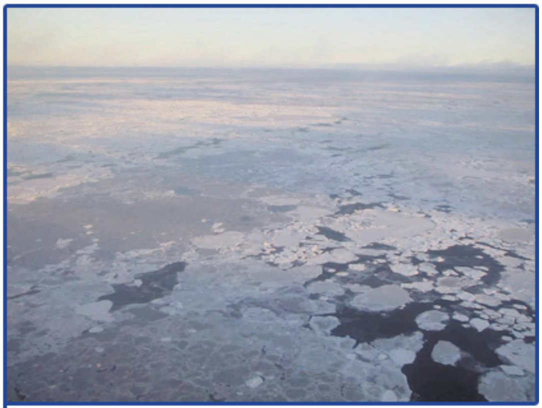

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Photo 2.3: Various stages of ice development. In the foreground, grey ice and nilas mixed with small floes of thin first-year and grey-white ice. Total concentration 9/10's ice.

Beyond the thin first-year ice category, the colour differences are negligible and it is no longer possible to distinguish thicker ice types on the basis of colour alone, except for old ice floes. When ice is very thick it becomes more of a blue-white colour. The colour is most apparent during the melt period, but it can be observed at other times. To distinguish thick first-year ice from second- or multi-year ice, additional surface features (e.g. topography) need to be considered. This is because there is little difference in colour between the three types, except during the melt period. The melt ponds on thinner ice types become blue-grey, then green-blue and finally black as they continue to melt deeper and thaw holes begin to appear. Their colour remains blue on old ice types unless the floes become very deteriorated.

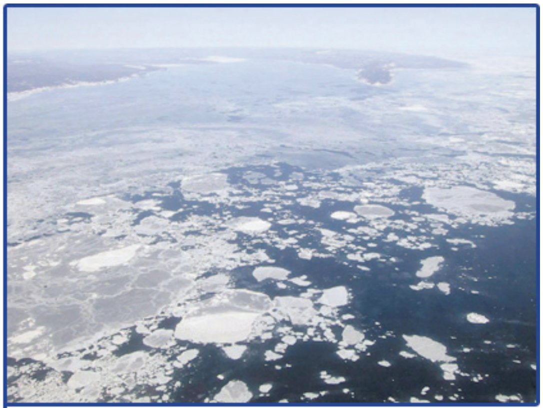

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Photo 2.4: **Northumberland Strait:** in the background, very close pack grey ice, and in the foreground, open to very open grey-white and grey ice.

A complicating factor in winter ice observation is the presence of snow cover on the ice surface. This requires the ISS to pay much closer attention to the orientation and severity of the surface topography, since colour and other surface features are hidden. Visibility limits are often reduced over snow-covered ice, as it becomes difficult for the ISS to detect changes in ice colour or surface roughness.

Visual observation of ice types in summer or melt conditions requires attention to melt patterns. As the snow melts on first-year ice, it produces pools of fresh water very similar to old-ice conditions. These pools initially make the surface of old ice and thick first-year ice appear blue. Unlike first-year ice, old ice has an established drainage pattern at this point and so has fewer melt ponds with small connecting streams.

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Photo 2.5: Melt ponds and drainage pattern on old ice.

Despite these guidelines and even with the benefit of much experience, there will be situations where ice types cannot be identified with reasonable confidence. In all such cases, the ISS shall still make an observation to the extent possible and designate all other unknown or unidentified categories with an **X** designator. A partial observation is better than none at all.

2.1.3 Boundary Placement:

The placement of ice boundaries is just as important as the identification of ice types. These boundaries indicate differences in ice conditions that relate to total concentration, floe size, surface features or ice types.

It is important to locate ice boundaries as accurately as possible. Determining the distance from the aircraft to ice edges or other ice features requires a good deal of practice and attention to detail. When beginning a period of visual observation, an ISS should make an attempt to identify a significant land or ice feature which will be evident on radar and ask the radar ISS for the exact distance. This technique is also useful for experienced ISS when the decision is taken to fly a mission at a higher or lower than normal altitude, as it allows the ISS to quickly orient oneself.

Visibility limits shall be drawn on the chart paralleling the flight track for all sections of the flight where visual observations are made.

The ISS should avoid drawing overly complex ice charts by merging areas of similar ice conditions.

2.1.4 Estimating Ice Concentration:

Observations from airborne platforms allow for a more accurate estimate of ice concentration. An ISS with weather-observing experience will find the procedure of estimating ice cover in tenths quite straightforward. In the higher concentrations (6-10 tenths), it is often easier to estimate how much of the area is ice-free rather than how much is ice-covered.

Figure 2.2 (p. 2-15) provides a visual guide to estimating ice concentrations. The ISS should use judgment in recording ice conditions to the maximum detail that their chart scale will allow.

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Photo 2.6: In the Woods' Island area, very close pack grey and nilas.

2.1.5 Chart Production: In an aerial-observing situation, the data collected by visual observation, radar observation and the ART are placed on a single chart. This compilation of all data sources allows the ISS to correlate the various information sources and improve accuracy. The resulting chart is the main product of the mission; therefore its accuracy is crucial to a successful mission.

Visual observation of surface ice features is a very accurate means of determining ice type and concentration. However, estimated distances are not as accurate as radar measurements. For this reason, whenever radar and visual observations are to be correlated, edges that are distinct should be taken from radar. Ice type concentration should normally be taken from the visual chart. When available, ART data should be included as spot observations.

Figures 3.4 (p. 3-26) and 3.5 (p. 3-27) are examples of actual aerial ice charts produced from operational flights. Procedures for coding the chart are described in Chapter 3.

2.1.6 Helicopter Observations: Ice reconnaissance carried out from a helicopter provides a very good opportunity to collect detailed ice information over a fairly large area. Helicopters are used extensively on ships for ice reconnaissance and other purposes. The shipboard ISS should make every effort to accompany as many of these flights as possible.

During helicopter reconnaissance, special attention must be paid to positioning. Most of the helicopters now in use for ice reconnaissance can provide latitude and longitude information. On helicopters equipped with position display navigation systems such as GPS, the ISS can accurately record positions along any particular flight lines. Where the helicopter does not have positioning equipment on board, the ISS shall constantly dead reckon his/her position using aircraft heading, speed and elapsed time.

Prior to a flight, the shipboard ISS will normally undertake basic pre-flight planning in consultation with the ship’s captain and helicopter pilot. Factors to be considered should include the specific requirements relating to the ship’s area of interest, desired flight track/area of coverage, weather conditions (specifically wind speed/directions), obscuring phenomena and precipitation. Before takeoff the ISS should plot the ship’s position, speed and heading on his working chart. During takeoff, he/she should make note of the time and update the ship’s position if required. This information will allow the vessel to be used as a reference point on both the outbound and inbound legs.

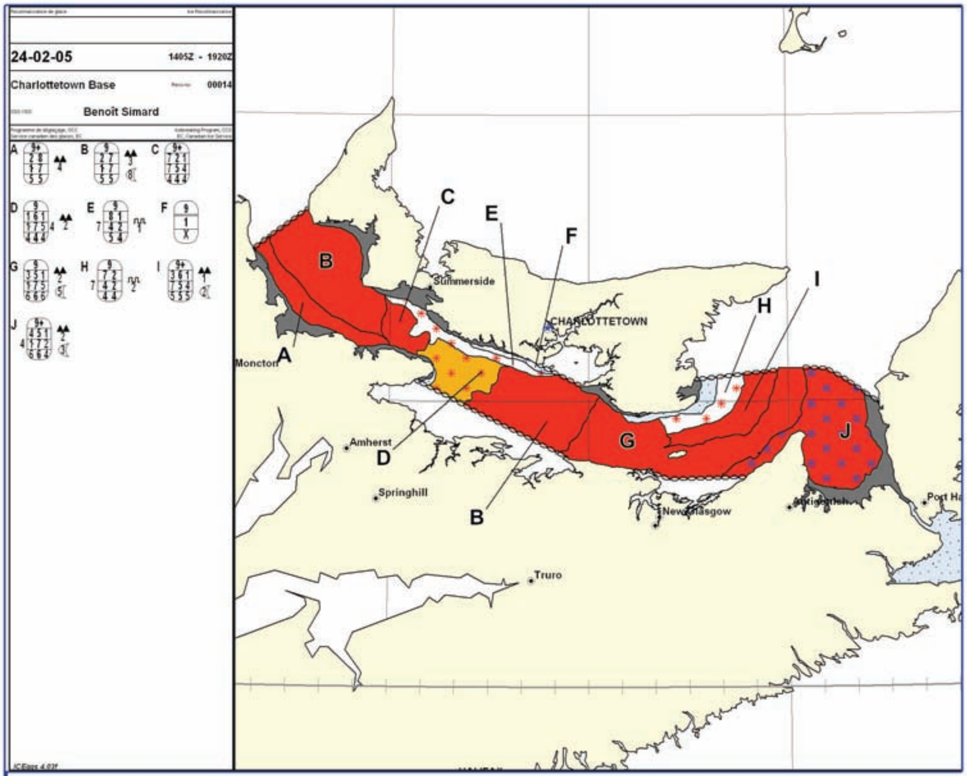

Figure 2.1: An example of an ice chart produced from a helicopter flight.

In situations where it is necessary to have daily information in nearshore waters, a shore-based helicopter reconnaissance program may be established, such as the St. Lawrence River winter ice-reconnaissance program at Quebec City or a similar ice-reconnaissance program at Charlottetown. The ISS is expected to be aware of and report all significant changes in ice cover, thickness and movement on a daily basis.

In areas normally covered by a shore-based helicopter, each day's chart should be compared to the previous day's chart to ensure consistency and accuracy. As well, the ISS should be aware of all shore-based ice information sources for potential information on fast ice thickness.

2.2 Shipboard Ice Observations

Shipboard ISS are a very important part of the ice-observation network. They provide very detailed ice observations, as well as report characteristics of the ice not collected by aerial reconnaissance methods such as snow depth, ice thickness and ice behaviour.

These detailed observations of the ice are used to make more accurate interpretations of aerial charts as well as for climatological studies. Therefore shipboard ISS should always record ice conditions to the maximum possible detail.

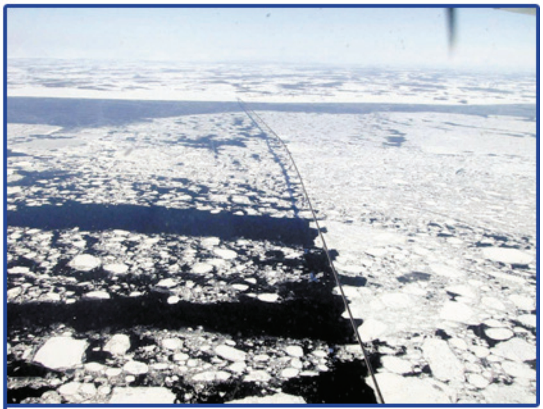

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Photo 2.7: Very close pack first-year and grey-white ice moving under Confederation Bridge.

Ice information to be collected should include, but not be limited to:

- concentration
- behaviour of the ice (i.e. movement, developing or releasing pressure)
- thickness
- topography
- ridge heights
- ridges per linear mile
- iceberg observations
- depth and surface coverage of snow
- water temperature
- melt state

Whenever possible, the ISS should disembark from the ship to the ice surface in order to measure its thickness and snow depth and to estimate or measure ridge heights.

Don Isaacs (CIS)

Photo 2.8: A shipboard perspective.

The shipboard perspective is similar to the far-range of the aerial perspective as the ice cover is viewed from an extreme angle; this, along with its slow speed, limits the geographic extent of a ship-based ice observation. The low angle perspective of a ship's deck requires special attention to maintain ice observation accuracy. Whereas an aerial observation depends primarily on surface features to determine ice types, a shipboard ISS should normally use ice thickness.

2.2.1 Use of Electronic Aids: The ISS on board the icebreaker has several electronic aids which can provide useful information and be combined with visual observations. The ISS can use the onboard marine surveillance radar to indicate the range and bearing of surface targets such as icebergs or ice edges.

As well, airborne imaging radar data (either SAR or SLAR) can be downloaded to most Coast Guard ships through the use of a downlink receiver and Ice-Vu display software. This will provide the ISS with a source of mapped ice information identical to that available to the ISS on board the ice reconnaissance aircraft. This data is mainly used for navigating the vessel through the ice, but can also help in assessing the general ice conditions in the area. In some cases accurate boundaries and features can be extracted from the imagery for the ice chart.

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Photo 2.9: Ship moving through very close pack grey-white ice and patches of nilas.

2.2.2 Ice Type Identification: Accurate estimates of ice thickness can be made by observing ice being turned up along the ship's hull. To help improve accuracy, any known reference point can be used such as the ship's deck rail, the sea bucket or pieces of wood tossed over the side.

To record conditions further away from the vessel, surface topography becomes more important for ice type recognition.

The identification of old ice floes from the ship perspective requires special attention to the surface topography ahead of the vessel. Old ice floes in a mixed field of ice types are often detected by observing a significant difference in freeboard between these floes and other first-year ice floes around them. In many cases there is significant rubble and ridging around these floes; this is caused by the pressure of thinner ice types against the much thicker old ice floe.

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Photo 2.10: Airborne view of close pack concentration of vast floes of old ice.

The local ice climatology should also be known in order to know what ice types are normal for the area, as well as determining the normal behaviour of the ice.

The ISS should also refer to previous ice charts and imagery (if available) collected and/or generated in the days prior to the ship entering the area. This will help to maintain consistency in the observations and help in ice recognition. For example, if the presence of an ice type has been previously reported in the area, the ISS should be looking for that ice type.

2.2.3 Estimating Ice Concentration: The low observing position from the ship causes separate ice floes to lose their distinction. This can result in over-estimation of the concentration and/or floe size.

In good light conditions, the ISS shall record ice conditions to a distance of no more than 5 nm from the vessel. Experience has indicated that observations beyond 3 nm are very subjective, but this is left at the discretion of the ISS. Attempts should be made to locate an iceberg or another vessel in the 3-5 nm range from the vessel using the ship's marine radar which will help to estimate distances.

Consideration should be given to the fact that ice conditions in the immediate vicinity of the ship are not always representative of those within the accepted observation limits of 3-5 nm. However, the initial assessment of conditions in the near range serves as a good starting point or baseline and can be modified if required as the ship moves through the ice.

Whenever an ice-reconnaissance aircraft is in the area, efforts should be made to speak to the ISS on board. The ISS should try to convey as much information as possible to the aircraft, to help improve the accuracy of the aerial ice charts as they are being generated. Also, an attempt should be made to receive any charts or radar imagery that might be available. The charts or imagery will provide a better overall picture of the ice conditions and will aid in estimating the concentration from the ship perspective.

It is worth noting that aerial ice charts typically display much larger areas due to their perspective. For this reason, the vessel may find itself in a high-concentration area recorded as a low-concentration area on the aerial chart. It is likely that the ship is in a very localized area of high ice concentration, the limits of which cannot be seen by a shipboard ISS because of the visibility or extent of the ice coverage. When this happens, the ISS should look for signs in the distance to verify the differing concentration, but shall not alter the shipboard chart to comply with the aerial one. Nevertheless, this matter should be discussed with the airborne ISS, if possible.

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Photo 2.11: Large pans of grey-white ice devoid of snow cover.

2.2.4 Chart Production: A daily chart of observed ice conditions shall be produced for the entire area the vessel has travelled while the ISS was on duty. The only exception is when a vessel is in ice-free waters that are not normally subject to sea-ice cover or iceberg intrusion. Data obtained from helicopter reconnaissance flights can either be merged with the daily ice-track chart or plotted as a separate observation. The shipboard charts shall be numbered consecutively from the start of the voyage.

2.2.5 Synoptic Observations: Individual ice observations from ships are an important part of the ice information required to prepare the daily ice analysis chart produced at the Canadian Ice Service. These observations are used to confirm interpretations of remotely sensed imagery. They also serve as a check on observed charts generated from visual aerial ice reconnaissance.

Marine weather synoptic observations are normally made every 3 hours while a vessel is in transit. The ISS will usually take 3 or 4 observations during the course of their duty day. Synoptic ice observations are taken and recorded using the WMO ice code described in MANMAR (cf. 2). It is important that these observations reach the Canadian Ice Service in a timely manner, so they can be incorporated into the daily ice analysis.

At times when the ISS is engaged in other duties or is off duty, the ship's officers should be encouraged to take, record and transmit marine weather and ice observations in accordance with the codes contained in MANMAR (cf. 2).

2.3 Iceberg Observations

Iceberg observations are acquired in several different ways from the air and from the surface. The method of reporting iceberg observations is the same for both types and the coding procedures are described in chapter 4. Iceberg observations from the air are collected by visual means as well as using airborne radar. This manual will briefly describe visual iceberg observations only. Radar detection of icebergs is dealt with in references 4 and 5 (*List of References, p. viii*).

Aerial iceberg observations are made by dedicated flights or as part of the collection of sea ice data. For dedicated iceberg flights, basic sea-ice boundaries and concentrations shall be recorded. Otherwise icebergs have a lower priority but should be reported whenever possible.

The principal objective of iceberg observations is to identify and report all icebergs that are present within the area covered. The ISS should set his/her observing limits to the extent that he/she can be certain that all icebergs have been reported with a high degree of confidence.

Visual priority flights shall not be undertaken unless visibility along 90% of the planned flight track is forecast to be 15 nm or more. The optimum altitude for visual observation is approximately 1500 feet. Fig 2.2 and 2.3 illustrate the size, shape and types of icebergs.

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Photo 2.12: Bergy Water

2.4 Ice Thickness Observations

Ice thicknesses are measured routinely at selected shore stations, ranging from the Arctic to the Great Lakes. Occasional thickness measurements are obtained from icebreakers. All thickness observations are desirable and should be obtained where and when possible.

These measurements serve to help verify aerial and shipboard observations by providing the exact WMO thickness category at the point of measurement. This data can be used to compare estimates made in the same area at the same time or during future observations. It can also be used to predict future ice thicknesses.

Chapter 6 describes the procedures for coding and reporting ice-thickness observations.

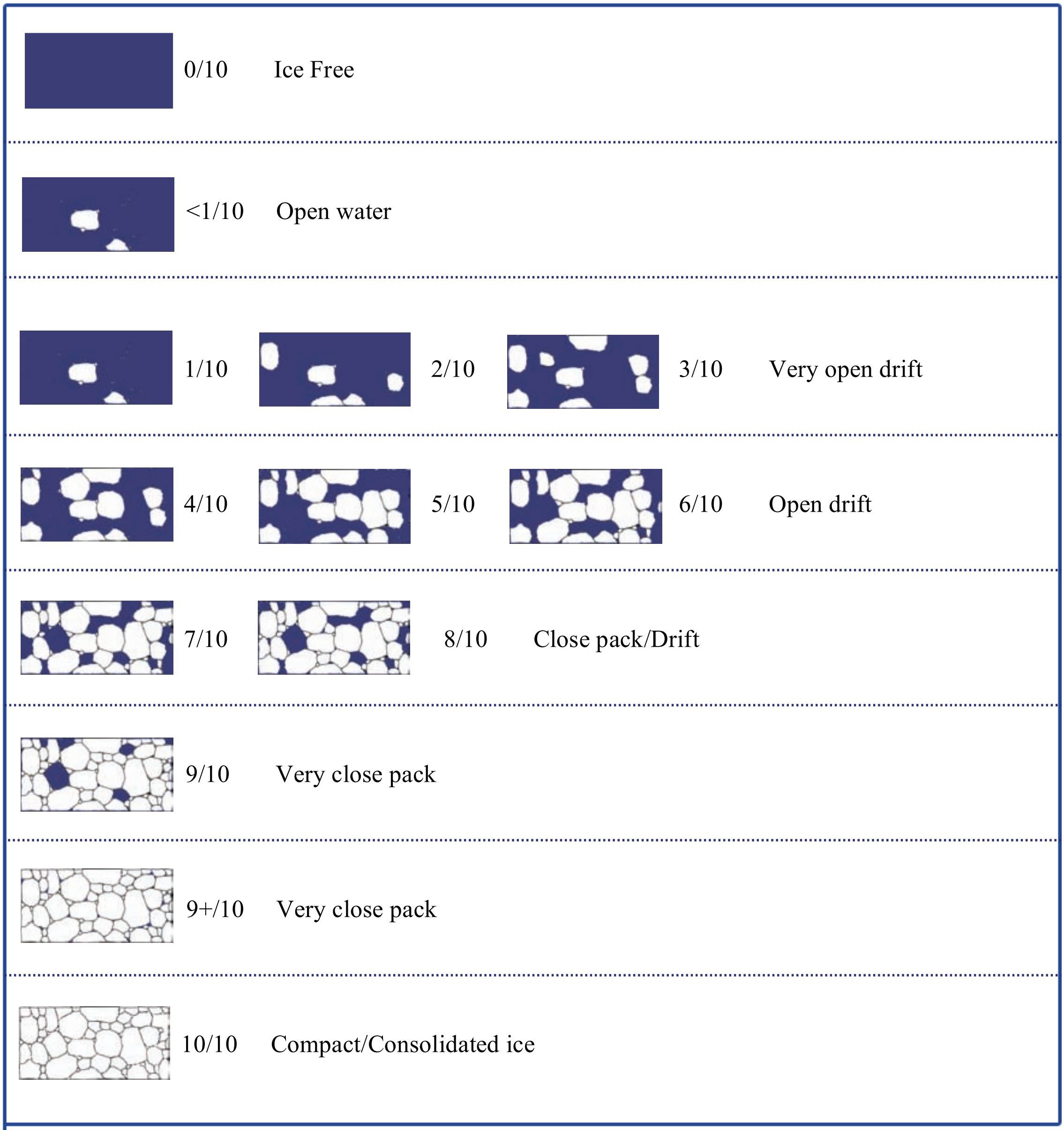


Figure 2.2: Diagram of Ice Concentrations from an Aerial Perspective

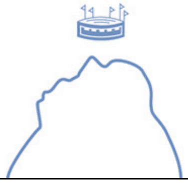
Iceberg Size	Height above sea surface (meters)	Length (meters)	Weight (Megatons)
Growler 	less than 1 m	less than 5 m	0.001
Bergy Bit 	1 m to less than 5 m	5 m to less than 15 m	0.01
Small Berg 	5 m to 15 m	15 m to 60 m	0.1
Medium Berg 	16 m to 45 m	61 m to 120 m	2.0
Large Berg 	46 m to 75 m	121 m to 200 m	10.0
Very Large Berg 	Greater than 75 m	Greater than 200 m	Greater than 10.0

Figure 2.3: Iceberg Size

Shape	Average height to draft ratio	Shape	Average height to draft ratio
Tabular 	1:5	**Wedge** 	1:5
Non-Tabular 	1:5	**Drydock** 	1:1
Domed 	1:4	**Blocky** 	1:5
Pinnacle 	1:2		

Figure 2.4: Iceberg Shape

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