Ice Profiler

What is this sensor?

This sensor is used to determine ice draft in Arctic locations, as ice freezes, melts, advances or retreats over a certain area. Ice draft is the amount of ice that is below the water line. For example, when you float an ice cube in a drink, most of the ice is below the water level with a small amount above. When ice draft is measured, the measurement is from the waterline down. Most ice data are collected over the winter, though it is not unusual for icebergs to be detected or studied with ice profilers in the summer as well. The ice profiler is at a fixed location, meaning that it only takes measurements as ice forms or travels over top of it. Windblown ice, such as icebergs, can appear and disappear on ice profilers in the summer season. Ice draft is an important variable in understanding the influence of ice on the Arctic and global climate. Ice can greatly impact the interactions between the ocean and atmosphere, as the annual freezing prevents heat and gasses from being exchanged with the atmosphere. Equally, ice helps to maintain Earth's temperature by reflecting a large percentage of light we receive from the sun. This reflection reaction is known as Albedo: white and light-coloured objects, such as ice, reflect energy, and dark-coloured objects absorb light. The bright white surface of the ice reflects the suns energy, keeping the Earth cool. An ice profiler allows researchers to understand ice in three dimensions (draft, width and breadth) and provides a better picture of the behavior of ice and its influence on the local and global climate.

How does an ice profiler work?

Ice profilers use upward facing sonar to measure the thickness of the ice. Like all sonar devices, the ice profiler emits a high frequency beam of sound and then detects the returning echo. When it detects a return echo, the ice profiler determines the difference between the signal being reflected by the sea-ice interface and the pressure sensor. This gives the overall ice draft.

Further, the sonar can be used to examine the surface of the bottom of the ice, just as downward facing sonar would be used to determine the surface of the sea floor. The profiler can take several measurements a minute, allowing researchers to monitor how the ice "grows" over time. Furthermore, profilers can be used to detect the movement of ice over the senor; this may be the growth and retreat of ice from shore or it may be icebergs that float over the sensor.

How is Ice thickness measured?

(m) Metres

Ice draft is usually expressed in metres. During winter, ice usually forms at a fairly consistent rate, provided that the temperature is consistently cold enough, ending up several meters thick. As ice melts during the spring, there can be more variability as the ice melts at different rates depending on the location and temperature.

What is the normal range for this data? What variables influence it?

Quick reference for **Cambridge Bay**:

Summer: no ice coverage, icebergs may be present.

Winter: 2-5 metres of ice.

Detailed explanation

Salt lowers the freezing temperature of water, and thus it takes colder temperatures to freeze seawater than freshwater (freshwater freezes at 0°C). Sea water with a salt content of about 35ppt won't begin to freeze until it is about -1.8 °C, if the water contains even more salt, this can push the temperatures necessary for freezing even lower. If the water is brackish (only a little salt) the water will freeze a little below 0°C. Thus, the formation of sea ice has considerable variability depending on temperature and salinity of the water.

Latitude will also play a large role in ice formation as some areas of the high Arctic Ocean have ice all year, while many areas experience a seasonal freeze and thaw. In the high latitudes, ice is may be present all year, and each winter it builds in thickness (this is known as multi –year ice). In lower latitudes the ice may be a winter occurrence, with open water in the summer. Ice that forms and melts in one year is known as first year ice. In Cambridge Bay, our sensors measure ice that forms in the bay, due to the latitude of the bay, this will be first year ice.

As the seasons change, it is not unusual to see some variability in ice data from our network as temperatures may become low enough to allow freezing for a few days, only to warm up again, melting the ice. As first year ice forms, it is common to see a bell curve pattern of increasing ice thickness over the course of the winter. Once winter is established and temperatures become consistent, the ice builds up until it reaches its maximum thickness (again, dependent on area, temperature, and salinity); during the spring thaw, the ice will melt much more quickly than it formed.

Although ice formation is impacted by a number of factors, it also impacts factors on its own. For example, ice needs consistent low temperatures to form, but once formed, it can impact the salinity and density of the water around it.

Factors that **impact** ice formation:

Temperature: For ice formation to occur, temperatures need to be consistently cold enough (less than -1.8 ^{o}C) for ice to form for a salinity of 35 ppt.

In the data, you may notice a relationship between temperature (both of water and air) with ice formation/draft. Over the long term (several years) it may be possible to identify trends in ice formation and temperature.

Solar radiation: Related to the seasons and a driving force behind temperature, solar radiation can induce sea ice melting

In the data, you may notice that ice will begin to melt as solar radiation increases with seasonal changes. Bear in mind though that this is ONE factor that may be noticeable. Although temperature is the main driver in ice formation and thickness, solar radiation is also part of the equation.

Salinity: Salt lowers the freezing point of water, so a high salt content can prevent the seawater from freezing at a given temperature. Equally, as ice forms and the freshwater in seawater freezes, the salt gets left behind. This can cause the remaining water to become saltier and denser, requiring even lower temperatures to induce freezing.

In the data, you may notice that this is supported by temperature and salinity readings from the CTD.

Factors that will be **impacted** by ice:

Solar radiation: Once sea ice forms, the bright white surface of the ice reflects much of the light and heat energy we get from the sun; in a reaction known as albedo. The presence of sea ice decreases the amount of radiation that enters and heats the oceans, acting like a shield.

In the data, you may notice a seasonal increase in solar radiation that coincides with spring, and a decrease of solar radiation in the fall. You may be able to correlate this data to ice draft and formation, though it is not exclusively responsible for this process.

Gas exchange/phytoplankton growth: Ice can prevent the exchange of gases with the atmosphere, resulting in a noticeable decline of oxygen as the available oxygen in the water is consumed by animals in the environment. Depending on ice thickness, phytoplankton growth may be restricted and this can impact primary production and oxygen levels. The ice sheet restricts primary production as it blocks the light (especially when covered with snow). As the light levels return, allowing plankton to grow, oxygen levels begin to increase in this environment.

This data will be supported with data from the fluorometer, oxygen sensor and the underwater camera.

Salinity: Sea ice is made of freshwater, and as it freezes, gravity forces salt out of the water. As more freshwater freezes, the remaining seawater becomes even saltier. Equally, when the sea ice begins to melt in the spring, a decrease in salinity is observed as the fresh water enters back into the sea water and dilutes the saltier water from winter.

This data may be supported with temperature and salinity data from the CTD and meteorological station

Biology: Many animals are affected by seasonal ice. For example, birds, mammals and humans may experience both benefits and challenges due to increased ice formation or reduction. For example, many seals require ice to act as a platform for them to give birth to their pups. Polar bears also rely on the same ice to allow them to hunt seals and move throughout the arctic.

This data will be supported with camera data from above and below the ice.

Detailed Explanation of principles and variables

The seasonal growth and melt of ice has both local and global effects on the environment. Local life, both humans and animals, can often be affected by the seasonal freeze and thaw. Furthermore, our global ocean depends on ice formation to move heat, reflect sunlight, and continue the ocean conveyor-like circulation of seawater around the world.

Ice is both affected by other variables, and is itself a strong variable on many other processes. Variables affecting ice, and the impact of ice on other processes are discussed in alphabetical order below. Bear in mind, many of these variables and impacts may have other affects, or may need to be combined with other data to understand the whole picture.

Temperature

Temperature, will have the largest impact on the formation of ice. Salt lowers the freezing temperature of water, thus generally ocean water temperature must be below -1.8 ^{o}C before ice can form. If the water has less salt the freezing temperature would be above -1.8 ^{o}C. Air temperature may be below freezing for days or weeks before ice begins to form, as water has a very high heat capacity and will resist sudden changes in temperature. In recent years, warming temperature trends have been observed, due to climate change. As long term investigations into Earth's temperature continue, it is possible to observe changes over time in ice as well. For example, sea ice extent, thickness, and duration have been well documented in an overall declining trend.

Biology:

Organisms above and below the water will be affected by sea ice. Ice reflects solar radiation, affecting water temperature, and can impact oxygen levels, salinity, and primary production which can make survival difficult for some animals. Equally important, some animals, such as polar bears and seals, depend on ice for hunting and shelter.

Additionally, humans are greatly impacted by snow and ice cover. In northern communities, goods and services must arrive before the ice freezes, and equipment (ships and vehicles) must be prepared or specially equipped to deal with snow and ice cover.

Gas exchange/ phytoplankton growth

Ice can act as a thick "cover" for the ocean, preventing the exchange of gases with the atmosphere. This can prevent oxygen and other gases from entering the water through upper level mixing (wind and wave actions). As the oxygen is used by organisms in the environment under the ice, this can result in a decline of oxygen.

Equally, as the ice prevents sunlight from penetrating into the water, it can inhibit primary production. This can also affect oxygen levels as marine algae are not able to photosynthesize, and thus do not create oxygen as a byproduct. As ice forms, primary production (and the presence of chlorophyll) will decline and then stop until the ice melts again. As temperatures warm and ice thins and melts away, chlorophyll will increase as algal populations increase and create a seasonal 'bloom'.

Salinity

Salinity lowers the freezing point of water, thus sea ice can only form when water temperatures fall below -1.8 ^{o}C if salinity is 35 ppt. As the freshwater cools and freezes, it forces the salt to eject from the forming ice into the surrounding seawater. This makes the surrounding seawater even saltier and denser. In comparison, as ice melts, it causes an influx of freshwater into the surrounding water which can in turn lower the salinity and thus the density of the water.

Solar Radiation

Solar radiation (sunlight), affects the formation of ice and can be reflected when it hits the white surface of ice.. When solar radiation hits a dark surface such as ocean water, the energy of the light is absorbed by the water. When it hits a white or light-coloured surface such as ice, most of the energy is reflected back (like a mirror). This reflective power, known as albedo, has a major impact on the temperature of the earth. In the summer, when solar radiation is high, this can slow down the formation of ice as the seawater is warmed by the increased energy of the sun. In the winter, when there is little or no solar radiation, ice can form into a thick layer. Once formed, the ice reflects solar radiation, preventing it from warming the water and melting the ice. This is known as a feedback loop. If a lot of water is exposed, solar energy can enter the water, causing it to warm and thus limiting the amount of ice, thus allowing more sunlight to enter the water and so on. Similarly, if a lot of ice has formed, it can reflect solar radiation, thus preventing the water from warming, thus protecting the ice. Thus, climate scientists are worried about an increase in global temperature; as the temperature increases reducing global ice coverage, the amount of light reflected decreases and further increases the amount of heat entering the Earth/ocean, further decreasing the amount of ice. This is known as a positive feedback loop because as the event occurs, it feeds into the same process, building on itself.

Ideas for classroom explorations

This section is intended to inspire you and your students to explore different ways of accessing, recording and interpreting data. These suggestions can be used 'as is', or can be freely modified to suit your needs. They can also be used to generate discussion and ideas, or as potential staring points for projects.

- Record the oxygen, temperature and ice draft on a daily basis. Does ice begin to form as soon as the atmosphere cools, or is there a delay? Does oxygen begin to decline as soon as ice forms, or is it stable for a few days?
- Monitor oxygen levels, chlorophyll, ice and atmospheric conditions. What is their relationship over time? Can your data help you make further predictions?
- Compare ice draft readings after specific atmospheric events. For example, does a storm felt on the surface have an impact below the ice? Does fallen snow register on the ice profiler? Can the snowfall rate be determined due to a change in ice draft?
- Predict when the ice will freeze and thaw, and compare your prediction to the actual data.

Ideas for projects

This section contains suggestions for long-term projects you and your students may be interested in investigating using the data. These projects may require support from multiple data sources, experts in the field or additional experimentation.

- Compare the data and inquire about relationship among other seasonal trends. For example, during fish migrations is there a trend in the data? In successful spawning or hunting years, are there differences observed from unsuccessful spawning or hunting years?
- Compare data from several years. What trends, if any, appear?
- Explore how biology responds to changes in draft of ice.

Common misconceptions or difficult concept elements

This section is intended to help you anticipate where students may struggle with difficult concept elements or ideas. We've noted content that may require additional support for students to fully understand, or content that may lead to misconceptions.

- Air temperature may vary considerably, whereas ice or water temperature may vary little due to the high heat capacity of water.
- Feedback loops – if ice exists, it can reflect a large portion of sunlight, thus preventing the ice from melting. If there is not a lot of ice, water can heat up, preventing ice from forming. In both situations, the larger the patch of ice (or open water) the more it feeds into the process, thus creating positive feedback "loops".