University of Victoria

Department of Physics & Astronomy

PROCESSING IPS DATA

By

Malcolm Newson

ASL Environmental Sciences Inc.

Victoria, B.C.

Acknowledgments:

I want to acknowledge my two supervisors and reviewers, Alex Slonimer and Dawn Sadowy, who provided my data processing training at ASL. Their comments and feedback through the review process helped me learn how to interpret the data and what standards to uphold me work to. They were friendly, responsive, and available. I would also like to thank my project supervisor Edd Ross who provided another review perspective on beta curves and helped me during my research and development coding project.

Table of contents:

List of Figures

Introduction:

The use of upwards looking sonar to measure sea ice thickness facilitates higher time resolution data than that obtained by large scale acquisition such as satellite imagery provides ice characterization of keels but is limited to discrete locations. At ASL Environmental (ASL), the Ice Profiling Sonar (IPS) device is designed, manufactured, and operated for various contracting customers, including industrial companies looking for engineering hazards and research organizations collecting environmental data. After deployment, the IPS collects data autonomously at a selected sample interval, and after recovery, its raw data has to be decoded, processed, and cleaned. The final time series of ice draft is a quality controlled product and can be interpreted or investigated by oceanographers at ASL or by the customer.

Instrument and environment:

The IPS uses mechanical sound waves to measure the distance between it and the surface above, either open water or ice. Other measurements were taken, including local water properties like temperature, pressure, and the device tilt components. Both the IPS and other instruments, like an Acoustic Doppler Current Profiler (ADCP), are attached to a cage and flotation device, with a line anchored to a bottom mooring (See Figure 1). The ADCP uses sonar to measure water speed and direction in multiple water layers above the device, providing ice velocity data. This time series can be combined with an ice draft series to convert into a spatial series.

Upwards looking sonar has been used on submarines under the arctic ice pack since the 1960s. The Acoustic Doppler Current Profiler was developed in the late 1980s. Dr. Humfrey Melling of the Canadian Dept. of Fisheries and Oceans at the Institute of Ocean Sciences (IOS) began working on the IPS to combine it with ADCP measurements shortly after. In 1995, a significant redesign of the IPS instrument was undertaken by IOS, with ASL Environmental Sciences Inc. involved in some of the design and testing. Subsequently, ASL obtained a license to manufacture the new IPS Model 4 instrument and has been engaged in product maintenance and upgrading activities ever since. ASL started to offer the IPS model 5 in 2007, which included many new features and larger memory.

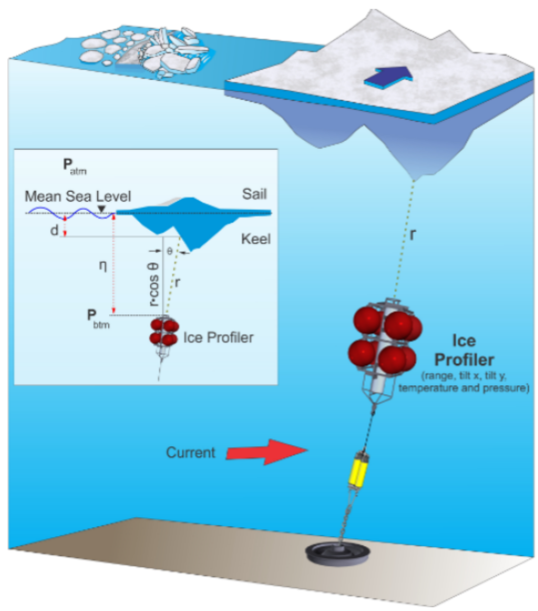

Figure 1: IPS Mooring Configuration

The IPS is an active sonar device, which means it sends out sound pulses into the water and detects echoes. Whenever the sound wave encounters a change in the medium's density, some energy ratio is transmitted and reflected. The range, r, is the distance of the target from the instrument and is calculated as r=ct/2, where c is the average speed of sound over the acoustic path, and t is the travel time. The strength or amplitude of the return pulse depends on both the range and the target's reflectivity. Targets in the field of view of the IPS may be sea-ice or open water surface. Potential "false" targets include bubbles, fish, or zooplankton. The return signal's strength must fall within a threshold to register as a target, and the new IPS5 can register and record multiple targets. At the operating frequency of 420 kHz, the sea ice's underside is effectively a very smooth reflector. However, the ice's underside is rarely perpendicular to the incoming wave, so the return signal is generally a scattered return. The sensor's beamwidth is ~1.8 degrees. The area illuminated by it on the surface 40 m away is 1.2 m, meaning that features smaller than this resolution will not be resolved, and the beam can sometimes catch edges of features.

Because the buoyant force on the flotation device always acts vertically and the line to the anchor is fixed, pull down events can occur when the current blow the device off vertical. A tilt sensor allows a correction to be applied:

$$r = r` \cos\theta \quad (1)$$

Where

$$\theta^2 = xtilt^2 + ytilt^2. \quad (2)$$

See Figure 1 for a diagram that shows this tilt correction.

A variety of environmental events can impact the data at a site. Malcolm's project during his Co-op term was located in the Beaufort Sea, just north of the Alaska and Yukon border and near the Mackenzie River delta. Each site's locations are shown in Figure 2, where four sites are located near the river delta, and a single site is further north and near the Chukchi Sea between Alaska and Russia. Their water depths range from 30 m to 160 m, with the instrument around 40 m from the surface. Spring meltwater running out of the Mackenzie river will mixing fresh water into the ocean nearby. The Chukchi Sea site is located near an

Figure 2: Site locations

ocean floor plateau edge, and upwelling events can occur, which mix cold water from depth up through the water column. This site is also much further north and in open water, whereas the other sites are near the land and can have landlocked ice or ice build-up. Keeping these aspects of each respective site in mind is essential during the beta curve step for data processing.

Data Processing:

The IPS data processing procedure takes the raw time of travel information that the instrument records and produces a quality controlled time series of ice draft. If ice velocity data is available from an ADCP, this time series can be turned into a spatial series where the time axis is converted to distance. This is valuable because there is no sense of volume for the ice features that pass overhead in the time series.

First, the raw data file outputted by the IPS4 or IPS 5 must be converted into a binary file and a header file created, which includes information about the data set such as start and end date, sample interval, and location. The header file is updated with the parameters and input files used, and which steps are performed. It is common for there to be several phases in a year data set, where different sample intervals are used. A higher sample interval might be used in the season of interest, but the interval is lowered to preserve power and memory in the offseason.

The raw range data is displayed as a distance, r, calculated using an approximate sound speed. This sound speed would vary throughout the year as water properties in the column above change, and a later step will adjust it. All of the data sets; range, pressure, and tilt components, are passed through a series of automatic de-spiking steps, and then manually checked to remove anomalous data. They are also chopped to remove the deployment and recovery sections where the device is being deployed or recovered. A time drift can occur in the IPS device's onboard clock, and by comparing it to a GPS clock at deployment and recovery, correction can be applied.

To achieve the desired quantity of ice draft, defined as the depth of ice from the mean water level, the equation

$$d = \eta - r` \tag{3}$$

is used, where d is the draft, η is the water level calculated using the pressure and $r`$ is the uncorrected range to the surface. After correcting for the tilt, this equation becomes

$$d = \eta - r \bullet cos\theta. \tag{4}$$

One of the largest and most time-consuming steps is the beta curve correction. In this step, the differences in sound speed throughout the water column above is accounted for by using a unitless variable β as shown in equation

$$d = \eta - \beta \bullet r \bullet cos\theta \tag{5}$$

where d is the ice draft from the mean water level. The speed of sound in water is dependent on properties of the water like temperature and salinity (how salty the water is), and the IPS device can only measure these properties locally. A beta value is assigned to each discrete sample by creating a curve of beta vs time. This curve is modified by the data analyzer using various data sources to aid in interpretation and goes through an extensive review process before it is finalized. When open water is above the instrument for an extended period, the signal shows a clear periodic wave structure. A beta value is calculated to force the average to a draft of zero. This method of picking beta values to force open water sections to zero drafts is used through the time series. However, it can be challenging to interpret the data when mixtures of ice and waves are present. When there is no open water, the beta values are assigned to a straight line between neighboring open water sections. Various information sources are used to help interpret the data, including local temperature and salinity, surface temperature, satellite images, and ice charts. These are used to help assess whether data points are open water, ice, or possible anomalies or spikes. By developing a beta curve and applying it to a corrected ice draft, it is possible to see where the data has shifted and re-evaluate the beta curve.

Beta curves are site-dependent, but similarities in different years of the same site or nearby sites can be used to help develop an understanding of what beta curves might be reasonable—the seasons of the year display different characteristics. In the summer, warm surface temperature generally means no ice is present. Once temperatures drop below -2C for a sustained period, thin ice can develop and progress into thicker sheets. Waves can still be present in thin ice, and weather events like warm air or storms can break thin ice. Once winter settles in and a steady sheet of ice is present, no data points will represent the surface unless ice motion separates sheets, and a gap of open water appears. However, during this time, the water is insulated from the surface, and ice cover minimizes wave activity that would mix surface water down. So during this winter season, it is reasonable for the beta curve to be reasonably flat. Once temperatures rise in the spring and the ice cover breaks, mixing resumes and the beta curve will vary. This process is very subjective. To ensure some validity of the changes made to the draft, an extensive review process is employed where the project lead and commissioning researcher are consulted. After the beta curve is approved and applied, the last step is to set open water sections to zero drafts.

Conclusions and results:

The resulting ice draft data set is used to characterize the ice in the region. Industrial projects in the arctic, such as offshore oil rigs, might use this information to develop design specifications. Governments might be interested in shipping or other boat travel potential, and environmental researchers might want to test mathematical models or investigate relationships between ice and other environmental factors. This information is beyond the data processor's role, who is taking the raw data and producing a quality-controlled product. Some of the ice draft data's possible results include what percent of different seasons there is ice cover and what thickness that ice cover might be.

References:

IPS Processing Toolbox User’s Guide - ASL Environmental Sciences Inc.