NORTEK MANUALS

Principles of Operation ICE

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1 Introduction

This manual is designed to give an overview of the principles of operation when using the Ice application in a Nortek instrument. This application is available for Signature 1000, Signature 500, and Signature 250. For more general information about current measurements using Nortek instruments, please refer to Principles of Operation - Currents and for information about wave measurements refer to Principles of Operation - Waves

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2 Ice measurements

Both the Nortek Signature 1000, 500, and 250 can be used to measure both ice thickness and ice drift. The instruments use their center beam as an altimeter to measure the distance to the ice-water boundary, together with pressure readings this can give information about the ice draft. In addition, the instruments uses the slanted beams to measure the Doppler shift from the velocity of the ice sheet or iceberg to get information about the ice drift. Note that a specific firmware needs to be used in order to enable ice measurements with the Signature instruments. The previous generation of AWAC instruments also have the possibility to measure ice thickness, this is not an option with AWAC 2.

2.1 Ice draft (keel)

The instrument measures the distance to the submerged part of the ice sheet directly with the central beam. There are two ways to decide the distance to the boundary interface (water-air or water-ice) using the altimeter profile. The boundary can be detected either using the max peak of the return signal or the leading edge (Figure 1). The max peak method of detecting the surface searches for the largest value in the return signal and is used to detect the water-aire boundary when measuring waves. The leading edge method detects the boundary by finding the where the return echo has the largest change in value. This method is better suited for echoes that increase at the boundary but do not decrease rapidly. This is typical for water-ice boundaries, and the leading edge method is therefore mostly used to detect ice.

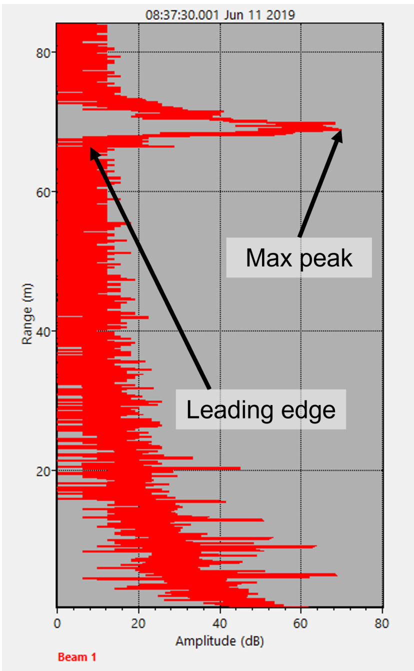

Figure 1: The return signal profile from the altimeter showing the location of the max peak and leading edge.

The instrument will output time series with distance to surface, detected by both methods. In your data you will there have one time series called AST (using the max peak) and one called LE (short for leading edge). The approach used by the instrument to detect the surface using the leading edge method is relatively simple, and can be broken down into the following sequence of automatic steps:

1. Transmit a relatively short pulse
2. Specify a receive window covering the range of all possible wave heights
3. Apply a match filter process which uses a leading edge detector over the profile to locate a surface
4. Use quadratic interpolation of the peak point and its neighbors to precisely estimate surface location

Note that this procedure is carried out internally in the instrument, resulting in a time series with distances to the surface found in the raw data. For more details about the AST method and its use in measuring waves, please refer to Principles of Operation - Waves.

After the distance to the surface is measured, the thickness of the ice draft itself can be calculated by subtracting the location of the leading edge of the altimeter peak from the mean depth determined from the high accuracy, temperature-compensated pressure sensor. These are calculations the user has to do in post processing and is not done internally by the instrument.

$$Ice\ draft\ (keel) = Water\ depth - Distance\ to\ ice \tag{1}$$

In post-processing it is necessary to convert the pressure measurements to an equivalent height of the free water surface, and to apply various corrections (see below) to both types of data.

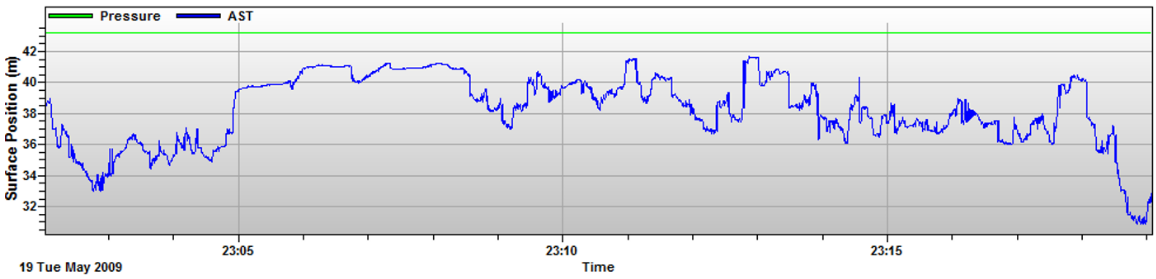

Figure 2: Example of time series of pressure and distance estimates. From this one can find the ince draft thickness.

2.2 Ice drift (tracking)

To measure the drift of the ice, the four slanted beams transmit long pulses, compared to normal current profile pings. A long transmit pulse means the ice is ensonified for the full beam width. This generates a strong, sharp and accurate echo back to the instrument which is Doppler shifted proportional to the velocity of the ice. A Nortek proprietary algorithm is used for estimating the ice tracking and the instrument gives out the ice velocity in the set coordinate system.

Figure of Merit (FOM) is a quality parameter that estimates the white noise (or Doppler noise) for each ping, and gives a snapshot of the quality of the measurement. In general, a lower FOM is better, and if the number is high it should be considered removing the velocity estimate from the series. FOM is scaled to be proportional to the standard deviation.

3 Corrections

Several corrections should be taken into account when measuring the ice with the methods described above.

Atmospheric variations:
In addition to the instruments pressure measurements there needs to be a correction for the atmospheric pressure variations. The pressure sensor measures absolute pressure, but the data are presented relative to a nominal value of atmospheric pressure at the time that pressure offset was taken (i.e., a constant mean value of atmospheric pressure is already subtracted from the absolute pressure measurements). The data must be corrected for fluctuations of the actual atmospheric pressure relative to the assigned mean pressure. These fluctuations, which are associated with the passage of high and low pressure zones in the atmosphere, occur on daily to weekly time scales and can have an amplitude equivalent to +/- 0.5 m of water height, if not corrected. A time series record of barometric pressure is required to make this important correction. Since atmospheric pressure variations are associated with large-scale synoptic weather systems, the barometric pressure measurement does not have to be made right at the location of the instrument. Atmospheric pressure measurements obtained within a few tens of kilometers from the deployment site typically result in residual errors after correction of less than +/- 0.05m [Waves in the summer, ice in the winter]. It should also be mentioned that care should be taken when estimating the density, which is used to convert pressure to depth.

Density:
Salinity affects density more than temperature in freezing conditions. Because seawater freezes as a function of temperature and salinity, and the temperature is measured, it is possible to infer salinity. It is reasonable to assume that the water column is not highly stratified during ice conditions.

Speed of sound:
The Signature's acoustic range measurement technique uses an estimate of the vertically-averaged speed of sound to convert acoustic travel-time measurements into distance estimates. Salinity plays a relatively minor role in sound velocity (about 1.34 m/s per psu at 0 degrees C), so the uncertainty in salinity is not expected to contribute significantly to errors in the acoustic range data. For example, uncorrected salinity variations over the range of 30-35 psu would contribute errors in calculated water depth of only about 0.05 m. Temperature is important for sound velocity so an uncorrected temperature change of -2.5 degrees C to +2.5 degrees C would result in a depth error of 0.15m. By using the measured temperature to correct the speed of sound, combined with an estimate of salinity based on the assumption that the water column is near the freezing point, it is possible to reduce the residual error due to density uncertainty to less than +/- 0.05 m. It is reasonable to assume that the water column is not highly stratified during ice conditions.

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