Guidelines on measuring Infragravity Waves and seiches using Nortek Signature and Gen 2 AWAC instruments

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INTRODUCTION

Long Period waves are surface gravity waves with periods typically ranging from 25 to 250 seconds (0.004–0.04 Hz) and long wavelengths. These motions encompass a wide range of physical phenomena, such as Infragravity (IG) waves, seiches, tsunamis, very long swells, and continental shelf waves (Holthuijsen, 2010). Although these processes have different generation mechanisms, they share similar observational challenges. This document addresses the measurement and calculation of oscillatory motions within the 25 to 250 seconds period band, thereby excluding sea and swell (periods lower than 25 s), tides, and other processes with periods above one hour.

Over the years, the demand for instruments capable of measuring long period waves have been increasing. Among long period waves, IG waves have attracted particular attention, as their amplification within semi-enclosed bays can trigger seiches, generating strong low-frequency currents, and inducing operational hazards, raising safety concerns and high economic losses. These include mooring line snap-backs, destabilized offshore moorings, and interruptions to harbour activities. Despite their importance, standardized methodologies for quantifying IG wave parameters have not been incorporated into harbour design guidelines or operational monitoring frameworks.

Traditional wave measurements are based on up to 40 minutes of data collection of sea surface displacement or dynamic pressure data (Emery and Thompson, 2001; Holthuijsen, 2010). This time window most likely ensures stationarity to calculate wave statistics, which are needed for practical applications (Holthuijsen, 2010). On the other hand, empirical evidence and field experience suggest that at least 100 cycles of a given wave period are required for reliable statistical calculations (Group, 2025). For a typical IG wave period of 150 s, this would require over four hours of continuous measurement, far exceeding the time scales over which stationarity can reasonably be assumed. This highlights why standard sea–swell processing approaches applying frequency-domain techniques into a sea-level technique are not suited for IG waves analysis (Costas et al., 2022).

The implementation of long period wave calculation into Nortek instrument is a result of a series of interviews conducted with professionals from diverse fields, including Public sector, Hydrographic surveyors, Numerical Modelling consultants, Academic researchers, and Instrument providers. The interviewees reported the limitation of traditional measurement methods: pressure sensors often suffer from sensor drift, provide only indirect measurements (requiring transfer functions), lack real-time data capability, and can be difficult to recover once deployed. Radars systems rely on fixed structures, are highly sensitive to weather conditions, and come at a significantly higher cost.

Based on the interviews regarding the need for developing new tools to measure and analyse IG waves, we concluded that an effective firmware-software solution should (1) enable both pressure sensor and acoustic sensor to collect data in continuous mode; (2) provide real-time estimates of wave height and peak period with visualization tools to support operational decision-making reducing the downtime periods; (3) the sensor should have low drift, high precision, minimal power consumption with cost-effective sensors requiring minimal maintenance and (4) potential integration with mooring line tension analysis.

In response to these requirements, Nortek initiated firmware changes designed specifically to enhance IG-wave measurement capability. In this document, we outline how to effectively measure, calculate, and visualize IG waves using pressure sensors and the Acoustic Surface Tracking (AST) sensors in AWAC Gen 2 and Signature. We start by showing the instrument configuration process, how to use the algorithm developed by Nortek and finalise with some results, with which we hope to support safer operations and reduce harbour downtime disruptions.

INSTRUMENT CONFIGURATION

Since its latest update, Nortek Signature Deployment (v. 4.7.29) can be configured to measure long period waves by setting continuous Altimeter sampling using Acoustic Surface Tracking (AST) and Pressure reading under Signature 1000 and 500 ADCPs. There are two available options in the software: single plan (Option 1) and alternating plans (Option 2).

Option 1 (single plan) should be used when long period waves are the main target, and no sea/swell directionality or current data are needed. The instrument will be configured to turn off directionality measurements while keeping the Altimeter on, to ensure optimal battery consumption. Directional resolution in the IG band is hard to obtain due to non-linearity in the wave orbitals, and most of the power consumption is associated with multi-beam directional measurements rather than AST sampling.

For Option 1, the user can start by selecting the "Burst using altimeter" option under "2. Application" on Signature Deployment Fig. 1. That option disables the velocity measurements and provides customization options similar to a standard wave burst.

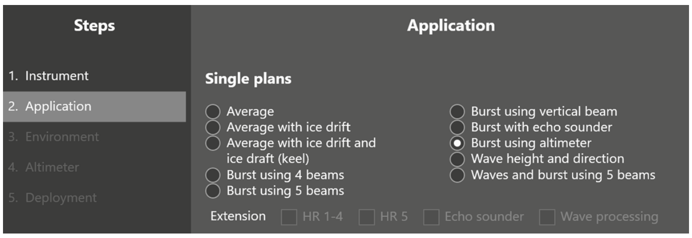

Figure 1. Single plan option on Signature Deployment, where directionality is turned off and a continuous altimeter measurement is enabled

For long period waves observation, we recommend selecting an adequate sample rate (1,2,4,8 or 16 Hz) and number of samples to ensure continuous measurement. In the example shown in Fig. 2, the instrument is configured to collect one hour of altimeter data at 1 Hz. Note that higher sampling rates can resolve shorter period waves, however, it increases power consumption. This trade-off should be considered when defining the setup.

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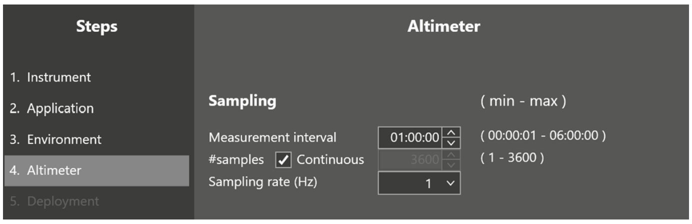

Figure 2. Example of configuration under Single Plan Altimeter on Signature Deployment

Option 2 (alternating plan) should be used when current data or sea and swell wave directionality are also required. This includes burst measurement of orbital velocities and can be either configured through Nortek Deployment or by editing the configuration file. To configure an Alternating Plan on Signature Deployment the user will need to choose the "Burst using Altimeter" option under "Application" on Signature Deployment (Fig. 3).

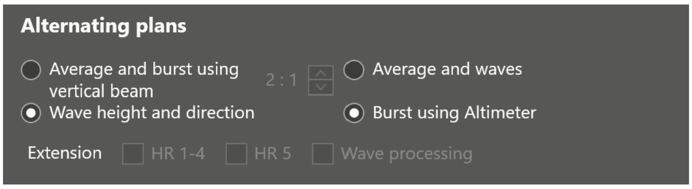

Figure 3. Alternating plans option on Signature Deployment, where both directionality and continuous altimeter measurement are enabled

The long period wave data collection configuration will be set on steps "4. Waves" and "5. Altimeter". The "5. Altimeter" step is all greyed out as it only reflects the configuration on step "4. Waves". Start by configuring the wave burst on step "4. Waves" according to your sea/swell wave research. In this document, we will consider the example of a measurement interval of 3600 s, with 1024 #samples at 1 Hz for the wave burst (Fig. 4). In this case, sea and swell directionality would be measured for ~17 minutes. The interval, number of samples and sample rate can be adjusted based on the user's requirements;

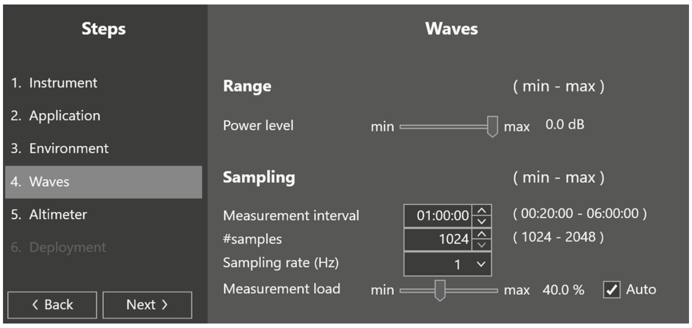

Figure 4. Configuration of an Alternating plan on Signature Deployment – step "4. Waves"

As a response, step "5. Altimeter" will display the same Measurement interval and the accurate number of samples (Fig. 5). The measurement interval of this second burst is calculated based on the full interval at which the entire sampling scheme is intended to be repeated. The sample rate is identical to burst one, Considering our example (3600 s measurement interval with 1024 samples), then the second burst will have a length of 2556s.

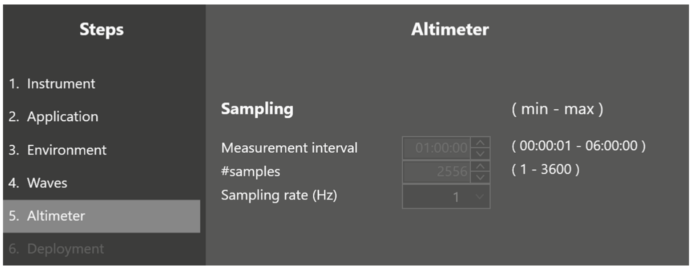

Figure 5. Configuration of an Alternating plan on Signature Deployment – step "5. Altimeter"

This is calculated considering the instrument idle time, which is needed to ensure correct function, being 10s after each burst. In this case, the number of samples is calculated as:

$$\frac{N_{\mathrm{AST}}}{f_s(Hz)} = t_{\mathrm{meas}(s)} - \frac{N_{\mathrm{wave}}}{f_s(Hz)} - 2t_{\mathrm{idle}(s)} \tag{1}$$

where N_{AST} and N_{wave} are the number of AST and wave samples respectively, $f_s(Hz)$ is the sampling rate, t_{meas} is the measurement interval, and t_{idle} is the idle time. For our example:

$$\frac{2556}{1} = 3600 - \frac{1024}{1} - 2 * 10 \tag{2}$$

IG WAVE PROCESSING

We developed a code based on MATLAB® and Python to process both Acoustic Surface Tracking (Nortek AST®) and pressure sensor data, now freely available on https://github.com/NortekSupport/LongPeriodWaves. In the future, our intention is to implement this analysis on our processing software suite. Three different techniques were implemented: **FFT** spectral analysis, **Time-series** filtering with zero-crossing analysis and **Wavelet** transform spectrum (Morlet function).

We used datasets from 3 different sources. The first dataset was collected in Gijon by Puertos del Estado, Spain. In both datasets, we knew when the IG phenomena occurred, so we were able to reproduce their effect using the 3 techniques using both the pressure sensor and AST. Fig. 6 shows the comparison between IG wave height calculated from pressure sensor in the frequency domain ($H_{\mathrm{m0,IG,S_{pp}}}$) and in the time domain ($H_{\mathrm{m0,IG,TS}}$). These signals are ultimately correlated with the incidence of Sea-Swell waves ($H_{\mathrm{m0,SS,S_{pp}}}$), also included in the package. The bottom panel in Fig. 6 shows the Wavelet analysis for the same period indicating the presence of very low frequency waves down to 0.02 Hz (50 s). The white line on top shows the most energetic part of the spectra for the period.

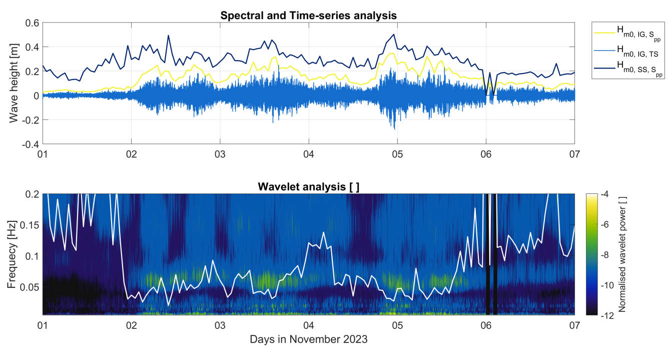

Figure 6. Dataset from Puertos del Estado where IG waves have been deteceted in Gijon (Spain). Top panel shows IG significant wave height calculated from a pressure sensor (yellow), using the time-series filter (light blue) and the wavelet analysis (dark blue). Bottom panel shows the normalized wavelet power for the period with the peak frequency (white line).

The second dataset was collected near Rotterdam harbor and published by Rutten et al. (2024), allowing us to directly compare results. We applied an extra AST filtering technique to remove outliers based on the standard deviation to improve the AST results. That resulted in similar output, but with fewer spikes in the time series. The dataset highlights the importance of using the AST to complement pressure sensor data. At lower frequencies, the energy is similar between the AST and the Pressure sensor, however, the AST outperforms the pressure sensor over higher frequencies by capturing higher energy levels (Fig. 7 on the left). This can also be seen on the right-hand side of Fig. 7 which shows the Welch coherence between the two spectra. Coherence values close to 1 indicate strong agreement between spectra, which is observed for frequencies below ~0.25 Hz. For frequencies beyond ~0.25 Hz (~4 s) the AST captures higher energy, which is expected due to pressure attenuation over the water column.

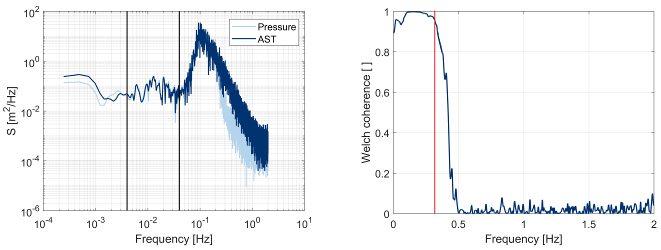

Figure 7. Dataset from Rutten et al., 2024. On the left panel a comparison between the spectra generated from pressure sensor and AST sensor. On the right panel, the coherence between the two datasets.

Finally, the third dataset was collected in Puerto Madryn (Argentina) under our supervision for deployment and data analysis. Results show that while IG wave height from Rotterdam and Gijon reached almost 50 cm, with wave period ranging between 150 to 200 s, in Argentina Fig. 8 it was always under 10 cm. We further developed a confidence level test to ensure IG wave data in Argentina was more than just noise. The test was finally incorporate into the final algorith available on Github.

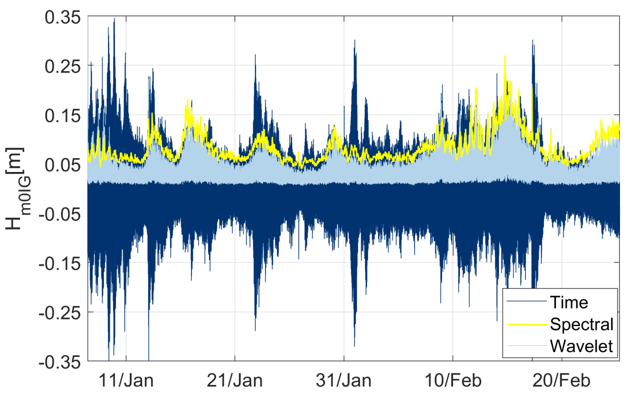

Figure 8. Dataset from Puerto Madryn (Argentina).

Currently we are in the development phase to include directionality into the IG wave calculation. The algorithm is based in the orbital velocities measured by the 4 slanted beams (in the Nortek Signature series) or 3 slanted beams (in the Nortek AWAC series). At the moment, these instruments are capable of measuring directionality for sea and swell waves, which represents an advantage when compared to the lack of directionality of pressure sensors and radars. With our research, we aim to help port and harbour operators to deploy reliable sensors to measure IG waves in their sites.

Questions and comments please contact Nortek Support at support@nortekgroup.com.

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