

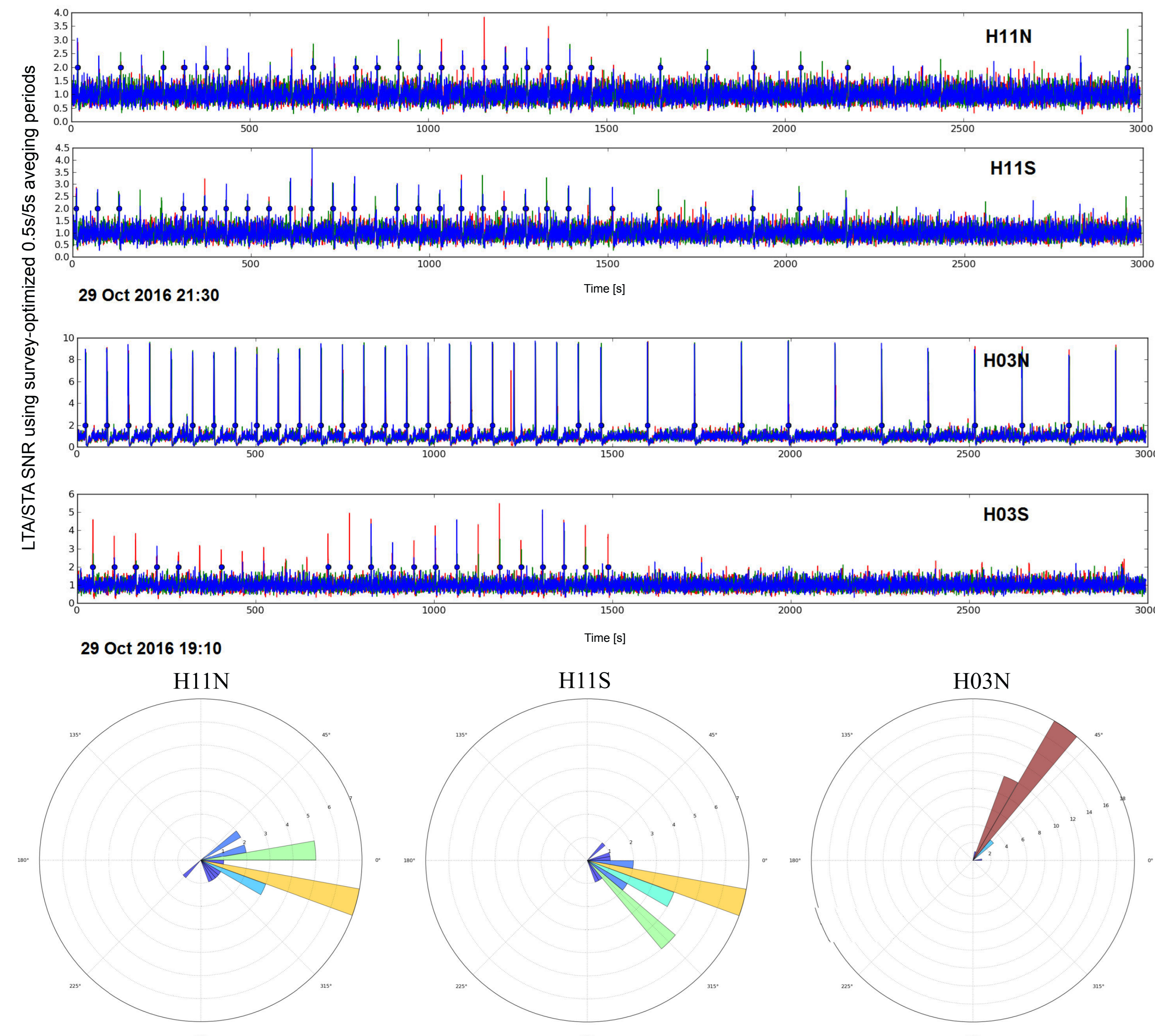
### Disclaimer

The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO

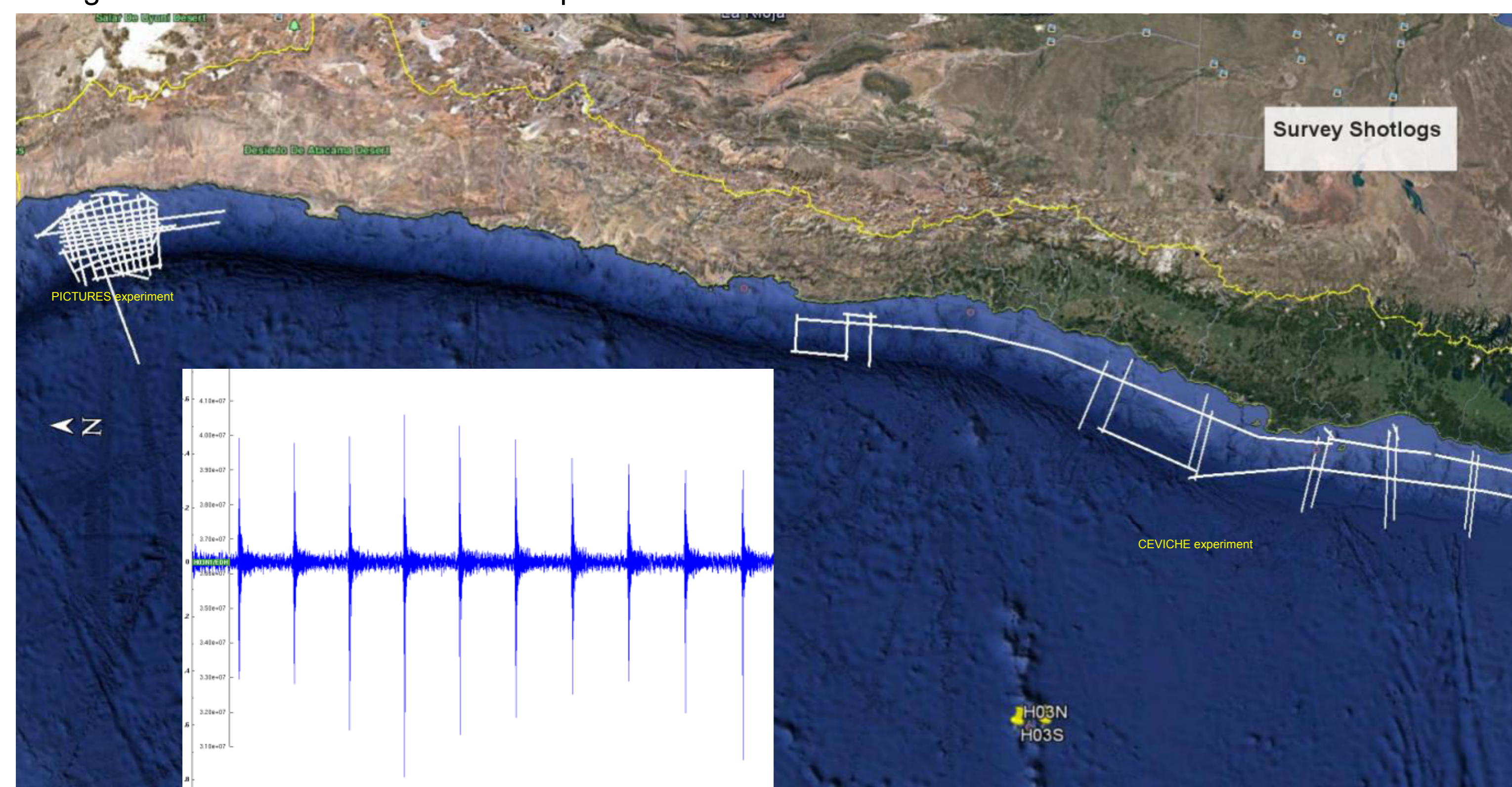
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### Abstract

Throughout November 2016, and in January and February 2017, the IMS H03 (Juan Fernandez, Chile) hydroacoustic station detected prolonged series of short-duration high-frequency signals at an approximate one-minute interval, consistent with a ship-based survey. The signals could also be observed, at much attenuated level, at the H11 (Wake Island, US) station. The quantity of signals and their SNR at H03 are exceptional. The SNR at H11 was high enough to record many events at both H03 and H11. This allows for various venues of analysis and means of verifying station and processing performance not normally available.

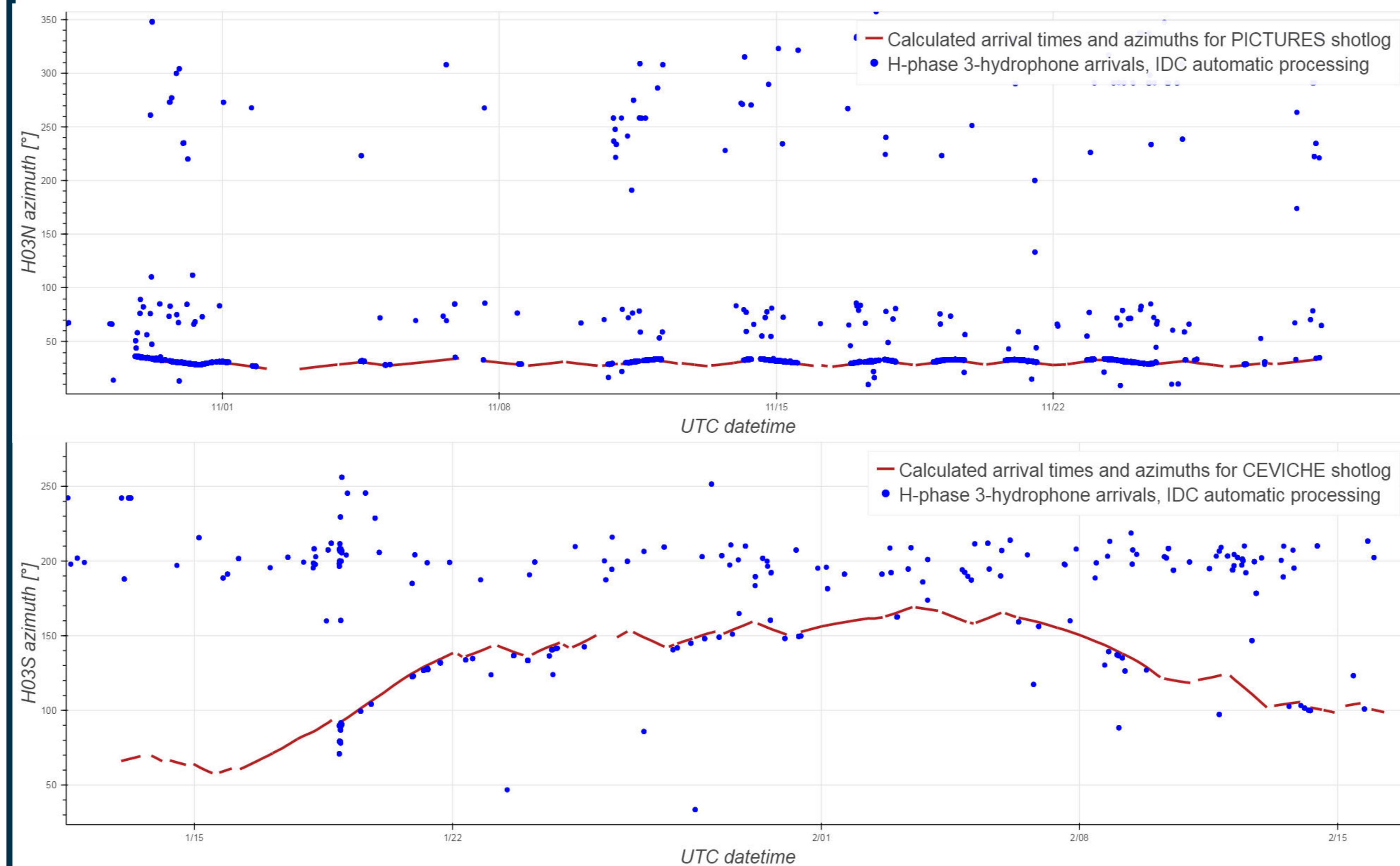


Triangulation of the H03 and H11 detection azimuths located the source for the November 2016 events off the coast of north Chile. Detective work led us to the PICTURES high-resolution controlled-source seismic experiment that was run jointly by Oregon State University (OSU), Universidad de Chile, and GEOMAR using the LDEO vessel Marcus G. Langseth. The Langseth uses an air-gun array and can deploy up to four hydrophone streamers to capture the reflections. The top figure shows the STA/LTA traces for all three hydrophones in the four triads recording the transition when the period of the shots went from 1 min. to 2 min. The polar histograms show the directional statistics as obtained from the specialized processing clearly pointing to the area of the PICTURES experiment.

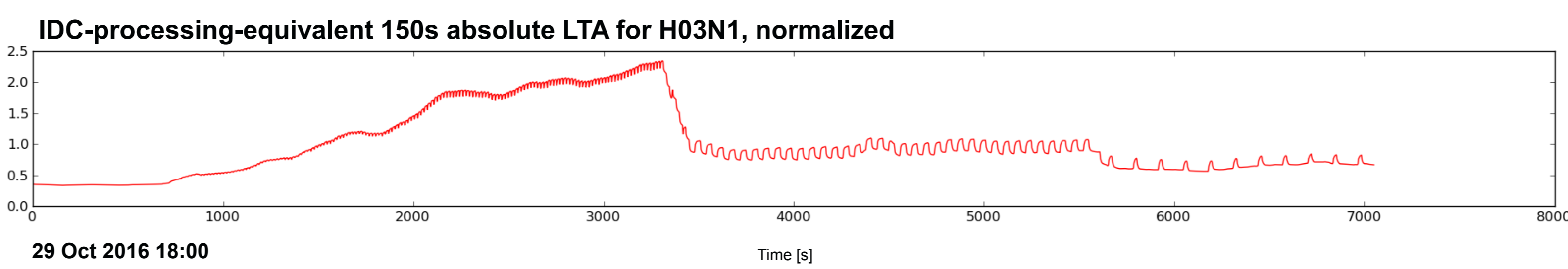


Prof. Anne Tréhu of OSU, chief scientist of the experiment, graciously provided us with shot logs for both the late 2016 PICTURES experiment and the early 2017 CEVICHE experiment. These logs record the times and locations of the shots fired by the air-gun source and comprise a total of 150 thousand shots. The corresponding GPS tracks are shown in the figure above together with a sample of the raw data recorded at H03N1.

The survey led to an excess of hydroacoustic H-phase arrivals in the IDC automatic processing record of H03 as shown in the figure below. The expected arrival times and azimuths were calculated from the shot logs and hydrophone coordinates and plotted as continuous curves for comparison.



As seen, excess arrivals are found both for predicted and off-prediction azimuths at coincident times. It follows that the survey signal gives rise to arrivals for which the IDC processing pipeline (the HASE stage) frequently estimates the azimuth incorrectly. Part of the explanation can be found in the use of a 10s/150s short-term average / long-term average (STA/LTA) detector. This is suboptimal for detecting the short repetition period (typically 1-minute) shots since multiple shot signals will contribute to the LTA that is supposed to reflect a background noise average.

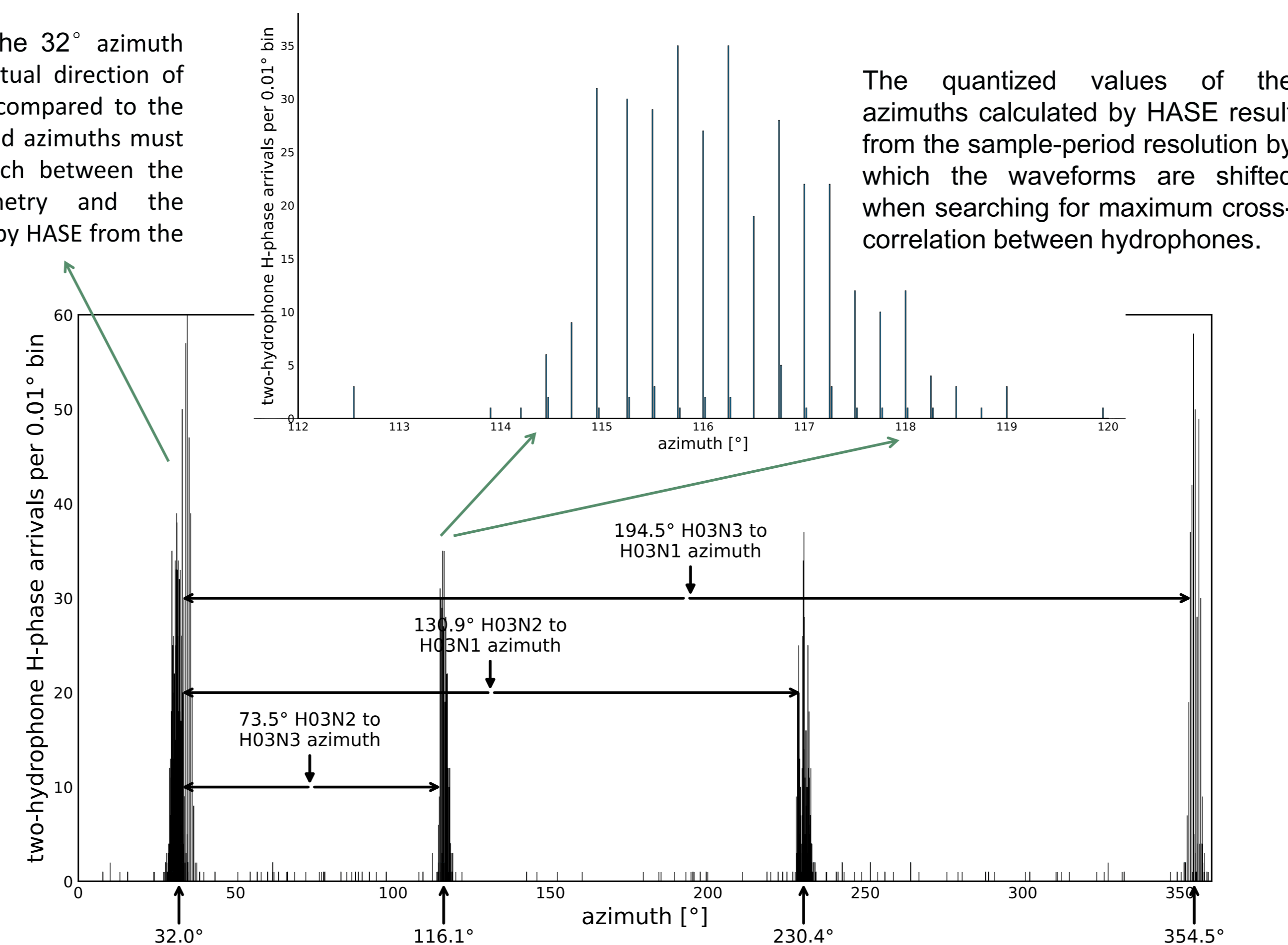


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The plot above shows that the LTA used for IDC processing is strongly affected by the air-gun signal. During the shown time range, shots were initiated and the repetition period was stepped down from sub-minute to once-a minute, and then to every other minute. The LTA grows to a multiple of the pre-survey level (left side of plot) thereby requiring a correspondingly higher signal level for the STA/LTA detection threshold to be reached. It follows that the detection capability of the H03N station was reduced. This makes it yet more likely that the observed off-azimuth arrivals detected during the survey are survey-related.

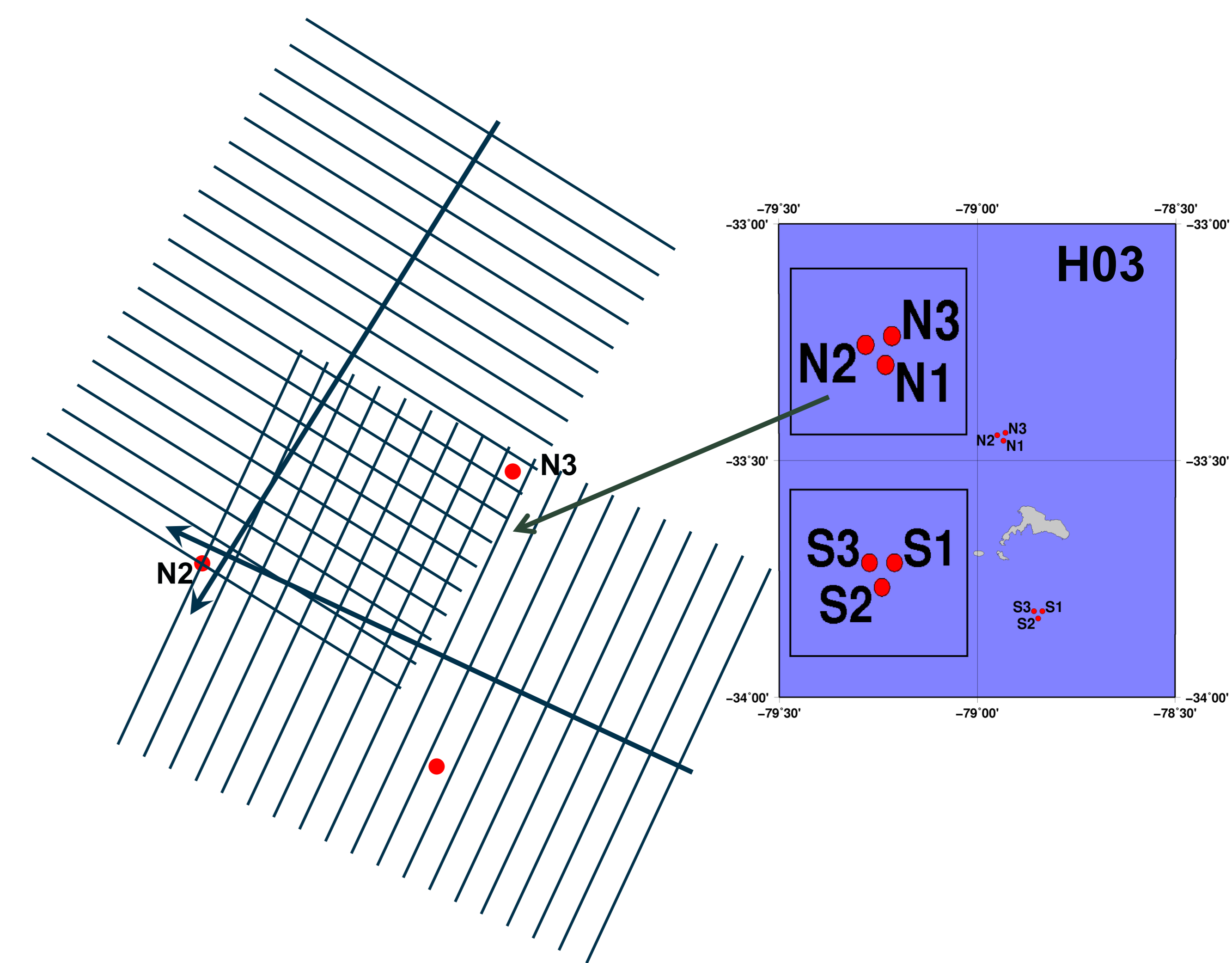
Interestingly, the shot log starts only at 19:17 (4620s) so the preceding high-repetition-rate shots (and correspondingly high LTA) seems to be part of a pre-experiment testing phase.

The broadening of the 32° azimuth peak matching the actual direction of the PICTURES survey compared to the three peaks at mirrored azimuths must result from a mismatch between the actual triplet geometry and the coordinates extracted by HASE from the STATIC.SITE table.



To obtain better understanding, the subset of H-phase arrivals to which only two hydrophones contribute was examined. For these, the remaining hydrophone of the triplet remains below-threshold. The prior histogram shows the distribution of the azimuths of the two-hydrophone arrivals. Aside from near 32° azimuth arrivals matching the direction of the PICTURES survey, three strong peaks at offset azimuths are present.

As indicated in the histogram plot, the three offset peaks relate to the geometry of the hydrophone triplet. Given a time delay between two hydrophones as determined using cross-correlation by HASE, there are two solutions for the azimuth. Consider for example the two incident plane waves depicted below: they propagate with the same time delay from hydrophone N3 to N2 and have propagation directions bisected by the hydrophone-to-hydrophone azimuth.



### Closing Remarks

Surveys such as those conducted by the Marcus G. Langseth can transiently impair the detection capability of IMS hydrophone arrays. From the historical record of hydroacoustic waveforms, it is possible to quantify the impact of surveys. The predictable shot-to-shot delay can in principle be used to automatically spot an ongoing survey and mask out shots. This could take the form of an extension to the libwaveformqc library which already provides analogous masking functionality.

Current handling of two-hydrophone H-phase arrivals is suboptimal. Automatic processing produces two arrivals with azimuths matching the two possible solutions, only one of which corresponds to the incident wavefront. By enhancing HASE to cross-correlate waveform data from the third hydrophone around the arrival time predicted from the two-hydrophone solution, it should be possible to select the right azimuth with high confidence. This is assuming that in most cases, when only two picks are present that the third was not picked automatically because of lower signal to noise ratio.

The source-directed azimuths calculated by HASE on these two surveys are quite accurate and have very good shot-to-shot consistency. There are, though, small persistent offsets on the order of one degree relative to the calculated source azimuths. This, together with the observed broadening of the two-hydrophone source-directed azimuths, may indicate that the triplet geometry for H03N during the PICTURES experiments was slightly at odds with the coordinates present in the IDC database.

The rich set of ground truth data comprised by the shot logs, available to us shortly before SNT2017, provides avenues for further exploration and generating ideas for software improvements. These include:

- A closer look at the spurious, and seemingly survey-related 3-hydrophone arrivals.
- An examination of travel times and a comparison to the monthly travel time models used by the IDC.
- A tuning of the triplet coordinates.
- Comparison to transmission loss models.
- Examination of the statistics of cepstral peaks.
- On-the-fly detection of a third component of a group when only two detections are available.
- Potential look into masking of seismic surveys to allow for better detection of signals of interest.