The Baleakanta project. A database of hydroacoustic signatures of large cetaceans. A few cases of individual animal identification.

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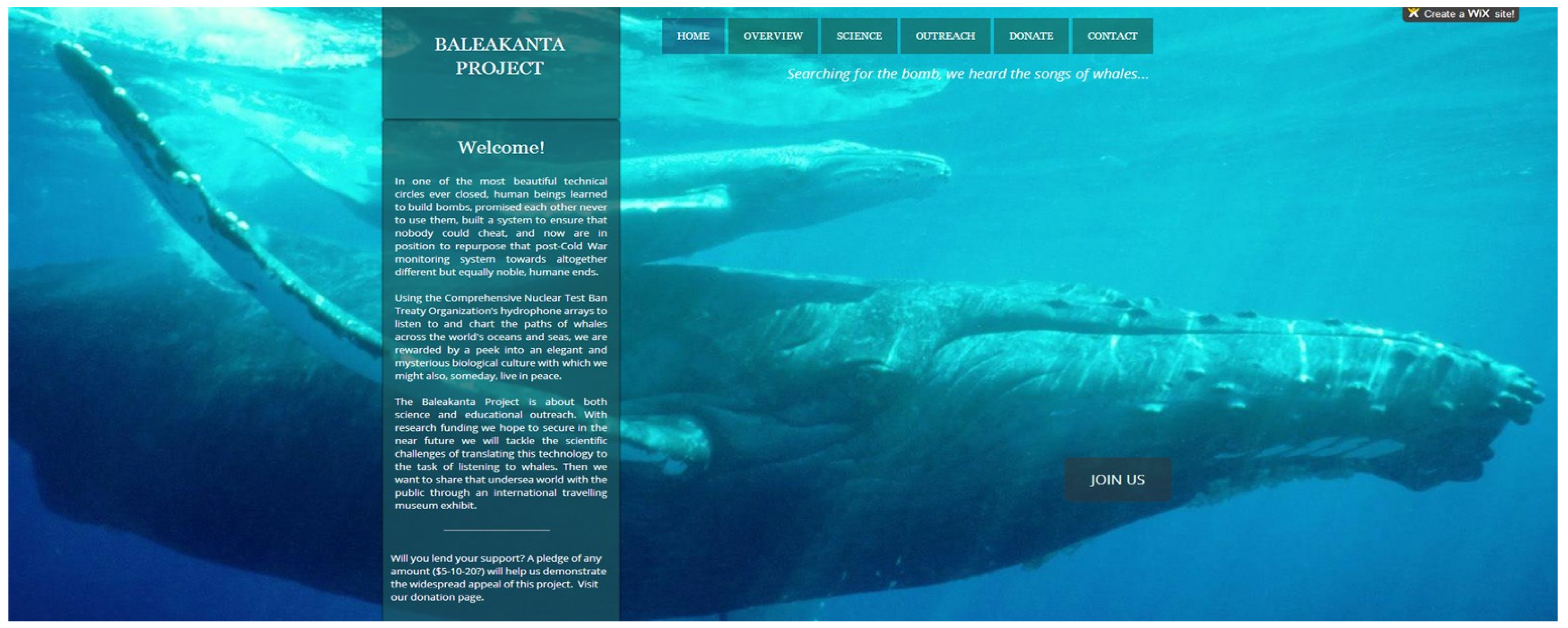
Abstract

The Baleakanta project was initiated in 2013 with the goal of establishing a database of large cetacean calls recorded at the IMS hydrophones. These calls are recorded on a continual basis at the six hydrophone stations of the network, whose main purpose is to serve the mission of detecting nuclear explosions in the oceans. The calls are scientifically valuable as a means of studying the animal's migration patterns. Statistical information about the signal characteristics, frequency, seasonality, density of these calls are some of the expected outcome of the project and we are planning to make the information available to the marine mammal community. We will report in particular on observations which led us to distinguish two distinct blue whale individuals with type 9 acoustic signature and open the possibility to search for time-frequency methods of individual classification.



The Baleakanta project www.baleakanta.org

Out of one of mankind's greatest scientific understandings, that matter and energy are fundamentally tied together, sprang the most terrifying weapon ever invented: the nuclear bomb. Yet, from this horror has sprung what must be surely one of our most noble endeavors – the Comprehensive Test Ban Treaty (CTBT) which is a promise by nations to one another not to test and deploy such weapons against each other. It is a great credit to our world that since the a moratorium in 1992 and inception of the treaty in 1996 only a handful of nuclear tests have been conducted and only by nations who had not then, or still have not signed the treaty. In the first thirteen years of the twenty first century, only three nuclear explosions, all conducted and claimed by the Democratic People's Republic of North Korea, have disturbed the nuclear silence. As far as detecting bombs goes, whale songs are noise on the IMS network. They are often registered in exactly the frequency bands that the network is tuned to record and they can interfere with the location of the hundreds of non-nuclear seismic events (earthquakes) which the network must catalogue each day lest a nuclear event be lost in the earth's natural rumblings. This "noise" however, contains a rich source of information for marine biologists. A data analysis system could be built which mirrors the International Data Centre (IDC's) data crunching machinery, but, instead of being focused on locating nuclear events and earthquakes, it could be tuned to understanding biological signals. The result would be a better understanding of whales, their communication, migration patterns and even, perhaps, the personal habits of individual cetaceans. Science wouldn't stop there, however, because the whale songs provide a predictable set of source signals which could be used to refine our understanding of the propagation of sound in the oceans (which would feed back into nuclear-event resolution capacity.

And finally, because the migratory patterns of whales are thought to remain constant over long periods, monitoring fluctuations in how the songs are received over decades could contribute to an understanding of how sound transmission in the oceans changes over time.

The end goal of this project is to provide a large dataset of marine mammal detections at global IMS hydro-acoustic stations. It is envisioned that this data set would be augmented automatically as new continuous hydro-acoustic data was acquired.

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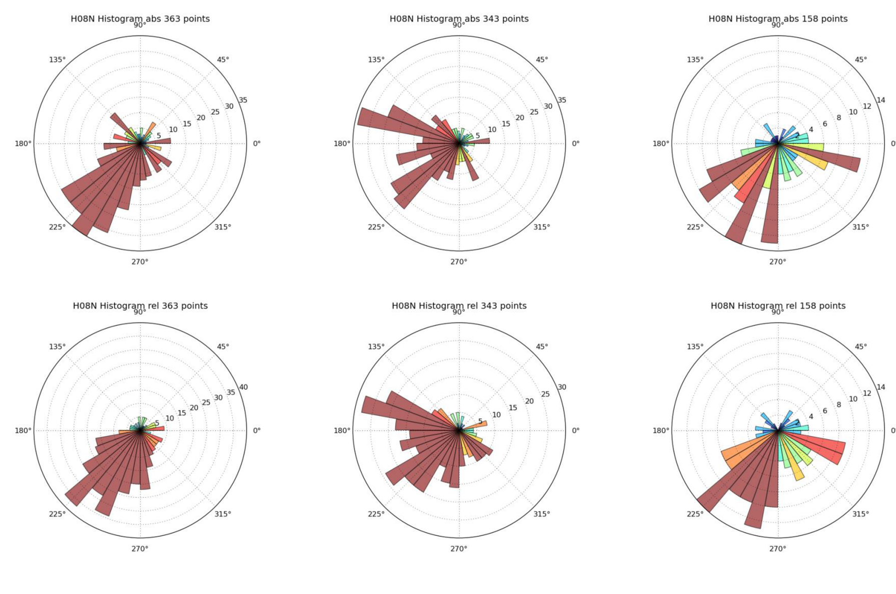
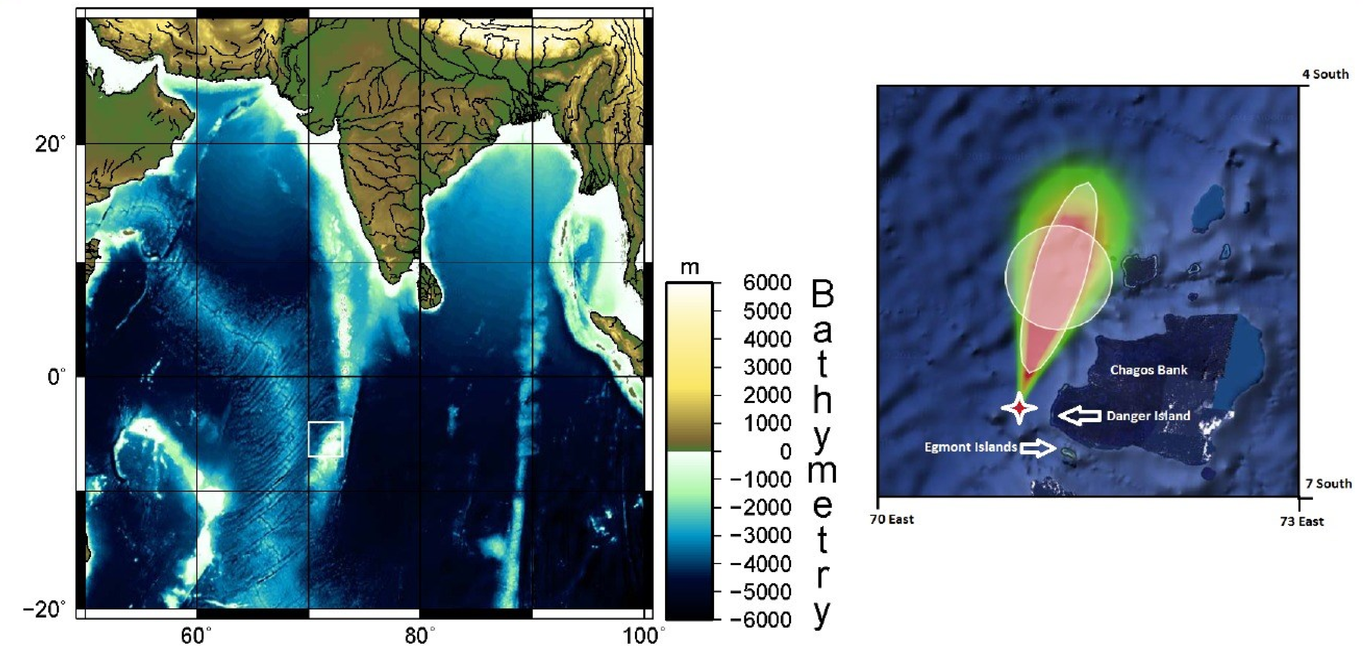
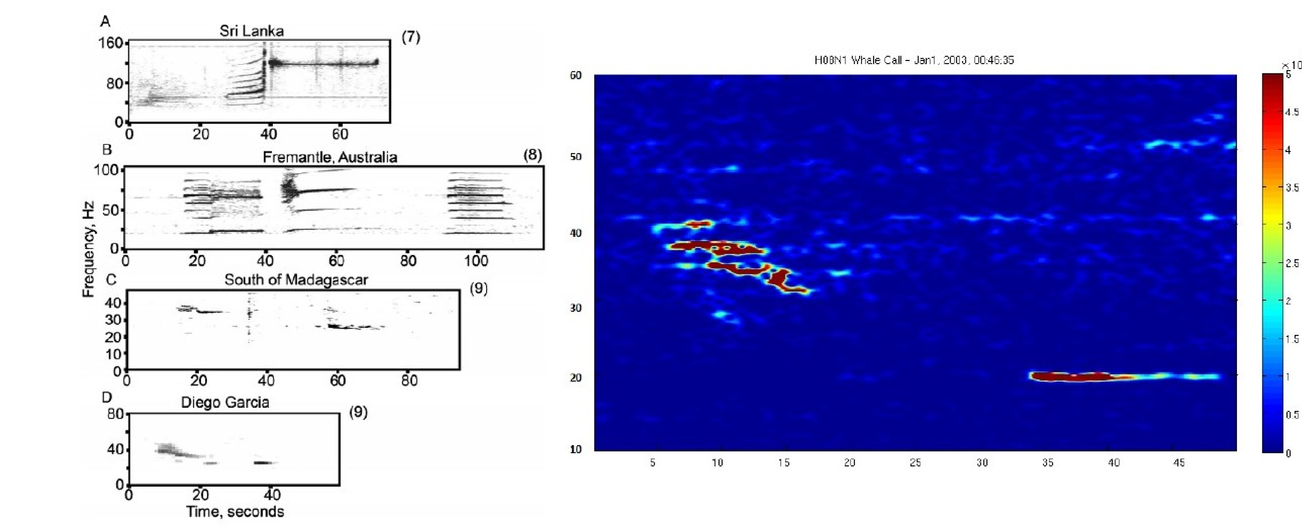


This figure shows bearing determination statistics over 12 days, 491 grouped by bins of four days each. The top three histograms show the directional statistics using 492 the absolute time picking method and the bottom histograms show the statistics using the relative 493 time picking method on the cross-correlation envelope. A threshold of 2 on the STA/LTA trace 494 was used to compute these statistics. The time blocks are January 1-4, January 5-8, and January 495 9-12.

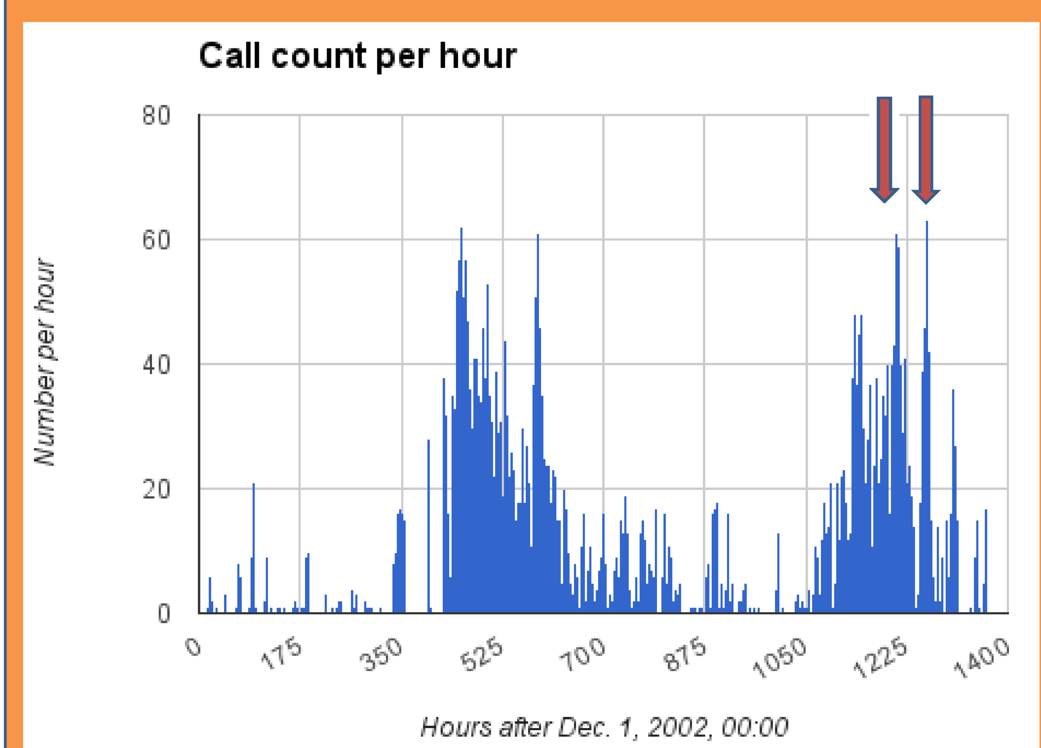


Map of the probability distribution function (PDF) for the location of 527 the whale on January 1st, 2003. The contextual map is shown on the left, with the boundaries at 528 70 to 73 degrees East in longitude and the 7 to 4 degrees South in latitude. Also shown are a 529 circle and ellipse centered at the expected location value (not the maximum of the PDF) which 530 corresponds to 68% probability (1 sigma.)



The right side of the figure shows the spectrogram for a whale call 454 recorded on 1st January, 2003, starting at 00:46:35. This sequence is typical of South West 455 Indian Ocean type 9 blue whales as described by McDonald et al. (2006) whose Figure 5 is 456 reproduced on the left side of the figure for comparison. The vertical axis is frequency in Hertz 457 and the horizontal axis is in seconds. The figure from McDonald et al. (2006) shows four 458 sequences (A, B, C, and D) from three different types of balaenoptera musculus, indicated by the 459 numbers 7, 8, and 9 on the upper left of each sequence.

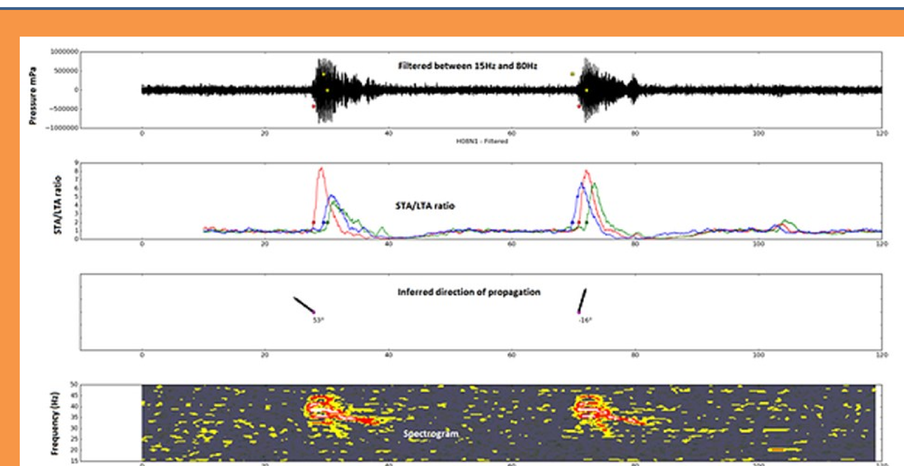
Pilot processing project. 57 days of data at H08N1 - Dec 1, 2002 – Jan 26, 2003.



A pilot project was conducted to test the research algorithms previously developed. The time period used is Dec 1, 2002 to Jan 26, 2003. A Python module does the data acquisition, detection and whale type 9 identification algorithm and saves the results into an SQLite database.

A total of 23,963 detections were made at the triad. The identification algorithm determined that 10,912 are blue whale calls seen at all three hydrophones. The bar graph above shows the hourly count of whale calls for the period processed so far.

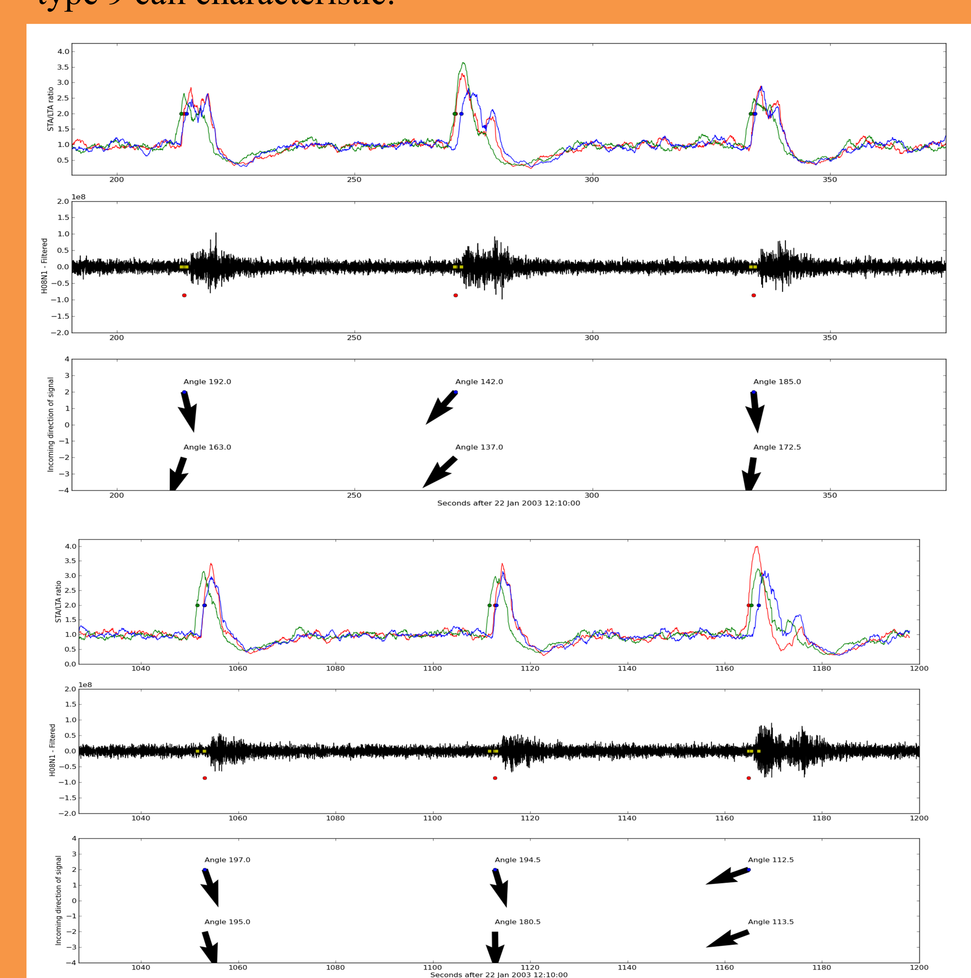
The vertical lines are placed every 24 hours. The arrows show the days of the three examples of separate individual identifications provided in this panel (18 January and 22 January.)



The top trace is the filtered observation at the H08N1 station. The red dot below the trace shows the detection time at H08N1, the green dots show the detections at the other two stations. The panel below shows the STA/LTA ratio at H08N1 (red), H08N2 (green), and H08N3 (blue) with the detection times as well. The order of the detections is red-blue-green for the first call and blue-red-green for the second call, indicating the two very different directions that the calls from the two individuals are coming from. The third panel shows the two estimated directions (to the North is zero degree, to the West is 90 degrees). Finally the bottom panel shows the spectrogram for the time section between 15Hz and 50Hz.

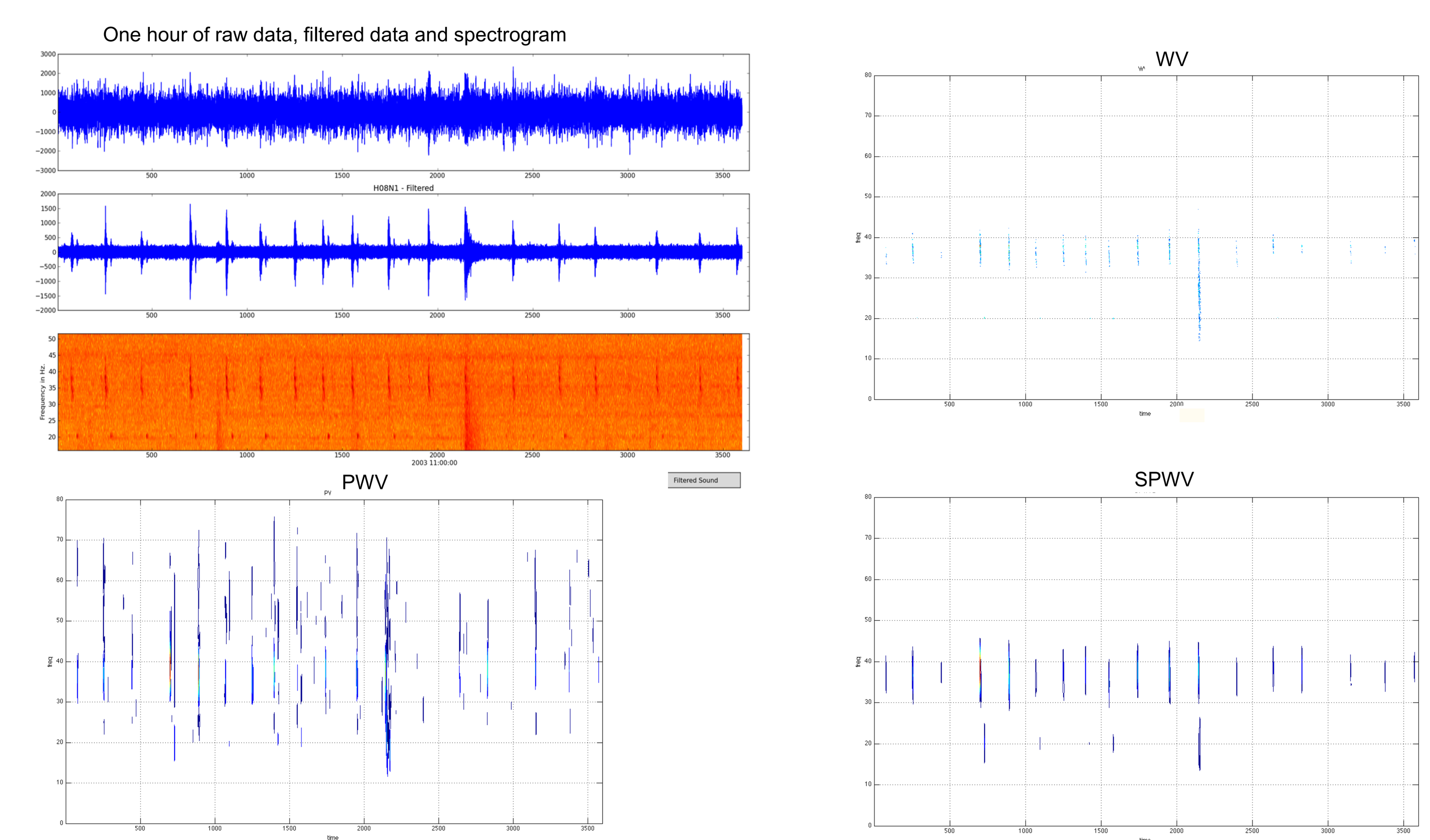
Previous to the collection of data over the two months, one example of a sequence of two calls with clearly distinct directional parameters was made on 18 January 2003. This is a milestone in the project, since it became clear that the hydrophone triad configuration will allow, at least in some cases, to identify multiple whales unequivocally.

The figure to the left shows a two minute sample at the Northern triad of the Diego Garcia hydrophone station H08N on January 18th, 2003. In a short two minute sample, two calls with high signal to noise characteristics are clearly visible and the calls are coming from two very clearly different directions. Given that the time difference between the calls is about 40 seconds, it would be impossible for one individual to swim fast enough between the two calls to explain these observations. At 20 km/h, 40s would be sufficient to travel 220m, a fraction of the distance between two hydrophones. We are therefore very likely observing two different individuals of the blue whale (Baleanoptera musculus) species with type 9 call characteristic.



Based on this first example of clear evidence of observation of two distinct individuals, and given the additional information of the density of calls within the two months where data was processed, we concentrated on the highest density hour (63 calls detected that hour) and the two figures to the left show examples of three consecutive calls where one of the calls comes from a direction clearly very distinct from the other two.

This shows that directional information collected using the algorithm used to process the two months of data is reliable enough to separate different individuals. In turn, this should allow us to tag the signals as coming from specific individuals for which we should be able to collect at least a few waveform samples, since the animals call repeatedly (about twenty times within an hour when a single animal appears to call.)



These figures show the results of enhancing the one hour long sequence from January 7th starting at 11:00 (top left) using three different time-frequency methods. The top right panel shows the results of the standard Wigner-Ville (WV) method, the second (bottom left) is the Pseudo Wigner-Ville (PWV) and the third (bottom right) is the Smoothed Pseudo Wigner-Ville (SPWV). A particular aspect of the benefit of using such methods is to allow separation of the whale signals from the background noise. It can be judged from the figures that the SPWV is able to separate a whale signal from a T phase arriving coincidently in time around 2200 s.