Detection and localization of ice rifting and calving events in Antarctica using remote hydroacoustic stations

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ABSTRACT

Global warming induced by the greenhouse effect will affect the Antarctic ice sheet primarily in the form of disintegration of the ice shelves surrounding the continent. Calving of large icebergs can be observed post factum from satellites, whereas numerous ice shelf breaks of smaller volumes and ice rifting processes that precede the calving events are not well monitored and analysed. Detection and localization of acoustic signals emitted by ice rifting and calving in Antarctica, using remote hydroacoustic receive stations in the ocean, can be an efficient and cost-effective way to monitor disintegration of the Antarctic ice sheet. An analysis of acoustic noise recordings at the hydroacoustic listening station installed off Cape Leeuwin, Western Australia as part of the International Monitoring System of the Comprehensive Test Ban Treaty, has shown that the majority of the signals arriving from Antarctica have a pulse-like waveform, a frequency band limited within 5 - 30 Hz, and spectrograms that reveal strong waveguide dispersion typical for long-range propagation in the Polar environmental conditions. The azimuthal location of the detected events is not uniformly distributed along the observed sector of the Antarctica coast, and the rate of events varies with the seasons of year. The results of numerical modelling of acoustic propagation from Antarctica to the Cape Leeuwin station show that the origin of the observed signals is short, pulse-like physical processes on the Antarctic shelf, which are most likely ice rifting and calving events.

INTRODUCTION

The calving activity of the Antarctic ice shelves is one of the major indicators of global climate change. Global warming induced by an increase in atmospheric CO2 will affect the Antarctic Ice Sheet primarily in the form of disintegration of the Antarctic ice shelves surrounding the continent. The processes of calving on the ice shelves may lead to a substantial increase of sea level around the world, with damaging effects on the continental coasts and low-lying islands. The ice shelf calving events observed for the past two decades have led to noticeable changes in the Antarctic ice sheet. According to Allison (Allison 1992), the total ice mass discharge due to those events is greater than the average Antarctic snow accumulation. The enormous amount of ice discharged from the recent major events of ice calving is of particular interest to climatologists. However, it is still a subject of discussions whether the calving rate is staying within the natural bounds or steadily increasing. Whereas massive calving events are well observed post factum from satellites, numerous ice shelf breaks of smaller volumes are not monitored and statistically analysed. Moreover, the calving events are preceded long before by ice rifting, which is not remotely observable by conventional means. To predict the further disintegration of the Antarctic ice sheet, it is expedient to gather statistics of ice rifting all around the Antarctic shelf. Seismo-acoustic recordings and geodetic observations of ice fracture zones on the Antarctic ice sheet are capable of local monitoring of ice rifting. However, such methods of observation require great effort and expense for logistic support of Antarctic expeditions and at present cannot provide long-term, real time monitoring of the multi-megametre long Antarctic shelf.

Remote acoustic observation in the ocean is a new approach to the problem of creating an efficient and cost-effective system to monitor rifting and calving of the Antarctic ice shelves. Rifting and calving of the ice shelves produce intense low frequency noise in form of elastic (compressional and shear) waves that are transformed into acoustic signals in the surrounding water. These low frequency acoustic signals can propagate over thousands of kilometres in the ocean. The source of signals can be located using a pair of remote receive stations that consist of several receivers separated horizontally to provide bearing onto the source. A network of hydroacoustic listening stations has been installed in the ocean as part of the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Thus, the CTBT hydroacoustic network may provide us with supplementary, but highly important information on temporal and spatial statistics of ice disintegration in Antarctica. This information is essential for developing more realistic global climate models. Also the results of acoustic observation can be used for determining ice shelf regions of particular research interest for more detailed in-situ observations.

The feasibility of employing the IMS stations to remotely monitor events of ice rifting and calving in Antarctica is considered in this paper using an analysis of noise recordings at one of these stations installed off Cape Leeuwin, Western Australia. The analysis results are compared with the results of numerical modelling of acoustic pulse propagation from Antarctica to Cape Leeuwin.

IMS CTBT HYDROACOUSTIC NETWORK AND THE CAPE LEEUWIN STATION

The existing IMS CTBT hydroacoustic network consists of six receive stations deployed in the Indian Ocean (off Cape Leeuwin, Western Australia; off Crozet Islands; and the Chagos Archipelago, Diego Garcia US Navy support facilities), in the Pacific Ocean (off Juan Fernandez Islands and off Wake Island) and in the Atlantic Ocean off Ascension Island Guadeloupe (Figure 1). Each of the IMS hydroacoustic stations consists of either one or two so-called triplets, i.e.

triangular horizontal arrays of three hydrophones separated approximately 2 km from each other.

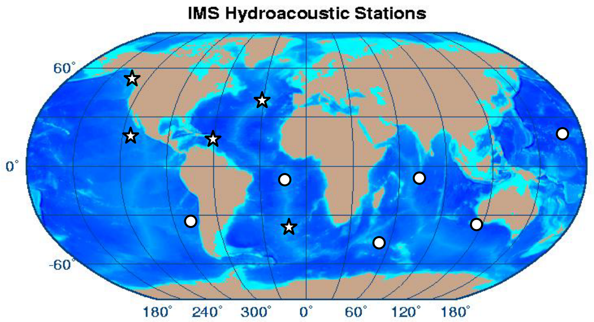

Figure 1. Location of the IMS CTBT T-phase (stars) and hydroacoustic (circles) stations in the ocean.

The stations are cabled to the shore, which allows listening to the ocean in real time. All the coastline of Eastern Antarctica (from 0^0 to about 150^0E) can be observed from three IMS stations operated in the Indian Ocean. The sector of acoustic observation from the Cape Leeuwin station HA01 covers the Antarctic shelf from approximately 55^0E to 150^0E. Such location of the hydroacoustic stations in the Indian Ocean affords an opportunity to remotely monitor the Eastern Antarctica shelf in a real-time, year-round regime.

The HA01 station was installed at about 100 km south-west of Cape Leeuwin in 2002. The station consists of three hydrophones (one triplet) spaced approximately 2 km from each other (Figure 2). The hydrophones are submerged near the SOFAR acoustic channel axis at a depth of about 1100 m, so that they are capable of long-range acoustic reception.

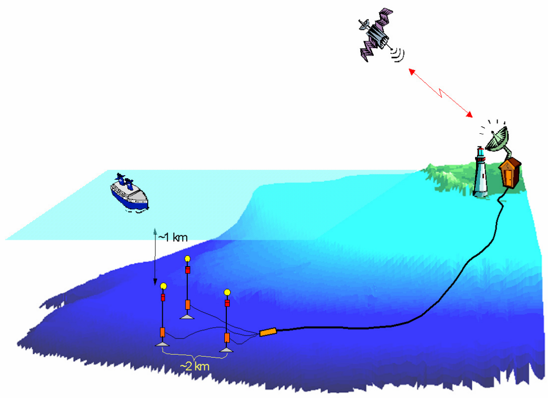

Figure 2. General design of the Cape Leeuwin hydroacoustic station

The sea depth at the moorings is approximately 1500 m. The frequency passband of the receivers at the –3 dB level is from 1 Hz to 100 Hz, which is nearly ideal for long-range detection of pulse-like signals from remote sources such as ice rifting and calving events. The sampling rate of acoustic recordings is 250 Hz. The acoustic sensitivity of the station is high, because the dynamic range of the receiving system is 120 dB. Shipping off Cape Leeuwin is not very intense, so that the ambient acoustic noise level at the HA01 station is moderate and depends mainly on the local weather conditions. In the frequency band of interest, the noise level is varying from 70 to 85 dB re. 1 μPa/Hz$^{1/2}$. The acoustic signals on the hydrophones are digitized and transmitted in real time to the International Data Centre of the CTBT Organization in Vienna and to Geoscience Australia. The results presented in this paper were obtained from the HA01 acoustic data collected from January to August 2003.

DETECTION AND PROCESSING OF ACOUSTIC SIGNALS FROM ANTARCTICA

Discrimination of acoustic transients in ambient noise is performed in the signal processing algorithm by cross-correlation of signals on the receivers. The correlation coefficient is calculated for each pair of the receivers for every 30-second window of noise recordings. A minimum correlation threshold of 0.5 was selected to detect arrivals of coherent signals (events) at the triplet. The back-azimuth to the source of signal can be determined on a triangle array by a number of different methods, such as conventional hyperbolic location, plane wave fitting inversion (e.g. Del Pezzo *et al.*, 2002), and a frequency-wavenumber (F-K) analysis (e.g. Clark, 1992). The former two methods use the differential travel times of signals to the individual receivers derived from the cross-correlation of the signal arrivals. The F-K analysis is based on coherent summation of the signal spectra on individual receivers followed by incoherent summation of all frequency components within a selected band. Hyperbolic location provides both the back-azimuth and range, but the errors of range estimates are large if the distance to the source is large compared to the triplet size. Moreover, a triangular array has ambiguity zones of source location in the X-Y plane. If a source of signal is located within the ambiguity zone, the system of equations for hyperbolic location has two different solutions of which one corresponds to a false source (Spiesberger 2001). The azimuthal resolution of hyperbolic location on a triplet is constrained by possible uncertainties of the receivers' position and the sound speed, as well as by errors of differential travel time measurements. Both plane wave inversion and F-K analysis are based on an assumption that the source of signal is infinitely distant from the array relative to the array size. Compared to hyperbolic location, the back-azimuth estimates by two latter methods are less sensitive to the errors of receivers' horizontal position.

We used hyperbolic location to separate the signals arrived from nearby sources, such as vessels, other sources of man-made noise, whale calls, and other sources of biological noise, from the signals emitted by remote sources. The azimuthal sector of bearings onto the Antarctic coast from the HA01 triplet is partly overlapped by one of its ambiguity zones (Figure 3).

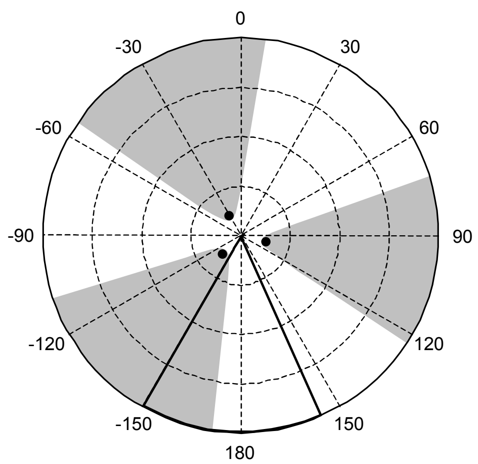

Figure 3. Geometry of the HA01 triplet (dots), the ambiguity zones of hyperbolic location (grey sectors), and the sector of back-azimuth to the Antarctic coast (solid lines)

Therefore, if the hyperbolic algorithm gave two different solutions for a single event of which one was located within the intersection of the ambiguity zone and the Antarctic observation sector, we kept such an event for further analysis.

Then we determined the back-azimuth to the source of event using the F-K analysis and selected those events which arrived within the Antarctic observation sector. The accuracy of bearing from the F-K analysis is also constrained by the Signal-to-Noise Ratio (SNR) and by an uncertainty of the receivers' horizontal position due to deviation of the moorings from the vertical position under variable currents. The latter is more critical, if the SNR exceeds 10 dB. For the standard deviation of the receivers' relative position of 20 m and the SNR of 10 dB, the STD error of back-azimuth estimates is about 1^0. However, the actual horizontal deviation of the receivers may be much larger than 20 m, since the length of moorings is about 500 m. Therefore a thorough investigation of the motion of the HA01 moorings is needed to make more accurate estimates of bearing errors.

Assuming the maximum possible error of bearing of 3^0, we selected all the signals arrived at the HA01 station from remote sources within the azimuthal sector from 155^0 to 213^0, which was a little wider than the actual sector of observation covering the Antarctic coast.

SIGNALS ARRIVED FROM ANTARCTICA

Basically three different types of signals arrived in the direction to the Antarctic coast can be distinguished. The signals of tectonic origin commonly have low frequency components dominating below 10 Hz, last for tens of seconds, and do not reveal any waveguide dispersion features in their spectra. Such signals arrive most likely from seismic events along the Southeast Indian Mid-ocean Ridge.

The signals of the second class referred sometimes as harmonic tremors (Tolstoy 2004), may last for minutes and have spectra with distinct harmonic lines of which the frequency varies slowly with time (Figure 4a). The origin of those signals is not yet really understood, although there is a hypothesis that such sort of noise can be produced by flexural oscillations of large icebergs induced by their collisions with the other ones or with the seafloor (Talandier 2002).

The third class of most frequent events observed in the direction to Antarctica comprises pulse-like signals that have a specific dispersion characteristic clearly recognized in their spectrograms. The back-azimuth of these signals, as well as that of harmonic tremors, always lies within the bearing sector to Antarctica. The maximum intensity level of most pulse-like signals varies within 125-135 dB re. 1 μPa. The duration and frequency band of these signals can be somewhat different, but they always terminate with a temporally dispersed pulse (Figure 5) that becomes sharp in the frequency-versus-time representation via a spectrogram (Figures 4b-d). The low frequency components of the pulse arrive noticeably earlier than the higher frequencies. This type of frequency dispersion can be referred as negative, because the propagation speed of acoustic waves decreases with frequency. Most of these pulse-like signals do not have frequency components above 30 Hz and consist of only one distinct pulse that can be discriminated in the spectrogram (Figure 4b). A noise-like precursor often precedes the distinct final pulse. In some events, when the frequency band of signal is broader, another distinct pulse can be recognized in the spectrogram preceding the ultimate pulse (Figure 4c). The dispersion characteristic of this preceding pulse is less sloping. The pulse-like Antarctic events often consist of a series of similar pulses following each other with a variable time interval (Figure 4d).

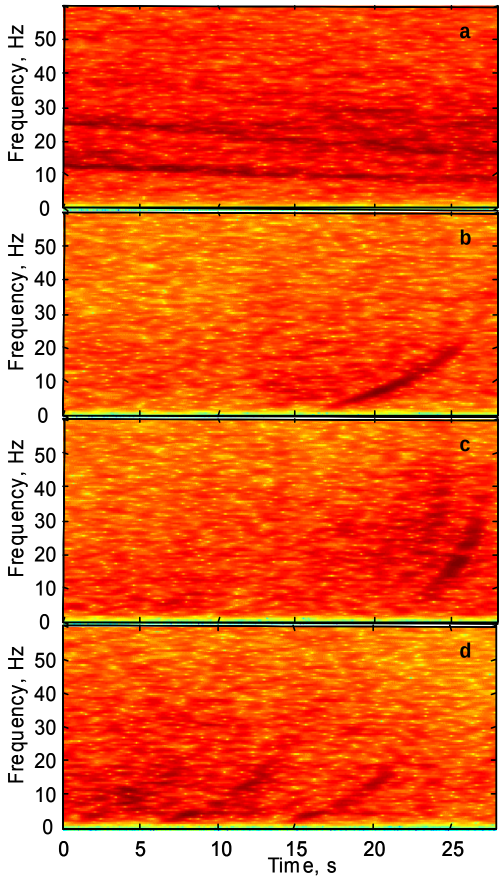

Figure 4. Typical spectrograms of signals from Antarctica: a – harmonic tremors; b-d – pulse signals

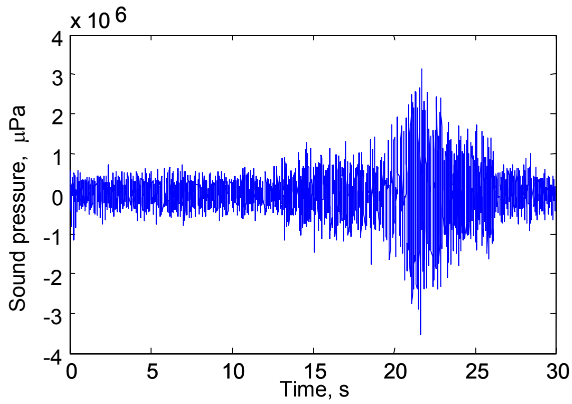

Figure 5. Typical waveform of a pulse-like signal arrived from Antarctica (the spectrogram is shown in Fig.4c)

Location of distant events is only possible when using signal arrivals at two remote hydroacoustic stations. Since the acoustic data from the HA08 station off the Chagos Archipelago were not available for our analysis, we ascribed all pulse-like signals with the negative dispersion characteristic to ice events occurred along the Antarctic coast. The rationale for such an assumption is discussed in the next section using the results of numerical prediction for acoustic propagation from Antarctica.

To analyse the spatial distribution and seasonal variation of ice events, we chose two 30-day periods in the peak summer (April) and winter (August) seasons in Antarctica.

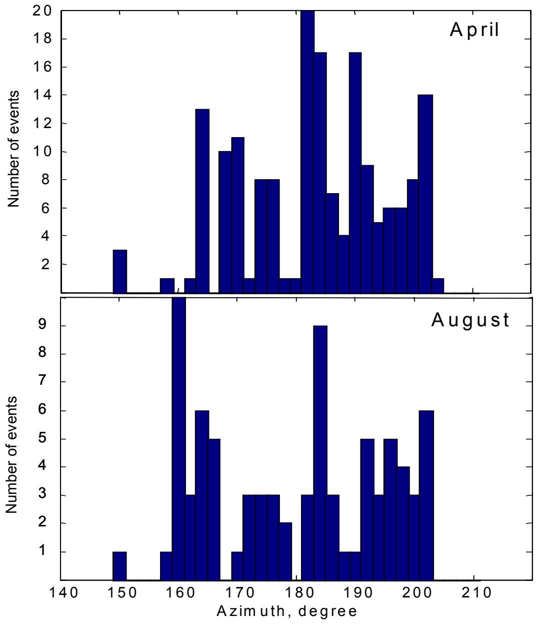

Figure 6. Azimuthal distribution of Antarctic pulse-like events detected in April (top) and August (bottom) of 2003

Figure 6 demonstrates the azimuthal distribution of pulse-like events observed in these two months. As clearly seen in the histograms, the spatial distribution of events was not uniform along the observed Antarctic shelf. The pulse-like events were much more often observed within a number of narrow azimuthal sectors. Two of these azimuthal clusters of most frequent ice events around 185^0 and 201^0 are prominent in both summer and winter distributions. Hanson and Bowman (Hanson 2004) analysed all events of different origin located off the Antarctic coast using the HA01 and HA08 acoustic data, and found similar clusters in the spatial distribution of detected events. The total number of pulse-like events observed at the HA01 station in April was nearly 170. In August, the number of events was substantially smaller, about 80. Hanson and Bowman also noticed the seasonal change in the occurrence of Antarctic-related events with a double decrease of the event rate in the winter period.

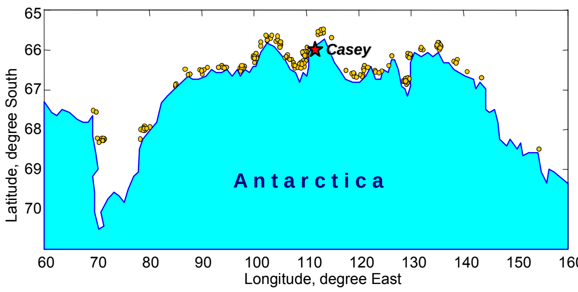

Figure 7. Distribution of pulse-like ice events along the Antarctic coast as observed at HA01 in April 2003

Assuming the origin of pulse-like signals to be ice related, we projected bearing to these events onto the Antarctic coastline. Figure 7 demonstrates the result of projection. The pulse-like ice events were most frequent in the region of the Vincennes Bay in the neighbourhood of the Australian polar station Casey operating year-round.

RESULTS OF NUMERICAL MODELLING

In order to identify the origin of pulse-like signals arriving from Antarctica, it is expedient to model the acoustic propagation from Antarctica to the IMS hydroacoustic stations and to study the temporal and spectral characteristics expected for the signals generated by ice rifting events and propagated across the Southern and Indian Oceans over multi-Mm paths.

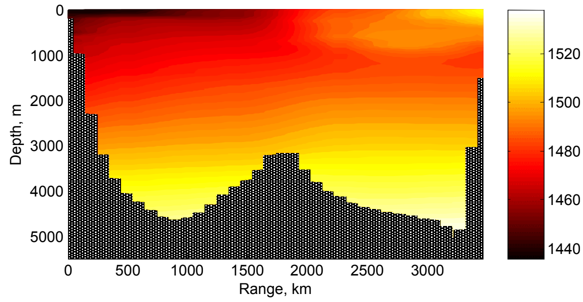

Figure 8. Sound speed profile from 65.9142S, 111.6112E to 34.89S, 114.14E, winter. The Southeast Indian Mid-ocean Ridge crosses the acoustic path in the middle.

We used the analysed and gridded CTD data derived in the World Ocean Atlas 2001 for four seasons to build the sound speed profiles from the Antarctic coast to the HA01 station. The sound speed vertical cross-section along the path from the Vincennes Bay to HA01 is shown in Figure 8. The major feature of the sound speed field along the acoustic path is the frontal zone at the Antarctic Convergence that divides the acoustic path in two sections of principally different conditions of acoustic propagation. Along the southern section, signals propagate in the near-surface acoustic channel and hence strongly interact with the rough sea surface, which results in fast attenuation of their energy. The acoustic propagation loss rapidly increases with frequency due to surface scattering, and hence only low frequency signals can propagate over large distances in such conditions. To the north of the Antarctic Convergence, the axis of the acoustic channel abruptly dives to a depth of about 1000 m and the shallow-angle rays (low-order modes) propagate in the SOFAR channel with no interaction with the sea surface and the seafloor.

At low frequencies, the acoustic pressure field far from a source of sound in the ocean can be modelled as a superposition of so-called normal modes that have different distribution of acoustic pressure in the vertical plane and different phase changing with the distance from the source (Brekhovskikh, 1982). The variation of modal phase with range is different for different modes. The shape of modes strongly depends on the sound speed profile and the acoustic frequency.

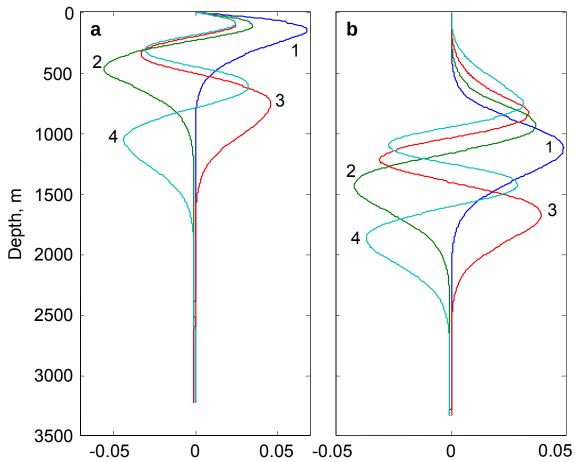

Figure 9. Shapes of modes 1-4 at 20 Hz modelled for the sound speed profiles at distances of 300 km (a) and 3000 km (b) along the path from Antarctica to HA01

The shapes of four low-order modes at 20 Hz modelled for different environmental conditions (south and north of the Antarctic Convergence) are shown in Figure 9.

We used the adiabatic mode approximation to numerically model the propagation of acoustic signals in a frequency band from 3 to 50 Hz. The propagation loss due to surface scattering was calculated using the Kirchoff small-slope approximation. The emitted signal was modelled by a 10-ms wide Gaussian pulse band-pass filtered in the frequency band of modelling. The waveform of received signal was derived from the waveguide transfer function via inverse Fourier transform.

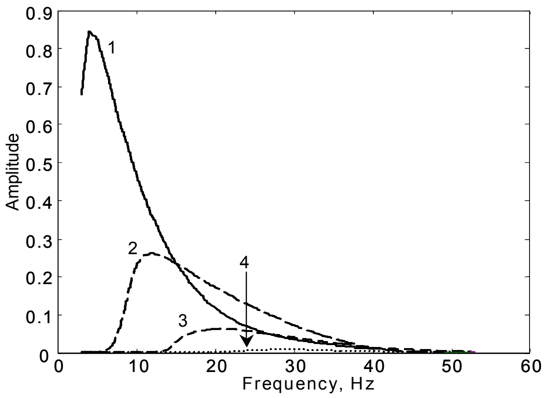

Figure 10. Magnitude of the transfer function of modes 1 – 4 numerically modelled for the propagation path from Antarctica to the HA01 station.

Figure 10 demonstrates the transfer function of modes 1, 2, 3, and 4 calculated for the propagation path from the Vincennes Bay to the HA01 station. The RMS hight of surface waves was assumed as high as 3 m. The amplitude of modes rapidly decreases below the cut-off frequency which is different for different modes. The propagation loss at low frequencies is mainly due to interaction of acoustic waves with the seafloor along a relatively short section of shallow water over the Antarctic continental shelf, which causes absorption and scattering of acoustic energy. In shallow water, this interaction increases with the mode number, and therefore mode 1 has the lowest cut-off frequency and dominates the other modes in the propagated acoustic signals below 10 Hz. At higher frequencies, acoustic scattering by the rough sea surface becomes the major factor for the propagation loss along the 1.5-Mm section of the acoustic path south of the Antarctic Convergence. Scattering loss rapidly increases with frequency. Mode 1 is trapped in a thinner layer of the near-surface acoustic channel and therefore experiences more interaction with the sea surface and higher attenuation.

The thickness of the layer within which the acoustic modes are trapped by the near-surface channel increases with the frequency decrease, which results in more acoustic energy propagating in deeper water layers where the sound speed is higher. Consequently, in the polar environment the low frequency components in the modal energy spectra propagate faster than the higher frequency ones. This is clearly seen in Figure 11 that shows the frequency dependence of the group velocity of modes 1 and 2 along the propagation path. The frequency dispersion of modes 1 and 2 is strong only along the southern section of the path, whereas north of the Antarctic Convergence it becomes negligibly small. Mode 1 experiences stronger dispersion below 30 Hz, while the dispersion of mode 2 within 5-30 Hz is weaker.

The resulting slope of the modal dispersion characteristic at the receiving site depends on the length of path along which the signal propagates in the near-surface channel. This gives a way to estimate the distance to the source of a pulse-like signal by measuring the slope of the modal dispersion characteristic within narrow frequency bands in the spectrum of the received signal.

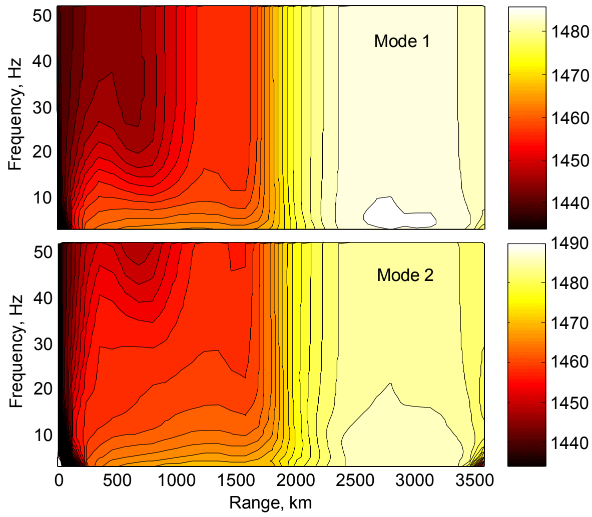

Figure 11. Variations of group velocities of modes 1 (top) and 2 (bottom) versus frequency and range along the modelled acoustic path from Antarctica to the HA01 station

Figure 12 shows change of the dispersion slope with frequency and distance from the HA01 station to the source located along the modelled acoustic path. In order to have the slope of dispersion characteristic similar to that of the events shown in Figures 4b and 4d, the observed signals should be emitted far beyond the Antarctic Convergence and travel more than 3 Mm to the receive station.

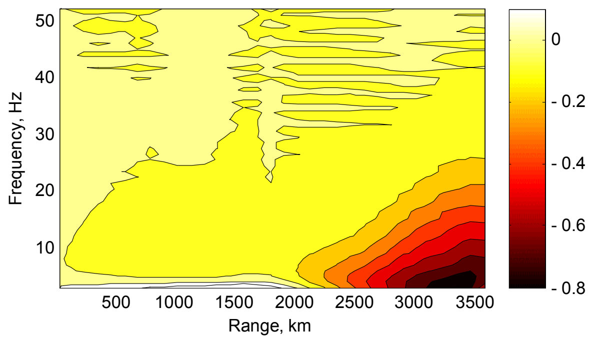

Figure 12. The slope of dispersion characteristic as a function of frequency and distance from the HA01 station to a source located along the modelled acoustic path

Figure 13 demonstrates the spectrogram of the modelled signal received at a depth of 1000 m at the end of the path. The arrivals of two low-order modes are distinct in the spectrogram. The trace of mode 3 can also be recognized in front of mode 2 arrival, however its magnitude is about 20 dB lower. Mode 1 arrives later and has the broadest frequency band and the highest magnitude. Mode 2 does not have frequency components below 10 Hz and its dispersion characteristic is less sloping. The modelled signal spectrogram pattern is roughly similar to the experimental one shown in Figure 4c, with some minor discrepancy in the slope of the dispersion characteristic and the difference of the modal travel times. The relation between the magnitude and frequency band of modes 1 and 2 strongly depends on the sea depth at the source location and the source depth. The spectrogram in Figure 13 was obtained for the sea depth of 200 m at the source. If it is reduced to 100 m, modes 2 and 3 vanish in the spectrogram due to stronger interaction with the seafloor, which causes higher propagation loss. The acoustic properties of the seafloor along the shallower section of the path also influence the magnitude and frequency span of the modes in the received pulses. However, we did not study the influence of the seafloor in more detail for lack of geoacoustic data for the Antarctic shelf.

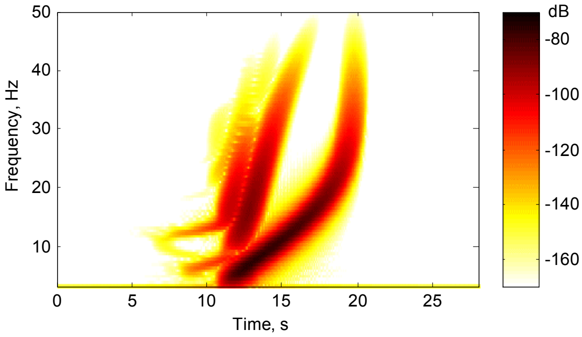

Figure 13. Spectrogram of numerically modelled pulse-like signal propagated from the Antarctic coast to the HA01 station and received at a depth of 1000 m

It follows from the comparison of experimental and modelling results that most of the pulse-like signals arrived from Antarctica should have a very short duration of tens of millisecond at the origin, and hence Antarctic ice cracking is one of the most likely sources of such signals. Taking into consideration the typical magnitude of the received pulses (about 130 dB re. 1 μPa) and the total propagation loss (at least 110 dB estimated from the numerical model), one can conclude that the signal level at the source should be as high as 240 dB at 1 m from the source assuming it to be point-like, i.e. much smaller in size than the wavelength. However, ice rifts are likely to be longer than the acoustic wavelength at 3 – 50 Hz, which means that the actual level of acoustic signals near the rifting zone may be noticeably lower within this frequency band than that estimated. On the other hand, a substantial portion of the energy contained in ice-cracking signals at frequencies below 3 Hz and above 50 Hz dissipates near the source and does not propagate in the ocean channel, which means that the peak intensity of emitted signals can be much higher than the level predicted from numerical modelling in a limited frequency band. It is unlikely that thermal fracturing of sea ice could generate signals of such magnitude. Ridging of sea ice under wind stress and currents produces intense low frequency noise rather than short discrete pulses of high amplitude. Therefore, rifting of ice shelves, sea glaciers and separate icebergs is one of the most likely origine of the observed signals. Collisions of separate icebergs can be another possible source of such signals.

CONCLUSIONS

The analysis of acoustic noise recordings at the HA01 station of the IMS hydroacoustic networks has shown that an unexpectedly large number of acoustic signals regularly arrive from the Antarctic coast. Most of these signals are short pulse-like and reveal strong negative waveguide dispersion, which is a distinctive feature of acoustic propagation in polar seas. The spectral analysis of detected signals and numerical modelling have demonstrated that most of the received signals had a very short duration at the origin, which justifies the assumption that ice rifting processes on the Antarctic shelf are a likely source of such signals. The frequency of pulse-like ice events observed in the summer period was nearly two times higher than that in winter. The spatial distribution of pulse-like events located along the Antarctic shelf revealed a number of regions within which generation of acoustic signals is more intense.

More comprehensive numerical modelling with a spatially distributed source of acoustic signal is needed to more accurately predict the waveform and magnitude of ice-rifting signals. The influence of different conditions of signal generation and propagation, such as different location of sources along the Antarctic shelf, different sea depth at the source, seasonal change in the propagation conditions, and some others, will also be studied in more details via modelling. Further research will also involve processing and analysis of acoustic data from the HA01 station for different time periods in 2003-2005, as well as spatial location of ice events using acoustic data from the HA01 and HA08 stations.

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REFERENCES

Allison, I., 1992. *The Antarctic cryosphere: evidence of the impacts of change and strategies of detection*, in Impact of Climate Change on Antarctica – Australia, AGPS, Canberra

Del Pezzo, E. and Giudicepietro F., 2002. *Plane wave fitting method for a plane, small aperture, short periodseismic array: A MATHCAD program*, Comput. Geoscience,28, pp. 59–64

Clark M. P. and Scharf L. L., 1992. *Frequency-Wavenumber Spectrum Analysis*, In Proceedings of Workshop on Statistical and Array Processing, Victoria, BC. October 1992

Spiesberger, J.L., 2001. *Hyperbolic location errors due to insufficient number of receivers*, J. Acoust. Soc. Am., 109(6), pp. 3076-3079

Tolstoy, M., Bohnenstiehl, D., and Chap E., 2004. *Long range acoustic propagation of hight frequency energy in the Indian Ocean from icebergs and earthquakes*, In Proceedings of the 26-th Annual Seismic Research Review, Orlando FL, pp. 568-578

Talandier, J.O., Hyvernaud, O., Okal, E.A., and Piserchia P.F., 2004. *Long range detection of hydroacoustic signals from large icebergs in the Ross Sea*, Antarctica, Earth Planet Science Letters, 203(1), pp. 519-534

Hanson, J.A. and Bowman J.R., 2004. *Methods for monitoring hydroacoustic events using direct and reflected T waves in the Indian Ocean*, Journal of Geophysical Research, submitted in December 2004

Brekhovskikh L. and Lysanov Yu., 1982. *Fundamentals of Ocean Acoustics*, Springler-Verlag, Berlin - New York.