



# A Mobile Infrasonic Array

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## Introduction

Infrasound lies within the sub-audible frequency range of roughly 0.01-20 Hz. Both man-made and natural events are known to produce infrasound including nuclear explosions, ocean storms, aurora, volcanoes, earthquakes, thunderstorms, and tornadoes [1,2]. Due to reduced atmospheric attenuation at low frequencies, infrasonic sound waves may propagate for thousands of miles allowing long range detection. These propagation paths are characterized by alternating surface reflections and upper-atmosphere refractions where the refraction height, typically 30-100 km, is defined by the vertical profiles of wind and temperature of the atmosphere [3,4].

Among the numerous sources of infrasound, sound waves generated by ocean wave activity, known as "microbaroms", are consistently recorded by detection systems around the world [4]. These 0.2-0.3 Hz waves have typical amplitudes of a few hundred nanobars and are produced by standing or nearly standing ocean surface waves [1]. Due to the ubiquity of microbaroms, we used them for initial tests of the capabilities of our new mobile infrasonic array. The primary goals of these tests were (1) to measure the microbaroms' spatial coherence (over several hundreds of meters) and (2) to determine the angle of arrival (AOA) and trace velocity of received microbarom wave packets.

## Detection Equipment

State-of-the-art, quartz-crystal broadband barometers (ParoScientific, Inc.) are used for the mobile infrasonic array. With a precision of about 0.01 Pa at a sampling frequency of 10 Hz, they are sensitive enough for the detection of microbaroms. Output from the barometers is fed into an in-house developed portable data logging system that provides GPS time stamping, hard disk storage and power to the barometer [5]. Detection packages, each consisting of a barometer, a logger, a GPS antennae, and batteries, were placed in three vehicles parked on campus as shown in Figure 1.

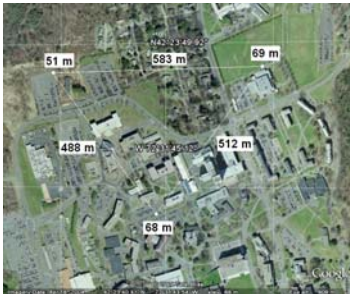


Figure 1: Location of vehicles for the June 17th 2009 study. The elevation of each vehicle and spacing are indicated. Image and coordinates obtained via Google Earth.

## Array Calculations

Accurate calculation of the trace velocity and AOA of incoming infrasound requires the detection of a coherent signal at a minimum of three properly placed sensors. The sensor spacing and geometry determine the resolution of the sensor array and limit the frequency and velocity range of infrasonic waves that can be resolved [6]. This makes a mobile setup especially attractive as the relative sensor locations can be precisely tuned for a variety of applications with ease.

Determining the AOA and trace velocity of coherent infrasound waves propagating across the array is based on a least squares estimation approach outlined by Olson and Szuberla [7]. By using cross correlation techniques, the time lag of received signals between each sensor can be determined. These time lags, along with the relative coordinates of each sensor, can then be used to estimate the AOA and trace velocity of a plane wave propagating across the array.

For a given data set, calculations of AOA and trace velocity involve performing analysis over a sliding time window defined by a desired window length and overlap. Before being divided into windows, the data is first filtered to produce the signal content for set frequency intervals over a frequency range of interest. The power contained in each frequency component is calculated and stored. The filtered data is then divided into windows for AOA and velocity calculations of each frequency component. The results of these calculations are then scanned in order to extract values that correspond to resolvable velocities and plane wave events. The end result is the AOA, the trace velocity and the power contained in each frequency component of detected plane waves for each window.

## Results

On the night of June 16th 2009 an array of three cars containing detector packages was deployed on the UMass Amherst campus arranged in a roughly equilateral triangle (~500 m sides). From shortly after 16 Jun 2200 EDT to 17 Jun 0600 EDT, coherent infrasound waves in the microbarom frequency band were recorded at all three locations allowing AOA and velocity calculation. The average inter-sensor coherence is displayed in Figure 2.

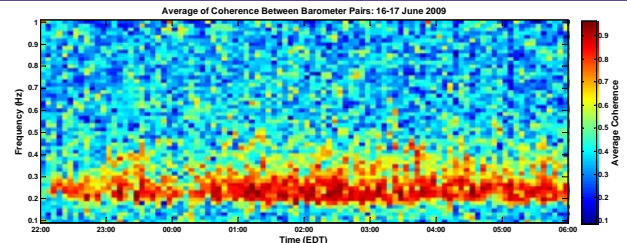


Figure 2: Five minute average of coherence between sensors normalized between zero and one with red indicating high coherence

For AOA and trace velocity calculations a window of thirty seconds was chosen with an overlap of fifteen seconds. These values were selected based on the observed duration of microbarom wave packets. Data was filtered in intervals of 0.02 Hz over a range of 0.1-0.5 Hz. As shown in Figures 3a and 3b most of the power received was contained in the 0.2-0.3 Hz components of waves with AOAs ranging between 80 and 130 degrees (counting clockwise from North) with trace velocities ranging between 350 and 450 m/s. Minimal variation in AOA and trace velocity was observed during the night.

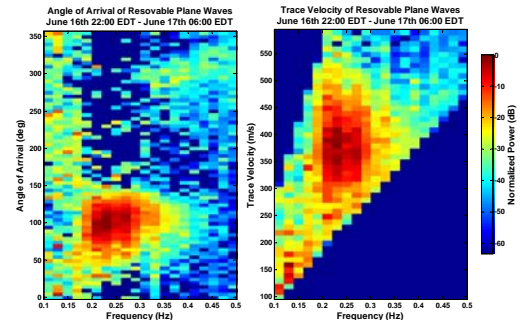


Figure 3a,3b: Power received from .02 Hz separated frequency components of plane waves and their respective AOA and trace velocity from 22:00 EDT on June 16th to 06:00 EDT on June 17th 2009. The sharp cut-offs in figure 3b indicate the range of resolvable trace velocities of the array over the displayed frequency window.

## Conclusions

The results of the June 16th-17th field experiment show that a mobile infrasonic array with the aforementioned specifications can be used to perform AOA and trace velocity calculations for microbaroms, that is, atmospheric infrasound generated by ocean surface waves. The intrinsic flexibility of the array setup will allow for focused studies on other sources of infrasound, including wind flow over mountains, thunderstorms, and tornadoes.

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