STUDIES OF MICROBAROMS USING MULTIPLE INFRASOUND ARRAYS

Henry E. Bass and Kenneth Gilbert[1], Milton Garces[2] , Michael Hedlin and John Berger[3],
John V. Olson , Charles W. Wilson and Daniel Osborne[4]

[1]University of Mississippi,[2] University of Hawaii, [3]Scripps Institute of Oceanography,
[4]University of Alaska, Fairbanks

Sponsored by Defense Threat Reduction Agency
Contract No. DTRA01-00-C-0078

US Army Space and Missile Defense Command
Contract No. DASG60-99-C-0018

The Preparatory Commission for the
Comprehensive Nuclear-Test-Ban Treaty Organization
Provisional Technical Secretariat
Contract No. 00/30/6021

ABSTRACT

Microbaroms, known to be produced by marine storms, are a prevalent infrasound signal due to the presence of strong storms over the oceans. Often the microbarom wave trains last for tens of hours allowing us to track the storm. When we perform a least-squares fit to plane-wave arrivals on the data we find the apparent source azimuth points to the center of the storm low-pressure center. Early research has shown that microbarom signals are associated with wave height in storms but the theoretical description for the coupling between water waves and acoustic waves in the atmosphere is not complete. Studies of microbaroms from multiple locations are better able to identify the source of microbaroms in the storm and to give an indication of the propagation paths from the storm center to the receivers. We have also begun to study the spatial coherence of microbaroms using the Hilbert Transform technique. We find that the mean packet length is of the order of 2 to 5 wavelengths. With this information we plan to break the wave trains into individual packets in order to explore the extent to which the source is localized.

KEY WORDS: Microbaroms, Marine Storms, Hilbert transform

OBJECTIVE

The objective of our study is to perform multiple detections of microbarom signals from marine storms using multiple infrasound sites. This exercise serves as a test of the data collection and analysis procedures used by each array site as it comes on line. As multiple detections of signals from a storm are made we expect to gather information about the sources and propagation paths of the infrasound generated by the storm.

RESEARCH ACCOMPLISHED

Introduction

Infrasound Arrays that are part of the International Monitoring System of the Comprehensive Nuclear-Test-Ban Treaty are operating at several sites in the United States. During the installation and testing phases of these arrays, natural signals from many sources have been detected. Microbaroms are continuous signals that are associates with severe weather in the ocean. In this report we will describe the microbarom signals from several marine storms with special emphasis on tropical storm Barbara that traversed the Pacific near Hawaii in mid-June of 2001. Microbarom signals from Barbara were especially strong in the IS59 infrasound array located near Kona, HI. The infrasound array in Fairbanks, AK observed signals from several marine storms in the Pacific during this time and the azimuths of one group of signals was consistent with the location of Barbara.

Microbarom signals are observed worldwide with periods in the 3-8 second 0.12 – 0.33 Hz) range and amplitudes of a few tenths of a Pascal. Due to their pervasiveness, they routinely set the noise levels and thus determine the detection thresholds in that band. They have been extensively studied and it is well known that their generation depends upon the amplitudes of ocean waves produced by storms. Posmentier (1967) and Gossard and Hooke (1975) have given comprehensive reviews of microbarom generation and propagation. Recent studies by Arendt & Fritts (2000) show that the acoustic radiation results from a non-linear coupling of atmospheric waves with the ocean wave spectrum.

RESEARCH ACCOMPLISHED

Tropical Storm Barbara

Tropical storm Barbara began as a low-pressure area off the west coast of Mexico in mid-June, 2001. By June 17 the system was producing microbarom signals detectable by the Hawaiian infrasound station. As it moved westward and northward the system deepened and was officially identified as tropical storm Barbara on June 20. At this point it was producing winds of over 60 mph with gusts up to 70 mph. By June 22 the storm weakened to a tropical depression with winds below 35 mph. Details are available on the NOAA web site: http://www.nhc.noaa/gov/archive/2001. Figure 1 shows the storm track from June 20 through June 23 as Barbara moved toward the Hawaiian Islands.

Observations from the IS59 infrasound station in Hawaii

Even before Barbara achieved tropical storm status it contained winds large enough to produce sizeable ocean waves and the concomitant microbaroms. The infrasound station, IS59, near Kona, Hawaii, observed these microbaroms. Figure 2 shows the June 17and June 18 detections of the microbarom source obtained from frequency-wave number (FK) analyses. The radial line from the center to the maximum provides the slowness and azimuth of the detection. The storm continued to produce microbarom signals and was tracked continuously for the next 5 days by the Hawaiian station. Figure 3 shows the results of array processing of the microbarom signals from Barbara for 24 hours on June 19. The data were band-pass filtered between 0.1 and 0.5 Hertz for this analysis. The top panel shows the inverse of the apparent horizontal phase speed, or slowness; the middle panel shows the azimuth of arrival of the microbaroms and the bottom panel shows the waveform indicating a steady presence of microbaroms over this 24 hour period

Observations from the prototype infrasound station in Fairbanks, Alaska

As is evident from the map in Figure 1 the north Pacific was under the influence of several storm systems during June 2001. Observation of the microbarom signals from Barbara at the Fairbanks station was made difficult because of the clutter of signals from other storms. Figure 4 shows three maps with estimates of wave heights in the north Pacific (obtained from the web page supported by the Fleet Numerical Meteorology and Oceanography Center: http://152.80.49.205). As can be seen in the top panel, showing wave heights and wind directions on June 19, there was major activity in the Gulf of Alaska. The middle panel, showing the winds and wave heights for June 20 continues to show activity, although somewhat diminished. The bottom panel, showing the winds and wave heights for June 21 shows that the major activity has shifted west of the Gulf of Alaska.

Figure 5 shows the microbarom signals detected at the Fairbanks infrasound array for June 19 through 22. The diagrams are polar plots with apparent speed in km/sec as a radial coordinate and the azimuth as the angular coordinate. Microbarom signals are seen each day. The straight-line bearing from Fairbanks to Barbara lies at an azimuth between 158^{o} and 162^{o}. Note that only on June 20 are microbaroms observed in the sector between 150^{o} and 180^{o}. Signal amplitudes during this interval were in the range of a few tenths of a Pascal. Signals from this azimuth lasted several hours during the local afternoon of June 20, the day that Barbara's winds grew to tropical storm status above 40 mph. The other diagrams in Figure 5 show microbaroms associated with the various storm centers then present in the north Pacific.

CONCLUSIONS AND RECOMMENDATIONS

The infrasound wave field, in the period range between 3 and 8 seconds (0.12 – 0.33 Hz), is populated by microbarom signals. These signals, generated by marine storms, form the background against which detection in the CTBT program must be made. We have shown that a wide variety of marine storms can be producing microbarom signals simultaneously and that they can be detected from a distance of several thousand kilometers from the source. Once detected marine storms can be tracked for days using the microbarom signals from several infrasound stations.

REFERENCES

Arendt, S. and C. Fritts (2000), Acoustic Radiation by Ocean Surface Waves, *J. Fluid Mech*., **415**, 1.

Gossard E. and W. Hooke (1975), Waves in the Atmosphere, *Elsevier.*

Posmentier, E (1967), A Theory of Microbaroms, *Geophys. J. R. Astr. Soc*., **13**, 487.

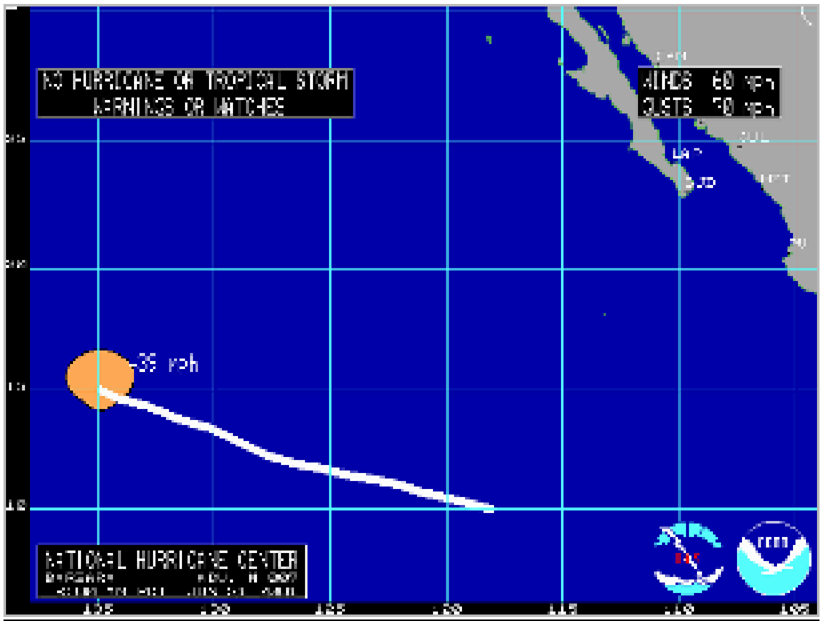

Figure 1a. Track of tropical storm Barbara during the period from June 17 to June 22, 2001.

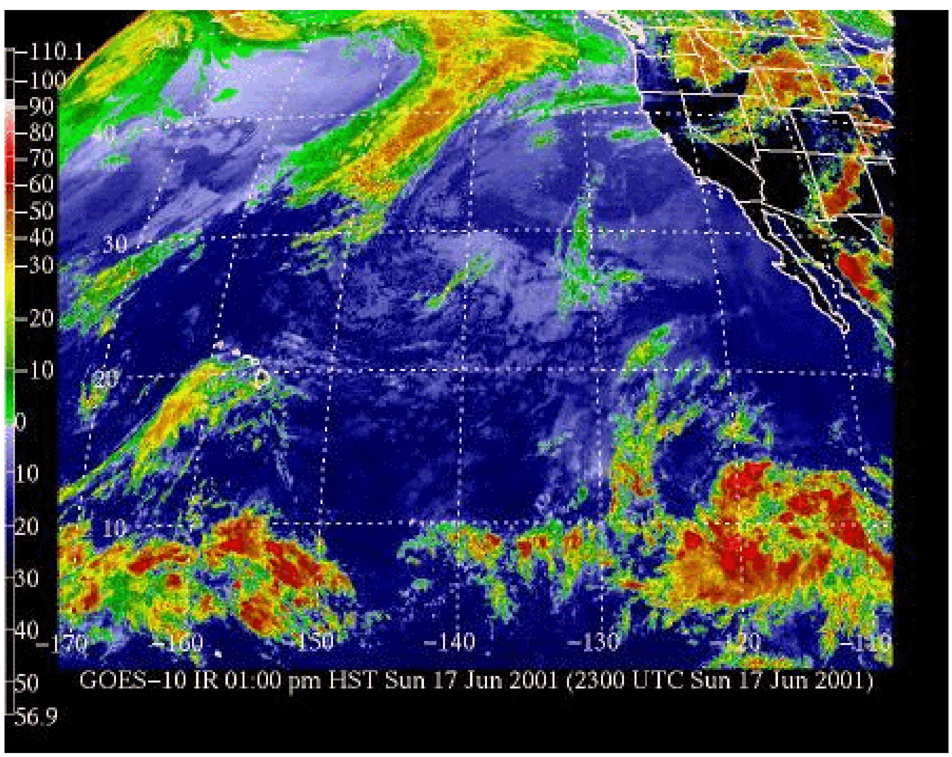

Figure 1b. Infrared image of the conditions in the north Pacific on June 17, 2001.

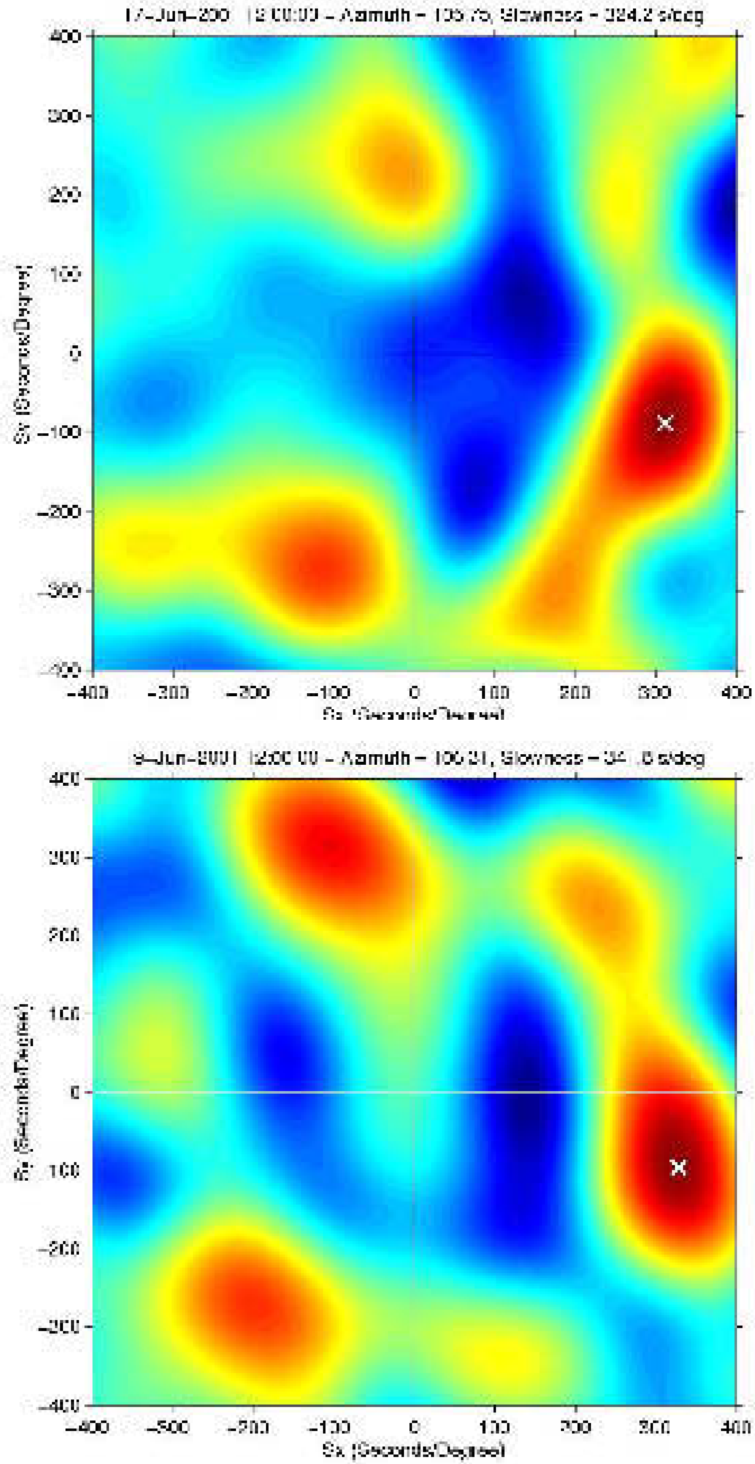

Figure 2. FK detection of the microbarom source by IS59 on June 17 and June 19, 2000, several days before the disturbance grew to tropical storm status.

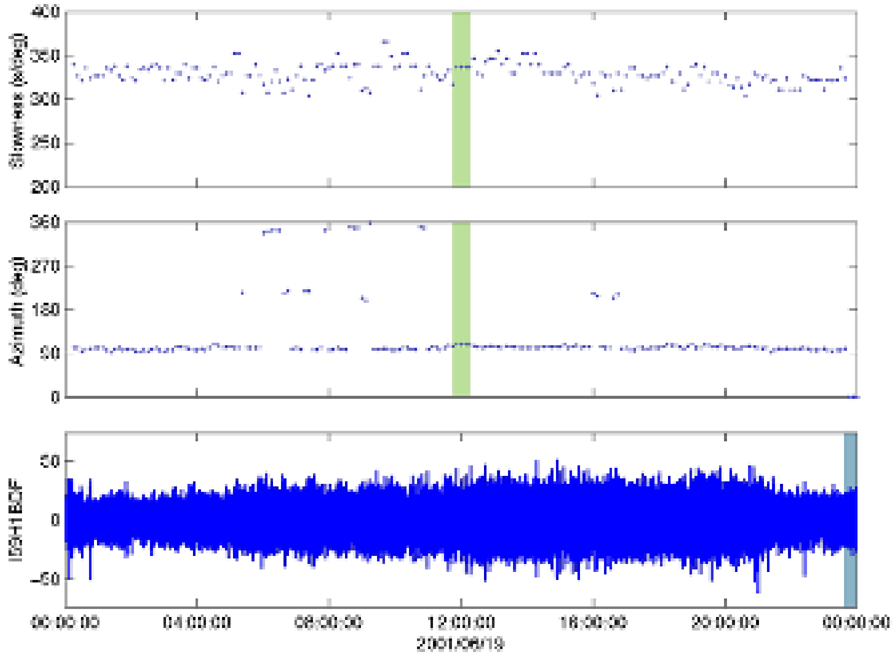

Figure 3. This figure shows the continuous microbarom waveform during the 24 hour period on June 19, 2001. The top panel shows the slowness of the wave train with the maximum correlation, the middle panel shows its direction of arrival (measured clockwise from North), and the bottom panel shows the waveform filtered in the 0.1 – 0.5 Hz frequency band.

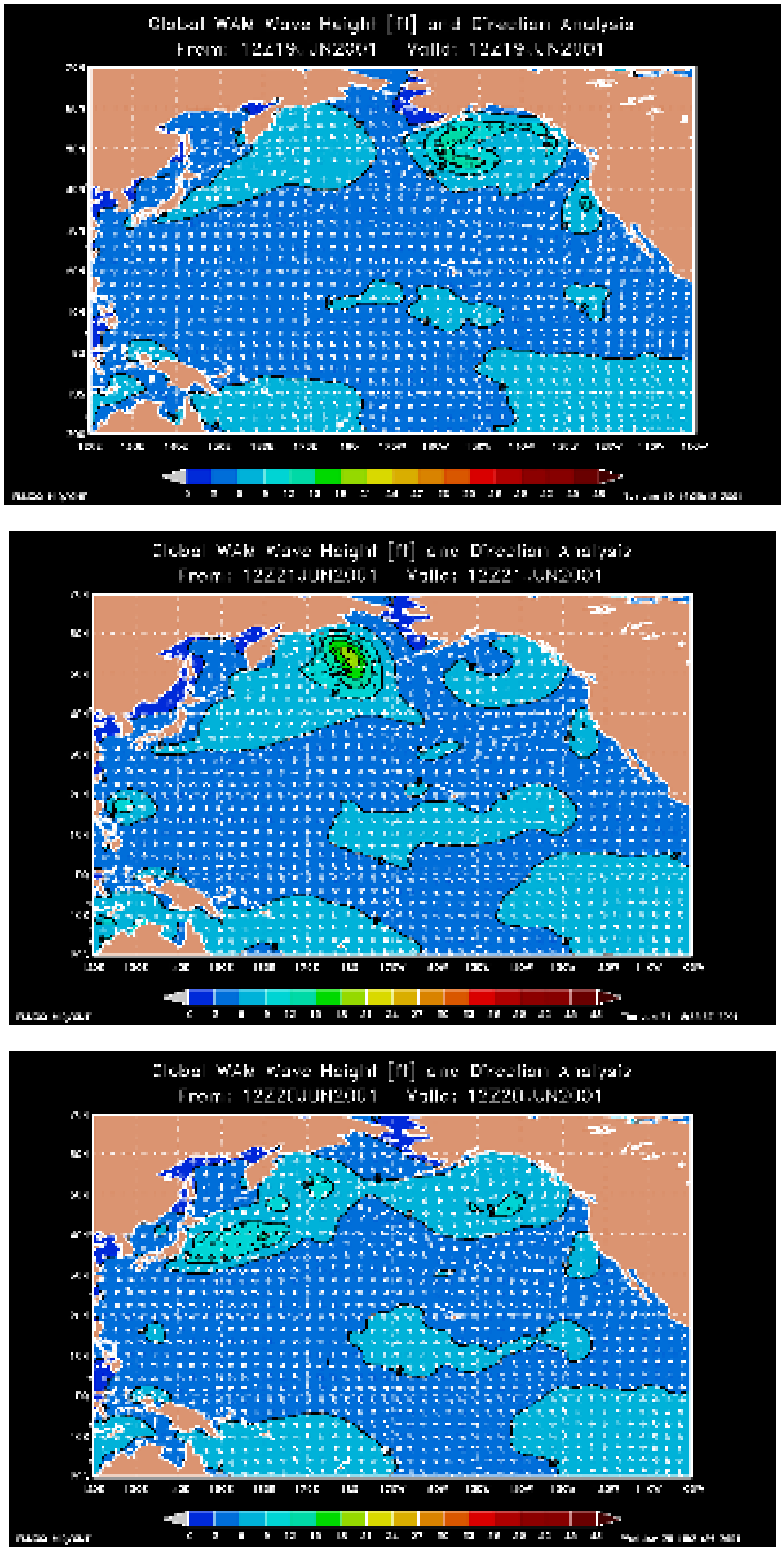

Figure 4. The top panel shows the wind and wave heights in the north Pacific for June 19, 2001. The middle panel shows the wind and wave heights for June 20 and the bottom panel shows the wind and wave heights for June 21. Note the steady activity in the Gulf of Alaska during this period.

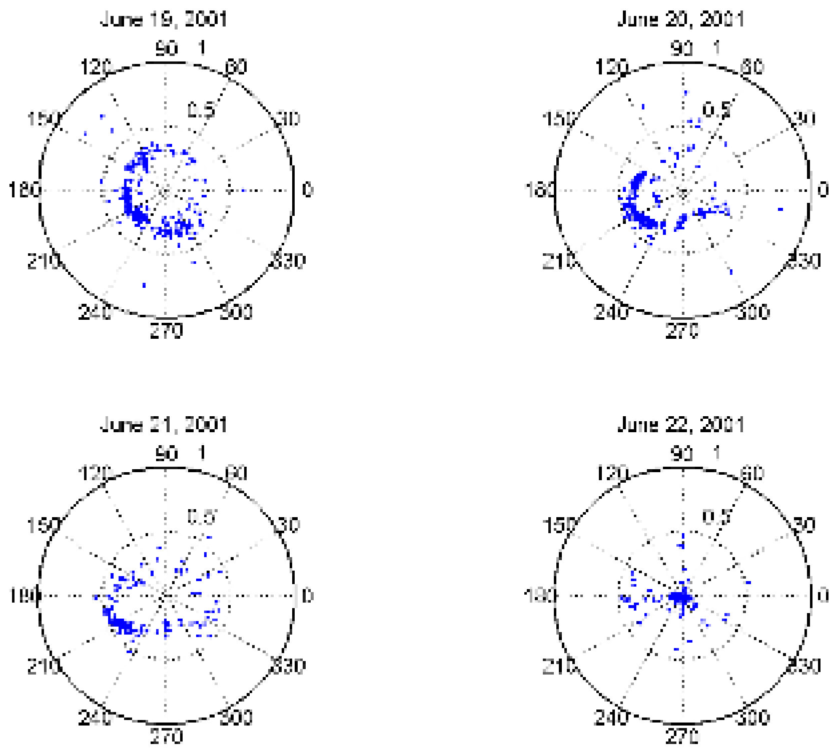

Figure 5. This figure shows four panel each containing the microbarom arrivals for one day from June 19 to June 22, 2001. The polar diagrams are created with the apparent phase speed as the radial component and the azimuth of arrival as the angular component. See the text for details.