Assignment for the "Acoustic Remote Sensing" course

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This assignment consists of two parts. The first part is more of an engineering exercise while the second part uses actual infrasound data. The first part is fictive but your solutions might well be considered in real practical applications. The second part combines infrasound recordings with atmospheric specifications and is a topic of ongoing scientific research. Your results will be taken into account in the course of this research.

Part I: The infrasound noise reducer

Infrasound measurements are negatively affected by local winds in the boundary layer near the array elements, i.e., microbarometers. Arrays are used to reduce this effect through signal summation. The signal-to-noise ratio of the recorded energy ideally increases with the square root of the number of array elements. Furthermore, arrays enable the characterization of the signal in terms of back azimuth and apparent sound speed.

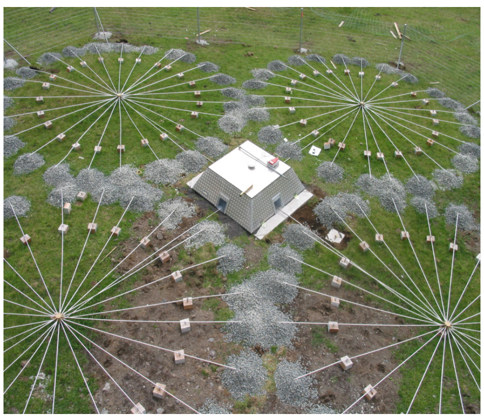

Figure 1.2: An array element with its noise reducer (IS49, Tristan da Cunha (left) and IS09 Brasilia (right)). The microbarometer is located in the vault in the center of the picture. The noise reducer consists of pipes with discrete inlets. Typical sizes are 20 to 70 meter depending on the expected wind speeds.

Wind alters the signal coherency; the stronger the wind the larger the coherency loss. Attempts are made to reduce the influence of wind by spatially integrating the pressure field near the microbarometer. The coherency length of wind is much smaller (10+ cm) than the infrasound signal (100+ m) of interest. By summing the pressure field over a certain area, the incoherent wind field is canceled out while the signal of interest remains unaffected. Such an analog filter system can consist of pipe arrays with discrete inlets (see Figure 1.1) or porous hoses (see Figure 1.2).

Figure 1.2: A noise reducer as applied in the Netherlands on Air Force Base Deelen. The system consists of six porous hoses of 7 meters length. The porous hose is commercially available as soaker hose.

Question 1.1: Design an alternative noise reducers, other than pipe arrays and porous hoses. Keep in mind that it should be an operational system that can be used all year round on all geographical locations. Describe the operating principles of your design (why and how does it work?), make an estimate of the costs and have sustainability in mind while designing.

Part II: Infrasound from exploration activities in a goldmine

Explosions are conducted in a goldmine in Sweden for exploration purposes from 2006 up to 2009. These explosions generate both seismic and infrasound signals. The seismic signals, that traveled through the earth, can be used to determine the origin time, i.e., the time of occurrence. Furthermore, these signals look quit similar throughout the years indicating that the source is practically the same. The infrasound signals on the other hand highly differ as function of time. Variations in the infrasound signal properties can therefore be attributed to different atmospheric conditions. Some geographical characteristics of the source and receiver can be found in Table I.

source location (deg N, deg E)	67.420640	26.39018
receiver location (deg N, deg E)	67.9015	25.3910
back azimuth (deg)	322	
azimuth (deg)	141	
distance (km)	68.4	

Table I: The location of the source (goldmine) and receiver (infrasound array), azimuths and distance

With a known origin time from seismic data, the traveltimes of the observed infrasound waves can be derived. Such sources are also called "ground-truth" sources since both the location and origin time are known. With this knowledge we can assess the infrasound propagation as function of the state of the atmosphere. In this exercise, we will use one of signal properties namely, the propagation time in terms of celerity. The celerity is the horizontal distance (see Table I) divided by the propagation time. The use of celerity is convenient since direct waves and refractions can be identified based on the absolute value. The lower the celerity, the higher the refraction altitude in the atmosphere. Figure 2.1 shows the celerity values throughout the years for the observed infrasound waves.

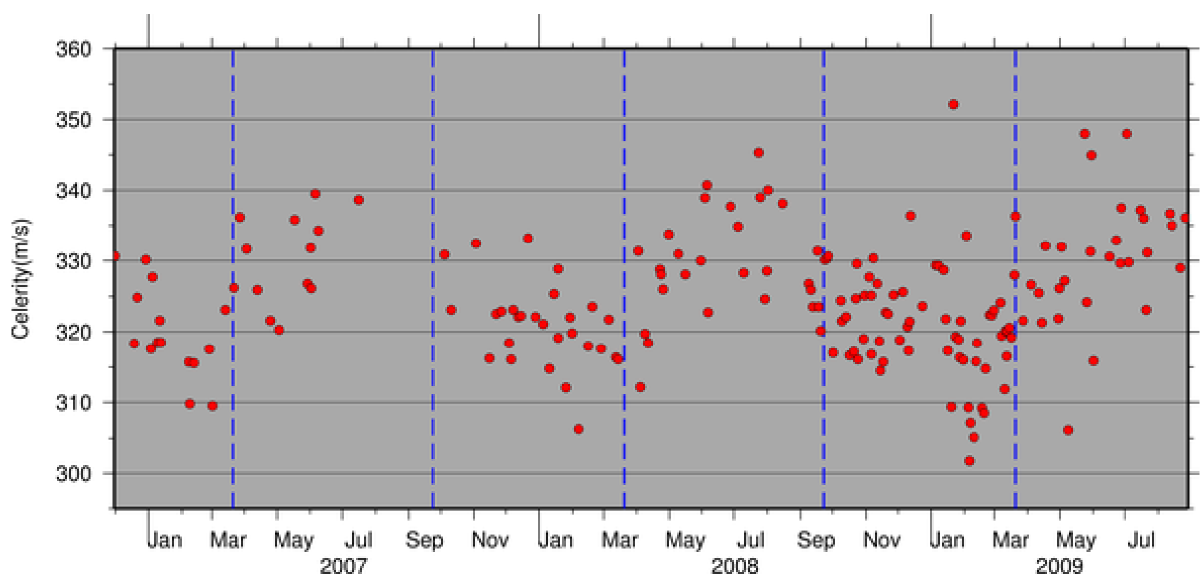

Figure 2.1: The celerity (horizontal distance divided by the propagation time) as function of time for the observed infrasound from the explosions. Blue dashed lines represent the equinoxes.

Precaution: You are working with real data from an noise environment, i.e., the atmosphere. Some data points might not be explained by the proposed modeling. Most of them should, however.

Question 2.1: The celerities are given in the file named “time-celerity.txt”. The first column gives the observation time formatted as *year-month-dayThour:min:sec.msec.* The second column represents the celerity in m/s. Plot the measurements, celerity versus time, in a similar way as Figure 2.1. Derive the temperatures of function of time for the lower atmosphere by assuming a wind less atmosphere and a direct propagation path from source to receiver.

Question 2.2: Compare the derived temperatures (from question 2.1) to the values given in the file named “time-temp.txt”. These temperatures are from 4-hourly weather analysis. Plot the sound speed in the same figure. Compare both and give explanations for the differences between the infrasonically derived and true temperatures.

Question 2.3: One of the possible explanations for the differences between the derived and true temperatures is the presence of wind. In a down-wind situation the celerity will be reduced, and vice versa, since the energy travels faster from the source the receiver. The values of the wind are given in the file named “time-wind.txt” (formatted as column 1 time, column 2 zonal wind (m/s) and column 3 meridional wind (m/s)). Plot the effective sound speed in the same figure, based on the wind values from the file “time-wind.txt”. Compare both and give explanations for the differences between the observed celerities and the effective sound speed.

Question 2.4: Refractions might cause the celerity to be lower than the effective sound speed since the waves have traveled a longer distance than the direct path. Firstly, calculate the refraction altitudes by assuming ray trajectories being straight lines, reflected at a certain altitude. Secondly, this only works for situations that the effective sound speed is larger than the celerity, explain why.

Question 2.5: If the refraction altitudes are limited to the first 7 km of atmosphere, how could we improve our modeling?

Congratulations, you have now imaged the atmosphere with infrasound!