School & Home Infrasound Monitor

Geophysics Research on a budget

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www.starfishprime.co.uk

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Abstract

Described here is a well established opensource geophysics project to monitor atmospheric infrasound 24/7. It employs a modern digital, I^2C enabled differential pressure sensor - unlike the analog devices often used. Python software automatically plots and uploads graphs whilst data is stored in standard *.mseed* format for further analysis. Very open-ended with lots of opportunities for students of all levels, schools and above, to redesign and test replacement components. Real science in a little studied area the equipment required is relatively cheap and offers many opportunities for students to build and refine a sensing system of research quality. It may be of interest as a national school's network producing results of real scientific and educational value at low cost.

Why Infrasound?

CTBTO Infrasound Array, Greenland

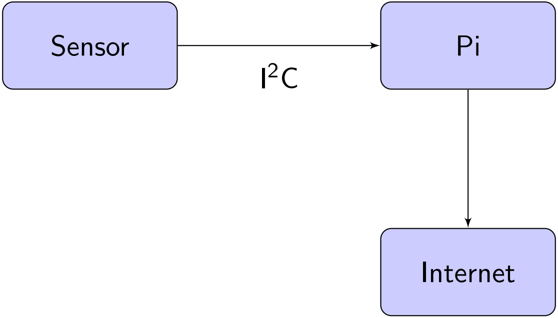
This is a fascinating, relatively little studied area of geophysics wide open to further study. The monitor may be used as a static station, after storms, sonic booms etc. one may download the raw data files and analyse the signal. As a portable device it permits field studies near sites of interest such as wind turbines, quarries, airfields, and beaches.The system described here allows students to build a monitor capable of recording pressure variations of $< 10^{-6}$Pa in the range 10^{-2}Hz to 20Hz.

Infrasound Sources

Infrasound may be generated by natural and man-made events. Natural sources include volcanoes, earthquakes, avalanches, tides, lighting - especially in the upper atmosphere and meteors. Man-made sources may be air-conditioning, wind-farms, aeroplanes, rockets, large industrial plant, and explosions. An international network of infrasound monitors is used by the Comprehensive Nuclear-Test-Ban Treaty Organization seeking signals indicating an atmospheric nuclear explosion

Australian Antarctic Division

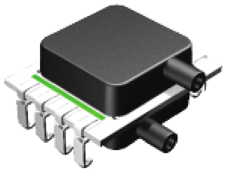
Overview



System Overview

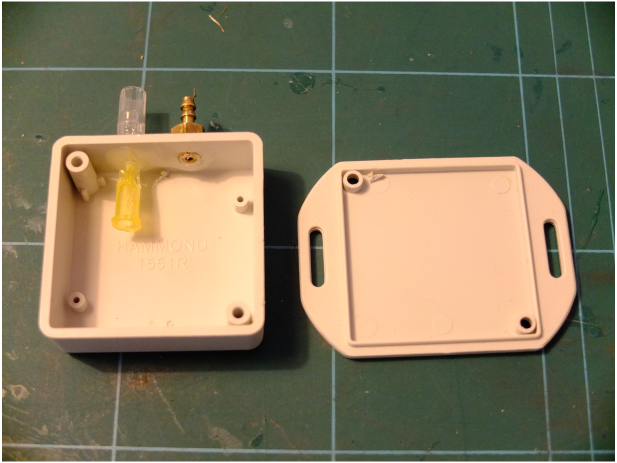
m.e.m.s. Sensor

The system's sensor is the Amphenol DLVR-F50D, a micro-electromechanical system (mems) where both electronic and mechanical components are fabricated on silicon. This particular device is a piezo-resistive differential pressure sensor with inbuilt temperature compensation.



It internally converts the varying analog voltage across a silicon membrane into a digital signal which is transmitted over a 2 wire output using the I^2C protocol. The sensor's range of $\pm$ 125Pa is divided into 6,553 steps giving a resolution of $<$ 0.04 Pa. It is very simple to use with only 4 connections required. Gnd and +3.3V inputs are taken directly from the Raspberry Pi's header pins whilst the two I^2C outputs (SDA & SCL) lead back to the Pi.

Backing Volume



Backing Volume constructed from small Hammond enclosure with hypodermic needle leak.

Backing Volume

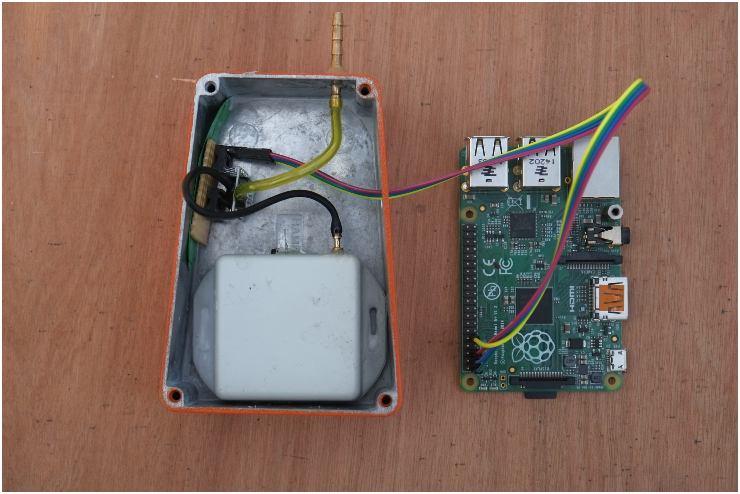
A differential pressure transducer measures difference in pressure between two ports, one connected to the atmosphere, the other to a sealed container known as the backing volume. This backing volume needs a slight, calibrated leak acting to protect the sensor and as a pneumatic filter. Too great a pressure difference due to weather changes may damage the sensor. As the ambient air pressure gradually changes pressure within the backing volume equalises with this via the leak - effectively zeroing the sensor. The leak thus acts as a pneumatic filter, removing very low frequency signals, less than 0.01 Hz caused by atmospheric pressure variation.

Raspberry Pi I

The Raspberry Pi is the workhorse of the system. Software has been written in Python which interrogates the mems sensor approximately 40 times per second. These pressure readings are stored every few minutes until midnight when the cumulative day's readings are saved and a new day's recording begun. At intervals (15 minutes in the case of our own systems) two plots , one of raw pressure and one of acoustic power are generated and saved to disc. These are uploaded to a remote website hourly via ftp by a crontab script. The entire system draws about 8 watts and has been left running unattended now for over 2 years. Data is viewed and downloaded for detailed analysis over the Internet.

see: `www.starfishprime.co.uk/projects/infrasound/infrasound.html`

Raspberry Pi II



Complete rig no 3 - Gamma

Windfilter

Air turbulance across the sensor input leads to noise, this becoming more pronounced at lower frequencies. Some sort of wind-filter is thus desirable. Many different designs have been investigated - indeed area is ripe for original studies by students. Filters can be thought of as averaging local pressure variations across their surface, i.e. random turbulence causing a higher pressure at one part of the filter is likely to be negated by a similarly lower pressure elsewhere whilst the desired low frequency coherent signal is passed.

Pond Filter Wind Suppressor

Common filers include; pipes, porous hose, buckets of gravel, foam blocks and tents. Notably missing from literature is the humble loft-space.

Windfilter II

A simple loftspace appears to do a good job of reducing noise presumably as localised pressure variations cancel across its large surface. We have had two rigs running since 2018. One in a domestic loft whilst the other is 8m away, outside in the lee of an 8ft fence with a 30cl square foam pond filter acting as both noise and environmental filter. Despite the external rig requiring a 2m hose, of 2mm bore, running from the foam wind-shield it typically records absolute pressure variations almost double those of the loft-space.

We have tested the use of porous 'garden sprinkler' hose. A 20m length was adapted by plugging both ends. From one plug emerges a narrow flexible tube to the sensor head. This can be laid on the ground in a spiral or straight line. Tests on an exposed windy beach indicated that the hose performed better than the foam block at noise reduction.

Windfilter III

Pond filter tested alongside porous hose

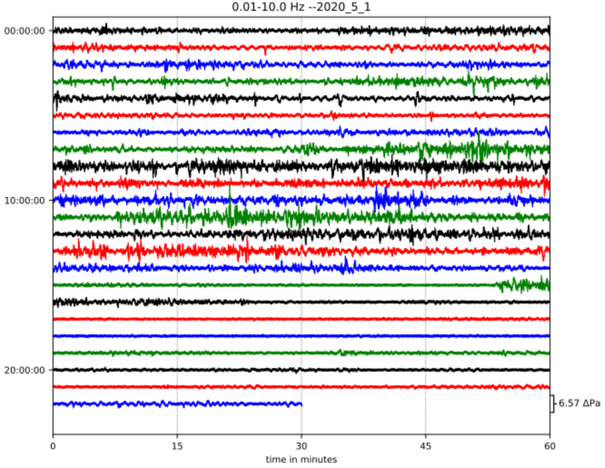
Data Analysis

The static device may left in some dusty forgotten corner of a loft-space or outbuilding uploading plots to a website. When some notable event occurs, such as a storm or sonic boom one downloads the raw data file for more detailed analysis

ObsPy
A Python Framework for Seismology

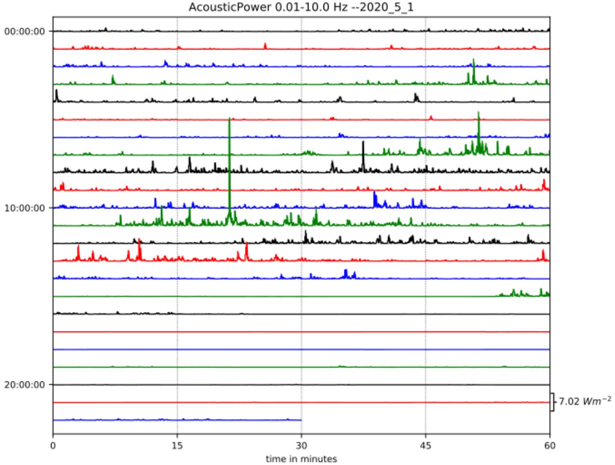
Data are saved in the geophysics standard *.mseed* format permitting signal analysis using a range of geophysics software. Routines have been written in the open-source Python ObsPy suite to facilitate a range of analysis. These may be readily extended by keen students giving a valuable insight into programming and such signal processing techniques as Fourier Analysis. A general purpose Python program has been developed to give students a start on this.

Data Analysis - Daily Plots I



Raw pressure plot auto generated and uploaded to web by Pi.

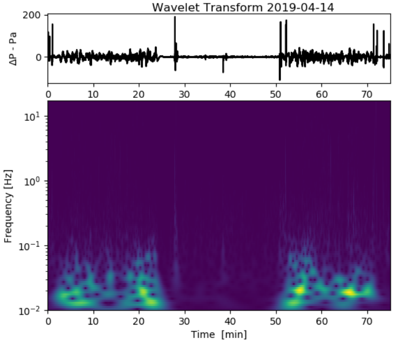
Data Analysis - Daily Plots II



Acoustic power plot auto generated and uploaded to web by Pi.

Wind Turbine

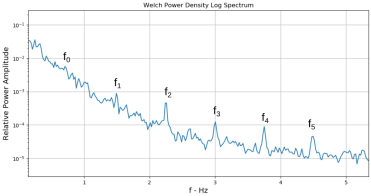
On a blustery day we took readings some 100m from a local wind-turbine using a spiralled 20m porous hose as a wind-filter. Interestingly infrasound levels during the car journey dwarfed those at the site itself .



Quiet gap in centre windfarm, either side - car journey

Wind Turbine II

Using the Obspy python routines Saul analysed the signals. Having filmed the turbine he determined a 'blade pass frequency' of 0.75Hz. He could reasonably expect this to be the fundamental frequency f_0 and see signals at this and its harmonics nf_0. After trying various F.F.T. visualisations he did, exactly where predicted except for f_0 which, whilst strong, was masked by noise (note: log-log scale)



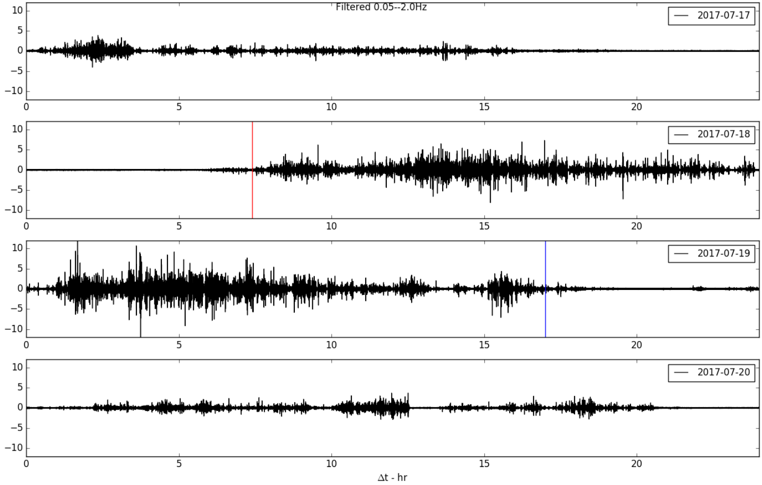
Wind Turbine: f.f.t. showing fundamental and harmonics

Gas Flare

About 5.5 km from the sensor and separated by low hills sits the Olefins No 6 plant on Teesside, a large liquid naphtha cracker. The plant began 'flaring' - burning off gas, at approx 07:25 on 18/7/2017. A clear signal was picked up for the 36 hours of the event. Shown in next slide with the red and blue lines denoting approximate start and end of the flare. The vertical axis shows pressure variation in Pa.

`https://www.youtube.com/watch?v=QsZzawj1l8s`

Gas Flare II

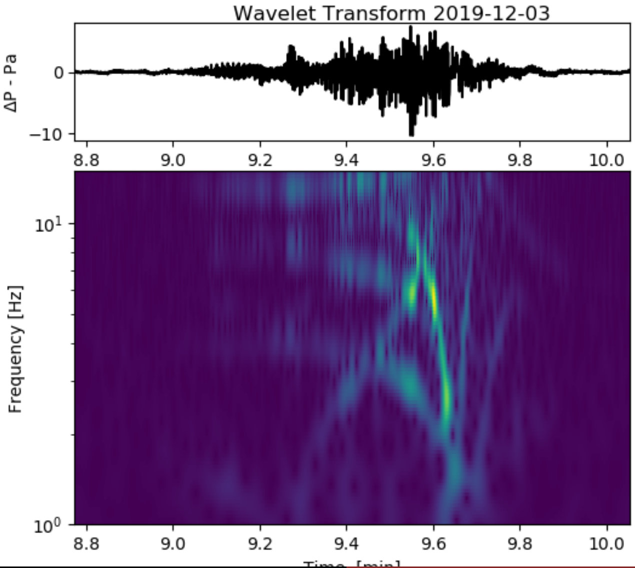


Gas plant flaring 6km away

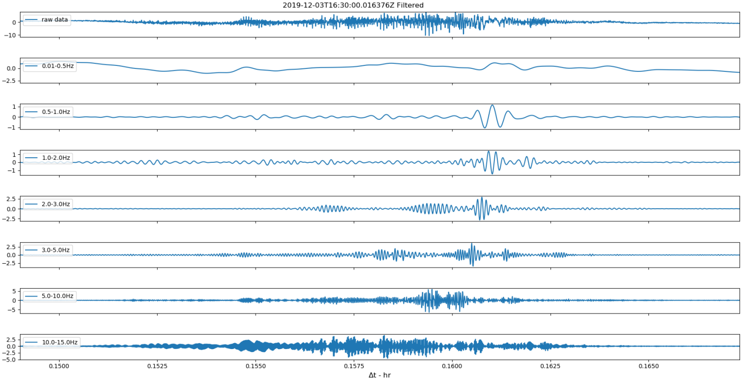
Helicopter

A Chinook helicopter passed overhead with clear signals picked up by both monitors (loftspace and outside). A simple wavelet analysis shows a clear signal in the 5-12Hz range, with clean sin components at 2-3Hz - following slides.

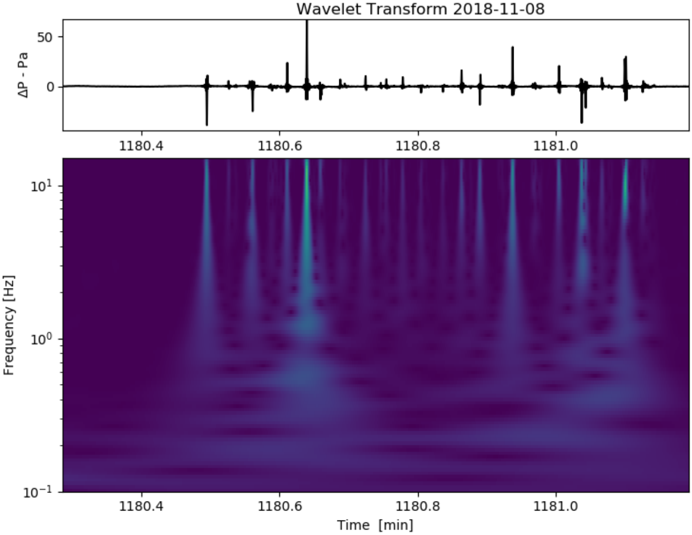
Helicopter - wavelet transform



Helicopter - acoustic power bands



Fireworks - wavelet transform



Further Development I

I firmly believe that it is possible for a school, particularly an 11-18 school or sixth form to build an ongoing science enrichment program which permits students to engage in real research. Opening up the possibility of ongoing engagement with researchers and contributing to real papers. Indeed a few bold schools in the UK have done this such as Simon Langton Grammar School. Regrettably rare in the UK this type of thing is much more common on the continent with programs such as HiSparc.

Rather than provide a pre-built, polished design my intent is to provide initial designs that can be quickly built and got running in a school. This could easily lead to students testing and making improvements or simply gathering and analysing data. Even the software layers are written in python to allow easy adaptation.

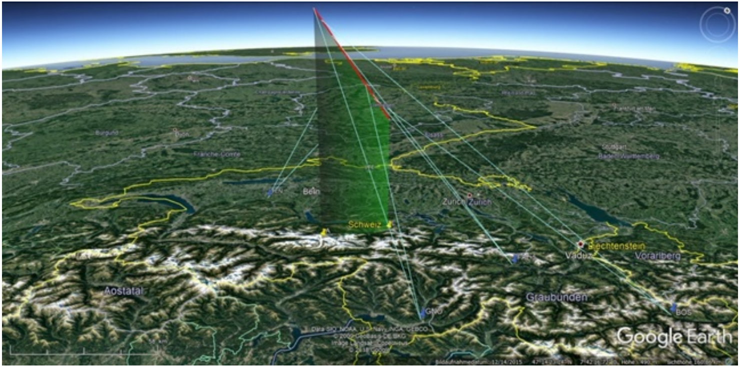
Further Development II

The infrasound system works well. I propose 4 areas for initial further development:-

- Testing of alternate windfilters. Using Obspy one can determine noise reduction and frequency attenuation.
- Use of different sensors.
- Analysis software. Development of the initial testbed program for analysing data, possibly adding a simple GUI. Using alternate seismic analysis software.
- It would be interesting to compare signals from a few km apart - note: at 0.01HZ $\lambda = 30$km. Our 3 systems are currently within one property. By October we hope to move one 3km away to a site in the local town centre.

Further Development III

A local or national network could potentially detect meteors in the upper atmosphere. This could get very interesting.



https://www.meteornews.net/2018/10/15/meteor-detection-by-infrasound-method/

Educational Benefits I

Few pre-university science students have direct experience of real science. Projects such as this can combine real science with real-world systems engineering. Students may work in teams to build, test and install rather sophisticated real-time geophysics monitoring systems. When the initial install is up and running it can them be further developed, different pressure sensors, various wind-shields such as porous hose may be tested, wireless links between the sensor and base station, statistical filters added to the software. The system is designed this to be sufficiently simple to allow construction by 11-16 yr olds (this has been done) whilst offering sufficient development potential for older students. Students are attracted to the combination of physics, computing and electronics along with space science and geophysics.

Educational Benefits II

Geophysics is under-appreciated, even at A-level despite the stellar career prospects. Projects such as this could stimulate interest in geology, physics and computing. The hardware costs are small, each sensor rig will cost no more than £100, less if one has a spare P.C. or Raspberry Pi.

There are few national infrasound networks outside those operated under the aegis of the C.T.B.T.O. Seismometer networks such as IRIS have proved very popular with schools. This is a new field and national networks of infra-sound stations could generate much interest in budding physicists and geologists as well as producing real scientific data.

Interested?

Detailed construction instructions and the software can be downloaded from

`www.starfishprime.co.uk/downloads/downloads.html`

The authors have no commercial interest in this project nor with any equipment supplier. The project was entirely self-funded pro-bono. Design and code are released open-source.

Authors

Ian has taught physics, computing & engineering in 6^{th} Forms for over 20 years - periodically running electronics/coding projects in primary & secondary schools. He recently completed a Ph.D in Computational Physics involving the Monte Carlo simulation of lattice gases. Outside of the day job he is developing a number of educational projects in geophysics, computational physics and digital electronics.

Saul is a secondary school pupil with a keen interest in mathematics, physics and computing.

Nathan is a 6^{th} form student studying geology, mathematics and physics.

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