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Deployment of Seismo Wave MB3d at Nanyang Technological University

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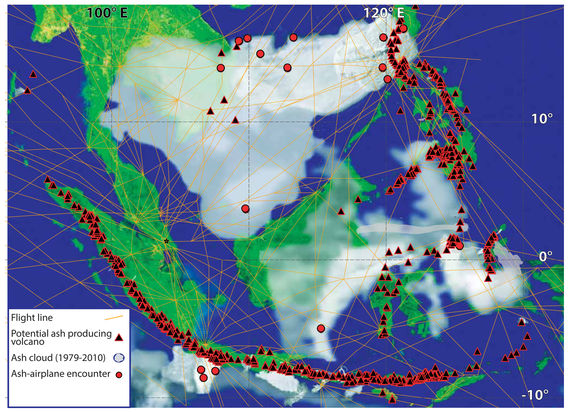
T4.3-P11

Only Have 2 Minutes ?

- SE Asia has a high number of volcanoes with a high decadal probability of an impactful eruption
- Infrasound is being investigated for a cloud cover independent volcano monitoring techniques (Taisne et al, 2019)
- There is a coverage gap in terms of delay time between eruption and detection
- This project is a test of the MB3 array configuration before deployment for a regional array
- System configuration was tested on the NTU campus and results compared to the local Singapore Array (SING)
- Both arrays were able to pick up the June 9, 2019 Sinabung eruption

Volcanic Ash and Air Traffic

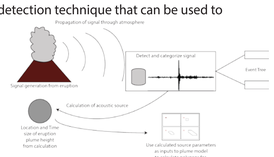


Plotted are the observed ash clouds as measured from satellite from 1979-2010 along with the active or potentially active volcanoes in the region, and flight lines and reported airplane and ash encounters. It is worth noting that the total extent of ash is likely larger, as the 1991 eruption of Pinatubo did result in ash deposition in Singapore at a concentration that would today close the airport.

Project Aims

Southeast Asia has 70% of the global volcanic threat, and Indonesian volcanoes alone account for almost 40% of all recorded global volcanic fatalities (Auker et al., 2015). Infrasound (sound below 20Hz) is a cloud cover independent remote detection technique that can be used to detect volcanic activity.

Our overall project aim is to:
- Detect volcanic activity in the region
- Identify it as such in near real time
- Calculate the attenuation based on atmospheric conditions
- Calculate source parameters



These results could then be used by the aviation industry for plume modeling runs.

This project focuses on decreasing the delay time between an eruption and its detection by focusing on optimizing the regional infrasound network for the detection of volcanic activity within the region, augmenting the existing satellite observation.

This poster focuses on the testing of the configuration of an additional regional infrasound array.

References

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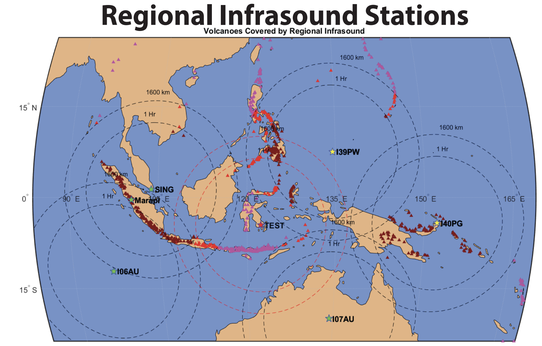
Cansi, Y. (1995). An automatic seismic evert procesing for detedtion and location; The PMCC method. Geophysical research letters. 22(9), 1021-1024.

Taisne B., Perttu A., Tailpied D., Caudron C., Simonini L. (2019) Atmospheric Controls on Ground- and Space-Based Remote Detection of Volcanic Ash Injection into the Atmosphere, and Link to Early Warning Systems for Aviation Hazard Mitigation. In: Le Pichon A., Blanc E., Hauchecorne A. (eds) Infrasound Monitoring for Atmospheric Studies. Springer, Cham. 1079-1105.

Whelley, P.L., Newhall, C.G. & Bradley, K.E. (2015) The frequency of explosive volcanic eruptions in Southeast Asia. Bulletin of Volcanology. 77: 1.

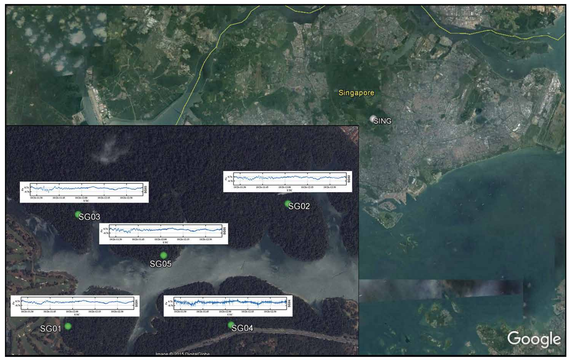
Earthworm ISTI; http://www.isti.com/products/earthworm/

Regional Infrasound Stations



Regional infrasound stations and volcanoes within the study area. Volcanoes are plotted from a dataset which identified 991 active or potentially active volcanoes within the study area(Whelley et al., 2015). Volcanoes within one hour travel time of any infrasound station are plotted in maroon, volcanoes within 1600 km of an infrasound station are plotted in red, and stations where the closest infrasound station is over 1600 km away are plotted in magenta. Infrasound stations are plotted as stars. Regional IMS (International Monitoring System) infrasound stations available in realtime from IRIS are plotted in green, IMS stations without public realtime data are plotted in yellow. EOS opperated stations in Singapore (SING) and Marapi Volcano are plotted along with an example location for the final EOS station the regional array (TEST). The location of the array is subject to an optimization of the network detection capability considering several parameters

Singapore MacRitchie (SING) Array

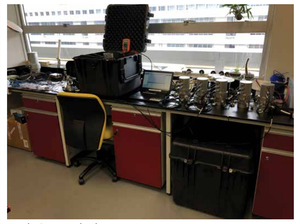


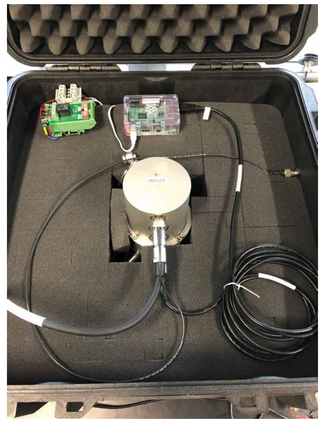
Location of the Singapore Infrasound Station (SING) elements within MacRitchie Reservoir Park. This station is designed to be "IMS like" and has been operating since late 2014.

Nanyang Technological University (NTU) Array

The NTU array, located in western Singapore, is a temporary deployment of Seismo Wave MB3d sensors to be installed at a remote regional site within the region. The RPi system was disconnected due to poor WIFI coverage at the sites, and therefore the realtime telemetry will be tested at a later date. The layout for the array was constrained by the campus geometry, construction projects and large mechanical systems that could overwhelm the instruments at times. Site locations are plotted in green and the geometry used for array processing is plotted in orange. The longest distance between two sensors is 1466m.

MB3d/RPi, Hardware Setup





Each Site includes:
- Power systems
  - DC/DC 5V for RPi
  - 12V DC for MB3d
  - Battery power w/LVD for temporary deployments
- Cabling
  - USB for MB3d
  - GPS for MB3d
  - Power for MB3d
  - Power for RPi
- System housing
  - Pelican case 0340

Realtime Data Acquisition with Raspberry Pi Setup

The RPi was selected for simplicity and functionality, combining computing and communication in an inexpensive, simple and easy to use package. Initial setup of the RPi included updates to the latest Raspbian OS, and installing several software packages to facilitate the MB3d and Earthworm installation.

Basic System Software:
- ser2net; allows serial and USB communication via service
- subversion; versioning software for collaborative software development
- make; utility for recompiling large software projects
- gcc; GNU compiler that supports various programming languages including C
- g++; GNU compiler that supports various programming languages including C++
- wpagui; GUI interface to help connect to NTU Enterprise WAP2 WIFI

Ser2net, a com port translator, is the service that allows Earthworm and Dionisos software to communicate with the MB3d via the RPi's USB ports, internally and externally, via ethernet or WIFI. In practice, the USB port runs as fast as the communications between the two devices allow, regardless of the baud rate set in the config file.

Line for ser2net configuration in /etc/ser2net.config
<Port>: <data Sending option>:< time out>: <Device>: <Baud Rate> <Data bits> <flow control > <stop bit> <options>
8282:raw:600:/dev/ttyACM0:9600 8DATABITS NONE 1STOPBIT

Earthworm, maintained by ISTI, is a modernized and update of seismic data acquisition software for modern computing platforms. Subversion was used to download the latest source code, revision 7555; accommodates ARM processer and the Linux environment in the environmental settings, thus eliminating compile and setup issues of earlier revisions. The Earthworm SVN can be downloaded and run once the standard folder hierarchy is in place. Subversion download command: svn co svn://svn.isti.com/earthworm/trunk . (dot at the end is for placing the svn in the current directory).

Earworm modules used:
- startstop: core Earthworm module that starts and stops all processes
- statmgr: Earthworm state of health monitor; restart and error alerts
- slink2ew: SeedLink importer module for bring in data from MB3d
- wave_serverV: network-based data server with circular buffer for each channel
- archman: archival tool for near realtime creation of CSS data
- export_generic: data export module for data exchange between Earthworm systems

```
pi@MP106:~ $ status
using default config file startstop_unix.d
NOTE: If next line reads "ERROR: tport_attach...", Eartworm is not running.
      Sent request for status; waiting for response...

                    EARTHWORM-32 SYSTEM STATUS

      Hostname-OS:          RPi06 - Linux 4.14.52-v7+
      Start time (UTC):     Fri Sep 14 07:44:39 2018
      Current time (UTC):   Fri Oct 19 06:47:34 2018
      Disk space avail:     6825640 kb
      Ring  1 name/key/size: WAVE_RING / 1000 / 1024 kb
      Startstop's Log Dir:  /opt/earthworm/run_working/log/
      Startstop's Params Dir: /opt/earthworm/run_working/params/
      Startstop's Bin Dir:  /opt/earthworm/earthworm_7.10/bin
      Startstop Version:    v7.9 2016-10-21

       Process  Process          Class/   CPU
        Name      Id    Status  Priority  Used  Argument
      ---------  -------  ------  --------  ----  ----------
      startstop    460    Alive      ??/ 0 00:02:07  -
        statmgr    476    Alive      ??/ 0 00:02:43  statmgr.d
       slink2ew  19523    Alive      ??/ 0 00:13:59  slink2ew.d
    wave_serverV    478    Alive      ??/ 0 00:53:24  wave_serverV.d
        archman    479    Alive      ??/ 0 00:03:28  archman.d
```

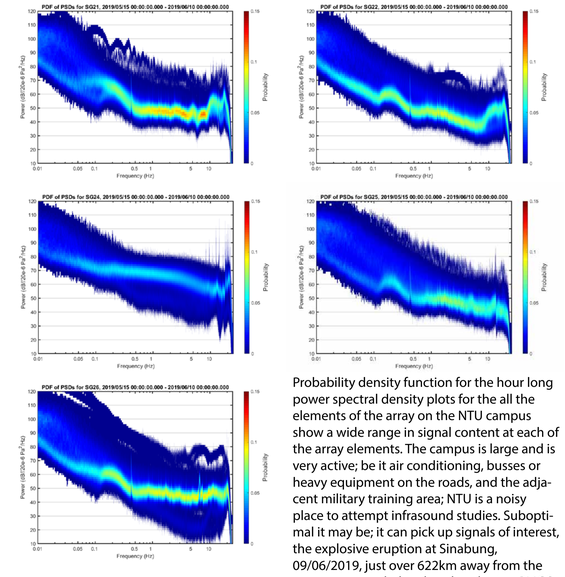
Flexibility is the primary reason Earthworm is being used in this system. The MB3d has 1GB of internal miniseed storage and can be connected to Dionisos via USB for data access; Earthworm provides near real-time data streaming and has the added functionality of retrieving, storing and archive CSS data with or without network connectivity. Using archman, wfdisk CSS archive utility, data is easily integrate into our workflow at EOS and archive when the system is available.

Data Download Procedure

Due to the lack of wifi connection for all elements within the campus deployment manual data downloading was required for this first phase of testing. Power consumption was an additional concern for the final array configuration, and the RPi's were left disconnected while the temporary deployment. For reference the MB3d uses ~80mA whereas the RPi uses ~230 - 280mA of power.

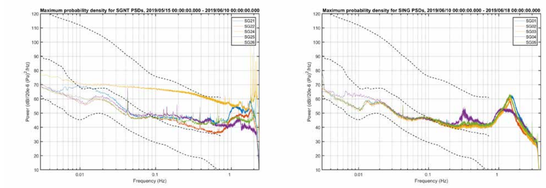
Data downloading utilized an RPi configured to be used as a terminal server with a Slinktool script. Lab experiments where conducted to assess the performance of the standard serial terminal server versus the RPi with a USB connection. It was found that consistently, a week's worth of data took about 3.5 hours to download with the serial terminal server, and ~7 minutes using the RPi configuration.

Long duration PSD's of NTU array



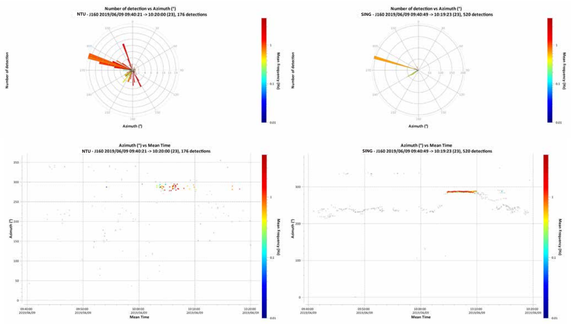
Probability density function for the hour long power spectral density plots for the all the elements of the array on the NTU campus show a wide range in signal content at each of the array elements. The campus is large and is very active; be it air conditioning, busses or heavy equipment on the roads, and the adjacent military training area; NTU is a noisy place to attempt infrasound studies. Suboptimal it may be; it can pick up signals of interest, the explosive eruption at Sinabung, 09/06/2019, just over 622km away from the array was recorded and analysed using PMCC.

NTU vs SING Arrays



Results from the probability density function calculations (PDF-PSD) plotted above plotted here for each element (NTU on left). Also plotted for comparison is an example of a PDF-PSD for the Singapore infrasound station (SING).

Array Processing Results Sinabung Erruption



The NTU array performance with all 5 elements vs the SING array at MacRitchie reservoir, with two elements down for repair, illustrates the superiority of a quiet and stable array located away from the bulk of human activity, in a forest reserve in the heart of Singapore and off campus. The eruption, at 622km from NTU, was still picked up and processed using PMCC (Cansi, 1995), and still gives us usefull informaiton on the proformace of the system desigh and configuration for future deployments of the systems.

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