Seismic Monitoring at MVO - the Rough 'n' Ready Guide

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Contents

1 Overview **4**

2 Instrumentation **4**
2.1 List of Stations . . . 4
2.1.1 MVO seismic network . . . 4
2.1.2 Spiders . . . 4
2.1.3 CALIPSO stations . . . 5
2.1.4 Regional stations . . . 5
2.2 List of equipment . . . 7
2.2.1 Infrasound, Strain and non-seismic data . . . 7
2.2.2 Telemetry . . . 8
2.3 Documentation . . . 8

3 Acquisition **8**
3.1 Hardware (servers) . . . 8
3.1.1 Main: . . . 8
3.1.2 Backups: . . . 8
3.1.3 Spiders: . . . 9
3.2 Software . . . 9
3.2.1 Scream! . . . 9
3.2.2 Spiders . . . 9
3.2.3 earthworm . . . 10

4 Processing **10**
4.1 Hardware . . . 10
4.1.1 Servers . . . 10
4.2 Software . . . 10
4.2.1 Primary earthworm . . . 10
4.2.2 Secondary earthworm . . . 13
4.2.3 Tertiary earthworm . . . 14
4.2.4 Winston WaveServer (WWS) . . . 15
4.3 Alarms . . . 16
4.3.1 Types of Alarm . . . 17
4.3.2 Alarm implementation . . . 17

5 Data Storage and Analysis **18**
5.1 Hardware . . . 18
5.1.1 File shares and storage . . . 18
5.1.2 Processing PCs . . . 20
5.2 Software . . . 20
5.2.1 SEISAN and associated tools . . . 20
5.2.2 Cron . . . 21
5.3 Missing data . . . 22
5.4 Matlab . . . 22
5.4.1 webobs . . . 22
5.4.2 Seismologist's iMac . . . 23
5.5 Routine analysis . . . 24
5.6 Display and access . . . 25

5.6.1 Tools . . . 25
5.6.2 Display computers . . . 26
5.6.3 Access . . . 26

6 Other miscellaneous information **26**
6.1 Hosting of virtual machines . . . 26
6.2 Seiscomp . . . 27
6.3 Nagios . . . 27
6.4 Webobs . . . 28
6.4.1 Overview . . . 28
6.4.2 Boot issues . . . 28
6.4.3 Development site . . . 29

1 Overview

MVO maintains a seismic monitoring system for continuous real time monitoring of SHV. This encompasses: acquisition from the MVO seismic network, Spiders, CALIPSO stations and other regional stations, as well as automatic data processing including event triggering, alarms based on RSAM, plotting and display and data archiving and storage. A catalogue of local volcanic earthquakes and associated metadata is also maintained. This document describes the key information regarding the operation of the seismic monitoring system, and is intended more as a technical and practical guide rather than a scientific manual to aid interpretation of the data.

2 Instrumentation

2.1 List of Stations

2.1.1 MVO seismic network

MVO currently has 8 seismic stations in operation:

MVO seismic stations		
Code & Network	**Name**	**Type**
MBBY MV	Broderick's Yard	3-Component Broadband
MBFL MV	Flemmings	Single component vertical short-period
MBGB MV	Garibaldi Hill	3-Component Broadband
MBGH MV	St. George's Hill	3-Component Broadband
MBHA MV	Harris	Single component vertical short-period
MBLY MV	Lee's Yard	3-Component Broadband
MBRY MV	Roches Yard	3-Component Broadband
MBWH MV	Windy Hill	3-Component Broadband

There are several stations that have been offline in the long-term, but not decommissioned: MBFR, MBLG, MBWW. Changes are planned for the network upgrade. See Figure 1.

See information on webobs:
http://webobs.mvo.ms/cgi-bin/afficheRESEAUX.pl?reseau=MMB
for more details.

2.1.2 Spiders

MVO has imported seismic data from several Spiders that have been deployed since June 2014. Only one, MSS1 in the 2010 Collapse Scar is currently operational:

MVO Spiders		
Code & Network	**Name**	**Type**
MSS1 MV	Scar	Single component vertical short-period

See information on webobs:
http://webobs.mvo.ms/cgi-bin/afficheRESEAUX.pl?reseau=UMS
for more details. Data from the Spiders are acquired separately, using the software *Manifold*

on a dedicated spider acquisition server **mvocobweb1**, before being stored in a local Winston WaveServer and exported to the main earthworm installation on **earthworm3**.

2.1.3 CALIPSO stations

MVO imports seismic, strain and barometric data from the following 4 CALIPSO borehole stations:

CALIPSO station		
Code & Network	**Name**	**Type**
AIRS MC	Air Studios	Borehole strainmeter
GERD MC	Geralds	Borehole strainmeter
OLV1 MC	Olveston	Borehole strainmeter
OLV2 MC	Olveston	Borehole strainmeter
TRNT MC	Trants	Borehole strainmeter

See information on webobs:
http://webobs.mvo.ms/cgi-bin/afficheRESEAUX.pl?reseau=MMS
for more details. Data from these stations are acquired from IRIS via their public seedlink server, using a *slink2ew* module on the secondary earthworm installation on the **nagios** machine.

2.1.4 Regional stations

MVO imports seismic data from the following regional stations:

Regional seismic stations		
Code & Network	**Name**	**Country/Island**
ANWB CU	Willy Bob	Barbuda
GRGR CU	Grenville	Grenada
SABA NA	St. John	Saba
GCMP TR	Mt. Pleasant	Carriacou
GRHS TR	Sauteurs	Grenada
GRSS TR	Sisters	The Grenadines
GRW TR	Mount Saint Catherine	Grenada
SVB TR	Belmont	St. Vincent
ABD WI	Anse Bertrand	Guadeloupe

The stations in the CU, NA and WI networks are imported from IRIS via their public seedlink server, using a *slink2ew* module on the secondary earthworm installation on the **nagios** machine. Stations in the TR network are acquired directly from SRC using an *import_ack* module on the same earthworm installation.

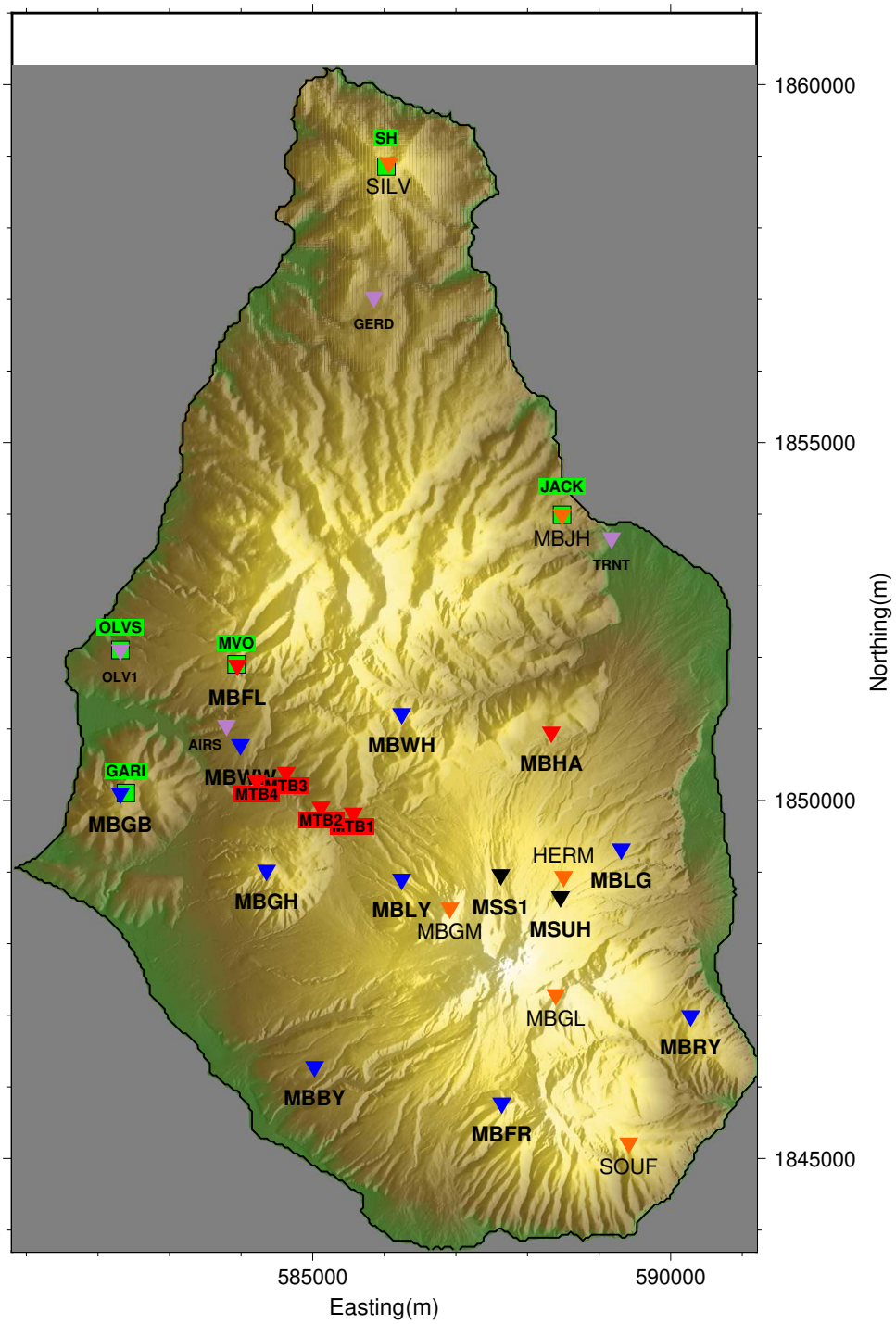

Figure 1: Map of the MVO Seismic Network. Current MVO seismic stations are shown in blue (broadband) and red (short-period). Repeaters for telemetry are marked by the green boxes. Spiders are shown in black and the CALIPSO boreholes site in lilac. The temporary installation of stations in the Belham Valley are shown in red. Potential candidate sites for the network upgrade and the soon to be installed VSAT station are marked in light-brown.

2.2 List of equipment

For the MVO seismic network, mostly Guralp hardware is used, with a mix of different seismometer and digitiser models and vintages. This includes mostly CMG-40T (30s) 3-component broadband seismometers but also several newer CMG-3ESPC[EAM] (60s) models with Guralp DM24 digitisers. Several Mark Products L4C short-period (1Hz) vertical component sensors are also in use, e.g. at MBFL, MBHA and also MSS1. See webobs page:
http://webobs.mvo.ms/cgi-bin/afficheRESEAUX.pl?reseau=MES
for more details of current instrumentation. Changes are planned for the coming upgrade of the seismic network, with 10 Guralp posthole Radian instruments and Minimus digitisers ordered.

2.2.1 Infrasound, Strain and non-seismic data

Several stations in the MVO network have infrasound sensors:

Infrasound sensors		
SCN	**Name**	**Status**
MBFL HDF MV	Flemmings	Operational
MBGB HDF MV	Garibaldi Hill	No data
MBGH HDF MV	St. George's Hill	Bad data
MBLG HDF MV	Long Ground	Station Offline

See information on webobs:
http://webobs.mvo.ms/cgi-bin/afficheRESEAUX.pl?reseau=GMS
for more details. Additional sensors are planned as part of the coming upgrade.

The four CALIPSO borehole stations (AIRS, GERD, OLVN, TRNT) contain Sacks-Evertson strainmeters, 3-component seismometers (geophones) and a barometer (for pressure correction but can also be used as infrasound sensors). Details of the strain and barometric (and seismic) channels are as follows:

Network	Channel	Description	Shoebox/SAC channel
Seismic Channels - 200Hz sampling rate			
MC	BHZ	Vertical seismic channel	slv
MC	BHN	horizontal seismic channel	s2h
MC	BHE	horizontal seismic channel	s1h
Other channels - 50Hz sampling rate			
MC	BLE	Barometric channel	bar
MC	BLN	DT2 strain channel	s2a
MC	BLZ	DT1 strain channel	s1a

Prior to May 2018, data from the CALIPSO boreholes were not acquired in real-time or integrated into the seismic network. The data were retrieved from the Shoeboxes in the form of daily (1Hz sampling) and hourly (50Hz sampling) *SAC* format files. These were retrieved and stored on the CALIPSO iMac machine (currently down?!) and also on the *Deformation* share of the **volcano01** fileserver.

2.2.2 Telemetry

With the exception of MBFL which is cabled directly to the MVO building, the seismic data are telemetered in realtime - mostly via Freewave 900MHz Spread Spectrum Radios, some of which are ethernet radios and some of which use Lantronix Serial-LAN converters to connect to the MVO network. For a list of ip addresses see individual station information in webobs or *Scream* on the main acquisition server **mvoscream3**. Some stations are telemetered directly to MVO, whilst others are telemetered to Silver Hill and then onto the GoM/MVO network or repeated via Garibaldi Hill. Recently some stations, such MBWH and those telemetered via Garibaldi have trialled the use of 2.4/5GHz WiFi radios.

See information on webobs:
http://webobs.mvo.ms/cgi-bin/afficheRESEAUX.pl?reseau=MMR
for more details. Additional changes are planned as part of the coming upgrade.

2.3 Documentation

Manufacturer documentation for the seismometers and digitisers is available from each individual station page on webobs, and is also stored on the **volcano01** fileserver at *volcano01/Seismic_Data/documentation/*. These contain important calibration information needed to create appropriate *SEISAN* response files. See MVO Procedures 042 "*Seisan response files for MVO broadband stations*", stored in *volcano01/mvo/Procedures/* for more details on this process.

For the planned upgrade, SEED response files (compatible with seisan) are able to be automatically generated from the Minimus digitiser web interface.

3 Acquisition

Information on the acquisition of seismic data is recorded and documented in the "MVO Seismic" section listed under the "Data acquisition" network on **webobs**. See http://webobs.mvo.ms/cgi-bin/afficheSTATION.pl?id=VMQMVOS for more details.

3.1 Hardware (servers)

3.1.1 Main:

- **mvoscream3** (172.20.0.39) Main/primary Scream server. Hosted at MVO. Windows Server 2012 R2 64-bit.
- **earthworm3** earthworm3 (172.20.0.38) Main/primary earthworm server. Hosted at MVO. Windows Server 2012 R2 64-bit.
- **earthworm01** (172.20.0.14) Main Winston WaverServer, first choice earthworm backup. Hosted at MVO. Windows Server 2008 64-bit. [**CURRENTLY DOWN**]

3.1.2 Backups:

- **mvoscream1** (172.20.0.31) 1st choice Scream backup. Hosted at MVO. Windows Server 2008 64-bit. [**CURRENTLY DOWN**]

- **mvoscream02** (172.20.0.32) 2nd choice Scream backup. Hosted offsite. Windows Server 2008 64-bit.
- **earthworm02** (172.20.0.33) Backup Winston Waverserver and second choice earthworm backup. Hosted offsite. Windows Server 2008 64-bit. [**CURRENTLY OPERATIONAL for Winston**]

For more details of switching between operational servers see MVO Procedures 25 "*MVO backup seismic servers*", stored in *volcano01/mvo/Procedures/*

3.1.3 Spiders:

- **mvocobweb1** (172.20.0.64) Spider acquisition server. Windows Server 2012 R2 64-bit.

Access
All virtual servers can be accessed via Remote Desktop session using the "seisan" username.

3.2 Software

3.2.1 Scream!

The primary means of data acquisition for the MVO seismic network is via the proprietary Guralp software *Scream!*. This connects to each of the digitisers and retrieves the data in real-time in Guralp's own compressed GCF format. Scream is also used to connect to, manage and configure the digitisers at each station.

MVO currently uses the latest version 4.6, and each of the main/backup servers runs *two instances*. This is mainly for historical reasons as the second instance is used only to acquire from MBWH which is exported to the Puerto Rico Seismic Network to the following ip address/port: 136.145.162.203:4567 via UDP from Scream.

Data are stored locally on the server in GCF format in the *c:\scream\data* directory and disk space is managed by Scream from the File → Setup → Recording menu

Scheduled tasks are enabled that should automatically start Scream in the event of a server reboot. The configuration (.ini) files are also backed up daily by a scheduled task to the following directory on **volcano01**: *volcano01/SF1/MVO-SEISMIC-INSTALLATION -files/Scream/*. This folder also contains various Scream related files including copies of the executables.

3.2.2 Spiders

Acquisition of seismic and GPS data from the Spiders takes place on a dedicated server **mvocobweb1**, and access is via Remote Desktop session under the "seisan" username. There are several inter-connected tools that are used:

- **Manifold**: acquisition of data from spiders; exports to main earthworm, Valve and local Winston.
- **WWS**: Winston WaveServer used for local storage of data in a MySQL database
- **ImportEW**: used to import data in the WWS
- **rinex-fetch**: fetches the GPS data from the Spiders in *rinex* format
- **vdx**: used to connect to Valve to serve the interactive web interface for data display - see: http://webobs.mvo.ms/cgi-bin/putHtml.pl?h=mvo_valve.htm

Each of these processes runs in its own DOS cmd window, and all are automatically started via a desktop shortcut. See information on webobs:
http://webobs.mvo.ms/cgi-bin/afficheSTATION.pl?id=VMQSPID
for more details.

3.2.3 earthworm

Earthworm is the main seismic processing system, and as such is not used for acquisition. However, *some* data are acquired by the secondary earthworm installation running on the **nagios** linux Desktop PC, currently in the back of the Ops Room. Due to unresolved firewall issues seemingly blocking incoming connections on the main installation on **earthworm3**, two modules running on the secondary **nagios** earthworm installation are used to acquire data:

- **slink2ew** retrieves CALIPSO and other regional data from the IRIS public seedlink server
- **import_ack** receives regional station data exported from SRC in Trinidad. [Note there is an accompanying *export_scn_src* module that sends MBFL, MBGH and MBWH data to SRC]

Data are sent to the main earthworm installation via a *ringtocoax* module.

4 Processing

4.1 Hardware

4.1.1 Servers

The main virtual servers available for seismic data processing are listed in Section 3.1 . In summary, the primary operational earthworm server is **earthworm3**, with **earthworm01** the primary Winston WaveServer and backup earthworm server and **earthworm02** an additional backup to both.

In addition to the main earthworm installation, there are two other instances of earthworm installed on desktop PCs:

- **nagios** (172.20.0.62). Desktop PC in the Ops Room primarily used for *nagios* (network monitoring tool), but running secondary earthworm installation. Dell Precision WorkStation T7400, running Debian GNU/Linux buster/sid x86_64.
- **MVOWXP002** (172.20.0.71). Desktop PC in the Ops Room primarily used for Swarm display, but also running a tertiary earthworm installation used only for the alarm call. Dell Precision T3500 running Windows XP.

4.2 Software

4.2.1 Primary earthworm

Earthworm is an open source software system that is used globally for regional and local seismic networks and is the main seismic processing software used at MVO. It consists of a series of independent modules that perform specific functions, while passing messages between each other using shared memory rings. The setup at MVO uses version v7.8 and features a combination of standard modules as well as several custom MVO specific modules developed by BGS.

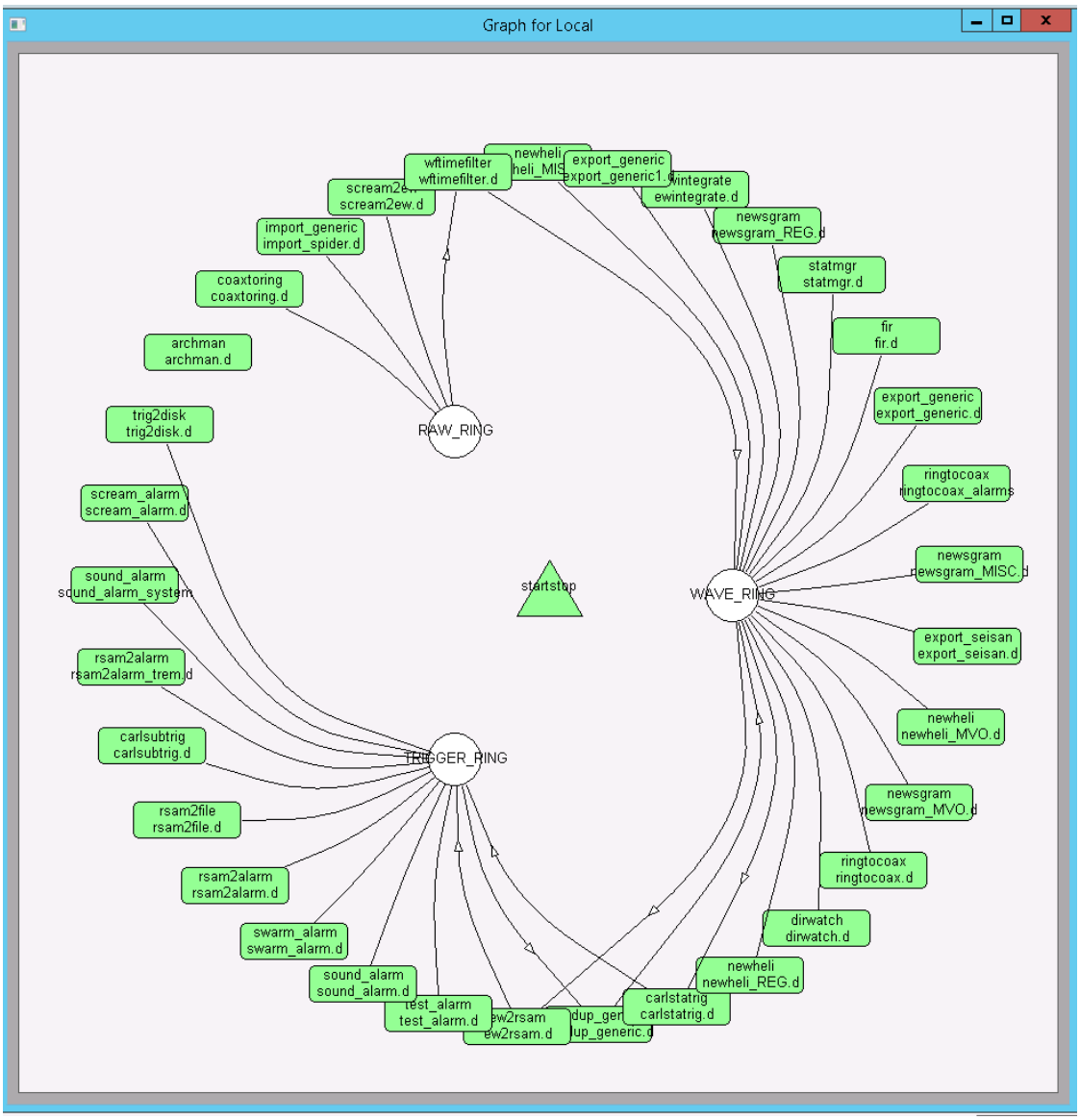

Figure 2: Diagram of earthworm memory rings and modules for the primary earthworm installation on **earthworm3**. Incoming waveform data is imported into the RAW_RING before passing through *wftimefilter* into the WAVE_RING. Trigger, RSAM and ALARM messages are written to the TRIGGER_RING. Modules are controlled by *startstop* and *statmgr*.

The main earthworm installation is on the **earthworm3** server. The installation directory is *C:\earthworm\run_mvo*, with the configuration files stored in the *params* directory and log files in the *log* directory. Each module has an associated ".d" file which contains configuration information and a ".desc" file that controls restart behaviour.

Earthworm is started by the desktop shortcut to the *start_ew* script, which brings up the *status* output in a new command window, showing the status of all running modules.

List of modules Currently there are 3 memory rings: RAW_RING, WAVE_RING and TRIGGER_RING, and 35 modules running, with the following functions:

Module Name	Function
archman	Archive manager. Wrapper module to call *waveman2disk* to pull data from the Winston Waveserver and write out continuous data to 20 minute seisan (rbuffer) files.
carlstatrig	Performs trigger calculations using a standard STA/LTA algorithm
carlsubtrig	Reads trigger messages and performs the subnet trigger logic.
coaxtoring	Receives waveform data sent from a *ringtocoax* module on secondary earthworm installation on nagios (Regional/CALIPSO)
copystatus	Copies messages from RAW_RING $\rightarrow$ WAVE_RING
copystatus	Copies messages from TRIGGER_RING $\rightarrow$ WAVE_RING
dirwatch	Monitors directories to keep a fixed number of days of data
ew2rsam	Calculates RSAM for given list of stations/channels
ewintegrate	Numerically integrates data from velocity to displacement Currently runs for MBGH, MBLY, MBWH $\rightarrow$ HHZ channel codes
export_generic	Exports ALL data to the Winston WaveServer on **earthworm01**
export_generic1	Exports ALL data to the Winston WaveServer on **earthworm02**
export_seisan	Copies continuous seisan files from local disk to server locations
fir	Filtering module to simulate short-period (1Hz) data from broadband data. BH[ZNE] $\rightarrow$ SH[ZNE] channel codes
import_generic	Imports Spider data from *Manifold* on **mvocobweb1**
newheli	Plots static helicorder images for MVO stations
newheli	Plots static helicorder images for CALIPSO and infrasound data
newheli	Plots static helicorder images for Regional stations
newsgram	Plots static spectrograms for MVO stations
newsgram	Plots static spectrograms for CALIPSO and infrasound data
newsgram	Plots static spectrograms for Regional stations
ringdup_generic	Copies all ALARM messages from TRIGGER_RING $\rightarrow$ WAVE_RING
ringtocoax	Exports MVO data, Spider data & ALARM messages to **nagios**
ringtocoax	Exports all ALARM messages to tertiary earthworm/Alarm PC
rsam2alarm	Triggers RSAM_ALARM messages based on 60s RSAM thresholds at 3+ stations
rsam2alarm	Triggers RSAM_ALARM messages based on 1800s RSAM thresholds at 3+ stations
rsam2file	Writes 60s RSAM data to binary files, one file per channel per year
scream2ew	Imports the MVO seismic data from *Scream* on **mvoscream3**
scream_alarm	Triggers SCREAM_ALARM message if $<$2 channels are coming in
sound_alarm	Sends out RSAM_ALARM, SWARM_ALARM emails to ALL scientific staff
sound_alarm	Sends out SCREAM_ALARM emails to seismic/technical staff

statmgr	Status manager. Looks after health of other modules and sends status messages/emails [seisan@mvo.ms]
swarm_alarm	Triggers SWARM_ALARM messages based on event rate threshold
test_alarm	Triggers TEST_ALARM messages at 01:00UTC/9pm LT daily
trig2disk	Writes waveform data to event triggered seisan files
wftimefilter	"Sanitizes" timestamps of incoming data, removes duplicate packets etc.
startstop	Controlling module/executable that includes the list of modules to be run.

Despite *startstop* and *statmgr* taking care of most module problems, occasionally some modules can encounter problems which require a manual restart. To circumvent this, a perl script *check_ew.pl* runs in a separate window (see desktop shortcut) that checks hourly that all modules are alive. If the correct number of modules are not "alive" then it attempts to forcefully restart "dead" modules and sends out email alerts to relevant staff.

Scheduled tasks are enabled that should automatically start earthworm in *the background* in the event of a server reboot. Hence, once logged into a desktop session it is best to re-run *start_ew* to bring up the cmd window.

IMPORTANT: it may be necessary to "run as administrator" (right-click menu) in order to kill and restart the existing processes.

The configuration files (params directory) are also backed up daily/monthly by scheduled tasks to the following directory: *volcano01/SF1/MVO-SEISMIC-INSTALLATION -files/earthworm3_backup*.

Further scheduled tasks routinely backup the RSAM and helicorder plots to the *Seismic_Data* share on **volcano01** and to **earthworm01** in case it is necessary to switch to a backup server. See Section 3.1.2 and MVO Procedures 25 "*MVO backup seismic servers*", stored in *volcano01/mvo/Procedures/*, for more details.

4.2.2 Secondary earthworm

In addition to the main earthworm installation, MVO also maintains a secondary earthworm installation on the **nagios** linux PC. This performs several additional functions that, for a variety of reasons, cannot be completed by the main server. This installation runs earthworm version v7.9, and is installed in the */home/seisan/ew/run_mvo* directory, with the configuration files again in the *params* directory and log files in the *log* directory. Relevant environment variables in the file */home/seisan/ew/envmvo* are sourced automatically in the .bashrc file of the "seisan" user.

There are 12 modules currently running:

Module Name	Function
archman	Due to problems with the *seiputaway.c* routine in *waveman2disk* module which caused data gaps, data from the **Spiders** is archived in *miniSEED* format by this module. Further separate shell scripts convert this to seisan format
coaxtoring	Receives waveform data and ALARM messages sent from a *ringtocoax* module on the primary earthworm installation on **earthworm3** (MVO stations/Spiders)
export_generic	Exports ALL waveform data to the **local** Winston WaveServer
export_scnl_actv	Exports MBFL, MBGH and MBWH waveform data to SRC/Trinidad
gdi2ew	Testing *gdi2ew* module with temporary station MTGH, can probably be disabled.
import_ack	Imports waveform data from Regional stations (TR network) from SRC/Trinidad

ringdup_scn	Converts location of SCNL waveform data by mapping the location code from "00" → "- -" to match other channels
ringtocoax	Exports imported data (CALIPSO/Regional stations) to **earthworm3**
slink2ew	Imports Regional and CALIPSO data from the IRIS public SEEDlink server
sound_alarm	Calls a custom script *alarm_send_heli.sh* to send out alarm emails with mini-helicorder image
statmgr	Status manager. Looks after health of other modules and sends status messages/emails [seisan@mvo.ms]
startstop	Controlling module/executable that includes the list of modules to be run.

Earthworm should start automatically *in the background* on reboot of the PC. This is controlled by two scripts in the crontab:

- */home/seisan/ew/check_ew_modules*: which runs every minute to check the status of earthworm and restarts (by calling: /home/seisan/ew/run_mvo/params/EW_START) earthworm if necessary.
- */home/seisan/ew/remove_lock*: which runs at boot time to remove the lock file which prevents multiple instances of earthworm running

4.2.3 Tertiary earthworm

MVO maintains a minimal tertiary earthworm installation on the Windows PC **MVOWXP002**. This is purely for the purposes of the alarm calls. The minimal earthworm setup (v7.7) features a *coaxtoring* import module that listens for any ALARM messages passed to it and triggers *sound_alarm* to make the phone calls via the attached modem. The 6 modules in use are:

Module Name	Function
coaxtoring	Receives any ALARM messages (RSAM, SWARM, SCREAM and TEST types) sent from a *ringtocoax* module on primary earthworm (**earthworm3**)
dirwatch	Monitors the log file directory to keep 31 days of log files
sound_alarm	Calls a kermit script *alarmcall.ksc* to make phone calls to all scientific staff
sound_alarm	Makes phone calls to all seismic staff for SCREAM alarms only
statmgr	Status manager. Looks after health of other modules and sends status messages/emails [seisan@mvo.ms]
startstop	Controlling module/executable that includes the list of modules to be run.

Earthworm is again started via the *start_ew* desktop shortcut. A scheduled task is enabled that should automatically start earthworm in *the background* in the event of a reboot. Again, once logged into a desktop session it is best to re-run *start_ew* to bring up the cmd window.

IMPORTANT: it may be necessary to "run as administrator" (right-click menu) in order to kill and restart the existing processes.

See Section 4.3 for a more comprehensive overview of the alarm system.

4.2.4 Winston WaveServer (WWS)

Winston is a Java-based seismic wave server developed by USGS, which stores seismic data in a MySQL database to provide data and plots and serves data to *Swarm*, web browsers and other clients such as *earthworm*. MVO has 3 Winston installations maintained on 3 different machines:

Main Winston on *earthworm01* and *earthworm02*

This is the main installation containing all of the MVO seismic data, including all imported channels. At the time of writing **earthworm01** is currently down, so the backup server **earthworm02** is in use. This runs version 1.2.12, installed in *C:\Winston1.2*. A typical installation consists of two main scripts: *WWS* the actual WaveServer and *ImportEW* which imports data into the database. These two scripts (either batch files on Windows or bash scripts on linux) typically run in their own command windows, and are controlled by the configuration files:

- *Winston.config* controls the MySQL database access (user=root, password=mont-serrat)
- *WWS.config* controls the ip address, port and connections
- *ImportEW.config* normally controls the data import. However, in this case the import is run from three separate batch files: *imp-wws.bat*, *imp-wws01.bat* and *imp-wws02.bat*. Each of these scripts has an associated ".d" file, e.g. *imp-www.d* which replaces the normal *ImportEW.config*. [NB: these are in the *earthworm* params directory]. Various import parameters are set, including the data source but also the amount of data that can be stored via the "maxDays" parameter. This can be set on a per network/station/channel basis, so to avoid disk space issues the current settings are: 21 days storage for MVO and CALIPSO channels (MV and MC networks) and 7 days for all others (CU, NA, TR, WI).
- *NTP.conf* controls the ntp server for Winston to get its timing. NB: it is important to leave this set to something reliable and accessible, as when this was set to the internal time server (webobs), problems with communication caused Winston to fail to start.

The main Winston used at MVO actually has 3 separate ImportEW instances to retrieve data from the different possible earthworm sources (see MVO Procedures 25 "*MVO backup seismic servers*", stored in *volcano01/mvo/Procedures/*, for more details.)

Winston is started via the desktop shortcut *start_winston* which automatically starts the Winston server (WWS) and all ImportEW modules in their own command windows (NB: this is will automatically kill any existing Winston processes first).

Station metadata (locations, names etc) for the map display in Swarm is controlled by the Winston, and is stored in the *channels*, *grouplinks*, *groupnodes* and *instruments* tables in the *W_ROOT* MySQL database. There is a python script in the Winston directory *UpdateWinston-Metadata.py* that can be used to automate this process. The MySQL server can be accessed via the command line client (Desktop shortcut) or *Navicat* Lite software, with a GUI. Some useful links:

https://github.com/usgs/winston/blob/master/src/main/resources/docs/index.md
https://volcanoes.usgs.gov/software/winston/index.shtml
https://avo.alaska.edu/Software/winston/W_Manual_TUT.html

Winston on *nagios*

MVO also maintains a Winston WaveServer on the **nagios** machine (linux environment) to store waveform data locally and to act as an additional backup to the main servers. This is installed in: */home/seisan/Winston/Winston1.2*. Configuration is similar to the main Winston, but slightly simpler as data is only imported directly from the local earthworm via a partner *export_generic* earthworm module. The configuration files are:

- *Winston.config* controls the MySQL database access (user=**seisan**, password=mont-serrat)
- *WWS.config* controls the ip address, port and connections
- *ImportEW.config* controls the data import, 21 days storage for all channels.
- *NTP.conf* controls the ntp server for Winston to get its timing, set to public pool.ntp.org servers

Python script *UpdateWinstonMetadata.py* can be used to update the station metadata.

Also, see file: */home/seisan/Winston/Winston1.2/mysql_steps_to_work.txt* which contains some notes on the installation and configuration process.

Winston should start automatically on reboot of the PC. This is controlled from the "Sessions and Startup" menu of the XFCE Desktop environment Settings menu. The Winston server and the ImportEW scripts should automatically start in new command prompt windows on boot/login. If for some reason this fails, navigate to the Winston directory (*/home/seisan/Winston/Winston1.2*) in a bash shell/command prompt and start the two scripts (WWS.sh and ImportEW.sh) manually.

Winston on *mvocobweb1* - Spiders

Finally, a third Winston is maintained on the **mvocobweb1** server for local storage of imported data from the Spiders. This is installed in *C:\Winston1.2* and again runs two processes: WWS and ImportEW. Configuration files are:

- *Winston.config* controls the MySQL database access (user=Winston, password=Winston)
- *WWS.config* controls the ip address, port and connections
- *ImportEW.config* controls the data import from Manifold, 1 year of storage. Export properties/communication are set in the Manifold *packet.properties* file in *C:\Manifold\dist*
- *NTP.conf* controls the ntp server for Winston to get its timing, set to public pool.ntp.org servers

The two windows are started, along with Manifold, rinex_fetch and vdx, by the *start_spiders* desktop shortcut.

4.3 Alarms

Seismic monitoring forms one of the key components of the MVO monitoring efforts, and since it is the most readily available and understood real-time tool, it is used for the alarms sent to staff to alert them to any rapid changes in volcanic activity. Since this is such an important part of the monitoring it deserves special attention and is described in detail in this section.

4.3.1 Types of Alarm

All alarms are controlled and triggered by the main *earthworm* system (see Section 4.2). There are actually several types of alarm that can be triggered by the seismic monitoring system, which are:

- **RSAM** triggering. These are alarm messages triggered when preset RSAM (amplitude) thresholds are exceeded at several stations simultaneously. Currently two sets of criteria are used based on 60s RSAM to catch large events, and a longer 1800s RSAM value designed to detect *sustained* volcanic tremor or other seismic activity. These are controlled by the *rsam2alarm* earthworm modules and currently require exceedance at 3 or more stations in the network to trigger an alarm. The threshold values were determined systematically based on a 10 μms^{-1} ground velocity threshold and various scaling factors. See the document "*MVO Procedures 44: RSAM alarm thresholds at MVO*" stored in *volcano01/mvo/Procedures/*, for more details of this process.
- **SWARM** alarms are triggered based on event rate. This is controlled by the *swarm_alarm* earthworm module and is currently set to a threshold of 20 events in 3600s (1 hour).
- **SCREAM** alarms are a type of system alarms designed to catch a problem with the acquisition from *Scream*. This alarm is controlled by the *scream_alarm* module and is triggered if < 2 channels are being received by earthworm from the *scream2ew* modules for more than 10 minutes. Note this requires a separate *sound_alarm* module, as the list of recipients is different.
- **TEST** alarms are designed to test the alarm system and are currently (and have traditionally) been set to occur daily at 9pm local time (01:00 UTC) by the *test_alarm* module.

4.3.2 Alarm implementation

Once an alarm has been triggered, a *TYPE_ALARM* message is passed into the ring, where it is processed by the *sound_alarm* module(s). There are 3 steps in the implementation of the alarms that involve all 3 of the MVO earthworm installations.

1. **PHONE CALL**. Due to problems connecting a physical modem to a "virtual" server, this is performed by the **MVOWXP002** Windows PC in the Ops Room, using the tertiary earthworm installation (see Section 4.2.3), which receives *TYPE_ALARM* messages passed to it. The alarm calls utilise a Kermit 95 script (*alarmcall.ksc*) that dials a list of phone numbers via the modem that is connected to a phone line in at the back of the Ops Room and a serial port on the PC. The phone number used for the calls is currently: **+1 664 491-8870**. Two separate *sound_alarm* modules are used, one for the SCREAM (system) alarms, and one for all others (RSAM, SWARM, TEST). The list of phone numbers called (in order) is controlled by the module parameter files: *sound_alarm.d* and *sound_alarm_system.d*. NB that these modules are **NOT** configured for emails, so the email addresses are irrelevant. Each phone number is called a maximum of 5 times until answered. Returned modem status for each call attempt is recorded in the *alarmcall.ksc.log* file in the earthworm log directory. To test the modem/phone call system there is a desktop shortcut to perform a test call to the seismologist (default: +1 664 492-2900) or any other number entered as an argument. **Note**: this PC can also be accessed via remote desktop session (172.20.0.71, password=Administrator, password=BLANK)

2. A **First EMAIL** is sent out via the *sound_alarm* module on **earthworm3**. This is sent immediately as soon as an alarm message is received, and includes details on the time and type of alarm (RSAM[60,1800], SWARM, TEST, SCREAM) triggered. Emails are sent by the command line email programme *blat*. This is controlled by the *sound_alarm.d* parameter file, which contains the list of email recipients and mailserver details, which due to continual unreliability of the MVO mailserver, is currently sent from a dedicated gmail account: *mvo.seismic.alarm@gmail.com* (password=mont-serrat). Details are recorded in the the *blat.log* file in the earthworm log directory. Again there are two separate modules due to a different recipient list for the SCREAM/system alarm. This module does **NOT** send phone calls, so numbers here are irrelevant.

3. A **Second EMAIL** is sent from the secondary earthworm installation on **nagios** that contains an attached mini-helicorder image. This is not used for SCREAM/system alarms, so only one *sound_alarm* module is required. The parameter file *sound_alarm.d* controls the external script called (*alarm_send_heli.sh*), the mailserver and the list of recipients. Once an alarm message has been received, the script waits for 60s before sending to allow more waveform data to be received and displayed on the attached helicorder. The emails are sent using the command line Perl tool *smtp-cli*, and is again sent from the *mvo.seismic.alarm@gmail.com* account.

5 Data Storage and Analysis

5.1 Hardware

5.1.1 File shares and storage

Data storage

The main storage for the MVO seismic (waveform and event metadata) is on the *seismic_data* share of one of the new virtual fileservers **mvofls2** (172.20.0.52). This a 5TB share that contains ALL of the MVO seismic waveform data (seisan WAV directory) and event catalogue (seisan REA directory) since the installation of the MVO digital seismic network in October 1996. Since the installation and deployment of the MVO Spiders in 2014, waveform data from these station is stored in the same folder structure as *separate* 20 minute seisan format files.

Seisan uses a *NETWORK/yyyy/mm/* directory structure to store archive data. Continuous waveform data from the MVO network is stored in the *WAV/DSNC_/* directory as 20 minute *seisan* format files, and event triggered waveform data in *WAV/MVOE_/*. Note that archived waveform data older than the current year is typically stored compressed (bzip format, .bz2 extension) to save on disk space. Older data that were originally in *OS9* format have been converted to seisan format.

In addition to the main seismic network data, this share also contains the following network folders under WAV and/or REA:

- **IRIG_** This network contains event waveform data from the pre-1996 analogue network. Note this continued to operate until February 2001. For more details see Luckett (2005): “Seismic Data from the Montserrat, Eruption at BGS., Open Report OR/09/57”.
- **GEOTM** Originally standing for *geothermal* this WAV network folder contains waveform data from a variety of recent temporary deployments, for station codes MT[XX]. This was

initially used for the several temporary stations (MTAC, MTM2, MTWW) deployed to monitor seismicity associated with injection of the geothermal wells, but has since been supplemented by temporary stations to monitor lahars in the Belham Valley (MTB1, MTB2, MTB3, MTB4) and a temporary installation at the St. George's Hill site (MTGH) to test a new Guralp Radian instrument. A special *incoming* directory is used to store raw data (typically in miniSEED format) that has not been converted to 20 minute seisan files.

Pre-eruption SRC data

Additionally, there is some event triggered waveform data acquired from SRC, covering the pre-eruptive period in a ten year dataset spanning 1990 up to 2000. This contains data from Montserrat stations that were telemetered to SRC/Trinidad, mostly MBET (Bethel's) and MGHT (St. George's Hill). This data is stored on **piton** in */mnt/local_data/seisan/WOR/Monty_SRC_WAV_pre2000* and backed up in the WAV directory on the *SF1* share on **volcano01**.

Backups

The MVO seismic data is also *backed up* in several places:

- the *SF1* share on **volcano01** (172.20.0.40) was previously used as the main network storage, but subsequently became almost full, and so is now mainly used for backups of the WAV and REA directories from the past few years.
- Note SF1 is separate to the *Seismic_data* share on **volcano01**, which perhaps confusingly does NOT contain seismic waveform data, but is instead used to store helicorder images, spectrograms, RSAM and documentation etc. **NOTE**: there are currently some disk issues with this share and it is likely to become obsolete and/or replaced. Some of the most important data has been backed up on the *seismic_data* share on **mvofls2**.
- The *SF1a* share on **volcano2** (172.20.0.7) also contains a backup of some of the seismic waveform data. However this server has BEEN DOWN/OFFLINE FOR SEVERAL YEARS, please contact DW for current status information.
- An additional backup of the data is stored on a USB RAID disk attached to the **seisan** (172.20.0.25) linux PC. This is a 2.8TB disk, configured in RAID1, that contains a single contiguous backup of the seismic WAV/REA directories. Data is automatically synchronised to this disk daily via a cron/shell script (∼*/bin/seis_data_backup_daily.sh*) on the **seisan** PC.

Temporary data storage

Before being archived to its final location of the **mvofls2** server, data is also stored in several *temporary* locations. These include:

- **mvoscreamXX**: as well as being sent to earthworm, incoming data acquired from the MVO seismic stations are also stored locally on the operational *Scream!* server, in Guralp GCF format in the: *C:\scream\data* directory. This folder is shared and mounted/accessible from **seisan**, **piton** and **seis-imac**.

- **earthwormXX**: continuous data written out as 20 minute seisan files is also stored locally on the operational *earthworm* server, for up 14 days, in the: *C:\monitoring_data\rbuffers* directory. This folder is shared and mounted/accessible from **seisan**, **piton** and **seis-imac**. Storage is controlled by the *dirwatch* earthworm module.
- **volcano01** the continuous seismic data files are also copied to the *current_rbuffers* folder on the *seismic_data* share on **volcano01**, where they are stored for up to 50 days. This folder is shared and mounted/accessible from **seisan**, **piton** and **seis-imac**. Storage is controlled by the *dirwatch* earthworm module.
- **Spiders** - miniSEED and seisan format waveform data files from the Spiders are also temporarily stored in the *monitoring_data\spiders* folder on the *seismic_data* share on **volcano01**, again controlled by *dirwatch* which currently retains up to 7 days of data.
- **Helicorders, Spectrograms and RSAM**. Static helicorder and spectrogram images (gif files), as well as the binary RSAM files are created by *earthworm* and stored locally on the operational earthworm server in the *C:\monitoring_data* folder. These are also stored in the *monitoring_data/* folder on the *seismic_data* share on **volcano01**.

5.1.2 Processing PCs

There are several computers in the Ops room that are used for daily/routine seismic data analysis and processing:

- **seisan** (172.20.0.25) used by the seismic analyst (VB), located on the left-hand side of the Ops room. This is running Debian GNU/Linux 9.7 (stretch) x86_64. This is primarily used for analysis using the *seisan* software package, but performs a variety of other tasks and functions (see next Section(s)).
- **piton** (172.20.0.163) used by the seismologist, located at the back of the Ops, but connected to a screen on the front desk via KVM. This is running Debian GNU/Linux buster/sid x86_64, and is also primarily used for analysis using the *seisan* software package, but again performs a variety of other tasks and functions (see next Section(s)).
- **imac** or **seis-imac**/Seismologist's iMac (172.20.0.162) is an Apple iMac running OS X 10.11.5 (El Capitan) that is used for a variety of non-routine analysis of seismic data, located on the right-hand side of the front desk in the Ops room. It contains an additional (backup) seisan installation, but also uses a Matlab installation to produce daily automated plots (megaplots, pan plots, strain plots etc.), see Section 5.4 for more details.

5.2 Software

5.2.1 SEISAN and associated tools

SEISAN is an open source earthquake analysis software suite developed by The University of Bergen. Written in a mixture of mostly fortran and some C, it is the primary tool used for seismic analysis by MVO, and is installed on: **seisan** (v9.1), **piton** (v11.0) and **seis-imac** (v8.3). It has mostly been compiled from source (the *PRO* directory) with some additional bug fixes and custom modifications made to tailor it for MVO use.

The primary seisan functions used by MVO are: storage and archiving of waveform and event metadata in its *databases*, plotting of waveform data, classification, picking, locations and

focal mechanisms of individual earthquakes in the event catalogue. See Section 5.5 for more information. The seisan manual is located in the *~/INF* directory, with the filename *seisan.pdf*.

Various other associated tools, such as those used to recreate missing helicorders (*rbuffer2heli*) or recover missing data (e.g. *scream2rbuffer*) are stored in the *~/bin* directory). Configuration files (e.g. *rbuffer2heli.d*) for various scripts and programmes are stored in the *~/etc* directory on both **seisan** and **piton**.

5.2.2 Cron

Cron (or cronjobs) is the primary tool used for scheduling tasks on linux or OSX based machines, and is controlled by the *crontab* command. This tool is used extensively to automate a variety of tasks associated with seismic monitoring and processing at MVO. The following are some of the most important/relevant seismic related tasks/scripts for reference:

- **piton**
  - */home/seisan/bin/webobs_wrapper.csh* - This is a wrapper bash script that calls several other perl scripts which parse and filter earthquake metadata from SEISAN S-files into plain text files for use in various matlab scripts on webobs. These are: *webobs_counts.pl* (for earthquake counts data), *webobs_hypos.pl* (for earthquake hypocenters), *webobs_fps.pl* (for focal mechanisms) and *hypos_picks.pl* (earthquake/station pick data). Output is to the *WebObs_Bulletins* directory on the *seismic_data* share on **volcano01**.
  - */home/seisan/bin/clean_scream_dirs.sh* - Delete/removes junk digitiser directories from current *Scream* server that result from corrupted data packets.
  - */home/seisan/bin/latest_events.sh* (and beta version for MVO website) - This script provides a list of the type and time of recent earthquakes as the input for the *latest_events.cgi* script on webobs. See: http://webobs.mvo.ms/cgi-bin/latest_events.cgi.
  - */home/seisan/bin/seismic_data_monthly_report.sh* - emails a monthly report to the seismologist and seismic analyst with details of any missing continuous data from the previous month.
  - *find* and *grep* command to determine list of triggering stations for each triggered event. Output is to the file: *~/Rod/carlsubstalist/carlsubstalist.txt*
- **seisan**
  - */home/seisan/bin/seis_data_backup_daily.sh* - backs up the seismic data (event and continuous waveforms, and event catalogue) to BOTH the locally attached USB disk and to **volcano01** *SF1* share.
  - */home/seisan/bin/mseed2seisan_hourly.sh* - Because of problems with data gaps, seismic data from the spiders is first written as miniSEED files. These are created by the *archman* module on the secondary *earthworm* installation on **nagios**. These miniSEED files are then copied to the *monitoring_data/spiders/ms* folder on the *seismic_data* share on **volcano01**. The *mseed2seisan* script **converts** these files to *seisan* format and outputs the results to the *monitoring_data/spiders/seisan* folder on the *seismic_data* share on **volcano01**.

- **imac**
  - */Users/seisan/src/panacea/pan_cron2.sh* - bash wrapper to call matlab script to produce the daily retrospective "panacea" or "pan" plots (helicorder/spectrogram/seismogram)
  - */Users/seisan/src/MVOMonitoringPlot/megaplot_cron.sh* bash wrapper to call matlab script to produce/update the MVO megaplot(s)
  - */Users/seisan/src/panacea/strain_cron.sh* - bash wrapper to call matlab script to produce the daily retrospective strain plots (similar to the pan plots)

5.3 Missing data

Data from the MVO seismic network is acquired in realtime, and continuous data files are automatically written and archived. Occasionally, however, things can go wrong and data files may end up missing from the continuous data archive. The are several options to attempt to recover any missing data files, depending on the nature of the cause. If data were initially acquired by *Scream!* then there is a good chance they can be retrieved, from either the *Scream*, *earthworm* or *Winston* servers. For a more detailed guide to this process, see: MVO Procedures 26 "*Recovering missing seismic data*", stored in *volcano01/mvo/Procedures/*.)

Note: as data is only stored in some locations for a limited time period, there is also an automatic script (see Section 5.2.2) that runs on the first day of each month to report (by email) to the seismologist and analyst any missing data files.

5.4 Matlab

Matlab is a proprietary scientific software environment developed by Mathworks, that is used at MVO for various analysis, plotting and processing tasks. There are two licensed matlab installations that are relevant to the MVO seismic network on the following machines:

5.4.1 webobs

Matlab is used extensively by the *WEBOBS* system to produce automated plots of MVO monitoring data (not only seismic data) and aid in real-time display. The most relevant matlab scripts for the seismic data, contained in the */mvo/webobs/WWW/TOOLS/MATLAB* directory are:

- *readhyp.m* and *readfps.m* are used to import the hypocenter and focal mechanism data from the text files generated by the perl scripts on **piton** (Section 5.2.2).
- *seismic_hypo.m* - plots maps and graphs of the earthquake hypocenter data (VTs and hybrids) for fixed time periods for display in webobs.
- *seismic_fps.m* - plots maps and graphs of the earthquake focal mechanism (fault-plane solution or *fps*) data (VTs only) for fixed time periods for display in webobs.
- **Note**: there are also standalone versions of these two scripts to generate plots for report writing purposes. The directory *~webobs/seismic/* contains various *ksh* scripts that call the matlab scripts to produce images for a given time period. The output plots appear in, e.g., the */mvo/acqui/Seismic/Hypocentres/Graphs/* directory, with the time code *_xxx.png* in the filenames.

- *mvo_rsam.m* - creates plots of the RSAM data for all stations for fixed time periods for display in webobs.
- *sismobul.m* - creates plots of the counts of different event/earthquake types for fixed time periods for display in webobs.

Relevant here, although not strictly using matlab, are several perl cgi scripts that are used to serve webpages within webobs. These, contained in the */mvo/webobs/WWW/cgi-bin* are:

- *seismic_plot_viewer.cgi* and *seismic_plot_viewer_2.cgi* - used to display the static helicorder, spectrogram and pan plot images. http://webobs.mvo.ms/cgi-bin/seismic_plot_viewer.cgi
- *seismic_plot_viewer_disp.cgi* - similar script, based on the above that displays the integrated displacement channels helicorders http://webobs.mvo.ms/cgi-bin/seismic_plot_viewer_disp.cgi
- *infrasound_plot_viewer.cgi* - similar script, based on the above that displays the infrasound helicorder plots. http://webobs.mvo.ms/cgi-bin/infrasound_plot_viewer.cgi
- *wws_heli_viewer.cgi* - creates adjustable/dynamic helicorder images on demand from the Winston Wave Server. http://webobs.mvo.ms/cgi-bin/wws_heli_viewer.cgi
- *wws_rsam_viewer.cgi* - creates adjustable/dynamic rsam plots on demand from the Winston Wave Server. http://webobs.mvo.ms/cgi-bin/wws_rsam_viewer.cgi
- *latest_events.cgi* - displays the latest earthquakes from the last week superimposed and labelled on a helicorder plot. http://webobs.mvo.ms/cgi-bin/latest_events.cgi
- *taup_arrivals.cgi* - displays the arrival times of phases from recent teleseismic earthquakes for the MVO stations (calculated using *taup*). http://webobs.mvo.ms/cgi-bin/taup_arrivals.cgi

5.4.2 Seismologist's iMac

The matlab installation on the **seismologist's imac** (172.20.0.162) is used for a variety of routine and non-routine seismic analysis.

Matlab scripts are mostly contained in the */home/seisan/src/* directory and include scripts for:

- automatic generation of "**pan plots**" - files are located in the *∼/src/panacea* directory. The shell script *pan_cron2.sh*, calls the matlab script *pan_cron2.m*, which in turn calls *create_panplots2.m* to produce plots for the previous day. The task runs via cron at 01:00 daily.
- In a similar manner, and based on the above - the automatic generation of "**strain plots**" - files are located in the *∼/src/panacea/strain* directory. The shell script *strain_cron.sh*, calls the matlab script *pan_strain.m*, which in turn calls *create_panplots_strain.m* to produce plots for the previous day. The task runs via cron at 07:30 daily.
- automatic generation of the MVO "**megaplot**" - files are located in the *∼/src/MVOMonitoringPlot* directory. The shell script *megaplot_cron.sh*, first calls *fetch_all.m* to retrieve the latest data, then calls the matlab script *megaplot_cron.m*, which in turn calls *create_megaplot.m* to produce plots for the fixed time periods: the whole eruption and last 3 years. It also calls

plot_sgg.m to produce plots of the seismic, GPS and SO_2 data for the last: 2 years, 1 year and 6 months. The task runs via cron at 06:00 daily.

- Various shell and matlab scripts for the analysis of **VT Strings** are located in the *∼/src/MVOMonitoringPlot/VT_strings* directory. This also contains a spreadsheet: *VT_strings_manual_counts.xls* that contains details and a database of manually counted (as opposed to automatically triggered) VT earthquakes during VT strings.

  IMPORTANT NOTE: databases of VT string dates and durations etc. are stored in PLAIN TEXT files in the *∼/src/MVOMonitoringPlot/data* directory. The files to update are:

  1. *VT_string_dates.txt*
  2. *VT_string_dates_only.txt*
  3. *VT_string_dates_SurfAct.txt*

  FURTHER IMPORTANT NOTE: this same directory (*∼/src/MVOMonitoringPlot/data*) also contains the csv file: *SO2_traverse_data_from_TC_latest.csv* that is used to store the SO_2 helicopter *TRAVERSE* flux values. It is currently **MANUALLY UPDATED** on receipt of flux values from TC.

- Other various scripts for producing standard figures for the MVO scientific reports etc. These are typically stored in their own folders within *∼/src/MVOMonitoringPlot*, e.g. *MVO_OFR1802/* for the latest MVO 6-month report, and can be copied and adjusted as required.

- Other scripts and functions useful for matlab are stored in the *∼/Documents/MATLAB/* directory. Note this includes the seismological packages *GISMO* and *waveform_suite*, whose directories have been added to the Matlab path. These are contain extremely useful tools, in particular via the use of waveform objects, and are used extensively in the creation of e.g. the pan plots. See: https://geoscience-community-codes.github.io/GISMO/ and https://seiscode.iris.washington.edu/projects/thewaveformsuitezetatest

5.5 Routine analysis

Most routine analysis of seismic *events* from individually triggered earthquakes at MVO is conducted via SEISAN. The basic workflow for triggered events is as follows:

1. Run “fetch_events” to retrieve new event files to the current directory (typically the seisan WOR/working directory). This identifies event files in the *monitoring_data/events* folder on the operational earthworm server that have NOT been registered into the SEISAN event database, copies the waveforms to the working directory, and uses the *dirf* command to create a list (*filenr.lis*) of events which can be viewed via *mulplt*.
2. The “mulplt” command is used to display and view the earthquake waveforms before → classification.
3. Classification is first based on distance: Teleseismic (D), Regional (R) or Local (L) plus, if volcanic, there is the special Local volcanic (LV) category, with the following sub-categories:

- Long-period rockfalls/LPRF (e)
- Hybrid (h)
- Long-period (l)
- Rockfalls/PFs (r)
- Volcano-Tectonic/VT (t)
- Explosions (x) - RARELY USED

4. Earthquakes are then located (if appropriate: normally only VTs, Hybrids). P and S-wave arrivals are picked, plus polarities and amplitudes for local magnitudes.

5. The location programme *hypocenter* is called from within seisan (eev) using the 'l' command. Changes are confirmed by "updating" the event. The location algorithm parameters, station information and the velocity model are controlled by the **STATION0.HYP** file in the seisan *DAT* directory. For more details of hypocenter and the adjustments to the velocity model used at MVO since the introduction of the spiders see the document: MVO Procedures 45 "*Changes to the datum and velocity model used for MVO earthquake hypocenters*", stored in *volcano01/mvo/Procedures/*.

6. Focal mechanisms. These are normally calculated using ALL 3 available tools from in seisan: PINV (*fi* command), FPFIT (*fp*) and HASH (*fh*). Only FPFIT good quality (A) solutions are used for plots/analysis, e.g. in the matlab scripts to produce plots for webobs and scientific reports (Section 5.4)

7. The *weekly_counts* script can be used to produce counts of volcanic earthquake/event types during the previous 7 days for the MVO weekly reports.

5.6 Display and access

5.6.1 Tools

Several software tools and packages are used for access and display of the realtime MVO seismic data. The first is via **webobs** whose web interface can be used to view static/dynamic helicorders, spectrograms, pan plots, counts, hypocenters, focal mechanisms and RSAM data:

- http://webobs.mvo.ms/cgi-bin/seismic_plot_viewer.cgi
- http://webobs.mvo.ms/cgi-bin/wws_heli_viewer.cgi
- http://webobs.mvo.ms/cgi-bin/putHtml.pl?h=mvo_rsam_visu.htm
- http://webobs.mvo.ms/cgi-bin/wws_rsam_viewer.cgi
- http://webobs.mvo.ms/cgi-bin/latest_events.cgi
- http://webobs.mvo.ms/cgi-bin/putHtml.pl?h=sismobul_visu_30d.htm
- http://webobs.mvo.ms/cgi-bin/putHtml.pl?h=sismohyp_visu.htm
- http://webobs.mvo.ms/cgi-bin/putHtml.pl?h=seisfps_visu.htm

However for more interactive display of the real-time waveform the java-based **SWARM** software, developed by USGS is used (https://volcanoes.usgs.gov/software/swarm/). This software partners well with Winston (see Section 4.2.4) and is designed to pull data from a Winston WaverServer (or other source).

5.6.2 Display computers

There are two dedicated (Windows-based) *display* PCs in the Ops Room, facing the door. These are:

- **MVOWXP002**. This Windows XP PC typically runs *SWARM* to show the real-time waveform data in map mode (this is saved as a layout in the swarm menu). On the secondary (portrait) monitor it also displays the helicorder images from webobs in a web browser window. **NOTE:** This machine also runs a tertiary earthworm installation for the alarm phone calls (see Section 4.3)
- **seis-display** - This Windows XP PC runs *SWARM* on multiple monitors to display interactive live helicorder displays from several (usually 4) key seismic stations. These typically display the last 12 hours of data (these are saved as layouts in the swarm menu for different station combinations)

5.6.3 Access

NOTE: once the correct datasources/Winston servers are configured, *Swarm* can be used to access and display real-time waveform from ANY (internal) location within MVO. Since it is *java* based Swarm should run on most operating systems. The Winston Wave Servers that can be accessed are:

- **earthworm01** - 172.20.0.14
- **earthworm02** - 172.20.0.33
- **nagios** - 172.20.0.62

(see Section 4.2.4).

To use these in Swarm, click on the add datasource icon in the top left hand corner and input the ip address into the Winston Wave Server box (port is default: 16022)

6 Other miscellaneous information

6.1 Hosting of virtual machines

The following is a list of host and virtual machines in use by MVO, showing which VMs are hosted where (disclaimer: this is only to the best of my knowledge - please contact DW for more info):

- host **mvohvs1** (172.20.0.28) - windows server using HyperV to host the following guest/virtual servers:

  - **earthworm3** - 172.20.0.38

- host **mvohvs2** (172.20.0.29) - windows server using HyperV to host the following guest/virtual servers:
  - **mvocobweb1** - 172.20.0.64
  - **mvofls2** - 172.20.0.52
  - **mvolinuxtest** - 172.20.0.63
  - **mvoscream3** - 172.20.0.39
  - **seiscomp1** - 172.20.0.61
  - **webobs** - 172.20.0.16

  .

- host **mvohvs3** (172.20.0.30) - windows server using HyperV to host the following guest/virtual servers:
  - **mvoex1** - 172.20.0.45

  .

6.2 Seiscomp

Seiscomp3 is a seismic processing software package, developed by GFZ Potsdam, that is becoming a standard used in various seismological observatories. In order to explore the possibility of using Seiscomp as an additional component of MVO's seismic processing workflow, a virtual machine dedicated for the use of Seiscomp was created: **Seiscomp1** (172.20.0.61). This a linux-based server running Debian GNU/Linux 9.7 (stretch) x86_64, hosted on the **mvohvs2** physical server. This currently has a basic and largely unconfigured version of Seiscomp installed. Access is via *ssh* or *rdesktop* (a VNC server is configured for graphical sessions) using the normal seisan account username/password. **NOTE:** the root password for the machine is the *same as that used for* **webobs**

6.3 Nagios

Nagios is an open-source network monitoring tool, designed for monitoring connectivity and disk shares across a computer network. MVO maintains a nagios installation to monitor the status of monitoring hardware (PCs, stations, radios, other ethernet-enabled devices) and disk shares on the MVO network and report to key staff via email (including the seismologist).

Nagios is installed on the **nagios** (172.20.0.62) PC, a linux-based PC situated at the back of the Ops Room. Configuration is controlled by files in the: */usr/local/nagios/etc/* directory. Due to time constraints a more detailed discussion of the nagios installation and configuration is beyond the scope of this document.

This PC also has several other functions including a secondary earthworm installation (see Section 4.2) and a backup Winston Wave Server (see Section 4.2.4)

NOTE: it also serves as backup to **webobs** as the original webobs environment is still installed on a secondary hard drive attached to this machine (mounted as: */mnt/webobs0/* on **nagios**). This backup can be utilised by a dual-boot setup on the PC, which allows the choice to boot into the old webobs environment.

Root password
The normal login for this machine is under the normal *seisan* username and password. However, the root password is simply: “nagios”.

6.4 Webobs

6.4.1 Overview

WEBOBS is the main internal webserver used by MVO for accessing and displaying incoming monitoring data. The webserver is hosted by an Apache2 installation on a dedicated virtual linux-based webserver: **webobs** (172.20.0.16), hosted on the physical server (**mvohvs2**, 172.20.0.29)

See the “webobs” network page http://webobs.mvo.ms/cgi-bin/afficheSTATION.pl?id=VMQWEB0 for more details.

6.4.2 Boot issues

NOTE: this server is currently experiencing booting issues - possibly due to a conflict between the HyperV server manager and an unsupported linux kernel/version which causes the server to **HANG ON BOOT**. Should the server reboot/be restarted (due to a crash/power failure) it currently requires **MANUAL INTERVENTION** in order to choose to boot into rescue mode and start the operating system. To do achieve this, the user must first log into the host machine (**mvohvs2**, 172.20.0.29) via a remote desktop session in order to then connect to the **webobs** server and intervene in the boot process.

The steps to follow if webobs reboots and hangs are:

1. Connect to host machine **mvohvs2** (172.20.0.29) via an rdesktop session. I believe that currently only DW and PS accounts have access to this - NEED TO GET DW TO GIVE SOMEBODY ELSE (RS??) this status
2. Once logged in, open the HyperV manager
3. Connect to the **webobs** server and bring up a window/display
4. If webobs is hung, it will probably be stuck at ”loading initial RAM disk”. Right click on webobs server in HyperV-manager and click ”reset”
5. Return to connected webobs window
6. From the boot menu choose “Advanced options for Debian GNU/linux” $\rightarrow$, then from the next menu choose the top/latest kernel with **(recovery mode)** displayed.
7. Boot will now proceed, but will not complete. Once it stops or gets stuck press “CTRL-D” as instructed and webobs will COMPLETE BOOT normally.

6.4.3 Development site

MVO maintains a separate development (DEV) version of the webobs website, primarily for testing purposes. Some versions of seismic related scripts and functionality (e.g. the helicorder viewer: *seismic_plot_viewer.cgi*) are slightly different compared to the main webobs site. Scripts and configuration are found in the */mvo/webobs/WWW_DEV/* directory.

The development site can be accessed at https://webobs.mvo.ms:8000/ (note the http**s**) but only **from internally** at MVO.