Response Hydra v1.47

User Guide

Contents:

Chapter 1: Getting Started

1.1 Response Hydra Overview

Response Hydra has been designed and developed by USGS/NEIC in the context set by Ray Buland and Harley Benz. It is currently used for detection, processing and reporting of world-wide earthquakes by the National Earthquake Information Center (http://earthquake.usgs.gov/regional/neic/). The latest released version of Response Hydra is 1.47 (released in 2007).

Figure 1 depicts an overview of the Response Hydra earthquake processing system. Real-time data processing is carried out by Earthworm-based protocols (Section 1.2). The purpose of this system is to process trace data for picks, associate picks into origins, determine initial rough locations and insert all data into Oracle Hydra database for further processing.

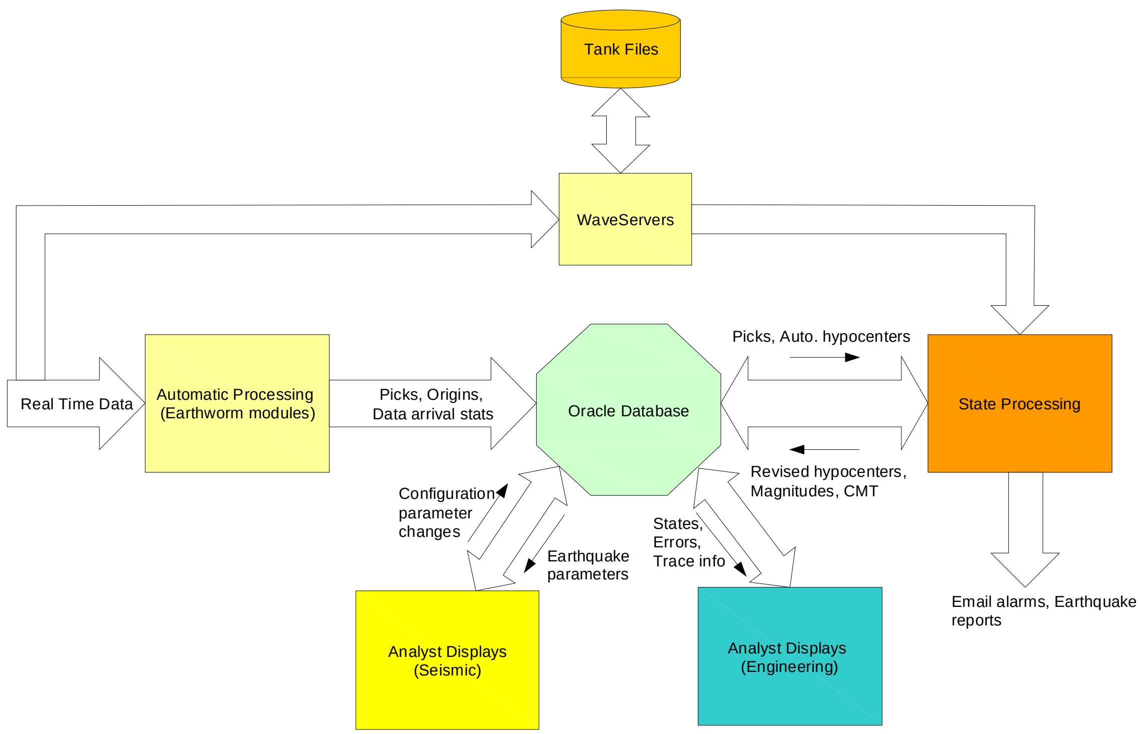


Figure 1: Hydra Architecture Overview

The Response Hydra database is an Oracle 9i system. The data stored in the database consists of nearly everything generated by the real-time and state processing layers as well as human-assisted changes made via Analyst Displays. The only major data type not stored in the database is the actual trace data. Trace data is stored by waveservers (tank files) which are running as part of the Earthworm layer.

Near real-time and post processing of event data is carried out by State Processing modules which depart from Earthworm-style protocols (Section 1.3). They encompass the idea of passports. A passport is a collection of settings used to calculate parameters for a particular event. State processing modules calculate event locations, magnitudes, moment tensors, publish event bulletins and send out event notifications. State processing is triggered either by Earthworm layer inserting another origin into the database or by human interactions via Analyst Displays. Engineering Analyst Displays enable the user to view Hydra state-of-health. Seismic Analyst Displays enable manual re-processing of seismic events. It is important to note that the displays do not do any processing and are just used for manual passport changes and viewing of seismic results.

1.2 Earthworm Hydra Layer

Earthworm Hydra processing layer consist of a series of standard and Hydra-specific Earthworm modules. It is tasked with analyzing real time data, discovering new origins and passing them on to State Processing layer for near-real time and post processing. Figure 2 depicts modules that make up Earthworm automatic data processing layer and its data flow:

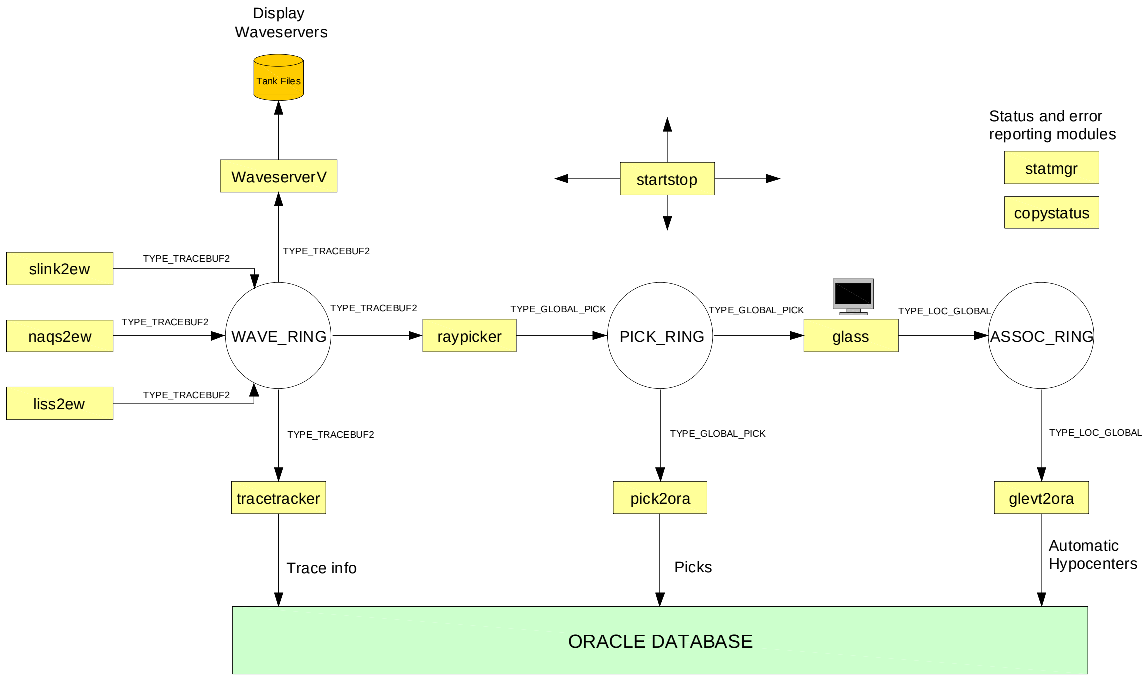


Figure 2: Earthworm Data Processing Layer

Naqs2ew, Slink2ew and *Liss2ew* are all standard Earthworm modules used to acquire data from Nanometrics NaqsServer, SeedLink Server and Live Internet Seismic Server respectively. All trace data is placed in WAVE_RING memory buffer for further processing. *WaveserverV* module stores trace data into Tank files in which data is kept for use by State Processing modules and Analyst Displays. *Tracetracker* module keeps track of the total number of trace packets received for each channel as well as the time of the last received packet. This information is inserted into the database and can be viewed through SCNLTracker Analyst Display (Section 3.3.2).

Raypicker uses an STA/LTA-based algorithm to process data for picks after filtering it first. Picks are placed in PICK_RING memory buffer. Every pick is inserted into the Oracle database by *Pick2ora* module.

Picks are associated into events by *GLASS* (GLobal ASSociator) module. *GLASS* consists of four mechanisms for producing earthquake origins: Associator, Nucleator, Locator and Filters. Nucleator (core GLASS technology) is responsible for discovering new origins. Associator associates new picks with existing origins. Locator refines origin hypocenters and Filters eliminate origins and pick-origin associations that do not meet certain hard-coded and user-defined criteria. Filters also determine which, and how often origins get published to ASSOC_RING. For more information on GLASS operation and configuration, consult GLASS Manual that is supplied in conjunction with Response Hydra v1.47 User Guide. *Glevt2ora* module is in charge of inserting new origins into Oracle database. Inserting a new origin into the database sets in motion Hydra State Processing Layer as described in Section 1.3.

Additional Earthworm-based modules not shown in Figure 4 can be incorporated into the system as per user requests. For example, *Waveman2disk* and *Contrec* modules can be included to convert continuous, on demand or trigger trace data into any of the following formats: SAC, SUDS, Seisan, GSE and AH.

1.3 State Processing Hydra Layer

Hydra State Processing layer modules are responsible for calculating earthquake parameters for events residing in the Hydra database. Hydra state processing is performed in parallel and independently of real-time automatic Hydra Earthworm processing described in Section 1.2.

Figure 3 illustrates software utilities involved as well as typical state processing sequence.

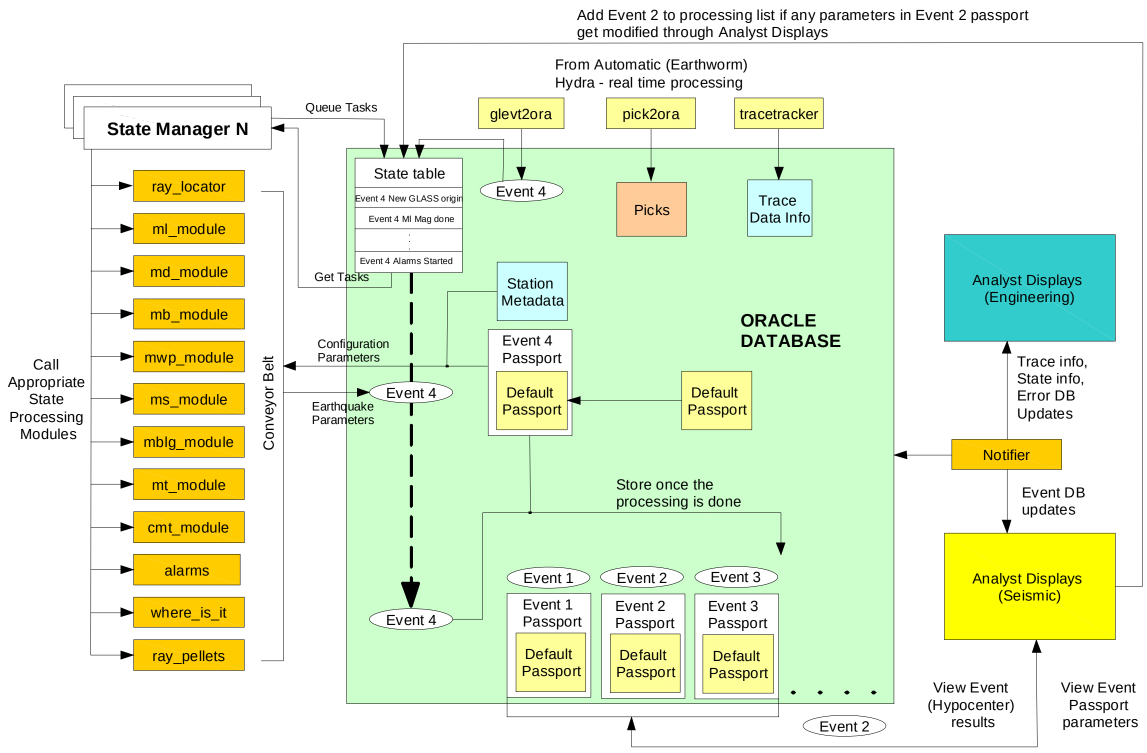


Figure 3: State Processing Layer

The event processing is driven by a State Table (sort of a To Do list) that is maintained within the database. The State Table maintains a queue of outstanding work that is to be done. For example, the table may contain entries (states) such as “New Event 56 origin inserted” or “ms_module calculated Ms Magnitude for Event 34” etc. These entries indicate the state of each event that is being actively processed by the system. The State Table is monitored by State Manager modules.

The State Managers are responsible for keeping track of states of all events being processed at the time, and invoking appropriate state processing modules (“conveyor belt”). The configuration settings for all state processing modules are kept in Passports. Each event that exists in the database has a corresponding passport which contains unique settings used to calculate that event’s earthquake parameters. As a new origin or a new origin for an existing event is inserted into the database, the State Manager invokes *Ray_locator* module to refine its location. This is as GLASS module performs only rudimentary earthquake locations (its main purpose is associating picks and discovering new origins). Once the *Ray_locator* module has finished its execution, a new state is inserted into the State Table indicating that the location has been computed, and that the origin is ready for magnitude calculations. The next available State Manager checks the new state and invokes magnitude calculation modules to do their processing on the origin. Hydra magnitude modules can run concurrently (as the output of one does not affect the calculations performed by the other). The following magnitudes are currently supported: Md, Ml, Ms, Mb, Mwp and Mw. Additionaly, Moment Tensor (*mt_module*) and Centroid Moment Tensor (*cmt_module*) solutions are produced if calculated Ms or Mb magnitudes are larger than 5.5 and several additional constraints are satisfied.

The “conveyor belt” processing of the event is completed by *Alarms*, *Where_is_it* and *Ray_pellets* modules. *Alarms* module sends email notifications based on the official magnitude and location of the event. In Nanometrics implementation of Hydra, *Alarms* module output is not used as event notification functionality is built into Athena publishing software. *Where_is_it* module asks an external geographical server (Geo Server) for the geographical region in which the earthquake occurred as well as the distances to the closest cities. Geo Server is USGS-specific software and is not supplied as part of standard Hydra installation. Consequently, *Nearest Cities* and *Region* sections in all Hydra displays (Section 3.0) are left empty. *Ray_pellet* module is in charge of generating IMS1.0 format bulletins (raypellets) which catalog all earthquake parameters and are parsed by Athena.

Once the event has passed through the conveyor belt, it is stored in the database together with its Passport. An event can be reprocessed (put back on the “conveyor belt”) in one of two ways: new origin for that event has been inserted by Earthworm modules (as new arrivals get associated with an existing event by GLASS), or by a seismologists making changes through Analyst Displays (as described in Section 3.0).

At Hydra Server installation time a default passport is inserted into the database. It contains all information required by state processing modules to calculate various earthquake parameters. The first set of earthquake parameters is always calculated using the default passport. All subsequent parameters may be calculated using Passports edited through Analyst Displays.

Analyst Displays enable seismologists and system administrators to see view and modify earthquake parameters (see Section and observe the current Hydra system state of health.

1.4 Hydra Software Structure

All Response Hydra Server processes run as part of the following four services:

1. *Earthworm StartStop* Service (Section 1.4.1)
2. *Hydra Guardian Angel* Service (Section 1.4.2)
3. *Hydra Cleandir* Service (Section 1.4.3)
4. *Hydra Reaper* Service (Section 1.4.4)

The services are installed automatically by Hydra Server installer (Section 2.1). All four services are set to start automatically on boot up. In addition to the four Hydra-specific services, there are two more Oracle services that have to be running on the Response Hydra machine:

1. *OracleOraHome92TNSListener*
    - TNS Listener service allows communication between the Oracle database server and its clients. This service has to be running in order for Analyst Displays running on different workstations to be able to connect to Oracle Hydra database. The installation and configuration of this service is described in Section 2.1.1.2.
2. *OracleServiceewdb*
    - Hydra database instance. This service is installed and configured during Response Hydra Server installation by *HydraServer_windows_1_47.exe* installer (Section 2.1.2).

1.4.1 Earthworm StartStop Service

Earthworm StartStop service ensures that all Earthworm-based Hydra modules are running. When the service is started up, it looks at */hydra/run/params/startstop_nt.d* configuration file to get a list of modules that should be started. Once started, the modules send out heartbeat messages every 30 seconds. The heartbeats are monitored by *Statmgr* module. If the heartbeat for a particular module has not been received for 60 seconds, the *Statmgr* issues a request to StartStop service to restart that particular module. The following is a list of modules started and maintained by StartStop service:

- *Naqs2ew*
  - Acquires trace data from Nanometrics NaqsServer
- *Slink2ew* (optional)
  - Acquires trace data from SeedLink Server
- *Liss2ew* (optional)
  - Acquires trace data from Live Internet Seismic Server
- *WaveServerV*
  - Stores trace data in Tank files and services external data requests.
- *Tracetracker*
  - Keeps track of the total number and the time of the last received trace data packet.
- *Raypicker*
  - Processes real-time trace data for phase picks.
- *Pick2Ora*
  - Inserts picks into Hydra Oracle database.
- *GLASS*
  - Discovers new origins, associates picks with existing origins and does *rudimentary locations.*
- *Glevt2ora*
  - Inserts new and updated origins into the Hydra Oracle database.
- StatMgr
  - Monitors heartbeats of all Earthworm processes and restarts them if they are hung.

1.4.2 Hydra Guardian Angel Service

Hydra Guardian Angel service ensures state processing modules are automatically started and continuously running. It does so by starting and maintaining *State Managers* which are in turn responsible for invoking all other state processing modules. Unlike *Statmgr* in Earthworm-based system, Hydra Guardian Angel does not use heartbeats but keeps track of process ids and restarts any hung processes. The following is a list of processes started and maintained by Hydra Guardian Angel as listed in */hydra/run/params/GuardianAngel.d* configuration file:

- *Notifier*
  - Sends database heartbeats that drive database connection widgets on all displays (thus indicating live connection).

  - Sends database updates to all displays.
- *State Manager 1*
  - Checks Hydra database State Table and calls appropriate state processing modules.
- *State Manager 2*
  - Checks Hydra database State Table and calls appropriate state processing modules.
- *Gen_assoc_stats*
  - Generates pick association statistics for all incoming channels (ratio of total number of picks to associated picks).
- *Post_bulletin*
  - Monitors /hydra/outdir folder for new raypellets and posts them to Athena event publisher database.

1.4.3 Hydra Cleandir Service

Hydra Cleandir service deletes files in specified directories that are older than configurable time period. The purpose of this service is to ensure that the hard drive does not get filled up with log files which are created on a daily basis. The folders that are to be monitored and the time after which files are to be deleted are specified in */hydra/run/params/cleandir.d* configuration file. The following directories are monitored by default:

- /hydra/run/log
- /hydra/run/params/picks
- /hydra/run/log/locator

The user can also add any other non-Hydra related directories to be monitored by this service.

1.4.4 Hydra Reaper Service

The Hydra Reaper service checks and deletes data from the Hydra database that is older than a configurable time period. Hydra database table space is of finite size and if it were to get filled up, no new events could be inserted or processed. The service is configured through */hydra/run/params/hydra_reaper.d* configuration file. By default, data older than 60 days is deleted from the database.

1.4.5 Hydra Directory Structure

Figure 4 depicts Response Hydra directory structure. The default installation root directory is C:\hydra. It is recommended that the user install all files in the default root directory.

All Hydra (Earthworm modules, Services, State Processing modules, Analyst Displays) executables are located in */hydra/bin* directory. The path to this folder is added to the Path environment variable so that all modules can be accessed from any directory. Installation-specific setup files are located in */hydra/install_main* folder. This folder can be deleted following the successful installation.

Response Hydra outputs IMS1.0 bulletins (also referred to as raypellets) containing all earthquake parameters. These files are parsed by Athena event publisher and stored in */hydra/raypellets* folder. This folder is monitored by Clean_dir service to ensure raypellet files older than 15 days are deleted.

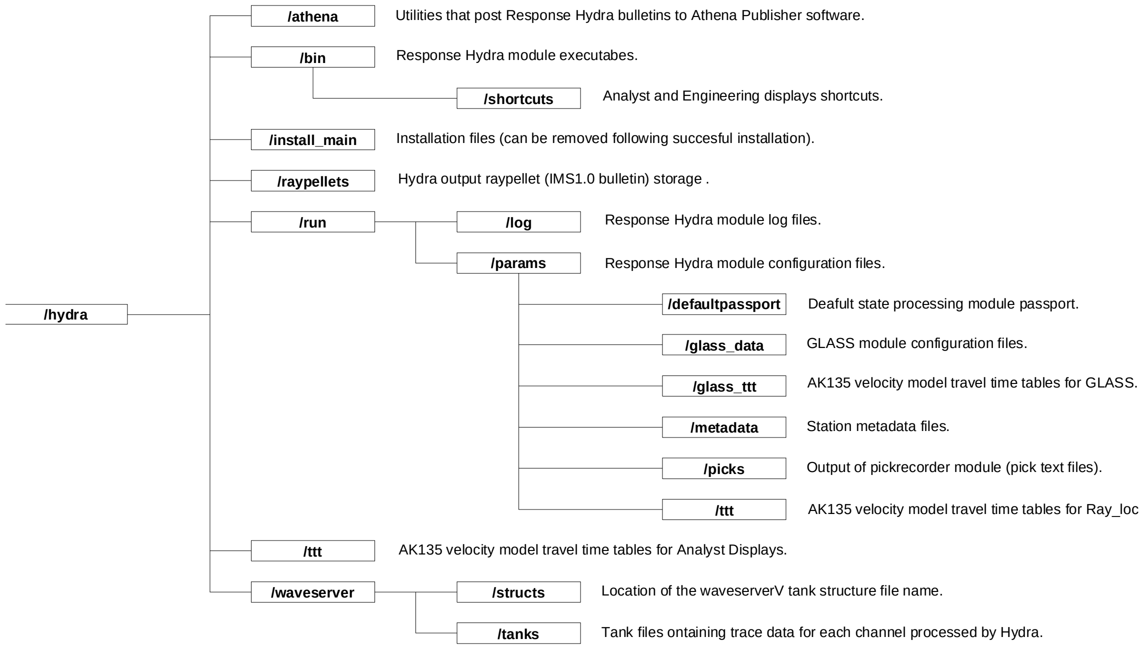


Figure 4: Response Hydra Directory Structure

All modules and displays produce log files which are stored in */hydra/run/log* folder. This folder is also monitored by Clean_dir service and logs older than 15 days are deleted. */hydra/params* folder contains configuration files for all Earthworm-based modules, State Processing modules and Hydra services. Default passport is stored in the */hydra/run/params/defaultpassport* folder. Default station metadata and poles and zeros files are stored in */hydra/run/params/metadata* folder. It is recommended that the user keep up to date copies of station metadata files in this folder in case this information ever has to be re-inserted into the database. GLASS Earthworm module has additional configuration files which are stored in /hydra/run/params/glass_data.

Finally, there are three sets of AK135 velocity model travel time tables:

- /hydra/run/params/glass_ttt -> Used by GLASS module.
- /hydra/run/params/ttt -> Used by Ray_loc state processing module.
- /hydra/ttt -> Used by Analyst Displays.

Chapter 2: Installation

Response Hydra components are grouped and installed as two separate systems.

1. Response Hydra Server containing:
   - Hydra Oracle database instance
   - Hydra real-time data processing Earthworm modules
   - Hydra State Processing modules
   - Hydra Wave Server modules
2. Response Hydra Displays Client containing:
   - Hydra Seismic Data Analysis displays
   - Hydra State-of-Health displays

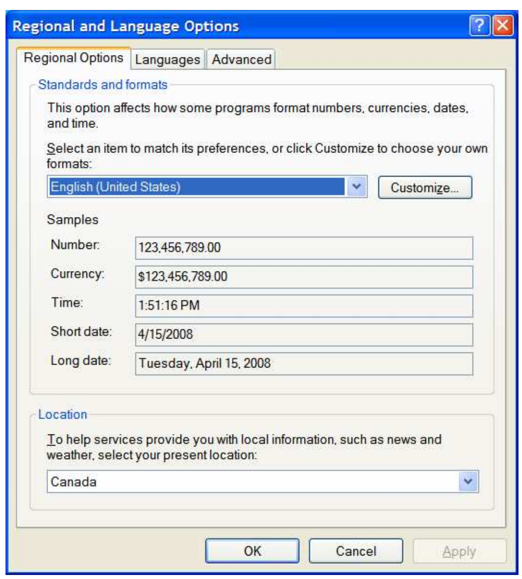
Response Hydra Server can be installed on two separate workstations to operate in Primary/Backup configuration. In this configuration, Primary (referred to as Red) and Backup (referred to as Blue) Hydra Servers are installed and running in parallel. The Primary Server produces IMS2.0 format bulletins and interfaces to event publishing software. The Backup Server processes all real-time data independently, and can take over as the primary system in case of Red Hydra failure. Response Hydra Displays Client installation produces user interfaces for connections to both databases.

2.1 Response Hydra Server

2.1.1 Pre-installation Tasks

IMPORTANT NOTES:

- Prior to Oracle 9i Server installation, the user should confirm the workstation language settings are correct.
  1. Go to Control Panel -> Regional and Language Options.
  2. Ensure that the language setting is set to English (United States).



- The Hydra Server workstation ha to be configured with a working *STATIC IP ADDRESS* and physically connected to the network.

- The following three tasks must be performed prior to Response Hydra Server installation and setup:
    1. Oracle 9i software installation (Section 2.1.1.1)
    2. TNS Listener setup (Section 2.1.1.2)
    3. Disabling of unnecessary Oracle services (Section 2.1.1.3)

2.1.1.1 Oracle 9i Software Installation

1. Insert the CD labeled *Oracle 9i Database Release 2 (9.2.0.1.0) for Microsoft Windows NT/2000/XP CD 1 of 3* into the CD-ROM drive.
2. The Oracle Installer should auto run. If The CD does not auto run, execute the program *setup.exe* in the root directory of the CD.
3. From the Installer, choose *Install/Deinstall Products*.
4. The Oracle Universal Installer should now run. Click next.
5. In the *File Locations* Selection menu, ensure that the Destination path is set to "c:\oracle\ora92". If the Destination path is not this case, the Response Hydra Server Installer will be unable to automatically configure the TNS Listener.
6. In the next menu, *Available Products,* choose the first selection, *Oracle9i Database 9.2.0.1.0*. Click Next.
7. Choose *Enterprise Edition* in the *Installation Types* menu. Click Next.
8. Select *Software Only* in the *Database Configuration* menu.
9. In the *Oracle Services For Microsoft Transaction Server* menu, accept the default port number. Click Next.
10. The next menu is a summary of the installation choices made in the previous steps. Click *Install* to confirm these choices and install Oracle 9i.
11. Provide the installer with the CDs labeled *Oracle 9i Database Release 2 (9.2.0.1.0) for Microsoft Windows NT/2000/XP CD 2 of 3* and *Oracle 9i Database Release 2 (9.2.0.1.0) for Microsoft Windows NT/2000/XP CD 3 of 3* as prompted.
12. When he installer is finished, click *Installed Products.*
13. Browse to *Oracle Homes -> ora92 -> Oracle 9i Database*. Check the box next to *Oracle Intelligent Agent*. Click *Remove.*
14. Confirm the removal of *the Oracle Intelligent Agent* and 7 additional dependant products. Click Yes.
15. Click Exit to close the Installer.
16. The *Oracle Enterprise Manager* will now auto run.
17. In *Add DBMS to Tree*, select *Cancel*, and exit the *Oracle Enterprise Manager.*
18. The Oracle 9i database software is now installed.

2.1.1.2 TNS Listener Setup

TNS Listener service establishes and maintains client connections with Oracle database services.

1. Launch the *Net Configuration Assistant* by choosing *Start -> Programs -> Oracle – OraHome92 -> Configuration and Migration Tools -> Net Configuration Assistant.*
2. In the *Welcome s*creen, choose *Listener Configuration.* Click Next.
3. In the *Listener Configuration* screen, select *Add*. Click Next.
4. In the *Listener Name* screen, accept the default name *LISTENER*. Click Next.

5. In the *Select Protocols* screen, accept the default selected protocol *TCP*. Click Next.
6. In the *TCP/IP Protocol* screen, accept the standard port number *1521*. Click Next.
7. In the *More Listeners* screen, select *No*. Click Next.
8. Listener configuration is complete. Click Next.
9. Click Finish to exit the *Net Configuration Assistant.*
10. The Listener is now set up. It will be automatically configured by the Response Hydra Server Installer.

2.1.1.3 Disabling Unnecessary Oracle Services

1. Launch the *Services* manager by choosing *Start -> Settings -> Control Panel -> Administrative Tools -> Services.*
2. Select the service named *OracleMTSRecoveryService*, Right Click, and choose *Properties.*
3. In the *Properties* screen, choose *Stop* to stop the service.
4. In the *Startup Type* section of the *Properties* screen, choose Disabled.
5. Choose *Ok* to confirm the changes and exit the *Properties* screen.
6. Select the service named *Oracleora92HTTPServer*, Right Click, and choose *Properties.*
7. In the *Properties* screen, choose *Stop* to stop the service.
8. In the *Startup Type* section of the *Properties* screen, choose Disabled.
9. Choose *Ok* to confirm the changes and exit the *Properties* screen.
10. The unnecessary Oracle Services are disabled. Confirm that *OracleOraHome92TNSListener* service Status is *Started* and that its Startup Type is *Automatic*.
11. Reboot the computer.

2.1.2 Response Hydra Server Installation and Setup

1. Ensure that you have Administrator privileges on the machine where the installation is taking place. Copy Response Hydra Server Installer to the root directory.
2. Start the Response Hydra Server Installer by launching *HydraServer_windows_1_47.exe*.
3. On *Select Components* screen click on Next.
4. On *Select Destination Directory* screen it is recommended that Destination directory be left as C:\hydra. Click Next.
5. On *Hydra Configuration* screen, enter the appropriate values as follows:

   <u>Hydra Server IP Address</u> – static IP address of the workstation on which Hydra Server is being installed

   <u>System Installation</u> – select if this is a Primary (Red) or Backup (Blue) Hydra Server installation (if only one server is to be installed, select Red).

   <u>Earthworm Installation ID INST_</u> – enter the unique Earthworm installation ID as assigned by Barbara Bogaert (bogaert@usgs.gov) to be included in the earthworm_global.d file.

   <u>Hydra Notifier Multicast IP and Port</u> – multicast IP and port on which Hydra Notifier utility will broadcast Hydra database updates and heartbeats.

   <u>EW Oracle Domain</u> – domain name of the Oracle database.

Wave Server Port – port on which client modules connect to Wave_Server.

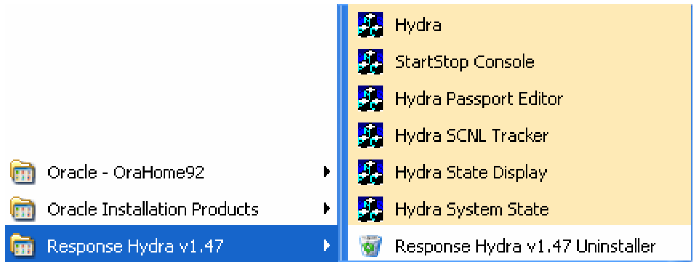
6. Click Next on *Hydra Configuration* window. An Information screen will come up stating that Ruby on Rails installer will now auto-run. Click Next.
7. On *Welcome to the Ruby-186-26 Setup Wizard* window click Next.
8. Select *I Agree* on *License Agreement* window.
9. Leave the default components selected and click Next on *Select Components* window.
10. Leave the default installation location and click Next on *Choose Install Location* window.
11. Click Install on *Choose Start Menu Folder* window.
12. Once the installation is complete click Next. Uncheck the *Show Readme* checkbox on *Completing the Ruby-186-26 Setup Wizard* window, and click Finish.
13. Following the installation of Ruby, Hydra Server installer will resume database instance installation, database schema setup and Hydra module configuration. These steps may take up to 45 minutes depending on the speed of the workstation.
14. Once the Setup has finished, reboot the workstation when prompted to do so.
15. Following the reboot, insert a DVD marked “Green’s Functions”. This CD contains a file gfs_lp_1km.zip with Green’s functions used by Mt module. Unzip the contents of this file to *c:\hydra\run\params\gfs_lp_1km* folder. Please note that Green’s functions are 3.5Gb in size and thus file extraction may take a long time.

2.1.3 Confirming Successful Installation

Note: All steps in 2.1.3 and 2.1.4 sections assume that Hydra Server has been installed in the default C:\hydra root directory.

Following the workstation reboot in step 6 of the previous section, confirm that the Response Hydra Server has been successfully installed as follows:

- Verify that two State Managers, Association Statistics and Post_bulletin modules are running by checking that there are four Command Prompt windows open named: *state_manager state_manager.d 1*, *state_manager state_manager.d 2* and *gen_assoc_stats gen_assoc_stats.d* and *outdir* (post_bulletin module monitoring /hydra/outdir folder for new raypellets).
- Verify that GLASS module is running by confirming that the following seven interfaces are up and running: *ManQuake, Residuals, Map, Catalog, Summary, Publisher* and *Glass Status – v1.61*.
- Go to Control Panel -> Administrative Tools -> Services and confirm that the following six services are running and that their Startup Type is set to *Automatic*): *Hydra cleandir, Hydra Guardian Angel*, *Hydra Reaper, Earthworm StartStop, OracleOraHome92TNSListener* and *OracleServiceewdb*. If any of the aforementioned four Hydra services have not been installed, they can be installed manually as follows:
    - C:\hydra\bin\cleandir.exe –install
    - C:\hydra\bin\hydra_reaper.exe –install
    - C:\hydra\bin\startstop_service.exe -install
    - C:\hydra\bin\GuardianAngelConsole install_db
- Verify that all Earthworm-based modules have started by going to Start -> All programs -> Response Hydra v1.47 -> StartStop Console. Click on *Create New Console* button and type *status* in the newly created Command Prompt window. This should list all Earthworm-based modules that have been installed. Confirm that the Status column for each module (except for *raypicker*) shows Alive.



2.1.4 Post Installation Setup

Once the successful installation of the Response Hydra Server software has been confirmed, the system has to be configured with customer-specific seismic station information. Before proceeding to the following steps, ensure to stop all four Hydra services (Control Panel -> Administrators Tools -> Services) for the duration of the setup. Once the configuration is complete all four services can be restarted by rebooting the machine.

The first step is to insert default passport and station metadata into the database, followed by creation of Glass and picker station files, wave_server tank file setup and finally data acquisition module setup.

2.1.4.1 Default Passport Insertion

A passport is a collection of parameters for a given event. For each Hydra Server installation, a default passport has to be inserted into the database to be used in automatic data processing. Some passport parameters can be changed during post processing through Analyst Displays. In order to insert default passport into the database, do the following:

1. Go to Start -> All Programs -> Response Hydra v1.47 -> Hydra Passport Editor. Hydra Passport Editor should now run.
2. Click on *Retrieve Passport*.
3. Click on *Load From Local File* and under Path/File name type : c:\hydra\run\params\defaultpassport\defaultpassport.txt and click OK. Passport parameters should now be displayed in the main text area.
4. Click on *Check Passport*.
5. If no error messages get displayed, the passport is ready for insertion into the database. Click on *Insert Passport*.
6. Enter the database connection parameters: ewdb_main (User), main (Password) and eqs.hydra and click on *OK*.
7. If the insertion has been successful, the messages “Successfully inserted 99 rows into DB for default passport” and “SUCCESS Inserted Passport to DB” will be displayed.

2.1.4.2 Station Metadata Insertion

The next step in setting up Hydra Server is the insertion of seismic station metadata into the database. There are two sample metadata files provided with the default installation package (in C:\hydra\run\params\metadata): blessed_channel_list.dk and blessed_pz_list.pzray. To insert station metadata into the database, perform the following steps:

1. Edit blessed_channel_list.dk and add station metadata for all channels that are to be processed, as shown in ALFO station example. See Appendix A.1 for file format explanations.

```
ALFO  HHE  PO  --  45.6283  -74.8842   0  10.000  CMG-3E  396000000  90   0        0 Alfred, Ontario
ALFO  HHN  PO  --  45.6283  -74.8842   0  10.000  CMG-3E  396000000   0   0        0 Alfred, Ontario
```

```
ALFO   HHZ    PO     --  45.6283  -74.8842     0  10.000  CMG-3E  396000000   0 -90         0 Alfred, Ontario
```

2. Edit blessed_pz_list.pzray and add required channel poles and zeros for all channels that are to be processed, as shown in ALFO station example. There should be one entry for each channel that is to be processed by Hydra. See Appendix A.2 for file format explanations.

```
ALFO  HHZ PO --
* Sensor: CMG-3E
CONSTANT              1.4437E+09
ZEROS   3
0.0000E+00  0.0000E+00
0.0000E+00  0.0000E+00
0.0000E+00  0.0000E+00
POLES   5
-5.0265E+02  0.00000E+00
-1.0053E+03  0.00000E+00
-1.1309E+03  0.00000E+00
-4.4420E-02  4.44200E-02
-4.4420E-02 -4.44200E-02
```

3. Once the blessed_channel_list.dk file is complete, insert its contents into the database by running:

   Stalist_dk2ora blessed_channel_list.dk ewdb_main main eqs.hydra

4. Once the blessed_pz_list.pzray file is complete, insert its contents into the database by running:

   Pzray2ora blessed_pz_list.pzray ewdb_main main eqs.hydra

5. Stalist_dk2ora should display “Successfully inserted channel …” for all channels listed in blessed_channel_list.dk if the insertion was successful.
6. Pzray2ora should display “Successfully inserted poles and zeros for …” for each channel listed in blessed_pz_list.pzray if the insertion was successful.

2.1.4.3 Station List File Setup

Once the station metadata has been inserted into the database, it can be extracted into Hydra Picker and GLASS station files. These files specify stations that are to be processed by Hydra raypicker and GLASS modules. Both station list files can be generated manually as well however, it is much easier to create them by extracting data already inserted into the database. This procedure would have to be repeated every time new station is added to the system.

1. To create a picker station list file, execute the following command:

   Stalist_ora2picker stalist.picker ewdb_main main eqs.hydra

2. Copy the newly created file stalist.picker to c:\hydra\run\params directory. If the picker station list file name other than stalist.picker is selected, ensure to change raypicker.d file appropriately.
3. To create GLASS station list file, execute the following command:

   Stalist_ora2hinv stalist.hinv ewdb_main main eqs.hydra

4. Copy the newly created file stalist.hinv to c:\hydra\run\params\glass_data directory. If the GLASS station list file name other than stalist.hinv is used, ensure to change glass.d appropriately.
5. Edit cmtStationsToUse file in c:\hydra\run\params and ensure that it contains a complete list of stations to be processed by Hydra Server.
6. Edit mwStationsToUse file in c:\hydra\run\params and ensure that it contains a complete list of stations to be processed by Hydra Server.

2.1.4.4 Wave Server Setup

Hydra Server State Processing modules grab trace data for processing from Earthworm's wave_serverV tank files. Therefore, before Hydra can start processing waveforms. Wave_serverV tank files have to be created for each channel as follows:

1. Go to c:\hydra\run\params and edit wave_serverV station file wave_serverV.tlst.
2. Add a new line for each channel that is to be processed by Hydra Server as shown with ALFO station example:

```
Tank ALFO  HHZ PO --  4096  INST_WILDCARD   MOD_WILDCARD     10  10000  C:\hydra\waveserver\tanks\ALFO_HHZ.tnk
Tank ALFO  HHN PO --  4096  INST_WILDCARD   MOD_WILDCARD     10  10000  C:\hydra\waveserver\tanks\ALFO_HHN.tnk
Tank ALFO  HHE PO --  4096  INST_WILDCARD   MOD_WILDCARD     10  10000  C:\hydra\waveserver\tanks\ALFO_HHE.tnk
```

3. Note that the seismic data is stored in tank files in an uncompressed format. As such, tank files should be as large as possible in order to store several days' worth of data for post-processing. Column 6 (record size – 4096 in the example above) and Column 9 (tank file size – 10 in the example above) settings in wave_serverV.tlst file determine the amount of data that will be stored in each tank file. See Appendix C for more details on how to configure these parameters.

2.1.4.5 Data Acquisition Module Setup

Default Hydra installation package comes with two Earthworm modules that allow for acquisition of real-time seismic data: naqs2ew and slink2ew. Naqs2ew allows for data acquisition from Nanometrics NaqsServer utility, and Slink2ew allows for data acquisition from SeedLink Server utility. The following steps indicate how to set up these two modules:

1. (for naqs2ew) Go to c:\hydra\run\params, edit naqs2ew.d file and set the NaqsServer IP Address and Port.
2. (for naqs2ew) Add a new RequestChanSCNL line for each NaqsServer channel that Hydra Server is to subscribe to as shown in ALFO example:

```
#               sta  chan net loc  pinno  delay(s) format  sendbuf
RequestChanSCNL   ALFO  HHZ  PO  --   2001    30      0       0
RequestChanSCNL   ALFO  HHN  PO  --   2002    30      0       0
RequestChanSCNL   ALFO  HHE  PO  --   2003    30      0       0
```

3. (for naqs2ew) Leave all other parameters in naqs2ew as defaults.
4. (for slink2ew) Go to c:\hydra\run\params, edit slink2ew.d file and set the Seedlink Server IP Address and Port.
5. (for slink2ew) Add a new Stream line for each channel that Hydra Server is to subscribe to as shown in COR example:

```
Stream    IU_COR      00BH?.D
```

6. (for slink2ew) Leave all other parameters in slink2ew as defaults.
7. At this point Hydra Server is configured to start acquiring and processing seismic data. In order for all configuration changes to take effect, reboot the workstation.

2.1.4.6 Post_bulletin Utility Setup

The last step in Hydra configuration is the setup of the modules that Hydra uses to communicate with Athena Publisher software. There are two utilities, located in /hydra/Athena folder, used for this purpose: post_bulletins and post_sites. Post_bulletins parses raypellets stored in /hydra/outdir folder and sends them to Athena Publisher. As such, post_bulletins runs continuously and is started and maintained running by Hydra Guardian Angel service. Post_sites is used to insert new station metadata into Athena MySQL database. Post_sites utility is run once at the initial Hydra setup and every time a new station is added to the system.

1. Go to c:\hydra\athena and edit post_sites.bat file.
2. Replace the default dk channel list file path on line 4 (..\run\params\metadata\blessed_channel_list.dk) with the actual file name (and path) used in Section 2.1.4.2.
3. Replace the default Athena URL (athena.nanometrics.ca) on line 6 with the URL of the Athena Publisher that is linked to this installation of Hydra.
4. Execute post_sites.bat.
5. Go to c:\hydra\run\params and edit GuardianAngel.d file.
6. Replace the default Athena URL (athena.nanometrics.ca) with the URL of the Athena Publisher that is linked to this installation of Hydra.
7. Reboot the workstation to restart all Hydra services.

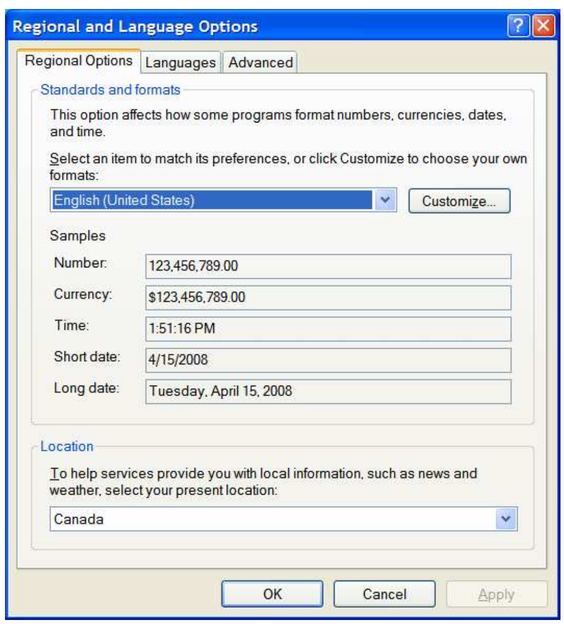
2.2 Response Hydra Displays Client

2.2.1 Pre-installation Tasks

IMPORTANT NOTE:

- Prior to Oracle 9i Client installation, the user should confirm that the language settings on the destination workstation match those of the workstation running Hydra Server. This can be done as follows:

1. Go to Control Panel -> Regional and Language Options.
2. Ensure that all entries in the *Standards and formats* section under *Regional Options* tab are the same on both machines.



3. Go to *Languages* tab and click on *Details* button. Ensure that the entries in *Installed services* text area are the same on both workstations.
4. Go to *Advanced* tab and ensure that the language selected under "*Select a language to match the language version of the non-Unicode programs you want to use*" is the same on both workstations.
5. Click on *Apply* and *OK.*

- The following task must be performed prior to Response Hydra Displays Client installation and setup:
  1. Oracle 9i Client installation (Section 2.2.1.1)

2.2.1.1 Oracle 9i Client Installation

1. Insert the CD labeled *Oracle 9i Database (9.2.0.1.0) for Microsoft Windows NT/2000/XP* into the CD-ROM drive.
2. The Oracle Installer should auto run. If The CD does not auto run, execute the program *setup.exe* in the root directory of the CD.
3. From the Installer, choose *Install/Deinstall Products*.
4. The *Oracle Universal Installer* should now run. Click Next.
5. In the *File Locations* selection menu, leave the Source path as is, but modify the Destination path as desired. The general case is “c:\oracle\ora92”. If the Destination path is not this case, the Hydra Analyst Display Client Installer will be unable to automatically configure the TNS Names File.
6. In the *Available Products* menu, choose *Oracle9i Client 9.2.0.1.0*. Click Next.
7. In the *Installation Types* menu, choose *Administrator*. Click Next.
8. The next menu is a summary of the installation choices made in the previous steps. Click *Install* to confirm these choices and install Oracle 9i Client.
9. Once the installation is complete, the Net Configuration Assistant automatically runs. Select *Cancel*, then *Yes* to exit out of this tool. Exit the *Oracle Universal Installer.*
10. The *Oracle Enterprise Manager* will now automatically run.
11. In *Add DBMS to Tree*, select *Cancel*, and exit the *Oracle Enterprise Manager.*
12. The Oracle 9i Client is now installed.

2.2.2 Response Hydra Displays Client Installation and Setup

1. Ensure that you have Administrator privileges on the machine where the installation is taking place. Copy Response Hydra Analyst Display Client Installer to the root directory.
2. Start the Response Hydra Analyst Display Client Installer by launching *HydraDisplayClient_windows_1_47.exe*.
3. On *Select Components* screen click on Next.
4. On *Select Destination Directory* screen it is recommended that Destination directory be left as C:\hydra. Click Next.
5. On *Hydra Configuration* screen, enter the appropriate values as follows:

   Red Hydra Server IP Address – static IP address of the workstation on which Primary (Red) Hydra Server is running

   Blue Hydra Server IP Address – static IP address of the workstation on which Backup (Blue) Hydra Server is running (if applicable, if not - leave defaults)

   Earthworm Installation ID INST_ – enter the unique Earthworm installation ID as assigned by Barbara Bogaert (bogaert@usgs.gov) to be included in the earthworm_global.d file.

   Red Hydra Notifier Multicast IP and Port – multicast IP and port on which Primary (Red) Hydra Notifier utility will broadcast Hydra database updates and heartbeats.

   Blue Hydra Notifier Multicast IP and Port – multicast IP and port on which Backup (Blue) Hydra Notifier utility will broadcast Hydra database updates and heartbeats (if applicable).

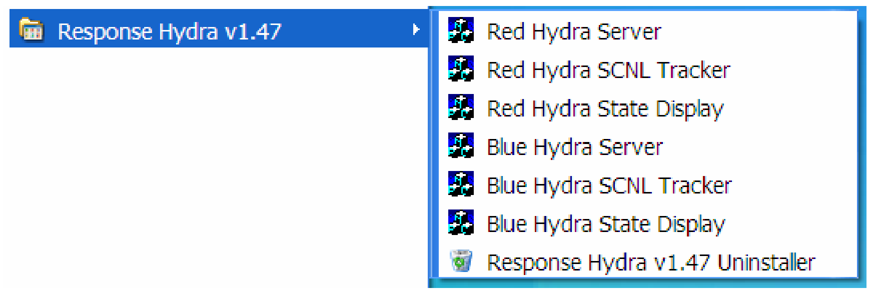
6. Click *Next* and select “Yes” when prompted to reboot the workstation.

2.2.3 Confirming Successful Installation

Note: All steps in 2.1.3 and 2.1.4 sections assume that Hydra Server has been installed in the default C:\hydra root directory.

Following the workstation reboot in step 5 of the previous section, confirm that the Response Hydra Analyst Display Client has been successfully installed as follows:

- Verify that the Map Display interface can connect to the Red Hydra database by running Response Hydra v1.47 -> Red Hydra. The Map Display interface should start up, load the list of events from the primary database (eqs.red) and display them one the map.
- (Optional) Verify that the Map Display interface can connect to the Blue Hydra database by running Response Hydra v1.47 -> Blue Hydra. The Map Display interface should start up, load the list of events from the backup database (eqs.blue) and display them one the map.



2.3 Changing the IP Address of a Hydra Server Workstation

The following procedure describes which files need to be edited whenever Hydra Server static IP address is changed:

1. Go to c:\hydra\run\params and edit naqs2ew.d. Change the NaqsServer IP address to match the new static IP (this is only in case NaqsServer is running on the same machine as Hydra Server).
2. Go to c:\hydra\run\params and edit slink2ew.d. Change the Seedlink Server IP address to match the new static IP (this is only in case Seedlink Server is running on the same machine as Hydra Server).
3. Go to c:\hydra\run\params and edit state_manager.d. Change the MyIPAddress parameter to the new static IP.
4. Go to c:\hydra\run\params and edit wave_serverV_ip_addr.d. Change the ServerIPAddr parameter to match the new static IP.
5. Start All Programs -> Response Hydra v1.47 -> Hydra Passport Editor.
6. Click on “Retrieve Passport” and supply the following login information: ewdb_main (User Name), main (Password) and eqs.hydra (Service Name). Click “OK”.
7. Once the passport has been loaded, scroll down to the end of the list of passport parameters. Second, third and fourth parameters from the bottom are SrvAddGeo, WSAddDisp and WSAddProc. Select each one of these three parameters and click on “Edit Passport Line”. Change the IP address to the new static IP and click on “Check Passport Line”. Once the format of the line has been checked, click on “OK”.
8. After all three IP address parameters have been changed, click on “Check Passport”.
9. If the passport check completes with no errors, click on “Insert Passport”.
10. If the insertion completed without errors, the following message should pop up: “Succesfully Inserted 99 rows in to DB for default passport. Eqs.hydra”.
11. Go to c:\oracle\ora92\network\admin and edit listener.ora and tnsnames.ora. In both files modify the “HOST =” parameter to reflect the new IP address. Restart the workstation.

Chapter 3: Response Hydra Analyst Displays

3.1 Response Hydra Analyst Display Overview

Response Hydra allows user interaction via a series of Analyst Displays. The displays can be grouped by functionality into two groups: Seismic Data Processing displays and Engineering displays. Seismic Data Processing displays enable seismologists to review and manually initiate reprocessing of automatically-generated earthquake parameters. The following is a list of main Seismic Data Processing displays and sections in which they are described in further detail:

- Map Display (Section 3.2.2)
- Event Summary (Section 3.2.3)
- Location Display (Section 3.2.4)
- Add Trace Display (Section 3.2.5)
- Waveforms (Section 3.2.6)
- Mwp Display (Section 3.2.7)
- Mb Display (Section 3.2.8)
- Ms Display (Section 3.2.9)
- Ml Display (Section 3.2.10)
- Mblg Display (Section 3.2.11)
- Md Display (Section 3.2.12)
- MT and CMT Displays (Section 3.2.13)

Engineering displays enable users to view the current operation of the system by looking at the state processing table, module execution times, errors, data acquisition statistics, set up notification groups and routes as well as modify and insert default passport entries. The following is a list of Response Hydra Engineering displays:

- Passport Editor Display (Section 3.3.1)
- SCNL Tracker Display (Section 3.3.2)
- State Display (Section 3.3.3)
- System State Display (Section 3.3.4)
- StartStop Console Display (Section 3.3.5)

3.2 Seismic Data Processing Displays

3.2.1 Common Seismic Analyst Display Features

There are several features that are present on multiple Seismic Data Processing displays and the functionality of which is common to all. These features include Database Connection and System Widget and *Rework for All Changes* button.

Database Connection and System Widget indicates whether a particular display is connected to the Hydra Server database and receiving updates and whether the connection is to the Primary (red) or Backup (blue) system. Database connection is confirmed by the rotating letters P or S. The letter rotates every time the display receives a heartbeat from the Notifier utility running on the Hydra Server thus indicating that the display is showing the latest database state.

Widget	Description
	• Display connected to Primary (Red) Hydra Server. • Grey background indicates that the widget is on a display that is not event specific (Map Display, SCNL Tracker etc.).
	• Display connected to Backup (Blue) Hydra Server. • Grey background indicates that the widget is on a display that is not event specific (Map Display, SCNL Tracker etc.).
	• Display connected to Primary (Red) Hydra Server. • Green background indicates that the widget is on an event-specific display and that there have been no changes to the event passport since last state processing cycle.
	• Display connected to Primary (Red) Hydra Server. • Yellow background indicates that the widget is on an event-specific display and that the event is currently being processed by at least one state processing module.
	• Display connected to Primary (Red) Hydra Server. • Red background indicates that the widget is on an event-specific display, that there have been changes to the event passport since the last state processing cycle and that the new state processing cycle has not been initiated yet.
	• Display connected to Primary (Red) Hydra Server. • Red cross in the lower right corner indicates that this display does not have a live connection to the database. This means that Notifier multicast heartbeats are not getting through. The user can still ensure that the information on the displays is up to date by pushing *Refresh* button.

Table 1: Database Connection and System Widget

The second feature that is present on event-specific displays is the *Rework for All Changes* button. This button is present on all event-specific displays which allow the user to change event passport parameters. As soon as the event passport parameters are changed, Database Connection and System widget changes its color to red indicating that the currently-listed origin parameters have to be re-calculated. *Rework for All Changes* button is the trigger that starts the new state processing cycle.

3.2.2 Map Display

Map Display serves as the focal Seismic Data Processing user interface from which seismic event parameters can be viewed and modified. Map Display is started by invoking *Start -> Response Hydra v1.47 -> Hydra* on Hydra Server machine or *Primary (Red) Hydra* and *Backup (Blue) Hydra* on Analyst Display Client machine.

Map Display GUI is shown in Figure 4. The upper part of the screen contains a high resolution map of the world. The map is centered longitude-wise on the event that is currently selected in the table which is listing recent events (in the lower part of the window). The lines connecting selected event location with stations depict different phase arrivals that were used to locate that event. The explanation of which color corresponds to which phase is provided below the map.

The icons that are used to denote event locations on the map differ in shape, color and size in order to group events by depth, time and size respectively.

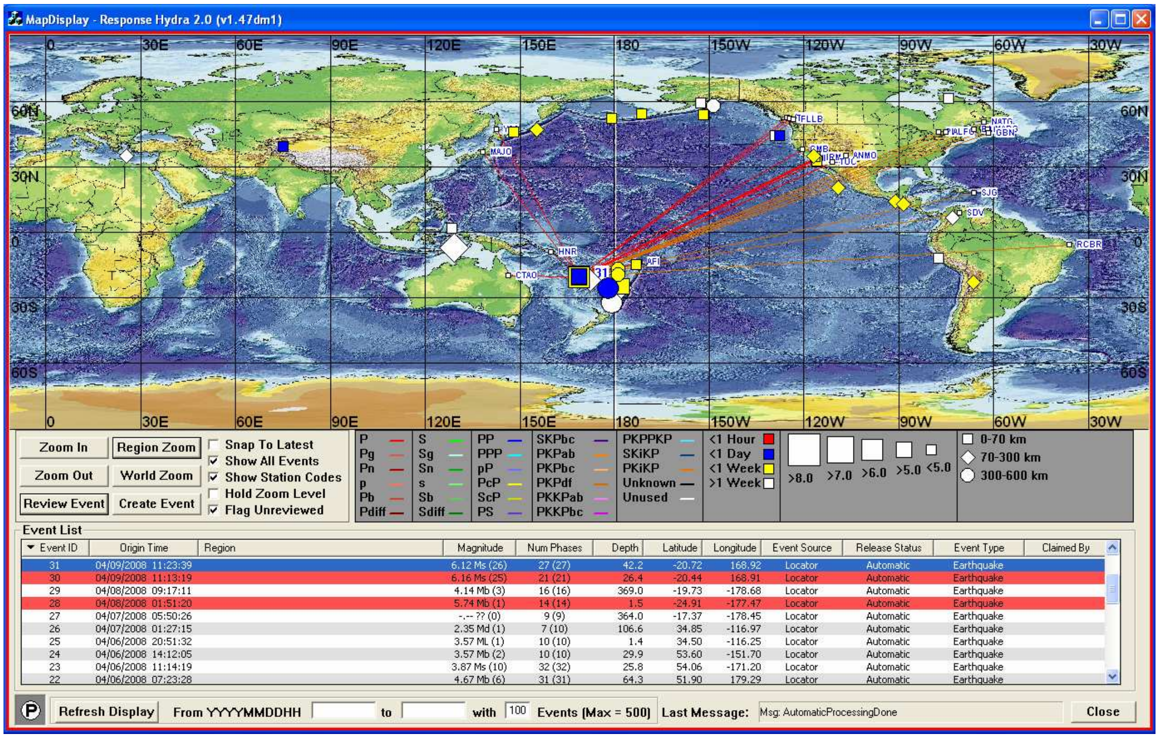


Figure 4: Response Hydra Map Display

The middle part of the window contains six buttons and five checkboxes with their functions described in Tables 2 and 3.

Button	Purpose
Zoom In	Zoom in on the selected event.
Zoom Out	Zoom out of the selected event.
Review Event	Brings up Event Summary display (see Section 3.2.3).
Region Zoom	Zooms in to the region around the event view.
World Zoom	Zooms back to the World view.
Create Event	Brings up CreateEvent display (see Section 3.2.2.1)

Table 2: Map Display Buttons

Checkbox	Purpose (if checked)
Snap to Latest	Ensures that the latest event is selected once the display is refreshed.
Show All Events	Enables display all recent events listed in the Event List table as opposed to only the last one.
Show Station Codes	Toggles the display of station codes.
Hold Zoom Level	Holds currently selected zoom level. Does not zoom back to World view when different events are selected.
Flag Unreviewed	Marks with either red or yellow events listed in the Event List table that are more than 5.0 in magnitude and have not been reviewed by a seismologist

Table 3: Map Display Checkboxes

The lower part of the window contains *Event List* table listing most recent events. The background color of each entry depends on the magnitude of the event. If the magnitude is less than 5.0, the background color of the row will either be white or light grey (to distinguish between consecutive rows). For all significant events with magnitudes larger than 5.0, the row color will be red, yellow or green:

- Red - Significant events that have not been reviewed or published by a seismologist.
- Yellow - Significant events that have been reviewed but not published by a seismologist.
- Green - Significant events that have been reviewed and published by a seismologist.
- White/Grey - Event with magnitude less than 5.0.
- Blue - Currently selected event (overrides all other colors).

Event List table columns are described in Table 4.

Column	**Meaning**
Event ID	Hydra database ID assigned to the event.
Origin Time	Time of the event.
Region	Event location region (applicable only if Geo Server present).
Magnitude	Event Magnitude.
Num Phases	Number of phases used to locate event.
Depth	Event hypocenter depth.
Latitude	Event epicenter latitude.
Longitude	Event epicenter longitude.
Event Source	Indicates the processing status of the event: *Locator* – Event processing done *Processing* – Event is currently being processed
Release Status	Indicates event publishing status: *Automatic* – The event has not been reviewed or published. *Quick Reviewed* – The event has been reviewed but not published. *Published* – The event has been reviewed and published.
Event Type	Event type as selected on Event Summary page (see Section 3.2.3). Possible values: *Earthquake, Explosion, Induced, Dubious* and *Unknown*.
Claimed By	Computer name of the workstation on which the event was reviewed and published.

Table 4: Event List Column Descriptions

The bottom of the Map Display window contains a *Refresh Display* button. Pressing this button forces the display to synchronize itself with the database, and display any events that have been detected since the last update. The user can also limit the number of events in the *Events List* (and therefore displayed on the map) by specifying start time (*From YYYYMMDDHH* text box), end time (*to* text field) and number of events to display (*Events (Max = 500)* text field). The events will only be displayed if they reside in the Oracle database.

3.2.2.1 Create Event Display

CreateEventDisplay window is invoked by pressing *Create Event* button on Map Display. It enables the user to manually insert an event into the database in case it was not detected by Response Hydra automatic processes.

The display shown in Figure 5 enables the user to manually enter perceived origin time (MM/DD/YYYY HH:MM:SS), perceived origin location latitude (D,M,S), perceived origin location longitude (D, M, S) and perceived origin depth. Pressing *Create* button will insert specified origin parameters into the database.

The user will next have to manually pick phase arrivals for the newly entered event by selecting that event in the Event List and launching *Event Summary*, *Location Display* and *Add Trace Display* windows.

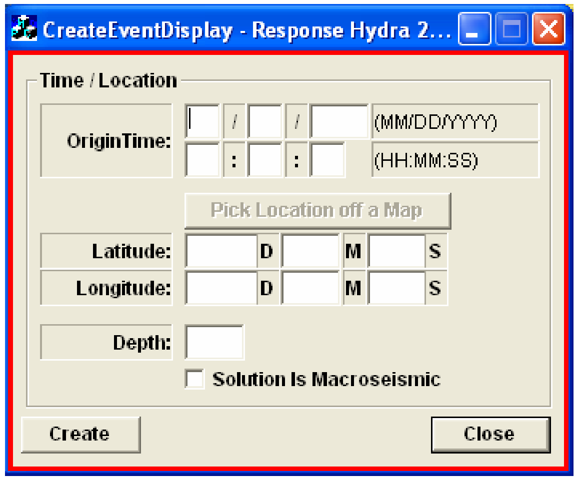


Figure 5: Create Event Display

3.2.3 Event Summary Display

Event Summary display is invoked by pressing *Review Event* button on Map Display page. This display summarizes the main event parameters, shows event processing status, provides access to event states and passport parameters, allows event characterization and provides links to magnitude, moment tensor and location summary displays. Figure 6 depicts an example Event Summary display.

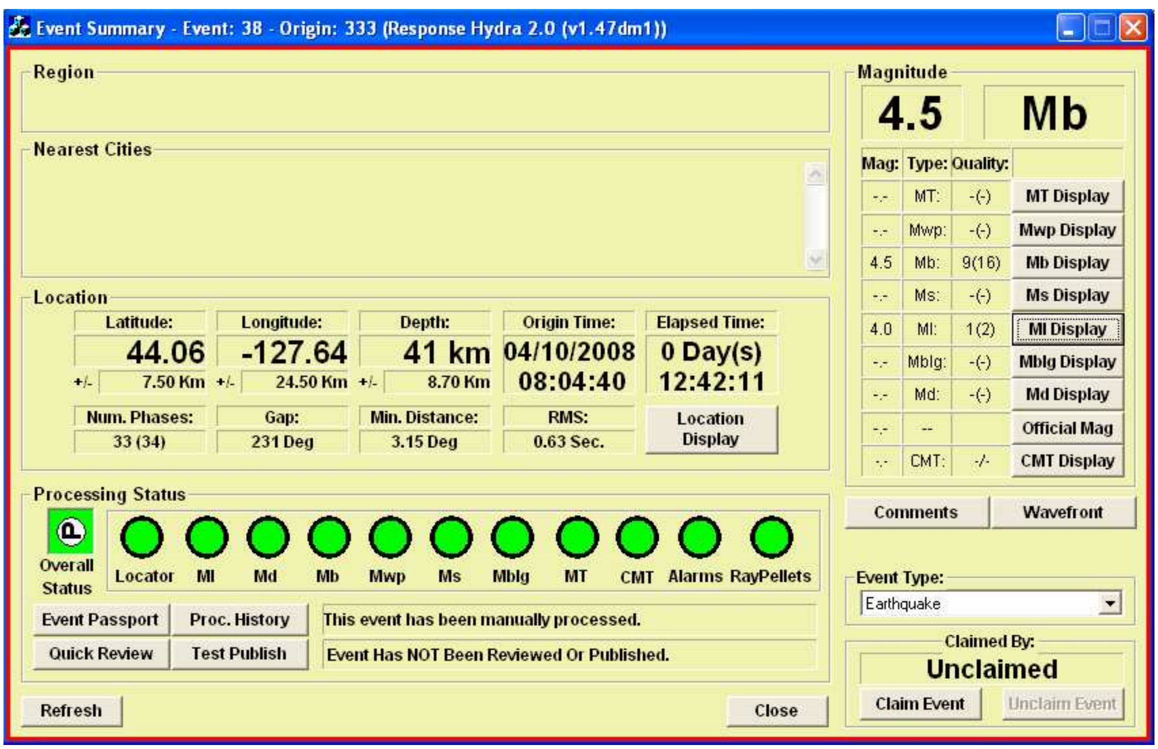


Figure 6: Event Summary Display

The two top sections, *Region* and *Nearest Cities,* display text describing the region of the world in which the event occurred as well as distances to a number of closest large cities. This text is only present if USGS/NEIC Geo Server software is running and accessible by Hydra Server.

Location section lists some of the most common earthquake parameters as described in Table 5.

Parameter	Description
Latitude (+/-)	Event epicenter latitude and its error.
Longitude (+/-)	Event epicenter longitude and its error.
Depth (+/-)	Event hypocenter depth and its error.
Origin Time	Time of the event.
Elapsed Time	Time elapsed since the event.
Num. Phases	Number of P-wave and S-wave arrivals used in the location of the earthquake. Number of phase arrivals initially associated with the earthquake is indicated in the brackets.
Gap	The largest azimuthal gap between two azimuthally adjacent stations. The smaller this parameter, the more reliable the location of the earthquake.
Min. Distance	Horizontal distance (in degrees) between the epicenter and the closest station used in event location. In general the smaller the number, the more accurate the location.
RMS	The root-mean-square of all travel time residuals. This parameter provides a measure of the fit of the observed arrival times to the predicted arrival times.

Table 5: Location Section Parameter Description

Processing Status section of the Event Summary display indicates the status of the current event. There is one icon displayed for each State Processing Module and its color explains its current status:

Red - Changes have been made to this event's passport and this State Processing Module has not been invoked yet (processing scheduled).

Yellow - This State Processing Module is currently doing operations on the event (processing currently taking place).

Green - There have been no changes made to this event's passport since the last time this module was invoked (processing complete).

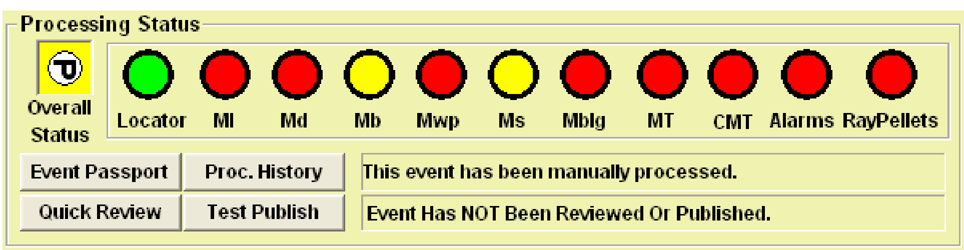


Figure 7: Processing Status

Event Passport button (brings up Event Passport Display) allows the user to view the contents of the passport used to calculate this event's parameters. *Proc. History* button (brings up Event History Display) displays all versions of the event starting with the first time the event was inserted into the database. The user can see the changes that had contributed to the creation of new origins for that event. Event History display allows the user to save processing history to a text file.

Event Summary also contains *Quick Review* and *Test Publish* buttons. These buttons enable the user to indicate to the publishing software and Hydra users whether an event has been manually reviewed or revised by a seismologist. The two text fields to the right of the buttons indicate processing and publishing state of the event. Table 6 shows the effect user actions have on Hydra Displays and raypellet (IMS1.0 bulletins) outputs.

Action	Results
• Event inserted in the	• The top text field in Event Summary window

database • No seismologist interaction	indicates “*This event has been automatically processed*”. • The bottom text field in Event Summary window indicates “*This event has NOT been reviewed or Published*.”. • *Release Status* column in *Event List* table on Map Display page changes to “*Automatic*”. • Ray_pellet comment indicates “… UNCHECKED, FULLY AUTOMATIC LOCATION…”.
• Event parameters changed by seismologist • *Quick Review* and *Test Publish* buttons not pushed	• The top text field in Event Summary window indicates “*This event has been manually processed*”. • The bottom text field in Event Summary window indicates “*This event has NOT been reviewed or Published*.”. • *Release Status* column in *Event List* table on Map Display page changes to “*Automatic*”. • Ray_pellet comment indicates “… UNCHECKED, FULLY AUTOMATIC LOCATION…”.
• *Quick Review* button pushed	• The top text field remains unchanged. • The bottom text field in Event Summary window changes to “*Event quick reviewed at HH:MM:SS DD/MM/YYYY*”. • *Release Status* column in *Event List* table on Map Display page changes to “*Quick Reviewed*”. • Ray_pellet comments indicates “… MANUALLY REVIEWED LOCATION …”.
• *Test Publish* button pushed	• The top text field remains unchanged. • The bottom text field in Event Summary window changes to “Event published at HH:MM:SS DD/MM/YYYY”. • *Release Status* column in *Event List* table on Map Display page changes to “*Published*”. • Ray_pellet comments indicates “ … MANUALLY REVISED LOCATION …”.

Table 6: Event Processing and Publishing Sequence

The right section of the Event Summary window contains Magnitude summary table. The preferred magnitude is displayed in the top right corner. The preferred magnitude is selected from calculated magnitudes (listed in the columns below) using an algorithm described in Appendix XX. The user has the option of manually overriding default Hydra preferred magnitude by entering an official magnitude through *Official Mag* button. The magnitude entered in such a way becomes the new preferred magnitude and is published as such in raypellets. The user can reach each magnitude display by clicking on the corresponding button in the magnitude table (Sections 3.2.7 – 3.2.13).

Directly below the magnitude table are *Comments* and *Wavefront* buttons. Refer to Sections 3.2.3.1 and 3.2.3.2 for displays invoked by these two buttons.

In the lower left corner of the Event Summary window is *Event Type* drop down list and *Claim Event* and *Unclaim Event* buttons. *Event Type* drop down list allows the user to select type of the event from the following: *Earthquake, Explosion, Induced, Dubious and Unknown*. The user selection is published in the *Event List* table on Map Display window and included in raypellets as well as Athena event bulletins.

Claim Event button will insert the user name of the person logged in into *Claimed By* column of the *Event List* table on Map Display window. In this way, the seismologist which reviewed and published the event is identified. *Claimed By* information is only displayed in Map Display column and is not copied to raypellets.

3.2.3.1 Event Comments Display

Comments button on Event Summary display brings up Event Comments window as shown in Figure 8. *General Comments* text area is for comments that are to be published with the rest of the event parameters. *Editorial Comments* text area is for comments that are for internal use only. Both sets of comments show up in ray_pellets, however, only comments in *General* text area are made visible in event bulletins generated by Athena publishing software.

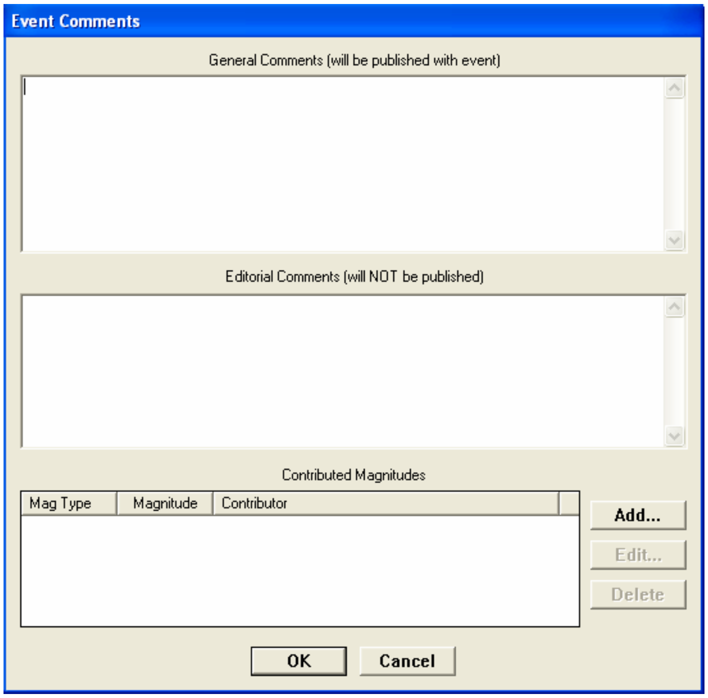


Figure 8: Event Comments Window

Contributed Magnitudes section enables the user to enter magnitudes that have been contributed by other institutions. These magnitudes can be made into preferred magnitudes through *Official Mag* button. All three columns (*Mag Type, Magnitude* and *Contributor*) will show up in ray_pellet and will be published by Athena.

3.2.3.2 Wavefront Display

Wavefront button on Event Summary page invokes Wavefront display as shown in Figure 9. Wavefront display is designed to help the user visualize different phase travel times and display actual arrival times (of associated and unassociated picks) relative to predicted ones. In order for Wavefron display to work, travel time tables for each listed phase have to be present in hydra/ttt directory.

The main part of the screen is taken up by the same world map shown in Map Display. All stations known to Hydra are also displayed on the screen as well as the location of the selected event.

To the right of the map, is a graph showing predicted travel times for each phase listed in the table below the world map. Travel Time graph horizontal X scale denotes distance traveled (in degrees) and vertical Y scale denotes time (in minutes). Solid lines of different colors denote predicted phase arrival times. Small crosses indicate actual phase arrival times (picks). Crosses which have the same color as one of the solid phase lines have been associated with this event. The horizontal line moving in the vertical direction represents the passage of time relative to the origin time and is controlled by *Switch To Realtime*, *Switch to Playback* and *Pause* buttons.

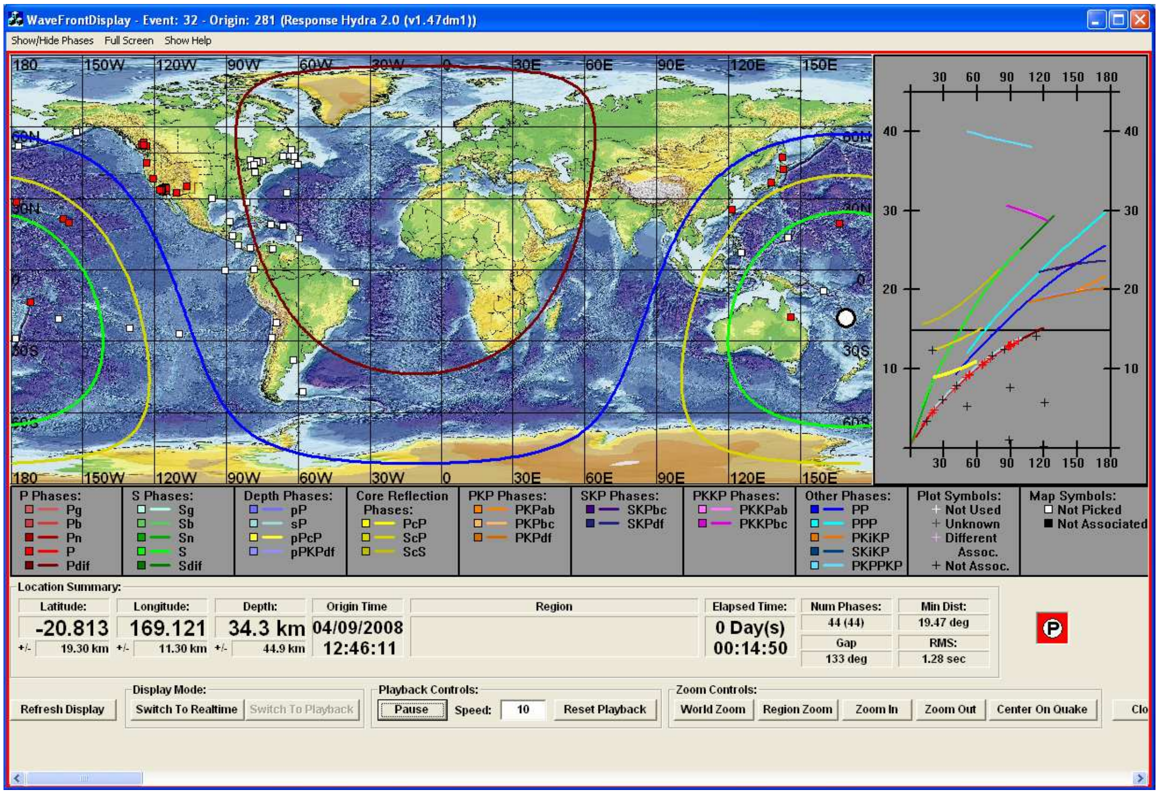


Figure 9: Wavefront Display

The Location Summary Section contains the parameters described in Table 5. Travel time Display Mode can be either real-time or playback as determined by *Switch to Realtime* and *Switch to Playback* buttons. Real-time mode will only work if the Wavefront display is invoked up to 50 minutes following the origin time, as all phases tracked in Hydra travel time tables cover the whole earth in less than 50 minutes. If the display is invoked after this time, the only way to view travel times graphics is to put the display in playback mode by pushing *Switch To Playback* button.

Playback Controls allow the user to pause phase travel time graphics, specify the playback speed and reset the display. These controls are only available in playback mode. Zoom Control allows the user to specify map zoom level.

3.2.4 Location Display

Location Display shown in Figure 10 is invoked by pushing *Location Display* button on Event Summary window. This display is used to set initial earthquake location constraints and to view picks associated with this event. It provides links to pages that allow waveform viewing, existing pick editing and addition of new picks.

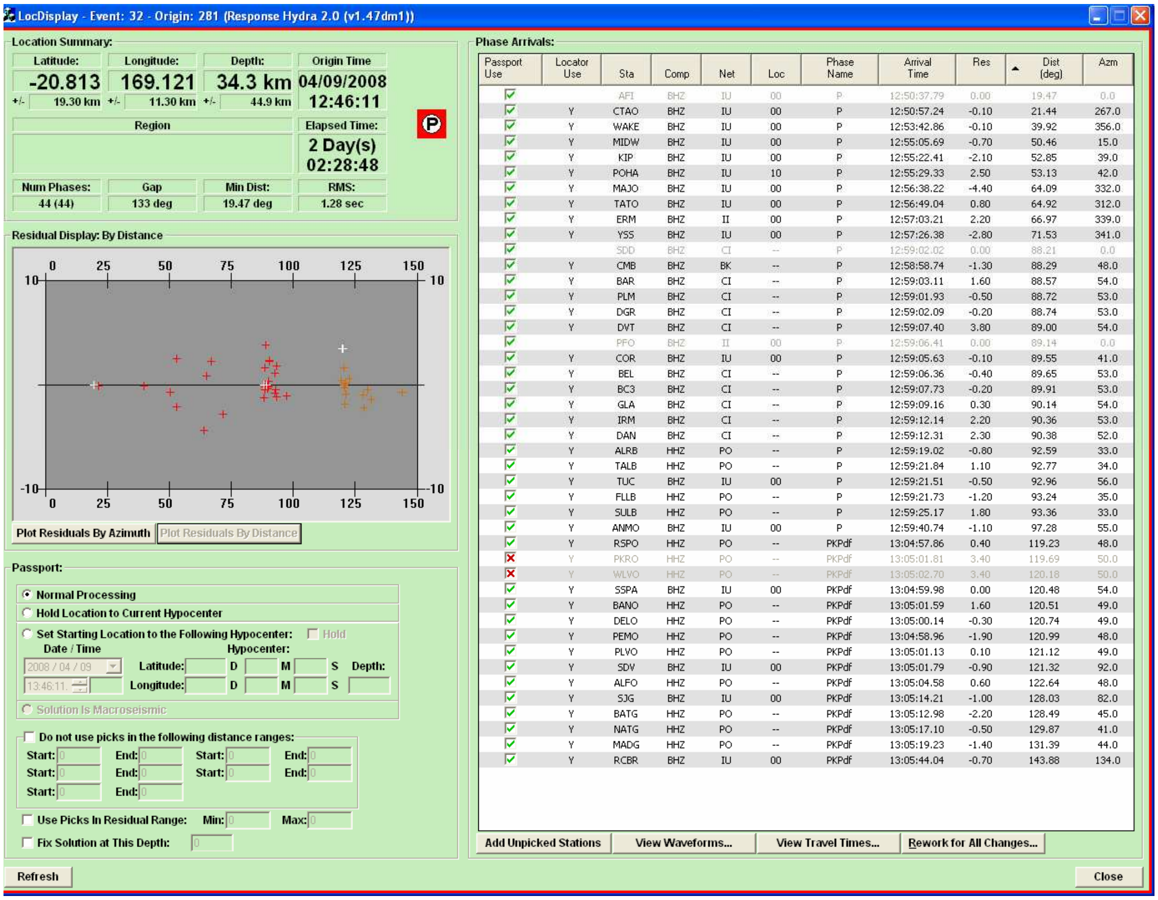


Figure 10: Location Display

Location Summary section parameters are described in Table 5. Below Location Summary section is the graphic display of phase arrival time residuals sorted by azimuth and distance as shown in Figure 11.

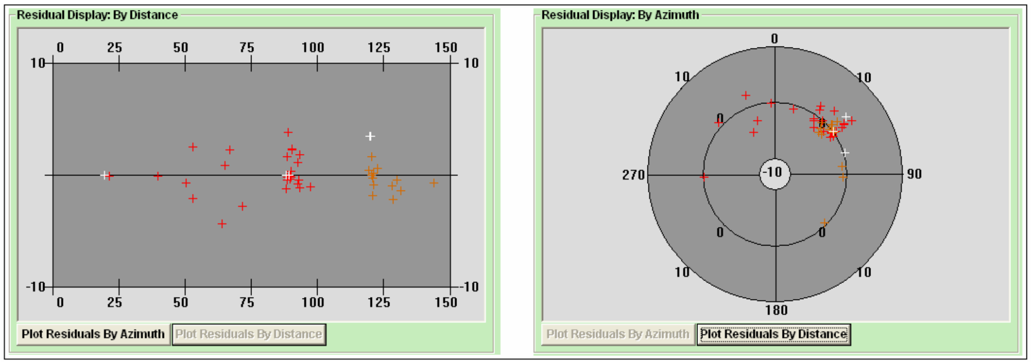


Figure 11: Residual Display

In the residuals plot by distance, the vertical Y axis depicts residual value (-10 to +10) taken from the *Res* column in the *Phase Arrivals* table. The horizontal X axis represents the distance of the station from the earthquake epicenter in degrees taken from the *Dist (deg)* column in the *Phase Arrivals* table. The color of the cross depends on the phase type as shown in Map and Wavefront displays.

In the residuals plot by azimuth, the inner circle represents the residual of -10, the middle circle the residual of 0 and the outer circle the residual of 10. The crosses representing phase arrivals are distributed depending on their azimuth relative to the epicenter of the earthquake as listed in *Azm* column of the *Phase Arrivals* table as shown in Table 7.

Column	**Meaning**
Passport Use	If checked, this phase is to be used by locator module in the next iteration of the event location processing.
Locator Use	If yes, this phase was used by the locator module in the last iteration of the event location processing.
Sta	Station name.
Comp	Station channel name.
Net	Station network name.
Loc	Station location name.
Phase Name	Phase name.
Arrival Time	Phase arrival time.
Res	Phase arrival time residual in seconds. • If negative, actual phase arrival is ahead of the predicted one. • If positive, actual phase arrival is behind the predicted one.
Dist (deg)	Distance from the station to the earthquake epicenter in degrees.
Azm	Azimuth of the station location relative to the earthquake epicenter in degrees.

Table 7: Phase Arrivals Table Columns

The bottom left corner of the Location Display window contains *Passport* section outlining initial conditions for earthquake location processing module. All origins generated automatically are processed using Normal Processing option. The user has the option of setting initial conditions and constraints by selecting the following:

Select *Hold Location to Current Hypocenter*

- This option is used either to add residual and magnitude parameter calculations for phase arrivals added by a seismologist OR to remove these parameters for phases that have been removed by a seismologist, without recalculating the location of the earthquake.

Select *Set Starting Location to the Following Hypocenter*

- This option enables the user to manually set the starting location and time of the earthquake (instead of the ones provided by GLASS or previous state processing iterations). The last calculated origin is always used as the starting location by default. The user also has the option to hold this as the preferred location (*Hold* checkbox) and only calculate residuals and magnitudes of the associated phase arrivals.

Select *Do not use picks in the following distance ranges*

- This option allows the user to manually tell the software not to use picks in the selected distance ranges. Up to six different distance ranges can be specified, which means that there can be up to six phase arrival exclusion zone rings relative to the earthquake epicenter.

Select *Use Picks in Residual Range*

- This option allows the user to specify maximum and minimum phase arrival residual. All picks whose residuals fall outside of this range will be ignored.

Select *Fix Solution at This Depth*

- This option specifies fixed hypocenter depth so that all new origin changes will only occur in the horizontal plane.

Location Display window provides links to displays that allow addition of new waveforms (*Add Unpicked Stations* button – Section 3.2.5), changes to waveforms with currently associated picks (*View Waveforms* button – Section 3.2.6) and view locations of associated and unassociated picks relative to predicted phase travel times *(View Travel Times* button – Section 3.2.4.1).

3.2.4.1 Travel Time Display

Travel Time display is invoked by pushing *View Travel Times* button on Location Display window. It represents an enlarged view of the actual phase arrivals compared to the predicted phase travel times as shown in the Wavefront window and explained in Section 3.2.3.2.

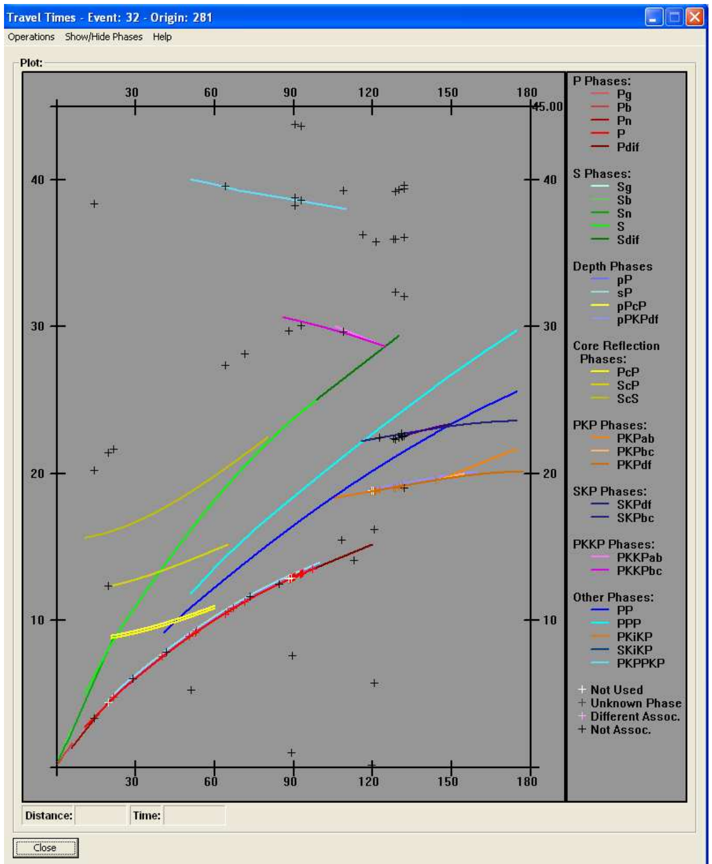


Figure 12: Travel Time Display

Lower left corner of the graph represents the origin. Horizontal X axis is the distance from the epicenter in degrees and vertical Y axis represents the time in minutes from the origin time. Crosses indicate actual picks that have occurred during the 50 minutes following the origin time. This display can be used to check if there are any unassociated picks that should be associated with this event and is a general view of how phase arrivals fir with the used velocity model. In order for this display to work, travel time tables for all listed phases have to be present in /hydra/ttt directory.

3.2.5 Add Trace Display

Add Trace Display is invoked through *Add Unpicked Stations* button on Location Display window. This display allows the seismologist to add phase arrivals from stations that had not been picked or associated by automatic Hydra processes raypicker and GLASS.

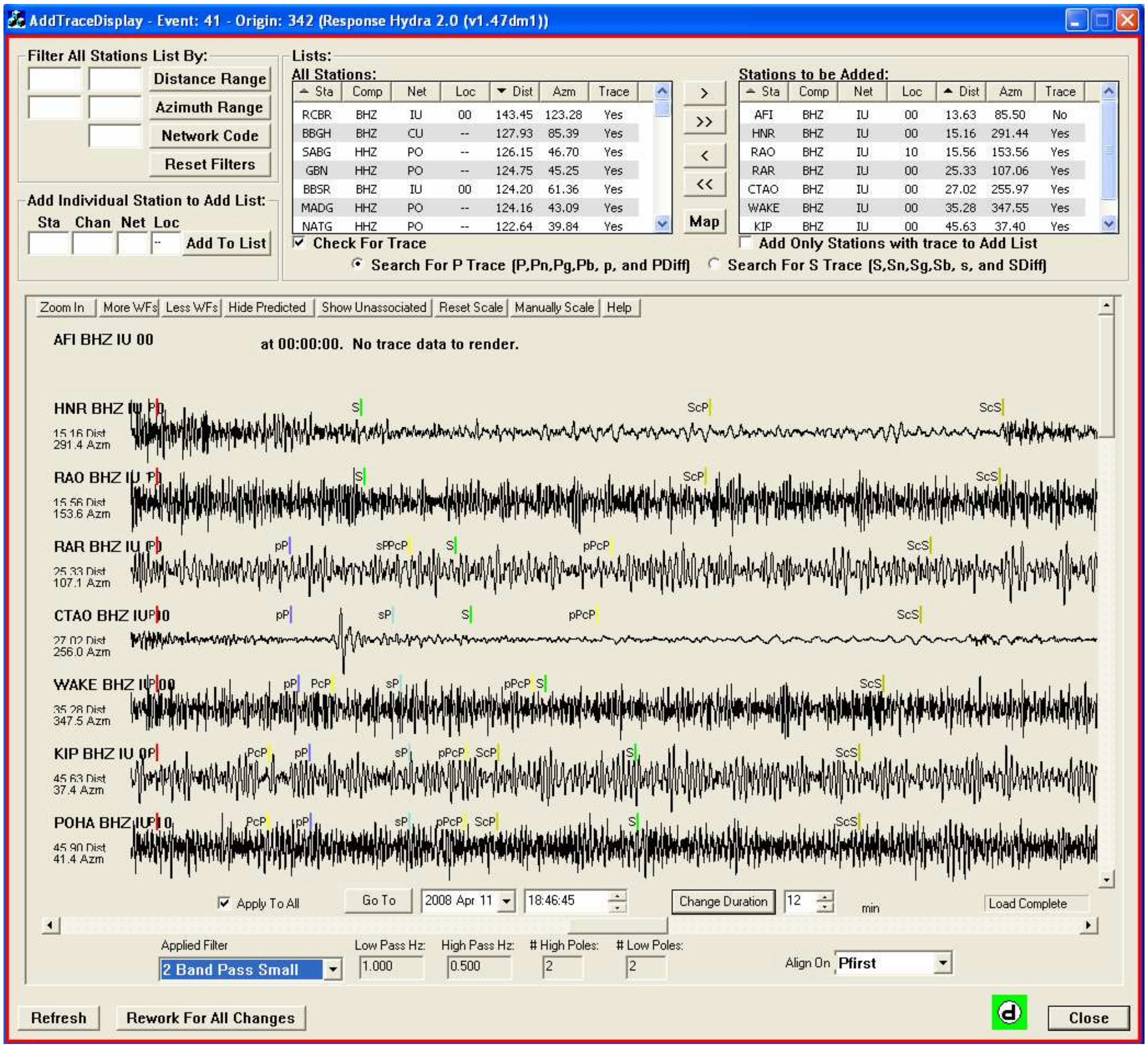


Figure 13: Add Trace Display

All Stations List section contains a list of all stations known to Hydra that have not been picked and included in the current solution. By selecting *Check For Trace* checkbox, the *Trace* column gets filled in as Hydra checks with wave_server if the tank files for each station contain data for the requested time period. The requested time period corresponds to the predicted P-phase arrival times if *Search for P Trace (P,Pn,Pg,Pb,p and PDiff)* option is selected. The requested time period corresponds to the predicted S-phase arrival times if *Search or S Trace (S,Sn,Sg,Sb,s, and SDiff)* option is selected.

The stations displayed in the All Stations List can be filtered by distance range relative to the epicenter in degrees (max and min – *Distance Range* button), azimuth range relative to the epicenter in degrees (max and min – *Azimuth Range* button) and network code (*Network Code* button). *Reset Filter* button removes all filter constraints and lists all unpicked stations.

The user can also manually add stations to the station list

Once the appropriate stations have been listed in the All Station List, the user can specify individual stations and move them to the *Stations To Be Added List* by using “>*”* and “>>*”* buttons. If a particular station has trace data in its tank file for the specified time period (*Trace* column states “*Yes*”), its waveform will show up in the waveform section below. If a particular station does not have trace data in its tank file for the specified time period (*Trace* column states “*No*”), there will be a new slot created for this station in the waveform display. However, this slot will display the following message "**at 00:00:00. No trace data to render.**". The user can further eliminate stations with no trace data by selecting *Add Only Stations with trace to Add List* checkbox.

Instead of having to go through the complete station list and select individual stations which data is to be displayed and analyzed, the user can invoke the map view of all stations, and select stations to be added and analyzed by drawing a polygon. The map display is invoked by pressing the *Map* button (see Section 3.2.5.2).

3.2.5.1 Trace Display Window

The main part of the Add Trace Display screen is taken up by waveforms of the stations that are to be potentially added to the current event. Waveform data can be manipulated using the buttons in the top left corner of the waveform window:

Button	Action
Zoom In/Out	Zoom In – Display 1 minute of waveform data. Zoom Out – Display the duration of data indicated in the Change Duration text field.
More WF	Add one more waveform to the visible waveform window by reducing vertical scale resolution.
Less WF	Remove one waveform by increasing vertical scale resolution.
Show/Hide Predicted	Show or hide predicted phase arrivals.
Show/Hide Unassociated	Show or hide unassociated picks.
Reset Scale	Reset the vertical scale on all waveforms.
Manually/Auto Scale	
Help	Display Waveform display help topics.

Table 8: Waveform Manipulation Buttons

The bottom part of the waveform window contains start time and duration buttons and text fields. The user can specify the start time of data to be displayed manually by selecting appropriate date and time and pushing *Go To* button. This will override default behavior in which the origin time is used as the start time for the data segment to display. The user can manually select the duration of data to display in the window by entering between 1 and 22 (minutes) and pushing *Change Duration* button.

The user has an option of selecting how displayed traces get aligned through *Align On* pull down menu. In order to ensure that all traces are aligned in time (vertical line drawn through all waveforms intersects each one at exactly the same time); the user should select *Align On "Origin Time"* option. In all other options, the waveforms will be aligned to specified predicted phase arrival times. If a channel is not located at a distance from the hypocenter such that the selected theoretical phase will arrive at that station, then the trace for that channel is aligned on the event origin time. Note that aligning on theoretical "*Pfirst*" is defined as the earliest arrival amoung Pg, Pn, P and Pdif out to 105 degrees, and then after 105 degrees the earliest of PKiKP and PKPdf arrivals are used.

Trace data displayed in the waveform window can be filtered using one of the seven filters available in the *Applied Filter* pull down menu. Table 9 provide some basic information about each of the available filters. Response Hydra version 1.47 does not allow for user-defined filters to be added.

Filter	Low Pass Corner (Hz)	High Pass Corner (Hz)	# of High Poles	# of Low Zeros
Default				
Band Pass Small	1.0	0.5	2	2
Band Pass Medium	1.5	0.5	4	4

Band Pass Large	2.0	0.5	4	4
High Pass One	5.0	0.5	8	8
High Pass Two	4.0	1.5	8	8
High Pass Three	5.0	1.5	8	8

Table 9: Response Hydra Default Filters

Once the waveforms have been loaded, aligned and filtered, the user can place phase picks that are to be added to the existing event location calculations. Phase picks are added by right-clicking on the trace at the point at which the pick is to be placed, and selecting the appropriate phase from the menu that is displayed as shown in Figure 15.

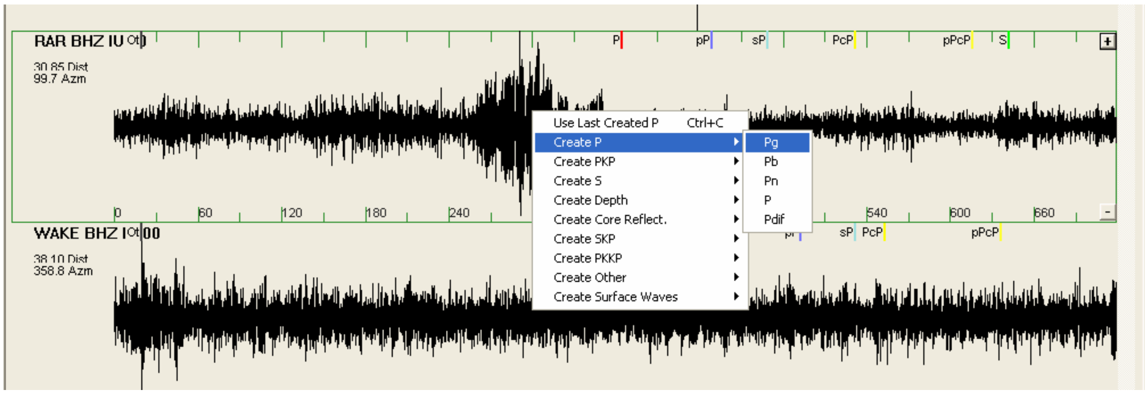


Figure 15: Phase Picking

Once the pick has been placed, the user can change its location by selecting it (left-clicking on the pick changes its color from blue to green indicating that it is selected) and dragging it to a new location.

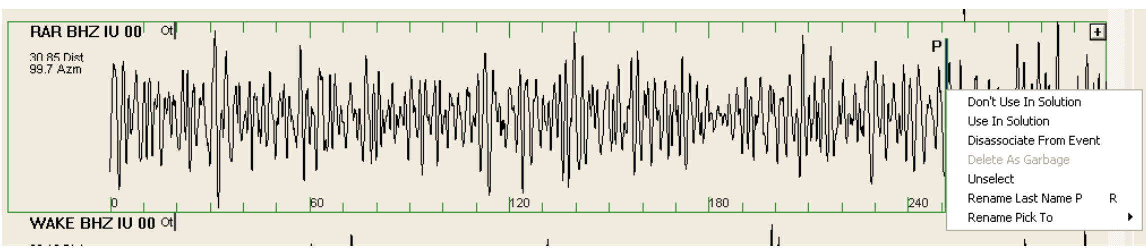


Figure 16: Pick Options

Response Hydra v1.47 does not allow picks to be deleted once they have been placed either manually or automatically. However, picks can be renamed, disassociated, marked to be used or not used in a solution as shown in Figure 16. Table 10 lists all options available when the user right-clicks on a pick.

Option	**Explanation**
Don't Use In Solution	Leave the selected pick associated with this event but do not use it in its location solution (the pick will still be published)
Use in Solution	Leave the selected pick associated with this event and use it in its next location solution.
Disassociate From Event	Disassociate selected pick from this event. The pick will not be used in the next solution and will not be published.
Unselect	Unselect selected pick (changes color from green to blue).
Rename Last Name P	This option is used to turn unassociated pick (created by raypicker module automatically) into a P-phase pick. Unassociated picks are black and marked with a letter U.
Rename Pick To …	Changes the phase name of the selected pick. The options are the

	same as shown in Figure II4.

Table 10: Pick Manipulation Options

3.2.5.2 Add Stations Map Display

Figure 17 shows a map display (invoked through *Map* button on Add Trace Display window) which enables the user to select stations whose trace data is to be displayed, and analyzed for picks that have not been associated with the current solution.

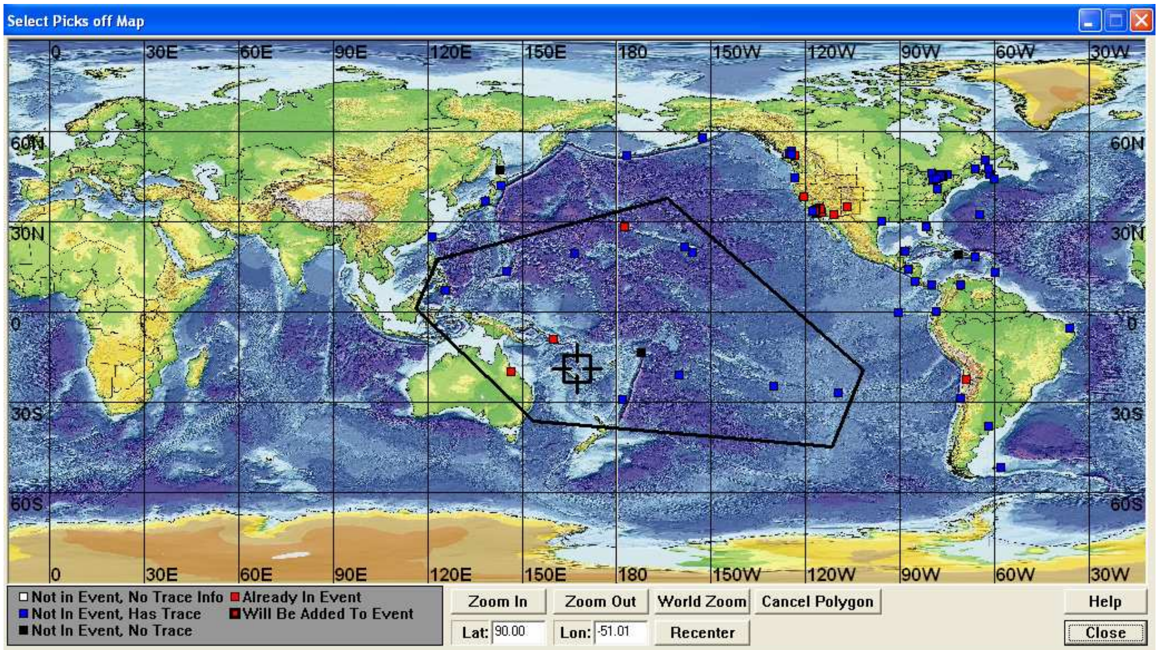


Figure 17: Add Station Map

The map of the world contains locations of all stations known to Hydra. The color of the station icons indicates if the station has trace data for the requested time period and whether its data has already been included in the event solution. The user can draw a polygon by right-clicking on the map. Every click creates a new polygon vertex. Vertices are connected with red lines. Once the polygon is complete, the color of the sides changes to black. To re-draw the polygon, the user can left-click anywhere on the map outside the polygon.

When the user is satisfied that the polygon drawn encompasses all stations (not in the event) whose data is to be displayed and analyzed, the stations can be added to the Stations to be Added List by right-clicking anywhere within the polygon and selecting Add All as shown in Figure 18.

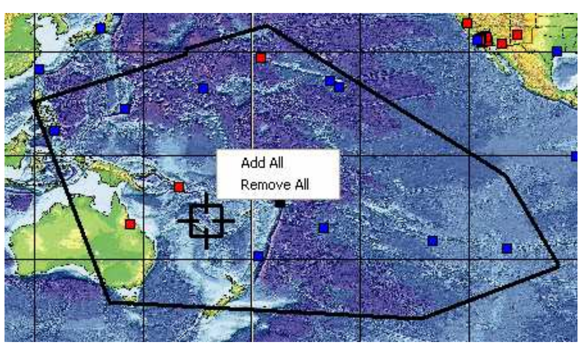


Figure 18: Add Stations within the Polygon

3.2.6 Waveforms Display

Waveforms display is invoked by pushing *View Waveforms* button on the Location Display page. Waveforms display shows all picks and traces that had been associated with the last calculated origin, and which are displayed in the *Phase Arrivals* table on the Location Display page (see Section 3.2.4).

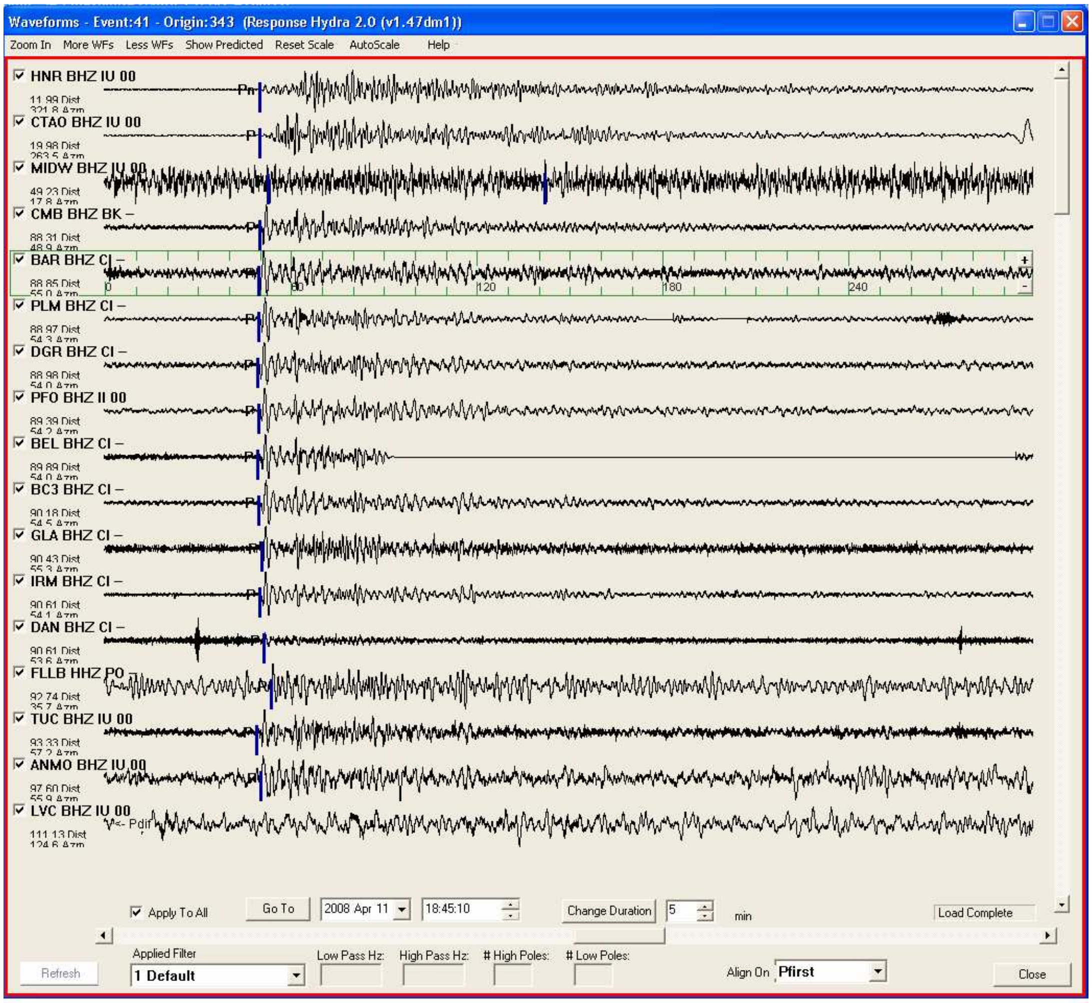


Figure 19: Waveform Display

All buttons, pull down menus and options as well as their functionality are identical to the ones shown in the Add Trace Display waveform window and described in Section 3.2.5.1. The only difference between the two is that in the Waveforms display, the user is processing traces and picks that had been associated with the last event origin. In AddTrace window, operations are performed on picks that have not yet been associated with any origins.

3.2.7 Mwp Display

Mwp Magnitude Display can be invoked by pushing *Mwp Magnitude* button on Event Summary window or any other magnitude display.

The display consists of several standard sections such as *Location Summary* (described in Table 5 for Event Summary display), *Magnitude* table (described in Section 3.2.3 for Event Summary Display) and *Station Magnitude Residuals Plot* by distance and azimuth (described in Section

3.2.4 for Location Display). The only difference between time residual plots of Location Display and magnitude residual plots of Magnitude displays is that the magnitude residuals vary between -2 and +2 units of magnitude whereas phase time residuals vary between -10 and +10 seconds.

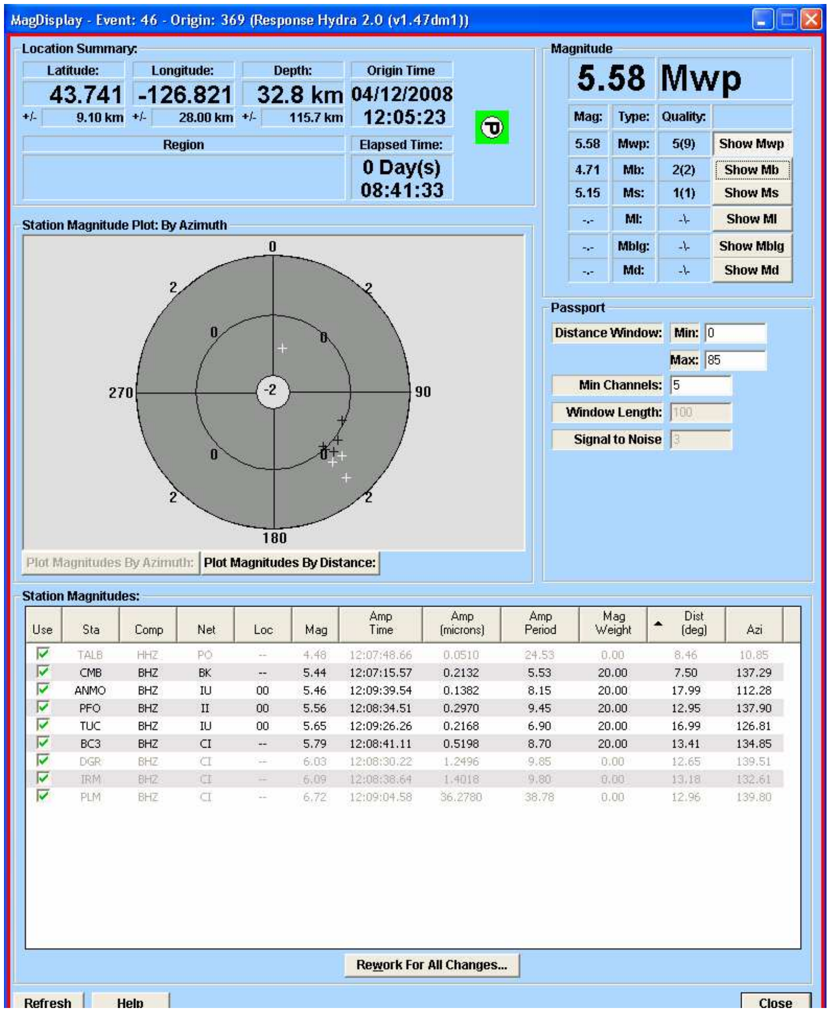


Figure 20: Mwp Magnitude Display

Just like all other magnitude displays, Mwp display has two unique sections: *Passport* and *Station Magnitudes*. Passport section contains passport entries that are used in Mwp calculations. The algorithm used to calculate Mwp magnitude as well as related passport entries are described in detail in Appendix B.3: Mwp Magnitude Module. *Station Magnitude* table entries are described in Table 11.

Column	Meaning
Use	Indicates whether this station's Mwp magnitude is to be used in overall magnitude calculation.
Sta	Station name.
Comp	Channel name.
Net	Network name.
Loc	Location name.
Mag	Calculated Mwp Magnitude.
Amp Time	Time of the first maximum amplitude peak.
Amp (microns)	Amplitude value of the first max amplitude peak in micrometers.
Amp Period	Period of the wave containing max amplitude peak.
Mag Weight	Magnitude weight which is used by the trimmed mean algorithm to

	calculate overall magnitude (all column entries add up to 100).
Dist (deg)	Station distance in degrees from the event epicenter.
Azi	Azimuth of the station relative to the event epicenter.

Table 11: Mwp Magnitude Table Parameters

3.2.8 Mb Display

Mb Magnitude Display can be invoked by pushing *Mb Magnitude* button on Event Summary window or any other magnitude display.

The display consists of several standard sections such as *Location Summary* (described in Table 5 for Event Summary display), *Magnitude* table (described in Section 3.2.3 for Event Summary Display) and *Station Magnitude Residuals Plot* by distance and azimuth (described in Section 3.2.4 for Location Display).

Just like all other magnitude displays, Mb display has two unique sections: *Passport* and *Station Magnitudes*. Passport section contains passport entries that are used in Mb calculations. The algorithm used to calculate Mb magnitude as well as related passport entries are described in detail in Appendix B.4: Mb Magnitude Module. *Station Magnitude* table entries are listed in Table 12.

Column	**Meaning**
Use	Indicates whether this station's Mb magnitude is to be used in overall magnitude calculation.
Sta	Station name.
Comp	Channel name.
Net	Network name.
Loc	Location name.
Mag	Calculated Mb Magnitude.
Amp Time	Time of the amplitude peak.
Amp (nanometers)	Max amplitude taken in the first 60s following the P-wave arrival with *Amp Period* in the appropriate range.
Amp Period	Period of the wave containing max amplitude peak. This value must be within specified *Period Window* (0.1s to 3s).
Mag Weight	Magnitude weight which is used by the trimmed mean algorithm to calculate overall magnitude (all column entries add up to 100).
Dist (deg)	Station distance in degrees from the event epicenter.
Azi	Azimuth of the station relative to the event epicenter.

Table 12: Mb Magnitude Table Parameters

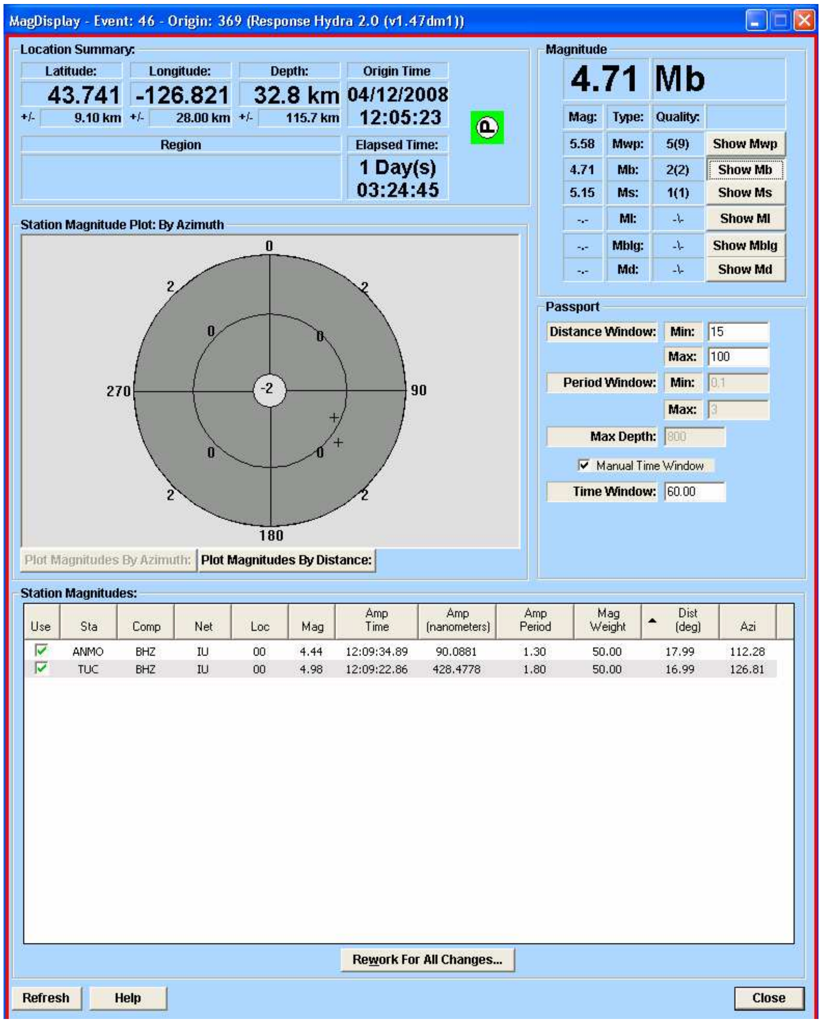


Figure 20: Mb Magnitude Display

3.2.9 Ms Magnitude Display

Ms Magnitude Display can be invoked by pushing *Ms Magnitude* button on Event Summary window or any other magnitude display.

The display consists of several standard sections such as *Location Summary* (described in Table 5 for Event Summary display), *Magnitude* table (described in Section 3.2.3 for Event Summary Display) and *Station Magnitude Residuals Plot* by distance and azimuth (described in Section 3.2.4 for Location Display).

Just like all other magnitude displays, Ms display has two unique sections: *Passport* and *Station Magnitudes*. Passport section contains passport entries that are used in Ms calculations. The algorithm used to calculate Ms magnitude as well as related passport entries are described in detail in Appendix B.5: Ms Magnitude Module. *Station Magnitude* table entries are listed in Table 13.

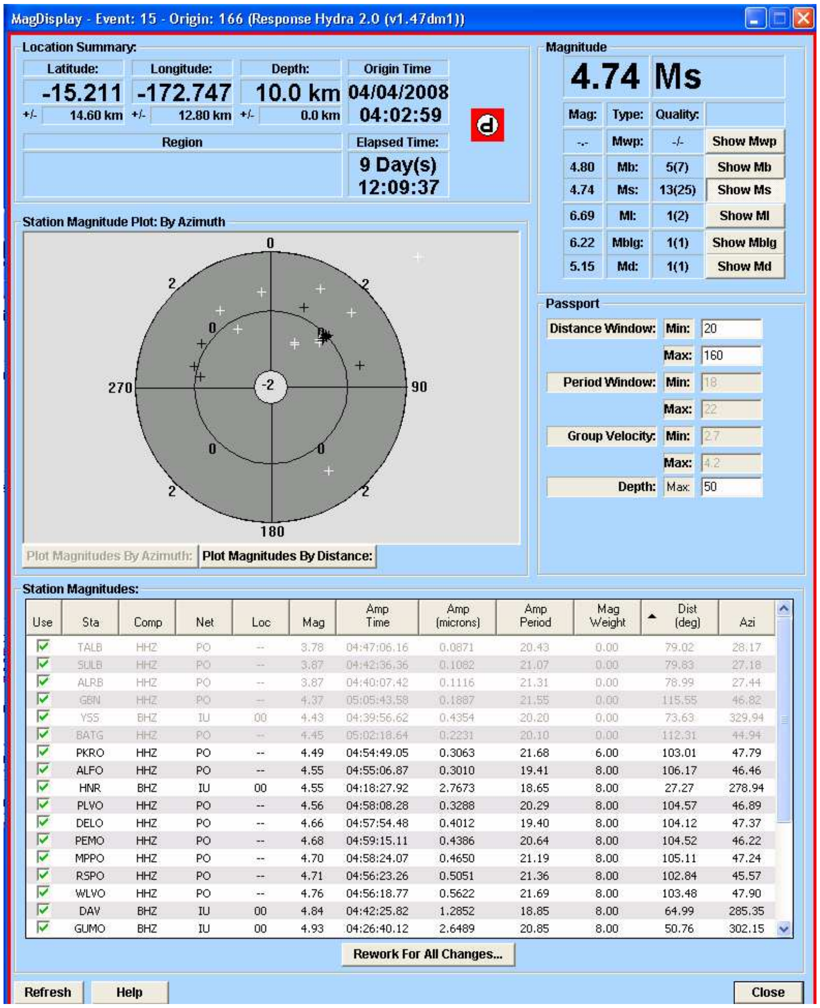


Figure 21: Ms Magnitude Display

Column	Meaning
Use	Indicates whether this station’s Ms magnitude is to be used in overall magnitude calculation.
Sta	Station name.
Comp	Channel name.
Net	Network name.
Loc	Location name.
Mag	Calculated Ms Magnitude.
Amp Time	Time of the maximum zero-to-peak amplitude.
Amp (microns)	Max zero-to-peak amplitude in micrometers taken in the expected Rayleigh surface wave arrival time window.
Amp Period	Period of the wave containing max zero-to-peak amplitude. This value must within specified *Period Window* (18s to 22s).
Mag Weight	Magnitude weight which is used by the trimmed mean algorithm to calculate overall magnitude (all column entries add up to 100).
Dist (deg)	Station distance in degrees from the event epicenter.
Azi	Azimuth of the station relative to the event epicenter.

Table 13: Ms Magnitude Table Parameters

3.2.10 Ml Magnitude Display

Ml Magnitude Display can be invoked by pushing *Ml Magnitude* button on Event Summary window or any other magnitude display.

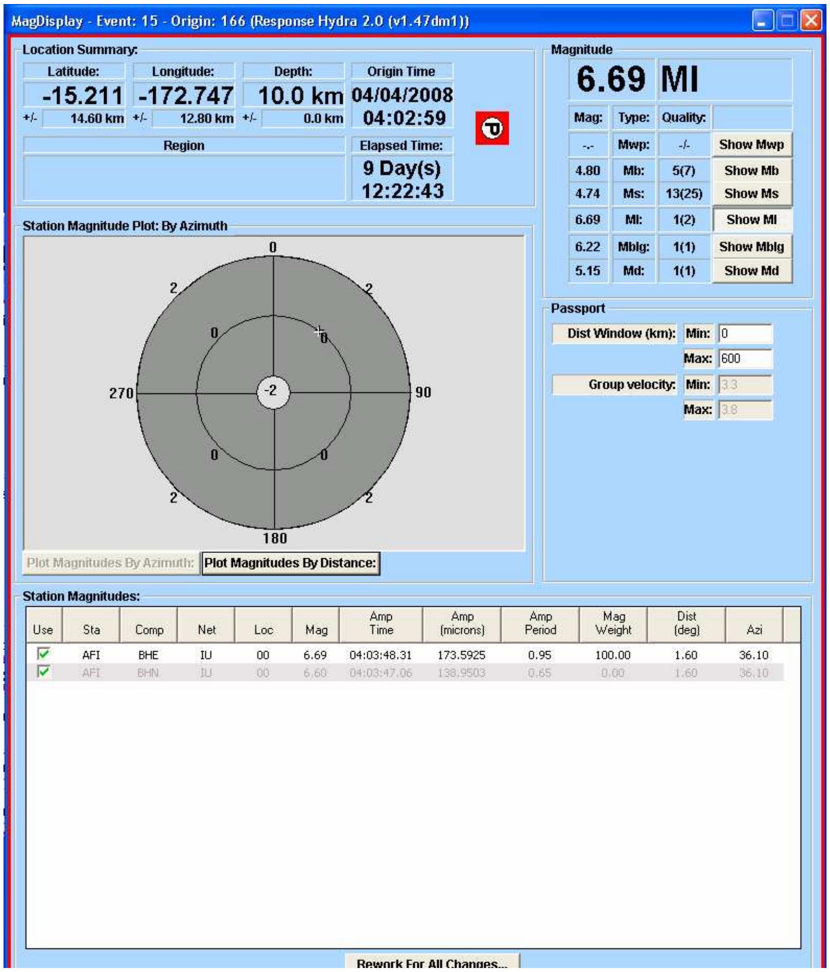


Figure 22: Ml Magnitude Display

The display consists of several standard sections such as *Location Summary* (described in Table 5 for Event Summary display), *Magnitude* table (described in Section 3.2.3 for Event Summary Display) and *Station Magnitude Residuals Plot* by distance and azimuth (described in Section 3.2.4 for Location Display).

Just like all other magnitude displays, Ml display has two unique sections: *Passport* and *Station Magnitudes*. Passport section contains passport entries that are used in Ml calculations. The algorithm used to calculate Ml magnitude as well as related passport entries are described in detail in Appendix B.1: Ml Magnitude Module. *Station Magnitude* table entries are listed in Table 14.

Column	Meaning
Use	Indicates whether this station's Ml magnitude is to be used in overall magnitude calculation.
Sta	Station name.
Comp	Channel name.
Net	Network name.
Loc	Location name.

Mag	Calculated Ml Magnitude.
Amp Time	Time of the maximum zero-to-peak amplitude.
Amp (microns)	Max zero-to-peak amplitude in micrometers taken in the expected S-wave arrival time window.
Amp Period	Period of the wave containing max zero-to-peak amplitude.
Mag Weight	Magnitude weight which is used by the trimmed mean algorithm to calculate overall magnitude (all column entries add up to 100).
Dist (deg)	Station distance in degrees from the event epicenter.
Azi	Azimuth of the station relative to the event epicenter.

Table 14: Ml Magnitude Table Parameters

3.2.11 MbLg Magnitude Display

MbLg Magnitude Display can be invoked by pushing *MbLg Magnitude* button on Event Summary window or any other magnitude display.

The display consists of several standard sections such as *Location Summary* (described in Table 5 for Event Summary display), *Magnitude* table (described in Section 3.2.3 for Event Summary Display) and *Station Magnitude Residuals Plot* by distance and azimuth (described in Section 3.2.4 for Location Display).

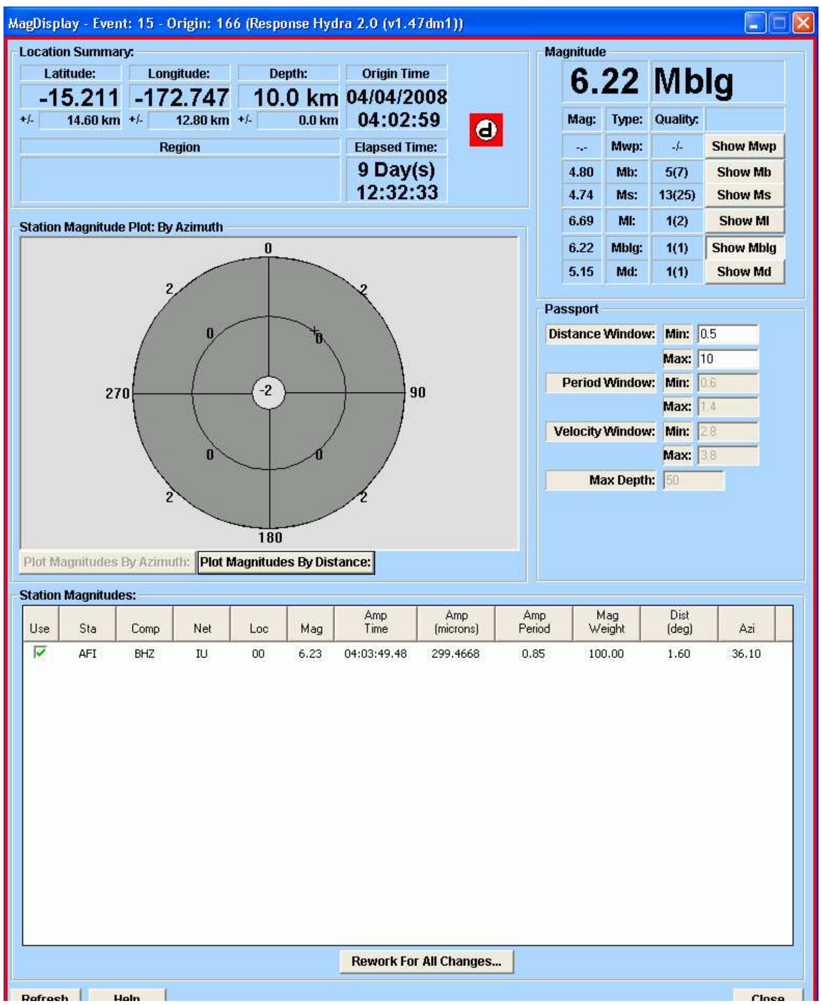


Figure 23: MbLg Magnitude Display

Just like all other magnitude displays, MbLg display has two unique sections: *Passport* and *Station Magnitudes*. Passport section contains passport entries that are used in MbLg calculations. The algorithm used to calculate MbLg magnitude as well as related passport entries are described in detail in Appendix B.5: MbLg Magnitude Module. *Station Magnitude* table entries are listed in Table 15.

Column	Meaning
Use	Indicates whether this station's MbLg magnitude is to be used in overall magnitude calculation.
Sta	Station name.
Comp	Channel name.
Net	Network name.
Loc	Location name.
Mag	Calculated MbLg Magnitude.
Amp Time	Time of the maximum zero-to-peak amplitude.
Amp (microns)	Max peak-to-peak amplitude in micrometers taken in the expected Lg Crustal Wave arrival time window.
Amp Period	Period of the wave containing max peak-to-peak amplitude. This value must within specified *Period Window* (0.6s to 1.4s).
Mag Weight	Magnitude weight which is used by the trimmed mean algorithm to calculate overall magnitude (all column entries add up to 100).
Dist (deg)	Station distance in degrees from the event epicenter.
Azi	Azimuth of the station relative to the event epicenter.

Table 15: MbLg Magnitude Table Parameters

3.2.12 Md Magnitude Display

Md Magnitude Display can be invoked by pushing *Md Magnitude* button on Event Summary window or any other magnitude display.

The display consists of several standard sections such as *Location Summary* (described in Table 5 for Event Summary display), *Magnitude* table (described in Section 3.2.3 for Event Summary Display) and *Station Magnitude Residuals Plot* by distance and azimuth (described in Section 3.2.4 for Location Display).

Just like all other magnitude displays, Md display has two unique sections: *Passport* and *Station Magnitudes*. Passport section contains passport entries that are used in Ms calculations. The algorithm used to calculate Md magnitude as well as related passport entries are described in detail in Appendix B.2: Md Magnitude Module. *Station Magnitude* table entries are listed in Table 13.

Column	Meaning
Use	Indicates whether this station's Md magnitude is to be used in overall magnitude calculation.
Sta	Station name.
Comp	Channel name.
Net	Network name.
Loc	Location name.
Mag	Calculated Md Magnitude.
Code Duration	Length of the event.
Coda Termination	Time at which waves from the event go back into background noise.
Mag Weight	Magnitude weight which is used by the trimmed mean algorithm to calculate overall magnitude (all column entries add up to 100).
Dist (deg)	Station distance in degrees from the event epicenter.
Azi	Azimuth of the station relative to the event epicenter.

Table 15: Md Magnitude Table Parameters

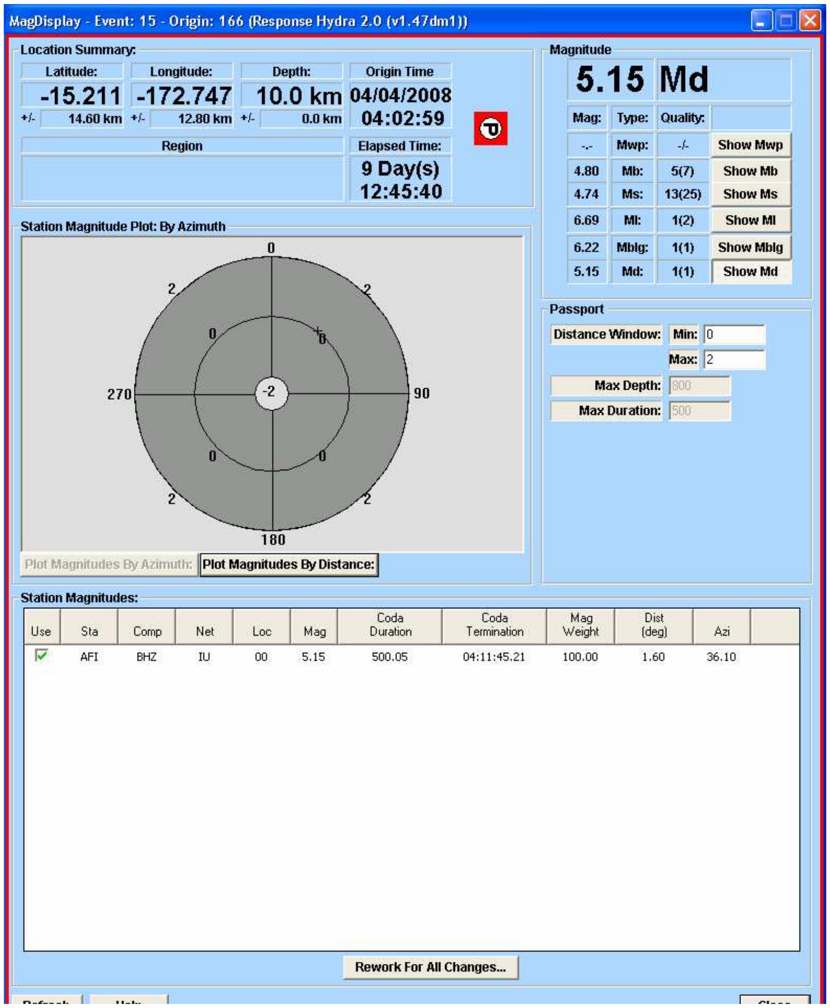


Figure 24: Md Magnitude Display

3.2.13 MT and CMT Module Displays

Table 16 highlights the basic differences between moment tensor solutions produced by MT and CMT modules.

	CMT Module	**MT Module**
Data used for calculations	Body Waves	Surface Waves
Wave frequency range	10 – 80 seconds	120 – 1000 seconds
Good Solution computation time	Approximately 12 – 18 minutes	Approximately 45 minutes
Valid Mw Magnitude Range	5.5 – 7.5	6.0 – 8.0
Green's Functions	Computed during CMT calculations	Pre-computed and stored in /hydra/run/params/gfs_lp_1km
Hypocenter relocation	Depth only	Depth and Epicenter

Table 16: CMT and MT Module Features

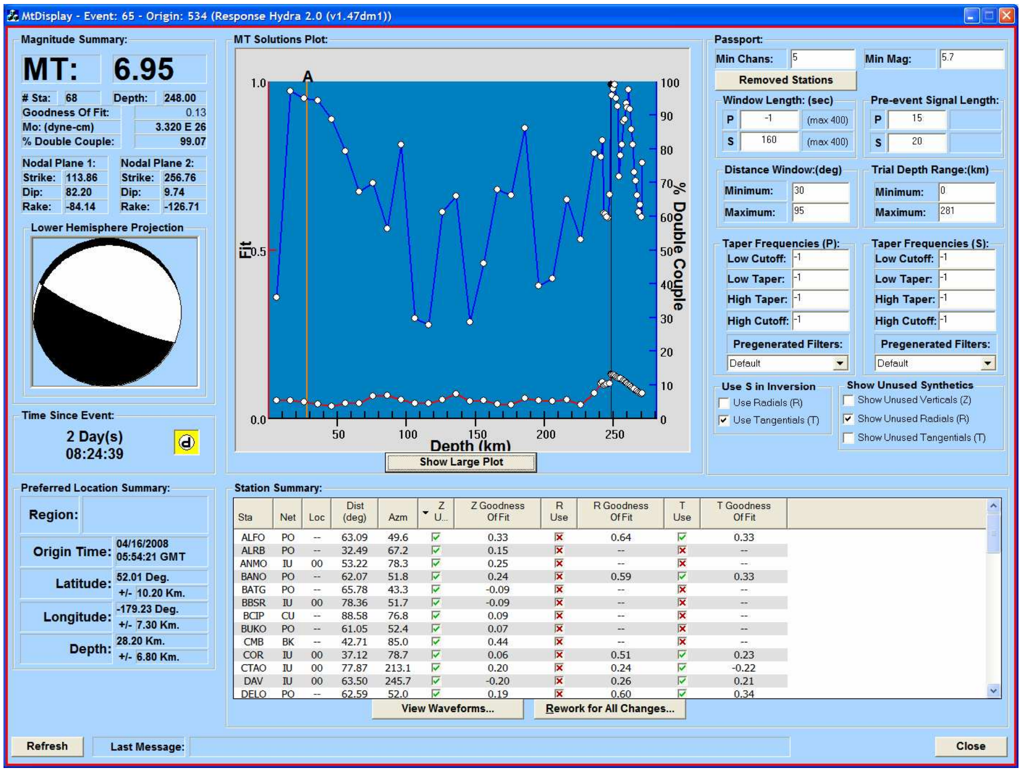


Figure 25: MT Display

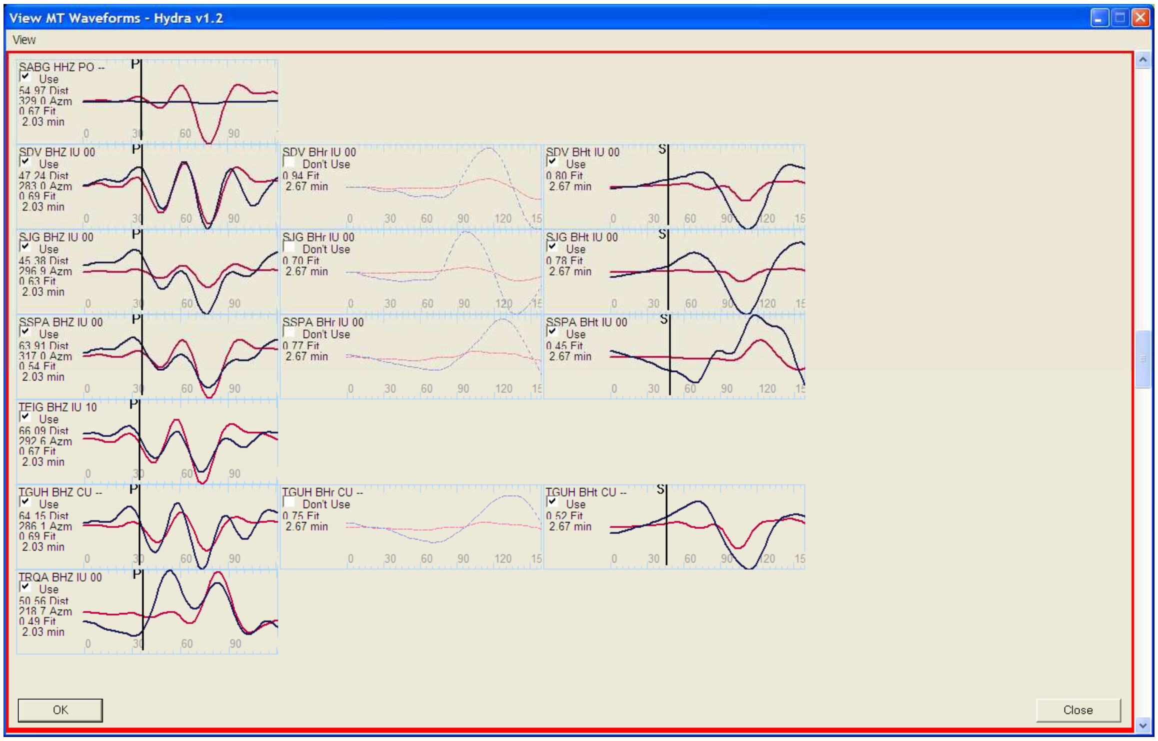


Figure 26: Synthetic (Red) vs Actual (Black) Waveforms used in MT Inversion

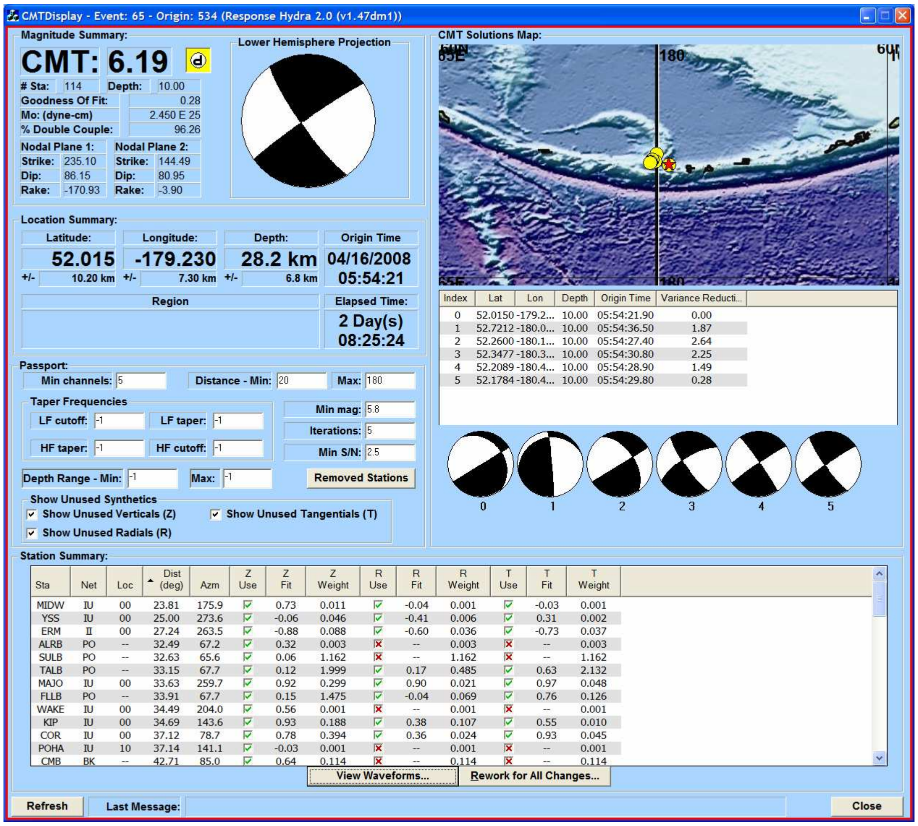


Figure 27: CMT Display

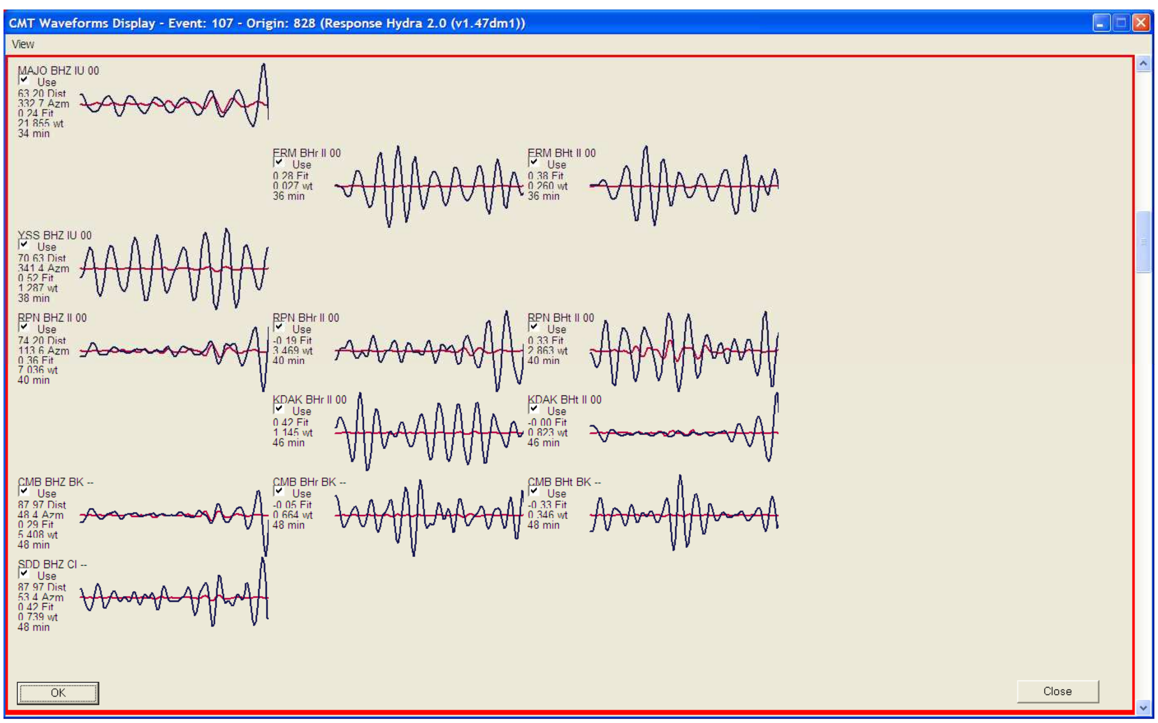


Figure 28: Synthetic (Red) vs Actual (Black) Waveforms used in CMT Inversion

3.3 Engineering Displays

Engineering displays that are bundled with standard Hydra Server and Display Client installations enable the user to track incoming trace data (SCNLTracker), edit passport parameters (PassportEditor), view system processing states (State Display), change system role from primary to backup or vice versa (SystemState Display), manipulate real-time Earthworm-based processing modules (StartStop Console) and set up event notifications (NotificationManager).

3.3.1 Passport Editor Display

Passport Editor display comes bundled with Hydra Server installation. It can be invoked by selecting *All Programs -> Response Hydra v1.47 -> Hydra Passport Editor* on either Primary (Red) or Backup (Blue) Hydra Server. Passport Editor allows the user to manually edit individual passport entries, check to see that the new entries are in correct format and insert updated passport into Hydra database.

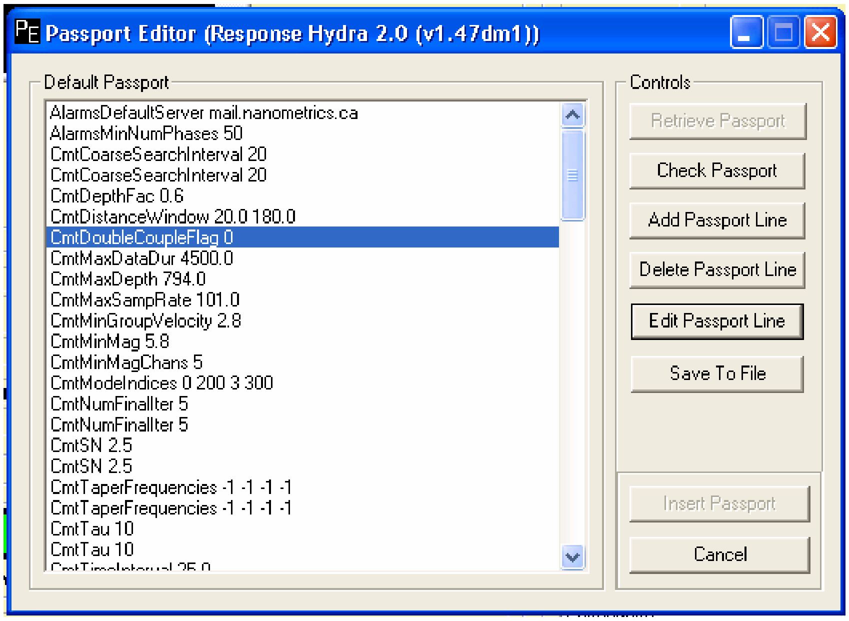


Figure 29: Passport Editor Display

Passports contain configuration parameters for all state processing modules. Some of the configuration parameters can be accessed and changed through Analyst Displays, however, the majority can only be accessed through Passport Editor. Once an event has been inserted into the database and processed once, only the passport parameters accessible through Analyst Displays can be changed. If the default passport is retrieved from the database and updated through Passport Editor, the parameter changes will only have effect on events processed after the insertion of the updated passport.

As Figure 30 shows, the passport can be retrieved for editing either by being loaded from the Hydra database or from a local text file. If the passport is loaded from the database, the user has to connect to the database using standard login parameters:

User:	**ewdb_main**
Password:	**main**
DBMS Name:	**eqs.hydra**

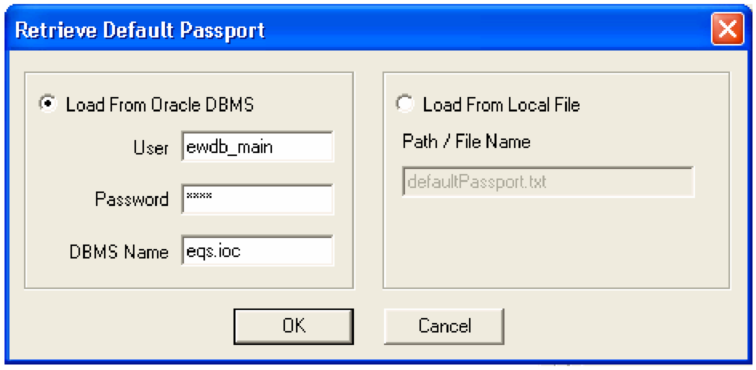


Figure 30: Loading Passport for Editing

If the passport is loaded from a text file, the user has to specify full path to the passport text file. Once the passport has been loaded, Table 17 describes available Controls:

Button	Function
Retrieve Passport	Load default passport to Passport Editor from Hydra database or a text file as shown in Figure XX2.
Check Passport	Confirm that the passport is in correct format for insertion into Hydra database.
Add Passport Line	Add a new parameter line to the passport.
Delete Passport Line	Delete selected parameter line from the passport.
Edit Passport Line	Edit selected parameter line.
Save to File	Save loaded passport into a text file.
Insert Passport	Insert passport into Hydra database. This options is only available once the passport has been checked by pressing *Check Passport* button.
Cancel	Close the Passport Editor window.

Table 17: Passport Editor Buttons

3.3.2 SCNL Tracker Display

SCNL Tracker display is bundled with Hydra Server and Hydra Displays Client installations. It is started by invoking *All Programs -> Response Hydra v1.47 -> SCNL Tracker* on Hydra Server machine or *Primary (Red) SCNL Tracker* and *Backup (Blue) SCNL Tracker* on Display Client machine. The main purpose of SCNL tracker is to track waveform data information from all channels known to Hydra Server. IT is usually invoked to see which channels are currently being processed by real-time processing modules. This is as Hydra does not have real-time waveform viewer.

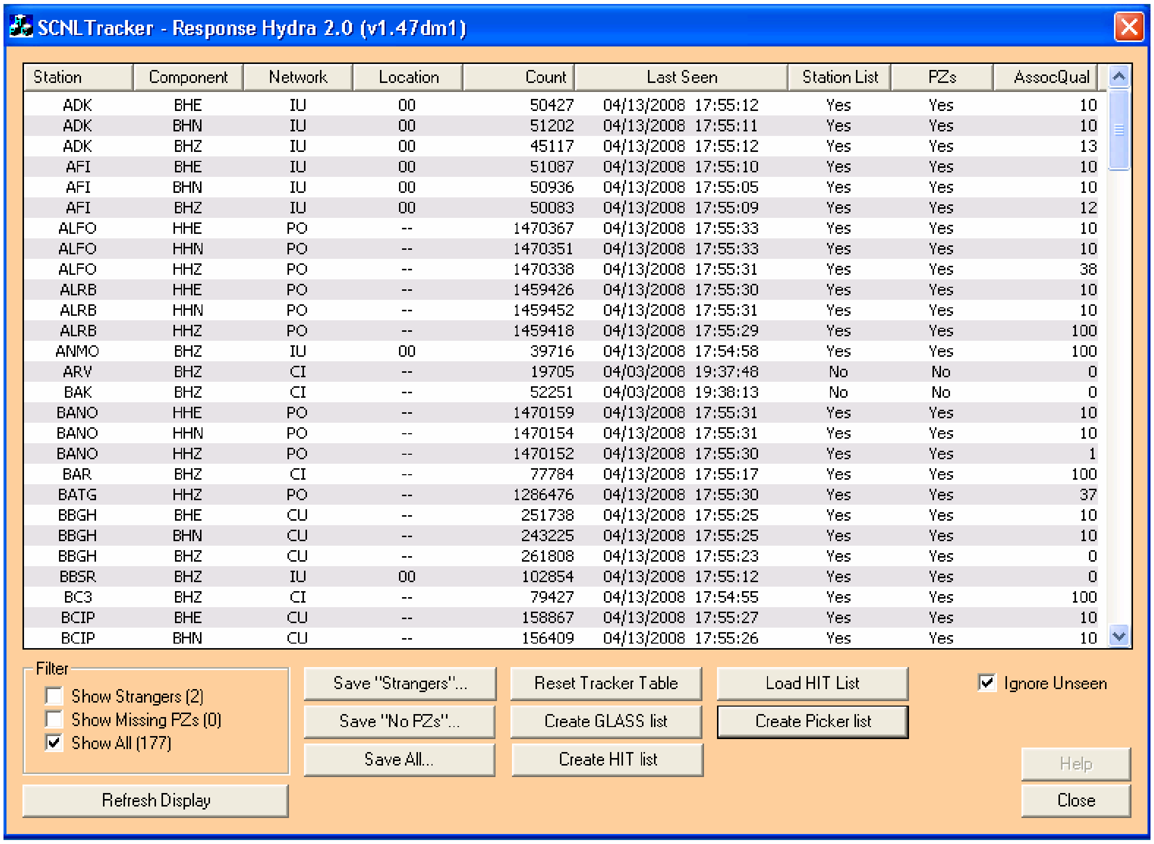
SCNL Tracker connects to the database and reads data availability information from tables that are populated by tracetracker Earthworm-style module. Pick association statistics displayed in the *Assoc Quality* column are calculated and inserted into the database by gen_assoc_stats module (maintained by Hydra Guardian Angel service).

SCNL Tracker is shown in Figure 31. The main part of the window is taken up by the table containing all channels known to Hydra. Table columns are described in Table 18:

Column	Meaning
Station	Station code.
Component	Channel code.
Network	Network code.
Location	Location code
Count	Number of trace messages received since last reset.
Last Seen	Time of the last received trace message.

Station List	Channel metadata inserted successfully into database using stalist_dk2ora command (see Section 2.1.4.2).
PZs	Channel poles and zeros inserted successfully into database using pzray2ora command (see Section 2.1.4.2).
AssocQual	Percentage of associated picks from this channel.

Table 18: SCNL Tracker Table Columns



Station	Component	Network	Location	Count	Last Seen	Station List	PZs	AssocQual
ADK	BHE	IU	00	50427	04/13/2008 17:55:12	Yes	Yes	10
ADK	BHN	IU	00	51202	04/13/2008 17:55:11	Yes	Yes	10
ADK	BHZ	IU	00	45117	04/13/2008 17:55:12	Yes	Yes	13
AFI	BHE	IU	00	51087	04/13/2008 17:55:10	Yes	Yes	10
AFI	BHN	IU	00	50936	04/13/2008 17:55:05	Yes	Yes	10
AFI	BHZ	IU	00	50083	04/13/2008 17:55:09	Yes	Yes	12
ALFO	HHE	PO	--	1470367	04/13/2008 17:55:33	Yes	Yes	10
ALFO	HHN	PO	--	1470351	04/13/2008 17:55:33	Yes	Yes	10
ALFO	HHZ	PO	--	1470338	04/13/2008 17:55:31	Yes	Yes	38
ALRB	HHE	PO	--	1459426	04/13/2008 17:55:30	Yes	Yes	10
ALRB	HHN	PO	--	1459452	04/13/2008 17:55:31	Yes	Yes	10
ALRB	HHZ	PO	--	1459418	04/13/2008 17:55:29	Yes	Yes	100
ANMO	BHZ	IU	00	39716	04/13/2008 17:54:58	Yes	Yes	100
ARV	BHZ	CI	--	19705	04/03/2008 19:37:48	No	No	0
BAK	BHZ	CI	--	52251	04/03/2008 19:38:13	No	No	0
BANO	HHE	PO	--	1470159	04/13/2008 17:55:31	Yes	Yes	10
BANO	HHN	PO	--	1470154	04/13/2008 17:55:31	Yes	Yes	10
BANO	HHZ	PO	--	1470152	04/13/2008 17:55:30	Yes	Yes	1
BAR	BHZ	CI	--	77784	04/13/2008 17:55:17	Yes	Yes	100
BATG	HHZ	PO	--	1286476	04/13/2008 17:55:30	Yes	Yes	37
BBGH	BHE	CU	--	251738	04/13/2008 17:55:25	Yes	Yes	10
BBGH	BHN	CU	--	243225	04/13/2008 17:55:25	Yes	Yes	10
BBGH	BHZ	CU	--	261808	04/13/2008 17:55:23	Yes	Yes	0
BBSR	BHZ	IU	00	102854	04/13/2008 17:55:12	Yes	Yes	0
BC3	BHZ	CI	--	79427	04/13/2008 17:54:55	Yes	Yes	100
BCIP	BHE	CU	--	158867	04/13/2008 17:55:27	Yes	Yes	10
BCIP	BHN	CU	--	156409	04/13/2008 17:55:26	Yes		10

Figure 31: SCNL Tracker Display

The lower part of the window contains Filter section and several buttons enabling the user to create picker and GLASS station lists based on the real-time data availability. The functionality of all check boxes and buttons is described in Table 19:

Check box or Button	Function
Shown Strangers (X)	Display only the channels which are coming in but whose metadata (stalist_dk2ora) and poles and zeros (pzray2ora) have not been inserted into the database. X is the number of such channels.
Show Missing PZs (Y)	Display only the channels which are coming in and whose metadata (stalist_dk2ora) is inserted into the database BUT whose poles and zeros have not been inserted into the database. Y is the number of such channels.
Show All (Z)	Display all channels which are coming in. Z is the total number of such channels.
Save "Strangers"	Create a text file containing SCNL information for each channel coming in whose metadata and poles and zeros have not been inserted into the database.
Save "No PZs"	Create a text file containing SCNL information for each channel coming in whose poles and zeros have not been inserted into the

	database.
Save All	Create a text file containing SCNL information for each channel coming in.
Reset Tracker Table	Reset Count and Last Seen columns entries in the database for each channel.
Create GLASS list	Create a GLASS channel list in hinv file format which includes PickAssoc statistics.
Create HIT List	
Load HIT List	
Create Picker List	Create raypicker channel list.
Ignore Unseen	Ignore channels which are not coming in and whose metadata has been loaded in the database.

Table 19: SCNL Tracker Widgets

3.3.3 State Display

State display is bundled with Hydra Server and Hydra Displays Client installations. It is started by invoking *All Programs -> Response Hydra v1.47 -> State Display* on Hydra Server machine or *Primary (Red) State Display* and *Backup (Blue) State Display* on Displays Client machine. The purpose of this display (Figure 32) is to show state processing module statistics such as number of times each module was invoked, average execution time, average wait time and state manager involved. The information displayed is for a time period specified by *Browse start* and *Browse for* text fields. The display is updated for the new time period after the user presses *Browse* button.

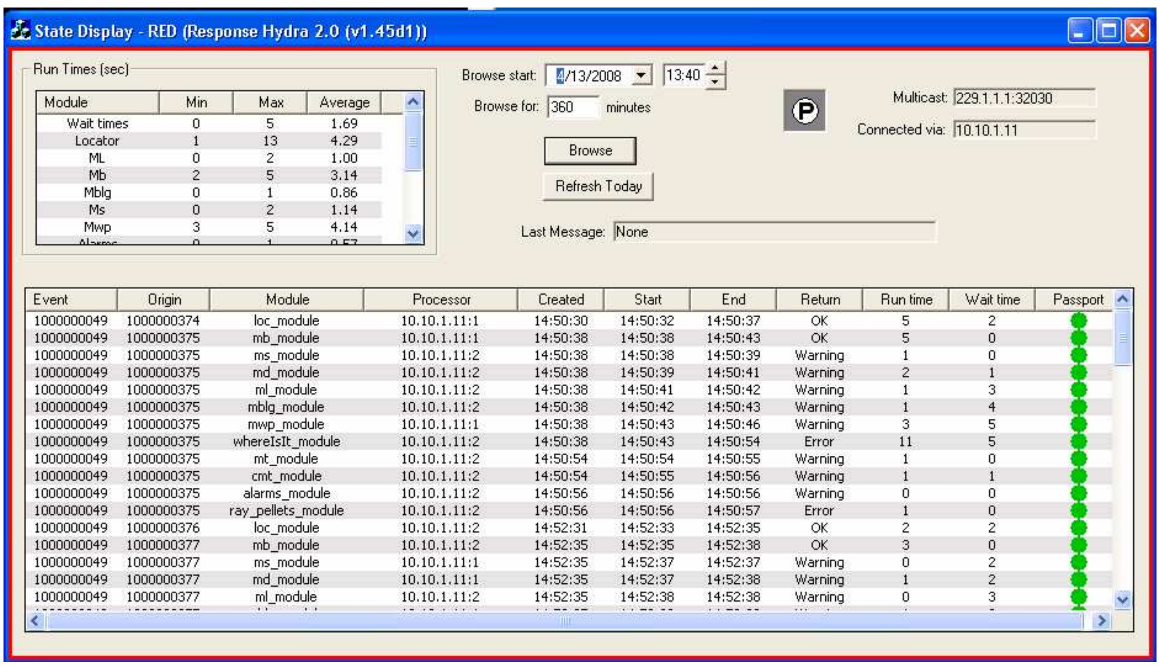


Figure 32: State Display

Run Times (sec) table lists all state processing modules as well as minimum, maximum and average run time of each for the time period indicated. These statistics can be obtained for a maximum duration of one week and give an indication of the system performance. The main table lists states that had been inserted into the state processing table for each origin processed.

Column	Function
Event	Hydra Event ID.

Origin	Hydra Origin ID.
Module	State processing module.
Processor	State Manager ID as the IP address of the machine running that State Manager and its serial number. Default Response Hydra installation runs two State Managers.
Created	Time when the new task (state) was scheduled.
Start	Time when the execution of the task started.
End	Time when the execution of the task completed.
Return	Message returned by the module in question (*OK, Warning, Error*).
Run Time	Task run time (difference between *Start* and *End* time).
Wait Time	Task schedule wait time (difference between *Created* and *Start* time).

Table 20: State Display Table

3.3.4 System State Display

System State display only comes with Hydra Server installation. It can be invoked by selecting *All Programs -> Response Hydra v1.47 -> Hydra System State*. Its purpose is to designate particular Hydra Server as either Primary (Red) or Backup (Blue). Both Hydra installations are identical except for the fact that Backup (Blue) Hydra Server does not produce raypellets. Therefore, the results of event processing on Backup (Blue) Server are not published by Athena publishing software.

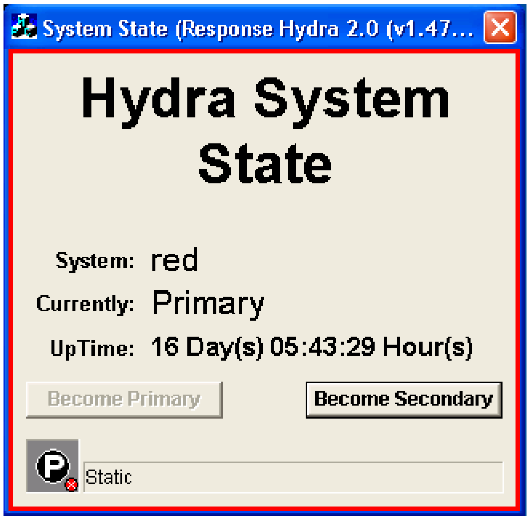


Figure 33: System State Display

Pushing *Become Primary* button will change rotating database connection widget letter from S to P on all connected displays. Pushing *Become Secondary* button will change rotating database connection widget letter from P to S (see Table 1) on all connected displays.

3.3.5 StartStop Console

StartStop console is distributed as part of the standard Earthworm package. It enables the user to check the status and restart all Earthworm-based Hydra modules. StartStop Console is only supplied as part of Hydra Server installation. It can be invoked by selecting *All Programs -> Response Hydra v1.47 -> StartStop Console* and then clicking on *Create New Console* button as shown in Figure 34.

Figure 34: StartStop Console Startup

Create New Console button generates a new Command Prompt Window with all appropriate Earthworm paths set up. The following is a list of commands that can be executed in the StartStop console window:

Command	Function
Status	Prints the status of all rings and modules listed in startstop_nt.d file (see Figure XX12).
Restart pid	Restart specific module with process id *pid*.
Reconfigure	Reload startstop_nt.d configuration file so that any modules added since the last start up are started.

Table 21: StartStop Console Commands

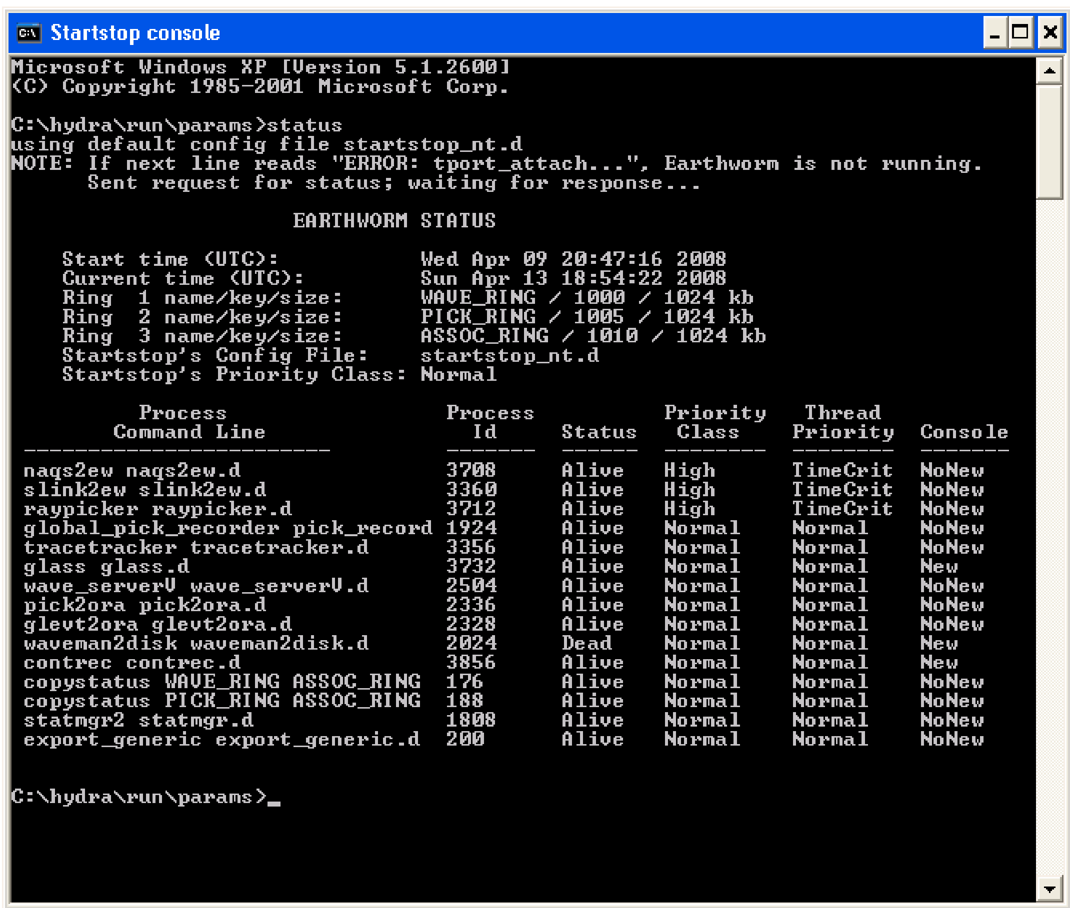


Figure 35: Status Command Output

Appendix A: Station Metadata File Formats

The default installation of Hydra Server software contains two sample configuration files (blessed_channel_list.dk and blessed_pz_list.pzray) outlining the format in which station metadata (SCNLs, sensor poles and zeros, station locations, sample rates etc.) is to be specified in order to be inserted into the Hydra Oracle database.

Appendix A.1: Blessed_channel_list.dk File Format

The next entry exemplifies the format in which seismic channel metadata is to be listed in blessed_channel_list.dk file followed by explanations of the individual columns:

```
ALFO   HHE    PO     --  45.6283  -74.8842     0  10.000  CMG-3E  396000000  90   0         0 Alfred, Ontario
```

- Column 1 (ALFO) – station name
- Column 2 (HHZ) – channel name
- Column 3 (PO) – network name
- Column 4 (--) – location name
- Column 5 (45.6283) – station location latitude (negative for South)
- Column 6 (-74.8842) – station location longitude (negative for West)
- Column 7 (0) – station elevation
- Column 8 (10.000) – channel sampling rate
- Column 9 (CMG-3E) – seismometer type
- Column 10 (396000000) – the time (t_{on} in long seconds) at which the current metadata parameters became valid
- Column 11 (90) – azimuth of the seismic channel (90^o for East-West channel, 0 otherwise)
- Column 12 (0) – dip of the seismic channel (-90^o for Vertical channel, 0 otherwise)
- Column 13 (0) – the time (t_{off} in long seconds) at which the current metadata parameters became invalid (0 means that the listed parameters are still valid)
- Column 14 (Alfred, Ontario) – comment field which is usually filled in with station location name

Appendix A.2: Blessed_pz_list.pzray File Format

The next entry exemplifies the format in which poles and zeros metadata is to be listed in blessed_pz_list.pzray file followed by explanations of the individual rows and columns:

```
ALFO  HHZ PO --
* Sensor: CMG-3E
CONSTANT                 1.4437E+09
ZEROS   3
0.0000E+00  0.0000E+00
0.0000E+00  0.0000E+00
0.0000E+00  0.0000E+00
POLES   5
-5.0265E+02  0.00000E+00
-1.0053E+03  0.00000E+00
-1.1309E+03  0.00000E+00
-4.4420E-02  4.44200E-02
-4.4420E-02 -4.44200E-02
```

Row 1

- Column 1 (ALFO) – station name
- Column 2 (HHZ) – channel name
- Column 3 (PO) – network name
- Column 4 (--) – location name

Row 2

- Sensor type comment

Row 3

- Column 1 (CONSTANT) – do not change
- Column 2 (1.4437E+09) – Hydra channel gain constant (see Appendix A.3 for Hydra gain constant calculation procedure)

Row 4

- Column 1 (ZEROS) – do not change
- Column 2 (3) – number of zeros in seismometer response*

Rows (5,6,7)

- Seismometer response zeros. Real part is listed in column 1 and imaginary part in column 2.

Row (8)

- Column 1 (POLES) – do not change
- Column 2 (5) – number of poles in seismometer response

Rows (9, 10, 11, 12, 13)

- Seismometer response poles. Real part is listed in column 1 and imaginary part in column 2.

* Seismometer response is specified in displacement. In order to convert from velocity response to displacement response, add one zero at 0 (Re) 0 (Im). For acceleration, add two zeros at 0 (Re) 0 (Im).

Appendix A.3: Hydra Channel Gain Constant Calculation

Appendix A.3.1: Hydra Channel Gain Constant Calculation Example

Hydra Channel Gain Constant Calculation (row 3 column 2 of each channel entry in the blessed_pz_list.pzray file):

1. Obtain the seismometer normalization factor A_{0V} (in velocity) from the seismometer manual. The normalization factor is usually given in seismometer response section together with poles and zeros.

   Ex. Trillium 40 normalization factor A_{0V} = 133310

2. Obtain the seismometer sensitivity (S_{Seis} in $^{V}/_{m/s}$) and the digitizer sensitivity (S_{Dig} in $^{counts}/_{V}$) and calculate system gain in velocity S_{GV}:

   $$S_{GV} = S_{Dig}\ (^{counts}/_{V}) \times S_{Seis}\ (^{V}/_{m/s})$$

   Ex. Trident digitizer with sensitivity of 0.4 $^{counts}/_{\mu V}$ and Trillium 40 seismometer with sensitivity of 1500 $^{V}/_{m/s}$:

$$S_{GV} = 400000\ (^{counts}/_{V}) \times 1500\ (^{V}/_{m/s}) = 0.6\ ^{counts}/_{nm/s}$$

3. Calculate Hydra Gain Constant C_{Hydra}:

$$\mathbf{C_{Hydra} = A_{0V} \times S_{GV}}$$

Ex. Using the values calculated in previous steps:

$$\boxed{C_{Hydra}} = 133310 \times 0.6 = \boxed{7.9986 \times 10^4\,*}$$

* Value that is entered in row 3 column 2 of the .pzray poles and zeros file (see Appendix A.2).

Appendix A.3.2: Hydra Constant Parameters in IRIS Response Files

The following example outlines how to obtain necessary information for Hydra Constant calculation if USGS/IRIS GSN stations are being added to a Hydra installation. The user can obtain response information for channels being added from IRIS SeismiQuerry utility (http://www.iris.edu/SeismiQuery/help.html#info).

Taking ANMO, BHZ, IU, 00 SCNL as an example, Figure 34 depicts the top part (Stage 1) of the response file as provided by SeismiQuerry. Stage 1 contains seismometer poles and zeros (in velocity) as well as the required normalization factor and frequency (highlighted).

```
#
##################################################################################
#
B050F03     Station:      ANMO
B050F16     Network:      IU
B052F03     Location:     00
B052F04     Channel:      BHZ
B052F22     Start date:  2002,323,21:07:00
B052F23     End date:     2599,365,23:59:59
#
#                         +-----------------------------------+
#                         |            Response (Poles and Zeros)     |
#                         |              IU          ANMO   00  BHZ                   |
#                         |             11/19/2002 to 12/31/2599      |
#                         +-----------------------------------+
#
B053F03     Transfer function type:                  A
B053F04     Stage sequence number:                   1
B053F05     Response in units lookup:                M/S - Velocity in Meters Per Second
B053F06     Response out units lookup:                           V - Volts
B053F07     A0 normalization factor:                 +8.60830E+04
B053F08     Normalization frequency:                 +2.00000E-02
B053F09     Number of zeroes:                                    2
B053F14     Number of poles:                                     5
#               Complex zeroes:
#                i  real                imag              real_error    imag_error
B053F10-13     0  +0.00000E+00        +0.00000E+00  +0.00000E+00  +0.00000E+00
B053F10-13     1  +0.00000E+00        +0.00000E+00  +0.00000E+00  +0.00000E+00
#               Complex poles:
#                i  real                imag              real_error    imag_error
B053F15-18     0  -5.94313E+01        +0.00000E+00  +0.00000E+00  +0.00000E+00
B053F15-18     1  -2.27121E+01        +2.71065E+01  +0.00000E+00  +0.00000E+00
B053F15-18     2  -2.27121E+01        -2.71065E+01  +0.00000E+00  +0.00000E+00
B053F15-18     3  -4.80040E-03        +0.00000E+00  +0.00000E+00  +0.00000E+00
B053F15-18     4  -7.31990E-02        +0.00000E+00  +0.00000E+00  +0.00000E+00
#
```

Figure 34: Stage 1 of the IRIS Response File

In this example, the A_{0V} normalization factor is highlighted:

$$\mathbf{A_{0V}} = 8.6083 \times 10^4$$

Figure 35 outlines the very last part (Stage 0) of the IRIS response file. The highlighted component denotes system gain used in Step 3 in Appendix A.3.1.

```
#
#                      +-----------------------------------+
#                      |          Channel Sensitivity/Gain  |
#                      |           IU        ANMO  00  BHZ            |
#                      |          11/19/2002 to 12/31/2599   |
#                      +-----------------------------------+
#
B058F03   Stage sequence number:          0
B058F04   Sensitivity:                    +9.24400E+08
B058F05   Frequency of sensitivity:       +2.00000E-02
B058F06   Number of calibrations:         0
```

Figure 35: Stage 0 of the IRIS Response File

In this example, the highlighted value denotes SGV:

$$\mathbf{S_{GV}} = 0.9244\ ({}^{counts}/_{nm/s})$$

Appendix B: Response Hydra Magnitude Calculation Algorithms

Appendix B.1: Ml Magnitude Module

Task: Calculate ml

Results written to database

primary amplitude (dAmp1): peak-to-peak amplitude in digital counts

secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts

event magnitude – is calculated ONLY from peak-to-peak amplitudes

Overview

ml_module is a state processing module that finds the peak-to-peak and zero-to-peak amplitudes (mm of Wood-Anderson trace amplitude), the equivalent peak-to-peak and zero-to-peak amplitudes (counts), period at measured amplitude (seconds), and estimated time of peak (zero crossing of mid-cycle). If the period is shorter than 3.5 seconds, the result is assumed to be valid. Otherwise, the maximum event amplitude is interpreted to be below the microseism and is rejected.

Note that the maximum peak-to-peak equivalent Wood-Anderson trace amplitude (p2p) and the maximum zero-to-peak amplitude (z2p), both measured in mm, are measured at the same point. Thus, in general, z2p >= .5*p2p. The equivalent maximum peak-to-peak and zero-to-peak amplitudes in counts (np2p and nz2p, respectively) are just p2p and z2p multiplied by the input sensor response at the measured period. That is, they can be treated as though an amplitude in counts over the response at the measured period is a ground motion rather than the trace amplitude of a different sensor.

Wood-Anderson torsion seismometers are horizontal sensors with a very broadband response (i.e., flat to displacement to some very high frequency). For this reason, the best results will be obtained from horizontal component broadband sensors. The algorithm will reject short period (and some broadband) sensors because the results can't be guaranteed to be valid if the high-frequency analog low-pass corner is below the assumed brickwall FIR filter corner.

This routine gets P picks from the database. These picks will generally be on the vertical components. However, we want to use only horizontal components in calculating the Ml magnitude. Therefore, we will get a list of all available channels. If there is a P pick on a vertical component, we will search the station list for a corresponding horizontal component. If a horizontal exists, we will associate the P arrival time with the horizontal component data for determining the peak search window.

Ml algorithm flow

1) Obtain origin information, eventID, and passport from the database.
2) Allocate and initialize reusable response function and filter structures used by this routine. Load Wood-Anderson response.
3) Obtain list of channels within 600 km of the origin, arrival times, and any other relevant info from the database
4) For each station retrieved from the database, create and initialize a channel structure to hold channel, magnitude, and amplitude info. SCNLs are rejected if:

   a. Associated pick is not a P pick (currently accept szObsPhase == P, P_n, P_g, P_b, P_{dif}, or p)
   b. Epicentral distance is not in allowed range. (default: 0 ≤ dist (km) ≤ 600)
   c. SCNL has neither IRIS band code ‘H’ nor “B’
   d. SCNL is not a horizontal component

5) For each arrival, look in the database for an ml amplitude.
6) If there is an amplitude in the database, accept it if it falls within a specified time window. Then convert the database amplitude from digital counts to mm of Wood-Anderson amplitude.
7) If there is no acceptable ml amplitude in the database, get data from the waveserver and calculate this value using the method outlined below.
   a. Get data from the waveserver in the time window:
      i. start time: minimum of: (P-wave arrivalTime – preEventSignal) and (originTime + (epicentralDistance/maxGroupVelocity))
      ii. end time: originTime + (epicentralDistance/minGroupVelocity)
   b. Massage the data by checking for gaps in the data and filling them with zeroes, checking for gaps in the search window, computing and removing the DC offset from the non-gap data, and checking for clipping.
   c. Load the instrument response for this channel, create a linear filter which approximates this instrument response, and find the bandwidth within dblim dB of the filter peak
   d. Define the passband of the desired result and check that it falls entirely within the passband of the instrument for this SCNL; if not, throw out this channel
   e. Add a five-pole lowpass Butterworth filter to the instrument response in order to stabilize the IIR filter to be constructed
   f. Construct an IIR filter such that the frequency response of the seismograph/ filter system replicates that of a Wood-Anderson seismograph. Note that the Wood-Anderson response is close to the high corner of typical broadband sensors. This results in the need to apply additional filtering (in the form of a five-pole Butterworth low-pass filter applied above) to stabilize the IIR filter. It also requires that sensors with their analog low-pass corner frequency below their brickwall FIR corner frequency be rejected on stability grounds. Note that these sensors wouldn't have produced suitable results anyway because the Wood-Anderson response is relatively broadband itself.
   g. Filter the time series, remove the LP drift, and measure the period and maximum amplitudes and time associated with the amplitude measurement.
   h. Convert nm of trace amplitude to amplitude in counts (well, sort of) for later storage in the database. Note that this requires first evaluating the input sensor transfer function at the Ml period.
8) Compute magnitude from the amplitude for the channel using the IASPEI Commission on Seismological Observation and Interpretation Working Group on Magnitudes formula for ml. This formula is based on that of Hutton and Boore (1987) except that the constant term (-2.09) is based on a static magnification of 2080 for the Wood-Anderson seismograph (Uhrhammer and Collins, 1990) rather than the theoretical magnification of 2800 specified by Wood-Anderson instrument manufacturer.
   $Ml = \log_{10}(0.5 *A) + 1.11 \log_{10}(D) – 0.00189D – 2.09$ where:
   a. A = max peak-to-peak trace amplitude (in mm) on a Wood-Anderson torsion seismometer. Note that the NEIC uses zero-to-peak amp rather than 0.5 *peak-to-peak amp in calculating Ml

   b. D = distance where D <= 600 km

9) Mark as “no use” any stations on the exclude list. (Note: Moving the exclude check to this late in the code allows for computation of channel magnitudes that the analysts may wish to see, but not use.)
10) Step through the channels looking for magnitudes for both horizontal components; keep only the larger of the two values.
11) Step through the channels looking for magnitudes on more than one component per site. Hierarchy for retaining component magnitudes: location code preferential order: 00, 10, -- and then component code preferential order: HHx, BHx, HLx, BLx, EHx, SHx, VHx, ELx, SLx VLx where x = (N, E), i.e., accept broad-band sensors over short-period sensors (very few of which will survive the filter test) and higher sampling rates over lower sampling rates.
12) Calculate the event magnitude from the remaining acceptable channels using the trimmed mean algorithm of Rosenberger, J.L., and Gasko, M. (1983). "Comparing Location Estimators: Trimmed Means, Medians, and Trimean", in Understanding Robust and Exploratory Data Analysis, ed. Hoaglin, D.C., Mosteller, F., and Tukey, J.W., p. 297-338, John Wiley, NY.
13) Write the channel amplitudes, periods, times, magnitudes, etc. into the database. Note that:
    a. primary amplitude (dAmp1): peak-to-peak amplitude in digital counts
    b. secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts
       event magnitude – is calculated ONLY from peak-to-peak amplitudes

Algorithm specific configurable parameters

MlMaxSta – max number of stations the algorithm ever expects to see (not really that critical as we reallocate the station array if we find too many stations) (default: 3000)

MlMaxSampRate – maximum sampling rate of data (default 201)

MlDistanceWindowKm – distance window in km for stations used in calculating ml (default: 0-600 km; NB: the Richter table used in this code only extends to 10º (1120 km))

MlGroupVelocity – group velocity used in determining search window (recommended: 3.3 – 3.8 km/sec)

MlMaxPeriod – maximum period of waves used in computed Ml (default: 3.5 sec)

MlPreEventSignal – length of pre-event signal (default: 10 sec)

MlExcludeSCNL – SCNLs not to be used in solution

MlIncludeSCNL – previously excluded SCNLs to be re-included in solution

Appendix B.2: Md Magnitude Module

Task: calculate Mb

Results written to database

primary amplitude (dAmp1): peak-to-peak amplitude in digital counts

secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts

event magnitude – is calculated ONLY from peak-to-peak amplitudes

Overview

mb_module is a state processing module that finds the peak-to-peak and zero-to-peak amplitudes (microns of ground motion), the equivalent peak-to-peak and zero-to-peak amplitudes (counts), period at measured amplitude (seconds), and estimated time of peak (zero crossing of mid-cycle) from the vertical component seismogram.

Note that the maximum peak-to-peak ground amplitude (p2pAmp) and the maximum zero-to-peak amplitude (z2pAmp), both measured in microns, are measured at the same point. Thus, in general, z2pAmp >= .5*p2pAmp. The equivalent maximum peak-to-peak and zero-to-peak amplitudes in counts (np2p and nz2p, respectively) are just p2pAmp and z2pAmp multiplied by the instrument response at the measured period.

Mb algorithm flow

1) Obtain origin information, eventID, and event passport from the database.
2) Allocate and initialize reusable filters and response function structure used by this routine; read in the WWSSN SP response.
3) Obtain a list of arrivals with associated channel information for the origin from the database for events with a specified maximum hypocentral depth (default: 800 km).
4) Create and initialize a channel structure to hold magnitude / amplitude info for each component. SCNLs are rejected if:
    a. SCNL is not a vertical component
    b. station does not lie within an acceptable distance from the event epicenter: minDist ≤ Epicentral distance (º) ≤ maxDist (default: minDist = 15º; maxDist = 100º)
    c. arrival is not a P, P_g, P_n, P_b, or P_{dif} pick
    d. SCNL is a 1 Hz channel
5) Determine the length of the time window in which to search for the Mb amplitude; if the estimated PP travel time can be retrieved from the travel time tables, the search window length is the greater of the difference between the estimated travel time for the PP and first P phases and the time window parameter retrieved from the passport; otherwise the search window length is the time window length retrieved from the passport
6) Read in the Qtable file. NB: THIS FILE MUST BE NAMED "Mb_qfac.tbl". IT MUST LIVE IN THE "EW_PARAMS" DIRECTORY.
7) For each channel, look in the database for an mb amplitude.
8) If there is an amplitude in the database, accept it if it falls within a specified time window. Then convert the database amplitude from digital counts to microns of ground motion.
9) If there is no acceptable mb amplitude in the database, get data from the waveserver and calculate this value using the method outlined below.

a. Get data from the waveserver in the time window: start time: arrivalTime - PRE_EVENT_SIGNAL end time: arrivalTime + window length

b. Massage the data by checking for gaps in the data and filling them with zeroes, checking for gaps in the search window, computing and removing the DC offset from the non-gap data, and checking for clipping.

c. Load the instrument response for this channel, create a linear filter which approximates this instrument response, and find the bandwidth within dblim dB of the filter peak

d. Define the passband of the desired result and check that it falls entirely within the passband of the instrument for this SCNL; if not, throw out this channel

e. Add a three-pole lowpass Butterworth filter to the instrument response in order to stabilize the IIR filter to be constructed

f. Construct an IIR filter such that the frequency response of the seismograph/ filter system replicates that of a WWSSN SP seismograph

g. Find the peak-to-peak amplitude (in counts), zero-to-peak amplitude (in counts), period (in seconds), and the time associated with the max amplitude (in epoch seconds) from the drift corrected, filtered time series data.

h. Evaluate the instrument response for this channel at the measured mb period and use the result to convert the amplitudes to microns of ground motion.

10) Compute magnitude from the amplitude for the channel using the definition:

Mb = $\log_{10}(0.5 *A/T)$ + qval(depth, distance) where:
A = max peak-to-peak ground amplitude (in microns);

note that this differs from NEIC convention in which 0.5 *A is replaced by zero-to-peak ground amplitude. T = period in seconds; NEIC uses 0.1 <= T (secs) <= 3.0; default values for this code: 0.1 <= T (secs) <= 3.0 qval(depth, distance) = standard value as a function of distance D and depth h

D = geocentric distance (station to epicenter); default: 15 ≤ D(º)≤ 100

Reject any negative magnitudes.

11) Mark as “no use” any stations on the exclude list. (Note: Moving the exclude check to this late in the code allows for computation of channel magnitudes that the analysts may wish to see, but not use.)

12) Step through the channels looking for magnitudes on more than one component per site. For SCNLs with the same S and N, preferentially accept SCNLs by location code in the order 00, 10, --. Then accept component magnitudes in the following order: HHZ, BHZ, HLZ, BLZ, EHZ, SHZ, VHZ, ELZ, SLZ VLZ. NB: even though the IRIS band code convention is L = long-period (sample rate ~1 Hz) and V = very-long-period (sample rate ~0.1 Hz), accept band code 'V' and not band code 'L' since a number of networks use band code 'V' as if it were analagous to band code 'S'.

13) Calculate the event magnitude from the remaining acceptable channels using the trimmed mean algorithm of Rosenberger, J.L., and Gasko, M. (1983). "Comparing Location Estimators: Trimmed Means, Medians, and Trimean", in Understanding Robust and Exploratory Data Analysis, ed. Hoaglin, D.C., Mosteller, F., and Tukey, J.W., p. 297-338, John Wiley, NY.

14) Write the channel amplitudes, periods, times, magnitudes, etc. into the database as appropriate.
Note that:

a. primary amplitude (dAmp1): peak-to-peak amplitude in digital counts

b. secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts

c. event magnitude – is calculated ONLY from peak-to-peak amplitudes

Algorithm specific configurable parameters

MbMaxSampRate – maximum sampling rate of data (default 201)

MbDistanceWindowDeg – distance window in degrees for stations used in calculating mb (default: 15.0º - 100.0º)

MbTimeWindow - length (sec) of time window in which to search for maximum P amplitude (default 60.0 secs)

MbPeriod – period of body waves to use in calculating Mb (default: 0.1-3.0 secs)

MbMaxDepth – maximum hypocentral depth of events for which Mb will be calculated (default: 800 km)

MbExcludeSCNL – SCNLs not to be used in solution

MbIncludeSCNL – previously excluded SCNLs to be re-included in solution

Appendix B.3: Mwp Magnitude Module

Task: calculate Mwp, the broadband P-wave moment magnitude

Acknowledgment: this module is based on code written and graciously provided by Paul Whitmore of the WC&ATWC

Results written to database

dAmp1: integrated peak-to-peak amplitude in pseudo-digital counts

dAmpPeriod1: time from the P-wave arrival to the 2nd integrated displacement peak if there was one or the first peak otherwise (in seconds)

tAmp1: epoch time of the maximum amplitude of the integration peak

event magnitude: broadband P-wave moment magnitude

Overview

mwp_module is a state processing module that computes moment magnitudes based on an integrated broadband P-wave displacement seismogram (Mwp).This program calculates the integrated peak-to-peak amplitude (m-sec), the time between the P-wave arrival and the maximum amplitude of the integration peak (seconds), and the time associated with the maximum amplitude of the integration peak for the vertical component of a broadband waveform. For insertion into the database, the peak-to-peak amplitude is converted to a pseudo-equivalent peak-to-peak amplitude in counts.

The Mwp technique was first developed by Tsuboi et al. (1995, BSSA) and later extended in order to improve results (Tsuboi et al., 1998, BSSA; Whitmore et al., 2002, Science of Tsumnami Hazards). In summary, assume the P-wave is recorded on a seismometer with a velocity response flat over the period of the P-wave. This signal is integrated to obtain a displacement seismogram and then integrated again to get an approximation of the moment rate function (the integrated displacement seismogram). As desired features of this algorithm include simplicity, robustness, and speed of calculation, the moment magnitude estimated in this algorithm does not include a correction for the fault mechanism. Rather, in this technique, in order to correct for the average of the radiation pattern over the focal sphere, 0.2 is added to each channel's moment magnitude (Tsuboi et al., 1995). Finally a magnitude dependent correction is applied to correct for differences between the computed Mwp and the Harvard Mw relation (Cor Mw=(Mw-1.03)/0.843; Whitmore et al., 2002).

Some problems with this technique are:

1) The technique works well for quakes in the range 6-7.5. Above this, it sometimes underestimates the magnitude.
2) Seismometers with insufficient response characteristics (such as the USNSN flat velocity response to 30s) also underestimate the magnitude. In more detail, this technique assumes a flat velocity response over the frequency range of the P-wave. Generally, this means less than 60 secs, although for larger quakes (M>6.5), it may be longer. STS1 seismometers are fine for this technique as they have a flat velocity response to periods as long as 360 sec. Broadband seismometers with LP cutoff periods less than the STS1 can be used with this technique; however, as strictly speaking, deconvolution of the instrument response might be necessary for these instruments, and deconvolution is not done here, the larger the earthquake, the greater the magnitude underestimation. Consequently, care must be taken when using these stations.
3) If the DC is not properly removed from the signal, Mwp will be overestimated due to an integration of the DC component.

4) The LP signal must be above background levels; otherwise the main component of the integrations will be on noise.
5) The integration window must be lengthened in multiple shock quakes so that the entire P-wave is within the window.

The integration window should be specified so that one cycle of the P-wave displacement seismogram is covered. The technique was developed for shallow, regional quakes in Japan. Studies at the WC&ATWC show that the technique also works for deep and teleseismic quakes world-wide. This study along with Tsuboi et al. (1998, BSSA) suggest that the maximum integrated displacement should be based on the difference between the amplitudes of the first and second peaks of the integrated displacement when that difference is larger than the first peak amplitude value alone. This case, which accounts for pP arrivals, may occur when later arrivals show a larger amplitude than and a polarity opposite to that of the direct P-wave.

Mwp algorithm flow

1) Obtain origin information, eventID, passport, and a list of arrivals with associated channel information for this origin from the database.
2) Create and initialize a channel structure to hold magnitude / amplitude info for each component. SCNLs are rejected if:
    a. instrument is not a broadband (IRIS band code ‘B’ or ‘H’)
    b. SCNL is not a vertical component
    c. arrival is not a P, P_n, P_g, P_b, P_{dif} or p pick
    d. SCNL is not within the allowable distance range: minDist ≤ Epicentral distance (º) ≤ maxDist; default: minDist = 0º; maxDist = 100º
3) Allocate and initialize all reusable arrays needed by the algorithm.
4) For each channel, look in the database for an Mwp amplitude.
5) If there is an amplitude in the database, accept it if it falls within a specified time window. Then convert the database amplitude from (pseudo) digital counts to m-s of integrated displacement.
6) If there is no acceptable Mwp amplitude in the database, get data from the waveserver and calculate this value using the method outlined below.
    a. Get data from the waveserver in the time window:
        i. start time: P-wave arrivalTime - PRE_EVENT_SIGNAL
        ii. end time: P-wave arrivalTime + mwpSeconds
    b. Massage the data by checking for gaps in the data and filling them with zeroes, checking for gaps in the search window, computing and removing the DC offset from the non-gap data, and checking for clipping.
    c. Obtain the instrument response for this channel from the database and calculate the channel sensitivity (magnification). NB: the poles and zeroes information is used only in order to calculate the sensitivity which is later used to convert the data to velocity seismograms in units of m/sec.
    d. Compute the pre-event signal level.
    e. Convert data to velocity signal and integrate to get displacement.
    f. De-trend the displacement data using linear trend removal and check for acceptable signal-to-noise ratio.
    g. Determine window length for next integration.
    h. Integrate the de-trended displacement signal for the time window just determined.

i. Integrate the integrated displacement signal and find local extrema. Return the two largest extremal values and their positions within the time series if they are of opposite polarity. If the second largest extremal value is of the same polarity as the largest extremal value and is significant with respect to the largest value, return the value and position within the time series of the earlier of the two peaks. Use these extrema and their positions within the time series to determine the peak-to-peak amplitude (in m-sec) and the time between the P-wave arrival and the integration peak.

7) Compute magnitude from the amplitude for the channel using the definition Mwp = ((1./1.5*($\log_{10}$(moment) - 9.1) + 0.2) - 1.03) / 0.843 where:

   a. moment = max(integrated displacement) * 4 * PI * rho * (alpha)^^3 * r / Fp Assuming that the radiation pattern, Fp, can be neglected, then for rho = 3.4 x 10e3 kg/m3 and alpha = 7.9 km/sec which are representative values in the uppermost mantle:
   moment = 2.106542x10e16 * max(integrated displacement) * r. i.e., moment = 2.1065416E16 * chan->mwpIntDis. * deltaT * 111194.9; The above moment magnitude formula is composed of the following parts:

   b. Mw = (1/1.5)*($\log_{10}$ (Mo) - 9.1), Kanamori's (1977, JGR) formula for moment magnitude

   c. Addition of 0.2 to correct for average of the radiation pattern: Mwp = Mw + 0.2

   d. empirical correction to account for differences between the moment magnitude values calculated in this routine and the Harvard moment magnitude: MwpCorrected = (mwp - 1.03) / 0.843

8) Mark as "no use" any stations on the exclude list. (Note: Moving the exclude check to this late in the code allows for computation of channel magnitudes that the analysts may wish to see, but not use.)

9) Step through the channels looking for magnitudes on more than one component per site; Accept component magnitudes in the following order: HHZ, BHZ, HLZ, BLZ, i.e., accept high broadband sensors over broadband sensors and higher sampling rates over lower sampling rates

10) Calculate the event magnitude from the remaining acceptable channels. First, throw out any magnitudes for components for which the integration time is not acceptable. Next, throw out all Mwp's more than 1 standard deviation from the average of the computed magnitudes. Finally, recompute the average of the remaining magnitudes.

11) Write the channel amplitudes, periods, times, magnitudes, etc. into the database as appropriate. Note that:

   a. dAmp1: peak amplitude in pseudo digital counts, dAmpPeriod1: time in seconds between the P-wave arrival and the 2nd peak if there was one or the first peak otherwise

   b. tAmp1: epoch time of the max amplitude of the integration peak event magnitude: average broadband P-wave moment magnitude for this event

Algorithm specific configurable parameters

MwpMaxSta – max number of stations the algorithm ever expects to see (not really that critical as we reallocate the station array if we find too many stations) (default: 3000)

MwpMaxSampRate – max sampling rate of the incoming data (samples/second) (default: 201)

MwpMinMagChans – minimum number of channel magnitudes needed in order to compute an event magnitude (default: 5)

MwpDistanceWindow – distance window in degrees for stations used in calculating mwp (recommended: 0.0º - 100.0º)

MwpWindowLength – max window length for data used in calculating Mwp (default: 100.0 secs)

MwpSN – signal-to-noise ratio required in order to calculate compoment Mwp (default: 3.0)

MwpExcludeSCNL – SCNLs not to be used in solution

MwpIncludeSCNL – previously excluded SCNLs to be re-included in solution

Appendix B.4: Mb Magnitude Module

Task: calculate Mb

Results written to database

primary amplitude (dAmp1): peak-to-peak amplitude in digital counts

secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts

event magnitude – is calculated ONLY from peak-to-peak amplitudes

Overview

mb_module is a state processing module that finds the peak-to-peak and zero-to-peak amplitudes (microns of ground motion), the equivalent peak-to-peak and zero-to-peak amplitudes (counts), period at measured amplitude (seconds), and estimated time of peak (zero crossing of mid-cycle) from the vertical component seismogram.

Note that the maximum peak-to-peak ground amplitude (p2pAmp) and the maximum zero-to-peak amplitude (z2pAmp), both measured in microns, are measured at the same point. Thus, in general, z2pAmp >= .5*p2pAmp. The equivalent maximum peak-to-peak and zero-to-peak amplitudes in counts (np2p and nz2p, respectively) are just p2pAmp and z2pAmp multiplied by the instrument response at the measured period.

Mb algorithm flow

1) Obtain origin information, eventID, and event passport from the database.
2) Allocate and initialize reusable filters and response function structure used by this routine; read in the WWSSN SP response.
3) Obtain a list of arrivals with associated channel information for the origin from the database for events with a specified maximum hypocentral depth (default: 800 km).
4) Create and initialize a channel structure to hold magnitude / amplitude info for each component. SCNLs are rejected if:
    a. SCNL is not a vertical component
    b. station does not lie within an acceptable distance from the event epicenter: minDist ≤ Epicentral distance (º) ≤ maxDist (default: minDist = 15º; maxDist = 100º)
    c. arrival is not a P, P_g, P_n, P_b, or P_{dif} pick
    d. SCNL is a 1 Hz channel
5) Determine the length of the time window in which to search for the Mb amplitude; if the estimated PP travel time can be retrieved from the travel time tables, the search window length is the greater of the difference between the estimated travel time for the PP and first P phases and the time window parameter retrieved from the passport; otherwise the search window length is the time window length retrieved from the passport
6) Read in the Qtable file. NB: THIS FILE MUST BE NAMED "Mb_qfac.tbl". IT MUST LIVE IN THE “EW_PARAMS” DIRECTORY.
7) For each channel, look in the database for an mb amplitude.
8) If there is an amplitude in the database, accept it if it falls within a specified time window. Then convert the database amplitude from digital counts to microns of ground motion.
9) If there is no acceptable mb amplitude in the database, get data from the waveserver and calculate this value using the method outlined below.

a. Get data from the waveserver in the time window:
    i. start time: arrivalTime - PRE_EVENT_SIGNAL
    ii. end time: arrivalTime + window length
b. Massage the data by checking for gaps in the data and filling them with zeroes, checking for gaps in the search window, computing and removing the DC offset from the non-gap data, and checking for clipping.
c. Load the instrument response for this channel, create a linear filter which approximates this instrument response, and find the bandwidth within dblim dB of the filter peak
d. Define the passband of the desired result and check that it falls entirely within the passband of the instrument for this SCNL; if not, throw out this channel
e. Add a three-pole lowpass Butterworth filter to the instrument response in order to stabilize the IIR filter to be constructed
f. Construct an IIR filter such that the frequency response of the seismograph/ filter system replicates that of a WWSSN SP seismograph
g. Find the peak-to-peak amplitude (in counts), zero-to-peak amplitude (in counts), period (in seconds), and the time associated with the max amplitude (in epoch seconds) from the drift corrected, filtered time series data.
h. Evaluate the instrument response for this channel at the measured mb period and use the result to convert the amplitudes to microns of ground motion.

10) Compute magnitude from the amplitude for the channel using the definition Mb = $\log_{10}(0.5 * A/T)$ + qval(depth, distance) where:
    a. A = max peak-to-peak ground amplitude (in microns); note that this differs from NEIC convention in which 0.5 *A is replaced by zero-to-peak ground amplitude.
    b. T = period in seconds; NEIC uses 0.1 <= T (secs) <= 3.0; default values for this code: 0.1 <= T (secs) <= 3.0
    c. qval(depth, distance) = standard value as a function of distance D and depth h

    D = geocentric distance (station to epicenter); default: 15 ≤ D(º)≤ 100

    Reject any negative magnitudes.

11) Mark as “no use” any stations on the exclude list. (Note: Moving the exclude check to this late in the code allows for computation of channel magnitudes that the analysts may wish to see, but not use.)
12) Step through the channels looking for magnitudes on more than one component per site. For SCNLs with the same S and N, preferentially accept SCNLs by location code in the order 00, 10, --. Then accept component magnitudes in the following order: HHZ, BHZ, HLZ, BLZ, EHZ, SHZ, VHZ, ELZ, SLZ VLZ. NB: even though the IRIS band code convention is L = long-period (sample rate ~1 Hz) and V = very-long-period (sample rate ~0.1 Hz), accept band code 'V' and not band code 'L' since a number of networks use band code 'V' as if it were analagous to band code 'S'.
13) Calculate the event magnitude from the remaining acceptable channels using the trimmed mean algorithm of Rosenberger, J.L., and Gasko, M. (1983). "Comparing Location Estimators: Trimmed Means, Medians, and Trimean", in Understanding Robust and Exploratory Data Analysis, ed. Hoaglin, D.C., Mosteller, F., and Tukey, J.W., p. 297-338, John Wiley, NY.
14) Write the channel amplitudes, periods, times, magnitudes, etc. into the database as appropriate.
    Note that:
    a. primary amplitude (dAmp1): peak-to-peak amplitude in digital counts

b. secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts
event magnitude – is calculated ONLY from peak-to-peak amplitudes

Algorithm specific configurable parameters

MbMaxSampRate – maximum sampling rate of data (default 201)

MbDistanceWindowDeg – distance window in degrees for stations used in calculating mb (default: 15.0º - 100.0º)

MbTimeWindow - length (sec) of time window in which to search for maximum P amplitude (default 60.0 secs)

MbPeriod – period of body waves to use in calculating Mb (default: 0.1-3.0 secs)

MbMaxDepth – maximum hypocentral depth of events for which Mb will be calculated (default: 800 km)

MbExcludeSCNL – SCNLs not to be used in solution

MbIncludeSCNL – previously excluded SCNLs to be re-included in solution

Appendix B.5: Ms Magnitude Module

Task: calculate ms

Results written to database

primary amplitude (dAmp1): peak-to-peak amplitude in digital counts

secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts

event magnitude – is calculated ONLY from peak-to-peak amplitudes

Overview

ms_module is a state processing module that finds the peak-to-peak and zero-to-peak amplitudes (microns of ground motion), the equivalent peak-to-peak and zero-to-peak amplitudes (counts), period at measured amplitude (seconds), and estimated time of peak (zero crossing of mid-cycle) of the vertical component of the surface wave with period T where $18 \le T$ (secs) ≤ 22. Although the NEIC produces Ms magnitudes only for events with hypocentral depths of ≤ 50 km, by request, this routine calculates Ms magnitudes for events with depths of ≤ msParams.maxDepth km. This allows the analysts to get a feel for the size of events for which either the calculated depth is incorrect or for which the hypocentral depth is only slighter deeper than 50 km.

Note that the maximum peak-to-peak ground amplitude (p2pAmp) and the maximum zero-to-peak amplitude (z2pAmp), both measured in microns, are measured at the same point. Thus, in general, z2pAmp >= .5*p2pAmp. The equivalent maximum peak-to-peak and zero-to-peak amplitudes in counts (np2p and nz2p, respectively) are just p2pAmp and z2pAmp multiplied by the instrument response at the measured period.

Although Ms should be calculated from horizontal components, for consistency with past NEIC practice, this routine calculates Ms from vertical component seismograms.

Ms algorithm flow

1) Obtain origin information, eventID, and passport from the database for events shallower than the maximum allowed hypocentral depth.
2) Allocate and initialize reusable response structures and read in the WWSSN LP response.
3) Obtain a list of channels within an appropriate distance of the origin from the database.
4) Create and initialize a channel structure to hold magnitude / amplitude info for each component. SCNLs are rejected if:
    a. SCNL is not a vertical component
    b. Instrument is not a broadband
    c. minDist ≤ Epicentral distance (º) ≤ maxDist; (default: minDist = 20º; maxDist = 160º)
5) For each channel, look in the database for an ms amplitude.
6) If there is an amplitude in the database, accept it if it falls within a specified time window. Then convert the database amplitude from digital counts to microns of ground amplitude.
7) If there is no acceptable ms amplitude in the database, get data from the waveserver and calculate this value using the method outlined below.
    a. Get data from the waveserver in the time window:
        i. start time: originTime - PRE_EVENT_SIGNAL

   ii. end time: originTime + (epicentralDistance/minGroupVelocity)

  b. Massage the data by checking for gaps in the data and filling them with zeroes, checking for gaps in the search window, computing and removing the DC offset from the non-gap data, and checking for clipping.
  c. Obtain the instrument response for this channel from the database; create a linear filter which approximates this instrument response, and find the bandwidth within dblim dB of the filter peak
  d. Define the passband of the desired result and check that it falls entirely within the passband of the instrument for this SCNL; if not, throw out this channel
  e. Create a digital filter to convert the instrument response to a WWSSN long-period response.
  f. Filter the time series, remove the LP drift, and measure the period and amplitude associated with the largest period-weighted amplitude and the time associated with the amplitude measurement.
  g. Convert amplitude in counts to ground motion in microns. Note that this requires first evaluating the input sensor transfer function at the Ms period.

8) Compute magnitude from the amplitude for the channel using the definition Ms = $\log_{10}(0.5 * A/T) + 1.66D + 3.3$ where:
  a. A = max peak-to-peak ground amplitude (in microns); note that this differs from NEIC convention in which 0.5 *A is replaced by zero-to-peak ground amplitude.
  b. T = period in seconds; $18 \le T$ (secs) ≤ 22
  c. D = geocentric distance (station to epicenter); $20 \le D(^{o}) \le 160$

   Calculation is done for events with hypocentral depths ≤ msParams.maxDepth km (Note: NEIC posts Ms values for depth ≤ 50km; however, by request, the Ms values may be calculated for greater depths to allow for incorrect hypocentral depth.)

   Reject any negative magnitudes.

9) Mark as “no use” any stations on the exclude list. (Note: Moving the exclude check to this late in the code allows for computation of channel magnitudes that the analysts may wish to see, but not use.)
10) Step through the channels looking for magnitudes on more than one component per site. For SCNLs with the same S and N, preferentially accept SCNLs by location code in the order 00, 10, --. Then accept component magnitudes in the following order: HHZ, BHZ, HLZ, BLZ, EHZ, SHZ, VHZ, ELZ, SLZ VLZ, LHZ, LLZ. NB: even though the IRIS band code convention is L = long-period (sample rate ~1 Hz) and V = very-long-period (sample rate ~0.1 Hz), accept band code 'V' over band code 'L' since a number of networks use band code 'V' as if it were analagous to band code 'S'.
11) Calculate the event magnitude from the remaining acceptable channels using the trimmed mean algorithm of Rosenberger, J.L., and Gasko, M. (1983). "Comparing Location Estimators: Trimmed Means, Medians, and Trimean", in Understanding Robust and Exploratory Data Analysis, ed. Hoaglin, D.C., Mosteller, F., and Tukey, J.W., p. 297-338, John Wiley, NY..
12) Write the channel amplitudes, periods, times, magnitudes, etc. into the database. Note that:
  a. primary amplitude (dAmp1): peak-to-peak amplitude in digital counts secondary
  b. amplitude (dAmp2): zero-to-peak amplitude in digital counts event magnitude – is calculated ONLY from peak-to-peak amplitudes

Algorithm specific configurable parameters

MsMaxSta – max number of stations the algorithm ever expects to see (not really that critical as we reallocate the station array if we find too many stations) (default: 3000)

MsMaxSampleRate – max sample rate expected for incoming data (default: 201 samples/sec)

MsDistanceWindow – distance window in degrees for stations used in calculating ms (default: 20.0º - 160.0º)

MsMaxDepth – maximum hypocentral depth for events for which Ms is computed (default: 50 km)

MsPeriod – period of surface waves to use for calculating Ms (default: 18.0-22.0 secs)

MsTraceTimes – range of group velocity used in determining search window for surface waves (default: 2.7 – 4.2 km/sec)

MsIntervalDelta – slop allowed in window when getting amps from DB (default: 3 secs)

MsExcludeSCNL – SCNLs not to be used in solution

MsIncludeSCNL – previously excluded SCNLs to be re-included in solution

Appendix B.6: MbLg Magnitude Module

Task: calculate mbLg

Results written to database

primary amplitude (dAmp1): peak-to-peak amplitude in digital counts

secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts

event magnitude – is calculated ONLY from peak-to-peak amplitudes

Overview

mblg_module is a state processing module that finds the peak-to-peak and zero-to-peak amplitudes (microns of ground motion), the equivalent peak-to-peak and zero-to-peak amplitudes (counts), period at measured amplitude (seconds), and estimated time of peak (zero crossing of mid-cycle) from the vertical component seismogram.

Note that the maximum peak-to-peak ground amplitude (p2pAmp) and the maximum zero-to-peak amplitude (z2pAmp), both measured in microns, are measured at the same point. Thus, in general, z2pAmp >= .5*p2pAmp. The equivalent maximum peak-to-peak and zero-to-peak amplitudes in counts (np2p and nz2p, respectively) are just p2pAmp and z2pAmp multiplied by the instrument response at the measured period.

MbLg algorithm flow

1) Obtain origin information, eventID, and event passport from the database.
2) Exit if hypocentral depth is greater than maximum allowed (default: 50 km).
3) Allocate and initialize reusable filters and response function structure used by this routine. Load WWSSN SP response.
4) Obtain a list of channels within an appropriate distance of the origin from the database.
5) Determine if event origin lies in an exclude area.
6) Create and initialize a channel structure to hold magnitude / amplitude info for each component. SCNLs are rejected if:
    a. SCNL is not a vertical component
    b. SCNL is a 1 Hz channel
    c. station does not lie within an acceptable distance from the event epicenter: minDist ≤ Epicentral distance (º) ≤ maxDist (default: minDist = 0º; maxDist = 10º)
    d. cannot estimate travel time for first arriving P phase
    e. both source and receiver lie within an exclude box
7) For each channel, look in the database for an mbLg amplitude.
8) If there is an amplitude in the database, accept it if it falls within a specified time window and has an acceptable period. Then convert the database amplitude from digital counts to microns of ground motion.
9) If there is no acceptable mbLg amplitude in the database, get data from the waveserver and calculate this value using the method outlined below.
    a. Get data from the waveserver in the time window: start time:
        i. arrivalTime - PRE_EVENT_SIGNAL
        ii. end time: arrivalTime + (distance / minLgVel)

b. Massage the data by checking for gaps in the data and filling them with zeroes, checking for gaps in the search window, computing and removing the DC offset from the non-gap data, and checking for clipping.

c. Load the instrument response for this channel, create a linear filter which approximates this instrument response, and find the bandwidth within dblim dB of the filter peak

d. Define the passband of the desired result and check that it falls entirely within the passband of the instrument for this SCNL; if not, throw out this channel

e. Add a three-pole lowpass Butterworth filter to the instrument response in order to stabilize the IIR filter to be constructed

f. Construct an IIR filter such that the frequency response of the seismograph/ filter system replicates that of a WWSSN SP seismograph

g. Find the peak-to-peak amplitude (in counts), zero-to-peak amplitude (in counts), period (in seconds), and the time associated with the max amplitude (in epoch seconds) from the LP-drift corrected, filtered time series data for waves of the desired frequencies

h. Evaluate the instrument response for this channel at the mbLg period and use the result to convert the amplitudes to microns of ground motion.

10) Compute magnitude from the channel amplitude using the definition

mbLg = 2.96 + log10(0.5 * A) + 0.8333*log10(ri/10) + log10e*gamma*ri where:

a. A = max peak-to-peak ground amplitude (in microns); note that this differs from the NEIC convention in which 0.5 *A is replaced by zero-to-peak ground amplitude. This definition conforms to the IASPEI Commission on Seismological Observations and Interpretation Working Group on Magnitudes recommeded mbLg formula mbLg = 5.0 + log10[Ai(10)/110] (Nuttli, 1986) where:

b. Ai(10) = A(ri)*(ri/10)^(1/3)*[sin(ri/111.1)/sin(10/111.1)]^0.5*exp[gamma*(ri -10)]

and:

c. Ai(10) = amplitude in um of "hypothetical" Lg wave at a distance of 10 km, extrapolated from observation at station i

d. A(ri) = "sustained ground-motion amplitude" in um at station i = third largest amplitude in the time window corresponding to group velocities of 3.6 to 3.2 km/sec with period in the range of 0.7 - 1.3 sec; NB: For this code, default group velocity range is 2.8 – 3.8 km/sec and default period range is 0.6 – 1.4 sec

e. ri = epicentral distance of ith station in km; default: 0 ≤ D(º)≤ 10

f. gamma = coefficient of attenuation in (1/km)

Reject any negative magnitudes.

11) Mark as “no use” any stations on the exclude SCNL list. (Note: Moving the exclude check to this late in the code allows for computation of channel magnitudes that the analysts may wish to see, but not use.)

12) Step through the channels looking for magnitudes on more than one component per site. For SCNLs with the same S and N, preferentially accept SCNLs by location code in the order 00, 10, --. Then accept component magnitudes in the following order: HHZ, BHZ, HLZ, BLZ, EHZ, SHZ, VHZ, ELZ, SLZ VLZ. NB: even though the IRIS band code convention is L = long-period (sample rate ~1 Hz) and V = very-long-period (sample rate ~0.1 Hz), accept band code 'V' over band code 'L' since a number of networks use band code 'V' as if it were analagous to band code 'S'.

13) Calculate the event magnitude from the remaining acceptable channels using the trimmed mean algorithm of Rosenberger, J.L., and Gasko, M. (1983). "Comparing Location Estimators: Trimmed Means, Medians, and Trimean", in Understanding Robust

and Exploratory Data Analysis, ed. Hoaglin, D.C., Mosteller, F., and Tukey, J.W., p. 297-338, John Wiley, NY.

14) Write the channel amplitudes, periods, times, event magnitude, etc. into the database as appropriate.
Note that:
primary amplitude (dAmp1): peak-to-peak amplitude in digital counts secondary amplitude (dAmp2): zero-to-peak amplitude in digital counts event magnitude – is calculated ONLY from peak-to-peak amplitudes

Algorithm specific configurable parameters

MbLgMaxSampRate – maximum sampling rate of data (default 201)

MbLgMaxSta – max number of stations the algorithm ever expects to see (not really that critical as we reallocate the station array if we find too many stations) (default: 3000)

MbLgDistanceWindowDeg – distance window in degrees for stations used in calculating mb (default: 0.5º - 10.0º)

MbLgPeriod – period of body waves to use in calculating MbLg (default: 0.6-1.4 secs)

MbLgVelocity – period of body waves to use in calculating MbLg (default: 2.8-3.8 km/sec)

MbLgMaxDepth – maximum hypocentral depths of events for which MbLg will be calculated (default: 50 km)

MbLgExcludeArea– channel MbLgs are not to be computed if both the event epicenter AND the receiver lie within any of the specified exclude areas; default exclude areas are:

31.0 ≤ lat ≤ 45.0 && -130.0 ≤ lon ≤ 107.0

45.0 ≤ lat ≤ 50.0 && -130.0 ≤ lon ≤ 112.0

50.0 ≤ lat ≤ 55.0 && -140.0 ≤ lon ≤ 120.0

50.0 ≤ lat ≤ 55.0 && 170.0 ≤ lon ≤ 180.0

50.0 ≤ lat ≤ 55.0 && -180.0 ≤ lon ≤ 150.0

55.0 ≤ lat ≤ 65.0 && -135.0 ≤ lon ≤ 125.0

55.0 ≤ lat ≤ 74.0 && -175.0 ≤ lon ≤ 135.0

MbLgExcludeSCNL – SCNLs not to be used in solution

MbLgIncludeSCNL – previously excluded SCNLs to be re-included in solution

Appendix B.7: CMT Module

Task: Compute the Centroid Moment Tensor elements and determine the scalar moment

Acknowledgment: This module is based on code graciously provided by Jascha Polet. In addition, parts of this document were liberally plagiarized from a description of the CMT algorithm provided by Jascha Polet.

Results written to database

Moment tensor elements and scalar moment
Filtered, deconvolved, decimated time series data and corresponding synthethics for each channel
Fit for each channel and variance reduction for the final solution

Overview

This code is based on code originally written by Kawakastu (1989) and later modified by Kenji Satake, Hong Kie Thio, and Jascha Polet.. The method is similar to the Harvard CMT scheme of Dziewonski *et al.* (1981)

The CMT method utilizes the entire waveform from the beginning (usually the P-wave arrival) until just before the arrival of the first surface waves. This portion of the waveform contains the arrivals of many different body waves, each of which departs from a different part of the focal sphere. The use of this portion of the waveform significantly increases the coverage of the focal sphere and thus the resolution of the moment tensor.

The dependence of the waveforms on centroid location and duration is non-linear so the problem of a centroid moment inversion is linearized by limiting the inversion to small perturbations around an initial solution, with the assumption that for small changes the effects of the perturbations are linear with respect to the parameters that are inverted.

Seismograms are constructed by a linear summation of fundamental Green's functions weighted by the amplitude of their corresponding moment tensor element. This linearity implies that the perturbations in the moment tensor elements are also linear, and, thus, the fundamental Green's functions also act as kernels for the non-linear inversion. In this code, the Green's functions are constructed by normal mode summation of tabulated eigenfunction values for the spheroidal and toroidal modes of model 1066a.

The first (zero index) iteration is a linear inversion for the elements of the moment tensor with all other parameters fixed. This and all subsequent inversions are performed assuming a zero trace (no volumetric source) constraint. This linear solution is the basis for subsequent non-linear inversions. After this linear inversion for the moment tensor elements, the code computes the partial derivatives for the moment tensor elements with respect to changes in location, depth, and centroid time. The partial derivatives which are identical to the kernels for the linear inversion, and are, in fact, the fundamental Green's functions, are recomputed in every iteration using analytical expressions in Kawakatsu (1989) for the higher order moment tensor elements. In the final iteration, a linear inversion is followed by a non-linear inversion. The moment tensor elements and centroid location are computed during the linear inversion while the non-linear inversion is used to check the convergence of the solution.
The data are weighted by the inverse of the variance of the original data in the linear and first non-linear iteration. This ensures that high amplitudes traces do not skew the solutions. In subsequent non-linear iterations, the inverse residual variance is used to weight the data. This is to ensure that poorly fit data (large residual variance) are down-weighted.

The code inverts for the entire moment tensor and then determines the best fitting double couple mechanism afterwards from the moment tensor. The code contains an option for performing a non-linear inversion for the double couple mechanism at the end of the run, but this is turned off by default. A large non-double-couple component may be indicative of either a poor solution, or, in the case of large earthquakes, a complex mechanism.

CMT Algorithm Flow

1) Obtain origin information, eventID, and event passport from the database.
2) Kick out if event's hypocentral depth is greater than the maximum allowed.
3) Fix the event depth at 10 km if it is 10 km or shallower.
4) Retrieve all other magnitudes previously computed for this origin. If none of them is greater than or equal to the value set by the CmtMinMag passport entry, do not invert for the CMT.
5) Initialize the travel time library and some other arrays.
6) Read in the 1066a model parameter file as well as the spheroidal and toroidal mode files. Note that the names of all of these files are hardwired into the code. If these files do not exist in the expected place, the code will return reporting a fatal error.
7) Read in the list of acceptable station/network pairs. Again, the name of this file is hardwired into the code. If this file does not exist in the expected place, the code will return reporting a fatal error.
8) Retrieve a list of all SCNLs matching each desired SN pair from the database. SCNLs are rejected if:
    c. station does not lie within an acceptable distance from the event epicenter: minDist ≤ Epicentral distance (º) ≤ maxDist (default: minDist = 20 maxDist = 19º)
    d. P or S travel time cannot be computed from the travel time table
9) Order retrieved SCNLs by location code in the order 00, --, 10. Within each location code grouping, order by component in the order LHx, BHx, HHx, LLx, BLx, HLx where x is in the order Z, N, E, 1, 2. Reject all SCNLs which do not have location code 00, --, or 10 and third letter of component code Z, N, E, 1, or 2.
10) Create and initialize a channel structure to hold data and other information for each acceptable component.
11) Set up and initialize reusable arrays and matrices that are used in the inversion.
12) Allocate and initialize decimation filters. (A separate filter is needed for each data sampling rate seen.)
13) Retrieve data from the waveserver. We want data from only one vertical and a pair of matching horizontal components for each SN pair. The vertical and horizontal component data need not come from the same instrument nor be of matching type, i.e, for a given SN, it is acceptable to have vertical component LHZ xx and horizontal components BHN yy and BHE yy where xx and yy are location codes. Xx and yy need not be identical.
    a. Get data from the waveserver in the time window: start time: originTime + predicted P traveltime – PRE_EVENT_SIGNAL – FILTER_DELAY where FILTER_DELAY is empirically determined from the time delay inherent in the filter implementation end time: start time + MIN(dist/groupVelocity - predicted P traveltime + PRE_EVENT_SIGNAL + FILTER_DELAY, 4500); NB: this sets the maximum amount of data used for any channel to 4500 secs
    b. Massage the data by checking for gaps in the data and filling them with zeroes, checking for gaps in the search window, computing and removing the DC offset from the non-gap data, and checking for clipping.
    c. Apply a cosine taper to both ends of the data.
    d. Load the instrument response for this channel, and convert the gain from nm/count to microns/count.
    e. Remove the instrument response from the data, using a filter of 3 – 7.5 mHz in the deconvolution.
    f. If the data are not of the desired sampling rate (.04 Hz), decimate them.
    g. Copy the decimated, deconvolved, filtered data into the working data array and compute the start and end times of these data..

14) Compute variance for each retrieved component and toss any SCNL whose variance is unacceptably large. Note that if either of a pair of horizontal components fails the variance test, the data from the matching horizontal of the pair must also be discarded.
15) Look for data for a less desirable SCNL for any component discarded in the variance test.
16) Do a final check of the channel variances and discard any SCNLs whose variance is unacceptably large.
17) Rotate the horizontal components to R and T. Note that at this time, this algorithm only handes N and E horizontalsl 1 and 2 components are discarded.
18) Check to see if any of the remaining SCNLs are on the exclude list; mark any that are as "no use" for the inversions.
19) Compute the number of degrees of freedom in the system.
20) Confirm that there are enough channels with usable data for performing the inversions; if not, quit reporting a warning of insufficient data.
21) Allocate some more reusable arrays for use in the inversions.
22) Determine the range of starting depths for the depth trial inversions. If any analyst has set a range of trial depths on the GUI, limit the trial depth range based on the analyst input. Note that the actual trial depths depend on the coarseSearchInterval set by the passport entry CmtCoarseSearchInterval as well as the requested trial depth range. For example, if the trial depth range is 0 – 50 km and the coarseSearchInterval is 20 km, the starting trial depths will be 0, 20, 40, and 60, while if the requested trial depth range is 50 -100 km and the coarseSearchInterval is 20 km, the starting depths for the depth tests will be 50, 70, 90, and 110 km. In all cases, the range of trial depths will be the smallest depth range which starts at the shallowest depth and includes the requested trial depth range. If the trial depth range has not been set by an analyst, it will be determined automatically using information in the depth statistics file. However, for automatically determined trial depth ranges, if the locator believes that the event is less than 80km deep, the maximum trial depth will be limited to 160 km. Also, automatically determined trial depth ranges are required to include the hypocentral depth determined by the locator.
23) Invert data for each trial starting depth; compute goodness-of-fit for each channel and for the event using Hermann's goodness-of-ft methodology for each depth test. Keep track of the final depth for the depth trial for the final solution has the largest goodness-of-fit.
24) Perform one final inversion with a starting depth of the final depth in the depth test with the best goodness-of-fit.
25) Find the best double couple solution corresponding to the moment tensor determined in the final inversion. The automated HYDRA CMT does not do this.
26) Compute synthetic time series based on the final moment tensor for any channels marked as no-use but for which the displayUnusedSynthetics flag is turned on.
27) Write the filters, data and synthetic time series, moment tensor components, scalar moments, channel weight and goodness-of-fit, etc. into the database as appropriate.

Algorithm specific configurable parameters:

The following passport entries are editable from the user GUI.
CmtMinMagChans – minimum number of channels of data necessary in order to invert data for CMT
CmtMinMag – min precomputed mb, mblg, ms, ml, md, mt, or mwp needed before CMT attempts to run
CmtTrialDepthRange – range of starting trial depths used to determine the starting range in the final set of inversions; the values selected here are combined with the value of the CmtCoarseSerarchInterval passport entry to determine the actual starting depths; for example, if the trial depth range is 0-50 km and the coarseSearchInterval is 20 km, the code will try inversions starting at 0, 20, 40, and 60 km.If the trial depth range is 50-100 km and the coarseSearchInterval is 20 km, the code will try inversions starting at 50, 70, 90, and 110 km
CmtDistanceWindow - distance window in degrees for stations used in calculating cmt (default: 20.0º - 180.0º)

CmtTaperFrequencies - frequencies used in filtering data in the order: low-frequency cut-off, low-frequency taper, high-frequency taper, high-frequency cut-off (defaults: 3.0 mHz, 3.5 mHz, 7.0 mHz, 7.5 mHz)
CmtTau – source half duration (secs)
CmtNumFinalIter – index of final iteration (default = 5)
CmtSN – minimum required signal-to-noise ratio for using channel data (default: 5.0)
CmtExcludeSCNL – SCNLs not to be used in solution
CmtIncludeSCNL - previously excluded SCNLs to be re-included in solution
CmtDisplayUnusedSynthetics– compute synthetics for SCNLs for which there is data but which were not used in the inversion process; select TRUE/FALSE (on/off) for vertical, radial, and tangential components (note: this option is global to all Z, R, and T components; it does not work on a channel-by-channel basis)

The following passport entries are not editable from the user GUI.
CmtMaxDepth – max depth for which CMT will be computed (NB: Jasch Polet's code implies that this value should be 794 km; however, the normal mode files supplied by Jascha preclude trial depths of greater than about 700 km. I do not know the exact maximum depth allowed.)
CmtCoarseSerarchInterval – depth spacing between trial starting depths (default: 20 km)
CmtTimeInterval – time between sample points used in inversion (default: 25 seconds)
CmtMinGroupVelocity – group velocity used in determining length of signal to use Iin inversion (default: 2.8 km/sec)
CmtWeightFlag – flag for determining which type of weighting to apply (default = 11; Note that I have stripped the code for weight flags other than 11 from the HYDRA CMT code as it is my understanding the Jascha never uses those types of weighting.)
CmtDoubleCoupleFlag – flag for computing best double couple solution after final inversion (default = no)
CmtDepthFac – factor that reduces the depth perturbations in the non-liner iterations to prevent serious overshoot (default: 0.6)
CmtModeIndices – min and max n (radial order) and l (angular order) indices for normal modes in the order: nmin, nmax, lmin, lmax (default 0 200 0 300)
CmtMaxDataDur – max length of signal used in inversion (default: 4500 secs)
CmtMaxSampRate – max sampling rate of incoming data (default: 101 samps/sec)

Referrences
Dziewonski, A.M., T.-A. Chou and J.H. Woodhouse, Determination of earthquake source parameters from waveform data for studies of global and regional seismicity, J. Geophys. Res., 86: 2825-2852, 1981.
Kawakatsu, H. Centroid single force inversion of seismic waves generated by land slides, J. Geophys. Res., 94, 12363-12374, 1989.

Appendix C: Configuring Wave_serverV Tank File Parameters

Hydra state processing modules obtain trace data for processing from wave_serverV tank files. As Tank files operate are of fixed size and the oldest data is overwritten, Tank file parameters need to be configured carefully to ensure the required amount of data is stored and available for post processing of events.

There are two main parameters required to calculate Tank file size: maximum size of the TRACEBUFF2 message for a particular channel and rate at which TRACEBUFF2 messages are received for that channel. These two values may be obtained by using sniffwave utility supplied with standard Hydra Server installation package. The following is an example of how to execute this command:

```
Sniffwave WAVE_RING BBSR BHZ wild wild n
```

The output of this command will display to the screen each TRACEBUFF2 message received from station BBSR channel BHZ (any network and any location). Using this output, the user can capture the maximum size of the TRACEBUFF2 message (shown as lenXXXX value) as well as the message rate. The size of the tank file is then calculated using the following formula:

Tank Size Ts (bytes) = recsize (bytes) x TRACEBUFF2 rate (messages/s) x duration (s)

Where:

Recsize – record size as specified in column 6 of the wave_serverV.tlst file

TRACEBUFF2 rate - # of TRACEBUFF messages received for this channel each second

Duration – duration of historical data to be stored in tank files (typically 1 week)

Sample Calculation

The following calculation is done for ADK GSN station channel BHZ which is recorded at 20 sps, and with the assumption that the user requires 1 week (604800s) worth of data in each tank file:

The largest message size (as shown by sniffwave) = 1456 bytes

Set recsize (column 6) for ADK BHZ channel in wave_serverV.tlst file to 1600 bytes.

The amount of data contained within each message (as shown by sniffwave)= 16.5 seconds

TRACEBUFF2 packet rate = (1/16.5) = 0.06 packets/s

Tank Size Ts = (1600 bytes) x (0.061 packets/s) x (604800 s) = 5902848 bytes = 56.3Mb

Set tankSize (column 9) for ADK BHZ channel in wave_serverV.tlst file to 57 Mb.