QUICK REFERENCE

for

System Operation, Maintenance & Training Procedures

at the

Mauritius Meteorological Office
Seismic Monitoring Station

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Tuesday January 30th 2007

Overview

This document summarizes procedures that may be used for various tasks related to the operation and maintenance of the seismic monitoring station.

This document outlines procedures described during training conducted at the Met Office and is intended to be used as a quick reference guide. Detailed information regarding any of the software and / or equipment mentioned herein may be obtained from the appropriate manual. Please note that this is not an officially released Nanometrics document. It is simply a collection of potentially useful information that I have pulled together into one place to help you as you get familiar with Nanometrics equipment and seismology.

There are four areas discussed in this document:

- ➔ Seismic Event Analysis
- ➔ Archived Event Data Retrieval
- ➔ Trigger Tuning Suggestions
- ➔ Hypoinverse Configuration

Seismic Event Analysis

This section provides a high-level summary of a general analysis process that may be used for determining event location and magnitude upon receipt of notification that an event has occurred.

Sequence of Events

- ➔ Event detected
- ➔ Verify event is an earthquake
- ➔ Retrieve supplemental data from at least three other stations
- ➔ Incorporate station coordinate and instrument response information into the supplemental data
- ➔ Load supplemental data into Atlas as a SEED file Data Source
- ➔ Add local station traces to the event
- ➔ Position P picks and iteratively minimize station residuals to determine location
- ➔ Apply WOOD-ANDERSON Instrument Simulation filter and position Amplitude Picks to calculate event Local Magnitude, M_L
- ➔ Position Duration Picks to calculate event Duration Magnitude, M_d

Detailed Explanations

1 Event Detected

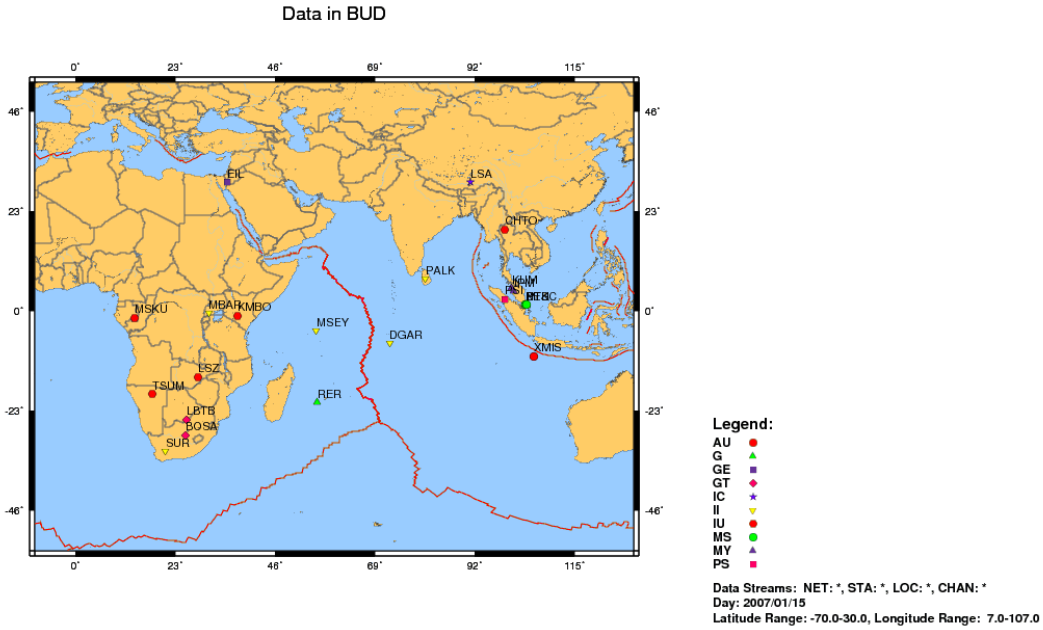
The NAQS Server automatic triggering mechanism detects an event and a notification email is generated.

2 Verification

Operator examines local station event data in Atlas to verify the event is not a false trigger before proceeding.

3 Supplemental Data Retrieval

The Operator retrieves event data from as many other Indian Ocean stations as possible. This can be done using the IRIS BUD mechanism. Currently there are three Indian Ocean stations available from IRIS: G.RER, II.MSEY and II.DGAR.



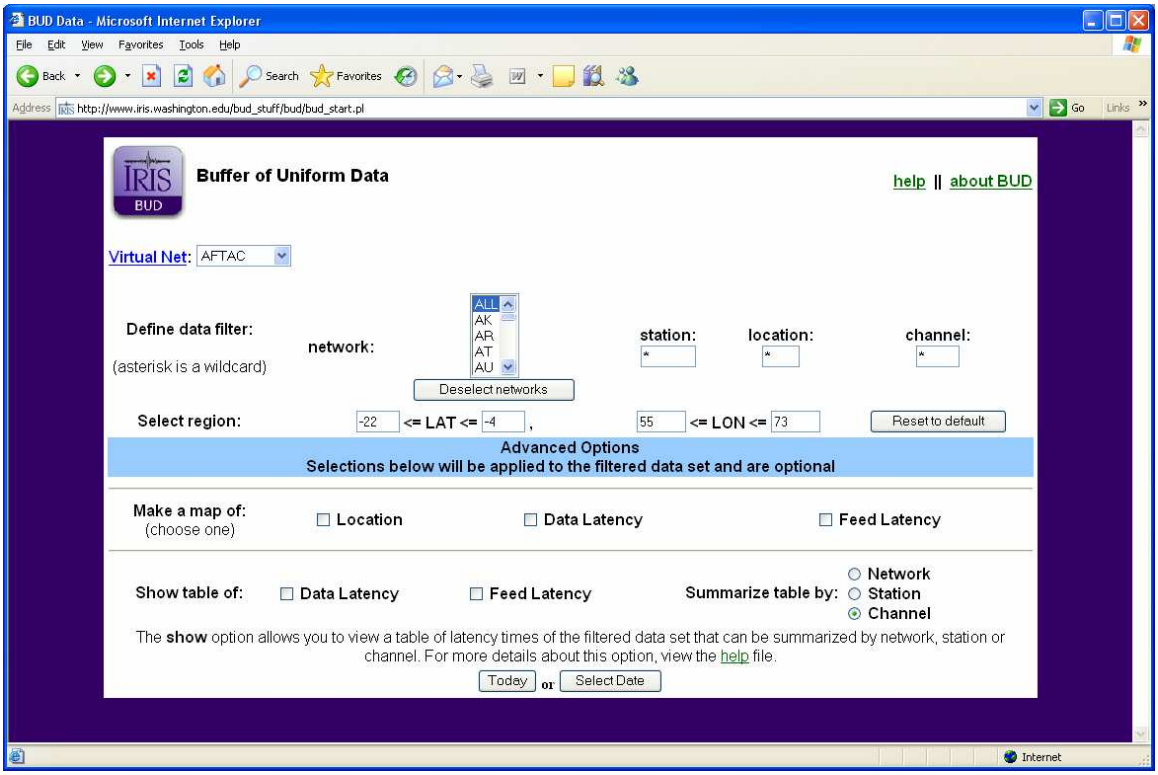
Near real-time trace data is retrieved from IRIS via ftp using the BUD web interface:

http://www.iris.washington.edu/bud_stuff/bud/bud_start.pl

First, perform a regional station search with the following parameters to select stations RER, MSEY and DGAR:

Networks:	G and II
Latitude:	-22 to -4
Longitude:	55 to 73

Click the 'Today' or 'Select Date' button depending upon when the event occurred.

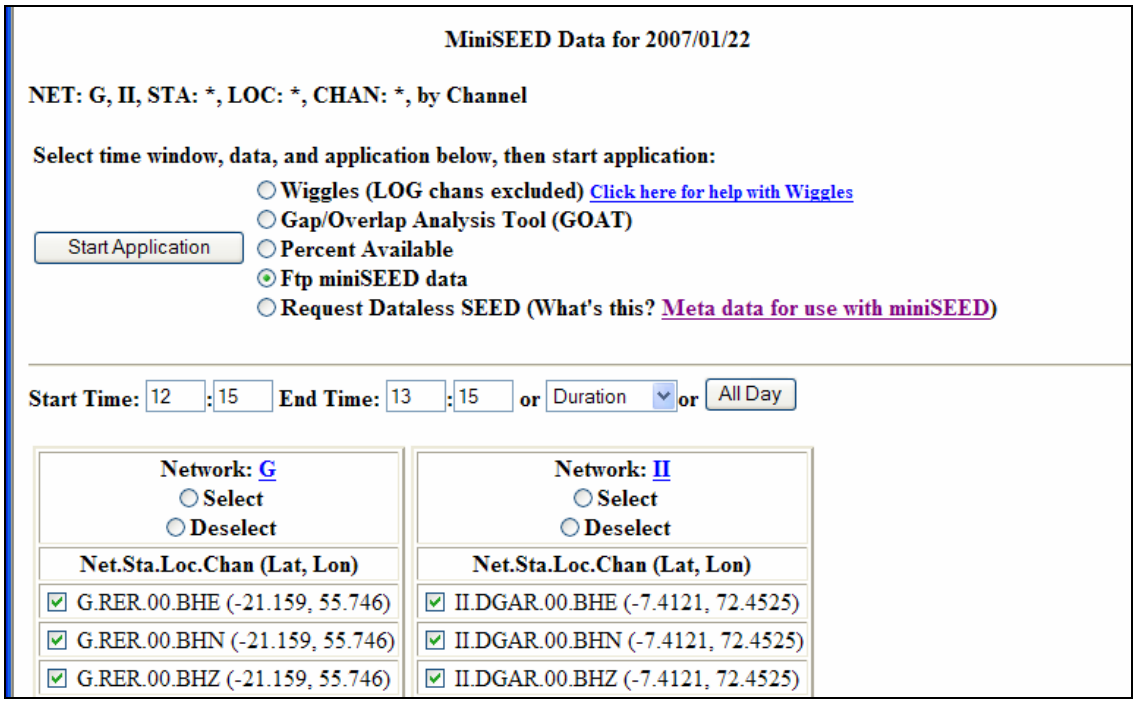


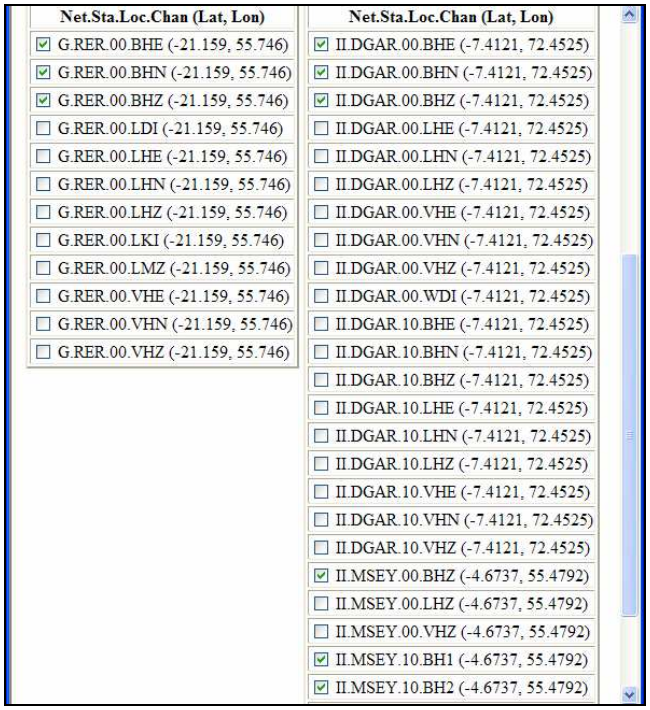
On the data retrieval page, check the check boxes for the channels of interest:

- G.RER.00.BHZ
- G.RER.00.BHN
- G.RER.00.BHE
- II.DGAR.00.BHZ
- II.DGAR.00.BHN
- II.DGAR.00.BHE
- II.MSEY.00.BHZ
- II.MSEY.10.BH1
- II.MSEY.10.BH2

Note that if any of the stations or channels do not appear, that indicates that it was offline during the requested time period.

Select 'Ftp miniSEED data', enter start time and duration corresponding to event and click 'Start Application'. Typically, a start time chosen five minutes prior to the event and duration of thirty minutes is reasonable.





Download the miniSEED format file using the link provided in the new window. Give the received file a meaningful name (ex. 20070122-1_IRIS.mseed).

4 Include Metadata

The miniSEED format omits two important pieces of information for each trace: station coordinates and instrument response. Station coordinates are required to solve for event hypocenters. Instrument response information is required to perform Local Magnitude calculations. There are two options for incorporating metadata to convert the miniSEED file into a full SEED file:

- ➔ Retrieve a 'dataless SEED file' from IRIS via the same mechanism (the BUD web interface) used to download the miniSEED file. Merge the two files using the IRIS tool **jrdseed** to create a complete SEED file. Refer to the **jrdseed** and **rdseed** manuals on the IRIS website for details.
    - o http://www.iris.edu/manuals/jrdseed.htm
    - o http://www.iris.edu/manuals/rdseed.htm

- ➔ Use the Nanometrics **MiniSeedToSeed** utility to specify the station coordinates. **MiniSeedToSeed** will create a SEED file from a miniSEED file using the station coordinates defined in its configuration file. **MiniSeedToSeed** should be executed from the DOS prompt in the same directory as the input miniSEED file. The configuration file, *MiniSeedToSeed.ini*, should also be in the same directory. The generated SEED file will have the same name as the input miniSEED file with the prefix 'FullSeed_' (ex. FullSeed_20070122-1_IRIS.mseed). **MiniSeedToSeed** may also be used to incorporate instrument response information; however, the response information must be defined in a NMX formatted response file generated using the Playback utility **tresponse**. **tresponse** is specific to Nanometrics digitizers and can not be used to simulate the response of digitizers produced by other manufacturers.

Give the resulting SEED file a meaningful name (ex. 20070122-1_IRIS.seed).

5 Load Supplemental Data into Atlas

Open Atlas and create a SEED file data source for the file created in the previous step (ex. 20070122-1_IRIS.seed). Open the event.

6 Add Local Station Data

If not already present, create a NAQS Server data source in Atlas. Use the username and password specified in the c:\nmx\user\dataserver.ini configuration file. If it does not exist, create a channel data catalog for the NAQS Server data source and open the channel list: MRI.HHZ, MRI.HHN, MRI.HHE

With the event from the previous step selected, double-click on each channel in the NAQS server channel catalog to add the MRI channels. Note that the local station channels from the NAQS server data source will have the required metadata incorporated already.

Create a new SEED file data source (ex. 20070122-1.seed) and save the event with all twelve channels (MRI: HHZ/HHN/HHE; RER: BHZ/BHN/BHE; DGAR: BHZ/BHN/BHE; MSEY: BHZ/BH1/BH2) to the new data source.

7 Solve for the Event Location

Position P (or S) picks on one channel per station. Use the channel on which the arrival of the P (or S) wave is most clearly visible. If necessary, apply filters in Atlas to suppress cultural noise and make the arrival more visible.

Click the Locate button to solve for the event location. Set the result to be the reference solution. Copy it to a new solution for editing.

Determine which station has the largest P (or S) pick residual. Adjust the P (or S) pick for that station to minimize the residual. Solve and compare to the reference solution. Repeat for the remaining stations.

Compare the resulting pick offsets to solutions for previous events to determine trends (ex. the P pick for station MSEY must always be moved ahead 1 second to minimize the MSEY P pick residual). Incorporate any observed trends into the crustal model using the station delay file.

Compare the result to the values published by other seismic monitoring organizations such as USGS or IRIS to evaluate accuracy. While still developing the crustal model, fix the solution depth to the published value and repeat the iterative residual minimization process.

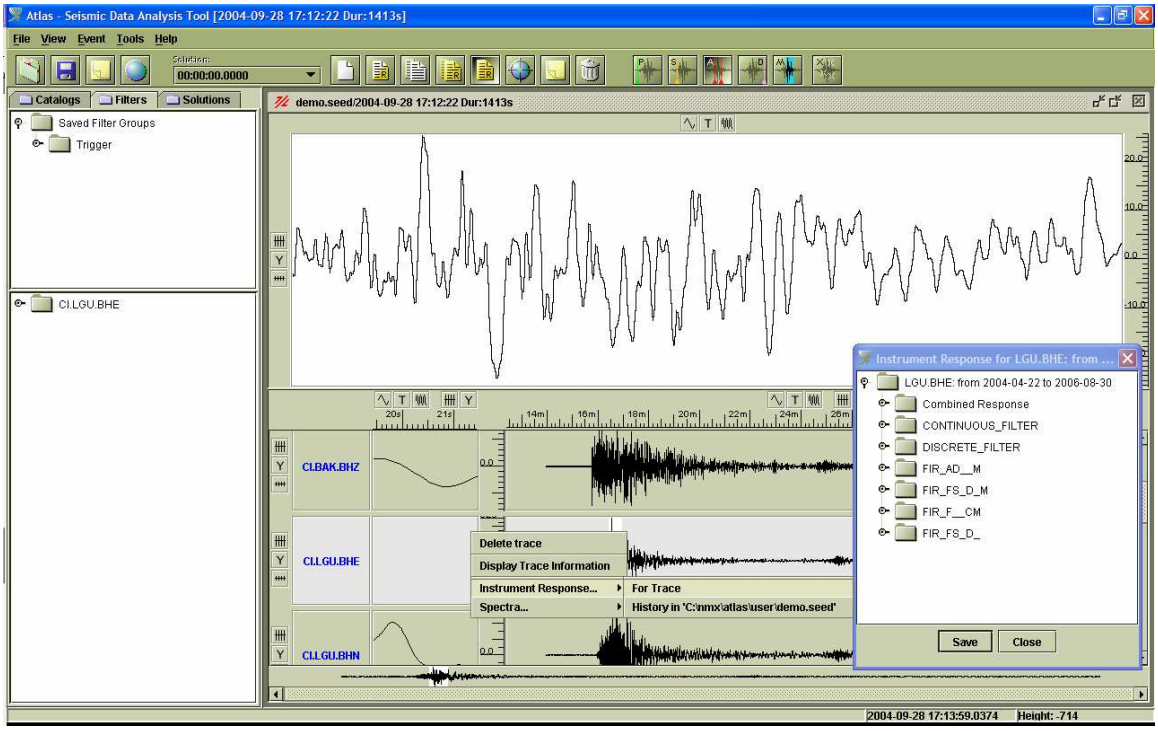
8 Calculate the Event Magnitude

Local Magnitude, M_L

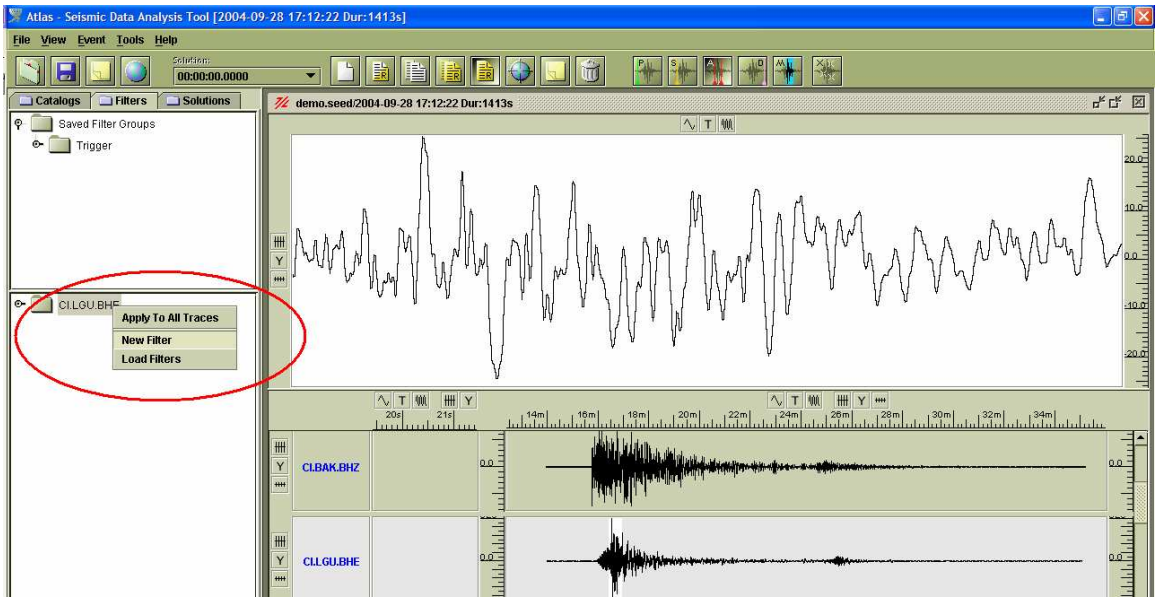
Local Magnitude is a measure of earthquake size based upon the maximum ground displacement caused by the event. The maximum displacement is typically caused by the S wave. Note that Hypoinverse, the location program used by Atlas, assumes amplitude picks are in mm. As such, it is necessary to apply the Wood-Anderson instrument response filter to convert the waveform

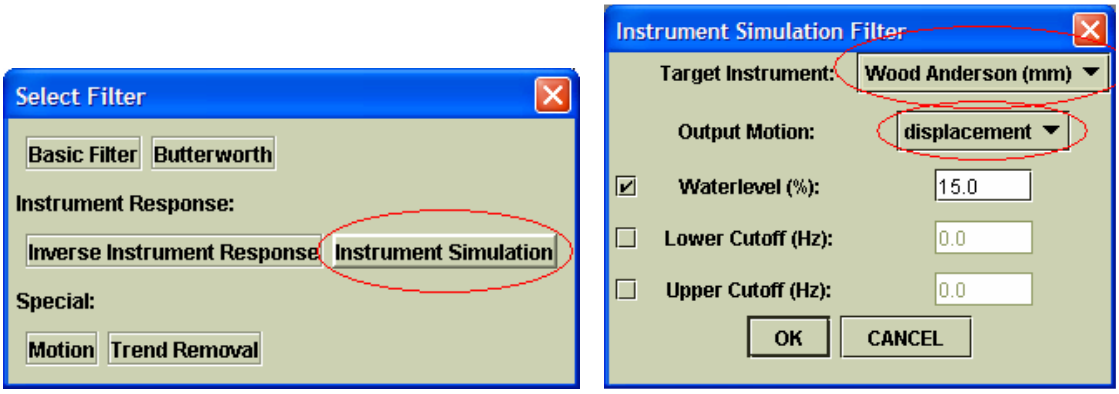
from velocity to displacement. Local Magnitude is then determined by making A picks on one or more traces as follows (if multiple traces are used, the average of the local magnitude value corresponding to each is output):

➔ Ensure that instrument response information has been successfully incorporated into the SEED file by right-clicking on the trace and selecting Instrument Response.



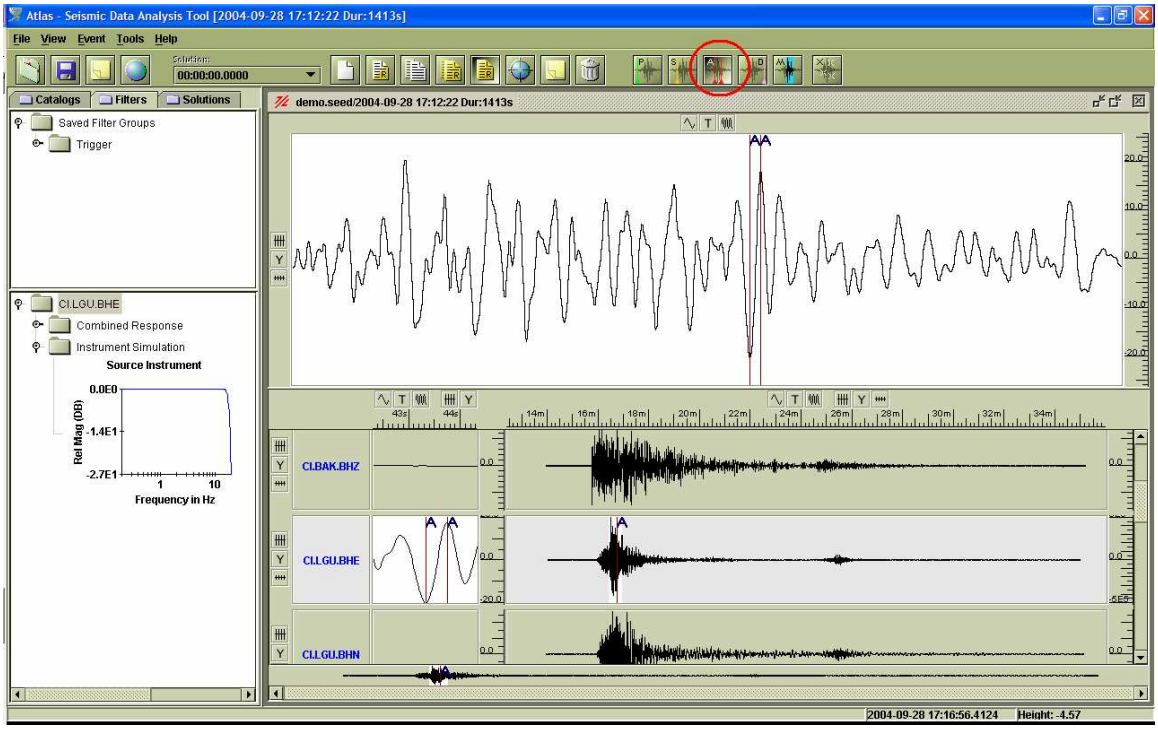
➔ Apply a WOOD-ANDERSON Instrument Response filter (displacement output) to the selected trace.



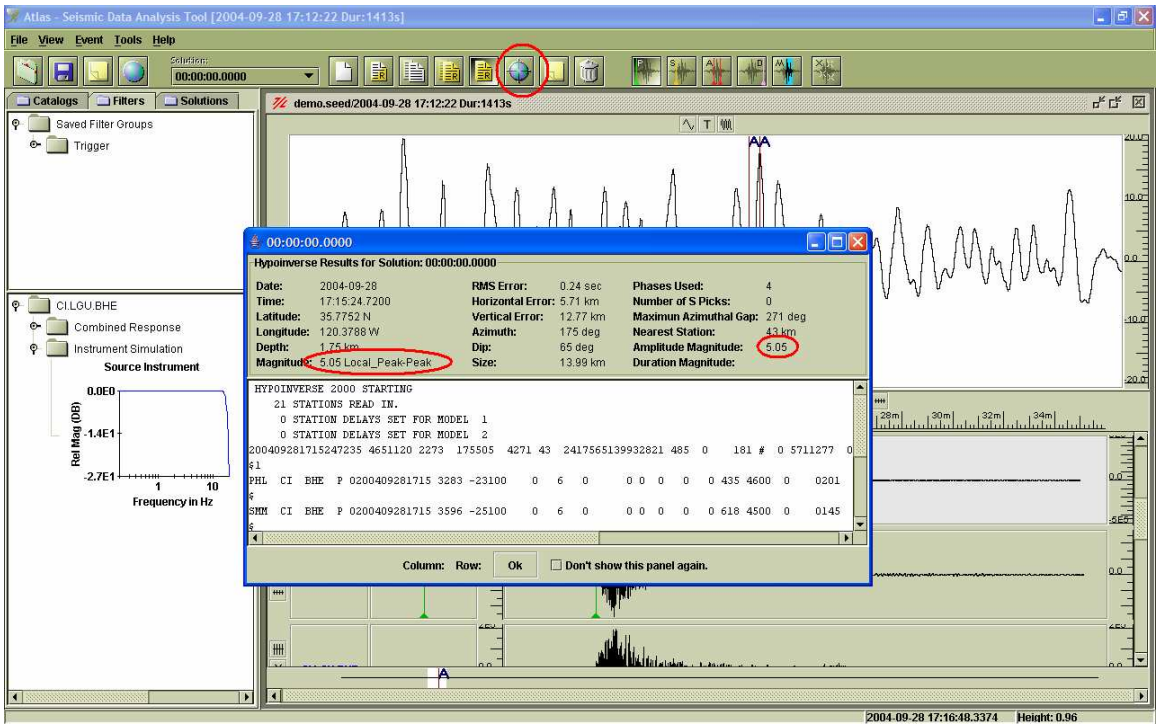


You will notice a change in the shape of the selected trace as it is converted from representing velocity to representing displacement.

➔ Apply an A pick to the single largest peak-to-peak amplitude change.



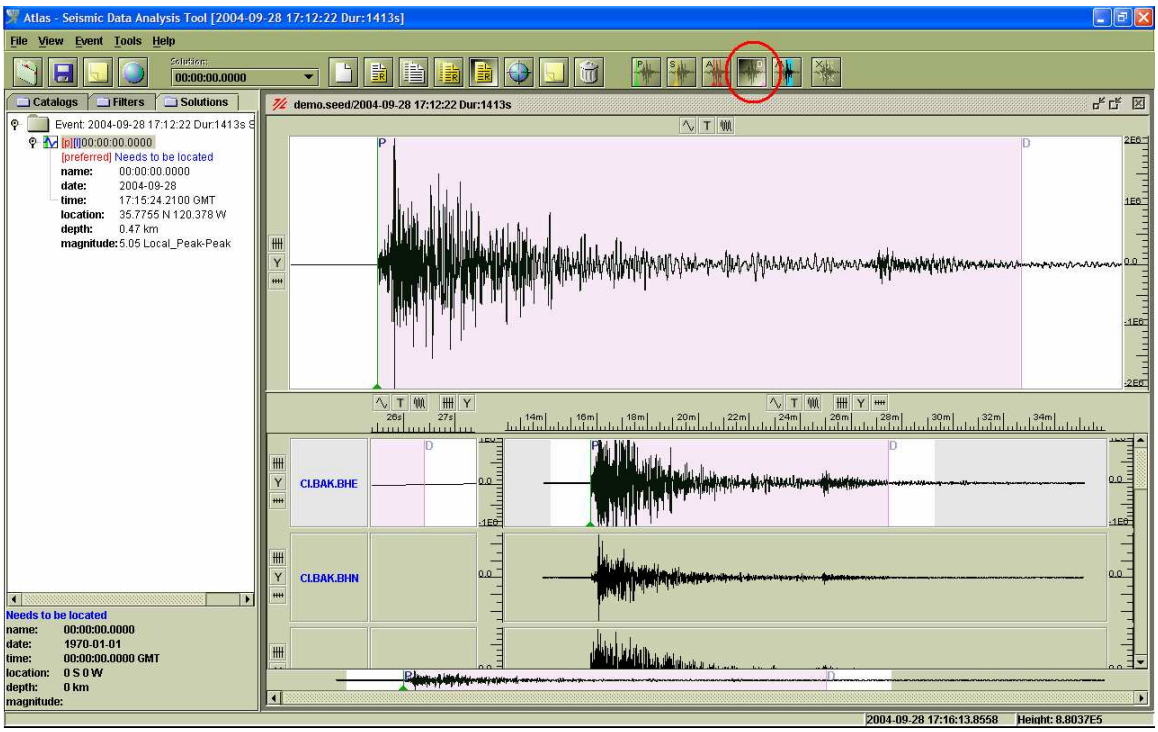
➔ Click on the Locate button to perform the calculation. Note that the event location should have already been determined and the corresponding P (or S) picks still active.



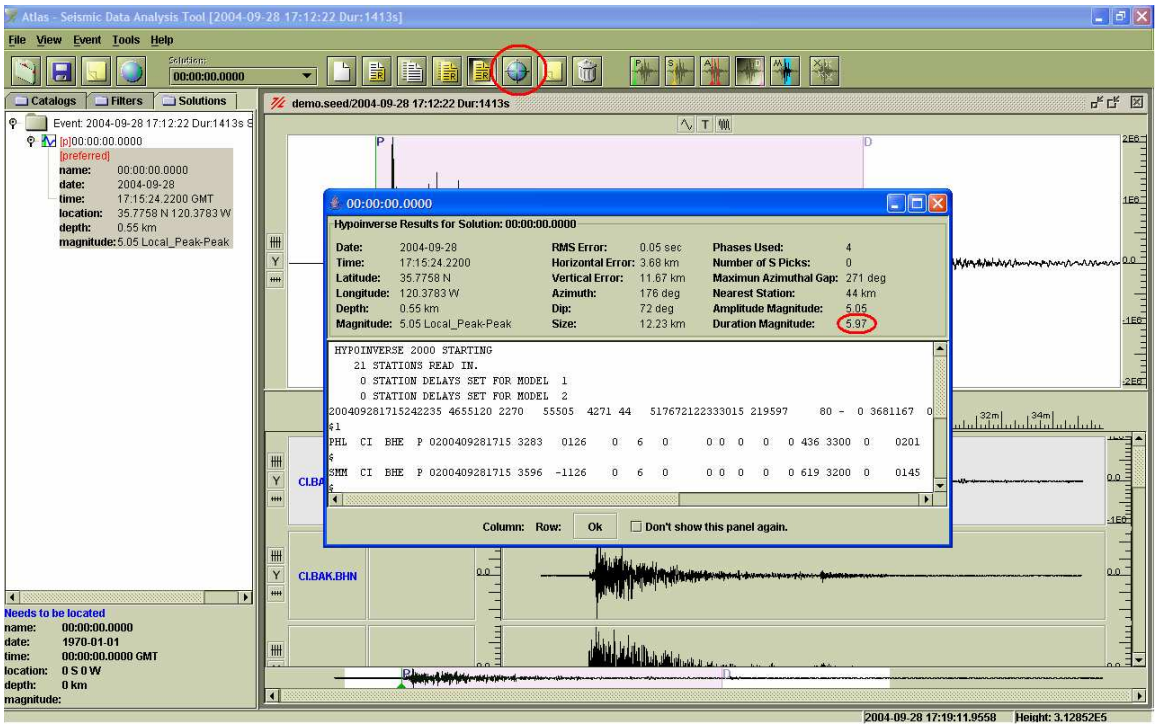
Duration Magnitude, M_d

Duration Magnitude is a measure of earthquake size based upon the duration of the shaking at a station as a result of the event. Instrument response information is not required and Duration Magnitude is a quick way to calculate an initial estimate of the event magnitude. However, in general it is less accurate than amplitude magnitude techniques. It is determined by making D picks on one or more traces that already have P picks, as follows (if multiple traces are used, the average of the duration magnitude value corresponding to each is output):

➔ Apply a D pick on the selected trace to indicate the time at which the shaking at the corresponding station, caused by the event, came to end. The selected trace must also have a P pick indicating the time at which the shaking began.



➔ Click on the Locate button to perform the calculation. Note that the event location should have already been determined and the corresponding P (or S) picks still active.



Archived Event Data Retrieval

To develop knowledge and skills, it is recommended that operators practice generating solutions for event location and magnitude using known events.

The following section outlines a procedure which may be used to search for known events and retrieve the corresponding data required for analysis.

Sequence of Events

- ➔ Event Selection (SeismiQuery)
- ➔ Determine Stations in the Region of Interest (SeismiQuery)
- ➔ Determine Data Availability (SeismiQuery)
- ➔ Data Retrieval (WebRequest)

1 Event Selection

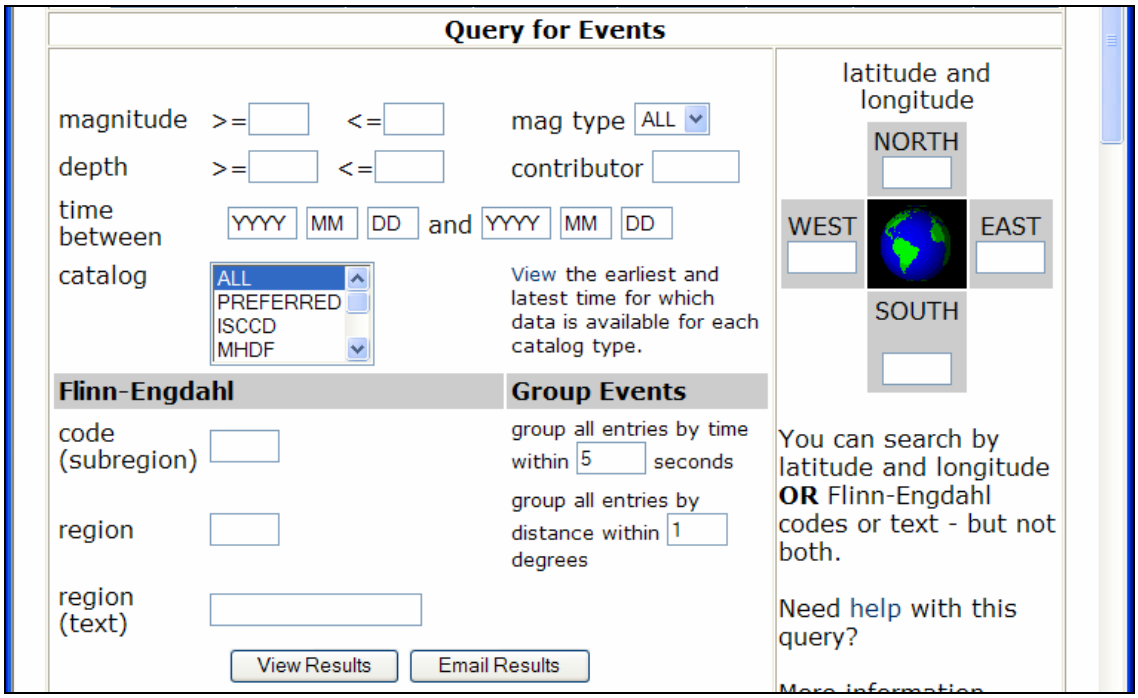
A list of known events may be generated for a particular region using the IRIS SeismiQuery tool:

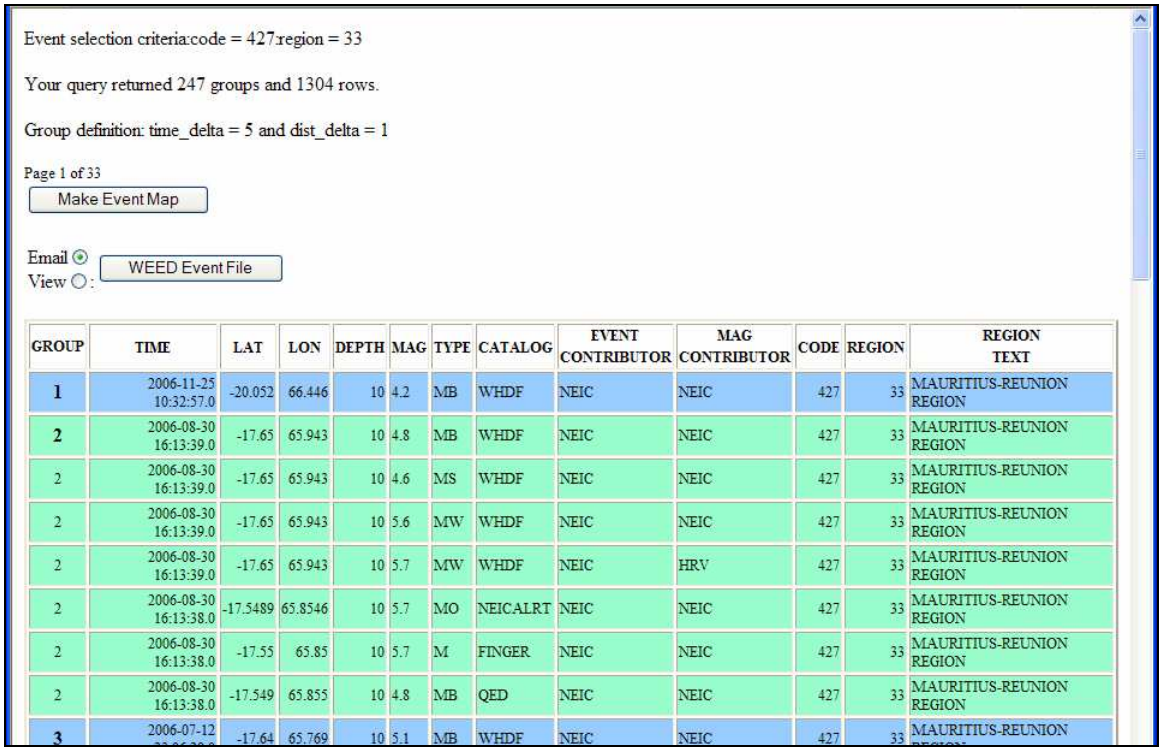
http://www.iris.edu/SeismiQuery/events.htm

The search may be limited using additional criteria such as time of occurrence, magnitude and depth.

Enter the desired criteria and select the 'View Results' button. A new window will open with the results of the search presented in tabular form. Note that the geographic search region may be defined using latitude and longitude boundaries or by specifying Region and Subregion codes. The Mauritius-Reunion area corresponds to region 33 and subregion code 427.

Each row corresponds to a different solution for an event. There are often multiple solutions from different organizations or representing different magnitude measures for a single event. Separate events are defined using the Group ID column.





Event selection criteria:code = 427:region = 33

Your query returned 247 groups and 1304 rows.

Group definition: time_delta = 5 and dist_delta = 1

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Make Event Map

Email / View : WEED Event File

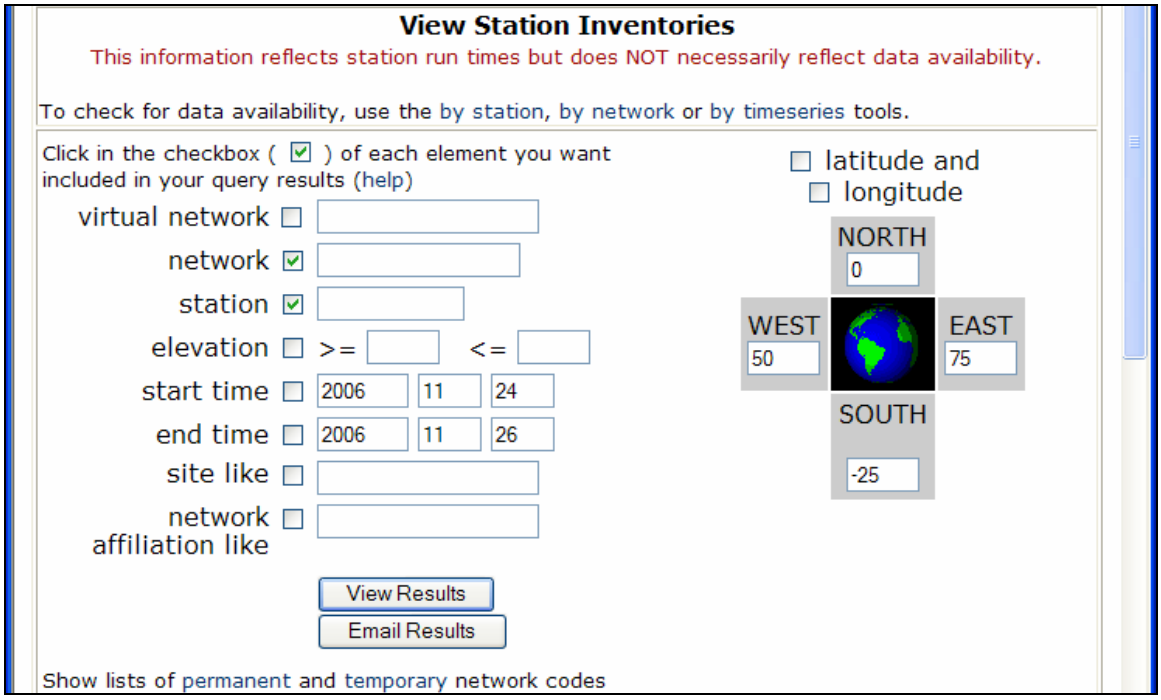
GROUP	TIME	LAT	LON	DEPTH	MAG	TYPE	CATALOG	EVENT CONTRIBUTOR	MAG CONTRIBUTOR	CODE	REGION	REGION TEXT
1	2006-11-25 10:32:57.0	-20.052	66.446	10	4.2	MB	WHDF	NEIC	NEIC	427	33	MAURITIUS-REUNION REGION
2	2006-08-30 16:13:39.0	-17.65	65.943	10	4.8	MB	WHDF	NEIC	NEIC	427	33	MAURITIUS-REUNION REGION
2	2006-08-30 16:13:39.0	-17.65	65.943	10	4.6	MS	WHDF	NEIC	NEIC	427	33	MAURITIUS-REUNION REGION
2	2006-08-30 16:13:39.0	-17.65	65.943	10	5.6	MW	WHDF	NEIC	NEIC	427	33	MAURITIUS-REUNION REGION
2	2006-08-30 16:13:39.0	-17.65	65.943	10	5.7	MW	WHDF	NEIC	HRV	427	33	MAURITIUS-REUNION REGION
2	2006-08-30 16:13:38.0	-17.5489	65.8546	10	5.7	MO	NEICALRT	NEIC	NEIC	427	33	MAURITIUS-REUNION REGION
2	2006-08-30 16:13:38.0	-17.55	65.85	10	5.7	M	FINGER	NEIC	NEIC	427	33	MAURITIUS-REUNION REGION
2	2006-08-30 16:13:38.0	-17.549	65.855	10	4.8	MB	QED	NEIC	NEIC	427	33	MAURITIUS-REUNION REGION
3	2006-07-12	-17.64	65.769	10	5.1	MB	WHDF	NEIC	NEIC	427	33	MAURITIUS-REUNION

2 Station Selection

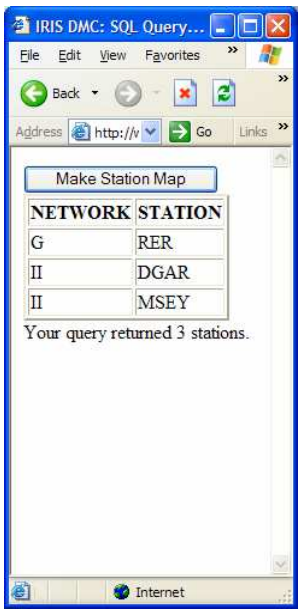
SeismiQuery may also be used to determine what stations are located in the region of interest:

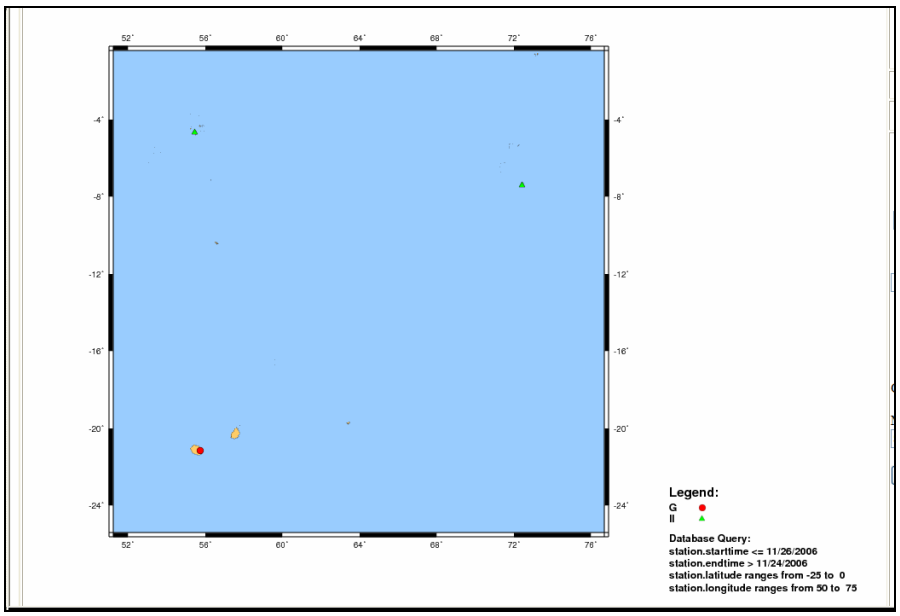
http://www.iris.edu/SeismiQuery/station.htm

Define a geographic search region using latitude and longitude boundaries surrounding the event epicenter. Specify a start and end time corresponding to when the event occurred to insure that only stations active during the event are returned.



A new window opens listing the stations matching the search criteria. Use the 'Make Station Map' button to generate a map displaying the station layout.



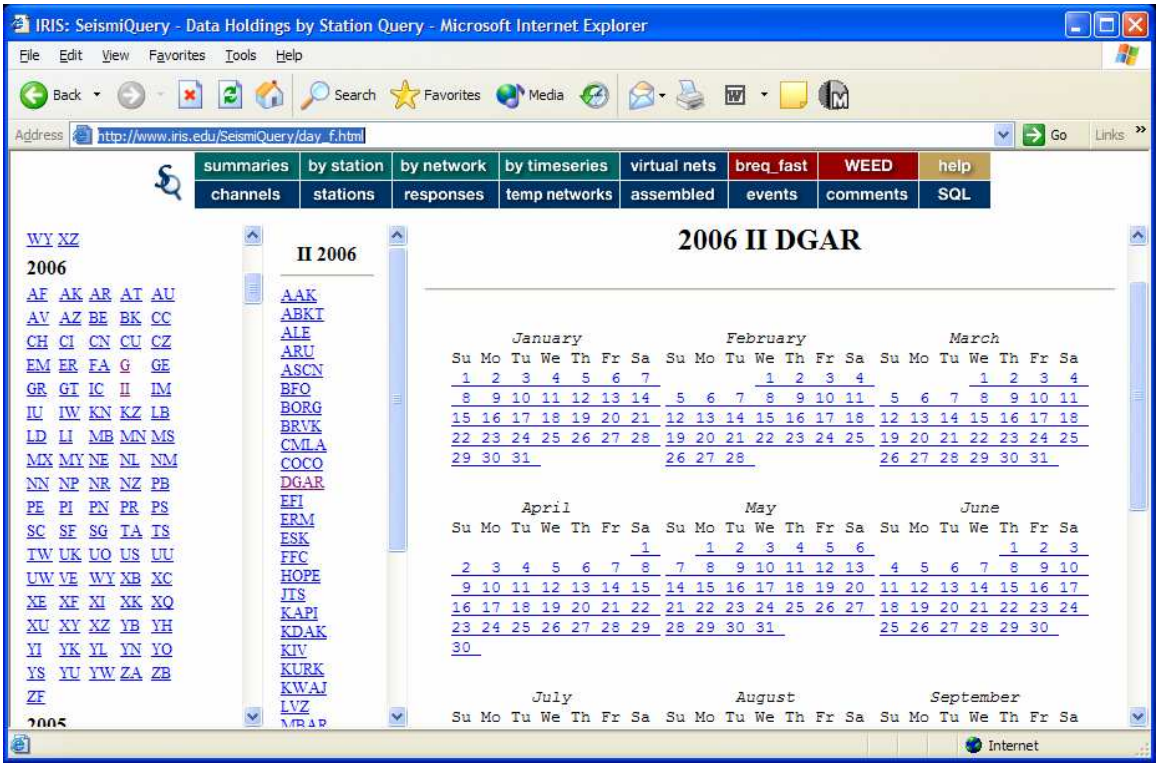


3 Determine Data Availability

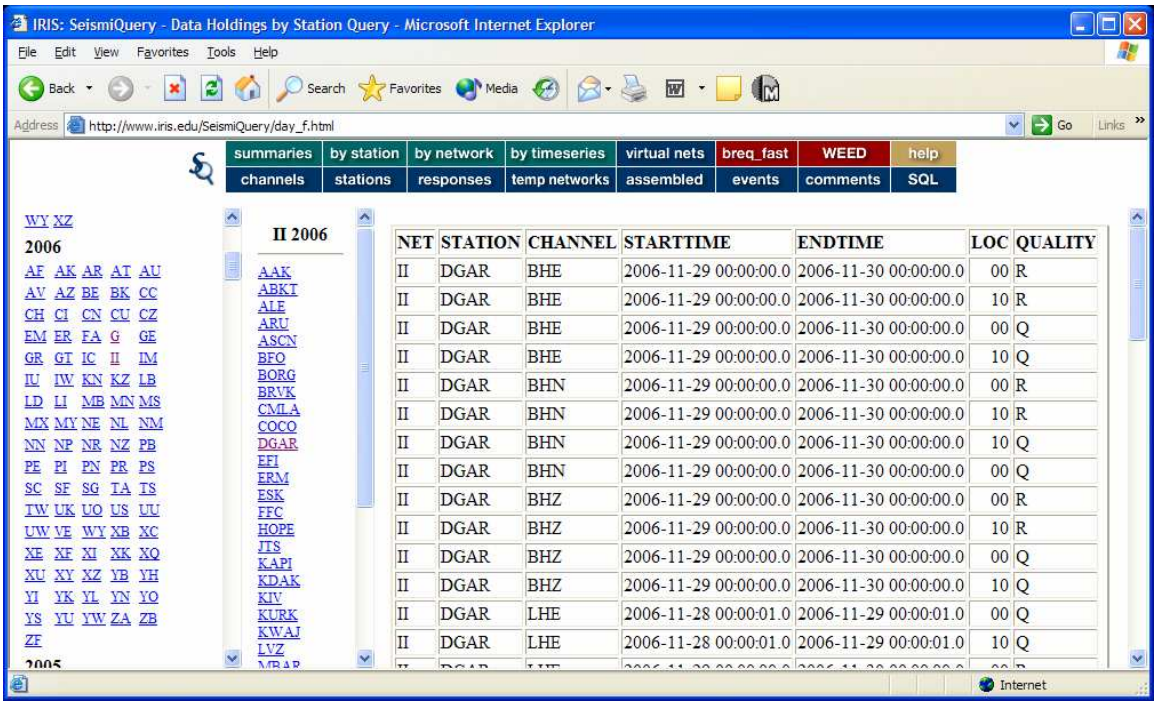
Use the SeismiQuery tool to verify that the stations in the region of interest have data available when the event occurred.

http://www.iris.edu/SeismiQuery/day_f.html

Select the link on the left corresponding to the station network and year in which the event occurred. Select the link corresponding to the station in the list that appears in the next column. Select the day of the year on which the event occurred.



A table is presented summarizing the data available on a channel by channel basis for the day selected.



NET	STATION	CHANNEL	STARTTIME	ENDTIME	LOC	QUALITY
II	DGAR	BHE	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	00	R
II	DGAR	BHE	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	10	R
II	DGAR	BHE	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	00	Q
II	DGAR	BHE	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	10	Q
II	DGAR	BHN	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	00	R
II	DGAR	BHN	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	10	R
II	DGAR	BHN	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	10	Q
II	DGAR	BHN	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	00	Q
II	DGAR	BHZ	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	00	R
II	DGAR	BHZ	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	10	R
II	DGAR	BHZ	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	00	Q
II	DGAR	BHZ	2006-11-29 00:00:00.0	2006-11-30 00:00:00.0	10	Q
II	DGAR	LHE	2006-11-28 00:00:01.0	2006-11-29 00:00:01.0	00	Q
II	DGAR	LHE	2006-11-28 00:00:01.0	2006-11-29 00:00:01.0	10	Q

Confirm that data is available for the time period corresponding to the event occurrence for each channel of interest. Repeat for all stations.

4 Data Retrieval

The available data may be retrieved using the IRIS WebRequest tool:

http://www.iris.edu/data/WebRequest.htm

Fill out the required user information, enter 'B' to request the best data quality, select 'Electronic (FTP) for the media choice and enter a meaningful label for the dataset.

Scroll down and define the requested data set by entering station, network, start and end time, channel specifier and, optionally, location information. Click on the 'Send Request' button to submit the request to IRIS.

A new window opens indicating that the request has been delivered. A request confirmation email is generated immediately by IRIS and sent to the address specified in the User information section.

Once IRIS has compiled the requested dataset, a second email is sent to the address specified in the User information section indicating an ftp site at which the data may be retrieved. In my experience, this process takes three minutes.

WebRequest

This is a data request form that allows users to submit BREQ_FAST-formatted data requests to the DMC.
[* required fields]

User Information

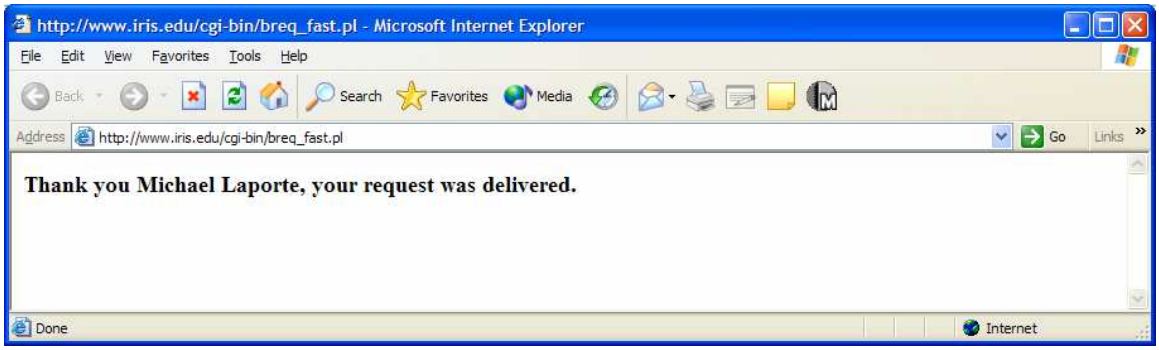
*NAME:	Michael Laporte
*INSTITUTION:	Nanometrics
*ADDRESS:	Ottawa, Canada
*E-MAIL:	michaellaporte@nanometrics.ca
*PHONE:	6135926776
*QUALITY:	B

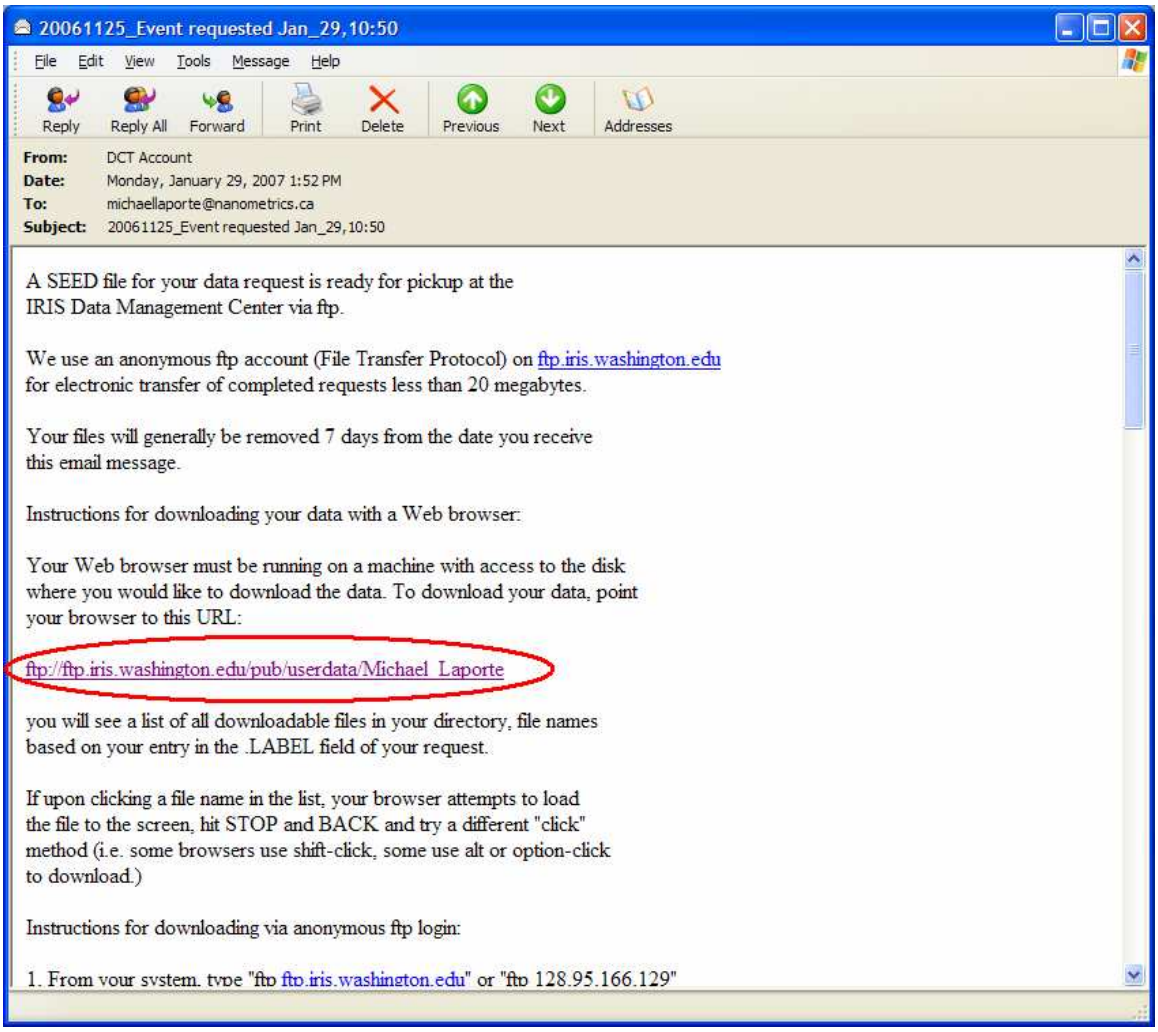
Media and Label choices

MEDIA:	Electronic (FTP)
ALTERNATE MEDIA:	DAT 4mm
ALTERNATE MEDIA:	DLT
LABEL:	20061125_Event

use '?' when wildcarding	CANNOT wildcard this field	STARTING TIME						ENDING TIME						use '?' when wildcarding	LOCATION
Station	Network or Virtual Network	Year YYYY	Month MM	Day DD	Hour 00	Min 00	Sec 00.0	Year YYYY	Month MM	Day DD	Hour 00	Min. 00	Sec. 00.0	Channel names	LOC ID
GRFO	IU	1995	01	02	00	18	10.4	1995	01	02	00	20	10.4	SH? B??	
RER	G	2006	11	25	10	30	0	2006	11	25	10	45	0	BH?	
DGAR	II	2006	11	25	10	30	0	2006	11	25	10	45	0	BH?	
MSEY	II	2006	11	25	10	30	0	2006	11	25	10	45	0	BH?	

Send Request





Proceed to the indicated ftp site and retrieve the complied dataset.

The dataset is in SEED format and should include all required metadata. As such, the file may be opened as a new SEED data source in Atlas and event analysis may begin immediately.

It is important to note that it may be appropriate and necessary to make modifications to hypoinverse configuration files depending upon the location and geometry of the stations used. For this reason, it is recommended that events occurring in Northern California be used for at least the initial familiarization period. The default hypoinverse configuration is tailored for Northern California.

Trigger Tuning Suggestions

Part of the initial development and configuration of the system will be to fine-tune the triggering mechanism. The goal is to be able to detect as many real events as possible while minimizing the number of false triggers.

Triggers are configured in the NAQS Server configuration file c:\nmx\user\Naqs.stn. They define a passband of interest in the frequency domain by specifying a low pass filter and a high pass filter. Short term (STA) and long term averages (LTA) of the signal in the passband are continuously calculated and compared to each other. If the STA exceeds the LTA by a defined ratio, a trigger is activated. If a predefined number of triggers occur concurrently on separate channels within a predefined time period, an event is considered to have occurred. The trigger to event relationship is defined in the NAQS Server configuration file c:\nmx\user\Naqs.ini.

More detailed information about STA/LTA triggers may be found in the NAQS Server User Guide, the Taurus User Guide (8.1.3) and the NMSOP (IS8.1).

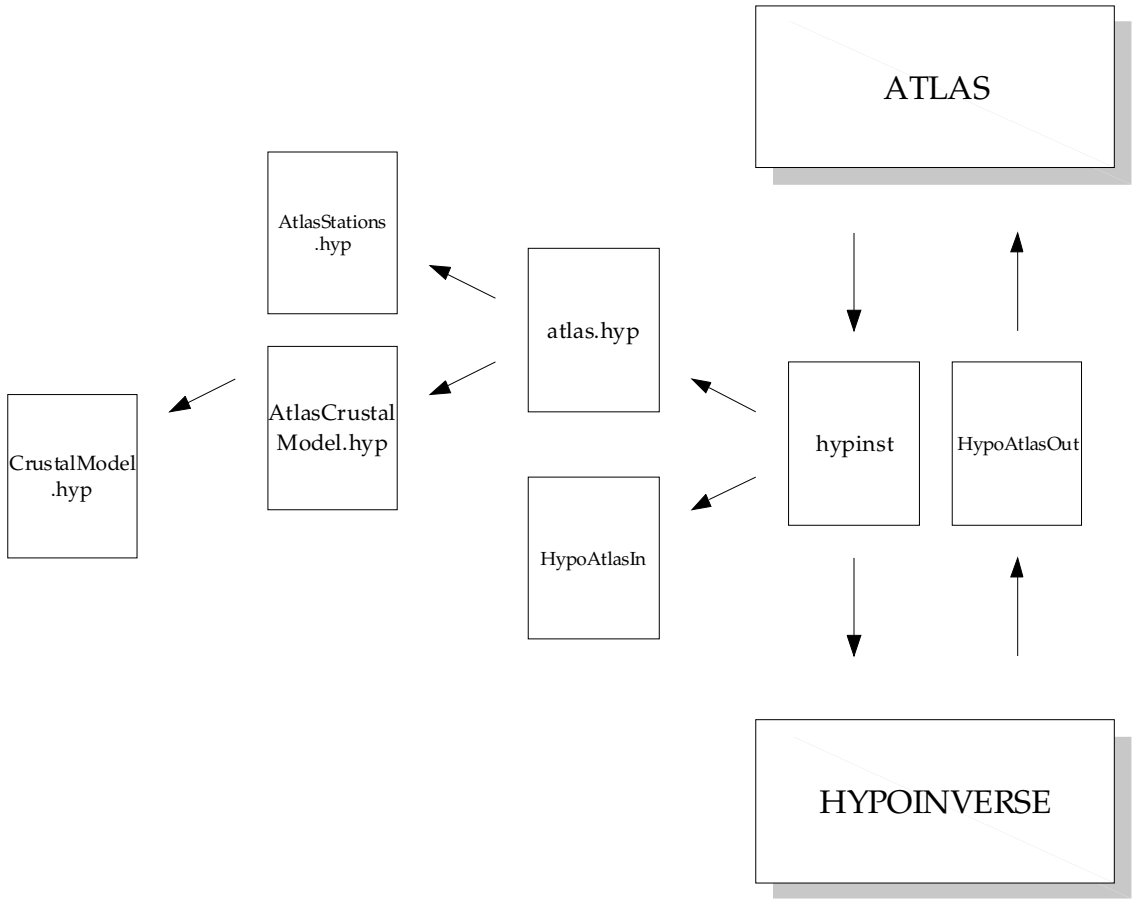
In general, trigger performance is something that must be continually monitored over time and adjustments made accordingly. If a particular configuration is generating a large number of false triggers, it should be adjusted to be less sensitive by increasing the threshold ratio, increasing the STA time constant or decreasing the LTA constant for example. If the trigger is missing too many real events, the configuration should be adjusted to be more sensitive.

The passband of the trigger should be defined to include the frequency range corresponding to seismic waves from a local or near-regional event and to filter out or suppress cultural noise. One way to evaluate trigger performance in this regard, without having to wait for events to occur, is to load data from known events into Atlas, apply high and low pass filters corresponding to the trigger passband and observe the change in the waveform. Ideally the onset of the event would become more pronounced as cultural noise is suppressed. Various trigger passbands may be evaluated quickly in this way.

Hypoinverse Configuration

Alas uses Hypoinverse for event location and measurement. Hypoinverse is a command based program written and used by USGS. Atlas creates a command input file (c:\nmx\atlas\user\hypinst) that references additional files which include commands that define everything required by Hypoinverse to produce a solution (the crustal velocity model, station information, pick information, magnitude calculation details, etc).

When the Locate button is clicked, Atlas invokes the Hypoinverse executable and passes it the high-level command file (hypinst). Hypoinverse processes hypinst and all of the commands in the files it references, solves for event location and magnitude and generates an output file, HypoAtlasOut. Atlas parses the output file and summarizes the results generated by Hypoinverse.



Hypoinverse requires initial set-up and fine-tuning. This includes developing a velocity model for the region of interest, updating station information (location, weighting, delays) and configuring magnitude calculation parameters.

To develop expertise, an important first step is for operators to read the Atlas User Guide, the Atlas Installation & Maintenance Guide and the Hypoinverse Users Guide.

Some of the more important files and commands are described below.

C:\nmx\atlas\user\hypinst

High level command file passed to Hypoinverse. It references Atlas.hyp and HypoAtlasIn. There should be no need to edit this file.

C:\nmx\atlas\user\hypinverse\Atlas.hyp

Primary command file. It includes commands to define station information, crustal velocity model, magnitude calculation parameters, etc. It references AtlasStations.hinv and AtlasCrustalModel.hinv. It may be edited and is an important file with which to be familiar.

C:\nmx\atlas\user\HypoAtlasIn

Defines all pick information (P, S, A, D) passed to hypoinverse. This file is created when the Locate button is pressed based upon the picks made in the currently active solution. In general, this file should not be edited manually. It may be necessary to become familiar with its format for debugging purposes.

C:\nmx\atlas\user\hypoinverse\AtlasStations.hinv

Contains details about stations and their channels. It is created by Atlas every time the Locate button is clicked. Atlas creates it using all stations defined in the UserStations.hinv file and than adds entries for all stations currently in memory. If there are duplicates, hypoinverse uses the first entry.

C:\nmx\atlas\user\hypoinverse\AtlasCrustalModel.hyp

Defines the crustal velocity model. This file references additional files that define crustal models and station delays. It associates the referenced crustal models with geographic locations and station delay files specific to the given model. This file and those it references must be edited manually and it is important to be familiar with its structure and the associated commands.

C:\nmx\atlas\user\HypoAtlasOut

Output file generated by Hypoinverse. It defines the results of processing from the last time Hypoinverse was invoked. This file is parsed by Atlas and loaded into memory. A summary of the results is presented along with the raw contents of the file in the Hypo Display window opened after Hypoinverse is invoked.

Atlas.hyp Commands

- DIS Distance weighting
  - For progressive down-weighting of distant stations
  - DIS <ITRDIS> <DISCUT> <DISW1> <DISW2>
  - ITRDIS = iteration at which distance weighting begins
  - DMIN2 = distance to second closest station in km
  - weight = 1 for stations closer than DMIN2*DISW1
  - weight = 0 for stations farther than DMIN2*DISW2
  - cosine taper in between
  - if DMIN2 < DISCUT, use DISCUT instead of DMIN2
  - can expand the circle for epicenters outside the network but won't get too small for epicenter in a dense part of network
  - DIS 4 15.0 3.5 7.0 ➔ good for Northern California
  - DIS 20 1000 1 3 ➔ recommended start point for Indian Ocean

- RMS Residual weighting
  - For progressive down-weighting of stations with larger travel time residuals
  - RMS is root-mean-square travel time residual in seconds
  - RMS <ITRRMS> <RMSCUT> <RMSW1> <RMSW2>
  - ITRRMS = iteration at which residual weighting begins
  - weight = 1 for stations closer than RMSCUT*RMSW1
  - weight = 0 for stations farther than RMSCUT*RMSW2
  - cosine taper in between
  - RMS 4 0.16 1.5 3.0 ➔ default, good for Northern California
  - RMS 4 1000 1.0 3.0 ➔ recommended start point for Indian Ocean

- WET Weight Codes
  - Map weight factors to P and S wave weight codes 0, 1, 2 and 3
  - codes 4 to 9 always have weight 0
  - code 0 gets full weight
  - Atlas only supports codes 0 and 6 (weights 1 and 0)
  - WET 1.0 0.75 0.5 0.25 ➔ default

- DAM Set iteration and damping parameters effecting hypocenter adjustments
    - Last field is D2FAR
    - D2FAR = maximum distance for the second closest station before iteration is terminated
    - DAM 7 30 0.5 0.9 0.012 0.02 0.6 50 250 ➔ default
    - DAM 7 30 0.5 0.9 0.012 0.02 0.6 50 2500 ➔ recommended starting point for Indian Ocean

AtlasCrustalModel.hyp Commands

- CRT Read a linear time gradient model in now
    - CRT <#> 'filename'
    - generated using TTGEN

- CRH Read a homogeneous layer crustal model in now
    - CRH <#> 'filename'

- DEL Read in station delays in seconds for crustal model
    - DEL <#> 'filename'
    - use 0 for all models
    - each line of delay file has: STN NETWORK delay(sec)

- NOD Define circular epicenter region over which crustal model / delays apply
    - NOD <lat> <log> <radius> <transitionWidth> <#>

- MUL Indicate whether multiple, region dependent models will be used
    - MUL T | F <#>
    - if True, indicate default model for regions not defined