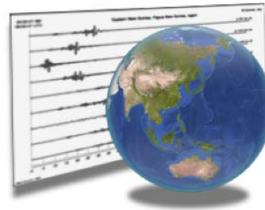# Earth Motion Monitor User's Manual

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Version 1.9.5

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Acknowledgments

Introduction

The seismological community, through the Incorporated Research Institutes for Seismology (IRIS) has invested heavily in establishing methods for direct access to the large and growing seismic data sets that are stored in the Data Management System (DMS), and in particular at the Data Management Center (DMC) in Seattle, WA. The IRIS Data Handling Interface (DHI) provides the framework for direct access to seismograms and near real-time signals. A number of interfaces to the data are available, including old standards such as BREQFAST, which provides indirect access through email messaging and ftp mechanisms, and WILBER II, which provides web- ftp-based access. These are fine ways to access the data, but both necessitate using multiple tools - the request tool, an ftp client, a SEED file converter or reader, and a display program. This is an acceptable process flow for research efforts, but takes more time than one generally can afford for simply looking and displaying recent and near-real-time seismograms.

But the framework to quickly access the data exists. I developed this application to acquire and to display such signals. The goal is browsing data - nothing is ever written to the disk, so when you quit the application, the data are gone (you can always get them again). IRIS is not the only data center that provides a DHI server. SCEC, UC Berkeley, GEOFON, and others are operating compatible DHI servers. These groups are active improving the servers and developing client tools. Future versions of this application may allow direct communication with those servers but for now, the IRIS servers have enough data to keep me busy and to use for the educational purposes targeted by this application.

Earth Motion Monitor

Earth Motion Monitor is a Mac OS X (10.4.x and later) application (a DHI client) that allows browsing seismogram data available through the Incorporated Research Institutes for Seismology (IRIS) Data Handling Interface (DHI) seismogram servers. I designed the program to browse the data in an earthquake-centric way (as opposed to station-centric). My goal was to develop a tool that I could use in front of both introductory and advanced classes to show and to discuss ground motions produced by earthquakes. Thus the target audience for this application is a teaching seismologist or a very dedicated enthusiast, not a busy high-school teacher who already has too much to do, or a non-specialist. As such, the interface contains options that may only be clear to some-

one with experience using seismic data or dealing with time series. Unfortunately, I have no time to simplify and explain the options in detail.

Another, less interesting development goal was to learn the IRIS-FISSURES-DHI system that I use to access the data in the application. This was not easy, but is part of my research plans, so I invested quite a bit of time in it. The objective-C codes that are the basis of this application are research quality, which means that they are hard to decipher (at times, even for me) and are not intended for release. If you are interested in producing similar tools, I recommend using the Java-based FISSURES packages, or the libraries that are being developed to add DHI capabilities in the Seismic Analysis Code (SAC). Examples for those packages are available from the University of South Carolina (http://www.seis.sc.edu/) and IRIS (http://www.iris.edu).

Installation

Place the EarthMotionMonitor application where ever you want (such as /Applications) and then if you want, place the folder EarthMotionMonitor in

$$~/\text{Library/Application Support/} \quad .$$

Acquiring Seismograms

The main activity of the application is acquiring seismograms from the IRIS servers. Obviously, for any of this to work, you have to have an active and relatively fast network connection. The program doesn't check for the network, so if nothing seems to be working, check your network connection. Most requests are set to time out after a few minutes. The status of potentially long queries generally are indicated using small spinning progress indicators common in Mac applications.

As the program launches, a connection with the IRIS name server (kind of like an telephone switchboard operator) is established. Next connections are made to several other information and seismogram servers. These connections are valid until something changes on the server. But if the servers at IRIS are restarted while you are running the application, you will have to restart this client application. I hope to remove this limitation eventually, but I have run this client in monitor mode for days without problems. Results of the initial connection process are logged to the console (which you can see on the Mac using Apple's Console Application, located in Applications/Utilities).
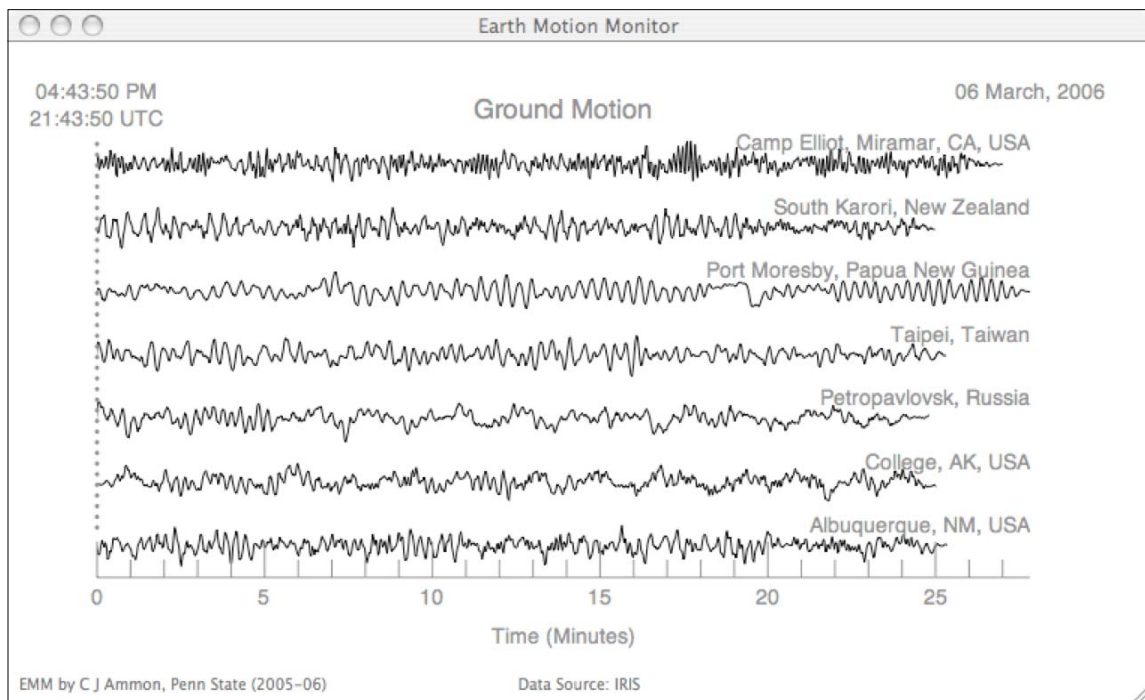
The IRIS Seismogram Servers

To use EMM effectively, you have to understand the difference between the two servers for which I implemented connections. The DHI interface contains a number of computer processes that serve different types of information. Network servers provide information on seismic stations including locations, operation dates, instrument responses, etc. Event servers provide information on seismic events, including locations, magnitudes, etc. Data centers provide seismograms, which are the primary focus here. EMM provides access to two IRIS servers, the BUD and the POND servers. You choose which server that you are talking to with the Server Radio Button on the Acquire Tab of the Settings Window.
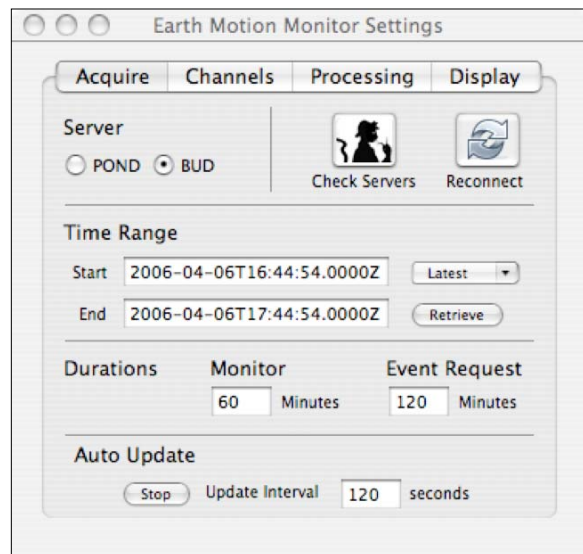
Most of my efforts have gone into the BUD connections since they provide the most recent data and that's what I've wanted to browse lately. In fact, the channel search features are implemented only for the BUD server. The POND server is similar to the IRIS FARM archive, which contains special data collections for large earthquakes. I believe that it is the same collection that WILBER accesses. Use this server when you want to browse signals from large older events (I believe that the generic magnitude cutoff is 6.0). I am not sure how fast events make it into the POND, but for events in the few weeks you can use BUD.

Specifying Times

If you want to look at an older earthquake, set up the "Start" and "End" time fields and make a request to the POND server. The time specification format is a little strange, but you must enter the strings in the format that is shown in the window above. The letter "T" separates the date and the time, and the letter "Z" indicates UTC, or Greenwich time. You need the 4 places after the decimal point, which is overkill for what we're doing, but those positions are needed for some data. Finally, make sure you include the leading zeros for days and hours with only one digit (1-9).

Earth Motion Monitor

04:43:50 PM
21:43:50 UTC

Ground Motion

06 March, 2006

Camp Elliot, Miramar, CA, USA

South Karori, New Zealand

Port Moresby, Papua New Guinea

Taipei, Taiwan

Petropavlovsk, Russia

College, AK, USA

Albuquerque, NM, USA

0   5   10   15   20   25

Time (Minutes)

EMM by C J Ammon, Penn State (2005–06)   Data Source: IRIS

Getting Started: A Simple Example

Launch the application, make sure that the BUD server is selected, and then select 30 minutes from the "Latest" popup menu. As soon as you let go of the menu, you should see an active progress indicator in the lower right of the seismogram display window. After a few seconds (perhaps a few 10s of seconds) you should see the seismograms on the display. Right now the default channel set includes nine stations, but you may not see all of them. Stations come in and out of the near real status. When data are available they will join the other signals on the display. Likewise the signal duration and latency may not all be equal - although we asked for 30 minutes, we only received about 28 minutes of signal in the example.

The channel latency depends on a number of issues related to communications and processing. Since the example request was for long-period channels and they are derived from broad-band channels, the latency is a few minutes. Broad band channels generally have a shorter latency (than their the long-period equivalents), but communications are potentially 20 times more lengthy because the broad-band signal is more densely sampled. For general browsing or monitoring of larger events, the long-period channels are fine. Even a five-minute latency is not a big issue unless you are staring at the screen.

The reference time is shown in the upper left (local and UTC reference frames) the date in the upper right. A simple time scale in minutes is shown along the bottom (the axis drawing routine is very simple and designed for lengths of one or two hours or less). A channel label is printed above and to the right of each signal. These can be customized as described later. The plot title can be set using the text field on the Display Tab of the Settings Window.

To plot the seismograms you must account for different instrument gains, band widths, as well as time-varying noise and signal levels. To produce a relatively simple scaling I normalize each signal by its root-mean-square amplitude. This accounts for time-varying signal strengths and eases plot scaling. Note that the global plot scale factor depends on the maximum normalized amplitudes of all the traces, which varies. You can adjust the scaling of the traces using the slider on the Display Tab of the Settings Window. This comes in handy to see smaller body waves when the display is dominated by the surface waves.

How Data Requests Work

All data requests are made for a list of channels using a time range. Although you can request data with a specific time window, the latest "XX" minutes, starting with recent earthquake origin times, or in the automatically updated monitor mode, all the requests employ the "Start" and "End" time fields shown in the Acquire Tab of the Setting Window. Each request first updates the date-time in these time fields and then uses time-field strings to acquire the signals from IRIS.

The seismograms are returned from IRIS in mini-seed format and I can only decode Steim compressions I and II right now. So I am not sure that all stations can be browsed with the tool. I have had browsed a large number of stations from a number of seismic networks, so this is not a serious limitation. Since requests are generated using time windows, if you ask for a time window that spans more than one event, the DHI may send back multiple seismogram segments. If more than one seismogram is returned for a single channel, only the signal with the longest time window is retained, the others discarded. Again, I can see this being annoying on rare occasions, but it has not been a problem.

Channel Lists

You select which channels you want to browse using the Channels Tab in the Settings Window. Each line in the text field corresponds to a seismogram in your request. The parameters for each channel are separated by a semicolon and include the network code, the station code, the channel code, the site code and a label string. The channels must of course be offered by BUD or contained in the POND for a successful request.
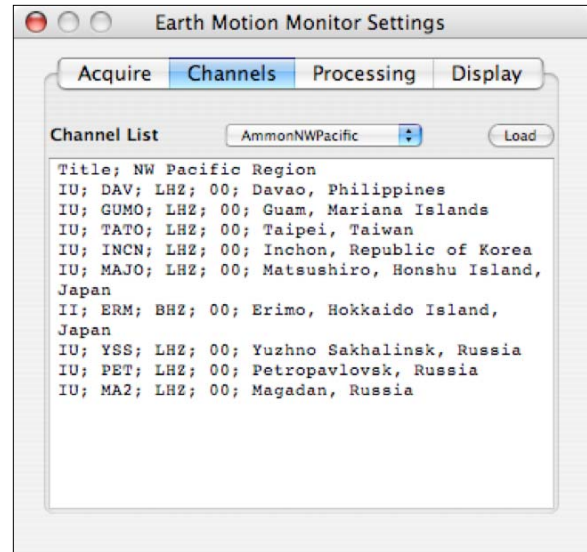
You can edit the Channel List text directly.

If you make changes you must click the "Load" button to secure the change. For long lists of stations, loading the stations can take some time since each channel produces a call to the IRIS DHI for station information. The implementation is not the most efficient, but this has not been too much of a problem and is a fine temporary approach.

The popup menu contains the list of text files that contain custom channel lists. Save them in the folder:

Where to put channel lists

~/Library/Application Support/EarthMotionMonitor/ChannelLists .

Files in the folder should have UNIX line terminations and be named something like PacificRim.txt. The base name (PacificRim in this case) is what is added to the popup menu. The directory is scanned when the application is launched. If you add files after that, you will have to quit and relaunch to see the new options.

You can add an optional title line to the list by using the string "Title" as the first element and then following with a title string, as in
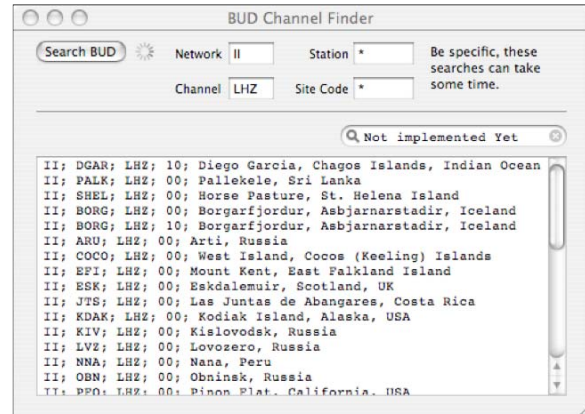
"Title; Pacific Rim Stations".

You can toggle the option on and off using the check box in the "Display" tab of the Settings Window.

Finding Seismogram Channels

A simple channel finder can be accessed from the Windows Menu. You set the search parameters in the Network, Channel, and Site Code text fields and then click the Search BUD button. The results are listed in the text view and you can copy and paste these into the Channel Tab of the Settings Window to load them. Some of these searches can take a long time, so be as specific as you can with the fields - it will save you time. I specify a time of one hour for the channel search. The result is that you only see stations that have been reporting during the last hour. On a different day, you may find different stations.

Seismogram Processing Options

The raw signals from the DHI are not always the best way to look at the seismic signals they contain. With the exception of the largest events, you need to apply some filter to enhance the interesting part of the signal. Most observational seismologists have their favorite bandwidths to see what interests them. EMM allows for simple processing of the incoming signals.
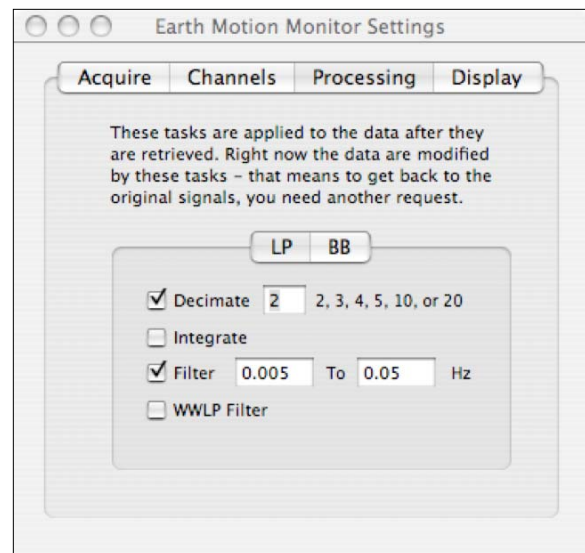
You set the processing options using the Processing Tab in the Settings Window. Right now, the processing is applied in a stupid way - only one copy of the data are retained and the filter is applied immediately after the data are acquired. The situation may be improved in a later version. Only a few basic processing commands are available, and most of those are simply to allow you to see different parts of the signal more easily. At the start, each seismogram has a linear trend and the mean removed. For the most

part, I hope that the options are self explanatory. I include separate controls for long-period and broad-band channels, which usually require different parameters.

Decimation

The decimation factor doesn't change the calls to the DHI, but it can impact the display. Valid decimation factors of 2, 3, 4, 5, 10, or 20. The seismograms are filtered before decimation to avoid aliasing. Why decimate a signal? Seismograms with fewer points in them are faster to draw and if you have too many points, you are wasting time. Broad-band channels sampled at 20 samples per second contain 72,000 time samples in an hour. Since that's much more than the number of pixels across any common display, to try and show them all is a waste of time.

Filters

The filters are applied as a low-pass and high-pass Butterworth filters, with two passes to retain the original signal phase. The WWLP and WWSP filters correspond to the old World-Wide Standardized Seismological Network long-period and short-period responses. They are narrow-band, causal filters that bracket the pervasive spectral peak in earth motion caused by microseisms. The WWLP is less useful, but the WWSP shows a nice short-period range, suitable for small local and regional earthquakes that don't excite large longer-period signals above microseism levels.

Browsing Recent Earthquakes

Earth Motion Monitor includes a window that contains a list of recent events contructed with information provided by the National Earthquake Information Center (NEIC) of the U.S. Geological Survey.

Origin Time	Flinn Engdahl Region	Magnitude	Depth	Latitude	Longitude	Contributor	Ca
2006–03–01T09:36:45.0000Z	Xizang	5.10	37.1	35.346	89.514	us	N
2006–03–01T11:04:12.0000Z	Mindoro, Philippine Islands	5.80	22.1	13.424	120.527	us	N
2006–03–01T14:36:02.0000Z	Off west coast of northern Sumatera, Indonesia	5.00	19.9	2.695	95.897	us	N
2006–03–01T20:21:43.0000Z	Northern Chile	5.20	128.3	−18.280	−69.074	us	N
2006–03–02T15:24:58.0000Z	Fiji Islands region	5.30	616.9	−17.849	−178.509	us	N
2006–03–02T23:35:44.0000Z	Leeward Islands	5.30	24.8	19.358	−63.787	pr	N
2006–03–03T23:11:34.0000Z	Southern Alaska, United States	5.00	99.2	59.780	−153.040	ak	N
2006–03–03T23:36:27.0000Z	Southern Mid–Atlantic Ridge	5.90	10.0	−55.712	−4.135	us	N
2006–03–04T00:53:31.0000Z	Central Mid–Atlantic Ridge	5.60	10.0	0.862	−27.993	us	N
2006–03–04T08:11:36.0000Z	Off coast of central America	5.70	27.8	12.576	−89.286	us	N

Data Source: USGS – National Earthquake Information Center

The information is updated when the window is first opened, and can be refreshed using the "Update" button. To limit your earthquake list by magnitude, change the minimum

magnitude field in the upper left and push the update button. You can sort the events by clicking on the column headings. The table allows you to select one row (earthquake) at a time. To see an earthquake's epicenter on the Google Maps website, select it and then click to "GoogleMaps" button. This will launch your default browser and place a marker on the map at the epicentral location. To view the NEIC summary page for the event, click the "NEIC Info" button and your browser will load that page.

To load the seismograms from the selected earthquake, click the "Load Seismograms" button. The current channel set is used for the request, which starts at the event origin time and continues for the duration that is entered in the "Event Request Duration" text field on the Acquire Tab of the Settings Window. Everything else is pretty much the same - if you want to see a different set of stations, use the Channels Tab in the Setting Window to set up the new list, load the channels, and make another request. If you want to fine-tune the time window, change either the request duration or the Start and End Times on the Acquire Tab. If you edit the times directly, use the "Retrieve" button to make the new request, since the "Load Seismograms" button recomputes the time window using the earthquake origin time and the event request duration value.

I use this feature in more advanced classes to show students seismograms from recent earthquakes. The objectives of this activity include seismic phase identification based on arrival times and signal characteristics. I try to emphasize the repeatability of the observations from event to event - what's common in signals from all shallow, or from all deep events. Comparisons of mainshocks and aftershocks often allows students to see the similarity in seismograms from earthquakes in the same sequence (as well as the differences). The goal is to get students to observe earthquakes for themselves, noting characteristics such as dispersion. I also show the spectral content of different seismic arrivals (and background noise) by filtering the data into distinct bandwidths, or by downloading broadband and long-period channels from the same station.

Monitor Mode (Automatic Updates)

You can use the program to monitor ground motion on a set of channels. Set up the channels as you would for any other request, then set the duration of signals that you want to display in the "Monitor Duration" text field on the Acquire Tab of the Settings Window. Set the update interval on the Acquire Tab and then click the "Start" button in the

Auto Update section. The display will automatically update at the interval you requested. I suggest that you don't update too frequently - it's a waste of bandwidth and resources. To stop the process, click the "Stop" button under Auto Update. The display is more or less the same as that used for specific time windows, but the time origin is moved to the right of the plot and the time of the last request is used as the time reference.

I use the auto update mode in my seismology and my larger undergraduate natural hazards classes. I am fortunate to have two large screens in the larger classroom, and I can let the monitor run on one, while I use the other for the focus of the class that day. I was lucky enough to have the class watch a magnitude 5.8 earthquake radiate waves around the Pacific basin during one class period. Even the small events that are evident only close to the source often garner some interest from the students. The key concept I try to communicate to students is the frequent occurrence of earthquakes, a point that I also make with another Mac application, Epicentral, that you can download from my website.
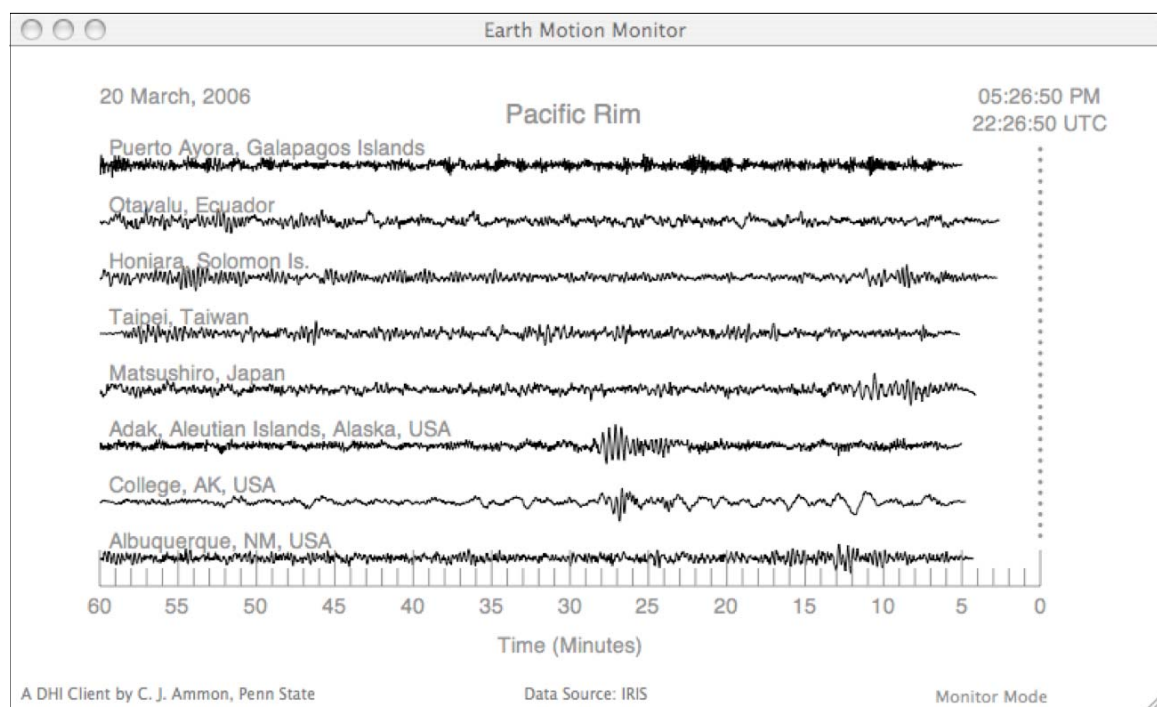
Default Startup Settings

To automatically initiate monitor mode whenever EarthMotionMonitor launches create a file called autoUpdate.txt in application's the support directory:

~/Library/Application Support/EarthMotionMonitor .

To select one of the installed channel lists as the default channel list, create the file "defaultChannelListName.txt" in the application support directory. The file should contain the file name for the default channel list, such as, "AmmonGlobal00.txt". Note that this approach is only temporary until I get everything into the defaults system that Apple provides (which may be some time).

If you want to have this run automatically, set up a user that has limited access permissions to automatically log into the machine on reboot, and add the Earth Motion Monitor application to that user's "launch on startup" list. You will still have to restart it when the DHI is reinitialized, but you can do this remotely from the command line (if you allow ssh connections to the machine - again, understand security issues if you do this).

The NEIC event list is also updated during monitor mode and any origin times that are located in the time range that is being displayed are identified by vertical lines. For smaller events, less than magnitude 5.0, the line is yellow. For magnitudes equal to or larger than 5.0 but less than 6.0, the line is orange, and for events larger than equal to 6.0, the line is red.

A Few Final Caveats

This is a tool that is designed to browse seismograms. I do not use it to analyze the signals, just to watch what is going on and to show signals in my classes. If you use it, problems will arise and at times you will have to relaunch the program. The program is not supported and I am not sharing it in order to receive suggestions or feature requests. I don't have the time to make the application anything more than it is already. I hope that you may find it useful under these conditions.

Version History

Changes Implemented in Version 1.9.5:

- Added reconnect button and implemented a method that may allow recovery from broken BUD connections (time will tell).
- Added event list updates as part of monitor mode. Origin times will be shown on the display by color vertical lines.

Changes Implemented in Version 1.9.4:

- Added default startup file checks: autoUpdate.txt, defaultChannelListName.txt.
- Added optional titles to channel lists.