AEIC Processing Manual

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Contents

1. Data processing organization at AEIC.

AEIC has in place an automatic arrival detection and event location system. A computer module continuously scans waveform data and detects seismic arrivals in real time. Once a group of concurring arrivals is identified (at least 6), the best fit hypocentral location is determined by a grid-search over precalculated three-dimensional grids. For every location, a local magnitude ML is determined, given there is at least one suitable station within 0-5 degree distance range (station in magnitude table, signal is not clipped, signal to noise ratio of at least 3).

Analyst tasks include review of automatic locations and scan of selected waveforms to identify additional events missed by automatic detectors. Processing is organized by daily volumes (UTC time). All data are supposed to be processed within seven days. Each analyst checks out one day for processing and is responsible for finishing it and submitting back into the system. All processed data resides in */home/YOU/process* in subdirectories called according to the date - *YEAR_MO_DA*, all databases called *process_YEAR_MO_DA* (e.g. */home/natasha/process/2005_12_31/process_2005_12_31*). All data is stored in CSS3.0 database format.

When processed day is checked back into the system, a number of different tasks are performed. A subset of locations and picks is e-mailed to PGC (Pacific Geoscience Center, Canada), events with M>=2.5 are sent to NEIC to be included into PDE catalogs, days that are less than one week old are displayed on USGS Recent Earthquake web-maps, our own earthquake databases and web-sites are updated, and finally, waveform data are segmented and stored for processed events.

Terms:

dbloc2 - interactive hypocenter location program;

aeic_dbml - program for computing local magnitudes;

dbpick - program to review waveforms, pick arrivals;

smartpick - graphical driver for *dbpick*;

dbchecker_tool - graphical driver for database error checks, designed to run with *dbloc2*;

aeic_dbchecker - checks an *orid* in a database for possible errors;

aeic_dberrchk - reviews an event database for a series of possible errors and reports them to the user;

CSS3.0 - database schema (CSS stands for Center for Seismic Studies).

See man pages for more detailed information.

2. Processing procedure.

Analysts's time is very valuable. Ideally, all data have to be processed within a couple of days (1-3, to be specific). In case of a major earthquake in the state, it's important to start processing aftershocks right away without being burdened with a backlog of several days of unprocessed data prior to this event's occurrence. Aftershock distribution is one of the most important contributing factors for assessing the size of ruptured fault. Therefore, the

processing procedure outlined below has been designed to be streamlined, efficient and productive. An experienced analyst should be able to process about 50 events within a regular work day.

2.1. Checking out day for processing:

a. R-click on screen to open "Root Menu"

b. L-click "Seis_apps"

c. L-click "Analysis_control"

d. L-click on a day to check out

e. Accept and quit

2.2. Opening processing program:

a. R-click on screen to open "Root Menu"

b. L-click "New Window" -> Local (or a faster computer if needed/allowed)

c. On a command line type:

cd process/YEAR_MO_DA

dbloc2 process_YEAR_MO_DA

The program will open with your control panel and the database you selected to work on.

Note: Our earthquake database has grown quite large over the recent years so that orid's and evid's are 5-digit numbers now. Some analysts find it easier to work with the database if they renumbered orid's to start from 1. To do that in the command line type (before opening *dbloc2*):

dbfixids process_YEAR_MO_DA orid 1

2.3. Processing.

2.3.1. Waveform scan. First, the waveform scans. Two scans have to be done: (1) Aleutians and (2) mainland Alaska. Station lists for the scans get updated as new stations come online or die. Seismologist will usually provide and update those regularly. These lists are also available on AEIC internal webpage. To start scanning:

a. Click on "Waveforms" button on the bottom row to bring up waveforms. This opens *dbpick*, the *smartpick* control panel, and some collapsed windows.

b. Turn off "Predicted arrivals" button, lower left side of *dbloc2* screen.

c. Click on "Set Default phase P" yellow button, right side of *smartpick* control panel.

d. Display waveforms from either list 1 or 2 for scanning:

Open file with scan lists (command window or text editor). Open collapsed dialog box *smartpick_dbpick* ("Restore"). Select the first scan list (L-click & drag) and copy it into *smartpick_dbpick* window (M-click). Bring the waveforms back to front by clicking on the rim of the waveform screen.

e. Filter data with 1HP filter through "Filter" pull-down menu on top of *dbpick* window.

f. Compress waveforms to ~6 minutes per screen for the mainland scan or ~8 minutes for Aleutians (Shift+R-click & drag compresses-zooms out and Shift+ L-click & drag expands-zooms in).

g. Slide arrow bar at the *dbpick* screen bottom to far left (00:00:00). Make sure you stay within your day. If your day is less than 3 days old you'll have more than 1 day of waveforms in your database.

h. Advance to the next time window by L-click (R-click to go back, M-click to drag the screen position to where you want). Note: the location of the mouse will determine how much time the screen will advance or move back in time (the further to the right the mouse is clicked, the larger the time advance or retreat).

i. To add P arrivals, L-click "Add Arrival" button at *dbpick* screen top:

R-click - allows you to keep adding more arrivals;

L-click - places only one arrival;

M-click - turns off arrival function.

j. Make sure you don't go beyond the end of your day. For the most recent data there could be more than one day of the waveform data in the database.

Note: Add only P arrivals during initial waveform scans. You don't have to be very careful with where you place your pick while scanning. You'll be reviewing and correcting these picks later. Do not place error bars at this time.

Repeat above instructions to bring up and scan 2nd station list.

Helpful hints:

a. Every arrival that you add will appear in the *dbloc2* screen. It is best to slide the time bar at the top of this screen forward and click "Next" for about every 6 hours of picks, to avoid having too much data piled up in one spot and slowing things down.

b. For the mainland, the scan stations are organized from north through Interior to Cook Inlet to Prince William Sound to south-east. For Aleutians, the list starts with the Kodiak and Katmai stations and continues west through Shemya with one station from each AVO volcano network and AEIC and ATWC regional stations.

c. Waveforms automatically scale to the largest amplitude in the window you are looking at, therefore it is important to look at times before and after large events without that event in the window.

d. It's best to exit *dbloc2* after the scan, remove tmp directory and restart *dbloc2* to continue processing. To do that, on the command line type:

certainly_remove tmp

dbloc2 process_YEAR_MO_DA

2.3.2. Locating earthquakes. Points to remember for a beginner-analyst:

- Familiarize yourself with type of tectonic regimes in the state (strike-slip in the southeast and Interior vs. subduction along the Aleutian trench, volcanic activity).

- Familiarize yourself with the locations of seismic stations early and often.
- Be sure you have a seismic station map close enough to your work place that you can easily look up to find stations.
- Try to remember what stations are neighbors ASAP.

Points to remember for everybody:

- Get a list of stations that are 'misbehaving' for the dates you are analyzing (i.e. bad timing) and do not use it.

2.3.2.1. Event types. Various types of events, not just earthquakes, produce ground shaking and therefore get recorded by seismographs. Such examples include ice-quakes, quarry blasts, rock or snow avalanches. *dbloc2* allows you to assign event type through the *etype* pull-down menu at the bottom of the window:

a - a-type volcanic event (shallow ~<20km, within volcanic center, high-frequency);

b - b-type volcanic event (usually 15-30km depth, within volcanic center, low-frequency);

G - glacial, obviously should be located within a glacial field, shallow;

Q - explosion. We regularly record explosions from the Fort Knox gold mine and Usibeli Coal Mine. The former is located just north of Fairbanks, first station GLM, normally occurs around 4 pm local time. The latter are located near Healy, occur at various times during the day and show up on MCK first.

How to tell the difference between a tele, a quarry blast and an icequake? "Location, location, location. . ." There are no huge ice masses just north of Fairbanks, so if a quake originates near GLM, has very clear P arrivals, and a long period coda, it is a quarry blast. Similarly, there are no huge mines in southern Alaska, so an event that is all long period squiggles centered around College Fjord is most likely an icequake. Teleseismic events show up on just about every station in the state and come from all kinds of exotic locales. See examples at the end of this manual.

2.3.2.2. What kind of events to locate and not:

a. We are only responsible for tectonic events within the state of Alaska (western Canadian events should also be located since they complement our catalog for the research purposes).

b. Do not worry about teleseismic events (but make sure they really are, see below 2.3.2.2.b).

c. Do not locate volcanic events unless they are big enough to show on several regional stations in addition to its own net's stations. Other people (AVO analysts) deal with these events.

d. Locate an event only if it has at least 5 clear P-arrivals (exceptions - Seward Peninsula and southeast Alaska where 4 stations can be satisfactory for the lack of thereof).

e. Do not locate regional earthquake if it is recorded by a singe AVO subnet only. It has to be at least 2 different sub-networks and a couple of regional stations (AEIC and/or ATWC). This mostly concerns Aleutian events. Regional events located with single AVO subnet generally have huge location uncertainties and rather small magnitudes. Don't feel bad about skipping some small, poorly recorded events. There will be more.

f. Does this event belong to my day or next (or previous)? If origin time is within the day you process - locate it even if some arrivals fall into the next day.

2.3.2.3. Calculating location for an event.

If you start processing a new day, *dbloc2* will display the first set of arrivals it finds in the database. If you already worked on this day and didn't remove tmp directory then *dbloc2* will start form where you left off the last time. The first set of arrivals in *dbloc2* screen can be either an automatic location or a set of scanned arrivals.

a. Automatic regional location:

Bring up the waveforms, pick additional P- and S-arrivals, get new location, save it. Click "Next" at the top or bottom of *dbloc2* window to go to the next group of arrivals.

b. Teleseismic event:

Check it and make sure it really is. Sometimes a regional event is combined with a noise/glitch pick and mislocated as a teleseismic event. So, for a teleseismic event, bring up the waveforms, click "Display associated picked traces" orange button from *smartpick* window (on the left side), back up to see the arrivals. If this is true tele, delete it and move on. If this is a mislocated regional (or two), get correct location.

c. Scanned arrivals:

In this case there is no associated location. R-click on the first "P" and choose "Display waveforms assuming this as source". It will bring up a set of waveforms for neighboring stations. Mark a few additional P and S arrivals (4-5 and 1-2, respectively). You don't have to be very careful about your arrivals this first time. Also, no error bars are needed at this point. If this event ends up being too small or recorded by too few stations you may decide to skip it. In this case no time was wasted on refining picks and error boxes for something that was not worth saving. Next, get a first rough location. Click on "Waveforms" button again to display waveforms according to the distance to this new location. If you can see enough stations to locate this event, then continue working on it. Otherwise you may skip it (too few stations, poor quality of arrivals). If all your P's are aligned more or less along the vertical, then your location is relatively good. If you're not satisfied with your 1st trial location, pick a couple of more arrivals and get a new trial location using your previous solution as a starting location. Repeat "Waveforms". Once your trial location is satisfactory, pick additional stations, refine all your picks, add error bars, get a final location and save it.

2.3.2.4. Guidelines picking arrivals.

A variety of different sensors are installed at seismic sites. Arrivals for processing are typically picked on short period (SH or SN) or broadband (BH) channels. Strong-motion channels (HH or HN) can be used under special circumstances: to obtain magnitude for a major event, to close large station gap, etc.

a. All clear P arrivals should be picked (except for dense AVO subnets, see below).

b. For 3-component stations, pick P on vertical channel (Z) (it's OK to use horizontal if vertical is out and station is critical for this locality).

c. Always pick arrival on the 1st recording station. If your 1st station is offset by more than a couple of seconds compared to the rest of the arrivals, it is more likely that the location is biased than that the station is having some kind of a problem.

d. For co-located broadband and short period instruments, give preference to the broadband.

e. For array stations pick only one element: IL01 (Eielson), BC03 (Beaver Creek), BM03 (Burnt Mountain), and IM03 (Indian Mountain) (it's OK to use another element if the default element is out).

f. Pick only 2-3 stations on each volcanic network (6-8 in the Katmai group). Why? If you pick all 12 Spurr stations and only 5 regional cites, your solution will be heavily weighted towards the Spurr stations which may bias your location. Similarly, if you pick 10 Akutan stations and only 1 Wesdahl or Makushin, the solution will be heavily influenced by Akutan stations. Try to get a balanced solution.

g. Pick at least 5 S arrivals if possible:

- Include closest 2-3 stations.
- Use horizontal components when possible (BHE/BHN or SHE/SHN).

h. Every station should have no more than one P and/or one S arrival. It is possible to place picks on both horizontal and vertical components, thus creating duplicate picks.

i. Put error bars on all picks (shift-click-drag on red flag). Make sure your error bars are realistic, i.e. small for clear impulsive arrivals, larger for noisy, emergent arrivals.

j. Pick accuracy. It is important to correctly identify and pick arrivals. Look for noise bursts picked as arrivals, multiple events, crossfeeding of one station signal into another or misidentified phases. In many cases the larger amplitude crustal arrivals (Pg, Sg, and Lg) will be picked instead of faster mantle arrivals (Pn, Sn) by automatic detector. Care must be taken to correctly identify true arrivals. Use predicted arrivals to guide picking of S arrivals, but do not abuse this option. See also 2.3.2.4.d.

k. For large regional events use only stations within 10 degree epicentral distance (shown in *dbloc2* arrival panel next to the station code name).

Helpful tips:

- Do not set default phase when processing data. It helps to distinguish between already existing picks and your newly added arrivals (you have to set phase while scanning, however).
- Use "Magnify" option to examine and adjust arrivals and put error boxes rather than opening selected stations in a new *dbpick* window. It takes less time. New *dbpick* window is useful for examining 3-component stations to pick S arrivals.
- Use filters to enhance signal-to-noise ratio. Use 1HP filter for smaller events and/or distant stations. Large events have clear impulsive arrivals in most cases. It is better not to use filters if you already have clear signal. For smaller events, especially recorded on broadband instruments, a filter is a must.

2.3.2.5. Guidelines for locating events.

a. Starting location is important. If there was a location already in the current *dbloc2* time window when you opened it, the program will use it as an initial location. If this starting location is too far off from the actual location, then *dbloc2* could fail in getting a solution (e.g., mislocated events). In this case change "Starting location:" button in the middle of the lower portion of the *dbloc2* window to "program will estimate starting location". Alternatively, if you know approximate location of this event (for example, it is an aftershock and you know location of the mainshock), you can type these values into "Longitude" and "Latitude" boxes as your starting point and choose your starting depth from the *depth* pull-down menu. In the absence of an existing location, the program would start search from a default depth of 50 km. This could be a problem for shallow crustal events. If you know this is a shallow event, fix depth in your first couple of runs to get a rough estimate of where this event is located. For the later, more refined runs, try to get a free depth estimate.

b. Velocity models. Use *northak* model for events located north of 62.5 latitude. *scak* applies to events south of 62.5N. Exceptions: 1) For events in the Gulf of Alaska seaward of the Aleutian trench use *gulfak*; 2) events near the trench in the Aleutians sometimes are better located with *pav_dut* model. If nothing else works, last resort is *iasp91* model.

c. Earthquake depth. Check that depth is appropriate for location. No negative depths! Deeper earthquakes (>=40km) are located in the subducted slabs only, i.e. along the Aleutian chain, in the Cook Inlet and as far north as ~64N latitude. Exception to this include Wrangell Mountains, where you can have events as deep as 100 km. Outside of the subduction zones, events occur within the crust, i.e. anything with depth ~>35 km should be subjected to an additional scrutiny. In case of a problem depth (negative or too deep), events in the Gulf of Alaska and Aleutians should be fixed at 10 km. Subcrustal events in northern and western Alaska and western Canada (d~>30 km) should also be fixed at 10 km. For events in southcentral Alaska with negative depths fixing depth should be either 1 or 10 km.

d. Hypocenter quality. Try to get the error (*sdobs*) below 1.0. Sometimes for an event in remote area (western Alaska, western Canada, western Aleutians) where there is lack of stations it’s impossible to get low residual. Check picks with large residuals (highlighted by orange color in *dbloc2* arrival display). In many cases individual residuals will be large because the velocity model cannot account for the complex upper mantle and/or crustal structure. For example, S arrivals from a slab event will often arrive early. This is most pronounced at stations to the north, near Fairbanks, and might likely be due to wave propagation, along strike, in the high velocity slab. Other known instances of large residuals: early arrivals at the Prince William Sound stations from the slab events; late arrivals at FIB, VOGL, NKA stations due to thick underlaying sediments. In these cases it’s important to pick actual arrival time and not where model suggests simply to minimize the residual. Poor quality automatic picks should be deleted or moved to reflect true arrival time. Try to do the best you can to correct bad arrivals but don’t move your arrivals just to minimize the residual.

A common problem is picking correctly distant arrivals for crustal events. In many cases the larger amplitude, crustal arrivals (Pg, Sg) will be picked instead of the faster mantle arrivals (Pn, Sn) (see 4.8). In Alaska, the regional crossover distance, where Pn/Sn arrive before Pg/Sg, is typically between 100-150 km. So care must be taken to correctly identify them if the epicentral distance is near or greater than the crossover distance. This problem often manifests itself in increasing residuals for more distant stations that may indicate attenuation of the true 1st arrival.

Check that no extraneous arrivals are included in your location calculation. For example, if you have a M2 event and most stations are within 3 deg distance range with a single station at a much larger distance, chances are this arrival does not belong to this event. "Show Map with reporting stations" is a very helpful tool in identifying these outlying stations.

e. Magnitudes. Turn off magnitudes that are +/- more than ~1.0 from the average. Also remove stations with clipped signals or glitches. Large magnitude residuals may indicate a problem, such as wrong parameters in the station database.

f. Station gap. Pick enough stations to minimize station gap. Use "Show Map with reporting stations" button often to asses quality of the location. A regional event in Cook Inlet located with the use of only one or two of the AVO networks would have a large location uncertainty. Make sure you have all available regional stations included into the location.

Note: *dbchecker_tool* allows to check an *orid* in a database for possible errors (missed 1st station, bad depth, large magnitude and travel time residuals, large station gap, etc.). Enter database name (*proces_YEAR_MO_DA*) and *orid* into spaces at the top of the tool and click yellow button "run event error check".

2.3.2.6. Saving event:

a. Turn on the "Prefor" button to save next to your final location (be sure "Mark reviewed" button is on).

b. Change "Keep" button to "Delete" if you are making changes to an existing location.

c. Click "Next".

2.4. Finishing a day.

- Once you get to the point when you get a message "arrivals: no more arrivals", do a check of your processed database:

a. R-click on "Database" (at the bottom of *dbloc2* window on the right side).

b. Choose database *process_YEAR_MO_DA*, it will bring up the database editor.

c. L-click on origin, it will bring up all of your processed events (some empty raws will remain from deleted solutions).

d. L-click on "depth", sort. Make sure there are no negative depths.

e. L-click on "lat", sort. Make sure velocity models (stored in "algorithm" field) are appropriate.

f. L-click on "auth", sort. Make sure there are no *orb* (automatic) locations remaining in the database.

If you have to go back and redo some of your locations note its *orid* or *evid* numbers and use "Find" option in the right top part of the *dbloc2* window to return to these problematic locations and fix them.

- Check database for possible errors by running "run complete database error checker", orange button on *dbchecker_tool* (don't forget to enter database name *proces_YEAR_MO_DA*). While the event error checker will flag more possible errors, the full database error checker flags only gross errors (magnitude residuals > 1, travel time residuals > 4 sec, etc.). View the database error report (grey button), assess the importance of any reported errors, and fix them if necessary. (For example, a magnitude residual of more than 1 for an event with 20 other magnitude readings not is as bad as the same value for a smaller event with only 5 magnitude readings. Or, a single large travel time residual for a large event with 100 phases is not as crucial as the same residual for a smaller event with a handful or arrivals).
- When you are finally satisfied with the results, choose "File"->"Quit" from *dbloc2* pull-down menu in the left top corner.
- To check processed day back in:
    a. R-click on screen to open "Root Menu"
    b. L-click "Seis_apps"
    c. L-click "Analysis_control"
    d. L-click on a day you have just completed
    e. Accept (it will take a minute or two for all check-in tasks to complete).
    f. Check out a new day or just quit out of it.

Just like a library, no one else can check out a day that you have, so be sure to check them back in as soon as you're done!

2.5. Helpful tips for using *dbloc2* and *dbpick* programs.

- Set up your screens to optimize your work space.
- Zoom in on the waveforms you are looking at.
-M-click on picks in *dbpick* screen to change arrival type.
-R-click on picks in *dbpick* screen to delete arrivals or open a new window for that waveform.
-L-click on blue orid button in *dbloc2* for important functions:
    - Show residuals = selects that solution (needed for "Waveforms" and "Show map with reporting station" functions to work;
    - Start at = runs the location starting at the lat/lon/depth specified in that line + any changes to arrivals that have been made since;
    - Remove = gets rid of that event;

- Set evid = allows you to specify an event identification number different from that the program has selected.

- Useful options when having more than one event per window:
  - "Select All" or "Ignore All" selects or ignores all arrivals in current window;
  - "Ignore Associated" or "Mark Associated": Allows to see if you have unprocessed arrivals in this window;
  - "Unmark" reverses "Mark Associated" action.

- Important Functions in Bottom Tool Bar of *dbloc2*:
  - "Fix Depth" useful for events with few good arrivals or in tricky spots;
  - "Depth" pull-down allows you to choose the starting depth;
  - "Station" pull-down allows you to choose starting point from stations originally on that screen;
  - "ttdcvl/..." the algorithm you are using to calculate location;
  - "Starting location:" uses the parameters (lat/lon/depth) you see, turn off to allow program to estimate starting location;
  - "Maximum Iterations" usually keep at 40, above this a different algorithm is used;
  - "Waveforms" this button is your friend, after you have selected "Show residuals" from the orid pull-down, click here to see the waveforms associated with that event;
  - "Closer" and "Further" move you to stations by their radial distance from the origin. This can also be done in dbpick window;
  - "channels" allows to pick a group of different channels:

    "Process" - all broadband and short period channels;

    "Process2" - all broadband, short period, and strong motion channels;

    the rest are self-explanatory;
  - "Database" R-click and select process_YEAR_MO_DA to see the database you create:

    a.origin

    b. R-click, sort on any parameter (depth, lat, auth, etc.) to see sorted list

    c. View, arrange to select the parameters you wish to view and the order

    * Use this function when you finish a day to check that the correct algorithm was used for each event *

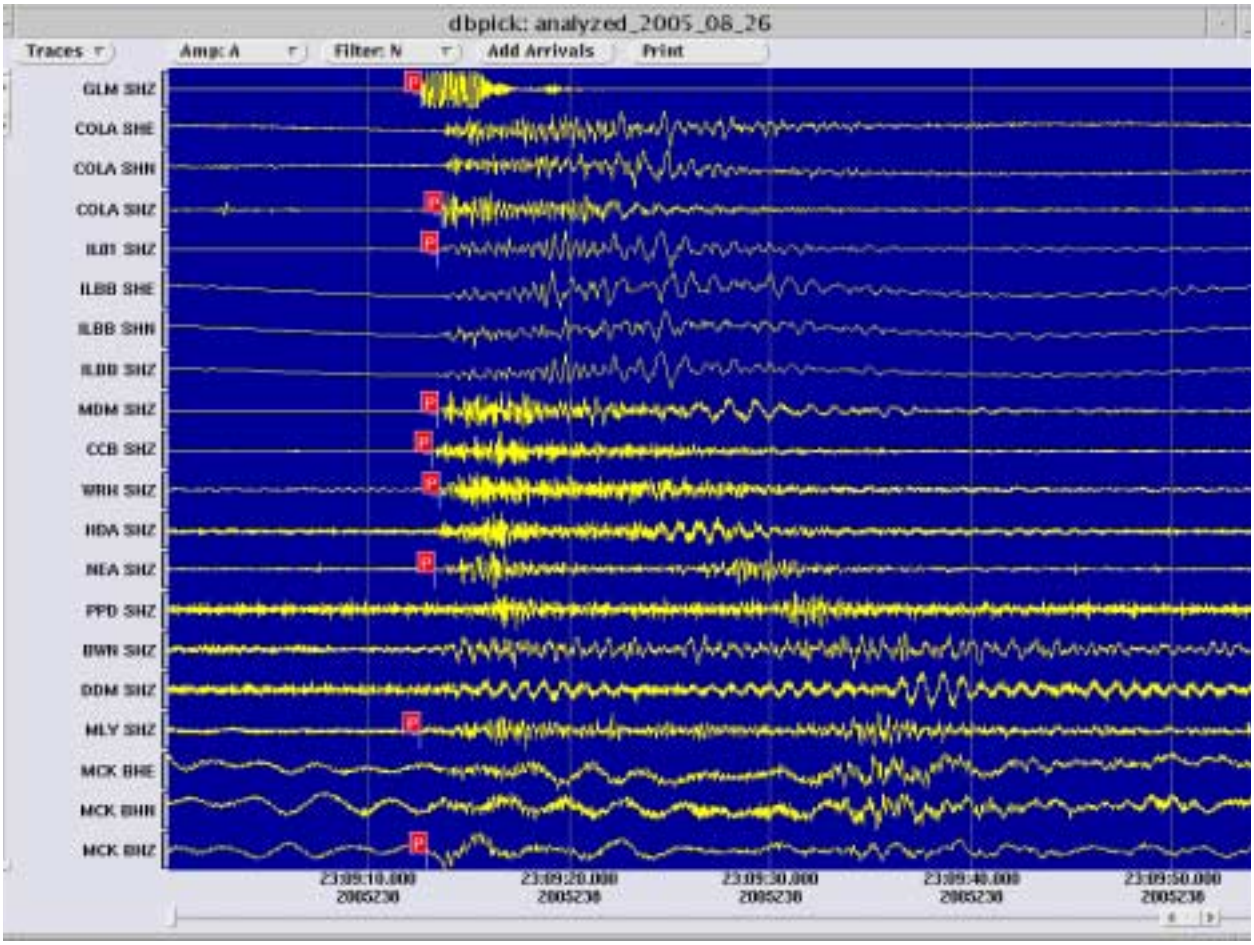
3.Troubleshooting

Problem	Possible solutions
Maximum number of iterations reached	Increase number of iterations from 40 to 80. If already at 80, try to come up with a better initial location. Change "Starting location" to "program will estimate starting location". Try to fix depth if you have some idea about this event's location. Try to remove some of the stations with worst residuals. Add a couple of additional S-arrivals if you have too few. Check station map for any outlying stations recording a different event.
Negative depths and mantle earthquakes	Fix depth at something reasonable, try to relocate. Check arrivals with large residuals, check map for any outlying stations recording a different event.
dbloc2 freezes	Most likely, it isn't your fault. Check to see if Mitch is fiddling with things, or if other analysts are having a similar problem.
Two events at the same time	Start by finding stations closest to the epicenters (shortest time between P and S arrivals) or group station-neighbors and build events from there. Locate each only with the stations you're sure belong to that event. Make sure events have different evids.
P-arrivals appear in *dbpick* window but not in *dbloc2*	Change time in the top part of *dbloc2* window by a couple of minutes, hit "Previous" (if you increase time) or "Next" (if you decrease time). If doesn't help, remove and pick these arrivals again.
Have many arrivals but no magnitude is computed	Most likely you have more than one P-arrival picked on the same channel. In rare instances it could be that no suitable stations for magnitude calculations were found (data gaps, clipped signals, not in magnitude table, etc.).
"Show Map with reporting stations" brings up global map	Choose your event of interest by "Show residuals" option from blue "orid" pull-down menu, repeat "Show Map with reporting stations".
Some station names in *dbloc2* window do not correspond to picks in *dbpick*	Bug. No known solution except to go to previous (or next) solution and then return back.
Tried everything, nothing helps	Find Natasha.

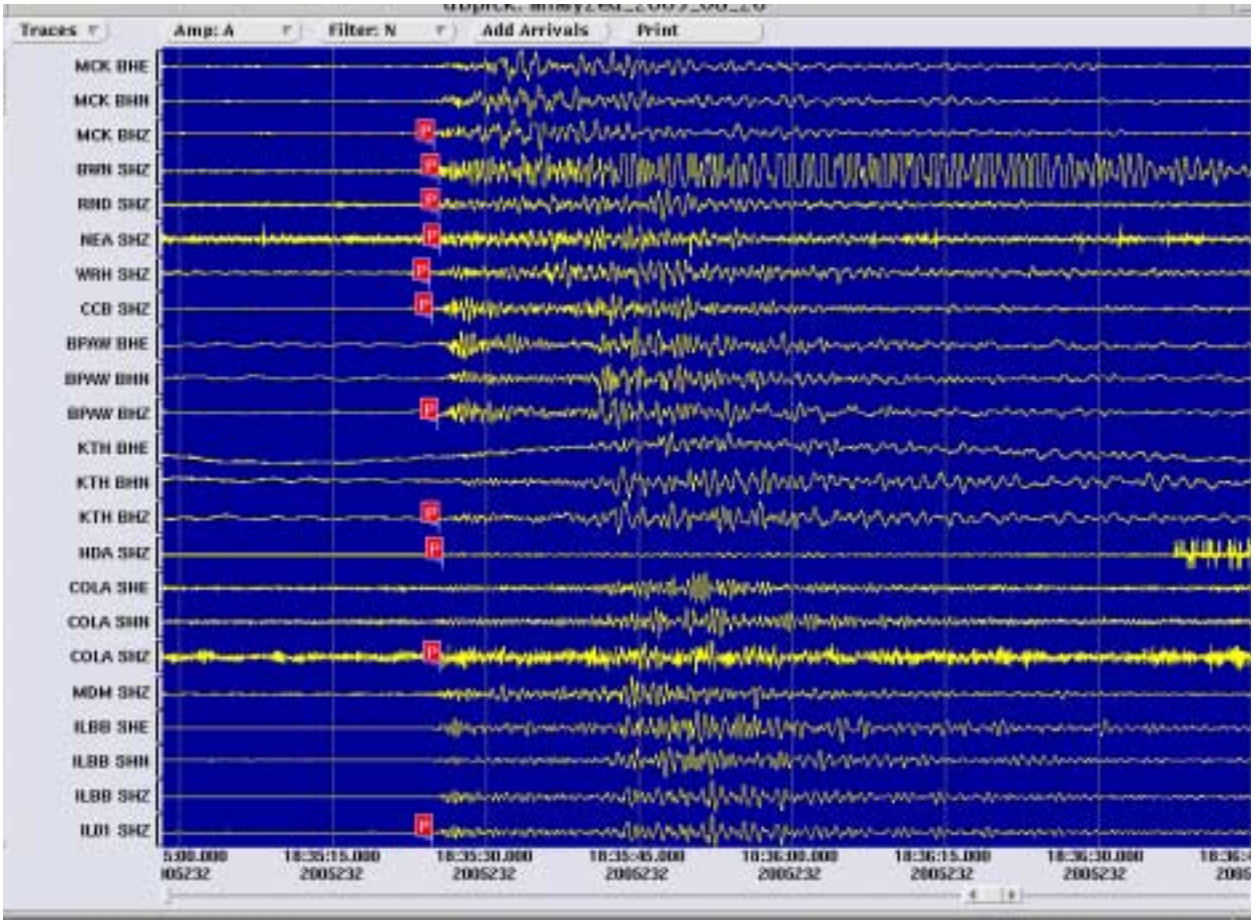
Acknowledgements. Parts of this document were originally written by Dan McNamara (AEIC Seismologist, 1999) and Leslie Almberg (AEIC analyst, 2003). This manual benefited greatly from constructive reviews by Jamie Roush, John Sandru, and Lily Wong (AEIC analysts).

4. Examples.

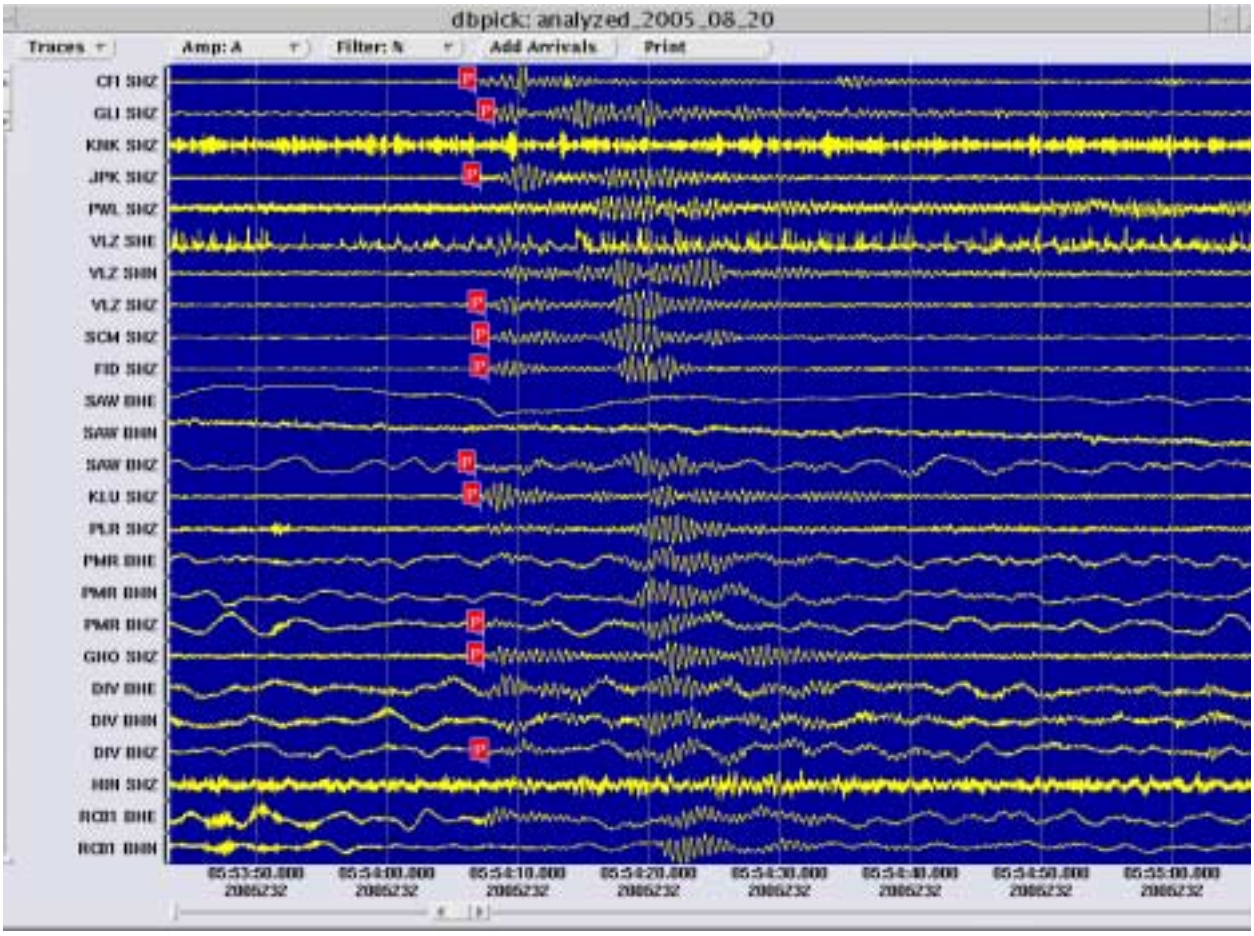
4.1. Typical events.



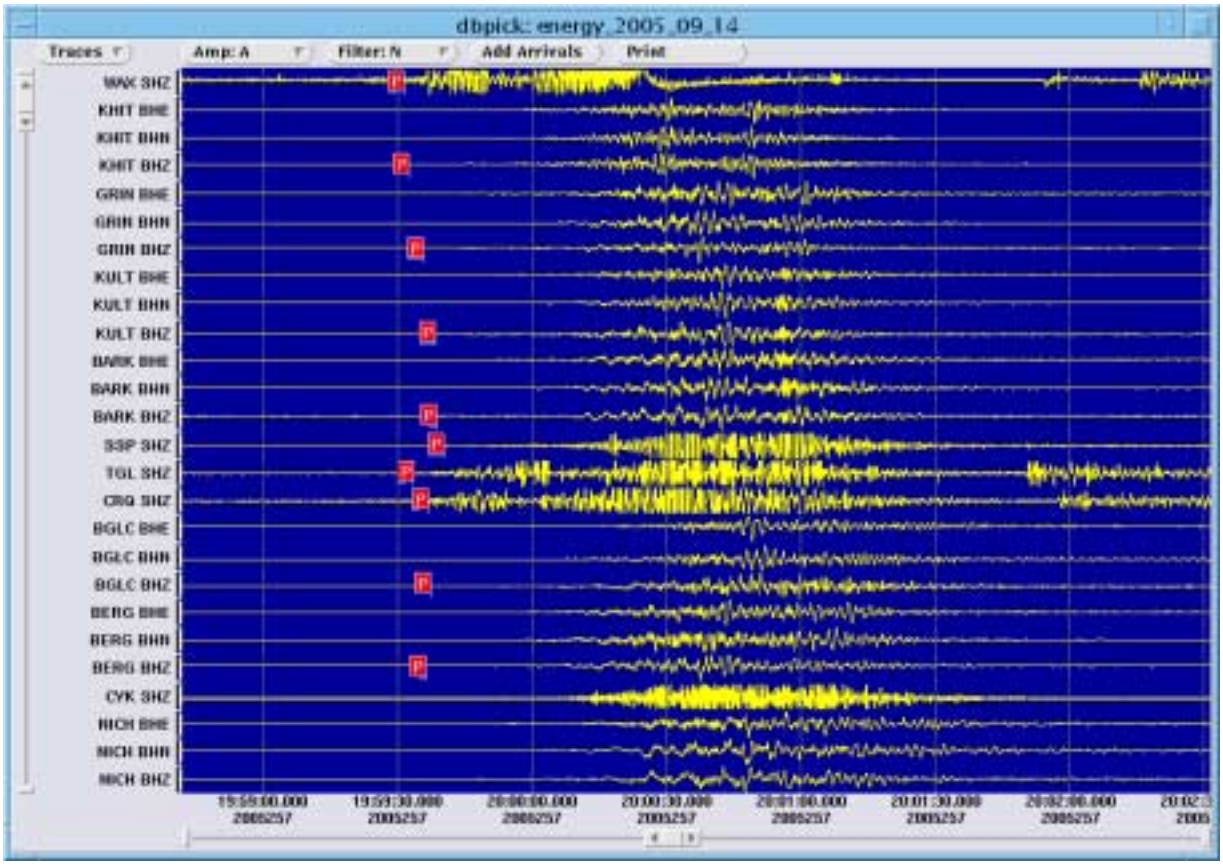
4.1.1. Quarry blast at the Fort Knox gold mine. Quarry blasts are distinguished by their distinct (long and monoharmonic) S-wave coda.



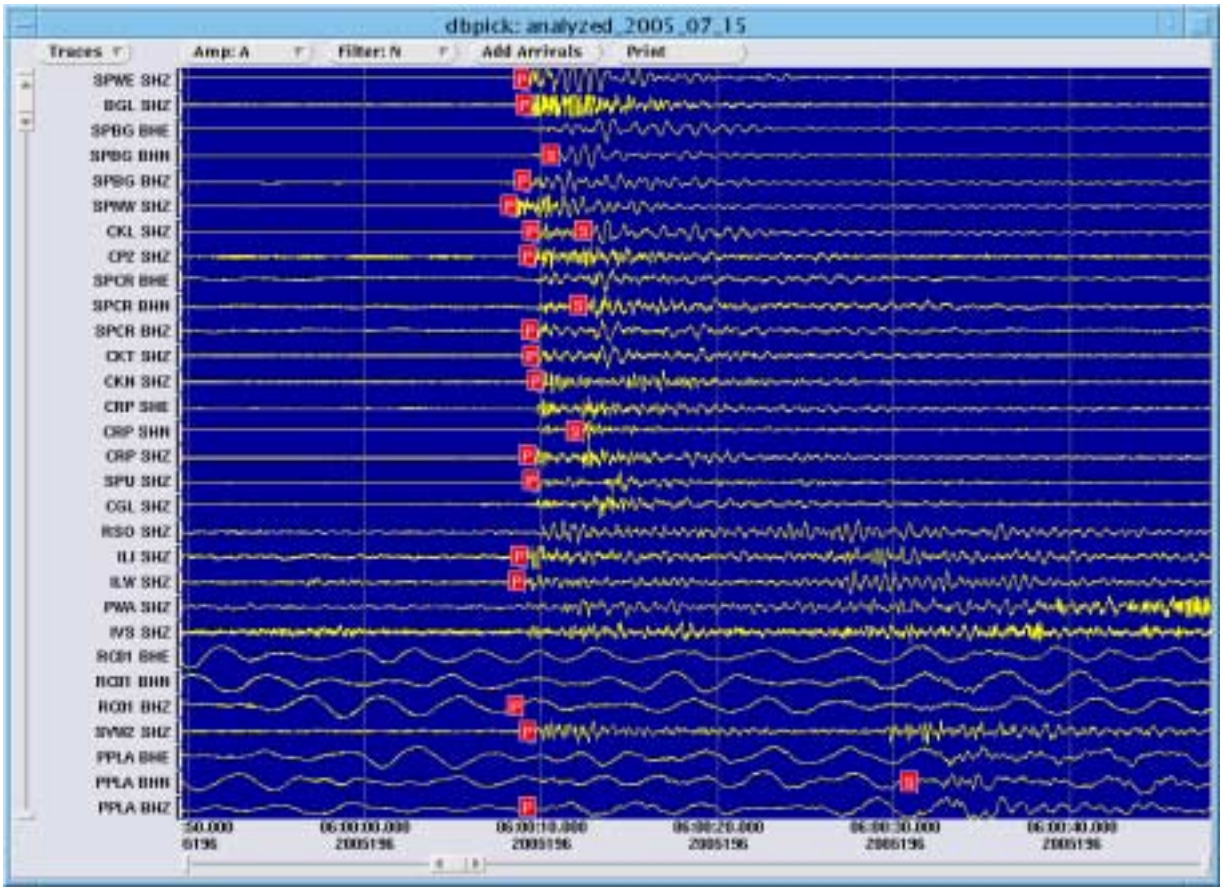
4.1.2. Quarry blast at the Usibelli coal mine near Healy.



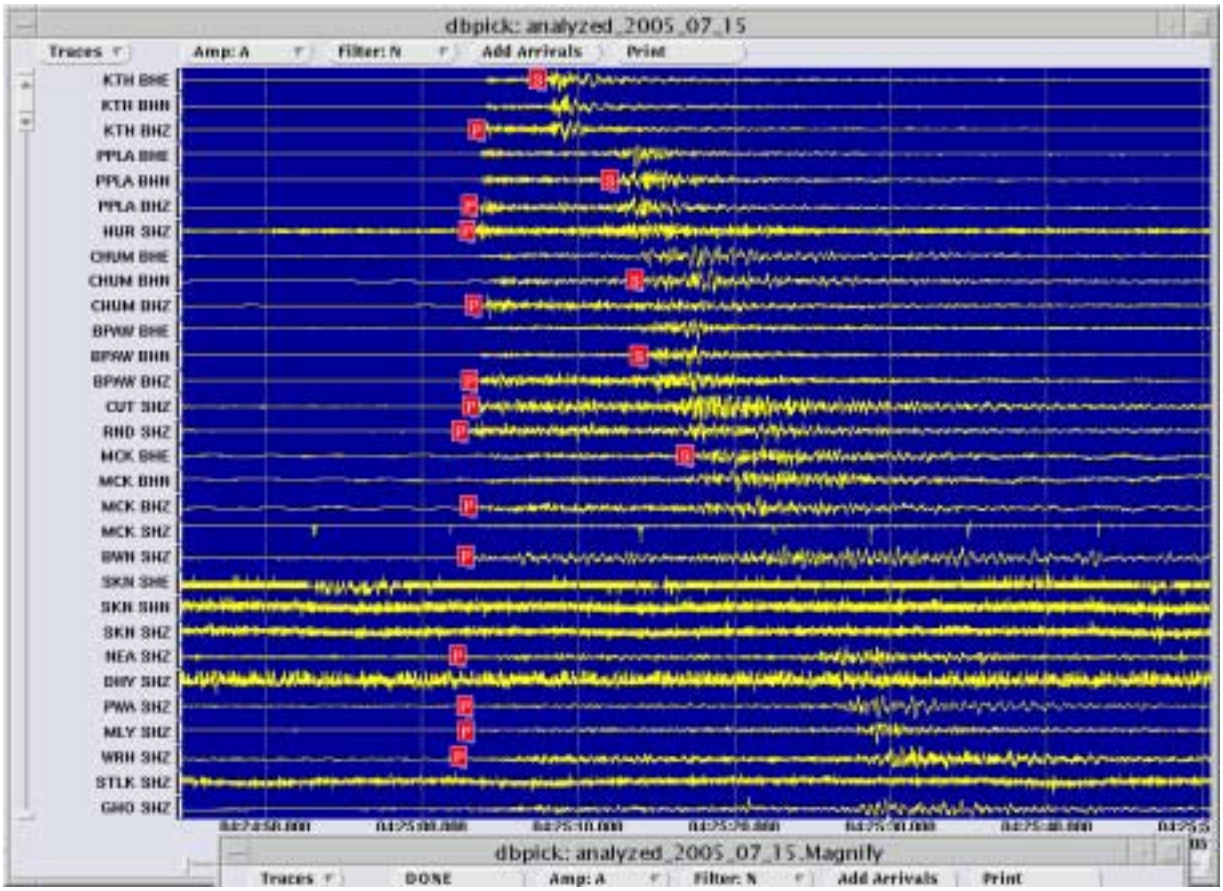
4.1.3. Glacial event. Note absence of high-frequency content and monoharmonic waves.



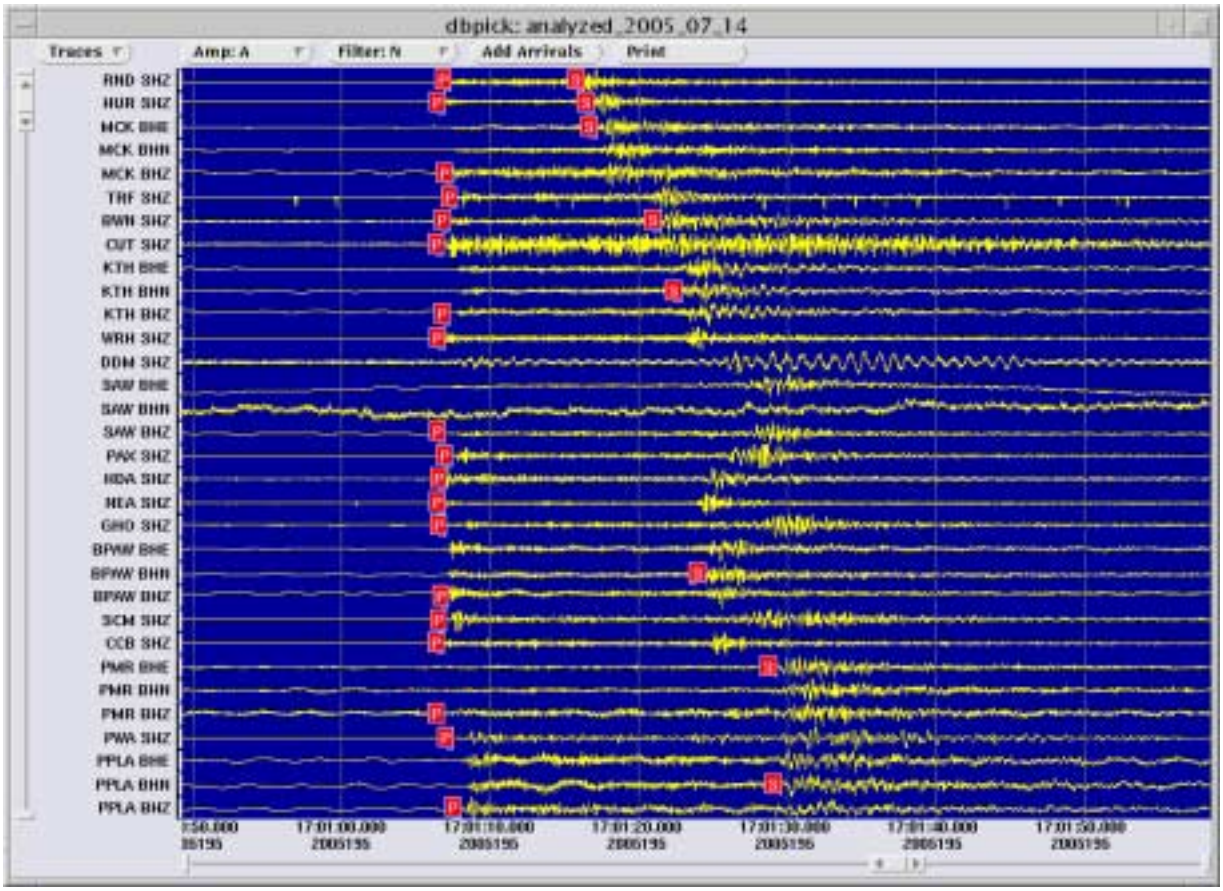
4.1.4. Rock avalanche at Mt. Steller in St. Elias Mnts. Avalanche signals have very emergent, long first arrivals probably due to a gradual build-up of the rock/ice/snow mass and its momentum.



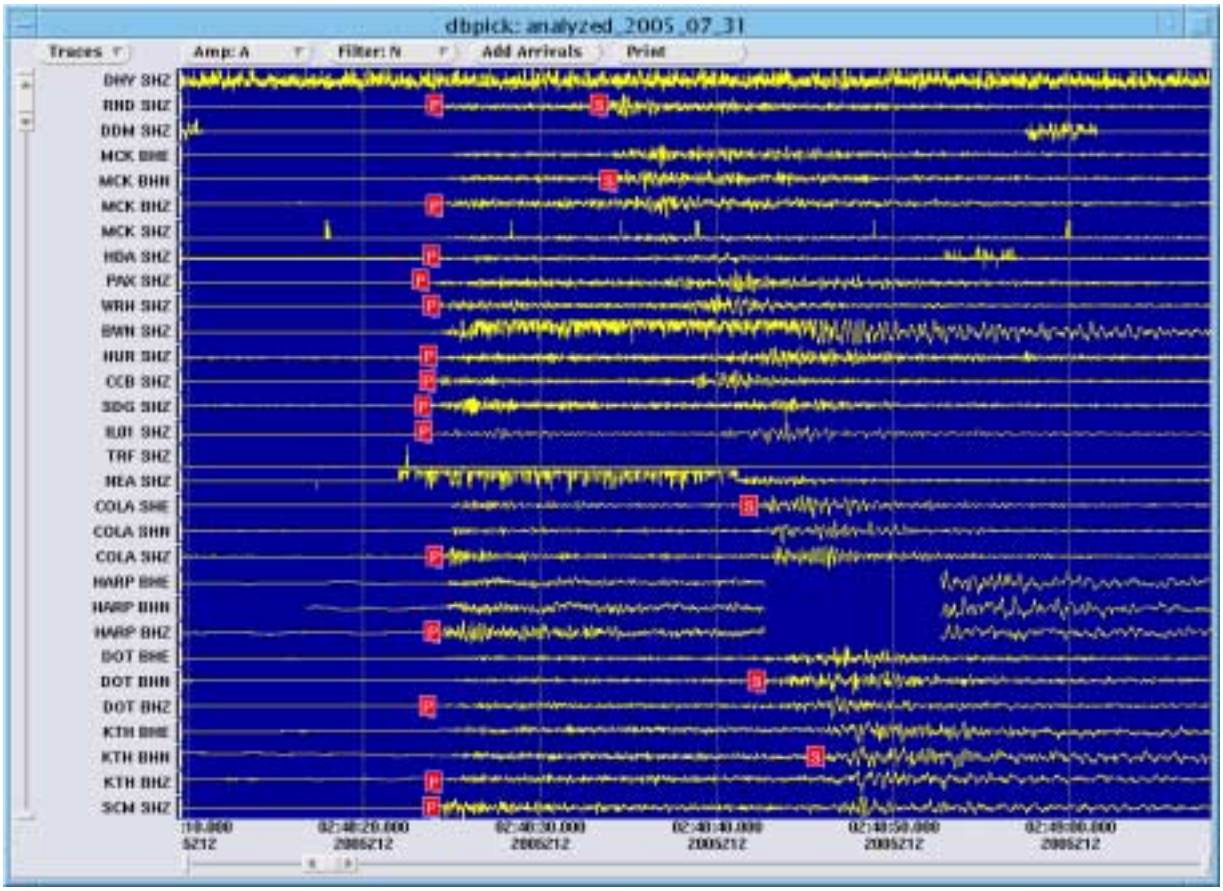
4.1.5. Volcano-tectonic earthquake at Mt. Spurr (M1.8). Note that most of the Spurr stations are picked to better constrain location.



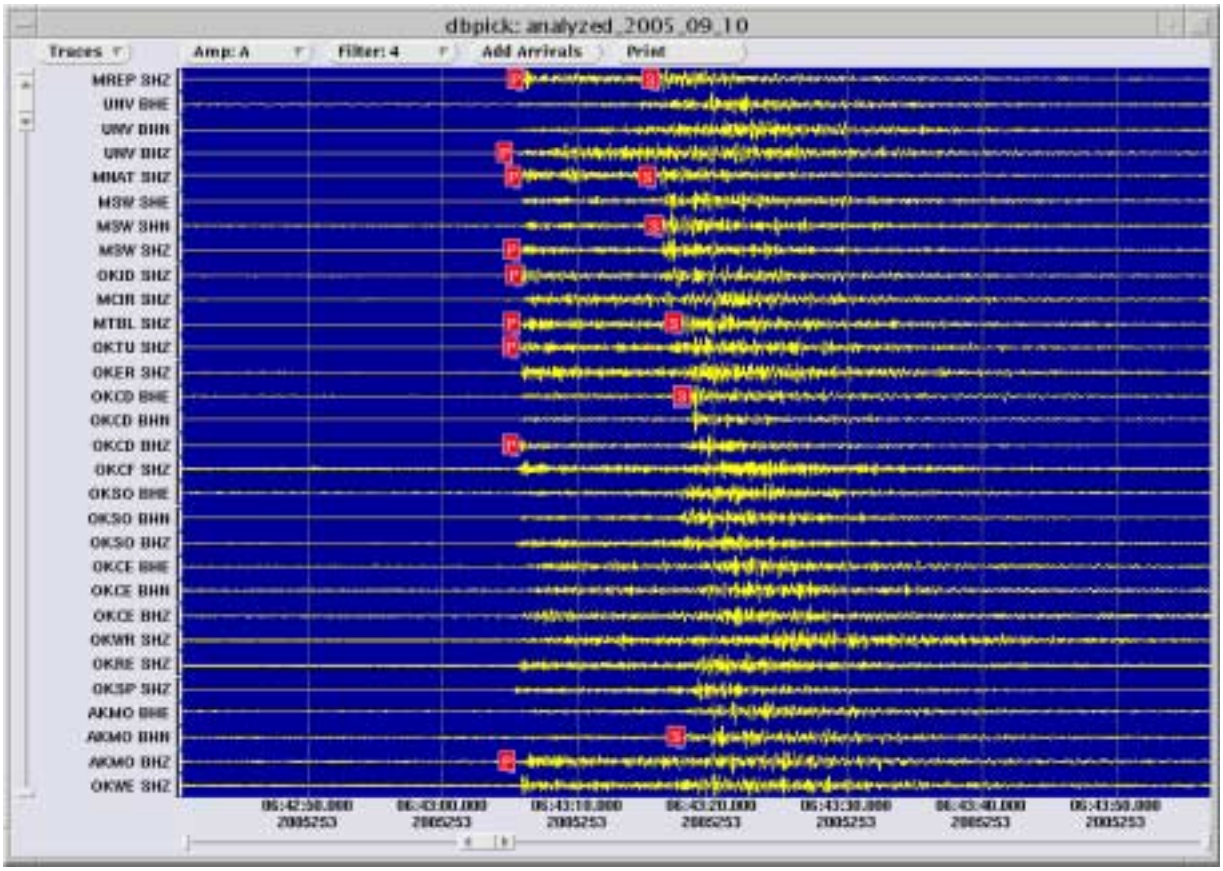
4.1.6. A typical shallow Kantishna event (M2.6). Note that S-arrivals are picked on all 3-component stations. All clear P-arrivals are picked.



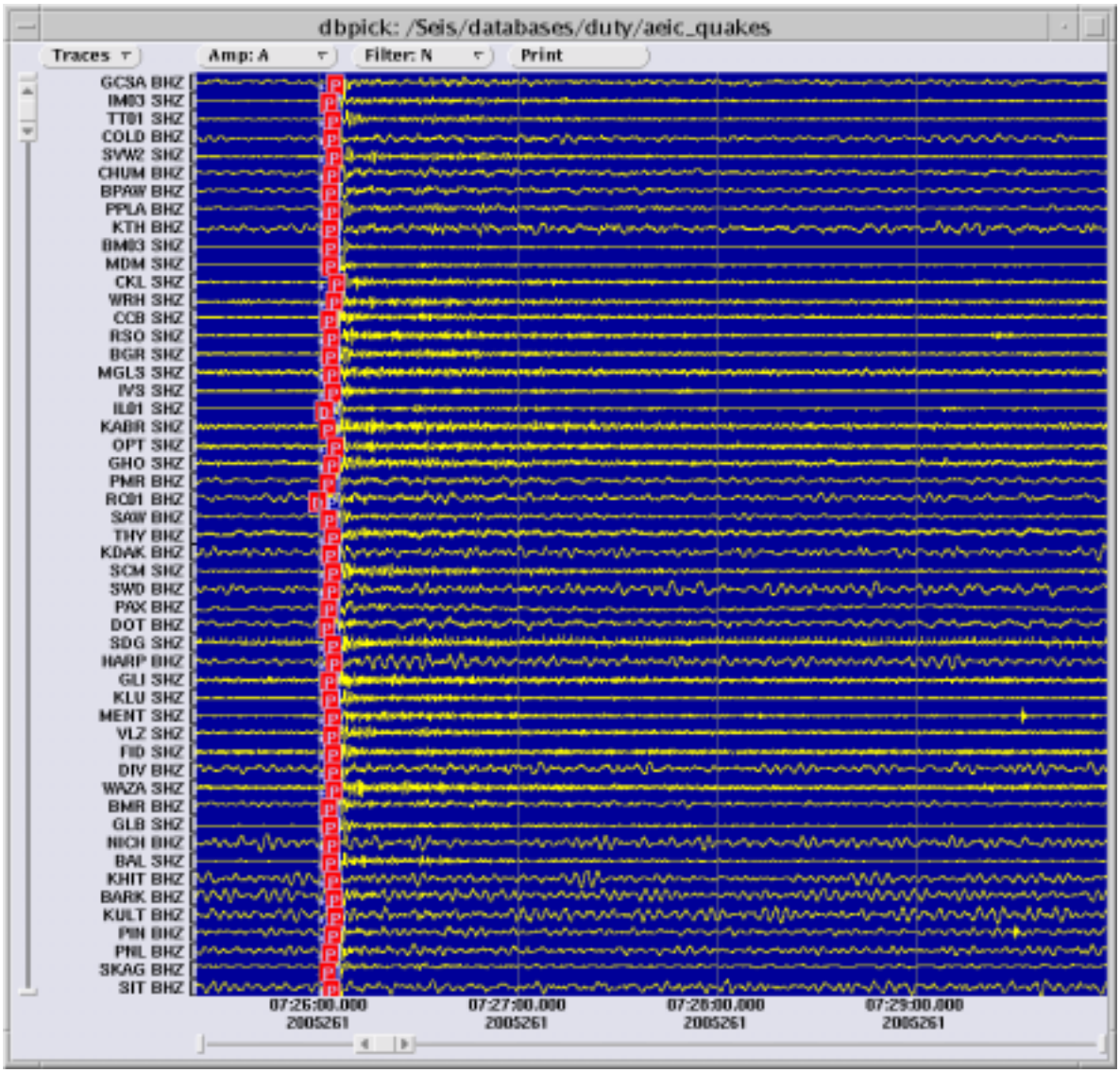
4.1.7. A typical slab event (M2.7). Note that S-arrivals are picked on all 3-component stations. All clear P-arrivals are picked.



4.1.8. A typical aftershock of the M7.9 Denali Fault earthquake.

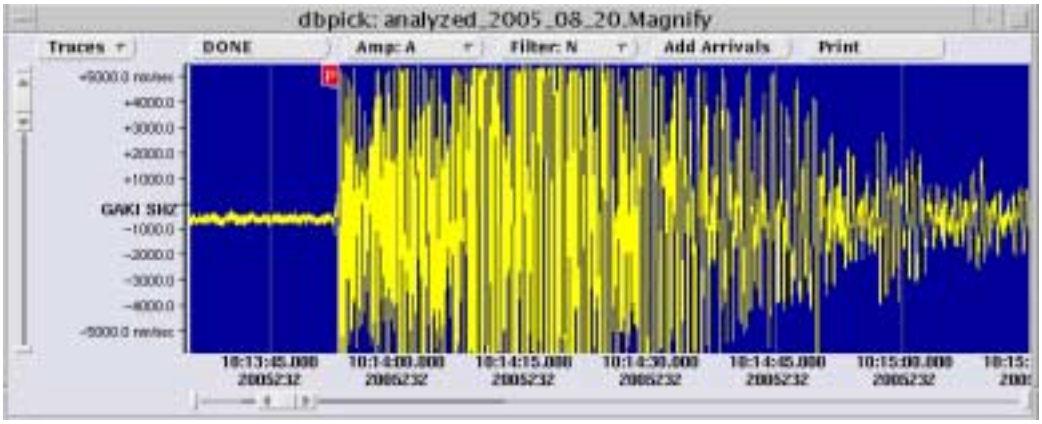


4.1.9. A typical shallow Aleutian event. Note the different waveform signature as compared to deep a subduction zone event (see 4.7). Only a subset of stations from Makishin, Akutan, and Okmok subnets are picked.

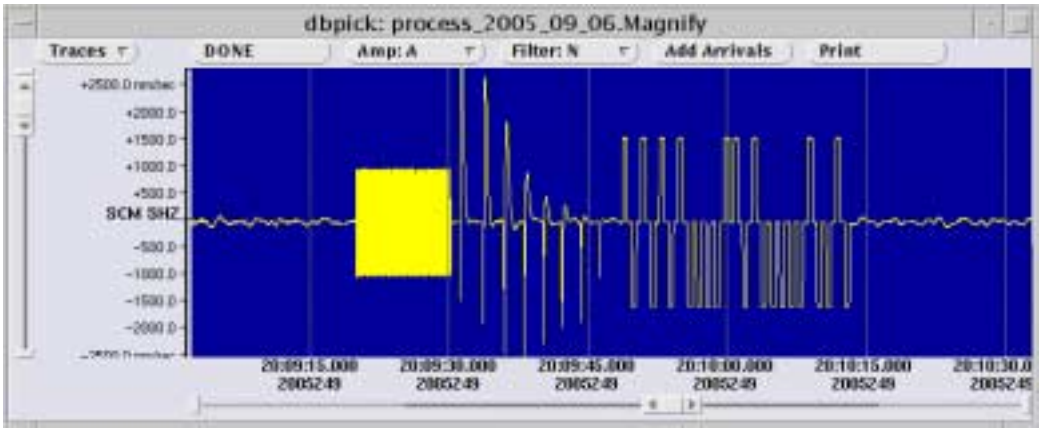


4.1.10. Teleseismic event (Burma-China Border, M5.7).

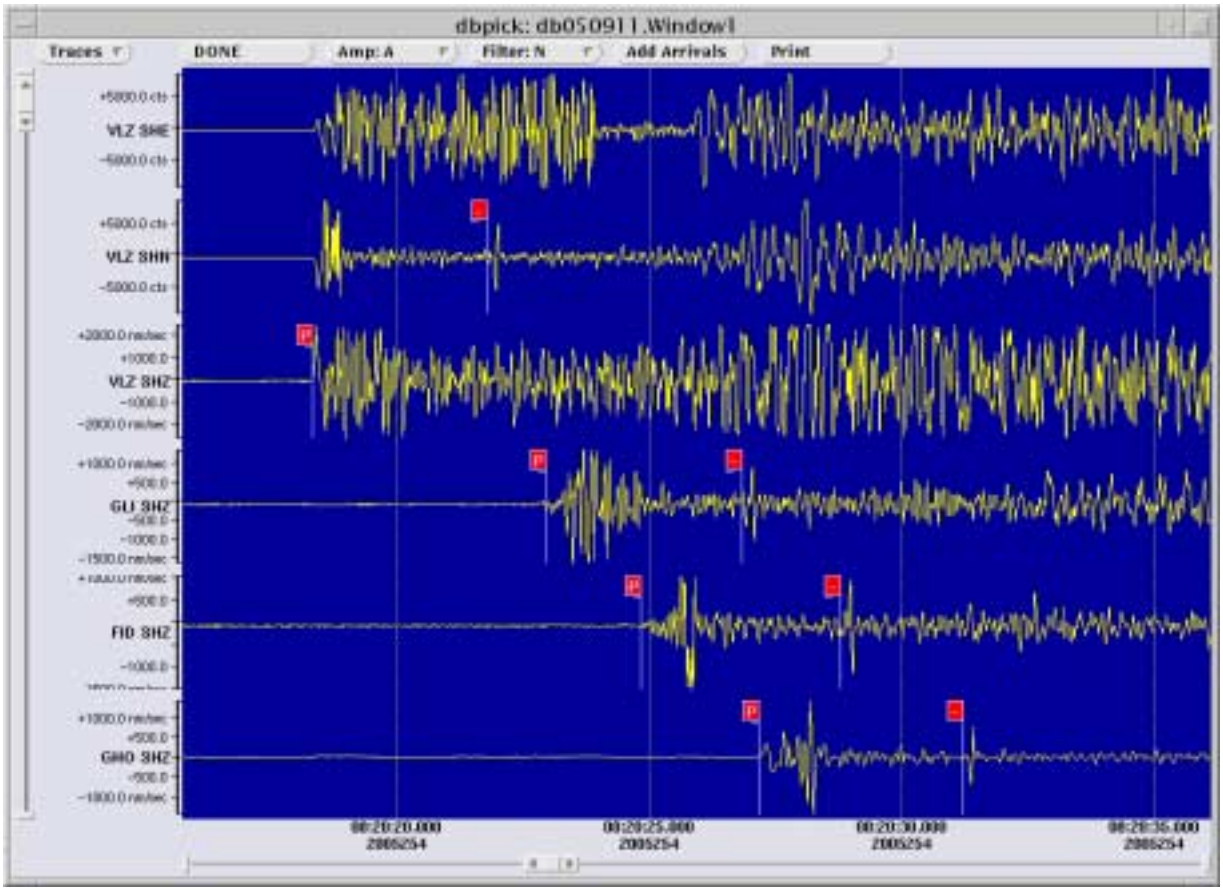
4.2. Typical arrivals and signals.



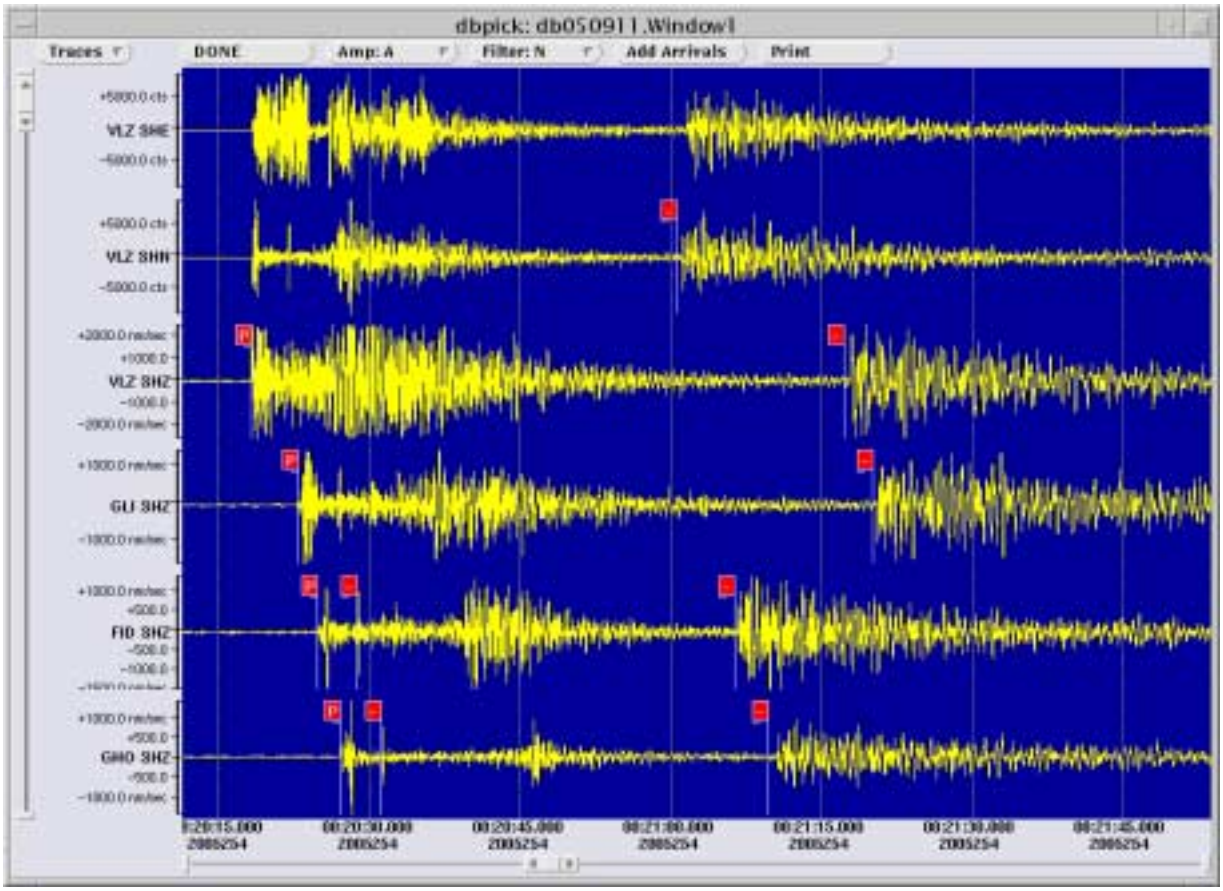
4.2.1. Clipped signal. Magnitude should not be used.



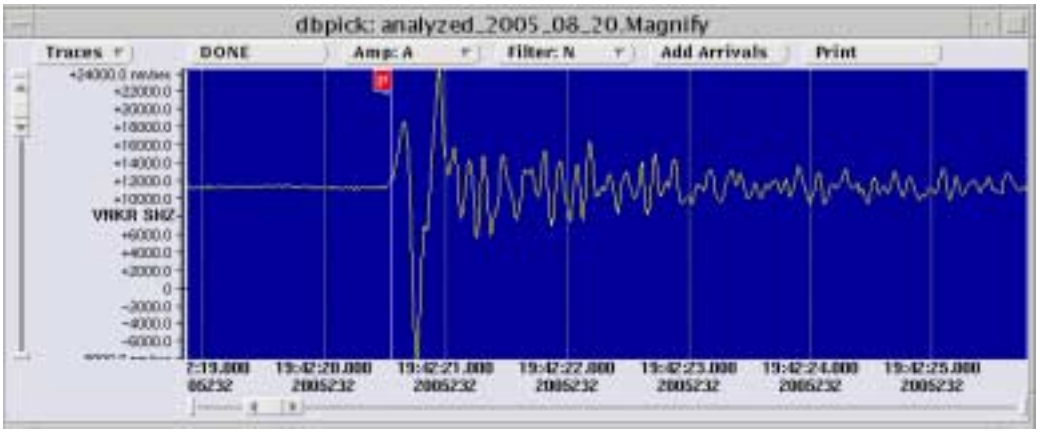
4.2.2. Calibration pulse. Occurs every 12 hours on all short period stations.



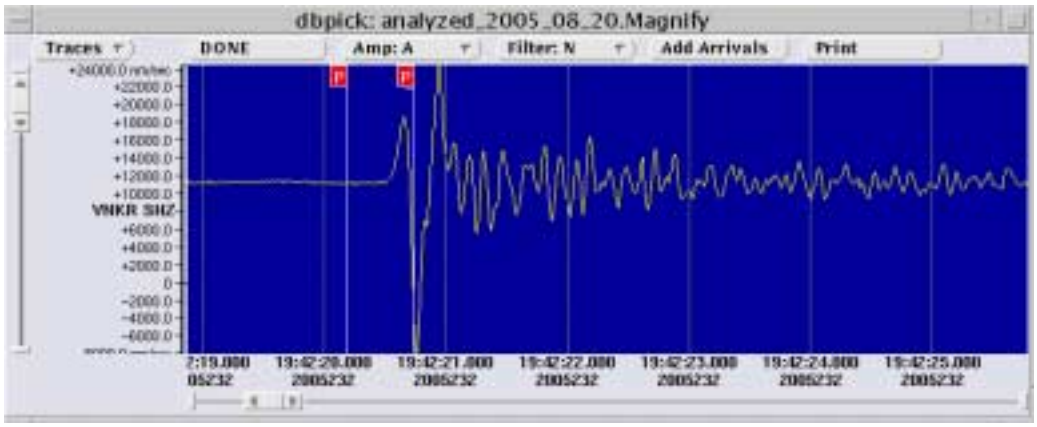
4.2.3a. Gain-ranging stations. Indicated by "-" is an instrument response, not seismic arrival.



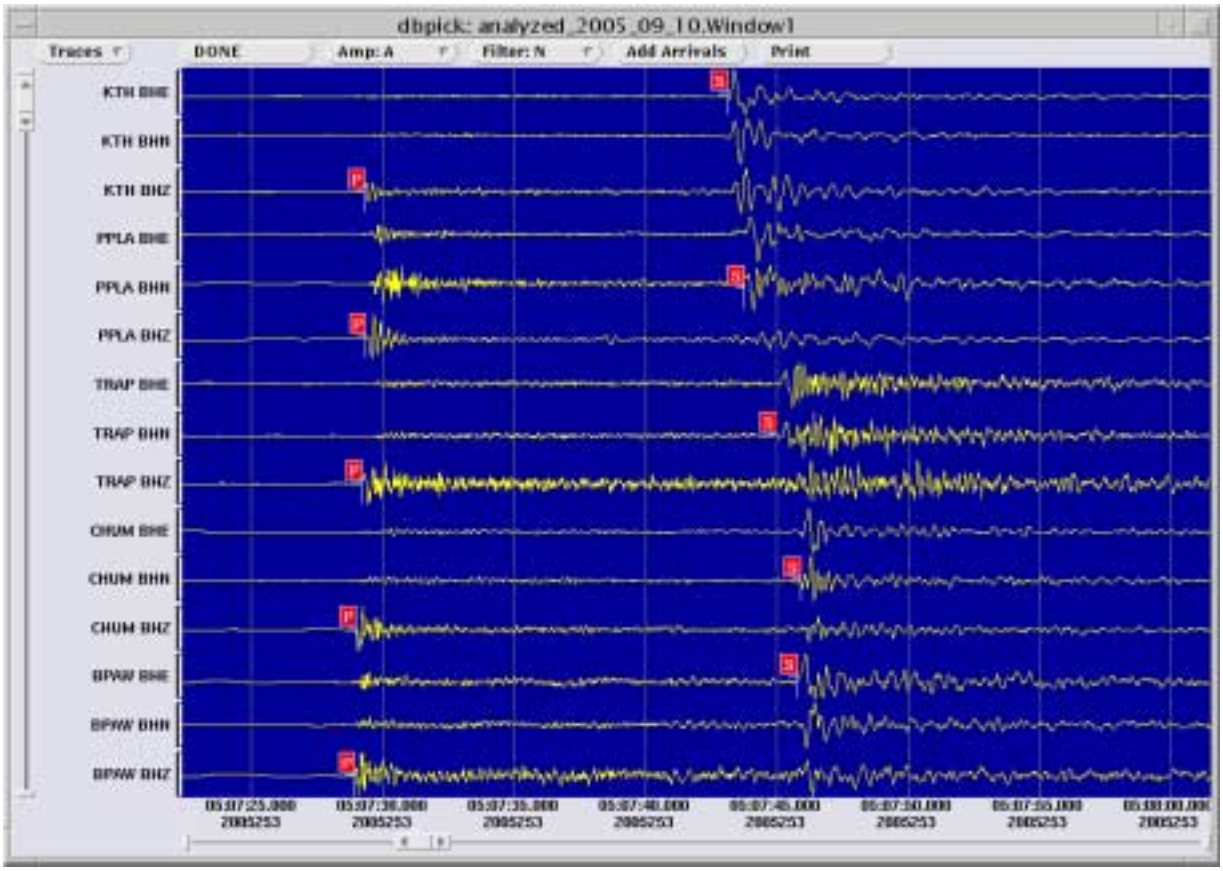
4.2.3b. Gain-ranging stations. Indicated by "-" is an instrument response, not seismic arrival.



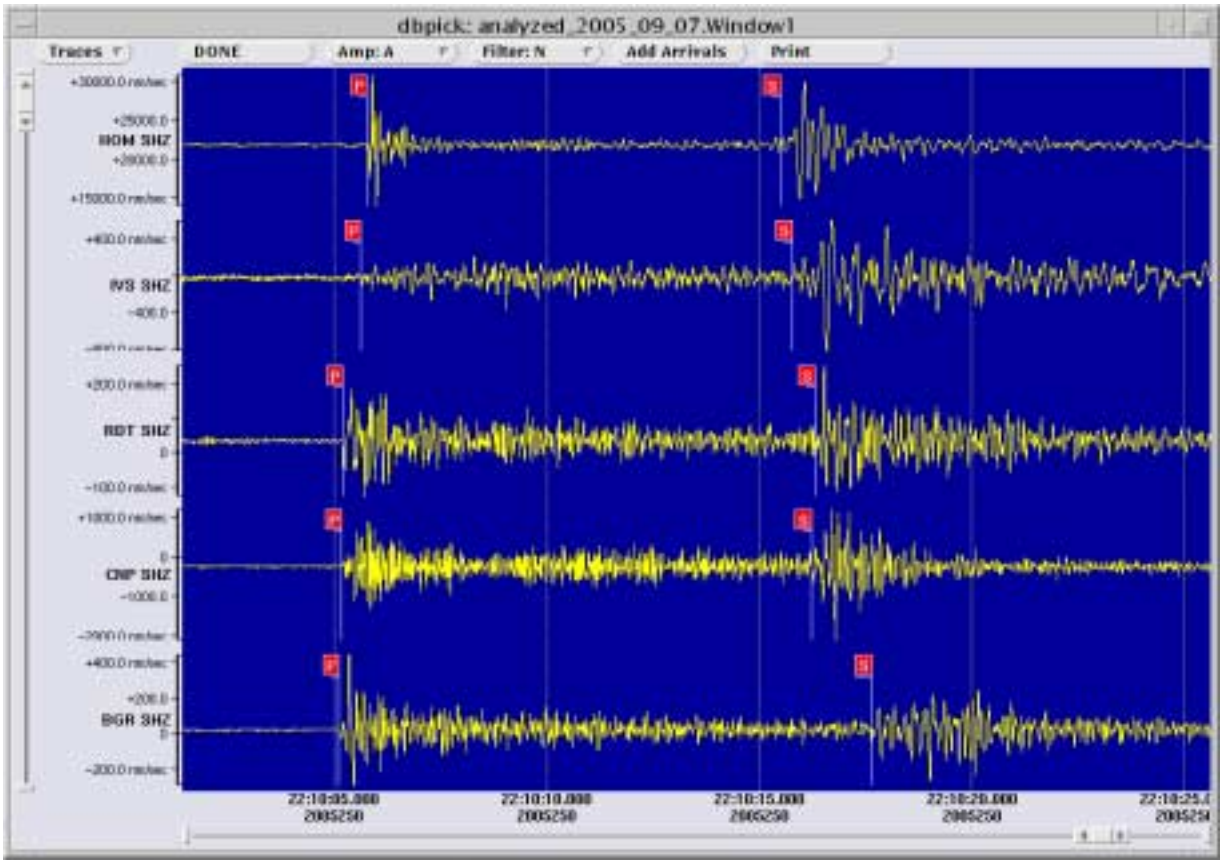
4.2.4. Correct placement of arrival onset.



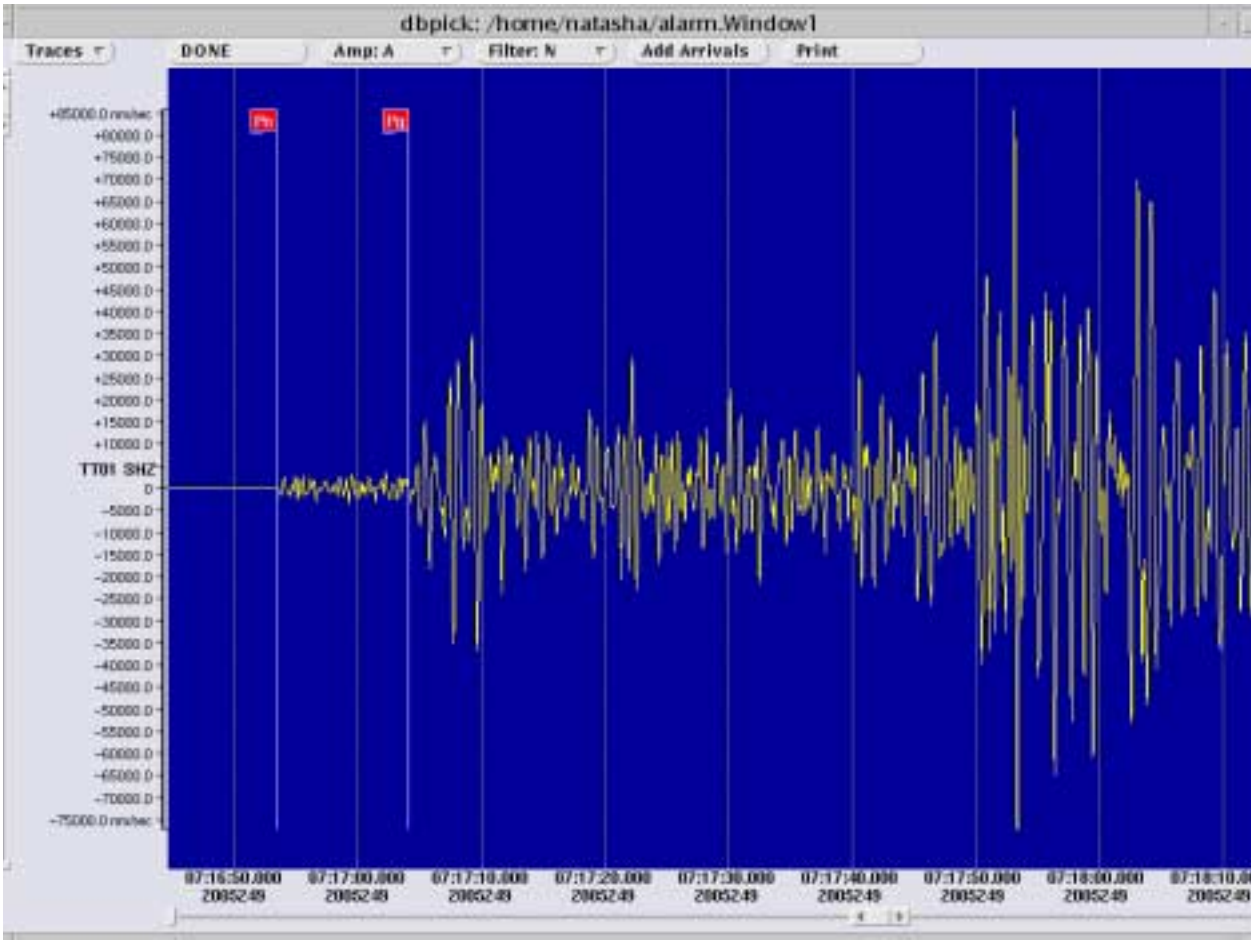
4.2.3. Examples of wrong placements of arrival onset.



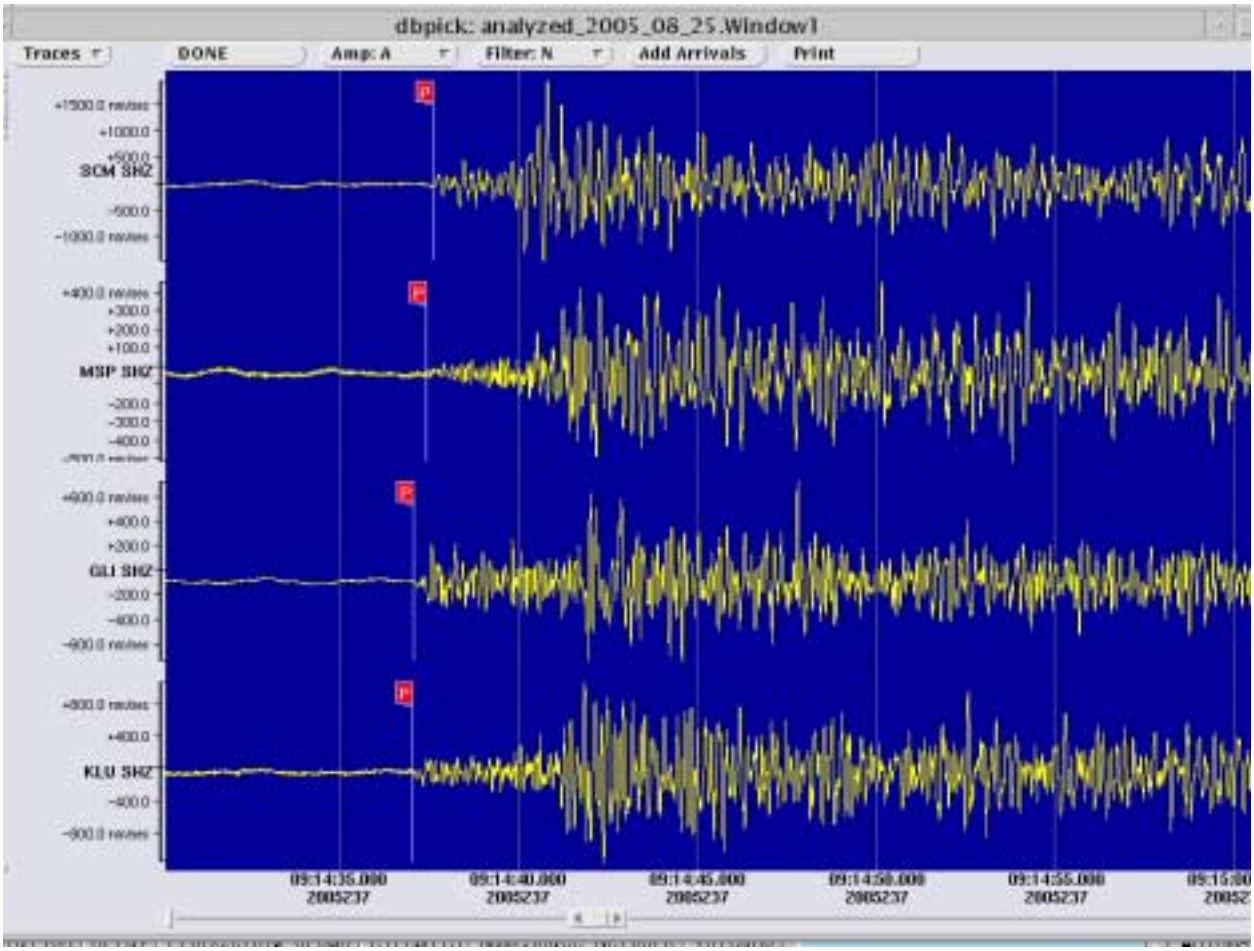
4.2.4. S-arrivals from a slab event recorded by 3-component stations.



4.2.5. S-arrivals from a slab event on vertical channels.

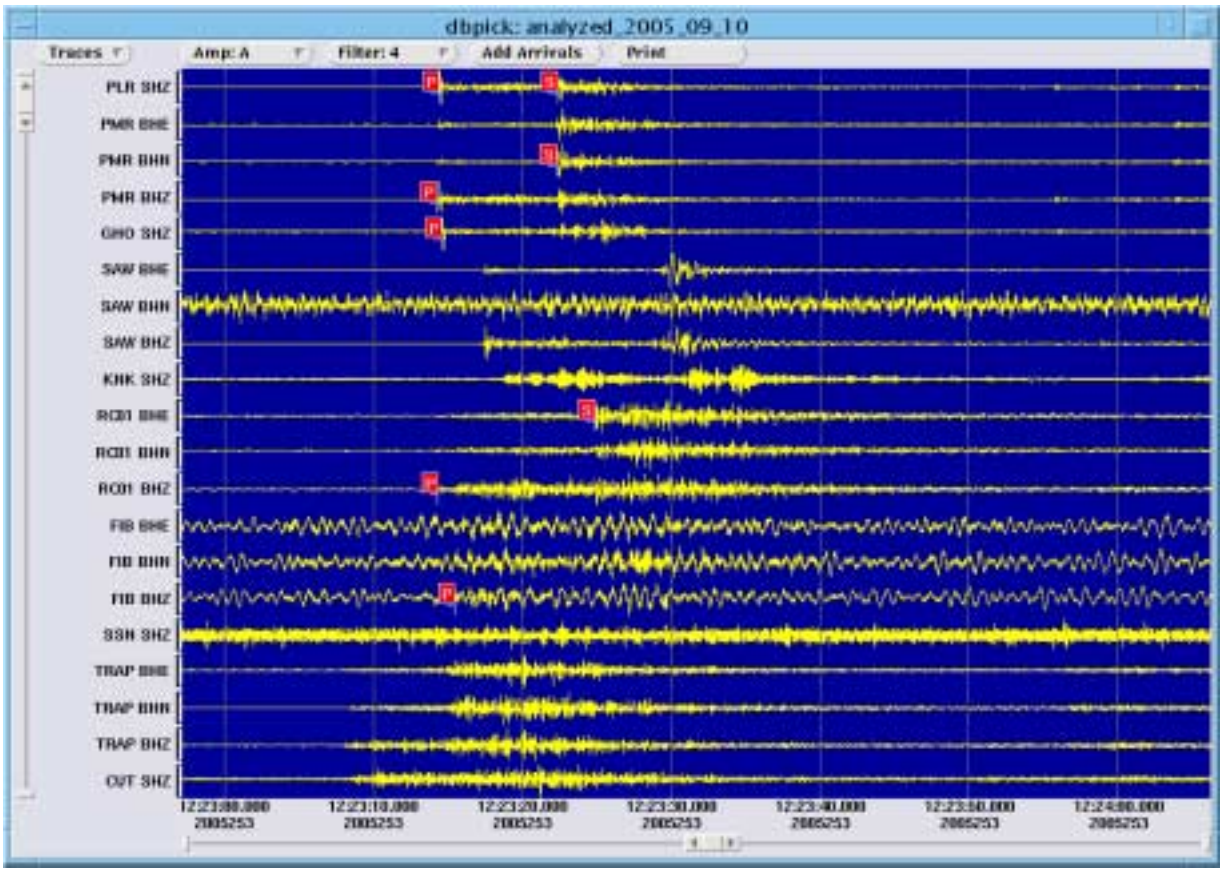


4.2.6. Typical crustal arrivals. For smaller events, Pn is more difficult to correctly identify. Too many Pg's in place of Pn's in a solution would cause negative depth, large residuals, misaligned stations and other kinds of problems.

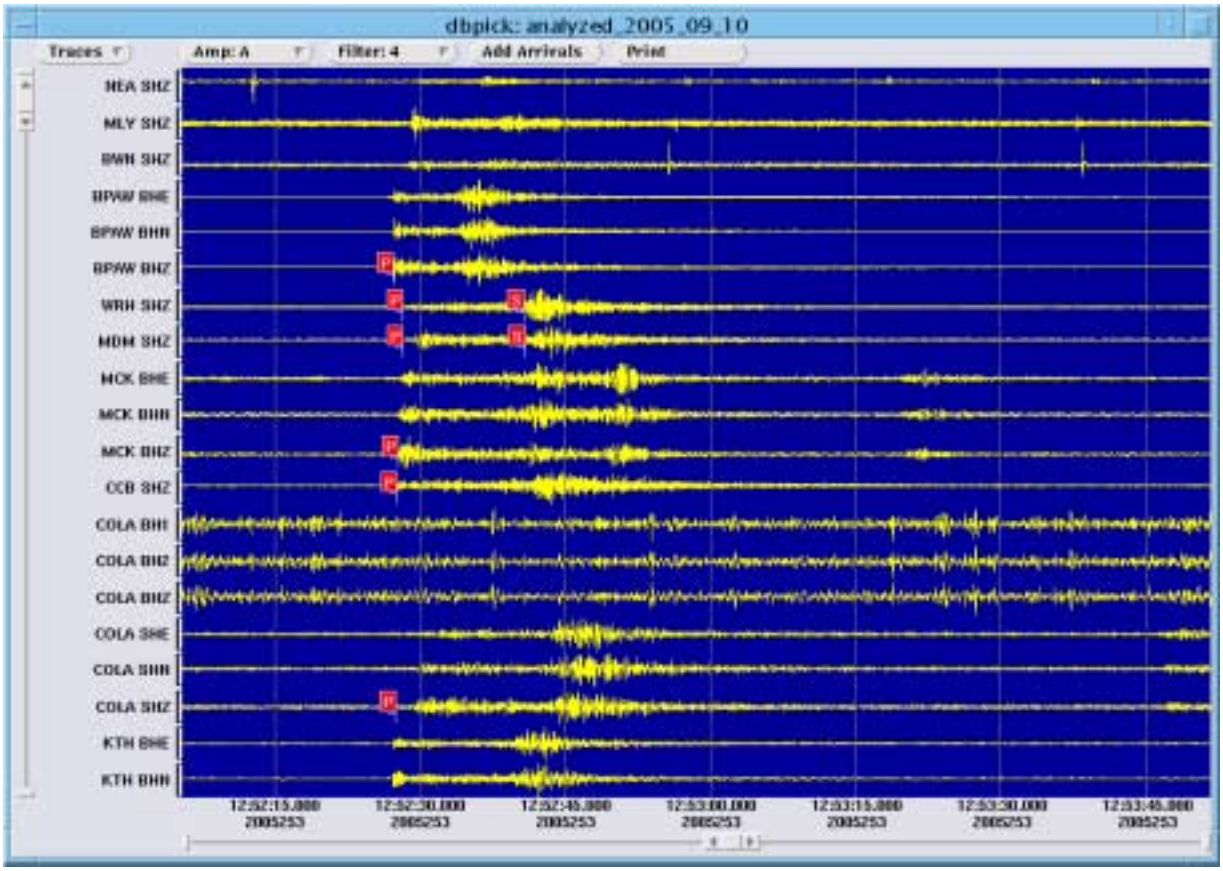


4.9. Early small amplitude arrivals from a slab event. These arrivals often have large negative residuals. It is important to identify correct arrival and not to move it just to minimize the residual.

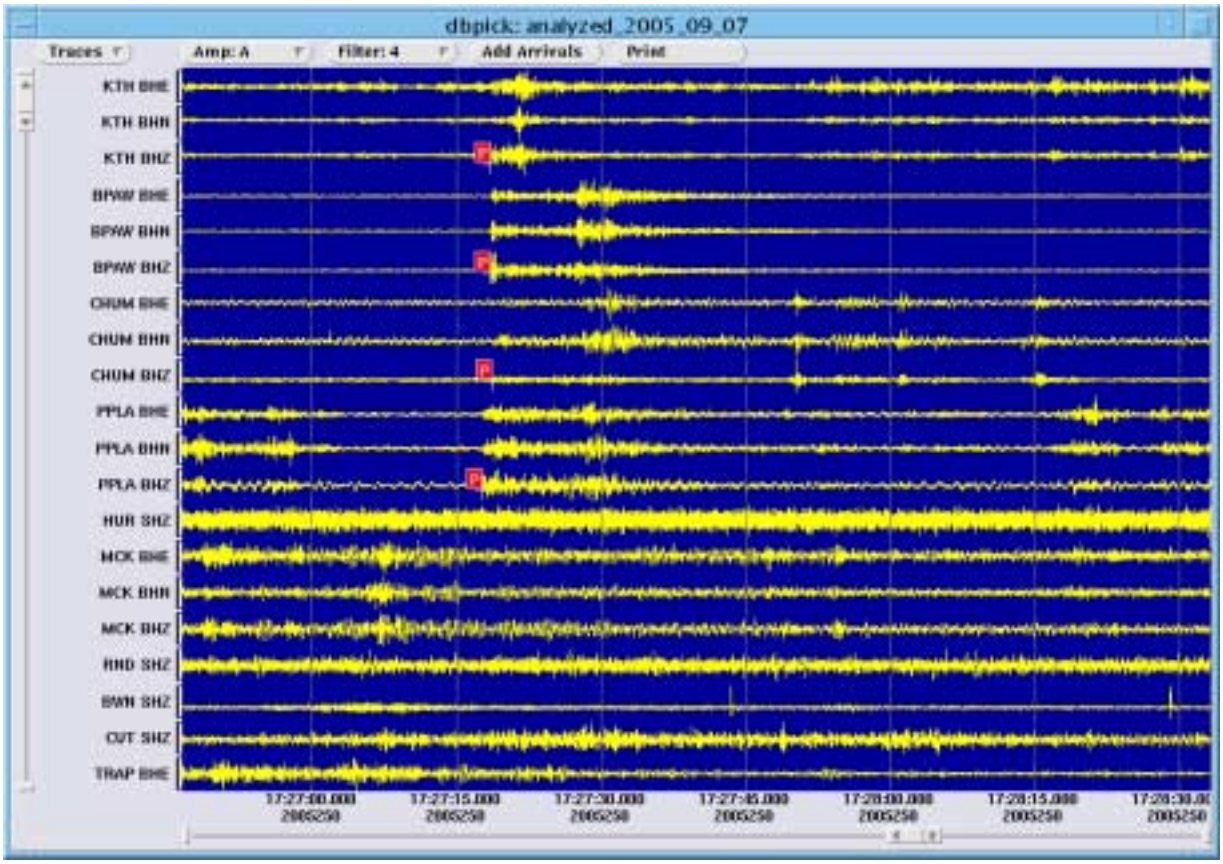
4.3. Common mistakes.



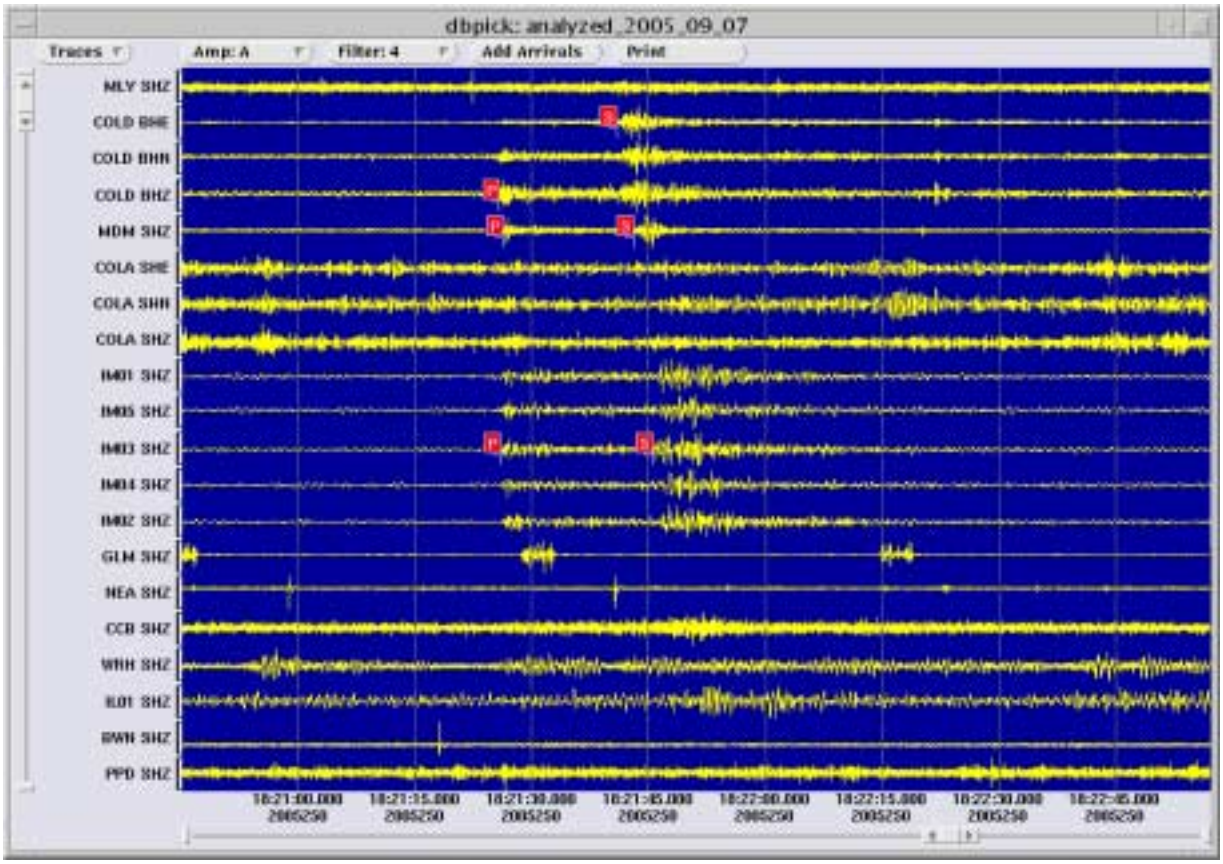
4.3.1. Mislocated event. While all picked arrivals agree with the saved location, a number of unpicked stations have a misaligned move-out. While system timing errors could cause this type of problem occasionally, analysts are normally warned about misbehaving stations. In this case the problem is caused by a poor location rather than timing problems.



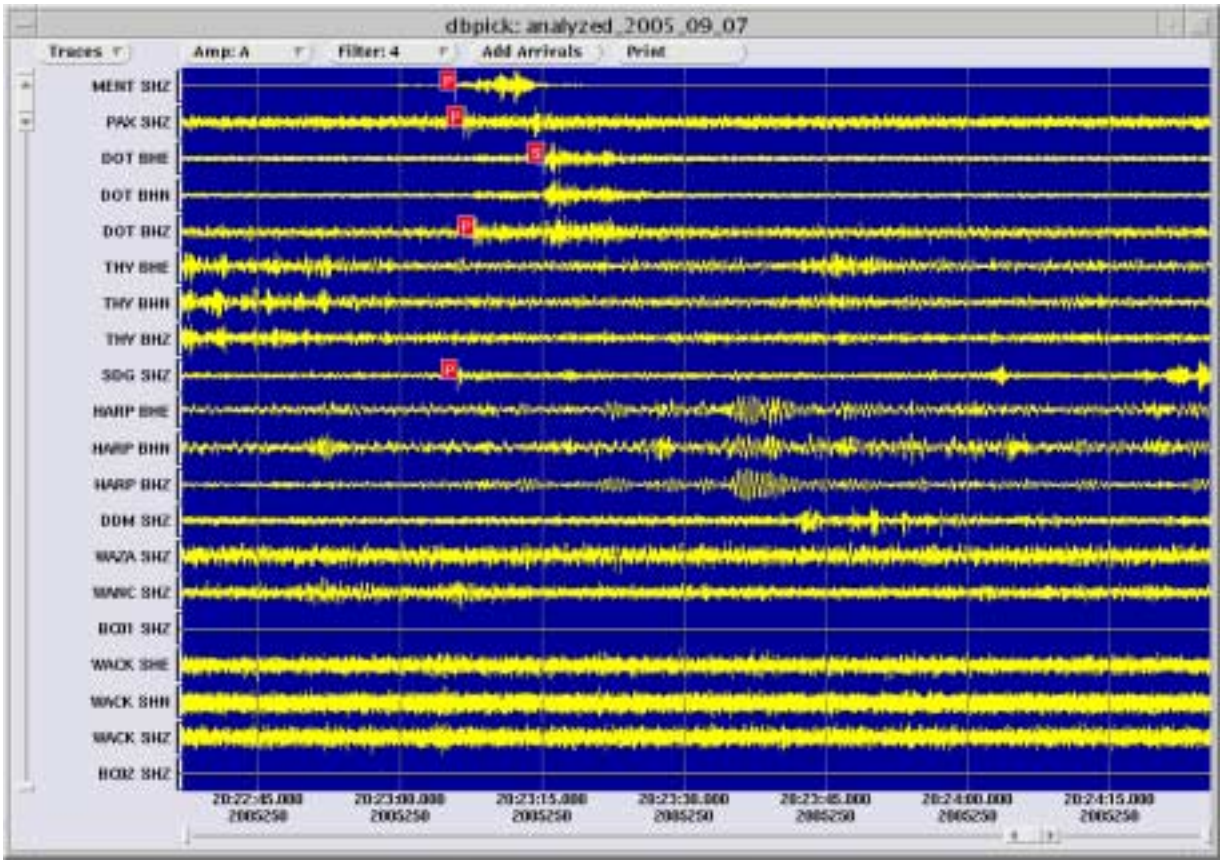
4.3.2. Mislocated event. The problem with this location is that the first three stations were not included. While the recorded signal is noisy, it is possible to identify P-arrivals on NEA, MLY and BWN stations. These arrivals should be included into location.



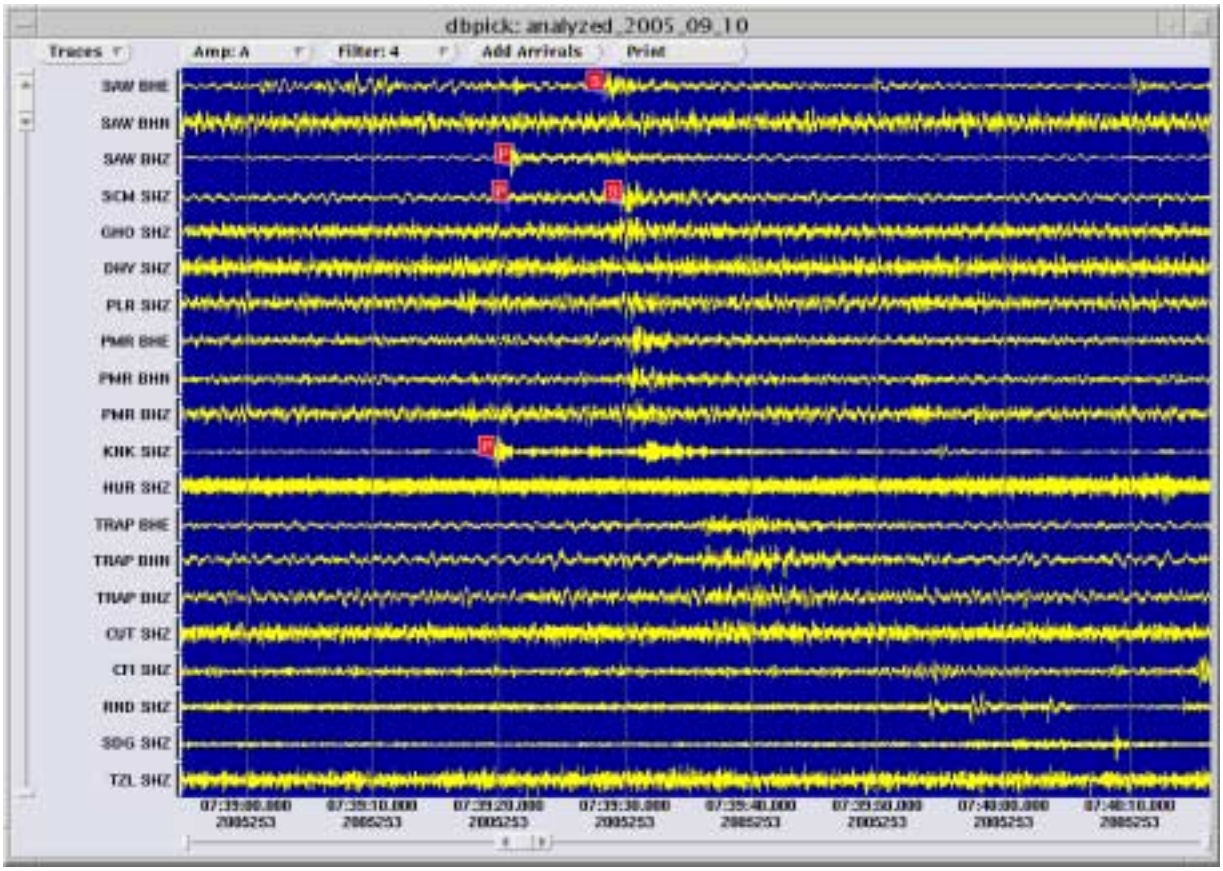
4.3.3. Small Kantishna event with poor arrivals should not be located.



4.3.4. Another example of small event with too few arrivals that would make it very difficult to get a well-constrained depth estimate.



4.3.5. Example of small aftershock. Not enough stations with good arrivals.



4.3.6. Small event in southcentral Alaska. Not enough stations with good arrivals.

5. Notes