Creating arrivals, Measuring amplitudes and Calculating magnitudes

Introduction

This document describes how arrivals are created with *geotool*. It also describes how amplitudes are measured and used to calculate magnitudes. Geotool's interface allows waveforms to be filtered or beamed and visually inspected for signals, whose arrival times are interactively picked. Other arrival attributes, such as azimuth, slowness, amplitude, and period can be automatically or manually measured. The calculation of arrival and amplitude attributes depends on the type of waveform display window. For example, arrivals can be created in the main waveform window and also in the waveform displays within the *FK, FKSignal,* and *Polarization* windows. Some attributes will be calculated differently in these windows. The calculation of attributes also depends on the type of waveform data, three-component data or array data. Many attributes can be both automatically and manually measured. The set of parameters that guides the automatic measurement is described here and the methods for manually measuring arrival and amplitude attributes are explained.

The *geotool* windows that are discussed in this document include:

- *Option/Arrivals*
- *Option/Amplitudes/Magnitudes*
- *File/Preferences/Arrival Keys*
- *File/Preferences/Arrival Parameters*
- *File/Preferences/Amplitude Parameters*
- *Arrivals/Option/Measure Amp Per*
- *Amplitudes/Magnitudes/Option/Manual Measurement*

Creating Arrivals

In the *geotool* waveform window, arrivals are created by positioning a phase line over a selected waveform at the desired time as shown in Figure 1. There are two ways to display a phase line in the waveform window. The *Arrivals* popup window allows you to select a phase name from a list at the left to display a phase line in the waveform window. Position the phase line over a selected waveform and click the *Add* button to create an arrival. You can also display a phase line with a mouse button and key combination in the waveform window. If you press and hold down the left mouse near the waveform of interest and at the same time also type one of the keys that are listed in the *Arrival Key Table*, a phase line will be displayed at the mouse cursor location. Hold the left mouse button down and drag the phase line to the desired position. When you release the mouse button, the arrival will be created. The order of the mouse button press and the key press does not matter. The key (for example 'p', 'n', 'g', 's', or 'a' in Figure 1) can be pressed and held before the left-mouse button, or vice versa. Once the phase line is displayed, it is no longer necessary to hold down the key. Edit the *Arrival Key Table* to change the default key assignments or add more phase/key pairs. Note that some letters cannot be used in the *Arrival Key Table*, since they are already used in the *Key Actions* table (*File/Preferences/Key Actions*) that has precedence over the *Arrival Key Table*. The *Key Actions* table (see Figure 2) can be changed to prevent it from interfering with the *Arrival Key Table*.

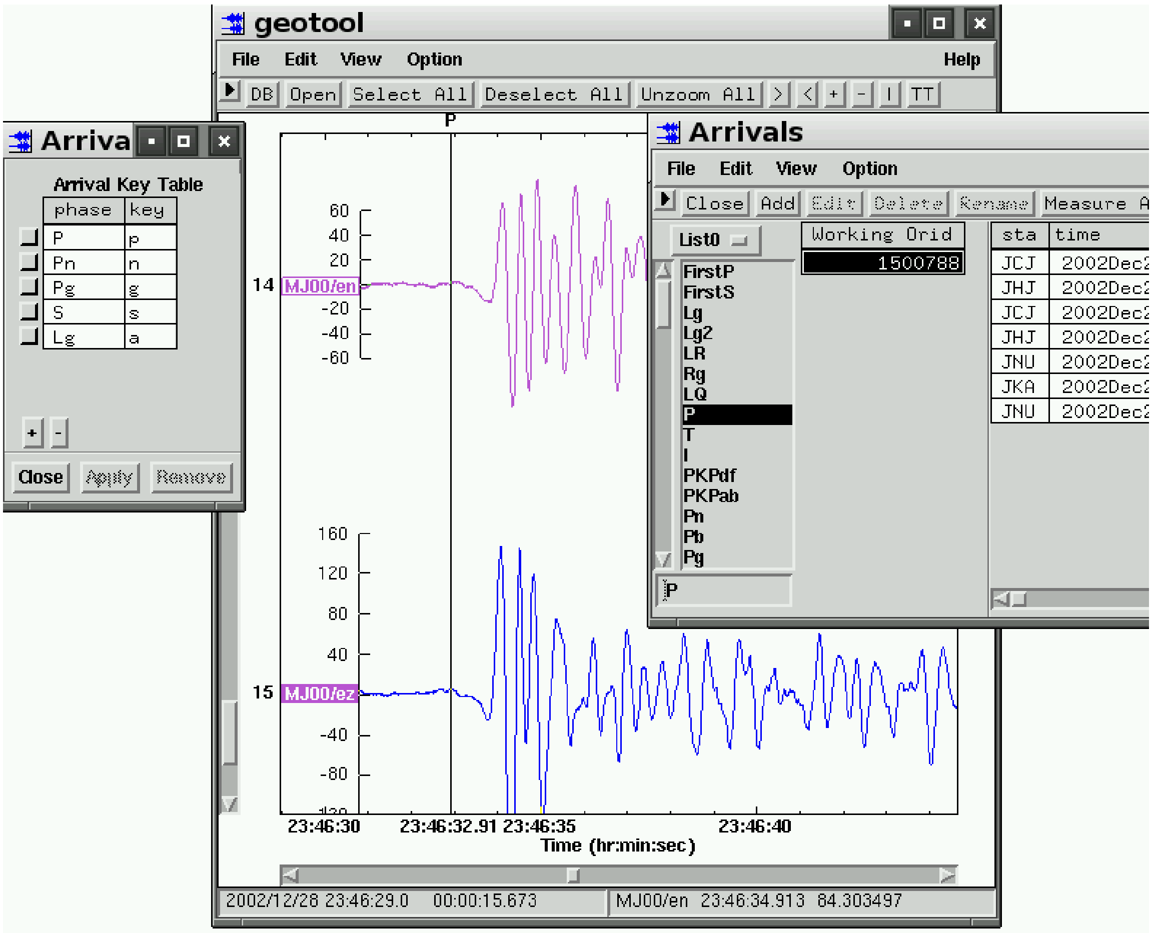
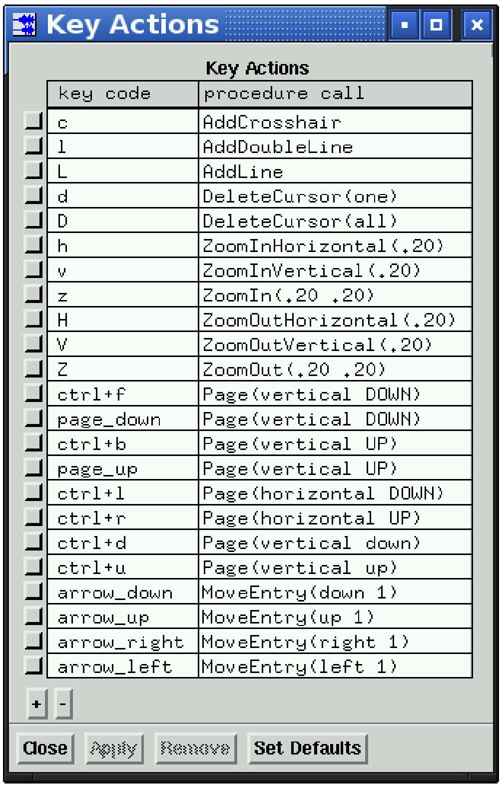


Figure 1: Add an arrival with the Arrivals window or a left-mouse button/key combination.

The mouse-button key combination method of displaying a phase line and creating an arrival works in most *geotool* windows that display waveforms. In particular, it is possible add arrivals to waveforms that are displayed in the *FK*, *FKSignal*, *Spectrogram* and *Polarization* window. The difference in attribute calculation in these windows is explained below.



key code	procedure call
c	AddCrosshair
l	AddDoubleLine
L	AddLine
d	DeleteCursor(one)
D	DeleteCursor(all)
h	ZoomInHorizontal(.20)
v	ZoomInVertical(.20)
z	ZoomIn(.20 .20)
H	ZoomOutHorizontal(.20)
V	ZoomOutVertical(.20)
Z	ZoomOut(.20 .20)
ctrl+f	Page(vertical DOWN)
page_down	Page(vertical DOWN)
ctrl+b	Page(vertical UP)
page_up	Page(vertical UP)
ctrl+l	Page(horizontal DOWN)
ctrl+r	Page(horizontal UP)
ctrl+d	Page(vertical down)
ctrl+u	Page(vertical up)
arrow_down	MoveEntry(down 1)
arrow_up	MoveEntry(up 1)
arrow_right	MoveEntry(right 1)
arrow_left	MoveEntry(left 1)

Figure 2: Key Actions table.

The *Key Actions* table assigns keys to actions in the waveform window, such as cursor control and zooming in or out. The *Key Actions* table overrides the *Arrival Key Table*. The *Key Actions* table can be changed, if keys are needed for the *Arrival Key Table*.

Arrival Attributes

Arrival attributes are calculated from the selected waveforms when the arrival is created. These calculations depend on the waveform type, three-component data or array data, and on the window that displays the waveforms. The arrival attribute names are displayed in Table 1, along with a short description of their calculated values for three-component and array data. The procedures for calculating the attributes are described in this section. The automatic calculations are controlled with the parameters from the Arrival Parameters window shown in Figure 3.

The attributes for three-component data are calculated from polarization analysis of the waveforms bandpass-filtered between *polar_lofreq* and *polar_hifreq*. The maximum polarization is found for a sliding window of length *polar_window* and overlap *polar_overlap_fraction,* that slides over the time period specified with *polar_signal_lead* and *polar_signal_len*. The attributes for array data are computed from FK analysis of the waveforms for the time period specified by *fk_lead* and *fk_lag*, and bandpass-filtered between *fmin* and *fmax*. The FK slowness is restricted by *signal_slow_min* and *signal_slow_max*.

sta For three-component data, the *sta* field is the station name of the selected waveforms. For array-data, it is the array or network name.

chan For three-component data, the *chan* field is the channel name of the selected waveform. For array-data, it is the name of the beam recipe that specifies the array elements that are included in the automatic attribute measurements. It defaults to "cb" and is accessible in the *Arrival Parameters* window shown in Figure 3.

deltim The formula for the calculation of the *deltim* attribute is $deltim=\delta t_{max}-\frac{\delta t_{diff}*\log(snr/snr_{min})}{\log(snr_{max}/snr_{min})}$. The signal to noise ratio *snr* is computed from the waveform. The other parameters in the formula are set in the *Arrival Paramters* window. δt_{max} is *max_deltim*, δt_{diff} is (m*ax_deltim – min_deltim*), snr_{min} is *min_snr* and snr_{max} is *max_snr*.

azimuth Polarization analysis is used to determine the azimuth for three-component data. FK analysis is used for array data. The array elements that are included in the FK computation are specified by the beam recipe *arrival_beam_recipe* in the *Arrival Parameters* table

slow For array data, the slowness is computed from FK analysis. For three- component data, the slowness is calculated from the incidence angle as $\alpha_{polar}*\sin(.5*\theta_i)*180/\pi$, where θ_i is the polarization incidence angle and α_{polar} is the parameter *polar_alpha* in the *Arrival Parameters* table.

delslo The d*elslo* attribute is calculated for three-component data with the formula $\sqrt{.5*dk_{polar}^2*(1-recti)}*(\frac{180}{\pi})$, where *recti* is the polarization rectilinearity and dk_{polar} is the parameter *polar_dk* in the *Arrival Parameters* table. For array data, the *delslo* attribute is computed as $\frac{dk_{fk}}{\sqrt{fstat*cfreq}}*(\frac{180}{\pi})$, where dk_{fk} is the parameter *fk_dk* in the *Arrival Parameters* table. The central frequency, *cfreq* is .5*(*fmax – fmin*), where the FK frequency limits *fmin*, *fmax* are specified in the *Arrival Parameters* table. Finally, the parameter *fstat* is a function of the maximum FK value.

$$fstat = \frac{(number\ of\ array\ elements-1)*fk_{max}}{(1.0-fk_{max}+10^{-6})} .$$

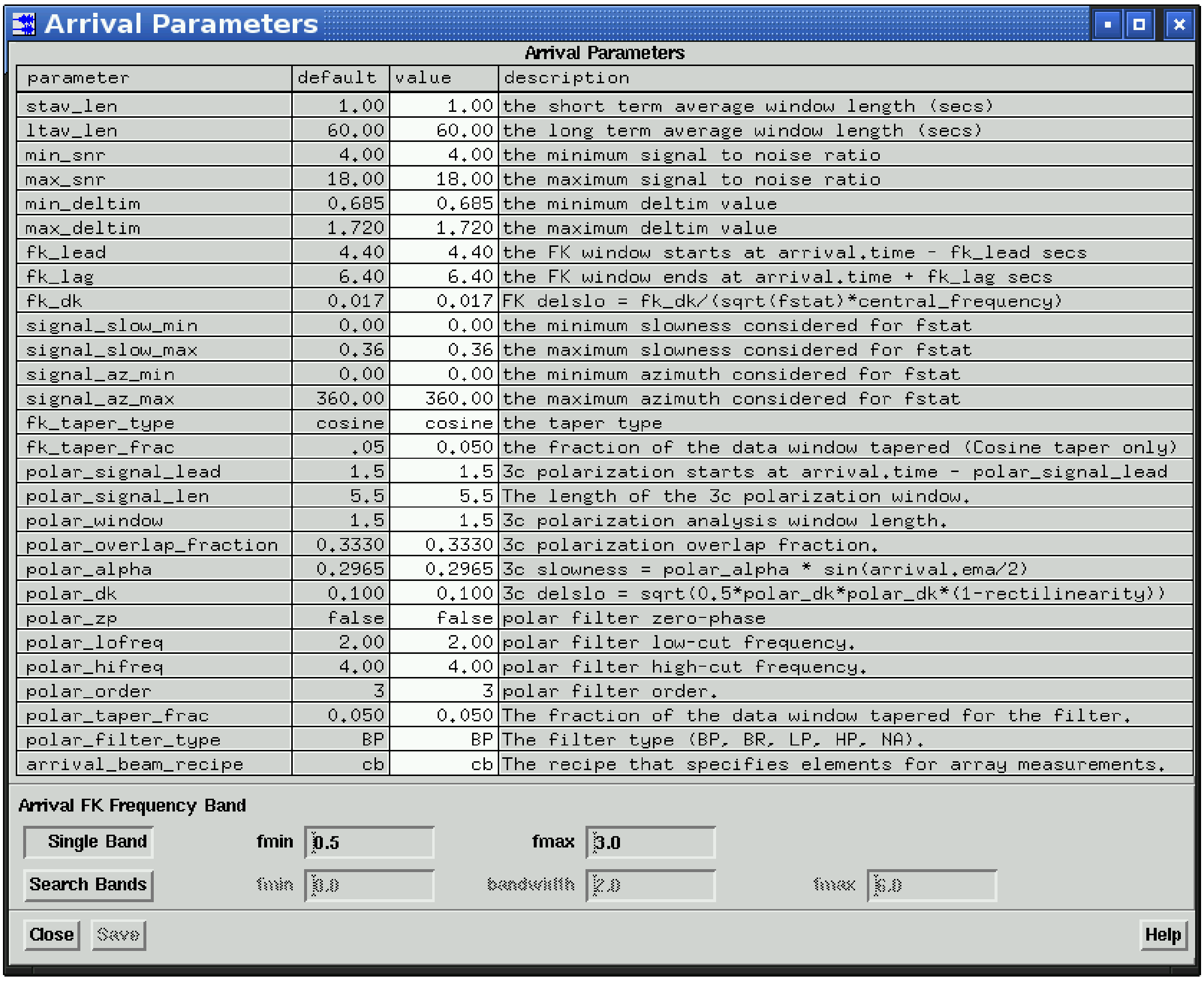
delaz The *delaz* attribute is the same for three-component and array data. It is calculated as $2*\arcsin(\frac{delslo}{2*slow})*(\frac{180}{\pi})$

snr The signal to noise ratio is the ratio of the short-term average to the long-term average, where the short-term average is the average absolute data value in a window of length *stav_len* beginning at the arrival time, and the long-term average is the average absolute data value in a window of length *ltav_len* that ends at the arrival time. The parameters *stav_len* and *ltav_len* are in the *Arrival Parameters* table.

amp and ***per*** The amplitude and period attributes are measured when the arrival is added to a three-component waveform. See the section on amplitude measurement.

Attribute	**3-component waveform**	**Array waveform**
sta	The station name	The array or network name
time	Epoch time	Same
arid	New arid	Same
jdate	YYYYDOY	Same
stassid	Null value (-1)	Same
chanid	chanid from sitechan	chanid for the beam.
chan	The channel name	The beam recipe name.
iphase	The phase name	Same
stype	Null value (“-”)	Null value (“-”)
deltim	$\delta t_{max} - \frac{\delta t_{diff} * \log(snr/snr_{min})}{\log(snr_{max}/snr_{min})}$	Same
azimuth	Polarization azimuth	FK azimuth
delaz	$2 * \arcsin(\frac{delslo}{2 * slow}) * (\frac{180}{\pi})$	Same
slow	$\alpha_{polar} * \sin(.5 * \theta_i) * 180/\pi$	FK slowness
delslo	$\sqrt{.5 * dk_{polar}^2 * (1 - recti)} * (\frac{180}{\pi})$	$\frac{dk_{fk}}{\sqrt{fstat * cfreq}} * (\frac{180}{\pi})$
ema	Incidence angle (θ_i)	Null value (-1.)
rect	Polarization rectilinearity	Null value (-1.)
amp	Measured amplitude	Measured amplitude from beam
per	Measure period	Measure period from beam
logat	Null value (-1.)	Null value (-1.)
clip	Null value (“-”)	Null value (“-”)
fm	Null value (“-”)	Null value (“-”)
snr	$\frac{short-term\,average}{long-term\,average}$	Beam $\frac{short-term\,average}{long-term\,average}$
qual	Null value (“-”)	Null value (“-”)
auth	User login name	User login name
commid	Null value (-1)	Null value (-1)
lddate	Load date	Load date

Table 1: Arrival attributes



Arrival Parameters

Arrival Parameters

parameter	default	value	description
stav_len	1.00	1.00	the short term average window length (secs)
ltav_len	60.00	60.00	the long term average window length (secs)
min_snr	4.00	4.00	the minimum signal to noise ratio
max_snr	18.00	18.00	the maximum signal to noise ratio
min_deltim	0.685	0.685	the minimum deltim value
max_deltim	1.720	1.720	the maximum deltim value
fk_lead	4.40	4.40	the FK window starts at arrival.time - fk_lead secs
fk_lag	6.40	6.40	the FK window ends at arrival.time + fk_lag secs
fk_dk	0.017	0.017	FK delslo = fk_dk/(sqrt(fstat)*central_frequency)
signal_slow_min	0.00	0.00	the minimum slowness considered for fstat
signal_slow_max	0.36	0.36	the maximum slowness considered for fstat
signal_az_min	0.00	0.00	the minimum azimuth considered for fstat
signal_az_max	360.00	360.00	the maximum azimuth considered for fstat
fk_taper_type	cosine	cosine	the taper type
fk_taper_frac	.05	0.050	the fraction of the data window tapered (Cosine taper only)
polar_signal_lead	1.5	1.5	3c polarization starts at arrival.time - polar_signal_lead
polar_signal_len	5.5	5.5	The length of the 3c polarization window.
polar_window	1.5	1.5	3c polarization analysis window length.
polar_overlap_fraction	0.3330	0.3330	3c polarization overlap fraction.
polar_alpha	0.2965	0.2965	3c slowness = polar_alpha * sin(arrival.ema/2)
polar_dk	0.100	0.100	3c delslo = sqrt(0.5*polar_dk*polar_dk*(1-rectilinearity))
polar_zp	false	false	polar filter zero-phase
polar_lofreq	2.00	2.00	polar filter low-cut frequency.
polar_hifreq	4.00	4.00	polar filter high-cut frequency.
polar_order	3	3	polar filter order.
polar_taper_frac	0.050	0.050	The fraction of the data window tapered for the filter.
polar_filter_type	BP	BP	The filter type (BP, BR, LP, HP, NA).
arrival_beam_recipe	cb	cb	The recipe that specifies elements for array measurements.

Figure 3: Parameters for the automatic calculation of arrival attributes.

Creating arrivals in the FK window

Arrivals can be created on the waveforms that are displayed at the bottom of the *FK* and *FK Multi-Band* windows. Use the mouse button key combination to display and position a phase line in these windows. When an arrival is added to the waveform that is displayed in the *FK* window, the azimuth and slowness values that are displayed at the the top of the window (and associated with the current *FK* cursor position) will be saved as arrival attributes. To add an arrival to one of the *FK Multi-Band* waveforms, position the mouse cursor nearest to the waveform (fk1, fk2, fk3 or fk4) that corresponds to the frequency band *FK* that you prefer. The left-mouse/key combination will display the phase line which can be positioned at the desired arrival time. When the arrival is created, the azimuth and slowness values for the frequency band will be saved as the arrival attributes. The corresponding *fstat* will be used to compute *delslo* and *delaz*.

Creating arrivals in the Polarization window

Arrivals can also be created in the *Polarization* window. First, position the line cursor that is displayed in the Rectilinearity, Incidence, P Azimuth and S Azimuth plots. The values for azimuth, incidence and rectilinearity that are displayed at the top of each line cursor will be used to compute the arrival attributes. Next, use the left-mouse button key combination to display and position a phase line in the waveform plot at the bottom of the Polarization window. It does not matter which waveform the cursor is nearest, the vertical component will always be used for attribute calculations and the vertical component channel name will be saved in the arrival.

Creating arrivals in the Spectrogram window

Arrivals can also be created on the waveform displayed at the bottom of the *Spectrogram* window. In this case, all of the attributes are calculated the same as if the arrival were created on the corresponding waveform in the main waveform window.

Association with an origin

When arrivals are created in *geotool*, they are automatically associated with the current working orid. The working orid can be selected in several different windows, including the *Origins* window and the *Arrivals* window. If a working orid is selected, an assoc record is created when an arrival is created and associated with an origin.

Automatic Amplitude and Period Measurement

When an arrival is created in geotool, the amplitude and period of the signal are automatically measured and saved in an amplitude record. The amplitude attributes are shown in Table 2. Depending on the distance of the station from the origin, two different amplitude measurements are made, one for *ml* magnitudes and one for *mb* magnitudes.

Ml amplitudes

If the arrival phase is one of the *ml_phases* and the distance is between *ml_dist_min* and *ml_dist_max* and the origin depth is between *ml_depth_min* and *ml_depth_max*, the *ml* type amplitude is calculated. The parameters that control the automatic *ml* amplitude measurement are set in the *SBSNR* tab of the *Amplitude Parameters* window which is shown in Figure 4.

Ml amplitudes for three-component data

For three-component data, the data samples for the selected waveform are re-read as raw counts for a window about the arrival time, with *start_time* and *end_time* times calculated as:

start_time = arrival time – *ml_lta_lead* – *mb_filter_margin*

end_time = arrival time – *ml_lta_lead* + *ml_lta_length* + *mb_filter_margin*

Both ends of the waveform are tapered with a cosine taper whose length is equal to 5% of the length of the waveform, and then the waveform is filtered with an IIR filter defined by the filter parameters *ml_filter_type, ml_filter_order, ml_filter_zp, ml_filter_locut* and *ml_filter_hicut*. The waveform is multiplied by the *calib* calibration value. A long term average (*lta*) is computed as the sum of the absolute value of each sample divided by the number of samples in a time window with *start_time* to *end_time* defined as:

start_time = arrival time – *ml_lta_lead*

end_time = *start_time* + *ml_lta_length*

A short term average (*sta*) is computed for a sliding time window of length *ml_sta_length*. The first short term average window is positioned at the *start_time*:

first *sta* window *start_time* = arrival time – *ml_sta_lead*

The short term average window is shifted by one sample until the last window is reached that has an *end_time* of:

last *sta* window *end_time* = arrival time – *ml_sta_lead* + *ml_sta_window*

The maximum short term average for these windows is used in the amplitude formula:

$$amp_{ml} = \sqrt{sta_{max}^2 - lta^2}$$

Ml amplitudes for array data

The beam recipe *arrival_beam_recipe* (specified in the *Arrival Parameters* window) determines the array elements that are used in the ml amplitude measurement. The array waveforms are re-read as raw counts for the time window with *start_time* and *end_time* defined as

start_time = arrival time - ml_lta_lead – mb_filter_margin

end_time = arrival time – *ml_lta_lead* + *ml_lta_length* + *mb_filter_margin*

Both ends of each array waveform are tapered with a cosine taper whose length is equal to 5% of the length of the waveform, and then the waveform is filtered with an IIR filter defined by the filter parameters *ml_filter_type, ml_filter_order, ml_filter_zp, ml_filter_locut* and *ml_filter_hicut*. An incoherent beam is calculated using the azimuth and slowness for the associated origin and the arrival phase. (An incoherent beam is a beam made from the absolute values of the array waveform samples.) The same algorithm is then used to compute the ml amplitude from the beam as:

$$amp_{ml} = \sqrt{sta_{max}^2 - lta^2}$$

Attribute	Amplitude for mb magnitude	Amplitude for ml magnitude
ampid	New ampid	Same
arid	Associated arrival arid	Same
parid	Null value (-1)	Same
chan	Channel name	Same
amp	Half peak to trough amplitude[1]	$\sqrt{sta_{max}^2 - lta^2}$
per	Period (secs)	Null value (-999.)
snr	Arrival snr	Snr for the ml filter band
amptime	Arrival time	Same
start_time	Start of the waveform segment	Same
duration	Length of the waveform segment	Same
Bandw	*mb_filter_hicut - mb_filter_locut*	*ml_filter_hicut - ml_filter_locut*
amptype	*mb_amptype* ("A5/2")	*ml_amptype* ("SBSNR")
units	Null value ("-")	Same
clip	Null value ("-")	Same
inarrival	"y"	"n"
auth	User login name	Same
lddate	Load date	Same

Table 2: Amplitude attributes for mb and ml magnitudes.

Mb amplitudes

If the arrival phase is one of the *mb_phases* and the distance is between *mb_dist_min* and *mb_dist_max,* the *mb* type amplitude is calculated. The parameters that control the automatic *mb* amplitude measurement are set in the *A5/2* tab of the *Amplitude Parameters* window which is shown in Figure 5.

Mb amplitudes for three-component data

For three-component data, the data samples for the selected waveform are re-read as raw counts for a window about the arrival time, with *start_time* and *end_time* times calculated as:

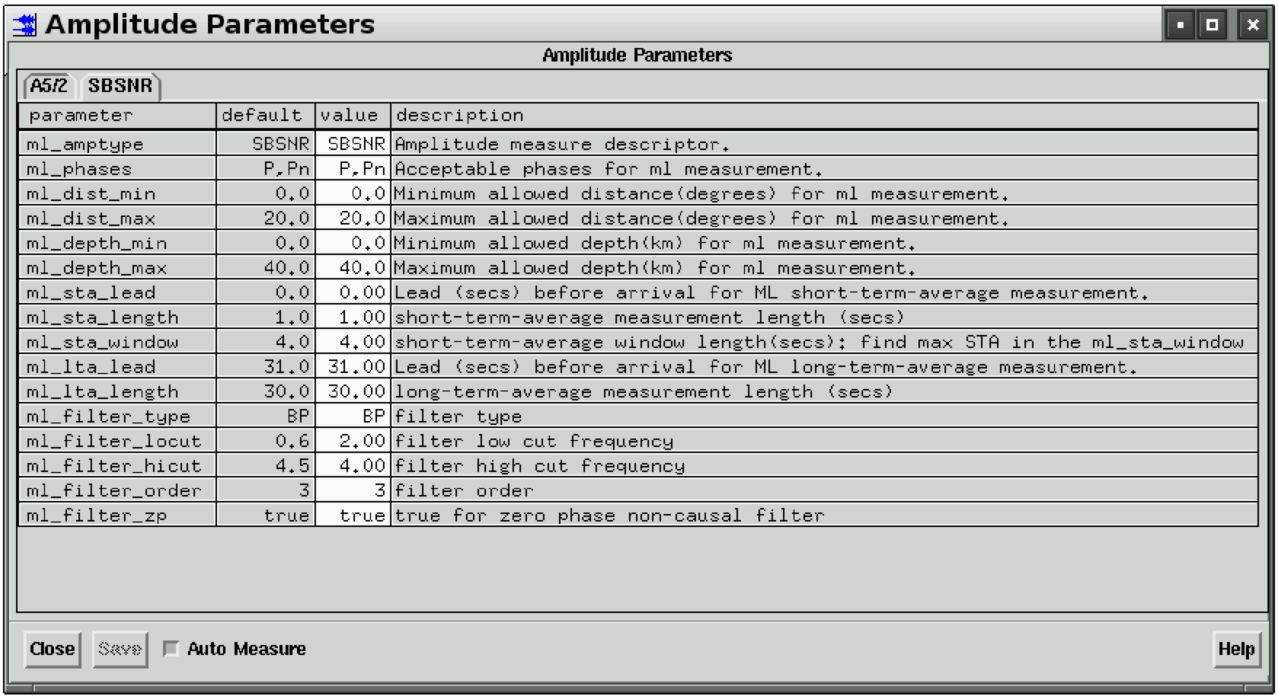
start_time = arrival time – *mb_lead* – *mb_filter_margin*

end_time = arrival time – *mb_lead* + *mb_length* + *mb_filter_margin*

Both ends of the waveform are tapered with a cosine taper whose length is equal to *mb_taper_frac* of the length of the waveform, and then the waveform is filtered with an IIR filter defined by the filter parameters *mb_filter_type,* *mb_filter_order, mb_filter_zp, mb_filter_locut* and *mb_filter_hicut*. The waveform is then scanned in the window

start_time = arrival time – *mb_lead*
end_time = *start_time* + *mb_length*

for a peak-to-trough pair that satisfies an algorithm that is not discussed here, but is controlled by the *mb_amp_threshold#* parameters and the *allowed_hp_ratio* and *allowed_lp_ratio* parameters. The instrument response for the waveform is then used to convert the half trough to peak amplitude from counts to nanometers.


Amplitude Parameters
Amplitude Parameters
A5/2 SBSNR

parameter	default	value	description
ml_amptype	SBSNR	SBSNR	Amplitude measure descriptor.
ml_phases	P,Pn	P,Pn	Acceptable phases for ml measurement.
ml_dist_min	0.0	0.0	Minimum allowed distance(degrees) for ml measurement.
ml_dist_max	20.0	20.0	Maximum allowed distance(degrees) for ml measurement.
ml_depth_min	0.0	0.0	Minimum allowed depth(km) for ml measurement.
ml_depth_max	40.0	40.0	Maximum allowed depth(km) for ml measurement.
ml_sta_lead	0.0	0.00	Lead (secs) before arrival for ML short-term-average measurement.
ml_sta_length	1.0	1.00	short-term-average measurement length (secs)
ml_sta_window	4.0	4.00	short-term-average window length(secs): find max STA in the ml_sta_window
ml_lta_lead	31.0	31.00	Lead (secs) before arrival for ML long-term-average measurement.
ml_lta_length	30.0	30.00	long-term-average measurement length (secs)
ml_filter_type	BP	BP	filter type
ml_filter_locut	0.6	2.00	filter low cut frequency
ml_filter_hicut	4.5	4.00	filter high cut frequency
ml_filter_order	3	3	filter order
ml_filter_zp	true	true	true for zero phase non-causal filter

Close Save Auto Measure Help

Figure 4: Parameters that control the ml type amplitude measurement.

Mb amplitudes for array data

The beam recipe *arrival_beam_recipe* (specified in the *Arrival Parameters* window) determines the array elements that are used in the mb amplitude measurement. The array waveforms are re-read as raw counts for the time window with *start_time* and *end_time* defined as

start_time = arrival time - mb_lead – mb_filter_margin

end_time = arrival time – *mb_lead* + *mb_length* + *mb_filter_margin*

Both ends of each array waveform are tapered with a cosine taper whose length is equal to *mb_taper_frac* of the length of the waveform, and then the waveform is filtered with an IIR filter defined by the filter parameters *mb_filter_type, mb_filter_order, mb_filter_zp, mb_filter_locut* and *mb_filter_hicut.* A coherent beam is calculated using the azimuth and slowness for the associated origin and the arrival phase. The waveform is then scanned in the window

> *start_time* = arrival time – *mb_lead*
> *end_time* = *start_time* + *mb_length*

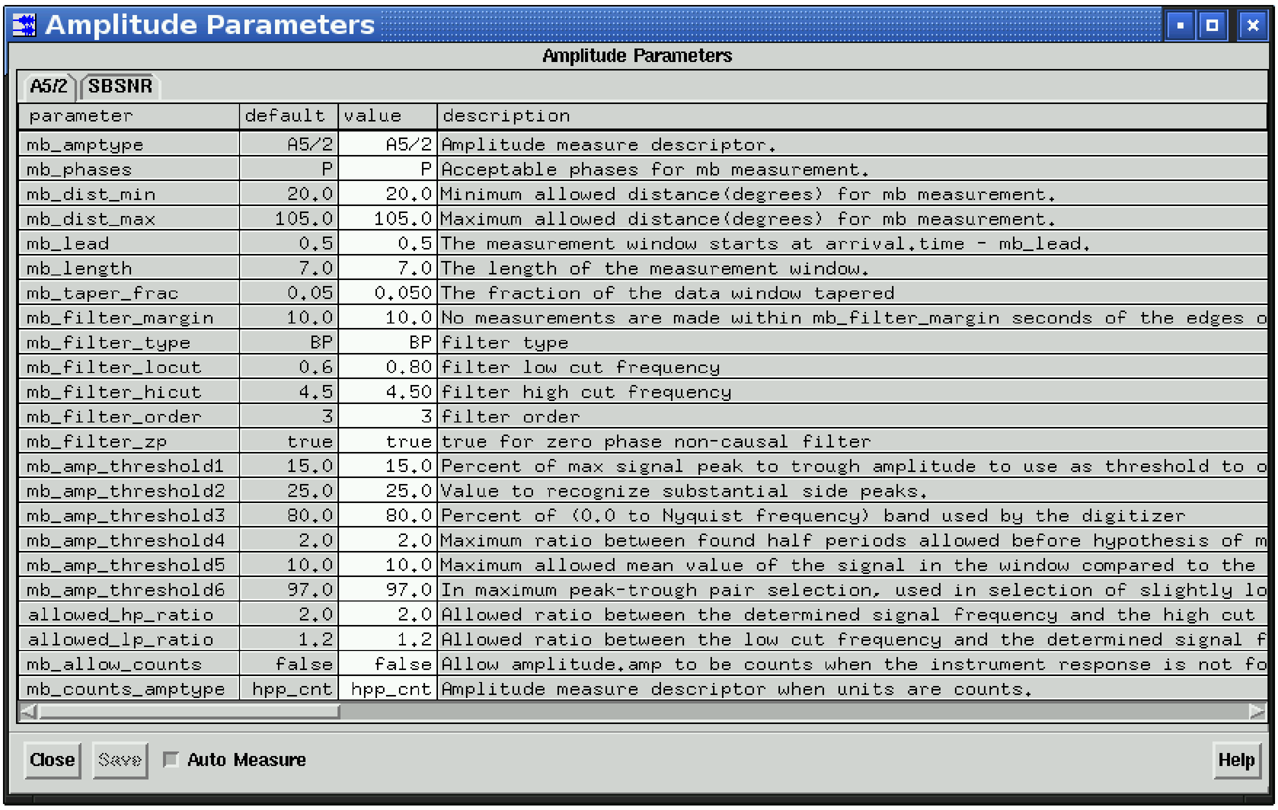
for a peak-to-trough pair that satisfies an algorithm that is not discussed here, but is controlled by the *mb_amp_threshold#* parameters and the *allowed_hp_ratio* and *allowed_lp_ratio* parameters. The instrument response for the first element of the array is then used to convert the half trough to peak amplitude from counts to nanometers.

Amplitude amptype

The *amptype* field of the amplitude record is set to *mb_amptype* (default *A5/2*) for *mb* amplitude measurements and *ml_amptype* (default *SBSNR)* for *ml* amplitude measurements.

No instrument response

If an instrument response cannot be found to convert *mb* amplitude from counts to nanometers, the amplitude measurement will not be saved, unless the parameter *mb_allow_counts* is true. If *mb_allow_counts* is true, the amplitude is saved as counts in the *amp* field and the *amptype* is set to *mb_counts_amptype* (default *hpp_cnt)*.



parameter	default	value	description
mb_amptype	A5/2	A5/2	Amplitude measure descriptor.
mb_phases	P	P	Acceptable phases for mb measurement.
mb_dist_min	20.0	20.0	Minimum allowed distance(degrees) for mb measurement.
mb_dist_max	105.0	105.0	Maximum allowed distance(degrees) for mb measurement.
mb_lead	0.5	0.5	The measurement window starts at arrival.time - mb_lead.
mb_length	7.0	7.0	The length of the measurement window.
mb_taper_frac	0.05	0.050	The fraction of the data window tapered
mb_filter_margin	10.0	10.0	No measurements are made within mb_filter_margin seconds of the edges o
mb_filter_type	BP	BP	filter type
mb_filter_locut	0.6	0.80	filter low cut frequency
mb_filter_hicut	4.5	4.50	filter high cut frequency
mb_filter_order	3	3	filter order
mb_filter_zp	true	true	true for zero phase non-causal filter
mb_amp_threshold1	15.0	15.0	Percent of max signal peak to trough amplitude to use as threshold to o
mb_amp_threshold2	25.0	25.0	Value to recognize substantial side peaks.
mb_amp_threshold3	80.0	80.0	Percent of (0.0 to Nyquist frequency) band used by the digitizer
mb_amp_threshold4	2.0	2.0	Maximum ratio between found half periods allowed before hypothesis of m
mb_amp_threshold5	10.0	10.0	Maximum allowed mean value of the signal in the window compared to the
mb_amp_threshold6	97.0	97.0	In maximum peak-trough pair selection, used in selection of slightly lo
allowed_hp_ratio	2.0	2.0	Allowed ratio between the determined signal frequency and the high cut
allowed_lp_ratio	1.2	1.2	Allowed ratio between the low cut frequency and the determined signal f
mb_allow_counts	false	false	Allow amplitude.amp to be counts when the instrument response is not fo
mb_counts_amptype	hpp_cnt	hpp_cnt	Amplitude measure descriptor when units are counts.

Figure 5: Parameters that control the mb type amplitude measurement.

Measuring Amplitudes for existing arrivals

Automatic amplitude measurements can be also made and re-made for existing arrivals. The arrival popup menu contains three options to measure amplitudes. Display the arrival popup menu by clicking the right mouse button on the arrival label as shown in Figure 6. The *Measure Amplitude* button causes amplitudes to be measured that meet the distance and depth restrictions of the *Amplitude Parameters* window. On the other hand, the *Measure ml amp* and *Measure mb amp* button cause the corresponding amplitude measurement to be made without respect to the distance and depth restrictions.

The Option menu of the *Amplitudes/Magnitudes* window also contains *Measure Amplitude, Measure ml amp, and Measure mb amp* buttons. They measure amplitudes for all selected arrivals in the main waveform window.

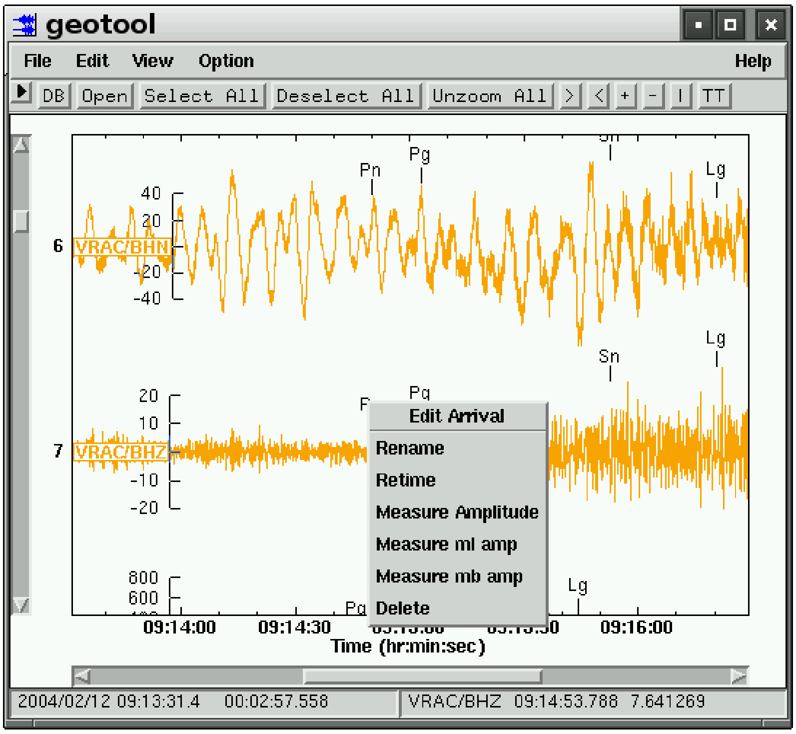


Figure 6: The arrival popup menu has options for measuring amplitudes.

Amplitude Measurement Review and Manual Measurements

Mb amplitudes measurements with *amptype "A5/2"* or *"hpp_cnt"* can be reviewed in the *Amplitudes/Magnitudes* window. Simply select the amplitude record and click the *Review Amplitude* button to display the amplitude measurement box on the waveform or beam. The measurement box can be resized and moved to adjust the *amp*, *per* or *amptime* of the corresponding amplitude record. Click the *Save* or *Cancel* button to save or cancel the changes. Figure 7 shows the *Amplitudes/Magnitudes* window with an amplitude review box drawn on a beam. The filtered waveform or beam on which the amplitude measurement was originally made are re-created and displayed with the amplitude/period box overlying the waveform.

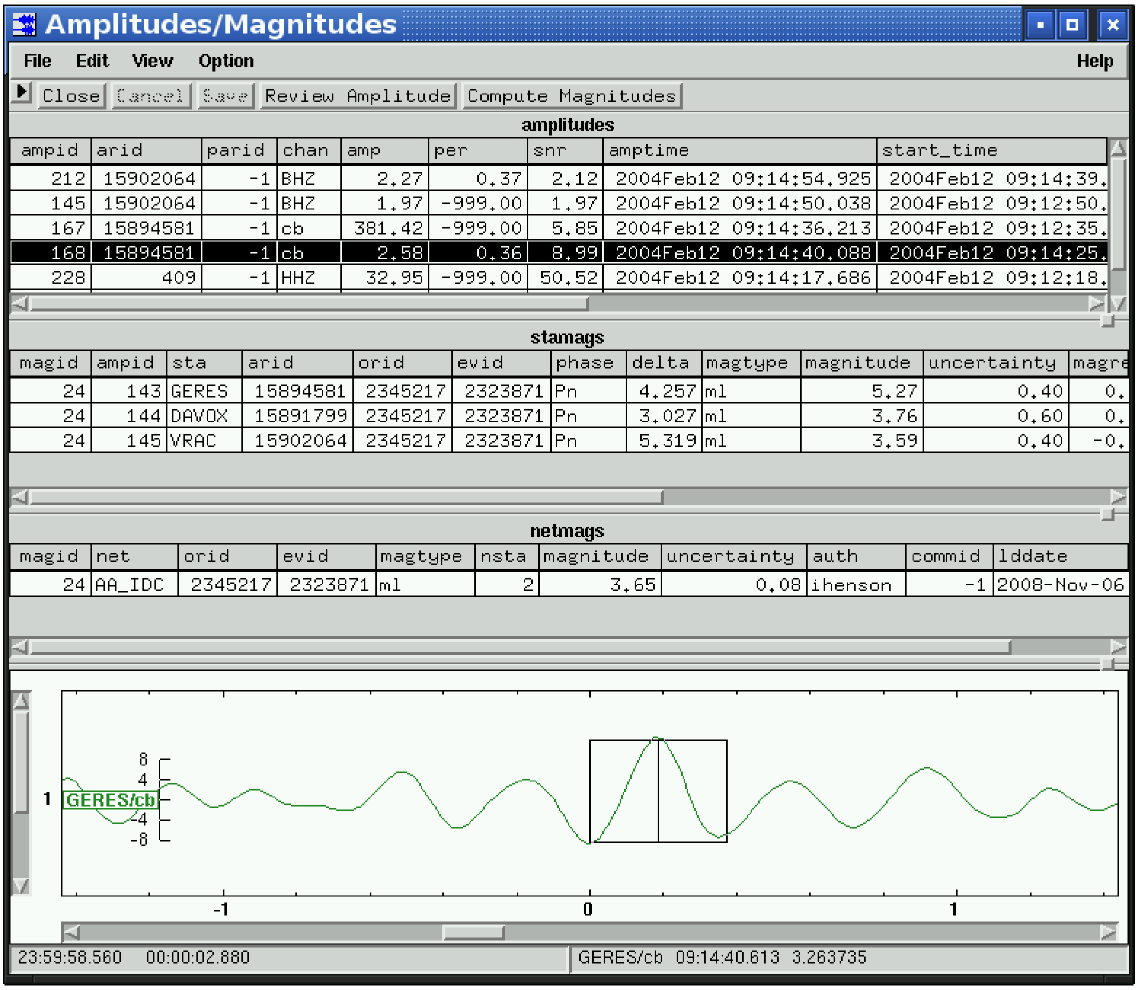


Figure 7: Amplitude measurements can be reviewed and adjusted in the Amplitude/Magnitude window.

The *Measure Amp Per* window provides for the manual measurement of amplitude and period. This window is accessible from both the *Arrivals Option* menu and the *Amplitudes/Magnitudes Option* menu. When the Measure Amp Per window is displayed, a shift-key right-mouse-button click will cause a measurement box to be drawn on the waveform. The box can then be moved and resized with left mouse button drags. The *Save* button creates an Amplitude record with the measured amplitude and period, converted to nanometers.

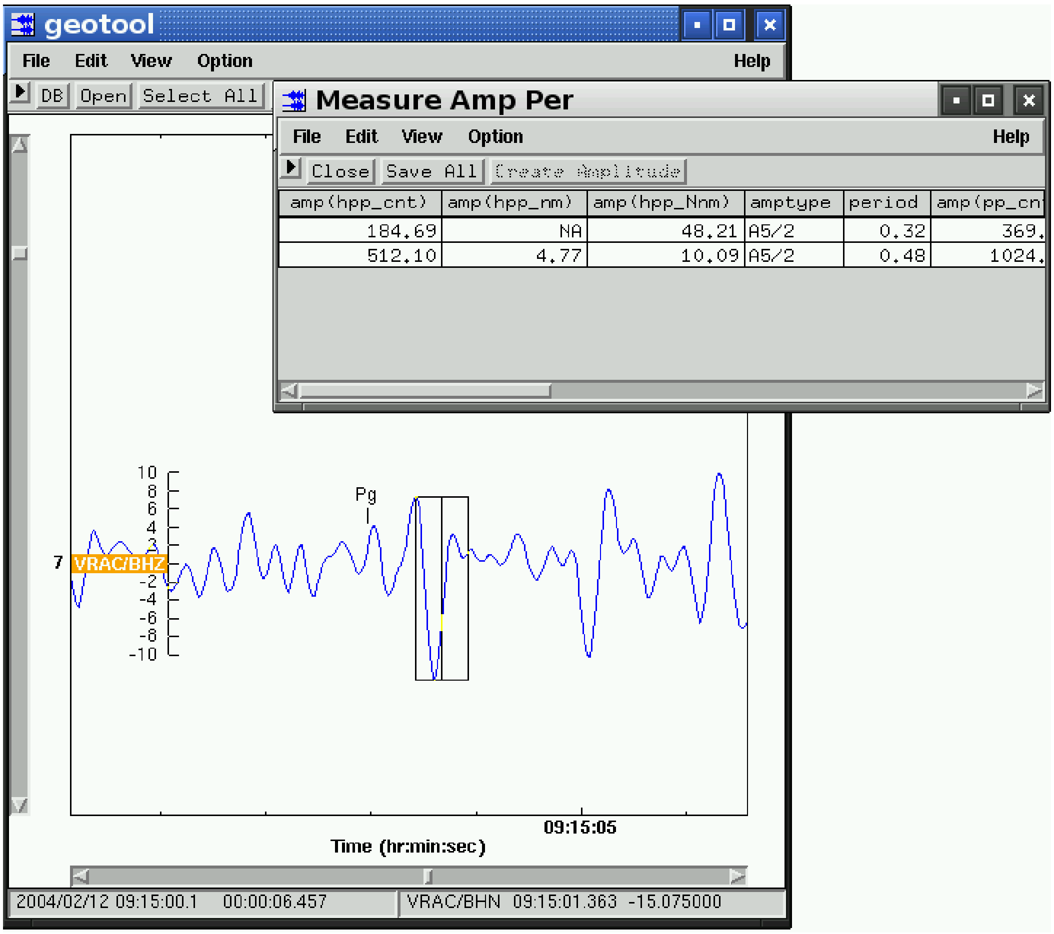


Figure 8: The Measure Amp Per window allows interactive amplitude/period measurement.

Calculating Magnitudes

The *Compute Magnitudes* button in the *Amplitudes/Magnitudes* window will create *stamag* records for all amplitudes and calculate magnitude values which are stored in *netmag* records. If no amplitude records are selected, then all amplitudes are used in the magnitude calculation. If some of the amplitude records are selected, then only those amplitude measurements are used in the magnitude calculation.