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GMS Interactive Analysis (IAN) User's Guide

Version 1.27 (for GMS PI 27 Open Source Release)

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ABSTRACT

This document is a user's manual for the Geophysical Monitoring System (GMS) Interactive Analysis (IAN) User Interface.

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REVISIONS

Revised Sections and Subsections

Added subsection for Azimuth Slowness display (Section 5.10).

Moved subsection under Section 5.3, Signal Detections, to occur before Waveform Options subsection to improve overall flow of document. Signal Detections is now Section 5.3.5 and Waveform Options is now Section 5.3.6.

Added Section 5.3.6.4 to describe the rotation menu in the Waveform display.

Moved discussion of split mode and waveform selection to its own section (Section 5.3.3).

Updated Measure Window section (Section 5.3.6.7) to discuss effects of waveform selection.

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1. GENERAL OVERVIEW

The Geophysical Monitoring System (GMS) Interactive Analysis (IAN) User Interface (UI) is a web-based application that allows a user to access and process waveform data and station definition metadata.

The IAN UI will primarily be used by Analysts, who process waveforms to enhance event signals while suppressing background noise. The Analysts will use the IAN UI to detect, build, refine, locate, and discriminate events.

Currently, the IAN UI has 9 displays:

1) Azimuth Slowness – supports viewing and modifying FK
2) Events – supports viewing bridged event information, the initial event location calculated by automated processing, and location uncertainty bounds
3) Filters – view filter lists and the available filters that can be applied to waveforms in the Waveform display
4) Map – a map of bridge station and site locations, SDs, and events
5) Signal Detections List – supports viewing detailed metadata information about bridged SDs, including association status, in a tabular format
6) Station Properties – provides detailed metadata information about a station selected in the Map or Waveform display, including its channel group and channel configuration
7) Undo/Redo – provides provenance on user actions taken in the UI and supports undoing and/or redoing said actions
8) Waveform – supports querying, viewing, and analysis of bridged waveform and SD data for a set of stations in a time range selected via the Workflow display.
9) Workflow – allows analysts to open, close, and view the current status of data processing intervals. A data processing interval is a discrete portion of the bridged waveform data to be processed by an analyst

This document is an in-depth user's guide for the current version of the IAN UI, including browser requirements and an overview of each interactive display. It will periodically be updated throughout the development of the IAN UI.

2. BROWSER REQUIREMENTS

The UI is currently supported by Chrome and Firefox. Chrome is the preferred browser while Firefox is no longer being tested. The UI will also function on Apple Safari and Microsoft Edge, but with degraded performance.

3. LOGIN

To log into the IAN UI, enter the provided URL (e.g., https://ian.cluster-name:port-number/interactive-analysis-ui/#/) into a supported web browser (Section 2).

After entering the URL, the user will be directed to the login screen (Figure 1).

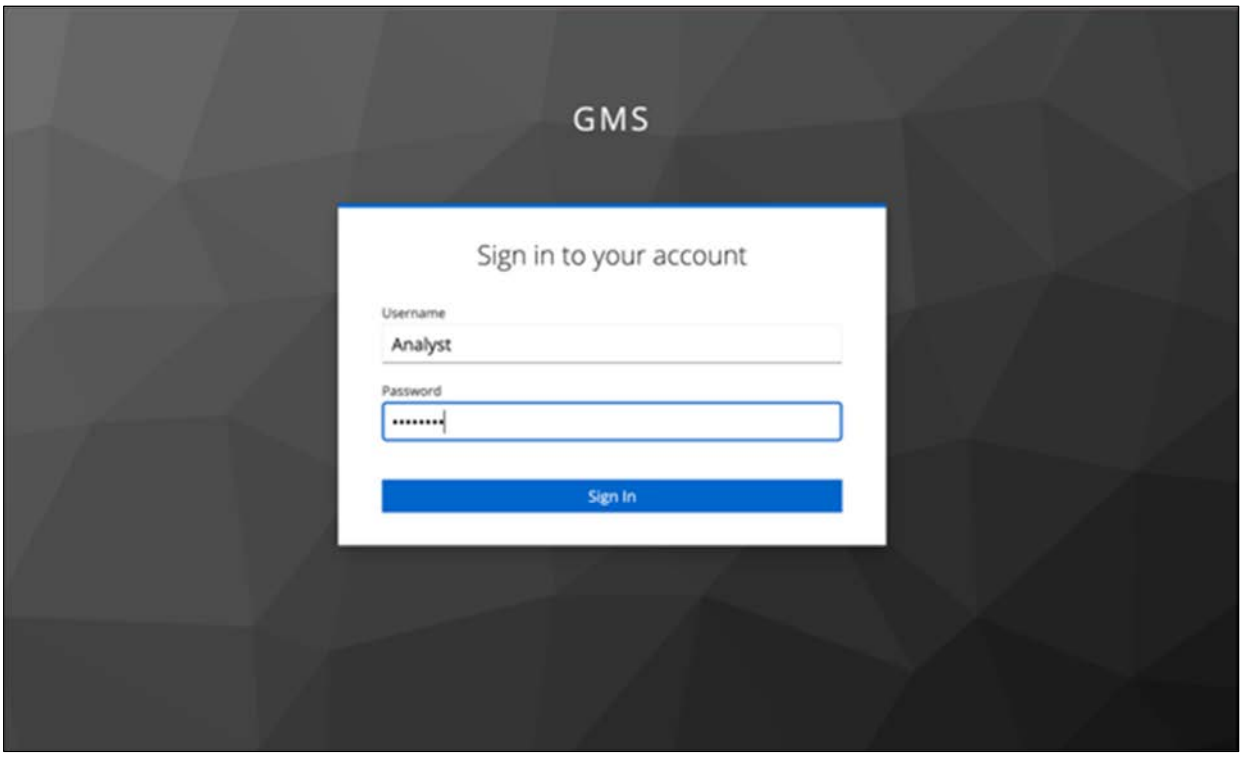


Figure 1. Login Screen for the IAN UI.

At the login page, users enter their username and password to access the UI. IAN will use Keycloak and LDAP credentials to login.

An Update Needed popup may appear in IAN development when there is updated application functionality (Figure 2). This provides the opportunity to cancel or to perform an update. Updating will refresh all open tabs and any unsaved changes will be lost.

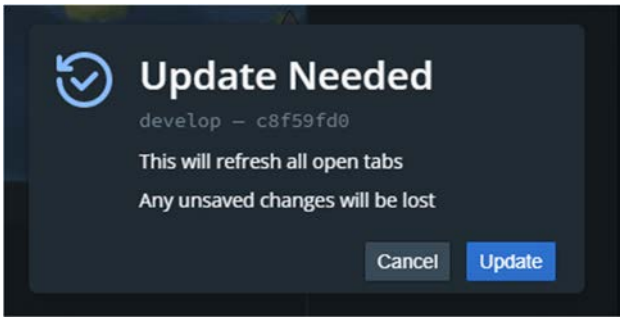


Figure 2. Update Needed popup.

4. DEFAULT WORKSPACE LAYOUT

After logging in, the user will be taken to the default IAN UI workspace layout, currently called Analyst Displays (Figure 3).

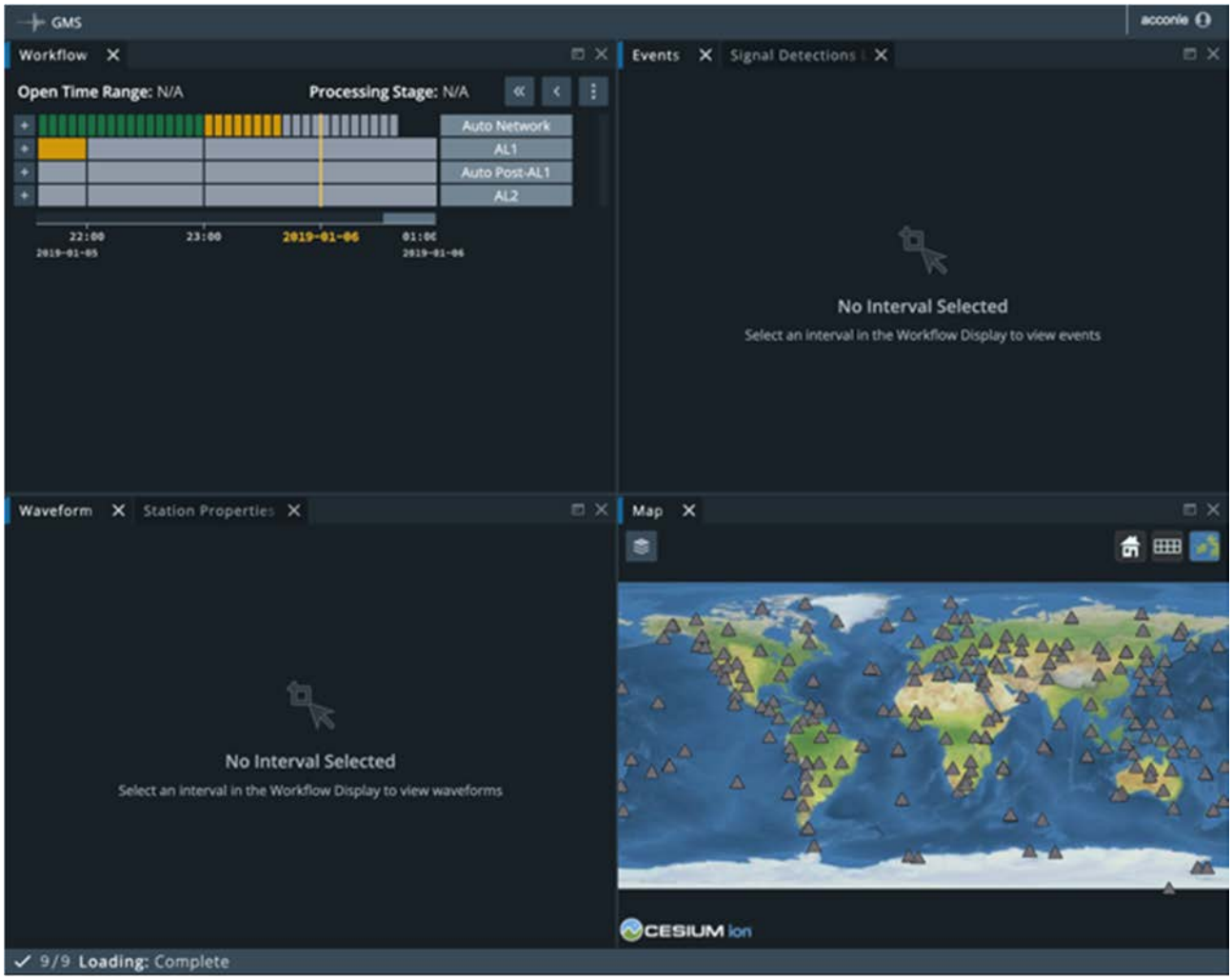


Figure 3. Analyst Displays Layout (Default).

The default IAN UI workspace consists of six synchronized displays:

1. Events (Figure 3, upper right)
2. Map (Figure 3, bottom right)
3. Signal Detections List (Figure 3, upper right)
    - This display can be viewed by clicking on the corresponding tab
4. Station Properties (Figure 3, bottom left)

- This display can be viewed by clicking on the corresponding tab

5. Waveform (Figure 3, bottom left)
6. Workflow (Figure 3, upper left)

Initially, the Waveform, Station Properties, Events, and Signal Detections List displays are unpopulated. The Map display will show the locations of all configured stations within all configured station groups available to GMS as gray triangles. Available stations and their color are configurable (see Configuration documentation). To load 1) waveform data, signal detections (SDs), and quality control (QC) masks into the Waveform display, 2) SDs and events into the Map display, 3) event information into the Events display, 4) SD information into the Signal Detections List display, and 5) filter lists into the Filters display (not shown), an interval, i.e., time range, must be opened from the Workflow display. This action will be described in detail in Section 5.1.1. The Station Properties display will not be populated until a station is selected from the Waveform display (Section 5.3.2), a station is selected from the Map (Section 5.6.2) display, or a station is selected directly from the Station Properties display (Section 5.7). This action will be described in greater detail in Section 5.7.

The default IAN UI also includes an application-level menu button labelled with the user's username in the top-right corner (Figure 4).

Figure 4. Application-Level Menu Button.

The default layout and any other user-defined layout can be modified in six ways:

1) Displays can be moved by clicking the corresponding tab and dragging it to the desired position; this includes placing multiple displays in one window with the display tabs next to each other.

2) Displays can be expanded to full-screen by clicking the maximize button (i.e., box symbol) in the top-right corner of the display. Once full-screen, it can be returned to its original size by clicking the minimize button (i.e., dash symbol) at the top-right corner.

3) Displays can be widened horizontally or vertically by hovering the cursor over their window edge; when the window edge is highlighted blue, it can be clicked and dragged to the desired position.

4) An individual display can be removed from the default layout by clicking the X next to the display name or the X in the top-right corner of the window containing the display. If multiple displays share a window, clicking the X in the window's right corner will result in those displays being removed.

5) Once removed, individual displays can be restored to the default layout by selecting one of the following options from the application-level menu:

a) Select Analyst Displays from the Displays section of the application-level menu (Section 5.1), then select one of the following display names:

i) Azimuth Slowness

ii) Events

iii) Filters

iv) Map

v) Signal Detections List

vi) Station Properties

vii) Undo/Redo

viii) Waveform

ix) Workflow

This action will be described in greater detail in Section 5.1.

b) Select Open Workspace from the workspace section of the application-level menu, then select Analyst Displays Layout (default). This restores the workspace layout to the default layout (Figure 3) unless a personalized layout was made default by the user (see Section 5.1).

c) Select Developer Tools, then select Clear Layout. This restores the default workspace layout (Figure 3). If another workspace layout was saved as the default (see Section 5.1), this will restore to the saved default layout. If the UI has been open for a significant period of time, selecting Clear Layout will cause the user to logout and they will need to log in again.

6) One or more individual displays can be opened in separate browser tabs called "tearable tabs" to allow for more flexibility in arranging the workspace. See Section 5.1.1 for details.

5. DISPLAY INTERACTIONS

5.1. Application-Level Menu

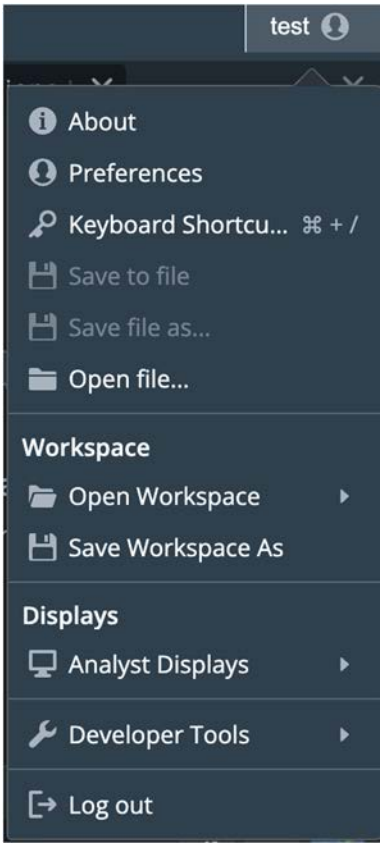


Figure 5. Application-Level Menu Options as appears in Windows.

Application-level menu options include:

1) About – Displays the version of the IAN UI, its latest version, and its latest commit. The latest commit is used by system developers for troubleshooting.

2) Preferences – Provides a menu with User Preference options. Current user preferences include “Color Map” and “Theme.” Hovering over the field will reveal a clickable information icon.

a) The “Color Map” dropdown allows users to select the color map that will be used when displaying FK images. Ten color maps are currently available (see Figure 7). The selected color map is stored in user preferences and will remain effective until the user changes it again.

b) The “Theme” dropdown allows users to select a color theme for the IAN. Two dark modes and one light mode are currently available and still in development (see Section 6).

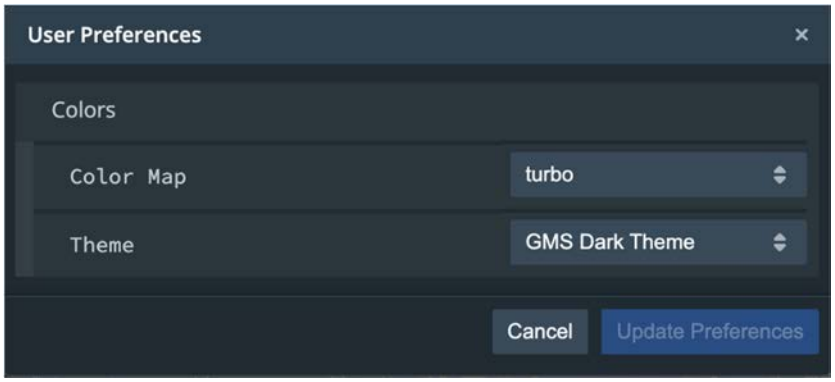


Figure 6. Preferences Menu.

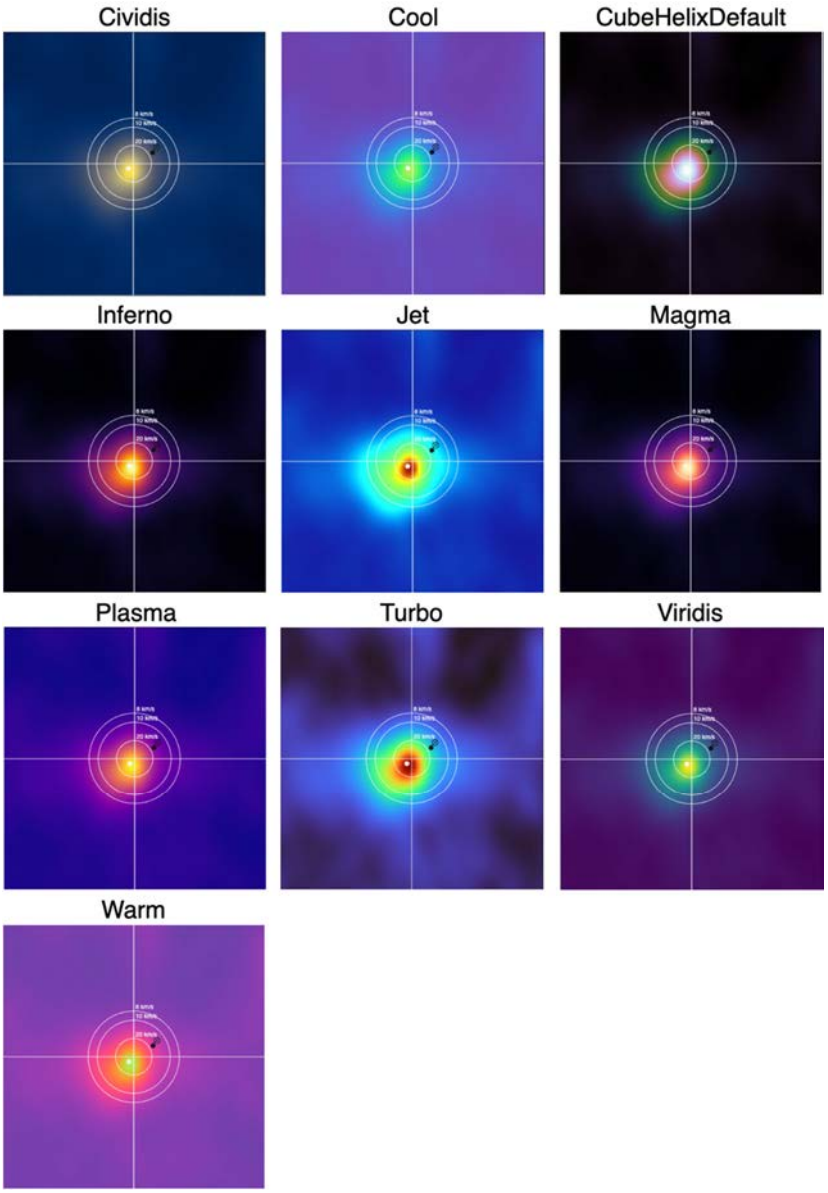


Figure 7. Color Map Options.

3) Keyboard Shortcuts – Provides a list of keyboard shortcuts (i.e., hotkeys) that can be used in the IAN UI (Figure 8). The full list of keyboard shortcuts can be found in Appendix C.

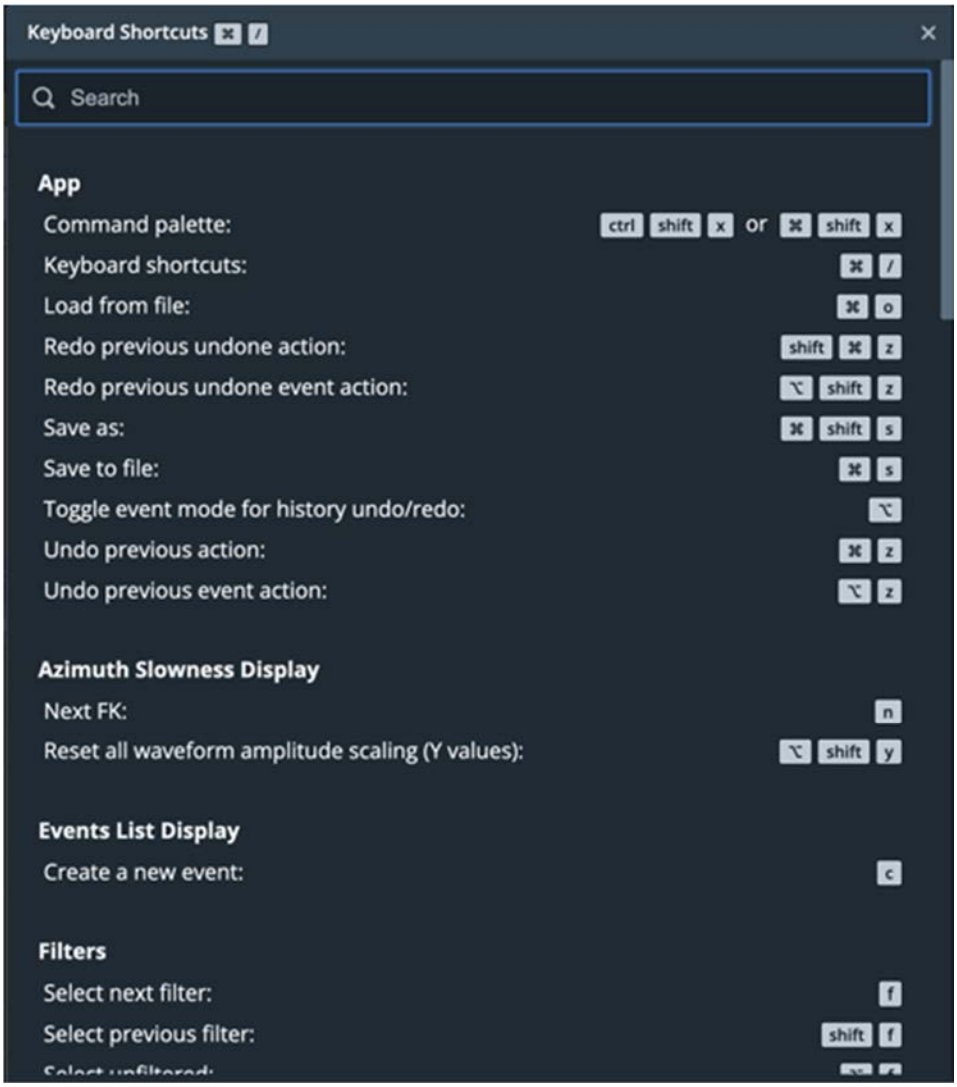


Figure 8. Keyboard Shortcuts List.

Note that in some hotkey combinations mod, short for modifier key, is a stand-in for the modifier key on the OS being run. The mod key will visually update to the OS modifier key (Ctrl/Command or Alt/Option on Windows/Mac, respectively). For instance, in Figure 8, the hotkey combination to retrieve the Keyboard Shortcuts menu appears as mod + /. If the user is on a Mac, mod is replaced by the Command key and the hotkey combination would be Command + / (e.g., Figure 8). If the user is on a Windows machine, the mod key is replaced by the Ctrl key and the hotkey combination would be Ctrl + /.

Within the menu, users can view hotkeys for use within all displays. These hotkeys will be discussed in later sections and are also listed in Appendix C.

In addition, a set of configurable global hotkeys exist that can be utilized within any display. These are:

- The Command Palette hotkey (mod + shift + x), which allows the user to search for available commands in the IAN UI and execute them by clicking the desired command in the dropdown Command Palette Menu (Figure 9).

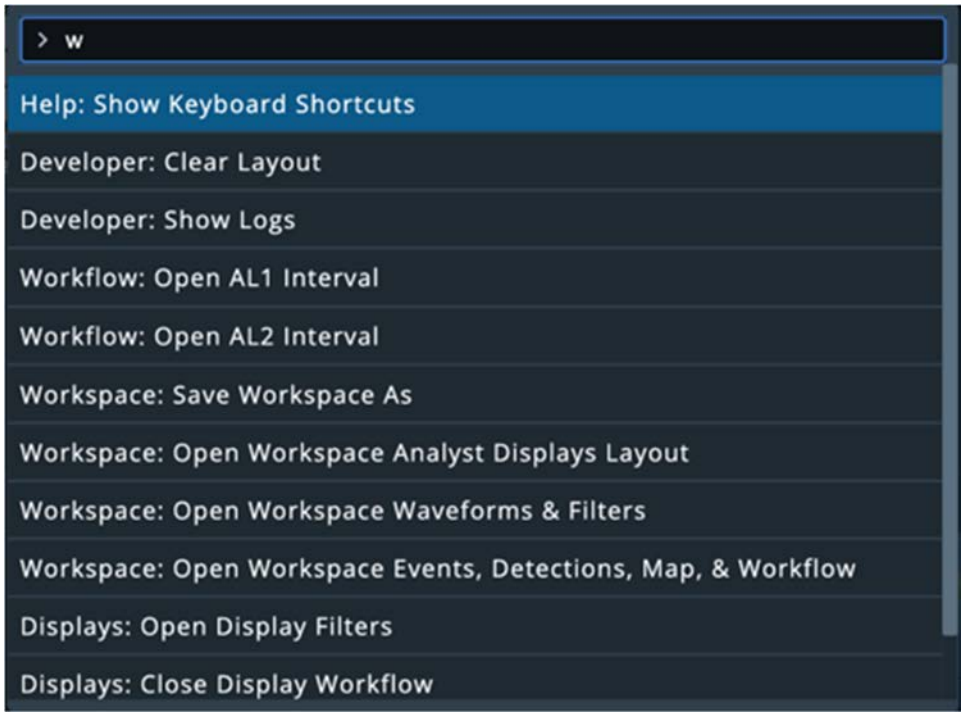


Figure 9. Command Palette Menu with Example Search.

For instance, if the user clicks the Save Workspace As command in the Command Palette Menu (Figure 9), the Command Palette Menu will close and the Save Workspace As menu (Figure 17) will be brought up directly; the user need not access it via the Application-level menu as typically performed (see bullet 4 of this section). To close the Command Palette Menu without selecting a command, click anywhere in the main display or press Esc.

- The Keyboard Shortcuts hotkey (mod + /), which brings up the Keyboard Shortcut menu
- Three hotkey combinations allowing the user to load or save .gms files, which save the state of the IAN UI. These actions and .gms files will be described in bullets 4, 5, and 6.
- Five hotkey combinations providing various undo/redo actions

- These hotkey combinations are specifically discussed in Section 5.9

Information on any hotkey combination in the Keyboard Shortcuts menu can be viewed by hovering to the left of the desired hotkey, which will result in a tooltip appearing.

Hotkey combinations can be searched for via the search bar above the menu. The search will account for anything typed that is based on display, description, or key. For example, typing 'Map' will pull up Map display hotkeys, 'Pan' will pull up panning commands in the relevant displays (i.e., Workflow and Waveform displays), and 'left' will pull up hotkeys with 'left' in the description or the left arrow in the key combination.

4) Save to file (mod + s) – This option allows the user to save the state of the IAN application to a .gms file with an automatically generated filename indicating the processing stage and interval saved, e.g., AL1-2019-01-05T20_00_00.000Z.0.1.gms. When no intervals have been opened in IAN, this option remains grayed out as there is no state to save. The option is made available upon opening an interval.

Upon opening an interval, the user can make changes in the available displays as described in the remainder of this document. Once the user decides that the desired changes are in place, the user can save the state by selecting 'Save to file' or using the hotkey combination mod + s (see Appendix C).

Once the user takes one of these actions, they will be prompted to save the file under the automatically generated file name (Figure 10). The user can modify the name in the save prompt if desired.

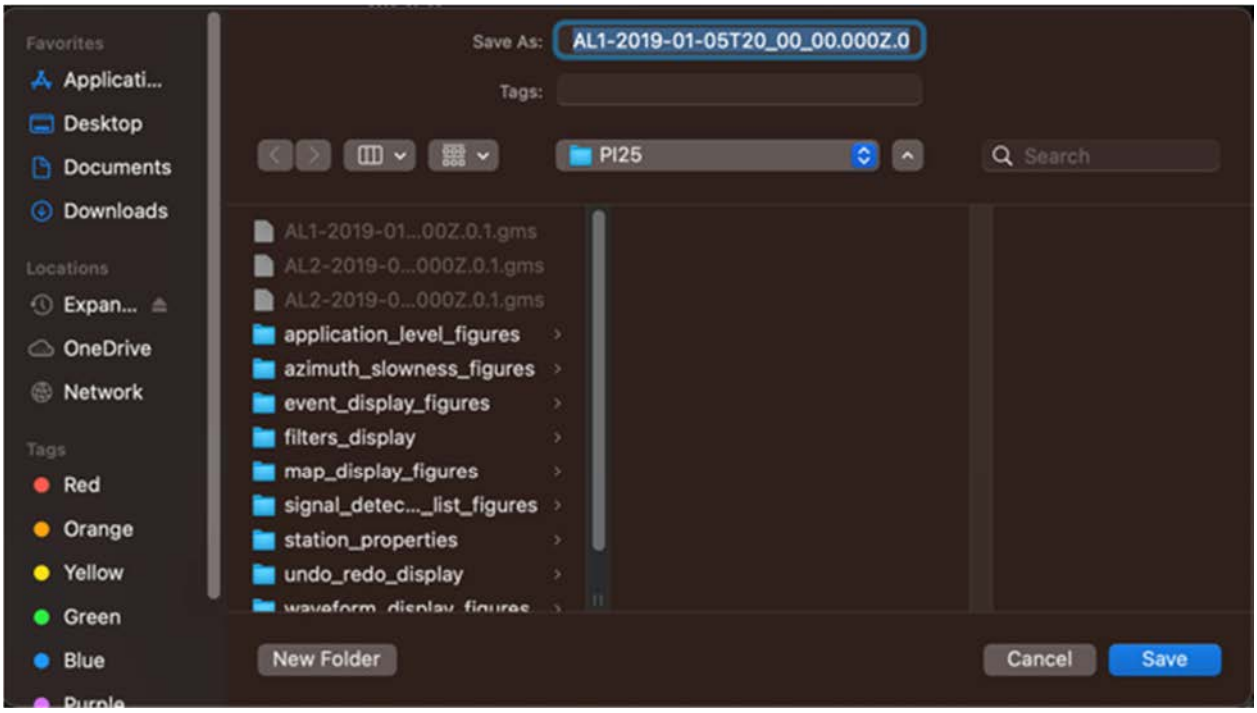


Figure 10. Prompt to Save IAN Application State on a Mac.

Upon clicking Save, the IAN UI will indicate that a state is being saved in the lower-left corner of the UI (Figure 11).

Figure 11. Message Indicating IAN UI State File is Being Saved.

A warning message will appear at lower-right of the IAN UI if there are problems with saving the file (Figure 12).

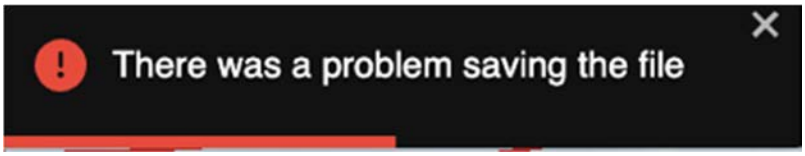


Figure 12. Message Indicating IAN UI State File Failed to Save Correctly.

Because the 'Save as' option automatically generates filenames, if the user wants to save a particular interval's state more than once, the user must either 1) override the original state or 2) manually modify the filename in the prompt (e.g., Figure 10).

Alternatively, the user can use the 'Save file as' option to avoid filename conflicts. This action is described in bullet 5 below.

5) Save file as (mod + shift + s) – 'Save as is the same as 'Save to file', except it allows the user to manually enter a filename for the saved state immediately using the save file prompt (e.g., Figure 10).

6) Open file (mod + o) – Allows the user to restore a state saved in a .gms file. When a state file is opened, the IAN UI will indicate a state is being loaded in the lower-left corner of the UI

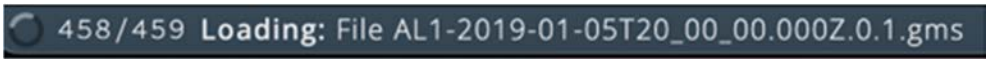


Figure 13. Message Indicating IAN UI State File is Being Loaded.

Once the file is loaded, the state saved in that file will be restored in the IAN UI, including all changes the user made in the displays. This restoration includes restoring open events (Sections 5.4.4, 5.6.4) and undo/redo actions in the Undo/Redo display (Section 5.9).

7) Open Workspace – Shows the current user's available workspace layouts. The layout in Figure 3, titled Analyst Displays Layout, is one example. Two more layout options are provided with the IAN UI. These are the Events, Detections, Map, & Workflow layout (Figure 14) and the Waveforms & Filters layout (Figure 15).

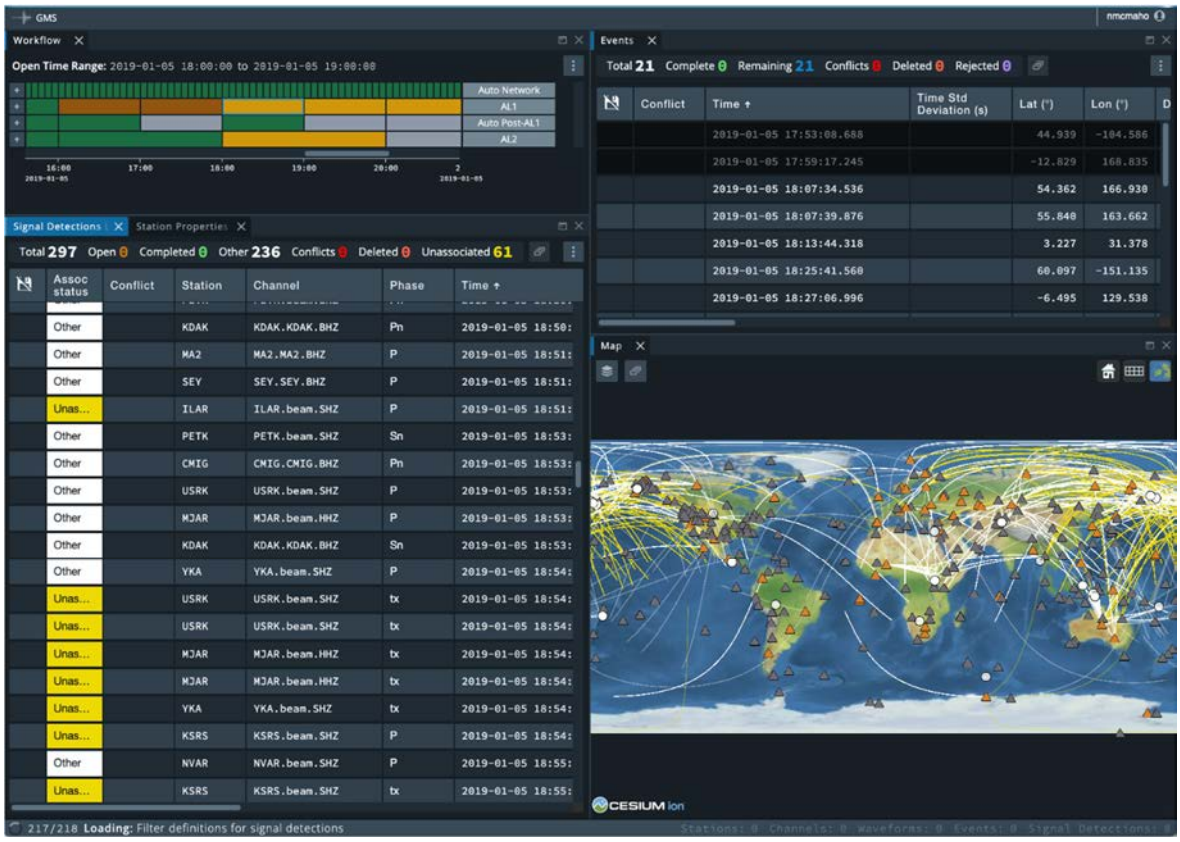


Figure 14. Events, Detections, Map, & Workflow Layout.

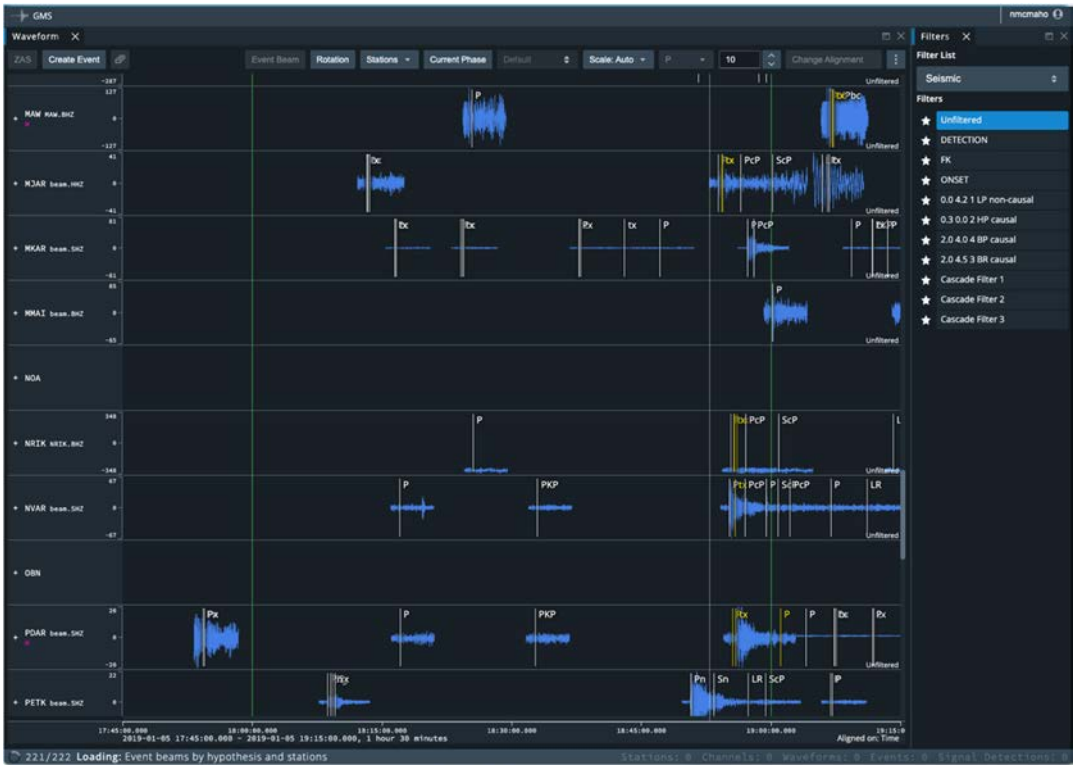


Figure 15. Waveforms & Filters Layout.

More layout options can be made available when the user saves customized layouts by selecting Save Workspace As. If the user makes changes to the current workspace layout and does not save it, they will be prompted to save or discard the changes when attempting to open another workspace (Figure 16). A tooltip providing a brief description of each option can be brought up by hovering the cursor over the desired option.

Figure 16. Prompt to Save or Discard Changes.

From the prompt, the user can choose to open a new workspace layout while either saving or discarding the changes. To save the changes, the user should select Save Changes and Open Analyst Displays Layout. To discard changes, the user should select Discard Changes and Open Analyst Displays Layout. The user can also select Cancel to return to the current workspace layout.

8) Save Workspace As – Saves a preferred UI layout (see Figure 17).

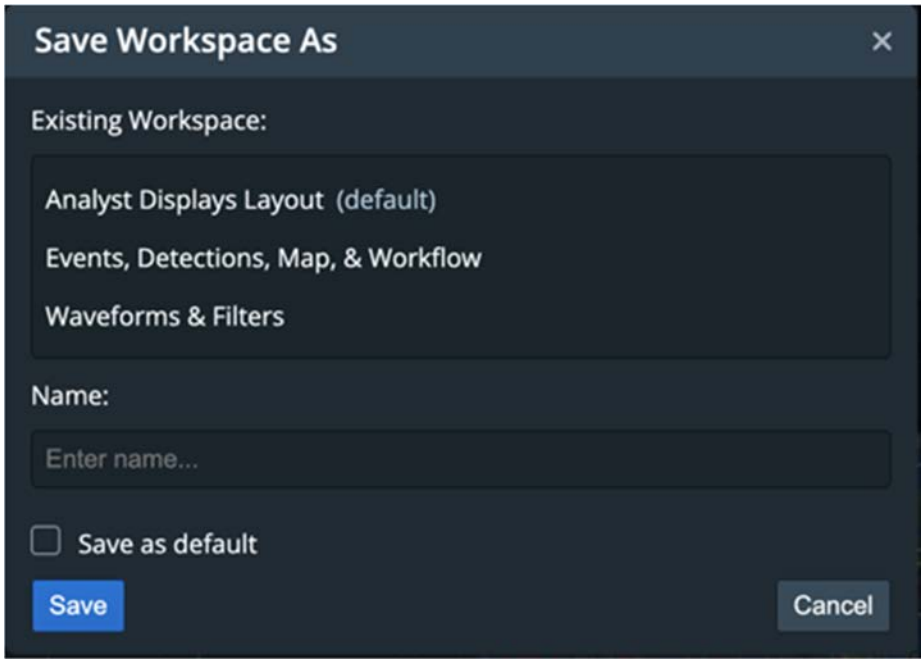


Figure 17. Save Workspace as Menu Options.

A new workspace layout can be saved under the name of an existing layout by clicking on its name in the Existing Workspace dialog box or by typing the entry in the Name field. Alternatively, the user can create a new workspace layout by typing a new entry in the name field. The user can make the new workspace layout the default by checking the 'Save as default' option at the bottom of the context menu. Once saved, the new workspace layout can be accessed by going to Open Workspace (see bullet 2). Currently, saving a new layout as default will affect all users of the system. In a future release, saving a new layout will only affect the current user.

9) Analyst Displays – Adds workspace displays. Only one display instance can be open at a time. Displays already open are grayed out within the Analyst Displays menu. For example, in Figure 18, the Events display is grayed out because it is already open.

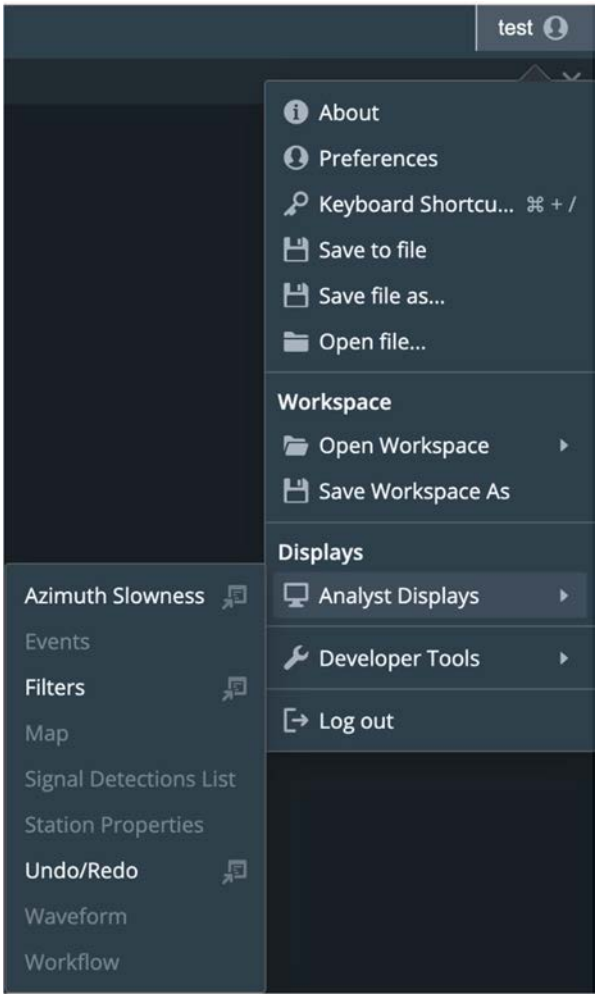


Figure 18. Analyst Displays Menu Options.

The icon to the right of each display option provides the option to open one or more displays in tearable tabs, described in Section 5.1.1.

10) Developer Tools – Provides the user two options:

a) Logs – Lets the user view searchable logs tracked in the UI (debug, info, warn, error, fatal, etc.).

b) Clear Layout – Resets the UI display to the default layout. This option resets the UI to the layout shown in Figure 3 if the user does not have a default custom layout.

11) Log Out – Logs the user out of the IAN UI. If any changes were made to the open workspace layout, the user will be prompted to save or discard the changes before logging out (see Figure 19). A tooltip providing a brief description of each option can be brought up by hovering the cursor over the desired option.

Figure 19. Log Out Menu Options.

5.1.1. Tearable Tabs

In the IAN UI, displays are typically opened within a single workspace layout. However, the user can also open or move individual displays to their own tab using the "tearable tabs" capability. This capability allows for a more flexible workspace arrangement in which users can work across displays in multiple tabs that are still synchronized with the main workspace. Two methods are available for opening tearable tabs, discussed below.

From the main workspace, a tearable tab can be opened by right-clicking on the name of the display, which will produce the option to 'Open DISPLAY_NAME in new tab' (Figure 20); clicking on this option will open the display in its own tab.

Figure 20. Workflow Display with Tearable Tab Option Shown.

Alternatively, the user can click on the arrow and page icon next to the desired display in the Analyst Displays menu (e.g., the Filters display in Figure 18) to open that display in a tearable tab. Hovering over the arrow and page icon will print out this usage to screen in a tooltip.

When a display is opened in a tearable tab, it will automatically be closed in the main workspace. If, prior to closing the created tearable tab, the user attempts to 1) restore that display to the main workspace or 2) open the same display in another tearable tab via the Application menu (Figure 18), a non-ideal state error message will be shown in the tearable tab. This error message indicates that the display is already open in another tab.

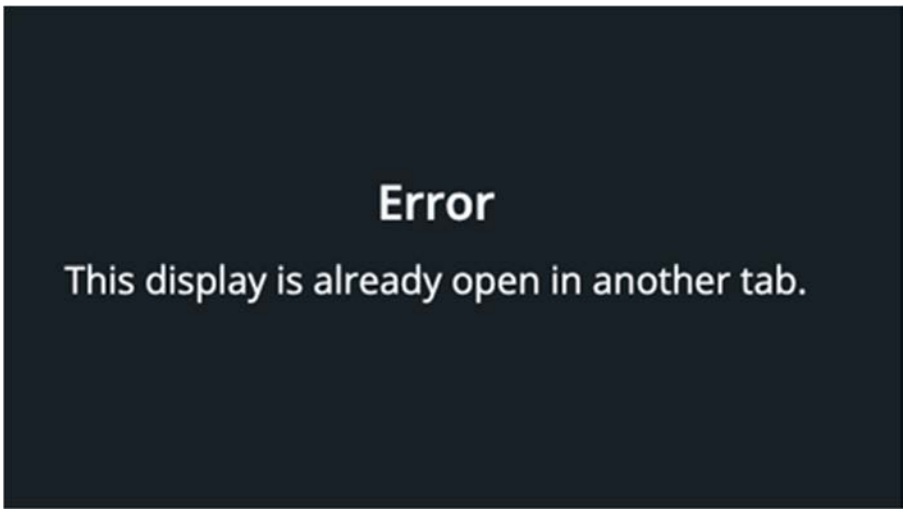


Figure 21. Error Resulting from Same Display Being Opened in Multiple Tabs.

It is recommended that the user close all tabs displaying this error until the display is shown in just one tab.

Note that all displays can be opened in tearable tabs if desired. If all displays are placed in tearable tabs at the same time, the main workflow display will be empty (Figure 22). The user will be prompted to add a display using the Application menu (Figure 18) or the Command Palette (Figure 9, Appendix C) if they would like to continue using the main workspace.

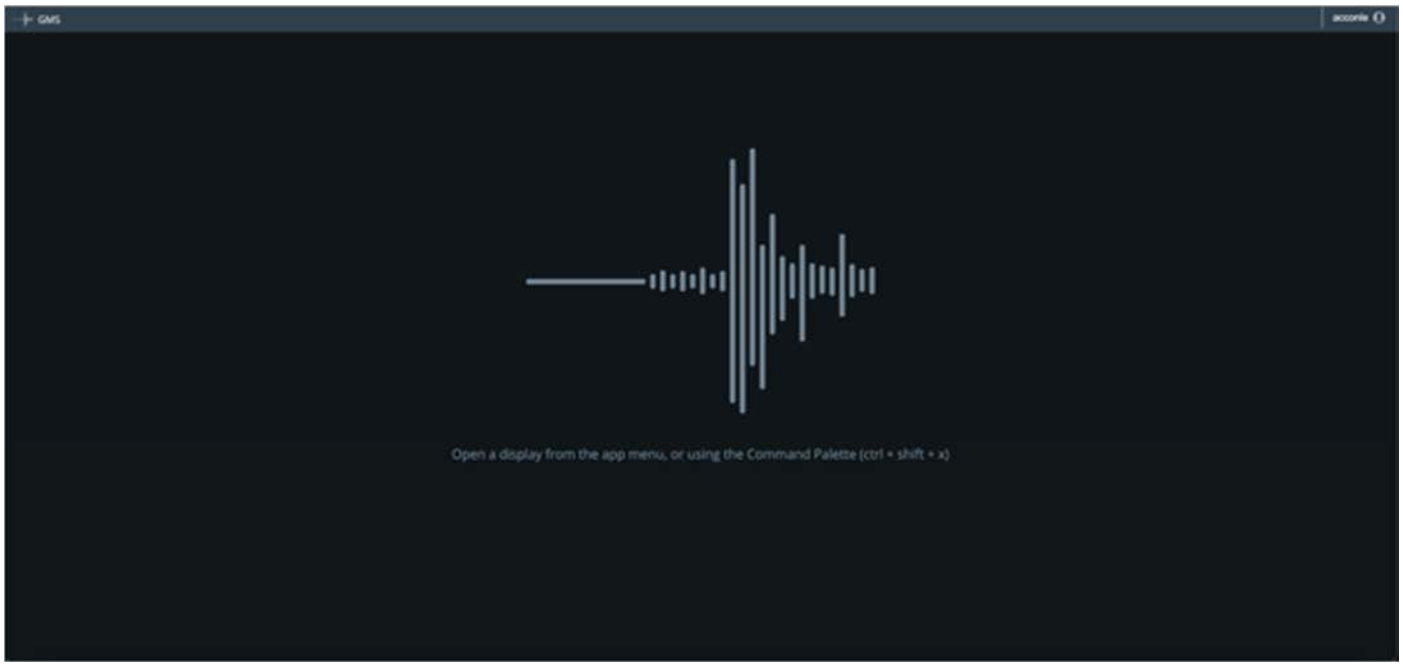


Figure 22. Main Workspace with No Displays Opened.

5.2. Workflow Display

When using the IAN display, both the GMS system and human analysts work on the available waveform data in different processing stages, where each processing stage consists of a different set of processing sequences or activities applied to the data. These stages are listed in the rightmost column of the Workflow display (Figure 23).

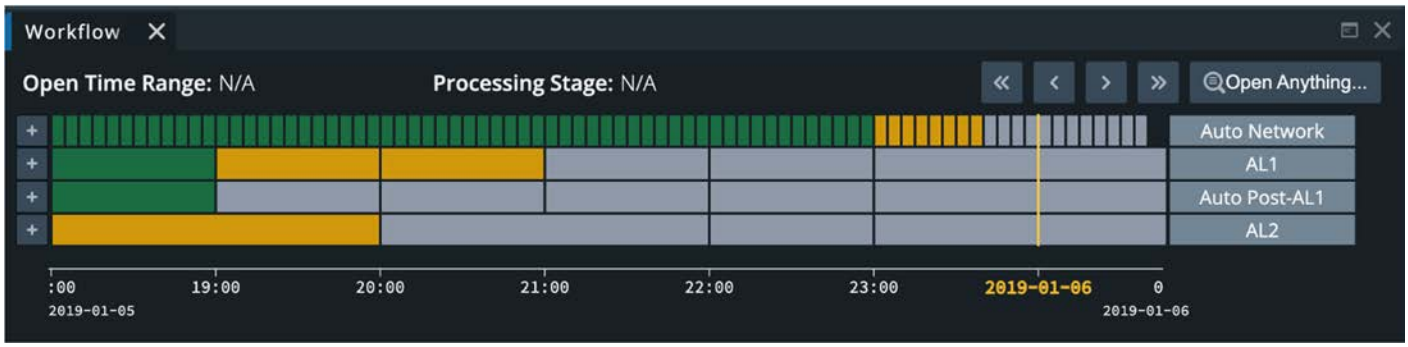


Figure 23. Workflow Display.

The currently configured processing stages are Auto Network, AL1, Auto Post-AL1, and AL2. Auto Network and Auto Post-AL1 are automatic processing stages performed by GMS without analyst input, i.e., not editable by the analyst; this is denoted by an arrow cursor when hovering over an associated interval. These stages are configurable (see Configuration documentation). Under these stages, processing sequences consisting of several processing steps (e.g., association, conflict resolution under Auto Network) are automatically applied to the data. Steps in the sequence are applied to the data one at a time and in order. The current processing sequences are shown in Appendix A and are configurable (see Configuration documentation).

Processing stages AL1 and AL2 are interactive versus automatic, meaning analysts can interact directly with the waveform data, as denoted by a hand cursor when hovering over an associated interval. These interactive stages are configured with a list of activities for the analyst to complete, currently Event Review and Scan.

All processing stages are shown as rows stacked over a shared timeline and are further broken down into blocks of time, i.e., processing intervals, as shown in Figure 23. Processing interval durations are configurable (see Configuration documentation) and can differ between stages. For instance, in Figure 23, the Auto Network processing stage has 5-minute intervals, the AL1

and Auto Post-AL1 processing stages have one-hour intervals, and the AL2 processing stage has two-hour intervals.

By default, the display will show processing intervals for the configurable operational time period (see Configuration documentation). Currently, only twenty-four hours of data are shown (see Section 6). A vertical yellow line indicates the start of a new day. The dates listed at the bottom corners of the display indicate the date range covered by the intervals currently being viewed in the Workflow display. For example, in Figure 23, the left size of the display is showing intervals from 2019-01-05 whereas the right side of the display is showing intervals from 2019-01-06.

Earlier (or later) processing intervals can be viewed by scrolling with the horizontal scroll bar at the bottom of the Workflow display, whether by clicking and dragging or clicking in the scroll gutter. Alternatively, pan buttons within the toolbar at the upper-right of the display (Figure 23) can be used to move forward/backward in time. If the Workflow display is not wide enough, the pan arrow buttons will be placed in an overflow menu denoted by three vertical dots,  . A single or double arrow will jump forward/backward by one day or one week, respectively. Hotkeys are also available for traversing in time (Appendix C). To move by one day, press the left or right arrow key to go backward or forward, respectively. To move by one week, also hold the Shift button while pressing the left or right arrow. These hotkeys are listed in the Keyboard shortcuts menu (Figure 8) or can be viewed via a tooltip by hovering over the pan arrows. The length of time to move forward or backward using the pan arrows or keyboard shortcuts is configurable (see Configuration documentation).

These panning options cannot be used to view processing intervals beyond the configurable operational time period (see Configuration documentation). Since the operational time period is currently set to twenty-four hours (Section 6), the user cannot view data from the previous week by panning.

Populating the UI with waveform data is achieved by opening a processing interval. Only intervals under the two interactive stages (AL1, AL2) can be used to populate the UI, as denoted by the hand symbol when hovering over them. A processing interval is opened by 1) right-clicking the desired processing interval and selecting ‘Open Interval’ (or ‘Reopen Interval’ if the user selected a different interval without closing the current interval) or by 2) double-clicking on the interval. An opened interval is outlined in blue and filled in yellow, where yellow indicates an interval status of *In Progress*. Interval statuses will be described later this section. An example of an opened interval is shown in Figure 24, where the two-hour interval from 18:00 to 20:00 in the AL2 stage has been opened for interaction. The Open Time Range and

Processing Stage being viewed in the UI are shown at the upper left and upper middle of the display, respectively. When no interval is open, these will have values of N/A (e.g., Figure 23). When the Workflow display is too narrow, this information will be in the overflow menu, i.e., the three vertical dots in the upper-right corner of the display. Time is specified in standard Coordinated Universal Time (UTC), formerly referred to as Greenwich Mean Time (GMT), throughout the application.

Each row in the default Workflow display represents all activities of an entire processing stage. To view intervals associated with a specific activity, a processing stage row can be expanded by clicking the plus sign to the left of the row (outlined in green for processing stage AL1 in Figure 24). When a row is expanded, the plus sign becomes a minus sign (outlined in red for AL2 in Figure 24). Clicking on the minus sign will hide activity intervals again.

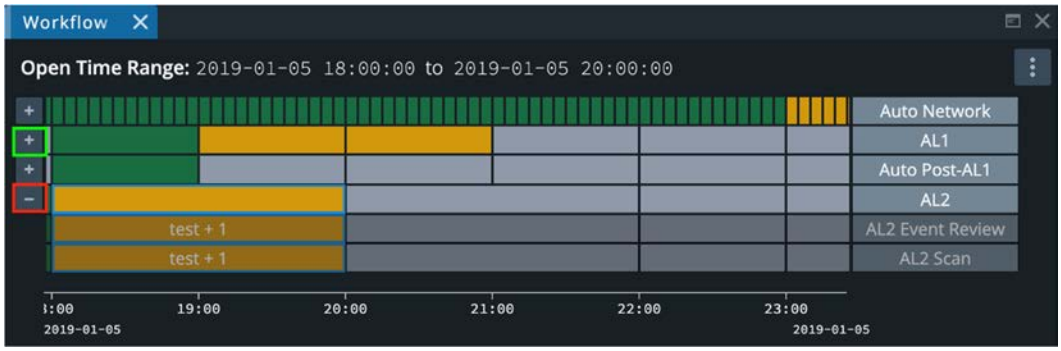


Figure 24. Workflow Display with Processing Stage Expanded.

When the row of processing stage AL1 or AL2 is expanded, intervals associated with Event Review and Scan processing activities are shown. Automatic processing stages can also be expanded to view intervals associated with their respective processing sequences.

An interval can be opened from one of the processing stages (i.e., AL1 or AL2), in which case all corresponding activity intervals within the processing stage will be opened and thus outlined in blue and colored in yellow (i.e., set to *In Progress* status) when expanded (Figure 24). Note that the UI will populated with waveforms from the station group associated with the *first* activity (i.e., Event Review) when an interval is opened from the processing stage row, plus any additional stations on which Signal Detections were made for any Event in the opened interval. To view data for the station group associated with the Scan activity for either AL1 or AL2, the processing stage row must be expanded (Figure 24) and the Scan activity explicitly opened by right clicking or double-clicking the Scan activity interval.

When an interval in one of the activity rows (Event Review, Scan) is opened, both the activity interval and the corresponding processing stage interval are outlined in blue and colored in yellow. One or both activity intervals under a processing stage can be opened; if both are opened, the UI will be populated with waveforms from the station group associated with the *first* opened activity. For instance, if a Scan activity interval is opened prior to opening an Event Review interval, the UI is populated with data from the Scan activity station group.

If the user attempts to open another processing stage or its activity interval(s) without closing all opened intervals under the current processing stage, the warning in Figure 25 will appear. The user can either cancel to remain on the current interval(s) or discard their changes. If the user discards their changes, the current interval(s) will close and the newly selected interval(s) will be opened.

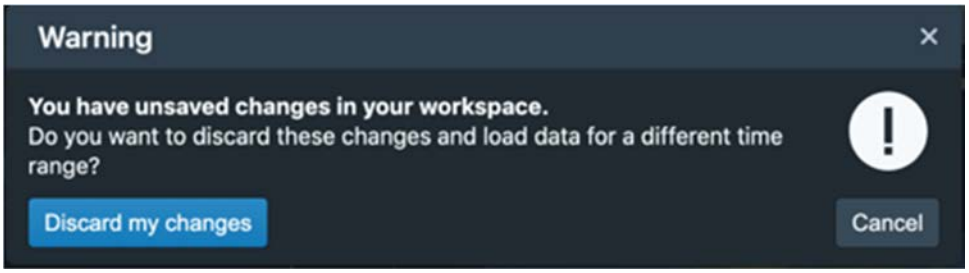


Figure 25. Unsaved Changes to Workflow Display Warning.

When the user opens an interval, their username will be added to the list of active analysts and displayed for the processing stage interval and corresponding activity interval(s). If the user is the only active analyst for the interval, their username will appear in the cell(s) for the opened activity interval(s) (Figure 24). Multiple users can simultaneously work on the same interval(s), in which case, the interval will display the username of the first analyst to open it, plus a count of *additional* active analysts. Usernames of other analysts can be viewed by hovering over the processing interval activity, which produces a tooltip. As analysts open and close intervals, these changes will appear in the Workflow display in real time.

Figure 26 is an example opened interval tooltip, which displays interval status, a list of active analysts, interval start and end time, and the last time the interval was modified. If there are no active analysts, the Active Analysts row will not appear in the tooltip.

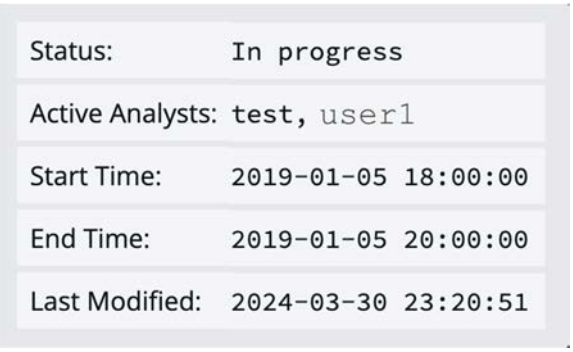


Figure 26. Workflow Display Tooltip.

Once an interval is opened, several IAN UI displays are populated:

- The Waveform display is populated with waveform data, SDs (vertical markers colored based on association status), and QC masks. The selected interval dictates the time range of data displayed in the Waveform display.
- The Map display shows the locations of all stations within all configured station groups in GMS, with stations belonging to the stations shown in the Waveform display colored orange and colored gray otherwise. Note that station locations will be updated in the Map display based on the selected time range and sites are not shown by default. If SDs are available for the selected time range, they will be indicated by great circle paths in the Map display and colored based on their association status. Available events within the selected time range will be indicated by circle markers in the Map display.
- The Events display is populated with event information for events occurring during the selected time range.
- Finally, the Signal Detections List display is populated with signal detection information for the SDs occurring during the selected time range.

With an interval opened, the user can perform analysis of the data using these populated displays.

To close a processing stage interval or processing activity interval, right-click the opened interval(s) in the Workflow display and select 'Close Interval', or double click the opened interval(s). If the Waveform, Events, and Signal Detections List displays are open at the same time all interval(s) are closed, these displays are unpopulated and all triangle icons on the Map display revert to gray.

The status of an interval is indicated in the Workflow display by interval color. A legend of all possible interval statuses and corresponding colors is shown in Figure 27 below. These colors

are configurable (see Configuration documentation). Note that this legend is for demonstration purposes and is not included in the IAN UI.

Figure 27. Interval Status Legend for Automatic (Left) and Interactive (Right) Processing Stages in the IAN Workflow Display.

For automatic processing stages, interval colors indicate the following:

- Dark Gray = Skipped; processing has been skipped by GMS
    - Skips can occur when not enough data are available
- Light gray = Not Started; processing has not begun
- Yellow = In Progress; processing is currently running
- Green = Complete; processing has finished running
- Red = Failed; an error occurred during processing

For interactive processing stages, interval colors indicate:

- Light gray = Not Started; data are available, but the interval has not yet been opened by an analyst
- Yellow = In Progress; at least one analyst has the interval open for analysis
- Orange = Not Complete; an interval has been opened and closed but has not been marked as completed by an analyst
- Green = Complete; an analyst has marked an interval as completed

Note that the color of an individual sequence or activity interval is a shade darker than the processing stage until the user directly hovers the cursor over that interval. Then the interval

color will have the same shading. The darker shading is a visual means to help the user distinguish a processing stage from a sequence or activity.

The status of an interactive processing stage (AL1, AL2) interval is determined via roll-up of the status of all activities in that processing stage. Currently, the available activities are Event Review and Scan. All possible roll-ups are listed in Table 1 below. Roll-ups are read from left to right; for example, in row 5 the combination of the *Not Started* status of Activity 1 and the *In Progress* status of Activity 2 results in an *In Progress* status for the Processing Stage.

Table 1. Status Roll-Ups of Interactive Processing Stages AL1 and AL2.

Activity 1 (Event Review) Status	Activity 2 (Scan) Status	Processing Stage Status (Roll-up)
Not Started	Not Started	Not Started
In Progress	In Progress	In Progress
Not Complete	Not Complete	Not Complete
Complete	Complete	Complete
Not Started	In Progress	In Progress
Not Started	Not Complete	Not Complete
In Progress	Not Complete	In Progress
Not Started	Complete	Not Complete
In Progress	Complete	In Progress
Not Complete	Complete	Not Complete

A Complete (green) status will not be seen in interactive processing stages unless produced by a data simulator since the ability to mark an interval as Complete has not been implemented yet (see Section 6). Note that a Complete status will be seen in the automatic processing stage Auto Network. Hovering over an interval will produce a tooltip that states interval status, as seen in Figure 26.

5.2.1. Open Anything

The Open Anything option (Figure 28), located at the upper-right corner of the Workflow display (see Figure 23) allows the specification of the time range of viewable data, the interactive processing stage from which to load data, and a station group to be used to initially populate the Waveform display. If the Workflow display is too narrow, the Open Anything option can be found in the overflow menu described in the previous section.

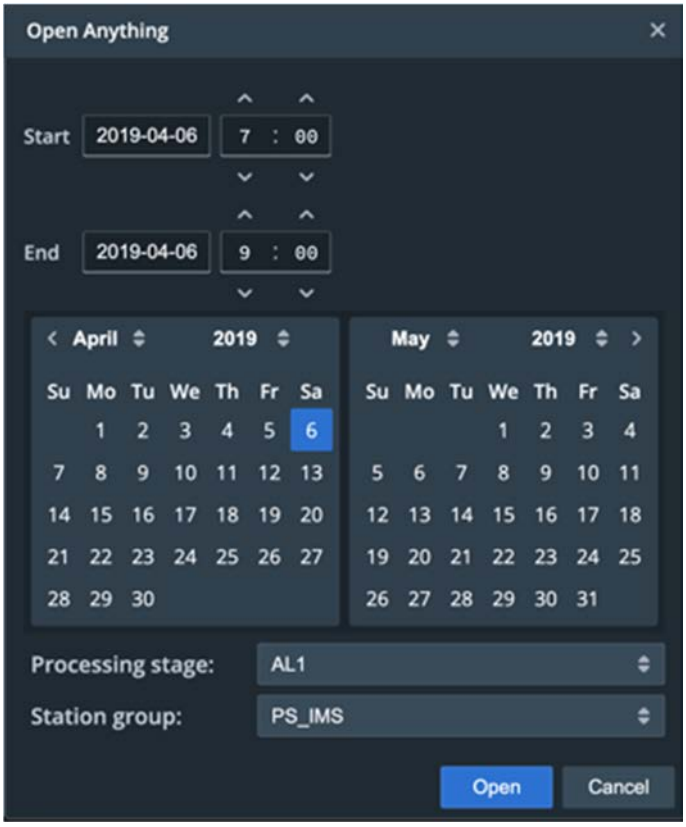


Figure 28. The Open Anything Menu.

The Open Anything option only applies to interactive processing stages (AL1, AL2). While the time range is definable from December 31, 1969, to the current date, permitting testing of Open Anything and viewing of data from the 2019 static test dataset, eventually, the allowable open time range will be restricted to the configurable operational time period (Section 6). Dates unavailable for selection are grayed out.

Within the operational time period, the time range of viewable data can be set via the Start and End entry widget or the calendar. The time entry widgets and calendar are synced such that entries in the widget will highlight (in blue) the corresponding dates on the calendar, while

selections on the calendar will fill the time entry widgets accordingly. Specific hours and minutes will still need to be manually entered in the context boxes.

If the selected start date exceeds the end date when using the context boxes, a warning will be displayed and the Open button will be grayed out. When using the calendar, the UI will automatically use the earliest selected date as the start date.

Figure 29. Open Anything Menu Warnings.

When using the Start and End context boxes, enter each date in ***YYYY-MM-DD*** format. If a different format is used, e.g., 2021:09:12, the entry widget will read Invalid Date and be highlighted in light red (Figure 29, middle). If a date outside the allowed time range is entered (Figure 29, right), e.g., a date in the future, the entry widget will turn light red and read as Out of range. In either case, a valid date must be manually entered by the user.

The hour and minute can be set by either manually entering values or using the up/down arrows to increase/decrease the hour and minute. An incorrect value will highlight the box in red, indicating error. Note that entering new dates in the Start and End context boxes will cause the hour and minute to revert to 0:00. Clicking anywhere will result in the time entry widget reverting to the last valid entry.

Currently, only up to two hours of data can be opened at a time; this length of time is configurable (see Configuration documentation). Exceeding the maximum time range results in a warning and the Open button grayed out (Figure 29, left-bottom).

The time range selected in Open Anything will be listed as the Open time range value at the top of the Workflow display. The interval corresponding to the first interval in the time range opened via Open Anything will be outlined in blue. Otherwise, time ranges opened via Open Anything will not be reflected in the interval table (e.g., interval status will not be set to In Progress and no intervals in the selected time range are opened).

When using the calendar, different months can be viewed using the horizontal arrows at the upper left and upper right of the calendars. (Note that the calendars are synced such that only

consecutive months are shown.) The left/right arrow will shift the calendars back/forward by one month, provided the new month is available, otherwise the arrow will be grayed out. Alternatively, clicking on the month and/or year will produce a dropdown menu from which selections can be made (Figure 30). The same start and end date can be selected by clicking on the desired date twice, which will fill the Start and End entry widgets accordingly.

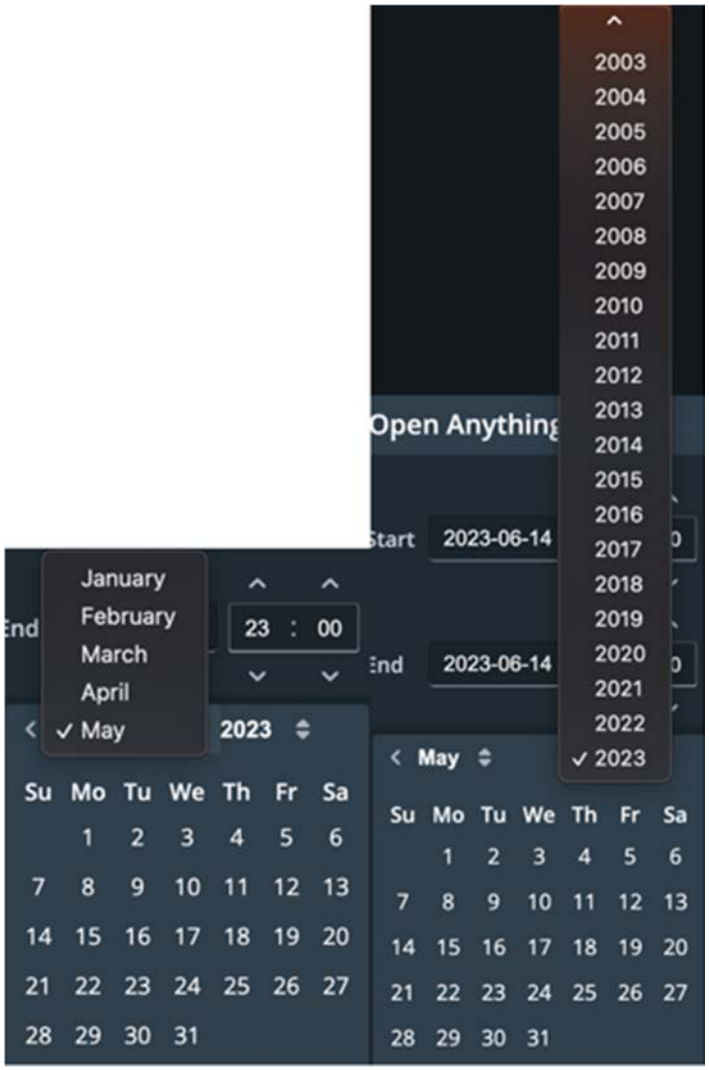


Figure 30. Open Anything Month and Year Dropdown Menus.

Located at the bottom of the Open Anything menu are dropdown menus for the (interactive) processing stage, i.e., AL1 or AL2, and configured station group to view in the UI. By default, the station group is set to that configured for the first activity in the processing stage. For instance, if processing stage AL2 is selected, the station group is automatically set to AuxDel, the group

currently configured for the first activity under AL2, i.e., Event Review. Station groups other than the default group in a processing stage can be selected. Table 2 provides all activities and their currently configured station groups.

Table 2. List of Interactive Processing Activities and Their Configured Station Groups.

Activity	Configured Station Group
AL1 Event Review	Primary
AL1 Scan	AuxDel
AL2 Event Review	AuxDel
AL2 Scan	Primary

Once a valid time range, processing stage, and station group to view are selected, clicking 'Open' will load all relevant data into the displays. The Open Anything menu loads the same data into the Waveform, Map, and Signal Detections List, and Events display as that load when an interval is opened.

If Open Anything is used without first closing an opened interval, a prompt to discard changes will appear (Figure 25). If changes are discarded, the opened interval will be marked as *Not Complete*.

5.3. Waveform Display

5.3.1. Loading and Viewing Waveforms

The Waveform display supports the querying, viewing, and analysis of beams, the raw waveforms they are comprised of, the quality control (QC) masks applied to said raw waveforms, and the beams' associated signal detections (SDs).

Here a beam is defined as a single derived channel representing the sum of a station's raw channels and a "station" can represent 1) a single station (typically a 3-component station), where the station consists of only one physical site (i.e., physical installation) or 2) an array, where the station consists of three or more physical sites. Stations can be seismic, infrasonic, or hydroacoustic. For simplicity, both beams and raw waveforms will be described generally as waveforms through the remainder of Section 5.3 except when a topic specifically relevant to beams or raw waveforms is discussed.

When the UI initially opened, the Waveform display is not loaded with data. The user is prompted to select an interval in the Workflow display (Section 5.2), as shown in Figure 31.

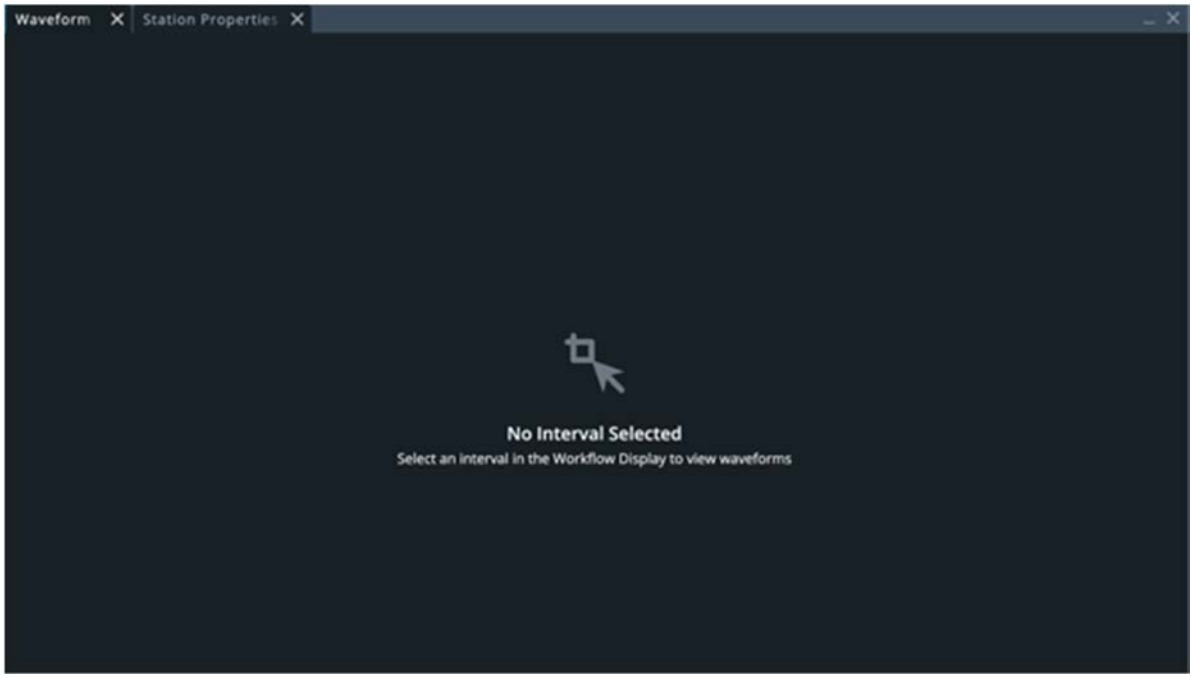


Figure 31. Prompt to Select an Interval to Populate Waveform Display.

When loading begins, a loading indicator (Figure 32) will appear at the bottom-left corner of the IAN UI display (Figure 34). The requested objects being loaded (e.g., Stations by name in Figure

32, left) are listed in the loading indicator, along with a progress indicator showing the number of requests that have successfully loaded over the total number of requests (e.g., 417 of 421 requests have been loaded in Figure 32, left). The loading indicator will read as Complete when all requests are loaded into the display (Figure 32, right). New requests resulting from actions taken in the UI will be added to the total number of requests until the user clears the layout or logs out of the UI (see Section 5.1), which results in the request counter being reset. Note that requests from all other IAN UI displays are also included in the loading indicator count.

Figure 32. The Waveform Loading Indicator.

To view what requests have been loaded into the UI, the user can click on the loading indicator icon to bring up the request list shown in Figure 33.

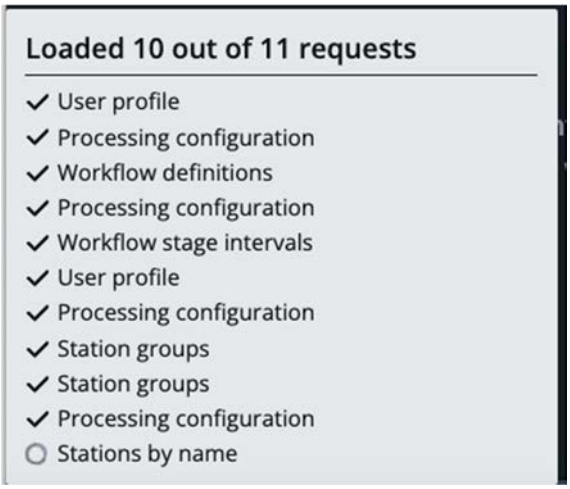


Figure 33. List of Requests Loaded into the IAN UI.

In this list, the total number of requests loaded is indicated at top. Individual requests are shown from oldest at top to newest at bottom. A maximum number of requests is shown in the list at a given time. The number of older requests not shown is indicated at the top of the request list. If the list is opened as requests are being processed, requests in processing will have a circle loading icon to the left of the request. Requests that are complete have a checkmark icon to the left of the request. Finally, requests that fail to complete will be indicated by an icon showing a circle with an exclamation point in the center; the main loading indicator (Figure 32) will show this icon also. To close the request list, click anywhere else in the UI or press Esc.

When loading is complete, the user will see the Waveform display populated as in Figure 34.

Figure 34. The Waveform Display.

Each row in the Waveform display shows the waveforms recorded by a particular station, as indicated by the station name label. These rows are designated as station waveform panels from herein. In the station waveform panels, loaded waveforms are shown in their configured color for the UI theme (blue in the default GMS Dark Theme) and observed SDs are indicated with phase labels colored based on their association status; SDs and their association status are fully described in Section 5.3.5. In the lower right corner of each station waveform panel, a label indicating the applied filter is shown. Upon initial loading, waveforms will be filtered with the default filter of the opened processing activity. A different filter can be applied using the Filters display or its related hotkeys (Section 5.8).

Station waveform panels will show a variety of waveforms including bridged FK beams, bridged event beams, and user-created event beams. For array stations, the waveforms shown will be beams, while for single stations, the waveforms shown will be raw data. In either case, each waveform will have a configurable 5-minute duration (see Configuration documentation). Note that a station waveform panel may be blank if 1) none of the station's waveforms have an associated SD, 2) the request for waveforms fails during loading, 3) the requested data do not exist, or 4) the default filter failed to apply to the waveforms (see Section 5.8).

Waveforms are shown aligned by time by default, as indicated by the text 'Aligned on: Time' at the lower-right corner of the Waveform display (e.g., Figure 34). Waveform alignment is discussed in detail in Section 5.3.8.2.

Vertical green lines in the Waveform display indicate the start and end of the open time range with a 15-minute data buffer on each side. The default time range and data buffer durations are configurable (see Configuration documentation). The date and time durations shown in the bottom-left corner of the display (e.g., 2019-01-05 19:45:00.000 – 2019-01-05 21:15:00.000, 1 hour 30 minutes) indicate the beginning/end times and the total duration being viewed (Figure 34). Changes to the dates/times being viewed in the Waveform display via actions such as zooming or panning will cause the date and time durations to update; these actions will be described later this section.

The user can zoom in or out of a specific time interval by:

- holding down the Ctrl key (Command on Mac) while using the mouse wheel or a two-finger drag on a touchpad (release when desired zoom is achieved); the center of the zoomed frame will be at the cursor location

- pressing the w or s key to zoom in or out by one step, respectively; the center of the zoomed frame will be at the cursor location

- holding the Ctrl key (Command on Mac) while clicking and dragging the cursor to highlight a specific area in which to zoom

- pressing the space bar to completely zoom out

These hotkeys are also described in Appendix C.

There is a limit to how far a user can zoom in; a pop-up message will appear in the lower-right corner of the Waveform display if maximum zoom is achieved. A horizontal scroll bar will appear above the time axis of the Waveform display when zoomed in.

When zooming into a specific time range (i.e., third bullet above), a translucent white window indicating the new time range will appear (Figure 35, Left), along with a ruler and pop-up stating 1) the date, 2) the start and end times of the window and 3) the window duration indicated by the ruler (Figure 35, right).

Figure 35. Window Indicating Time Interval to Zoom Into (left) and Pop-Up Showing Window Duration Information (right).

The ruler shown in Figure 35 can be displayed without zooming in by only clicking and holding the left mouse button. By dragging the white vertical cursor across the screen while holding the left mouse button, time durations can be measured. The duration shown is the time difference between the current and initial cursor locations. Pressing the left mouse button at a specific location will display the date and time for that exact instance. No start time or end time is shown in this case.

The default number of waveform panels in the Waveform display is configured for the activity interval opened in the Workflow display. For instance, the default number of waveform panels is currently configured as 10 for an Event Review activity and 20 for a Scan activity (see Configuration documentation). Additional waveform panels can be viewed by scrolling via the scroll bar. The number of waveform panels can be modified by either manually entering a number in the Number of Channels dialog box at the top-center of the display, located between the Default Phase and Change Alignment dropdown menus (Figure 34), or by using the up/down arrows to add/remove waveform rows. The maximum number of panels to view, currently set to 100, is configurable, while a minimum of one panel can be viewed per screen. At these maximum/minimum values, the up/down arrows are disabled, respectively. The user can manually enter a value that exceeds the minimum or maximum values via the dialog box; this action will result in an red flash of the box and an automatic adjustment of the number of waveform panels to the configured minimum or maximum value.

By default, waveforms loaded into the Waveform display are in units of nanometers (nm) for seismic data, Pascals (P) for infrasound data, and microPascals (µP) for hydroacoustic data. These units reflect the multiplication of the original raw waveform counts by the calibration factor for a given calibration period and are not configurable.

When all data are loaded, the station waveform panels for the configured station group of the open interval may show multiple waveforms. Each waveform (beam or raw) is a 5-minute segment associated with a particular SD; this segment duration is configurable (see Configuration documentation). Every observed SD associated with a given beam or raw

waveform is marked on the station waveform panel and labeled by its phase (e.g., Pn, S, Lg). The color of the phase label indicates the event association status of that phase. SDs and their event association status will be fully discussed in Section 5.3.5.

For array stations with data, the recording station name and beam types displayed in each station waveform panel are provided in a label to the left of the panel (Figure 34). A station label will assume different formats depending on what types of beams and/or raw waveforms are loaded into the station waveform panel, i.e., whether 1) one or more beam types are shown for a station, 2) beams are generated from single or multiple channel components, and 3) SDs from raw channels are shown with the beams in the station waveform panel.

Currently, available beam types are FK beams, which point at the peak energy point in the fk spectra for an associated SD.

Finally, stations with no waveform data will simply be labeled with the recording station name.

Given the above, station labels will appear as one of the following:

- STATION – no data are shown in the station waveform panel.
- STATION beam.CHANNEL – all beams shown in the station waveform panel are the same type and generated from the same channel component. For example, if all beams shown in the ARCES row are FK beams generated from raw SHZ channels, the label will be ARCES beam.SHZ.
- STATION *.CHANNEL – multiple beam types and/or raw channel data generated with the same channel component are shown in the station waveform panel. Three possible scenarios exist:
    - Beams consist of one beam type (i.e., FK or event) generated from the same channel component and raw channel data from that same channel component is also displayed. For example, if the ARCES panel shows FK beams generated with SHZ channels and raw channel data from SHZ channels, the label will be ARCES *.SHZ.
- STATION beam.* – all beams shown in the station waveform panel are the same type and these beams are generated from multiple channel components. For example, if the ARCES panel shows FK beams generated from both SHZ and LHZ components, the label will be ARCES beam.*.
- STATION * – multiple beam types generated with multiple channel components are shown in the station waveform panel and/or raw channel data from the same and/or different channels are also shown. Scenarios described in the STATION *.channel and

STATION beam.* apply here. Finally, this label can occur when an SD unassociated with any data is created (Section 5.3.5.4) in a station waveform panel with data.

- STATION temp.--- – this type occurs when an SD unassociated with any data is created (Section 5.3.5.4) in a station waveform panel with no waveform data.

To view raw waveform data, the station waveform panel can be expanded as shown in Figure 36 by clicking the '+' symbol to the left of the station label (see Figure 34).

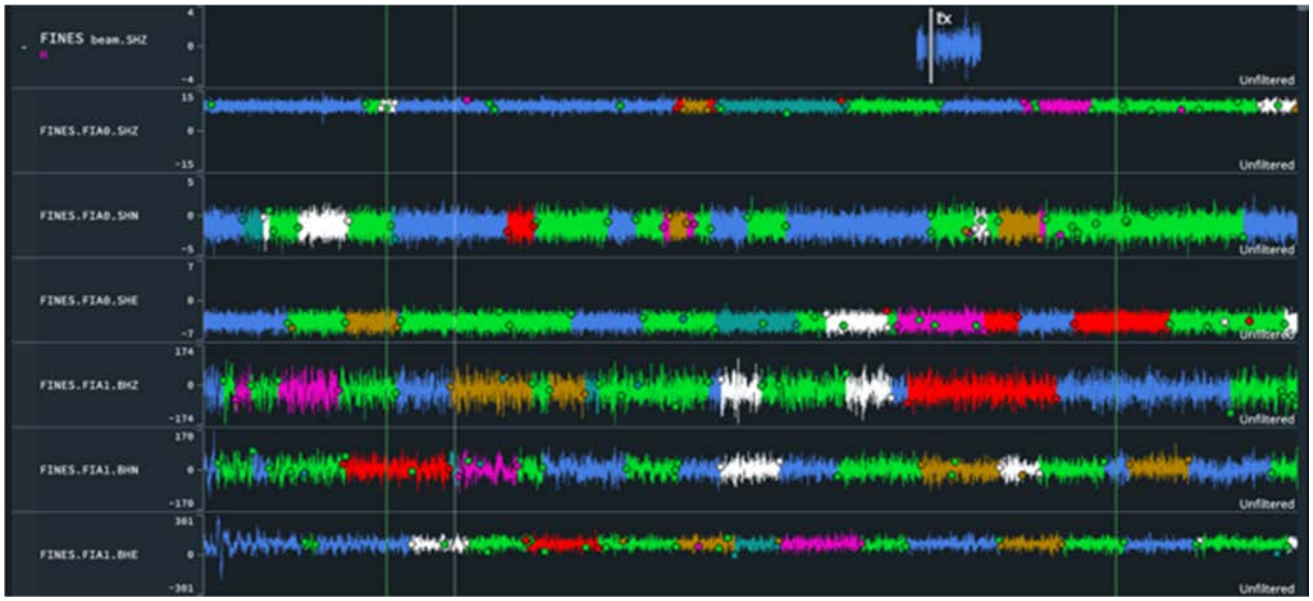


Figure 36. Waveform Display for Station Array FINES With Additional Site/Channel Combinations Shown.

When a station waveform panel is expanded, all available channels for that station are listed in descending alphabetical order (e.g., FINES.FIA0.SHZ, FINES.FIA0.SHN, FINES.FIA0.SHE, etc.). These channels are labeled as STATION.CHANNELGROUP.CHANNEL, e.g., FINES.FIA0.SHZ in Figure 36. For single stations, the STATION and CHANNELGROUP in the channel name are the same, e.g., KIRV.KIRV.SHZ. The raw waveforms in the expanded station waveform row are queried for on demand and load upon expansion unless they were previously loaded via pre-caching or direct retrieval; this loading will be recorded in the loading indicator (Figure 32). To hide the additional channels and their waveforms, click the '-' symbol that replaced the '+' symbol when the station waveform row was first expanded (Figure 36).

Finally, station waveform panels labeled with a magenta M (color is configurable; see Configuration documentation) have QC masks applied to their raw waveforms within the

viewable time range; this M will disappear if the viewable time range does not contain QC masks. These QC masks are visible upon panel expansion, as indicated by different colored waveform segments and dots (e.g., Figure 36). QC masks will be discussed in Section 5.3.7.

5.3.2. Station Selection in the Waveform Display

The Waveform display allows the selection of a station waveform panel. Selection is indicated by highlighting the selected station waveform panel in white, as shown in Figure 37 for station FINES. A station waveform panel is selected by clicking its station label. Note that clicking on the station waveform panel itself will not result in its selection.

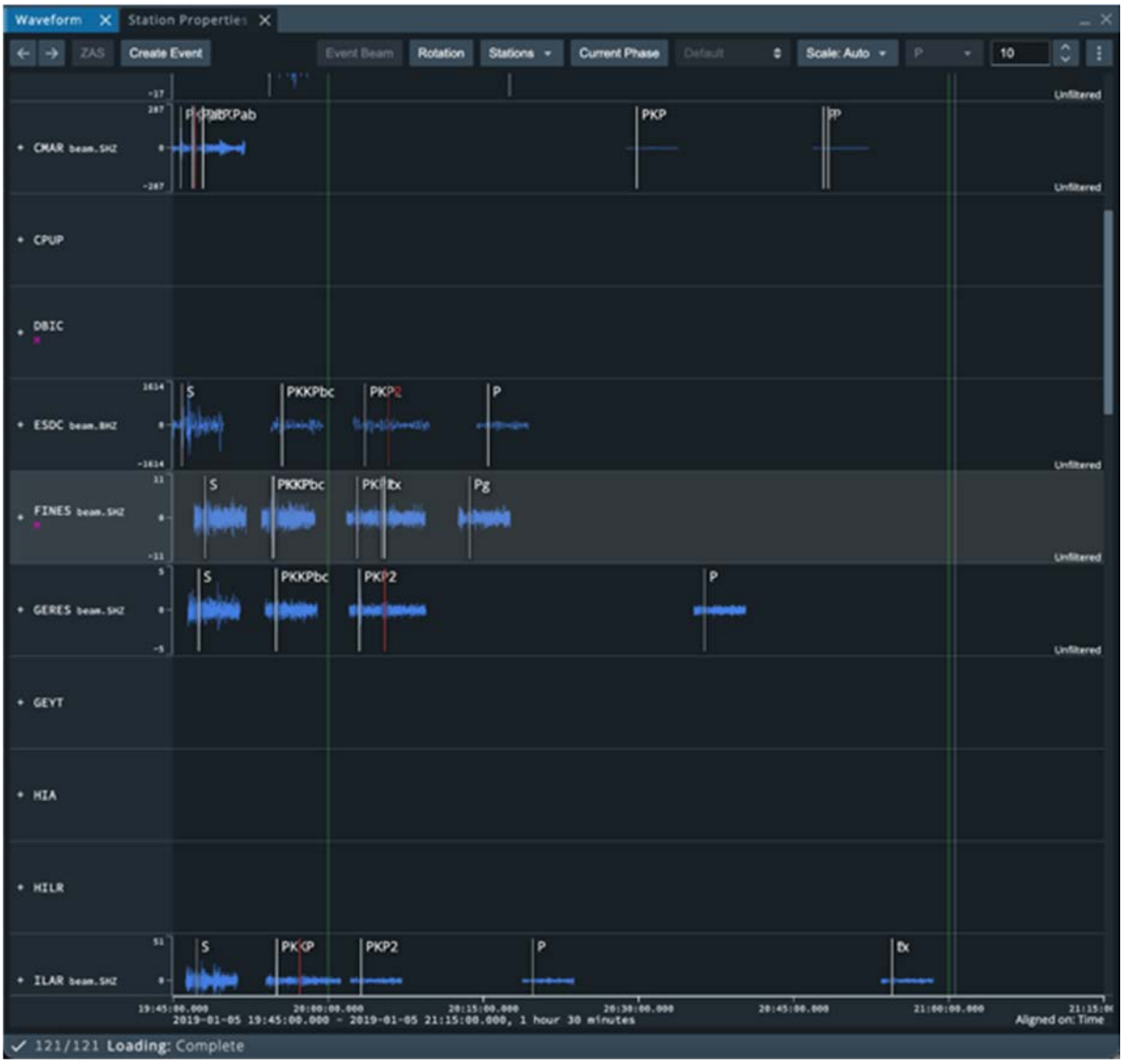


Figure 37. Waveform Display with Station FINES Selected.

The station selection feature is used to 1) synchronize station selections across displays to easily view data in multiple displays, 2), populate the Station Properties display (see Section 5.7), 3) modify waveform amplitude scaling using hotkeys (see Section 5.3.6.5), and 4) perform signal processing operations (e.g., filtering, Section 5.8).

A specific station's channel can also be selected in the Waveform display by first expanding the station waveform panel and clicking on the desired channel label.

In the Waveform display, multiple stations and/or raw channels can be selected in the following ways (also see Appendix C):

- Hold Ctrl (Command on Mac) while clicking on the desired station (and/or channel) labels.
- To select a range of stations (and/or channels), hold Shift and click on the first and last desired station (and/or channels) labels in the range.
- To select a station and all its channels, hold Alt (Option on Mac) and click on the station label.
- To select a range of stations and all their channels, hold Shift + Alt (Option on Mac) and click on the first and last desired station labels in the range.

To remove one or more selections, the user can:

- Click on another station or channel label, causing the initial selection(s) to be removed.
- Hold Alt (Option on Mac) and click on another station label, causing the initial selection(s) to be removed.
- Click on one of the selected stations or channels. This action will remove all selections.
- Click on one of the selected stations or channels while holding Ctrl (Command on Mac) to remove a single station or channel from the existing selection.
- Clicking on the Selected Items button in the Waveform Display toolbar and manually removing stations and/or channels
- Clicking on the Selected Items button in the Waveform Display toolbar and manually removing groups of items by selecting "Deselect All" from a group
- Double-clicking on the Selected Items button in the Waveform Display toolbar to deselect all selected items

5.3.3. Waveform Selection in the Waveform Display

The Waveform display allows the selection of individual waveform segments to visually aid the user in 1) distinguishing waveform segments from each other and 2) indicating which waveform segment to associate a created SD to (SD creation will be discussed in Section 5.3.5.4).

To select a waveform segment, directly click the segment of interest. This action will result in the selected waveform segment appearing in light blue while all other waveform segments in the station waveform panel are dimmed (Figure 38). When a waveform is selected, all associated SDs are also selected. Multiple waveforms can be selected by hold Ctrl (Command on Mac) while clicking on the desired waveforms. Alternatively, they can be selected by holding Shift while clicking on the desired waveforms.

Figure 38. Example Selected Waveform Segment.

Waveform segments in other station waveform panels will be unaffected by the waveform segment selection.

Often, waveform segments overlap each other in a station waveform panel. When clicking an overlapping waveform segment, the user will enter split mode (e.g., Figure 39).

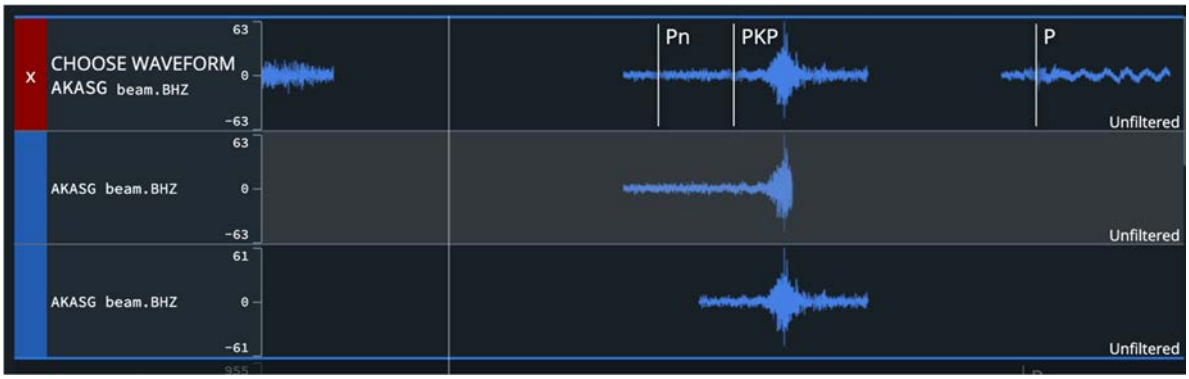


Figure 39. Station Waveform Panel in Split Mode for Station AKASG.

In this mode, the original station waveform panel with all waveform segments is shown at top. Overlapping waveform segments are plotted individually in new station waveform panels shown beneath the original station waveform panel. These panels are surrounded by a blue highlight (e.g., Figure 38) indicating 1) that the user is in split-mode and 2) which panels belong

to that mode. At the same time, panels outside the split-mode are dimmed. Panels are sorted by SD start time such that the waveform segment with the earliest SD arrival time is shown at top and the segment with the latest SD arrival time is shown at bottom.

Hovering over a panel will cause that panel to be highlighted (e.g., the first waveform segment panel in Figure 39). Further, the user can zoom in (Section 5.3.1), manually scale (Section 5.3.6.5), or filter (Section 5.8) the waveform segments in split-mode. Note that if a filter cannot be applied to one or more of the waveform segments in split-mode, its panel will disappear while the user remains in split-mode; cycling to an applicable filter will restore the waveform segment panel(s). The actions described here are the only user actions that can be performed in split-mode. These actions are particularly useful for SD creation, which will be described in Section 5.3.5.4.

Once in this mode, the user can select the desired waveform segment by clicking on the waveform segment in its individual panel. This action will result in the waveform segment being highlighted as shown in Figure 38 and the user will exit split mode. Note that clicking waveform segments in the original station waveform panel in split mode will result in no changes.

To exit split mode without selecting a waveform segment, the user can 1) click anywhere other than the waveform segment in that waveform segment's individual panel, 2) click the red X to the left of the original station waveform panel, or 3) press Esc.

5.3.4. Waveform Display Menus and Options

Several menus and buttons are provided at the top of the Waveform display (Figure 34). Options with an asterisk are currently disabled (Section 6). From left-to-right, these are:

- The Zoom-Align-Sort (ZAS) button used to 1) zoom into a 60-second window (configurable), 2) align all waveforms on the predicted P phase (configurable), and 3) sort stations by epicentral distance from nearest to farthest. An event must be open to use ZAS
- The Create Event button used to create a new event from selected SDs or a new virtual event when no SDs are selected
- Dropdown menu for Selected Items which shows users which items are currently selected across the displays (Figure 40). Users can manually deselect individual items from this menu, deselect all items from a group, or double-click the button to deselect all items in all groups
- The Event Beam button used to manually adjust beamforming parameters and create event beams. An event must be open to use the Event Beam button

- The Rotation button used to manually adjust rotation parameters and create rotated waveforms
- Stations dropdown menu for selecting stations to show in the display; contains all configured stations bridged by GMS
- The Current Phase button used to bring up the menu to set the current phase in the Waveform display. The current phase can be used in SD editing, beamforming, and rotation
- Dropdown menu for setting the display mode*
- Dropdown menu for controlling waveform amplitude scaling
- Dropdown menu for setting the default phase of new SDs*
- Dialog box for adjusting the number of waveform rows displayed per screen
- Change Alignment button for selecting how waveforms should be aligned, either by time or by observed/predicted phase. An event must be open to use Change Alignment
- Dropdown menu for sorting the station list by alphabetical ascending order (default), alphabetical descending order, or by distance (an event must be open the use the distance sorting option)
- Radio button for showing/hiding time uncertainty bars on SDs
- Radio button for showing/hiding predicted phases. An event must be open to use the Predicted Phases radio button
- Dropdown menu for showing/hiding SDs
- Dropdown menu for showing/hiding categories of QC masks
- The Create QC Segment button used to create one or more QC segments in the opened time range. One or more raw channels must be selected (Section 5.3.2) for this option to be available
- Radio button for showing/hiding the Measure Window, which allows the user to view a zoomed-in selected waveform at top of the Waveform display while simultaneously viewing multiple waveforms, including the selected waveform, below
- Arrow buttons that will load more waveform, signal detection, event, and QC mask data before and after the open time range; the amount of waveform data loaded is configurable and set to 15 minutes (see Configuration documentation) of waveform data is loaded; the maximum amount of data loaded with the arrows is configurable and set to 45 minutes (see Configuration documentation)

If the Waveform display is too narrow, one or more of these menu options will be placed in an overflow menu denoted by three vertical dots  in the upper right corner of the display.

The following sections group these menus/options together based on their applications. Section 5.3.5 describes SDs and their associated menus/options (show/hide time uncertainty bars, etc.). In Section 5.3.6, menus/options relating directly to waveforms (pan waveforms arrows, hide/show stations, etc.) will be discussed. An additional option to export waveforms not included in the list above will also be described. Section 5.3.7 will describe QC masks and their associated menus/options (QC mask dropdown menu, etc.). Finally, Section 5.3.8 will detail menus/options that are only available when an event is open (ZAS, alignment dropdown menu, etc.).

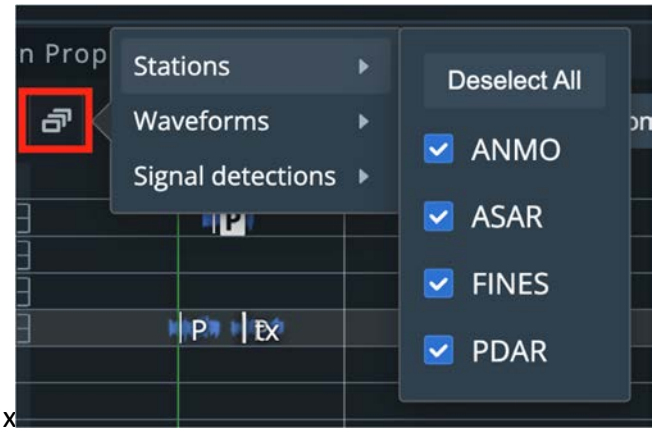


Figure 40. Selected Items Dropdown Menu.

5.3.5. Signal Detections

Signal detections (SDs) in the Waveform display are shown in each waveform panel as vertical lines with a label at the top and to the right of the line (e.g., Figure 41).

Figure 41. An Example Signal Detection.

The position of the line indicates the time at which the signal arrived at the recording station. The label indicates the phase type of the SD. For instance, the phase label in Figure 41 indicates the SD is a first-arrival P phase.

Note that the position of the label is one of two indicators (the other being color, see next paragraph) that shows whether the phase is an observed phase or a predicted phase. A predicted phase represents the estimated arrival time of a particular phase based on a specific earth model (ak135 by default; see Configuration documentation) given the station location and the estimated event location; these predicted phases are calculated by GMS. When the phase is observed, the label is located at the upper-right of the line, e.g., Figure 41. When the phase is predicted, the label is located at the lower-right of the line. Predicted phases will be discussed in detail in Section 5.3.8.

The color of the SD indicates 1) its association status with an open event (see Sections 5.4, 5.6.4 for details on opening events) and 2) whether the SD corresponds to an observed or predicted phase. These colors are configurable (see Configuration documentation). Here, an SD's association status indicates whether that SD was generated by, i.e., associated to a particular event or was deleted. The possible colors are:

- Orange – the SD is associated to a currently open event
- Green – the SD is associated to an event marked as complete (functionality to be enabled in a future release; see Section 6)
- White – the SD is associated to another, unopened event
- Yellow – the SD is not associated to any event
- Red-orange – the SD is deleted and can no longer be modified or associated with any event
- Gold – the SD shown is a predicted phase. Predicted phases are only shown when an event is opened and the predicted phase radio button (see Section 5.3.8.3) is enabled

When the Waveform display is initially loaded, no events are open.

Refer to Sections 5.4, 5.6.4 for how to open an event using the Event and Map displays, respectively. Section 5.3.8 provides a description of the Waveform display when an event is open and includes examples of SDs associated to the open event (orange) and predicted phases (gold); these types of SDs will be discussed further there.

Note that if an SD is associated to multiple events, a red circle with an exclamation point will be shown next to the label of the SD (Figure 42). This icon indicates that there is a conflict, i.e., a single SD is associated to more than one event.

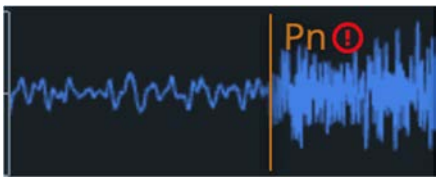


Figure 42. Example of a Signal Detection Association with a Conflict.

When a conflict occurs, the conflict icon will appear in

- the Waveform display next to the phase label
- the conflict column of the row in the Events display corresponding to the opened event (Section 5.4)
- the conflict column of the row in the Signal Detections List display (Section 5.5) corresponding to the conflicted SD
- the Signal Detection Details popup
- the Event Details popup

Additionally, an asterisk will appear in the unsaved changes columns of the Events and Signal Detection List displays next to the rows with a conflict. Events and SDs with conflicts cannot be saved.

Hovering over the conflict icon in the Signal Detection List will display a tooltip indicating which events the conflicted SD is associated to (Figure 43). The same tooltip will be display when hovering over the conflict icon in the Signal Detection Details popup.

Figure 43. Tooltip Indicating Events with a Conflict.

Hovering over the conflict icon in the Event List will display a tooltip indicating which SDs are in conflict (Figure 44). The same tootlip will be displayed when hovering over the conflict icon in the Event Details popup.

Figure 44. Tooltip indicated SDs with a Conflict.

These tooltips are intended to aid the user in deconflicting the SDs, i.e., modifying associations until the SD is only associated to only one event.

Event association and SD conflict will be discussed further in Sections 5.3.8.4, 5.4, 5.5.5.

As mentioned in Section 5.3.1, each SD is associated with a configurable 5-minute waveform segment, which can either be a beam, a rotated waveform, or a raw waveform. The waveform segment will begin 1 minute before the SD; this lead duration is configurable (see Configuration documentation).

Signal detections can be modified in a variety of ways. The following sections detail how to select an SD and all available options regarding SDs in the Waveform display.

5.3.5.1. Signal Detection Selection

To select an SD in the Waveform display, hover over the desired SD. This action does not immediately result in selection, but it causes the SD and its phase label to glow, providing the user a visual aid to select the desired detection. To complete selection, click on the SD; this will cause the SD label to show as a letter bordered by a colored square (e.g., Figure 45) with color indicating association status (see Section 5.3.5). The waveform associated to the waveform will also be selected and highlighted.

Figure 45. Selected Signal Detection (left) Versus an unelected Signal Detection (right).

Multiple SDs can be selected by holding Ctrl (Command on Mac) while clicking on the desired detections. Alternatively, they can be selected by holding Shift while clicking on the desired detections.

To deselect one or more SDs, the user can:

- Click on another SD without holding Ctrl (Command on Mac), thereby deselecting all selected SDs except the current one.
- Click again on a selected SD to deselect all selected SDs.
- Click again on a selected SD while holding Ctrl (Command on Mac), causing that SD to become deselected. All other selected SDs remain selected.
- Click again on a selected SD while holding Shift, causing that SD to become deselected. All other selected SDs remain selected.
- Clicking on the Selected Items button in the Waveform Display toolbar and manually removing SDs individually or by selecting “Deselect all” from the SD group
- Clicking on the Selected Items button in the Waveform Display toolbar and manually removing Waveforms individually or by selecting “Deselect all” from the Waveforms group
- Double-clicking on the Selected Items button in the Waveform Display toolbar to deselect all selected items

When an SD(s) is selected in the Waveform display, it is also selected in the Signal Detections List display (Section 5.5), where the row is highlighted in blue, and the Map display (Section 5.6), where the great circle arc associated with the SD glows. Note that selection of an SD in one of these synchronized displays will also select that SD in the Waveform display; see Sections 5.5 and 5.6 for details.

By implementing SD selection in the Waveform display and synchronizing it with the Signal Detections List and Map displays, IAN provides users the capability to:

- easily view the same data across multiple displays
- associate one or more SDs to an event (Section 5.3.8.4)
- set the phase of one or more SDs (Section 5.3.5.2.2)
- adjust SD arrival time (Section 5.3.5.3)
- perform signal processing operations (e.g., filtering, see Section 5.8)

5.3.5.2. Signal Detection Popup Menu

To view further options regarding SDs, the user can right-click on a desired SD's phase label to pull up the Signal Detection Popup menu (Figure 46).

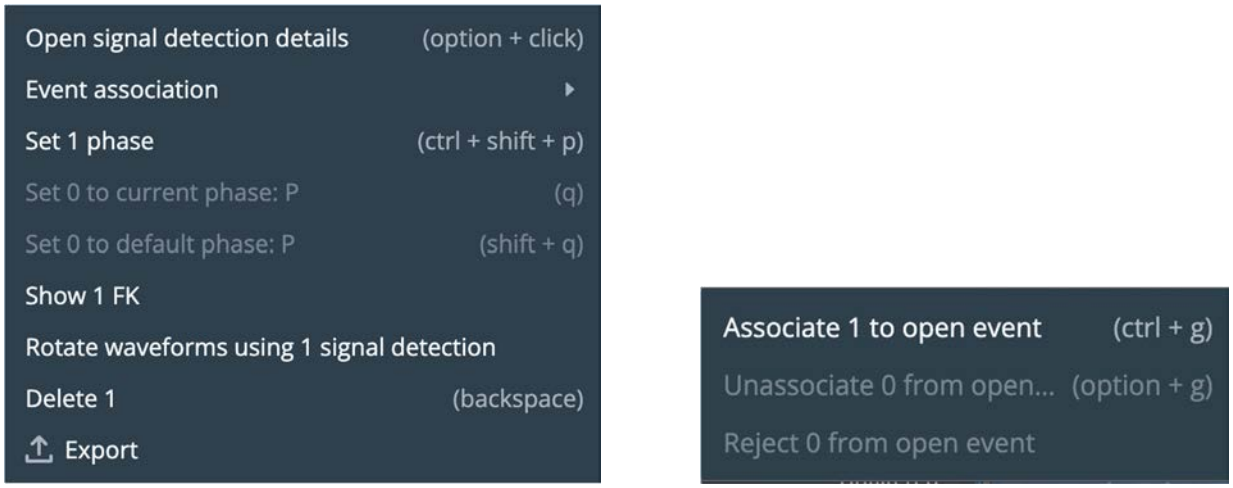


Figure 46. Signal Detection Popup Menu (left) and Event Association Menu (right).

This menu provides the following options:

- Open signal detection details – opens the Signal Detection Details menu shown in Figure 47. This menu provides information about the selected SD and its previous versions
- Event association – allows the user to associate, unassociate, or reject or more selected SDs. An event must be open for this option to be available
- Set # phase – allows the user to set the phase of one or more selected, valid SDs. The total number of valid SDs selected is shown in the option label, e.g., Set 1 phase in Figure 46. Valid SDs are those that actions can be applied to.
- Set # to current phase – allows the user to set the phase of one or more selected, valid SDs to the phase selected as the current phase using the Current Phase menu. The total number of valid SDs selected and the current phase are shown in the option label, e.g., Set 0 to current phase: P in Figure 46
- Set # to default phase: P – allows the user to set the phase of one or more selected, valid SDs to the default phase. Currently, the default phase is set to P; this default is configurable (see Configuration documentation). The total number of valid SDs selected and the default phase are shown in the option label, e.g., Set 0 to current phase: P in Figure 46

- Show # FK – allows the user to view FK plots for each selected, valid SD
- Rotate waveforms using # signal detection – allows the user to rotate each selected, valid SD's associated waveform segment using that SD's source to receiver azimuth.
- Delete # – allows the user to delete one or more selected, valid SDs. This option will cause the SD color to change to red-orange in the Waveforms, Signal Detections List (Section 5.5.5), and Map (Section 5.6.3) displays; the Assoc status and Deleted column in the Signal Detections List display will also update to indicate the SD is deleted. Deleted SDs cannot be modified or associated to any event
- Export – allows the user to export a JSON file containing the SDs' metadata and data of the selected SDs' associated waveform segment. See Section 5.3.6.3 for details on exporting

To close the Signal Detection Popup menu, click anywhere in the IAN UI or press Esc.

The following sections will go through each available option in the Signal Detection Popup menu in detail except for the 'Event association' option, which will be described in Section 5.3.8.

5.3.5.2.1. Signal Detection Details Menu

To view details about an SD, the user can either right-click on the phase label of the SD and select 'Open signal detection details' from the Signal Detection Popup menu (Figure 46) or click on the phase label of the SD while holding Alt (Option on Mac) to bring the details up directly (Appendix C). These actions will bring up the Signal Detection Details menu shown at left in Figure 47. Note that if multiple SDs are selected, the user cannot right-click one of the selected SDs to bring up its Signal Detection Details menu. Instead, the user must use the hotkey combination described above to bring up the menu for a selected SD or right-click on another unselected SD.

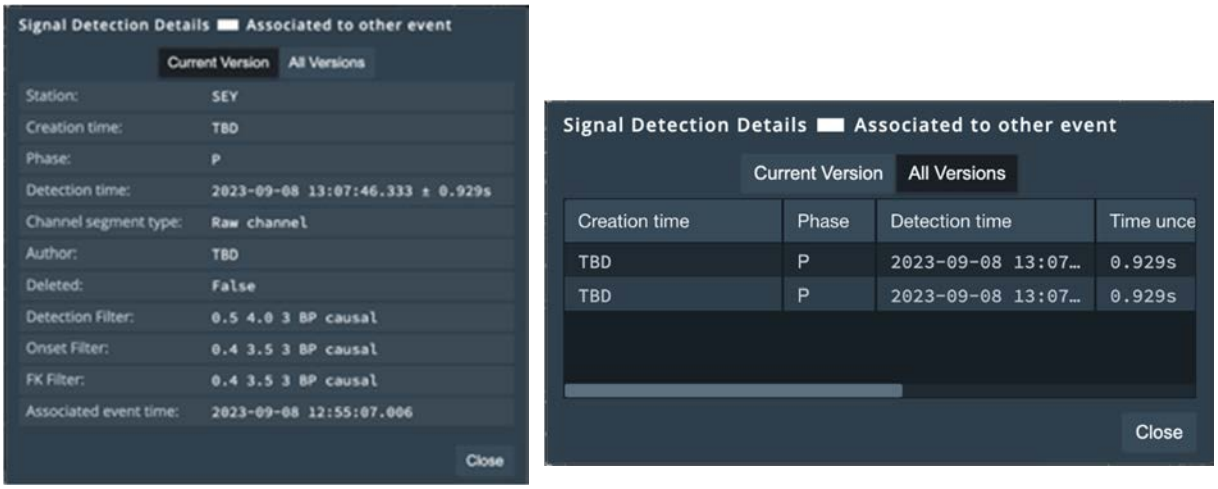


Figure 47. Signal Detection Details Menu Showing (Left) Current Version Information and (Right) All Versions Information for a Signal Detection Associated to Another Event.

In the Signal Detection Details menu, metadata details of the current version of the SD hypothesis are shown. These details include:

1) Station – the name of the station that recorded the SD
2) Creation time – the time the SD was created. Currently always reads as TBD (Section 6)
3) Phase – the SD phase type
4) Detection time – the time the SD was detected (i.e., the arrival time) and its standard deviation in seconds
5) Channel segment type – the type of waveform segment; can be an FK beam, Event beam, or raw channel. These types are described later this section
6) Author – the automatic processing stage or analyst that created the SD. Currently always reads as TBD (Section 6)
7) Deleted – indicates whether an SD has been deleted. Can be True or False
8) Detection Filter – the filter applied to the waveform to detect the signal. This filter is described in Section 5.8
9) Onset Filter – the filter applied to the waveform to determine the onset. This filter is described in Section 5.8
10) FK Filter – the filter applied to calculate the FK. This filter is described in Section 5.8

11) Associated event time – the origin time of the event the SD is associated to. This value is set to N/A when an SD is unassociated or deleted. If the SD is associated to multiple events, multiple times will appear here

Further, at the top of the table a colored box and its corresponding label indicate the association status of the SD being viewed. The colors and their corresponding statuses were described earlier in Section 5.3.5. If the SD is in conflict, the circle icon in Figure 42 is shown to the right of the association status label. A tooltip indicating which events are in conflict as a result of the SD conflict can be displayed to screen by hovering over the circle icon (e.g., Figure 43).

In addition to the Current Version tab selected in Figure 47, left, the user can select the All Versions tab in the Signal Detection Details table to bring up the table shown in Figure 47, right. This version of the Signal Detection Details menu shows the provenance of the selected SD and details how that detection may have changed over time. In particular, the creation time, phase, etc., of each SD version up to the most recent version is shown in column format, with the most recent version at top. The horizontal scroll bar must be used to view all columns.

Information from the Current Version tab of the Signal Detection Details menu (Figure 47, left) can be copied and pasted to external files; this applies to all entries in the table. Information from the All Versions tab (Figure 47, right) cannot be copied in this way.

5.3.5.2.2. Setting Phases

There are three options in the Signal Detection popup menu (Figure 46) that can be used to change the phase type of an SD: 1) ‘Set # phase’, 2) ‘Set # to current phase’, and 3) ‘Set # to default phase’.

The ‘Set # phase’ option can be applied by selecting the SDs for which the phases are to be changed, then 1) selecting the ‘Set # phase’ option from the Signal Detection popup menu (Figure 46) or 2) using the hotkey combination Ctrl + Shift + e (Appendix C). Either action will bring up the Set Phase menu (Figure 48).

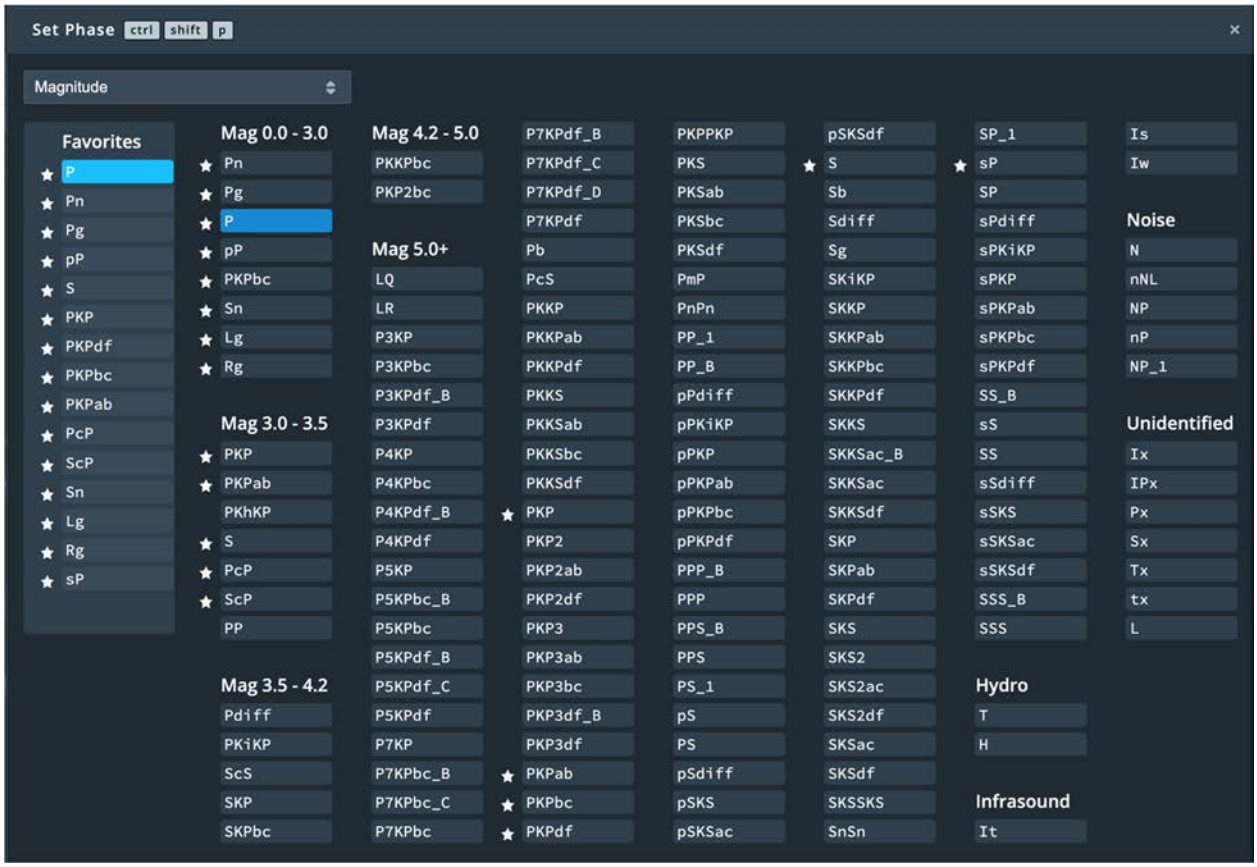


Figure 48. The Set Phase Menu, with Phases Sorted by Event Magnitude.

The Set Phase menu allows the user to choose from a configured set of phase lists (see Configuration documentation). Each phase list is populated with a predefined configured set of phases that may be sorted into configurable phase categories (e.g., Figure 48). A detailed definition of each phase type included in the provided phase lists is beyond the scope of this document. Note that the phases of the SD(s) to be modified are highlighted in the menu in blue.

At the far left of the menu, a list of commonly used phases, i.e., favorites, is provided. The remainder of the menu shows seismic phases sorted by event magnitude, hydroacoustic phases (listed under Hydro), and infrasound phases (listed under Infrasound). By sorting by event magnitude in the case of seismic phases, users can view what phases are expected to be generated by an event of a particular size. For instance, an event between magnitude 0 and magnitude 3 (the Mag 0.0-3.0 category) is expected to generate the phases Pn, Pg, P, pP, PKPbc, Sn, Lg, and Rg. The available magnitude categories are Mag 0.0-3.0, 3.0-3.5, 3.5-4.2, 4.2-5.0, and 5.0+, i.e., magnitudes ≥ 5.0.

The phases in Favorites are drawn directly from the phases listed in the main table, as indicated by the star symbol to the left of the phase label. Phases can be removed from the Favorites list by clicking the star icon next to the undesired phase in the main table (e.g., Pn in the Mag 0.0-3.0 category). Clicking a phase's star icon will cause the icon to disappear and the phase to be removed from the Favorites list. This action can also be performed by clicking the star icon next to the phase in the Favorites list. To add phases to the favorites list, hover to the left of the desired phase label; this action will bring up a star outline. Clicking on the star outline will cause the phase to be appended to the end of the Favorites list. Phases cannot be added back to the Favorites list via the Favorites list.

Note that the default phase, currently configured to be P, cannot be removed from the Favorites list. Any attempt to remove the P phase from Favorites results in a warning in the lower-right corner of the UI indicating that the action cannot be taken.

A dropdown menu (Figure 49) at the upper-left of the Set Phase menu (Figure 48) provides the user three different phase lists that can be viewed in the Set Phase menu. These lists and the categories contained within them are configurable (see Configuration documentation).

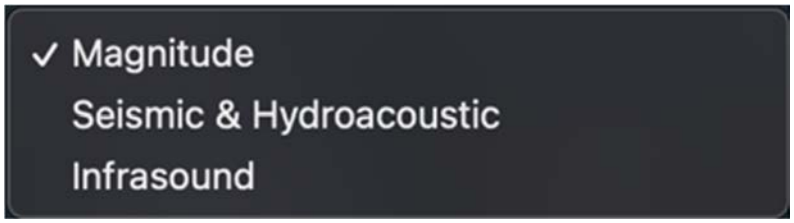


Figure 49. Set Phase Category Dropdown Menu.

Click on the desired phase list in the dropdown menu to update the Set Phase menu to that list. The list currently being viewed is indicated by a check mark to the left of the list name.

From any of these phase lists, the user can click on a desired phase in either the Favorites list or the main menu. This action will change all selected phases to the phase type chosen in the Set Phase menu and the Set Phase menu will disappear. Note that changing the phase type will not change the association status of the SD. To close the Set Phase Menu without applying changes, the user can click on the 'x' in the top corner of the menu, anywhere else in the IAN UI, or press Esc.

So far, the actions described have been related to the 'Set # phases' option in the Signal Detection Popup menu (Figure 46). The other two options, 'Set # to current phase' and 'Set # to default phase' perform a similar role.

By default, the current phase is set to the default phase (here P). To change the current phase using the 'Set # to current phase' option, the user must set the current phase to the desired phase using the Current Phase button within the upper-middle portion of the Waveform display toolbar (Figure 34). When Current Phase is clicked, the Set Phase menu (now named the Current Phase menu) described above pops up, allowing the user to select a new current phase. Once the selection is made, the user can use the 'Set # to current phase' option or the hotkey q to set all selected phases to the current phase. The current phase selected can be viewed in the Signal Detection Popup menu. For instance, in Figure 46, the option reads as 'Set 0 to current phase: P', indicating that the current phase is a P phase; this text will change when the current phase is changed.

Finally, the 'Set # to default phase' option will change all selected SD phases to the configured default P phase. See Configuration documentation for how to change the default phase.

For all three options, the # value updates to the number of phases the option can *validly* be applied to. For instance, in Figure 50, three SDs are selected (Pn, PKP, P). In the Signal Detection Popup menu, the 'Set # phases' option updates to 'Set 3 phases' accordingly. However, both the 'Set # to current phase: P' and 'Set # to default phase: P' options indicate that only 2 SDs will have their phase changed to P. This difference occurs because 1 of the 3 selected SDs is already a P phase; applying either of these two options would have no effect on it. Thus, it is invalid to apply the 'Set # to current phase: P' and 'Set # to default phase: P' options to that SD.

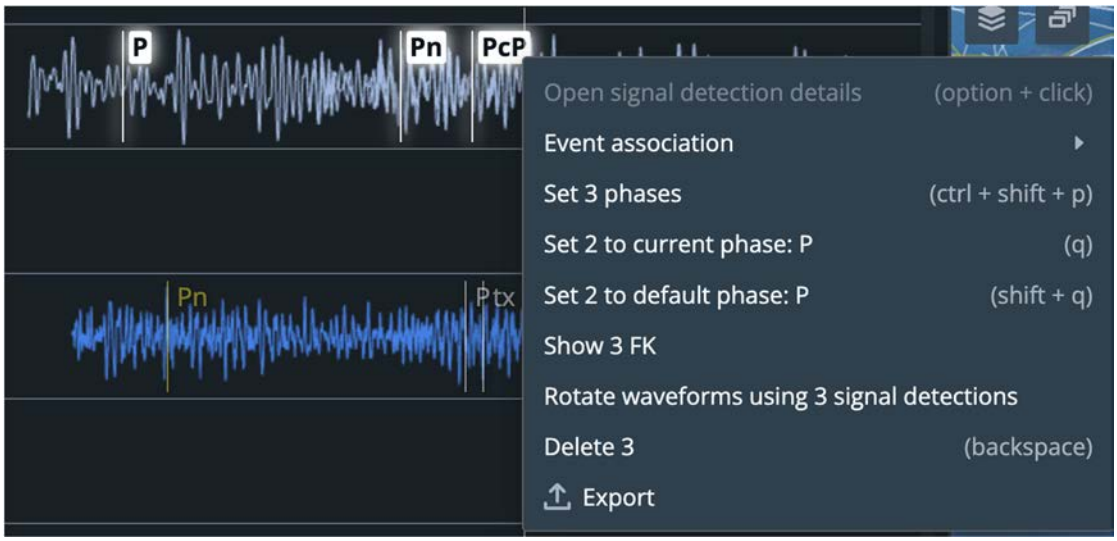


Figure 50. Example Application of Set Phase Options to Signal Detections.

In addition to the # values in the Signal Detection Popup menu changing, the selected SDs the option will be applied to will glow and appear brighter than all other SDs when the user hovers over that option.

Any phase changes made to an SD(s) using the actions described above will cause the same SD(s) to simultaneously update in the Signal Detections List (Section 5.5) and Map (Section 5.6) displays.

The actions described in this section can be undone using the hotkeys Ctrl + Z (Command + Z on Mac) or Alt + Z (Option + Z on Mac; Appendix C) or via the Undo/Redo display (see Section 5.9). Undone actions can be redone using the hotkeys Shift + Ctrl + Z (Shift + Command + Z on Mac) or Alt + Shift + Z (Option + Shift + Z on Mac; Appendix C) or via the Undo/Redo display (see Section 5.9).

5.3.5.2.3. Showing FK Plots

The 'Show # FK' option in the Signal Detection Popup menu (Figure 46) is used to manually populate the Azimuth Slowness display (Section 5.10). The Azimuth Slowness display is used to measure azimuth and slowness and allows analysts to view and interact with FK plot(s) of the selected SD(s) associated waveform segment. The Azimuth Slowness display is not a part of the default workspace layout and must be added using the Application Level menu (see Section 5.1).

To use the 'Show # FK' option to populate the Azimuth Slowness display, select one or more SD(s) (see Section 5.3.5.1 for SD selection) then click the 'Show # FK' option. Note that the # value updates to the number of SDs the FK option can *validly* be applied to.

The FKs and interactions resulting from this action are described in Section 5.10.

5.3.5.2.4. Rotating Waveforms of Selected Signal Detections

The 'Rotate waveforms using # signal detections' option in the Signal Detection Popup menu (Figure 46) is used to rotate configured raw waveforms using the selected SD's azimuth and arrival time. Rotation is described fully in Section 5.3.6.4 and the user is referred there for details.

5.3.5.2.5. Deleting a Signal Detection

In cases where an SD is completely erroneous and thus should not be associated to any event, the user can delete it using the 'Delete #' option in the Signal Detection Popup menu (Figure

46). A deleted SD will not be persisted to the database when saving SDs and/or events. When the user clicks 'Delete #', the SD and its phase label turn red-orange; this color is configurable. Simultaneously, the Events (Section 5.4), Signal Detections List (Section 5.5), and Map (Section 5.6) displays update such that 1) the event row associated to the SD (if any) updated to indicate the change is unsaved (indicated by an asterisk in the unsaved changes column), 2) the row associated with the deleted SD in the Signal Detections List display updates to indicate that the SD was deleted and the change is unsaved (indicated by an asterisk in the unsaved changes column), and 3) the great circle arc associated with the SD in the Map display also turns red-orange. Further, the Signal Detection Details table (Figure 47) will indicate that the phase has been deleted (see Section 5.3.5.2.6).

Once an SD is deleted, no additional actions can be applied, e.g., changing arrival time, phase, association. The Signal Detection Details table using the Signal Detection Popup menu (see Section 5.3.5.2.1).

The actions described in this section can be undone using the hotkeys Ctrl + Z (Command + Z on Mac) or Alt + Z (Option + Z on Mac; Appendix C) or via the Undo/Redo display (see Section 5.9). Undone actions can be redone using the hotkeys Shift + Ctrl + Z (Shift + Command + Z on Mac) or Alt + Shift + Z (Option + Shift + Z on Mac; Appendix C) or via the Undo/Redo display (see Section 5.9).

5.3.5.2.6. Exporting a Signal Detection Waveform Segment

The export option in the Signal Detection Popup menu works is functionally identical to the export option in Section 5.3.6.3 (also see Figure 61, Figure 63) except that the waveform segment associated to the SD is downloaded in JSON format rather than all waveforms for a selected station. Refer to Section 5.3.6.3 for more details on exporting.

5.3.5.3. Modifying Signal Detection Arrival Time

An SD's arrival time can be modified by the user by clicking the desired SD, dragging it to the desired time, and releasing it. This action automatically results in the SD's selection (Section 5.3.5.1). Only one SD can be modified in this way at a time.

Modifying an SD's arrival time in the Waveform display will cause 1) the detection time value in the Signal Detection Details table to update (Figure 47, left), 2) the provenance in the All Versions tab of the Signal Detection Details menu to update (Figure 47, right), 3) the value in the Time column of the Signal Detection List display to update and 4) the SD's great circle arc in the Map display to be recalculated and replotted based on the new arrival time. Currently, only

the position of the SD in the Waveform display changes; the arrival time remains unchanged in the cases described above (Section 6). The action will be registered in the Undo/Redo display (Section 5.9).

If an SD associated to a raw waveform is moved more than 10 seconds from its original time, a new trimmed channel segment will be created around the time of the SD in the station panel and replace the previous trimmed channel segment. The lead and duration of this new channel segment is configurable as well as the amount of time triggering new channel segment creation (see Configuration documentation).

The actions described in this section can be undone using the hotkey Ctrl + Z (Command + Z on Mac; Appendix C) or via the Undo/Redo display (see Section 5.9). Undone actions can be redone using the hotkey Shift + Ctrl + Z (Shift + Command + Z on Mac) or via the Undo/Redo display (see Section 5.9).

5.3.5.4. Creating Signal Detections

To create an SD, right-click anywhere in the waveform panel to bring up the Create Signal Detection menu in Figure 51.

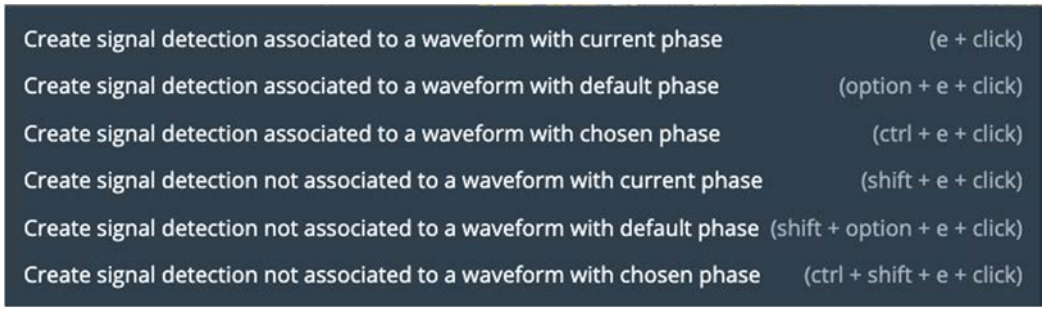


Figure 51. Create Signal Detection Menu.

This menu provides four options to create SDs. These are:

1. 'Create SD associated to a waveform with current phase' – create an SD with phase type set to the current phase (see Section 5.3.5.2.2). The created SD is automatically associated to the single waveform nearest where the user clicked. Alternatively, when waveforms are overlapping, the user can associate the SD to a specific selected waveform segment within split mode (see Section 5.3.3). To create via hotkey, press e + click
2. 'Create SD associated to a waveform with default phase' – create an SD with phase type set to the default phase (see Section 5.3.5.2.2). The created SD is automatically

associated to the single waveform nearest where the user clicked. Alternatively, when waveforms are overlapping, the user can associate the SD to a specific selected waveform segment within split mode (see Section 5.3.3). To create via hotkey, press Alt + e + click (Option + e + click on Mac)

3. 'Create SD associated to a waveform with chosen phase' – create an SD associated to a waveform with phase type set by selecting it from the 'Select Phase for Signal Detection' popup. To create via hotkey, press Ctrl + e + click
4. 'Create SD not associated to a waveform with current phase' – create an SD with phase type set to the current phase (see Section 5.3.5.2.2). This SD is not associated to any waveform. To create via hotkey, press Shift + e + click
5. 'Create SD not associated to a waveform with default phase' – create an SD with phase type set to the default phase (see Section 5.3.5.2.2). This SD is not associated to any waveform. To create via hotkey, press Shift + Alt + e + click (Shift + Option + e + click on Mac)
6. 'Create SD not associated to a waveform with chosen phase' – create and SD not associated to any waveform with phase type set by selecting it from the 'Select Phase. To create via hotkey, Ctrl + Shift + e + click

The user can select one of these options by clicking the option in the menu or alternatively by using one of the hotkey combinations listed above (also see Appendix C).

If an event is open when an SD is created, the SD will be associated to the opened event. If no event is open when and SD is created, the SD will be unassociated to any event.

In all cases, the created SD must have a phase type equivalent to the current phase or the default phase. The current phase can be set using the Current Phase menu as described in Section 5.3.5.2.2 while the default phase is configured to be a first-arrival P phase (see Configuration documentation, Section 5.3.5.2.2).

To create an SD (with either the current or default phase type) that is associated to a waveform, i.e., a waveform-associated SD, the user positions the cursor over the desired waveform and selects one of the two options that associate an SD to a waveform (bullets 1 and 2). If the user selects an area in a waveform panel where segments overlap, the waveform panel will automatically switch to the split-mode detailed in Section 5.3.3.

Figure 52. Signal Detection Creation in Split-Mode for Station ASAR.

When in split mode, the Waveform display cursor shows an SD label with either the current or default phase, depending on user selection (e.g., the P arrival in the first selection panel in Figure 52). This SD, which follows the user's cursor, can be moved by the user until a placement for the new SD is decided. The SD will be shown both in the original station waveform panel and in the individual waveform segment panel.

Once a placement is chosen, click the panel while keeping the cursor in place. This action will automatically close the split mode and the new waveform-associated SD will appear on the station waveform panel in the place originally marked by the cursor. The created SD will automatically be selected (Section 5.3.5.1). Note that although the SD is intended to be associated to a waveform segment, the user can create an SD in areas with no data. As waveform segments cannot be created on the fly by GMS, no waveform segment will be created to pair with that SD. This functionality is intended to target situation where external information suggests an SD but waveforms may not exist.

To exit the split-mode without creating a new SD, 1) click anywhere outside of the split-mode rows , automatically closing the view, 2) press the X button highlighted in red at the far-left of the main waveform row (Figure 52), or 3) press the Esc hotkey (Appendix C).

If the user creates a waveform-associated SD on a waveform that does not overlap, including on a station's expanded channel panels (e.g., Figure 36; Section 5.3.1), the split-mode window will not appear and the SD will be created wherever the cursor was placed when the option was selected. If the waveform-associated SD is created on a raw waveform in an expanded channel panel, it will appear both in the channel panel and in the station waveform panel.

Note that if an SD is created on a raw waveform, the new SD will appear on the raw waveform panel and in the station panel. A segment of the raw waveform will be copied with to the station panel as a new trimmed channel segment (Figure 53). The lead and duration of this new channel segment is configurable (see Configuration documentation).

Figure 53. Example of a Signal Detection Created on a Raw Waveform Panel.

Any changes made to such an SD in the station waveform panel will also be applied to the original SD in the channel waveform panel.

To create an SD (with either the current or default phase type) that is not associated to a waveform, the user positions the cursor over any empty space in the station/channel waveform panel or over a waveform and selects one of the two options that creates an SD without associating to a waveform (bullets 4, 5, and 6). The SD will be created wherever the cursor was originally placed. Again, the created SD will automatically be selected (Section 5.3.5.1). Note that creating this type of SD in a station waveform panel will result in an SD being shown in the station waveform panel only. If this SD is created in a channel panel, the SD will be showing in both the channel and station waveform panels. The purpose of creating SDs in this way is to allow the user to place an SD based on relevant external information.

Note that the creation of new SDs using any of the actions described above may result in changes to the type of waveform data shown in a station waveform panel. If the waveform data type of a station waveform panel does change, the station label will update accordingly to indicate the new data types being shown; see Section 5.3.1 for naming conventions.

Finally, an SD of any type (bullets 1,2,3,4) can be created in a row without any waveforms. This SD will be unassociated to any waveform, even if a waveform-associated option was selected.

In all cases, the newly created SD can be modified or associated in the same ways as other SDs. Any newly created SD will 1) automatically have its Signal Detection Details menu (Figure 47; Section 5.3.5.2.1) populated and 2) have a populated row added to the Signal Detections List Display, with an asterisk indicating the new SD is unsaved (Section 5.5). Newly created SDs will *not* have a great circle arc added to the Map display (Section 5.6.3) because no azimuth

measurement exists for the SD. Currently, the creation time and author fields in the Signal Detection Details menu will always be TBD (Section 6).

5.3.5.5. Creating an Event

To create an event in the IAN UI, the user first selects a set of SDs from which an event can be created. At least one SD must be selected to create a missing event, otherwise a virtual event will be created; virtual events will be described later this section. Signal detections can be selected from one or more station waveform panels and can be any association status except deleted (see Section 5.3.5, Section 5.3.6).

Once the desired phases are selected, click the Create Event button at the upper-left of the Waveform display (Figure 34). Alternatively, the user can press the hotkey c (Appendix C). Either action will create a new event, with the selected SDs automatically being associated to that event. The new event will have an origin time equal to the arrival time of the earliest SD used to create the event. The location of the new event will be set equal to the station location where the earliest SD was recorded. Thus, a new event created in this way is always expected to overlay a station/site. At the same time, the selected SDs association status will change to 'Associated to other event'. If the selected SDs were unassociated, they will change from yellow to white. If the selected SDs were associated to an open event or to another unopened event, their labels will not change color but a conflict icon (e.g., Figure 43) will appear as the selected SDs are now associated with multiple events.

Simultaneously, the Events (Section 5.4), Signal Detections List (Section 5.5) and Map (Section 5.6) displays update such that 1) a new row is added to the Events display detailing the created event, with an asterisk in the unsaved changes column indicating the event has not been saved, 2) the selected SDs rows in the Signal Detections List display update to indicate the SDs new association status, with an asterisk in the unsaved changes column indicating the SDs new statuses have not been saved, and 3) the new event is plotted in the Map display. Further, the Signal Detection Details menu (Figure 47) will update the associated event time to show the origin time of the newly created event (see Section 5.3.5.2.1).

To create a virtual event, click the 'Create Event' button without selecting any SDs. This action will bring up the menu in Figure 52.

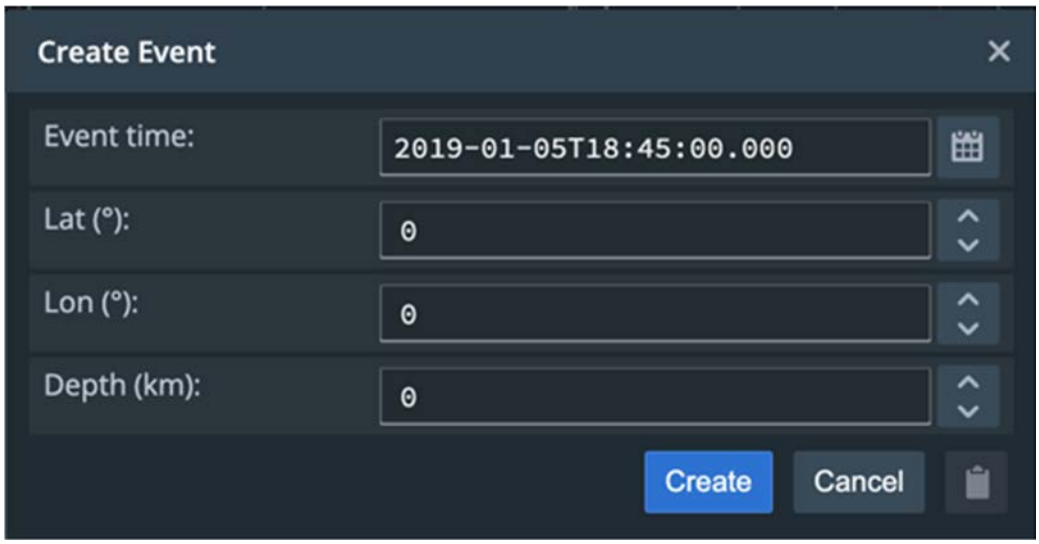


Figure 54. Create (Virtual) Event Menu.

From this menu, the user can enter the event time, i.e., origin time, of the virtual event along with its latitude and longitude in degrees and its depth in km. When first opened, a default origin time, latitude, longitude, and depth are provided (e.g., Figure 52). The default origin time is set to the earliest time (left edge) within the viewable time range on the Waveform Display. Note that this default origin time will update if the viewable time range is changed via zooming or panning. The default latitude, longitude, and depth will always be set to 0 degrees and 0 km, respectively.

To enter a new origin time, the user can either manually enter a value into the context box or click on the calendar icon at right to bring up the calendar menu in Figure 55.

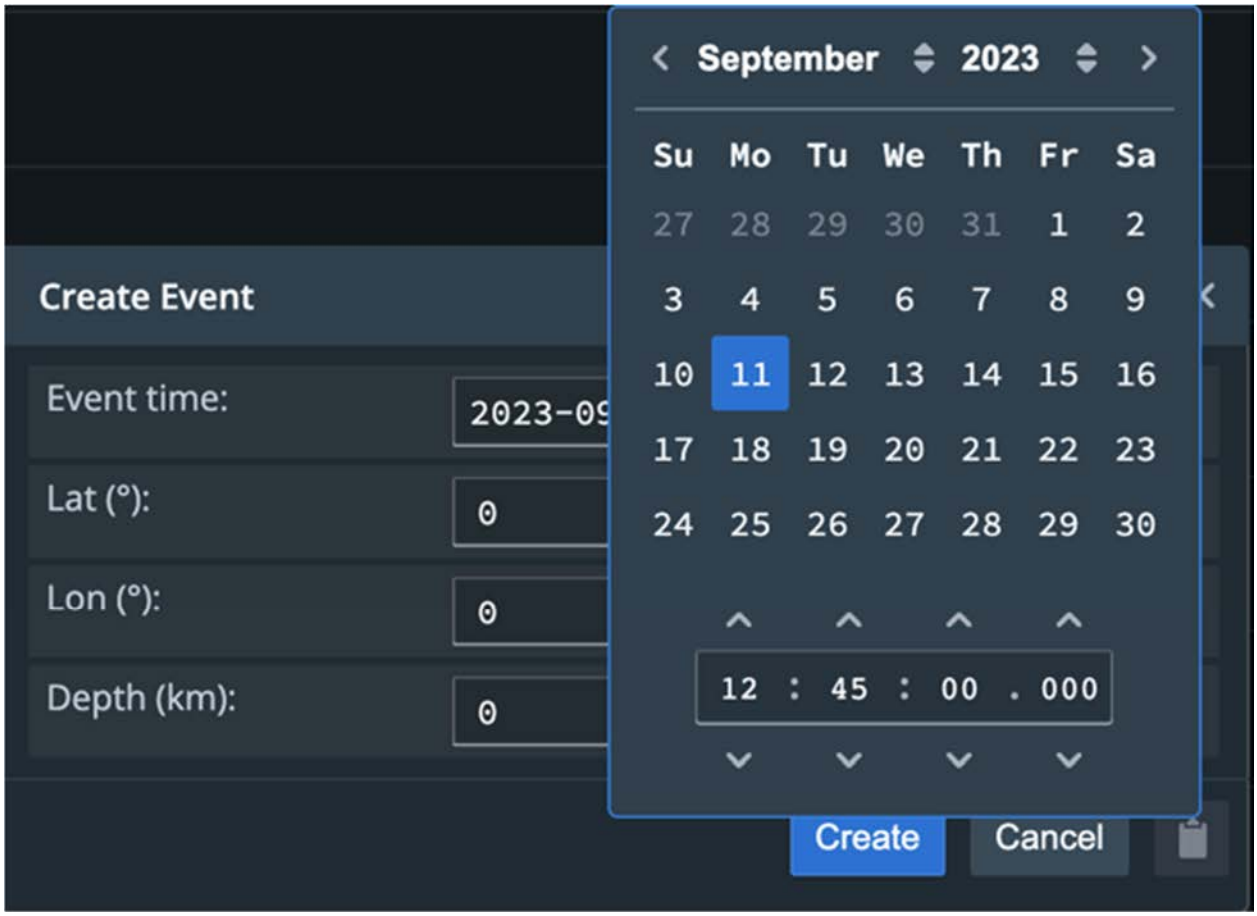


Figure 55. Calendar Used to Set Virtual Event Origin Time.

If entering the date manually into the context box, the format must be in YR-MON-DAYTHR:MIN:SEC.MSEC. Entering in a date in the wrong format will result in an 'Invalid event time error' (Figure 56, left) while entering in an incorrect date will result in a 'Not a valid date' error (Figure 56, center). If a date outside the viewable time interval of the Waveform display is entered either manually or with the calendar, an 'Event time outside of viewable interval' error will result (Figure 56, right).

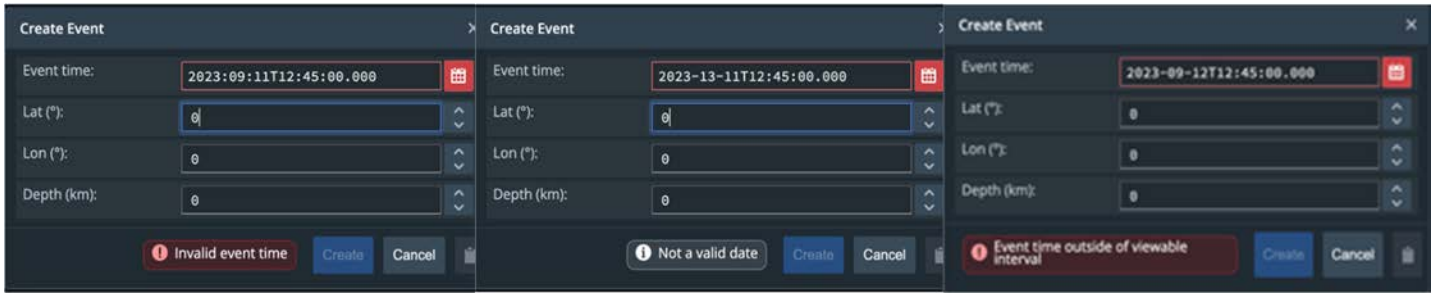


Figure 56. Create Event Menu with Warnings.

The calendar functions in a very similar way to the Open Anything calendars in the Workflow display (Figure 28, Section 5.2.1) but with some exceptions. First, the date can only be set with the calendar and only one day can be selected at a time. Second, the context box to set time is now at the bottom of the calendar and the time is now HR:MIN:SEC.MSEC rather than HR:MIN:SEC. The reader is referred to Section 5.2.1 for a detailed description of remaining calendar usage and behavior.

To enter in latitude, longitude, and depth, the user can manually enter information into the respective context boxes or press the up/down arrows to the right of each entry. Only numerical values can be entered into the latitude, longitude, and depth boxes and these must occur in a valid range (-90° to 90° latitude, -180° to 180° longitude, and -100 km (inclusive) to 1000 km (exclusive) depth), otherwise errors will result. Additionally, the user can copy a latitude and longitude from the Map display (see Section 5.6.4) and paste the latitude and longitude into the Create Event menu by clicking the clipboard icon in the lower-right corner. This action is only available when a latitude and longitude are copied from the Map display; details on how to copy latitude and longitude are provided in Section 5.6.4.

Once valid entries are entered into the Create Event menu, click Create to create the event or Cancel to exit out of the menu without creating the event. Users can also cancel the creation of events by clicking anywhere else outside the menu or pressing Esc. If Create is selected, the event is mapped into the Map display (Section 5.6.4) and an event row is added to the Events display (Section 5.4), with an asterisk in the unsaved changes column indicating the new event is not saved. Once created, the user can open the event in the Map or Events displays (Section 5.6.4, Section 5.4) to associate measured or created SDs to the event, create event beams, and perform other refinements of the virtual event; these and other available actions are described in Section 5.3.8.

5.3.5.6. Show/Hide Signal Detection Arrival Time Uncertainty

The show/hide time uncertainty radio button (Figure 57) is used to show or hide arrival time uncertainty error bars on SDs. The width of the bar indicates the time uncertainty of that SD in seconds. The bar is centered on the SD, i.e., it is the same length on each side of the SD.

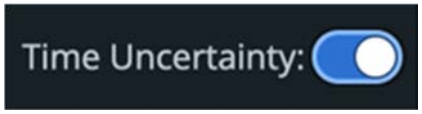


Figure 57. Show/Hide Time Uncertainty Radio Button.

When the radio button is in the on position, horizontal bars indicating the time uncertainty are shown for all SDs in the Waveform display (e.g., Figure 58).

[i]**Figure 58. Signal Detections with Time Uncertainty Bars Shown.**

To hide the uncertainty bars again, click on the radio button to return it to the off position. Alternatively, the user can press Ctrl + Shift + u to show and hide the uncertainty bars (See Appendix C).

If the SD was created by the user (Section 5.3.5.4), the time uncertainty is set to a configurable global default value (see Configuration documentation).

The user can resize an uncertainty bar by holding the hotkey combination Ctrl + Alt + e (Ctrl + Option + e on Mac) while hovering over one of the vertical ends of the uncertainty bar. This action will cause the vertical end to glow and the cursor will become a double-arrow. Once the user sees these visual indicators, they can click and drag the uncertainty bar to the desired length, all while holding the hotkey combination. Updating the uncertainty bar in the Waveforms display will update the 'Time Std Deviation (s)' value in the Signal Detections List display as well as the SD Details menu.

5.3.5.7. Show Detections Menu

The Show Detections dropdown menu (Figure 59) allows the user to select which SDs to view in the Waveform display.

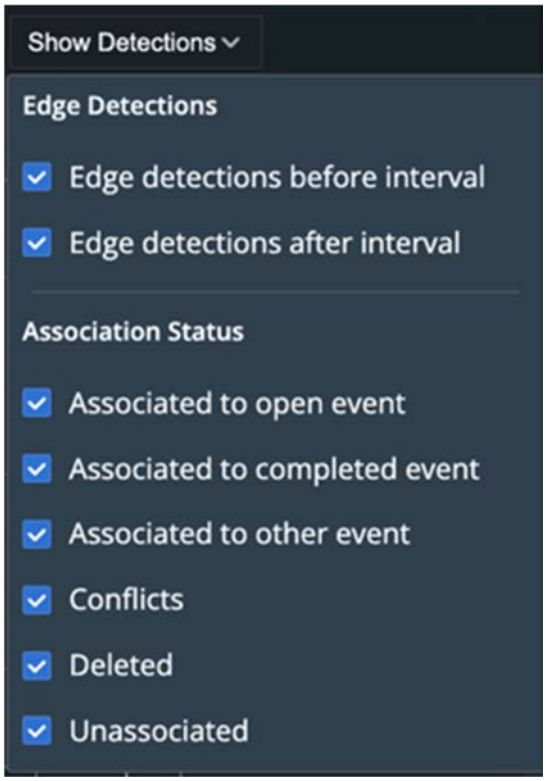


Figure 59. Show Detections Dropdown Menu.

Users can show/hide edge detections, SDs that occur before and after the time interval denoted by the green lines (see Section 5.3.1 for a definition of the time interval) or show/hide SDs based on their association, deletion, or conflict status. This action is performed by clicking checking/unchecking the SD type to show/hide.

5.3.6. Waveform Options

5.3.6.1. Load Additional Data Arrows

When the user clicks on either the left or right load arrow, additional data will be loaded beyond the opened time range in the Waveform Display. Additional waveform, event, signal detection, and QC mask data are loaded and associated displays updated. The following displays are updated as a result: 1) corresponding waveforms and SDs will be added to the Waveform display, along with any stations that recorded the SDs that weren't previously shown, 2) SDs will be added to the Signal Detections List display (Section 5.5) and the Map display (Section 5.6), 3) the corresponding events will be added to the Events display (Section 5.4) and the Map display (Section 5.6). As data loads, the waveform loading indicator will appear in the bottom-left corner of the Waveform display until data loading is complete (see Figure 32). 15 minutes (see Configuration Documentation) of waveform data is loaded each

time an array button is pressed. A maximum of 45 minutes (see Configuration Documentation) of data can be loaded before or after the initially loaded time range.

5.3.6.2. Hiding and Showing Stations and/or Channels

The Stations dropdown menu (Figure 60) allows the user to add stations and their respective data (i.e., beams, raw waveforms, SDs, QC masks) to the Waveform display in addition to the data loaded when an interval is opened. The dropdown menu also enables the removal of stations and their respective data from the Waveform display. By default, all stations in an interval's configured station group are shown along with any stations that recorded an SD occurring within the interval.

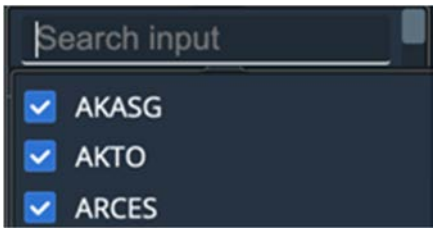


Figure 60. Stations Dropdown Menu.

Checked/unchecked stations are added/removed from the Waveform display. Checking a station's box will add its data to the Waveform display, automatically retrieving the station's waveform data, QC mask data, and corresponding SD data. Note that these actions will also update the Map and Signal Detections List displays (Sections 5.5, 5.6); checking/unchecking a station name in the Waveform display will add/remove any corresponding SD data from the Map and Signal Detections List displays. Further, checked stations will appear as orange triangle icons in the Map display, while unchecked stations will appear as gray triangle icons (Section 5.6).

To quickly find a station in the Stations dropdown menu, enter the first few letters of the station name into the Search field to filter the station list. Click anywhere outside the dropdown to hide the dropdown menu when finished adding/removing stations.

Stations can also be hidden (i.e., removed) via the Waveform display by right-clicking on their station labels and selecting the option 'Hide STATION', as shown in Figure 61 for station FINES. Stations can be shown (i.e., added) again via the Stations dropdown menu.

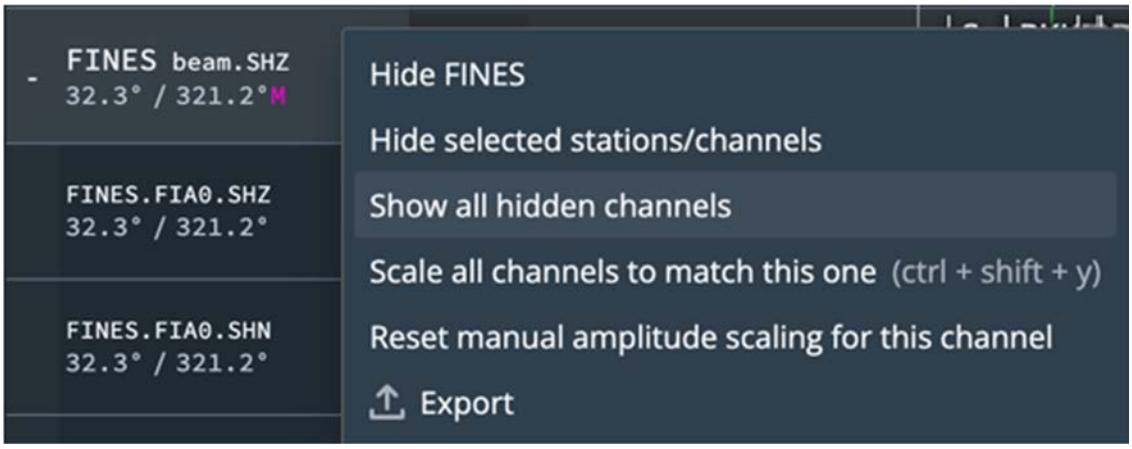


Figure 61. Station Options Menu Including Options to Hide STATION (here FINES) and to Show All Hidden Channels.

Specific channels can also be hidden by right-clicking the channel label after expanding the station waveform row, as shown in Figure 62. To add a station's channels back to the Waveform display, select the 'Show all hidden channels' menu option (Figure 61).

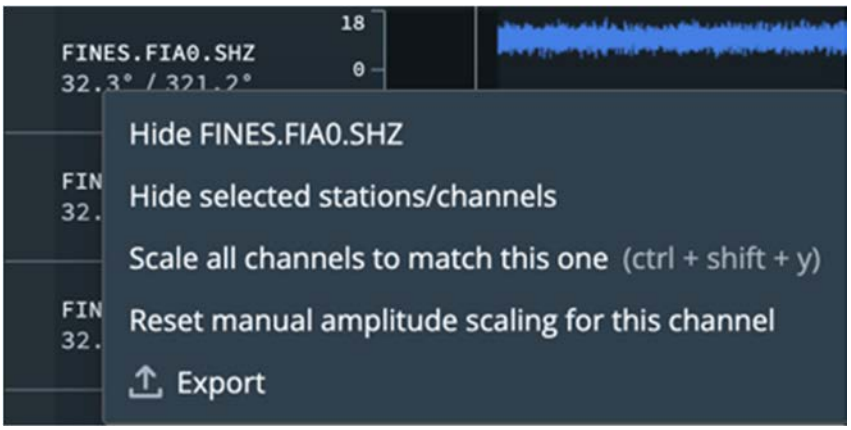


Figure 62. Channel Options Menu Including Option to Hide CHANNEL (here FINES.FIA0.SHZ).

Multiple stations and/or channels can be hidden by 1) selecting the stations and/or channels to hide (see Section 5.3.2), 2) right-clicking on a station or channel to bring up an options menu (Figure 61, Figure 62), and 3) clicking the 'Hide selected stations/channels' option.

Note that stations can also be added or removed from the Waveform display via the Map display. See Section 5.6 for details.

Any changes to station and channel visibility are maintained until the analyst workspace is closed (upon logout) or when a new interval is opened.

5.3.6.3. Export Waveforms

In the previous section, the menus shown in Figure 61 and Figure 62 include an additional option to export waveforms (Figure 63).

Figure 63. Option to Export Waveforms.

When Export is selected, a JSON file containing the metadata and data of the selected station/channel's waveform segments is downloaded with an automatically generated file name indicating the time range of the waveform segments and the channel name. For example, downloading the waveform segments of FINES may result in a file name like waveform-2023-09-06T19_13_22.483Z-to-2023-09-06T21_48_55.233Z-FINES.beam.SHZ.json. Inside the JSON file (e.g., Figure 64), the metadata associated with the segments, such as the units, start times, endtimes, and creation time, are provided along with the actual waveform samples. The different attributes of the waveform segments can be viewed by clicking the arrow to the left of a value to expand that value's contents. Note that if a filter was applied to the waveform segments before downloading, the JSON file will provide the filter definition along with filtered waveform samples.

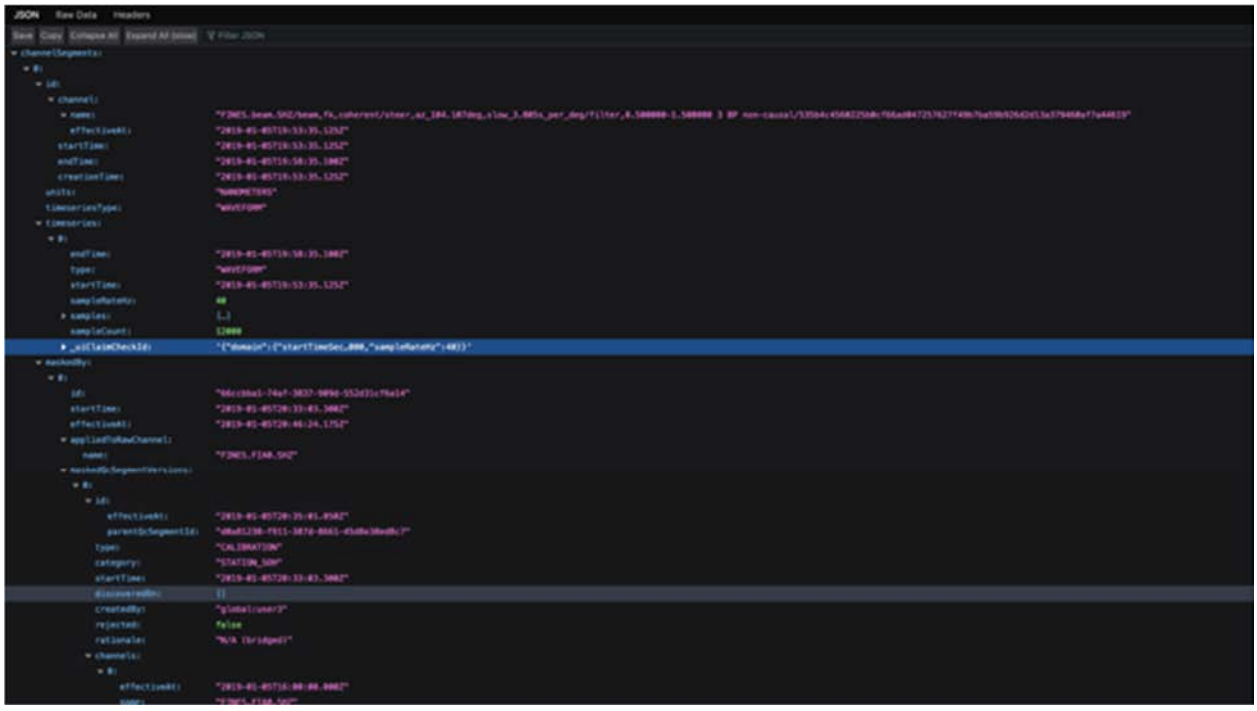


Figure 64. Example of an Exported JSON File for Station FINES.

Alternatively, a single waveform segment can be exported by right clicking on its associated SD (see Sections 5.3.5.1, 5.3.5.2.6). This action brings up a menu from which Export (Figure 63) can be selected. The SD menu is described in further detail in Section 5.3.5.2. As before, the metadata and data of the waveform segment are downloaded in JSON format with an automatically generated name; this time the name indicates just the time range of the waveform segment, e.g., waveform-2023-09-06T19_13_22.483Z-to-2023-09-06T19_18_22.458Z-FINES.beam.SHZ.json. Note that the time range indicated in the JSON name may begin and/or end outside the interval opened in the Workflow display if the waveform segment downloaded was on the edge of the interval.

A list of downloads (Figure 65) is printed to screen whenever waveforms are exported to JSON files.

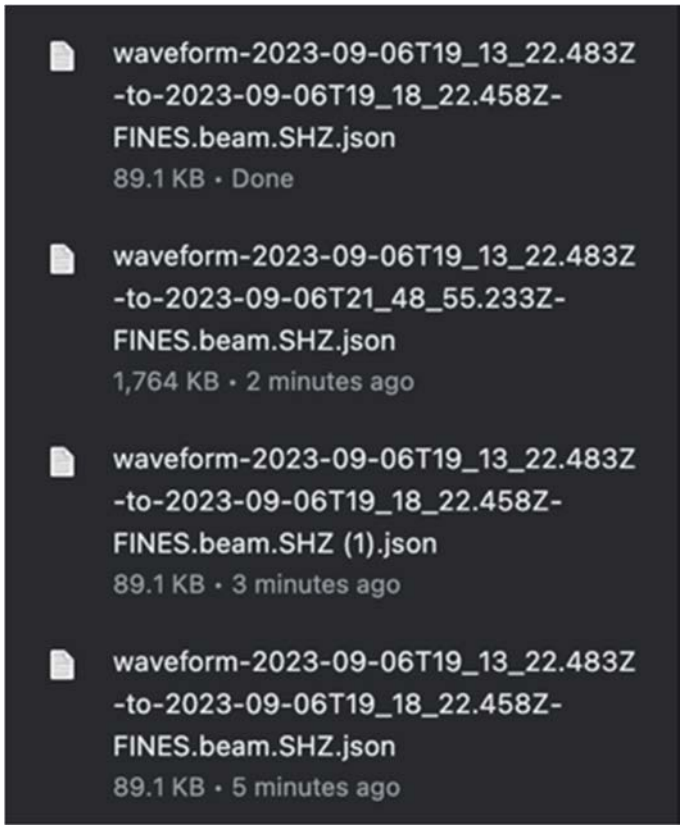


Figure 65. List of Downloaded/Exported Waveforms.

Note that if the downloaded JSON file is empty, the file name will indicate that by replacing the station name with 'empty', e.g., waveform-+055657-03-24T17_34_50.000Z-to-+055657-03-24T17_34_50.000Z-empty.json. Empty files can occur when a selected station or channel has no waveform data.

5.3.6.4. Rotation (DRAFT)

The Rotation button provides the user a menu in which rotation parameters can be defined (Figure 66). Once the user has all values set, they can click Rotate in the lower-right corner to rotate the selected waveforms using the entered parameters.

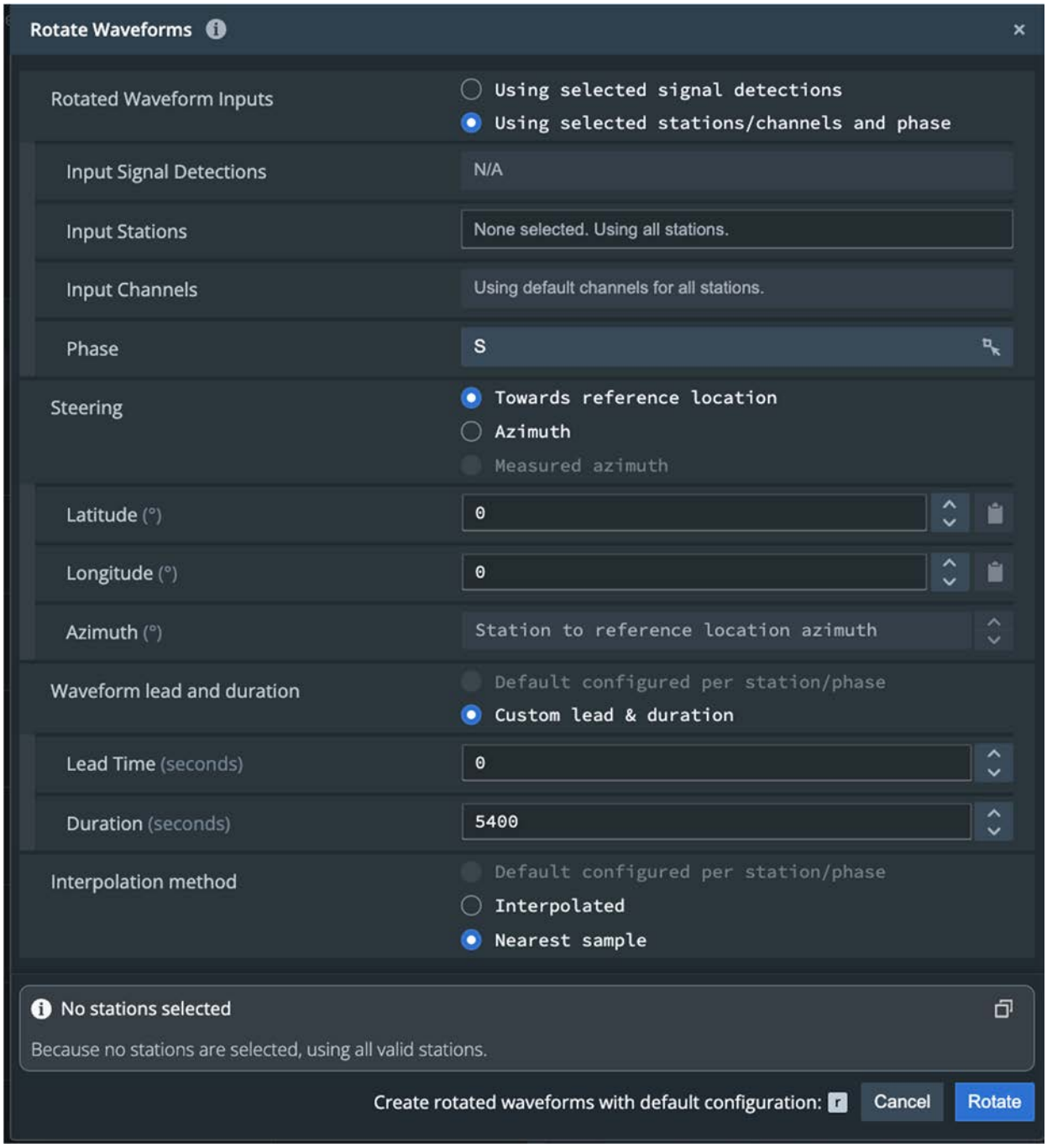


Figure 66. Rotate Waveforms Menu.

A full description of the Rotate Waveforms menu and its functionality can be printed to screen by hovering over the info icon in the upper-left corner of the menu to print out the tooltip in Figure 67.

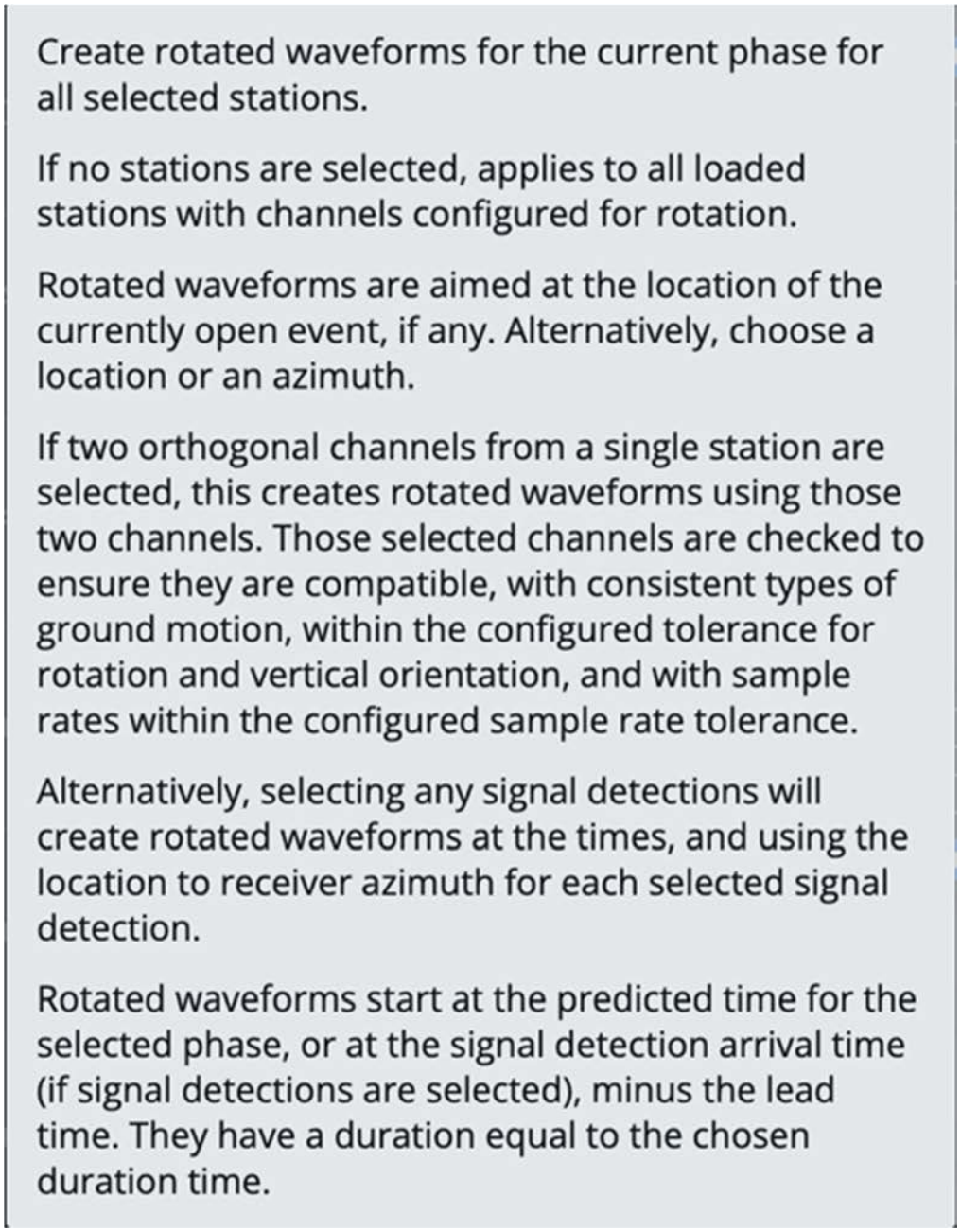


Figure 67. Rotate Waveforms Menu Tooltip.

In the Rotate Waveforms menu, the user has the following input options that can be applied to waveform rotation:

- Rotated Waveform Inputs – allows the user to choose whether to 1) rotate waveforms recorded by specific stations/channels at the arrival time of a predicted phase or 2) rotate waveforms on all stations using the selected SD(s) arrival time

- Input Signal Detections – a dropdown menu listing the selected SDs to be used in rotation
- Input Stations – a dropdown menu listing the stations that will have waveforms rotated
- Input Channels – a dropdown menu listing the channels that will be used in rotation
- Phase – a button used to bring up the Set Rotation Phase menu. The Set Rotation Phase menu is identical to the Set Phase menu (Figure 48)
- Steering – Sets which azimuth to steer the rotation to. The user can steer towards:
    - A reference location defined by Latitude (°) and Longitude (°)
    - An azimuth
- Latitude (°) – The latitude of the Steering reference location in degrees
- Longitude (°) – The longitude of the Steering reference location in degrees
- Azimuth (°) – The azimuth to steer all station waveforms to during rotation. Orientation is defined as degrees from North
- Waveform lead and duration – Sets whether to use the default lead and duration for a station/phase pair ('Default configured per station/phase') or custom values ('Custom lead & duration'). By default, the 'Default configured per station/phase' option is used
- Lead Time (seconds) – The lead time before the predicted phase, arrival time, or start of loaded time range
- Duration (seconds) – Sets the duration of the rotated waveform
- Interpolation method – defines how to align waveform samples. In IAN, waveform samples can either be aligned to the nearest sample or interpolated. If the Interpolation method is set to 'Default configured per station/phase', the default method for each station/phase combination (either Nearest sample or Interpolated) is applied

To set the Rotated Waveform Inputs, the user clicks on the radio button of the desired option. The two options available are 'Using selected signal detections' and 'Using selected stations/channels and phase'. By default, this option is set to 'Using selected stations/channels and phase'.

Applicable error and warning message at the bottom of the window alert the users to invalid selections and entries.

The next two subsections describe the Rotate Waveforms menu setup in each case.

5.3.6.4.1. Rotate Waveforms Using Selected Signal Detections

When Rotated Waveform Inputs is set to 'Using selected signal detections', rotation is applied to all waveforms associated with a selected SD(s). One or more SDs must be selected prior to performing rotation. If the user attempts to perform a rotation without selecting SDs an error is printed at the bottom of the menu and the Rotate button is disabled (Figure 68). Note that this rotation is the same as the one applied by selecting the 'Rotate waveforms using # signal detection' option in the Signal Detection popup menu (Section 5.3.5.2), except that the user can now modify the default rotation options of each selected SD in the Rotate Waveforms menu (Figure 66).

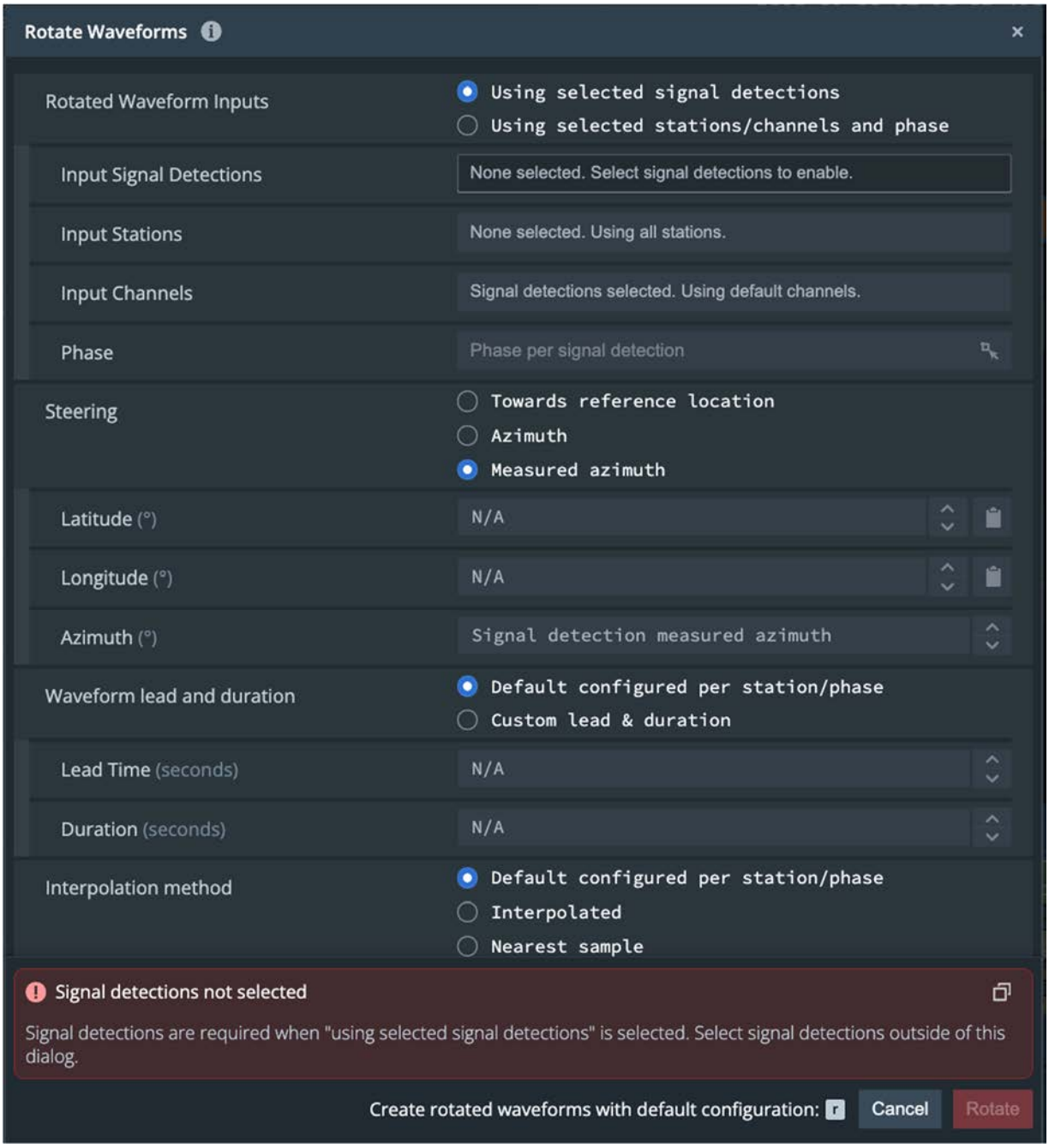


Figure 68. Rotate Waveforms Menu with Signal Detections Not Selected Error Message.

As indicated by the warning, SD selection must be done outside the Rotate Waveforms menu in the Waveform display (Section 5.3.5.1), Signal Detections List display (5.5.4), or Map display (Section 5.6.3). Once one or more SDs are selected, the Rotate Waveforms menu is populated as shown in Figure 69.

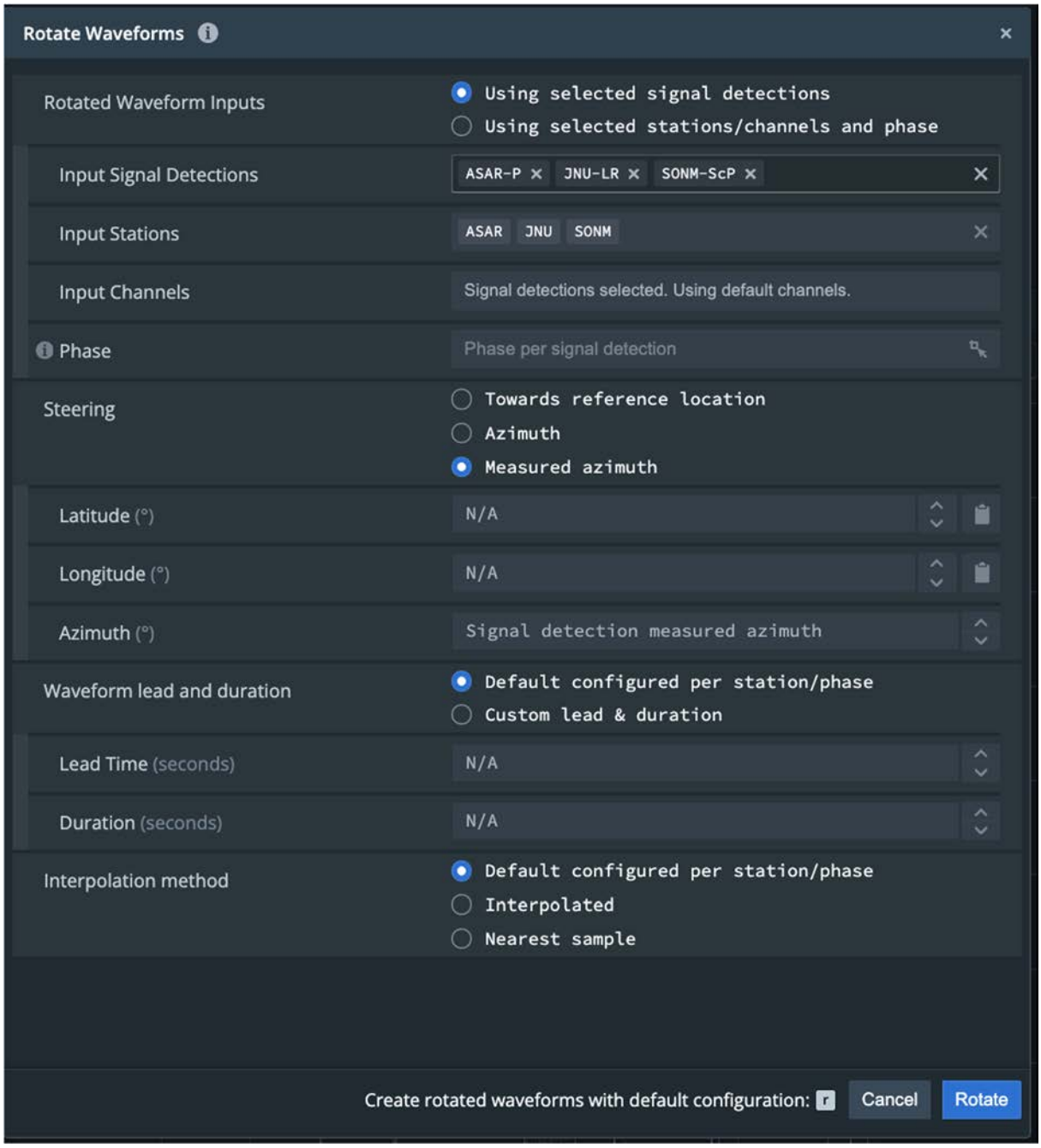


Figure 69. Rotate Waveforms Menu with Selected Signal Detection Inputs.

The Input Signal Detections option is automatically populated with the selected SDs, here ASAR-P, JNU-LR, and SONM-ScP. SDs can be removed from the Input Signal Detections list by either clicking the X icon to the right of the SD name or manually backspacing in the dialog box. To restore a selected SD back to the list, the user can click on the Input Signal Detections dialog box to bring up a dropdown menu listing all available selected SDs (Figure 70).

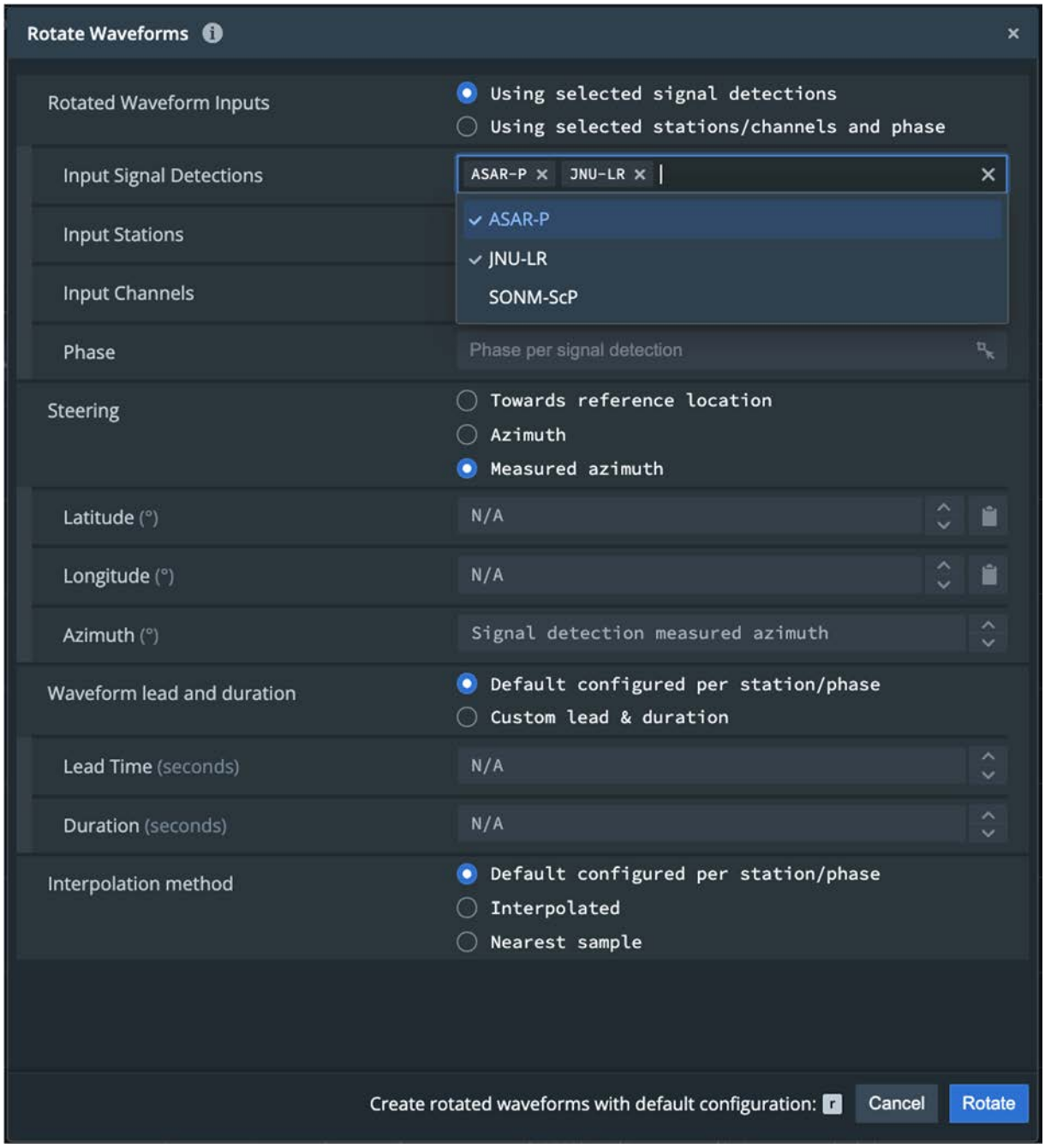


Figure 70. Rotate Waveforms Menu with Input Signal Detections Dropdown Menu.

The dropdown menu shows the list of available selected SDs, with a checkmark to the left indicating that the SD is included in the list. In this example, ASAR-P and JNU-LR are included in the list while SONM-ScP is not; to restore SONM-ScP, the user can click on it in the dropdown menu. Note that this dropdown menu cannot be used to add unselected SDs. To collapse the dropdown menu, click anywhere else in the Rotate Waveforms menu.

Finally, to remove all SDs from the Input Signal Detections list, the user can click the X icon at the far right of the dialog box.

The Input Stations option, like the Input Signal Detections option, is automatically populated, this time by the stations that recorded the selected SDs (e.g., ASAR, JNU, and SONM in Figure 69). At the same time, the Input Channels option is automatically set to use each SD's default channels and the Phase option is automatically set to use the SD's phase arrival time. The phase option is specifically used to define the beginning of the rotation window, which is defined as the phase arrival time minus the waveform lead time, defined later in the menu. These options cannot be modified by the user, as they all are dictated by the default values associated with the selected SDs. Note that the SDs default values can be configured (see Configuration documentation).

By default, the Steering option is set to Measured azimuth, i.e., each SD's waveforms are rotated using the azimuth measured for that SD. When using Measured azimuth, the Latitude and Longitude options are set to N/A, as they are not used. At the same time, the Azimuth option is set to 'Signal detection measured azimuth'. These three options can only be changed by the user if a different steering option is selected.

To change the Steering option, the user can click on the desired radio button to either steer towards a reference location or to a user-defined azimuth. When the user chooses to steer 'Towards reference location', the options Latitude(°), Longitude(°), and Azimuth(°) are automatically set in the menu. If no event is open, Latitude(°) and Longitude(°) are set to 0 degrees while Azimuth(°) is set to 'Station to reference location azimuth'. If an event is open (refer to Sections 5.4, 5.6 on how to open an event, Latitude(°) and Longitude(°) are set to the latitude and longitude of the opened event while Azimuth(°) is set to 'Station to reference location azimuth', i.e., the azimuth from the station to the opened event.

In either case, the user can change the reference location latitude and longitude by manually entering a new value into the dialog box or using the arrows to the right of the dialog box to increase/decrease the latitude/longitude by 1 degree. Note that the reference location latitude and longitude will be rounded to 4 significant figures if the arrows are used to modify latitude/longitude. This rounding will also be applied to the original latitude/longitude of the opened event. For example, if the opened event initially has a latitude of -6.530333 degrees, it will be set to -6.5303 degrees if the user tries to return to the original value using the arrows. To fully return to the original latitude/longitude values, the user must close the Rotate Waveforms menu and repeat the steps described so far in this section.

To the right of the Latitude(°) and Longitude(°) dialog box and arrows, clipboard icons are shown. In a future release, these clipboards will allow the user to copy latitude and longitude from the Rotate Waveforms menu (Section 6). Finally, when Steering is set to 'Towards reference location', the Azimuth(°) is required to be defined as 'Station to reference location azimuth'. Thus, it is grayed out and cannot be changed by the user.

The final Steering option is Azimuth. When Steering is set to Azimuth, Latitude(°) and Longitude(°) are set to N/A and grayed out as they are not used to steer in this mode. The user is instead prompted to enter an azimuth, with the Azimuth(°) dialog box showing the message 'Enter an azimuth for all rotated waveforms'. To enter an azimuth, the user can either manually enter a value into the dialog box or use the arrows to the right of the dialog box to increase/decrease the azimuth by 1 degree, starting from 0 degrees.

Next, the user can specify the Waveform lead and duration. By default, the radio button to use each station's default waveform lead and duration values is selected (these defaults are configurable; see Configuration documentation). When this radio button is selected, the Lead Time and Duration options are set to N/A and are grayed out.

If the user instead sets Waveform lead and duration to the 'Custom lead & duration' option, the Lead Time and Duration dialog boxes are automatically filled with a value of 60 seconds and 300 seconds, respectively. Arrows to the right of the dialog boxes can be used to increase/decrease the Lead Time and Duration in 60 second increments.

Finally, to select an Interpolation method, the user clicks the radio button next to the desired option. By default, the default interpolation method for each selected station/phase pair is used (these defaults are configurable; see Configuration documentation). Otherwise, the nearest sample or interpolated methods can be used.

Note that if an invalid entry is input into any of the options in the Rotate Waveforms menus, a warning or an error will be displayed at the bottom of the menu (Figure 71).

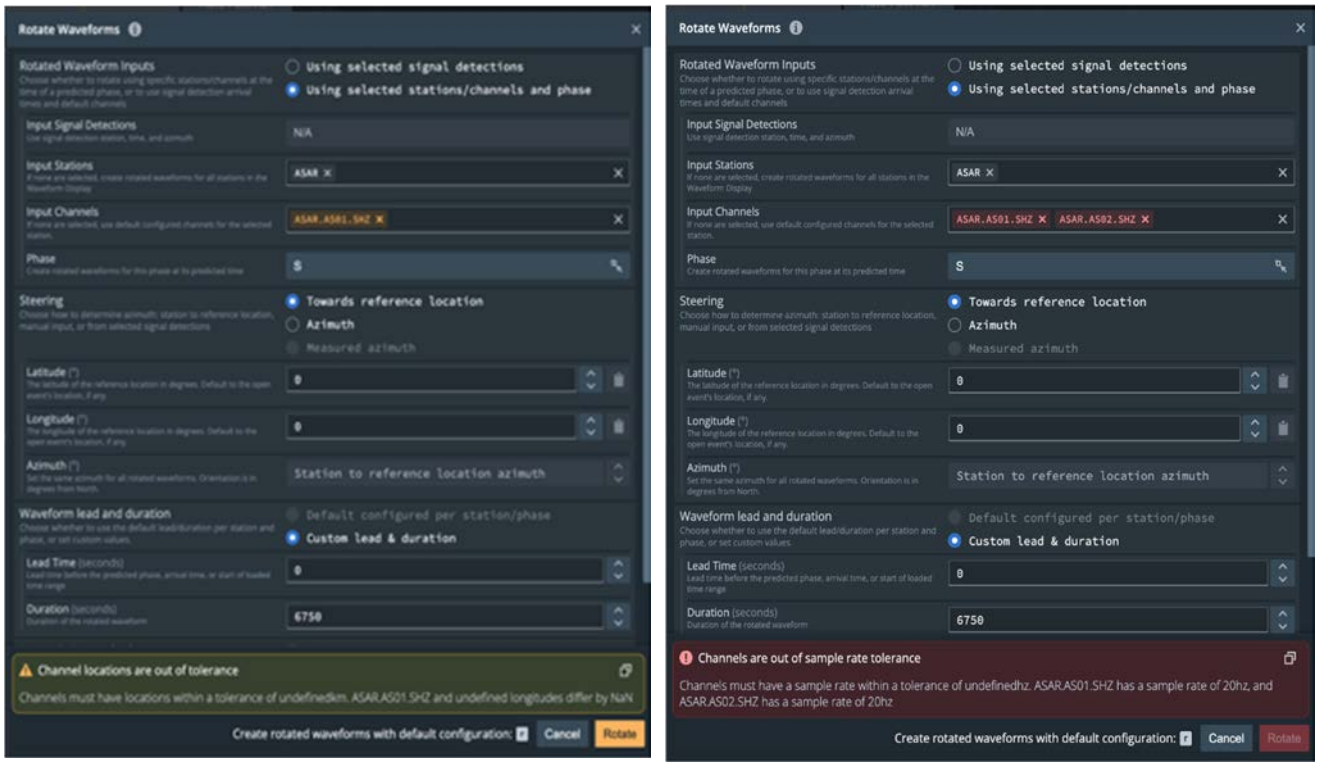


Figure 71. Example Warning (Left) and Error (Right) Messages in the Rotate Waveforms Menu.

The warning/error can be copied to clipboard by selecting the copy icon at the upper-right corner of the warning/error.

5.3.6.4.2. Rotate Waveforms Using Selected Stations/Channels and Phase

By default, the Rotate Waveform Inputs option is set to 'Using selected stations/channels and phase'. When set to this option, rotation is performed on the waveform segments of all selected stations, with the beginning of the rotation window defined based on the predicted phase arrival time minus the waveform lead duration time.

In this mode, the Input Signal Detections option is automatically set to N/A and cannot be changed.

The Input Stations option will include all valid available stations by default if no stations are selected. If the user does select stations in the Waveform display (Section 5.3.2), the Input Stations option will automatically be populated with the selected stations. Stations can also be added to the Input Stations list by clicking on the Input Stations dialog box to bring up a dropdown menu listing all available stations (Figure 72).

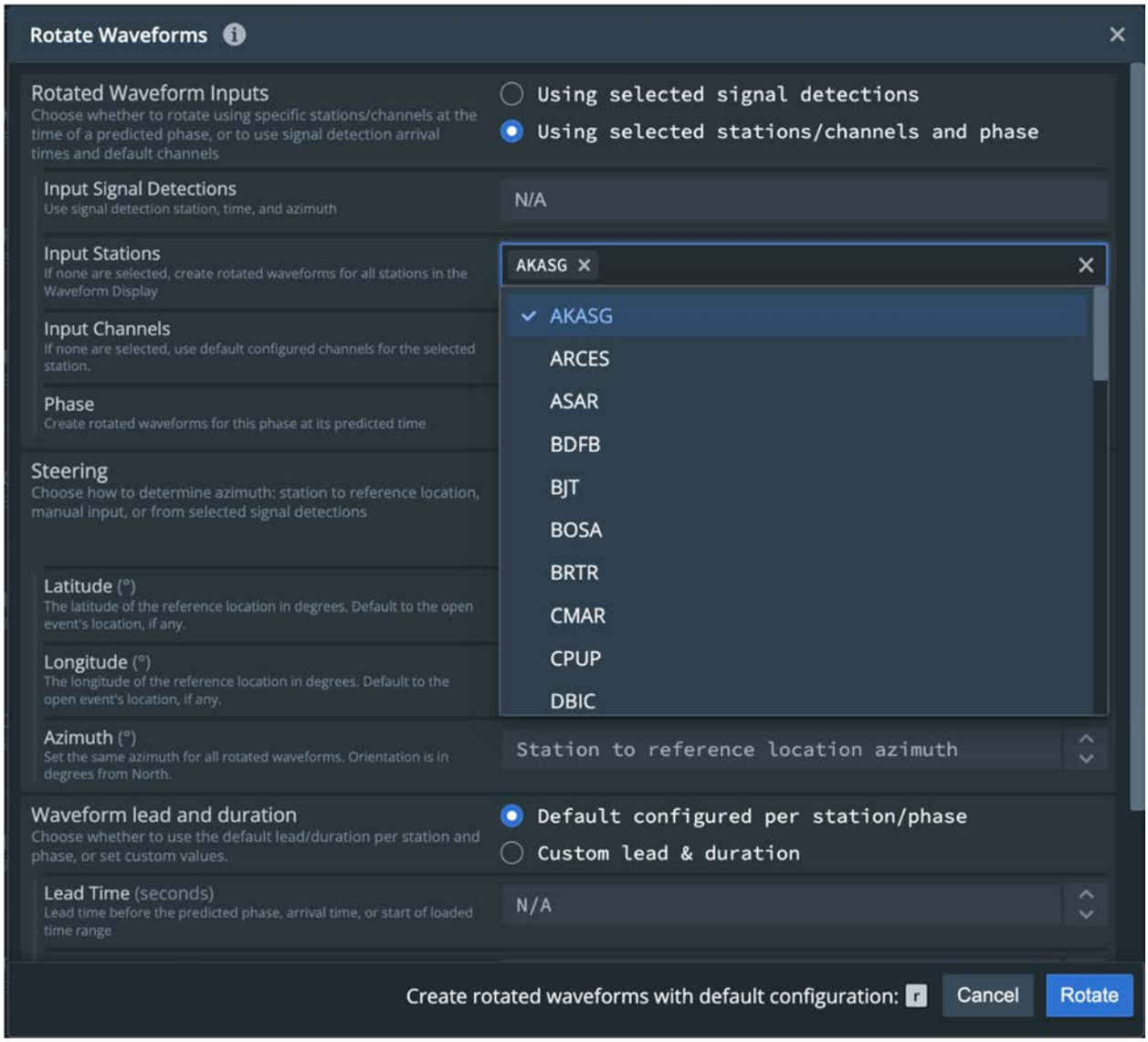


Figure 72. Rotate Waveforms Menu with Input Stations Dropdown Menu.

The dropdown menu shows the list of available stations, with a checkmark to the left indicating that the station is included in the list. Stations can be added/removed from the list using the dropdown menu by clicking on the station to be added/removed. Stations can also be manually entered into the Input Stations dialog box. Entering a partial name will filter the dropdown menu to show only those stations including the partial name.

Stations can be removed from the Input Stations list by either clicking the X icon to the right of the station name or manually backspacing in the dialog box. Finally, to remove all stations from the Input Stations list, the user can click the X icon at the far right of the dialog box.

To collapse the dropdown menu, click anywhere else in the Rotate Waveforms menu.

The Input Channels option will use each valid, available station's configurable default channels (see Configuration documentation) to perform rotation if no station is selected. When no station is selected, the Input Channels option cannot be modified.

If a single station is selected, the Input Channels option is automatically set to use the configurable default channels of that station (see Configuration documentation). In this case, the user can click the Input Channels dialog box to bring up a dropdown menu listing all valid channels for that station (Figure 73). Note that channels that cannot be used in rotation (e.g., vertical channels) will not be listed.

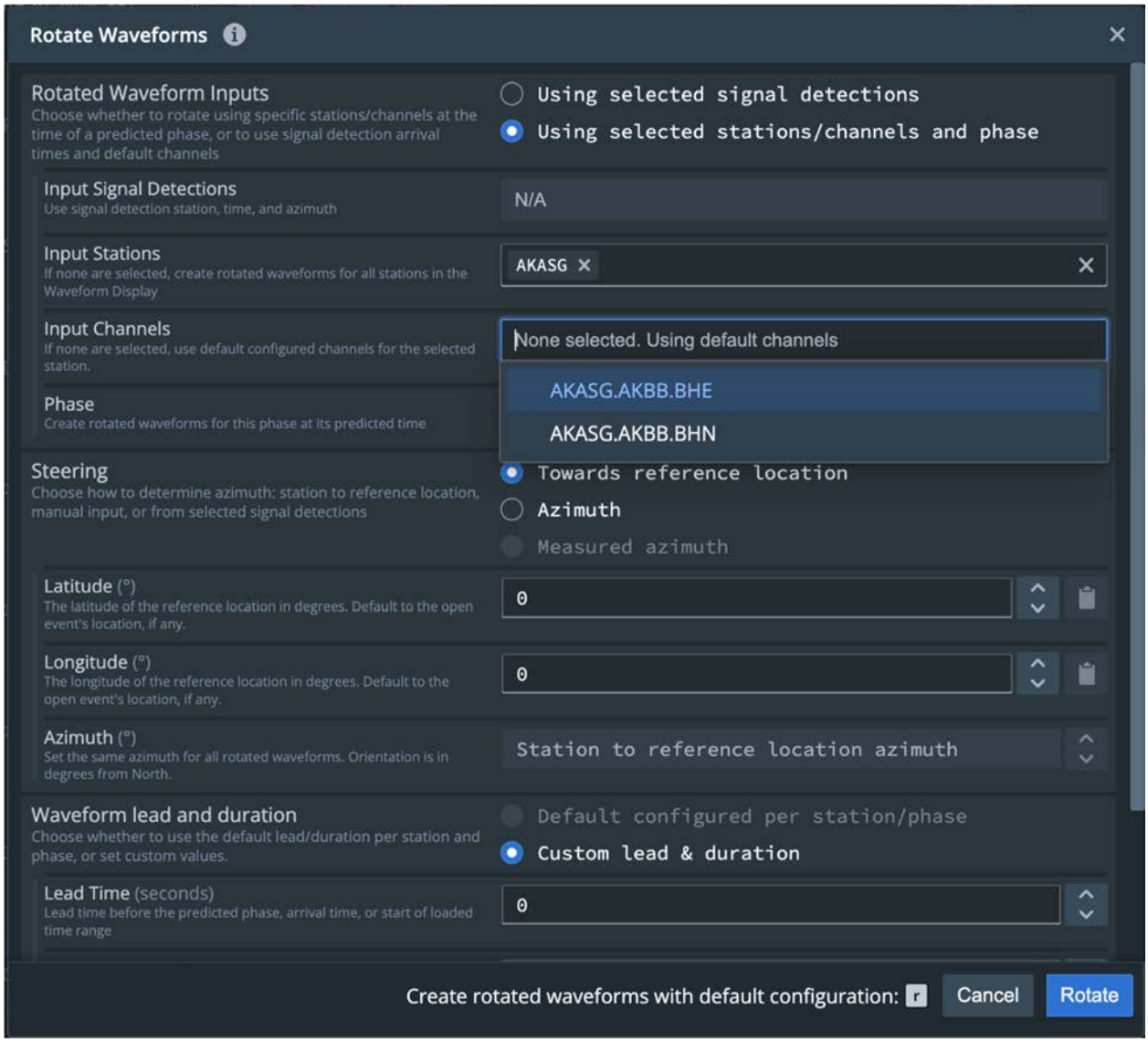


Figure 73. Rotate Waveforms Menu with Input Channels Dropdown Menu.

The dropdown menu/dialog box behavior of the Input Channels menu is identical to that of the Input Stations menu.

Finally, if multiple stations are entered into the Input Stations option, the Input Channels option will indicate that multiple stations are selected and the default channels of each station will be used. The user cannot modify the channels in this case.

By default, the Phase option will be set to the S phase. Thus, the beginning of the rotation window for each input station's waveforms is defined as the predicted S-wave arrival time minus the waveform lead time defined later in the menu. The phase used can be modified by

clicking on the Phase option. This action will pull up the menu to set phases discussed in Section 5.3.5.2.2 (e.g., Figure 48). Refer to Section 5.3.5.2.2 for details on how to choose a new phase using this menu.

By default, the Steering option will be set to 'Towards reference location' although the 'Azimuth' option can also be specified. Note that the 'Measured azimuth' option provided when using selected SDs to perform rotation is not available when rotating selected stations/channels. Refer to the previous section (Section 5.3.6.4.1) for details regarding steering.

The Waveform lead and duration option must be set to the 'Custom lead & duration' option when rotating selected stations/channels as the same window values will be applied to all station/channel waveforms. By default, the configurable Lead Time(seconds) is set to 0 seconds and the Duration(seconds) is set to 5400 seconds (i.e., 90 minutes); see Configuration documentation. Note that because the Lead Time is set to 0 seconds, the beginning of the waveform rotation window will be set equal to the predicted S-wave arrival time by default. As in the previous section (Section 5.3.6.4.1), the Lead Time and Duration can be manually modified or increased/decreased by 60 second intervals using the arrows to the right of the dialog boxes.

Finally, the Interpolation Method can only be set to 'Nearest sample' or 'Interpolated' when rotating selected stations/channels as the same method will be applied to all station/channel waveforms. Refer to Section 5.3.6.4.1 for more detail.

5.3.6.5. Waveform Amplitude Scaling

The amplitude scaling dropdown menu (Figure 74) provides two options for persistent waveform amplitude scaling.

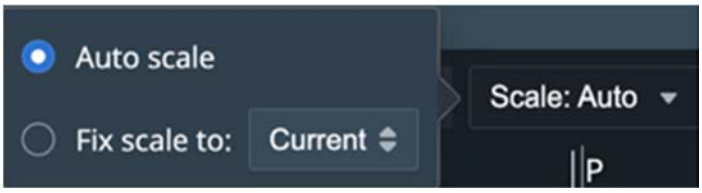


Figure 74. Scale Dropdown Menu.

The default option, 'Auto scale', causes the y-axis scale of each beam/waveform to be automatically scaled such that the minimum and maximum y-axis values are equal to the absolute maximum absolute value of the beam/waveform amplitude currently on screen. For

instance, if station YKA's beam has a maximum amplitude of 52027, the y-axis will range from -52027 to 52027, centered around zero. This scale will be adjusted as the user pans and/or zooms and the maximum amplitude changes. If the maximum amplitude of the YKA beam on screen is now 21475 after panning, the y-axis will now range from -21475 to 21475. A small buffer is provided above and below the maximum and minimum amplitudes on the y-axis scale to improve viewing. This buffer is not configurable.

If the 'Fix scale to' option is selected, the y-axis scales will remain fixed to one of the scale options in its dropdown menu (Figure 75).

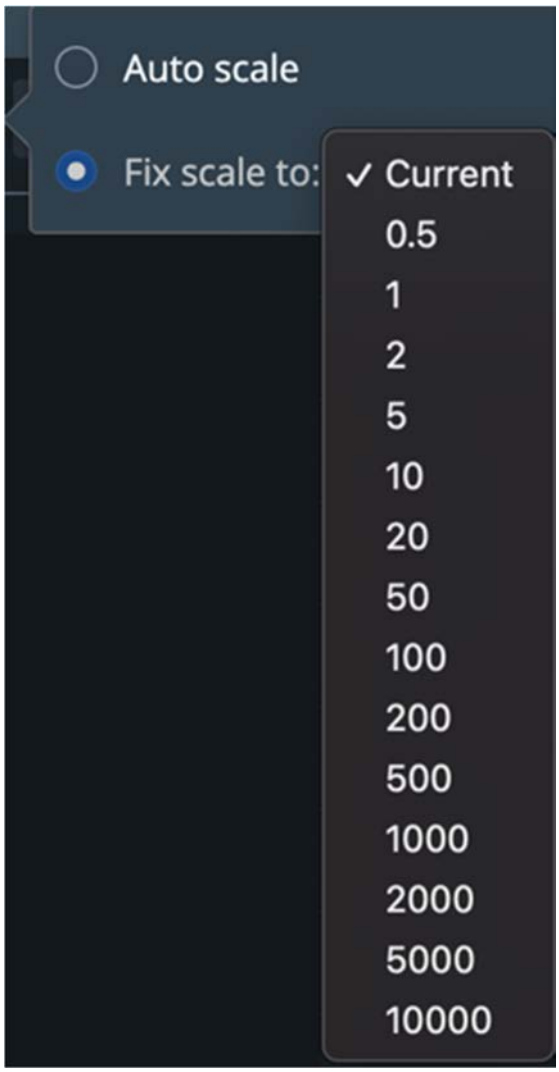


Figure 75. Fix Scale Y-Axis Range Options.

Selecting 'Current' will freeze the y-axis scales of each panel to whichever amplitude scale was on-screen at the time of selection. Otherwise, the y-axis scales can manually be set to a desired range, e.g., from -0.5 to 0.5, if the 0.5 option is selected. When the 'Fix scale to' option is selected, the y-axis scale is not adjusted when the user pans or zooms. The available scale values are configurable and currently range from 0.5 to 10000.

In addition to the options provided by the scale dropdown menu, users can right-click on a station or channel label to view the context menus shown in Section 5.3.6.2 (Figure 61, Figure 62) which provide the option to apply scaling based on a particular beam/waveform's amplitude: 'Scale all channels to match this one'.

When the 'Scale all channels to match this one' option is applied, the y-axis range of all waveforms will be set equal to the absolute maximum value of the selected station's (e.g., Figure 61) or channel's (e.g., Figure 62) waveform amplitude. For example, in Figure 76 (Right) all stations' and channels' y-axes are scaled based on the y-axis scale of the waveform for station FINES (Figure 76).

Figure 76. Example of Y-Axes Scaled to Amplitude of FINES Beam. (Left) Y-Axes Prior to Scaling; (Right) Y-Axes After Scaling Applied.

The above can also be performed by first selecting a station or channel by clicking on its label and then pressing Ctrl + Shift + y (see Appendix C).

The user can also manually scale a waveform by holding down the y key, then left-clicking and dragging up/down while the cursor is over the waveform to be scaled (Appendix C). Drag down to reduce the y-axis range and drag up to increase the y-axis range. Manual rescaling will override any previously applied scaling option. Stations/channels with manually scaled amplitudes are indicated by having their y-axis values shown in magenta (color is configurable; see Configuration documentation). Manual scaling can be applied to as many waveforms as desired by performing the above actions on each waveform.

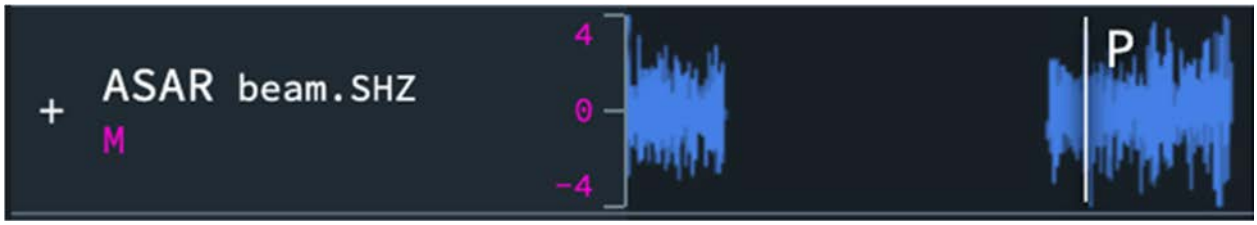


Figure 77. ASAR Waveform with Manual Amplitude Scaling Applied.

There are several ways to reset scaling options applied to one or more waveforms:

- the amplitude scale dropdown menu (Figure 74) can be used
- all waveform amplitude scalings can be reset by pressing Alt + Shift + y (Option + Shift + y on Mac; see Appendix C)
- all amplitude scalings of selected waveforms (Section 5.3.2) can be reset by either pressing Alt + y (Option + y on Mac; see Appendix C) or selecting the option 'Reset amplitude scaling for this channel' from the menus described in Section 5.3.6.2. (Figure 61, Figure 62)
    - Note that if multiple stations/channels are selected, the reset amplitude option will read as 'Reset amplitude scaling for # selected channels', where # is the total number of stations and channels selected

5.3.6.6. Sort Dropdown Menu

The Sort dropdown menu (Figure 78) can provide the option to arrange stations either 1) alphabetically descending/ascending by station name or 2) by epicentral distance from an opened event to the station, ranging from closest to furthest. The distance option can only be used when an event is opened (see Section 5.3.8), either from the Events (Section 5.4) or Map (Section 5.6) display. Otherwise, the option will remain grayed out.

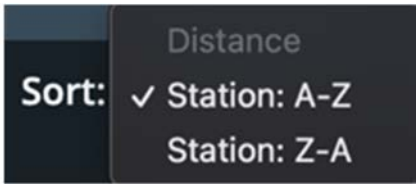


Figure 78. Sort Dropdown Menu.

If no event is open, stations will be sorted alphabetically descending by station name, by default. If an event is open, stations will be sorted by distance, by default.

5.3.6.7. Measure Window

The Measure Window radio button at the upper right of the Waveform display (Figure 34) provides the ability to simultaneously view a zoomed-in, detailed view of a desired waveform and its SDs while still viewing waveforms in the original Waveform display (Figure 79).

Figure 79. Waveform Display with Measure Window Option on for Station AKASG.

To view the Measure Window for a particular waveform, hold Shift while left-clicking and dragging over the desired portion of the waveform. A ruler displaying the date, start time, and end time of the window, along with the window duration, will appear (see Figure 35). The waveform does not need to be selected (Section 5.3) to be shown in the Measure Window. Note that only one station waveform panel at a time can have an open Measure Window. These actions can also be applied to waveforms recorded by a station's channels when its station waveform panel is expanded (see Section 5.3, Figure 36).

The selected area will be highlighted in gold as shown for station AKASG in Figure 79. The Measure Window can be moved by left-clicking the gold window and holding and dragging it (left or right) to the desired position (Appendix C). As the window is dragged, the vertical marker and ruler in Figure 35 will appear, with the marker and ruler shown in gold rather than

white. The selected waveform segment, including its SDs, can now be viewed in detail in the top window, while the Measure Window radio button will be in the on-position.

Waveform selection (Section 5.3.3) will also be reflected in the Measure Window. If a waveform segment is selected in the original station waveform panel the Measure Window is in, that selected waveform segment will appear in light blue and all other waveform segments will disappear in the Measure Window, with only their associated SDs shown. This Measure Window behavior allows for the user to specifically focus on the details of a single waveform segment. Note that waveform segments cannot be selected directly in the Measure Window. To change which waveform is displayed in the Measure Window, users can select a different SD in the station waveform panel. Deselecting all SDs will show all waveforms in the Measure Window.

The Measure Window acts as its own station waveform panel in the Waveform display, such that zooming and scaling options (see Sections 5.3, 0) update the waveform as they would for regular waveform rows within the Waveform Display. Panning, zooming, and scaling in the Waveform display will not update the Measure Window scale and vice versa. The window duration and alignment information specific to the Measure Window can be seen at the bottom of the Measure Window (Figure 79).

To stop showing the Measure Window for a station, the user must do one of the following:

- create another window using the same actions described above, either on the same station waveform panel or a different station waveform panel
- click the Measure Window button to the off position (button moves to left and no longer appears blue
- click ‘Hide Measure Window’ if the button is placed under the overflow menu indicated by 3 vertically stacked dots
- press the Esc button

In the first bullet, the Measure Window is populated with the newly selected waveform segment. In the latter bullets, the Measure Window is removed and the display returns to the same view as seen in the default display (Figure 34).

The Measure Window can be opened via the radio button or ‘Show Measure Window’ dropdown menu option without selecting any waveform for viewing. This action will produce the message, ‘No Measure Window Data Selected’ (Figure 80). The Measure Window can be vertically expanded or scaled down by hovering over the bottom of the panel, i.e., where it meets the top of the Waveform display, and dragging it up or down.

Figure 80. Measure Window with No Data Selected.

5.3.7. QC Segments

Quality Control (QC) masks are created in the automated processing pipeline to identify waveform segments that may have quality issues, e.g., gaps, noise, sensor problems, etc. QC masks appear as color-coded waveform sections in the Waveform display, as shown in Figure 81.

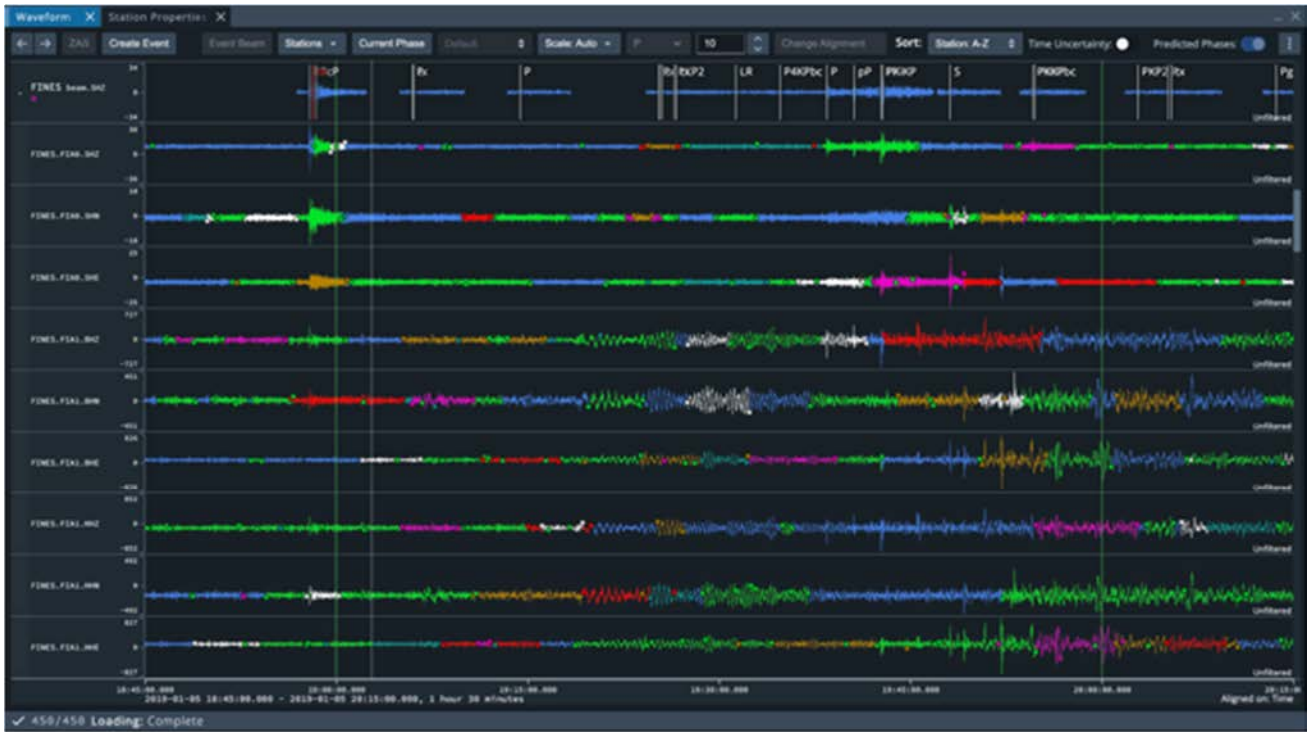


Figure 81. QC Segments Applied to Channels of Station FINES.

QC masks are computed for raw waveform data only as they are used to 1) indicate where the raw waveform data had quality issues and 2) to indicate which raw data were not used when performing a signal processing operation such as beamforming or rotation. These two cases result in two types of QC mask: 1) QC segments and 2) processing masks. These QC mask types will be further defined later this section.

To view QC masks, the user must expand a station row with raw waveform data that has QC masks applied; see Section 5.3.1 on how to expand. As mentioned in Section 5.3.1, station panels containing waveforms with QC masks are denoted by a magenta "M" directly beneath the station name (e.g., Figure 82). This M disappears if the viewable time range is updated and there are no longer visible QC masks.

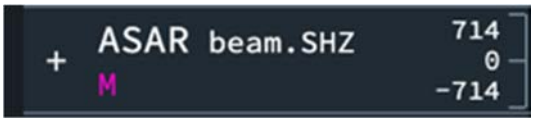


Figure 82. QC Mask Badge.

Once expanded, the user can identify the type of QC mask being shown based on color. To view a color legend and toggle on/off QC masks, the user can click the QC masks dropdown menu

(Figure 83) at the upper right of the Waveform display (Figure 34). These colors are configurable (see Configuration documentation).

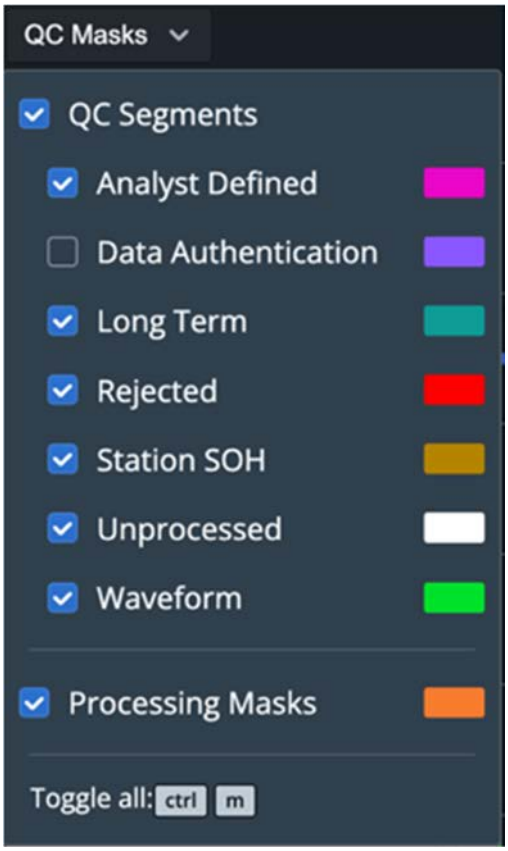


Figure 83. QC Masks Dropdown Menu.

In the QC masks dropdown menu, two types of QC masks are listed. These are:

- QC segments – QC masks that identify the type of QC issue affecting a waveform and the time interval over which the issue occurs
- Processing masks – QC masks created from QC segments used to exclude raw waveform data with QC issues from being used in a signal processing operation. Processing masks are created based on a configuration unique to each signal processing operation. Note that in addition to being toggled on in the QC masks dropdown menu, a waveform with an associated processing mask must be selected (Section 5.3.5.1) to view the processing mask

Descriptions of the different QC Segment categories and their subcategories, i.e., types, are provided in Table 3 below.

Table 3. QC Segment Categories and Definitions.

QC Segment Category	Definition	QC Segment Type
Analyst Defined	QC issue marked by an Analyst.	Type is defined by the user (Section 5.3.7.1). Can be any of the QC segment types defined for the Station SOH and Waveform categories.
Data Authentication	QC issue related to an authentication problem between an external station and GMS.	Type is defined by the user (Section 5.3.7.1). Can be any of the QC segment types defined for the Station SOH and Waveform categories.
Long Term	QC issue indicating a standing issue with a channel's waveform samples.	Type is defined by the user (Section 5.3.7.1). Can be any of the QC segment types defined for the Station SOH and Waveform categories.
Rejected	A special QC segment type indicating a QC Segment of another type was rejected by an Analyst.	N/A
Station SOH	QC issue indicated in metadata acquired along with a channel's waveform samples.	Any of the following QC segment types can result in a Station SOH QC Segment: • Calibration – Waveform samples contain an instrument calibration signal. • Sensor Problem – A QC issue limited to a single sensor (e.g., clipped, digitizer problem, etc.) • Station Problem – A QC issue affecting an entire station (e.g., power failure, vault door opened, etc.) • Station Security – A security related QC issue affecting an entire station (e.g., authentication seal broken, etc.) • Timing – Time values in the waveform samples are incorrect.

Unprocessed	A special QC segment type indicating that the waveform samples have NOT been processed for QC issues.	N/A
Waveform	QC issue within waveform samples.	Any of the following QC segment types can result in a Waveform QC Segment: • Aggregate – A QC issue resulting from the combination of several other QC issues. • Flat – Adjacent waveform samples do not vary in amplitude. • Gap – Waveform samples are missing. • Noisy – Waveform is contaminated by noisy waveform samples that cannot be attributed to background noise. • Spike – A short duration amplitude spike contaminating the waveform.

By default, all QC masks (both QC segments and processing masks) except for the Data Authentication QC segment type are shown in the Waveform display. To include/remove a particular QC segment, all QC segments, and/or processing masks, check/uncheck the desired segment(s) and/or processing masks. Alternatively, use the hotkey combination Ctrl + m (Appendix C) to toggle all QC Masks on or off. Note that if all QC Masks in a station's raw data are toggled off, the magenta M (Figure 82) will disappear from the station panel's label.

When the desired QC masks are toggled on, they are indicated as colored waveform segments (see Figure 83) over a given time interval with a dot of the same color marking the start and end time of the QC mask, as shown in Figure 84.

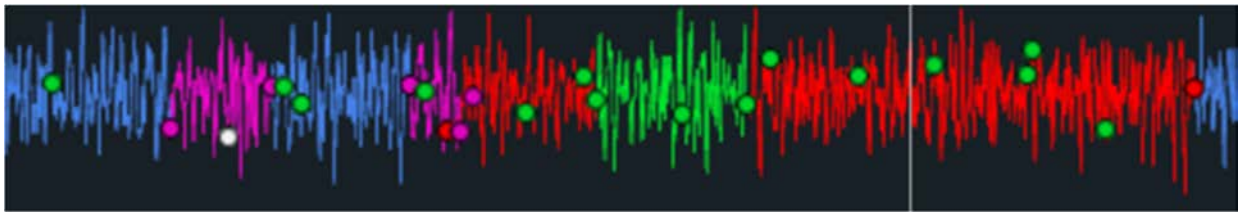


Figure 84. Example QC Masks.

QC masks may overlap such that one QC mask completely covers another; shorter QC masks will be shown on top of longer ones. Note, Processing Masks will always be displayed on top of QC Segments where they exist. The dots marking a QC mask's endpoints are visible for all QC Masks, allowing the user to know whenever there is an overlap. Also, in the case of a spike QC segment, which may only be one sample in duration, the endpoint dots will overlay each other, thus visually appearing as a single dot. Finally, QC masks are only shown where waveform samples are available – they are not shown when there are no data.

5.3.7.1. Displaying QC Mask Information

5.3.7.1.1. QC Segment Details Menu – Current Version

To learn more about a QC mask, the user can right-click on a QC Mask or its endpoint dots to bring up the popup menu in Figure 85, then click 'Select QC segment'. If there are no overlapping QC masks, this action will bring up the menu in Figure 86, then the user can click 'Open QC segment details'.

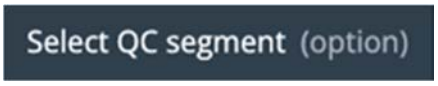


Figure 85. QC Segment Popup Menu With Overlapping Segments.

Figure 86. QC Segment Popup Menu Without Overlapping Segments.

Alternatively, QC segment details can be brought up directly by pressing Alt + Click (Option + Click on Mac; Appendix C) on the desired QC mask. Note that currently, the hotkey is incorrectly shown as just option, rather than option + click, in the QC Segment Popup menu (Section 6).

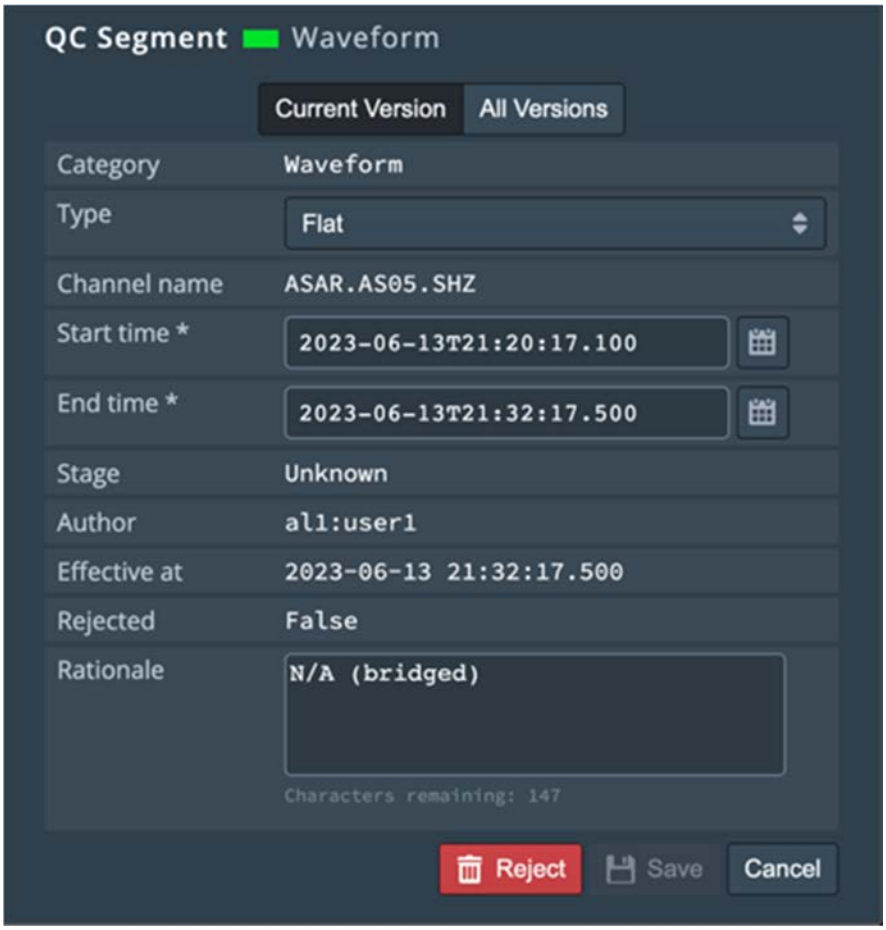


Figure 87. QC Segment Details Menu Current Version.

If there are overlapping QC Masks, the actions described will instead bring up the table in Figure 88.

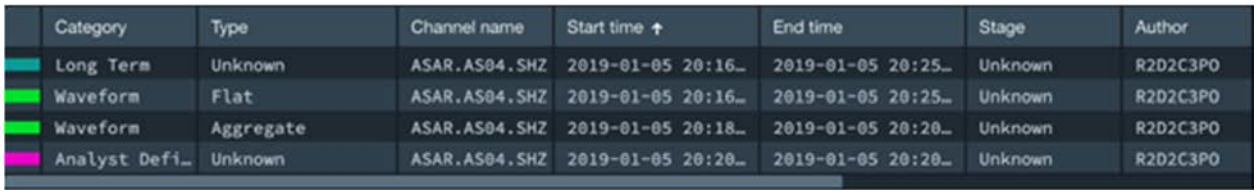


Figure 88. QC Segment Details Menu Showing Multiple QC Masks.

This table is the same as that shown in Figure 87 except the information for each QC mask is shown in a row rather than vertically and the user needs to use the scroll bar to view all columns. To view just one QC mask, double-click on the desired QC mask row. This action will cause that QC mask's information to be displayed as in Figure 87. Note that this description is

for a QC Segment type of QC mask; the menu for a Processing mask is described later this section.

In the QC Segment Details menu, metadata details of the current version of the QC mask are shown. These details include:

1) Category – the general QC issue indicated by the selected QC segment. See Table 3 for definition. Category will automatically be set to N/A if the QC segment is rejected (see bullet 8)
2) Type – the specific QC issue indicated by the selected QC segment (optional). See Table 3 for definition. Category will automatically be set to N/A if the QC segment is rejected (see bullet 8)
3) Start time – the time the QC segment begins
4) End time – the time the QC segment ends
5) Stage – the workflow stage the QC segment was created in. QC segments created by auto processing will have stage set to Unknown. Otherwise, Stage will indicate the workflow stage (AL1 or AL2) the QC mask was created in
6) Author – the analyst's name or the automatic processing stage that created the QC segment
7) Effective at – the time at which the QC segment went into effect
8) Rejected – indicates whether a QC segment has been rejected. Can be True or False
9) Rationale – A comment providing the reason an analyst created or rejected a QC segment (optional)

Further, at the top of the menu a colored box and its corresponding label indicate the category of QC segment being viewed. The colors and their corresponding statuses were described earlier in Section 5.3.7.

In addition to providing metadata information about a QC segment, the QC Segment menu can also be used to modify a QC segment unless the category was Rejected or Unprocessed (Table 3). First, the QC Segment type can be reassigned by clicking the Type dropdown menu, see Figure 89, and selecting a desired type.

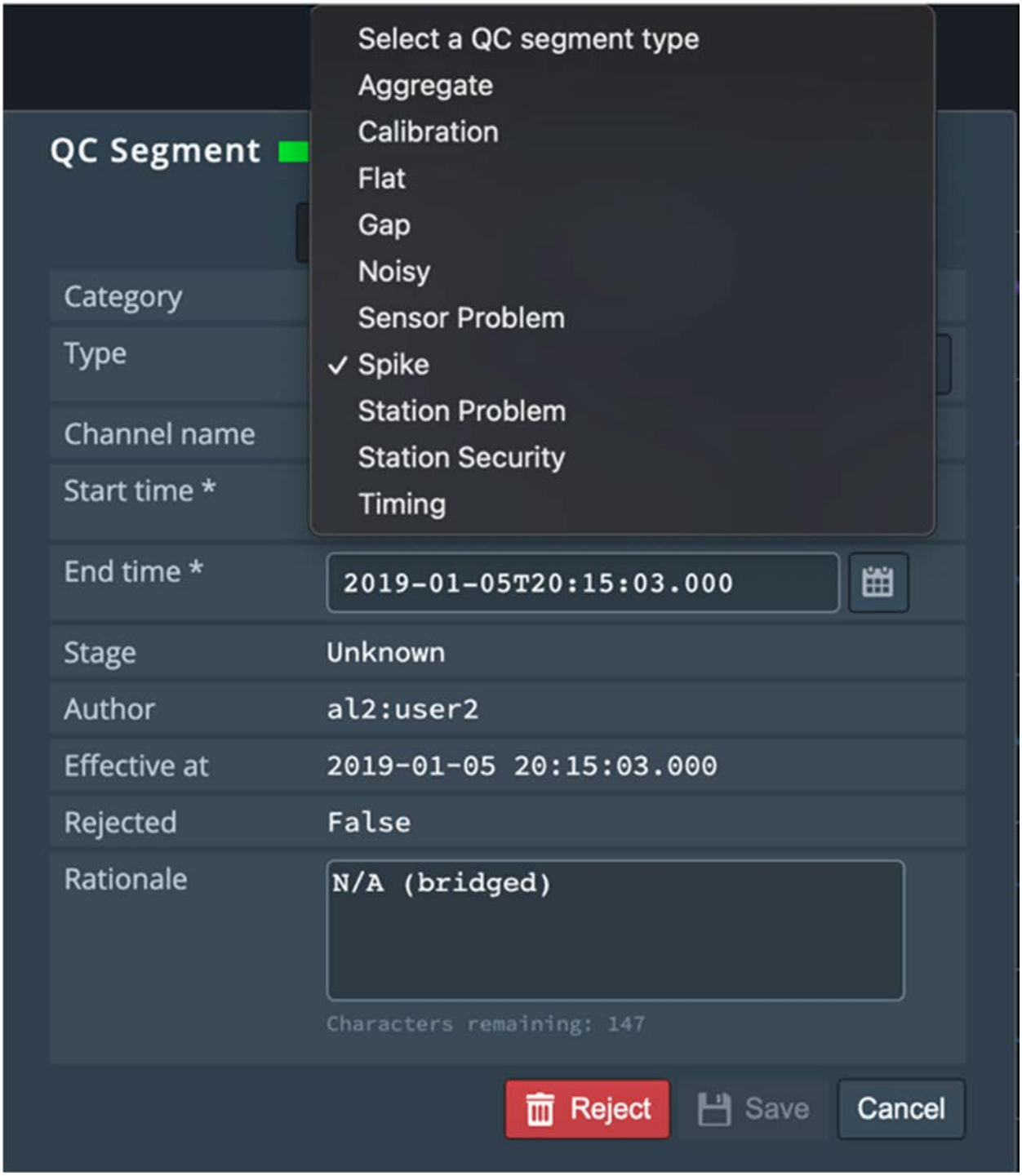


Figure 89. QC Segment Type Dropdown Menu.

Any of the types described in Table 3 can be assigned.

Next, Start and End times can be manually entered using their time entry inputs or a time can be assigned using a calendar (Figure 90) by clicking the calendar buttons to the right of the time entry inputs.

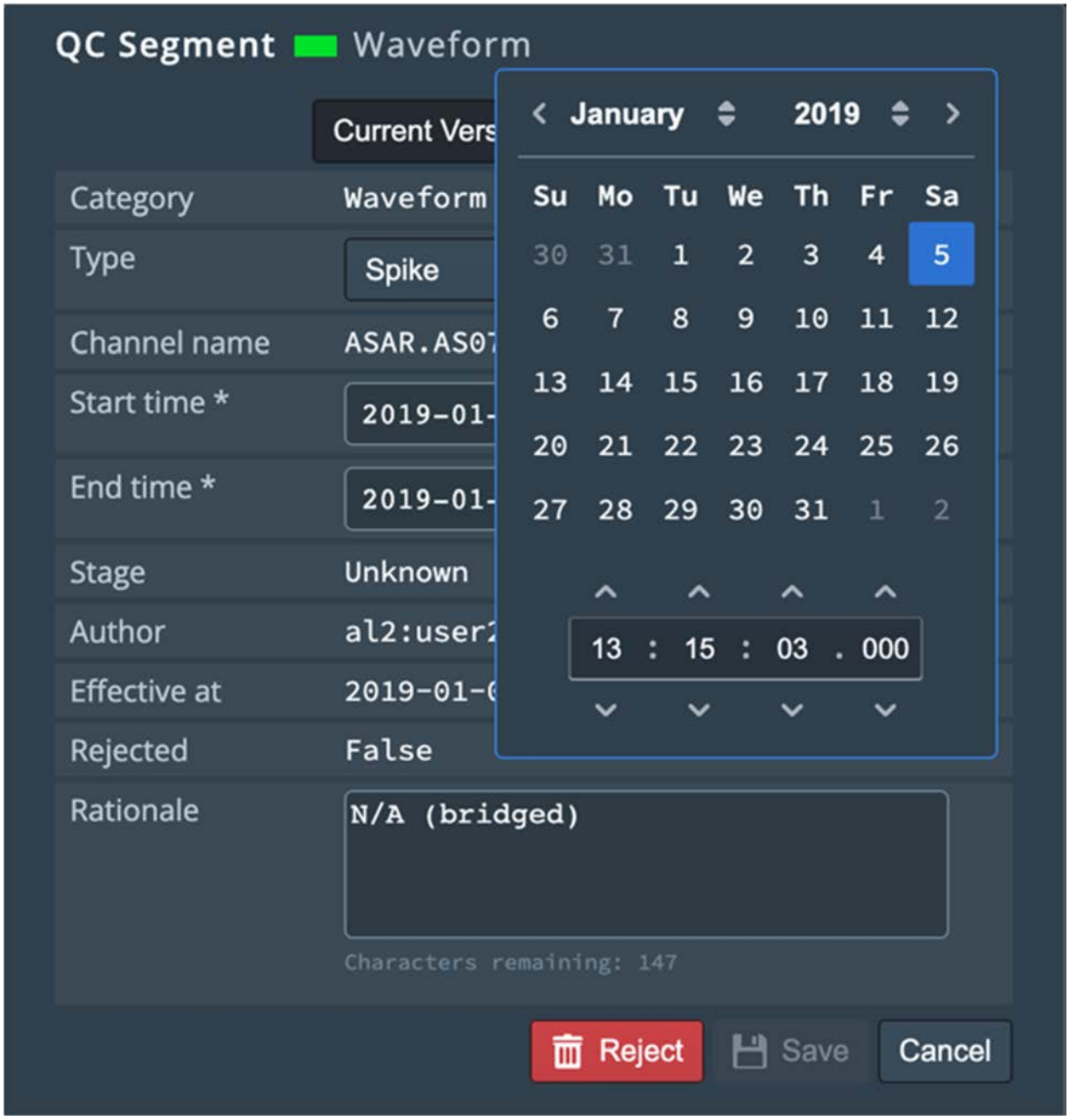


Figure 90. QC Segment Start/End Time Calendar.

The calendar usage is very similar to what was described in Section 5.2.1 for the Open Anything feature and is identical to the calendar in Section 5.3.5.5 used in the Create Event feature. The reader is referred to these sections for more detail on calendar usage.

Finally, a Rationale for the creation or rejection of a QC mask can be entered in the context box at the bottom of the QC Segment table. The total number of characters allowed is 160. Entering a Rationale is optional and can be undone by pressing Ctrl + Z (Command + Z on Mac). By default, a Rationale of 'N/A (bridged)' is included by the GMS system.

If any of the options to modify a QC mask described above are applied, the QC mask category automatically becomes Analyst Defined (Table 3), regardless of what the previous category was; the color of the modified QC segment automatically becomes magenta (Figure 83). If a change to Start/End time or Rationale is undone using Ctrl + Z, the QC mask category will revert to the previous category. If QC segment type is changed for Station SOH or Waveform categories, the previous QC segment category can be restored by restoring the QC segment type to its original value. Note that because type cannot be restored for categories Data Authentication and Long Term, which have no inherent type, these categories will permanently change to Analyst Defined.

Once a change is made, the Save button at the bottom of the QC Segment Details table becomes active, allowing the user to save all changes. Upon saving, 1) the stage and author entries update to reflect the stage the change was made in and the author that made the change, 2) the updated/new QC segment's metadata is added to the All Versions table (Figure 92) discussed later this section, 3) the QC segment length visually updates to reflect the new start/end time, if these parameters were changed, and 4) the menu closes. Once saved, the changes cannot be undone using Ctrl + Z. Alternatively, the user can close the QC Segment Details menu without saving changes by 1) clicking the Cancel button at the bottom of the table, 2) pressing the Esc key, or 3) clicking anywhere outside the QC Segment Details menu.

In addition to the Save and Cancel buttons, the Reject button is provided if the user wants to reject a QC segment. Once rejected, the QC segment turns red (Figure 83) in the Waveform display and the QC segment can no longer be modified using the QC Segment Details menu (Figure 91, Left). In the QC Segment Details menu, the Category and Type entries automatically update to N/A upon rejection and the Mask Type dropdown menu (Figure 89) is no longer available. QC segments with an Unprocessed QC type also cannot be modified (Figure 91, Right).

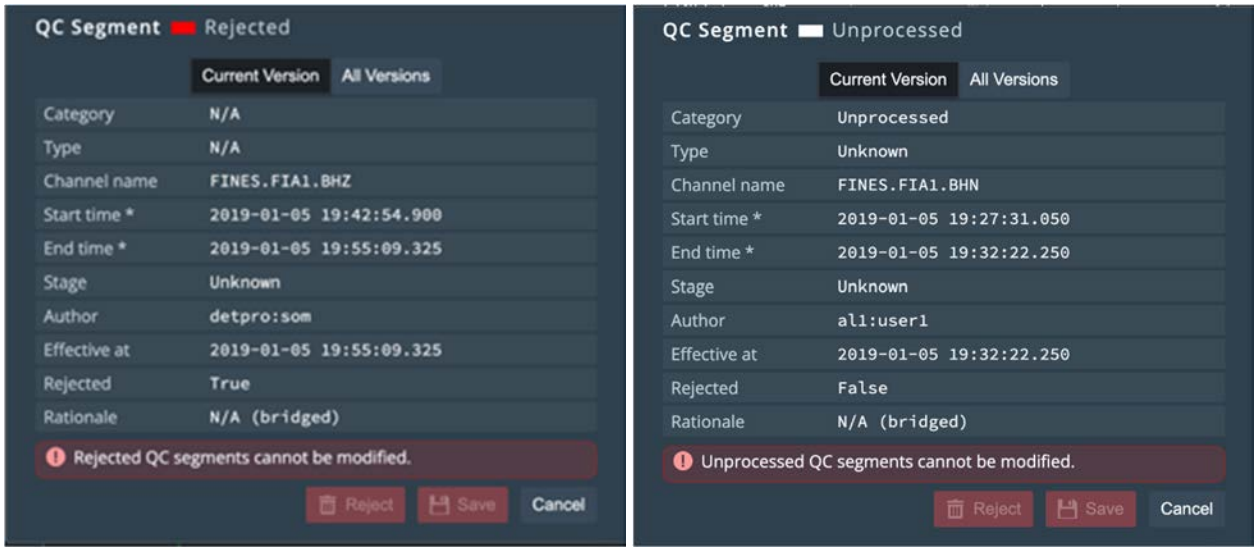


Figure 91. QC Segment Details Table Showing a Rejected QC Segment (Left) and an Unprocessed QC Segment (Right).

Finally, information from the QC Segment Details Current Version tab can be copied and pasted to external files**.**

5.3.7.1.2. QC Segment Details Table – All Versions

In addition to the Current Version tab selected in Figure 87, the user can select the All Versions tab in the QC Segment Details menu to bring up the table shown in Figure 92.

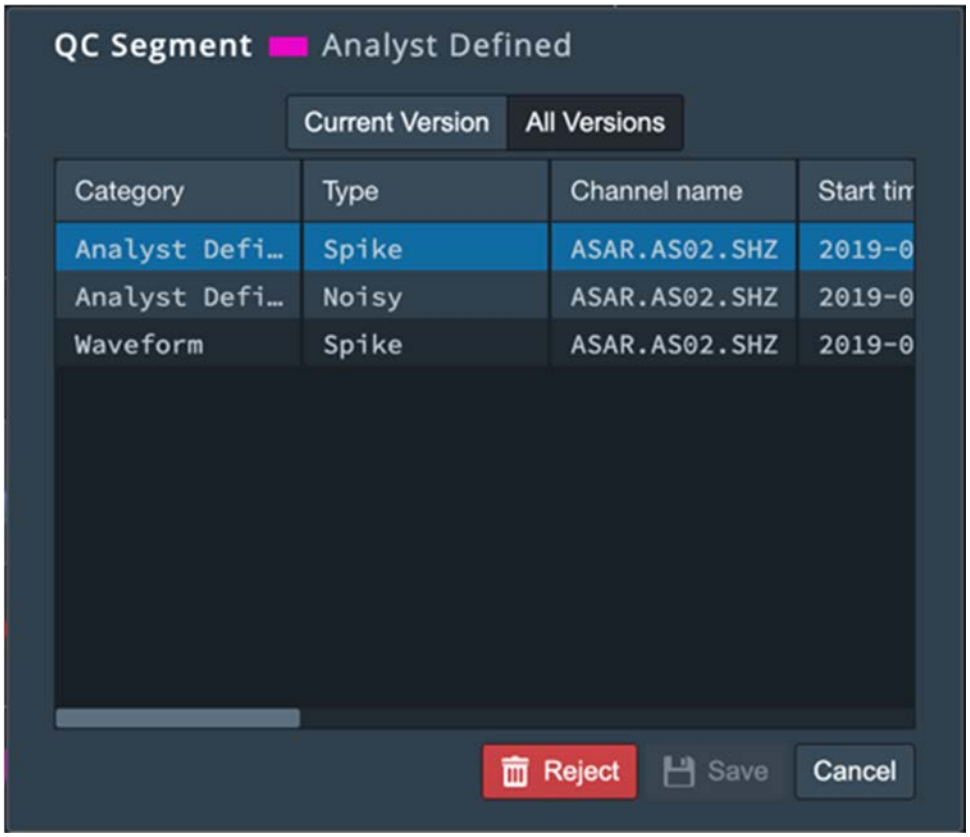


Figure 92. QC Segment Details Table All Versions.

This version of the QC Segment Details table shows the provenance of the selected QC segment and details how that segment may have changed over time. In particular, the category, type, etc., of each QC segment version up to the most recent version is shown in column format, with the most recent version at top and highlighted in blue. Note that category remains Analyst Defined after the first version has been modified unless the QC segment has been rejected. The horizontal scroll bar must be dragged to view all columns.

To use the Save button in this tab, changes must have already been applied in the Current Version tab (Section 5.3.7.1.1). The user can Reject and Cancel in this tab as before.

5.3.7.1.3. Processing Mask Details Menu

To view a processing mask's details, the processing mask option in the QC masks dropdown menu (Figure 83) must be toggled on and a waveform with an associated processing mask must be selected (Section 5.3.5.1). If either of these actions aren't taken, the processing mask will not be visible in the Waveform display. Currently, only a small number of SDs in the Waveform display will have a processing mask; these masks are mocked for demonstration purposes and

will be fully implemented in a future release (Section 6). The UI can create processing masks for during beamforming, waveform rotation, and FK analysis.

Once processing masks are visible in the Waveform display, the user can bring up the Processing Mask Details table using the same actions as described for the QC Segment Details menu in Section 5.3.7.1.1.

As with the QC Segment Details menu (Figure 87), the Processing Mask Details table shows the attributes of the selected processing mask in a tabular view.

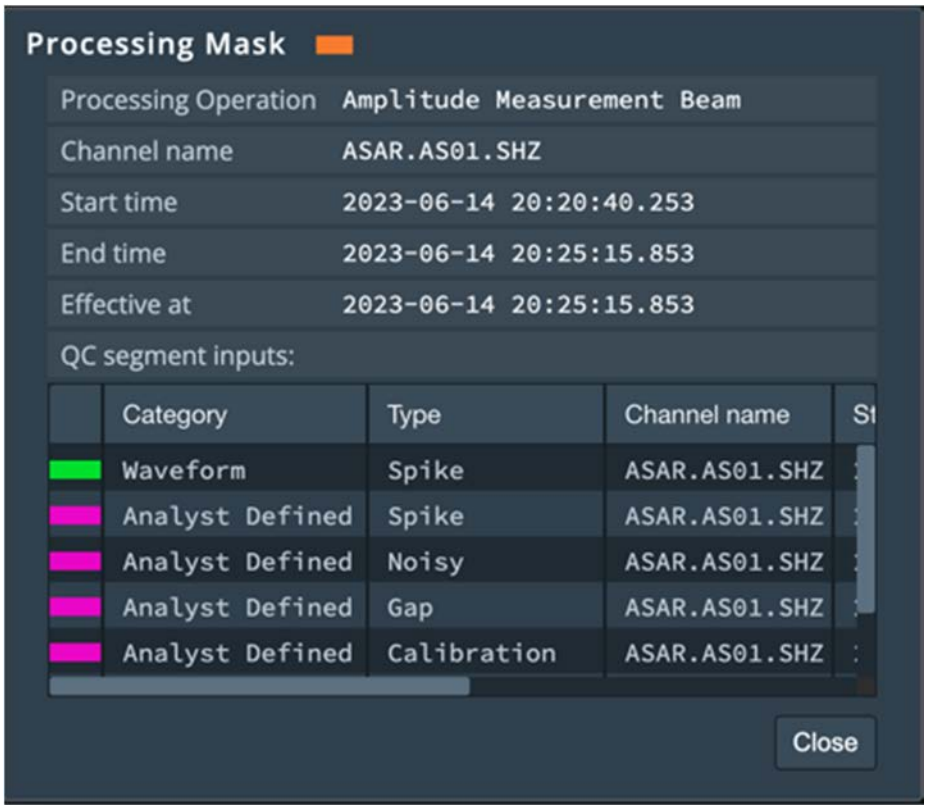


Figure 93. Processing Mask Details Table.

In the Processing Mask Details table, the following metadata details are shown:

1) Processing Operation – the signal processing operation that uses the selected processing mask. Signal processing operations can be one of the following:
    a. Display filter
    b. Rotation
    c. FK spectra

d. Amplitude measurement

e. Beams

i. Signal detection beam

ii. FK beam

iii. Event beam

iv. Virtual beam

f. Spectrogram

2) Channel name – the name of the channel the processing mask is applied to.

3) Start time – the time the processing mask begins.

4) End time – the time the processing mask ends.

5) Effective at – the time the processing mask went into effect.

6) QC segment inputs – a list of QC segments that were combined to create the processing mask, with each row representing a single segment. Each row shows that segment's category color, category, type, channel name, start time, and end time. These values were described in Section 5.3.7.1.1. The rows are order by start time initially.

a. The rows in this list can be sorted by column value by clicking to the right of the desired column's label. This action will sort the rows by the ascending column value. To sort the rows by descending column value, click the arrow again such that it points downward.

b. Note that the QC segment types that can be used to make a processing mask will vary based on the processing operation the segment was made for. The allowed QC segment types for an operation are configurable (see Configuration documentation).

5.3.7.2. Creating QC Segments

To this point, the QC mask examples shown were generated via automatic processing. Oftentimes, the user must also create new QC masks, specifically QC segments, to mask out undesirable data that may have been allowed through prior stages or for the purpose of excluding it from a processing operation. Note that processing masks cannot be created by the user, as processing masks are automatically generated by IAN based on the configured rules of a given processing operation (see Configuration documentation).

To create a QC segment, the user must expand a station waveform panel and select one or more of its channels (Section 5.3.2). This action will cause the Create QC Segment option at the upper-right of the Waveform display (Figure 34) to become available. Once the desired channels to be masked have been selected, the user can click on Create QC Segment to bring up the menu shown in Figure 94.

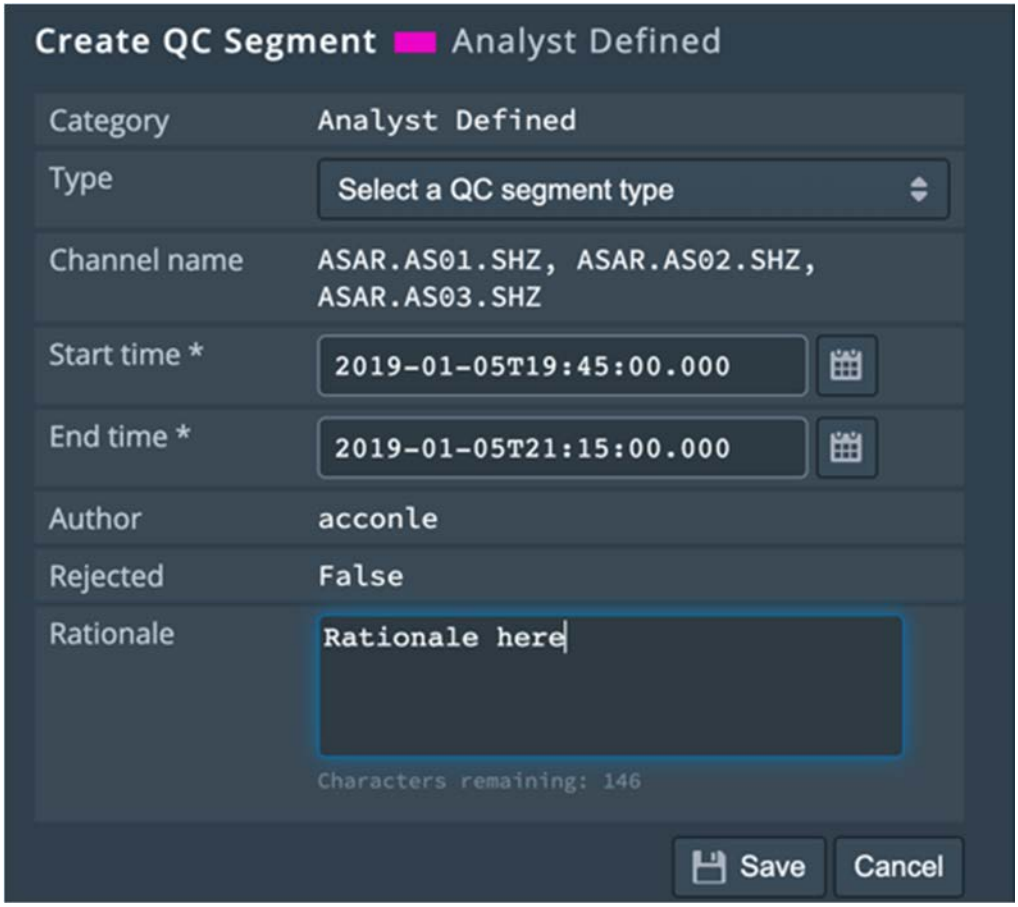


Figure 94. Create QC Segment Menu.

In this menu, the user can set the type of QC Segment to be generated, the start and end times, and the rationale for creating the segment. The category will automatically be set to 'Analyst Defined' and cannot be changed. Note that the default start and end times are set to equal the duration of the open time interval plus the configurable buffer. Thus, if the buffer duration was increased by panning, the default start and end times will result in a longer duration than may otherwise be expected. The actions to set these parameters are identical to those described for the QC Segment Details table in Section 5.3.7.1.1 and thus will not be described further here.

Once the parameters are set to the desired values, click Save to create the QC segment or Cancel to avoid creating the QC segment. Users may also cancel the creation by clicking anywhere else or pressing Esc. If saved, a QC segment will be created in the Waveform display; the Analyst Defined QC segment category must be enabled in the QC masks dropdown menu (Figure 83) for these new QC segments to be viewed. Saving or cancelling will automatically close the Create QC Segment menu.

Note that the user does not need to set any of these parameters to create a QC segment(s); if the user clicks Save without setting them, an Analyst Defined QC segment of no type will be created with a duration set to the interval time range. In this case, the created QC segment can be assigned a type and/or modified in other ways using the QC Segment Details menu in Section 5.3.7.1.1.

Alternatively, the user can also create a QC mask via hotkey by holding m while clicking and dragging over the desired channel waveform (Appendix C). This action will highlight the area to be included in the QC segment in green, with duration indicated in the ruler pop-up window; this ruler pop-up window is the same seen during zooming or the creation of a Measure Window (see Sections 5.3.1, 5.3.6.7). If the user wishes to create QC segments on multiple channels via this method, they must first select the desired channels.

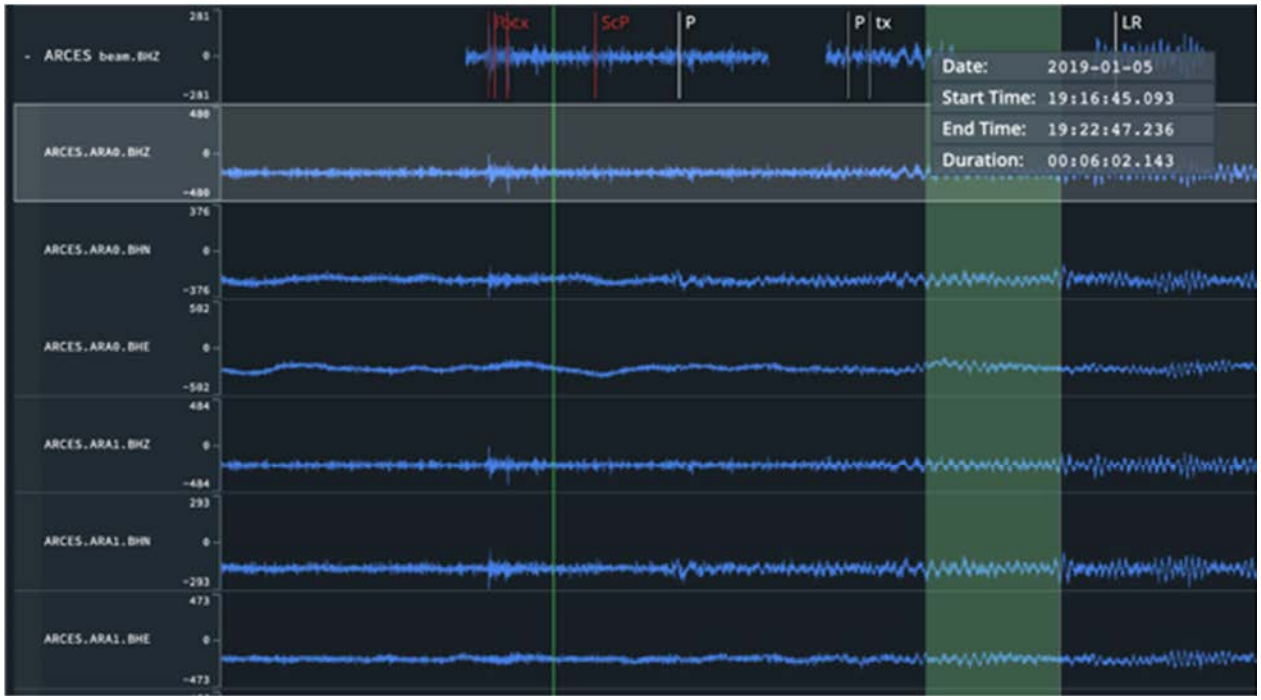


Figure 95. QC Segment Creation Window.

Note that the green window vertically stretches across the entire Waveform display rather than over just the channel the QC segment is being created on. The cursor and/or ruler can be used to identify which channel the QC segment will be created on.

Once the window is set to the desired duration, release the m + click. This action will cause the Create QC Segment menu (Figure 94) to pop up next to the green window. At this point, the user enters in the desired information as described at the beginning of this section and saves to create the QC segment. If there are no data in the section highlighted, the warning in Figure 96 will be shown.

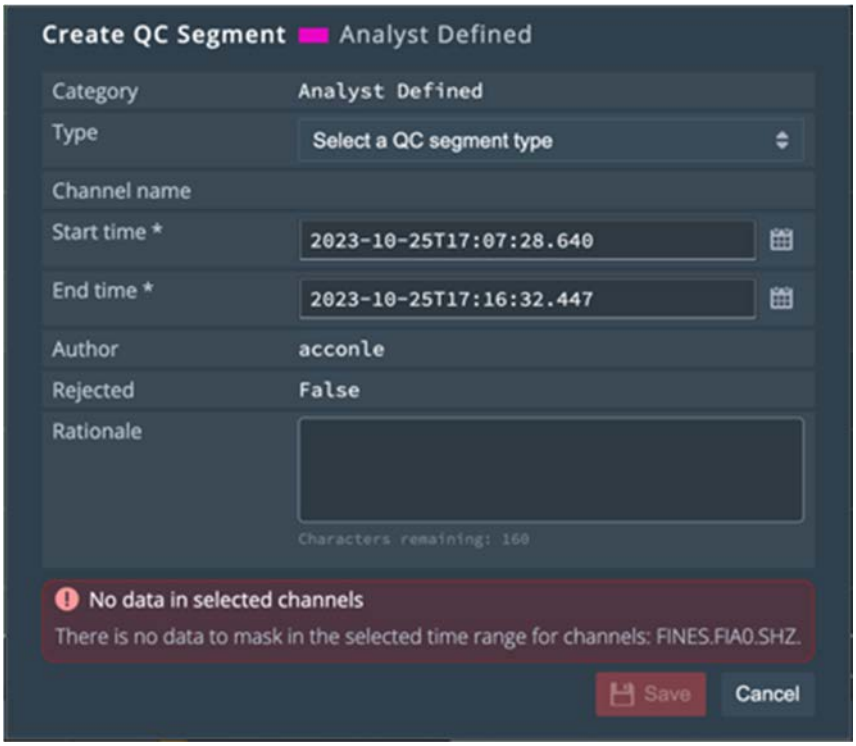


Figure 96. Create QC Segment Menu with no Data Selected.

Finally, note that if the m + click hotkey combination is attempted on a station waveform panel rather than on a channel waveform panel containing the necessary raw waveforms, a warning will pop up in the lower-right corner of the IAN UI (Figure 97).

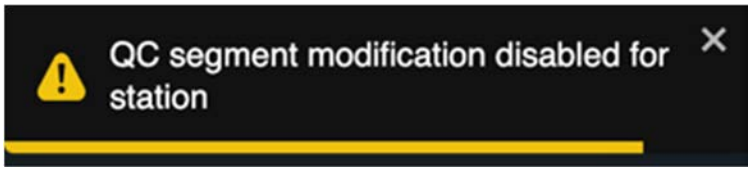


Figure 97. QC Segment Creation Warning.

5.3.8. Changes to Waveform Display When Event Opened

To this point, the Waveform display has been described in its default state, i.e., with no events opened for analysis. This section will describe changes to the display when an event is opened in the Events display (Section 5.4) or the Map display (Section 5.6). Refer to Sections 5.4 and/or Section 5.6 on how to open an event.

When an event is opened, the Waveform display will automatically Zoom-Align-Sort (ZAS). First, the display will zoom (Z) into a 60-second window centered on the predicted first-P phase (indicated by a gold-colored phase label at the bottom of the pick marker, see Section 5.3.5 for details) associated with the station closest to the opened event. Both the window length and the phase to align on are configurable (see Configuration documentation). Second, the predicted first-P phases of the remaining stations are aligned (A) relative to the predicted first-P phase of the closest station. Last, stations are sorted (S) by epicentral distance from the open event, with closest at top and farthest at bottom. The epicentral distance and source-to-receiver azimuth in degrees are shown beneath the station name on the station label. The epicentral distance and azimuth are calculated between the station/channel location and the preferred location solution of the opened event. These actions result in the Waveform display appearing as shown in the example in Figure 98.

Figure 98. Waveform Display with ZAS Applied.

To shift the timeline appropriately such that the aligned phases are always plotted in the center of the window, the timeline may be expanded or shrunken as needed, although new data will not be loaded. Areas of the timeline that do not include new data are indicated by having a darker background than areas with data as shown in Figure 99. Stations will remain sorted by epicentral distance from the event. Note that these dark areas will typically only be visible if the user pans or zooms out from the originally applied ZAS viewable range.

Figure 99. Waveform Display with Timeline Expanded to Accommodate Phase Alignment.

If the user modifies the Waveform display such that the window duration changes (e.g., if the user zooms out or pans) or aligns to a different phase or time via the alignment dropdown menu (described further in Section 5.3.8.2), clicking the ZAS button in the upper-left corner of the display will restore the Waveform display to the ZAS view described.

When an event is opened, predicted SDs are shown in the Waveform display. These SDs are indicated by gold phase labels that appear at the bottom of the pick marker rather than the top as is seen for observed SDs. The predicted phase may be a standard predicted phase, where the calculated phase *is* expected to be recorded by the station, or an extrapolated predicted phase, where the calculated phase *is not* expected to be recorded by the station. Note that if predicted phases fail to return from GMS when attempting to open an event, a warning message (Figure 100) will appear in the lower-right corner of the IAN UI, ZAS will not be applied, and the ZAS button will be disabled.

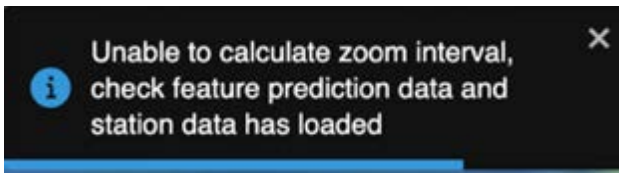


Figure 100. ZAS Warning.

Observed SDs associated with the opened event are now colored orange. All other SDs remain the same as before. All SD statuses are described in Section 5.3.5.

Upon opening an event, three new options (Figure 98) will be enabled: the event beam menu, alignment menu, and the predicted phase radio button. Automatically, the alignment menu will toggle from aligning on time to aligning on phase and its label will update to 'Align on: Predicted P' (or to configured default phase). At the same time, the predicted phase radio button will automatically be enabled to display predicted phases. These two options/menus will be described in further detail in Sections 5.3.8.2 and 5.3.8.3, respectively.

When an opened event is closed again (see Sections 5.4 and 5.6 on how to close an event), the changes described here revert to the default state described in earlier sections.

5.3.8.1. Create Event Beams Menu

Event beams are retrieved for all loaded stations when an analysis interval is opened, extend, or a station is added. The Waveform display shows all event beams for the currently open event. Analysts can view the raw channels that contributed to a single selected event beam. This contribution is indicated with a beam input label above the channel label. Non-contributing channels will be dimmed and not have the beam input label (Figure 101).

Figure 101. Beam Input for Event Beams

When an event is open, the user can create event beams for one or more array stations using the Create Event Beams menu (Figure 102) or hotkey.

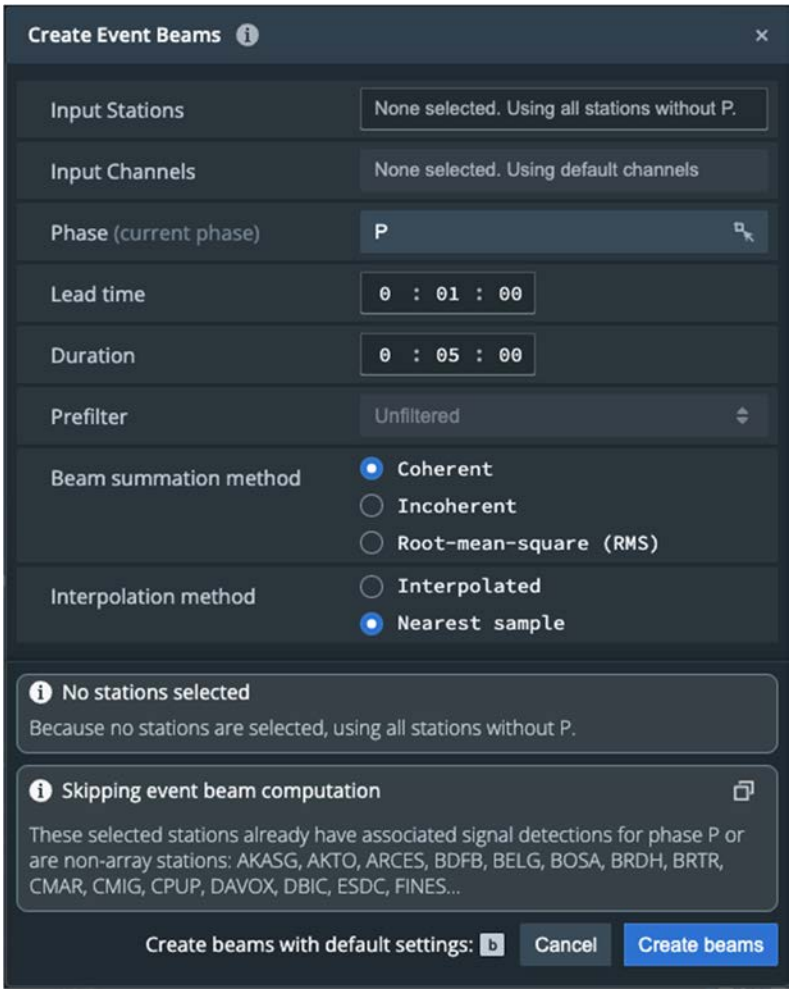


Figure 102. Create Event Beams Menu.

Event beams are created by aligning and stacking the raw waveforms recorded by an array station's channels and are used to enhance the desired features of a waveform. A description of the Create Event Beams menu usage can be viewed by hovering over the info icon  to the right of the Create Event Beams title to bring up a tooltip (Figure 103).

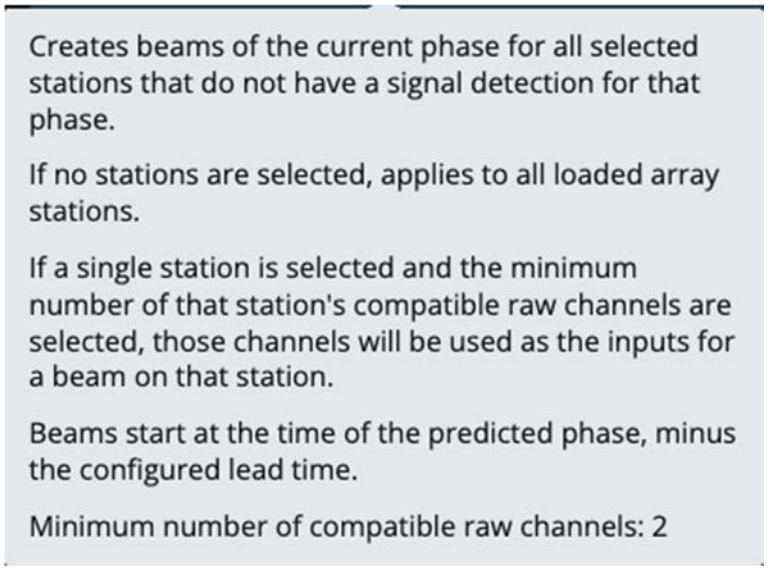


Figure 103. Create Event Beams Menu Tooltip.

In the Create Event Beams menu, the user has the following input options to create a beam:

- Input Stations – specifies which array stations to create beams for. If no stations are selected, beams will automatically be created for any stations that do not have an SD of the current phase type (see Section 5.3.5.2.2)
- Input Channels – specifies which of a selected station's channels to use in beamforming. If no channels are selected, default channels are used. The default channels used are configurable (see Configuration documentation). Only a single station's input channels can be selected
- Phase (current phase) – specifies which phase to steer the beam to. The beam will be created based on predictions of arrival time, azimuth, and slowness for the selected phase. Phase will automatically be set to the current phase defined by the Current Phase menu (Figure 48; Section 5.3.5.2.2)
- Lead time – sets the start time of the beam, defined as the arrival time of the current predicted phase minus the lead time. Lead time is defined in HR:MIN:SEC. By default, the lead time is set to 1 minute. This default is configurable (see Configuration documentation)
- Duration – the total length of the beam to be created in HR:MIN:SEC. By default, the duration is set to 5 minutes. This default is configurable (see Configuration documentation)

- Prefilter – the filter to be applied to the raw waveforms prior to beamforming. The set of pre-filter options in the dropdown are configurable (see Configuration documentation)
- Beam summation method – the method with which to create the beam. Three methods are available (coherent, incoherent, and Root-mean-square, i.e., RMS)
- Interpolation method – defines how to align waveform samples. In IAN, waveform samples can either be aligned to the nearest sample or interpolated

An additional input that is used in beamforming, but is not modifiable, is the sample rate tolerance. Sample rate tolerance is used to ensure that raw waveform data of similar sample rates are used when beamforming. The sample rate tolerance is set to a station-specific value and is configurable (see Configuration documentation); this value is not shown in the Create Event Beams menu.

To set the input station(s), the user can either select one or more station waveform panels in the Waveform display (see Section 5.3.2) to populate the Input Stations context box with stations or click the context box to bring up the Input Stations dropdown menu (Figure 104, Left).

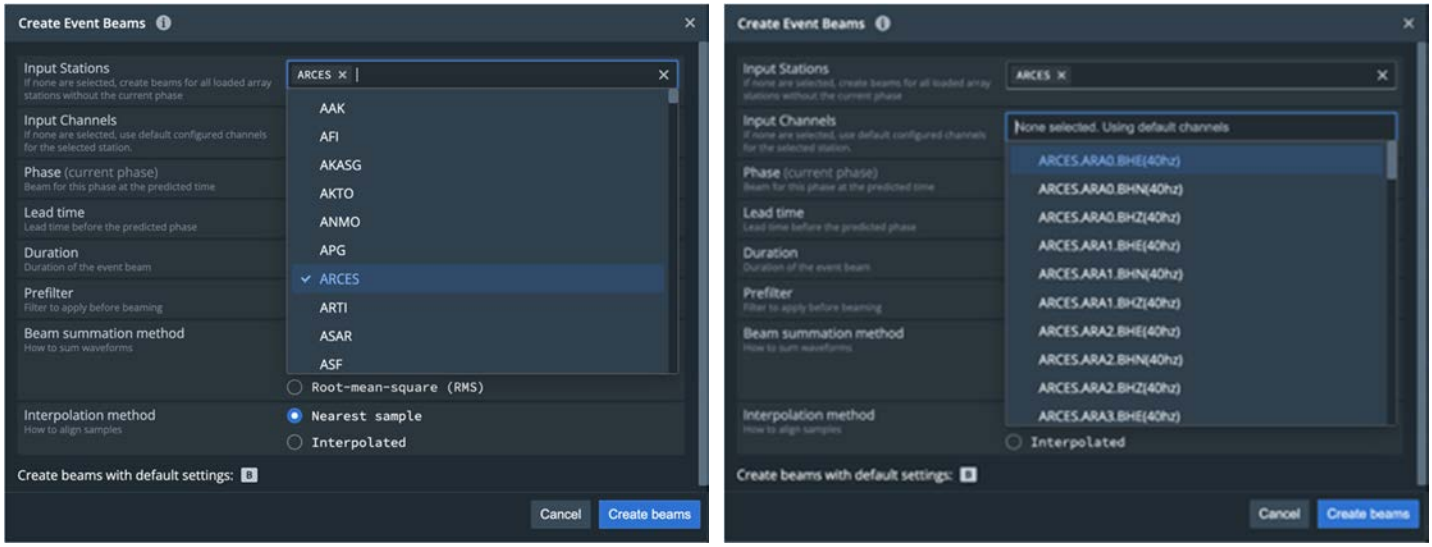


Figure 104. Input Stations (Left) and Input Channels (Right) Dropdown Menus in the Create Event Beams Menu.

In the dropdown menu, the user can click on a desired station(s), causing a checkmark to appear next to that station(s). The user may have to scroll down to find the desired station. Alternatively, the user can begin to write part or the entire station name to filter the station list and/or enter a station name directly into the context box.

To remove a station(s) from the Input Stations context box, the user can 1) click the X icon next to the station to be removed or 2) click the X icon at the far right of the context box to remove all stations from the context box. Note that changing selections in the Input Stations context box will not affect selections made in the Waveform display (Section 5.3.2).

Once all selections are made, click anywhere else in the Create Event Beams menu to close the list.

The behavior to input channels into the Input Channels context box is the same as the Input Stations context box. A single input station must be selected in the Create Event Beams menu prior to selecting input channels. If no station is selected or multiple stations are selected, the dropdown menu becomes unavailable and indicates to the user that default channels will be applied when a beam is created.

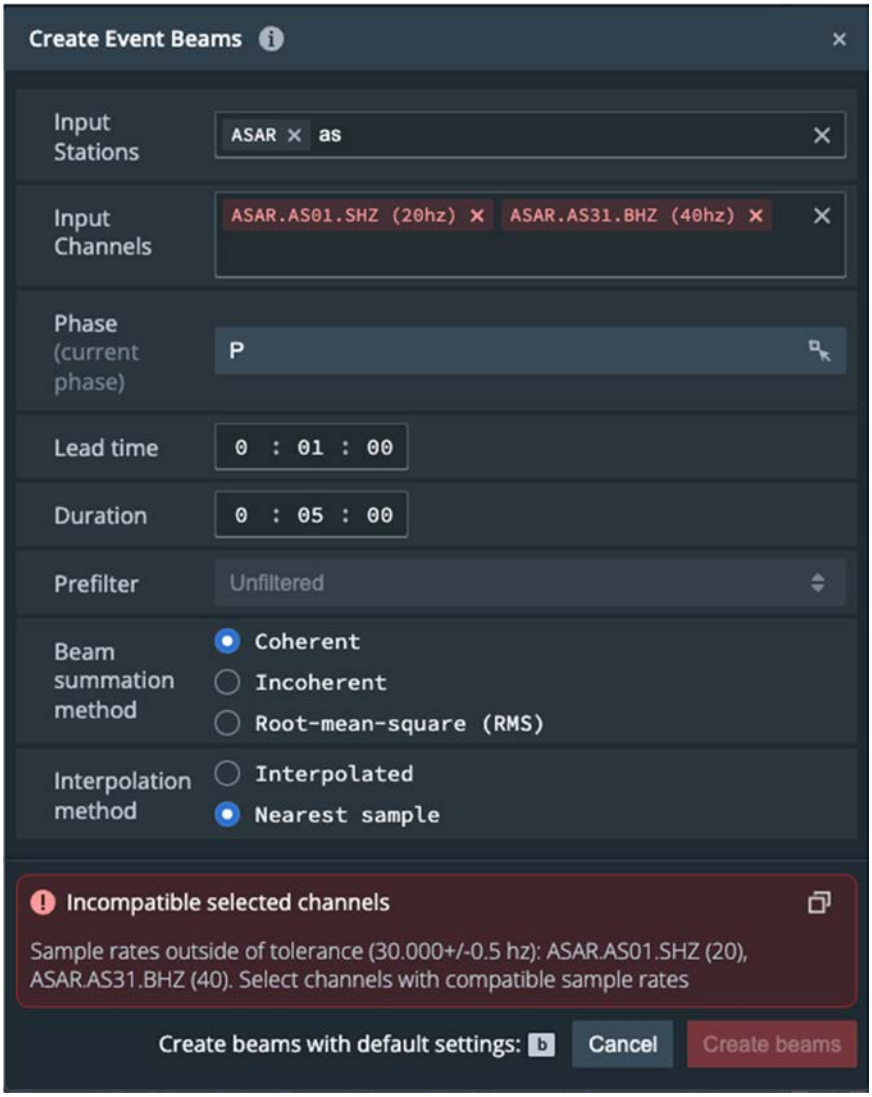


Figure 105. Invalid Selection Warning in Create Event Beams Menu.

In the example in Figure 105, two channels from station ASAR were selected. This action results in the warning that the selected channels have sample rates outside the tolerance of ±0.5 Hz. This tolerance is configuration (see Configuration documentation. Note that this and other warnings can be copied to Clipboard by clicking on the copy icon at the right corner of the warning. An 'Invalid Selection' warning will be shown for the following scenarios:

- channels from multiple stations and input channels are selected
- selected channels have inconsistent units
- selected channels have inconsistent band codes
- selected channels have inconsistent instrument codes
- selected channels have orientation angles beyond the configurable tolerance (see Configuation documentation)

In addition to the channel name, the Input Channels dropdown menu lists the sample rate of each channel (Figure 104, Right). This information allows the user to know whether the selected channels can be beamed together, i.e., whether they fall under the configured sample rate tolerance. Also, a minimum of 2 channels must be specified to perform beamforming; this value is configurable (see Configuration documentation). Otherwise, a warning will result when the user tries to create a beam (Figure 106) and issues will be highlighted in red.

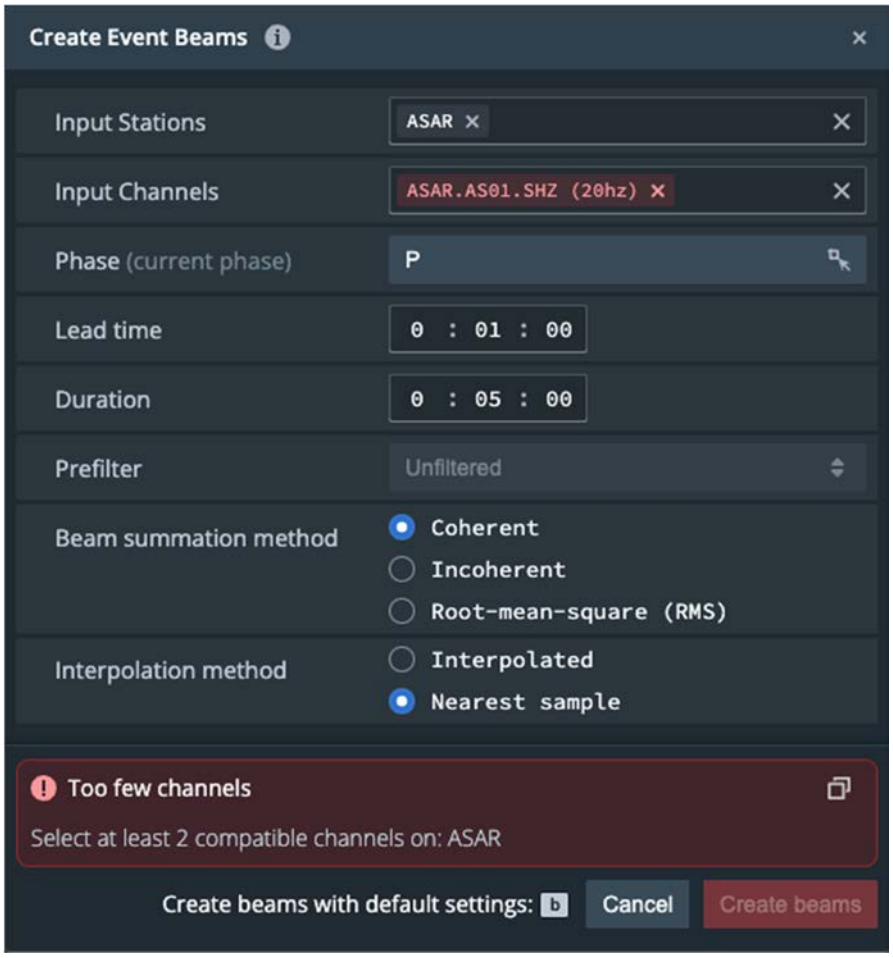


Figure 106. Too Few Channels Warning in Create Event Beams Menu.

The Phase (current phase) input can be changed by clicking the phase name (e.g., P in Figure 102). This action will bring up the Set Phase menu (Figure 48); the reader is referred to Section 5.3.5.2.2 regarding its usage. Once a phase is selected, the phase name in the Create Event Beams menu will update to reflect the selection. Note that changing the current phase in the Create Event Beams menu will change the current phase in all relevant IAN displays if the 'Create Beams' button is pressed.

The HR, MIN, and SEC context boxes of the Lead Time and Duration can be manually modified. If the user puts in an invalid time, the context box will glow red, then automatically revert to the last valid time entered when the user clicks anywhere in the Create Event Beams menu.

The filter to apply to the data prior to beamforming (if any) is set using the Prefilter Dropdown menu (Figure 107). The Prefilter Dropdown menu is populated by a configurable set of filters (see Configuration documentation).

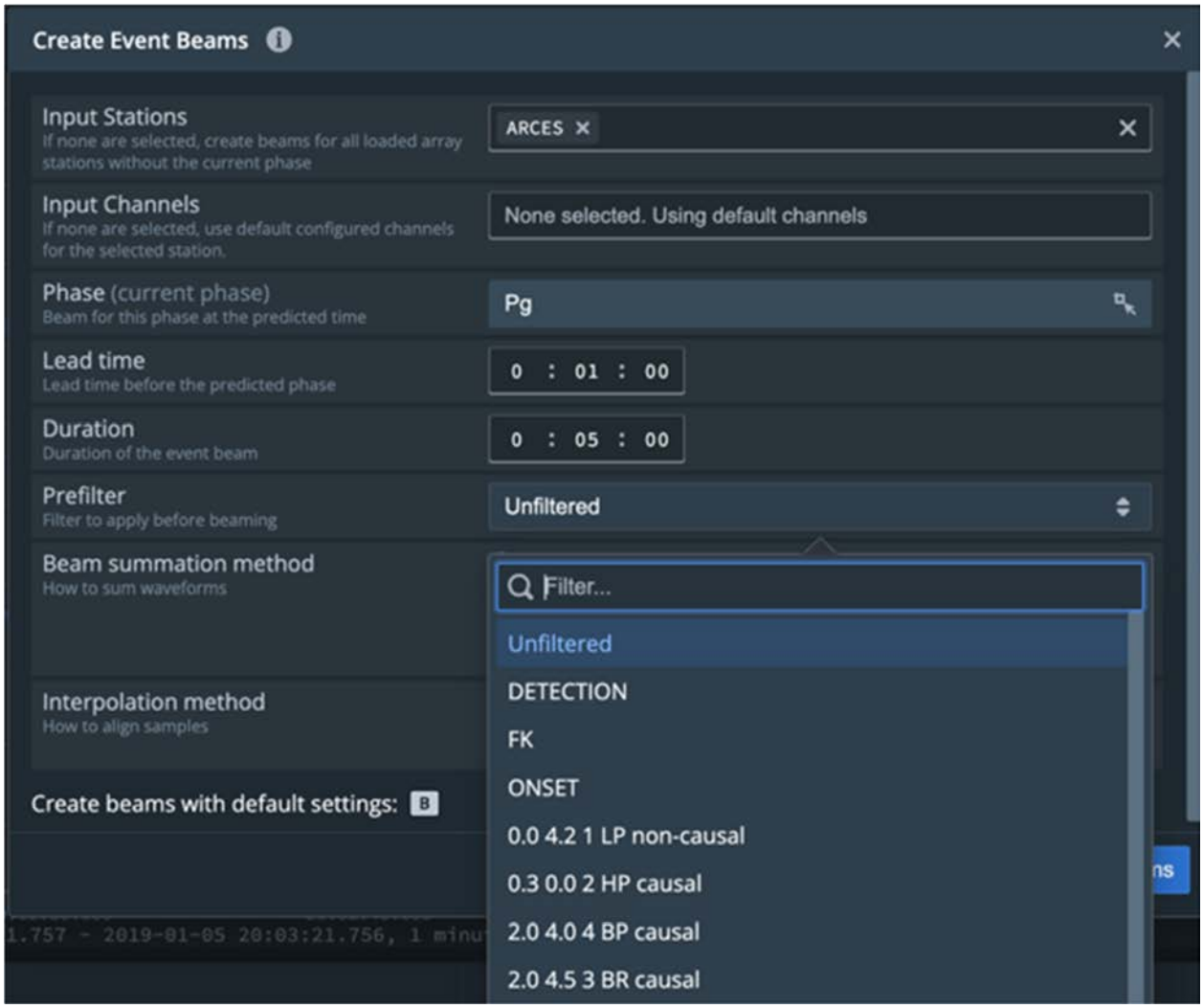


Figure 107. Prefilter Dropdown Menu in the Create Event Beams Menu.

To change the filter directly in the Prefilter Dropdown menu, the user can scroll through and select (via clicking) any of the available configured filters in the IAN UI. The filter name shown in the Prefilter box will update to reflect the user selection.

To select a Beam summation method and an Interpolation method, the user can click the radio button next to the desired option. The option being applied is indicated by the radio button appearing blue with a white dot in the center (e.g., Coherent and Nearest Sample are selected in Figure 102). By default, the Beam summation method is set to Coherent and the Interpolation method is set to Nearest sample. These default selections are configurable (see Configuration documentation).

Once all desired settings are applied, the user can click Create beams at the bottom right corner of the Create Event Beams menu (Figure 102). To exit the Create Event Beams menu without beamforming, click Cancel at the bottom right corner of the Create Event Beams menu (Figure 102), click anywhere else in the IAN UI, or press Esc.

Finally, if the user does not wish to set specific parameters prior to beamforming, beamforming with default configured settings can quickly be applied to all stations in the Waveform display by pressing the hotkey b. Users can select specific stations or channels on a single station for beamforming using the hotkey. Event beams will be created for the current phase. I no stations or channels are selected, Event Beams will be created for all loaded array stations that down ot have an associated SD for the current event and current phase.

Newly created event beams will be automatically filtered using the currently selected filter in the Filter Display (Section 5.8).

While beams are being created, the loading indicator will indication all the stations for which beams are being created with individual entries (Figure 108).

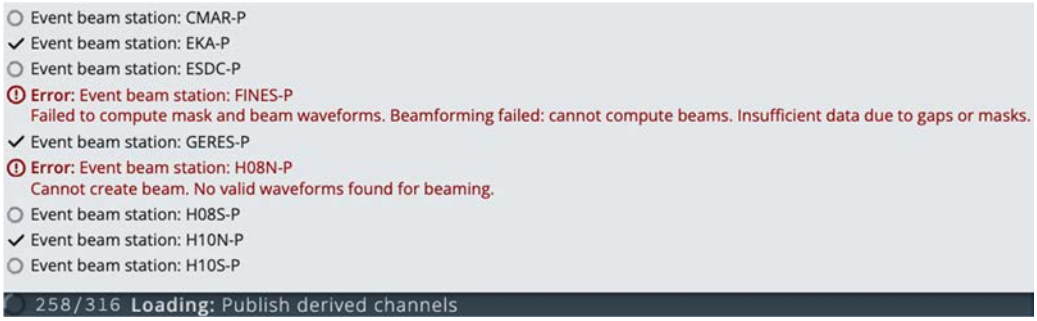


Figure 108. Loading Indicator While Event Beams Are Being Created

If beams cannot be created for any reason (e.g., configuration errors, system errors (e.g., failed to retrieve predictions, beamforming configuration, no valid waveforms, algorithm processing error, etc.), toasts will appear in the bottom right of the UI indicating on which stations beams were not created (Figure 109). Additional details about the cause of the error for each station can be found in the browser's console logs.

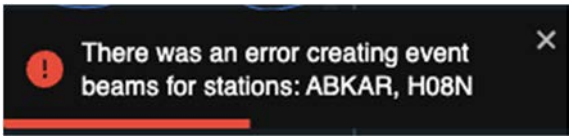


Figure 109. Error Message When Creating Event Beams.

If a user attempts to create Event Beams when an event is *not* open, a toast will appear indicating to the user that an event must be opened in order to create Event Beams.

Event Beams can only be created on array stations, not three-component stations.

Only a single event beam for each station-phase combination is shown for the currently opened event.

If an event beam is created for an exact event location / station / phase combination as an existing event beam (either bridged for user-created), the existing event beam will be deleted and the new beam will be displayed in the UI.

Signal Detections can be created on Event Beams. For information on creating SDs, see Section 5.3.5.4.

Users can view the Processing Masks applied to event beams by expanding the station to see the channels and selecting the event beam (Section 5.3.7).

5.3.8.2. Change Alignment Menu

The Change Alignment menu (Figure 110) provides the option to align all waveforms on the Waveform display either by time or by a selected predicted or observed SD phase (see Section 5.3.5 for more detail on SDs). Aligning on a predicted phase allows the user to scan waveforms more efficiently by scanning vertically across stations rather than scanning both vertically and horizontally to locate the appropriate time frame for individual stations.

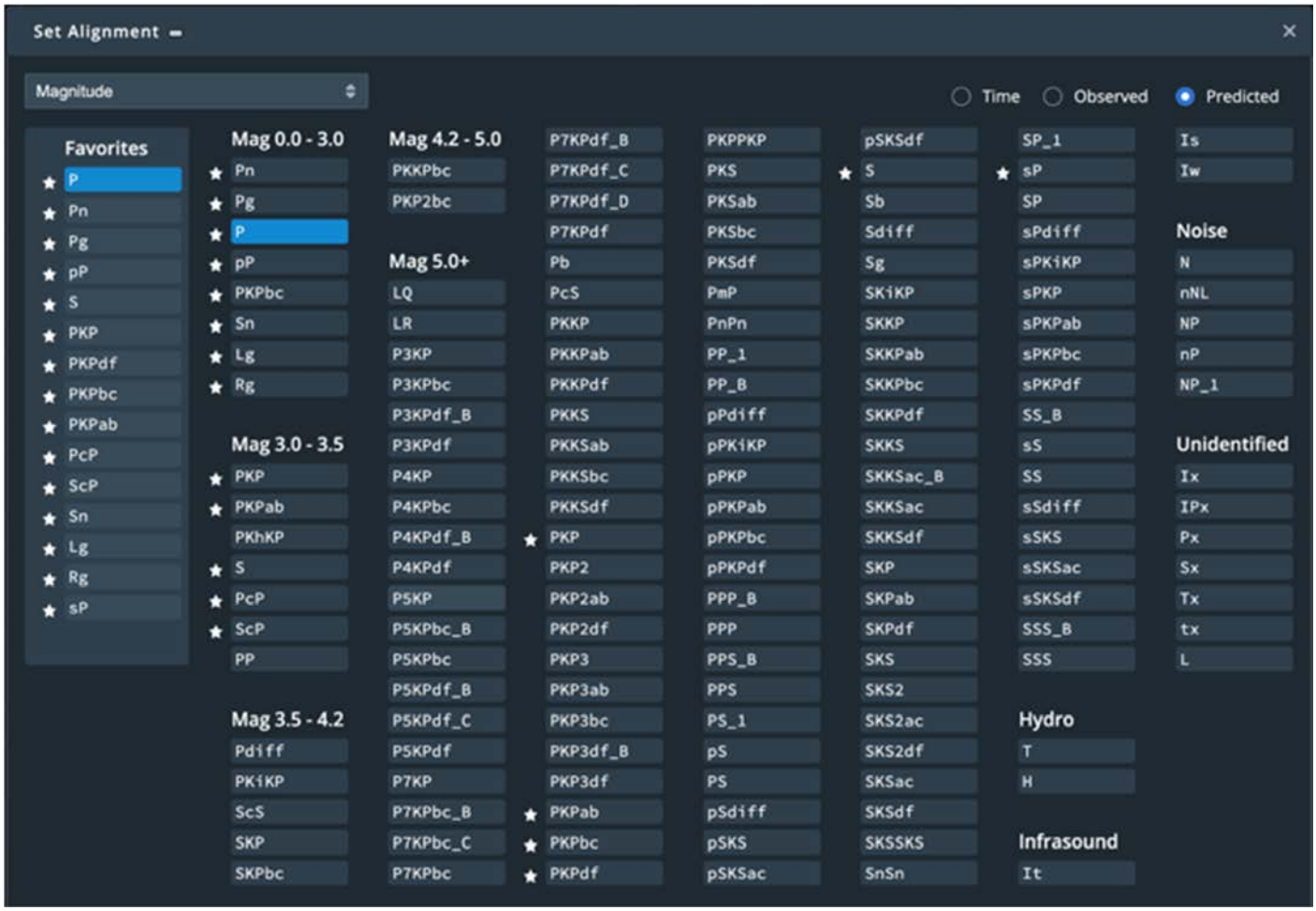


Figure 110. Change (Set) Alignment Menu.

Phase alignment is only available when an event is open (Section 5.3.8), otherwise the Change Alignment button, located at the upper right of the Waveform display (Figure 34), will remain grayed out and waveforms will be aligned by time by default.

When the user clicks the Change Alignment button, the menu in Figure 110 pops up. This menu is highly similar to the Set Phase menu (Figure 48) described in Section 5.3.5.2.2. Thus, only new functionality will be described here; the user is referred to Section 5.3.5.2.2 for further details.

When an event is opened, the phase will automatically be aligned using the default configured predicted phase option in the Change Alignment dropdown menu (Figure 110); here the default is the predicted first-arriving P phase. To align by an observed phase or by time, click the radio button to the left of the desired option at the upper right corner of the menu (Figure 110). The selected option is indicated by a blue dot with a white center. In the case of the predicted and

observed phase options, the phase to align on is indicated by the phase highlighted in blue and can be changed by selecting a different phase from one of the provided phase lists (see Section 5.3.5.2.2).

Additionally, the user can use the hotkey p to toggle between time and phase alignment (see Appendix C). Note that this hotkey only toggles between time and predicted phase alignment. The Change Alignment dropdown menu must be used to align by observed phase.

Clicking on a phase in the Change Alignment dropdown menu will align the waveforms on that phase in the center of the window (still based on the closest station), where the timeline at the bottom of the display will shift accordingly. If a station has no observed phases matching the user phase selection, alignment will be based on either 1) that station's corresponding predicted phase, where the calculated predicted phase is expected to be recorded by the station or 2) that station's extrapolated predicted phase, where the calculated predicted phase is not expected to be recorded by the station. To shift the timeline appropriately such that the aligned phases are always plotted in the center of the window, the timeline may be expanded or shrunken as needed, although new data are not loaded. Areas of the timeline that do not include new data are indicated by having a darker row background than areas with data. This behavior is the same as described for the ZAS functionality; see Figure 99, Section 5.3.8.

Once done with the Change Alignment dropdown menu, click the X icon at the upper right corner (Figure 110), anywhere else in the IAN UI to close it, or press Esc.

Upon closing the opened event, alignment will automatically revert to time alignment, regardless of what alignment options were applied while the event was open.

5.3.8.3. Predicted Phases Radio Button

When an event is opened using the Events (Section 5.4) or Maps displays (Section 5.6.4), the predicted phases radio button (Figure 111) at the top-center of the Waveform display (Figure 98) will be toggled on automatically. This button makes predicted phases viewable in the Waveform display. To hide the predicted phases from view, click the button to toggle it to the left.

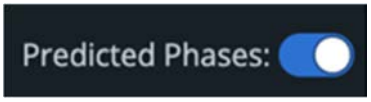


Figure 111. Predicted Phases Radio Button.

If there is insufficient space on the screen for the Predicted Phases Radio button, it will be placed in an overflow menu denoted by three vertical dots,  . In this overflow menu, the button will appear as the text option 'Hide predicted phases' instead (Figure 112).

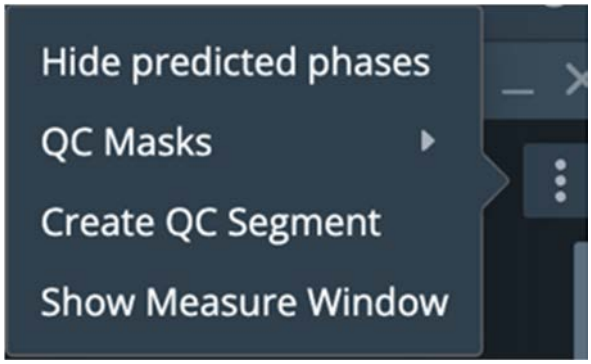


Figure 112. Predicted Phases Radio Button Shown as a Text Option.

Note that if waveforms are being aligned by phase, either predicted or observed, and the Predicted Phases Radio button is then used to hide predicted phases, alignment will automatically revert to time. The alignment will remain based on time, even if the Predicted Phases Radio button is turned back on, until the Change Alignment dropdown menu or hotkey is used to align by phase again (Section 5.3.8.2). Finally, if the Predicted Phases Radio button is toggled off and the Change Alignment dropdown menu is used to select alignment by phase, the button will automatically be toggled on to show the predicted phases.

Once the event is closed, this button will be grayed out, making it unavailable for interaction.

5.3.8.4. Event Association Menu

The Event Association menu (Figure 113) is used to associate, unassociate, or reject association of one or more SDs to an open event. This option is only available when an event is opened (see Sections 5.4, 5.6.4 on how to open an event).

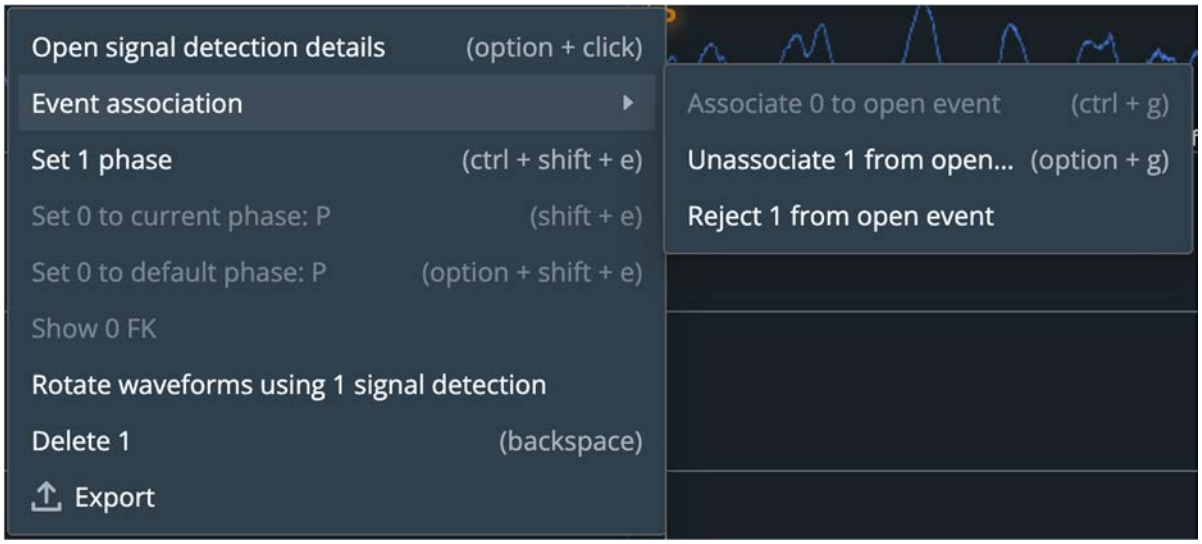


Figure 113. Event Association Menu.

To access the Event association menu, hover over the Event association option in the Signal Detection Popup menu (see Section 5.3.5.2, Figure 46).The Event association menu provides the following options:

- 'Associate # to open event' – allows the user to associate one or more SDs to an open event. The total number of valid SDs selected is shown in the option label, e.g., Associate 1 to open event in (Figure 113)
- 'Unassociate # from open event' – allows the user to unassociate one or more SDs from an open event. The total number of valid SDs selected is shown in the option label, e.g., Unassociate 0 from open event in (Figure 113). The selected SDs must already have been associated with the open event for this option to be available
- 'Reject # from open event' – allows the user to reject one or more SDs association from an open event. The total number of valid SDs associations to be rejected is shown in the option label, e.g., Reject 0 from open event in (Figure 113). The selected SDs must already have been associated with the open event for this option to be available

The 'Associate # to open event' option is only available when at least one of the selected SDs has an association status of unassociated or it is associated to another event (see Section 5.3.8.4). If all the selected SDs are already associated to the open event, the 'Associate # to open event' option is disabled. Further, if the SD is deleted, the entire Event association menu is disabled as a deleted SD cannot be associated with any event or modified. To apply the 'Associate # to open event' option, the user must select the desired SDs to associate, then either 1) open Event association menu and select 'Associate # to open event' as shown in Figure 113 or 2) use the hotkey combination Ctrl + g (Appendix C).

Associating an unassociated SD will cause the SD label to turn from dark red to orange. Associating an SD associated to another event to the open event will cause the SD label to turn from white to orange. Because the SD was already associated to another event, a conflict will arise; this conflict is indicated by a red circle with an exclamation point at the center. See Section 5.3.5, Figure 43, for the definition of conflict and an example of a conflict icon. These changes are reflected in the Signal Detections List and Map displays (Sections 5.5, 5.6). Further, in the Signal Detections List and Events displays an asterisk will appear in the unsaved changes column in each SD row and event row associated to the SD that changed.

The 'Unassociate # from open event' option is only available when at least one of the selected SDs are already associated to the open event. Unassociating an associated SD will cause the SD to turn from orange to dark red or orange to white depending on its previous association status. This option can be used to deconflict an SD (see Section 5.3.5) by unassociating the SD from all but one event; once this is done, the conflict icon (Figure 43) will disappear. To apply this option, the user must select the desired SDs to unassociate, then either 1) open the Event association menu and select 'Unassociate # from open event' as shown in Figure 113 or 2) use the hotkey combination Alt + g (Option + g on Mac; Appendix C).

The 'Reject # from open event' option is also only available when at least one of the selected SDs are already associated to the open event. By rejecting an SD, the SD is not only unassociated from the event, but it is also no longer available for association with the open event in later stages. Thus, rejection allows the user to assert that the SD is not associated to the open event and prevents future automatic processing from ever re-associating that SD to the open event. Rejecting the association will cause the SD to turn from orange to dark red or orange to white depending on its previous association status. This option can be used to deconflict an SD (see Section 5.3.5) by rejecting an association of an SD from all but one event. To apply this option, the user must select the desired SDs to reject, then open the Event association menu and select 'Reject # from open event'. There is no hotkey combination to reject associating an SD to an event.

As was the case when setting phases, the # value in the options above will indicate how many *valid* selected SDs the specific option can be applied to. Valid selected SDs will glow while all other SDs will dim. Refer to Section 5.3.5.2.2 for details.

The Events, Signal Detections List, and Map displays (Sections 5.4, 5.6, 5.5.5) are synced such that changes to association status and conflict status in the Waveform display are reflected in these displays as well. Asterisks will appear in the unsaved changes columns of the Events and Signal Detections List displays corresponding to the event(s) and SD(s) with conflicts,

respectively. Association status and conflict changes are also reflected in the Signal Detection Details table (see Section 5.3.5.2.1, Figure 47).

5.4. Events Display

The Events display allows users to view detailed event information for bridged events within the time range selected in the Workflow display (Section 5.1.1).

When initially opened, the Events display has no information loaded and will prompt the user to select an interval in the Workflow display (Section 5.1.1) as shown in Figure 114.

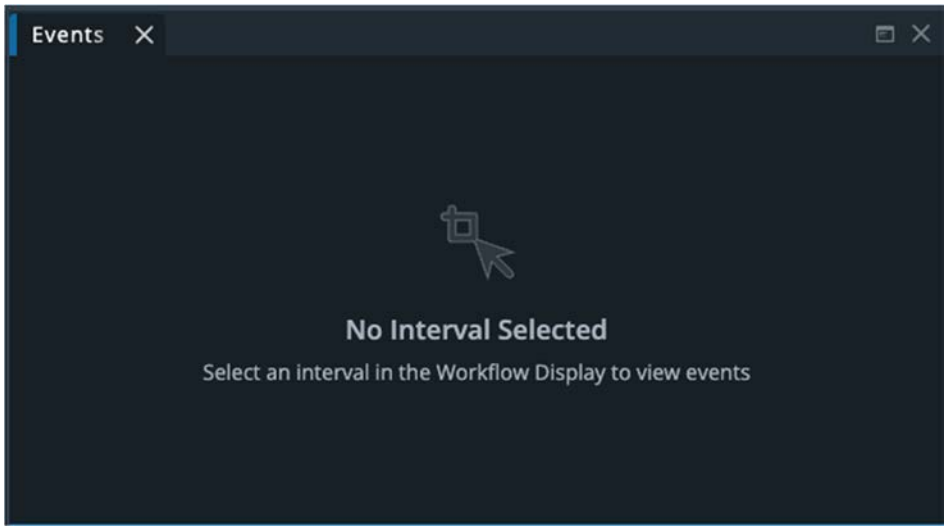


Figure 114. Prompt to Select an Interval to Populate Events Display.

Once the analyst opens an interval, the Events display is populated with a list of events and their current preferred event hypotheses and locations for the currently open time range, as shown in

Figure 115.

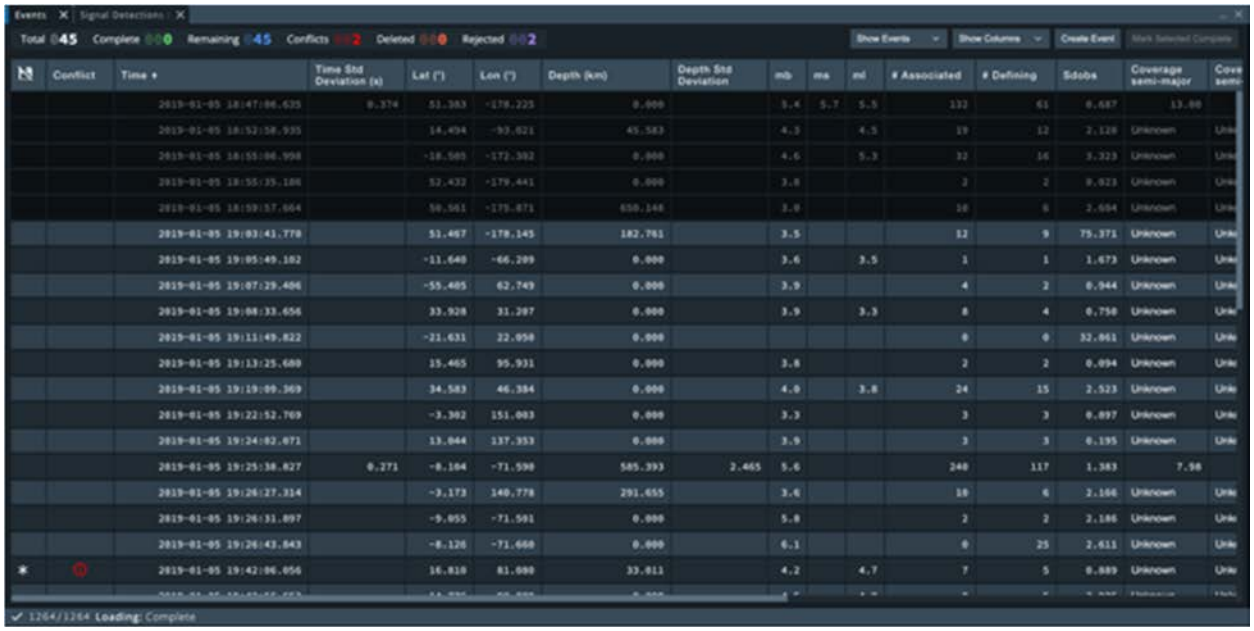


Figure 115. The Events Display.

Dimmed rows in the Events display denote ‘Edge Events’, i.e., events beyond (before or after) the open time range or interval in the Workflow display (Section 5.2), while non-dimmed rows denote events within the open time range. The duration of the “Edge” is configurable (see Configuration documentation).

To view a condensed tabular view with limited event metadata, users can right-click on an event and select ‘Open event details’ as shown in Figure 123. Alternatively, user can use alt + click (option + click on Mac) to reveal the details.

5.4.1. Viewing Columns in the Display

Several columns are available for viewing in the Events display. To toggle which columns to view, use the 'Show columns' dropdown menu (Figure 116) at the upper right of the Events display (

Figure 115). Checked columns indicate columns that are shown in the display, while non-checked columns are hidden. Column selections will be saved if the user changes intervals or closes/reopens the Events display, but do not persist upon logout. The Events display with all available columns made visible is shown in

Figure 115. By default, all columns are shown.

Figure 116. Events Display Show Columns Dropdown Menu.

Events display columns provide the following information:

Unsaved changes – Shows a star/asterisk if the user has modified an event and thus has changes that need to be saved (e.g., row 7 in

- Figure 115). This column is labeled with a floppy disk icon with a slash through it

Conflict – Flags events that have conflicts, i.e., the same SD is associated with different events in the same processing stage. A circled exclamation point will be shown if an event has a conflict (e.g., rows 7 and 8 in

- Figure 115). The exclamation will appear red for unopened events and black for open events; the color is for visual convenience only
- Time – Origin time of event in YEAR-MO-DY HR:MN:SEC.MSEC format
- Time Std Deviation (s) – Standard deviation of the origin time in seconds
- Lat (°) – Event latitude in degrees
- Lon (°) – Event longitude in degrees
- Depth (km) – Event depth in km
- Depth Std Deviation (km) – Standard deviation of depth in km
- mb – Body wave magnitude
- ms – Surface wave magnitude
- ml – Local magnitude
- # Associated – Number of SDs associated with that event
- # Defining – Number of SDs used to calculate the event location
- Sdobs – Standard deviation of location
- Coverage semi-major (km) – The length of the semi-major axis of the coverage ellipse in km
    - The coverage ellipse is defined as a location-solution-error ellipse computed assuming knowledge of exact values of prior errors. The coverage ellipse is preferred for events with few defining associations.
- Coverage semi-minor (km) – The length of the semi-minor axis of the event coverage ellipse in km

- Coverage semi-major trend (°) – The trend in degrees of the semi-major axis of the event coverage ellipse
- Confidence semi-major (km) – The length of the semi-major axis of the event confidence ellipse in km
    - The confidence ellipse is defined as a location-solution-error ellipse computed based on the final set of data residuals resulting from convergence of an event solution. Unlike the coverage ellipse, the confidence ellipse does not assume any prior knowledge of error.
- Confidence semi-minor (km) – The length of the semi-minor axis of the event confidence ellipse in km
- Confidence semi-major trend (°) – The trend in degrees of the semi-major axis of the event confidence ellipse
- Region – Geographic region of the event. Currently will always read as TBD (Section 6)
- Active analysts – List of analysts who have that event opened for processing
- Preferred in stage – Indicates whether the event displayed is preferred for this processing stage. If it is preferred, the value will be set to True. Otherwise, the value will be set to False
- Workflow status – Indicates the current status of each event, where the status can be:
    - Not started – the event has never been opened by an analyst in this processing stage
    - In progress – at least one analyst has the event open
    - Not complete – the event has previously had an 'In progress' status but has not been marked complete
    - Complete – the event hypothesis has been marked complete and is no longer being refined by analysts in this processing stage.

To mark an event complete, right-click on an event and select 'Mark as complete' or select the event and click the 'Mark selected complete' button in the upper-right corner of the Events display (

    - Figure 115). (Currently, the functionality to mark an event complete is disabled; see Section 6.)
    - Rejected – If set to True, the event hypothesis has been rejected. It is no longer included in this processing stage, it will not be persisted to the database when

saving events, and the event will not be recreated by future automatic processing stages. SDs associated to this event prior to rejection will become unassociated following rejection. Otherwise, it will be set to False

- Deleted – If set to True, the event hypothesis has been deleted. It is no longer included in this processing stage, it will not be persisted to the database when saving events, and the event may be recreated by future automatic processing stages. SDs associated to this event prior to deletion will become unassociated following deletion. Otherwise, it will be set to False

Note that the event status is displayed on load such that an event opened by another analyst will have their name appear in the 'Active analysts' column, while the workflow status will display 'In progress' if the user opens an interval that may have been opened by another analyst.

The total number of events, along with the number of Complete, Remaining (i.e., the sum of events with Not started, In progress, and Not complete statuses), Conflicts, Deleted events, and Rejected events, are shown at the upper left of the Events display (

Figure 115). Total is shown in white, Complete is shown in green, Remaining in blue, Conflicts in red, Deleted in red-orange, and Rejected in lavender (based on their configurable colors). Note that only the numbers will be shown if the Signal Detections List display is too small to support viewing the status labels and numbers. Currently, events cannot be marked as Completed. This capability will be added in a future release (see Section 6).

5.4.1.1. Events Display Table Layout

The fully populated Events display shown in

Figure 115 represents its default table layout. In addition to the layout options described in Section 4, this table can be further modified in the following ways. Note that the Events display table layout is generic. Thus, the modifications described here can be applied to tables in other displays (e.g., the Signal Detection List display).

1) Each column's position can be rearranged by clicking anywhere in the column title cell and dragging the column to the desired position.

2) Columns can be pinned such that they remain in place while scrolling. To pin columns, drag a desired column to the far left or far right of the table, then hold until a pushpin icon appears (Figure 117).

Figure 117. Pushpin Icon.

Once the pushpin appears, release the column: this action will generate a pinned area of the table (any columns left of the divider). Note that two pinned areas can be made at the same time – one to the far left and one to the far right. The user can now place as many columns as desired in the pinned area(s) by dragging and dropping a desired column to the left (or right) of the divider(s).

The horizontal scroll bar will shrink as columns are placed in the pinned area(s). Further, the scroll bar will be placed to the right (or left) of the divider(s). These changes to the scroll bar are used to indicate which columns can still be scrolled through.

To remove the pinned area(s), drag and drop each column in the pinned area(s) to a desired position on the right (or left) of the divider(s) until all columns have been moved and the divider(s) is no longer visible.

3) Column width can be modified by hovering over a column title edge until a double-arrow symbol appears. Then the user can click and drag the column edge to the desired width.

4) Columns can be added or removed by deselecting the column from the Show columns dropdown menu (e.g., Figure 116).

5) Columns can be sorted alphanumerically, ascending or descending, by clicking to the right of each column title. This action will bring up an arrow symbol (Figure 118, Left) to the right of the column title that indicates whether the column is ascending or descending. To sort multiple columns at the same time, hold Shift while clicking on the desired columns to sort. When multiple columns are selected, a number indicating the order in which the columns were selected will appear between the column name and the arrow, e.g., in (Figure 118, Right) ‘Time’ and ‘Lon’ are selected for sorting, with ‘Time’ selected first.

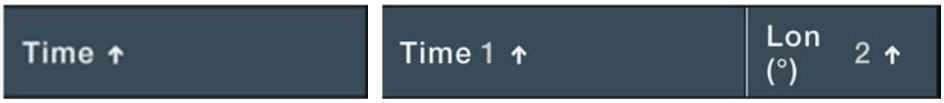


Figure 118. Sorting Arrow (Left) and Multi-Sorting Indicators (Right).

The arrow symbol will only be visible in the column(s) being sorted. By default, columns are sorted ascending (arrow points up). To change to descending, click once anywhere in the column title, except on the bar menu button which is used to open the filter menu (Bullet 7). To change to unsorted, click the column a second time and the arrows (and numbers if multi-sort is being applied) will be removed.

6) Rows can be filtered to show one or more desired values by hovering to the far right of a desired column title to bring up a bar menu button (Figure 119).

Figure 119. A Close-up of the Bar Symbol Used to Pull Up a Filter Menu.

When this button is clicked, it will bring up a filter menu (Figure 120, Left). When a value is entered into the filter field, the menu expands giving the option to apply another AND/OR filter (Figure 120, Center) with its own filtering options (Figure 120, Right). This option can be used once. Once the values are entered, click anywhere in the display to hide the filter. A funnel-shaped symbol will appear to the right of the column title, indicating a filter is in place. To remove the applied filter, bring up the filter menu once more and delete the entered value(s).

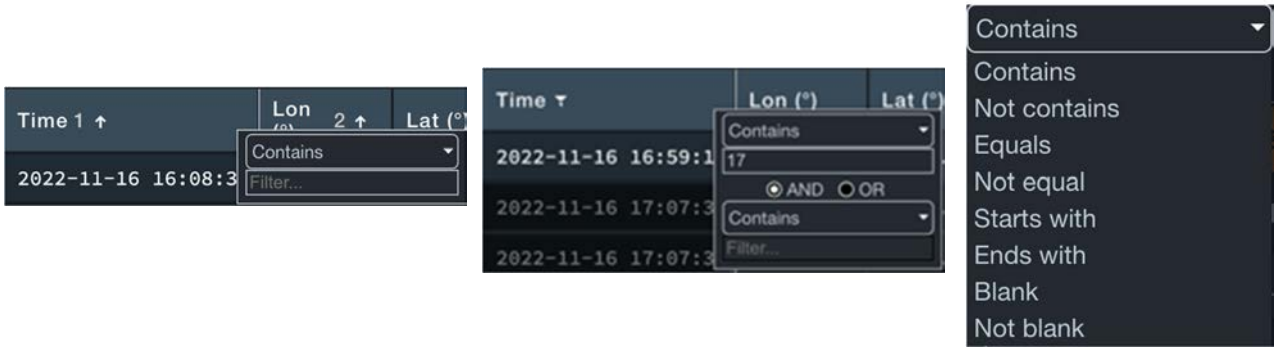


Figure 120. (Left) Filter Application, (Center) Menu Expansion for Applying Another AND/OR Filter, and (Right) Available Filter Options.

5.4.2. Show Events Dropdown Menu

By default, events occurring in the configurable lead and lag buffers are shown as visually distinguished edge events in the Events display, indicated by darker (dimmed) rows than events occurring within the selected time range. This time buffer is the same buffer seen in the Waveform display outside of the vertical green lines (see Section 5.3.1) and is configured to be 15 minutes on either side. These events can be removed or added to the display by clicking the 'Show events' dropdown menu, shown in Figure 121, in the upper right of the Events Display (

Figure 115) and checking/unchecking the events to add/remove. Events can be hidden/shown based on event status in the same manner.

In addition, events can be added/removed from the Events display based on their event status (Complete, Remaining, Conflicts, Deleted, Rejected; see Section 5.4.1) by checking/unchecking the desired statuses. Note that if an event status is removed from view in the Events display, the corresponding counter (upper-right of

Figure 115) is dimmed.

Because events cannot currently be marked as Complete (Section 6), adding/removing the Complete event status will only change whether the Complete counter is dimmed. As a further consequence of being unable to complete an event, the Remaining event status must be selected to view events in the Events display; an event is counted as Remaining until it can be marked as complete. Finally, because events can't be marked as complete, the Remaining counter will never vary, even when events are deleted or rejected.

These selections will be saved if the user changes intervals or closes/reopens the Events display, but do not persist on logout.

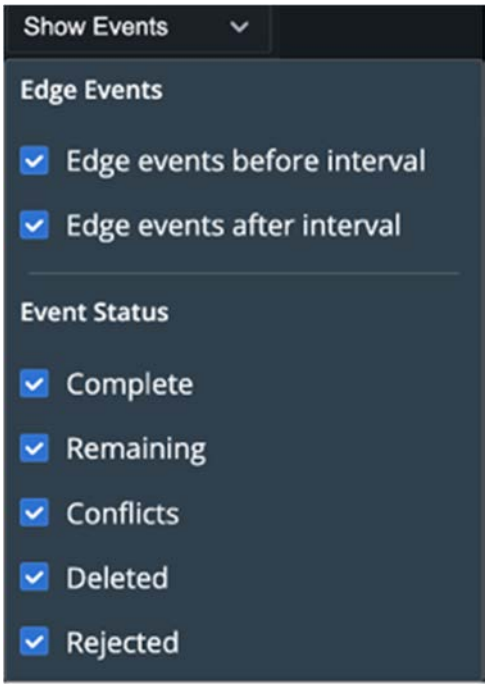


Figure 121. Show Events Dropdown Menu.

5.4.3. Creating Events

The Create Event button at the upper-right corner of the Events display (

Figure 115) brings up the same menu as in the Waveform display. If SDs are selected in the Waveform display (Section 5.3.5.1), the Signal Detections List display (Section 5.5.4), or the Map display (Section 5.6.3) they will be used to create the event, otherwise a virtual event is created. Details on the Create Event functionality are provided in Section 5.3.5.5; the user is referred there.

5.4.4. Selecting and Modifying Events

Event selection is synchronized between the Events display and Map display (Section 5.6), such that events selected in one display will also be selected in the other. Events can be selected by

single-clicking an event. Selection will result in the event row being highlighted in a blue box as shown in Figure 122.

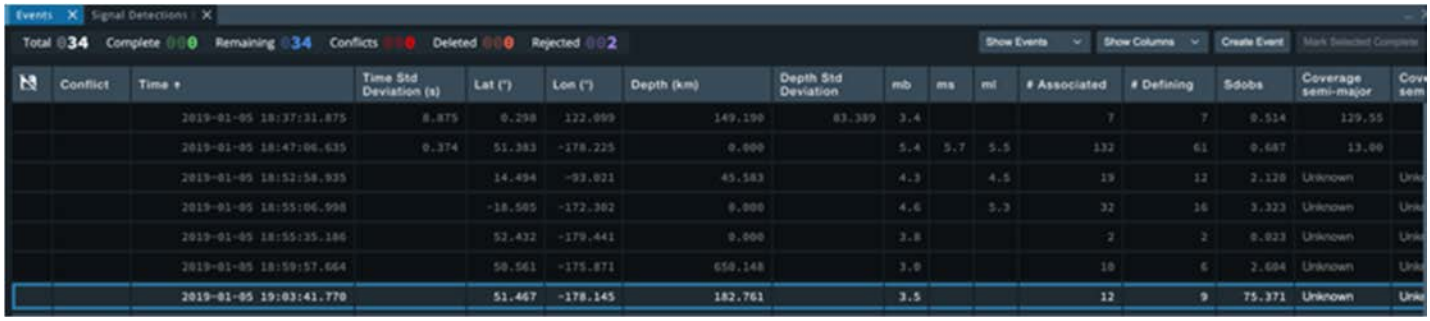


Figure 122. Events Display with an Event Selected.

To select multiple events, the user can:

- Hold the Ctrl key (Command on Mac) while selecting desired events or
- Click the initial desired event, press and hold Shift, and click again on the final desired event. This action selects all events between and including the initial and final events

To open or close an event in the Events display, right-click anywhere in an event's row to bring up the necessary menu (Figure 123). Alternatively, an event can be opened or closed by double-clicking 1) the desired row in the Events display or 2) the desired event icon in the Maps display (Section 5.6).

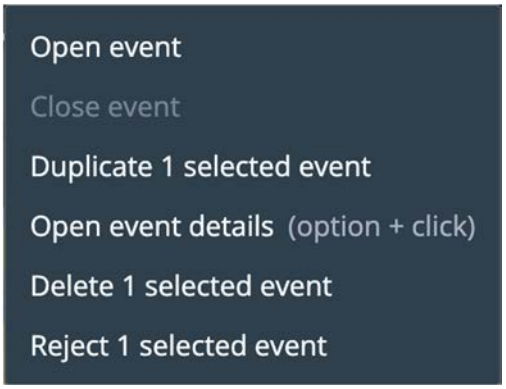


Figure 123. Menu to Open, Close, Duplicate Events, Open Event details, Delete Events, or Reject Events.

If another analyst is actively working on an event, an Open Event Confirmation popup will appear in the center of the workspace (Figure 124).

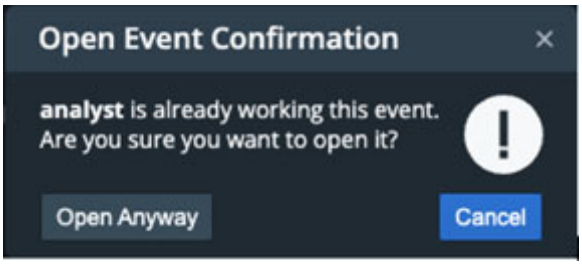


Figure 124. Open Event Confirmation Popup.

Clicking the Cancel option will result in no changes and close the popup, while clicking Open Anyway will result in the normal behavior described below.

When an event is opened, the row of the opened event will be colored orange to indicate that it is currently open, and the username of the analyst who opened the event will be added to the 'Active analysts' column. Finally, Workflow status will now show a status of *In Progress*. Note that if the user opens an event while another event is open, the previously opened event will close, will no longer be colored orange, and will remain with a status of *In Progress*.

Figure 125. Events Display with Event Opened.

When an event is closed using the menu in Figure 123 without being marked as *Complete*, the row color will return to gray, the 'Workflow status' will update to *Not Complete*, and the analyst's username will be removed from the 'Active analysts' column (Figure 126).

Figure 126. Events Display with Event Closed.

Opening an event in the Events display will enable several options in the Waveform display (Section 5.3.1). The effects of opening an event on the Signal Detections List display and Map display are described in Sections 5.5 and 5.6, respectively.

When an event is duplicated using the menu in Figure 123, that event's information is copied to a new row directly beneath the original event's row. Event duplication allows the user to easily split a single event into multiple events in cases where automatic processing mistakenly combined multiple events into one event. The duplicated event is a completed copy of the original event, including the associated SDs.

Note that when an event is duplicated, the Map display will update such that the duplicated event icon overlays the original event icon. The number of overlaid events is shown in the topmost event icon. See Section 5.6.4 for details.

Duplication automatically results in a conflict as there cannot be multiple event hypotheses with the exact same SDs (Section 5.3.5). SDs of the duplicate events can be unassociated, created, rejected, or deleted in the Waveform, Signal Detection List, or Map displays (Sections 5.3.5, 5.5.5, 5.6.3) until the conflict is resolved. Duplication will also result in asterisks being shown in the Unsaved changes column for the newly added event as well as in the Unsaved changes column corresponding to the event's associated SDs in the Signal Detections List display (Section 5.5.5). Finally, duplicating an event will cause the Total and Remaining event counters to increase by one. Note that if multiple events are selected, each selected event will be duplicated; the number of events to duplicate is indicated in the menu (e.g., 'Duplicate 1 selected event' in Figure 123).

When an event is deleted, the row will not be removed from the Events display. Rather, the value in the Deleted column will switch from False to True. Once an event is deleted, it can be opened and closed as before, but it cannot be modified in any way. For instance, the options to duplicate, reject, and delete the event in the menu in Figure 123 will become inactive. If multiple events are selected and the delete action is chosen, each selected event will be deleted; the number of events to delete is indicated in the menu (e.g., 'Delete 1 selected event' in Figure 123). Deleting an event will cause no change to the Remaining counter; it will increase the Deleted counter by one.

Deletion allows the user to remove events that were 1) erroneously created by the system or another user or to remove 2) events that were created/duplicated to make a new event but did not result in a quality event, thereby preventing these erroneous events from being persisted in

the database account upon saving. Note that these events may be recreated by automatic processing.

Deletion will cause the deleted event's SDs to have updated association statuses (and colors) in the Waveform, Events, and Map displays (Sections 5.3.5, 5.4, 5.6.3). Asterisks will be shown in the Unsaved changes column for the deleted event as well as in the Unsaved changes column corresponding to the event's formerly associated SDs in the Signal Detections List display (Section 5.5.5).

When an event is rejected, the value in the Rejected column will switch from False to True. As with deletion, once an event is rejected it can be opened or closed, but not modified. If multiple events are selected and the reject action is chosen, each selected event will be rejected; the number of events to reject is indicated in the menu (e.g., 'Reject 1 selected event' in Figure 123).

Like deletion, rejection allows the user to reject an event that was erroneously created by the system or another user. Unlike deletion, rejection indicates to the automatic processing system that the rejected event is not to be recreated. Rejection will cause the rejected event's SDs to have updated association statuses (and colors) in the Waveform, Events, and Map displays (Sections 5.3.5, 5.4, 5.6.3). Asterisks will be shown in the Unsaved changes column for the rejected event as well as in the Unsaved changes column corresponding to the event's formerly associated SDs in the Signal Detections List display (Section 5.5.5).

For the duplicate, delete, and reject options, the # value updates to the number of events the option can *validly* be applied to. For instance, in Figure 127, three events are selected, one of which is rejected and one of which is deleted. Note that columns in Figure 127 were removed from view to make the Rejected and Deleted columns easily viewed. In the event modification menu, the 'Duplicate # selected event', 'Delete # selected event', and 'Reject # selected event' all indicate that only 1 event can be duplicated, deleted, or rejected. This difference occurs

because only the normal event, i.e., the event that is not rejected or deleted, can be duplicated, deleted, or rejected.

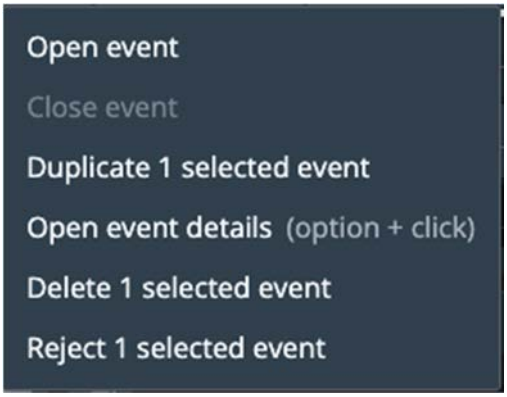


Figure 127. Example Application of Event Modification Options to Events.

In addition to the # values in the event modification menu changing, any selected events the option cannot be validly applied to will dim when the user hovers over that option. For instance, in Figure 127, the user hovers over the 'Duplicate 1 selected event' option, causing the rejected and deleted events to dim as these events cannot be duplicated.

The user can undo event duplication, deletion, or rejection by pressing Ctrl + Z (Command + Z on Mac; Appendix C) or by using the Undo/Redo display (Section 5.9).

Finally, any changes made in the Events display currently cannot be saved. Saving will be a part of future functionality (Section 6).

5.5. Signal Detections List Display

The Signal Detections List display shows a tabular view of bridged SDs and their corresponding metadata. It is intended to assist a user in performing tasks such as scanning and event building.

When initially opened, the Signal Detections List display has no waveform data loaded. The user is prompted to select an interval in the Workflow display (Section 5.1.1) as shown in Figure 128.

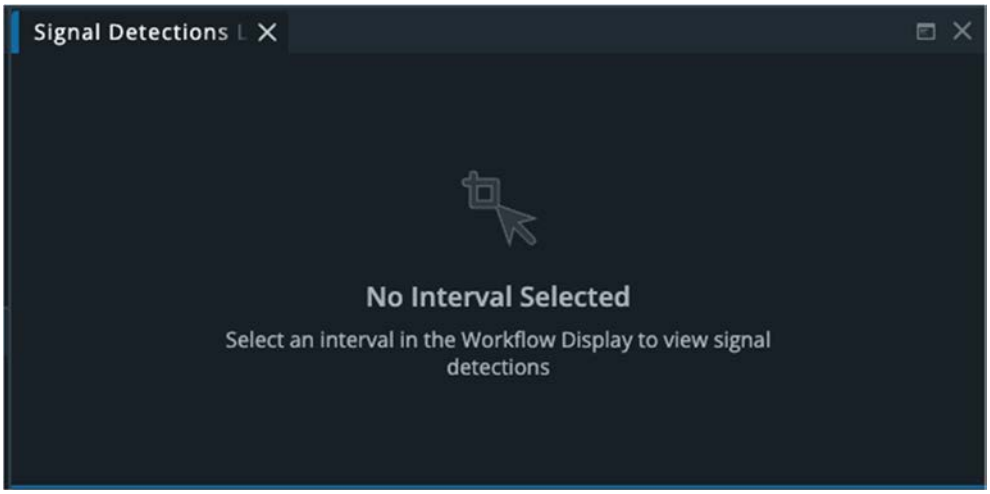
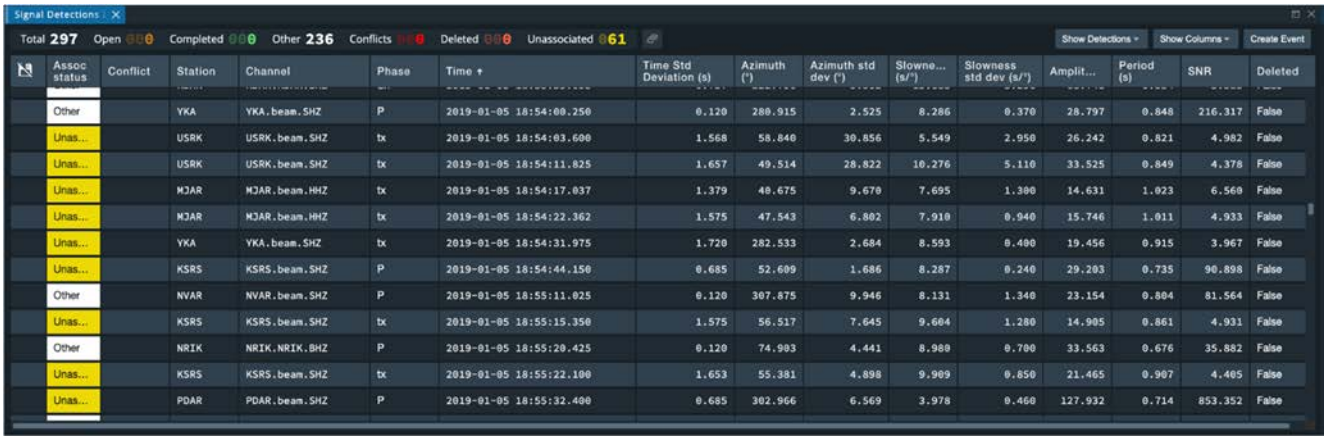


Figure 128. Prompt to Select an Interval to Populate Waveform Display.

Once an interval is selected, the Signal Detections List display is populated with a list of SDs that exist for the open time range, their association status, and metadata describing the SD, as shown in Figure 129.



Assoc status	Conflict	Station	Channel	Phase	Time	Time Std Deviation (s)	Azimuth (°)	Azimuth std dev (°)	Slowne... (s/°)	Slowness std dev (s/°)	Amplit...	Period (s)	SNR	Deleted
Other		YKA	YKA.beam.SHZ	P	2019-01-05 18:54:00.250	0.120	280.915	2.525	8.286	0.370	28.797	0.848	216.317	False
Unas...		USRK	USRK.beam.SHZ	tx	2019-01-05 18:54:03.600	1.568	58.840	30.856	5.549	2.950	26.242	0.821	4.982	False
Unas...		USRK	USRK.beam.SHZ	tx	2019-01-05 18:54:11.825	1.657	49.514	28.822	10.276	5.110	33.525	0.849	4.378	False
Unas...		MJAR	MJAR.beam.HHZ	tx	2019-01-05 18:54:17.037	1.379	40.675	9.670	7.695	1.300	14.631	1.023	6.560	False
Unas...		MJAR	MJAR.beam.HHZ	tx	2019-01-05 18:54:22.362	1.575	47.543	6.802	7.910	0.940	15.746	1.011	4.933	False
Unas...		YKA	YKA.beam.SHZ	tx	2019-01-05 18:54:31.975	1.720	282.533	2.684	8.593	0.400	19.456	0.915	3.967	False
Unas...		KSRS	KSRS.beam.SHZ	P	2019-01-05 18:54:44.150	0.685	52.609	1.686	8.287	0.240	29.203	0.735	90.898	False
Other		NVAR	NVAR.beam.SHZ	P	2019-01-05 18:55:11.025	0.120	307.875	9.946	8.131	1.340	23.154	0.804	81.564	False
Unas...		KSRS	KSRS.beam.SHZ	tx	2019-01-05 18:55:15.350	1.575	56.517	7.645	9.604	1.280	14.905	0.861	4.931	False
Other		NRIK	NRIK.NRIK.BHZ	P	2019-01-05 18:55:20.425	0.120	74.903	4.441	8.980	0.700	33.563	0.676	35.882	False
Unas...		KSRS	KSRS.beam.SHZ	tx	2019-01-05 18:55:22.100	1.653	55.381	4.898	9.909	0.850	21.465	0.907	4.405	False
Unas...		PDAR	PDAR.beam.SHZ	P	2019-01-05 18:55:32.400	0.685	302.966	6.569	3.978	0.460	127.932	0.714	853.352	False

Figure 129. Signal Detections List Display.

Dimmed rows, known as 'Edge Detections', in the Signal Detections List display represent SDs outside of (i.e., before or after) the open time or interval range, while non-dimmed rows represent SDs within the time or interval range, as shown in Figure 129.

The total number of SDs, along with the number of SDs with an Open status, Completed status, Other (i.e., associated to unopened events) status, Conflicts, Deleted SDs, and SDs with an Unassociated status are shown at the top of the Signal Detections List display (Figure 129). Total is shown in white, Open in orange, Completed in green, Other in white, Conflicts in red, Deleted in red-orange, and Unassociated in yellow based on their configurable colors. Note that if the display is too small to support viewing the status labels and numbers concurrently, only the numbers will be shown. Currently, SDs cannot be marked as Completed as events cannot be marked as completed. This capability will be added in a future release (see Section 6).

To view additional SD metadata, i.e., the signal detection menu shown when user's view additional SD details from the Wavefrom Display (see Figure 47), users can right-click on an SD and select 'Open signal detection details' as shown in Figure 123. Alternatively, user can use alt + click (option + click on Mac) to reveal the details.

5.5.1. Show Detections Menu

The Show Detections dropdown menu (Figure 130) is in the upper right of the Signal Detections List display. In this menu, there is an option to 'Sync to Waveform Display visible time range'. When this option is selected, the Signal Detections List display will be filtered to include only SDs visible in the Waveform display. When this syncing is enabled, as users zoom and/or pan within the Waveform Display, only the SDs shown in the updated zoomed and/or panned time range will be displayed in the Signal Detections List display. When the sync option is deselected, all SDs will be displayed, while changing the Waveform display time range will have no effect on which SDs are displayed within the Signal Detections List display. This option is deselected by default.

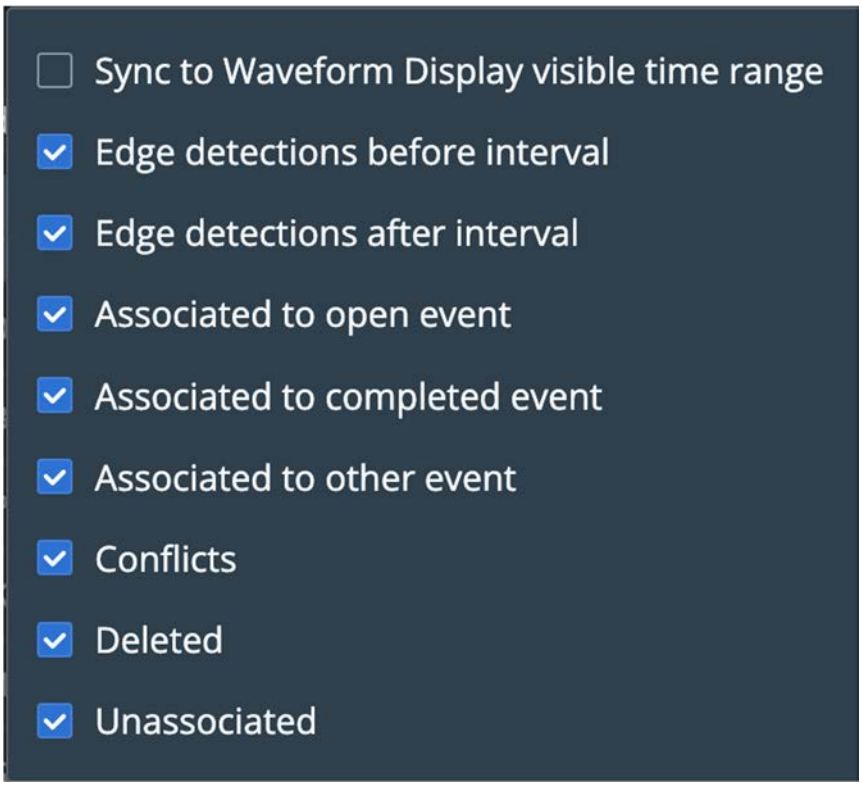


Figure 130. Show Detections Dropdown Menu.

Note that if syncing is turned on and the time range selected by the user includes no SDs, the user will be prompted to pick a new time range as shown in Figure 131.

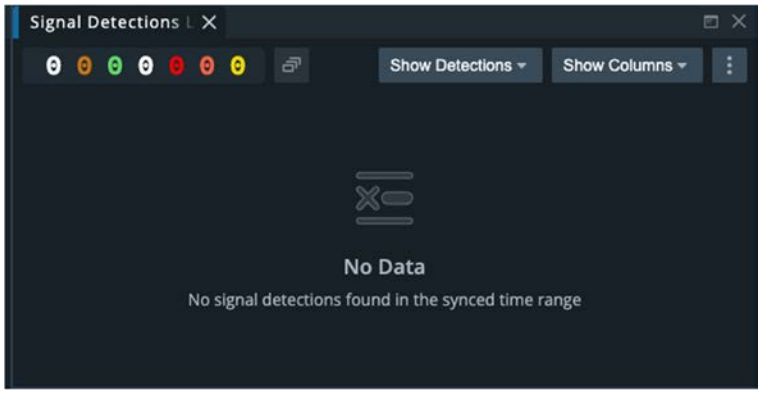


Figure 131. Prompt to Select a New Time Range to See Signal Detections.

By default, edge detections before and after the interval are shown; these can be shown/hidden by checking/unchecking their boxes in the Show Detections dropdown menu

(Figure 130). The concept of edge detections is the same as edge events described in Section 5.4.

Similarly, by default, all SDs are shown based on their association status and users can choose to hide/show them to remove/display them within the Signal Detections List display by clicking on the boxes within the Association status menu area.

All selections within the 'Show Detections' dropdown menu will be saved if the user changes intervals or closes/reopens the Signal Detections List display, but do not persist on logout.

5.5.2. Viewing Columns in the Display

The user will not be able to view all Signal Detections List columns at once. The horizontal scroll bar at the bottom of the panel allows users to scroll right and left to view all the columns.

In Table 4, each column is defined, and relevant notes are provided. Columns with an asterisk next to their column name are not shown by default.

Table 4. List of Columns in the Signal Detections List Display.

Column Name	Definition	Notes
Unsaved changes	Indicates whether a modified SD has unsaved changes.	This column name is only visible in a tooltip. In the table, the column is labeled with a floppy disk icon.
Assoc status	Indicates association status of an SD. Assoc status is indicated by both color and text. The available statuses are: • Open (orange): SD associated to currently open event • Completed (green): SD associated to a completed event • Other (white): SD associated to an unopened event • Deleted (red-orange): SD is deleted and can no longer be modified or associated with an event • Unassociated (yellow): SD is unassociated	Note, a completed (green) Assoc status will be unavailable until the capability to mark an event as completed. See Section 6.

Conflict	This column will appear as  when an SD is associated to more than one event.	See Section 5.3.5 for conflict definition.
Station	Name of the station on which the SD was observed.	
Channel	Name of the channel on which the SD was observed.	The channel can either represent a raw waveform (e.g., JAY.JAY.BHZ) or a beam (e.g., MMAI.beam.BHZ). See Section 5.3.1 for more detail, including what beam types are available.
Phase	Phase type (e.g., P, Pg, S, Lg) of the SD.	See **Error! Reference source not found.** for a list of available phases.
Phase Confidence*	A qualitative estimate of the confidence that an SD's phase has been correctly identified. Phase confidence can be between 0 and 1, where 0 is no confidence that the phase is correctly identified and 1 is complete confidence the phase is correctly identified.	Phase confidence is only defined if the SD is read in from the ASSOC table in the database. Specifically, the phase confidence is read in from the Belief column. See Section 6.
Time	Arrival time of the SD.	
Time std dev (s)	Standard deviation of the SD arrival time in seconds.	
Azimuth (°)	Observed receiver-to-source azimuth in degrees.	
Azimuth std dev (°)	Azimuth standard deviation in degrees.	
Slowness (s/°)	Observed slowness in seconds per degree.	

Slowness std dev (s/°)	Slowness standard deviation in seconds per degree.	
Amplitude	Amplitude of the SD.	Currently, only a5/2 amplitude measurements are available. In future releases, any amplitude type associated to an SD via the AMPLITUDE table in the database will be reported. See Section 6.
Period (s)	The measured period at the time of the amplitude measurement in seconds.	
SNR	Signal to noise ratio of the SD	The SNR shown is unitless.
Rectilinearity*	The signal rectilinearity of the SD. This value describes the linear polarization of the wavefield of the SD. Rectilinearity ranges from 0 to 1, with 1 indicating 100% linear polarization and 0 indicating no linear polarization.	If the signal rectilinearity is unavailable for an SD, it is set to Unknown.
Emergence angle (°)*	Angle at which the SD emerges in degrees.	If the emergence angle is unavailable for an SD, it is set to Unknown.
Short period first motion*	The first motion of the focal mechanism seen on short-period channels. The three possible motions are: • COMPRESSION	An INDETERMINATE motion indicates the first motion associated with that SD is not defined in the ARRIVAL database table.

	• DILATATION • INDETERMINATE	Currently all cases are INDETEREMINATE. See Section 6.
Long period first motion*	The first motion of the focal mechanism seen on long-period channels. The three possible motions are: • COMPRESSION • DILATATION • INDETERMINATE	An INDETERMINATE motion indicates the first motion associated with that SD is not defined in the ARRIVAL table. Currently all cases are INDETEREMINATE. See Section 6.
Deleted	Indicates if the SD was deleted by an analyst. Will either be False or True.	A deleted SD cannot be used in subsequent processing steps.

To add or remove columns from the Signal Detections List display, the user must select the 'Show columns' dropdown menu (Figure 132) located in the upper-left corner of the display.

Figure 132. Signal Detections List Display Show Columns Dropdown Menu.

From here, the user can add or remove columns by checking or unchecking the desired columns. Columns not shown by default (indicated by an asterisk in Table 4) can be added via this menu.

Column selections are saved in the Signal Detections display when the user changes intervals or closes/reopens the display, but they do not persist upon logout.

The Signal Detections List table can be modified in the same ways as the Events table in the IAN UI. See Section 5.4.1.1 for available actions.

5.5.3. Creating Events

The Create Event button at the upper-right corner of the Signal Detections List display (Figure 129) brings up the same menu as in the Waveform or Events displays (Section 5.3.5.5, Section 5.4.3). If SDs are selected in the Signal Detection Lists display (Section 5.5.4), Waveform display (Section 5.3.5.1), or Map display (Section 5.6), they will be used to create the event, otherwise a virtual event is created. Details on the Create Event functionality are provided in Section 5.3.5.1; the user is referred there.

5.5.4. Signal Detection Selection

In the Signal Detections List display, the user can select an SD by clicking on the desired row, which will highlight the selected row in blue (Figure 133).

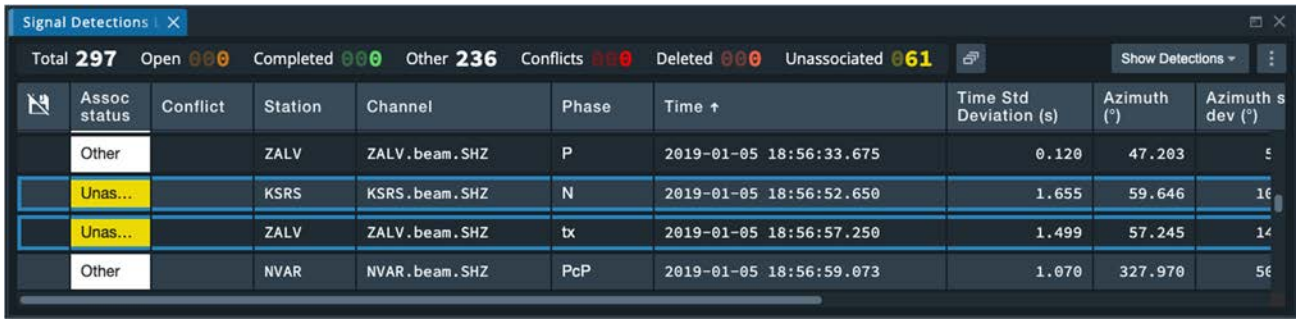


Figure 133. Signal Detections List Display with a Signal Detection Selected.

Multiple SDs can be selected by holding either Shift or Ctrl (Command on Mac) while clicking SD rows.

To deselect a single selected SD, click again on the selected SD. Clicking on another SD in the Signal Detections List display will also deselect the originally selected SD. When multiple SDs have been selected, a single SD can be deselected without deselecting the remaining SDs by holding Ctrl (Command on Mac) and clicking on the desired SD(s).

Users can also deselect SDs by clicking on the selection menu  in the Signal Detection List Display or the Waveform Display. All SDs will be deselected by double-clicking the menu icon. Individual deselection can be selected by a single-click of the menu.

Signal detection selection is synchronized across the Waveform (Section 5.3.5.1), Signal Detections List (Section 5.5.4), and Map displays (Section 5.6.3), such that selection of one or more SDs in any of these displays will result in selection across the other displays.

5.5.5. Signal Detection Association Status

The Signal Detections List is synced to the Waveform (Section 5.3.5), Events (Section 5.4.4), and Map displays (Section 5.6.3) such that opening/closing an event affects the association status (Assoc status) of SDs associated with that event. While an event is closed, its corresponding SDs will have an Assoc status of Other, i.e., the SDs are associated to an unopened event. When an event is opened, the Assoc status of its associated SDs changes to Open, i.e., the SDs are associated to an opened event (Figure 129); the remaining SDs either have a status of Other or Unassociated, i.e., the SDs aren't associated with any event. If an opened event is closed again, the Assoc status of its associated SDs will revert from Open back to Other. Note that SDs in the Waveform and Map displays undergo an identical change in color when switching from opened to unopened events (Sections 5.3.8, 5.6.3).

When an event is open via the Events or Map displays (Sections 5.4.4, 5.6.4), the association status of an SD can be changed. First, the user can double-click on an SDs row to change its status. If the SD is Unassociated, double-clicking will cause the Assoc status to go from Unassociated to Open, i.e., the SD is now associated to the opened event, and an asterisk will be shown in the Unsaved changes column. Double-clicking again will cause the Assoc status to revert to Unassociated. If the SD Assoc status is Other, double-clicking will again cause the Assoc status to become Open. However, because this SD was already associated to another event, this action will also cause a conflict, which will be indicated by a red exclamation point icon in the Conflict column. To remove the conflict, the SD must be unassociated from one or both events. Note that double-clicking to change an SD association status can be done anywhere in the row except for over the Time and Time std dev columns; double-clicking a cell in these columns allows the values to be modified and does not change SD association status (see Section 5.5.6).

Alternatively, association can be changed by right clicking on an SD row to bring up the Signal Detection Popup menu (Figure 46; Section 5.3.5.2). From there, the Event Association menu (Figure 113) first described in Section 5.3.8.4 can be accessed. The user is referred to Section 5.3.8.4 for details on the usage of the Event Association menu to change an SD association.

Previously described options to view SD details (Section 5.3.5.2.1), set the SD phase (Section 5.3.5.2.2), show FK plots (Section 5.3.5.2.3), rotate SD associated waveforms (Section 5.3.5.2.4),

delete SDs (Section 5.3.5.2.4), and export an SD waveform segment (Section 5.3.5.2.6), are provided in the Signal Detections List display Signal Detection Popup menu. Again, the user is referred to these prior sections for details on the functionality of each of these options.

For any of the above options that modify the SDs, the option's # value indicates the number of valid selected SDs that will be modified by that option and invalid selected SDs will dim in comparison to valid SDs. These behaviors are the same as those in the Events display; refer to Section 5.4.4, Figure 127.

5.5.6. Modifying Signal Detection Arrival Time

The user can double-click on a cell in the Time column and/or a cell in the Time std dev column of the Signal Detections List display to modify the arrival time and/or arrival time standard deviation, respectively. After double-clicking the cell, the cell background color will become lighter and a cursor can be seen (Figure 134).

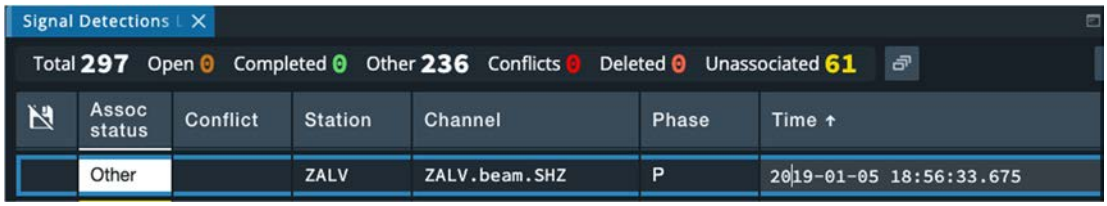


Figure 134. A Signal Detection with Time Being Modified.

Once the cursor is in view, the user can manually modify the data entry. These modifications must be valid data entries, with Time entered as YR-MON-DY HR:MIN:SEC.MSEC and Time std dev entered in as a positive integer or floating point value. If an invalid entry is entered into either cell, a warning is shown (Figure 135) and the invalid entry reverts to the last valid available entry.

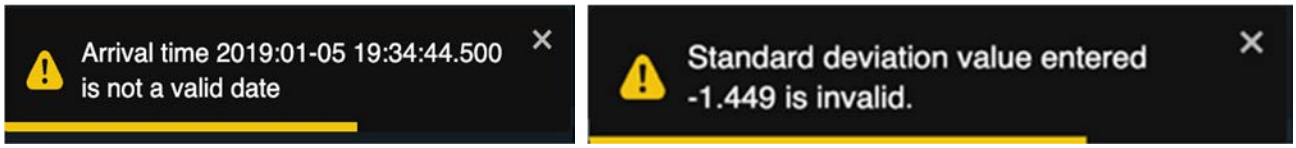


Figure 135. Example Invalid Time (Left) and Time Std Dev (Right) Data Entry Warnings.

Once the modification is made, click anywhere in the UI or press Enter. This action will save the new value in the Signal Detections List table and the SD in the Waveform display and Map display will be synced such that 1) the SD marker in the Waveform display (Section 5.3.5) will

move to the new arrival time and its uncertainty bars will change width to match the new standard deviation, 2) the SD's great circle arc will be recalculated and plotted in the Map display (Section 5.6.3), and 3) the Signal Detection Details table (Figure 47; Section 5.3.5.2.1) will update to show the new arrival time and/or standard deviation as well as add a version to the All Versions tab.

Note that if the manually entered arrival time ± standard deviation is outside the opened interval, the newly entered time will not persist and a warning indicating the arrival time ± standard deviation is outside the interval will be printed at the lower-right of the IAN UI.

5.6. Map Display

The Map display (Figure 136) shows 1) the locations of all stations and sites in the configured station groups available to GMS, including single stations, three-component (3-C) stations, and arrays, 2) the locations of all events available in the selected Workflow interval, and 3) the paths of all SDs available in the open time range. Stations and sites are represented by a triangle icon. All available configured stations within the configured set of station groups in GMS are always displayed on the map. Note that by default, sites are not automatically shown. Event locations are shown as circles. Finally, SDs are shown as great circle arcs from the event to the recording receiver, if the SD is associated to an event, or from the recording receiver to a configurable fixed distance (see Configuration documentation) if the SD is unassociated.

Once a time range is opened in the Workflow display (Section 5.1.1), station and site definitions and locations are updated to reflect the time range of the open interval, and all stations currently loaded in the Waveform display will be shown in orange, see Figure 136. This orange station icon color is unrelated to the orange color indicating a Not Complete status in the Workflow display (Section 5.1.1) or the orange color indicating an SD's association status in the Waveform display (Section 5.3.1) and Signal Detections List display (Section 5.5). Stations not currently in the Waveform display are gray (Figure 136). Events are shown as white (event is unopened), orange (event is opened), red-orange (event is deleted), or lavender (event is rejected) with edge events appearing dim and transparent; a detailed description of event statuses is given in Section 5.4. Finally, SD colors indicate their association status; these statuses are described in detail in Section 5.5.

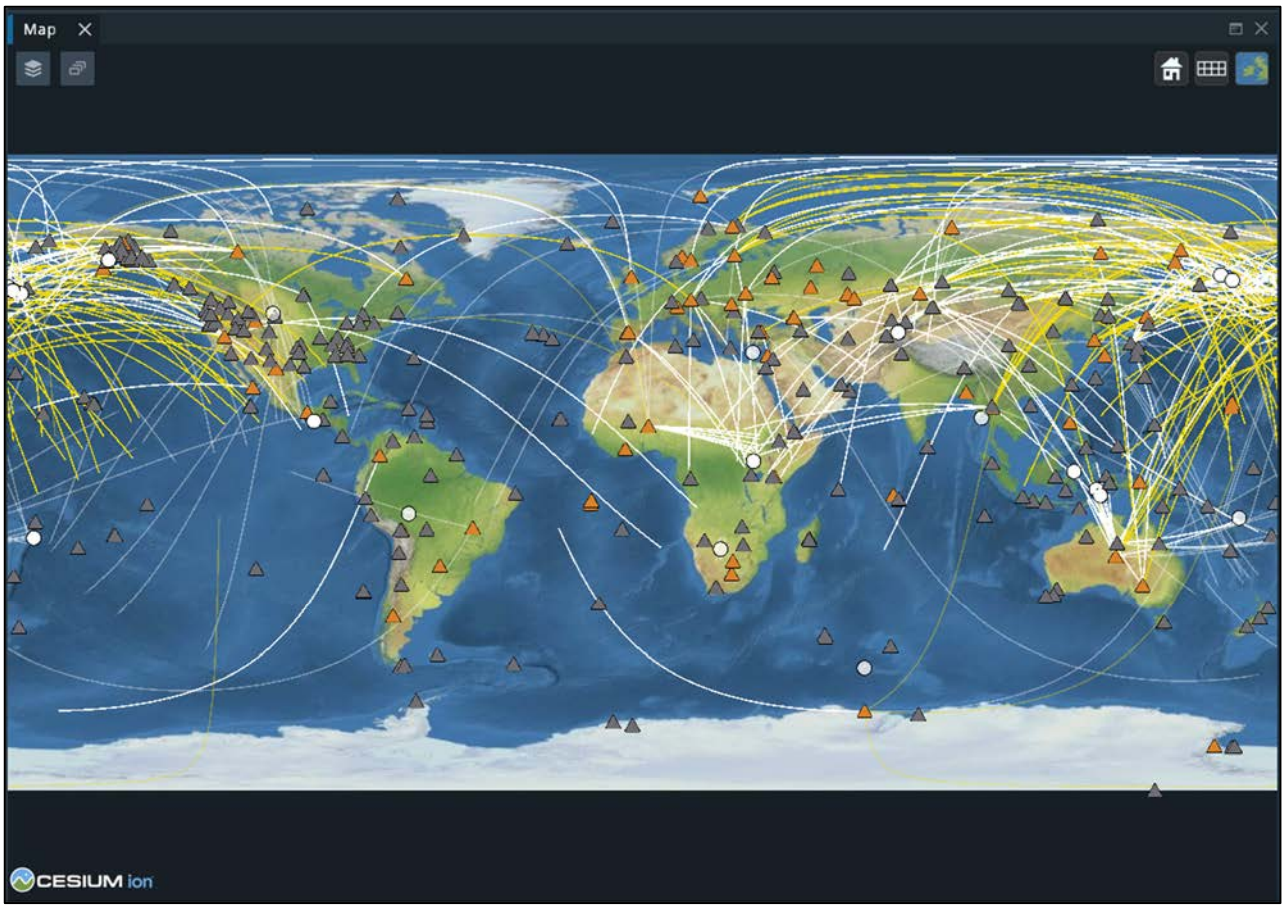


Figure 136. The Map Display.

By default, the map is shown as a 2D projection. In this default projection, the user can click and drag to pan across the map. The user can also zoom in and out by 1) using the mouse scroll wheel (scroll up to zoom in and scroll down to zoom out) or 2) using a two-finger drag on a touchpad (drag towards yourself to zoom in, push away from yourself to zoom out). If zoomed in sufficiently, the station name will appear next to the corresponding station marker and an origin time in HR:MIN:SEC.MSEC format will appear next to the corresponding event marker.

5.6.1. Map Display Options

Three buttons are provided in the upper right corner of the Map display (Figure 136) as shown in Figure 137.

Figure 137. Map Display Buttons.

From left to right, the buttons are the View Home button, Projection button, and Imagery and Terrain button. Hovering over a button with the cursor will provide a tooltip briefly describing that button. An additional button, the Select Map Layers button is available at top-left of the Map display (Figure 136).

When the user clicks the View Home button, the map will automatically zoom out to the default map view centered on the United States. Note that if the map is already in the default view, clicking on the View Home button will result in no change.

When the user clicks the Projection button, a dropdown menu showing available projections is provided (Figure 138, left). Hovering the cursor over each option in the dropdown menu will provide a tooltip briefly describing the projection. Currently, in addition to the default 2D projection, a 3D globe (Figure 138, right) is provided.

In the 3D globe projection, click and drag to rotate the sphere; to zoom, perform the same actions described for the default 2D projection in Section 5.6.

Figure 138. Projection Dropdown Menu (Left) and 3D Globe Projection (Right).

When a projection option is selected, the Projection button label changes to the current projection being viewed.

The Imagery and Terrain button provides a dropdown menu (Figure 139) showing the appearance of the map and the ellipsoid to be used to define the terrain.

Figure 139. Imagery and Terrain Dropdown Menu.

Currently, only default options are provided for imagery and terrain (see Section 6). These defaults are automatically applied to the map and cannot be changed or removed.

5.6.2. Stations in the Map Display

If a station is an array, i.e., it consists of multiple physical sites, the ability to view its sites can be activated; this action is described in Section 5.6.5. When site viewing is enabled, the user can zoom in on the station to view the individual sites that make up that station (e.g., TXAR in Figure 140). These sites are represented by gray triangle icons and are not updated based on the station's visibility within the Waveform display. If zoomed in sufficiently, the site name will appear next to the corresponding site marker. Black lines connecting the sites to the reference station are used to indicate that the sites are part of an array; the color of these lines is configurable (see Configuration documentation). The black lines also allow users to visualize the array geometry. Note that the Map's default tile, Natural Earth, does not have sufficient resolution to resolve topographic features at this level of zoom.

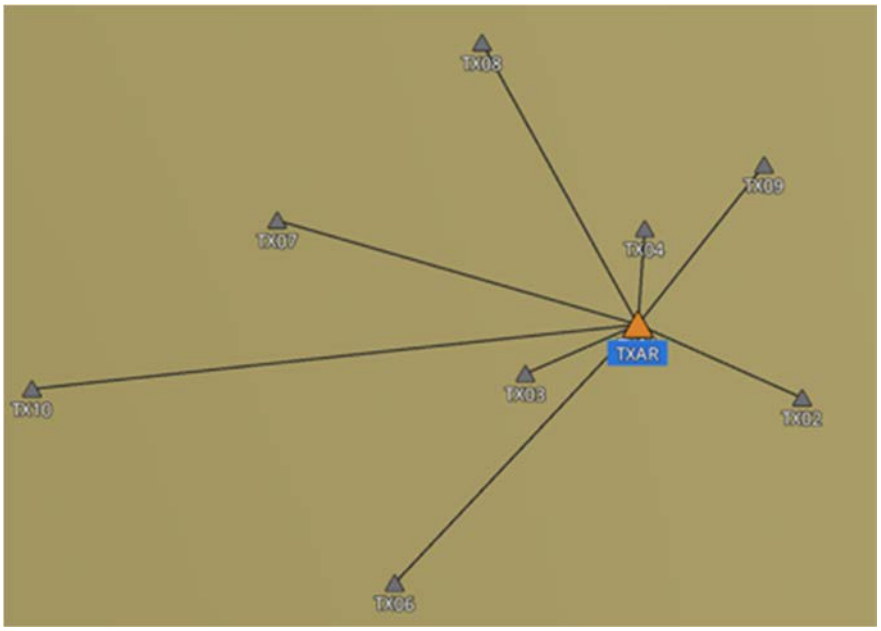


Figure 140. Map of TXAR Array Station and Site Locations.

Hovering over a station or site will show a basic tooltip with the station/site name. To view detailed information, the user can right-click on the desired station or site to pull up a Station/Site Popup menu (Figure 141, Left) and select 'Open station/site details'.

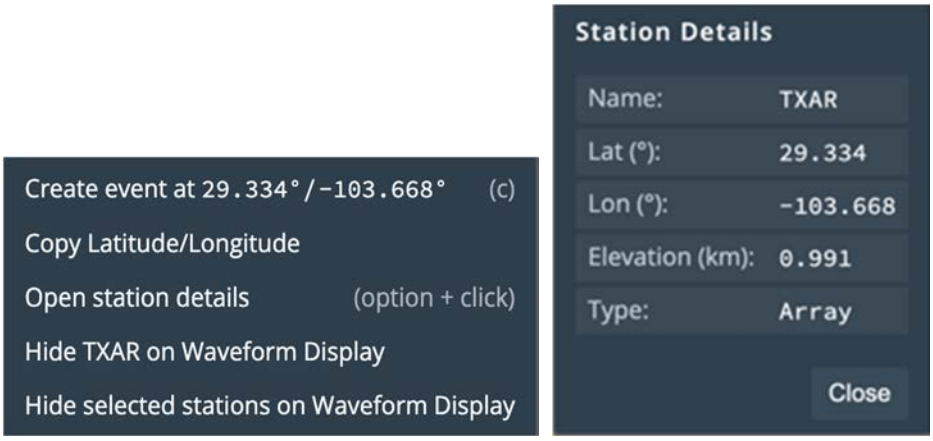


Figure 141. Station Popup Menu (Left) Menu and (Right) Tooltip for Station TXAR.

Station (or site) details can also be pulled up directly by pressing Alt (Option on Mac) + click on the desired station/site (Appendix C). A station details menu contains:

- Name – Name of the station
- Lat(°), Lon(°) – Latitude, Longitude in degrees
- Elevation (km) – Station elevation in km
- Type – Type of station being viewed. Can be single or array

A site details menu contains the same information as a station details menu except for the Type category. The information in the menu can be copied and pasted using the hotkeys Ctrl + C (Command + C on Mac) and Ctrl + V (Command + V on Mac), respectively. The menu can be closed by clicking Close, pressing Esc (Appendix C), or clicking anywhere else in the Map display.

The additional options in the Station Popup menu will be discussed through the remainder of Section 5.6.

A station can be selected on the map by clicking its respective icon; note that sites cannot be selected. When a station is selected, its representative triangle is made larger than the unselected stations and its name is highlighted in blue. Figure 142 shows the reference station TXAR selected.

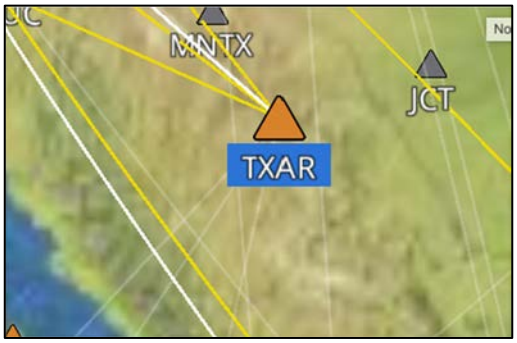


Figure 142. Map Display with Station TXAR selected.

Selecting multiple stations at once can be done by 1) holding Shift while clicking on the desired stations or 2) make multiple selections in the Waveform display (Section 5.3).

To deselect a station, either 1) select a different station in the Map display, 2) hold Shift + click to deselect an individual station while keeping other stations selected, 3) click the selected station to de-select it (if single station selected) or 4) deselect the station in the Waveform display (Section 5.3.2).

Station selection is synchronized across the Map, Waveform (Section 5.3.2), and Station Properties (Section 5.7) displays. If the station selected in the Map display is orange, i.e., the station belongs to the station group shown in the Waveform display or it recorded SDs associated to events in the open time range, that station will be selected in the Waveform display (Section 5.3) and the Station Properties display will be populated with its information (Section 5.7). If the selected station is gray, the Station Properties display will be populated with its station information, but the Waveform display will not show the station selection until it is explicitly added to the Waveform display directly via the 'Stations' dropdown menu (Section 5.3.6.2) or via the Map display (see below). If multiple stations are selected, the Station Properties display will not be populated (Section 5.7).

Waveforms corresponding to a single station are added to the Waveform display 1) via the Stations dropdown menu in the Waveform display (Section 5.3.6.2) or 2) by right-clicking on the desired station in the Map display and selecting the 'Show STATION on Waveform Display' option in the Map Popup menu as shown in Figure 143 (Left) for station TXAR. Alternatively, to show multiple stations in the Waveform display, select the desired stations via the actions described in this section and select the 'Show selected stations on Waveform Display' option. Note that if some selected stations are already visible in the Waveform display, their status won't change when this option is selected; only those stations that aren't visible are added.

Figure 143. Option to Show (Left) or Hide (Right) a Given Station (here TXAR) on the Waveform Display via the Map Display.

When a station(s) is added to the Waveform display, the station icon will turn orange in the Map display and a checkmark will appear in the Waveform display Stations dropdown menu (Figure 60). If the station(s) waveforms are already shown in the Waveform display, the same steps can be performed to hide one or more station(s) in the Waveform display (Figure 143, Right).

When a station(s) is hidden in the Waveform display, the station(s) icon will revert to gray in the Map display and the checkmark in the Stations dropdown menu in the Waveform display (Figure 60) will be removed. Changes to station visibility are maintained until the analyst workspace is closed (i.e., upon logout) or a different interval is opened. Note that the user will only be able to use these Hide and Show options when an interval (Section 5.2) and the Waveform display (Section 5.3) are both open.

5.6.3. Signal Detections in the Map Display

If the opened interval has SD data, the SDs will be plotted as great circle paths from the event to the recording station; SDs are only shown for stations visible on the Waveform display (Section 5.3). An unassociated SD's great circle path will originate from the station that detected the signal and end at a fixed distance. Currently, this fixed distance is a configurable parameter (see Configuration documentation); in future releases, distance will be based on slowness (Section 6). For associated SDs, the distance will be calculated based on the distance between the station and the preferred event location. The arc of an SD's great circle path is determined by the source-to-receiver azimuth. The color of an SD's path indicates the association status of that SD. Available statuses are identical to those defined for the Waveform and Signal Detections List displays. See Section 5.3.5 and Table 4 in Section 5.5 for color definitions.

Characteristics of an SD's path in the Map display indicates the following:

- the association status of the SD
- whether the SD occurs within the open time interval
- whether the SD has been selected in either the Waveform, SD Detections List, or Map display.

When an event is opened, SD path colors in the Map display, Waveform display (Section 5.3.5, Section 5.3.8), and Signal Detections List display (Section 5.5) are updated based on their association statuses. As in the Signal Detections List display (Section 5.5), edge SDs occurring before or after the open time interval are dim relative to SDs within the time interval.

To select an SD, click on its great circle arc. This action will cause the SD to glow relative to other SDs, e.g., Figure 144.

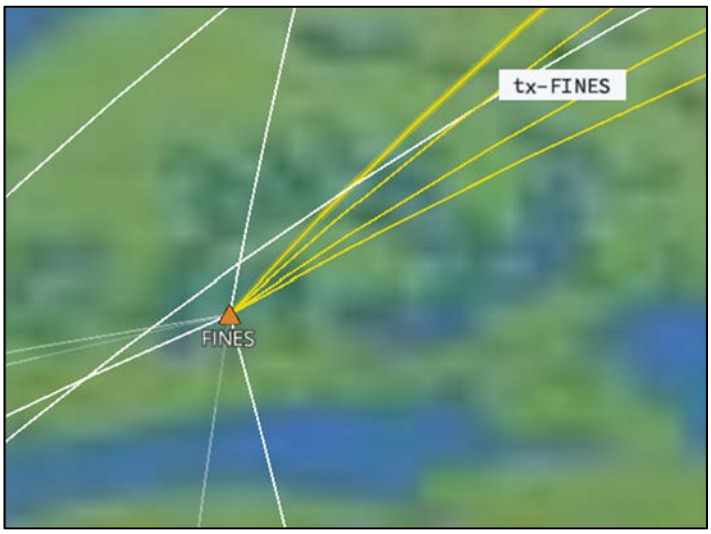


Figure 144. A Selected Signal Detection Recorded by Station FINES.

To select multiple SDs, hold Shift while clicking all desired SDs. To deselect an SD, the user can 1) click the selected SD to deselect it, 2) select another SD to automatically deselect all other selections or 3) hold Shift while clicking to deselect only chosen SDs. As SDs are synchronized across the Waveform (Section 5.3.5), Signal Detections List (Section 5.5.4), and Map displays, any selections or modifications to SDs in the Map display will also be reflected in the Waveform and Signal Detections List displays.

To aid in selection, the user can hover over an SD path to display its respective phase type and the recording station name (e.g., tx-FINES) as shown in Figure 144. This feature is useful when an SD path is associated to an event on the other side of the globe or when multiple SDs overlay each other, as it allows the user to know what station the SD originated from and whether it is the SD they intended to select.

To obtain more information about a particular SD, the user can right-click on a desired SD's path to pull up the Signal Detection Details Popup menu (Figure 145, Left). Alternatively, SD details can be retrieved directly by pressing Alt (Option on Mac) + click. Either action pulls up the Signal Detection Details table (Figure 145, Right). This table is identical to the Waveform display Signal Detection Details table (Figure 47) discussed in Section 5.3.5.2.1; the user is referred to Section 5.3.5.2.1 for details.

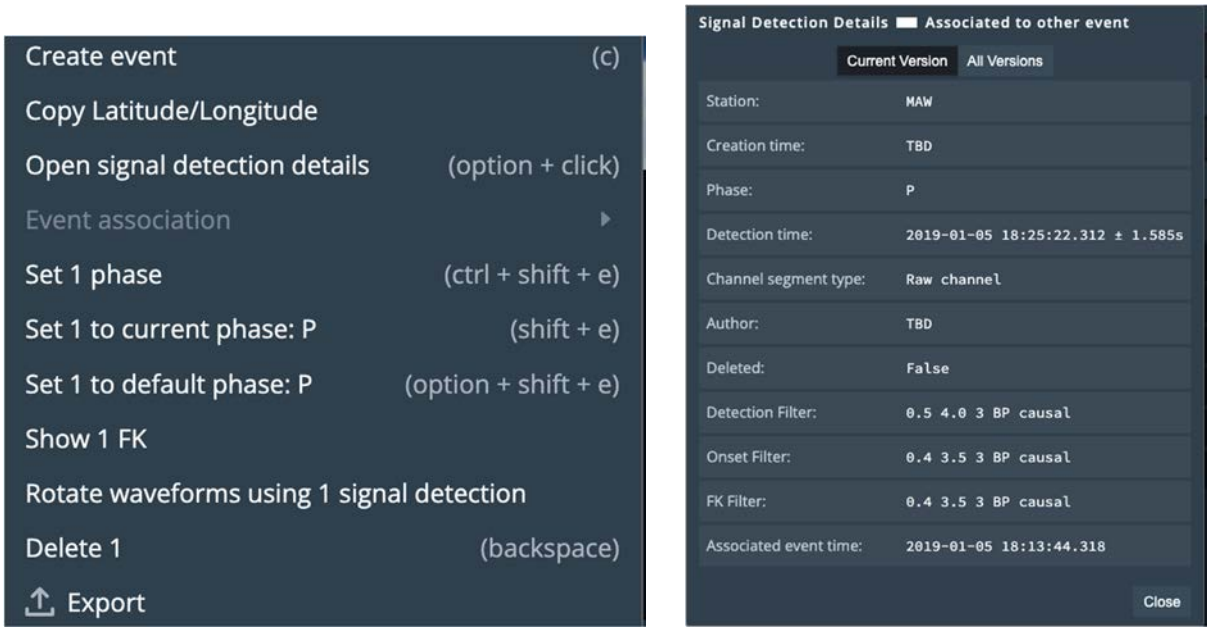


Figure 145. Map Display Signal Detection Popup Menu (Left) and Table (Right) for an Associated Signal Detection.

The remaining options in the Signal Detection Popup menu are also discussed in other sections of this document. The 'Create event' and 'Copy Latitude/Longitude' options are discussed in Section 5.6.4. The 'Event association' option, used to associate the selected SD(s) to an open event, is discussed in Section 5.3.8.4. The options to set phases ('Set # phase', 'Set # to current phase: P', 'Set # to default phase: P') are detailed in Section 5.3.5.2.2. The option to 'Show # FK' is mentioned in Section 5.3.5.2.3. The option to 'Rotate waveforms using # signal detection' is discussed in Section 5.3.5.2.4. The 'Export' option is discussed in Section 5.3.6.3. The user is referred to these sections for details on any of these options.

Finally, the 'Delete #' option performs the same function as the delete option discussed in the Waveform display (Section 5.3.5.2.5). The only difference is that rather than a label marker changing color, it is the great circle arc representing the SD in the Map display that changes to red-orange, indicating a deleted status.

5.6.4. Events in the Map Display

Events are shown as colored circle icons. Colors indicate the status of the event. Available statuses are:

- White – Event is unopened. The event can be duplicated, deleted, or rejected only. Otherwise, the event cannot be modified
- Orange – Event is opened. The event can be modified using the tools described throughout this document
- Red-orange – Event is deleted by the user. The event can no longer be modified, even when the event is opened. The event may be recreated by the automatic processing system (see Section 5.4.4 for definition of deleted)
- Lavender – Event is rejected by the user. The event can no longer be modified, even when the event is opened

Event origin time labels can be viewed by sufficiently zooming into the map. As in the Events display, edge events occurring before or after the open time interval appear dimmed compared to events that occurred during the time interval (see Section 5.4).

Hovering over an event will show a basic tooltip with the origin time. To view detailed information, the user can right-click on the desired event to pull up the Event Popup menu (Figure 146, Left) and select 'Open event details'. Event details can also be brought up directly by pressing Alt (Option in Mac) + click.

Figure 146. Event Popup (Left) Menu and (Right) Tooltip.

By default, the Event details menu provides the following information in tabular format (Figure 146, Right):

- Event Time – Origin time of the event in YR-MON-DY HR:MIN:SEC

- Lat(°), Lon(°) – Latitude, Longitude in degrees
- Depth (km) – Event depth in km
- Workflow status – Status indicating what work has been done to the event. Can be *Not started*, *In progress*, *Not complete*, *Complete*, or *Rejected*. Descriptions of these event statuses and the required actions for setting them in the Events display are provided in Section 5.4.
    - Currently, the functionality to mark an event as complete is disabled (Section 6), so a status of *Complete* will not be shown.

Clicking Close, Esc, or anywhere else in the Map display will close the Event details menu. The table can be copied and pasted in the same way as the station/site tables.

In the Map display, any event can be opened or closed by 1) right-clicking the desired event to bring up the Event Popup menu shown in Figure 146 (Left), then selecting 'Open/Close event' or 2) double-clicking the desired event.

As in the Events display, if another analyst is actively working on an event, an Open Event Confirmation popup will appear in the center of the workspace (Figure 124). Clicking the 'Cancel' option will result in no changes and close the popup, while clicking 'Open Anyway' will result in the normal sequence described below.

When an unopened event is opened in the Map display, its circle icon will update from white to orange to indicate that the event is now open; all SDs associated to the event will have their SD paths updated based on their association status to the event. Events that have been deleted or rejected will not change status or color when opened. And because deleted and rejected events do not have any SDs associated to them, SD statuses will not change either. Opening these types of events only allows the user to view waveforms aligned to the opened event's predicted P phase (Section 5.3.8) (or other phases of their choosing). Note that opening/closing a deleted or rejected event will cause the event's workflow status to update to *In progress/Not complete* as described earlier (Section 5.2).

When an event (that has not been deleted/rejected) is opened from the Map or Events displays, the Waveform display, Events display, and Signal Detections List displays will be updated accordingly (Sections 5.3.8, 5.4.4, 5.5.5). When an event is closed again, all associated SDs revert to their prior state in the Map display as well as in the synchronized Waveform, Event, and Signal Detections List displays, e.g., SDs will once again be shown in white in the

Map display. This level of synchronization allows analysts to easily visualize SD association status and event status information across multiple displays.

In addition to viewing event details and opening/closing events, the Event Popup menu (Figure 146, left) provides several other options. These will be described in the following sections.

5.6.4.1. Creating Events

As in the Waveform (Section 5.3.5.5), Events (Section 5.4.3), and Signal Detections List (Section 5.5.3) displays, events based on SDs and/or virtual events can be created in the Map display. The user is referred to Section 5.3.5.5 for a full description of event creation. This section will only detail functionality specific to event creation in the Map display.

To create events with associated SDs, the user must first select one or more SDs in the Map (Section 5.6.3), Waveform (Section 5.3.5.1), or Signal Detections List (Section 5.5.4) displays. Once the desired SDs are selected the user can perform one of the following actions:

- Right-click anywhere in the map to bring up the Event Popup menu and select 'Create event'. This action will cause the Create Event menu seen in the Waveform display (Figure 54) to pop up with default values. See Section 5.3.5.5 for details on the Create Event menu. Note that only options relevant to event creation remain in the menu (Figure 147).

Figure 147. Truncated Event Popup Menu with SDs selected.

  Once selected, an event will be created at the location of the station that recorded the earliest arriving SD (see Section 5.3.5.5).

  - If the user right-clicks on an event or a station, the full Event Popup menu (Figure 146, left) or Station Popup menu (Figure 141) will be shown, respectively. The event creation options ('Create event' and 'Copy Latitude/Longitude') are shown at the top of these menus.

- Press the hotkey 'c'. This action will automatically create the event at the location of the station that recorded the earliest arriving SD (see Section 5.3.5.5).

To create events without SDs, i.e., virtual events, the user can perform one of the following actions:

- Right-click anywhere on the map to bring up the Event Popup menu and select the 'Create event at lat/lon' option (Figure 148). The latitude and longitude values in the menu reflect the location the user right-clicked. Selecting this option will cause the Create Event menu seen in the Waveform display (Figure 54) to pop up, with latitude and longitude fields populated by the location values shown in the Event Popup menu. See Section 5.3.5.5 for details on the Create Event menu.

Figure 148. Truncated Event Popup Menu with no SDs Selected.

- Right-click on a station or event icon and select the 'Create event at lat/lon' option at the top of their respective menus (Figure 141, left and Figure 146, left, respectively). The latitude and longitude values in these menus will reflect the location of the station or event that was right-clicked. Selecting this option will cause the Create Event menu seen in the Waveform display (Figure 54) to pop up, with latitude and longitude fields populated by the location of the station or event that was right-clicked. See Section 5.3.5.5 for details on the Create Event menu.
- Press the hotkey 'c'. This action will cause the Create Event menu seen in the Waveform display (Figure 54) to pop up with default values. See Section 5.3.5.5 for details on the Create Event menu, including defaults.

Finally, the option 'Copy Latitude/Longitude' available in the Station/Event popup menus (Figure 141, Figure 146, Figure 147, Figure 148) is used to aid in event creation by allowing the user to easily copy a desired latitude/longitude pair. Once copied, the user can paste the copied latitude and longitude into the Create Event menu (Figure 54) described in Section 5.3.5.5 using the clipboard icon at the lower-right of the menu.

5.6.4.2. Event Selection and Modification

Event selection is synchronized between the Events display (see Section 5.4) and Map display, such that events selected in one display will also be selected in the other. An event can be selected in the Map display by clicking on its circle marker, which will highlight it in blue and

display the event time beneath it. Multiple events can be selected by holding Shift and clicking on the desired markers (Figure 149). Deselection works the same for events as it does for stations (Section 5.6.1). Note that right-clicking on a single event as described in the previous section also results in event selection.

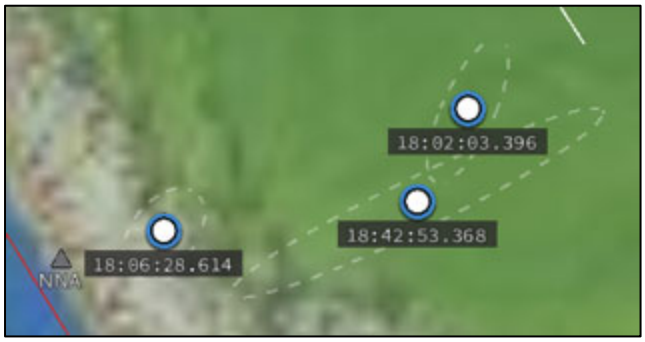


Figure 149. Multiple-Event Selection in the Map Display.

After selecting one or more events, the options to duplicate, delete, or reject event(s) in the full Event Popup menu (Figure 146, Left) can be used.

If the user chooses to duplicate one or more events, the event locations will be shown with a number inside the circle icon (Figure 150).

Figure 150. Duplicated Events.

The numbers indicate that more than one event is in the same location. For instance, in Figure 150, there are 2 events in each of the 3 locations that exactly overlap each other due to the event duplication. If an event is duplicated in the Map display, it is synchronously duplicated in the Events display (Section 5.4.4) and the SDs will automatically be associated to both events (Section 5.5.5); this will result in conflicts in the Events and Signal Detections List displays.

If the user chooses to delete one or more events, the event location(s) turn red-orange (Figure 151).

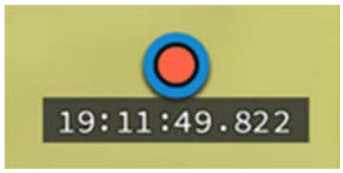


Figure 151. Deleted Event.

If an event is deleted in the Map display it is synchronously deleted in the Events display; refer to Section 5.4.4 for deletion effects in the Events display.

Finally, if the user chooses to reject one or more events, the event location(s) turn lavender (Figure 152).

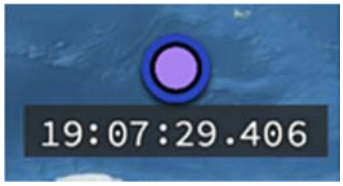


Figure 152. Rejected Event.

If an event is rejected in the Map display it is synchronously rejected in the Events display; refer to Section 5.4.4 for rejection effects in the Events display.

5.6.4.3. Event Location Uncertainty Coverage and Confidence Ellipses

Location uncertainty coverage and confidence ellipses, as defined in Section 5.4, are displayed by default in the Map display via solid and dashed ellipses, respectively, which can be seen surrounding the event; the user may need to zoom in to view smaller uncertainty ellipses. Uncertainty ellipses can help analysts visualize the confidence in the event location during event refinement. An example of an event and its location uncertainty confidence ellipse is shown in Figure 153. Uncertainty ellipses can be toggled on and off via the Map Layers menu described in a later section (Section 5.6.5).

Figure 153. Example Event and Location Uncertainty Confidence Ellipse.

If an event is rejected or deleted as described in the previous section, its uncertainty ellipse(s) is removed from the Map display.

5.6.5. Map Layers

Clicking the 'Select Map Layers' button (i.e., the layers icon on the left-hand side of the Map display in Figure 136) will display the menu in Figure 154 to the left of the Map display.

Figure 154. Map Layers Menu.

This menu lists the available layers, i.e., Stations, Sites, Signal Detections, Events, where checked layers are currently shown on the map. By default, all map layers except Sites are displayed. To remove a layer from viewing, the user can uncheck that layer. Station and site layers currently have no additional layer configuration available, while additional configurability exists for the Signal Detections and Events layers. This configurability allows analysts to customize the type of information they would like to visualize regarding SDs and events.

The Signal Detections layer information being viewed can be modified using the Signal Detections layer options (Figure 155), which are accessed by selecting the gear icon to the right of Signal Detections in the Map Layers menu (Figure 154).

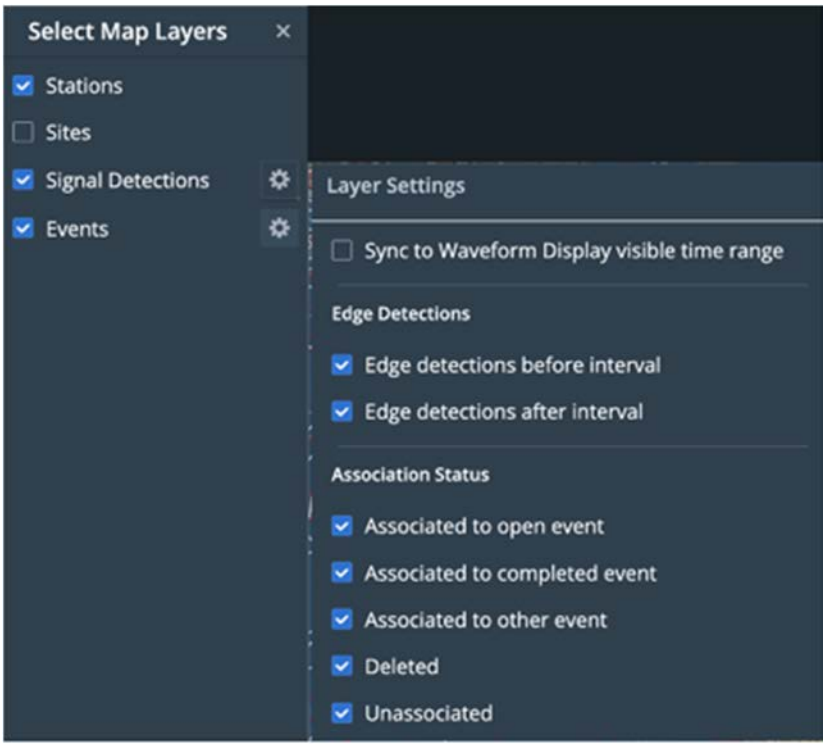


Figure 155. Options to Modify Signal Detections in Map Display.

SDs can be synced to the Waveform display's visible time range such that only SDs within the viewable time range are shown in the Map display (Figure 155). The behavior of this syncing feature is identical to the Signal Detection syncing feature in the Signal Detections List display; refer to Section 5.5.4 for more details. By default, SDs are not synced to the Waveform display.

Edge detections before/after the interval and all SD association status types, including unassociated SDs, are also shown by default as part of the SD layer (Figure 155). Toggling on or off any of these additional Signal Detection layer settings will add or remove them from the Map display, respectively.

Finally, SDs can be shown/hidden based on association status. Note that toggling associated to completed event will result in no change as the IAN UI cannot yet mark events as complete (Section 6).

Event layer information being viewed can be modified using the Events layer options (Figure 156), which are accessed by selecting the gear icon to the right of Events in the Map Layers menu (Figure 154).

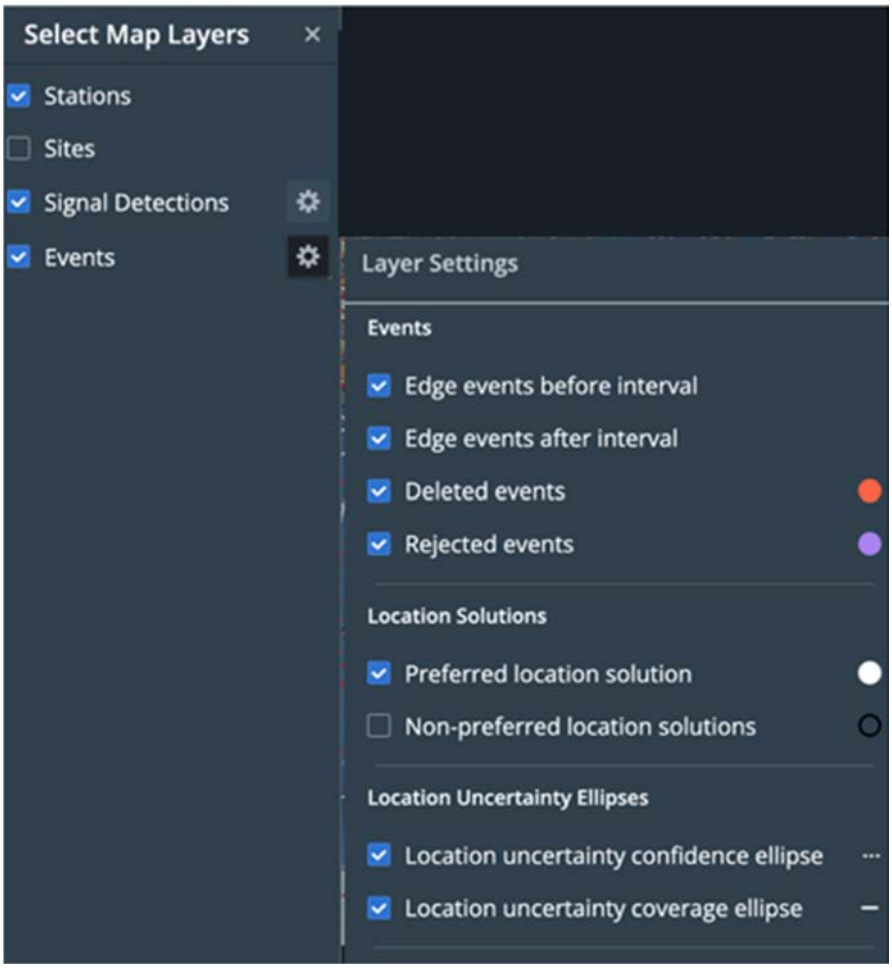


Figure 156. Options to Modify Events in Map Display.

By default, all events loaded into the Events display are shown in the Map display, regardless of which events are open, deleted, or rejected. These include edge events occurring before and after the selected interval, identical to the edge events in the Events display (Section 5.4).

Preferred and non-preferred location solutions of events are indicated by solid dots and open black circles, respectively. By default, only preferred location solutions are shown; non-preferred location solutions must be toggled on in the Events layer options (Figure 156) to be shown in the Map display. Currently, non-preferred location solutions cannot be shown in the IAN UI (Section 6). This feature will be enabled in a future release.

Location uncertainty confidence and coverage ellipses are shown by default and denoted by dashed and solid white lines, respectively. Definitions of these location uncertainty ellipses are provided in Section 5.4.

5.7. Station Properties Display

The Station Properties display allows users to view detailed metadata information about a selected station (channel group and channel configuration) and will eventually provide information about the station that is configured on GMS (e.g., beam definitions). It is also a helpful tool to validate that bridged information is correct.

There are several cases where the Station Properties display will not be populated, as shown in Figure 157.

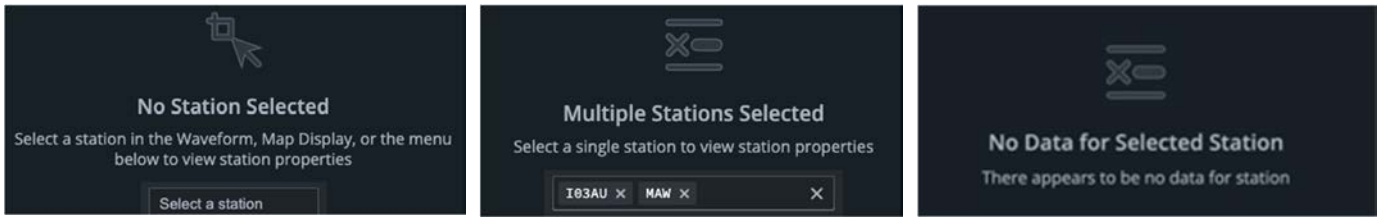


Figure 157. The Station Properties Display With (Left) No Station Selected, (Center) Multiple Stations Selected, and (Right) No Data for Selected Station.

First, a station must be selected in the Waveform display (Section 5.3), the Map display (Section 5.6), or by manually entering a station into the text box of the Station Properties Display. If no station is selected, the user will be prompted to choose a station (Figure 157, left). Only one station may be selected at a time. Note that choosing a site/channel from a station's expanded waveform panel, e.g., FINES.FIA0.SHZ in Figure 36, will not populate the Station Properties display. Second, if multiple stations are selected in the Waveform or Maps displays, the user will be prompted to select just one station as shown in Figure 157, center. Finally, if no data are available for the selected station (usually because of a service error), the user will be warned as shown in Figure 157, right. In this case the user should select a different station.

Once a station with data is selected, the Station Properties display will be populated with information for all channel group configurations, as shown in Figure 158.

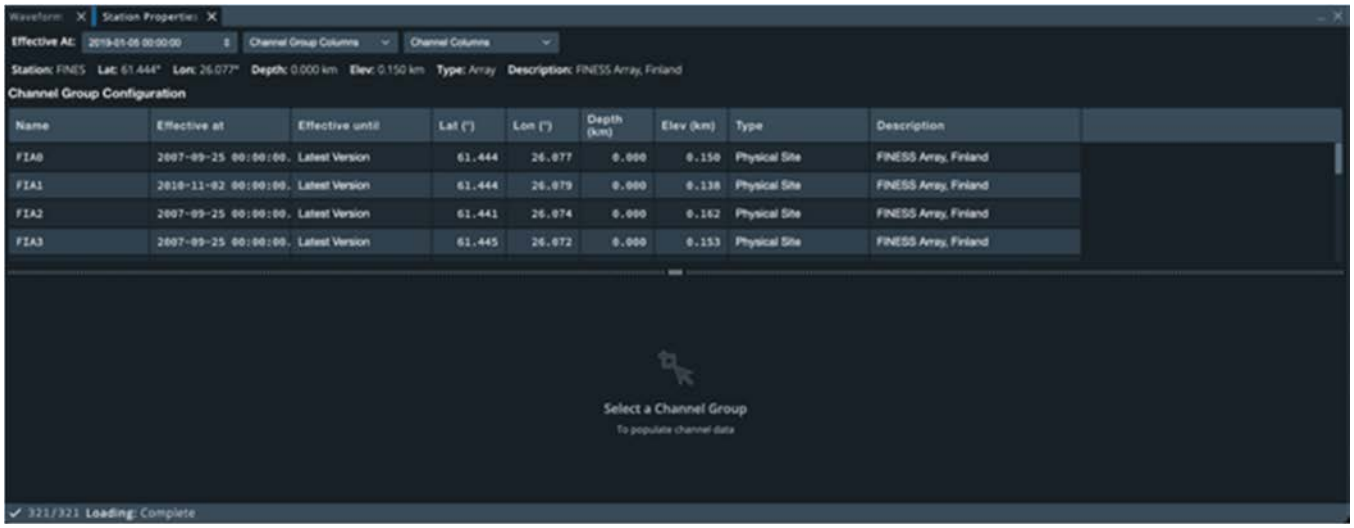


Figure 158. Station Properties Display with Top Panel Populated.

At the top of the display, the following station information is shown from left-to-right, top-to-bottom:

Table 5. Station Information at Top of Station Properties Display.

Item	Description
Effective at	Dropdown menu listing dates on which the station and/or any of its aggregated objects (channel group, channel, or response) changed within the configured operational time range
Channel group columns	Dropdown menu used to select which columns in the Channel Group Configuration table to view
Channel columns	Dropdown menu used to select which columns in the Channel Configuration table to view
Station	Name of station being viewed
Lat, Lon	Latitude and longitude of station in degrees
Depth	Depth of station burial in km
Elev	Elevation of station in km
Type	Type of station being viewed (i.e., single or array)

Description	Description of the station

A tooltip providing a brief description of each dropdown menu and station information entry can be brought up by hovering the cursor over the desired menu or entry.

The ‘Effective at’ dropdown menu is shown in Figure 159 below.

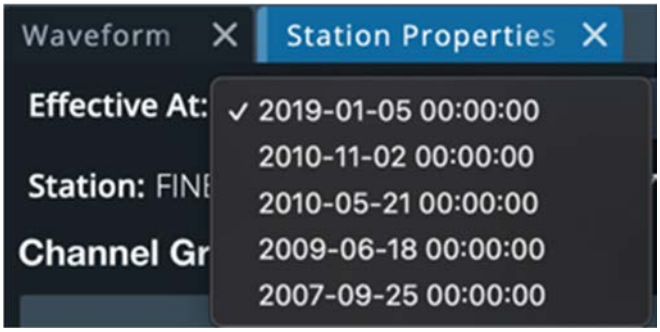


Figure 159. Effective At Dropdown Menu.

The set of date/time options in the dropdown menu represents an ordered collection of effective times where the selected station and/or any of its aggregated objects (i.e., channel groups, channels, responses) changed within the configured operational time range. Note that the dates/times shown in Figure 159 are generated by a data simulator and thus change more often than would be expected in a real-world scenario. By default, the corresponding metadata with the latest effective time is displayed. Selecting a different date/time will update the metadata shown in the Channel Group Configuration and Channel Configuration tables to the configuration that was effective at that date/time. By default, the channel group effective at the given date/time is populated in the Channel Group Configuration table.

The Channel group columns dropdown menu (Figure 160) allows the user to select which columns to view in the Channel Group Configuration panel. By default, all columns will be checked for viewing. The user can uncheck any undesired columns to customize the table. The order in which the columns are listed is the order in which they appear in the Channel Group Configuration panel from left to right.

Column selections are saved in the Station Properties display when an interval is opened/closed or closed/reopened but do not persist on logout.

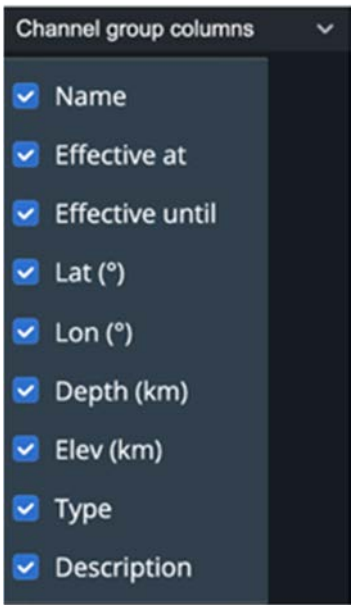


Figure 160. Channel Group Columns Dropdown Menu.

Finally, the Channel Columns dropdown menu is the same as the Channel Group Columns dropdown menu, but for columns in the Channel Configuration panel. This menu will be described later this section.

Directly beneath the station information described above, the Channel Group Configuration panel is populated with every active channel group during the respective effective time. From left-to-right, the following information is shown:

Table 6. Channel Group Configuration Columns.

Column	Description
Name	Name of the channel group
Effective at	Start date/time when the channel group configuration being viewed was effective
Effective until	End date/time when the channel group was no longer effective since it was either no longer needed or superseded by a new channel group. If the channel group configuration is the current configuration, it will be listed as Latest Version.
Lat (°), Lon (°)	Latitude and longitude of the site corresponding to the channel group configuration in degrees

Depth (km)	Depth of burial of the channel group in km
Elev (km)	Elevation of the channel group in km
Type	Type of channel group
Description	Description of the channel group

The channel group type listed in the Type column can be either 1) a Processing Group or 2) a Physical Site. A processing group is a collection of raw channels used together to perform a desired automatic or interactive data processing (e.g., beaming), while a physical site is a collection of raw channels corresponding to sites with physical locations. For arrays, 'Elev' represents the average elevation of its sites, rather than the station's elevation.

To view information on every channel within a particular channel group configuration, the user can click the channel group of interest, which will highlight the selected row in blue (see Figure 161). This action will populate the Channel Configuration table as shown in Figure 161. The Channel Configuration table is populated with the channels that were effective for that channel group during the given effective date/time. Only one channel group row may be selected at a time.

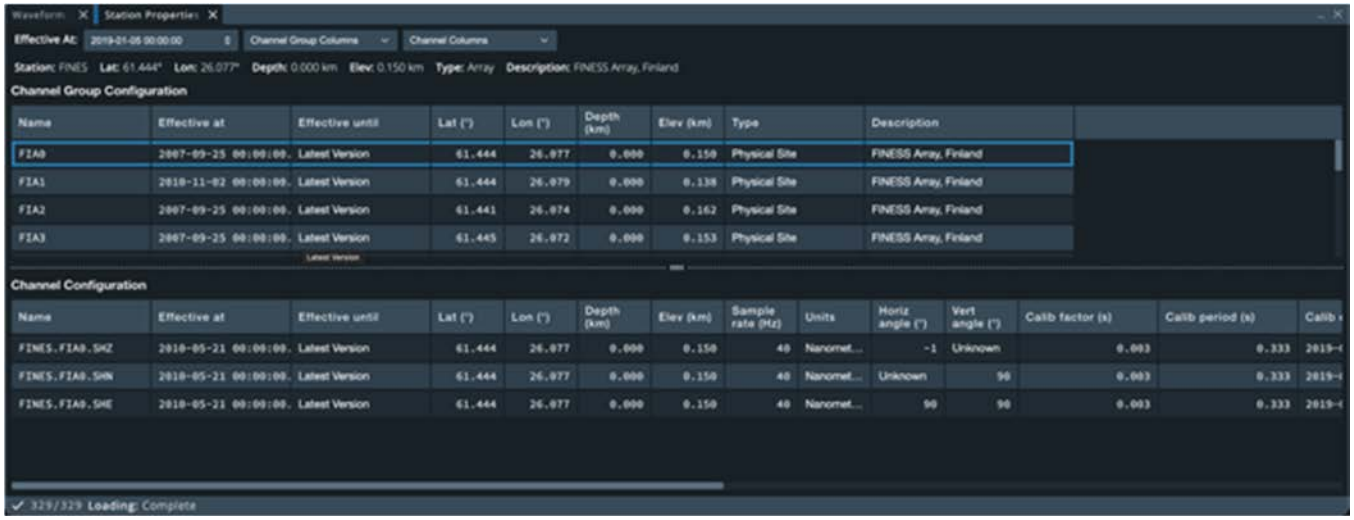


Figure 161. Station Properties Display with Top and Bottom Panel Populated.

When populated, the channel configuration columns from left-to-right are listed in Table 7. Entries with asterisks are not shown in the Channel Configuration panel by default.

Table 7. Channel Configuration Columns.

Column	Description
Name	Name of the channel
Effective at	Start date/time when the channel configuration being viewed was effective
Effective until	End date/time when the channel configuration was no longer effective since it was either no longer needed or superseded by a new configuration. If the channel configuration is the current configuration, it will be listed as Latest Version.
Lat (°), Lon (°)	Latitude and longitude of channel in degrees
Depth (km)	Depth of burial of the channel in km
Elev (km)	Elevation of the channel in km
Sample rate (Hz)	Nominal channel sample rate in Hz
Units	Units reported by the specific channel. Can be nanometers (seismic), microPascals (hydroacoustic), or Pascals (infrasound)
Horiz angle (°)	Channel orientation horizontal angle in degrees, i.e., the horizontal orientation of the instrument in the horizontal plane measured clockwise from North
Vert angle (°)	Channel orientation vertical angle in degrees. Measures the angle between the sensitive axis of the instrument and the outward pointing vertical direction
Calib factor (s)	Calibration factor in seconds used to multiply the original raw waveforms recorded by the station and convert them to physical units. This factor converts a waveform from unitless counts to nanometers (nm) for seismic data, pascals (P) for infrasound data, and micropascals (μP) for hydroacoustic data. These units are not configurable
Calib period (s)	Period in seconds over which the calibration factor is valid
Calib effective at	Start date/time when the channel configuration had the calibration factor being viewed

Calib time shift (s)	Calibration time shift in seconds, used as a correction factor for clock errors at the channel
Calib std dev	Standard deviation of the calibration factor
North/East/Vert displacement (km)	North/east/vertical displacement or position of the channel relative to the reference station
Description	Description of the channel
Data type*	Channel data type. Current types can be seismic, hydroacoustic, infrasound, weather, diagnostic SOH, or diagnostic weather.
Band type*	Channel band type. Corresponds to the first character in a channel name (e.g., B for broadband). Specifies the general sample rate and response band of the instrument. The potential band types are provided in Appendix B, and follow SEED standards.
Instrument type*	Channel instrument type. Corresponds to the second character in a channel name (e.g., H for high gain seismometer). Specifies the instrument type to which the sensor belongs to. The available instrument types are provided in Appendix B, and follow SEED standards.
Orientation code*	Channel orientation code. Corresponds to the last character in a channel name (e.g., Z for vertical). Indicates the directionality of the sensor measurement. For instruments other than seismometers, the orientation code is used for instrument-specific purposes other than direction. Available orientation codes and their usages are provided in Appendix B, and follow SEED standards.
Orientation type*	Channel orientation type, i.e., description of specific sensor corresponding to Orientation Code. For instance, when band type is E (extremely short period), instrument type is D (pressure), and orientation code is H (Hydrophone), Orientation Type will be listed as Hydrophone. Table B3 in Appendix B can be used to determine the Orientation Type for a given channel.
Calib ID	Calibration response ID
FAP resp ID	Frequency-amplitude-response ID

To add or remove columns from viewing, the user can check/uncheck any column using the Channel Columns dropdown menu (see Figure 162) to customize the Channel Columns panel.

The order in which the columns are listed is the order in which they appear in the panel from left to right.

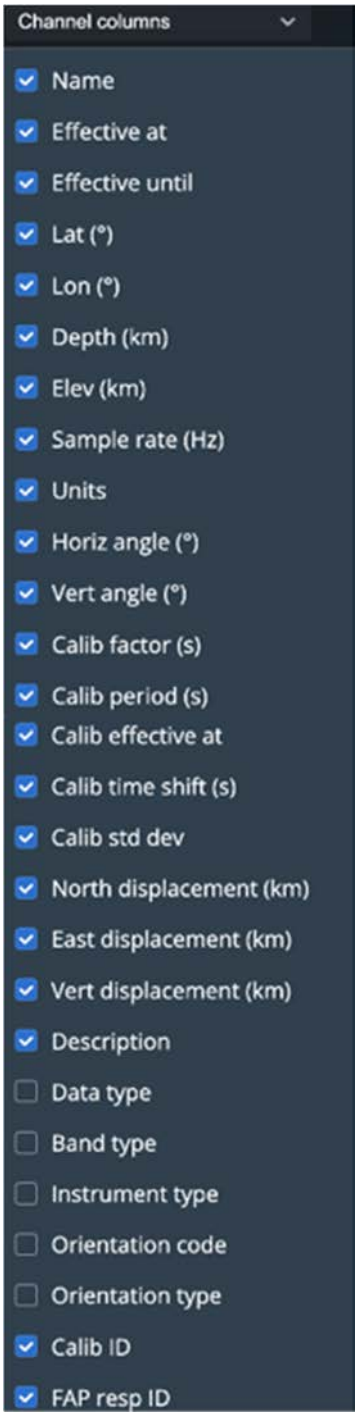


Figure 162. Channel Columns Dropdown Menu.

Due to the number of columns in the Channel Configuration panel, the user will have to scroll down to add or remove some columns.

When the default number of columns is shown, the user will typically not be able to view all columns at once. Instead, the user must scroll the panel towards the right or left using the horizontal scroll bar at the bottom of the panel.

Finally, the table layouts shown in the Station Properties display can be modified in the same way as those in the Events and Signal Detection Lists displays; see Section 5.4.1.1 for details. Additionally, the tables can be vertically resized by clicking and dragging the dashed horizontal bar in the center of the display to the desired position (Figure 161). The bar will turn blue as this action is being performed to indicate that resizing is enabled.

5.8. Filters Display

Filtering is applied by analysts to enhance signals that may be hidden in noise; it can be used to improve SD arrival times, add missing SDs, etc. The IAN UI provides filtering capabilities via the Filters display (Figure 163). The filters in this display are directly applied to the waveforms in the Waveform display (Section 5.3).

Figure 163. The Filters Display.

The Filters Display is accessed from the Analyst Displays option under the Displays section of the application-level menu (Figure 18), as it is not part of the default layout.

The Filters display is only populated with data when a time interval is opened in the Workflow display (Section 5.2). If no interval is open, the user will be prompted to open an interval to view available filters (Figure 164).

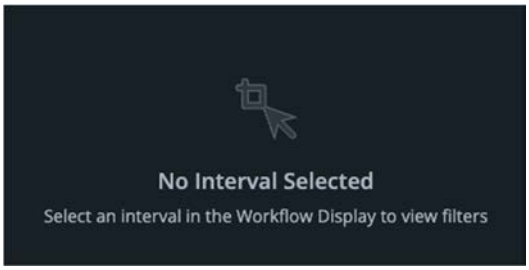


Figure 164. Filters Display Prompt with No Opened Interval.

Upon opening an interval, the Filters display will automatically be populated with the default configured filter list and its filters for that stage and processing activity.

Currently, three filter lists are available: Seismic, Long Period, and Hydro. These filter lists provide filters that are considered most suitable for extracting seismic signals, long period signals, and hydroacoustic signals, respectively. The filter lists and their corresponding filters are configurable (see Configuration documentation).

Each processing stage has its own default configured filter list: Seismic for AL1, Hydro for AL1 Scan, Seismic for AL2 Scan, and Long Period for AL2 Event Review. The user can select a different list by clicking the field at the top of the Filters display (Figure 163), which produces a dropdown menu of filter lists to choose from.

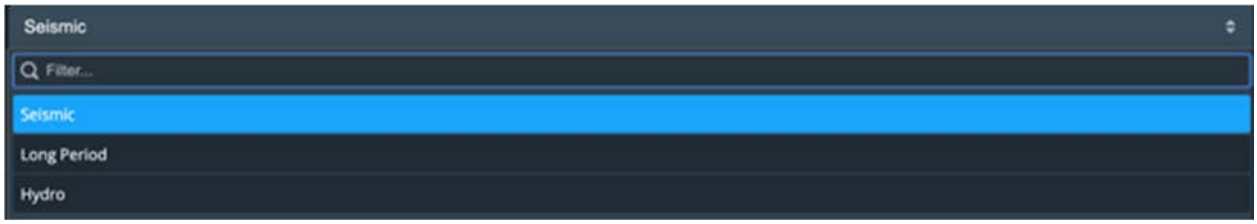


Figure 165. Filter Lists Dropdown Menu.

The user can also search for the desired filter list using the search field in the dropdown menu. The currently selected filter list is highlighted in blue.

The Long Period filter list is shown in Figure 166 as an example list. The filters included in each filter list are configurable (see Configuration documentation).

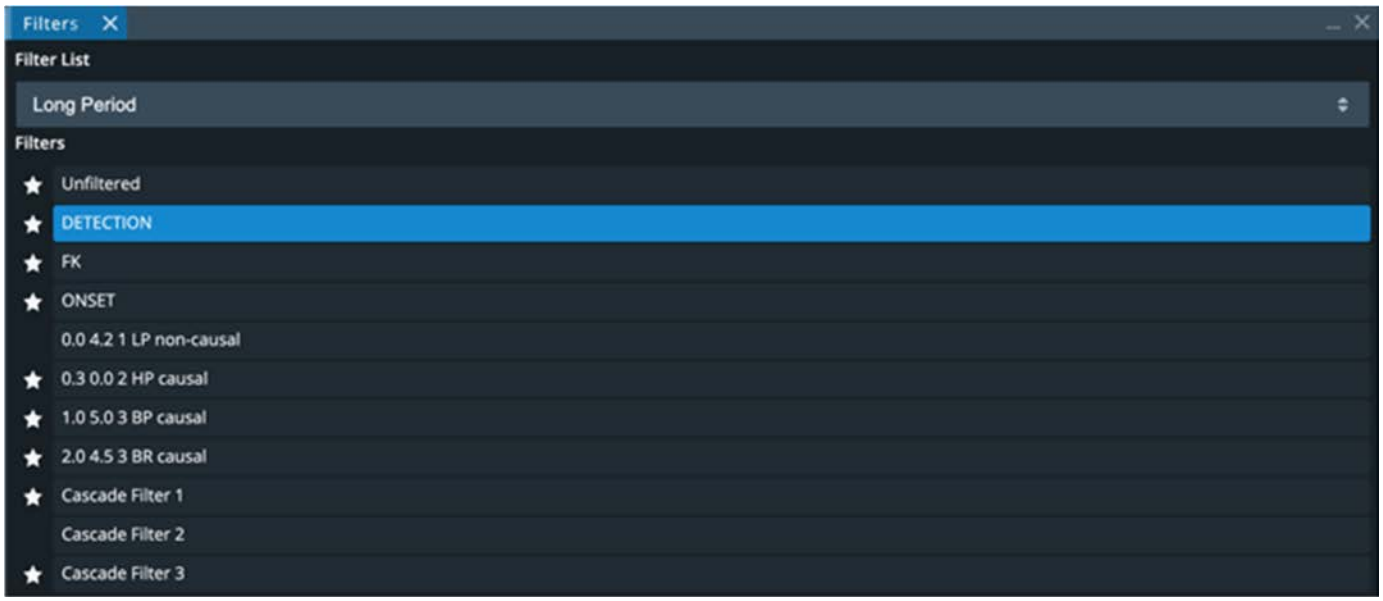


Figure 166. Long Period Filter List.

As the Filters display directly affects waveforms in the Waveform display (Section 5.3.2), it is visually convenient to use the workspace layout 'Waveforms & Filters' (Figure 167). See Section 5.1 for a description of how to change the workspace layout.

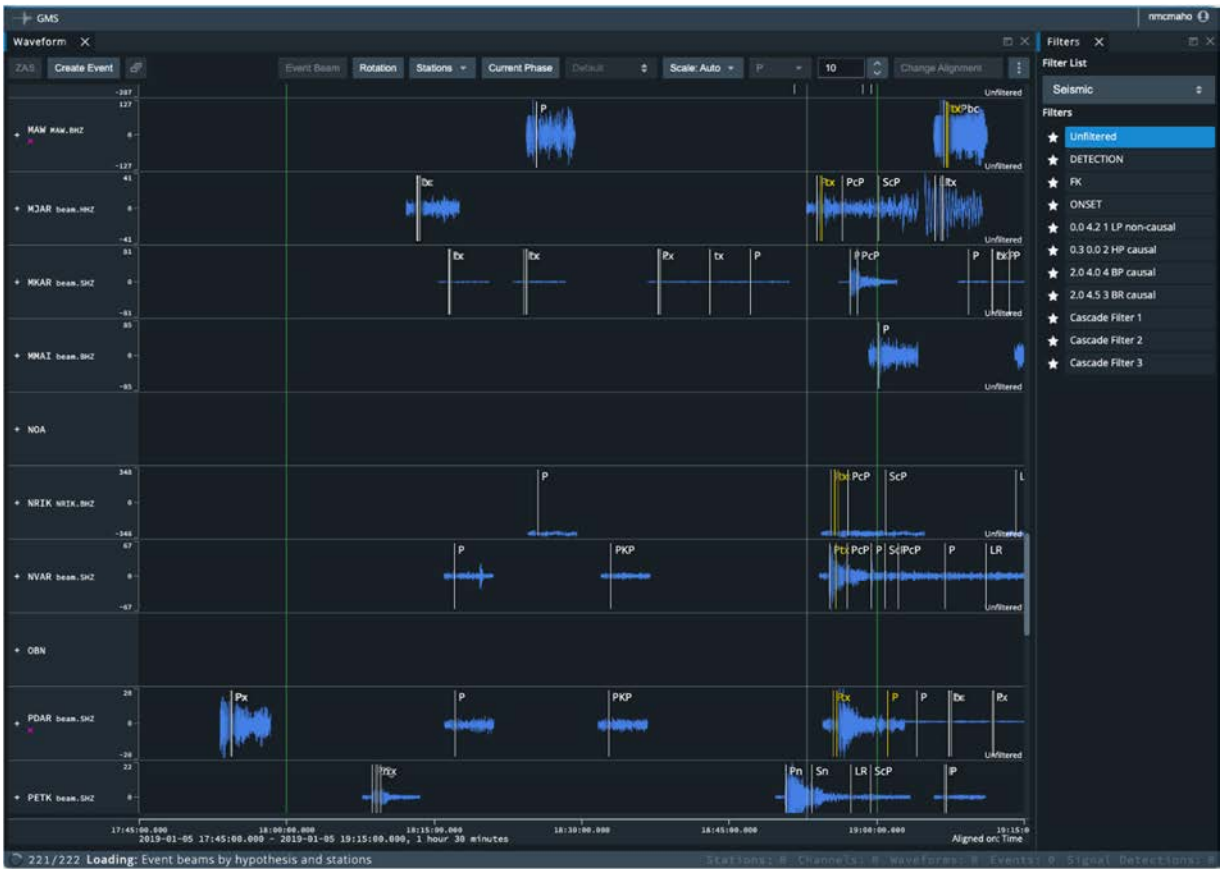


Figure 167. Waveforms & Filters Workspace Layout.

In this layout, the highlighted filter (DETECTION in Figure 167) has been applied to all stations' waveforms. Note that the filters are only automatically applied to the waveforms shown in the station waveform panel; the waveforms of a station's individual channels/sites (e.g., Figure 36) remain raw and unfiltered unless directly selected.

In the Waveform display, the filter applied is indicated at the bottom-right corner of each station panel. Each filter list automatically applies a default filter, with Seismic applying Unfiltered, Long Period applying DETECTION, and Hydro applying FK based on the processing stage and activity opened or filter list chosen. These and other filters are defined below.

The first filter, Unfiltered, is not a true filter but rather is used to return waveforms to an unfiltered state. Thus, when the Seismic filter list is chosen, all waveforms are shown raw and unfiltered. If another filter is applied to a waveform(s), Unfiltered can be used to return the waveform to its original state.

The next three filters, DETECTION, FK, and ONSET are special named filters that are bridged from the database together with the SDs. These are defined as:

- DETECTION – the filter applied to a waveform when an SD was initially created
- FK – the filter that was applied when the FK peak was chosen, resulting in the creation of an FK beam
- ONSET – the filter used to refine an SD's onset time

These named filters are applied to waveforms in one of the following ways:

- When an SD in a station waveform row is bridged with a named filter, that named filter is applied to the SD's associated waveform. For instance, if an SD was detected using a specific filter and that filter is bridged with the SD, that filter will be applied to the SD's waveform when DETECTION is selected.
- When an SD in a station waveform row is bridged without a specific named filter, a default version of the named filter is applied to the SD's associated waveform. The default named filter will vary by station/channel and is configurable (see Configuration documentation).
- When a waveform exists without an SD in a station waveform row, a default version of the named filter is applied to the waveform. The default named filter will vary by station/channel and is configurable (see Configuration documentation).

Named filters are applied to SD waveforms based on the following criteria:

- If no stations were selected prior to applying named filtering, the named filter is applied to all waveforms according to the rules detailed above.
- If a station is selected, but no SDs are selected, the named filter is applied to that station's waveforms according to the rules detailed above.
- If a raw channel is selected, but no SDs are selected, the configured default named filter for that channel is applied to the selected raw channel.
- If a single SD is selected and a raw channel is selected, the named filter bridged with the selected SD is applied to the selected raw channel.

- If multiple SDs are selected and a raw channel is selected, the configured default named filter for that channel is applied to the selected raw channel.

Note that if a filtering operation fails, the filter label at the lower-right corner of the selected station waveform row will show an error message in red.

Because each SD in a station waveform panel can have its own associated named filters, the filter label at the lower-right corner of the selected station waveform panel will only show the generic name of the named filter being applied (e.g., DETECTION). To view details on an SD's associated named filters, the user can go to the Signal Detection Details menu for that SD (see Section 5.3.5.2.1).

The next four filters are Butterworth filters commonly used on waveforms. The names of these filters (e.g., 0.0 4.2 1 LP non-causal) provide the following information:

- Low frequency limit – the lowest frequency allowed by the Butterworth filter
- High frequency limit – the highest frequency allowed by the Butterworth filter
- Order – a measure of how steeply the filter attenuates frequencies outside the passband, with higher orders applying greater attenuation
- Passband type – the type of Butterworth filter applied. The filter can be one of the following:
    - LP – lowpass filter. This filter only passes signals below the cutoff frequency defined by the high frequency limit
    - HP – highpass filter. This filter only passes signals above the cutoff frequency defined by the low frequency limit
    - BP – bandpass filter. This filter only passes signals between the cutoff frequencies defined by the low and high frequency limits
    - BR – bandreject filter (aka bandstop filter). This filter only passes signals outside the cutoff frequencies defined by the low and high frequency limits
- Causality – sets whether the filter is causal or non-causal

These are just some relevant Butterworth filters included by default with IAN. The user can configure more filters as desired (see Configuration documentation).

Finally, three cascade filters are provided (Cascade Filter 1, Cascade Filter 2, Cascade Filter 3). Each cascade filter consists of multiple filters that are applied in sequential order. For instance, applying Cascade Filter 1 results in 10 filters being applied sequentially to a waveform.

To view detailed information on a filter, including what individual filters make up a cascade filter, hover over the far-right side of the desired filter label. This action will cause the filter label to be highlighted in gray and an info icon will appear. Hovering directly over the info icon will bring up a tooltip like the example tooltip in Figure 168.

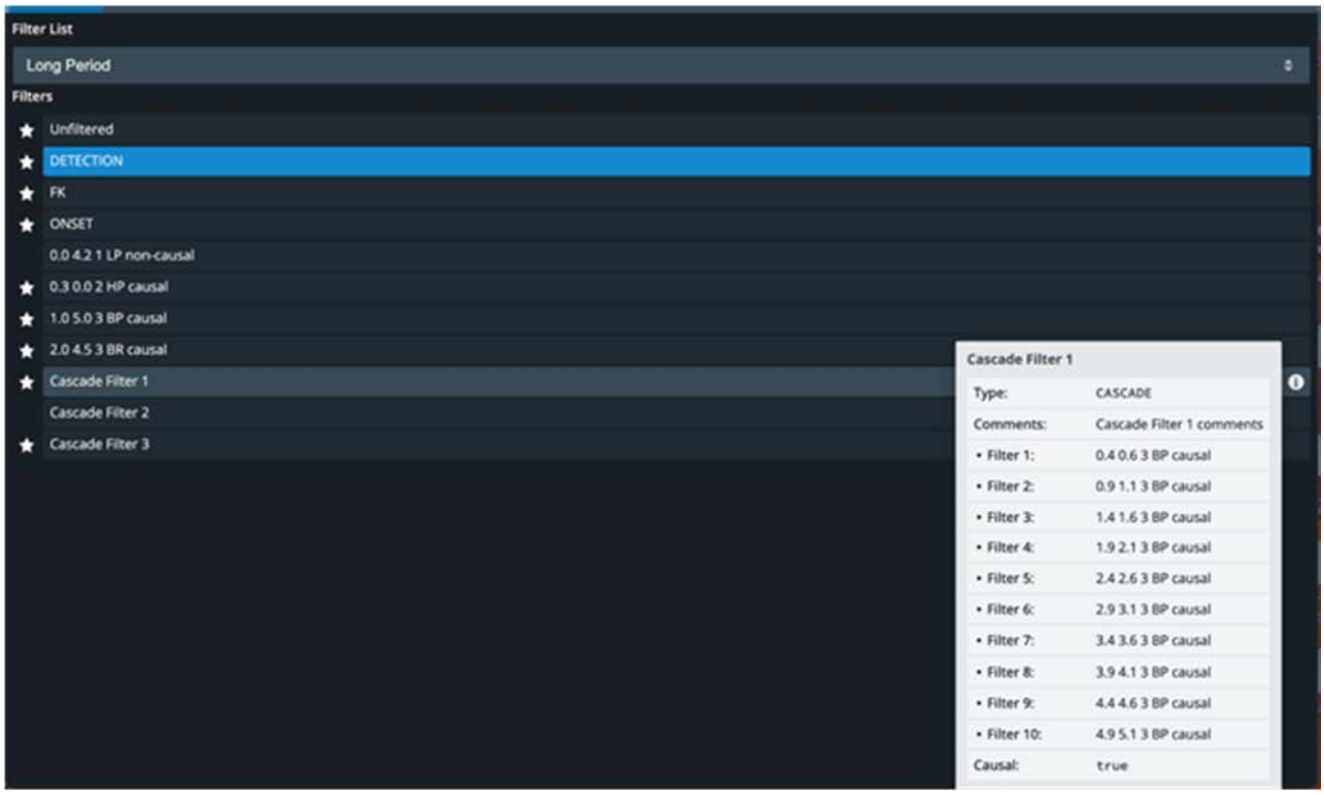


Figure 168. Tooltip for Cascade Filter 1.

The tooltips for the three different types of filters (named filters, Butterworth filters, cascade filters) differ in the information they provide. The named filters (DETECTION, FK, ONSET) merely

print the filter name to screen. Close-up examples of Butterworth filter and cascade filter tooltips are provided in Figure 169.

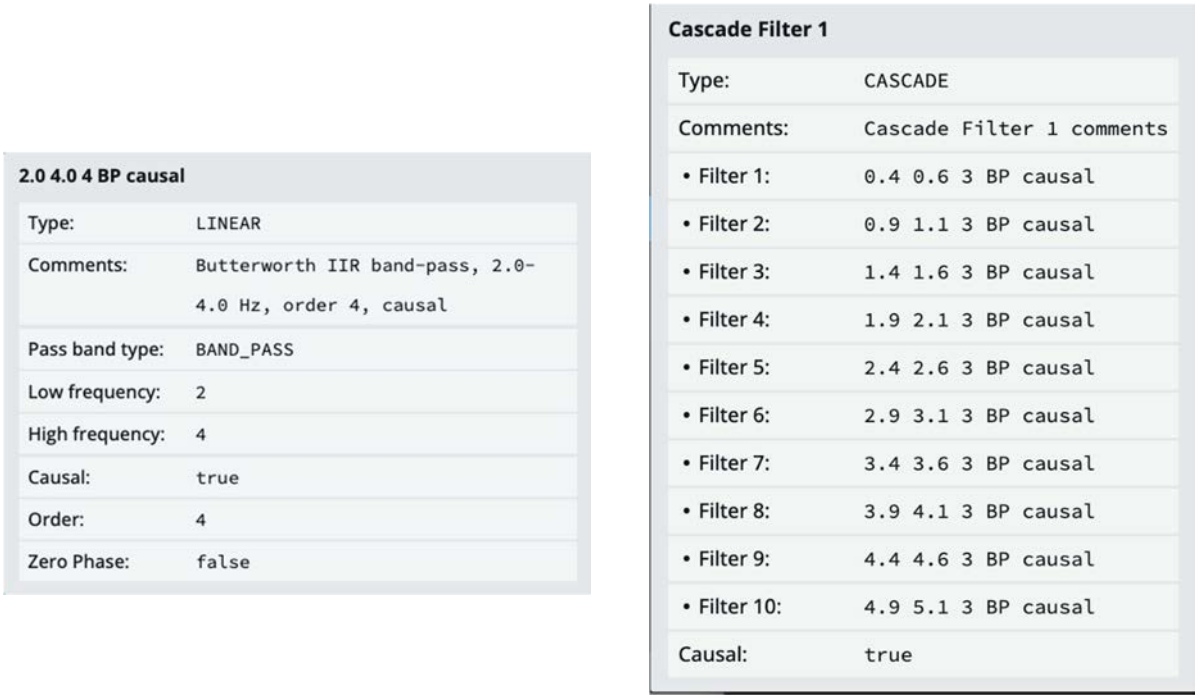


Figure 169. Example Tooltips for (Left) a Butterworth Filter and (Right) a Cascade Filter.

In a Butterworth filter tooltip (Figure 169, left), the name of the filter being viewed is displayed at the top. The following information is provided below:

- Type – the type of filter being viewed. Currently, the type is IIR_BUTTERWORTH for all Butterworth filters provided with IAN.
- Comments – a string description of the Butterworth filter.
- Pass band type – a string description of the pass band type. Pass band type can be LOW_PASS, HIGH_PASS, BAND_PASS, or BAND_REJECT.
- Low frequency – a filter's low frequency limit. A low frequency limit is only shown for filters with low frequency cutoffs. Thus, a tooltip for a low pass filter would not have a low frequency row.
- High frequency – a filter's high frequency limit. A high frequency limit is only shown for filters with high frequency cutoffs. Thus, a tooltip for a high pass filter would not have a high frequency row.
- Causal – indicates whether the filter is causal (true) or non-causal (false).

- Order – indicates the order of the filter.
- Zero Phase – indicates whether the filter is a zero-phase filter (true) or not (false). Zero-phase filters do not cause phase shifts when filtering. A zero-phase filter must be non-causal. Thus, if Causal is set to true, Zero Phase must be set to false.

In a cascade filter tooltip (Figure 169, right), the name of the filter is again shown at the top of the tooltip and the type, comments, and causal fields are the same as in the Butterworth tooltip. The remaining fields differ, with each row showing the filters that make up the cascade filter. The order the filters were applied in goes from top to bottom, with Filter 1 being applied first and Filter 10 (in the example in Figure 169, right) being applied last. Details on these individual filters cannot be displayed within the tooltip.

A maximum of 10 filters can be configured in a single cascade filter.

5.8.1. Filter Selection and Filter Cycling Via Hotkey

In the previous section, filters were automatically applied to the waveforms in the Waveform display (e.g., Figure 167) based on the default filter configured for the selected filter list (Figure 165). To manually apply a filter to waveforms in the Waveform display, the user must select a filter from the filter list.

To aid selection, the user can use the up/down arrows or tab to scroll through the filter list, highlighting each filter in blue (Figure 170).

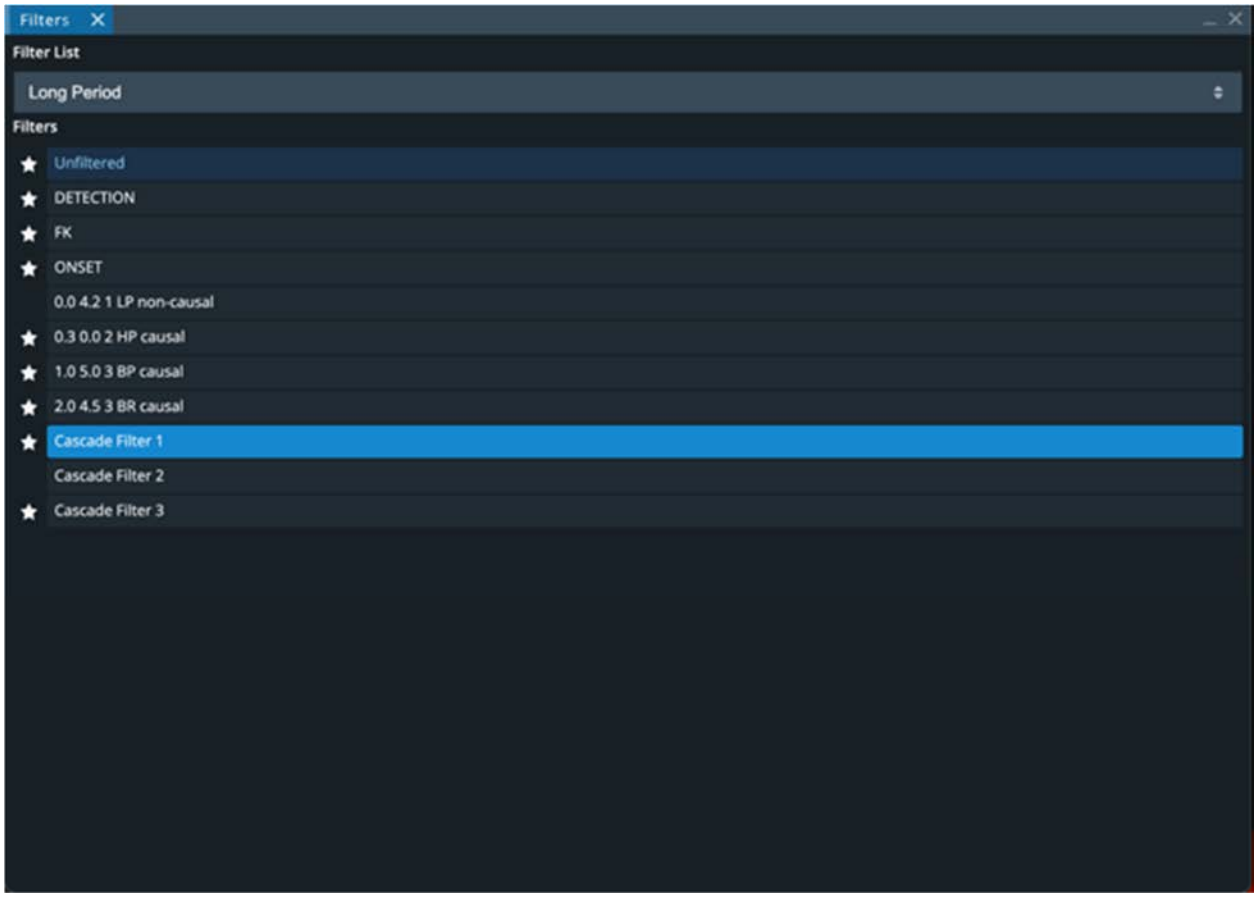


Figure 170. Filters Display with Unfiltered Highlighted but not Selected.

As can be seen in Figure 170, where Unfiltered is highlighted for viewing and Cascade Filter 1 is being applied to waveforms, the viewing highlight appears dimmer and it causes the filter label to appear blue. Once the desired filter is found, the user can click its label or press Enter. This action will cause all waveforms in the Waveform display, except for raw waveforms recorded by individual sites/channels, to be filtered.

If the user wants to only filter waveforms from specific stations, they can select stations in the Waveform display (see Section 5.3.2 for details on selection) then select a filter in the Filters display. This action will cause only the selected waveforms to be filtered. This action can also be used to apply filtering to waveforms recorded by sites/channels by expanding a station's waveform panel and selecting the sites/channels to be filtered. Raw channels will only be filtered if specifically selected.

Finally, filters can be cycled through, selected, and applied via hotkeys. Note that filters must be selected for inclusion in hotkey cycling. Filters that are included in the hotkey cycle are

indicated with a star to the left of the filter (e.g., Figure 163). By default, all filters are included in the hotkey cycle for the Seismic filter list, while the 0.0 4.2 1 LP non-causal and Cascade Filter 2 are excluded for the Long Period filter list, and FK, 0.3 0.0 2 HP causal, Cascade Filter 1, and Cascade Filter 3 are excluded for the Hydro filter list. The filters included in the hotkey cycle are configurable for each filter list (see Configuration documentation). Filters can be added/removed from the hotkey cycle by clicking the area to the left of the desired label to toggle on/off the star icon. Hovering over this area when there is no star will cause a star outline to appear that can be clicked to toggle the star icon back on (e.g., Figure 171).

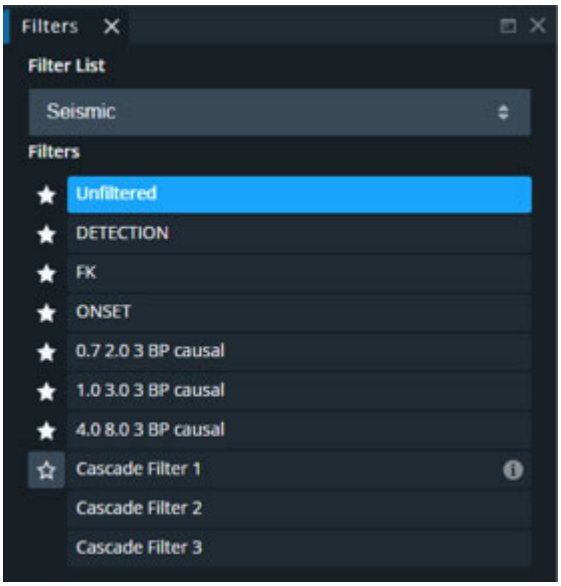


Figure 171. Filters Display with Deselected Filters.

Once the desired filters are added/removed from the hotkey cycle, the following hotkeys can be used to perform the filter cycling:

- F for next.
- Shift + F for previous.
- Alt + F (Option + F on Mac) for Unfiltered.

Pressing F will cause the filter selection to go down the list to the next available filter in the hotkey cycle. Pressing Shift + F will cause the filter selection to go up the list to the next available filter in the hotkey cycle. Finally, Alt + F will cause the filter selection to be Unfiltered, regardless of whether Unfiltered is included or excluded from the hotkey cycle.

The hotkey cycle can be applied to the Waveform display, even when the Filters Display is not open. This capability allows users to quickly cycle through filters, making it faster and simpler to find the ideal filter for the waveforms being viewed. Changes to which filters are part of the hotkey cycle persist for each filter list when toggling between lists, opening/closing intervals, or opening/closing the Filters display. Upon logout, filter hotkey cycles revert to their configured default state.

5.9. Undo/Redo Display

INFO: this section needs to be updated to change the unassociated color (red -> yellow), incorporate beamforming actions, and incorporate rotation actions.

The Undo/Redo display tracks the history of SD and event modifications and allows users to undo/redo these actions as needed. This display is not part of the default workspace layout and thus it needs to be added by the user (see Sections 4, 0). By allowing the user to undo/redo actions pertaining to events and SDs, the user can change event and/or SD data to explore different event solutions until an optimal event solution is found.

Upon opening an interval, the Undo/Redo display will always be empty as shown in Figure 172. Note that closing an interval clears the actions related to that interval. Thus, the Undo/Redo display will be empty upon reopening that interval.

Figure 172. Undo/Redo Display with no Actions Taken.

Once actions modifying an SD and/or event are taken, the Undo/Redo display will be populated with a history of actions that can be undone and redone (Figure 173).

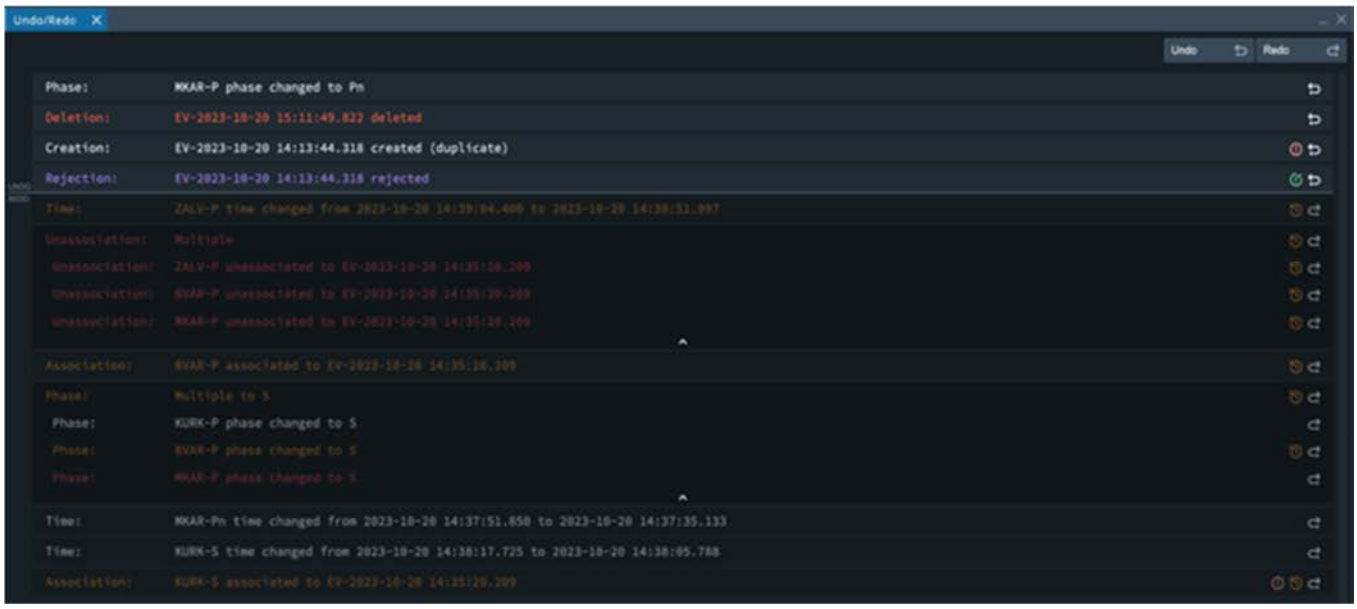


Figure 173. Undo/Redo Display with Actions Taken.

The Undo/Redo display is split into two stacks by a horizontal white bar. The top stack, labeled UNDO, records actions that were taken by the user that can be undone (i.e., UNDO actions). The bottom stack, labeled REDO, records actions that were taken by the user and then later undone by the user (i.e., REDO actions); this stack is not populated until one or more actions are undone. REDO actions are dimmed in comparison to UNDO actions.

Note that if the user performs a new, undoable action for an event/SD (e.g., modifies SD time), all actions in the Redo stack are cleared and can no longer be redone. For instance, in Figure 173 there are several actions in the REDO stack. If the user performed a new action in IAN, e.g., they changed the phase of an SD, these REDO actions would disappear from the Undo/Redo display.

Actions in these stacks are ordered by modification time such that the oldest action taken by the user is at the top of the stack and the newest action taken by the user is at the bottom of the stack. A configurable maximum of 500 total actions can be included in the undo/redo stack (see Configuration documentation); once the user exceeds this value, actions will be removed from the list until the number of actions equals 500.

Each action is represented by a row containing a description of that action, e.g., *'Phase: MKAR-P phase changed to Pn'* at the top of Figure 173. A row consists of three parts. These are:

- Label (leftmost part of the row) – an indicator of the type of action taken. For example, in the top row of Figure 173, the label is *Phase*. There are 8 available labels, listed below.
    - Deletion – The deletion of an SD (Section 5.3.5.2.5) or event (Section 5.4.4)
    - Rejection – The rejection of an association to an event (Section 5.4.4)
    - Association – The association of an SD to an open event (Section 5.3.8.4)
    - Unassociation – The unassociation of an SD from an open event (Section 5.3.8.4)
    - Creation – The creation of an SD (Section 5.3.5.4); the creation or duplication of an event (Sections 5.5.3, 5.3.5.5)
    - Phase – Modifying the phase type of an SD (Section 5.3.5.2.2)
    - Time – Modifying the arrival time or uncertainty of an SD (Sections 5.3.5.3, 5.5.6)
    - Event Beam – The creation of event beams
    - Rotation – The creation of rotated waveforms
- Description (middle of the row) – a string providing a detailed description of the action taken (as indicated by the label; see above bullet). For example, in the top row of Figure 173 the comment is *MKAR-P phase changed to Pn*, indicating that an SD recorded by station MKAR with phase P was changed to a Pn phase by the user.

  The description will vary depending on whether the action was applied to an SD or an event. If the action is applied to an SD, the SD name will be listed as STA-Phase (e.g., MKAR-P in the top row of Figure 150); this naming scheme is identical to that in the Map display (Section 5.6.3). If the action is applied to an event, the event name will be listed as EV-ORIGIN_TIME (e.g., EV-2023-10-20 15:11:49.822 in the second row of Figure 150). The remainder of the description details the action taken.
- Icons (rightmost part of the row) – icons indicating 1) whether the action can be undone/redone, 2) whether the action created or resolved a conflict, and 3) whether an action can be undone/redone in event mode; event mode will be described in Section 5.9.2. For example, in the top row of Figure 173, the only icon visible is the ‘Undo this action’ icon, indicating that the action can be undone. There are 5 available icons in total, listed below. The descriptions below can be printed to screen in the UI by hovering over the desired icon to bring up its tooltip.
    -  – Undo this action

-  – Redo this action
-  – This action created a conflict
-  – This action resolved a conflict
-  – Action may be undone/redone in event mode

All actions are colored based on SD/event association status unless the SD/event is deleted/rejected, in which case they're colored based on deletion/rejection status; see Sections 5.3.5, 5.6.4 for SD and event association status definitions and colors, respectively.

Note that if a single action is applied to multiple SDs or multiple events, the action row will have the special description, '*Multiple*', indicating that the action was applied to multiple SDs or events. For example, in Figure 174 (top), the action row indicates that multiple SDs had their phase type changed to S.

Figure 174. Example of a Single Action Applied to Multiple SDs in the Undo/Redo Display with Action Row Unexpanded (Top) and (Bottom) Expanded.

To view which SDs or events the single action was applied to, the user can click on the downward arrow directly beneath the *Multiple* action row (e.g., Figure 174, top) to expand the

row and view detailed descriptions of each SD or event affected. For example, in Figure 174 (bottom) the expanded action row shows that three SDs recorded by stations KURK, BVAR, and MKAR, respectively, had their phase types changed from P to S. To collapse the row once more, click the now upward facing arrow (e.g., Figure 174, bottom). Note that when the action row is expanded, the arrow beneath the expanded window will now point up and will be highlighted in blue (e.g., Figure 174, bottom), indicating that the expanded action row can be collapsed.

The Undo/Redo display has two modes available to the user: the global mode (Section 5.9.1) and the event mode (Section 5.9.2). The global mode allows the user to undo/redo any action in the undo/redo stack. By default, the Undo/Redo display is in global mode. In event mode, undo/redo actions can only be applied to actions that affect the currently open event (see Sections 5.4, 5.6.4 on how to open an event).

In the following sections, these two modes will be illustrated using specific examples.

5.9.1. Global Mode

In global mode, the user can undo/redo any actions in the UNDO/REDO stack. A simple example of one potential UNDO/REDO stack and its associated behaviors is shown below, with figures accompanying each step. This example is done with an event opened (see Sections 5.4, 5.6.4 for how to open an event). An example of each action row type, discussed in Section 5.9, will be provided here.

Initially, the UNDO/REDO stack is empty as in Figure 172.

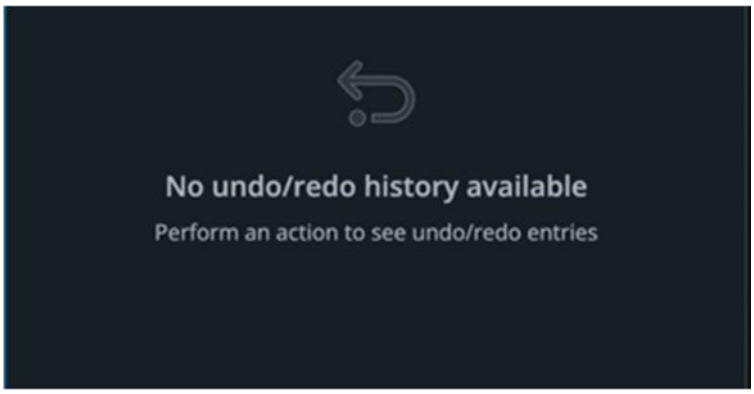


Figure 175. Undo/Redo Display with no Actions Taken.

The user then changes an SD recorded by station MJAR from a P phase to a Pn phase. This action is added to the UNDO stack. The action row label indicates the action was a change in Phase, with the description string describing the action in detail and the icon indicating this action can be undone (see Section 5.9 for a thorough description of action rows).

Figure 176. Undo/Redo Display with 1 action taken

Next, the user deletes an event (EV-2023-10-20 13:57:52.866). This action is added to the bottom of the UNDO stack (nearest the UNDO horizontal marker), indicating that it is the most recent action taken. The label indicates that the action is a deletion action and the undo icon indicates the action can be undone.

Figure 177. Undo/Redo Display with 2 actions taken

The user then duplicates event EV-2023-10-20 14:11:12.839. This action is added to the bottom of the UNDO stack as it is now the most recent action taken, with the prior actions shifting up in the stack. The label indicates this action is a creation action, with the comment specifically indicating the action is a duplication. Along with the undo icon, indicating the action can be undone, a conflict icon appears as the duplicated event is associated to the same SDs as the original event (see Sections 5.4.4, 5.6.4.2).

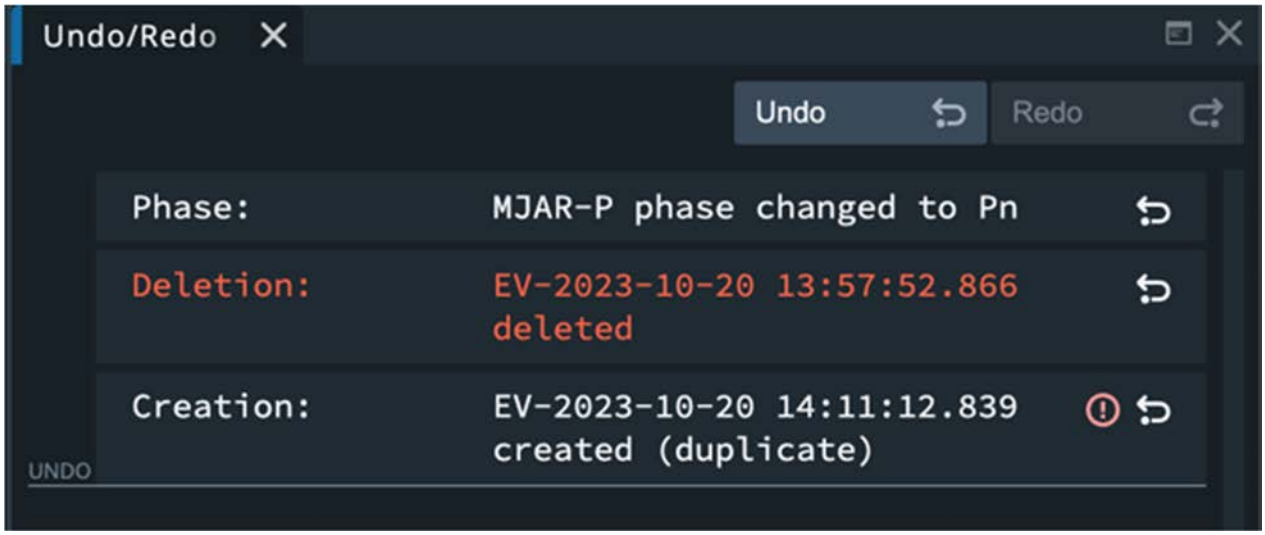


Figure 178. Undo/Redo Display with 3 actions taken

Next, the user rejects the duplicated event created via the previous action. This action is added to the bottom of the UNDO stack as it is now the most recent action taken, with the prior actions shifting up in the stack. The label indicates this is a rejection action. There are two icons associated with the rejection action. First, the undo icon indicates the action can be undone. Second, the resolved conflict icon indicates that a conflict was resolved by rejecting the event. In this case, the conflict is resolved because the rejected duplicate event no longer shares SDs with the original event.

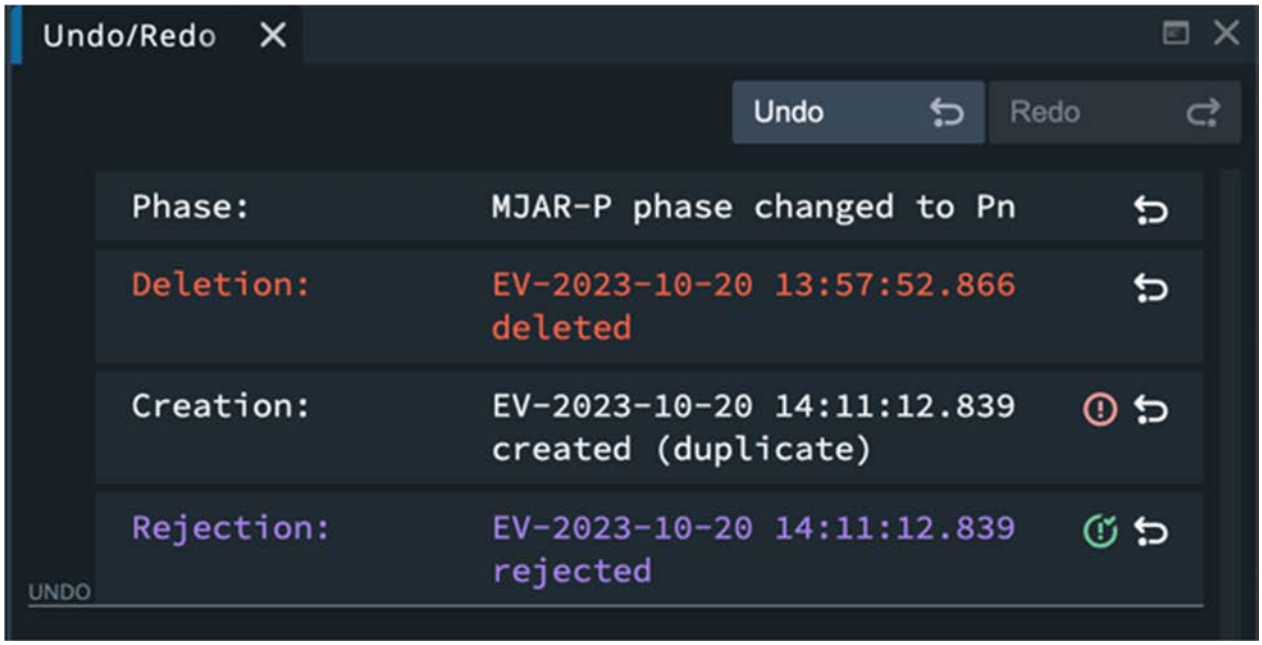


Figure 179. Undo/Redo Display with 4 actions taken

The user then moves the SD MKAR-P to a new time. This action is added to the bottom of the UNDO stack as it is now the most recent action taken, with the prior actions shifting up in the stack. The action row label indicates this is a Time action. Along with the undo icon, the icon indicating that the action may be undone in event mode appears, as this action directly affects the opened event. Event mode will be discussed in Section 5.9.2.

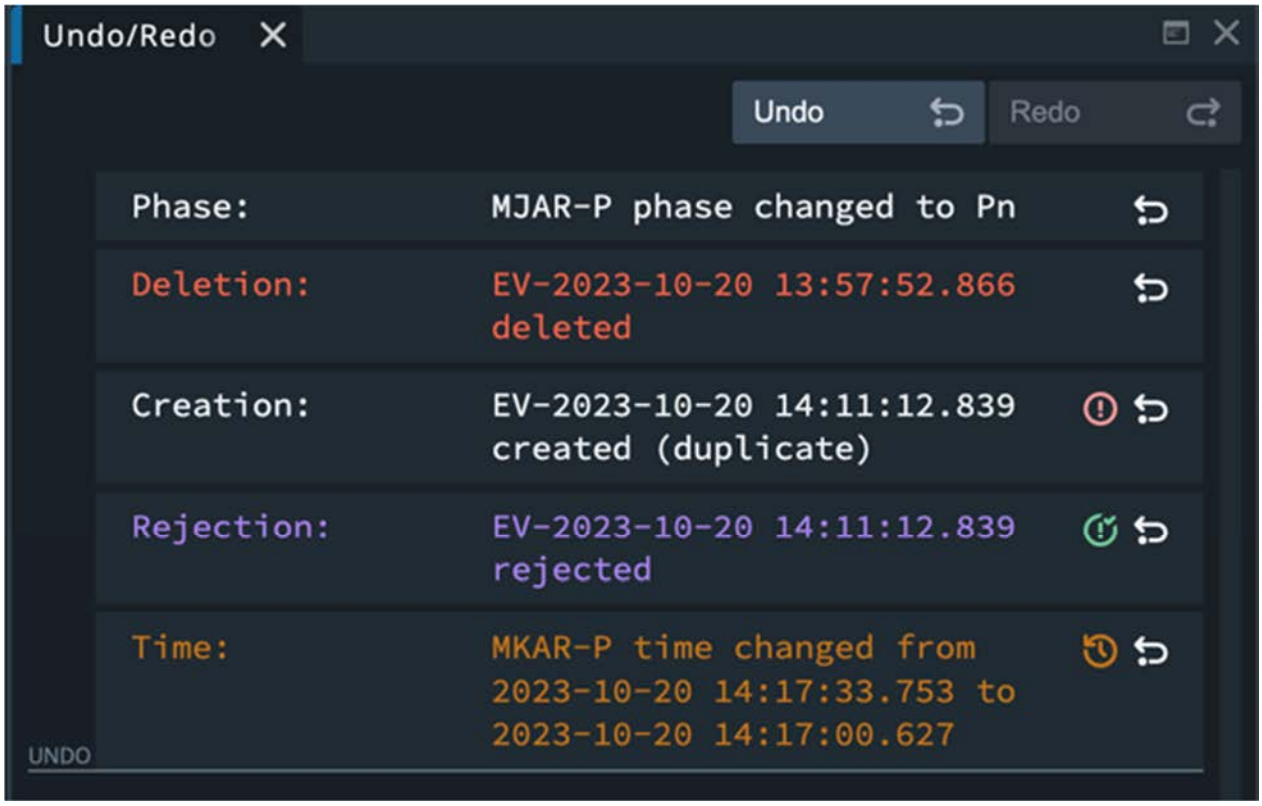


Figure 180. Undo/Redo Display with 5 actions taken

The user then unassociates multiple SDs from the open event. This action is added to the bottom of the UNDO stack as it is now the most recent action taken, with the prior actions shifting up in the stack. The action row label indicates this is an Unassociation action. The icon indicating that the action may be undone in event mode appears, as this action directly affects the opened event. Event mode will be discussed in Section 5.9.2.

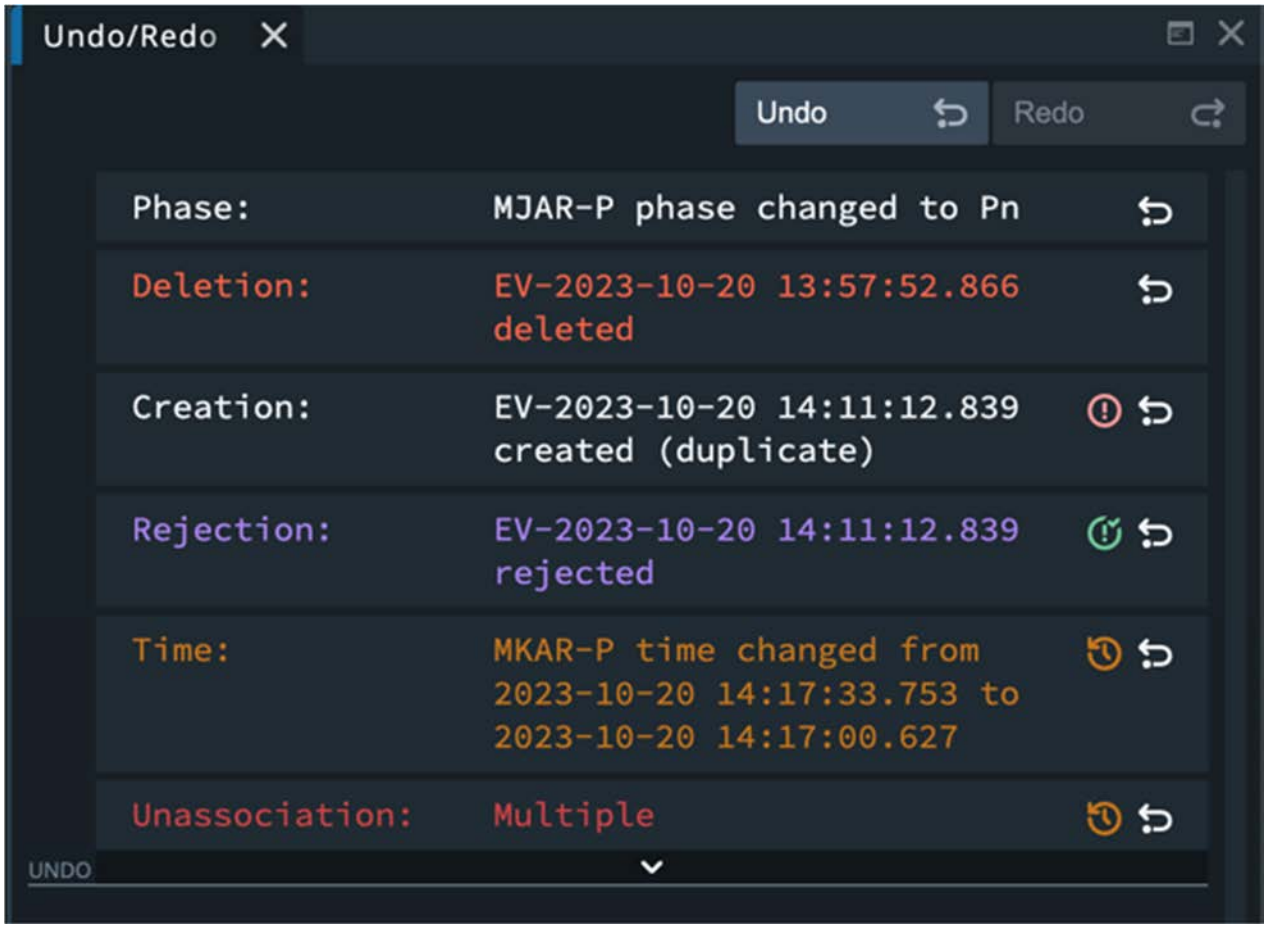


Figure 181. Undo/Redo Display with 6 action types taken, with multiple unassociation actions

Upon expanding the Unassociation action row, the user can see that 3 SDs were unassociated from open event EV-2023-10-20 14:08:21.685; these 3 SDs are MKAR-P, MAW-P, and MKAR-tx, respectively. The icons indicate that all 3 of these actions can be undone and they can specifically be undone in event mode (Section 5.9.2).

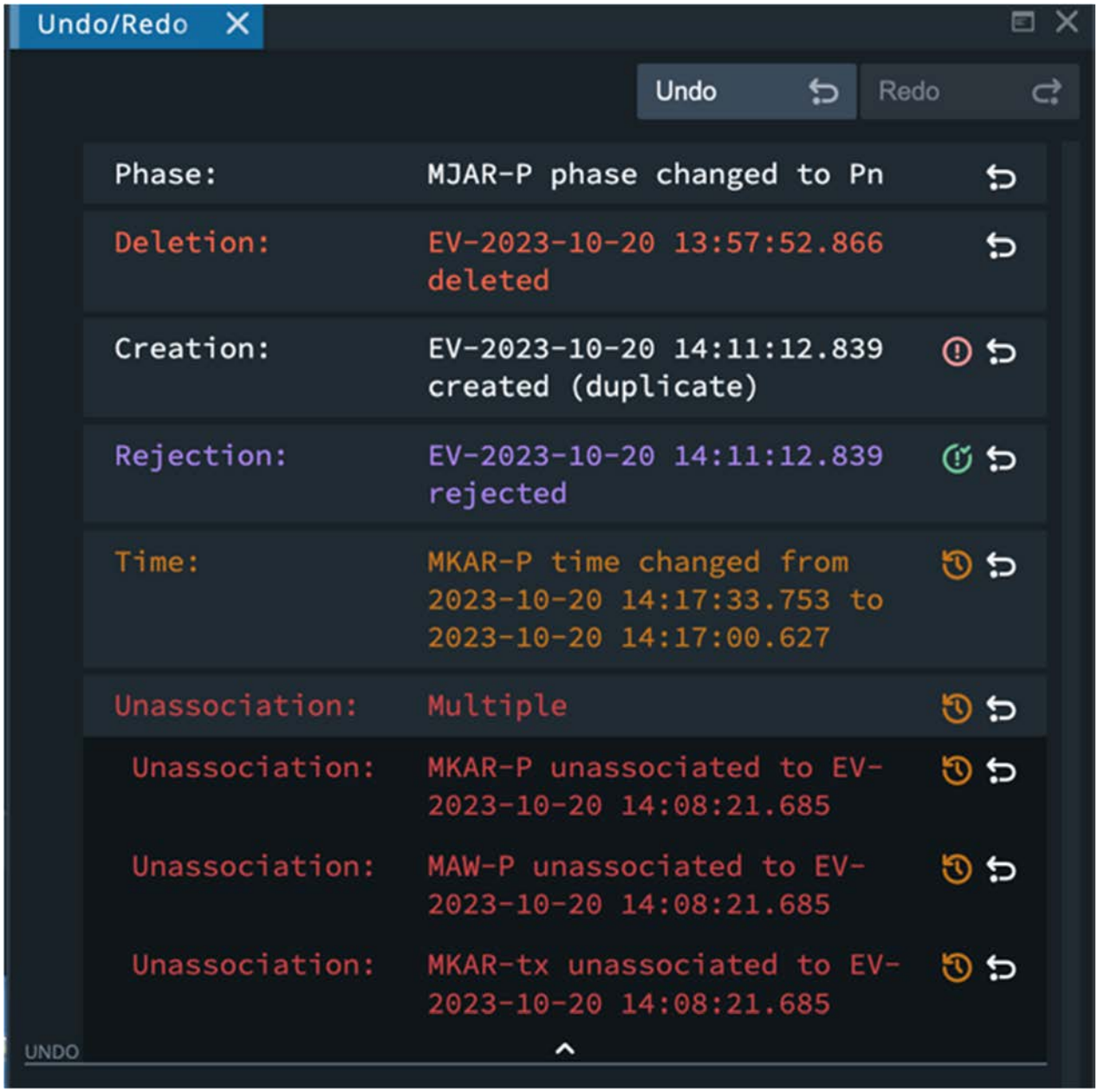


Figure 182. Undo/Redo Display with 6 action types taken, with multiple unassociation actions shown

Next, the user associates the SD ASAR-PKP to the open event EV-2023-10-20 14:08:21.685. This action is added to the bottom of the UNDO stack as it is now the most recent action taken, with the prior actions shifting up in the stack. The action row label indicates this is an Association action. The icon indicating that the action may be undone in event mode appears, as this action directly affects the opened event. Event mode will be discussed in Section 5.9.2.

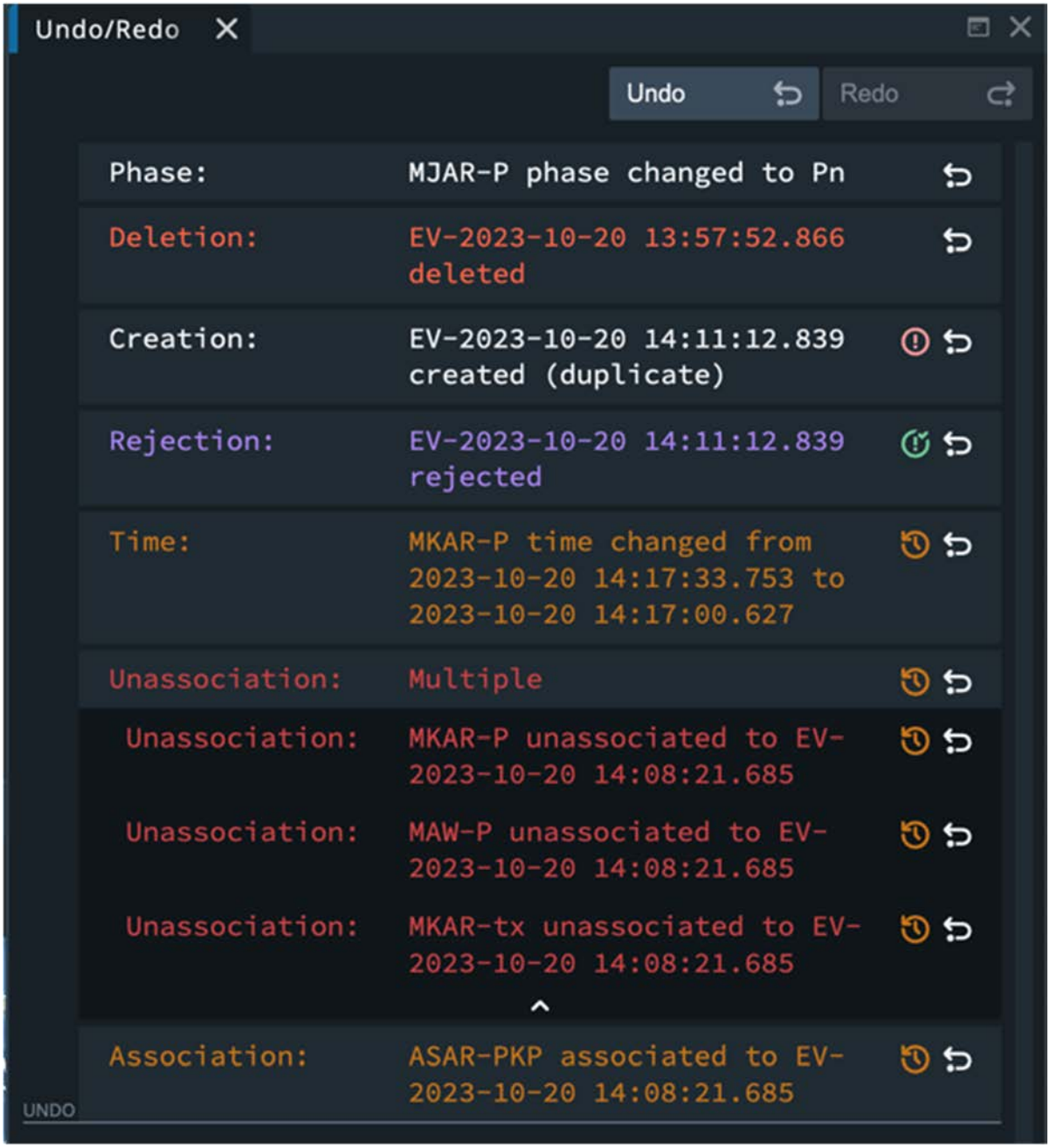


Figure 183. Undo/Redo Display with 7 action types taken

Then the user changes multiple SD phases to S. This action is added to the bottom of the UNDO stack as it is now the most recent action taken, with the prior actions shifting up in the stack. The action row label indicates this is a Phase action. The icon indicating that the action may be undone in event mode appears, as this action directly affects the opened event. Event mode will be discussed in Section 5.9.2. Further, note that the main action row appears orange,

indicating that at least one of the SDs that the action was applied to is associated to the open event.

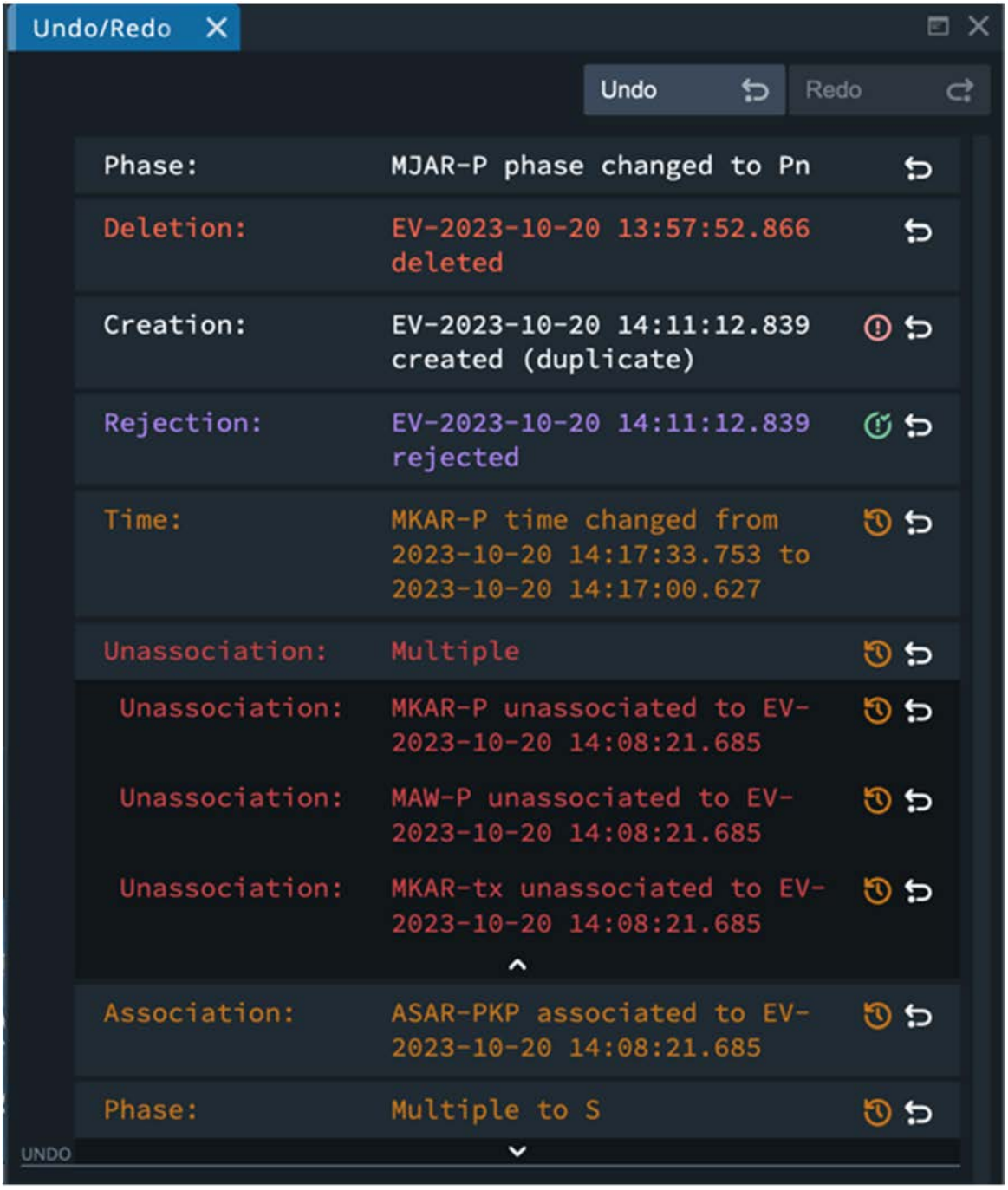


Figure 184. Undo/Redo Display with 8 action types taken, with multiple new phase actions

Upon expanding the Phase action row, the user can see that 3 SDs had their phases changed; these 3 SDs are WRA-PKP, ASAR-tx, and WRA-P, respectively. Note that only the second action, *ASAR-tx phase changed to S*, has an icon indicating that the action may be undone in event mode; this occurs because the other two phases are not associated to the currently opened event.

This case of applying a single action to multiple SDs, only some of which affect the open event, leads to important behaviors in event mode; its effects will be discussed in Section 5.9.

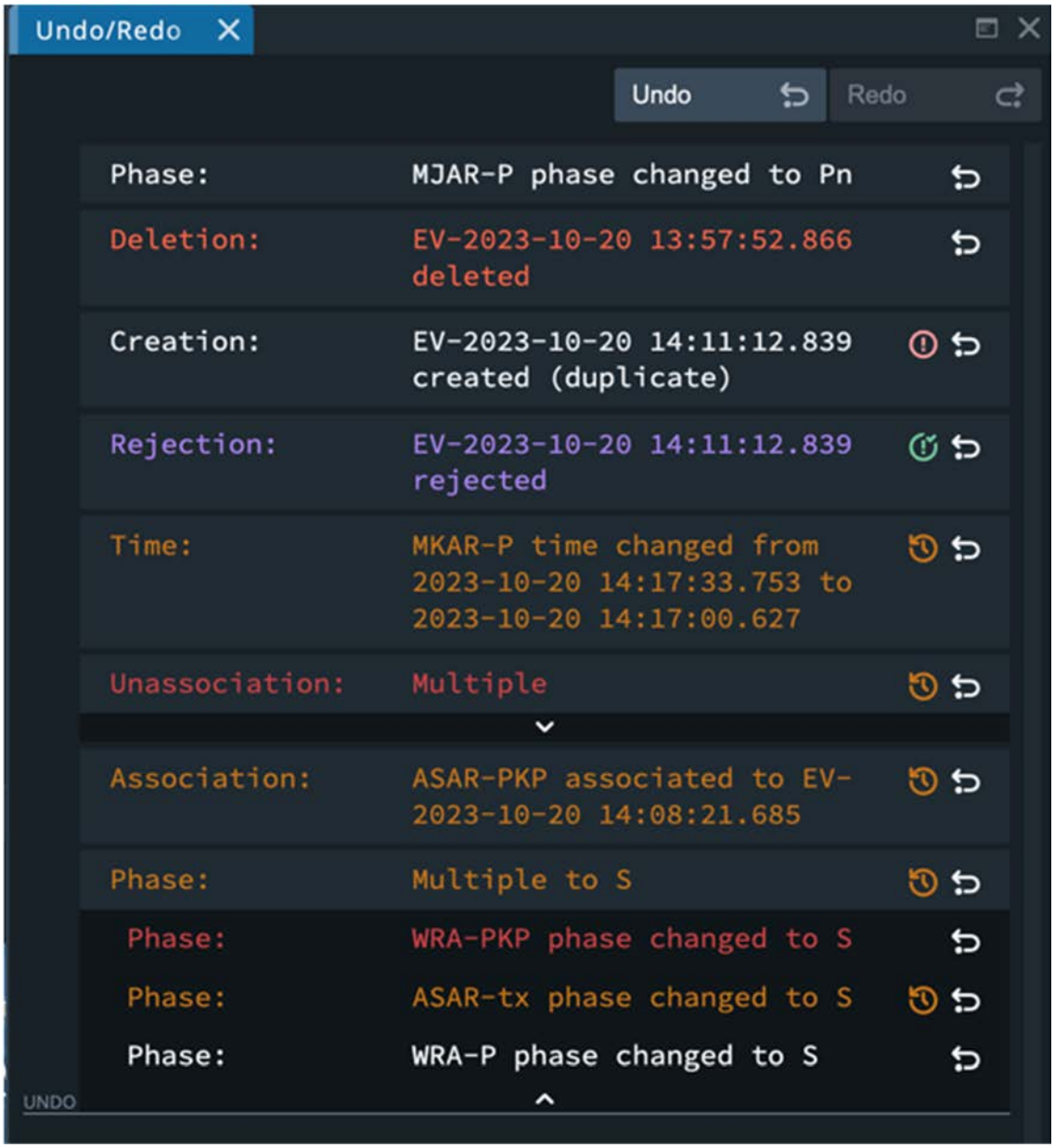


Figure 185. Undo/Redo Display with 8 action types taken, with multiple new phase actions shown

At this stage, at least one example of each action that can be undone in IAN has been provided, including application of a single action to multiple SDs. These actions have all added to the UNDO stack. The example will now continue by 1) demonstrating how to undo these actions and 2) describing the resulting REDO stack.

In the example, the user has taken multiple actions to reach an optimal event solution but is unsatisfied with the result. To explore alternative actions, the user decides to undo the Association action *ASAR-PKP associated to EV-2023-10-20 14:08:21.685*.

To visually aid the user in selecting the action to be undone (the Association action in this example), the user hovers their cursor over the action. Hovering highlights the action row to be undone in the same color as the action's SD association status, in this case orange, as the SD is associated to the open event. In global mode, to get back to the state when a specific action existed, all actions taken after the specific action must be undone in chronological order. In this example, a Phase action to convert multiple SDs to an S phase occurred after the Association action. Thus, to do undo the Association action, the Phase action must also be undone. This necessity is indicated by the orange outline around the Phase action row as well as the outlines around its expanded sub-actions, which are colored based on SD association status.

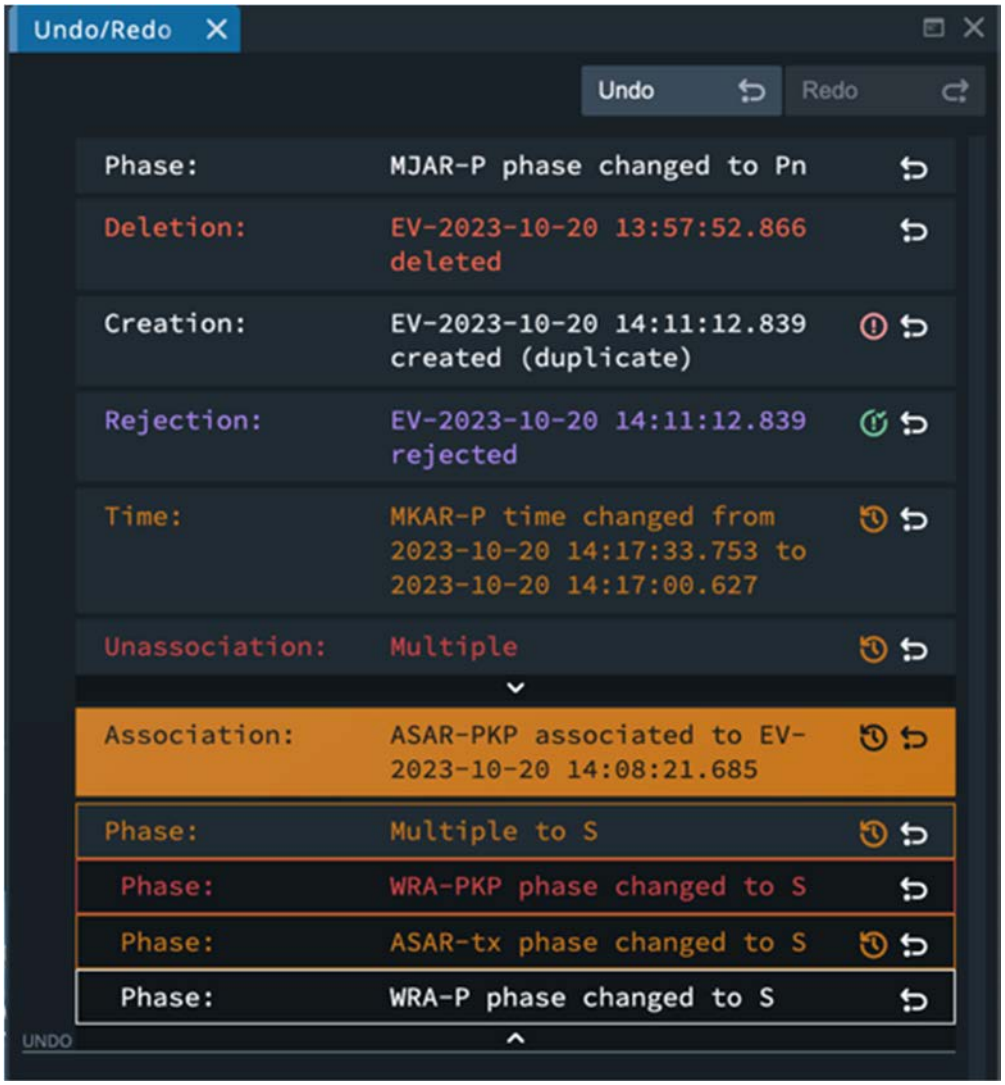


Figure 186. Undo/Redo Display with association and all phase actions being undone.

With the Association action highlighted, the user clicks the action to undo it. To undo the Association action, the system first undoes the Phase action and its sub-actions to get back to the state where the Association action existed. Then the system undoes the Association action.

Note that the user could alternatively have used the Undo button in the upper-right corner of the Undo/Redo display (Figure 173) or the hotkey combination Ctrl + Z (Command + Z on Mac) to undo the Association action in this example. Using either the button or the hotkey combination requires the user to undo one action at a time, starting with the most recent action taken, until all desired actions are undone. The hotkey combination has the advantage of allowing the user to undo actions anywhere in the IAN UI, even if the Undo/Redo display is closed.

Upon undoing the Association action (and consequently the Phase action), these actions are moved into the REDO stack.

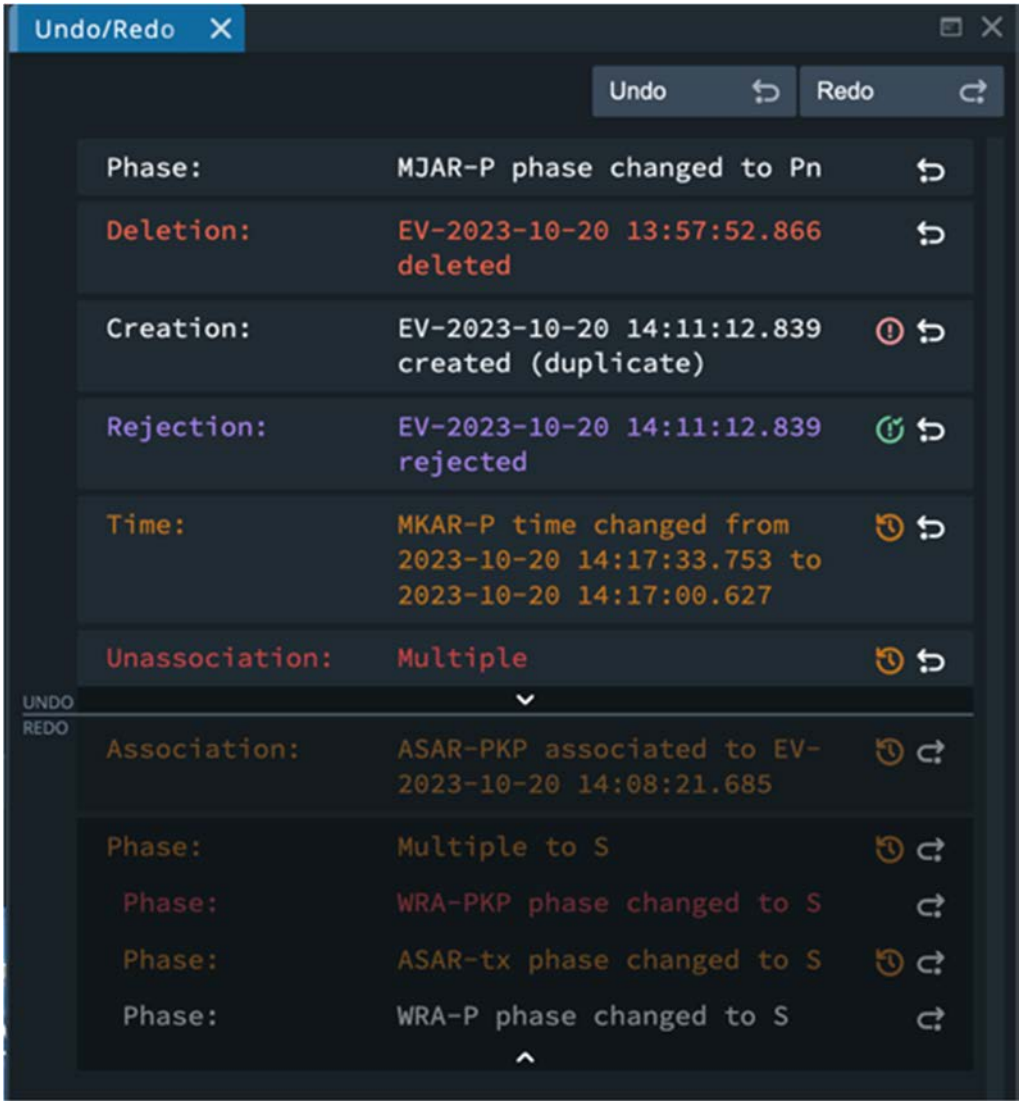


Figure 187. Undo/Redo Display with association and phase actions shown in redo stack.

Once in the REDO stack, the actions are dimmed, and the arrow icon changes from undo to redo. At the same time, the redo button in the upper-right corner of the Undo/Redo display (Figure 173) is now active and can be used. As in the UNDO stack, the actions in the REDO stack are ordered, such that the oldest action taken by the user is at the top and the newest action taken by the user is at the bottom.

As with the UNDO stack, the user can hover over an action to highlight it as a visual aid. In this example, the user decides that both undone actions should have been kept. They hover over

the Phase action, as that was the most recent action taken. Hovering highlights the action with the same color as the SD's association status, in this case orange since one of the SD's affected by this action is associated to the open event. In order to redo this action, all actions in the REDO stack that were redone prior to it must also be redone, as indicated by the orange outline around the Association action in this example. Again, the outline is colored based on SD association status.

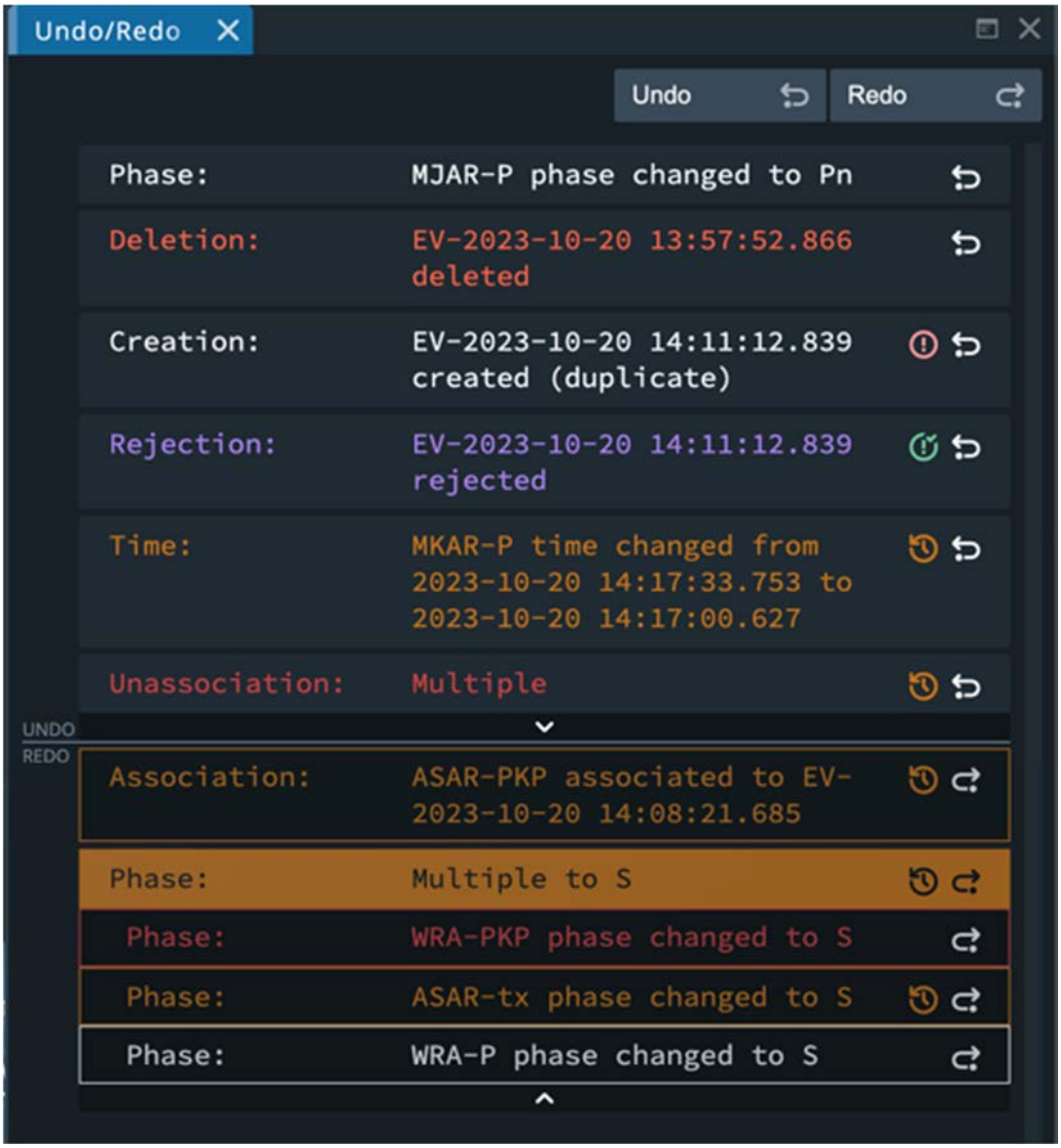


Figure 188. Undo/Redo Display with phase actions being redone.

With the Phase action highlighted, the user clicks the action to redo it.

Note that the user could alternatively have used the Redo button in the upper-right corner of the Undo/Redo display (Figure 173) or the hotkey combination Shift + Ctrl + Z (Shift + Command + Z on Mac) to redo the Phase action in this example. Using either the button or the hotkey combination requires the user to undo one action at a time, starting with the oldest action taken, until all desired actions are redone. The hotkey combination has the advantage of allowing the user to redo actions anywhere in the IAN UI, even if the Undo/Redo display is closed.

Upon redoing the Association action (and consequently the Phase action), these actions are moved back into the UNDO stack.

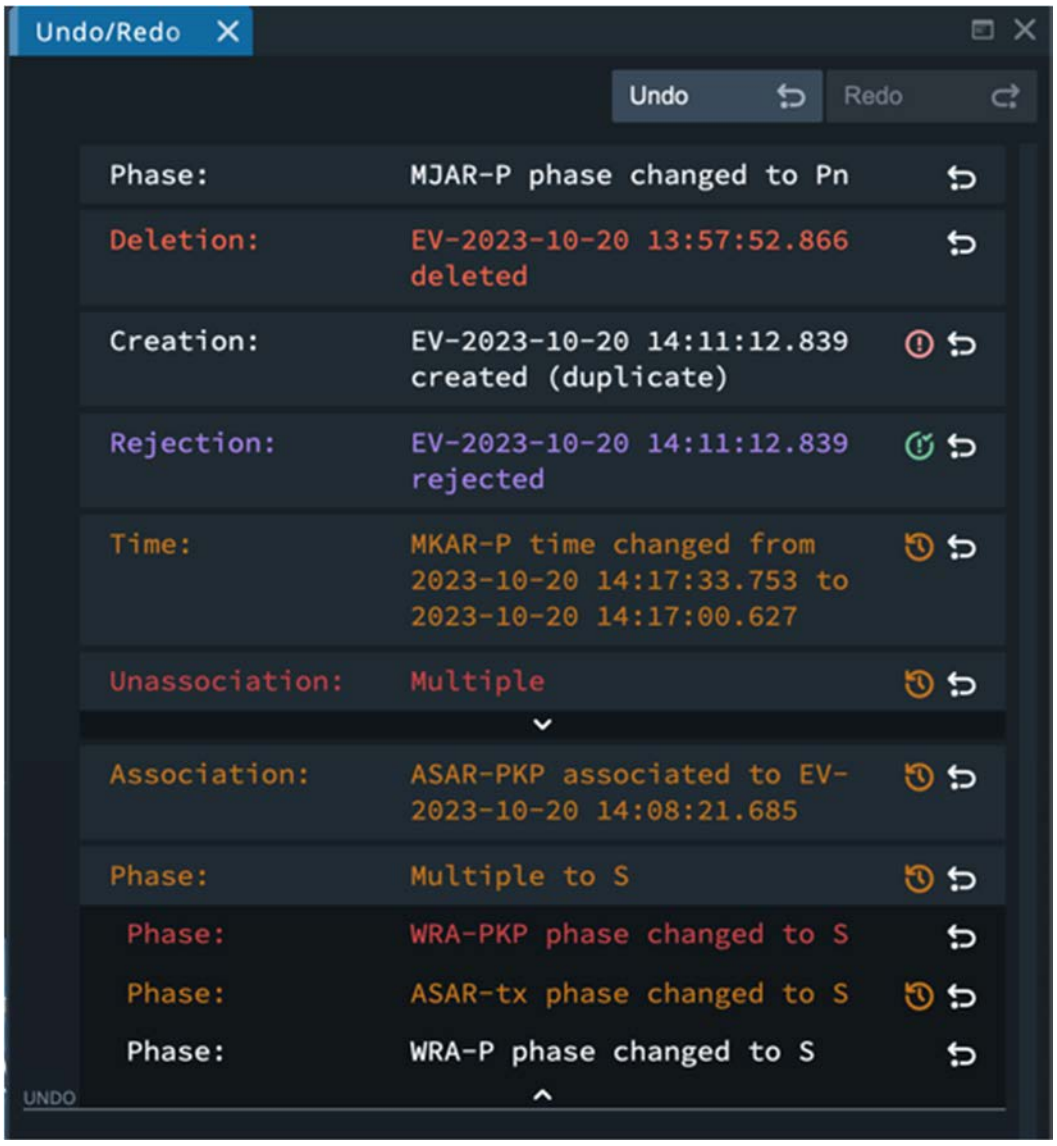


Figure 189. Undo/Redo Display with association and phase actions not redone.

Finally, if the user had not redone the Phase and Association actions in this example prior to performing another undoable SD or event action, those actions in the REDO stack would be cleared and would no longer exist in the IAN UI provenance. Below, the user retimed the SD ASAR-PKP, resulting in the Association and Phase actions that were in the REDO stack being cleared and lost.

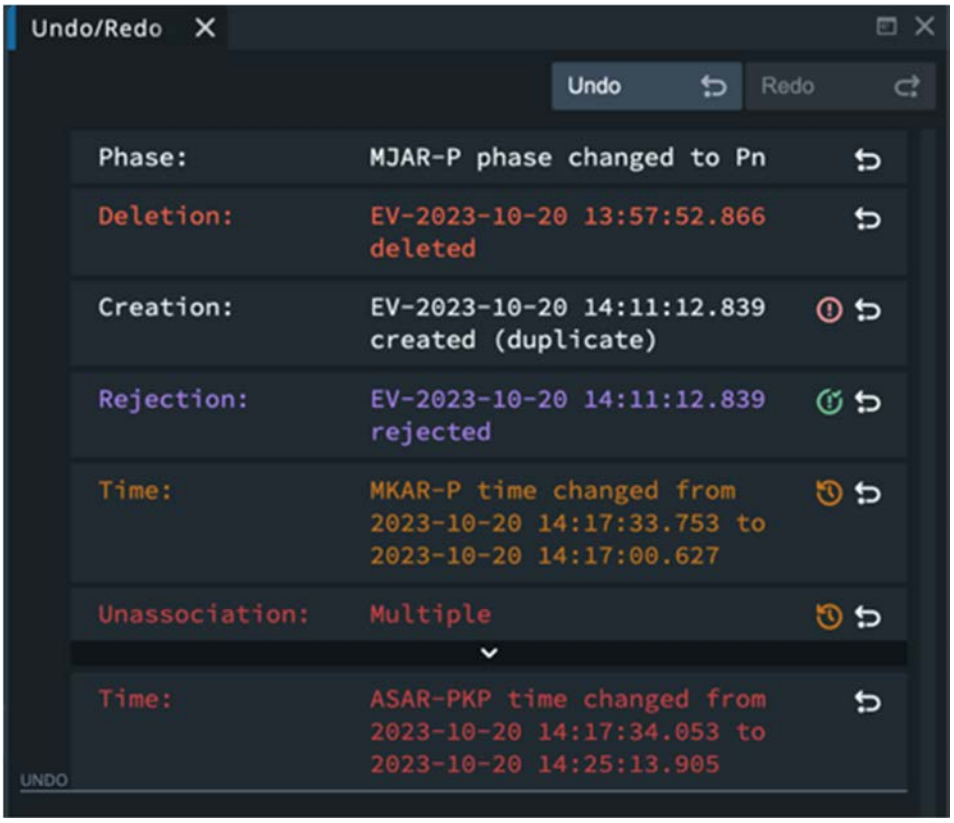


Figure 190. Undo/Redo Display with association and phase actions cleared.

This example provides a full demonstration of global mode in the Undo/Redo display but is by no means exhaustive. Several other scenarios may occur upon use.

In the next section, the event mode of the Undo/Redo display will be discussed.

5.9.2. Event Mode

GMS includes a new event mode capability. In event mode, only actions that affect the currently open event can be undone/redone. This mode allows the user to review the actions applied to a single event and to compare different versions of that event via this history,

allowing the user to find the best solution for an event. Further, it allows the user to work on multiple events in parallel, as the user can open different events, view the actions applied to each, and modify each of them separately.

Actions that can be undone/redone in event mode are indicated by the orange circle icon  . Hovering over this icon will print the following tooltip to screen:

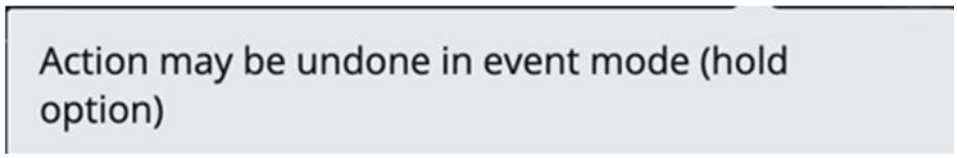


Figure 191. Message shown when hovering over action that can be undone/redone.

In addition to clarifying that the action can be undone/redone in event mode, the tooltip also indicates the hotkey to enter event mode; here, Alt (Option on Mac).

Using the example UNDO stack from the previous section, the stack in Event Mode will appear as below.

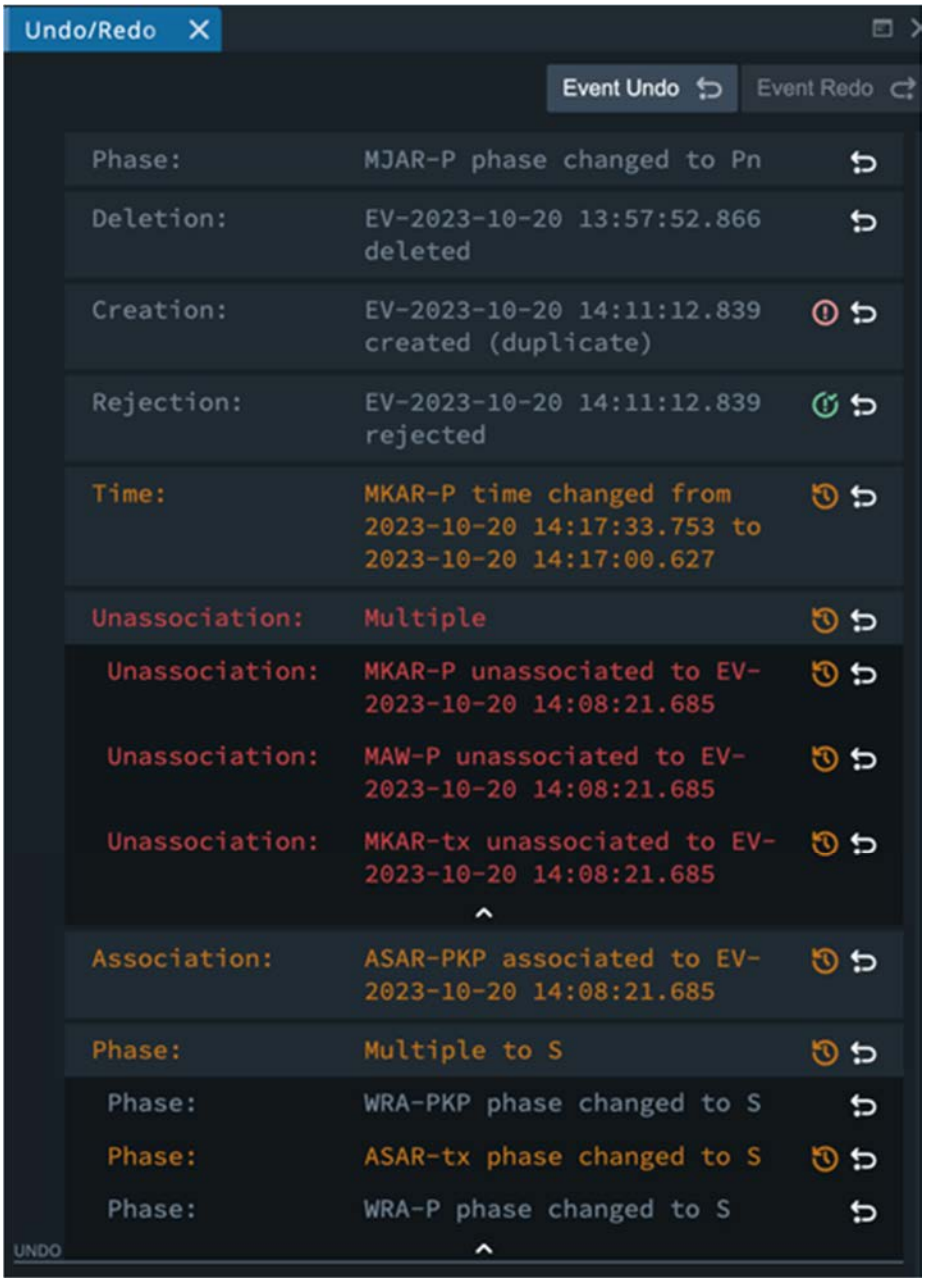


Figure 192. Example of actions that cannot be redone in event mode.

Actions that do not affect the open event are now shown in gray, indicating that they cannot be undone in event mode.

Notably in this example, because there is a mix of actions in the UNDO stack that can and cannot be undone in event mode, actions can be taken out of the chronological order originally found in global mode.

For instance, in event mode, the user decides to undo the Association action applied to SD ASAR-PKP. As in global mode, the user can hover over the action to highlight it as a visual aid. Unlike in global mode, the highlight will be striped, visually indicating that the action is being undone in event mode. Further, because only one of the phases in the Phase action is associated to the open event (*ASAR-tx phase changed to S*), only that sub-action is shown with an outline and striping. This outlining/striping indicates that only that part of the Phase action will be undone in event mode.

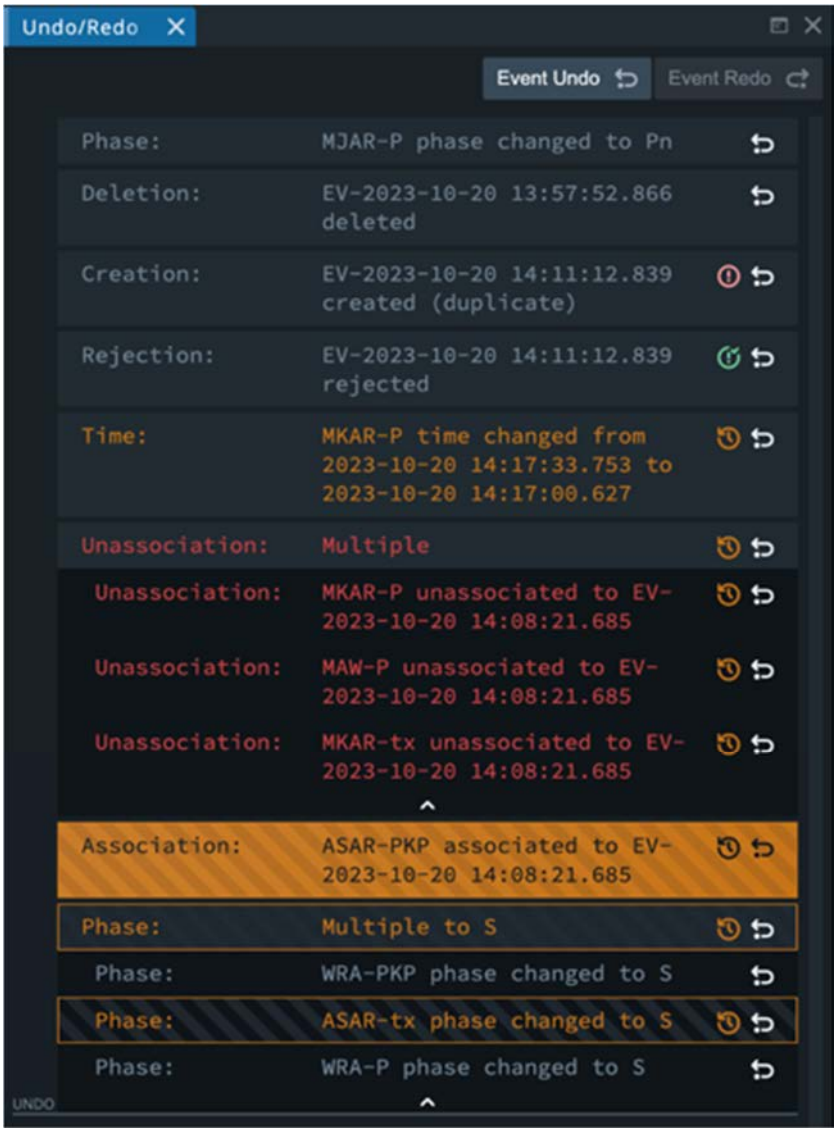


Figure 193. Example of actions that can only partially be undone in event mode.

The user clicks on the Association action to undo it, while holding Alt (Option on Mac) to keep the Undo/Redo display in event mode. The alternative actions to apply undo/redo, either using

the buttons in the upper-right corner of the display (note that these now say Event Undo, Event Redo) or the hotkeys, remain the same as in the previous section.

As before, once the actions are undone, they move to the REDO stack, with the oldest action at the top and the newest action at the bottom. Note that because two of the sub-actions under the Phase action (*WRA-PKP phase changed to S, WRA-P phase changed to S*) could not be undone, those two sub-actions remain gray in event mode and still show an undo icon despite being in the REDO stack.

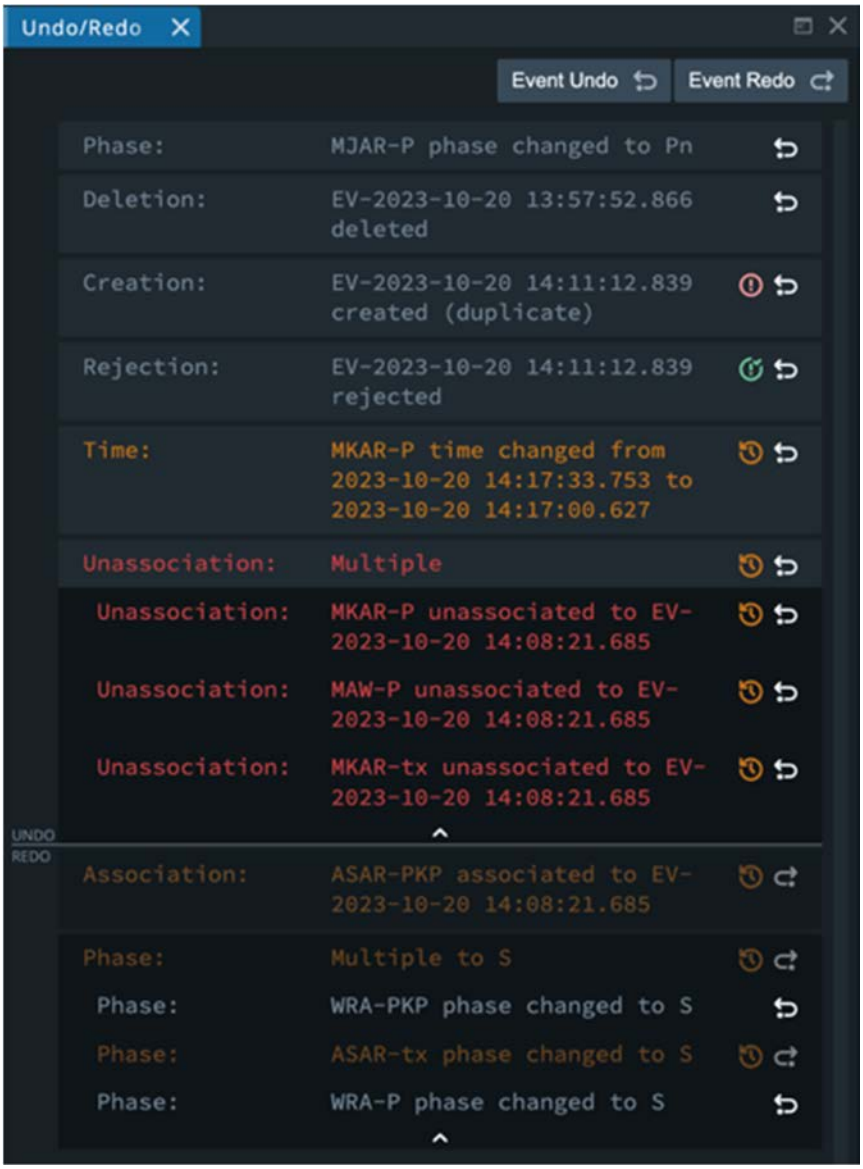


Figure 194. Example of actions that could not be modified in event mode but still have undone icons next to them.

At this stage, if the user exits event mode by releasing the Alt (Command on Mac) button, the Undo/Redo display will return to global mode and the UNDO/REDO stacks will appear as shown in the figure below.

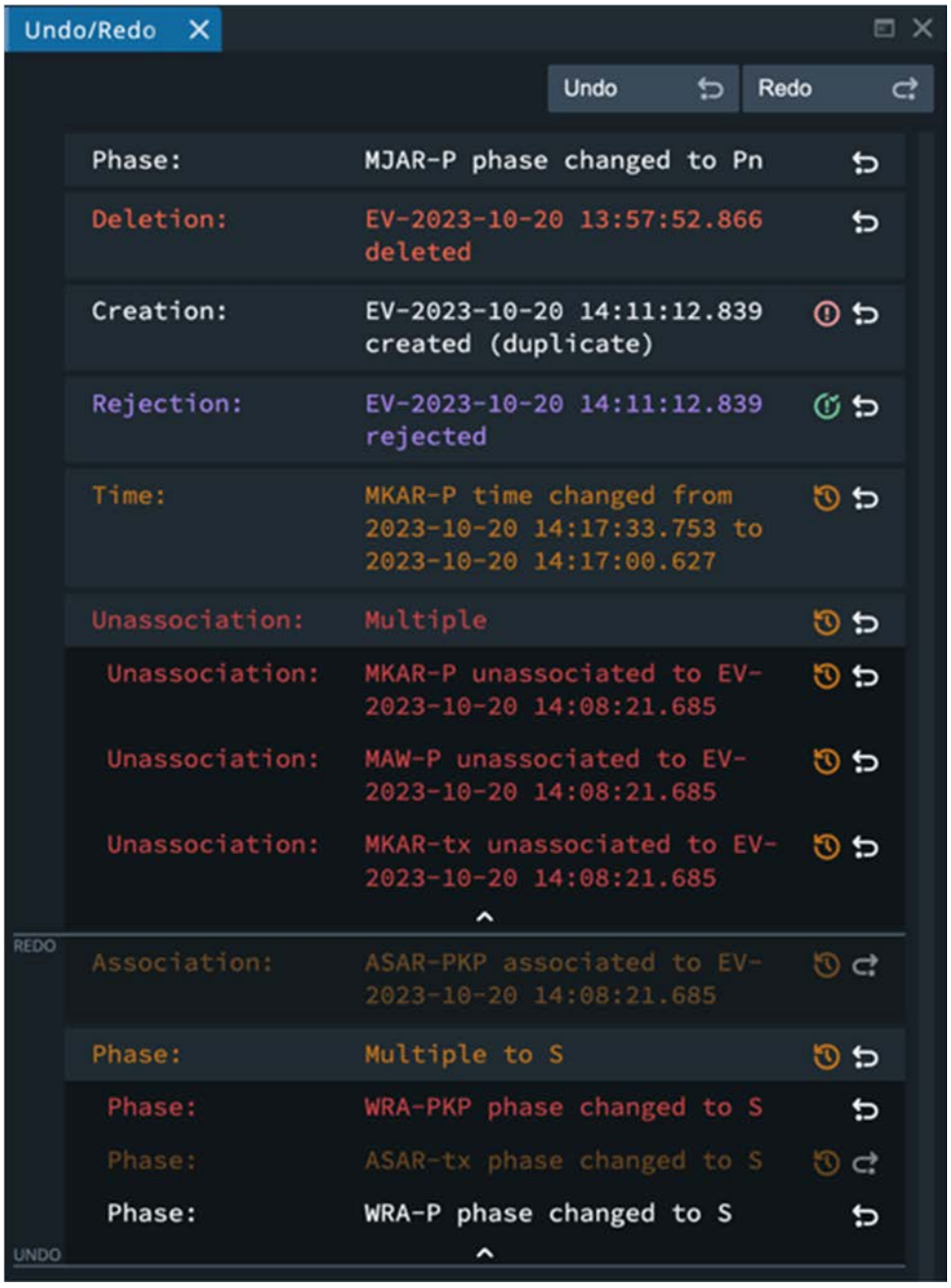


Figure 195. Example of undo/redo display returning to global mode.

Unlike in Section 5.9.1, the UNDO/REDO stacks now appear “mixed”, i.e., undo actions and redo actions appear to be in the same stack. For instance, in the figure above, the Association action, which can be redone, appears in the same stack as the Phase action, which can be undone. Further, the sub-actions under the Phase action are mixed, with the sub-actions *WRA-PKP phase changed to S* and *WRA-P phase changed to S* able to be undone and the sub-action *ASAR-tx phase changed to S* able to be redone. This mixing is further indicated by the position of the UNDO and REDO labels; unlike in Section 5.9.1, the UNDO label now appears beneath the REDO label.

This mixing of undo/redo actions occurs because the sub-action *ASAR-tx phase changed to S* was undone outside the chronological order of the other sub-actions (*WRA-PKP phase changed to S, WRA-P phase changed to S*). Thus, the main Phase action (*Multiple to S*) has two sub-actions that are part of the UNDO stack and one sub-action that is part of the REDO stack. As these sub-actions cannot be split apart, the only alternative is to mix the UNDO and REDO stacks together in global mode.

The user can use the undo/redo arrow icons to clarify which actions actually belong to the UNDO stack and which belong to the REDO stack. Note that as in this example, the user may need to expand Multiple action rows to fully see how actions are split between stacks. The user can also tell the two stacks apart by seeing which actions are dimmed, i.e., part of the REDO stack. In this example, the Association action and the Phase sub-action *ASAR-tx phase change to S* are dimmed as they are in the REDO stack.

Finally, the user can use the outlining feature discussed previously to clarify which actions belong to which stack. For instance, if the user hovers over the Phase action *MJAR-P phase changed to Pn* (which is part of the UNDO stack as indicated by brightness and its icon arrow), all actions that need to be undone prior to undoing the Phase action are outlined. In this example, one can see that although the Phase action *Multiple to S* and its sub-actions *WRA-PKP phase changed to S* and *WRA-P phase changed to S* appear to be under the REDO stack, they are actually part of the UNDO stack as indicated by the outlines.

Figure 196. Example of actions listed under redo stack that are actually within the undo stack.

To “unmix” the stacks, the user can undo/redo actions in global mode until the UNDO/REDO stacks no longer show mixed undo/redo actions (e.g., Section 5.9.1). In this example, unmixing can be achieved by, at minimum, undoing the Phase action *Multiple to S*. Undoing the Phase action will cause the two undoable sub-actions to be undone. Once the Phase action and its undoable sub-actions are undone, the undo and redo actions are no longer mixed and the UNDO/REDO stacks appear as shown in the figure below. Once again, the UNDO label is above the REDO label and there are no undo actions in the redo stack or vice versa as indicated by the undo/redo icons. Alternatively, entering event mode and redoing the sub-action *ASAR-tx phase changed to S* would also unmix the stacks to achieve the figure below.

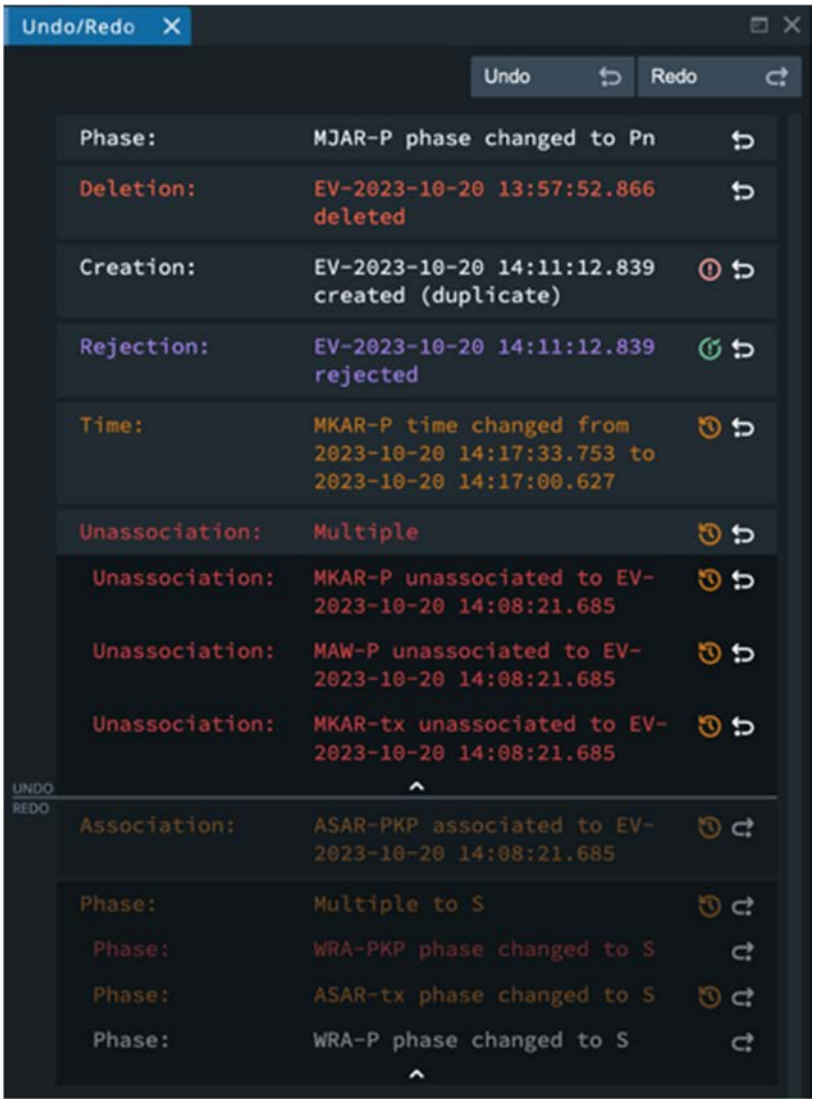


Figure 197. Example of unmixed undo/redo stack.

Finally, in event mode, the REDO stack can be cleared by performing an undoable action in the IAN UI prior to redoing the actions in the REDO stack. Once the REDO stack is cleared, those redo actions are permanently lost. If more than 500 actions are in the event mode UNDO/REDO stacks, the stacks will be cleared automatically.

This example of event mode is a relatively simple case. In future versions of this user guide, more complex examples will be provided in the appendix. Due to its ability to allow the user to work on multiple events and to perform undo/redo on actions outside of the basic chronological order present in global mode, the event mode can quickly result in highly complex and potentially confusing scenarios. The user is cautioned to keep careful track of actions undone/redone in event mode and how they appear when returning to global mode.

5.10. Azimuth Slowness Display (DRAFT)

The azimuth slowness display may only be opened by clicking on the username in top right, highlighting ***Analyst Displays***, and then clicking on ***Azimuth Slowness*** in the dropdown menu that appears. The Azimuth Slowness display can be maximized by clicking the leftmost top-right button in the display and can be closed by clicking the rightmost top-right button in the display.

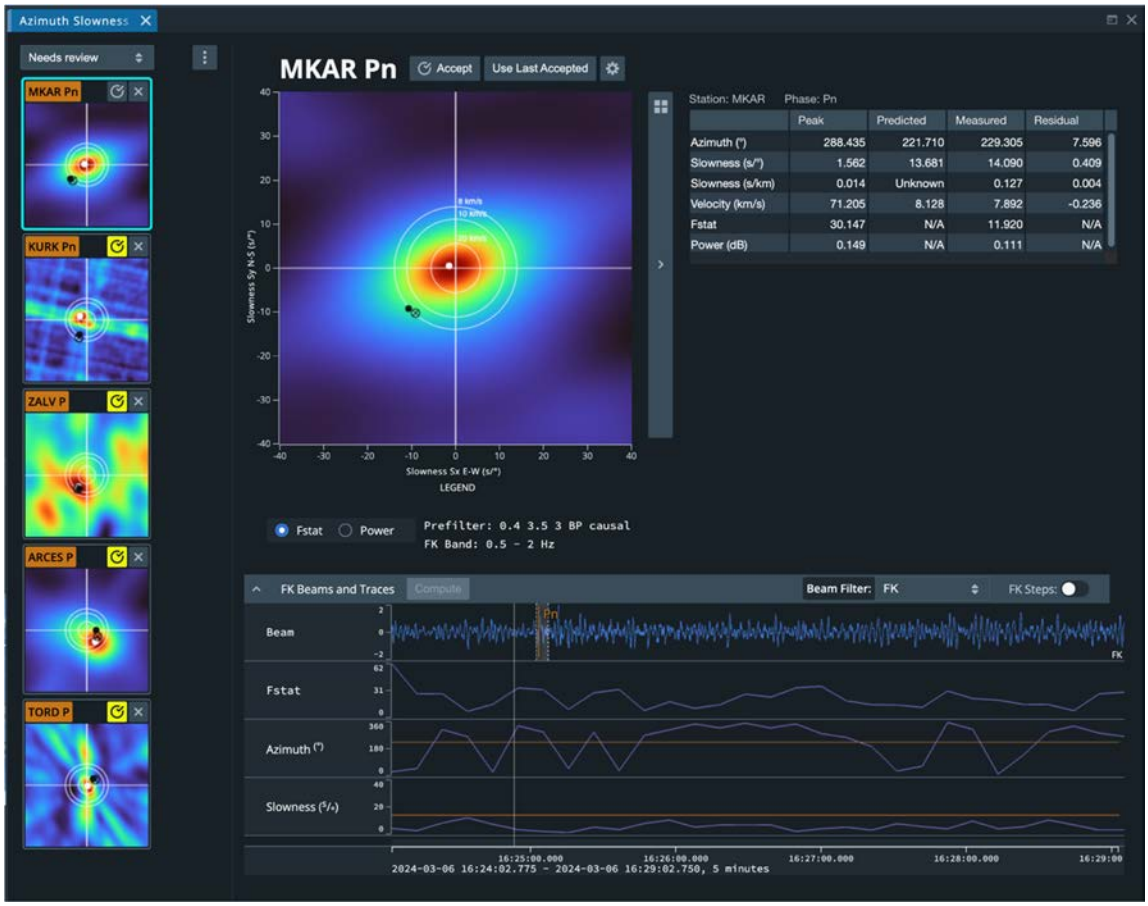


Figure 198. Example of full Azimuth Slowness display.

There are four main components of the display (Figure 192):

- Thumbnail images of the FK, always shown on the left (Section 5.10.1)
- The primary FK display for the selected FK thumbnail (specific station and phase), currently shown in center (Section 5.10.2) (Figure 192).

- The *FK Beams and Traces* window showing the timeseries associated with the FK shown in the primary display window (Section 5.10.3), currently shown at the bottom (Figure 192).

- A table of predicted, measured, and residual values for the FK shown in the primary display window (azimuth, slowness, velocity, Fstat, and Power) (Section 5.10.4), currently shown on the right (Figure 192).

The thumbnail display is separated from the other three, and the size of the display can be changed by dragging the vertical line separating the thumbnail display from the other displays. As the FK thumbnail display is widened, option buttons appear; these are the same options accessible from the three vertical dot option menu on the right of the thumbnail display. When the whole azimuth slowness display is maximized, the FK display, FK Beams and Traces display and FK information table are rearranged to better fit the space.

NOTE: The current Azimuth Slowness display is connected to an older, prototype version of the FK calculation endpoint. The prototype version will be replaced by a production quality endpoint in the future but is currently being used during development of the display.

5.10.1. Thumbnail Display

For every FK (specific station and phase), opened as part of an event and/or opened from the signal detection window, a thumbnail will appear along the edge of the Azimuth Slowness Display (Figure 193). The thumbnail displayed in the main FK display is highlighted by a turquoise outline. To open one of the FK thumbnails in the main display window, double-left click on the image.

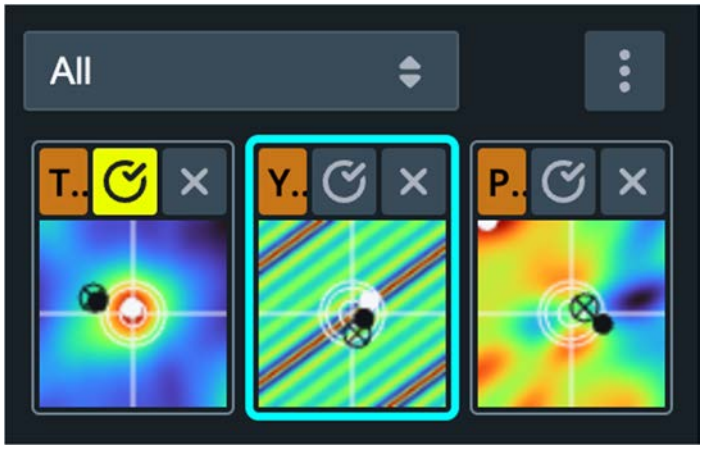


Figure 199. FK Thumbnail Display (with small thumbnail images).

Multiple FK thumbnails may be selected by holding down the shift button and left-clicking on each desired thumbnail (Figure 194). When this is done, all selected thumbnails are highlighted with a blue outline.

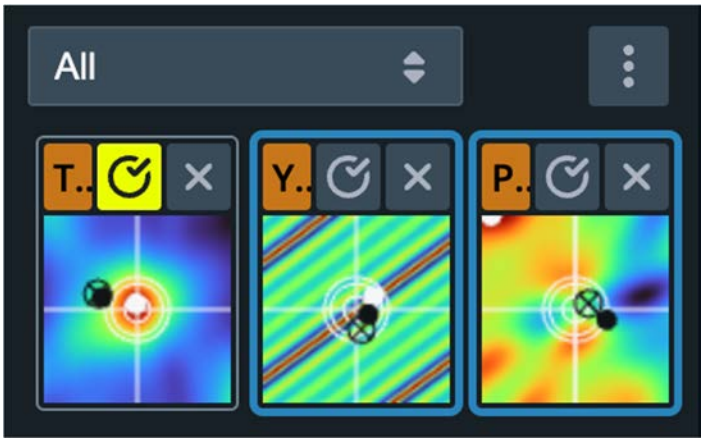


Figure 200. Example of several selected FK thumbnails.

All selected FK thumbnails may be acted on at once by right-clicking on one of the selected FKs and selecting from several available options (Event association, Set *X* phases, Rotate waveforms using *X* signal detections, Delete, and Export) (Figure 195). When only one FK thumbnail is selected, all those same options are available, as well as Open signal detection details. The Set to current or default phase options are only available when the selected FK is not the same as the current of default phase; this is explained in more detail in Section 5.10.1.2.

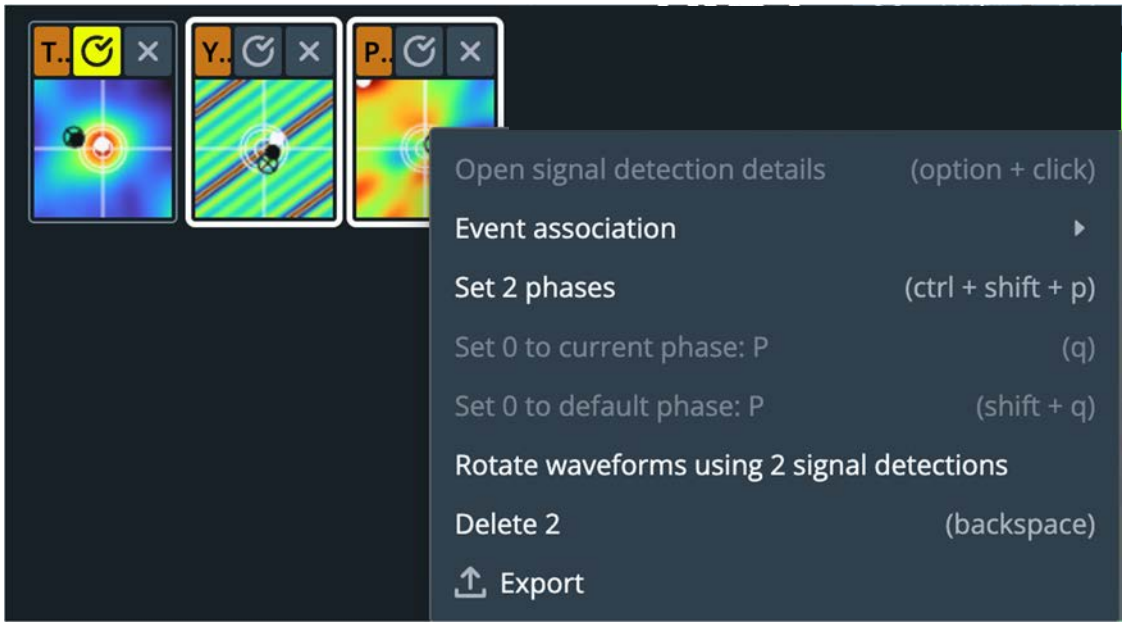


Figure 201. Example of several selected FK thumbnails.

For each FK, the status is displayed at the top, as a color within a circle-checkmark icon. The meaning of the colors are as follows: Yellow=Needs Review, Gray=Not Required to be Reviewed or Already Reviewed and not Accepted, and Green=Accepted. The ***Next*** button at the top of the FK thumbnail display (left of option menu), will cycle through each FK that still needs review (still has the yellow, needs review, status).

5.10.1.1. FK thumbnail filters

The dropdown menu at the top of the thumbnail display has four persistent options and one conditional option to select from:

- Key Activity Phases – Filters out all FKs for the event, except for those listed as key analysis phases for that stage and activity (Event Review or Scan) in configuration (more detail in Section 5.2).
- All – Displays all FKs opened as part of an event or individually from the Signal Detection.
- Open Event – Filters out all FKs, except those associated to the open event.

- Needs Review – Displays all FKs that are required to be reviewed by the analyst; all FKs in this list remain, regardless of whether the analyst has already reviewed them. However, once the analyst views them in the full display, the status color in the circle-check box will change (from yellow to gray if not accepted, and from yellow to green if accepted).

- Custom (conditional) – Only after specific FKs are hidden from view, a custom filter is created. More description is provided in Section 5.10.1.4

Depending on which of the above are chosen from the dropdown menu, the corresponding set of FK thumbnails are displayed in the order corresponding to the Waveforms Display (by distance or alphabetically).

5.10.1.2. FK thumbnail options

The functionality of options displayed in Figure 195 are as follows:

- Open signal detection details (*option + click*) – This is available when only one FK thumbnail is selected. The following will be displayed for the ***Current Version*** of the signal detection (Figure 196).

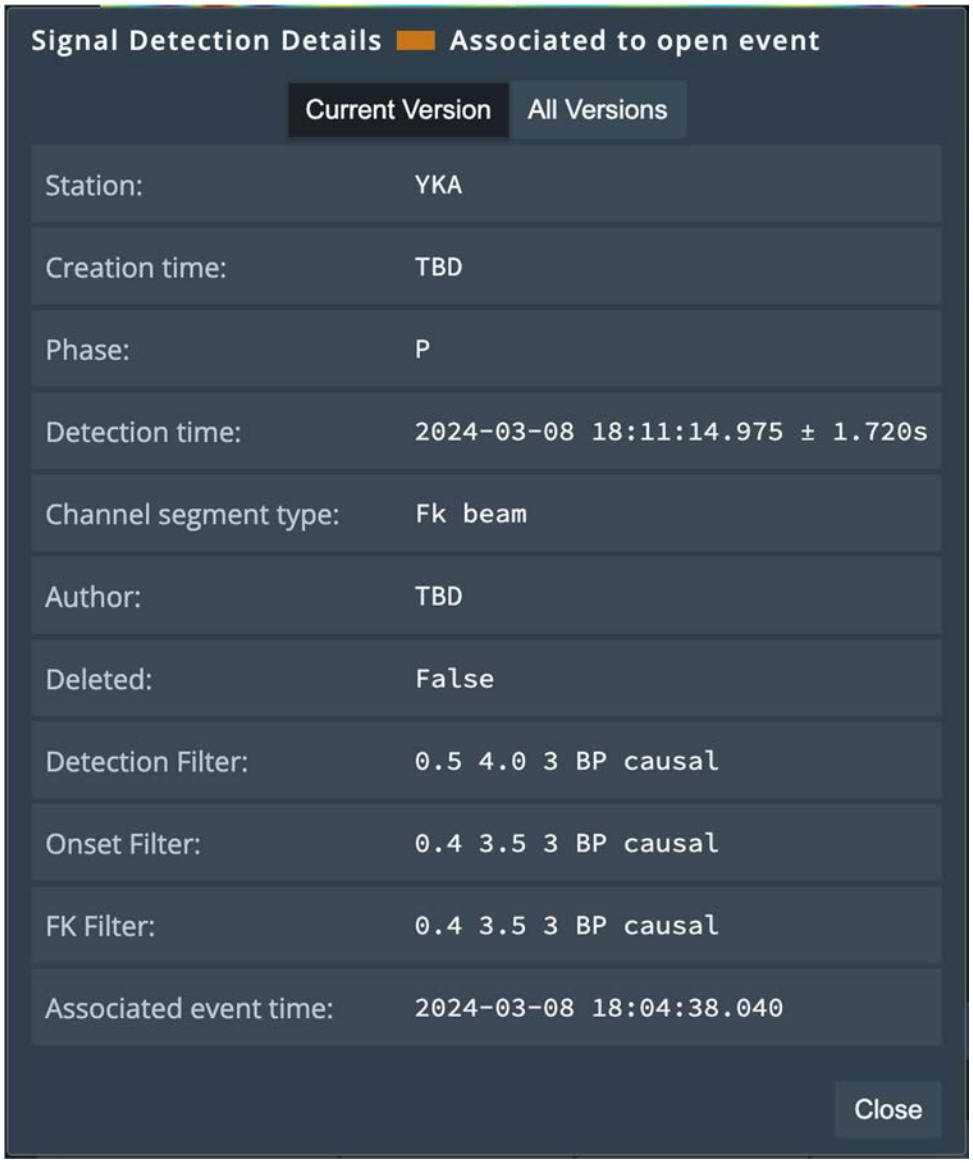


Figure 202. Example of *Open signal detection details* display for the Current Version of the signal detection

If the ***All Versions*** option is selected, less detailed information about each signal detection version will be displayed (Figure 197), including the Creation time, Phase, Detection time, Time uncertainty, Channel segment type, Author, and Deleted status.

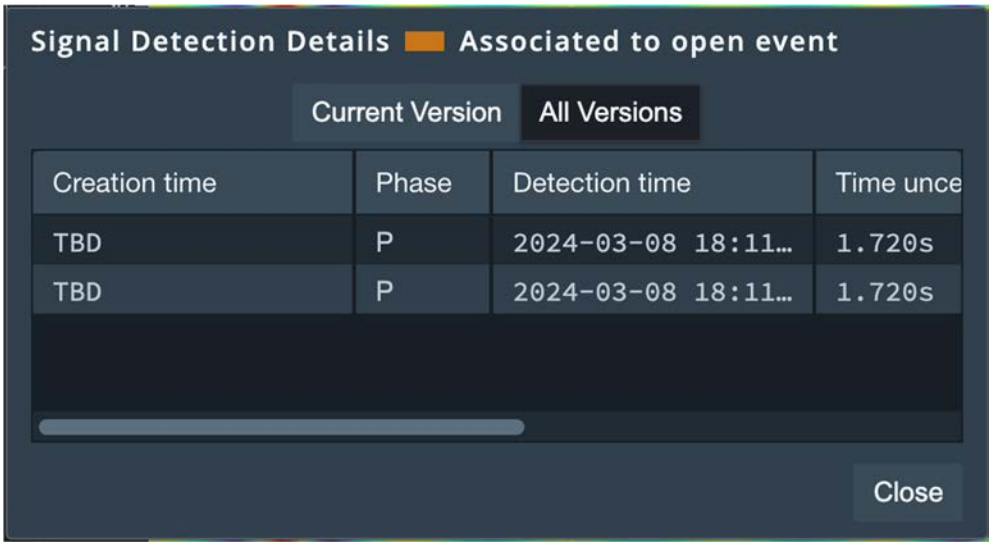
- 

Figure 203. Example of *Open signal detection details* display for All Versions of the signal detection

- Event association (available when one or more FK thumbnails are selected) – Three different event association actions are listed as previously described in Section 5.3.8.4 (Figure 107). If the selected FK is not currently associated to the open event, the user may associate it to the open event. This is possible when an FK is opened for a beam from the Waveforms display and is currently not associated to the open event. If the selected FK is currently associated to the open event, the user may unassociate it from the open event. Lastly, the user can choose to reject it from the open event.

- Set *X* phases (*cntrl + shift + p*) – *X* is non-zero when one or more FK thumbnails are selected. When set phase is selected, the menu to select the current phase is displayed (described in detail in Section 5.3.5.2.2). The user may select between 3 different phase selection menus, including the Magnitude, Seismic & Hydroacoustic, or Infrasound (Figures 44-48).

- Set *X* to current phase: *Y* (*q*) – *X* is non-zero when one of the selected FKs can be changed to the set current phase *Y* (Section 5.3.5.2.2 and Figure 48). In other words, if all phases in the selected FK are already P, then none can be changed to P.

- Set X to default phase: Y (*shift + q*) – *X* is non-zero when one of the selected FKs can be changed to the default, configured phase *Y* (Section 5.3.5.2.2 and Figure 48). In other words, if all phases in the selected FK are already the same as the default phase, then none can be changed.

- Rotate waveforms using X signal detections – This option allows the user to rotate the selected waveforms according to the azimuth from the last saved and accepted analyst result.
- Delete *X* (backspace) – This option allows the user to delete *X* number of FKs.
- Export – This option allows the user to export the FK results into a .json file for use outside of the GMS system.

5.10.1.3. FK thumbnail sizes

The size of the FK thumbnails may be altered by left-clicking on the three vertical dot option button in the top right of the FK thumbnail display, selecting ***Thumbnail size***, and choosing from ***Small, Medium***, or ***Large*** (Figure 198).

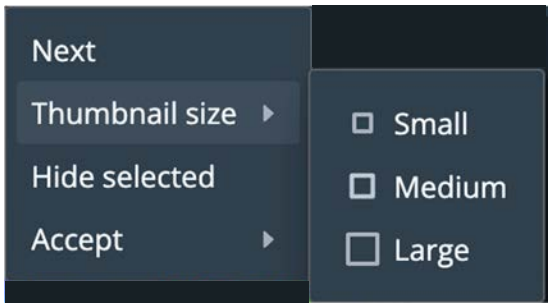


Figure 204. Menu to change size of FK Thumbnail.

If the large thumbnail is selected, then any error messages are displayed below the error icon on top of the plain, black background of the thumbnail (Figure 195).

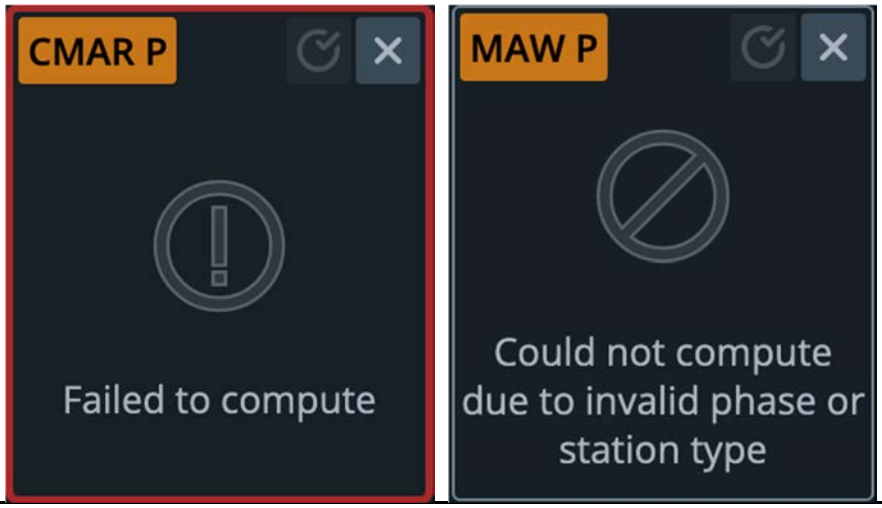


Figure 205. Examples of error messages displayed on an FK thumbnail.

Otherwise, when small or medium thumbnails are chosen, the error message is displayed when the mouse hovers over a thumbnail with an error icon on top of a plain, black background (Figure 200).

Figure 206. Examples of error messages displayed on an FK thumbnail.

5.10.1.4. Hide selected

If ***Hide selected*** is chosen from the options, the selected FKs are removed from the thumbnail display and a ***Custom*** filter for the FK display is created (Figure 199).

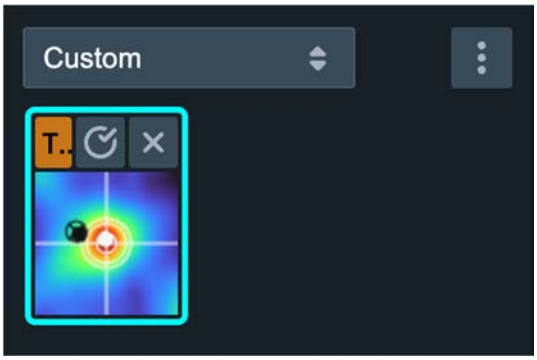


Figure 207. Example of display after FKs are hidden and a custom filter is created in the dropdown menu.

If the user again clicks on another option from the dropdown FK selection menu (Key Activity Phases, All, Open Event, or Needs review), their Custom selection is removed and cannot be returned to, unless the user hides the selected FK thumbnails again.

5.10.1.5. Accept thumbnails

The user may also choose to accept all the selected or all the visible FK thumbnails (Figure 202).

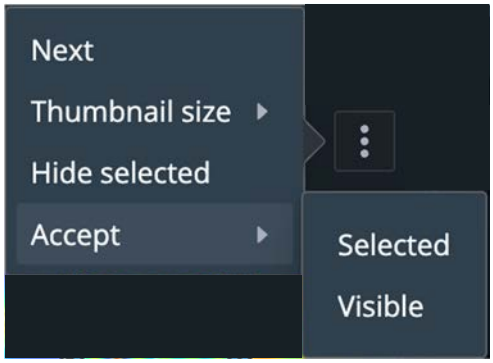


Figure 208. Menu to accept selected or visible FK thumbnails.

5.10.2. FK Display

The main FK display shows a large version of the FK result, with information about the type of FK calculation (power or fstat), prefilter information, and FK spectrum band information below (Figure 203). In the center of the display, concentric circles denote constant apparent velocities of 8, 10, and 20 km/s.

Within the display, there are three different marker types that indicate details about the azimuth and slowness results. The white dot shows the azimuth and slowness result with the highest power or fstat (depending on which option is selected in the display radio boxes below the FK plot). The black dot is the current analyst pick for the best azimuth and slowness; this can be easily changed by clicking anywhere within the FK window. The circled X marker indicates the azimuth and slowness corresponding to the currently opened event location solution.

The top of the main FK display shows the station and phase, options to accept or use the last accepted result, and a settings menu to change the FK parameters. Along the right of the FK, is

an option to show or hide (as in Figure 203) FK previews at different FK frequency bands for the current FK spectrum (explained more within Sections 5.10.2.2 and 5.10.4).

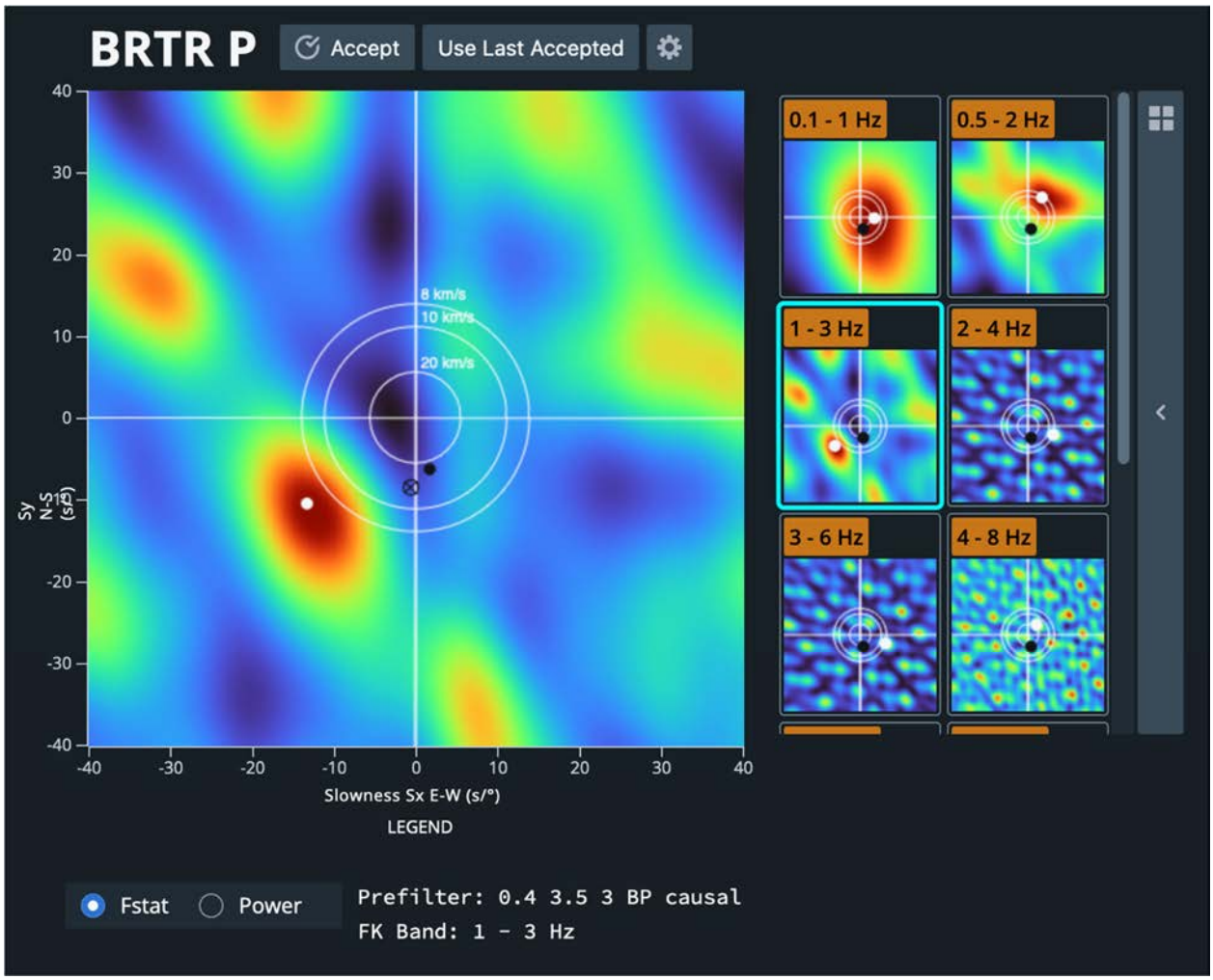


Figure 209. Example of main FK Display.

To see a description of the legend, hover the mouse over the word "LEGEND" at the bottom of the FK plot. This will reveal the colorbar and range associated with either the Fstat (if selected) or Power (if selected) colorbars. The legend also describes the various dots on the plot and what they correspond to (Measured, Peak, or Predicted).

5.10.2.1. FK Parameters Menu

The FK parameters menu allows the user to modify the parameters that are used to calculate the FK (Figure 204). When first opened, the parameters are populated with the default

configuration for the specific station and phase corresponding to the currently opened FK, and the “Reset to Default” and “Cancel” buttons may be selected by the user. If a parameter within the menu is changed, the user may also select “Compute FK”.

A tooltip for the FK parameter menu appears when the user hovers the mouse over the information icon. For each individual parameter, an information icon appears when the user hovers the mouse over the parameter name, and if the user clicks on the information icon, a tooltip appears that describes the parameter.

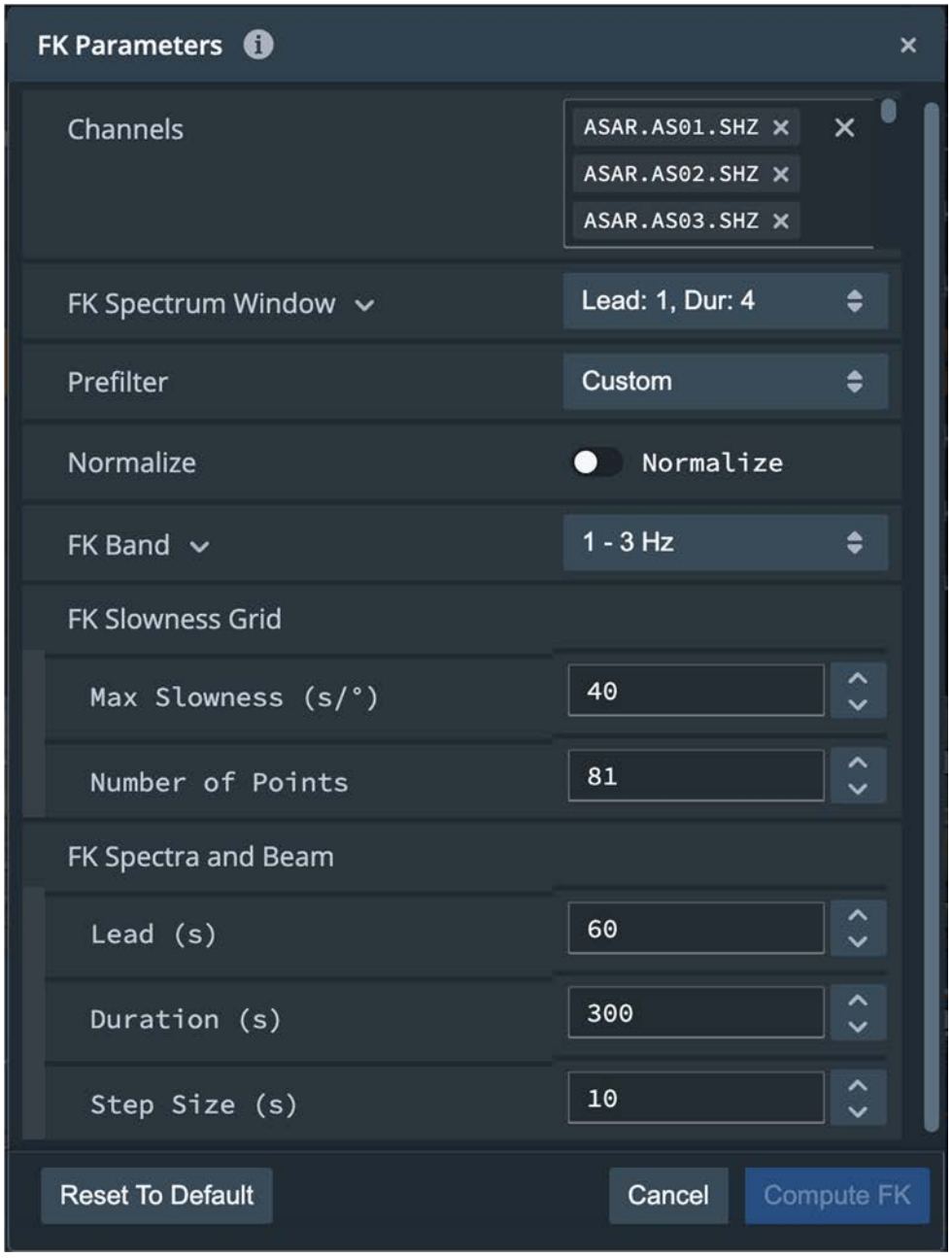


Figure 210. Example of FK Parameters Menu

Two of the parameters (FK Spectrum Window and FK band) may be expanded by the user in order to populate specific values into the boxes, as shown in Figure 205.

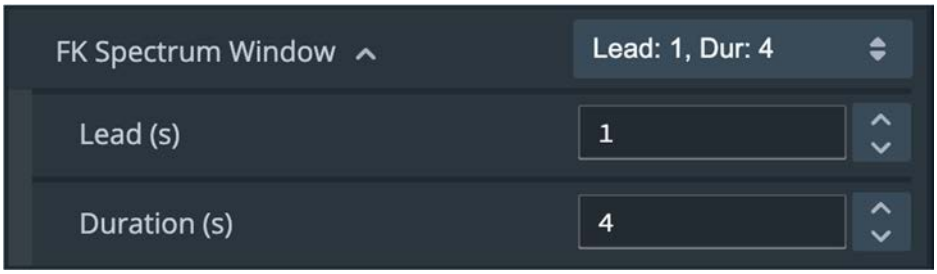


Figure 211. Example of Expandable FK Spectrum Window parameter

We provide more detail about each parameter below:

- Channels – The user can clear all channels by clicking on the x button in the top right, or the user may clear channels individually by clicking the x to the right of each channel name (Figure 206). When the user clicks within the channels box, a scrollable dropdown list appears containing every channel that can be added into the FK calculation for that station. Only channels with the same sample rate appear in that list.

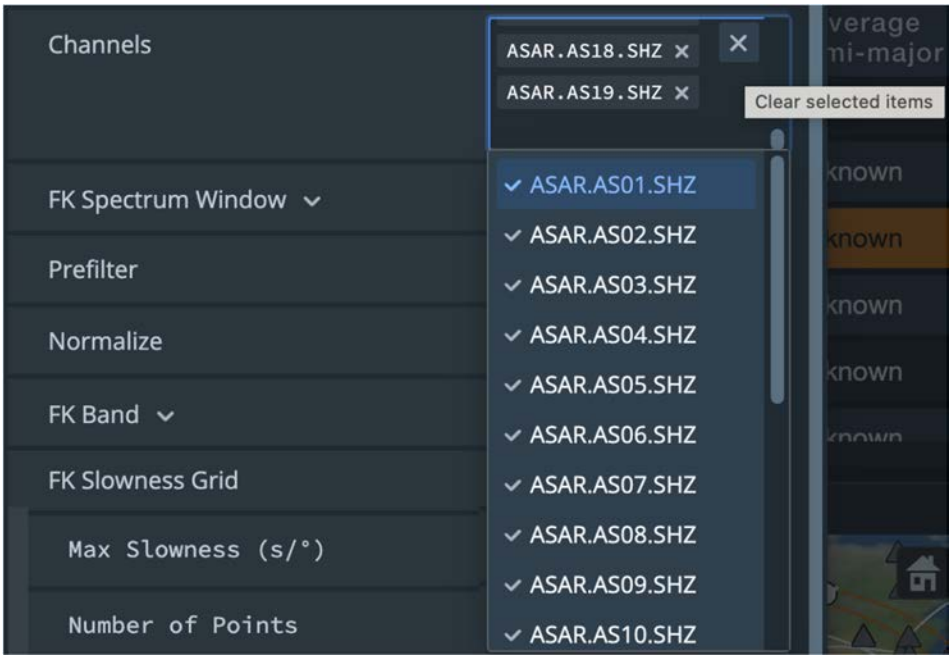


Figure 212. Example of channel list for ASAR.

- FK Spectrum Window – The user can modify the lead and duration times used to calculate each FK spectrum. If the user clicks on the FK spectrum window, a searchable dropdown list of configured FK spectrum windows appears. The user may select one of the spectrum windows listed, or may type a value within the search bar at the top to limit the lead and duration times returned (Figure 207). If the user searches for an FK spectrum window that does not exist in the list, nothing is returned. If the user wishes to create a custom FK Spectrum Window, they may do that by populating values for lead and duration separately into the expanded menu for FK Spectrum Window (Figure 205).

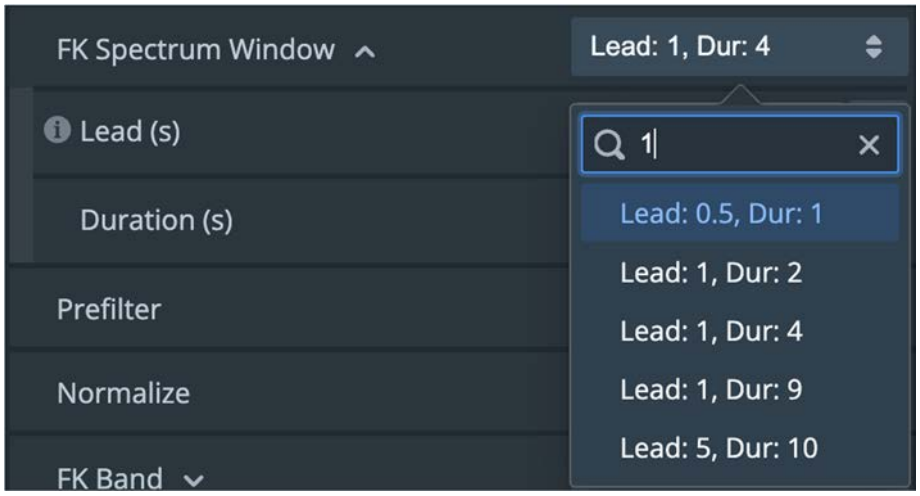


Figure 213. Example of searchable dropdown list for FK Spectrum Window

- Prefilter – The prefilter (filter applied before calculating the FK) also may be selected from a searchable dropdown menu (Figure 208).

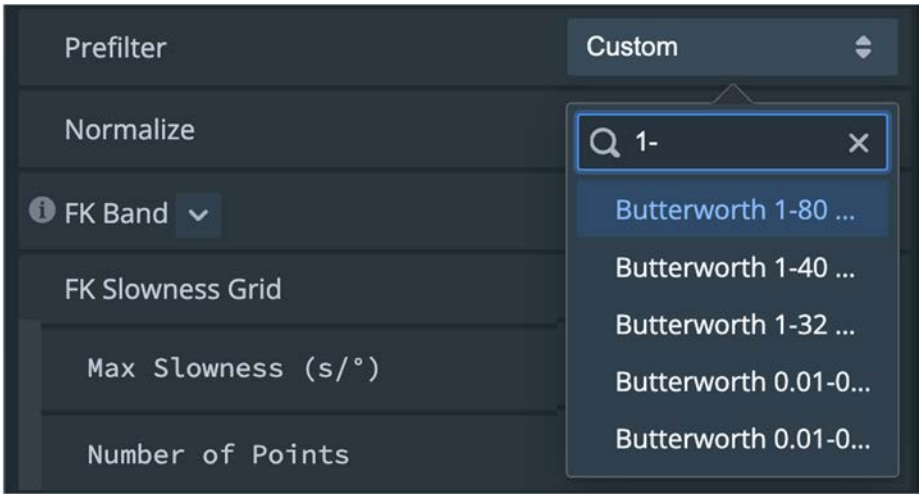


Figure 214. Example of searchable dropdown list for Prefilter

- Normalize – The calculated FK may be normalized by toggling the slider on or off (Figure 209).

Figure 215. Example of toggle option for Normalize.

- FK Band – The FK Band (frequency range for the FK) may be modified in the same way as the FK Spectrum Window (Figure 210); the user may choose to search for a pre-configured FK Bands within the searchable dropdown list provided or they may populate specific values for Low (Hz) and High (Hz), when the FK Band option is expanded.

Figure 216. Example of searchable dropdown list for FK Band.

- FK Slowness Grid – The FK Slowness Grid parameter allows the user to change the parameters for the max slowness and number of points (resolution) used to calculate and plot the FK (Figure 211). For each of the two parameters, the user may modify the values with the up/down arrows or by typing specific values into the window.

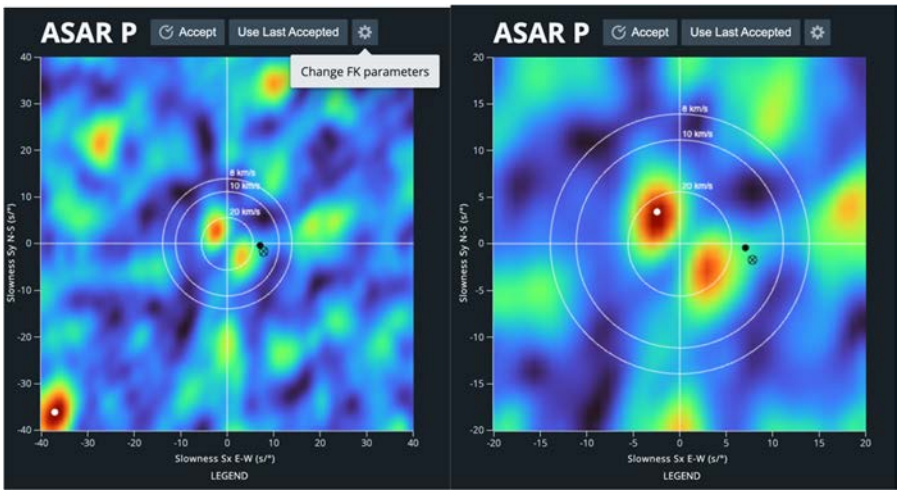


Figure 217. Example of two different FK grids calculated and plotted for ASAR P.

- FK Spectra and Beam – The lead time (sec), duration (sec), and step size (sec) can all be modified for the calculated spectra and beam. For each of the three parameters, the user may modify the values with the up/down arrows or by typing specific values into the window.

5.10.2.2. FK Previews

FK Previews for different FK Bands may be shown or hidden by clicking on the FK Bands bar. The FK previews may be displayed either below or to the right of the calculated FK, depending on the size of the Azimuth Slowness display. When expanded, a set of FK previews (thumbnails) are shown at a range of different FK Bands; depending on the orientation and available space, this may be shown as a scrollable list.

The FK previews are a single FK spectrum calculated around the arriving phase, using the FK Spectrum Window lead and duration (Figure 207), rather than the full spectra for the beam. This is done to provide the analyst with a quick view; if the analyst chooses a specific FK Band, then the system calculates the full FK spectra and shows that calculation in the main FK displays.

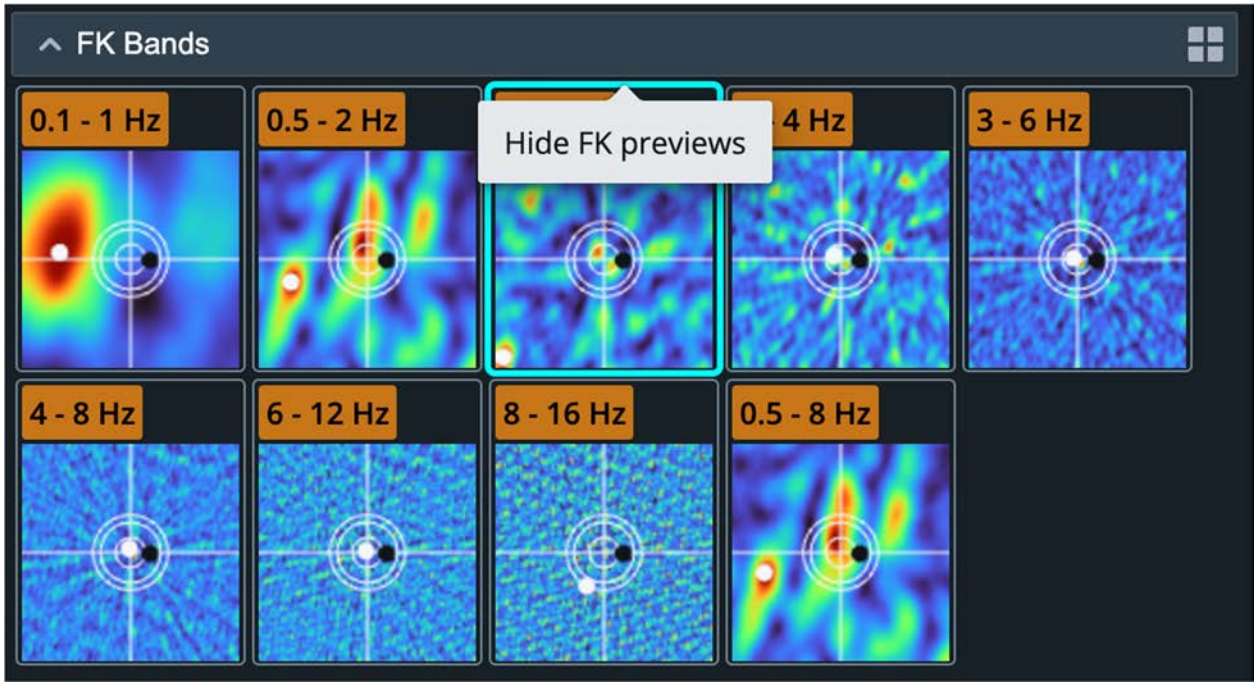


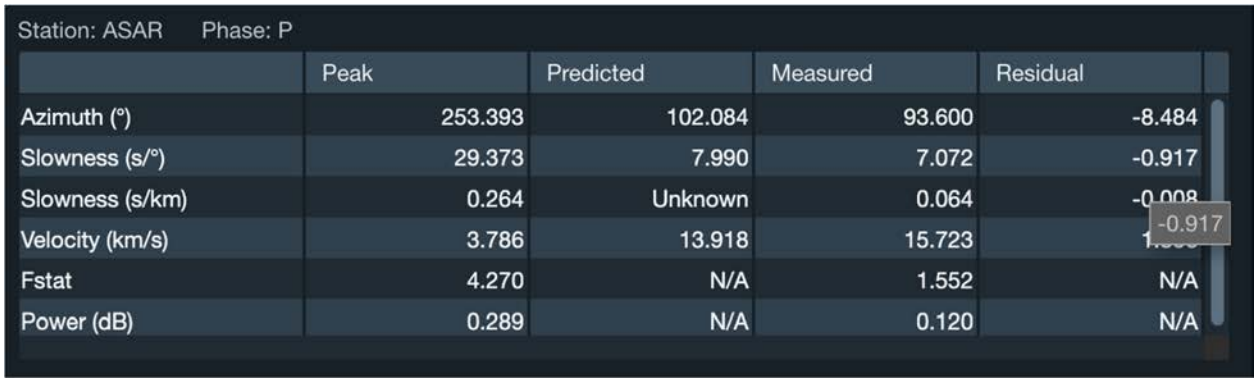
Figure 218. Example of FK previews corresponding to different FK Bands.

5.10.3. FK Information Table

The table of FK information either to the right or below the main FK result, depending on the size of the Azimuth Slowness window. The station and phase type are listed at the top of this table.

The table contains information about result peak values, measurements, predictions, and residuals for the displayed FK result for the following: azimuth (°), slowness (s/° -and- s/km), velocity (km/s). For Fstat and Power (dB), only result peak values and measurements will be shown; for these, N/A will be displayed in the predicted and residual columns.

As the measurement is changed by the analyst (black dot on main FK display), the value for ***Measured*** will update, and the residual (difference between the measured and predicted values) will be recalculated. If the value for ***Predicted*** cannot be calculated for one of the azimuth, slowness, or velocity rows, the table will display "Unknown".


Station: ASAR Phase: P

	Peak	Predicted	Measured	Residual
Azimuth (°)	253.393	102.084	93.600	-8.484
Slowness (s/°)	29.373	7.990	7.072	-0.917
Slowness (s/km)	0.264	Unknown	0.064	-0.008
Velocity (km/s)	3.786	13.918	15.723	
Fstat	4.270	N/A	1.552	N/A
Power (dB)	0.289	N/A	0.120	N/A

-0.917

Figure 219. Example of table showing information for an ASAR P FK calculation

5.10.4. FK Beams and Traces

The FK Beams and Traces display plots the filtered beam from the full FK spectra. Below the beam, the calculations at discrete time steps for each of the fstat, azimuth, and slowness are plotted (Figure 214). The FK Beams and Traces display may be shown or hidden by clicking on the arrow on the far left of the display title bar.

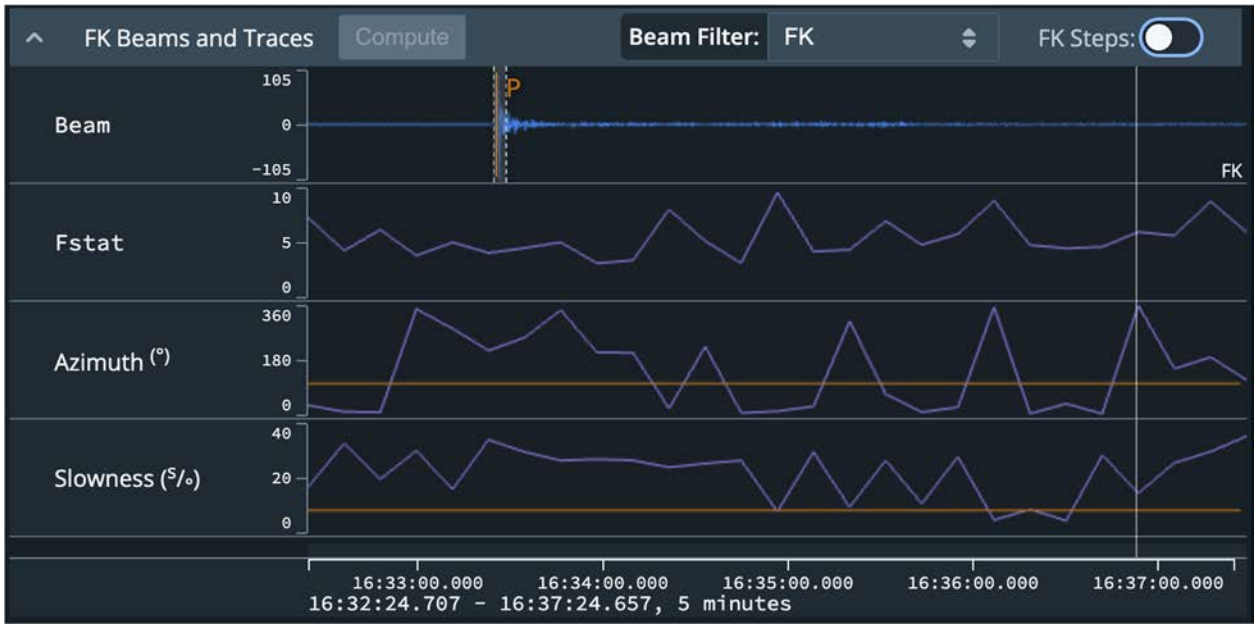


Figure 220. Example of FK Beams and Traces display

The step size for the FK spectra and Beam parameter specified and recalculated after modifying values within the FK parameters menu (Section 5.10.2.1). The lead and duration for the FK Spectrum Window parameter may also be specified and recalculated after modifying values within the FK parameters menu (Section 5.10.2.1) or may be modified interactively by dragging the vertical dashed lines around the phase arrival (Figure 215). After a modification has been made for FK spectrum lead or lag, the Compute button may be selected, and a revised FK spectrum will be calculated according to the changes.

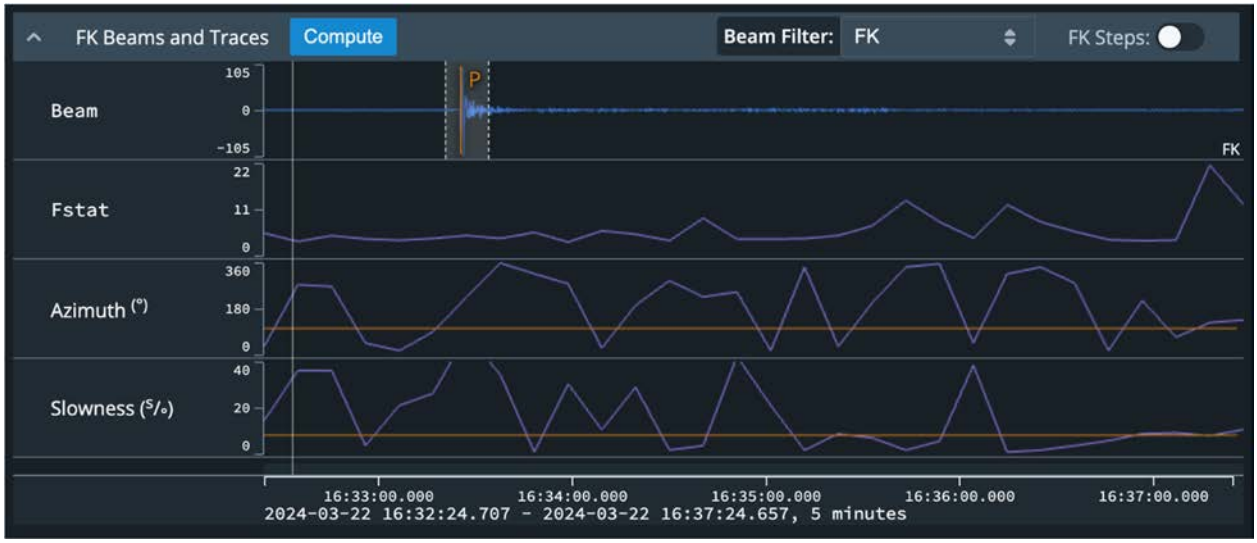


Figure 221. Example showing interactively modified lead and duration time for FK spectrum calculation

The beam may be filtered differently within the display, by choosing another option from the Beam Filter menu in the top display title bar. This produces a selectable menu from which different filter bands may be chosen (Figure 216).

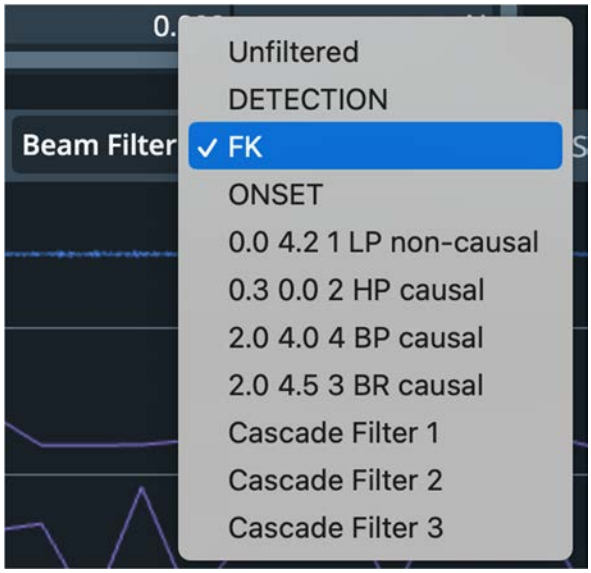


Figure 222. Example showing selectable Beam Filter options

The discretized steps can be displayed within the window by toggling the FK Steps option to on (Figure 217); again this corresponds to the step size specified within the FK spectra and Beam parameter within the FK Parameter menu (Section 5.10.2.1).

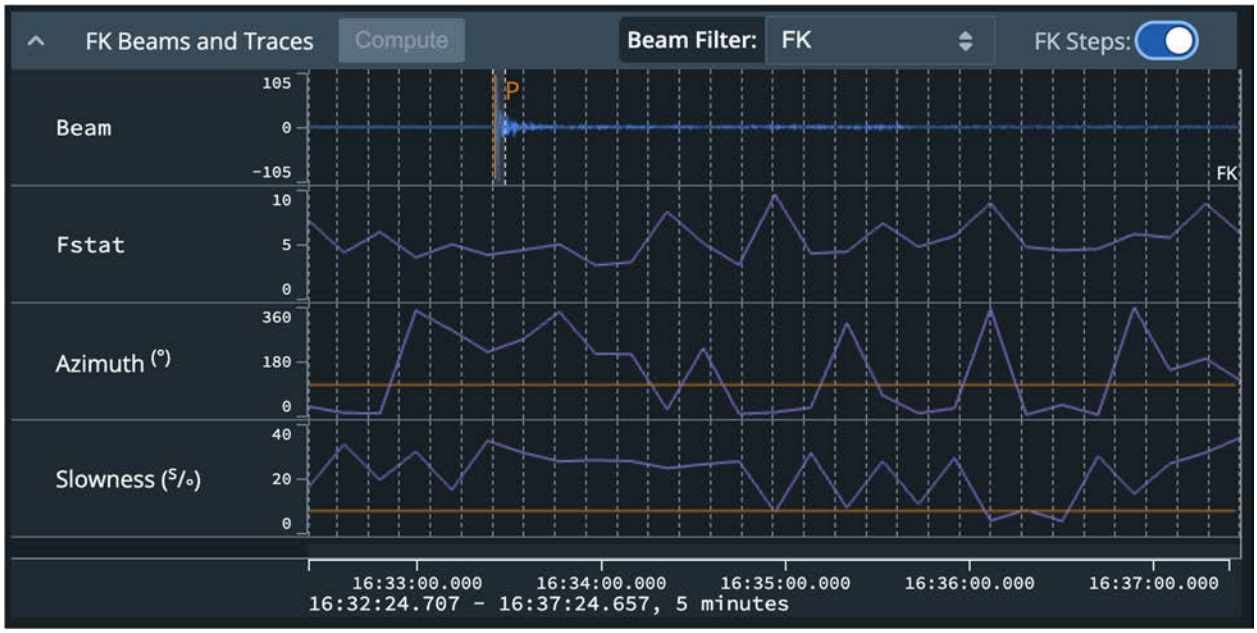


Figure 223. Example of FK Beams and Traces display with the FK Steps toggled on.

6. CURRENT LIMITATIONS

Regarding the color theme of the UI, two dark modes and one light mode are currently available (Section 5.1). More modes are under development.

Intervals cannot be marked as Complete (see Section 5.2). A complete (green) status will only appear in interactive processing stages when produced by a data simulator.

IAN is delivered with 24 hours of configured data (see Configuration documentation). IAN is capable of handling up to 45 days of data (see Section 5.2).

Currently, users can open any time range back to December 31, 1969, with the Open Anything menu. This unrestricted time range is only being used to test the Open Anything menu and view data from the 2019 static test dataset. In future releases, the allowable time range will be restricted to the configurable operational time period (see Section 5.2).

In the Waveform display, single stations with data only show the recording station name in their label. In a future release, single station labels will show the recording station name and the component(s) of the raw data being displayed, e.g., BDFB BDFB.BHZ (see Section 5.3.1).

The buttons used to set display mode and to set the default phase of new SDs are disabled (Section 5.3.4).

SDs cannot be associated to an event marked as complete, as event completion is currently not enabled (Section 5.6.4.2).

All SDs will have a Creation time and Author of TBD in the Signal Detection Details table (Figure 47; Section 5.3.5.2.1).

The hotkey combination used to bring up the QC segment details menu is incorrectly shown as Alt (Option on Mac), rather than Alt + click (Option + click on Mac) in the QC Segment Popup Menu (Figure 85; Section 5.3.7.1.1).

Only a small number of SDs in the Waveform display will have a processing mask; these masks are mocked for demonstration purposes and will be fully implemented in a future release (Section 5.3.7.1.3).

Geographic region in the Events display table will always read as TBD (Section 5.4.1).

The ability to mark an event complete in the Events display is disabled (Section 5.4.1).

Events in the Events display or Map display cannot be marked completed (Section 5.4.1, Section 5.6.4).

Any changes made in the Events display currently cannot be saved (Section 5.4.4).

A completed (green) SD association status will be unavailable in the Signal Detections list display will be unavailable until the capability to mark an event as complete is enabled (Section 5.5.2).

Phase confidence is only defined if the SD is read in from the ASSOC table in the database (Section 5.5.2).

All amplitudes reported in the Signal Detections List display are calculated as a5/2 measurements. Other amplitude types will be made available in a future release (Section 5.5).

Currently, only a5/2 amplitude measurements are available in the Signal Detections List display. In future releases, any amplitude type associated to an SD via the AMPLITUDE table in the database will be reported (Section 5.5.2).

Currently, all short period and long period first motions are classified as INDETERMINATE, i.e., the first motion associated with the SD is not defined in the ARRIVAL database (Section 5.5.2).

In the Map display only the default imagery and terrain options (Natural Earth and WGS84, respectively) can be used (Section 5.6.1).

In the Map display, SD arc length is a configurable parameter based on a fixed distance for unassociated SDs and calculated by the distance between the station and preferred event location for associated SDs. In future releases, arc lengths will be based on slowness (Section 5.6.3).

The functionality to mark an event complete in the Map display is disabled (Section 5.6.4).

Toggling on the map layer option to view completed events will result in no change as events cannot be marked completed in the IAN UI (Section 5.6.5).

In the Map display, non-preferred location solutions cannot be shown (Section 5.6.5).

Currently, the FK spectra are calculated using an older, prototype version of the FK calculation endpoint. As mentioned, this prototype will be replaced by a production quality endpoint in the future (Section 5.10).

Appendix A. Automatic Processing Sequences

The steps performed in the current Auto Network and Auto-Post AL1 stage processing sequences are shown in Table A1. These steps can be configured (see Configuration documentation).

Table A8. List of Processing Steps in Automatic Processing Sequences under Auto Network and Auto-Post AL1 Stages.

Auto Network Sequence	**Auto-Post AL1 Sequence**
Partial Processing (covers all station processing)	Origin Beam Short Period (SP)
Association	Origin Beam Long Period (LP)
Conflict Resolution	Recall
Origin Beam SP	Arrival Beam SP
Arrival Beam SP	Detection LP
	Recall LP
	Magnitude
	Hydro EDP
	HAE

Appendix B. Band, Instrument, and Orientation Codes

The following tables provide a list of band codes, instrument codes, and orientation codes that may be available in GMS. These codes were originally listed in the SEED manual. Channel names will consist of band code + instrument code + orientation code, e.g., B(roadband) + H(igh gain seismometer) + Z(vertical component) or BHZ. Note that not all bands, instruments, and orientations listed below are available at this time.

Table B1. Band Codes with Band Type, Range of Sample Rates in Hz, and Corner Period in Seconds.

Band Code	Band Type	Sample Rate (Hz)	Corner Period (sec)
F	...	≥ 1000 to < 5000	≥ 10 sec
G	...	≥ 1000 to < 5000	< 10 sec
D	...	≥ 250 to < 1000	< 10 sec
C	...	≥ 250 to < 1000	≥ 10 sec
E	Extremely Short Period	≥ 80 to < 250	< 10 sec
S	Short Period	≥ 10 to < 80	< 10 sec
H	High Broadband	≥ 80 to < 250	≥ 10 sec
B	Broadband	≥ 10 to < 80	≥ 10 sec
M	Mid Period	> 1 to < 10	
L	Long Period	≈ 1	
V	Very Long Period	≈ 0.1	
U	Ultra Long Period	≈ 0.01	
R	Extremely Long Period	≥ 0.0001 to < 0.001	
P	On the order of 0.1 to 1 day	≥ 0.00001 to < 0.0001	
T	On the order of 1 to 10 days	≥ 0.000001 to < 0.00001	

Q	Greater than 10 days	< 0.000001	
A	Administrative Instrument Channel (e.g., State of Health)	Variable	NA
O	Opaque Instrument Channel	Variable	NA

Table B2. List of Instruments with Codes and Descriptions.

Instrument	Instrument Code	Description
Seismometer	H	High Gain Seismometer
	L	Low Gain Seismometer
	G	Gravimeter
	M	Mass Position Seismometer
	N (L,G)*	Accelerometer *Note: Historically, some channels from accelerometers have used instrumentation codes of **L** and **G**. The use of **N** is the FDSN convention defined in August 2000.
Rotational Sensor	J	Measures solid-body rotations about an axis. Units may be in displacement (radians), velocity (radians/sec) or acceleration (radians/sec^2)
Tilt Meter	A	Measures tilt from the horizontal plane. Azimuth is typical N/S or E/W
Creep Meter	B	Measures the absolute movement between two sides of a fault
Calibration Input	C	Usually only used for seismometers or other magnetic coil instruments. This signal monitors the input signal to the coil to be used in the response evaluation
Pressure	D	A barometer or micro barometer that measures pressure. This includes infrasonic and hydrophone measurements
Electronic Test Point	E	Used to monitor circuitry inside a recording system, local power, or seismometer. Usually for supply or line voltages
Magnetometer	F	Measures the magnetic field where the instrument is sitting

Humidity	I	Absolute or relative measurements of the humidity
Temperature	K	Measurement of the temperature at some location.
Water Current	O	Measures the velocity of water in a given direction
Geophone	P	Very short period seismometer with a natural frequency of 5-10 Hz or higher
Electric Potential	Q	Measures the electric potential between two points
Rainfall	R	Measures total rainfall, or an amount per sampling interval
Linear Strain	S	Very sensitive displacement measuring device
Tide	T	Depth of water at the monitoring site
Bolometer	U	Infrared instrument used to evaluate average cloud cover
Volumetric Strain	V	Unknown
Wind	W	Wind vector or velocity
Derived/Generated	X	Time series derived from observational data or entirely generated by a computer seismogram
Non-specific Instrument	Y	Used for instruments not covered but the SEED format
Synthesized Beam	Z	Used when forming beams from the individual elements of an array

Table B3. List of Instruments with their Instrument Codes, Orientation Codes, Type, and Description.

Instrument	Instrument Code	Orientation Code(s)	Type	Description
Seismometer, Rotational Sensor, or Derived/Generated	H, L, G, M, N J X	Z, N, E	Geophysical	Traditional (Z=Vertical, N=North-South, E=East-West) within 5 degrees
		A, B, C		Triaxial (along the edges of a cube turned up on a corner)
		T, R		For formed beams (T=Transverse, R=Radial)
		1, 2, 3		Orthogonal, but non-traditional, components
		U, V, W		Optional components
Tilt Meter	A	N, E	Geophysical	Traditional
Calibration Input	C	A, B, C, D	Unspecified	Different letters used to differentiate between different calibration sources for the same device. Meaning is device-specific
		Blank		if there is only one calibrator for the device
		Z, N, E		If present, matches calibration channel to traditional channel

Pressure	D	O	Weather *or* State-of-Health	Outside
		I		Inside
		D		Down hole
		F		Infrasound
		H		Hydrophone
		U		Underground
Electronic Test Point	E	Varies	State-of-Health	Different values depending on device vendor
Magnetometer	F	Z, N, E	Geophysical	Traditional (Z=Vertical, N=North-South, E=East-West) within 5 degrees
Humidity or Temperature	I K	O	Weather *or* State-of-Health	Outside environment
		I		Inside building
		D		Down hole
		1, 2, 3, 4		Cabinet sources
		All Other Letters		Different values Depending on device vendor
Geophone	P	Z, N, E	Geophysical	Traditional (Z=Vertical, N=North-South, E=East-West) within 5 degrees

Linear Strain	S	Z, N, E		Traditional (Z=Vertical, N=North-South, E=East-West) within 5 degrees
Tide	T	Z		Always vertical
Wind	W	S	Weather	Wind speed
		D		Wind direct vector relative to geographic north
Creep Meter, Electric Potential, Water Current, Volumetric Strain	B Q O V	Unknown	Geophysical	
Rainfall, Bolometer	R U	Unknown	Weather	
Non-Specific	Y	Varies		Different values depending on instrument and vendor

Appendix C. Hot Keys and User Interactions

The following tables list hot keys and user interactions available for each display. Hot keys will reflect the user's OS. The figures in this section were taken on a Mac. The Command key ⌘ is equivalent to the Control key on Windows and the Option key ⌥ is equivalent to the Alt key on Windows.

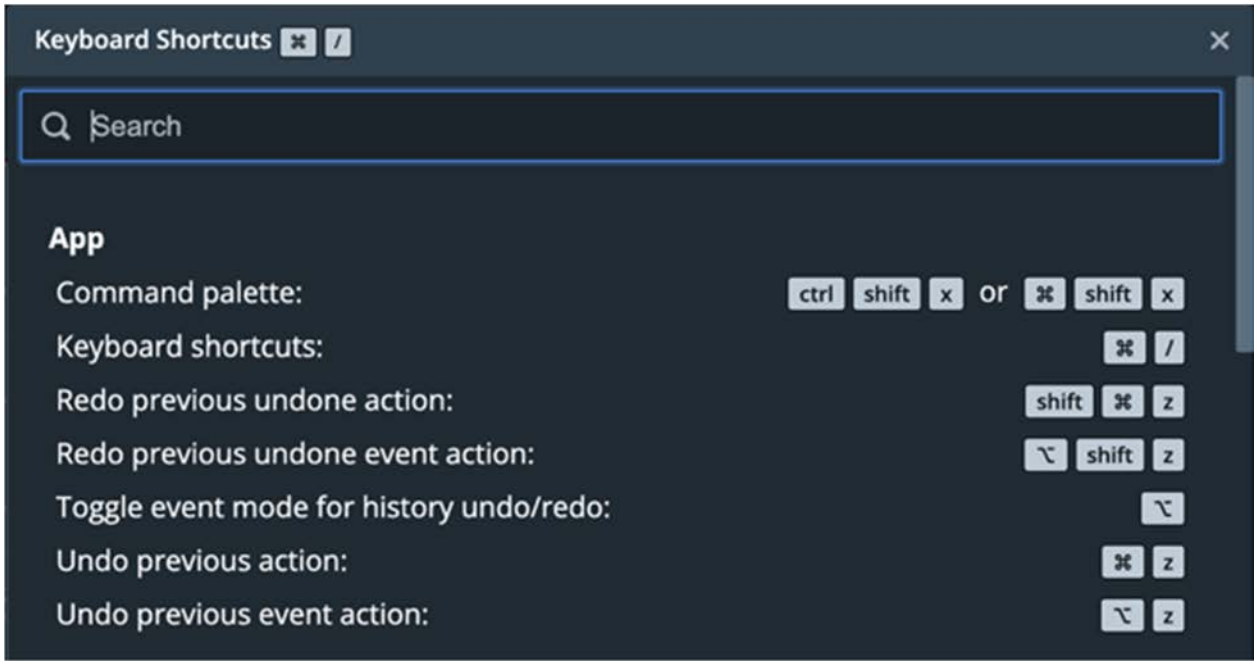


Figure 224. App Hotkeys.

Figure 225. Events Display Hotkey.

Figure 226. Filters Display Hotkeys.

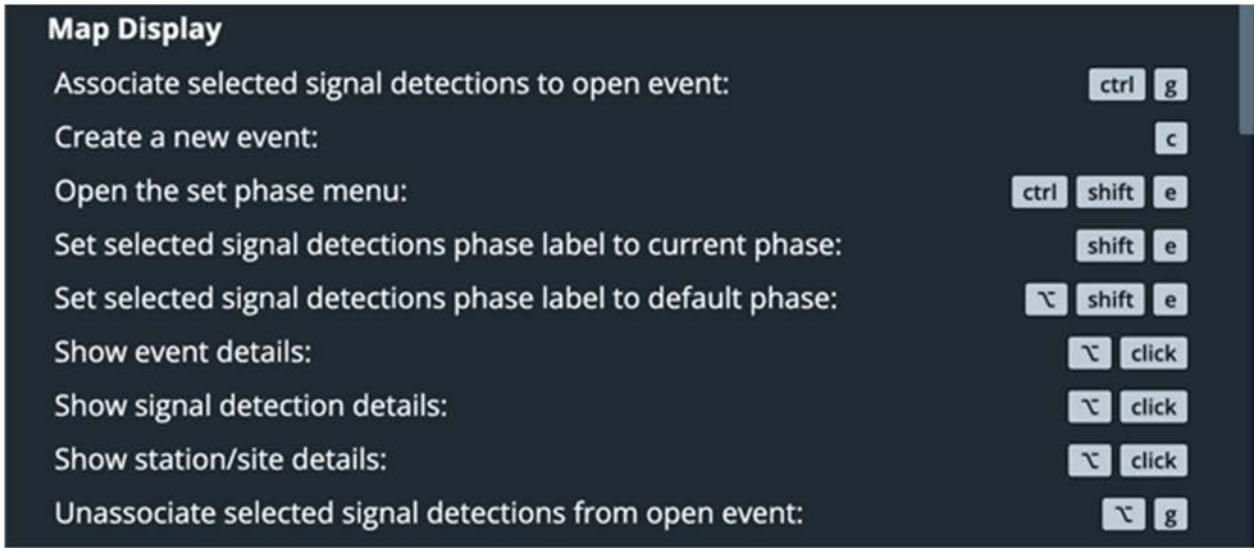


Figure 227. Map Display Hotkeys.

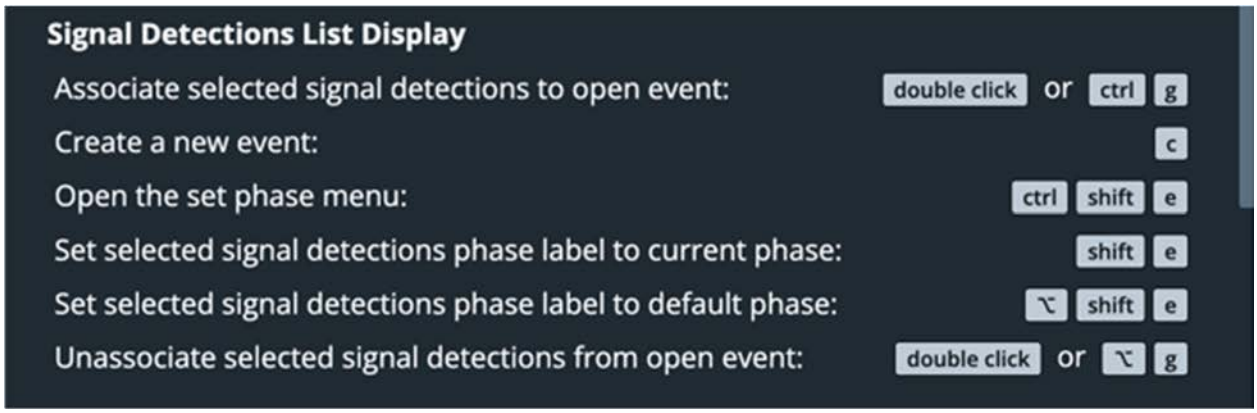


Figure 228. Signal Detections List Display Hotkeys.

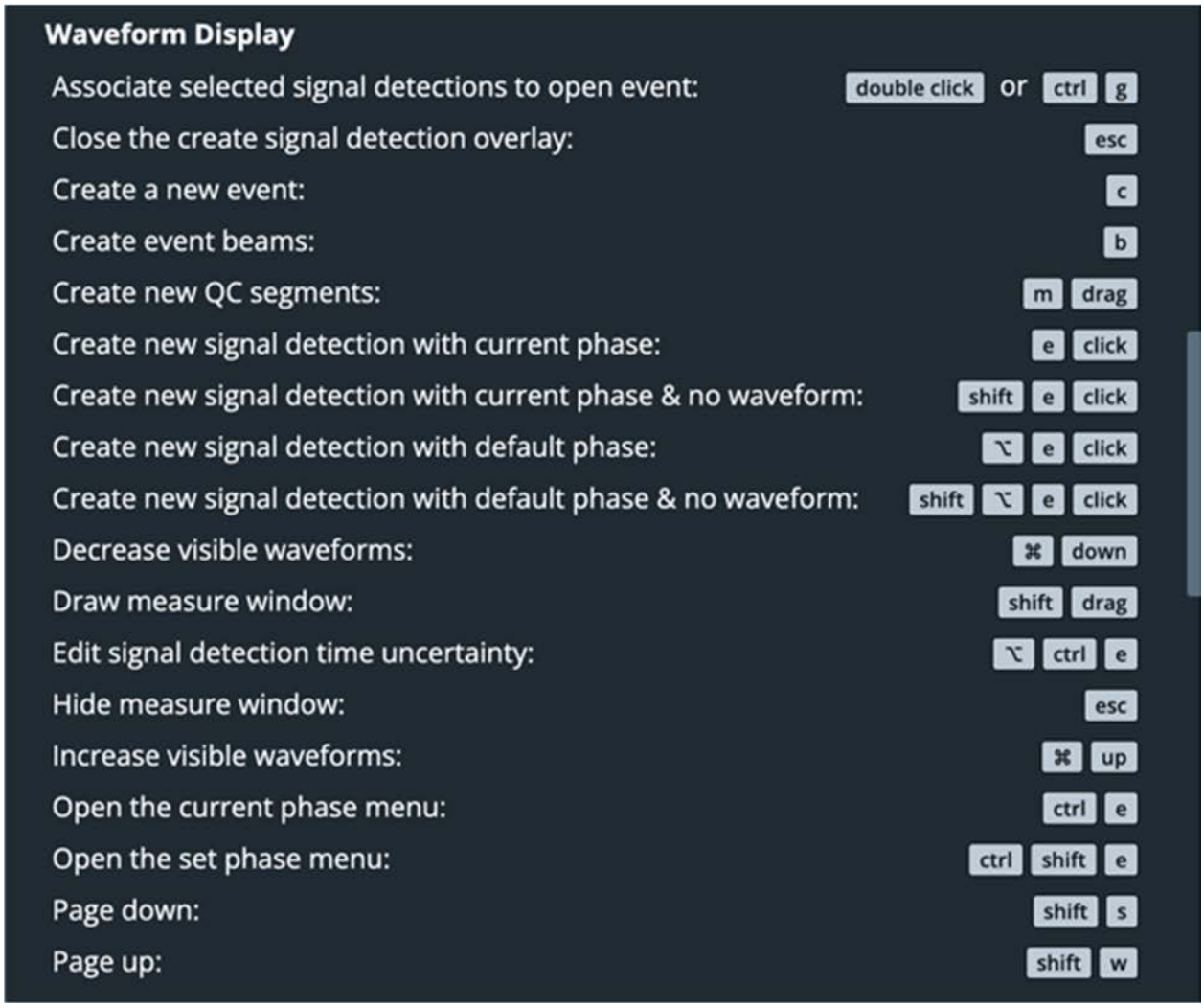


Figure 229. Waveform Display Hotkeys.

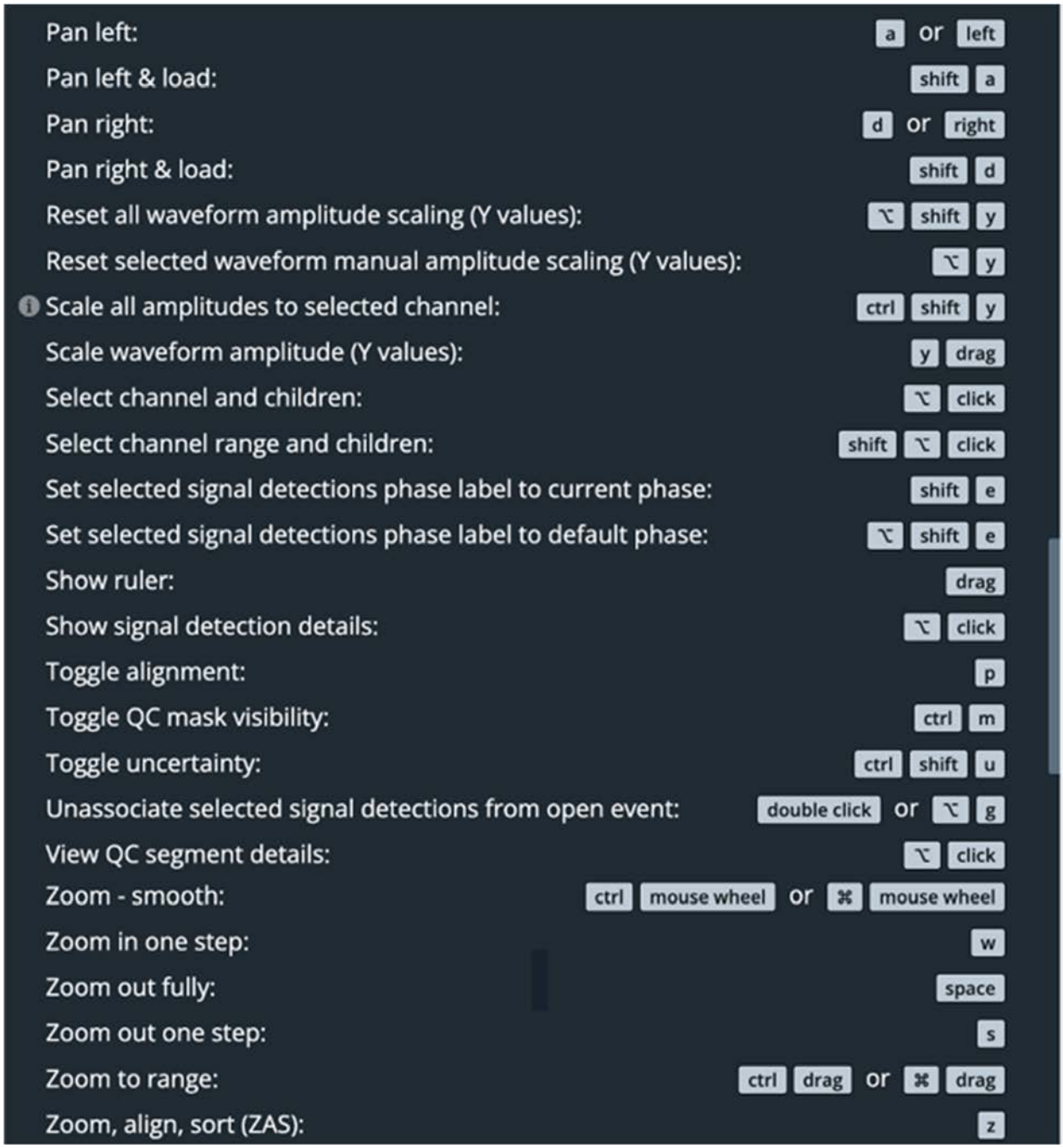


Figure 230. Waveform Display Hotkeys (Cont).

Figure 231. Workflow Display Hotkeys.

Appendix D. QC Segment Definitions

The following table lists available QC Segment Types (Section **Error! Reference source not found.**), their definitions, and relevant comments.

Table 9. QC Segment Types and Definitions.

QC Segment Type	Definition	Comments
Analyst Defined	QC issue marked by an Analyst.	An analyst defined QC segment may be of any QC segment type or may not have a QC segment type
Data Authentication	QC issue related to an authentication problem between an external station and GMS.	Does not have a QC segment type
Long Term	QC issue indicating a standing issue with a channel's waveform samples.	Does not have a QC segment type
Rejected	A special QC Segment Type indicating a QC Segment of another type was rejected by an Analyst.	Does not have a QC segment type
Station SOH	QC issue indicated in metadata acquired along with a channel's waveform samples.	Any of the following QC issues can result in a Station SOH QC segment: • Calibration – Waveform samples contain an instrument calibration signal.

		• Noisy – Waveform is contaminated by noisy waveform samples that cannot be attributed to background noise. • Sensor Problem – A QC issue limited to a single sensor (e.g., clipped, digitizer problem, etc.) • Station Problem – A QC issue affecting an entire station (e.g., power failure, vault door opened, etc.) • Station Security – A security related QC issue affecting an entire station (e.g., authentication seal broken, etc.) • Timing – Time values in the waveform samples are incorrect.
Unprocessed	A special QC Segment Type indicating that the waveform samples have NOT been processed for QC issues.	Does not have a QC segment type
Waveform	QC issue within waveform samples. Found by automatic processing.	Any of the following QC issues can result in a Waveform QC segment: • Aggregate – A QC issue resulting from the combination of several other QC issues. • Flat – Adjacent waveform samples do not vary in amplitude. • Gap – Waveform samples are missing. • Noisy – Waveform is contaminated by noisy waveform samples that cannot be attributed to background noise. • Spike – A short duration amplitude spike contaminating the waveform.

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