SMEI Display tools: User's Guide

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Contents

List of Figures

List of Tables

1 Introduction

This document describes the features of the display package for the Solar Mass Ejection Images (SMEI). This package is available as part of the SolarSoft environment.

This document is intended as a summary of the capabilities of the package. If you have never used the package before, then you should check out the SMEI Display tutorial for a guided tour of the major features of the package.

The Administrator's Guide gives information on how to install the package and make sure that the data are accessible.

1.1 Summary of Features

- Display SMEI images as a movie
- Select SMEI images by date.
- GUI tools to control display.
- CLI tools to control display.
- Tools for doing calculations on the images.

2 The command-line tools

Since on entering sswidl you will initially need to start the SMEI environment with a command-line procedure, it makes sense to provide a summary of the command-line procedures first.

smei_add_image Add one or more images to a sequence.

smei_calculate Make a new sequence derived from an old one.

smei_calc_menu Menu to make a new sequence derived from an old one.

smei_colour Change the colour table.

smei_compact Compact the images in a sequence.

smei_delay Set the delay between images.

smei_delete_image Delete an image from a sequence.

smei_docs Display the PDF documentation in a suitable viewer.

smei_image Get a specific SMEI_IMAGE from a sequence.

smei_image_header Get the FITS header from a SMEI_IMAGE.

smei_image_image Get the actual image data from a SMEI_IMAGE.

smei_image_info Return various information about a SMEI_IMAGE

smei_image_move Move an image within its sequence.

smei_image_print Send an image to a PostScript file.

smei_join Join two SMEI_SEQUENCEs into a single sequence.

smei_mask_bits Return the masking bit definitions.

smei_menu The main display menu (Section 3). N.B. the functionality of `smei_sequence` and `smei_show` are incorporated.

smei_movie Save a sequence as a movie (Section 5.3).

smei_null_index Select a colour index to use for missing data (including areas outside the sky).

smei_opts Set display and/or printing options.

smei_print Print a smei sequence.

smei_profile Create a profile from a sequence (Section 7).

smei_range Set the data range to display.

smei_restore Restore a `SMEI_SEQUENCE` from a file. (Formerly called `restore_sequence`).

smei_save Save a sequence to an IDL SAVE file.

smei_sequence Create a new sequence.

smei_seq_info Return various information about a `SMEI_SEQUENCE`

smei_show Display a sequence as a movie (Section 4).

smei_subtract_model Subtract a background model from the sequence.

smei_zoom Set the zooming options for a sequence.

Full details of the arguments for these procedures can be obtained either from the reference manual or by invoking the procedure with the help keyword set (e.g. `smei_movie, /help`).

3   The main menu

The simplest way of displaying data is to use the menu-driven interface, starting from the `smei_menu` procedure e.g.

```
$
$ sswidl
IDL> device, retain=2 ; This can be added to your site
                 ; startup file in SSW
IDL> smei_menu, ss
```

The argument (`ss`) to smei_menu will contain an object reference to the `SMEI_SEQUENCE` generated, this can then be accessed by another call to `smei_menu` or by any of the command-line tools.

Sequence name: allows you to enter a name for the sequence. This is purely a mnemonic tag and is not used in any way by the processing.

Sequence settings: shows the buttons which allow you to add images, save the sequence etc. In IDL versions 5.6 and later this is a tab selector, in 5.5 it is an exclusive button.

    Add images: generates a menu to allow you to specify which images you wish to incorporate into the sequence (Section 5.1). If you are starting with a new sequence, this will be the only usable option until you have added some images.
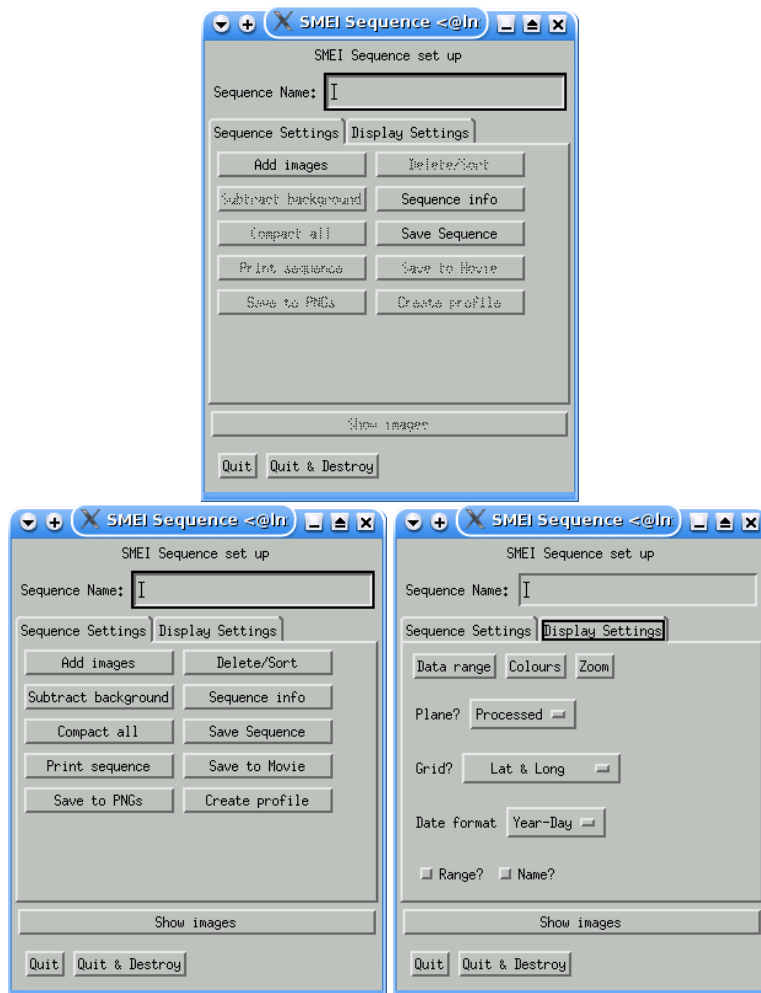
Figure 1: The main SMEI display environment menu. Top: As it appears when the sequence hasn't yet got any images; Lower left: The "Sequence settings" tab after images have been loaded; and Lower right: The "Display settings" tab.

Delete/sort image(s): Allows you to delete images from the sequence (e.g. if there are bad images), or to re-order the images. (Section 5.2)

Sequence info: Provide a brief summary of the sequence (how many images, time range covered etc.) (Figure 2[Right])

Subtract Background: generates a menu to allow you to select a background model to subtract from the sequence. Since this operates on the raw image planes but only updates the processed image, different models can be tried without needing to undo the subtraction of a previous model. (Section 5.4)

Compact all: Normally each image in the sequence is retained both in the raw form (with weighting values) and as a normalized image. This option allows you to remove the raw images and weights and is useful if long sequences are using too much memory.

Save sequence: allows you to save the sequence to an IDL save file. When you select this option, you will get the standard IDL file selection dialogue to choose a name to which to save the sequence.

Print sequence: Make a PostScript plot of all the images in the sequence. (Section 5.5)

Save to Movie: This will save the images of the sequence as a movie. There are several formats available depending on the availability of the programs needed to do the conversions. See section 5.3 for a more detailed discussion of the movie generation options.

Save to PNGs: This allows the images of the sequence to be saved to a sequence of PNG (Portable Network Graphics) files that can then be fed to a movie encoder (such as `transcode`) to make movies (Section 5.3).

Create Profile: This allows you to create radial or circumferential profiles from the sequence (Section 7). Owing to the needs of the profile menu, this option is not available for IDL 5.5.
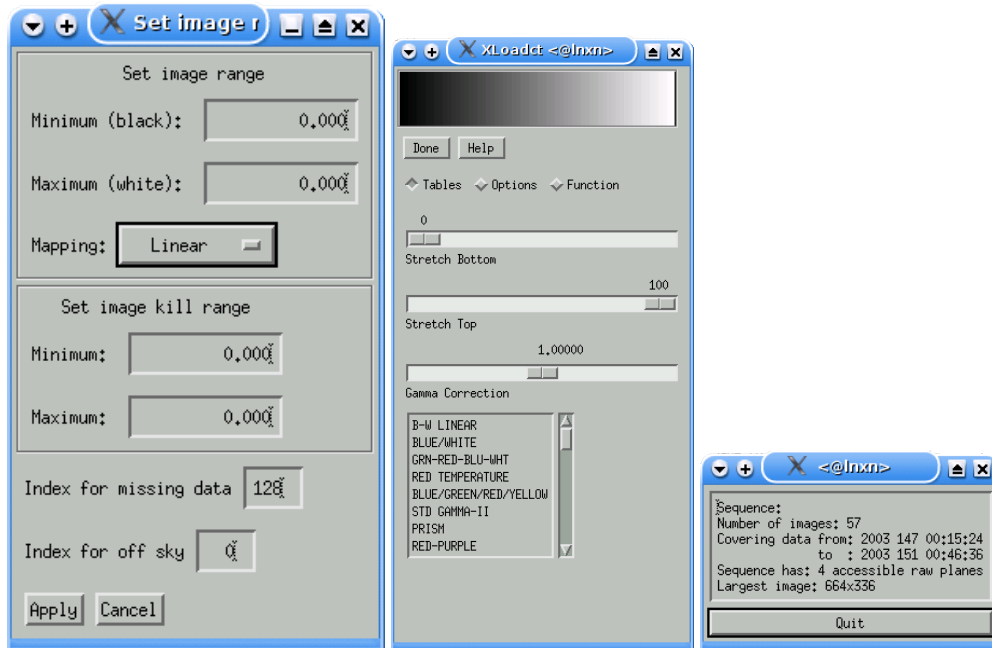

Figure 2: Left: The data range setting menu; Centre: The colour control menu and; Right: The information on a sequence.

Display settings: shows the buttons that allow you to adjust how the sequence will be displayed. In IDL versions 5.6 and later this is a tab selector, in 5.5 it is an exclusive button.

Data range: Sets the minimum and maximum values to display in the movie. Also allows you to select a colour index to use for pixels with no data, and to set a range of values to be considered as good data (values outside this range are treated as missing data) (Figure 2[Left], Section 5.6).

Colours: Use XLOADCT to adjust the colour table for the sequence (Figure 2[Centre]).

Zoom: Allows you to select a zoom factor for the main display window.

Mask: Allows the selection of contaminant flags to exclude. (Only shown if the data have contaminant flag information.)

Plane: Select which plane to show (this allows you to display any of the raw image planes provided that the sequence has not been compacted).

Centre: For "Rectangular" images select the direction to place at the centre of the displayed image. Not shown for other projections.

Grid: Controls the type of grid to add to the images displayed. "Lat & Long" adds a grid of ecliptic latitude and longitudes to the images, "Elong & PA" adds a grid of elongations and position angles to the images. The annotated versions add numbers to the grid lines.

Date format: Select the format in which to display the date in the top left corner of the image.

Range: Toggles whether to print the display range in the bottom left corner of the images displayed.

Name: Toggles whether to print the filename in the bottom right corner of the images displayed.

Show images: Display the images of the sequence as a movie (Section 4).

Quit, Quit & Destroy: Both of these destroy the menu and return you to the command line. "Quit & Destroy" destroys the sequence before exiting (if no argument is given to smei_menu then the sequence is always destroyed on exit as the sequence would become unreferenceable).

For simple use, you just need to select some images and then show them.

4 The Movie Display Window

4.1 Basic controls

Once you click on "Show images" from the main menu, you will see a movie of the sequence (Figure 3). To control it, you need to click with the **right** mouse button in the image area. This generates a context menu which allows several options:

Pause/Resume When the movie is running, then pause it; when it is paused, then resume normal running.

Reverse/Forward Change the direction of playing the movie.

Change colours Run XLOADCT to update the colour table.

Faster Halve the pause between frames.

Slower Double the pause between frames.

Grid Generates a pop-up menu to change the type of coordinate grid added to the images.

Centre Change the central PA for rectangular projection images, not present for other formats.

Date Format Change whether the date is displayed on the plot, and its formatting.

Add/Drop Filename change whether the filename is shown on the plot.
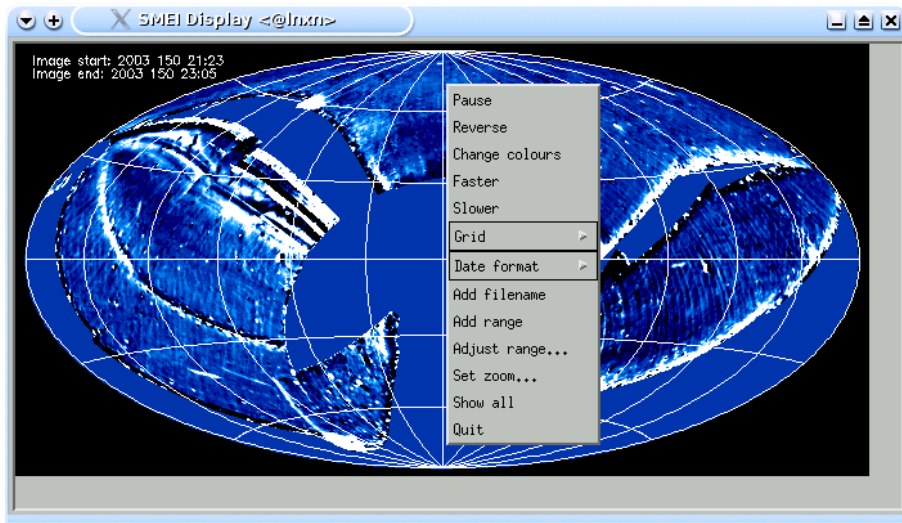
Figure 3: The movie display window, with the context menu showing.

Add/Drop Range change whether the data range is shown on the plot.

Adjust Range bring up a menu to alter the range of values to be displayed.

Set Zoom bring up a menu to change the zoom factor at which the images are displayed.

Masking Bring up a menu to select the contaminant masking options. Only for NSO version 2 pipe images.

Show all Clear all image hiding flags.

Quit quit the movie display.

Figure 4: The movie display in the paused state.

When the movie is in the paused state a number of extra controls are added below the image display:

Mark points instead of bringing up the context menu mouse clicks are used to mark the positions of features on the image. (See the detailed description in section 4.2).

Print Send the current image to a PostScript file (Section 4.1.1).

Dump PNG Dump the currently-displayed image to a PNG file.

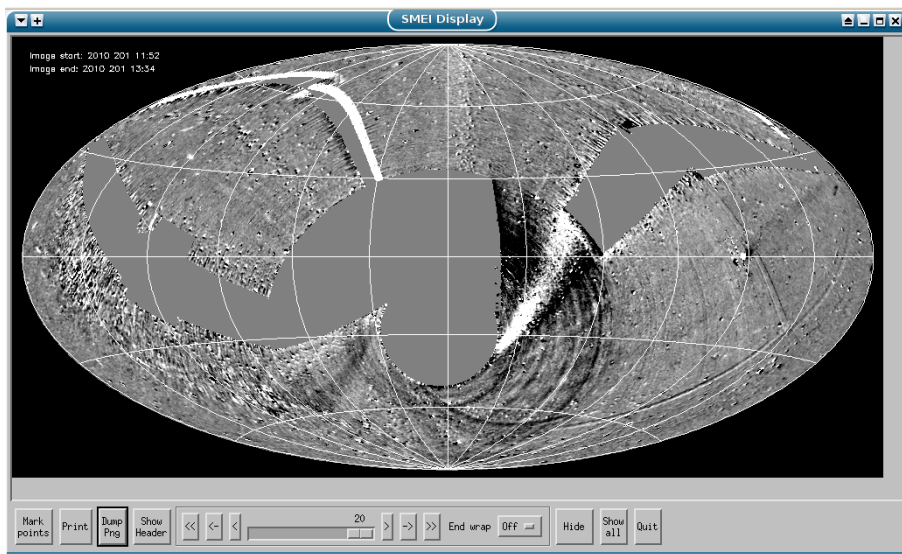$<<$ Resume playing the movie backwards.

$< -$ Go back to the first image.

$<$ Go back to the previous image.

The Slider can be used to move quickly to any position in the movie. The number of the current image is indicated above the slider.

$>$ Go forward to the next image.

$- >$ Go forward to the last image.

$>>$ Resume normal play mode.

End wrap Select whether to wrap around the ends of the sequence when scrolling through it.

Hide/Unhide Toggle whether the current image is displayed in movie mode. The single-step keys when the movie is paused ignore this setting (otherwise you would never be able to unhide images individually).

Show all Clear all hidden flags in the current sequence.

Quit Destroy the movie display and return to the main menu or the command line.

Clicking with the **middle** button of the mouse on a paused movie invokes the zoom tool which allows you to examine a region of the image in detail (section 4.3).

A **Left**-click with a control or shift modifier will print details of the point beneath the cursor in the same format as that used in marking mode (section 4.2), but without recording the points.

In addition, if you have a wheel mouse; then the wheel can be used to move back and forth through the paused movie, honouring the hidden flags. With the normal mapping, pulling the wheel towards you will go forwards, pushing it away will go backwards. For wheels with a left-right movement, this should also work. Navigation can also be accomplished with the cursor arrow keys:

Forward arrow Move to next image.

Back arrow Move to previous image.

Up arrow or Page Up Move to first image.

Down arrow or Page Down Move to last image.

A full list of the mouse button functions in all modes is given in Table 1.

Button	Playing	Paused	Marking
1 (Left)	None	None	Mark point
Ctrl-1	None	Display point	Mark point
2 (Centre)	None	Zoom View	Suspend marking
Ctrl-2	None	Zoom View	Suspend marking
3 (Right)	Context menu	Context menu	Quit marking
Ctrl-3	Context menu	Context menu	Quit marking
4 (Wheel away)	None	Previous image	Previous image
Ctrl-4	None	Previous image	Blink current & previous
5 (Wheel towards)	None	Next image	Next image
Ctrl-5	None	Next image	Blink current & next

Table 1: The mouse actions on the SMEI display tool image area.
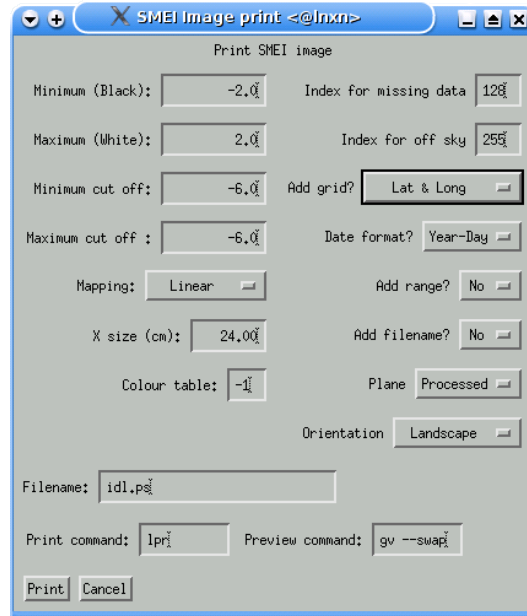

Figure 5: The menu for printing the current image of a sequence

4.1.1 Printing images

The image printing menu allows you to set the options for printing the current image of a sequence. Most of the options are either inherited from the current sequence display settings (Section 3) or the sequence print settings (Section 5.5).

Minimum (Black) & Maximum (White) The range of data values to display.

Minimum cut off & Maximum cut off The "kill" range.

Mapping Linear or logarithmic scaling of the display.

X size (cm) The X dimension of the displayed image (Y is set by the need to preserve aspect ratio).

Colour table The colour table to use, an IDL colour table number or −1 for monochrome postscript.

Index for missing data & Index for off sky The colour indices to use where data are missing and for areas of the image outside the sky.

Add grid The type of grid to add to the plot.

Date format What form of date to add to the image

Add range Whether to add the data range on the file.

Add filename Whether to add the FITS file name to the image.

Plane Which image plane to print.

Orientation Select Landscape or portrait page orientation or encapsulated postscript.

Filename The name for the postscript file.

Print command & Preview command The commands to send the file to the printer and to view it on the screen.

Print Make the postscript file.

Cancel Quit and forget all about it.

4.1.2 A note on display rates

The speed of the movie is set by a delay between images (for the technically inclined, when an image is displayed a timer event is sent which triggers the display of the next image). This means that the actual frame rate is the determined by sum of the delay and the draw time.

In order to reduce the draw time, when an image is displayed, it is copied to a pixmap window and flags are set. Then when it is displayed again, the pixmap is copied to the display window rather than redrawing the image from scratch. If changes are made to the drawing options during the display of the movie, then the pixmap flags are cleared and the images are redrawn from scratch. Whether changing the colour table clears the pixmaps depends on the graphics visual that you are using. As a result of this the first full cycle of a movie from the start or after a change to the options will generally be significantly slower than subsequent cycles, especially if the software is being run on a remote machine.

4.2 Mark mode

Mark mode allows you to record locations on an image and then save them to a file or to a variable at the top ($MAIN$) level. When in mark mode, the cursor is changed to an arrow and the "Mark points" button is desensitized.

When the "Mark points" button is clicked, a menu is produced to select the marking options. These are

Marking mode The normal method of marking is to click each point. If click and drag is selected, then pressing the left mouse button starts to trace a leading edge, releasing it ends the trace.

Decimation factor In drag marking mode, recording every event tends to produce too many points, therefore this option allow you to mark only every n^{th} point. The default is every fifth point. If you tend to drag quickly, a lower value may be useful.

Show points with You can select whether to show the points marked with a plus sign, a dot or nothing (the default).

Pressing the "Cancel" button cancels the mark mode entry, clicking "Apply" starts marking.
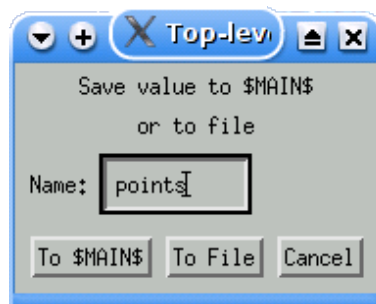

Figure 6: The options for saving the marked points of a height-time profile.

In mark mode, the context menu is not available but the controls in the paused bar are still active to allow you to move between images. The mouse buttons are remapped as:

Left Record the current cursor position. (In click and drag mode, pressing initiates tracing a feature and release ends it).

Centre Exit mark mode without saving or destroying the recorded positions. (I.e. if you re-enter mark mode new positions will be added to those already marked).

Right Exit mark mode and save or destroy the list of recorded positions. This will generate a menu (Figure 6) that allos you to save the measurements to a variable or to a file.

Wheel Move back and forth through the sequence (i.e. the same behaviour as in normal paused mode).

Ctrl or Shift Wheel Blink the current image with the next image or the previous image. A left-click while in this mode records the position for the current image and stops the blinking. An unmodified wheel event also stops the blinking.

Any button that resumes playing the movie will also exit mark mode, keeping the recorded locations.

If the values are saved to a variable, it is an array of structures of type SMEI_POINT, which has the fields listed in Table 2.

When output to a file, the first line is a header listing the column contents and then the contents of the above structure, 1 line per point.

Name	Type	Contents
DATE	DOUBLE[2]	Julian Date of the start and end of the image
LONGITUDE	FLOAT	The solar ecliptic longitude of the marked location.
LATITUDE	FLOAT	The ecliptic latitude of the marked location.
RA	FLOAT	The Right Ascension of the marked point.
DEC	FLOAT	The Declination of the marked point.
VALUE	FLOAT	The value of the image at the point marked.
P	FLOAT	The perpendicular distance from the line of sight to the Sun = sin(elongation)
ELONGATION	FLOAT	The elongation angle of the marked point.
PA	FLOAT	The position angle of the marked point measured anti-clockwise from ecliptic North.
X	LONG	The column number of the marked pixel in the image.
Y	LONG	The row number of the marked pixel in the image.

Table 2: The fields in the SMEI_POINT structure.

4.3 The zoom tool

The zoom tool (Figure 7) allows you to examine part of an image in detail. It is invoked by clicking on the image in a paused movie with the **middle** button of the mouse. The initial display shows a region centred on the location clicked and with a zoom factor of 4.

There are a number of explicit controls and in addition the display can be controlled with the mouse:

Zoom Factor: A slider that allows you to adjust the zoom factor from 1 to 25.

Refresh: Redraws the image from the current main display (e.g. if you are single stepping through the sequence and want to focus on the same region of a new image).

Smooth: If this is checked, then IDL's REBIN function is allowed to use its internal interpolation to smooth the zoomed image, by default this is disabled.

The mouse buttons have the following meanings:

Button-1 *(Usually the left button)* Recentre the zoomed image to the point clicked.

Button-2 *(Usually the centre button)* Recentre the zoomed image and decrease the zoom factor.

Button-3 *(Usually the right button)* Recentre the zoomed image and increase the zoom factor.

Button-4 *(Usually wheel away)* Decrease the zoom factor while maintaining the centring of the image.

Button-5 *(Usually wheel towards)* Increase the zoom factor while maintaining the centring of the image.

For the operations that change the zoom factor, a plain click changes the zoom by 1, control-click changes by 2, shift-click by 5 and control-shift- click by 10.

If the zoom factor exceeds 25, the slider is hidden. The zoom factor is limited to the range from 1 to the size of the zoom window (512).

If you centre-click on a paused sequence while the zoom tool exists, then the existing zoom tool is updated to the new location (retaining zoom factors etc.).
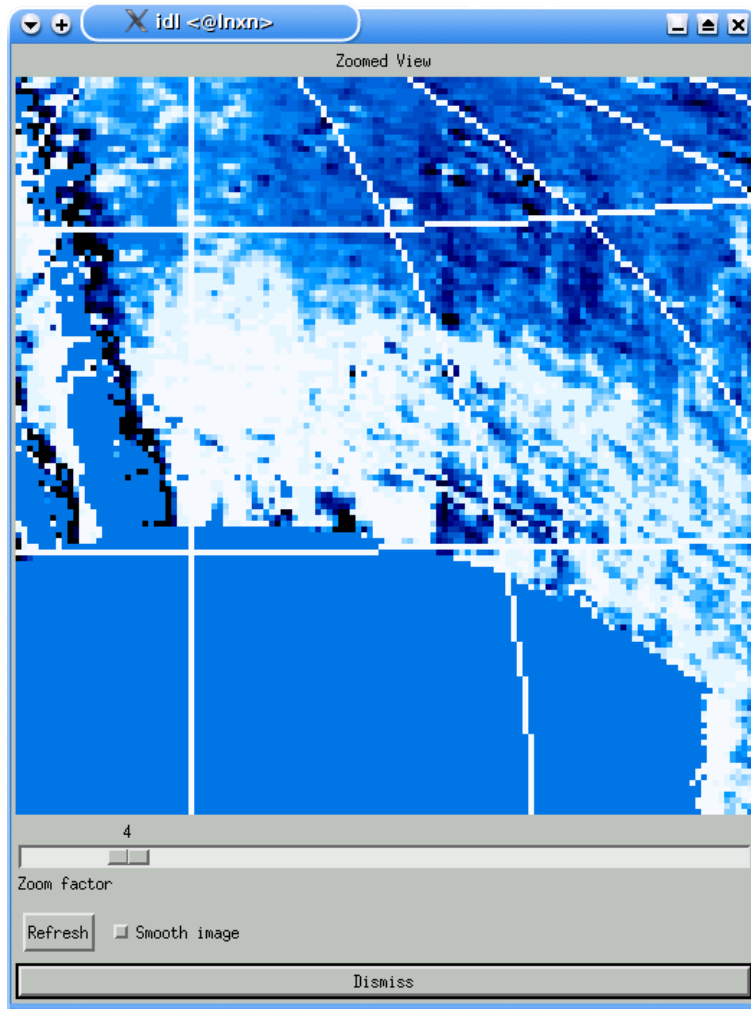
Figure 7: The zoom tool for examining regions of a SMEI image.

The difference between setting a zoom factor and using the zoom tool: The zoom tool and zoom factors for the main display window work in quite different ways. The zoom of the main display can be a reduction as well as an increase and is applied **before** the annotations are added. This type of zoom can be used in movies and the text and grids look smooth, although the menu limits it to 0.5, 1, 2, 3, 4, the command line tool can apply any integer or 1/integer zoom. The drawback is that very large pixmaps are generated to store the image for display (in fact with a large zoom it is quite easy to exceed the limit of 32k by 32k pixels). The zoom tool on the other hand reads the main display window and zooms a section of it, thus text and grid lines are also zoomed and so will look blocky. The zoom tool does not update when the main image is updated, only when an update is requested.

5 Other Major Menus

5.1 Adding images to a sequence.

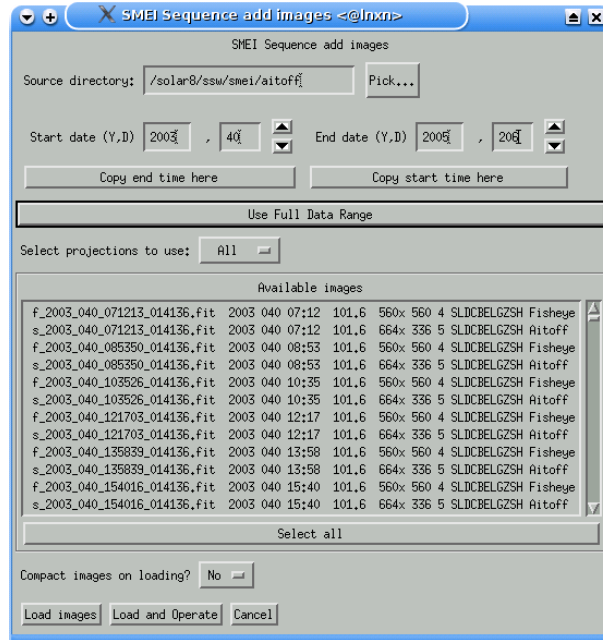In order to make a movie you first need to select some images to display.

Figure 8: The menu for adding images to a SMEI_SEQUENCE

In the current version, a single directory tree is searched for images. The default is given by the setting of the SMEI_IMAGES environment variable, or the current directory if SMEI_IMAGES is not set. This may be changed by entering a new value in the "Source directory" text box, or by clicking on the "Pick..." button and using a GUI to select a directory. By default, SMEI_IMAGES is set to ${SSWDB}/smei/aitoff, this can be changed in your site settings if desired. N.B. The *first* time you run the selector, or when you change the path, there will be a possibly substantial delay while the system generates a list of the available images. The images may be plain fits files or compressed with gzip or bzip2, although in the latter case searching and reading them will take considerably longer as bzip2 has to be spawned, while gzip files can be read directly.

The time range over which to look for images may be specified in year and day of year form, by entering values in the "Start date" and "End date" boxes. If you wish to revert to seeing all available data, click on the "Use Full Date Range" button.

The Copy end time here and Copy start time here buttons allow you to copy the current end time to the start time or *vice versa*. The arrow buttons to the right of the entry fields allow you to increase or decrease the start or end time by 1 day at a time.

The "Select projections to use" droplist allows you to restrict the images displayed to those in the selected projection. N.B. A sequence may only contain a single projection.

The list of available images displays the following information about each image:

- The file name

- The start time to the nearest minute (Year, day, hour, minute).

- The duration of the image in minutes.

- The size of the image (X and Y)

- The processing flags, this is a ten character string with the following fields.

  S Saturated images excluded

15

L Large-scale flat field applied

D Dark offset removed

C Cosmic rays or spikes filtered

B Bright object (Moon and planet) removal

E Camera equalization applied

L Frame pointing corrections applied

G Global pointing correction applied

Z Zodiacal background removed

S Stellar background removed

H Hot pixels masked

A dash indicates the unset state, a dot indicates that the information is not available.

- The image projection. At present two projections are recognized: "Aitoff", the Hammer-Aitoff projection we have been using since the start of the mission; and "Fisheye" the equiangular fisheye projection.

The list allows the selection of multiple images, following the normal selection rules for IDL list widgets, namely:

- A simple click selects the image clicked on and deselects all others.

- Clicking while holding down the Control key toggles the selection of that image. The state of other images is unchanged.

- Clicking while holding down the Shift key, selects all images between the previous click and this click.

- Dragging the mouse over a range of images while holding down the left button will select the range dragged over. (Unix/X-Motif only).

- The "Select all" button below the list selects all files currently displayed.

If you have a very long sequence of images then you may wish to save memory by compacting the images as you load them. As a guide, a compacted image uses about 2Mb while an uncompacted image uses about 2Mb+2Mb per raw image plane (this may be from 2 to 5 depending on the date of processing). Some image operations require uncompacted images.

The "Load images" button destroys the menu and reads the images into the sequence. The "Load and Operate" button allows you to apply an image calculation (e.g. running differences) to the sequence on loading (see section 6 for details). The "Cancel" button is used to abort the operation.

5.2 Deleting and sorting images

When you choose the Delete/Sort button on the main menu the delete/sort menu (Figure 9) is generated. This allows you to do a number of things.

Sort If you click on this, the images are sorted into the correct time sequence. Useful if you add some images earlier than the start of the original sequence.

Up & Down Both of these are enabled if and only if a single image is selected. Up moves the image one place earlier in the sequence, and Down moves is later.

Delete If one or more images is selected, then the selected image(s) are deleted from the sequence. The multiple selection rules are the same as for the Add Images menu (5.1).

Delete all Deletes all the images in the sequence (*Dangerous*).
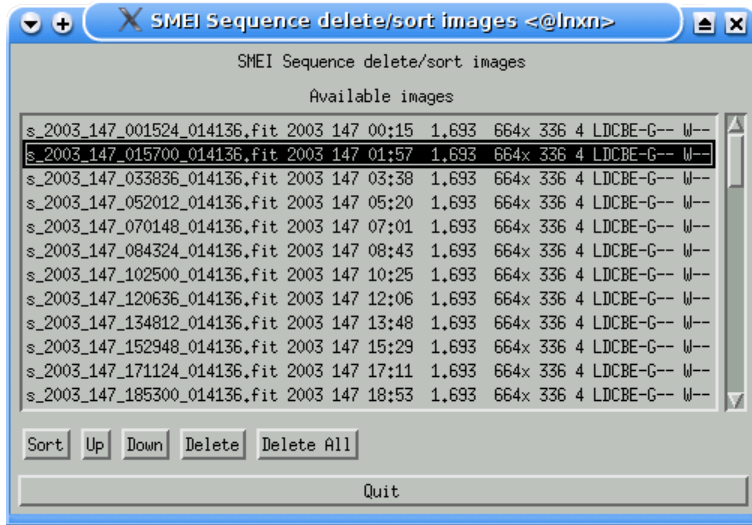
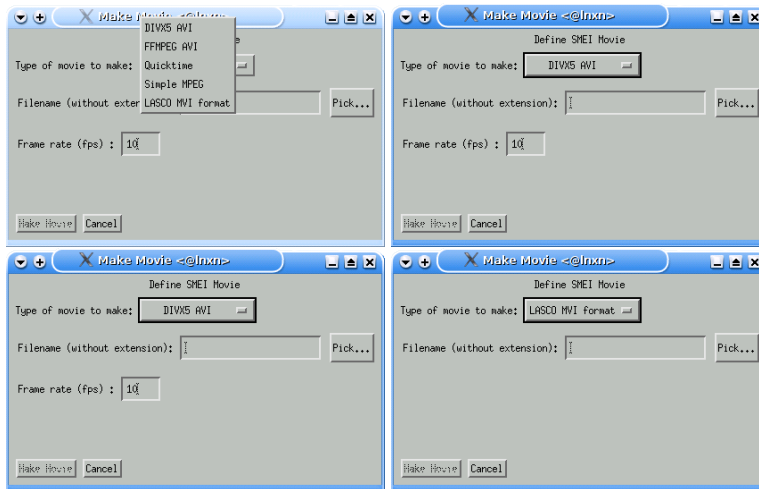Figure 9: The menu for deleting and sorting images.

5.3 Making Movies

Figure 10: The movie generation menu in its various guises. Top left: showing the codec selection pull-down; Top right: The options settings for FFMPEG movies; Bottom left: the options for plain mpeg and; Bottom right: the lack of options for MVI movies.

The SMEI display tools allow you to save a sequence to a movie file, provided you have suitable encoding software installed on your computer. This facility is accessed from the main menu via the Save to movie button, which generates the movie menu (Figure 10).

The selection of codecs depends on what encoding software you have installed, but the full rnge supported is:

DIVX5 AVI MS AVI video, using the DIVX 5 codec, requires `transcode`. Requires a frame rate to be specified.

FFMPEG AVI An AVI video using the ffmpeg encoder and the mpeg4 codec. This also requires `transcode`. Requires a frame rate to be specified.

Quicktime Apple quicktime format with the mjpa codec, also requires `transcode`. Note that this format has rather poor compression. Requires a frame rate to be specified.

MPEG A very basic mpeg format, requires `mpeg_encode`. If you do not have one of the PBM packages installed, then depending on your X visual you may only be able to make greyscale movies. Reqires a quality setting and also a frame duplication factor (this is because the minimum frame rate is 25 frames per second which is usually too fast for SMEI movies).

MVI The LASCO MVI movie format. This doesn't have any compression, but may be useful if you are only interested in playing from within IDL, doesn't need any external software.

All codecs require you to give a filename without the extension.

The `smei_movie` routine used from the command line allows the selection of alternative codecs for the ffmpeg and quicktime formats, however you should be aware that not all of these work satisfactorily.

For maximum control, you can save the sequence to PNG images and then run an encoder manually (Figure 11). You need to specify a directory in which to put the images and a filename stem (each image will

Figure 11: The menu for saving the sequence to a set of PNG files.

then have a name generated by adding a number and `.png` to that stem).

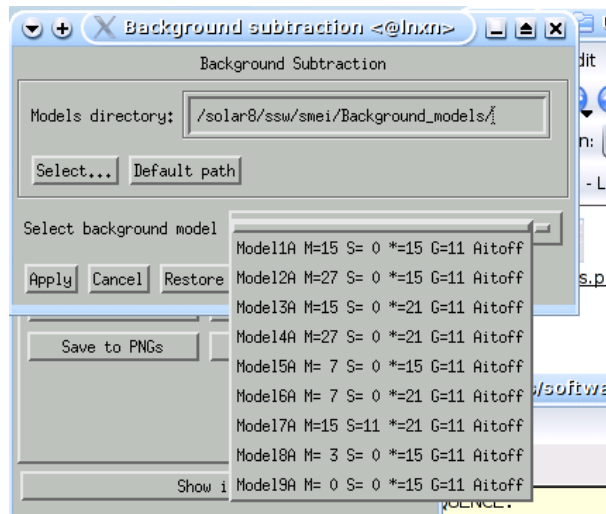## 5.4 Background Subtraction

Figure 12: The menu for selecting the background models to subtract.

In order to see transient in the SMEI data, it is necessary to remove the background signals. This can be done with running differences (Section 6) or by removing a background model.

The model selector menu allows you to choose from the available models (Figure reffig:background). Normally they should be stored in the default path of `$SSWDB/smei/Background_models`, but if you have some stored elsewhere the upper part of the panel allows you to choose a new path.

The models are generated from a long-term sky map which gives the contribution of the galaxy, and a solar & stellar component derived from "daily" median images. The parameters are as follows:

M= The length of the median (in days) used to smooth the daily medians in making the solar component.

S= The length of the smoothing (in days) used to smooth the daily medians in making the solar component.

∗**=** The linear size of the high-pass filter (in pixels) used to separate the stellar component from the daily medians.

G= The linear size of the low-pass filter used to separate the stellar and galactic components from the long term map.

For transients the short smoothing models (8 & 9) are recommended.
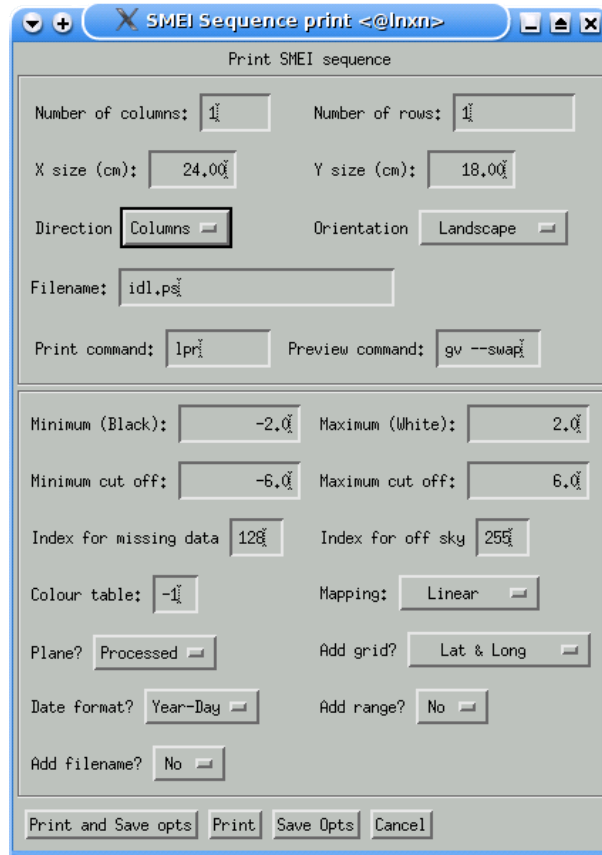
5.5 Printing

Figure 13: The sequence printing menu

The sequence printing menu (Figure 13) is divided into two parts: The upper area controls the page layout, and the lower the image formatting.

The page layout options are:

Number of columns & Number of rows These boxes allow you to select how many images to place on each page.

X size (cm) & Y size (cm) The allow you to set the size of the drawing area on the page.

Direction Select whether to arrange the images in columns or in rows.

Orientation Select Landscape or Portrait orientation on the page, or select encapsulated PostScript.

Filename Choose the name of the file to which to write the PostScript plot.

Print command & Preview command Select the command for sending the file to the printer and the command for viewing it on the screen.

The formatting options mostly default to the same values as the display settings. The available options are:

Minimum (black) & Maximum (white) Set the data display range.

Minimum cut off & Maximim cut off The kill range.

Index for missing data & Index for off sky Select the colour indices for missing or killed data and for areas of the image outside the sky.

Colour table Select the colour table, the numbers are IDL colour table indices, the special value of -1 indicates use monchrome postscript (rather than colour postscript with a greyscale colour table).

Mapping Select linear or logarithmic mapping (not useful for background-subtracted or running-difference images).

Plane Select the image plane to display

Add grid Select they type of grid to plot.

Date format Select what format to use for the dates on the images.

Add range Select whether to add the data range on the images.

Add filename Select whether to add the names of the FITS files to the images.

Print and Save opts Generate the postscript file and also save the layout options (plus the colour index selections).

Print Generate the postscript file but don't save any changes to the layout options.

Save Opts Save the layout options, but don't generate the postscript file.

Cancel Forget all about it.

5.6 Data range

The data range menu (Figure 2[Left]) allow you to set the range of data displayed.

Minimum (black) & Maximum (white) Select the range of values from black to white. For background-subtracted or running difference images values in the range -0.5 to 0.5 up to about -3 to +3 are probably useful.

Mapping Select linear or logarithmic mapping (only useful for raw data planes).

Kill range The kill range is used to exclude regions of bad data whose values lie well outside the range of interest. For most cases a range a few times the display range is suitable. Values outside the specified raneg are treated as missing data.

Index of missing data & Index for off sky Select colour indices for regions of missing (and killed) data and for areas of the image that are not part of the sky map.

Table 3: The operators recognized by the calculation framework.

+	−	*	/	^	>	<	#	##	mod
not	or	and	eq	gt	lt	le	ge	ne	xor

Table 4: The special operators defined in the SMEI operations language

Operator	Function
%mean	Compute an average of all the images in the argument list
%sum	Compute the sum of the images in the argument list
%min	A pixel by pixel minimum of the images in the argument list
%max	A pixel by pixel maximum of the images in the argument list
%cat	Concatenate the arguments (restricted to sequence arguments only)
%median	A median of all the images in the argument. (N.B. this is memory-intensive as an image block must be created).
++	A synonym for %mean.

6   Calculations

Calculations on images producing other images can be done using the "SMEI calculation" language, or by combining the calculation routines manually.

6.1   Calculation Language

This is a very simple language with a somewhat LISP-like syntax that allows images and numbers to be combined using any combination of IDL operators and functions.

An operation is specified in the form of:

```
( <operator> <argument> ...  )
```

An operator is: an operator from the IDL language (Table 3); a function known within the current IDL environment; or a special operator (Table 4). The restrictions are that the result must be of the same size as the input image.

Most of the special operators (currently all except %cat) generate a sequence with a single image.

An argument is one of: another rule; an argument descriptor; an explicit numerical value or an IDL keyword setting. At least one of the arguments must be an argument descriptor or another rule.

Numerical values are denoted by a preceding hash (#) sign. (e.g. #7.4). The treatment of numerical values depends on their dimensionality:

scalar The number is inserted in every calculation.

1-d array The nth element of the array is applied to the nth image in the sequence.

2-d array The array is used whole for each calculation.

3-d array The `[*,*,n]` sub array is used for the nth image of the sequence.

A descriptor is a string containing: the name of the sequence or image (under normal circumstances this will be the name at the `$MAIN$` level in IDL); a plane number in braces (e.g. {3}) the special number of {−1} instructs the interpreter to pass the image object to the processing routine rather than extracting the image; and a range specifier in square brackets. The range specifier consists of up to 3 numbers separated by colons, the first is the start image (default =0), the second is the end image (default = last image) and the last is the step length (default = 1). Any of these may be omitted, if the final image is negative that means that many from the end.
Examples of valid range specifiers:

`[5]`	Image 5 to the end of the sequence
`[:-1]`	Start of sequence to the penultimate image.
`[::2]`	All the even numbered images (starting at 0)
`[0:4]`	The first 5 images (same as `[:4]`)
`[0:0]`	The first image only.
`[1:5:2]`	Images 1, 3 and 5.

IDL keywords are only valid when the operator is an IDL function call. They are identified by the presence of a slash character or an equals sign. These are then passed directly to the function.

Descriptors, keywords and numerical values may not contain spaces.

6.2 Examples

Running difference

This code generates a running difference sequence.

```
(- ss[1] ss[:-1])
```

Subtract each image from its successor. Obviously, a running ratio can be similarly generated.

Edge enhancement

This uses the SOBEL edge-enhancement routine from the IDL users' library to make an edge enhanced version of a sequence.

```
(+ ss (/ (sobel ss) #5))
```

The resulting images are `i + sobel(i)/5`, where `i` is any image of the sequence.

Subtract a "Pre-event image"

This program subtracts the average of the first 3 images of the sequence from the rest.

```
(- ss[3] (%mean ss[0:2]))
```

6.3   Using it

Command line

From the `IDL>` prompt, the calculation tools are most easily accessed by calling the `smei_calculate` procedure. This allows you to specify either a file with the program, or to pass the program as a string array. In addition, if the sequence names in the program file do not match those in your environment you can map your names to those in the program; e.g. suppose the running difference example above is in `rdiff.sop` but your sequence is called `may10` rather than `ss`, then you could use:

```
smei_calculate, may10d, file='rdiff.sop', ss=may10
```

To make a running difference sequence from it. To give an explicit program, you could use:

```
smei_calculate, may10d, "( - may10[1] may10[:-1] )"
```

If a file is specified without a directory, then if it is not found in the current directory the directories in the path specified by the `SMEI_OPS_PATH` environment variable are searched. The default setting of this is: `${HOME}/sop_files:${SSW}/smei/bham/sop_files`.

The latter currently contains the following programs:

rdiff.sop A simple running difference.

rratio.sop A running ratio.

rdiff5.sop A running difference followed by a 5×5 median filter.

diff1.sop Subtract the first image of the sequence from all the others.

base5.sop Subtract the average of the first 5 images from the remainder.

All these programs operate on a single sequence called `ss`.

Menu based

The `smei_calc_menu` procedure provides a simple GUI interface for the calculator (Figure 14). This allows you either to pick a program file, or to enter a program. Like the command-line version this procedure allows you to use keywords to map your sequence names to those expected by the program.

6.4   Explicit construction

It is also possible to construct calculations explicitly. There are two main routines to do this:

make_smei_op

This is the procedural version. It takes an operator and up to 10 arguments and unlimited keywords.

The call is:

```
make_smei_op, seq, operator, arg0[, ... arg9] [keys]  $
      [,/return_operator][,get_level=get_level]
```
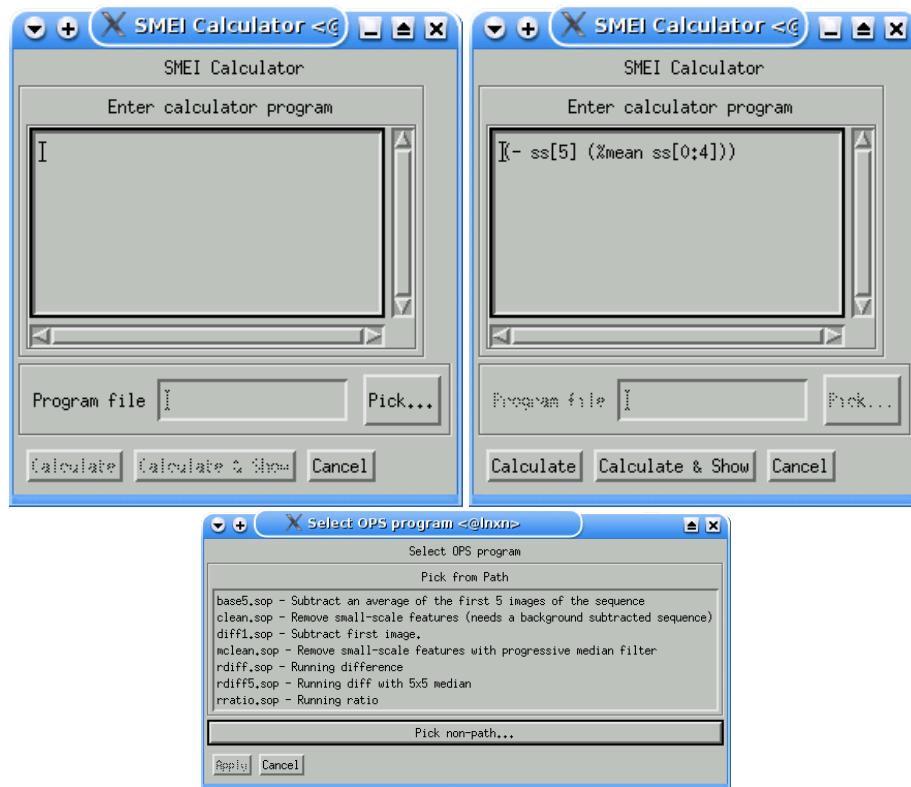
Figure 14: The SMEI calculator menu. Left: With an explicit program (to subtract the first image from the rest). Right: With a program file selected. Below: The selector for choosing a predefined program.
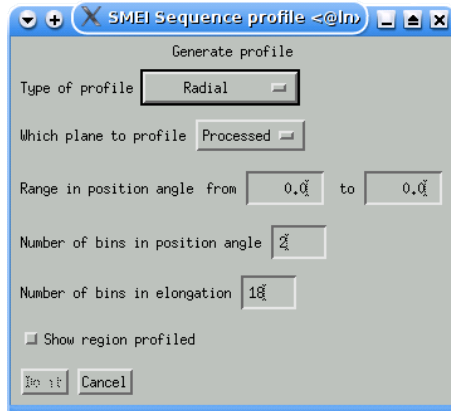
Figure 15: The menu for generating profiles.

Where

seq is a named variable that will contain the SMEI_SEQUENCE object generated.

operator is a string with the operator, function or special operator.

arg0...arg9 are 1 through 10 arguments which may be descriptors as used in the definition language, numerical constants or expressions or variables containing SMEI_* object references.

/return_operator If this is given, then seq is a SMEI_OPERATOR object rather than a SMEI_SEQUENCE object.

get_level=get_level Use this to specify an IDL calling level at which to search for objects specified by descriptors – this is normally only used by the definition system to resolve names reassigned by keyword.

keys Any other keywords given are passed directly to the IDL function called (they are ignored for true operators or special operators).

This method of performing calculations allows you to do some things that are not possible via the language interpreter, for example using function calls to generate numerical arguments.

make_smei_opf

This is a functional wrapper for the same routine. Instead of the `seq` argument, the sequence is returned as a function return value. This is useful for concatenating operations.

7 Profiles

The profile generator allows you to make radial or circumferential profiles of the images in a SMEI sequence. The main menu (Figure 15) allows you to select the type of profile and the range of position angle (for radial profiles) or of elongation (for circumferential profiles); in either case the units are degrees, position angle is measured anti-clockwise from the north pole. In addition you can select how many bins in each direction will be generated. Setting the "show region profiled" checkbox causes the region being profiled to be shown as the first image is processed. By default the profile is made of the same image plane as that selected for display, but the "Plane" selector allows you to change it.
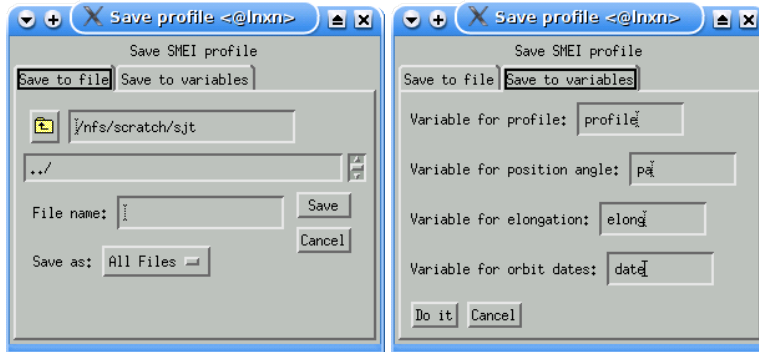
Figure 16: The menu for saving profiles. Left: saving to a file, Right: saving to top-level variables.

After the profile has been generated, you will be asked how to save it. This can either be to an ASCII file or to named variables at the top ($MAIN$) level in IDL. The file has the following format:

1. The dimensions of the profile, in the order: position angles, elongations and number of images.

2. The position angles, 12 numbers per line

3. The elongations, 12 numbers per line

4. The start and end JD of the image

5. The values in the profile for that image, 12 numbers per line.

6. The previous 2 lines are repeated for each image in the sequence.

Whether a profile is radial or circumferential, the indices of the array are always in the same order: First position angle, Second, elongation and Third image number.

A img_hdr.txt

If the image loader has to read the headers of every image available, it takes ages. Therefore it is possible to place a summary of the contents of the images in a directory in a text file (`img_hdr.txt`), then the loader only has to open any images that have been added to the directory since `img_hdr.txt` was updated.

The `mk_imghdrtxt` procedure generates the `img_hdr.txt` file, which has the following fields:

Field #	Contents	Format	Field #	Contents	Format
1	Filename	A35	6	Image duration	F7.3
2	Start Year	I5	7	X Size	I5
3	Start Day	I4	8	Y Size	'x',I4
4	Start Hour	I3	9	Flags	' ',A7
5	Start Minute	':',I2	10	Projection	' ',A7

A suitable format to read a line in IDL or FORTRAN would be:
`(A35,I5,I4,I3,1X,I2,F7.0,I5,1X,I4,1X,A7,1X,A7). e.g.:`

IDL:

```
filename=''
y0=0 & d0=0 & h0=0 & m0=0
dur=0. & nx=0 & ny=0 & flags=''
project=''
readf, 1, filename, y0, $
     d0,h0,m0,dur,nx,ny,flags,project, format= $
     '(A35,I5,I4,I3,1X,I2,F7.0,I5,1X,I4,1X,A7,1x,A7)'
```

Fortran:

```
   character*35 filename
   character*7 flags, project
   integer y0,d0,h0,m0,nx,ny
   real dur

   read (1, 400) filename,y0,
  +      d0,h0,m0,dur,nx,ny,flags,project
400  format(A35,I6,I5,I4,I3,1X,I2,
  +      F7.0,I5,1X,I4,1X,A7,1X,A7)
```

B   Glossary

LASCO The Large Angle Spectrographic Coronagraph, carried on the SOHO spacecraft.

SMEI The Solar Mass Ejection Imager, carried on the Coriolis satellite.

SMEI_IMAGE A data object containing a single SMEI image.

SMEI_SEQUENCE A data object containing a sequence of SMEI_IMAGE objects in a doubly-linked list, and the display settings.

SolarSoft A collection of solar and heliospheric software, collected by Lockheed-Martin and distributed from a number of mirror sites (home page: `http://www.lmsal.com/solarsoft`). Mostly written in IDL.

Index