FV2200 User Guide

Version 2.0 rev 1 Dec 2013

Introduction

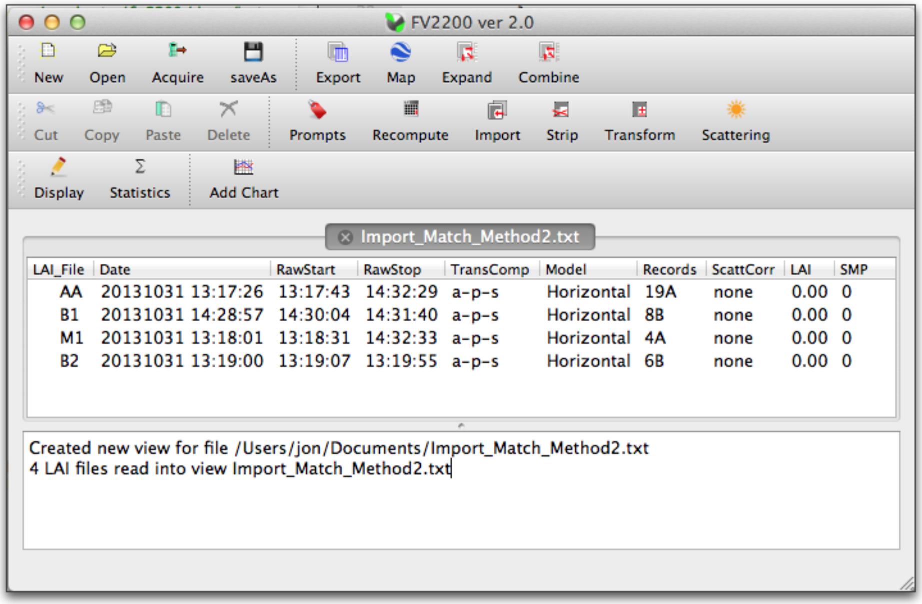
FV2200 version 2 introduces two major new features: the option to apply a model (Kobayashi et al.[1]) to correct for scattering errors in LAI measurements, and support for GPS records from the LAI-2200C.

The scattering corrections involve some important new recommendations for how to take measurements with LAI-2x00 instrumentation. These recommendations are laid out in the operating manual of the LAI-2200C, and are summarized at the end of this document (Appendix A: Scattering Corrections on page 35).

Throughout this document, the generic model number designation LAI-2x00 refers to any of the LAI-2000, LAI-2200, or LAI-2200C instruments. If material is specific to any one of those, then that specific model number is used.

1. Kobayashi H., Y. Ryu, D.B. Baldocchi,J.M.Welles, J.M.Norman. 2013. On the correct estimation of gap fraction: How to remove scattered radiation in gap fraction measurements? Ag. and For. Meteorology, 174-175: 170-183

Quick Reference



Acquire - Read files from an LAI-2000 or LAI-2200 via RS-232 (1.1 Loading Data Files into FV2200 on page 4).
Add Chart - 3.1 Charts on page 25.
Combine - 2.5 Combine Multiple Files (FV2200) on page 21.
Cut - Removes selected files from current view, adds to file clipboard.
Copy - Copies selected files from current view, adds to file clipboard.
Delete - Removes selected files from current view.
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Expand - Split an LAI file into pieces (2.6 View LAI for each B record on page 22).
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Paste - Copies files in file clipboard (see Copy, Cut), and adds them to the current view.
Prompts - 2.7 Edit Prompts and Remarks on page 22.
Recompute - 2.0 Recomputing Files on page 14.
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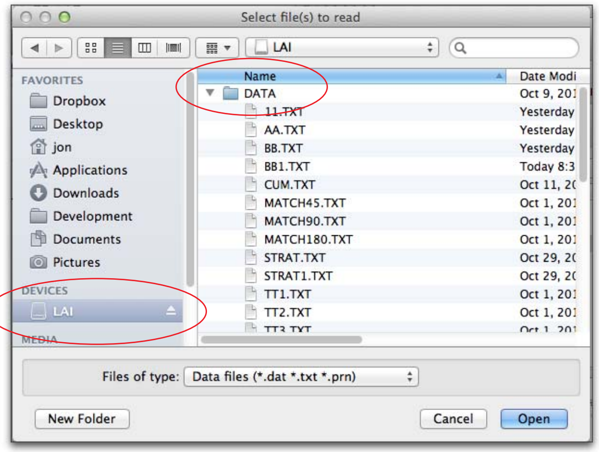
1.0 Basic Operations

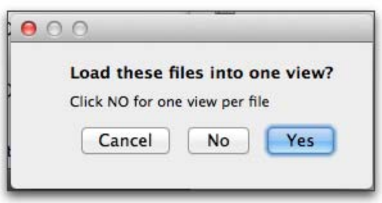
1.1 Loading Data Files into FV2200

LAI files can be read directly from an LAI-2200 or LAI-2200C when it is attached to the computer via USB. Click the Open tool button (or **File > OPEN**)

The LAI-2200 shows up as an external drive named LAI. The data files are in the folder named DATA.



When reading files from disk, if more than one is selected, you are prompted with

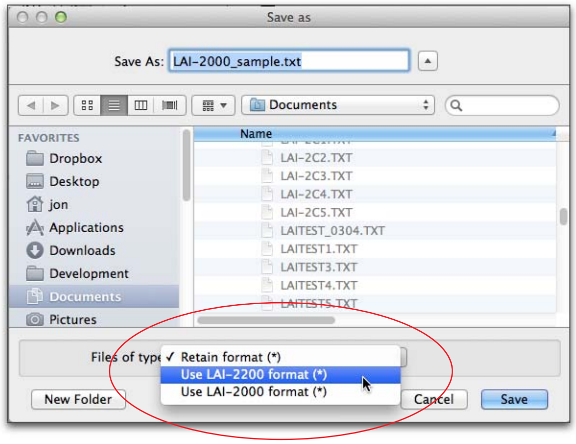


Data can also be read via RS-232 from LAI-2000 and LAI-2200 consoles. Click the Acquire tool button (or **File > Acquire**) to open the Acquire Wizard, and follow the steps.

1.2 Saving files in a view

All of the files in a view can be saved by **File > saveAs**, or by clicking the **saveAs** button. Usually, each file retains its format (LAI-2200 or LAI-2000), but this can be overridden (see below).

You can explicitly specify the format to be used when saving files.



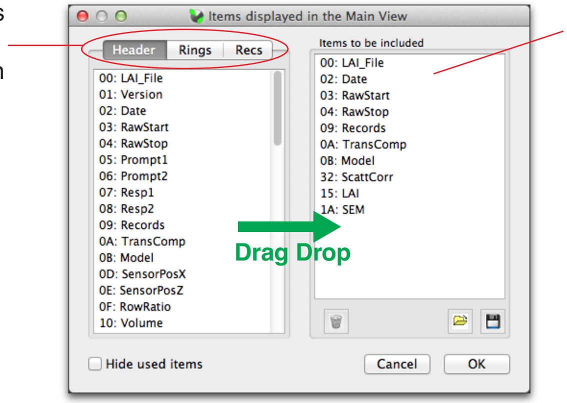
Another (perhaps better) method of converting a file from LAI-2000 to LAI-2200 format is given in 2.10 Convert LAI-2000 to LAI-2200 on page 24, which allows you to specify sensor serial numbers.

There is probably no good reason to convert an LAI-2200 format to LAI-2000, as much ancillary data (scattering corrections, GPS information, etc.) will be in the old format.

1.3 Change the Displayed Variables

Click the Display tool icon (or **View > Display**) and bring up the Display dialog.

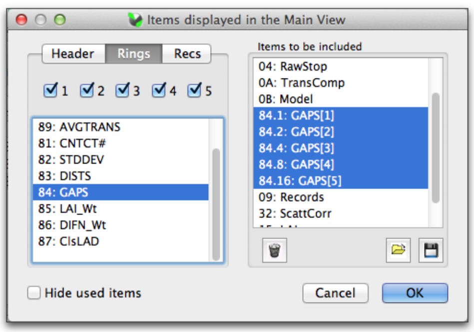
The list of all viewable items is divided into three categories:
Header - single-value items in an LAI file's header.
Rings - Ring summary items from the file's header.
Recs - Items from the raw data records.

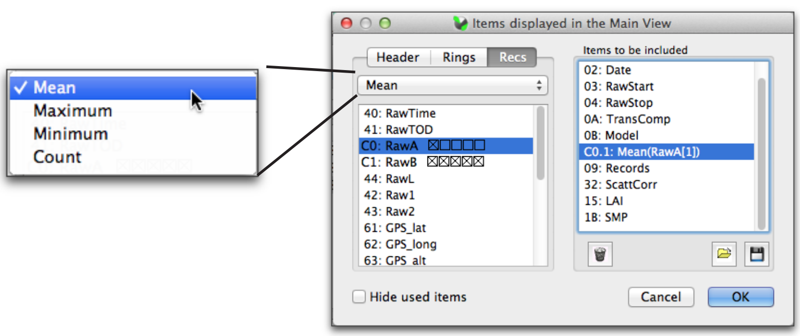


List of items displayed in the main view. Items can be **added** to the list by drag and drop from the left side.

The list is **sortable** (click and drag). Items can be removed by selecting them and using the **trash** button. The list can be **saved** and **read** from disk.

With **Ring** items, you can specify which ring(s) you want to view. For each box checked, an separate entry is created in the display list. For example, dragging over Gaps results in GAPS[1] through GAPS[5] when all the rings are checked.





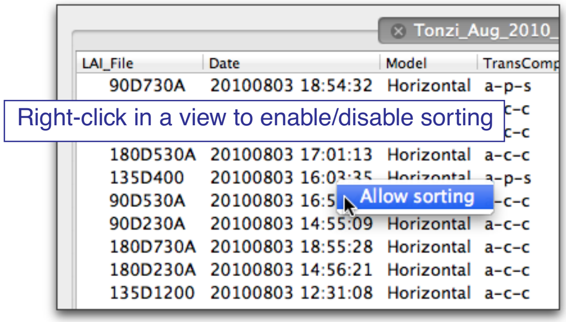
For any **Recs** item, specify the transformation you wish performed to make that value a single item that can be displayed. Some Recs items are 5-value ring items, and these let you specify which ring(s) to display. Each ring becomes a separate entry.

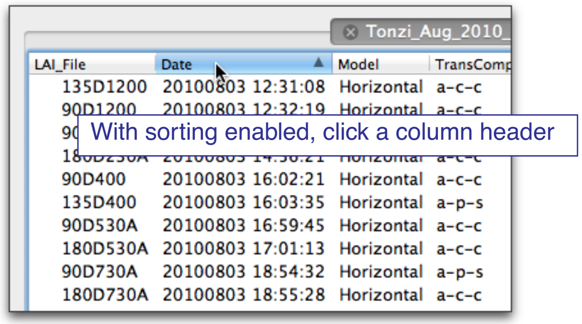
For example, dragging over Raw with one ring checked and the transform set to Mean results in Mean(RawA[1]).

Figure 1: The dialog used to pick which variables to display in a view. It is also used to pick variables to export in spreadsheet format or picking the set to get statistics.

1.4 Sorting the Displayed Variables

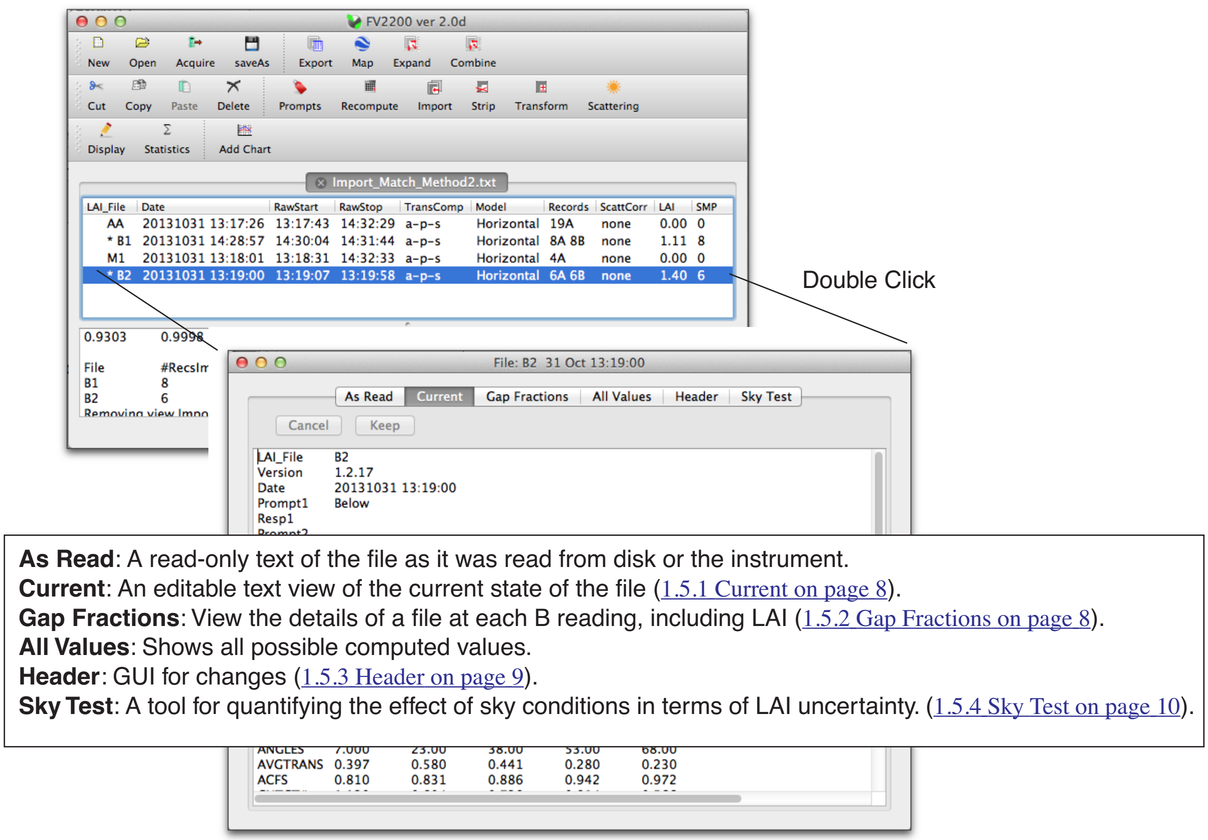
The order in which files are displayed in a view can be sorted by right-clicking in a view and enabling **Allow Sorting**. When sorting is enabled, just click a column heading to sort the files by order of items in that column. Click the column again to reverse the sort order.





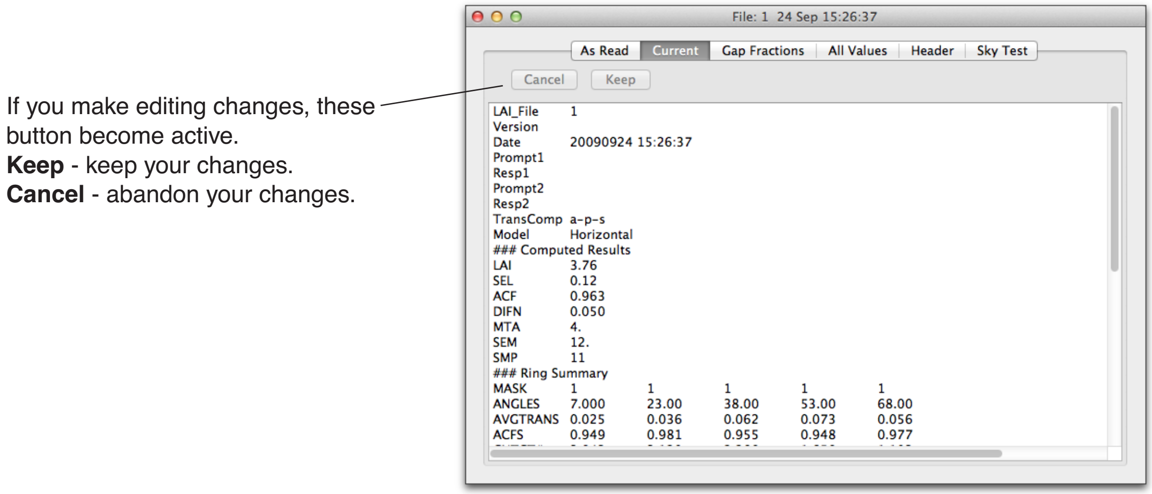
1.5 Viewing File Details

Double click a file entry to bring up the File Details window.



1.5.1 Current

The **Current** tab shows an editable text view of the current state of an LAI file.



1.5.2 Gap Fractions

The **Gap Fractions** tab shows the LAI and Gap Fractions for each B record that was used in the LAI calculation (Figure 2). If a file is scatter corrected, there is more information on each line: the pre-correction gap fraction, and the K record information that is associated with each B reading (Figure 3 on page 9).

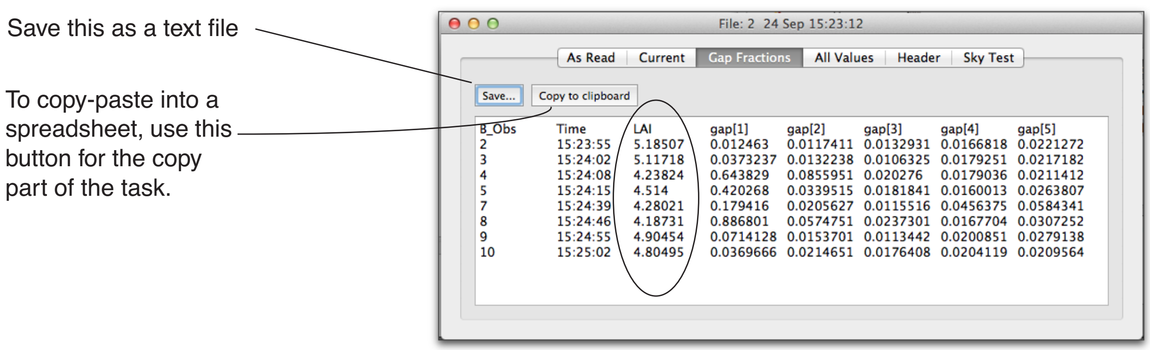


Figure 2: The Gaps Fractions tab shows LAI and gap fractions for each B reading in a file.

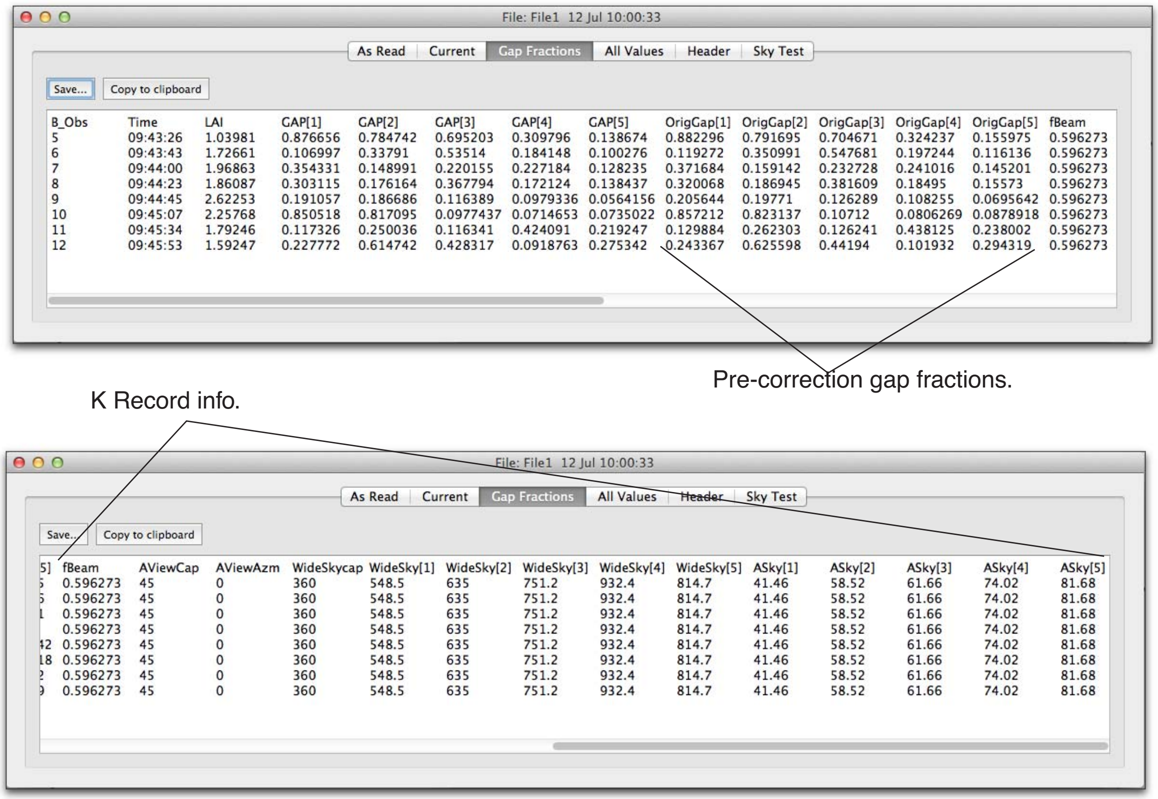
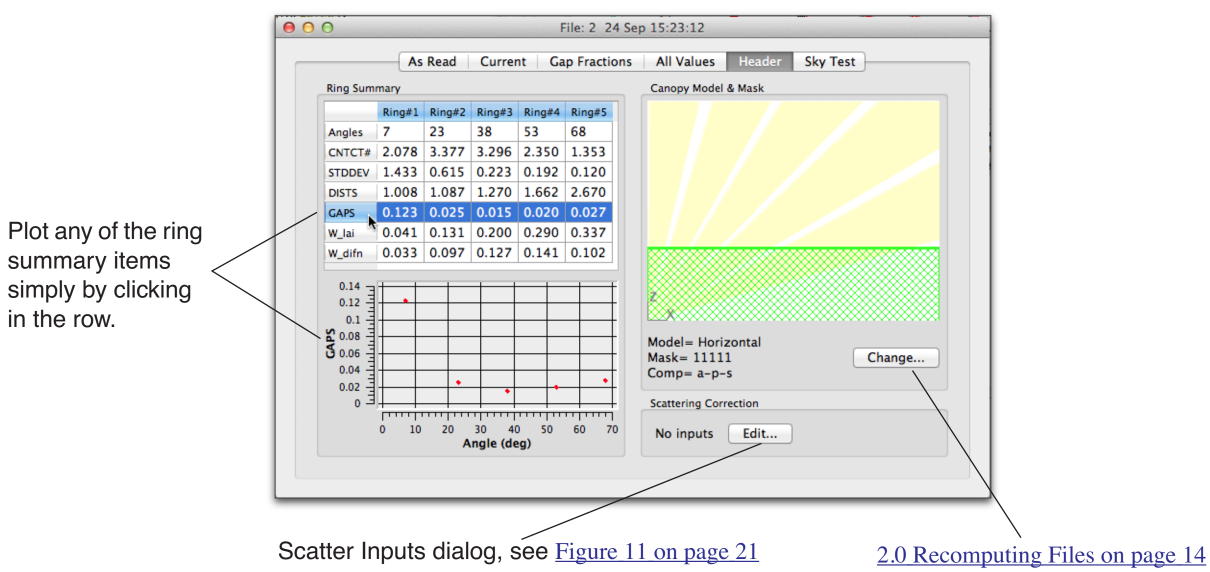


Figure 3: The Gap Fractions view for a file with scattering corrections.

1.5.3 Header

The **Header** tab provides a graphical summary of the header information in a file.



1.5.4 Sky Test

The **Sky Test** tab in the Details Window (Figure 4 on page 11) provides a tool to quantify the variability of the sky conditions in terms of uncertainty in the LAI that would exists if you were making LAI measurements then. You can use the Sky Test analysis to measure sky stability (with time), or to get an indicator of sky uniformity (consistency with direction of view).

You can apply this test to the A readings in a normal file, or in an above file, to see the potential sky-induced variability for the sky conditions you had.

The analysis consists of using the first A record (or whatever record type you choose) as the standard, then compare subsequent A records to it. Gap fractions are computed for each ring for each pair. If there is no change from one to the next, all the gap fractions would be 1.0, and the LAI is 0. If there is a change in one or more rings, then LAI increases. (Note: for this analysis gap fraction is always computed such that it is < 1. That is, gap fraction for a ring is the “below” value divided by the “above” value. If that turns out to be > 1, we simply invert it so it is < 1.)

The analysis either runs through the whole file comparing all records to the first, or whenever the time difference exceeds some limit set by you, that record becomes the new reference. Figure 4 indicates that for a clear blue day, gaps in time between reference readings and below canopy readings up to 300 seconds will result in an LAI uncertainty of only 0.01. With a 30 second difference, the uncertainty drops to 0.001. Clearly, blue skies are nice for stability.

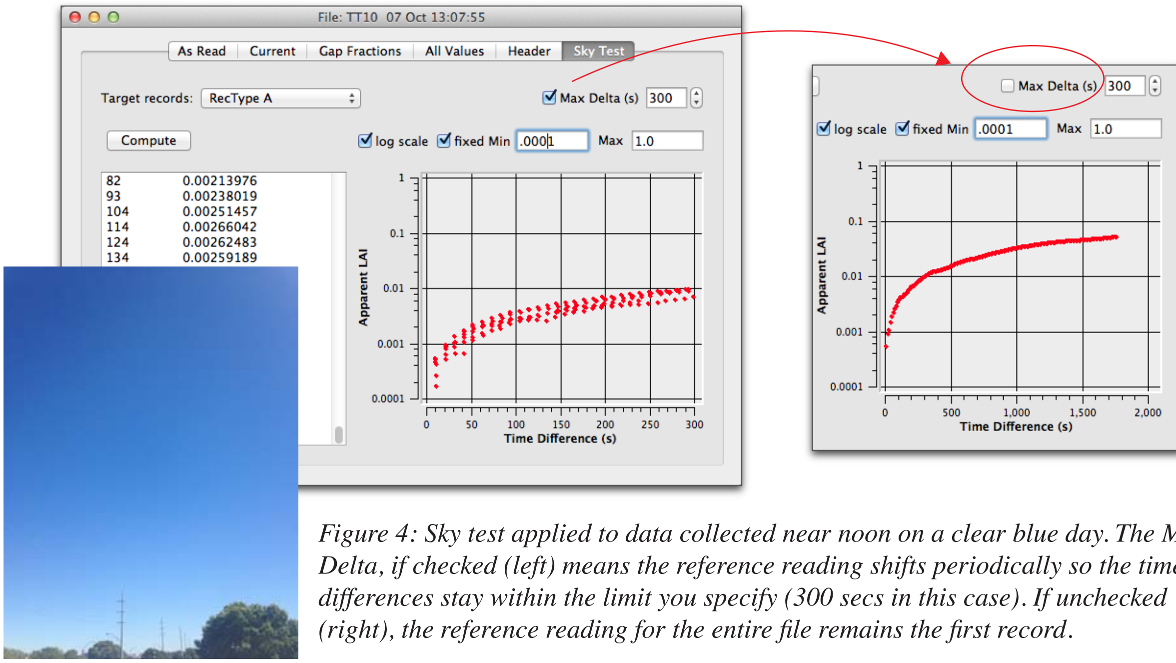


Figure 4: Sky test applied to data collected near noon on a clear blue day. The Max Delta, if checked (left) means the reference reading shifts periodically so the time differences stay within the limit you specify (300 secs in this case). If unchecked (right), the reference reading for the entire file remains the first record.

Some other sky types are shown in the figures below.

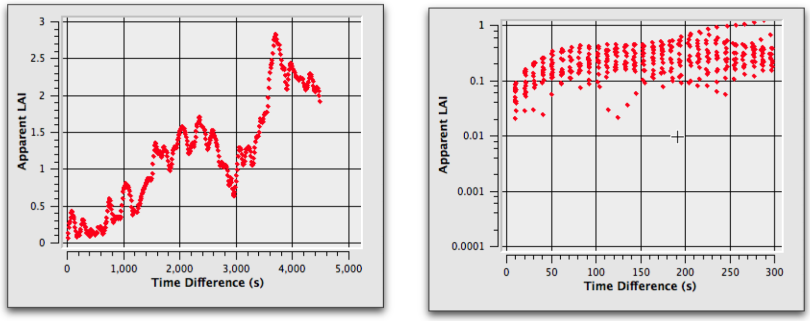
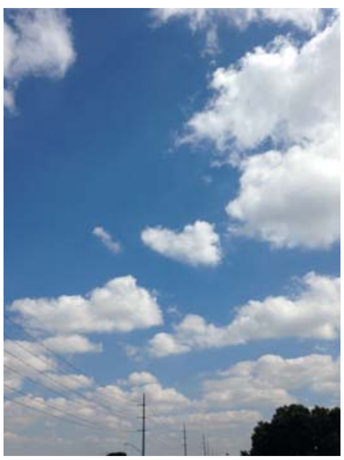


Figure 5: A heavy, non uniform overcast moving quickly with the wind is a tough sky to work with. Even with only 10 seconds between A and B readings, you can still have LAI uncertainties of up to 0.1. If you let that time stretch out to 60 secs, the uncertainty can get up to 0.5 in some of the cases captured here



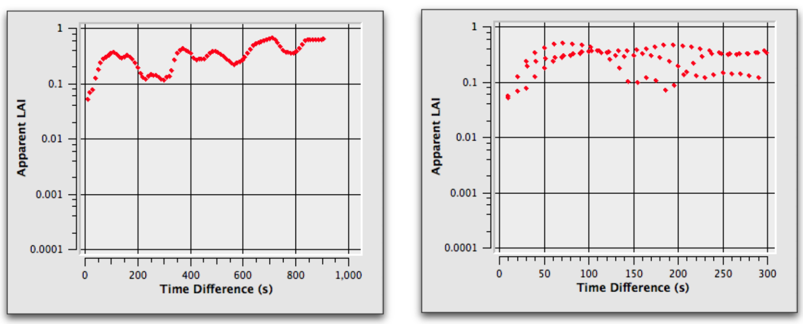


Figure 6: A twenty minute period of broken to scattered cumulus on a fairly windy day. This is also a difficult sky to work with. Time differences between A and B readings need to be kept as short as possible.

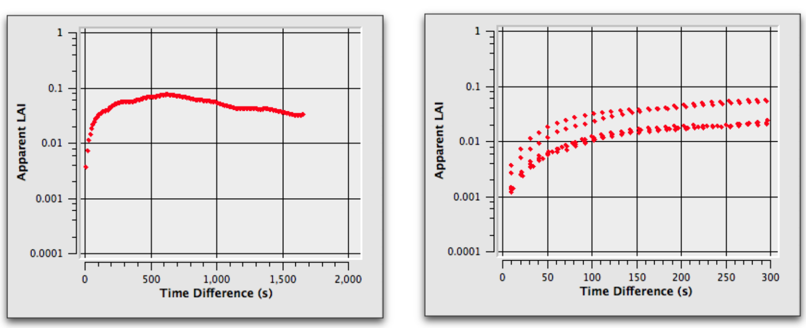


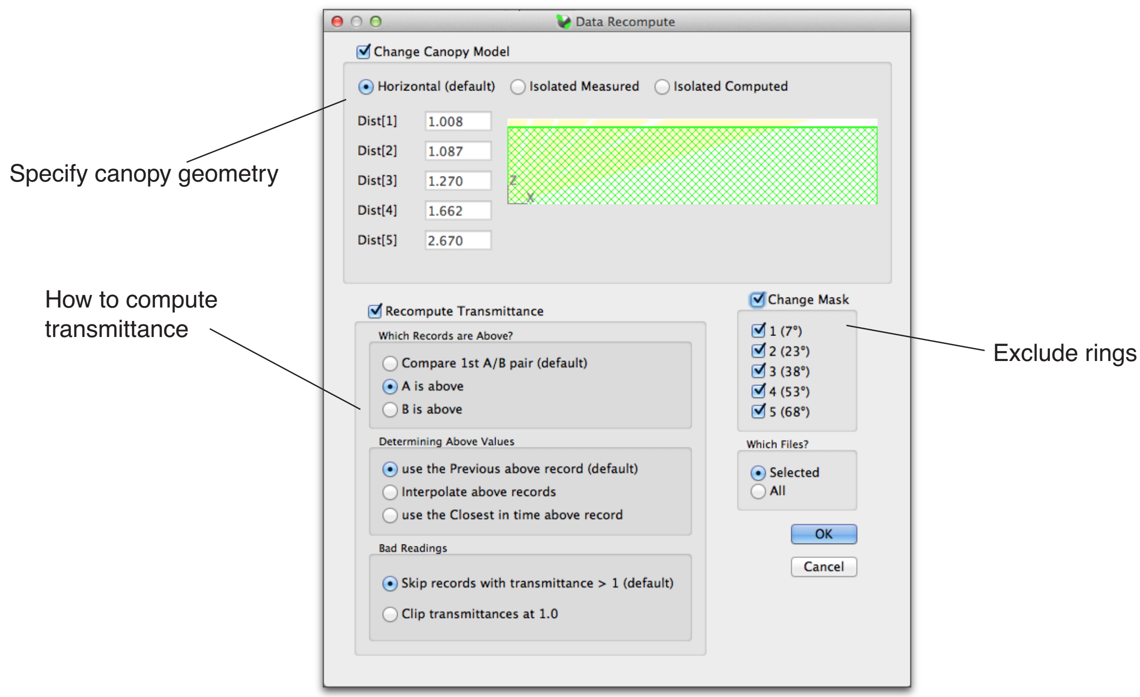
Figure 7: Thirty minutes under cirrus clouds. This is a fairly easy sky to work with, as LAI uncertainties are well under 0.1 even for 5 minutes time intervals. For under one minute, the uncertainty is 10 times lower.

You can also use the Sky Test to measure the penalty for not having above and below readings exactly aligned (Figure 8 on page 13). Open a file and log about 10 or 12 readings in the general direction of interest. For example, if you are using a 45 degree view cap and intend to make LAI measurements aimed to the North, then make those readings between NW and NE; use whatever azimuth range you think can be easily maintained during a measurement session, bearing in mind that in a tall canopy, you may not keep your bearings quite as well as you might hope, and the below readings may have a wider range of direction than you think.

Figure 8: A fairly uniform overcast. The data plotted on the left were collected over 1 minute, with the wand aimed in a variety of directions +/- 45° of the target direction. View cap was also 45°. This gives an indication of directional uniformity. The data plotted to the right is about 20 minutes of data collected with the wand fixed on a tripod.

2.0 Recomputing Files

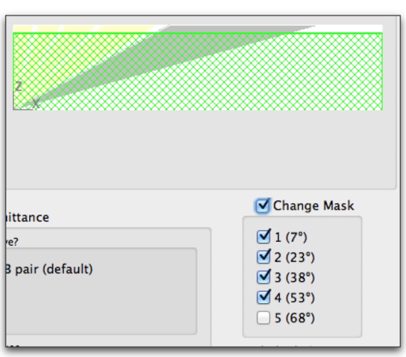
Recomputing a file usually happens automatically as needed, such as after importing A records, or adding scattering corrections. There are times, however, when you might need to remove a ring, or change how transmittance is computed, and for those you can use the Recompute Dialog. This is available by clicking the Recompute tool (or **Edit > Recompute**). The dialog is also accessible for a single file from the Header tab of the Details view (1.5.3 Header on page 9).



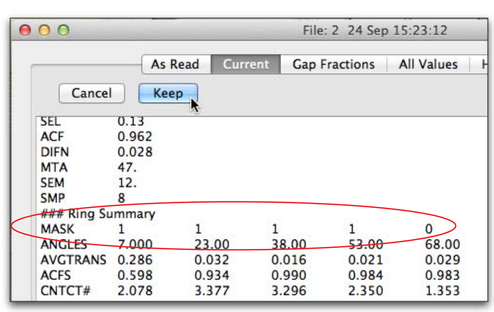
2.1 Exclude Rings from Analysis

You can use the Change Mask in the Recompute Dialog, or edit the file directly in the Details Window (1.5.1 Current on page 8).

In Recompute Dialog.



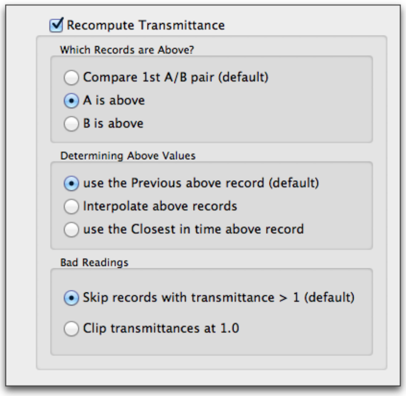
In Details Window



2.2 Interpolate A Records

You can use the Recompute Dialog. For a single file, you can use the Detail View, Header tab, or Current tab.

In Recompute Dialog.

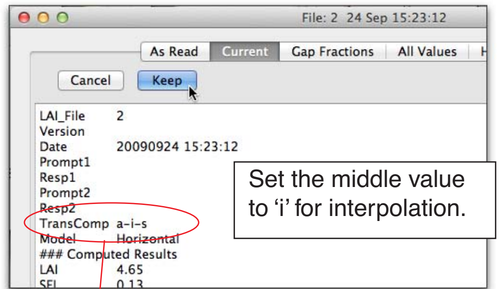


c
a
b

p
i
c

s
c

In Details Window



The three groups refer to the three groups in the Recompute Transmittance. The options for each group are shown here.

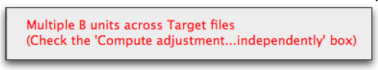
2.3 Import and Adjust A Records

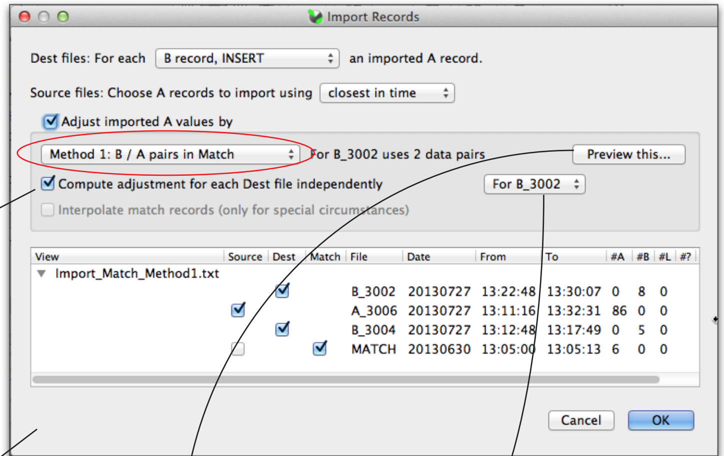
When one sensor collects B records, and another sensor collects A records, that data needs to be put together. Unless the sensors were matched prior to collecting data, an adjustment needs to be made to one of the data sets. The discussion of this is in Appendix B. Three Methods for FV2200 Matching on page 47.

Once you've collected the data, merging and adjusting is quite simple. Follow the steps below. If you wish to try this with same sample data, open one of the built-in sample files found in **File > Samples** (pick **Import_Match_Method1**), then go to step 3.

1. Open the above and below files. You may elect to put them into one view.
2. If the data was collected with Match Method 1 or 2, load in the associated Match files.
3. Click the Import tool button to open the Import Records Dialog.

Match Method 1 Example.
The **source** file contains 86 A records made by sensor PCH-3006. We have two **destination** files, each with only B records, made with two different sensors, PCH-3002 and PCH-3004. The **match** file, made on an earlier day, contains 6 A records: two each for the three sensors.
In this case, we need this **box** checked. Otherwise, we would have multiple sensors in our destination files, and would not be able to compute a single adjustment factor per ring. Note: there is a warning displayed when this is the case:

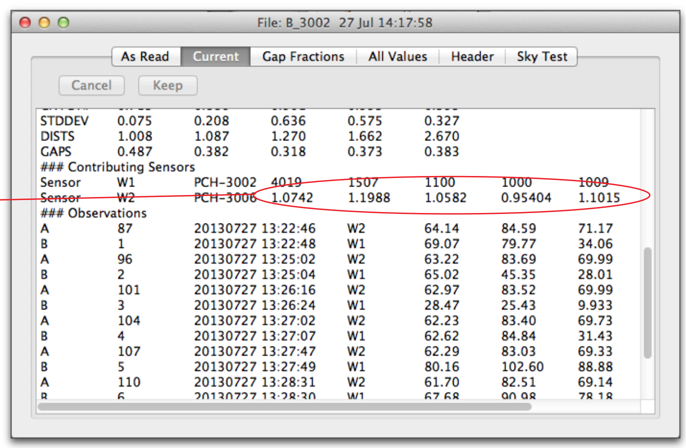




You can preview what the adjustment factors will be for each ring by clicking **Preview this....** When computing them for each individual file, as we are here, you can select which **file** that information is for.

4. Click the OK button to perform the import (and adjustment, if that box is checked). Sample results for the example above are shown below:

Method 1 Example Results
Closest in time A records have been imported. The imported records are from sensor PCH-3006, and are labelled W2 in the records.
The adjustment factors that the W2 rings were multiplied by as they were imported are shown here.



Interpolate match records. One of the options for Methods 2 and 3 is to interpolate the adjustment factors over time. This is normally not necessary or recommended, unless a) you have good match data (i.e. viewing clear, blue sky) at the start and end of your measurements, and b) something happened during the measurements that would lead you be believe this is necessary, such as dust accumulation on the above sensor lens. Note: this is NOT the same as interpolating A records; this is interpolating the *adjustment factors* for modifying those records as they are imported.

Examples for using Match Methods 2 and 3, and a combination of the two, are shown in Figure 27 on page 50, Figure 28 on page 51, and Figure 29 on page 52.

2.4 Scattering Corrections

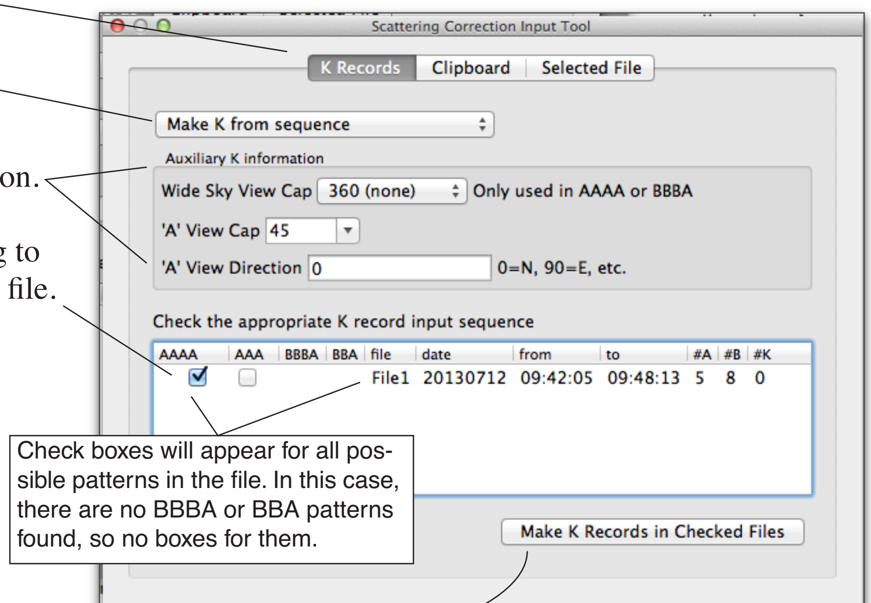
The scattering corrections are discussed in Appendix A: Scattering Corrections on page 35.

LAI-2000 Note: Applying scattering corrections to a file in LAI-2000 format will automatically change its format to LAI-2200 format. If you wish to include some sensor information in the new format, you might wish to convert the file yourself (2.10 Convert LAI-2000 to LAI-2200 on page 24) prior to adding scattering corrections.

2.4.1 Generate K records from Sequences

The data for a K record is usually in the form of a 4A sequence, but other patterns are possible (Other Ways to Make K records on page 40). To convert such sequences to a K record, do the following:

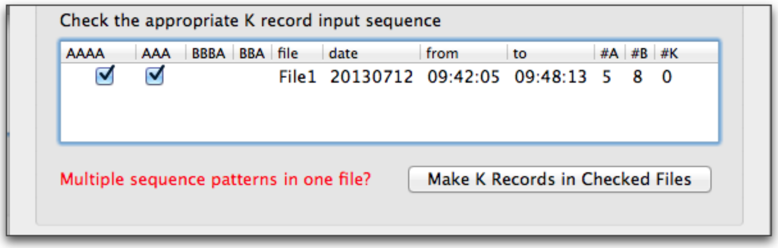
1. Load the file into FV2200.
2. Click the Scattering tool icon (or **Edit** > **Scattering**).
3. Click **K Records**
4. Select **Make K from Sequence**
5. Enter ancillary information.
6. Check the files according to the input sequence(s) in the file.



7. Click the **Make K Records...** button.

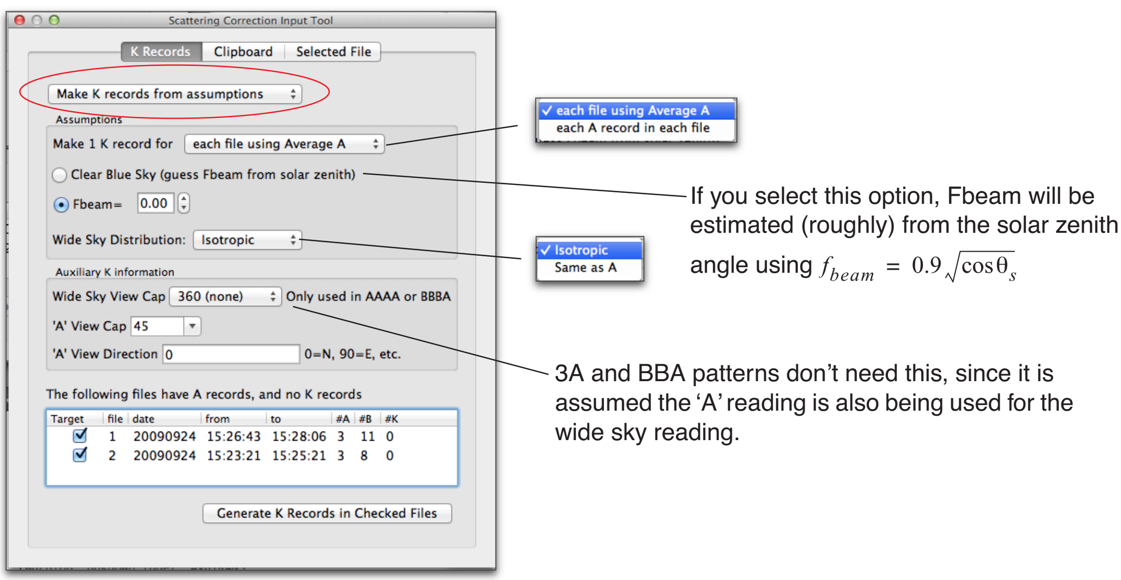
Normally, you only check 1 pattern (AAAA, AAA, etc.) per file. You can get away with mixing certain patterns, however, such as AAAA and AAA, or BBBA and BBA provided the sequences do not run together. In other words, 4A or 3A sequences surrounded by B records would be fine, or 3B or 2B records surrounded by A records would be fine. (You would not want to mix A sequences with B sequences, however). The order that FV2200 converts records in a file (if doing more than one sequence in the file) is this: 4A, then 3A, then 3BA, then 2BA. So, if you have 4A and 3A together, the 4As will be done first, before the 3As.

If you do check more than one pattern for a file, you will see a warning. It won't stop you, it's just a check to see if you know what you are doing.



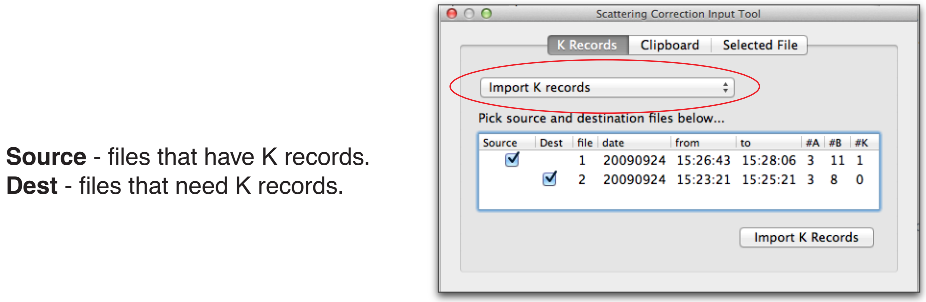
2.4.2 Generate K Records from assumptions

Sky inputs for scattering corrections can be generated for old files using some assumptions and the measured A records. If the sun was obscured, you know the fraction beam was 0. If it was a clear blue day with the sun not obscured, you can opt for the software to guess at a reasonable fraction of beam value for you.



2.4.3 Import K records

If you have K records, but not in the right file, or need to share K records among multiple files, then use the Import K Records option of the Scattering Tool.



2.4.4 Setting Scattering Inputs for a group of files

The **Clipboard** tab of the Scattering Input tool is designed to set inputs for a range of files, rather than just one file (2.4.5 Enter or Edit all inputs for one file on page 19).

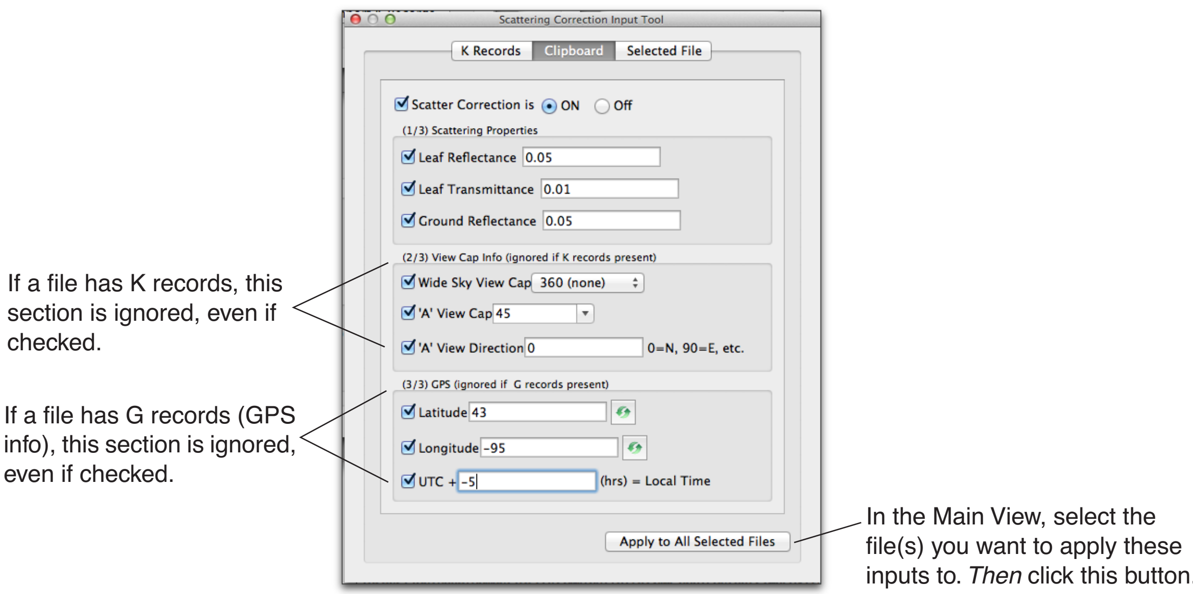


Figure 9: The Clipboard tab of the Scattering Correction Input tool.

2.4.5 Enter or Edit all inputs for one file

Usually the sky inputs for the scattering corrections are done with K records (K Records on page 39), but this can be bypassed and done entirely in one dialog. The Scattering Input Dialog is accessible via the Scattering Tool (**Edit > Scattering**) as shown in Figure 10 on page 20. A file in the main view must be selected.

If the file has scattering inputs, the relevant part of the file header with those inputs is shown in an editable text box.

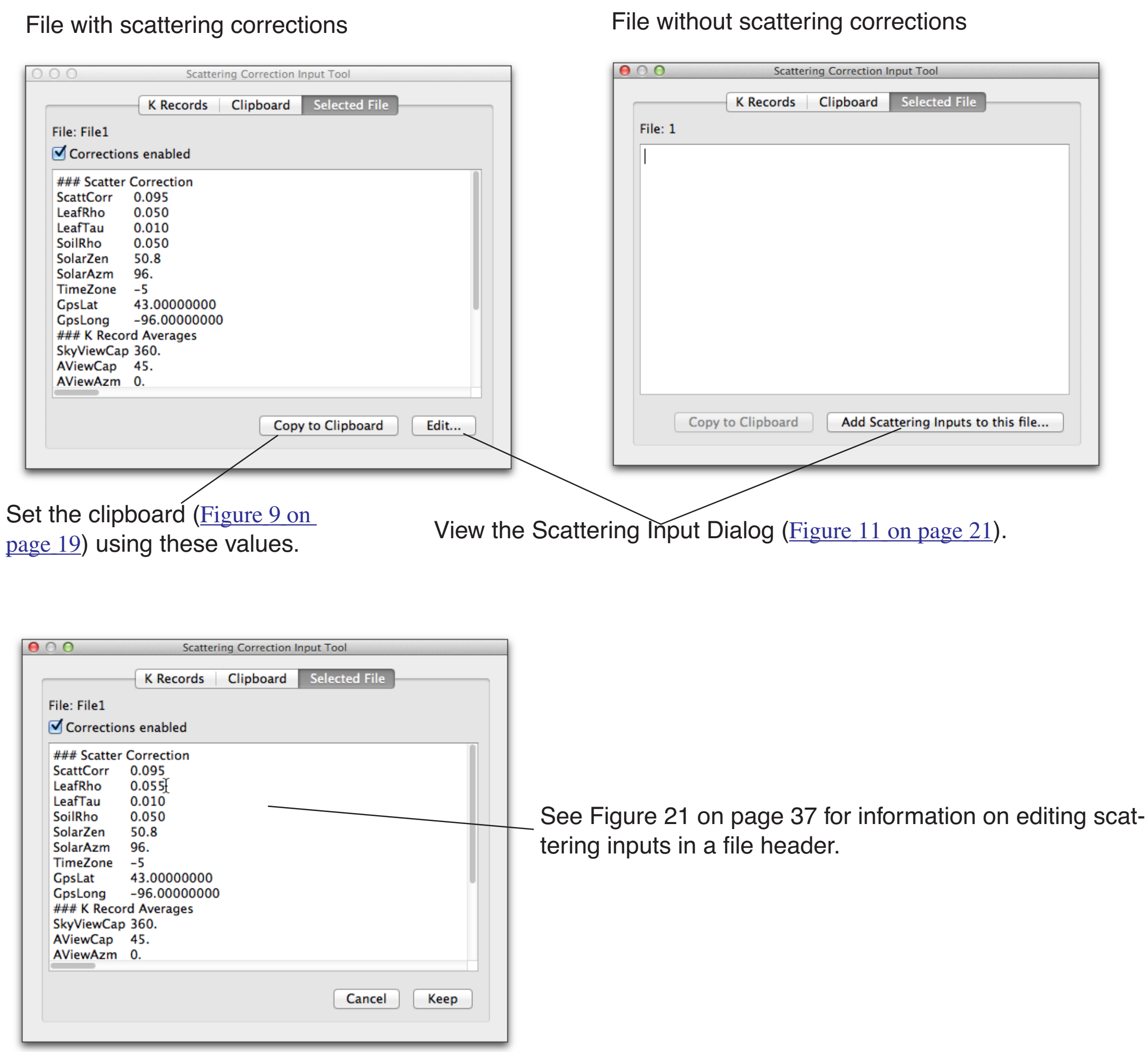


Figure 10: Select File tab of the Scattering Tool.

A dialog box for entering or viewing all the scattering inputs for a file is shown below.

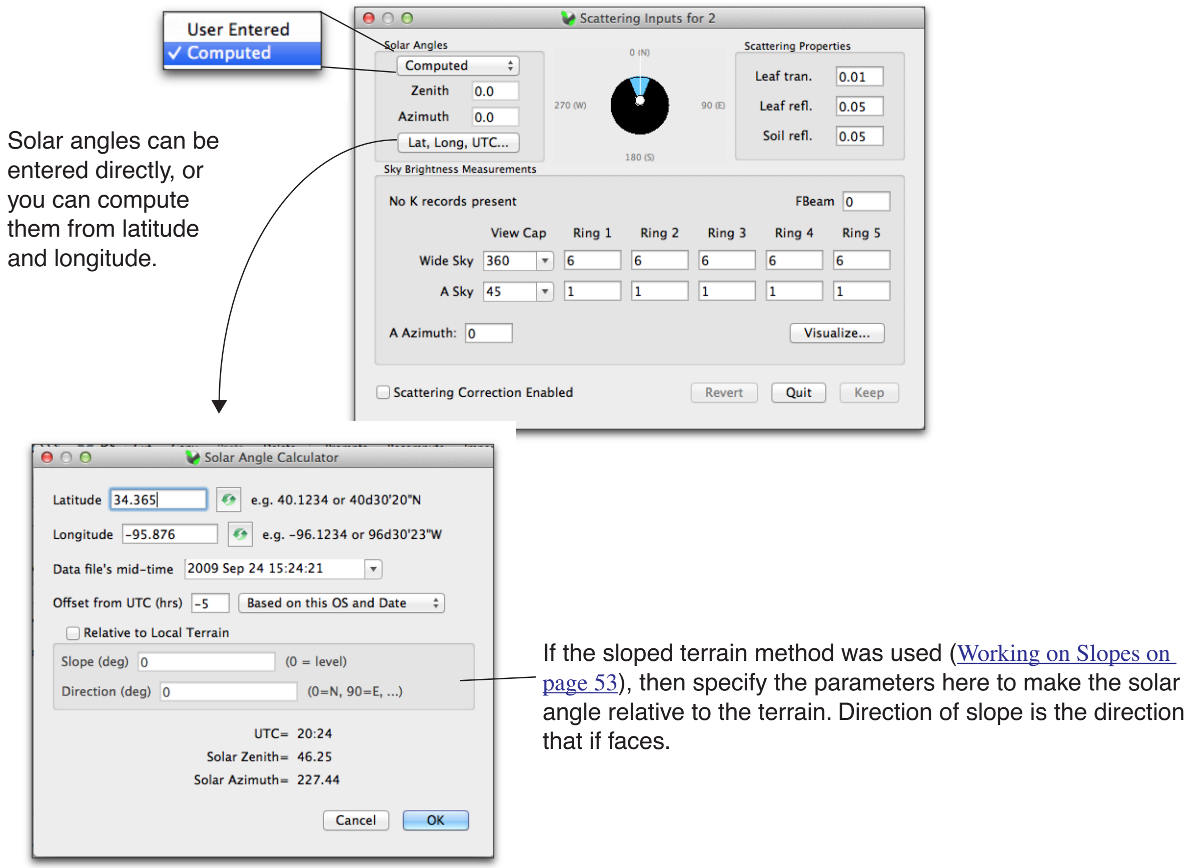
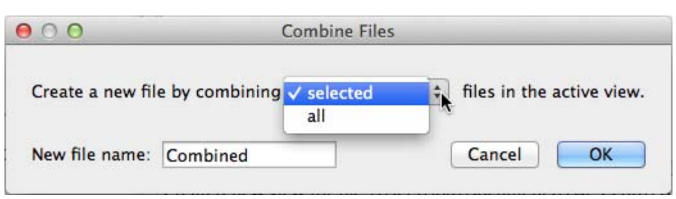


Figure 11: The Scattering Inputs dialog can be used to view the inputs for a file that has them, or to add all the inputs to a file that needs them. If you use K records, you can avoid entering information with this dialog.

2.5 Combine Multiple Files (FV2200)

The Combine Files dialog (**File > Combine**) lets you pick a selection of files for which all of the data records are to be combined. The file header information of the resulting file will be based on the first file's headers in the source list.

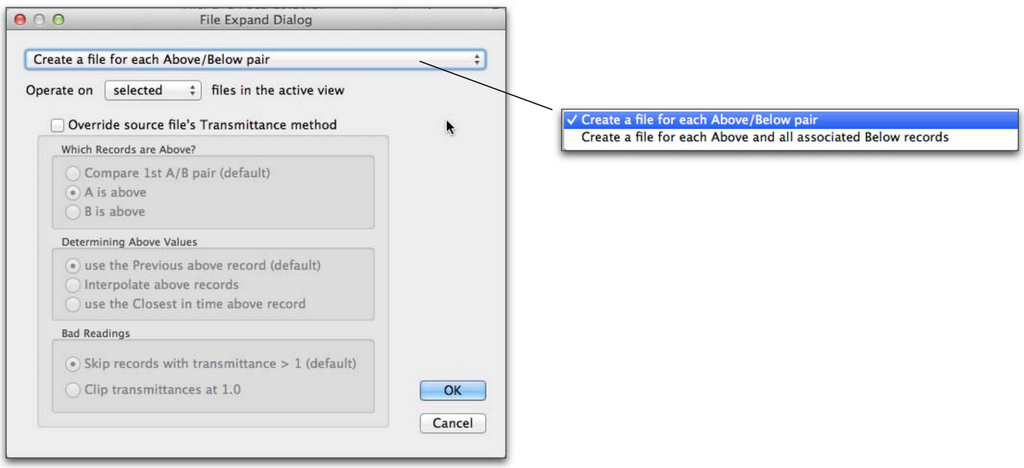


If you need a more customized method to combine files, there is always cutting and pasting from the Detail View. The thing to watch if you do that, however, is the Contributing Sensor information and the Sensor ID values of each record. The Combine Files automated routine takes care relating sensor IDs (W1, W2, etc.) to the proper sensor in a new list. For example, if one file has one Contributing Sensor, say serial # 1234, and another file has a different one (#4321), if you combine by cut-and-pasting records, all files will have sensor ID's of W1, and differences will be lost. The automated Combine, however, will leave you with W1 and W2 records, with both sensors appearing in the Contributing Sensor list labelled appropriately as W1 and W2.

2.6 View LAI for each B record

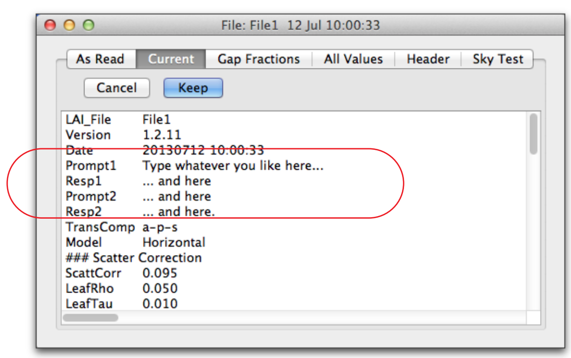
The simplest method is simply double click the file and view the Gap Fractions tab in the Details Window (Figure 2 on page 8).

The harder method (before version 2.0, it was the only method) is to click the Expand dialog icon (**File > Expand**). This will let you generate a lot of files from one file. You have the option to change the transmittance computation method for all the files, as well.

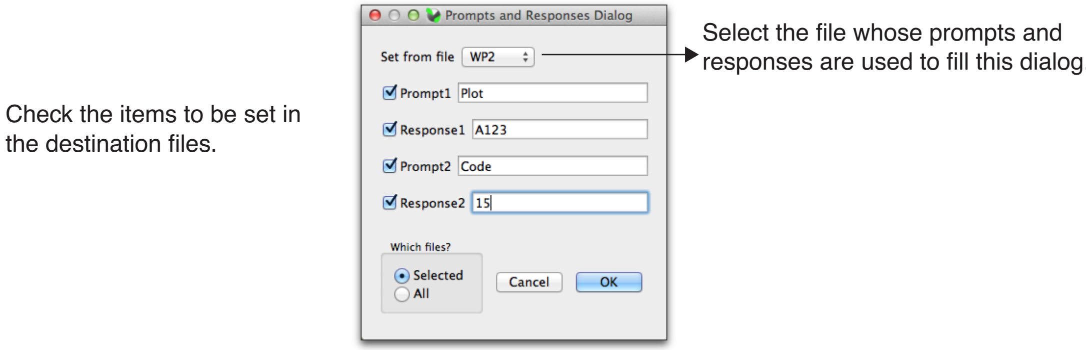


2.7 Edit Prompts and Remarks

For a single file, this is most easily done using the Detail Window for a file: 1.5.1 Current on page 8.



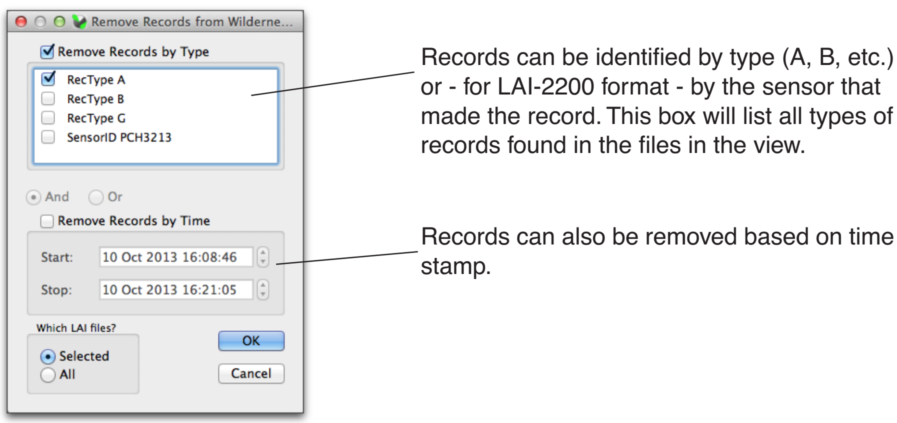
For a group of files, this can be done all at once using the Prompts and Responses Dialog (**Edit > Prompts**).



2.8 Strip Records

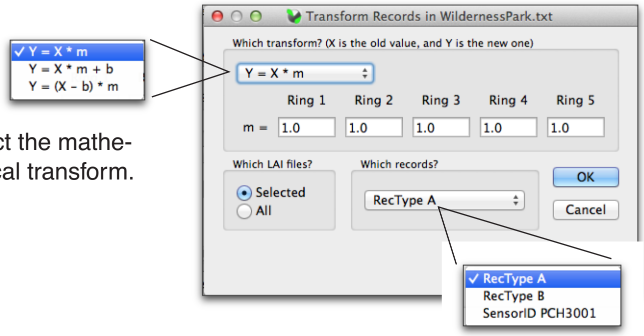
Records can be stripped from an individual file by editing them in the Details window (1.5.1 Current on page 8).

For a range of files, use the Strip Records dialog (**Edit > Records > Strip**)



2.9 Transform Records

Records can be mathematically transformed using the Transform Dialog (**Edit > Records > Transform**).



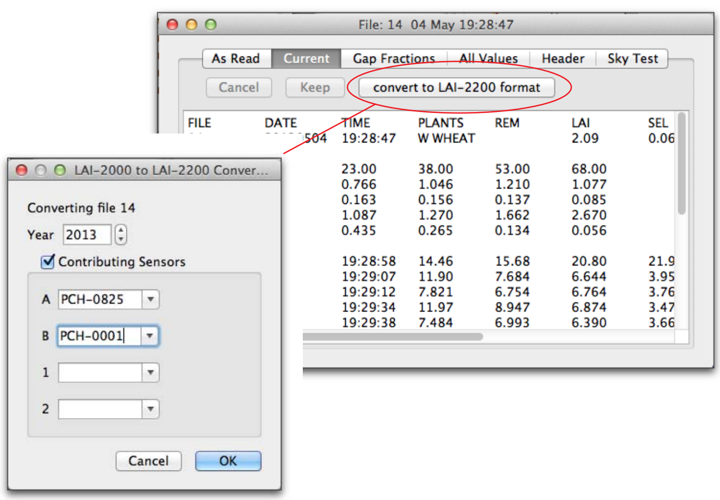
Select the mathematical transform.

Select the record type to be transformed. The list will show the wand and light sensor records it found. They can be selected by sensor ID, or by type.

You will probably never have occasion to use this dialog; it was introduced early on to apply after-the-fact calibrations to sensors. Now that importing and adjusting has become one step (2.3 Import and Adjust A Records on page 15), this dialog may be obsolete, but it is here if you need it.

2.10 Convert LAI-2000 to LAI-2200

There are a couple of ways to do this. To convert a single file, you can use the Current tab of the Details Window (Figure 12 on page 24). The advantage of this method is that you have an opportunity to specify sensor serial numbers, which are useful when doing importing and adjusting records (2.3 Import and Adjust A Records on page 15).



When you convert formats, you have an opportunity to specify the year (not included in the clock of an LAI-2000), and also the instrument serial numbers of A, B, 1, and 2 records.

If you leave a field blank, or uncheck the Contributing Sensors box, then the converted file will not contain a Contributing Sensors section.

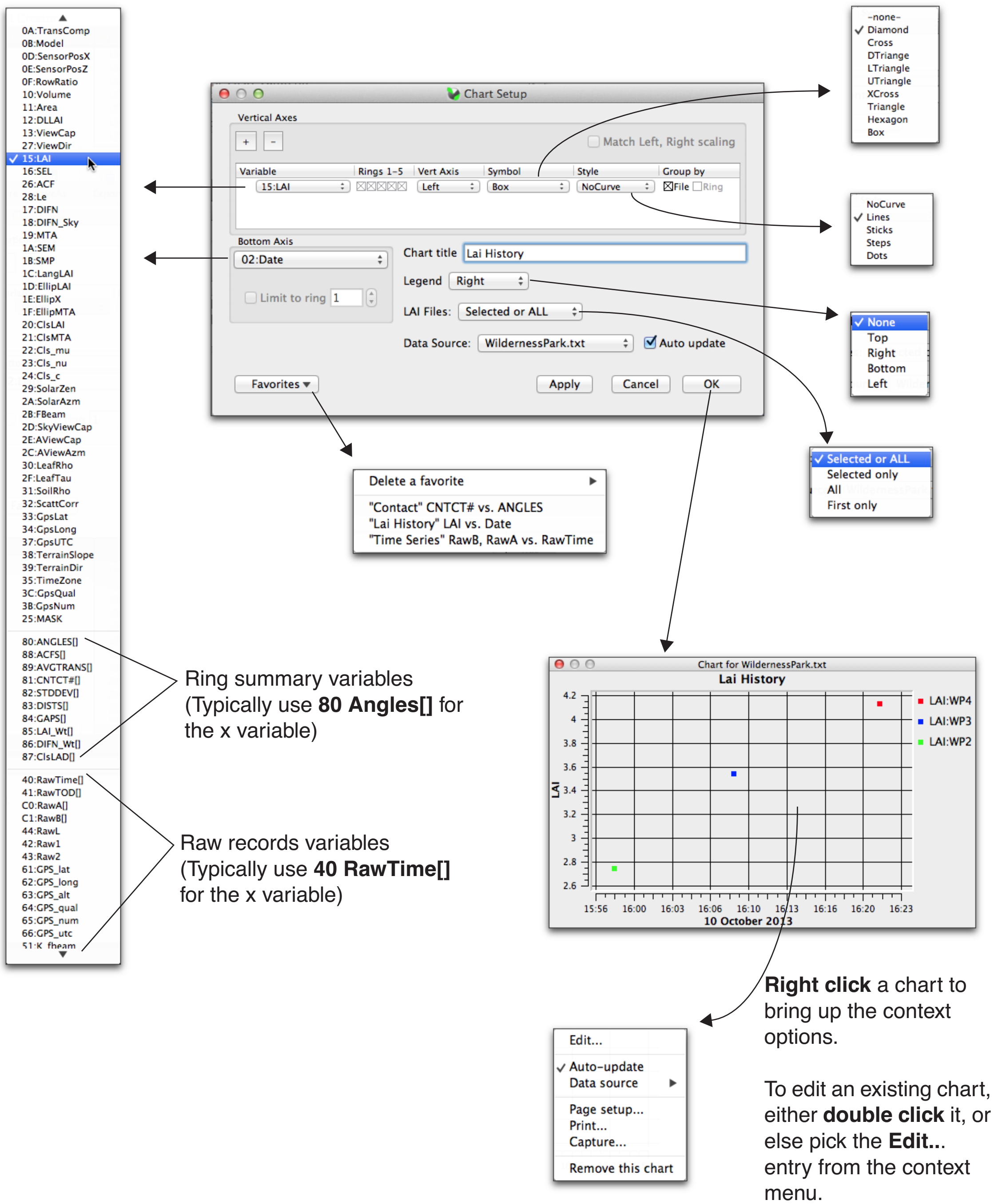
Figure 12: Converting LAI-2000 to LAI-2200 in the Details view.

Another method of converting formats is when saving a view (1.2 Saving files in a view on page 5).

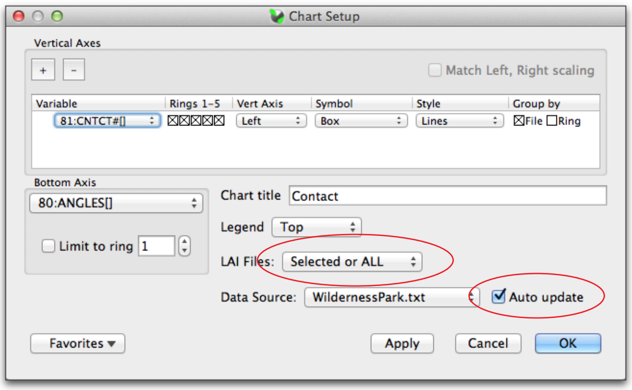
3.0 Viewing Data

3.1 Charts

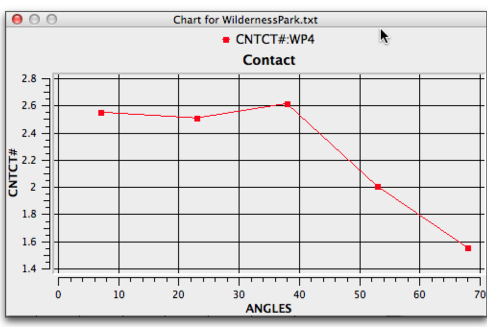
Click the Add Chart button (or **View > Add Chart**) to bring up the Chart Setup dialog.

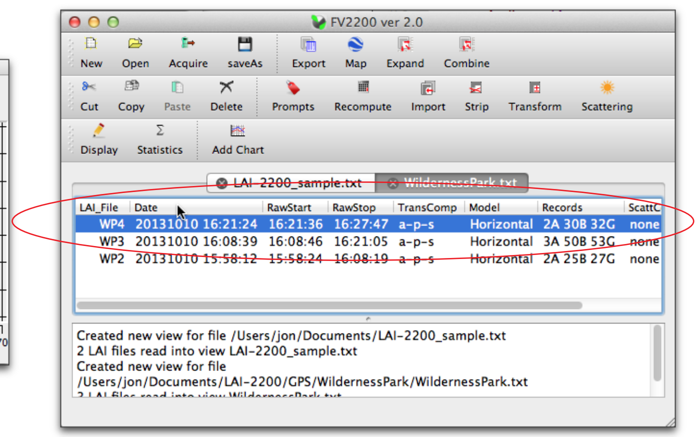


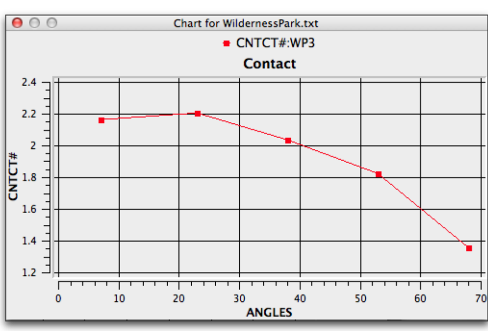
Charts can be made to plot data from the currently selected file(s), and update whenever the selection changes. This makes it very simple to step through a long list of files examining some relationship for each.

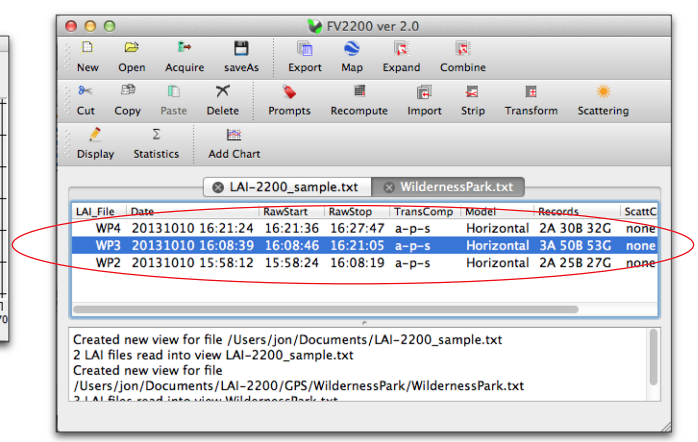


When Auto update is selected, changing the selected file(s) in a view will change the plot.

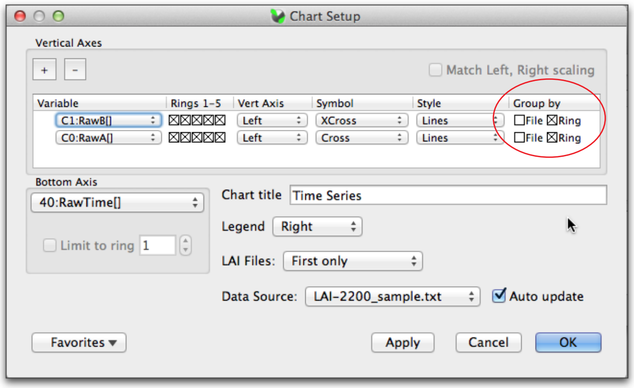




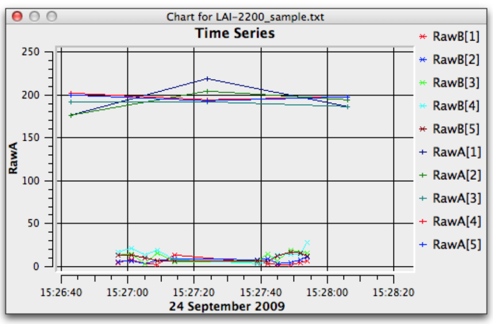




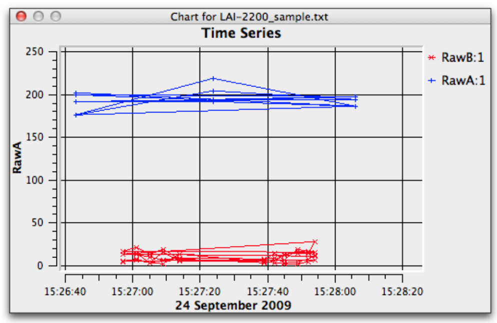
The raws records are usually plotted as time series plots.



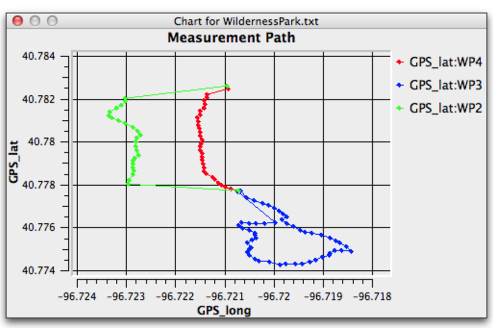
Grouped by **Ring**

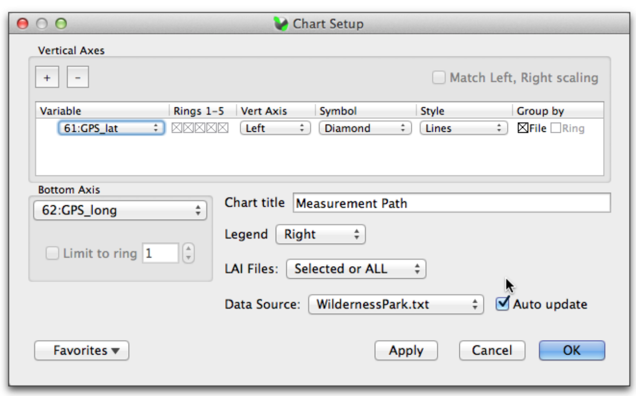


Grouped by **File**



If files have G records, you can make a chart of the measurement track by plotting latitude vs. longitude. A better way to plot GPS data is 3.2 GPS Maps on page 28, however.





3.2 GPS Maps

FV2200's Map tool (**File > Maps**) (Figures 13) provides a mechanism for exporting a .kml file for Google Earth.

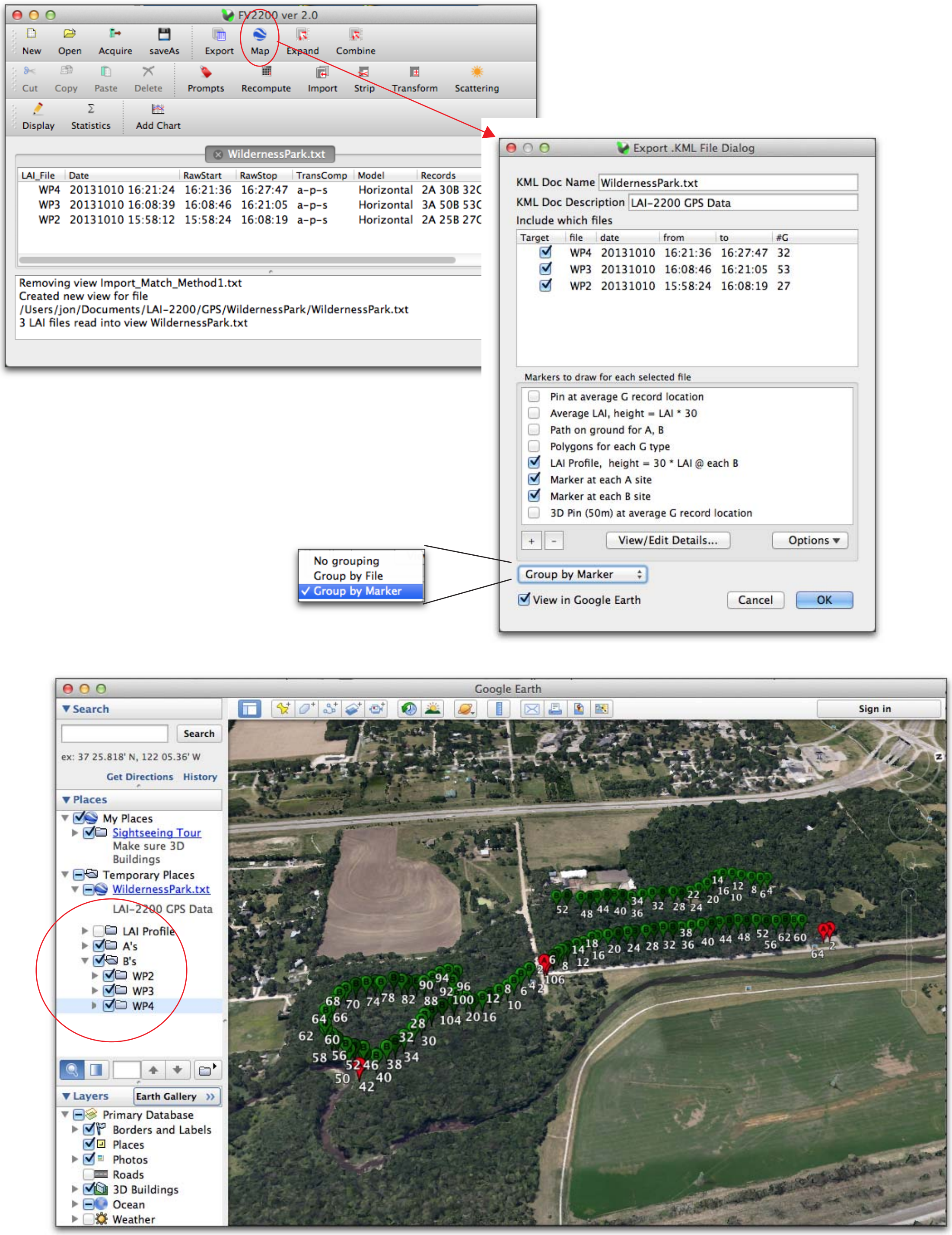


Figure 13: Markers at A and B for three files. The numbers are the record number for the G records associated with the A or B readings. The LAI profile (turned off here) is shown in the next figure.

Figure 14 illustrates some of the default marker styles available. Any can be modified, however.

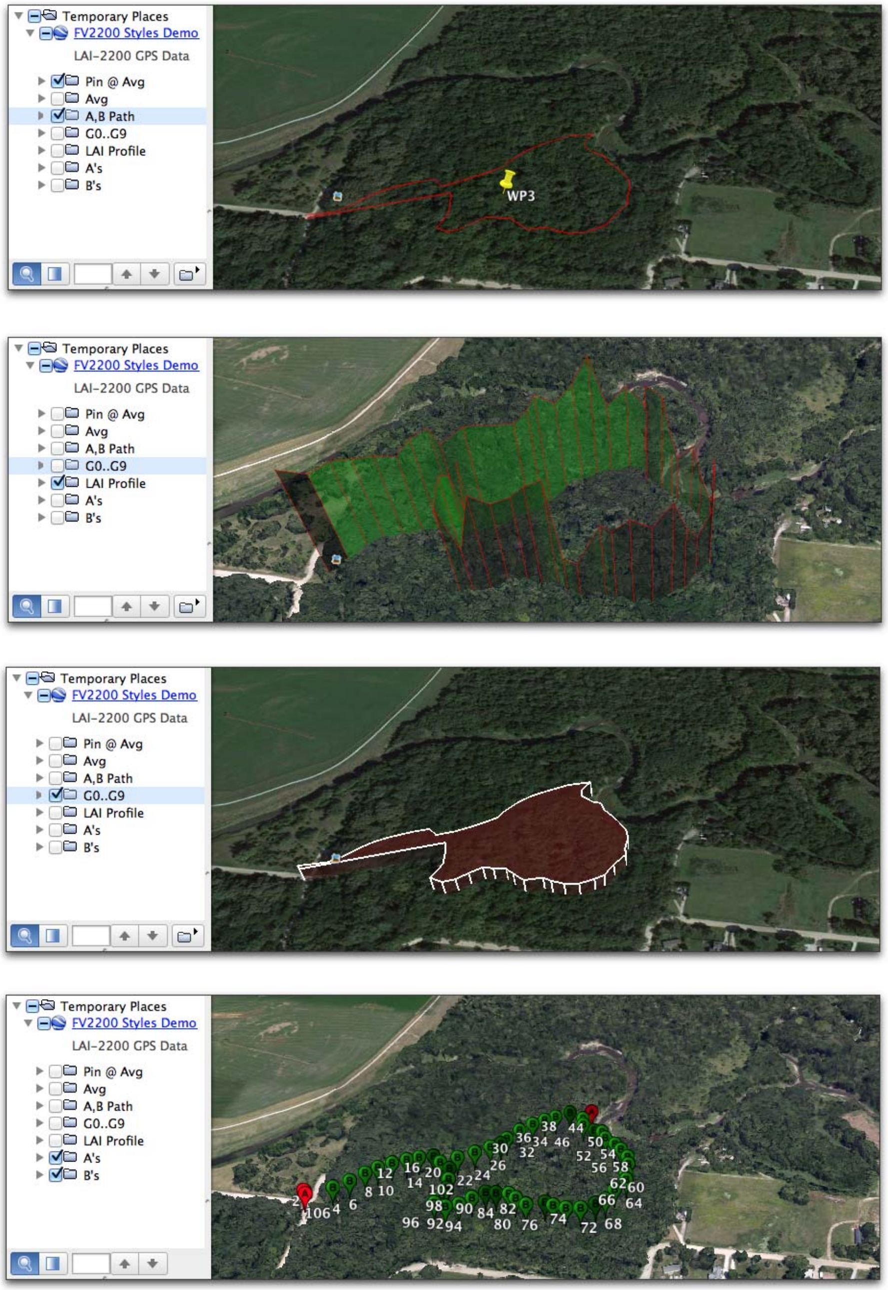


Figure 14: Some of the default marker options with FV2200.

Figures 15 through 20 illustrate how to edit a marker, or add a new one.

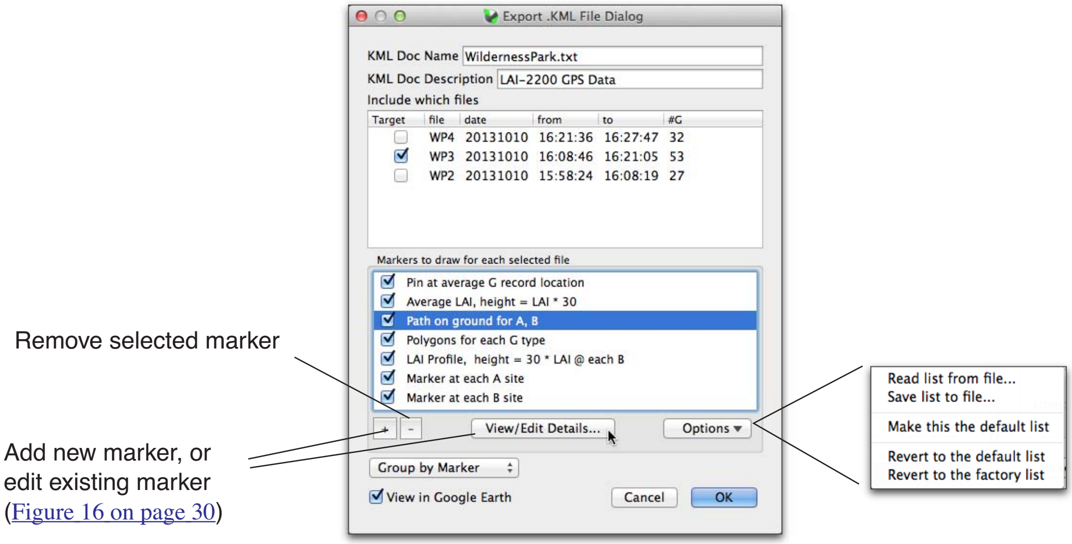


Figure 15: the KML export dialog.

The marker edit dialog is shown in Figure 16.

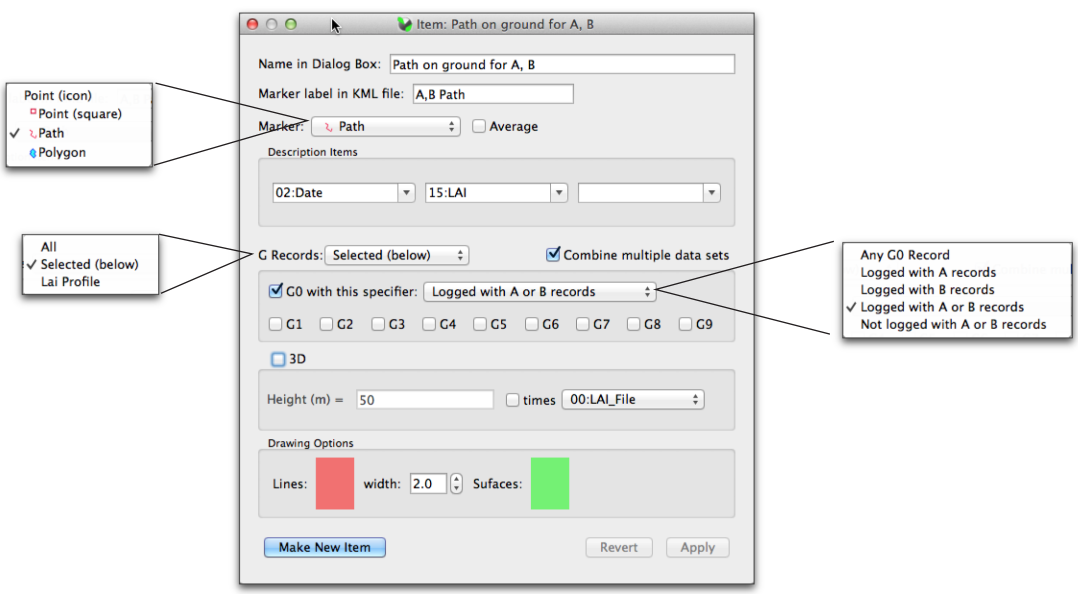


Figure 16: The marker idem dialog is presented when adding a new marker, or editing an existing one.

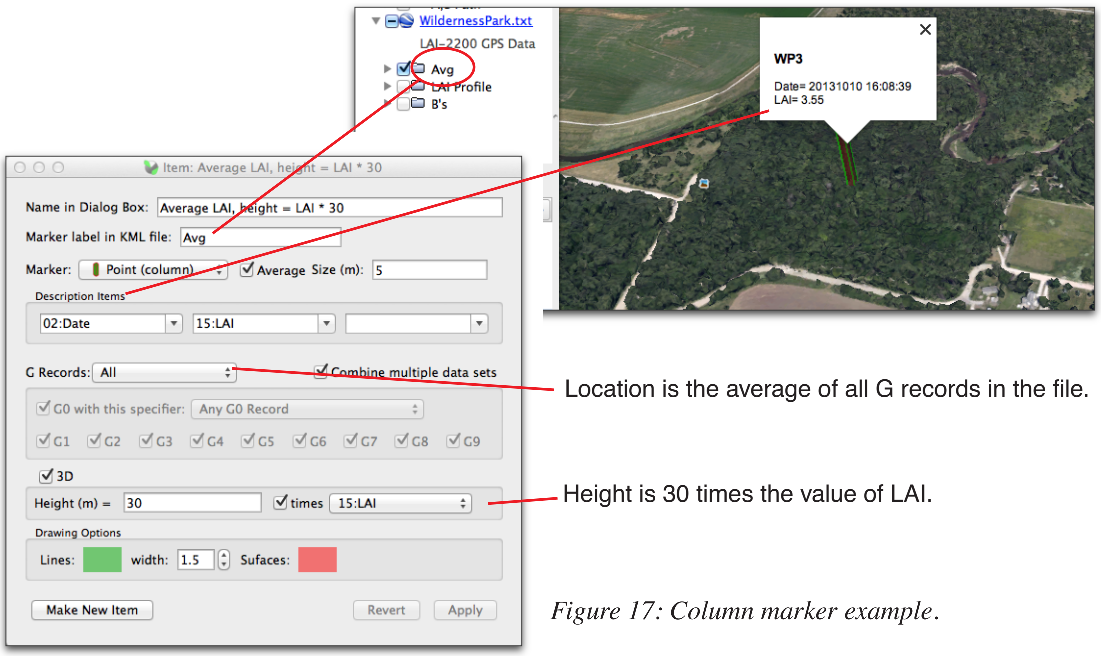


Figure 17: Column marker example.

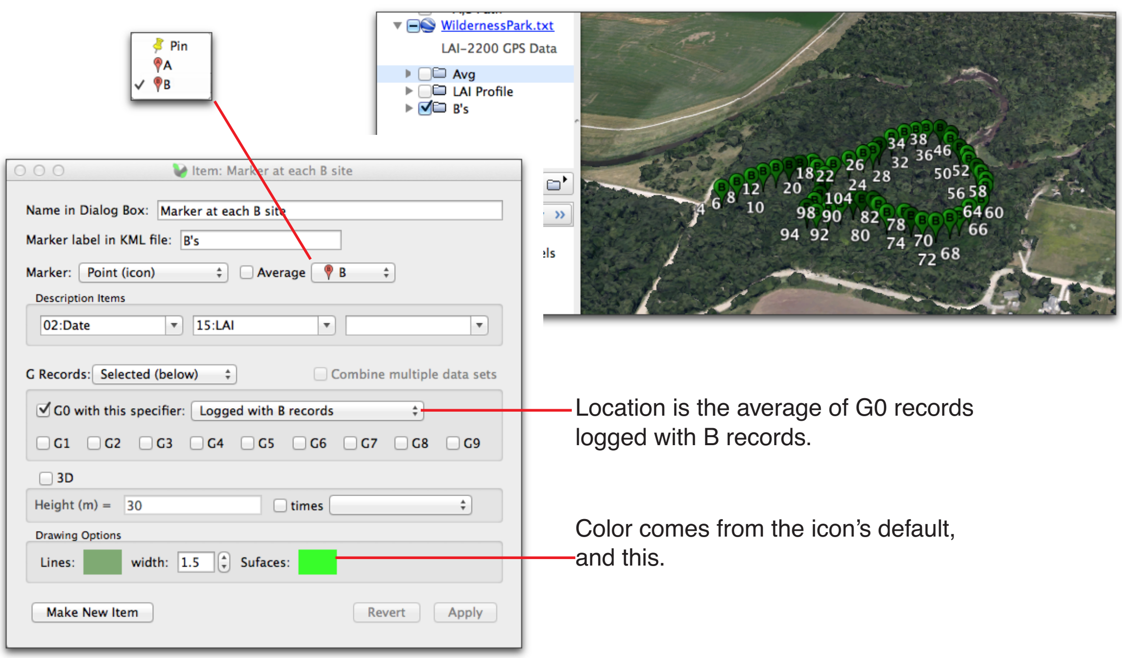


Figure 18: The B marker example.

G	1	20130822	11:34:33	G1	40.856701	-96.658795	354	6		
G	2	20130822	11:35:30	G1	40.856308	-96.658751	353.4	7		
G	3	20130822	11:35:52	G1	40.856322	-96.658491	353.5	6		
G	4	20130822	11:36:39	G1	40.856413	-96.657747	360.3	7		
G	5	20130822	11:36:59	G2	40.856237	-96.657657	354.3	7		
G	6	20130822	11:37:18	G2	40.856038	-96.657624	357.7	7		
G	7	20130822	11:37:40	G2	40.855781	-96.657705	345.7	7		
G	8	20130822	11:38:09	G2	40.85559	-96.658067	354.6	7		
G	9	20130822	11:38:19	G2	40.855626	-96.658261	355.3	7		
G	10	20130822	11:38:49	G2	40.855933	-96.658471	352.1	7		
G	11	20130822	11:39:38	G2	40.856219	-96.657822	364.3	7		
G	12	20130822	11:40:00	G3	40.856119	-96.657425	360.5	7		
G	13	20130822	11:40:25	G3	40.856037	-96.656957	362.5	7		
G	14	20130822	11:40:38	G4	40.85593	-96.657023	359.7	7		
G	15	20130822	11:40:51	G4	40.855783	-96.657	354.8	7		
G	16	20130822	11:41:22	G4	40.855823	-96.656467	344.4	7		
G	17	20130822	11:41:35	G4	40.855935	-96.656506	339.6	7		
G	18	20130822	11:42:07	G3	40.856024	-96.656713	342.9	7		
G	19	20130822	11:42:25	G3	40.856191	-96.656709	347.4	7		
G	20	20130822	11:42:36	G5	40.856197	-96.656552	369.4	7		
G	21	20130822	11:42:52	G5	40.856043	-96.656528	367.2	7		
G	22	20130822	11:43:02	G5	40.856041	-96.656428				
G	23	20130822	11:43:18	G5	40.856203	-96.65646				
G	24	20130822	11:43:23	G3	40.856216	-96.656368				
G	25	20130822	11:43:54	G6	40.85596	-96.656008				
G	26	20130822	11:44:10	G6	40.855763	-96.655986				
G	27	20130822	11:44:27	G6	40.855754	-96.65574				
G	28	20130822	11:44:43	G6	40.855934	-96.655706				
G	29	20130822	11:45:09	G3	40.85623	-96.655722				
G	30	20130822	11:45:57	G7	40.856191	-96.654914				
G	31	20130822	11:46:16	G7	40.856069	-96.654627				
G	32	20130822	11:46:32	G7	40.856179	-96.654419				
G	33	20130822	11:46:49	G7	40.85632	-96.654571				
G	34	20130822	11:47:55	G3	40.856642	-96.655653				
G	35	20130822	11:49:21	G3	40.856608	-96.657093				
G	36	20130822	11:49:46	G8	40.856831	-96.657164				
G	37	20130822	11:49:52	G8	40.856828	-96.657134				
G	38	20130822	11:49:59	G8	40.85686	-96.657052				
G	39	20130822	11:50:22	G8	40.857026	-96.656997				
G	40	20130822	11:50:42	G8	40.857095	-96.657277				
G	41	20130822	11:50:56	G8	40.857008	-96.657357				
G	42	20130822	11:51:48	G1	40.856449	-96.657573				
G	43	20130822	11:52:15	G1	40.856749	-96.65758				
G	44	20130822	11:52:35	G1	40.856983	-96.657546				
G	45	20130822	11:53:35	G1	40.857103	-96.65855	342.5	8	1.08	20130822 16:56:04
G	46	20130822	11:54:01	G1	40.856825	-96.658784	350.5	8	1.08	20130822 16:56:30

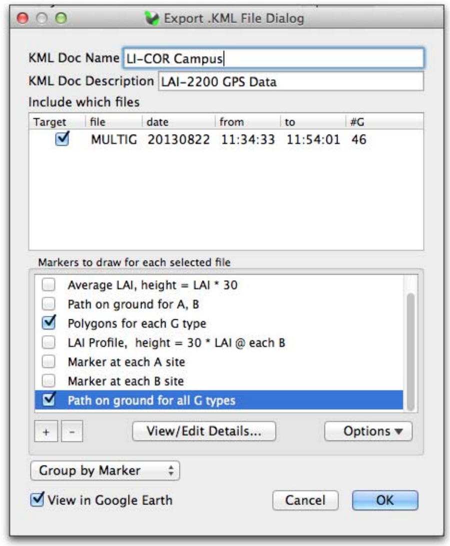


Figure 19: Illustration of plotting G records with differing IDs. This file (data shown in background) is data obtained on a walk around the LI-COR campus. Each building or area was marked by logging with a numeric key instead of the Log key. When plotted as a path (top), you see the walk progress. When plotted as polygons, we get 8 independent entities on the map.

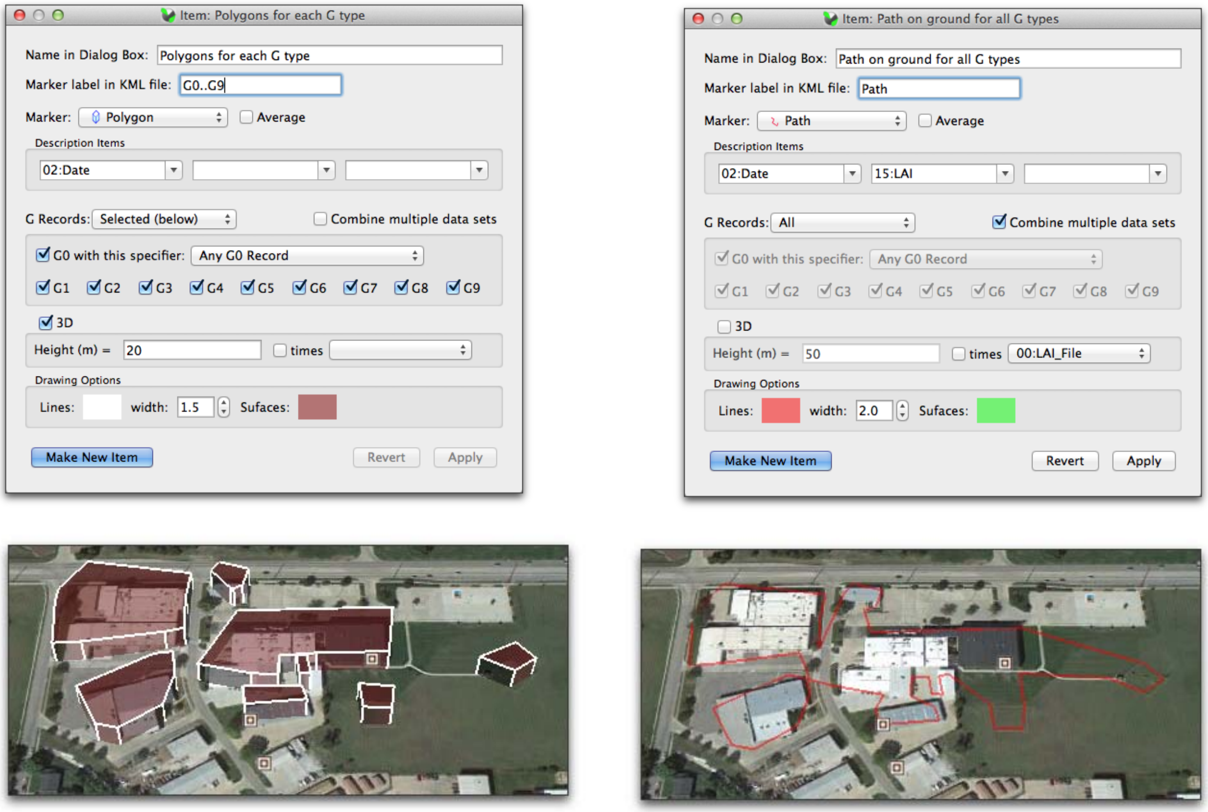
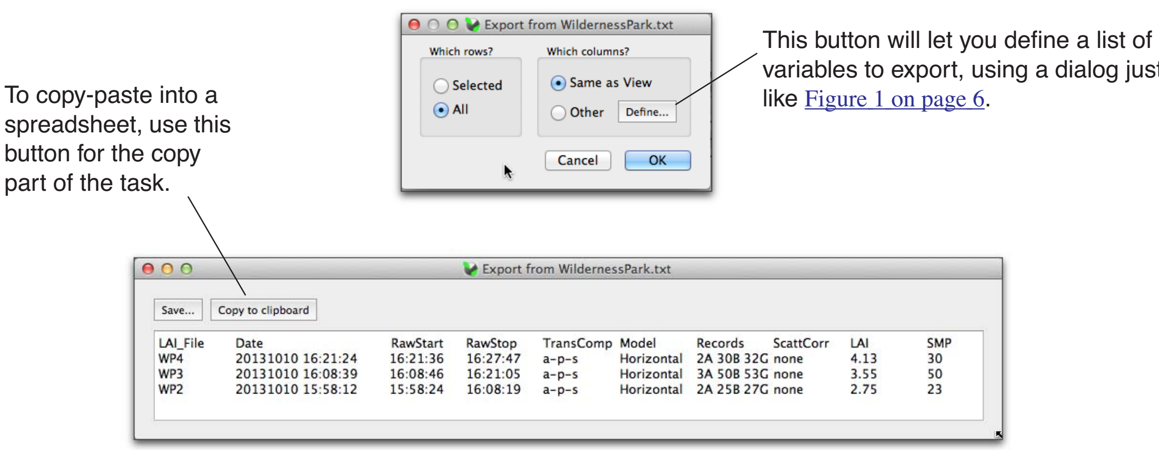


Figure 20: Marker configurations used in Figure 19. Note the use of the **Combine multiple data sets** *check box.*

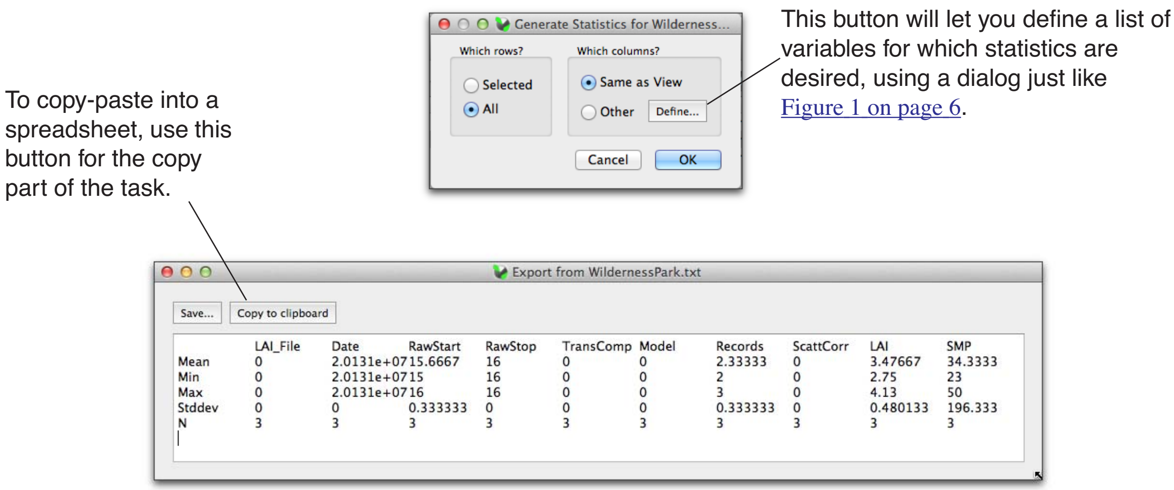
3.3 Spreadsheet Export

You can export data in spreadsheet format by **File > Export**.



3.4 Summary Statistics

Summary statistics for some or all files in a view is available by **View > Statistics**.



Appendix A: Scattering Corrections

One of the traditional underlying assumptions of the LAI-2x00 has always been that foliage absorbs all the radiation in the waveband seen by the sensor (320-490 nm). Starting with version 2.0, FV2200 allows this assumption to be set aside, and provides a model (Kobayashi et al, 2013) for correcting measurements for the radiation reflected and transmitted by the foliage. You should apply this correction for data taken in direct sun, since that's when the scattering errors are the highest, but you can also correct data taken when the sun is obscured, adjusting for the actual foliage scattering properties in your canopy, rather that assuming reflectance and transmittance are both 0.

How It Works

The algorithm that FV2200 uses for correcting for scattering goes something like this:

1. Compute gap fractions
From the measured gap fractions, calculate a first guess of leaf area index (LAI) and leaf angle distribution (LAD).

2. Predict the scattering effect on gap fractions
Run the Kobayashi model to predict the error that an LAI-2200 would make in a canopy based on LAI, LAD, and the other scattering correction inputs (leaf properties, sky brightness distribution, etc.). The model is a one-dimensional, multi-layer model, having foliage properties that you have specified. Foliage orientation, clumping, and total LAI is based on Step 1.

The model propagates beam and diffuse radiation through the layers, and predicts fractional irradiances on sunlit and shaded leaves in each layer. It then predicts the view that the LAI sensor, and the bottom of the canopy, has of the sunlit and shaded foliage throughout the model, and the resulting radiation errors each ring of a B reading would have.

3. Subtract the scattering effect from gap fractions.
The gap fractions are then adjusted to remove the predicted scattering effects.

4. Compute new LAI and LAD. Quit, or go to Step 2.
The adjusted gap fractions are used to compute a new LAI and LAD. If they have not changed, the process is done. Otherwise, it's back to step 2 with the adjusted gap fractions.

This process usually takes 4 or 5 iterations.

The *ScattCorr* Variable

All computed values in FV2200 (LAI, MTA, Gaps, etc.) reflect the effects of the scattering correction if is enabled. Thus, there are no duplicate sets of values (i.e. no LAI_with_scattering, LAI_without_scattering, etc.). There is one quantity (*ScattCorr*) that tells you the status of scattering corrections for any file (Table 1). When *ScatterCorr* = a numeric value, all values associated with that file reflect the effects of the scattering correction. While it is very simple (once the inputs are in place) to turn the correction on and off and examine how any particular value changes, the ScattCorr value directly gives you this difference for the LAI value.

ScattCorr is a quantity you'll want displayed (1.3 Change the Displayed Variables on page 6).

Table 1: The *ScattCorr* variable

Value	Meaning
none	The file does not have the necessary inputs to be scatter corrected.
off	Scattering inputs present, but correction is turned off.
value	The file is scatter corrected, and *value* is the difference in LAI that the correction makes.

Note: the numeric value of *ScattCorr* is the difference in LAI as measured by the *EllipLAI* variable, not the normal *LAI* variable. The reason is that the scattering correction model uses the inversion scheme of Norman and Campbell (1989)[1], which is based on an ellipsoidal representation of leaf angle distribution. This scheme is also built in to FV2200, and the leaf area index parameter and leaf angle parameter are available as *EllipLAI*, and *EllipX*. The two LAI values (*LAI* and *EllipLAI*) are generally fairly close.

Required Inputs for the Scattering Model

To correct a measurement for scattering, a model is used that requires some extra inputs, which are summarized in Table 2.

Table 2: Required Inputs for the scattering correction

Item	Description
LeafRho	Average foliage reflectance in the blue (230-490 nm waveband).
LeafTau	Average foliage transmittance in the blue.
SoilRho	Surface reflectance beneath the canopy in the blue.
SolarZen	Solar zenith angle (0° = overhead, 90° = on horizon).
SolarAzm	Solar azimuth angle (0° = North, 90° = East, etc.)
SkyViewCap	The azimuthal view size of WideSky values (e.g. 270°)
AViewCap	The azimuthal view size of ASky values (e.g. 45°)
AViewAzm	The azimuthal direction of ASky values (0° = N, 90° = East, etc.)

1. Norman, J.M., Campbell, G.S. 1989. Canopy Structure.In:Pearcy, R.W., Ehleringer, J., Mooney, H.A., Rundel, P. (Eds.), Plant Physiological Ecology. Chapman and Hall, London, pp. 301-325.

Table 2: Required Inputs for the scattering correction

Item	Description
FBeam	The fraction of the total incident radiation from the sky that is direct beam, in the blue.
WideSky	The 5 ring values read by the sensor using the SkyViewCap
ASky	The 5 ring values read by the sensor using the ASky Cap.

Figure 21 shows the additions to the file header when scattering corrections and/or GPS data are present in a file.

```
### Scatter Correction
ScattCorr    0.095
LeafRho      0.050
LeafTau      0.010
SoilRho      0.050
SolarZen     51.1
SolarAzm     94.
TimeZone     -5
GpsLat       40.85600000
GpsLong      -96.65780000
### K Record Averages
SkyViewCap   360.
AViewCap     45.
AViewAzm     0.
FBeam        0.60
WideSky      560.00   639.35   761.65   922.60   827.40
ASky         42.50    59.07    62.13    72.03    82.15
```

If G records are present (GPS data), then these three lines not there, but the normal header entries for GPS records instead.

If this comment is present, then K records are also present, and the values beneath it represent averages of the K records, not direct inputs.

Figure 21: The items added to the file header when scattering correction inputs are applied.

ScattCorr indicates the state of scattering corrections, and its values are explained in Table 1 on page 36.

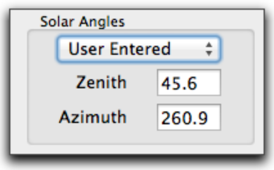
The three values for average vegetative reflectance, transmittance, and the surface beneath the canopy (***LeafRho***, ***LeafTau***, and ***SoilRho***) should be for the 320-490 nm waveband. The values could come from spectroradiometric measurements integrated over this wave band, or from a radiometer sensitive in that wave band. Kobayashi et. al. present a technique for using the LAI-2x00 wand and a reference panel to determine these values.

The location information (***GpsLat***, ***GpsLong***, and ***TimeZone***) will be present only for units that do not have G records. *GpsLat* is degrees latitude (North > 0, South < 0), *GpsLong* is degrees longitude (East > 0, West < 0). *TimeZone* is the difference in hours between UTC and the time used in the LAI file's header. If the instrument's clock was set to local standard time, *TimeZone* would likely be longitude/15. Note that for negative (west) longitudes, the *TimeZone* is also negative. If the instrument's clock was set to UTC, then *TimeZone* would be 0.

The solar position values ***SolarZen*** and ***SolarAzm*** represent the zenith (0=overhead, 90=horizon) and azimuth (0=North, 90=East, etc.) angles of the direction *toward* the sun. These angles are either computed from location, or can be entered directly. Values that have been entered directly, and not computed, are marked with an asterisk (*).

```
SolarZen  34.5*
SolarAzm 224.*
```

Hint: if, for example, you wish to experiment with the affect of changing solar angle on a file that has GPS information to compute solar angles, you can do it from the text window in Figure 10 on page 20 by entering both zenith and azimuth values with asterisks following them, and clicking the Keep button. To undo that and go back to computed values based on latitude and longitude, just remove the asterisks and click Keep. This can also be done in the single file dialog (Figure 11 on page 21 by selecting "User Entered" in the Solar Angle box.



The next six values pertain to sky condition. Note that if K records are present, then these values represent the average of the K records that were used in the correction, and editing these values in the file header will have no effect. If K records are not present, then the values are inputs, not outputs. ***FBeam*** is the fraction of total radiation that is direct beam in the blue (320-490 nm). ***WideSky*** is the reading from the 5 rings with no (or the 270) view cap, sun blocked. ***ASky*** is the narrow sky distribution. ***SkyViewCap*** is the size of the view cap (degrees open) used for *WideSky*, and ***AViewCap*** is the size of the view cap (degrees open) used for *ASky* and for your normal A and B measurements. ***AViewAzm*** is the view direction of view (0=looking North, 90=looking East, etc.) for *ASky* and for the normal A and B measurements.

Both *WideSky* and *ASky* have the following constraints:

- They need to be made with an unobstructed view of the sky.
- They should be made with the same wand.
- That wand making the measurements should be using the factory calibration values. This is the calibration that relates one ring to another. With this calibration, all of the sensor's rings will read the same in a purely isotropic environment. This (*WideSky* and *ASky*) is the one time in LAI-2x00 processing that the rings of the sensor are NOT treated independently, and the factory isotropic calibration is needed.

Making it Practical

Calculating Solar Angles

The best method of getting solar angles is to calculate them. To do that, one needs to know location (latitude and longitude) and time (UTC). The LAI-2200C (and upgraded LAI-2200s) have a GPS chip, that allows all of this data to be logged along with the LAI measurements.

If you don't have GPS, FV2200 allows you to specify the latitude and longitude for the files you wish to correct, and some time zone information. UTC comes from the average time of data in the file and the time zone.

Fraction Beam

The fraction of the total incident radiation that is in direct beam in the waveband seen by the LAI wand is best measured by that wand. Kobayashi et al made this measurement by mounting a downward looking wand above a reflectance panel, restricting the center ring to a narrow field of view, and recording the sunlit and shaded readings of the panel. Subsequent experimentation has shown that by simply putting a diffuser on an upward viewing sensor gives very good agreement (unpublished data).

A suitable diffuser made from white Plexiglas is available from LI-COR (part number 6522-117), and is machined to slide onto the wand over the lens and stay in place in the wind, if tipped, etc. Alternatives are readily found (any stiff, flat, translucent material is a candidate: paper, plastic, etc.), so if you lose or misplace the good diffuser in the field, you might be able to find some alternatives (the bottom of a paper cup, for example) to keep you going (Figure 22).

6522-117

Scrap piece of white Plexiglas

Paper cut from bottom of a drinking cup. (Thumb required)

Figure 22: Some of the options for measuring fraction beam with an LAI-2x00 wand.

K Records

To aid in getting the sky brightness data and fraction of beam information in the field as painlessly as possible with a minimum of extra equipment, we developed a measurement protocol illustrated in Figure 23, called a **4A Sequence**. The name comes from the fact that you are taking four A readings in a row, which will later be condensed into something called a **K Record**.

The first two A readings use a white diffuser. With your back to the sun, and the sun shining on the diffuser cap, level the sensor, and take the first A reading. Then, rotate just a bit to shade the diffuser cap with the shadow of your head, and take the second A reading. (If the sun is too high to shade the diffuser with your head, hold the sensor with one hand and reach up and out with the other to shade the diffuser; you want the entire diffuser completely shaded, but not much more than that.) For the third A record, remove the diffuser and either shade the sensor with your head, or simply put a 270 view cap in place. This reading needs to have the sun blocked, but retain as wide a view of the sky as possible. The final A record in the 4A sequence is a normal A reading: use the view cap and view direction you are using for measurements.

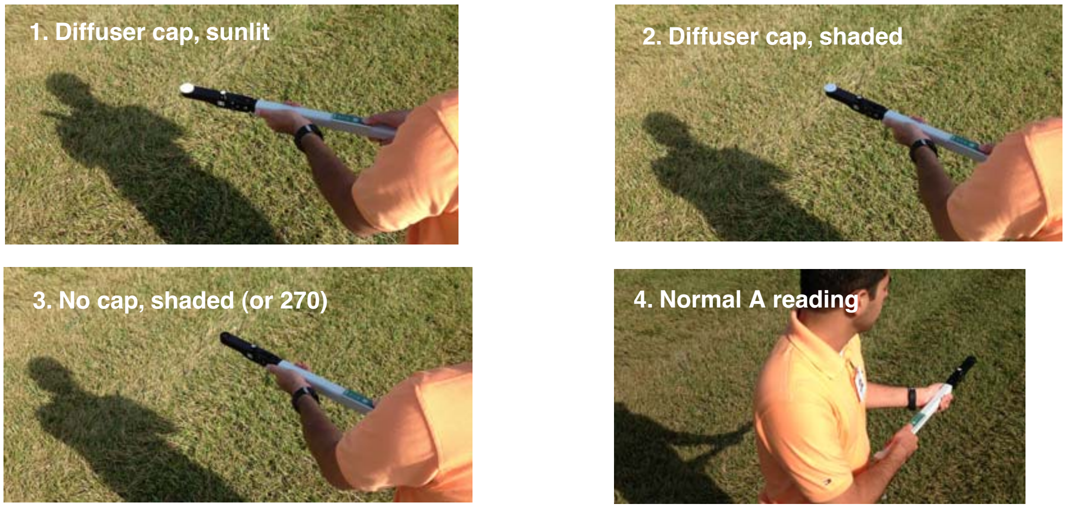


Figure 23: The 4A sequence.

Ultimately, each LAI-2200 file that is to be scatter-corrected will need to have at least one K record in it. This does not necessarily mean that when you are collecting data in the field, you need to do a 4A sequence in every file. K records to be copied (by FV2200) into other files that need them, so you can perform a 4A sequence somewhere in a data file (beginning, middle, end, it doesn't matter), or as part of a below-canopy file if you are in two sensor mode, or accumulate a series of them into their own separate file. It is a simple matter with FV2200 to turn the 4A sequences into K records (2.4.1 Generate K records from Sequences on page 17), then copy them to whatever files need them (2.4.3 Import K records on page 19). When FV2200 copies K records, it does it based on time, and uses the closest ones available in source files to the B records in the destination file.

How Many K Records Needed. Sky conditions will determine how often K records (i.e. 4A sequences) are needed. The determining factor is how fast the fraction of beam is changing. The simplest case (as always) is clear blue sky. During the middle of the day, one K record per hour would be fine. The worst case is fast-moving scattered or broken clouds, with the sun coming and going. The choice in those conditions might come down only taking data (A, B, and 4A sequences) when the sun is between clouds, or only taking data (A and B) when the sun is obscured behind clouds (you know the fraction of beam is 0 then, so you so don't need K records), or waiting for a better day.

Another consideration is if your measurement involves multiple view directions. In principle, you should have a K record for each view direction used. However, *if your view azimuths are symmetric about the solar azimuth* (e.g. sun is South, and your views are East and West), then you would not need multiple K records unless there were distinctly differing cloud formations in those two directions.

Other Ways to Make K records
4A sequences are not the only way to make a K record.

3A Sequence. If you are using the same view cap for the last two A readings, you can forego the wide sky view (the 3rd A of a 4 A sequence). FV2200 will use the last A reading in the sequence for both the wide and narrow views. This of course makes the assumption that the brightness distribution in the direction of your A readings is the same as for the entire sky.

Operational hint: For a 3A sequence, you can leave the view cap in place for all three A readings (unless it is quite windy); simply lay the diffuser upsidedown on the view cap to do the first two A readings. Orient the diffuser so the open side is toward the sun so the diffuser doesn't self-shade. This is especially helpful for the larger view caps (180 and 270), since they can be troublesome to put on with one hand.

1A + Assumption. If your LAI data was collected with the sun obscured by cloud, or below the horizon, then you already know the fraction of beam is 0. If you are also willing to make the assumption that the sky brightness distribution in the direction of your measurement is the same as for the rest of the sky, then you can forego 3A or 4A sequences entirely; FV2200 will let you build K records based on the normal A readings in the file and your assumption of the fraction beam value. This is also useful for correcting old data for the effects of actual foliage reflectance and transmittance.

3BA and 2BA Sequence. Consider the following situation (LAI-2200 only): You are in multi-sensor operation mode, with one sensor devoted to A readings, and other sensor(s) doing B readings. You need to get K records from the A sensor, since that's the only one with a suitable clearing. Suppose further that the A unit is just a wand that is automatically logging A records at regular intervals, so there's no chance of interrupting autologging and putting 4A sequences into a separate file. Can you get K records in this situation? You can if there is enough time between autologs (you probably need at least 30 seconds) to do a few simple steps:

When it's time to collect data for another K record, do this:

1) Wait for an autolog to occur.
2) Push the A/B button to change to B records.
3) Remove the view cap, and put the white diffuser in place.
4) With the sun on the diffuser, press the LOG button.
5) Shade the diffuser, and press the LOG button again.
6) (Optional wide sky view). With the sensor shaded, or with a wide view cap, press LOG again.
7) Place the normal view cap back on, and press the A/B button to change back to A records, so that the next autologged reading will be an A.

You are essentially doing a 4A or 3A sequence, but labelling all but the last as B records.

Useful variation: if you are skipping step 6 (i.e. doing a BBA sequence), you can avoid having to remove the view cap at all. Simply do steps 3 through 5 by laying the diffuser on the view cap upsidedown (or use an alternative diffuser - see Fraction Beam on page 39 for suggestions).

What you will end up with is a file filled with A records, with an occasional 2B or 3B sequence. The A record that immediately follows each 2B or 3B sequence will also be used to make the K record. Thus, a 3BA (i.e. BBBA) is just like a 4A sequence, and a 2BA (i.e. BBA) is just like a 3A sequence.

Again, the 3BA and 2BA are usually only for above files that are otherwise full of A records.

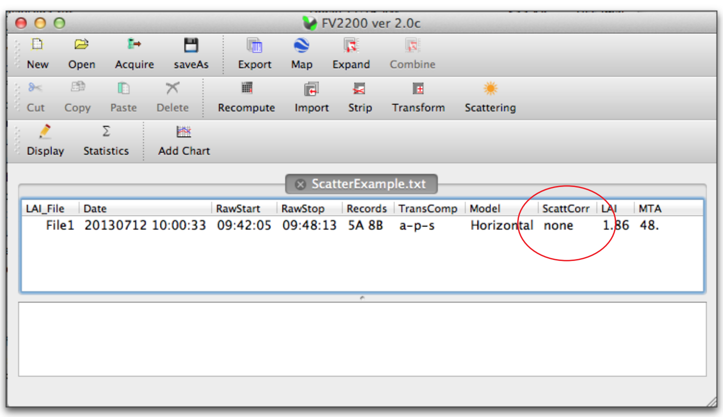
An Example

We present an example of making a single sensor measurement complete with scattering correction. We illustrate with a data file that is included in the sample data files built-in to FV2200. This will let you follow along on data already taken for you.

For this example we measured a site using 8 B records, and a starting and ending A record. (Final A records are only useful when you have interpolation enabled; we'll do that when we are done). Thus, the measurement sequence without scattering corrections would be ABBBBBBBBA. Because we are doing scattering corrections, we need to replace at least one of the A readings with a 4A sequence; we'll replace the first, leaving us with a measurement sequence that is AAAABBBBBBBBA. Those first 4 readings, however, are done as shown in Figure 23 on page 40.

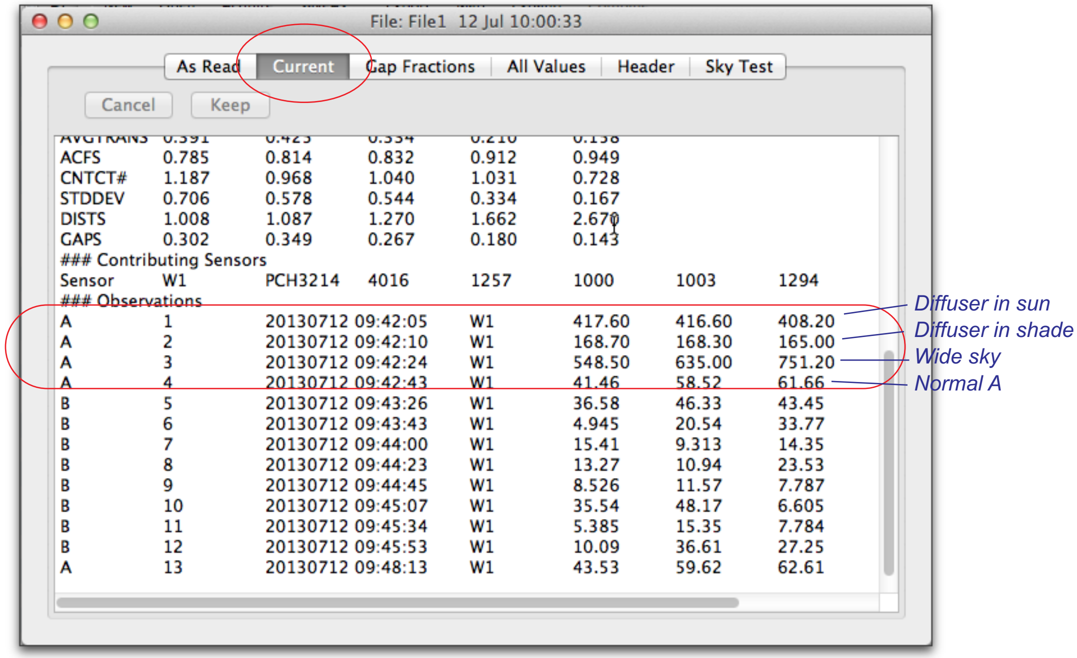
You can load this data file into FV2200 (Do **File > Sample files > ScatterExample.txt**). The state of the file is like it just came from the field - the 4A sequence is there, but hasn't yet been turned into a K record.

Step 1. You will want to add a variable named *ScattCorr* (The ScattCorr Variable on page 35) to the list of displayed items in the main view of FV2200, if it is not there already. (See 1.3 Change the Displayed Variables on page 6 for how to do this).

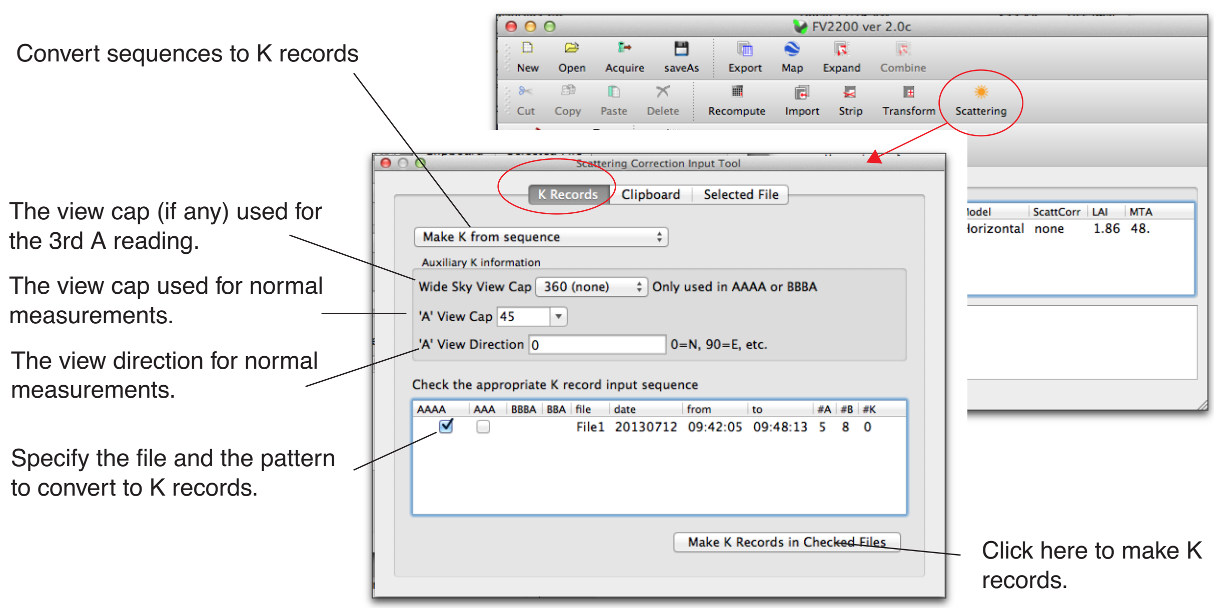


'none' means the scattering input data is not there yet.

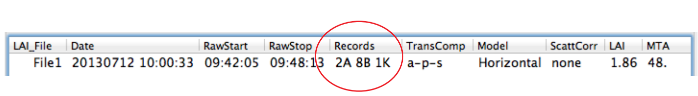
If you wish to view the data records, double click the File1 entry, and select the Current tab.



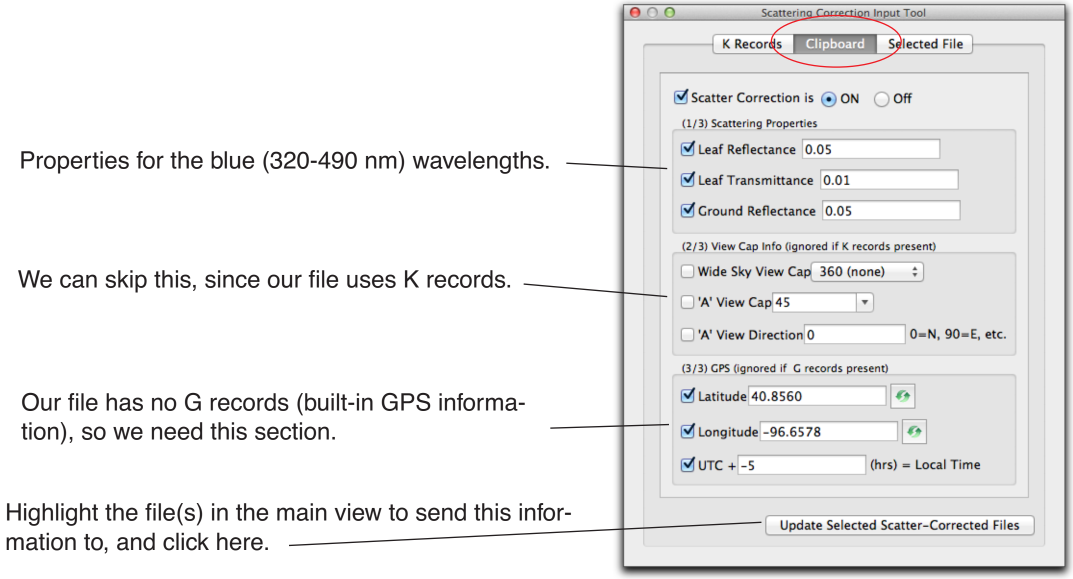
Step 2. Click the Scattering Tool icon to open the Scattering Correction Tool, then click the K Records tab. Set the values as shown.



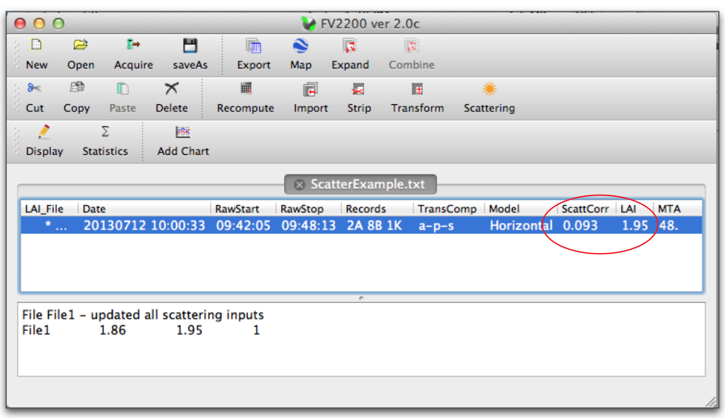
Once the K records are made, the Records field in the main view will show the change (Added 1 K, 'removed' 3 As).



Step 3. Click the Clipboard tab in the Scattering Correction Input tool, and fill in the fields as shown.



The file is now corrected for scattering, and the LAI increased from 1.86 to 1.95.



One final step would be to enable interpolation of the A readings, since we have that final A record in the file. If you do that, following 2.2 Interpolate A Records on page 15, you will find that the LAI for this file changes from 1.95 to 1.94.

When the scattering correction is applied (as evidenced by the ScattCorr variable having a numeric value), all computed values (LAI, MTA, GAPS, etc.) reflect the scattering correction. The value of ScattCorr itself is the difference in leaf area index (actually, it's the difference in the parameter EllipLAI, the leaf area index based on the inversion scheme of Norman and Campbell (1989) using the ellipsoidal representation of leaf angle. This is the computation used internally when iterating through the scattering correction model).

Model Limitations

The scattering correction is based on a simple model, and how well it works in any particular circumstance depends on how well those circumstances conform to the assumptions of the model. A very fundamental assumption of the model is that the canopy is one dimensional (vertical), with foliage that can be clumped. The sun is above the canopy looking down, and the LAI sensor is below the canopy looking up. The model canopy is a good approximation to a fairly uniform, full cover actual canopy. But how about other settings?

Here is a key factor in how well the model will predict scattering errors: *The model will fail when the relation between gap fraction at any particular view angle and the sunlit leaf area that is visible in that view angle differs from what would be predicted in a horizontal canopy* (Figure 24).

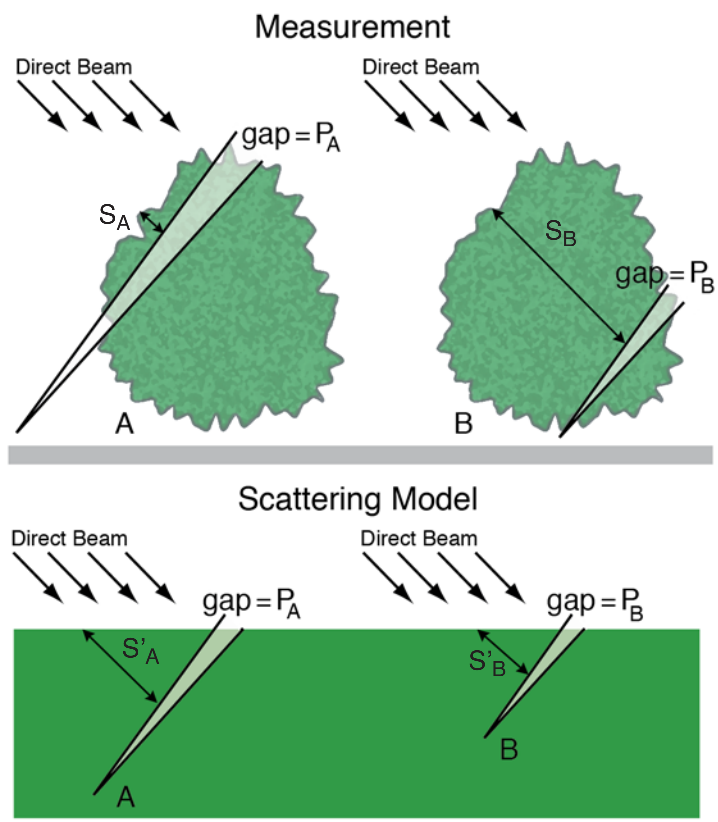


Figure 24: Representation of how the scattering model can fail in an isolated canopy setting. Measurements A and B have gap fractions P_A and P_B for a particular ring (top). These are mapped to an idealized canopy (bottom) in a layer with the same gap fraction at that view angle. The problem in case A is that the measured sunlit area (and thus scattered radiation) that was measured is much greater than what the model would predict. This is seen by comparing the relative path lengths of sunlight through the canopy to get to the ring's view in the measurement vs. the scattering model. I.e. $S_A < S'_A$ *. In case B, the measured sunlit area is much smaller than the model would predict, since* $S_B > S'_B$ *)*

Another way to look at the problem presented by case A in Figure 24 is that unlike in the model (sun above, viewer below), the viewer and the sun are now effectively on the *same side* of the canopy. And the lower the sun is in the sky, the more the measurement will be dominated by sunlit leaf area, which the model cannot begin to predict, since it assumes the viewer is on the *opposite* side of the canopy.

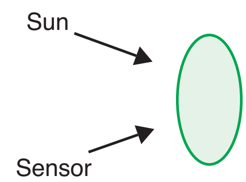


Figure 24 illustrates the problem and offers a clue about how to reduce the problem. If we can choose a view direction that minimizes the differences between the view path lengths through the canopy (they determine gap fraction) and the direct beam path lengths through the canopy that determine sunlit leaf area, then we might minimize the model's errors. If having the sensor look directly away from the sun, as in Figure 24, maximizes the problem, it suggests that viewing more toward the sun (the sun can't be in the sensor's view, of course) might reduce the problem.

This suggests the following measurement guideline <u>for canopies with significant gaps</u>: *As much as possible, keep the sun in front of you, not behind you* (Figure 25).

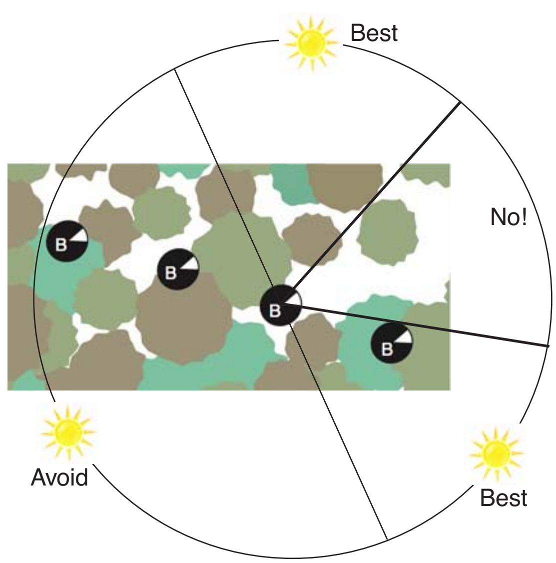


Figure 25: Illustration of suggested measurement protocol for non-uniform canopies. The higher the sun is in the sky, however, the less important this suggestion becomes.

Testing the Model

Since no canopy fits the model, it is a good idea to test your measurement protocol (and scattering correction inputs) for each situation. A simple way to do this to pick a representative transect or plot and measure it (*at identical locations*) when the sun is obscured, such as at twilight, and compare those results with the scatter-corrected results. Actually, you can scatter-correct both, but the data set with the sun obscured will have an FBeam value of 0. It's best to do this sort of comparison under clear blue sky, as clouds introduce their own variability (1.5.4 Sky Test on page 10).

Appendix B. Three Methods for FV2200 Matching

Scattering corrections have some implications for multi-sensor operations, so read this section, even if you think you are familiar with multi-sensor operation.

When two or more sensors are used to collect LAI data (e.g. one sensor collects above canopy A records, the other below canopy B records), two things have to happen to produce final LAI values:

1) Combining. The A records and the B records have to be combined into one file. Normally, some of the A records are inserted into the B file based on times of the B records.
2) Matching. One of the record types (A or B) must have its values adjusted to account for calibration differences between the two wands.

While it is possible to do both combining and matching entirely on an LAI-2200 console, we highly recommend that you use the FV2200 software for both of these tasks instead. Here are the reasons:

- K records (i.e. 4A sequences, 3A sequences, etc.) should be done with a wand with factory calibration factors, *not* one matched to another sensor. FV2200 matching allows all wands to always use their factory calibration values. This allows any wand to be used for the K record precursors needed to do scattering corrections.
- Console matching is done with one snapshot reading, which is dangerous when there are clouds. FV2200 matching is based on as many readings as you wish to average.
- FV2200 matching is not limited to two LAI-2200 wands, like console matching is: it can be used for any number of wands, including old (LAI-2000) instrumentation.
- Collecting the data for FV2200 matching can be done anytime, not just at the time or place of data collection. This means you can collect matching data under the best sky conditions for matching (clear blue sky), and in a place with the best view of the sky (e.g. the roof of your building).
- FV2200 matching simplifies what needs to be done in the field, reducing the chances for errors.
- Once the relevant files are on your computer, FV2200 combining and matching can be done in one simple step.

There are three variations you can use to do FV2200 matching. The method you choose will depend on the circumstances.

For this discussion, we will assume that there is a sensor (the A unit) that is to be used for logging A records in a clearing, and there is one (or more) B unit collecting below canopy B records. Note that either “unit” could be a) an autonomous wand, or b) an LAI-2000 or LAI-2200 console and wand.

The three methods listed here are named for the setting in FV2200 that you would use to do the match while importing records. The FV2200 import dialog (2.3 Import and Adjust A Records on page 15) lets you specify source files (the ones with A records), destination files (the ones with B records that need corresponding A records), and - when needed - match files (files that contain some or all of the information on how the sensors compare, so adjustments can be made to imported A records).

Method 1: B / A pairs in Match

(Recommended) This method puts the match readings from both A and B units into the one special file, known as a match file. This can be done before or after the measurements. If you are careful about keeping lenses cleaned, this file can be generated once and used over an extended period (weeks, months, etc.). When you have a calibration session, you might want to generate several files, one for each view cap you might use. You could name the files M45, M90, M180, for example, meaning they are for the 45, 90, and 180 degree view cap.

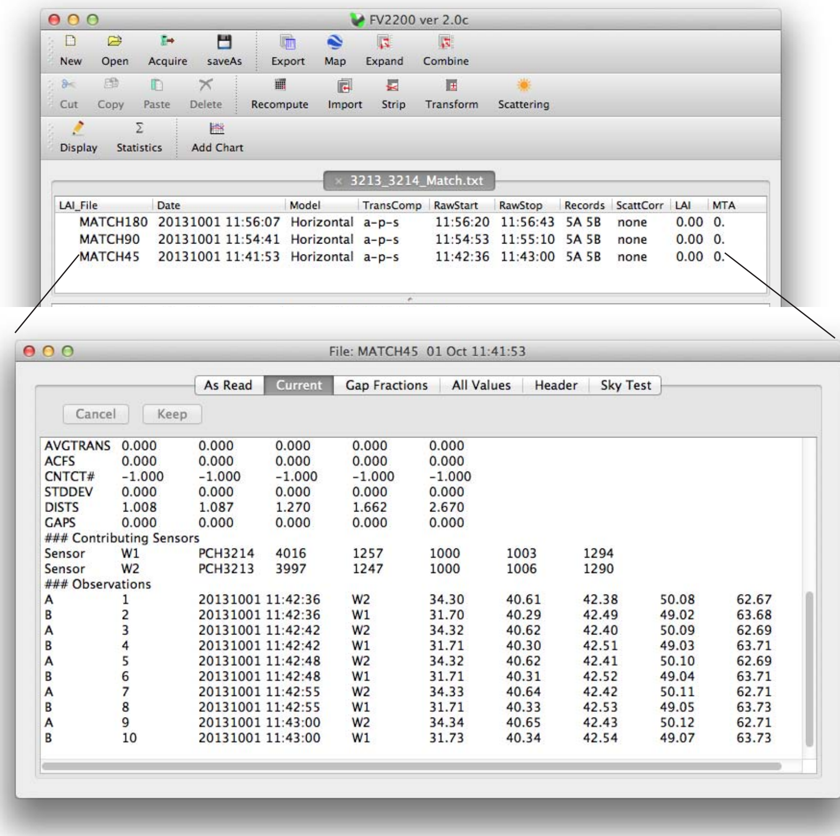


Figure 26: Sample match data for two sensors, PCH3213 and PCH3214. There are three files for three view caps, and in each file several data pairs, all logged while viewing clear blue sky. Since FV2200 uses serial numbers when applying this data, it doesn't matter what record types (A or B) the sensors logged. They could be mixed (as shown), or all A, or all B. If you are doing this with LAI-2000 format files, however, then the only way to identify sensors is by record type, so the A records and B records in a match file should be made by the same sensors as did the A and B records in source and destination files. (You can convert formats, however, and avoid this constraint.)

2.3 Import and Adjust A Records on page 15 illustrates how to do match file adjustments when importing A records.

The main advantage of Match Method 1 is that it eliminates all matching-related field work at the time of LAI data collection. Just collect your LAI data and you're done; all the matching work has already been done. (Or will be done; your calibration session could also happen after the fact.)

The remaining two match methods involve collecting matching data at the time of regular data collection. *If the sky is cloudless*, then they can work as well as Method 1.

Method 2: B (or A) in Match / A in Source

This method collects match data on-site, and creates a match file that contains only the below canopy sensor's match readings; the corresponding above canopy sensor's readings are in the above canopy file. The situation in which you might use this method is illustrated in Figure 27 on page 50: There is a clearing in which the A unit will reside, and a forest or other tall canopy in which one or more B units will log a series of files along transects or in plots.

Method 3: A in Dest / A in Source

This method collects match data on-site, but does not use a separate match file. Instead, each B file contains its own match data, in that every B file contains at least one A record that can be used for matching. To make this work, it must be possible for each B unit to get to the A site and take at least one A record for each file it creates. Figure 28 on page 51 illustrates.

A potential advantage of Method 3 is that since you have an A record logged, you can compute an LAI estimate in the field based on that one reading (if it is done first, or if you pick the "closest in time" option for using A records). That way, if disaster strikes (e.g. a bear makes off with the A unit), you still have some results.

Combining 2 and 3

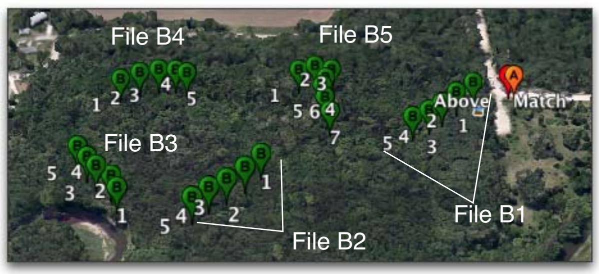
You can also do a combination of these methods: If you use Method 3 for the first and last transect that you measure (with the A reading for the last transect coming at the end of the file), you can use those files as match files for any other below files that you create in between the first and the last ones. Those intermediate files would have only B records. Figure 29 on page 52 illustrates.

1. Set up the A sensor and get it logging at regular intervals in the Above file.

2. Before leaving the clearing, each B sensor makes a few matching measurements next to the A sensor. Log these into a file named 'Match', or something to identify it as a match file.

3. Each B unit goes off and collects multiple below canopy files. All have only B readings.

4. (Optional) Upon returning to the clearing, append a few more readings into the Match file (or make a new match file), before shutting down the A unit.



5. When importing the A records, use Match Method 2 to adjust the readings according based on corresponding readings between the above file and the match file.

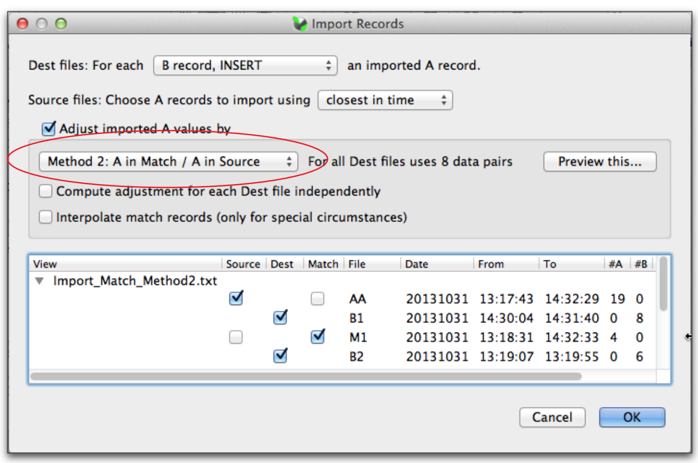
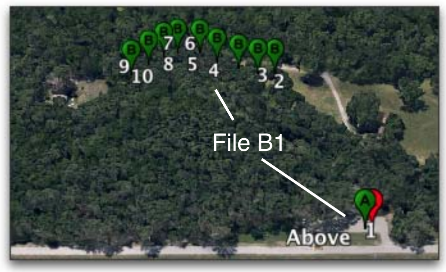


Figure 27: Method 2 illustration of data collection and processing steps.

1. The A unit is set up and logging in a clearing.

2. (Going out) Begin the first B file with an A record logged alongside the Above unit. Then go do the rest of the B records along the transect.



3. (Coming back) File B2 with an A record logged beside the above unit.

4. Import A records to files B1 and B2 using Match Method 3.

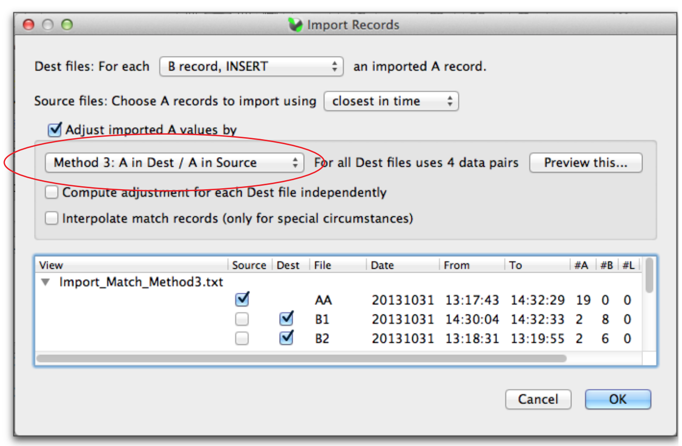
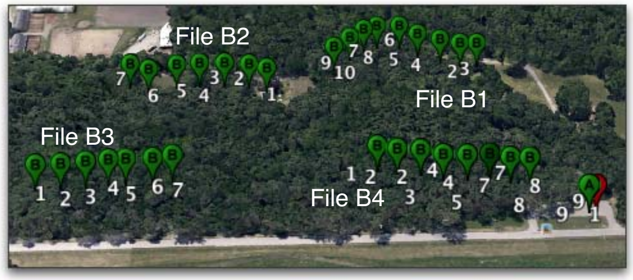


Figure 28: Method 3 illustration of data collection and processing steps.

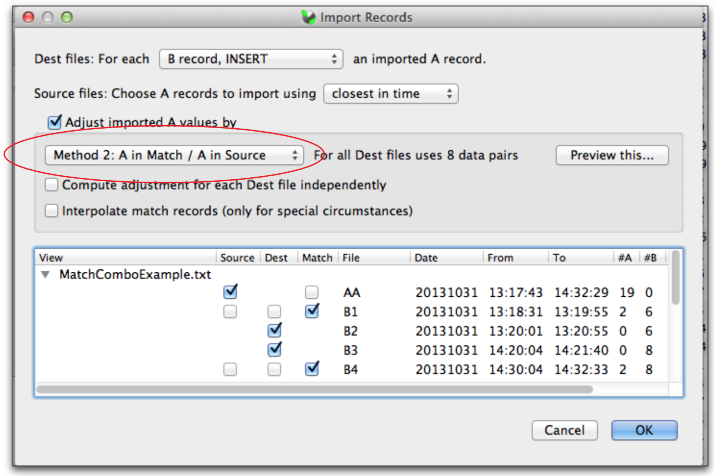
Data Collection

1. File B1 starts with an A record.
2. File B2 with no A records.
3. File B3 with no A records.
4. File B4 ends with an A record.



Data Analysis

1.Use Method 2 for B2 and B3, with B1 and B4 as Match files.



2. Use Method 3 for B1 and B4.

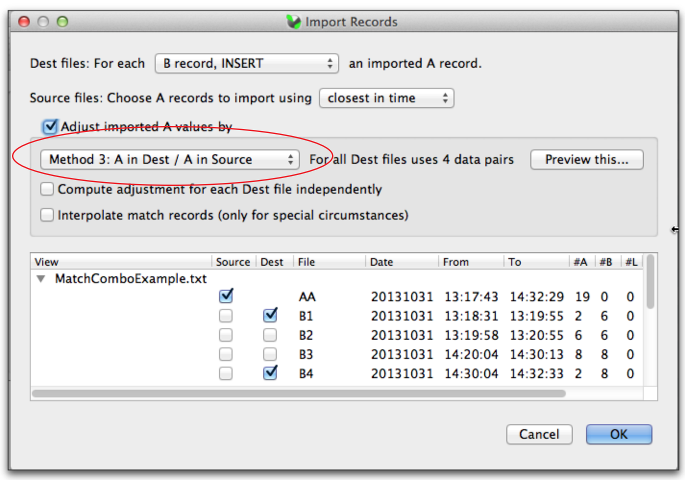


Figure 29: Illustration of data collection and analysis using a combination of Methods 2 and 3. Files B1 and B4 do double duty as both data files and match files.

Appendix C: Some Protocol Suggestions for Direct Sun

General

These are based on Model Limitations on page 45.

Test the Model

Test how well the scattering corrections are working for you. A suggested test is described in Testing the Model on page 46.

Keep Some Canopy Between You and the Sun.

This is never a problem in a uniform canopy - the canopy is always overhead. However, in a canopy with large gaps, or wide rows, or when measuring individual crowns, you will need to avoid making readings with the sensor having an unobstructed view of the sunlit side of a subcanopy (Figure 25 on page 46).

Working on Slopes

If you are collecting data on a significant slope, we recommend holding the sensor parallel to the slope, rather than level, when making A and B readings. In this case you also need to measure the 3rd and 4th A readings of a 4A sequence also parallel to the ground. The 1st and 2nd readings (to get fraction beam with the white diffuser) should always be with the sensor level, however. See Figure 11 on page 21 for where to enter slope information in FV2200.

Single Sensor

- Make sure the sensor calibration is the factory default, and hasn't been modified by matching to another sensor.
- You don't need to do a K record for every file, unless sky conditions are very changeable. You can import K records from files that have them to files that need them (2.4.3 Import K records on page 19).
- You can intersperse K record 3A or 4A sequences and single A records. For example, a series of records such as AAAAB...AB...AB...AAAA would turn into KAB...AB...AB...KA.
- You might opt to keep the K's in a separate file. Whenever you need to do another K reading, re-open that file (named K, for example), and append another 4A sequence (or 3A sequence, but be consistent) into it.

Multiple Sensors

- Make sure ALL the sensors have their factory default calibrations.
- Use Method 1: B / A pairs in Match on page 48 for your inter-sensor calibration scheme. Get the data for this once on a clear blue day, and then don't worry about it after that.
- If you are operating in separate sensor mode (remote above, and remote below), and there is only one person to do the work, then plan on doing K readings with the below sensor, putting them in a separate file. Later you can import A records from the above file, and import K's from the K file.
- If there are enough people to dedicate someone to doing the K records, then ideally they also have a separate instrument (or just a wand) to dedicate to it as well. However, if the A unit has

to do double duty as the “K unit”, one option is to do nothing but K records (recall that a K record includes a normal A record): Go though a 4A or 3A sequence as frequently as you think is needed, or as frequently as your sanity can stand. In clear blue sky, one K record every 10 or 15 minutes would be plenty. However, if you think you need a higher frequency of reference A records than K records, then see 3BA and 2BA Sequence on page 41 for how to do that.