FV2200 Version 2.0

Scattering Corrections and GPS

17 May 2013 - 2.0a
21 May 2013 - 2.0b (replaced Scatttering Setup Dialog with Scattering Input Tool)
5 Sept 2013 - 2.0c (K records, G records, and measurement protocols)
31 Oct 2013 - 2.0d (Improved GPS plotting, Display editor, Prompt editor)

Preface to Beta Testers

Changes to FV8100
The changes to version 2 are the addition of scattering corrections, and support for the GPS option in the console.

Scattering corrections allow LAI measurements to be made in any sky condition, and corrected for the errors due to the foliage scattering radiation, rather than absorbing it all as the basic theory assumes. The corrections are all done in the FV2000 program, and can be done on data taken with any LAI-2000 or LAI-2200.

LAI-2200 consoles can now have an optional GPS device built-in. Version 2.0 of FV2200 adds some support for this in files for which this data is present.

There is some overlap between GPS and scattering corrections: among the required inputs for scattering corrections is solar zenith and azimuth angle, which is calculated from latitude, longitude, and UTC. If data files already have GPS data present, it saves you the trouble of having to enter it when setting up scattering corrections.

Beta Version Updates
The current released version of FV2200 lets you check for new versions, and reports updates automatically when the app is run. The Beta version has a parallel arrangement: subsequent updates (and also when the final released version is available) will be reported automatically, or you can check manually via the Help menu.

In the meantime, please report all bugs and suggestions to me (jon.welles@licor.com).

Thank you for your help.

Contents

Part 1: GPS

Part 2: Scattering

GPS Support

File Changes

When the optional GPS is installed in the LAI-2200 console, LAI files can include location information. This takes the form of G records in the data set, with summary information in the header. (Figure 1).

```
LAI_File    FIELD1
Version     1.2.12
Date        20130816 15:01:31
:
SEM         4.
SMP         19
### G Record Averages
GpsLat      40.85611060
GpsLong     -96.66023160
GpsUTC      20130816 20:07:42
GpsAlt      342.8
GpsNum      8
GpsQual     0.97
:
MASK        1       1       1       1       1
ANGLES      7.000   23.00   38.00   53.00   68.00
:
A   7   20130816 15:02:27  W1  138.30     144.00      151.30  149.70  107.20
G   8   20130816 15:02:27  G0  40.856184  -96.659128  346.8   9       0.87   20130816 20:04:48
B   9   20130816 15:03:21  W1  43.35      44.99       38.33   24.27   30.67
G   10  20130816 15:03:21  G0  40.856543  -96.659496  346.3   9       0.87   20130816 20:05:42
:
```

Present when there are G records

Identifier | Latitude | Longitude | Altitude (m) | Satellites | Quality | UTC

Figure 1: Illustration of added header entries and G records in an LAI data file.

Note the record *identifier*, usually G0 for G records. The number following the G indicates what triggered the G record to be logged. Normally (depending on how the console is configured), logging an A or B or L record with also trigger a G record to be logged, with the ID = G0. You can also log a G record by itself by pressing a numeric key (1-9) on the console if GPS is enabled, and a file is open. In that case, the G record identifier will be G1 through G9, depending on the key that was pressed. This allows you to mark areas in your plot (the corners, for example) while making measurements without logging spurious sensor readings.

Making Maps

FV2200's Map tool (Figures 2 through 5) allows the export of this data as a .kml file for Google Earth. Figure 2 shows how to mark the average location with a pin, or track all the G records as a path along the ground. Figure 3 shows several other styles, including how to show an LAI profile of your data points. Figure 4 illustrates using multiple types of G records to mark distinct regions. Figure 5 illustrates how to modify or create your own marker styles.

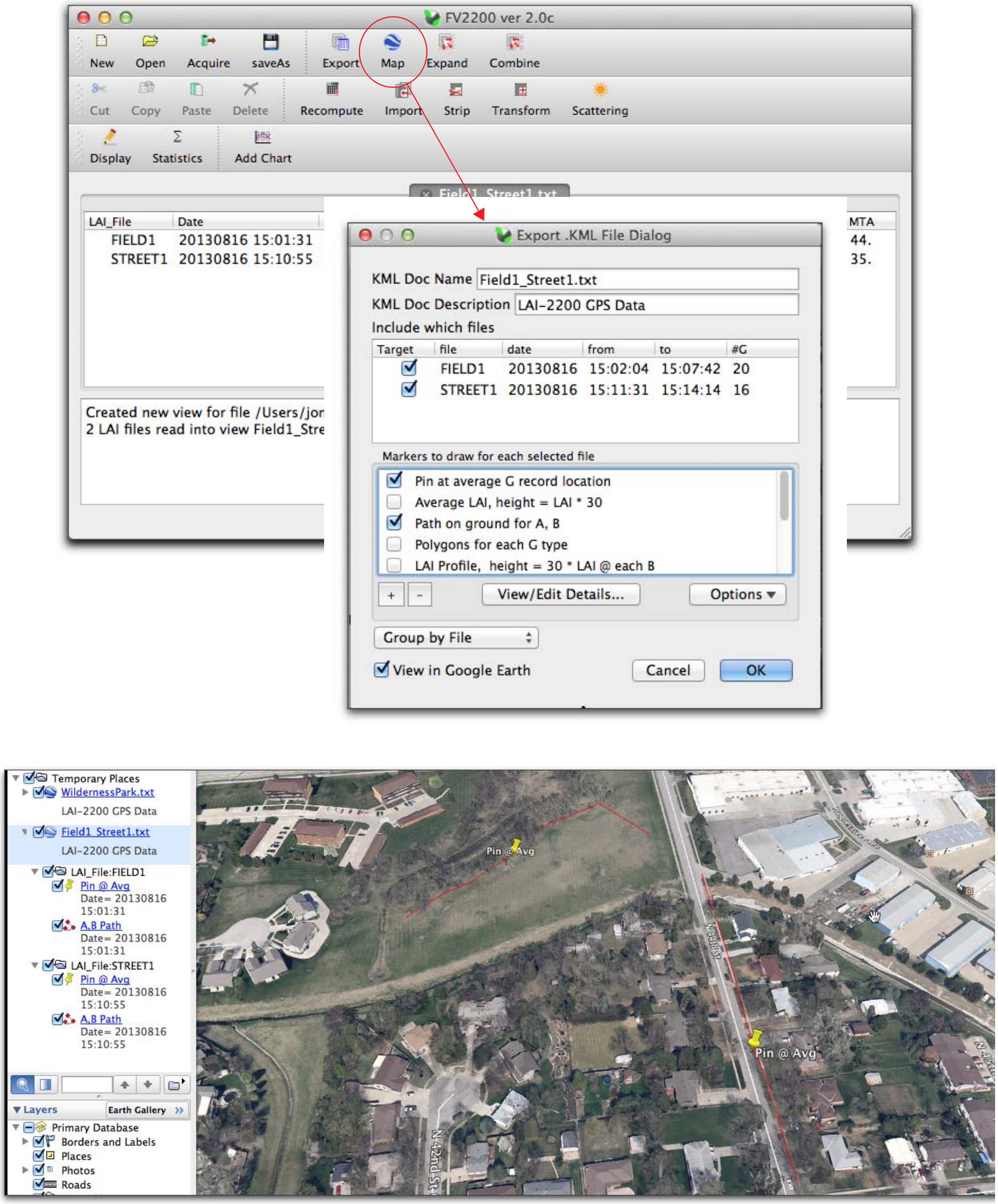


Figure 2: Examples of the styles available when exporting GPS data from LAI files. In this case, the averaged location is marked with a pin, and all the GPS records are shown as a red line path along the ground.

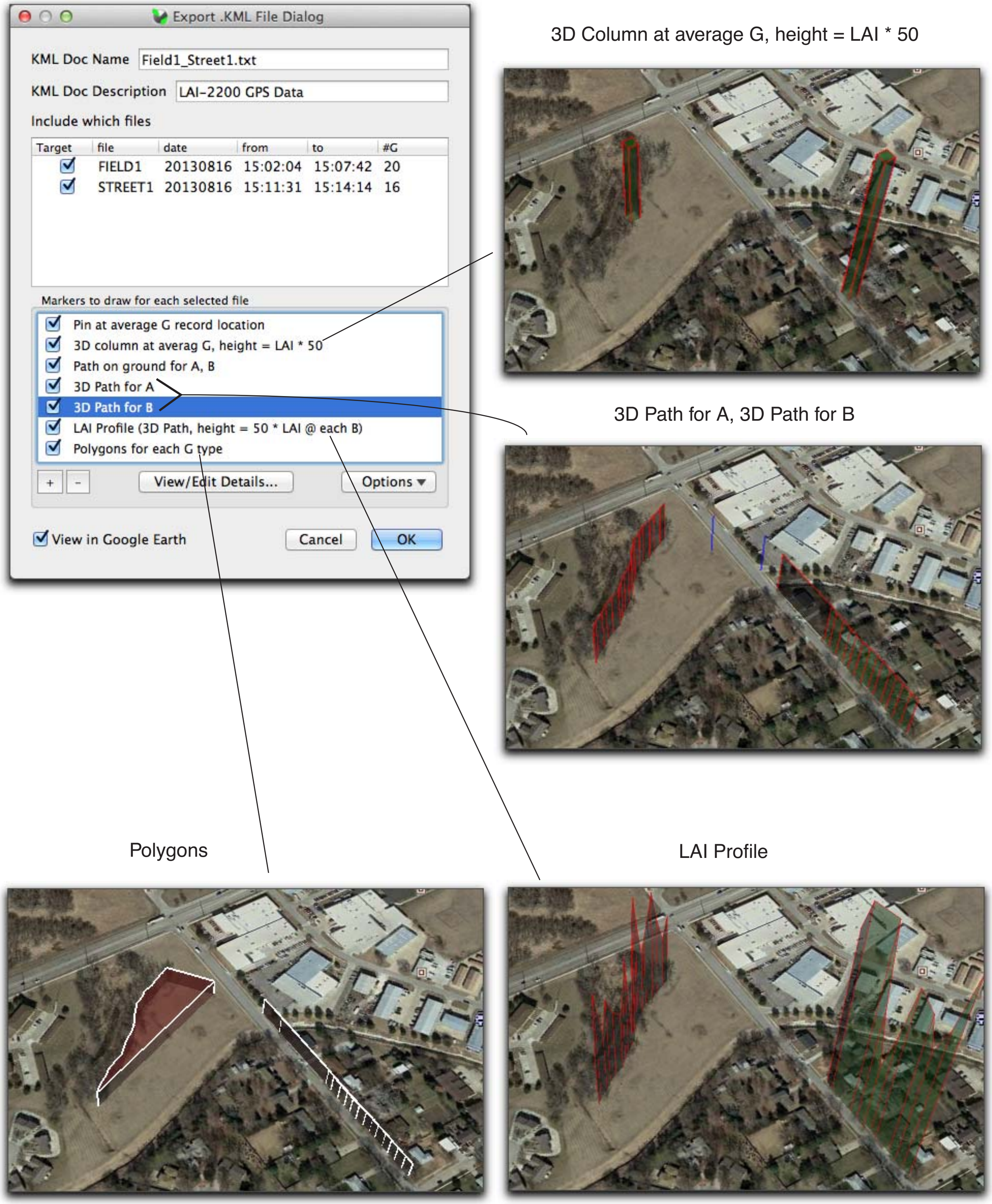


Figure 3: Some of the other default display styles for LAI data.

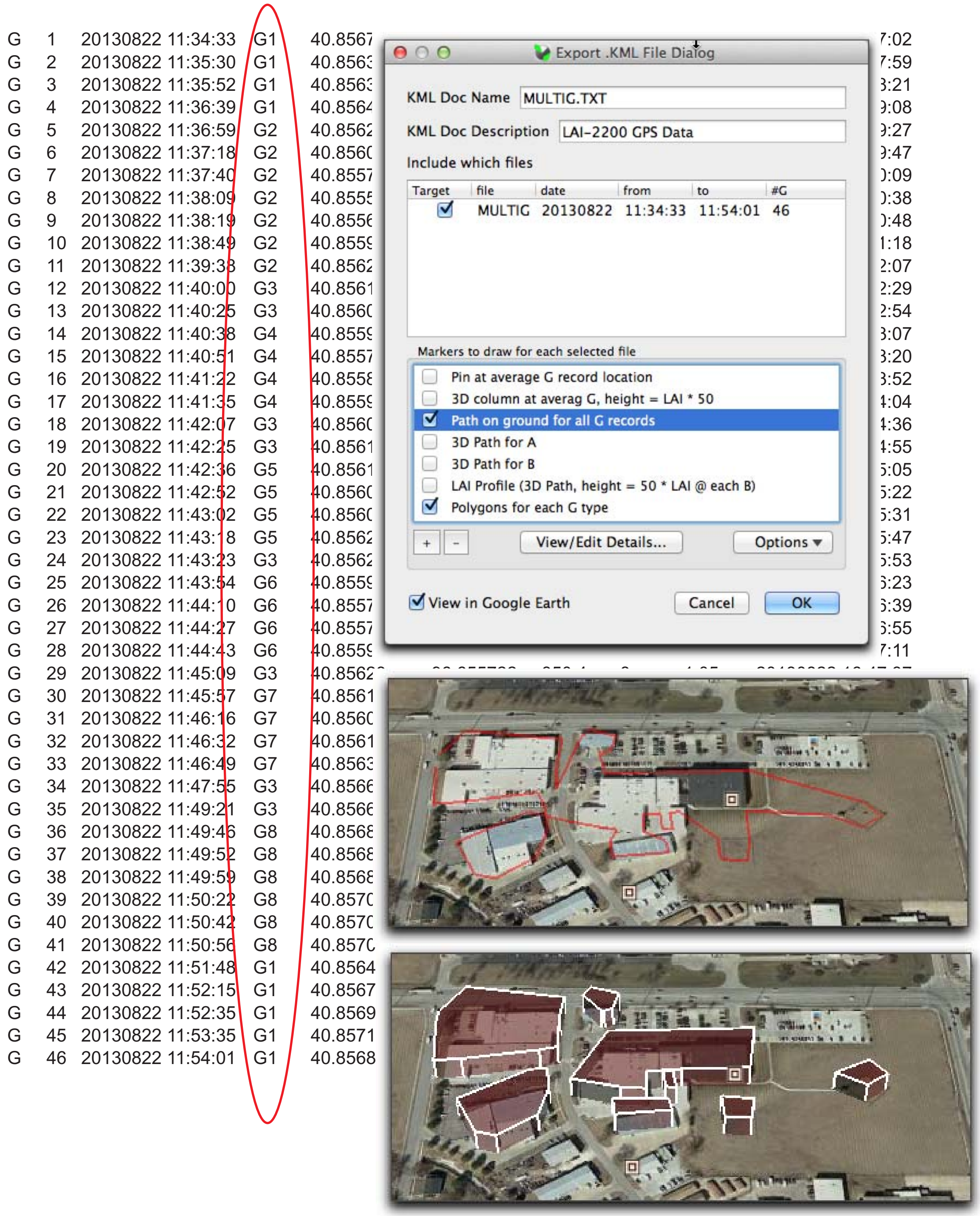


Figure 4: Illustration of plotting G records with differing IDs. This file (data shown in background) is data obtained on a walk around the LI-COR campus. Each building or area was marked by logging with a numeric key instead of the Log key. When plotted as a path (top), you see the walk progress. When the 'Polygons for each G type' option is selected (bottom), the record IDs are used to separate the records, resulting in 8 independent entities on the map.

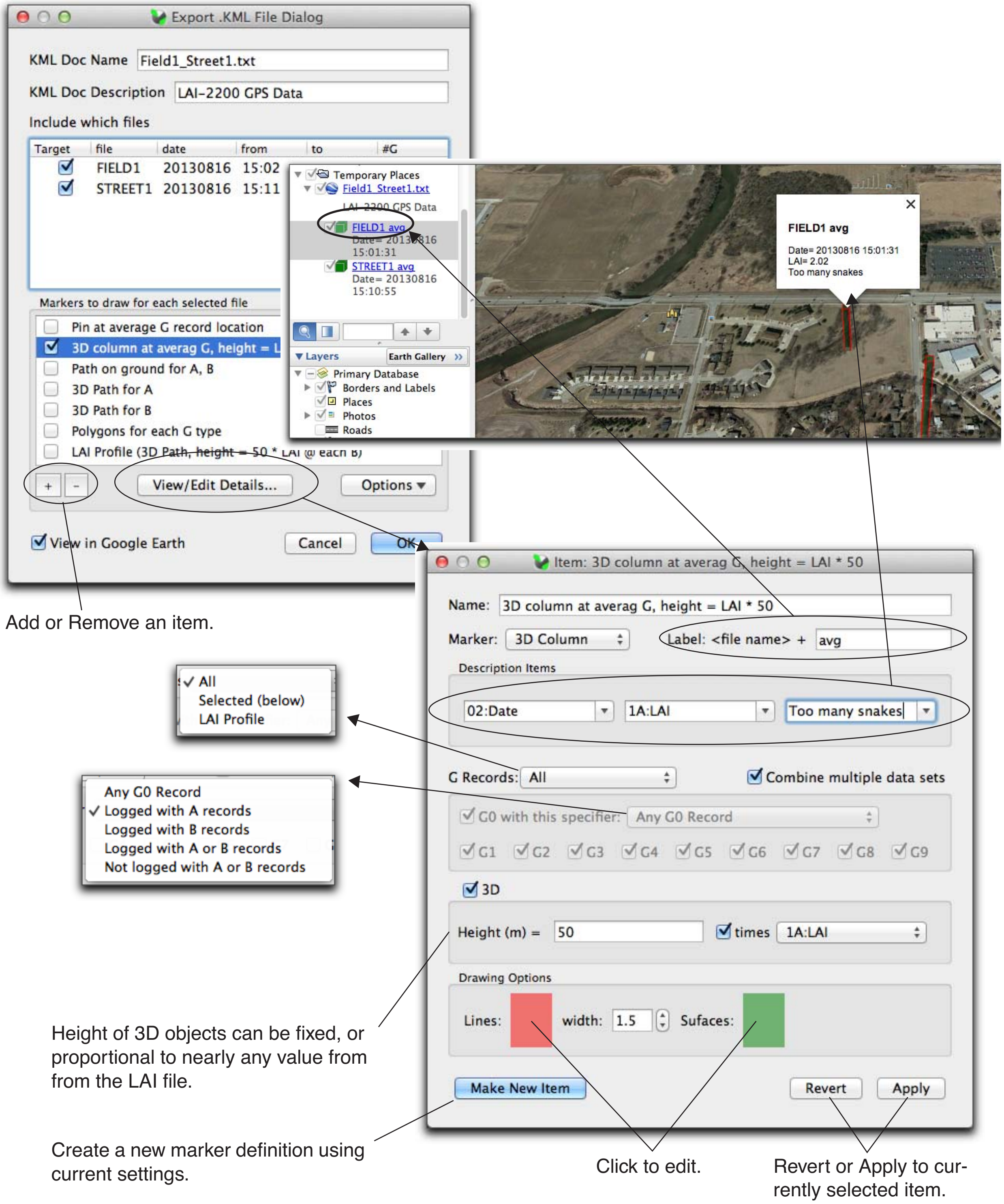


Figure 5: The Details view of the selected marker. You can modify the default styles, or create your own.

What are Scattering Corrections?

LAI-2200 / LAI-2000 measurements of gap fraction are made by comparing above and below canopy measurements of sky radiation. It is assumed that the below canopy measurements do not include any light that was reflected by or transmitted through the leaves or stems. If the sun is not directly illuminating the canopy, this is not a bad assumption, since the sensor is filtered for blue light (320-490 nm), which is largely absorbed by chlorophyll. If direct sun does illuminate the canopy, or if the foliage is not highly absorbent in the blue, the resulting scattered radiation becomes potentially large enough to significantly effect the below-canopy measurements and compromise the LAI calculation.

The model presented in Kobayashi et. al.[1]provides a mechanism to account for scattered radiation in the LAI-2200 / LAI-2000 measurements. This model has been incorporated into the FV2200 version 2 software to allow post-measurement correction for scattered radiation.

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.).

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.

1. Kobayashi H., Ryu Y., Baldocchi D.B.,Welles, J.M., Norman, J.M. (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.

ScattCorr is a quantity you'll want displayed, and Figure 8 on page 13 shows how to set it up.

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 (see Figure 6). 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.

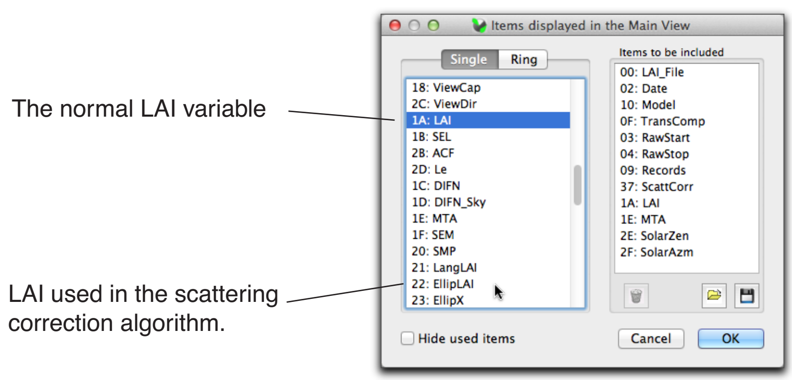


Figure 6: Several LAI values are available in FV2200. The scattering correction model uses the ellipsoidal one.

What Extra Inputs are Needed?

Solar Position: FV8100 will compute solar zenith and azimuth angles for you based on location and time. If the LAI-2200 console is GPS equipped, then this is all automatic. Otherwise, you will need to specify latitude, longitude, and time zone information.
Sky Brightness: We need a wide view (270 deg or greater) of the sky, with the sun masked.
Fraction Beam: We need to know what fraction of the total incident radiation (in the blue) is from direct beam. Kobayashi et al used a Halon reflectance panel and a view cap with a small hole drilled in the center to measure this. We present a simpler approach in this document.
Scattering Properties: Leaf reflectance and transmittance, and ground surface reflectance, all for the blue.

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.

A Complete Example

Collecting the Data
The data in this example was collected for a small grove of trees. Reference readings were made far enough away from the grove so there were not obstructions in the measurement direction. There were 8 locations within the grove where the below canopy measurements were made. A 45 degree view cap was used, aimed directly North. Normally to make this measurement, one would do a sequence something like this:

A (in clearing)
B-B-B-B-B-B-B-B (in grove)
A (in clearing)

The final A allows interpolation of A readings. However, to do the scattering corrections, we will modify what we do in the clearing to this:

A-A-A-A (in clearing)
B-B-B-B-B-B-B-B (in grove)
A-A-A-A (in clearing)

Why 4 A readings? Each one serves a different purpose:

1st A - White diffuser on wand, fully in the sun.
2nd A - Same as 1, but shaded. Operator can rotate just a bit so their shadow falls on the diffuser.
3rd A - Same position as 2, but no diffuser or view cap. Just open lens. (Or 270 blocking sun).
4th A - Normal A reading (45 degree view cap aimed N, for this example).

Figure 7 illustrates one set of the A reading sequence.

1st A reading: Diffuser, in sun.

2nd A reading: Diffuser, in shade.

3rd A reading: No view cap, sensor shaded. (Or 270 view cap blocking sun)

4th A reading. Normal A. (measurement view cap in measurement direction).

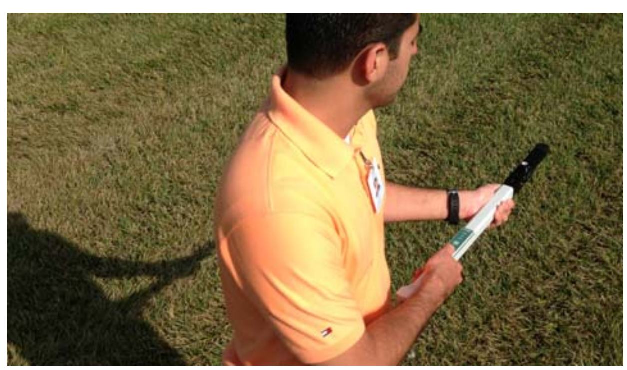


Figure 7: The 4 A readings when making scatter-corrected LAI measurements.

The data is below. Note: this data set is built into the FV2200, and is available as ScatterExample.txt, under Sample files, in the Files menu.

LAI_File	FILE1	
Version	1.2.11	
Date	20130712 10:00:33	
Prompt1		
Resp1	1	
Prompt2	PLOT	
Resp2		
TransComp	a-p-s	*Note: the p means use Previous A for each B , so only the final A reading of each set is used for gap fracts*
Model	Horizontal	
### Computed Results		
LAI	1.86	*This is the uncorrected LAI.*
SEL	0.11	
ACF	0.887	
DIFN	0.236	
MTA	49.	
SEM	4.	
SMP	16	

### Ring Summary					
MASK	1	1	1	1	1
ANGLES	7.000	23.00	38.00	53.00	68.00
AVGTRANS	0.403	0.428	0.329	0.208	0.155
ACFS	0.797	0.811	0.826	0.926	0.948
CNTCT#	1.130	0.963	1.058	1.022	0.737
STDDEV	0.670	0.583	0.563	0.304	0.172
DISTS	1.008	1.087	1.270	1.662	2.670
GAPS	0.320	0.351	0.261	0.183	0.140

### Contributing Sensors							
Sensor	W1	PCH3214	4016	1257	1000	1003	1294

Observations

A	1	20130712 09:42:05	W1	417.60	416.60	408.20	391.70	363.60	*Diffuser in sun*
A	2	20130712 09:42:10	W1	168.70	168.30	165.00	158.50	146.10	*Diffuser in shade*
A	3	20130712 09:42:24	W1	548.50	635.00	751.20	932.40	814.70	*Wide sky*
A	4	20130712 09:42:43	W1	41.46	58.52	61.66	74.02	81.68	*Normal A*
B	5	20130712 09:43:26	W1	36.58	46.33	43.45	24.00	12.74	
B	6	20130712 09:43:43	W1	4.945	20.54	33.77	14.60	9.486	
B	7	20130712 09:44:00	W1	15.41	9.313	14.35	17.84	11.86	
B	8	20130712 09:44:23	W1	13.27	10.94	23.53	13.69	12.72	
B	9	20130712 09:44:45	W1	8.526	11.57	7.787	8.013	5.682	
B	10	20130712 09:45:07	W1	35.54	48.17	6.605	5.968	7.179	
B	11	20130712 09:45:34	W1	5.385	15.35	7.784	32.43	19.44	
B	12	20130712 09:45:53	W1	10.09	36.61	27.25	7.545	24.04	
A	13	20130712 09:47:39	W1	432.10	430.70	422.10	403.10	363.20	*Diffuser in sun*
A	14	20130712 09:47:44	W1	169.40	169.10	165.80	159.00	145.10	*Diffuser in shade*
A	15	20130712 09:47:56	W1	571.50	643.70	772.10	912.80	840.10	*Wide sky*
A	16	20130712 09:48:13	W1	43.53	59.62	62.61	70.03	82.61	*Normal A*

Note that because the “extra” A readings come before each “real” A reading, they do not affect the computed results, so the readings you get in the field are legitimate (uncorrected) values, provided you aren’t interpolating.

Processing the Data

There are two parts to processing the data. First, we need to turn the "extra" A records into K records. (What is a K record? K is for sKy, and a K record contains all of the relevant of sky-related information to do scattering corrections).

Before

A	234	20130712 09:42:05	W1	417.60	416.60	408.20
A	235	20130712 09:42:10	W1	168.70	168.30	165.00
A	236	20130712 09:42:24	W1	548.50	635.00	751.20
A	237	20130712 09:42:43	W1	41.46	58.52	61.66
B	238	20130712 09:43:26	W1	36.58	46.33	43.45
B	239	20130712 09:43:43	W1	4.945	20.54	33.77
B	240	20130712 09:44:00	W1	15.41	9.313	14.35
B	241	20130712 09:44:23	W1	13.27	10.94	23.53
B	242	20130712 09:44:45	W1	8.526	11.57	7.787
B	243	20130712 09:45:07	W1	35.54	48.17	6.605
B	244	20130712 09:45:34	W1	5.385	15.35	7.784
B	245	20130712 09:45:53	W1	10.09	36.61	27.25
A	246	20130712 09:47:39	W1	432.10	430.70	422.10
A	247	20130712 09:47:44	W1	169.40	169.10	165.80
A	248	20130712 09:47:56	W1	571.50	643.70	772.10
A	249	20130712 09:48:13	W1	43.53	59.62	62.61

After

K	0	20130712 09:42:05	W1	0.59627	45	0
A	237	20130712 09:42:43	W1	41.46	58.52	61.66
B	238	20130712 09:43:26	W1	36.58	46.33	43.45
B	239	20130712 09:43:43	W1	4.945	20.54	33.77
B	240	20130712 09:44:00	W1	15.41	9.313	14.35
B	241	20130712 09:44:23	W1	13.27	10.94	23.53
B	242	20130712 09:44:45	W1	8.526	11.57	7.787
B	243	20130712 09:45:07	W1	35.54	48.17	6.605
B	244	20130712 09:45:34	W1	5.385	15.35	7.784
B	245	20130712 09:45:53	W1	10.09	36.61	27.25
K	0	20130712 09:47:39	W1	0.60572	45	0
A	249	20130712 09:48:13	W1	43.53	59.62	62.61

Second, we provide the other constants we need for the correction. FV2000 has a scattering tool that will help with these steps.

1. Read in the file.

First read in the file (ScatterExample.txt, under Sample files, in the Files menu). If the variable *ScattCorr* is not present, add it into the summary view (Figure 8). This tells you what files have been scatter-corrected, and by how much.

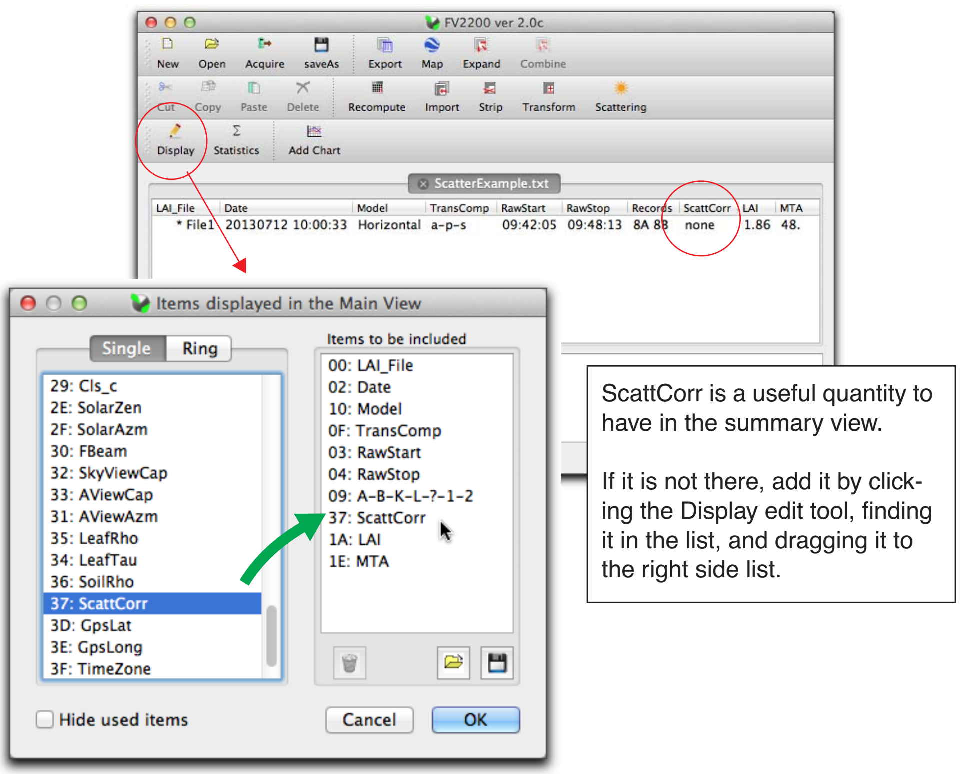


Figure 8: Preparing the main view for scattering corrections.

2. Generate the K records

Figure 9 illustrates how to convert the AAAA sequences into K records.

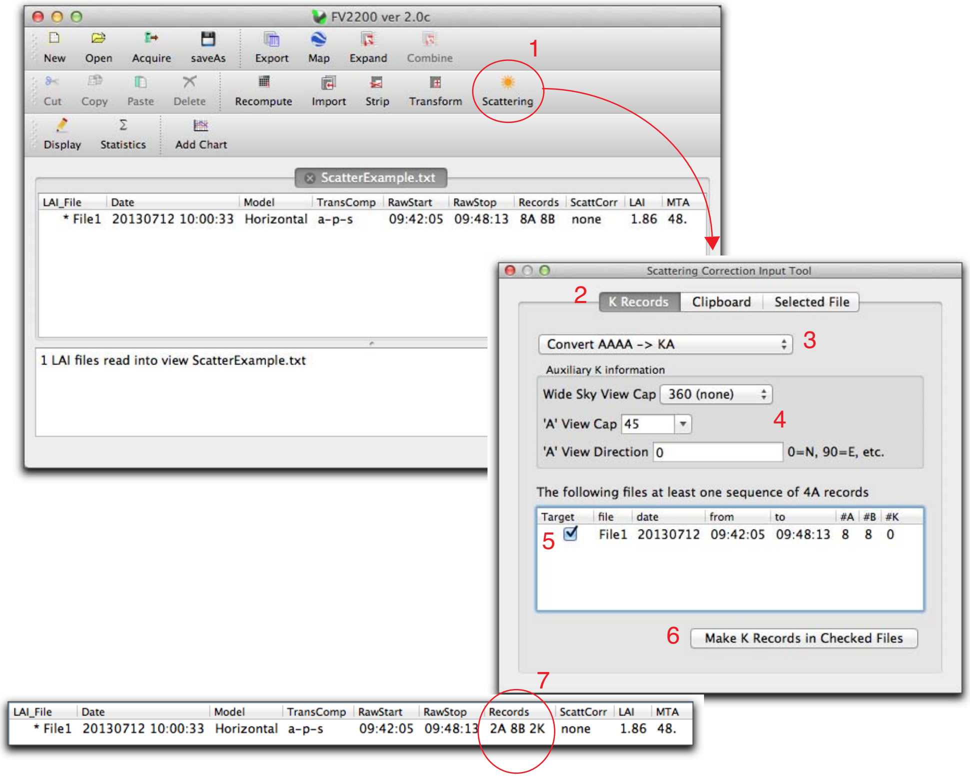


Figure 9: Converting A records to K records. 1) Open the Scattering tool. 2) Click the K Records tab. 3) Select AAAA -> K. 4) Enter view cap information. 5) Check the file. 6) Click the Make Records button. 7) Verify the file now has 2 A and 2 K records.

The data records portion of our file now looks like this, with two K records added, and the three "extra" A records are gone. Well, not really gone: all 4 source A records live within the K record, so they can be undone if you wish, or if you converted them by mistake.

Observations

K	0	20130712 09:42:05	W1	0.596	45	0	360	A	234	20130712 09:42:05	W1	417.60	416.60...
A	237	20130712 09:42:43	W1	41.46	58.52	61.66	74.02	81.68					
B	238	20130712 09:43:26	W1	36.58	46.33	43.45	24.00	12.74					
B	239	20130712 09:43:43	W1	4.945	20.54	33.77	14.60	9.486					
B	240	20130712 09:44:00	W1	15.41	9.313	14.35	17.84	11.86					
B	241	20130712 09:44:23	W1	13.27	10.94	23.53	13.69	12.72					
B	242	20130712 09:44:45	W1	8.526	11.57	7.787	8.013	5.682					
B	243	20130712 09:45:07	W1	35.54	48.17	6.605	5.968	7.179					
B	244	20130712 09:45:34	W1	5.385	15.35	7.784	32.43	19.44					
B	245	20130712 09:45:53	W1	10.09	36.61	27.25	7.545	24.04					
K	0	20130712 09:47:39	W1	0.605	45	0	360	A	246	20130712 09:47:39	W1	432.10	430.70...
A	249	20130712 09:48:13	W1	43.53	59.62	62.61	70.03	82.61					

3. Add the rest of the correction inputs.

The final step is to use the Clipboard part of the Scatter Tool (Figure 10) to define location, view caps, and scattering properties. The Clipboard is designed to add scattering corrections to multiple files at once (provided their inputs are the same, of course). Therefore, these inputs do not include things that might change within a file or from one file to the next. Thus, for example, we have latitude, longitude, and time zone, instead of solar zenith and azimuth angle. Also, none of the items that can be contained in K records are here, either.

Fill in the form, make sure the appropriate boxes are checked, and click the “Apply to All Selected Files” button, and these inputs will be added to all selected files in the main view. If the file had a GPS record, we wouldn’t need to bother with the GPS section, but since it doesn’t, fill in something close to what is indicated.

Once scattering inputs are added, the clipboard can be used to go back and change any subset of them for a group of files all at once. You can control what is changed by which boxes are checked.

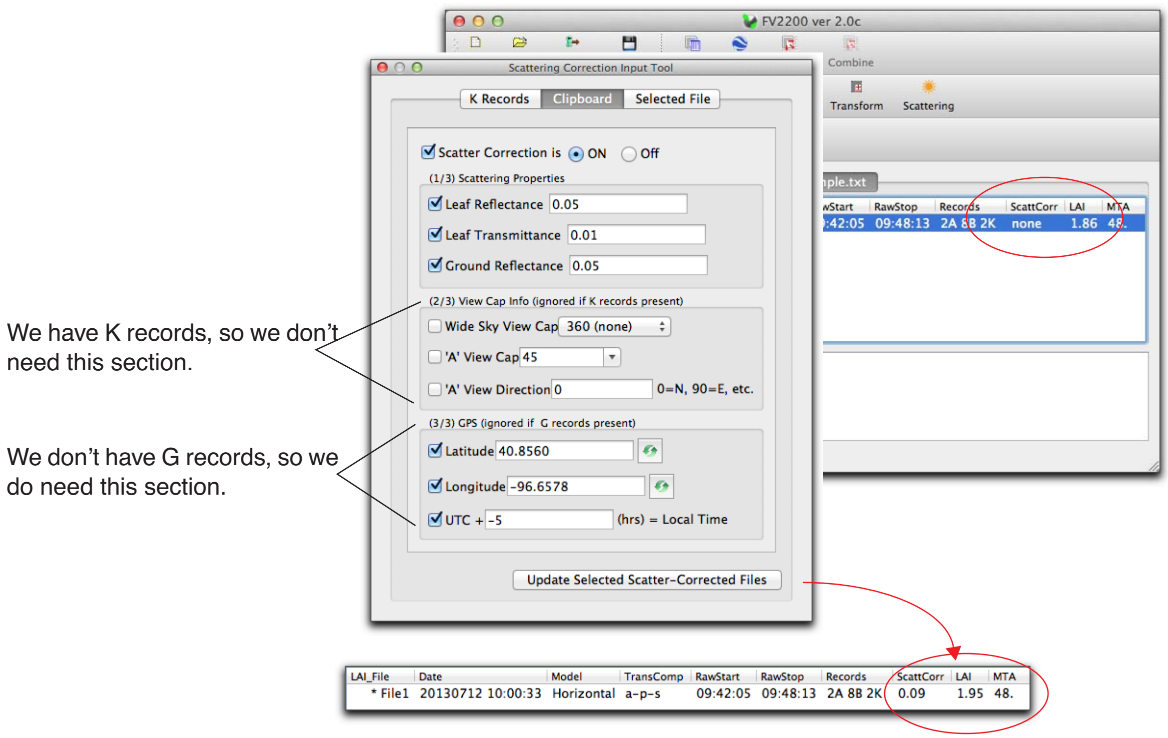
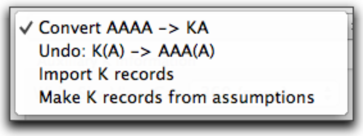


Figure 10: Using the Scattering Tool’s Clipboard feature to add scattering correction inputs to multiple files, or to modify existing inputs for multiple files. In this example, the LAI increased by 0.09.

The Scattering Input Tool Details

There are three panels in Scattering Input Tool: K Records (Figure 11 on page 17) provides two methods of making K records, as well as for importing them or undoing them. Clipboard (Figure 13 on page 18) provides is the tool for setting the non-sky scattering inputs on one or more files with one operation. Selected File (Figure 14 on page 19) is the method to view/edit all scattering inputs on a single file.

K Records
The K Records panel provides four options for manipulating K records:



Convert AAAA->K (Figure 11A) has been demonstrated on page 8. The assumption is that every sequence of 4 consecutive A records matches the pattern shown in Figure 7 on page 11. This type of K record can be undone with **Undo: K(A)->AAA(A)** (Figure 11B). The undo scheme is this: If the record immediately following the K record in the file matches the original 4th A record in the AAAA sequence, then it is not restored, since it is already there. Thus, a sequence of ..BKB.. would turn to ..BAAAAB.., for example, while ..BKAB.. would also turn to ..BAAAAB..

Import K Records (Figure 11C) lets you pick one or more source files with K records, and one or more destination files (that need K records), and copy them. When K records are added to a file, FV2200 uses this strategy: import any K record that falls within the first and last time record of the destination file. If there is a K record that is earlier than that, but closer to the earliest record than any other K record, it is imported. Similarly, any K record that falls after the last record, but is closer to the last record than any other K record, is imported.

There is another method to generate K records: **Make K records from assumptions** (Figure 11D) will use an A reading (or the average of all the A readings in a file) to generate what the wide sky distribution would have been, either by assuming it is isotropic, or else that it matches the one measured by the A reading. In either case, the magnitude of the wide sky readings will be in direct proportion to the view cap size difference that you specified. Fraction of beam is left for you to guess at. This is about the only recourse for applying the scattering correction to old files when it is too late to actually measure the wide sky brightness distribution. If the file was collected with the sun obscured, then Fbeam is of course 0. This type of K record cannot be “undone”, since there is nothing to undo: no A records are “consumed”.

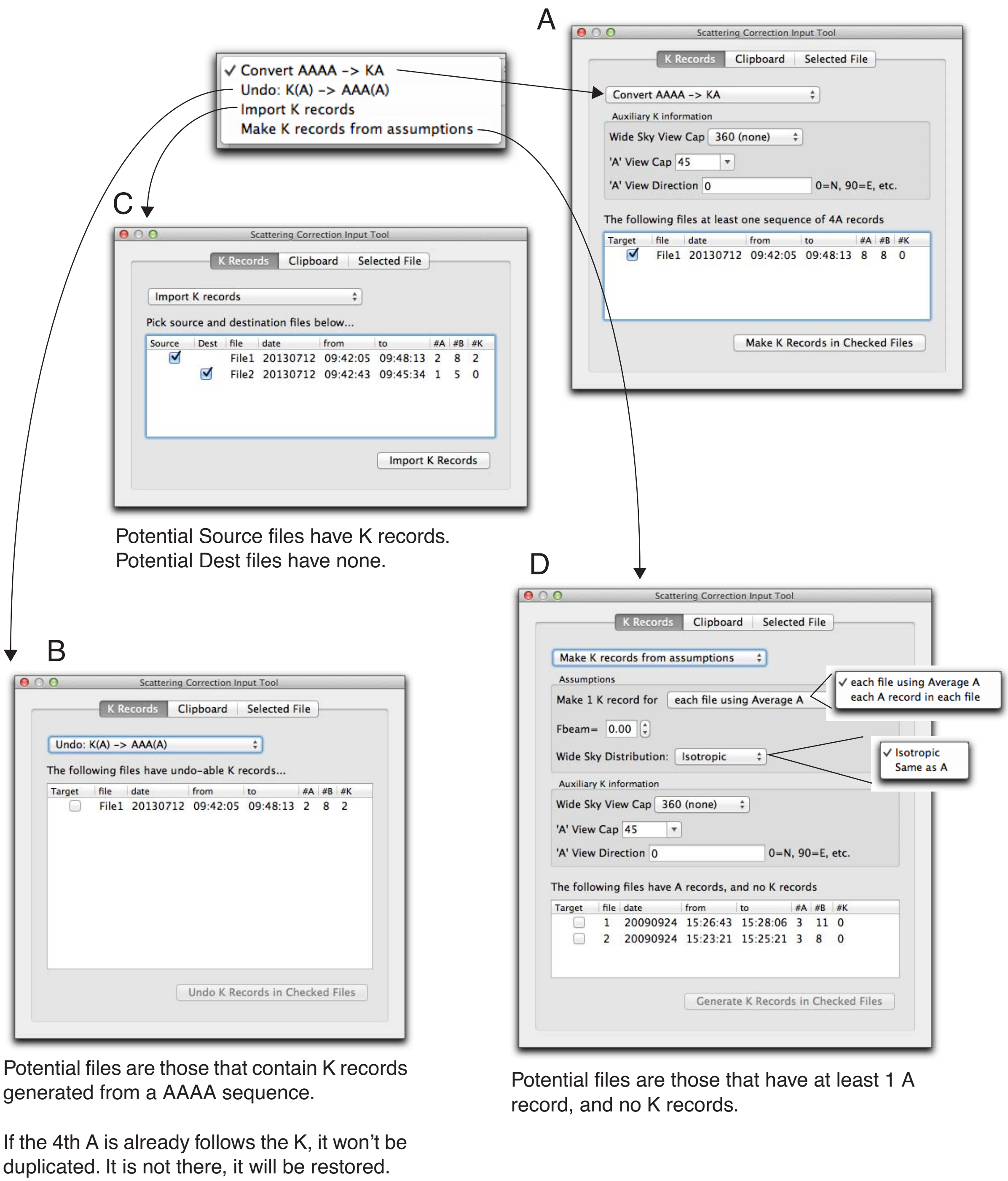


Figure 11: The options for dealing with K records in the Scattering Input Tool. A) Generate a K record for each group of 4 consecutive A records found. B) Undo K records generated by the 4A method. C) Import K records (copy from source to destination) D) Generate a K records form a single A record, with assumptions.

Note that K records come in two different formats, that differ following the wide sky view cap value (Figure 12).

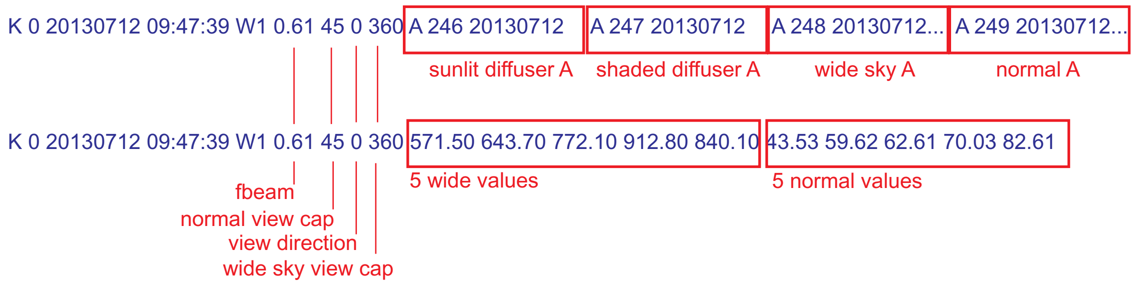


Figure 12: The two formats for K records. The top one is generated from 4 A readings. The bottom is generated from one A reading plus some assumptions.

Clipboard

The Clipboard is a tool to input or modify most of the scattering inputs into a group of files. As such, it does not include items that might be file-specific, such as sky brightness or fraction of beam. If the target files already have scattering inputs, this is a convenient way to adjust just one or two parameters in all of them (check the items to change). If a file has no scattering inputs, then all items must be checked, unless there are already K and/or G records present.

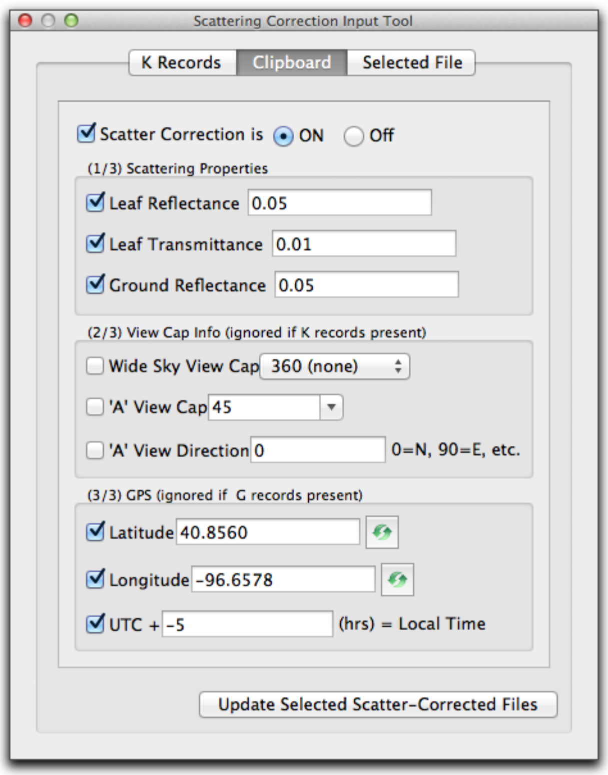


Figure 13: The Clipboard panel allows scattering inputs to be set or changed in a group of files.

Selected File

All scattering inputs for a single file can be viewed and edited in the third tab of the Scatter Tool, the <u>Selected File</u> tab (Figure 14). Whatever file is selected in the main view shows up in this window, provided it has scattering correction inputs ($ScattCorr \neq none$).

The editing can be done in a text list, or in a dialog box.

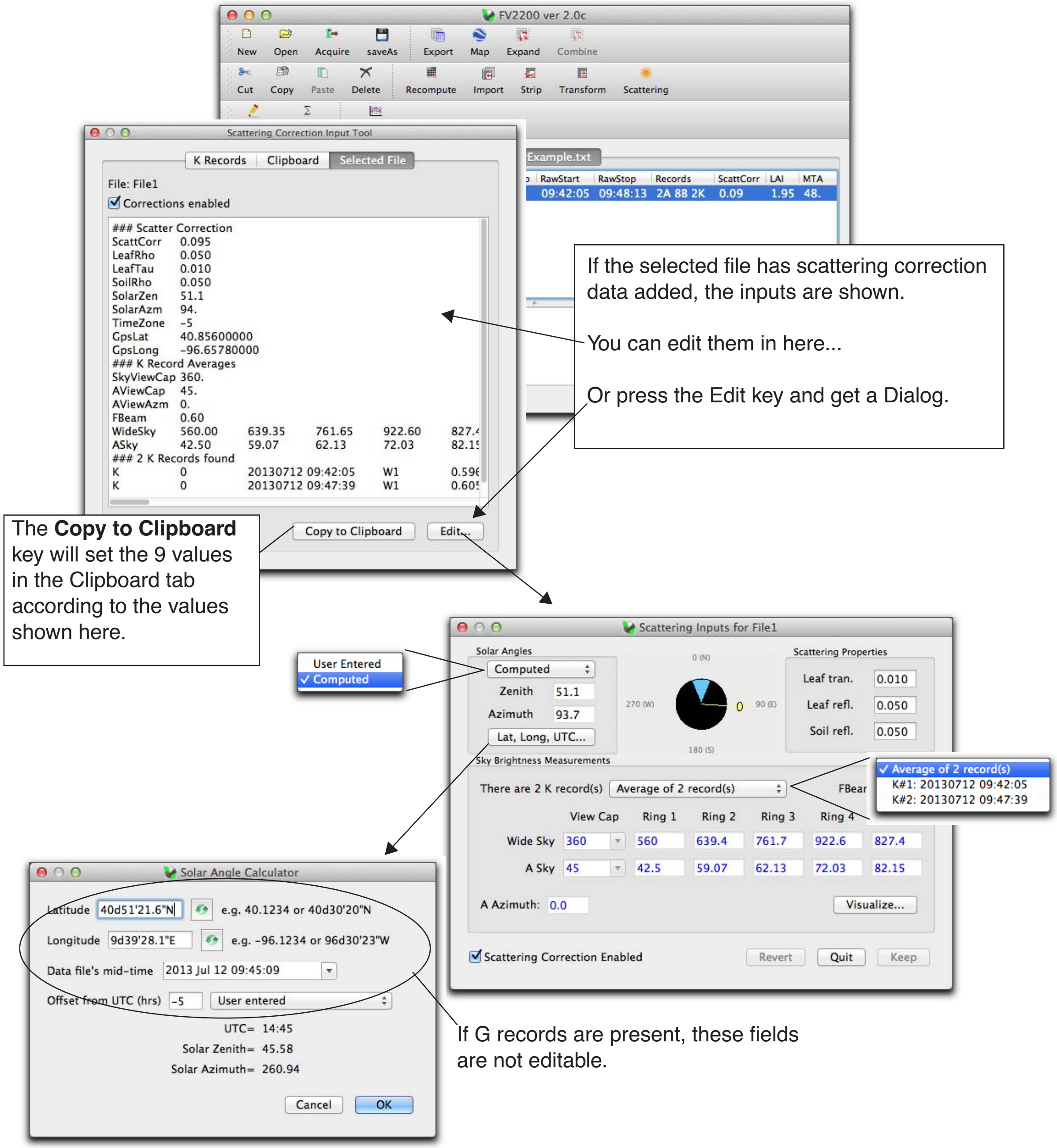


Figure 14: The Selected File tab allows you to view and edit all the details of scattering inputs for one file, either as a list of text entries (this is what is added to a scatter corrected header file), or in a dialog. In the dialog, if K records are present (left), individual values or means can be viewed.

Scattering Inputs in LAI Files

Header Changes

Figure 15 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 record header items in Figure 1 on page 3. will be.

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 15: 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 9.

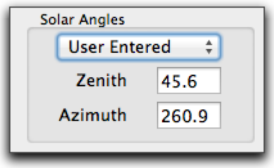
The three values for average vegetative reflectance, transmittance, and the surface beneath the canopy (***LeafRho***, ***LeafTau***, and ***SoilRho***) should be for the 230-490 nm waveband. The values could come from spectroradiometric measurements integrated over this wave band, or from a radiometer 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 14 on page 19 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 14 on page 19 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 should be made with the same wand.
- That wand 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 <u>one</u> time in LAI-2x00 processing that the rings of the sensor are NOT treated independently, and the factory isotropic calibration is needed.

All About K Records

K records are not obligatory: you can enter that information by hand using the individual file editor (Figure 14 on page 19). If no K records are present when the file is scatter-corrected, *FBeam*, *SkyViewCap*, *AViewCap*, *AViewAzm*, *WideSky*, and *ASky* become input values.

Position in the file (first record, last record, lumped together in the middle, etc.) is not important for K records. When gap fractions are computed (i.e. for each B record), the closest-in-time K record in the file is located and associated with that particular gap fraction. The number of K records used may therefore be less than the number present.

When scattering corrections are performed on gap fractions, the radiation model is run once for each K record *in use*. Then, when gaps fractions are adjusted for that iteration, each gap record is adjusted by the model results belonging to its associated K record.

How may K records are necessary? K records contain fraction beam, the wide sky distribution, the narrow sky distribution, and view cap information. Of the three radiation measurements, fraction beam has the most potential to change drastically in a short time (sun moves behind a cloud, for example). So, the more stable the sky, the fewer K records you need. The most stable condition is clear blue sky: fraction beam changes slowly, and 1 K record per hour would be sufficient near midday. At the other extreme, fast moving, scattered cumulus clouds could make rapid changes, and you may have to resort to a strategy of either only recording any reading (K, A, or B) with the sun obscured, or only with the sun unobstructed.

Another consideration for the number of K records is view direction: if the file contains readings in multiple directions, then at the very least you need a K record for each of those directions.

The K Record approach works with one or multiple wands. "A Complete Example" on page 10 collected all the data with one sensor in one file. If you have two or more wands, you have other options, as explained next.

Some Protocol Suggestions

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 the 4A readings every time. You can intersperse those with single A readings like this: A-B-B-B-A-A-A-A-B-B-B-A-B-B-B. When you convert to K records, only group(s) of 4 are affected (resulting in A-B-B-B-K-A-B-B-B-A-B-B-B).
- Another strategy is 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 4 A records into it. Later, transform them with the Scatter Tool, and use that file for importing (also with the Scatter Tool).

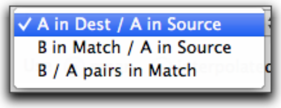
Hint: Appending to a file is simpler with the LAI-2200 console (as opposed to the LAI-2000), because you can sort the list of existing files by modification date, with most recent files near the top of the list. To sort the list that way, press the Menu key when viewing the existing file list, and select "Reverse Date". That sort order will remain for subsequent uses until you change it to something else.

Multiple Sensors

- Make sure the ALL the sensors have their factory default calibrations. Forget matching them. Ever. (There are better approaches described below).
- If you are operating in two 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 you have two people and two sensors, use the second person on the above sensor to manually perform the 4A readings at some regular interval. Later, convert As to Ks on that above file, then import Ks, and As, to your below files.

Matching Sensors the Better Way

Use only the factory calibration for all sensors, and never match them (i.e. never adjust their multipliers in the field). This will make K record distributions done by any sensor accurate. When LAI is based on two sensors, however, matching still has to take place. Here are three methods you can use to collect the necessary data in the field to mathematically (and automatically) “match” sensors later when you import A records. Each one is named for the setting used in the FV2200 import dialog.



Method 1 - A in Dest / A in Source. Use this method if you can get to an adequate clearing at some point while doing each B file. The method is to simply log one or more A readings in each file. Later, when importing A readings from the Above file, FV2000 will use the A’s you already have in the B files to adjust the incoming A’s. Refer to Figure 16 on page 25 for a detailed example.

Method 2 - B in Match, A in Source. Use this method when you can’t get useful A readings in each B file. Whenever you *are* able to get to an adequate clearing, however, make a special file (name it MATCH, for example), into which you log B records that have the same view of the sky as your A wand. (Basically, these are like A records, but you are labelling them as Bs.) Later, when importing A records from your above file to your below file, you can tell FV2000 to look in this MATCH file for some B records to use to make adjustment factors for the imported As. Refer to Figure 17 on page 26.

Method 3 - B / A pairs in Match. Use this method when you can connect both above and below wands to the console at the same time. It can be anytime before and after the normal data collection. Open a file, and name it MATCH or something similar to remind you what it is. Have the above wand set to log A records, and the below wand set to log B records. Have the same view cap size as used for the measurements in place on both sensors. Log several readings with both sensors looking at the exact same part of the sky. (If at all possible pick a clear region of the sky for both sensors to look at. Clouds can be much brighter than blue sky, so the narrower the field of view, the bigger the impact of not seeing exactly the same view.) Then, when importing A records to B files, specify this file for FV2200 to look to for computing how to adjust incoming A records. See Figure 18 on page 27.

<u>In general, method 3 is probably the best way to go, even if you are not doing scattering corrections</u>. The big advantages are: 1) Once you have this file (or files, for various view cap sizes), you can re-use it for days or weeks or months. 2) You can generate the file(s) under ideal (clear blue) conditions. The things that will affect a sensor comparison (and thus a match file) are cleanliness (keep the lenses cleaned), view cap size (make one file for each view cap size you are using), and view cap orientation (be consistent).

In circumstances (e.g. large experiments) where a large number of LAI-2x00s might be involved, having an A/B match file for each combination of wand might be a struggle. In that case, use Method 1 or Method 2, and you won’t have to worry about combinations.

2 Sensor Mode Exception

There is an exception to this alternative matching business, and that is when using two sensor mode (both wands plugged into the same console, logging both A and B simultaneously). In this case:

- Match by adjusting the B sensor. The reason for this is that the 4A sequence will be done by the A sensor, and that's the one that needs the factory default calibration.
- When doing the first 3As of a 4A sequence (with the A sensor), unplug the B wand from the console. Plug it back in for the 4th A. The reason for this is that you want 4 As in a row, not interspersed with B readings. Alternatively (or if you are using an LAI-2000 which will log a port even if nothing is connected), you can delete the extra B records prior to generating the K records.

Matching Method Example Figures

Method 1 Example.

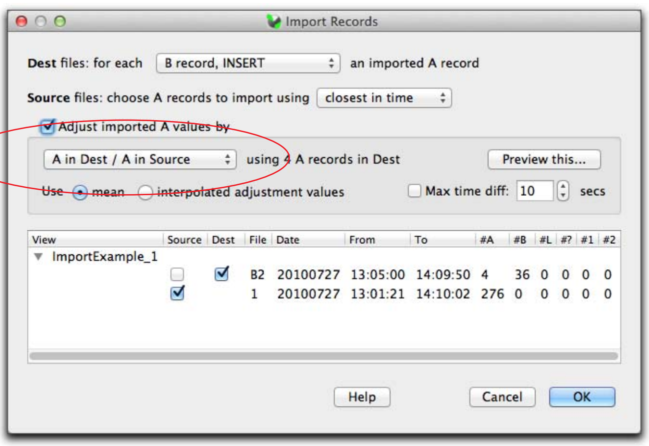
1. The below (destination) file. Note the two A readings made along side the A unit 17 minutes prior to the start of the B's. Not shown: are two more A readings at end.

A	1	20100727 13:05:00	W1	79.28	103.10	87.83	77.50	58.16
A	2	20100727 13:05:13	W1	75.77	100.90	85.72	75.70	57.03
B	3	20100727 13:22:48	W1	69.07	79.77	34.06	23.84	18.86
B	4	20100727 13:25:04	W1	65.02	45.35	28.01	30.47	22.66
:	:	:	:	:	:	:	:	:

2. The above (source) file. Nothing but A readings.

A	1	13:01:21	10.62	12.14	11.41	11.05	12.18
A	2	13:01:32	10.62	12.12	11.40	11.05	12.17
A	3	13:01:46	10.60	12.11	11.39	11.06	12.16
A	4	13:02:01	10.52	12.07	11.35	11.06	12.15
A	5	13:02:16	10.48	12.04	11.34	11.06	12.14
:	:	:	:	:	:	:	:
A	87	13:22:46	8.530	10.08	9.609	9.539	10.89
:	:	:	:	:	:	:	:

3. The Import dialog settings.



Each imported record is multiplied by the adjustment vector.
e.g. ring1 = 8.53 * 7.945 = 67.77

Adjustment vector based on the 4 A records in the destination and 4 corresponding A records in the source.

4. The destination file after import.

Contributing Sensors

Sensor	W1	PCH-30024000		1500	1100		1000	1010
Sensor	W2	unknown	7.9449	8.8231	7.9535		7.2858	4.9192

Observations

A	1	20100727 13:05:00	W1	79.28	103.10	87.83	77.50	58.16
A	2	20100727 13:05:13	W1	75.77	100.90	85.72	75.70	57.03
A	87	20100727 13:22:46	W2	67.77	88.94	76.42	69.50	53.57
B	3	20100727 13:22:48	W1	69.07	79.77	34.06	23.84	18.86
A	96	20100727 13:25:02	W2	66.79	87.99	75.14	68.71	53.18
B	4	20100727 13:25:04	W1	65.02	45.35	28.01	30.47	22.66
:	:	:	:	:	:	:	:	:

Figure 16: Example of using the "A in Dest / A in Source" method of matching during importation of A records. The actual files are built into FV2200 as an example: Select "ImportExample_1" from Sample files in the File menu.

Method 2 Example.

1. The below (destination) file. Just B readings.

Contributing Sensors

Sensor			W1	PCH-30024000	1500	1100	1000	1010

Observations

B	1	20100618 18:53:27	W1	7.916	12.18	9.976	9.806	6.750
B	2	20100618 18:53:54	W1	7.479	7.253	4.701	5.490	5.105
B	3	20100618 18:54:23	W1	3.983	4.249	3.383	6.129	1.753
:	:	:	:	:	:	:	:	:

2. The match file. Contains two B readings made when the sensor was next to the A unit.

Contributing Sensors

Sensor			W1	PCH-30024000	1500	1100	1000	1010

Observations

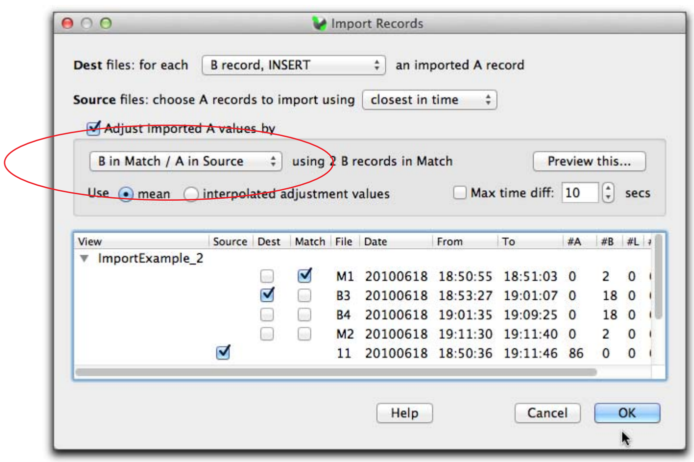
B	1	20100618 18:50:55	W1	9.018	13.21	13.87	16.00	14.79
B	1	20100618 18:51:03	W1	9.015	13.20	13.84	16.01	14.81

3. The above (source) file. Just A readings.

:	:	:	:	:	:	:	:
A	12	18:53:16	1.213	1.720	2.054	2.626	3.738
A	13	18:53:31	1.205	1.709	2.043	2.611	3.715
A	14	18:53:46	1.199	1.699	2.031	2.596	3.693
A	15	18:54:01	1.191	1.689	2.019	2.580	3.670
A	16	18:54:16	1.185	1.679	2.007	2.565	3.647
A	17	18:54:31	1.179	1.669	1.995	2.550	3.623
:	:	:	:	:	:	:	:

Each imported record is multiplied by the adjustment vector.
e.g. ring1 = 1.205 * 7.066 = 8.515

4. The Import dialog settings.



Adjustment vector based on the 2 B records in the match file and 2 corresponding A records in the source.

5. The destination file after import.

Contributing Sensors

Sensor			W1	PCH-30024000	1500	1100	1000	1010
Sensor			W2	unknown 7.0662	7.3037	6.4084	5.7947	3.7535

Observations

A	13	20100618 18:53:31	W2	8.515	12.48	13.09	15.13	13.94
B	1	20100618 18:53:27	W1	7.916	12.18	9.976	9.806	6.750
A	15	20100618 18:54:01	W2	8.416	12.34	12.94	14.95	13.78
B	2	20100618 18:53:54	W1	7.479	7.253	4.701	5.490	5.105
	:	:	:	:	:	:	:	:

Figure 17: Example of using the "B in Match / A in Source" method of matching during importation of A records. The actual files are built into FV2200 as an example: Select "ImportExample_2" from Sample files in the File menu.

Method 3 Example.

1. The below (destination) file. Just B readings.

```
### Contributing Sensors
Sensor      W1      PCH-30024000   1500    1100       1000    1010
### Observations
B   1   20100618 18:53:27   W1   7.916    12.18    9.976    9.806    6.750
B   2   20100618 18:53:54   W1   7.479    7.253    4.701    5.490    5.105
B   3   20100618 18:54:23   W1   3.983    4.249    3.383    6.129    1.753
:   :   :                   :    :        :        :        :        :
```

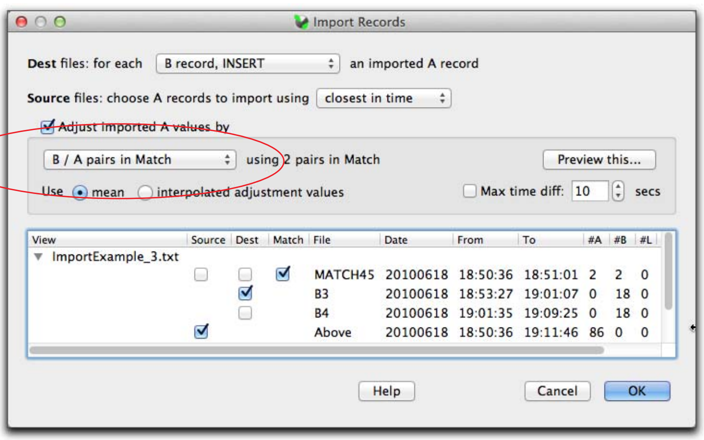
2. The match file. Contains A,B with both wands attached to a console.

```
### Contributing Sensors
Sensor      W1      PCH-30024000   1500    1100       1000    1010
Sensor      W2      PCH-30034007   1487    1094       1000    1042
### Observations
A   1   20100618 18:50:36   W2   1.288    1.825    2.180    2.786    4.325
B   2   20100618 18:50:36   W1   9.018    13.21    13.87    16.00    14.79
A   3   20100618 18:51:01   W2   1.276    1.808    2.162    2.762    3.943
B   4   20100618 18:51:01   W1   9.015    13.20    13.84    16.01    14.81
```

3. The above (source) file. Just A readings.

```
:   :   :          :      :      :      :      :
A   12  18:53:16   1.213  1.720  2.054  2.626  3.738
A   13  18:53:31   1.205  1.709  2.043  2.611  3.715
A   14  18:53:46   1.199  1.699  2.031  2.596  3.693
A   15  18:54:01   1.191  1.689  2.019  2.580  3.670
A   16  18:54:16   1.185  1.679  2.007  2.565  3.647
A   17  18:54:31   1.179  1.669  1.995  2.550  3.623
:   :   :          :      :      :      :      :
```

4. The Import dialog settings.



Each imported record is multiplied by the adjustment vector.
e.g. ring1 = 1.205 * 7.033 = 8.475

Adjustment vector based on the A and B records in the match file.

5. The destination file after import.

```
### Contributing Sensors
Sensor      W1      PCH-30024000     1500     1100       1000     1010
Sensor      W2      PCH-30037.0332   7.2695   6.3819     5.7696   3.5801
### Observations
A   13  20100618 18:53:31   W2   8.475    12.42    13.04    15.06    13.30
B   1   20100618 18:53:27   W1   7.916    12.18    9.976    9.806    6.750
A   15  20100618 18:54:01   W2   8.376    12.28    12.88    14.89    13.14
B   2   20100618 18:53:54   W1   7.479    7.253    4.701    5.490    5.105
    :   :                   :    :        :        :        :        :
```

Figure 18: Example of using the "B / A pairs in Match" method of matching during importation of A records.

Example 2: Scatter Correcting Old LAI Data Files

Even if data were taken with the sun obscured, correcting for scattering still makes some sense: Without this correction, you are assuming the foliage is black; with this assumption, you are assuming more reasonable values for foliage transmittance and reflectance.

For this example we will choose a some LAI-2000 data files that are built-in to FV2200. *Note that implementing a scattering correction on an LAI-2000 file will automatically convert it into an LAI-2200 format.*

1. Read the file

Choose "LAI-2000_sample.txt" under "Sample files" in the File Menu (Figure 19.

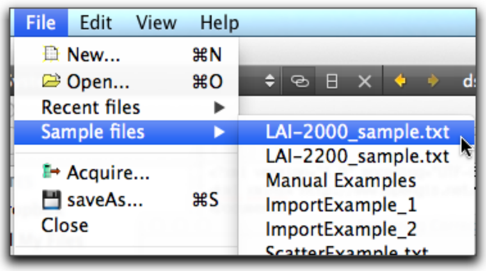


Figure 19: Loading some old data.

2. Generate a K record

Open the Scattering Correction Tool, select the "K Records" tab, and pick the "Make K records from assumptions" option. We'll assume the sun was obscured, so make Fbeam = 0. When the other fields are filled in, check the files to build K records for, and click the Generate K Records button.

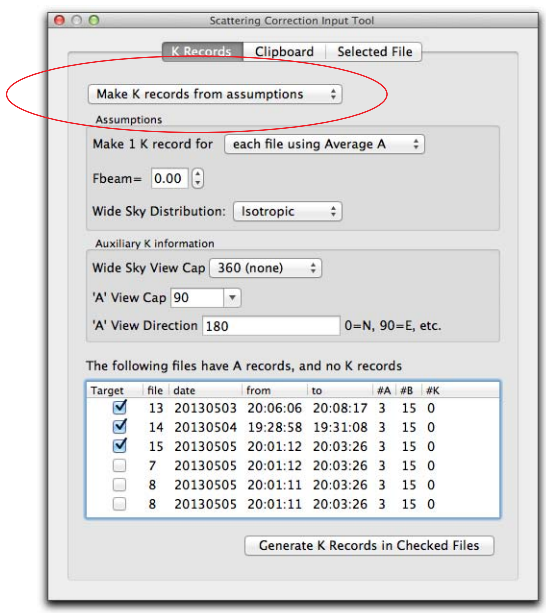


Figure 20: Setting up for a K record for an old data file.

3. Add other inputs

With the target files selected in the main view, select the Clipboard tab in the Scattering Correction Tool. We'll need latitude and longitude, but if Fbeam is 0, then it really won't matter. When the inputs are what you want, click the Update Selected Files button, and the corrections will be applied.

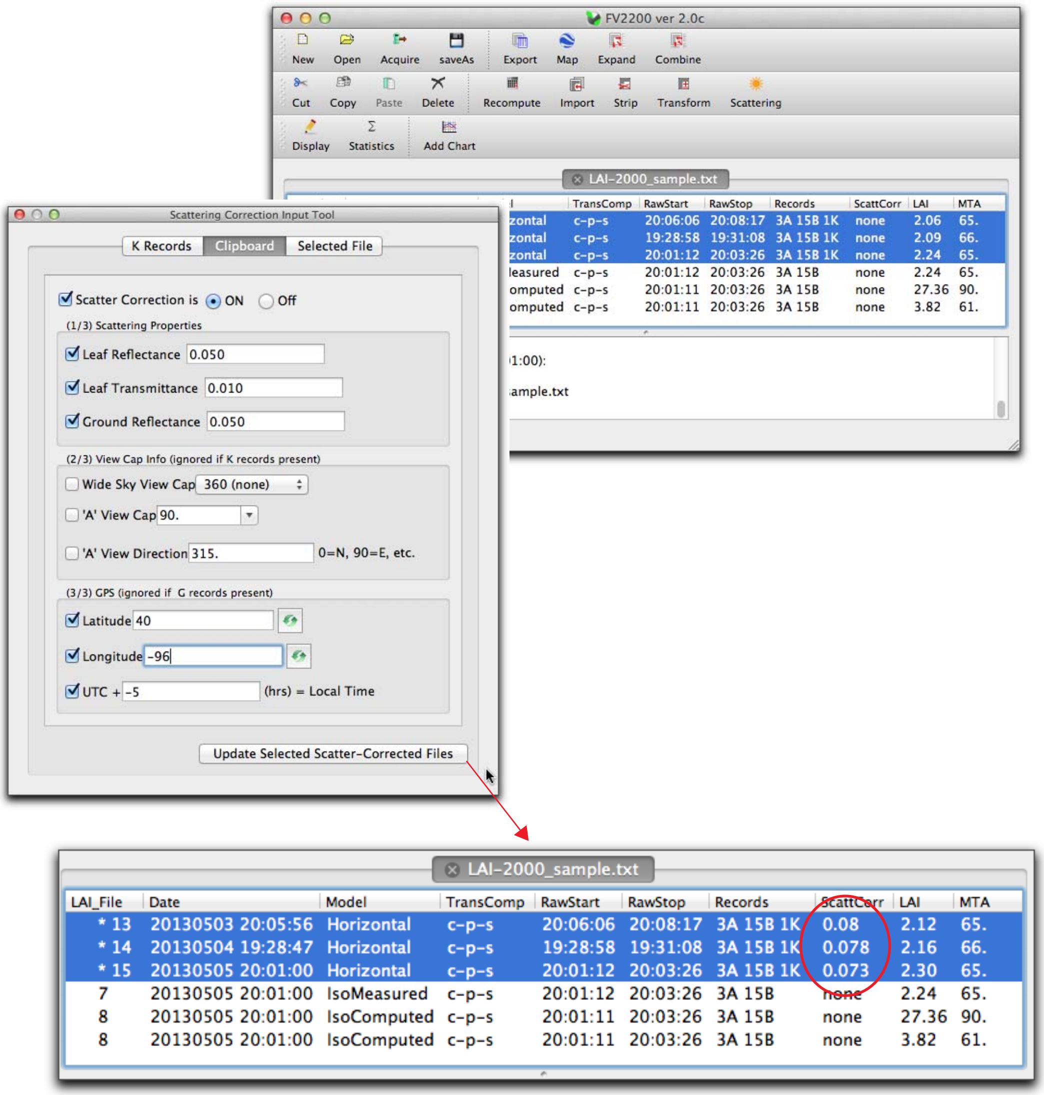


Figure 21: In this case, even with the sun obscured, the LAI comes out 3 to 4 percent higher by using more reasonable assumptions for leaf transmittance and reflectance.