LAI-2000 / LAI-2200 Scattering Corrections
in FV2200 version 2.0

May 2013

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Preface to Beta Testers

Changes to FV8100
The biggest change to version 2 is the addition of scattering corrections. There is a new dialog box (Scattering Correction Control Panel, Figure 2 on page 4) that lets you see the "state" of scattering corrections for any LAI file, and to perform related tasks. There are three states a file can be in with respect to scattering corrections: 1) a file does not contain the inputs (normal), 2) a file has the inputs, but the correction is disabled, and 3) a file has the inputs, and the correction is enabled. Figure 6 on page 7 shows what the file looks like when it contains this input data. You could just edit a file directly to add this, but the better method is to click the edit box for an LAI file in the Scattering Control Panel to bring up a dialog that assists you in entering the required input data (Figure 3 on page 5).

All computed values in FV2200 (LAI, MTA, Gaps, etc.) reflect the effects of the scattering correction if is enabled; there are no duplicate sets of values (i.e. no LAI_with_scattering, LAI_without_scattering, etc.). There is one quantity (*ScattCorr*) however that tells you whether the correction has been applied to that file, and if so, how much it affected LAI (see Figure 5 on page 6). This is a quantity you'll want displayed, and Figure 1 on page 3 shows how to set it up.

Sample Data Files
In the File Menu, under Samples, is a sample file containing data from Tonzi in August, that has the scattering inputs included. The corrections are disabled, however. So, the quickest way to see an example is to open this file, click the Scattering tool to open the Scattering Control Panel, check the boxes to enable the corrections on as many files as you wish, then click OK.

Beta Version Updates
Just as the normal released FV2200 software reports updates (when you run the app), and lets you look for new versions, the Beta version will do a parallel arrangement. So when updates to the Beta version become available, you will find out. And also, or course, when the final version is released.

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

Thank you for your help.

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, which is largely absorbed by chlorophyll. If direct sun does illuminate the canopy, even if the foliage absorbs most of it, the small fraction of the direct beam that is scattered is potentially large enough to significantly effect the below canopy measurement 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 software to allow correction for scattered radiation.

The process is iterative:

1. Measure gap fractions with LAI-2200
From the measured gap fractions, we 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 predicts the error that an LAI-2200 would make in a canopy based on LAI, LAD, and the other inputs.

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, we are done. Otherwise, go back to step 2 with the adjusted gap fractions.

Usually, after 4 or 5 iterations, we have a consistent set of gap fractions, LAI, and LAD.

How to Apply Scattering Corrections

The scattering corrections should be the last step in processing an LAI data file. Do all the other post-processing steps, such as merging A reading from another file, applying calibration adjustments, etc., before doing the scattering corrections.

There is also another constraint: All A and B readings in the file should be aimed in the same compass direction. It is always the case that the As and Bs that are paired should be aimed in the same direction; however, if the file is to be scatter corrected, and the file has paired readings in multiple

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.

directions, the file should be split into multiple files so that all the readings are in the same direction. For example, suppose a file consists of a North-facing sequence of ABBBB followed by an East-facing sequence of ABBB. Split it in two so you have one file that is North ABBB and another file that is East ABBB. Apply the scattering correction to both files, then average the LAIs at the end.

Step 1. Put the variable *ScattCorr* into the summary view (Figure 1). This tells you what files have been scatter-corrected, and by how much.

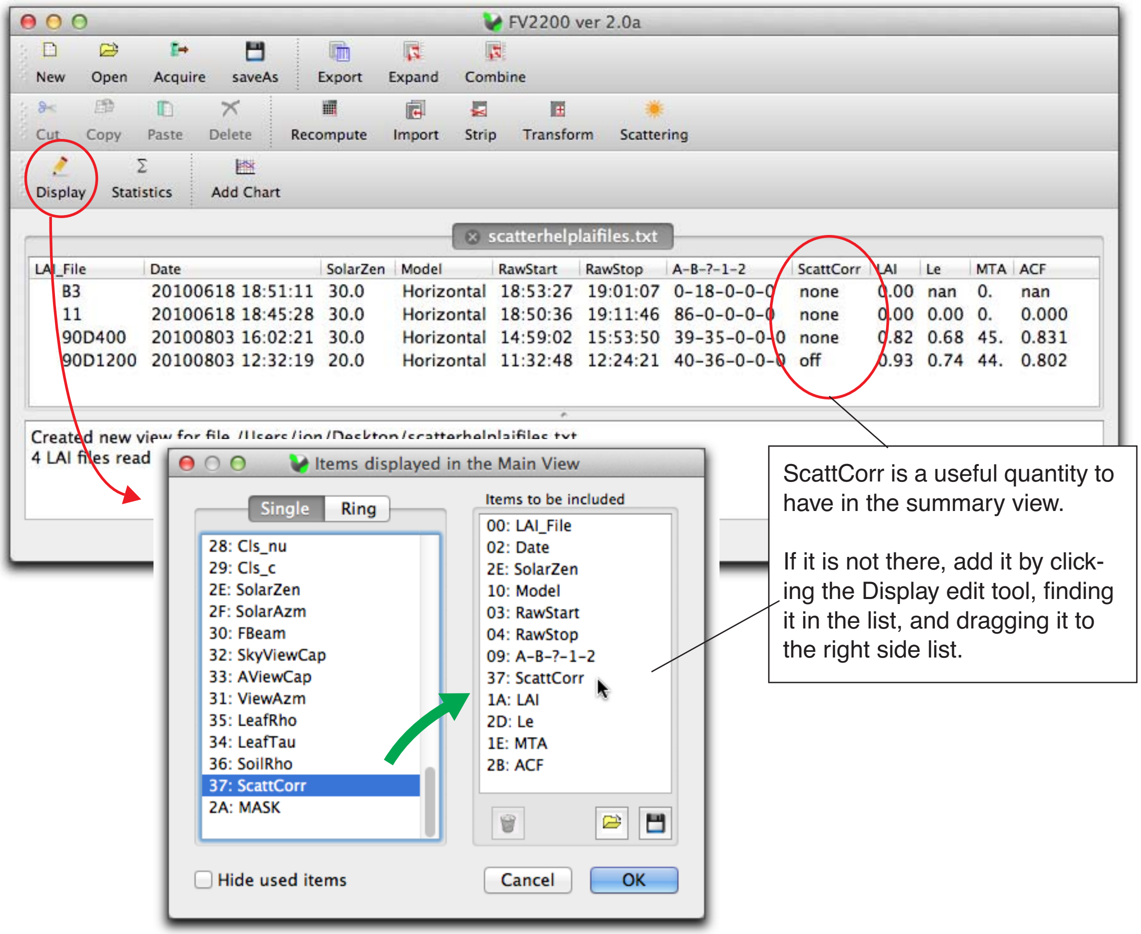


Figure 1: Preparing the main view for scattering corrections.

Step 2. Open the Scattering Correction Control Panel (Figure 2). If you select some files first, the dialog will only include those files. Otherwise, it will include all files in the view.

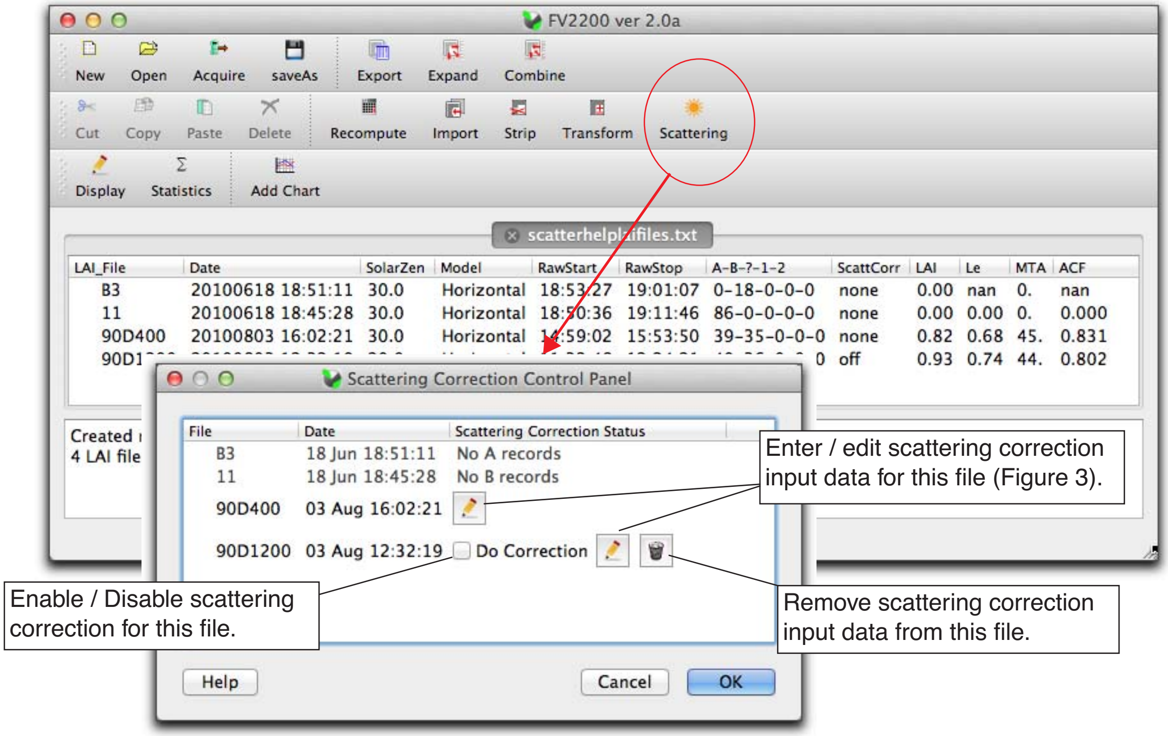


Figure 2: The Scattering Correction Setup Dialog. The figure illustrates the three possible states of a file with respect to scattering corrections: impossible, not present, or present. If it is impossible, the reason is given (e.g. "No A Records"). If the inputs to do the correction are not present (e.g. file 90D400), a setup button is provided. If inputs are present (e.g. file 90D1200), three controls are present: an on/off box, and edit button, and a remove button.

Step 3. Enter the required inputs. The details are described in “Scattering Correction Input Details” on page 8.

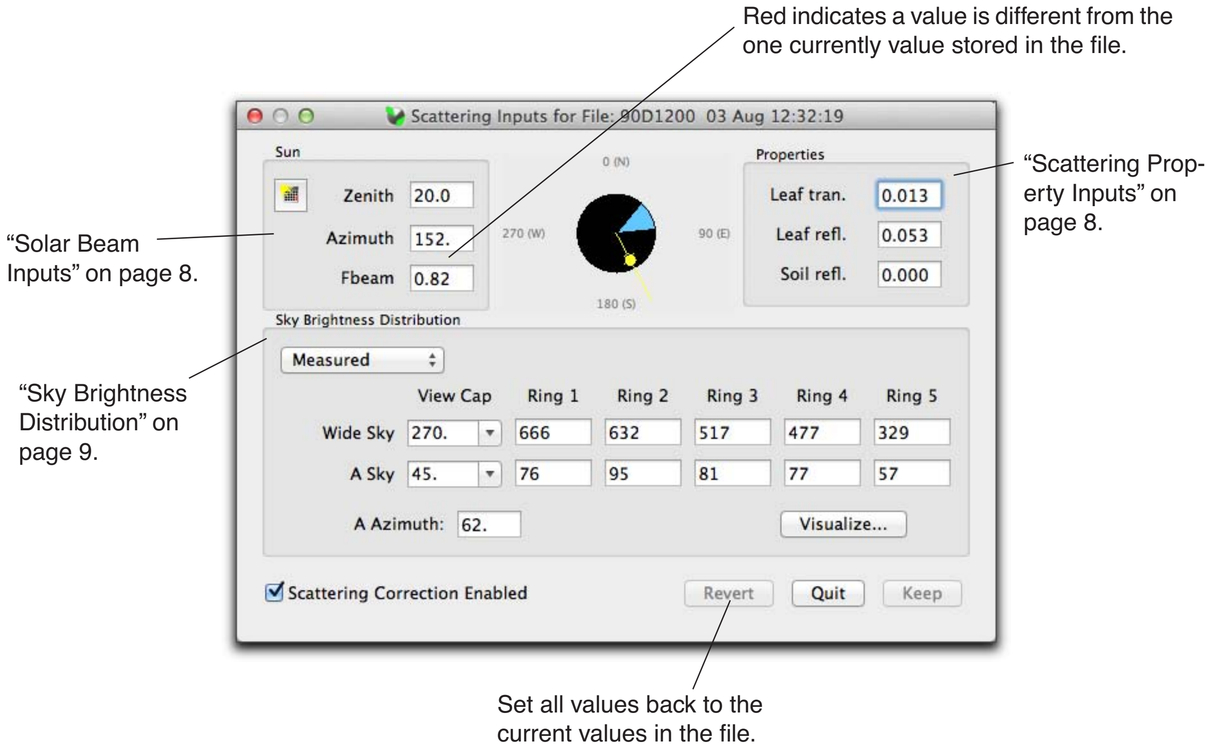
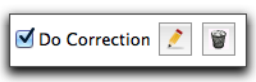
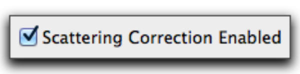


Figure 3: The Scattering Correction Input Dialog for FV2200.

When all the inputs are in place, the actual scattering correction can be enabled either from the check box in the Control Panel 

, or from the check box in the Inputs dialog 

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Step 4. Perform the correction on all properly prepared files by pressing OK in the control panel.

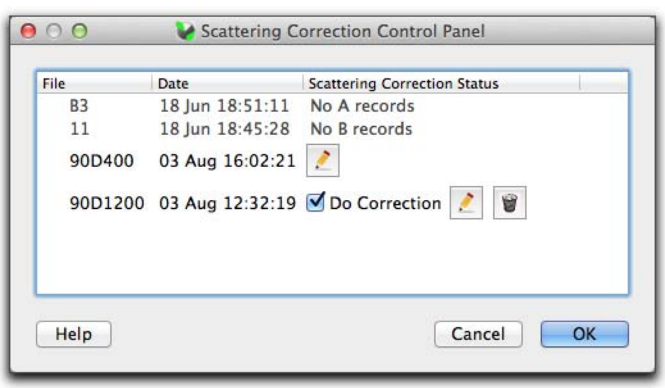
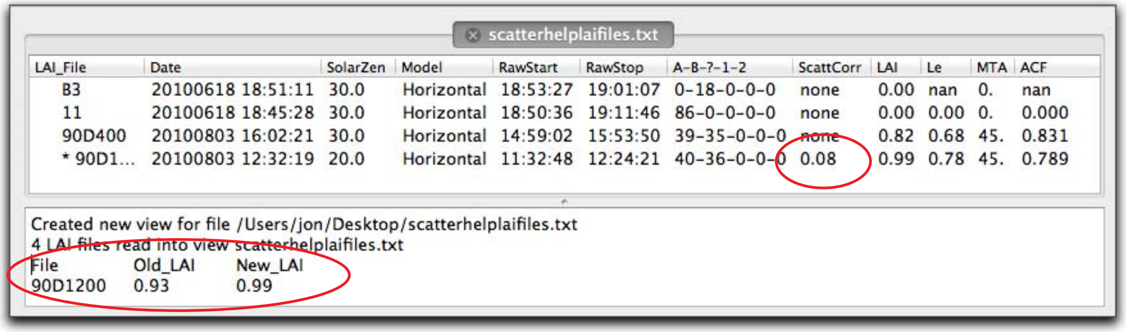


Figure 4: Scattering Control Panel with corrections for one file enabled. Pressing OK will cause it to happen.

Step 5. View the results. All files which have a numeric value in the *ScattCorr* column have had scattering corrections applied, and the other computed values (*LAI*, *Le*, *MTA*, etc.) reflect the influence of the scattering corrections. The numeric value under *ScattCorr* represents the change in LAI that the scattering corrections caused during the model iterations.



scatterhelplaifiles.txt

LAI_File	Date	SolarZen	Model	RawStart	RawStop	A-B-?-1-2	ScattCorr	LAI	Le	MTA	ACF
B3	20100618 18:51:11	30.0	Horizontal	18:53:27	19:01:07	0-18-0-0-0	none	0.00	nan	0.	nan
11	20100618 18:45:28	30.0	Horizontal	18:50:36	19:11:46	86-0-0-0-0	none	0.00	0.00	0.	0.000
90D400	20100803 16:02:21	30.0	Horizontal	14:59:02	15:53:50	39-35-0-0-0	none	0.82	0.68	45.	0.831
* 90D1…	20100803 12:32:19	20.0	Horizontal	11:32:48	12:24:21	40-36-0-0-0	0.08	0.99	0.78	45.	0.789

Created new view for file /Users/jon/Desktop/scatterhelplaifiles.txt
4 LAI files read into view scatterhelplaifiles.txt

File	Old_LAI	New_LAI
90D1200	0.93	0.99

Figure 5: When there is a numeric value under ScattCorr, it means the scattering corrections have been applied, and are reflected in the computed values. The ScattCorr *value of 0.08 means the LAI increased by that amount during the iterations of the scattering layer model. Note that LAI is computed using the ellipsoidal method (*EllipLAI *in FV2200) while iterating the scattering model, so the change value is usually close to, but not exactly, the change in LAI as computed by the LAI-2200 method. In the above example, according to the log information at the bottom, the LAI change was 0.99 - 0.93 = 0.06, while the* EllipLAI *change was 0.08.*

A Scatter-Corrected LAI File

Double-clicking on a file in the main view will bring up the single file view shown in Figure 6. This illustrates how the scattering correction inputs are integrated into the LAI-2200 file structure.

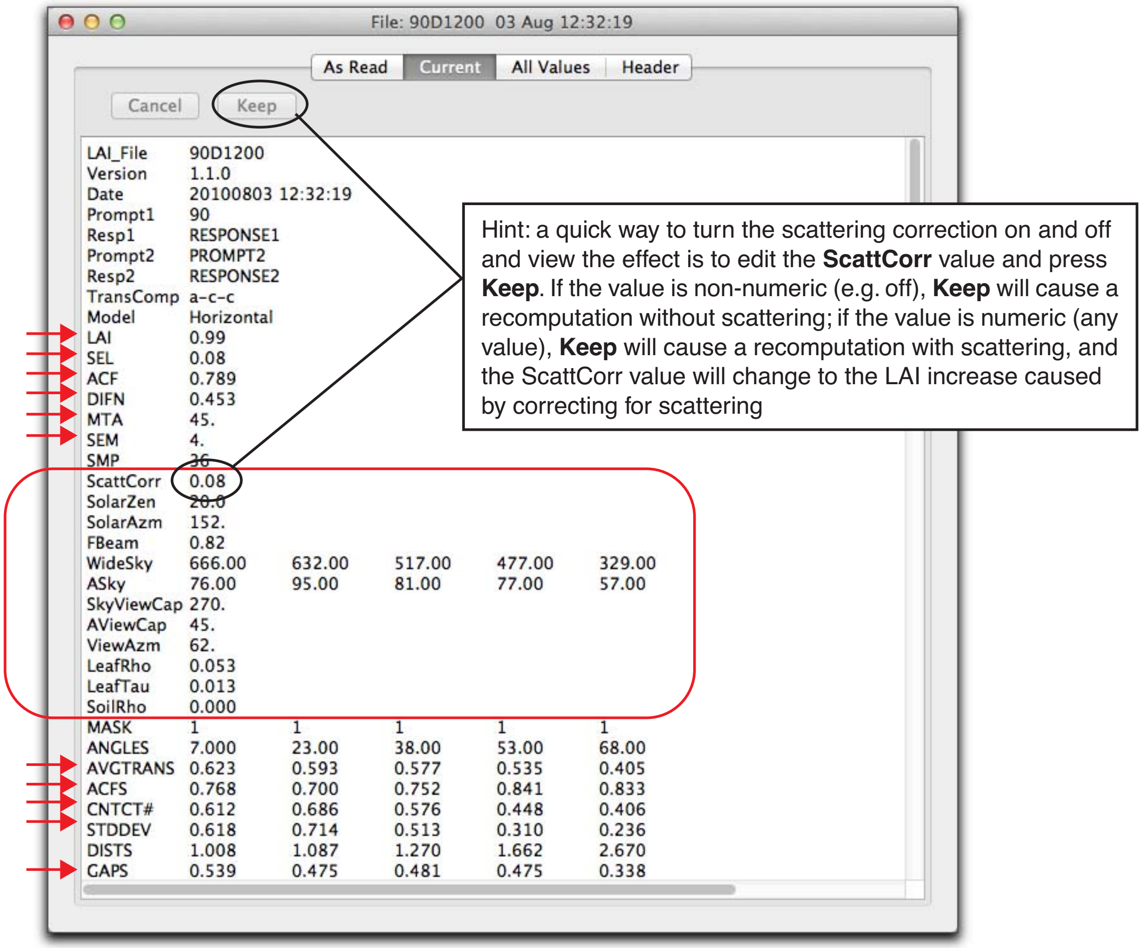
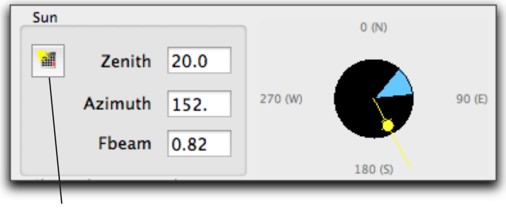


Figure 6: When scattering correction inputs are added to an LAI file, they appear as the items in the red rectangle. The ScattCorr value will be 'off' if the scattering correction is not actually applied, and a numeric quantity if it is applied. Quantities marked with a → are dependent on whether or not scattering corrections are applied.

Scattering Correction Input Details

Solar Beam Inputs

The position inputs are zenith angle (in degrees: 0° is overhead, and 90° is at the horizon), azimuth (in degrees: 0° is north, 90° is east, etc.). These angles can be found by using an on-line calculator, given your location and time (e.g. www.esrl.noaa.gov/gmd/grad/solcalc).



Open website for a solar calculator.

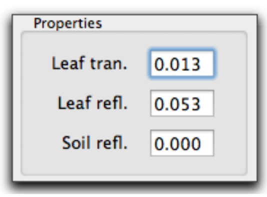
FBeam is fraction of beam, which the fraction of the total incoming sky radiation that is direct beam (not from clouds or sky) *in the waveband used by the LAI-2x00*.

All three inputs show up on the indicator diagram: the yellow line indicates azimuth, the distance of the sun from the center of the view cap along that yellow line indicates zenith ($\sin\theta$, actually), and fraction beam shows up as color, somewhere between yellow (1.0) and white (0.0).

ToDo: How to measure FBeam with a wand....and perhaps how to estimating with a quantum sensor, given sky conditions?...

Scattering Property Inputs

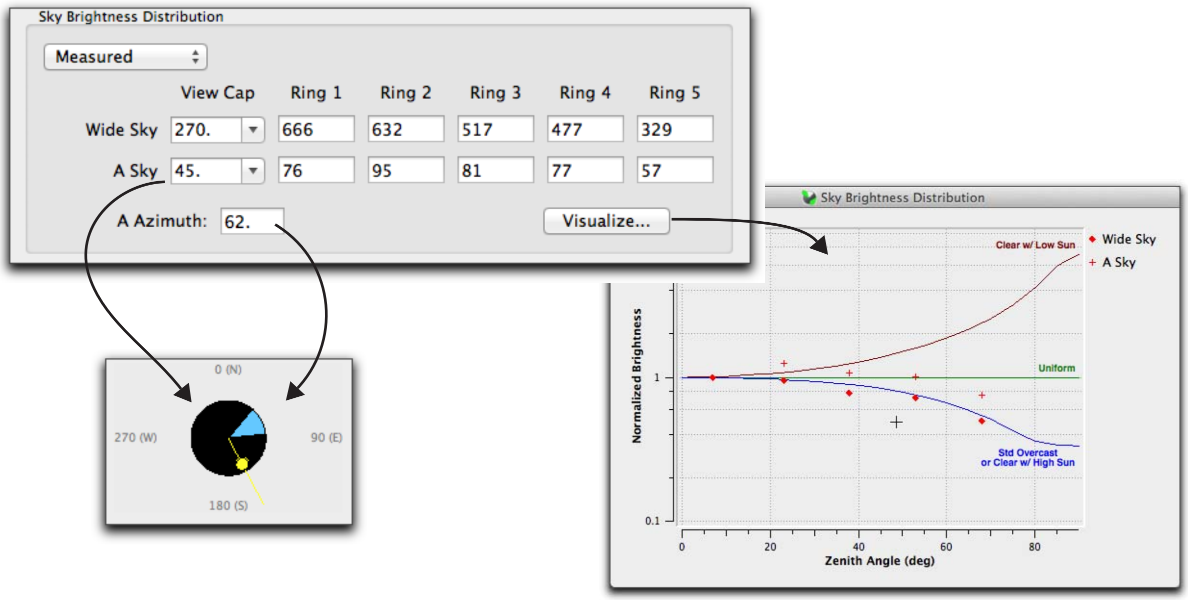
Leaf transmittance, leaf reflectance, and soil reflectance are all for the waveband used by the LAI-2x00. Typical values might be 0.01, 0.05, and 0.2 respectively. It is important to get these correct, as these are at the heart of the scattering correction.



ToDo: How to measure with a wand...

Sky Brightness Distribution

We need to know how the sky brightness is distributed, both for the potentially narrow band viewed during the measurement, and also for the entire sky (minus the sun, of course). Thus, two sky readings are required for this, one (A Sky) with the same sized view cap as is used for the measurement, and the other (Wide Sky) with as wide a view as possible. If the sun is not obscured, use a 270° cap, and orient the sensor so the sun is in the blocked part of the view.



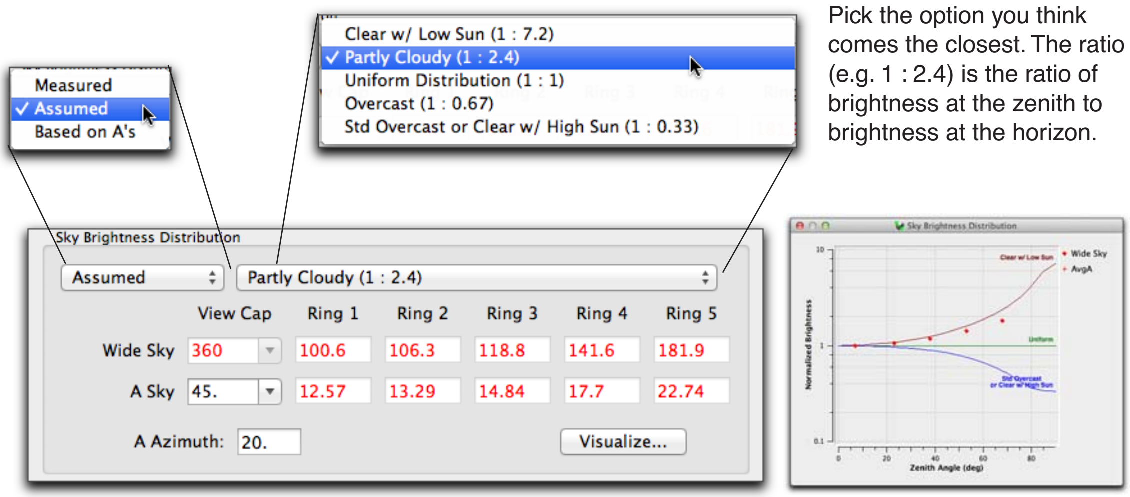
Very Important: Both sets of readings (Wide Sky and A Sky) must a) with the same LAI-2x00 wand, and b) the calibration parameters (ring multipliers) in effect for the readings *must* be the ones on the calibration sheet for that particular wand. This is necessary here (unlike for normal measurements) because the relative ring-to-ring readings are important, and the factory calibration numbers were generated with the wand viewing an isotropic source (a large integrating sphere).

The view caps used for both readings need to be known. No view cap means 360°.

The A Azimuth is the azimuthal direction toward which the center of the view cap was aimed during the for the A Sky distribution. *This must also be the same direction (and view cap) as all A and B readings in the data file*.

The best option is to measure the Wide Sky and A Sky distributions, but there are alternatives that you might fall back on if those readings weren't performed at the time the data was collected:

Option 1. You can assume an idealized distribution (Figure 7), based on observed sky condition.



The Wide Sky ring values are based on the chosen distribution.
The A Sky rings are computed from Wide Sky, and the ratio of view caps.

e.g.for ring 2, $13.29 = 106.3 \times \frac{45}{360}$

Figure 7: Using an Assumed sky brightness distribution option. This represents a method of getting a reasonable approximation if you hadn't made the required measurements at the time of data collection.

Option2. Assume the wide sky distribution was identical to that measured by the A readings in the file (Figure 8). Be careful with this option however: The portion of the sky viewed with a narrow view cap may not at all be representative of the whole sky, especially if scattered clouds are present. Also, before using this option, remember that the multipliers for the A rings need to be for isotropic conditions (factory cal), and *not* factors that have been adjusted to match a B sensor. At the very least, view the plotted distribution to see if it falls into the idealized range.

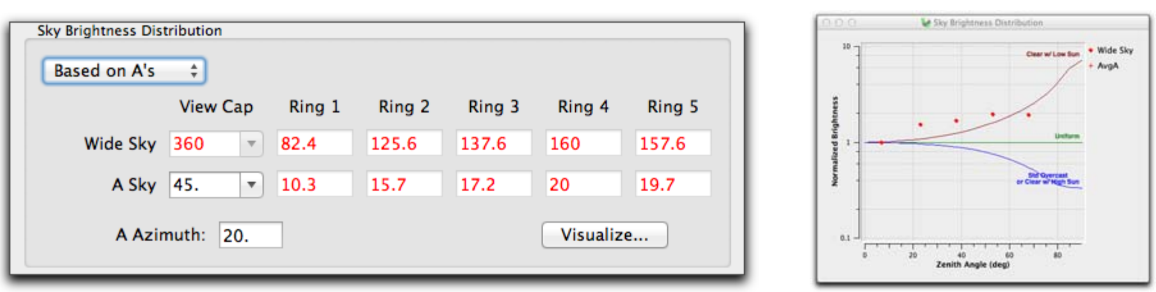


Figure 8: In the right circumstances, you could use the average of the A readings in a file and assign it to the sky distribution. There are a number of reasons this can go wrong, so it's good to view the distribution plot, which in this case does look suspicious.