ARM TR-010

Surface Cloud Grid (SfcCldGrid) Value-Added Product: Algorithm Operational Details and Explanations

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1. Introduction

This document describes the algorithm used for the Surface Cloud Grid (SfcCldGrid) value-added product (VAP). This VAP uses as input the 15-minute output from the shortwave (SW) flux analysis VAP (see Long 2001; Long and Ackerman 2000; Long et al. 1999) from the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) Central and Extended Facilities. This network of 21 sites is unevenly spaced over Northern Oklahoma into Southern Kansas, covering an area from 95.5 degrees to 99.5 degrees west longitude and 34.5 degrees to 38.5 degrees north latitude. For research applications such as single-column modeling, an estimate of the cloud and cloud effects distribution over this entire domain is desirable. The SfcCldGrid VAP applies a multi-pass weighted sum analytic approximation technique (Caracena 1987), which uses Gaussian weighting and an imposed scale length, to interpolate to a 0.25 degree by 0.25 degree latitude/longitude grid over the SGP domain. The output, like the input, includes only solar elevation angles of 10 degrees or greater

The SfcCldGrid VAP produces gridded output for cloud fraction, the ratio of measured over clear-sky SW total (both unshaded pyranometer and sum of direct+diffuse) and direct irradiance, the estimated clear-sky fit total SW irradiance, and the estimated clear-sky fit direct SW irradiance. The ARM SGP Extended Facilities (EF) is not as well maintained as the Central Facility (CF). The clear-sky irradiance accuracy is dependent on the instruments, but does include climatogical column water vapor and aerosol effects. In practice, because the direct and diffuse measurements are dependent on a tracking system and two separate instruments, the unshaded pyranometer ratio data is sometimes more consistent. On the other hand, the sum of the direct+diffuse SW is recognized as the more accurate measurement of the two, given good performance of the tracker and the two instruments used for the measurements. The ratio of measured over clear-sky direct SW, in conjunction with the total SW ratio and clear-sky total and direct irradiance, allows for component evaluation of the irradiance and cloud effects.

These output variables were chosen because the intent is to use the SfcCldGrid VAP output for model comparisons, as well as climatological and statistical research. As is shown in Long and Ackerman (2000), using the ratio of measured over clear-sky fit SW irradiance effectively removes instrument characteristics such as cosine response errors and calibration drifts. This same ratio can be produced with a model, i.e., the ratio of cloudy model calculations over cloudless model calculations, thus eliminating model-measurement discrepancies in the comparison. Comparisons with the SfcCldGrid VAP output allow one to effectively separate the problem into three components:

1. Does the model and measurements agree (the clear-sky case is the "easiest")?

2. Does the model and measured cloud amounts agree (i.e., are the model cloud predictions right)?

3. If the model can generate the proper amount of clouds in the right places, then does the model produce the right cloud properties and treat the clouds right (i.e., do the cloudy/clear ratios agree)?

2. Input Data

The input data for this VAP are standard ARM netCDF files created from the SW flux analysis VAP as mentioned above, both the current Solar Infrared Station (SIRS) data as well as the historical solar and infrared observing system (SIROS) data. Data from the SW FLUX VAP for these platforms are only available when there is daylight. This implies that the netCDF files will contain more samples during the summer months when daylight periods are longer, and fewer during the winter

The algorithm uses a technique to calculate the value used at the CF where three stations (sgp15swfanalsirs1longC1.c1, sgp15swfanalsirs1longE13.c1, and sgp15swfanalbsrn1longC1.c1) are available. If all three stations report, we take the average of the closest 2 values. If only two stations report then we use the average. Otherwise, use the only station that reports a value. (Note: These data have already had some data quality control (QC) applied during processing by the SW flux analysis VAP. See Long 2001 for details.) The input netCDF files contain 15-minute data. In order to produce gridded data, values from at least 15 different locations must be present (with the CF counting as one). Because of this last limitation, the VAP only produces output starting in 1997, when there were sufficient EF installed to fairly consistently have at least 15 locations available

The input files involved in this VAP are:

(1) **sgp15swfanalbsrn1longC1.c1**[1] – used to determine value for CF
(2) **sgp15swfanalsirs1longC1.c1**[1] – used to determine value for CF
(3) **sgp15swfanalsirs1longE1.c1**[2] – always used (if data exists)
(4) **sgp15swfanalsirs1longE2.c1**[2] – always used (if data exists)
(5) **sgp15swfanalsirs1longE3.c1**[2] – always used (if data exists)
(6) **sgp15swfanalsirs1longE4.c1**[2] – always used (if data exists)
(7) **sgp15swfanalsirs1longE5.c1**[2] – always used (if data exists)
(8) **sgp15swfanalsirs1longE6.c1**[2] – always used (if data exists)
(9) **sgp15swfanalsirs1longE7.c1**[2] – always used (if data exists)
(10) **sgp15swfanalsirs1longE8.c1**[2] – always used (if data exists)
(11) **sgp15swfanalsirs1longE9.c1**[2] – always used (if data exists)
(12) **sgp15swfanalsirs1longE10.c1**[2] – always used (if data exists)
(13) **sgp15swfanalsirs1longE11.c1**[2] – always used (if data exists)
(14) **sgp15swfanalsirs1longE12.c1**[2] – always used (if data exists)
(15) **sgp15swfanalsirs1longE13.c1**[1] – used to determine value for CF
(16) **sgp15swfanalsirs1longE15.c1**[2] – always used (if data exists)
(17) **sgp15swfanalsirs1longE16.c1**[2] – always used (if data exists)
(18) **sgp15swfanalsirs1longE18.c1**[2] – always used (if data exists)
(19) **sgp15swfanalsirs1longE19.c1** – always used (if data exists)
(20) **sgp15swfanalsirs1longE20.c1**[2] – always used (if data exists)
(21) **sgp15swfanalsirs1longE22.c1**[2] – always used (if data exists)
(22) **sgp15swfanalsirs1longE24.c1**[2] – always used (if data exists)
(23) **sgp15swfanalsirs1longE25.c1** – always used (if data exists)

[1] Indicates that only one value is used for the CF.
[2] Indicates that historical SIROS platforms can be used in place of the current SIRS.

This VAP uses BW library, which standardizes input and output between automated procedures and the netCDF files. It is a standard library used by developers in the ARM Experiment Center and External Data Center.

The desired fields from each input file are listed in the SFCCLDGRID1LONG_retriever.info file described in the next section. All the above files can be ordered online from the ARM Archive Center (http://www.archive.arm.gov).

3. Configuration Files

Three configuration files for this VAP are used. They are:

1. SFCCLDGRID1LONG_main.info
2. SFCCLDGRID1LONG_retriever.info
3. SFCCLDGRID1LONG_maker.info

3.1 SFCCLDGRID1LONG_main.info

The default is for the file to contain "measurement." This file is hardly edited.

3.2 SFCCLDGRID1LONG_retriever.info

This file specifies what input platforms and fields should be retrieved by the VAP. The fields retrieved for all platforms (including historical data) are shown in Table 1.

Table 1. Field name and description retrieved from the input netCDF files.

Field Name	Description
cloudfraction	estimated average fractional sky cover over the hemispheric dome
gswfluxdn_measured	measured downwelling global SW irradiance
gswfluxdn_clearskyfit	clear-sky fit estimated downwelling global SW irradiance
dirfluxdn_measured	measured downwelling direct SW irradiance
dirfluxdn_clearskyfit	clear-sky fit estimated downwelling direct SW irradiance
sswfluxdn_measured	measured downwelling summed SW irradiance (direct+diffuse)
sswfluxdn_clearskyfit	clear-sky fit estimated downwelling summed SW irradiance (direct+diffuse)

3.3 SFCCLDGRID1LONG_maker.info

This file describes the format for the two output files generated by the VAP, including file name, fields and attributes (global or field). The output platforms created are:

1. sgpswfanaltrim15long.c2.yyyymmdd.hhmmss.cdf
2. sgpswfanalgrid15long.c2.yyyymmdd.hhmmss.cdf

(See Section 4, "Algorithm," for more details about the contents of these two output files.) Table 2 lists the field names, along with their respective units and description, for sgpswfanaltrim15long.c2.yyyymmdd.hhmmss.cdf netCDF files. Table 3 is similar to Table 2, but for the sgpswfanalgrid15long.c2.yyyymmdd.hhmmss.cdf netCDF files.

Table 2. Field names, units, and description for sgpswfanaltrim15long.c2.yyyymmdd.hhmmss.cdf

Field Name	Units	Description
base_time	Seconds since 1970-1-1 0:00:00 0:00	
time_offset	Seconds	time offset from base_time
cloudfraction	unitless	fractional sky cover
tswfluxdn	unitless	ratio of measured over clear-sky total SW down
dirfluxdn	unitless	ratio of measured over clear-sky direct SW down
sswfluxdn	unitless	ratio of measure over clear-sky (direct + diffuse) SW down
clrfluxdn	W/m^2	estimated clear-sky fit total SW down
cdirfluxdn	W/m^2	estimated clear-sky fit direct SW down
lat	degrees	north latitude for all input platforms
lon	degrees	east longitude for all input platforms
alt	meters	altitude
plat	unitless	abbreviated names of the stations

Table 3. Field names, units, and description for sgpswfanalgrid15long.c2.yyyymmdd.hhmmss.cdf files

Field Name	Units	Description
base_time	Seconds since 1970-1-1 0:00:00 0:00	
time_offset	Seconds	time offset from base_time
cloudfraction	unitless	fractional sky cover
tswfluxdn	unitless	ratio of measured over clear-sky total SW down
dirfluxdn	unitless	ratio of measured over clear-sky direct SW down
sswfluxdn	unitless	ratio of measure over clear-sky (direct + diffuse) SW down
clrfluxdn	W/m^2	estimated clear-sky fit total SW down
cdirfluxdn	W/m^2	estimated clear-sky fit direct SW down
lat	degrees	north latitude of grid points
lon	degrees	east longitude of grid points
azimuth	degrees	solar azimuth referenced to the CF
alt	meters	altitude

3.4 Configuration File (Optional)

An additional and optional feature to the sfccldgrid1long VAP is running the program without using the command-line options. This VAP has more command-line options than usual, which allows the user to customize the VAP without having to recompile the source code.

The configuration file should be named sfccldgrid1long.cnf and placed in the directory $VAP_HOME/conf. The format for this file is <key>=value. Lines that begin with'#' are considered to be comment lines and are omitted. You can have as many comments as you would like, before, in between, and after valid lines. In order to use the configuration file, the user should run the VAP without any command-line options; e.g., 'sfccldgrid1long'. If no arguments are specified, the VAP looks in the appropriate directory for a configuration file; if it finds one, it begins to process the file else it aborts the program abnormally without causing any core dumps.

The <key>s should be followed by an '=' with or without any blank spaces followed by the value. <key>s that are not valid will not cause any harm to the program and its values are discarded. Valid keys are listed below with their proper use in the configuration file and corresponding command-line argument.

1) scale=value
   This key corresponds to the scale length in kilometers.
   The default is 100 km. To set this value to 150,
   you can use the following:
   scale=150
   Command-line argument: -scale 150

2) pass={m,o}
   The default value is m for 'multi-pass' as opposed to
   o for 'optimal'. In order to use type of pass as
   optimal, the user should use:
   pass=o
   Command-line argument: -pass o

3) npass=value
   This value indicates to the VAP how many passes to use
   if using 'multi-pass'. The default value is 16.
   Valid values are: 1,2,3,4,8,16,32. To use 4 passes, use:
   npass=4
   Command-line argument: -npass 4

4) minimum=value
   This key corresponds to the minimum number of stations
   necessary to create grid data. The default value is 15.
   To have at least 12 stations present, use:
   minimum=12
   Command-line argument: -min 12

5) max_cf=value
   This key changes the maximum allowable value to use for the
   cloudfraction variable. To change the max value
   to 1.1 use:
   max_cf=1.1
   Command-line argument: -cf 1.1

6) max_tsw=value
   This key changes the maximum allowable value to use for the
   ratio of measured clear-sky total SW down variable.
   To change the max value to 1.3 use:
   max_tsw=1.3
   Command-line argument: -tsw 1.3

7) max_ssw=value
This key changes the maximum value to use for the ratio of measured over clear-sky (direct+diffuse) SW down variable. To change the max value to 1.5 use:
max_ssw=1.5
Command-line argument: -ssw 1.5

8) max_dir=value
This key changes the maximum value to use for the ratio of measured over clear-sky direct SW down variable. To change the max value to 1.45 use:
max_dir=1.45
Command-line argument: -dir 1.45

9) max_clr=value
This key changes the maximum value to use for the estimated clear-sky fit total SW down variable.
To change the max value to 1450 use:
max_clr=1450
Command-line argument: -clr 1450

10) max_cdir=value
This key changes the maximum value to use for the estimated clear-sky fit direct SW down variable.
To change the max value to 1450 use:
max_cdir=1450
Command-line argument: -cdir 1450

11) date=value
This specifies the day to run the VAP on. If using a configuration file, this variable has to be present otherwise the VAP will not read in any data files.
The value for this is in the form of: [yy]yymmdd.
To run on October 12, 1999 use:
date=19991012 or date=991012
Command-line argument: -d 19991012 or -d 991012

12) text=value*
Enabling this option causes the VAP to create text files corresponding to the netCDF files that are generated. This value is disabled by default.
To enable this option, use:
text=1
Command-line argument: -text

13) plot_only=value*

    This option intends to create quick-look images only without processing any data. This option is disabled by default. To enable, use:
    plot_only=1
    Command-line argument: -P

14) quicklook=value*

    This disables the VAP from creating quick-look images. This option is generally enabled by default. To disable, use:
    quicklook=1
    Command-line argument: -N

15) use_x=value*

    This key causes the VAP to use the X device for the quick-look images instead of creating png or mng images.
    To set this value, use:
    use_x=1
    Command-line argument: -X

*Any value used will activate the corresponding key.

Note, not all command-line options have valid keys in the configuration file.

4. Algorithm

The SFCCLDGRID1LONG VAP uses a 2-pass technique to produce grid data (Figure 1). During the first pass, the VAP retrieves the data from the input platforms and performs the necessary calculations. Then, valid samples containing the minimum number of stations are captured into a netCDF file called sgpswfanaltrim15long.c1.yyyymmdd.hhmmss.cdf. The set of data created during this pass is better known as “trim” data. During the second pass, the VAP processes the “trim” data to create “grid” data and captures this output dataset in the netCDF file, sgpswfanalgrid15long.c1.yyyymmdd.hhmmss.cdf. For more information on the logic used to create “grid” data, see Section 1, “Introduction.”

After the grid data is produced, the VAP uses Interactive Data Language (IDL) to create contour plots for the newly created “grid” data and capture the results as Portable Network Graphics (png). The png images are then used to create multi-image network graphics (mng) animations.

5. Criteria/Limits

5.1 Stations

There must be at least 15 different locations present for a successful run of the VAP. Keep in mind that there are three instruments co-located at the CF, but only 1 value will be used.

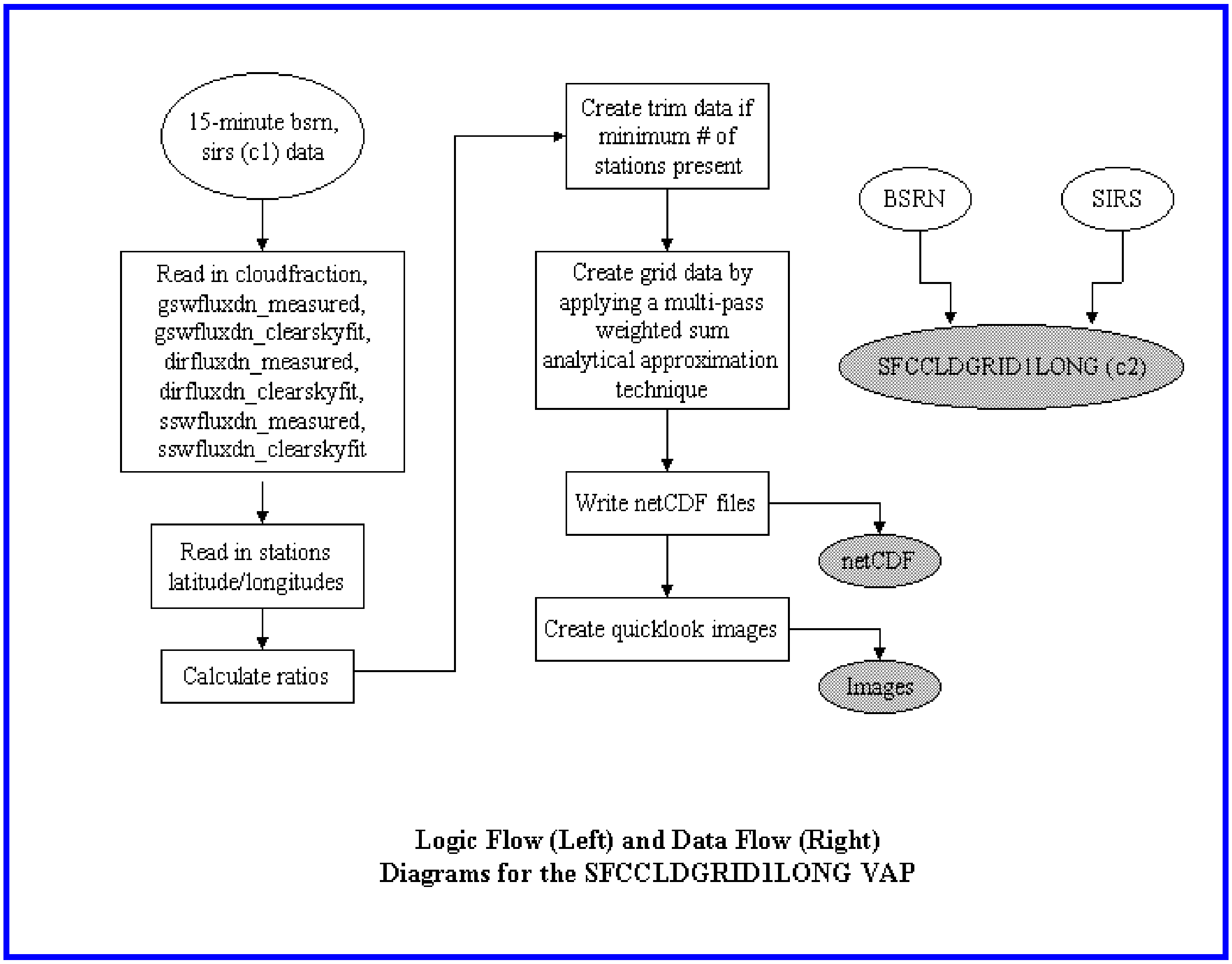

Figure 1. The logic/data flow for the sfccldgrid1long VAP.

5.2 Fraction Sky Cover

Values greater than 1.0 or less than 0.0 are treated as missing data.

5.3 Ratio of Measure Over Clear-Sky Total SW Down

Values that are greater than 25% of the maximum of 1.1 are truncated to the maximum. This allows for slight inaccuracy of the clear-sky fitting, and periods of moderate positive cloud forcing, to be included in the gridded output. Values greater than an additional 25% of the maximum of 1.1 or less than 0.0 are treated as missing data.

5.4 Ratio of Measure Over Clear-Sky Direct SW Down

Values that are greater than 25% of the maximum of 1.1 are truncated to the maximum. This allows for slight inaccuracy of the clear-sky fitting to be included in the gridded output. Values greater than an additional 25% of the maximum of 1.1 or less than 0.0 are treated as missing data.

5.5 Ratio of Measure Over Clear-Sky (direct+diffuse) SW Down

Values that are greater than 25% of the maximum of 1.1 are truncated to the maximum. This allows for slight inaccuracy of the clear-sky fitting, and periods of moderate positive cloud forcing, to be included in the gridded output. Values greater than an additional 25% of the maximum of 1.1 or less than 0.0 are treated as missing data.

5.6 Estimated Clear-Sky Fit Total SW Down

Values that are greater than an additional 25% of the maximum of 1300 are truncated to the maximum. Values greater than that or less than 0.0 are treated as missing data.

5.7 Estimated Clear-Sky Fit Direct SW Down

Values that are greater than an additional 25% of the maximum of 1300 are truncated to the maximum. Values greater than that or less than 0.0 or treated as missing data.

6. Data Qc Tests and Qc Flags

The data used in the SfcCldGrid VAP underwent various quality control assessments in the SW Flux Analysis VAP (see Long 2001; Long and Ackerman 2000; Long et al. 1999). One such is a maximum/minimum test; others include sophisticated tests that lend at least some assurance of data quality.

7. Output Files

The SfcCldGrid VAP produces two sets of 15-minute resolution output files. One file called the sgpswfanaltrim15long.c1.yyyymmdd.hhmmss.cdf, contains data with at least the minimum number of stations required to produce the gridded results. The other file called the sgpswfanalgrid15long.c1.yyyymmdd.hhmmss.cdf, contains the aforementioned gridded data over the entire SGP CART site.

The output files for this VAP have the following format:

sgpswfanaltrim15long.c1.yyyymmdd.hhmmss.cdf
sgpswfanalgrid15long.c1.yyyymmdd.hhmmss.cdf

where yyyymmdd represents the date of the run; yyyy is the 4-digit year, mm and dd are the 2-digit month and day, respectively.

hhmmss represents the time of day for the run; hh, mm, ss represent the 2-digit hour, minute, and seconds, respectively.

The output fields, units, and descriptions are listed in Section 3.3, "SFCCLDGRID1LONG_maker.info."

8. Results

The plots below are sample quick-look image for each of the scientific quantities generated during the SfcCldGrid VAP for September 19, 2000, at 1500 Universal Time Coordinates (UTC). In Figures 1-7, a "red" filled circle represents the CF. An open "green" circle indicates that particular facility did not report any data for that particular time sample. A filled "green" circle indicates that particular was present for the time sample and reported data. In Figure 2, the shaded "cyan" areas represent where the cloud fraction was 0.0, while the shaded "gray" areas represent overcast. In Figures 3, 4, and 5, the shaded "gray" areas represent were the respective ratios were 1.0. The filled "yellow" circles in Figure 6, indicates the solar azimuth referenced to the CF. Figure 2 is an image of the fractional sky cover; Figure 3 is the ratio of measured over clear-sky total SW down; Figure 4 is the ratio of measured over clear-sky direct SW down; Figure 5 is the ratio of measured over clear-sky (direct+diffuse) SW down; Figure 6 is the estimated clear-sky fit total SW down.

The VAP output values were chosen for maximum information in the most compact form. All clear-sky and all-sky values can be produced by simple mathematical manipulation of the output grids. For instance, if the user would like the measured (all-sky) total downwelling SW, simply multiply the ratio of measured over clear-sky sum SW (or total SW) grid by the estimated total clear-sky irradiance grid. Table 4 lists the value of interest and the corresponding mathematical process to produce all components of the downwelling SW.

9. Analysis: Uncertainty Assessment

An analysis was performed on the SfcCldGrid VAP to calculate the uncertainty due to interpolation across the SGP Cart site. To calculate the uncertainties, two datasets were used; one from the normal VAP run; the other for a VAP run with a particular facility omitted. Daily, weekly, monthly, and yearly averages were created using 15-minute resolution data to generate magnitudes for each of the time frames for the grid point closest to the omitted facility. For instance, to generate daily magnitudes, the average of the nearest grid points for each day of the year was calculated for each VAP run separately. To calculate the daily uncertainty, the absolute difference between the daily magnitudes from both VAP runs was calculated. To generate the average absolute nearest grid point difference, the average of all the daily magnitude absolute differences was calculated. This process was repeated for several variables at each of the aforementioned time scales. The tables below contain the results for each of the time scale averages for the year 2001.

Figure 8 is a representation of the grid area with spacing of 0.25 degrees produced by the SFCCLDGRID1LONG VAP, along with all the EF sites (denoted with blue diamonds). The 2 omitted facilities used to generate the uncertainty assessment; E9 and E19 are circled in black. The CF is highlighted with a large red dot. Area outlined in red is the gridded area produced by the VAP. The facility at E9 is located in a region that is considered to be data "rich" since there are surrounding facilities on all sides. On the other hand, the facility at E19 is located in a region that is considered data "poor" because the surrounding facilities are further away and there is only one platform to the south with unknowns beyond to influence the interpolation.

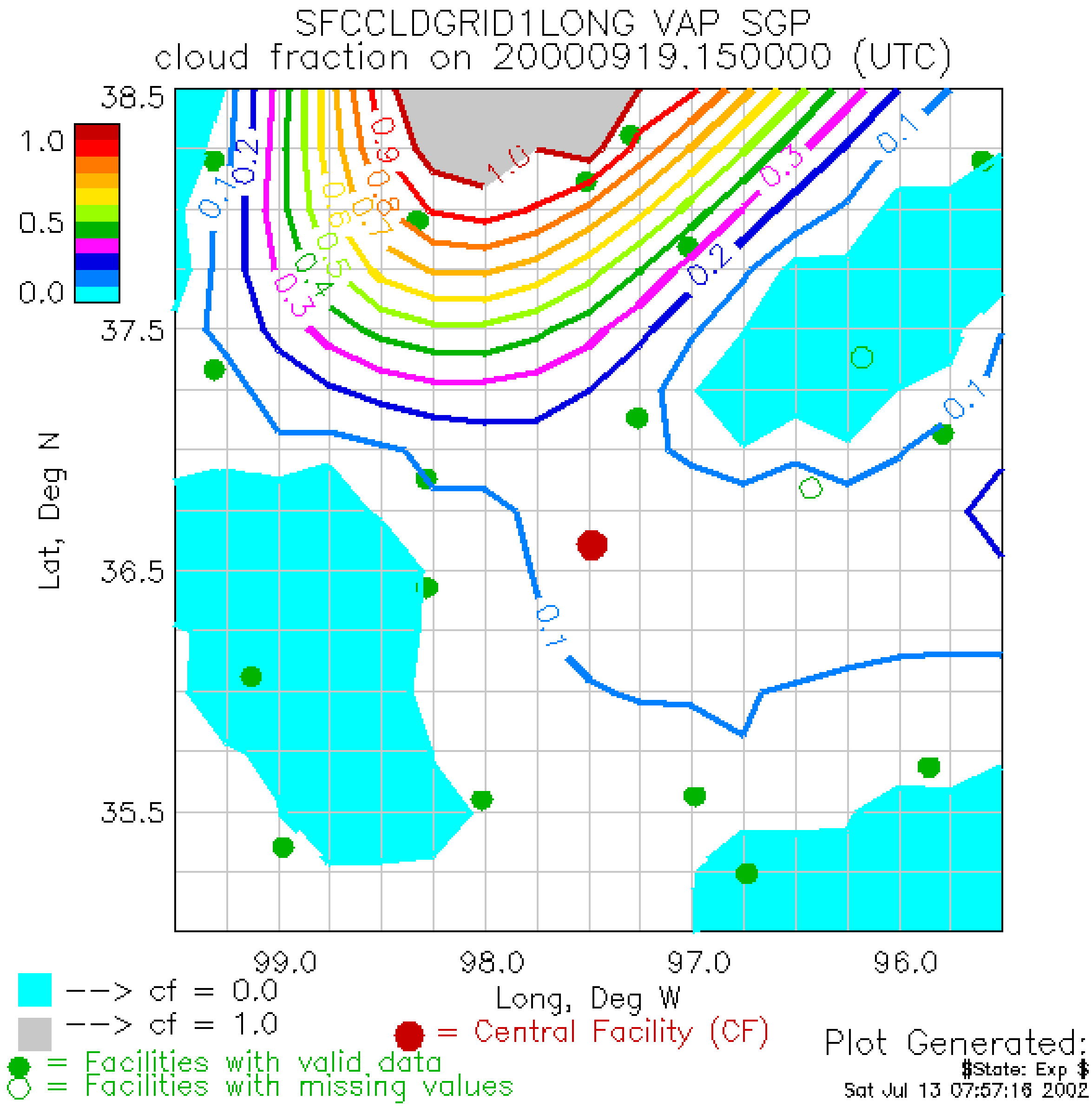

Figure 2. Fractional sky cover.

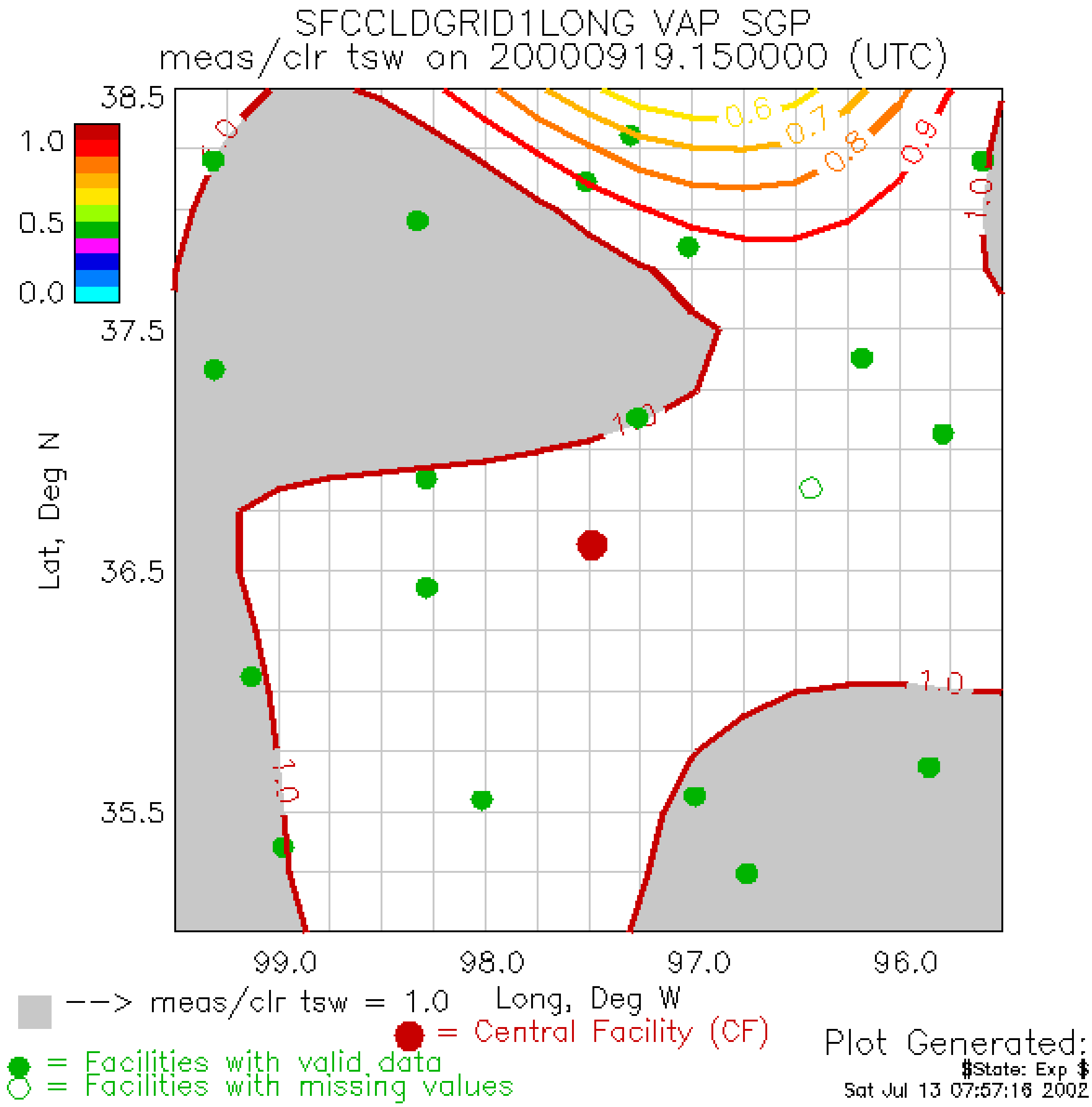

Figure 3. The ratio of measured over clear-sky total SW down.

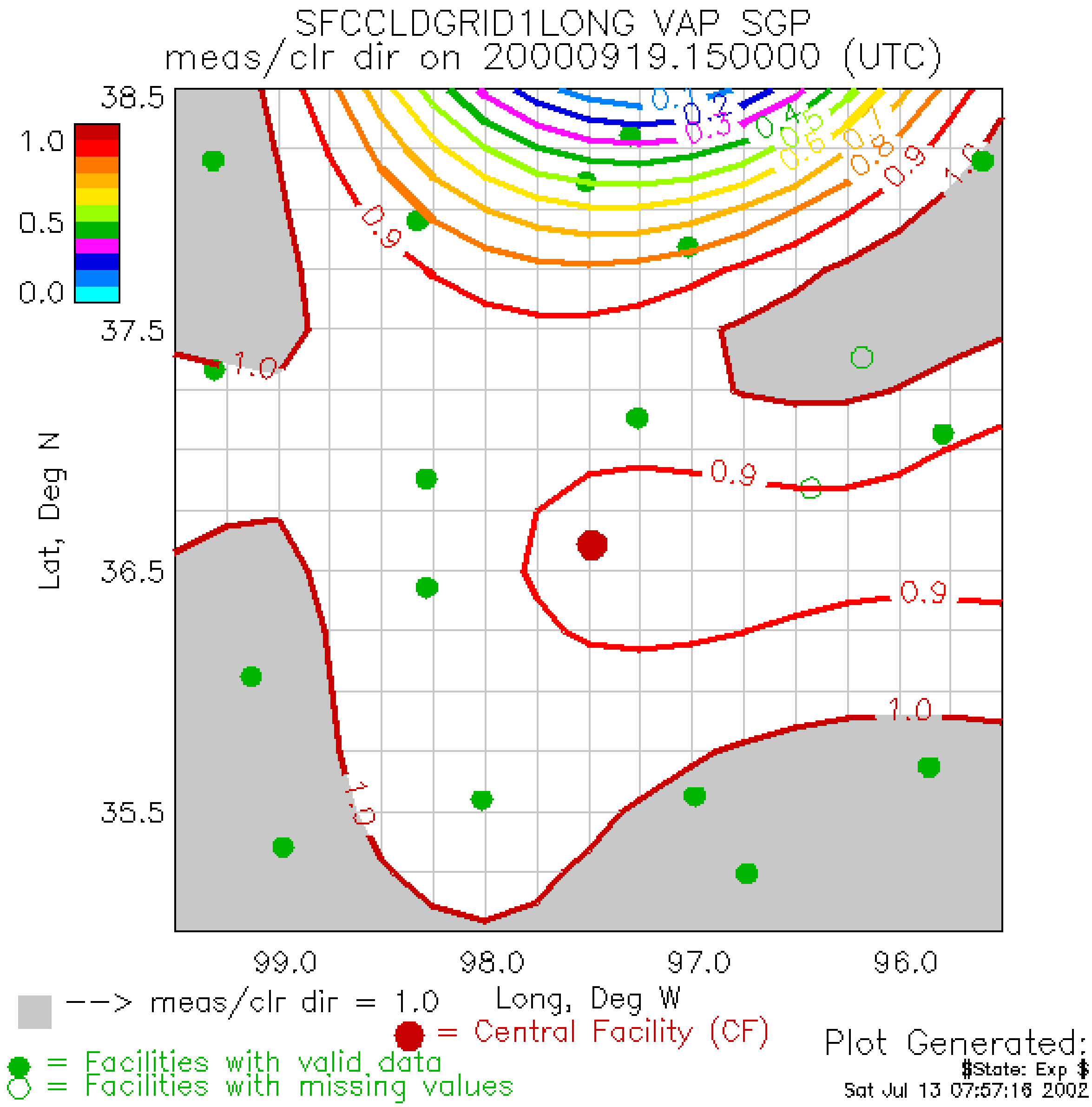

Figure 4. The ratio of measured over clear-sky direct SW down.

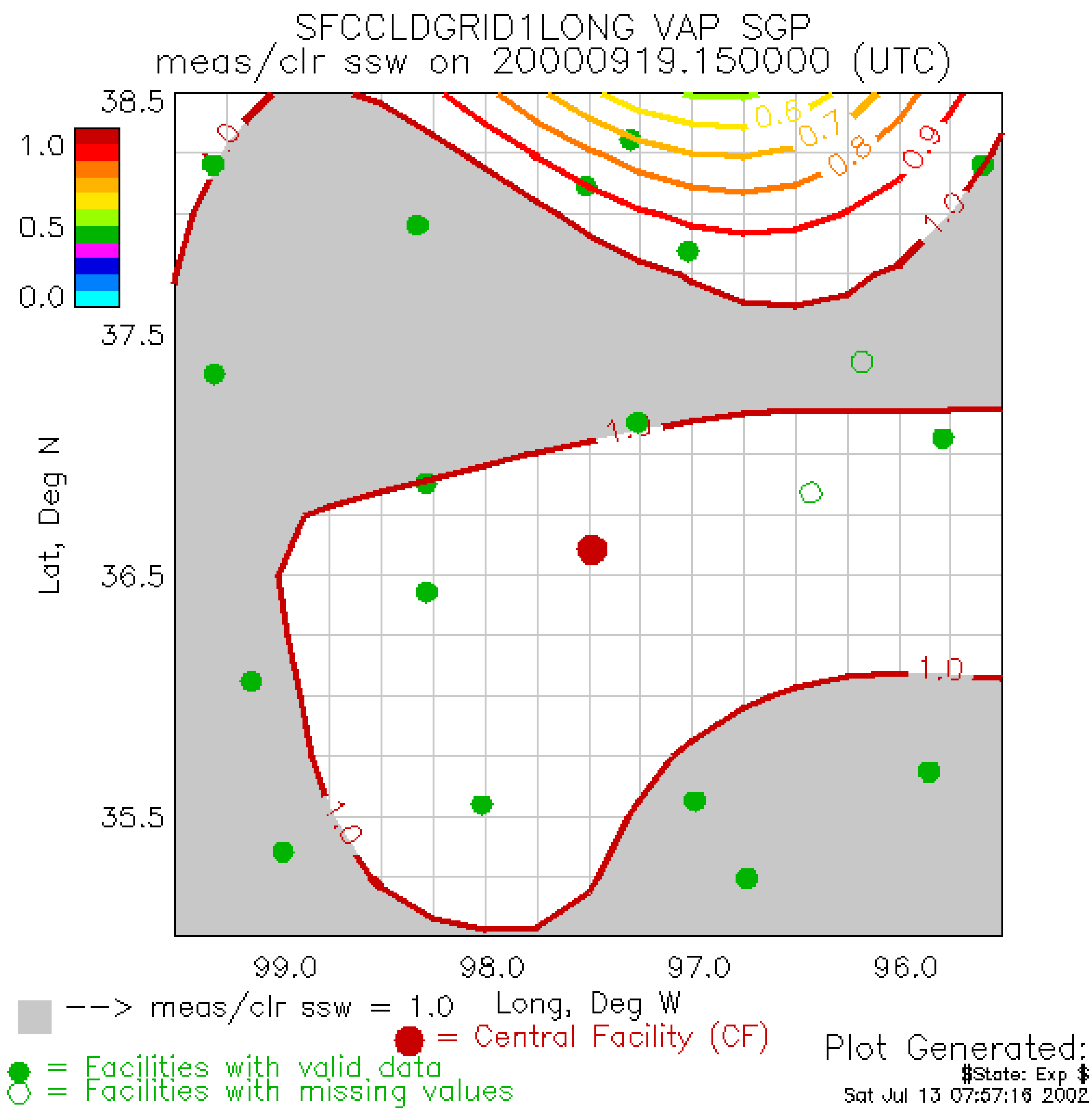

Figure 5. The ratio of measured over clear-sky (direct+diffuse) SW down.

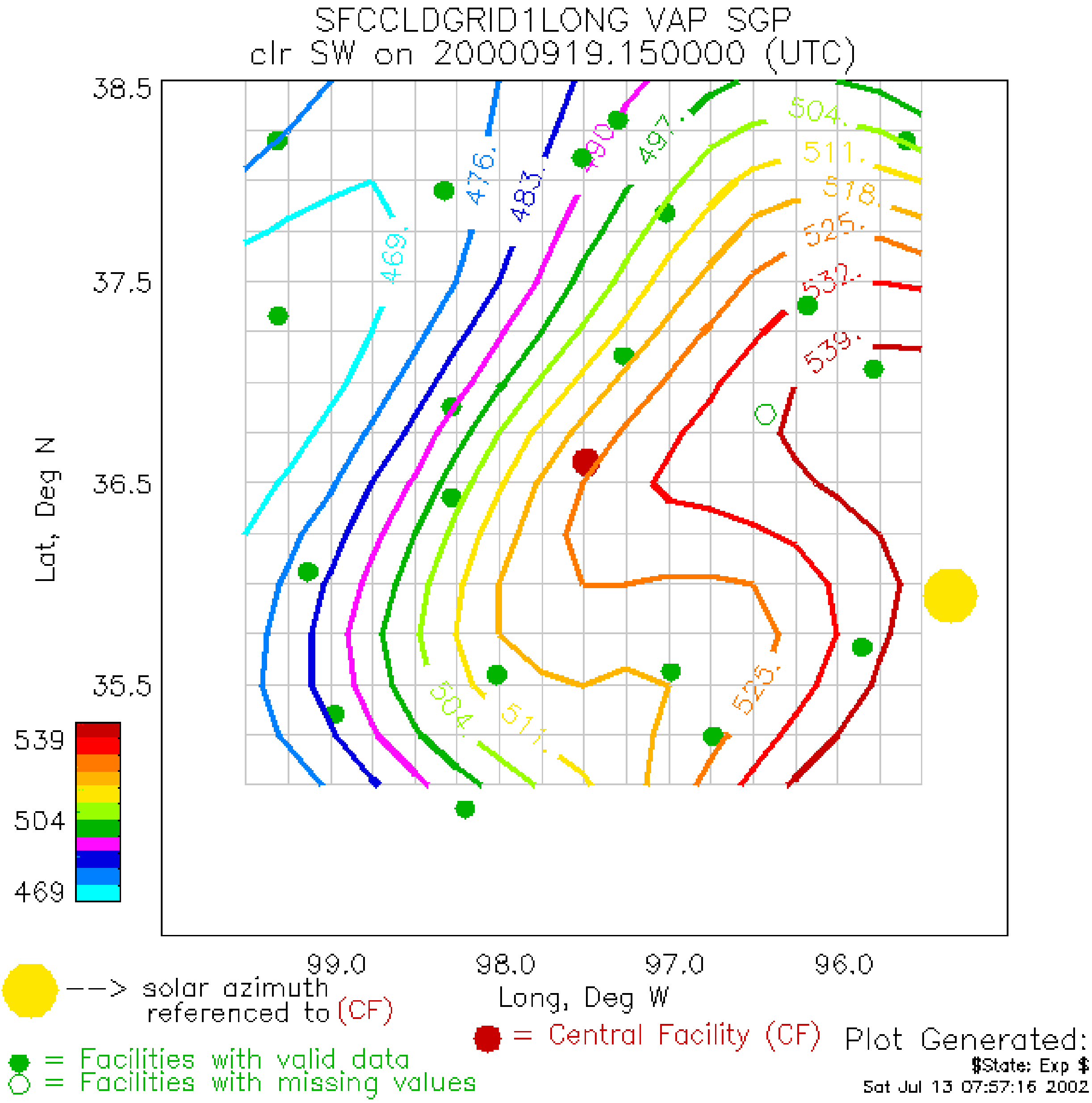

Figure 6. The estimated clear-sky fit total SW down.

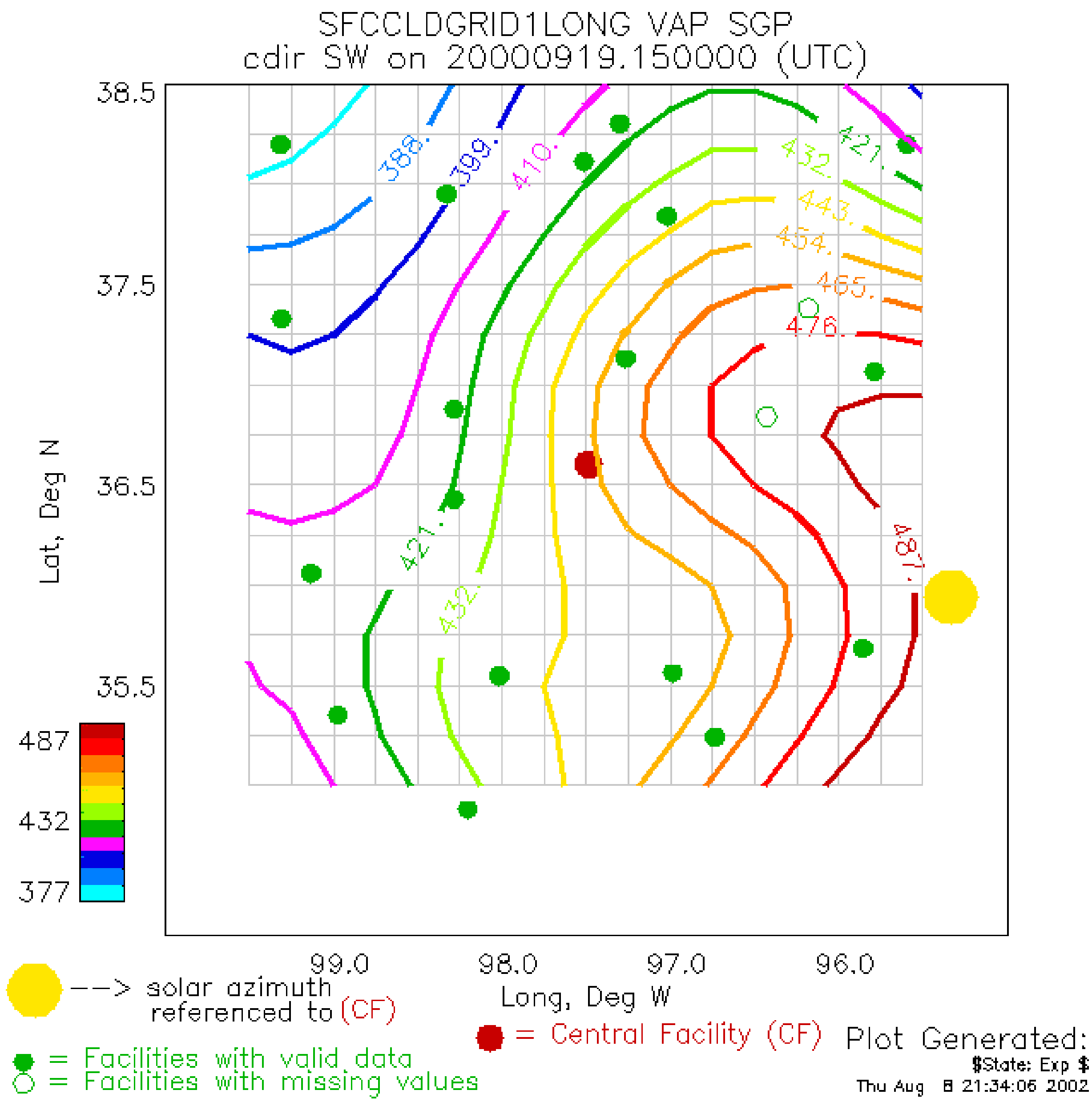

Figure 7. The estimated clear-sky fit direct SW down.

Table 4. Production of components of downwelling SW from output grids.

Value of Interest	Produced by:
All-sky Total SW	(Sum [or Total] Meas/Clear SW ratio) X (Estimated clear-sky Total SW irradiance)
All-sky Direct SW	(Direct Meas/Clear SW ratio) X (Estimated clear-sky Direct SW irradiance)
All-sky Diffuse SW	(All-sky Total SW) - (All-sky Direct SW)
Clear-sky Diffuse SW	(Estimated clear-sky Total SW) - (Estimated clear-sky Direct SW)
All-sky Diffuse Ratio	(All-sky Diffuse SW) / (All-sky Total SW)
Clear-sky Diffuse Ratio	(Clear-sky Diffuse SW) / (Estimated clear-sky Total SW)

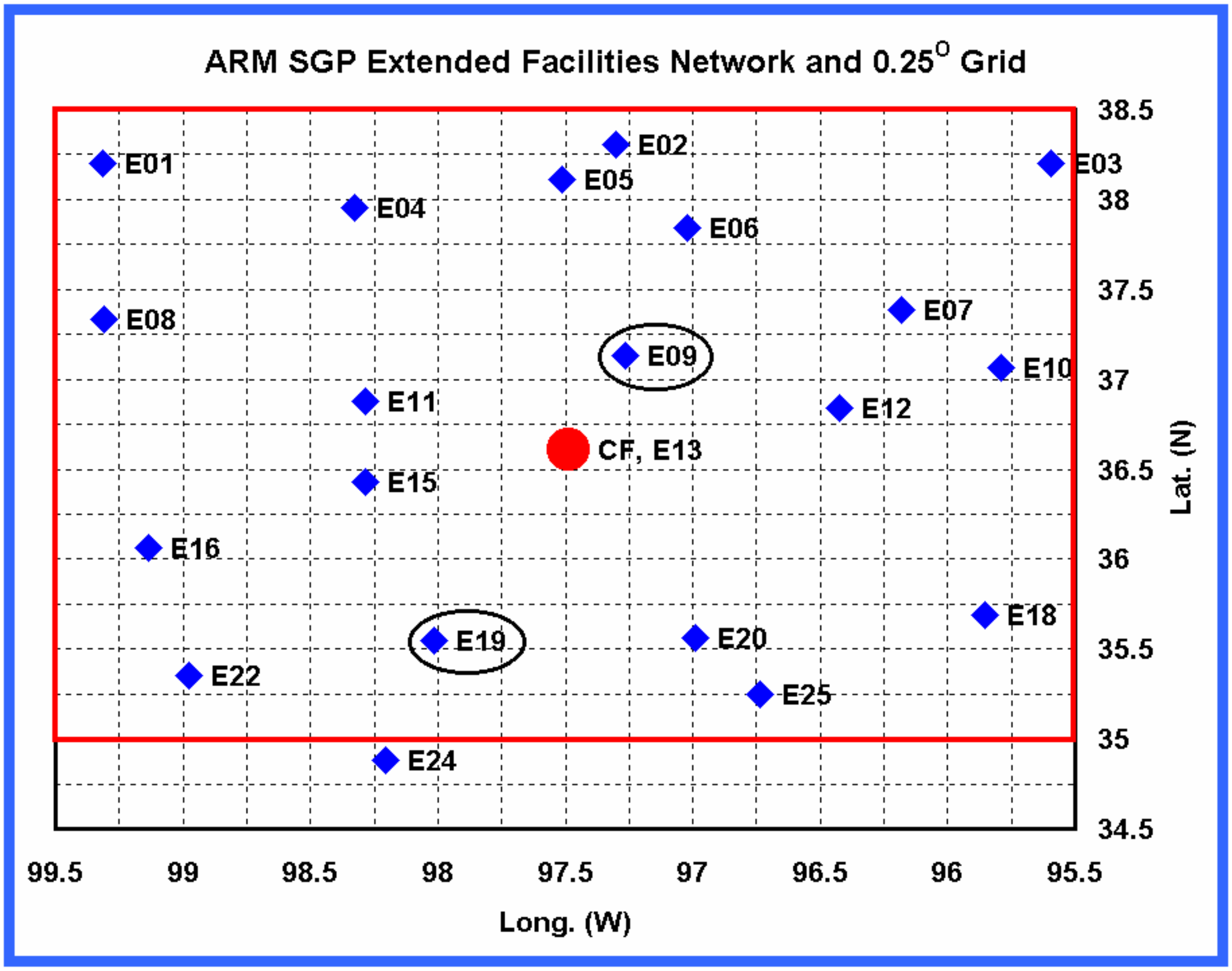

Figure 8. Map of the SGP CART site with blue diamonds representing the station facilities, the red circle indicates the CF, and facilities E9 and E19 encircled in black.

The uncertainty for a particular time frame for any of the variables at an omitted facility can be calculated as follows. Select from Tables 5-12 the appropriate one that represents the variable and omitted facility that one seeks the uncertainty. For example, one who wants the daily uncertainty for the cloudfraction when facility E19 was omitted should select Table 5. Then, take the ratio between the values representing the "Av of Diff" and "Mag Av" on the row that represents the desired time frame. So, using the daily statistics for cloudfraction, the uncertainty would be 0.046 / 0.456 = 0.1008 or 10.08%. And so on for any variable, time frame and omitted facility. Tables 13-15 contain the daily, weekly, monthly, and yearly percent uncertainties for the cases when E19 and E9 were omitted for variables: cloudfraction, clear-sky fit total SW down and ratio of measure over clear-sky direct SW down.

<u>Table Acronyms</u>

Av of Diff	=	Average of time scale differences
Std of Diff	=	Standard deviation of time scale differences
Mag Av	=	Average of time scale magnitudes for the normal VAP run
Mag Std	=	Standard deviation time scale magnitudes for the normal VAP run

Omit Av = Average of time scale magnitude for the VAP run with an omitted facility
Omit Std = Standard deviation of time scale magnitude for the VAP run with an omitted facility

Cloudfraction

E19

Table 5. Statistical results for the cloudfraction variable with facility E19 omitted for the year 2001.

	Av of Diff	Std of Diff	Mag Av	Mag Std	Omit Av	Omit Std
Day	0.046	0.055	0.456	0.356	0.456	0.346
Week	0.028	0.025	0.464	0.213	0.466	0.21
Month	0.02	0.02	0.461	0.154	0.461	0.149
Year	0	0	0.444	0	0.444	0

E9

Table 6. Statistical results for the cloudfraction variable with facility E9 omitted for the year 2001.

	Av of Diff	Std of Diff	Mag Av	Mag Std	Omit Av	Omit Std
Day	0.042	0.047	0.465	0.355	0.444	0.336
Week	0.031	0.032	0.474	0.199	0.45	0.186
Month	0.024	0.019	0.471	0.112	0.449	0.11
Year	0.023	0	0.458	0	0.435	0

Estimated clear-sky fit total SW down

E19

Table 7. Statistical results for the estimated clear-sky fit total SW down variable with facility E19 omitted for the year 2001.

	Av of Diff	Std of Diff	Mag Av	Mag Std	Omit Av	Omit Std
Day	8.175	6.551	595.117	79.077	594.676	81.619
Week	7.344	5.931	595.268	78.562	595.232	81.287
Month	5.227	3.879	595.242	78.825	595.106	81.607
Year	0.217	0	607.757	0	607.974	0

E9

Table 8. Statistical results for the estimated clear-sky fit total SW down variable with facility E9 omitted for the year 2001.

	Av of Diff	Std of Diff	Mag Av	Mag Std	Omit Av	Omit Std
Day	5.972	4.783	584.823	92.017	583.463	89.006
Week	5.126	3.633	585.628	92.059	584.356	88.993
Month	3.995	2.316	584.945	92.294	583.553	89.167
Year	1.898	0	599.944	0	598.046	0

Ratio of measured over clear-sky direct SW down

E19

Table 9. Statistical results for the ratio of measured over clear-sky direct SW down variable with facility E19 omitted for the year 2001.

	Av of Diff	Std of Diff	Mag Av	Mag Std	Omit Av	Omit Std
Day	0.045	0.058	0.587	0.356	0.594	0.342
Week	0.023	0.021	0.59	0.22	0.601	0.218
Month	0.019	0.016	0.597	0.163	0.608	0.164
Year	0.012	0	0.615	0	0.627	0

E9

Table 10. Statistical results for the ratio of measured over clear-sky direct SW down variable with facility E9 omitted for the year 2001.

	Av of Diff	Std of Diff	Mag Av	Mag Std	Omit Av	Omit Std
Day	0.035	0.036	0.587	0.35	0.597	0.347
Week	0.021	0.019	0.591	0.203	0.606	0.2
Month	0.015	0.014	0.597	0.127	0.612	0.129
Year	0.015	0	0.61	0	0.625	0

Ratio of measured over clear-sky total SW down

E19

Table 11. Statistical results for the ratio of measured over clear-sky total SW down variable with facility E19 omitted for the year 2001.

	Av of Diff	Std of Diff	Mag Av	Mag Std	Omit Av	Omit Std
Day	0.032	0.04	0.772	0.256	0.774	0.249
Week	0.016	0.018	0.765	0.157	0.768	0.149
Month	0.006	0.004	0.768	0.111	0.77	0.112
Year	0.002	0	0.783	0	0.785	0

E9

Table 12. Statistical results for the ratio of measured over clear-sky total SW down variable with facility E9 omitted for the year 2001.

	Av of Diff	Std of Diff	Mag Av	Mag Std	Omit Av	Omit Std
Day	0.026	0.03	0.768	0.255	0.769	0.253
Week	0.013	0.012	0.762	0.143	0.763	0.142
Month	0.007	0.004	0.764	0.094	0.766	0.094
Year	0.001	0	0.775	0	0.776	0

Cloudfraction uncertainties

Table 13. Daily, weekly, monthly, yearly percent uncertainty due to interpolation for cloudfraction in cases when facilities E19 and E9 were omitted.

	E19	E9
Day	10.08	9.03
Week	6.03	6.54
Month	4.33	5.09
Year	0.00	5.02

Clear-sky fit total SW down

Table 14. Daily, weekly, monthly, yearly percent uncertainty due to interpolation for clear-sky fit total SW down in cases when facilities E19 and E9 were omitted.

	E19	E9
Day	10.37	1.02
Week	1.23	0.88
Month	0.88	0.68
Year	0.04	0.32

Ratio of measured over clear-sky direct SW down

Table 15. Daily, weekly, monthly, yearly percent uncertainty due to interpolation for ratio of measured over clear-sky direct SW down in cases when facilities E19 and E9 were omitted.

	E19	E9
Day	10.08	9.03
Week	6.03	6.54
Month	4.33	5.09
Year	0.00	5.02

The results clearly show that as the time span increases the uncertainty decreases. For example, take the ratio of measured over clear-sky direct SW down results in table 15; the daily, weekly, monthly, and yearly uncertainties when facility E19 was omitted are 7.67%, 3.90%, 3.18%, and 1.95%, respectively. Similarly when facility E9 was omitted, the daily, weekly, monthly, and yearly uncertainties are 5.96%, 3.55%, 2.51% and 2.46%, respectively. Tables 13-15 also demonstrate how data "rich" environments tend to produce less uncertainty than data "poor" for a given time frame. For example, the daily uncertainties when facilities E19 and E9 are omitted are 7.67% and 5.96%, respectively, which is what is expected since there are more surrounding stations that contribute to interpolation for E9. This means that the gridded data for a 100 km on a side "box" centered on the CF will have less uncertainty in general than the larger 300 km on a side "box," since the perimeter grid points of the larger "box" contain more uncertainty.

10. Summary

In conclusion, the SfcCldGrid VAP uses as input the 15-minute output netCDF files generated from the SW flux analysis VAP (see Long 2001; Long and Ackerman 2000; Long et al. 1999). The SfcCldGrid VAP applies a multi-pass weighted sum analytic approximation technique (Caracena 1987), which uses Gaussian weighting and an imposed scale length to interpolate the SW flux analysis VAP results for the 21 sites in the SGP network to a 0.25 degree by 0.25 degree latitude/longitude grid across the SGP domain. Scientific quantities generated by this VAP are gridded output for cloud fraction, the ratio of measured over clear-sky SW total (both unshaded pyranometer and sum of direct+diffuse) irradiance, the ratio of measured over clear-sky SW direct irradiance, the estimated clear-sky fit total SW irradiance, and the estimated clear-sky fit direct SW irradiance.

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12. References

Caracena, F., 1987: Analytic approximation of discrete field samples with weighted sums and the gridless computation of field derivatives. *J. Atmos. Sci.*, **44**, 3753-3768.

Christy, J. E, C. N. Long, and T. R. Shippert, 2002: Interpolation uncertainties across the ARM SGP Area. In *Proceedings of the Twelfth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, ARM-CONF-2002. U.S. Department of Energy, Washington, D.C. Available URL: http://www.arm.gov/docs/documents/technical/conf_0204/christy-je.pdf

Long, C. N., 2001: *The shortwave (SW) clear-sky detection and fitting algorithm: Algorithm Operational Details and Explanations*. Atmospheric Radiation Measurement Program Technical Report, ARM TR-004. Available URL: (http://www.arm.gov/docs/documents/tech_reports/arm-tr-004.pdf)

Long, C. N., and T. P. Ackerman, 2000: Identification of clear skies from broadband pyranometer measurements and calculation of downwelling shortwave cloud effects. *JGR*, **105**, No. D12, 15,609-15,626.

Long, C. N., T. P. Ackerman, J. J. DeLuisi, and J. Augustine, 1999: Estimation of fractional sky cover from broadband SW radiometer measurements. In *Proceedings of the Tenth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, U.S. Department of Energy, Washington, D.C.