Interpolation Uncertainties Across the ARM SGP Area

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Interpolation Grids Across the SGP Network Area

The U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program operates a network of surface radiation measurement sites across north central Oklahoma and south central Kansas. This Southern Great Plains (SGP) network consists of 21 sites unevenly spaced from 95.5 to 99.5 degrees west longitude, and from 34.5 to 38.5 degrees north latitude. We use the technique outlined by Long and Ackerman (2000) and Long et al. (1999) to infer continuous estimates of clear-sky downwelling shortwave (SW) irradiance, SW cloud effect, and daylight fractional sky cover for each site, then interpolate these quantities to a 0.25 degree grid for the SGP area using the analytic approximation method of Caracena (1987). This algorithm is implemented in the ARM Surface Cloud Grid 1Long (SFCCLDGRID1LONG) value-added product (VAP). The output of this VAP is a site-wide representation of the various quantities at 15-minute resolution for daylight hours (Figure 1). The uncertainties inherent in the estimation of clear-sky irradiances and sky cover are included in the Long et al. papers referenced above. We will show the added uncertainty due to interpolation of the ARM SGP point measurements to the 0.25-degree grid by creating statistics of the average difference between the normal VAP run and runs with a particular facility omitted. We will present statistics of the interpolation uncertainty for various time scales run yearly, monthly, and over a period of a week for each season when the number of facilities with valid data is at its maximum. In addition, we will present climatologies of cloud amounts and cloud effects representative of the SGP network area on various time scales.

The plots in Figure 1 are sample quick-look images of the cloud fraction (Figure 1a), SW measured/ clear-sky ratio (Figure 1b), clear-sky SW irradiance (Figure 1c), and direct SW measured/clear-sky ratio (Figure 1d) variables for September 19, 2000, at 1500 Universal Time Coordinates (UTC). The “green” dots represent the extended facilities where data is obtained. An open “green” circle indicates data was missing for that site, while a filled one indicates data is available. The “red” dot represents the central facility (CF). The shaded “cyan” areas indicate where the cloud fraction was 0.0 in the upper left plot while the shaded “gray” areas indicate areas of overcast. The “gray” areas in the right-hand plots indicate areas where the ratio value is 1.0. The yellow dot outside the grid in Figure 1c indicates the solar azimuth referenced to the CF (red dot).

Analysis

The data for the SFCCLDGRID1LONG VAP was compared with the results when a particular facility was omitted. This was done three separate times for the various facilities that were omitted (Figure 2). Data were withheld for the sites E8, E9, and E19.

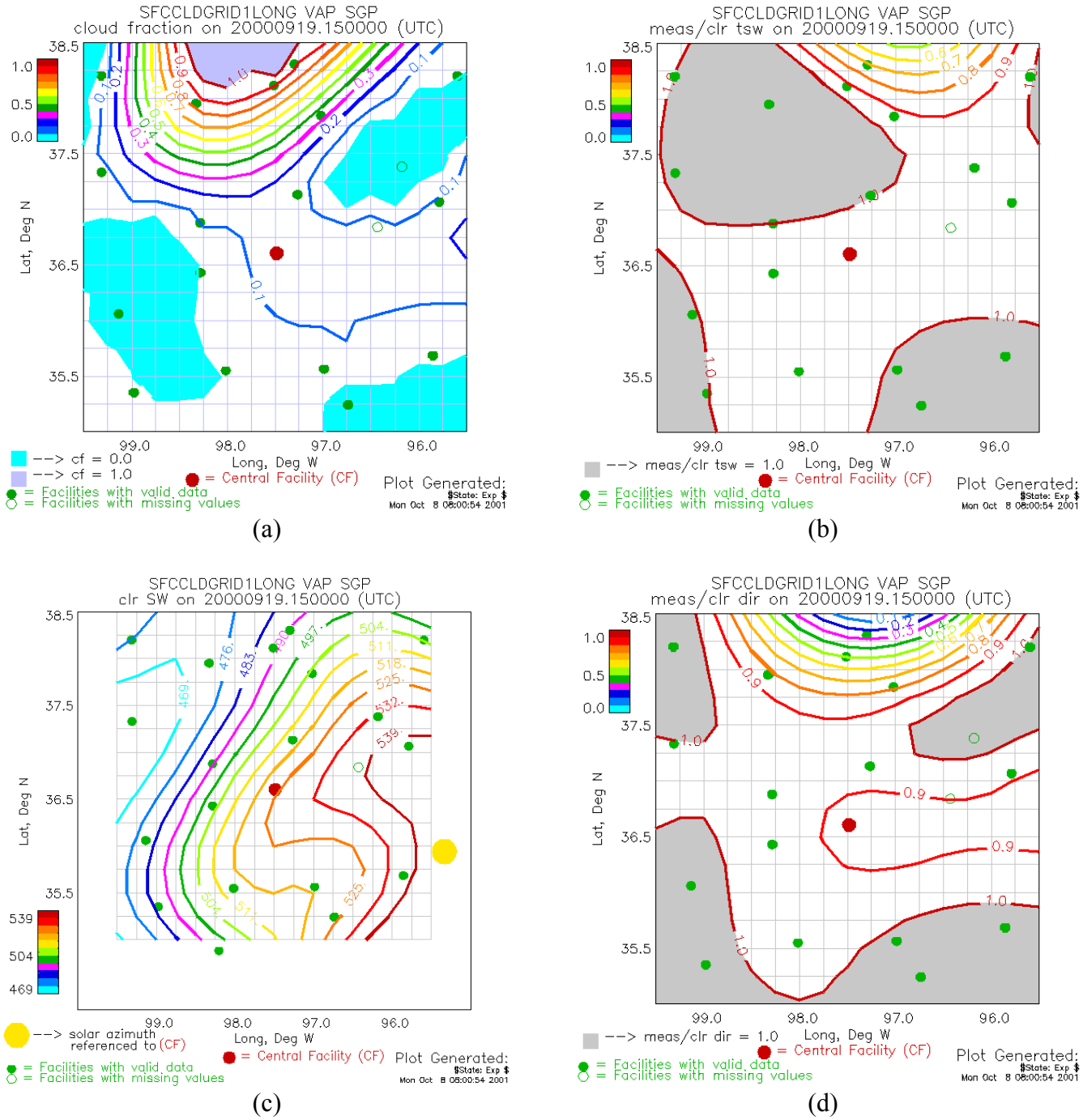

Figure 1. Sample quick-look plots for the SFCCLDGRID1LONG VAP, September 19, 2000, at 1500 UTC.

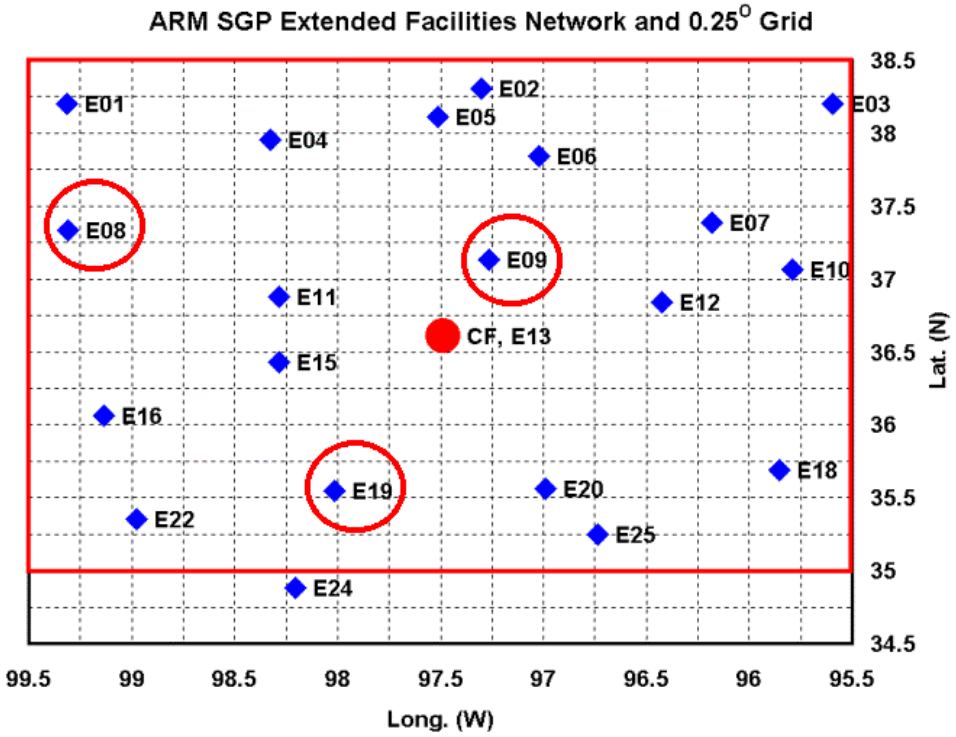

Figure 2. Latitude/longitude plot of SGP extended facilities.

E8: This facility is geographically located at 37.333 degrees north latitude and 99.309 degrees west longitude, which is located at the far-left side of the SGP Cloud and Radiation Testbed (CART) site, just north above the CF. Therefore there are no facilities to the west of E8 that will have any influence on the interpolations for the grid points in this region, and omitting this data has a large effect. We recommend that the grid results be used for the area from 96 to 99 west longitude, and 35 to 38 north latitude, so the grid points have some information outside this roughly 300 km on a side general circulation model (GCM) grid box-sized area.

E9: This facility is geographically located at 37.133 degrees north latitude and 99.266 degrees west longitude. This facility is located in the midst of other facilities.

E19: This facility is geographically located at 35.549 degrees north latitude and 98.017 degrees west longitude. This site has other facilities in its region, however there are none that are very close by, and there is only one site (E24) more southerly outside the recommended usable area along the southern border. Therefore, of the recommended area of use, this site should have the largest interpolation uncertainties in this analysis.

The analysis was performed on five scientific products generated by the VAP. The variables are:

1. cf: fractional skycover.
2. tsw: ratio of measured over total clear-sky total SW down.
3. ssw: ratio of measured over total clear-sky (direct + diffuse) SW down.

4. dir: ratio of measured over total clear-sky direct SW down.
5. clr: estimated clear-sky fit total SW down.

Since the interpolation algorithm uses Gaussian weights, the differences tend to zero in a "bell" shape for grid points that are further away from the actual facility omitted (Figure 3). Therefore, results from the analysis will be referenced to the nearest 0.25 x 0.25 degree point with respect to the particular facility omitted because the points with the greatest difference will be in the region where the facility was omitted.

The nearest grid point for each of the omitted facilities is:

Facility	Degree West Longitude	Degree North Latitude
E8	99.5	37.25
E9	97.25	37.25
E19	98.0	35.5

Omitted Facilities and Effects of Gaussian Weights

Figure 2 is a representation of the grid area with spacing of 0.25 degrees produced by the SFCCLDGRID1LONG VAP, along with all the extended facilities sites (denoted with blue diamonds). The three omitted facilities, E8, E9, and E19, are circled in red. The CF is highlighted with a large red dot. The area outlined in red is the gridded area produced by the VAP.

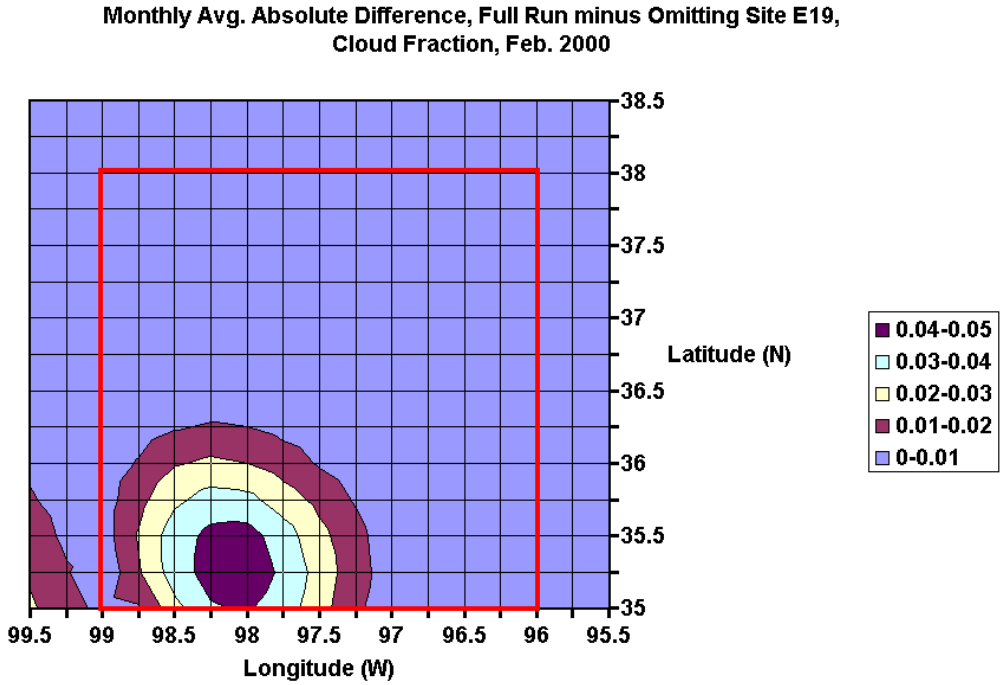

Figure 3. Difference plot for February 2000 cloud fraction.

Figure 2 is a representation of the grid area with spacing of 0.25 degrees produced by the SFCCLDGRID1LONG VAP, along with all the extended facilities sites (denoted with blue diamonds). The three omitted facilities, E8, E9, and E19, are circled in red. The CF is highlighted with a large red dot. The area outlined in red is the gridded area produced by the VAP.

Figure 3 is an example of the monthly absolute differences across the entire network for the cloud fraction variable when the data from facility E19 is omitted for February 2000. The X-axis represents degrees west longitude; the Y-axis represents degrees north latitude. The nearest grid point to E19 is 98.0 degrees west longitude and 35.5-degree north latitude. The greatest differences occur near this grid point and get smaller as the distance increases. The area in red is the suggested usable grid area, representing a box roughly 300 km on a side.

Interpolation Uncertainties

To perform this analysis, the absolute difference was taken between the magnitudes of the "normal" VAP run with that of a VAP run with a particular facility omitted. The differences were taken using various grid-averaging time-scales for the entire year 2000. The grid averages are: 15-minute, hourly, daily, weekly, monthly, and yearly. The results intend to show that as the grid averaging time increases, the interpolation uncertainties decrease. The following charts display the yearly (Figure 4) results at the grid point nearest the omitted facility for all the variables and omitted facilities. Then, to demonstrate how the uncertainties change with averaging time, monthly (Figure 5), weekly (Figure 6), daily (Figure 7), hourly (Figure 8), and 15-minute (Figure 9) results for the various VAP variables are shown.

Figure 4 shows the yearly results and demonstrates that for yearly averages the interpolation uncertainty is small, on the order of 1% or less of the yearly average magnitude, for all variables inside the suggested usable grid area. The chart below summarizes the annual results for all variables (Var) with respect to each omitted facility (Fac) at the grid point nearest the omitted facility. As one can see, the absolute differences (Diff) are quite small with respect to the average magnitude of the "normal" VAP run (Mag).

The results in Figure 5 are for the monthly average absolute differences (Diff) of cloud fraction for each month (Mon) over the year 2000 with respect to the omitted facility (Fac), at the grid point nearest the omitted facility. The table also includes the magnitude of the "normal" VAP run (Mag) for comparison, and the overall average (Average) absolute difference and magnitude for the year. Note that the

Var	Fac	Diff	Mag	Fac	Diff	Mag	Fac	Diff	Mag
clr	**E19**	4.379	591	**E8**	6.771	586	**E9**	0.698	583
cf	**E19**	0.009	0.462	**E8**	0.004	0.431	**E9**	0.002	0.481
dir	**E19**	0.000	0.602	**E8**	0.010	0.644	**E9**	0.013	0.590
ssw	**E19**	0.001	0.760	**E8**	0.002	0.787	**E9**	0.004	0.754
tsw	**E19**	0.009	0.764	**E8**	0.001	0.790	**E9**	0.004	0.757

Figure 4. Differences for yearly average grid between normal and site omitted runs.

Month	Fac	Diff	Mag	Fac	Diff	Mag	Fac	Diff	Mag
Jan	**E19**	0.043	0.489	**E8**	0.015	0.600	**E9**	0.001	0.625
Feb	**E19**	0.044	0.509	**E8**	0.007	0.484	**E9**	0.013	0.492
Mar	**E19**	0.030	0.566	**E8**	0.014	0.574	**E9**	0.002	0.613
Apr	**E19**	0.003	0.501	**E8**	0.002	0.406	**E9**	0.006	0.467
May	**E19**	0.018	0.430	**E8**	0.000[1]	0.450	**E9**	0.013	0.480
June	**E19**	0.003	0.662	**E8**	0.031	0.531	**E9**	0.011	0.578
July	**E19**	0.028	0.375	**E8**	0.014	0.282	**E9**	0.008	0.359
Aug	**E19**	0.003	0.226	**E8**	0.022	0.322	**E9**	0.033	0.353
Sep	**E19**	0.009	0.185	**E8**	0.008	0.182	**E9**	0.019	0.287
Oct	**E19**	0.011	0.594	**E8**	0.072	0.521	**E9**	0.007	0.521
Nov	**E19**	0.005	0.532	**E8**	0.030	0.423	**E9**	0.013	0.502
Dec	**E19**	0.010	0.564	**E8**	0.014	0.512	**E9**	0.002	0.603
Average		**0.017**	**0.468**		**0.019**	**0.441**		**0.011**	**0.490**

Figure 5. Cloud fraction differences by month for monthly average grid between normal and site-omitted runs.

(a)

Var	Fac	Diff	Mag	Fac	Diff	Mag	Fac	Diff	Mag
cf	**E19**	0.025	0.475	**E8**	0.035	0.445	**E9**	0.019	0.491
tsw	**E19**	0.021	0.758	**E8**	0.033	0.784	**E9**	0.016	0.751
ssw	**E19**	0.02	0.754	**E8**	0.032	0.781	**E9**	0.017	0.747
dir	**E19**	0.027	0.587	**E8**	0.039	0.626	**E9**	0.02	0.578
clr	**E19**	7.3	573.1	**E8**	10.0	566.2	**E9**	5.6	563.1

(b)

Var	Fac	Diff	Mag	Fac	Diff	Mag	Fac	Diff	Mag
cf	**E19**	0.051	0.469	**E8**	0.073	0.44	**E9**	0.039	0.49
tsw	**E19**	0.037	0.759	**E8**	0.064	0.784	**E9**	0.031	0.75
ssw	**E19**	0.038	0.754	**E8**	0.063	0.781	**E9**	0.032	0.747
dir	**E19**	0.051	0.583	**E8**	0.078	0.621	**E9**	0.037	0.567
clr	**E19**	7.6	575.8	**E8**	10.6	568.6	**E9**	6.1	565.5

(c)

Var	Fac	Diff	Mag	Fac	Diff	Mag	Fac	Diff	Mag
cf	**E19**	0.108	0.464	**E8**	0.121	0.434	**E9**	0.084	0.483
tsw	**E19**	0.079	0.759	**E8**	0.117	0.786	**E9**	0.062	0.752
ssw	**E19**	0.095	0.754	**E8**	0.116	0.783	**E9**	0.078	0.749
dir	**E19**	0.192	0.589	**E8**	0.21	0.633	**E9**	0.155	0.577
clr	**E19**	7.9	564.5	**E8**	10.8	557.1	**E9**	6.5	549.4

(d)

Var	Fac	Diff	Mag	Fac	Diff	Mag	Fac	Diff	Mag
cf	**E19**	0.133	0.462	**E8**	0.14	0.431	**E9**	0.11	0.481
tsw	**E19**	0.099	0.764	**E8**	0.143	0.790	**E9**	0.081	0.757
ssw	**E19**	0.130	0.760	**E8**	0.150	0.787	**E9**	0.112	0.754
dir	**E19**	0.276	0.602	**E8**	0.289	0.644	**E9**	0.237	0.590
clr	**E19**	8.2	591.0	**E8**	11.2	582.5	**E9**	6.8	574.0

Figure 6. Average absolute differences between normal and site-omitted runs for (a) weekly, (b), daily, (c) hourly, and (d) 15-minute data.

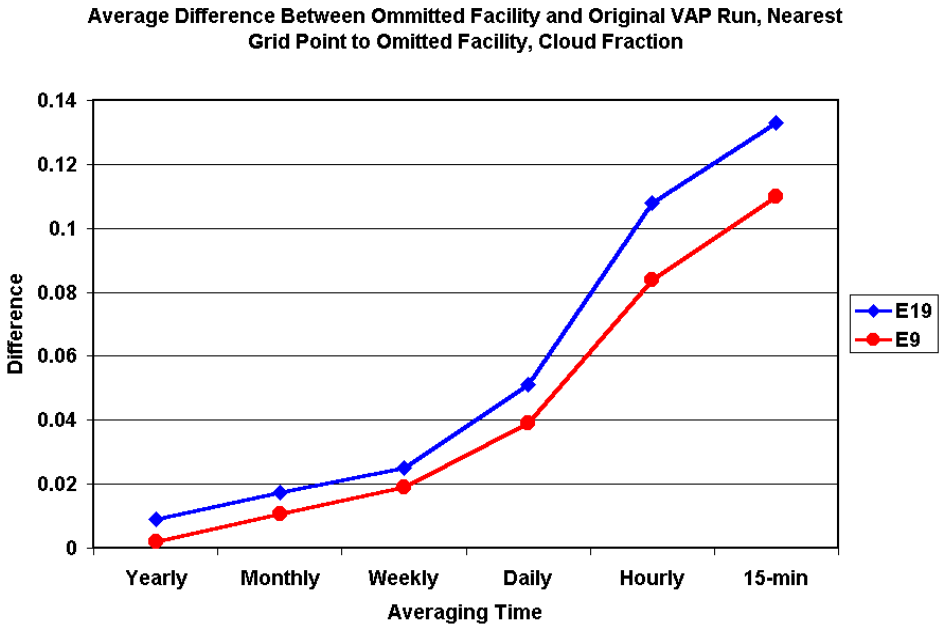

Figure 7. Average difference by time scale, cloud fraction.

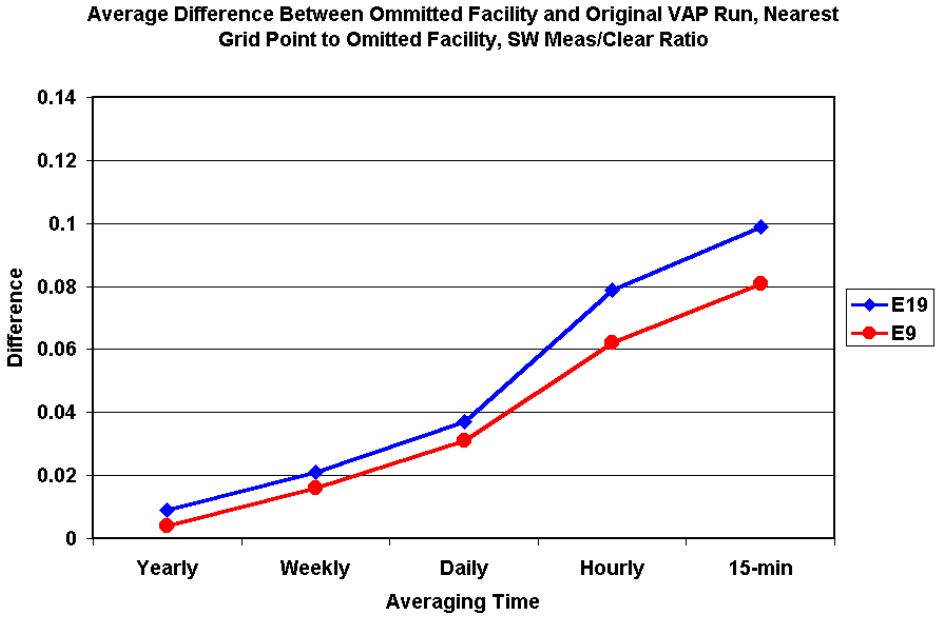

Figure 8. Average difference by time scale, meas/clr SW.

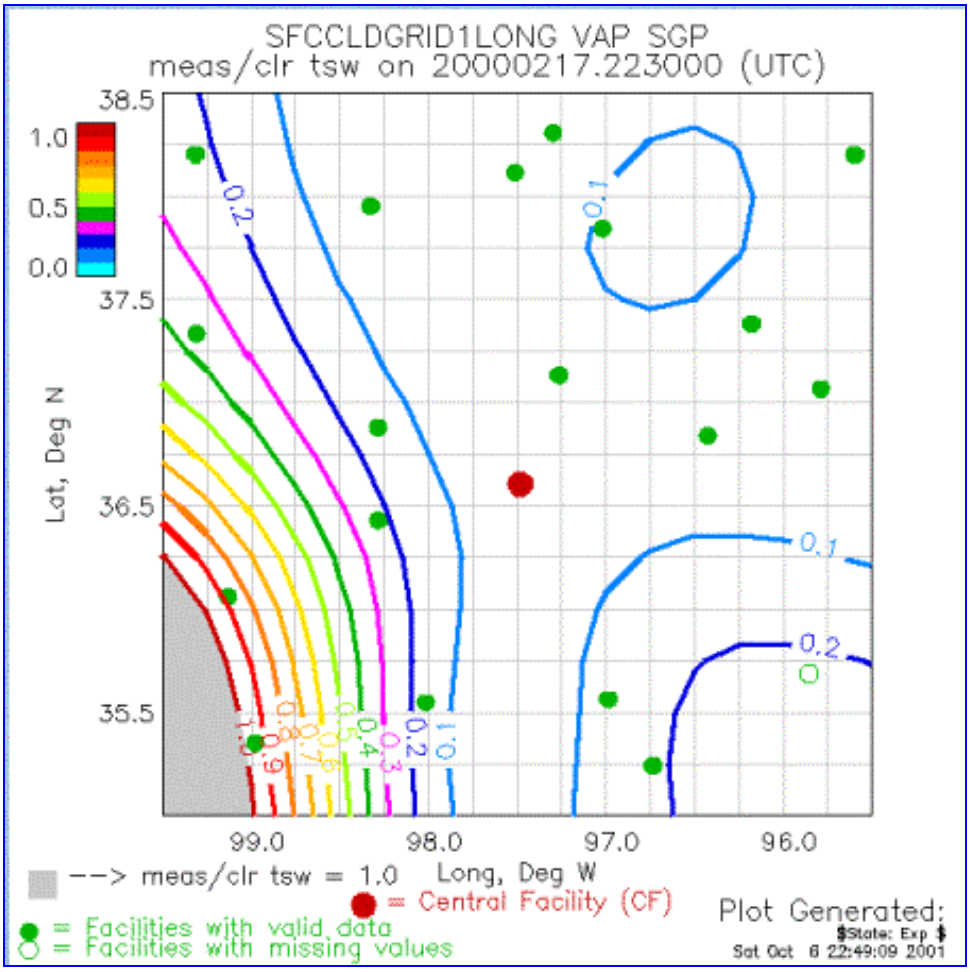

Figure 9. Meas/Clr SW "normal" run example.

difference for May for site E8 is 0.0 because the data for facility E8 was missing from the latter part of April until the end of May. When this is the case, the "normal" VAP run will produce the same results as if the facility was omitted.

The results in Figure 6 represent the average absolute differences (Diff) derived using various averages of the gridded data for the year 2000 for each variable (Var) with respect to the omitted facility (Fac), at the grid point nearest to the omitted facility. Included is the respective average magnitude (Mag) at the grid point nearest to the omitted facility for the "normal" VAP run. The results are for weekly (Figure 6a), daily (Figure 6b), hourly (Figure 6c), and 15-minute (Figure 6d) data.

Figures 7 and 8 summarize the results of Figures 4, 5, and 6 for the cloud fraction (Figure 7) and SW measured/clear-sky ratio (Figure 8). Since these differences are for the grid point nearest the omitted site, these represent the maximum difference on the grid (Figure 3), thus on average the worst case for interpolation uncertainty. The results for E19 represent a site on the edge of the recommended usable grid area, and in a "data poor" part of the grid. Site E9 represents a site more imbedded in the grid, and in a more "data rich" part of the grid (Figure 2).

Interpolation Uncertainty Summary

In summary, the absolute difference between the full and omitted runs for all variables increases as the grid averaging time decreases. In addition, the values presented here are for the grid point nearest the omitted facility and thus, represent the maximum uncertainty for the grid (see Figure 3). The average difference for site E19 cloud fraction is 0.009 and 0.017 for the yearly and monthly results, respectively. For site E9, the yearly and monthly results are smaller, at 0.002 and 0.011, respectively. Site E19 is far from other surrounding sites, is close to the edge of the recommended usable grid area, and has only one site on that entire side of the recommended usable area (Figure 2). Thus, these results for E19 have the larger uncertainty inside the usable grid area, comparable to that from site E8, which is outside the recommended usable area. The interpolation uncertainty for site E9, which is embedded in a "data rich" portion of the area, is less than that for site E19. Thus, the maximum interpolation uncertainty "truth" lies between the E19 and E9 results for the recommended useful area but in general likely closer to the site E9 results. The E19 results can thus be considered the "worst case." For the E19 "worst case" results, the average difference increases from 0.025 to 0.051 for weekly and daily average grids, respectively.

In addition, the results for site E8 show that interpolation to the edge of the SGP area is greatly affected when there is no data beyond to interpolate to. Thus, we recommend that the grid results are most valid inside the roughly 300 km on a side "box" from 96 to 99 west longitude, and 35 to 38 north latitude, the "usable area" of the gridded product.

A Note on Missing Data

Study of the VAP grids during this analysis points out one underlying situation that affects the gridded differences between "normal" and "site omitted" runs. This situation is the result of "missing" data at nearby surrounding facilities. As was stated before, facility E8 and any other facility along the boundary of the SGP CART site will be affected significantly by nearby missing data. This also holds true for inner facilities. Figure 1 demonstrates a situation when the facility E9 "omitted" run will be affected, since there was no available data from facilities E7 and E12 to the east at this time. Thus, some portion of the average difference results presented here are the result of missing data in the various nearby site time series, rather than from the "omitted site" itself.

Another situation that has an effect on our study of differences is when there is large variability from site to nearby site. For example, Figures 9 and 10 show images for the "normal" VAP run (Figure 9) and the run with facility E19 omitted (Figure 10) on February 17, 2000, at 2230 UTC. The resulting value for the grid point nearest E19 for the "normal" VAP is 0.140. Omitting the value for facility E19 produces a value of 0.430 for the nearest grid point due to the smoothing of the Gaussian interpolation. Over longer time periods of analysis, unless the missing data period is significantly long (e.g., for a week or more), then long-term statistics on seasonal or longer time scales should not be unduly affected.

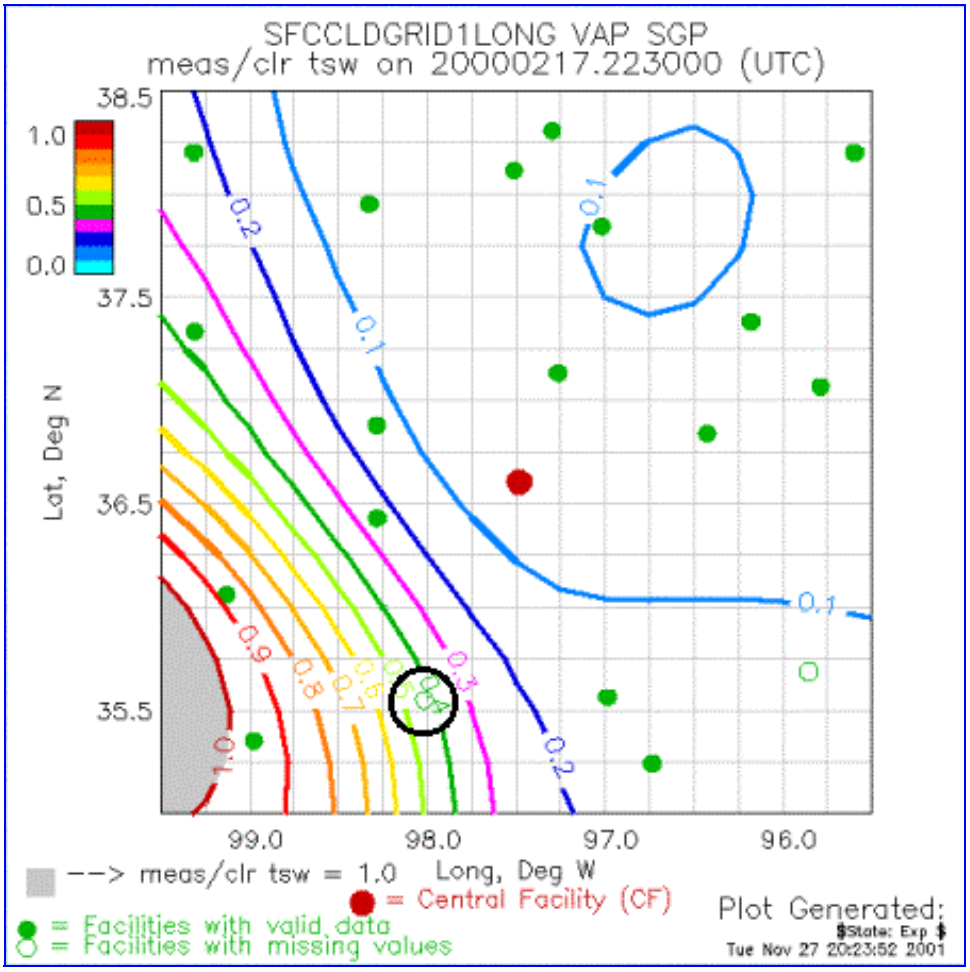

Figure 10. Meas/Clr SW "omitted" run example.

In summary, one significant concern for the gridded output of the VAP is missing site data. The nature of long-term measurement activities ensures that there will be some missing data, for various reasons. This is unavoidable. Thus, the gridded output depends, to some extent, on our ability to produce a high "good data" return rate for all extended facilities in the ARM SGP Network. At present, there are some persistent problems noted in the weekly SGP site data reports for a few of the extended facility broadband instruments. These problems need to be given some priority, and resolved in a timely manner.

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