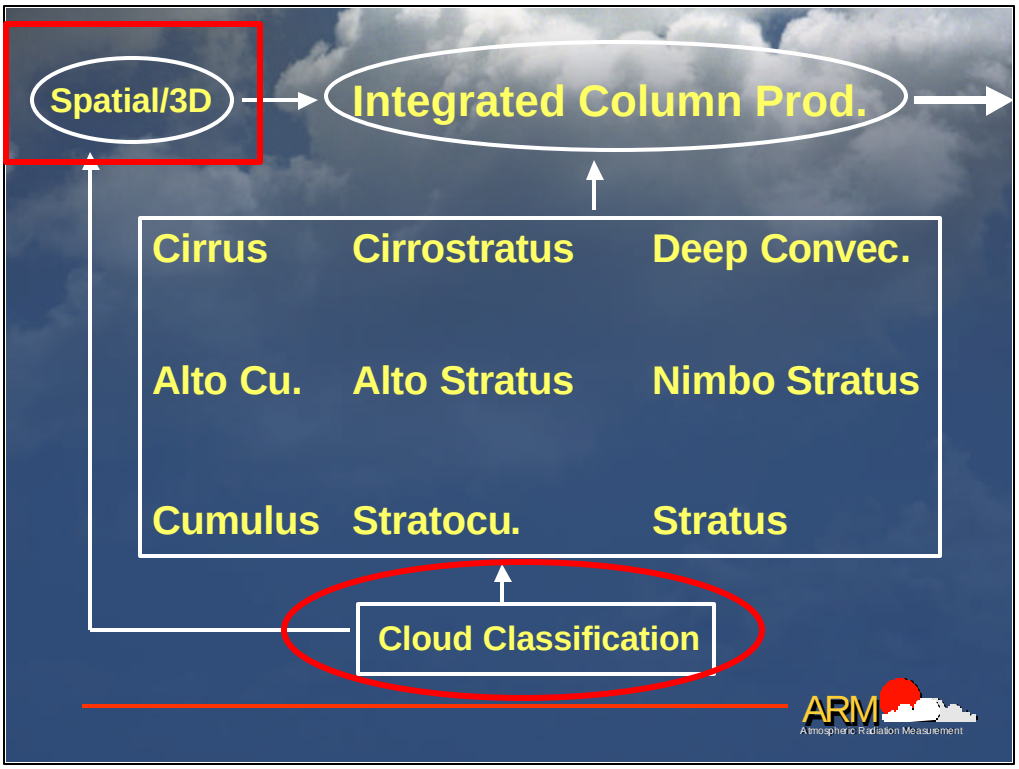
SGP Site-Wide Cloud Information from ARM Surface Measurements and Plans for Combining Site-Wide Surface and Satellite Data.

Chuck Long

PNNL/ARM



Current proposed strategy of the ARM Cloud Properties Working Group. The over-arching goal is to provide details on cloud properties by cloud type and expected cloud properties such as water phase. Inherent in this plan is the need to "sort through" the time series of data to determine cloud type so that the proper cloud property retrieval methods can be applied. In addition, it is desirable and in some sense necessary to collect the information into a spatial/3D representation of the ARM SGP area for use in developing sub grid scale parameterizations for GCM and SCM efforts.

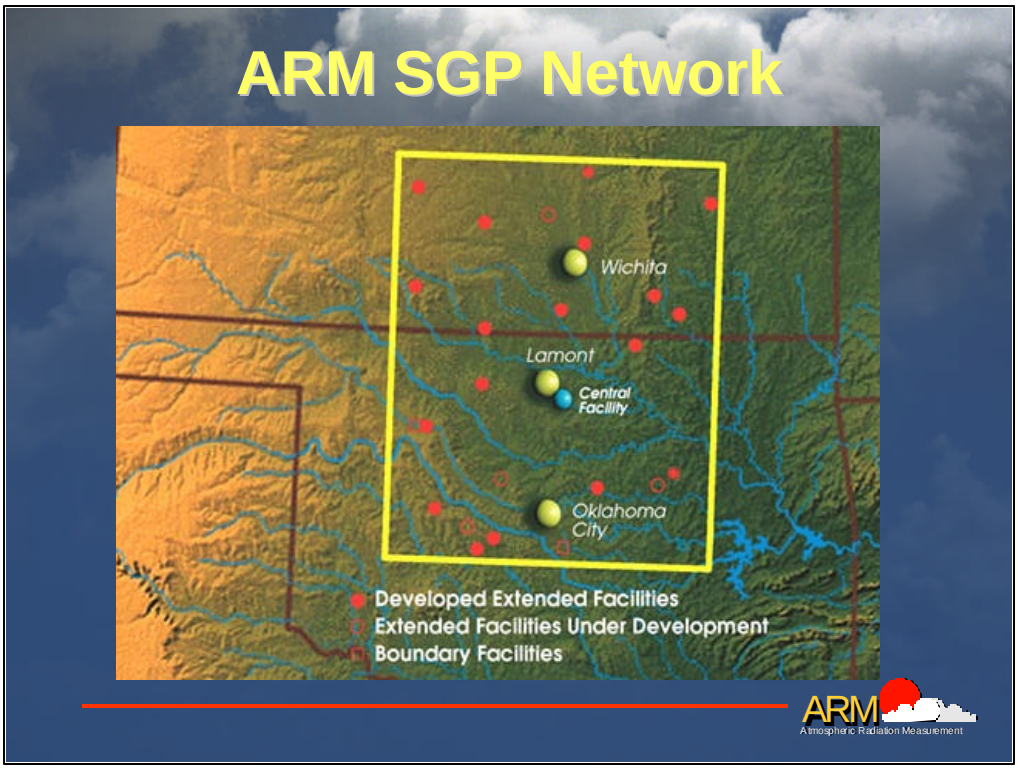
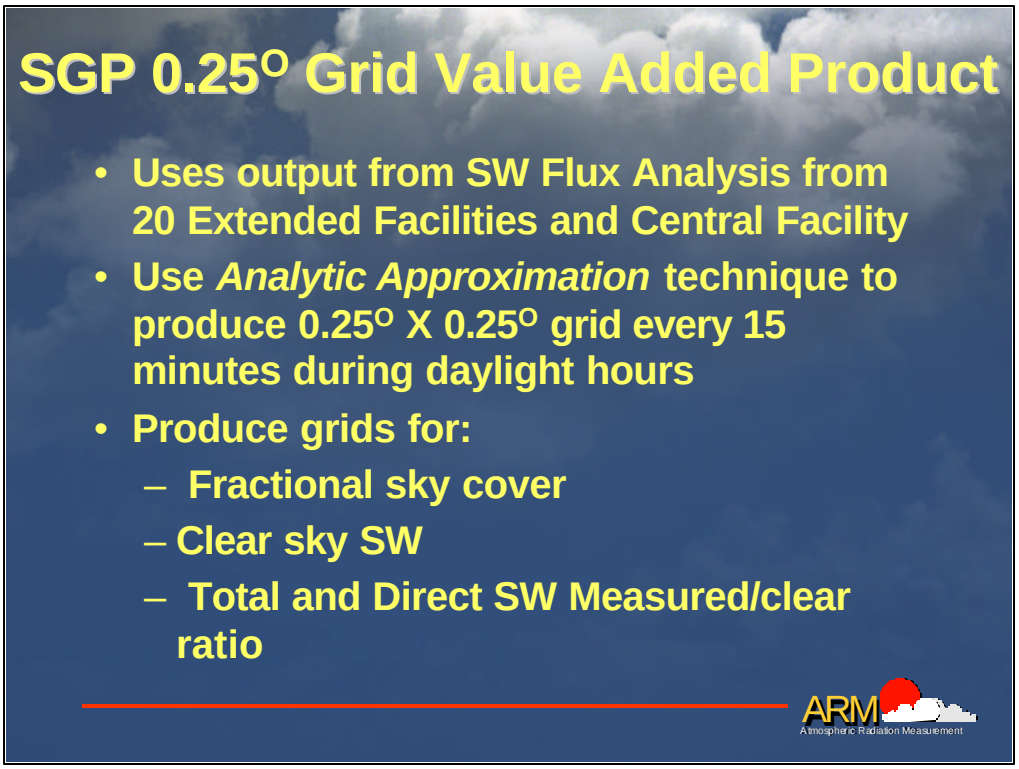
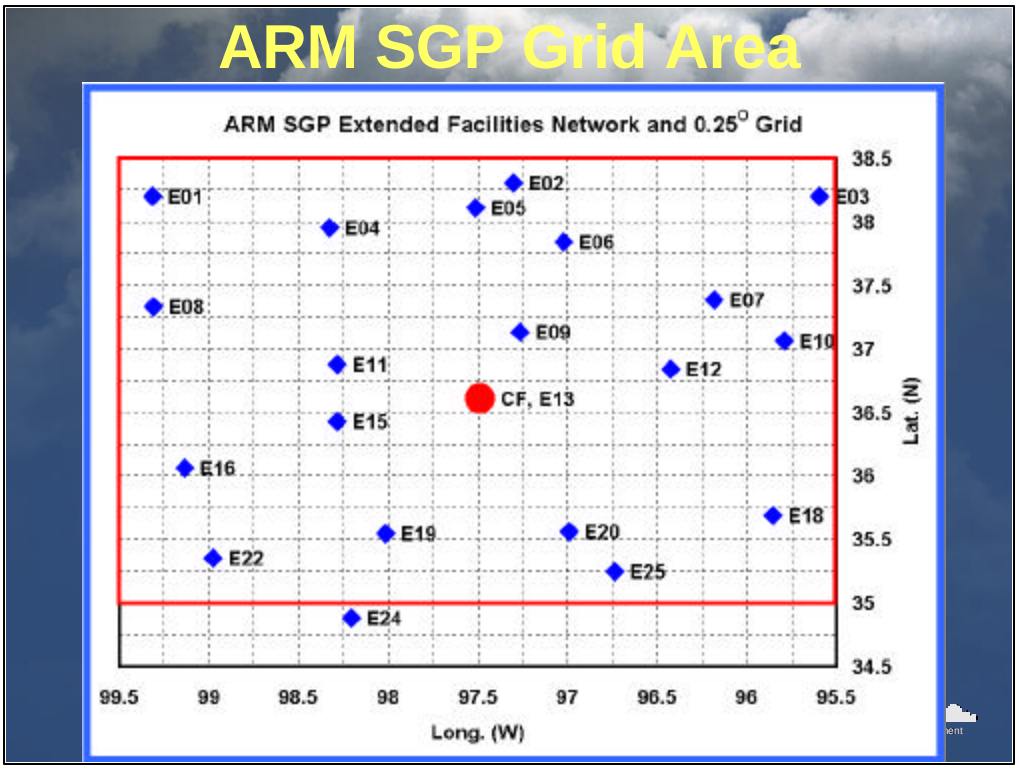


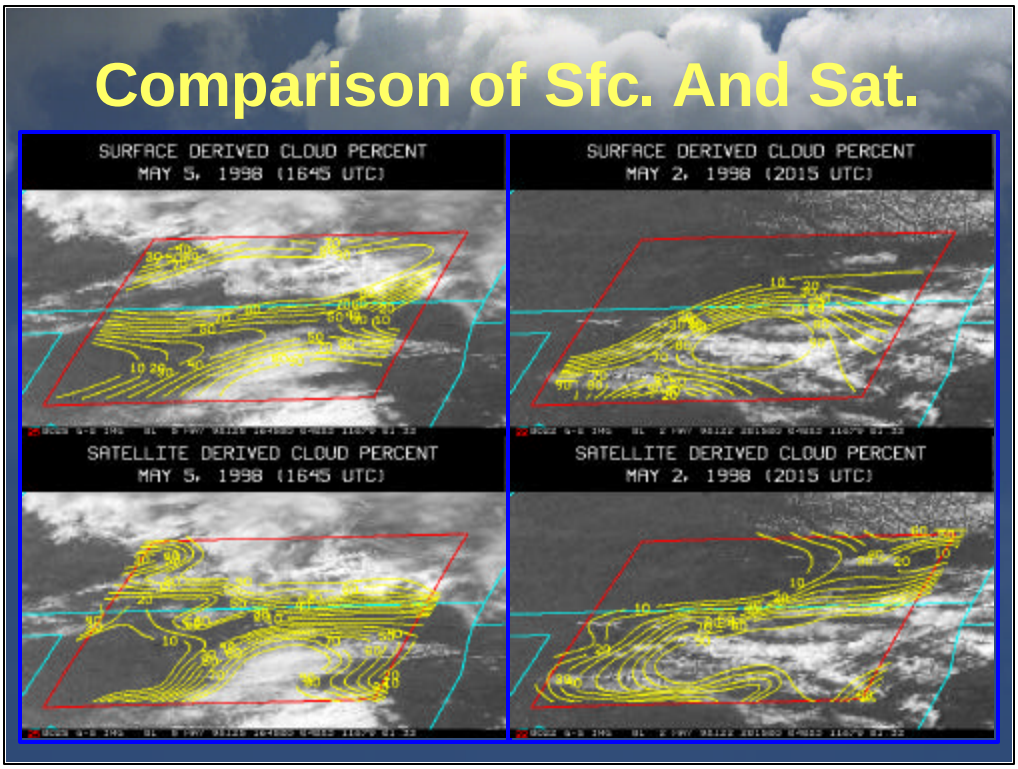
Figure of SGP Area Network of surface sites.



Outline describing the ARM "SfcCloudGrid1Long" Value Added Product (VAP) currently under development.



Lat/Long plot of ARM SGP Extended and Central facilities. Area outlined in red is the area for which the SfcCloudGrid1Long VAP produces output.



Examples of comparison of SfcCloudGrid1Long VAP estimates of area cloud amounts, and the corresponding satellite retrievals of Minnis et al. using the LBTRM methodology. Comparisons have shown generally good agreeme nt between the two methodologies, give the inherent differences and sensitivities of each.

SGP Area Grid Analysis

- Given: by far, most analyses and comparisons to date have used SGP CF data.
- Question: How well does the SGP CF represent the broader area on various time and spatial scales?

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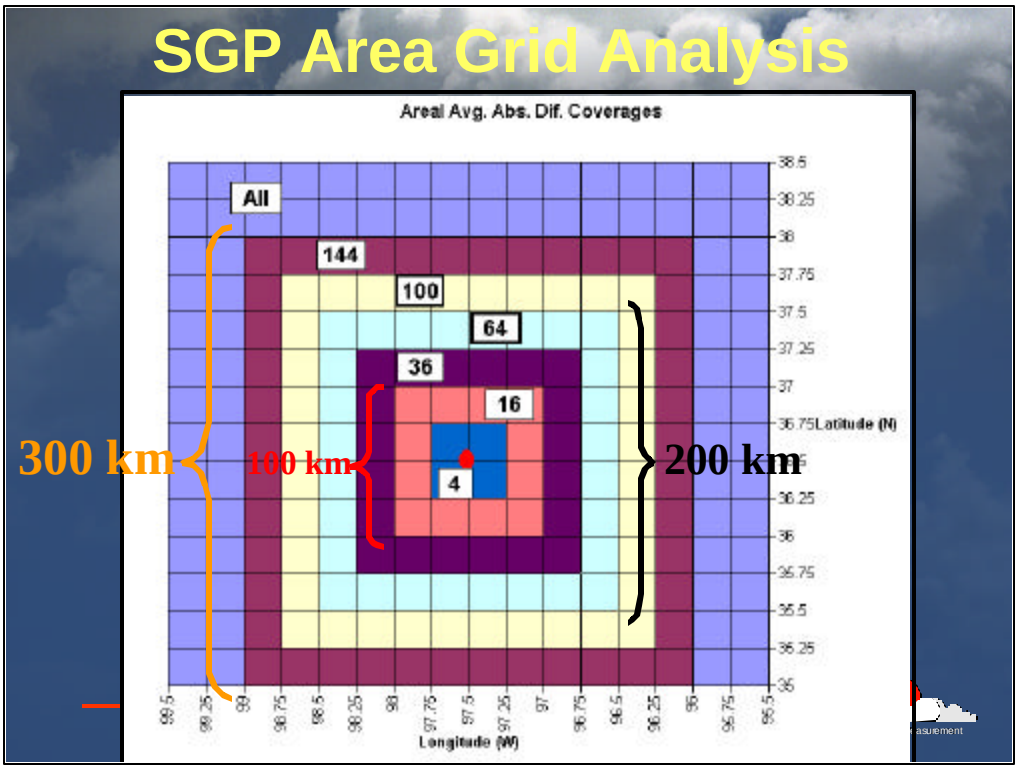
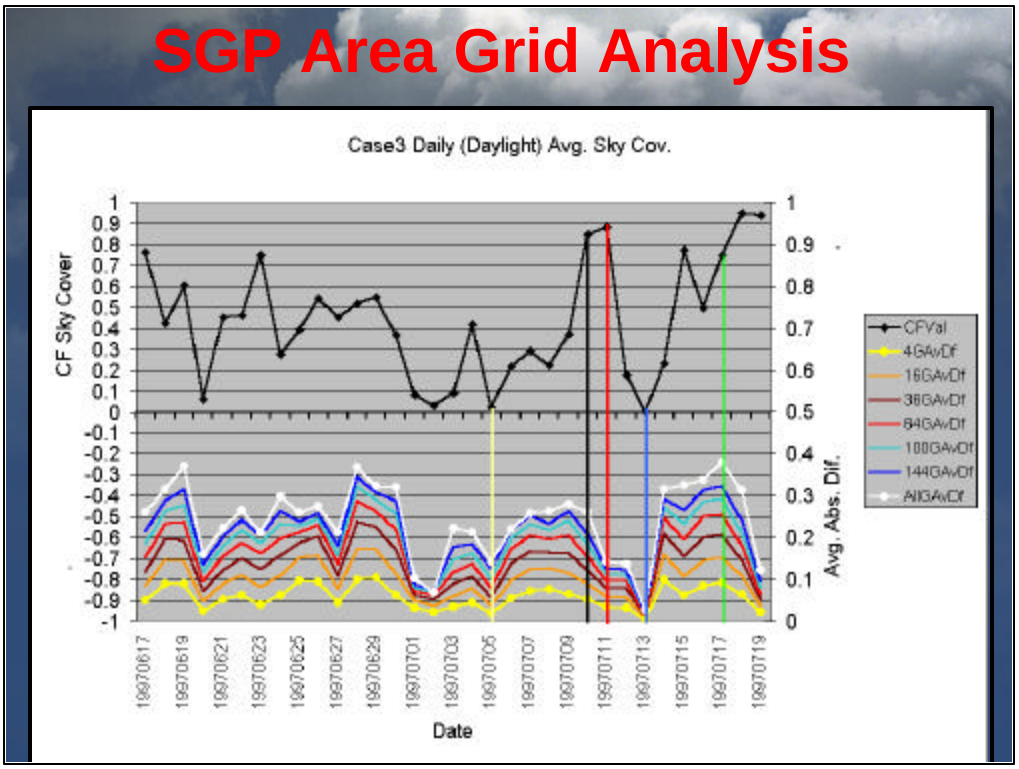
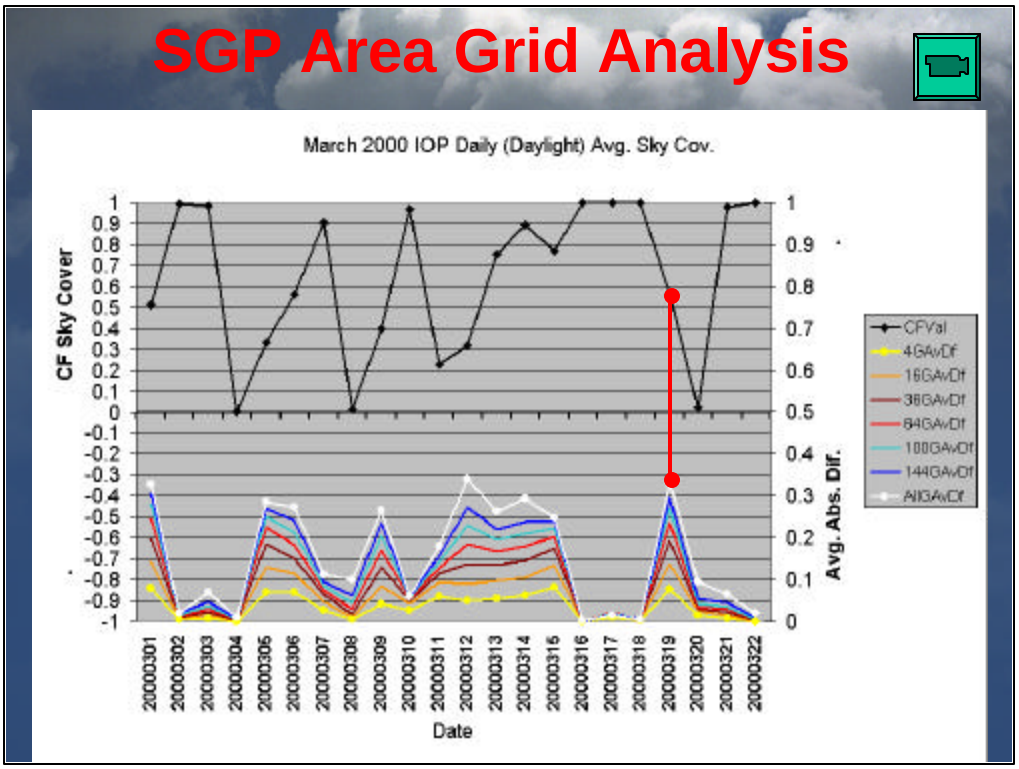


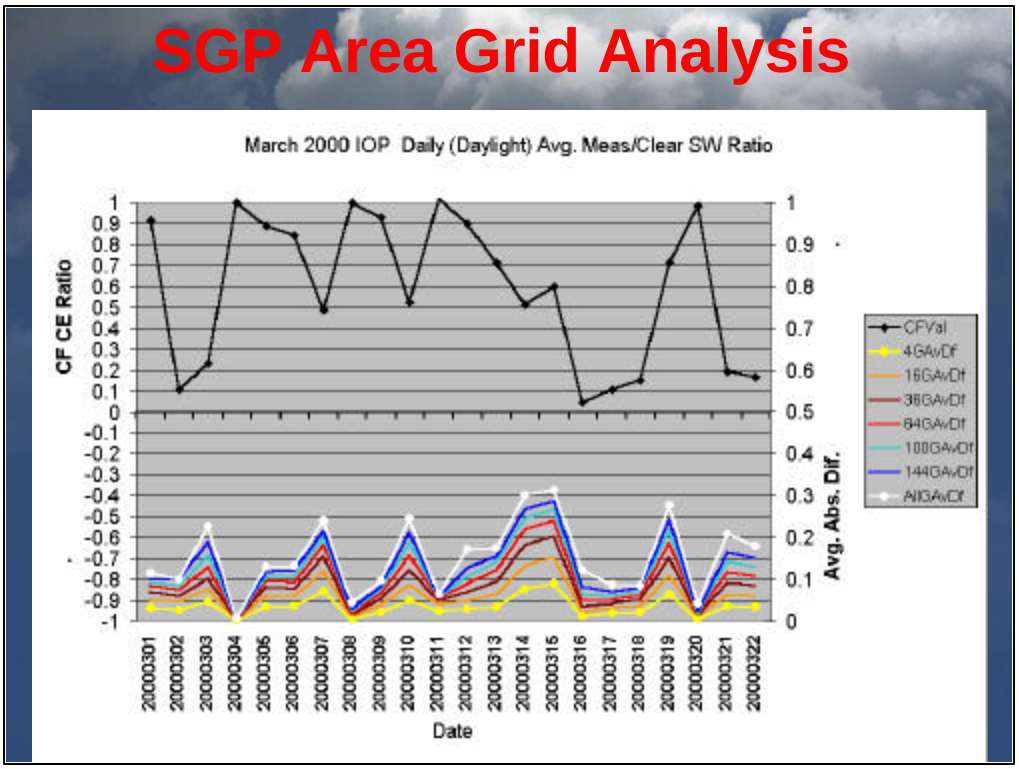
To address the question posed in panel 7, we take the surface grid output and calculate statistics for various spatial scales for areas centered on the (approximate) Central Facility location.



For the ARM 1997 Cloud IOP (the Cloud Parameterization and Modeling Working Group "Case 3"), this plot shows the daily average "Central Facility (CF)" value of cloud amounts (top panel), and the corresponding average absolute difference from this CF value by area size. Note that on some days, the CF value does reasonably represent some larger area. However, on daily time scales, more often the CF does not well represent GCM grid box scales. Thus, on these days, comparing the model output to the CF data will not necessarily represent a "good" comparison.

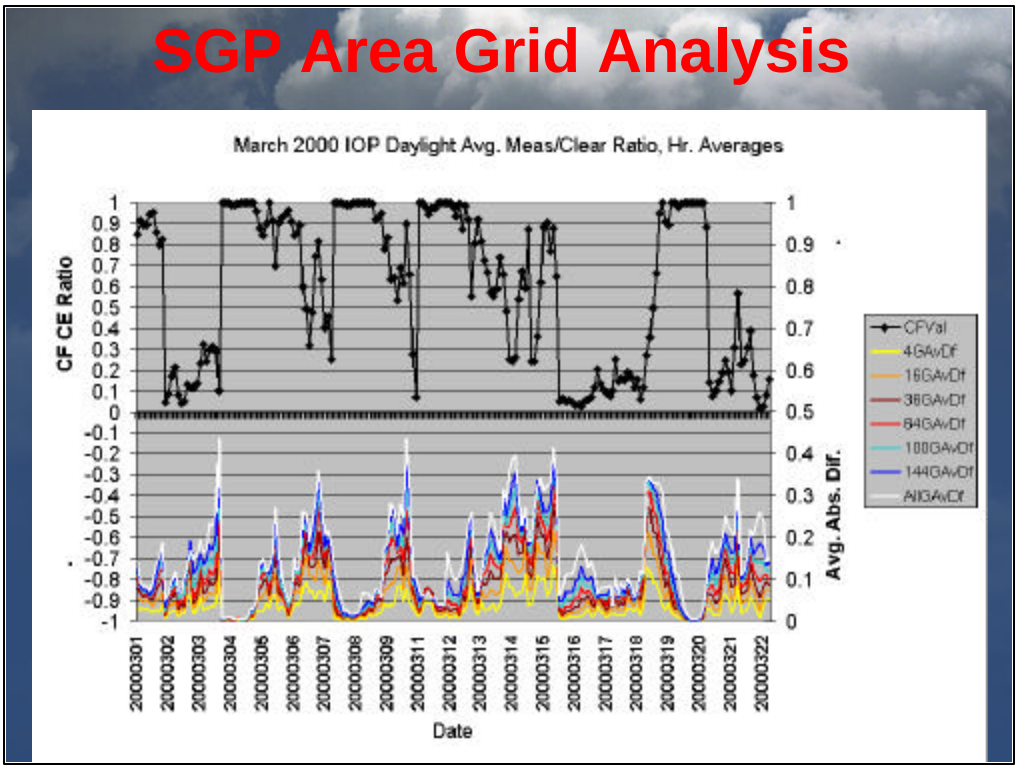


Same as panel 9, but for the time period of the 2000 Cloud IOP.

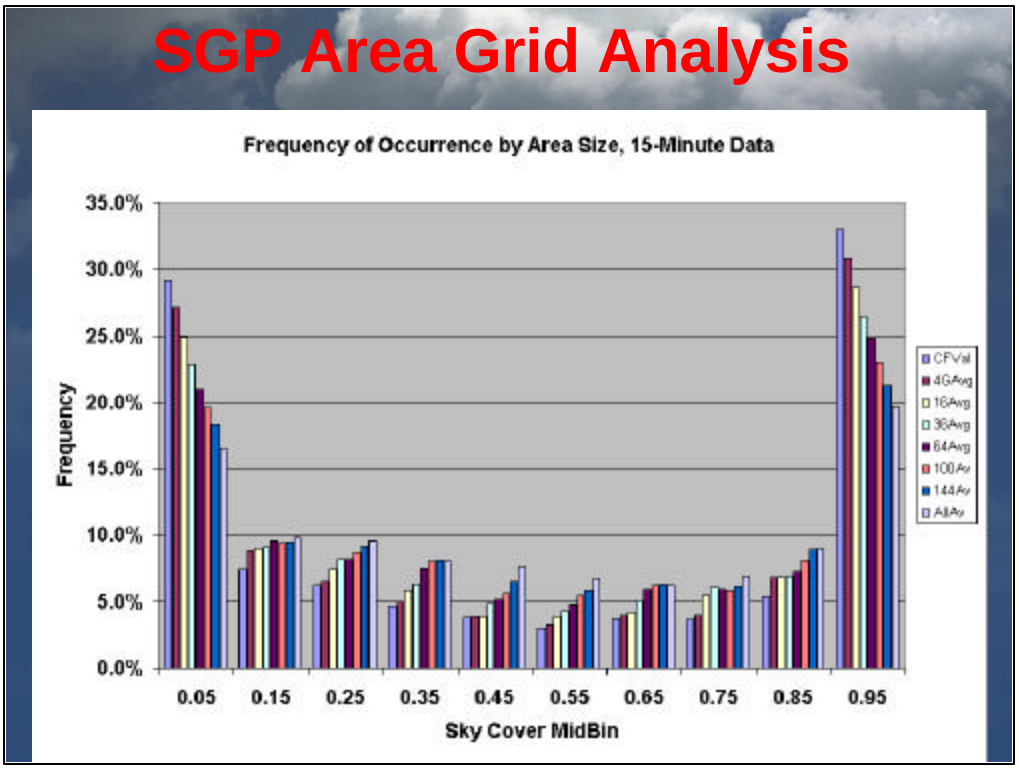


Same as panel 10, but for SW measured/clear-sky (Cloud Effect) ratio.

SGP Area Grid Analysis

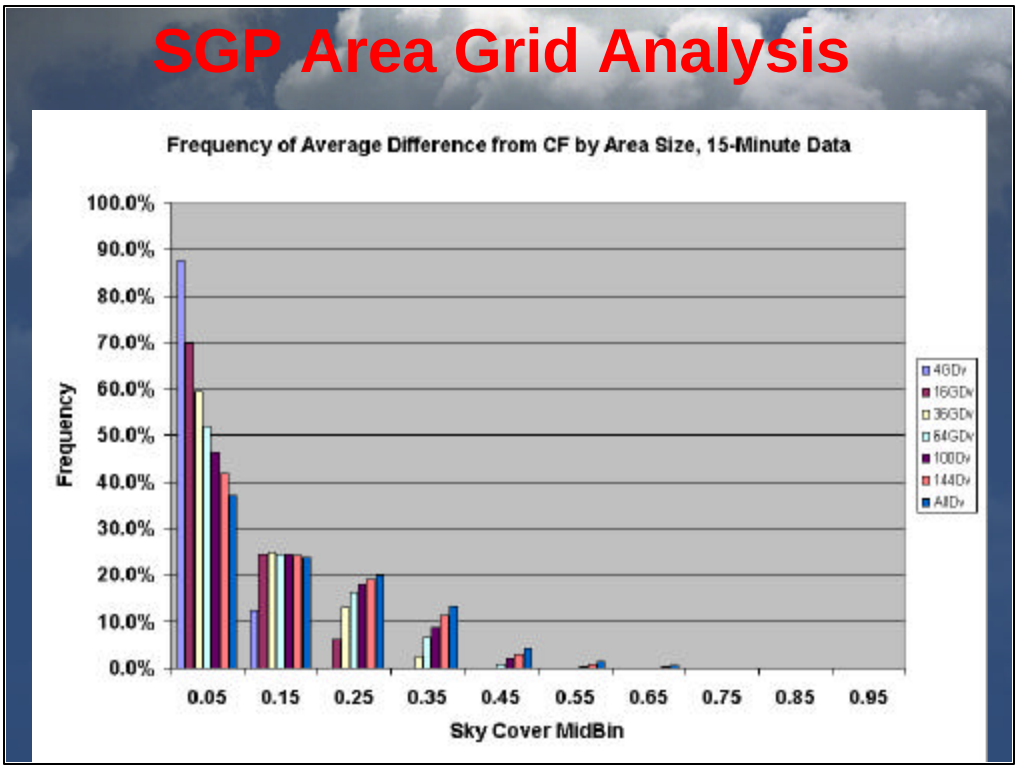


Same as panel 11, but here showing hourly averages (rather then daily). In essence, the representativeness of the CF value tends to decrease with decreasing time averages.

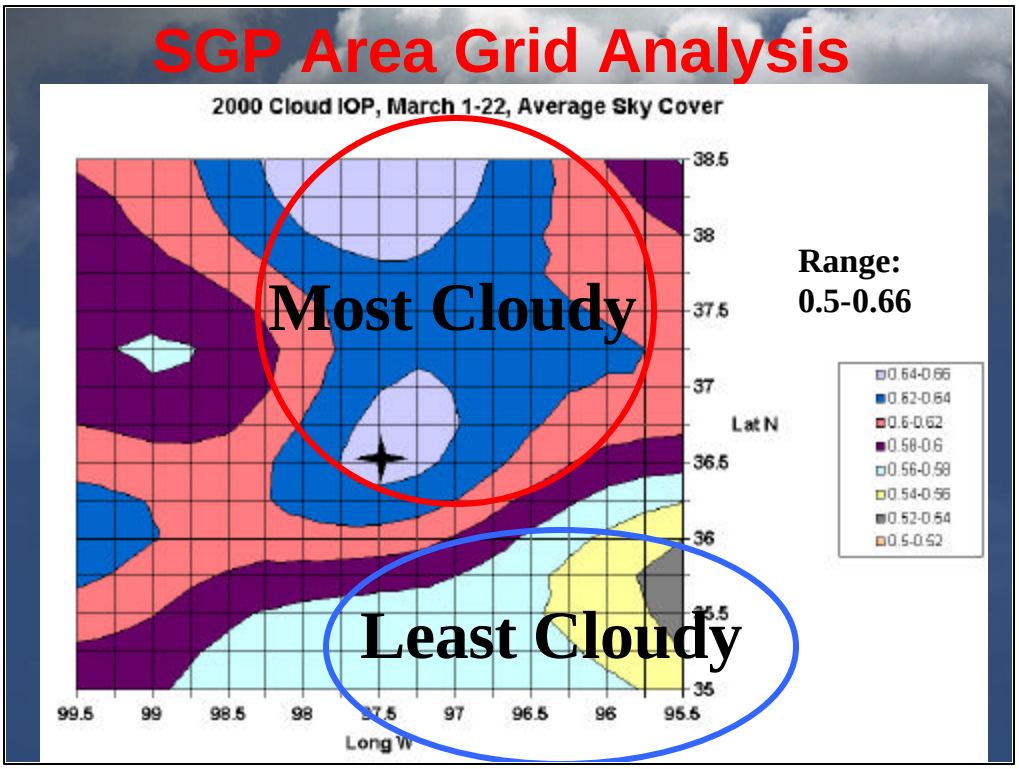


Frequency histogram of sky cover by area size for the 2000 Cloud IOP. Note that the occurrence of extreme values decreases as the area size increases. To understand this, imagine the frequency distribution of cloud cover for an area the size of the continental United States. The number of times that the entire country is cloud free, or completely overcast, would be infinitesimal if ever. Thus, care must be taken in statistical model/CF comparisons. The statistics for an area the size of a GCM grid box are not those expected for a surface point measurement.

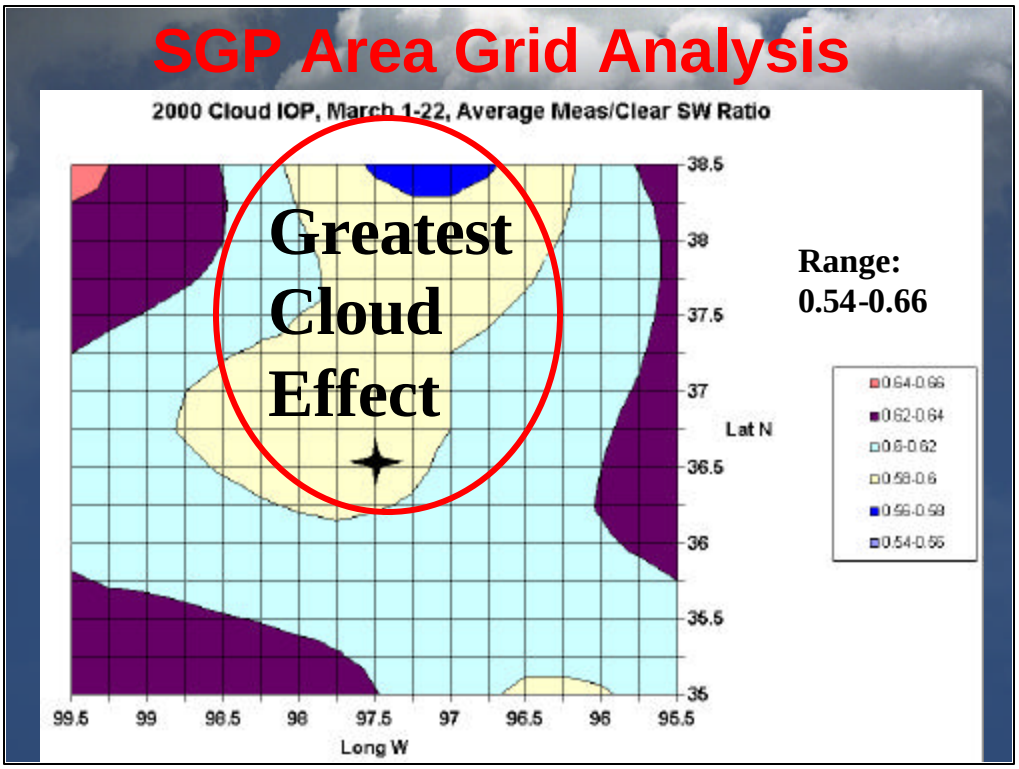
SGP Area Grid Analysis



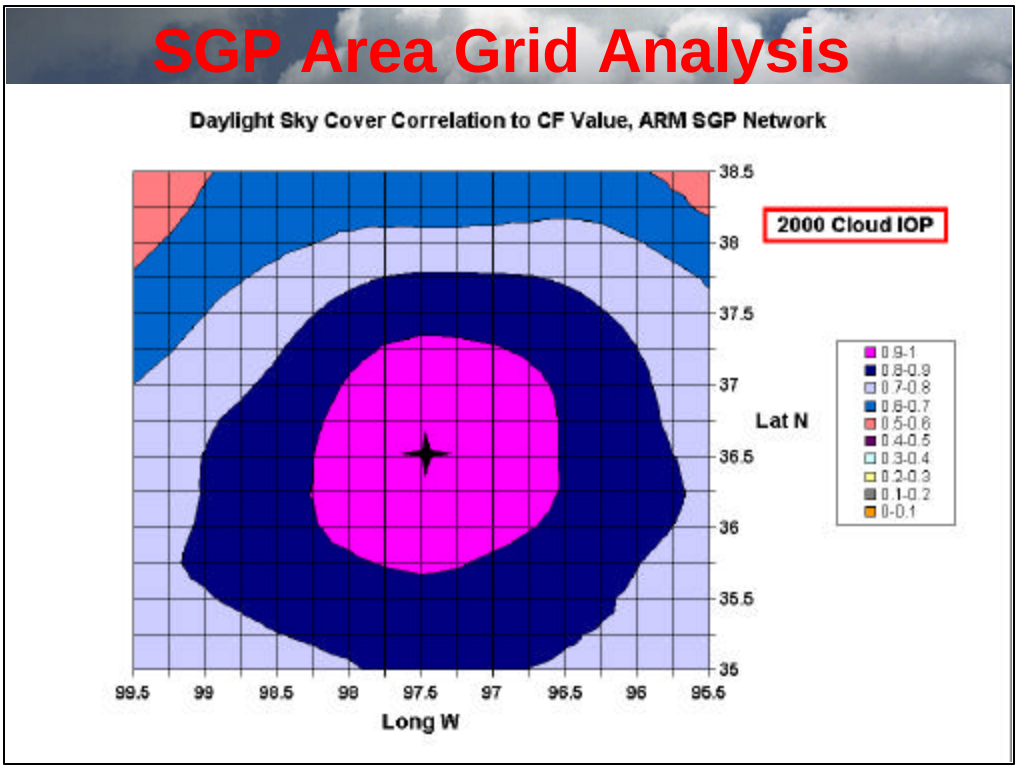
Frequency histogram of average absolute difference from the CF value of sky cover by area size, showing that as the area size increases the representativeness of the CF measurements decreases.



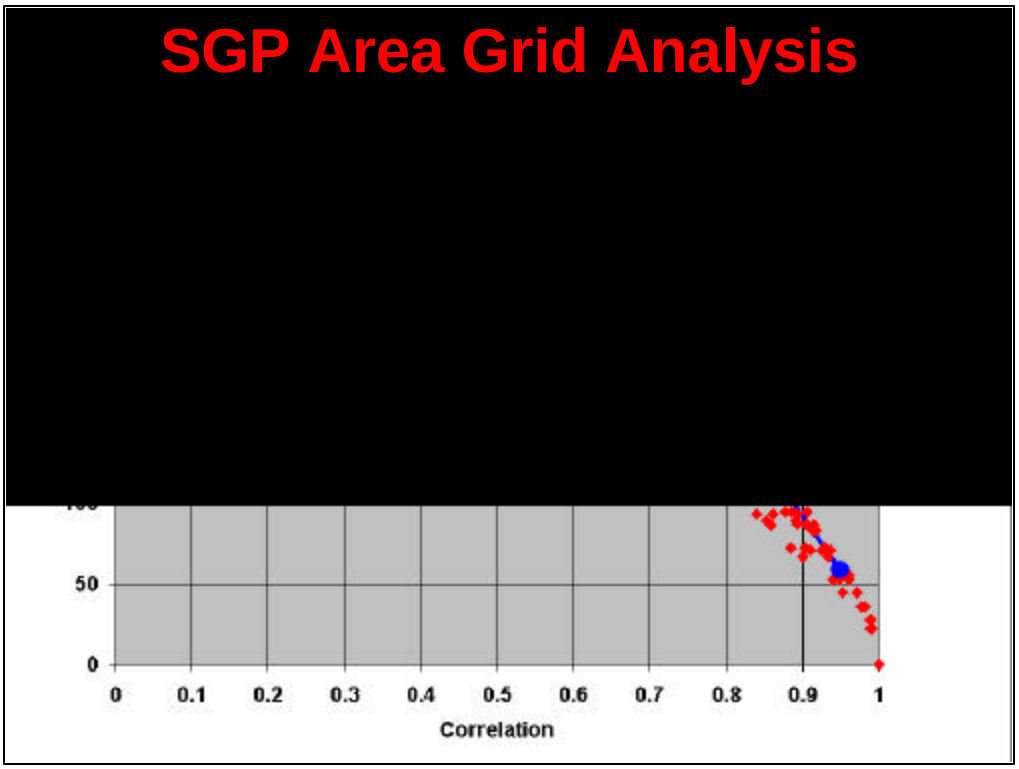
Plot of average sky cover across the SGP area for the entire 2000 Cloud IOP period. During the three weeks of the IOP, the CF happened to experience more cloud cover than most of the SGP area, especially the south-southeast portion of the area.



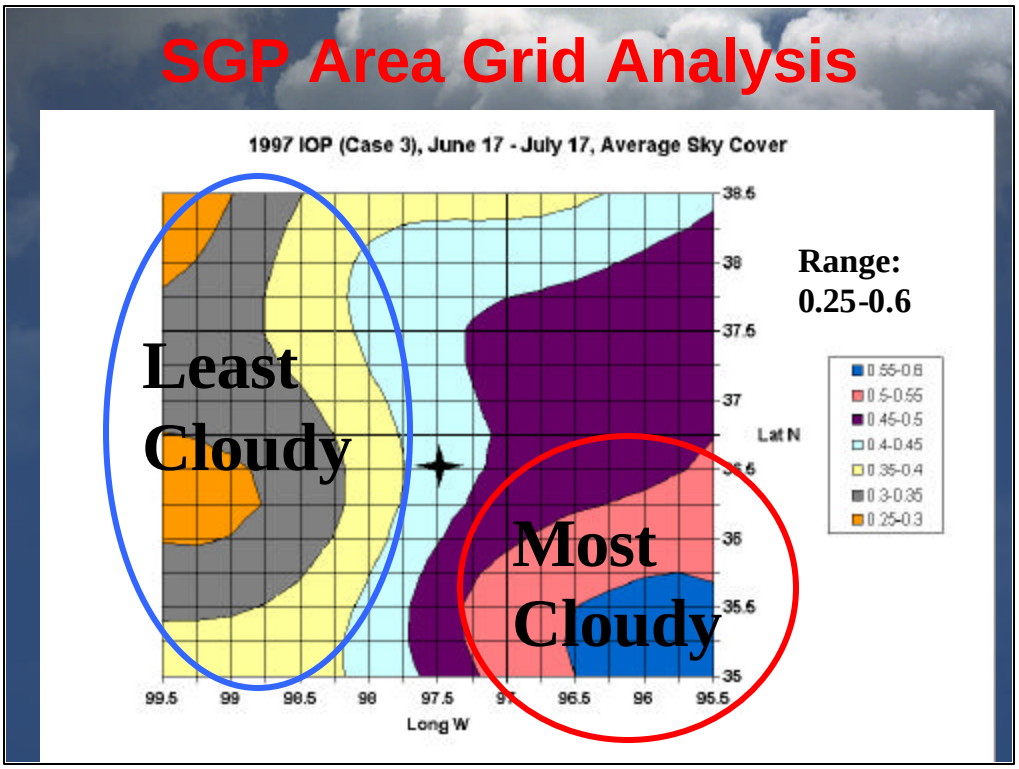
Same as panel 15, but for SW measured/clear-sky (Cloud Effect) ratio. Naturally, where there occurred more cloudiness, there occurred a greater cloud effect. Thus, for the 2000 Cloud IOP, the CF measurements exhibit more cloud effect than most of the SGP area.



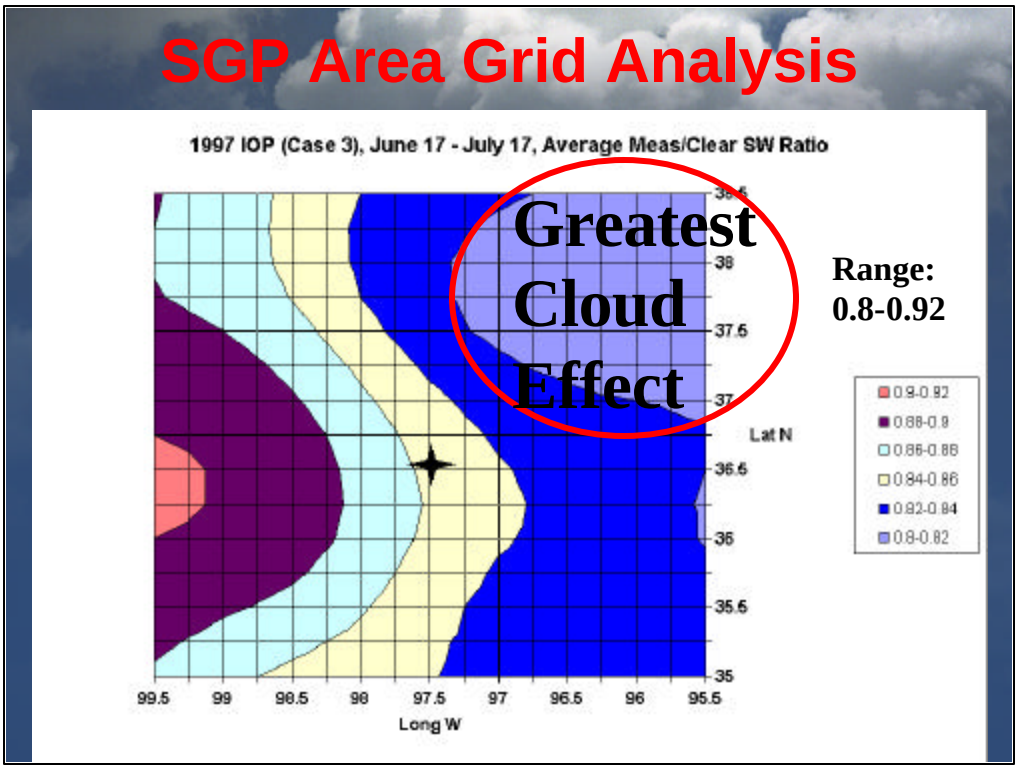
This plot shows the correlation to the CF value for the 2000 Cloud IOP period. As expected, the correlation to the CF value decreases with distance. Thus, a statistical comparison using only CF data to represent the IOP is less representative the larger the area. And while the IOP mean of the CF was more representative of the north central portion of the area (panel 15), apparently the temporal evolution of the sky cover was not. The greater east-west correlation with distance, compared to north-south, is evidence of the generally west-east movement of weather systems across the area.



This plot shows the correlation of each grid point from the plot in panel 17 versus the distance between the grid point and the CF grid point. The blue line is the average distance of the points in that correlation bin range. For this three week period, a study using CF data and requiring a degree of correlation of 0.8 or better would only represent an area within about 125 km radius of the CF.

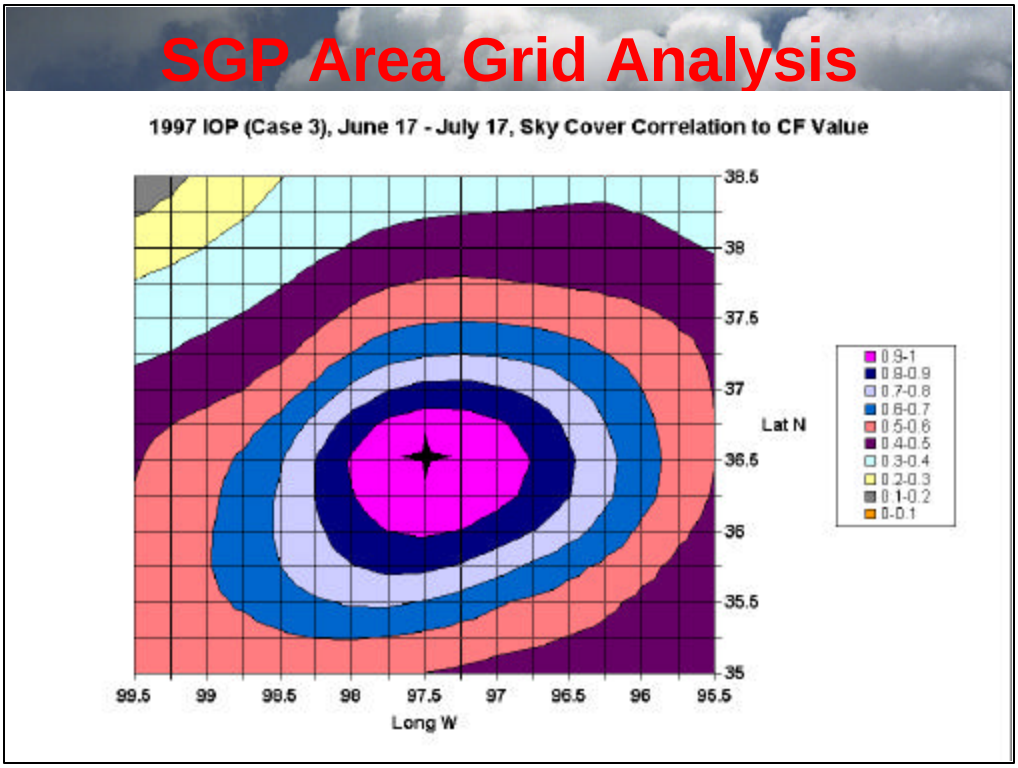


Same as panel 15, but for the one month of the 1997 Cloud IOP. Note the larger range of values (0.25 – 0.6) compared to the 2000 IOP (0.5 – 0.66). The 1997 IOP exhibited less cloudiness in general than the 2000 IOP. In this case, the CF value is roughly representative of the mean, but this IOP had larger variability across the area than the 2000 IOP.

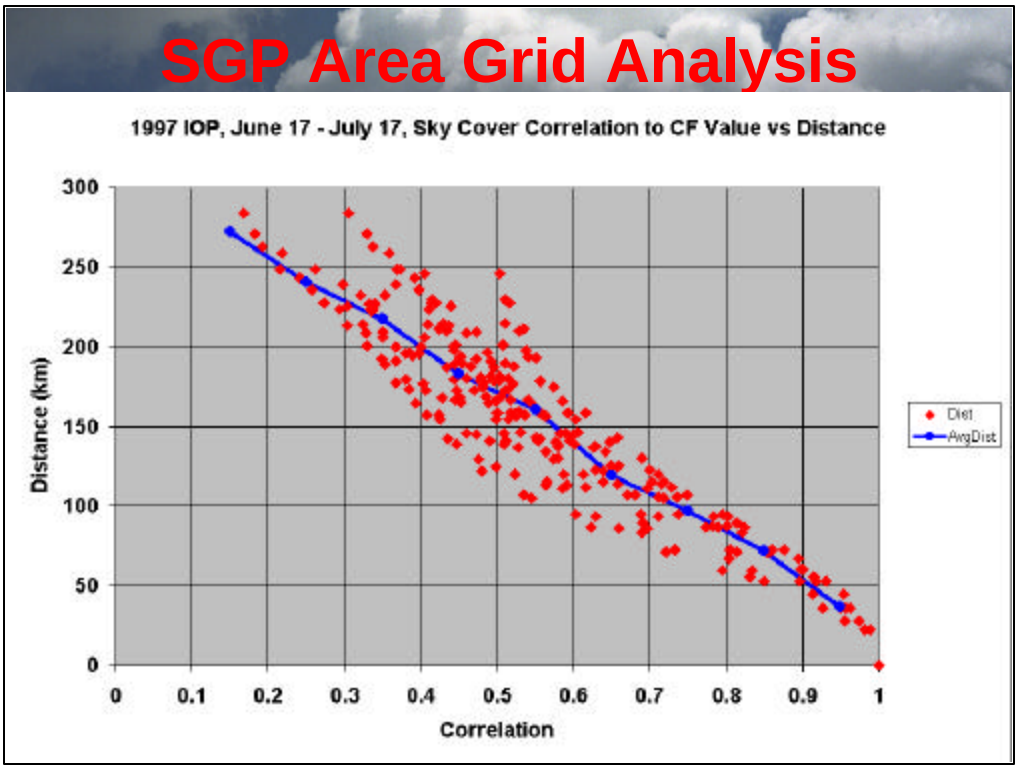


Same as panel 16, but for the 1997 Cloud IOP period. In this case, the greatest cloud effect occurred in the northeast portion of the area.

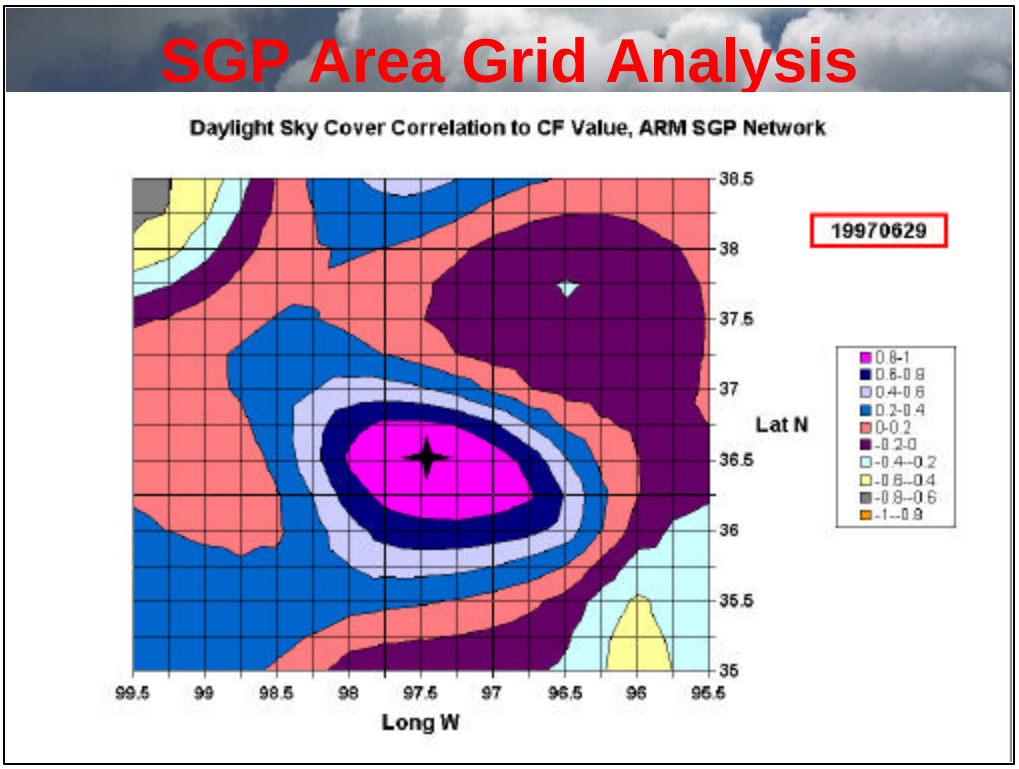
SGP Area Grid Analysis



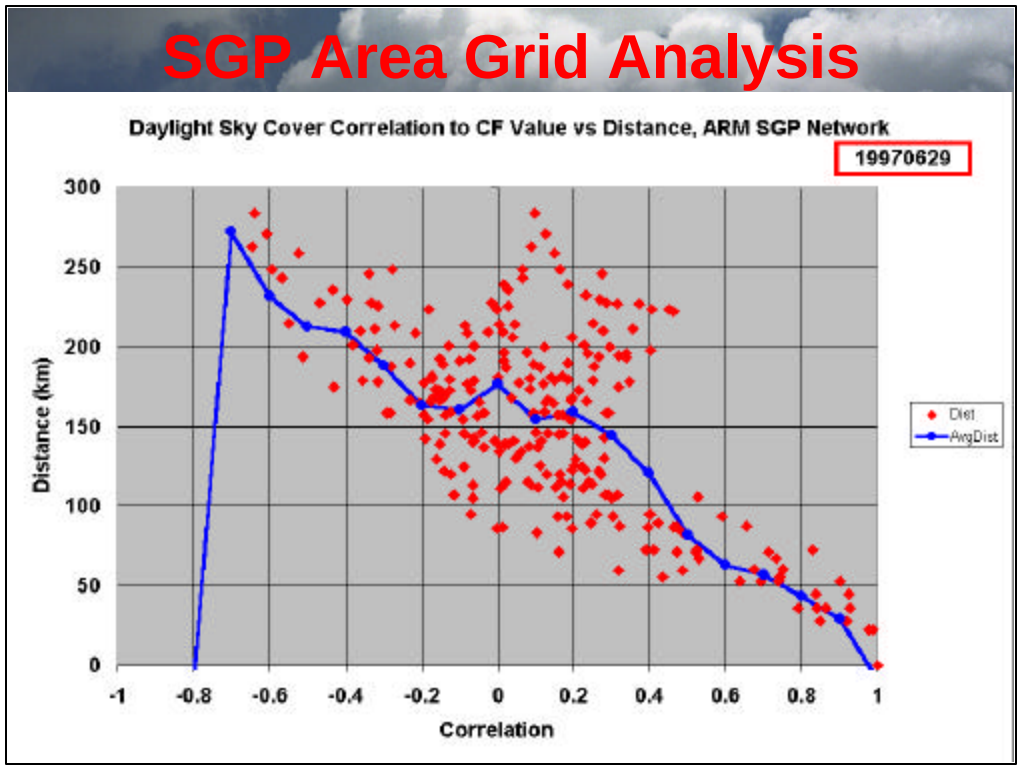
Same as panel 17, but for the 1997 Cloud IOP. In this case, given the greater range of sky cover experienced during this IOP, the larger area is less correlated with the CF data. Again, however, there is a greater east-west correlation than north-south due to the generally west-east movement of weather patterns.



Same as panel 18, but for the 1997 Cloud IOP. For this IOP, a study using CF data and requiring a degree of correlation of 0.8 or better would only represent an area within about 75 km radius of the CF, or about half that of the 2000 IOP.



Same as panel 17, but for the day of June 29, 1997 during the 1997 Cloud IOP. The previous panels dealt with the one month period of the IOP as a whole. As can be seen here, dealing with the shorter time period of a single day can result in the CF data having far less correlation with distance with the rest of the SGP area. Thus, studies using even daily averages of cloud measurements from such instruments as the Millimeter Cloud Radar must exercise great care in assessing what temporal and spatial resolution these data actually represent.



Same as panel 18, but for the day of June 29, 1997 during the 1997 Cloud IOP. For this day of the IOP, a study using CF data and requiring a degree of correlation of 0.8 or better would only represent an area within about 40 km radius of the CF, or about half that of the 1997 IOP as a whole.

Summary 1

- As the spatial domain increases:
  - Variability increases
  - Frequency distribution of area averages tends toward median values
  - The CF data is less representative of (correlated with) the larger area
- As the temporal averaging time decreases:
  - the area representativeness of the CF data decreases
- One month average of CF values may still not well represent the larger scale, either in mean or variability

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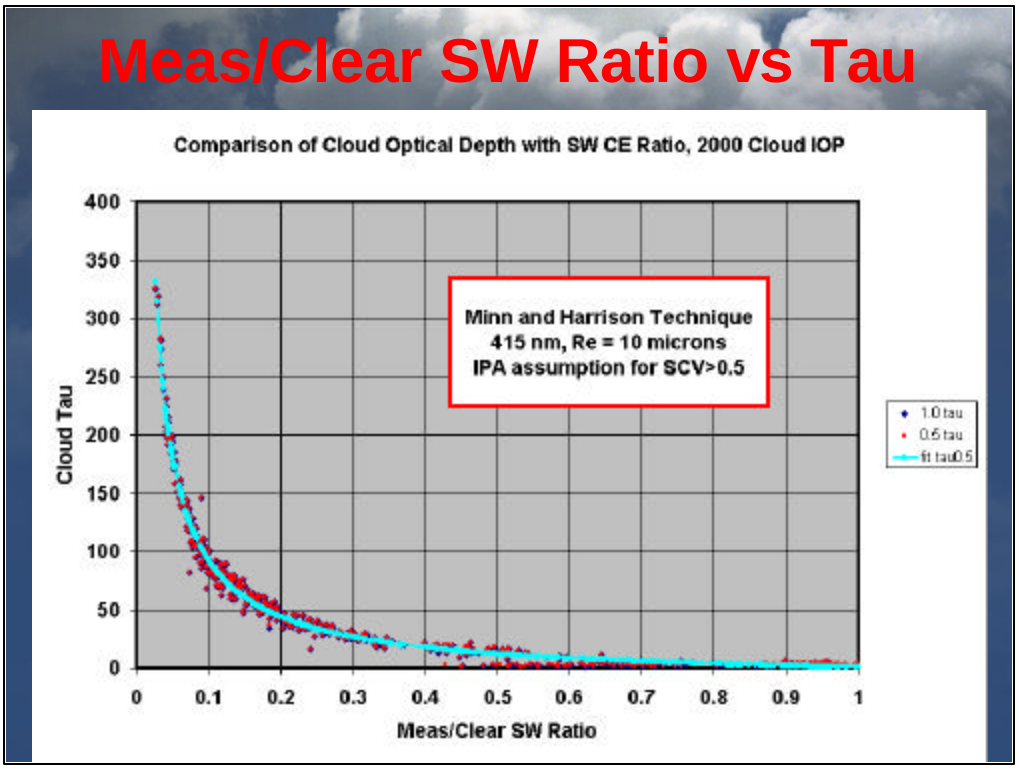
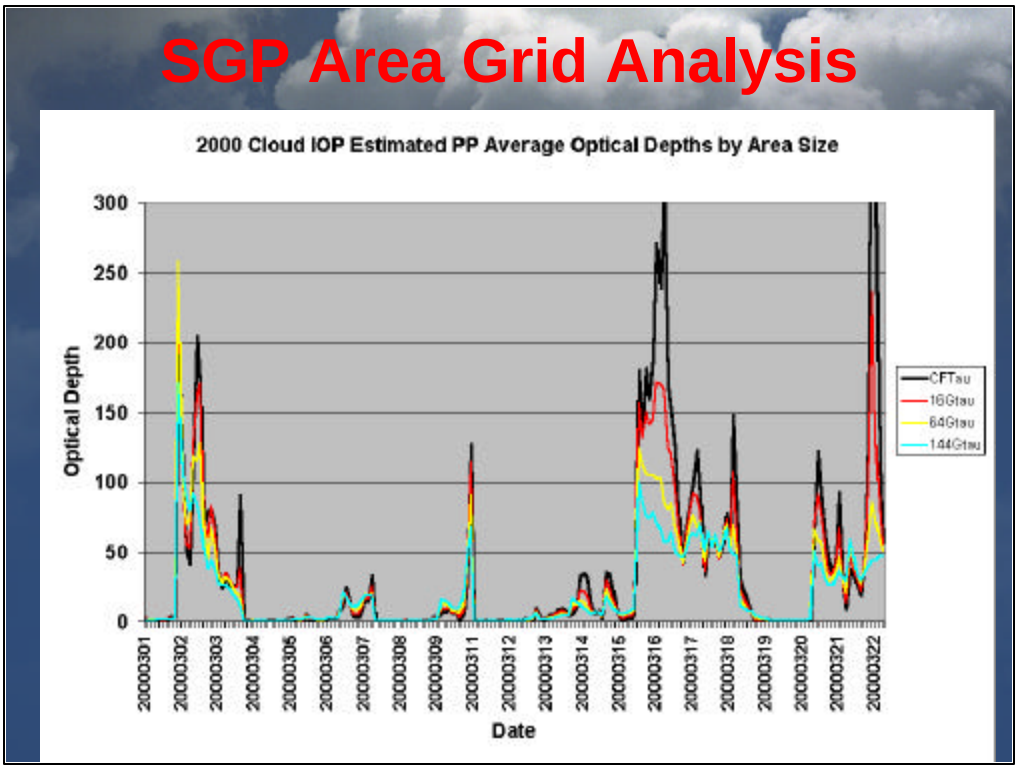


Plot of the relationship between SW Measured/Clear-sky (Cloud Effect) ratio and 415 nm cloud optical depths as estimated by the Min and Harrison technique (GRL, 1996) applied to MFRSR data. While this work is currently highly preliminary, indications are that in cases where there is no other available means for estimating cloud optical depths, the SW Cloud Effect ratio may give a reasonable ball-park estimate.



Example of estimated aerial plane-parallel equivalent cloud optical depth derived by applying the relationship shown in panel 26 to the aerial average SW Cloud Effect ratio, by area size. Not surprisingly, as the area increases the equivalent plane parallel cloud optical depth tends to decrease.

Sky Classification

- Cooperative effort with Dr. Josep Calbo, Universitat de Girona, Spain
- Method uses surface time series of BB SW and LW radiation and Met measurements
- Primarily a statistical analysis coupled with classical maximum likelihood method
- Can be applied for all EF, BSRN and SURFRAD sites

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Sky Classification Results

Category	Description	# records in class	Number of correct	% correct
A	clear sky	568	493	**87**
B1	cloudless, boundary haze	57	49	**86**
B2	cloudless, sub-visual cirrus	100	83	**83**
B3	almost cloudless, unknown cloud type	572	500	**87**
K	OVC, thin high or mid [Cs or cirrus]	148	93	**63**
H	OVC, Thick mid [Ac, As, Ns]	48	40	**83**
I	OVC, thin mid [Ac, As, Cs]	34	18	**53**
G	Fog	68	46	**68**
F1	Dark thick low clouds	103	75	**73**
F2	Thick low clouds	104	87	**84**
E	Thin stratus	50	30	**60**
C	Fair weather Cu (or stratoCu)	97	61	**63**
D	StratoCu invading sky	153	94	**61**
O	Other scattered or broken sky	150	75	**50**
		Weighted average of correct		**77**

NOTE: THIS COMPARISON USES ARM SGP OBSERVER REPORTS AS "TRUTH". THIS "TRUTH" HAS SIGNIFICANT UNCERTAINTIES.

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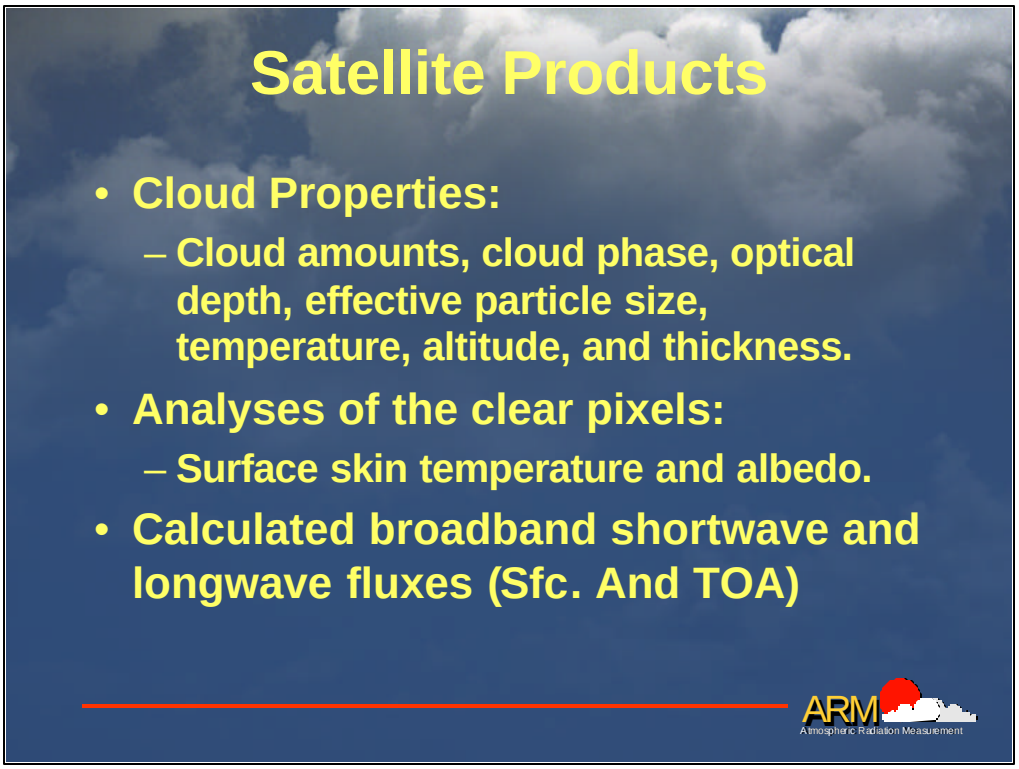
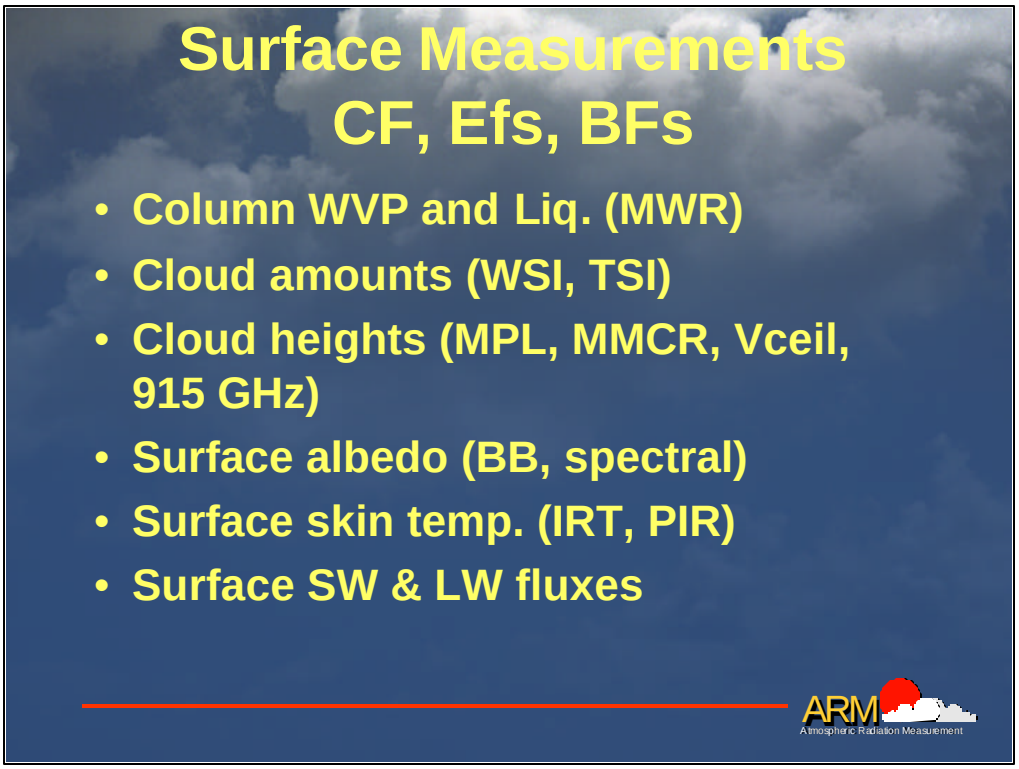
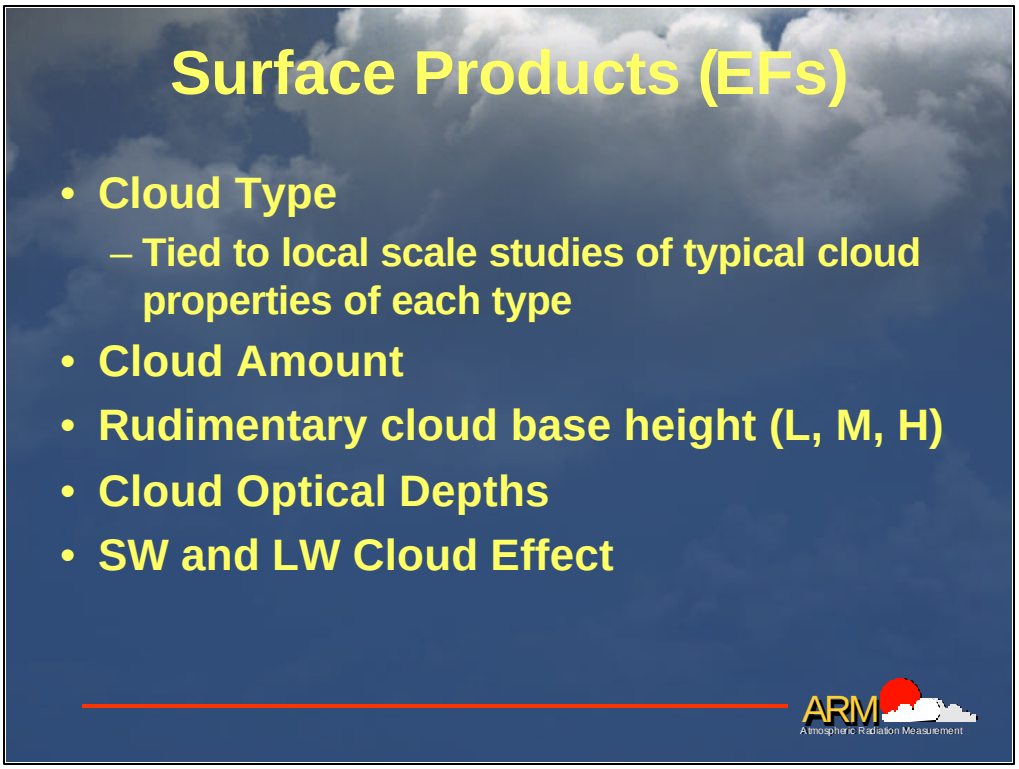
This is work in progress. Shown here is the success to date of our sky classification effort: 14 classifications with an average success rate of 77%. We are struggling to produce adequate “truth” with which we can compare these retrievals. However, these results are highly encouraging, and we are continuing with this research. We will be applying this classification methodology to measurements at sites with more sophisticated cloud measurement instruments, such as the ARM SGP CF, TWP, and NSA sites. The intent is to relate each type of sky classification category to the corresponding retrievals of cloud properties. Thus, for less sophisticated BSRN-style sites, given a sky classification we will also then be able to say something about the expected typical properties of the clouds present.



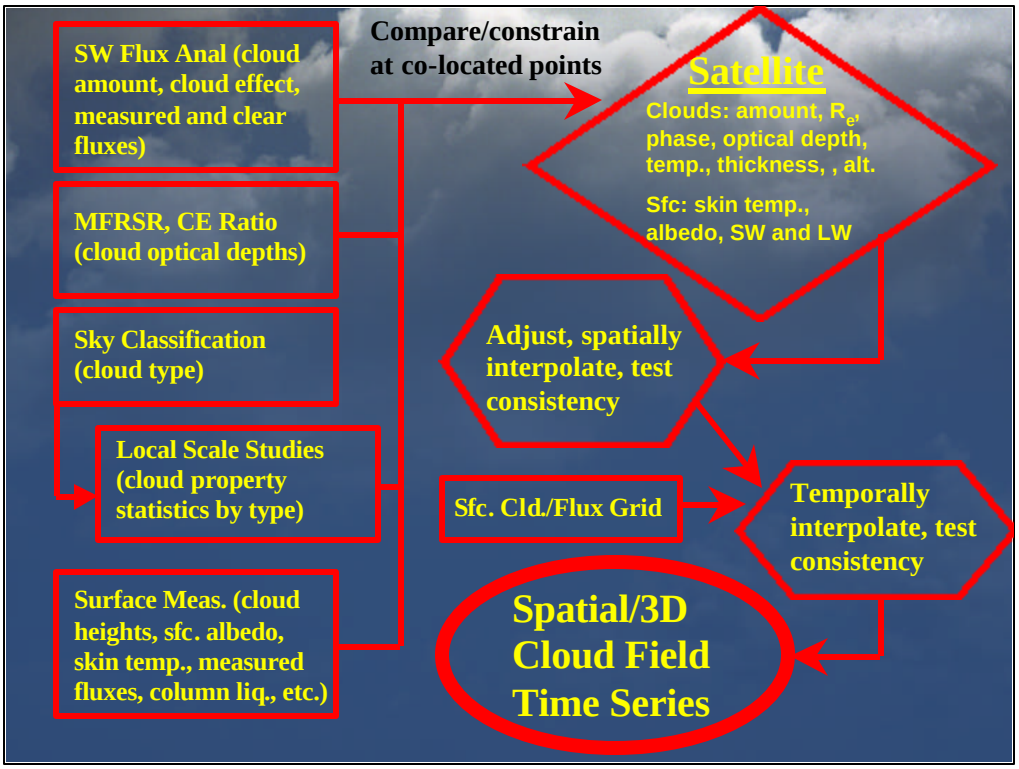
Minnis et al. at NASA Langley are currently producing retrievals of cloud and radiative properties for the SGP area, as listed here, at 30 minute intervals during daylight hours.



There are some instruments for measuring cloud and radiative properties at some sites across the SGP area.



In addition, we have shown in this presentation that we are developing the means to infer cloud and radiative properties using the SGP Extended Facility network.



Our ultimate goal is to combine the surface and satellite information to produce a Spatial/3D time series of cloud and radiative properties across the entire SGP area. We envision this effort to be a necessary and useful component toward the development of model parameterizations that will include sub grid scale variability and issues of representativeness presented here. This will be a multi-year collaborative effort by teams at the Pacific Northwest National Laboratory, NASA Langley, and the University of Utah.

3D Summary

- We are developing/refining analysis methods to produce cloud information applicable to BRSN-type sites
- We are embarking on a project to produce a Spatial/3D time series for the SGP area
  - This includes a local-scale study applicable to ARM ARCS sites

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