# Mesoscale Variability of a Continental Stratus Cloud Event at the SGP CART Site During 1999

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## Introduction

Current observational data bases of continental stratus are mainly composed of observations from a single location. It has been shown, however, that marine stratus decks show both mesoscale and diurnal variability (Albrecht et al. 1988; Albrecht et al. 1995; Miller and Albrecht 1995; Miller et al. 1998). Such variability may be even more prevalent in continental stratus clouds. The issue of mesoscale variability of stratus clouds is an important topic with regards to numerical modeling. A number of questions need to be addressed for modeling efforts to continue to progress. For instance, is mesoscale variability of macroscopic cloud properties observed via ground-based remote sensors evident in visible satellite imagery? Observations of cloud base height, liquid water path, surface energy budget, and sub-cloud stability most likely vary dramatically over an area representative of a general circulation model (GCM) grid box. Moreover, it is important to understand how correlations in these properties observed across the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site vary as a function of temporal and spatial averaging. Furthermore, how do processes that lead to the development and maintenance of stratus differ between continental and maritime air masses. The work here begins to look at some of these questions.

Cloud and boundary layer data from across the ARM SGP Cloud and Radiation Testbed (CART) site provide an excellent means to determine how representative single-point measurements are in continental clouds that exhibit mesoscale and diurnal structure. We focus on a continental stratus deck observed over the ARM site and develop statistics for cloud macroscopic properties and other boundary layer characteristics using data from a number of locations across the ARM domain.

We analyze ceilometer, Microwave Radiometer (MWR), and conventional rawinsonde data across the ARM site to calculate statistics for cloud base height and liquid water path and to evaluate the sub-cloud stability for various times. Moreover, characterizations of boundary layer properties such as surface energy budget fluxes, boundary layer temperature, and wind are obtained through measurements from Energy Balance Bowen Ratio (EBBR) and 915-MHz wind profiler/Radio Acoustic Sounding System (RASS) instrumentation.

Time correlations between cloud base height and liquid water path are examined to explore the relationship between these important cloud properties across the site. Different averaging intervals are used to investigate how the relationship may change with temporal resolution for modeling purposes. This case study provides a start in developing and evaluating strategies for routinely characterizing the mesoscale variability of continental stratus clouds.

## Cloud Properties

The case study presented uses data collected from January 7-8, 1999. Figure 1 is a visible satellite image for 1739 Universal Time Coordinates (UTC) January 8, 1999. It is clearly evident from the satellite imagery that substantial variability exists across the SGP domain at this time. Across the southern and northern regions of the SGP site, it is clear that more uniform and thicker low-level cloudiness exists, whereas across the center portion of the SGP site (northwest of the central facility [CF]) more broken stratocumulus is present.

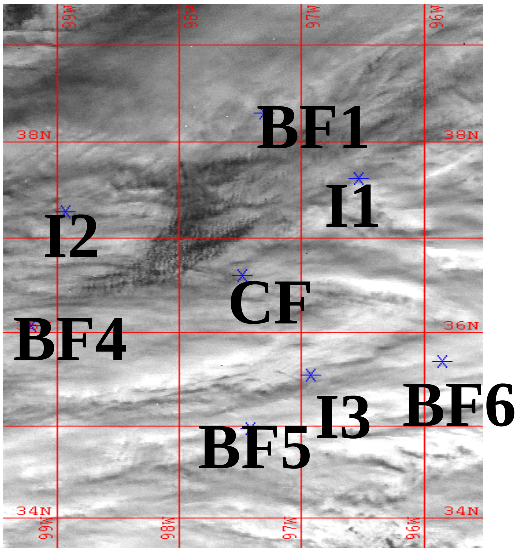


**Figure 1**. Visible satellite imagery over the SGP site for 1739 UTC January 8, 1999. The boundary facilities (BFs), intermediate facilities (IFs), and the CF are highlighted in black.

The differences apparent from the satellite image would certainly alter cloud and environmental properties on the mesoscale and therefore impact the evolution and maintenance of the stratus in an area contained within a GCM grid box.

Some of the variations depicted by the satellite image are detected by ground-based remote sensors. Figures 2 and 3 illustrate time series of cloud base height and liquid water path for the period from 1730 UTC to 1900 UTC on January 8, 1999.

Figure 2 shows substantial temporal variability in cloud base height at two sites (BF5 and BF6), less than 100 km apart. This variability becomes even more apparent when observations are averaged over 5-minute intervals (thicker lines). The BF6 time series shows a distinct oscillation in cloud base height, whereas BF5 does not.

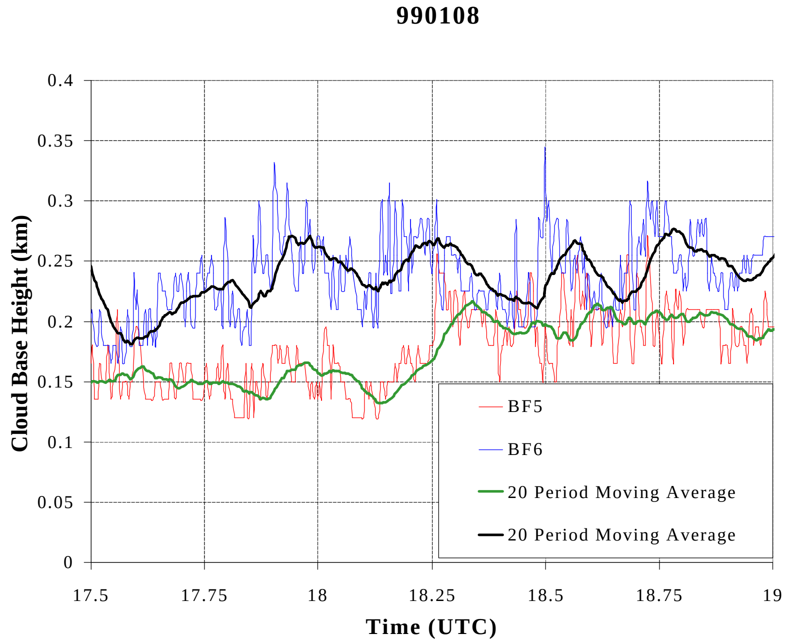


**Figure 2**. Time series of cloud base height (km) for BF5 and BF6 from 1730 UTC to 1900 UTC on January 8, 1999. The data are taken from the Vaisala Ceilometer (VLC). The thicker lines are 5-minute moving averages of cloud base height (km).

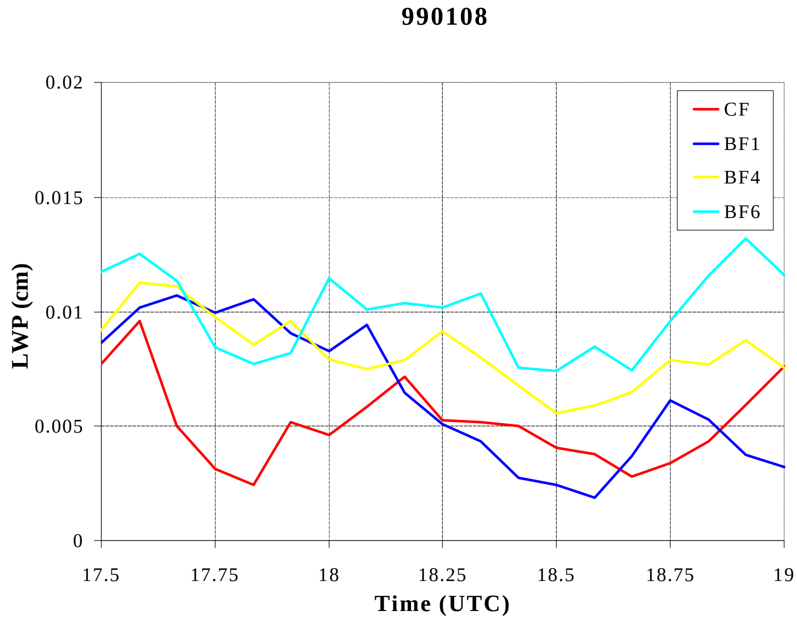


**Figure 3**. Time series of liquid water path (cm) for CF, BF1, BF4, and BF6 from 1730 UTC to 1900 UTC on January 8, 1999, from the MWR.

This indicates that surface and cloud top feedback processes may be more closely linked to the maintenance and evolution of the stratus at BF6 than at BF5. The liquid water path data from the MWR for the same time period (Figure 3) also shows substantial variability across the ARM site.

The BF6 time series shows an oscillation in the data similar to the cloud base height time series again highlighting the fact that feedback processes are closely linked to the evolution of the stratus.

An important concept for modeling is how the relationship between data across the ARM site changes with data averaging interval. If the data behave more consistently over a particular time interval, then perhaps it is more reasonable to incorporate these averaged data when developing cloud parameterizations. Figure 4 shows the cross correlations of cloud base height among several sites as a function of the averaging interval.

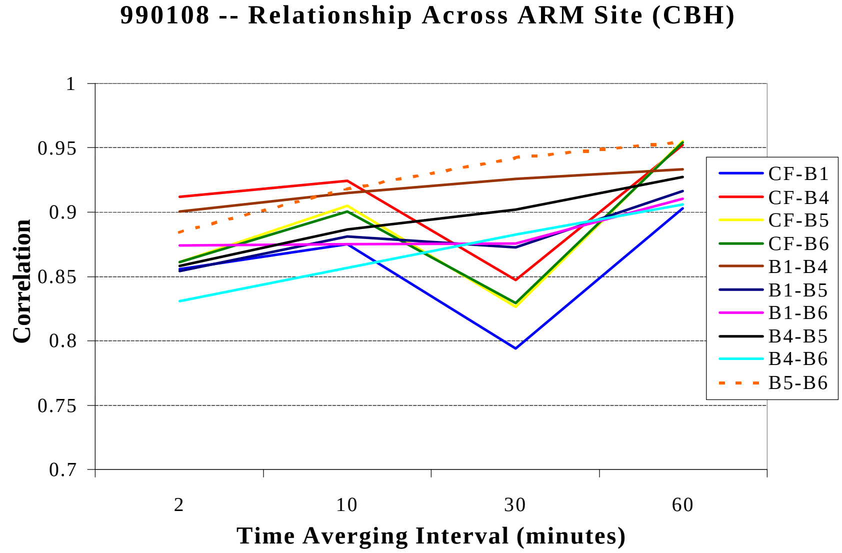


**Figure 4**. The correlation between all sites (CF and BFs) as a function of time averaging interval for cloud base height for January 8, 1999.

It can be seen that the correlation for all sites is greater at a 60-minute averaging interval than at 2 minutes. Second, it is interesting to note that at 30 minutes the sites related to the CF all show a decrease in the correlation at a 30-minute averaging interval whereas the other relationships do not. This perhaps is in some way related to the more broken cloudiness near the center of the SGP site where the frequency of rising and falling cloud base height was on the order of 30 minutes (Figure 1).

## Environmental Properties

Not only is it important to understand what the variability is of the cloud properties but also that of the environmental components since they are closely linked to the maintenance of the clouds through feedback processes. For example, Figure 5 illustrates the net radiation for a number of sites across the SGP site.

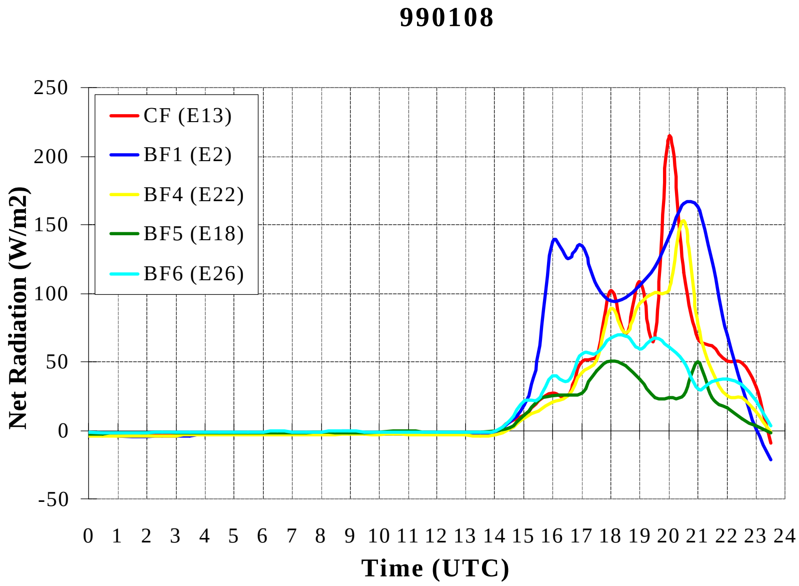


**Figure 5**. Time series of net radiation for a number of sites across the SGP site as close to CF, BF1, BF4, BF5, and BF6 as possible for January 8, 1999.

The figure shows two main points. First, it is evident that there is significant mesoscale variation in the surface radiation budget across the SGP site. Second, it is apparent by viewing the BF6 time series (focusing between 1600 UTC and 2000 UTC) that the oscillation seen in both the cloud base height and liquid water path data (Figures 2 and 3) is evident in the net radiation as well. Therefore, it is consistent with the idea that there is a distinct connection between cloud and surface processes that may be more important for continental stratus than maritime stratus.

## Summary

This continental stratus case shows considerable mesoscale variability in a number of cloud and boundary layer properties across the ARM SGP site. We have illustrated variations in cloud base height, liquid water path, and surface energy budget fluxes. Differences are apparent in sub-cloud stability and boundary layer wind speed and direction also (not shown). The variations evident here highlight some important ideas and problems when diagnosing cloud properties to later be used in developing improved cloud parameterizations for GCM modeling purposes. Visible satellite imagery shows significant differences within the ARM domain during this case as a number of different regimes are seen. The correlation between sites for cloud base height data indicate variations that depend on the time averaging interval used. No significant change, however, in correlation was observed with the liquid water path data. Relationships among cloud base height, liquid water path, and net radiation indicate that feedbacks may be important for the maintenance and evolution of continental stratus.

## References

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