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The Systematic Errors of Geosynchronous Satellite Data

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ABSTRACT

A type of error was found through statistical analysis of geosynchronous satellite data. This systematic error may seriously compromise the integrity of cloud climate. Case studies of cloud-top temperature in the Mei-Yu front and ITCZ revealed the level and the locations of contamination. The errors became the dominant feature on the radiance histogram unless some correction was made.

Cloud climatology collected from geosynchronous satellites provides a unique set of information on the earth system. The satellite data, with a resolution as fine as one kilometer, as wide as the Pacific, covers a broad range of atmospheric phenomena that no other device can match. Only recently the value of satellite observations for climatic diagnosis has been recognized. A notable example is the International Satellite Cloud Climatology Project (ISCCP, Rossow *et al.*, 1985), a network of operational weather satellites which compiled global radiance measurements in the visible (0.6 μm) and the infrared (11 μm) spectral windows with a spatial resolution no less than 10 km, a time resolution no less than 3 hours. It is expected that the results from ISCCP will greatly enhence our understanding of longterm radiative and hydrological budget.

Following the same token, this study was initially aimed to analyze the cloud patterns of major weather systems, i.e., Mei-Yu front, ITCZ etc., in an area under the Japanese weather satellite GMS-4. To our surprise, a systematic error was found. The type of error was geographically evenly distributed, therefore, unless a statistical mean was employed, it cannot be detected by mere visual scan. A small deviation it seems, yet, if left unchecked, it will persist to the extent--that they might become the dominant features of cloud climate. The same type of error also appears in other geosynchronous satellite data. Both GOES-west and METEOSAT data inherited the same flaw. Fortunately the observations from Polar Orbiting Satellite, Tiros-N/NOAA Series , using instrumental package Advanced Very High Resolution Radiometer (AVHRR), instead of the standard equipment Visible and Infrared Spin Scan Radiometer (VISSR) on geostationary satellite (see Rao *et al.*, 1990), are clean. This set of clean data can be used as verification.

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Two cases of the Mei-Yu front were chosen (Figure 1) for nephanalysis. The digital, infrared, black-body temperature data with a spatial resolution of 5km from GMS-4 covered a frontal area embedded with intensive cloud activities. Figure 2 plotted the histograms of cloud-top temperature of two separate fronts. The similarities seem striking, though misleading. In both histograms the cloud tops were stratifed, they reached some identical heights and generally showed a five-mode distribution. What looks unususally coincidental are the locations of the modes; they appeared at every six or eight degree interval and appeared at exactly the same spots, i. e., -16, -34, -46, -52 degrees. These are neither tropopause (around -60 degrees in this area) nor the boundary layer top (some sounding analysis will not be shown here), hence we can not find a plausible expaination on physical grounds. We also failed to enlist any theory that the cloud tops should be quantized according to certain fixed heights (e.g., Cotton and Anthes, 1989), especially for middle clouds. This particular feature has to come from error.

Further analysis quickly proved the above assumption. We investigated ITCZ on the same satellite diagram and found the same results. A more detailed study of radiance (Figure 3) revealed that the spurs of cloud-top temperature distribution are directly related to the spurs of radiance distribution, which spread over the whole domain without spatial discrimination. The spurs do shift for different periods of time. Since the radiance data are calibrated into 256 digitized categories, the spur error becomes obscured when radiance scale are transformed to a broader temperature scale.

Although we cannot pinpoint the exact source of errors, it is expected that most likely it is the discontinuities when VISSR converts the electric signals into radiance. In some intervals a band of electric signals resides on one single address of radiance, which leads to overlapping of signals. The exact values within the overlapped bands was lost forever, perhaps. The only remedy is through statistical correction.

The percentage of aliasing signals is estimated around 16.5% in the Mei-Yu front. The error level depends, of course, on weather, It should be noticed here that essentially the error inclines more to generating, ambiguity than simply giving out wrong numbers. Hence it seems to be tolerable if the users only concern is cloud maps. But the error will become serious when we study the cloud climate. Figure 4 presents the composed histogram of six Mei-Yu front cases. The aliasing errors turn out to be the most obvious feature in the histogram.

The data from polar-orbiting satellite Tiros-N/NOAA Series are free of aliasing errors. Figure 5 compares cloud-top temperature histograms from GMS-4 and from Tiros-N/NOAA Series for the same case. Except the aliasing errors, they agree very well. We were told that a team of satellite specialists in National Central University is working on the correction problems now.

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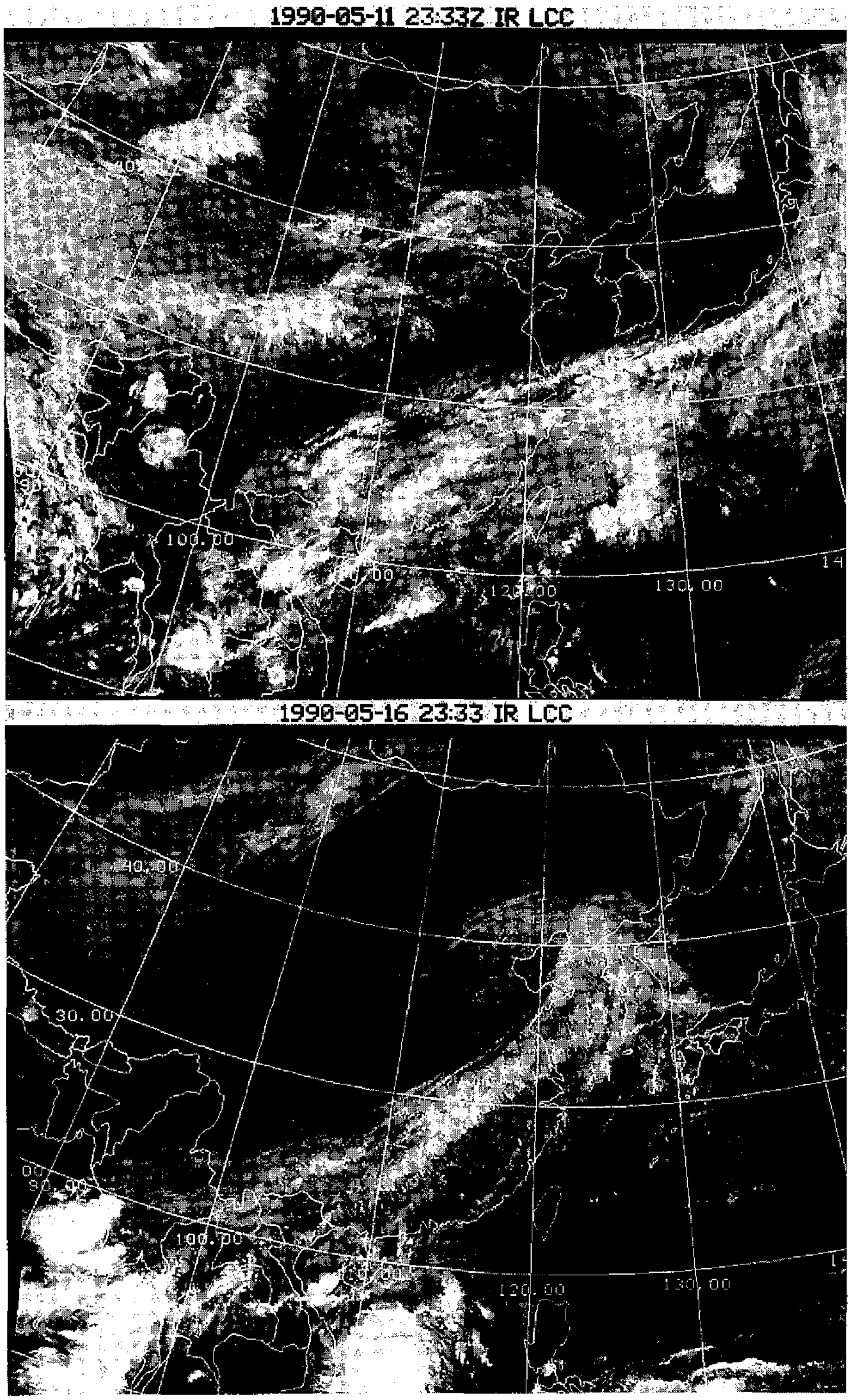

Fig. 1. GMS-4 IR channel images of two seperate cases of Mei-Yu fronts (1.a) on May, 12, 1990. (1.b) on May, 17, 1990. Both images were taken at 00Z GMT.

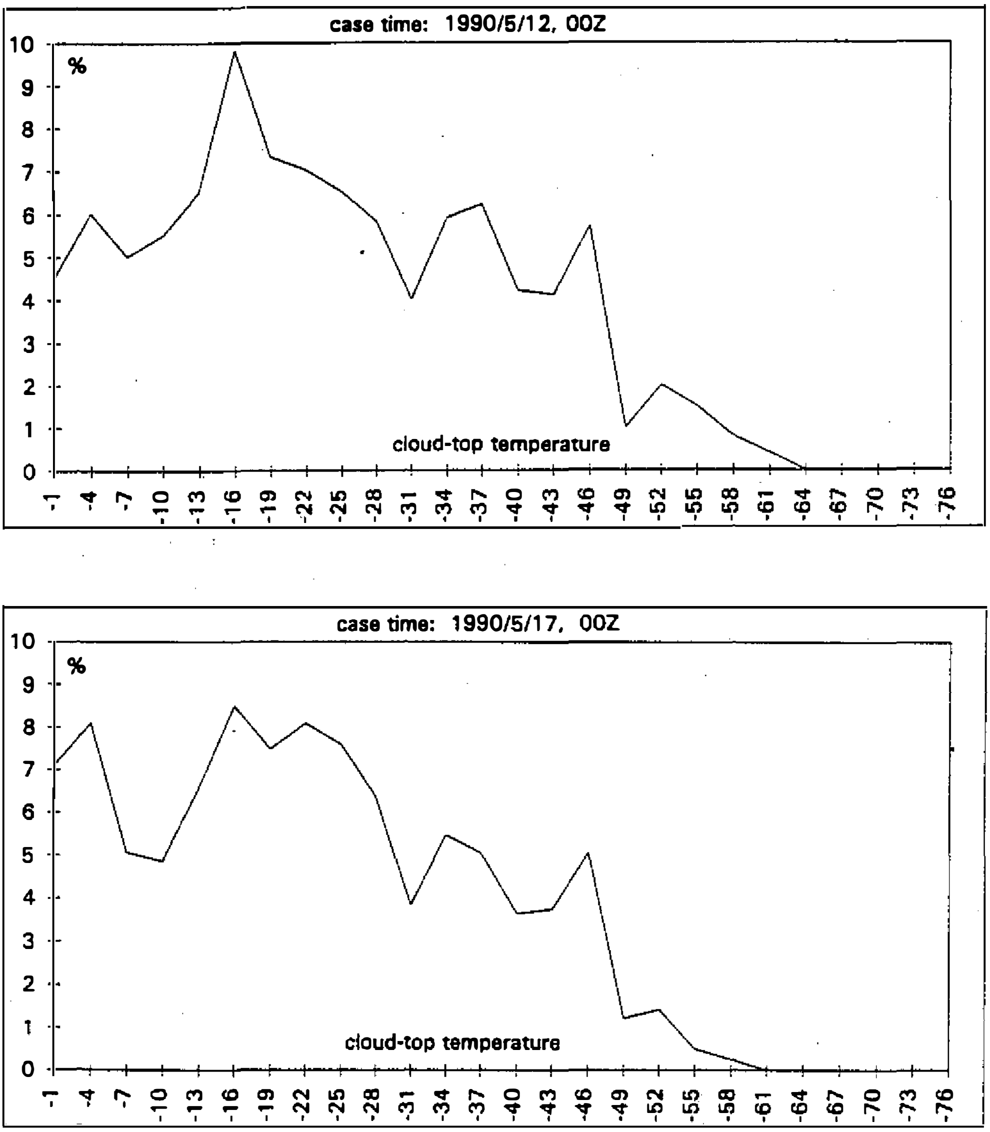

Fig. 2. The histograms of cloud-top temperatures. Two distributions are almost identical except for the interval between -19C and -25C.

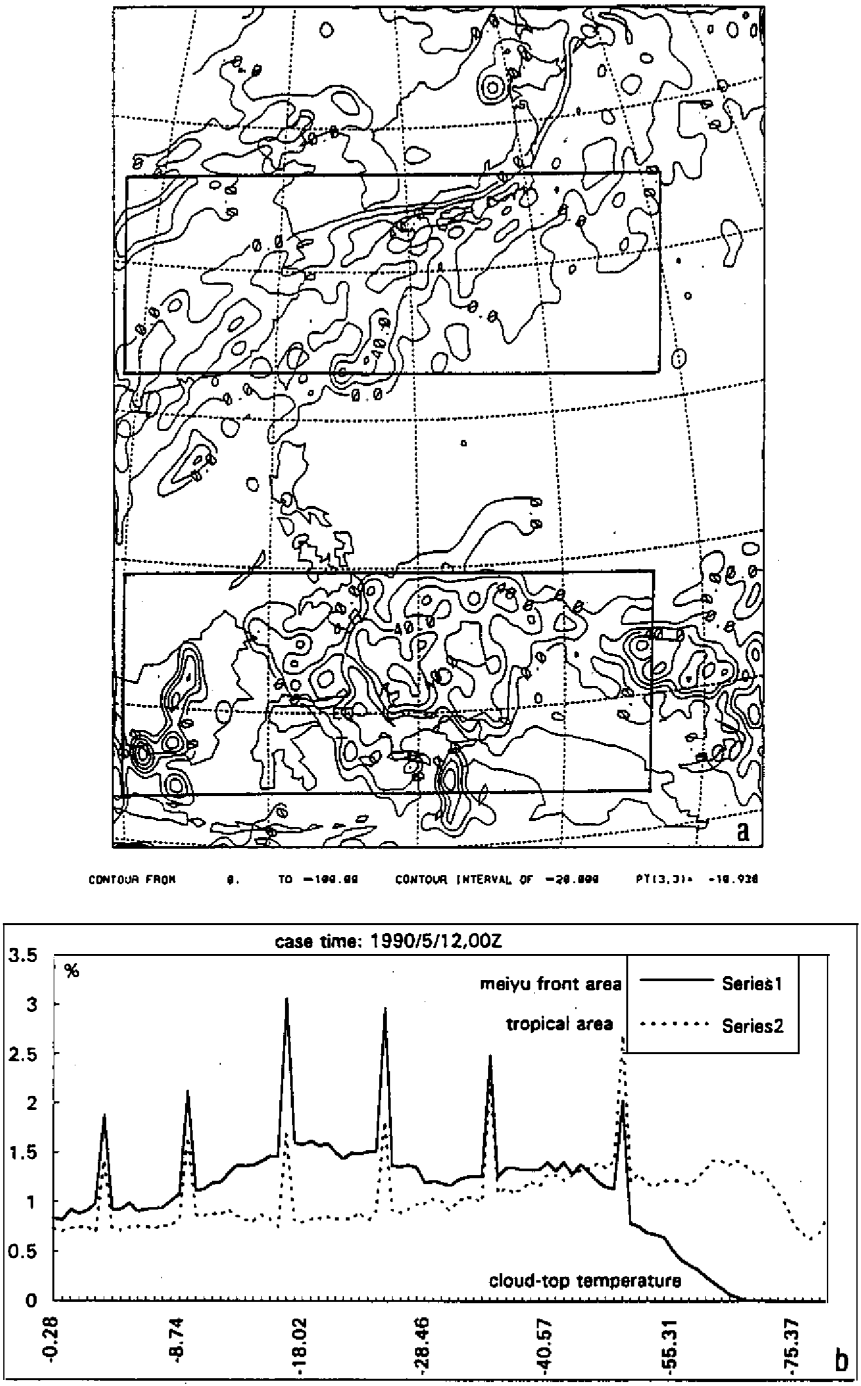

Fig. 3. (3.a) Two areas were chosen from the same image of case (1.a). The upper area covered Mei-Yu front region. The lower area covered ITCZ. (3.b) shows the radiance distributions of two areas. Solid line represents the Mei-Yu region and dotted line represents ITCZ.

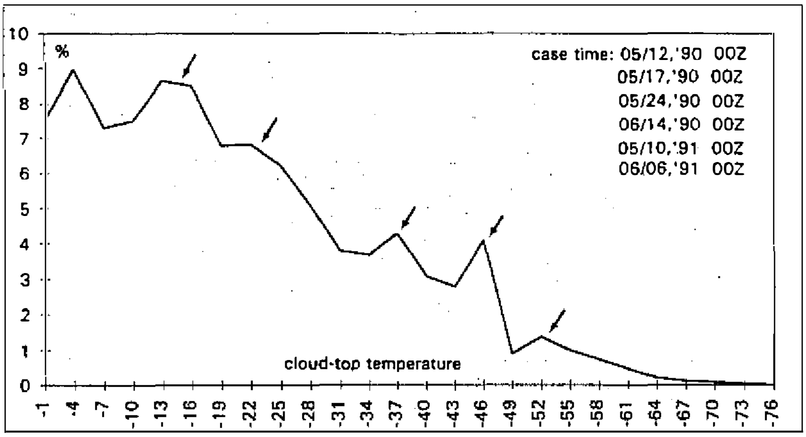

Fig. 4. The composited histogram of cloud-top temperature for six Mei-Yu front cases. The systematic errors, marked by arrows, dominated the picture.

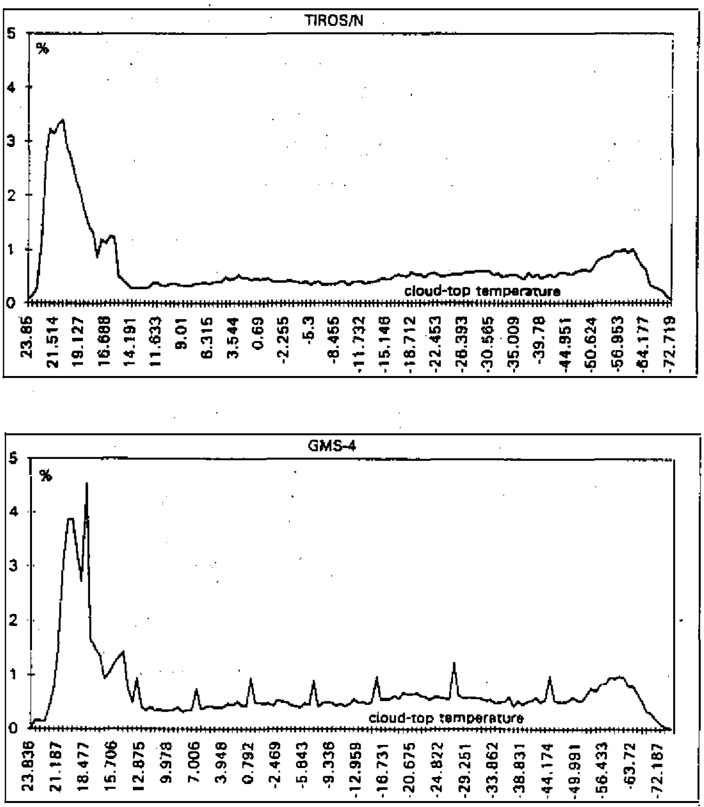

Fig. 5. The statistical analysis for TIROS-N/NOAA Series (in dotted line), comparing with the GMS (in solid line) analysis. The polar orbiting satellite, using the more advanced instrument AVHRR, seems to be free of alising errors.

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