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# TIME-CUMULATED VISIBLE AND INFRARED HISTOGRAMS USED AS DESCRIPTOR OF CLOUD COVER

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**ABSTRACT**

To study the statistical behavior of clouds for different climate regimes, the spatial and temporal stability of VIS-IR bi-dimensional histograms is tested. Also, the effect of data sampling and averaging on the histogram shapes is considered ; in particular the sampling strategy used by the International Satellite Cloud Climatology Project is tested.

## I - INTRODUCTION

Meteorological satellites allow a quasi-continuous observation of the cloud cover over the globe. These observations provide an opportunity to study the behavior of clouds on space and time scales that have been inacessible from ground based and other platforms and a better comprehension of the cloud characteristics associated with different climate regimes. However, interpretation of satellite measured radiances in terms of cloud physical properties is not straightforward. From the radiance images, some descriptors must be defined to characterize the different cloud cover properties. Several studies have looked to the distribution shape of the VIS-IR bidimensional histograms and shown that one cloud type can be related to a specific histogram shape.

The aim of this study is to test the spatial and temporal stability of the characteristic shape of radiance histograms for given climate regimes and to study the effect produced by sampling (as in the International Cloud Climatology Project ; Schiffer and Rossow, 1985) or averaging the radiance data.

## II - THE DATA

Data used are the VIS and IR Meteosat images at 12 GMT from the 15 July to 10 August. The resolution is 5 km at the subsatellite point. The radiometric resolution is 64 levels (counts) in VIS and 128 in IR, which is equivalent to 2% in reflectivity, 1 K in temperature for surface temperature and 2 K in temperature for high cloud.

Seven areas have been specially studied. They were chosen to be representative of some main climate regimes (**Fig. 1**) : North Africa (1), Europe (summer) (4), North Atlantic (summer) (5), South Tropical Atlantic (6), Sahel (7), Central (tropical) Africa (8), Tropical Atlantic (9). The size of these areas is (120 x 240) pixels, which corresponds to 5 degrees in latitude and 10 degrees in longitude at the subsatellite point. Histograms have been constructed for regions of (60 x 60) pixels (2.5 x 2.5 degrees), (60 x 120) pixels (2.5 x 5 degrees), (90 x 180) pixels (3.75 x 7.5 degrees), (120 x 240) pixels (5 x 10 degrees), centered on these areas.

From these data, that we call FULL resolution data, two other data sets with reduced spatial resolution have been built : (1) data sampled to 30 km spacing (called sampled B3 ; similar to the ISCCP data set) by taking one line out of 6 and one pixel out of 6, and (2) data averaged to 30 km resolution (called averaged B3) by averaging radiances on (6 x 6) pixel subregions.

## III - TIME-CUMULATED VIS AND IR HISTOGRAMS

One of the most important ways to illustrate the characteristic distribution of radiances observed in a particular region is with the two dimensional histogram formed by counting the frequency of occurrence of every pair of VIS and IR radiances. These histograms can be considered to represent the VIS and IR band spectral characteristics of clouds and surfaces for the considered area. These VIS-IR distributions have been used as part of several techniques to identify clouds in satellite images ; typical histogram shapes corresponding to the main kind of clouds have also been described in several studies (Platt, 1982 ; Rossow et al., 1985 ; Desbois et al., 1982 ; Sèze and Desbois, 1986 ; Simmer et al., 1982 ; Arking and Childs, 1985).

The histograms can also be used to study the variation of radiances in time for a given area (Sèze and Desbois, 1986). The results presented here support the idea that different climate regimes, associated with different cloud types, are characterized by particular patterns in the histograms that are consistent over time. This idea is illustrated in **Fig. 2**, where the VIS-IR histograms cumulated over 17 days for two of the 7 regions defined in Part II are shown. In this figure, the cumulated histogram for the South Tropical Atlantic region (region 6) shows a very small IR radiance variation, but significant VIS radiance variation, which is characteristic of low-lying stratocumulus over the sea. The histogram for the Central (tropical) Africa region (region 8) shows large dispersion in both the VIS and IR, which is characteristic of a mixture of high, middle, low level clouds in convective regime over land.

Looking at these cumulated histograms, it is clear that all possible radiance values in the VIS-IR radiance space are not observed in any one region, and that, depending on the area, these histograms are more or less dispersed. As a measure of histogram dispersion, we have used the percentage of the total possible radiances occurring in each histogram. For a radiometric resolution of 64 counts in VIS and 128 counts in IR (giving 8192 possible radiance pairs), the percentage of points occupied in region 6 histograms is typically 3.5 % and in regions 8 it is 24 %. To study the stability of these histogram shapes, we have built VIS-IR histograms for each area for individual days, then cumulated over 2, 3, 4, ... 17 days, and then computed for each of these histograms the percentage of total possible points occupied in the VIS-IR space (**Fig. 3**).

For the different areas these percentages show generally that, after 5 to 10 days, the area occuped by the cumulated histograms in the VIS-IR radiance space is relatively constant ; in other words, the percentage of new VIS-IR radiance pairs appearing in the studied area after 5 to 10 days is small (0.4 % for region 6 and 1.3 % for region 8 after 10 days). However, in some cases this percentage can suddenly increase on a specific day if a rare event happens, such as cirrus over the Sahara (Fig. 3, region 1) or cirrus over the stratocumulus area.

The stability of these cumulated histogram shapes over various sized regions has also been tested by varying the size of the studied area from (60 x 60 pixels) to (120 x 240) pixels. Decreasing the size does not change the shapes ; but increasing the size can change the shape for certain areas due to a change in the climate regime (e.g., the Sahara area near the edge of the ITCZ). This last remark stresses the importance of the location and size of the area chosen for histogram analysis.

## *IV - COMPARISON OF HISTOGRAMS WITH DIFFERENT SPATIAL RESOLUTION*

These time cumulated VIS-IR radiance histograms appear to be a good desciptor of different climate regimes ; hence, it is important to study the effect on these histogram shapes produced by a reduction in the spatial resolution of the data, as with the sampling applied to the ISCCP data.

For the two reduced resolution data sets defined in part I (sampled B3, averaged B3), mono- and bi-dimensional histograms have been built and compared with the FULL resolution histograms. In **Fig. 4**, mono- and bi-dimensional histograms at full resolution are shown for a particular day in region 4, overlayed by the corresponding histogram for sampled B3 resolution (dark dots). In this figure mono-dimensional histograms are normalized by their mode value. In the bi-dimensional histogram, the lower frequencies are in darker gray shades and the higher frequencies in lighter gray shades. The sum of frequences contained in the dark area represents 20 % of the total population as the sum of frequencies in the light area represent 80 %. Comparisons of the histograms were performed for the 7 regions over different time periods and different sized areas. Typically, these results show a good correspondance between FULL and sampled B3 histograms in their high frequency parts, but some discrepancies in their low frequency parts as shown in Fig. 4.

A way to qualify the discrepancy between these histograms is to compare the percentage of radiance position in the VIS-IR space occupied by each of these histograms, as in Part II. **Fig. 5** shows for region 8 how the ratio between the percentage attained for sampled B3 and FULL resolution histograms increases when the are size and length of the time period increase. For comparison of histogram shapes, we have also used the sum of absolute value of the frequency differences between the FULL and sampled B3 histogramms (differences computed for each VIS-IR radiance point in the histograms). In **Table 1** is shown how these differences decrease as the number of days increases (for 1, 5 and 10 days) and how these differences depend on the size of the region. Similar results are found when increasing the time period is replaced by increasing the area size.

For the mono-dimensional histograms, characteristic quantities, such as the mode radiances, mode frequency, mean radiances, radiance variances, and the minimum and maximum radiances, have been compared. For the modes, mode frequencies, means, and variances, good agreement is found ; this agreement generally improves with increasing time period and area size. For the minimum and the maximum radiance values, however, if the time period or area size is too small, large differences can appear. On the other hand, comparison of results obtained for averaged B3 histograms versus FULL resolution histograms shows a much poorer correspondance than between FULL and sampled B3 histograms, especially when the time period or area size is larger.

## V - CONCLUSION

The time-cumulated histogram shape is clearly a meaningful statistic that distinguishes among different climate regimes (by the cloud types that can be defined by the histograms themselves) (**Fig. 6**). Further this characteristic is relatively constant for spatial scales up to about 500 - 1000 km. The ISCCP B3 data, which have been sampled from higher resolution images, can replicate the full resolution histogram shapes if the area and/or time period used to construct the histograms are sufficiently large. Further studies must be pursued for longer time scales (1 to 2 month) and for different seasons. Interpretation of these shapes in terms of physical cloud properties and variability has to be developed, as does the relation with the types of clouds defined by ground-based cloud climatologies.

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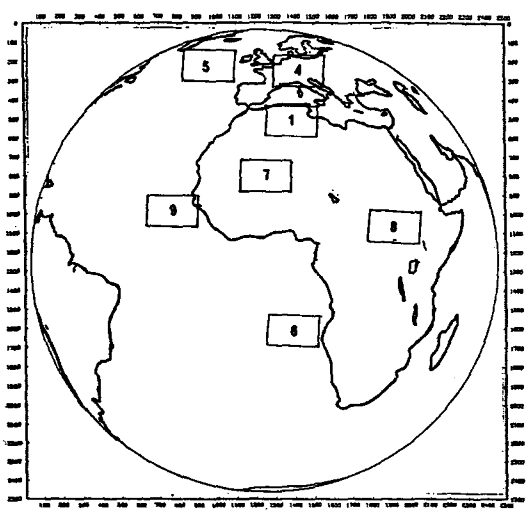


**Figure 1**

Schematic map showing Meteosat view, indicating continents and special case study regions.

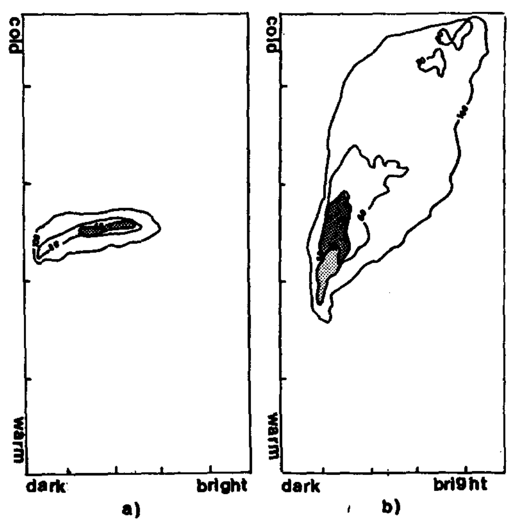


**Figure 2**

Time cumulated histograms on 17 days :
a) for region 6 over south tropical atlantic. b) for region 8 over Central Africa.

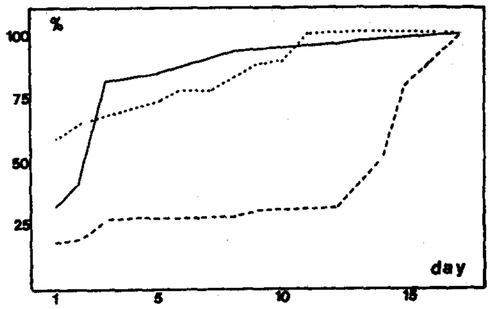


**Figure 3**

Ratio between percentage of radiance occupied for a n-day cumulated histogram and percentage of radiance occuped for the 17 days cumulated histogram, for region 8 (solid line), for region 6 (short dashed line), for region 7 (long dashed line).

| Day | Tropical Atlantic | Central Africa |
|---|---|---|
| 1 | 48 | 52 |
| 5 | 39 | 37 |
| 10 | 31 | 29 |
| | **Sahel** | **South Tropical Atlantic** |
| 1 | 35 | 22 |
| 5 | 23 | 14 |
| 10 | 20 | 11 |

**Table 1**

Sum of the absolute values of frequency differences between FULL resolution and sampled B3 histograms for histograms cumulated on 1, 5, 10 days and 4 different regions.

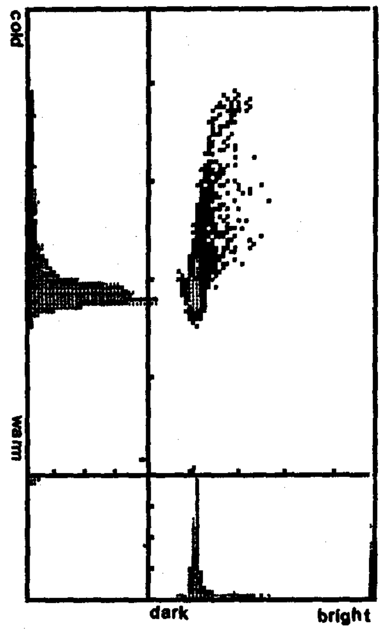


**Figure 4**

Mono and bidimensional full resolution histograms overlayed by sampled B3 histograms (dark dots) for region 4 over Europe the 27 of July.

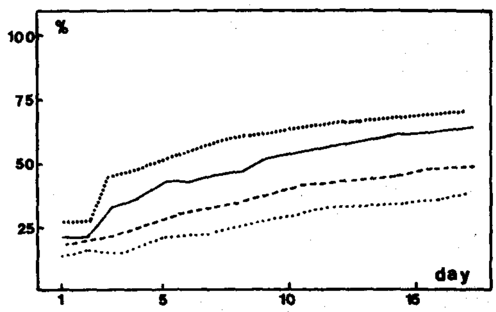


**Figure 5**

Ratio between percentage of occuped radiance in the sampled B3 histogram and percentage of occupied radiance in the full resolution histogram for different time scale and size area for region 8 over Central Africa.
Size box : (60x60) = short dashed line, (60x120) = long dashed line, (90x180) = solid line, (120x240) = dot line.

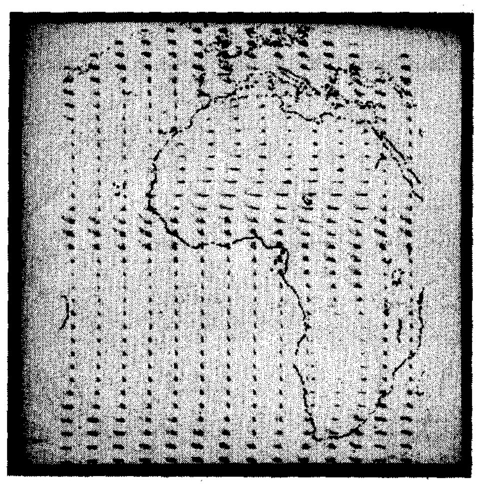

**Figure 6**

Meteosat map where is plot for each (60x120) pixel box the corresponding sampled B3 (VIS.IR) bidimensional histogram cumulated on 17 days.