An Examination of the Reliability of Densitomeric Analysis

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Abstract

This paper demonstrates that the reliability of densitometric analysis is very sensitive to the quality of the data to be fed into the analysis device and to the mechanical ability of the device. It is also found that unsatisfactory quality is caused mainly by the lack of a uniform assignment of densities.

1. Introduction

Semi-quantitative analogue data analysis is widely applied in many countries using densitometric measurments and enhancement techniques, e. g. Streten and Kellas (1976), Browner et al. (1977), and Corbell et al. (1976). A densitometric data analysis is performed as part of the daily analysis sequence in the Analysis Division in Meteorogical Satellite Center (MSC) by using a device known as False Colour Data Analysis System (FCDAS). The resulting analysis called the False Colour Data Analysis (FCDA) reveals the characteristic features of clouds and their time change associated with disturbances in an area covering the Asian regions and the western North Pacific Ocean. The results of the analysis are utilized in the nephanalysis charts which are broadcast to neighbouring countries and the domestic weather service stations. Also, they are utilized in the Satellite Meteorogical Analysis Information (SMAI) which is sent to the Forecasting Division of JMA H. Q. for domestic applications. As these two media are the only ones through which the analysts of the Analysis Division in MSC are able to communicate the results of their satellite analyses, the presentation of the results is very important. FCDA is performed daily and its results frequently affect the analysis content in those media. In this context, the reliability of the results of FCDA must be kept within certain degrees of accuracy.

Recently, it has been pointed out that in a few cases the cloud temperaures obtained by FCDA are warmer than those shown in the original data of GMS. This suggests that the reliability of FCDA has declined and certain investigations are required. As possible sources of this temperature deviation seem to occur in the production of the data to be analysed and in the operation of the FCDAS device, the authors have carried out an examination of these two problem areas.

2. Characteristic features of FCDAS

FCDAS is one of the devices which enable

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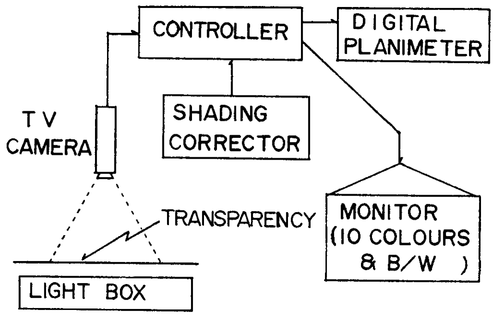

Fig. 1 A schematic diagram of FCDAS. Video-signals of a transparency brought through TV camera are mixed up with other signals in the controller and displayed on the screen as an enhanced imagery with 10 colours and B/W. The sum of areas occupied by one colour within a fixed area is obtainable in digital value of per cent.

us to achieve densitometric measurements and enhancement of analogue data. An examination described in this paper was achived by FCDAS (Fig. 1) which will display any analogue data wherein the information is represented by the optical densitometric variation. For the sake of simplicity and clarifying the reliability of operation work such as that in MSC, the following discussion will be confined to cloud analyses with ordinary positive IR transparency (POSIT) in routine work as the data to be fed into FCDAS.

The density assignment to temprature ranges on a POSIT is made by a full automated processor in accordance with signals of the Visible and Infrared Spin Scan Radiometer (VISSR). Principally, a certain temperature range must be exactly represented by a certain density value whenever and wherever VISSR signals within the temperature range are fed into the processer (Fig. 2).

A sequence of limited density values can be set within the full range of density values and subdivided equally into ten density steps within an appropriate density resolution.

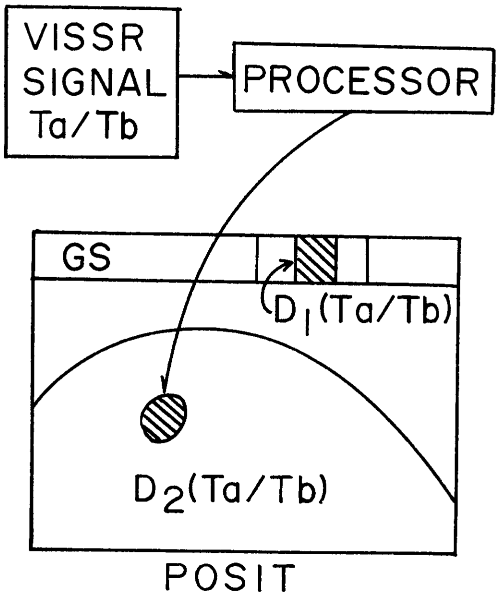

Fig. 2 The principle of the density assignment on POSIT, where D_i (T_a/T_b) is a density value corresponding to a temperature range between T_a and T_b. When the VISSR signal within that range is fed into the processor, density value of D_2 (T_a/T_b) must be assigned the same value as the standardised one of D_1 (T_a/T_b) in GS.

This density sequence is arbitrarily selected by an analyst of FCDA accorcing to the desired purpose. Ten sequential colours are assigned to each subdivided density step and black and white (B/W) are also allocated to all the other density values beyond the extremities of the ten density steps. Black and white are usually assigned respectively to the warmest and the coldest portions. within the assigned limits ten sequential colours are allocated to the ten subdivided density steps from the colder to the warmer limits, viz. cyanic blue (CY), dark blue (DB), light green (LG), orange (OR), yellow (YL), brown (BR), olive (OL), red (R), violet (V), and magenta (MG). An imagery enhanced by ten false colour (FC) and B/W then appears on the screen of FCDAS, and this can facilitate the analysis, with twelve discrete mosaics, depicting the fine structure of clouds. The calibration of temperature ranges represented by colours is made by reading colours on the "grey scale (GS)" which is attached on the top of a POSIT as standardised density values corresponding to given temperature ranges (see Fig. 4). The GS on a POSIT is composed of 19 grey scale elements which are called "grey step (or step)" in this paper and are employed as the unit of the discrete density (or temperature) differences in the following results and discussions.

FCDAS enables us to measure the sum of fractions coloured by one of ten colours in terms of the percentage within an arbitrarily fixed area of interest. The results of the measurements is defined as "percentage of areas" in this paper.

Such kinds of device as FCDAS are very sensitive to the lack of uniformity of the light box on which the data is put. FCDAS has a specially designed unit which is called a "shading corrector" in order to avoid misleading densitometric measurements caused by the abovementioned effect (see Fig. 1). Therefore, the "shading corector" must be operated prior to any analysis measurements.

3. Measuring Procedures

It is apparent that one of the best ways to proceed with the investigation is to carry out a comparison of enhanced imagery on the screen of FCDAS with corresponding IR digital data referred to in future as "the reference data". "The reference data" has about the same spacial and temperature resolutions as those of the corresponding enhaced imagery. The following two measurements were made.

(A) Comparison of temperature ranges

Table 1 Various measuring conditions (see the text). The measurements in all cases were made at the camera height of 19 cm from POSIT. Notations, C, M and W, in types of colour assignment correspond to those in Fig. 3.

Case	Data	Type of colour assignment	Camera height in colour assignment	Camera
I	00GMT 12th CT '78	C	59 cm	CAMERA 1
II	〃	C	19	〃
III	〃	M	59	〃
IV	〃	M	19	〃
V	〃	W	59	〃
VI	〃	W	19	〃
VII	〃	M	19	CAMERA 2
VIII	03GMT 30th JUN '79	M	19	〃

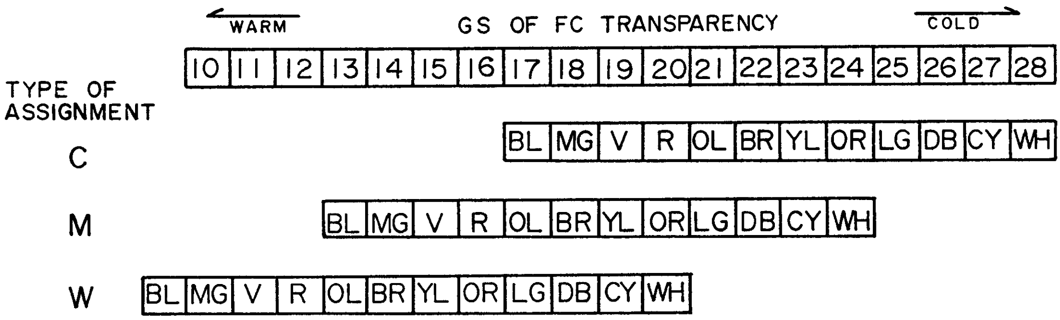

Fig. 3. Three colour assignments C, M and W correspond to three different colour assignments for colder, middle and warmer portions in GS.

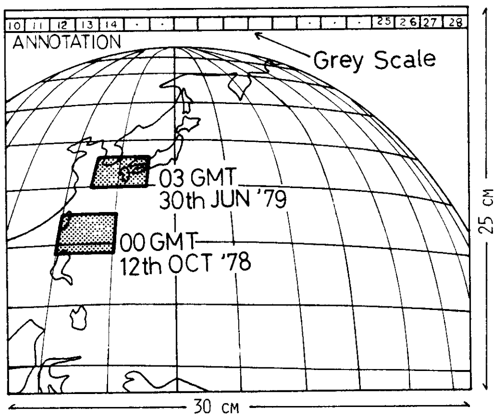

Fig. 4 Areas examined in this paper shown on an example of POSIT. Size of POSIT is about a quarter of HR-FAX full size transparency. GS is available from No. 10 to No. 28 which are enough for daily analysis.

(colours) on the FCDAS screen with those of the reference data at all the grid points within whole measuring areas (shown in Fig. 4).

(B) Measurment of the percentage of areas for all colours appearing on the screen within the same areas as in (A) and compare them with those obtained from the reference data.

The former measurement, (A), yields the average temperature deviation in FCDA, whilst the latter one, (B), tells us whether or not the density assignment on a POSIT was made correctly according to temperature ranges within the whole area of POSIT. If D_2 (T_a/T_b) in Fig. 2 where D_2 (T_a/T_b) is the density value corresponding to a temperature range between T_a and T_b, is different from D_1 (T_a/T_b) in Fig. 2, the shape of the percentage of areas over certain density steps (colours) shall not agree with that in the reference data within an acceptable degree of accuracy.

The abovementioned measurements were carried out for two cases within limited areas and under different measuring conditions depending on the quality of the input data (POSIT) and the mechanical ability of FCDAS (See Table 1 and Figs. 3 and 4). In this paper, three different series of ten grey steps were selected in warmer, middle and colder portions within the whole gray steps on a POSIT and the ten colours were then assigned to each series for the measurement. As seen in Table 1 and Fig. 3, these series are named C, M and W, respectively. It is expected that different results will occur in each measurment when the γ-curve* is unsatisfactory. Camera height above the light box corresponds to magnifi-

* The relationship between density values and density step numbers. An idealised one is not a curve but a line in most portion.

cation of the imagery on the screen. Different camera heights in assigning colours are also taken into account because of the suspicion that the sensitiveness of the camera is different at different heights i. e. at different light strengths. In the present case, the measurements were all made at a camera height of 19 cm from the light box. Two cameras were used in the measurements. Camera 1 was very sensitive to the light and only used for a short period during maintenance of Camera 2 which is less sensitive and used normally in routine work.

4. Results and Discussion

The results of the measutement, (A) and (B) in the previous section, are shown in Figs. 5 and 7.

For measurement (A), a careful examination of Fig. 5 in reference to Table 1 reveals the following:

(a) The average deviation of temperature in grey steps ($\overline{\Delta L}$) is about 6—8 (20—28°K) on the screen by using Camera 1.

(b) The use of Camera 2 in lieu of Camera 1 can reduce the average temperature deviation by 2—3 (7—10°K).

(c) The smaller deviation always occurs with the camera height at 59 cm in colour assignment rather than at 19 cm.

(d) The colour assignment to the colder temperature range (C in Teble 1 and Fig. 3) results in larger deviations than for the other temperature ranges.

The temperature deviation on the screen is quite large as in item (a). Fortunately, possible deviation is reduced to about 5 steps (18°K) in operation because the Camera 2 is usually used routinely as mentioned before. The result, (c), suggests that the sensitivity

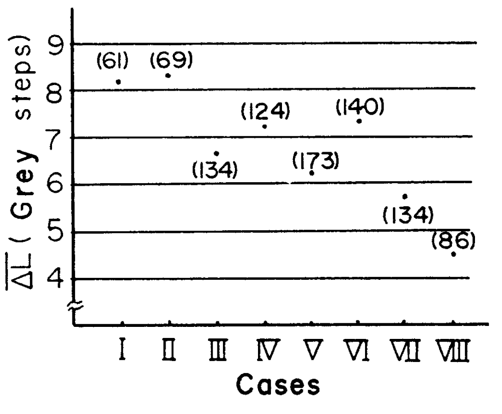

Fig. 5 Mean temperature deviation measured in grey steps at all the points in the areas examined. Numerals in brackets are sampling numbers for all ten colours. Difference of sampling numbers is due to no measurement available when B/W is at the points.

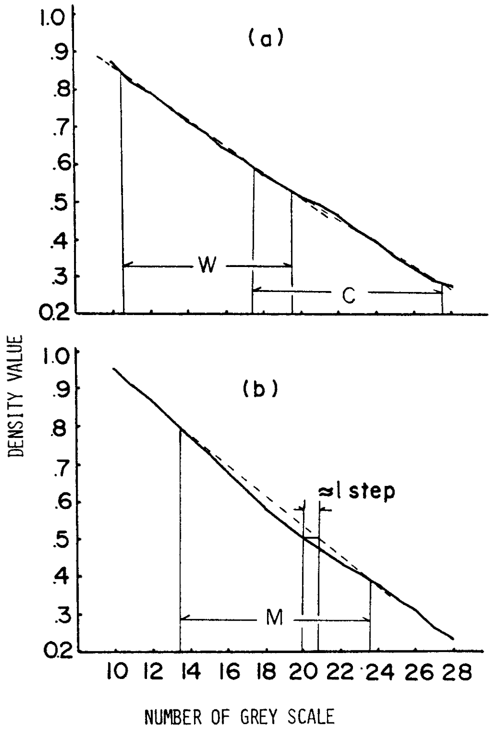

Fig. 6 γ-curves of POSITs in two cases. Heavy curves and dashed lines are actual averaged ones, respectively (C, M and W are the type of colour assignment). (a) 0000 GMT 12th October 1978, (b) 0300 GMT 30th June 1979.

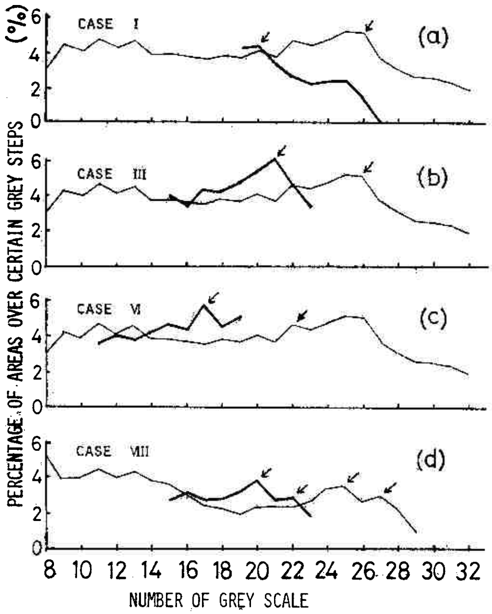

Fig. 7 Persentage of areas over certain grey steps in different cases. Heavy and thin lines are the measurements on the screen of FCDAS and on "the reference data".

of cameras changes at different strength of light. When Camera 1 is used the strong light has a tendency to amplify the mean deviation of temperature. The cause of the result, (d), is attributed to the inadequate local shape of γ-curve within the grey steps though the shape of γ-curve must be linear at least within certain grey steps being made the colour allocation.

Fig. 6 shows γ-curves in both cases examined in this paper. A γ-curve of POSIT on 0000 GMT 12th Oct. 1978 (Fig. 6(a)) is an example of a rather regularly shaped γ-curve. Even in such a good example, irregularity in the γ-curve still exists in the middle portion within the full range of the colour assignment C, whilst the γ-curve is approximately straight within the full range of another assignment W. For this reason, the average temperature deviation becomes

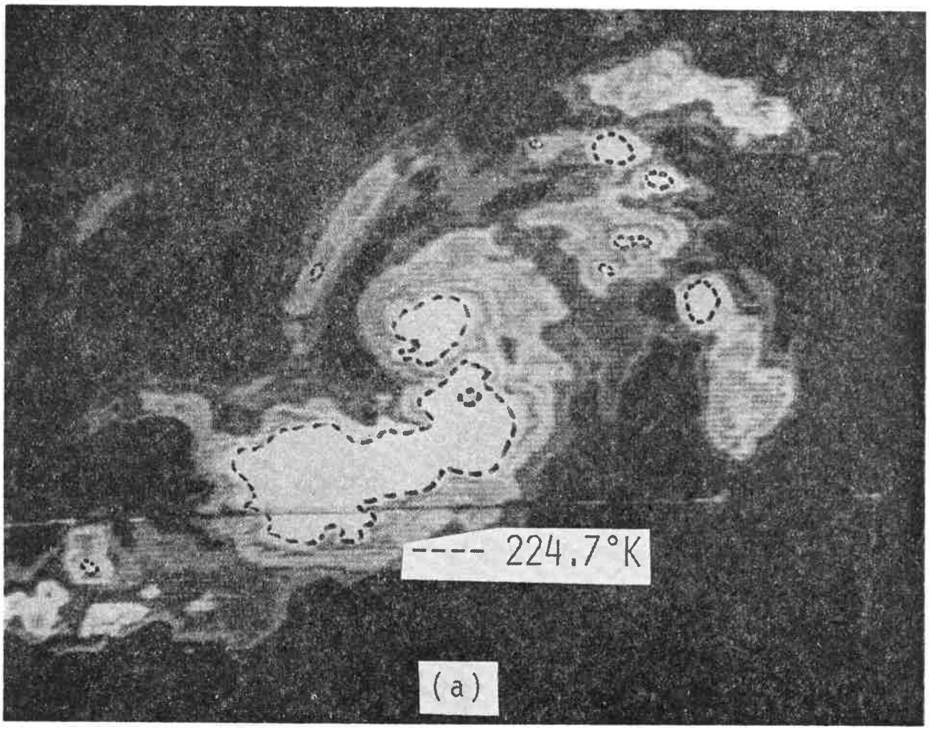

Fig. 8(a)

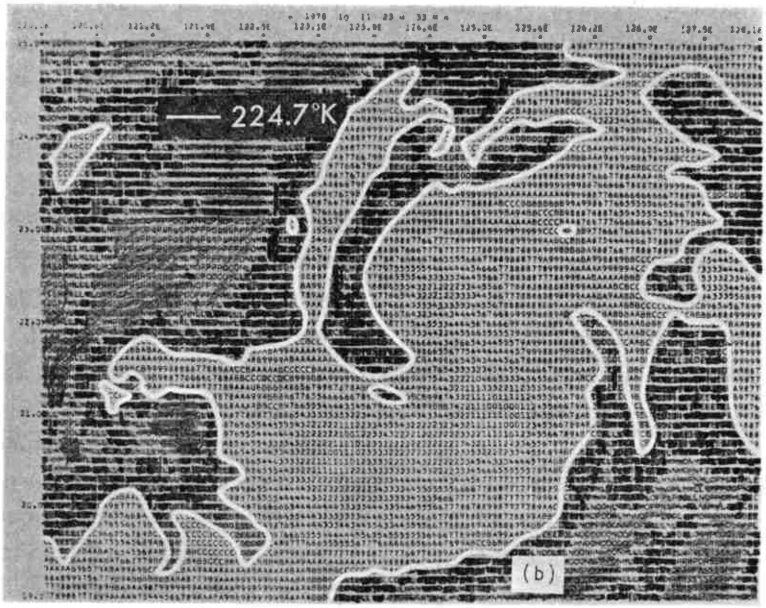

Fig. 8(b)

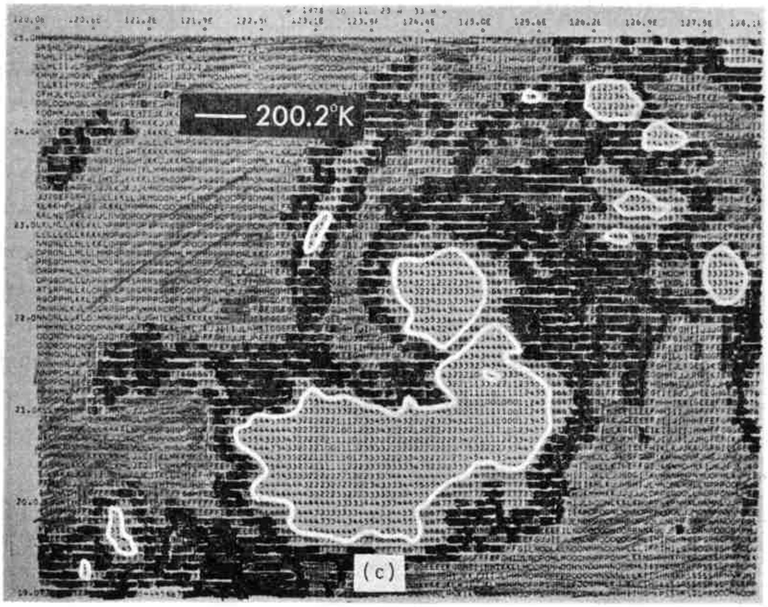

Fig. 8(c)

Cloud temperature patterns, in the case of Ⅳ in the table 1 and Figs. 5 and 6. (a) On the screen of FCDAS with black broken lines of 224.7°K, (b) On "the reference data" with white lines of 224.7°K, (c) Same as in (b) except for white lines of 200.2°K. Patterns of (a) are very close to those of (c) representing warmer temperature patterns observed on the screen.

larger in the colour assignment C than in the colour assignment W. Fig. 6(b) shows also the γ-curves for another case study, which exemplifies an irregular one which has a remarkable concave shape in the middle of the curve. It is expected that the negative deviation by about one step will occur on the screen if colour assignment M is applied in densitometric measurment.

The results of measurment (B) are shown in Fig. 7 and are described as follows:

(e) Fine and heavy lines in all the cases are approximately parallel to each other.

(f) Heavy lines are shifted towards warmer temperature ranges by about 5—7 steps in (a), (b) and (c) and by about 5 in (d).

These results are quite agreeable with the results previously obtained in the measurement (A), qualitatively and quantitatively. The most remarkable feature to be mentioned is that the tempurature deviation in the former measurement $(\overline{\Delta L})$ is strongly suggestive of being systematically generated and considered as a "bias". Shapes of fine and heavy lines in Fig. 7 also show that data examined in this paper are generally distributed rather evenly from colder temperature ranges to warmer temperature ranges, indicating that the measurements and results in this paper are not made under special data so that the results are reliable.

Fig. 8 is one of the examples showing temperature patterns on the screen of FCDAS and on the reference data in this case that of IV in Table 1 and Fig. 5. when thermal pattern in Fig. 8(a) is compared with that in Fig. 8(b) with reference to a given isotherm of 224.7°K the discrepancy between them is revealed remarkably. On the other hand, the pattern encompassed by isotherms of 200.2°K on the reference data in Fig. 8(c) is quite similar to the one in Fig. 8(a). The temperature deviation in these patterns is almost 24.5°K wich is about equivalent to 7 steps in GS. These results confirm the previous results in both measurements (A) and (B).

H. Koba (1979) investigated the quality of HR-FAX transparency which is the original data of POSIT and found that a density value D_i (T_a/T_b) is gradually changed along N-S direction but only a little in W-E direction. The N-S change of the density is proportional to the distance from the top of the transparency where GS is attached. The increment of D_i (T_a/T_b) is about equivalent to 3 steps of GS over the regions where the measurements were carried out in this paper. Therefore, even if ten colours are assigned to the standardised density values on GS correctly, colours representing colder temperature ranges do not appear in the southern regions of interest wherever there exist very cold clouds. This is considered as the main reason to the systematic temperature deviation mentioned as "the bias".

In addition to this, two minor reasons for the "bias" exist in the FCDAS. One is the change of the sensitivity with the strength of the light and another results from the burned-out of the camera (NAC's manual for FCDAS). Each of them is attributed to about one step deviation of temperature.

5. Concluding remarks

An attempt has been made in this paper to quantitatively diagnose the causes of the temperature deviation although these various causes are actually integrated on the screen. It is concluded that the reliability of the densitometric analysis is greatly affected by the quality of the data and the ability of the analysis device.

As for the FCDA in MSC, the follwing

items should be taken into account as fundamental information for the analysts/researchers.

1. Cloud top temperatures are altogether 5 steps (~18°K) warmer than IR digital data in middle latitudes.
2. The 3-step deviation out of 5 results from the degraded quality of the data.
3. The remaining 2 steps are attributed to the mechanical difficulties of the device.

The reliability is less affected by item 2 when we measure on the approximate temperature change of cloud systems associated with disturbances moving only zonally in either westerly or easterly directions. Unfortunately, many other disturbances occur with predominant meridional components of movement and there are operational and research requirements to measure more precise cloud top temperatures and their temporal changes without the use of IR digital data. In this case, reliability of the measurements will be adversely affected by the errors caused by item 2. Therefore, the cause of item 2 must be strictly reduced in the earlier stages i.e. in the production of the data in the photographic system because this kind of deficiency has been integrated in the whole photoprocessing system and has never been compensated in any way. The other cause of item 3 must be also suppressed in the design stages and the maintenance stages of the device.

The abovementioned causes of the lower reliability of densitometric analysis would commonly be found in any other analysis system such as the one in MSC which was examined in this paper. Therefore, all the analysts/reserchers who want to use such analysis method as those investigated in this paper should always be aware of those causes prior to the analysis.

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References

Browner, S. P., W. L. Woodley and C. G. Griffith (1977): Diurnal oscillation of the area of cloudiness associated with tropical storms. Mon. Wea. Rev., **105,** 856-864.

Corbell, R. P., C. J. Callahan and W. J. Kotsch, Ed. (1976): The GOES/SMS User's Guide. (Amendments issue) NOAA and NASA.

Koba, H (1979): Personal communication. In printing.

NAC (1976): Manual for the Colour Data System 1200 B.

Streten, N. A. and W. R. Kellas (1975): Some applications of simple image analysis techniques to very high resolution satellite data. Australian Met. Magazine, **23,** 7-19.