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Cloud Motion Winds from FY-2 and GMS-5 Meteorological Satellites

Summary and purpose of paper

Cloud Motion Winds (CMW) from FY-2 and GMS-5 meteorological satellites were calculated. The algorithm was described in the previous paper "Calculation of Cloud Motion Wind with GMS-5 in China" presented at the third international winds workshop. The test operation showed that one of the major errors came from inappropriate height assignment. To reduce height assignment error, the following modifications to the algorithm were made:

1. Further distinction between high and low level clouds was achieved by correlation analysis between IR and WV measurements in tracer regions.

2. For GMS-5 CMWs, brightness temperature (BT) difference of split window channels (BTDIR) was adopted as one of the thresholds for the distinction between high and low level clouds.

The above mentioned procedures improved the height assignments greatly. With the improved algorithm, FY-2 and GMS-5 CMWs were calculated. Error analysis was made.

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Abstract

Cloud Motion Winds (CMW) from FY-2 and GMS-5 meteorological satellites were calculated. The algorithm was described in the previous paper "Calculation of Cloud Motion Wind with GMS-5 in China" presented at the third international wind workshop. The test operation showed that one of the major errors came from inappropriate height assignment. To reduce height assignment error, the following modifications to the algorithm were made:

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1. Introduction

At the third international winds workshop, the authors submitted a paper "Calculation of Cloud Motion Wind with GMS-5 Images in China" (Xu and Zhang, 1996) which described an algorithm developed in National Satellite Meteorological Center (NSMC) China for CMW calculation. This algorithm has been put into operation for GMS-5 winds since Oct. 1996. The calculation results were compared with radiosonde data. The comparison showed that one of the major error sources came from inappropriate height assignment. The worst cases were found at places where high level winds were assigned as low, or vise versa. Thin cirrus clouds are good tracers. But some thin cirrus clouds are so thin that their BTs are almost same in magnitude as the one of low-level clouds. Thus, it becomes difficult to distinguish them.

In order to reduce errors caused by inappropriate height assignment, horizontal coincidence check and height adjustment methods were tested. Those procedures did not show ideal results. After careful exam to the data, a revised algorithm was achieved. This paper describes our approach to seek proper height assignment. Section 2 of this paper describes contribution from IR-WV channel correlation analysis. Section 3 refers to the utilization of split window channels of GMS-5 at height assignment. Section 4 compares our calculation results to the radiosonde observations.

2. Contribution of IR-WV Channel Corrections in Tracer Regions to Height Assignment

As described in the introduction of this paper, inappropriate height assignment is one of the major error sources for CMW calculation. Fig. 1 shows the scatter diagram of IR and WV

BTS at different cloud conditions (from Xu and Zhang, 1996). It gives an insight to the physical reason why it is difficult to distinguish thin cirrus clouds from low clouds. The explanation to Fig. 1 may be found in Xu and Zhang's paper (1996). In Fig 1. Cirrus clouds are located along a slope line, with dense cirrus at the down-left part, and thin cirrus at the up-right part; while low clouds are located along a horizontal line, with middle level clouds at the left part and lower clouds at the right part. For cirrus clouds, the more thinner (thicker), the further to the up-right (down-left) part along the slope line; for low clouds, the more lower (higher), the further to the right (left) part along the horizontal line. Since the thin cirrus clouds and low clouds are both quite close on the scatter diagram to the cross point of the slope line and the horizontal line which represents the surface. It becomes difficult to distinguish them.

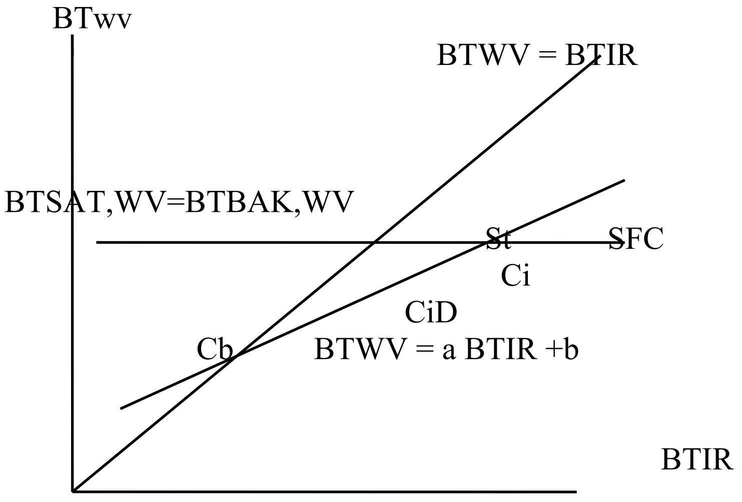
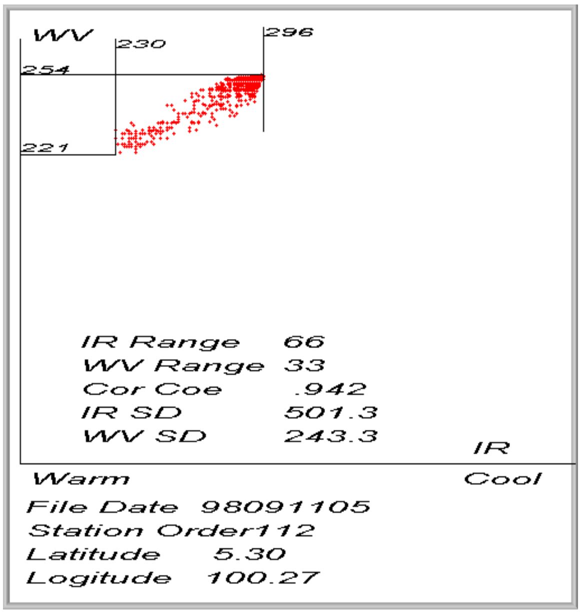


Fig. 1 Scatter diagram of IR and WV BTs at different cloud conditions (from Xu and Zhang, 1996)

Notice that when we make height adjustments with the scatter diagram. Only the coldest 5% BT or their adjustment values are used. The distributions of IR and WV measurements in the tracer regions are ignored. By examination to many cases, we mentioned that although extreme BT values of IR and WV in the tracer regions may not be sensitive in some cases to the distinction between high and low clouds, the distributions of them do have such ability. For tracers with high level clouds, IR and WV measurements have high correlation values; while such correlation values are very low for tracers with low level clouds. It is in the distribution of IR and WV measurements, in their relationship, there is information based on which we can make distinction between high and low level clouds. And the distinctions between high and low clouds consists of the majority of the height assignment. Correct allocation of cloud types (high or low), may reduce much error of CMWS, The examples are shown as below:

Fig. 2 is an example of high level clouds. This example is taken from FY-2 at 5.3 N 100.27 E 06Z 11 Sept. 1998. Fig. 2 a is scatter diagram of IR and WV BTS, Fig. 2 b is radiosonde diagram. Radiosonde observation was taken at 00Z. The IR (left) and WV (right) images in the tracer region, are at the top of Fig. 2 b. For this tracer, the correlation coefficient between IR and WV measurements is 0.942, The good relation between IR and WV measurements can also be noticed from IR and WV images. Their distribution patterns are quite similar. The radiosonde data verifies that the height assignment is correct. The wet level top shown at radiosonde diagram is at high level above 200 hPa.



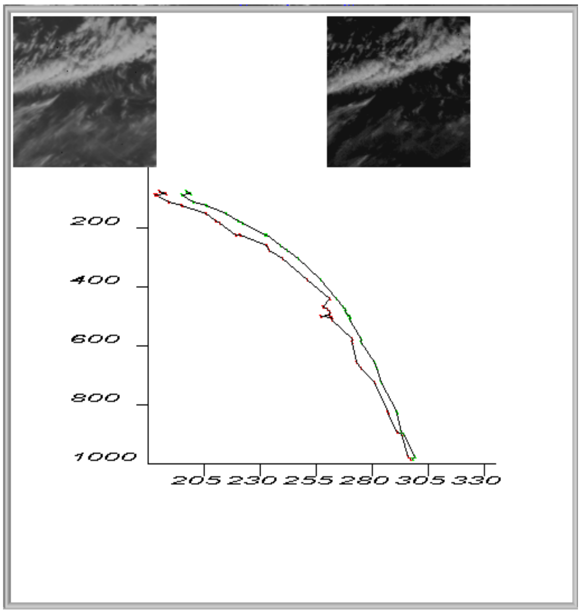
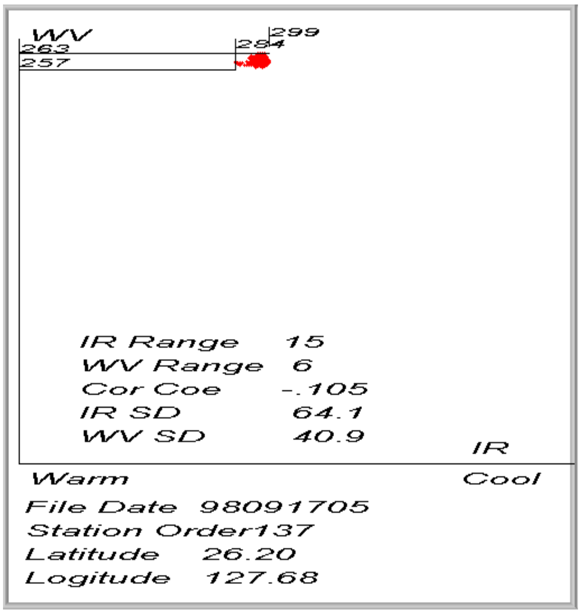


Fig. 2 scatter diagram of IR / WV measurements (a), radiosonde diagram and IR (left), WV (right) images (b), for a FY-2 tracer at 5.3 N 100.27 E 06z 11 Sept. 1998.

Fig. 3 is an example of low-level clouds. This example is taken from FY-2 at 26.2 N 127.68 E 06Z 17 Sept. 1998. The key for Fig. 3 is same as Fig. 2. For this tracer, the correlation coefficient between IR and WV measurements is -0.105. In Fig. 3, while the IR image of the tracer visuals low clouds, the WV image of the tracer appears very smooth. This indicates the absent of high level cloud in this tracer region. Radiosonde curve in Fig. 3 b verifies that the wet layer top is at low level around 850 hPa.



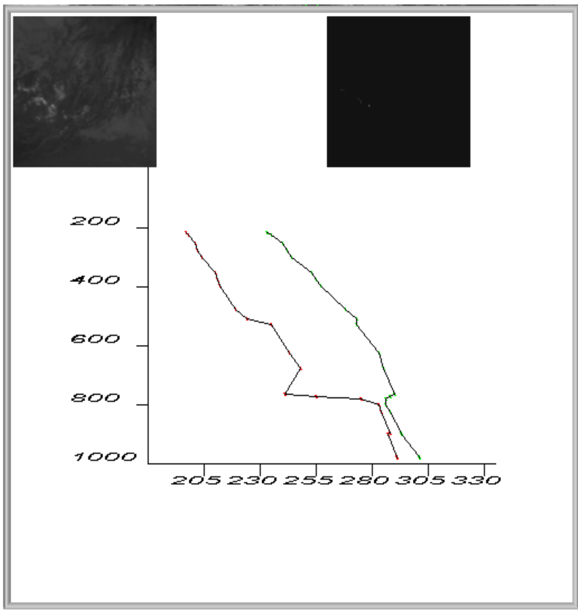


Fig. 3 scatter diagram of IR / WV measurements (a), radiosonde diagram and IR (left), WV (right) images (b), for a FY-2 tracer at 26.2 N 127.68 E 06Z 17 Sept. 1998.

The above case study shows that correlation between IR and WV measurements can be used to distinguish tracers with high level clouds from the ones with low level clouds. After examination to a big amount of tracer data, the following thresholds were adopted in our new algorithm:

Threshold 1: Tracers with correlation between IR and WV measurements greater than 70% should perform height adjustment procedure. Those are normally high level clouds .

Threshold 2: Tracers with correlation between IR and WV measurements less than 30% should not perform height adjustment procedure. Those are normally low-level clouds.

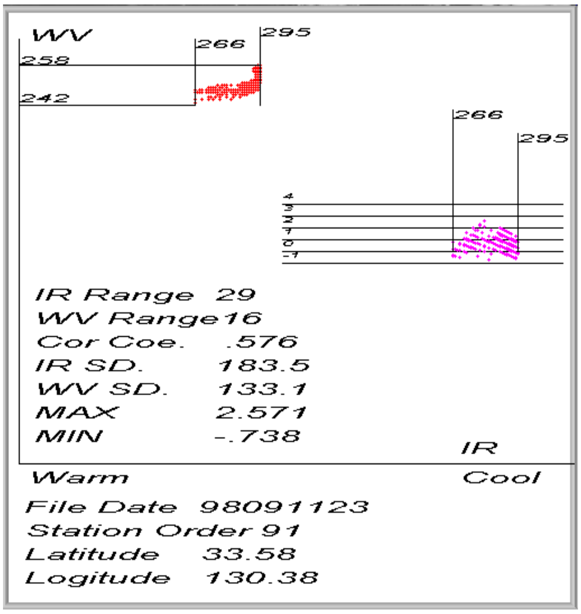
IR-WV correlation with values between 70% and 30% are in a mixed region. Tracers with such intermediate correlation values are possible to be high, middle or low-level clouds. As we described in the previous paper (Xu and Zhang, 1996), slopes in WV-IR scatter diagrams have some ability to make the distinction. Those are:

Threshold 3: Tracers with IR-WV correlation between 70% and 30% and with slope at the WV-IR scatter diagram less than 0.1 should not perform height adjustment.

Threshold 4: Tracers with IR-WV correlation between 70% and 30% and with slope at the WV-IR scatter diagram greater than 0.1 should perform height assignment.

3. Contribution of BTDIR in Tracer Region to Height Assignment

When individual data were examined, it was noticed that among the tracer group which fit threshold 4, some are thin cirrus clouds, some are low level clouds, inappropriate height assignments still exist. Fig. 4 and Fig. 5 are examples. Fig. 4 is taken at 33.58 N 130.38 E, 00z 12 Sept. 1998, Fig. 5 is taken at 27.08 N 142.17 E, 00z 12 Sept. 1998. They are both from GMS-5 images. The keys for Fig. 4 and Fig. 5 are same as Fig. 2, except IR/BTDIR scatter diagram and split window channel difference image BTDIR are contained.



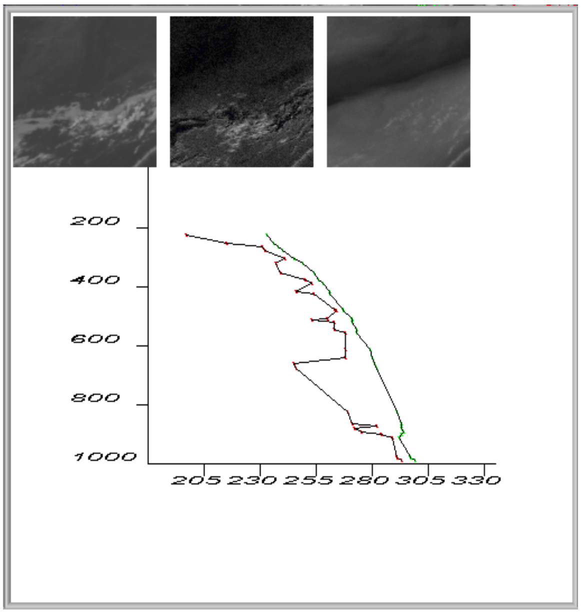


Fig. 4 scatter diagrams of IR / WV(up left) and IR / BTDIR (down right) measurements (a), radiosonde diagram and IR (left), BTDIR (middle) WV (right) images (b) for a GMS-5 tracer at 33.58 N 130.38 E, 00z 12 Sept. 1998.

From IR and WV images in Fig. 4b, we may judge that the tracer in Fig. 4 contains high clouds. The thin cirrus clouds are both apparent at IR and WV images. From IR and WV images in Fig. 5 a and b, we may judge that the tracer in Fig. 5 contains middle or low clouds. The low clouds are visual at IR image, rather than at WV image. The correlation coefficients between IR and WV measurements are 0.576 and 0.6333 for Fig. 4 and Fig.5 respectively. Although the cloud heights are apparently shown at the radiosonde diagrams, based on the parameters from the image scatter diagrams, we unable to make distinguishment to heights of tracers in Fig. 4 and Fig.5.

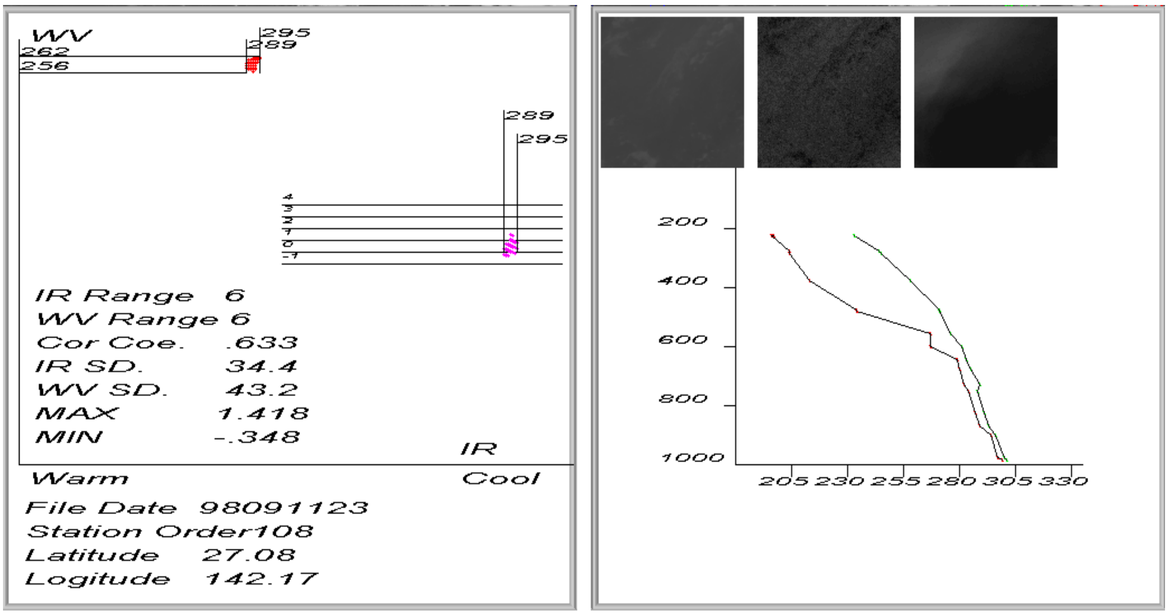


Fig. 5 scatter diagrams of IR / WV(up left) and IR /BTDIR (down right) measurements (a), radiosonde diagram and IR (left), BTDIR (middle) WV (right) images (b) for a GMS-5 tracer at 27.08 N 142.17 E, 00z 12 Sept. 1998.

Is there further information exist in the tracer images based on which we may make batter distinction between high and low level clouds? In our new algorithm, for GMS-5 data, BTDIR for split windows is adopted to improve the distinction. The reason why split window channels contain information on cloud heights may be explained as below.

Fig. 6 is BTDIR from GMS-5 at 17z 3 Sept. 1998. Fig. 6 shows that the BTDIR values are normally higher near the boundary of the major cloud systems where thin semi-transparent cirrus are usually exist, such as the boundaries of a tropical cyclone and cloud clusters in the image. In the region with low clouds, BTDIR values are lower. This phenomenon has been indicated by many authors, such as Inoue (1985), Parol etc (1991) Baum etc. (1994).

Fig. 7 a is an image taken from NOAA at 2036z 2 Aug. 1993. In this image, we take two small regions to make scatter diagrams of BTDIR to BTIR. Fig. 7 b is scatter diagram in sub region 1 (39.1-39.5 N 116.1-116.5 E) where high level clouds are exist. Fig. 7 c is scatter diagram in sub region 2 (42.5-43.0 N 117.8-118.5 E) where low clouds are exist. It is apparent that the BTDIR peaks are much bigger in magnitude for thinner high cloud region 1 (Fig. 7 b) than for low cloud region 2 (Fig. 7 c). The above case study shows that BTDIR may be used to distinguish tracers with high level cloud from the ones with low-level clouds. After many data are examined, the threshold 5 is supplemented to threshold 4 for GMS-5 CMW calculations (For FY-2 CMW calculations, threshold 4 is still used).

Threshold 5: For GMS-5 tracers that meet the condition of threshold 4, further exam to BTDIR should be performed. Those with BTDIR less than 1.9 K should not perform height adjustment.

Note that BTDIR values are normally small in magnitude at dense high cloud regions. This phenomenon may be noticed in Fig 6. But dense cloud region normally have high IR / WV correlation coefficients. They have already been classified into high cloud group by threshold 1.

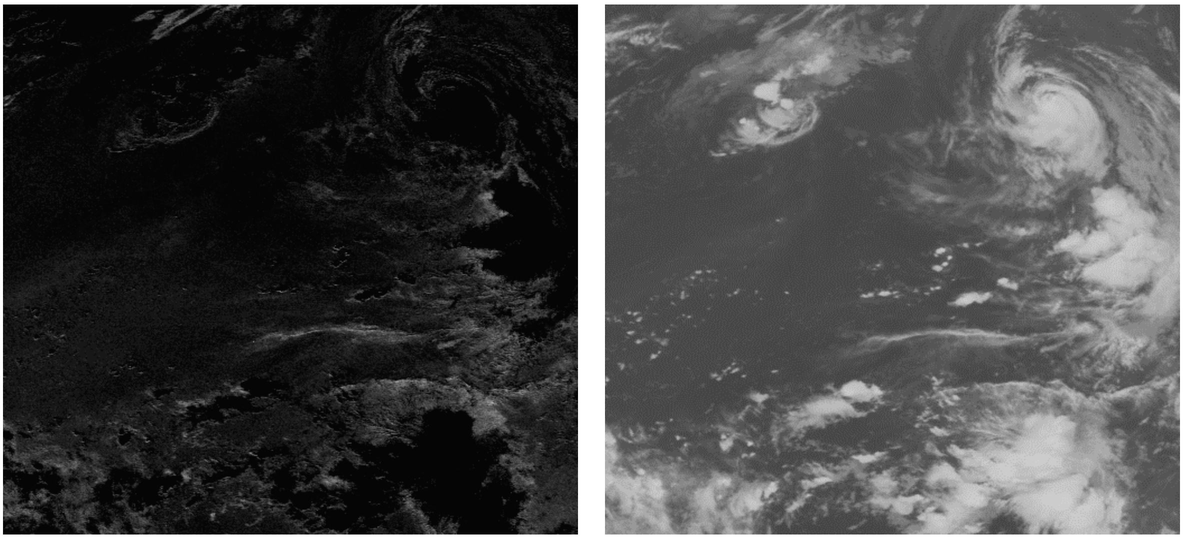
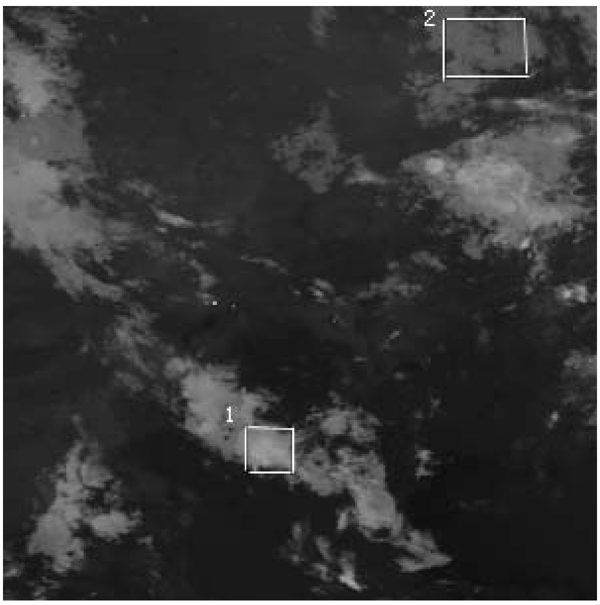


Fig. 6 BTDIR(a) and IR(b) images for GMS-5 at 17z 03 Sept. 1998.



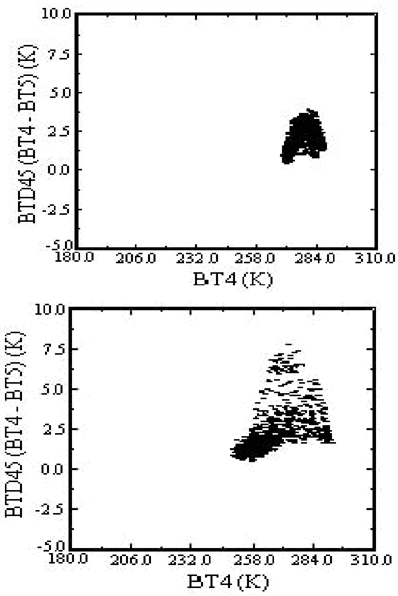


Fig. 7 a IR image from NOAA at 2036z 2

Aug. 1993,

b Scatter diagram of BTDIR- BTIR for high cloud region 1 in Fig. 7 a,

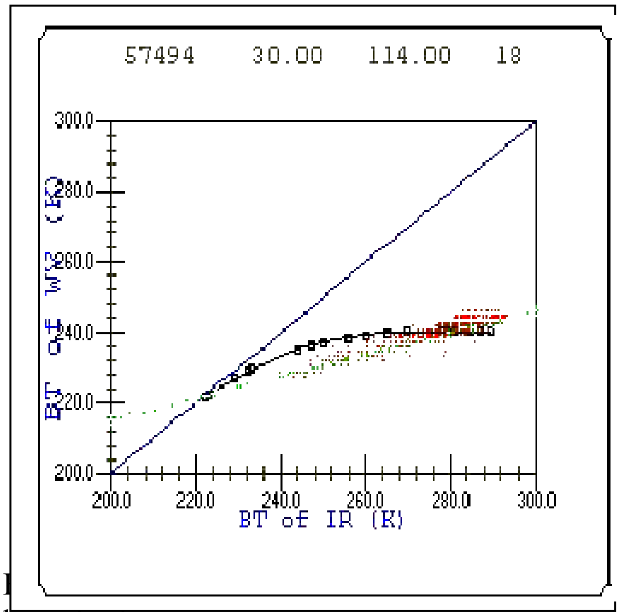
c Scatter diagram of BTDIR- BTIR for low cloud region 2 in Fig. 7 a.

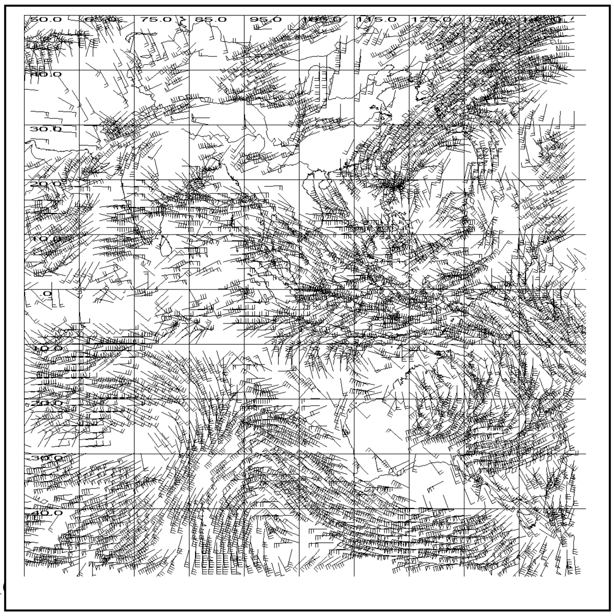
4. Discussion on Possible Error Sources of the Algorithm

The physical basis of our algorithm is laid on the linear relationship between WV-IR measurements in tracer region with high clouds that was first indicated by Schejwach (1982). From Fig. 1, we see that since the height adjustments are made based on the cross point of the two lines: BTWV= BTIR, and BTwv = BTIR＋b, the possible errors may be caused by one of the following two reasons:

1. Inappropriate expression of opaque cloud WV-IR BT relationship.

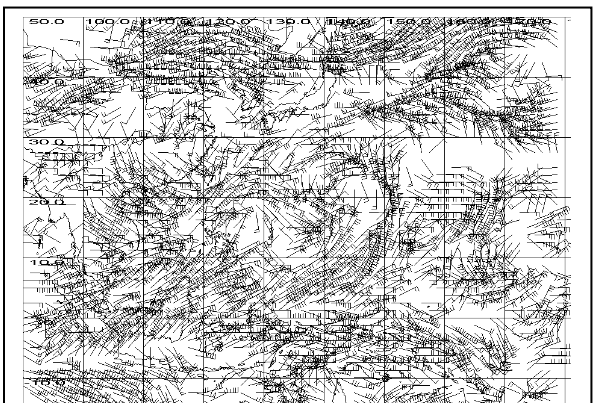
In our algorithm, we use BTWV=BTIR to express high opaque cloud BTIR-BTWV relationship. Schmetz etc. (1993) used numerical simulation calculation based on radiation transmission equation. In order to exam the difference of the two expressions, at places with radiosonde data, comparisons were made. Fig 8 is an example. Fig. 8 shows WV and IR measurement relationship (curve line) for different level opaque clouds calculated with lowtran-7, and BTWV=BTIR (straight line) which we use to express WV IR measurements relationship for opaque clouds at high levels. The comparison shows that at high levels where height adjustment values are usually located , the two lines are very close with each other. Such comparisons show that our hypothesis BTIR=BTWV may not cause big errors to the height assignments for high level clouds.





hypothesis.

Fig. 9 FY-2 CMWs at 06z 15 Oct. 1998



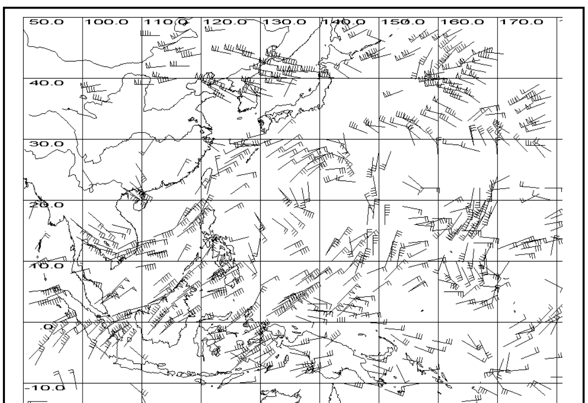


Fig. 10 GMS CMWs form NSMC at 00z 13 Sept. 1998.(left)
Fig. 11 GMS CMWs from the GTS at 00z 13 Sept. 1998(right).

2. Errors in statistical relationship BTIR = a BTIR +b.

Efforts made in this paper are attempted to reduce errors caused by the IR-WV statistical relationship. We suggest in this paper to use IR-WV correlation and BTDIR to judge if it is needed to make height adjustment. By doing so, the distribution of cloud motion winds become more reasonable. The following Figs show FY-2 CMWs (Fig.9), GMS CMWs form NSMC (Fig. 10) and GMS CMWs from the GTS (Fig. 11) .

Acknowledgment

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