Representative Heights of GMS Satellite Winds

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Abstract

Seasonal variation of the representative height of cloud motion winds derived routinely from GMS images is studied by means of comparing the cloud winds with nearby radiosonde winds over Northern Hemisphere.

A low-level satellite wind derived by man-machine interactive procedure of GMS Cloud Wind Estimation System (CWES) is compared with the radiosonde winds at 9 pressure levels (from 600 mb through 1000 mb at 50 mb intervals) reported by a nearby radiosonde station. As the result of the comparison, it is found that:

1) Through out the year, low-level satellite wind agrees with nearby radiosonde wind at 850 mb,

2) In winter, the satellite wind with the tracked cloud top height lower than 800 mb agrees with the radiosonde wind at 1000 mb as well as at 850 mb,

3) In summer, the satellite wind agrees with the radiosonde wind at any level lower than 700 mb, and

4) When the tracked cloud height is lower than 600 mb in winter or 700 mb in summer, the satellite wind agrees with radiosonde wind very well.

A high-level satellite wind derived by film-loop procedure of CWES is compared with the radiosonde winds at 9 pressure levels (from 500 mb through 100 mb at 50 mb intervals) reported from a nearby radiosonde station. As the result of the comparison, it is found that:

1) Over tropical region through out the year, the satellite wind agrees with nearby radiosonde wind at 200 mb,

2) Over extratropical region, it agrees with nearby radiosonde wind at 250 mb in summer, at 400 mb in winter and at 300 mb in spring or autumn, and

3) The boundary between the tropical region and the extratropical region mentioned above is the latitude of 35°N in summer or 25°N in other seasons.

On the basis of these results, new height assignment procedure of CWES was adopted and has been effective as from 12z, December 21, 1981, at Meteorological Satellite Center. According to the new procedure a height is assigned to the satellite wind as a wind representative level. The height for low-level wind is 850 mb, and for high-level wind varies seasonally and regionally. For further detail, see Hamada (1982). After that, the satellite wind data are compared with the radiosonde wind to get the difference between both winds. The results show that:

1) The difference is extremely smaller this time than a year ago, and

2) The difference is almost same as that of GOES winds derived by NESS.

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1. Introduction

Since April 6, 1978, Meteorological Satellite Center (MSC) has routinely derived cloud motion winds twice a day using GMS Cloud Wind Estimation System (CWES). CWES has three procedures for cloud tracking, which are MM-1*, MM-2 and FL procedure. The former two are man-machine interactive procedures and the latter is film-loop procedure as in Table 1. All vectors derived from these procedures are quality-controlled and transmitted to worldwide users through Global Telecommunication System (GTS). The processing of the CWES system is described in detail by Kodaira *et al.* (1981) and Hamada *et al.* (1978).

MM-1 procedure is used for deriving low-level satellite winds by tracking cumulus clouds and FL procedure is used for deriving high-level satellite winds by tracking cirrus clouds. MM-2 procedure is that for deriving low-level winds, but is little used routinely.

For low-level satellite winds, the cloud top height estimated from infrared image of a target cloud had been assigned to the wind until December, 1981. But the satellite wind does not represent the wind at the cloud top but that at the cloud base, as stated in several articles shown later.

For high-level salellite winds, climatological tropopause level (monthly mean) had been assigned as an estimated wind level to the wind until December 1981. But the satellite wind does not often represent the wind at the assigned level but at the lower level than that.

At the early stage of satellite wind derivation, Hubert *et al.* (1971) showed that a cumulus tracked wind represented the wind at 850 mb, by the introduction of the idea of a level of best fit (LBF) between the cloud motion and nearby radiosonde wind. On the other hand, for cirrus tracked wind, the LBF was 200 mb.

By means of aircraft observation of the cloud motion and ambient wind, Hasler *et al.* (1977 and 1979) verified that a trade cumulus over the tropical oceans would move with an ambient wind at cloud-base (900-950 mb), and that a cumulus over frontal region would move with the mean ambient

* An automatic procedure (AS procedure) of target cloud selection for deriving satellite winds had been developed in 1980 and 1981, and was put into routine operation at Meteorological Satellite Center on April 1, 1982, instead of MM-1 procedure. The processing of AS procedure will be written on the Meteorological Satellite Center Tech. Note in due course, but no detailed description on the AS procedure is now available both in English and Japanese.

Table 1 The procedures of wind derivation in GMS Cloud Wind Estimation System.

GMS Cloud Wind Estimation System (CWES)	Man-machine interactive procedures	Manual target cloud selection and automatic tracking (MM-1 procedure)
		Manual target cloud selection and tracking (MM-2 procedure)
	Film-loop procedure	Manual target cloud selection and tracking (FL procedure)

wind in the cloud layer. The average magnitude of the vector differences between the trade cumulus cloud motion and cloud-base wind ranged from 0.9 to 1.7 m/s. For cumulus clouds near frontal regions, the cloud motion agreed best with the mean cloud layer wind with the difference of about 2.3 m/s. It was shown in the same article as above, five cirrus cloud motions over tropical region agreed with the mean wind in the cloud layer with the difference of 1.7 m/s.

Hamada (1980) got representative heights of GMS satellite winds during May and June in 1979. The representative level of low-level satellite wind was that at between 850 and 950 mb and of high-level satellite wind at 200 mb (over tropical region) or 300 mb (over extratropical region).

In this article, the satellite tracked winds are compared with nearby radiosonde winds in four seasons, for the purpose of estimating representative heights of satellite winds derived routinely by the CWES system.

2. Comparison of GMS satellite wind with radiosonde wind

1) Period

The comparisons are carried out during four periods representing four seasons respectively. They are:

July 1-July 31, 1980 (Summer),
Oct. 13-Nov. 15, 1980 (Autumn),
Jan. 10-Feb. 15, 1981 (Winter), and
Apr. 12-May 16, 1981 (Spring).

2) Satellite wind data

Used satellite wind data are those which were derived routinely by the CWES system and transmitted to worldwide users through GTS. They are routinely quality-controlled both automatically and man-machine interactively.

3) Radiosonde wind data

Radiosonde reports available from 51 stations through GTS are used for the comparison. The reporting stations are in the Northern Hemisphere as in Fig. 1.

4) Selection of compared data

A pair of compared winds are selected on the following conditions.

- The distance between the location of a satellite wind and a radiosonde wind is to be no more than 196 km.
- The difference between the observation times of the both winds is to be no more than 3 hours.

5) Procedure of comparison

(i) High-level wind

A satellite wind data is compared with the radiosonde winds at 9 pressure levels reported from a radiosonde station. The 9 pressure levels are: 100, 150, 200, 250, 300, 350, 400, 450 and 500 mb. For the comparison at 350 mb or 450 mb, a significant level wind within the pressure difference of 25 mb is used if it is available. For the comparison at any other level, standard level wind is used. The magnitude of the vector difference between compared winds is to be no more than a threshold value of 30.0 m/s. Otherwise the difference is rejected from the statistics.

(ii) Low-level wind

Comparison is carried out for low-level satellite winds in the same manner as for high-level winds. The compared levels are: 600, 650, 700, 750, 800, 850, 900, 950 and 1000 mb. For the comparison at 700, 850,

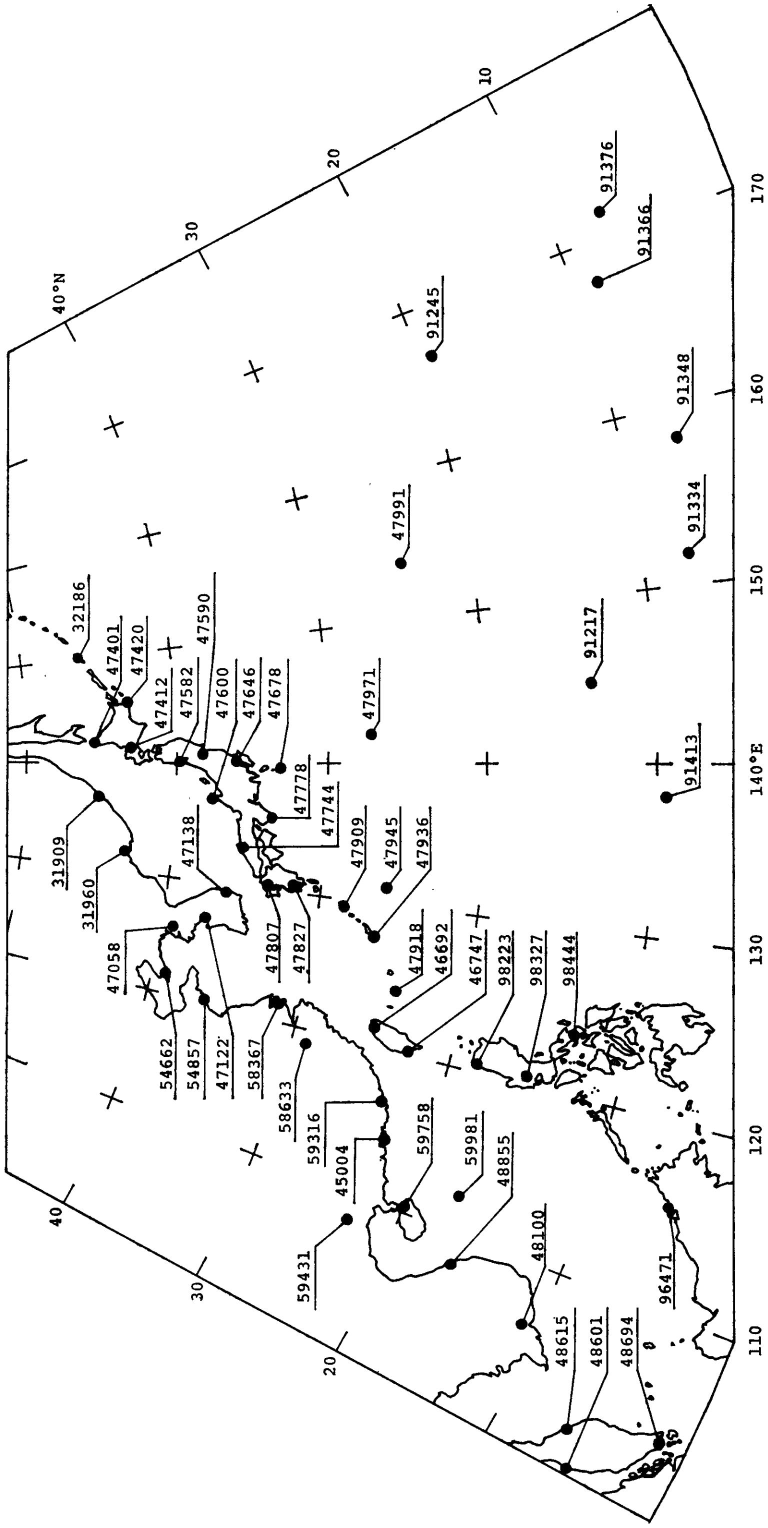


Fig. 1 Distribution of radiosonde stations.

and 1000 mb, standard level wind is used, and at any other level, significant level wind is used if it is available. The same threshold value of 30.0 m/s as for the comparison of high-level winds is effective for the comparison of the low-level winds also.

3. Results

3.1. High-level winds

First of all, results on comparisons over five subareas in winter are shown in Fig. 2a. In tropical subareas, (B) and (C), the minimum differences appear at 200 mb, which is regarded as a statistical representative level of the satellite winds. In extratropical subareas, (D) and (E), they appear at 400 mb. Fig. 3 shows the fact more clearly than above. Over the tropical region (Fig. 3b), the minimum vector difference is observed at 200 mb and algebraic mean differences of direction, u-component, and v-component are almost zero at the same level. Over the extratropical region (Fig. 3c), the level is 400 mb.

According to the results (Obana, 1981) on a comparison of satellite winds with radiosonde winds at four reporting stations along the meridian of 140°E (Table 2a), the LBF's are 495 mb at Wakkanai (45°N), 389 mb at Tateno (36°N), 427 mb at Chichijima (27°N) and 182 mb at Guam Is. (14°N). These

Table 2 The difference between GMS high-level satellite wind and radiosonde wind at reported height and at level of best fit (LBF). (After Obana, 1981)

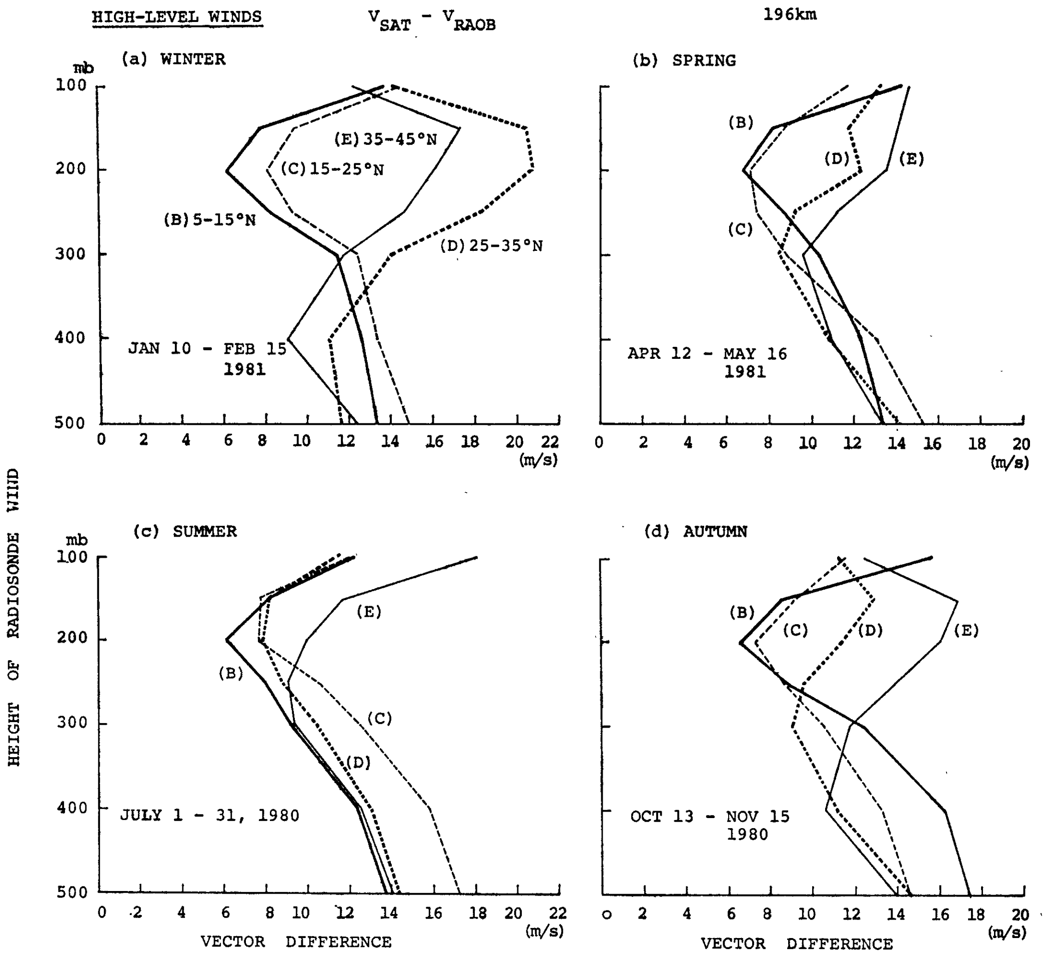
(a) Winter HIGH-LEVEL WINDS JAN/FEB 1979

Radiosonde Station	Location		N	Satellite Wind Speed		Reported Height* of Sat. Wind		Level of Best Fit (LBF)		Difference			
										At Reported Height		At LBF	
	Lat.	Lon.		Mean	S.D.**	Mean	S.D.**	Mean	S.D.**	Dir.	Spd.	Dir.	Spd.
	°N	°E		m/s	m/s	mb	mb	mb	mb	°	m/s	°	m/s
Wakkanai 47401	45	142	10	29.6	13.3	320	0	495	96	13.9	13.5	10.3	2.3
Tateno 47646	36	140	11	39.7	16.3	270	0	389	44	11.0	17.4	11.4	2.8
Chichijima 47971	27	142	24	36.1	10.3	167	58	427	111	9.6	22.7	4.6	2.6
Guam Is. 91217	14	145	16	12.6	2.7	90	0	182	44	75.6	6.6	20.5	2.6

(b) Summer JUL/AUG 1978

Radiosonde Station	Lat.	Lon.	N	Mean	S.D.**	Mean	S.D.**	Mean	S.D.**	Dir.	Spd.	Dir.	Spd.
Wakkanai 47401	45	142	26	27.4	10.5	193	20	256	100	15.7	10.2	6.8	2.9
Tateno 47646	36	140	16	18.1	6.0	146	16	200	43	41.4	6.0	10.4	3.8
Chichijima 47971	27	142	40	19.3	7.2	140	7	207	62	50.0	8.2	10.3	3.5
Guam Is. 91217	14	145	33	15.7	6.6	136	29	202	36	41.8	6.2	15.4	4.0

* Reported height of satellite wind was climatological tropopause level in this period.
** S.D.; Standard deviation.



SEASON / SUB-AREAS / ITEM	(a) WINTER		(b) SPRING		(c) SUMMER		(d) AUTUMN	
	N	MEAN WIND	N	MEAN WIND	N	MEAN WIND	N	MEAN WIND
(B) 5 - 15°N	111	15.3	52	13.4	68	14.3	53	14.3
(C) 15 - 25°N	35	25.2	122	24.6	126	17.4	115	17.3
(D) 25 - 35°N	42	40.6	214	32.5	227	17.1	145	33.3
(E) 35 - 45°N	72	40.5	161	32.7	238	28.8	94	39.5

Fig. 2 The mean magnitude of vector differences between GMS high-level satellite wind and nearby radiosonde wind over six subareas in Northern Hemisphere. The subareas are defined as areas with the latitudes shown in annexed table, but the comparisons over two subareas, *A* (EQ-5°N) and *F* (45-50°N), are rejected, because the number of compared pairs are too few. When the magnitude of vector difference between compared pairs is greater than the threshold value of 30.0 m/s, the difference is rejected from the statistics.

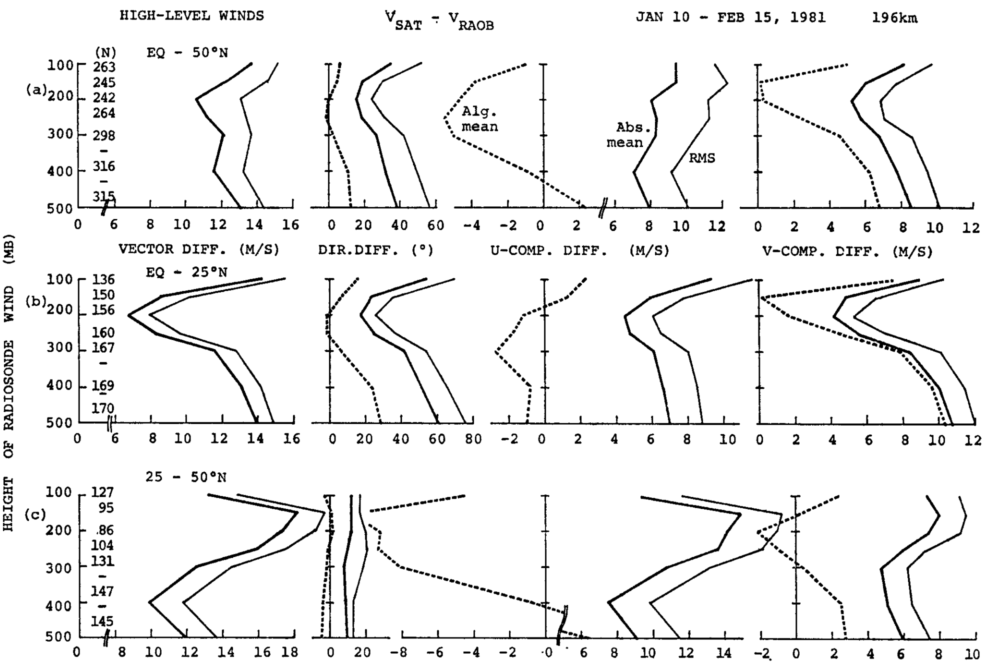


Fig. 3 Differences between GMS high-level satellite wind and nearby radiosonde wind in winter. VECTOR DIFF. means the average magnitude of vector difference between satellite wind and radiosonde wind. Broken line, thick line and thin line denote algebraic mean, absolute mean and root-mean-square (RMS) difference respectively. The sub-figure (a) shows the results over the whole observation region (Eq.-50°N), (b) over tropical region (Eq.-25°N) and (c) over extratropical region (25-50°N). The rejection with the same threshold value as in Fig. 2 is effective in these comparisons also.

results confirm the representative wind levels stated above.

In three seasons besides winter, the comparisons have been made in the same manner as in winter. The results are shown in Figs. 2b, 2c, 2d and 4, though the detailed description has been omitted from this article. Table 2b is results on the comparison in summer carried out by Obana (1981).

It is concluded from these results that the representative height of cirrus tracked satellite wind is 200 mb through out the year over tropical region and that it varies seasonally from 250 mb to 400 mb over extratropical region. These are summerized in Table 3.

Table 3 Representative wind heights of high-level satellite winds derived routinely by FL procedure of CWES system.

SEASON	WINTER	SPRING	SUMMER	AUTUMN
25°N–50°N	400	300		300
35°N–50°N			250	
EQ–35°N			200	
EQ–25°N	200	200		200

3.2. Low-level winds

The results on the comparison in winter are shown in Fig. 5. Any satellite wind with a tracked cloud top height between surface and 600 mb agrees best with nearby radiosonde wind at 850 mb. But the satellite wind with the tracked cloud top height lower than 800 mb agrees with the radiosonde wind at 1000 mb as well as at

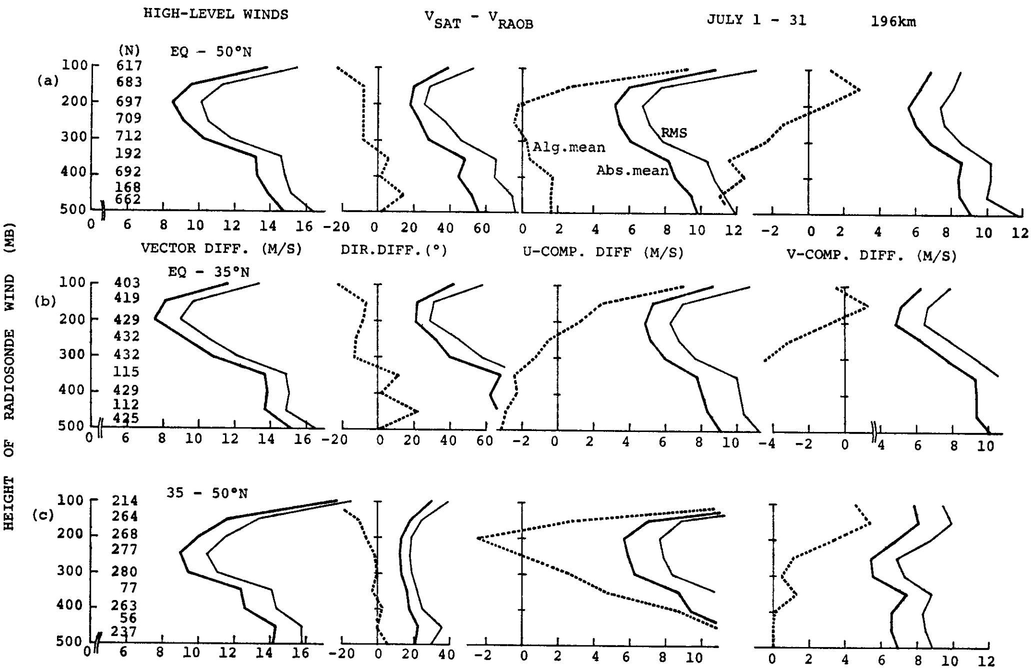


Fig. 4 Same as Fig. 3, but for in summer. July 1-31, 1980.

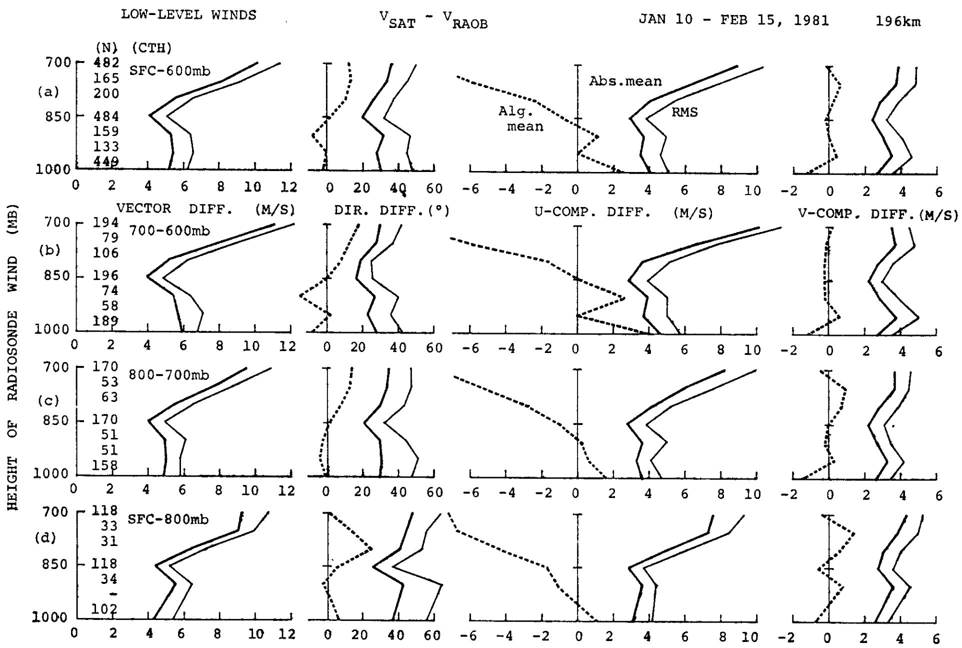


Fig. 5 Difference between GMS low-level satellite winds and nearby radiosonde winds in winter. The ranges of the tracked cloud top height (CTH) are: (a) from surface to 600 mb, (b) from 700 to 600 mb, (c) 800 to 700 mb, and (d) lower than 800 mb.

850 mb.

On account of the fact that the comparison levels of 900 mb and 950 mb are not standard levels of radiosonde report, the representative wind level can not be focussed on a certain level. However, it can be concluded that the cumulus tracked winds represent those at 850 mb or lower in winter.

Fig. 6 shows the results on the comparison in summer. When the target cloud top height is lower than 700 mb, the satellite wind agrees with the radiosonde wind at any level lower than 700 mb. The lower the target cloud top height is limited to, the smaller the difference between a satellite wind and a radiosonde wind becomes slightly. The cumulus lower than 700 mb is a very good tracer for deriving a low-level satellite wind, and the cumulus with a cloud top height between 700 mb and 600 mb seems not to be a good tracer.

In other two seasons, the satellite winds also agree with the nearby radiosonde winds at 850 mb or lower, though the results are omitted from this article.

It can not be clarified by the results of these comparisons whether or not the level of statistical best fit varies regionally.

4. Changing the procedure of height assignment of GMS Cloud Wind Estimation System (CWES)

On the basis of the results mentioned above on the comparison of GMS satellite winds with nearby radiosonde winds, the procedure of height assignment of CWES system has been changed as of December 21, 1981. In the new procedure of height assignment, to all cumulus tracked winds a fixed height of 850 mb is assigned, and to cirrus tracked winds some heights, which

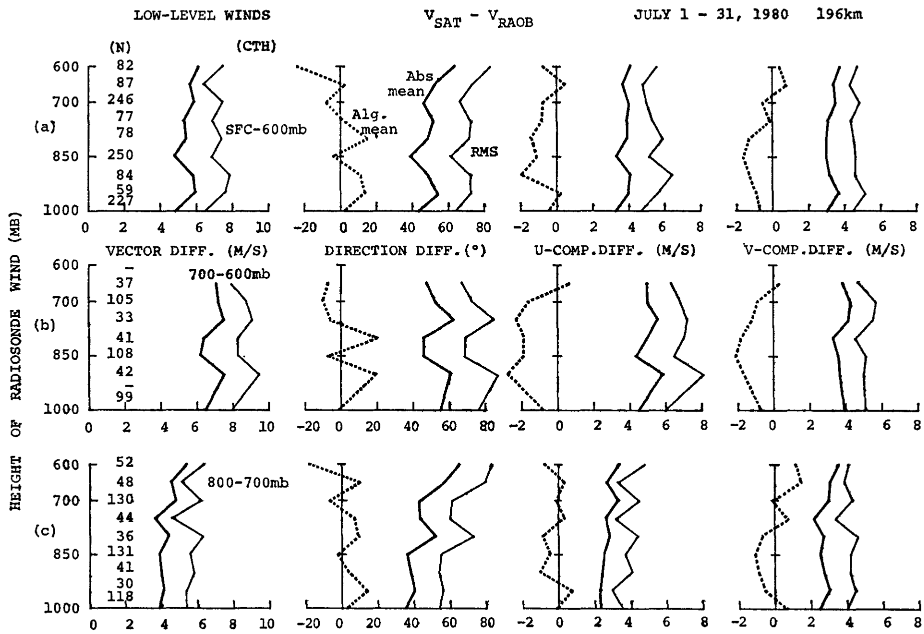


Fig. 6 Same as fig. 5, but for in summer. The results on the comparison for the satellite winds with cloud top heights lower than 800 mb are omitted, because the number of compared paire are too few.

vary seasonally and regionally, are assigned. For further detail, see Hamada (1982).

In order to get the efficiency of changing the procedure of height assignment, the heights of satellite winds operationally derived were reassigned using the new procedure during the four semi-anual periods of International Comparison of Satellite Winds. The satellite winds with newly assigned heights were compared with nearby radiosonde winds and Type 2 Reports of International Comparison of Satellite Winds (see Appendix A) were reproduced (Hamada, 1982). The Reports showed that considerable improvement would be expected if the new procedure of height assignment was introduced to CWES.

5. Verification of the operational satellite winds

The Type 2 Reports, which were produced using operational satellite winds for about two months after introduction of the new procedure, are tabulated in Table 4.

For low-level winds, average magnitude of vector differences is 4.4 m/s and root-mean-square (rms) difference is 5.7 m/s. These differences are extremely smaller than those of the GMS Type 2 Reports in Jan./Feb. 1981, and are comparable to those of GOES Type 2 Reports in the same period or before. The statistics on direction difference, u-component and v-component differences give the same features as those on the vector difference. The frequency distribution of the differences after the introduction of new height assignment procedure are shown in Fig. 7, though the period is longer than that in Table 4.

For high-level winds, average magnitude of vector differences is 11.0 m/s, and rms difference is 14.6 m/s as in Table 4(b). These differences for high-level winds are also extremely improved this time. The frequency distributions are shown in Fig. 8.

Acknowledgement

This work was carried out in order to

Table 4 Comparison results of Type 2 Reports for International Comparison of Satellite Winds both before and after introduction of new procedure of height assignment.

(a) Low-level winds Vsat—Vraob WINTER

DATA PRODUCER	PERIOD JAN/ FEB	N	Mean Speed of Sat. Wind	DIFFERENCE										
				Vector		Direction			u-comp.			v-comp.		
				Abs. mean	RMS	Alg. mean	Abs. mean	RMS	Alg. mean	Abs. mean	RMS	Alg. mean	Abs. mean	RMS
MSC/ JAPAN	1982	353	8.4	4.4	5.7	0.4	23.6	36.5	−0.8	3.0	4.3	0.2	2.7	3.8
	1981	202	7.6	7.1	8.6	10.7	31.7	45.4	−4.9	5.7	7.6	0.3	3.0	4.1
NESS/ USA	1982	607	8.4	4.8	5.6	8.8	26.6	40.5	0.9	3.0	3.9	1.3	3.1	4.0
	1981	768	8.6	4.8	5.8	−1.7	27.9	40.0	1.0	3.2	4.2	0.9	3.0	4.0

(b) High-level winds

MSC/ JAPAN	1982	190	27.9	11.0	14.6	−1.1	16.0	22.5	−1.5	7.3	11.5	1.9	6.4	8.9
	1981	220	27.4	20.3	40.7	1.2	36.5	65.4	−6.4	15.0	22.2	1.3	10.2	34.1
NESS/ USA	1982	60	25.7	9.4	11.2	0.6	19.6	32.5	−0.3	5.6	7.6	0.3	6.3	8.2
	1981	322	29.6	12.7	15.0	−2.5	20.7	32.6	−0.1	8.6	11.2	1.5	7.6	10.1

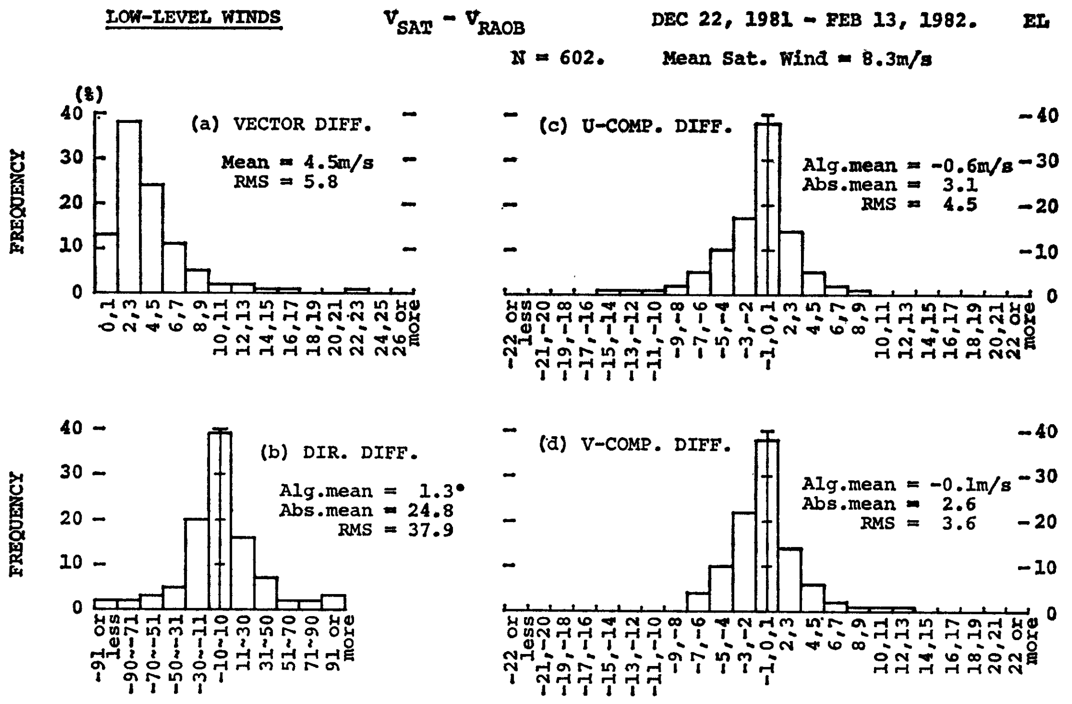


Fig. 7 Frequency distributions of the deviations of low-level satellite wind from nearby radiosonde wind. The elliptical co-location area shown in Table A.1 of Appendix A is used for the comparison. Any rejection by the threshold value of vector difference is not effective in this comparison.

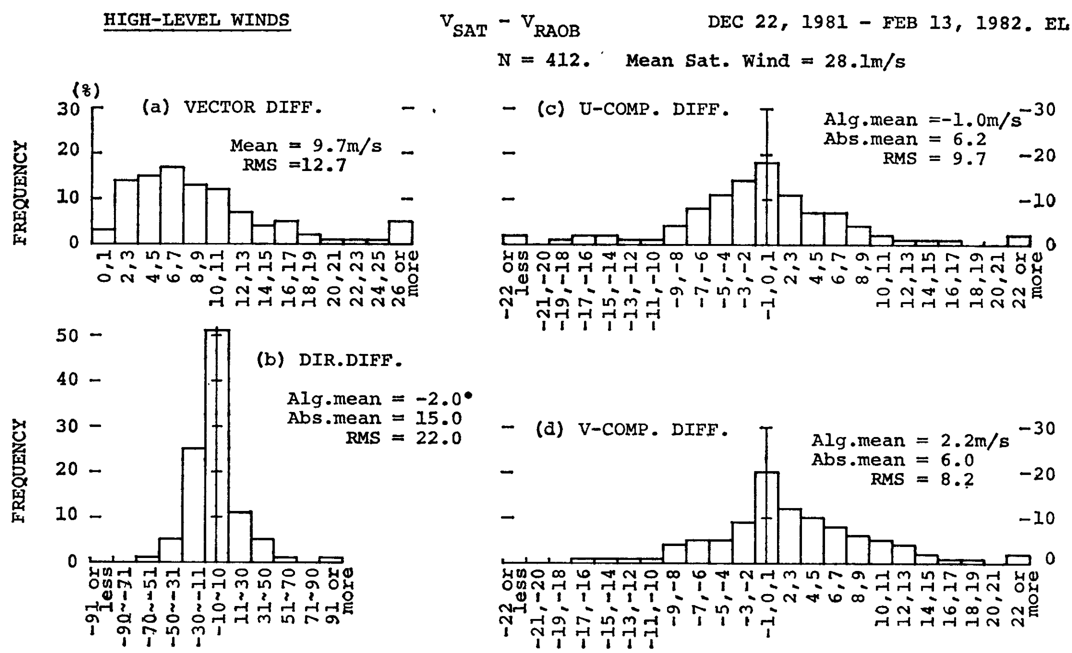


Fig. 8 Same as Fig. 7, but for high-level satellite winds.

get basic data for improvement of height assignment procedure to GMS operational satellite winds. The results presented in this article were discussed at the meetings of working group for better height assignment to GMS satellite winds at Meteorological Satellite Center in 1981. The members of the working group were; Messrs K. Kato, N. Maeda, S. Hashimoto, T. Yamagishi, K. Suzuki, A. Kamoshida, S. Ishizaka and the author. The author wishes to thank the members for earnest discussion and Mr. S. Kadowaki for useful comments and suggestion.

In this work the computer programmes developed by Mr. Mikio Morikawa for International Comparison of Satellite Winds were partially revised and used.

Appendix A. International Comparison of Satellite Winds*

The eighth Coordination Meeting on Geostationary Meteorological Satellites (CGMS-VIII, in Paris in March 1977) agreed on the need for international intercomparison of satellite winds in order to assess the homogeny and accuracy of the satellite wind vectors produced by the Operating Agencies (OA's). Two following forms of comparison were proposed and accepted:

(1) Type 1 Reports—Direct intercomparison between satellite winds in the areas of overlap between adjacent satellites, and

(2) Type 2 Reports—Intercomparison with conventional data.

The intercomparison between adjacent satellites (Type 1 Reports) is achieved by all OA's sending wind data on magnetic tape to the USA, where the co-locations are found and results computed. The comparisons with conventional data (Type 2 Reports) are the responsibility of each OA, but the results are mailed to the USA for inclusion in a coordinated report. The first comparison took place in July 1978, and therafter two periods each year.

A.1. Co-location area for comparison

The co-location area for comparison has been changed a few times, but the latest one was proposed at CGMS X (in Geneva in March 1980) and was confirmed at CGMS XI (in Washington, D.C. in February 1982). The area is defined as an elliptical co-location area as in Table A. 1.

* After the Consolidated Reports on CGMS Activities (5th Edition, Revision 1-April 1982) published and distributed by European Space Agency (ESA).

Table A.1. The size of elliptical colocation area for International Comparison of Satellite Winds specified by CGMS.

Wind Level	Satellite Wind Speed	Major Axis	Minor Axis
High-level Winds (less 400mb) and Mid-level Winds (400-699mb)	Less than 10m/s	225km	175km
	10 - 25m/s	250	140
	Larger than 25m/s	300	100
Low-level Winds (700-surface)	Any Speed	225	175

°The major axis must be oriented along the satellite wind direction.

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GMS 画像より算出された衛星風の代表する高度について

浜 田 忠 昭

気象衛星センターシステム管理課

日本（気象衛星センター，MSC）の風計算システムにより現業的に算出されている衛星風がどの高度の風を最も良く表わしているかを，北半球について季節別に調べた。

対話型処理により追跡雲の選定を行なうマンマシン法（MM 法）から算出されるひとつの下層衛星風を，近傍の1観測所から得られたラジオゾンデ風の9つの高度（1000 mb から 600 mb まで 50 mb 毎）の風とそれぞれ比較した。その結果，(1) 年を通じて衛星風は 850 mb のラジオゾンデ風とよく一致していること，(2) 冬期には追跡雲の雲頂高度が低くなれば 850 mb より低い高度でも両者はよく一致すること，(3) 夏期には明確に一致する高度は決められないが 700 mb 程度より低い ラジオゾンデ風との差が小さいこと (4) 追跡雲頂高度が，冬期は 600 mb 夏期は 700 mb 程度より低い場合に周辺の風とよく一致していることなどがわかった。

ループフィルムを使用して雲の選定・追跡を行なう方法（LF 法）から算出される上層衛星風についても，下層風と同様にラジオゾンデ風の9つの高度（500 mb から 100 mb まで 50 mb 毎）の風とそれぞれ比較した。その結果，(1) 熱帯領域では年を通じて衛星風は 200 mb のラジオゾンデ風とよく一致していること，(2) 中緯度領域では，夏は 250 mb，冬は 400 mb，春秋は 300 mb のラジオゾンデ風とよく一致していること，(3) 熱帯領域と中緯度領域の境界線は，夏が 35°N，その他の季節は 25°N 付近であることがわかった。

これらの結論から，既報（Hamada, 1982）の様に，気象衛星センターでは1981年12月21日21時から，一定高度（LF 法による衛星風の場合は季節と領域により変化する）を風の推定高度とする方法を採用した。それ以後のラジオゾンデ風との比較結果によると，上下層とも (1) 前年の同期間の比較と比べて著しく改善されていること，(2) NESS が行なった GOES 衛星風とラジオゾンデ風の比較の場合と同程度の差であること，などが示された。