IMPROVEMENTS IN THE METHOD TO EXTRACT OPERATIONAL CLOUD MOTION WINDS AND WATER VAPOR MOTION WINDS OF THE GMS-5 SYSTEM

Masami Tokuno

Meteorological Satellite Center, Japan Meteorological Agency
3-235, Nakakiyoto, Kiyose-shi, Tokyo
JAPAN

ABSTRACT

The Meteorological Satellite Center (MSC) of the Japan Meteorological Agency (JMA) improved a method to extract Cloud Motion Winds (CMWs) and Water Vapor Motion Winds (WVMWs). The MSC has carried out, on a trial basis, the extraction of high-density wind vectors once a day and evaluated the improved height assignment method since April 23, 1998. The improvements are summarized as follows:

1. These experimental wind products give around 1,000 high level CMWs (HCMWs) and 2,000 WVMWs, i.e. three and four times more than the current products, respectively. This is achieved by the improvement of a wind production software.
2. The current height assignment of WVMW is carried out without distinguishing between cloudy and clear sky segments. A new method discriminates cloudy and clear sky segments by a threshold brightness temperature by the WV channel. The threshold value is computed with a radiative transfer model using the vertical profile forecasted by the NWP. The height of WVMWs in the clear sky segments is assigned by a histogram method and that in the cloudy sky segments by the IR and WV intercept technique.
3. The IR and WV intercept technique is newly introduced for the height assignment of HCMWs instead of the current infrared histogram method.
4. A cloud cluster boundary is estimated from an infrared histogram. This cloud cluster boundary is assumed as cloud base. The cloud base temperature is applied for the height of low level CMWs (LCMWs) although LCMWs are currently assigned to a fixed height of 850 hPa.

This report describes the methodology and the results of the trial operation.

1. Introduction

The Meteorological Satellite Center (MSC) of the Japan Meteorological Agency (JMA) has produced Cloud Motion Winds (CMWs) and Water Vapor Motion Winds (WVMWs) from GMS-5 image at six hourly intervals, e.g. at 00, 06, 12 and 18 UTC since June 13, 1995. Approximately 300 CMW and 200 WVMW vectors are produced at each cycle. A description of the MSC operational production of GMS-5 Satellite Motion Winds (SMWs) and data processing techniques are described in (Tokuno, 1996).

The MSC also has been made a experimental operation once a day for producing high density SMWs and improvements of current height assignment techniques since April 23, 1998.

This report describes the methodology and the results of the trial operation.

2. Improvements of SMWs' Extraction

2.1 Tracer selection

In the current objective automatic target cloud selection, firstly the candidate grid point (1 degree latitude/longitude box is automatically selected in accordance with a certain regulation to get wind data uniformly in the GMS coverage. Next, the grid area is judged by the screening steps, i.e. a check on ocean/land discrimination, a check on zenith angle of the satellite and the sun, histogram analysis, a check on cumulonimbus. When the number of the wind vectors obtained reaches the fixed number, i.e. 800 LCMW, 500 HCMW and 1000 WVMW vectors (3000 WVMW vectors since 06 UTC July 311998), this procedure is stopped as the current vector file is limited in storing capacity.

More than half of the total candidate grid points cannot be searched in the current objective automatic target selection due to the limitation. For example, the ratio of the searched grid points to the total candidate grid point is approximately 50 % for visible LCMW, 20% for IR HCMW and 20 % (40 % since 06 UTC July 31 1998) for WVMW.

To minimize the limitation, we improved the procedure of tracer selection to enable us to search all of the candidate grid points. In addition, the following screening step was added in the procedure of tracer selection for HCMWs.

- If a coefficient of correlation and a slop of a regression equation between IR and WV brightness temperature in a grid point is smaller than a threshold value, the grid point is rejected.

As a result, the procedure is performed until the number of the wind vectors obtained reaches the fixed number, i.e. 3000 LCMW, 3000 HCMW and 6000 WVMW vectors.

2.2 Height assignment

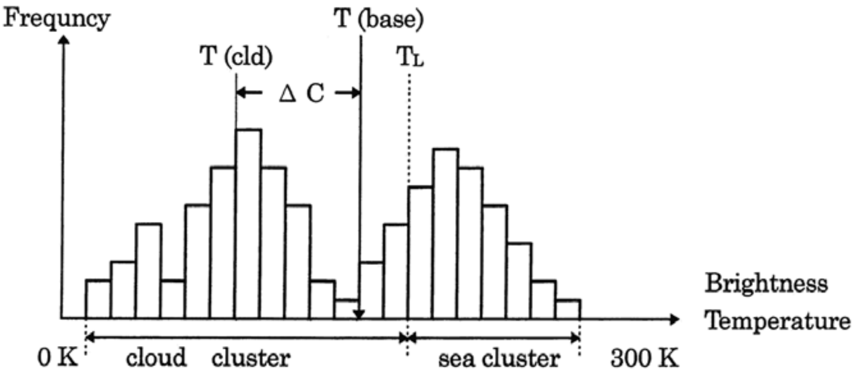
In low-level winds, it is widely accepted that the velocity of LCMW vectors agrees with that of the environmental wind at the altitude of the cloud base. In MSC, we made some statistical investigation (Hamada, 1982) on comparing LCMWs with that of radiosonde winds, which revealed that the velocity of the LCMW vectors well represents that of the atmospheric winds at the altitude of 850 hPa. The current fixed representative height, 850 hPa, is assigned to all resultant winds from low-level target cloud with the Cloud Top Height (CTH) lower than the limitation height, 700 hPa.

Schmetz et al. (1996) reported that the cloud base height estimated from the histogram of brightness temperature from a low level cloud and clear ocean provides a better fit to a low level wind vector height in agreement with Le Marshall et al. (1994). We also experimentally adopt the technique to estimate a low level wind vector height in addition to a fixed height of 850 hPa.

Following the same procedure as that of Schmetz et al.(1996), we firstly infer cloud base temperature T(base) from the histogram according to:

$$T(\text{base}) = T(\text{cld}) - \sqrt{2}\,\sigma(\text{cld})$$

where T(cld) is the mean temperature of the cloud cluster and σ(cld) is the standard deviation of the temperature of the cloud cluster (Figure 1). T(base) is transformed into the cloud base height (CBH) using vertical temperature profiles obtained from the six hourly forecast of JMA numerical weather prediction. If the CBH is assigned to two pressure levels due to a inversion layer, the pressure level with higher humidity is selected. In addition, if the CBH is higher than that of 850 hPa, the CBH is reassigned to a fixed height of 850 hPa.



$$T_L = T_{925} - \Delta T_{925} + \Delta T$$

where T_L : boundary brightness temperature between cloud and sea cluster

T_{925} : air temperature in the 925 hPa level

ΔT_{925} : atmospheric correction temperature in the 925 hPa level

ΔT : bias correction temperature

T (base) : estimated cloud base temperature (for details see text)

ΔC : $\sqrt{2}\,\sigma$ (cld)

Fig. l Schematic diagram showing the histogram of brightness temperature from a low level cloud and clear ocean. The estimated cloud base temperature is indicated.

In infrared high-level winds, a following new step is adopted to estimate a high-level wind vector height. Firstly two dimensional histogram is made from both infrared and WV image data in a grid point selected in tracer selection (Figure 2). A threshold of IR brightness level to discriminate between a clear cluster and a cloud cluster is determined as a coefficient of correlation between IR and WV data in the cloud cluster becomes a maximum value. Then brightness level of cloud height (Tc) is calculated using the IR and WV intercept technique in the cloud cluster based on the theory described by Bowen and Saunders (1984). The procedure of transforming Tc into CTH is the same as that of LCMWs.

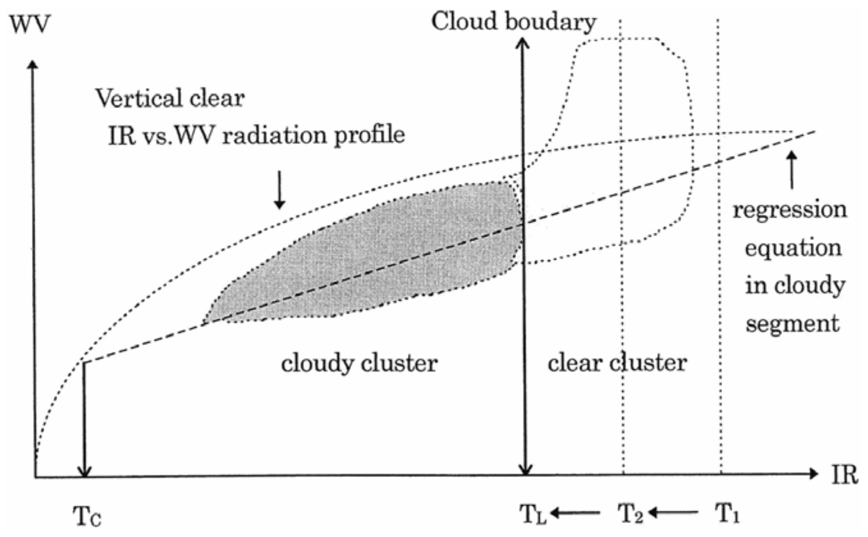


Fig. 2 Schematic diagram showing the two dimensional histogram between IR and WV.
T_C : brightness level of cloud height T_L : threshold of IR brightness level
T_1, T_2 : IR brightness level in a specified vertical pressure level

In water vapor motion winds, firstly we discriminate between cloudy and clear area in a WV histogram by a cloudy boundary temperature (T_L) according to :

$$T_L = T_{1000} - \Delta T_{1000} + \Delta T$$

where T_L is a WV brightness temperature for a cloud boundary, T_{1000} is the WV brightness temperature in 1000 hPa level, ΔT_{1000} is the atmospheric correction temperature in 1000 hPa level for WV channel, which is computed with a radiative transfer model using the vertical profile forecasted by the NWP, and ΔT is a bias temperature. Next we calculate cloud amount (L (%)) according to:

$$L = \left(\sum_{i=T_{min}}^{T_L} (f(i)) \Big/ \sum_{i=T_{min}}^{T_{max}} (f(i)) \right) \times 100$$

where f (i) is frequency in brightness temperature level T (i).

If cloud amount (L (%)) is larger than a threshold value, the grid is determined as the cloudy sky segment. In the contrary case, the grid is determined as the clear sky segment.

If a grid is determined as a cloudy sky segment, the procedure of height assignment is the same as that of HCMWs. On the other hand, if a grid is determined as a clear sky segment, we adopt the WV brightness level (WVTBB) corresponding to a threshold of frequency accumulated from the lowest brightness level of a histogram of WV brightness level in the clear sky segment as the brightness level of WVMW height. WVTBB is transformed into the WVMW height using vertical WV clear brightness temperature profile calculated with a radiative transfer model using the vertical profile forecasted by the NWP. However, if WVTBB is warmer than WV clear brightness temperature calculated with a radiative transfer model, we adopt approximately a peak level of weighting function of WV channel as WVMW height.

3. Results

We show the experimental result in July and August 1998 when we had experimental procedure once a day, i.e. 00 UTC. To evaluate the accuracy of CMWs and WVMWs derived experimentally, they are compared with collocated radiosonde winds which locate with 150 km from the satellite winds. Monthly mean statistics are calculated to compare between the operational results and the experimental results.

3.1 Low-level Cloud Motion Winds

Table 1 shows the monthly total number of visible LCMWs (VIS-LCMWs) at a multi-layer at 00 UTC in July and August 1998 in all regions (50N-50S). The ratio of the number of experimental VIS-LCMWs adopted cloud base height (851 to 1000 hPa) as LCMW height to the total number of experimental VIS-LCMWs is about 47 %. Most of the height of VIS-LCMWs adopted cloud base height as LCMW height is a height between 850 hPa to 900 hPa. The number of experimental VIS-LCMWs is about 1.3 times as many as operational VIS-LCMWs.

Table 1. The number of experimental and operational VIS-LCMWs

50N - 50S	VIS-LCMWs	851-900 hPa	901-950 hPa	951-1000 hPa	851-1000 hPa	Fixed 850hPa	Total
July 1998	Experiment	6,656	329	19	7,004	7,926	14,930
	Operation	------	------	------	------	11,869	11,869
August 1998	Experiment	7,465	458	50	7,973	9,199	17,172
	Operation	------	------	------	------	12,241	12,241
Total	Experiment	14,121	787	69	14,977	17,125	32,102
	Operation	------	------	------	------	24,110	24,110

Table 2 shows a monthly comparison results of VIS-LCMWs and radiosonde winds in a circular co-location area where a radius is 150 km in July and August 1998 in all regions (50N-50S). The accuracy of experimental VIS-LCMWs with a height between 900 hPa and 851 hPa is the same as that of operational VIS-LCMWs with a fixed height, 850 hPa, although the quality control of experimental VIS-LCMWs is fully automatic and no manual intervention is being performed, in contrast to the operational VIS-LCMWs. On the other hand, experimental VIS-LCMWs with a fixed height, 850 hPa, is a little inferior to the operational LCMWs in accuracy. In addition, it is an interesting characteristic that mean wind speed of experimental VIS-LCMWs with a height between 900 hPa and 850 hPa is faster than that with a fixed height of 850 hPa.

Table 2. A monthly comparison between VIS-LCMWs and radiosonde winds (VIS-LCMWs - Radiosonde).
NUM : number of comparison, MVD (m/s) : mean vector difference, RMSVD (m/s) : root mean square error of vector difference, BIAS (m/s) : average speed difference, SPD (m/s) : radiosonde speed, RMSSP (m/s) : root mean square error of speed difference, SI (%) : scatter index (RMSSP / SPD)

50N-50S	VIS-LCMWs		NUM	MVD	RMSVD	BIAS	SPD	RMSSP	SI
Experi-ment	SFC-901 hPa	July	9	2.0	2.8	0.4	9.1	2.5	27.5
		August	20	2.2	2.5	- 0.1	6.9	1.7	24.6
	901-851 hPa	July	124	2.8	3.5	0.1	9.0	2.7	28.9
		August	181	3.1	3.8	- 0.4	7.7	2.7	36.4
	850 hPa	July	133	3.3	3.9	- 0.2	8.1	2.7	33.3
		August	152	3.4	4.1	- 0.3	7.2	2.9	40.3
Opera-tion	850 hPa	July	352	2.9	3.5	- 0.1	8.5	2.5	29.8
		August	424	3.1	3.7	0.2	6.9	2.5	36.2

3.2 High-level Cloud Motion Winds

Table 3 shows the monthly total number of HCMW s at 00 UTC in July and August 1998 in all regions (50N-50S). The total number of experimental HCMWs after automatic assessment and objective quality check is about three times as many as HCMWs which are operationally distributed to the world via GTS.

Table 3. The number of experimental and operational HCMWs

50N-50S HCMWs	July 1998	August 1998	Total
Experiment	19,643	17,694	37,337
Operation	5,167	5,916	11,083

Table 4 is the same as Table 2 except for a comparison results of HCMWs and radiosonde winds at 100 hPa intervals. MVD and RMSVD in experimental HCMWs in 300 hPa to 101 hPa level is the same as operational HCMWs with manual quality control, however an increasing in negative speed bias is seen in experimental HCMWs. It is noticeable that a decrease in number of experimental HCMWs is occurred in the layer lower than 300 hPa due to the effect of the adoption of the screening step newly added in the procedure oftracer selection for HCMWs.

Table 4. The same as Table 2 except for a monthly comparison between HCMWs and radiosonde winds at a multi-layer

50N-50S		HCMWs	NUM	MVD	RMSVD	BIAS	SPD	RMSSP	SI
July 1998	SFC ~	Operation	187	3.4	4.3	0.3	8.6	3.4	39.5
	501 hPa	Experiment	-----	-----	-----	-----	-----	-----	-----
	500 ~	Operation	8	4.6	5.1	- 0.9	22.4	4.2	18.8
	401 hPa	Experiment	-----	-----	-----	-----	-----	-----	-----
	400 ~	Operation	92	8.1	10.6	- 3.8	28.8	8.8	30.6
	301 hPa	Experiment	2	8.0	10.2	- 6.7	10.8	8.5	78.7
	300 ~	Operation	492	6.6	8.2	- 2.5	22.6	6.5	28.8
	201 hPa	Experiment	722	7.1	8.8	- 4.2	17.9	7.2	42.4
	200 ~	Operation	232	6.5	8.0	- 1.9	18.6	6.1	32.8
	101 hPa	Experiment	743	5.9	7.1	- 2.5	14.1	5.2	36.9
	100 hPa	Operation	-----	-----	-----	-----	-----	-----	-----
	~	Experiment	2	6.1	6.1	- 2.9	3.9	3.0	76.9

50N-50S		HCMWs	NUM	MVD	RMSVD	BIAS	SPD	RMSSP	SI
August 1998	SFC ~	Operation	268	3.2	4.1	0.0	7.2	3.0	41.7
	501 hPa	Experiment	-----	-----	-----	-----	-----	-----	-----
	500 ~	Operation	7	7.5	8.1	0.1	12.4	5.1	41.1
	401 hPa	Experiment	-----	-----	-----	-----	-----	-----	-----
	400 ~	Operation	97	7.9	9.5	- 3.2	26.0	8.0	30.8
	301 hPa	Experiment	12	14.4	18.2	- 12.2	23.0	17.7	77.0
	300 ~	Operation	627	7.0	8.4	- 2.6	24.1	6.8	28.2
	201 hPa	Experiment	659	7.3	8.9	- 4.2	18.0	7.3	40.6
	200 ~	Operation	262	7.1	8.6	- 2.4	18.5	5.9	31.9
	101 hPa	Experiment	619	6.1	7.3	- 2.4	14.6	5.3	36.3
	100 hPa	Operation	4	9.9	9.9	- 5.5	25.0	6.0	24.0
	~	Experiment	3	13.9	15.5	- 1.6	12.1	3.1	25.6

3.3 Water Vapor Motion Winds

Table 5 shows the monthly total number of WVMWs at 00 UTC in July and in August 1998 in all regions (50N-50S). The total number of experimental WVMWs after automatic assessment and objective quality check is about nine times (in July) and about four times (in August) as many as WVMWs which are operationally distributed to the world via GTS. The total number of experimental WVMW s in clear sky segment is about two times as many as experimental WVMW s in cloudy sky segments. An example of experimental WVMWs is given in Figure 3.

Table 5. The number of experimental and operational WVMWs

50N - 50S	WVMWs	Cloudy	Clear	Cloudy + Clear
July	Operation	----------	----------	6,095
1998	Experiment	18,048	38,400	56,448
August	Operation	----------	----------	19,878
1998	Experiment	20,439	53,698	74,137
Total	Operation	----------	----------	25,973
	Experiment	38,487	92,098	130,585

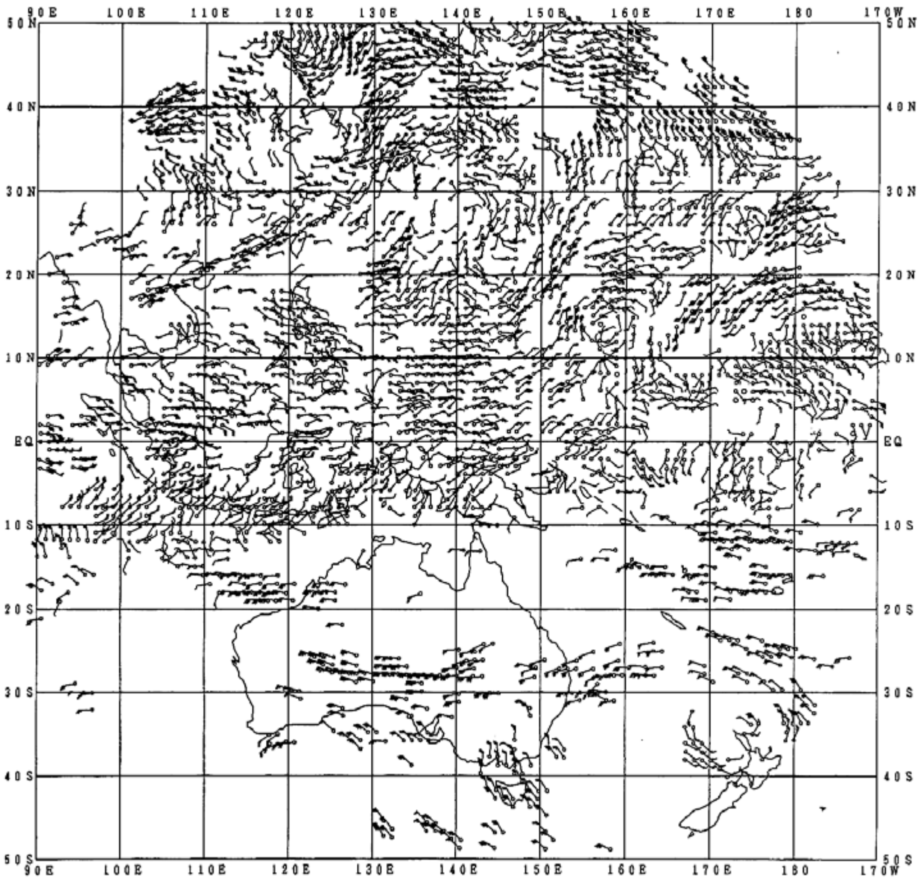


Fig. 3 An example of experimental WVMWs at 00 UTC in July 26, 1998.
2,516 WVMW vectors are shown.

Table 6 is the same as Table 4 except for a comparison results of WVMWs and radiosonde winds at a multi-layer. As expected, the number of experimental WVMWs with a height lower than 300 hPa increases in comparison with operational WVMWs. MVD and RMSVD of experimental WVMWs with a height between 300 hPa to 101 hPa, which consist chiefly of WVMWs derived in cloudy sky segment is the same as that of operational HCMWs with no manual quality control check. However an increasing of negative speed bias is also seen in experimental WVMWs as seen in HCMWs. It seems that one of the causes is the adoption of the IR and WV intercept technique in cloudy area in height assignment. On the other hand, MVD and RMSVD in experimental WVMWs with a height lower than 300 hPa which consist chiefly of WVMW derived in clear sky segment, is larger than that in experimental WVMW with a height higher than 300 hPa. In addition, an increasing of positive speed bias is seen in experimental WVMW with a height lower than 300 hPa.

Table 6. The same as Table 4 except for a monthly comparison between WVMWs and radiosonde winds

50N-50S		WVMWs	NUM	MVD	RMSVD	BIAS	SPD	RMSSP	SI
July 1998	500 ~ 401 hPa	Operation	131	6.7	8.8	- 1.1	14.4	6.8	47.2
		Experiment	1403	8.5	10.5	2.2	10.4	7.8	75.0
	400 ~ 301 hPa	Operation	394	6.7	8.2	0.7	14.0	6.2	44.3
		Experiment	2415	8.3	10.5	2.7	9.6	8.3	86.5
	300 ~ 201 hPa	Operation	630	6.3	7.5	- 0.4	16.4	5.6	34.1
		Experiment	823	7.0	9.6	- 3.1	20.1	7.9	39.3
	200 ~ 101 hPa	Operation	105	6.2	7.4	- 1.1	16.4	5.4	32.9
		Experiment	928	6.4	7.9	- 2.5	15.5	5.9	38.1
	100 hPa ~	Operation	.....	.....	.....	.....	.....	.....	.....
		Experiment	4	7.0	7.7	- 4.5	11.2	6.2	55.4

50N-50S		WVMWs	NUM	MVD	RMSVD	BIAS	SPD	RMSSP	SI
August 1998	500 ~ 401 hPa	Operation	381	7.2	8.7	2.3	12.5	7.0	56.0
		Experiment	2318	8.2	10.1	1.9	10.1	7.9	78.2
	400 ~ 301 hPa	Operation	1426	7.1	8.5	1.7	14.0	6.8	48.6
		Experiment	2979	8.0	9.7	2.7	9.7	7.4	76.3
	300 ~ 201 hPa	Operation	2066	6.2	7.3	- 0.2	16.9	5.6	33.1
		Experiment	860	7.0	8.5	- 3.0	20.1	6.9	34.3
	200 ~ 101 hPa	Operation	208	6.3	7.4	- 1.9	17.4	5.7	32.8
		Experiment	930	6.1	6.1	- 2.0	15.1	5.4	35.8
	100 hPa ~	Operation	.....	.....	.....	.....	.....	.....	.....
		Experiment	7	6.8	7.2	- 0.6	14.4	4.4	30.6

4. Concluding Remark

MSC has carried out, on a trial basis, the extraction of high-density wind vector once a day and evaluated the improvement of height assignment since April 23, 1998. The results of the trial operation lead to the following conclusion. The improvement of a wind production software for the extraction of high-density wind vectors is useful especially for HCMWs and WVMWs. The VIS-LCMW height assignment method, in which cloud base height is adopted as LCMW height, is considered as an useful method for the improvement of the accuracy of LCMWs with a height lower than 850 hPa. It seems that the IR and WV intercept technique for the height assignment of HCMWs and WVMWs in the cloudy segments works relatively well, however, further investigation is required to confirm the efficiency of the method. The histogram method for the height assignment of WVMWs in the clear sky segments is required more studies as the accuracy of WVMWs (P > 300 hPa) is poorer than that of WVMWs (P < 300 hPa).

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