WIND EXTRACTION FROM WATER VAPOR IMAGES

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ABSTRACT

WV wind extraction scheme has been developing at Meteorological Satellite Center (MSC). The preliminary extraction of the WV winds for seven cases was performed and the WV winds were compared with high-level IR winds (p<400hPa) and the objective analysis winds from Numerical Prediction Division of Japan Meteorological Agency (JMA). The area where WV winds are extracted is larger than that where IR winds are extracted. The quality of high-level WV winds (p<400hPa) using the combined height assignment method is expected to be comparable to that of IR winds.

1. Introduction

The Geostationary Meteorological Satellite-5 (GMS-5), which is scheduled to be launched in 1995, has an improved Visible and Infrared Spin Scan Radiometer (VISSR) with a visible (VIS) channel, a water vapor (WV) channel and infrared (IR) split window channels. Using the WV data, Meteorological Satellite Center (MSC) will produce WV wind.

The WV wind extraction scheme has been developing using METEOSAT data. This scheme is basically the same as that of IR and VIS wind extraction (Meteorological Satellite Center, 1989). So, the tracking technique used for IR and VIS wind extraction is applied to WV images. However it is necessary to develop particular methods of the target selection and the height assignment for WV wind extraction because WV feature observed by WV channel is different from cloud feature observed by VIS or IR channel.

This paper describes the preliminary extraction scheme of WV wind, the characteristics of the WV winds and the quality of the WV winds assessed by comparing with the objective analysis winds from Numerical Prediction Division of Japan Meteorological Agency (JMA).

2. Extraction scheme

WV wind extraction using successive three WV images at an interval of 30-minute without any preprocessing was performed automatically. Although the derived IR wind data in operation are checked through automatic and manual quality control procedures, any quality checks were not made on the WV winds.

2.1. Target selection

The targets are selected automatically on the middle image of three successive WV images. Ten thousand of candidate grid points with intervals of 1° in longitude and latitude over the 130°W-49°E and

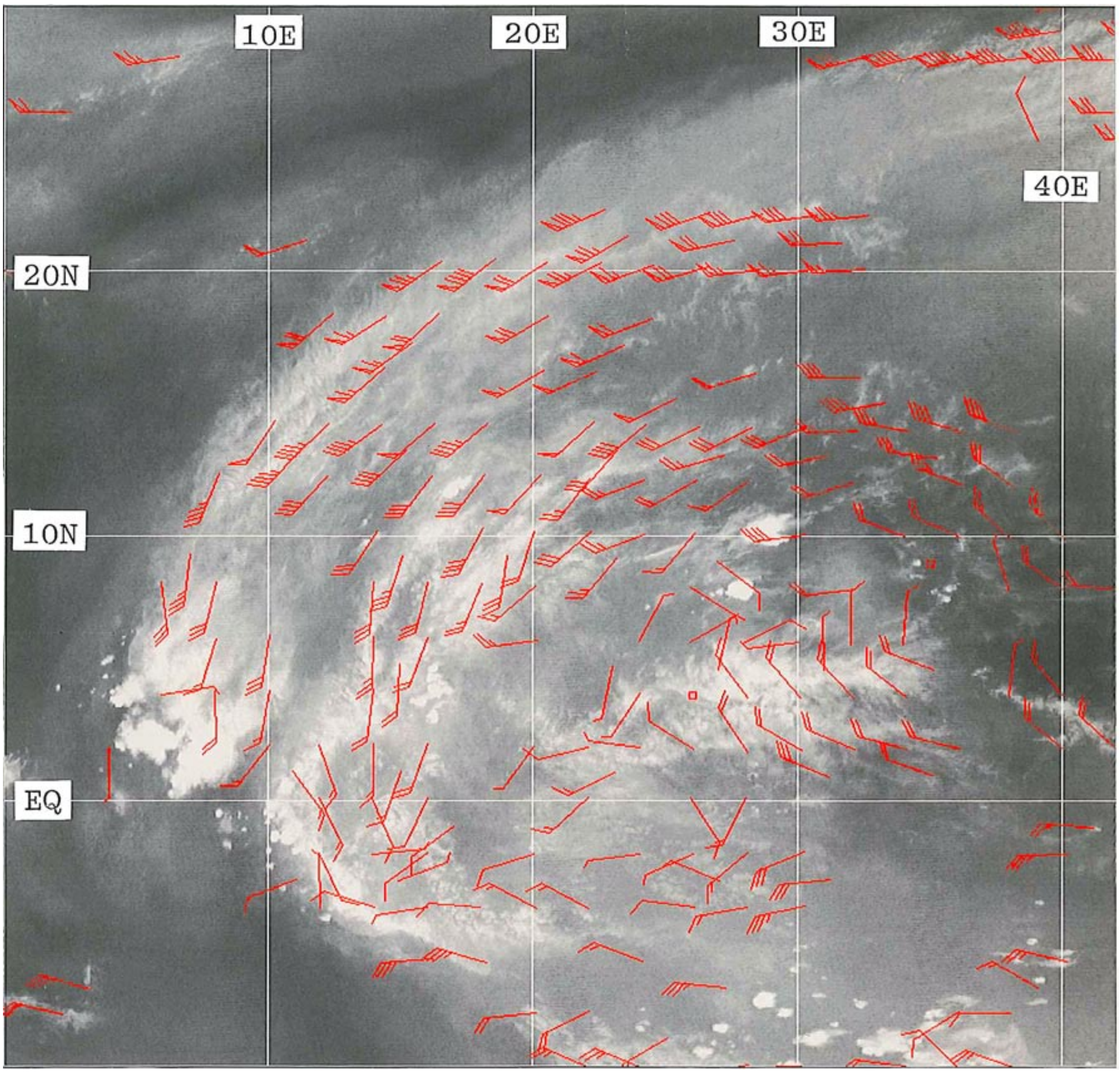

Figure 1. WV winds and WV image at 12UTC on April l5, 1992.

50°N-49°S domain are prepared. If the lowest brightness temperature in the small area of 32 lines x 32 pixels (hereafter target element: 160 km x 160 km) centered at grid point is colder than the temperature at 500hPa, it is selected as a target. Because the feature of WV image is smooth and vague, strict assessment of the WV data in target element is not done by such histogram analysis as performed in the operational wind extraction.

The maximum number of the targets recorded in data file is 1200, therefore target selection from ten thousand of candidate elements is performed at random until the number of selected elements reaches 1200 to avoid some area of no selected target elements in spite of the existence of suitable elements.

2.2. Tracking

The target element selected on the middle WV image of the three is tracked on the other images before and after 30-minute using cross-correlation method and two successive displacement vectors are calculated from the target in consequence. If the vector magnitude of the difference between the two successive vectors does not exceed 10 m/s, the latter vector is regarded as the resultant wind.

2.3. Height assignment

The teacked targets are clouds (mid- or high-level) and water vapor structures. Therefore WV radiance is from the clouds and the atmosphere above the background. Previous studies on WV wind extraction from

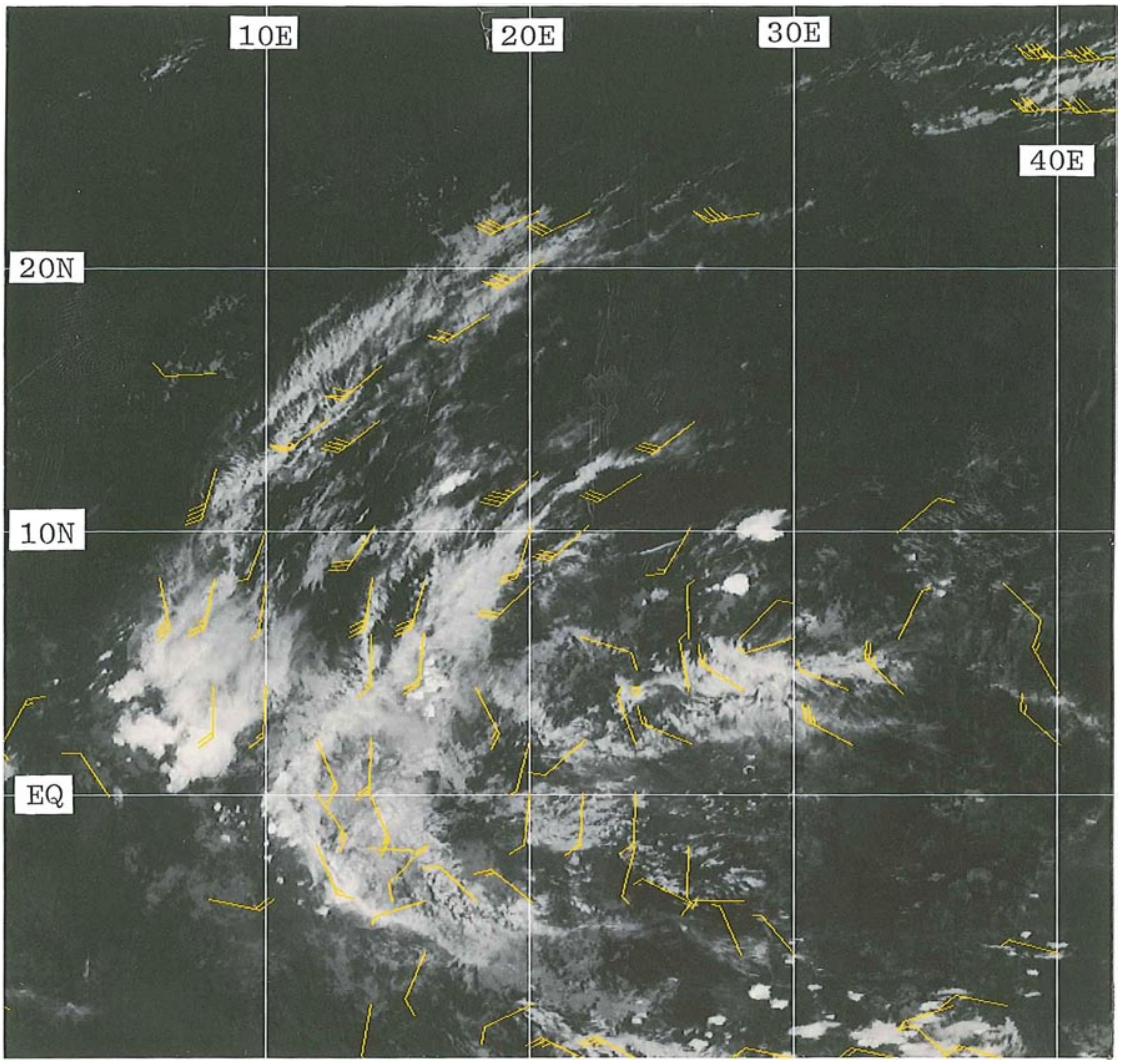

Figure 2. Same as Figure 1, but for high-level IR winds and IR image.

METEOSAT WV images showed that the height determined from WV brightness temperature was assigned to WV wind; that is, Szantai et al. (1991) and Laurent (1991 and 1993) used the lowest and the lowest 20 % of the temperature in the target (32 lines x 32 pixels) respectively.

In this study, two height assignment methods were tested. One is the method that the heights corresponding to the lowest 1, 5, 10, 20 and 30 % of WV brightness temperature in the target element are assigned to WV winds. The other is the method that the heights determined by the same method stated before to the WV winds calculated from the element containing thick clouds or water vapor structures and the cloud top heights estimated from IR and WV intercept technique using the theory described by Bowen and Saunders (1984) are assigned to the WV winds calculated from the element containing semitransparent clouds.

3. Case studies and Verification

The WV winds were derived automatically for seven cases from April 1991 to April 1992. The winds were compared with high-level IR winds in order to clear the characteristics of WV winds and were also compared with the objective analysis winds of JMA in order to assess the quality depending on the height assignment methods.

3.1. Example of WV wind

Figure 1 shows a part of WV winds at 12 UTC on April 15, 1992. Figure 2 shows simultaneous high-level IR winds derived through automatic procedure without automatic and manual quality control procedures. Both of the WV and IR winds are not calculated for all of prepared candidate target elements as described in subsection 2.1. Therefore exact discussion about the number of extracted WV and IR winds is not appropriate here. WV wind field represents spatial consistency and the area where WV winds are derived is larger than that where IR winds are derived. This result is the same as described by Laurent (1993). From (10°N, 10°E) to (20°N, 30°E), cirrus tracers appear along strong wind axis in both of WV and IR images. There WV winds are calculated numerously and widely compared with IR winds. In cloud-free rectangular area described by 10°N - 20°N and 20°E - 40°E, numerous WV winds are calculated while no IR winds are calculated.

3.2. Comparison between WV winds and high-level IR winds

The relationship between WV winds and high-level IR winds (p<400hPa) calculated from the same target element was investigated. It means that high-level cloud features are tracked on both of WV and IR images.

The results of the comparison among 145 samples for 12 UTC on April 15, 1992 are as follows;

– RMS vector difference and speed bias (WV wind – IR wind) are 4.2 and 0.7 m/s respectively and
– mean speed of WV winds (23.1 m/s) is greater than that of IR winds (22.2 m/s).

Figure 3 shows cumulative percentage frequency of the vector magnitude difference. The vector magnitude difference for more than 90% cases of the samples is smaller than 5 m/s. Figure 4 shows frequency distribution of the speed difference. The most common class of speed bias is in the range between -1 and +1 m/s. These comparison results indicate good agreement between the two winds.

3.3. Comparison between WV winds and analysis winds of JMA

WV winds extracted for seven cases were compared with objective analysis winds of JMA, to assess the quality and the performance of height assignment methods. For this purpose, bad winds that affect the

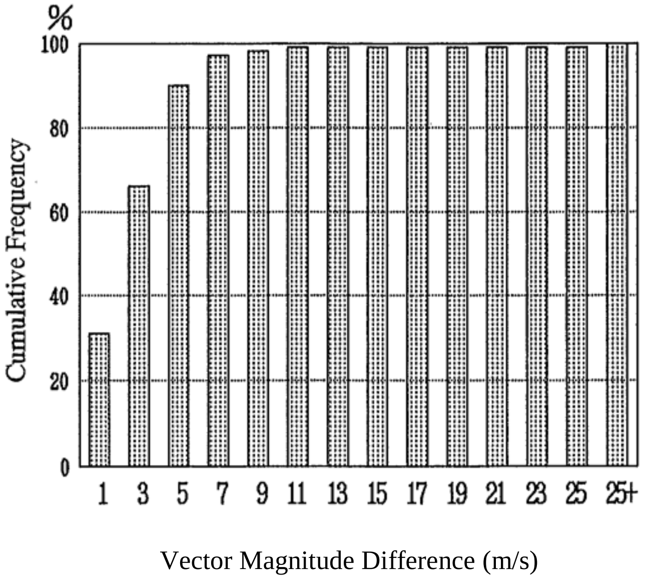

Figure 3. Cumulative percentage frequency of the vector magnitude difference (m/s) between WV winds and high-level IR winds calculated from the same target element.

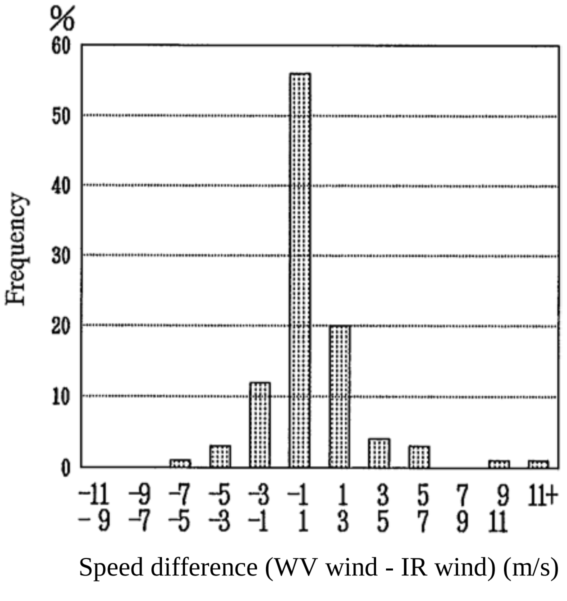

Figure 4. Percentage frequency distribution of the speed difference (WV wind - IR wind) (m/s) between WV winds and high-level IR winds calculated from the same target element.

statistics were rejected. That is, the WV wind whose minimum vector magnitude difference from the analysis wind is larger than 10 m/s is excluded. The analysis winds to be compared withWV winds are interpolated at the same levels as those of the WV winds.

(1) Comparison 1. (Height assignment method using WV brightness temperature)

The comparison was performed at the wind heights determined from WV brightness temperature by five manners, that is, the heights corresponding to the lowest 1, 5, 10, 20 and 30 % of WV brightness temperature in the target element. The results are tabulated in Table 1.

In 300-200 and 200-100 hPa layers, RMS vector and speed differences (WV wind – analysis wind) for five heights are in the range from 8.2 to 8.5 m/s and from -1.0 to 2.1 m/s respectively. In 400-300 hPa layer, they are worse than those of 300-200 and 200-100 hPa layers and are in the range from 9.8 to 10.5 m/s and from 2.4 to 4.0 m/s respectively. In 500-400 hPa layer, they exceed 11.1 and 4.4 m/s respectively for all heights. It shows that mid-level WV winds (p>400hPa) make the statistic results poor as described by Laurent (1991). Improvement is observed by the elimination of WV winds in 500-400 hPa layer from the statistics in 500-100 hPa layer.

(2) Comparison 2. (Height assignment method using WV brightness temperature and cloud top height)

The WV winds calculated by tracking high-level clouds show good agreement with high-level IR winds as described in subsection3.2. This suggests that it is possible to assign cloud top heights to

Table 1. The quality of WV wind extracted for seven cases against analysis wind of JMA. RMS vector difference (m/s), speed bias (m/s) (WV wind – analysis wind) and the number of samples at the wind heights (hPa) corresponding to the lowest 1, 5, 10, 20 and 30 % (h1, h5, h10, h20 and h30) of WV brightness temperature in every 100 hPa layer and thick layers of 400-100 and 500-100 hPa.

	h1			h5			h10			h20			h30		
	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias
200-100hPa	8.2	389	-0.7	8.3	258	-0.4	8.3	192	-0.4	8.2	117	-0.3	8.3	78	-1.0
300-200hPa	8.2	1540	1.3	8.2	1320	1.4	8.3	1169	1.7	8.3	961	1.9	8.5	823	2.1
400-300hPa	9.8	557	2.4	9.8	662	3.1	10.0	684	3.2	10.3	754	3.5	10.5	756	4.0
500-400hPa	11.1	60	6.1	11.1	108	4.6	12.0	148	4.4	11.3	153	4.9	11.6	194	4.4
400-100hPa	8.6	2486	1.3	8.7	2240	1.7	8.9	2045	2.0	9.2	1832	2.4	9.4	1655	2.9
500-100hPa	8.7	2546	1.4	8.8	2348	1.8	9.2	2193	2.1	9.4	1985	2.6	9.7	1849	3.0

Table 2. Same as Table 1, but for the height assignment method. WV wind height is determined by the method combined WV brightness temperature and cloud top height (hl+CTH, h5+CTH, h10+CTH, h20+CTH and h30+CTH). The CTH in the last column indicates the results for the WV winds derived from the target elements containing semitransparent cloud.

	h1+CTH			h5+CTH			h10+CTH			h20+CTH			h30+CTH			CTH		
	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias	RMS vec. diff.	Sample	Bias
200-100hPa	8.3	461	-0.4	8.3	353	-0.1	8.3	303	-0.1	8.2	239	0.1	8.1	203	0.0	8.0	128	0.8
300-200hPa	7.9	1586	1.2	7.9	1477	1.3	7.9	1387	1.4	7.9	1288	1.6	8.0	1209	1.7	7.5	654	1.8
400-300hPa	9.3	496	1.9	9.2	513	2.0	9.5	514	2.2	9.6	518	2.2	9.8	515	2.5	9.5	183	1.5
500-400hPa	11.8	84	6.6	11.1	106	5.4	11.5	123	5.0	11.3	116	5.4	10.7	126	4.4	12.6	36	7.1
400-100hPa	8.3	2543	1.3	8.3	2343	1.2	8.4	2204	1.4	8.4	2045	1.6	8.5	1927	1.8	8.0	965	1.6
500-100hPa	8.5	2627	1.3	8.4	2449	1.4	8.6	2327	1.6	8.6	2161	1.8	8.7	2053	1.9	8.2	1001	1.8

WV winds. At the present stage, tracked elements are not classified in cloud structure or water vapor structure except for semitransparent cloud. Therefore the corrected cloud top heights by WV and IR data are assigned to WV winds derived from the target elements containing semitransparent clouds. To other WV winds derived from the target elements containing thick clouds or water vapor structures, the heights calculated from WV brightness temperature by the five manners are assigned as stated in comparison 1. The comparison results are tabulated in Table 2.

It shows that the height assignment method to combine the height corresponding to the WV brightness temperature and the cloud top height improves the quality of WV wind. In 400-100 hPa layer, the reduction of RMS vector and speed differences for five heights by the height assignment method using WV brightness temperature and cloud top height are in the range from 0.3 to 0.9 m/s and from 0.0 to 1.1 m/s respectively. In this layer, RMS vector difference and speed bias vary from 8.3 to 8.5 m/s and from 1.2 to 1.8 m/s respectively. There is not distinct difference of the quality depending on the WV brightness temperature height (h1 - h30) judging from the results in the seven cases.

4. Concluding remarks

The WV winds were extracted in seven cases by a preliminary method and their quality was assessed. The results are summarized that;

(1) WV winds are derived consistently and continuously in space. The area where WV winds are derived is larger than that where IR winds are derived.

(2) The quality of high-level WV winds (p<400hPa) is expected to be comparable to that of IR winds and the quality of mid-level WV winds (p>400hPa) is poorer than that of high-level WV winds.

(3) The height assignment method by WV brightness temperature and cloud top height is efficient in height assignments.

More studies on methods of target selection, height assignment and automatic quality control should be done before operational extraction of WV winds.

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