The Effects of Different Time Intervals on the Wind Estimation

Abstract

The magnitude of the wind speed and the number of the data deduced from pictures obtained in different time interval are compared. It is revealed that wind speeds are little affected by the interval of pictures and the number of wind data is increased with time interval getting shorter.

1. Introduction.

Initially it was anticipated that smaller scale feature of the atmospheric motion can be detected, as the interval of picture is getting shorter. However our study fails to substantiate our expectation.

Wind vectors have operationally obtained from displacement of cloud targets within a 90-minute interval using a loop film which consists of four frame imageries.

In June 27th 1978 a limited scan by satellite was made. Each imagery was taken every 4 to 6 minutes in middle latitude, and the center of the scan is over 35°N latitude. The detail of the observation is shown in Table 1. A purpose of this report is to investigate whether

(1) wind speeds are variable with time, and

(2) the number of cloud targets to derive satellite wind increase or decrease

depending upon different time interval of picture taking. Namely, our intent is seeking for a more suitable time interval to get wind data from satellite with good accuracy.

The factors to come forth error in wind speeds are considered, and then a reliabilty of the wind speed is discussed. The word "wind" used in this report is defined as the wind vectors obtained by the Loop Film method.

2. Error due to poor registration.

A more suitable condition for wind estimation by tracking clouds is that there should be three land marks at least; each land mark should be placed separately within one frame in order to perform precise registration. In daily routine we treat full disk imageries, registration is made by using land marks selected from those in Asia and Oceania. In the area (30°N-40°N lat.) of this observation, land marks are few, and especially they are none in the east of 145°E longitude. However, some points can be adopted as land marks, for example, Shantong Peninsula, Pohai Bay, Korea, the coastline near Shanghai etc.. They are very close for

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Table 1 The Time Schedule of Obsevation by Limited Scans

Observation Time		June 27th 1978 from 0400Z to 0510Z	
Central Latitude		35°N	
Number of Scan Line		250 lines	
Number of Segment		11 volumes	
Segment No.	Initial line	Final line	Starting Time of Observation
1	469	719	0407Z
2	469	719	0411Z
3	469	719	0415Z
4	469	719	0419Z
5			
6	469	719	0432Z
7	469	719	0437Z
8	469	719	0443Z
9	469	719	0448Z
10			
11	469	719	0457Z
12	469	719	0502Z
13	469	719	0507Z

precise registration. So, another land marks, different from land marks we mentioned above, are necessary. Each frame of negatives, on which longitudes and latitudes had been inserted with the aid of attitude information of satellite, is registered by matching the longitudes and latitudes at this time. Error caused by using the loop films which are made up in the way described in section 1 will be assessed in this section.

If it is assumed that registration had been achieved precisely, displacement-vectors of earth features, for example, a shape of coastline of continent, a tip of cape, would be zero because they are fixed at the same positions on each frame. And if the prediction of attitude of satellite is made accurately, the longitudes and latitudes inserted in every imagery would be roughly located at the same position on the earth surface as the time of observation for each picture we used does not differ apparently. Therefore, an intersection of longitude-latitude can be regarded as one of land marks. Namely, computing a displacement of a intersection point will be equal to computing that of land marks. It is considered that a distribution of the displacement-vectors obtained in such the procedure give us a field of error by registration. In order to determine the magnitude of error, tracking the intersection points is made within the area surrounded by the latitudes of 30°N and 40°N, and by the longitudes of 110°E and 170°E. The results are shown in Fig. 1, Fig. 2 and Fig. 3. As shown in Fig. 2, for example, considerable errors are noted in the east of 160°E longitude

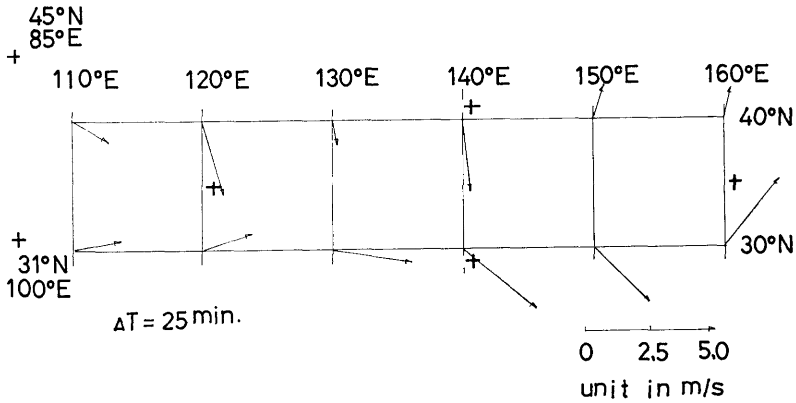

Fig. 1 The distribution of error in magnitude due to poor registration. It is assumed that the information of satellite-attitude is good. The direction of arrows indicates the displacement of longitude/latitude intersection points. The plus mark "+" shows the position of bench mark by which error has been evaluated. Used imageries are taken at time from 0407Z to 0432Z.

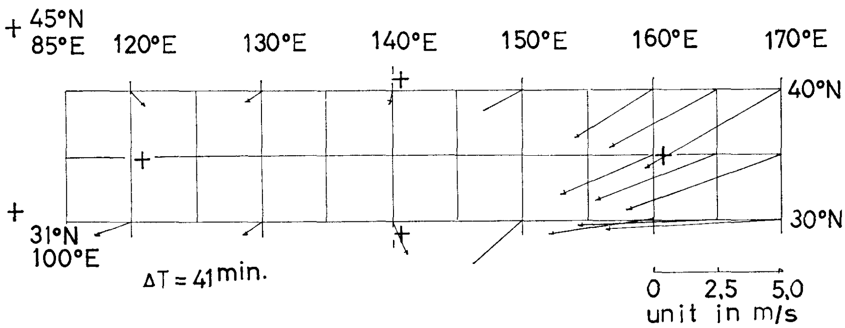

Fig. 2 The same as Fig. 1, excepting that the used imageries are taken at time from 0407Z to 0448Z.

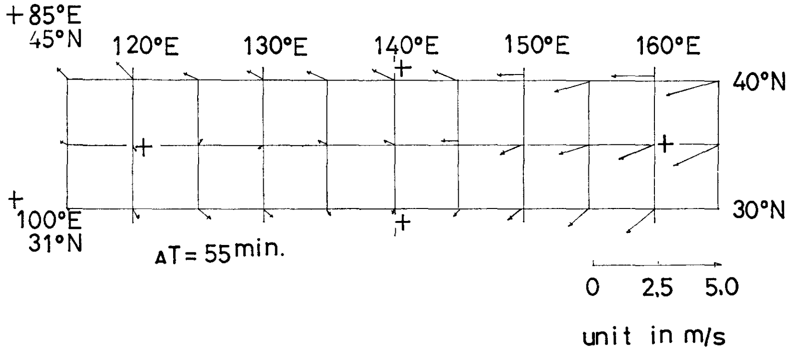

Fig. 3 The same as Fig. 1, excepting that the used imagries are taken at time from 0407Z to 0502Z.

Table 2

Time Interval	12 min.	25 min.	41 min.	55 min.
Mean (m/s)	—	2.2	1.7	0.82
S.D. (m/s)	—	8.3×10	-1.7×10	1.7×10

due to the lack of bench mark[N.B.1]. Now, the mean value and its standard deviation are computed with 12 pieces of data which are in the west of the 160°E longitude. From Table 2, it will be deduced that a mean value decreases in magnitude as time interval is lengthened, which implies that wind speeds can be obtained rather accurately when one uses pictures which are taken at longer interval. Turning our interest to the standard deviation, it is evident that the standard deviation is large in magnitude at the short interval.

Although it is difficult to interpret what these two factors are meant by, one can speculate as follows. An experience in selecting cloud targets gives us the fact that bench marks inserted on loop film do scarcely move on a screen, so that designation of the initial and final position of a bench mark is hard beyond expectation.[N.B.2]. Displacement of a certain bench mark is noticeable for the frame taken in longer time interval. It means that relative error in wind estimation decreases in magnitude as time interval is lengthened.

In order to obtain better wind data, it is recommended that,

(1) the wind operation should be made in the area which includes land marks as many as possible, and

(2) interval of time should be taken enough for defining a bench mark displacement.

The above requirement decreases the time resolution of the detection of the meteorological phenomenon. To analyze a fine atmospheric structure, fine mesh data are needed in terms of time and space. Making time-resolution coarse would be led to decreasing space-resolution. Relation between the resolution and satellite winds will be discussed in a later section.

3. A comparison of wind speeds computed in different interval of time.

A vector at time $t=t_0$ will be written as

$$V_{t_0}=V_{\mathrm{TRUE}}+\varepsilon_B+\varepsilon_C \tag{3.1}$$

Similarly, a vector at time $t=t_k$ $(t_k>t_0)$ will be

$$V_{t_k}=V_{\mathrm{TRUE}}+\left(\frac{\partial V}{\partial t}\right)d(t_k-t_0)+\varepsilon'_B+\varepsilon'_C \tag{3.2}$$

where

V_{t_0} is the apparent observed vector at time $t=t_0$.

V_{t_k} is the same one at time $t=t_k$.

V_{TRUE} is the true vector, not contami-

N.B. 1: A wind vector is determined from the displacement of a cloud over the earth surface. The cloud is to be earth located. In order to do this, bench marks are used as a medium to transform from tracking board coordinate to earth coordinate.

N.B. 2: When a 24-hour loop film is projected on a screen, a locus of bench mark makes the figure of the character "8". When the time period between the starting picture and the ending picture is so short, the locus forms a curve which is a part of the character "8".

nated.

ε_B, ε'_B are error in the indistinguishing the initial and final points of bench mark-displacement due to its short distance.

ε_C and ε'_C are error caused by the poor location of the initial and final points of cloud-displacement. ε_B are bias error in general, while ε_C would be shown a Gaussian distribution.

Other letters and operators follow conventional usage.

Let's compare the two vectors.

$$\boldsymbol{V}_{t_k}-\boldsymbol{V}_{t_0}=\left(\frac{\partial \boldsymbol{V}}{\partial t}\right)d(t_k-t_0)$$
$$+(\varepsilon_B-\varepsilon'_B)+(\varepsilon_C-\varepsilon'_C) \quad (3.3)$$

Apart from the accelaration term, we can not evaluate the two terms of the right hand side, $(\varepsilon_B-\varepsilon'_B)$, $(\varepsilon_C-\varepsilon'_C)$. To eliminate ε_B, ε'_B, ε_C and ε'_C, vectors within a domain have been averaged.

A wind vector at a point "i" is written as

$$\boldsymbol{V}_i=\boldsymbol{V}_0+\frac{\partial \boldsymbol{V}}{\partial t}dt+\frac{\partial \boldsymbol{V}}{\partial x}dx+\frac{\partial \boldsymbol{V}}{\partial y}dy$$
$$+\varepsilon_B+\varepsilon_C$$

where

$\boldsymbol{V}_i$ is the vector at a point $(x_i,\ y_i,\ t_i)$

$\boldsymbol{V}_0$ is the vector at a point $(x_0,\ y_0,\ t_0)$

Now, we will average some vectors within a domain. Then,

$$\varepsilon_B=\text{constant}=C$$

$$\bar{\varepsilon}_C\cong 0$$

If there are many samples of the wind vector in the domain, Eq. (3.3) is reduced to

$$\bar{\boldsymbol{V}}_i=\boldsymbol{V}_0+C \quad (3.4)$$

where "—" bar indicates an operator of algebraic mean. As the domain is small for our limited scan,

$$\frac{\partial \boldsymbol{V}}{\partial x}dx\sim\frac{\partial \boldsymbol{V}}{\partial y}dx\cong 0\,.$$

In the above discussion, the term of $\left(\frac{\partial \boldsymbol{V}}{\partial t}\right)dt$ was ignored because all these displacement of cloud are computed using loop films of different time interval whose first frame is taken at 0407Z, in this case. We assume that samples are distributed uniformly around the geometric center of a domain, and $\boldsymbol{V}_0$ is the vector at its center. In such a case, it is reasonable to assume that mean vector in the domain equals to $\boldsymbol{V}_0$.

Eq. (3.4) had been introduced under an assumption that a number of samples were distributed within a domain. Although there are a few samples in the domain 5° long.×5° lat. as shown in Table 3 and Table 4, it is considered that the difference more than 2.2 m/s in magnitude is significant. Then, these differences among the three cases are labelled by the mark "$*$" in Table 3 and Table 4.

We will consider why the difference has arisen. First, we are aware that anvil cirrus had been selected as cloud target in this area. In another area, most of targets were cirrus clouds associated with jet stream.

In a guidance for selecting tracers, Hubert et. al. (1971) stated that; "Take care in tracking clouds that appear to penetrate vertical shear layers. In these cases, try to track the upshear edge rather than the center of mass. For example, in areas of active convection the cloud area grows rapidly because of anvil growth. The origin of anvil (brightest area at rear of the growth area) moves with the middle- and low-level wind. The leading edge

Table 3 Symbol u and v indicate u- and v-component respectively, which are averaged within an area 5° long.×5° lat.. Symbol n indicates the number of sample included in the area. The values labelled the mark "*" are considered to have significant difference among the three cases.

Latitude	Time Interval (min.)		105E–110E	110E–115E	115E–120E	120E–125E	125E–130E
40°N ~ 35°N	55	u	22.7	25.6	21.5	25.6	38.1
		v	14.2	13.5	4.1	−3.8	−10.9
		n	2	8	4	6	3
	41	u	20.1	24.3	12.4*	25.1	37.2
		v	14.2	14.6	4.5	−4.3	−9.1
		n	3	5	2	5	4
	25	u	22.0	27.2	22.6	25.7	33.0*
		v	10.9	10.3	4.2	−3.1	−6.6
		n	5	8	6	8	7
35°N ~ 30°N	55	u			16.4	17.7	16.3
		v			1.1	−4.5	−8.2
		n			1	2	2
	41	u				13.7	6.9*
		v				−0.2	−6.2*
		n				3	2
	25	u		13.0	11.4	17.1	14.9
		v		7.4	2.9	−1.3	−4.1*
		n		2	2	2	5

Table 4 The same as Table 3.

Latitude	Time Interval (min.)		130E–135E	135E–140E	140E–145E	145E–150E	150E–155E	155E–160E
40°N ~ 35°N	55	u	33.4	36.7	22.6	24.5	−19.1	21.3
		v	−13.0	−8.2*	−9.2	−16.5	−11.3*	−4.4
		n	3	2	2	9	3	5
	41	u	34.3	33.7	22.3	22.9	−17.3	19.4
		v	−10.0	−5.4	−11.8	−17.3	−7.1*	−4.0
		n	4	1	5	8	1	5
	25	u	32.3	28.7	22.2	25.4	18.7	22.3
		v	−6.7*	−4.8	−9.1	−15.1	−4.2*	−6.5*
		n	8	5	5	17	10	8
35°N ~ 30°N	55	u	6.3*	10.3	11.6	13.7	15.2*	11.9
		v	−11.8	−7.8	−13.3	−19.0	−14.4	−14.5
		n	3	2	12	9	6	5
	41	u	3.7*	6.1*	9.9	13.4	10.2*	12.0
		v	−11.8	−8.6	−13.4	−21.9	−16.6	−14.9
		n	2	4	11	10	6	9
	25	u	9.0*	12.2	12.9	14.1	13.6*	12.2
		v	−10.0	−7.8	−11.4	−20.2	−17.4	−13.8
		n	1	9	15	15	13	10

of the anvil, while advancing with the high-level wind, may be moving more slowly than the wind because of evaporation. Thus the leading edge of growing cirrus plumes should be avoided."

We feel that the differences in magnitude among three cases will probably be caused by evaporation or by a fact that height of anvil cirrus varied with time.

From Table 3 and Table 4, we are not aware, however, how these three cases differ in wind speed totally. Fig. 3 and Fig. 4 are graphical representation of Table 3 and Table 4, including such data deduced from anvil cirrus which was regarded as inaccurate data. In these Figures, broken lines indicate an upper and lower limites of error, ± 2.2 m/s, described in section 2.

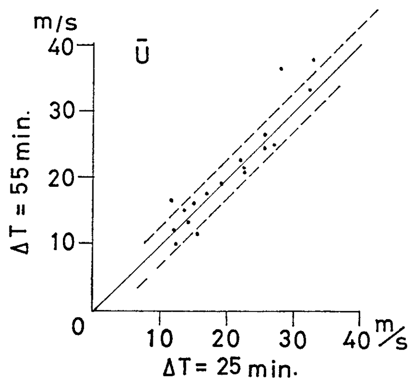

Fig. 4 The comparison of u-component in the time interval 25 minutes and 55 minutes. Broken lines indicate the range of error within ± 2.2 m/s.

Judging from inspection, it will be reasonable that there are little differences in magnitude among three cases, in other words, wind speeds are independent of the time interval of pictures acquired.

4. Relation of the number of cloud targets for wind estimation to interval of picture acquired.

Some guidelines on selecting good target had been presented by Hubert et al. (1971). Taking these guidelines into consideration, we made an effort to track some cloud targets as much as possible. The number of target having been tracked is shown in Table 5. The tendency that the sample number increases as the time interval is shortened was recognized.

Table 5

Time Interval (min.)	12	25	41	55
Number of sample	213	205	147	146

From the result that the wind speeds show little change with interval of picture acquired, it is speculated that a vector field deduced from cloud displacement represents the characteristic scale feature. Accordingly, cloud targets should be selected in such a density as to obtain representative wind field. Increasing the number of wind vectors does not mean a vector field of a small scale can be reproduced, because it appears that the neigh-

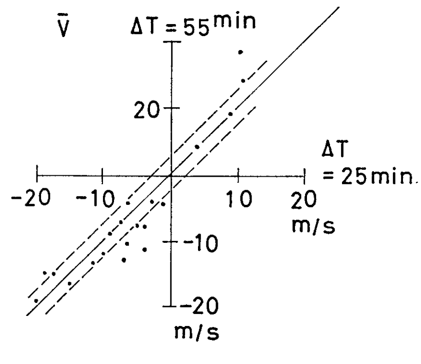

Fig. 5 The comparison of v-component. Others are the same as Fig. 4.

boring satellite-wind vectors are not independent each other.

Therefore, the conclusion in this section is: Although the number of cloud targets apparently increase when the time interval of picture is made shorter, wind field in small scale may not be obtained.

5. A wind field represented by statellite-winds.

Wind vectors obtained by the RAWIN respond to the atmospheric motions ranging from ultra long wave to intermediate scale motion. The response of satellite-winds to atmospheric motion is studied. The area to be analysed this time is nearly 1000 km×5000 km, which is too small to analyze a vector field in synoptic scale, but it is enough for analysing a vector field in the intermediate scale.

Therefore, instead of making wave number analysis strictly, we would like to search what scale of atmosphric field are imbedded.

Fig. 6, Fig. 7, and Fig. 8 are graphical representation of Table 3 and Table 4. The distribution of $\bar{u}$ at 35°N-40°N ($\bar{u}$ is a mean value within an area 5°long.× 5° lat.) is shown in Fig. 6, in which the maximum value is found around 130°E and 140°E longitude. It is likely that the wave of which wave length is 2000 km-3000 km and smaller exist. Fig. 7 is also the distribution of $\bar{u}$ at 30°N-35°N latitude, whose pattern differs from those in Fig. 6 in phase completely. The waves, of which wave length 2000 km-3000 km is recognized in the Figure, however. The distribution of $\bar{v}$ at 35°N-40°N is shown in Fig. 8, in which the wave having the minimum wind speed around 150°E and the maximum

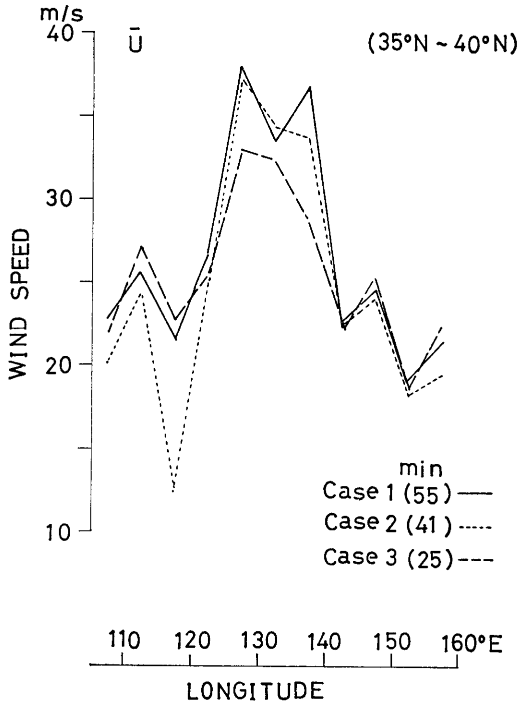

Fig. 6 The zonal distribution of u-component along the longitudinal belt, 35°N-40°N. $\bar{u}$ treated here is a algebraic mean of the wind speed within an area 5° long.×5° lat..

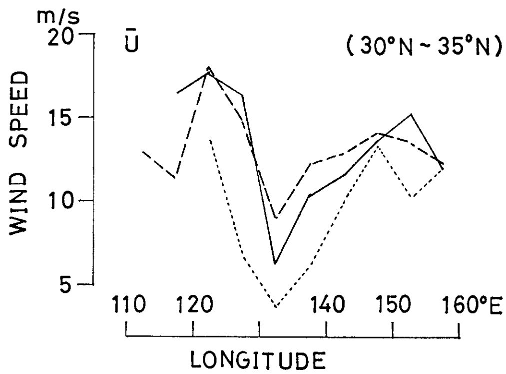

Fig. 7 The zonal distribution of $\bar{u}$-component along the belt 30°N-35°N. Scale and symbols are the same as Fig. 6.

wind speed at the west of longitude is found. Probably this wave may be related to a ultra long wave. On this wave, the

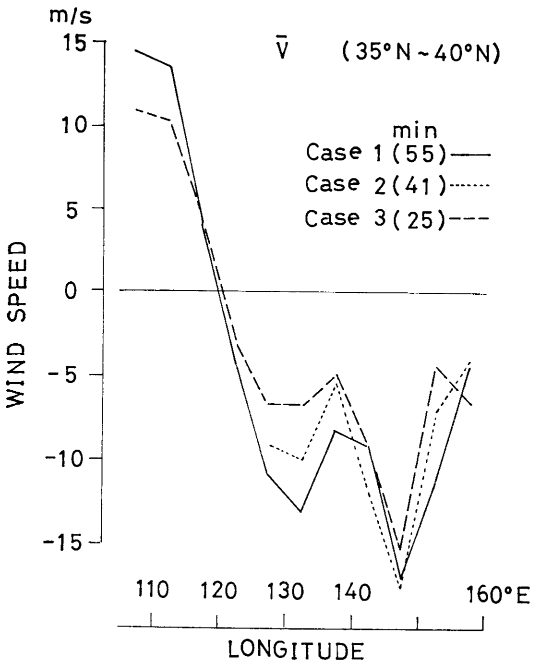

Fig. 8 The distribution of $\bar{v}$-component along 35°N-40°N. Scale and symbols are the same as Fig. 6.

wave of 2000 km-3000 km wave length seems to be imbedded.

A smaller wave could not be apparently depicted, because the data is plotted every 5° longitude interval. In order to extract the small waves from the original data, the difference between the original data and its running mean value is computed.

As the original data are not distributed uniformly, a data set composed of grid point value has been produced by the aid of objective analysis (correction method). Differences then were calculated.

Now, a set of the grid point value of 51 pieces had been prepared for a longitude (from 110°E to 160°E). According to rough inspection, the wave having a wave lengh in order of 1000 km is found, which may be found with 11 grid point values over a certain latitude. Then differences between these grid point values and running mean of 11 grid point values have been calculated for the u- and v-component along 35°N latitude respectively. The results obtained with such a procedure are shown in Fig. 9 and Fig. 10. It is revealed that there are the waves of which wave length are approximately 600 km to 2000 km in the $\bar{u}$-field and in the $\bar{v}$-field. Composited wind vector field using u and v is displayed in Fig. 11. By comparing Fig. 11 to the 300 mb weather map, we found that its pattern coincide with each other, although the numerical values differ in

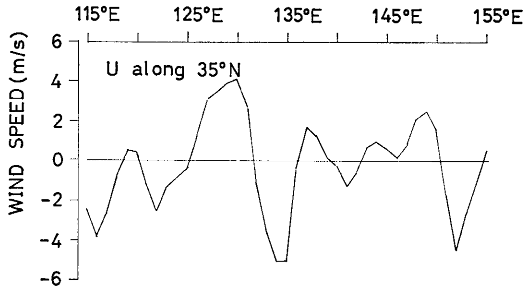

Fig. 9 Smaller scale waves on a u-field extracted from interpolated data by the running mean method. The ordinate corresponds to a scale of an amplitude of the wave, the abcissa corresponds to a scale of a wave length, respectively.

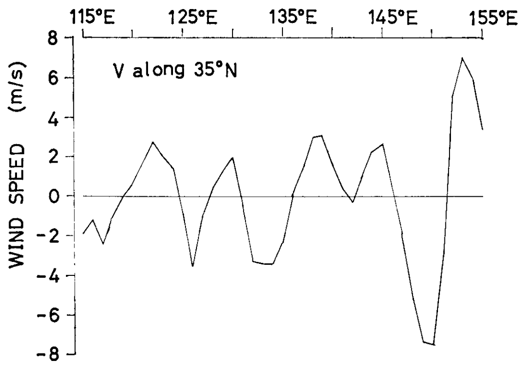

Fig. 10 Smaller scale waves on a v-field. Others are the same as Fig. 9.

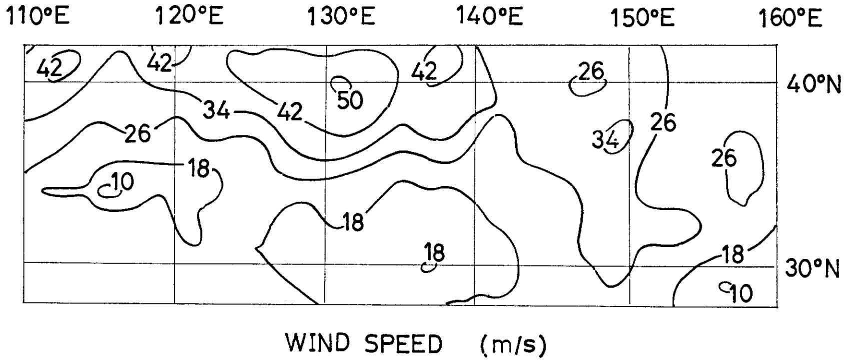

Fig. 11 The interpolated wind speed field. Unit is in m/s. The ordinate is the latitude, while the abscissa is the longitude.

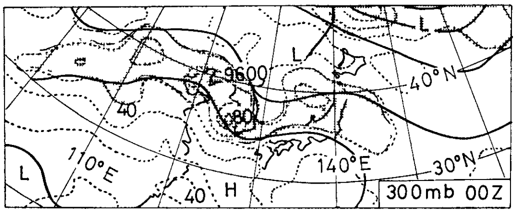

Fig. 12 The 300 mb chart at 0000Z June 27th 1978. The solid lines show contour, the interval of which is 120 meters. The dotted lines indicate iso-tach, the interval of which is 20 m/s. The area of more than 40 m/s in wind speed is stippled.

magnitude (see Fig. 12).

Wind vectors treated in this report are on cirrus level, while wind vectors observed by the RAWIN are those on the 300 mb pressure-level. Accordingly it is speculated that the difference of wind vector between them is due mainly to the height difference of wind level.

Next, we will discuss a relation between the divergence field (Fig. 13) and the satellite picture. This divergence field is computed from u and v which are interpolated with the aid of an objective analysis. The comparison of the former to the latter follows. The region of the East China Sea and West Japan are mostly cloud free with several cumulus clouds. Here, convergence is predominant where downward motion is expected. Cirrus clouds

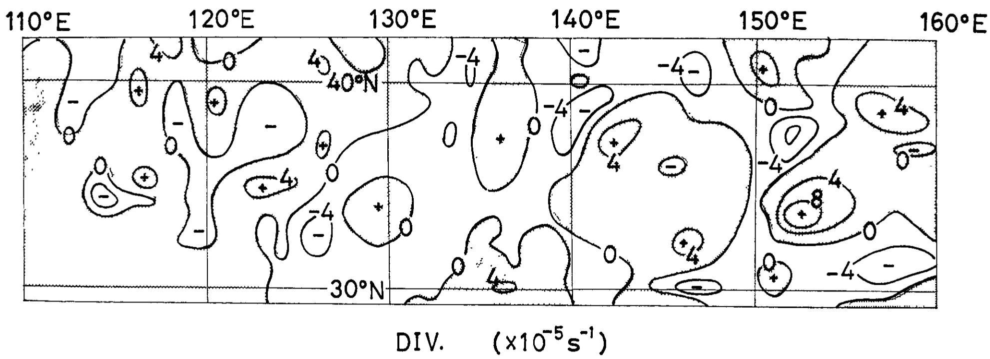

Fig. 13 The divergence field calculated from interpolated u- and v-component, in which 1° longitude/latitude is used as the grid interval. Positive areas are stippled. Unit is in $\times 10^{-5}$ sec^{-1} and interval of iso-value is 4.

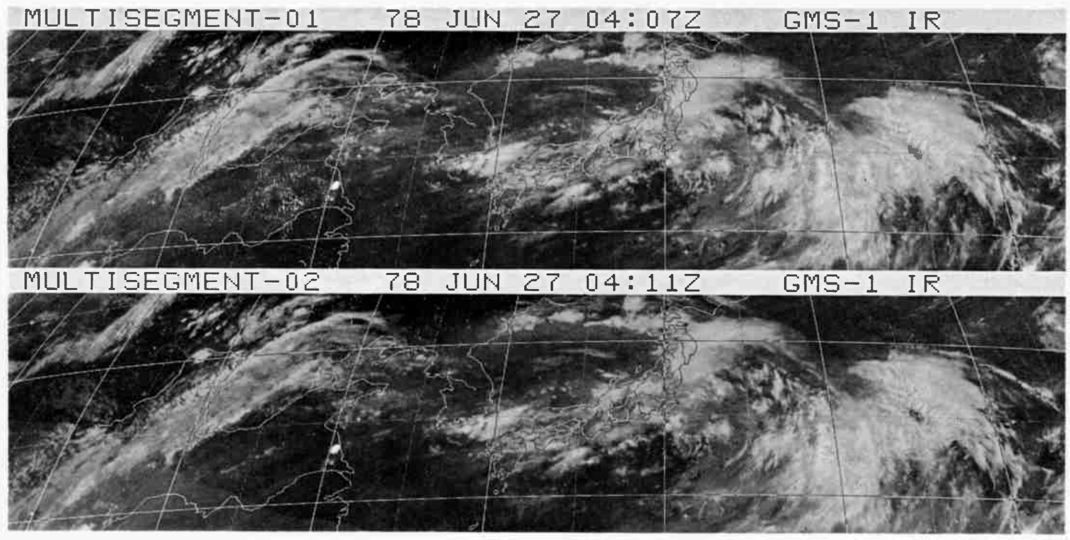

Fig. 14 IR imageries.
Frames of limited scan taken by the GMS special operation, from which satellite wind vectors are derived. "White" shows clouds, "black" shows earth-surface. The inserted mark "+" indicates position of bench marks. (See our text.)

are extensive over the sea in the east of Japan. Here, divergence is found where upward motion can be expected.

These two are led to the conclusion that satellite-winds respond to the wind vector field in the synoptic scale or in the intermediate scale.

6. Summary.

The results obtained in this report are as follows.

(1) Satellite-wind velocity little varies with the interval of pictures.
(2) To get a good wind data, an area including a number of land marks should be taken.
(3) The interval of time should be taken enough for distinguishing a bench-mark displacement.
(4) Satellite-winds respond to the wind vector field in the synoptic and/or in the intermediate scale motions.
(5) Cloud targets should be tracked in a density as to obtain the representative vector field.

It can be said that the satellite-wind vectors close to each other are not independent. Although satellite-wind vectors are reliable on an accuracy of the order of 2-3 m/s, the problem of assigning levels still remains, as is found on comparing the wind vectors to the 300 mb wind vector. It is craved, here, that a skill determining cirrus cloud height with reasonable accuracy be developed.

Reference

Hubert, L.F. and L.F. Whitney, Jr. (1971): Wind Estimation from Geostationary Satellite Pictures. Mon. Wea. Rev., Vol. 99 665-672.