Summary of Operational Wind Derivation Systems Used during and after FGGE*** Period*

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1. Introduction

During the First GARP Global Experiment (FGGE) period, cloud motion winds were derived at four operating centers (agencies); the Meteorological Satellite Center of Japan (MSC/JMA), the National Environmental Satellite, Data and Information Service (NESDIS/NOAA), the European Space Operations Centre (ESOC/ESA) and Space Science and Engineering Center of the University of Wisconsin (SSEC/UW). The former three operating centers have kept the operational cloud motion wind derivation since the FGGE period. This article presents the summary of the wind derivation systems used during and after the FGGE.

In the following section, the satellite wind derivation procedures are generally summarized and in section 3, each center's system is described including a brief history of the wind derivation system during and after the FGGE.

2. Satellite Wind Derivation System

1) Images and their Registration

Either infrared (IR) or visible (VIS) images usually taken at 30-minute interval are used for target cloud selection and tracking, and IR, VIS and/or water vapour (WV) channel's images are used for the estimation of target cloud height and wind representative height. The nominal time of images used for tracking is shown in Table 1.

For correct tracking of the target cloud, the relationship between target cloud location on the image and the location on the earth must be accurately determined. For this purpose, the orbital and attitude data of the satellite and some other imaging information like scan geometry are used to calculate the relationship between them. The error (absolute error) is generally 10 km or more on the earth surface. But the absolute error of image registration is not so serious because it vanishes in the calculation of vector from two time-sequential images if the images are relatively well registered. In order to increase the accuracy, the SSEC developed a new method in which a set of landmarks were used to adjust the image location to earth location. Both of the NESDIS/NOAA and the MSC/JMA adopted similar method. In addition to this method

* This article is a part of material prepared for a lecture with a title, "Improvements in geostationary satellite wind observations as a result of the Global Weather Experiment (GWE***) and Applications of these in the context of the WWW system," which was presented at a conference on the Results of the GWE and their Implications for the WWW held in Geneva, on 27-31 May 1985. The lecture note will be printed in the proceedings of this conference to be published in autumn 1985. Further detailed paper of the author's lecture will be contributed to the coming issue of the Meteorological Satellite Center Technical Note.

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*** The FGGE is currently called the Global Weather Experiment (GWE), because there is no more plan to implement the Second GARP Global Experiment (SGGE).

Table 1 Nominal times of images used by operating agencies for wind derivation.

	MSC/JMA			NESDIS/NOAA						ESA	
Satellite	GMS			GOES-E			GOES-W			METEOSAT	
Synoptic time(GMT)	0000Z		1200Z	1200Z	1800Z	0000Z	1200Z	1800Z	0000Z	0000Z	1200Z
Tracking	VIS	(*)	IR	IR	IR	IR	IR	IR	IR	IR(*)	IR(*)
Low-level	2300 2330 0000	(A) (B) (C)	1100 1130 1200	1000(0900) 1030(0930) 1100	1500(1500) 1530(1530) 1600	2200(2100) 2230(2130) 2300	1015(1015) 1045(1045) 1115	1545(1545) 1615(1615) 1645	2215(2145) 2245(2215) 2315	1000(21) 1030(22) 1100(23)	2200(45) 2230(46) 2300(47)
High-level	2230 2300 2330 0000	(Z) (A) (B) (C)	1030 1100 1130 1200	0900(0900) 0930(0930) 1000(1000) (1030) (1100)	1530(1500) 1600(1530) 1630(1600) (1630) (1700)	2100(2100) 2130(2130) 2200(2200) (2230) (2300)	0915(0845) 0945(0915) 1015(0945) (1015) (1045)	1615(1445) 1645(1515) 1715(1545) (1615) (1645)	2045(2045) 2115(2115) 2145(2145) (2215) (2245)	(same as low-level)	
* Image names for wind derivation. 1. Actual imaging time is approximately from T-29 min. to T-4 min., where T is nominal time.				1. Times between parentheses were effective until 1982. 2. Nominal times shown above are approximately actual start times. 3. For low-level wind derivation, two of those three images are used for tracking.						* slot number	

the MSC/JMA redetermine the attitude of the satellite using the landmark locations determined on five VIS images a day, and then predict the attitude for 4 days on. Furthermore, when each image is ingested the earth-edge is extracted from the IR full disc image and then earth location in the image is finely tuned. The predicted attitude and orbital data, scan geometry of the satellite and fine-tuned earth location are used for wind vector calculation.

2) Target Cloud Selection and Tracking

There are generally two types of target cloud selection and tracking procedures; namely, manual and automatic procedures. In the automatic procedure, the cloud height information is used for selection of suitable target to be tracked. The tracking is performed by a pattern matching technique. In the manual procedure, on the other hand, an operator selects and tracks suitable targets either on a digitizer board on which photo-processed film-loop is projected or on a TV-screen on which animated movie-loop is electronically displayed. At the several centers, combined procedures are used to various extents. The selecting and tracking procedures are summarized in Table 2.

Table 2 Target selection and tracking procedures for satellite wind derivation.

	Manual		Combined		Automatic
	Film-loop procedure	Man-machine interactive procedure			Automatic procedure
Target cloud selection	Manual (off-line)	Manual			Automatic
Tracking	Manual (off-line)	Manual	Semi-manual	Automatic	
Image display	Film-loop	TV-display			

(Operating agencies)

NESDIS/NOAA	High-level (-July '82)	High-level (July '82-)			Low-level
ESOC/ESA					High/low
MSC/JMA *procedure	High-level *FL	Low-level *MM-2		Low-level (-Mar.82) *MM-1	Low-level (April 82-) *AS
SSEC/UW		High/low-level			

3) Height assignment

The satellite wind is assigned to the most probable altitude which is estimated from (a) IR brightness temperature (TBB), (b) TBB and WV channel (6 μm) observation, (c) TBB and VIS brightness, (d) statistical wind representative height based on a previous investigation, or (e) subjective wind representative height. The height assignment procedures are shown in Table 3.

4) Quality control

It is necessary to remove unrepresentative winds among the resultant vectors. Some vectors are removed or flagged in the automatical procedure, and some in the manual procedure by a skillful analyst.

5) *Delivery and archiving*

Final vectors are coded into WMO formats (SATOB) for the teletype transmission to worldwide users through the GTS (Global Telecommunication System). During the FGGE period, the wind data were stored in tape in Level II-b Data formats to be sent to the FGGE Level II-b Space-based and Special Observing Systems Data Centre in Sweden. A sample of cloud motion vectors delivered by three operational centers through GTS at 12 z, March 28, 1985 is shown in Fig. 1.

3. Operational Satellite Wind Derivation System

3.1. Meteorological Satellite Center (MSC/JMA)

Japan has been deriving cloud motion winds by the Cloud Wind Estimation System (CWES) at the MSC since April 6, 1978. Cumulus tracked winds (low-level) and cirrus tracked winds (high-level) have been produced continuously except for short interuption due to satellite anomaly from the end of 1983 to mid-1984. The procedure for high-level wind derivation has been retained virtually unchanged since 1978, but that for low-level was changed on April 1, 1982 from the man-machine interactive operation to the full automatic one. The height assignment procedure was changed on December 21, 1981, and since then statistical best-fit levels have been assigned to the satellite winds. Until then climatological tropopause level had been assigned to the high-level winds and only cloud-top heights had been assigned to the low-level winds. On October 4, 1983, new quality control procedure, i. e., objective quality control (OQ) procedure was added to the existing ones; automatic assessment and *manual quality control*. The detailed procedures of the CWES operated during the FGGE period are described in Kodaira *et al.* (1980) and of current CWES in Meteorological Satellite Center (1984).

(1) Images

The nominal times of images used for wind derivation were shown in Table 1. Four images used at each synoptic time are called Image-Z, A, B and C each as shown in the table. The set of images has been unchanged since 1978.

(2) Low-level cloud tracking

Man-machine interactive (MM-1) procedure. In the CWES system, low-level winds had been derived in MM-1 procedure until March 31, 1982 and since April 1, 1982 in automatical procedure or objective procedure. The man-machine interactive target cloud selection is performed by an analyst by a use of TV-display on which time-sequential cloud pictures with 30-minute interval are superimposed in different colors. Operationally a suitable target is selected on the second image (Image B) by putting a cross

Table 3 Height assignment procedure at each center for satellite wind derivation.

	(extracted information)
MSC/JMA low-level TBB → Tc → Pc (VTP ↑ Tc) 650/600 < Pc < 950mb ⇒ Pw=850mb	→ Target cloud top height No wind representative height (- Dec. 21, 1981) → Wind representative height (Dec. 21, 1981 -)
MSC/JMA high-level Fixed height. Pw=300mb Climatological tropopause Statistical best-fit level	→ Indication of cirrus tracked wind (- Dec. 21, 1981) → Wind representative height (Dec. 21, 1981 -)
ESOC/ESA TBB WV radiance VIS radiance → ε → Tc → Pc=Pw	→ Wind representative height
NESDIS high-level (-July 1982) TBB → Tc → Pc=Pw or Subjective wind height	→ Wind representative height
NESDIS high-level (July 1982-) and SSEC TBB, VIS — Tc → Pc, Tb → Pb → Pw	→ Wind representative height
NESDIS low-level TBB → Tc → Pc (VTP ↑ Tc) Pw=900mb	→ Target cloud top height → Wind representative height

TBB : Equivalence Black Body Temperature
Tc(Pc) : Cloud-top temperature (pressure height)
Tb(Pb) : Cloud-base temperature (pressure height)
ε : Emissivity
Pw : Wind representative height
VTP : Vertical temperature profile

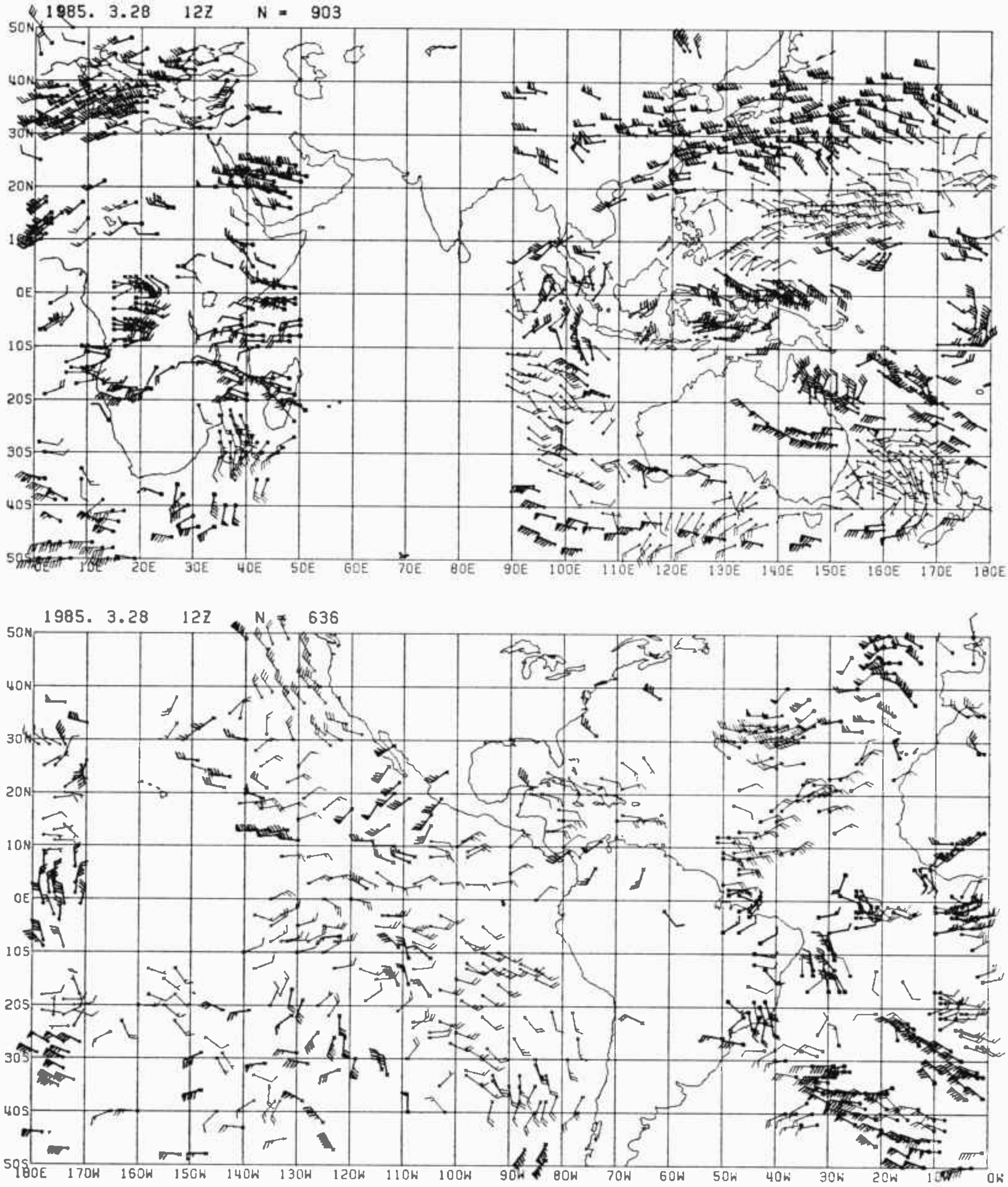

Fig. 1 Global cloud motion winds at 12z March 28, 1985, which were available through the GTS. Bold wind arrows are high-level winds and others low-level ones, partially mid-level ones.

mark on the target and the target is tracked automatically in three time-sequential images by a pattern recognition technique; cross-correlation technique. At first the tracking is carried out with coarse resolution images to obtain a first estimates of cloud motion vector (coarse vector), and then with original resolution images to obtain a final cloud motion vector. The vector is transformed into wind vector with earth coordinates (latitude and longitude) using orbital and attitude predicted data and fine tuned earth location information as described in section 2.

Automatic (AS) procedure. The automatic or objective target selection of CWES is performed on the basis of infrared histogram analysis method at each grid points with a certain degree spacings in latitude and longitude. The spacings are 2 degrees both in latitude and in longitude but partially 1 degree each. Various parameters are used for the histogram analysis but most effective one is the lowest temperature of the target cloud, i. e. the cloud top temperature. The condition for the selection of suitable target is that the cloud top height obtained from the lowest temperature using climatological vertical temperature profile is between 600/650 mb and 950 mb. Thereafter the automatically selected target clouds are processed in the same manner as the man-machine interactively selected target clouds are.

(3) High-level cloud tracking

Film-loop (FL) procedure. High-level winds have been derived by the use of film-loop device with a digitizer board, a film-loop projector, and a card punch machine. A 35 mm film-loop photographically produced from four consecutive images with 30-minute intervals is projected on the digitizer board and an analyst selects and tracks cirrus level target clouds. The starting and ending points of the target clouds and bench-marks inserted in the images are digitized using cursor dial and their physical locations on the digitizer board are punched on data cards. The card data are put into a computer and converted into high-level wind vectors referring the bench marks' locations which have been exactly known. Thereafter the wind vectors are processed in the same manner as the low-level wind vectors are.

(4) Height assignment

Low-level winds. The lowest temperature of IR brightnesses over the target cloud area is regarded as the target cloud top temperature. The temperature is converted into the pressure height using a monthly climatological vertical temperature profile (VTP). When the cloud-top height is between 600/650 mb and 950 mb, the satellite wind is assigned to the fixed altitude, 850 mb, which is considered as a wind representative level. The level is determined by the investigation on the statistical relationship between satellite wind and radiosonde wind (Hamada, 1982b). As from 1200Z December 21, 1981, the fixed height assignment procedure has been effective (Hamada, 1982a).

Until 0000Z on the day, the low-level satellite wind did not have wind representative height but target cloud top height.

High-level winds. Climatological tropopause level had been assigned from the beginning of the CWES operation in April 1978, but it seemed mostly higher than actual altitude. Therefore, since 1200Z December 21, 1981, the cirrus tracked cloud motion has been assigned to statistical best-fit level which varies seasonally and regionally (Hamada, 1982a). The levels are 200 mb

Table 4 Wind representative height to be assigned to high-level cloud motion wind derived from CWES* system. (After Meteorological Satellite Center, 1984)

SEASON	WINTER	SPRING	SUMMER	AUTUMN
35°N– / 25°N–	400 mb	300	250	300
NORTHERN HEMISPHERE	200	200	200	200
EQ				
SOUTHERN HEMISPHERE	200	200	200	200
25°S– / 35°S–	250	300	400	300
SEASON	SUMMER	AUTUMN	WINTER	SPRING
	DEC 14/15	MAR 14/15	JUNE 14/15	SEP 14/15 — DEC 14

* CWES: Cloud Wind Estimation System. Operational wind derivation system at the Meteorological Satellite Center.

for tropical region and 250 mb or lower for mid-latitudes (Table 4). Those levels were determined by the investigation on the statistical relationship between satellite wind and radiosonde wind (Hamada, 1982b).

(5) Quality control

The cloud motion vectors are quality-controlled in three stages of: (a) automatic assessment, (b) objective quality control (OQ), and (c) manual quality control. The second one, OQ process, has been introduced into the CWES system as from October 4, 1983.

Automatic assessments are performed in each step of the CWES processings. They are to check (a) the feature of matching surface, (b) picture-to-picture variation of cloud-top height (CTH), (c) wind acceleration, and (d) missing lines of the images used for tracking and CTH extraction. Through these assessments unreliable vectors are rejected or flagged automatically.

Objective quality control is performed on the resultant wind vectors. It consists of three procedures of (a) horizontal consistency check, (b) vertical wind shear check, and (c) comparison with numerical weather prediction (NWP) winds available from JMA. Through these procedures unreliable data may be automatically rejected or flagged. The flagged data are to be assessed in the process of manual quality control.

Manual quality control is performed by the operator using a graphic display, TV-display and film-loop projector. It consists of the procedures of; (a) horizontal consistency check, (b) comparison with radiosonde winds, (c) checking on the feature of a matching surface using a graphic display, (d) checking on reasonableness of automatical tracking using TV-display, and (e) checking manual tracking using film-loop projection method. The operator may reject unreliable vector through these procedures.

(6) Delivery and archiving

Finally, the satellite winds are coded into WMO formats (SATOB) to be transmitted to world-wide users through the GTS, stored on magnetic tape both in MSC's own formats and in FGGE level II-b data formats. The tapes in latter formats are available from the beginning of the CWES operation to present. A reel of the tape (1600 bpi, 1200 ft) includes 6 month data.

(7) Evaluation

International Comparison of the Satellite Winds are required twice a year (for one month each) by the CGMS (Coordination of Geostationary Meteorological Satellites). But at the MSC the comparison is carried out at every observation and the statistics are obtained every month for assessment of the homogeny and accuracy of the satellite winds.

3.2. National Environmental Satellite, Data and Information Service (NESDIS/NOAA)

The NESDIS has routinely derived cloud

motion winds from two geostationary satellites three times a day since mid-1970s including the FGGE period. Cumulus tracked winds (low-level) and cirrus tracked winds (high-level) have been produced. The procedure for low-level wind derivation has remained virtually unchanged since then, but that for high-level was changed in December 1982 from film-loop procedure to man-machine interactive procedure. The man-machine interactive system is similar one to the McIDAS to be described in section 3.4 later (Suomi, 1975). The procedures described in this section are mostly summarized from Hubert (1979) and Whitney (1984). Detailed explanation on the procedures is available in Bristor (1975).

The nominal starting times of images used wind derivation were shown in Table 1. Three images are available, but two of them are used for low-level wind derivation. Five consecutive images had been used for manual high-level wind derivation before July 1982 and three have been used for man-machine interactive wind derivation since then.

(1) Low-level cloud vectors

Step 1—Image navigation. Image navigation is performed by a general procedure using the orbital parameters of spacecraft and its scan geometry and using landmark matching for fine-tuning.

Step 2—Cloud selection and tracking. Each grid point to be a center of target area appears either one of corners or center of 5° latitude-longitude boxes. An area with about 125×125 km at a grid point is examined automatically and that covered with more than 70% middle or upper clouds are discarded. The infrared image with 16×16 pixels centered at the selected point is a template area on the first image, and one with 32×32 pixels is a search area on the second image. Cross-correlation coefficients array between both images is computed and cloud motion is determined as a vector from the center to the location with maximum value over the correlation coefficient array (matching surface).

The cloud motion is automatically checked and assigned by certain quality indicators; those of neighbor check, first guess check, and peakedness of correlation field. Final judgement of the vector is performed manually by an editor.

Step 3—Height assignment. All low-level cloud motion vectors are assigned to the 900 mb pressure level.

Step 4—Editing. The satellite winds are compared with an objective analysis and the vectors which are too inconsistent with the analysis are discarded. At first, the objective analysis from both the most recent operational 850 mb analysis and the satellite winds of the previous observation is compared with the latest satellite winds. The satellite winds with differences exceeding 120° in direction or 14 m/s in speed are discarded. At this point, the surviving latest satellite winds are introduced to the field. The analysis field is reproduced and smaller threshold values are used for the deletion. This process is repeated twice more and final threshold values are 19° and 4 m/s. The basis of this editing is an analysis procedure described by Thomasell (1979).

The vectors are displayed as wind arrows on a TV-screen and checked by a human editor. Referring satellite images and recent various analyses, errorneous vectors are deleted by the editor.

(2) Manually derived upper level winds

As from July 1982, high-level winds have been derived using an interactive computer device, VIRGS (VISSR Image Registration and Gridding System). This system is virtually identical to the McIDAS wind derivation system (WINDCO), which is briefly described later in section 3.4.

Until adoption of VIRGS system in July 1982, animated movie-loop is used for tracking high-level cirrus cloud. Five consecutive images are manually registered and 16 mm movie-loop is photographically produced. The movie-loop is projected on digitizer board and the reference marks photographically inserted are digitized by an operator and punched by means of a cursor and coupled card-punch.

Target clouds are subsequently tracked by the operator on the digitizer board. The each target trajectory is digitized and automatically punched onto cards. Referring the reference marks' locations, the target cloud motion is converted into wind on the earth surface.

Temperatures of cloud targets are estimated on basis of their apparent (infrared) temperature, which is converted into pressure level using the vertical temperature profile of the most recent upper air analysis. When the temperature cannot be well estimated due to the cirrus cloud being too thin, pressure heights are subjectively estimated directly on the basis of their location and appearance. Tropical cirri are assigned to the 250 mb or 200 mb level, mid-latitude cirrus to 300 mb, and some warmer targets to 500 mb.

Editing is performed with both tabulated manual-derived vectors and plotted map of the most recent upper air analysis for final screening. The vectors, which appear to be incompatible either with their neighbors or with the general synoptic situation, are not still recorded because such targets were not selected. In this final screening stage the gross errors such as mispunching a temperature card are checked.

(3) Finally the surviving vectors are transmitted to the GTS.

3.3. European Space Operations Centre (ESOC/ESA)

European Space Agency (ESA) derived cloud motion winds from METEOSAT-1 imagery at the Meteorological Information Extraction Centre (MIEC, ESOC) in Darmstadt, F. R. G. But the operation terminated on November 25, 1979 by satellite failure. In May 1982, they resumed their wind derivation once a day (00Z) from METEOSAT-2 imagery and in September 1982, twice a day. The description of this section is mostly summarized from Bowen *et al.* (1979).

At the MIEC, the satellite winds are derived automatically using three consecutive images at all levels. The wind derivation scheme has remained virtually unchanged since 1978.

The target cloud at all levels are selected through segment processing of the central image among three consecutive images with 30-minute intervals. Full disk image data are devided into segments, one of which is an array of 32×32 IR or WV pixels (64×64 VIS pixels). Each segment is about 150 km square (at sub-satellite point) to 250 km (at 50°N, 0°). In the segment processing, at first, the status of the segment is determined, and then multi-spectral histogram analysis is performed. Bi-dimensional histograms of IR and WV data, and of IR and VIS data when VIS is available are formed from each segment. Through this analysis, all cloud clusters identified by finding out the underlying Gaussians with the mean, standard deviation and number of pixels from the histograms. Each cluster is identified to land, sea or cloud at up to three levels. The segments including cloud cluster(s) are put into the next processing, wind vector determination.

The segment of the central image at H hour having suitable tracers is the target to be tracked. From the adjacent images (at H±1/2 hour), 3×3 segments are cut as search area. The image matchings are taken between H and H±1/2 hour's images by a cross-correlation technique. From both matchings all peaks on the correlation matrix (surface) are picked up, and at the end all peaks which are not symmetrical are rejected. Only one pair of symmetric peaks is selected for further processing.

Height attribution is basically calculated from mean 11 μm IR radiance of the cloud cluster. From the radiance an equivalence black body temperature is extracted, and then converted into pressure level using vertical temperature profile (VTP). The VTP is obtained from the 12 hour forecasts of U. S. National Weather Service, which are transmitted twice a day. It is assumed that the emissivity of the cloud is unity, but it causes significant error on the calculation of cloud cluster's temperature. This is corrected by two simultaneous measurements of a cluster in one segment by both the 6 μm WV and 11 μm IR channels.

At each of the processing stages, the suitability of histogram peak, cloud cluster, correlation peak, or segment are checked by threshold previously set. If insufficient suitability is realized, processing of the very segment is no more performed.

Before final processing, manual editing is carried out on an interactive display on which calculated wind vectors and associated images can be displayed in animated sequence.

Finally a wind vector calculated from the correlation peaks from H−1/2 hour and H+1/2 hour images. This means that final wind vector is one hour mean cloud motion. They are then coded into standard WMO formats (SATOB) for transmission through GTS and archived on magnetic tape and as plotted charts.

3.4. Space Science and Engineering Center (SSEC/UW)

The Space Science and Engineering Center of the University of Wisconsin (SSEC/UW) participated in the FGGE by supporting the collection of meteorological geostationary satellite data, and processing of cloud drift winds from these data. Following cloud drift winds were derived and sent to the FGGE Level II-b Space-based and Special Observing Systems Data Center in Sweden during the FGGE period (Mosher *et al.*, 1980a and 1980b). The produced wind data sets are:

(a) Indian Ocean Wind Set: a cloud wind data set for the Indian Ocean region approximately 50°N to 50°S, 10°E to 110°E, from GOES Indian Ocean twice a day for the entire FGGE year,

(b) Tropical Wind Set: a high-density cloud wind data set for the tropical region approximately 15°N to 15°S, 20°W to 170°E from GOES-E and GOES-W once a day for the entire FGGE year,

(c) MONEX Wind Set: a high density cloud wind data set from GOES-IO for the summer MONEX region from approximately 30°N to 20°S, 30°E to 100°E twice a day for a 100 day period starting on 1 May 1979, and

(d) GMS Wind Set: additional cloud wind data set from the GMS imagery for the region approximately 50°N to 50°S, 90°E to 170°W for the entire FGGE year.

The used images, observation times, etc. for the production of those wind data sets are shown in Table 5. After the end of FGGE period, no operational satellite winds have been derived at the SSEC.

The SSEC have developed the Man-computer Interactive Data Access System (McIDAS) since its foundation in 1969 (Suomi, 1975; Smith, 1975). The McIDAS has great capability to handle the large amount of satellite image data, weather report etc. and to process the data to extract various kinds of meteorological parameters (Chatters *et al.*, 1975). As one of processings of the McIDAS, the WINDCO was developed to derive cloud motion winds. The WINDCO is basically man-machine interactive wind derivation system by the use of TV-display on which animated time sequential images can be displayed.

The target clouds are selected and tracked by an analyst on TV-screen using cursor dial. The tracked points are the first guess of cloud motion and the fine tuning of the displacement is performed by a cross-correlation technique or Euclidian Norm method. This tracking method is called LP method. Another tracking method is called SP (single pixel) method, in which the manual tracked points are used for cloud motion calculation. Usually three time-sequential images are used to track a target to get two consecutive vectors. The vectors are converted into winds in earth coordinates using the satellite navigation data. In this system the landmarks are used to get accurate navigation data.

Height assignment to the cloud motion wind is performed either automatically using both 11 μm IR and VIS radiance (day time only) or subjectively (Mosher, 1974). *In day time* VIS image is used to determine optical thickness (τ) and emissivity of the target cloud. From τ, the physical thickness (z) is estimated. The cloud top temperature (Tc) is estimated from IR image, and converted into cloud top pressure height (Pc) using climatological vertical temperature profile. From z and Pc, the cloud-base pressure level (Pb) is estimated.

In night time, for high-level wind the lowest temperature of the cloud is given as Tc, which is converted into Pc in the same way as in day time. Pb is given as: $Pb = Pc + 100$ mb. For low-level wind the coldest

Table 5 Wind data sets produced by the SSEC during the FGGE period.

	GOES IO		GOES E & W	GMS
Data set	Indian Ocean	MONEX	Tropical Wind	GMS
Period	entire FGGE	100-days	entire FGGE	entire FGGE
Synoptic Time	0000Z 1200Z	0600Z 1800Z	1800Z	0000Z 1200Z
Tracking	IR VIS/IR	VIS/IR IR	VIS/IR	VIS/IR
Resolution (mile)	3	2(1)	2	—
Time int. (min.)	30	15(7)	15/10	30

and warmest pixels are regarded as Tc and Tb respectively, which are converted into Pc and Pb using climatological VTP.

Thereafter, the wind representative level is determined as follows;

$$Pw = Pb, \quad \text{when } Pb > 850 \text{ mb},$$

$$Pw = \frac{Pc+Pb}{2}, \quad \text{when } 850 \text{ mb} \geqq Pb \geqq 200 \text{ mb},$$

or $$Pw = Pc, \quad \text{when } 200 \text{ mb} > Pb,$$

where Pc : cloud-top height (mb),

Pb : cloud-base height (mb), and

Pw : representative wind height (mb) assigned to the cloud motion.

On a character display automatically assigned heights are displayed together with resultant cloud motion winds and checked by the operator, who may reassign subjective height or reject the vector manually.

At each of the processing stages the correlation peak, acceleration of the cloud motion and cloud top height variation from a picture to picture are assessed automatically and unreliable vectors are rejected or flagged.

Finally the resultant vectors are displayed on a TV-screen with associated movie-loop and checked by an operator who may reject unreliable vectors.

Acknowledgment

The author wishes to thank Mr. L. F. Whitney of NESDIS and Dr. B. D. Mason of ESOC for contribution of much material and information for the preparation of this summary. The author thanks Messers I. Kubota, K. Kato, J. Ichizawa, T. Oshima and K. Kimura and other staff of MSC for reviewing the manuscript and sharing their knowledge and some material.

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FGGE 期間およびその後に使用された風計算システムの要約

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第1回地球大気全球実験 (FGGE) 期間にデータ作成のために使用された風計算システムの処理方式の概要，および FGGE 後の方式変更の歴史を要約した。

FGGE の期間に風データの算出を行なったのは，日本の気象衛星センター (MSC/JMA)，欧州衛星運用センター (ESOC/ESA)，米国の環境衛星局 (NESS, 現在の NESDIS/NOAA) および米国ウイスコンシン大学宇宙科学技術研究所 (SSEC/UW) の4つのセンターである。

風計算の処理方式には，一般的に言って，自動的に (計算機のみで) 行なう方法と，マンがTVディスプレイ等の画像を見ながら行なうマニュアルの方法がある。各センターでは，両方式を適当にミックスした方式を採用している。

4つのセンター (MSC, ESOC, NESDIS および SSEC) は，FGGE の期間中5個の静止気象衛星 (GMS, METEOSAT, 2個の GOES 又は SMS および GOES-Indian Ocean) からそれぞれ風のデータの算出を行なった。このうち SSEC は GOES/SMS の領域の熱帯地方で特別の高密度のデータの算出および GMS の領域で追加の風データの算出も行なった。SSEC を除く他の3つのセンターは，FGGE 後も，衛星の不具合による中断期間があるものの，現在までルーチンの風計算の処理を行なって来ている。

本稿は，1985年5月27日～31日スイスのジュネーブで開催された「WMO/ICSU 全球実験の結果と WWW に関する会議」で著者が行なった「衛星風の算出とその応用」の発表のため準備した資料のうち風計算システムに関するもののみをまとめたものである。会議で筆者が発表した内容については，1985年秋発行予定のプロシーディングスに掲載される他，本技術報告にさらに詳細な講議録を投稿する予定である。