IMPACT EXPERIMENTS ON NWP WITH RAPID SCAN AMVS

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ABSTRACT

JMA performed impact experiments on NWP with rapid scan winds derived from GMS5. We compared typhoon track forecast with control run which are not used rapid scan winds. Atmospheric Motion Vectors (AMVs) are retrieved in the domain of 0°N-50°N and 90°E-170°W by three successive images of 15 minutes intervals. The winds are provided with QI (Quality Indicator) for the model experiments. In this paper, verification of experiments is limited only typhoon track forecast. The result suggest the rapid scan AMWs give positive impact on the numerical prediction especially FT=00-48.

1. Design of the Experiments

Japan Meteorological Agency (JMA) has implemented 3D-Var data assimilation system for a global model in September 2001. We investigate the effect to the typhoon track forecast used 3D-Var with rapid scan winds. And we also implemented meso 4D-Var in operation from March 2002. We want to investigate the effect with dense satellite winds to the typhoon forecast at the next opportunity. As first step, we compared global model typhoon track forecast used OI and 3D-Var analysis, which is not used rapid scan winds. As second step, we investigate the effect of the rapid scan winds compared to control run which is not used it. So we conducted next 4 experiments.

	Abbreviation
(1) Control run used OI	(Cntl1)
(2) Control run used 3D-Var	(Cntl2)
(3) 3D-Var + 16-pixels rapid scan data	(Rapid16)
(4) 3D-Var + 32-pixels rapid scan data	(Rapid32)

“Rapid16” means the experiment with 16-pixels data, and “Rapid32” means the experiment used 32-pixels data. They are derived from pattern matching method with satellite winds. Dates of initial are as follows,

(1) 06UTC initial on June 21, 2001 (Typhoon0102)
(2) 06UTC initial on June 22, 2001 (Typhoon 0102)
(3) 06UTC initial on July 23, 2001 (Typhoon 0106)
(4) 06UTC initial on July 25, 2001 (Typhoon 0106)

If same rapid scan data distribute within 50km, data are thinned out. Observation error is set as 3.0m/s at 500hPa or lower, and it increase gradually. At the point of 0.1hPa, it was set as 7m/s. And we adjust observation error by next procedure.

(1) The observation error is adjusted according to the density of around rapid scan data.
(2) As a function of QI, observation error is adjusted. For example, at the point of QI=80 observation error is multiplied the value by 1.1.

Rapid scan data have QI, and in these experiments, we only use the data QI equal 0.8 or more.

Fig.1 shows a diagram of analysis method compared with operation and our experiments. In main operation system, analysis method of base cycle is 3D-Var. In the case of forecast at 00UTC initial, to forecast rapidly, operation takes next procedure.

(1) Forecast 6 hours from 18UTC initial
(2) Execute 3D-Var analysis used data with early cut off time, it is called early analysis.
(3) Execute 90 hours forecast from 00UTC.

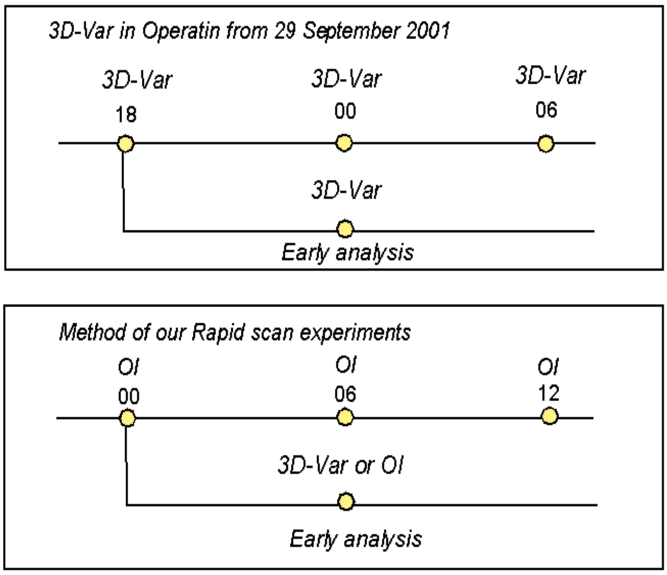


Fig.1 Diagram of analysis

On the other hand, in our rapid scan experiments, analysis method of base cycle are OI and we execute early analysis used 3D-Var or OI to make initial field.

Because of in the period of our experiments, analysis method was OI in operation. After these procedure, forecast are executed till FT=72.

Rapid scan observation was conducted at 04UTC with GMS5. It is 2 hours different from the analysis time compared to observation time. But we don't adjust this time difference.

2. The Data of Rapid Scan Winds Derived from GMS-5

Meteorological Satellite Center takes charge of rapid scan data calculation. Data domains are 0^oN-50^oN and 90^oE-170^oW, and the data are obtained with dense latitude and each 0.5 longitude interval. Rapid scan winds are observed only at 04UTC. Kinds of data are IR, VIS and WV. 1 pixel of IR and WV picture has 5km x 5km area and VIS picture has 1.25km x 1.25km area respectively. Using 32x32 or 16x16 pixels template, pattern matching is performed from the picture of 15 minutes after, and AMVs are computed.

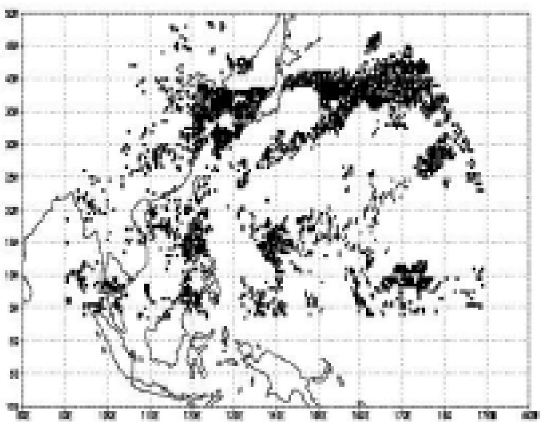


Fig. 2 IR winds at 04UTC on 21 June

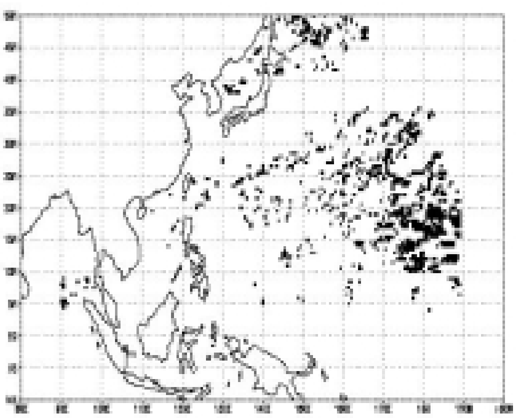


Fig. 3 VIS winds at 04UTC on 21 June

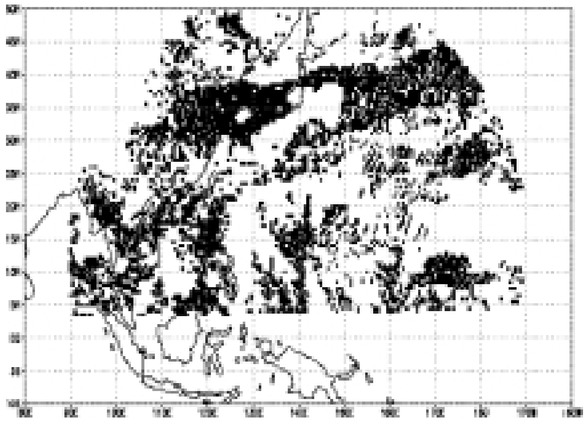


Fig. 4 WV winds at 04UTC on 21 June

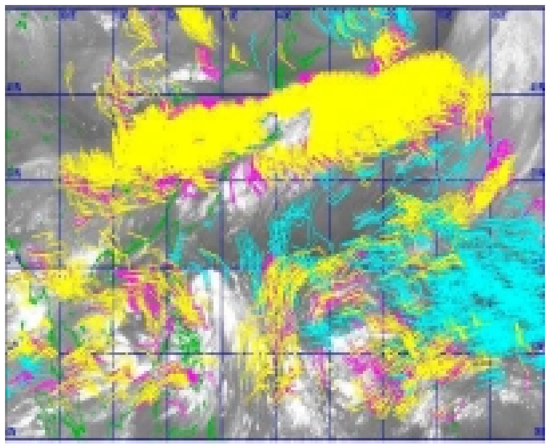


Fig. 5 WV image and rapid scans at 04UTC on 21 June

Table 1 The number of rapid scans at 06UTC on 21 June 2001

The number of data	IR	VIS	WV
32--pixels data (Total)	5294	1325	9977
QI>=0.8	1646	828	2756
16--pixels data(Total)	4051	1046	7848
QI>=0.8	857	423	1581

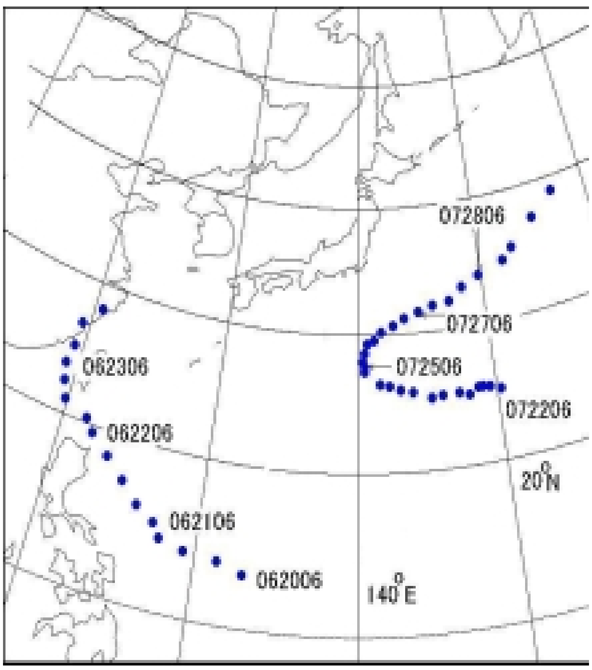


Fig. 6 The track of Typhoon 0102 and Typhoon 0106, it is shown every 6 hour

Fig. 2 shows the distribution of the rapid scan winds derived from IR image. Fig. 3 and Fig. 4 show the winds derived from VIS and WV image respectively. Fig. 5 shows WV image and each rapid scans.

There was Typhoon 0102 at 127.2°E, 15.2°N. At that time, a front extended from east to west, and it was laid on Japan. Dense data distributed near this front.

In the data selection process, a cumulonimbus is discriminated and the moving vectors are excluded, it is a reason that why there are a few data in the typhoon neighborhood. Many satellite winds of IR and WV are obtained near this front, and many VIS winds are derived in the southeast sea of Japan.

The number of derived rapid scan winds used in this experiment at 06UTC on 21 June is shown as Table 1. WV winds at 700hPa or than lower level are not used in these experiments, since it is found that the height of WV wind vectors are always assigned to be quite low in a clear region and QI don't works well.

3. The Typhoon for Experiments

One of targets for experiments is Typhoon 0102 (CHEBI) which was generated in the east sea of Philippines on 20 June 2001, and it passed the south sea of Taiwan, and then it changed extra-tropical cyclone near Shanghai. The next target is Typhoon 0106 (KONG-RAY), which was generated in the southeast sea of Japan on 22 July 2001, it progressed west at the beginning, but it turned suddenly to northward near the 140^{o}E, and left to east sea of Japan. Fig.7 shows the sea level pressure analysis with 3D-Var at 06UTC on 21 June. Location of typhoon was the east sea of Philippines. Similarly Fig.8 shows the sea surface pressure at 06UTC on 23 July. Location of typhoon was the southeast sea of Japan.

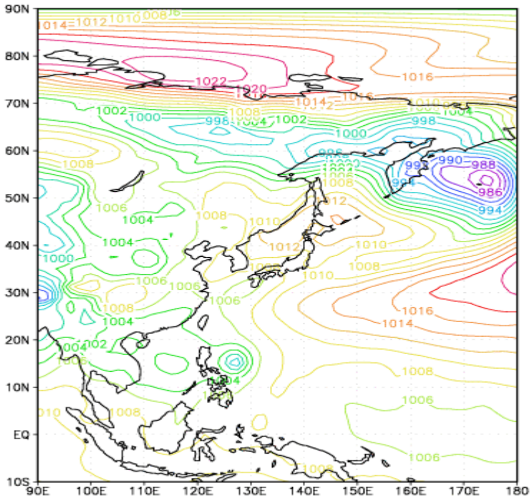


Fig.7 06UTC on 21 June 2001
Analysis of sea surface pressure

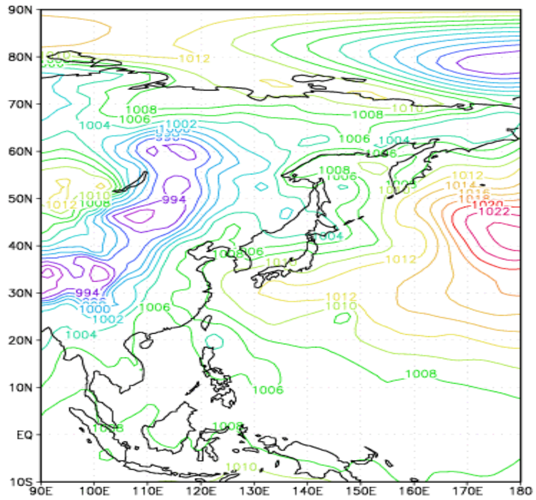


Fig.8 06UTC on 23 July 2001
Analysis of sea surface pressure

The difference (Rapid32 - Cntrl2) of geopotential height at 06UTC on 21 June is shown in Fig. 9 at 500hPa. Similarly the difference (Rapid32 – Cntrl2) of geopotential height at 06UTC on June 22 is shown as Fig. 10 at 500hPa. The difference of the analysis winds between Rapid32 and Cntl2 is also shown as Fig. 11 at 06UTC on 21 June and Fig. 12 at 06z on 22 June. In Fig. 9, the geopotential height is low around 160^{o}E, 20^{o}N. It was caused by cyclonic increment with rapid scan winds (See Fig. 11). On the contrary, change of geopotential height is small in low latitude because of coriolis force is small. There are few rapid scan winds near center of typhoon, so that increments of wind vectors are small in this area.

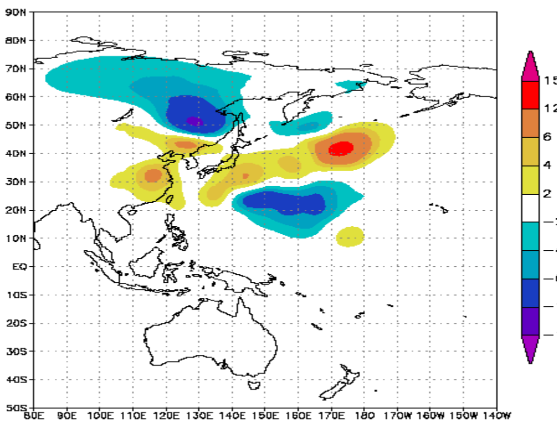


Fig. 9 06UTC on 21 June (Rapid32 –Cntl2
Difference of geopotential height at 500hPa

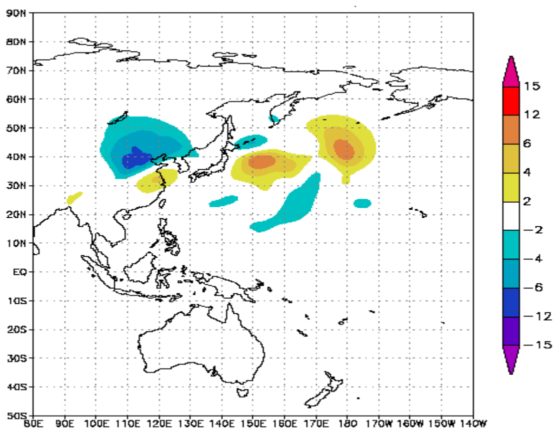


Fig.10 06UTC on 22 June (Raipd32–Cntr2)
Difference of geopotential height at 500hPa

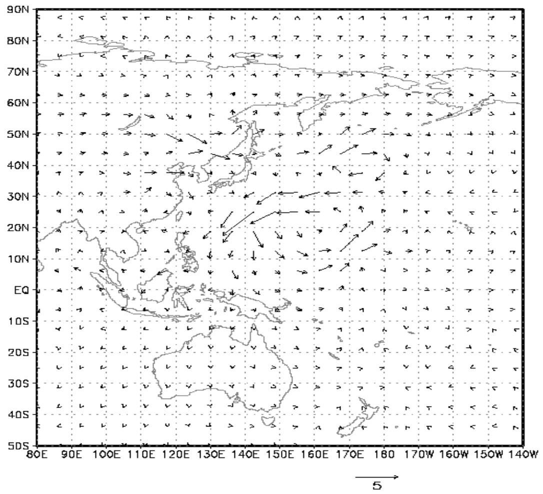


Fig. 11 06UTC on 21 June (Rapid32 –Cntl2)
Difference of wind field at 500hP

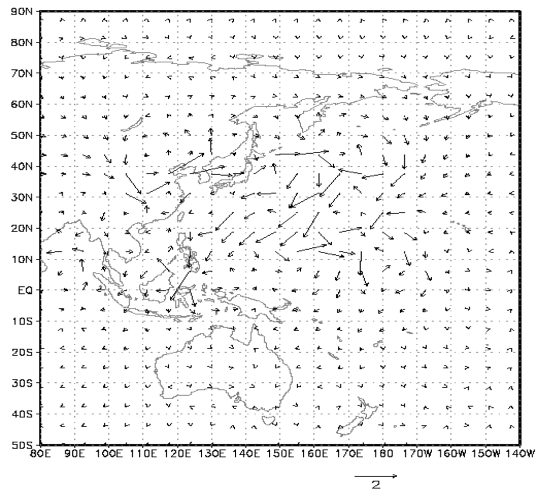


Fig. 12 06UTC on 22 June (Rapid32–Cntl2)
Difference of wind field at 500hPa

4. Score of the Each Experiment

(1) 06UTC initial on 21 June 2001, Typhoon 0102

Fig.13 shows the actual typhoon track and forecast for Typhoon 0102 from 06UTC initial on 21 June. In Fig.13, red circle means actual typhoon track. Yellow circle and blue square means control run analyzed OI and 3D-Var respectively. Moreover, black circle and black cross means typhoon track used 32-pixels and 16-pixels rapid scan data respectively used 3D-Var analysis.

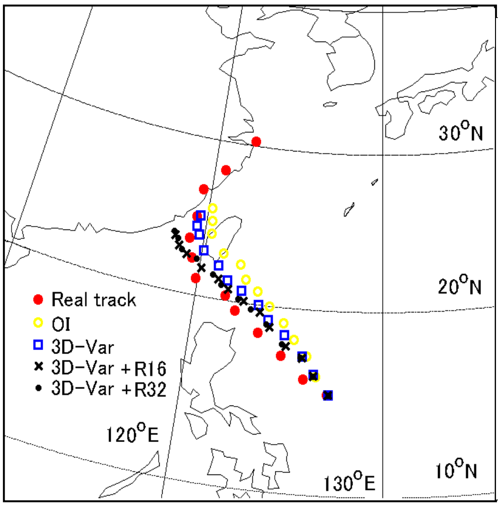


Fig.13 Typhoon 0102 on 21 June

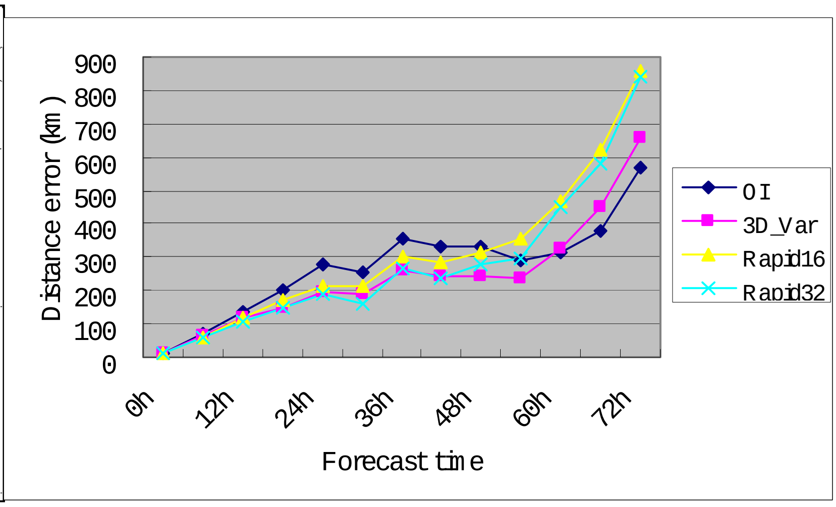


Fig.14 Time sequence of typhoon track forecast error

Table 2 Mean distance error of the each forecast period. (06UTC initial on 21 June 2001)

June21	OI	3d-Var	Rapid 16	Rapid 32	ΔOI	ΔRapid16	ΔRapid32
0-24	139.68	106.58	114.84	103.18	33.10	8.26	-3.40
24-48	310.53	226.95	265.39	226.75	83.58	38.44	-0.20
48-72	377.60	381.11	523.18	489.08	-3.51	142.08	107.97

Table2 shows average of distance error, in the term of FT=00-24,FT=24-48,FT=48-72 from 06UTC initial on 21 for Typhoon 0102. ΔOI means distance error average of OI - 3D_Var, ΔRapid32 means a value of Rapid32 - 3D_Var, and ΔRapid16 means a value of Rapid16 - 3D_Var. These are shown in the right side of Tables 2. If this value is negative, it means to improve typhoon track prediction error compared to Cntl2

In the experiments from 06UTC initial on June 21, track forecast changed to the western side in the order of experiments Cntl1, Cntl2, Rapid32 and Rapid16. The typhoon forecast is improved by Rapid32 up to FT= 48 or before. However, the speed of proceeding north in the model after FT= 48 becomes slow compared to the actual typhoon track. And forecast track is gradually separated from the actual typhoon track. At the time of FT=72, although the actual typhoon had progressed at 30^{o}N, all forecasts are only progressed to about 25^{o}N.

(2) 06UTC initial on 22 June 2001, Typhoon 0102

The experiments from 06UTC initial on June 22, all experiments forecast the typhoon track well, especially 3D-Var analysis improved typhoon track forecast. In the term of FT=0-24, although Rapid32 has improved the forecast, the term of FT=24-48, Rapid16 has improved the forecast. In the order of experiments Cntl1, Rapid32, Cntl2, Rapid16 bring the typhoon forecast east, and also bring the typhoon forecast north.

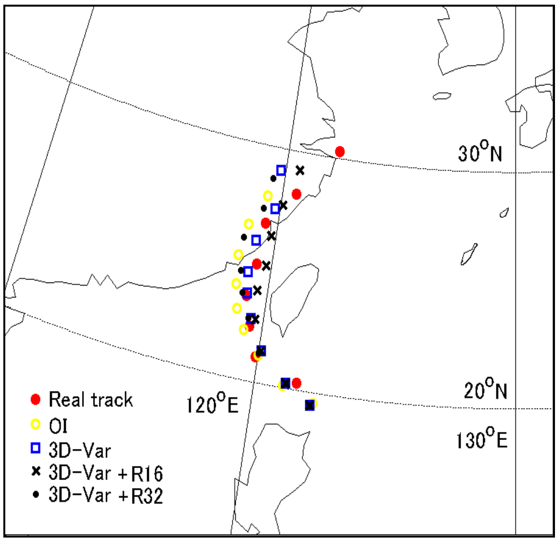


Fig.15 Typhoon 0102 on 22 June

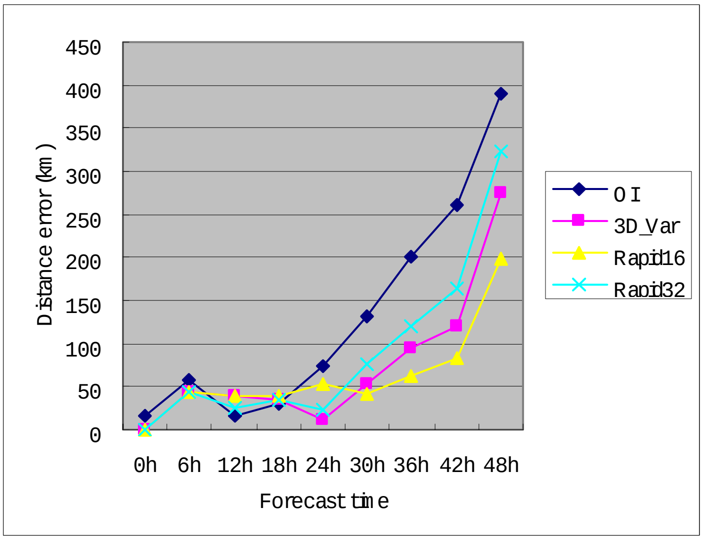


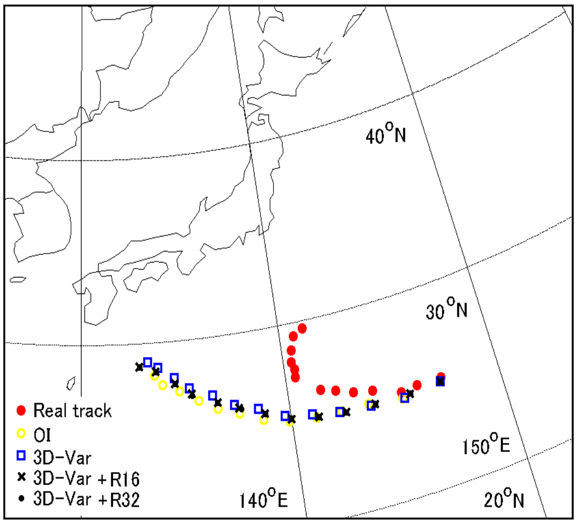
Fig.16 Time sequence of typhoon track forecast error

Table 3 Mean distance error of the each forecast period. (06UTC initial on 22 June 2001)

June 22	OI	3d-Var	Rapid16	Rapid 32	ΔOI	ΔRapid16	ΔRapid32
0-24	38.37	25.50	35.03	25.29	12.86	9.52	-0.22
24-48	211.58	110.67	87.61	141.23	100.91	-23.06	30.56

(3) 06UTC initial on 23 July 2001, Typhoon 0106

The track forecast of Typhoon 0106 from 06UTC initial on 23 July could not predict to change the course north suddenly. The Cntl2 makes track forecast north a little, but rapid scan data could not change the typhoon track north direction. However, because of improvement of initial field, advance speed becomes slow, the score of experiments with rapid scans becomes good in the term of FT=00-48. This is only experiment that OI is better than 3D-Var for typhoon track. In this case, it may be necessary to enlarge the size of typhoon bogus.



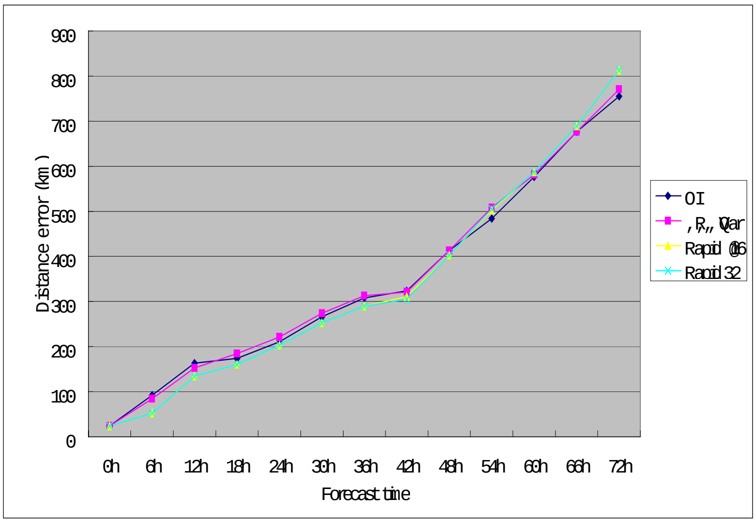


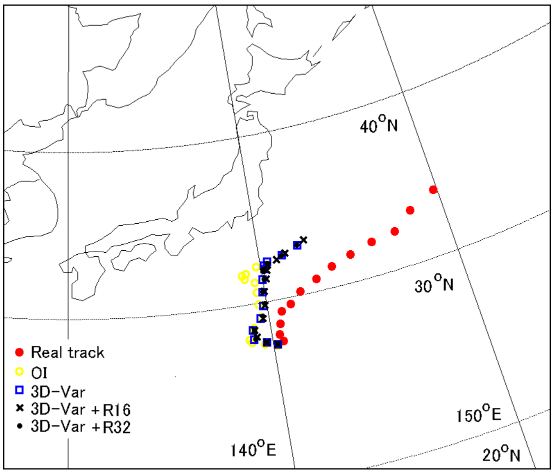
Fig.17 Typhoon 0106 on 23 June

Fig.18 Time sequence of typhoon track forecast error

Table 4 Mean distance error of the each forecast period. (06UTC initial on 23 July 2001)

July 23	OI	3d-Var	Rapid 16	Rapid 32	ΔOI	ΔRapid16	ΔRapid32
0-24	133.14	133.62	114.91	114.91	-0.48	-18.71	-18.71
24-48	304.87	308.27	291.43	290.46	-3.40	-16.84	-17.81
48-72	581.80	589.66	598.89	599.36	-7.86	9.23	9.69

(4) 06UTC initial on 25 July 2001, Typhoon 0106



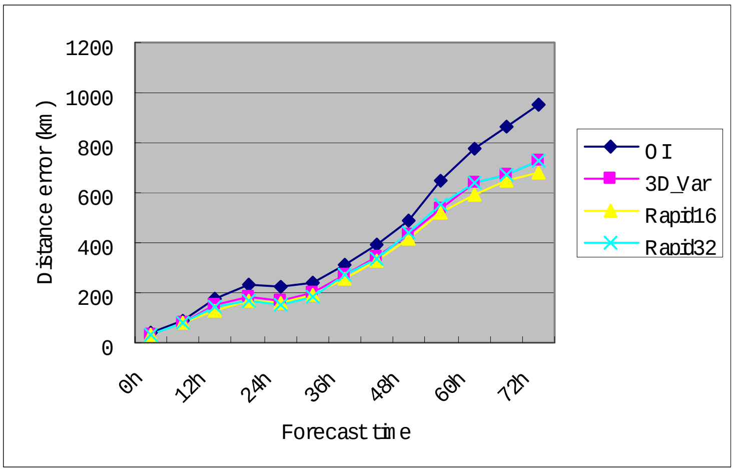


Fig.19 Typhoon 0106 on 25 July

Fig.20 Time sequence of typhoon track forecast error

Table 4 Mean distance error of the each forecast period. (06UTC initial on 25 July 2001)

July 25	OI	3d-Var	Rapid 16	Rapid 32	ΔOI	ΔRapid16	ΔRapid32
0-24	150.78	121.47	113.43	163.80	29.31	-8.03	42.33
24-48	330.91	281.11	269.68	276.07	49.80	-11.43	-5.04
48-72	746.76	600.47	573.21	604.32	146.29	-27.26	3.85

Similarly, typhoon track from the initial 06UTC on 25 July is shown Fig.19. Fig.20 and Table 4 show the forecast error of typhoon track. In the experiment of Rapid32, the forecast of typhoon track was almost changeless compared to Cntl2. On the other hand, the experiment of Rapid16 has improved the typhoon track effective in all terms.

5. Summary

We get the good response to put into rapid scans for typhoon track forecast, especially FT=00-48. But in the period of FT= 48-72, some experiments show the rapid scan data make typhoon track forecast worse. We must explore the cause. One of the reasons may be a difference of observation time and analysis time. And we should also explore the optimal observation error or threshold of QI.

We conducted experiments used two type of rapid scan winds. One kind of them is 32-pixels pattern matching data, and the other is 16-pixels pattern matching data. Unfortunately, the clear conclusion that which data are more effective is not obtained. In JMA system, instead of covariance of observation error is set as 0, variance of observation error is adjusted by around data density. At once time we investigated about the impact to the OI with 32-pixels and 16-pixels data. The result was 32-pixels data seems better than 16-pixels data. But in 3D-Var, 16-pixels data seems better than 32-pixels data. The reason is not known.

6. Problems and Future Measurements

According to investigation of meteorological satellite center, it is found that optimum wind and QI was not produced for 15-minute interval observation compared with radiosonde data. Next change might be executed in future. We prolong the interval of picture 30 minutes from present 15 minutes. And we reduce the weight for vector consistency test in QI process.

Figures 2-5 shows that the rapid scan winds affect around a typhoon much, but not significantly in the typhoon. One of the reasons is inferred that wind vector calculation was inhibited for cumulus clouds. Some trials to solve this problem should be done.

It is two hours different from observation time compared with analysis time. Once upon a time, we adjusted the effect of time difference used FGAT (First Guess at Appropriate Time). As the result, FGAT improved typhoon track especially FT=00-48. JMA has implemented meso 4D-Var operational system from March 2002. We want to investigate the effect of 4D-Var with satellite winds to typhoon track forecast. Introduction of this system or future global 4D-Var system will solve this problem. MTSAT-1R will be launched in summer in 2003. These satellite observations will provide accurate wind vectors in every 6 hours or more instead of GMS5.

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