An Improvement in Tropical Cyclone Bogussing for Numerical Models at the JMA

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Abstract

Tropical cyclone bogussing procedure for numerical models at the JMA was improved. A statistical verification study revealed that the initial fields derived through the new bogussing procedure are more realistic and thus improve the prediction of tropical cyclone tracks especially in low latitudes.

1. Introduction

Data sparsity over the ocean is a long-pending problem for the analyses of tropical cyclones because they remain in the ocean areas during most of their lifetimes. Scarce data even make the initial vortex structure for numerical models unrealistic and deteriorates their capability in tropical cyclone forecasting as a result. Bogus observations (*e.g.* geopotential heights and wind velocities) are therefore introduced in order to compensate for the lack of data and thereby fix more appropriate initial fields for the numerical models.

An outline of the JMA operational forecast system is given by Kitade (1988). The bogussing aspects of the system are described in greater detail. As for the operational typhoon numerical forecasts, the bogussing techniques carried out in the general-purpose forecast models (*e.g.* global spectral model) and the typhoon track prediction model (TYM) are described by Ueno (1989).

On 3 September 1991, the JMA improved the operational procedure for tropical cyclone bogussing. In the new bogussing procedure, the formula to determine the pressure profiles of storms was modified and actual surface observations were employed to correct the profile given by the formula. This paper gives a brief summary of the improvement and its impact on tropical cyclone forecast by the operational numerical models of the JMA.

2. The improvement in the bogussing procedure

Bogus observations are employed in the tropical cyclone analysis of the assimilation system when a tropical cyclone exists within the area of the JMA's responsibility, north of the equator from 100°E to 180°. The general procedure for the tropical cyclone analysis is outlined as below:

Step-1 To fix the storm size using the objectively-analyzed radius of over 30-knot winds area;

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Step-2 To generate bogus data from the storm size and objectively-analyzed central pressure with empirical formulae;

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Step-3 To perform pre-analysis to revise the first guess field using only the bogus data; currently, prognosis of the Global Spectral Models is used operationally as the first guess field;

⇓

Step-4 To perform objective analysis for the revised first guess field.

Note that the bogus data are not used in the objective analysis but used in the pre-analysis exclusively to revise the first guess field. In this improvement, primary changes were made in the Step-1 and -2, and are briefed as follows:

(1) The following basic (Fujita's) formula was adopted to represent an axis-symmetric sea-level pressure (SLP) pattern of a tropical cyclone as a function of **r** (radial distance from the center).

$$P(r) = P_\infty - (P_\infty - P_c)\{1+(r/R_o)^2\}^{-1/2}$$

where P_∞ is the SLP at infinite distance, P_c is the central pressure, and R_o is the parameter to prescribe the SLP profile of a tropical cyclone.

(2) R_o is determined from the gradient wind relation by introducing pressure gradients derived from Fujita's formula and the analyzed wind profile.

(3) The SLP profile is rectified by synoptic surface observations by use of the least-squares-fitting method when five synoptic reports or more are available in the cyclone's vicinity.

(4) The central pressure was increased to be adapted to the horizontal resolution of the objective analysis for preventing the initial fields from being distorted by the extreme pressure gap between the inner and outer region of the cyclone.

(5) 100 hPa level was adopted instead of 150 hPa level of the former version, where the positive anomaly of temperature within the cyclone become zero while it reaches the maximum at 250 hPa level (at 300 hPa level in the former version).

(6) Bogus observations were increased in the number in such a manner as to make the observation density uniform in space.

3. Impact of the changes

Bogus observations derived by the current and former methods are compared with real observations in Figure 1. The mean bias errors and their root-mean-square in the figure imply the current method has significantly improved the bogus cyclone in its consistency with the real one particularly in lower troposphere. However, the errors are still relatively large in upper troposphere mainly due to the increase of asymmetry in the wind fields of storms (for this reason bogus observations are used only for the middle and lower troposphere at the pre-analysis).

Tables 1 and 2 present a summary of track forecast errors of Global Spectral Model (GSM) and Asia Spectral Model (ASM) for some of the tropical cyclones in 1990 and 1991; As shown in the tables, the improvement in the bogussing procedure is apparently reflected in the forecast performances. It is more explicit in Figure 2 where the forecast errors in both cases are comparatively displayed as triangles in scatter diagrams; the triangle in the upper side of the dashed line indicates that the NEW method outperforms the OLD one.

Further comparisons were made between the two methods. In Figure 3, the forecast tracks of Severe Tropical Storm GLADYS (9112) by GSM and those of Typhoon PERCY (9006) by ASM based on the old and new bogussing methods are shown with their best tracks. In both the cases the method adopting the new bogus field demonstrated improvements upon track forecast. In addition, Figure 3-(b) shows the mitigation of the northward bias that is frequently observed in the models' forecast of tropical cyclone tracks in low latitudes Ueno (1989).

4. Concluding Remarks

For the more accurate forecast of tropical cyclones, it is crucial to provide numerical models with more realistic initial vortices along with improvements in models' physical processes. Above results prove the importance of description of axis-symmetric wind components of tropical cyclones and the effectiveness of employing actual observations in initial fields. Therefore, it is fully expected that new information about the satellites observations such as that by microwave sounders will make further contributions to the improvements of model's performance in tropical cyclone forecasting. Above results prove the effectiveness of more precise description of axis-symmetric wind components of tropical cyclones and hence suggest that it is crucial to provide numerical models with more realistic initial vortices for the more accurate forecast of tropical cyclones.

REFERENCES

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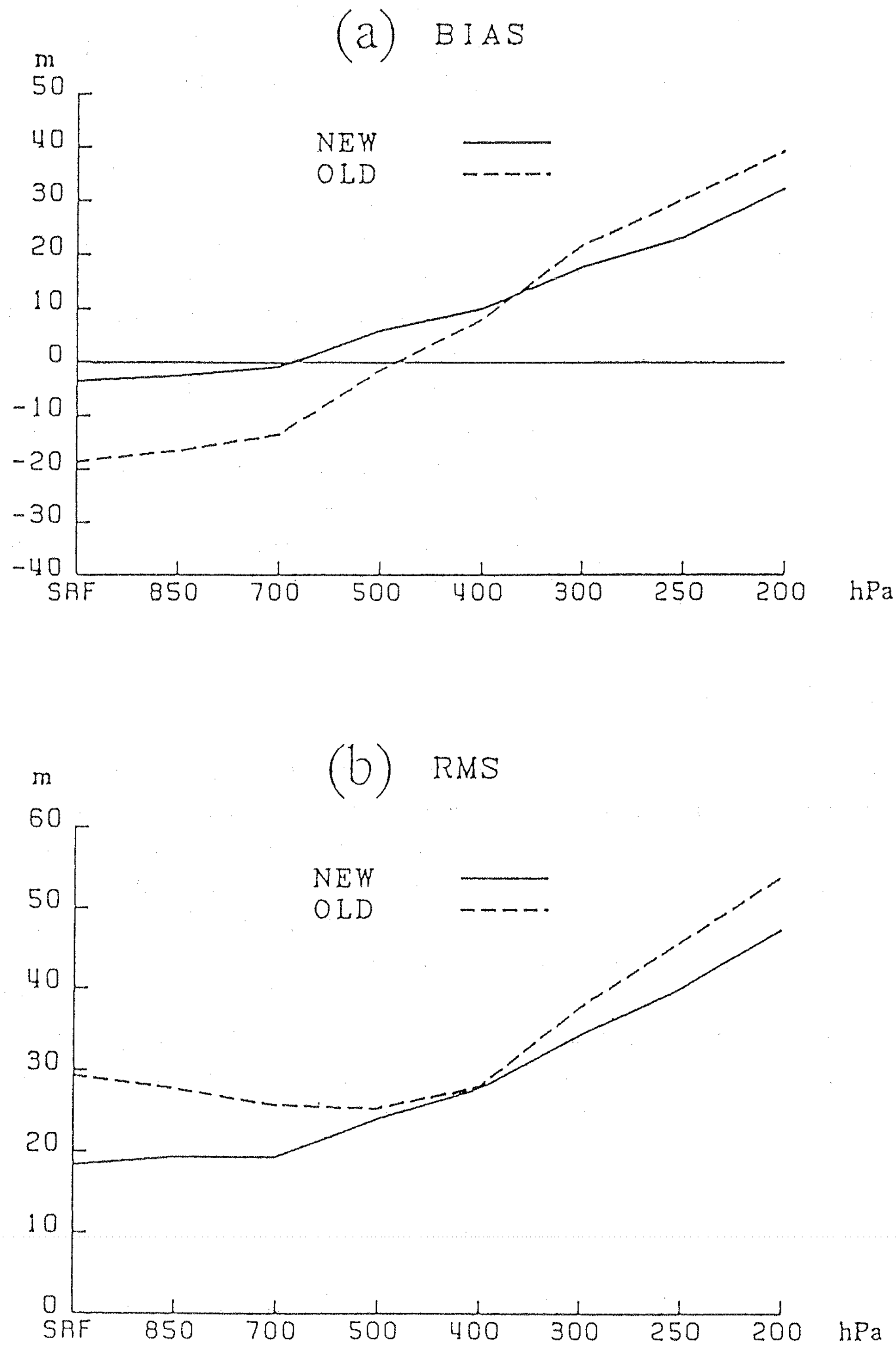

Fig. 1. (a) Mean differences in isobaric height (m) between bogus observations and real observations as a function of vertical levels (abscissa); bogus observations are derived through the current (NEW) and former (OLD) bogussing method. (b) Same as (a) but root mean square of the differences.

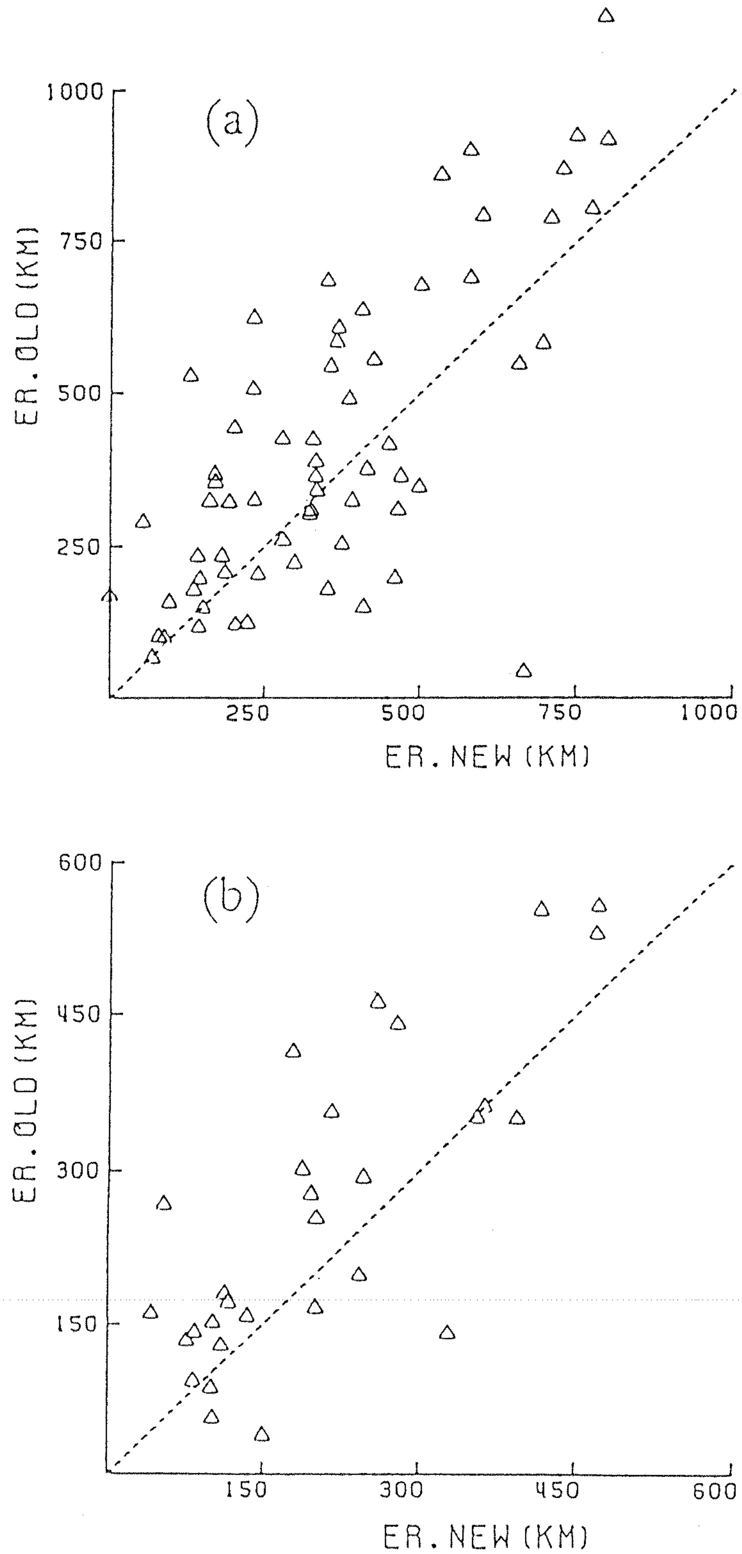

Fig. 2. Scatter diagram of the errors for 48-hour forecasts by (a) GSM and (b) ASM using NEW and OLD bogussing method.

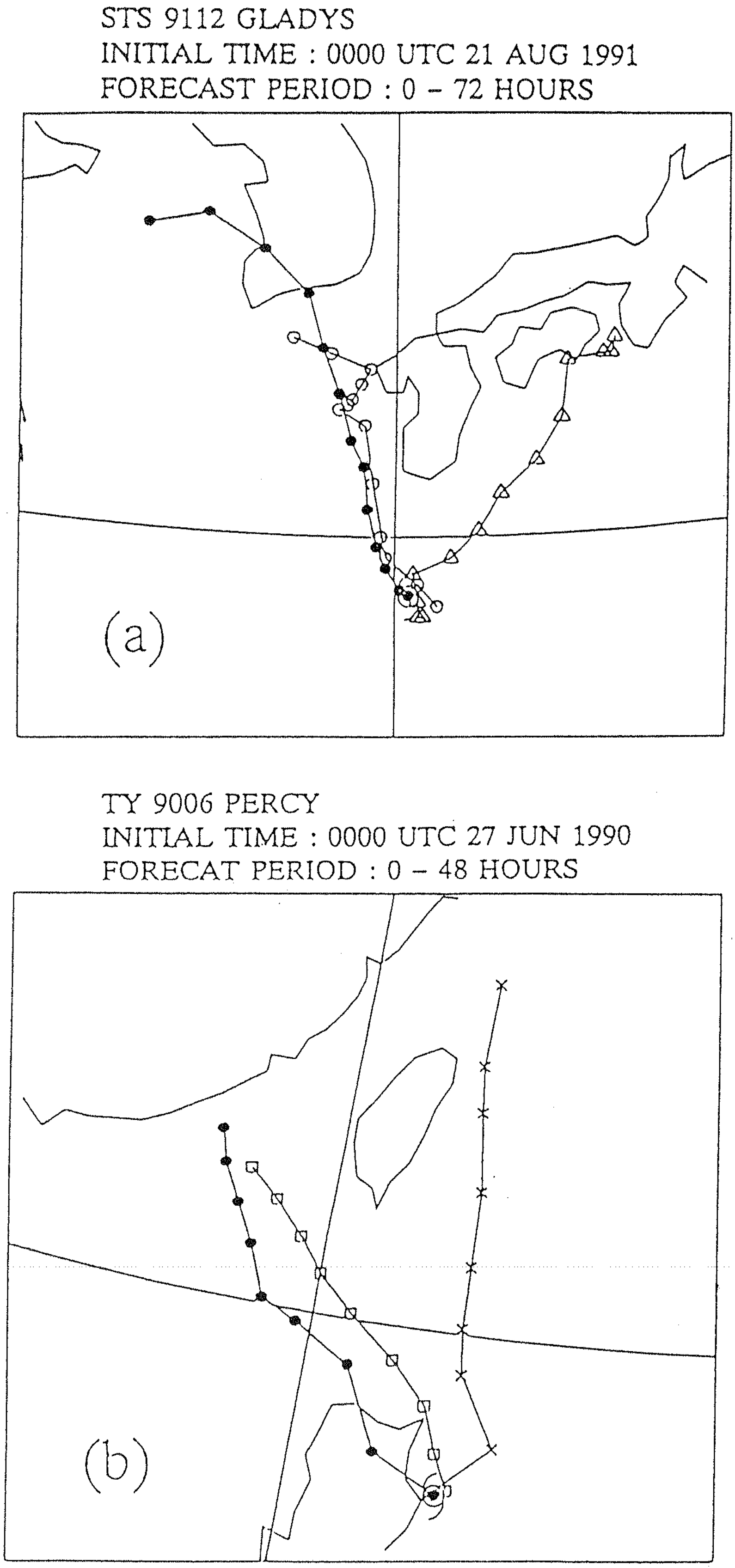

Fig. 3. Track forecast examples. (a) 72-hour forecast track of STS 9112 GLADYS by GSM using OLD bogussing method (marked with triangles at 6-hour intervals) and NEW one (with open circles). Best track is marked with solid circles. (b) 48-hour forecast track of TY 9006 PERCY by ASM using OLD bogussing method (marked with slant crosses at 6-hour intervals) and NEW one (with squares).

Table 1. Mean forecast errors (km) for GSM using OLD and NEW bogussing method. The number of cases is in parentheses.

TROPICAL CYCLONE	BOGUS	T=12	T=24	T=36	T=48	T=60	T=72
TY 9006 PERCY	OLD NEW	265 (7) 162 (7)	414 (6) 313 (6)	630 (6) 488 (6)	862 (6) 660 (6)	1145 (5) 862 (5)	1463 (5) 1110 (5)
TY 9008 STEVE	OLD NEW	375 (1) 279 (1)	673 (1) 519 (1)	923 (1) 708 (1)	1118 (1) 792 (1)	1207 (1) 647 (1)	998 (1) 584 (1)
TY 9010 VERNON	OLD NEW	86 (11) 82 (11)	148 (11) 135 (11)	214 (11) 208 (11)	256 (10) 240 (10)	337 (10) 334 (10)	471 (7) 464 (7)
TY 9018 ED	OLD NEW	122 (5) 102 (5)	193 (5) 146 (5)	275 (5) 206 (5)	382 (5) 291 (5)	476 (5) 382 (5)	585 (5) 444 (5)
TY 9019 FLO	OLD NEW	126 (5) 105 (5)	213 (5) 186 (5)	294 (5) 296 (5)	380 (5) 417 (5)	462 (4) 565 (4)	215 (3) 409 (3)
TY 9104 WALT	OLD NEW	122 (18) 109 (18)	213 (18) 177 (18)	303 (18) 265 (18)	413 (16) 346 (16)	521 (14) 432 (14)	659 (13) 563 (13)
TY 9109 CAITLIN	OLD NEW	122 (6) 106 (6)	183 (6) 177 (6)	264 (6) 284 (6)	365 (6) 404 (6)	553 (6) 614 (6)	687 (5) 652 (5)
TY 9110 ELLIE	OLD NEW	147 (9) 113 (9)	250 (7) 224 (7)	358 (5) 281 (5)	385 (4) 313 (4)	388 (4) 381 (4)	369 (4) 491 (4)
TY 9111 FRED	OLD NEW	69 (4) 102 (4)	139 (4) 91 (4)	188 (4) 74 (4)	175 (4) 217 (4)	281 (3) 124 (3)	371 (3) 173 (3)
STS 9112 GLADYS	OLD NEW	142 (9) 112 (9)	206 (9) 151 (9)	312 (9) 205 (9)	411 (8) 276 (8)	514 (8) 351 (8)	675 (7) 490 (7)
MEAN	OLD NEW	136 (75) 112 (75)	221 (72) 182 (72)	318 (70) 264 (70)	415 (65) 353 (65)	527 (60) 449 (60)	651 (53) 553 (53)

Table 2. Same as Table 1 but ASM.

TROPICAL CYCLONE	BOGUS	T=12	T=24	T=36	T=48
TY 9006 PERCY	OLD NEW	295 (6) 210 (6)	463 (6) 326 (6)	543 (6) 381 (6)	592 (5) 417 (5)
TY 9010 VERNON	OLD NEW	113 (2) 106 (2)	203 (2) 153 (2)	292 (2) 231 (2)	406 (2) 316 (2)
TY 9104 WALT	OLD NEW	165 (5) 122 (5)	249 (5) 194 (5)	326 (5) 256 (5)	400 (5) 308 (5)
TY 9109 CAITLIN	OLD NEW	44 (1) 90 (1)	93 (1) 83 (1)	323 (1) 169 (1)	542 (1) 318 (1)
TY 9110 ELLIE	OLD NEW	229 (7) 192 (7)	288 (6) 292 (6)	288 (5) 308 (5)	337 (4) 426 (4)
TY 9111 FRED	OLD NEW	70 (3) 91 (3)	105 (3) 104 (3)	140 (3) 117 (3)	212 (3) 153 (3)
STS 9112 GLADYS	OLD NEW	104 (7) 70 (7)	174 (7) 128 (7)	242 (7) 184 (7)	335 (7) 290 (7)
MEAN	OLD NEW	175 (31) 138 (31)	259 (30) 209 (30)	322 (29) 255 (29)	394 (27) 325 (27)