4.6 Typhoon Model (JMA-TYM0306)

4.6.1 Introduction

TYM produces 84 hour predictions from initial fields at 00, 06, 12, 18 UTC for up to two target Tropical Cyclones (TCs) in the western North Pacific , which is the responsibility area of the RSMC Tokyo - Typhoon Center.

TYM uses an identical dynamical framework and physical package to those of RSM except for the following aspects.

4.6.2 Structure of the model

(a) Horizontal Domain

The model domain is relocated on each occasion of prediction according to the forecasted track of the target TC and fixed during the time integration. The domain is set in such a way that the TC's entire track can stay as far away as possible from the lateral boundaries.

(b) Horizontal and vertical representation

TYM adopts a circular wave number truncation at 179 in the x and y directions in a square domain projected onto a Mercator (Lambert) map when the target TC exists south (north) of 20°N at the initial time. A regular 271×271 transform grid with intervals of 24 km at the typhoon center covers the domain of approximately 6480 km×6480 km.

In the vertical the model uses a $\sigma - p$ hybrid coordinate of 25 layers with their interfaces defined at 1000, 985, 965, 940, 910, 875, 835, 785, 735, 685, 635, 585, 535, 485, 435, 385, 335, 285, 245, 210, 175, 140, 105, 70, 35 and 0 hPa in case of surface pressure at 1000 hPa.

4.6.3 Dynamical Process

The integration time step length, time scales for the lateral boundary relaxation and the horizontal diffusion coefficient are determined depending on the horizontal resolution of the model. The time scale for the lateral boundary relaxation is 27 minutes and the e-folding time of horizontal diffusion for shortest wave is 12 minutes.

4.6.4 Physical Process

(a) Roughness lengths over the sea

For the sea surface, the roughness lengths of TYM are different from those of RSM. Following the method of

Beljaars (1995) for z_{0m} and Garratt (1992) for z_{0h}, roughness lengths over the sea are obtained by Charnock(1955) Relation,

$$
\begin{aligned}
z_{0m} &= \frac{0.11\nu}{u_*} + \frac{\alpha}{g} u_* \\
z_{0h} &= z_{0m} \times \exp(-2.48\,\mathrm{Re}_*^{0.25} + 2.0)
\end{aligned}
\tag{4.6.1}
$$

where $\mathrm{Re}_* = \frac{u_* z_{0m}}{\nu}$ is the roughness Reynolds number, g the acceleration of gravity, u_* the friction velocity, ν the kinematic viscosity of air (=$1.5\mathrm{x}10^{-5}\mathrm{m}^2/\mathrm{s}$), and α the Charnock coefficient (=0.020).

(b) Vertical diffusion above the surface layer

The non-local PBL scheme is not adopted.

(c) Parameterizations of precipitation

The precipitation processes (large scale condensation, middle level convection, cumulus convection and evaporation of raindrops) of TYM are different from those of RSM. In 2003, the new precipitation processes those of GSM are introduced into TYM, which are described in subsection 4.2.4(cumulus convection) and 4.2.5(clouds and large-scale precipitation) with the following exceptions;

(c-1) cumulus convection

(c-1-1) the cloud base level is fixed near 950hPa.

(c-1-2) instead of equation (4.2.34), the parameter $\lambda_{\min}$ is defined as follow;

$$
\lambda_{\min} = \max\left[\min\left[\frac{0.9 - RH}{0.002}, 1\right], 10^{-6}\right]
$$

(c-1-3) instead of equation (4.2.33), the parameter f is defined as follow;

$$
f = \frac{l_a - l_0}{l_a} + \frac{\omega}{\omega_0} + \frac{A_i}{A_{i0}} + c
$$

where l_0 denotes the mixing length of the planetary boundary layer, l_a is empirically determined constant.

(c-1-4) the downdraft mass flux M_d at cloud base is given by

$$
M_d = M_B \frac{E^d}{E^{d0}} (1 - E)
$$

where E^d denotes the energy that a unit downward mass flux gets from negative buoyancy and friction with raindrops and E denotes the precipitation efficiency (Fritsch and Chappell, 1980). The entrainment from the environment is assumed to occur above the cloud base, while the detrainment to occur below the cloud base. In both cases, a linear profile of the mass flux is assumed.

(c-1-5) convective momentum transport described in 4.2.4(e) is not adopted.

(c-2) clouds and large-scale precipitation

The stratocumulus scheme described in 4.2.5 is not adopted.

(d) Radiation

The cloud amount which is prognostically determined in precipitation process is used for radiation process.

(e) Targeted moisture diffusion

The target moisture diffusion described in 4.4.8(f) is not adopted.

4.6.5 Implantation of synthetic initial TC structure

In order to prepare TCs with reasonable reality at the initial time, synthetic TCs are implanted into the initial fields of TYM, which are derived from the TC Analysis (a regional version of the Global Analysis) with a spatial interpolation. The synthetic TCs are constructed based on some parameters manually analyzed by forecasters: the center position (latitude, longitude), the central pressure (P_c) and the radius of 30kt(15m/s) winds (R_{15}). The implantation consists of the following processes:

(a) Set several characteristic radii.

$$R_{EO} = \mathrm{Max}(2R_{15}, 500\mathrm{km})$$
$$R_{EI} = \mathrm{Min}(0.6R_{EO}, 500\mathrm{km})$$

which specify an annulus to calculate environmental mean values,

$$R_{D1} = 3R_0$$
$$R_{D2} = 4R_{15}/3$$
$$R_{D3} = 2R_{15},$$

which determine the horizontal scale of the TC,

$$R_{CO} = Min(Min(2R_{15}, R_{15} + 300\,\mathrm{km}), 800\,\mathrm{km})$$
$$R_{CI} = 0.5R_{CO},$$

which specify an annular zone to blend the synthetic structure and the initial fields, where R_0 is the characteristic radius for pressure profile.

(b) Specify TC's sea-level pressure profile with Fujita's (1952) formula.

$$P(r) = P_E - \Delta P\left[1 + (r / R_0)^2\right]^{-\frac{1}{2}} \quad , \Delta P = P_E - P_C , \qquad (4.6.2)$$

which is modified so that $\dfrac{\partial P}{\partial r} = 0$ at $r = R_{D3}$,

where P_E is the environmental sea-level pressure, ΔP the pressure deficit at the TC center $(P_E - P_C)$ and R_0 is determined so that gradient-wind speed becomes 15 m/s at the radius of 30kt (15m/s) winds (R_{15}) . The environmental value is obtained by averaging the initial fields over the annulus with inner and outer radii of R_{EI} and R_{EO} , respectively, around the typhoon center.

If the sea-level pressure profile is too sharp, it is adjusted in order that the maximum pressure gradient radius is large enough in comparison with the resolution of the model.

(c) Set values of geopotential height deviation from the environment (*D*) at the cloud top determined by the intersect of the moist adiabat from the sea surface temperature (SST) with the environmental temperature profile.

$$D(r, P_t) = \begin{cases} ar^2 + b & \text{for} \quad r < R_{D1} \\ cr + d & \text{for} \quad R_{D1} < r < R_{D2} \\ e(r - R_{D3})^2 & \text{for} \quad R_{D2} < r < R_{D3} \end{cases} \qquad (4.6.3)$$

where *b*, which determines the intensity of the upper-level anticyclone at the cloud top (denoted by subscript "t"), is assumed to be proportional to the surface pressure deficit at the TC center Δp in the form of

$$b = D(0, P_t) = -0.3 D(0, P_s) , \qquad (4.6.4)$$

where P_s is the surface pressure.

The other parameters *a, c, d* and *e* are determined with the conditions that the value D and its first derivative are continuous at the two boundaries at R_{D1} and R_{D2} .

It is assumed that the value *D* vanishes at $P_m = 20\text{hPa}$ and *D (r, P)* is obtained by the interpolation formula using $D(r, P_s)$, $D(r, P_t)$ and $D(0, P)$

$$D(r,P)=\begin{cases}\dfrac{\{D(r,P_s)-D(r,P_t)\}D(0,P)+D(r,P_t)D(0,P_s)-D(r,P_s)D(0,P_t)}{D(0,P_s)-D(0,P_t)} & \text{for} \quad P_s>P>P_t \\ \dfrac{D(r,P_t)D(0,P)}{D(0,P_t)} & \text{for} \quad P_t>P>P_m\end{cases} \tag{4.6.5}$$

(d) Calculate temperature profile at the TC center.

$$T(0,P)=\begin{cases}C_1(T_C(P)-T_E(P))+T_E(P) & \text{for} \quad P_s>P>P_t \\ C_2\{\ln P-\ln(P_m)\}\{\ln P-\ln(P_t)\}+T_E(P) & \text{for} \quad P_t>P>P_m\end{cases} \tag{4.6.6}$$

where C_1 and C_2 are determined so that the temperature profile is in the hydrostatic balance with the geopotential height profile.

(e) Use the gradient-wind balance to calculate tangential components of winds above the planetary boundary layer (PBL).

(f) Solve the steady-state axi-symmetric momentum equations with frictional force included and advective terms omitted to give inflow at the lowest level.

(g) Use the Ekman spiral to produce inflows at other levels in PBL.

(h) Calculate upper-level outflows of a Gaussian-form distribution in the vertical with its maximum at 2 km below the tropopause so that they counterbalance the low-level inflows.

(i) Set the relative humidity at 90 % in the troposphere near the TC center.

(j) Implant (blend) the synthetic TC structure into the initial fields using the following linear weighting function

$$f(r,\theta)=f_s(r,\theta)w(r)+f_i(r,\theta)(1-w(r)),$$

$$w(r)=\begin{cases}1 & \text{for} \quad r<R_{CI} \\ (R_{CO}-r)/(R_{CO}-R_{CI}) & \text{for} \quad R_{CI}<r<R_{CO} \\ 0 & \text{for} \quad R_{CO}<r\end{cases} \tag{4.6.7}$$

where f_s and f_i represent field variables in the synthetic TC and the initial fields (interpolated from the TC Analysis fields), respectively.

4.6.6 Initial asymmetry

Asymmetries of TC structure are taken from the TC prediction in previous predictions by TYM or GSM, and they are added to the symmetric synthetic TC. TYM predictions are preferentially used unless their predictions have larger errors. Three latest predictions from the initial fields at T_0-6h, T_0-12h, and T_0-18h, where T_0 denotes the initial time for the ongoing prediction, are compared and the best one is chosen for use. Asymmetric components derived from the best TYM prediction are then adjusted in orientation and amplitude so that the initial track of the TC matches the latest analyzed track.

4.6.7 Performance of TYM

TC track and intensity predictions are verified against the RSMC Tokyo-Typhoon Center's best track data. Fig. 4.6.1 and Fig. 4.6.2 show the TYM's mean errors of TC track and intensity predictions of TCs in the western North Pacific respectively.

References

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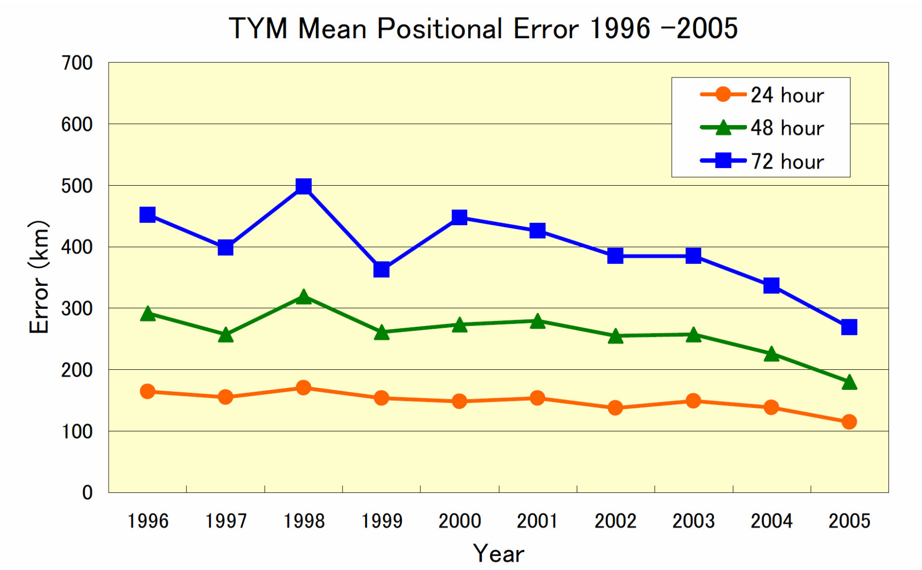

Fig. 4.6.1 TC track error of TYM prediction since 1996.

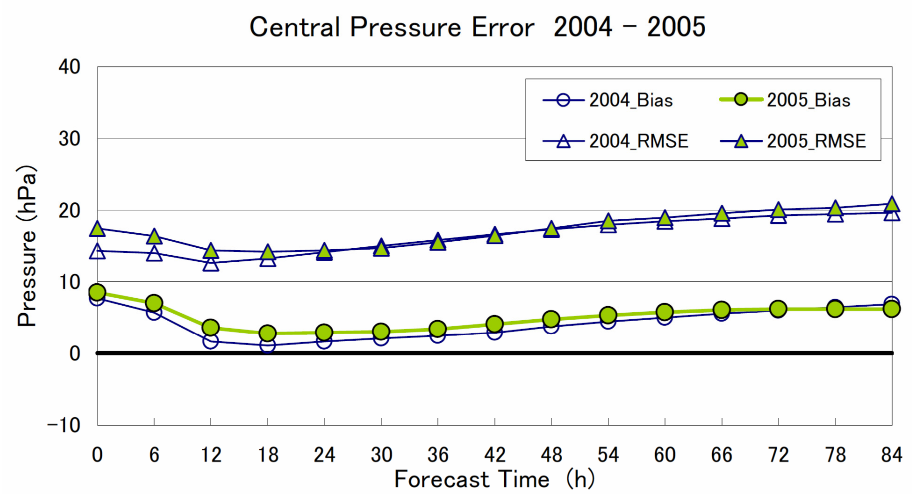

Fig. 4.6.2 TC central pressure errors of TYM prediction for 2004 and 2005.