# A role of surface boundary processes in a typhoon-ocean coupled model

Akiyoshi Wada

*Meteorological Research Institute, Tsukuba, Ibaraki, 305-0052, Japan*
*E-mail:awada@mri-jma.go.jp*

## 1. Introduction

In the numerical simulation, intensification of a simulated typhoon could be suppressed when the variation of sea surface temperature (SST) was taken account of during the passage of the typhoon. Otherwise, tuning parameters of sea surface processes, modification of sea surface roughness length, could also suppress intensification of the typhoon under the presumption of Monin-Obukhov similarity theory. The former is usually observed by ship and satellite observation. On the other hand, the latter is closely related to the ratio of the enthalpy coefficient to the drag one and remains ambiguity. Theoretical approach (Emanuel, 1995) suggested that the ratio was from 0.75 to 1.5, while observation (e.g. Fairall et al. 1996) showed that the ratio was 0.4 under windy (more than 20m/s) condition. For the purpose of investigating the identification between the ocean coupling process and the sea surface process, numerical simulations were conducted using a typhoon-ocean coupled model with two parameterizations of sea surface processes.

## 2. Sea surface processes

The sea surface processes in the typhoon-ocean coupled model have been based on formulas by Louis (1981), which the Monin-Obukhov similarity theory is presumed. The bulk coefficients are functions of sea surface roughness length and Richardson number, depending on wind velocity at the height of 10m. One parameterization of sea surface roughness length was derived from Kondo (1975). The formulation (1) and (2) depends on wind velocity at 10m height.

$$z_0 = -34.7\times10^{-6} + 8.28\times10^{-4}u^* \qquad u_{10} \le 25(m/s) \tag{1}$$

$$z_0 = -0.227\times10^{-2} + 3.39\times10^{-3}u^* \qquad u_{10} > 25(m/s) \tag{2}$$

These lengths are used as $z_{0m}$ for momentum and $z_{0h}$ for turbulent heat. The other approach that (3) in Beljaars (1995) is used for momentum and (4) in Garratt (1992) is used for turbulent heat.

$$z_{0m} = \frac{0.11\nu}{u^*} + \frac{\alpha}{g}u^{*2} \tag{3}$$

$$z_{0h} = \exp\left\{-2.48\times\left(\frac{u^* z_{om}}{\nu}\right)^{0.25} + 2.0\right\} \tag{4}$$

Four kinds of simulations were conducted taking account of whether ocean coupling was including or not, and the parameterization of sea surface roughness length was that of Kondo 1975) or Beljaars(1995) and Garratt (1992). Detail information for experiments is summarized in Table 1. Typhoon BILIS in August 20, 2000, Typhoon WUTIP in August 28, 2001, and Typhoon PHANFONE in August 13, 2002, which dates respectively mean the initial time of time integration, are selected as the case study.

## 3. Results

Results of minimum sea level pressure (MSLP) in the predictions of three typhoons are respectively shown in Fig. 1(a)-(c). The MSLPs of CMJMA and CMKON are higher than those of TYMJMA and TYMKON. The greatest difference of MSLP between TYMJMA and CMJMA is from 8.8hPa of Typhoon BILIS to 11.9hPa of Typhoon WUTIP (Table 2-1), while that of MSLP between TYMKON and CMKON is from 9.4hPa of Typhoon BILIS to 16.3hPa of Typhoon PHANFONE (Table 2-2). Thus, the greatest difference of MSLPs between TYMKON and CMKON is higher than that between TYMJMA and CMJMA. The result is particularly prominent in the predictions of Typhoon WUTIP and Typhoon PHANFONE. By comparing the result shown in Table 2-1 with that shown in Table 2-2, the ocean coupling effect is more significant in the MSLP prediction than the effect of sea surface roughness length concerning. This result concerning with the intensity predictions is closely related to the size of the typhoon. A radius of 15m/s wind velocity is defined as an index shown in the size of a typhoon. The ratio of size by four experiments is shown in Table 3-1 and Table 3-2. The ocean coupling effect causes the reduction of the size, while the size in the CMKON experiment is larger than that in the CMJMA experiment except Typhoon BILIS. The result is opposite to the MSLP prediction. The ratio is so large in the predictions of Typhoon WUTIP and Typhoon PHANFONE that the effect of parameterization of sea surface roughness length is greater than that by ocean coupling in turn. Because the size of typhoons is considered to have a large influence on the track of typhoons, the effect of parameterization of sea surface roughness may affect the track of Typhoon WUTIP and Typhoon PHANFONE more than that by ocean coupling. The intensity and the size of typhoons have a great impact on cooling of the sea surface through the air-sea interaction. The air-sea interaction depends on the ratio of enthalpy coefficients to drag coefficients. According to Bao et al. (2002), the ratio of enthalpy coefficient to drag coefficient was less than 0.7 under windy ( more than 20m/s wind velocity) conditions. The difference of cooling of the sea surface (Table 4) may be related to the ratio. In this study, the ratios of TYMJMA and CMJMA tend to be smaller than those of TYMKON and CMKON.

## Acknowledgements

The original codes of modified physical processes were offered by Mr. Takuya Hosomi and Mr. Ryota Sakai in JMA.

## References

Bao et al. (2002): Sensitivity of numerical simulations to parameterizations of roughness for serface heat fluxes at high winds over the sea. *Mon. Wea. Rev.* **130**, 1926-1932.

Beljaars (1995): The parameterization of surface fluxes in large-scale models under free convection. *Quart. J. Roy. Meteor. Soc.*, **121**, 255-270.

Emanuel (1995): Sensitivity of tropical cyclones to surface exchange coefficients and a revised steady-state model incorporating eye dynamics. *J. Atmos. Sci.*, **52**, 3969-3976.

Fairall et al. (1996):Bulk parameterization of air-sea fluxes for tropical ocean global atmosphere coupled-ocean atmosphere response experiment. *J. Geophys. Res.*, **101**, 3747-3764.

Garratt (1992): The atmosphere boundary layer. Cambridge University Press, 316pp.

Kondo (1975): Air-sea bulk transfer coefficients in diabatic conditions. *Bound. Layer Met.*, **9**, 91-112.

Louis et al. (1981): A short history of the operational PBL-parameterization at ECMWF, Workshop on Planetary Boundary Layer Parameterization 25-27 Nov. 1981, 59-79.

Table 1 Kinds of numerical experiments and their naming convention

| Experiments | Coupling? | Roughness Length |
|---|---|---|
| TYMJMA | No | Beljaars and Garratt |
| CMJMA | Yes | Beljaars and Garratt |
| TYMKON | No | Kondo |
| CMKON | Yes | Kondo |

Table 2-1 The greatest MSLP difference between TYM and CM.

| CM-TYM | BILIS(hPa) | WUTIP(hPa) | PHANFONE(hPa) |
|---|---|---|---|
| JMA | 8.8 | 11.9 | 11 |
| KON | 9.4 | 15.9 | 16.3 |

Table 2-2 The greatest MSLP difference between JMA and KON.

| JMA-KON | BILIS(hPa) | WUTIP(hPa) | PHANFONE(hPa) |
|---|---|---|---|
| TYM | 6.2 | 10.5 | 15.9 |
| CM | 6.8 | 6.4 | 9.8 |

Table 3-1 Averaged ratio of size by the couple model to that by the non-coupled model

| CM/TYM | BILIS | WUTIP | PHANFONE |
|---|---|---|---|
| JMA | 0.979 | 0.959 | 0.955 |
| KON | 0.979 | 0.967 | 0.954 |

Table 3-2 Averaged ratio of size by Kondo to that by Beljaars and Garratt

| Couple | BILIS | WUTIP | PHANFONE |
|---|---|---|---|
| KON/JMA | 0.99 | 1.07 | 1.05 |

Table 4 Maximum SST decrease during 72 hours by coupled models

| | BILIS | WUTIP | PHANFONE |
|---|---|---|---|
| JMA | -2.30℃ | -1.98℃ | -2.48℃ |
| KON | -1.71℃ | -1.96℃ | -2.75℃ |

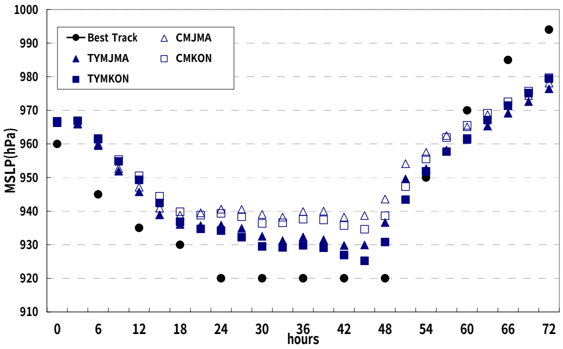

Fig.1(a) Minimum sea level pressure for Typhoon BILIS.

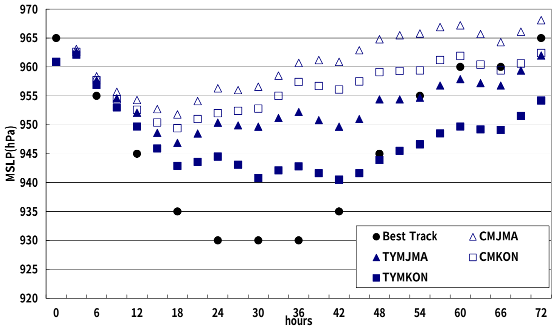

Fig.1(b) Minimum sea level pressure for Typhoon WUTIP.

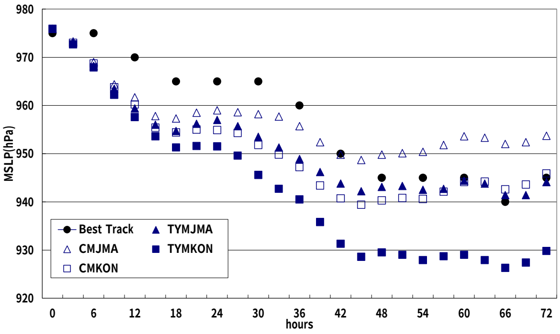

Fig.1(c) Minimum sea level pressure for Typhoon PHANFONE.