# Conversion from 700-hPa level wind speed to surface wind speed for the core of Typhoon Saomai (2006)

Xiaowei Tan, Yihong Duan

*National Meteorological Center of China Meteorological Administration*

## 1. Introduction

The surface (10 m) winds of tropical cyclone (TC), especially the maximum values, are just what the TC forecaster and the public are especially interested in. This is because that most of people activities and infrastructures reside in the BL, damaging storm surge and waves largely depend on TC surface winds. However, even in these days, understanding the detailed structure in the boundary layer (BL) of a tropical cyclone (TC) core is a challenging exercise because the comprehensive observation data there is very hard to obtain with both the safety considerations and instrumentations limitations. Flight-level reconnaissance and research data is often the only data available for directly describing the winds in the tropical cyclone core. So that the way of estimating the surface winds from the flight-level reconnaissance and research wind becomes more interested data (e.g. Franklin et al. 2003; Dunion et al. 2003).

For where the sparse observations cover, such as the northwest Pacific basin, a numerical simulation reproducing TC well with a satisfied resolution is a good supplement to address the issue on a statistical analysis of the surface wind factor (SWF; the ratio of the 10-m wind speed to that at some reference height in the free atmosphere)

## 2. Numerical simulation

Typhoon Saomai (2006) is simulated using the version (V3.1.1) of the Advanced Research Weather Research and Forecasting (ARW-WRF) modeling system. Table 1 shows the design details. The 1-km resolution simulation results are verified against the track and intensity from the best track of CMA. Figure 1a shows the simulated track in the 1-km mesh is very similar to the best track. Figure 1c shows most of the simulated track errors less than 80km in the 36 hours, even at the times after landing. Figure 1b shows the simulated typhoon intensities in all the meshes match well with the observed intensity in the trend except about 3-hour earlier to reach the minimum pressure and then weaken. The 1-km simulation maintains its intensity between 929.44 and 932.0 hPa and is weaker about 15 hPa than the observed intensity of 915 hPa during the maintenance stage. Although a little difference exists from the observation, it is reasonable to consider this 1-km resolution simulation reproduced typhoon Saomai from 0000UTC 9 to 1200UTC 10 August 2006, which includes the three stages of rapidly deepening, maintenance and weakening.

Table 1: Design for the numerical simulation of Saomai (2006)

| Domain | D1 | D2 | D3 | D4 |
|---|---|---|---|---|
| Grid points (x,y) | 204×204 | 490×490 | 403×403 | 403×403 |
| Grid size (km) | 27km | 9km | 3km | 1km |
| Time step (s) | 60 | 20 | 6.67 | 2.22 |
| Integral hours | 0-60 | 24-60 | 24-60 | 24-60 |
| Explicit moisture | Single-Moment 3-class | Single-Moment 3-class | Single-Moment 3-class | Single-Moment 3-class |
| Cumulus scheme | Kain-Fritsch | No | No | No |
| PBL parameterization | YSU | YSU | YSU | YSU |

| Values of σ levels | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.000 | 0.993 | 0.983 | 0.970 | 0.960 | 0.950 | 0.940 | 0.930 | 0.920 | 0.910 |
| | 0.900 | 0.890 | 0.880 | 0.845 | 0.807 | 0.765 | 0.719 | 0.672 | 0.622 | 0.571 |
| | 0.520 | 0.468 | 0.420 | 0.376 | 0.335 | 0.298 | 0.263 | 0.231 | 0.202 | 0.175 |
| | 0.150 | 0.127 | 0.106 | 0.088 | 0.070 | 0.055 | 0.040 | 0.026 | 0.013 | 0.000 |

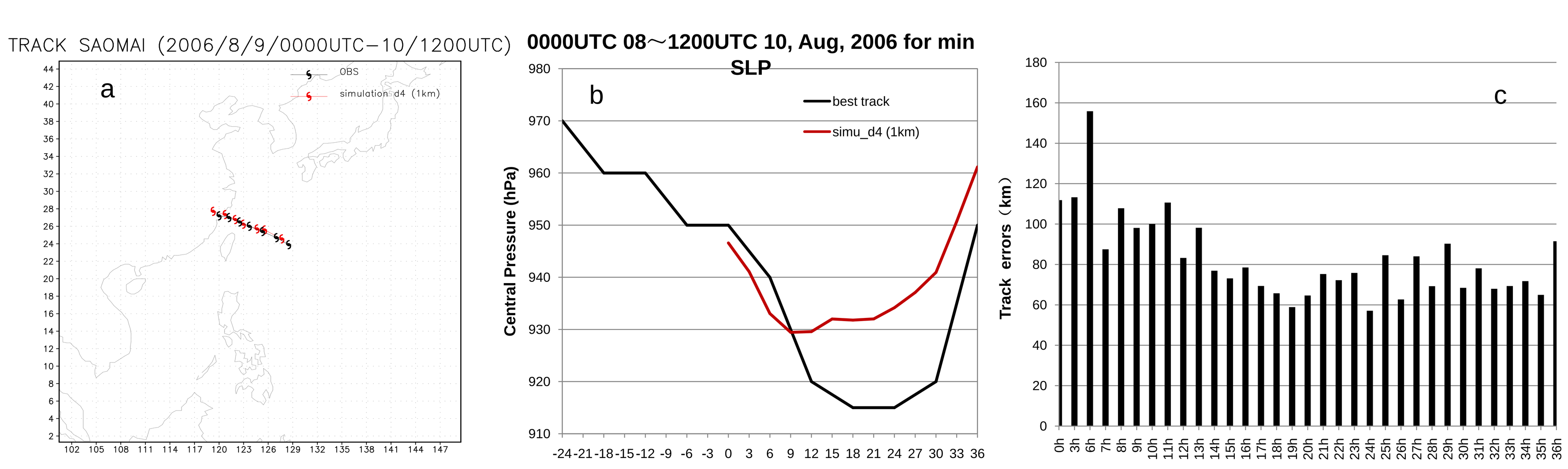



Figure 1. a) Typhoon Saomai (2006) track and b) minimum sea level pressure in the simulations and CMA observation; c) typhoon track errors between the simulations and CMA best track.

## 3. Comparison between 700-hPa level winds and MBL winds

The winds data in the 1-km simulation are interpolated to height level with a 50-m height interval below 1500-m height level. The samples for the statistic are selected at 12-h model time in the 1-km simulation on the four directions of East, North, West, and South. The samples on other directions or at other model times over sea also show similar characters (not shown here).

One step of conventional surface adjustment of flight-level data is adjusting flight-level winds to MBL winds. Based on the numerical simulation data, the MBL wind speed relates to both the 700-hPa flight-level wind speed and the radius away from the TC center, which is consistent with the previous results based on dropsonde data (Dunion et al. 2003).

The adjustment of a 700-hPa flight-level wind speed (U700) to an equivalent MBL wind ($U_{MBL}$) is represented by a third-order polynomial (see Figure 2) given as:

$$U_{MBL}=\begin{cases} U_{700}\times\left[1.702\times\left(\frac{R}{RMW}\right)^3-2.8337\times\left(\frac{R}{RMW}\right)^2+1.043\times\left(\frac{R}{RMW}\right)+1.194\right], & \left(\frac{R}{RMW}\right)<1 \\ U_{700}\times\left[4.2417\times10^{-2}\left(\frac{R}{RMW}\right)^3-0.22644\times\left(\frac{R}{RMW}\right)^2+0.403\times\left(\frac{R}{RMW}\right)+0.64319\right], & \left(\frac{R}{RMW}\right)\geq 1 \end{cases},(1)$$

Where R is the radius from the circulation center, RMW is the radius of maximum wind speed on 700-hPa flight-level.

## 4. Comparison between surface winds and MBL winds

Based on the numerical simulation data, it is found that the ratio of surface wind speed to MBL wind speed not only relates to the MBL wind speed but to the radius away from TC center. There are two tendencies (Fig. 3) in and outside the RMW of MBL. A statistics is represented by two third-order polynomials stratified by distance ratio (Fig. 3):

$$U_{sfc}=\begin{cases} U_{MBL}\left[(-6.9949\times10^{-7})\times U_{MBL}^3+(3.2994\times10^{-5})\times U_{MBL}^2-(2.4048\times10^{-3})\times U_{MBL}+0.89768\right], & \frac{r}{RMW_{MBL}}<1 \\ U_{MBL}\left[(-7.4094\times10^{-6})\times U_{MBL}^3+(1.0517\times10^{-3})\times U_{MBL}^2-(4.7376\times10^{-2})\times U_{MBL}+1.3831\right], & \frac{r}{RMW_{MBL}}\geq 1 \end{cases},(2)$$

Where $U_{MBL}$ represents the MBL wind speed, $U_{sfc}$ is the equivalent 10-m surface wind speed.

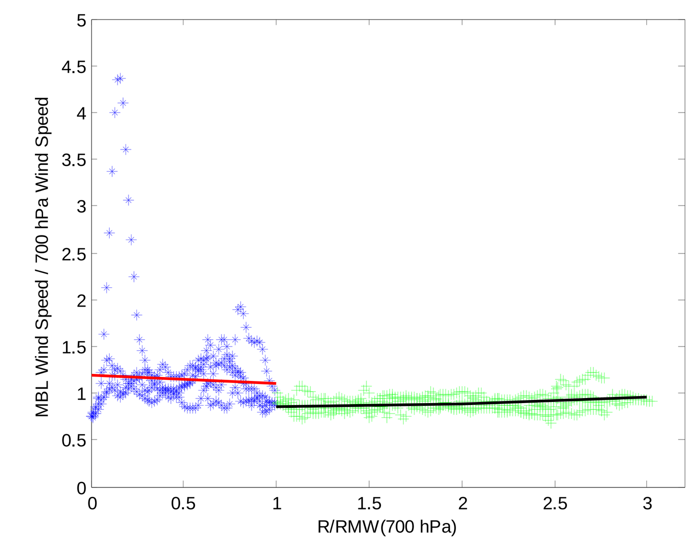



Figure 2. Relationships between the ratio of the radius away from TC center to the RMW of 700-hPa level and the MBL wind speed to 700-hPa wind speed ratio sampled on eastward, northward, westward and southward at 12-h run time in 1-km simulation and the best-fit curve. The parts in the RMW(700-hPa) (blue star) and outside (green cross) are separated .

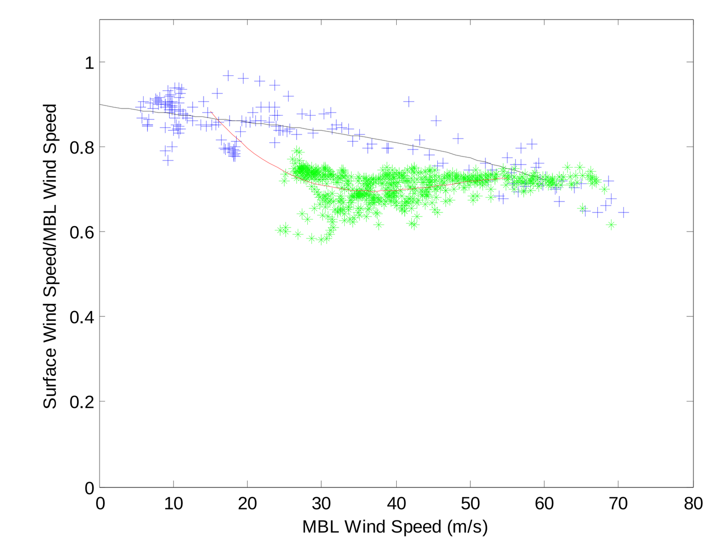



Figure 3. Relationships between the MBL wind speed and the 10-m surface wind speed sampled on eastward, northward, westward and southward at 12-h run time in 1-km simulation and the best-fit curve. The parts in the RMW(MBL) (blue cross) and outside (green star) are separated .

## 5. Converting surface wind speed from flight-level data

In consideration of the perfect model hypothesis, the data of wind speed on 700-hPa level from ARW-WRF system and the statistics third-order polynomials (Eq. 1and Eq. 2) are used to figure the surface wind speed. The parameter $RMW_{MBL}$ is selected as 80% of RMW on 700-hPa flight-level. Figure 4 shows difference between the equating surface wind speed and the simulated surface wind speed in ARW-WRF system at two model times over the ocean (0700 UTC and 1200 UTC 9 August 2006). The error of the simulated surface wind speed is -5 ~ 5 m/s in the most areas and -15 ~ 15 m/s in the secondary areas. Only a little of pieces appear more than -20 m/s errors where around the west of TC center. Comparing the equating surface wind speed with the model surface wind speed (Figure 5), the symmetrical selection of parameters on RMW contrast to the asymmetrical distribution of real winds may be main responsible for the larger error parts.

Figure 4. Difference (m/s) between the equating surface wind speed and the simulated surface wind speed in ARW-WRF system for a) 0700 UTC and b) 1200 UTC 9 August 2006.

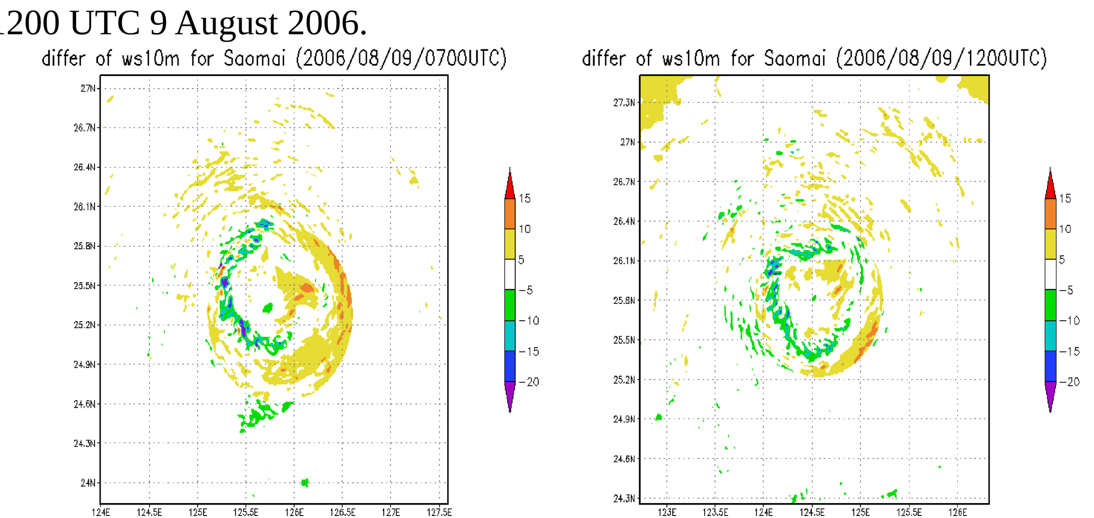
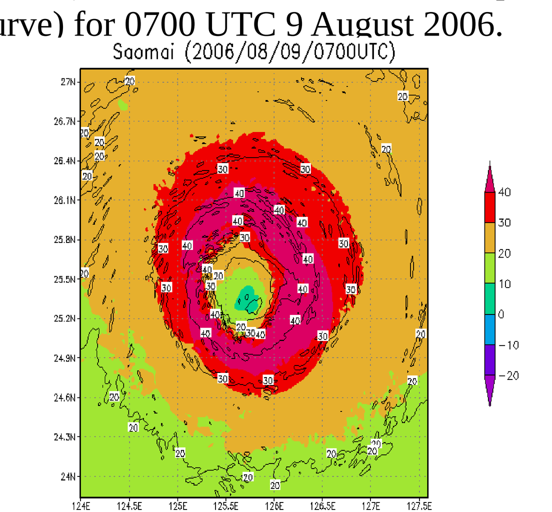



Figure 5. Equating surface wind speed (shaded) and model surface wind speed (curve) for 0700 UTC 9 August 2006.




## Summary

In this study, Typhoon Saomai (2006) is reproduced well by an ARW-WRF system with 1-km resolution and the conversion of 700-hPa flight-level winds to surface winds is discussed. Based on the simulated data at the time of 1200UTC 9 August 2006 on four directions of east, north, west and south away from TC center, most results are shown consistent with those analysis (Dunion et al. 2003) based on dropsondes data for the TC core during the 1998 and 1999 Atlantic and northeast Pacific hurricane seasons. But an important different finding is that the ratio of MBL wind to surface wind has two trends which depends on the value of R/RMW. Furtherly, some statistic third-order polynomials are obtained for the two steps of both equating 700-hPa flight level winds to MBL winds and equating MBL winds to surface winds. These third-order polynomials are then used to obtain the surface wind speed at several model times with the model winds data on 700-hPa level, based on the perfect model hypothesis. And the equating surface wind speeds are compared with the model surface wind speed. The error of the simulated surface wind speed is -5 ~ 5 m/s in the main areas and -15 ~ 15 m/s in the secondary areas. Only a little of pieces appear more than -20 m/s errors where around the west of TC center.

These statistic third-order polynomials are also used in another tropical cyclone case of Kahnum (2005) as further verification (not shown here) and the similar errors level are found.

### *MAIN REFERENCE:*

1. *Dunion, J. P., C. W. Landsea, S. H. Houston, and M. D. Powell, 2003: A reanalysis of the surface winds for Hurricane Donnna of 1960. Mon. Wea. Rev., 131, 1992–2001.*
2. *Franklin, J. L., M. L. Black, and K. Valde, 2003: GPS dropwindsonde wind profiles in hurricanes and their operational implications. Wea. Forecasting, 18, 32–44.*

***Author E-mail: xwtan@mail.iap.ac.cm***