THE IMPROVEMENT OF TRAP BY CONSIDERING TYPHOON INTENSITY VARIATION

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ABSTRACT: For years, the flash floods, mudflows and landslides brought by typhoons always cause severe loss of property and human life. For this reason, it is crucial to develop a more accurate and prompt typhoon rainfall prediction technique and thus can provide necessary rainfall potential information to the relevant disaster mitigation agencies.

Kidder et al. (2005) developed the Tropical Rainfall Potential (TRaP) technique, which applied satellite-borne passive microwave radiometers, to retrieve a tropical cyclone’s rainfall amount and predict its 24-h accumulated rainfall distribution. However, the effects of a tropical cyclone’s rainband rotation and intensity variation were not considered in their method. To obtain a better approximation to the actual rainfall system, this study will improve the TRaP technique by considering those effects. In the typhoon intensity variation part, the method proposed by DeMaria (2006) was applied to predict the 6-h intensity change with GOES-9 and MTSAT satellites, and the result was further extended to predict the 24-h intensity change and accumulated rainfall. After comparing the predicted rainfall with the rain gauge data gathered from Taiwan’s offshore small islands, it shows that the accuracy of the predicted accumulated rainfall could be improved significantly while considering the effects of rainband rotation and intensity variation.

1. INTRODUCTION

In Taiwan, typhoons are one of the important sources of precipitation/water resources, but their heavy rainfall often causes huge damages and causalities. Therefore, if the heavy rainfall can be predicted before a typhoon makes landfall, it will provide crucial information to disaster mitigation agencies.

Kidder et al. (2005) developed the TRaP technique to predict the heavy rainfall of a typhoon and was validated by Ferraro et al. (2005). However, the effects of the typhoon rainband rotation and intensity change were not considered in TRaP. Thus, Liu et al. (2008) improved TRaP by considering a typhoon’s rainband rotation. As for typhoon intensity prediction, DeMaria (2006) tried to improve the Statistical Hurricane Intensity Prediction Scheme (SHIPS) by adding GOES and airborne observations. In 1994, Rodgers et al. proposed a precipitation intensity parameter (PIP) to relate a typhoon’s intensity to its precipitation intensity. Lonfat et al. (2004) implied that there was a higher correlation between typhoon intensity and precipitation characteristics within 100 km radius or 150 km to 200 km radius. Therefore, the purpose of this research is to improve TRaP by considering the effects of typhoon rainband rotation and intensity change.

2. METHODOLOGY

2.1 Typhoon Intensity Estimation and Prediction

For typhoon intensity prediction, DeMaria (2006) applied GOES and airborne observations to improve the 6-h typhoon intensity prediction of SHIPS. The potential predictors considered by DeMaria are: (1) the 100~300 km radially averaged Tb standard deviation, (2) the percent area from r=50 to 200 km with Tb < -20℃, (3) the maximum Tb from 0 to 30 km (eye temperature), (4) the radius of maximum Tb from 0 to 30 km, (5) the minimum Tb from 20 to 120 km (eyewall "cold ring" temperature), and (6) the radius of minimum Tb from r=20 to 120 km. In this research, in order to predict the 6-h typhoon intensity change, these six potential predictors will be analyzed by the regression method and used to construct a new model for estimating the typhoon intensity as well as predicting the 6-h typhoon intensity.

2.2 The Relationship between Typhoon Intensity and Precipitation

Then, the relationship between typhoon intensity and rainfall characteristics were needs to be established. Rodgers et al. (1994) proposed the PIP method to relate a typhoon's intensity to its corresponding precipitation. Furthermore, Lonfat et al. (2004) implied that there was a relationship between the typhoon intensity and the percentage of the non-raining area within 100 km radius, or 150 km to 200 km radius. Therefore, this research will analyze the percentage of the non-raining area within different radius of a typhoon and its intensity to find out the relationship between intensity and precipitation. By combining together of the typhoon intensity estimation, 6-h prediction models, and the relationship between typhoon intensity and precipitation, the typhoon precipitation change in the next six hours can be predicted. Furthermore, the 6-h prediction of precipitation change could be extended to the 12, 18, and 24-h prediction of precipitation change. Furthermore, the result can be applied to the improvement of TRaP.

3. RESULTS AND DISCUSSIONS

3.1 Typhoon Intensity Change Prediction

In this research, the potential predictors regarding to typhoon intensity in the research of DeMaria (2006) were analyzed to find out the typhoon intensity estimators and the 6-h intensity predictors that are suitable for the Northwest Pacific. The results were shown in Table 1 and the typhoon intensity estimation ($V_{MAX}(0)$) and prediction ($V_{MAX}(6)$) model could be expressed by Equations (1) and (2).

Table 1. The parameters that are used as the typhoon intensity estimators and the 6-h intensity predictors.

Intensity Estimators	Intensity Predictors (6-h)
1. 250~350 km radially averaged Tb standard deviation	1. 50~250 km radially averaged Tb standard deviation
2. Percent area from r=50 to 250 km with Tb < -40℃	2. Percent area from r=50 to 250 km with Tb < -40℃
3. Maximum Tb from 0 to 30 km	3. Maximum Tb from 0 to 30 km
4. Radius of maximum Tb from 0 to 30 km	4. Radius of maximum Tb from 0 to 30 km
5. Minimum Tb from 20 to 120 km	5. Minimum Tb from 20 to 120 km
6. Radius of minimum Tb from 20 to 120 km	6. Radius of minimum Tb from 20 to 120 km

$$V_{MAX}(0) = -100.58 - 1.70 \times P_1(0) + 62.23 \times P_2(0) + 0.46 \times P_3(0) - 0.47 \times P_4(0) + 0.26 \times P_5(0) - 0.08 \times P_6(0) \tag{1}$$

$$V_{MAX}(6) = 4.96 - 2.02 \times P_1(0) + 33.22 \times P_2(0) + 0.45 \times P_3(0) - 0.19 \times P_4(0) - 0.17 \times P_5(0) + 0.03 \times P_6(0) \tag{2}$$

Where $P_1(0)$ to $P_6(0)$ are intensity estimators and $P_1(6)$ to $P_6(0)$ are intensity predictors described in Table 1. In order to verify the models in this research, Equations (1) and (2) were applied to seven typhoon cases from 2003 to 2005. Figure 1 shows that the results of typhoon intensity estimation and the 6-h intensity prediction of Typhoon Dujuan (2003) and compared with the JTWC best track data. The result shows that when a typhoon is intensifying, the estimated (Figure 1a) and predicted (Figure 1b) typhoon intensity trend to consistent with the best track data, but sometimes the estimated and predicted typhoon intensity will vary in a short time. While a typhoon begins to weakening, the estimated and predicted typhoon intensity results trend to not consistent with the JTWC intensity data. Generally speaking, the results show that the other six typhoons demonstrated a similar behavior to Typhoon Dujuan, the mean absolute errors of the estimated and predicted typhoon intensity are shown in Table 2.

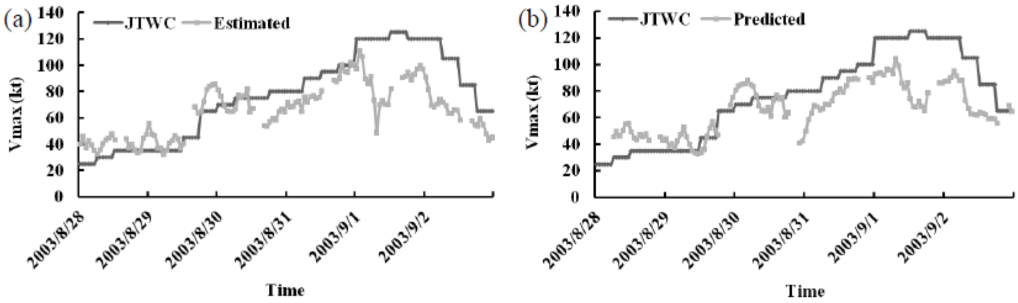

Figure 1. (a) The intensity estimation and, (b) the 6-h intensity prediction results for Typhoon Dujuan (2003) and compared with the JTWC best track data.

Table 2. The mean absolute error of estimated and predicted (6-h) typhoon intensity in this research.

Typhoon	Estimated (kt)	Predicted (kt)
2003 NangKa	12.8	12.9
2003 Soudelor	17.0	14.5
2003 Morakot	18.2	19.3
2003 Dujuan	17.7	18.8
2004 Mindulle	21.4	15.6
2004 Aere	21.9	18.6
2005 Matsa	15.1	14.9
Total	17.7	16.4

3.2 The Relationship between Typhoon Intensity and Precipitation Characteristic

For 18 typhoon cases in 2003 and 2004 over the Northwest Pacific, this research applies SSM/I data and the rainfall retrieval algorithm of Ferraro (1997) to estimate the percentage of the non-raining area within different radius of each case. The estimated percentage of the non-raining area is analyzed with the JTWC intensity data. For the intensifying typhoon cases from Jul to Sep in 2003 and 2004, there is a better relationship between the percentage of the non-raining area within 1° to 1.5° radius and typhoon intensity (Figure 2), but for the percentage of the non-raining area within 1° and 1.5° to 2° (Figure 3), it seems no relationship. Thus, the relationship between the typhoon intensity and its percentage of the non-raining area within 1° to 1.5° radius will be used in this research, such as Equation (3) shows.

$$A_{non-raining} = -0.5937 \times V_{MAX} + 70.952 \tag{3}$$

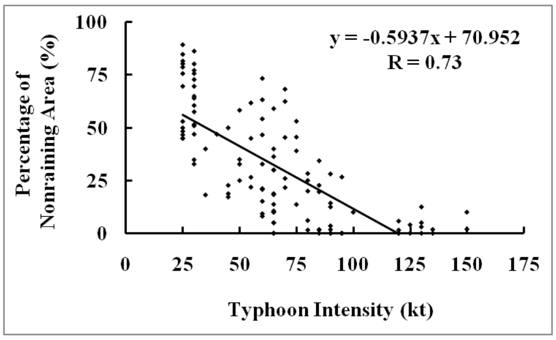

Figure 2. The relationship between the JTWC best track intensity and the percentage of the non-raining area within 1° to 1.5° radius of typhoons (Jul to Sep in 2003 and 2004, intensifying cases).

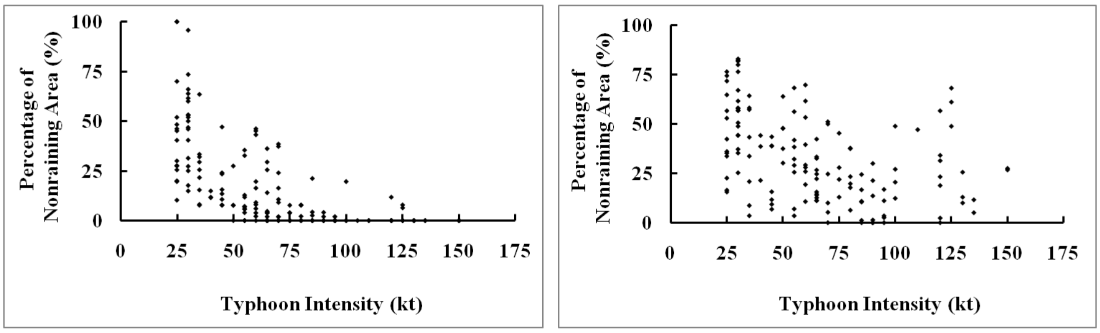

Figure 3. Same as Figure 2, but for (a) within 1° radius, and (b) within 1.5° to 2° radius.

By using Equation (3), the typhoon intensity can be transferred to the percentage of the non-raining area within 1° to 1.5° radius ($A_{non\text{-}raining}$), and the rainrate after six hours ($RR(6h)$) can be predicted by,

$$RR(6h) = RR(0h) \times \frac{A_{non-raining}(6h)}{A_{non-raining}(0h)} \quad -(4)$$

Of course, the 6-h typhoon rainrate prediction model could be further extended to predict the 12, 18, and 24-h rainrate, and is used to improve TRaP. For Typhoons Dujuan, Morakot, Nangka, and Soudelor in 2003, Aere and Mindulle in 2004, and Matsa in 2005, the results of TRaP, TRaP with the consideration of rainband rotation, and TRaP with the consideration of rainband rotation and intensity change were compared with the in-situ observations of Islands Peng-Jia-Yu, Dong-Ji-Dao, and Lan-Yu stations operated by the Central Weather Bureau (CWB). The intensity data is from the model developed in this research. The mean absolute error analysis as a function of prediction time was shown in Figure 4. There is a significant improvement for the 12-, 18-, and 24-h accumulated rainfall when considering a typhoon's rainband rotation. If the intensity change is also considered, there is a slight improvement for the 24-h accumulated rainfall. This may be caused by the variation of the estimated and predicted typhoon intensity during a short time period. Furthermore, if the typhoon intensity data is from JTWC, the results of 18- and 24-h accumulated rainfall are improved much more. This demonstrates that when typhoon intensity data is more accurate, the predicted typhoon precipitation will be more accurate.

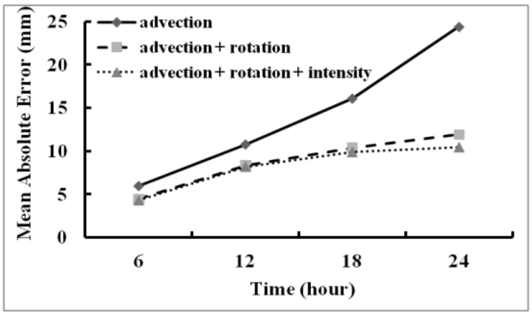

Figure 4. The mean absolute error as a function of time for TRaP (e.g. advection), TRaP with the consideration of typhoon rainband rotation (advection + rotation), TRaP with the consideration of typhoon rainband rotation and intensity change (advection + rotation + intensity).

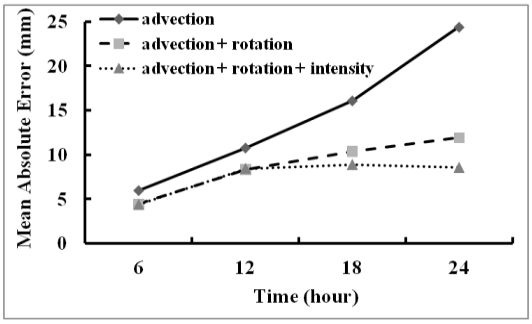

Figure 5. Same as Figure 4, but for the JTWC intensity data is used.

4. CONCLUSIONS

In this research, the effects of a typhoon’s rainband rotation and intensity change on its precipitation are considered to improve TRaP. Based on the mehod of DeMaria (2006) this research additionally applied the geostationary satellite data to estimate and predict typhoon intensity. Furthermore, the relationship between the typhoon intensity and the percentage of the non-raining area was also constructed and used to improve TRaP.

The evaluation showed that the improvement is not significant when considering only the typhoon intensity change. The reason may be that sometimes the typhoon intensity prediction varies during a short time period. However, after the usage of the JTWC intensity data, the result showed that when the estimated and predicted typhoon intensities are more accurate, the predicted typhoon precipitation will be much more accurate. This result reveals that the feasibility of considering typhoon intensity to improve TRaP.

5. ACKNOWLEDGEMENTS

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