# The Operational Procedure on Estimating Typhoon Center Intensity using Meteorological Satellite Images in KMA

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**ABSTRACT**

Korea Meteorological Administration(KMA) has issued the tropical storm(typhoon) warning or advisories when it was developed to tropical storm from tropical depression and a typhoon is expected to influence the Korean peninsula and adjacent seas. Typhoon information includes current typhoon position and intensity. KMA has used the Dvorak Technique to analyze the center of typhoon and it's intensity by using available geostationary satellites' images such as GMS, GOES-9 and MTSAT-1R since 2001. The Dvorak technique is so subjective that the analysis results could be variable according to analysts. To reduce the subjective errors, QuikSCAT seawind data have been used with various analysis data including sea surface temperature from geostationary meteorological satellites, polar orbit satellites, and other observation data. On the other hand, there is an advantage of using the Subjective Dvorak Technique(SDT). SDT can get information about intensity and center of typhoon by using only infrared images of geostationary meteorology satellites. However, there has been a limitation to use the SDT on operational purpose because of lack of observation and information from polar orbit satellites such as SSM/I. Therefore, KMA has established Advanced Objective Dvorak Technique(AODT) system developed by UW/CIMSS(University of Wisconsin-Madison/Cooperative Institude for Meteorological Satellite Studies) to improve current typhoon analysis technique, and the performance has been tested since 2005. We have developed statistical relationships to correct AODT CI numbers according to the SDT CI numbers that have been presumed as truths of typhoons occurred in northwestern pacific ocean by using linear, nonlinear regressions, and neural network principal component analysis. In conclusion, the neural network nonlinear principal component analysis has fitted best to the SDT, and shown Root Mean Square Error(RMSE) 0.42 and coefficient of determination($R^2$) 0.91 by using MTSAT-1R satellite images of 2005. KMA has operated typhoon intensity analysis using SDT and AODT since 2006 and keep trying to correct CI numbers.

**KEY WORDS:** typhoon intensity, infrared satellite image, Dvorak, Neural networks

## 1. Introduction

Tropical storms which are occurred in northwestern pacific and influence the Korean peninsula, typhoon, are important marine event. Remote sensing from geostationary meteorological or polar orbital satellite is one of the most available method to estimate typhoon center position and intensity.

KMA has used the Subjective Dvorak Technique(SDT) to estimate the center of typhoon and it's intensity by using available geostationary satellites' images such as GMS, GOES-9 and MTSAT-1R since 2001. The drawback of the SDT is that the analysis results could be variable and subjective according to analysts. To reduce the subjective errors, QuikSCAT seawind data have been used with various analysis data including sea surface temperature from geostationary meteorological satellites, polar orbit satellites, and other observation data. On the other hand, SDT can get information about intensity and center of typhoon by using only infrared images of geostationary meteorology satellites. However, there has been a limitation to use the SDT on operational purpose because of lack of observation and information from polar orbit satellites such as SSM/I. Therefore, KMA has established Advanced Objective Dvorak Technique(AODT) system developed by UW/CIMSS(University of Wisconsin-Madison/Cooperative Institude for Meteorological Satellite Studies) to improve current typhoon analysis technique, and the performance has been tested since 2005.

## 2. The data and analysis method

In order to compare with the result of AODT CI(Current Intensity) numbers and SDT CI numbers, we analyzed the typhoons from 2004 to 2005, which include typhoon SUDAL, MINDULLE, MEGI, CHABA, NALGAE, NABI and so on. We used 123 times data from GOES-9 satellite platform for 24 typhoons occurred in 2004 and 232 times data from MTSAT-1R satellite platform for 17 typhoons occurred in 2005. And then we tried to evaluate the result for typhoon SUDAL and NIDA in 2004 and for typhoon HAITANG and NALGAE in 2005.

We have developed statistical relationships to correct AODT CI numbers according to the SDT CI numbers that have been presumed as truths of typhoons occurred in northwestern pacific ocean by using linear, nonlinear regressions, and neural network principal component analysis.

### 3. The Dvorak Technique

The most widely used satellite technique was developed by Dvorak(1975 and 1984). This technique employs image pattern recognition and empirically based rules to derive an estimate of typhoon intensity in T numbers. This parameter was developed to be representative of a simple model of typhoon evolution such that T number increments correspond to typical observed changes in intensity. The T number may be adjusted in several situations such as weakening events. Therefore, Dvorak defines the CI number as the final adjusted value, which is related to conventional intensity quantities.

Several researchers have tried to estimate accurately tropical storm intensity and eliminate the subjectivity of the Dvorak Technique(May et al, 1997, Zehr, 1989, Bankert et al, 2002). The concept of using digital IR data was originally proposed by Dvorak(1984). Based on these ideas, a computer-based algorithm, AODT(Advanced Objective Dvorak Technique), was developed by UW/CIMSS(velden et al, 1998).

The AODT utilizes automated computer-based algorithms to objectively identify pattern types, calculate the eye/convection temperatures, apply selected rules, and derive intensity estimates.

The ODT first determines the eye temperature of the storm by using the warmest pixel temperature within a 40 km radius of the chosen storm center(warm values represent ocean surface or low cloud within the eye).

The ODT then analyzes temperatures on concentric rings(1 pixel wide) centred on the eye between 24 and 136km from the eye location(this range was empirically determined by many observations of coldest ring radii).

After identifying the eye and surrounding temperatures, the basic ODT utilizes a lookup table(Dvorak 1995) to estimate the intensity.

Selected empirically determined constraints are imposed upon the final derivation of the estimate, such as confining the minimum T number to be no less than 3.5 and limiting the maximum intensity of non-eye storms such as CDO(Central Dense Overcast) patterns to a T number of 5.0.

### 4. Conclusion

We analysed statistical relationships to correct AODT CI number according to the SDT CI numbers that have been presumed as truths of typhoon occurred in norhwestern pacific ocean by using linear, nonlinear regressions, and neural network principal component analysis.

In the research, the correlation coefficient of SDT CI number and AODT CI number is comparatively high, 0.83. Although the close relationship between SDT CI number and AODT CI number, there are systematic differences and we tried to perform linear and nonlinear regression analysis to correct them.

As the result of the linear regression analysis, RMSE is 0.60 and $R^2$ is 0.7(Figure 1). We recognized that the linear regression is not appropriate from the residual. We tried to perform polynomial regression analysis and RMSE is 0.67 and $R^2$ is 0.72. The improvement is not large and then we tried to perform the PCA(principal component analysis) through neural network. As the result of PCA, RMSE is 0.37 and $R^2$ is 0.91 for typhoons occurred in 2004(Figure 2) and RMSE is 0.42 and $R^2$ is 0.87 for typhoons occurred in 2005(Figure 3).

In spite of small sample data, we could identify the availability for AODT and validate the possibility of improvement of correction.

KMA has operated typhoon intensity analysis using SDT and AODT since 2006(Figure 6) and keep trying to estimate the accurate typhoon intensity.

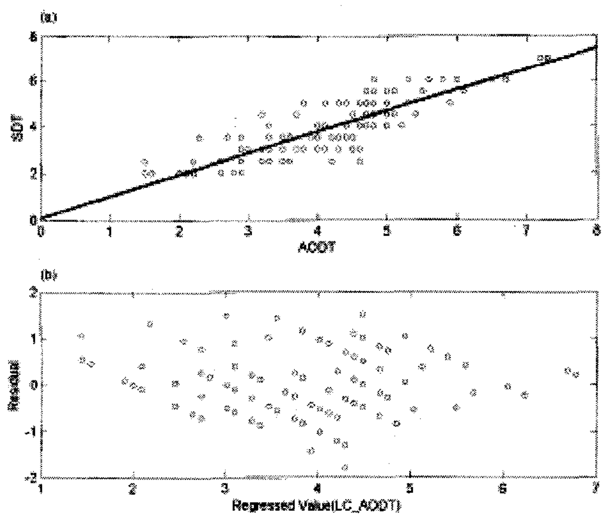


Figure 1. (a) The results of linear regression analysis by using both SDT CI numbers and AODT CI numbers of typhoon events occurred in 2004. AODT CI number is used as a predictor(independent variable) and SDT CI number is used as a predictand(response variable). The regression coefficient is 0.92 and bias parameter is estimated as 0.07. (b) Residual scatter diagram produced by the results of linear regression analysis. X axis is regressed value(LC_AODT) which can be obtained by the straight line in(a). Y axis is the residual which can be calculated by the difference between SDT and LC_AODT.

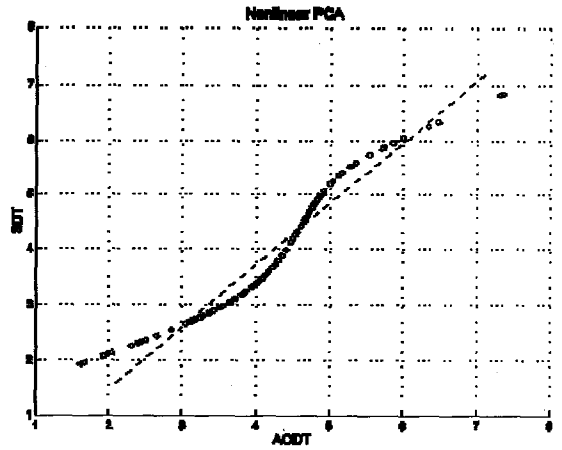


Figure 2. The result of nonlinear regression analysis by using CI numbers of typhoon events occurred in 2004. X-axis shows the input AODT CI number and Y-axis correspondes to SDT CI number. The curve connected by red circle shows the nonlinear regression curve. The blue line indicates the linear PCA(Principal Component Analysis) result.

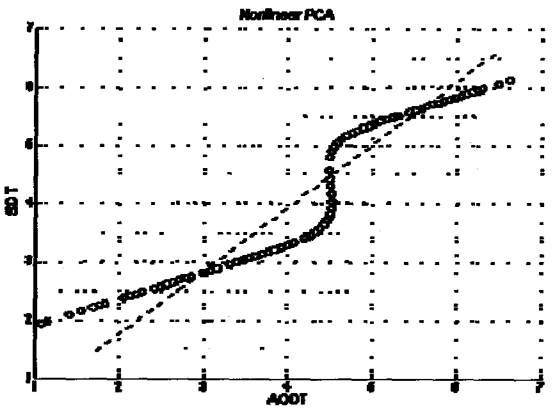


Figure 3. same as Fig. 2 except for typhoon events occurred in 2005.

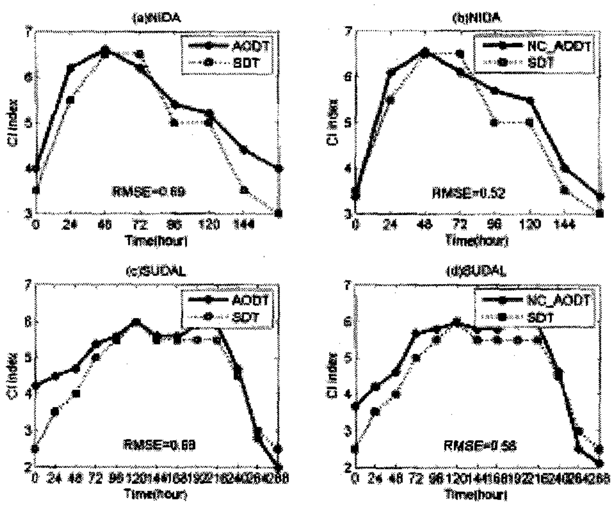


Figure 4. Correction result applied to typhoon NIDA and SUDAL occurred in 2004 independent of training period. (a) and (c) shows AODT CI number(solid) and SDT CI number(dotted). (b) and (d) shows the result of corrected(solid) NC_AODT.In each figure, RMSE(Root Mean Square Error) value is shown to estimate quantitatively the effect of correction.

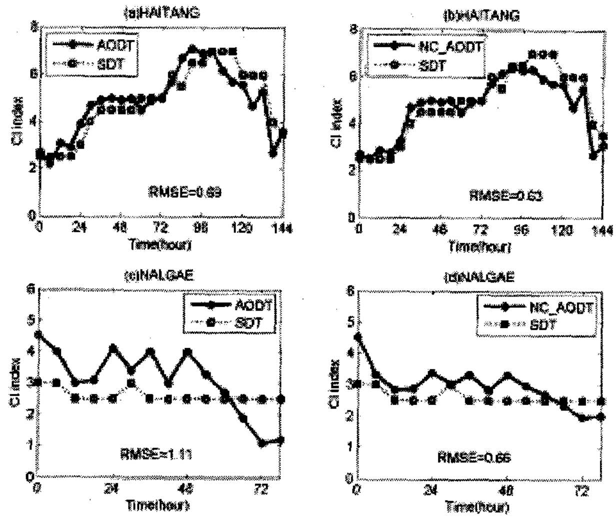


Figure 5. Correction result applied to typhoon(arbitrary chosen) HAITANG and NALGAE occurred in 2005 independent of training period. (a) and (c) show AODT CI number(solid) and SDT CI number(dotted). (b) and (d) show the results of corrected(solid) NC_AODT. In each figure, RMSE value is shown to quantitatively estimate the effect of correction.

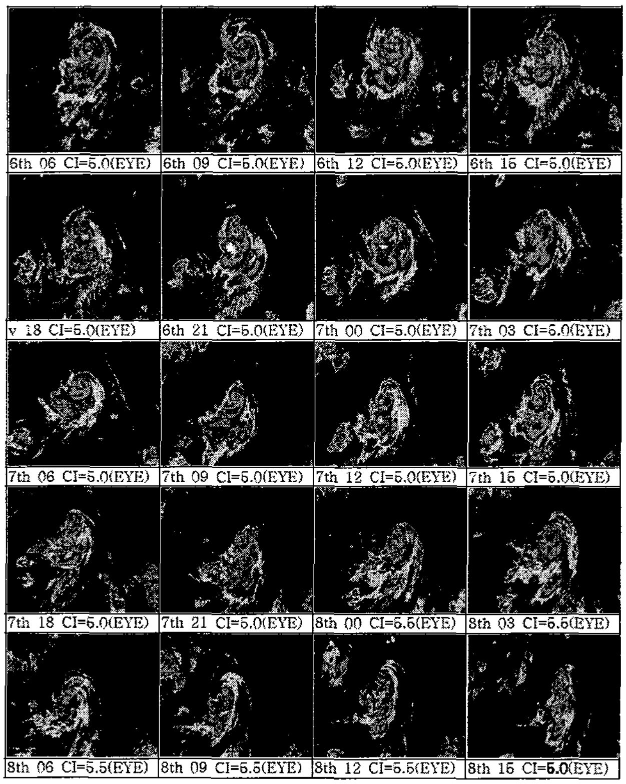


Figure 6. MTSAT-1R enhanced infrared images and typhoon intensity analyzed in KMA during typhoon EWINIAR from 06UTC 6 July 2006 and to 16UTC 8 July 2006.

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