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Determination of Typhoon Intensity by Using Objective Satellite Image Processing Technique

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Abstract. An objective technique for obtaining features associated with the shape of cloud structures embedded in typhoon from satellite infrared images is described. As a typhoon usually develops from an unstructured cloud cluster to the cloud structures with more axis-symmetric for an identified reference point (usually is the eye of typhoon). This study analyze the MTSAT_IR1 image data of six severe typhoon cases (2005~2011) from tropical depression to severe typhoon stage. The gradient of the brightness temperatures in the IR1 image is calculated from the horizontal and vertical derivatives by using Sobel's template, then the deviation angle of each gradient vector relative to a radial line extending from the reference point is calculated. Next, an intensity index is proposed from the distribution of deviation angle. The results show a high positive correlation between the intensity index and maximum wind speed of the six severe typhoon cases. Therefore, the intensity index is probably useful for weather operational center to determine the typhoon intensity while typhoons are over oceans.

Keywords: typhoon, remote sensing, deviation angle

1. Introduction

The physical processes associated with typhoon development have been a subject of considerable interest [1], [2]. Techniques using satellite measurements are perhaps the only way to reliably detect [2],[3]. A combination of visual patterns in the infrared (IR) and visible (VIS) channels brightness temperatures of clouds were usually used to detect rotation, the coldest brightness temperatures are suitable used to detect deep thunderstorms in the eyewall, and the warm brightness temperatures are used to detect an eye at the center of circulation. The level of organization of a cloud cluster is obtained by quantifying its axis-symmetry by satellite images [2],[4]. Accordingly, the organization and axis-symmetry increases as the storm develops from tropical depression (TD) stage to severe typhoon stage. Piñeros et al study the axis-symmetric degree of cloud organization through the deviation angle of image which is calculated by using the Sobel's image edge processing [4]. This study develops an intensity index by using the distribution of deviation angle to determine the typhoon intensity, even to predict as possible.

2. Methodology

The satellite data used in this study is the infrared data from Multi-functional Transport Satellite (MTSAT) during the period from 2005 to 2011. Succeeding the Geostationary Meteorological Satellite (GMS), the MTSAT is the next generation of geostationary meteorological satellites covering East Asia and the Western Pacific roughly 35,800km above the equator at 140 degrees East longitude. The MTSAT carries one visible (0.55 - 0.90 micrometers) and four infrared channels (IR1, 10.3~11.3; IR2, 11.5~12.5; IR3, 6.5~7.0; IR4 3.5 - 4.0 micrometers). The input data to the technique are digital brightness temperatures from long-wave IR1 satellite scenes. Seven hundred and seventy five hourly images from the MTSAT including

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six typhoons from early tropical depression (TD) to severe typhoon stage during the period from 2005 to 2011 were analyzed in this study. The details of six severe typhoons were listed in Table 1.

An intensity index for typhoon is proposed by using the distribution of deviation angle of MTSAT-IR1 satellite images which calculated by using Sobel's template [2],[4]. Since the shape of the cloud cluster structures becomes more axis-symmetric from tropical depression to severe typhoon stage. Therefore, the intensity index (I-index) is defined as following equation:

$$\text{I - index} = \frac{\left(\begin{array}{l}\text{The probability density of the peak}\\ \text{of the deviation angle dis}\end{array}\right) \times \left(90 - \text{the degree of the peak}\right)}{\left(\text{The standard deviation of the deviation angle distribution}\right)}$$

Table 1 The information of six severe typhoons used in this study

Severe Typhoon Name	Period				Total times from TD to Severe Typhoon (hrs)
Talim	2005	8/26	~	9/1	127
Longwang	2005	9/25	~	10/2	143
Krosa	2007	10/1	~	10/7	115
Jangmi	2008	9/23	~	10/1	103
Songda	2011	5/20	~	5/29	181
Nanmadol	2011	8/22	~	8/31	106

3. Discussion

There are seven hundred and seventy five hourly images from the MTSAT_IR1 of six typhoons including early TD stage to severe typhoon stage from 2005 to 2011 used in this study through Sobel's template to calculate the deviation angle. Fig.1 shows that the deviation angle distribution become approaching normal distribution when the intensity of typhoon increase from TD to severe typhoon stage, and the structures of cloud cluster will become more axis-symmetric to the reference point. The result is similar to the results of research of Piñeros et al [4]. Furthermore, the deviation angle distribution could be used to characterize the intensity of typhoon from TD to severe typhoon stage.

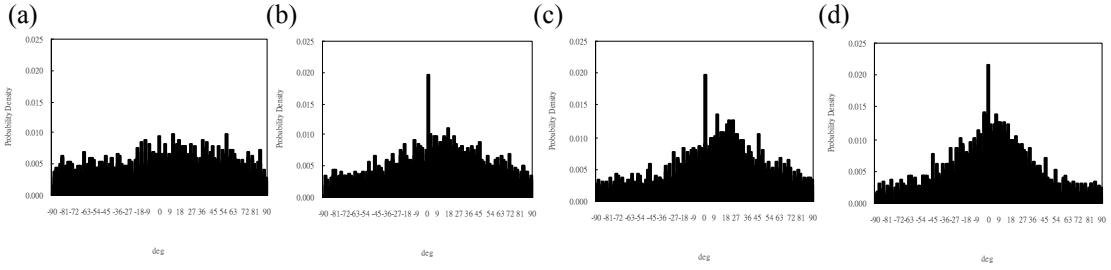

Fig. 1 The deviation angle distribution of typhoon in TD(a), mild stage(b), moderate stage(c), and severe stage(d) in Longwang case.

Since Fig.1 show that the deviation angle distribution become approaching normal distribution when the intensity of typhoon increase from TD to severe stage, and the structures of cloud cluster will become more axis-symmetric. Therefore, we develop a new index (I-index) in order to quantify the degree of the deviation angle distribution. Furthermore, the correlation distribution between wind speed (WS) and I-index is shown in Fig.2. The present results show that there exists a high correlation between the intensity index calculated by deviation angle distribution and the intensity of typhoon. The regression equation for WS and I-index as following:

$$WS = 94.5 \times I_{index} + 17.9, \quad R = 0.73$$

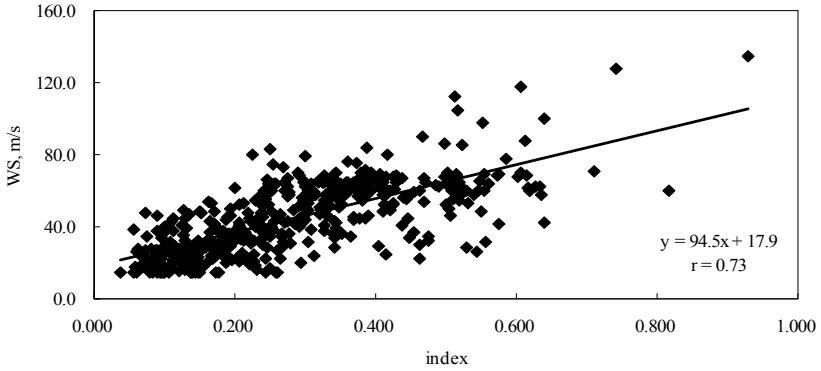

Fig. 2 The correlation distribution between wind speed (WS) and index of typhoons from TD to severe stage

4. Remarks

It is clearly that the intensity index can characterize efficiently the level of axis-symmetry of the typhoon structure when a typhoon intensity increase from TD to severe stage. In this study, we develop a new index by calculated from the deviation angle distribution, and there is a good relationship between maximum wind speed and intensity index of typhoon. It may be a useful for weather operational center to measure the typhoon intensity. We will analyze the tendency of index and propose a more reliable index not only for measurement but also for forecast of typhoon intensity.

5. References

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