AUTOMATED TYPHOON IDENTIFICATION FROM QUIKSCAT WIND DATA

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1. INTRODUCTION

Typhoons, which are also known as hurricanes in western hemisphere, pose one the greatest natural threats to coastal areas and maritime interests. Every year, typhoon will cause huge loss of life and property. Accurate track and intensity forecast with skill extending out several days are required to minimize the financial impact and eliminate the loss of life caused by these extreme weather events.

In addition to the readily apparent effects to life and infrastructure, tropical cyclones serve as a significant mechanism for global heat dissipation. Some scientists believe that an increase in sea surface temperatures brought on by greenhouse warming will be correlated with a statistical trend of increased tropical cyclone intensity. Frequent and accurate tropical cyclone observation from genesis to dissipation is important in understanding their role in Earth's climate. A better understanding of the processes involved in tropical cyclones is also requisite for improvements in track and intensity forecasting.

Meanwhile, temporary phytoplankton bloom can be triggered due to upwelling of nutrient-rich sub-surface water, and due to increase of time of exposure to solar radiation after the typhoon[1-3]. To better understand the Biochemical mechanism of this phenomenon, frequent and accurate tropical cyclone observation data is required.

In the past half century, satellite technologies have been extensively applied to estimate the movement and intensity. One of the most widely accepted techniques is the Dvorak technique[4,5], which assigns a wind intensity value (called the TC number) based on the size, shape, and vorticity of the dense cloud shield adjacent to the center of the storm.

Based on Dvorak’s theory, each tropical cyclone goes through a life cycle that may be classified into one of several types by its appearance in visible or enhanced infrared images[6]. However, due to the high variation of typhoon patterns, the visible and enhanced infrared Dvorak techniques are subjective, requiring professional training to be done effectively for good wind estimates.

The microwave remote sensor has also proven their effectiveness in studying tropical cyclones, because of its unique ability to infer wind speed and direction regardless of cloud cover and solar illumination. Recent research has shown that QuikSCAT data could be useful in early identification of tropical depression [7] and early detection of tropical cyclones[8,9]. Also, an ensemble learning technology based on a committee of support vector machines using features extracted from QuikSCAT wind sensor data are used for cyclone identification[10].

In this paper, we are trying to develop an automated typhoon identification algorithm using QuikSCAT wind data. The histogram features of the wind speed and wind direction of typhoon is used for a coarse identification, and then a more precise identification which makes use of the circulation property of typhoon is applied to the wind data which can pass the coarse identification.

The histogram features of the wind speed and wind direction of typhoon is used for a coarse identification at first. The term tropical cyclone encompasses a wide variety of storms. It describes the weather system's formation in the tropics and the nature of wind circulation within the system counter-clockwise in the northern hemisphere and clockwise in the southern. Specially, a tropical cyclone is a warm-core, synoptic-scale cyclone with organized convection and closed circulation of surface winds about a well defined center[11]. If winds reach 33 m/s (64 kt, 74 mph), then they are called typhoon, or hurricane in western hemisphere. So the wind speed is set to be a criterion to identification typhoon from the QuikSCAT datellite data. If a potential typhoon exist within a pre-defined bounding box extracted from a QuikSCAT image, the maximum rain-free wind speed within the box must exceed a certain minimum wind speed (8.0 m s-1 is chosen in this paper), and this criteria must be met at least 300 times within the box(i.e., approximately an area of 1800 km by 1800 km).

The wind direction histogram is set to be another criteria. Because of the helical structure of typhoon, the distribution of the wind direction for a cyclone shows a “near linear” distribution. So that if a potential typhoon exist within a pre-defined bounding box, the number of cells for each wind direction bin should exceed a certain minimum number (i.e.,10 is chosen in this paper).

To further discriminate between cyclone and non-cyclone events, a precise identification is employed after the coarse identification by checking the circulation property in the bounding boxing. When a bounding box contains a cyclone, at least one “circulation path” can be found within the box. Fig. 2 shows a typical “circulation path”, which is represented by thick black line. On this circulation path, three criteria should be all met.

(1) On the circulation path, the difference of wind direction between two neighborhood cells should less than a certain minimum to insure the wind direction change continuously along the circulation path. If the QuikSCAT wind direction are grouped into 20° bins, the typical value of this minimum value can be set to be 20° .

(2) The angle between the wind direction and the path direction at each cell on the path should less than a certain minimum angle, which is set to be 45° in this study.

(3) If we bins the wind direction of all the cells on the path with 20° step, each bin of the wind direction histogram should contain at least one cell, so that at least one circle is contained in the circulation path.

If a potential typhoon exists within a pre-defined bounding box extracted from a QuikSCAT image, at least one circulation path can be found. To search for the circulation path in a bounding box, we develop a circulation path finder processor. The processor employs a “seed growing” strategy to search for the circulation path in a bounding box. A threshold grid is chosen as a seed to start from, and then the seed will be supposed to grow according to the pre-defined criteria.

The whole typhoon identification process can be described as follows: A coarse identification based on the histogram features of the wind speed and wind direction is applied to the pre-defined bounding box extracted from QuikSCAT. When the bounding box can pass the coarse identification, the circulation property of the bounding box will be checked with the circulation path finder module. Due to the non-uniformity in the measurements taken by the QuikSCAT satellite on a spherical surface, the QuikSCAT L2B wind product needs to be interpolated on a uniformly gridded flat surface. And then the wind direction are grouped into 20° bins, the wind direction bin number will then be used to represent the real wind direction of each gird in the "circulation path finder" process.Before we start the circulation path finder process, some procedure should be taken to avoid the finder process fall into an "impasse". The wind direction bin with number of cells less than 6 will be merged into the geographical nearby bin. The same process will be performed to the isolated grid, in the neighborhood of the isolate grid, no more than 2 grids which belong to the same bin with the isolate grid can be found. Then the path finder process is started to search for the circulation path in the bounding box.

Note that in the case that only part of the typhoon are seen by QuikSCAT, the path will be truncated at the edge of swath, or the grid which is flagged by land or ice. To account this case in our identification, an additional process is applied after the normal rotation pass finder, which employs the same methodology as the circulation path finder, but use the grid located at the edge of swath or the one flagged by land or ice as the seed at the beginning of the finding. If a path starting at a edge or flagged grid, also ending at another edge or flagged grid can be found, and the bin number in the path can exceed a minimum number(which is set to be 6 in this study), the "finder" will also declare that a circulation path have be found.

After all these work has been done, the identification process check whether a circulation path has been found. If a circulation path has been found, then the processor will declare that a potential typhoon exists within a pre-defined bounding box.

To validate our method, a sequence of QuikSCAT data obtained from PO.DACC for Typhoon Morakat from August 3 to August 8 2009 is used in the typhoon identification experiments, the results shows that all typhoon events observed by QuikSCAT in Typhoon Morakat including the one located at the edge of QuikSCAT swath and the one located near the coast can be correctlly identified, indicating the utility and feasibility of our methodology.

Key word: Typhoon, automated identification, QuikSCAT

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