SIMULATION OF TYPHOON'S ANOMALOUS TRACK (I)

—RANKINE VORTEX MODEL*

Lin Mian (林绵) Li Jiachun (李家春) Li Li (李栋)

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Abstract

This paper proposes a method for simulating symmetric and asymmetric typhoon by using Rankine vortex model. Considering similarity between tropical cyclone and the Rankine vortex, the paper has qualitatively discussed the feasibility of the methods. In order to decide quantitatively Rankine vortex's parameters to simulate typhoon's structure, the paper has dealt with TCM data for Yancy Typhoon (9012) as initial fields. These results are considered as a foundation for further studying typhoon motion by CD approach.

Key words typhoon, Rankine vortex, least square method

I. Introduction

Tropical cyclone is one of the severest natural disasters which causes catastrophic damages. Statistics have shown that the number of the injured and economical losses caused by typhoon in China rank the first and the death toll the second. So it is important to improve the forecasting accuracy of the typhoon's track and alleviate the disasters especially for China.

For a long time, forecasting error in track is always around 400~500 kilometer in 72 hours. Scientists assume that such error may be attributed to the typhoon's inner asymmetrical structure, which gives rise to the occurrence of anomalous trajectory, i.e., sudden change of motion, meandering or looping. Recently, meteorologists have paid special attention to the formation of asymmetrical structure and succeeded in predicting the anomalous track to certain extent. However, they seldom noticed the physical mechanism of typhoon activities.

In this paper we have applied the Rankine vortex model for simulating typhoon's symmetrical and asymmetrical structure. At first we discuss the feasibility of simulating typhoon with Rankine vortex model and then analyze how to substitute a real typhoon by Rankine vortices. Finally we point out that it is very useful for predicting typhoon's anomalous motion.

II. Rankine Vortex Model

(a) Symmetric typhoon

As is well-known, the tangent velocity component and pressure field are the most important parameters reflecting typhoon's inner structure. Usually, they can be written as:

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1 Institute of Mechanics, CAS, Beijing 100080, P. R. China
2 Department of Mechanics, Qinghua University, Beijing 100080, P. R. China
by empirical formulae where $R_0$ indicates the radius of maximum wind speed, $R_{\text{max}}$ the typhoon’s radius, $V(R_0)$ the maximum wind speed, $\chi$ a parameter between 0.5 and 0.7. In equation (2.1b), $R_0 = A^{1/2}, A = R_0^2, A = 31.6 - 25.3, B = 1.0 - 2.5^{[4]}$.

Now we turn to consider a Rankine vortex that represents a circular vortex patch with constant vorticity, i.e.,

$$\Delta \phi = -\zeta = \begin{cases} -\Omega & (r \leq R_0) \\ 0 & (r > R_0) \end{cases}$$  \hspace{1cm} (2.2)

where $\phi$ is the stream function, $\zeta$ is the vorticity, $R_0$ is the vortex radius. Therefore its azimuthal

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{streamline.png}
\caption{Streamline analysis with asymmetric structure}
\end{figure}