

## The Beginnings of the Numerical Prediction of Typhoons in Japan

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In 1959, the Japan Meteorological Agency (JMA) began its routine operation of weather forecasting with an electronic computer. It was based on previous work carried out by researchers who had formed a study group called the "Tokyo NP group." The present lecture attempts to describe the early developments of numerical prediction by those meteorologists in the 1950s. Particular attention will be paid to the prediction of the movement of a typhoon, the method for which was developed independently in Japan.

Numerical weather prediction with an electronic computer was first conducted in 1950 in the United States. It was done by a research group led by J. Charney at the Institute for Advanced Study in Princeton. The results of Charney and others greatly impressed S. Syono, then professor at Tokyo University and an expert in dynamical meteorology. One of Syono's students, K. Gambo, made contact with Charney and studied at Princeton from 1952 to 1954. The American success pushed Japanese meteorologists to investigate numerical prediction, and Syono organized the "NP group" at the end of 1953. Gambo became a de facto leader after his return to Japan.

One of the characteristics of the "NP group" was that the members came from both academic and practical institutions: Tokyo University, the Central Meteorological Observatory (CMO, reorganized into JMA in 1956), and the Meteorological Research Institute (MRI, associated with CMO/JMA). As far as the prediction of typhoons was concerned, the main contributions in the 1950s were made by Y. Sasaki and K. Miyakoda from Tokyo University; E. Terauchi, Y. Nabeshima, and others from CMO/JMA; and Y. Masuda from MRI. When the computer-aided forecasting at JMA was begun in 1959, works for typhoon prediction were prepared by Terauchi, Masuda, and others.

Before the advent of electronic computers, the forecasting of a typhoon was performed in empirical ways. Weather forecasters had obtained some practical rules for the movement of typhoons, of which the primary one was that a typhoon is carried by a general flow, i.e., the flow of atmosphere surrounding the vortex of a typhoon. Sasaki and Miyakoda incorporated this empirical idea into the method of numerical predictions. By separating the vorticity field into that of the typhoon itself and the residue, they succeeded in reproducing the course of some typhoons. Because of the lack of computational machines, they performed their calculations by hand. Their result, published in 1954, was immediately deemed to be an important contribution made in Japan.

The Sasaki-Miyakoda method was soon adopted and extended by other meteorologists. At JMA, the method was tested for several typhoons in 1955 and compared with other methods. In the next year, researchers at JMA could use the ETL Mark II, a relay computer constructed at the Electrotechnical Laboratory. Using this opportunity, Terauchi and his collaborators modified their model to incorporate the effect of baroclinicity. On the other hand, the necessity of improving a barotropic model was insisted upon by Masuda, who proposed in 1957 an alternative method whereby the stream function is employed. In performing his computations, Masuda used another relay computer, the FACOM 128 of Fujitsu, as well as the FUJIC, a small electronic computer developed at Fuji Photo Film. It was through these earlier efforts that JMA could launch the operational forecasting of typhoons as soon as the IBM 704 was installed in 1959.

While the calculating tools changed from human hands to relay and electronic computers, the Sasaki-Miyakoda method, which was based on earlier empirical knowledge, provided a basic idea for modeling work through the 1950s. The early development of the numerical prediction of typhoons shows a continuity, rather than discontinuity, before and after the emergence of electronic computers.

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