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TYPHOON RAINFALL OVER TAIWAN AREA: THE EMPIRICAL FUNCTION MODES AND THEIR APPLICATIONS ON THE TYPHOON RAINFALL FORECAST

Tien-Chiang Yeh
Central Weather Bureau
64 Kung Yuan Road, Taipei, Taiwan
yeh@cwb.gov.tw

1. INTRODUCTION

The island of Taiwan situates in one of the main paths of north Western Pacific typhoons. As the Central Mountain Range, with peak higher than 3,900m, occupies most area of the island, many interesting typhoon-topography interaction phenomena have been observed and documented. The damage due to the strong wind and the severe rainfall associated with typhoons caused the most economical losses among all other weather related disasters. The forecast of the movement, wind and rainfall distributions of the destructive typhoons is one of the most challenging and important tasks of the Central Weather Bureau in Taiwan. However, as reported by Chen (1995) and Elsberry (2001), the rainfall associated with typhoon was much less studied than other topics of tropical storm, therefore more appropriate methods for operational usage of typhoon rainfall forecast remain to be developed.

In the past, Wu and Chi (1973) shown that typhoon rainfalls over Taiwan area are correlated with the locations of typhoon center. A typhoon rainfall forecasting technique of using the climatologic average (based on the spatial distribution of typhoon center) was then developed (Wang et al. 1986) and was applied in Central Weather Bureau. Yeh et al. (2000) recently indicated that the rainfall forecast based on the climatologic average is capable of showing the trend of the rainfall, however the method underestimates all of the heavier rains. By considering the deviations from the climatologic average, they examined the so-called “Deviation Persistence Method” and found that the forecast results were improved by simply assuming the rainfall deviation from the climatologic average will persist in time.

In the follows, the characteristic of the typhoon rainfall over Taiwan area is briefly reviewed by using the empirical orthogonal function (EOF) analysis. Regression equation forecast is demonstrated to shown the EOF modes can be used to improve the rainfall forecast. Due to the length scale of Taiwan, the 6-h accumulated rainfall forecast is the most critical information for the water resources management and disaster mitigation during the invasion of typhoon and will be the focus of this study.

2. DATA AND THE EOF MODES

The data set used in this study includes the hourly 6-h accumulation rainfall observations at 19 surface stations, distributing evenly over Taiwan area, when typhoons were inside the domain between 18^{o}N and 28^{o}N, 116^{o}E and 126^{o}E from 1961 to 1996. EOF analysis results show that the first three EOF modes are well separated from the other modes. Those three modes contain about 66% of the total rainfall variances. At some stations, only the first three modes can effectively represent the rainfall. The first EOF mode not only reveals the in-phase change of increasing or decreasing rainfall at all stations of Taiwan but also shows that larger rainfall occurred at area of higher elevation with larger slope. The enhancement of rainfall on mountainous areas is an indication of topography effect on redistributing typhoon rainfall. The second and the third rainfall modes both show out-of-phase distribution of typhoon rainfall over Taiwan when typhoons were nearby. The rainfalls were enhanced on the up-wind sides of the mountain, and hence were suppressed on the down-wind sides. Those distributions again reveal the effects of redistributing rainfall by Central Mountain Range of Taiwan.

3. THE FORECAST METHODS

To demonstrate the EOF analysis information is useful to the typhoon rainfall forecast, several prediction methods were compared. Those methods include four basic methods and four ensemble forecasts. The basic methods are: the Climatologic Average Method, the Deviation Persistence Method, the regression equation prediction based on station rainfall, and the regression equation prediction based on the amplitudes of the first three EOF modes. The ensemble forecasts are the simple averages from the last three basic methods.

The regression equations based on the rainfall EOF modes were conducted by selecting each of the mode amplitudes of the first three modes as dependent variable and forecasting each of the mode amplitudes to re-construct the rainfall at the 19 stations. To simplify the calculation, the independent variables were chosen from the current rainfall and the information obtained from the best track data analyzed by Joint Typhoon Warning Center, Hawaii, United States. No other meteorological parameters, although those parameters maybe significant to the typhoon rainfall forecast, were included. In details, the current typhoon center maximum wind speeds (m/s), moving speeds (m/s), moving directions (degree), center latitude and longitude locations (degree), Julian day function values (Neumann 1992), distances (degree) of typhoon centers from central Taiwan (defined at 24^{O}N, 121^{O}E), and the rainfall or the amplitudes of EOF modes were used as independent variables of the regression equations. In which, the typhoon moving speeds and directions were calculated by the current and the past 6-hour typhoon center locations. The typhoon moving directions were prescribed as zero degrees when typhoons were moving southeastward to minimize the effect of value discontinuity between 0^{O} and 360^{O}.

4. RESULTS

The results show those basic rainfall prediction methods are compatible to each other except the Climatologic Average Method that underestimates all heavier rains and is outperformed by the others. Since the amplitudes of EOF modes depend on how the rainfall is distributed spatially over all stations of Taiwan, therefore a prediction method based on the EOF modes is capable of providing different information from other methods that based on parameters only related to the single station. Our results also show that the ensemble forecast outperforms its corresponding member forecasts. The detail rainfall forecast verifications would be presented in the conference. Different rainfall forecast difficulties in different areas of the island would also be addressed.

ACKNOWLEDGMENTS This study was supported by the Central Weather Bureau and the National Science Council, R.O.C. under Grant NSC89-2625-Z-052-017.

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