A CLIMATOLOGICAL MODEL FOR FORECASTING TYPHOON RAINFALL IN TAIWAN

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1. INTRODUCTION

For most of years, Taiwan was affected by three to five typhoons (maximum at nine). The average yearly number of typhoon affecting Taiwan was 4.5, with 1.8 of them making landfall. The terrain lifting of the warm and moist air associated with a typhoon often caused continuous torrential rainfall on the windward side leading to serious flooding, landslide or debris flow. This study investigated the features of precipitation and developed a usable scheme for forecasting rainfall amount during typhoon period.

2. TYPHOON RAINFALL IN TAIWAN

To study the characteristics of typhoon rainfall in Taiwan, we collected the hourly rainfall data taken at 371 stations around the whole island for 58 typhoons in 1989-2001. The elevation of stations ranged from 1 m to 3,845 m. The 6-hourly fixes of JTWC best tracks were interpolated to provide hourly center positions. However, when typhoon was around Taiwan area, mesoscale analysis was performed to provide hourly center positions. Results showed that the rainfall rate associated with typhoon decreased with radius except inside the eye. The average hourly rainfall amounts were smaller for stations with lower elevation. For the island station, the average hourly rainfall amount was 6.9 mm at 0-25 km radius, but increased to 12.8 mm and 10.8mm at 25-50 km and 50-75 km radial ranges, respectively. Results also showed that the averaged rainfall at radius of 0-225 km and 225-450 km (about 0-2° and 2-4°), were similar to as those of Frank (1977) if the terrain effect was minimized.

The averaged hourly rainfall increased generally with station elevation, except a local maximum (3.3 mm) at 400-700 m. The occurrence of hourly rainfall at 1-9.5 mm and 10-19.5 mm also increased with station elevation except at 250-700 m, where might be the level of free convection. The average cumulative rainfall during typhoon period generally was larger over the mountain area especially at the northeast mountain area and the eastern slope of the Central Mountain Range. Five out of top ten maximum cumulative rainfalls of individual typhoon occurred at these regions. Among these top ten rainfalls, four occurred during typhoon Nari (2001). When considering the occurrence of the intense hourly rainfall (eg.≧50 mm), the distribution pattern of higher percentage appeared to be more random. However, the effect of topography was still very important in producing the intense hourly rainfall.

3. THE RAINFALL CLIMATOLOGICAL MODEL

The basic consideration in developing the climatology model was that the terrain slope lifting of the typhoon circulation played one major role in determining the rainfall amount besides the rainfall variations with radius. The model contained a set of rainfall climatology maps, each for one rainfall station. To construct the rainfall climatology map for a rainfall station, all the hourly rainfall data at that station when typhoon centers were within one 0.5° latitude Ｘ 0.5°-longitude grid box were averaged to represent the climatology value at that grid box. Similar analysis with 2°Ｘ2° grid box had been done by Chang et al. (1993) for 22 surface stations. We then applied a interpolation scheme to fill in the blank grid box and to increase the grid resolution from 0.5°x0.5° to 0.1°x0.1° (around 11 km).

After the rainfall climatology map for a station was developed, the hourly rainfall amount at that station could be estimated for a given typhoon center. During the typhoon period, the hourly rainfall at the station can be computed for every hourly center position along the forecasted typhoon track. The cumulative rainfall at each station especially where valuable to debris flow, during the whole typhoon period can then be computed. The distribution of cumulative rainfall around the whole island also can be produced from 371 rainfall data. Besides the 371 rainfall stations, the rainfall climatology maps for 32 river basins were also

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developed. For simplicity, we took the averaged rainfall of all stations within a river basin to represent the rainfall of that river basin.

Since the rainfall climatology could represent only the average condition during the time period of available data, it was highly desirable to understand how the climatology could explain the variations in individual cases. Results showed that the model tended to underestimate the larger rainfall and overestimate the light rainfall (or no rain). However, the bias, defined as the ratio of the total model estimated rainfall to the total observed rainfall, was 1.03 for two major river basins (DSH and KPS) and the R^2 values reached 0.70 and 0.81, respectively. These results indicated that the climatology model could give reasonable estimate of cumulative rainfall for most typhoons if an accurate typhoon track forecast was provided. However, the R^2 values decreased from 0.70 and 0.81 to 0.69 and 0.73 if individual stations were considered. The decreases in R^2 values were even more pronounced (from 0.70 and 0.81 to 0.41 and 0.51) if 3-hourly time period (instead of the whole typhoon period) was considered. The decrease in R^2 value was evident if shorter time period was considered due to the transient convective features embedded in a typhoon system.

From the hazard mitigation point of view, the early warning of torrential rain, especially at areas valuable to inundation or debris flow is highly desirable. To evaluate the capability of climatology model in estimating the torrential rain during typhoon period, the threat score (TS) for the model to give correct estimate of the cumulative rainfall exceeding a certain threshold value was computed. The threat score was defined as TS = C / (A+B+C), where A (B) was the number of cases when the observed (model estimated) rainfall amount exceeding the assigned threshold (TH), and C, the number of cases when both the observed and the estimated rainfall amounts exceeding the assigned threshold. Results showed that the threat score generally decreased with increasing threshold value (0.66 and 0.90 for TH = 75 mm, 0.67 and 0.45 for TH = 200 mm). Results also showed that the pre-figurance (defined as C/A) was often greater than the post-agreement (defined as C/B) for TH of 75 mm and 130 mm indicating that the model tended to overestimate for light to moderate torrential rain. However, the post-agreement was generally greater than the pre-figurance for TH of 200 mm (0.86 and 0.83 vs. 0.75 and 0.50). The very high values of the post-agreement (ranging from 0.83 to 1.0) could assure that the intense torrential rain (≧ 200 mm) event would occur if the model indicated that such condition would occur.

4. DISCUSSIONS AND CONCLUSIONS

To evaluate how the model performed for the independent cases, Typhoons Rammasun, Nakri and Sinlaku affecting Taiwan in 2002 were considered. Results showed that the model tended to underestimate rainfall for Rammasun and to overestimate rainfall for Nakri. For Sinlaku, the model estimated cumulative rainfall (100 mm) for DSH was about the same as the observation (103 mm). However, the difference between observation and model estimate might be large for hourly rainfall, due to the effects of rainbands and convective cells embedded in typhoon. For Rammasun, the observed cumulative rainfall at DSH was 122 mm while the model estimate was only 28 mm. This was due to that the outer rainbands associated with Rammasun were relatively active. Therefore, the rain- fall at DSH was still significant when the typhoon center was about 400 km away, leading to the underestimate of the climatology model. For Nakri, the model estimated cumulative rainfall at DSH was still quite reasonable for the first 24 hours, or 85 mm (model estimate) vs. 76 mm (observed). The difference between model estimate and observation increased at later time period when Nakri made landfall on Taiwan and weakened.

In summary, though it is more desirable to forecast typhoon rainfall based on the numerical model outputs, the climatology model that we developed can provide reasonable cumulative rainfall estimate for each river basin and around the whole island. However, It had to be noted that the climatology model could give only the average condition, thus any deviations from the average condition inherited in the individual case would appear as error when applying the climatology model during real-time operation. Fortunately, the strong dependence of typhoon rainfall on radius and the strong topographical lifting effect made the current climatology model a useful tool in estimating the cumulative rainfall during typhoon period in Taiwan.

References:

Chang, C. P., Yeh, T. C., and Chen J. M., 1993: Effects of terrain on the surface structure of typhoons over Taiwan. *Mon. Wea. Rev.*, **121,** 734-752.

Frank, W. M., 1977: The structure and energetics of the tropical cyclone. I. Storm structure. *Mon. Wea. Rev.*, **105**, 1119-1150.