A Study on Accuracy of Tropical Cyclone Position Forecast

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Abstract

In this study we investigated the relation between the distance error of tropical cyclone (TC) forecast and the probability of correctly forecast events ("hits") on a certain spatial region, which provides more intuitive value of TC forecasting verification for decision makers. The 2 x 2 contingency table associated with dichotomous forecast is adapted for evaluating the probabilities of hits (S), thereat score (Ts), false alarm rate (F) etc. by the case number of TC positions forecast and observation. The data of TC track forecast 2002 to 2005 is from Central Weather Bureau (CWB).

The result shows that S was decreased with forecast time and increased with the domain size. The Ts had been reasonably estimated by the mean distance error and the radius of domain. The correlation coefficient is 0.98 for the comparison the estimate Ts and the Ts, calculated from the elements of 2 x 2 contingency table. By this relationship, the changes of S are proportion to mean distance error and the change rate of S (K*) , which is a function of three parameters: bias (B), mean distance error (E) and the radius of domain (R). On the conditions of small domain and the less of distance error, the S is more sensitive on the change of mean distance error.

Introduction

With the strong wind and heavy rainfall, tropical cyclones often caused the large amount of life loss and property damage. Resident cares about the local situation about that whether the tropical cyclone will invade their country and how should they take preparation, while typhoon occurred on the ocean. The weather forecasters will pay more attention on the forecast issue. Most people judged the forecast performance by the correct or false alarm from forecasters, but the forecaster showed the verification results with the distance error (Lee 2006, Lu 2006). Obviously, the knowing of the accuracy of tropical cyclone forecast is quit different between public and forecaster.

The distance error is a continuous value which can represent as mean absolute error, bias, skill score etc. for measuring the forecast performance. As concerning on the event for a certain spatial domain, TC is a rare event (Doswell et al. 1990) and can be evaluated by the probability of correctly forecast from 2 x 2 contingency table associated with dichotomous forecast.

Data and Method

In this study, we assumed that each TC forecast, update in every 6 hours, is an independent event and can be verified by the rate of hitting the target domain as the domain is defined. The number of hits (a), false alarms (b), misses (c) and correctly forecasted non-events (d) are the elements in the 2 x 2 contingency table associated with dichotomous forecast (table 1). The domains with the radii of 200, 300, 400, 500 km centered at 23.5°N and121°E are the targets for practical application in this study. The positions of TC and the number within each circle events are depicted as Fig. 1.

To relay the distance error and the probability of hits (S), we assumed Ts is a function of mean distance error (E) and the radius of spatial domain (R). For Ts is defined as the ratio of the number of observation to the number of the union of forecast and observation, the ratio can be seen as the area of target to the area of target extend with the mean distance error. Then the Ts can be estimated by T*, where

$$T^{*} = R^{2} / (R+E)^{2} \qquad (1)$$

Fig. 2 shows that T* can well estimate Ts around Taiwan in 24-/48-/72-h. and the correlation coefficient of T* and Ts is 0.98.

While $T^{*} \approx Ts$ and the bias (B) is nearly constant, the probability of hit and the change rate can be written as

$$S^{*} = \frac{1+B}{B} \times \frac{R^{2}}{R^{2} + (R+E)^{2}} \qquad (2)$$

Results and Discussion

The quantitative relation between hit score (probability of correctly forecast) and the distance error was linked successful by the well estimation of Ts. This result can offer more intuitive value to match the public concern from forecasts issue.

Around Taiwan, the accuracy in dichotomous forecast of CWB tropical cyclone track forecast is summary as in table 1. The accuracy is decreased with forecast time and increased with the domain size. For the domain with radius of 400 km around Taiwan, hit score were 0.72/0.65/0.52 for 24-/48-/72-h forecasts while the distance errors were 135/190/341 km. For the radius of domain is 200 km, the hit scores were decrease as 0.47/0.29/0.25.

By the assumption about the thereat score as equation (1), hit score can be well estimate by the equation (2) as a function of mean distance error. Figure 3 shows a plot of S versus distance error for four different domains. The values of S* are higher for a larger domain of target when compared to small area, regardless of distance error. And S is large at distance error is small. The curves in Fig. 3 show the greatest slope for the relatively low distance errors. It implies the number of hits is more sensitive on the short term forecast (error is small) than the same increment change of E in the long term forecast (error is large).

The hit score of TC position forecast is a relative and intuitive number and can be estimated by distance error in a simple way. Basically, this approach is valuable, but the environment of TC forecasting is not as simple as the assumption in this study. More study on the different condition is necessary as well in the future.

Reference

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Lee, T.C. 2006: Advances and Requirements for Operational Tropical Cyclone Track Prediction. Sixth WMO International Workshop on Tropical Cyclones (IWTC-VI), San Jose, Costa Rica, 21-30 November 2006, 376-389.

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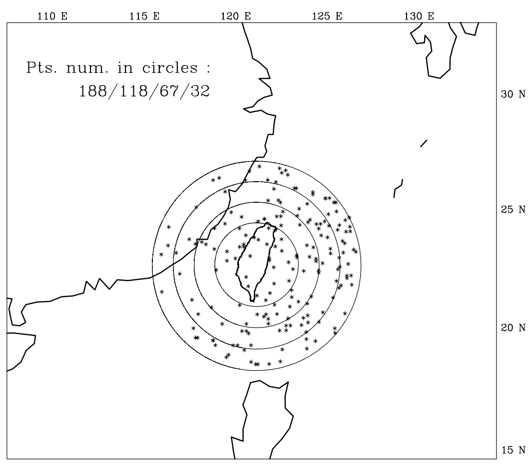
Table 1. Probabilities of hit (S), mean distance error (E), estimated Probabilities of hit (S*) of named tropical cyclone (2002~2005) on the radii of 200 km and 400 km circled the point of 23.5°N and 121°E, and the four elements *(a-d)* of standard 2 x 2 contingency table are also indicated for each forecast group.

		S	E (km)	S*	*a*	*b*	*c*	*d*
200 km	24-h	0.47	161	0.48	16	18	16	2247
	48-h	0.29	227	0.37	10	24	22	2241
	72-h	0.25	351	0.26	7	21	25	2244
400 km	24-h	0.72	135	0.71	88	34	30	2145
	48-h	0.65	190	0.64	62	34	56	2145
	72-h	0.52	341	0.49	53	49	65	2130

Note: S=a/(a+b)



0-h 72-h

FIG..1. The distribution of tropical cyclone in every 6 hours during 2002~2005 and the cases number in the radii of 200, 300, 400 and 500km circled the point of 23.5°N、121°E. The sign ”*” in left panel represent the locations of observation within these circles. The sign ”+” in right panel are the 72-h forecast positions within the circles. The sign ”x” are the points which 72-h forecast for ”* ” as shown for left panel) and located outside the radius of 500km.

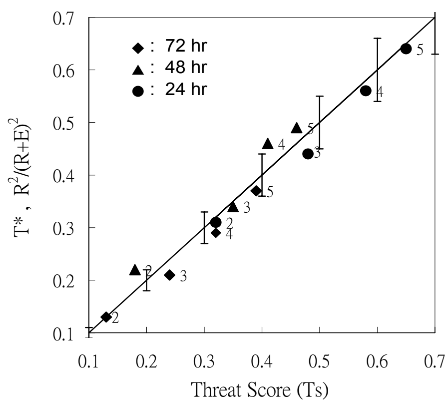


FIG. 2. Plot of the estimate threat score and of the threat score in 24-/48-/72-h for the domains with radii of 200, 300, 400 and 500 km circled the point of 23.5°N and 121°E. The numbers on the right side of symbols are the radii in the unit of hector-kilometer.

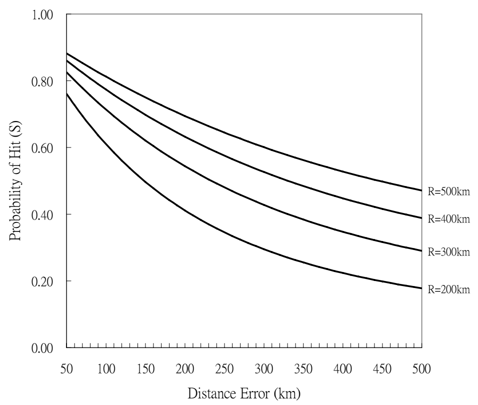


FIG. 3. Plot of probability of hits (S*) as the function of mean distance error for the domains with radii of 200, 300, 400 and 500 km circled the point of 23.5°N and 121°E.