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AN OBJECTIVE PREDICTION SCHEME FOR TROPICAL CYCLONES MAKING LANDFALLS IN EASTERN CHINA

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ABSTRACT: The landfall of tropical cyclones in the eastern part of China falls in the category of small probability events. Constructing a step function with intervals adequately divided can help reflect the non-linear distribution of conditional probability for a landfall event. For the prediction of landfall event probability, factors applying the step function in transformation are superior to the standardized factors that are linearly related. The prediction scheme discussed in the work uses transformation factors of step function to formulate prediction models for tropical cyclones making landfalls in eastern China, through screening with non-linear correlative ratios and REEP analysis. Classified models for statistic-synoptics, statistic-climatology and statistic-dynamics have been constructed using initial field data and numerical prediction output. Forecasting skills have been improved due to ensemble of predictions using these classified models. As shown in forecasting evaluations and experiments, the scheme is capable of predicting tropical cyclones that make landfalls in eastern China.

Key words: tropical cyclone; landfall; forecast

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1 INTRODUCTION

In the present research on the landfall of tropical cyclones, the forecast of landfall location is essentially important for periods leading up to it. In fact, it is always an issue people are concerned with after the genesis of the storm.

Generally, within 24 ~ 36 hours before the landfall, a tropical cyclone tends to be so clear that the point at which the motion forecast intersects with the coastal line of the continent is usually where the storm moves over land. It is during the pre-landfall 48 hours or even 72 ~ 120 hours that the determination of landfall point becomes much more difficult, due to the interactions between the storm and the ambient field over the course of movement, which is aggregated by changes of their own. The forecast of motion is itself losing much of the reliability when the validity is over 48 hours, and it is much more difficult when such forecast is depended on to judge where, or even if, the landfall would occur.

In the current paper, a scheme for direct, objective forecasting of tropical cyclone landfall is proposed, without reliance on the motion forecast. It is designed to forecast the landfall over a long valid duration between 72 and 120 hours over the coast of eastern China. A quantitative forecast is in effect one dealing with the probability of landfall.

2 CLIMATOLOGICAL PROBABILITY FOR TROPICAL CYCLONE MAKING LANDFALL IN EASTERN CHINA

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When we say a tropical cyclone has made landfall in eastern China, it means that it moves inland from the East China Sea on the coast of mainland China between 23.5°N and 32.5°N. Waters within 10°N ~ 30°N and 120°E ~ 150°E are the areas of forecast.

For the period from 1949 to 1998, there were a total of 973 tropical cyclones acquiring the intensity of tropical storm, severe tropical storm or typhoon in the forecast area as defined above. Ninety-eight of them made landfall in the eastern part of China, with a climatological probability of 10%. Tab.1 presents a list of various landfalls in every month of the year. The landfall occurs at a probability of 0 in January ~ April and November ~ December and it is less than 3% even in May ~ June. The months July through September becomes the season that has the most genesis and landfall of tropical cyclones, in which the number of both tropical cyclone and landfall are having the most in August and the probability of landfall is the highest in July. During the three months, there were 542 tropical cyclones and 94 landfalls inside the area of forecast, with a climatological probability of 17.3% for landfall. It is then known that landfall in eastern China is still an event of small probability even in the typhoon season in which tropical cyclones generate frequently and stay active.

Tab.1 Climatological probabilities of tropical cyclone landfalls in the eastern part of China

Month	1	2	3	4	5	6	7	8	9	10	11	12	年
Total number of tropical cyclone	18	5	10	23	34	70	162	209	171	137	82	52	973
Landfall number	0	0	0	0	1	2	35	40	19	1	0	0	98
Landfall probability ／%	0	0	0	0	3	3	22	19	11	1	0	0	10

3 TRANSFORMATION OF PREDICTORS

3.1 *Step function and transformation of predictors*

For a tropical cyclone moving into the area of forecast, the landfall probability $p(Y=1)=1$ if it is expected to move over land in eastern China; $p(Y=1)=0$ if it is not going to do so; the landfall probability of forecast $\hat{p}(Y=1)\in[0,1]$.

As the object of forecast is the probability form of 0 and 1 in the forecast, it is necessary to introduce predictors with various dimensions and associated values for transformation so as to adopt to the object to be forecast. In most of the present forecasts of probability, the transformation of predictors are performed by standardizing relevant sequence $\{X_j\}$:

$$\hat{x}_j = (x_j - \bar{x})/s_x$$

$$\bar{x} = \frac{1}{N}\sum_{j=1}^{N} x_j \qquad (j = 1,2,3,\cdots,N)$$

$$s_x = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}(x-\bar{x})^2}$$

in which j is the sequence of sample and N the total number of sample.

Then, the standardized predictor sequence and predictants are statistically studied for linear correlation and a model of probability prediction is constructed applying the REEP (Regression Estimation of Event Probabilities) analysis.

The fact is, however, that a majority of the predictors x are in non-linear relation with the occurrence probability of landfall events $P(Y=1|X=x)$. It is assumed that the probability $P(1|x)$ for a landfall event Y to take place is a simple quasi-normal distribution function that varies with the distribution of the predictors (Fig.1). If the linear correlation is based to determine a straight line $L=ax+b$ for the fitting of $P(1|x)$, it is apparent that an approximate fitting of $P(1|x)$ can be derived for L over the interval $[x_1, x_2]$ while L and $P(1|x)$ are deviating far from each other over extensive intervals for $x \langle x_1$ or $x \rangle x_2$. In contrast, the $P(1|x)$ distribution of most of the predictors is more complicated than that of the quasi-normal mode. It is therefore difficult for the linearly correlated L to fit the non-linear distribution of $P(1|x)$.

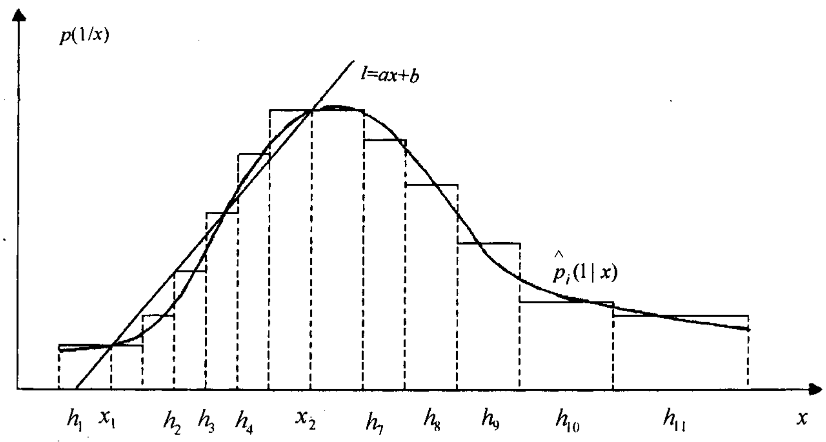

Fig.1 Distribution of $P(1|x)$, the occurrence probability for the landfall of a tropical cyclone, with x and the step function $\hat{p}_i(1|x)$.

Divide the range $[x_{\min}, x_{\max}]$ of the predictor sequence $\{X_j\}$ into H intervals of h_i and the mean probability for a landfall event to occur is that:

$$\hat{p}_i(1|x)=\frac{M_i}{N_i} \qquad \begin{pmatrix} i=1,2,\cdots,H \\ x\in h_i \end{pmatrix} \tag{1}$$

Specifically, N_i is the total number of sample within the interval of h_i and M_i is the number of sample for the occurrence of landfall events in the particular interval.

For $\hat{p}_i(1|x)$ in all of the intervals, the predictor sequence has constituted a first-order step function.

When all of the values of the predictor sequence $\{X_j\}$ inside different intervals of h_i are replaced by the step function values $\hat{p}_i(1 \mid x)$ within a relevant interval, the predictors have been transformed, in which the sequence $\{X_j\}$ is transformed into one in the distribution of $\hat{p}_i(1 \mid x)$:

$$\{x_j\} \Rightarrow \hat{p}_{ij}(1 \mid x) \qquad \begin{pmatrix} i = 1,2,\cdots,H \\ j = 1,2,\cdots,N \\ x \in h_i \end{pmatrix}$$

It can be seen from Fig.1 that $\hat{p}_i(1 \mid x)$ is generally reflecting the characteristics of $P(1|x)$ distributing with *x*, though being incapable of fully fitting it. It is obvious that $\hat{p}_{ij}(1 \mid x)$, with transformation, fits $P(1|x)$ better than *L*, especially within the intervals of $[x_{\min}, x_1]$ and $[x_2, x_{\max}]$.

3.2 *Ratio of correlation*

In the statistical study of the correlation between the non-linear predictor $\hat{p}_i(1 \mid x)$ and landfall event *Y*, it is adequate to use the ratio of correlation h_{yx}[3]:

$$h_{yx} = \sqrt{1 - \frac{1}{s_y^2} E[(Y - E[Y \mid X])^2]} \tag{2}$$

where *E* [ ] is the mathematical expectation or mean value. The minimum mean square deviation of the auto-regressive curve of *Y*, $y_x = E[Y|X]$, can be represented by its standard deviation, $s_y = E[(Y - E[Y]^2], E[(Y - E[Y|x]^2]$.

If *Y* takes 0 and 1 only, $\hat{p}_c$ is the estimated value of climatological probability of the landfall event, *Y*=1, $\hat{p}_i(1 \mid x)$ is the step function, then Eq.(2) can be reduced to:

$$h_{yx} = \sqrt{\frac{\sum_{i=1}^{H} \hat{w}_i (\hat{p}_i(1 \mid x) - \hat{p}_c)^2}{\hat{p}_c(1 - \hat{p}_c)}} \qquad \begin{pmatrix} i = 1,2,\cdots,H \\ x \in h_i \end{pmatrix} \tag{3}$$

where $\hat{w}_i = N_i / N,\ \hat{p}_c = M_i \big/ N, M = \sum_{i=1}^{H} M_i$.

M is the total occurrence of landfall events of tropical cyclones among *N* samples, with M_i, N_i and $\hat{p}_i(1 \mid x)$ carrying the same definition as that in the expressions above.

With the transformation of Eq.(1) and estimation of Eq.(3), the non-linear ratio of correlation between the predictor $\{x_j\}$ and the landfall event can be assessed.

3.3 *Effects of transformation on the predictability of predictors*

To assess the effects of transformation on the predictability of the predictors, the current paper has calculated the standardized sequence, $\left\{\hat{x}_j\right\}$, and step-function-transformed sequence, $\hat{p}_{ij}(1|x)$, of the 500-hPa geopotential field *H*, surface pressure field *P*, 200-hPa wind field V_{200}, 850-hPa wind field V_{850}, physical quantity fields (see the following text) and the parameter of tropical cyclone, as well as the highest linear correlation coefficient $r_{\max}$, highest non-linear ratio of correlation $h_{\max}$ and the number of highest correlation predictors *n* for $|r| \ge 0.4$ and $h \ge 0.40$ (Tab.2).

Tab.2 Correlation between the landfall event of tropical cyclones and the predictors before and after the transformation.

	Parameter of TC	H	P	V_{200}	V_{850}	Physical quantities
$r_{\max}/\hat{x}_j$	0.45	0.43	-0.38	0.41	-0.36	0.42
$h_{\max}/\hat{p}_{ij}(1\|x)$	0.67	0.58	0.52	0.54	0.58	0.59
$n/\|r\| \ge 0.40$	4	15	0	2	0	6
$n/h \ge 0.40$	12	116	48	55	44	63

As the predictor responds to the landfall event in some rather than all intervals, whether the characteristic can be distinguished or not is just where the difference lies between the two transformations. For the linear correlation between the standardized predictor and the landfall event, differences due to intervals are not considered. When the mean correlation over the entire interval is statistically studied, anti-correlation will be counteracted each other between the intervals, causing low overall correlation. After the transformation of predictors using the step function, the ratio of correlation is used to calculate the correlation between the predictor and the landfall event for individual intervals. Although high correlation is found between the predictor and the presence of landfall events over some intervals and between the predictor and the absence of landfall events over others, we can still learn from Eq.(3) that the variance is always positive for both the step function and climatological probability and there is no counteracting each other. Consequently, the overall ratio of correlation increases and it is higher than the linear correlation. It shows that the transformation of predictors with the step function indeed reveals the internal linkage between the predictor and the non-linear distribution of probability for the landfall event of tropical cyclones, with the predictability much higher than the original sequence of predictors.

For the prediction model constructed with predictors that have been transformed, both the fitting rate and forecast skills have been much improved. Refer to Tab.3 and Tab.4.

3.4 *Some issues arising from the transformation of predictors*

Adequate division should be done to the interval h_i before the predictors are transformed. It is clearly seen that h_i should be sufficiently small to avoid excessive smoothing of $\hat{p}_i(1|x)$

within the interval and to increase accuracy; meanwhile it should not be too fine so that there is enough number of sample for each of the intervals and $\hat{p}_i(1|x)$ is representative and stable, making its value free from substantial fluctuation due to abnormal influence from isolated samples.

As $p(1|x)$ is non-linearly distributed, the h_i inside the interval must be so divided as to adapt to it. It is therefore unevenly distributed to secure the accuracy and reliability of $\hat{p}_i(1|x)$.

The step function $\hat{p}_i(1|x)$ is the mean probability for a landfall event to take place within the interval h_i, whose value is constant therein. It is against the fact and easily causes errors in transformation. When *x* enters an interval from the one adjacent to it, the value of $\hat{p}_i(1|x)$ will change in jumps, showing discontinuity of the function at the point of break. Any minute change of *x* at this point may result in drastic fluctuation of $\hat{p}_i(1|x)$ and errors in transformation. Parzen, wherefore, proposes a deviation-free estimation model for the density of probability[4]. Over the interval h_i for *x*, the hyperbolic function is used to replace the step function using the method of histogram so that the fitted probability curve is continuous and free of breaking points over any successive intervals, thus reducing the fitting error. The estimation model is only an ideal situation, which has errors even larger than the step function does when samples are few within the interval. In addition, it requires enormous amount of computation. It is then easier and more convenient to use the step function if the sample is less than 1000 in number.

In practice, the value of predictor *x* may be outside the historical range of $[x_{\min}, x_{\max}]$ such that errors are still possible in the transformation, which is conducted with $\hat{p}_i(1|x)$ that is the closest to the interval for *x*.

4 PREDICTORS

Three predictors, climatological persistence, initial environmental field and numerical prediction product, are selected after experimental study.

4.1 *Climatological persistence*

The predictor contains parameters of the initial position, direction and speed, intensity and near-center wind, of the tropical cyclone, and their variables in the coming 6, 12 and 24 hours, the β effect and mean climatological turning point, etc.

4.2 *Initial environment*

4.2.1 Geopotential field

The predictor involves itself with geopotential field at the layers of 850 hPa, 700 hPa, 500 hPa and 200 hPa and their 24-h variables.

4.2.2 Temperature field

The predictor is made up of temperature field at the layers of 850 hPa, 700 hPa, 500 hPa and

200 hPa and their 24-h variables.

4.2.3 Surface field

The predictor concerns with sea level pressure field, surface temperature field and their 24-h variables.

4.2.4 Flow field

The predictor considers longitudinal / latitudinal wind speed at the layers of 850 hPa, 500 hPa and 200 hPa and their 24-h variables.

4.2.5 Physical quantity field

(1) Environmental flow

As shown in many studies, the environmental wind field, which is 5 ~ 7 latitudes from the eye, is closely linked with the air flow in the cloud region surrounding the tropical cyclone and the importance of mid-tropospheric layer in steering the storm is emphasized[6, 7]. In our work, the predictors of the longitudinal and latitudinal speed of the environmental geostrophic flows of u_g and v_g, flow direction dg, omnidirectional wind speed $\left|\vec{v}\right|$ and environmental kinetic energy K_k at points at varying distance from the center of the tropical cyclone:

$$v_g = \frac{g}{f}\left(\sum H_w - \sum H_E\right)/16D$$

$$u_g = \frac{g}{f}\left(\sum H_s - \sum H_N\right)/12D$$

$$dg = \mathrm{arctg}\left(\frac{v_g}{u_g}\right)$$

$$|\vec{v}| = \sqrt{v_g^2 + u_g^2}$$

$$E_K = \frac{g^2}{4f^2D^2}\left[(H_w - H_e)^2 + (H_s + H_n)^2\right]$$

where g is the gravitational acceleration, f the Coriolis parameter, grid interval D=556 km, $\sum H_w$ and $\sum H_E$ are the sum of geopotential heights for four gridpoints in 5°×5° meshes respectively to the east and west of the center of a tropical cyclone, $\sum H_s$ and $\sum H_N$ are the sum of heights for three gridpoints respectively to the south and north of the meshes, H_w, H_e, H_s, H_n are the heights at gridpoints five latitudes to the west, east, south and north of the point that is five latitudes from the tropical cyclone.

(2) Natural empirical orthogonal function EOF for the geopotential field

In the domain ranging within 20°N ~ 45°N, 100°E ~ 140°E, a total of 54 (6 × 9) gridpoints in 5° × 5° are taken in terms of 500-hPa geopotential height and are then put through the EOF[8], i.e. the geopotential height field H_{ij} is decomposed into a characteristic vector function that is only related with space, X_{pj}, and a time coefficient that is only related with time, T_{ip}:

$$H_{ij} = \sum_{p=1}^{n} T_{ip} X_{pj} \qquad \begin{pmatrix} i = 1,2,\cdots,n \\ j = 1,2,\cdots,54 \\ p = 1,2,\cdots,54 \end{pmatrix}$$

Decided by the characteristics inherent in all the sample sequences themselves in a given field, the characteristic vector X_{pj} reflects the characteristics and nature of the field. T_{ip} is the time weight coefficient of the characteristic function in question. The EOF geopotential field has so fast a converging field that when p=1 ~ 10 is taken, the sum of the first 10 terms is as large as 93% of the total variance. T_{ip} is made the predictor in this work.

(3) Typical field with Chebyshev orthogonal polynomial expansion

With the same domain and mesh of grids as in (2), Chebyshev orthogonal polynomial, $y_k(j)\ y_s(l)$, is used for the geopotential field $H(j, l)$ at 500 hPa[9], and the truncation number of order k=5, s=8 is taken during the expansion:

$$H(j,l) = \sum_{K=0}^{K} \sum_{S=0}^{S} A_{KS} y_K(j) y_S(l)$$

$$A_{KS} = \frac{\sum_{j=j_0}^{j_N} \sum_{l=l_0}^{l_M} H(j,l) y_K(j) y_S(l)}{\sum_{j=j_1}^{j_N} y_K^2(j) \sum_{l=l_1}^{l_m} y_S^2(l)}$$

The numerical value of the function $y_k(j) y_s(l)$ is a typical field that is independent of time variation and has some synoptic significance, especially when it is of lower order, which represents quite definitely the characteristics of atmospheric circulation. The expansion is rapid in convergence, with the approximate error amounting for only one in a thousand in the total variance when the expansion is conducted with the number of order above. The Chebyshev coefficient A_{ks} is just the time weight coefficient in the typical field, which is used as a predictor.

(4) Characteristic quantity of circulation

Some large-scale synoptic systems are closely related with the motion of the tropical cyclone. Examples are seen in the position and intensity of the westerly trough and ridge, the line of the ridge, westernmost tip, northern boundary, area and index of the subtropical high in western Pacific. These characteristic quantities are objectively constructed using the 500-hPa-geopotential field before being taken as predictors.

(5) Zonal spectrum

With the method of harmonic spectral analysis, the 500-hPa-geopotential field is expanded in Fourier series along the zonal circle:

$$H(j, l) = a_0(j) + \sum_{k=1}^{\infty} [a_k(j) \cos kl + b_k(j) \sin kl]$$

$$a_0(j) = \frac{1}{2p} \int_0^{2p} H(j, l)\,\mathrm{d}\,l$$

$$a_k(j) = \frac{1}{p} \int_0^{2p} H(j, l) \cos kl\,\mathrm{d}\,l$$

$$b_k(j) = \frac{1}{p} \int_0^{2p} H(j, l) \sin kl\,\mathrm{d}\,l$$

The expansion is conducted along the zonal circles between 20°N and 80°N by taking on each of them 72 gridpoint geopotential heights and calculating such parameter spectra of the harmonic wave as the Fourier coefficients $a_k(j)$ and $b_k(j)$ corresponding to k=1 ~ 10, the amplitude $c_k(j)$, the phase spectrum $q_k(j)$, in addition to the spectra of energy $E_k(j)$, angular momentum transfer $J_k(j)$, conversion rate between perturbation and mean kinetics $E^{'}\bar{E}_k(j)$, to be used as predictors. Corresponding to characteristics of general circulation, the predictors of wave spectra have temporal and spatial scales identical to those in medium-term weather events, thus being significant to medium-term forecast of tropical cyclone landfalls.

4.3 *Numerical prediction output and the derived predictors*

Various predictors as described in 4.2 are constructed using the 24 ~ 120 h forecast output in numerical weather prediction.

4.4 *Explanations*

(1) The structure of typhoon itself is also playing major effect on its landfall. It is difficult to be made a predictor because quantitative data are not ready to obtain in forecasting.

(2) Most of the predictors of physical quantity are constructed with the 500-hPa-geopotential field. Some of them may be dependent but will be eliminated in the REEP analysis and moved out of the predictive model if they are linearly related.

5 FORECAST SCHEME

In view of the fact that there is limited forecast information contained in a predictive model, the forecast scheme has to be designed so that a number of classified models are constructed before integrating the forecast results from the models.

5.1 *Transformation and preliminary selection of predictors*

First, the step function $\hat{p}_i(1|x)$ is used to perform non-linear transformation of all candidate predictors. Then, correlation ratio is studied to include those at confidence level $a = 0.05$.

5.2 *Construction of classified models*

The preliminary predictors for climatological persistence is worked on with REEP analysis to construct a statistic-climatological forecast model SC;

The preliminary predictors for initial environmental field is worked on with REEP analysis to construct a statistic-synoptic forecast model SS;

The preliminary predictors for environmental field in simultaneous time is worked on with the perfect prediction (PP) to construct a statistic-dynamic forecast model SD (predictors from numerical prediction output replace simultaneous ones when the method is applied).

$$\begin{array}{ll} \hat{p}_r(Y=1|X_{r1},X_{r2},\cdots,X_{rM})=b_{r,0}+\sum_{k=1}^{M}b_{r,k}X_{r,k} & \left(\begin{array}{l} r=sc,ss,sd \\ k=1,2,\cdots,M \\ i=1,2,\cdots,H \\ x\in h_i \end{array}\right) \\ X_{r,k}=\hat{p}_{ri,k}(1|x) & \end{array}$$

5.3 *Ensemble of prediction*

The forecasts by the three classified predictive models, SC, SS and SD, are used to ensemble the prediction with analysis of total regression:

$$\hat{p}_{CF}(y=1\,|\,\hat{p}_r)=B_0+\sum_{r=1}^{3}B_r\,\hat{p}_r \qquad (r=1，2，3)$$

Tab.3 presents the regression parameters of the classified models and prediction ensemble for the landfall in eastern China. Therein, *F* is the verified value of *F*, *L* is the number of predictors, *R* is the coefficient of complex coefficient, *S* is the residual standard deviation. $\hat{p}_{SF}$ is the predictive model constructed with the predictor of standard deviation.

Tab.3 shows that $\hat{p}_{SF}$ has the worse effect when it is constructed with the standardized predictors. It has been much improved in the three classified models SC, SS and SD, which are constructed using the predictors transformed with the step function. SD produces the best effect as it uses the output of numerical prediction. The ensemble of prediction $\hat{p}_{CF}$ is superior over the classified models in terms of forecasting effect. It is due to the fact that the former has integrated more information for forecast and smoothed errors produced in the classified models, both positive and negative and with varying trends.

Tab.3 Regressive parameters in the prediction models

	$\hat{p}_{SF}$	$\hat{p}_{Sc}$	$\hat{p}_{SS}$	$\hat{p}_{SD}$	$\hat{p}_{CF}$
F	1.8	4.5	5.0	8.0	23.0
L	15	13	13	12	3
R	0.65	0.85	0.88	0.92	0.96
S	0.46	0.24	0.19	0.15	0.11

6 MODEL VERIFICATION AND FORECAST EXPERIMENTS

The prediction model was verified using 115 samples (not included in model construction) of 31 tropical cyclones from 1993 to 1997 and fourteen tropical cyclones in 1998 ~ 1999 were experimented in real-time forecasts (Tab.4). In the assessment of forecast results, the Brier score (*B*) and B_s are used:

$$B=\frac{1}{N}\sum_{i=1}^{N}(F_i-O_i)^2$$

$$B_s=(1-B/B_C)\times 100\%$$

In the expressions above, F_i is the landfall probability, O_i is the landfall probability observed: $O_i(Y=1)=1$, $O_i(Y=0)=0$, *N* is the number of forecast. B_c is *B* score for the climatological probability of landfall in the prediction.

The value of B lies within [0, 1], which is better if it is smaller. When B=0, it means that all of N forecasts are right; when B=1, it equals that all of N forecasts are wrong. B_s is the relative error between the model forecast score B and climatological probability score B_c. When the results of the model forecast are better than those of the climatological probability ($B < B_c$), $B_s > 0$, suggesting that the model is of predicting skill; when the model forecast has a poor score than the climatological probability ($B > B_c$), $B_s < 0$, suggesting that the model is of negative forecast skill.

Tab.4 Assessment of forecast results of the forecasting schemes

	B score		B_s score	
	standardization	Predictor transformation	standardization	Predictor transformation
Model verification	0.33	0.19	13	39
Forecast experiment	0.35	0.17	-5	31

From the results of model verification and forecast experiment, we know that the model forecasts, with the predictors transformed with the step function, yield results that are higher by 0.14 ~ 0.18 and 26% ~ 36% than the control groups using standardized predictors, concerning the B and B_s scores.

Using the predictive models, the Typhoon Todd (No.9806), which took a reverse parabolic motion and made landfall on Zhoushan, Zhejiang province, was forecast for 6 times, with the mean probability of landfall, B and B_s respectively at 80%, 0.06 and 43%; the Typhoon Dan (No.9914), which traveled westward then northward and made landfall on Longhai, Fujian province, was forecast for 5 times before the recurvature, with the mean probability of landfall, B and B_s respectively at 77%, 0.08 and 52% (Fig.2).

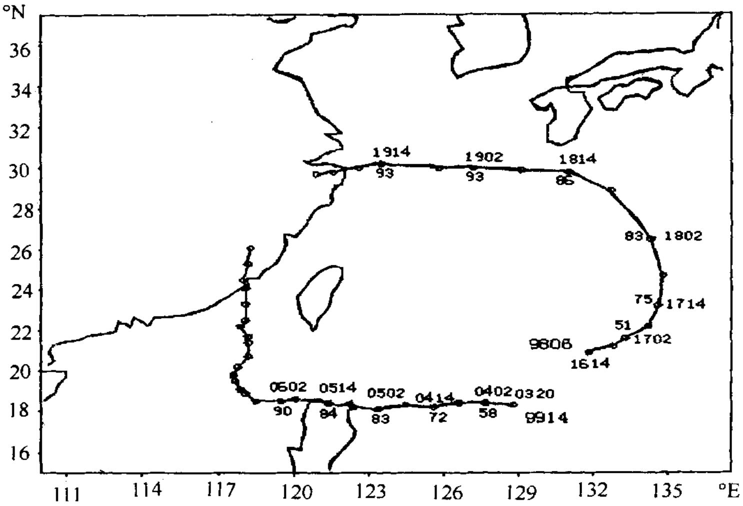

Fig.2 The model forecasts of Typhoons Todd and Dan. The numbers on the left side of the moving direction are landfall probability forecasts (%) and those on the right are the time of the day.

As shown in the model verification and forecast experiment, the current scheme is of forecasting skill for the landfall events of tropical cyclone in eastern China.

7 CONCLUDING REMARKS

a. The landfall of tropical cyclones in eastern China is an event of small probability.

b. The step function, which is established on the basis of interval probability, well reflects the non-linear distribution of conditional probability of landfall events. If transformed with the step function, non-linear predictors are better than correlated predictors in the forecasting capacity. Adequate division of the intervals of step function is a key to conducting better transformation. The use of both the transformed predictors and non-linear ratio of correlation screening / REEP analysis helps build an efficient prediction model for the landfall of tropical cyclones.

c. Selecting and constructing predictors that are definite in physical sense is a prerequisite for improving the capability of prediction models.

d. The statistic-dynamic forecast model, which is constructed using the technique of statistical interpretation of numerical prediction output, is dynamically founded such that it is of high forecasting capacity. Integrating results from the classified models can help increase the forecasting capacity due to inclusion of more forecasting information and smoothing of classified forecasts.

e. As shown in the model verification and forecast experiment, the current scheme is of forecasting skill for the landfall events of tropical cyclone in eastern China.

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