# A STATISTICAL PREDICTING SCHEME OF THE INTENSITY OF THE STH OVER THE WESTERN NORTH PACIFIC

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ABSTRACT

By performing error analysis of the information from the 48-hr forecasting charts of the 500-hPa fields by the B model over eastern Asia in the period of July to September 1982 and expansions of the height fields of westerlies and the subtropical zone by use of the Chebyshev polynomial and EOF, respectively, a scheme is developed for predicting the synchronous STH coefficient (i. e. time coefficient) in terms of the Chebyshev one, thus making possible statistical forecasting of the 500-hPa subtropical field within 48 hr. Tests with independent samples indicate that, to a certain extent, this scheme can be used in operational prediction as a reference.

## I. INTRODUCTION

The subtropical high (STH) over the western North Pacific is an important system affecting the occurrence of precipitation, and drought or flood over a larger part of the mainland of China in the summer half year and the changes in its intensity, configuration and position have substantial influence upon typhoon tracks. In view of this fact, Tao (1962), Zhang (1975), Huang (1963) and others have made intensive studies of the relations of the STH to drought/flood, meiyu (plum rain) and typhoon tracks, respectively, thus providing a better understanding of the activities of the STH together with its influence on various weather processes. However, the numerical forecasting models now in general use are unable to describe the atmospheric processes completely and truly. (Zhu and Cheng, 1981) In our study, when applied to the prediction of the STH at lower latitudes for July—September 1982, these models show, at each gridpoint, considerably greater mean absolute errors than the persistence forecasts. Hence it is necessary to make an analysis of the errors of the outputs from the numerical models of the STH so as to get a simpler and more efficient way to develop a scheme for predicting the STH's intensity, position and configuration as a supplementary means.

## II. ERROR ANALYSIS OF PRODUCTS OF NUMERICAL SITUATION FORECASTING

For practical purposes and an evaluation of the quality of the products an error-analysis has been made of the 48-hr forecasts of the B model during July—September 1982, covering an area of 15°—60°N and 70°—150°E. The chart consisting of forecasting skills helps to illustrate the reliability of the B model used for various gridpoints with the skill of the persistence prediction as a measure of assessment. (Zhu and Yang, 1983) The skills on the map are found out by virtue of

$$\Delta E=\frac{1}{N}\sum_{K=1}^{N}[|\phi_P-\phi_o|_K-|(\phi_o)_{K-1}-(\phi_o)_K|], \tag{1}$$

where $\phi_p$ denotes the height of the 500-hPa surface to be forecasted at a gridpoint; $\phi_o$ the height observed or obtained through objective analysis; $K$ the serial number of the date of a sample; $N$ the number of times that statistical mean is found.

Fig. 1 depicts a distribution of the skills by the B model of forecasting the 500-hPa height field for 48 hr ahead. It is apparent that, for the western North Pacific and the area southwest of the Qinghai-Xizang (Tibetan) Plateau at low latitudes, the skills given by the B model are very low as compared with the persistence prediction, whereas the model has higher ability to foresee the height of the 500-hPa field within westerlies over eastern Asia north of 35°N. Since the two simultaneous circulations interact with each other, an attempt is made to seek for the possibility of applying the 500-hPa height in westerlies by the B model to foreshadowing the synchronous activity of the STH in the western North Pacific and thereupon errors from the local situation prediction are reduced, which is in essence a statistical interpretation of the products of numerical forecasting as well.

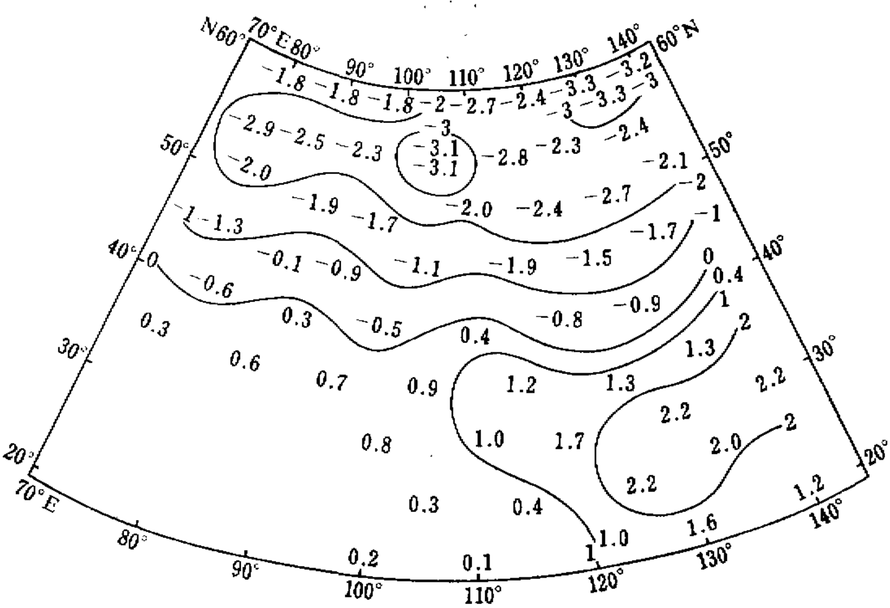


Fig. 1. A distribution of the skills for predicting the 500-hPa height field for 48 hr in advance obtained by the B model in the period of July—September 1982.

## III. EXPANSION OF THE HEIGHT FIELDS BY EOF

To analyse the interrelation between the element fields it is necessary to describe and interpret more objectively the main characteristics of these fields in their spatial and temporal distribution. In the case of irregularly-spaced gridpoints over a finite region, the resolution of the EOF (empirical orthogonal function) (Wang and Li 1974; Paegle and Haslam, 1982) and Chebyshev polynomial (Zhou, 1983) is widely used as an efficient means in the meteorological field study, which can provide clear interpretations of these fields and is marked by quick convergence as well, thus leading to the fact that the real state of affairs can be approached by use of a few terms. Using 297 typhoon samples for July—September, 1958—1979 the authors have expanded, by the Chebyshev polynomial, the 500-hPa height fields over the finite region 40°—60°N and 75°—140°E with 5×7 gridpoints characterizing the main features of westerlies in eastern Asia, and, through EOF, in the given sector 20°—35°N and 120°—145°E (4×6 gridpoints) of the STH over the western North Pacific, and explored the interrelation among the principal items of both.

1. *EOF Expansion of the 500-hPa Height Field in the Subtropical Zone*

$$Z_{ij}=\sum_{k=1}^{n} T_{ik}\phi_{kj}, \qquad \begin{pmatrix} i=1,2,\cdots,297 \\ j=1,2,\cdots,24 \end{pmatrix} \tag{2}$$

where $i$ is the number of samples employed and $j$ of gridpoints and whose expansion is given in Wang et al. (1974). The calculation results are summarized in Table 1. It can be seen that the first four terms of EOF used to approach the 500-hPa height field at subtropical latitudes have a total variance 99.94% and the principal eigenvectors of the STH and their coefficients are of considerable synoptic significance.

**Table 1.** Main Eigenvalues of STH and Their Accumulated Ratios

| Value | 149763.70 | 73.73 | 45.34 | 30.67 |
|---|---|---|---|---|
| Ratio | 0.9855 | 0.9985 | 0.9992 | 0.9994 |

The distribution of the first eigenvector (figure omitted) illustrates a mean STH given by the typhoon samples during July—September, 1958—1979, and the ridge line of the high is situated around 29°—30°N. The products of the eigenvector and its corresponding time coefficient (the STH coefficient) $T_1$ cover most of the field observed. Hence the region denoted by the first eigenvectors can be viewed as a basic field and those by the others as disturbances superimposed on this field.

Different from the first ones, the second eigenvectors have both positive and negative components (figure omitted), with the zero-value line around 28°—29°N, north and south of which lie a negative and a positive region, respectively. The STH coefficients relative to the second eigenvector field $T_2$ are indicative of the north—south movement of the position of the STH.

As the second ones, the third eigenvectors have the same types of components (figure left out). But they are distributed in an east—west orientation, with the zero-value line stretching about 130°—132°E, east and west of which are a positive and a negative region, respectively. The STH coefficient in relation to this eigenvector field $T_3$ is a representation of the east—west displacement of the STH.

The fourth eigenvectors (figure omitted) show a very strong positive-value sector between 120°—140°E over the North Pacific, with a stronger positive center to the south of Chejudo. Hence, the corresponding $T_4$ indicates the intensification or diminution of the STH in this area.

2. *Chebyshev Polynomial Expansion of the 500-hPa Height Field in Westerlies*

$$Z_{ij}=\sum_{k=0}^{K_0}\sum_{s=0}^{S_0} A_{ks}(Z)\varphi_k(i)\varphi_s(j), \qquad (i=1,2,\cdots,I_0;\ j=1,2\cdots,J_0) \tag{3}$$

where

$$A_{ks}(Z)=\sum_{i=1}^{I_0}\sum_{j=1}^{J_0} Z_{ij}\varphi_k(i)\varphi_S(j). \quad (k=0,1,2\cdots,K_0;\ s=0,1,2,\cdots,S_0). \qquad (4)$$

The expansion is performed in Zhou (1983). In our paper expanded is a finite region with $I_0=7$ and $J_0=5$. When the highest order of the polynomial is $K_0=S_0=2$, only nine coefficients from the expansion can be used to approach, to a certain extent, the characteristics of the $Z_{ij}$ distribution on a primitive field.

There is no need for detailing the standard Chebyshev polynomial $\varphi_K(i)$ $\varphi_S(j)$ because of its special form (Zhou, 1983). The coefficient $A_{00}$ corresponding to it represents the weighing of the sample average of the height fields in westerlies; $A_{01}$ the weighting of the field, high in the south and low in the north; $A_{02}$ low in the middle and high in the north and south; $A_{20}$ low in the middle and high in the east and west.

## IV. STATISTICAL PREDICTION OF THE INTENSITY OF THE STH

The above analyses indicate that the STH coefficients are able to display the chief features of the STH more clearly while the Chebyshev coefficients have ability to reflect the evolutive tendency of atmospheric waves more evidently, and both can attain required accuracy. Therefore the STH prediction is in fact a problem of forecasting its coefficients. (Huang, 1978; Paegle and Haslam, 1982)

The STH coefficients $T_1$, $T_2$, $T_3$ and $T_4$ are assumed to be predictands and the Chebyshev ones $A_{00}$, $A_{01}$, $A_{02}$, $A_{10}$, $A_{11}$, $A_{12}$, $A_{20}$, $A_{21}$, $A_{22}$ predictors, based on 297 samples for July—September, 1958—1979, and the regression equations are developed by means of multivariate linear regression (see Table 2). The fitting results are, to a great extent, close to the STH coefficients.

Table 2. Regression Equations for Predicting STH Coefficients in a Tabulated Form

| Predictor / Predictand | $b_0$ | $A_{00}$ | $A_{01}$ | $A_{02}$ | $A_{10}$ | $A_{11}$ | $A_{12}$ | $A_{20}$ | $A_{21}$ | $A_{22}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | Regression Coefficient | | | | | | | | | |
| $T_1$ | 315.7549 | 0.1582 | 0.2794 | 0.6602 | 0.1326 | 0.1303 | 0.5460 | −0.0791 | −0.3951 | −0.0392 |
| $T_2$ | 108.8373 | −0.2483 | −0.3900 | −0.4483 | −0.1958 | −0.3108 | −0.3418 | −0.0624 | 0.1090 | −0.1339 |
| $T_3$ | −10.3590 | 0.0232 | 0.0014 | 0.0026 | 0.0465 | 0.1719 | 0.2138 | 0.2559 | 0.3894 | 0.1388 |
| $T_4$ | 23.1986 | −0.0511 | −0.1110 | 0.0335 | −0.0274 | −0.0118 | 0.1780 | −0.0171 | −0.1683 | −0.1379 |

## V. TESTS OF THE MAIN ITEMS

To test the availability of the STH forecasts made by the statistical model developed in this article for the finite region over the western North Pacific, independent sample tests are performed of the predictions of the simultaneous 500–hPa height fields in the subtropical area in terms of the height fields within westerlies on the 500–hPa forecast charts prepared for 2000 each day over the period of July—September 1982 for the next 48 hr by the B model. The comparison of the forecasts of both the models are illustrated in the following tables.

Table 3. Comparison of Mean Absolute Errors in the Forecasts of the STH Ridge Line Location*

| Model | July | Aug. | Sept. | Mean |
|---|---|---|---|---|
| | Mean Absolute Error (in Lat.) | | | |
| B | 3.3 | 6.9 | 4.1 | 4.8 |
| Statis. | 3.0 | 4.5 | 3.1 | 3.5 |

* The average position is assumed to be only at 120°, 125°, 130°, 135° and 140°E.

Table 4. Comparison of Mean Absolute Errors in the Forecasts of the Western Point of the STH Ridge*

| Model | July | Aug. | Sept. | Mean |
|---|---|---|---|---|
| | Mean Absolute Error (in Lat.) | | | |
| B | 24.6 | 15.2 | 20.6 | 20.1 |
| Statis. | 18.3 | 12.6 | 13.7 | 14.9 |

* If the ridge point found out is beyond the range from 120° to 145°E, then 120° and 145°E are used respectively for statistics.

Table 5. Comparison of Mean Absolute Errors in the Forecasts of the Height of the 500-hPa Fields in the Subtropical Zone

| Model | July | Aug. | Sept. | Mean |
|---|---|---|---|---|
| | Mean Absolute Error (in 10 gpm) | | | |
| B | 3.8 | 4.0 | 4.1 | 4.0 |
| Statis. | 3.4 | 3.5 | 3.4 | 3.4 |

Table 6. Comparison of Area Indices and Intensity of the STH*

| Month** | Area Index | | Intensity | |
|---|---|---|---|---|
| | B Mdl | Statis. Mdl | B Mdl | Statis. Mdl |
| | Mean Error of Statistics | | | |
| July | 6.6 | 5.4 | 3.0 | 3.0 |
| Aug. | 5.8 | 4.1 | 2.8 | 2.6 |
| Sept. | 4.6 | 3.9 | 2.1 | 1.8 |
| mean | 5.7 | 4.5 | 2.6 | 2.5 |

* The area index is obtained in terms of the number of points with the area enclosed by the line of 5880 gpm and the intensity is expressed in 10 gpm.

** The monthly averages for 1958—1979 are used.

## VI. CONCLUSIONS

As indicated in Tables 3—6, our statistical model is superior to the B model in any item for any of the months, particularly in the prediction of the STH ridge line location and the western point of the line. Such improvement of the accuracy is of importance to forecasting typhoon tracks and the occurrence of drought or flood. It follows that there is some feasibility in employing the 500–hPa height field within westerlies predicted by the B model to modify the synchronous field in the subtropical zone and, therefore, the present scheme can be used as an operational reference.

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