Lecture No. 9

TYPHOON MOVEMENT

by S. Y. W. Tse

Introduction

Forecasting typhoon movement is not an easy task, though many objective or semi-objective methods have been evolved, some of which are found to be capable of giving reasonably reliable 24-hour forecasts of typhoon positions. To satisfy operational requirements, the forecast methods used must provide a good average performance in accuracy. The comprehensive survey on this subject presented by Gentry (1964) adequately covers contributions from 1898 to 1963. However, research meteorologists have continued to study the problem in search of improved techniques or new predictors. Techniques reported by Miller et al. (1966, 1968), Tse (1966), Renard (1968), Rao (1969) and Chin (1970 b) are notable examples of recent contributions.

The scope of this lecture is mainly restricted to a brief review on the age-old steering concept with particular emphasis on the existence of optimum steering levels in the western north Pacific and the South China Sea. Performance evaluations are discussed in more detail in these areas than in the Atlantic. The advantages and shortcomings of four of the methods used at the Royal Observatory, Hong Kong (ROKH), which have proved to give persistently good results, are examined. The method of Veigas-Miller (1959) which was modified by ROKH through the introduction of 12-hour persistence, the method of persistence-climatology, $\frac{1}{2}(P+C)$, the fixed "Control point" method are now covered, while the method developed by Tse (1966) will be dealt with in the next lecture. Special procedures are suggested for overcoming some of the inherent shortcomings with a view to achieving better scores in operational practice.

Steering concept and optimum steering levels

The motion of mature tropical cyclones is well related to the mean wind flow integrated through a deep layer and over a substantial area surrounding the cyclone centre (Jordan 1952, Miller 1958, Riehl and Burgner 1950). A theoretical treatment on the motion of tropical cyclones and their interaction with the basic current was presented by Yeh (1950). In the Atlantic, the mean resultant 200 mb winds tend to parallel climatological tropical cyclone tracks (Ramage 1970). However, the situation in the western North Pacific is unfortunately more complicated. For the months from June to November, the modal direction of typhoon movement generally agrees better with the resultant wind flow at 700 mb than at 500 mb and all other levels. For the month of August, during which the maximum frequencies of typhoons and tropical cyclones often occur, both the modal and vector mean direction of movement agree fairly well with the resultant wind flow at 700 mb or 500 mb (Figures 8 and 9 of Lecture 7). The 700 mb flow pattern exhibits better agreement for regions north
of 15°N, while the steering effect becomes more pronounced at 500 mb further Equatorwards. In broad general terms, deviation from the mean flow patterns at all levels below 300 mb is biased to the left (i.e., predominant movement towards low pressure). Above 15°N, contributions from all levels other than 700 mb and 500 mb are relatively much less significant. However, for latitudes below 10°N, movement parallel to 300 mb or 200 mb becomes more conspicuous and the deviation is now biased to the right of the mean wind flow. The good agreement under discussion seems to lend strong support to the concept of steering in general and confirms the existence of optimum steering levels in particular.

In this seminar, Professor Sadler and Colonel Harris have shown in their lecture and laboratory series that the 500 mb flow pattern can become extremely complicated in the daily sequence, the practical usefulness of this as the steering level is thus markedly reduced. Furthermore, much more useful information near the storm is available at 700 mb, because it is the main level of aircraft reconnaissance. In view of all the facts under consideration, the use of 700 mb as the optimum steering level is likely to stand the test of time.

Performance evaluations

Performance evaluations on many of the available techniques in the western North Pacific and the South China Sea were presented by Bell (1963), Geraldson (1968), and Chin (1970 a, 1970 c), while those for hurricanes in the Atlantic were reported by Dunn, Gentry and Lewis (1968). These statistics reveal that for storms in the Atlantic the average error of 24-hour forecasts is not better than 100 n mi in regions where observations are abundant and of the order of 150 n mi in data-sparse areas. The performance of the various methods used at the Royal Observatory, Hong Kong for tropical cyclones developed within or entered the Hong Kong warning area (10°N to 30°N and 105°E to 125°E) during the ten-year period 1961-1969 is shown in Table 1.

The figures in Table 1 indicate that on average the methods of Veigas-Miller, persistence-climatology, fixed “control point” and Tse give good results with comparable performance. The first three methods depend heavily on the performance of persistence, while Tse's method is almost independent of persistence. In the years 1962 and 1965, persistence was worse but Tse's method remained close to its average performance while all other methods gave relatively large mean errors in phase with persistence.

Other methods (Arakawa 1961, 1963, Miller and Moore 1960 and Miller et al. 1966) were also tested at the Royal Observatory, Hong Kong for periods ranging from one to three years, but they generally gave less encouraging results than the four under consideration.

The method of Veigas-Miller (1959)

This statistical method is originally meant for storms in the Atlantic. However, performance evaluations show that it is capable of giving reasonably good results in the western north Pacific and the South China Sea, particularly after the introduction of 12-hour persistence. For practical purposes, the modified equations
are best presented in the form of a computation sheet as shown in Table 2. The sea-level pressure values used are to be extracted from a corresponding analysed surface chart at each five-degree grid point with the aid of a transparent grid overlay.

The method is very stable with respect to surface pressure values, but sensitive to errors in locating the storm centres (Gentry 1964). Large errors in the forecasts may be experienced just before and well after recurvature. If the storm slows down abruptly, this method tends to predict "false" recurvature. It usually fails to predict recurvature, unless the storm undergoes a relatively long period of slow movement prior to recurvature. The advantage of using 12-hour persistence to replace 24-hour persistence in the original equations is two-fold; the modification gives slightly better results and allows the first forecast to be made 12 hours earlier.

The method of persistence-climatology

In this method, the persistence vector is obtained by linear extrapolation from the current and the best past 12-hour positions of the storm for the subsequent 24 hours. The best-fit past 12-hour storm track may be used but the elaboration does not yield significant improvement on average scores. The climatology vector can be obtained from Tables 2 - 7 of Lecture 7 for the months June - November for any initial position of the storm in each appropriate 2½ deg square by compositing the modal direction with the mean speed of displacement. The forecast position is given by the mid-point of the straight line joining the termini of these two vectors which are centred at the initial position of the storm.

Experience shows that this method gives reasonably good results when the storm follows a steady track, but fails drastically in recurvature cases and when the initial position of the storm lies north of 25°N. Table 3 which shows the variation of mean errors given by this method with latitude and synoptic patterns as classified by Tse (1966) may be used as an additional forecasting aid to indicate when and where it is more reliable or more likely to fail.

The fixed "control-point" method

The fixed "control point" method developed by Chin (1970 b) appears to offer considerable promise in improving the skill in forecasting the direction of typhoon movement over the method of persistence-climatology (\(\frac{1}{4}P+C\)). The method may be looked upon as an attempt to introduce a directional correction to accord with the flow pattern at 700 mb. Although 500 mb may also be used for this purpose, the evidence presented by Professor Sadler and Colonel Harris in this seminar seems to markedly reduce the practical usefulness of this level because of complications in the day-to-day flow patterns. Since the \("(P+C)/2\) speed is used to predict the displacement, dependence on persistence becomes inherent as shown in Table 1. However, on long term performance, a slight but definite improvement over persistence-climatology
in forecasting the direction of movement has been achieved. The method is stable and easy to apply. The "control point" may be determined simply as follows:

(a) Determine the best past 24-hour track and linearize it with respect to the initial position of the storm as illustrated in Figures 1 and 6(a) in Chin (1970b);

(b) Draw a straight line through the initial storm position perpendicular to the "linearized" track to the right of the storm;

(c) The "control point" is located at a distance of 5 deg lat. from the typhoon centre along the "perpendicular", using 4 deg lat. for less intense tropical cyclones;

(d) Estimate the wind direction at the location of the "control point" on the current 700 mb chart, elaborating the streamline pattern if necessary;

(e) Combine this direction with the \((P+C)/2\) speed to obtain the resultant forecast.

Further refinement of the method may be achieved by using the intersection of the "perpendicular" with the surface isobar drawn to the nearest mb, the value of this isobar being determined by the normal pressure at the position of the tropical cyclone centre for the corresponding month. In this context, any climatological charts may be used, e.g., "Climatological Charts of the Far East" published by the Royal Observatory, Hong Kong (1959). Although this refinement has given more encouraging results than the fixed "control point" method on a small test sample in 1969, it suffers from one drawback that the variable "control point" may often protrude into the deformation field in the 700 mb flow pattern to such an extent as to invalidate any practical and reliable determination of the "steering" flow there. This effect is particularly pronounced in late autumn and winter storms. It must be borne in mind that the method is inapplicable in all these cases. The fixed "control point" method is much more stable in this respect.

Acknowledgments

Grateful thanks are due to Mr. G. J. Bell, J.P., Director of the Royal Observatory, Hong Kong for valuable advice and encouragement, Professor C. S. Ramage of the University of Hawaii, Director of this Seminar for guidance and enlightening discussions, Mr. G. Verploegh of the World Meteorological Organization for constant encouragement and to Mr. Hwang Tiaw-Soo, Senior Meteorological Officer of the Singapore Meteorological Service, the local co-ordinator of the Seminar and members of the Seminar secretariat for their most helpful co-operation and excellent assistance.
References


———. 1970 c: Royal Observatory, Hong Kong, Technical Note No. 31 (to be published).


Royal Observatory, Hong Kong, 1959: Climatological Charts of the Far East.


<table>
<thead>
<tr>
<th>Year of tropical cyclone</th>
<th>Number of tropical cyclone</th>
<th>Official forecasts by Royal Observatory</th>
<th>Official forecasts by Guam</th>
<th>Persistence (P)</th>
<th>Climatology (C)</th>
<th>( \frac{1}{2} (P + C) )</th>
<th>Velgos-Miller method</th>
<th>Tse's method</th>
<th>Fixed control point method</th>
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<tbody>
<tr>
<td>1961</td>
<td>8</td>
<td>118.0</td>
<td>125.0</td>
<td>119.0</td>
<td>132.0</td>
<td>128.0</td>
<td>100.0</td>
<td>87.0</td>
<td>-</td>
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<td>7</td>
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<td>153.0</td>
<td>144.4</td>
<td>161.3</td>
<td>159.1</td>
<td>123.5</td>
<td>83.7</td>
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<tr>
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<td>7</td>
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<td>105.2</td>
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<td>119.1</td>
<td>108.1</td>
<td>70.9</td>
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<td>86.9</td>
<td>143.6</td>
<td>129.7</td>
<td>93.2</td>
<td>93.5</td>
<td>-</td>
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<td>1965</td>
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<td>116.5</td>
<td>132.6</td>
<td>146.7</td>
<td>151.1</td>
<td>132.1</td>
<td>124.1</td>
<td>95.3</td>
<td>122.3</td>
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<td>1968</td>
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<td>102.4</td>
<td>99.2</td>
<td>107.3</td>
<td>123.3</td>
<td>107.4</td>
<td>111.8</td>
<td>106.7</td>
<td>91.8</td>
</tr>
<tr>
<td>1969</td>
<td>9*</td>
<td>116.8</td>
<td>115.3</td>
<td>102.6</td>
<td>163.2</td>
<td>109.3</td>
<td>99.0</td>
<td>123.3</td>
<td>94.1</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>981.3</strong></td>
<td><strong>1105.6</strong></td>
<td><strong>1039.1</strong></td>
<td><strong>1288.2</strong></td>
<td><strong>986.5</strong></td>
<td><strong>1001.0</strong></td>
<td><strong>813.1</strong></td>
<td><strong>740.2</strong></td>
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**Mean**
- Official forecasts by Royal Observatory: 109.0
- Official forecasts by Guam: 122.9
- Persistence (P): 115.5
- Climatology (C): 143.1
- \( \frac{1}{2} (P + C) \): 109.6
- Velgos-Miller method: 111.2
- Tse's method: 90.3
- Fixed control point method: 105.7

**Number of forecasts**
- 448
- 498
- 473
- 466
- 462
- 382
- 372
- 104

**Mean error**
- 103.0
- 119.1
- 115.0
- 136.0
- 106.3
- 111.9
- 99.4
- 103.3

**Standard deviation**
- 56.4
- 68.5
- 69.5
- 78.8
- 62.4
- 64.2
- 54.5
- 62.2

**Range**
- 0-350
- 0-440
- 6-390
- 9-450
- 10-325
- 10-330
- 0-300
- 10-311

* Small sample: 20 forecast positions in total.
* The time of issue of these forecasts is much earlier; therefore the results are not strictly comparable.
<table>
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<tr>
<th>Name</th>
<th>Intensity</th>
<th>Date</th>
<th>B.T.G.</th>
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<tr>
<td>Present lat. ((l_{t0}))</td>
<td>N</td>
<td>Present long. ((L_{t0}))</td>
<td>E</td>
</tr>
<tr>
<td>Past 12-hr lat. ((l_{t-12}))</td>
<td>N</td>
<td>Past 12-hr long. ((L_{t-12}))</td>
<td>E</td>
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**Prediction**

<table>
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<tr>
<th>Verification</th>
<th>Displacement Error</th>
<th>Vector Error</th>
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<tr>
<td>Lat. ((l_{t24}))</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Long. ((L_{t24}))</td>
<td>E</td>
<td>E</td>
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</table>

**Latitude:**

<table>
<thead>
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<th>A-terms (+)</th>
<th>B-terms (-)</th>
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<tr>
<td>(l_{t0})</td>
<td>(x 2.208 = P_{5})</td>
</tr>
<tr>
<td>(l_{t14})</td>
<td>(x 0.232 = P_{47})</td>
</tr>
<tr>
<td>(l_{t30})</td>
<td>(x 0.042 = P_{51})</td>
</tr>
<tr>
<td>(l_{t35})</td>
<td>(x 0.137 = P_{70})</td>
</tr>
<tr>
<td>(l_{t79})</td>
<td>(x 0.056 =)</td>
</tr>
<tr>
<td>Sum ((A))</td>
<td>(B = )</td>
</tr>
</tbody>
</table>

**Longitude:**

<table>
<thead>
<tr>
<th>A-terms (+)</th>
<th>B-terms (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(l_{t0})</td>
<td>(x 2.529 = P_{3})</td>
</tr>
<tr>
<td>(l_{t14})</td>
<td>(x 0.580 = P_{9})</td>
</tr>
<tr>
<td>(l_{t42})</td>
<td>(x 0.161 = P_{33})</td>
</tr>
<tr>
<td>(l_{t66})</td>
<td>(x 0.147 = P_{44})</td>
</tr>
<tr>
<td>(l_{t79})</td>
<td>(x 0.083 = P_{71})</td>
</tr>
<tr>
<td>Sum</td>
<td>(l_{t-12})</td>
</tr>
<tr>
<td>(3.54)</td>
<td>(1.12)</td>
</tr>
<tr>
<td>(A =)</td>
<td>(B =)</td>
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</table>

\(L_{t24} = (A - B) =\)

---

\(P_{47}\) is placed at the corner of the 5 deg square box nearest the current storm center. \(l_{t0}\), \(l_{t-12}\), \(L_{t0}\) and \(L_{t-12}\) are expressed in deg, lat. and long. \(P_{i}\), etc. are given by \(\text{as read value - 1000}\text{mb for each grid point; e.g., 1003.5}\) \(\text{mb} \) is entered in the above form as 0.5(mb) and 997.6 \(\text{mb} \) as -2.4(mb).
### TABLE 3

**Errors of forecasts given by the \( j(P + C) \) method under various synoptic conditions: 1961 - 1965**

<table>
<thead>
<tr>
<th>Latitude</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>All types</th>
</tr>
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<tr>
<td>25.0°N.-30.0°N.</td>
<td>139(8)</td>
<td>112(11)</td>
<td>152(17)</td>
<td>244(7)</td>
<td>97(6)</td>
<td>147(49)</td>
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<tr>
<td>20.0°N.-24.9°N.</td>
<td>79(26)</td>
<td>114(17)</td>
<td>120(23)</td>
<td>179(16)</td>
<td>114(32)</td>
<td>102(116)</td>
</tr>
<tr>
<td>15.0°N.-19.9°N.</td>
<td>85(46)</td>
<td>114(16)</td>
<td>115(31)</td>
<td>89(17)</td>
<td>91(20)</td>
<td>97(130)</td>
</tr>
<tr>
<td>10.0°N.-14.9°N.</td>
<td>88(19)</td>
<td>84(10)</td>
<td>-10(0)</td>
<td>87(4)</td>
<td>70(1)</td>
<td>86(34)</td>
</tr>
<tr>
<td>All latitude ranges</td>
<td>80(101)</td>
<td>106(54)</td>
<td>126(71)</td>
<td>110(44)</td>
<td>104(59)</td>
<td>105(329)</td>
</tr>
</tbody>
</table>

*Note: The figure inside the brackets denotes the number of forecasts verified.*

*(After Chin, 1970)*
Lecture No. 10

TYPHOON MOVEMENT
(continued)

by S. Y. W. Tse

Introduction

This lecture is based on a study by S. Y. W. Tse, published in 1966 and in which storm tracks which crossed the area between the Equator and 35°N, 105°E and 160°E, during the period 1957 to 1960 have been analysed.

The method, tested in 44 forecasts on 8 storms during May to September 1961, gave an average error of 87 nautical miles; this compares favourably with other objective methods.

The main features of the method are recapitulated here in order to facilitate reference. Suggested forecasting procedures are given to cater for various operational requirements with different degrees of sophistication.

Main features of the method

For each storm position values of the 700 mb contour height (geopotential metres) $H_e$, $H_w$, $H_s$ and $H_n$, were extracted at four selected grid points labelled as E, W, S and N respectively. E and W were at distances of $10^\circ$ longitude east and west of the storm centre, S and N at distances of $10^\circ$ latitude south and north of the storm centre. The differences $(H_e - H_w) = \Delta \phi H$ and $(H_s - H_n) = \Delta \lambda H$ were computed for 516 storm positions and used as predictors. The subsequent 24-hour meridional and zonal displacements of the storm in degrees latitude and longitude, $\Delta \phi$ and $\Delta \lambda$, were chosen as predictands. The overall synoptic pattern at 700 mb was then introduced as an additional criterion. Regression lines corresponding to a few easily recognized synoptic patterns were derived from scatter diagrams of $\Delta \phi H$ versus $\Delta \phi$, $\Delta \lambda H$ versus $\Delta \lambda$. A nomogram was constructed to give $\Delta \phi$ and $\Delta \lambda$, for values of $\Delta \phi H$ and $\Delta \lambda H$ respectively.

The 700 mb synoptic patterns are classified into five types according to the following criteria:

Type A: The grid-point N lies on or south of a ridge axis.

Type B: The grid-point N lies north of a ridge axis.

Type C: For both types A and B, troughs in the upper westerlies must be at distances of more than 10 deg. longitude from N measured along the latitude of N. If this restriction breaks down, the pattern becomes Type C.
Type D: A cyclonic circulation is present within the north semi-circle centred at N with a radius of 600 n mi.

Type E: A cyclonic circulation exists within the west semi-circle centred at W with a radius of 600 n mi.

Although the synoptic patterns are classified on a mutually exclusive basis to maintain objectivity in the original investigation with dependent data, experience shows that in practice, it is advisable to use combined or mixed patterns (e.g., (A+B)/2, (A+D)/2, (C+E)/2, (D+E)/2) on bordering cases or when any single type cannot be determined with confidence in order to stabilize the scheme in coping with complicated or rapidly changing patterns.

Thus if the grid-point N lies between two ridge lines, one to the north and one to the south, or when N is very close to a ridge line, (A+B)/2 may be used.

The forecaster may use any combination at his discretion, but in all cases, the latitudinal and the longitudinal components have to be treated separately, because they are influenced by the various environmental systems in different ways. For example, Type D does not affect the meridional displacement and Type E may not significantly influence the longitudinal component. The 24-hour forecast position may easily be obtained with the aid of a nomogram (Figure 14*). If information is scanty near any grid point, the histograms in Figures 15-20 may be used as aids to supplement the analysis. To facilitate the identification of synoptic patterns, Figures 9-13 may be used as a quick guide, but each type chosen must satisfy the corresponding criterion.

Shortcomings

Contour heights at the 700 mb level have to be analysed at intervals of one geopotential decametre and refined analysis requires time and patience. This is most trying when the forecaster is working against a tight schedule. The choice of pattern and the contour analysis are both influenced by subjective variations or personal bias. The method is sensitive to errors of reported heights and radiosonde differences and usually fails when the storm moves overland or is disorganized by sufficiently large land masses such as Taiwan and Luzon. In these cases, the predicted position tends to follow the 700 mb centre, while the surface circulation breaks up into vortices pending reorganization. However, if the typhoon is very well organized to overcome topographical obstructions, then the discrepancy is much less marked.

Experience in post-mortem analyses seems to indicate that it is difficult to discriminate objectively whether the errors involved are due to variations in the choice of pattern and subjective analysis or inherent deficiency in the method. If the same set of initial data is given to a number of forecasters without mutual communications, they may come up with different forecast positions with a fair amount of scatter. This characteristic scatter is confirmed in one of the laboratory sessions.

N.B.* Unless otherwise stated the figure numbers referred to in this lecture are those in Tse's paper (1966).
in the present seminar in applying this method to obtain a 24-hour forecast for Tropical Cyclone "Fran" from the 700 mb chart for 290000Z July 1967. Since "Fran" was then a newly developed storm, the analysts could not rely on continuity in synoptic pattern, contour configuration or past movement. In fact, they had no idea whether the storm would move rapidly or drift slowly. (I must admit that it is not very fair to the delegates).

However, it is encouraging to note that their "average" forecast position which is the centroid of the scatter is only about 20 n mi from the verification position and that the mean of their individual errors is slightly less than 60 n mi, though the scatter ranges from 15 to 130 n mi.

Advantages

The inclusion of synoptic patterns in the scheme in general will make some allowance for the stage of storm development, the size of the storm, and the interaction between the storm circulation and the basic current as well as the influence of nearby storms or other significant disturbances. The method is almost independent of persistence and gives comparable accuracy for recurving as well as non-recurving storms. The predicted direction is generally satisfactory but the forecast displacement is biased towards the low side, particularly so when the typhoon accelerates well after recurvature. This systematic error may be corrected when the data sample becomes sufficiently large for analysis with appropriate stratification with respect to synoptic pattern, latitudes or zones. This may be viewed as a potential for further elaboration or improvement.

Practical hints.

In practice, there should not be much difficulty in determining the contour heights at grid points N and W for storms in the western North Pacific and the South China Sea, apart from occasional contamination by conflicting observations. However, information is often scanty near the grid points E and S. This is where subjectivity comes into play. If feasible, it is advisable to do a post-mortem analysis of the previous chart (backdate 24 hours) and see how close you can make it give an accurate "forecast" of the current (initial) position. Use this as a reference chart to find out the changes in synoptic pattern or contour configuration since that time. In general, significant changes in either or both will be followed by marked deviations from the past track under consideration. For example, an approaching deep trough in the westerlies will bring about recurvature. Weakening or recession of a pronounced ridge of "high pressure" to the north is in favour of reduction in the zonal component. The development of a well organized cyclonic centre just off the grid point W is likely to reduce the meridional component. The development of a deep cyclonic centre in the westerly trough tends to delay recurvature by 24-36 hours. In all cases, development, intensification or weakening must be diagnosed carefully by comparing changes in the wind field as well as the contour configurations. An abrupt rise or fall in the contour height of only one station not accompanied by marked changes in the wind field in its vicinity must be treated with reserve. Negligence in this respect is likely to result in relatively large errors in the forecast.
If the upper easterlies are very strong at 300 mb and 200 mb, maximization of negative south-north (or positive north-south) contour difference usually yields better results. Conversely, if the storm lies under 300 mb and/or 200 mb westerly troughs minimization of positive north-south contour difference often improves the forecast. In general, when the storm comes under the influence of the upper westerlies at all levels above 700 mb, maximization in both components may be able to overcome the inherent bias of the scheme towards slow movement. Since conservation of momentum along the past track tends to delay recurvature for some time, the first predicted eastward component displacement in the forecast sequence should be minimized to counterbalance this effect.

Under all circumstances, reasonable continuity should be maintained from chart to chart with respect to contour configuration and the positions of ridges, troughs and cyclonic centres. Information in the wind field should be used to full advantage to supplement the contour analysis and maintain continuity.

Suggested forecasting procedures

In the light of the foregoing discussions, the following two schemes are suggested in order to cater for diversified operational requirements with different degrees of sophistication:

Scheme A:

For each main synoptic hour, prepare separate 24-hour forecast positions by the Veigas-Miller (1959), the fixed "control point" (Chin 1970) and Tse's methods. (For both schemes, the 0000Z and 1200Z 700 mb charts may also be used for 0600Z and 1800Z forecasts). Use the centroid of the three as the resultant forecast position. In this way, refined analysis is not necessary, because the error in the individual methods tend to cancel one another to some extent. Although the crude analysis may lead to poor performance in Tse's method on an individual basis, the "centroid" is likely to give better results than any of its components. This scheme has the advantage of simplicity and is time saving.

Scheme B

For each forecast assignment, reproduce, say, ten sets of initial data and give them to ten analysts (forecasters, scientific or meteorological assistants) for the preparation of forecast positions by Tse's method on an individual basis without mutual communications. They can do what they like and refined analysis is not absolutely necessary. However, continuity in each individual series should be maintained. They will probably give a collection of different positions the scatter of which is dependent on the complexity of the existing synoptic pattern and data coverage. Compute the arithmetic mean position and the standard deviation. Use this mean position as the resultant forecast and the magnitude of the standard deviation to indicate the degree of confidence to be placed on the resultant forecast. If the standard deviation is less than 60, 90 or 120 n mi, the degree of confidence may be rated as very good, good or fair accordingly. For values greater than 120 n mi, we can say confidence "poor". For cases with standard deviation larger than 90 n mi, combination with Veigas-Miller and fixed "control point" positions
is recommended. Since each individual forecast may be prepared in about ten minutes, the man-hour requirement does not seem to be high for a large meteorological service. In all cases, it is advisable to check the choice of pattern and record height values at all grid points for further studies. It is expected that after about one typhoon season the scatter is likely to come within reasonable limits for any individual group.

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