HONG KONG OBSERVATORY

Technical Note (Local) No. 71

IMPROVEMENT TO THE HONG KONG OBSERVATORY SYNOPTIC ANALOGUE FORECAST SYSTEM

by

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1. INTRODUCTION

A synoptic analogue forecast system (Poon and Ma, 1992) has been used in the Central Forecasting Office (CFO) since 1992. The technique is based on the assumption that weather patterns repeat themselves approximately from time to time. It also assumes perfect prognosis of numerical model in the sense that the system matches 12 UTC prognoses from the European Centre for Medium-Range Weather Forecasts (ECMWF) with historical ECMWF 12 UTC analyses (The ECMWF/TOGA Basic Level-III datasets 1985-1995). If a close match is found, the weather which occurred on the date of the matched analysis is taken to be a forecast for the weather on the day of the prognosis.

The matching statistic that measures the closeness of two weather maps is the similarity score (SS), a linear combination of the anomaly correlation coefficient (ACC) for pattern matching and the S1 skill score for gradient matching. SS is normalized to lie between 0 and 1. Their definitions are listed in Appendix I. All the ECMWF fields available in CFO (i.e. surface pressure, 850 hPa level wind and temperature, 500 hPa level geopotential height, 200 hPa level wind) can be used in the calculation of SS. The analogue system allows the forecaster to select weights of the various fields, the ratio of ACC to S1, and the area over which SS is calculated. Due to the limited size of the available historical dataset, the system only generates four analogues (with decreasing SS) together with the actual weather which occurred on the dates of the analogues for reference of the forecaster. Hereafter the weather associated with the analogues will be referred to as the analogue forecast. An example of analogues and analogue forecasts produced by the system is given in Appendix II.

In this study the analogue forecasts were verified and two experiments were conducted with a view to improving the performance of the system. In experiment "DWS" different weighting schemes were tried out and in experiment "SA" a selective averaging method was proposed to produce a composite analogue forecast.

2. VERIFICATION

Forecasters generally consider that the system is useful when the local weather is governed by synoptic scale rather than mesoscale systems. Thus, the basic data used in this study are thirty winter monsoon surge cases selected from the 1994/95 and 1995/96 winters (loosely defined as October to March), with approximately equal proportion of fine (F), cloudy with or without rain (W) and mixed bag of sunshine and rain (M) cases. It is well accepted that monsoon surges are essentially a synoptic scale phenomenon. Details of these cases are listed in Appendix III. Since the system assumes perfect prognosis, ECMWF analyses of these cases were used to search for analogues in the database. In this verification, the weights of all ECMWF fields were set to one, the domain of matching was fixed at 10°N-40°N, 95°E-130° E, and the ratio of ACC to S1 set to one. This scheme is referred to as EQ. This domain was so selected to adequately cover synoptic scale factors producing local weather. Four meteorological elements were considered in the verification: daily maximum temperature (TMAX), daily minimum temperature (TMIN), rain occurrence (RF) during the day, and number of hours of sunshine (SUN). For the sake of simplicity, rain occurrence instead of rainfall amount was verified (RF = N or Y, trace amount of rainfall was regarded as N). A simple verification scheme was devised as follows:

<u>TMAX , TMIN, SUN</u>	<u>Score</u>
$0 \leq \mid \text{analogue - actual} \mid \leq \varepsilon$	100
otherwise	0
<u>RF</u>	<u>Score</u>
analogue = actual	100
otherwise	0

The number ε is a tolerance limit. Following the CFO verification Scheme 4 (Li, 1996), forecasts of daily maximum and minimum temperatures with deviations within 1.5 degrees from the actual observations were considered correct. For the SUN forecast, a deviation of two hours from actual observation was considered acceptable. Thus, ε was taken to be 1.5 for TMAX and TMIN, and 2 for SUN. Scheme 4 was not used in this study because the scheme requires human translation of plain language forecasts into categorical forecasts, then comparison is made between the categorical forecasts and quantitative figures. The simpler scheme described above was employed in this study.

Tables 2.1 to 2.4 shows the verification results for rank 1 to rank 4 analogue forecasts, respectively.

Rank 1	F	W	M	average
TMAX	50	20	30	33
TMIN	30	40	40	37
RF	100	50	30	***60***
SUN	40	50	0	30

Table 2.1 : Rank 1 analogue. Scheme EQ.

Rank 2	F	W	M	average
TMAX	60	60	60	***60***
TMIN	90	70	50	***70***
RF	80	50	0	43
SUN	60	50	20	***43***

Table 2.2 : Rank 2 analogue. Scheme EQ.

Rank 3	F	W	M	average
TMAX	60	30	10	33
TMIN	60	30	10	33
RF	100	30	30	53
SUN	60	30	10	33

Table 2.3 : Rank 3 analogue. Scheme EQ.

Rank 4	F	W	M	average
TMAX	60	40	20	40
TMIN	70	60	20	50
RF	80	50	20	50
SUN	*30*	*80*	*10*	*40*

Table 2.4 : Rank 4 analogue. Scheme EQ.

The bold italics are the maximum average score of a particular meteorological element among the four ranks. Comparison of the average scores of individual elements does not suggest a trend of scores decreasing with ranks. In fact, for most cases, the differences in SS between consecutive ranks are 0.01 or less. Probably the decreasing trend will become more apparant if more analogues had been included in the comparison. Interestingly, three out of the four maximum scores fall on rank 2.

Denote the maximum TMAX, TMIN, RF, SUN scores among the four ranks (the bold italics) by ***TMAXEQ, TMINEQ, RFEQ, SUNEQ***. Then, ***TMAXEQ* = *60*, *TMINEQ* = *70*, *RFEQ* = *60*, *SUNEQ* = *43***. These numbers will be used in comparison in the following sections.

3. EXPERIMENT DWS (DIFFERENT WEIGHTING SCHEME)

The weights of the ECMWF fields were varied to see if better analogues would show up. Scheme SF, 85, 50, 20 denote weighting schemes of greater weight (set to be 3, while weights at the other levels are set to be 1) at the surface, 850 hPa, 500 hPa, 200 hPa level, respectively, and Tables 3.1 to 3.16 show the verification results for these schemes. For each scheme, denote the maximum TMAX, TMIN, RF, SUN scores among the four ranks by ***TMAX&&***, ***TMIN&&***, ***RF&&***, ***SUN&&***, where ***&&*** are alpha-numerals representing the relevant scheme.

Rank 1	F	W	M	average
TMAX	40	40	20	33
TMIN	50	70	20	47
RF	100	60	20	***60***
SUN	60	50	0	***37***

Table 3.1 : Rank 1 analogue. Scheme SF.

Rank 2	F	W	M	average
TMAX	30	50	40	40
TMIN	60	50	30	47
RF	90	30	20	47
SUN	20	70	10	33

Table 3.2 : Rank 2 analogue. Scheme SF.

Rank 3	F	W	M	average
TMAX	60	70	40	***57***
TMIN	80	60	40	***60***
RF	70	40	20	43
SUN	40	40	20	33

Table 3.3 : Rank 3 analogue. Scheme SF.

Rank 4	F	W	M	average
TMAX	60	20	40	40
TMIN	40	30	50	40
RF	90	60	20	57
SUN	50	40	0	30

Table 3.4 : Rank 4 analogue. Scheme SF.

Rank 1	F	W	M	average
TMAX	40	40	50	43
TMIN	20	60	40	40
RF	100	50	20	57
SUN	60	30	0	30

Table 3.5 : Rank 1 analogue. Scheme 85.

Rank 2	F	W	M	average
TMAX	70	40	40	***50***
TMIN	70	60	30	***53***
RF	90	20	20	43
SUN	40	50	10	33

Table 3.6 : Rank 2 analogue. Scheme 85.

Rank 3	F	W	M	average
TMAX	80	50	10	47
TMIN	70	40	40	50
RF	80	70	20	57
SUN	50	50	30	***43***

Table 3.7 : Rank 3 analogue. Scheme 85.

Rank 4	F	W	M	average
TMAX	40	50	20	37
TMIN	50	60	40	50
RF	90	60	30	***60***
SUN	50	40	40	43

Table 3.8 : Rank 4 analogue. Scheme 85.

Rank 1	F	W	M	average
TMAX	40	40	40	40
TMIN	40	30	30	33
RF	100	40	20	53
SUN	70	40	10	***40***

Table 3.9 : Rank 1 analogue. Scheme 50.

Rank 2	F	W	M	average
TMAX	40	50	40	***43***
TMIN	50	50	40	47
RF	90	50	20	53
SUN	40	20	0	20

Table 3.10 : Rank 2 analogue. Scheme 50.

Rank 3	F	W	M	average
TMAX	70	40	10	40
TMIN	90	40	20	***50***
RF	90	50	30	***57***
SUN	50	50	10	37

Table 3.11 : Rank 3 analogue. Scheme 50.

Rank 4	F	W	M	average
TMAX	50	30	0	27
TMIN	50	50	10	37
RF	90	30	40	53
SUN	50	50	20	40

Table 3.12 : Rank 4 analogue. Scheme 50.

Rank 1	F	W	M	average
TMAX	30	40	50	40
TMIN	50	40	50	***47***
RF	100	40	10	50
SUN	30	60	10	33

Table 3.13 : Rank 1 analogue. Scheme 20.

Rank 2	F	W	M	average
TMAX	60	50	10	40
TMIN	70	40	30	47
RF	80	30	20	43
SUN	50	60	10	***40***

Table 3.14 : Rank 2 analogue. Scheme 20.

Rank 3	F	W	M	average
TMAX	30	40	30	33
TMIN	60	50	30	47
RF	90	50	20	***53***
SUN	40	60	10	37

Table 3.15 : Rank 3 analogue. Scheme 20.

Rank 4	F	W	M	average
TMAX	50	50	30	***43***
TMIN	60	60	20	47
RF	90	10	40	47
SUN	40	30	30	33

Table 3.16 : Rank 4 analogue. Scheme 20.

A trend of scores decreasing with ranks is again not apparent. For ease of comparison, the maximum scores of each scheme are put together in Table 3.17.

	Scheme EQ	Scheme SF	Scheme 85	Scheme 50	Scheme 20
TMAX&&	***60***	57	50	43	43
TMIN&&	***70***	60	53	50	47
RF&&	***60***	60	60	57	53
SUN&&	***43***	37	43	40	40

Table 3.17 : Maximum TMAX, TMIN, RF and SUN scores achieved in various weighting schemes.

It is interesting to note that, ***TMAXEQ*** ≥ ***TMAX&&***, ***TMINEQ*** ≥ ***TMIN&&***, ***RFEQ*** ≥ ***RF&&***, ***SUNEQ*** ≥ ***SUN&&***, for ***&&*** = ***SF***, ***85***, ***50***, ***20***. In other words, simply increasing the weight of individual levels does not improve the accuracy of the analogue forecasts. In fact, the analogues sometimes just swapped in rank when the weights were varied. A noteworthy feature is that the maximum scores in general increase with the greater weight shifting towards lower level.

4. EXPERIMENT SA (SELECTIVE AVERAGE)

As shown in Tables 1.1 to 1.4, rank 1 analogue forecast in general does not have the highest scores of all of the four meteorological elements. The forecaster may at times exercise subjective judgement and take lower rank analogue forecasts into consideration. Following WMO's recommendation (WMO, 1991), an average approach was tried out for the four analogue forecasts. RF of the average was taken as Y if one or more of the analogue forecasts had RF equal to Y. Table 4.1 shows the verification results of the Four-Average (4A) for Scheme EQ.

4A	F	W	M	average
TMAX	90	100	50	***80***
TMIN	90	90	30	70
RF	60	60	30	50
SUN	20	20	50	30

Table 4.1 : 4A. Scheme EQ.

Recalling that ***TMAXEQ = 60*** and ***TMAXEQ ≥ TMAX&&*** for ***&& = SF, 85, 50, 20,*** the improvement in TMAX forecasts is prominent. The number of correct forecasts increases by 20 percent. The RF and SUN scores does not improve much. Careful examination of the entries in Table 4.1 and comparison with Table 1.1 to 1.4 indicates that RF and SUN forecasts in F cases, and SUN forecasts in W cases are worse than the individual analogue forecasts; while RF and SUN forecasts in M cases, and RF forecasts in W cases are better than the individual analogue forecasts. The average process mingled different kinds of weather situations. 4A of the other weighting schemes were also verified and the results are shown in Tables 4.2 to 4.5.

4A	F	W	M	average
TMAX	80	80	40	67
TMIN	100	80	40	73
RF	50	70	40	53
SUN	20	30	50	***33***

Table 4.2 : 4A. Scheme SF.

4A	F	W	M	average
TMAX	90	90	40	73
TMIN	100	90	40	*77*
RF	60	70	60	***63***
SUN	20	10	40	23

Table 4.3 : 4A. Scheme 85.

4A	F	W	M	average
TMAX	80	90	40	70
TMIN	90	90	30	70
RF	70	60	50	60
SUN	30	10	40	27

Table 4.4 : 4A. Scheme 50.

4A	F	W	M	average
TMAX	70	70	30	57
TMIN	80	80	50	70
RF	70	60	50	60
SUN	20	10	30	20

Table 4.5 : 4A. Scheme 20.

For the other weighting schemes, both TMAX and TMIN forecasts improve significantly. At least 70 percent of TMIN forecasts are correct. The average method gives a rather accurate forecast for the daily minimum temperature, an element of great concern during winter. Recall that ***RFEQ = 60*** and ***RFEQ ≥ RF&&*** for ***&& = SF, 85, 50, 20. RFEQ*** is exceeded here by using 4A with Scheme 85.

As discussed above, simply averaging the analogue forecasts will include undesirable members. A selective averaging approach could hopefully get around this problem. The idea is to screen out undesirable analogues and to identify the majority group of weather suggested by the analogues left. The average is then taken within the majority group. An algorithm as follows was developed to find the majority group of the analogues:

(a) Discard the analogues having local prevailing wind direction inconsistent with the forecast surface chart. This helps to screen out the situations when local weather was controlled by mesoscale systems.

(b) Group the analogues according to the following scheme:

SUN ≤ 4, RF = N	SUN > 4, RF = N
SUN ≤ 4, RF = Y	SUN > 4, RF = Y

(c) Identify the group with three members or more out of four as the majority group, and take average within the group.

(d) If the majority group cannot be identified in (2) and (3), group the analogues according to the following schemes:

SUN ≤ 4	SUN > 4

and

RF = N
RF = Y

(e) Identify the group with greatest number of members as the majority group, and take average within the group.

(f) If both schemes in (d) give groups with same number of members, all analogues in the two groups will be averaged.

(g) If the majority group cannot be determined in any way, simply average the analogues.

In the situations of (f) and (g), there is a high degree of uncertainty in the weather suggested by the analogues.

Some examples of applying the algorithm are given below. Except for examples (iv) and (vi), the majority group is shaded. In examples (iii) and (v), one analogue is discarded by criterion (a). The selective average is taken within the shaded area.

(i)	SUN≤4	SUN>4
RF=N	•	•••
RF=Y		

(ii)	SUN≤4	SUN>4
RF=N	•	•
RF=Y	••	

(iii)	SUN≤4	SUN>4
RF=N	•	••
RF=Y		

(iv)	SUN≤4	SUN>4
RF=N		•
RF=Y	•	••

(v)	SUN≤4	SUN>4
RF=N	••	
RF=Y		•

(vi)	SUN≤4	SUN>4
RF=N	•	•
RF=Y	•	•

The verification results of SA for Scheme EQ, SF, 85, 50, 20 are shown in Table 4.6 to 4.10, respectively.

SA	F	W	M	average
TMAX	80	80	50	70
TMIN	80	80	20	60
RF	90	60	20	57
SUN	60	30	50	47

Table 4.6 : SA. Scheme EQ.

SA	F	W	M	average
TMAX	60	50	30	47
TMIN	90	90	40	73
RF	90	50	30	57
SUN	40	40	60	47

Table 4.7 : SA. Scheme SF.

SA	F	W	M	average
TMAX	90	70	50	70
TMIN	100	70	40	70
RF	90	70	40	67
SUN	60	40	40	47

Table 4.8 : SA. Scheme 85.

SA	F	W	M	average
TMAX	70	70	30	57
TMIN	80	80	20	60
RF	100	60	30	63
SUN	60	20	40	40

Table 4.9 : SA. Scheme 50.

SA	F	W	M	average
TMAX	60	70	30	53
TMIN	70	90	30	63
RF	80	20	30	43
SUN	30	10	40	27

Table 4.10 : SA. Scheme 20.

Some interesting results are observed if the scores obtained in each scheme are put together as shown in Table 4.11.

SA	Scheme EQ	Scheme SF	Scheme 85	Scheme 50	Scheme 20
TMAX	70	47	***70***	57	53
TMIN	60	***73***	70	60	63
RF	57	57	***67***	63	43
SUN	47	47	***47***	40	27

Table 4.11 : TMAX, TMIN, RF and SUN scores of SA obtained in various weighting schemes.

The maximum score of TMIN is achieved in Scheme SF; while those of the other three meteorological elements are achieved in Scheme 85. ***TMAXEQ, TMINEQ, RFEQ*** and ***SUNEQ*** are exceeded here. The scores generally increase with the greater weight shifting towards lower level. This finding is in accordance with the usual thinking that the lower atmosphere is more important in controlling local weather during winter.

5. AN EXAMPLE

There was a cold spell in February 1996. Starting from 18 February, the cold spell lasted for more than ten days and the daily minimum temperature stayed below ten degrees for a whole week. The daily minimum temperature dropped drastically from 15.7 degrees on 17 February to 8.5 degrees on 18 February. The SA method with Scheme 85 was applied to 18 February 1996. The results are shown in Table 5.1.

Scheme 85	TMAX	TMIN	RF	SUN	DIR
Actual (18-2-96)	15.7	8.5	Y	0.6	010
SA	15.0	10.2	Y	1.9	
Rank 1	17.8	11.4	Y	5.8	360
Rank 2	20.7	15.5	N	1.1	070
Rank 3	15.5	11.5	N	0	010
Rank 4	11.6	7.6	Y	0	010

Table 5.1 : SA, Scheme 85 for 18 February 1996.

In generating the SA, rank 2 was discarded because it was an easterly situation whereas the actual situation was a northerly one. The other three analogues were then averaged according to the algorithm. If the T + 48 hr ECMWF prognosis based on 16 February 1996 was used to run the system, TMIN of SA, Scheme 85 would be 11.1 degrees. Although TMIN of the SA did not fall within 1.5 degrees of the minimum on 18 February, the forecaster would have been alerted to possible significant drop in temperature because the TMIN on 17 February was 15.7 degrees. All the other weather elements were essentially correct.

6. CONCLUDING REMARKS

Within the sample of data studied, a selective averaging algorithm together with Scheme 85 produced composite analogue forecasts which outperformed the forecasts generated by the existing system. SA Scheme 85 has been incorporated into the CFO graphics menu "fctools" which should help the forecaster in better interpreting guidance provided by the synoptic analogue forecast system. The individual analogue forecasts are still available to the forecaster to alert the forecaster of possible diversified weather scenarios.

The results in this study only apply to winter situations. Further work could be carried out for summer situations but as convective rain and tropical cyclones are mesoscale systems the usefulness of a synoptic analogue forecast system in summer will be very limited.

7. POST STUDY NOTE

Prognosis up to T+120 hr from Japan Meteorology Agency (JMA) can now also be used in the system. As the system assumes perfect prognosis, the results in this study also apply to the situation when JMA forecasts are used in the analogue search.

8. REFERENCES

1.	Poon H. T. and W. M. Ma	1992	The Royal Observatory Synoptic Analogue Forecast System, paper presented at the Seventh Guangdong-Hong Kong-Macau Joint Seminar on Harzardous Weather held at Macau in December 1992.
2.	WMO	1991	WMO Program on Short and Medium Range Weather Prediction Research Report Series No. 34, lecture presented at the WMO Training Workshop on the Interpretation of NWP products in terms of Local Weather Phenomena and their Verification.
3.	Li, S. W.	1996	Royal Observatory's Objective Forecast Verification Schemes, Royal Observatory Technical Note (local) 70.

Appendix I

List of formulae:

$ACC = \langle F - C - \overline{F - C} \rangle \langle A - C - \overline{A - C} \rangle$

F = Forecast

A = Analysis

C = Climatology

$S1 = (\Sigma(f - a)^{i}_{i,j} + \Sigma(f - a)^{j}_{i,j}) / (\Sigma g_i + \Sigma g_j)$

$t^{i}_{i,j} = | t(i,j) - t(i+1,j) |$

$t^{j}_{i,j} = | t(i,j) - t(i,j+1) |$

$g_i = \max\{|f^{i}_{i,j}|, |a^{i}_{i,j}|\}$

$g_j = \max\{|f^{j}_{i,j}|, |a^{j}_{i,j}|\}$

f(i,j) = forecast

a(i,j) = analysis

The ACC for the wind field is calculated as follows:

$acc(uv) = sgn(z(u,v)) \sqrt{|z(u,v)|}$

where $z(u,v) = sgn(acc(u))acc(u)^2 + sgn(acc(v))acc(v)^2$

ACC and S1 score are normalized to be between 0 and 2.

Normalized ACC	(a) = -1*(ACC - 1)
Normalized S1	(s) = S1/100

The similarity score (SS) is calculated as follows:

$SS = (\sum_i r \frac{w_{i,a}}{\overline{w_a}} a_i + \frac{w_{i,s}}{\overline{w_s}} s_i) / 2(r + 1)$

r = ratio of weights between ACC & S1

$w_{i,a}$ = weight of ACC for field i

$w_{i,s}$ = weight of S1 for field i

$\overline{w_a} = \sum_i w_{i,a}$

$\overline{w_s} = \sum_i w_{i,s}$

a_i = normalized ACC score for field i

s_i = normalized S1 score for field i

Appendix II

Sample output of the HKO synoptic analogue system :

```
*** Analogues from T+ 48 forecast by ECMF based on 96112512 ***


Section 1 : Parameters

Date/time   :96112512
Fcst Hour   : 48
West  long:    95.0   East  long: 130.0
South lat :    10.0   North lat :  40.0
Weights      SFPP     50HH     85TT     85UV     20UV
  ACC        1.00     1.00     3.00     3.00     1.00
   S1        1.00     1.00     3.00     3.00     1.00
RATIO (ACC/S1) :      1.0
Search starts from 8501 to 9609
Within  30 days from the date (MMDD) of forecast
The first  4 analogues are listed
Fields to be displayed : SFPP  50HH  85TT  85UV  20UV

Section 2 : Weather Information
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YYMM	DD	MSLP	TMAX	TMIN	DP	RH	CLD	R/F	SUN	DIR	SPD
8612	25	1020.3	22.9	17.5	15.1	75.0	56.0	.0	4.2	6.0	4.8
9412	13	1019.6	20.3	16.3	14.9	85.0	98.0	3.6	.0	2.0	9.1
9512	15	1019.1	20.6	17.7	17.3	88.0	99.0	7.9	.0	4.0	9.5
9111	8	1016.0	27.0	22.0	18.4	72.0	41.09000.0		7.2	3.0	5.4

Section 3: Scores

Date	Rank	Score	SFPP		50HH		85TT		85UV		20UV	
			ACC	S1	ACC	S1	ACC	S1	ACC	S1	ACC	S1
861225	1	.53	.55	50.5	.53	33.6	.70	48.1	.50	73.7	.16	81.4
941213	2	.53	.70	50.4	.85	28.7	.67	54.6	.31	80.4	.59	76.3
951215	3	.53	.70	52.2	.76	34.4	.60	53.4	.36	78.9	.64	73.4
911108	4	.53	.42	57.2	.76	40.8	.64	56.1	.48	73.2	.44	73.9

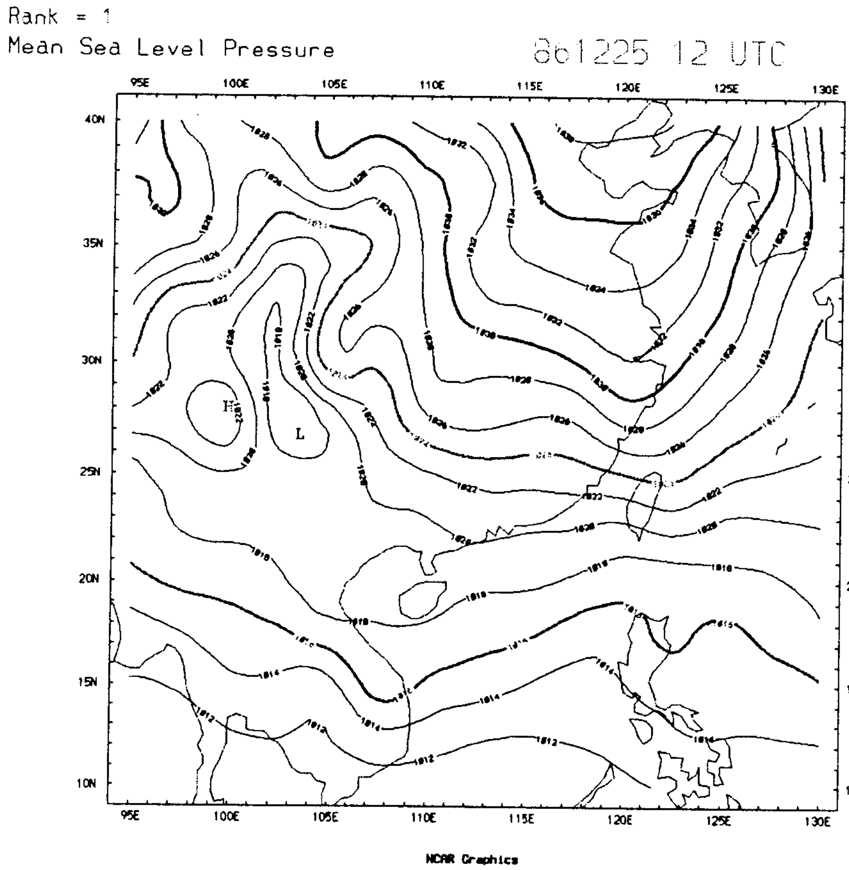

Figure A.1 : Surface pressure. Rank 1 analogue of T+48 hr forecast based on 25-11-1996.

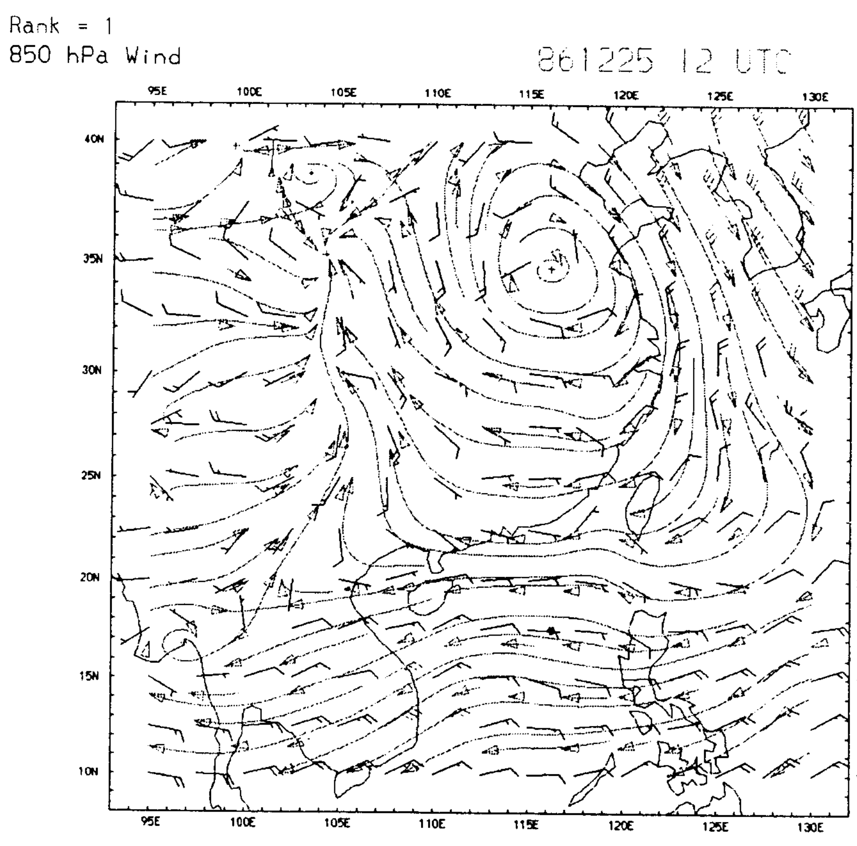

Figure A.2 : 850 hPa level wind. Rank 1 analogue of T+48 hr forecast based on 25-11-1996.

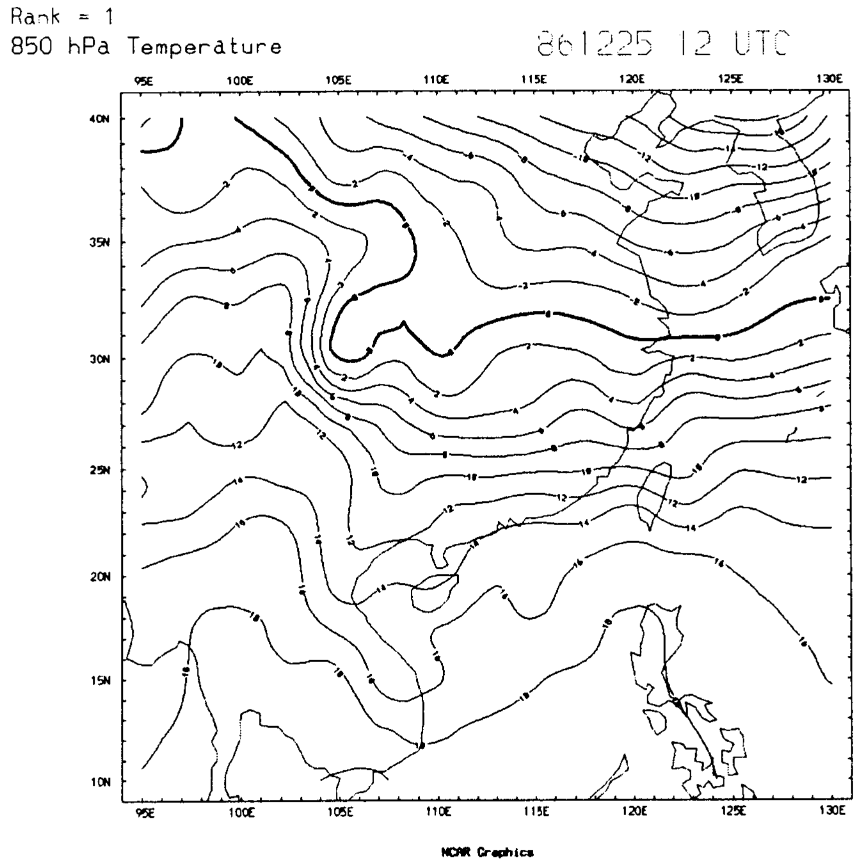

Figure A.3 : 850 hPa level temperature. Rank 1 analogue of T+48 hr forecast based on 25-11-1996.

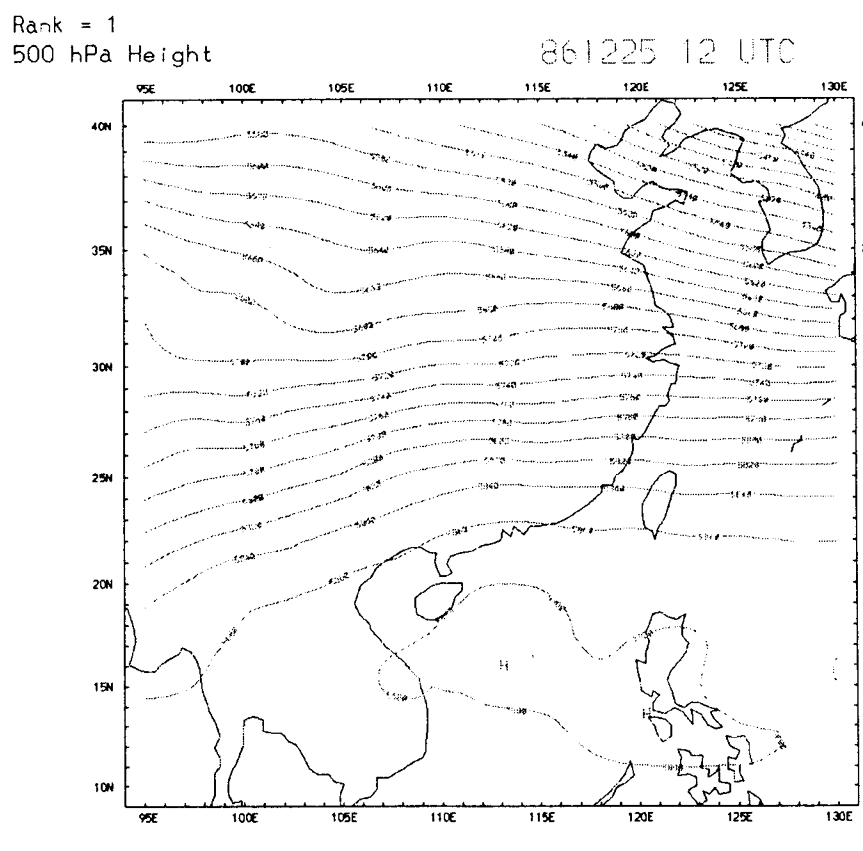

Figure A.4 : 500 hPa level geopotential height. Rank 1 analogue of T+48 hr forecast based on 25-11-1996.

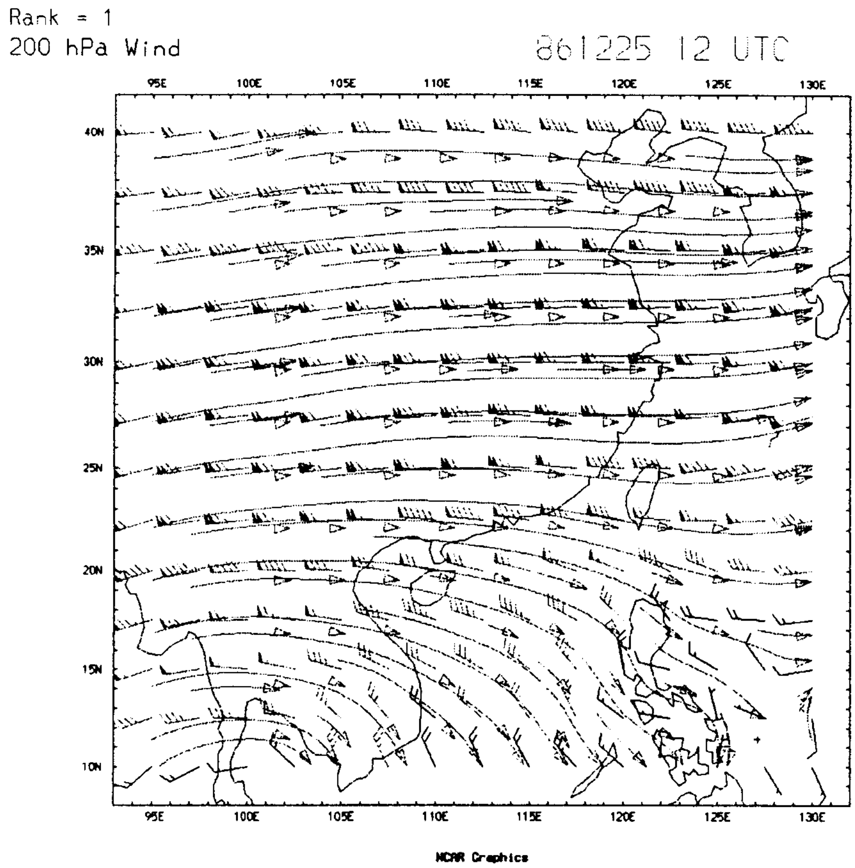

Figure A.5 : 200 hPa level wind. Rank 1 analogue of T+48 hr forecast based on 25-11-1996.

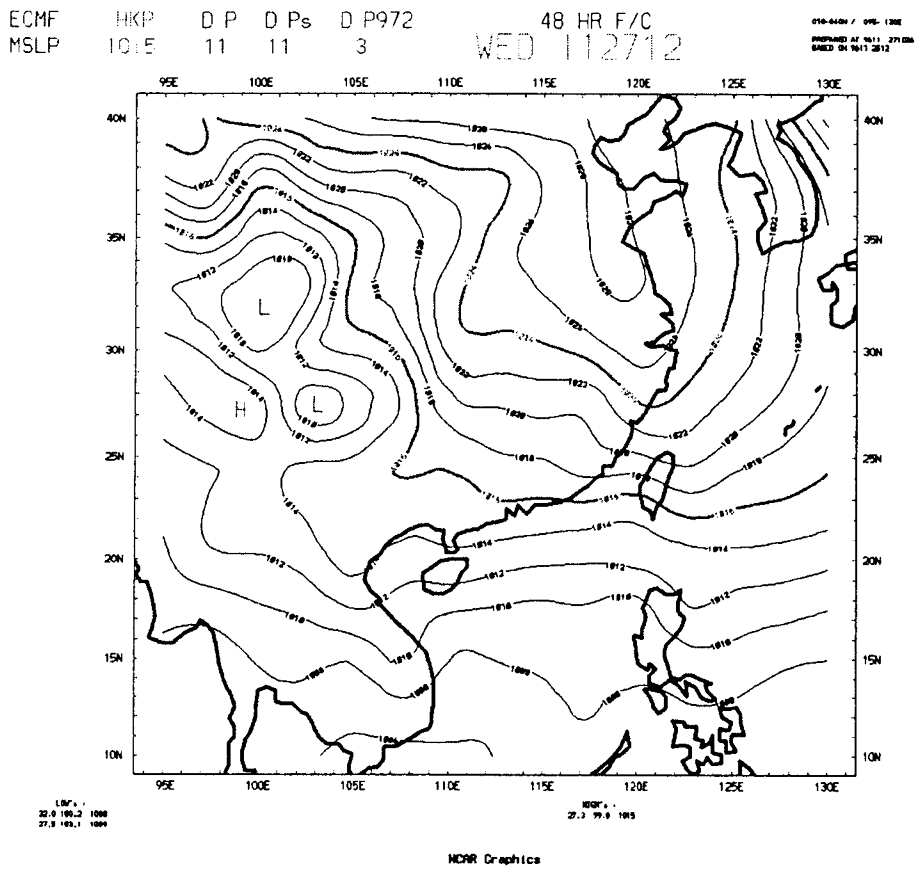

Figure A. 6 : Surface pressure. T+48 hr forecast based on 25-11-1996

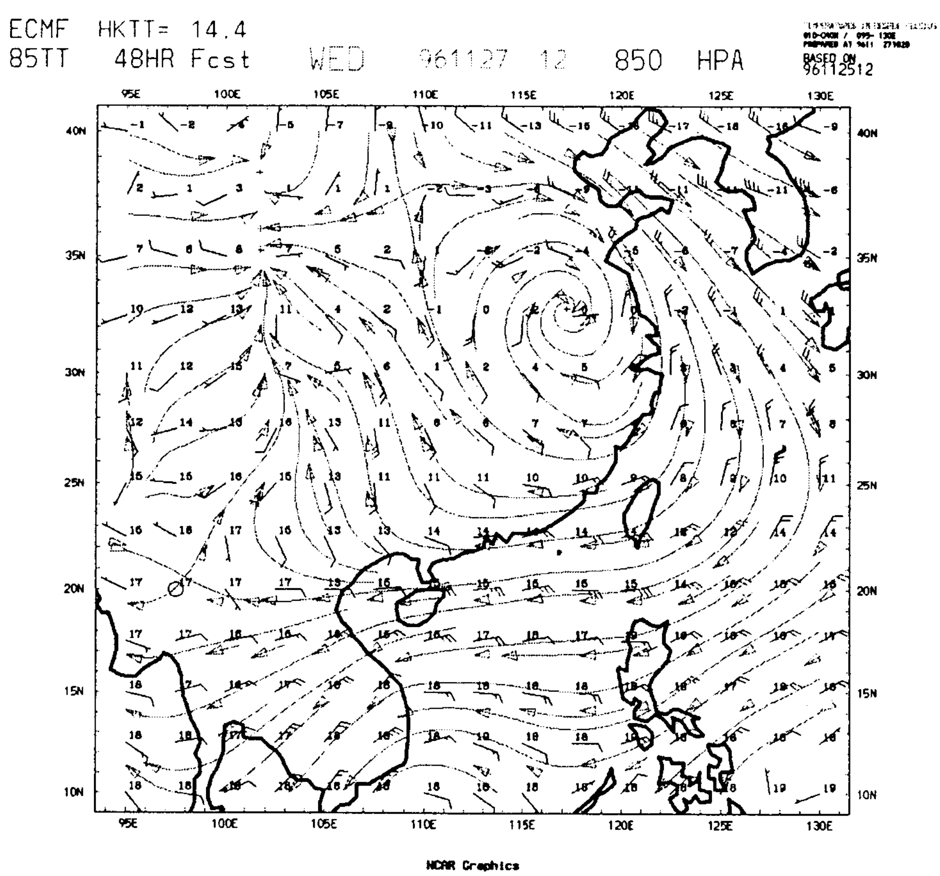

Figure A.7 : 850 hPa level wind. T+48 hr forecast based on 25-11-1996.

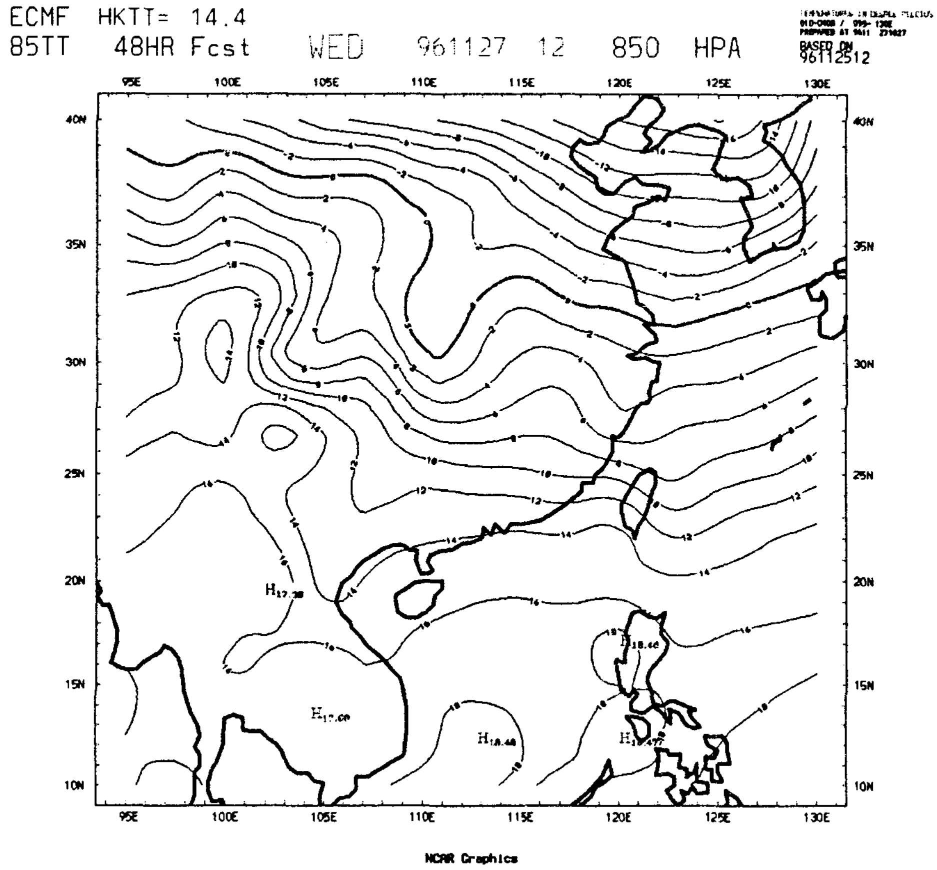

Figure A.8 : 850 hPa level temperature. T+48 hr forecast based on 25-11-1996

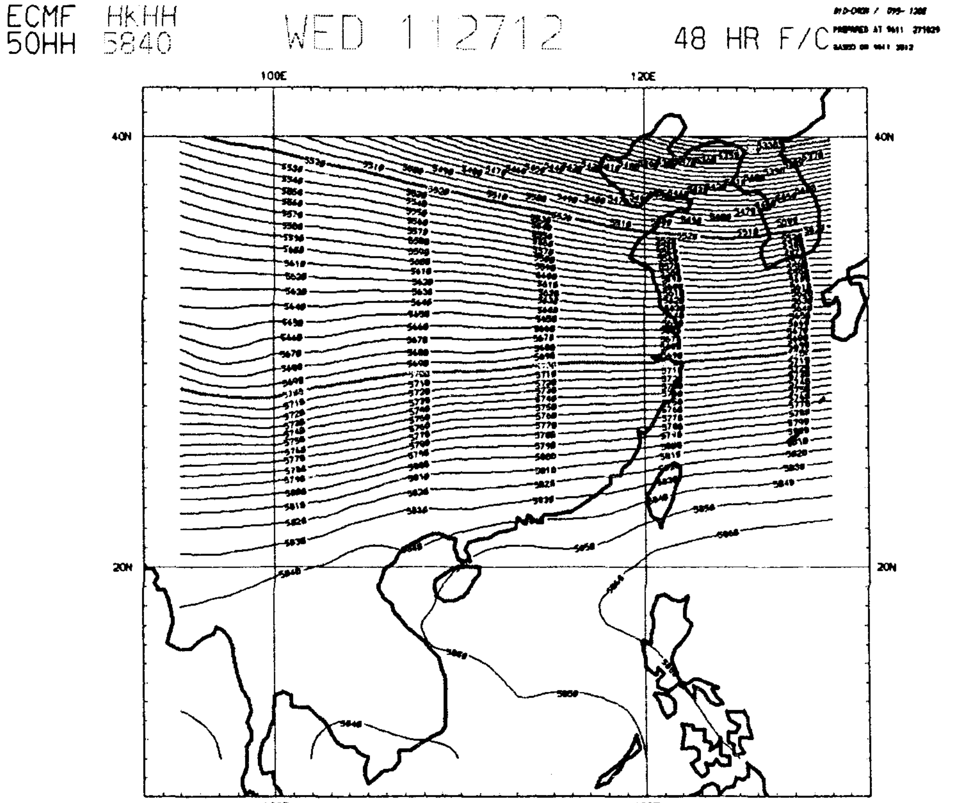

Figure A. 9 : 500 hPa level geopotential height. T+48 hr forecast based on 25-11-1996.

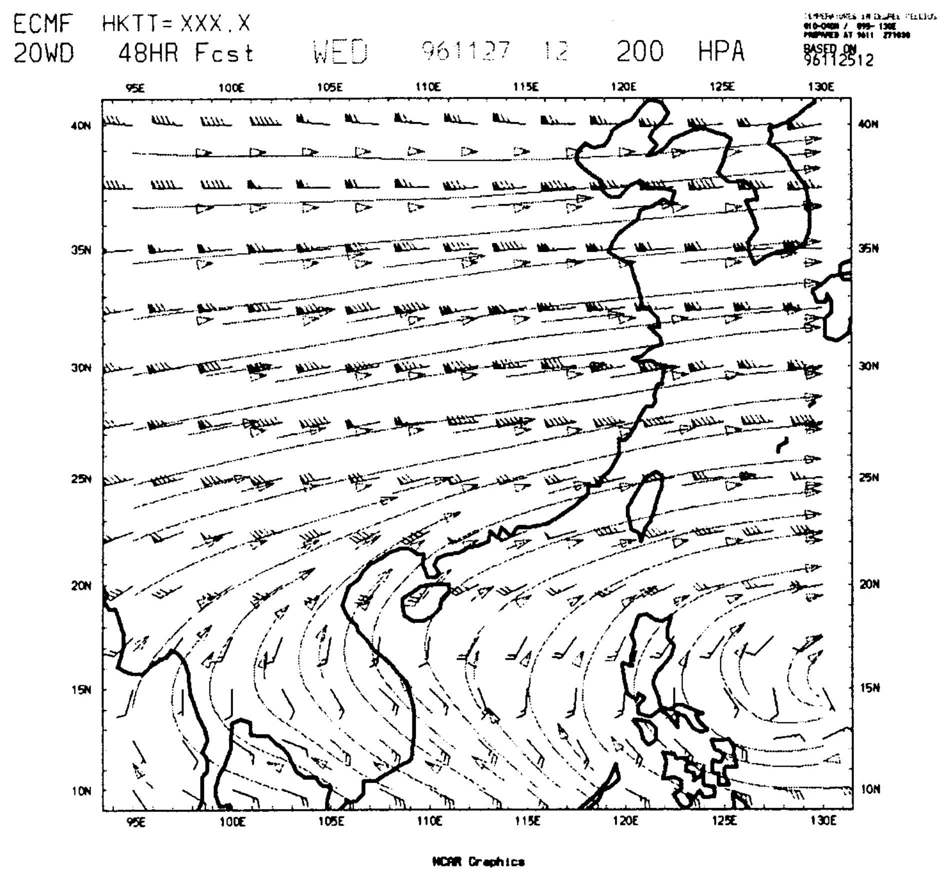

Figure A.10 : 200 hPa level wind. T+48 hr forecast based on 25-11-1996.

Appendix III

Data sample used in this study:

Date	Daily Maximum Temperature °C	Daily Minimum Temperature °C	Total Rainfall mm	Total Bright Sunshine hours	Prevailing Wind Direction degrees
23 November 1994	23.8	20.2	0.2	2.6	100
4 December 1994	22.0	17.8	0.7	6.2	030
16 December 1994	20.5	17.7	0.8	6.0	080
4 January 1995	16.2	11.5	0.2	9.6	010
5 January 1995	16.3	9.8	-	10.1	010
10 February 1995	18.7	15.1	-	10.3	070
13 February 1995	22.0	16.9	3.4	2.1	040
14 February 1995	17.5	15.2	13.9	-	080
8 October 1995	28.8	23.1	Trace	9.9	070
9 October 1995	28.8	24.1	6.3	7.4	020
17 October 1995	26.6	23.6	-	10.4	080
14 November 1995	23.4	16.0	0.5	-	010
20 November 1995	24.6	18.7	-	9.2	020
15 December 1995	20.6	17.7	7.9	-	040
18 December 1995	18.3	14.9	Trace	0.3	020
25 December 1995	18.3	13.9	-	4.8	070
4 January 1996	19.0	15.4	-	7.2	070
6 January 1996	22.6	19.6	0.4	2.2	050
16 January 1996	19.8	17.2	Trace	1.5	040
17 January 1996	19.3	16.6	0.6	0.5	080
24 January 1996	18.7	17.2	0.2	2.2	080
6 February 1996	17.8	13.4	2.7	0.2	070
7 February 1996	19.0	13.9	-	-	070
10 February 1996	17.5	12.8	-	10.1	080
11 February 1996	19.0	13.1	-	9.6	070
16 February 1996	22.3	17.4	0.5	-	080
5 March 1996	22.3	16.4	-	8.5	070
22 March 1996	22.4	17.8	1.5	-	030
27 March 1996	23.6	19.0	0.5	5.4	070
29 March 1996	24.8	19.3	55.9	3.8	070