THIRD YEAR FINAL TECHNICAL REPORT

TO

CENTRAL WEATHER BUREAU

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Research-Development and Technology Transfer of Mei-Yu and Typhoon Long-Range Forecasting in Taiwan

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1. REMARKS

The third year effort in this project is focused on the quantitative forecasting of Mei-Yu with single and multiple regression approaches. Following the first and second year effort that established the predictability of Mei-Yu at the seasonal range (up to three seasons), we have developed a general forecasting scheme that involves both the single and multiple regressions. Forecast experiments have been performed with both historical data and real-time data of 1990 fall and 1990-91 winter.

The forecast scheme and results of Mei-Yu experiments are described in the following sections of this report. Some important findings of this year's effort in the long-range forecasting of Mei-Yu are highlighted here:

1. The single-regression method can adequately forecast in the normal year. In the abnormal year with extreme situations such as Mei-Yu failure, however, the multiple-regression method must be employed. Thus the standard scheme should include the use of both single and multiple regressions.

2. Because of the localized scale of Mei-Yu phenomena, the consistency of the global teleconnection is vital. For this consistency we should check forecasts with various predictors, at different teleconnection sites, and with different months of predictors.

3. Sea surface temperatures (SSTs) account for the largest portion of variance. However, we may effectively substitute the 850mb temperature (T) for SST. The statement concerning SST in this report, thus may be read as 850mb T except proper modification to regressions should be made.

4. We recommend the use of three predictors in a multiple regression equation with a database period of ten years. The database period for the single regression should be more than thirty years.

5. Synoptic interpolation of regression forecast should consider the cross-correlation charts between predictands and predictors.

6. Effective employment of the developed scheme will allow a dependable long-range forecast of Mei-Yu. However, a proper updating of the scheme with new data and operational demand will be essential.

For the problem of typhoon long-range forecasting the main effort has been devoted to the background study as the Mei-Yu study progressed in the actual forecast study. Both the direct and indirect forecasts appear to be necessary for typhoon forecasting. For the latter it is recommended to first forecast the low and middle latitude configuration of circulation systems, and then interpret the configuration in terms of typhoon predictands. The problems for future study are discussed, and future approaches are suggested.

2. APPROACHES AND METHODS

The Mei-Yu long-range forecast is studied with both the single and multiple regressions. On the basis of last year's experience and successful real-time forecast, we have attempted to explore the general applicability of the single regression scheme through the study of historical cases for the long-term period. The multiple regression scheme has been simultaneously constructed, and its forecast experiment carried out with both real-time and historical records. Through examination of single and multiple regression forecasting, a forecast scheme has been designed to properly use regression methods, and to properly update and modify the scheme.

The method of single regression is detailed in our second year technical report (1990), and will not be reported here. This report assumes the familiarity of readers to the second year report, which may be regarded as an inseparable entity of this report. To formulate the multiple regression forecast the least-squares fitting of predictors are made to the general linear regression equation

$$\hat{y}=C_0+C_1X_1+C_2X_2+C_3X_3 \qquad (1)$$

where $\hat{y}$ is the expected value of a predictand y, c_i the regression coefficient, and x the predictor, where $i = 1$, 2 and 3. Three predictors are determined as sufficient to properly describe the regressions. More predictors would not gain in prediction (see Kung and Sharif, 1982; Kung and Tanaka, 1985). The number of necessary predictors are actually dependent on the period of database, which will be discussed later in this report. The first predictor x_1 is selected from the pool of predictors utilized in the single regression forecast, examining the cross-correlations and stability of predictors in the long-term time series. Such cross-correlation maps were previously forwarded to the Central Weather Bureau.

The second and third predictors, x_2 and x_3, are selected by the cross-correlation of the predictors and the residual components $e = \hat{y} - y$. The procedures are detailed in Kung and Tanaka (1985). Such a multiple regression scheme is formulated so that the regression residuals are minimized with the fewest possible predictors, and the collinearity among predictors is effectively reduced to near zero. For a single predictand (onset, recess, length of period or precipitation) with a single month's observed parameters (SST, 700mb T, 500mb Z and 700-500mb H, where Z is the geopotential height and H is the thickness) at least several multiple regressions are formulated.

In the real-time forecast, monthly data from September 1990 to February 1991 are utilized: all monthly data with the single regression, and October 1990 and January 1991 data for the multiple regression. In the historical case forecast we used January data from 1956 to 1990. The former are for the long-term database, and the latter for the 10-year database. In the historical case experiments, the predictands are obtained from regression equations, which are based on data of years preceding the forecast year. Thus the forecasting is completely free of the influence of database in model construction.

The database used in formulating the regressions include 700mb T, 500mb Z and 500-700mb H from the National Meteorological Center's (NMC) Northern Hemisphere octagonal data and SST grid data north of 20°S. The monthly means of

NMC octagonal data are averaged over 17x16 grid points from the original 47x51 grid points. The 9-point averaged 17x16 grid system is shown in Fig. 1. The real-time upper air data are processed at the Central Weather Bureau. After their use, they are averaged with existing NMC data as the updating of the basic dataset. The monthly SST data are obtained from NMC for January 1956-January 1991. These monthly SST values on a 2°x2° latitude-longitude grids are utilized as 4°x6° grid data by skipping grids in between.

A special note should be made about the use of SST data. As the real-time SST data are not available at the Central Weather Bureau, some alternatives must be sought. In a separate analytical study during this experiment period (Kung et al. 1991), we found that the 850mb T can replace SST as the parameter for the boundary forcing. The 850mb T has a special advantage in that it directly responds to the surface heating, and it can represent the heating field not only over the ocean, but also over the continental region. In the plateau region, such as the Eurasian continent, it is actually the level of heating. This is a fortunate finding which was not anticipated at the inception of this study. All the statements about SST thus apply to the 850mb T, and the modification of the scheme with 850mb T substituting for SST is recommended.

3. SINGLE REGRESSION FORECASTING

The real-time forecast for the 1991 Mei-Yu is summarized in Tables 1-5. **Table 1** lists single regression equations and predicted values of Mei-Yu onset with monthly real-time data of SST, 700mb T and 500mb Z from September 1990 to February 1991. Since the SST data in our possession are up to January 1991, SST is not used as a predictor for the month of February. Tables 2, 3 and 4 are respectively for the Mei-Yu recess, period, and total precipitation. Table 5 lists the results of the forecast separately for the different months of predictors. Two to six predictors of the same parameter in the same month at different locations, represent the strongest signal areas.

It is clear in these tables that the predicted values are reasonably consistent from location to location of high cross-correlations, and from month to month of predictors. The pattern shown here is about the same as reported in our second-year report of 1990 real-time prediction. The consistency among these 1991 forecasted values is actually better than that of 1990. On this basis we may assert that the mean values of these predictands for 1991 may be used as a reasonable forecast. The independently obtained length of the Mei-Yu period is consistent with the period calculated by recess-onset. In the case of small differences between these two lengths of period, it is suggested to take the independently obtained value from its own regression. This is because of our observation that the recess forecast is more difficult than those of the onset and length of period. It appears that the length of period is more closely related to the initial patterns of Mei-Yu, whereas the occurrence of recess is subject to many factors of related circulation systems.

Figures 2 and 3 illustrate the spatial distribution of forecast values by the location of predictors in September and October 1990. Those for other months are not shown, but they may be readily constructed from the listing in Tables 1-4. It should be noted that these locations move around in the Northern Hemisphere from month to month, suggesting an association of extremely slow moving waves with the predictability. It is strongly recommended that the synoptic interpretation of the forecast should consider the location of signal areas in reference to prevailing synoptic patterns.

Following the single regression forecast, a pertinent question is the stability of predictability with the single regression scheme. Table 6 lists some examples of differences of fitted and recorded Mei-Yu onset dates in experiments for the period of 1977-1990. It is readily seen that in some years, particularly in 1980 when Mei-Yu fails, the fitting notably fails for all predictands. It then indicates that the single regression will fail in these abnormal years. As will be seen later with the multiple regression experiments, the multiple regression can forecast well for these abnormal years (see Figs. 4 and 5). It should then be concluded that the use of single regression is not sufficient for Mei-Yu forecast, and we must also rely on the multiple regression. It is cautioned, however, that the need for the multiple regression does not negate the need for the single regression., Since the single regression gives a stable, convenient approach for the normal years, a parallel use of single and multiple regression methods will be mandatory.

4. MULTIPLE REGRESSION FORECASTING

Many series of forecast experiments have been conducted with multiple regression equations to study the optimum number of predictors, the optimum length of period for a database, the stability of predictability, etc. What is reported here is only the final conclusions after examination of an enormous volume of experimental data. The details omitted in this report's description may be obtained from our original records.

Figures 4 exemplifies typical results of forecasting experiments. With a 10-year database for regression formulation, the equation is used for the following 3 years. The first predictor is chosen from the single regression scheme predictors. Every year the regression is updated by shifting the period one year. Thus, except for the beginning and end of the experiment period, most years have three forecast values with three different equations of different levels of updating. When there is no close value with the record, the first predictor is replaced with an alternative, from either the 500mb Z or 700mb T field which performed well in the single regression forecast. When we choose one forecast closest to the record of the year in Fig. 4, we obtain the forecast results as shown in Fig. 5.

Comparison and examination of Figs. 4 and 5 shall reveal the following important information:

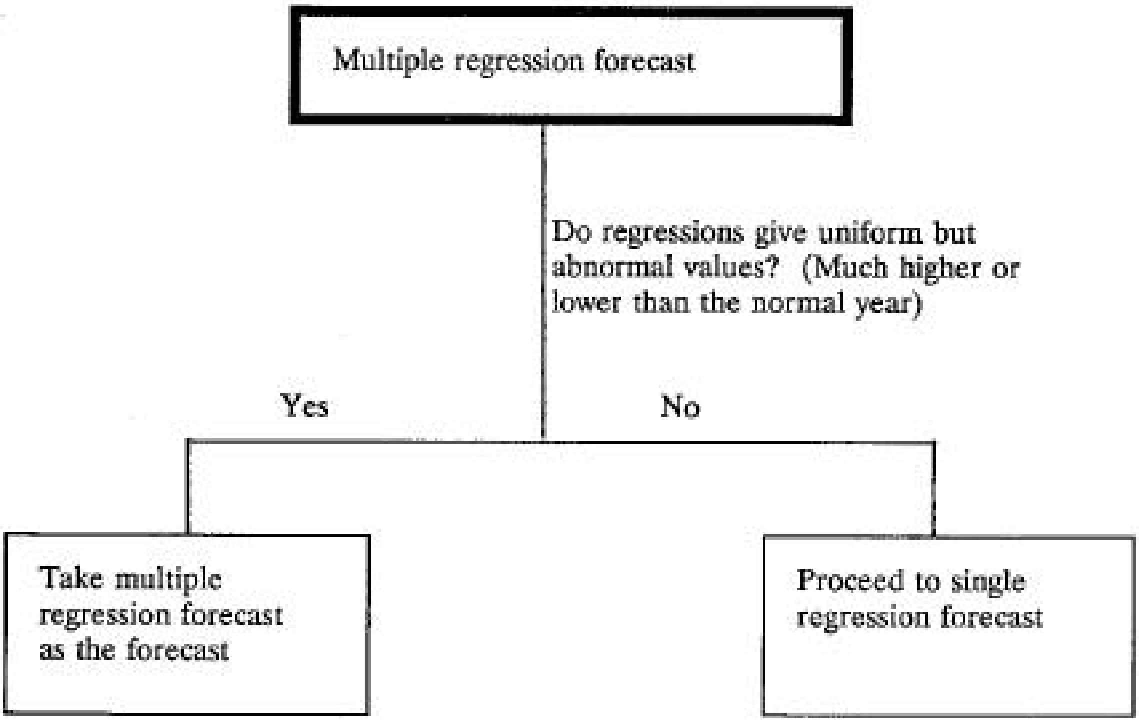
1. As shown in Fig. 4, in this group of predicted values there is a wide variation among the different regression equations, different in only the degree of updating. For the localized phenomena of Mei-Yu this is an inherent difficulty. However, as shown in Fig. 5, among a few predicted values of predictands, there is at least one forecasted value very close to the record. Clearly a good predictability exists.

2. With the 10-year database period for the formulation of regression equations, three predictors are sufficient. Increasing to five predictors does not give an apparent advantage. The examination of cumulative variance in regression fitting, the variance are saturated with three predictors at 96-99% of the total variance.

3. As shown in Fig. 5, the multiple regression scheme is able to forecast accurately in the abnormal years. Figure 4 further confirms that the variation among different regressions is the least in the abnormal years. As in the year 1980, the scheme very accurately forecasts the Mei-Yu failure except for the recess.

4. The Mei-Yu recess is more difficult to forecast than the length of the Mei-Yu period. It is suggested, in case of a conflict in the forecast for recess date and length of Mei-Yu period, that we should take the length of period and then determine the recess date by adding the length of period to the onset date. In the year of Mei-Yu failure as in 1980, the direct forecast of recess is difficult for almost nonexistent Mei-Yu patterns.

From the above information and our results from the single regression forecast, the forecast scheme to be employed should work in the following sequence:



First, multiple regression scheme should be used. If the results from various regressions (with SST, 700mb T, 500mb Z, and H at different points) give uniformly abnormal values of predictands, it shall be an abnormal year, and the forecast should be based on the multiple regression. However, if it give values in the normal range, we should proceed to a single regression forecast as we have developed, since the single regression gives more consistent results then multiple regression in the normal year.

The reason for the good results by the multiple regression in abnormal years is that the abnormal years represent the change in the operational mode of the general circulation, and this change should be reflected well in the second and third predictors. Conversely, when there is no such change (i.e., in normal years) single regression should provide an adequate and better forecast.

The real-time forecasts for 1991 are listed in Table 7. Regression equations are listed in Tables 8-11. It is clear that the forecasted values are within the normal year range with larger variations than those obtained with single regression (Table 5). According to the above discussion this is not the appearance of an abnormal year. Thus for 1991, we must take the forecasted values of the single regression method, which are listed in the second-year report and Table 5 of this report.

5. MEI-YU FORECAST SCHEME

Following the discussions in preceding sections, the long-range forecast scheme may be summarized as following. The equations employed in the forecast for this year are seen in Tables 1-4 for the single regression method and in Table 8 for the multiple regression.

1. Multiple regression forecast--The first step.

3 predictors

x_1 by the single regression scheme

x_2 and x_3 by objective selection (regressed on residual terms)

10-year database

Scheme useful for 3 consecutive years

Groups of regression equations for a single predictand (by month of data, location of x_i, and x_1)

If the abnormal Mei-Yu year is indicated (i.e. forecast values are consistently out of the range of 1.5 standard deviations of the recorded values), the forecast is completed.

If the normal Mei-Yu year is indicated, proceed to step 2.

2. Single regression forecast--The second step.

For the normal Mei-Yu year, take the results of the single regression forecast, as described in the second-year report and this report.

3. Check significant synoptic features. (Pay attention to the cross-correlation maps).

4. Update the database and regression equations for the next year.

6. TYPHOON FORECAST

As the major effort of this year is devoted to completing the Mei-Yu forecast scheme, the attention in the typhoon forecast is in exploration of viable methods in constructing the forecast scheme.

The forecast scheme of typhoon frequency in the Taiwan area, as reported in our second-year report, will be a basis for frequency and total precipitation for the typhoon origin. Additionally, the following information is obtained, and the continued work will proceed accordingly.

1. The predictands for the typhoon season include:

   Typhoon frequency in Taiwan area
   Precipitation from the Typhoon origin and during the typhoon season
   Typhoon strength
   Typhoon route

2. The forecast scheme will be constructed in accordance with the following steps:

   (1) Teleconnection analysis of typhoon frequency and precipitation with global observations in preceding seasons.

(2) Analyze the climatological data compiled by Mr. Shih-Ting Wang of the Central Weather Bureau to establish the relationship between predictands and circulation patterns in the low and middle latitude.

(3) Establish the teleconnections of the abovementioned circulation patterns with preceding global observations. Forecasted circulation patterns may then be interpreted in terms of typhoon strength and route. This indirect forecast shall be evaluated in conjunction with direct regression forecast.

(4) Real-time forecast experiment in 1992, 1993 and 1994.

7. TECHNOLOGY TRANSFER

Mr. Maw-Ching Chang and Mr. Yann-Jang Lin stayed two months each with the project from March to June 1991. They actively participated in the development research and have been given instruction and training for the use and modification of the forecast scheme. All of the related computer software and cross-correlation maps are forwarded through them.

REFERENCES

(All references listed in the second-year report are valid for this third-year report. The following list is for papers specifically referred to in this report.)

1. Kung, E.C., 1990: Second Year Final Technical Report to Central Weather Bureau.

2. Kung, E.C., and T.A. Sharif, 1982: Long-range forecasting of the Indian summer monsoon onset and rainfall with upper-air parameters and sea surface temperature. *J. Meteor. Soc. Japan*, **30**, 672-681.

2. Kung, E.C., and H. Tanaka: Long-range forecasting of temperature and precipitation with upper air parameters and sea surface temperatures in a multiple regression approach. *J. Meteor. Soc. Japan*, **60**, 619-631.

3. Kung, E.C., W. Min, J. Susskind and C.-K. Park, 1991: An analysis of simulated summer blocking episodes. (Submitted to *Quart. J. Roy. Meteor. Soc.*)

Table 1. Mei-Yu Onset date forecast for 1991 (Day 1=April 1) by upper air parameters and SST of preceding months. 700 mb T and SST are in the unit of °C, and 500 mb Z in m. 36-year database.
--- Regression $\hat{y} = a + B(x - c)$ ---

Month	Predictors (x)	a	b	c	x	$\hat{y}$
Sept.	SST					
	(34-42N, 153-141W)	48.05	3.54	21.51	21.16	47
	(2S-2N, 165-177E)	48.05	-4.29	28.92	29.82	44
	(18-14S, 165-159W)	48.05	10.70	26.64	27.44	57
	700mb T					
	(22-35N, 128-146E)	47.78	-4.51	283.40	282.72	51
	(38-47N, 117-104W)	47.78	-1.96	279.02	280.70	44
	(20-33N, 40-20W)	47.78	3.38	282.07	280.97	44
	500mb Z					
	(45-58N, 155E-180)	47.78	0.08	5569.83	5533.99	45
	(38-50N, 115-95W)	47.78	-0.12	5753.32	5806.93	41
	(20-30N, 30-15W)	47.78	-0.20	5891.77	5880.62	46
Oct.	SST					
	(42-50N, 165E-177W)	48.05	5.00	11.23	11.03	47
	(26-30N, 129-123W)	48.05	-6.14	20.81	21.78	42
	(2S-2N, 159-177E)	48.05	-7.11	28.94	29.80	42
	(14-10S, 89-105E)	48.05	9.99	26.30	27.21	57
	(18-10S, 135-117W)	48.05	-3.93	25.44	25.99	46
	700mb T					
	(50-70N, 115-140E)	47.79	1.59	257.27	258.56	50
	(30-38N, 110-100W)	47.79	-2.58	278.61	278.79	47
	(30-40N, 67-45W)	47.79	-2.70	278.53	278.59	48
	500mb Z					
	(15-23N, 47-28W)	47.79	0.22	5881.78	5878.82	47
	(15-28N, 6-14E)	47.79	0.22	5872.82	5888.16	51
	(23-28N, 72-80E)	47.79	0.21	5845.23	5858.91	51
Nov.	SST					
	(38-42N, 171-177E)	48.05	2.76	15.76	16.76	51
	(10-2S, 147-135W)	48.05	-4.75	26.56	26.82	47
	(6-2N, 98-87W)	48.05	-4.24	22.67	22.68	48
	700mb T					
	(21-33N, 148-165E)	47.79	-4.79	279.81	278.63	53
	(38-60N, 145-120E)	47.79	-1.06	264.47	263.32	49
	(25-40N, 77-55W)	47.79	-2.35	277.25	276.71	49
	(40-57N, 60-83E)	47.79	-2.12	263.28	264.95	44
	500mb Z					
	(32-40N, 175-165W)	47.79	0.07	5714.83	5726.75	49
	(23-38N, 117-101W)	47.79	0.18	5752.30	5782.22	53
	(15-27N, 54-66E)	47.79	0.15	5860.77	5869.68	48
	(40-48N, 73-85E)	47.79	-0.13	5619.65	5664.60	42

Dec.	SST					
	(30-34N, 165-177E)	48.05	9.99	20.08	20.18	49
	(10-14N, 87-93E)	48.05	-8.46	27.90	28.01	47
	(10-2S, 111-105W)	48.05	-1.86	23.87	23.61	49
	700mb T					
	(23-40N, 175E-175W)	47.79	3.53	275.03	274.33	45
	(45-62N, 120-147W)	47.79	-0.79	260.55	262.12	47
	(18-32N, 70-60W)	47.79	-2.03	279.34	280.07	46
	(23-38N, 33-48E)	47.79	1.81	273.79	276.11	52
	(40-50N, 83-98E)	47.79	-1.30	260.78	263.18	45
	500mb Z					
	(38-54N, 130-152E)	47.79	-0.09	5238.06	5303.84	41
	(21-31N, 177E-167W)	47.79	0.08	5792.14	5786.43	47
	(22-30N, 35-43E)	47.79	0.16	5764.89	5833.57	59
Jan.	SST					
	(26-30N, 165-171E)	48.05	10.65	21.59	21.38	47
	(10-6S, 147-141W)	48.05	-5.18	27.73	28.04	46
	700mb T					
	(23-30N, 168E-177W)	47.79	1.71	277.81	276.62	46
	(59-70N, 160E-160W)	47.79	1.12	252.96	253.10	48
	(50-60N, 113-96W)	47.79	-0.97	253.71	251.21	50
	(29-45N, 38-57E)	47.79	1.76	266.59	266.11	47
	500mb Z					
	(34-40N, 135-143E)	47.79	-0.06	5416.27	5415.21	48
	(34-40N, 140-130W)	47.79	0.05	5681.41	5727.25	50
	(20-25N, 10-3W)	47.79	0.10	5804.32	5814.29	49
	(32-42N, 45-60E)	47.79	0.12	5572.91	5576.80	48
Feb.	700mb T					
	(35-50N, 134-154E)	47.79	0.88	257.40	255.84	46
	(38-55N, 103-123W)	47.79	-0.97	263.40	263.40	48
	(10-24N, 70-55W)	47.79	-2.79	280.91	280.96	48
	500mb Z					
	(40-48N, 127-152E)	47.79	0.05	5275.46	5258.07	47
	(10-33N, 148-135E)	47.79	0.15	5771.57	5774.07	48
	(50-70N, 55-92E)	47.79	-0.07	5280.56	5299.02	47

Table 2. Mei-Yu Recess date forecast for 1991 (Day 1=April 1) by upper air parameters and SST of preceding months. 700 mb T and SST are in the unit of °C, and 500 mb Z in m. 36-year database.
--- Regression y = a + B(x - c)---

Month	Predictors (x)	a	b	c	x	ŷ
Sept.	SST					
	(34-38N, 177E-171W)	78.92	4.81	23.73	23.28	78
	(26-34N, 69-57W)	78.92	-6.70	27.84	28.07	77
	700mb T					
	500mb Z					
	(32-40N, 134-144E)	79.22	-0.16	5808.11	5840.37	74
	(30-38N, 38-63E)	79.22	-0.18	5850.70	5880.90	74
	(24-33N, 78-98E)	79.22	0.27	5847.43	5851.62	80
Oct.	SST					
	(34-38N, 177-165W)	78.92	4.20	20.98	22.18	84
	(22-26N, 153-159E)	78.92	7.19	28.38	27.98	76
	(14-18N, 111-117E)	78.92	3.71	28.34	28.09	78
	700mb T					
	(22-30N, 105-98W)	79.21	-3.24	281.60	282.09	78
	(35-42N, 18-8W)	79.21	2.03	275.87	274.98	77
	(37-52N, 97-110E)	79.21	-1.11	270.27	271.38	78
	500mb Z					
	(32-40N, 135-144E)	79.22	-0.16	5808.11	5840.37	74
	(30-38N, 38-63E)	79.22	-0.18	5850.70	5880.90	74
Nov.	SST					
	(22-30N, 165-171E)	78.92	10.29	25.99	25.48	74
	(30-38N, 75-57W)	78.92	-7.04	23.32	23.16	80
	700mb T					
	(16-28N, 168-178E)	79.21	3.08	232.23	280.65	74
	(30-40N, 165-145W)	79.21	2.39	275.70	274.15	76
	(30-43N, 44-63E)	79.21	-2.10	272.05	274.93	73
	500mb Z					
	(32-43N, 150-170E)	79.21	-0.10	5632.21	5712.22	71
	(33-40N, 67-57W)	79.21	-0.13	5730.09	5705.25	83
	(27-42N, 18-5W)	79.21	-0.12	5742.76	5767.39	76

Month	Predictors (x)	a	b	c	x	$\hat{y}$
Dec.	SST					
	(22-30N, 165-177E)	78.92	9.74	24.00	23.35	73
	(34-38N, 69-57W)	78.92	-4.69	21.02	21.15	78
	700mb T					
	500mb Z					
	(23-38N, 117-128E)	79.21	-0.12	5672.43	5700.86	76
	(26-34N, 144-136W)	79.21	0.13	5789.63	5771.73	77
		79.21	-0.10	5703.31	5695.50	80
Jan.	SST					
	(30-34N, 147-141W)	78.92	7.42	18.75	18.71	79
	(22-30N, 165-177E)	78.92	5.37	22.80	22.79	79
	(18-22N, 147-153E)	78.92	6.51	26.51	25.87	75
	(18-10S, 106-111E)	78.92	-6.70	27.83	27.80	79
	700mb T					
	500mb Z					
	(14-26N, 151-141W)	79.21	0.12	5819.63	5821.06	79
	(23-33N, 80-98E)	79.21	0.05	5700.46	5689.93	79

Table 3. Mei-Yu period forecast (days) for 1991 (Day 1=April 1) by upper air parameters and SST of preceding months. 700 mb T and SST are in the unit of °C, and 500 mb Z in m. 36-year database.

--- Regression $\hat{y} = a + B(x - c)$ ---

Month	Predictors (x)	a	b	c	x	$\hat{y}$
Sept.	SST					
	(34-38N, 177E-165W)	31.84	4.50	23.68	23.61	32
	(14-18N, 165-171E)	31.84	-6.80	28.89	28.70	33
	(14-18N, 147-141W)	31.84	5.70	26.70	27.54	37
	700mb T					
	500mb Z					
	(48-57N, 173E-180)	32.41	-0.13	5530.55	5481.33	39
	(23031N, 165-157W)	32.41	0.28	5870.16	5875.83	34
	(18-33N, 88-98E)	32.41	0.30	-5854.19	5847.00	30
Oct.	SST					
	(30-34N, 177-165W)	31.84	4.96	23.77	24.61	36
	(30-34N, 75-69W)	31.84	-5.89	25.89	25.80	32
	(18-26N, 135-141E)	31.84	6.84	28.73	28.64	31
	(18-22N, 69-63W)	31.84	11.01	28.55	28.59	32
	(2-6N, 177-171W)	31.84	5.54	28.49	29.76	39
	(22-26N, 147-153E)	31.84	14.00	28.31	28.44	34
	(10-6S, 165-171E)	31.84	10.04	29.24	29.73	37
	700mb T					
	(21-33N, 148-165E)	32.40	3.91	282.64	282.00	30
	(30-40N, 68-45W)	32.40	1.38	278.53	278.65	33
	(33-45N, 18-5W)	32.40	2.79	275.12	273.95	29
	(38-50N, 112-137E)	32.40	-2.15	267.21	268.09	31
	500mb Z					
	(33-42N, 100-88W)	32.40	0.13	5760.83	5767.13	33
	(19-21N, 25-17W)	32.40	-0.35	5883.45	5899.00	27
Nov.	SST					
	(22-26N, 177E-177W)	31.84	8.88	26.18	26.33	33
	(6S-2N, 129-117W)	31.84	2.40	24.65	24.79	32
	(14-10S, 105-111E)	31.84	-9.08	27.35	28.03	26
	(26-22S, 141-135W)	31.84	-6.25	23.70	24.82	25
	700mb T					
	(16-24N, 160-178E)	32.40	5.29	282.87	282.15	29
	(30-38N, 157-145W)	32.40	4.62	276.58	275.38	27
	(24-33N, 69-60W)	32.40	2.04	279.12	279.19	33
	(24-33N, 45-56E)	32.40	-3.68	277.85	278.96	28

	500mb Z					
	(55-70N, 120-160E)	32.40	0.07	5169.47	5184.97	33
	(31-39N, 173-176E)	32.40	-0.14	5938.86	5743.83	32
	(21-28N, 127-116W)	32.40	-0.27	5828.16	5839.91	29
	(18-25N, 98-113E)	32.40	-0.42	5854.72	5865.72	28
Dec.	SST					
	(18-22N, 135-141E)	31.84	12.51	27.17	26.94	29
	(2-6N, 105-99W)	31.84	3.96	25.81	26.61	35
	700mb T					
	(17-29N, 143-163E)	32.40	1.98	283.05	282.99	32
	(32-34N, 147-128W)	32.40	3.49	277.34	276.21	28
	(17-32N, 70-60W)	32.40	1.77	279.33	280.07	34
	(38-57N, 61-83E)	32.40	1.52	260.33	261.66	34
	(32-50N, 113-130E)	32.40	-1.24	261.23	262.82	30
	500mb Z					
	(23-32N, 174-167W)	32.40	-0.12	5782.70	5771.98	34
	(22-33N, 145-128W)	32.40	0.15	5804.58	5780.80	29
Jan.	SST					
	(38-42N, 171-177E)	31.84	-4.23	12.08	13.66	25
	(2S-6N, 177-171W)	31.84	3.08	28.98	28.98	35
	700mb T					
	(17-25N, 130-152E)	32.40	1.77	281.63	281.00	31
	(50-68N, 160-178E)	32.40	-1.31	253.72	254.46	31
	(40-50N, 105-92W)	32.40	1.28	259.90	258.66	31
	(28-37N, 38-47E)	32.40	-2.36	268.88	268.82	33
	(15-22N, 76-85E)	32.40	2.65	280.66	281.70	35
	500mb Z					
	(32-40N, 134-144E)	32.40	0.06	5416.27	5415.21	32
	(40-48N, 135-122W)	32.40	-0.06	5580.57	5675.27	27
	(30-39N, 37-62E)	32.40	-0.17	5617.72	5626.19	31
Feb.	700mb T					
	(16-24N, 143-162E)	32.40	2.13	281.80	280.85	31
	(14-21N, 158-145W)	32.40	-2.02	280.53	281.73	30
	(45-55N, 3-15E)	32.40	-1.32	262.35	260.99	34
	(35-52N, 98-108E)	32.40	-1.47	258.14	260.16	29
	500mb Z					
	(68-76N, 133-168E)	32.40	0.06	5152.72	5206.02	36
	(18-25N, 149-142W)	32.40	-0.14	5800.88	5812.29	31
	(57-67N, 50-30W)	32.40	0.03	5211.83	5129.21	30
	(18-29N, 23-42W)	32.40	0.12	5779.33	5798.41	35

Table 4. Mei-Yu precipitation forecast (mm) for 1991 (Day 1-April 1) by upper air parameters and SST of preceding months. 700 mb T and SST are in the unit of °C, and 500 mb Z in m. 30-year database.
--- Regression ŷ = a + B(x - c) ---

Month	Predictors (x)	a	b	c	x	ŷ
Sept.	SST					
	(42-46N, 153-159E)	436.07	-81.80	15.74	15.15	484
	(46-50N, 165-147W)	436.07	-61.22	13.08	13.12	434
	(22-26N, 177-171W)	436.07	-272.26	27.62	27.66	424
	(18-22N, 153-141W)	436.07	53.11	25.46	26.06	468
	(30-24N, 75-63W)	436.07	-256.80	27.43	27.31	466
	700mb T					
	(22-33N, 148-165W)	438.63	72.53	283.30	282.70	385
	(48-58N, 167-165W)	438.63	-104.23	267.55	264.90	715
	(27-42N, 88-78W)	438.63	-77.73	280.26	280.29	436
	(25-33N, 58-68E)	438.63	48.15	285.58	285.17	419
	(30-39N, 120-130E)	438.63	-91.51	280.01	280.35	408
	500mb Z					
	(30-38N, 120-130E)	438.63	-3.57	5814.32	5839.65	348
	(48-60N, 165E-165W)	438.63	-3.51	5515.25	5456.87	644
	(30-42N, 27-6W)	438.63	-3.63	-5840.91	5812.52	542
	(55N-65N, 50-70E)	438.63	-0.90	5506.92	5493.27	451
Oct.	SST					
	(38-46N, 159-171E)	436.07	-73.25	15.70	15.74	433
	(38-46N, 159-153W)	436.07	-29.16	16.15	16.82	417
	(26-30N, 123-129E)	436.07	-160.44	26.12	23.37	556
	(30-34N, 75-69W)	436.07	-103.87	25.89	25.80	446
	700mb T					
	(32-48N, 125-145E)	439.24	-62.79	271.19	271.51	419
	(20-30N, 160-178E)	439.24	421.00	282.71	281.83	401
	(38-48N, 137-120W)	439.24	12.32	273.23	271.44	417
	(16-33N, 102-86W)	439.24	-59.22	281.77	281.43	459
	500mb Z					
	(32-40N, 134-145E)	439.24	-2.19	5719.95	5750.65	372
	(52-63N, 140-160E)	439.24	1.81	5350.35	5415.37	557
	(14-27N, 29-17W)	439.24	-5.79	5875.79	5889.68	359
Nov.	SST					
	(38-42N, 171-177E)	436.07	-58.85	15.67	16.28	400
	(2-10N, 111-93W)	436.07	90.53	26.14	26.36	456
	(14-10S, 177E-177W)	436.07	212.86	28.76	28.79	442
	700mb T					
	(15-24N, 138-153E)	439.24	51.87	283.65	283.30	421
	(38-55N, 130-155E)	439.24	-35.11	258.83	260.99	363
	(38-55N, 18-30E)	439.24	25.39	266.85	265.71	410
	(36-45N, 145-120W)	439.24	-39.72	270.13	270.72	416

	500mb Z					
	(38-53N, 142-168E)	439.24	-1.85	5385.22	5519.36	191
	(53-63N, 140-120W)	439.24	1.09	5380.63	5251.11	298
	(43-52N, 78-65W)	439.24	-1.61	5452.19	5472.28	407
	(15-27N, 28-18W)	439.24	-5.87	-5854.25	5862.60	390
Dec.	SST					
	(38-42N, 159-177E)	436.07	-63.66	13.64	15.17	338
	(14-18N, 111-117E)	436.07	-47.32	26.11	26.02	440
	(18-22N, 177-171W)	436.07	-167.83	26.29	26.53	397
	(10-2S, 117-105W)	436.07	17.91	23.96	23.72	432
	(18-14S, 167-177E)	436.07	117.17	27.99	27.96	432
	700mb T					
	(31-50N, 110-135E)	439.24	-35.93	260.06	261.67	381
	(36-55N, 150-130W)	439.24	23.78	265.93	268.52	501
	(24-40N, 68-55W)	439.24	48.19	274.83	276.49	519
	(47-70N, 65-95E)	439.24	39.71	253.94	254.53	462
	500mb Z					
	(33-50N, 110-123E)	439.24	-2.97	5442.01	5497.95	273
	(53-70N, 70-97E)	439.24	1.57	5248.44	5238.95	424
	(18-25N, 90-98E)	439.24	4.66	5820.95	5840.39	529
Jan.	SST					
	(34-38N, 171-177E)	436.07	-158.15	15.73	16.66	288
	(6-10N, 159-171E)	436.07	-209.01	28.25	28.35	415
	(18-14S, 105-111E)	436.07	-179.57	27.33	26.93	507
	(14-10S, 171-177E)	436.07	103.49	29.10	29.85	514
	700mb T					
	(30-45N, 160-174E)	439.24	72.42	265.71	263.29	614
	(37-58N, 160-138W)	439.24	19.00	263.72	267.41	509
	(52-62N, 75-58W)	439.24	-20.72	250.31	243.66	577
	(30-38N, 38-48W)	439.24	-43.38	268.88	268.82	442
	(43-52N, 98-112E)	439.24	-34.88	253.36	255.16	377
	500mb Z					
	(20-34N, 123-138E)	439.24	1.45	5722.92	5736.33	459
	(22-35N, 132-118W)	439.24	-2.70	5767.72	5773.92	423
	(40-48N, 70-83E)	439.24	-1.99	5515.52	5505.70	459
Feb.	700mb T					
	(15-19N, 128-145E)	439.24	29.74	282.05	281.29	417
	(25-40N, 128-110W)	439.24	31.88	272.25	274.21	502
	(48-60N, 40-58E)	439.24	20.65	257.06	258.02	459
	(10-50N, 112-114E)	439.24	28.35	252.32	252.55	433
	500mb Z					
	(40-50N, 110-123E)	439.24	-2.20	5311.56	5339.87	377
	(45-55N, 10W-3E)	439.24	-1.19	5492.46	5491.39	441
	(27-34N, 15-34E)	439.24	3.40	5657.64	5661.13	451
	(18-23N, 82-90E)	439.24	4.37	5811.18	5829.06	517

Table 5. Summary of 1991 Mei-Yu forecast by SST and upper air parameters. 700mb T and SST are in the unit of °C, and 500mb Z in m. 36-year database. A is the average.

Predictors		Onset (1=April 1)	Recess (1=April 1)	Length (Days)	Precipitation (mm)
Sept. 1990	SST	47	77	32	484
		44	77	33	434
		57		37	424
		A=49.3	A=77.0	A=34.0	468
					466
					A=455.2
	700mb T	51			385
		44			715
		44			436
		A=46.3			419
					408
					A=472.6
	500mb Z	45	74	39	348
		41	74	34	644
		46	80	30	542
		A=44.0	A=76.0	A=34.3	451
					A=496.3
Oct. 1990	SST	47	84	36	433
		42	76	32	417
		42	78	31	556
		57		32	446
		46		39	
		A=46.8	A=79.3	34	
				37	
				A=34.3	A=463.0
	700mb T	50	78	30	419
		47	77	33	401
		48	78	29	417
				31	459
		A=48.3	A=77.7	A=30.8	A=424.0
	500mb Z	47	74	33	372
		51	74	27	557
		51			359
		A=49.7	A=74.0	A=30.0	A=429.3

Predictors		Predictands Onset (1=April 1)	 Recess (1=April 1)	 Length (Days)	 Precipitation (mm)
Nov. 1990	SST	51	74	33	400
		47	80	32	456
		48		26	442
				25	
		A=48.7	A=77.0	A=29.0	A=432.7
	700mb T	53	74	29	421
		49	76	27	363
		49	73	33	410
		44		28	416
		A=48.8	A=74.3	A=29.3	A=402.5
	500mb Z	49	71	33	
		53	83	32	
		48	76	29	
		42		28	
		A=48.0	A=76.7	A=30.5	
Dec. 1990	SST	49	73	29	338
		47	78	35	440
		49			387
		A=48.3	A=75.5	A=32.0	432
					432
					A=405.8
	700mb T	45		32	381
		47		28	501
		46		34	519
		52		34	462
		45		30	
		A=47.0		A=31.6	A=465.8
	500mb Z	41	76	34	273
		47	77	29	424
		59	80		529
		A=49.0	A=77.7	A=31.5	A=408.7

Predictors		Onset (1=April 1)	Recess (1=April 1)	Length (Days)	Precipitation (mm)
Jan. 1991	SST	47	79	25	288
		46	79	35	415
			75		507
			79		515
		A=46.5	A=78.0	A=30.0	A=431.3
	700mb T	46		31	614
		48		31	509
		50		31	577
		47		33	442
				35	377
		A=47.8		A=32.2	A=503.8
	500mb Z	48	79	32	459
		50	79	27	423
		49		31	459
		48			
		A=48.8	A=79.0	A=30.0	A=447.0
Feb. 1991	700mb T	46		31	417
		48		30	502
		48		34	459
				29	453
		A=47.3		A=31.0	A=457.8
	500mb Z	47		36	377
		48		31	441
		47		30	451
				35	517
		A=47.3		A=33.0	A=446.5

Table 6. Differences of fitted and recorded (fitted-recorded) Mei-Yu onset dates in single regression analysis from 1977 to 1990. The database period for regression formulation is 1956-1990. Each column is by the indicated predictor.

Year	(18-14S, 165-159W) Sept. SST	(42-50N, 165-177W) Oct. SST	(32-40N, 175-165W) Nov. 500mb Z	(23-38N, 33-48E) Dec. 700mb T
77	-2.73	-7.09	-0.59	6.11
78	-4.66	2.15	-5.76	-3.27
79	5.83	2.28	1.92	6.01
80	26.05	20.78	30.29	23.93
81	5.48	-0.47	4.94	9.89
82	-2.82	-6.47	-7.52	-8.41
83	3.34	5.03	7.14	5.24
84	-2.23	-1.47	1.30	3.89
85	-4.53	-10.10	-7.05	-12.65
86	-0.95	-5.09	-2.15	-1.29
87	4.83	-0.97	1.11	-2.07
88	-3.95	-4.47	-1.57	-3.13
89	-3.52	-4.84	3.77	0.11
90	-0.16	-0.25	-0.93	-0.95

Table 7. Forecasted values of 1991 Mei-Yu with multiple regression method. (See regression equations in Table 8).

Predictor month	Onset (1=April 1)	Recess (1=April 1)	Period (Days)	Precipitation (mm)
Oct. 1990	41.7	76.1	40.6	310
	45.9	91.3	39.9	435
	42.4	58.0	30.1	660
	45.8	81.4	44.4	516
	49.7	87.6	36.4	231
	48.4	73.0	25.8	562
	48.4			444
				413
				272
Jan. 1991	48.1	71.5	35.3	337
	51.1	40.7	27.8	214
	56.7		32.4	347
	40.9		29.4	483
			53.8	470
				376
				379

Note: This table shows large variation in the normal range. Thus this is a normal year, and we should take the values in Table 5 as the forecast, not this table which is only valid when consistent extreme values indicate an abnormal Mei-Yu.

Table 8. Multiple regression equations of 1991 Mei-Yu onset forecast.

Predictand : Onset (1 = April 1)

Month	Data	Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
	Period	a0	a1	a2	a3	X1	X2	X3
	1979-1988	-4691.2	11.465	0.716	1.569	SST	Z(20N, 34E)	T(59N, 31E)
	1980-1989	268.6	11.921	-11.490	-7.771	(42 - 50N	S(56N,138W)	S(28N,150E)
	1981-1990	1614.5	7.316	-13.565	-0.211	171E-171W)	S(8S,168E)	Z(17N,126E)
	1979-1988	1158.2	33.854	-0.331	-6.376	SST	Z(27N,170W)	S(16S, 60E)
	1980-1989	-1011.0	30.601	-0.362	0.389	(6 - 14N	Z(27N,170W)	Z(23N, 45E)
	1981-1990	348.3	12.630	-8.285	-0.090	135 -147E)	S(32S, 90W)	Z(48N,105E)
	1979-1988	1246.3	-26.225	-14.395	-4.335	SST	S(24S,162W)	S(16S, 72E)
	1980-1989	1587.5	-19.578	-11.380	-0.116	(2S- 6N	S(28N,150E)	Z(45N, 77E)
	1981-1990	-2756.6	-12.923	0.422	0.124	159 -165E)	Z(28N, 85E)	Z(26N, 56W)
	1979-1988	-4826.7	4.613	5.771	0.351	700mb T	T(46N, 39E)	Z(17N, 10E)
October	1980-1989	1764.1	4.405	-0.498	-0.283	(40 - 47N	H(69N, 21W)	Z(25N,153E)
	1981-1990	-1169.9	2.863	0.060	4.376	163 -150W)	Z(77N, 66E)	S(16N,126E)
	1979-1988	2568.8	-7.120	-9.644	-9.384	700mb T	S(28N,168E)	S(12S,174W)
	1980-1989	2666.0	-6.881	11.760	-0.327	(27 - 33N	S(40N,180)	H(20N, 14W)
	1981-1990	1416.6	-2.914	15.520	-0.373	120 -110W)	S(16N,144E)	H(33N,169E)
	1979-1988	-2937.3	0.358	0.133	6.506	500mb Z	Z(38N, 72W)	S(8N,174E)
	1980-1989	839.6	0.384	-0.421	-0.676	(42 - 50N	H(25N, 10E)	H(19N,136E)
	1981-1990	-524.0	0.294	-5.025	1.199	33 - 45E)	T(24N, 2E)	T(47N, 71W)
	1979-1988	-8061.7	0.846	1.175	3.301	500mb Z	H(41N, 2W)	S(16N,114E)
	1980-1989	-9126.8	0.902	1.273	2.083	(25 - 32N	H(41N, 2W)	T(32N, 0)
	1981-1990	-2610.5	0.421	-11.528	0.094	80 - 90E)	S(4N,162E)	Z(36N, 67W)

* Units : SST degree C, T degree K, Z meter, H meter.

Table 8 (cont.)

Predictand : Onset (1 = April 1)

Month	Data Period	a0	a1	a2	a3	X1	X2	X3
		Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
		a0	a1	a2	a3	X1	X2	X3
Jan.	1979-1988	-439.8	12.458	16.517	-7.140	SST	S(28N,180E)	S(16N,126W)
	1980-1989	-210.5	13.707	-15.018	9.037	(26 - 22S	S(24S,102W)	S(12S,126E)
	1981-1990	639.2	11.427	-3.362	2.482	171E-171W)	T(18N, 51E)	S(28S,162E)
	1979-1988	669.1	-16.538	-10.054	8.291	SST	S(12N,168E)	S(56N,156W)
	1980-1989	764.0	-14.407	-9.892	-7.108	(22 - 18S	S(12N,168E)	S(36N,162E)
	1981-1990	173.5	-8.591	0.040	-5.188	105 - 93W)	Z(86N,170W)	S(32S, 36E)
	1979-1988	294.4	-4.798	17.200	1.893	700mb T	S(16N,138E)	T(78N,118E)
	1980-1989	1861.8	-4.157	-21.777	-0.132	(50 - 70N	S(44N,150E)	Z(39N,104E)
	1981-1990	510.5	-2.833	-0.120	-0.327	125 -155E)	Z(48N, 85W)	H(33N, 45E)
	1979-1988	-1009.2	3.875	17.622	-0.068	700mb T	S(32S,150W)	Z(59N, 31E)
	1980-1989	-1006.9	3.384	12.919	-4.983	(27 - 40N	S(32S,150W)	S(12N,126W)
	1981-1990	-759.4	2.481	5.140	2.823	25 - 40E)	S(28S,180)	S(44N,168E)

* Units : SST degree C, T degree K, Z meter, H meter.

Table 9. As in Table 8, but for Mei-Yu recess.

Predictand : Recess (1 = April 1)

Month	Data Period	Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
		a0	a1	a2	a3	X1	X2	X3
October	1979-1988	-597.1	-23.799	0.084	2.695	SST	Z(72N,153E)	T(57N, 88E)
	1980-1989	1291.8	-26.592	-14.485	-1.785	(30 - 34N	S(40S,156E)	T(42N,130E)
	1981-1990	786.5	-15.743	-14.680	3.471	135 -123W)	S(8N,174E)	S(48N,174E)
	1979-1988	429.2	21.437	-28.198	-0.086	SST	S(32S,174W)	Z(46N,118E)
	1980-1989	-212.2	26.391	-21.574	-6.502	(10 - 2S	S(32S,168W)	S(36S,102E)
	1981-1990	-2251.9	15.193	0.799	-1.063	93 - 99E)	H(19N,136E)	T67NN, 82E)
	1979-1988	2595.5	-18.870	-8.069	3.254	SST	T(19N, 98W)	S(52N,168E)
	1980-1989	1224.7	-16.797	-0.316	-6.528	(42 - 30S	H(69N, 21W)	S(24S, 96E)
	1981-1990	883.4	-7.827	-1.963	-4.141	75 - 93E)	T(51N, 10E)	S(16N,168E)
	1979-1988	-1344.0	7.517	-17.078	-0.122	700mb T	S(28S, 90E)	H(86N,170W)
	1980-1989	-2062.6	6.904	-17.502	0.106	(42 - 50N	S(28S, 90E)	Z(46N, 98W)
	1981-1990	87.4	2.921	-2.174	-8.568	35 - 45E)	T(78N,118E)	S(8N,174E)
	1979-1988	-2042.7	0.307	14.493	6.583	500mb Z	S(24N,120E)	S(28S, 78W)
	1980-1989	-5621.7	0.336	22.082	0.557	(52 - 67N	S(8N,102E)	Z(24N, 19E)
	1981-1990	-955.8	0.148	4.695	4.649	120 -160E)	S(20S,114E)	S(16N, 72E)
	1979-1988	5895.1	-0.111	-0.930	9.628	500mb Z	Z(19N,158E)	S(12N,138W)
	1980-1989	6084.0	-0.081	-0.985	8.203	(55 - 65N	Z(19N,158E)	S(4N,120E)
	1981-1990	595.3	-0.045	-7.540	-6.350	0 - 20E)	S(40S, 78E)	S(8N, 60W)

* Units : SST degree C, T degree K, Z meter, H meter.

Table 9 (cont.)

Predictand : Recess (1 = April 1)

Month	Data	Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
	Period	a0	a1	a2	a3	X1	X2	X3
Jan.	1979-1988	-0.6	-19.289	0.272	-5.156	SST	H(48N, 38W)	S(28S,138W)
	1980-1989	677.1	-14.825	-9.771	-4.154	(10 - 18N	S(40N, 66W)	S(28S,132W)
	1981-1990	29.1	-6.629	11.134	-4.540	135 -123W)	S(8S,156E)	S(12N,138W)

* Units : SST degree C, T degree K, Z meter, H meter.

Table 10. As in Table 8, but for length of Mei-Yu period.

Predictand : Length of Period (Days)

Month	Data Period	a0	a1	a2	a3	X1	X2	X3
		Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
October	1979-1988	-572.9	9.669	9.614	6.814	SST	S(28S, 90W)	S(28N,174E)
	1980-1989	-2487.1	14.272	0.952	-0.168	(22 - 18S	H(27N,170W)	H(65N,170W)
	1981-1990	-2675.1	20.075	0.780	3.051	147 -135W)	H(27N,170W)	S(12N,120E)
	1979-1988	-307.4	11.869	7.753	4.144	SST	S(56N,150E)	S(32S,114W)
	1980-1989	105.5	13.182	6.053	-1.307	(34 - 26S	S(56N,150E)	T(49N,139W)
	1981-1990	-484.5	9.569	15.265	-3.427	99 - 93W)	S(20S,144W)	S(40N,126W)
	1979-1988	987.0	-3.317	-12.268	3.338	700mb T	S(36S,168W)	S(24N,162E)
	1980-1989	3924.2	-2.985	10.050	-1.246	(57 - 75N	S(4S, 60E)	H(14N, 90W)
	1981-1990	1319.3	-3.286	-0.225	4.629	0 - 20E)	H(77N, 66E)	S(12N,114W)
	1979-1988	1967.2	9.546	-0.775	-3.180	700mb T	Z(15N,148W)	S(32N,156E)
	1980-1989	2835.0	8.757	-0.882	-4.011	(20 - 27N	Z(13N,141W)	S(20N,114W)
	1981-1990	2883.7	7.628	-0.856	2.531	10 - 2W)	Z(15N,148W)	S(48N,150E)
	1979-1988	1384.6	-0.229	-9.875	8.166	500mb Z	S(20N,138W)	S(12S,168E)
	1980-1989	-59.2	-0.269	12.302	0.486	(30 - 40N	S(20N,162E)	H(15N, 5W)
	1981-1990	909.3	-0.195	10.592	5.110	65 - 48W)	S(40S,102W)	S(12S,132W)
	1979-1988	743.7	-0.215	15.791	6.565	500mb Z	S(4N, 54E)	S(36S,126E)
	1980-1989	359.3	-0.264	11.415	0.353	(30 - 38N	S(20S,144W)	H(32N, 0)
	1981-1990	570.8	-0.401	12.246	5.265	5 - 25E)	S(20S,144W)	T(28N, 44W)

* Units : SST degree C, T degree K, Z meter, H meter.

Table 10 (cont.)

Predictand : Length of Period (Days)

Month	Data Period	Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
		a0	a1	a2	a3	X1	X2	X3
Jan.	1979-1988	1903.7	-10.192	-5.102	-5.544	SST	S(40S,168E)	T(16N, 21W)
	1980-1989	1489.6	-9.230	-0.461	-2.611	(34 - 30S	H(28N, 85E)	S(36S,108W)
	1981-1990	-20.1	-11.289	11.784	4.110	171 -165W)	S(36S,120E)	S(36S, 90W)
	1979-1988	-93.5	-7.725	-8.846	0.082	SST	S(28S,114W)	Z(33N,149W)
	1980-1989	104.6	-6.434	-7.280	9.603	(42 - 38S	S(36S,174W)	S(32N,144W)
	1981-1990	408.4	-6.015	-8.309	-4.249	69 - 75E)	S(36S,174W)	S(12N,120W)
	1979-1988	1323.3	-2.930	-6.955	-1.312	700mb T	S(32S,174W)	T(77N, 46W)
	1980-1989	538.8	-3.057	-0.062	0.255	(22 - 28N	Z(77N, 46W)	H(46N, 19W)
	1981-1990	961.1	-3.260	-6.908	6.133	125 -118W)	S(32S,180)	S(32S,114E)
	1979-1988	1158.2	-3.756	-7.017	4.990	700mb T	S(4S,162W)	S(16S,102W)
	1980-1989	1195.5	-4.155	-5.619	5.224	(18 - 25N	S(4S,162W)	S(8S,150E)
	1981-1990	1134.8	-3.695	-5.163	4.252	25 - 37E)	S(4S,162W)	S(28N,120W)
	1979-1988	2031.1	0.165	-9.737	-3.530	500mb Z	T(13N, 31E)	S(28S,132W)
	1980-1989	753.4	0.208	-6.160	-1.827	(45 - 60N	T(13N, 31E)	S(28S, 72E)
	1981-1990	-149.2	0.190	-3.072	2.179	115 -145E)	T(21N,111E)	S(12N, 72W)
	1979-1988	2991.5	-0.297	-21.672	-0.239	500mb Z	S(8N, 96E)	H(27N,101W)
	1980-1989	2862.9	-0.312	-19.632	-1.704	(18 - 30N	S(8N, 96E)	T(27N,101W)
	1981-1990	2441.4	-0.403	19.485	-4.594	23 - 42E)	S(52N,162E)	S(16N, 90E)

* Units : SST degree C, T degree K, Z meter, H meter.

Table 11. As in Table 8, but for the total precipitation.

Predictand : Precipitation (mm)

Month	Data Period	Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
		a0	a1	a2	a3	X1	X2	X3
October	1979-1988	12221.6	-305.540	179.375	-3.107	SST	S(24S,108W)	H(36N, 62W)
	1980-1989	6759.0	-308.152	163.007	-81.642	(22 - 30N	S(24S,108W)	S(4N,168E)
	1981-1990	6706.7	-306.775	162.962	-80.950	153 -141W)	S(24S,108W)	S(4N,168E)
	1979-1988	42012.1	-366.683	-123.293	48.077	SST	T(23N, 25W)	S(40N,132E)
	1980-1989	23005.4	-396.432	-53.411	-66.371	(26 - 22S	T(78N,118E)	S(44N,150E)
	1981-1990	57909.6	-328.951	-9.652	200.491	81 - 83E)	Z(26N, 76E)	S(16N, 84W)
	1979-1988	68504.2	-103.174	-1.280	-5.803	700mb T	Z(61N, 10E)	Z(27N,101W)
	1980-1989	-59043.7	-109.332	15.405	-122.829	(50 - 70N	Z(22N, 83W)	S(28S,174W)
	1981-1990	25949.4	-95.850	125.109	-129.872	180 -140W)	S(28N, 90W)	S(8S,162E)
	1979-1988	-72901.8	-63.717	34.455	-151.955	700mb T	H(20N, 34E)	S(28S,102E)
	1980-1989	13137.6	-74.297	309.511	-92.643	(40 - 57N	S(20N, 66E)	S(32S, 78E)
	1981-1990	-2834.7	-61.891	-496.352	11.115	65 - 45W)	S(32N,132W)	H(25N,121W)
	1979-1988	32897.8	94.588	-271.782	-19.491	700mb T	S(28N,138W)	H(13N,116E)
	1980-1989	-14234.0	103.535	-276.015	-3.834	(12 - 25N	S(40N,132W)	H(54N, 51W)
	1981-1990	-49094.2	124.766	-301.856	83.270	23 - 30E)	S(16N,144E)	T(37N, 95W)
	1979-1988	117735.1	-88.102	-236.889	-14.996	700mb T	S(24N,138W)	Z(12N, 62W)
	1980-1989	71579.2	-92.125	287.323	-189.495	(43 - 52N	S(20S,144W)	T(14N, 88E)
	1981-1990	52971.8	-86.297	-70.825	-42.783	50 - 62E)	T(78N,118E)	T(42N,130E)

* Units : SST degree C, T degree K, Z meter, H meter.

Table 11 (cont.)

Predictand : Precipitation (mm)

Month	Data Period	Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
		a0	a1	a2	a3	X1	X2	X3
October	1979-1988	-70543.5	-3.762	15.999	-127.827	500mb Z	Z(22N, 7W)	S(56N,132W)
	1980-1989	-66728.0	-3.523	15.111	-125.890	(30 - 50N	Z(22N, 7W)	S(56N,132W)
	1981-1990	-22563.0	-4.346	-182.918	19.411	60 - 40W)	S(20N,144W)	H(16N, 41E)
	1979-1988	-7155.4	15.998	-21.651	-10.859	500mb Z	H(42N, 10E)	H(21N, 91W)
	1980-1989	-89151.6	15.816	-11.177	92.072	(20 - 26N	H(45N, 57W)	T(22N, 49W)
	1981-1990	538.7	10.873	-21.391	-3.195	10 - 2W)	H(42N, 10E)	H(83N, 10E)
	1979-1988	41508.2	-4.251	-340.502	-37.072	500mb Z	S(32N,132W)	T(78N,118E)
	1980-1989	-4819.7	-5.263	-321.477	15.571	(30 - 37N	S(40N,132W)	H(30N, 29E)
	1981-1990	55106.5	-6.984	378.771	-4.279	5 - 15E)	S(16N, 84W)	Z(26N, 76E)

* Units : SST degree C, T degree K, Z meter, H meter.

Table 11 (cont.)

Predictand : Precipitation (mm)

Month	Data Period	Y = a0 + a1*X1 + a2*X2 + a3*X3				Predictor		
		a0	a1	a2	a3	X1	X2	X3
	1979-1988	-3990.3	-160.379	258.970	82.804	SST	S(12S,102W)	S(48N,156W)
	1980-1989	347.8	-190.376	230.162	-100.458	(30 - 34N	S(12S,102W)	S(20S, 66E)
	1981-1990	-8746.1	-154.760	242.187	193.266	123 -129E)	S(12S,102W)	S(16S,168E)
	1979-1988	17647.7	-236.617	-278.638	-128.374	SST	S(8S,114E)	S(28S,156E)
	1980-1989	40721.6	-173.511	-238.105	-106.348	(26 - 22S	S(20N, 90E)	T(15N, 5W)
	1981-1990	41992.5	-195.935	-5.979	-78.437	129 -117W)	Z(22N, 49W)	S(28S, 90W)
	1979-1988	-4226.4	-177.288	-177.719	40.581	SST	S(40S,102W)	T(46N, 39E)
	1980-1989	4875.1	-183.847	-194.451	95.641	(42 - 34S	S(40S,102W)	S(36S, 60E)
	1981-1990	-21438.5	-210.848	8.701	143.671	69 - 75E)	H(38N, 13W)	S(32S,114E)
	1979-1988	39338.2	-94.632	-225.005	-30.050	700mb T	S(28S,108W)	T(59N, 11W)
Jan.	1980-1989	29488.3	-81.099	-343.113	112.353	(27 - 42N	S(16N, 90E)	S(40S, 60E)
	1981-1990	5877.6	-73.280	2.406	288.207	85 - 70W)	Z(38N, 13W)	S52NN,162E)
	1979-1988	28225.0	-103.279	215.099	-122.714	700mb T	S(28N,180)	S(4S,180)
	1980-1989	30946.1	-108.363	-104.420	80.555	(20 - 28N	S(36S,102W)	S(36S, 66E)
	1981-1990	32452.6	-99.879	-138.301	-66.061	30 - 20W)	S(32S, 84W)	S(32S, 54E)
	1979-1988	-10341.1	-1.110	196.819	58.141	500mb Z	S(44N, 42E)	T(48N, 58E)
	1980-1989	21660.2	-1.890	-343.179	-65.677	(30 - 40N	S(12N, 96E)	S(36S, 96W)
	1981-1990	-19286.4	-2.049	10.692	25.266	165E-175W)	H(34N,105W)	S(20N, 72W)
	1979-1988	-3857.0	1.159	188.657	-119.863	500mb Z	S(44N, 42E)	S(16S,114E)
	1980-1989	-11188.6	1.693	-201.391	2.439	(63 - 73N	S(40S,102W)	H(55N, 27W)
	1981-1990	9465.2	1.805	-108.125	42.144	70 -120E)	T(21N,111E)	T(20N, 14W)

* Units : SST degree C, T degree K, Z meter, H meter.

Grid System

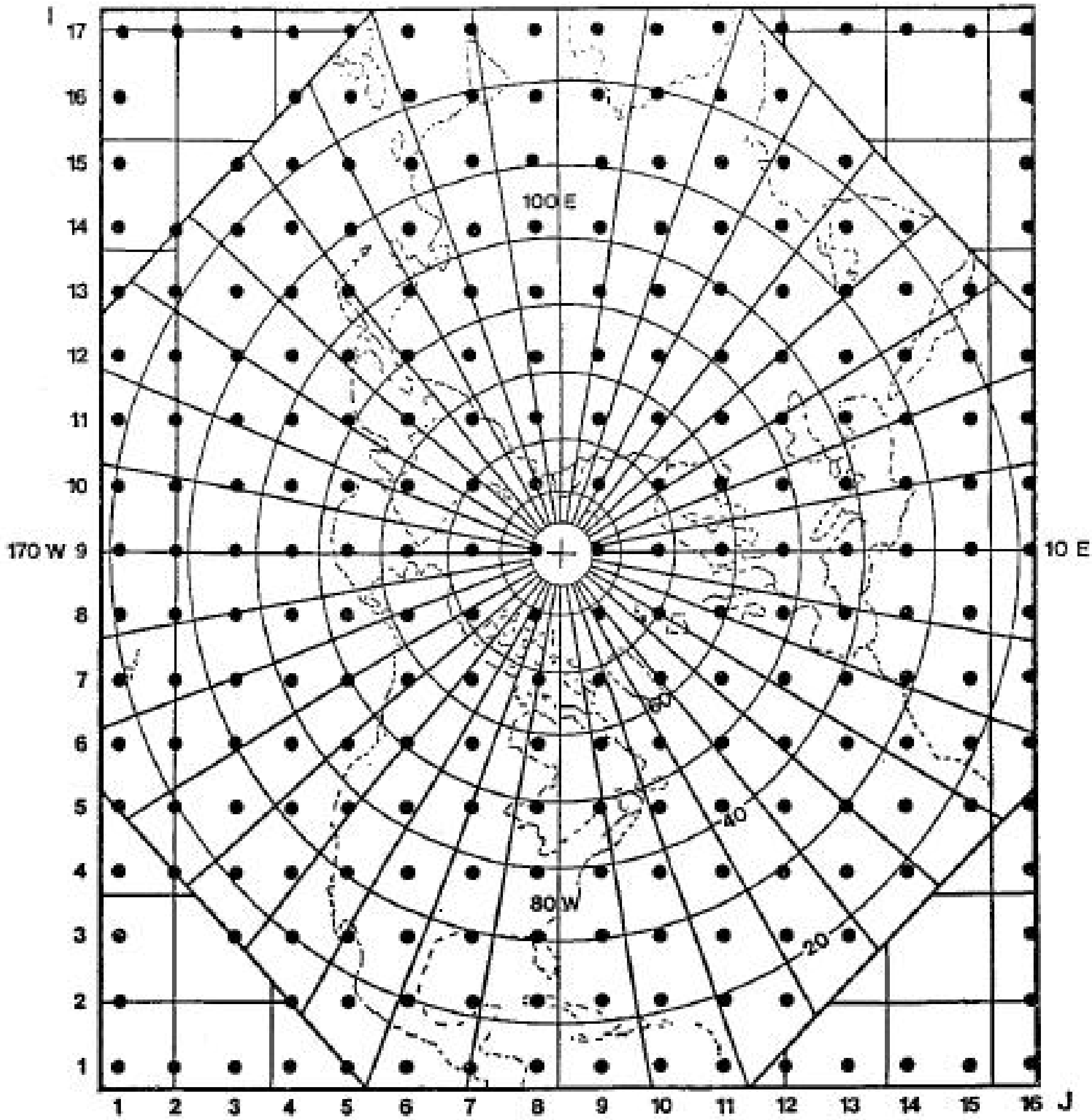


Fig. 1. Northern Hemisphere 17 X 16 grid system.

Fig. 2(a) 1991 Taiwan Mei-Yu Forecast by September Teleconnections

Onset Date (1=April 1) Recess Date (1=April 1)

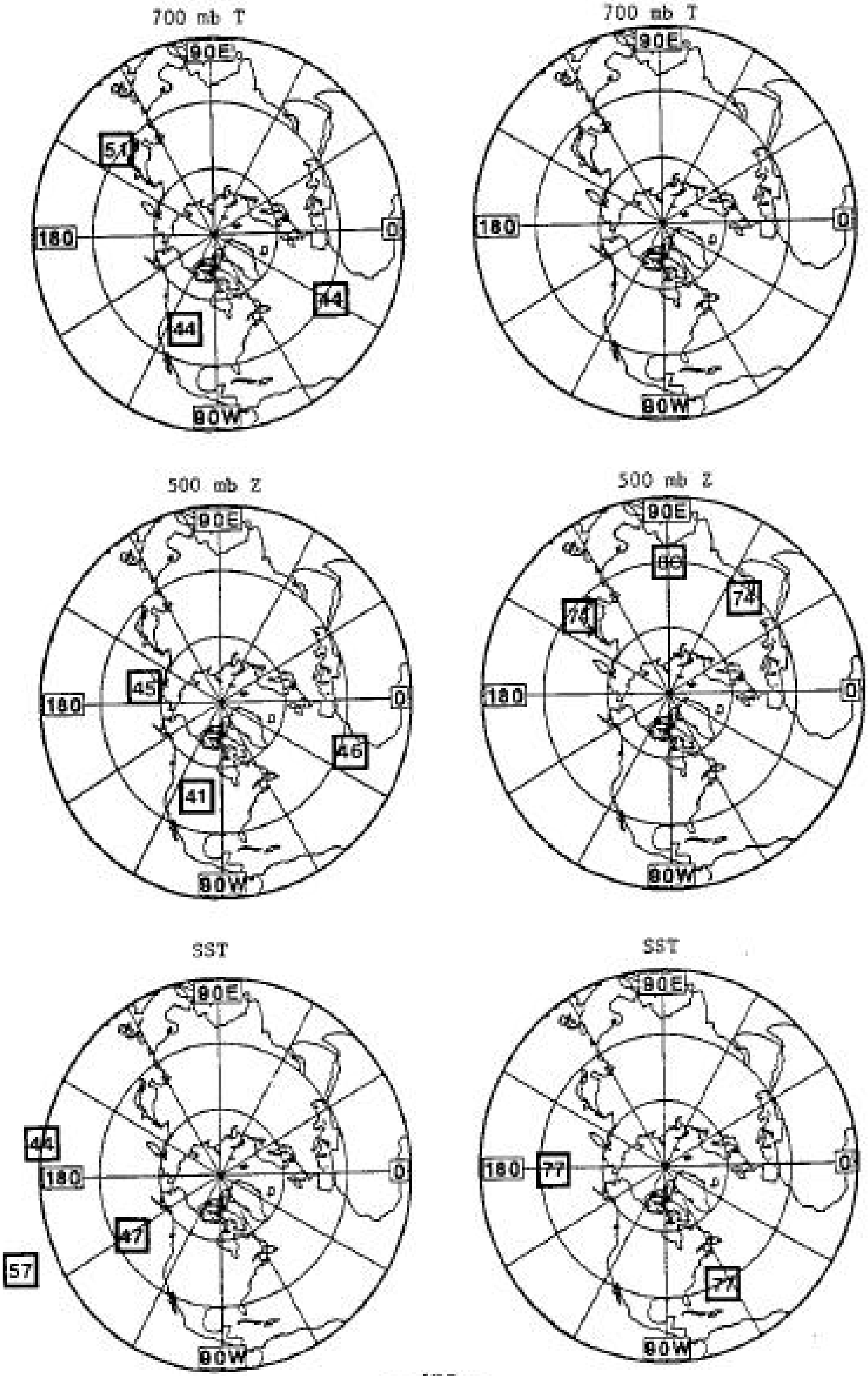


Fig. 2(b) 1991 Taiwan Mei-Yu Forecast by September Teleconnections

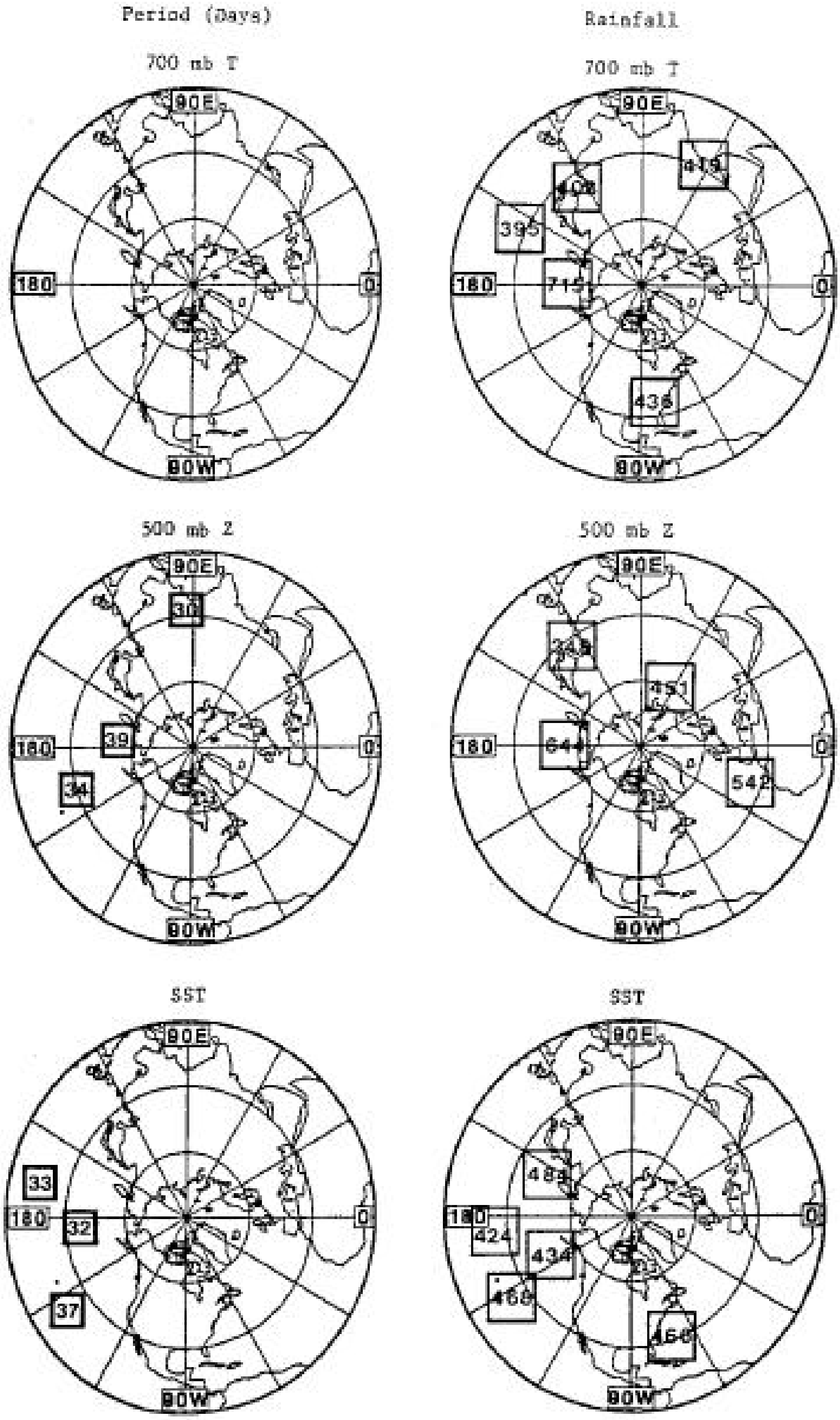


Fig. 3(a) 1991 Taiwan Mei-Yu Forecast by October Teleconnections

Onset Date (1=April 1) | Recess Date (1=April 1)

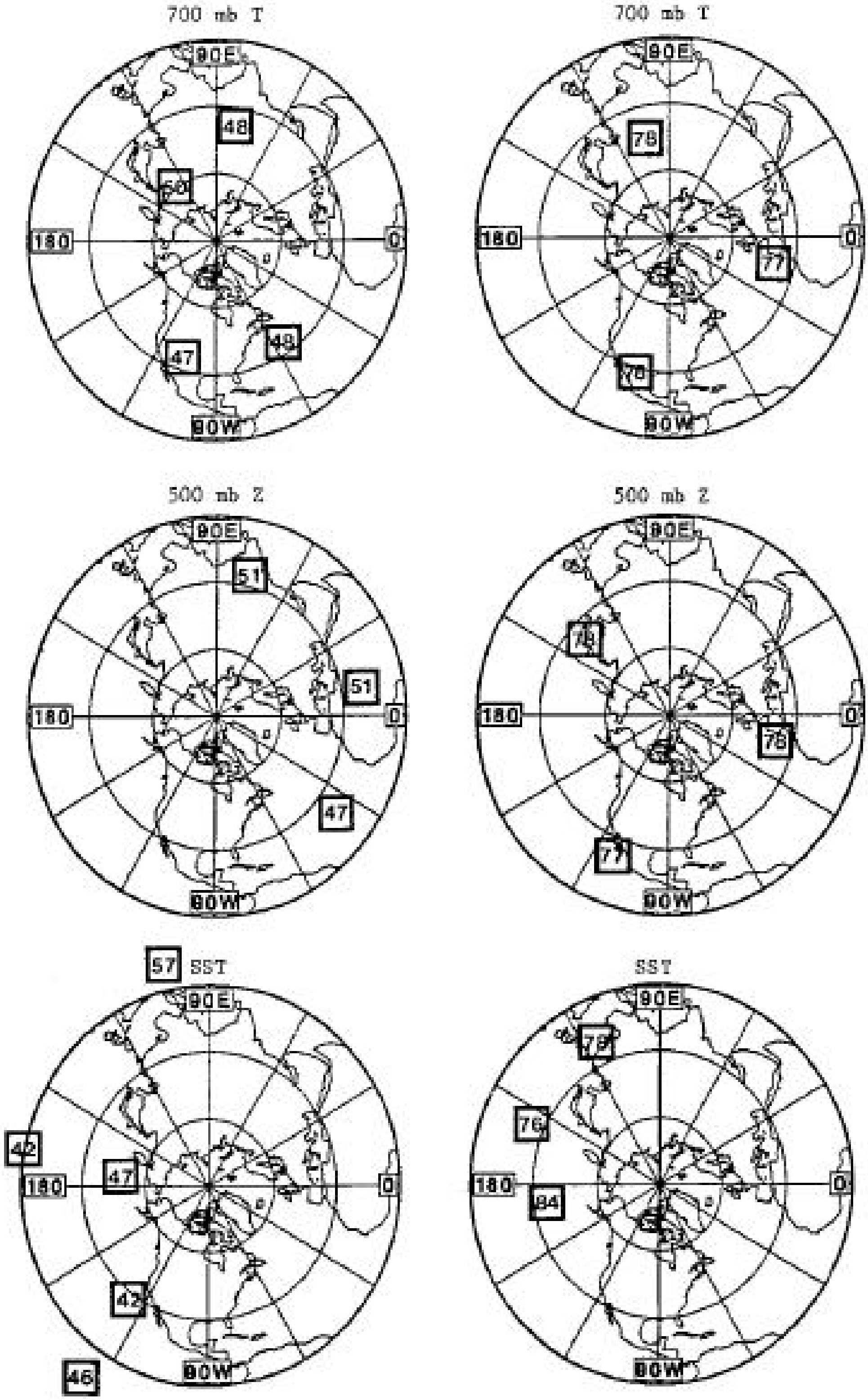


Fig. 3(b) 1991 Taiwan Mei-Yu Forecast by October Teleconnections

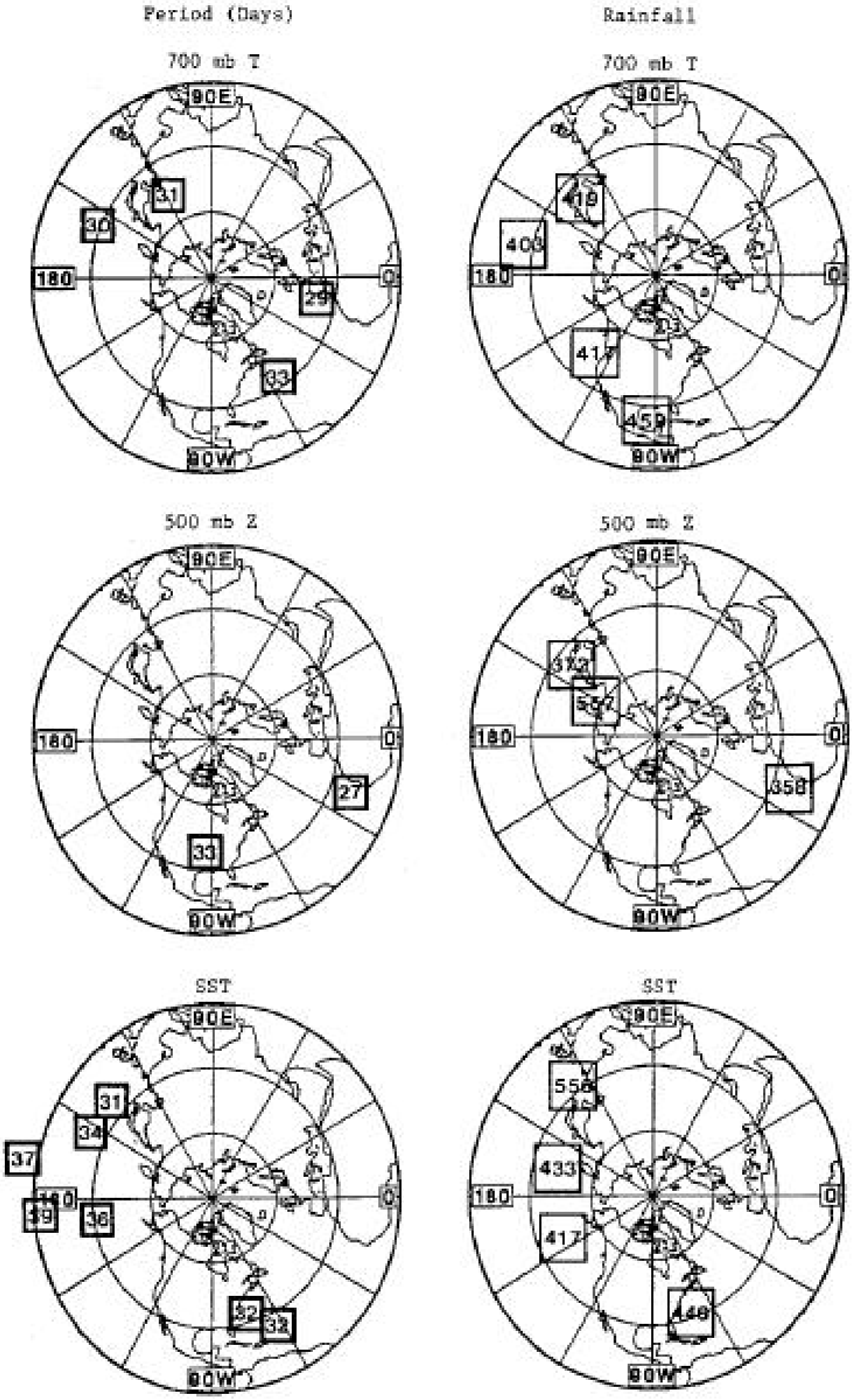


Fig. 4(a)

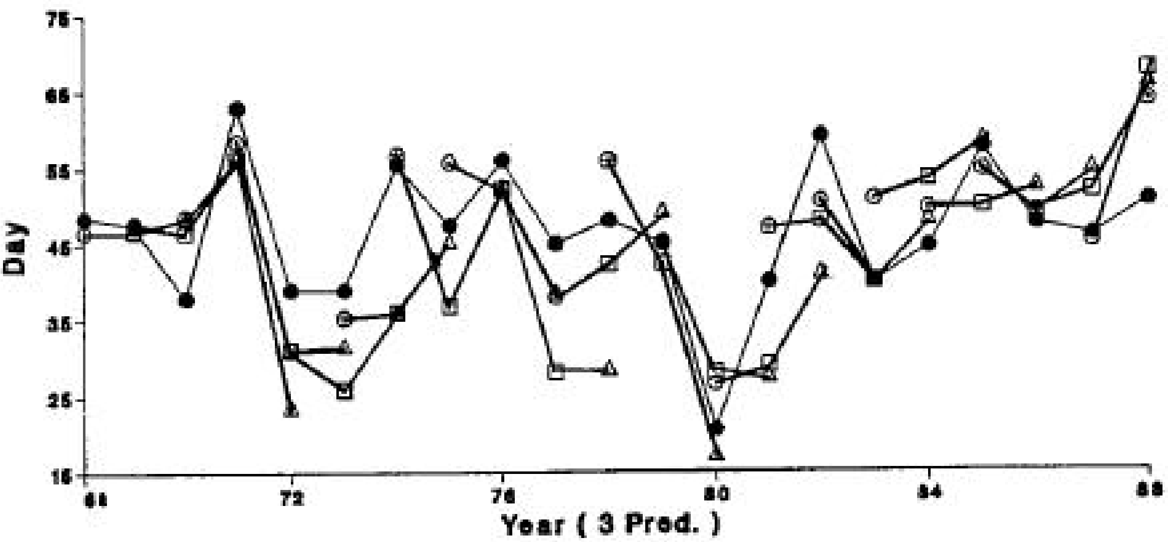
Prediction Experiment in the Jan. Predictors

(Mei-Yu Onset)

. 1st Fixed Pred.: SST
. Fitting Period : 10 Years

. Latitude : N 26 - 30 N
. Longitude : E 165 - 171 E

Record ● 1st yr ○ 2nd yr □ 3rd yr △
1st yr with alternative 1st predictor ⊕



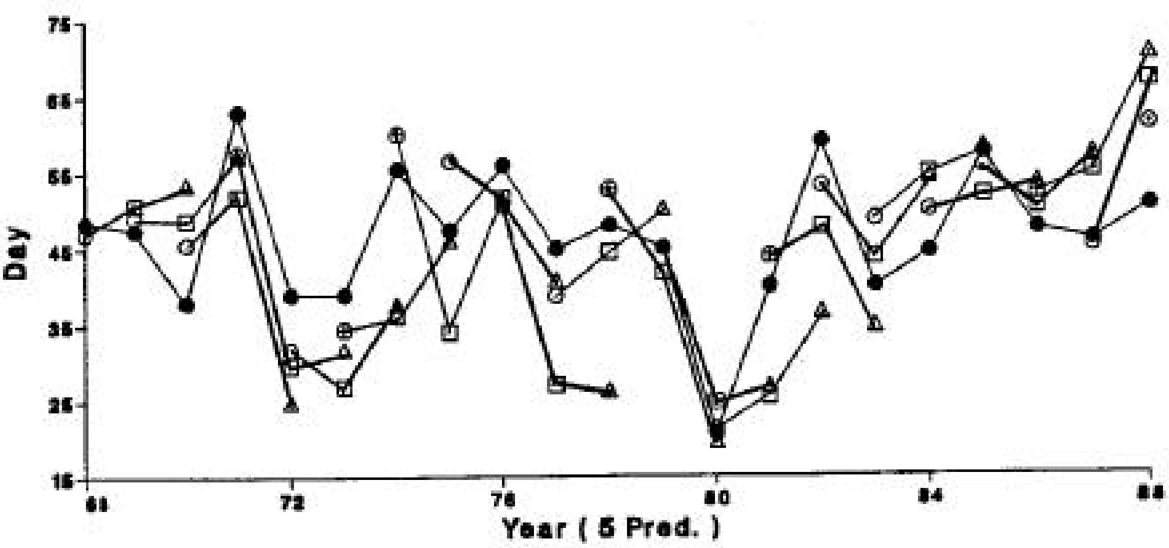


Fig. 4(b)

Prediction Experiment in the Jan. Predictors

(Mei-Yu Recess)

. 1st Fixed Pred.: SST
. Fitting Period : 10 Years

. Latitude : S 10 - 18 S
. Longitude : E 106 - 111 E

Record ● 1st yr ○ 2nd yr □ 3rd yr △
1st yr with alternative 1st predictor ⊕

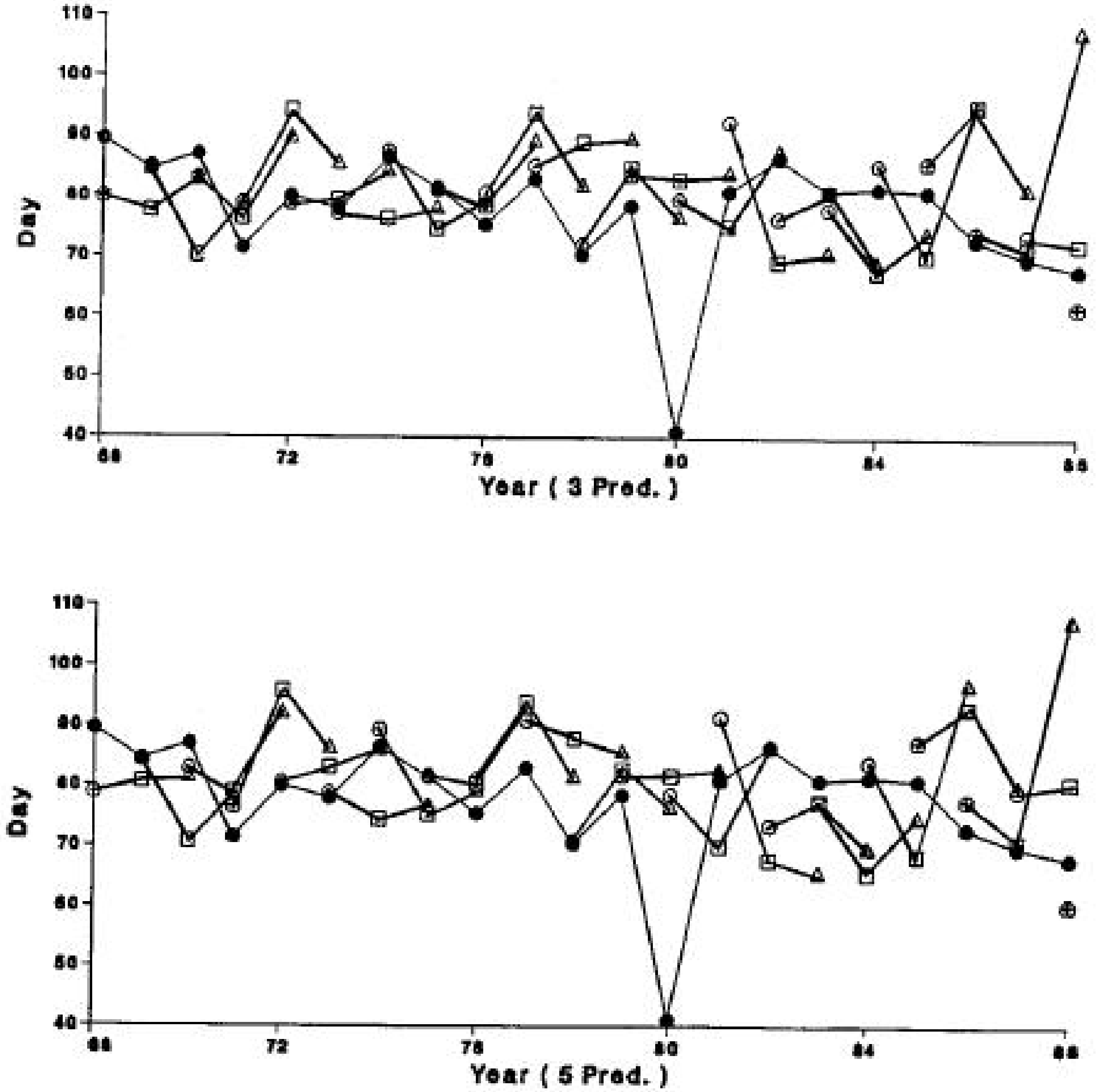


Fig. 4(c)

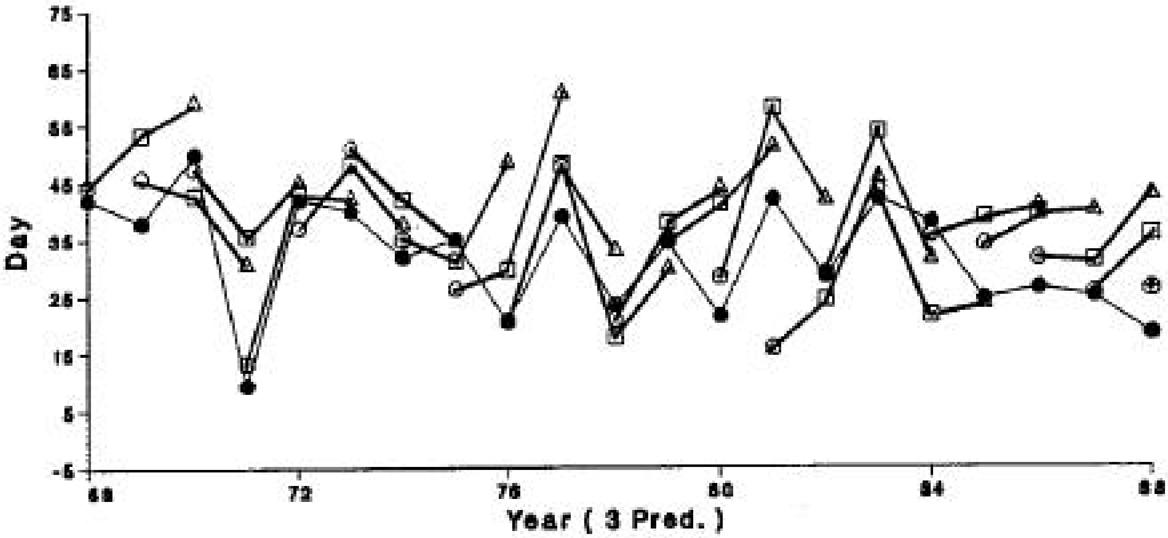
Prediction Experiment in the Jan. Predictors

(Mei-Yu Period)

. 1st Fixed Pred.: 500mb Z
. Fitting Period : 10 Years

. Latitude : N 30 - 39 N
. Longitude : E 37 - 62 E

Record ●   1st yr ○   2nd yr □   3rd yr △
1st yr with alternative 1st predictor ⊕



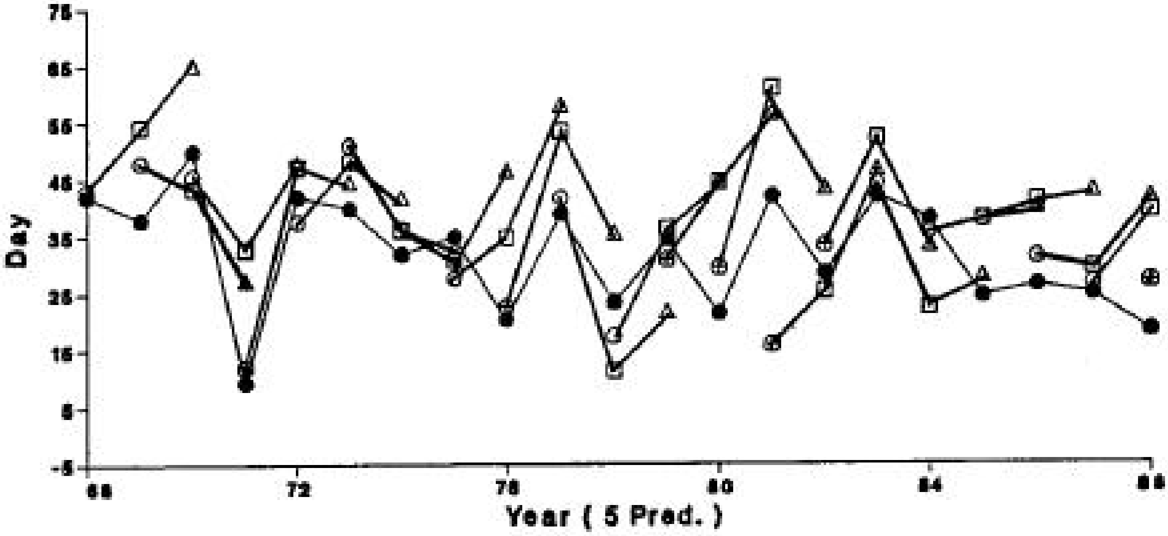


Fig. 4(d)

Prediction Experiment in the Jan. Predictors

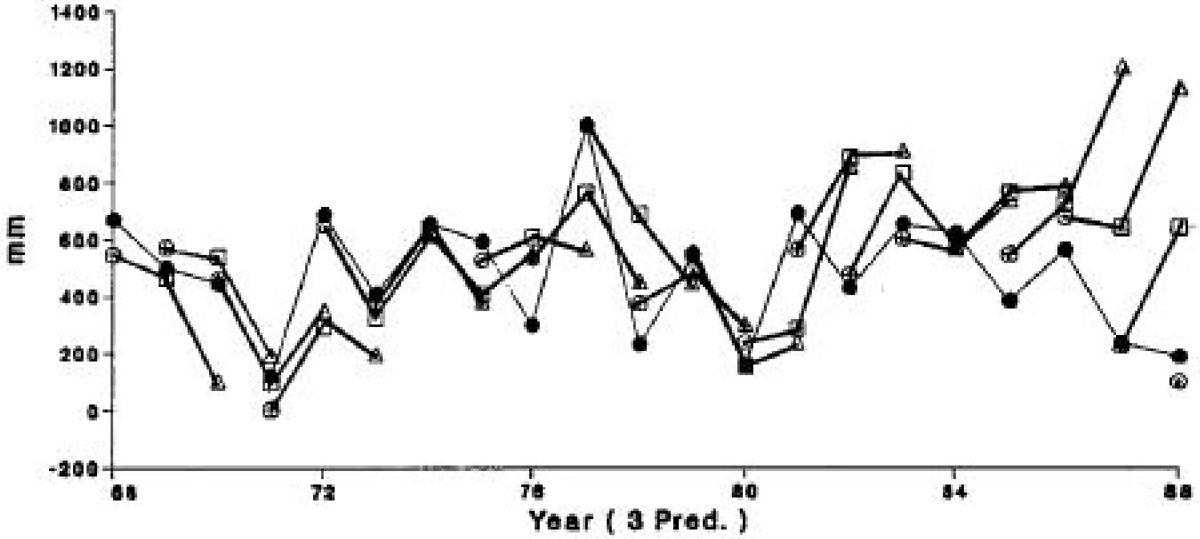
(Mei-Yu P.P.T.)

. 1st Fixed Pred.: SST . Latitude : S 18 - 14 S

. Fitting Period : 10 Years . Longitude : E 105 - 111 E

Record ● 1st yr ○ 2nd yr □ 3rd yr △

1st yr with alternative 1st predictor ⊕



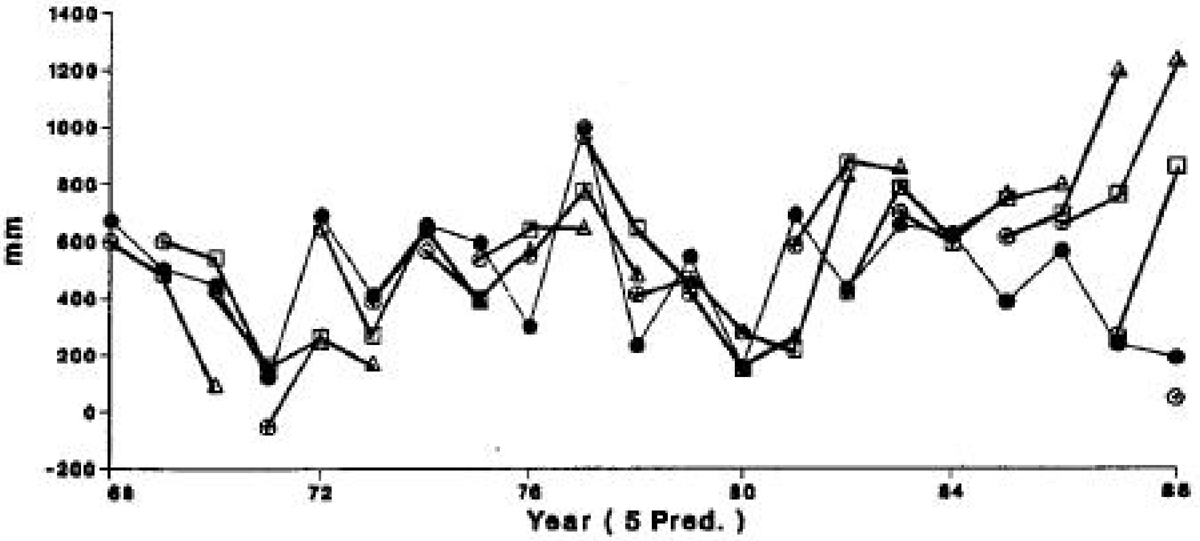


Fig. 4(e)

Prediction Experiment in the Jan. Predictors

(Mei-Yu P.P.T.)

. 1st Fixed Pred.: SST
. Fitting Period : 10 Years
. Latitude : N 6 - 10 N
. Longitude : E 159 - 171 E

Record ● 1st yr ○ 2nd yr □ 3rd yr △
1st yr with alternative 1st predictor ⊕

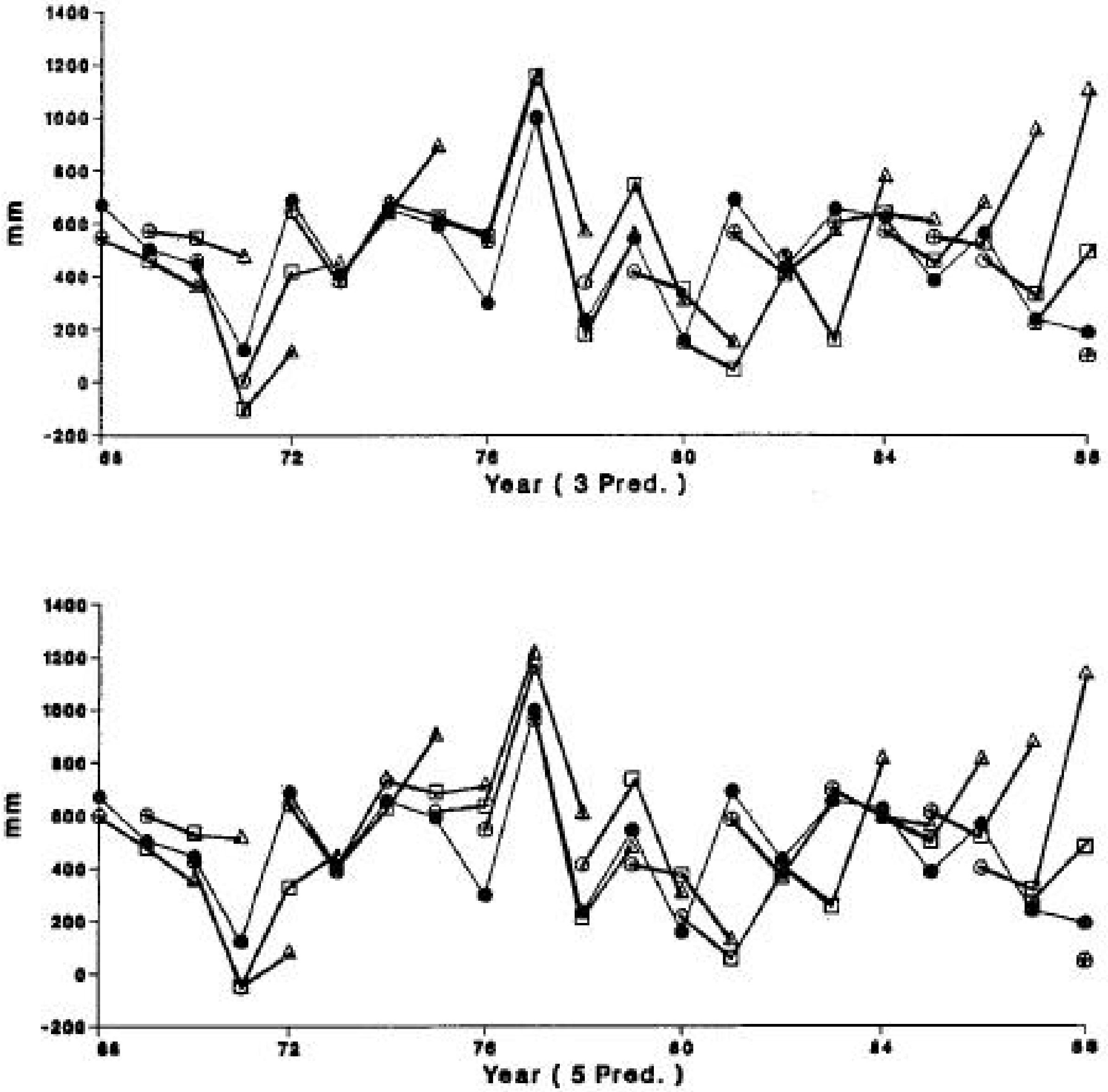


Fig. 5(a)

Prediction Experiment with the Jan. Predictors

(Mei-Yu Onset)

. 1st Fixed Pred.: SST (26 - 30 N; 165 - 171 E)
. Fitting Period : 10 Years

Record ● 1st yr ○ 2nd yr □ 3rd yr △
1st yr with alternative 1st predictor ⊕

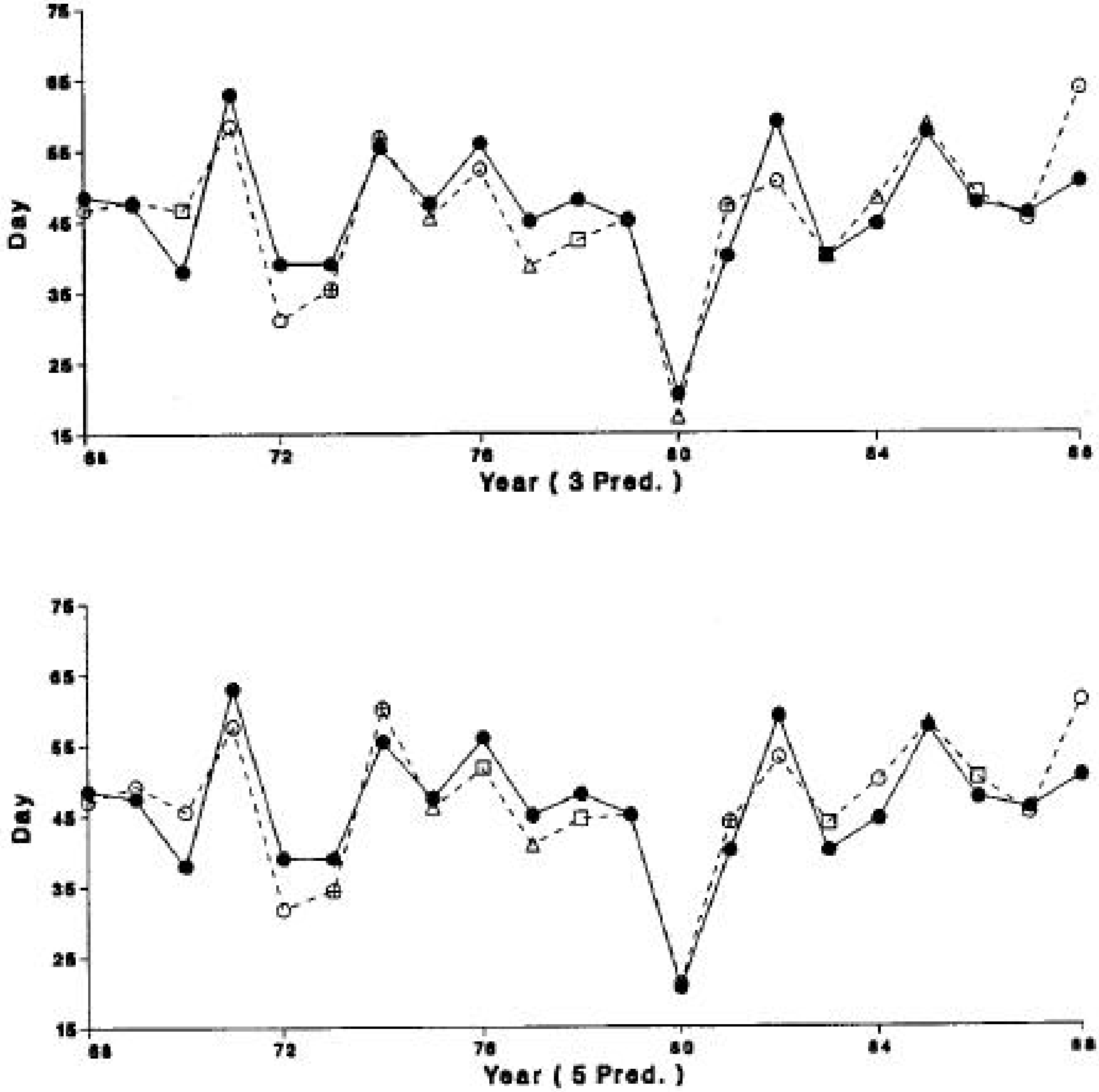


Fig. 5(b)

Prediction Experiment with the Jan. Predictors

(Mei-Yu Recess)

. 1st Fixed Pred.: SST (10 - 18 S; 106 - 111 E)
. Fitting Period : 10 Years

Record ● 1st yr ○ 2nd yr □ 3rd yr △
1st yr with alternative 1st predictor ⊕

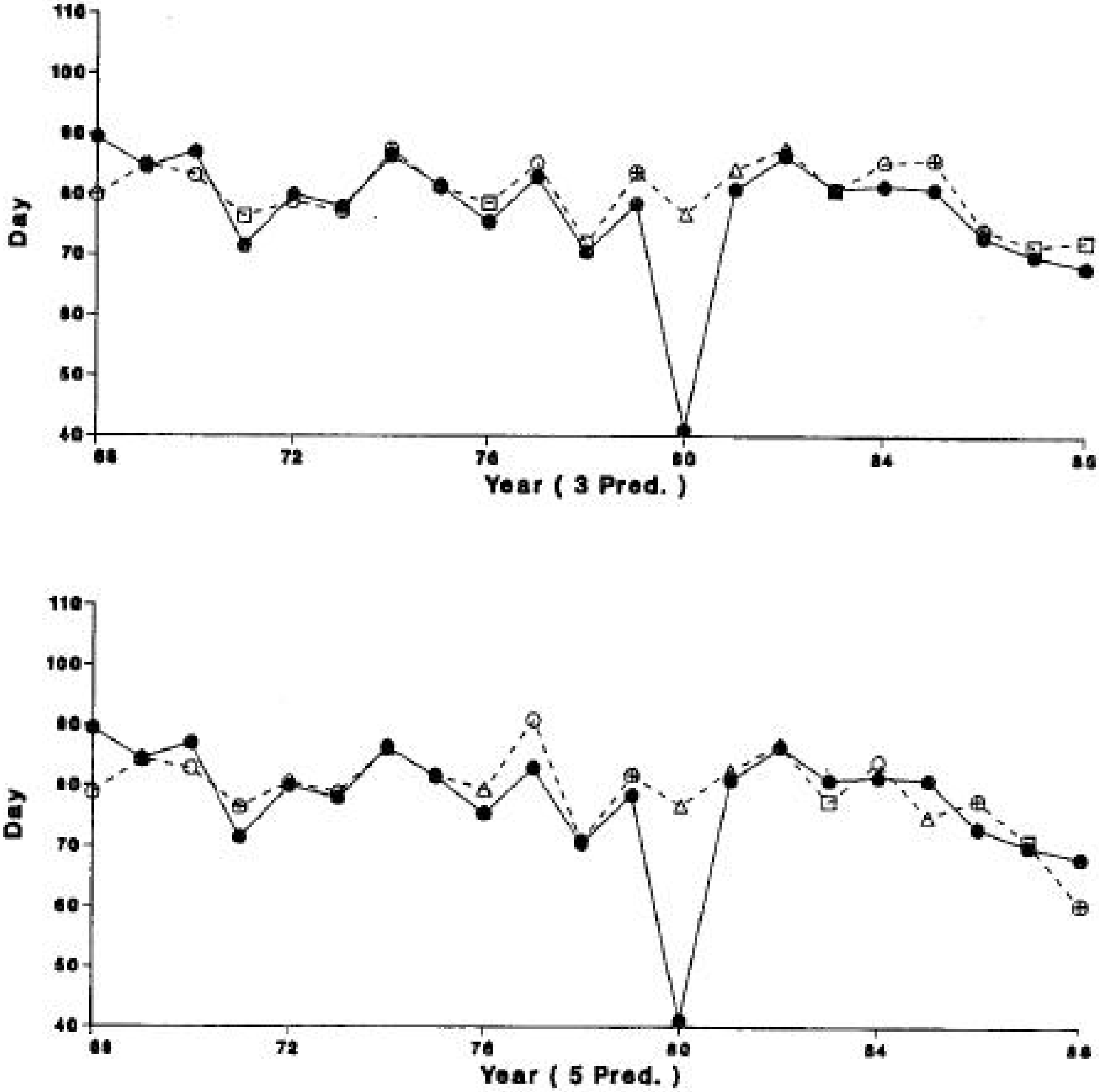


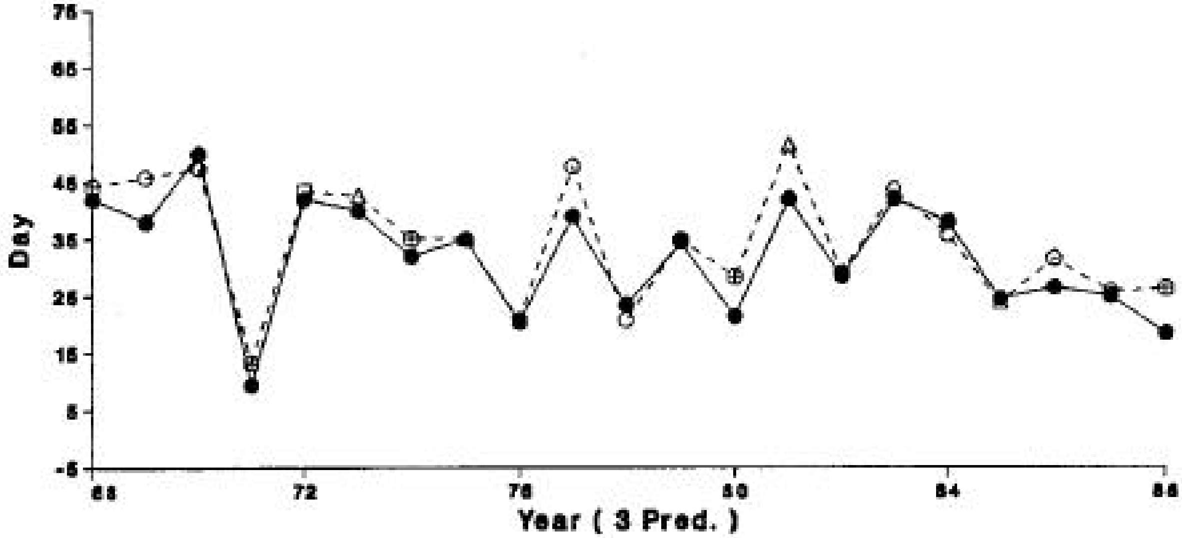
Fig. 5(c)

Prediction Experiment with the Jan. Predictors

(Mei-Yu Period)

. 1st Fixed Pred.: 500mb Z (30 - 39 N; 37 - 62 E)
. Fitting Period : 10 Years

Record ● 1st yr ○ 2nd yr □ 3rd yr △
1st yr with alternative 1st predictor ⊕



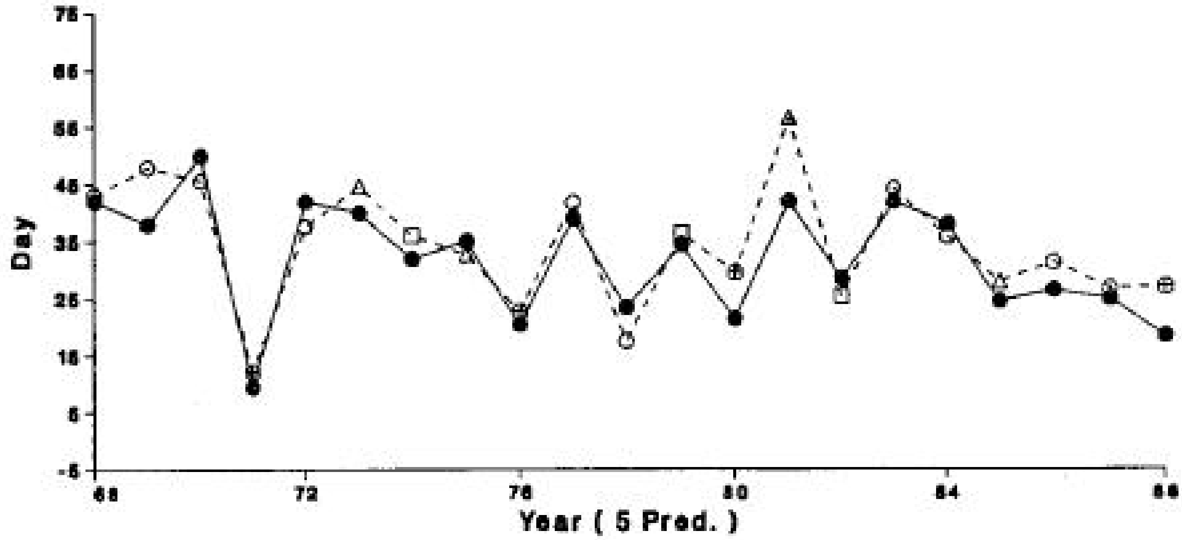


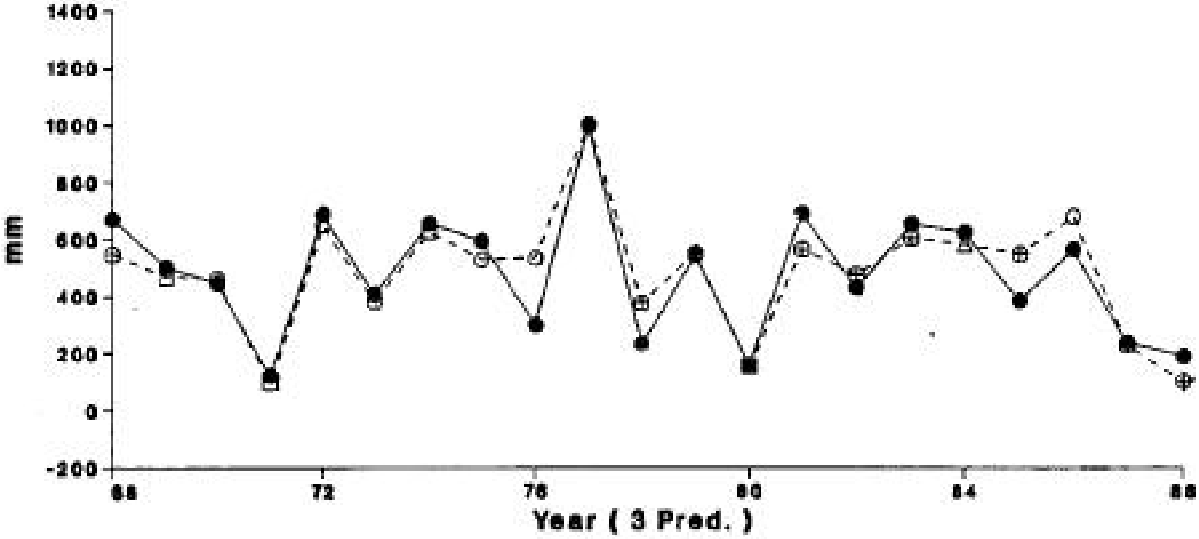
Fig. 5(d)

Prediction Experiment with the Jan. Predictors

(Mei-Yu P.P.T.)

. 1st Fixed Pred.: SST (18 - 14 S; 105 - 111 E)
. Fitting Period : 10 Years

Record ● 1st yr ○ 2nd yr □ 3rd yr △
1st yr with alternative 1st predictor ⊕



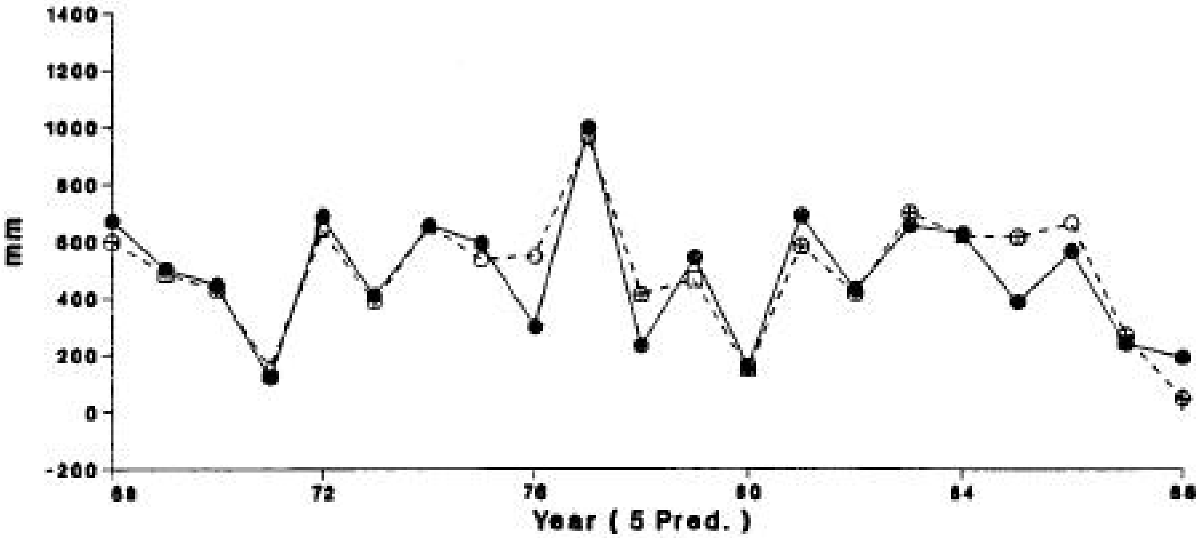


Fig. 5(e)

Prediction Experiment with the Jan. Predictors

(Mei-Yu P.P.T.)

. 1st Fixed Pred.: SST (6 - 10 N; 159 - 171 E)
. Fitting Period : 10 Years

Record ● 1st yr ○ 2nd yr □ 3rd yr △
1st yr with alternative 1st predictor ⊕