SECOND 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. SPECIFIC OBJECTIVES AND REMARKS

The major effort during the second year of the project is dedicated to the qualitative forecasting of the 1990 Mei-Yu with the real time data. This is a forecast experiment utilizing extensive teleconnections of Mei-Yu parameters with upper air parameters and sea surface temperatures (SSTs). Although the regressions in teleconnection give numerical values of predictands, the forecast should only be viewed as qualitative in reference to the multiple regression forecast of the third year, whose essential purpose will be to formulate numerically dependable forecast schemes.

The main purpose of the second year effort is to obtain pertinent preparatory information for the third year formulation of forecast schemes, rather than to succeed in Mei-Yu forecast with only apparent teleconnections. Specific objectives of this year's qualitative forecast may be summarized in the following:

1. Actual use of the real time data through their acquisition, process, and computation so that the data analysis can follow set and smooth procedures.

2. To study the stability of single regressions with various predictors at various regions of the observation data.

3. To study the stability of forecast with datasets of different months for the purpose of determining the forecast range preceding Mei-Yu.

4. To provide possible first predictors for the next years' multiple regression forecast schemes from the pool of this year's predictors.

These objectives have been accomplished. The analysis procedures for the monthly mean upper air analyses of the Central Weather Bureau and SST analyses of the National Meteorological Center (NMC) function efficiently and the computing programs are verified to be without error. Projected values of single regressions with various predictors are shown to fluctuate in narrow ranges. Predictions with different months' observations from October to March show a remarkable consistency, implying a considerable forecast time preceding Mei-Yu. These collectively point to the feasibility of construction of a multiple-regression scheme in the next stage for quantitative forecasting.

Additionally during this year's project, the method of typhoon long-range forecast has been explored. The frequency of Taiwan invading typhoons for 1990 has been projected; further plans in this area will be discussed later in this report. The climatological analysis of planetary waves in the Northern Hemisphere, described in last year's report, is in progress in an attempt to link the Mei-Yu and typhoon parameters to wave activities. We expect that this line of research will produce useful predictands and predictors in the multiple regression forecast. This is a continuing phase of the basic research and will be completed during the next effort period.

2. APPROACHES AND METHODS

On the basis of cross-correlation analyses of the Mei-Yu and typhoon predictands vs. 700mb T, 500mb Z and SST (see cross-correlation charts which were forwarded to the Central Weather Bureau as part of the final report of the first year project), single regressions are obtained in the regions of strong cross-correlations. These regions are established for each month preceding the Mei-Yu and typhoon (i.e., for each month's real time dataset with each predictand). To compute regression, data of all grid points in a region are averaged. Grid points in each regions are in the order of 10 to 100, with the majority in the range of 20 to 60.

After having obtained the real time upper air data in the Northern Hemisphere from the Central Weather Bureau and SST data in the Northern Hemisphere and low-latitude Southern Hemisphere from NMC, the forecast values were computed utilizing the regressions of predictands on the regional predictors. The forecast values of predictands are compared with each other to see the stability of prediction among teleconnections at different sites. The process is repeated for each month's real time data from October to March, and the stability of forecast values with different months' predictors is examined. Although the upper air data have been supplied by the Central Weather Bureau for October 1989 to March 1990, the SST data from NMC are only to December 1989. However, as indicated in the results to be presented in the following, the shortage of SST data from January 1990 apparently did not affect the forecast experiment during this period. The NMC's difficulty of SST data supply was caused by their updating/revision of SST analysis scheme from 1991, and we do not expect the problem to exist during our third year project. The prediction experiments with the data from April are not included in this report because of time constraints; however, it will be discussed in the third year report.

Unlike the multiple regression approach, the forecast by single regression or simple correlation is a dangerous approach unless a proper study of teleconnection has been done. This is the reason we have started the work from the cross-correlation analysis, and the predictors are utilized only at the locations of strong cross-correlation. Still, it is well recognized that the mode of the general circulation undergoes a significant change, and the correlations originally utilized will not be useful after a certain (less than ten years normally) period (see Kung and Sharif 1980, 1982). The use of teleconnection in the long-range forecast thus must be by the multiple regression scheme, not by single regression. It is emphasized here that we have done an extensive single regression forecast this year so that the multiple regression forecast schemes will be constructed next year on a sound ground of teleconnection study.

3. TELECONNECTION AND SINGLE REGRESSION FORECAST OF MEI-YU PARAMETERS

Table 1 lists the predicted values of Mei-Yu onset with monthly real time data of 700mb T and 500mb Z from October 1989 to March 1990, and SST data from October to December 1989. For each predicting parameter in each month (such as October 700mb T) there are a few to several predictors at different locations of significant cross-correlation. Predicted values of Mei-Yu recess, period, and precipitation are respectively listed in Tables 2-4, as done for Table 1. For each predictor in these tables, the regression equation, real time data (x) as averaged in the region from grid point values, and the predicted value $\hat{y}$, are presented. The unit °C is used for temperature from October to December, but it is switched to K from January. For those parameters where teleconnections are weak, no predicted values are given.

As exemplified in Figs. 1 and 2 (the complete sets of figures of this computation have been previously forwarded to the Central Weather Bureau), the scattered diagrams for each regression show a considerable variation by location and month of predictors. It is thus dangerous to base the projection of predictands on a single regression. One reasonable way to avoid this problem is to see the consistency of projection by predictors at various sites. Table 5 summarizes the forecasts presented in Figs. 1-4. It is evident that the range of projection is rather small. As seen in Table 6 of the climatological records, the standard deviations of onset and recess are 8.84 days and 8.25 days; that of period is 10.7 days and that of precipitation is 220.28. The range of projection of a predictand by a month's real time data at different locations is generally smaller than its standard deviation of the climatological data period. It is also noteworthy that the projections by 700mb T, 500mb Z, and SST for a predictand give consistent results, among which SST projections are most stable at different locations.

It should be pointed out that the length of Mei-Yu period is obtained independent of the onset and recess, not indirectly from onset and recess. However, the independently obtained Mei-Yu period is fairly consistent with what is indicated by the difference of onset and recess days.

Comparing predictions by datasets of different months, consistency and stability of predictions are once again apparent from October to March. This shall indicate that a useful predictability of the next year's Mei-Yu exists early in October. As a matter of fact, from the cross-correlations of predictands and antecedent circulation patterns, the strongest signals appear December and January as indicated in Park and Kung's (1988) study. This is a fairly encouraging result of this year's project.

Figures 3-14 illustrate the projected 1990 Mei-Yu onset, recess, period, and precipitation at various locations of 700mb T and 500mb Z teleconnections. If no projection is made by a certain predictor of a given month for weak cross-correlation, it has been left blank. This map will allow us, after this Mei-Yu season, to decide the locations of better predictors and less desirable ones. The location of teleconnection apparently moves from month to month, suggesting an existence of very slow moving waves which are useful for the long-range prediction.

Summarizing the Mei-Yu predictands as discussed in this section, the onset, recess, period, and precipitation of the 1990 Mei-Yu, are projected around their long-term means as listed in Table 5. This means that the 1990 Mei-Yu seems fairly close to that of the normal year. It is cautioned that, as indicated in Kung and Sharif (1982) and Kung and Tanaka (1985), the single regressions only account for 50-60% of the total variance. However, as indicated, the consistency of projections in space and time may have redeemed this deficiency. This effect will be analyzed when we develop the multiple regression schemes in the next year.

4. TYPHOON FREQUENCY PROJECTION

The projections of the frequency of Taiwan-invading typhoons for 1990 are listed in Table 7 for 500mb Z datasets from October to March and for SST datasets from October to December. The projections are done as for Mei-Yu parameters, but only the frequency projection is offered here. Since the long-term average frequency is 4.55 per year, with the standard deviation of 1.50 according to the 1949-86 statistics of the Central Weather Bureau, the projected frequency for 1990 is fairly close to the normal year typhoon frequency. The temporal and spatial stability of the projections is also well recognized.

The onset, recess, period, and precipitation are adequate gross predictands for Mei-Yu forecast, and they are all obtained from the same sets ot the real time data. The situation is quite different for typhoon forecast. The frequency forecast is treated like Mei-Yu parameters with the upper air and SST analyses. However, for its tropical origin, it will be appropriate to assume that the instability and divergence fields in the tropics play certain roles, and there is no way to assess the degree of variance accounted for by the analysis datasets of conventional observations. The necessity of such derived datasets of stability and divergence will be studied during the next year's project.

As far as the typhoon predictands which can be projected by conventional datasets are concerned, we may consider typhoon season precipitation in addition to the frequency as we have done in this year. The rainfall is a good parameter to express the overall typhoon activities if it is considered in conjunction with frequency, implying the strength of Taiwan-invading typhoon of the season. This will circumvent the difficulty in using other derived datasets, and will be studied continuously during the next year.

5. PLANETARY WAVE ACTIVITIES

The importance of planetary wave activities was discussed in the previously submitted first year report. In addition to the composite climatological analysis as reported last year, the analysis is extended to the individual year from 1956 to 1986. The trough-ridge diagrams (time-longitude diagram of the wave amplitude) of January of individual years are presented in Fig. 15 for $n=1$ and in Fig. 16 for $n=2$. The wave activities presented are for the 54-70°N band for the 500mb flow. The interannual differences of the planetary wave activities are very obvious. These diagrams may be directly associated with the Northern Hemisphere winter blocking and the Asian cold surge in January. In this project, however, an attempt is in progress to use these as predictors of Mei-Yu for the following summer. This will necessitate the classification of wave activity type in reference to Mei-Yu type as the first step. Further, the relationship between planetary and synoptic-scale waves needs to be studied. This ongoing part of research will be continued to the next year in the multiple regression forecast.

6. TECHNOLOGY TRANSFER

During the progress of this year's project, constant contact has been maintained with Dr. Beng-chun Lee of the Central Weather Bureau. A thorough review and planning of the investigation was conducted while Dr. Lee visited us during the summer, and nine volumes of analyses of principal components, cross-correlations, and scattered diagrams were forwarded to the Central Weather Bureau.

Ms. Shiou-Huey Sheng visited us during April 1990, and an extensive review and discussion of the qualitative forecast, as currently in progress, took place. The original results of computation and computer programs were also submitted to Ms. Sheng for retention at the Central Weather Bureau.

7. THIRD YEAR PLAN

As previously discussed, the third year investigation will be concerned with the completion of multiple regression forecast scheme. The investigation is expected to follow roughly the following plan:

7.1 Database

Our existing 1956-89 database of 500mb Z, 700mb T, 500-700mb thickness, and SST will be updated to include current observational analyses.

The 500mb analysis of the Northern Hemisphere planetary wave activities in the mid and low latitudes from $n=1$ to 4 in terms of amplitude and phase will form an additional database.

7.2 Regression analysis

The 1st predictors will be the predictors selected and utilized in this year's single regression projection, with those predictors which have given inferior projection being eliminated. The multiple regression analysis will then proceed according to the general procedures described in Kung and Tanaka (1985), for the 2nd to 5th predictors. They will be obtained by regressing the potential predictors on the residuals of the expected values of the preceding predictor, effectively eliminating the problem of multi-collinearity. Additional database of wave activities will also be tested as 1st predictors through a cross-correlation analysis.

During 1986, we collaborated with Mr. Cheng-Fa Tseng of the Central Weather Bureau in formulating a multiple regression scheme for Mei-Yu. The method of the regression formulation had some resemblance to this new effort; however, the new approach has important differences from the earlier effort as following:

(1) The 1st predictors have been meteorologically selected with a thorough examination for their stability as reported in this document.

(2) For each month's real time dataset one predictand will have a few to several sets of multiple regressions with different 1st predictors at different sites.

(3) Planetary wave activities will be additional predictors.

(4) The data are basically (except for planetary wave parameters) on the grid system instead of limited station observations.

(5) Forecast experiment will be conducted as stated in the next subsection.

7.3 Forecast experiment with existing database

After regression analysis, forecast experiments will be conducted in two ways with the existing database. First, the data of one year preceding the Mei-Yu event are excluded from the database in the regression analysis. Predictors (except for the

1st predictor) are selected and all regression coefficients are determined for the individual forecast years. The excluded data from the entire database are then used as the real time data to yield forecast values. Predictors and coefficients independently obtained for all forecast years will be compared to assess the basic stability of the scheme.

Second, the regression equations will be obtained with the first 25 years' database, and the forecast values will be obtained for individual years of the remaining data period with each year's data as the real time data input. The 25-year data period will be brought forward continuously for repeated experiments with a more recent database. Through this process we will be able to assess the period of utilities of obtained regressions, and determine when the updating of the regressions is necessary after the completion of the next year's project.

7.4 Real time forecast experiment

Regression forecast will be done for the 1991 Mei-Yu and typhoon with monthly real time data starting from October. As done with single regressions for 1990, forecast values will be obtained with all available multiple regression equations for each predictand with separate months' real time data. The projections will be communicated with the Central Weather Bureau during the experiment, and the results will be discussed in a comprehensive final report.

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Table 1. Mei-Yu Onset date forecast for 1990 (Day 1 from April 1) by upper air parameters and SST of preceding months. 700 mb T and SST are in the unit of °C from October to December, and K thereafter.

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Oct.	700mb T			
	(50-70N, 115-140E)	47.71+1.6734(x-257.29)	-15.92 °C	48 day
	(30-40N, 67-44W)	47.71-5.4152(x-278.34)	4.91	49
	(30-38N, 111-99W)	47.71-3.6637(x-278.10)	4.94	48
	(30-48N, 69-88E)	47.71-3.6457(x-274.52)	3.22	41
	500mb Z			
	(15-23N, 47-28W)	47.71+0.2295(x-5881.81)	5863.61m	44
	(15-28N, 6-14E)	47.71+0.2074(x-5873.86)	5872.94	48
	(22-28N, 72-81E)	47.71+0.2524(x-5847.36)	5863.67	52
	SST			
	(42-50N, 165E-177W)	48.02+5.1392(x-11.26)	11.37 °C	49
	(26-30N, 129-123W)	48.02-6.1660(x-20.82)	20.64	49
	(2S-2N, 159-177E)	48.02-7.4064(x-28.96)	26.53	51
	(18-10S, 135-117W)	48.02-3.9134(x-25.31)	25.19	49
Nov.	700mb T			
	(22-35N, 141-157E)	47.71-5.6417(x-279.88)	5.93 °C	52
	(38-60N, 144-121W)	47.71-1.1290(x-264.19)	-6.31	45
	(25-40N, 77-56W)	47.71-3.2428(x-277.04)	3.79	48
	(40-57N, 83-60W)	47.71-2.8210(x-263.27)	-13.84	59
	500mb Z			
	(32-40N, 174-166W)	47.71+0.0788(x-5712.61)	5723.00	49
	(23-38N, 117-101W)	47.71+0.2161(x-5748.95)	5765.08	51
	(15-27N, 54-66E)	47.71+0.1525(x-5860.18)	5872.84	50
	(40-48N, 73-85E)	47.71-0.1810(x-5620.46)	5646.50	44
	SST			
	(38-42N, 171-177E)	48.02+2.7718(x-15.74)	16.05 °C	49
	(10-2S, 147-135W)	48.02-4.9334(x-26.60)	26.72	47
	(6S-2N, 93-87W)	48.02-4.2733(x-22.69)	22.50	49
Dec.	700mb T			
	(23-40N, 170E-176W)	47.71+4.2308(x-274.94)	0.08 °C	41
	(45-62N, 147-121W)	47.71-0.8900(x-260.07)	-6.31	42
	x(23-38N, 33-48E)	47.71-3.1077(x-279.07)	-0.41	67
	(18-32N, 71-59W)	47.71+1.8515(x-273.940)	6.38	58
	(40-50N, 83-98E)	47.71-1.4587(x-260.60)	-7.35	40
	500mb Z			
	(38-54N, 113-154E)	47.71-0.0940(x-5236.32)	5281.04	44
	(23-31N, 177E-167W)	47.71+0.0830(x-5790.79)	5774.48	46
	(22-30N, 34-43E)	47.71+0.1365(x-5765.81)	5778.17	49

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Dec.	SST			
	(30-34N, 165E-177W)	48.02+10.3926(x-20.06)	20.36°C	51
	(10-14N, 87-93E)	48.02-8.8693(x-27.93)	27.78	49
	(10-2S, 111-105W)	48.02-1.8661(x-23.91)	23.58	49
Jan.	700mb T			
	(23-30N, 168E-177W)	47.71+2.2787(x-277.53)	276.42 K	45
	(59-70N, 160E-160W)	47.71+1.3541(x-253.22)	250.75	44
	(50-60N, 113-90W)	47.71-1.0466(x-253.35)	254.85	46
	(29-45N, 57-38W)	47.71-2.0309(x-266.71)	270.82	56
	500mb Z			
	(34-40N, 135-143E)	47.71-0.0715(x-5409.09)	5419.83	47
	(34-40N, 140-130W)	47.71+0.0505(x-5678.29)	5706.13	49
	(20-25N, 10-3W)	47.71+0.0951(x-5804.55)	5789.67	46
	(32-43N, 45-60W)	47.71+0.1339(x-5574.28)	5556.51	45
Feb.	700mb T			
	(35-50N, 134-154E)	47.71+1.0153(x-257.33)	259.12	50
	(38-55N, 123-103W)	47.71-0.9983(x-263.25)	261.55	49
	(10-24N, 70-55W)	47.71-3.7178(x-280.73)	279.88	51
	500mb Z			
	(40-48N, 127-152E)	47.71+0.0984(x-5270.98)	5423.57	63
	(20-33N, 148-137W)	47.71+0.1515(x-5773.11)	5747.50	44
	(50-70N, 55-92E)	47.71-0.0773(x-5280.06	5317.96	45
Mar.	700mb T			
	(28-45N, 148-173E)	47.71+1.8210(x-267.12)	263.41	41
	(45-68N, 160-130W)	47.71-1.2177(x-258.75)	261.57	44
	(10-25N, 95-78W)	47.71-5.0290(x-281.71)	281.60	48
	(20-28N, 10W-5E)	47.71-2.5427(x-279.52)	279.66	47
	500mb Z			
	(41-57N, 160-180E)	47.71+0.0757(x-5308.95)	5263.96	44
	(47-54N, 144-134W)	47.71-0.0515(x-5438.33)	5495.33	45
	(25-33N, 47-37W)	47.71+0.0936(x-5783.46)	5787.19	48
	(12-20N, 1-14E)	47.71-0.2258(x-5851.79)	5876.85	42

Table 2. As in Table 1, but for Mei-Yu recess forecast.

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Oct.	700mb T			
	(22-30N, 106-98W)	79.73-3.4116(x-281.25)	9.82	74
	(35-42N, 18-8W)	79.73+2.2826(x-275.79)	2.62	80
	(37-52N, 97-111E)	79.73-2.3132(x-270.63)	-2.13	79
	500mb Z			
	(33-40N, 134.146E)	79.73-0.1436(x-5722.25)	5715.20	80
	(17-27N, 119-106W)	79.73-0.2308(x-5862.64)	5867.30	79
	(33-42N, 18-8W)	79.73+0.0827(x-5767.88)	5776.38	80
	SST			
	(34-38N, 177-165W)	78.75+4.2005(x-20.99)	20.54	77
	(22-26N, 153-159E)	78.75+7.1525(x-28.37)	28.07	77
	(14-18N, 111-117E)	78.75+3.6813(x-28.34)	28.18	78
Nov.	700mb T			
	(16-28N, 168-178E)	79.73+4.1888(x-282.17)	7.97	75
	(30-40N, 145-165W)	79.73+5.1262(x-275.58)	1.82	77
	(30-43N, 44-63E)	79.73-2.5440(x-275.05)	-0.33	78
	500mb Z			
	(32-43N, 151-169E)	79.73-0.1219(x-5632.79)	5703.57	71
	(33-40N, 67-57W)	79.73-0.1335(x-5725.38)	5723.50	80
	(27-42N, 18-6W)	79.73-0.1180(x-5743.27)	5689.47	86
	SST			
	(22-30N, 165-171E)	78.75+10.3799(x-25.99)	25.49	74
	(30-38N, 75-57W)	78.75-7.1350(x-23.31)	23.15	80
Dec.	500mb Z			
	(23-38N, 117-128E)	79.73-0.1114(x-5671.14)	5666.93	80
	(26-34N, 144-136W)	79.73+0.1946(x-5787.11)	5789.89	80
	(28-37N, 6W-6E)	79.73-0.0986(x-5699.30)	5732.13	76
	SST			
	(34-38N, 69-57W)	78.75-4.9014(x-21.03)	19.98	84
	(22-10N, 165-179E)	78.75+9.7003(x-23.99)	23.99	79
Jan.	500mb Z			
	(14-26N, 51-41W)	79.73+0.1605(x-5820.04)	5833.15	82
	(23-33N, 80-98E)	79.73+0.1712(x-5698.57)	5745.15	88

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Feb.	(Not Taken)			
Mar.	700mb T			
	(20-27N, 114-103W)	79.73-4.1359(x-280.06)	280.69	77
	500mb Z			
	(15-28N, 5-15E)	79.73+0.1394(x-5817.32)	5842.43	83
	(22-30N, 58-80E)	79.73+0.1164(x-5776.91)	5778.06	80

Table 3. As in Table 1, but for Mei-Yu length forecast (days).

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Oct.	700mb T			
	(21-33N, 148-166E)	33.02+4.7940(x-282.58)	8.51	29
	(30-40N, 68-44W)	33.02+5.6281(x-278.34)	4.88	31
	(33-45N, 4-18E)	33.02+3.7643(x-275.03)	1.80	33
	(38-50N, 112-137E)	33.02+2.1648(x-267.32)	-5.98	33
	500mb Z			
	(33-42N, 109-88W)	33.02+0.1429(x-5959.65)	5764.00	34
	(15-19N, 24-17W)	33.02-0.3636(x-5884.45)	5879.00	35
	SST			
	(30-34N, 177-165W)	31.73+4.9668(x-23.77)	23.39	31
	(30-34N, 75-69W)	31.73-6.4848(x-25.94)	25.70	33
	(18-26N, 135-141E)	31.73+9.9330(x-28.36)	28.44	32
	(18-22N, 69-63W)	31.73+13.1987(x-28.58)	28.16	26
	(2-6N, 177-171W)	31.73+6.0760(x-28.52)	28.71	33
	(22-26N, 147-153W)	31.73+14.5787(x-28.29)	28.29	32
	(10-6S, 165-171E)	31.73+10.0313(x-29.24)	29.30	32
Nov.	700mb T			
	(16-24N, 160-178E)	33.02+6.7005(x-282.78)	8.90	28
	(30-38N, 157-146E)	33.02+7.8629(x-276.44)	2.69	28
	(24-33N, 69-59W)	33.02+3.3238(x-278.93)	5.58	32
	(24-33N, 46-56E)	33.02-3.7009(x-277.82)	4.80	33
	500mb Z			
	(55-70N, 121-161E)	33.02+0.0775(x-5165.41)	5209.41	36
	(31-39N, 173-176E)	33.02-0.1523(x-5736.21)	5778.50	27
	(21-28N, 127-116W)	33.02-0.2528(x-5826.37)	5831.25	32
	(18-25N, 98-113E)	33.02-0.4005(x-5854.27)	5870.67	26
	SST			
	(22-26N, 177E-177W)	31.73+9.3249(x-26.17)	25.78	28
	(6S-2N, 129-117W)	31.73+2.7909(x-24.72)	24.08	32
	(14-10S, 105-111E)	31.73-10.7195(x-27.32)	28.19	22
	(26-22S, 141-135W)	31.73-6.9944(x-23.66)	23.43	33
Dec.	700mb T			
	(17-29N, 143-163E)	33.02+3.3716(x-282.91)	7.86	27
	(22-34N, 147-128W)	33.02+5.0874(x-277.13)	4.67	37
	(17-32N, 71-59W)	33.02+4.2832(x-279.07)	6.83	37
	(38-57N, 61-83E)	33.02+1.7076(x-260.17)	-10.47	37
	(32-50N, 113-131E)	33.02-1.2269(x-261.18)	-12.85	34

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Dec.	500mb Z			
	(23-32N, 174-164W)	33.02-0.1180(x-5782.19)	5768.00	35
	(22-33N, 146-128W)	33.02+0.1966(x-5803.09	5803.00	33
	SST			
	(18-22N, 135-141E)	31.73+13.4863(x-27.20)	26.49	22
	(2-6N, 105-99W)	31.73+4.0007(x-25.81)	26.00	33
Jan.	700mb T			
	(17-25N, 130-152E)	33.02+3.5076(x-281.46)	279.62	27
	(50-68N, 160-178E)	33.02-1.6388(x-254.00)	254.02	38
	(40-50N, 105-92W)	33.02+1.5365(x-259.52)	263.77	40
	(28-37N, 38-47E)	33.02-2.4956(x-269.00)	268.17	35
	(15-22N, 76-85E)	33.02+5.4296(x-280.77)	282.82	44
	500mb Z			
	(32-40N, 134-144E)	33.02+0.0900(x-5409.09)	5463.87	38
	(40-48N, 135-122W)	33.02-0.0648(x-5578.15)	5594.29	32
	(30-39N, 37-62E)	33.02-0.1962(x-5518.33)	5613.17	34
Feb.	700mb T			
	(16-24N, 143-162E)	33.02+3.8112(x-281.66)	280.38	28
	(14-21N, 158-145W)	33.02-1.7652(x-280.43)	279.45	35
	(45-55N, 3-15E)	33.02-1.4749(x-262.12)	266.33	27
	(35-52N, 98-108E)	33.02-1.7250(x-258.35)	261.51	28
	500mb Z			
	(68-76N, 133-168E)	33.02+0.0655(x-5157.20)	5125.31	31
	(57-67N, 50-30W)	33.02+0.0414(x-5221.29)	5006.83	24
	(18-29N, 42-23W)	33.02+0.1218(x-5782.52)	5807.25	36
Mar.	700mb T			
	(25-40N, 128-145E)	33.02-2.5307(x-268.20)	269.44	30
	(45-55N, 148-130E)	33.02+1.5078(x-262.29)	264.40	36
	(20-28N, 115-105W)	33.02-4.8697(x-280.00)	279.89	34
	(20-28N, 5W-6E)	33.02+4.0947(x-279.22)	279.66	35
	500mb Z			
	(28-41N, 135-154E)	33.02-0.0894(x-5579.38)	5550.45	36
	(46-63N, 147-120W)	33.02+0.1124(x-5394.69)	5461.83	41
	(20-27N, 113-105W)	33.02-0.2437(x-5804.95)	5833.67	26
	(14-20N, 3W-14E)	33.02+0.3514(x-5851.79)	5876.95	42

Table 4. As in Table 1, but for Mei-Yu precipitation forecast (mm).

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Oct.	700mb T			
	(32-48N, 128-146E)	461.96-67.7626(x-271.27)	-2.83	525
	(20-30N, 159-178E)	461.96+80.0790(x-282.61)	8.85	414
	(38-48N, 137-119W)	461.96+36.1273(x-272.70)	-0.96	443
	(16-33N, 102-86W)	461.96-69.4893(x-281.59)	7.35	537
	500mb Z			
	(32-40N, 134-146E)	461.96-4.4163(x-5722.65)	5741.40	379
	(52-63N, 139-161E)	461.96+1.9949(x-5351.65)	5347.44	453
	(14-27N, 29-17W)	461.96-5.8427(x-5876.00)	5868.16	508
	SST			
	(38-46N, 159-171E)	444.40-78.8586(x-15.68)	16.30	396
	(38-46N, 159-153W)	444.40-41.3545(x-16.20)	16.69	424
	(26-30N, 123-129E)	444.40-158.9580(x-26.12)	26.68	513
	(40-34N, 75-69W)	444.40-163.1500(x-25.94)	25.70	484
Nov.	700mb T			
	(15-24N, 138-153E)	461.96+80.5850(x-283.57)	9.85	416
	(38-55N, 131-154E)	461.96-40.4544(x-258.95)	-13.15	419
	(38-55N, 144-121W)	461.96+31.2040(x-266.57)	-4.05	541
	(36-45N, 29-18W)	461.96-57.6298(x-270.37)	-2.29	433
	500mb Z			
	(38-53N, 142-168E)	461.96-2.5882(x-5384.90)	5460.64	266
	(43-52N, 78-66W)	461.96-1.7913(x-5453.12)	5333.00	677
	(15-27N, 28-18W)	461.96-7.5727(x-5855.70)	5826.75	681
	(53-63N, 141-121W)	461.96+1.1519(x-5382.59)	5300.81	368
	SST			
	(38-42N, 171-177W)	444.40-58.6175(x-15.66)	15.90	430
	(2-10N, 111-93W)	444.40-97.9909(x-26.11)	26.65	497
	(14-10S, 177E-177W)	444.40+212.8660(x-28.75)	29.14	527
Dec.	700mb T			
	(31-50N, 111-134E)	461.96-35.1804(x-260.01)	-12.72	447
	(36-55N, 149-131W)	461.96+27.9761(x-265.61)	-2.61	600
	(24-40N, 68-54W)	461.96+77.2502(x-274.66)	1.35	450
	(47-70N, 94-66W)	461.96+49.0550(x-253.91)	-23.55	251
	500mb Z			
	(33-50N, 111-123E)	461.96-2.9717(x-5439.03)	5500.77	279
	(53-70N, 71-97E)	461.96+1.5765(x-5254.69)	5207.30	387
	(18-25N, 89-98E)	461.96+6.8362(x-5320.96)	5812.87	407

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Dec.	SST			
	(38-42N, 159-177E)	444.40-70.0299(x-13.64)	13.75	437
	(14-18N, 111-117E)	444.40-73.2622(x-26.16)	25.52	491
	(18-22N, 177-171W)	444.40-159.4070(x-26.29)	25.83	517
	(10-2S, 117-105W)	444.40+12.0443(x-24.00)	23.90	443
	(18-14S, 165-177E)	444.40+129.8250(x-27.97)	28.15	467
Jan.	700mb T			
	(30-45N, 160-174E)	461.96-71.0491(x-265.66)	263.35	626
	(37-58N, 160-133W)	461.96+31.6788(x-267.94)	263.71	328
	(52-62N, 75-58W)	461.96-23.5309(x-250.41)	249.57	482
	(30-38N, 38-48E)	461.96-49.7129(x-269.00)	267.22	551
	(43-52N, 98-112E)	461.96-33.4441(x-253.40)	252.70	485
	500mb Z			
	(20-34N, 123-138E)	461.96+2.5519(x-5718.96)	5743.53	526
	(22-35N, 132-118W)	461.96-2.3362(x-5766.25)	5753.63	491
	(40-48N, 70-83E)	461.96-2.1312(x-5518.03)	5534.29	427
Feb.	700mb T			
	(15-19N, 128-145E)	461.96+59.4443(x-282.75)	281.99	417
	(25-40N, 128-110E)	461.96+41.1737(x-272.06)	271.56	441
	(48-60N, 58-40W)	461.96+42.6084(x-256.77)	249.35	146
	(40-50N, 112-114E)	461.96-29.780(x-252.28)	257.83	297
	500mb Z			
	(45-55N, 10W-3E)	461.96-1.1741(x-5492.90)	5473.47	475
	(40-50N, 110-123E)	461.96-2.7902(x-5308.95)	5451.57	64
	(27-34N, 15-34E)	461.96+3.0344(x-5660.00)	5676.83	523
	(18-23N, 82-90E)	461.96+5.8225(x-5811.52)	5809.62	451
Mar.	700mb T			
	(28-44N, 160-175E)	461.96-45.3827(x-267.52)	265.21	567
	(52-62N, 140-120W)	461.96+29.8711(x-257.85)	261.72	577
	(17-24N, 130-112W)	461.96-79.2263(x-280.18)	280.73	418
	(70-83N, 60-20W)	461.96-40.9423(x-249.79)	244.68	548
	500mb Z			
	(36-53N, 18-31E)	461.96+2.6919(x-5513.57)	5630.60	777

Table 5. Summary of 1990 Mei-Yu forecast by upper air parameters and SST of preceding months.

Predictors		Onset (1-April 1)	Recess (1-April 1)	Length (Days)	Precipitation (mm)
Oct. 1989	700mb T	48	74	29	525
		49	80	31	414
		48	79	33	443
		41		33	537
		A-46.5	A-77.6	A-31.5	A-479.8
	500mb Z	44	80	34	379
		48	79	35	453
		52	80		508
		A-48.0	A-79.7	A-34.5	A-446.7
	SST	49	77	30	396
		49	77	33	424
		51	78	32	513
		49		26	484
				33	
				32	
				33	
		A-49.5	A-77.3	A=31.2	A-454.3
Nov. 1989	700mb T	52	75	28	416
		45	77	28	419
		48	78	32	541
		59		33	433
		A-51.0	A-76.7	A-30.3	A-452.3
	500mb Z	49	71	36	266
		51	80	27	677
		50	85	32	681
		44		26	368
		A-49.0	A-79.0	A-30	A-499.0
	SST	49	74	28	430
		47	78	32	497
		49		22	527
		49		33	
		A-48.5	A-76.0	A-28.8	A-484.7

Predictors		Onset (1=April 1)	Recess (1=April 1)	Length (Days)	Precipitation (mm)
Dec. 1989	700mb T	41		27	447
		42		37	600
				37	450
		58		37	251
		40		34	
		A=45.3		A=34.4	A=437.0
	500mb Z	44	80	35	279
		46	80	33	387
		49	76		407
		A=46.3	A=78.7	A=34.0	A=357.7
	SST	51	84	22	437
		49	79	33	491
		49			517
					443
					467
		A=49.7	A=81.5	A=27.0	A=471.0
Jan. 1990	700mb T	45		27	626
		44		38	328
		46		40	482
		56		35	551
				44	485
		A=47.8		A=36.8	A=494.4
	500mb Z	47	82	38	526
		49	88	32	491
		46		34	427
		45			
		A=46.8	A=85.0	A=34.7	A=481.3
Feb. 1990	700mb T	50		28	417
		49		35	441
		51		27	146*
				28	297
		A=50.0		A=29.5	A=385.0
	500mb Z	63		31	475
		44		24	64*
		45		36	523
					451
		A=51.0		A=30.3	A=483.0

(*) Not included in A.

Predictors		Predictands			
		Onset (1-April	Recess (1-April 1)	Length (Days)	Precipitation (mm)
Mar. 1990	700mb T	41	77	30	567
		44		36	577
		48		34	418
		47		35	548
		A=45.0	A=77.0	A=33.8	A=527.5
	500mb Z	44	83	36	777
		45	80	41	
		48		26	
		42		42	
		A=44.8	A=81.5	A=36.3	A=777.0

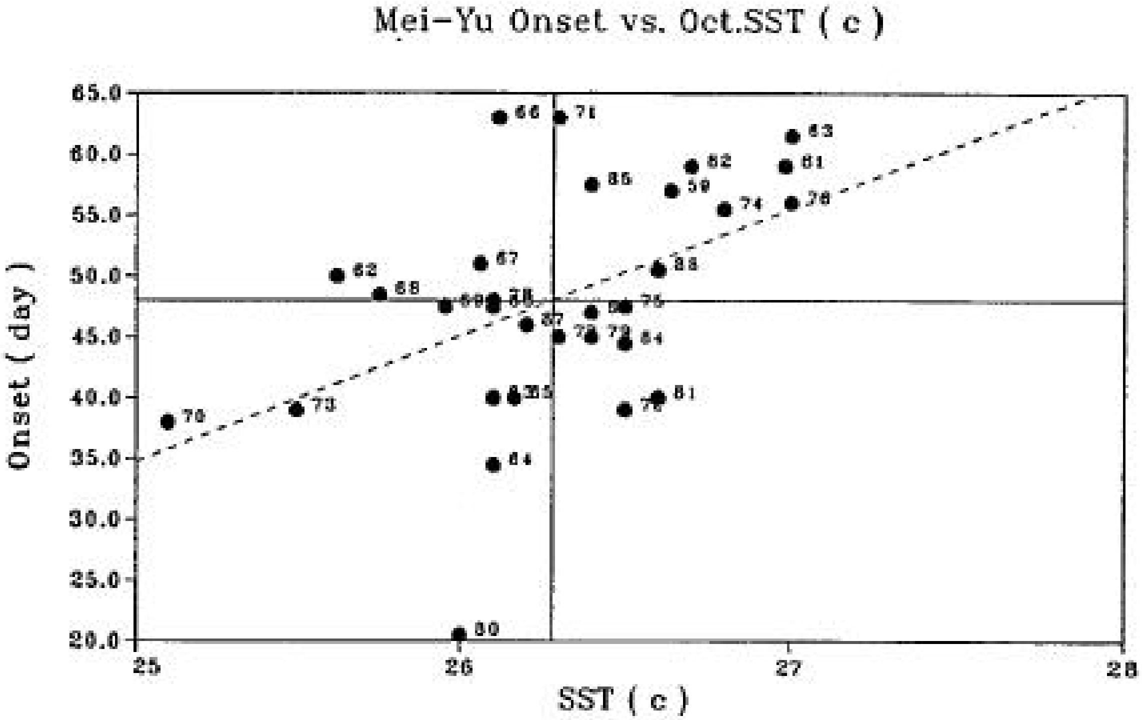
Table 6. Recorded Mei-Yu onset, recess, period and precipitation from 1941 to 1988 (Northern and Southern Taiwan averages).

Year	Onset (1=April 1)	Recess (1=April 1)	Period (Days)	Precipitation (mm)
1941	54.0	81.0	28.0	630.0
1942	41.5	88.0	47.5	443.5
1943	58.0	87.0	30.0	522.1
1944	30.0	80.0	51.0	860.5
1945	50.0	76.0	27.0	373.6
1946	43.0	72.0	30.0	347.3
1947	47.0	87.0	41.0	978.3
1948	57.0	86.5	30.5	286.6
1949	41.5	80.0	39.5	605.1
1950	47.0	85.5	39.5	502.5
1951	43.5	80.0	37.5	739.9
1952	50.0	88.0	39.0	440.3
1953	41.5	76.0	35.5	678.3
1954	60.0	67.0	8.0	101.6
1955	38.5	77.5	40.0	432.1
1956	40.0	78.0	39.0	332.9
1957	42.5	81.5	40.0	808.9
1958	52.5	87.5	36.0	277.1
1959	57.0	86.5	30.5	305.4
1960	47.0	79.5	33.5	486.7
1961	59.0	73.5	15.5	58.5
1962	50.0	79.5	30.5	270.6
1963	61.5	78.0	17.5	180.2
1964	34.5	89.0	55.5	359.2
1965	40.0	91.0	52.0	428.5
1966	63.0	80.5	18.5	589.5
1967	51.0	76.0	26.0	529.5
1968	48.5	89.5	42.0	671.8
1969	47.5	84.5	38.0	504.9
1970	38.0	87.0	50.0	446.3
1971	63.0	71.5	9.5	124.2
1972	39.0	80.0	42.0	688.7
1973	39.0	78.0	40.0	410.0
1974	55.5	86.5	32.0	655.7
1975	47.5	81.5	35.0	593.9
1976	56.0	75.5	20.5	301.4
1977	45.0	83.0	39.0	998.7
1978	48.0	70.5	23.5	233.7
1979	45.0	78.5	34.5	545.1
1980	20.5	41.0	21.5	159.0
1981	40.0	81.0	42.0	691.7
1982	59.0	86.5	28.5	432.5
1983	40.0	81.0	42.0	656.2
1984	44.5	81.5	38.0	626.4
1985	57.5	81.0	24.5	387.3
1986	47.5	73.0	26.5	565.5
1987	46.0	70.0	25.0	239.1
1988	50.5	68.0	18.5	190.9
MEAN	47.46	79.6	33.15	472.77
SD*	8.84	8.25	10.7	220.28

Table 7. Typhoon frequency forecast for 1990 with 500mb Z (m) and SST (°C).

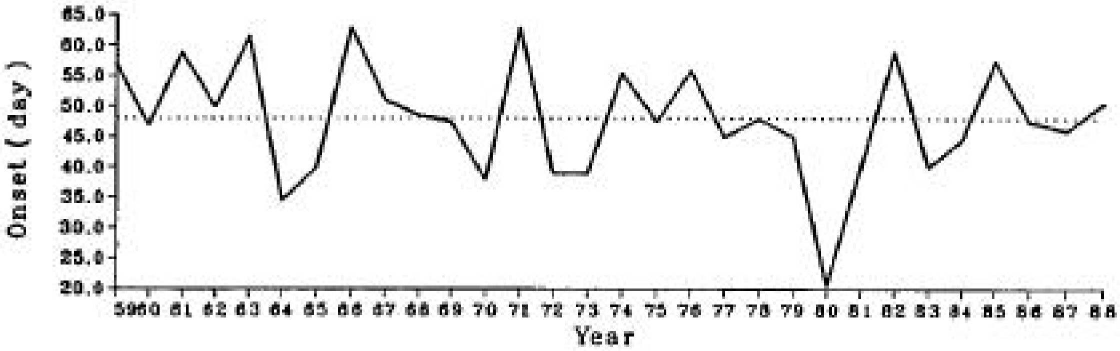
Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Oct.	SST			
	(22-26N, 135-141E)	4.39-1.2536(x-28.08)	27.96	4.5
	(22-14S, 153-165E)	4.39-1.0136(x-25.46)	25.98	3.9
	(10-14N, 177E-177W)	4.39+0.9030(x-28.62)	28.74	4.5
	(46-50N, 141-135W)	4.39+0.7695(x-13.24)	14.52	5.4
	(22-26N, 123-117W)	4.39+1.0335(x-22.85)	22.86	4.4
	(14-18N, 81-75W)	4.39+2.3356(x-28.86)	28.81	4.3
Nov.	500mb Z			
	(63-72N, 98-119E)	4.35-0.0069(x-5148.75)	5129.44	4.5
	(30-38N, 111-99W)	4.35-0.0238(x-5719.79)	5735.50	4.7
	(15-28N, 46-27W)	4.35+0.0365(x-5857.69)	5830.00	3.3
	(27-33N, 88-104E)	4.35+0.0380(x-5766.18)	5749.06	3.7
	SST			
	(26-30N, 129-135E)	4.39-1.1818(x-24.58)	24.67	4.3
	(30-34N, 153-159E)	4.39+1.0894(x-23.12)	23.41	4.7
	(14-10S, 153-159E)	4.39-1.0884(x-28.23)	28.78	3.8
	(34-30S, 177-171W)	4.39-0.8058(x-18.17)	19.54	3.3
	(10-14N, 165-159W)	4.39+1.1692(x-27.67)	27.79	4.5
	(14-22N, 129-111W)	4.39+1.2084(x-26.08)	25.88	4.1
	(14-18N, 81-75W)	4.39+2.3746(x-28.50)	28.49	4.4
	(22-26N, 75-57W)	4.39+1.5439(x-27.04)	27.11	4.5
Dec.	500mb Z			
	(32-46N, 124-104W)	4.35+0.0131(x-5650.36)	5676.19	4.7
	(26-36N, 42-27W)	4.35+0.0141(x-5750.74)	5667.71	4.6
	(45-58N, 10W-11E)	4.35-0.0116(x-5433.16)	5497.39	3.6
	(30-45N, 36-54E)	4.35+0.0322(x-5620.55)	5634.14	4.8
	SST			
	(26-30N, 129-135E)	4.39-0.4464(x-22.61)	22.43	4.5
	(26-30N, 147-153E)	4.39+0.6361(x-23.63)	23.26	4.2
	(6-10N, 159-171E)	4.39+1.0898(x-28.78)	28.94	4.6
	(10-18N, 171-165E)	4.39+1.2573(x-26.790)	26.93	4.6
	(34-30S, 171-165W)	4.39-0.6207(x-19.680)	19.93	4.2
	(10-14N, 153-147W)	4.39+0.3246(x-26.17)	26.76	4.6
	(46-50N, 135-129W)	4.39+0.9935(x-9.960)	10.60	5.0
	(22-26N, 123-117W)	4.39+0.9009(x-20.59)	20.78	4.6
	(22-26N, 69-57W)	4.39+1.6546(x-25.70)	26.10	5.1
Jan.	500mb Z			
	(40-48N, 140-153W)	4.35-0.0127(x-5221.29)	5222.12	4.3
	(40-48N, 163-153W)	4.35-0.0040(x-5428.98)	5491.94	4.1
	(34-43N, 75-52W)	4.35-0.0080(x-5579.43)	5643.90	3.8
	(15-25N, 96-130E)	4.35+0.0222(x-5827.63)	5832.40	4.5

Month	Predictors (x)	Regression ($\hat{y}$=---)	x	$\hat{y}$
Feb.	500mb Z			
	(20-30N, 126-133E)	4.35+0.0151(x-5768.05)	5813.53	5.0
	(27-35N, 145-135W)	4.35+0.0155(x-5743.25)	5704.10	3.7
	(18-28N, 88-70W)	4.35+0.0394(x-5840.11)	5859.94	5.1
	(28-38N, 5-15E)	4.35-0.0096(x-5673.13)	5748.10	5.1
Mar.	500mb Z			
	(25-35N, 128-140E)	4.35+0.0230(x-5688.18)	5703.12	4.7
	(15-32N, 164-147W)	4.35+0.0183(x-5810.75)	5816.06	4.5
	(37-49N, 65-40W)	4.35-0.0098(x-5485.48)	5559.67	3.6
	(36-44N, 18-28E)	4.35+0.0146(x-5553.11)	5680.33	6.2



r = 0.481 ; $\hat{Y}$ = 48.02 + 10.3545 * (X - 26.28).

Location: 4. ; S 14 - S 10 ; E 99 - E105 .



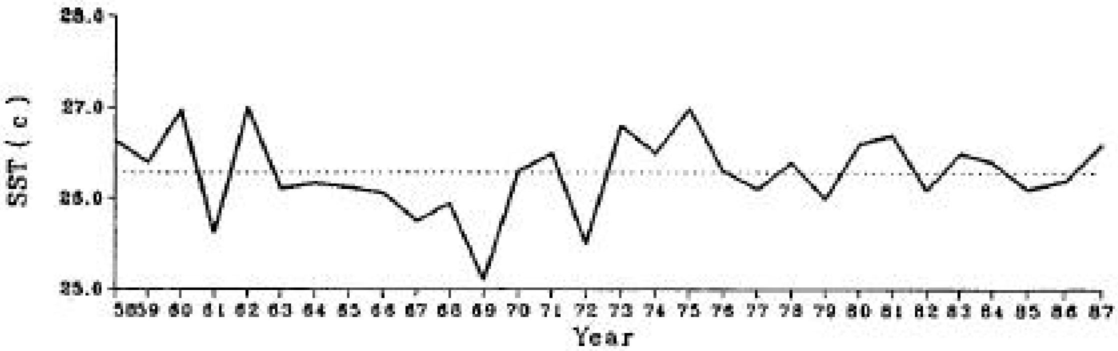
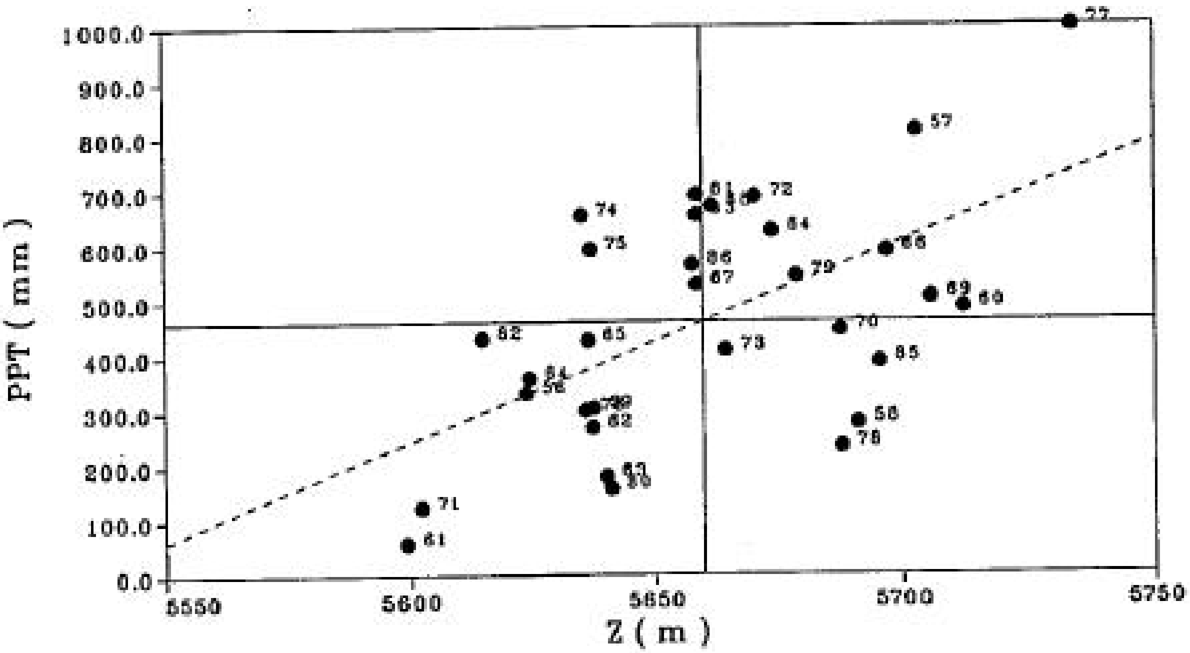


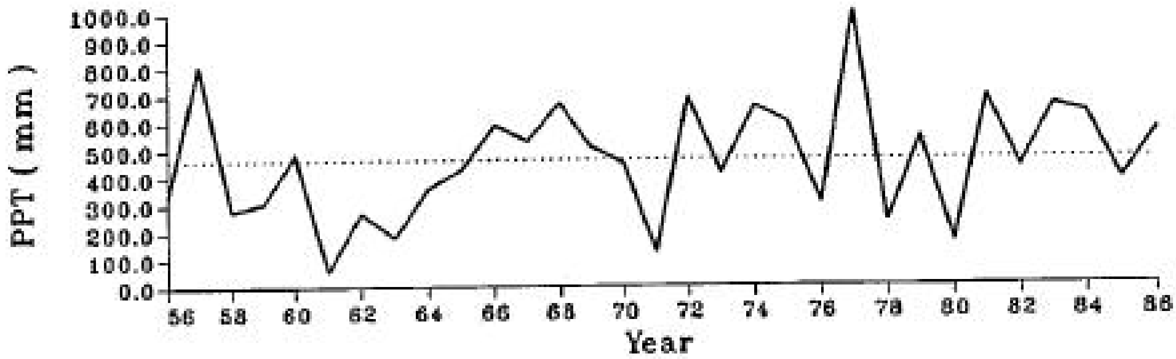
Fig. 1. Example of the regression and scattered diagram. Mei-Yu onset vs. October SST in (14-10°N, 99-105°E).

Mei-Yu PPT vs. Feb. Z (m)



$r = 0.570 \quad : \quad \hat{Y} = 461.96 + 3.6344 * (X - 5660.00)$.

Location: 3. ; N 27 - 34 ; E 15 - E 34



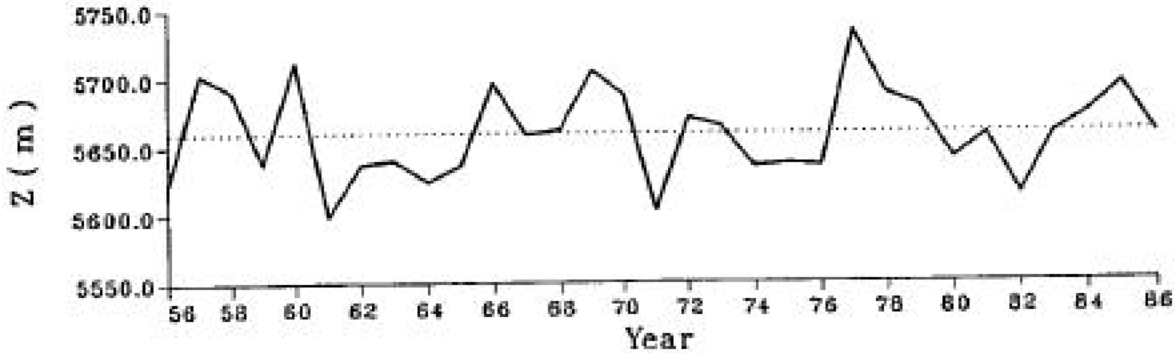


Fig. 2. As in Fig. 1, but for Mei-Yu precipitation vs. February 500mb Z in (27-34°N, 15-34°E).

1990 Taiwan Mei-Yu Forecast by October Teleconnections

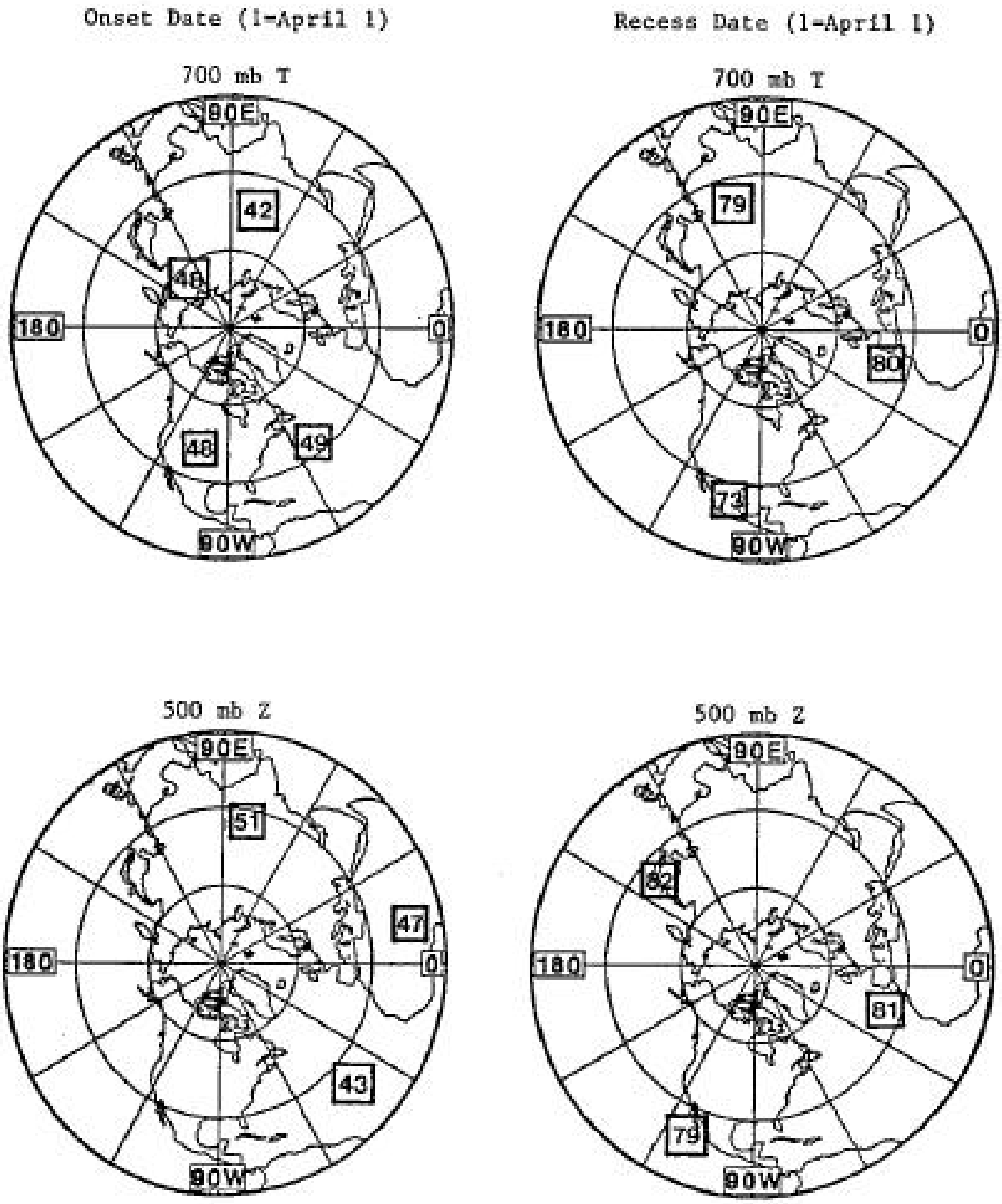


Fig. 3

1990 Taiwan Mei-Yu Forecast by October Teleconnections

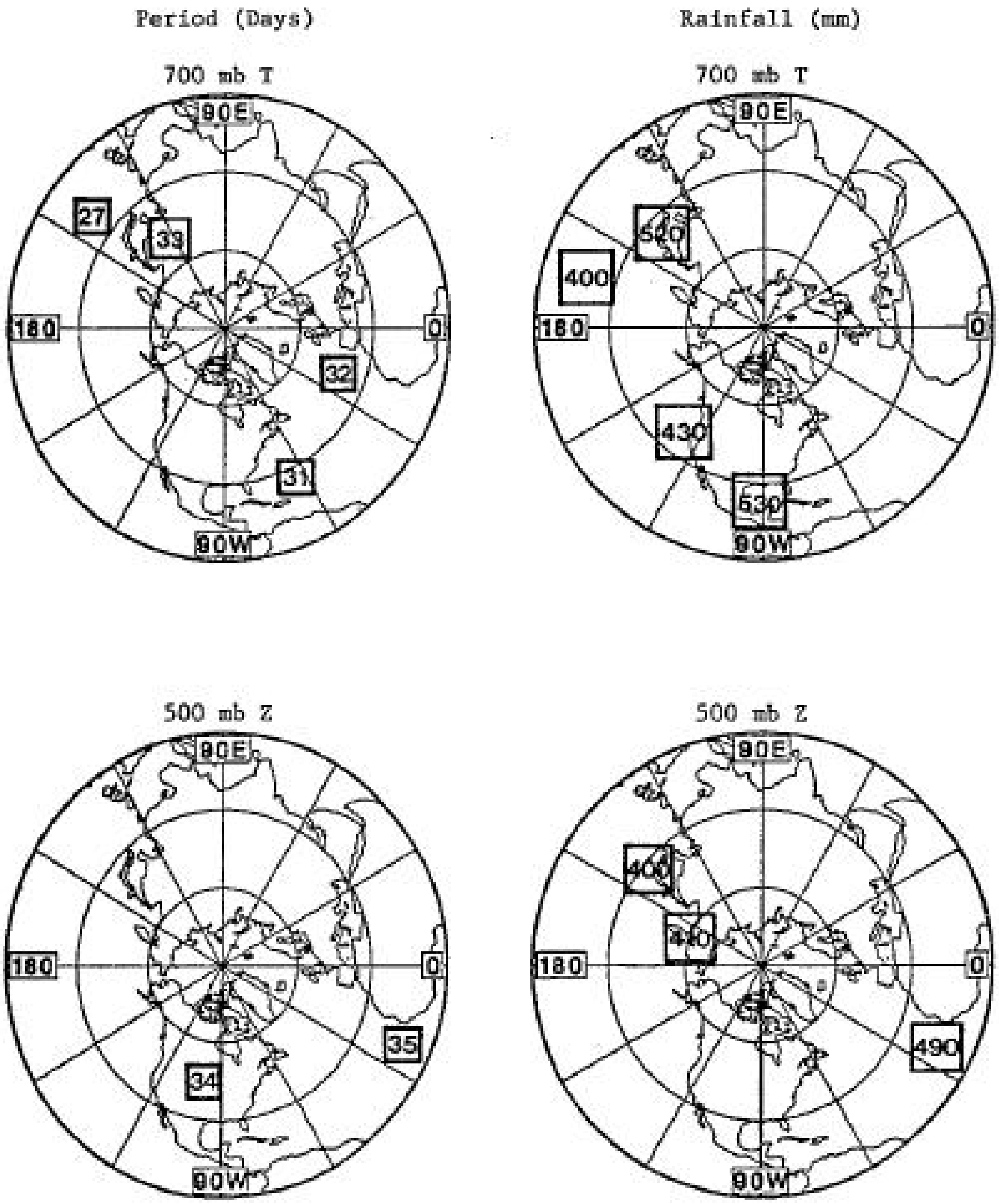


Fig. 4

1990 Taiwan Mei-Yu Forecast by November Teleconnections

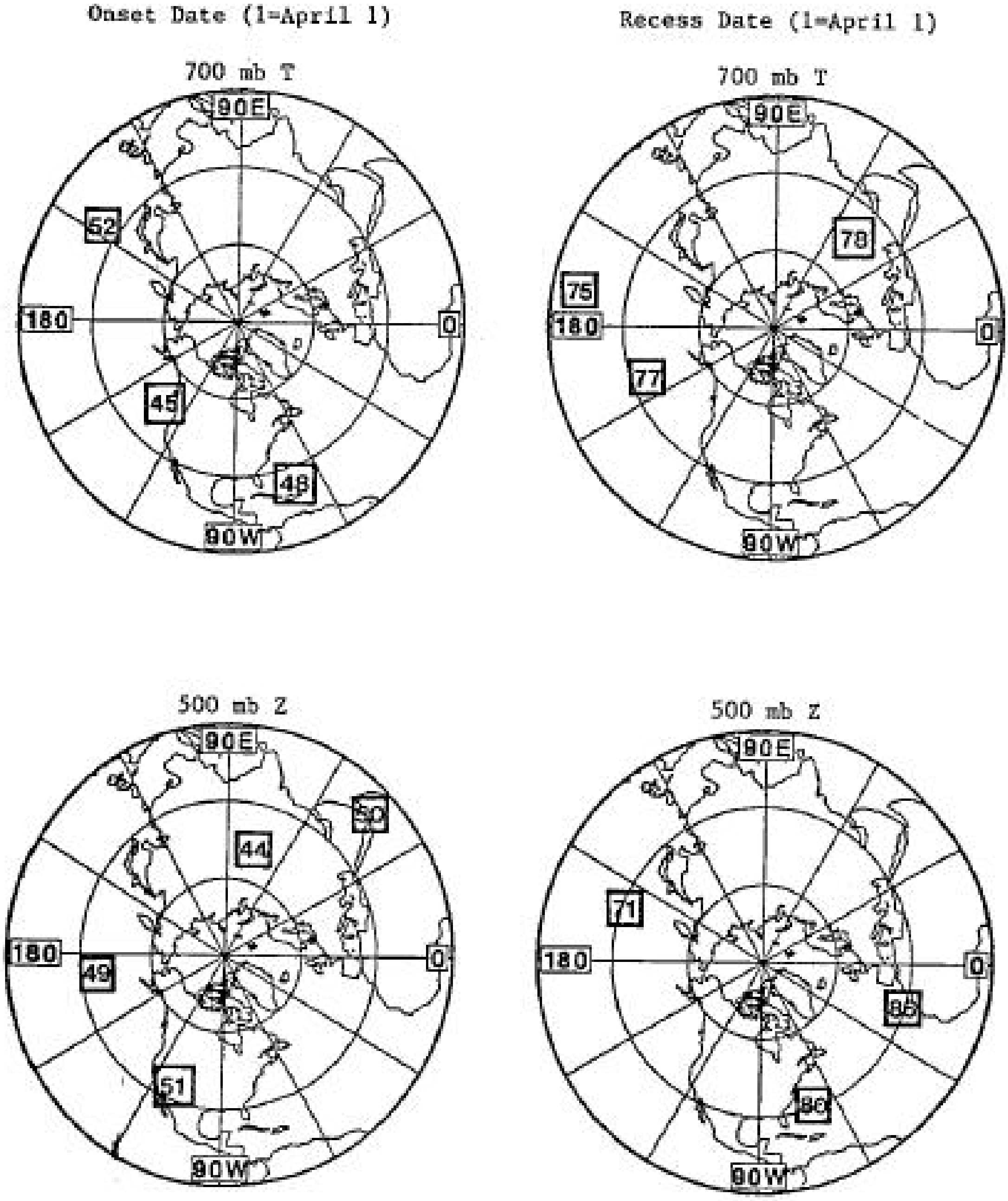


Fig. 5

1990 Taiwan Mei-Yu Forecast by November Teleconnections

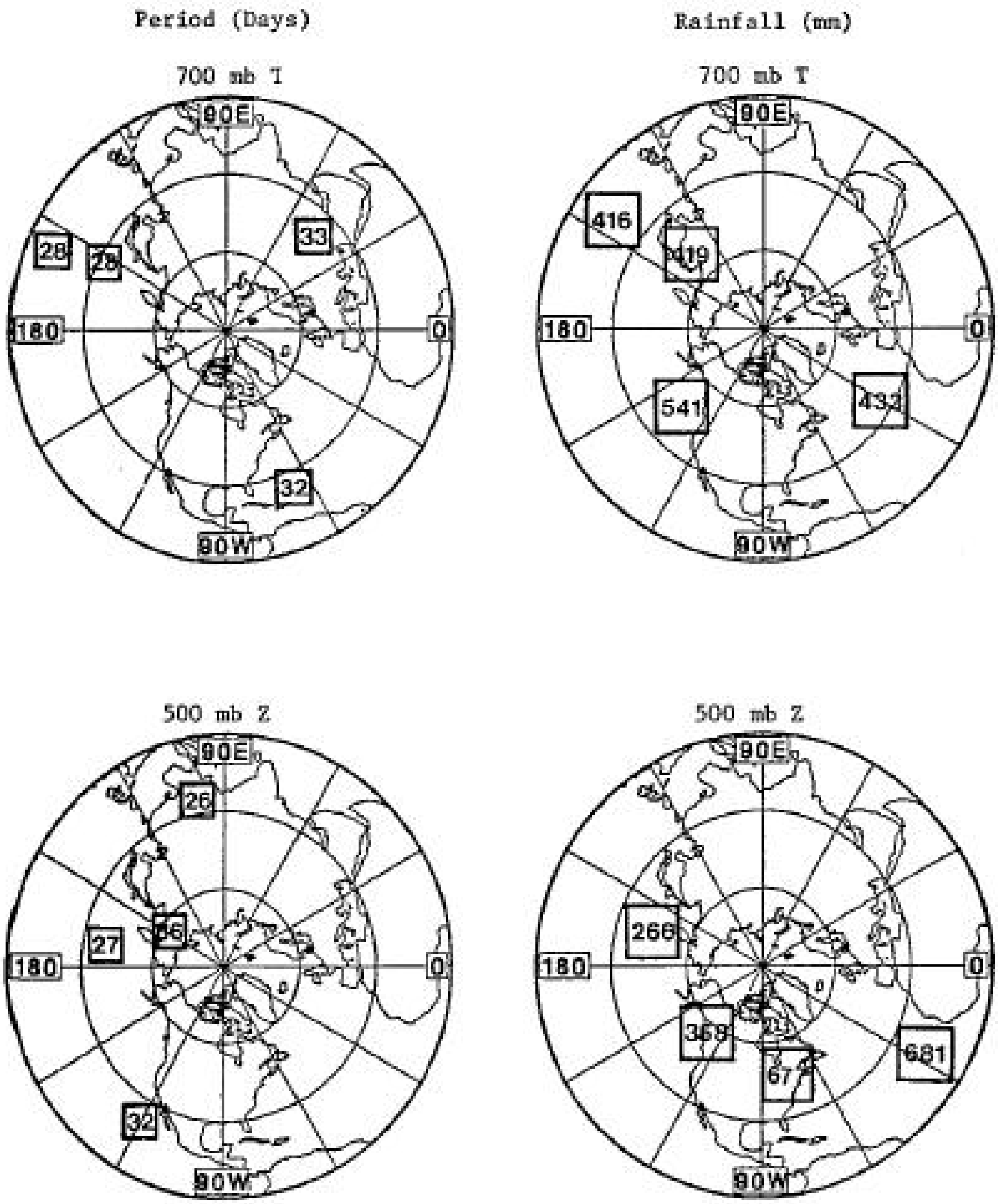


Fig. 6

1990 Taiwan Mei-Yu Forecast by December Teleconnections

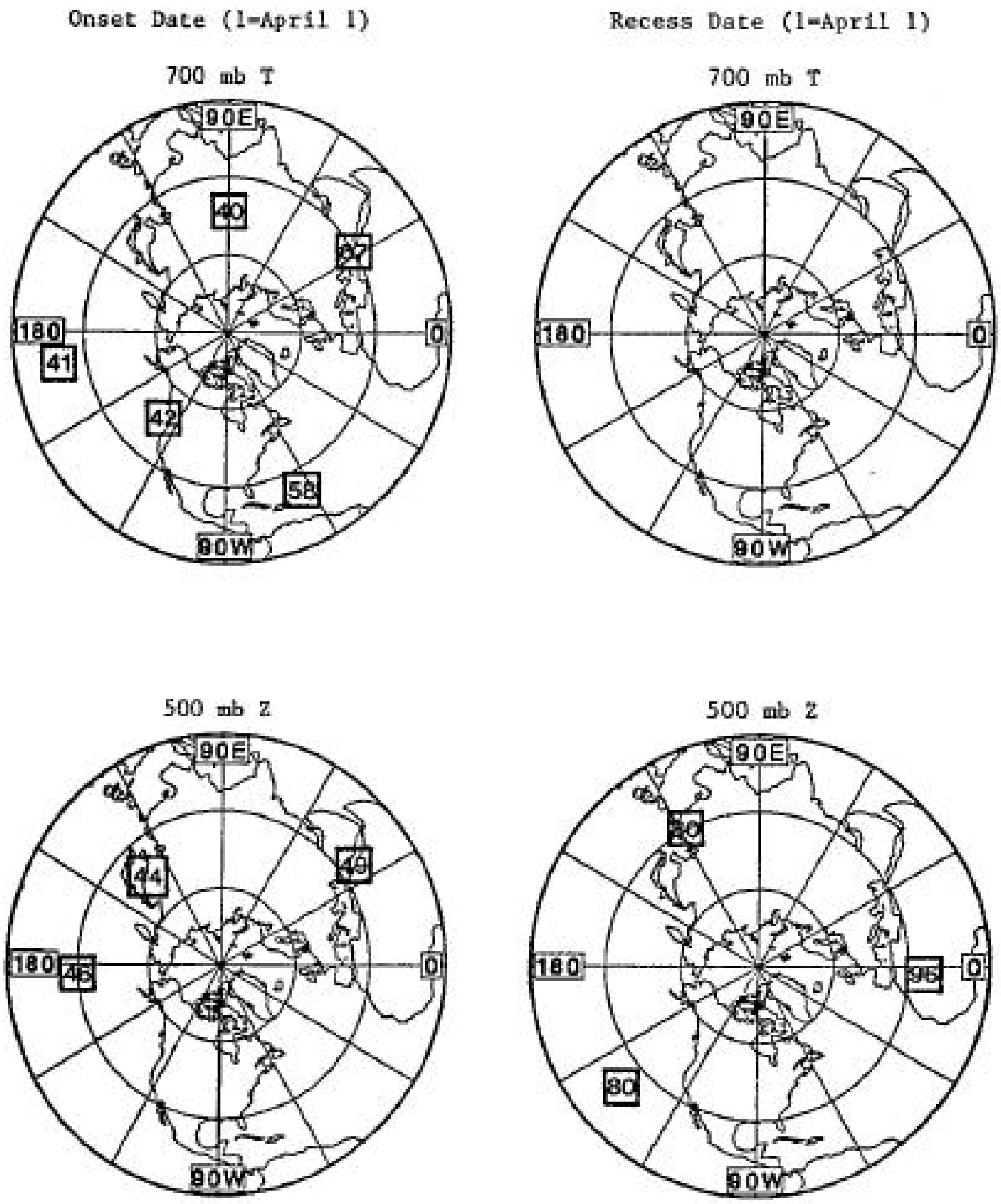


Fig. 7

1990 Taiwan Mei-Yu Forecast by December Teleconnections

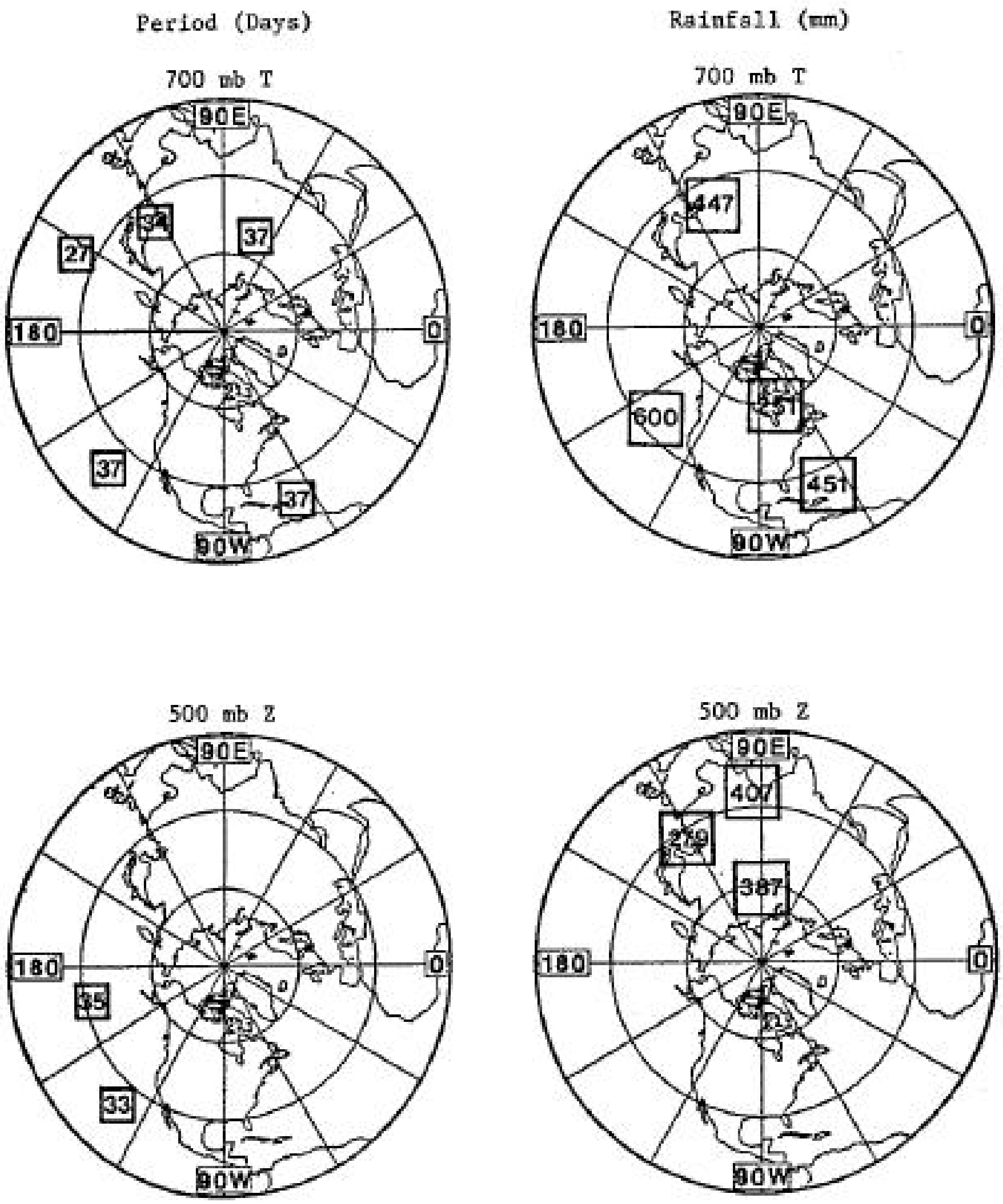


Fig. 8

1990 Taiwan Mei-Yu Forecast by January Teleconnections

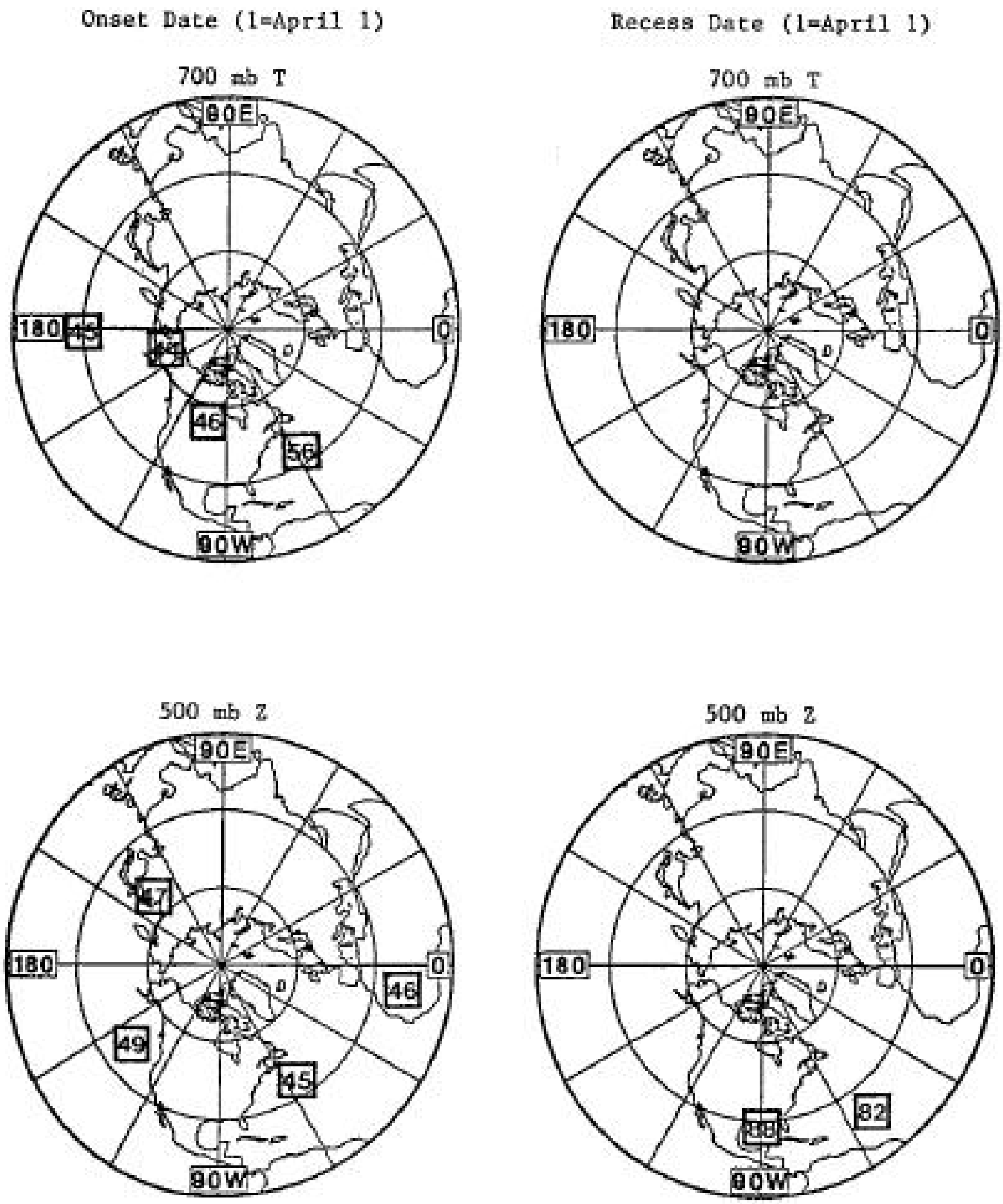


Fig. 9

1990 Taiwan Mei-Yu Forecast by January Teleconnections

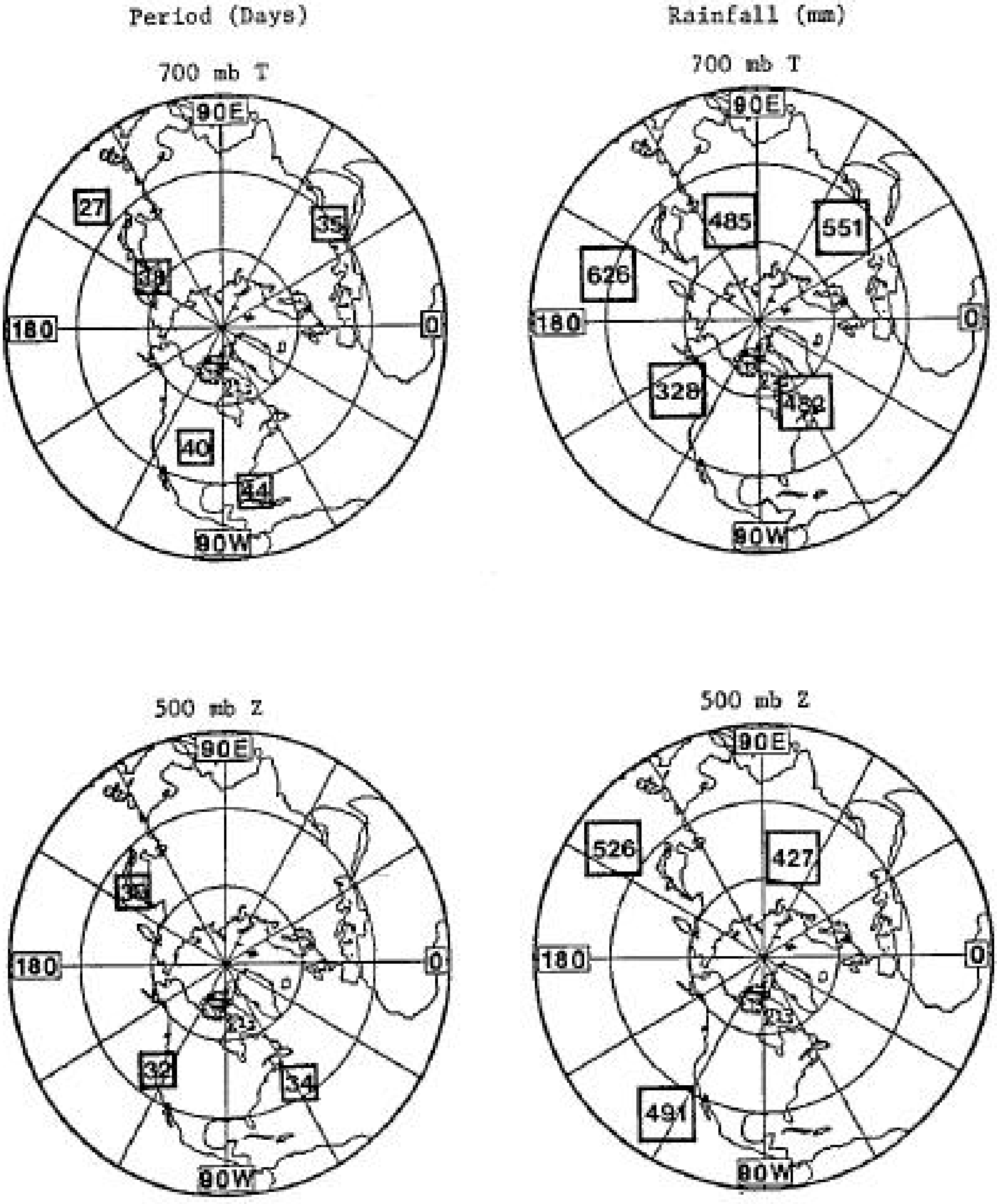


Fig. 10

1990 Taiwan Mei-Yu Forecast by February Teleconnections

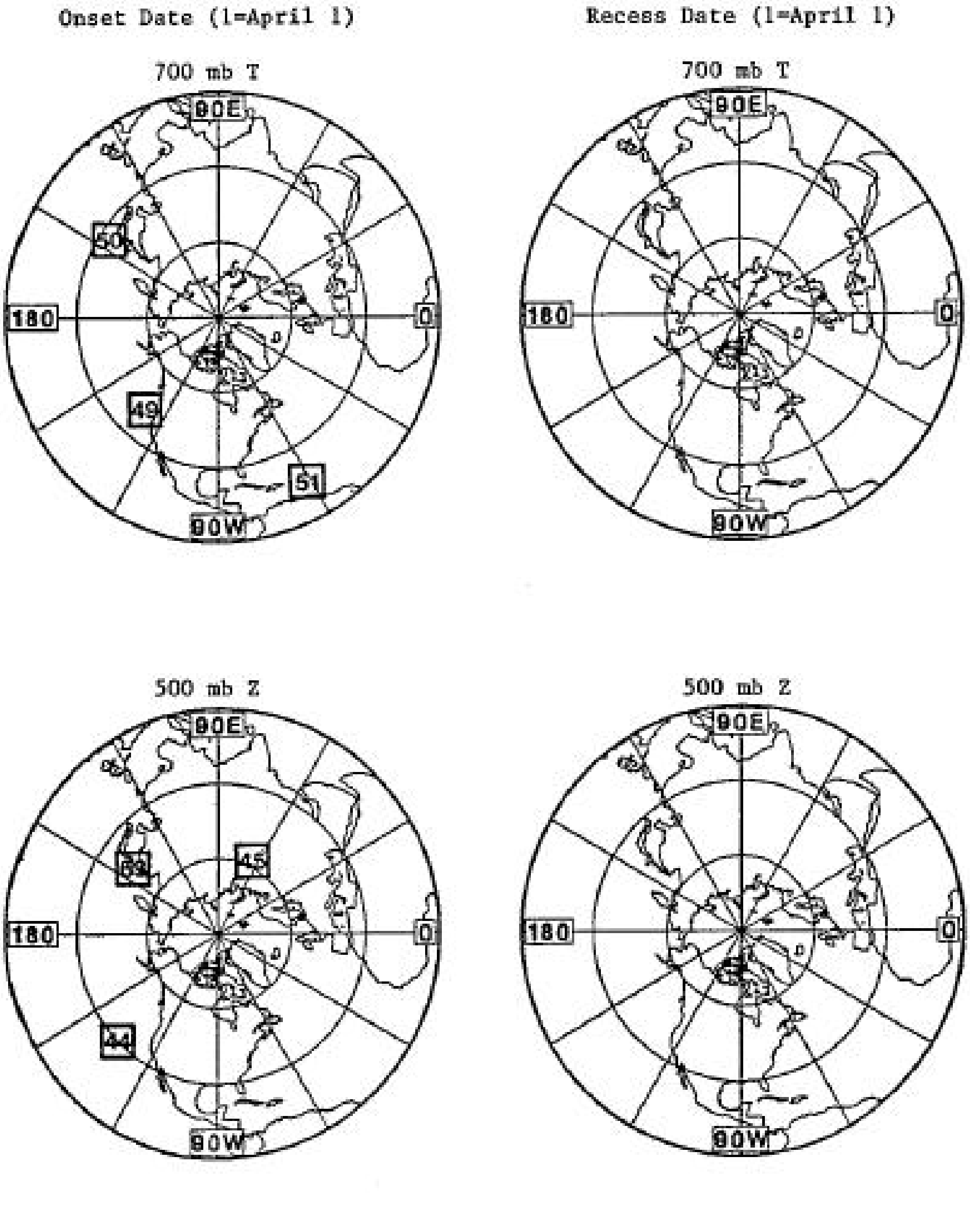


Fig. 11

1990 Taiwan Mei-Yu Forecast by February Teleconnections

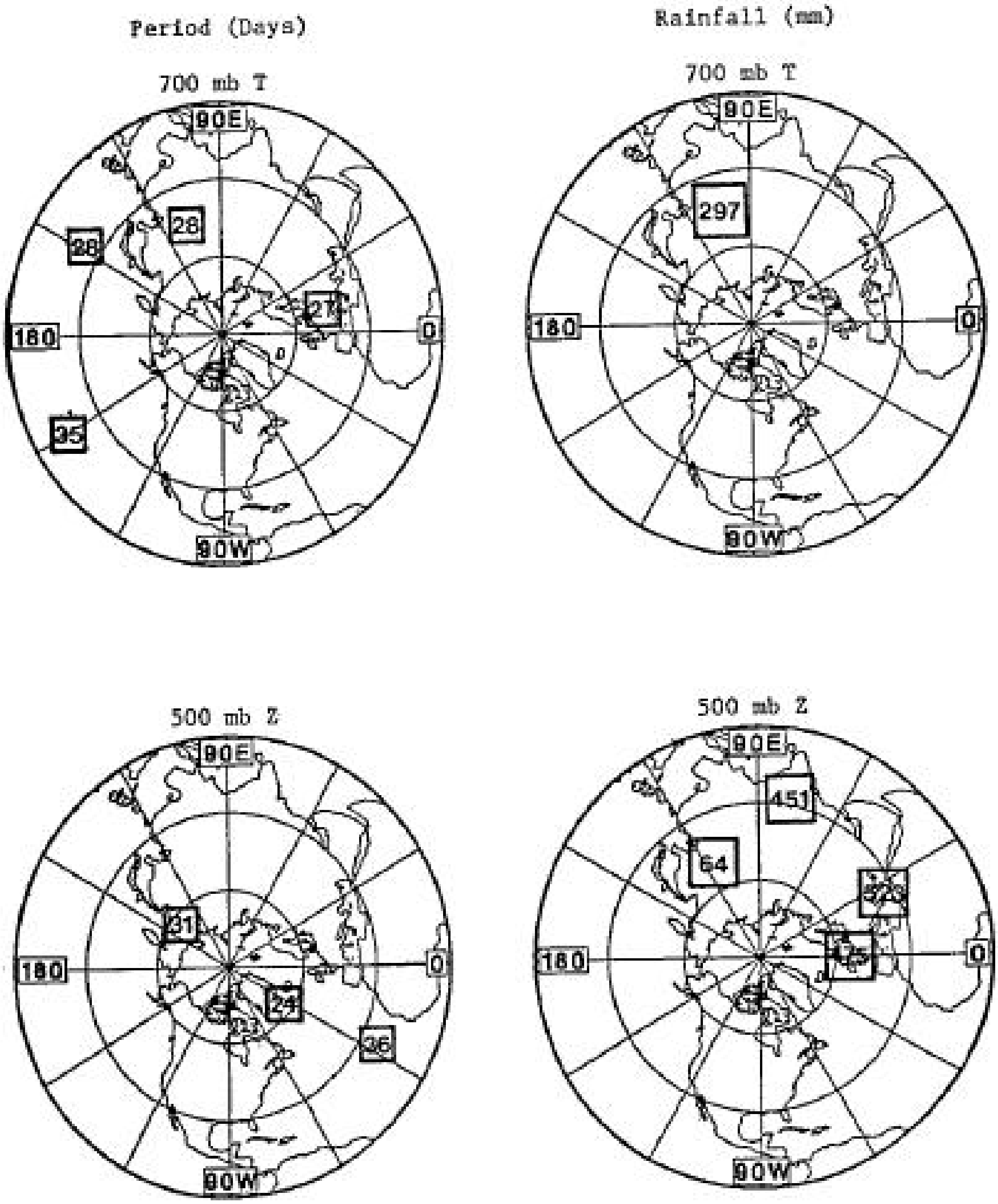


Fig. 12

1990 Taiwan Mei-Yu Forecast by March Teleconnections

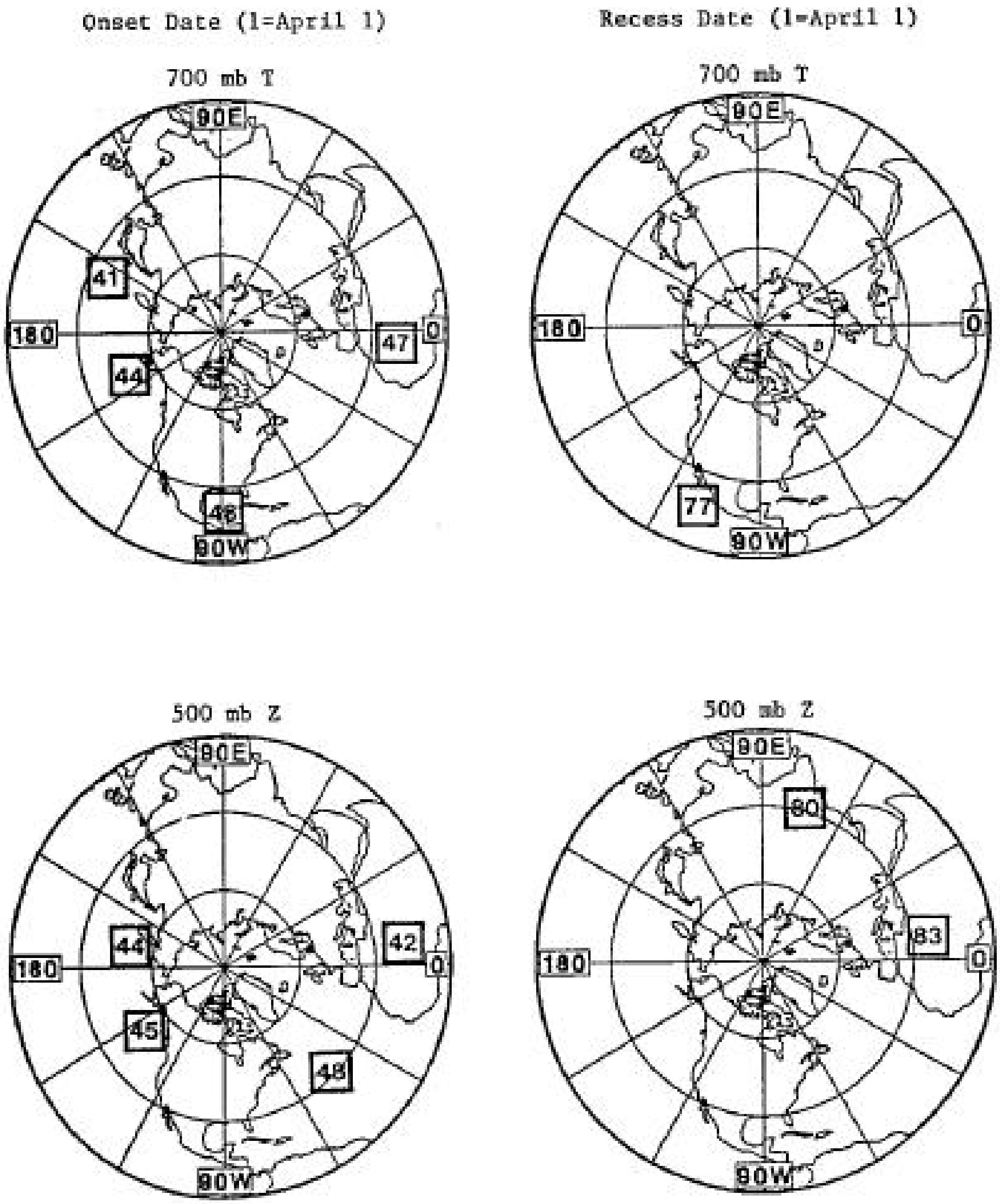


Fig. 13

1990 Taiwan Mei-Yu Forecast by March Teleconnections

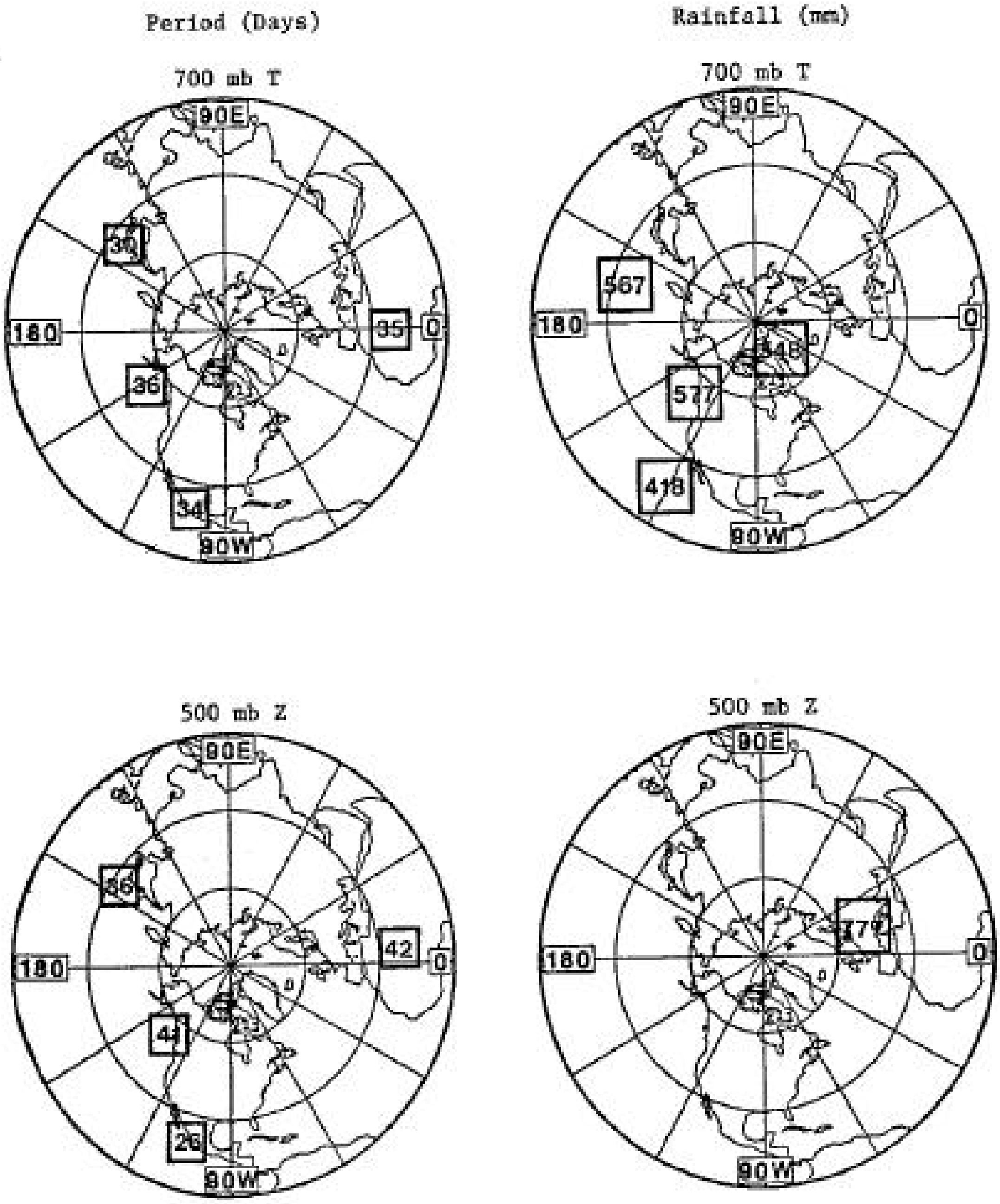


Fig. 14

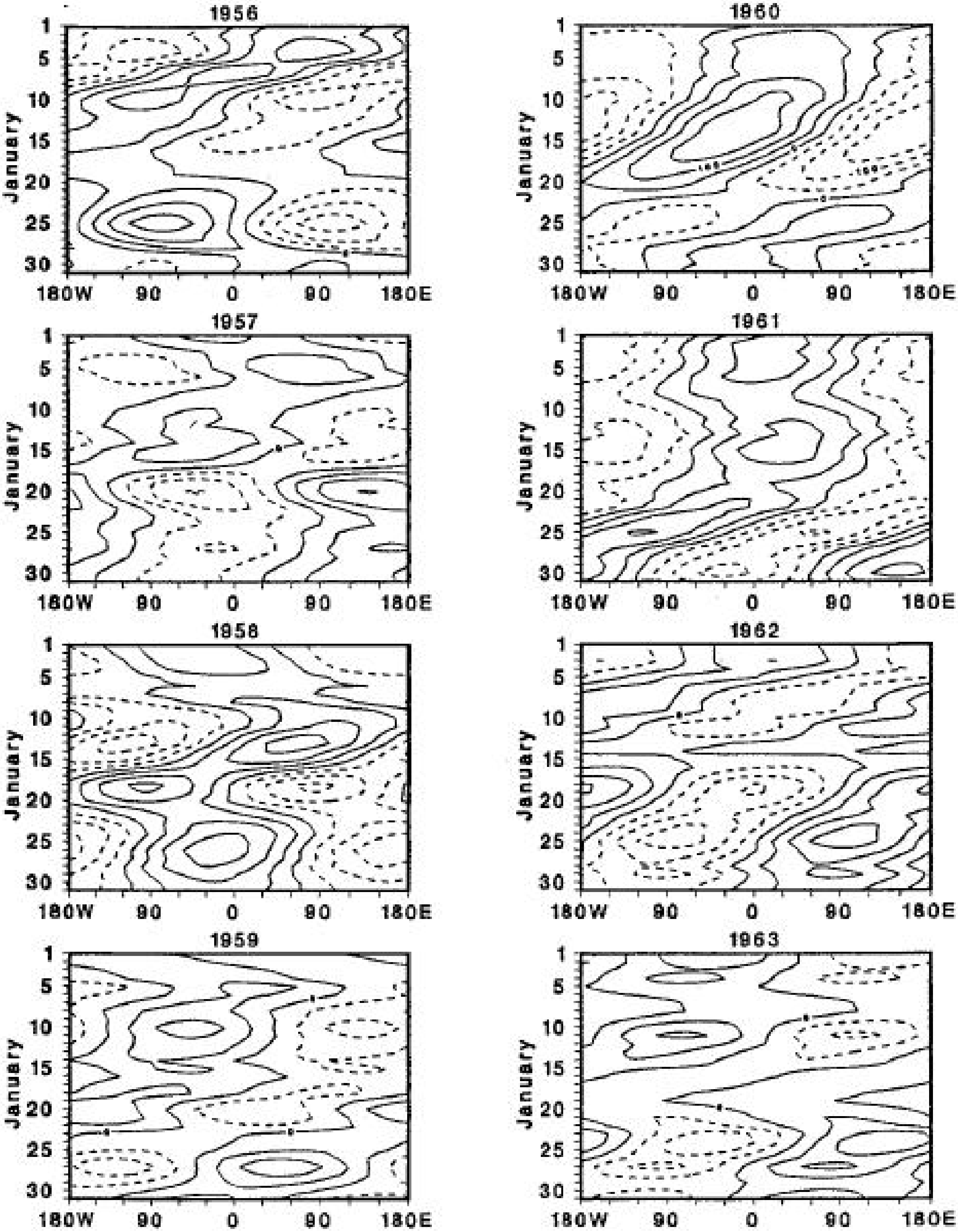


Fig. 15. Trough-ridge diagrams (500mb) of zonal wavenumber $n=1$ during January in the 50°-70°N band from 1956 to 1986. The contour spacing is 50m and negative lines are dashed.

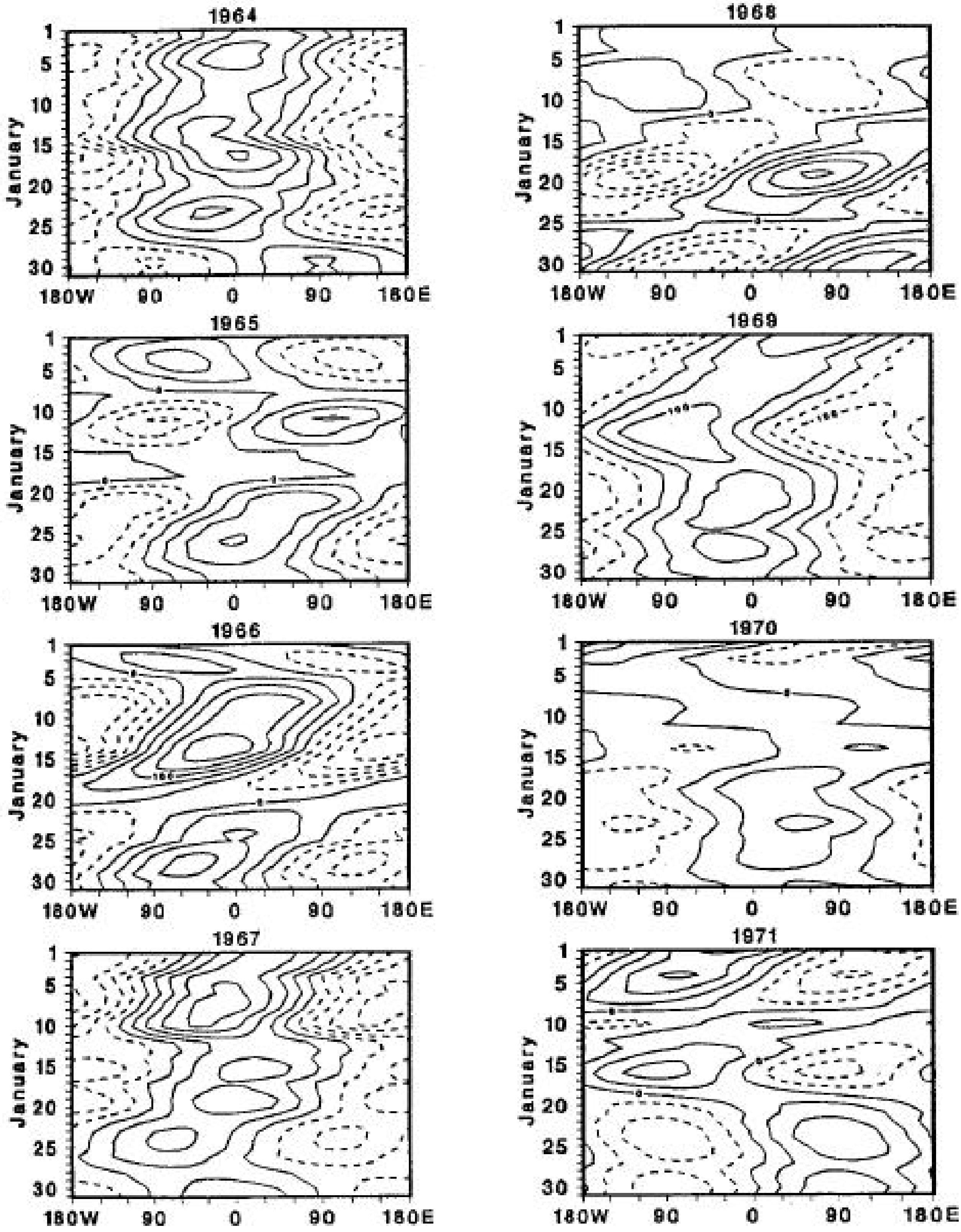

1964
1965
1966
1967
1968
1969
1970
1971
January
1
5
10
15
20
25
30
180W
90
0
90
180E

Fig. 15b

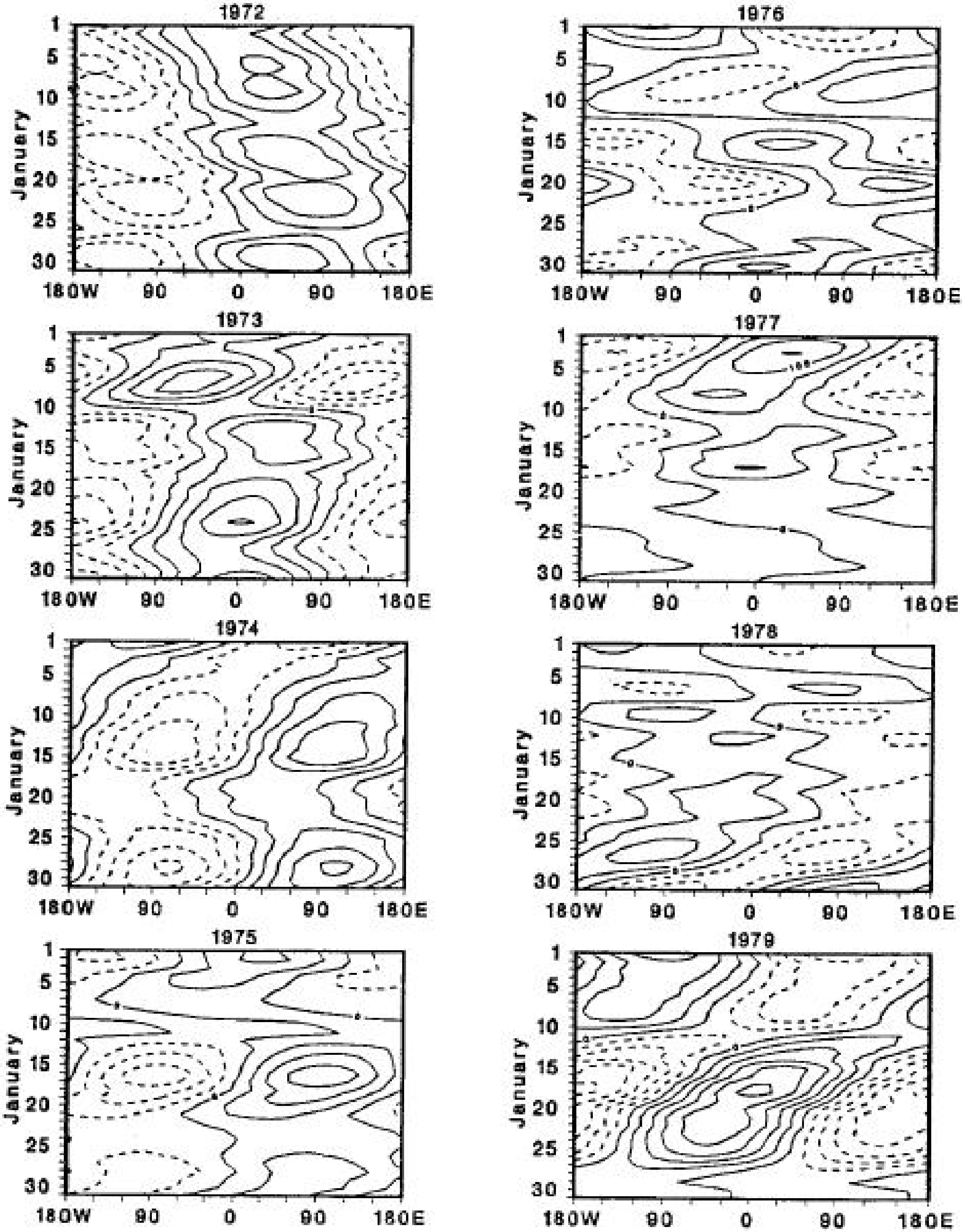

1972
1973
1974
1975
1976
1977
1978
1979
January
1
5
10
15
20
25
30
180W
90
0
90
180E

Fig. 15c

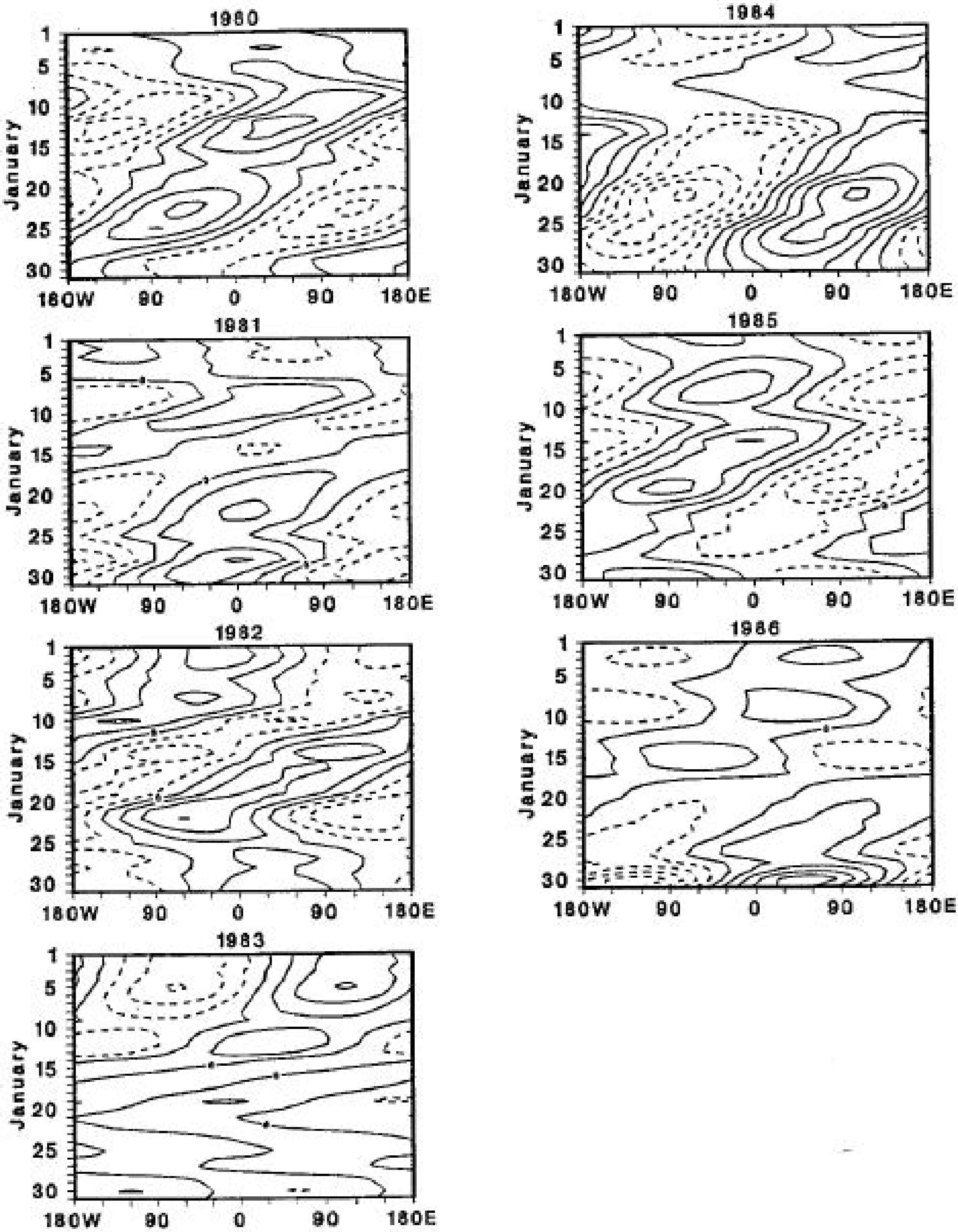

1980
1981
1982
1983
1984
1985
1986
January
1
5
10
15
20
25
30
180W
90
0
90
180E

Fig. 15d

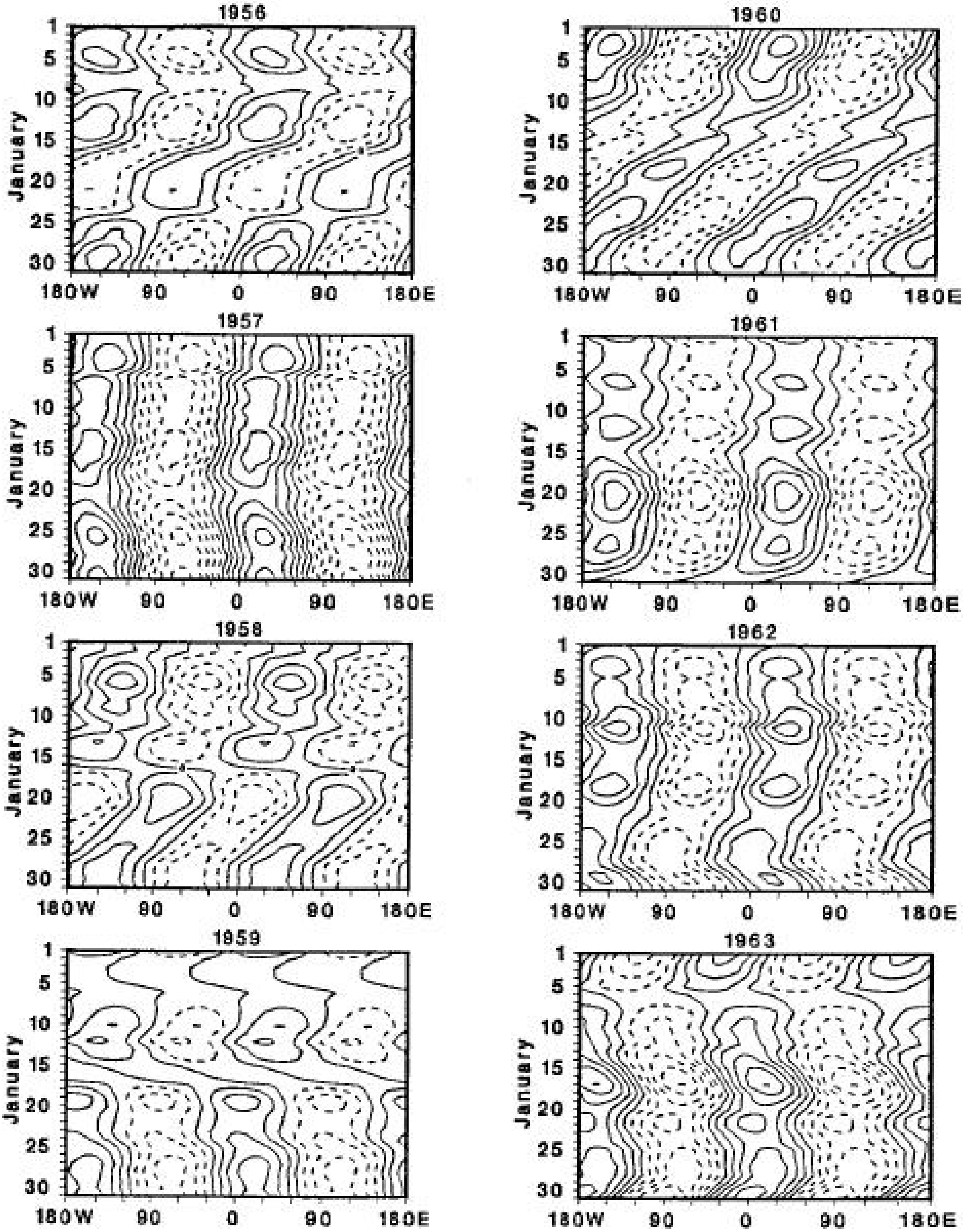


Fig 16. As in Fig. 15, but for n=2.

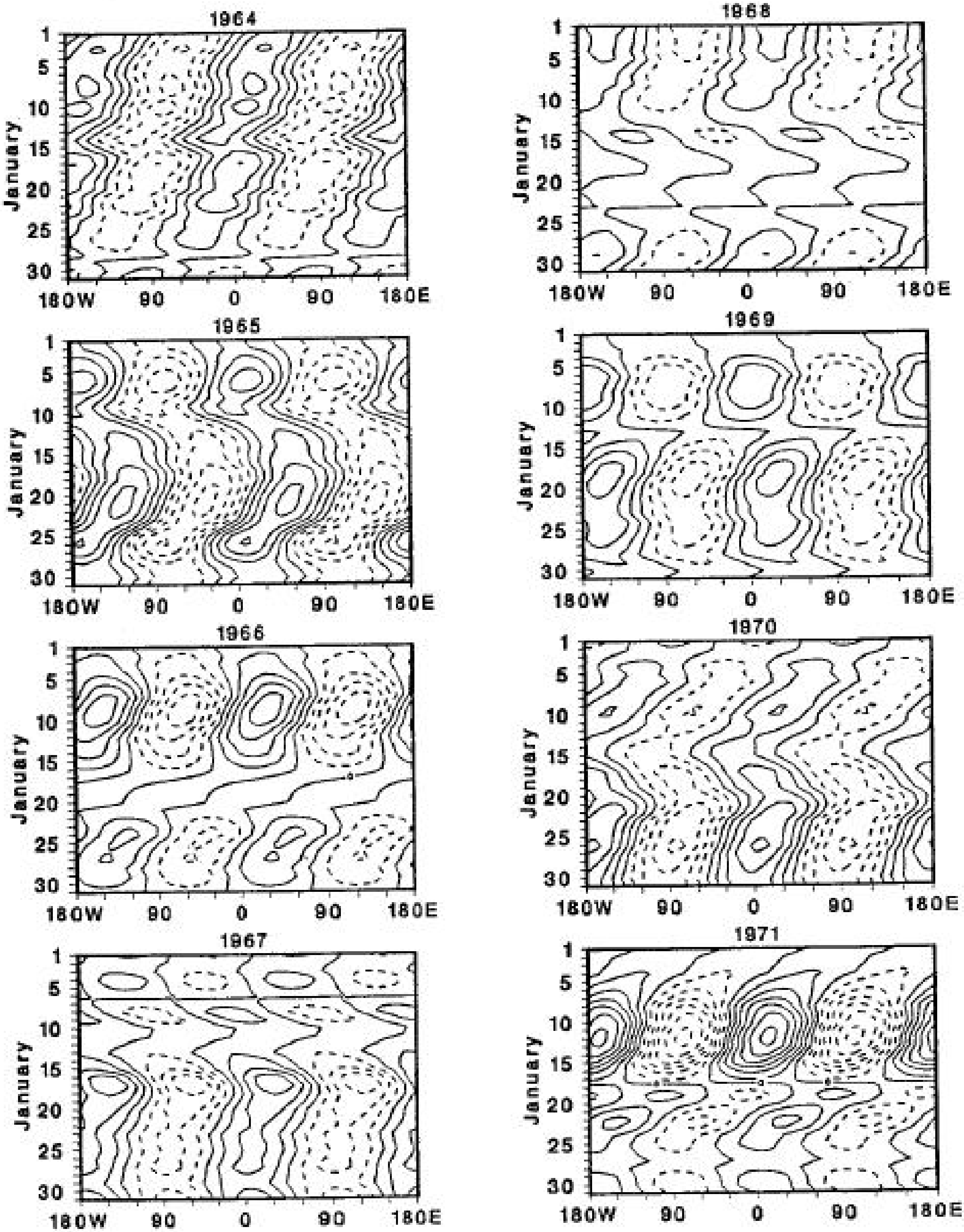

1964
1965
1966
1967
1968
1969
1970
1971
January
1
5
10
15
20
25
30
180W
90
0
90
180E

Fig. 16b

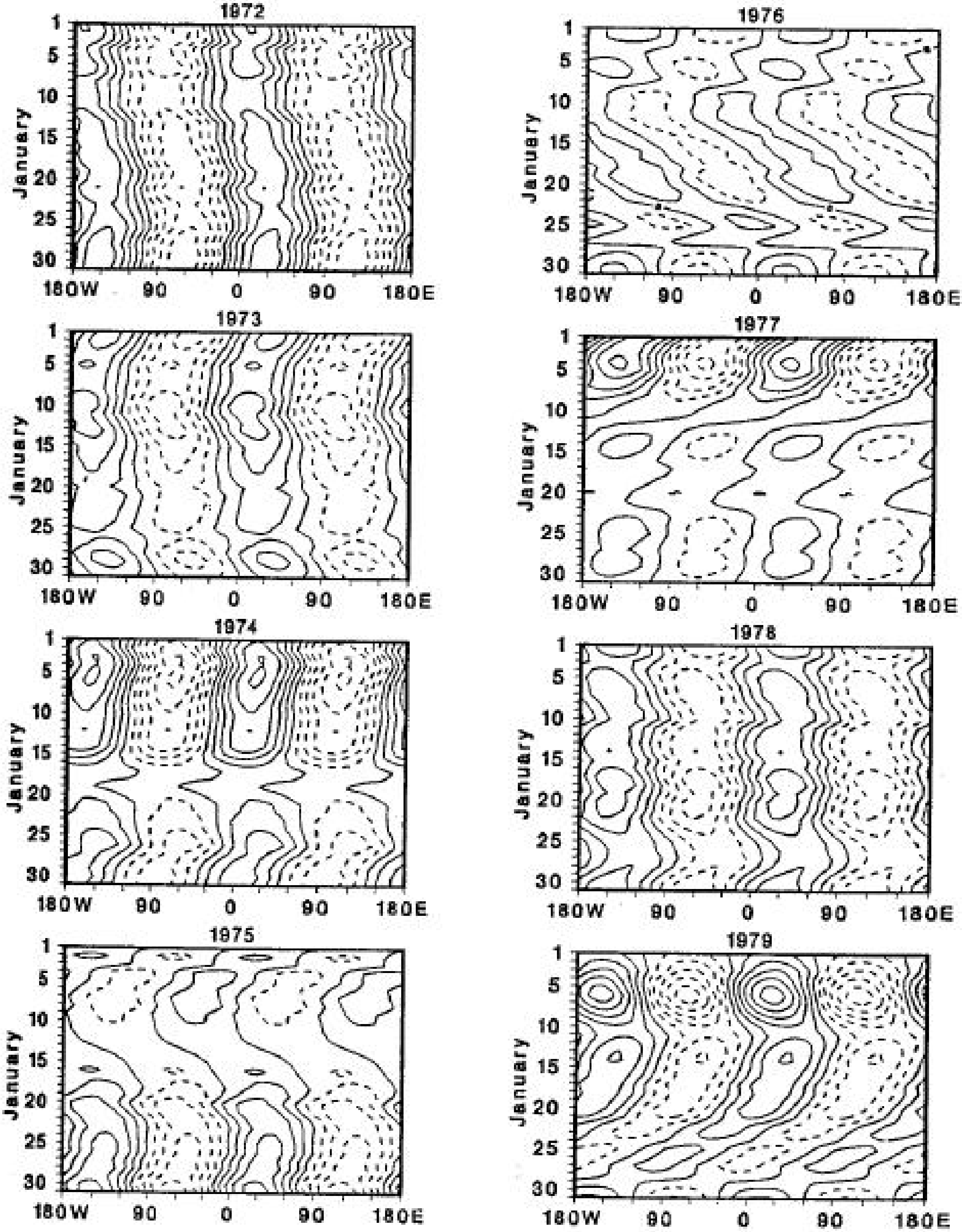

1972
1976
1973
1977
1974
1978
1975
1979
January
1
5
10
15
20
25
30
180W
90
0
90
180E

Fig. 16c

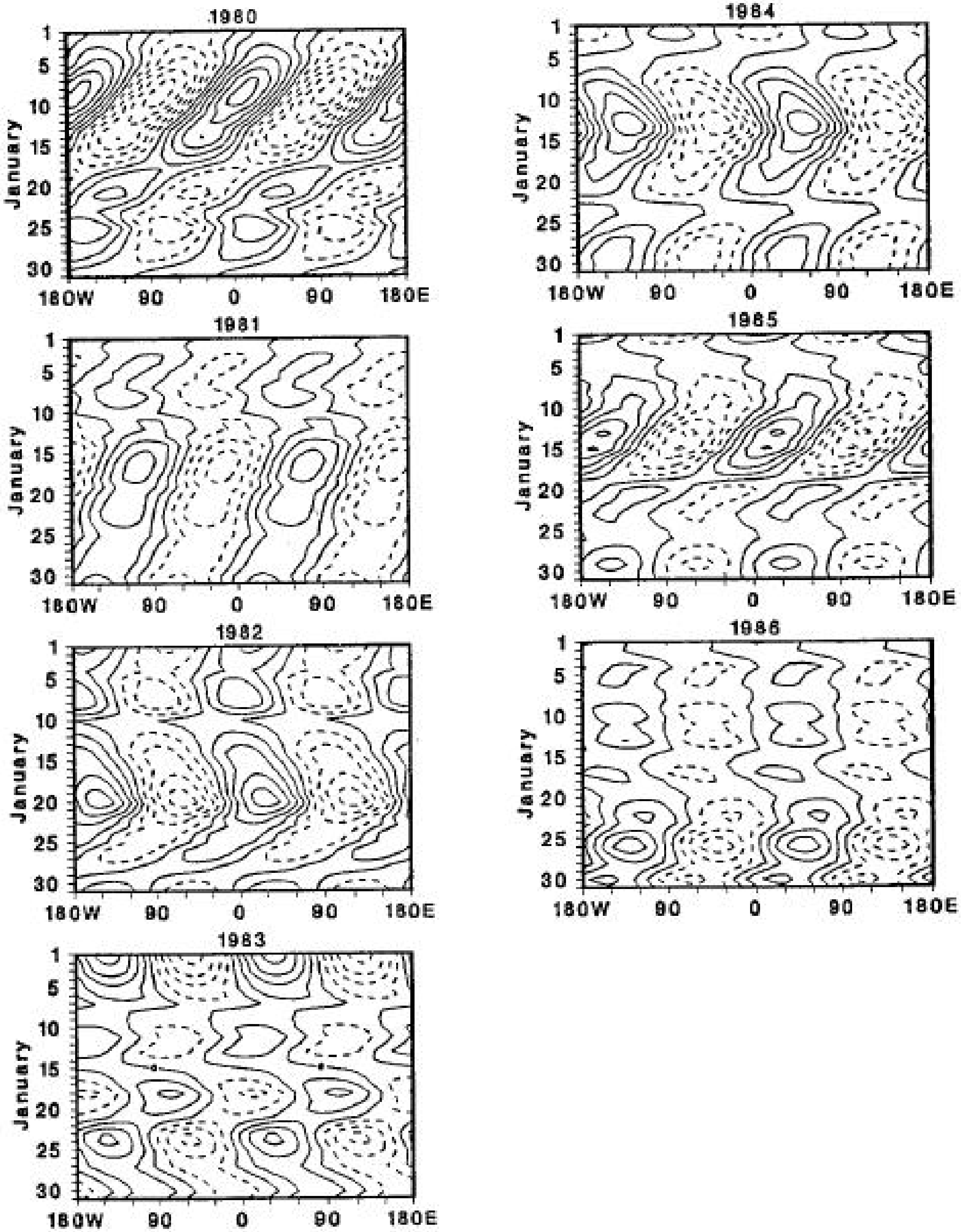

1980
1981
1982
1983
1984
1985
1986
January
1
5
10
15
20
25
30
180W
90
0
90
180E

Fig. 16d