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SYNOPTIC PERFORMANCE CHARACTERISTICS OF THE  
TWO-LEVEL ATMOSPHERIC MODEL

C. Schutz

RAND Corporation

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A Report prepared for  
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This analysis of the two-level atmospheric model compares daily changes during January from three experiments and five years of observed data for surface air temperatures at Columbia, Mo., and five basic characteristics in the vicinity of the Icelandic and Aleutian Lows. Strong diurnal changes were found in all simulated temperatures, but low and high diurnal ranges that would accompany specific synoptic events in nature are not well portrayed. The positions of the lows tested based on the lowest daily pressures were clumped, and in the North Atlantic were located southwest of the climatological center. Mean January pressures from these centers showed that the simulated Icelandic Low is 4.3 mb less intense, while the Aleutian Low is 1.9 mb more intense than observed. When all analyzed low pressure centers were combined, simulated speeds were slower and durations longer than observed. Finally, the simulated tracks were shown to be farther north. Refs.  
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# Synoptic Performance Characteristics of the Two-Level Atmospheric Model

C. Schutz



A Report prepared for  
**DEFENSE ADVANCED RESEARCH PROJECTS AGENCY**



PREFACE

This report is concerned with the daily synoptic performance displayed by the Mintz-Arakawa two-level atmospheric general circulation model (CCM). Such presentations, which afford a comprehensive and nearly instantaneous picture of the state of the atmosphere at a given time each day, can help to identify peculiarities of the model, and may serve as a guide for future adjustments. Others working in the field may also find these results useful for comparison with their results.

This report is part of the work of the Rand/ARPA Climate Program, one of whose aims is the systematic comparison of model simulations with observed climate. Other Rand publications related by subject to the present report are R-1005-ARPA, which presents a systematic comparison of the observed climate with the January control integration used here, and a report on the performance of a revised version of the model for both January and July, which is in preparation.

These publications and the project of which they are a part are sponsored by the Defense Advanced Research Projects Agency.

SUMMARY

The present analysis of the Mintz-Arakawa model compares the synoptic characteristics of the simulated temperature and pressure in three January experiments with five years of observed January data. Tests are made of the average surface air temperature at the model grid point near Columbia, Missouri (CBI), and five basic characteristics of the circulation across the North Atlantic and North Pacific in the vicinity of the Icelandic and Aleutian Lows. Since these ocean regions are prime weather producers, the degree of agreement between their modeled and observed characteristics has global significance for the general circulation model (GCM).

While the model correctly simulates many observed features of the monthly average *large scale* surface air temperature, present analysis shows that the *local* mean January surface air temperatures at CBI are also in agreement with observation. However, further analysis of the daily and hourly simulated temperatures reveals some disagreement in the simulated diurnal pattern of warming and in the locally-simulated standard deviation of the temperature.

The characteristics of the North Atlantic (Icelandic) and North Pacific (Aleutian) Lows in January were judged from a comparison of Synoptic Weather Maps at 1230Z each day during 1949-1953, and those simulated daily by the numerical experiments at 0000Z. These maps served to identify the positions of all closed lows each day, the depth or intensity of the low at those positions, and the related speed, days of duration, and track of the lows based on changes in the daily positions. In the Atlantic, positions of the mean *lowest* pressures for January were southwest of the climatological center documented in Schutz and Gates (1971). The daily frequency distribution of the lowest pressures gives a mean depth 4.3 mb higher than that observed in the Atlantic, and 1.9 mb lower than that observed in the Pacific. This individual or synoptic characteristic of the low pressure centers is not evident when only the monthly average simulated pressure is examined.

The analysis of cyclone speed, duration, and track was based on the daily positions of *all* closed low pressure centers across the North

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Atlantic and North Pacific. It is shown that on the average the model has fewer centers and moves these cyclones at a slower speed than is observed. More cyclone speeds above 45 knots are observed than simulated, which may be the result of a more irregular movement in nature during cyclogenesis and cyclolysis. The analysis of cyclone duration shows that the cyclones were simulated to have slightly longer duration than is observed. The tracks of all cyclones used for the speed and duration calculations show that in both the North Atlantic and North Pacific, simulated tracks are farther north than those observed.

ACKNOWLEDGMENTS

Sincere appreciation is extended to the Environmental Technical Applications Center (ETAC) of the U.S. Air Force for its cooperation in making available the latest magnetic tapes of hourly synoptic weather reports at Columbia, Missouri. Thanks are also extended to Rand colleagues for their assistance: to W. L. Gates, who originally suggested the investigation, and who, along with R. R. Rapp and N. A. Hanunian, made a careful review of the manuscript and extended many valuable suggestions; to E. Rodriguez, who developed the programs necessary to interrogate the relevant weather data bank; and to C. R. Huber, D. S. Pass, R. L. Mobley, A. B. Nelson, and J. J. Simac, who produced the various maps and grid point data.

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## 1. INTRODUCTION

For our present purposes, only the temperature simulated by the model every six hours at the grid point near Columbia, Missouri (map designation CBI), and the daily changes in closed surface low pressures across the North Atlantic and North Pacific were used to examine the model's performance from a synoptic viewpoint during January. The model's performance over three separate January experiments has been selected for comparison. The January control experiment itself has been analyzed by Gates (1975).

Simulated data are presented in tables, graphs, and histograms for comparison with similar data observed in January of the years 1949-1953. Hourly observations at CBI each day during the five years were obtained on tape from the Environmental Technical Applications Center (ETAC). The daily series of Synoptic Weather Maps for 1949-1953 published by the U.S. Weather Bureau were used to determine daily changes in the five variables related to closed surface lows across the North Atlantic and North Pacific.

II. SURFACE AIR TEMPERATURE

The average daily surface air temperatures used for this analysis were extracted every six hours--0000-0600-1200-1800 local standard time (LST)--from the 31-day January simulations of three separate runs of the same control experiment; the runs differed only to the extent of small differences in their initial conditions. The air temperature computed by the atmospheric general circulation model (GCM) is described in Gates et al. (1971), and the model's climatological performance in the control integration has been summarized elsewhere (Gates, 1975). The average daily temperatures observed at Columbia, Missouri, were taken from the ETAC observations of hourly weather by the method described in Rodriguez and Huschke (1974).

From these temperature data (tabulated in the Appendix), the monthly mean maximum and minimum temperature, and the mean, range, and standard deviation of the daily averaged temperature were determined as shown in Table 1. The average daily and six-hourly variations of January 1950 surface air temperature were calculated as shown in Fig. 1. The observed mean and standard deviation from the combined 1949-1953

Table 1  
TEMPERATURE (F°), COLUMBIA, MO., JANUARY  
(Computed daily from 0000-0600 - 1200-1800  
CST data)

	<u>Observed</u>					<u>Experiments</u>		
	<u>1949</u>	<u>1950<sup>a</sup></u>	<u>1951</u>	<u>1952</u>	<u>1953</u>	<u>1</u>	<u>2</u>	<u>3</u>
Maximum	58.0	58.3	53.0	58.3	54.0	43.5	47.6	44.9
Minimum	2.0	6.3	1.5	12.8	15.0	19.5	23.4	21.0
Range	56.0	52.0	51.5	45.5	39.0	24.0	24.2	23.9
Mean	27.9	31.9	30.2	33.7	33.6	32.8	34.6	35.2
Standard Deviation	12.5	13.4	13.3	12.5	8.1	5.2	5.9	5.5

<sup>a</sup>Synoptically representative year.

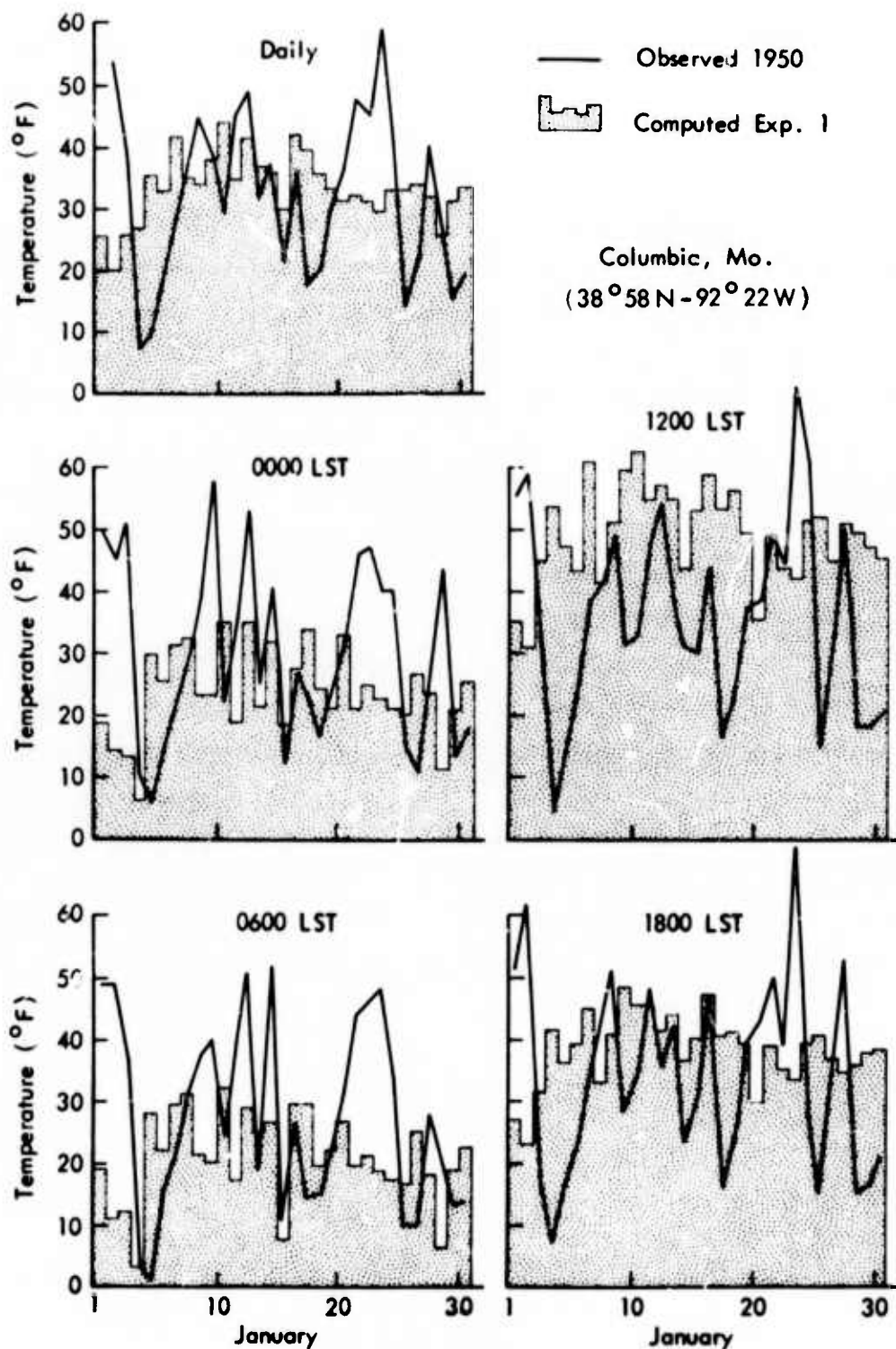


Fig. 1—Average daily and hourly variations of January surface air temperature, 1950, vs. Experiment 1

data indicate that 1950 is more synoptically representative in the sense that it most closely approximates mean conditions. In these 1950 data, marked excursions of daily mean temperature occur throughout the month, which are also reflected in the daily six-hour observations (see Fig. 1). In the *model*, while there is a strong diurnal change of all temperatures, the occurrence of the particularly low and high diurnal ranges that would accompany specific synoptic events is not well portrayed. Nevertheless, the simulated average surface air temperature is within 1°F of the mean for 1950 and equally close to that from approximately 30 years of recorded data (Schutz and Gates, 1971).

The histograms in Fig. 2 for all five years of observed data and for the three experiments show other differences. In general, the experiments' minimum temperatures are higher and their maximum temperatures are lower than those observed, while the experiments' standard deviation of 5.7°F is significantly less than the 12.3°F which occurred in nature for the years 1949-1953. Thus, although the model may adequately simulate the monthly average of such features as the surface air temperature, the local daily and hourly variations are such that there is a systematic underestimate of the observed variability.

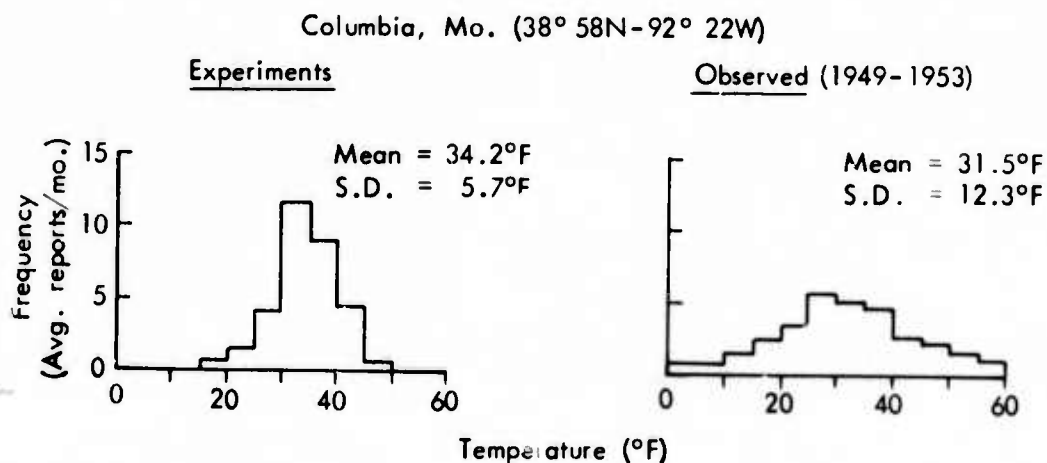


Fig. 2—Frequency distribution of daily surface air temperature (°F), January

III. SEA-LEVEL PRESSURE: ICELANDIC AND  
ALEUTIAN LOW CHARACTERISTICS

The mean climatological *position* and *intensity* of the Icelandic and Aleutian Lows are shown in Fig. 3, taken from Schutz and Gates (1971), and are based on approximately 30 years of January data. These centers are compared with the daily observed and simulated January values of the lowest pressures and their means. From synoptic data it is difficult to determine the position and intensity of the lowest daily pressure centers observed or simulated across the North Atlantic and North Pacific, due both to the inevitable errors of synoptic analysis and to the model's limited grid point resolution. The lowest daily simulated pressure at a grid point may not be the lowest implied pressure that could occur within the grid of 4° latitude and 5° longitude. Also, the "observed" lowest pressure depends on the analyst's interpretation of the available data; isobars may be added simply because of wind speed and direction at a single station some distance from the actual low center drawn. Therefore, no effort was made to adjust either the simulated grid point values or to consider interpolating observed values at the grid points used by the model.

POSITIONS

For the North Atlantic the mean January positions of the Icelandic Low based on *lowest* pressures for each test year and each experiment were obtained from the daily data in the Appendix, and are summarized in Table 2. The average pressure, standard deviation, and range for the years 1949-1953 again make 1950 appear synoptically representative, as was the case for surface air temperature at Columbia. Before averaging, the daily low positions from 1950 formed a distinct envelope of points around the mean climatological center from Schutz and Gates (1971) at 62°N-30°W (Fig. 4). Experiment 1, on the other hand, had a well-defined envelope of points southwest of the observed center. The mean January positions of the lowest Icelandic low pressure developed from each year's daily data and from the three January experiments fall into similar distinct groups (Fig. 5).

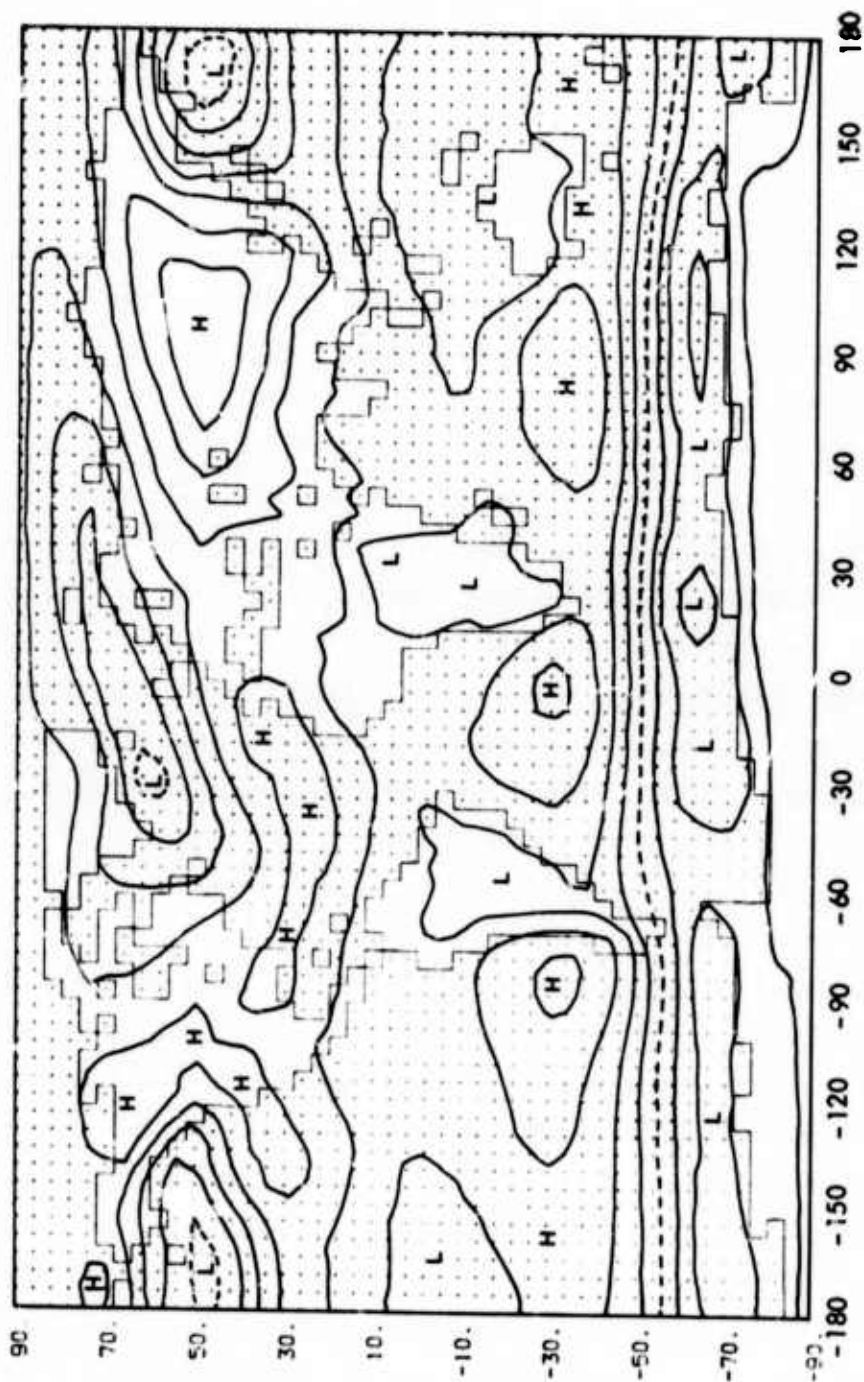


Fig. 3—Mean January sea-level pressure (mb). The analysis interval is 5 mb, and the 1000-mb isobar is dashed. Produced from data of Crutcher and Meservy (1970) and Taljaard et al. (1967).  
From Schutz and Gates (1971).

Table 2

PRESSURE (mb) AND MEAN POSITION, JANUARY  
(Based on daily lowest pressures)

		Icelandic Low						
		Observed (1230Z)			Experiments (0000Z)			
		1950 <sup>a</sup>	1951	1952	1953	1	2	3
Maximum		1000.0	990.0	995.0	995.0	986.2	990.7	998.2
Minimum		950.0	950.0	940.0	949.1	964.4	972.1	967.7
Range		50.0	40.0	55.0	46.0	21.8	18.6	20.5
Mean		970.1	971.2	970.4	977.5	975.2	979.5	975.7
Standard Deviation		13.9	9.7	15.9	10.3	5.36	5.16	5.62
Mean Position	Latitude	63.9N	58.9N	63.3N	61.7N	52.6N	55.3N	53.9N
	Longitude	19.7W	34.4W	24.5W	28.6W	40.8W	38.3W	45.0W
		Aleutian Low						
		Observed (1230Z)			Experiments (0000Z)			
		1950	1951 <sup>a</sup>	1952	1953	1	2	3
Maximum		998.3	990.0	995.0	985.0	996.8	994.0	987.3
Minimum		950.0	945.0	950.0	950.0	954.5	954.1	951.5
Range		48.3	45.0	45.0	35.0	42.3	39.9	35.8
Mean		975.9	973.8	973.5	968.6	973.95	974.2	971.2
Standard Deviation		11.7	10.4	8.8	8.7	7.42	7.31	7.58
Mean Position	Latitude	53.4N	51.6N	53.2N	47.1N	53.3N	55.2N	55.4N
	Longitude	175.3E	171.8W	167.0W	172.4W	173.4E	176.0E	174.4E

<sup>a</sup> Synoptically representative year.

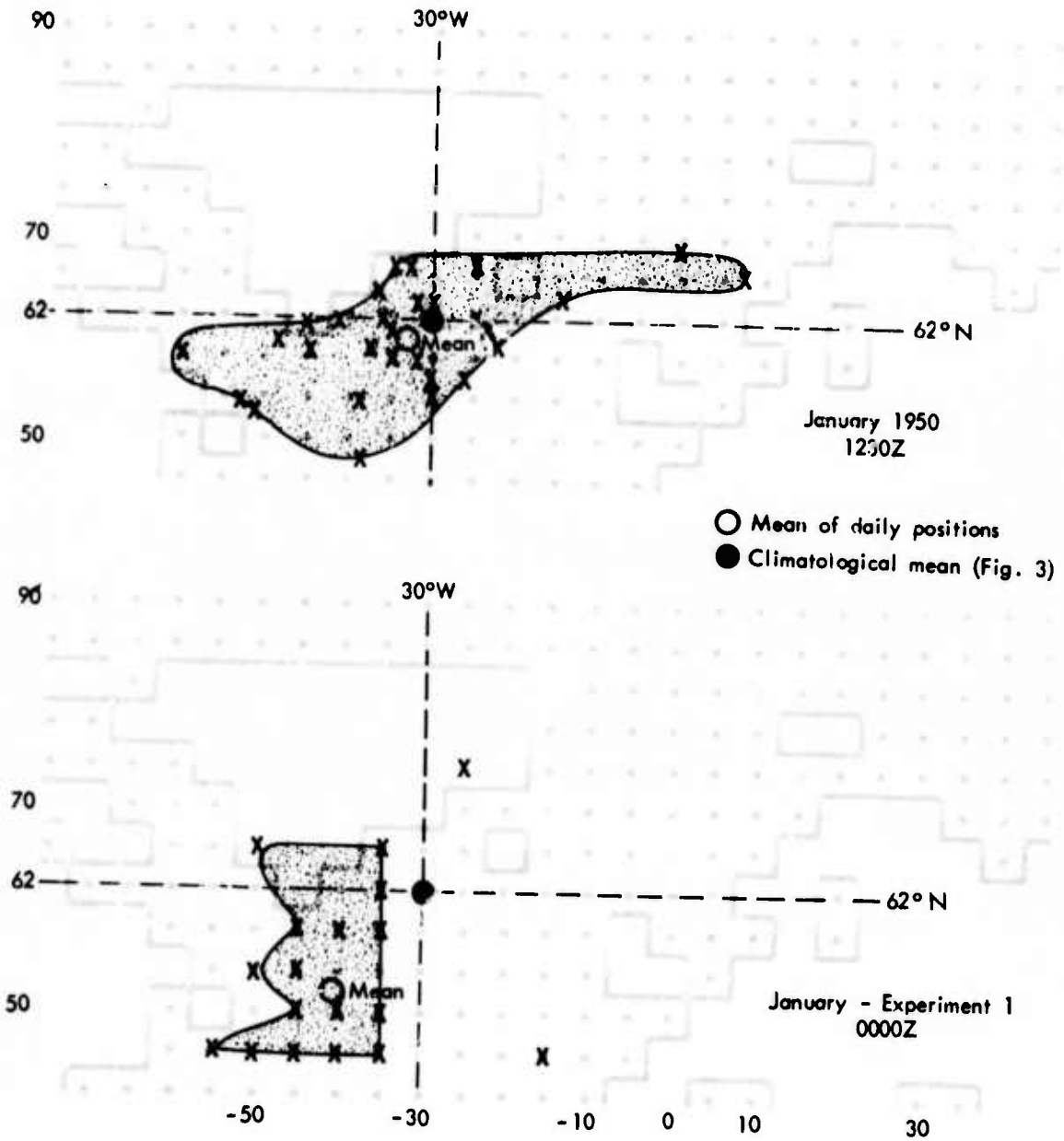


Fig. 4—Mean and daily positions of lowest pressure, Icelandic Low

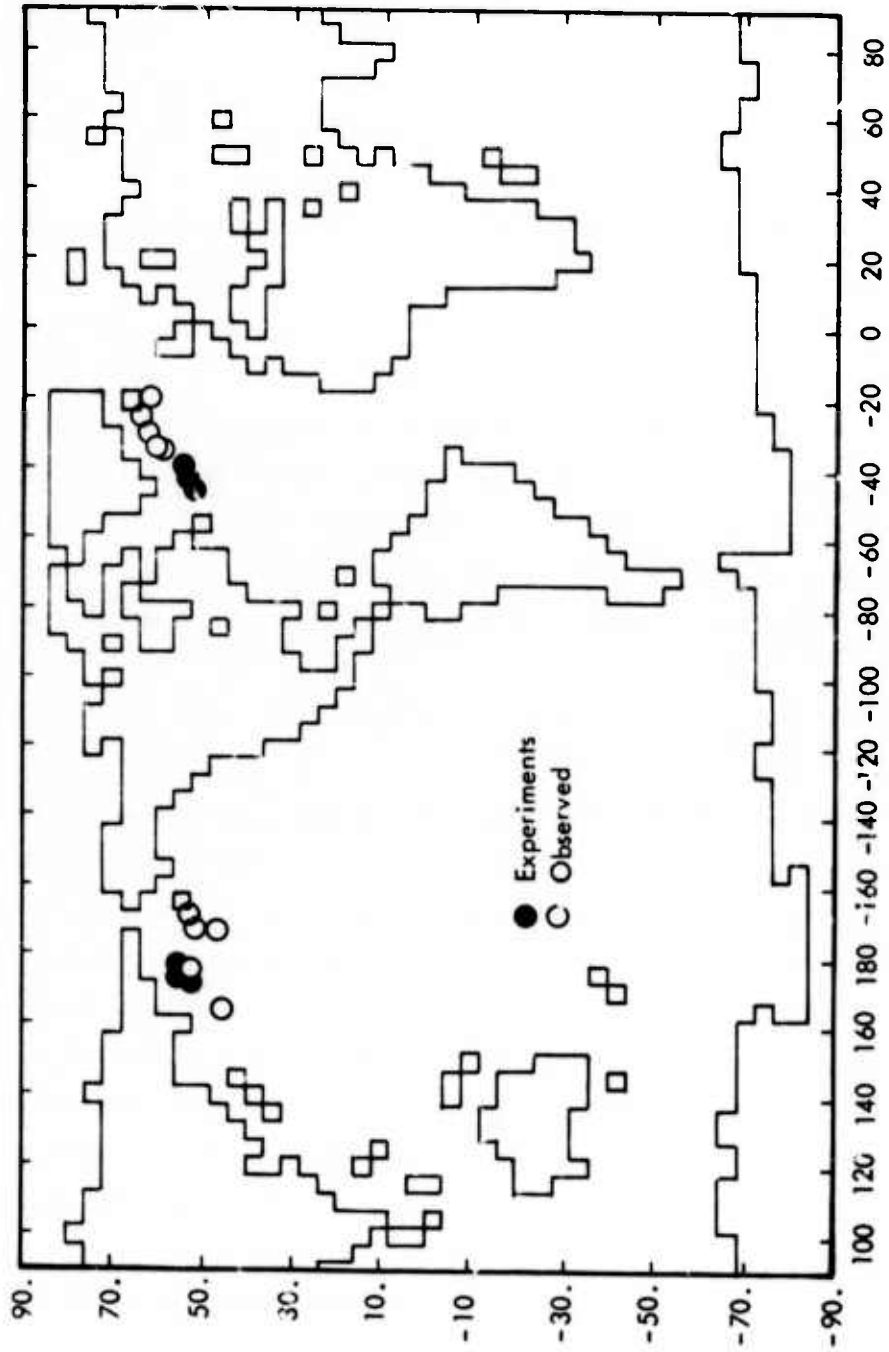


Fig. 5 — Mean positions for lowest pressure mean, January

Although the experiments indicate the Icelandic Low to be southwest of the mean climatological position, a check of Icelandic Low positions for Januaries from 1899-1960 reveals that only about 10 percent were observed in that locale (Bjerknes, unpublished). These anomalous observed positions of the Icelandic Low in January are generally near the positions simulated by the experiments.

The mean January positions of the Aleutian Low for each test year and each experiment were similarly determined from the daily data (see Appendix) and are also summarized in Table 2. The average pressure, standard deviation, and the range for the years 1949-1953 make 1951 the most synoptically representative of the test years. Before averaging, the daily positions from 1951 and from Experiment 1 each formed envelopes of points which covered the mean climatological center from Schutz and Gates (1971) at  $50^{\circ}\text{N}-170^{\circ}\text{E}$  (Fig. 6). When daily positions of the lowest pressure from all the experiments and test years are averaged and plotted, the resulting centers show good agreement (Fig. 5), even though the centers from the experiments are more tightly grouped.

#### INTENSITY

From the data in the Appendix, the highest and lowest of the lowest pressures, the range, mean, standard deviation (Table 2), and the daily variations of the lowest pressure were determined. Over the North Atlantic in the vicinity of the Icelandic Low the observed mean and standard deviation from the years 1949-1953 indicate that 1950 is synoptically representative of the intensity. The intensity range of the daily lowest pressures in 1950 was 55 mb, while in Experiment 1 it was 21.8 mb. The excursions of pressures within these ranges throughout January are shown in Fig. 7. In general, the simulated daily variations of pressure fall within the pattern established during January 1950. The histograms of the frequency distribution shown in Fig. 8 of intensity data show that within the range of lowest pressure the experiments give low pressures that are higher and high pressures that are lower than those observed. Druyan (1974) found that the GISS model also showed central pressures that were systematically too high in January. The frequency distribution of these daily January data for the North

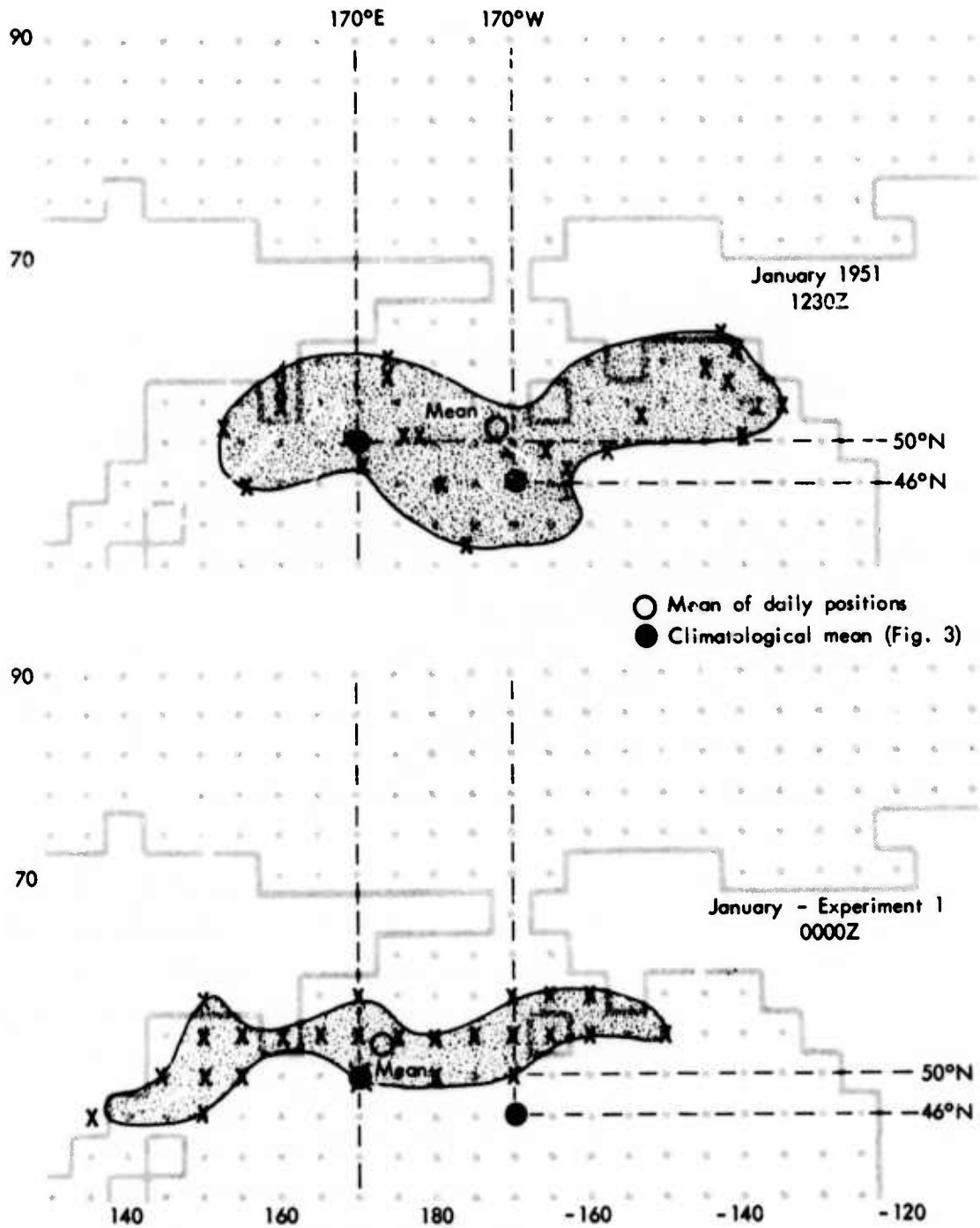


Fig. 6—Mean and daily positions of lowest pressure, Aleutian Low

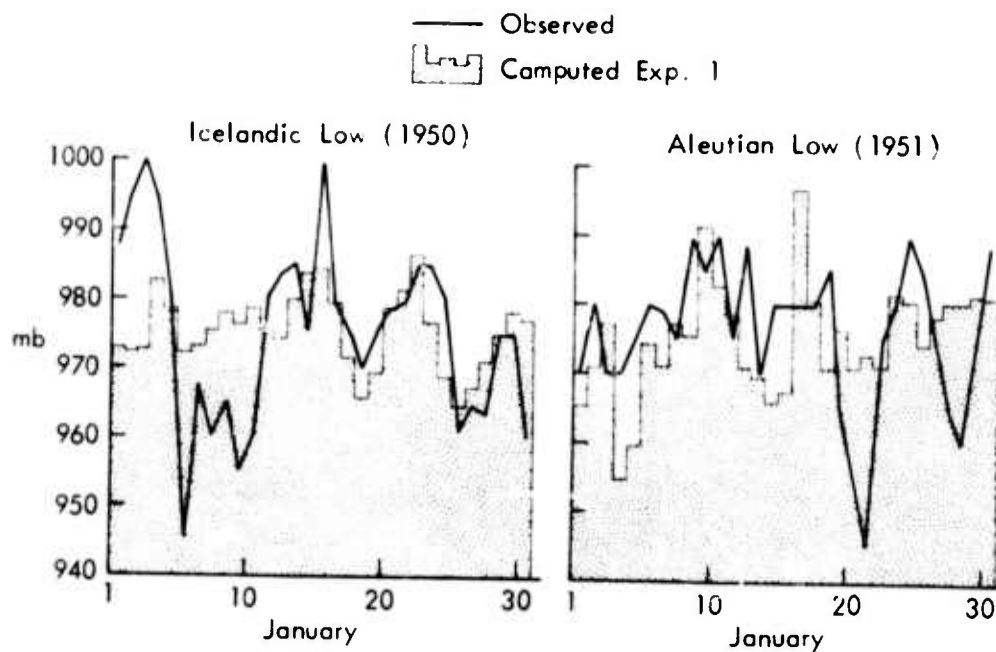


Fig. 7-- Daily variations of lowest pressure observed vs. Experiment 1, January

Atlantic indicates that the simulated pressures are also much less variable than those observed.

Over the North Pacific in the vicinity of the Aleutian Low, the observed mean and standard deviation from 1949-1953 indicate that 1951 is synoptically representative of the intensity. In 1951 the daily lowest pressure had a range of 45 mb, while in Experiment 1 the range was 42.3 mb. This similarity can be seen in the curve representing the plot of these daily data in Fig. 7. However, the histograms in Fig. 8, based on the frequency distribution of intensity data, show that within the range of lowest pressures, the experiments give low pressures that are higher and high pressures that are lower than those observed. As with the position data previously analyzed, there is better agreement between the experimental and observed intensity in the North Pacific than in the North Atlantic.

The difference in mean pressure shows that the simulated Icelandic Low is 4.3 mb less intense than is observed, while the simulated Aleutian

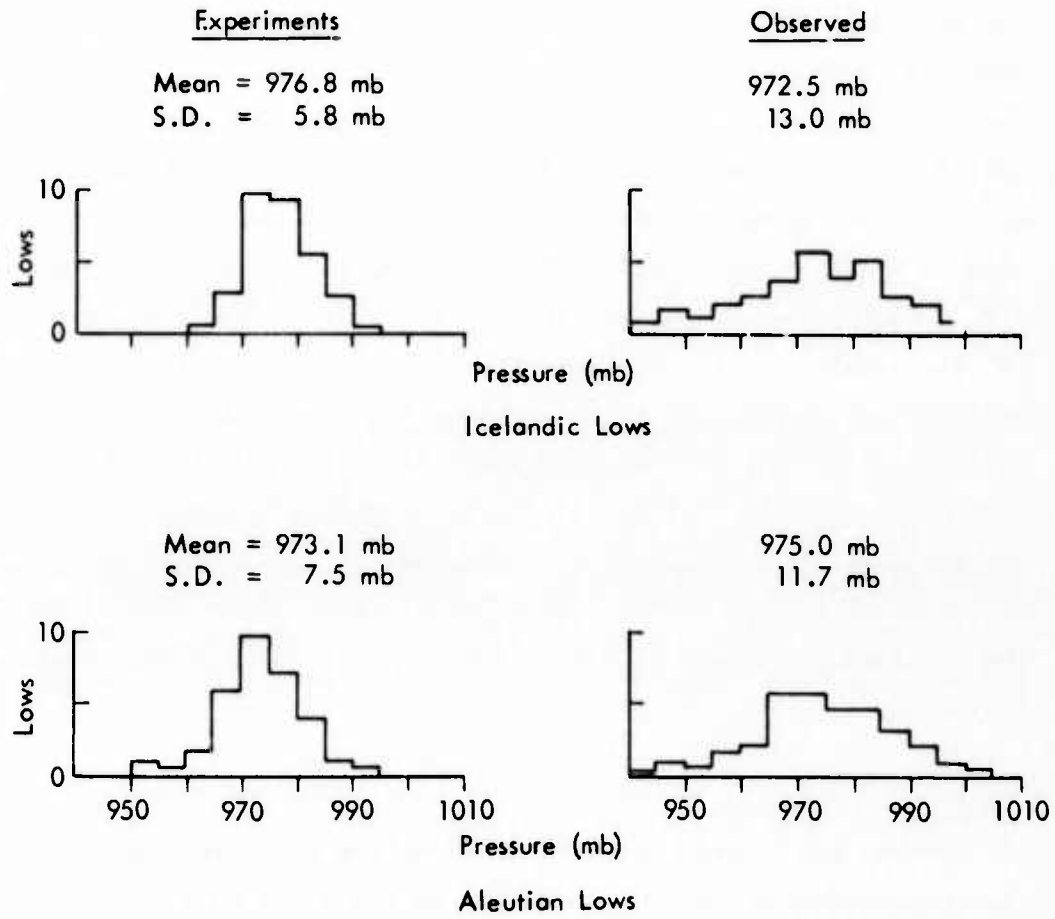


Fig. 8—Frequency distribution of combined intensities based on daily lowest surface pressures (mb), January

Low is 1.9 mb more intense than is observed on the average. When monthly means from the model are compared with long-term climatology, such as that from Schutz and Gates (1971), the model-simulated lows in Experiment 1 are 12-15 mb deeper than normal. This disagreement is due to the fact that the mean monthly pressure results from averaging the pressure for the month at each grid point without regard to the positions of individual lows. For example, if an exemplar grid point is chosen, then the average pressure there will take account of the occasional readings of relatively high pressure depending on the mobility of the low center. If the center is quite mobile, as was shown by the changing observed positions of the Icelandic Low in 1950 (Fig. 4), the selected grid point will experience many days of relatively high pressures, which implies a fairly high average pressure for the month; but if the low center hovers over and around the selected grid point, as in the case of Experiment 1 (Fig. 4), each day's reading will be low, from which it follows that the month's average value will be low. It can be recognized, therefore, that such an aggregate monthly statistic might make it appear that model results do not match their natural counterparts, while daily comparisons at the geographic centers of the individual lows could reveal a different result.

#### SPEED

Across the oceans, calculations for the mean and standard deviation of low center speeds were based on the daily positions of *all* "closed" low pressure centers, and not exclusively on the movements of the *lowest* pressure centers just discussed (Table 3). Also, only ocean points were used so that surface effects would be standard throughout the calculations. For both the North Atlantic and North Pacific, the calculation began when a low was at a land or ocean point nearest the western shore of the ocean. They were then continued across the ocean until cyclolysis occurred, or until an ocean or land point nearest the eastern shore of the ocean was reached. Although the calculation did not always begin at the time of cyclogenesis, there were instances where cyclogenesis and/or cyclolysis occurred over the ocean while the low was being tracked.

Table 3  
 SPEED (KNOTS), JANUARY  
 (Based on daily positions of  
 all pressure centers)

		<u>Icelandic Low</u>								
		<u>Observed (1230Z)</u>					<u>Experiments (0000Z)</u>			
		<u>1949</u>	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>	<u>1</u>	<u>2</u>	<u>3</u>	
Mean		23.7	22.1	18.0	20.6	19.3	16.8	14.4	17.2	
Standard										
Deviation		11.1	11.0	9.3	11.7	11.5	10.0	9.6	9.3	

		<u>Aleutian Low</u>								
		<u>Observed (1230Z)</u>					<u>Experiments (0000Z)</u>			
		<u>1949</u>	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>	<u>1</u>	<u>2</u>	<u>3</u>	
Mean		22.4	20.2	18.7	23.4	22.6	21.5	19.5	19.7	
Standard										
Deviation		10.1	11.3	11.1	12.2	12.9	8.6	9.3	7.7	

The frequency distribution of speed (knots) shown on the histograms (Fig. 9) is based on the distance a closed low moves each 24 hours. The distance between analyzed low centers from one map to the next is called a "period." Figure 9 indicates (1) that more periods were observed than were simulated and (2) that on the average the two-level model moves the lows slower than is observed. This same feature of model simulations has also been noted by Brown and Fawcett (1972) and Druyan (1974).

DURATION

Duration usually indicates the lifetime of a closed low center from cyclogenesis to cyclolysis. However, since these calculations were based on the same daily data used for the evaluation of speed, only data over the oceans were used and these did not always include a cyclone's complete cycle. In general, the experiments across both

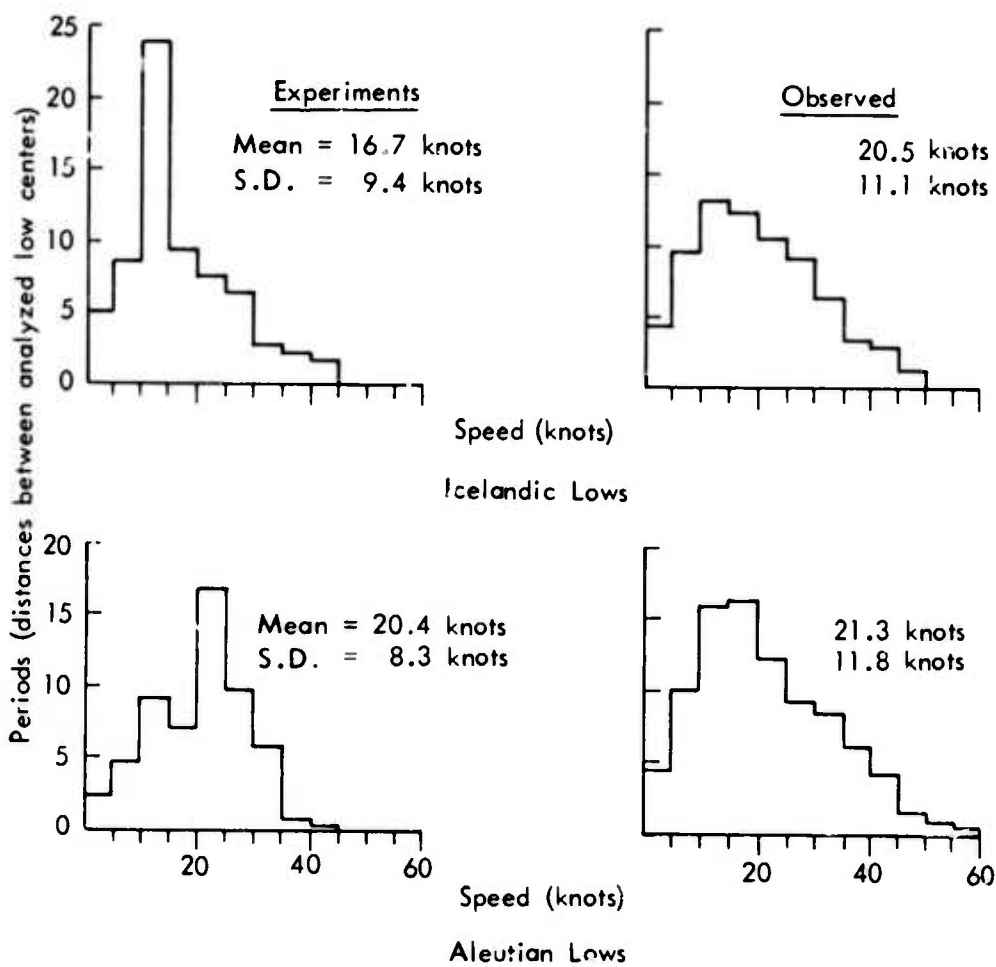


Fig. 9—Frequency distribution of combined speed (knots) based on daily positions of all low pressure centers, January

oceans showed that the lows continued slightly longer than those observed; longer duration being, of course, consistent with their lower speed.

Over the North Atlantic and North Pacific, the mean and standard deviation of duration shown in Table 4 indicate good agreement during the individual years observed and the experiments. The frequency distribution of the combined data given in Fig. 10 shows that the observed means are lower; however, the standard deviations are higher in the Pacific and lower in the Atlantic than those simulated.

Table 4  
DURATION (DAYS), JANUARY  
(Based on daily positions of  
*all* pressure centers)

		<u>Icelandic Low</u>								
		<u>Observed (1230Z)</u>					<u>Experiments (0000Z)</u>			
		<u>1949</u>	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>	<u>1</u>	<u>2</u>	<u>3</u>	
Mean		3.5	3.2	3.8	3.2	4.9	4.9	3.9	4.2	
Standard										
Deviation		1.0	1.4	1.8	1.8	3.2	4.0	2.9	2.9	

		<u>Aleutian Low</u>								
		<u>Observed (1230Z)</u>					<u>Experiments (0000Z)</u>			
		<u>1949</u>	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>	<u>1</u>	<u>2</u>	<u>3</u>	
Mean		3.8	4.3	3.3	4.5	4.0	5.5	4.4	3.9	
Standard										
Deviation		3.2	2.2	2.4	2.6	3.0	1.6	2.5	2.3	

TRACKS

The mean tracks or paths of *all* closed low centers shown in Fig. 11 were a by-product of the speed and duration calculations. They are presented to provide further insight into the differences between simulated and observed conditions. In both the North Atlantic and North Pacific, the simulated tracks of low-pressure centers are generally

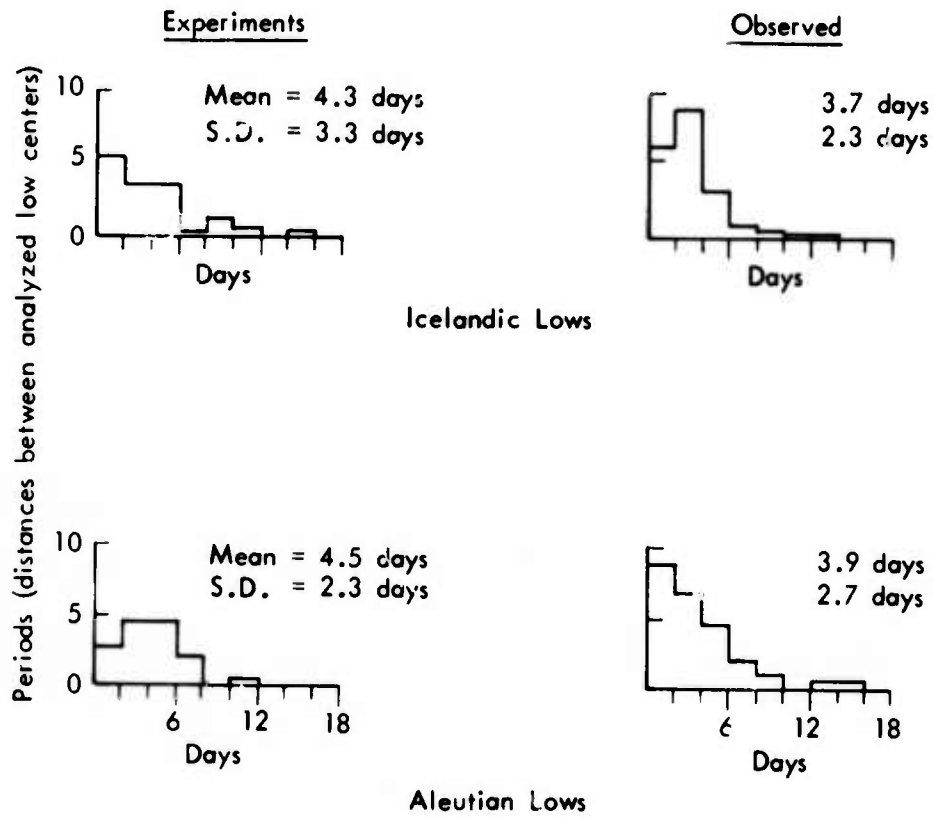


Fig. 10— Frequency distribution of combined duration (days) based on daily position of all low pressure centers, January

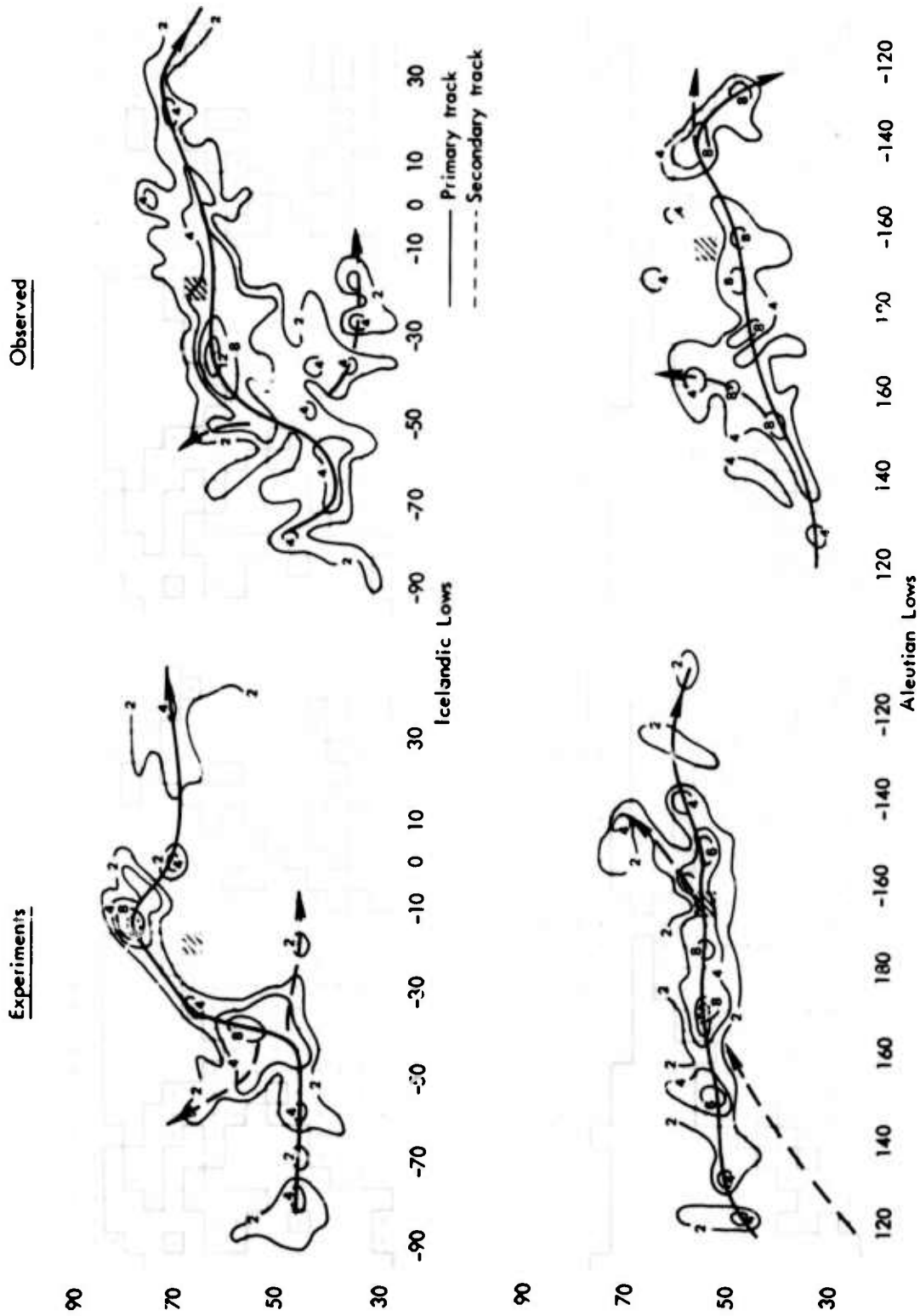


Fig. 11 — Combined low tracks on all closed low centers (not on lowest pressure centers alone)

north of those observed, as may be seen by referring to the cross-hatched grid square representing Iceland and the Aleutians. This is true not only for the primary track (solid line), but for the secondary track (dashed line) as well. A second important difference between the simulations and observation is the more random distribution of the individual tracks in the observed data. This is shown by the plotted numbers at each grid point representing the number of times a low passed near that grid point at map time. The track characteristics in Fig. 11 were determined by subjectively connecting the locations of the maximum number of such passages. The basic tracks developed by this procedure did not always go through either the mean center of lowest pressure (Fig. 5), or the latitude and longitude of the single lowest pressure for January. A summary of all low-pressure center tracks used indicates that more low "positions" are observed than are simulated, as shown in Table 5.

Table 5

LOW TRACKS, JANUARY

(Based on daily positions of  
all pressure centers)

		<u>North Atlantic</u>							
		<u>Observed (1230Z)</u>					<u>Experiments (0000Z)</u>		
		<u>1949</u>	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>	<u>1</u>	<u>2</u>	<u>3</u>
Tracks		15	25	21	20	20	14	16	17
		<u>North Pacific</u>							
		<u>Observed (1230Z)</u>					<u>Experiments (0000Z)</u>		
		<u>1949</u>	<u>1950</u>	<u>1951</u>	<u>1952</u>	<u>1953</u>	<u>1</u>	<u>2</u>	<u>3</u>
Tracks		16	24	29	20	25	11	13	13

#### IV. CONCLUSIONS

It has been shown that daily variations of surface-air temperature and five synoptic variables related to closed low-pressure centers give additional insight to model behavior when compared with representative observed data. The principal findings are:

1. Large diurnal variations of surface air temperature are simulated between 0600LST to 1200 LST at Columbia, Missouri, and these are systematically larger than those observed.
2. When daily surface pressure is used at fixed geographical points to determine the mean monthly pressure, the simulated Icelandic Low is less intense than observed, while the Aleutian Low is more intense than observed, as compared with the lowest reported pressure each day.
3. The simulated speeds of all low-pressure centers, including those with the lowest pressure, are systematically slower than the observed speeds.
4. Both the simulated daily and mean January positions of the Icelandic low-pressure center tend to occur southwest of the observed climatological center. There is better agreement, however, when comparing positions in the vicinity of the Aleutian Low.

It is hoped that future improvements of the model will reduce these errors in synoptic performance, even though the model is not intended to be used in short-range forecasting. In view of the systematic character of many of these errors, however, there is a possibility that they may affect the model's simulation of climatic statistics at time ranges well beyond the model's acknowledged predictability limit.

APPENDIX  
DATA TABULATIONS

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Table A-1

AVERAGE DAILY SURFACE AIR TEMPERATURE (°F), JANUARY  
(Computed daily from 0000-0600 - 1200-1800 CST data)

Day \ Yr	Observed						Simulated			
	1949	1950	1951	1952	1953	Avg.	Day \ Yr	1	2	3
1	23.	51.3	44.0	21.8	34.0	34.8	371	24.9	25.7	26.1
2	37.	53.8	45.0	17.8	34.0	37.5	372	19.5	27.1	27.0
3	45.	33.5	27.3	23.0	27.5	31.3	373	25.3	35.6	36.4
4	39.	6.3	27.3	29.5	27.5	25.9	374	26.1	31.9	30.2
5	26.	9.3	34.5	25.3	27.8	24.6	375	35.3	46.1	43.4
6	34.	19.5	21.8	23.5	27.0	25.2	376	32.2	37.4	38.1
7	44.	28.5	17.0	29.3	21.8	28.1	377	41.4	36.1	29.3
8	51.	36.0	22.0	39.0	26.0	34.8	378	34.2	37.8	33.9
9	35.	44.0	38.8	29.0	32.3	35.8	379	33.6	42.9	43.0
10	27.	39.3	36.8	22.0	29.8	30.9	380	37.7	36.4	39.3
11	31.	28.3	31.0	32.8	30.8	30.8	381	43.5	38.1	43.5
12	28.	42.5	40.0	39.3	45.8	39.1	382	34.0	30.2	33.6
13	30.	48.3	41.8	48.0	50.8	43.8	383	40.5	32.4	35.8
14	38.	31.0	37.0	58.3	54.0	43.7	384	36.0	31.2	41.2
15	58.	36.8	34.5	46.3	41.5	43.4	385	34.6	34.4	36.5
16	31.	20.8	40.3	56.8	15.0	32.8	386	29.6	35.3	31.6
17	17.	36.3	53.0	56.3	25.3	37.6	387	40.9	30.7	37.9
18	25.	17.3	49.0	39.5	31.0	32.4	388	39.1	34.0	37.4
19	14.	19.5	49.3	52.5	32.3	33.5	389	35.0	31.0	36.8
20	13.	29.5	29.5	32.8	32.3	27.4	390	32.6	33.3	35.7
21	29.	35.5	16.8	32.8	33.3	29.5	391	31.1	37.7	36.7
22	24.	47.0	30.3	26.8	37.3	33.1	392	31.8	44.1	31.4
23	36.	44.3	35.8	13.0	34.5	32.7	393	30.9	39.3	21.0
24	29.	58.3	23.5	21.8	29.5	32.4	394	29.1	30.3	34.3
25	17.	41.0	22.0	46.5	30.5	31.4	395	32.3	40.4	44.9
26	22.	13.5	38.5	40.5	41.5	31.2	396	32.3	47.6	41.1
27	28.	21.3	29.5	34.3	37.3	30.1	397	33.2	38.3	37.7
28	15.	39.8	9.8	23.8	30.0	23.7	398	31.4	32.7	32.5
29	2.	24.3	1.5	12.8	35.5	15.2	399	25.5	24.9	33.8
30	3.	15.0	3.5	27.55	46.3	19.1	400	30.9	23.4	26.4
31	14.	18.3	5.5	42.3	37.8	23.6	401	32.4	26.6	35.0
<b>Range</b>	56.0	52.0	51.5	45.5	39.0	28.6		24.0	24.2	23.9
<b>Mean</b>	27.9	31.9	30.2	33.7	33.6	31.5		32.8	34.6	35.2
<b>Standard Deviation</b>	12.5	13.4	13.3	12.5	8.1	12.3		5.2	5.9	5.5



Table A-3

SIMULATED HOURLY SURFACE AIR TEMPERATURE (°F), COLUMBIA, MO. (GRID POINT)

Experiment #1

Day	Hr	0000LST	0600LST	1200LST	1800LST	Avg
371		18.81	19.01	35.12	26.66	24.90
372		13.78	10.80	30.61	22.91	19.53
373		13.42	11.88	44.46	31.56	25.33
374		5.95	2.92	53.61	41.71	26.05
375		29.90	28.00	47.27	35.95	35.28
376		25.41	21.91	43.05	38.43	32.20
377		31.28	29.50	60.48	44.50	41.44
378		32.05	30.79	41.74	32.25	34.21
379		22.67	21.15	50.39	40.22	33.61
380		22.66	20.25	59.73	48.10	37.69
381		34.80	31.98	62.06	45.33	43.54
382		18.42	17.50	54.28	45.61	33.95
383		35.02	28.84	56.85	41.09	40.45
384		21.16	24.82	54.11	44.05	36.04
385		31.92	26.49	43.65	36.21	34.57
386		18.12	7.39	52.74	59.95	29.55
387		27.63	29.75	58.70	47.43	40.88
388		33.67	29.74	52.85	40.21	39.12
389		24.03	19.58	55.96	40.52	35.02
390		20.49	22.01	48.83	39.20	32.63
391		32.54	26.55	35.40	29.88	31.09
392		20.40	19.77	48.48	38.37	31.75
393		24.30	20.89	43.80	34.80	30.95
394		22.25	18.50	41.90	33.57	29.08
395		21.22	17.31	51.60	39.26	32.35
396		20.34	16.90	51.77	40.06	32.27
397		26.65	25.04	44.56	36.60	33.21
398		23.52	17.94	50.13	34.18	31.44
399		11.39	6.11	49.01	35.47	25.50
400		20.38	19.18	46.46	37.47	30.87
401		24.95	22.21	44.49	38.05	32.43
						32.8 TOTAL

POSITION AND INTENSITY OF LOWEST PRESSURE CENTER DAILY ACROSS NORTH ATLANTIC, JANUARY

YR	1230Z										0000Z					
	1949		1950		1951		1952		1953		EXP. 1		EXP. 2		EXP. 3	
	Lat	Press	Lat	Press	Lat	Press	Lat	Press	Lat	Press	Lat	Press	Lat	Press	Lat	Press
Day	Lon	mb	Lon	mb	Lon	mb	Lon	mb	Lon	mb	Lon	mb	Lon	mb	Lon	mb
1	53_7	955.0	63_30	987.7	54_6	980.0	61_28	995.0	40_64	985.0	50_35	972.9	50_35	973.4	50_35	973.5
2	63_+5	960.0	66_+9	995.0	55_39	980.0	66_+8	983.6	41_53	985.0	50_40	972.3	54_40	973.2	50_40	977.7
3	71_+13	965.0	56_26	1000.0	56_27	980.0	61_38	970.0	41_70	990.0	58_40	972.7	58_40	973.0	58_40	974.0
4	64_+5	985.0	60_22	994.4	57_19	980.0	65_37	975.0	67_17	984.0	58_40	982.8	58_40	983.1	58_45	983.5
5	65_19	975.3	61_23	980.0	51_56	977.5	65_25	940.0	73_+5	985.0	54_50	978.2	54_50	978.9	54_50	976.3
6	71_0	970.0	56_30	945.0	58_45	960.0	75_20	944.8	59_53	985.0	54_45	972.1	58_45	973.6	54_45	970.6
7	59_10	1000.0	55_30	967.7	60_43	973.2	68_26	960.0	73_+25	993.7	58_45	973.3	58_45	976.5	58_45	974.1
8	55_54	990.0	58_32	960.0	67_50	984.1	67_9	945.0	57_39	985.0	66_50	975.3	66_30	981.4	66_35	975.2
9	67_43	975.0	58_35	965.0	54_49	970.0	60_1	950.0	57_42	975.0	74_25	977.9	74_25	972.1	74_30	971.6
10	73_+10	950.0	51_32	955.0	60_34	950.0	66_+5	959.6	64_31	988.0	50_40	976.1	50_40	974.1	50_40	972.4
11	61_53	995.0	60_22	960.0	60_15	965.0	60_+2	968.8	67_22	981.0	46_55	978.5	58_40	976.9	58_40	976.9
12	64_32	980.0	69_0	980.0	60_4	967.9	58_40	970.0	61_61	980.0	50_40	975.8	50_45	975.1	50_50	972.5
13	65_32	975.0	64_15	983.4	61_28	975.0	66_25	948.0	65_55	975.0	58_35	974.2	54_40	975.8	54_40	971.1
14	74_+17	960.0	62_25	985.0	47_45	975.0	68_3	970.0	65_30	985.0	62_35	979.9	58_35	982.6	54_40	975.4
15	64_30	972.1	54_54	975.0	50_41	960.0	62_+5	955.0	70_25	982.2	66_35	983.5	62_35	984.6	62_40	983.2
16	66_5	975.0	48_39	1000.0	59_35	975.0	69_+6	975.0	75_+10	970.0	50_45	984.1	66_35	987.6	66_35	988.2
17	67_7	950.0	64_37	980.0	66_14	969.0	67_+5	984.2	53_53	970.0	54_45	979.6	58_55	984.3	46_51	977.1
18	65_25	970.0	59_45	975.0	54_46	995.0	55_43	980.0	59_45	990.0	46_45	971.3	62_45	978.9	50_45	967.7
19	68_6	950.0	53_53	970.0	45_38	990.0	53_60	972.8	70_10	990.0	54_45	965.5	50_40	984.9	58_50	967.7
20	68_3	950.0	62_37	975.0	59_35	975.0	60_54	980.0	72_+25	965.7	54_50	969.8	54_45	975.8	42_50	973.8
21	63_38	985.0	61_45	978.3	62_37	980.0	50_62	993.2	72_60	995.0	50_45	978.9	58_50	976.1	46_45	968.2
22	65_25	974.3	67_25	979.6	57_55	975.0	57_60	975.0	62_40	985.0	46_35	981.4	58_45	973.9	54_50	972.0
23	71_20	970.0	67_35	984.9	64_43	970.0	64_68	992.7	44_50	985.0	46_40	986.2	58_55	974.5	58_55	976.2
24	75_20	972.8	60_49	985.0	66_30	975.0	71_+15	985.0	57_37	970.0	46_50	976.4	50_35	984.3	58_60	986.2
25	64_38	955.0	67_34	980.0	64_35	980.0	67_+5	985.7	63_41	949.1	46_50	969.1	46_30	986.4	50_35	986.2
26	76_0	960.0	63_32	960.9	62_27	984.0	63_51	985.8	65_32	965.0	46_45	964.4	46_25	985.8	54_40	983.2
27	66_30	975.0	54_39	965.0	71_10	980.0	64_35	990.1	64_35	965.0	46_35	967.7	50_25	984.1	46_70	978.8
28	41_40	989.0	61_35	963.6	60_45	955.0	51_36	990.0	69_+13	965.0	50_35	971.6	46_20	984.4	46_55	968.4
29	39_39	985.0	62_41	975.0	61_37	965.0	64_39	975.0	69_+12	971.0	46_15	974.7	46_20	985.3	46_50	971.6
30	59_55	985.0	59_61	975.0	64_35	965.0	65_35	960.8	61_14	990.0	50_35	978.0	50_30	990.7	46_45	974.5
31	60_50	984.4	59_38	960.0	62_41	965.0	64_10	966.7	56_+4	975.0	46_40	977.4	-	-	-	-
Range	950.0-1000.0		945.0-1000.0		950.0-990.0		940.0-995.0		949.1-995.0		964.4-986.2		972.1-990.7		967.7-988.2	
Mean	970.1		973.5		971.2		970.4		977.5		975.2		979.5		975.7	
Standard Deviation	13.9		12.9		9.7		15.9		10.3		5.36		5.56		5.62	
Mean Lat	63.9N		60.0N		58.9N		63.3N		61.7N		52.6N		55.3N		53.9N	
Mean Lon	19.7W		32.7W		34.4W		24.5W		28.6W		40.8W		38.3W		45.0W	

\*Lat = Latitude, Lon = Longitude, (minus = west).

Table A-5

POSITION AND INTENSITY OF LOWEST PRESSURE CENTER DAILY ACROSS NORTH PACIFIC, JANUARY

YR	1230Z										0000Z					
	1949		1950		1951		1952		1953		EXP. 1		EXP. 2		EXP. 3	
Day	Lat <sup>a</sup> Lon	Press mb	Lat Lon	Press mb	Lat Lon	Press mb	Lat Lon	Press mb	Lat Lon	Press mb	Lat Lon	Press mb	Lat Lon	Press mb	Lat Lon	Press mb
1	43 <sub>176</sub>	995.0	56 <sub>159</sub>	990.0	45 <sub>155</sub>	970.0	48 <sub>163</sub>	985.0	59 <sub>153</sub>	979.9	54 <sub>175</sub>	965.6	54 <sub>175</sub>	966.3	54 <sub>180</sub>	966.4
2	52 <sub>165</sub>	980.0	57 <sub>177</sub>	995.0	44 <sub>172</sub>	980.0	58 <sub>175</sub>	985.0	42 <sub>164</sub>	975.0	58 <sub>170</sub>	971.1	58 <sub>170</sub>	971.9	58 <sub>170</sub>	970.3
3	58 <sub>153</sub>	969.0	49 <sub>157</sub>	990.0	50 <sub>169</sub>	970.0	62 <sub>165</sub>	975.0	42 <sub>160</sub>	965.0	50 <sub>145</sub>	977.6	50 <sub>145</sub>	979.6	50 <sub>145</sub>	975.8
4	50 <sub>156</sub>	980.0	44 <sub>155</sub>	990.0	50 <sub>175</sub>	970.0	49 <sub>163</sub>	970.0	50 <sub>158</sub>	950.0	54 <sub>155</sub>	954.5	54 <sub>155</sub>	954.1	54 <sub>155</sub>	951.5
5	49 <sub>157</sub>	975.0	54 <sub>159</sub>	970.0	50 <sub>177</sub>	975.0	59 <sub>172</sub>	995.0	55 <sub>175</sub>	960.0	54 <sub>170</sub>	959.5	54 <sub>165</sub>	960.4	54 <sub>165</sub>	958.5
6	54 <sub>167</sub>	970.0	39 <sub>148</sub>	995.0	47 <sub>170</sub>	980.0	60 <sub>145</sub>	990.0	41 <sub>147</sub>	970.0	54 <sub>175</sub>	974.3	54 <sub>175</sub>	976.4	54 <sub>180</sub>	975.0
7	52 <sub>162</sub>	975.0	48 <sub>159</sub>	990.0	53 <sub>168</sub>	979.2	68 <sub>140</sub>	985.0	46 <sub>140</sub>	970.0	50 <sub>170</sub>	971.4	50 <sub>170</sub>	970.4	50 <sub>170</sub>	967.8
8	55 <sub>175</sub>	970.0	54 <sub>161</sub>	970.0	60 <sub>158</sub>	975.0	56 <sub>144</sub>	970.0	40 <sub>141</sub>	970.0	50 <sub>170</sub>	976.8	50 <sub>170</sub>	978.4	54 <sub>170</sub>	972.9
9	62 <sub>175</sub>	984.4	55 <sub>159</sub>	992.5	45 <sub>180</sub>	989.0	56 <sub>140</sub>	970.0	44 <sub>179</sub>	980.0	54 <sub>150</sub>	975.8	54 <sub>150</sub>	976.0	58 <sub>155</sub>	974.8
10	44 <sub>172</sub>	995.0	39 <sub>150</sub>	960.0	52 <sub>153</sub>	985.0	55 <sub>137</sub>	980.0	47 <sub>173</sub>	975.0	50 <sub>155</sub>	991.5	66 <sub>145</sub>	977.8	66 <sub>150</sub>	983.3
11	49 <sub>180</sub>	985.0	44 <sub>160</sub>	950.0	48 <sub>166</sub>	990.0	64 <sub>175</sub>	990.0	47 <sub>174</sub>	985.0	50 <sub>170</sub>	982.3	54 <sub>165</sub>	974.2	50 <sub>170</sub>	987.3
12	52 <sub>172</sub>	980.0	48 <sub>162</sub>	960.0	59 <sub>142</sub>	975.0	59 <sub>148</sub>	985.0	39 <sub>146</sub>	975.0	50 <sub>150</sub>	978.2	54 <sub>180</sub>	976.9	50 <sub>150</sub>	974.4
13	56 <sub>168</sub>	985.0	47 <sub>165</sub>	970.0	60 <sub>143</sub>	988.8	56 <sub>139</sub>	975.0	47 <sub>166</sub>	975.0	54 <sub>160</sub>	970.7	54 <sub>165</sub>	968.8	54 <sub>165</sub>	967.0
14	56 <sub>165</sub>	995.0	47 <sub>170</sub>	985.0	56 <sub>160</sub>	970.0	42 <sub>132</sub>	980.0	51 <sub>158</sub>	980.0	54 <sub>165</sub>	969.8	54 <sub>165</sub>	961.5	54 <sub>170</sub>	961.8
15	60 <sub>165</sub>	998.3	42 <sub>160</sub>	985.0	58 <sub>174</sub>	980.0	44 <sub>156</sub>	975.0	43 <sub>175</sub>	975.0	54 <sub>180</sub>	965.9	54 <sub>175</sub>	965.1	58 <sub>175</sub>	965.7
16	50 <sub>158</sub>	985.0	43 <sub>164</sub>	970.0	53 <sub>135</sub>	980.0	54 <sub>154</sub>	950.0	47 <sub>174</sub>	960.0	58 <sub>165</sub>	967.4	58 <sub>170</sub>	974.5	62 <sub>170</sub>	962.4
17	54 <sub>167</sub>	970.0	43 <sub>168</sub>	970.0	57 <sub>145</sub>	980.0	57 <sub>162</sub>	980.0	52 <sub>174</sub>	962.0	46 <sub>135</sub>	996.8	50 <sub>170</sub>	974.3	60 <sub>170</sub>	967.2
18	61 <sub>175</sub>	980.0	42 <sub>163</sub>	985.0	56 <sub>142</sub>	980.0	45 <sub>159</sub>	975.0	52 <sub>177</sub>	974.0	46 <sub>150</sub>	980.2	54 <sub>175</sub>	975.8	56 <sub>175</sub>	971.1
19	62 <sub>170</sub>	985.0	41 <sub>142</sub>	988.4	42 <sub>161</sub>	985.0	54 <sub>166</sub>	960.0	52 <sub>177</sub>	969.9	50 <sub>170</sub>	970.2	62 <sub>160</sub>	972.2	58 <sub>175</sub>	968.8
20	55 <sub>165</sub>	960.0	42 <sub>156</sub>	980.0	50 <sub>140</sub>	965.0	58 <sub>164</sub>	975.0	47 <sub>162</sub>	963.0	50 <sub>180</sub>	976.3	54 <sub>170</sub>	994.0	62 <sub>165</sub>	971.2
21	55 <sub>165</sub>	955.0	47 <sub>158</sub>	980.0	53 <sub>139</sub>	955.0	46 <sub>163</sub>	965.0	52 <sub>148</sub>	965.0	54 <sub>150</sub>	970.7	54 <sub>165</sub>	987.7	46 <sub>170</sub>	986.8
22	58 <sub>170</sub>	970.0	53 <sub>162</sub>	985.0	53 <sub>160</sub>	945.0	43 <sub>160</sub>	974.9	48 <sub>160</sub>	975.0	54 <sub>155</sub>	972.3	54 <sub>160</sub>	977.5	50 <sub>180</sub>	982.2
23	55 <sub>165</sub>	990.0	41 <sub>152</sub>	1007.0	56 <sub>174</sub>	975.0	46 <sub>156</sub>	970.0	41 <sub>160</sub>	965.0	58 <sub>170</sub>	970.9	54 <sub>175</sub>	973.0	54 <sub>155</sub>	967.1
24	52 <sub>169</sub>	985.0	48 <sub>158</sub>	995.0	51 <sub>157</sub>	980.0	47 <sub>159</sub>	970.0	49 <sub>164</sub>	965.0	58 <sub>150</sub>	981.9	58 <sub>180</sub>	973.0	54 <sub>160</sub>	966.0
25	56 <sub>170</sub>	990.0	37 <sub>173</sub>	1005.0	44 <sub>164</sub>	990.0	51 <sub>152</sub>	971.9	55 <sub>164</sub>	975.0	54 <sub>170</sub>	981.1	58 <sub>165</sub>	978.2	58 <sub>150</sub>	973.7
26	38 <sub>155</sub>	985.0	39 <sub>179</sub>	1000.0	52 <sub>163</sub>	985.0	47 <sub>153</sub>	975.0	49 <sub>154</sub>	985.0	54 <sub>170</sub>	974.5	58 <sub>160</sub>	973.4	54 <sub>150</sub>	977.3
27	50 <sub>167</sub>	975.0	38 <sub>173</sub>	1005.0	39 <sub>176</sub>	975.0	47 <sub>168</sub>	974.8	42 <sub>161</sub>	985.0	54 <sub>165</sub>	978.5	54 <sub>170</sub>	975.9	54 <sub>150</sub>	977.3
28	54 <sub>175</sub>	950.0	48 <sub>148</sub>	1000.0	46 <sub>164</sub>	965.0	47 <sub>178</sub>	975.0	45 <sub>175</sub>	985.0	58 <sub>160</sub>	980.3	58 <sub>180</sub>	975.3	54 <sub>170</sub>	970.8
29	58 <sub>168</sub>	970.0	55 <sub>155</sub>	990.0	49 <sub>172</sub>	960.0	48 <sub>170</sub>	972.0	42 <sub>167</sub>	955.0	54 <sub>160</sub>	980.6	58 <sub>180</sub>	977.9	54 <sub>180</sub>	968.7
30	62 <sub>166</sub>	975.0	41 <sub>170</sub>	995.0	49 <sub>158</sub>	970.0	56 <sub>142</sub>	975.0	47 <sub>160</sub>	970.0	58 <sub>160</sub>	981.4	58 <sub>150</sub>	980.8	58 <sub>170</sub>	968.6
31	43 <sub>163</sub>	995.0	45 <sub>145</sub>	980.0	55 <sub>160</sub>	988.3	59 <sub>146</sub>	978.0	46 <sub>174</sub>	970.0	54 <sub>165</sub>	981.3	-	-	-	-
Range	950.0-998.3		950.0-1005.0		945.0-990.0		950.0-995.0		950.0-985.0		954.5-996.8		954.1-994.0		951.5-987.3	
Mean	976.9		982.2		973.8		973.5		968.6		973.95		974.2		971.2	
Standard Deviation	11.7		13.7		10.4		8.8		8.7		7.42		7.31		7.58	
Mean Lat	53.4N		46.0N		51.0N		53.2N		47.1N		55.2N		55.2N		55.4N	
Mean Lon	175.3E		165.0E		171.8W		167.0W		172.4W		173.4E		176.0E		174.4E	

<sup>a</sup>Lat = Latitude, Lon = Longitude, (minus = west).

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