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ARIZONA COOL SEASON CLIMATOLOGICAL SURFACE WIND AND PRESSURE GRADIENT STUDY

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This Technical Memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

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ARIZONA COOL SEASON CLIMATOLOGICAL SURFACE WIND AND PRESSURE GRADIENT STUDY

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ABSTRACT. The average sea-level pressure gradients which produce sustained surface winds above 8 kts for at least six consecutive hours during the cool season at predetermined key stations in or adjacent to Arizona are investigated. Only wind directions from northerly or easterly components are included in the developmental data sample. Graphs are provided in the developmental data sample. Graphs are provided which relate the derived pressure gradients to varying surface wind speeds at each key station.

I. INTRODUCTION

Surface wind direction and sustained speed forecasts during the cool season are not only essential to statewide aviation interests, but also to surface travelers and numerous outdoor enthusiasts. Model Output Statistic (MOS) products forecast trends of surface wind speeds reasonably well, but frequently fall well short of acceptable levels of accuracy in many critical cases (Grayson and Tuft, 1978). Since sustained wind speeds of less than 8 kts are generally not a problem, this study concentrated only on sustained speeds of 8 kts or greater at key stations. Gustiness of 25 kts or greater was also included provided the 8 kts sustained threshold was satisfied. In order that these winds be included in the developmental data sample, they had to persist at the key station for 6 consecutive hours without a major shift in direction.

Winds from a southerly component, as are common in advance of an upper-level trough and associated cold front, were not considered in this study. It was felt that Arizona forecasters, as well as MOS, handle these wind direction and speed forecasts reasonably well.

During the period of study, differences in sea-level pressure in millibars from selected stations to each key station were tabulated for each six-hour period used and averaged in each of six predetermined sustained 6-hour wind-speed categories. The categories selected were 8-12 kts, 13-17 kts, 23-27 kts, 28-32 kts, and greater than 32 kts. Wind directions at the key station for each category were also tabulated and averaged. The number of cases per-wind category were additionally recorded.

Following this procedure, for each surrounding station to each key station, the combined average wind speed and the corresponding average direction and pressure gradient were determined and plotted on a map for that particular key station.

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The key stations used in this study and the respective wind directions investigated for use in the developmental sample were as follows:

1.	Yuma, AZ	(YUM)	330° to 030°
2.	Phoenix, AZ	(PHX)	060° to 100°
3.	Flagstaff, AZ	(FLG)	030° to 070°
4.	Tucson, AZ	(TUS)	100° to 150°
5.	Douglas, AZ	(DUG)	070° to 120°
6.	Needles, CA	(EED)	330° to 030°
7.	Blythe, CA	(BLH)	320° to 020°.

Additional stations which were utilized to compute the sea-level pressure differences to the key stations included:

1.	Las Vegas, NV	(LAS)
2.	Cedar City, UT	(CDC)
3.	Blanding, UT	(BDG or 4BL)
4.	Gallup, NM	(GUP)
5.	Deming, NM	(DMN)
6.	Winslow, AZ	(INW).

II. DEVELOPMENTAL DATA ANALYSIS

The cool season was defined as the months of October through April. The period of study commenced October 1976 and ended April 1978. Figures 1-7 display the combined averaged wind direction, speed, and pressure gradients yielded by the developmental data for each of the key stations. The average sea-level pressure differences are in whole and tenths of a millibar. The difference, of course, at the key station being analyzed is always zero. The averaged wind direction and speed corresponding to the plotted pressure differences is indicated below the key station name.

In the cases of Figure 1 (YUM), Figure 2 (PHX), Figure 3 (FLG), Figure 4 (TUS), and Figure 5 (DUG), the 6-hour averages of wind speeds appeared to fall into two distinct categories and were so separated.

For all the key stations, the number of mutually exclusive 6-hour periods (N) that comprised the developmental data sample is indicated near the name of the key station. A total of four 6-hour periods is possible per day and 424 days were involved in the study. This yielded a maximum of 1696 six-hour periods possible in the study for each key station. Therefore, during this particular period of study, the winds which were used to develop Figures 1-7 were observed the following percentages of the total data sample:

STATION	AVERAGE WIND	N	PERCENT OF TOTAL SAMPLE	COMBINED PERCENT
YUM	3515G25	67	4%	9%
YUM	3510 to 3515	84	5%	
PHX	0815	32	2%	5%
PHX	0808 to 0813	56	3%	
FLG	0512G25	34	2%	6%
FLG	0510 to 0515	72	4%	
TUS	1215G25	45	3%	7%
TUS	1210 to 1215	71	4%	
DUG	0918G30	52	3%	8%
DUG	0910 to 0915	86	5%	
EED	3618G30	202	12%	12%
BLH	3415G25	192	11%	11%

At first glance, one might judge that these percentages are too small to be considered very meaningful. However, it must be remembered that these are percentages where moderate to strong sustained or gusty winds persisted for 6 consecutive hours. Aviators, boaters, and drivers of high profile vehicles would consider these sustained winds for this long a period very significant.

Combining the percentages where stronger and weaker winds were indicated (YUM, PHX, FLG, TUS, and DUG), and comparing these values with the remaining two stations, EED and BLH, provides a few additional points of interest. It would seem that the Colorado River region of western Arizona is rather susceptible to moderate to strong northerly winds. The key station farthest north within this river valley, EED, had the greatest percent frequency (12%) of the three stations analyzed, with YUM (southernmost) having the least (9%). This is borne out by Figures 1, 6, and 7 which show that the highest surface pressure for this pattern is normally located in the region between CDC and the Nevada border due west of CDC. The pressure gradients are indicated to be tighter between LAS and EED than between EED and YUM on each of these figures.

DUG, with a frequency of 8% for easterly winds was the fourth highest of the key stations. A review of the data indicated that this was largely in response to a southward plunge of high pressure into western New Mexico. This is commonly associated with a "backdoor-coldfront" situation. The frequency of 7% at TUS for southeast winds can be attributed to much the same reasoning as that applied to DUG. Figures 4 and 5 both show the southward plunge of higher pressure into western New Mexico. The tight pressure gradient indicated from Grand Canyon (GCN) to between FLG and INW and southeastward toward ShowLow (SOW) and DMN suggests the presence of a frontal boundary.

The northeast-to-east winds at PHX and FLG, as displayed by Figures 2 and 3 appear to be associated with an intermediate position of the high-pressure area between that shown by Figures 1, 6, and 7 and that of Figures 4 and 5. At this time, winds begin to decrease considerably along the Colorado River, while increasing in southeastern Arizona.

Further examination of Figures 1-7 gives insight as to which of the surrounding stations give the best correlation to each key station in terms of pressure difference and resulting surface wind speeds. These are listed as follows:

KEY STATION	BEST CORRELATING STATION
YUM	LAS
PHX	INW
FLG	CDC
TUS	DMN
DUG	DMN
EED	CDC
BLH	LAS

At this point, an attempt was made to provide prognostic utility from this study. The original averaged pressure gradients and wind directions for each of the predetermined sustained 6-hour wind-speed categories were plotted in graphical form for the above key and correlating station combinations. The mid-point, rather than the actual range of each wind-speed category, was labeled along the abscissa with the average pressure gradient along the ordinate. The graphs are shown in Figures 8-10. The combined averaged data for each key station are also on the graph close to the respective curve for that station. Near each plotted point, the wind direction in degrees and the number of cases are indicated.

For all the graphs, a definite "S" configuration resulted. The crest of the "S" was located near 20 kts in each case. These curves indicate that wind speed does not increase in a simple linear fashion with increasing pressure gradient. The slopes of each of the curves between 15 kts and 20 kts are larger in all cases than elsewhere on that same curve. This means that it takes more pressure gradient to cause an increase in the winds in this range than for other wind-speed ranges.

Experience has shown that with steadily rising pressure to the north or east, actual surface winds do indeed frequently increase rapidly up to about 15 kts, then level off for awhile, before increasing sharply once again. Perhaps an explanation is that the full potential of the surface pressure gradient wind is generally realized at approximately 15 kts under these conditions. Beyond that, further significant increases in surface winds apparently are delayed until turbulent mixing brings down the stronger upper-level winds. This appears to occur on the average at about 20 kts. The EED, BLH, and DUG curves suggest that once this 20-kt threshold is achieved, surface winds continue to increase quite rapidly with the continuing increase of pressure gradient.

III. CONCLUSIONS

Discussion with other forecasters at PHX WSFO indicates that the results of this study correspond exceptionally well to what has been subjectively analyzed over past years. Although this is really more of a diagnostic rather than prognostic tool, it does sustain objective operational utility--not only as a potential forecast tool, but from a familiarization standpoint for new Arizona forecasters as well.

IV. ACKNOWLEDGMENTS

Special thanks are in order, once again, for my two favorite secretaries, Mrs. Tommie McCabe and Mrs. Evelyn Allan.

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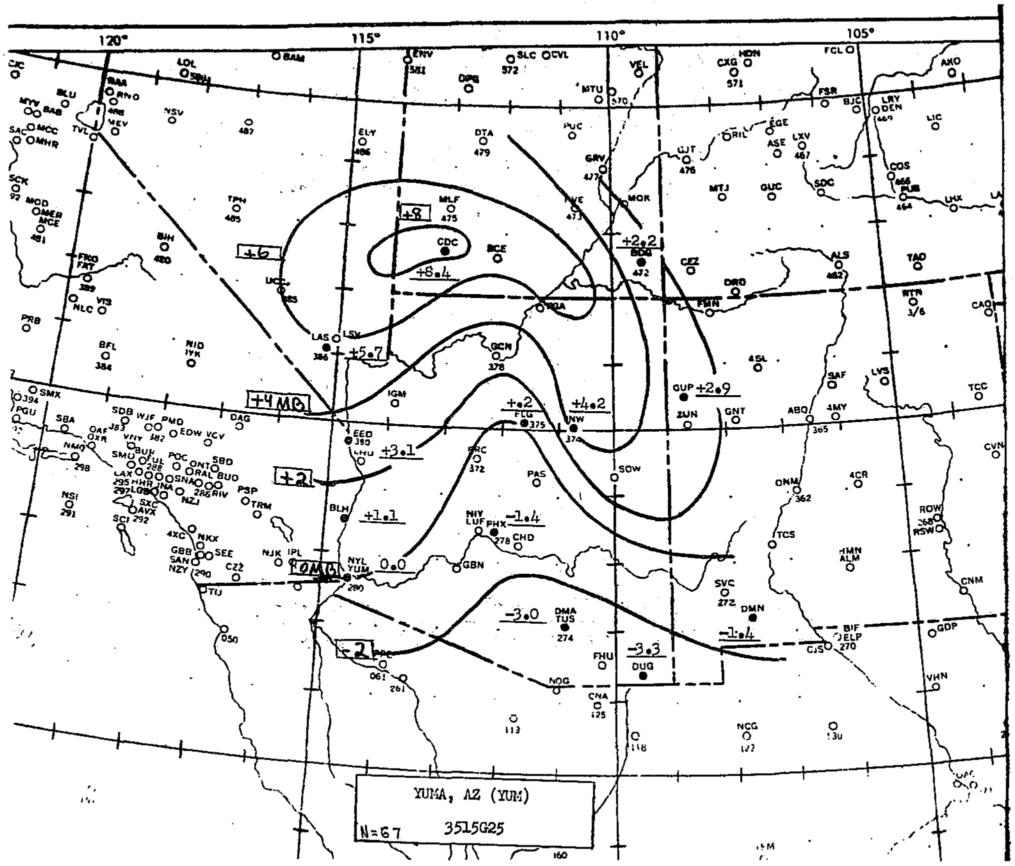

FIGURE 1A. AVERAGE SEA-LEVEL PRESSURE GRADIENTS THAT PRODUCE AVERAGE SUSTAINED SURFACE WINDS OF 3515G25 AT YUMA, ARIZONA, FOR SIX CONSECUTIVE HOURS.

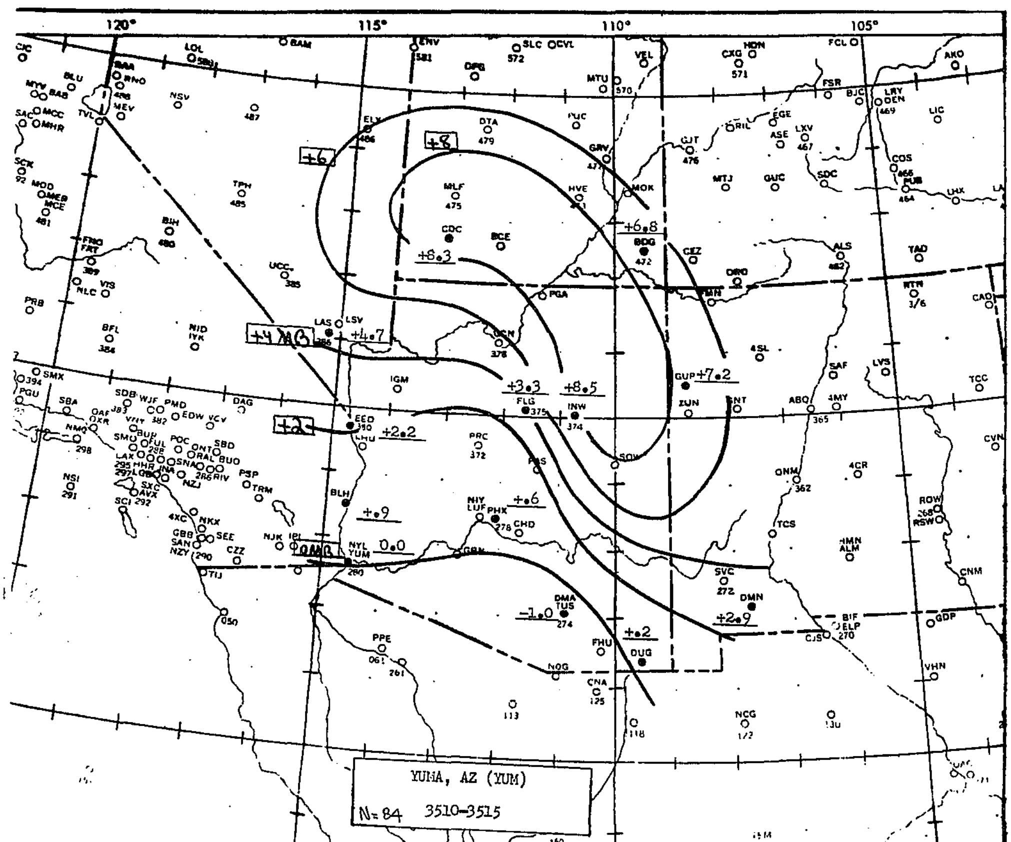

FIGURE 1B. SAME AS FIGURE 1A BUT FOR WINDS OF 3510-3515 AT YUMA, ARIZONA.

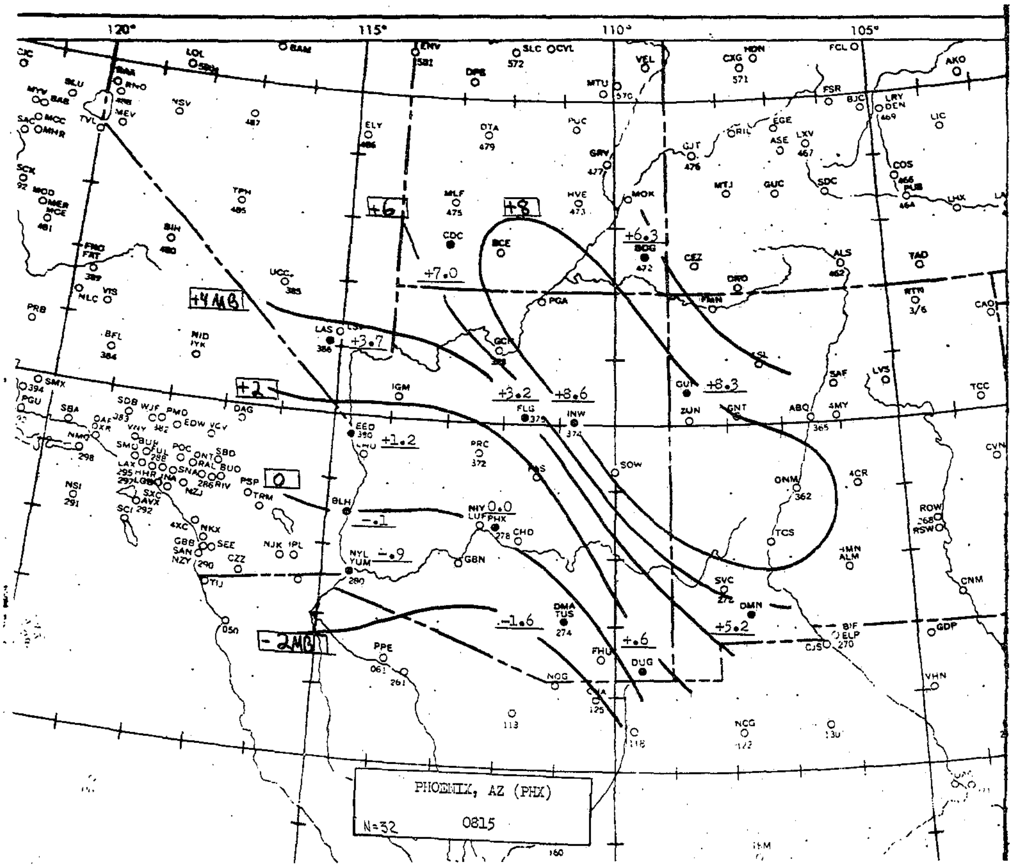

FIGURE 2A. AVERAGE SEA-LEVEL PRESSURE GRADIENTS THAT PRODUCE AVERAGE SUSTAINED SURFACE WINDS OF 0815 AT PHOENIX, ARIZONA, FOR SIX CONSECUTIVE HOURS.

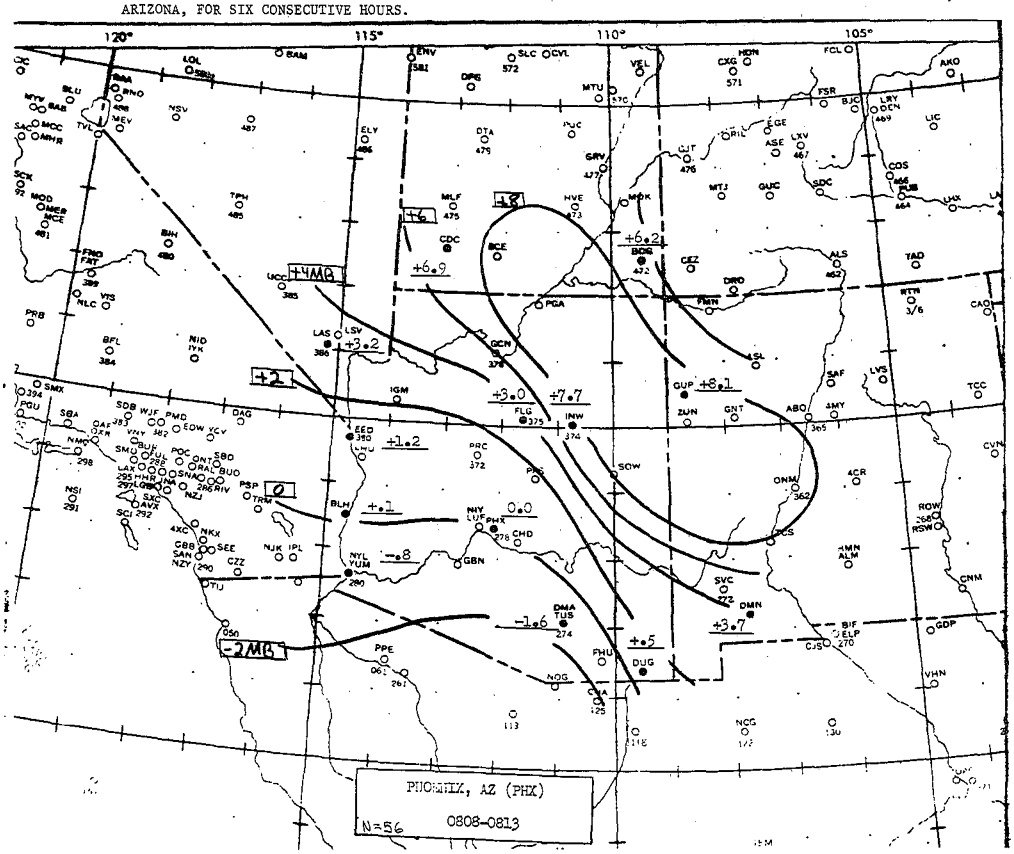

FIGURE 2B. SAME AS FIGURE 2A BUT FOR WINDS OF 0808-0813 AT PHOENIX, ARIZONA.

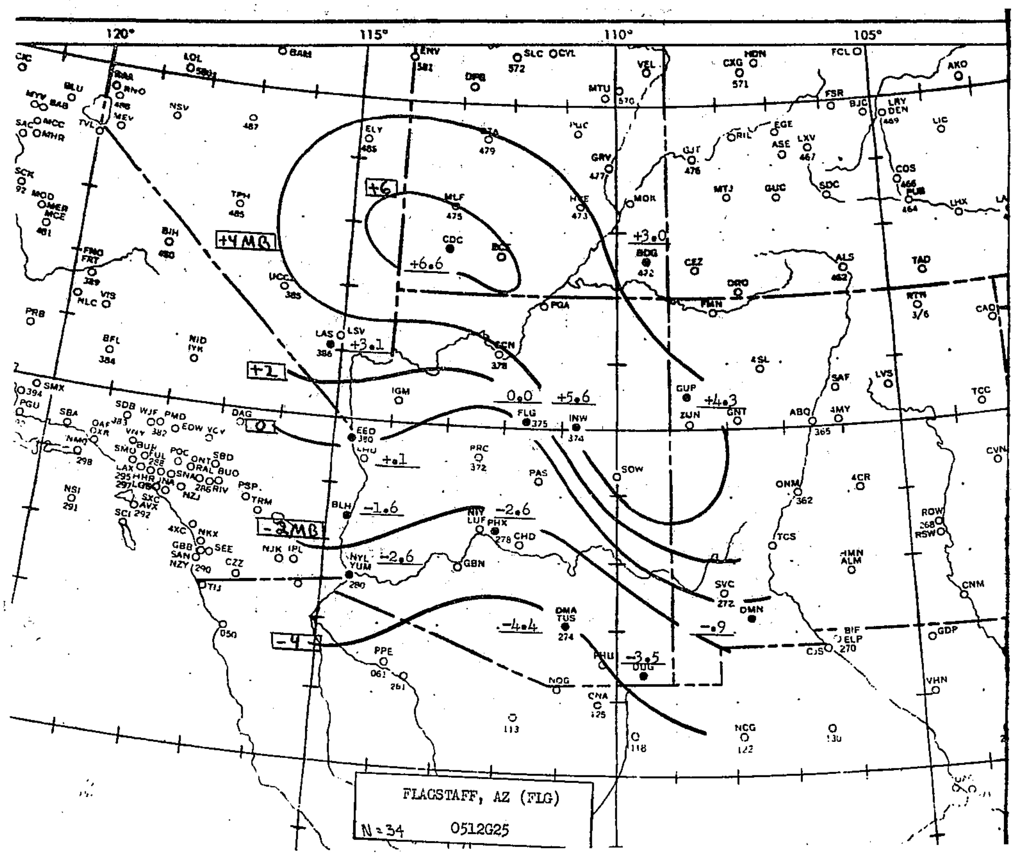

FIGURE 3A AVERAGE SEA-LEVEL PRESSURE GRADIENTS THAT PRODUCE AVERAGE SUSTAINED SURFACE WINDS OF 0512G25 AT FLAGSTAFF, ARIZONA, FOR SIX CONSECUTIVE HOURS.

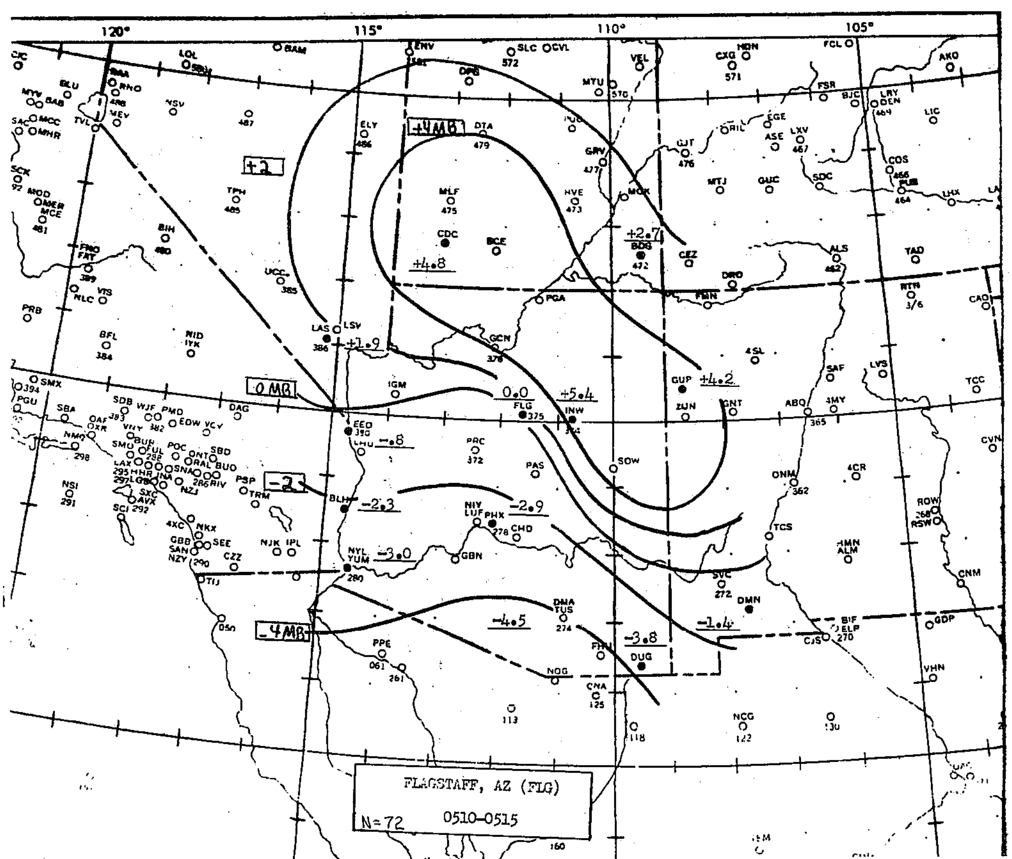

FIGURE 3B SAME AS FIGURE 3A BUT FOR WINDS OF 0510-0515 AT FLAGSTAFF, ARIZONA.

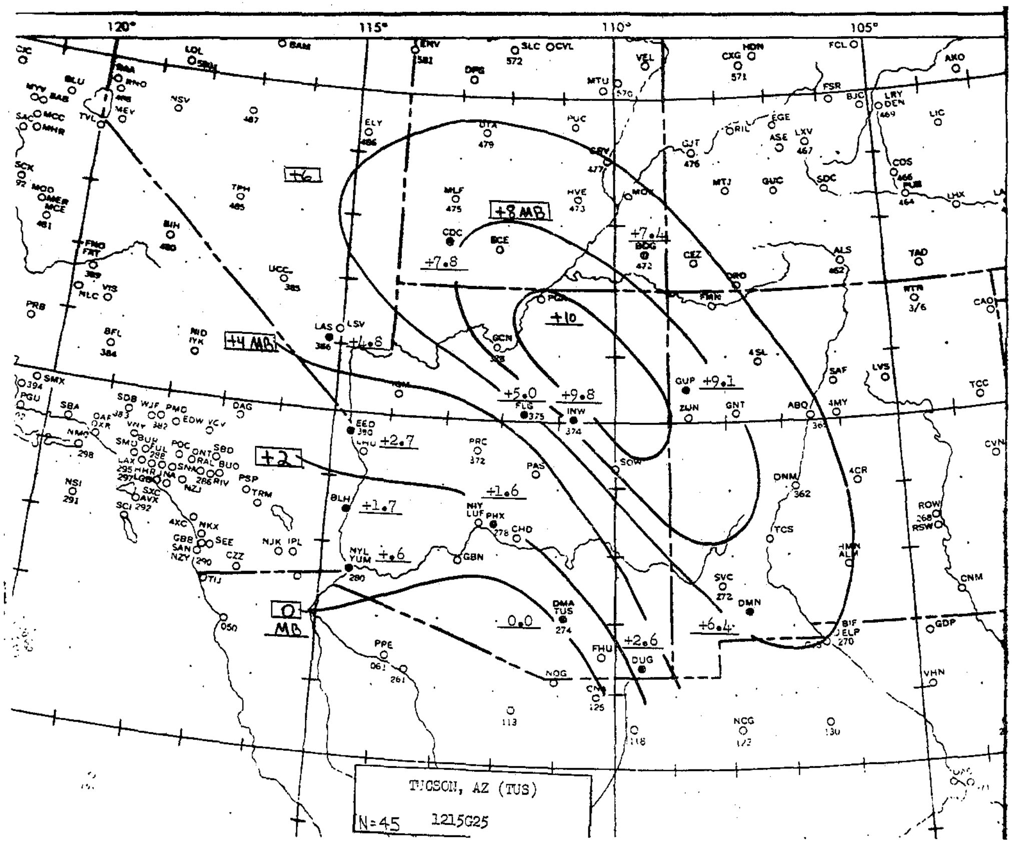

FIGURE 4A AVERAGE SEA-LEVEL PRESSURE GRADIENTS THAT PRODUCE AVERAGE SUSTAINED SURFACE WINDS OF 1215G25 AT TUCSON, ARIZONA, FOR SIX CONSECUTIVE HOURS.

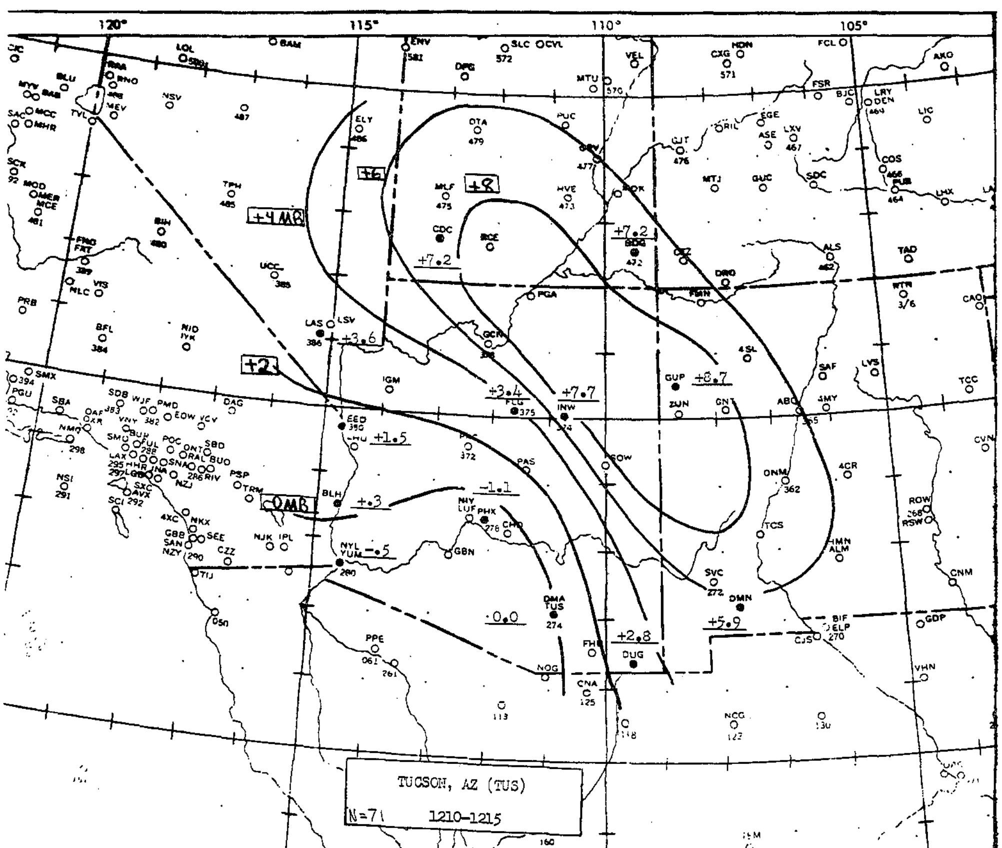

FIGURE 4B SAME AS FIGURE 4A BUT FOR WINDS OF 1210-1215 AT TUCSON, ARIZONA.

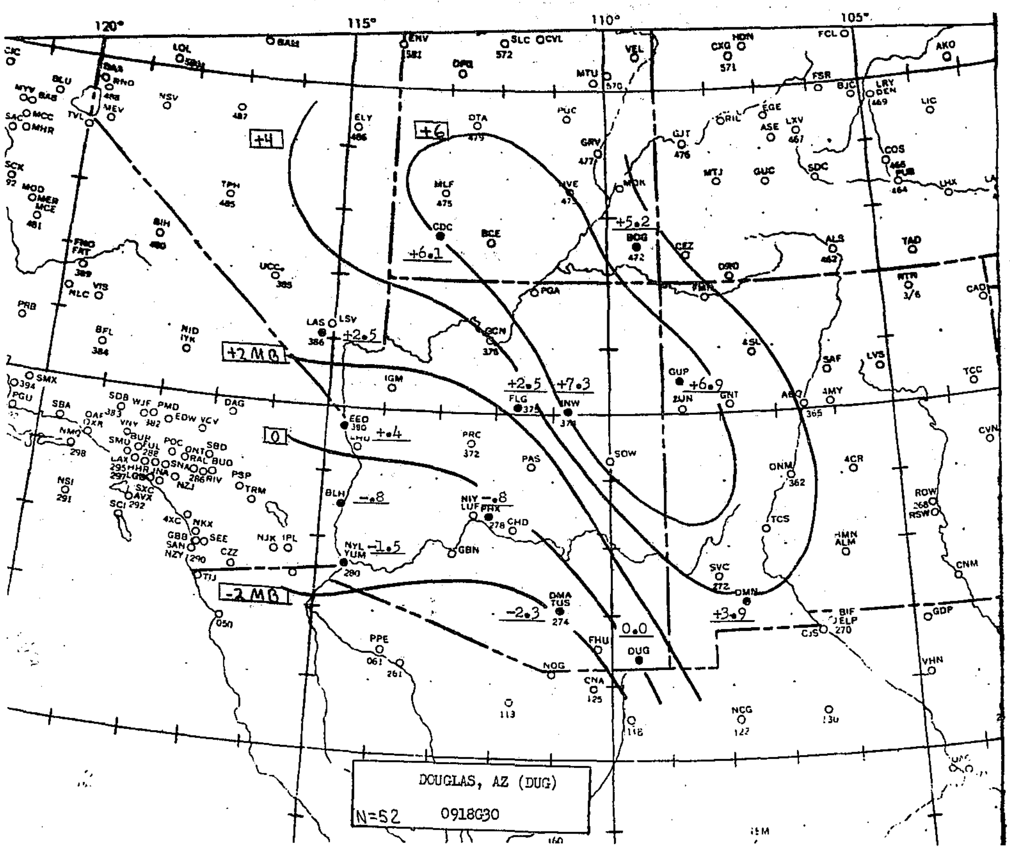

FIGURE 5A AVERAGE SEA-LEVEL PRESSURE GRADIENTS THAT PRODUCE AVERAGE SUSTAINED SURFACE WINDS OF 0918G30 AT DOUGLAS, ARIZONA, FOR SIX CONSECUTIVE HOURS.

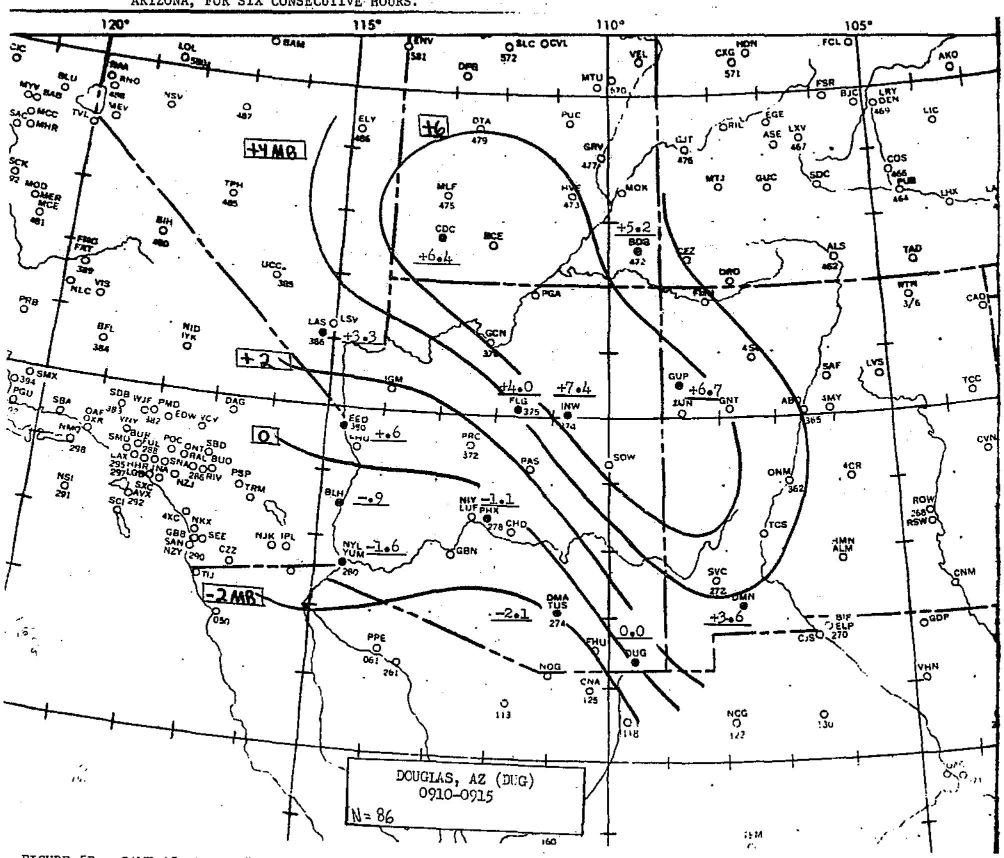

FIGURE 5B SAME AS FIGURE 5A BUT FOR WINDS OF 0910-0915 AT DOUGLAS, ARIZONA.

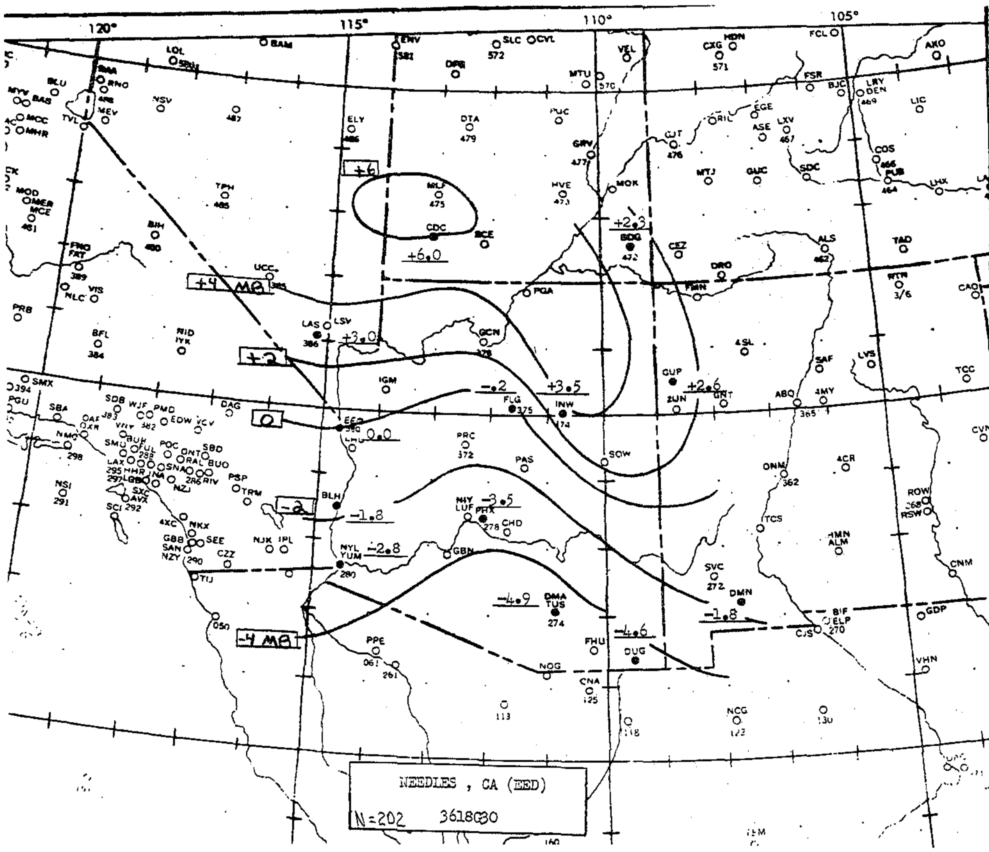

FIGURE 6 AVERAGE SEA-LEVEL PRESSURE GRADIENTS THAT PRODUCE AVERAGE SUSTAINED SURFACE WINDS OF 3618G30 AT NEEDLES, CALIFORNIA, FOR SIX CONSECUTIVE HOURS.

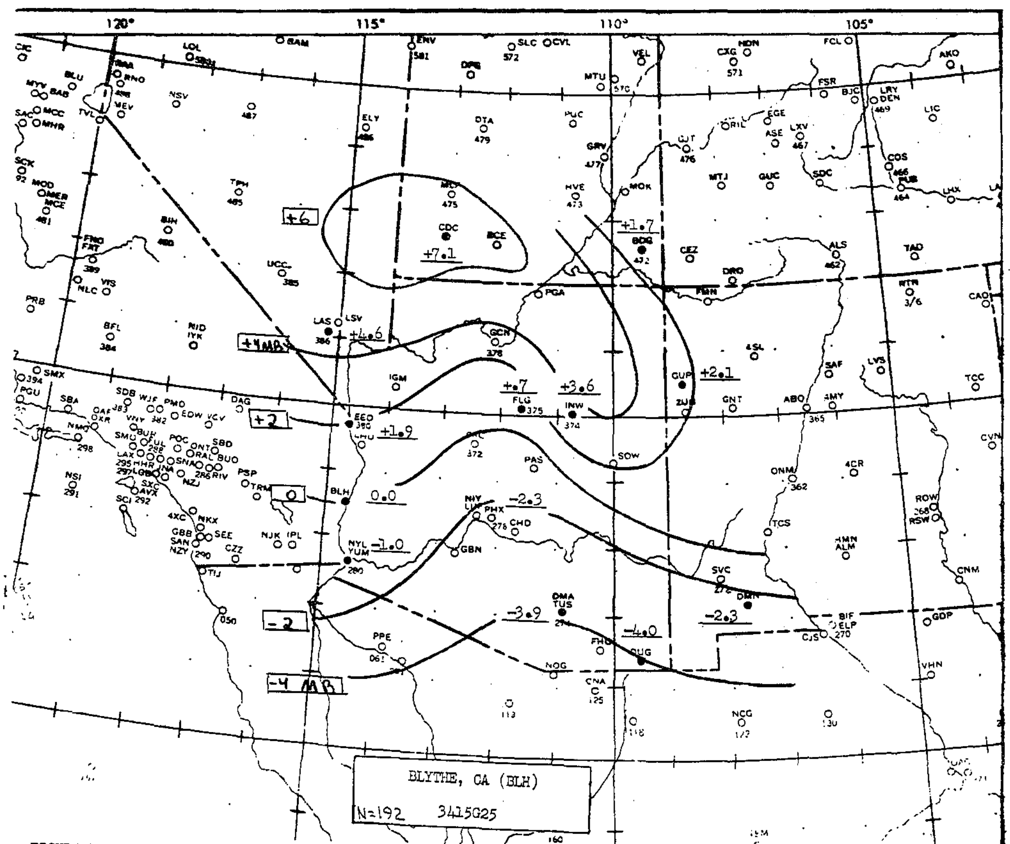

FIGURE 7. AVERAGE SEA-LEVEL PRESSURE GRADIENTS THAT PRODUCE AVERAGE SUSTAINED SURFACE WINDS OF 3415G25 AT BLYTHE, CALIFORNIA, FOR SIX CONSECUTIVE HOURS.

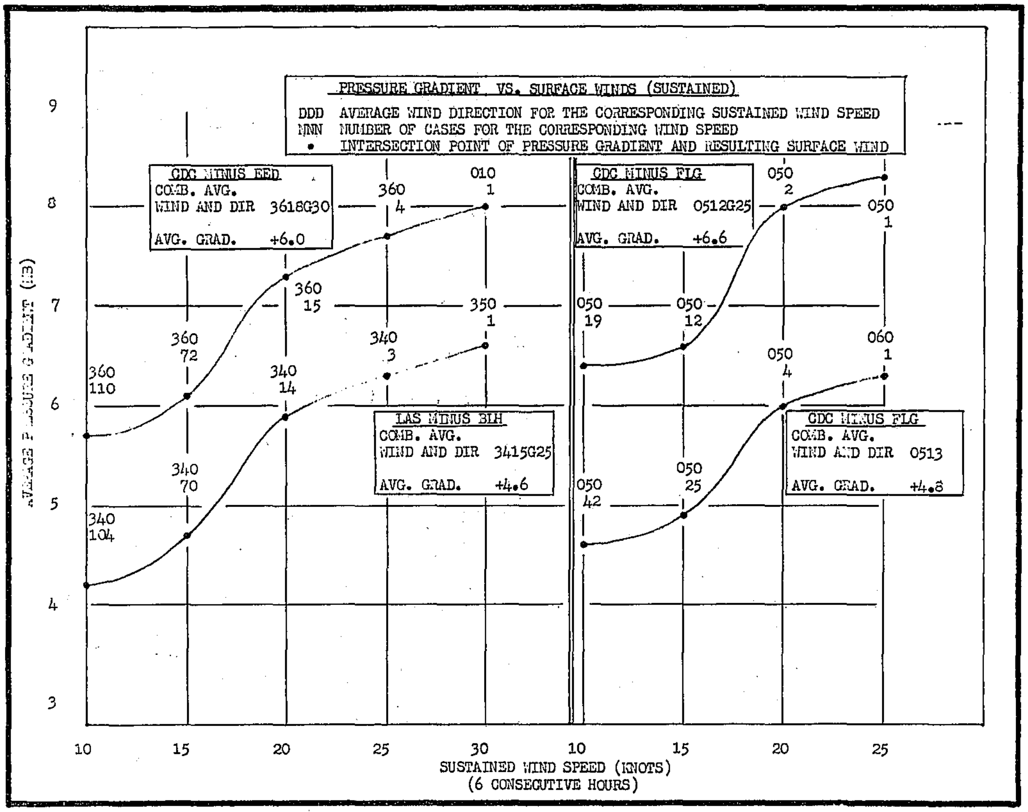

FIGURE 8. GRAPHS OF PRESSURE GRADIENT VS. SURFACE WINDS FOR NEEDLES AND BLYTHE, CALIFORNIA, AND FLAGSTAFF, ARIZONA.

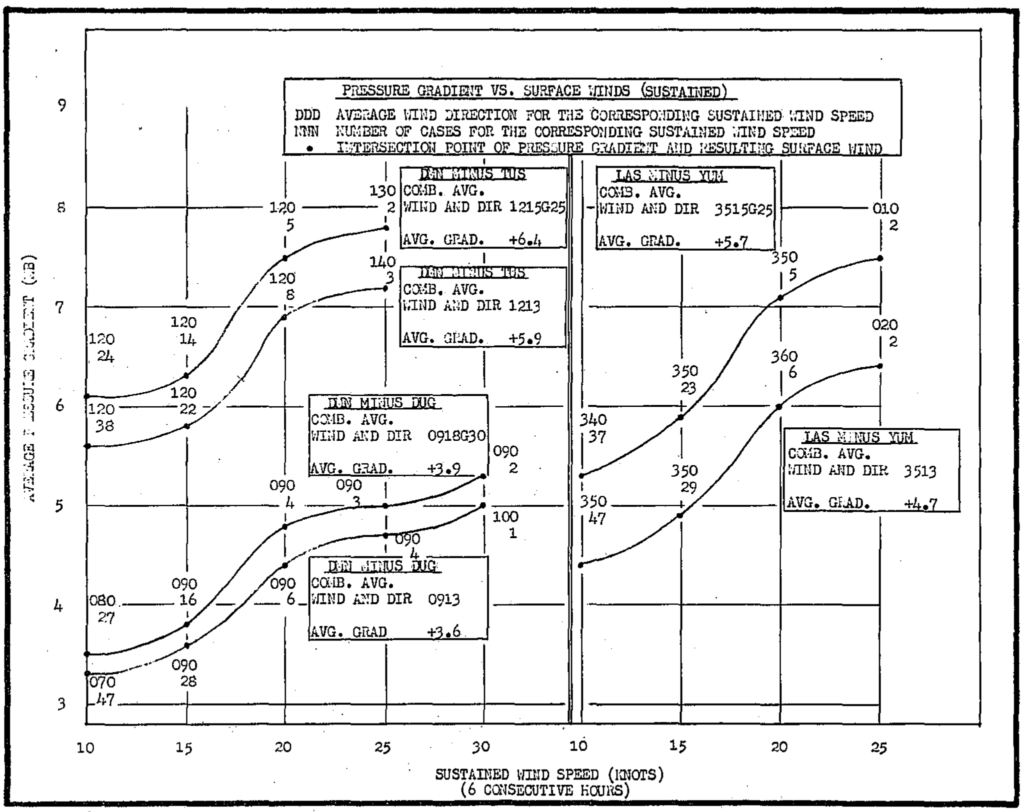

FIGURE 9. GRAPHS OF PRESSURE GRADIENT VS. SURFACE WINDS FOR TUCSON, DOUGLAS, AND YUMA, ARIZONA.

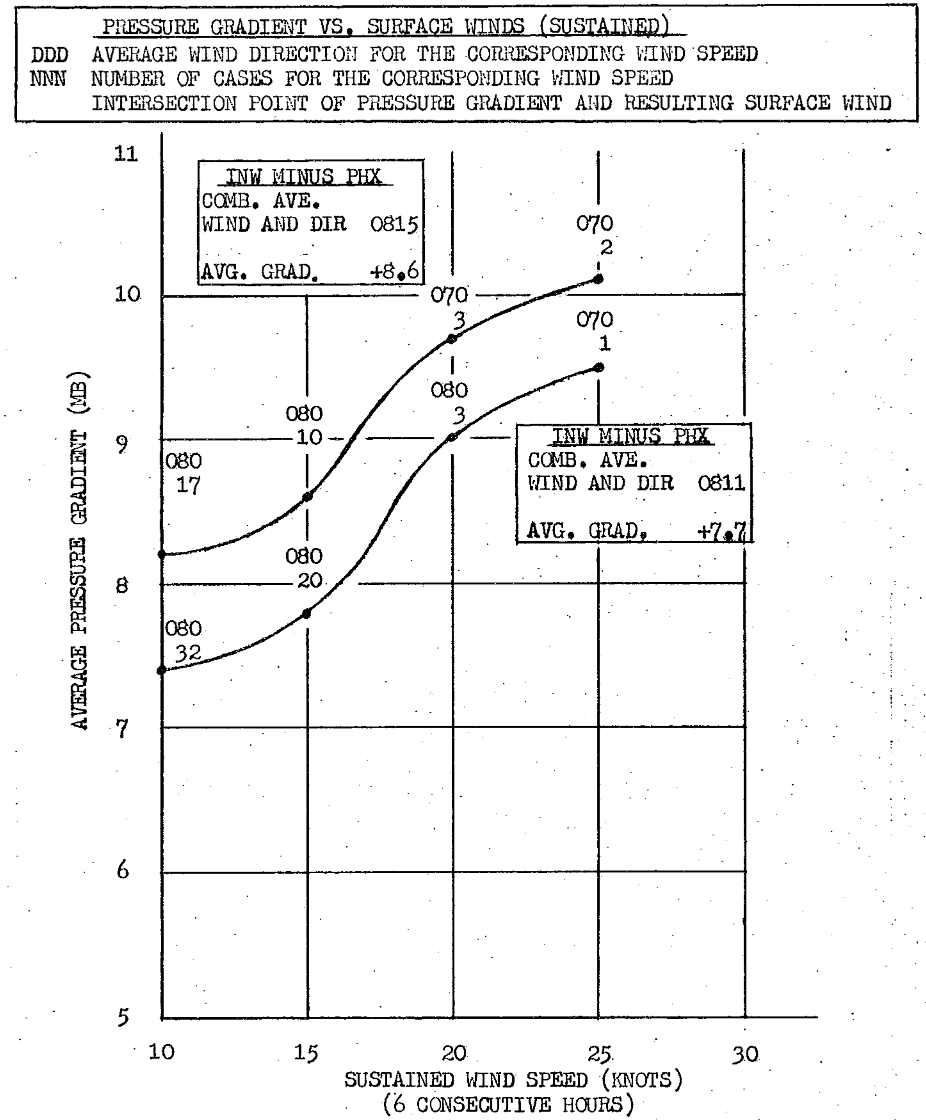

FIGURE 10. GRAPHS OF PRESSURE GRADIENT VS. SURFACE WINDS FOR PHOENIX, ARIZONA.

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