Western Region Technical Attachment
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FEEBLENESS AND TRANSIENCE OF A SOUTHWESTERN UNITED STATES MONSOON

[Editor's Note: This Technical Attachment is taken from the NWS Southern Region Forecaster Notes No. 2.]

1. Introduction

Rainfall statistics over Arizona and New Mexico (hereafter referred to as the Southwestern United States), for the most part indicate summertime precipitation maxima at many locations. This is especially true for southern Arizona and New Mexico. Occurrence of summertime rains over these states has been a primary reason for referring to them as monsoonal and associating summer rains with a "summer monsoon." This paper will not attempt to resolve whether the Southwestern United States is monsoonal or not, but rather will attempt to illustrate how weak and time varying in nature this circulation is over the Southwestern United States as compared to monsoon regimes elsewhere in the world.

2. Monsoon Definition

The term "monsoon," derived from Arabic "mausim" indicating a season, in its simplest definition is a seasonal reversal in wind direction (e.g., *Glossary of Meteorology*, 1959). Characteristics of a monsoon circulation have been defined by many meteorologists and climatologists in the past. Ramage (1971) gives a brief history of these definitions and provides one himself which, for the most part, is widely accepted by tropical meteorologists today. Ramage requires four surface circulation criteria for a monsoon, namely:

(1) The prevailing wind direction shifts by at least 120 degrees between January and July.

(2) The average frequency of prevailing wind directions in January and July exceeds 40%.

(3) The mean resultant winds in at least one of the months exceed 3 meters per second.

(4) Fewer than one cyclone-anticyclone alternation occurs every two years in either month in a 5 degree latitude-longitude rectangle.

Item (1) includes the classic seasonal wind reversal. Item (2) requires persistence of these seasonal wind shifts. Item (3) requires significant strength to the seasonal wind shift. Item (4) excludes seasonal wind shifts which are caused primarily by transient disturbances such as cyclones and anticyclones. Based upon these criteria, Ramage excludes the Southwestern United States from a monsoon regime, since one or more of these four criteria are typically not met!

It is important to note that there is **no** accepted definition of monsoon which incorporates rainfall criteria! Rather, rainfall may or may not be a consequence of monsoon circulations.

3. Observed Monsoon Circulations

Based simply upon criteria (1) and (4), monsoon circulations over the oceanic regions of North America, the Pacific, and East Asia are drawn with broad solid lines in Fig. 1a and 1b, which display long-term wind and pressure maps for January and July, respectively, taken from Sadler, et. al. (1987). Note that the entire western Pacific, Northern Australia, and East Asia meet requirements (1) and (4). Only a small portion of the eastern equatorial Pacific meets these criteria. All other oceanic regions shown are ***not*** monsoonal by Ramage's definition. Close examination of oceanic areas surrounding the Southwest United States indicates that mean circulations are not monsoonal, thus indicating that if land areas are monsoonal, their areal extent is very limited and not associated with monsoonal-type wind circulations over surrounding oceans. It is obvious that the Asian monsoon circulation displays a tremendous seasonal reversal in wind circulations and wind strength. In comparison, the eastern equatorial Pacific is a very localized and weaker monsoon regime, and the Southwestern United States is even weaker.

January and July pressure maps over the same regions clearly indicate the magnitude of seasonal pressure variations over oceans and land. For example, over Southeast Asia, January pressure is significantly higher than surrounding areas with sea level pressure exceeding 1020mb over large areas. In contrast, this region undergoes a major surface pressure reversal in July, during which time pressure is significantly lower than surrounding areas, and sea level pressure drops below 1008mb. Conversely, over the Southwest United States sea level pressure is a local minimum in both January and July. July displays a slight strengthening of low pressure. Clearly, both seasonal wind and pressure changes over the Southwestern United States show nowhere near the monsoonal characteristics that are observed over the western Pacific and Asia!

4. Closer Examination of the Southwest United States

Based upon the above definitions and mean conditions, it is obvious that any monsoon-type circulation over the Southwest United States is feeble indeed. Wind and precipitation climatologies for observing stations in Arizona and New Mexico are shown in Table 1 (taken from the *International Station Meteorological Climate Summary* [1990]). Table 1 indicates that most stations experience a summertime rainfall maximum. This does ***not*** have to occur in a monsoon circulation regime. For example, North Central Africa is characterized by a strong monsoonal circulation, but displays a wintertime precipitation maximum. Conversely, Alaska is not characterized by a monsoon circulation, but many locations are dominated by a summertime rainfall maximum. Hence, existence of a summer rainfall maximum over the Southwest United States does not indicate that it is dominated by a monsoon circulation regime. Interestingly, one of the clearest examples of a seasonal wind reversal is observed at Yuma where winds shift from north in winter to south in summer. Note that for the most part, summer is the driest season of the year in Yuma. The seasonal wind reversal at Yuma is controlled by development of a heat low centered over the California desert. This desert heat low is characterized by dry arid weather and clear skies. Yuma is far enough west in Arizona to be under the control of this localized desert heat low, ***not*** by a large scale monsoon circulation.

Note from Table 1 that Gila Bend shows a clear wind shift from NE in winter to WSW in summer. However, local topography is oriented NE to WSW in this region and likely has strong control on local winds. Note also that Gila Bend has both late summer and secondary winter rainfall maxima. Conversely, Tucson displays no seasonal wind shifts, but does display late summer and secondary winter rainfall maxima. Phoenix does display a brief wind reversal from easterly in winter months to westerly in June and July. Phoenix rainfall is characterized by a late summer maximum (not consistent with the wind shift to westerly) and a secondary winter maximum.

Roswell, located on the east slopes of the Rockies, is for the most part dominated by southerly winds in all months except December and January, during which time they become northerly. Roswell displays a clear summer rainfall maximum. Both Albuquerque and El Paso are dominated by a summer precipitation maximum, but winds are likely unrepresentative of monsoon-type circulations, since station elevations are high.

From the station climatologies described above, clear-cut indications of a monsoon circulation over the Southwest United States are difficult to determine. At best, a monsoon-type circulation regime is very weak, and local winds are likely dominated by station elevation and local topography.

For comparison with well defined monsoon regimes, winds at Singapore and Bombay, India, are also shown in Table 1. These stations show a well defined seasonal wind shift from summer to winter.

5. Conclusions

Based upon mean circulations over and surrounding the Southwest United States, well-defined monsoon-type circulations are difficult to identify as compared to monsoon regimes which meet all of Ramage's monsoon criteria. Mean circulations can be misleading without some indication of their persistence. From the standpoint of monsoon definition, the mean must be persistent. However, over the Southwest United States, clear monsoon-type circulations may be transient throughout the summer. Non-periodic, but well-defined rain events are characteristic over this region and are indicative of transient bursts of rain-producing weather and wind reversals. Despite the fact that this type of regime does not fit the monsoon definition, it can, on occasion, take on transient monsoon characteristics. This should ***not*** be reason for terming the area monsoonal. Keep in mind the feeble and transient nature of summer wind changes over the Southwest United States. This regime displays a markedly weaker seasonal wind shift as compared to the typical monsoon observed over Asia.

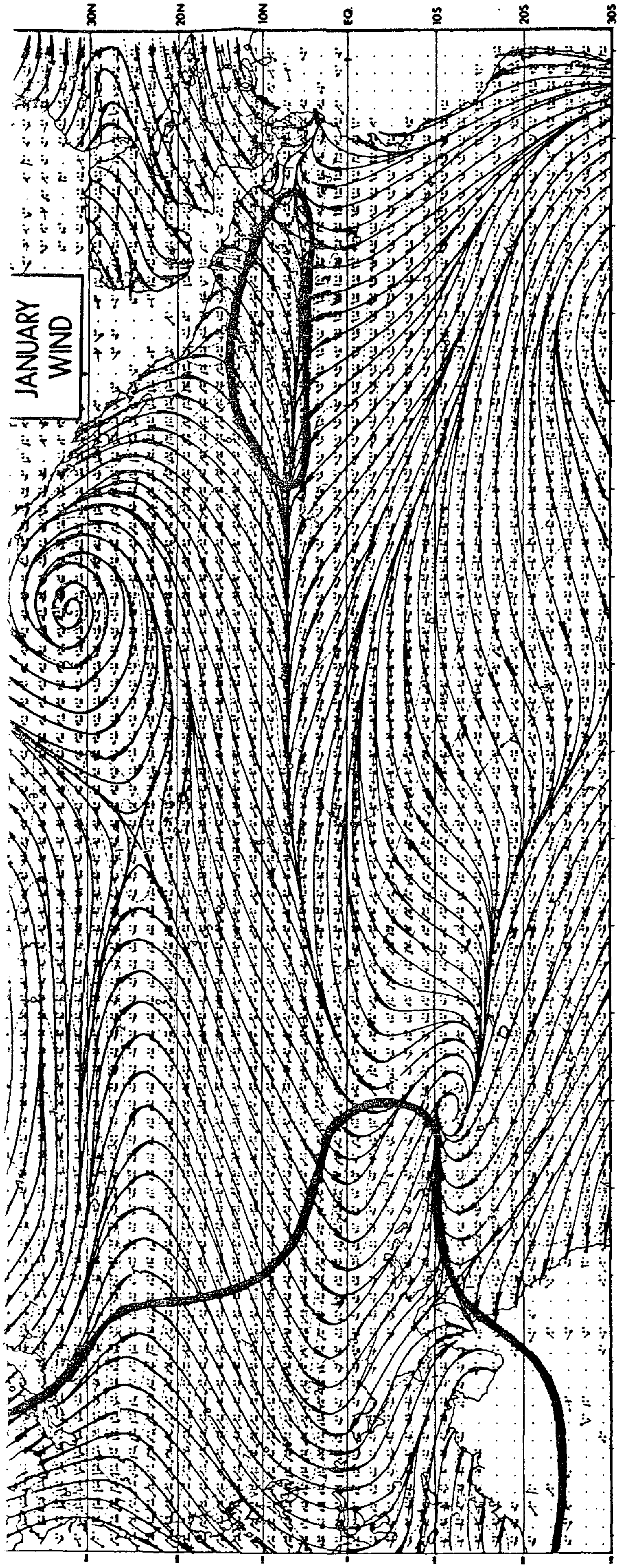
References

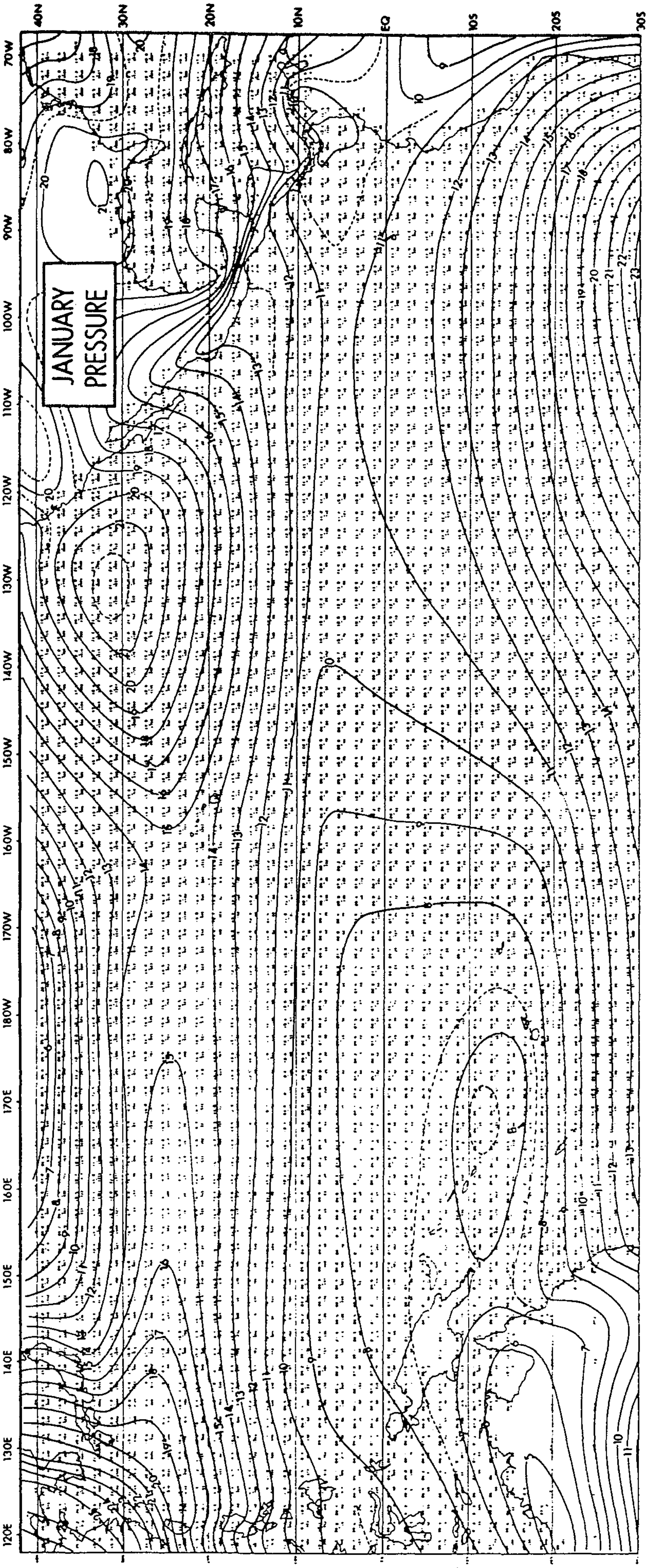
Glossary of Meteorology, American Meteorological Society, Boston, MA. Edited by Ralph E. Huschke, 1959.

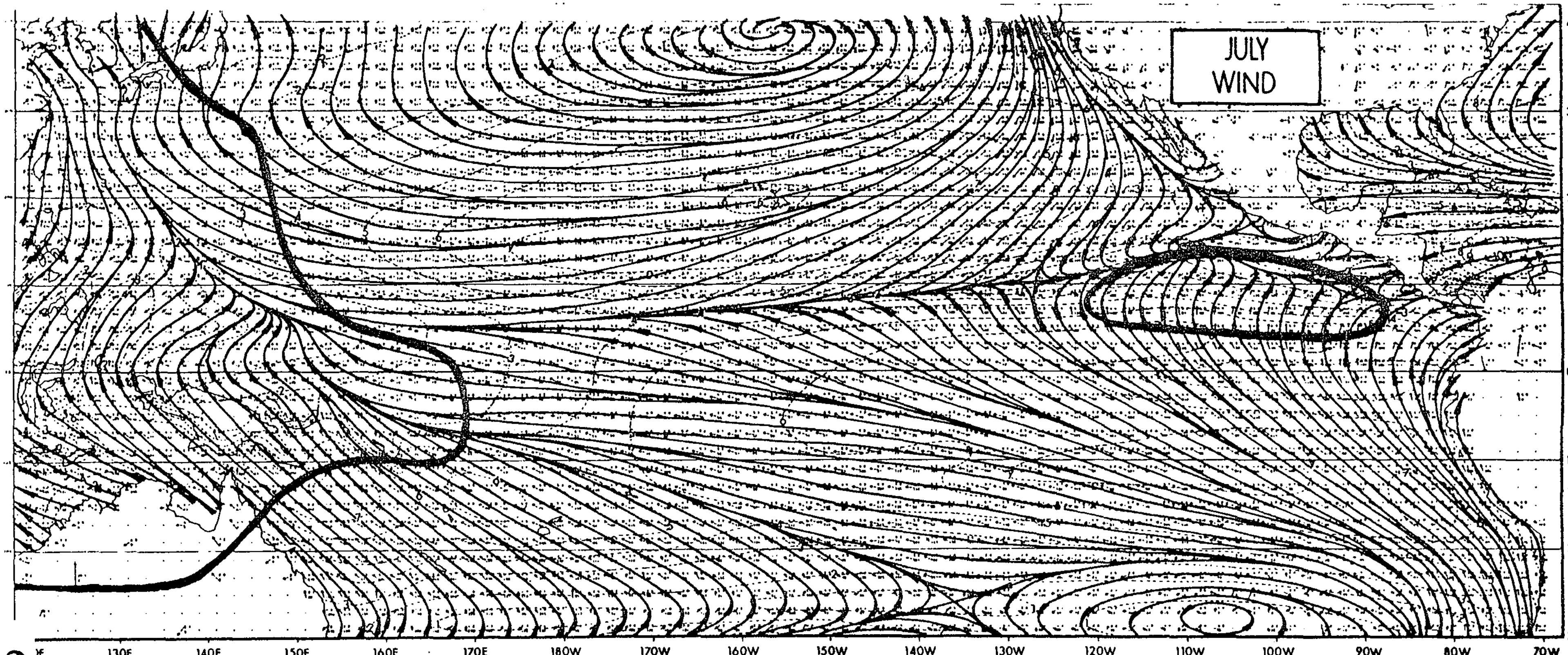
International Station Meteorological Climate Summary. Federal Climate Complex, Asheville, North Carolina, October, 1990.

Ramage, C. S., 1971: *Monsoon Meteorology. International Geophysics Series Volume 15*. Academic Press, New York and London.

Sadler, J. C., M. A. Lander, A. M. Hori, and L. K. Oda, 1987: *Tropical Marine Climatic Atlas, Volume II, Pacific Ocean*. Dept. of Meteorology, University of Hawaii, UHMET 87-02.


JANUARY
WIND


JANUARY
PRESSURE


JULY
WIND
40N
30N
20N
10N
EQ
10S
20S
30S
130E
140E
150E
160E
170E
180W
170W
160W
150W
140W
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100W
90W
80W
70W

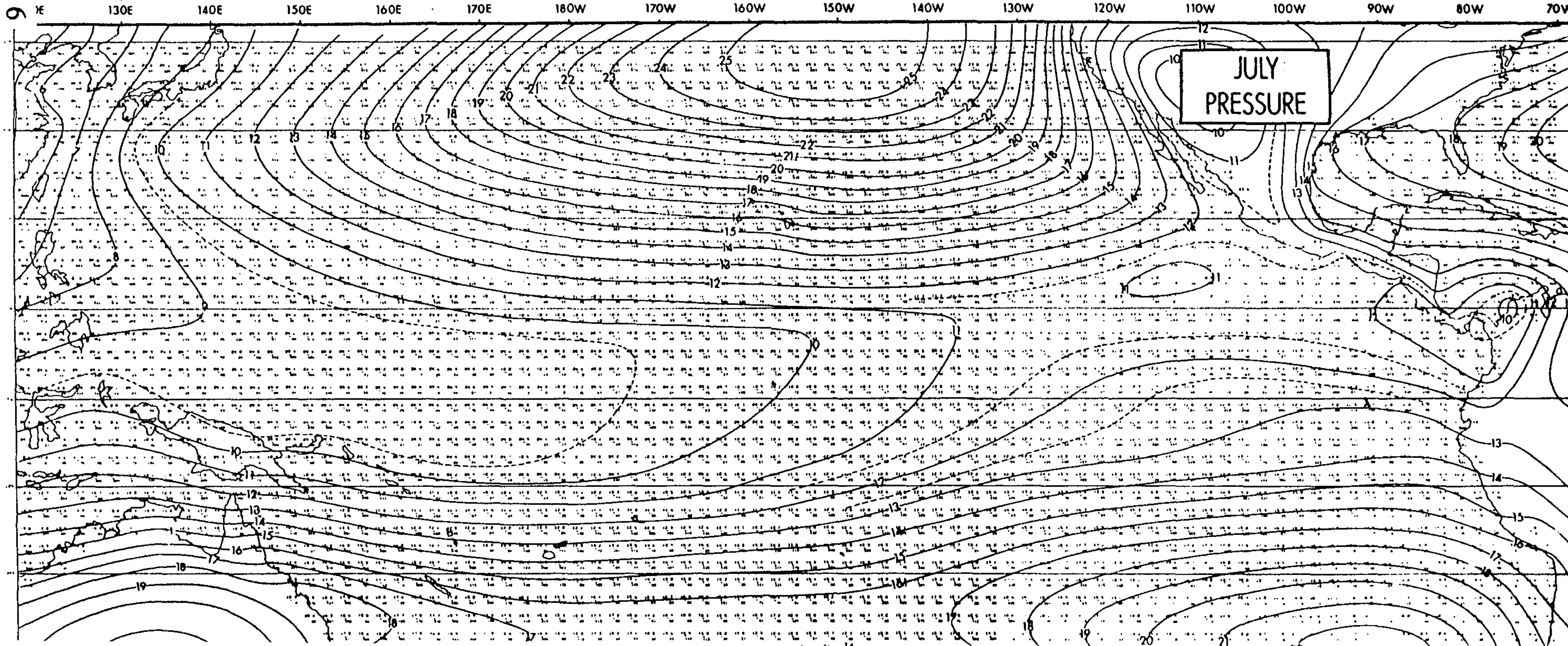
JULY
PRESSURE
40N
30N
20N
10N
EQ
10S
20S

TABLE I

Prevailing Wind Direction and Speed (kts)

Station

	TUS	PHX	G.Bend	YUM	ROW	ABQ	ELP	Singapore	Bombay
Jan	SE8	E6	NE4	N9	N8	N9	N6	NNE6	N3
Feb	SE7	E6	NE4	N9	S8	N9	W10	NE5	N3
Mar	SE7	E6	W4	W8	S9	S10	W12	NE4	S4
Apr	SE7	E6	WSW5	W9	S9	S9	W11	NE4	S6
May	SSE6	E7	WSW5	S7	S9	E14	W10	S3	S6
Jun	S7	W7	WSW5	S8	S8	E14	W8	S4	S5
Jul	S7	W7	WSW4	S9	SE9	E12	SE6	S4	S4
Aug	S7	E6	WSW4	S8	S7	E11	N6	S4	S4
Sep	SE8	E6	W5	S7	S8	E12	S5	S4	S4
Oct	SE7	E6	NE4	N7	S8	N7	N6	NNE4	N3
Nov	SSE7	E7	NE4	N8	S7	N8	N6	NNE4	N3
Dec	SE7	E6	NE4	N8	N8	N8	N8	NNE6	N3

Precipitation (inches)

Jan	.9	.7	.7	.4	.4	.4	.4
Feb	.7	.6	.5	.2	.4	.4	.4
Mar	.7	.8	.5	.2	.3	.5	.3
Apr	.3	.3	.2	.1	.5	.4	.2
May	.2	.1	.1	T	1.1	.5	.3
Jun	.2	.1	.1	T	1.4	.5	.7
Jul	2.4	.8	.7	.2	1.6	1.3	1.6
Aug	2.2	1.0	1.4	.5	2.1	1.5	1.5
Sep	1.4	.7	.6	.3	1.8	.9	1.4
Oct	1.0	.6	.4	.3	1.2	.9	.8
Nov	.6	.6	.4	.2	.4	.4	.3
Dec	.9	.9	.6	.4	.4	.5	.5