On a Statistical Relationship between Autumn Rainfall in the Central Equatorial Pacific and Subsequent Winter Precipitation in Florida

ARTHUR V. DOUGLAS[1]

Scripps Institution of Oceanography, University of California, San Diego, La Jolla 92093

PHILLIP J. ENGLEHART[2]

Climatology Program, University of Nebraska, Lincoln 68588

(Manuscript received 8 April 1981, in final form August 25 1981)

ABSTRACT

A statistical relationship is found to exist between autumn rainfall in the central equatorial Pacific and subsequent winter precipitation in the southern United States. In a case study, it was found that wet winters in south-central Florida are generally associated with warm water events along the equator, while dry conditions are more commonly associated with cold water events in the eastern tropical Pacific. Some suggestions are offered concerning the physical mechanisms responsible for this distant teleconnection.

1. Introduction

In the course of developing prediction equations for winter precipitation in the southern United States, we have noticed a number of potentially important relationships between Pacific air–sea interactions and rainfall in Florida. The purpose of this note is to draw attention to one strong and apparently useful teleconnection between autumn rainfall in the central equatorial Pacific and subsequent winter precipitation in south-central Florida. Some plausible physical explanations for the observed lag correlations are offered.

Much of the recent literature in the field of extended prediction emphasizes the use of different types of indices and key regions in order to characterize the variability of large-scale climatic features. For example, in the analog forecasting method developed by Barnett and Preisendorfer (1978), regions of high covariability in a given climate field are isolated through eigenvector (EOF) analysis. Once the key region is defined, a regional average or index is then formed by averaging all data points within the given area. By reducing the number of possible climate predictors into a limited number of indices, the chance of inducing artificial predictability into a climate model is minimized.

In this report we also are dealing with areal averages which are computed for two coherent rainfall regions. Winter precipitation (December–February) in south-central Florida is represented by divisional climatic data obtained from the National Climatic Center (Asheville, North Carolina). Recent state summaries indicate that the monthly means for this division are formed using about 25 stations. Autumn rainfall (September–November) for the central equatorial Pacific is represented by an index of island precipitation. This rainfall index (RI) was developed by Wright (1979), and it is based on the six stations shown in Fig. 1. In order to reduce the dominance of large rainfall values, Wright transformed the monthly rainfall totals at each station into cube-root values. For each station the monthly cube root data were then expressed as a percentage of the monthly mean cube root value for the period 1948–67. The rainfall index was then calculated by averaging the individual station data.

A high degree of intercorrelation among these stations has been well documented (Doberitz 1968, Wright 1979). Wright (1979) has examined in detail the temporal behavior of the index and he reports that month-to-month persistence is high, particularly during the fall months. This strong persistence in the rainfall index is consistent with the model envisioned by Bjerknes (1966, 1969), whereby the equatorial Pacific is known to experience long periods of anomalously warm sea surface temperatures and high rainfall, or anomalously cold sea surface temperatures and below normal rainfall. Since the stations used to produce the index are located great distances from each other, the index is believed to reflect broad-scale conditions in the central equatorial Pacific.

---

[1] Present affiliation: Department of Atmospheric Sciences, Creighton University, NE 68178.

[2] Present affiliation: Midwest Research Institute, Kansas City, MO 46110.

0027-0644/81/112377-06$05.50

© 1982 American Meteorological Society

Unauthenticated | Downloaded 12/12/24 06:08 PM UTC

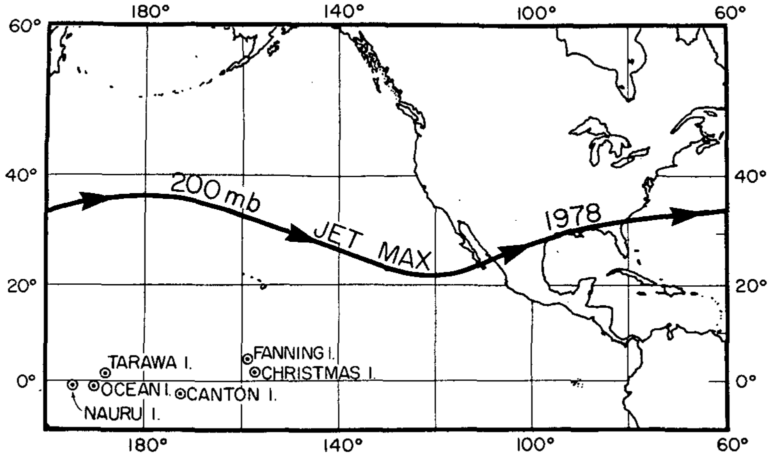

FIG. 1. Location of island stations comprising the equatorial rainfall index. Arrows indicate the 200 mb jet max during the winter of 1978.

2. Results

The regression equation relating the fall rainfall index and winter precipitation in south-central Florida is based on 28 years of data (1948–75). It takes the form

$$\text{WINTER PPT (FLA)} = 1.092\,(\text{RI}_{\text{FALL}})\text{mm} + 71.4\text{ mm}.$$

The simple correlation coefficient (r) for the relationship is 0.69, or in other words, changes in the autumn rainfall index account for 48% of the variation in south-central Florida's subsequent winter precipitation. The corresponding F ratio of 24.0 for the equation is significant at the 99% level. It should be noted that in our original research, the rainfall index was selected from the "screening" of a set of 10 potential predictors. Other available predictors included EOF's of both fall 700 mb height anomalies and fall North Pacific sea surface temperature anomalies. The results of Monte Carlo experiments patterned after those of Neumann *et al.* (1977), indicated that despite the potential for artificial skill involved in the screening approach, the equation can still be considered significant at the 99% level.

A scattergram has been constructed to show, by year, the relationship between the two parameters (Fig. 2). The four extreme positive cases (1957–58, 1963–64, 1965–66 and 1972–73) correspond to El Niño events of varying intensity (see Quinn *et al.* 1978). In each instance the winter precipitation in south-central Florida fell into the above-normal class (>201 mm). In the opposite sense, three of the four lowest rainfall index (RI) values were

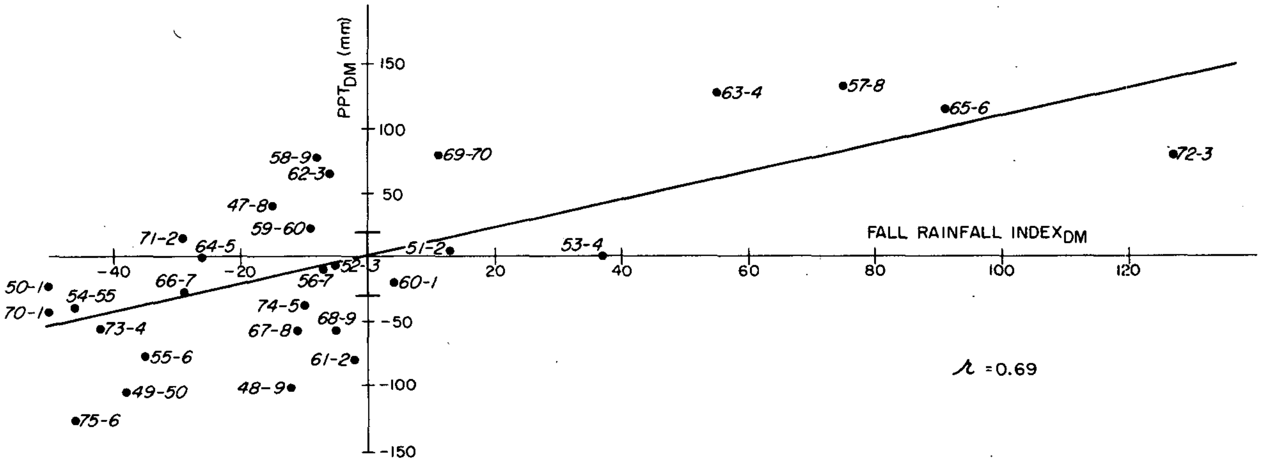

FIG. 2. Scattergram showing the relationship between the autumn rainfall index for the equatorial Pacific (abscissa) and subsequent winter precipitation in south-central Florida (ordinate). Numbers beside points indicate individual year (fall to winter). Note the strong contribution of El Niño year events to the correlation of 0.69. Dry year cases tend to show a second clustering with apparently a steeper slope.

Unauthenticated | Downloaded 12/12/24 06:08 PM UTC

Table 1. Classification of winter precipitation forecasts in south-central Florida for the independent test periods 1931–47 and 1976–79. Eq. (1) was used to predict the winter precipitation in Florida.

		Observed winter precipitation			
		Above	Normal	Below	Total
Predicted winter precipitation	Above	4	2	0	6
	Normal	2	1	4	7
	Below	1	0	6	7
	Total	7	3	10	20

associated with below-normal Florida precipitation (<152 mm).

Verification statistics computed on 20 years of independent data (1931–47 and 1976–79), confirm the equation's apparent usefulness. The reduction in error for this independent sample is 0.32. Though this figure is lower than the analogous R^2 of 0.48 obtained on the dependent data, it still represents a substantial improvement over using climatology (persistence) as a predictor of winter rainfall in central Florida. The skill during the independent period is shown in Table 1. In making this test the data have been divided into a standard three category (tercile) forecasting system.

3. Discussion

While a strong statistical relationship appears to exist between rainfall in Florida and the equatorial Pacific, the physical mechanisms associated with the teleconnection are undoubtedly complex. Some light can be shed on the problem by examining Northern Hemisphere 700 mb anomaly maps for wet and dry years along the equator. In preparing these maps, we composited winter height anomalies for six years with high autumn rainfall along the equator and six years with below-normal rainfall. The following wet autumns had RI values greater than 130: 1957, 1963, 1965, 1972, 1976 and 1977. Autumns with RI values below 70 included: 1949, 1950, 1954, 1970, 1973 and 1975. The composited data are presented in Figs. 3 and 4 for the wet and dry years, respectively.

The dry year composite map contains rather weak anomaly fields, though there is some suggestion of a weakened and northward displaced Aleutian low and weakened East Coast trough. This configuration of the anomaly fields in Fig. 4 suggests increased activity along the interior storm track from the Southern Plains into the Ohio Valley, with decreased storm activity in the Gulf of Mexico. This pattern generally favors a warm-dry winter in Florida.

In winters following a high autumn rainfall index

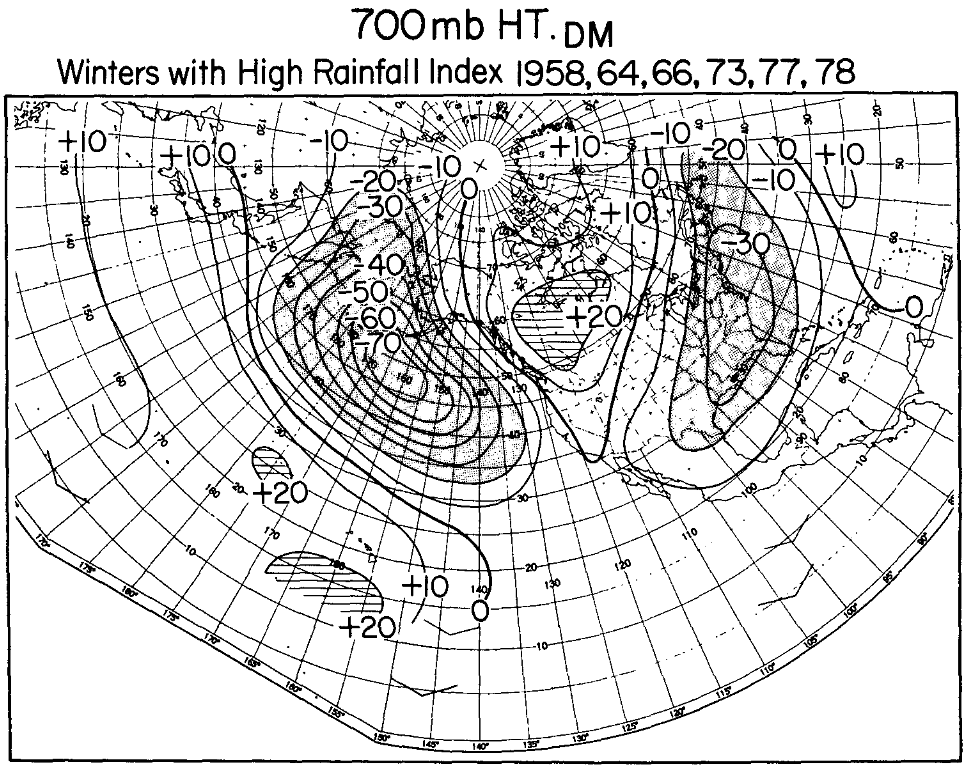

Fig. 3. Composite chart of the average 700 mb height anomalies (in meters) for the winters following high rainfall events during the fall in the equatorial Pacific. Note the tendency for abnormal deepening of the Aleutian low and trough over eastern North America.

Unauthenticated | Downloaded 12/12/24 06:08 PM UTC

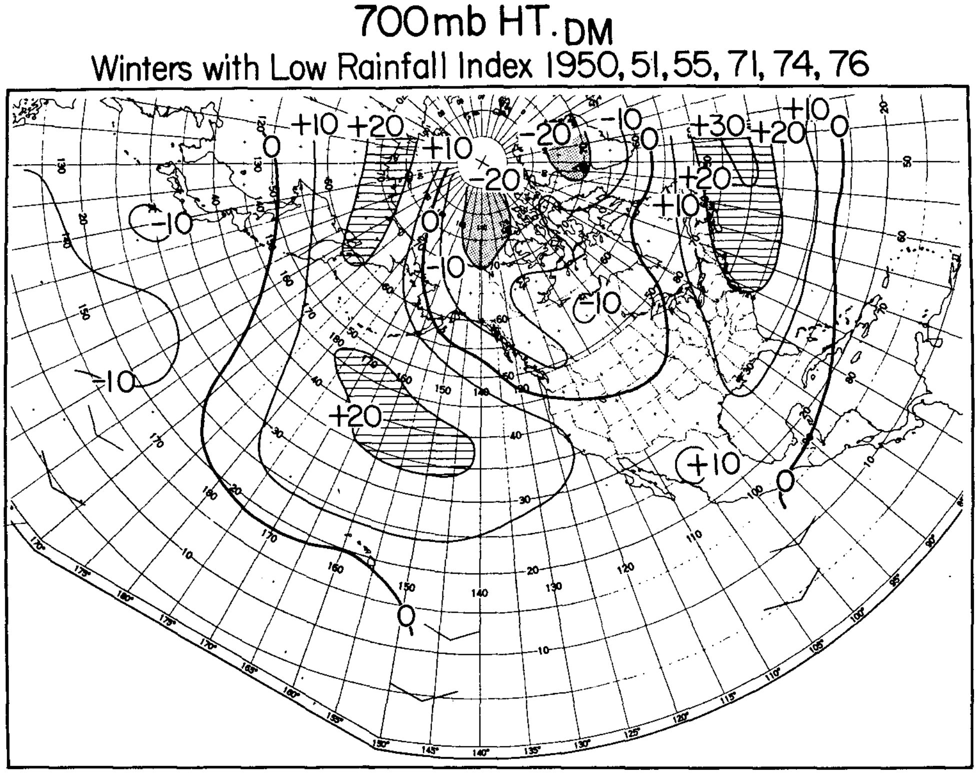

FIG. 4. Composite chart of the average 700 mb height anomalies (in m) for winters following dry autumns in the equatorial Pacific. Note the general tendency for somewhat weakened troughs in the central North Pacific and from the eastern Gulf of Mexico northeastward to New Foundland.

(RI > 130), the Aleutian low is generally stronger than normal and displaced to the southeast. A downstream ridge or block frequently occurs over western Canada in response to the Pacific trough. The trough over eastern North America also shows strengthening during the winters following wet autumns in the central equatorial Pacific. The anomaly patterns in Fig. 3 are similar to those shown by Dickson and Namias (1976) for cold winters in the southeastern United States and by Arkin *et al.* (1980) for years with a low Southern Oscillation Index. Namias (1976) has found that a deep wintertime Aleutian low is characteristic of events during strong El Niño years. The overall height pattern shown in Fig. 3 suggests southward displaced storm tracks in the North Pacific and increased storminess in the Gulf of Mexico, southeastern United States and western North Atlantic (Dickson and Namias, 1976). A study by Heckman and Thompson (1978) indicates that cyclogenesis in the Gulf of Mexico frequently is associated with a well-developed low-latitude flow across northern Mexico and the southern United States and a strong blocking ridge in southwest Canada. This pattern is similar to that shown in Fig. 3, where positive height anomalies are indicated over southwest Canada. Close examination of the height fields in Fig. 3 suggests that Pacific storms are likely to break across Baja California, since a field of weak negative heights is observed to stretch from the eastern Pacific into the Gulf of Mexico.

The below-normal height fields in the Gulf of Mexico suggest frequent invasions of polar fronts into the region and subsequent cyclogenesis in association with the low-latitude split flow. Erickson (1979) noted that heavy winter rains in the Gulf area during 1978–79 were a result of increased cyclonic activity. He indicates that the cyclogenesis was associated with a southward displacement of the uppertropospheric westerly flow and mean subtropical jet stream position. The winter of 1978–79 was preceded by an above normal rainfall index along the equator (Douglas, 1980). During the course of the winter, a number of low-latitude storms moved eastward across Baja California, bringing heavy rains to the coast of northwest Mexico. Cloud masses originating along the ITCZ near Fanning Island frequently were advected northeastward ahead of these upper level disturbances. Individual cloud surges could be tracked into the Gulf of Mexico and Florida.

Winston and Krueger (1978) indicate that during the winter of 1977–78, cloudiness from the eastern

Unauthenticated | Downloaded 12/12/24 06:08 PM UTC

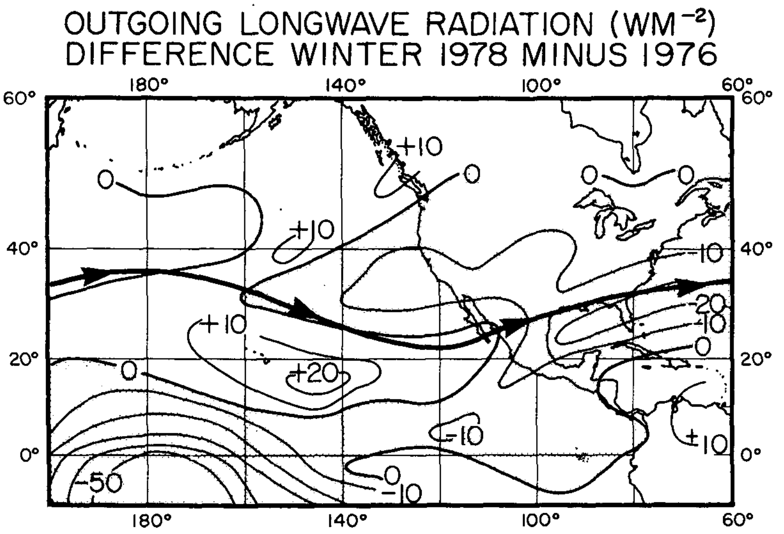

FIG. 5. Difference in the outgoing longwave radiation between a winter with heavy rainfall in the equatorial Pacific (1978) and a winter with low rainfall (1976). Arrows indicate the location of the 200 mb jet max in 1978. Shaded areas experienced decreased outgoing longwave radiation in 1978, suggesting greater cloudiness. Note the increased cloud cover on the south side of the subtropical jet stream from the eastern tropical Pacific northeastward to Florida.

tropical Pacific was advected toward Florida (Fig. 5). Rainfall totals in the peninsula exceeded 150% of normal during this winter. The outgoing longwave radiation shown in Fig. 5 indicates that cloudiness increased in the central equatorial Pacific. However, on a long-term basis this cloudiness was not directly advected towards Mexico.

The eastern tropical Pacific was warm in the winter of 1977–78, following the large-scale warming of 1976–77. With sea surface temperatures averaging 1°C above normal off western Mexico in early 1978, the potential remained for increased moisture transport into the low-latitude split flow. Since the precipitation in a large area of the southwestern United States shows significant correlation with the equatorial rainfall index (Fig. 6), it is likely that eastward moving low-latitude troughs and associated tropical cloudiness are important factors in the teleconnection.

Physical intepretations of the circulation patterns in Fig. 3 have been given by Wallace and Gutzler (1981) and Horel and Wallace (1981). In examining the 1000–500 mb thickness fields associated with this anomaly pattern, Wallace and Gutzler indicate that the system tends to have an equivalent barotropic structure. They also note that at mid-tropospheric levels this pattern is suggestive of a steady, linear response of a spherical atmosphere to either thermal and/or orographic forcing. Thermal forcing might be achieved by the existence of

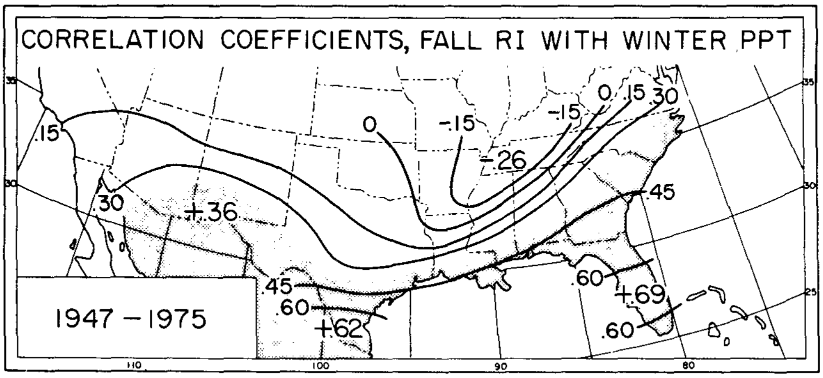

FIG. 6. Correlation between autumn rainfall in the equatorial Pacific and subsequent winter precipitation in the southern United States. Shading indicates areas with correlations significant at the 5% level.

Unauthenticated | Downloaded 12/12/24 06:08 PM UTC

anomalously low sea surface temperatures in the central North Pacific (in the vicinity of the negative height anomaly) and above-normal sea surface temperatures from the West Coast southwestward into the equatorial Pacific (Douglas, 1980). With West Coast ridging, the Rocky Mountains might have less snow cover and higher surface temperatures, and this could help to maintain ridge placement in western North America (in addition to the orographic forcing). Overall, this anomaly pattern represents a strengthening of the normal winter circulation, with a deep Aleutian low and a stronger-than-normal West Coast ridge.

Horel and Wallace (1981) have discussed the relationship between warming events in the central equatorial Pacific and the development of midlatitude circulation patterns similar to those in Fig. 3. They indicate that the positive height anomalies south of Hawaii are a response to heating along the equator as found in model results by Hoskins and Karoly (1981). They point out that while this region of positive heights has the largest perturbations in vorticity and streamfunction fields, larger anomaly patterns in the geopotential height fields develop poleward of the subtropical high. Horel and Wallace conclude that based on model results, the teleconnection between the tropics and midlatitudes is only possible in the winter half of the year when the westerlies expand equatorward toward the tropical heat source.

4. Summary

Wet winters in the extreme southern United States are frequently preceded by heavy rainfall events in the equatorial Pacific during the autumn. This teleconnection can be linked to large-scale circulation changes associated with warming events in the eastern tropical Pacific. After the establishment of a warm-wet regime in the eastern Pacific, the winter circulation becomes abnormally strong across the eastern North Pacific, Gulf of Mexico and western North Atlantic. The development of heavy precipitation in Florida is probably a result of a vigorous low-latitude mean flow across North America and increased frontal activity in the Gulf of Mexico. Cyclogenesis in the Gulf of Mexico may also increase during these winters.

Acknowledgments. The outgoing longwave radiation data were kindly provided by Art Krueger of the Climate Analysis Center. Dan Cayan and Jerry Namias made helpful comments on the manuscript. Carolyn Heintskill is acknowledged for her typing of the manuscript.

This research was sponsored by the National Science Foundation, Ocean Sciences Division under Contract OCE 8004668.

REFERENCES

Arkin, P. A., W. Y. Chen and E. M. Rasmusson, 1980: Fluctuations in mid and upper troposphere flow associated with the Southern Oscillation. *Proceedings of the Fifth Annual Climate Diagnostics Workshop*, Seattle, NOAA, 180–189.

Barnett, T. P., and R. W. Preisendorfer, 1978: Multifield analog prediction of short-term climate fluctuations using a climate state vector. *J. Atmos. Sci.*, **35**, 1771–1777.

Bjerknes, J. A., 1966: A possible response of the atmospheric Hadley Circulation to equatorial anomalies of ocean temperature. *Tellus*, **18**, 820–828.

——, 1969: Atmospheric teleconnections from the equatorial Pacific. *Mon. Wea. Rev.*, **97**, 163–172.

Dickson, R. R., and J. Namias, 1976: North American influences on the circulation and climate of the North Atlantic sector. *Mon. Wea. Rev.*, **104**, 1255–1265.

Doberitz, R., 1968: Cross-spectrum analysis of rainfall and sea surface temperature at the equatorial Pacific Ocean. *Bonn. Meteor. Abhandlugen*, No. 7, Meteorologisches Institut der Universitat Bonn, 61 pp.

Douglas, A. V., 1980: On the influence of warm equatorial conditions in the central Pacific on climatic patterns in the United States: 1977–1980. *Proceedings of the Fifth Annual Climate Diagnostics Workshop,* Seattle, NOAA, 239–250.

Erickson, C. O., 1979: The large scale upper-tropospheric circulation associated with unusually heavy rainfall over the southern United States, Spring 1979. *Proceedings of the Fourth Annual Climate Diagnostics Workshop*, Madison, NOAA, 108–119 (NTIS PB-201130).

Heckman, B. E., and A. H. Thompson, 1978: Extra tropical cyclogenesis over the Gulf of Mexico. *Preprints Conf. Weather Forecasting and Analysis and Aviation Meteorology*, Silver Spring, Amer. Meteor. Soc., 118–124.

Horel, J. D., and J. M. Wallace, 1981: Planetary-scale atmospheric phenomena associated with the Southern Oscillation. *Mon. Wea. Rev.*, **109**, 813–829.

Hoskins, B. J., and D. Karoly, 1981: The steady linear response of a spherical atmosphere to thermal and orographic forcing, *J. Atmos. Sci.*, **38**, 1179–1196.

Namias, J., 1976: Negative ocean-air feedback systems over the North Pacific in the transition from warm to cold seasons. *Mon. Wea. Rev.*, **104**, 1107–1121.

Neumann, C. J., M. B. Lawrence and E. L. Casco, 1977: Monte Carlo significance testing as applied to statistical tropical cyclone prediction models. *J. Appl. Meteor.*, **16**, 1165–1174.

Quinn, W. H., D. O. Zopf, K. S. Short and R. T. W. Kuo Yang, 1978: Historical trends and statistics of the Southern Oscillation, El Niño, and Indonesian Droughts. *Fish. Bull.* **76**, 663–678.

Wallace, J. M., and D. S. Gutzler, 1981: Teleconnections in the geopotential height field during the Northern Hemisphere winter. *Mon. Wea. Rev.*, **109**, 784–812.

Winston, J. S., and A. F. Krueger, 1978: Tropical circulation and radiation fluctuations: interactions with mid-latitude circulations during 1976–78. *Proceedings of the Third Climate Diagnostics Workshop*, Miami, NOAA, 8-1 to 8-16 (NTIS PB-298355).

Wright, P. B., 1979: Persistence of rainfall anomalies in the central Pacific. *Nature*, **277**, 371–374.

Unauthenticated | Downloaded 12/12/24 06:08 PM UTC