Relationship of El Niño–Southern Oscillation and Pacific Sea Surface Temperature with Rainfall in Various Regions of the Globe

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ABSTRACT

After characterizing every year in the 120-yr interval 1871–1990 as having an El Niño (EN) or Southern Oscillation minimum (SO), or equatorial sea surface temperature maximum (warm events W) or minimum (cold events C), or any combination of these, or none (nonevents), the rainfalls in various regions of the globe were examined for each category of year, using the data of Ropelewski and Halpert, who had identified some regions as having a negative response (deficit rains) and some as having a positive response (excess rains) to ENSO events. The author finds that this response is best with ENSOW-type events, especially the unambiguous ones (El Niño in the early part of the year and SO and W in the middle of the year), though, in some cases, even ambiguous ENSOW gave good results. Also, the response is reverse for C-type events. Out of the 46 years having El Niño (all types), and 36 years having cold (C) events, the response for some regions is good. But for some other regions, only about half could be associated with the expected response, making predictions uncertain in those regions. Factors other than ENSO may have considerable influence on rainfalls in different regions at different times, thus distorting the ENSO effects.

1. Introduction

Links between El Niño–Southern Oscillation (ENSO) and rainfall in various regions have been investigated for many years, for example, Rasmusson and Carpenter (1983), Shukla and Paolino (1983), Mooley and Paolino (1989), Kiladis and Diaz (1989), Hastenrath and Greischar (1993), and many others in recent years. Ropelewski and Halpert (1986) studied the relationship with North American precipitation and Ropelewski and Halpert (1987) extended the study to precipitation in other parts of the globe and identified four regions in Australia; two regions each in North America, South America, the Indian subcontinent, and Africa; and one region in Central America as having a coherent ENSO-related response. Later, Ropelewski and Halpert (1989) explored rainfall relationships with the high index phase of the Southern Oscillation. These publications will be referred to henceforth as RH1986, RH1987, and RH1989.

ENSO is considered as a manifestation of Walker circulation where the warm surface water episodes along the Ecuador and Peru coast (EN, El Niño) in the early part of some years are associated with the Southern Oscillation seesaw, namely increase (decrease) in the atmospheric pressure in the Indian Ocean–Australian region (e.g., Darwin, D) and decrease (increase) in the pressure in the southeastern tropical Pacific (e.g., Tahiti, T), showing a striking decrease (low index phase) of the Southern Oscillation (SO) index represented by $T - D$, and also with warm sea surface temperature in the equatorial eastern Pacific. Workers have used El Niños or SO minima or W events for comparison with rainfall deviations (Rasmusson and Carpenter 1983; Kiladis and Diaz 1989; Mooley and Paolino 1989). However, the lists of years for these three parameters do not always reconcile. Deser and Wallace (1987) examined these occurrences and concluded that El Niño events ''occurred both in advance of and subsequent to major negative swings of the Southern Oscillation'' and that EN and SO ''are more loosely coupled than other studies would imply.'' We examined this further and, for the 120-yr interval 1871–1990, characterized each year as having an EN, SO minimum, equatorial eastern Pacific sea surface temperature maximum (warm events, W), or minimum (cold events, C), or any combination of these, or none of these (nonevents). We found that there were 16 years of unambiguous ENSOW (El Niño in the early part of the year, SO and W in the middle of the early), 14 years of ambiguous ENSOW (El Niño in the early part of the year, SO, and/or W in the early or later part of the year), 6 ENSO, 1 ENW, 5 ENC, 4 EN (i.e., 46 events involving EN), 6 SOW, 4 SOC, 3 SO, 3 W, 36 C, and 22 nonevents. In this article, we examine whether the rainfalls in different parts of the globe have any preferential relationship with any of these categories of years.

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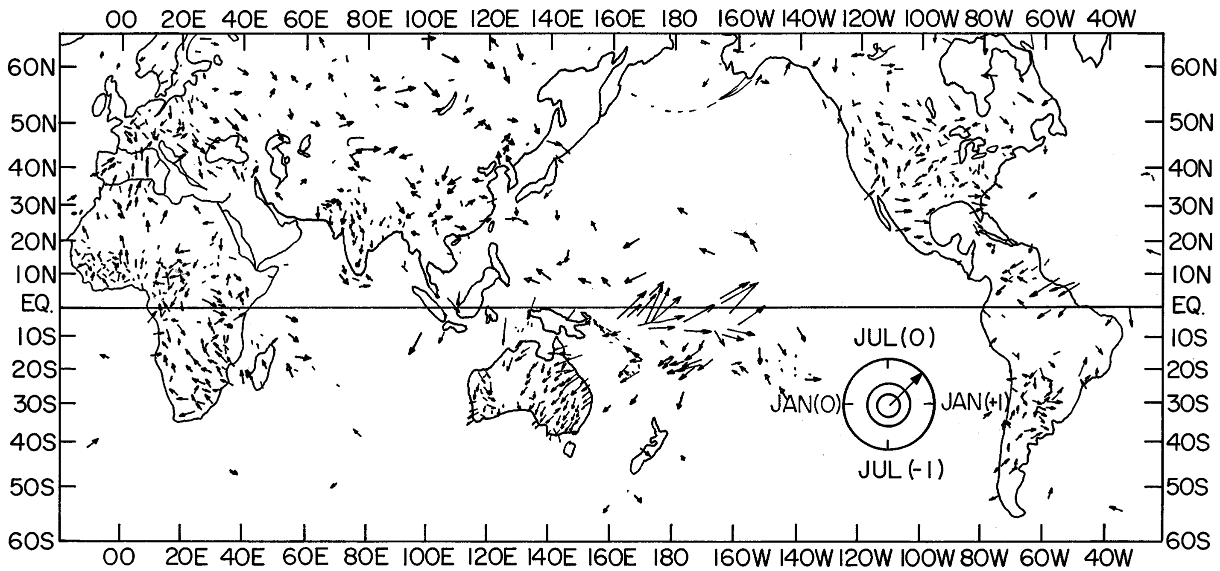

FIG. 1. Amplitudes and phases of ENSO composite ranked precipitation plotted as vectors based on a 24-month harmonic fitted to ranked precipitation composites for ENSO episodes (RH1987). In high-density areas, only one vector is plotted for a 2° × 2° grid.

2. Data

Our work is based completely on the data given in RH1987. Some missing values were supplemented from RH1989. Some recent data for India were obtained privately. Ropelewski and Halpert used monthly precipitation totals for over 1700 stations extracted from World Monthly Surface Station Climatology tape of the National Center for Atmospheric Research and supplemented by African data from Nicholson (1979, 1985). RH1987 do not mention the quality and homogeneity of the rainfall stations during the interval of about 120 years, nor the number of stations in each region. It is hoped that proper scrutiny has been made by them. They performed data analysis as follows. Monthly precipitation data at each station were expressed as percentile ranks and ENSO composites of these were formed for the 24-month period starting with the July preceeding the episode year (El Niño year), designated as July (−), using all 12 months of the episode year, and continuing up to the June of the following year, designated as June (+). RH1987 used 26 El Niños as episode years (taken from Rasmusson and Carpenter 1983). The 24 values [July (−) to June (+)] obtained as average composite for all El Niños for every station were fitted with a 24-month harmonic. A significant amplitude indicated significant ENSO relationship and the phase indicated the monthly interval for which the ENSO relationship (positive or negative) was meaningful. The amplitude and phase for each station were plotted as vectors on a world map, which is reproduced in Fig. 1, although not all 1700 stations are represented. In high data density areas, only one vector based on the longest data record is shown for each 2° × 2° grid. RH1987 found that in many areas the vectors had large amplitudes and similar phases. For each one of these areas, the ENSO composites for all stations therein were averaged, and the seasons within the ENSO cycle where the signal was largest were identified. For the seasons so identified, a time series for that region was obtained and examined with respect to relationship with ENSO.

RH1987 have shown the harmonic vector core regions for various regions separately (not shown here). Their results are summarized in Table 1, which lists the regions and their characteristics. For example, in the Pacific region, central Pacific (A-1) had a positive ENSO relationship (increased rainfall in El Niño years) when rainfall was considered for the months May (0) – April (+), that is, the 12 months from May of the El Niño year to April of the next year. For Hawaii (A-6), the relationship was negative (decreased rainfall in El Niño years) for Nov. (0) –May (+), that is, the 7 months from November of the El Niño year to May of the next year, and so on.

As can be seen, 12 regions, 4 in the Pacific (A3, A4, A5, A6), all 4 in Australia (B1, B2, B3, B4), and 1 each in the other regions (C1, D2, E1, F1) had negative relationships (droughts) with El Niños, while 6 other regions (A1, A2, C2, D1, E2, G1) had positive relationship.

The categorization of various years as having EN and/or SO minimum and/or W or C events in the equatorial eastern Pacific is illustrated in Fig. 2, for years 1871–1901, 1901–31, 1931–61, and 1961–91. In each panel, the first plot is for Southern Oscillation index (SOI) given by Wright (1975, 1977). It is based on principle component analysis [similar to that of Kidson (1975)] of seasonal mean pressure at eight locations—Cape Town, Bombay, Djakarta, Darwin, Adelaide, Apia, Honolulu, and Santi-

TABLE 1. Rainfall data characteristics.

Region	Interval	Symbol	Season	Expected relation with ENSO: Decrease	Expected relation with ENSO: Increase
(A) Pacific Basin					
1) Central Pacific	1932–79	CP	May (0)–Apr (+)		X
2) South Central Pacific	1940–79	SCP	Jul (0)–Jun (+)		X
3) Indonesia–New Guinea	1879–1982	ING	Jun (0)–Nov (0)	X	
4) Fiji–New Caledonia	1924–80	FNC	Oct (0)–Mar (+)	X	
5) Micronesia–W. Pacific	1921–82	MWP	Oct (0)–May (+)	X	
6) Hawaiian	1905–80	HAW	Nov (0)–May (+)	X	
(B) Australia					
1) Northern Australia	1875–1982	NAU	Sep (0)–Mar (+)	X	
2) Eastern Australia	1875–1982	EAU	Sep (0)–Feb (+)	X	
3) South Australia–Tasmania	1882–1982	SAT	May (0)–Oct (0)	X	
4) Central Australia	1876–1982	CAU	Mar (0)–Feb (+)	X	
(C) Indian Subcontinent					
1) India	1875–1983	IND	Jun (0)–Sep (0)	X	
2) Minicoy–Sri Lanka	1875–1982	MSL	Oct (0)–Dec (0)		X
(D) Tropical and southern Africa					
1) East equatorial Africa	1922–76	EEQ	Oct (0)–Apr (+)		X
2) Southeast Africa	1890–1982	SEA	Nov (0)–May (+)	X	
(E) South America					
1) Northeastern South America	1911–82	NSA	Jul (0)–May (+)	X	
2) Southeastern South America	1902–82	SSA	Nov (0)–Feb (+)		X
(F) Central America					
1) Central America–Caribbean	1899–1980	CEN	Jul (0)–Oct (0)	X	
(G) Gulf and North Mexico	1881–1982	GNM	Oct (0)–Apr (+)		X

ago—and is available for 1851–1974. Later, Chen (1982) recommended a simpler index, namely, Tahiti (18°S, 150°W) minus Darwin (12°S, 131°E) mean sea level pressure difference (T − D), which is available in Parker (1983) for the period 1935–83 and was updated from meteorological data reports. We found that the 12 monthly running means of the SO index of Wright and the T − D were very well correlated and the graph of SO versus T − D showed a straight line and could be used for converting recent T − D values to SO index of Wright. In Fig. 2 (panel 4), we have plotted SOI (Wright 1977) up to 1974 (marked by vertical line) and equivalent values obtained from T − D for later period. The SOI *minima* are marked black.

The next plots show the SST index of Wright (1984) for eastern equatorial Pacific (6°N–6°S, 180–90°W) and a similar index obtained by J. K. Angell (1981, and further personal communication) for the same region. Both of these were used for designating the year as W or C, whenever the SST values showed extremes, namely, maxima (marked black) or minima (marked hatched), irrespective of the actual values (no thresholds applied). This procedure is somewhat arbitrary, but it is gratifying to note that most of the SST maxima (minima) coincide with SOI minima (maxima) and most of the SOI minima and SST maxima (both marked black) seem to be associated with El Niños. As such, all such events should be ENSOW. The lowest part of each panel shows rectangles, characterizing each year as ENSOW, ENSO, ENW, ENC, SOW, SOC, W, or C. As can be seen, some events are ENSOW, but there are some EN not associated with SO (and vice versa), confirming the observation of Deser and Wallace (1987).

Years that had none of these are shown as blank (no rectangles) and are *nonevents*. For events involving EN, the symbols S, M, and W at the top of the rectangle indicate whether the El Niño was strong (S), moderate (M), or weak (W). All information about El Niños was obtained from Quinn et al. (1978, 1987). Among the ENSOW events, some had SO (minima) and W in the *middle of the calendar year*. We term these as *unambiguous* ENSOW. Others, where SO and/or W occurred in the early or later part of the calendar year, are termed *ambiguous* ENSOW.

3. Time series

For each of these regions, we have used the time series given by RH1987 as percentile-ranked precipitation, that is, the percentile index (0–100) with the mean value of the series at 50. We considered the data for each year as belonging to six categories: (+): percentile 50–60 (i.e., 0%–20%)—normal positive deviation; small circle: percentile 60–70 (i.e., 20%–40%)—mild floods; large circle: percentile >70 (i.e., >40%)—severe floods; (−): percentile 50–40 (i.e.,

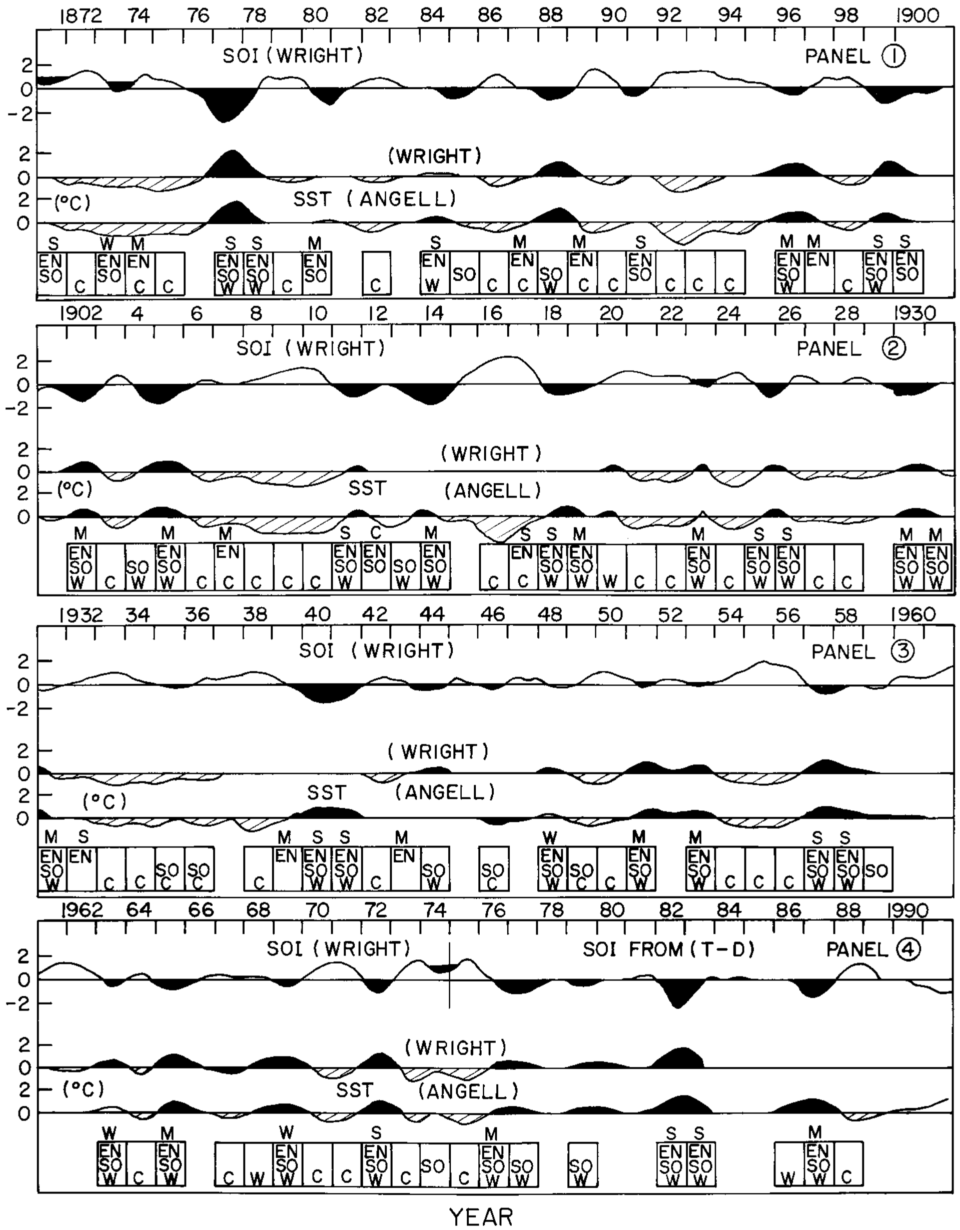

FIG. 2. Plots of 12-month running means of Southern Oscillation index (SOI) and sea surface temperatures in equatorial eastern Pacific (SST) for 1871–1991 (panels 1–4) and the characterization of each year as having El Niño (EN), SOI minima (SO), and/or warm (W) or cold (C) Pacific SST (rectangles). For years having EN, the symbols above the rectangle indicate strength (S—strong, M—moderate, W—weak) of the El Niño. SOI minima and SST maxima are shown in black.

0% to −20%)—normal negative deviation; small triangle: percentile 40–30 (i.e., −20% to −40%)—mild droughts; and large filled triangle: percentile <30 (i.e., <−40%)—severe floods.

4. Rainfall deviations for various types of years

a. ENSOW events

Figure 3 shows a plot for years when El Niños occurred. Figure 3a refers to the 16 unambiguous ENSOW years. The symbols S, M, and W before the year indicate the strength of the El Niño involved. Some of the El Niños occurred in two successive years. In these cases, I and II indicate whether the year was the first or second of such a pair (e.g., 1877 I, 1878 II). The symbol R indicates that this event was considered an ENSO episode by RH1987. The *first grid* of 12 columns represents the 12 regions where El Niños were expected (by RH1987) to be related with dry conditions (see Table 1). The *second grid* of six columns represents the six

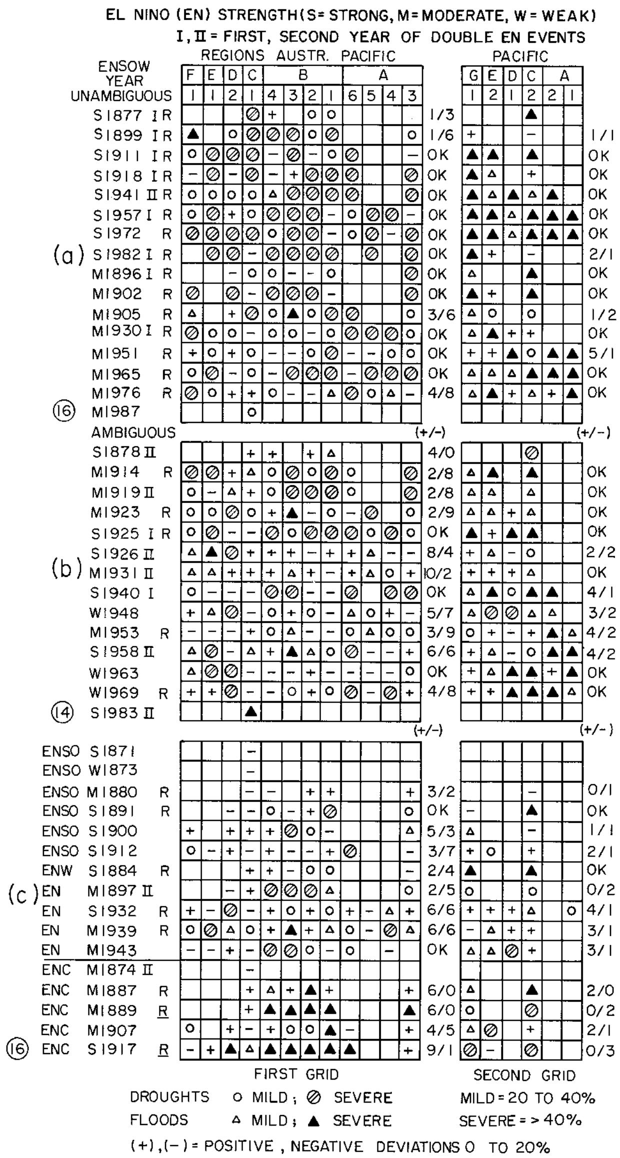

FIG. 3. Rainfall distributions in various regions (first grid, A3, A4, A5, A6; B1, B2, B3, B4; C1; D2; E1; F1; second grid, A1, A2; C2; D1; E2; G1) for various types of years involving EN: (a) unambiguous ENSOW, (b) ambiguous ENSOW, and (c) other types of EN events. Strengths of the El Niño involved are indicated by S—strong, M—moderate, and XW—weak. The symbol R indicates events used in RH1987 and R in RH1989. At the end of the first and second grids, OK indicates that the rainfall distribution was as expected, while the pair of numbers indicates the numbers of regions having positive and negative rainfall deviations from mean. The I and II indicate occurrences of El Niño in two successive years.

regions where El Niños were expected to be related to wet conditions. The following may be noted.

1) It is gratifying to note that from the 16 ENSOW, 15 are R, that is, selected by RH1987 also. (For one event, 1987, they did not have data.)
2) For 11 of these events (marked as OK at the end of the grid) the deviations in the first grid of 12 regions were mostly (all but two) negative and those in the second grid of 6 regions were mostly positive, thus confirming that at least for these El Niño events the results of RH1987 were fully justified. For another two events (1877 I and 1899 I, incomplete data), only one deviation was positive and the rest were negative in the first grid and mostly positive in the second grid. Thus, a total of 13 events conformed to the expectation. Some of these were the first years of double events.
3) Year 1905 had three regions showing positive deviations in the first grid and two regions showing negative deviations in the second grid. The pair of numbers at the end of the first and second grids shows the number of positive and negative deviations (e.g., 1899 I, 1/6, that is, one positive, six negative in the first grid; 1/1, one positive, one negative in the second grid). Thus, in these years, the ENSOW combination was not as effective as for the other events. The year 1976 also had unsatisfactory distribution in the first grid (4/8) but was acceptable for the second grid.

Figure 3b refers to ambiguous ENSOW events, that is, when El Niño appeared in the early part of the year but SO and W appeared in the early part or later part of the year, not in the middle of the year. In this group, only 1925 I, 1940 I, and 1963 showed as acceptable (all but two negative) results. Many events had three or more positive deviations in the first grid and negative deviations in the second grid. Incidentally, some of these events are second (II) years of consecutive EN years. Thus, second years, even though these are El Niño years, do not seem to give the expected results. RH1987 have avoided such years. But in Fig. 3b, there are five events of R and only one of these (1925 I) is acceptable.

b. *Other EN events*

Figure 3c (upper half) shows other types of 11 EN events, namely, ENSO, ENW, and EN. Only two events, ENSO 1891 and EN 1943, are acceptable. Others are mixed, that is, both positive and negative deviations occurred. RH1987 selected five events, and only one of them (1891) is acceptable. The worst cases are R events of 1932 and 1939 where the first grid showed equal numbers (six) of positive and negative deviations.

Overall, the best results are obtained for unambiguous ENSOW.

The lower part of Fig. 3c shows results for five ENC events. Here, EN and C are expected to give contradictory results. For 1874, there are inadequate data. But 1887 (an R event), 1889, and 1917 show mostly positive deviations in the first grid, indicating the overpowering influence of C. In 1907, positive and negative deviations were almost equal.

Incidentally, ENC 1889 and ENC 1917 (marked with R's) have been considered in RH1989 as high-index SO phase events (cold events) and do conform to the expectations of that category (excess rains in first grid, deficits in second grid) *in spite of the presence of an EN.*

From the 46 events (shown in Fig. 3) involving EN, 16 are clear-cut acceptable, and 5 are with 2 regions nonconforming. Thus, from 46 events, only 21 are roughly conforming and 25 are not conforming. Obviously, predictions based on the presence of El Niño alone could not be expected to come true in almost 50% cases. At the first indication of an El Niño in January, meteorologists in low latitudes are tempted to predict droughts in some regions. In view of the statistics presented above, such predictions may sometimes prove erroneous.

In a general way, our results are similar to those of RH1987. For acceptable cases, we have used the strict criterion that 10 or more in 12 regions show expected results and find that only about 50% (21 in 46) of the El Niño events show satisfactory results. If we reduce the expectation to 8 in 12 regions, the percentage will increase to about 60%. However, RH1987 did not use 46 El Niño events. They used 26 ENSO "years," as defined in Rasmusson and Carpenter (1983), whose list corresponds to the list of Quinn et al. (1978) and Quinn et al. (1987), except that II year events have been omitted. This omission of II years by them is fully justified; because, as seen from Figs. 3b,c, the response of these II years to droughts in the first grid and floods in the second grid is not very good. From the 26 El Niño events that RH1987 and Rasmusson and Carpenter (1983) selected, 11 in Fig. 3a, 1 (1925 I) in Fig. 3b, and 1 (1891) in Fig. 3c (total 13) are acceptable. Two events, 1877 and 1899 I in Fig. 3a, and two events, 1914 and 1923 in Fig. 3b, may be considered as more or less acceptable. Thus, a total of 17 (out of 26) are almost acceptable. Events 1905 and 1976 in Fig. 3a; 1953 and 1969 in Fig. 3b; and 1880, 1884, 1932, 1939, and 1887 in Fig. 3c (9 events out of 26) are not satisfactory.

c. Events without El Niño

Figure 4a (upper part) shows the results for SOW, W, and SO events. All these are expected to have the same effects as that of an El Niño, namely, negative deviations in the first grid and positive in the second grid. Only SOW of 1888, 1913, and 1977 and SO of 1885 conform to these expectations. All others have mixed deviations. The worst case is the SO of 1974 where the first grid has predominantly positive deviations and the second grid has predominantly negative deviations, just the reverse of expected.

The lowest part of Fig. 4a shows four SOC-type events. Here, SO and C are expected to give contradictory results. For 1935 and 1936, results are mixed in the first grid. For 1946, the first grid shows mostly negative deviations and the second grid shows positive deviations, indicating the effect of SO. For 1949, the situation is just the opposite, showing an effect of C.

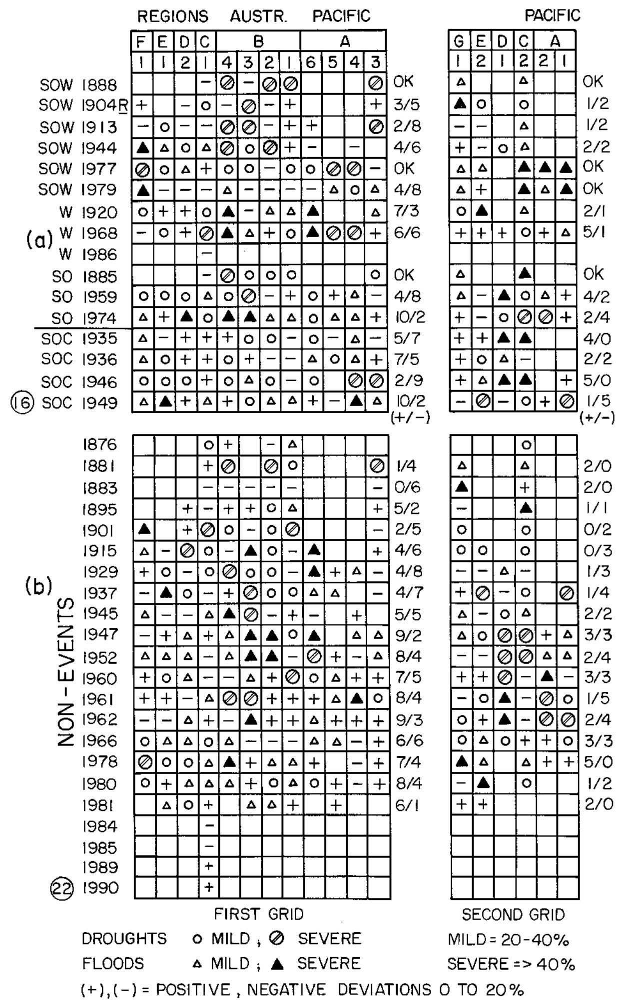

FIG. 4. Same as in Fig. 3 but for (a) SOW, W, SO, and SOC events and (b) nonevents.

Are all these results physically meaningful or are they random? A check could be made by examining the nonevents. Figure 4b shows the results. Since no EN or SO or W or C is involved, one would expect mostly normal (+) or (−) deviations. Instead, the first grid shows large positive deviations in some years and large negative deviations in some others. The same is true for the second grid. Thus, large positive or negative deviations can occur in several regions even in the absence of ENSO, or W, or C, events.

d. Cold events

Figure 5 shows the results for 36 cold (C) events. RH1989 studied the high index phase of SO, which should be similar to our C events. Out of their 19 events, 16 appear in Fig. 5 (marked as R). Here, the expectation is that the first grid should show mostly positive deviations and the second grid should show mostly negative deviations. From the 36 events, there are only 14 events

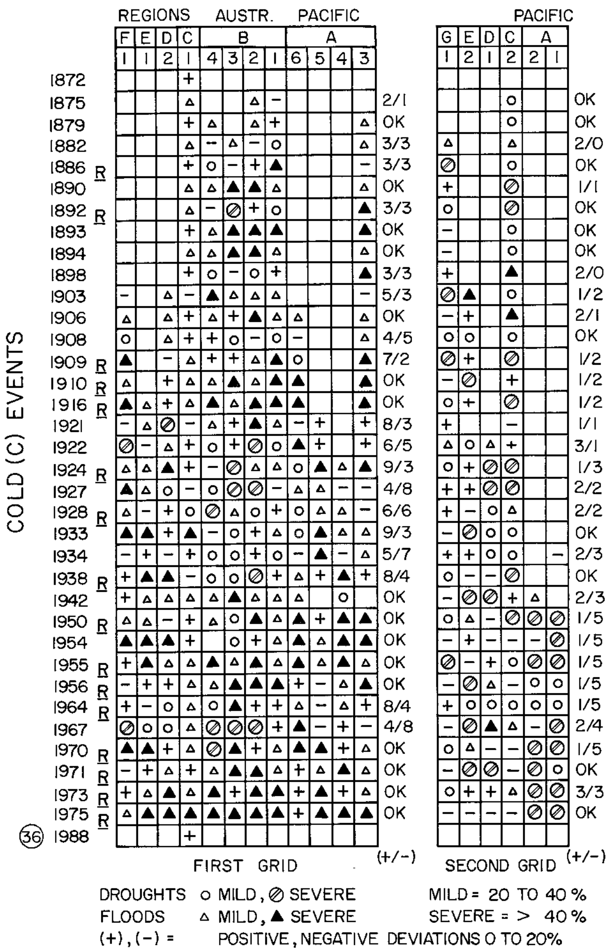

FIG. 5. Same as in Fig. 3 but for C events of the equatorial eastern Pacific sea surface temperature.

in the first grid (marked as OK) that conform to this pattern and 7 of these are R events (RH1989). Another four events (1875, 1909, 1950, 1956), three of which are R, may also be considered as acceptable as only one or two regions did not conform. In the other 18 events, three or more regions did not conform. The worst cases in the first grid are 1908 (4/5), 1922 (6/5), 1927 (4/8), 1928 (6/6, an R event), 1934 (5/7), and 1967 (4/8), where there is a disconcertingly large number of regions (latter numbers) having negative deviations.

From the three events of RH1989 (R) that do not appear in Fig. 5, two have appeared in Fig. 3 as ENC (1989) and ENC (1917) and conform to category C, in spite of the presence of an EN. The third event appears in Fig. 4 as SOW (1904) and shows characteristics of SOW rather than of a cold event. A part of the discrepancy may be because of the fact that we have used, for analysis, data given in RH1987 that have seasons appropriate for El Niño analysis, while for SO high-index phase, the seasons given in RH1989 are slightly different.

So far, we have discussed statistics indicating how widespread the drought or flood effects were. For individual regions, important statistics would be about the plus/minus in each vertical column.

Table 2 summarizes the performance of each region for the various categories of events of Figs. 3–5. For example, in Fig. 3a for unambiguous ENSOW, the region F1 showed three positive and nine negative deviations, giving a plus/minus of 3/9 and a ratio 0.3. The following may be noted in Table 2.

1) Since for the first grid El Niños are expected to be associated with droughts, the negative deviations should predominate and the plus/minus ratios should be very low. As can be seen, for events in Fig. 3a (unambiguous ENSOW, first two rows of Table 2, first grid) the ratios range from 0 to 0.4 with a mean of 0.13. In the second grid where El Niños are expected to be associated with floods, the reverse ratio plus/minus is also low (0–0.4) with a mean of 0.09. Thus, unambiguous ENSOW are undoubtedly associated with droughts in the first grid and floods in the second grid, much more for some regions (ratio 0) than for others.
2) For ambiguous ENSOW in Fig. 3b, the ratios are larger, in a larger range (0.1–1.0) with a mean value of 0.56 in the first grid and 0.25 in the second grid. For other EN events of Fig. 3c, the situation is much worse, a range of (0–2.0) with a mean value of 0.98 in the first grid and 0.70 in the second grid. These values are approximately 1.0, indicating almost equal number of events of positive and negative deviations, much more so for some regions than for others. Thus, for some regions, the score is only about 50% of the total events.
3) If all the El Niños are considered (Figs. 3a–c), the ratios are as shown in the bottom of Table 2. Here, for the first grid, the ratio has a range (0.2–6) with a mean value of 0.40. For some regions, the plus/minus ratio is 0.6, implying that 6/16 ≈ 40% of the total events proved to be plus (floods) instead of minus (droughts). In the second grid, the situation is better, with a mean value of 0.20 and a maximum value of 0.4. Thus, floods in the second grid locations are more certainly associated with El Niños than droughts in the first grid.
4) For events of Fig. 4a involving SO and W, the ratios are in the range 0.4–1.2 with a mean value 0.78 for the first grid and 0.2–1.2 with a mean value of 0.54 for the second grid. Thus, ratios are high, implying poor relationships, more so for some regions than for others.
5) For nonevents of Fig. 4b, the ratios in the first and second grids have mean values of 1.2 and 1.4, implying almost equal numbers of events of positive and negative deviations. But, for some regions, the ratios are much lower (0.6) or much higher (2.0), indicating that some extreme rainfalls have occurred. This is unexpected and indicates the importance of other factors unrelated to ENSO.

TABLE 2. Pairs of numbers indicating the numbers of events having positive (+) and negative (−) rainfall deviations in Figs. 3–5. For Figs. 3a–c and Figs. 4a and 4b, the values are (+/−) for the first grid and (−/+) for the second grid. For Fig. 5 (cold events), the values are reverse: (−/+) for the first grid and (+/−) for the second grid. Lower ratios represent better associations.

		First grid														Second grid						
		Regions				Australia				Pacific						Pacific						
		F	E	D	C	B				A						G	E	D	C	A		
		1	1	2	1	4	3	2	1	6	5	4	3	Mean		1	2	1	2	2	1	Mean
Fig. 3a	(+/−)	3/9	0/10	4/10	1/15	2/13	2/12	0/15	1/14	0/10	0/7	1/5	0/14		(−/+)	0/14	1/11	0/7	4/11	0/6	0/5	
Unambiguous ENSOW	Ratios	0.3	0.0	0.4	0.1	0.2	0.2	0.0	0.1	0.0	0.0	0.2	0.0	0.13	Ratios	0.0	0.1	0.0	0.4	0.0	0.0	0.09
Fig. 3b	(+/−)	6/6	4/8	3/9	8/6	5/8	6/6	5/8	2/11	3/9	3/6	1/8	3/9		(−/+)	1/11	1/11	5/5	3/10	0/6	0/4	
Ambiguous ENSOW	Ratios	1.0	0.5	0.3	1.3	0.6	1.0	0.6	0.2	0.3	0.5	0.1	0.3	0.56	Ratios	0.1	0.1	1.0	0.3	0.0	0.0	0.25
Fig. 3c	(+/−)	2/5	1/4	6/3	6/10	9/4	4/8	7/6	8/5	2/4	0/2	1/2	8/4		(−/+)	5/7	3/3	1/2	5/8			
Other EN events	Ratios	0.4	0.2	2.0	0.6	2.3	0.5	1.1	1.6	0.5	0.0	0.5	2.0	0.98	Ratios	0.7	1.0	0.5	0.6			0.70
Fig. 4a	(+/−)	7/6	4/8	7/6	7/9	6/9	4/11	4/11	7/8	5/7	3/5	5/5	7/7		(−/+)	3/12	7/6	3/5	6/9	1/5	1/6	
Events without El Niño	Ratios	1.2	0.5	1.1	0.8	0.7	0.4	0.4	0.9	0.7	0.6	1.0	1.0	0.78	Ratios	0.3	1.2	0.6	0.7	0.2	0.2	0.54
Fig. 4b	(+/−)	7/6	7/6	8/7	10/12	9/8	9/7	7/11	8/10	8/4	9/0	6/4	9/6		(−/+)	9/8	7/6	6/3	11/6	2/5	5/3	
Nonevents	Ratios	1.2	1.2	1.2	0.8	1.1	1.3	0.6	0.8	2.0	x	1.5	1.5	1.2	Ratios	1.1	1.2	2.0	1.8	0.4	1.7	1.4
Fig. 5	(−/+)	7/18	4/16	7/18	5/31	14/18	12/20	8/26	7/27	7/17	3/15	3/14	5/27		(+/−)	9/23	11/13	5/13	9/25	1/10	0/10	
Cold events	Ratios	0.4	0.3	0.4	0.2	0.8	0.6	0.3	0.3	0.4	0.2	0.2	0.2	0.36	Ratios	0.4	0.8	0.4	0.4	0.1	0.0	0.35
Figs. 3(a–c)	(+/−)	11/20	5/22	13/22	15/31	16/25	12/26	12/29	11/30	5/23	3/15	3/15	11/27		(−/+)	6/32	5/25	6/14	12/29	0/12	0/9	
All El Niños	Ratios	0.6	0.2	0.6	0.5	0.6	0.5	0.4	0.4	0.2	0.2	0.2	0.4	0.40	Ratios	0.2	0.2	0.4	0.4	0.0	0.0	0.20

6) For the cold events, the minus/plus ratio for the first grid is low (preponderance of plus, i.e., floods) as expected and the plus/minus ratio for the second grid is also low (preponderance of droughts). Thus, C events do give mostly expected results. However, here again, some regions have a better showing (lower ratios) than others.
7) An interesting fact is the differences in responses of regions in the same country. For example, for Australia in the first grid, ratios for B1, B2, B3, and B4 for Figs. 3b and 3c are 0.6, 1.0, 0.6, and 0.2, and 2.3, 0.5, 1.1, and 1.6. Thus, different parts of Australia may react very differently to the various El Niño events. The same is true for response to cold events (Fig. 5) also (ratios 0.8, 0.6., 0.3, 0.3).

5. Conclusions

1) From the various types of years, unambiguous ENSOW combination (El Niño in the early part of the year and *SO minima and W in the middle of the calendar year*) seems to be best associated with deficit rainfall in regions of the first grid and excess rainfall in regions of the second grid.
2) In the case of double event years (El Niño in two successive years), the second year does not generally conform to this pattern.
3) Ambiguous ENSOW (El Niño in the early part of the year and SO and W in the early or later part of the year, *not in the middle*) seem to show clear associations only for some regions. Other types of El Niño events show mixed results, indicating a lack of a clear relationship.
4) Predictions based on the presence of El Niño alone in the early part of the year are likely to come true in about 80% of the cases only for a few regions. In others, this number could be as low as 60%. The presence of SO and W in the middle of the year increases the probability, but predicting the same early enough would probably be very difficult.
5) Events involving SOW, or W or SO, only rarely give expected results.
6) The C events or the high-index phase of SO (i.e., SO maxima) seem to have some association with floods in regions of the first grid and deficits in regions of the second grid. Here again, predictions are likely to come true in about 80% of the cases for some regions but only about 60% in some other regions.
7) For nonevents, one would expect only normal rainfall. Instead, some nonevents show results similar to El Niño or C events.

As mentioned in RH1987 and RH1989, none of the core regions are equally coherent, and individual locations may have a better or poorer ENSO relationship, which may vary from episode to episode. All this certainly adds up to the uncertainty of predictions. In some regions, effects due to factors other than ENSO or eastern Pacific SST (e.g., central Pacific SST, Indian Ocean SST, Atlantic SST, or wind fields) may sometimes be overpowering.

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