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El Niño and tropical cyclone frequency in the Australian region and the northwest Pacific

Keqin Dong, Academy of Meteorological Science, State Meteorological Administration, China

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Based on the surface temperature in the eastern equatorial Pacific and the tropical cyclone data in the western north Pacific and Australian region, relationships between El Niño events and tropical cyclone frequencies have been investigated. After determination of an 'El Niño year period' and its intensity, and consideration of tropical storm or typhoon formation longitude it has been found that El Niño events have a definite suppression effect on tropical storm or typhoon activity in the western Pacific area (about 120°E–160°E in the north Pacific and about 145°E–165°E in the South Pacific), especially during four recent stronger El Niño year periods. These may be explained by variations in the Walker circulation.

Introduction

As first pointed out by Bjerknes (1969) and further confirmed by later studies, the axis of the Walker circulation in the equatorial Pacific during an El Niño year is located anomalously east, with rising motion in the central part of the ocean and sinking motion in the western part (see Julian and Chervin 1978). It might be expected that the circulation abnormality should be associated with the variability of tropical cyclone activity and in particular with tropical cyclone frequency. In the past few years there have been many studies on this topic. Comparing El Niño years with those before and after, Gray (1984) found that tropical cyclone activity during the El Niño year was apparently suppressed in the Atlantic basin. As for the western Pacific tropical cyclone basin, there were inconsistencies. Ramage and Hori (1981) suggested that no El Niño effect could be detected on the frequency of tropical cyclone developments in the western Pacific. Pan (1982) and Wei (1985) showed that the anomaly of the sea surface temperature in the eastern equatorial Pacific and the frequency of typhoons in the northwest Pacific changed in opposite directions. However, there is an exception during 1972-1973 (a strong El Niño period) in Pan's (1982) paper. Chan (1985) showed that, compared with the previous year, the annual number of tropical cyclones in the entire northwest Pacific decreased for all El Niño years except 1976. We may note that it was not compared with the later year and there was an exception. Li (1987) showed that an averaged typhoon frequency for eight El Niño years was less than normal. There have also been some studies of the relation between the Southern Oscillation (SO) and tropical cyclone activity. Chan (1985) pointed out that at the 3 to 3.5 year period and QBO frequency, the ENSO event was significantly correlated with tropical cyclone activity in the northwest Pacific. In his correlation analysis, Nicholls (1985) showed that low Darwin pressure during winter and spring indicated that more cyclones than usual could be expected in the ensuing Australian cyclone season, and vice versa. Revell and Goulter (1986) pointed out that a weak but definite statistical relationship existed between the SOI and the origin points of tropical cyclones in the South Pacific. Since the SO has close linkage with the El Niño the above studies imply that some relationship between El Niño and tropical storm frequency in the Australian region and northwest Pacific is likely.

It is likely that the study of the relation between El Niño events and tropical cyclone frequency may be confused by two factors: first, El Niño episodes appear at various times in the calendar year, but calendar year statistics are used for analysis of tropical cyclone frequencies; second, the El Niño event may have different effects on tropical cyclone development in different longitude intervals of a large geographical basin, through the Walker circulation variation, but the statistics are usually derived for the whole of a large geographical basin, such as the entire northwest Pacific or Australian region. Above-normal storm numbers in the eastern west Pacific were noted by Atkinson (1977), Ramage and Hori (1981), Gray (1984), Chan (1985) and Revell and Goulter (1986) for most of the El Niño years. For reasons given above, a concept called the El Niño year period is introduced in this study and the entire northwest Pacific and Australian regions are divided into several longitude intervals for the investigation of relationships between the El Niño and tropical storm frequency. These distinguish this study from previous papers on this topic.

Data

This study uses the mean sea surface temperatures in the eastern equatorial Pacific between 0°–10°S and 180°–90°W (described in the following as EEP-SST) during 1949-1986 for describing El Niño events. The data were obtained from the ENSO monitoring group of the State Meteorological Administration (SMA), China.

The tropical cyclone data in the Australian region during 1949-1986 up to April of that year come from the Bureau of Meteorology, Australia, by courtesy of Dr G. Holland and through papers by Thom (1984), Kuuse (1985) and Kingston (1986). We have also made use of the tropical cyclone tracks given by Lourensz (1981).

The northwest Pacific typhoon data during 1949-1986 were collected by the Shanghai Typhoon Institute, SMA. The greater part (1949-1980) was published by the Meteorology Press, Beijing, in 1984 and the rest was issued year by year.

Only tropical cyclones with maximum sustained wind greater than 17 m/s (in both basins) or with central pressure less than 995 hPa (in the Australian region only, see Bureau of Meteorology (1978), are counted in the tropical cyclone or typhoon frequency. The Australian tropical cyclones or northwest Pacific typhoons are further referred to several longitudinal divisions according to the longitude where a tropical depression first reached tropical storm intensity.

El Niño year periods

Since El Niño events are characterised by unusually high EEP-SST, we may define an El Niño year period (ENyp) as the twelve-month period with the highest EEP-SST. Figure 1 shows the time-series of 12-month running mean EEP-SST during 1949-1986. It is seen that there are nine obvious peaks in the series and they correspond to the nine generally acknowledged El Niño events (Fu et al. 1986). These define the nine El Niño year periods used in this study. Also, we have suggested the following criteria for the intensity estimation of the ENyps:

(a) Weak: 0.3°C < 12-monthly EEP-SST anomaly ≤ 0.8°C,
(b) Strong: 0.8°C < 12-monthly EEP-SST anomaly ≤ 1.2°C,
(c) Very strong: 1.2°C < 12-monthly EEP-SST anomaly.

The yearly or 12-monthly normal of the EEP-SST for 1949-1985 is 26.5°C. Some relevant features of the ENyps are shown in Table 1. Another El Niño intensity classification suggested by Quinn et al. (1978) is also shown in the table. It is clear that their weak and strong events coincide with our weak and strong ones respectively, and their moderate ones divide between our weak and strong classes. A further investigation on relationships between El Niño and tropical cyclone frequency is based on the determination of ENyps and estimation of their intensity, mentioned above.

El Niño and tropical cyclone frequency

Considering tropical cyclone or typhoon number may be somewhat under-reported before the middle 1960s, we follow Gray's (1984) way to compare cyclone frequency during the ENyps with those before and after the ENyp in the relationship analysis.

In the Australian region

Following Lourensz (1981), the Australian tropical cyclone region of this study is bounded between 105°E and 165°E, that is, only storms formed in this area are counted in the statistics. Table 2 shows some classified statistical results of relationships between El Niño events and the storm frequency in the region. These may be summarised as follows.

First, tropical storm formation is suppressed to some extent during the ENyp and it is reasonable that the storm number reduction during stronger (strong + very strong) El Niño events is greater than that during weak ones. Second, the year-periods of maximum reduction in storm number generally lag a couple of months behind the ENyp and it seems that the lag is greater for the weak ENyp than for the stronger one (the maximum reduction is marked by star symbols in Table 2). This indirectly coincides with the correlation analysis result shown by Nicholls (1985).

As is shown by Holland (1984), the Australian tropical storms are separately concentrated in three areas: the Gulf of Carpentaria, the Coral Sea

Fig. 1 Twelve-month running mean EEP-SSTs during January 1949-June 1987. The X-axis denotes the periods of twelve months running. The vertical bars show the periods chosen for ENyps.

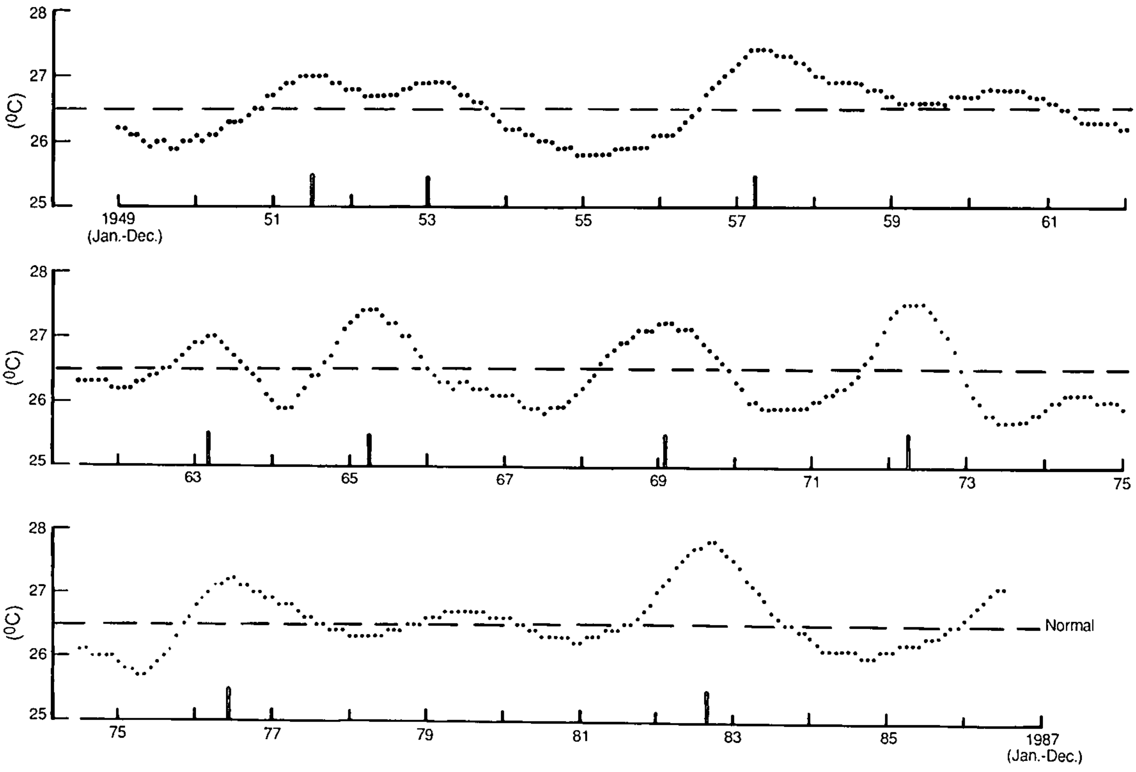

Table 1. Nine El Niño year periods, determined by the 12-monthly maxima of the EEP-SST, and their intensity estimation.

Duration of El Niño year periods	*Mean EEP-SST (°C)*	*12-monthly anomaly (°C)*	*Number of months with monthly anomaly* > 0.5°C	*Intensity estimation*	*El Niño intensity by Quinn et al. (1978)*
Jul. 1951-Jun. 1952	27.0	+0.5	6	Weak	Weak
Jan. 1953-Dec. 1953	26.9	+0.4	4	Weak	Moderate
Apr. 1957-Mar. 1958	27.4	+0.9	12	Strong	Strong
Mar. 1963-Feb. 1964	27.0	+0.5	6	Weak	Very Weak
Apr. 1965-Mar. 1966	27.4	+0.9	11	Strong	Moderate
Feb. 1969-Jan. 1970	27.2	+0.7	11	Weak	Weak
Apr. 1972-Mar. 1973	27.5	+1.0	10	Strong	Strong
Jun. 1976-May 1977	27.2	+0.7	10	Weak	Moderate
Sep. 1982-Aug. 1983	27.8	+1.3	12	Very strong	

and off northwest Australia. For this reason and because of the variation in the Walker circulation mentioned above, we have made a further investigation of the relationship between stronger El Niño events and storm frequencies in three longitude bands or subregions: 105°E–125°E, 125°E–145°E and 145°E–165°E, respectively. The results shown in Table 3 indicate that an apparent and consistent reduction in storm number appears only in the southwest Pacific or Coral Sea area (145°E–165°E) during four stronger El Niño year periods (two months lagged).

Table 2. Mean frequencies, and standard deviations (in brackets), of Australian tropical storms before (B), during (D) and after (A) all nine, 4 stronger and 5 weak El Niño year periods (ENyp) and their percentage reductions during El Niño year periods (D-ENyp) compared with those B-ENyp and A-ENyp, respectively.

		Twelve-month period before ENyp number of months in advance				*ENyp*	*Twelve-month period after ENyp number of months lag*				
		4	*3*	*2*	*1*		*1*	*2*	*3*	*4*	*5*
All nine events	B-ENyp	8.0 (3.0)	8.7 (3.7)	8.8 (3.8)	8.8 (3.3)	8.8 (3.8)	8.8 (4.7)	9.3 (5.3)	9.7 (5.3)	9.7 (5.6)	9.4 (5.9)
		−14	+4	+11	+16	+26	+21	+32	+41*	+35	+29
	D-ENyp	9.3 (5.9)	8.4 (5.4)	7.9 (5.0)	7.6 (4.4)	7.0 (3.8)	7.3 (3.6)	7.0 (2.8)	6.9 (2.8)	7.2 (2.4)	7.3 (2.4)
		−14	−5	+5	+7	+26	+22	+29*	+28	+17	+19
	A-ENyp	8.0 (3.9)	8.0 (3.9)	8.3 (3.8)	8.1 (3.6)	8.8 (3.7)	8.9 (3.8)	9.0 (3.8)	8.8 (3.7)	8.4 (3.6)	8.7 (3.9)
Four stronger events	B-ENyp	8.5 (3.4)	9.8 (4.3)	10.0 (5.0)	9.5 (3.8)	9.8 (4.0)	10.3 (4.7)	10.8 (5.4)	10.8 (5.4)	10.5 (5.8)	10.0 (6.9)
		−15	+11	+28	+27	+34	+47	+66*	+48	+31	+20
	D-ENyp	10.0 (6.3)	8.8 (4.7)	7.8 (5.4)	7.5 (4.5)	7.3 (4.5)	7.0 (3.7)	6.5 (3.1)	7.3 (3.1)	8.0 (1.8)	8.3 (1.5)
		+8	+23	+47	+40	+55	+57	+69*	+41	+25	+27
	A-ENyp	10.8 (2.5)	10.8 (3.6)	11.5 (2.1)	10.5 (2.9)	11.3 (2.7)	11.0 (2.9)	11.0 (2.9)	10.3 (3.4)	10.0 (3.2)	10.5 (3.7)
Five weaker events	B-ENyp	7.6 (2.9)	7.8 (3.5)	7.8 (2.9)	8.2 (3.1)	8.0 (3.8)	7.6 (4.8)	8.2 (5.6)	8.8 (5.6)	9.0 (6.0)	9.0 (6.0)
		−14	−5	−3	+5	+18	0	+11	+25	+36*	+36*
	D-ENyp	8.8 (6.3)	8.2 (6.4)	8.0 (5.2)	7.6 (4.9)	6.8 (3.7)	7.6 (3.8)	7.4 (2.9)	6.6 (3.0)	6.6 (2.9)	6.6 (2.9)
		−34	−29	−28	−18	0	−5	0	+15*	+9	+9
	A-ENyp	5.8 (3.4)	5.8 (2.7)	5.8 (2.9)	6.2 (3.0)	6.8 (3.3)	7.2 (3.7)	7.4 (4.0)	7.6 (3.8)	7.2 (3.7)	7.2 (3.7)

*** maximum reductions.**

Table 3. Tropical storm frequencies, and standard deviations (in brackets), in the Australian region in three longitudinal bands before, during and after each of 4 stronger El Niño year periods (two months lagged) respectively, and averaged situations with percentage reductions as in Table 2.

	105°E	-	*125°E*	*125°E*	-	*145°E*	*145°E*	-	*165°E*
	B-ENyp	D-ENyp	A-ENyp	B-ENyp	D-ENyp	A-ENyp	B-ENyp	D-ENyp	A-ENyp
Jun. 1956-May 1957	3			5			4		
Jun. 1957-May 1958		4			2			2	
Jun. 1958-May 1959			2			1			5
Jun. 1964-May 1965	4			4			2		
Jun. 1965-May 1966		3			3			1	
Jun. 1966-May 1967			3			1			5
Jun. 1971-May 1972	4			3			10		
Jun. 1972-May 1973		4			4			1	
Jun. 1973-May 1974			7			2			4
Nov. 1981-Oct. 1982	1			3			0		
Nov. 1982-Oct. 1983		2			0			0	
Nov. 1983-Oct. 1984			5			3			6
Average	3.0(1.4)	3.3(1.0)	4.3(2.2)	3.8(1.0)	2.3(1.7)	1.8(1.0)	4.0(4.3)	1.0(0.8)	5.0(0.8)
	-9	+30		+65	−22		+300	+400	

Table 4. Mean frequencies, and standard deviations (in brackets), of typhoons in the northwest Pacific in different longitude intervals, before (B), during (D) and after (A) ENyps (one month lagged).

	105°E-120°E	*120°E-140°E*	*140°E-160°E*	*160°E-180°E*
B-ENyp	4.3 (2.3)	13.2 (3.1)	11.7 (3.2)	1.4 (1.3)
D-ENyp	4.1 (1.8)	7.7 (1.9)	8.1 (1.7)	2.7 (2.7)
A-ENyp	6.6 (2.1)	12.3 (3.2)	9.7 (3.6)	1.8 (1.1)

For the period 1954 to 1983, the yearly normal of storm frequencies is 8.9 in the entire Australian region (105°E–165°E), 3.2 in the band (105°E–125°E), 2.4 in the band (125°E–145°E) and 3.2 in the band (145°E–165°E). Comparing these normal values with those shown in Tables 2 and 3, we may see that the averaged storm frequencies during El Niño year periods, no matter what intensity, are all below normal (Table 2) and that a consistent below-normal storm frequency appears in the Coral Sea area during each of the four stronger El Niño year periods (two months lagged) (see Table 3).

In the northwest Pacific

An investigation similar to the above has been carried out on the relationship between El Niño and typhoon frequency in the northwest Pacific basin, and quite similar results have been found in the basin, in a qualitative sense.

First, as is shown in Table 4, the typhoon activity is suppressed by El Niño events in the basin west of 160°E, especially in the longitude interval 120°E–160°E, but excited in the extreme eastern part of the basin (east of 160°E). This appears to confirm and supplement previous findings. For example, an above-normal number of tropical storms developed in the extreme eastern part of the basin during 1972 (Atkinson 1977), a record four typhoons developed east of 170°E in October and November of both 1957 and 1972 (Ramage and Hori 1981), many more tropical cyclones formed east of the dateline in the South Pacific during 1982-1983 than in any previous year of record (Gray 1984) and an above-normal number of typhoons east of 150°E and south of 15°N in most El Niño years (Chan 1985). This phenomenon may reasonably be explained by the eastward displacement of the Walker circulation during the ENyp, mentioned earlier. Hence, only the typhoons which formed west of 160°E in the northwest Pacific are counted in the following frequency statistics, in other words, those which formed east of 160°E are excluded.

Second, a clear reduction of typhoon frequency during the ENyp (about 0-2 months lagged) has been found in comparison with those before and after the year period. All nine cases are illustrated in Fig. 2, separately. From the figure, it is seen that the typhoon formation in the northwest Pacific (west of 160°E) is consistently suppressed during each of the nine ENyps (one month lagged), without exception. This result may clarify the main inconsistency in the past studies of the El Niño and typhoon frequency relationship noted in the Introduction.

Third, the typhoon number reduction during stronger El Niño events is somewhat greater than that during weak ones. Table 5 shows various mean frequency of typhoon numbers before, during and after all nine, four stronger and five weak ENyps. It is also seen that the year periods of maximum reduction in typhoon number lag a month behind the determined ENyp for the stronger event group, but 0 and 4 months for the weak group relative to those before and after the event, respectively.

Fig. 2 Typhoon frequency numbers in the northwest Pacific (west of 160°E) before (B), during (D) and after (A) each of the nine ENyps (one month lagged). The normal frequency number is 26.3. (σ = 4.99). A significance level (5%) for testing the mean frequency during 9 ENyps is 23.0. Both of them are shown by dashed lines, respectively.

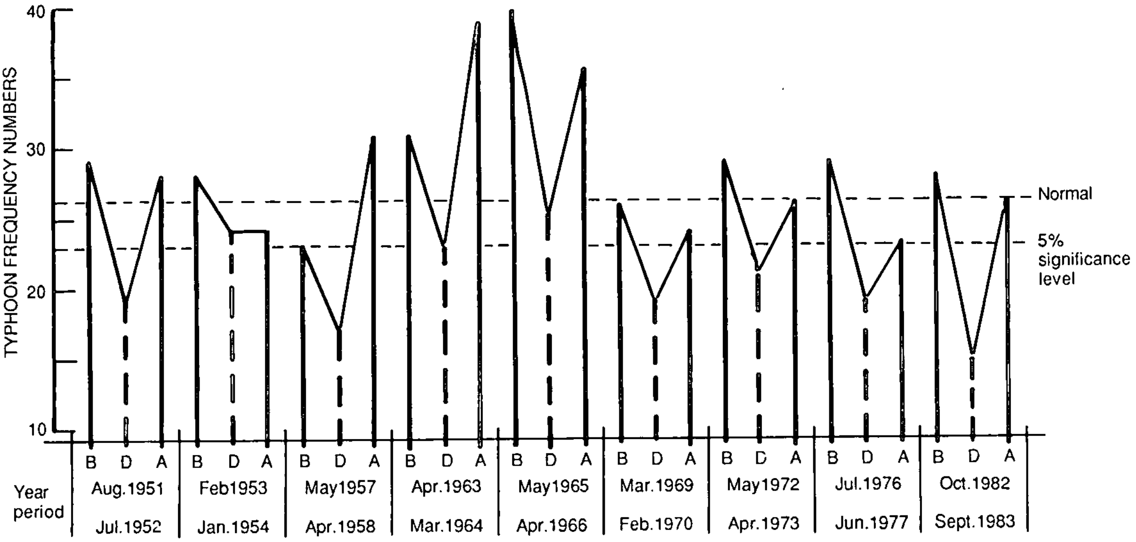

Table 5. Various mean frequency numbers, and standard deviations (in brackets), of typhoons in the northwest Pacific (west of 160°E) before, during and after all nine, 4 stronger and 5 weaker El Niño year periods and their percentage reductions during ENyp compared with those before and after ENyp.

		Twelve-month period before ENyp number of months in advance				*ENyp*	*Twelve-month period after ENyp number of months lag*				
		4	*3*	*2*	*1*		*1*	*2*	*3*	*4*	*5*
All nine events	B-ENyp	27.6	28.0	29.1	29.6	29.6	29.2	28.8	27.6	27.2	26.1
		(5.3)	(4.6)	(4.6)	(4.4)	(4.5)	(4.6)	(5.5)	(6.0)	(6.1)	(6.3)
		18	24	38	42	46*	45	41	31	24	9
	D-ENyp	23.4	22.6	21.1	20.8	20.3	20.2	20.4	21.1	22.0	24.0
		(4.1)	(3.8)	(3.8)	(3.8)	(3.8)	(3.3)	(2.4)	(2.6)	(2.9)	(2.2)
		10	19	28	34	41	42*	42*	41	35	22
	A-ENyp	25.7	26.9	27.1	27.8	28.6	28.6	29.0	29.8	29.6	29.2
		(4.6)	(5.3)	(4.9)	(5.5)	(5.7)	(5.7)	(5.4)	(5.3)	(6.8)	(5.9)
Four stronger events	B-ENyp	29.8	29.5	30.5	30.8	30.3	30.0	29.8	29.0	27.0	26.5
		(5.9)	(5.5)	(5.5)	(5.9)	(6.8)	(7.2)	(7.8)	(8.1)	(8.2)	(7.9)
		30	29	45	50	52	54*	47	39	18	8
	D-ENyp	23.0	22.8	21.0	20.5	20.0	19.5	20.3	20.8	22.8	24.5
		(4.8)	(4.3)	(4.3)	(4.0)	(3.8)	(4.4)	(3.0)	(2.2)	(2.5)	(2.5)
		17	20	32	40	50	53*	47	42	25	20
	A-ENyp	27.0	27.3	27.8	28.8	30.0	29.8	29.8	29.5	28.5	29.4
		(4.2)	(5.1)	(4.5)	(4.6)	(4.9)	(4.9)	(3.6)	(4.4)	(7.7)	(6.5)
Five weaker events	B-ENyp	25.8	26.8	28.0	28.6	29.0	28.6	28.0	26.4	27.4	25.8
		(4.5)	(4.0)	(4.1)	(3.2)	(2.3)	(1.8)	(3.5)	(4.3)	(5.0)	(5.6)
		8	20	32	36	41*	38	36	23	28	9
	D-ENyp	23.8	22.4	21.2	21.0	20.6	20.8	20.6	21.4	21.4	23.6
		(4.0)	(3.7)	(3.9)	(4.0)	(2.8)	(2.5)	(2.1)	(3.1)	(3.3)	(2.3)
		3	19	25	29	32	33	38	40	42*	23
	A-ENyp	24.6	26.6	26.6	27.0	27.2	27.6	28.4	30.0	30.4	29.0
		(5.0)	(6.0)	(5.7)	(6.5)	(6.7)	(6.7)	(6.8)	(6.4)	(6.8)	(6.2)

*** maximum reductions.**

A contrast

The El Niño event has a common suppression effect on the tropical storm or typhoon formation in both the Australian region and the northwest Pacific basin. The reduction in storm or typhoon number during stronger El Niño events is commonly greater than that during weak ones in both the region and the basin (see Tables 2 and 5). The longitude band or interval where the storm or typhoon formation is apparently most suppressed by the El Niño event is bounded between about 145°E–165°E in the South Pacific and between 120°E–160°E in the north Pacific (see Tables 3 and 4). The year periods of maximum reduction in storm or typhoon number during stronger El Niño events lag two months behind the ENyp in the Australian region and one month in the northwest Pacific (west of 160°E). The relationship between El Niño and tropical cyclone frequency is therefore seen to be essentially similar in the Australian region and in the northwest Pacific basin.

Conclusion

A concept of El Niño year periods and a division of their intensity are introduced and determined by the period of maximum warm 12-months and the degree of the sea surface temperature anomaly in the eastern equatorial Pacific in the study. Based on the El Niño year periods and consideration of the Walker circulation variation, it has been found that the El Niño has the effect of suppressing the tropical cyclone activity in both the Australian region and the northwest Pacific. The reduction in tropical cyclone frequency appears most consistently and is most marked in that part of the southwest Pacific from 145°E–165°E and in that part of the northwest Pacific from 120°E–160°E during each of the four stronger El Niño periods (two and one months lagged, respectively). These results help to explain why some earlier studies led to apparently inconsistent conclusions.

Although our results are reasonable, they remain to be confirmed in the future because of the small size of study samples.

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