ENSO AND SUMMER FIRE DANGER IN VICTORIA, AUSTRALIA

H. Stern and M. Williams
Bureau of Meteorology, Melbourne

INTRODUCTION

Williams (1987) describes the southern oscillation phenomenon as follows:

> It is well known that the Southern Oscillation (SO) has a strong influence on rainfall over the Australian region (e.g. Pittock, 1975; McBride and Nicholls, 1983). However, neither the mechanisms behind this relation, nor the link between the SO and the tropospheric circulation, is well understood.

The SO was first observed in the late 19th century and many of its features were mapped by Sir Gilbert Walker and his colleagues in the early decades of the present century. Walker characterised the SO as follows: `When the pressure is high in the Pacific Ocean it tends to be low in the Indian Ocean from Africa to Australia; the conditions are associated with low temperatures in both these areas and rainfall varies in the opposite direction to pressure'. In recent years a large number of papers describing the SO have been written giving detailed descriptions of various aspects of the phenomenon, e.g. Troup (1965), Bjerknes (1966, 1969), Trenberth (1976), Wright (1977), Rasmusson and Carpenter (1982) and Wright at al. (1985). The SO is now recognised as a planetary-scale phenomenon related to the intensity of the Walker circulation, essentially an east-west cell with its upward branch north of Australia and downward branch over the tropical eastern Pacific.

The phase and intensity of the SO can be quantified in terms of a Southern Oscillation Index (SOI), of which there are several definitions. For this paper the index described by Troup (1965), that is, the mean sea level pressure differences between Papeete (Tahiti) and Darwin, normalised for each calendar month, was chosen. This definition is suitable since Tahiti and Darwin are located close to the poles of the Walker circulation, and, together their pressures are indicative of the state of the circulation. Chen (1982) in an investigation of various indices recommends the above definition of the SOI for use in diagnostic studies. The SOI typically has a period of between 2 and 7 years (see Fig 1). In recent years an oscillation of pressure, as well as upper and lower tropospheric winds at a somewhat higher frequency than the so, has been noted, e.g. Madden and Julian (1971,1972). The oscillation has a period of 40 to 50 days in the mean, and appears to be a global eastward propagating tropical disturbance of order wave number one. Due to a difference in phase of this wave between Darwin and Tahiti longitudes and because the period of this wave is between one and two months, it is inevitable that some component of this 40 to 50 day cycle will be included in the monthly values of the SOI (see Madden and Julian, 1972). That is, the SOI each month appears to consist of a large component due to the effect of the SO, and a small component due to the 40 to 50 day cycle.

It is common practice to use three-monthly seasonal means for diagnostic studies of the SO. This has the effect of filtering the 40 to 50 day cycle from the SOI. For this study, however, monthly values of the SOI and tropospheric data have been utilised without any filtering. That is, there is no attempt to isolate the effects of the SO and the 40 to 50 day cycle on the Australian troposphere.

This approach has the advantage that, since there is temporal smoothing beyond one month, the structure of the response of the Australian SO through the seasons is documented.

The other clear advantage of using monthly mean data is that any given monthly values of the SOI (whether observed or forecast) can be used directly to estimate the effect of the SO on the Australian troposphere, without having to determine what proportion of the signal is due to the filtered and unfiltered components of the SOI.

Fire fighting authorities in Victoria have issued bans against the lighting of fires in the open since the 1945/46 season. Over the 22 seasons 1945/46 to 1986/87 inclusive, the number of such bans imposed have varied from nil to 27, the median being 8. As bans are only imposed when authorities consider the fire danger potential to be particularly high, the number imposed in a season may be regarded as an overall measure of the fire risk in that season.

The relationship between SOI and rainfall over Australia has already been discussed. This relationship is particularly marked in spring. It is with this in mind, that the present paper explores the relationship between an El Nino Southern Oscillation 'event' (associated with sustained negative values of the SOI) and Victorian seasonal fire danger.

DISCUSSION

For the purpose of this study, an El Nino Southern Oscillation (ENSO) 'event' shall be defined as follows:

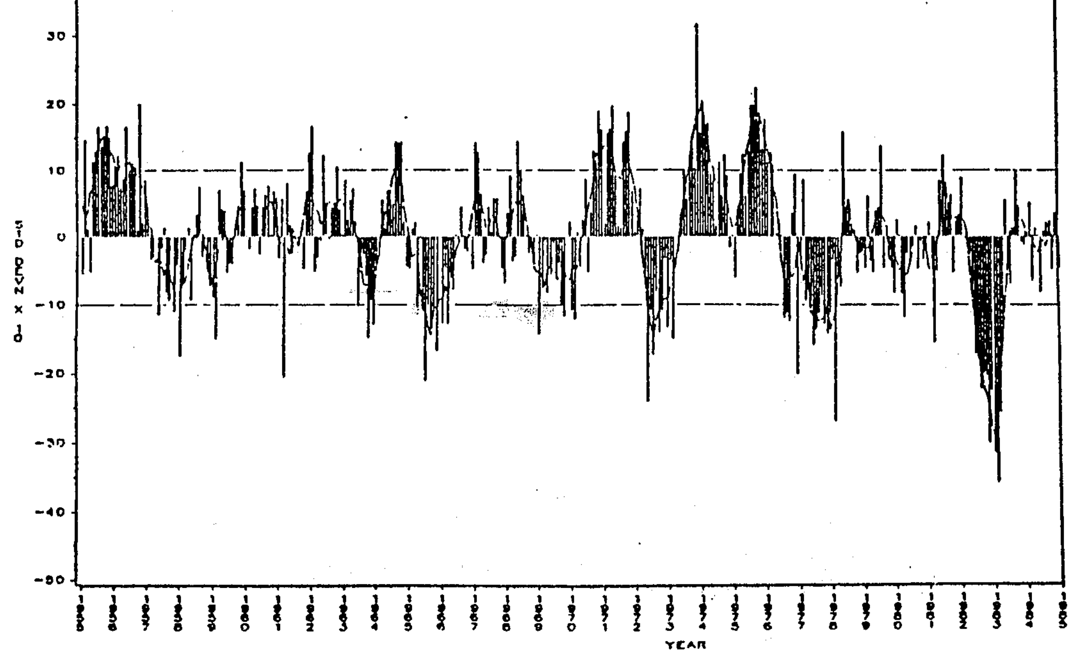
- a calendar month shall be considered to be included in an ENSO 'event' if it is located in a sequence of at least 12 consecutive months, at least 11 of which has a negative SOI and, if it is the first or last of such a sequence, its SOI is negative); and, conversely,
- a calendar month shall be considered to be included in a La Nina Southern Oscillation (anti-ENSO) 'event' if it is located in a sequence of at least 12 consecutive months, at least 11 of which has a positive SOI (and if it is the first or last of such a sequence, its SOI is positive).

That the SOI is highly correlated with Victorian rainfall is illustrated by Fig 2, which depicts how seasonal data for Melbourne relates to the occurrence of an ENSO or anti-ENSO 'event'. It shows that the probability of rainfall during spring being below the median during an ENSO 'event' is 86%, while in springs with a strong anti-ENSO signal, the probability is only 32%. A fairly strong relationship is also depicted for summer.

Jasper and Stern (1983) have classified southeast Australian synoptic situations into 38 different synoptic types (Fig 3). Table 1 shows that the majority of these synoptic types are associated with a lower probability of rainfall occurrence during ENSO 'events' than during anti-ENSO 'events'.

The relationship between ENSO and mean circulation parameters over Australia also has been well documented (Williams 1987). In Melbourne, the mean MSL pressure during ENSO is shown to be higher than that during an anti-ENSO 'event' for most times of the year, particularly winter and spring. The mean surface flow also possesses a southwesterly anomaly during ENSO 'events' for most times of the year, particularly during the summer half (see Table 2). Furthermore, a number of Jasper and Sterns' (1983) synoptic types occur with

FIG 1 (after Williams, 1987)



The SOI for the period 1955-1984. The dashed line represents a five month running mean.

FIG 2 PROBABILITY MELBOURNE SEASONAL RAINFALL IS BELOW THE MEDIAN

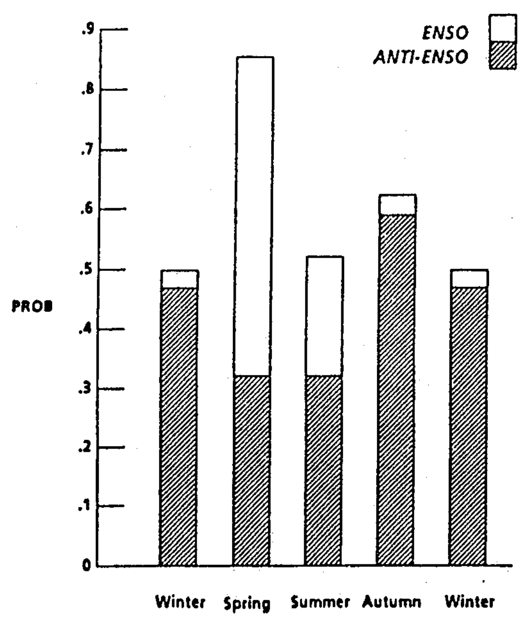
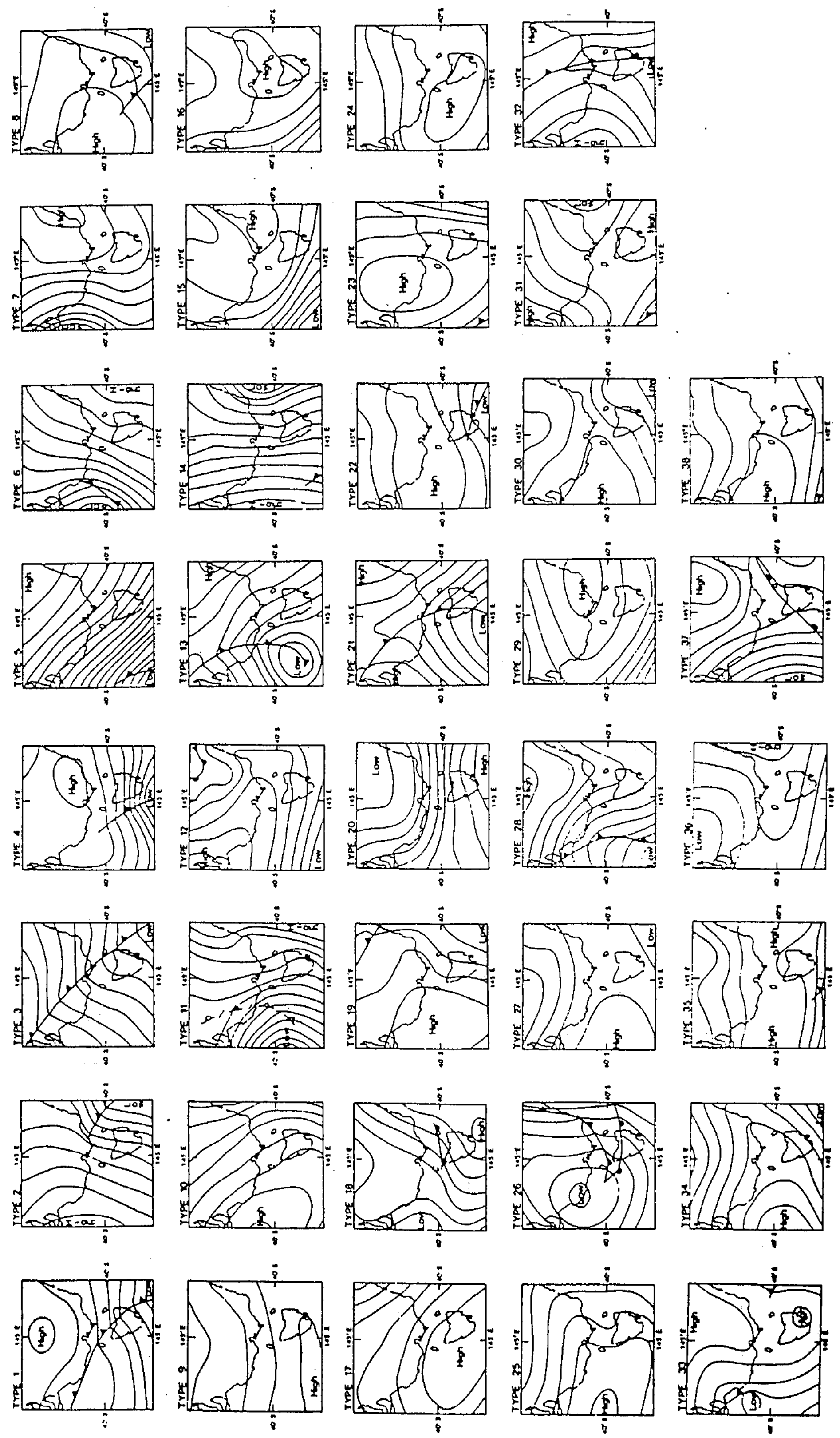
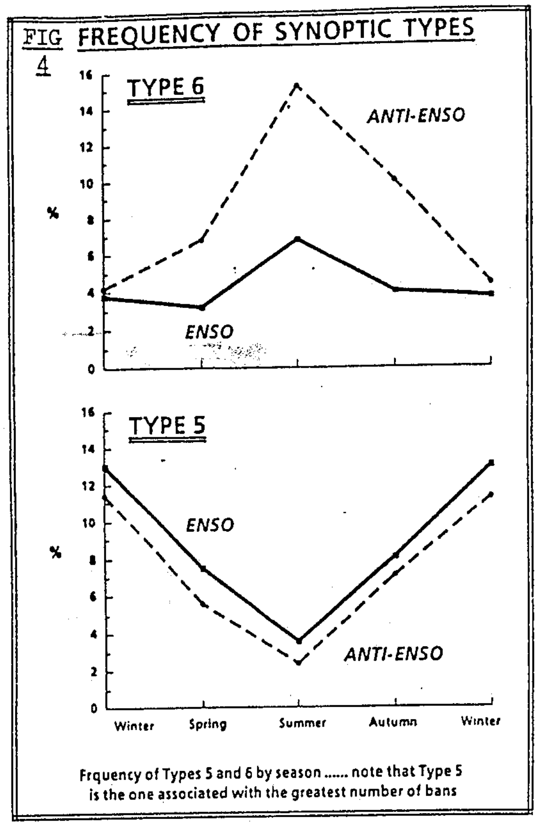
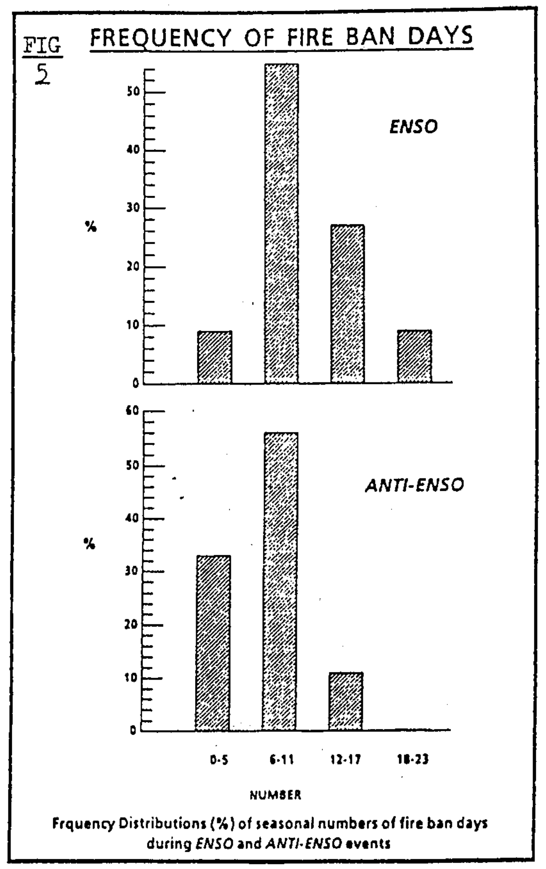
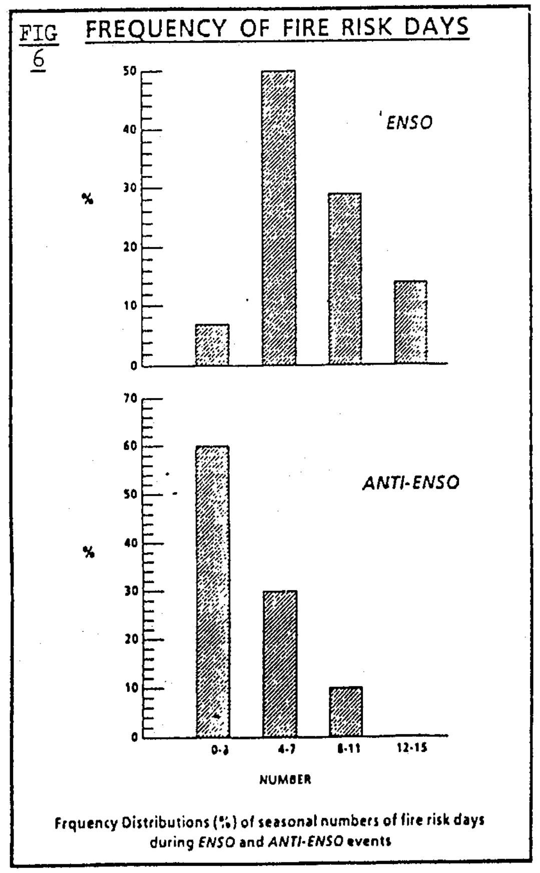


FIG 3 Jasper and Stern's (1983) synoptic types









significantly different frequencies during ENSO and anti-ENSO 'events' (see Fig 5 for an illustration of this relationship).

Table 1 Probability of precipitation in Melbourne, within 24 hours before or after the occurrence of each of Jasper and Sterns' (1983) synoptic types: (a) ENSO; (b) neither ENSO nor anti-ENSO; (c) anti-ENSO

Type	(a)	(b)	(c)	Type	(a)	(b)	(c)	Type	(a)	(b)	(c)
1	64	74	78	14	89	97	95	27	44	31	6
2	84	88	89	15	24	22	29	28	68	72	86
3	84	90	95	16	13	18	26	29	27	26	10
4	30	38	48	17	33	41	26	30	29	37	25
5	44	50	63	18	55	70	50	31	93	93	91
6	28	32	36	19	55	60	62	32	71	83	83
7	35	34	43	20	64	66	62	33	60	41	50
8	42	44	48	21	59	65	67	34	44	33	56
9	14	30	33	22	16	17	26	35	13	19	7
10	84	81	84	23	72	58	83	36	28	29	25
11	68	53	80	24	32	39	50	37	46	62	44
12	59	59	74	25	42	43	29	38	56	29	40
13	76	85	89	26	95	86	89				

Table 2 Frequency of synoptic types by season (%), for types with all 4 seasons having the ENSO 'event' frequency* greater than or equal to the anti-ENSO 'event' frequency#, and for types with all 4 seasons having the ENSO 'event' frequency less than or equal to the anti-ENSO 'event' frequency

Type		SU	AU	WI	SP	Type		SU	AU	WI	SP
2	*	7.8	7.3	9.6	11.2	12	*	3.5	2.0	0.7	2.0
	#	5.5	5.8	7.7	8.8		#	1.9	1.4	0.5	1.8
4	*	8.0	10.9	7.8	11.2	17	*	1.1	1.3	1.3	0.9
	#	5.2	6.3	4.2	6.8		#	1.2	3.0	2.6	1.5
5	*	3.5	8.2	13.0	7.5	19	*	3.3	2.0	0.7	1.3
	#	2.4	7.4	11.4	5.5		#	2.4	1.2	0.2	1.1
6	*	6.9	4.0	3.7	3.1	32	*	3.0	0.9	0.2	0.5
	#	15.2	10.0	4.4	6.8		#	1.9	0.5	0.2	0.2
8	*	7.0	5.8	2.6	6.6	34	*	1.3	0.9	0.2	0.7
	#	4.3	4.2	1.6	2.9		#	1.0	0.7	0.2	0.2
9	*	6.5	2.7	2.2	1.8	37	*	0.2	0.7	1.3	0.4
	#	10.0	7.0	2.9	1.8		#	0.0	0.5	1.2	0.4

Table 3 Seasonal variation of values of various synoptic parameters, represented by the seasonal mean during ENSO 'events' minus that during anti-ENSO 'events'.

(a) MSL pressure (tenths of hPa) at Melbourne.
(b) MSL pressure (tenths of hPa) at Mt Gambier minus that at Gabo Is.
(c) MSL pressure (tenths of hPa) at Hay minus that at Smithton.

	SU	AU	WI	SP
(a)	+5	+6	+28	+22
(b)	+13	+9	-3	+8
(c)	+13	+8	-3	+8

With this background, the relationship between a season's fire danger potential and ENSO is explored and shown to be strong. The probability of the median number of bans being exceeded is found to be 64% during an ENSO 'event', and to be only 22% when a strong anti-ENSO signal is observed (see Fig 5 for an illustration of this relationship).

Bans may not be entirely determined by the fire risk. A fire risk potential may be regarded as being associated with an observation of dry bulb 30.0 oC or more, dew point 10 oC or less, wind speed 15 knots or more, and rainfall over the past week 5.0 mm or less. This definition is applied to observations at Melbourne's main airport (Essendon /Tullamarine) over the seasons 1939/40 to 1986/87 and the median number of days when it is satisfied is 6. Tables 4 and 5 summarise the frequency of 'fire ban' and 'fire risk' days by synoptic type.

The relationship between the fire risk and ENSO 'events' is shown to be stronger under this definition (of fire risk) than when employing the imposition of bans as an indicator, the median being exceeded on 71% of ENSO cases and only 10% of anti-ENSO cases. This stronger relationship is illustrated by Fig 6.

CONCLUSION

The relationship between the ENSO phenomenon and fire danger in Victoria has been illustrated. The potential exists for using this relationship to provide some indication to fire control authorities of the likely severity of a forthcoming season (because of the stability of the SOI). This was successfully done for the 1988/1989 season, when a strong positive SOI was evident during the preceding spring. Fire control authorities were correctly advised that a 'quiet' season was likely.

ACKNOWLEDGMENT

The authors wish to thank Dr. N. Nicholls for his encouragement with this work.

Table 4. Frequency (8) of fire bans (seasons 1957/59 to 1978/79) by synoptic type.

Type	Frequency
5	17
11	17
6	14
7	10
21	7
13	6
4	5
3	3
15	3
8	2
18	2
26	2
32	2
1	1

(Other types all less than 1%)

Table 5. Frequency (%) of fire risk days (seasons 1957/58 to 1978/79) by synoptic type.

Type	Frequency
5	27
11	21
7	10
21	9
13	8
19	5
26	5
6	4
4	3
1	2
15	2
3	1
28	1

(Other types all less than 1%)

REFERENCES

Bjerknes, J. 1966. A possible response of the atmospheric Hadley circulation to equatorial anomalies of ocean temperature. *Tellus, 18,* 820-829.

Bjerknes, J. 1969. Atmospheric teleconnections from the equatorial Pacific. *Mon. Weath. Rev.,* ?? 163-172.

Chen, W. Y. 1982. Assessment of Southern Oscillation sea-level pressure indices. *Mon. Weath. Rev., 110,* 800-807.

Jasper, J.D. and Stern, H. 1983. Objective classification of synoptic pressure patterns over southeast Australia. *Proc II International Meeting on statistical climatology,* Lisboa.

Madden, R.A. and Julian, P.R. 1971. Detection of a 40-50 day oscillation in the zonal wind in the tropical Pacific. *J. Atmos. Sci., 28,* 702-708.

Madden, R.A. and Julian, P.R. 1972. Description of global-scale circulation cells in the tropics with a 40-50 day period. *J. Atmos. Sci., 29,* 1109-1123.

McBride, J.L. and Nicholls, N. 1983. Seasonal relationships between Australian rainfall and the Southern Oscillation. *Mon. Weath. Rev., 111,* 1988-2994.

Pittock, A.B. 1975. Climatic change and the patterns of variation in Australian rainfall. *Search, 6,* 498-504.

Rasmusson, E.M. and Carpenter, T.H. 1982. Variations in tropical sea surface temperature and surface wind fields associated with the Southern Oscillation/El Nino. *Mon. Weath. Rev., 110,* 354-384.

Trenberth, K.E. 1976. Spatial and temporal variations of the Southern Oscillation. *Q. Jl R. met. Soc., 102,* 639-653.

Troup, A.J. 1965. The Southern Oscillation. *Q. Jl R. met. Soc., 91.* 490-506.

Williams, M. 1987. Relations between the southern oscillation and the troposphere over Australia. *BMRC Research Report No. 6,* Bur. Met., Australia.

Wright, P.B. 1977. The Southern Oscillation - Patterns and mechanisms of the teleconnections and the persistence. *HIO-77-13,* Hawaii Inst. Geophys., University of Hawaii, 207pp.

Wright, P.B., Mitchell, T.P. and Wallace, J.M. 1985. Relationships between surface observations over the global oceans and the Southern Oscillation, *NOAA Data Report, ERL PMEL-12.*

SESSION 4

ADDITIONAL OBSERVATIONS