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1. INTRODUCTION

Some earlier definitions of El Niño or El Niño-Southern Oscillation (ENSO) focused specifically on anomalously warm sea surface temperatures (SSTs) along the coast of Ecuador and Peru (SCOR, 1983; Quinn et al., 1987; Meyers & O'Brien, 1995), and indeed the name originated in reference to such anomalies. Lately, and more commonly, definitions and references are likely to refer to larger scale phenomena encompassing anomalies within the Pacific basin (Cane et al., 1986, Linacre & Geerts, 1997; Trenberth, 1997). Usually such definitions are in the form of a quantitative analysis of indices associated with Equatorial or near Equatorial Pacific sea surface temperatures, or for ENSO, atmospheric pressure gradients such as those between Darwin and Tahiti. There have also been more subjective, although considered, analyses used to define El Niño events (Quinn et al., 1987; Ortlieb, 2000). There is no consensus on a definition.

Predominantly, qualitative El Niño definitions involve analysing data which have been averaged or smoothed over several months, usually over five or more months (Ropelewski & Jones, 1987; Meyers & O'Brien, 1995; Trenberth, 1997; Trenberth & Stepaniak, 2001). A long term average is used in an effort to reduce local noise (Trenberth, 1984). From such definitions lists of historical El Niño (and sometimes La Niña) events have been formed (Meyers & O'Brien, 1995; Trenberth, 1997; Legler et al., 1999; Larkin & Harrison, 2002). There is no full consensus on an event list.

Definitions of El Niño which require long term averages of indices are useful in studies of historical events. However, climate responses associated with El Niño (e.g. periods of low rainfall over Australia) may develop relatively quickly, with noticeable impacts often within the first few months of an El Niño event.

In an operational environment (i.e. one where real time climate monitoring takes place) it is important to be able to establish the onset of an El Niño as soon as possible. Thus, a definition which requires many months of consecutive real time data analysis would not be helpful in such an environment.

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The US National Oceanic and Atmospheric Administration (NOAA) recently proposed an operational definition of El Niño which is based on a three month average of Niño 3.4 SST anomalies being greater than or equal to 0.5°C (pers. comm.). The Japanese Meteorological Agency (JMA) proposes a definition based on six consecutive months of SST in the JMA region (4°N - 4°S, 150°W - 90°W).

Trenberth (1997) examines three different thresholds (0.3°, 0.4° and 0.5°C) over the two regions Niño 3 and 3.4. In comparing the resultant El Niño events list with "what have historically been considered as events" he found that a 0.4° threshold over a period of five months for the Niño 3.4 region identified his events list most closely.

This paper presents a brief analysis of SST and atmospheric data in an effort to establish the probability of a retrospective classification for El Niño given that a real time index has exceeded a certain threshold. The aim is to examine any validity in the use of three months of data to define El Niño.

2. METHOD

The statistical analysis is based on a simple contingency table (Table 1), using a dichotomous forecast of an El Niño event occurring or not occurring.

		Forecast	
		Yes	No
Observed	Yes	Hit (H)	Miss (M)
	No	False Alarm (FA)	Correct Rejection (CR)

Table 1. Deterministic forecast table (contingency table) showing the method of determining the hit, miss, false alarm and correct rejection rates.

Hit rates and false alarm rates were then calculated from the table using:

- Hit Rate (HR) = $H/(H + M)$ = the proportion of perfect forecasts.
- False Alarm Rate (FAR) = $FA/(FA + CR)$ = the proportion of forecasts of the event when it did not occur.

In an attempt to obtain an indication of the ability of each index it is important to examine probabilities of both:

- The occurrence of an El Niño given an index threshold (El Niño | index).
- Reaching an index threshold given an El Niño (index | El Niño).

These probabilities are then combined into one value of the form:

- Total Acceptance (TA) = (HR (El Niño | index) – FAR (El Niño | index)) + (HR (index | El Niño) – FAR (index | El Niño)).

Indices tested were SSTs anomalies in each of the Niño regions (Niño 1, 2, 3, 4 and 3.4) exceeding the thresholds of 0.4°, 0.5°, 0.6°, 0.7°, 0.8° and 0.9°C, and anomalies in each Niño region exceeding fractions (0.3, 0.4, 0.5, 0.6, 0.7) of the standard deviation. SOI below values of -3, -4, -5, -6, -7, -8 and -9 were also used as index thresholds.

SST data for the Niño regions were based on those from the Climate Prediction Center (CPC). For SOI the Troup method (Troup, 1965) has been used, with the base period for the calculation of the standard deviations being 1933 – 1992. These data were used to examine El Niño events over the last 50 years. Both three month running means and three consecutive months of values exceeding thresholds were examined, and compared to similar results based on five months of running means and five consecutive months exceeding a threshold. Combinations of indices (Niño X and/or SOI, Niño X and/or Niño Y) were also tested.

To implement this scheme it is necessary to have a list of El Niño events, including start and end months of each event. It would be almost impossible to arrive at a widely accepted consensus list of El Niño years, let alone a consensus of starting and ending months for those years. To obtain such a list we used SST maps of the Pacific region (Reynolds & Smith, 1994; Kaplan et al., 1998), sea surface heights, tide heights at Santa Cruz Galapagos Islands, rainfall over Australia and a Southern Oscillation Index (SOI). Once approximate dates were defined the start and end dates were refined by a visual analysis of SST maps. In compiling the list it was important to get a general consensus based on as much of the data source as possible, thus decreasing the reliance on one source of data over another. The more popular opinion was used, that an El Niño event is a Pacific basin-wide phenomenon rather than being confined to a warming along the Peruvian coast. The final list was then checked against lists compiled by others for consistency and to further refine start and end dates where necessary.

Importantly, this was a list which we felt we could be confident in, that was relatively defensible and did not rely too heavily or immediately on indices that would later be used as potential predictors.

In the list (Table 2) there are a total of 15 events over the 50 year period, averaging to an event approximately every 3½ years. The duration of the sum of events is 173 months, which is 1 in 3.5 months, with the average duration of each event being 11.5 months. From this it is apparent that the Pacific exhibits El Niño conditions approximately 29% of the time.

Begin	End	Duration
May 1951	Dec 1951	8
Mar 1953	Sep 1953	7
Mar 1957	Apr 1958	14
Jul 1963	Jan 1964	7
Mar 1965	Mar 1966	13
Jan 1969	Feb 1970	14
Mar 1972	Feb 1973	12
May 1976	Jan 1977	9
May 1977	Feb 1978	10
Apr 1982	Oct 1983	19
Sep 1986	Jan 1988	17
Apr 1991	May 1992	14
Feb 1993	Aug 1993	7
Aug 1994	Feb 1995	7
Mar 1997	Mar 1998	15

Table 2. A subjective list of El Niño events between 1950 and 2000. The start and end month of each event is given, along with the duration in months.

3. RESULTS

Results suggest that the SST indices tested here generally produce better probabilities of El Niño's than do the SOI indices alone. Running means of data produce better results than do three consecutive months of data reaching a threshold. Further, using a five month running mean is marginally better than using a three month running mean.

The results presented in Table 3 are based on the thresholds of SST anomalies exceeding 0.5 times the standard deviation of long term SSTs for the combination of Niño 3 or Niño 3.4. This was the best performer of the indices tested.

It is worth noting that other indices performed well. Two are worth mentioning. The thresholds based on a three month running mean of SSTs in the Niño 3 or Niño 3.4 region being greater than (0.4 and 0.5) of the average SST both performed very well, and indeed had a higher HR(El Niño | index) than did the best overall result. These indices were let down, however, in their FAR which was around 10%.

		HR	FAR	TA
3 month running mean	El Niño index	0.90	0.05	
	index El Niño	0.89	0.04	1.70
5 month running mean	El Niño index	0.90	0.04	
	index El Niño	0.90	0.04	1.72

Table 3. Results of Hit Rate, False Alarm Rate and Total Acceptance.

Table 4 presents the resultant list of El Niño events based on the best performed three month running mean index (as presented in Table 3). It is obvious that this definition simulates the subjective list quite well. The method correctly identifies each of the El Niño events of the last 50 years. The main anomaly, in comparison to the subjective list, is the event in 1977-1978 which is truncated here to a duration of four months. This event is not always recognised as an El Niño event, or is at most regarded as a weak event.

Begin	End	Duration
Jul 1951	Dec 1951	7
Mar 1953	Aug 1953	6
Apr 1957	Jul 1958	16
Aug 1963	Jan 1964	6
May 1965	May 1966	13
Nov 1968	Mar 1970	17
Apr 1972	Mar 1973	12
Jul 1976	Feb 1977	8
Oct 1977	Jan 1978	4
Apr 1982	Aug 1983	17
Aug 1986	Feb 1988	19
Apr 1991	Jun 1992	15
Mar 1993	Jul 1993	5
May 1994	Mar 1995	11
Apr 1997	May 1998	14

Table 4. List of El Niño events between 1950 and 2000 as a result of the quantitative analysis performed here. The start and end month of each event is given, along with the duration in months.

4. CONCLUSION

It has been shown that it is possible to use three months of current SST data to define an El Niño event, and this is perhaps suitable for an operational environment. A definition based on the three month running mean of either Niño 3 or Niño 3.4 exceeding $0.5 \times$ the standard deviation of those regions is able to correctly identify each of the El Niños for the last 50 years, and simulates the duration of each of these events reasonably well.

As an aside, it is worth noting that using this definition the current (2002) event would have been able to be declared in early August with a confidence of 90% and a false alarm rate of 5%. The current event would then have been declared as starting from May 2002.

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