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The El Niño–Southern Oscillation and daily temperature extremes in east Asia and the west Pacific

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[1] The numbers of warm nights and hot days, across most of the east Asia – west Pacific region, increase substantially in the year after the onset of an El Niño event. The number of cool days and cold nights tend to decrease, although the relationship with El Niño is weaker for these variables. The relationship is confounded, for warm nights and hot days, by a strong increasing trend in the numbers of extremes not matched by a trend in the El Niño. Removal of this trend leads to even stronger correlations with the El Niño. Strong correlations exist between some of the extremes indices and an index of the El Niño – Southern Oscillation in months prior to the occurrence of the extremes, indicating that predictions of the frequency of extreme temperatures across the region should be feasible. **Citation:** Nicholls, N., et al. (2005), The El Niño–Southern Oscillation and daily temperature extremes in east Asia and the west Pacific, *Geophys. Res. Lett.*, *32*, L16714, doi:10.1029/2005GL022621.

1. Introduction

[2] The El Niño – Southern Oscillation is known to be related to temperature across east Asia and the west Pacific [e.g., *Kiladis and Diaz*, 1989], with warmer temperatures generally associated with an El Niño episode. Less is known, however, about how the phenomenon is related to daily temperature extremes. *Trewin* [2001] found that the El Niño – Southern Oscillation was related to climate extremes in many parts of Australia, and suggested that the relationship was sufficiently strong to allow the prediction of extremes.

[3] The Asia-Pacific Network (APN) for Global Change Research has provided funding for five workshops on extremes since 1998, hosted by the Australian Bureau of Meteorology Research Centre (BMRC), and aimed at the preparation of consistent analyses of climate extremes (from daily data) across eastern and southeastern Asia and the western Pacific. This region historically has had lower data digitisation and availability rates than many other parts of the globe. Representatives from at least a dozen countries attended each workshop, and consistent methods of quality control and trend analysis were applied across the region. The results from the second workshop (1999) showed considerable spatial consistency within countries and across the Asia-Pacific region, in both the sign and magnitude of the trends in extreme temperature indices (the frequency of hot days, warm nights, cool days, and cold nights) [*Manton et al.*, 2001]. The third APN workshop (2001) reviewed data storage and analysis capacity in the Asia-Pacific countries, and exchanged software for quality control and analysis of climate extremes. Metadata and data rescue were the focus of the fourth workshop (2002), providing an assessment of metadata, data quality and availability in the Asia-Pacific region [*Page et al.*, 2004], and emphasising the need for data rescue projects to get data from paper to digital form.

[4] The fifth APN extremes workshop was held in Australia in March 2004, with participants from 16 countries (Australia, China, Fiji, French Polynesia, Indonesia, Japan, Korea, Malaysia, New Caledonia, New Zealand, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand, Vietnam) providing data between longitudes 87°E to 139°W, and from 46°N to 47°S. Data examined at that workshop have been examined for trends in the various indices of extreme temperatures [*Griffiths et al.*, 2005]. This paper focuses on the relationship between the El Niño – Southern Oscillation and extreme daily temperatures in the Asia-Pacific region.

2. Data and Analysis Methods

[5] A set of 89 high-quality data from stations across east Asia and the west and south Pacific (Figure 1 shows their locations) was used for analysis (see *Griffiths et al.* [2005] and *Manton et al.* [2001] for details of quality control and station selection). Most stations had data from 1961–2003. A small proportion of stations did not have data for the

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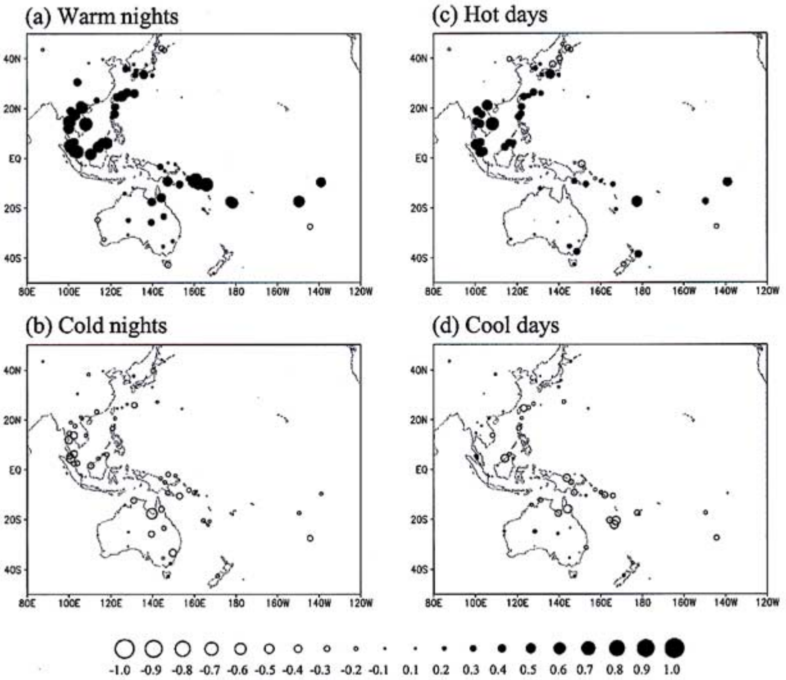

Figure 1. Lag correlation map between NINO3.4 August sea surface temperatures (Year −1) and (a) warm nights, (b) cold nights, (c) hot days, and (d) cool days in the following year (Year 0). Closed circles indicate positive correlations and open circles indicate negative correlations with symbol size proportional to correlation coefficient. Detrended data from 1961–2003 used.

complete period (e.g., Samoa, Solomon Islands, and Papua New Guinea). This study uses extreme indices based on percentiles calculated on daily data. The 1st and 99th percentiles in each calendar year for each of the variables described below were calculated using all non-missing days, the 1st percentile corresponding to the fourth lowest value and the 99th percentile to the fourth highest value in each year. These indices have been used for other studies with these data [*Manton et al.*, 2001; *Griffiths et al.*, 2005]. Four extreme indices were calculated for each year:

[6] ■ Hot days: frequency of days with maximum temperature above the 1961–1990 mean 99th percentile (the 1961–1990 period conforms to the World Meteorological Organization's recommended standard period for calculating normals).

[7] ■ Cool days: frequency of days with maximum temperature below the 1961–1990 mean 1st percentile.

[8] ■ Warm nights: frequency of days with minimum temperature above the 1961–1990 mean 99th percentile.

[9] ■ Cold nights: frequency of days with minimum temperature below the 1961–1990 mean 1st percentile.

Note that these are real extremes, i.e. they are not normalised for the time of year. Thus time series of annual values (January to December) break the warm season in the southern hemisphere and the cool season in the northern hemisphere. The daily temperature time–series were also used to compute an annual average for both maximum temperature and minimum temperature.

[10] Trends in each of these indices showed considerable similarity across the region [*Manton et al.*, 2001; *Griffiths et al.*, 2005]. Also, *Kiladis and Diaz* [1989] showed that across most of the region investigated here mean temperatures were related to the El Niño – Southern Oscillation in the same way, with above average temperatures tending to follow the onset of a warm event. The lag relationships between the four indices and an index of the El Niño, namely the NINO3.4 sea surface temperatures (averaged over the region 5°N–5°S, 120°W–170°W and obtained from the Climate Explorer web site at http://climexp.knmi.nl) were calculated for each station (Figure 1). The correlations for each of the variables were of the same sign over most of the region. For instance, the correlation between the number of warm nights and the NINO3.4 from August of the previous year (top left-hand frame of Figure 1) were positive except for one station in the central south Pacific and higher latitude stations in Australia, New Zealand, China and Japan. Similar spatial consistency in the sign of the correlations was found with NINO3.4 data from months between June of the previous year and March of the year for which the extremes were calculated.

[11] The overall similarity in correlations across most of the region means that a simple arithmetic mean of the indices at all stations can provide an index of regional temperature extremes. So a simple arithmetical mean across the 89 stations, of the annual values of each index, was calculated for each year 1961–2003. These areal-average extreme indices were then correlated with NINO3.4 sea surface temperatures. Note that the extremes indices refer to annual values – these were correlated with monthly NINO3.4 values starting 12 months before the start of the year to which the extremes indices apply, and continuing through to the end of the year to which the extremes indices apply (ie, from January in Year −1 to December in Year 0, where Year −1 is the year prior to that for which the annual value of the temperature indices apply and Year 0 is the year of the temperature indices). This approach meant that the

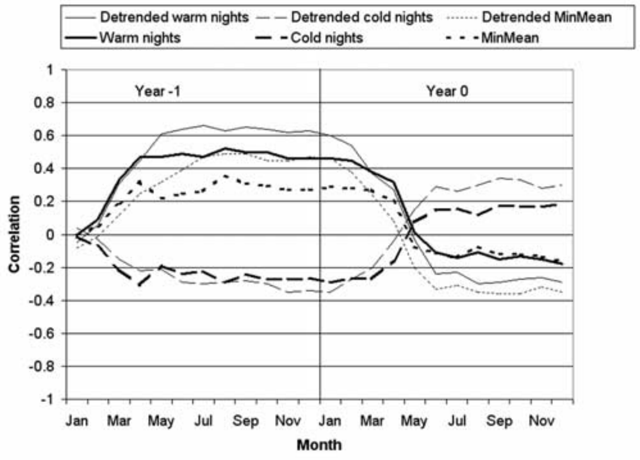

Figure 2. Correlations between monthly values of NINO3.4 and annual numbers of warm nights (full lines) and cold nights (long broken lines), and annual mean minimum temperature (short broken lines). Temperature data are averaged across entire APN region. Data from 1961–2003. Correlations calculated with detrended time series are shown as thin lines.

possibility of using NINO3.4 to predict the areal-average extremes indices could be judged. Examination of the scatter diagrams between the extremes variables and NINO3.4 (not shown) indicated that the relationships were quite linear.

[12] Because strong trends have been identified in the temperature extremes indices [*Manton et al.*, 2001; *Griffiths et al.*, 2005], correlations between NINO3.4 and the indices were calculated on linearly detrended data as well as on the "raw" data.

3. Results

[13] Figure 2 shows the correlations for the night-time indices. The number of cold nights tends to be lower in years following the onset of an El Niño event (i.e. NINO3.4 and this index are negatively correlated) although the correlation is rather weak (around −0.3). Detrending the data made very little difference in the correlations with the number of cold nights. However, detrending the data increased the magnitude of the correlations between NINO3.4 and the number of warm nights and the mean minimum temperature. The strongest correlations found in this study were between the detrended number of warm nights and monthly values of the detrended NINO3.4 index, from about May of the year preceding the extremes (ie, Year −1) through until early in the year of the extremes (ie Year 0). These correlations were above 0.6 in many months, indicating that predictions of the number of warm nights could be made with some skill from observations of NINO3.4 as early as May. The correlations with the number of warm nights were stronger than the correlations with mean minimum temperature. Typically, there are about four warm nights per year during a La Niña episode (eg., NINO3.4 value around −1) and about seven in an El Niño year (NINO3.4 about +1).

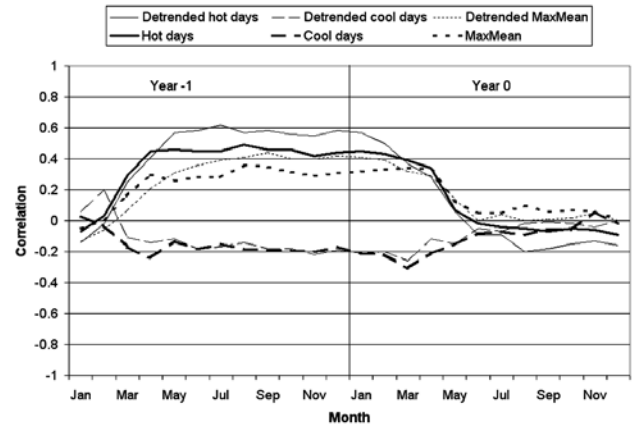

Figure 3. Correlations between monthly values of NINO3.4 and annual numbers of hot days (full lines) and cool days (long broken lines), and annual mean maximum temperature (short broken lines). Temperature data are averaged across entire APN region. Data from 1961–2003. Correlations calculated with detrended data are shown as thin lines.

[14] Figure 3 shows the correlations between the day-time temperature indices and the monthly NINO3.4 index. The number of cool days tends to be lower in years following the onset of an El Niño event, although the correlation is rather weak. There are stronger correlations with the number of hot days and the mean maximum temperature. Only minor differences in the pattern and magnitude of the correlations are seen between those calculated on the raw data and those on the detrended data, except for the number of hot days and the mean maximum temperature where the correlations on the detrended data were stronger. The strongest correlations are with the detrended number of hot days – more hot days tend to occur in the year following the onset of an El Niño event (i.e. when NINO3.4 is warmer than normal). Correlations of around 0.6 were found with NINO3.4 as early as the May preceding the year of the Hot Days index.

[15] Figure 4 shows time series of the number of warm nights (Year 0), along with the NINO3.4 index in the June

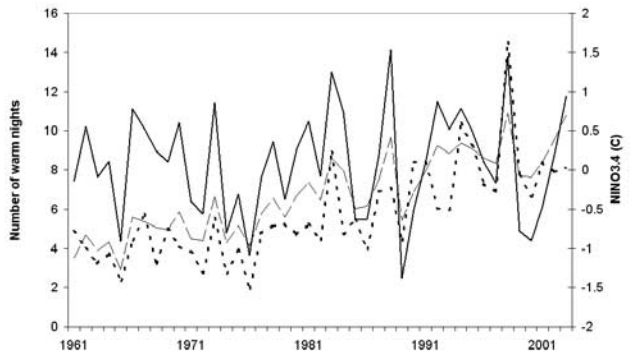

Figure 4. Time series of number of warm nights averaged over APN stations, (Year 0; short thick broken line) and NINO3.4 index of previous June (Year −1; full line). Long thin broken line is the time series of warm nights predicted by linear regression with "Year" and NINO3.4 as predictors.

of the previous year (Year −1). The strong trend in the number of warm nights is clear, as is the relationship between the NINO3.4 index and the subsequent number of warm nights. On average, the frequency of warm nights has approximately doubled since 1961. The strong trend in the number of warm nights, which is not matched by a similar trend in the NINO3.4 index, illustrates why the correlations on the detrended indices are stronger than those on the raw data. There were strong increases in the numbers of warm nights in the years after the El Niño events of 1965, 1972, 1982, and 1997.

[16] NINO3.4 and "Year" were used as predictors in a multiple linear regression to predict the number of warm nights. The multiple correlation coefficient was 0.84 (n = 43). The time series of the frequency of warm nights predicted by multiple linear regression with NINO3.4 and "Year" as predictors is shown in Figure 4. As expected from the strength of the multiple correlation, it is clear that the variations in the number of extremes can be predicted with the two predictors.

4. Conclusions

[17] The El Niño – Southern Oscillation has been shown to be strongly related to variations in the frequency of temperature extremes in the East Asia – west Pacific region. The numbers of warm nights and hot days increase substantially in the year after the onset of El Niño events. The number of cool days and cold nights tend to decrease, although the relationship with El Niño is weaker for these variables. The relationship is confounded, for at least warm nights and hot days, by a strong increasing trend in air temperature and the number of extremes, not matched by a trend in the index of the El Niño. Strong correlations exist between some of the extremes indices and an index of the El Niño – Southern Oscillation in months prior to the occurrence of the extremes, indicating that predictions of the numbers of days of extreme temperatures should be feasible. In general, knowing that an El Niño episode is underway towards the end of a calendar year one should expect an increased number of "hot" extremes and a smaller number of "cool" extremes, in the following calendar year, through the west Pacific and eastern Asia. The data sets used here only provide an annual index of extremes. Further work is necessary to examine seasonal variations in the relationships between extremes and the El Niño – Southern Oscillation, and to understand the mechanisms leading to increases in the frequency of extreme temperatures after El Niño events. Similarly, the relationships between the El Niño – Southern Oscillation and extremes based on different definitions of extremes, would be a useful extension of this study. It would also be useful to extend the analysis over a longer period to check stability of the relationships.

[18] **Acknowledgment.** The series of workshops which led to the preparation of this paper was made possible by funding from the Asia Pacific Network for Global Change Research.

References

Griffiths, G. M., et al. (2005), Change in mean temperature as a predictor of extreme temperature change in the Asia-Pacific region, *Int. J. Climatol.*, *10*, 1301–1330.

Kiladis, G. N., and H. F. Diaz (1989), Global climatic anomalies associated with extremes in the Southern Oscillation, *J. Clim.*, *2*, 1069–1090.

Manton, M. J., et al. (2001), Trends in extreme daily rainfall and temperature in southeast Asia and the South Pacific: 1916–1998, *Int. J. Climatol.*, *21*, 269–284.

Page, C. M., et al. (2004), Data rescue in the South-east Asia and South Pacific region: Challenges and Opportunities, *Bull. Am. Meteorol. Soc.*, *85*, 1483–1489.

Trewin, B. C. (2001), Extreme temperature events in Australia, Ph.D. thesis, Univ. of Melbourne, Melbourne, Australia.

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