Climate-pollution impacts on Sudden Infant Deaths (SIDS)

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Keywords: *Singular Spectrum Analysis (SSA); SIDS: Climate; ENSO; Change-point.*

EXTENDED ABSTRACT

The health of populations in Australasia will be affected by global climate change (IPCC. Climate Change, 2001). It is known that marked short-term fluctuations in weather cause acute adverse health effects, leading to a greater number of hospital admissions/increased deaths (Schwartz 2003, Kovats *et al.* 2005a,b, 2004). Numerous studies have reported that day-to-day changes in particulate air pollution are associated with day-to-day changes in deaths (Gryparis *et al.* 2004, Mc Michael *et al.* 2003, Mc Michael 2002, 2000). Statistical methods to control for season in climate-health studies have deficiencies. Sudden infant death syndrome (SIDS) remains a leading cause of death in the western world, hence any comprehensive analysis that leads to a better understanding of the SIDS risk profile, may assist researchers in identifying the underlying aetiology and cause(s) of this syndrome. Health research has, for some decades, looked at specific short/long-term climate variables as a contributor to e.g. SIDS. Earlier findings on climatic impacts on SIDS had not been consistent. Indeed many SIDS risk factors have been identified, apart from the winter season (Douglas *et al.* 1996), such as lower social status of parents (Leach *et al.* 1999) environmental tobacco smoke (Brooks *et al* 1997, Leach *et al.* 1999) and prone position (Douglas *et al.* 1996). Recently, Dalrymple *et al.* 2005, in a complete ascertainment study of all SIDS deaths in Christchurch NZ, 1968-1999; showed the first consistent pattern of climatic risk on SIDS. This work identified new SIDS risk factors, i.e. dewpoint, wind direction, wind speed and humidity, apart from temperature (seasonality) and formulated a mixture approach for time series (Dalrymple *et al.* 2005, 2003).

The major aim of this present paper is to investigate primarily the value of singular spectrum analysis (SSA) (Golyandina *et al.* 2001) in modelling climate with SIDS. All climate variables are day of SIDS-death specific. SSA shows significant current and lagged (up to 2-3 months) impacts of climate on SIDS and identifies seasonal and cyclic trends, as well as possible change points in the SIDS series. SIDS is shown to increase when wind direction changes from east to west, and when dewpoint increases. All climate variables impact on SIDS contemporaneously or within 1-3 months (mths). Rainfall, relative humidity and wind direction are highly *positively* correlated with SIDS, with a significant non-protective effect of increased rainfall and relative humidity (current to lag -3 mths) and of changing wind direction from east to west, contemporaneously (at lag 0) in the given SIDS month. Cross-correlation lag analysis of the major sub-component (RC1-3) of the SIDS and of all the climatic series, shows that wind speed, dewpoint, temperature, sunshine and radiation are highly *negatively* correlated with SIDS, with a significant *protective* effect on SIDS of increased temperature/sunshine (lag 0 to -2); wind speed and radiation (lag 0 to -3). This is the second study, to date, to show that dewpoint and wind direction are significant SIDS risk factors. The least dominant SSA sub-structures (RC4) confirm that: (i) differential climate effects on SIDS (above seasonality) operate across wet/dry epochs, defined by ENSO, as recently speculated by Dalrymple *et al.* 2005; (ii) increased wind speed significantly increases SIDS risk (RC4) in hot epochs, opposite to the negative effect of increased wind speed on lowering pollution. Climatic effects are not just a proxy for pollution effects on SIDS. Recently Fukuda *et al.* (2005a, b), Fukuda (2004) studied the effect of *daily* climate on air pollution, in Canterbury, but limited to a short, and recent period: 1998-2002, and identified 2-60 day lags between climate and pollution.

1. INTRODUCTION

NZ still has one of the highest rates of SIDS per 1000 live births (LB) in the world (0.9/1000 LB). The focus of this paper is a retrospective, complete ascertainment study of SIDS incidence in Canterbury, undertaken by the Christchurch Community Paediatric Unit, which gave daily SIDS counts from 1968-1999 (Dalrymple *et al.* 2005**,** Dalrymple 2004). Problems caused by changing diagnostic policy were eliminated by collecting information from pathology records and autopsy reports, resulting in a unique and unusually accurate chronological profile of approximately 12,000 days. Only 658 SIDS occurred in Canterbury over this time. Dalrymple et al. 2001 identified two significant change points in the chronological profile of Canterbury SIDS deaths, namely at 1972 and 1990. These effectively partition the time series into three (epochs) Periods 1 (1968-1972), 2 and 3 (1990-1999). Period 2 (1973-1989) has the highest mean number of SIDS/yr, 28.7, nearly double that in Period 1 (16.0) and more than triple the mean number in Period 3 (9.1). The massive reduction in SIDS in the final ten years of the study (1990s) corresponds to a NZ wide back-to-sleep campaign (Mitchell 1993), which encouraged parents to place babies on their backs to sleep. A similar UK campaign resulted in a drop of 70% in UK SIDS rates in the 1990's (Douglas *et al.* 1996). In this paper we analyse the *monthly* SIDS counts and climate variables (Table 1) from Period 2. The "spiky" observed SIDS incidence series, overlaid with Dalrymple *et al.* 2005's climate adjusted fitted SIDS (Dalrymple *et al.* 2005) obtained by novel discrete counts mixture methods for time series are given in Figure 1.

Table 1: Climate variables

Variable (notation) (units)
Temperature (Temp) (^oC)
Wind Direction (WDir)
Wind Speed (WS) (knots)
Relative Humidity (RH) (%)
Rainfall (Rain) (mm/hr)
Sunshine (Sun) (hrs)
Solar Radiation (Rad) (M_j/m^2)
Dewpoint (DP) (^oC)

2. METHOD

Singular spectrum analysis (SSA) (Golyandina *et al.*, 2001) is a powerful tool to decompose noisy time series into several components to highlight hidden structures. SSA extracts and separates out the main subcomponents (trend, cyclicity etc) from time series. Formal mathematical details are given in Golyandina *et al.* (2001) and Fukuda (2004). Recently SSA was successfully applied to flowering phenological - climate time series (Hudson *et al.* 2005, Hudson *et al.* 2004) and also to an air pollution - climate time series (Fukuda *et al.* 2005a,b). The main aim of these studies was to detect the impact of global climate on local weather and their impacts on flowering and air pollution. The focus of this paper is to study the impact of climate on SIDS. We also test the capability of SSA to better "capture" the extreme SIDS counts (Figure 1).

The SSA (Golyandina *et al.* 2001) procedure has four steps. The first step, *the embedding step*, involves transferring the original time series, F, using window length (L), to L-lagged vectors (X_i) (Figs. 2, 3). The L-trajectory matrix (**X**) of F is a Hankel matrix given in Figure 3. The second step, *singular value decomposition (SVD)*, decomposes X into a sum of rank one elementary matrices, X derived from eigen-triples, eigenvalues, principal components and eigenvectors (Fig. 4). The third step, *eigentriple (ET) grouping*, groups ETs and sums their matrices into similar components (Fig. 4). The fourth step *diagonal averaging*, reconstructs the resultant components from additive groups of ETs, to form reconstructed time series, so-called RC's (Fig. 5). Recently Fukuda *et al.*, 2004 derived a new FastGrouping software, which uses a Fourier expansion method (Golyandina *et al.* 2001) to computationally improve the ET grouping procedure for constructing RCs. In this study L=12 due to the monthly and seasonal nature of the SIDS counts (Fig. 1). Here the dominant reconstructed sub-component RC1-3, constructed from ET1-3 (97.18%), the second dominant RC5-15 (1.148%) from ET5 to ET15 and the least dominant RC4 (0.22%) from ET4 were calculated (Figures 6-7) and used in cross-correlation analysis (CCA) between the reconstructed climatic and SIDS series to determine significant short-term (1-3 months) and long term lagged (>6 months) climate impacts on SIDS. The reconstructed SIDS (98.55%) and climate series were compared to global ENSO profiles for 1950-2005 (Fig. 7) (NOAA, 2005). Note in general, lower numbered ETs, contain lower frequencies and account for larger variance, while higher numbered ETs contain higher frequencies and account for less variance.

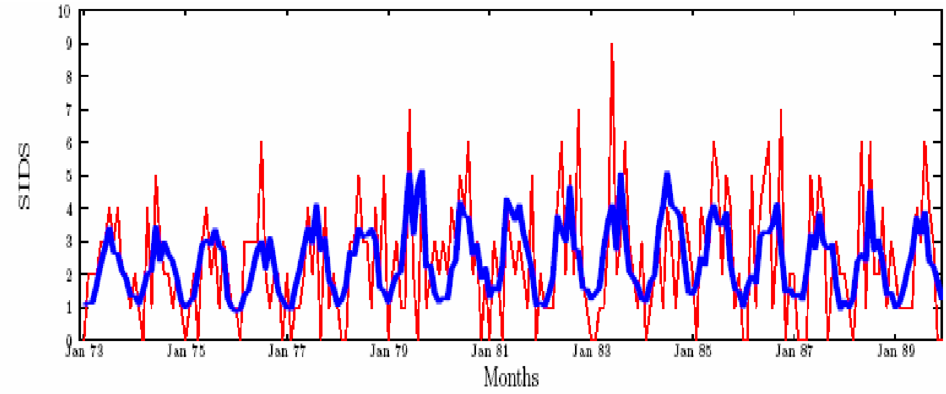

Figure 1. Period 2 (1973-1989) SIDS counts observed and fitted (Dalrymple *et al*. 2005).

3. RESULTS & DISCUSSION

3.1 RECONSTRUCTED RC1-3

Figure 6 shows a highly significant *seasonal cyclicity* in the most dominant (97.182%) reconstructed sub-component for both SIDS and climate variables (RC1-3) (P<0.00003). By contrast Figure 7 shows profiles of the least dominant, but statistically significant SSA sub-structures (RC4), for climate and SIDS series (0.22%), separated into those climate variables whose RC4 have a highly significant *positive* impact and cross-correlation (P<0.00005) with SIDS, contemporaneously at lag 0 and to lag -12 months, and those which have a highly significant *negative* impact and cross-correlation (P<0.00005) with SIDS, contemporaneously at lag 0 to lag -12 mths.

3.2 LAGGED CLIMATIC IMPACTS (RC1-3)

Short-term and longer-term CCA lags between the most dominant reconstructed climate series and the corresponding dominant SIDS series (RC1-3) were calculated. These effects are to be interpreted as climatic risk effects on SIDS *above seasonality*. Rainfall (rain), relative humidity (RH) and wind direction (WDir) are highly *positively* correlated with SIDS according to RC1-3 (Fig. 6). This indicates a significant non-protective effect of increased rainfall (contemporaneously (lag 0) and at lags -1 to -3 months); of increased relative humidity (RH) (at lag 0 and lags -1 to -3 mths) and changing wind direction (WDir), only contemporaneously i.e. at lag 0 months, where a change from east to west increases SIDS risk.

Fukuda (2004) showed that *pollution levels* of SO_2, PM_{10} and CO at a residential (non-industrial) site are elevated with increased relative humidity (RH), rain and a change in wind direction from east to west. These results are reported elsewhere (Fukuda *et al.* 2005a). Note that Fukuda *et al.* (2005b) also confirmed via SSA that climate effects levels of SO_2 before those of PM_{10} and have slowest effect on CO. The same positive risk factors (rain, RH and wind direction) are associated with increased SIDS.

CCA results show that wind speed (WS), dewpoint (DP), temperature, sunshine and radiation are highly *negatively* correlated with SIDS (Fig. 7). This indicates a significant *protective effect on SIDS* of increased wind speed (contemporaneously at lag 0 and at lags -1 to -3 mths); temperature (at lag 0, and at lags -1 to -2 mths); sunshine (at lag 0 and at lags -1 to -2 mths); and a protective effect on SIDS of increased radiation (at lag 0, -1 to -3 mths).

Similarly Fukuda *et al.* (2005a) showed that pollution levels decreased with increased temperature, radiation, sunshine and with increased wind speed (WS). This agrees with previous research that shows that high pollution levels in Canterbury occur during a light north-westerly wind (Spronken-Smith *et al.* 2002). The negative impacts of increased wind speed and temperature, radiation and sunshine, but on SIDS, are identified by SSA in this paper. Dalrymple *et al.* (2003) was the first to identify dewpoint (DP) as a SIDS risk factor, which is confirmed in this SSA analysis of SIDS counts. Fukuda (2004) did not study dewpoint.

3.3 CHANGE POINTS RC4

Impacts of global climate on air pollution level

Figure 7 shows the profiles of the least dominant, but statistically significant, substructures for climate and SIDS (0.22%) broken down into climate variables whose RC4 have a highly significant positive correlation with SIDS (RC4), with contemporaneous (lag 0) up to and including lag -12 mths) effect; and those which have a highly significant negative cross-correlation with SIDS (RC4), with contemporaneous lag 0 to lag -12 mths) effect. The least dominant RC4 (Fig. 7) of all the SIDS-climate variables indicate significant structural changes (change points) in 1980. Note the change in direction (turning point) to increased SIDS from 1980-1987 (Fig. 7). These shifts may be due to external impacts such as global climate changes. A possible scenario is hypothesised to be due to the change of the ENSO cycle in 1980 (NOAA, 2005): bringing a warmer period in 1980-1987 (Fig. 7). These global climate changes may impact on local climate, and consequently on SIDS risk.

A closer examination of Figure 7 shows that wind speed, wind direction, temperature, sunshine and radiation are highly *positively correlated* with SIDS, as based on CCA of RC4 of the climate-SIDS series. It is note-worthy that this is the exact opposite directionality to the negative (protective) impacts on SIDS of increased wind speed, temperature, sunshine and radiation on SIDS, as based on CCA of RC1-3 of the climate-SIDS series. We hypothesize that increased temperature (and its variants) adds to heightened SIDS risk due to possible over-wrapping and overheating of babies, in what is a significantly warmer epoch (Period 2). Overheating has been identified as a possible risk factor in SIDS (Dalrymple *et al.* 2003). According to studies of the SOI, rainfall and El Niño years (Fig. 7), Period 2 is recognized as a warmer, dryer period, than Periods 1 and 3 (Dalrymple *et al.* 2005). Likewise from Figure 7 rainfall and dewpoint are highly *negatively correlated* with SIDS, as based on CCA of RC4 of the climate-SIDS series. Note the effect of increased rain, as protective of SIDS, is the exact opposite directionality to the positive risk impact on SIDS of increased rain. We hypothesize that in-creased rain (and its cooling effects) is protective to SIDS risk, possibly due to a decreased risk of the effects of over-wrapping of babies, in the warmer Period 2. Increased wind speed (Fig. 7) significantly increases SIDS risk (according to RC4). This is opposite to the negative effect of increased wind speed on SIDS (CCA of RC1-3) and on lowering pollution, implying that climatic effects are *not just a proxy for pollution effects* on SIDS. Wind has long been associated with ill health in NZ. This study and Dalrymple *et al.* (2005) show a predominance of wind effects on SIDS in both Period 2 (1973-89) and Period 1 (1968-72). Wind variations, possibly more than pollution changes, are easily perceived and may change parental care, e.g. over-wrapping. The role of pollution on SIDS remains contentious (Lipfert *et al.* 2000, Knöbel *et al.* 1995).

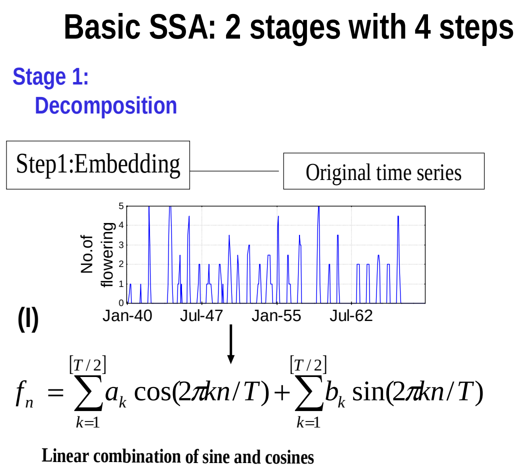

Figure 2. Decomposition Step.

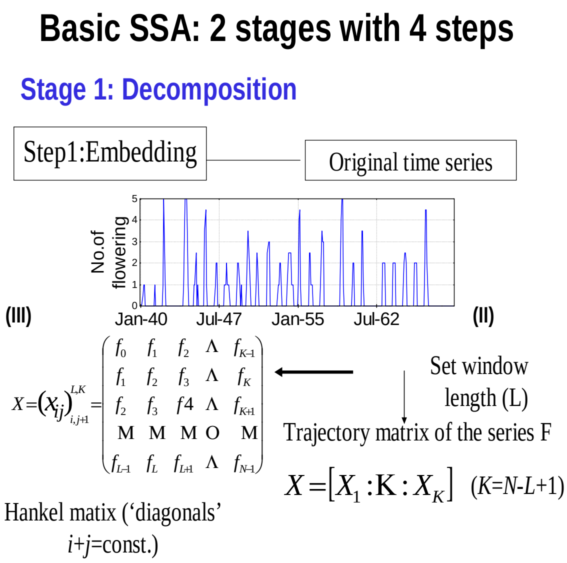

Figure 3. Trajectory Matrices.

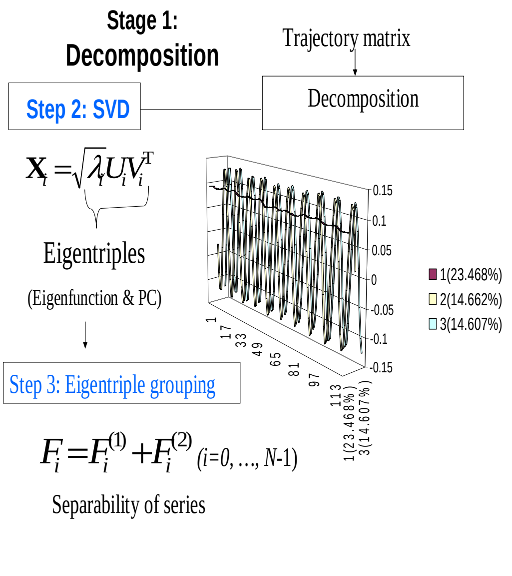

Figure 4. SVD & ET grouping.

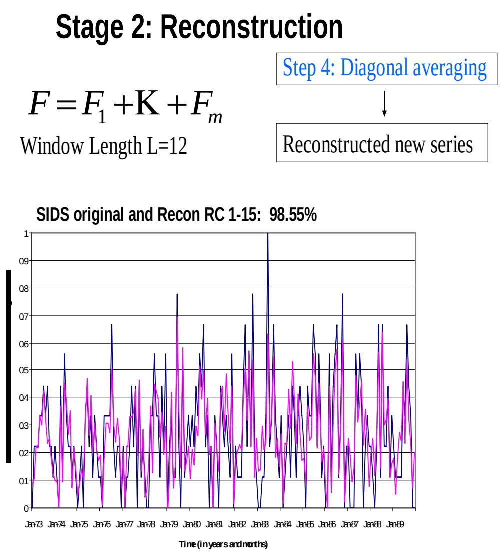

Figure 5. Reconstructed new series (RC's).

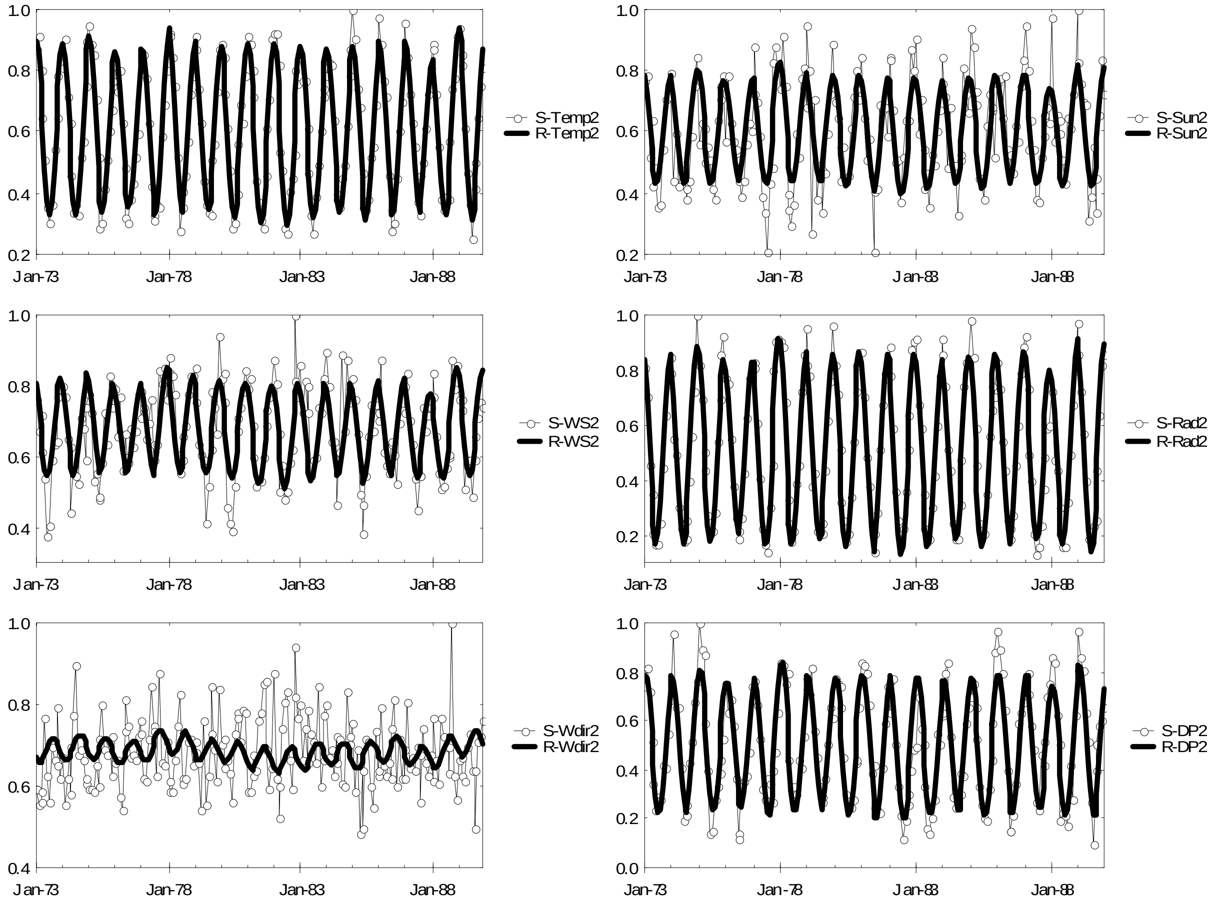

Figure 6. Most dominant RC1-3: Seasonal (98.55%)

Change point 1980: global ENSO

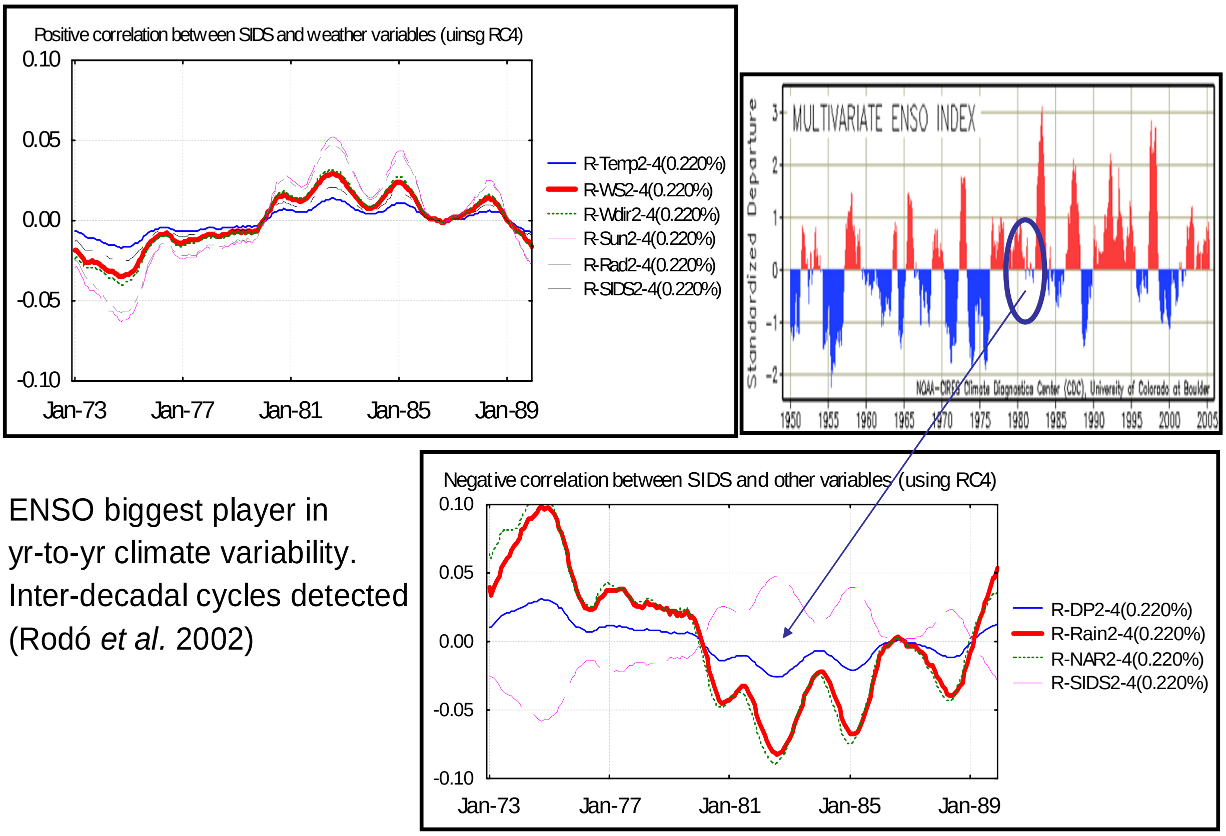

Figure 7. Reconstructed RC4 (0.22%) and global ENSO profile for 1950-2005.

4. ACKNOWLEDGEMENTS

K. Fukuda acknowledges the financial assistance from a personal grant-in-aid (Hudson, IL) to perform the SSA computations.

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