

Interdecadal-Decadal Climate Variability from Multi-Coral Oxygen Isotope Records
in the South Pacific Convergence Zone Region Since 1650AD

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ABSTRACT

Annual average oxygen isotope ($\delta^{18}\text{O}$) time series from five coral cores collected from Fiji and Tonga are used to construct a Fiji-Tonga Interdecadal-Decadal Pacific Oscillation (F-T IDPO) index of low frequency ($>9\text{yr}$ and $<55\text{yr}$) climate variability in this area back to 1650 A.D. Presently, both Fiji and Tonga are located in the South Pacific Convergence Zone (SPCZ) salinity front region where the Interdecadal Pacific Oscillation (IPO) variation is most pronounced. We first demonstrate the consistency between this F-T IDPO index and a MSL pressure-based SPCZ Position Index (SPI) (1891-2000), thus verifying the ability of coral $\delta^{18}\text{O}$ to record past interdecadal-decadal climatic variations in this region back to 1891. The F-T IDPO index is then shown to be synchronous with the IPO index (1856-2000), suggesting that this coral-based index effectively represents the interdecadal-decadal scale climate variance back to 1650. The consistently anti-phase spectrums of the F-T five-coral composite and the interdecadal-decadal components in equatorial Pacific coral $\delta^{18}\text{O}$ series from Maiana [Urban *et al.*, 2000] and Palmyra [Cobb *et al.*, 2001] suggest that the simultaneous eastern expansion (western contraction) of the eastern salinity front of Western Pacific Warm Pool (WPWP) occurs at the same time as the northeast (southwest) movement of the SPCZ during a positive IPO (negative IPO) phase.

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1. Introduction

The South Pacific Convergence Zone (SPCZ) is a reverse-oriented monsoon low-pressure trough stretching from the Intertropical Convergence Zone (ITCZ) near the Solomon Islands to Fiji, Samoa, Tonga and further southeast to French Polynesia. This region features a large sea surface temperature (SST) gradient and active low-level convergence. The low-level convergence of moisture leads to a persistent cloud band as well as showers and thunderstorms. Precipitation and convection within the band is seasonally dependent. Its equatorial portion, where it is connected to the ITCZ, is most active in the Southern Hemisphere summer, and the more southeasterly portion is most active during transition seasons of fall and spring. At the southeastern edge of the SPCZ, oceanic circulation around the feature creates a salinity gradient in the ocean, with fresher and warmer waters of the western Pacific lying to the west of the salinity front and cooler, saltier waters lying to the east. [Gouriou and Delcroix, 2002]. The salinity front shifts northwestward (southeastward) during El Niño (La Niña) events [Gouriou and Delcroix, 2002; Juillet-Leclerc *et al.*, 2006; Linsley *et al.*, 2006]. On interdecadal time-scales the SPCZ and associated salinity front migrate southwestward (northeastward) during the negative (positive) phase of the Interdecadal Pacific Oscillation (IPO), e.g., during the late-1940s to mid-1970s and after the mid-1970s, respectively [Delcroix *et al.*, 2007]. While the interannual-scale SPCZ displacement is relatively well known, the low-frequency displacement is less well understood due to the lack of long-term instrumental records. Folland *et al.* [2002] have developed a SPCZ position index (SPI) from the monthly instrumental mean sea level (MSL) pressure differences between Suva, Fiji (18°9'S, 178°26'E) and Apia, Samoa (13°48'S, 171°47'W) from November to April during the period 1891-2000. The SPI was found to be closely correlated with the phase of the IPO, with the SPCZ displaced towards Fiji during negative phases of the IPO and towards Samoa during positive phases of the IPO [Folland *et al.*, 2002]. At lower frequencies, Linsley *et al.*, [2006] have interpreted the secular trends in replicated coral oxygen isotope ($\delta^{18}\text{O}$) records from Fiji and Rarotonga as evidence that the SPCZ has been expanding since the mid-1800's.

In many studies $\delta^{18}\text{O}$ series in corals have been shown to provide a unique record of past climatic variability due both to: 1.) the precise dating provided by annual growth rings combined with $\delta^{18}\text{O}$ annual cycles and 2.) the ability of corals to record environmental changes in the geochemistry of their skeletons. However, limitations of using the coral $\delta^{18}\text{O}$ proxy include uncertainties in the combined effects of sea surface temperature and the $\delta^{18}\text{O}$ of seawater, and effect of poorly-understood potential biological artifacts such as inconsistent annual skeletal extension rates and calcification rates. The climatic significance of interdecadal-decadal modes in coral $\delta^{18}\text{O}$ time-series is still under debate [Jones *et al.*, 1998; Crowley *et al.*, 1999; Evans *et al.*, 2000]. To verify the reliability of the coral-based $\delta^{18}\text{O}$ proxy to reconstruct climate variability in the past, we isolated and examined the interdecadal-decadal modes in five coral $\delta^{18}\text{O}$ time-series (two from Fiji and three from Tonga). Both island chains are from an area of the South Pacific where the IPO is most pronounced (Figure 1). Folland *et al.* [2002] demonstrated the equivalence of the IPO and the North Pacific derived Pacific Decadal Oscillation (PDO) index. The IPO appears to be of similar magnitude in the South Pacific to the El Niño Southern Oscillation (ENSO). Although large uncertainties remain regarding the temporal and spatial coherence of this interdecadal-decadal variability prior to ~1950 when the instrumental data had less dense coverage and is generally thought to be less reliable. Here we will show that the correspondence between interdecadal-decadal modes extracted from the $\delta^{18}\text{O}$ series of multiple corals from Fiji and Tonga and their correlation with the SPI and IPO indices demonstrates the reliability of coral $\delta^{18}\text{O}$ as a proxy for climate changes at these frequencies and establishes that a five-coral $\delta^{18}\text{O}$ composite Interdecadal-Decadal Pacific Oscillation (IDPO) Index back to 1650AD documents past interdecadal-decadal climate oscillations.

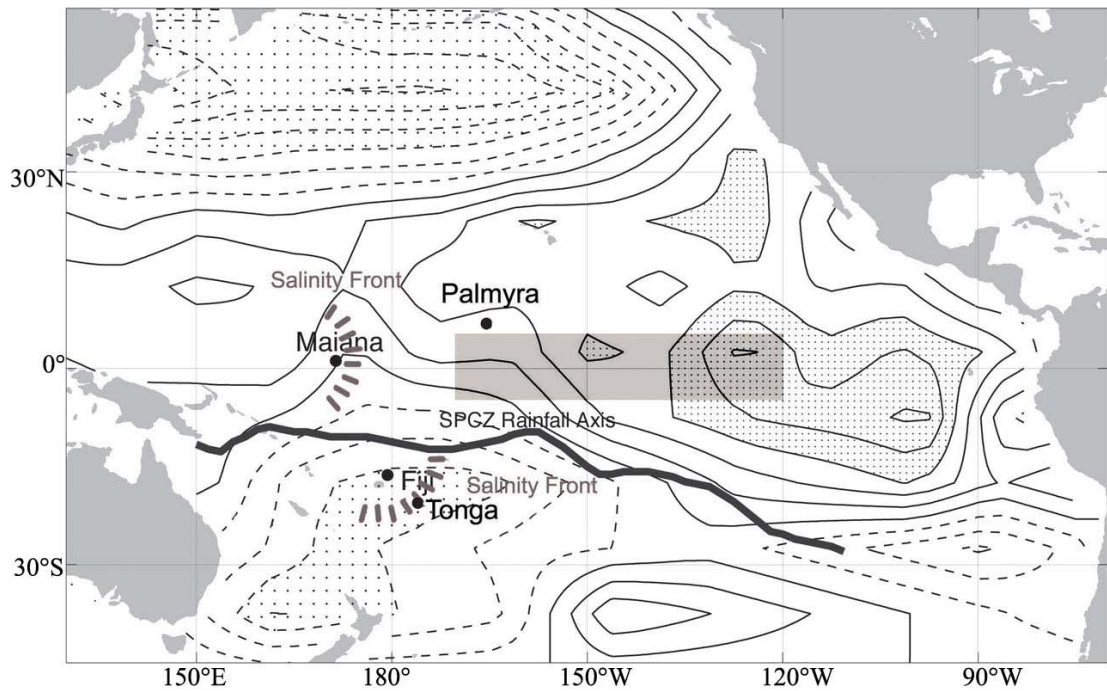


Figure 1. Location of Fiji, Tonga, Maiana, Palmyra and the Nino 3.4 area (shaded box, 5°N-5°S, 120°-170°W) in relation to the South Pacific Convergence Zone salinity front near Fiji and Tonga, the West Pacific Warm Pool salinity front near Maiana and the spatial pattern of the IPO [Folland *et al.*, 2002]. Background contours show the IPO as a covariance map of the 3rd EOF of low-pass filtered SST anomalies for 1911-1995. The contour interval is 0.04°C, negative contours are dashed, values < -0.12°C lightly stippled and those > +0.12°C heavily stippled. The rainfall maximum axis of the SPCZ for 1958-1998 is also shown as a thick black line. Figure modified from Folland *et al.* [2002].

2. Methods

2.1 Sampling and Chronology

In November 2004 three *Porites lutea* coral colonies were drilled at Tonga on the islands of Ha'afera, Malinoa and Nomuka Iki. At Ha'afera (19°56'S, 174°43'W) a large colony with a dead flat top but with live sides was cored. The colony was ~4.5 m high with ~1 m of water covering the top at low tide. Two coral cores TH1 Hole 4 (TH1-H4 hereafter) and TH1 Hole 5 (TH1-H5 hereafter) were collected. The 4.2m-long core TH1-H4 was drilled from the dead top of the colony and the 67cm-long TH1-H5 was collected from the live side of the colony. As discussed below, TH1-H4 and TH1-H5 were spliced together using the timing of known El Niño events. At Malinoa (21°02'S, 175°08'W), north of Nuku'alofa, a 1.63 m core (TM1) was collected from a living colony in 6 m of water. At Nomuka Iki (20°16'S; 174°49'W) two useable cores were collected from a large living colony in 3.5 m of water (TNI2-H1 and TNI2-H3). Due to a bio-eroded zone from ~1m to 1.68 m in TNI2-H1, TNI2-H3 was drilled to allow sampling around the bio-eroded zone by splicing the $\delta^{18}\text{O}$ record from H3 onto H1. The $\delta^{18}\text{O}$ data from the two Fiji cores (Fiji 1F and Fiji AB) used in this study were originally discussed in Linsley et al. [2004, 2006]. It should be noted that subsequent to publishing the Fiji core AB chronology in Linsley et al. [2006], we determined that a 2-year gap existed in this core (missing years 1727 and 1728) at a core break. For this current work we have inserted two years by calculating the average of each decade on either side of the gap.

Core ID	Years	$\delta^{18}\text{O}$ Sampling	Water Depth	Location	Latitude and Longitude
1F	1997-1780	Millimeter-scale	10 m	Savusavu Bay, Fiji	16°49'S 179°14'E
AB	2001-1617	Millimeter-scale	10 m	Savusavu Bay, Fiji	16°49'S 179°14'E
TH1	2004-1794	Millimeter-scale and annually	1 m	Ha'afera, Tonga	19°56'S 174°43'W
TNI2	2004-1650	Millimeter-scale and annually	3.5 m	Nomuka Iki, Tonga	20°16'S 174°49'W
TM1	2004-1837	Millimeter-scale and annually	6 m	Malinoa, Tonga	21°02'S 175°08'W

Table 1. List of five *Porites Lutea* coral cores used to develop the composite Interdecadal-decadal Pacific Oscillation (IDPO) index. Description of Fiji cores (designated 1F and AB) were given by Linsley et al. [2004] and Linsley et al. [2006].

All of the coral cores were cut into ~7 mm thick slabs in the laboratory with a modified tile saw, cleaned and air-dried. The slabs were X-rayed (35kV for 90 seconds) to reveal the density bands. X-radiographs of TH1-H5, TH1-H4 and TM1 are shown in Appendix 1. All of the slabs were then cleaned with a high-energy (500W, 20kHz) probe sonicator in a deionized water bath for approximately 6 minutes and air-dried. Dry slabs were sampled with a low-speed micro-drill with a 1-mm-diameter diamond drill bit parallel to corallite traces along growth axes (as identified in the X-radiographs). Each core was sampled at 1 mm intervals through the top ~30 years, by excavating a 4-5-mm-wide (perpendicular to the growth axis) and 2-3-mm-deep groove in the coral slabs. Below this a technique of annual-scale sampling technique was used (described below). Between some slab sections, the sampling track jumped from one growing axis to another to bypass possible gaps caused by breakage of the slabs. In these cases, all of the jumps were made along a distinct density band to avoid any temporal hiatus in our data.

Approximately 100µg of coral powder in each sample was dissolved in 100% H_3PO_4 at 90°C in a MultiPrep sample preparation device and the generated CO_2 gas was analyzed by a Micromass Optima gas-source triple-collector mass spectrometer at the University at Albany, State University of New York Stable Isotope Ratio Mass Spectrometer (SIRMS) Laboratory. Table 2 lists the number of samples analyzed from each Tonga core, the average difference between replicate samples, and the average isotopic compositions and precision in the analysis of international standard NBS-19. Approximately 10% of the 3,300 Tonga coral samples were analyzed in duplicate. All data are expressed in the conventional delta notation as per mil deviations relative to Vienna Pee Dee Belemnite (VPDB).

Core ID	Dates of Analysis	Number of Samples Analyzed	Average Difference of Replicates	Average $\delta^{18}\text{O}$ Composition and Precision of NBS-19 (n=number analyzed)
TH1-H4	12/06-1/07	522	0.036	-2.199±0.031
TH1-H5	10/06-10/06	192	0.039	-2.199±0.031 (n=135)
TM1	11/06-1/07	391	0.037	-2.195±0.030 (n=76)
TNI2-H1	1/06-6/06	889	0.056	-2.206±0.034 (n=152)
TNI2-H3	8/05-2/06	1306	0.047	-2.200±0.038 (n=218)

Table 2. The isotope analysis statistics.

For the last three decades of cores TH1-H4, TH1-H5, TM1, and TNI2-H3, the chronologies are based on the reconstructed annual cycle in millimeter-scale $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ data with two age control points per year. The 1977-78 El Niño, 1974-1975 La Niña, 1971-72 La Niña, 1964-1965 El Niño and 1955-57 La Niña events were set as control points to determine the age of TH1-H4 (the same colony as TH1-H5, but dead on the top). Figure 2 shows the mm-scale $\delta^{18}\text{O}$ results from cores TH1-H4, TH1-H5 and TNI2-H3 to illustrate the match of the interannual $\delta^{18}\text{O}$ changes with known ENSO events. We added TH1-H5 atop of TH1-H4 (the overlapping part was averaged) and named the combined time series dataset spanning 1794-2004 TH1.

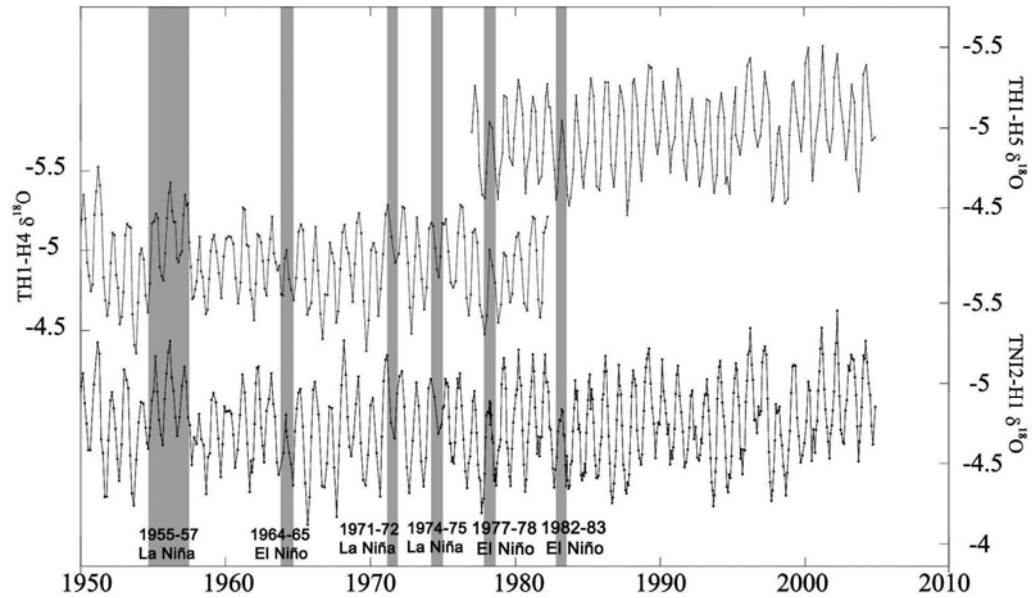


Figure 2 The plots of TH1-H5(top), TH1-H4(middle) and TNI2-H1(bottom) over the period of 1950-2004 to illustrate the match of the annual cycles during the ENSO events. The top of the TH1-H5 was added later on top of TH1-H4 and was assigned the name TH1.

Below the millimeter-scale sampling, we have utilized an annual-average sampling method which is based on the annual density cycles identified by using X-ray photos and ultraviolet light. Sampling was done along the maximum growth axis as with the mm-scale sampling, but only one continuous sample was drilled through each density band (~8-17 mm long, depending on the coral extension rates). Powder from each annual accretion drilling was well mixed and its $\delta^{18}\text{O}$ value was taken as a one-year average value of the corresponding year. Millimeter sampling was applied in

intervals where the density bands were not clear enough to identify the annual growth increments.

Unlike the millimeter-scale sampled Fiji cores, (Fiji 1F [Linsley *et al.*, 2004] and Fiji AB [Linsley *et al.*, 2006]), whose annual average $\delta^{18}\text{O}$ values were derived from all the data points between the two most negative $\delta^{18}\text{O}$ values of each year, the annual average $\delta^{18}\text{O}$ values from the annual-scale drilling of the Tonga cores are not necessarily 12-month averages. In the Tonga cores, although most of the dense bands appear right before the warmest time in each cycle, there are exceptions that cause differences in time spans of some years. Instead of an integrated one-year cycle, several months could be missed and added to the year before or after. However, since as will be discussed below, the fact that the resulting modes in different frequencies are similar among the five coral cores confirms the practical reliability of our sampling technique.

2.2 Statistical Analysis

Following the approach of Vautard and Ghil [1989] and Vautard *et al.* [1992] we performed Singular Spectrum Analysis (SSA) of the annually averaged coral $\delta^{18}\text{O}$ time-series. SSA decomposes time series into several significant frequency components. The resulting modes of variability, defined as SSA eigenvectors, are linear combinations of the individual data records so that the sums are uncorrelated with each other. The sampled time series X of length N is used in to fill a $(N-M+1) \times M$ matrix by taking as state vectors the consecutive sequences $Z_n = (X_n, X_{n+1}, \dots, X_{n+M-1})$ from $n=1$ to $N-M+1$. Variable M is called the embedding dimension or window width. Frequency separation increases as M increases, whereas statistical significance of correlations decreases. An M value of $N/3$ should not be exceeded [Vautard *et al.*, 1992]. Varying window widths were applied over a reasonable range to the annually averaged $\delta^{18}\text{O}$ time series data of each core. The stable features of the eigenvectors were evaluated and a window dimension (M) was selected to resolve the IPO band (~ 9 -55 years) which was the focus of this research. Since the time series are of different lengths, M varied between cores. The SSA results presented here are based on the following M setting: Fiji 1F with $M=40$ ($N=216$), Fiji AB with $M=55$ ($N=384$), Tonga TH1 with $M=30$ ($N=212$), TNI2 with $M=50$ ($N=355$) and TM1 with $M=40$ ($N=168$).

3. Results

As previously observed for other coral records [Tudhope *et. al.*, 1995; Linsley *et al.*, 1999, 2004, 2006; Cobb *et al.*, 2003], an offset in mean $\delta^{18}\text{O}$ value exists in some of the five corals and could be attributed to differences in disequilibrium “vital” effect between coral colonies. The 20th century mean values for annually averaged $\delta^{18}\text{O}$ are -4.64‰ for core AB, -5.06‰ for core 1F, -4.88‰ for core TH1, -4.70‰ for core TNI2 and -4.43‰ for core TM1. In the three Tonga corals, the offsets are relatively small and could be due to mean SST or SSS differences between sites TH1, TNI2 and TM1. In the case of the two Fiji cores, the offset is 0.42‰. These *Porites* colonies are growing in the same setting within 200m of each other in Savusavu Bay and this difference in mean $\delta^{18}\text{O}$ is probably due to a difference in the disequilibrium $\delta^{18}\text{O}$ offset. Given the uncertainty of the significance of this $\delta^{18}\text{O}$ offset we have subtracted the twentieth century mean $\delta^{18}\text{O}$ value of each core in order to compare the $\delta^{18}\text{O}$ time series. Centered $\delta^{18}\text{O}$ series for the five cores are shown in Figure 3. Since all five colonies are composed of the same species of coral and are from a relatively small area, we expected that they would contain common variance due to regional climatic variability. The consistency of the timing of interannual, decadal and interdecadal components is remarkable in our record. For example, the 1982-83 El Niño event (marked by arrows on figure 3) is shown by simultaneous decreases in coral $\delta^{18}\text{O}$ in all five corals. However, some variability in the response of the various coral colonies to certain single climatic events e.g. an individual El Niño event, is likely due to local environmental SST or sea surface salinity (SSS) changes, while some is probably due to biological effects. This can be seen for the 1982-83 El Niño which resulted in a decrease of about 0.15‰ in $\delta^{18}\text{O}$ in the Tonga cores TH1 and TNI2, and in the Fiji cores 1F and AB, but the same event resulted in a more pronounced 0.5‰ decrease in Tonga core TM1.

Four out of the five corals show a gradual trend toward warmer and fresher conditions since the early 1900's (figure 3), which probably indicates a southeastward expansion of the SPCZ [Linsley *et al.*, 2006]. The only exception is TNI2 which records an abrupt 0.32‰ decrease in $\delta^{18}\text{O}$ between 1915 and 1916. We believe this “jump” is the result of an unknown biological, digenetic effects

and/or possible tectonic shifting of water depth at the coral site (active Tonga trench is nearby) since the synchronous $\delta^{13}\text{C}$ values are normal and there did not exist any known climatic event that could change the temperature and/or salinity comparable to a 0.32‰ drop in $\delta^{18}\text{O}$ value.

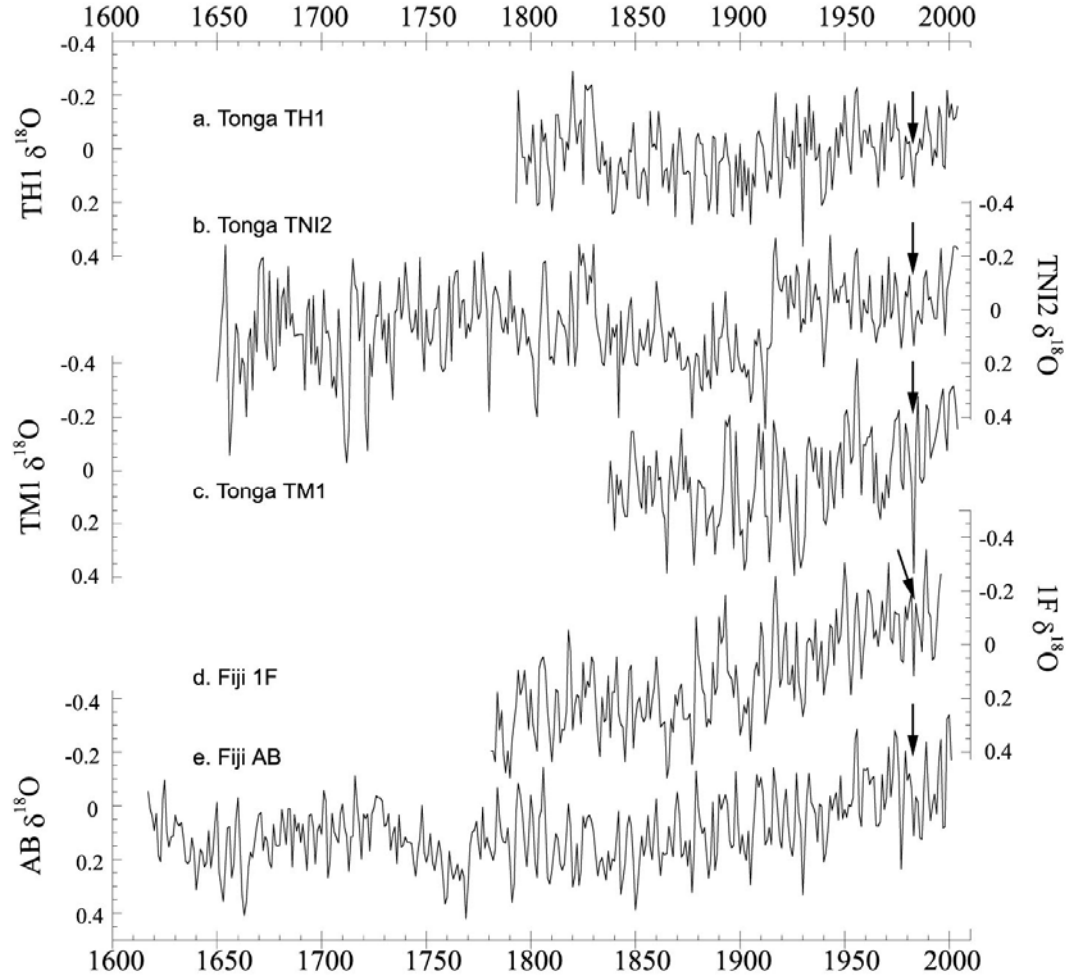


Figure 3. The annually averaged $\delta^{18}\text{O}$ data of the five corals from Fiji and Tonga with twentieth century mean values removed. The black arrows show the 1982-83 El Niño event. All five coral data were plotted on the same $\delta^{18}\text{O}$ (‰) scale.

As a well-established proxy, coralline $\delta^{18}\text{O}$ is known to track both water temperature and the seawater $\delta^{18}\text{O}$ value ($\delta^{18}\text{O}_{\text{seawater}}$). At both Tonga and Fiji, the $\sim 1.0\text{‰}$ annual amplitude of the millimeter-scale (near-monthly) analysis fits well with the annual 4°C - 5°C instrumental SST range from the NCEP SST database [Reynolds and Smith, 1994]. This suggests that seasonal water temperature change is the dominant influence on sub-annual changes in Fiji and Tonga coral $\delta^{18}\text{O}$ in

accord with Linsley et al [2006]. The weak, irregular seasonal SSS cycle in the 2°-10° latitude-longitude gridded SSS data [Gouriou and Delcroix, 2002] is in marked contract to the strong annual sea surface temperature cycles. On interannual time-scales, SSS variability of 1-1.2 p.s.u (~1 p.s.u. in Tonga and ~1.2 p.s.u. in Fiji) appears to be the dominant factor affecting coral $\delta^{18}\text{O}$ at these sites compared with ~1°C interannual SST variance in the region. This effect was previously discussed for Fiji cores 1F and AB [Linsley et al., 2006].

Figure 4 compares Tonga cores TH1, TNI2, and TM1 and Fiji cores 1F and AB annual-averaged $\delta^{18}\text{O}$ data to annual-averaged sea surface salinity (SSS) from Gouriou and Delcroix [2002] and annual SST anomaly from the Hadley Center Sea Ice and Sea Surface temperature database (HadISST1). Correlation coefficients (R value) between annual-averaged coral $\delta^{18}\text{O}$ and SSS over the interval from 1976 and 2000 are 0.61 for core TH1, 0.52 for core TNI2, 0.62 for core TM1, 0.66 for core 1F and 0.71 for core AB. Correlation coefficients between annual averaged $\delta^{18}\text{O}$ and local SST during 1870 and 1996 are -0.44 for core TH1, -0.46 for core TNI2, -0.41 for core TM1, -0.54 for core 1F and -0.64 for core AB.

Assuming that the relationship between coral $\delta^{18}\text{O}$ and SST is -0.21‰/°C (-0.17 to -0.23‰/°C is the common range of coral $\delta^{18}\text{O}$ -SST calibrations [Epstein et al., 1953; Dunbar et al., 1994; Wellington et al., 1996]) and the factors influencing coral $\delta^{18}\text{O}$ are independent from each other, the 1°C interannual range of annual SST of both Tonga and Fiji from the HadISST1 during 1976-2000 contributes ~0.21‰ to the change in coral $\delta^{18}\text{O}$ in this time interval. Subtracting this 0.21‰ SST portion from the total coral $\delta^{18}\text{O}$ range (~0.5‰) during the same period of time results in a residual of ~0.29‰. The magnitude of this “residual” is in accord with the 1-1.2 p.s.u. change (annually averaged) [Gouriou and Delcroix, 2002] based on the 0.27‰/p.s.u. between $\delta^{18}\text{O}_{\text{seawater}}$ and SSS found by Fairbanks et al. [1997] for the equatorial Pacific. SST and $\delta^{18}\text{O}_{\text{seawater}}$ (linearly related to SSS) drive the coral $\delta^{18}\text{O}$ in the same direction for a single ENSO event. During El Niño events and/or positive phases of the IPO and PDO indices, locally cooler and saltier conditions drive the coral $\delta^{18}\text{O}$ composition at Fiji-Tonga toward more positive values. The opposite occurs during

La Niña events or negative IPO/PDO intervals. Since greater precipitation amounts and warmer temperatures (or drier conditions with cooler temperatures) occur together in the study area [Folland *et al.*, 2002], we take coral $\delta^{18}\text{O}$ as an index of ENSO or IPO/PDO without disentangling the effects of SST and SSS.

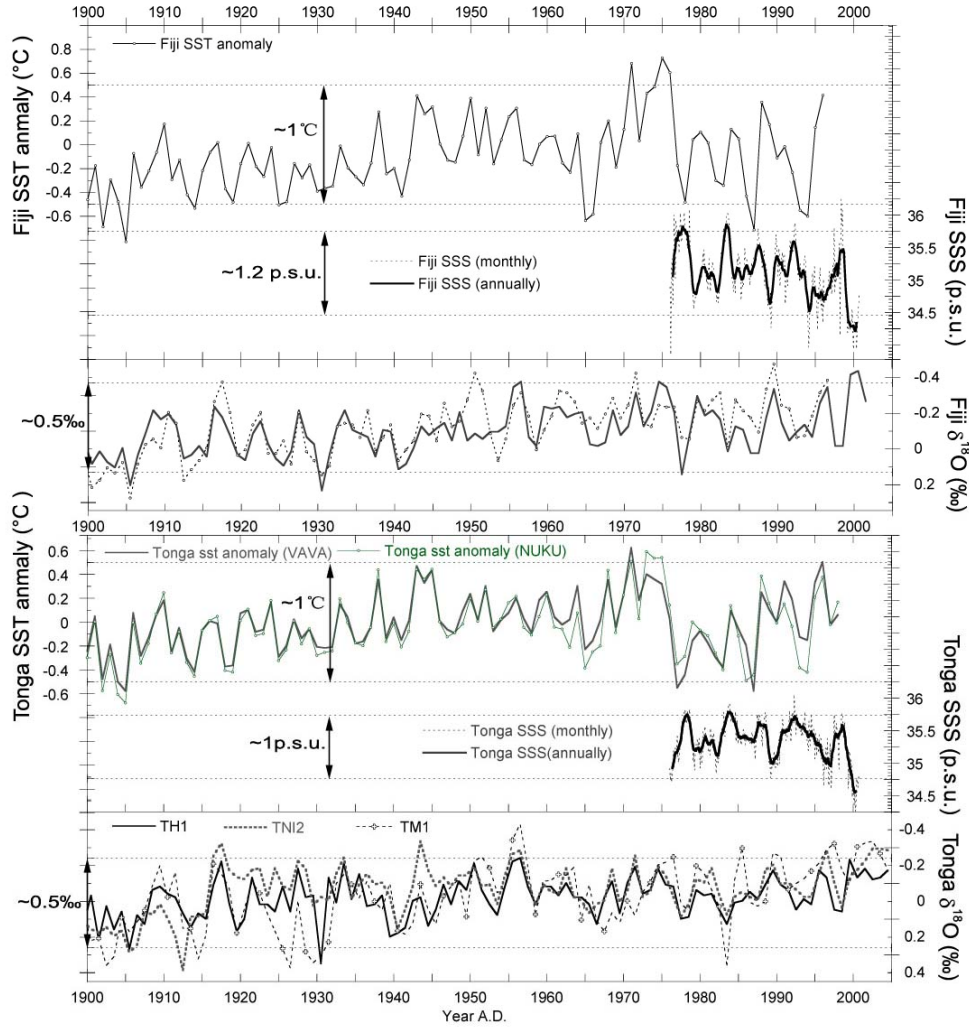


Figure 4. The relative contribution of SST and SSS changes to the coralline $\delta^{18}\text{O}$ variance in Fiji (top) and Tonga (bottom). The annual SST data back to 1900 is from the HadISST1. Note that there are two stations (VAVA and NUKU) in Tonga and we plotted them together in the figure. Local SSS data back to 1976 is from Gouriou and Delcroix [2002]. The SST ($^\circ\text{C}$) and $\delta^{18}\text{O}$ (‰) were plotted on a $0.2\text{‰}/^\circ\text{C}$ scale and the SSS (p.s.u.) and $\delta^{18}\text{O}$ (‰) were plotted on a $0.29\text{‰}/\text{p.s.u.}$ scale.

We performed SSA to quantify the variance in the annual-averaged coral $\delta^{18}\text{O}$ time series from

each core. SSA decomposes time series data into trends and significant oscillatory components in different frequencies. For the coral $\delta^{18}\text{O}$ series analyzed in this study, we separated the oscillatory components into two groups, an ENSO band with frequencies ranging between 3-8 years and an interdecadal-decadal band with mean periods between ~ 9 and ~ 55 years. Below, we will refer to this band as the interdecadal-decadal Pacific Oscillation (IDPO). This frequency cut-off for ENSO has been widely applied and is based on the recurrence interval of recent El Niño events. The SSA results for Core TH1 also show the biennial components that we did not include in the ENSO band. All other oscillations with mean frequencies >55 years are reported as secular trend components. We note that in the 5 coral $\delta^{18}\text{O}$ time series no oscillatory components have periods that fall between 55-75 years, thus 55 years appears to be logical frequency cutoff to separate the interdecadal variability from the secular trend. The resulting peak frequencies of SSA components are listed in the Table 1 in Appendix 2.

SSA of the Tonga and Fiji coral $\delta^{18}\text{O}$ records indicates that between 13%-38% of the variance in each annual-averaged time series is in the IDPO with mean periods between ~ 9 and ~ 55 years. The percent variance of IDPO or ENSO varies in each core with core TM1 having the most pronounced IDPO variance at 38.4%, which is about twice as large as other cores. Besides the exceptionally large variance, the IDPO of TM1 exhibits a perceptibly different amplitude pattern from the other four cores. A possible explanation is that TM1 (near Nuku'alofa, in southern Tonga) lies at the boundary between two climate regions [Salinger *et al.*, 1995] and is not only influenced by southeast trades winds but also by southern westerlies in the anticyclonic belt, while the four other corals are mainly controlled by southeast trade winds.

4. Discussion

4. 1 Fiji-Tonga Interdecadal-Decadal Pacific Oscillation Index

Although these five coral cores were collected from a relatively small area (5°- 6° latitude -longitude) along the salinity front at the southeast boundary of SPCZ, the colonies grew in water of different depths in different lagoon/fore-reef settings. TH1 was collected in an isolated lagoon in 1 m water. TNI2 was collected from a colony in 3.5 m of water in a well flushed passage. TM1 grew more slowly (~4-12 mm/yr) than the other cores (~7-15 mm/yr) and contained residue pigments along the density bands from fungal growth. Fiji Core AB [Linsley *et al.*, 2006] and Fiji core 1F [Linsley *et al.*, 2004] were collected at 10 m depth within 200 m of each other in Savusavu Bay.

Although various biological effects in these diverse settings could potentially influence the skeletal $\delta^{18}\text{O}$, we find that once the $\delta^{18}\text{O}$ series are corrected for differences in disequilibrium offset (as in Linsley *et al.*, 1999), the annually averaged $\delta^{18}\text{O}$ series contain variability that can be explained as due predominately to climate variability. The IDPO variance (periods between ~9 and ~55 years) isolated from the $\delta^{18}\text{O}$ data of these five corals by SSA align reasonably well with each other back to 1650 (Figure 5). We argue that the reproducibility of the timing of the summed interdecadal and decadal components in the multi-coral $\delta^{18}\text{O}$ series demonstrates a locally consistent, environmental origin for this mode of $\delta^{18}\text{O}$ variability despite the variations in amplitude observed in some intervals. The five-coral Fiji-Tonga $\delta^{18}\text{O}$ series are from a region with a common climatic forcing related to the SPCZ and associated changes in SST and SSS (e.g. Salinger *et al.*, 1995; Folland *et al.*, 2002). Folland *et al.* [2002] identified this region of the southwest Pacific as a “center of action” for the PDO/IPO. This observation motivated us to develop a Tonga-Fiji IDPO index from the five-coral $\delta^{18}\text{O}$ series we have generated. To develop the index we averaged the IDPOs isolated from the five $\delta^{18}\text{O}$ series and assigned it the name Fiji-Tonga Interdecadal-Decadal Pacific Oscillation (F-T IDPO) Index. The correlation coefficients of the IDPO’s for all of the five cores are listed in Table 3. TM1 is least correlated with other cores. This could be due its more southerly location between two different climatic zones [Salinger *et al.*, 1995] as previously mentioned and

may mean that TM1 contains climatic information from both regions. We note that removing TM1 from the index does not modify our F-T IDPO significantly (see Appendix Figure 4). A 15-year running averaged correlation coefficient highlights intervals when the IDPO temporally aligns in each coral series and when they do not. Positive r-values indicate positive linear regressions.

Correlation Coefficient	TNI2	TM1	1F	AB
TH1	0.67	0.35	0.47	0.55
TNI2		0.23	0.49	0.37
TM1			0.24	0.53
1F				0.45

Table 3. The correlation coefficients (R value) between the Fiji and Tonga coral $\delta^{18}\text{O}$ IDPO indices. The low correlation between TNI2 and AB may be due to their inconsistency during ~1750-1760 and ~1700-1720.

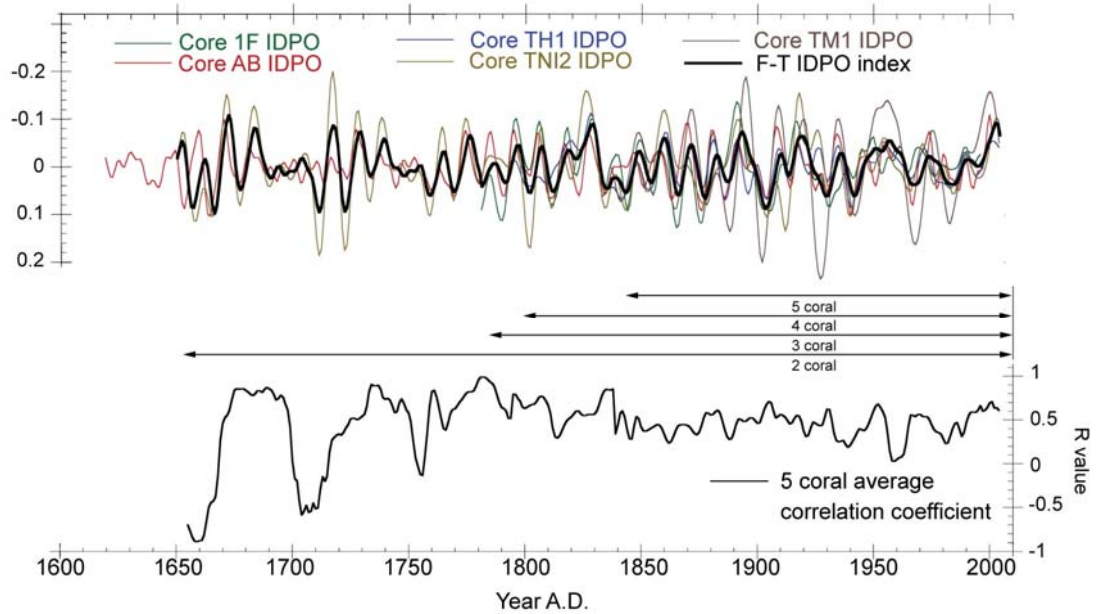


Figure 5. (Top) IDPO signals filtered by SSA of the five coral $\delta^{18}\text{O}$ series from Fiji and Tonga (thin colored lines), from which the average F-T IDPO index was created (thick black line). (Bottom) The 15-year window running average correlation coefficients.

Potential chronological errors (1-2 years) in the $\delta^{18}\text{O}$ series may reduce the alignment (R values), but chronological error is not likely to happen in all five cores in the same period of time and would not modify the five-coral composite greatly. Furthermore, ENSO-band (~3-8 years) variability in each coral $\delta^{18}\text{O}$ series was used to double check the accuracy of the chronologies (see Appendix 3) and the alignment of the ENSO-band between the five corals supports the reliability of

our chronologies back to at least 1715AD. We do note an ENSO-band offset between Fiji AB and Tonga TNI2 from 1715 to 1700AD and from 1650-1660AD which probably is interannual-scale chronology related. One motivation for developing a Fiji-Tonga IDPO index from multiple coral cores is to minimize the potential chronological errors and to reduce potential biological artifacts that affect individual $\delta^{18}\text{O}$ series, e.g., the variations in disequilibrium effect over time between coral colonies [Juillet-Leclerc *et al.*, 2005]. We suggest the F-T IDPO index is more representative of interdecadal-decadal climatic variability in this region than any one of the five $\delta^{18}\text{O}$ series.

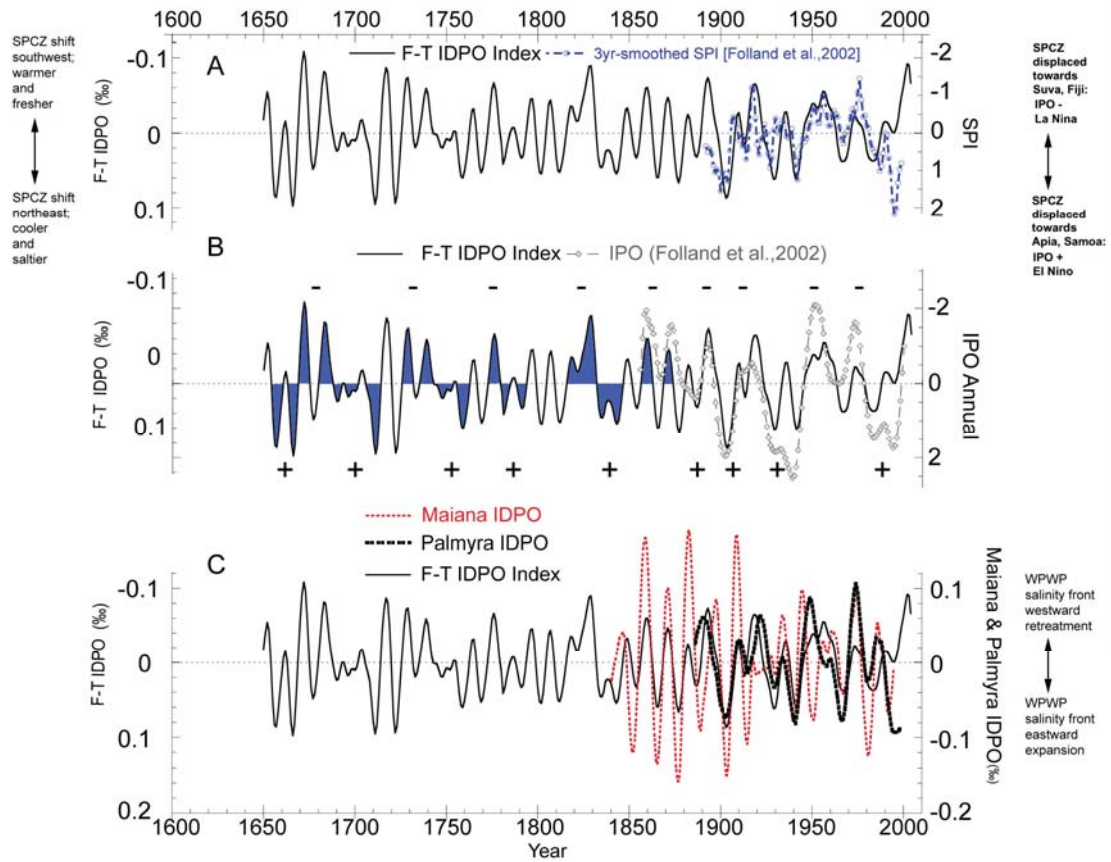


Figure 6. **A.)** The alignment between the F-T IDPO index and SPI [Folland *et al.*, 2002]. **B.)** The F-T IDPO index compared with the IPO Index [Folland *et al.*, 2002]. The colored areas show the IPO phases revealed by the F-T IDPO index back to 1650AD. "+" indicates positive IPO phases and "-" indicates negative IPO phases. After 1860, the IDPO phase changes are well recognized by instrumentally derived indices such as the IPO, PDO and SPI. **C.)** F-T IDPO with 2 coral $\delta^{18}\text{O}$ series from the equatorial Pacific, both filtered by SSA to isolate the IDPO band. Note that the scale of the right-hand Y-axis of the Maiana [Urban *et al.*, 2000] and Palmyra [Cobb *et al.*, 2001] $\delta^{18}\text{O}$ series have been reversed for an easier comparison with the left-hand Y-scale of the F-T IDPO index.

The coherence between this five-coral $\delta^{18}\text{O}$ IDOP composite and the SPI [Folland *et al.*, 2002]

supports the reliability of this coral $\delta^{18}\text{O}$ -based IDPO index and the method of SSA de-convolution to reconstruct interdecadal to decadal-scale climate changes in this region (Figure 6A). The correlation coefficient between the 3-year smoothed SPI and F-T IDPO is 0.39. Note that SPI combines both ENSO and IDPO variances [Folland *et al.*, 2002]. The anti-phase correlation in the last 10 years may be due to the two intense El Niño events in this time period (personal communication with J. Salinger). The low R value may be caused by the ENSO component in the SPI that is excluded from the F-T IDPO index. Positive SPI values indicate a northeast displacement of SPCZ towards Apia creating cooler and saltier conditions in the study area (Fiji and Tonga), which accords with times of more positive coral $\delta^{18}\text{O}$ in the F-T IDPO index. The consistency between the two indices, one oceanic and one atmospheric, confirms the climatic origin of the IDPO signal isolated in our five-coral composite index and the synchronous IDPO-scale oceanic and atmospheric changes in this area.

To evaluate the five-coral composite IDPO index further, we also compare it with the IPO index by Folland *et al.* [2002], which is defined as the third Empirical Orthogonal Function (EOF) of 13-year low-pass filtered Pacific SST over the period 1911-1995. The IPO is highly correlated with the PDO Index for the North Pacific, and Folland *et al.* [2002] suggested that the IPO could be regarded as the Pacific-wide manifestation of the PDO. The consistency between F-T IDPO index and IPO (Figure 6B) indicates that the interdecadal to decadal-scale displacement of SPCZ shown by F-T IDPO is also related to the IPO.

The interdecadal-decadal Pacific climate oscillation is relatively well recognized after 1860AD. However, prior to this time, little is known about interdecadal-decadal scale variability [e.g. Mantua *et al.*, 1997; Power *et al.*, 1999; Hare and Mantua, 2000]. Before 1860AD, our F-T IDPO index shows a regular progression of positive and negative IPO phases. From the ~1850 to mid-1830s the IPO was in a positive phase (warmer equatorial Pacific-cooler and saltier SPCZ region) following a pronounced negative IPO period (cooler equatorial Pacific-warmer and fresher SPCZ region) during the mid-1810s to 1830. In 1780s to mid-1790s the IPO was positive and from mid-1760s to 1780 negative. From the mid-1740s to the mid-1760s, a positive IPO existed, after a negative IPO phase

from mid-1720s to mid-1740s. A prolonged positive IPO phase lasted for ~ 30 years from the mid-1680s to the mid 1710s and is preceded by a pronounced negative IPO signal during ~1670-1680. The earliest IDPO phase in the F-T IDPO index is a positive phase from ~1650 to ~1670. It is interesting that the IDPO oscillation appears to have been muted during ~1740 to mid-1750s and also during mid-1680s to mid-1700s. These amplitude changes are observed in both of the coral records that span these intervals (AB and TNI2) (Figure 5) and were abrupt with pronounced IDPO variation before and after each period.

This coral $\delta^{18}\text{O}$ -based IDPO index extends the existing instrumentally derived interdecadal-decadal oscillation indices, e.g. IPO and PDO, back to 1650AD, providing a reliable reference for the future study of lower frequency climatic oscillations.

4.2 F-T IDPO in-phase in SPCZ and WPWP

Comparison of the IDPO signal at Fiji and Tonga with the IDPO signal in two equatorial coral $\delta^{18}\text{O}$ records at Palmyra [Cobb *et al.*, 2001] and Maiana [Urban *et al.*, 2000], yields a high anti-phase correlation ($R = -0.51$ between Palmyra and F-T IDPO; $R = -0.41$ between Maiana and F-T IDPO). This anti-phase correlation is expected because Palmyra and Maiana are both located in an area where SST variability positively correlated to the IPO while SST in the Fiji and Tonga region is negatively correlated with the IPO (Figure 1) [Folland *et al.*, 2002]. Palmyra (5.9°N, 162.1°W) is located in the center of the tropical Pacific but outside of the WPWP and 1° north of the Nino 3.4 region (shaded box in Figure 1), where the ENSO has a larger amplitude than the interdecadal-decadal oscillation [Cobb *et al.*, 2001]. If the coral $\delta^{18}\text{O}$ changes at Palmyra are interpreted strictly as temperature (using a range of published coral temperature- $\delta^{18}\text{O}$ regressions (0.17-0.23‰/°C) [Reynolds and Smith, 1984; Gagan *et al.*, 1994]), the total range of the Palmyra IDPO (~0.2‰) during 1998-1886 corresponds to ~1°C. This is the same order of magnitude as the IDPO variability derived from Nino 3.4 SST anomalies [Kaplan *et al.*, 1998]. This match suggests that the SST variability is the dominant factor affecting the coral $\delta^{18}\text{O}$ values in Palmyra over interdecadal-decadal time scales. In other words, warmer and fresher conditions in Tonga and Fiji

(SPCZ positioned further south-west) happen simultaneously with cooler conditions in the central equatorial Pacific on IDPO time-scales.

In contrast to Palmyra, the $\delta^{18}\text{O}$ signal in Maiana records both SST and the $\delta^{18}\text{O}_{\text{seawater}}$ (linearly related to salinity) [Urban *et al.*, 2000]. Maiana (01°N, 173°E) is located 25° west of Palmyra and is near the position of the salinity front on the eastern edge of West Pacific Warm Pool (WPWP) [Picaut *et al.*, 1996]. Maiana $\delta^{18}\text{O}$ IDPO contains a similar pattern as Palmyra and in an opposite phase with F-T IDPO. When a south-west shift of SPCZ creates locally warmer and fresher conditions (more negative $\delta^{18}\text{O}$ value) at Fiji and Tonga, it is accompanied by cooler and saltier conditions at Maiana caused by less rainfall and/or a westward retreat of the WPWP.

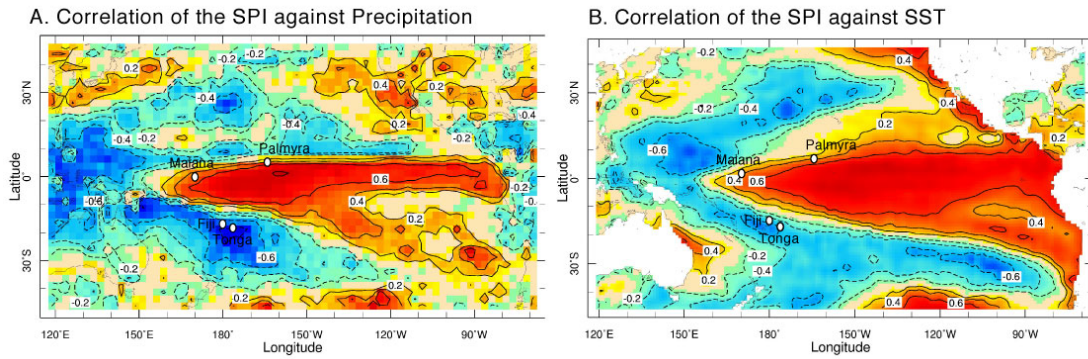


Figure 7. **A.)** Correlation of SPCZ position index (SPI) [from Folland *et al.*, 2002] against precipitation over the interval from 1979 to 2000 (R-values). Note that the SPI is based on the air pressure difference between Apia (Samoa) and Suva (Fiji). **B.)** Correlation of SPCZ position index (SPI) [from Folland *et al.*, 2002] against SST over interval from 1981 to 2000 (r-values). August to July annual means of precipitation and SST are computed from monthly analyses by Xie and Arkin [1996] and Reynolds *et al* [2001], respectively. Note the location of our other study sites at Fiji, Tonga and coral-climate study sites at Maiana [Urban *et al.*, 2002] and Palmyra [Cobb *et al.*, 2001].

The eastward (westward) migration of the warm pool during the El Niño (La Niña) phase of ENSO is well characterized by instrumental data [Picaut *et al.*, 1996; Delcroix and McPhaden, 2000;]. Due to the scarcity of long-term instrumental data, the interdecadal-decadal scale displacement of the WPWP eastern salinity front is less well understood. Recently, Delcroix *et al.* [2007] observed the presence of a PDO-like SSS signal in the WPWP, the SPCZ and the Equatorial Cold Tongue during 1970-2003. Figure 7 shows the regression pattern (R values) of the precipitation over the interval from 1979 to 2000 [Xie *et al.*, 1996] and SST over the interval from 1981 to 2000

[Reynolds *et al.*, 2001] on the SPCZ position index (SPI) [Folland *et al.*, 2002]. Negative correlations (dashed contours) in Figure 7 reflect below average precipitation and SST during positive SPI and positive correlations (thin solid contours) indicate above average precipitation and SST during positive SPI. From the figure, it is clear that precipitation and SST regimes in the Fiji-Tonga (SPCZ) area are reversed from those within Maiana-Palmyra area of the central equatorial Pacific. This observation agrees with the negative correlation between the five-coral composite F-T IDPO index and Maiana-Palmyra, as discussed above.

The precipitation changes in a positive SPI are of the same magnitude in Maiana and Palmyra (Figure 7). In other words, the SSS variance due to precipitation is comparable in these two places. This is interesting since variability in coralline $\delta^{18}\text{O}$ in Maiana is due to both SST and SSS while at Palmyra it is due mostly to SST [Urban *et al.* 2000; Cobb *et al.*, 2001]. Presently, Maiana is located on the WPWP eastern salinity front while Palmyra is in the center of the equatorial Pacific in a region without a pronounced east-west SSS gradient and away from the WPWP. The migration of the WPWP salinity front will modify SSS near Maiana, but not at Palmyra. An implication of this is that the SSS changes at Maiana are mainly the result of the salinity front displacement, and not precipitation. There is evidence that the excess or deficit of rainfall in the past could cause considerable local SSS variance [Delcroix *et al.*, 2007], but this can be compensated for by other factors such as evaporation (enhanced convection will bring greater-than-average rainfall but at the same time the increased temperature will accelerate evaporation) and the possible horizontal and vertical advection caused by thermocline displacement. We argue that the SSS variance observed in coral $\delta^{18}\text{O}$ in Fiji-Tonga and Maiana is largely the result of shifts in the SPCZ-related and WPWP-related salinity fronts, respectively. The coherent $\delta^{18}\text{O}$ IDPO indices from Maiana and Fiji-Tonga coral $\delta^{18}\text{O}$ suggest that significant interdecadal-decadal changes in the eastern salinity front of WPWP are in-phase with SPCZ shifts and SPCZ salinity front movement in the Tonga and Fiji region. In a positive IPO phase, the SPCZ shifts northeast creating a cooler and saltier conditions locally and simultaneously the WPWP salinity front expands eastward with warm and fresher conditions in the middle equatorial Pacific.

5. Summary

We have developed a coral $\delta^{18}\text{O}$ Fiji-Tonga Interdecadal-decadal Pacific Oscillation (F-T IDPO) index based on annually averaged $\delta^{18}\text{O}$ time series from five corals from Fiji and Tonga ($16^{\circ}49'\text{S}$ - $21^{\circ}02'\text{S}$; $179^{\circ}14'\text{E}$ - $174^{\circ}43'\text{W}$). The F-T IDPO index spans the period 1650-2004 AD and has been shown to closely track the IPO and SPI indices. Thus, this index effectively extends our knowledge of interdecadal-decadal ocean-climate variability for 250 years prior to the instrumental record. We note that during ~1740 to mid-1750s and during mid-1680s to mid-1700s the amplitude of the IDPO variability diminished sharply. We also observe an anti-correlation with coral $\delta^{18}\text{O}$ IDPO components isolated from other equatorial Pacific coral records at Maiana and Palmyra. This suggests the simultaneous but opposite behavior between the SPCZ and western equatorial Pacific regions. By examining the pattern of precipitation response in Maiana and Palmyra to a PDO positive phase, we conclude that at interdecadal-decadal time-scales, it is the displacement of a salinity front at the eastern WPWP, instead of the precipitation change, that contributes to the SSS variance recorded by coralline $\delta^{18}\text{O}$ series at Maiana. This observation suggests that the anti-phase IDPO variations between the equatorial Pacific and the SPCZ region can be interpreted as salinity fronts shifting in opposing directions in the eastern WPWP and the SPCZ. In other words, the interdecadal-decadal eastward expansion (westward contraction) of the WPWP salinity front occurs at the same time as the northeast (southwest) shift of the SPCZ salinity front.

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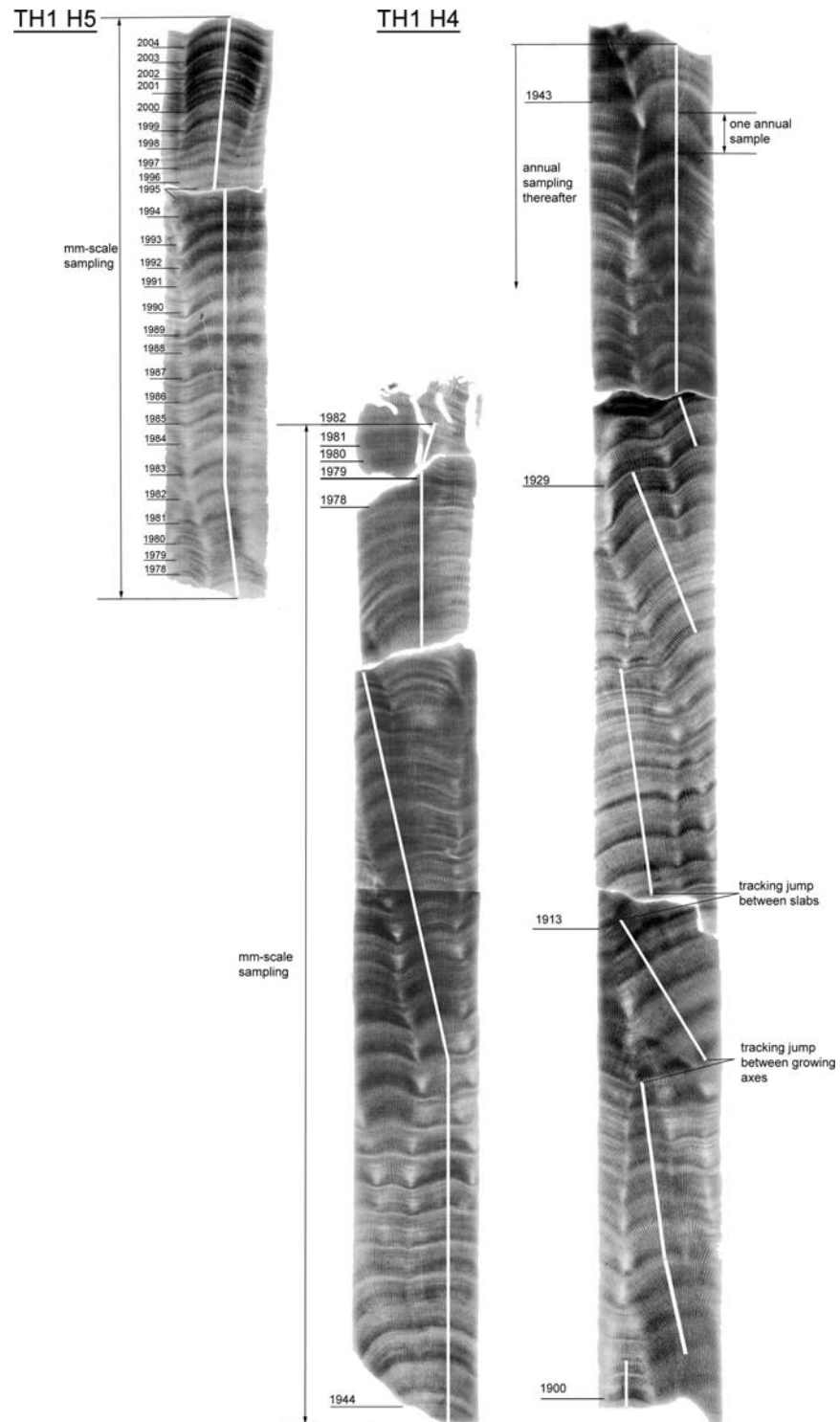
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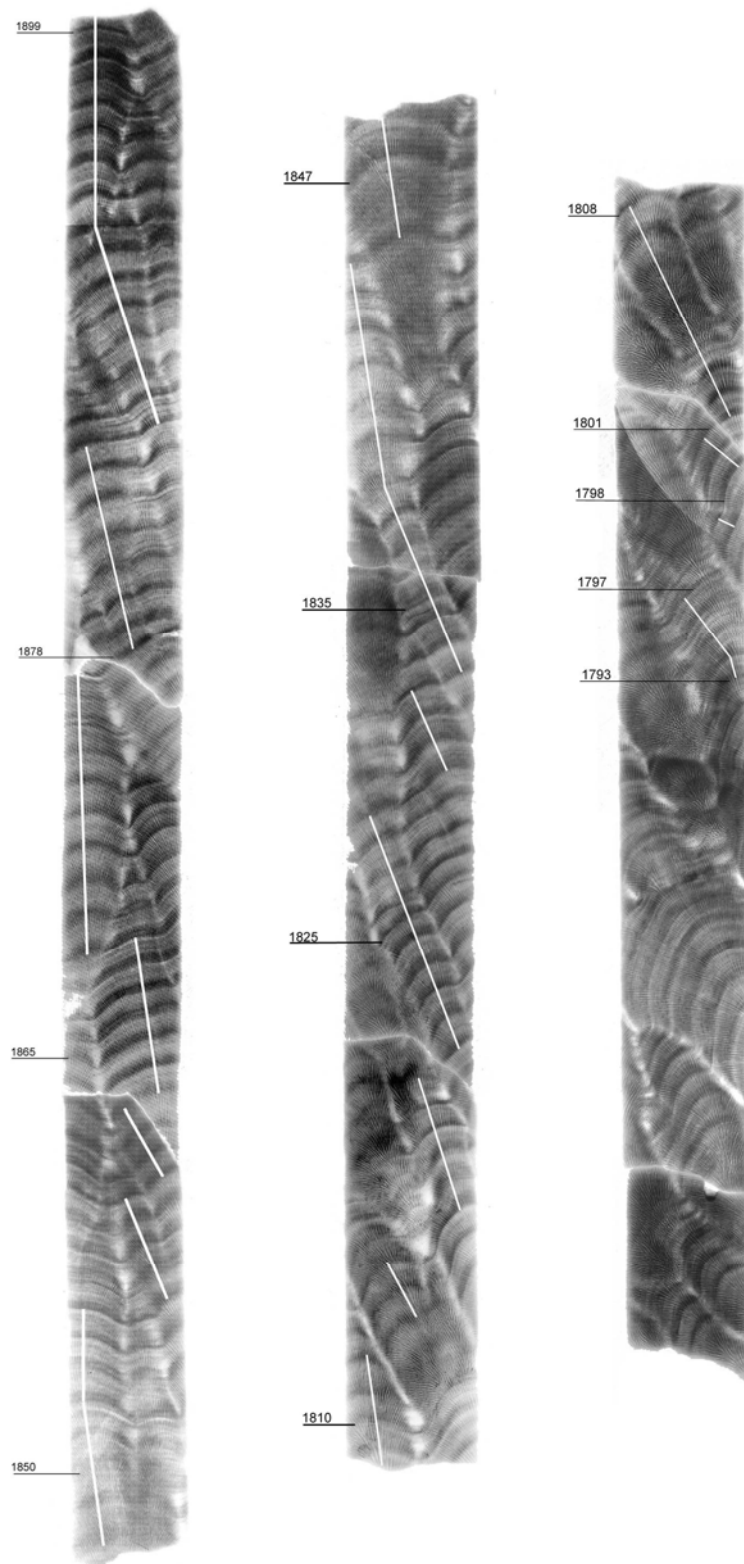
Wellington, G.M.; Dunbar, R. B. and Merlen, G.: Calibration of stable oxygen isotope signatures in Galapagos corals, *Paleoceanography* 11, p. 467-480, 1996.

Xie, P. and Arkin, P. A.: Analyses of global monthly precipitation using gauge observations, satellite estimates and numerical model predictions, *Journal of Climate*, 9, p. 840-858, 1996.

Appendix 1 Sampling Techniques

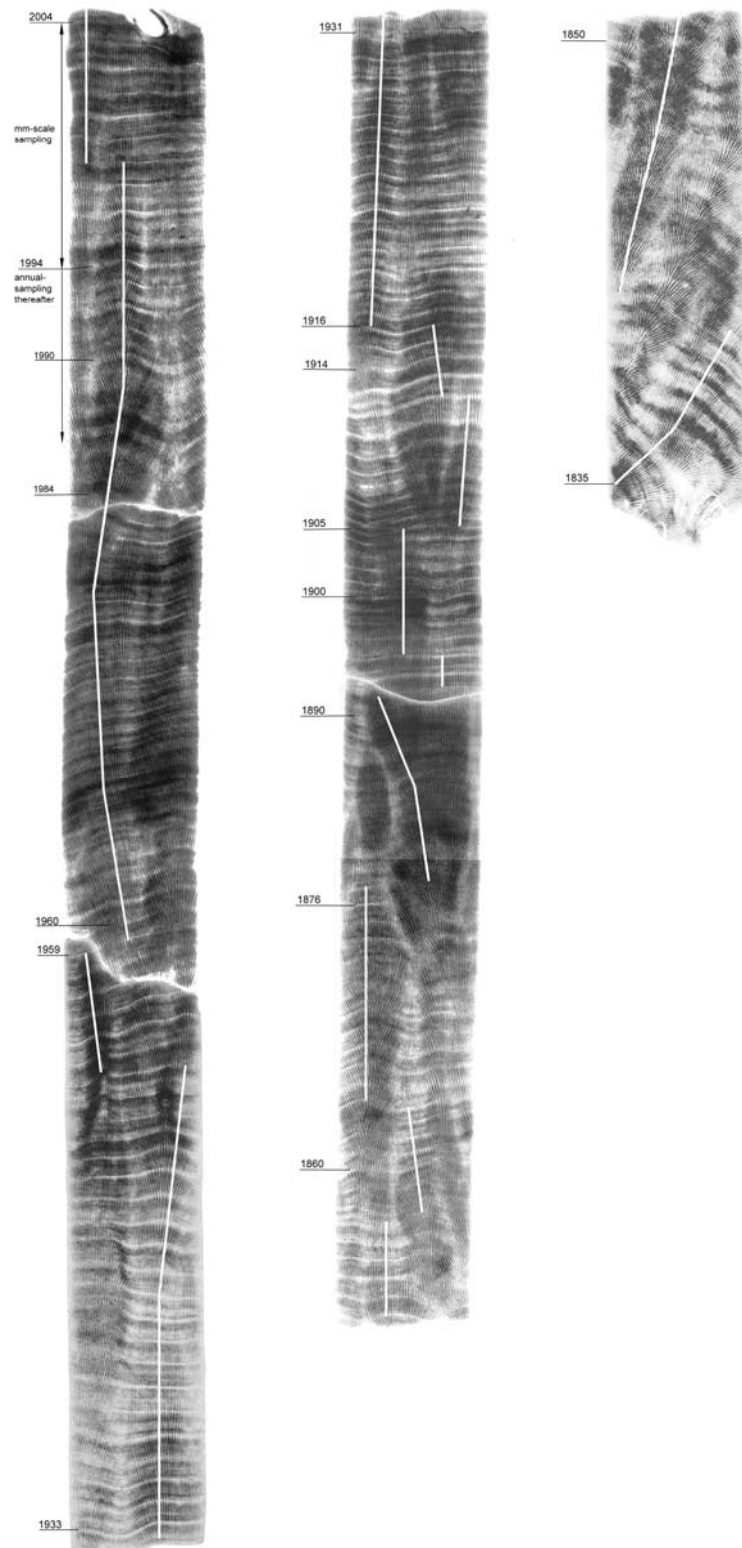


Appendix Figure 1. The X-ray photos of TH1-H5, TH1-H4 and TM1



Appendix Figure 1 (continued). The X-ray photos of TH1-H5, TH1-H4 and TM1

TM1



Appendix Figure 1 (continued). The X-ray photos of TH1-H5, TH1-H4 and TM1

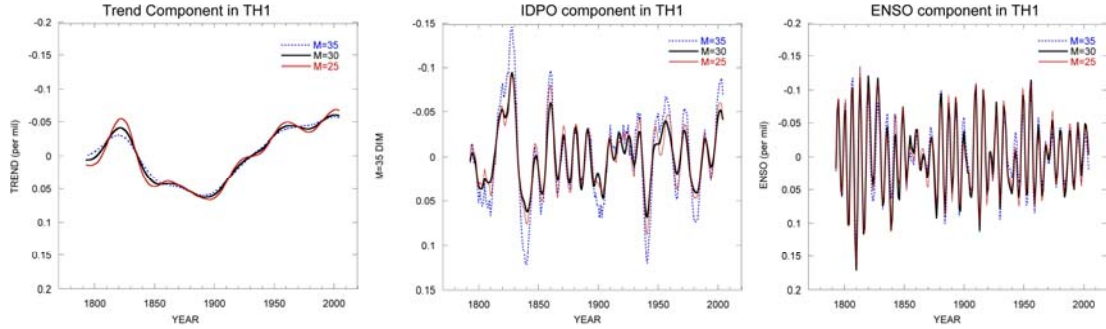
Sampling track jumps on coral slabs were made in two situations, (1) to keep the sampling along the growth axis or (2) to avoid overlaps between the slab breaks. In both situations, the sampling track jump from one growing axis to another was made along the same density band. In this way, no obvious data gap at track jumps occurred.

In most cores, density bands are not distinct throughout the entire core. In the sections where the density bands were not clear enough to parse the coral growth annually by the naked eye or with an ultraviolet lamp, we adopted a mm-scale sampling approach and used the oxygen isotope ($\delta^{18}\text{O}$) annual cycle to determine the annual increments and to calculate a $\delta^{18}\text{O}$ annual-average value for those years.

The annual sampling and the alternate sampling between annual-scale and mm-scale may cause chronological problems, if the denser bands are not always deposited at the same time of year. In the modern sections of the Fiji and Tonga corals examined, the dense bands are accreted in January-February during the warmest time of the year. For example, if a dense band was deposited in January of a certain year and the following dense band was deposited in March of the next year, the time span of the first year would be 14 months and the annual average value of this year would come from 14 months of growth instead of from 12 months of growth. This small potential chronology issue should not be a problem, since we are interested in oscillations with frequencies ~9-55 years and the deviation caused by annual sampling is less than one year. Furthermore, the density bands appear to be deposited at roughly the same time of the year based on their fairly even distribution through time. Given these observations, we treated the averaged $\delta^{18}\text{O}$ values as 12-month averaged values in this research. From the coherence between the interdecadal-decadal indices (SPI, IPO) and our five-coral IDPO index, this annual-sampling method appears to be reliable.

Appendix 2 SSA Analysis

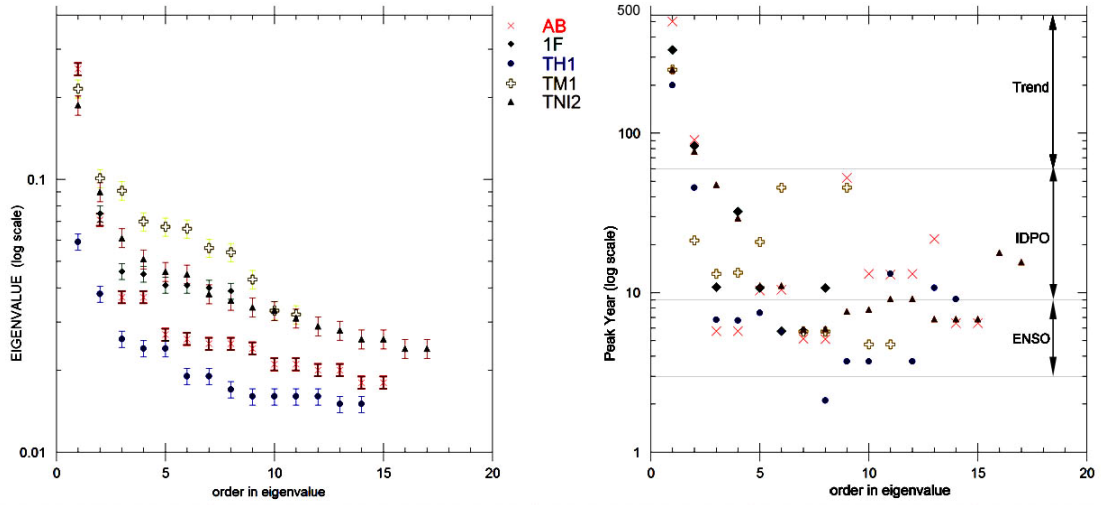
2.1 The Choice of Window Width



Appendix Figure 2. Trend, IDPO and ENSO component plots of TH1 with different window widths (M=25yrs, 30yrs and 35yrs).

In SSA, the choice of window width (M) is a tradeoff between resolution and significance. If M is too small, the coarse resolution may cause several neighboring peaks in the spectrum to combine and merge into one peak (with high statistical confidence). On the contrary, if there is an intermittent oscillation, reflected by a broad spectral peak, a large M (high resolution) will split the peak into several components with neighboring frequencies. Due to the different temporal lengths of the five corals, we adopted a different M for each coral. Generally, the longer the time record, the larger the M is set. We used different window widths over a reasonable range to evaluate the stable features of the eigensets. Figure 2 gives an example of the output component series of core TH1 with $M=25$, 30 and 35 years. As M increases, the number of the resulting eigen-values increases from 10 ($M=25$), to 14 ($M=30$) to 16 ($M=35$) because some of the intermittent oscillations are split into more than one peak. After we categorized these peaks into trend, IDPO and ENSO components, the component series do not differ much from $M=25$ to $M=35$, despite the number of the eigen-values. Other cores show similar results. We concluded that within a reasonable range, the output analysis by SSA is statistically stable and the choice of window width does not affect our arguments.

2.2 SSA Output result



Appendix Figure 3. (Left) SSA eigenvalue spectra for the five-coral oxygen isotope series, with 95% confidence limits based on the criterion of *North et al. (1982)*. (Right) The output result in peak frequencies of SSA components. The larger the order in eigenvalues, the less significant the signal is in the total variance of each stable isotope series. The slowly decreasing ramp in every series corresponds to the white-noise dominated components [*Vautard et al., 1992*] (decreasing significance in the total variance of each series). The tails of the spectra are not flat, due to the finiteness of the data.

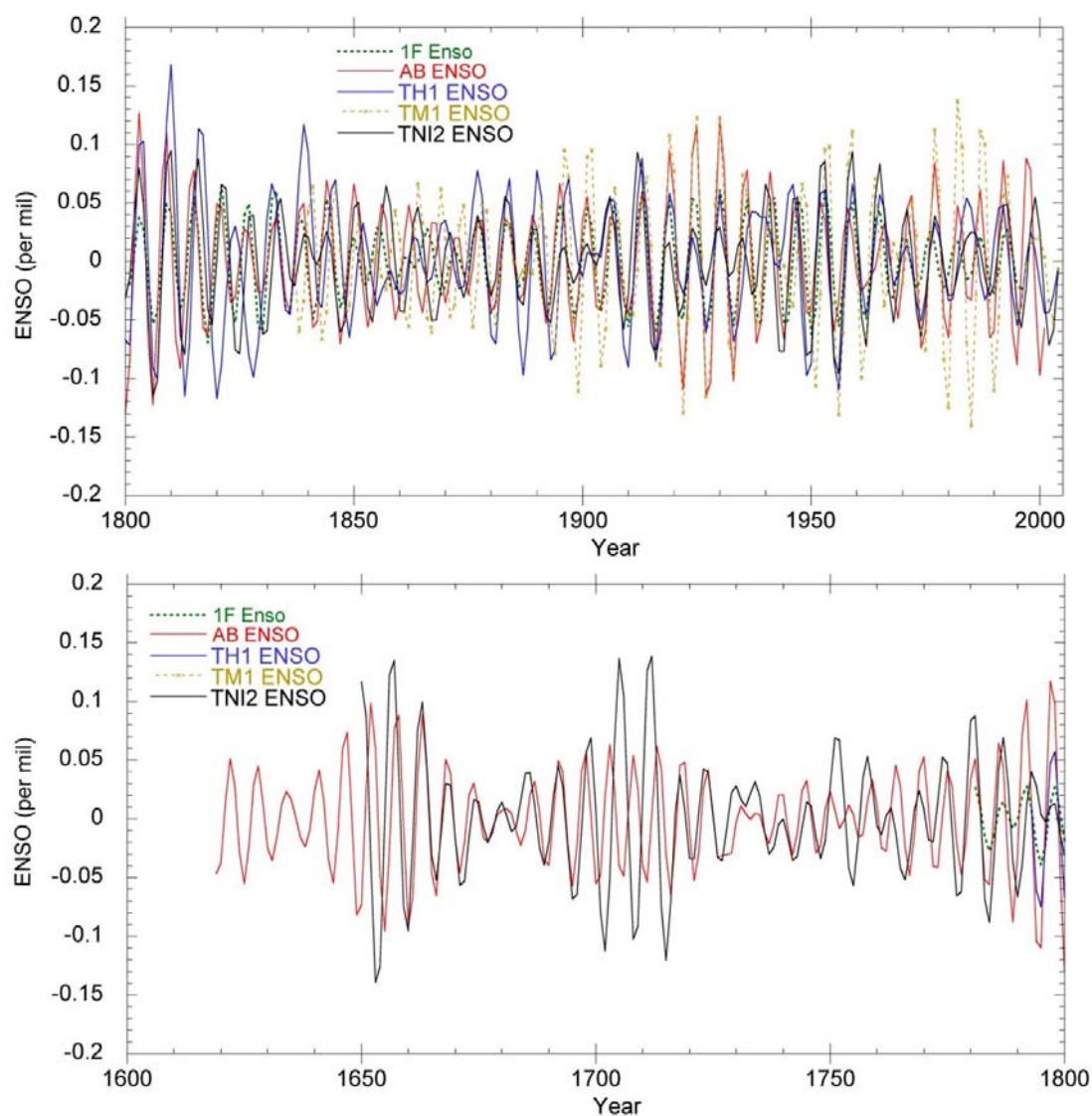
Core	Peak Frequencies of SSA components (signal strength: strong↔weak)							Variance
TH1	Trend							13.5%
	IDPO	45yr	13yr	11yr	9yr			19.0%
	ENSO	7yr	6yr	4yr				25.8%
TNI2	Trend	250	76					23.6%
	IDPO	48yr	30yr	18yr	16yr	11yr	9yr	26.5%
	ENSO	8yr	7yr	6yr				18.9%
TM1	Trend							18.9%
	IDPO	45yr	21yr	12yr				38.4%
	ENSO	6yr	5yr					15.3%
1F	Trend							52.1%
	IDPO	32yr	11yr					13.1%
	ENSO	6yr						6.2%
AB	Trend							35.5%
	IDPO	53yr	22yr	13yr	10yr			17.3%
	ENSO	6yr						17.3%
Maiana	Trend							40.0%
	IDPO	13yr						15.2%
	ENSO	7yr	6yr	4yr	3yr			26.2%
Palmyra	Trend							23.5%
	IDPO	33yr	13yr					13.4%
	ENSO							23.1%

Appendix Table 1. List of Peak Frequencies of SSA components.

We divided the resulting peak frequencies into three groups: trend, IDPO and ENSO. ENSO is set to

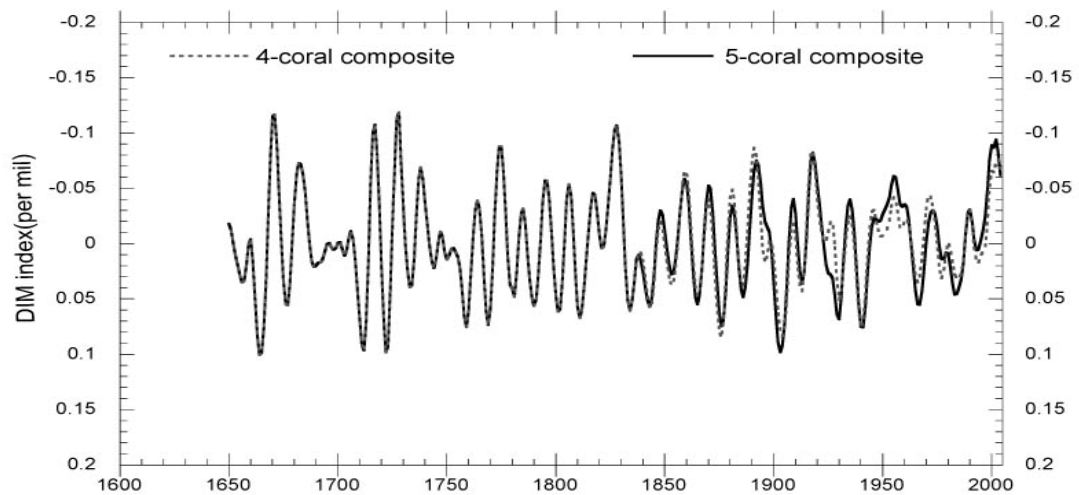
be ~3-8 years. The biennial ENSO effect has a fingerprint on the core TH1 with a ~8% variance. As TH1 is the only core that shows the biennial signal, we did not include it in the ENSO component. Since our research is on the interdecadal-decadal oscillations, this exclusion will not influence our conclusions. Interdecadal-decadal variance at about the same level of significance as ENSO is retained in the ~9-55 years band width. The mechanism of this low frequency component is still under debate and its frequency range is not well defined. Folland et al. [2002] argues the equivalence of the IPO and PDO in describing Pacific-wide variations in ocean climate. Following this idea, we included all of the signals between ENSO and secular trends in our analysis without separating the decadal and interdecadal signals. The secular trend is the largest component in all the cores with a peak frequency $>\sim 75$ years.

Appendix 3. The ENSO-band Plots of the Five Corals



Appendix Figure 4. ENSO band plot of five Fiji-Tonga cores separated by SSA used to double check the chronologies of the coral cores. (Top) 1800-2005 (Bottom) 1617-1800.

Appendix 4. Comparison Between Five-coral Composite and Four-coral Composite



Appendix Figure 5. The four-coral composite (dashed line) and five-coral composite (solid line) were calculated using the same procedure from the same dataset, though the four-coral composite does not include core TM1. The two indices do not differ significantly either in amplitude or frequency (TM1 spans 2004-1836, so the two are identical before 1836). Given that, we adopt the five-coral composite to avoid artificial selection of the coral series composing constituting the F-T IDPO index.

Appendix 5. $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ data of Tonga cores TH1-H5, TH1 H4 and TM1

$\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ data of Tonga cores TH1-H5

Depth (mm)	Year A.D.	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	Depth (mm)	Year A.D.	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$
1	2004.808	-2.06	-4.94	69	1998.780	-2.53	-4.56
3	2004.608	-1.79	-4.92	71	1998.637	-2.81	-4.52
5	2004.408	-2.16	-5.14	73	1998.494	-2.72	-4.66
7	2004.208	-1.50	-5.39	75	1998.351	-2.53	-4.82
9	2004.042	-0.76	-5.33	77	1998.208	-2.08	-5.01
11	2003.875	-2.19	-4.90	79	1998.083	-1.45	-4.96
13	2003.708	-2.26	-4.61	81	1997.958	-2.18	-4.77
15	2003.542	-2.31	-4.74	83	1997.833	-2.56	-4.57
17	2003.375	-2.03	-5.16	85	1997.708	-2.98	-4.54
19	2003.208	-0.99	-5.25	87	1997.583	-2.64	-4.78
21	2003.208	-1.09	-5.27	89	1997.458	-2.17	-5.16
23	2003.008	-2.40	-4.98	91	1997.333	-1.37	-5.28
25	2002.808	-2.42	-4.80	93	1997.208	-1.27	-5.35
27	2002.608	-2.46	-5.04	95	1997.042	-2.03	-5.05
29	2002.408	-2.03	-5.17	97	1996.875	-2.53	-4.95
31	2002.208	-2.24	-5.46	99	1996.708	-2.38	-4.88
33	2002.042	-1.12	-5.31	101	1996.542	-2.43	-4.99
35	2001.875	-2.04	-4.99	103	1996.375	-2.49	-5.13
37	2001.708	-2.19	-4.85	105	1996.208	-1.84	-5.44
39	2001.542	-2.15	-4.93	107	1996.042	-1.14	-5.39
41	2001.375	-2.85	-5.11	109	1995.875	-1.78	-5.23
43	2001.208	-1.51	-5.51	111	1995.708	-2.38	-4.98
45	2000.958	-1.77	-5.14	113	1995.542	-2.51	-4.83
47	2000.708	-1.93	-4.92	115	1995.375	-2.68	-4.88
49	2000.458	-1.01	-4.67	117	1995.208	-2.64	-4.96
51	2000.208	-2.39	-5.50	119	1995.208	-1.99	-5.25
53	2000.042	-1.69	-5.40	121	1995.065	-1.75	-5.16
55	1999.875	-2.45	-5.06	123	1994.923	-2.18	-4.94
57	1999.708	-2.58	-4.86	125	1994.780	-2.69	-4.59
59	1999.542	-2.58	-5.02	127	1994.637	-2.36	-4.70
61	1999.375	-2.25	-5.10	129	1994.494	-2.37	-4.66
63	1999.208	-2.01	-5.29	131	1994.351	-2.01	-5.07
65	1999.065	-1.58	-5.27	133	1994.208	-1.30	-5.22
67	1998.923	-2.34	-4.95	135	1994.042	-1.24	-5.07

137	1993.875	-2.41	-4.71	219	1988.083	-1.18	-5.28
139	1993.708	-2.62	-4.60	221	1987.958	-1.87	-4.85
141	1993.542	-2.42	-4.86	223	1987.833	-2.32	-4.55
143	1993.375	-1.86	-5.17	225	1987.708	-2.48	-4.45
145	1993.208	-1.52	-5.18	227	1987.583	-2.69	-4.78
147	1993.042	-2.03	-4.92	229	1987.458	-2.17	-5.11
149	1992.875	-2.39	-4.75	231	1987.333	-1.98	-5.23
151	1992.708	-2.42	-4.64	233	1987.208	-1.45	-5.26
153	1992.542	-2.44	-4.90	235	1987.065	-1.29	-5.07
155	1992.375	-2.06	-4.92	237	1986.923	-2.11	-4.77
157	1992.208	-1.39	-5.18	239	1986.780	-2.26	-4.63
159	1992.065	-1.34	-5.09	241	1986.637	-2.33	-4.77
161	1991.923	-2.21	-4.89	243	1986.494	-2.16	-5.08
163	1991.780	-2.43	-4.68	245	1986.351	-1.83	-5.28
165	1991.637	-2.48	-4.80	247	1986.208	-1.41	-5.29
167	1991.494	-2.39	-5.04	249	1986.065	-1.46	-5.13
169	1991.351	-1.99	-5.26	251	1985.923	-2.31	-4.75
171	1991.208	-1.44	-5.37	253	1985.780	-2.31	-4.61
173	1991.083	-1.94	-5.20	255	1985.637	-2.57	-4.64
175	1990.958	-2.37	-4.94	257	1985.494	-2.18	-4.92
177	1990.833	-2.60	-4.87	259	1985.351	-1.69	-5.20
179	1990.708	-2.44	-4.72	261	1985.208	-1.14	-5.31
181	1990.583	-2.61	-4.89	263	1985.083	-1.12	-5.18
183	1990.458	-2.54	-5.00	265	1984.958	-1.82	-4.91
185	1990.333	-1.97	-5.19	267	1984.833	-2.31	-4.76
187	1990.208	-1.50	-5.29	269	1984.708	-2.13	-4.63
189	1990.097	-1.87	-5.15	271	1984.583	-2.01	-4.70
191	1989.986	-2.21	-4.98	273	1984.458	-2.01	-4.85
193	1989.875	-2.51	-4.90	275	1984.333	-1.74	-5.04
195	1989.764	-2.57	-4.84	277	1984.208	-1.38	-5.20
197	1989.653	-2.68	-4.90	279	1984.083	-1.75	-5.05
199	1989.542	-2.59	-5.11	281	1983.958	-2.41	-4.74
201	1989.431	-2.01	-5.38	283	1983.833	-2.39	-4.57
203	1989.319	-1.54	-5.37	285	1983.708	-2.48	-4.51
205	1989.208	-1.73	-5.39	287	1983.583	-2.65	-4.58
207	1989.042	-1.94	-5.14	289	1983.458	-2.53	-4.76
209	1988.875	-2.45	-4.92	291	1983.333	-2.06	-4.97
211	1988.708	-2.29	-4.67	293	1983.208	-1.52	-5.05
213	1988.542	-2.28	-4.89	295	1983.097	-1.56	-4.91
215	1988.375	-2.22	-5.14	297	1982.986	-1.81	-4.80
217	1988.208	-2.35	-5.31	299	1982.875	-2.07	-4.60

301	1982.764	-2.09	-4.55	343	1980.065	-1.49	-5.17
303	1982.653	-2.09	-4.74	345	1979.923	-1.87	-4.94
305	1982.542	-2.11	-4.97	347	1979.780	-2.11	-4.77
307	1982.431	-2.05	-5.13	349	1979.637	-2.08	-4.82
309	1982.319	-1.77	-5.13	351	1979.494	-1.83	-4.97
311	1982.208	-1.61	-5.28	353	1979.351	-1.39	-5.19
313	1982.065	-1.52	-5.20	355	1979.208	-0.99	-5.20
315	1981.923	-1.82	-4.84	357	1979.065	-1.61	-4.84
317	1981.780	-2.04	-4.70	359	1978.923	-2.16	-4.71
319	1981.637	-1.95	-4.65	361	1978.780	-2.23	-4.56
321	1981.494	-1.95	-4.79	363	1978.637	-2.32	-4.74
323	1981.351	-1.88	-5.10	365	1978.494	-2.31	-4.87
325	1981.208	-1.25	-5.19	367	1978.351	-2.06	-5.00
327	1981.083	-1.25	-5.11	369	1978.208	-1.70	-5.04
329	1980.958	-1.74	-4.87	371	1978.042	-1.37	-4.72
331	1980.833	-2.08	-4.76	373	1977.875	-1.85	-4.56
333	1980.708	-2.63	-4.59	375	1977.708	-2.28	-4.59
335	1980.583	-2.46	-4.81	377	1977.542	-2.42	-4.76
337	1980.458	-1.97	-5.08	379	1977.375	-1.74	-5.11
339	1980.333	-1.72	-5.25	381	1977.208	-1.08	-5.26
341	1980.208	-1.62	-5.30	383	1977.042	-1.14	-4.97

$\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ data of Tonga cores TH1-H4

Depth (mm)	Year A.D.	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	Depth (mm)	Year A.D.	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$
3	1982.208	-1.43	-5.21	33	1979.922	-1.39	-4.97
5	1982.083	-0.74	-5.14	34	1979.779	-1.62	-4.73
7	1981.958	-1.12	-5.11	35	1979.637	-1.77	-4.68
9	1981.833	-1.40	-4.67	36	1979.494	-1.62	-4.81
11	1981.708	-1.54	-4.58	37	1979.351	-1.21	-4.96
13	1981.583	-1.78	-4.69	39	1979.208	-0.36	-4.98
15	1981.458	-1.67	-5.00	41	1979.008	-1.16	-4.66
17	1981.333	-1.37	-5.20	43	1978.808	-1.71	-4.55
19	1981.208	-0.79	-5.21	45	1978.608	-1.75	-4.80
21	1981.008	-0.99	-5.04	47	1978.408	-1.05	-4.90
23	1980.808	-1.21	-4.62	49	1978.208	-0.82	-5.00
25	1980.608	-1.88	-4.67	51	1978.042	-1.34	-4.59
27	1980.408	-1.46	-4.95	53	1977.875	-1.92	-4.48
29	1980.208	-1.06	-5.11	55	1977.708	-2.12	-4.59
31	1980.065	-0.93	-5.08	57	1977.542	-2.03	-4.66

59	1977.375	-1.71	-5.05	145	1970.708	-1.66	-4.76
61	1977.208	-1.20	-5.13	147	1970.542	-1.53	-4.59
63	1977.065	-1.21	-5.11	149	1970.375	-1.51	-4.99
65	1976.923	-1.14	-4.72	151	1970.208	-0.83	-5.05
67	1976.780	-1.51	-4.60	153	1970.042	-0.85	-5.00
69	1976.637	-1.82	-4.70	155	1969.875	-1.63	-4.56
71	1976.494	-1.64	-5.09	157	1969.708	-1.92	-4.37
73	1976.351	-1.16	-5.27	159	1969.542	-2.01	-4.68
75	1976.208	-0.85	-5.28	161	1969.375	-1.61	-5.11
77	1976.042	-0.64	-5.11	163	1969.208	-1.32	-5.23
79	1975.875	-1.31	-4.81	165	1969.065	-1.03	-5.17
81	1975.708	-1.58	-4.77	167	1968.923	-1.35	-4.92
83	1975.542	-2.20	-4.80	169	1968.780	-1.46	-4.68
85	1975.375	-1.71	-4.99	171	1968.637	-1.64	-4.84
87	1975.208	-1.27	-5.19	173	1968.494	-1.65	-4.98
89	1975.083	-1.10	-5.16	175	1968.351	-1.62	-5.02
91	1974.958	-0.88	-5.17	177	1968.208	-1.27	-5.16
93	1974.833	-1.14	-4.96	179	1968.065	-0.79	-5.11
95	1974.708	-1.32	-4.83	181	1967.923	-1.46	-4.88
97	1974.583	-1.52	-4.88	183	1967.780	-1.63	-4.62
99	1974.458	-1.87	-5.01	185	1967.637	-2.05	-4.55
101	1974.333	-1.63	-5.15	187	1967.494	-1.82	-4.92
103	1974.208	-1.19	-5.17	189	1967.351	-1.30	-4.98
105	1974.042	-1.15	-5.14	191	1967.208	-1.27	-5.05
107	1973.875	-1.63	-4.77	193	1967.042	-1.63	-4.72
109	1973.708	-1.80	-4.63	195	1966.875	-1.76	-4.73
111	1973.542	-1.88	-4.82	197	1966.708	-2.08	-4.45
113	1973.375	-1.67	-5.03	199	1966.542	-2.26	-4.60
115	1973.208	-1.15	-5.21	201	1966.375	-1.67	-4.87
117	1973.083	-1.13	-4.96	203	1966.208	-1.17	-5.15
119	1972.958	-1.74	-4.71	205	1966.065	-1.06	-4.94
121	1972.833	-2.05	-4.48	207	1965.923	-1.74	-4.67
123	1972.708	-2.34	-4.64	209	1965.780	-1.91	-4.64
125	1972.583	-2.31	-4.92	211	1965.637	-2.20	-4.60
127	1972.458	-2.05	-5.08	213	1965.494	-2.26	-4.82
129	1972.333	-1.03	-5.26	215	1965.351	-1.76	-5.13
131	1972.208	-1.19	-5.27	217	1965.208	-1.24	-5.16
133	1971.958	-1.52	-4.98	219	1965.042	-0.91	-5.12
135	1971.708	-1.65	-4.92	221	1964.875	-1.36	-4.83
137	1971.458	-1.51	-5.08	223	1964.708	-1.70	-4.69
139	1971.208	-1.12	-5.28	225	1964.542	-1.96	-4.76
141	1971.042	-0.73	-5.22	227	1964.375	-1.98	-4.82
143	1970.875	-1.25	-4.98	229	1964.208	-1.34	-5.00

231	1964.083	-0.99	-4.95	317	1958.319	-1.86	-4.87
233	1963.958	-1.52	-4.72	319	1958.208	-1.51	-5.09
235	1963.833	-1.77	-4.73	321	1958.108	-1.52	-4.94
237	1963.708	-1.88	-4.91	323	1958.008	-2.06	-4.81
239	1963.583	-1.98	-4.88	325	1957.908	-2.31	-4.76
241	1963.458	-2.09	-4.93	327	1957.808	-2.61	-4.71
243	1963.333	-1.75	-4.98	329	1957.708	-2.77	-4.70
245	1963.208	-1.40	-5.21	331	1957.608	-3.01	-4.90
247	1963.083	-1.43	-5.07	333	1957.508	-2.59	-5.05
249	1962.958	-1.47	-4.94	335	1957.408	-2.26	-5.29
251	1962.833	-1.82	-4.72	337	1957.308	-1.73	-5.28
253	1962.708	-2.06	-4.76	339	1957.208	-1.74	-5.35
255	1962.583	-2.52	-4.93	341	1957.097	-1.58	-5.22
257	1962.458	-1.83	-5.05	343	1956.986	-1.92	-4.99
259	1962.333	-1.65	-5.09	345	1956.875	-2.10	-4.97
261	1962.208	-1.27	-5.10	347	1956.764	-2.41	-4.93
263	1962.083	-1.49	-4.79	349	1956.653	-2.73	-4.95
265	1961.958	-1.47	-4.57	351	1956.542	-2.90	-5.18
267	1961.833	-1.64	-4.70	353	1956.431	-2.82	-5.18
269	1961.708	-2.20	-4.75	355	1956.319	-2.59	-5.25
271	1961.583	-2.04	-5.03	357	1956.208	-2.30	-5.43
273	1961.458	-2.00	-5.03	359	1956.083	-1.67	-5.37
275	1961.333	-1.33	-5.25	361	1955.958	-1.28	-5.20
277	1961.208	-1.14	-5.27	363	1955.833	-1.42	-4.98
279	1961.042	-1.46	-4.80	365	1955.708	-2.02	-4.81
281	1960.875	-1.98	-4.67	367	1955.583	-2.05	-4.84
283	1960.708	-2.24	-4.83	369	1955.458	-2.06	-4.90
285	1960.542	-2.14	-5.04	371	1955.333	-1.72	-5.20
287	1960.375	-1.85	-5.08	373	1955.208	-1.37	-5.23
289	1960.208	-1.59	-5.09	375	1955.065	-1.47	-5.18
291	1960.042	-1.40	-5.07	377	1954.923	-1.34	-5.17
293	1959.875	-1.50	-4.96	379	1954.780	-1.70	-4.79
295	1959.708	-1.87	-4.70	381	1954.637	-2.12	-4.61
297	1959.542	-1.98	-4.86	383	1954.494	-2.22	-4.72
299	1959.375	-2.07	-4.99	385	1954.351	-1.63	-4.94
301	1959.208	-1.74	-5.10	387	1954.208	-1.35	-5.01
303	1959.097	-1.87	-5.07	389	1954.083	-0.92	-4.98
305	1958.986	-1.42	-5.00	391	1953.958	-1.77	-4.67
307	1958.875	-1.26	-4.82	393	1953.833	-2.17	-4.36
309	1958.764	-1.69	-4.63	395	1953.708	-2.36	-4.41
311	1958.653	-2.11	-4.60	397	1953.583	-2.39	-4.60
313	1958.542	-2.53	-4.71	399	1953.458	-1.99	-5.14
315	1958.431	-2.35	-4.83	401	1953.333	-1.37	-5.15

403	1953.208	-1.29	-5.17	489	1947.833	-2.30	-4.67
405	1953.083	-1.28	-5.10	491	1947.708	-2.26	-4.53
407	1952.958	-1.92	-4.74	493	1947.583	-2.40	-4.64
409	1952.833	-2.12	-4.59	495	1947.458	-2.33	-4.83
411	1952.708	-2.27	-4.54	497	1947.333	-2.41	-5.07
413	1952.583	-2.50	-4.77	499	1947.208	-1.51	-5.23
415	1952.458	-2.02	-4.85	501	1947.097	-1.09	-5.19
417	1952.333	-1.37	-5.10	503	1946.986	-1.20	-5.21
419	1952.208	-1.39	-5.11	505	1946.875	-1.93	-4.84
421	1952.083	-1.55	-4.92	507	1946.764	-2.02	-4.71
423	1951.958	-2.18	-4.67	509	1946.653	-2.15	-4.68
425	1951.833	-2.33	-4.59	511	1946.542	-2.48	-4.66
427	1951.708	-2.31	-4.69	513	1946.431	-2.13	-5.00
429	1951.583	-2.21	-4.83	515	1946.319	-1.74	-5.09
431	1951.458	-1.93	-5.22	517	1946.208	-1.44	-5.23
433	1951.333	-1.83	-5.41	519	1946.083	-1.44	-5.22
435	1951.208	-1.76	-5.52	521	1945.958	-1.52	-5.05
437	1951.083	-1.03	-5.37	523	1945.833	-2.06	-4.65
439	1950.958	-1.81	-5.22	525	1945.708	-2.23	-4.37
441	1950.833	-2.12	-4.79	527	1945.583	-1.70	-4.54
443	1950.708	-2.15	-4.74	529	1945.458	-2.31	-4.57
445	1950.583	-2.22	-4.84	531	1945.333	-2.01	-4.97
447	1950.458	-2.19	-4.92	533	1945.208	-1.15	-5.19
449	1950.333	-1.82	-5.20	535	1944.875	-1.18	-5.15
451	1950.208	-1.13	-5.35	537	1944.625	-1.55	-4.92
453	1950.065	-1.35	-5.19				
455	1949.923	-1.43	-5.05	547.5	1943.708	-1.78	-4.89
457	1949.780	-1.97	-4.72	564.5	1942.708	-1.83	-4.87
459	1949.637	-1.99	-4.54	587	1941.708	-1.81	-4.72
461	1949.494	-2.18	-4.63	605	1940.708	-1.77	-4.69
463	1949.351	-1.77	-5.02	618	1939.708	-1.63	-4.67
465	1949.208	-1.31	-5.28	632	1938.708	-1.55	-4.90
467	1949.097	-1.43	-5.22	647.5	1937.708	-1.48	-4.85
469	1948.986	-1.36	-5.04	666	1936.708	-1.44	-4.84
471	1948.875	-2.16	-4.93	683	1935.708	-1.32	-5.02
473	1948.764	-2.10	-4.76	695	1934.708	-1.15	-4.88
475	1948.653	-2.34	-4.75	706	1933.708	-1.19	-5.08
477	1948.542	-2.43	-4.91				
479	1948.431	-2.30	-4.98	713	1933.608	-1.56	-4.78
481	1948.319	-1.62	-4.98	715	1933.508	-1.56	-4.84
483	1948.208	-1.23	-5.10	717	1933.408	-1.22	-5.18
485	1948.083	-1.33	-5.15	719	1933.308	-0.84	-5.37
487	1947.958	-1.89	-4.81	721	1933.208	-0.86	-5.40

*723	1932.708	-0.88	-5.02	1170	1903.708	-1.95	-4.71
*725	1932.208	-1.37	-4.57	1188.5	1902.708	-1.53	-4.84
727	1931.708	-0.28	-4.54	1206	1901.708	-1.83	-4.65
729	1931.208	-0.57	-4.73	1221.5	1900.708	-1.40	-4.90
731	1930.875	-0.87	-4.56				
733	1930.542	-1.61	-4.28	1229	1900.042	-1.69	-4.71
				1231	1899.875	-1.77	-4.32
746	1929.708	-1.76	-4.90	1233	1899.708	-1.86	-4.50
764	1928.708	-1.33	-4.89	1235	1899.542	-1.49	-4.65
778	1927.708	-1.46	-5.05	1237	1899.375	-1.66	-5.01
792	1926.708	-1.56	-4.81	1239	1899.208	-1.21	-5.20
809	1925.708	-1.56	-4.95	1241	1899.042	-1.10	-5.12
825	1924.708	-1.77	-4.81				
842	1923.708	-1.57	-4.85	1250	1898.708	-1.37	-4.86
858	1922.708	-1.19	-4.85	1264.5	1897.708	-1.51	-4.63
870	1921.708	-1.35	-5.00	1277.5	1896.708	-1.42	-4.64
882.5	1920.708	-1.41	-4.77	1292.5	1895.708	-1.46	-4.82
896.5	1919.708	-1.53	-4.70	1308.5	1894.708	-1.65	-4.86
912.5	1918.708	-1.45	-4.86	1326	1893.708	-1.62	-4.94
932	1917.708	-1.52	-5.09	1344.5	1892.708	-1.58	-4.85
951.5	1916.708	-1.58	-4.96	1362	1891.708	-1.43	-4.84
967.5	1915.708	-1.61	-4.77	1379	1890.708	-1.60	-4.83
				1396	1889.708	-1.63	-4.64
975	1915.208	-1.81	-4.41	1413	1888.708	-1.64	-4.92
977	1915.097	-2.01	-4.54	1430	1887.708	-1.68	-4.93
979	1914.986	-1.87	-4.34	1446	1886.708	-1.46	-4.70
981	1914.875	-2.09	-4.34	1462.5	1885.708	-1.43	-4.65
983	1914.764	-1.89	-4.73	1478	1884.708	-1.51	-4.78
985	1914.653	-1.64	-4.91	1494.5	1883.708	-1.63	-4.79
987	1914.542	-1.75	-4.86	1514	1882.708	-1.68	-4.90
989	1914.431	-0.55	-5.15	1533.5	1881.708	-1.58	-4.90
991	1914.319	-0.76	-4.99	1551	1880.708	-1.66	-4.94
				1567.5	1879.708	-1.21	-4.92
998.5	1913.708	-1.67	-4.72	1581.5	1878.708	-1.17	-4.70
1015	1912.708	-1.74	-4.80	1595	1877.708	-1.23	-4.60
1034.5	1911.708	-1.87	-4.89	1610	1876.708	-1.36	-4.79
1055	1910.708	-1.83	-4.91	1625	1875.708	-1.21	-4.80
1072.5	1909.708	-1.64	-4.95	1642	1874.708	-1.33	-4.79
1087.5	1908.708	-1.67	-4.93	1660	1873.708	-1.46	-4.79
1103	1907.708	-1.87	-4.74	1678	1872.708	-1.48	-4.89
1118.5	1906.708	-1.75	-4.79	1697.5	1871.708	-1.44	-4.96
1134	1905.708	-1.84	-4.60	1716.5	1870.708	-1.42	-4.84
1151	1904.708	-2.04	-4.81	1737	1869.708	-1.49	-4.63

1755	1868.708	-1.32	-4.90	2459	1825.708	-1.10	-4.75
1768.5	1867.708	-1.31	-4.81	2470	1824.708	-1.20	-4.99
1782.5	1866.708	-1.45	-4.72	2483.5	1823.708	-1.45	-4.97
1796	1865.708	-1.26	-4.81	2498	1822.708	-1.32	-4.90
1810.5	1864.708	-1.59	-4.80	2512	1821.708	-1.55	-4.99
1826	1863.708	-1.81	-4.74	2527	1820.708	-1.39	-5.17
1843	1862.708	-1.57	-4.94	2542	1819.708	-1.32	-5.01
1858	1861.708	-1.19	-5.02	2555.5	1818.708	-1.14	-4.88
1871	1860.708	-1.32	-4.88	2568	1817.708	-1.32	-4.91
1886	1859.708	-1.28	-4.90	2582	1816.708	-1.48	-4.80
1900	1858.708	-1.30	-4.89	2596.5	1815.708	-1.47	-4.92
1915.5	1857.708	-1.36	-5.02	2610	1814.708	-1.90	-4.92
1934.5	1856.708	-1.32	-4.67	2625.5	1813.708	-1.79	-5.01
1952	1855.708	-1.48	-4.78	2643	1812.708	-1.87	-5.01
1969	1854.708	-1.51	-4.81	2658	1811.708	-1.69	-4.72
1989	1853.708	-1.29	-4.79	2673	1810.708	-1.74	-4.65
2007.5	1852.708	-1.70	-4.70	2689	1809.708	-1.71	-4.78
2024	1851.708	-1.70	-4.70	2704.5	1808.708	-1.67	-4.83
2043.5	1850.708	-1.78	-4.84	2722	1807.708	-1.95	-4.94
2067	1849.708	-1.81	-4.98	2741.5	1806.708	-2.04	-4.91
2086	1848.708	-1.82	-4.87				
2101	1847.708	-1.83	-4.88	2753	1806.208	-1.86	-5.27
2118	1846.708	-1.83	-4.73	2755	1806.108	-1.70	-5.18
2138.5	1845.708	-1.83	-4.80	2757	1806.008	-1.80	-5.09
2157.5	1844.708	-1.33	-4.79	2759	1805.908	-1.78	-5.01
2174	1843.708	-1.37	-4.85	2761	1805.808	-1.83	-5.02
2195	1842.708	-1.54	-4.82	2763	1805.708	-1.98	-4.94
2215	1841.708	-1.84	-4.72	2765	1805.608	-2.22	-4.84
2233.5	1840.708	-1.76	-4.65	2767	1805.508	-2.43	-4.81
2256	1839.708	-1.95	-4.64	2769	1805.408	-2.35	-4.75
2276.5	1838.708	-2.39	-4.85	2771	1805.308	-2.15	-4.98
2293	1837.708	-2.58	-4.72	2773	1805.208	-1.43	-5.04
2307.5	1836.708	-2.36	-4.84	2775	1805.041	-1.07	-4.85
2319.5	1835.708	-2.47	-4.82	2777	1804.875	-1.56	-4.53
2331.5	1834.708	-2.24	-4.91	2779	1804.708	-1.58	-4.27
2345	1833.708	-2.10	-4.79	2781	1804.541	-1.89	-4.48
2360	1832.708	-2.27	-4.81	2783	1804.375	-1.59	-4.91
2375.5	1831.708	-1.32	-4.92	2785	1804.208	-0.70	-4.95
2389.5	1830.708	-1.27	-5.01	2787	1804.041	-0.96	-4.70
2404	1829.708	-1.55	-5.12	2789	1803.875	-1.36	-4.35
2418	1828.708	-1.46	-5.11				
2432.5	1827.708	-1.46	-5.10	2796	1802.708	-1.25	-4.83
2447	1826.708	-1.27	-5.12	2808.5	1801.708	-1.15	-4.97

2820	1800.708	-1.47	-4.83	2876.5	1795.708	-1.12	-4.95
2831	1799.708	-1.31	-4.86	2889	1794.708	-1.21	-5.10
2841.5	1798.708	-1.43	-4.75	2899	1793.708	-1.29	-4.68
2851.5	1797.708	-1.16	-4.85				
2863	1796.708	-1.25	-4.85				

* One year was inserted because of slab break.

$\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ data of Tonga cores TM1

Depth (mm)	Year A.D.	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$				
				34	2001.542	-2.48	-4.57
				35	2001.458	-2.62	-4.76
1	2004.833	-1.32	-4.58	36	2001.375	-2.45	-4.86
2	2004.708	-1.62	-4.57	37	2001.292	-2.19	-5.05
3	2004.583	-1.86	-4.63	38	2001.208	-1.85	-5.13
4	2004.458	-2.01	-4.74	39	2001.108	-1.35	-5.07
5	2004.333	-1.67	-4.86	40	2001.008	-1.50	-4.88
6	2004.208	-0.95	-4.92	41	2000.908	-1.77	-4.82
7	2004.097	-0.29	-4.57	42	2000.808	-1.82	-4.66
8	2003.986	-0.62	-4.42	43	2000.708	-1.81	-4.47
9	2003.875	-1.03	-4.46	44	2000.608	-2.17	-4.52
10	2003.764	-1.46	-4.28	45	2000.508	-2.46	-4.45
11	2003.653	-1.72	-4.46	46	2000.408	-2.77	-4.64
12	2003.542	-1.58	-4.62	47	2000.308	-2.73	-4.94
13	2003.431	-1.42	-4.84	48	2000.208	-2.29	-5.15
14	2003.319	-1.26	-4.91	49	2000.125	-1.86	-5.11
15	2003.208	-1.10	-4.95	50	2000.042	-1.04	-4.97
16	2003.117	-1.20	-4.83	51	1999.958	-1.23	-4.76
17	2003.027	-1.42	-4.75	52	1999.875	-1.74	-4.61
18	2002.936	-1.44	-4.61	53	1999.792	-1.82	-4.58
19	2002.845	-1.59	-4.48	54	1999.708	-1.96	-4.45
20	2002.754	-1.93	-4.46	55	1999.625	-2.14	-4.52
21	2002.663	-2.14	-4.45	56	1999.542	-2.34	-4.58
22	2002.572	-2.16	-4.54	57	1999.458	-2.56	-4.60
23	2002.481	-2.00	-4.68	58	1999.375	-2.31	-4.69
24	2002.390	-2.11	-4.91	59	1999.292	-2.05	-4.85
25	2002.299	-2.11	-5.05	60	1999.208	-1.74	-4.91
26	2002.208	-1.82	-5.21	61	1999.117	-1.46	-4.85
27	2002.125	-1.27	-5.06	62	1999.027	-1.56	-4.57
28	2002.042	-1.31	-4.83	63	1998.936	-1.68	-4.49
29	2001.958	-1.57	-4.74	64	1998.845	-1.70	-4.32
30	2001.875	-1.58	-4.66	65	1998.754	-1.73	-4.24
31	2001.792	-1.67	-4.52	66	1998.663	-1.99	-4.28
32	2001.708	-1.95	-4.53	67	1998.572	-2.23	-4.37
33	2001.625	-2.17	-4.45	68	1998.481	-2.45	-4.51

69	1998.390	-2.31	-4.58	112	1994.845	-1.74	-4.57
70	1998.299	-2.01	-4.70	113	1994.754	-1.95	-4.44
71	1998.208	-1.71	-4.76	114	1994.663	-1.91	-4.25
72	1998.125	-1.77	-4.72	115	1994.572	-2.20	-4.33
73	1998.042	-1.57	-4.62	116	1994.481	-2.17	-4.50
74	1997.958	-1.55	-4.60	117	1994.390	-2.08	-4.60
75	1997.875	-1.60	-4.59	118	1994.299	-1.65	-4.81
76	1997.792	-1.89	-4.48	119	1994.208	-1.30	-4.89
77	1997.708	-2.10	-4.35	120	1994.042	-0.90	-4.75
78	1997.625	-2.62	-4.38	121	1993.875	-1.08	-4.58
79	1997.542	-2.54	-4.36	123	1993.708	-1.60	-4.19
80	1997.458	-2.38	-4.65				
81	1997.375	-2.26	-4.79	128.5	1993.208	-1.70	-4.56
82	1997.292	-2.33	-4.99	139.5	1992.208	-1.61	-4.53
83	1997.208	-1.66	-5.15	151	1991.208	-1.60	-4.50
84	1997.125	-1.00	-4.97	163	1990.208	-1.68	-4.68
85	1997.042	-1.13	-4.71				
86	1996.958	-1.39	-4.71	170	1989.637	-1.75	-4.55
87	1996.875	-1.41	-4.61	171	1989.494	-2.04	-4.60
88	1996.792	-1.38	-4.66	173	1989.351	-2.40	-4.90
89	1996.708	-1.63	-4.56	175	1989.208	-2.18	-5.03
90	1996.625	-1.77	-4.60	177	1989.065	-1.67	-4.98
91	1996.542	-2.45	-4.50	179	1988.923	-1.58	-4.68
92	1996.458	-2.61	-4.67	181	1988.780	-1.81	-4.62
93	1996.375	-2.16	-4.89	183	1988.637	-2.27	-4.40
94	1996.292	-1.67	-5.03	185	1988.494	-2.44	-4.52
95	1996.208	-1.44	-5.11	187	1988.351	-2.22	-4.69
96	1996.131	-1.09	-5.05	189	1988.208	-1.16	-4.84
97	1996.054	-1.22	-4.80	191	1988.408	-1.18	-4.38
98	1995.978	-1.32	-4.77	193	1988.608	-1.46	-4.26
99	1995.901	-1.45	-4.66	195	1988.808	-2.02	-4.17
100	1995.824	-1.82	-4.45	197	1989.008	-1.80	-4.51
101	1995.747	-2.11	-4.39	199	1987.208	-0.83	-4.59
102	1995.670	-2.21	-4.49	201	1987.542	-1.10	-4.41
103	1995.593	-2.42	-4.54	203	1987.875	-1.89	-4.22
104	1995.516	-2.54	-4.58	205	1986.208	-1.97	-4.43
105	1995.439	-2.45	-4.64				
106	1995.362	-1.95	-4.93	214	1985.208	-1.79	-4.73
107	1995.285	-1.61	-5.00	227.5	1984.208	-1.22	-4.55
108	1995.208	-1.59	-5.07	236	1983.208	-0.42	-4.07
109	1995.117	-1.31	-5.00	244	1982.208	-0.73	-4.40
110	1995.027	-1.31	-4.85	252.5	1981.208	-0.82	-4.50
111	1994.936	-1.64	-4.70	260	1980.208	-0.76	-4.59

267	1979.208	-0.86	-4.63	689	1936.208	-1.21	-4.54
274	1978.208	-1.12	-4.38	699.5	1935.208	-1.19	-4.45
282.5	1977.208	-1.28	-4.42	709.5	1934.208	-1.02	-4.53
292.5	1976.208	-1.35	-4.68	720	1933.208	-1.06	-4.58
302	1975.208	-1.04	-4.65	730.5	1932.208	-1.25	-4.53
311	1974.208	-0.93	-4.64	739	1931.208	-1.22	-4.21
319.5	1973.208	-1.29	-4.54				
328.5	1972.208	-0.89	-4.49	743	1930.408	-2.25	-4.33
336.5	1971.208	0.13	-4.35	745	1930.208	-1.66	-4.57
343.5	1970.208	-0.26	-4.44	747	1930.008	-0.76	-4.26
351	1969.208	-0.02	-4.31	749	1929.808	-0.39	-4.05
358.5	1968.208	0.11	-4.37	751	1929.608	-1.00	-3.82
366.5	1967.208	-0.04	-4.27	753	1929.408	-1.76	-3.94
373.5	1966.208	-0.07	-4.32	755	1929.208	-0.64	-4.41
380.5	1965.208	-0.34	-4.52	757	1928.958	-0.11	-3.97
388.5	1964.208	-0.18	-4.33	759	1928.708	-0.42	-3.91
396	1963.208	-0.52	-4.62	761	1928.458	-1.32	-4.07
404.5	1962.208	-0.99	-4.58	763	1928.208	-0.97	-4.40
414.5	1961.208	-0.85	-4.58	765	1928.042	-0.32	-4.23
424.5	1960.208	-0.66	-4.55	767	1927.875	-0.08	-4.00
434	1959.208	-0.79	-4.55	769	1927.708	-0.92	-3.97
443	1958.208	-1.03	-4.36	771	1927.542	-1.42	-4.32
452	1957.208	-1.05	-4.63	773	1927.375	-0.86	-4.52
462	1956.208	-1.13	-4.87				
473.5	1955.208	-1.15	-4.78	777.5	1927.208	-0.57	-4.44
484.5	1954.208	-1.01	-4.51	784.5	1926.208	-0.39	-4.06
494	1953.208	-0.68	-4.48	791	1925.208	-0.39	-4.17
504.5	1952.208	-1.23	-4.62	798	1924.208	-0.54	-4.27
515.5	1951.208	-1.11	-4.68	805.5	1923.208	-0.75	-4.37
525.5	1950.208	-0.79	-4.66	814	1922.208	-0.83	-4.48
534.5	1949.208	-0.94	-4.35	823	1921.208	-0.87	-4.54
545	1948.208	-0.96	-4.56	832	1920.208	-0.96	-4.39
557	1947.208	-1.30	-4.52	841.5	1919.208	-0.87	-4.26
570	1946.208	-1.27	-4.46	851	1918.208	-0.81	-4.51
583	1945.208	-1.27	-4.31	861	1917.208	-0.77	-4.59
595	1944.208	-1.13	-4.39	871	1916.208	-0.67	-4.64
607	1943.208	-1.44	-4.53	879	1915.208	-0.62	-4.24
618	1942.208	-1.17	-4.31	886	1914.208	-0.72	-4.11
629	1941.208	-1.40	-4.25	893	1913.208	-0.80	-4.28
640.5	1940.208	-1.17	-4.27	900.5	1912.208	-0.88	-4.28
652.5	1939.208	-1.53	-4.54	909.5	1911.208	-0.99	-4.60
664.5	1938.208	-1.57	-4.39	920.5	1910.208	-0.97	-4.46
677	1937.208	-1.51	-4.43	931.5	1909.208	-0.97	-4.63

941.5	1908.208	-0.93	-4.52	1081	1886.708	0.15	-4.06
950	1907.208	-0.77	-4.38	1082	1886.542	-0.42	-4.32
956.5	1906.208	-0.57	-4.32	1083	1886.375	-0.63	-4.66
962.5	1905.208	-0.44	-4.26	1084	1886.208	-0.62	-4.75
968.5	1904.208	-0.60	-4.34	1085	1886.065	-0.30	-4.52
975	1903.208	-0.04	-4.12	1086	1885.923	-0.28	-4.52
981	1902.208	0.13	-4.08	1087	1885.780	-0.10	-4.38
986.5	1901.208	0.16	-4.23	1088	1885.637	-0.05	-4.12
992.5	1900.208	-0.03	-4.21	1089	1885.494	-0.39	-3.88
999	1899.208	-0.04	-4.37	1090	1885.351	-0.66	-3.90
1006	1898.208	-0.61	-4.60	1091	1885.208	-0.13	-4.10
1012.5	1897.208	-0.19	-4.16	1092	1885.065	0.37	-4.01
1018.5	1896.208	-0.31	-4.40	1093	1884.923	0.27	-3.73
1025.5	1895.208	-0.46	-4.66	1094	1884.780	-0.17	-3.58
1034	1894.208	-0.58	-4.62				
1044	1893.208	-0.56	-4.64	1097	1885.208	-0.48	-4.27
1052	1892.208	-0.26	-4.39	1103	1883.708	-0.13	-4.21
				1109.5	1882.708	-0.14	-4.39
1056	1891.208	-0.12	-4.61	1115.5	1881.708	-0.23	-4.39
1057	1891.042	-0.17	-4.41				
1058	1890.875	-0.19	-4.14	1119	1881.663	-0.21	-4.14
1059	1890.708	-0.31	-4.06	1120	1881.572	-0.40	-4.14
1060	1890.542	-0.19	-4.26	1121	1881.481	-0.65	-4.22
1061	1890.375	0.39	-4.25	1122	1881.390	-0.61	-4.51
1062	1890.208	0.30	-4.30	1123	1881.299	-0.55	-4.70
1063	1890.042	0.18	-4.19	1124	1881.208	-0.38	-4.71
1064	1889.875	0.00	-4.01	1125	1881.065	-0.33	-4.54
1065	1889.708	-0.37	-4.11	1126	1880.923	-0.16	-4.34
1066	1889.542	-0.34	-4.35	1127	1880.780	-0.23	-4.04
1067	1889.375	0.05	-4.53	1128	1880.637	-0.61	-4.24
1068	1889.208	0.01	-4.55	1129	1880.494	-0.77	-4.38
1069	1889.042	0.08	-4.30	1130	1880.351	-0.94	-4.60
1070	1888.875	-0.05	-4.24	1131	1880.208	-0.68	-4.73
1071	1888.708	-0.25	-4.08	1132	1880.097	-0.25	-4.69
1072	1888.542	-0.33	-4.01	1133	1879.986	-0.15	-4.46
1073	1888.375	-0.04	-4.25	1134	1879.875	-0.12	-4.33
1074	1888.208	0.13	-4.26	1135	1879.764	-0.20	-4.23
1075	1887.958	0.09	-4.15	1136	1879.653	-0.50	-4.15
1076	1887.708	0.12	-3.91	1137	1879.542	-0.82	-4.18
1077	1887.458	-0.29	-4.24	1138	1879.431	-1.22	-4.42
1078	1887.208	-0.03	-4.37	1139	1879.319	-1.29	-4.61
1079	1887.042	0.23	-4.28	1140	1879.208	-0.99	-4.79
1080	1886.875	0.11	-4.20	1141	1879.097	-0.58	-4.59

1142	1878.986	-0.44	-4.53	1354	1852.008	-0.51	-4.45
1143	1878.875	-0.35	-4.26	1355	1851.908	-0.44	-4.39
1144	1878.764	-0.18	-4.07	1356	1851.808	-0.40	-4.26
1145	1878.653	-0.62	-3.92	1357	1851.708	-0.68	-4.09
1146	1878.542	-0.91	-3.95	1358	1851.608	-0.74	-4.05
1147	1878.431	-1.16	-4.09	1359	1851.508	-0.88	-4.03
1148	1878.319	-1.24	-4.17	1360	1851.408	-1.23	-4.29
1149	1878.208	-0.90	-4.27	1361	1851.308	-0.78	-4.56
				1362	1851.208	-0.47	-4.71
1153.5	1877.708	-0.29	-4.10	1363	1851.097	-0.34	-4.66
1161.5	1876.708	-0.57	-4.25	1364	1850.986	-0.29	-4.45
1169.5	1875.708	-0.61	-4.43	1365	1850.875	-0.31	-4.37
1177	1874.708	-0.50	-4.37	1366	1850.764	-0.22	-4.14
1184	1873.708	-0.47	-4.51	1367	1850.653	-0.47	-4.20
1191.5	1872.708	-0.37	-4.38	1368	1850.542	-0.75	-4.25
1199	1871.708	-0.49	-4.61	1369	1850.431	-0.78	-4.40
1206	1870.708	-0.58	-4.49	1370	1850.319	-0.77	-4.70
1213.5	1869.708	-0.65	-4.39	1371	1850.208	-0.54	-4.82
1220.5	1868.708	-0.42	-4.34				
1228.5	1867.708	-0.74	-4.43	1377.5	1849.708	-0.88	-4.50
1238.5	1866.708	-0.55	-4.51	1390	1848.708	-0.64	-4.60
1247	1865.708	-0.59	-4.39	1401.5	1847.708	-0.88	-4.60
1254	1864.708	0.14	-4.07	1412.5	1846.708	-0.78	-4.44
1261.5	1863.708	-0.04	-4.27	1425	1845.708	-1.11	-4.28
1269	1862.708	-0.24	-4.30	1436.5	1844.708	-0.71	-4.28
1276.5	1861.708	-0.42	-4.43	1447.5	1843.708	-1.00	-4.32
1284	1860.708	-0.17	-4.42	1459.5	1842.708	-0.98	-4.42
1291	1859.708	-0.31	-4.53	1470	1841.708	-0.37	-4.36
1298.5	1858.708	-0.30	-4.36	1480	1840.708	-0.45	-4.44
1306.5	1857.708	-0.06	-4.32	1489.5	1839.708	-0.62	-4.23
1314.5	1856.708	-0.47	-4.47	1499	1838.708	-0.96	-4.39
1323.5	1855.708	-0.75	-4.47	1510.5	1837.708	-0.98	-4.49
1332.5	1854.708	-0.64	-4.29	1521	1836.708	-1.65	-4.33
1341	1853.708	-0.82	-4.51				
1346	1853.042	-0.56	-4.38				
1347	1852.708	-0.79	-4.20				
1348	1852.608	-1.06	-4.20				
1349	1852.508	-1.10	-4.22				
1350	1852.408	-1.11	-4.36				
1351	1852.308	-0.93	-4.59				
1352	1852.208	-0.72	-4.69				
1353	1852.108	-0.35	-4.62				

The space lines are the breaks between mm-samplings and annual samplings.

Appendix 6. Annually averaged $\delta^{18}\text{O}$ data of five Fiji Tonga Corals

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
2004			-5.04	-4.74	-4.93
2003			-5.00	-4.61	-4.94
2002			-4.99	-4.70	-4.94
2001		-4.81	-5.05	-4.77	-4.87
2000		-4.98	-5.00	-4.76	-4.82
1999		-4.96	-5.10	-4.74	-4.78
1998		-4.56	-4.81	-4.53	-4.61
1997		-4.56	-4.82	-4.61	-4.75
1996	-5.32	-4.89	-5.00	-4.76	-4.93
1995	-5.25	-4.80	-5.04	-4.72	-4.80
1994	-5.12	-4.61	-4.85	-4.65	-4.67
1993	-5.01	-4.68	-4.88	-4.60	-4.67
1992	-5.00	-4.64	-4.82	-4.56	-4.71
1991	-5.16	-4.59	-4.93	-4.53	-4.75
1990	-5.18	-4.69	-4.96	-4.50	-4.74
1989	-5.41	-4.88	-5.04	-4.68	-4.85
1988	-5.27	-4.72	-4.96	-4.70	-4.82
1987	-5.03	-4.52	-4.88	-4.43	-4.65
1986	-5.11	-4.52	-4.92	-4.41	-4.67
1985	-5.15	-4.65	-4.87	-4.43	-4.70
1984	-5.21	-4.67	-4.86	-4.73	-4.67
1983	-4.94	-4.53	-4.74	-4.55	-4.57
1982	-5.25	-4.71	-4.82	-4.07	-4.68
1981	-5.21	-4.76	-4.91	-4.40	-4.83
1980	-5.15	-4.73	-4.90	-4.50	-4.75
1979	-5.20	-4.84	-4.93	-4.59	-4.77
1978	-4.99	-4.62	-4.78	-4.63	-4.63
1977	-5.00	-4.40	-4.77	-4.38	-4.56
1976	-5.17	-4.75	-4.95	-4.42	-4.67
1975	-5.17	-4.89	-4.96	-4.68	-4.79
1974	-5.18	-4.92	-5.05	-4.65	-4.84
1973	-5.06	-4.75	-4.93	-4.64	-4.70
1972	-5.08	-4.67	-4.91	-4.54	-4.67
1971	-5.36	-4.86	-5.06	-4.49	-4.90
1970	-5.18	-4.67	-4.97	-4.35	-4.70
1969	-5.11	-4.62	-4.80	-4.44	-4.64
1968	-5.22	-4.76	-4.98	-4.31	-4.83
1967	-5.13	-4.58	-4.89	-4.37	-4.65
1966	-5.05	-4.56	-4.74	-4.27	-4.63

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
1965	-5.11	-4.57	-4.85	-4.32	-4.58
1964	-5.08	-4.75	-4.89	-4.52	-4.65
1963	-5.20	-4.74	-4.89	-4.33	-4.67
1962	-5.25	-4.72	-4.97	-4.62	-4.83
1961	-5.26	-4.78	-4.90	-4.58	-4.69
1960	-5.12	-4.77	-4.95	-4.58	-4.70
1959	-5.04	-4.78	-4.95	-4.55	-4.74
1958	-4.93	-4.56	-4.85	-4.55	-4.62
1957	-5.12	-4.61	-4.95	-4.36	-4.76
1956	-5.25	-4.92	-5.11	-4.63	-4.93
1955	-5.18	-4.89	-5.09	-4.87	-4.91
1954	-4.99	-4.67	-4.95	-4.78	-4.79
1953	-4.87	-4.64	-4.79	-4.51	-4.63
1952	-5.02	-4.64	-4.85	-4.48	-4.74
1951	-5.26	-4.60	-4.93	-4.62	-4.73
1950	-5.36	-4.63	-5.08	-4.68	-4.84
1949	-5.21	-4.59	-4.93	-4.66	-4.79
1948	-5.09	-4.75	-4.98	-4.35	-4.79
1947	-5.06	-4.59	-4.85	-4.56	-4.73
1946	-5.19	-4.69	-4.96	-4.52	-4.78
1945	-4.98	-4.66	-4.82	-4.46	-4.73
1944	-5.12	-4.62	-4.73	-4.31	-4.82
1943	-5.13	-4.67	-4.89	-4.39	-4.98
1942	-4.98	-4.55	-4.87	-4.53	-4.73
1941	-4.93	-4.46	-4.72	-4.31	-4.60
1940	-4.87	-4.43	-4.69	-4.25	-4.49
1939	-5.07	-4.64	-4.67	-4.27	-4.67
1938	-5.00	-4.65	-4.90	-4.54	-4.75
1937	-4.92	-4.50	-4.85	-4.39	-4.74
1936	-5.15	-4.61	-4.84	-4.43	-4.80
1935	-5.00	-4.63	-5.02	-4.54	-4.74
1934	-5.07	-4.65	-4.88	-4.45	-4.66
1933	-5.08	-4.76	-5.08	-4.53	-4.89
1932	-5.06	-4.67	-4.86	-4.58	-4.80
1931	-4.84	-4.51	-5.00	-4.53	-4.65
1930	-4.79	-4.31	-4.52	-4.21	-4.67
1929	-4.87	-4.57	-4.90	-4.13	-4.62
1928	-4.92	-4.61	-4.89	-4.09	-4.83
1927	-5.14	-4.76	-5.05	-4.15	-4.87
1926	-4.85	-4.53	-4.81	-4.44	-4.71
1925	-4.98	-4.45	-4.95	-4.06	-4.73
1924	-4.91	-4.49	-4.81	-4.17	-4.83
1923	-4.91	-4.57	-4.85	-4.27	-4.67
1922	-5.14	-4.70	-4.85	-4.37	-4.83

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
1921	-5.07	-4.63	-5.00	-4.48	-4.82
1920	-4.93	-4.48	-4.77	-4.54	-4.77
1919	-4.90	-4.51	-4.70	-4.39	-4.78
1918	-5.14	-4.62	-4.86	-4.26	-4.82
1917	-5.31	-4.72	-5.09	-4.51	-4.97
1916	-5.20	-4.78	-4.96	-4.59	-4.90
1915	-4.94	-4.50	-4.77	-4.64	-4.58
1914	-4.87	-4.56	-4.80	-4.24	-4.56
1913	-4.82	-4.51	-4.72	-4.11	-4.56
1912	-4.76	-4.49	-4.80	-4.28	-4.26
1911	-5.08	-4.68	-4.89	-4.28	-4.45
1910	-5.14	-4.74	-4.91	-4.60	-4.55
1909	-4.94	-4.71	-4.95	-4.46	-4.63
1908	-4.99	-4.76	-4.93	-4.63	-4.57
1907	-4.96	-4.63	-4.74	-4.52	-4.59
1906	-4.85	-4.51	-4.79	-4.38	-4.40
1905	-4.66	-4.34	-4.60	-4.32	-4.36
1904	-4.86	-4.55	-4.81	-4.26	-4.48
1903	-4.80	-4.44	-4.71	-4.34	-4.45
1902	-4.83	-4.47	-4.84	-4.12	-4.50
1901	-4.76	-4.53	-4.65	-4.08	-4.47
1900	-4.72	-4.46	-4.90	-4.23	-4.49
1899	-4.88	-4.58	-4.74	-4.21	-4.53
1898	-4.98	-4.77	-4.86	-4.37	-4.65
1897	-4.86	-4.49	-4.63	-4.60	-4.48
1896	-4.93	-4.48	-4.64	-4.16	-4.47
1895	-4.94	-4.51	-4.82	-4.40	-4.54
1894	-4.96	-4.64	-4.86	-4.66	-4.61
1893	-5.24	-4.68	-4.94	-4.62	-4.77
1892	-5.09	-4.66	-4.85	-4.64	-4.65
1891	-5.06	-4.63	-4.84	-4.39	-4.60
1890	-5.16	-4.68	-4.83	-4.29	-4.60
1889	-4.90	-4.46	-4.64	-4.25	-4.46
1888	-4.87	-4.40	-4.92	-4.24	-4.52
1887	-4.99	-4.65	-4.93	-4.14	-4.73
1886	-4.76	-4.44	-4.70	-4.32	-4.41
1885	-4.78	-4.37	-4.65	-4.29	-4.48
1884	-4.75	-4.46	-4.78	-4.27	-4.45
1883	-4.87	-4.56	-4.79	-4.21	-4.61
1882	-4.89	-4.54	-4.90	-4.39	-4.40
1881	-4.97	-4.57	-4.90	-4.39	-4.42
1880	-5.02	-4.64	-4.94	-4.41	-4.53
1879	-5.16	-4.77	-4.92	-4.42	-4.54
1878	-4.70	-4.45	-4.70	-4.26	-4.47

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
1877	-4.61	-4.32	-4.60	-4.10	-4.30
1876	-4.80	-4.51	-4.79	-4.25	-4.49
1875	-4.78	-4.41	-4.80	-4.43	-4.53
1874	-4.78	-4.51	-4.79	-4.37	-4.49
1873	-4.78	-4.46	-4.79	-4.51	-4.48
1872	-4.91	-4.45	-4.89	-4.38	-4.48
1871	-4.89	-4.61	-4.96	-4.61	-4.58
1870	-4.83	-4.69	-4.84	-4.49	-4.52
1869	-4.87	-4.62	-4.63	-4.39	-4.59
1868	-4.73	-4.45	-4.90	-4.34	-4.64
1867	-4.78	-4.50	-4.81	-4.43	-4.60
1866	-4.60	-4.56	-4.72	-4.51	-4.62
1865	-4.56	-4.46	-4.81	-4.39	-4.52
1864	-4.77	-4.46	-4.80	-4.07	-4.51
1863	-4.76	-4.46	-4.74	-4.27	-4.60
1862	-4.75	-4.38	-4.94	-4.30	-4.66
1861	-4.90	-4.48	-5.02	-4.43	-4.74
1860	-5.01	-4.67	-4.88	-4.42	-4.81
1859	-4.90	-4.56	-4.90	-4.53	-4.63
1858	-4.85	-4.44	-4.89	-4.36	-4.59
1857	-4.78	-4.49	-5.02	-4.32	-4.53
1856	-4.92	-4.60	-4.67	-4.47	-4.67
1855	-4.79	-4.49	-4.78	-4.47	-4.59
1854	-4.77	-4.45	-4.81	-4.29	-4.55
1853	-4.79	-4.53	-4.79	-4.51	-4.57
1852	-4.86	-4.44	-4.70	-4.31	-4.63
1851	-4.84	-4.33	-4.70	-4.34	-4.49
1850	-4.78	-4.25	-4.84	-4.43	-4.50
1849	-4.67	-4.44	-4.98	-4.50	-4.55
1848	-4.98	-4.56	-4.87	-4.60	-4.75
1847	-4.96	-4.60	-4.88	-4.60	-4.71
1846	-4.80	-4.56	-4.73	-4.44	-4.63
1845	-4.62	-4.42	-4.80	-4.28	-4.54
1844	-4.75	-4.36	-4.79	-4.28	-4.50
1843	-4.76	-4.31	-4.85	-4.32	-4.70
1842	-4.80	-4.62	-4.82	-4.42	-4.30
1841	-5.01	-4.53	-4.72	-4.36	-4.65
1840	-4.88	-4.43	-4.65	-4.44	-4.60
1839	-4.88	-4.44	-4.64	-4.23	-4.64
1838	-4.71	-4.40	-4.85	-4.39	-4.54
1837	-4.94	-4.47	-4.72	-4.49	-4.73
1836	-4.78	-4.36	-4.84	-4.33	-4.58
1835	-4.77	-4.40	-4.82		-4.49
1834	-4.86	-4.45	-4.91		-4.51

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
1833	-4.64	-4.43	-4.79		-4.58
1832	-4.72	-4.38	-4.81		-4.62
1831	-4.85	-4.46	-4.92		-4.68
1830	-4.99	-4.54	-5.01		-4.95
1829	-5.01	-4.58	-5.12		-4.81
1828	-4.90	-4.60	-5.11		-4.83
1827	-4.92	-4.60	-5.10		-4.72
1826	-4.86	-4.56	-5.12		-4.86
1825	-4.99	-4.60	-4.75		-4.91
1824	-4.76	-4.40	-4.99		-4.87
1823	-4.86	-4.34	-4.97		-4.95
1822	-4.87	-4.50	-4.90		-4.57
1821	-4.83	-4.38	-4.99		-4.49
1820	-4.74	-4.34	-5.17		-4.72
1819	-5.03	-4.56	-5.01		-4.85
1818	-5.11	-4.65	-4.88		-4.50
1817	-4.81	-4.53	-4.91		-4.60
1816	-4.74	-4.42	-4.80		-4.64
1815	-4.74	-4.40	-4.92		-4.65
1814	-4.69	-4.42	-4.92		-4.68
1813	-4.88	-4.51	-5.01		-4.70
1812	-4.89	-4.54	-5.01		-4.60
1811	-4.73	-4.47	-4.72		-4.50
1810	-4.62	-4.40	-4.65		-4.53
1809	-4.72	-4.35	-4.78		-4.52
1808	-4.81	-4.37	-4.83		-4.71
1807	-4.96	-4.58	-4.94		-4.89
1806	-5.01	-4.78	-4.91		-4.88
1805	-5.00	-4.62	-4.99		-4.73
1804	-4.97	-4.59	-4.68		-4.59
1803	-4.66	-4.37	-4.67		-4.31
1802	-4.71	-4.43	-4.83		-4.35
1801	-4.76	-4.60	-4.97		-4.52
1800	-4.89	-4.68	-4.83		-4.55
1799	-4.74	-4.52	-4.86		-4.60
1798	-4.84	-4.41	-4.75		-4.57
1797	-4.96	-4.50	-4.85		-4.68
1796	-4.90	-4.61	-4.85		-4.71
1795	-4.87	-4.68	-4.95		-4.60
1794	-4.96	-4.72	-5.10		-4.54
1793	-4.83	-4.62	-4.68		-4.64
1792	-4.77	-4.35			-4.72
1791	-4.70	-4.28			-4.66
1790	-4.56	-4.44			-4.85

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
1789	-4.66	-4.56			-4.61
1788	-4.58	-4.50			-4.68
1787	-4.65	-4.51			-4.62
1786	-4.81	-4.53			-4.64
1785	-4.74	-4.59			-4.73
1784	-4.88	-4.71			-4.76
1783	-4.62	-4.48			-4.79
1782	-4.66	-4.44			-4.76
1781	-4.66	-4.46			-4.63
1780		-4.49			-4.33
1779		-4.52			-4.70
1778		-4.48			-4.79
1777		-4.63			-4.92
1776		-4.44			-4.70
1775		-4.50			-4.67
1774		-4.58			-4.73
1773		-4.55			-4.89
1772		-4.54			-4.68
1771		-4.49			-4.62
1770		-4.35			-4.65
1769		-4.22			-4.60
1768		-4.37			-4.74
1767		-4.40			-4.73
1766		-4.36			-4.64
1765		-4.42			-4.85
1764		-4.39			-4.84
1763		-4.37			-4.79
1762		-4.40			-4.51
1761		-4.47			-4.83
1760		-4.30			-4.62
1759		-4.27			-4.49
1758		-4.38			-4.47
1757		-4.47			-4.50
1756		-4.51			-4.79
1755		-4.45			-4.71
1754		-4.40			-4.70
1753		-4.43			-4.60
1752		-4.54			-4.57
1751		-4.46			-4.60
1750		-4.43			-4.70
1749		-4.47			-4.47
1748		-4.64			-4.60
1747		-4.52			-4.90
1746		-4.47			-4.59

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
1745		-4.38			-4.70
1744		-4.43			-4.63
1743		-4.50			-4.62
1742		-4.50			-4.67
1741		-4.50			-4.78
1740		-4.52			-4.88
1739		-4.49			-4.71
1738		-4.48			-4.67
1737		-4.61			-4.82
1736		-4.42			-4.70
1735		-4.56			-4.69
1734		-4.53			-4.37
1733		-4.48			-4.51
1732		-4.61			-4.69
1731		-4.57			-4.50
1730		-4.56			-4.66
1729		-4.66			-4.59
1728		-4.67			-4.81
1727		-4.67			-4.68
1726		-4.68			-4.68
1725		-4.63			-4.60
1724		-4.61			-4.45
1723		-4.47			-4.57
1722		-4.61			-4.18
1721		-4.59			-4.30
1720		-4.61			-4.81
1719		-4.44			-4.66
1718		-4.57			-4.59
1717		-4.64			-4.77
1716		-4.75			-4.80
1715		-4.53			-4.89
1714		-4.53			-4.77
1713		-4.40			-4.25
1712		-4.53			-4.13
1711		-4.56			-4.21
1710		-4.65			-4.41
1709		-4.61			-4.58
1708		-4.50			-4.71
1707		-4.52			-4.38
1706		-4.54			-4.45
1705		-4.61			-4.41
1704		-4.43			-4.59
1703		-4.37			-4.62
1702		-4.66			-4.62

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
1701		-4.70			-4.78
1700		-4.53			-4.53
1699		-4.57			-4.42
1698		-4.54			-4.57
1697		-4.42			-4.50
1696		-4.56			-4.76
1695		-4.61			-4.50
1694		-4.60			-4.74
1693		-4.40			-4.70
1692		-4.49			-4.40
1691		-4.57			-4.61
1690		-4.50			-4.61
1689		-4.57			-4.61
1688		-4.55			-4.61
1687		-4.61			-4.61
1686		-4.41			-4.69
1685		-4.63			-4.64
1684		-4.63			-4.86
1683		-4.50			-4.63
1682		-4.56			-4.78
1681		-4.63			-4.75
1680		-4.49			-4.57
1679		-4.49			-4.82
1678		-4.49			-4.49
1677		-4.57			-4.48
1676		-4.41			-4.60
1675		-4.43			-4.85
1674		-4.51			-4.52
1673		-4.53			-4.59
1672		-4.47			-4.90
1671		-4.62			-4.89
1670		-4.61			-4.86
1669		-4.56			-4.55
1668		-4.50			-4.70
1667		-4.45			-4.40
1666		-4.47			-4.63
1665		-4.41			-4.59
1664		-4.28			-4.31
1663		-4.23			-4.50
1662		-4.31			-4.52
1661		-4.50			-4.43
1660		-4.67			-4.61
1659		-4.59			-4.65
1658		-4.42			-4.48

Year A.D.	1F $\delta^{18}\text{O}$	AB $\delta^{18}\text{O}$	TH1 $\delta^{18}\text{O}$	TM1 $\delta^{18}\text{O}$	TNI2 $\delta^{18}\text{O}$
1657		-4.37			-4.29
1656		-4.56			-4.16
1655		-4.56			-4.62
1654		-4.42			-4.94
1653		-4.28			-4.74
1652		-4.34			-4.66
1651		-4.39			-4.53
1650		-4.65			-4.44
1649		-4.57			
1648		-4.47			
1647		-4.41			
1646		-4.55			
1645		-4.43			
1644		-4.41			
1643		-4.46			
1642		-4.48			
1641		-4.40			
1640		-4.33			
1639		-4.47			
1638		-4.52			
1637		-4.43			
1636		-4.42			
1635		-4.43			
1634		-4.52			
1633		-4.58			
1632		-4.57			
1631		-4.57			
1630		-4.60			
1629		-4.53			
1628		-4.52			
1627		-4.49			
1626		-4.54			
1625		-4.74			
1624		-4.67			
1623		-4.43			
1622		-4.45			
1621		-4.61			
1620		-4.55			
1619		-4.60			
1618		-4.63			
1617		-4.69			