Supplementary Information for Stevenson et al. (2013)

1 SST/SSS Correlation with NINO3.4

Figure 1 shows the correlation of the NINO3.4 index with SST and SSS from four different combinations of reanalysis products; these are the same combinations of data products discussed in Section 5 of the main text. The structure of the NINO3.4 correlation differs in each panel, but the differences are especially apparent in cases where different salinity products are used. This is expected given the sparsity and generally lower quality of SSS observations relative to SST, and indicates that problems with SSS products may be the dominant contributor to the component of pseudo- δ^{18} O error caused by observational uncertainties.



Figure 1: Correlation coefficients for SST and SSS anomalies with NINO3.4 SSTA, for all combinations of reanalysis products. a) HadISST anomaly with HadISST NINO3.4 SSTA; b) same as a), for ERSSTv3b; c) Delcroix SSSA with HadISST NINO3.4 SSTA; d) Delcroix SSSA with ERSSTv3b NINO3.4 SSTA; e) ORA SSSA with HadISST NINO3.4 SSTA; and f) ORA SSSA with ERSSTv3b NINO3.4 SSTA. All correlations are calculated over the time period 1958-1985 for consistency with the coral δ^{18} O pseudoproxy calculations. Black circles indicate the positions of the δ^{18} O time series used in this analysis. Panels with differing SSS datasets (c vs e, d vs f) show larger discrepancies from one another than panels with differing SST datasets (a vs. b, c vs. d, e vs. f), suggesting that SSS is the dominant contributor to observational uncertainty.

2 Grid Point Selection

A manual grid point selection process was employed for the linear SST/SSS pseudoproxy conversions described in the main text. The four grid points closest to the location of each proxy site were examined, and one of those four selected using the following logic:

1. If an SST/SSS grid point was located within $+/-0.5^{\circ}$ of the proxy location, then this was chosen as the most appropriate point.

- 2. If no grid point fell sufficiently close to the proxy location (*i.e.* the proxy site lay equally between grid cells) then the correlation of δ^{18} O with data from all four points were compared. If one point had a significantly higher δ^{18} O correlation than the others, this point was used in the pseudoproxy calculations.
- 3. If no grid point fell sufficiently close to the proxy location *and* one or more points had correlations of comparable accuracy, the climatology and regional circulation in the area was considered, and an appropriate point chosen according to that assessment.

Details are provided below for each of the four data products employed in the pseudoproxy conversions.

2.1 ERSSTv3b

Sites where no grid point is sufficiently close: Bunaken, Laing, Madang, Maiana, Savusavu, Tarawa, Vanuatu (Malo Channel).

All other sites use the grid point closest to the proxy location.

- Bunaken: The proxy site is located roughly between the northern two neighbor points (Figure 2). The highest correlation with δ^{18} O is observed at 2°N, 126°E, so this point is adopted.
- Laing: Data is only available at 4°S, 146°E, so this point has been adopted (not pictured).
- Madang: Data is not available at the point nearest the proxy site (6°S, 146°E). Of the two nextnearest neighbors, there is a much stronger SST signal at 4°S, 146°E (Figure 3b), but the point at 6°S, 144°E has a much higher correlation with δ¹⁸O (-0.47 vs. -0.38). The latter point is therefore chosen.
- Maiana: The proxy site lies roughly equidistant from all four nearest grid points (Figure 2). The highest correlation with δ^{18} O is observed at 0°N, 174°E, so this point has been adopted.
- Savusavu: The highest correlation with δ^{18} O is observed at 18°S, 180°E, where the amplitude of the annual cycle in SST is stronger than at the other neighboring points (Figure 3d); this point is adopted.
- Tarawa: The proxy site is located nearly equidistant from each of the two eastern neighbor points (Figure 2). Of those, the correlations with δ^{18} O are comparable due to the very similar behavior of SST at all neighboring points (Figure 3e). The point at 0°N, 172°E is adopted.
- Vanuatu (Malo Channel): The highest correlation with δ^{18} O is observed at 16°S, 166°E (Figure 2), so this point is adopted.

2.2 HadISST

Sites where no grid point is sufficiently close: Bunaken, Laing, Madang, Maiana, Nauru, Palmyra, Secas, Tarawa, Vanuatu (Malo Channel), Vanuatu (Sabine Bank).

All other sites use the grid point closest to the proxy location.

- Bunaken: Although the northern points are farther away from the proxy site (Figure 4), they are more highly correlated with δ^{18} O than the southern points. This may possibly relate to an influence of the Indonesian Throughflow in the region, which could be improperly captured by the nearer-shore points in HadISST (Figure 5a). Since the point at 2.5°N, 125.5°E is a bit closer to the proxy site, this one has been chosen.
- Laing: No data is available for the point closest to the proxy site, since this overlaps with the landmass of Papua New Guinea. The correlation with δ^{18} O is highest at 4.5°S, 144.5°E, so this point has been chosen.
- Madang: The point at 5.5°S, 146.5°E has been chosen, as it has the highest correlation with δ^{18} O.



Figure 2: Locations of the four nearest grid points to the various proxy sites, taken from the ERSSTv3b product (*Smith et al.*, 2008). White circles indicate the location of the proxy site. Red circles indicate the point closest to the proxy site, blue an offset of 1 grid point in longitude, green an offset of 1 grid point in latitude, and black an offset of 1 grid point in both longitude and latitude relative to the nearest neighbor. Background shading in each panel indicates the climatological mean SST in the region of each proxy site.



Figure 3: SSS time series for selected nearest neighbors to proxy sites, taken from the ERSSTv3b product (*Smith et al.*, 2008). Color scheme is identical to that in the maps of Figure 2. a) Bunaken. b) Madang. c) Maiana. d) Savusavu. e) Tarawa. f) Vanuatu (Malo Channel).

- Maiana: The proxy site is roughly equidistant from all four grid points (Figure 4). The correlation with δ^{18} O is higher with the northern points than the southern, and of those (Figure 5d) the correlation is highest with the closest point (1.5°N, 172.5°E); this point has been chosen.
- Nauru: The proxy site is roughly equidistant from the two northern grid points (Figure 4). The correlation with δ^{18} O is higher with the point at 0.5°S, 166.5°E; this point has been chosen.
- Palmyra: The proxy site is located near a gradient in mean SST, and the southern grid points are more highly correlated with δ^{18} O than the northen points. These two points are fairly similar to one another (Figure 5f) so the closest has been chosen (5.5°N, 197.5°E).
- Secas: The three closest point have roughly equivalent correlation coefficients with δ^{18} O. Of these, the largest SST signal is seen at 7.5°N, 280.5°E (Figure 5g), and this point is additionally the closest to the open ocean. It is accordingly adopted for the pseudoproxy calculations.
- Tarawa: The eastern points are more highly correlated than the western points with δ^{18} O (Figure 4). The point at 0.5°N, 172.5°E sits further south and should therefore be more strongly influenced by water masses migrating from the Southern Hemisphere; this point has been chosen.
- Vanuatu (Malo Channel): Correlation coefficients with δ^{18} O are comparable between all data points. The closest point is chosen (15.5°S, 167.5°E) since it seems closest to the open ocean (Figure 4).
- Vanuatu (Sabine Bank): This site behaves markedly differently from the Malo Channel location; NONE of the four nearest grid points correlate significantly with δ^{18} O. As such it makes little difference which grid point is chosen, and the one nearest the proxy site is used (15.5°S, 166.5°E).



Figure 4: Locations of the four nearest grid points to the various proxy sites, taken from the HadISST product (*Rayner et al.*, 2003). White circles indicate the location of the proxy site. Red circles indicate the point closest to the proxy site, blue an offset of 1 grid point in longitude, green an offset of 1 grid point in latitude, and black an offset of 1 grid point in both longitude and latitude relative to the nearest neighbor. Background shading in each panel indicates the climatological mean SST in the region of each proxy site.



Figure 5: SST time series for selected nearest neighbors to proxy sites, taken from the HadISST product (*Rayner et al.*, 2003). Color scheme is identical to that in the maps of Figure 4: red indicates the point closest to the proxy site, blue an offset of 1 grid point in longitude, green an offset of 1 grid point in latitude, and black an offset of 1 grid point in both longitude and latitude relative to the nearest grid point. a) Bunaken. b) Laing. c) Madang. d) Maiana. e) Nauru. f) Palmyra. g) Secas. h) Tarawa. i) Vanuatu (Malo Channel). j) Vanuatu (Sabine Bank).

2.3 Delcroix et al. (2011) SSS

Sites where no grid point is sufficiently close: Amedee, Bunaken, Kiritimati, Laing, Madang, Nauru, Savusavu, Secas, Vanuatu (Malo Channel), Vanuatu (Sabine Bank).

All other sites use the grid point closest to the proxy location.

- Amedee (New Caledonia): All four grid points are here roughly equidistant from the proxy site (Figure 7a). The two northern points showh higher overall correlations with δ^{18} O than the two southern points (0.42 to 0.43 vs. 0.36-0.38). The point at 22°S, 167°E is chosen since its correlation is slightly higher.
- Bunaken: All the SSS/ δ^{18} O correlations are quite low, but appear somewhat higher for the two northern points (Figure 7b). Of these, the point at 2°N, 125°E is chosen since it lies closer to the mouth of the Indonesian Throughflow and should therefore see variability more directly related to Pacific Ocean circulation.
- Kiritimati: The proxy site here lies between the two northernmost points in the set of four (Figure 6). As for Nauru, the correlation coefficients with SSS are nearly identical between the two points... but are quite low (0.1549 and 0.1536). The SSS data for these points may be of questionable accuracy prior to 1975, as evidenced by the abrupt change in interannual variability around this time (Figure 7c). Since little difference is seen between the two points, again the nearest point is adopted (2°N, 157°W).
- Laing: The two southern points contain no data (Figure 7d), due to their proximity to Papua New Guinea. Of the two northern points, the point at 4°S, 144°E is chosen since its correlation with δ^{18} O is slightly higher (0.21 vs. 0.19).
- Madang: Of the four nearest points, only the one closest to the proxy location (5°S, 146°E) contains data; the rest are too close to Papua New Guinea. This point is therefore adopted.
- Nauru: The site lies roughly equidistant from the two nearest SSS grid points at 166°E. For these two points, the correlation coefficients are comparable (0.59 and 0.60). Visually, the largest difference between the SSS time series appears to be an offset in mean SSS, although the point at [] has a slightly larger amplitude. The nearest point (1°S, 166°E) is chosen since this point is slightly closer to the 'tongue' of salty water observed in this region (Figure 6) and should therefore be more sensitive to advective variations in SSS.
- Savusavu: The two southern points have substantially larger correlations of SSS with δ^{18} O than the two northern points (0.59-0.60 vs. 0.51). The point at 17°S, 179°E is chosen since it is slightly closer to the proxy site.
- Secas: Technically there is a grid point within 1° of the proxy site; however, this point is so close to land that no data is available in the *Delcroix et al.* (2011) gridded product. The two next closest points are at 7°N, 279°E or 7°N, 280°E (Figure 6), and we choose 7°N, 280°E due to its slightly higher correlation with δ¹⁸O and amplitude of variability.
- Vanuatu (Malo Channel): The southern pair of grid points once again shows a higher SSS/δ¹⁸O correlation than the northern pair. Again, in the absence of a better criterion, the closest point is chosen (16°S, 167°E).
- Vanuatu (Sabine Bank): As for Savusavu, the southern pair of grid points shows a higher SSS/δ¹⁸O correlation than the northern pair. Again, in the absence of a better criterion, the closest point is chosen (16°S, 166°E).

2.4 ORA-S4

Sites where no grid point is sufficiently close: Bunaken, Laing, Madang, Maiana, Nauru, Savusavu, Tarawa, Vanuatu (Malo Channel), Vanuatu (Sabine Bank).



Figure 6: Locations of the four nearest grid points to the various proxy sites, taken from the *Delcroix et al.* (2011) gridded SSS product. White circles indicate the location of the proxy site. Red circles indicate the point closest to the proxy site, blue an offset of 1 grid point in longitude, green an offset of 1 grid point in latitude, and black an offset of 1 grid point in both longitude and latitude relative to the nearest neighbor. Background shading in each panel indicates the climatological mean SSS in the region of each proxy site.



Figure 7: SSS time series for selected nearest neighbors to proxy sites, taken from the *Delcroix et al.* (2011) gridded SSS product. Color scheme is identical to that in the maps of Figure 6: red indicates the point closest to the proxy site, blue an offset of 1 grid point in longitude, green an offset of 1 grid point in latitude, and black an offset of 1 grid point in both longitude and latitude relative to the nearest grid point. a) Amedee (New Caledonia). b) Bunaken. c) Kiritimati. d) Laing. e) Nauru. f) Savusavu. g) Secas. h) Vanuatu (Malo Channel). i) Vanuatu (Sabine Bank).

All other sites use the grid point closest to the proxy location.

- Bunaken: The point closest to the proxy site (1.5°N, 124.5°E) has a much higher correlation with δ^{18} O than any of the other points (0.35 vs. 0.21-0.29). This point is adopted.
- Laing: The correlations with δ^{18} O are significant for these points, and range from 0.2-0.24. Data is only available for the two northern points, and of those the point at 3.5°S, 144.5°E has the higher correlation coefficient; this is adopted.
- Madang: None of the correlations of SSS at the four nearest grid points with δ^{18} O are statistically significant. The point farthest from the proxy site (4.5°S, 146.5°E) is closest to the open ocean, and has a slightly higher correlation coefficient; this point is adopted.
- Maiana: The correlation with δ^{18} O is higher for the two southern grid points (Figure 8). The SSS time series for these two points (Figure 9d) indicate that there may be a real precipitative or advective signal happening at 1.5°N which does not take place at 0.5°N, as stronger fresh SSS spikes occur at 1.5°N. The point at 0.5°N, 172.5°E is adopted.
- Nauru: The northern points are slightly more highly correlated with δ^{18} O than the southern (0.7-0.71 vs. 0.69), although this difference is likely insignificant. The 'spikes' in low SSS values are slightly stronger further west (Figure 9e), and the point at 0.5°S, 165.5°E is therefore adopted.
- Savusavu: The two western points have the best correlations with δ^{18} O (0.58-0.59 vs. 0.52-0.56). The point farthest from the proxy site (17.5°S, 178.5°E) is chosen, as it has the highest correlation with δ^{18} O; this point may be recording a small circulation around the island of Fiji (Figure 8).
- Tarawa: The southern points are slightly more highly correlated with δ^{18} O (Figure 8; 0.58 vs. 0.54). The closest point is adopted (0.5°N, 172.5°E).
- Vanuatu (Malo Channel): The correlations with δ^{18} O are nearly identical between grid points (0.69-0.70). The southern points should be able to record open-ocean conditions more directly without being influenced by conditions inside the channel, and therefore the nearer of those two points is adopted (16.5°S, 167.5°E).
- Vanuatu (Sabine Bank): The southern points are more highly correlated with δ^{18} O than the northern (Figure 9i; 0.67 vs. 0.63-0.64). The point at 16.5°S, 165.5°E has the highest correlation, and is therefore chosen.

Table 1: Grid point locations used for SST/SSS pseudoproxy data, in each of the four data products employed in the main text. The 'Proxy Location' column lists the coordinates of the reef from which the δ^{18} O time series was constructed.

Proxy site name	Proxy location	ERSSTv3b	HadISST	Delcroix	ORA-S4
Amedee	$22.5^{\circ}S, 166.5^{\circ}E$	$22^{\circ}S, 166^{\circ}E$	$22.5^{\circ}S, 166.5^{\circ}E$	$22^{\circ}S, 167^{\circ}E$	$22.5^{\circ}S, 166.5^{\circ}E$
Bunaken	$1.5^{\circ}N, 124.8^{\circ}E$	$2^{\circ}N, 126^{\circ}E$	$2.5^{\circ}N, 125.5^{\circ}E$	$2^{\circ}N, 125^{\circ}E$	$1.5^{\circ}N, 124.5^{\circ}E$
Clipperton	$10.3^{\circ}N, 109.2^{\circ}W$	$10^{\circ}N, 110^{\circ}W$	$10.5^{\circ}N, 109.5^{\circ}W$	$10^{\circ}N, 109^{\circ}W$	$10.5^{\circ}N, 109.5^{\circ}W$
Kiritimati	$1.87^{\circ}N, 157.4^{\circ}W$	$2^{\circ}N, 158^{\circ}W$	$1.5^{\circ}N, 157.5^{\circ}W$	$2^{\circ}N, 157^{\circ}W$	$1.5^{\circ}N, 157.5^{\circ}W$
Laing	$4.15^{\circ}S, 144.9^{\circ}E$	$4^{\circ}S, 146^{\circ}E$	$4.5^{\circ}S, 144.5^{\circ}E$	$4^{\circ}S, 144^{\circ}E$	$3.5^{\circ}S, 144.5^{\circ}E$
Madang	5.22° S, 14 5.82° E	$6^{\circ}S, 144^{\circ}E$	$5.5^{\circ}S, 146.5^{\circ}E$	$5^{\circ}S, 146^{\circ}E$	$4.5^{\circ}S, 146.5^{\circ}E$
Maiana	$1^{\circ}N, 173^{\circ}E$	$0^{\circ}N, 174^{\circ}E$	$1.5^{\circ}N, 172.5^{\circ}E$	$1^{\circ}N, 173^{\circ}E$	$0.5^{\circ}N, 172.5^{\circ}E$
Nauru	$0.5^{\circ}S, 166^{\circ}E$	$0^{\circ}N, 166^{\circ}E$	$0.5^{\circ}S, 166.5^{\circ}E$	$1^{\circ}S, 166^{\circ}E$	$0.5^{\circ}S, 165.5^{\circ}E$
Palmyra	$5.9^{\circ}N, 162.1^{\circ}W$	$6^{\circ}N, 162^{\circ}W$	$5.5^{\circ}N, 162.5^{\circ}W$	$6^{\circ}N, 162^{\circ}W$	$5.5^{\circ}N, 162.5^{\circ}W$
Rarotonga	$21.23^{\circ}S, 159.82^{\circ}E$	$22^{\circ}S, 160^{\circ}E$	$21.5^{\circ}S, 159.5^{\circ}E$	$21^{\circ}S, 160^{\circ}E$	$21.5^{\circ}S, 159.5^{\circ}E$
Savusavu	$16.8^{\circ}S, 179.2^{\circ}E$	$18^{\circ}S, 180^{\circ}E$	$16.5^{\circ}S, 179.5^{\circ}E$	$17^{\circ}S, 179^{\circ}E$	$17.5^{\circ}S, 178.5^{\circ}E$
Secas	$7.98^{\circ}N, 80.05^{\circ}W$	$8^{\circ}N, 80^{\circ}W$	$7.5^{\circ}N, 79.5^{\circ}W$	$7^{\circ}N, 80^{\circ}W$	$7.5^{\circ}N, 80.5^{\circ}W$
Tarawa	$1^{\circ}N, 172^{\circ}E$	$0^{\circ}N, 172^{\circ}E$	$0.5^{\circ}N, 172.5^{\circ}E$	$1^{\circ}N, 172^{\circ}E$	$0.5^{\circ}N, 172.5^{\circ}E$
Vanuatu (Sabine Bank)	$15.94^{\circ}S, 166.0^{\circ}E$	$16^{\circ}S, 166^{\circ}E$	$15.5^{\circ}S, 166.5^{\circ}E$	$16^{\circ}S, 166^{\circ}E$	$16.5^{\circ}S, 165.5^{\circ}E$
Vanuatu (Malo Channel)	$15.7^{\circ}S, 167.2^{\circ}E$	$16^{\circ}S, 166^{\circ}E$	$15.5^{\circ}S, 167.5^{\circ}E$	$16^{\circ}S, 167^{\circ}E$	$16.5^{\circ}S, 167.5^{\circ}E$



Figure 8: Locations of the four nearest grid points to the various proxy sites, taken from the ORA-S4 reanalysis (*Balmaseda et al.*, 2012). White circles indicate the location of the proxy site. Red circles indicate the point closest to the proxy site, blue an offset of 1 grid point in longitude, green an offset of 1 grid point in latitude, and black an offset of 1 grid point in both longitude and latitude relative to the nearest neighbor. Background shading in each panel indicates the climatological mean SSS in the region of each proxy site.



Figure 9: SSS time series for selected nearest neighbors to proxy sites, taken from the ORA-S4 reanalysis product (*Balmaseda et al.*, 2012). Color scheme is identical to that in the maps of Figure 8: red indicates the point closest to the proxy site, blue an offset of 1 grid point in longitude, green an offset of 1 grid point in latitude, and black an offset of 1 grid point in both longitude and latitude relative to the nearest grid point. a) Bunaken. b) Laing. c) Madang. d) Maiana. e) Nauru. f) Savusavu. g) Tarawa. h) Vanuatu (Malo Channel). i) Vanuatu (Sabine Bank).

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