Correction to "Late 20th century warming and freshening in the central tropical Pacific"

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[1] We present corrections to uncertainty estimates of late 20th century (1972-1998) coral-based sea-surface temperature (SST) and salinity (SSS) trends from Palmyra, Fanning and Christmas Islands of the central tropical Pacific reported in Nurhati et al. [2009] (*Geophysical Research Letters*, *36*, L21606, doi:10.1029/2009GL040270). In our original paper we had assigned relatively large error bars to coral Sr/Ca-based warming trends observed at all three islands, rendering those trends statistically insignificant with respect to the large errors. However, those large uncertainties originate from large errors associated with quantifying absolute SST at any given point, whereas the uncertainties for SST trends should reflect errors in quantifying relative changes, which are much lower. Late 20th century warming trends of 0.94–1.65°C at the three islands are statistically significant with the corrected error ranges of ±0.19–0.37°C (1σ; originally ±5.73–6.57°C). Freshening trends inferred from coral-based oxygen isotopic composition of seawater ($\delta^{18}O_{SW}$) of −0.32‰ and −0.12‰ (1σ) at Palmyra and Fanning, respectively, are associated with corrected error ranges of ±0.07‰ and ±0.08‰ (1σ; originally ±0.08‰ for both), respectively. Christmas experienced an insignificant +0.03 ± 0.11‰ (1σ; originally also ±0.11‰) trend in $\delta^{18}O_{SW}$ over this period. With the new, lower uncertainty estimates, the coral-based SST and SSS trends are statistically significant, thereby strengthening Nurhati et al.'s (2009) conclusions that robust warming and freshening have occurred in the central tropical Pacific over the late 20th century. Our detailed uncertainty calculations presented below will be of value to the paleoclimate community, as the correct calculation of absolute errors and relative errors represents a key component of paleoclimatic reconstruction. **Citation:** Nurhati, I. S., K. M. Cobb, C. D. Charles, and R. B. Dunbar (2011), Correction to "Late 20th century warming and freshening in the central tropical Pacific," *Geophys. Res. Lett.*, *38*, L24707, doi:10.1029/2011GL049972.

1. Introduction

[2] The reported error bars associated with late 20th century trends in coral $\delta^{18}O$, Sr/Ca-derived SST proxy, and $\delta^{18}O_{SW}$-based SSS proxy records reported by *Nurhati et al.* [2009] were derived from the error in quantifying the absolute value of any given month's Sr-Ca-derived paleo-SST, which resulted in artificially large error bars. Instead, trend errors should have been derived from the statistics of the long-term trends themselves (i.e., quantify relative changes; refer to the supporting materials section therein). Here, we present the corrected uncertainty estimates for the late 20th century warming and freshening trends at Palmyra, Fanning and Christmas Islands in the central tropical Pacific. Similar uncertainty analyses have been presented by *Nurhati et al.* [2011]. The new values for trend uncertainties are presented in Table 1.

2. Coral $\delta^{18}O$

[3] The late 20th century trends of coral $\delta^{18}O$, a climate proxy sensitive to SST and $\delta^{18}O$ of seawater variability (the later linearly correlates with SSS [*Fairbanks et al.*, 1997]), are −0.52‰ at Palmyra, −0.40‰ at Fanning and −0.32‰ at Christmas. Uncertainty estimates associated with absolute values and late 20th century trends of coral $\delta^{18}O$ records are calculated below.

2.1. Coral $\delta^{18}O$ Uncertainty (Absolute Values)

[4] The analytical precision of mass spectrometer accounts for uncertainty in coral $\delta^{18}O$ values. Thus, the mean coral $\delta^{18}O$ value and its analytical precision at each islands is −5.09 ± 0.05‰ (1σ) for Palmyra [*Cobb et al.*, 2001], −5.08 ± 0.06‰ (1σ) for Fanning, and −4.80 ± 0.06‰ (1σ) for Christmas.

2.2. Coral $\delta^{18}O$ Trend Uncertainty

[5] There are two sources of uncertainty that contribute to uncertainties in coral $\delta^{18}O$ trends: (1) the analytical precision of coral $\delta^{18}O$, and (2) slope error of coral $\delta^{18}O$ trend. The details are as follows:

[6] 1. Analytical precision of coral $\delta^{18}O$. The analytical precisions of coral $\delta^{18}O$ measurements via mass spectrom-

Table 1. Summary of the Mean Absolute Values of Coral $\delta^{18}O$, Sr/Ca-Derived SST and $\delta^{18}O_{SW}$ Records and Their (1σ) Uncertainties, Compared to the Magnitude of Late 20th Century Trends in Each Record, With Their Corrected (1σ) Uncertainties

	Mean Absolute Value	Late 20th Century Trend
	Coral $\delta^{18}O$ (‰)	
Palmyra	−5.09 ± 0.05	−0.52 ± 0.06
Fanning	−5.08 ± 0.06	−0.40 ± 0.07
Christmas	−4.80 ± 0.06	−0.32 ± 0.08
	Sr/Ca-Derived SST (°C)	
Palmyra	28.33 ± 7.85	0.94 ± 0.19
Fanning	27.78 ± 8.86	1.37 ± 0.23
Christmas	27.10 ± 7.40	1.65 ± 0.37
	$\delta^{18}O_{SW}$ (‰)	
Palmyra	0.62 ± 0.12	−0.32 ± 0.07
Fanning	0.57 ± 0.13	−0.12 ± 0.08
Christmas	0.96 ± 0.17	0.03 ± 0.11

Note the difference in error magnitudes for the absolute values versus the trends for each record. The inferred warming trends are now statistically significant at all islands. Lower errors for the calculated trends reflect lower error bars associated with quantifying relative changes in the various coral records. The origins of both the absolute and trend errors are outlined in detail below.

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eter are ±0.05‰ (1σ) at Palmyra [*Cobb et al.*, 2001], and ±0.06‰ (1σ) at Fanning and Christmas.

[7] 2. Slope error of coral $\delta^{18}O$ trend. The slope errors of late 20th century coral $\delta^{18}O$ trends are ±0.04‰ (1σ) at Palmyra and Fanning, and ±0.05‰ (1σ) at Christmas.

[8] Taken together, late 20th century coral $\delta^{18}O$ trends are −0.52 ± 0.06‰ (1σ) at Palmyra, −0.40 ± 0.07‰ (1σ) at Fanning and −0.32 ± 0.08‰ (1σ) at Christmas, quadratically combining terms (1)-(2) for the uncertainty estimates.

3. Sr/Ca-Derived SST

[9] The late 20th century coral Sr/Ca-derived SST trends are +0.94°C at Palmyra, +1.37°C at Fanning and +1.65°C at Christmas. Uncertainty estimates for absolute values and late 20th century trends for coral Sr/Ca-derived SST records are calculated below.

3.1. Sr/Ca-Derived SST Uncertainty (Absolute Values)

[10] The compounded error for any given absolute SST estimate in the coral Sr/Ca-based record (σ_{SST}) includes uncertainties associated with (1) the analytical precision of Sr/Ca measurements ($\sigma_{Sr/Ca}$) via ICP-OES, (2) the intercept (σ_a) and (3) the slope (σ_b) of the Sr/Ca-SST calibration. Starting with the equation for estimating SST from coral Sr/Ca and their associated errors:

$$\mathrm{SST} = \mathrm{a} + \mathrm{b} \cdot \mathrm{Sr/Ca} \quad (1)$$

$$\mathrm{SST} \pm \sigma_{SST} = (\mathrm{a} \pm \sigma_a) + (\mathrm{b} \pm \sigma_b) \cdot \left(\overline{\mathrm{Sr/Ca}} \pm \sigma_{Sr/Ca}\right) \quad (2)$$

The last term, a multiplicative compounded error associated with the Sr/Ca-SST calibration slope and the analytical precision of Sr/Ca measurements, $(\mathrm{b} \pm \sigma_b) \cdot \left(\overline{\mathrm{Sr/Ca}} \pm \sigma_{Sr/Ca}\right)$, is calculated via:

$$\sigma_{\mathrm{slope\_analytical}} = \left|\mathrm{b} \cdot \overline{\mathrm{Sr/Ca}}\right| \sqrt{\left(\frac{\sigma_b}{\mathrm{b}}\right)^2 + \left(\frac{\sigma_{Sr/Ca}}{\overline{\mathrm{Sr/Ca}}}\right)^2} \quad (3)$$

Thus, the compounded error for SST estimates by adding the calibration intercept error (σ_a) is:

$$\sigma_{SST} = \sqrt{\sigma_a^2 + \sigma_{\mathrm{slope\_analytical}}^2} \quad (4)$$

$$\sigma_{SST} = \sqrt{\sigma_a^2 + \left(\mathrm{b} \cdot \overline{\mathrm{Sr/Ca}}\right)^2 \cdot \left[\left(\frac{\sigma_b}{\mathrm{b}}\right)^2 + \left(\frac{\sigma_{Sr/Ca}}{\overline{\mathrm{Sr/Ca}}}\right)^2\right]} \quad (5)$$

Plugging in known values for each term and their uncertainties,

$$\text{Palmyra}: \mathrm{SST} \pm \sigma_{SST} = (130.43 \pm 5.54) + (-11.39 \pm 0.62) \cdot (8.97 \pm 0.012) \quad (6)$$

$$\text{Fanning}: \mathrm{SST} \pm \sigma_{SST} = (166.81 \pm 6.25) + (-15.47 \pm 0.70) \cdot (8.98 \pm 0.007) \quad (7)$$

$$\text{Christmas}: \mathrm{SST} \pm \sigma_{SST} = (141.57 \pm 5.21) + (-12.66 \pm 0.58) \cdot (9.04 \pm 0.022) \quad (8)$$

The different Sr/Ca analytical precision at each island reflects changes in the long-term stability of the ICP-OES. In any case, we only include data from analytical runs with long-term analytical precisions of better than 0.3% (1σ).

[11] The compounded errors for SST estimates at the three islands following equation (5) are:

$$\text{Palmyra } \sigma_{SST} = \sqrt{5.54^2 + (-11.39 \cdot 8.97)^2 \cdot \left[\left(\frac{0.62}{-11.39}\right)^2 + \left(\frac{0.012}{8.97}\right)^2\right]} = 7.85°\mathrm{C} \quad (9)$$

$$\text{Fanning } \sigma_{SST} = \sqrt{6.25^2 + (-15.47 \cdot 8.98)^2 \cdot \left[\left(\frac{0.70}{-15.47}\right)^2 + \left(\frac{0.007^2}{8.98}\right)\right]} = 8.86°\mathrm{C} \quad (10)$$

$$\text{Christmas } \sigma_{SST} = \sqrt{5.21^2 + (-12.66 \cdot 9.04)^2 \cdot \left[\left(\frac{0.58}{-12.66}\right)^2 + \left(\frac{0.022}{9.04}\right)^2\right]} = 7.40°\mathrm{C} \quad (11)$$

Therefore, the mean coral Sr/Ca-derived SSTs and their compounded errors are 28.33 ± 7.85°C (1σ) at Palmyra, 27.78 ± 8.86°C (1σ) at Fanning and 27.10 ± 7.40°C (1σ) at Christmas.

3.2. Sr/Ca-Derived SST Trend Uncertainty

[12] The compounded error for SST trend estimates takes into account errors associated with (1) the analytical precision of Sr/Ca measurements via ICP-OES, (2) the calibration slope of the Sr/Ca-SST calibration (the intercept of the calibration would not affect the Sr/Ca-derived SST trend error), and (3) the slope error of the trend. The details are as follows:

[13] 1. The Sr/Ca-derived SST trend errors associated with the analytical precision of coral Sr/Ca via ICP-OES are ±0.14°C, ±0.11°C and ±0.28°C (1σ) at Palmyra, Fanning and Christmas, respectively; which represents the conservative assumption of applying the maximum error ranges of the analytical precision.

[14] 2. The calibration slopes and slope errors of the coral Sr/Ca-SST regression are −11.39 ± 0.62 °C/ mmol/mol (1σ) at Palmyra, −15.47 ± 0.70 °C/mmol/mol (1σ) at Fanning, and −12.66 ± 0.58 °C mmol/mol (1σ) at Christmas. The uncertainties in coral Sr/Ca-derived SST trends associated with calibration slope error are ±0.05°C (1σ) at Palmyra, ±0.06°C (1σ) at Fanning and ±0.08°C (1σ) at Christmas, which represent the difference between the SST trends calculated with maximum and minimum Sr/Ca-SST slopes.

[15] 3. The late century Sr/Ca-derived SST trends have trend slope errors of ±0.13°C (1σ) at Palmyra, ±0.19°C (1σ) at Fanning, and ±0.23°C (1σ) at Christmas.

[16] Taken together, the late 20th century SST warming trends in the central tropical Pacific are statistically significant; 0.94 ± 0.19°C (1σ) at Palmyra, 1.37 ± 0.23°C (1σ) at

Fanning, and 1.65 ± 0.37°C (1σ) at Christmas, quadratically combining terms (1)-(3) above for the uncertainty estimates.

4. The $\delta^{18}O_{sw}$ (SSS Proxy)

[17] The $\delta^{18}O_{SW}$-based SSS records, estimated via the residual of coral $\delta^{18}O$ after removing the Sr/Ca-derived SST influence, contain late 20th century trends of −0.32‰ at Palmyra, −0.12‰ at Fanning, and +0.03‰ at Christmas. Uncertainty estimates associated with absolute values and late 20th century trends for $\delta^{18}O_{SW}$-based SSS are calculated below.

4.1. The $\delta^{18}O_{SW}$ Uncertainty (Absolute Values)

[18] The compounded error for $\delta^{18}O_{SW}$ estimates includes uncertainties associated with analytical precisions of (1) coral $\delta^{18}O$ via mass spectrometer and (2) coral Sr/Ca via ICP-OES, as well as the slopes of (3) coral Sr/Ca-SST calibration and (4) coral $\delta^{18}O$-SST regression. Starting with the equation for calculating changes in $\delta^{18}O_{SW}$ following the method of outlined by *Ren et al.* [2003]:

$$\Delta\delta^{18}O_{CORAL} = \Delta\delta^{18}O_{SST} + \Delta\delta^{18}O_{SW} \tag{12}$$

$$\Delta\delta^{18}O_{CORAL} \pm \sigma_{\Delta\delta^{18}O_{CORAL}} = \left(\Delta\delta^{18}O_{SST} \pm \sigma_{\Delta\delta^{18}O_{SST}}\right) + \left(\Delta\delta^{18}O_{SW} \pm \sigma_{\Delta\delta^{18}O_{SW}}\right) \tag{13}$$

where the delta sign (Δ) refers to the difference between values from two adjacent months.

[19] Taking the left-hand side of equation (13) first, the equation for $\Delta\delta^{18}O_{CORAL}$ is:

$$\Delta\delta^{18}O_{CORAL} = \delta^{18}O_{CORAL\ t} - \delta^{18}O_{CORAL\ t-1} \tag{14}$$

$$\Delta\delta^{18}O_{CORAL} \pm \sigma_{\Delta\delta^{18}O_{CORAL}} = \delta^{18}O_{CORAL\ t} \pm \sigma_{\delta^{18}O_{CORAL}} + \delta^{18}O_{CORAL\ t-1} \pm \sigma_{\delta^{18}O_{CORAL}} \tag{15}$$

[20] Analytical error associated with the coral $\delta^{18}O$ records was reported as ±0.05‰ (1σ) at Palmyra [*Cobb et al.*, 2001], and ±0.06‰ (1σ) at Fanning and Christmas. Thus, the calculation for the error associated with $\Delta\delta^{18}O_{CORAL}$ follows the equation:

$$\sigma_{\Delta\delta^{18}O_{CORAL}} = \sqrt{\sigma^2_{\delta^{18}O_{CORAL}} + \sigma^2_{\delta^{18}O_{CORAL}}} = \sigma_{\delta^{18}O_{CORAL}}\sqrt{2} \tag{16}$$

which yields $\sigma_{\Delta\delta^{18}O_{CORAL}}$ of 0.07‰ at Palmyra, and 0.08‰ at Fanning and Christmas.

[21] Taking the first term on the right-hand side of equation (13), the equation for $\Delta\delta^{18}O_{SST}$ is:

$$\Delta\delta^{18}O_{SST} = \left[\overline{\Delta Sr/Ca} \cdot \frac{\partial SST}{\partial Sr/Ca} \cdot \frac{\partial\delta^{18}O_{CORAL}}{\partial SST}\right] \tag{17}$$

where $\overline{\Delta Sr/Ca}$ is the mean of the absolute values of ΔSr/Ca (because the ΔSr/Ca timeseries contains both positive and negative signs). At Palmyra, the calculated value for $\overline{\Delta Sr/Ca}$ is 0.03 mmol/mol, with an error bar of ±0.02 mmol/mol, considering the ±0.012 mmol/mol analytical precision of Sr/Ca measurements and following these calculations:

$$\Delta Sr/Ca = Sr/Ca_t - Sr/Ca_{t-1} \tag{18}$$

$$\Delta Sr/Ca \pm \sigma_{\Delta Sr/Ca} = \left(Sr/Ca_t \pm \sigma_{Sr/Ca}\right) - \left(Sr/Ca_{t-1} \pm \sigma_{Sr/Ca}\right) \tag{19}$$

$$\sigma_{\Delta Sr/Ca} = \sqrt{\sigma^2_{Sr/Ca} + \sigma^2_{Sr/Ca}} = \sigma_{Sr/Ca}\sqrt{2} = 0.012\sqrt{2} = 0.02\ \text{mmol/mol} \tag{20}$$

[22] Similar calculations yield $\overline{\Delta Sr/Ca}$ = 0.03 ± 0.01 mmol/mol at Fanning and 0.04 ± 0.03 mmol/mol at Christmas. ∂SST/∂Sr/Ca is the slope of the Sr/Ca-SST calibration, which is −11.39 ± 0.62 °C/mmol/mol at Palmyra, −15.47 ± 0.70 °C/mmol/mol at Fanning, and −12.66 ± 0.58 °C/mmol/mol at Christmas. And $\partial\delta^{18}O_{CORAL}/\partial SST$ of −0.21 ± 0.03 ‰/°C is the mean empirical values of coral $\delta^{18}O$ sensitivity to SST compiled by *Ren et al.* [2003].

[23] The calculation for the error associated with $\Delta\delta^{18}O_{SST}$ is:

$$\sigma_{\Delta\delta^{18}O_{SST}} = \left|\overline{\Delta Sr/Ca} \cdot \frac{\partial SST}{\partial Sr/Ca} \cdot \frac{\partial\delta^{18}O_{CORAL}}{\partial SST}\right| \cdot \sqrt{\left(\frac{\sigma_{\Delta Sr/Ca}}{\overline{\Delta Sr/Ca}}\right)^2 + \left(\frac{\sigma_{SST-Sr/Ca\ slope}}{SST - Sr/Ca\ slope}\right)^2 + \left(\frac{\sigma_{coral\,\delta^{18}O-SST\ slope}}{coral\,\delta^{18}O - SST\ slope}\right)^2} \tag{21}$$

[24] Plugging in the known values yields:

$$\text{Palmyra}\ \sigma_{\Delta\delta^{18}O_{SST}} = \left|0.03 \cdot -11.39 \cdot -0.21\right| \cdot \sqrt{\left(\frac{0.02}{0.03}\right)^2 + \left(\frac{0.62}{-11.39}\right)^2 + \left(\frac{0.03}{-0.21}\right)^2} = 0.05‰ \tag{22}$$

$$\text{Fanning}\ \sigma_{\Delta\delta^{18}O_{SST}} = \left|0.03 \cdot -15.47 \cdot -0.21\right| \cdot \sqrt{\left(\frac{0.01}{0.03}\right)^2 + \left(\frac{0.70}{-15.47}\right)^2 + \left(\frac{0.03}{-0.21}\right)^2} = 0.04‰ \tag{23}$$

$$\text{Christmas}\ \sigma_{\Delta\delta^{18}O_{SST}} = \left|0.04 \cdot -12.66 \cdot -.021\right| \cdot \sqrt{\left(\frac{0.03}{0.04}\right)^2 + \left(\frac{0.58}{-12.66}\right)^2 + \left(\frac{0.03}{-0.21}\right)^2} = 0.08‰ \tag{24}$$

Having calculated $\Delta\delta^{18}O_{CORAL}$ and $\Delta\delta^{18}O_{SST}$, the compounded error for $\Delta\delta^{18}O_{SW}$ is calculated as the additive error propagation of the two terms:

$$\text{Palmyra } \sigma_{\Delta\delta^{18}O_{SW}} = \sqrt{\sigma^2_{\Delta\delta^{18}O_{CORAL}} + \sigma^2_{\Delta\delta^{18}O_{SST}}} = \sqrt{0.07^2 + 0.05^2} = 0.09‰ \quad (25)$$

$$\text{Fanning } \sigma_{\Delta\delta^{18}O_{SW}} = \sqrt{\sigma^2_{\Delta\delta^{18}O_{CORAL}} + \sigma^2_{\Delta\delta^{18}O_{SST}}} = \sqrt{0.08^2 + 0.04^2} = 0.09‰ \quad (26)$$

$$\text{Christmas } \sigma_{\Delta\delta^{18}O_{SW}} = \sqrt{\sigma^2_{\Delta\delta^{18}O_{CORAL}} + \sigma^2_{\Delta\delta^{18}O_{SST}}} = \sqrt{0.08^2 + 0.08^2} = 0.12‰ \quad (27)$$

And since

$$\Delta\delta^{18}O_{SW} = \delta^{18}O_{SW_t} - \delta^{18}O_{SW_{t-1}} \quad (28)$$

$$\Delta\delta^{18}O_{SW} \pm \sigma_{\Delta\delta^{18}O_{SW}} = \left(\delta^{18}O_{SW_t} \pm \sigma_{\delta^{18}O_{SW}}\right) - \left(\delta^{18}O_{SW_{t-1}} \pm \sigma_{\delta^{18}O_{SW}}\right) \quad (29)$$

$$\sigma_{\Delta\delta^{18}O_{SW}} = \sqrt{\sigma^2_{\delta^{18}O_{SW}} + \sigma^2_{\delta^{18}O_{SW}}} = \sigma_{\delta^{18}O_{SW}}\sqrt{2} \quad (30)$$

Thus, the mean coral-based $\delta^{18}O_{SW}$ values and their compounded errors are 0.62±0.12‰ (1σ) at Palmyra, 0.57±0.13‰ (1σ) at Fanning, and 0.96±0.17‰ (1σ) at Christmas.

4.2. The $\delta^{18}O_{SW}$ Trend Uncertainty

[25] The compounded error for $\delta^{18}O_{SW}$ trend estimates takes into account errors associated with: (1) the analytical precision of coral $\delta^{18}O$ via mass spectrometer, (2) the analytical precision of coral Sr/Ca via ICP-OES, (3) slope error in the coral Sr/Ca-SST calibration, and (4) slope error in the coral $\delta^{18}O$-SST regression, and (5) slope error of the trend; with the following details:

[26] 1. The analytical precisions of coral $\delta^{18}O$ via mass spectrometer are ±0.05‰ (1σ) for Palmyra [*Cobb et al.*, 2001] and ±0.06‰ (1σ) for Fanning and Christmas.

[27] 2. The analytical precision of coral Sr/Ca via ICP-OES of ±0.14°C (1σ) for Palmyra, ±0.11°C (1σ) for Fanning, and ±0.28°C (1σ) for Christmas. These values translate to ±0.03‰, ±0.02‰ and ±0.06‰ (1σ) $\delta^{18}O_{SW}$ trend error via the empirical mean $\delta^{18}O$-SST slope regression of −0.21‰/°C [*Ren et al.,* 2003].

[28] 3. The calibration slope and slope error of the coral Sr/Ca-SST regression is −11.39 ± 0.62 °C/mmol/mol (1σ) at Palmyra. This would yield an uncertainty in $\delta^{18}O_{SW}$ trends of ±0.01‰ (1σ), which is the difference between the minimum and maximum trends calculated with analytical error. Similarly calculations applied to Fanning and Christmas yield uncertainties in $\delta^{18}O_{SW}$ trends of ±0.01‰ and ±0.02‰ (1σ), respectively.

[29] 4. The empirical slope for coral $\delta^{18}O$-SST regression is −0.21 ± 0.03‰/°C following values compiled by *Ren et al.* [2003]. This would yield uncertainties in $\delta^{18}O_{SW}$ trends of ±0.03‰, ±0.04‰, and ±0.05‰ (1σ) at Palmyra, Fanning and Christmas respectively, which are the difference between the minimum and maximum trends calculated with when accounting for $\delta^{18}O$-SST slope error.

[30] 5. The fitting of trend line on coral-based $\delta^{18}O_{SW}$ records has slope errors of ±0.03‰ at Palmyra and Fanning, and ±0.04‰ at Christmas.

[31] Taken together, the late 20th century Palmyra coral-based $\delta^{18}O_{SW}$ trend and its associated uncertainty is −0.32 ± 0.07‰ (1σ) at Palmyra, −0.12 ± 0.08‰ (1σ) at Fanning and +0.03 ± 0.11‰ (1σ) at Christmas, quadratically combining terms (1)-(5) above for the uncertainty estimates.

5. Conclusions

[32] The revised uncertainty estimates for late 20th century (1972–1998) coral $\delta^{18}O$, Sr/Ca-derived SST and $\delta^{18}O_{SW}$ (SSS proxy) trends are significantly smaller than the uncertainties associated with the absolute values of these records. The reason for this difference is that relative changes in coral geochemistry (i.e., trends) are easier to quantify than the absolute value of, for example, Sr/Ca-derived SST, at any given point in the record. Our revised uncertainties make the observed coral proxy record trends statistically significant, strengthening the conclusions that robust late 20th century warming and freshening trends have occurred in the central tropical Pacific.

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