118-YEAR HYDROCLIMATE RECONSTRCUTION FROM CHRISTMAS ISLAND (INDIAN OCEAN): AN EXTENDED RECORD OF VARIABILITY IN THE INDONESIAN THROUGHFLOW

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STUDY MOTIVATION

Future climate trends indicate that changes in temperature and precipitation are likely to influence global supply chains, agricultural productivity, water security, health and well-being; particularly in densely populated nations across the southeast Indian Ocean region. The Indonesian Throughflow is an ocean current that transports low-latitude, warm fresh water from the western Pacific into the eastern Indian Ocean (figure 1). The Indonesian Throughflow has significant impacts on the climate and oceanography of the Indo-Pacific region. However, short coverage of observational records makes assessments of hydrological changes across the region challenging on longer timescales. Christmas Island, located in the southeast Indian Ocean (not to be confused with the Pacific Ocean Kiritimati Island), is located along an outflow of the Indonesian Throughflow. This Island is an ideal location to develop new palaeo-reconstructions of sea surface temperature and hydro-climate, extending our understanding of Indonesian Throughflow variability.

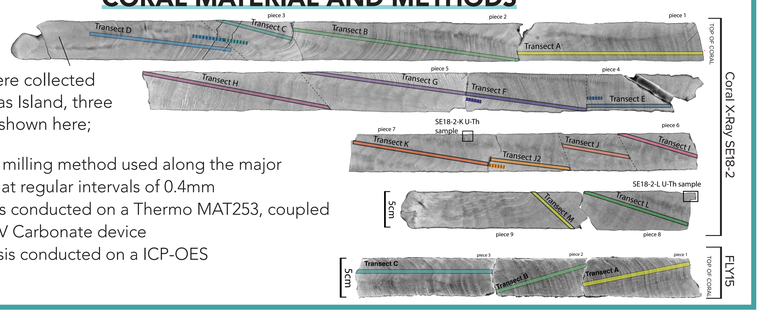
This study presents:

- **Monthly $\delta^{18}O$ and Sr/Ca from three Porities sp. colonies from Christmas Island**
- **Reconstruction of $\delta^{18}O_{seawater}$ at Christmas Island based on paired analysis, revealing Indonesian Throughflow variability for the region**

STUDY LOCATION

FIGURE 1. a) Average Salinity across the Indian Ocean, with an indication of Christmas Island,
b) top panel shows the location of previously published coral records (Coco's Keeling Island and Timor Island) along with Christmas Island and the location of main ITF currents in the area with a key.
c) inset of Christmas Island with locations of coral records used in this study.

CORAL MATERIAL AND METHODS



Five corals were collected from Christmas Island, three x-ray images shown here;

- Continuious milling method used along the major growth axis, at regular intervals of 0.4mm
- $\delta^{18}O$ analysis conducted on a Thermo MAT253, coupled with a KIEL IV Carbonate device
- Sr/Ca analysis conducted on a ICP-OES

SST CALIBRATION

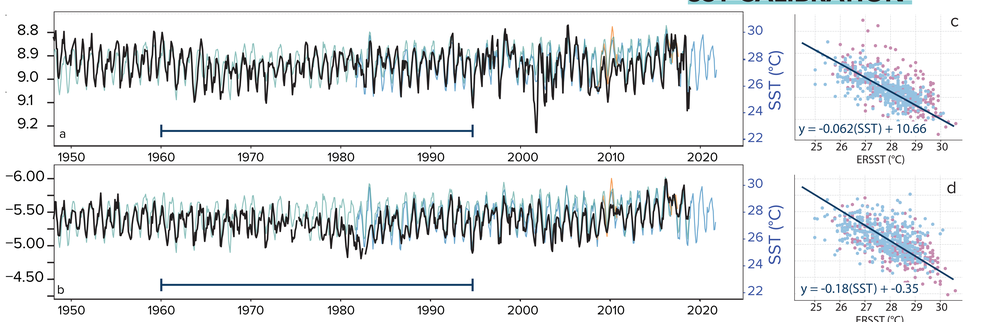


FIGURE 4. Monthly time series of the XI composite coral, **top** Sr/Ca and **bottom** $\delta^{18}O$. Monthly data are compared to ERSSTv5, with r-values displayed. **c and d** display the scatter plots of the SST, **top** Sr/Ca and **bottom** $\delta^{18}O$, blue data points are the values between 1960-1995 (with equation), purple are 1995-2018

KEY FEATURES

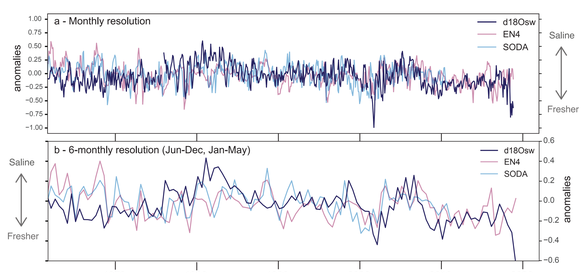
- 1960-1995 calibration period was used to determine slope and calculate $\delta^{18}O_{seawater}$ due to a reduced range in Sr/Ca results between 1999-2018.
- Reduced range is potentially due to thermal stress events between 1998-2018, with two bleaching level 2 thermal stress events and 5 smaller bleaching level 1 thermal stress events across the same period.
- Reconstructions of SST correlate well with Sr/Ca from 1960 onwards however prior to this SST is cooler than the Sr/Ca reconstructions.

SST Dataset	Core Data	r^2	n
ERSSTv5 monthly	**XI Composite (1960-2018)**	**-0.64**	**695**
OISSTv2 *monthly*	XI Composite (1982-2018)	-0.70	431

TABLE 2. Regression results for fig 4, and regressions for different periods across the corals. All regressions for the composite corals, with ERSSTv5 and OISSTv2

SST Dataset	Core Data	Method	Slope	Error	Intercept
ERSSTv5 monthly	**XI Composite (1960-1995)**	**WLS**	**-0.062**	**0.0023**	**10.67**
ERSSTv5 *monthly*	XI Composite (1995-2018)	WLS	-0.080	0.0040	11.19
OISSTv2 *monthly*	XI Composite (1995-2018)	WLS	-0.074	0.0036	11.02

$\delta^{18}O_{seawater}$ RECONSTRUCTION



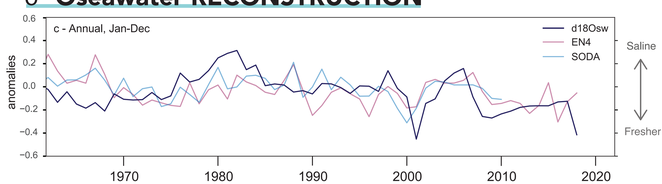


FIGURE 5. $\delta^{18}O_{sw}$ reconstruction using the Cahyarini et al., (2008) method. **A.** compared to EN4 product (pink), SODA (blue) at monthly resoltuion **B.** same datasets, at 6-monthly resoltuion. **C.** same dataset, however at annual resoltuion.

TABLE 4. Relationships between EN4 and SODA salinity datasets and XI composite $\delta^{18}O_{sw}$ reconstructions. Monthly relationships are not shown as they are not significant as the reconstruction error exceeds the salinity variability.

SSS Dataset	Resolution	Correlation r^2	p-value	n
EN4 (1980-2018)	6-monthly	0.32	0.0043	78
EN4 (1980-2018)	Annual (Jan-Dec)	0.38	0.016	39
SODA (1980-2010)	6-monthly	0.28	0.026	62
SODA (1980-2010)	Annual (Jan-Dec)	0.43	0.018	31

- Annual SSS range is 0.39psu, based on EN4. When transformed into $\delta^{18}O_{sw}$, assuming a $\delta^{18}O_{sw}$- SSS slope of 0.24‰/psu[3], it corresponds to a seasonal range of 0.09‰.
- The analytical error associated with $\delta^{18}O_{sw}$ is equivalent to 0.060‰ and as such the reconstruction error exceeds the seasonal range of SSS
- Reducing the resolution (transfering to 6-monthly) improves the relationship to salinity, and reduces the analytical error associated with $\delta^{18}O_{sw}$

INDONESIAN THROUGHFLOW COMPARISON

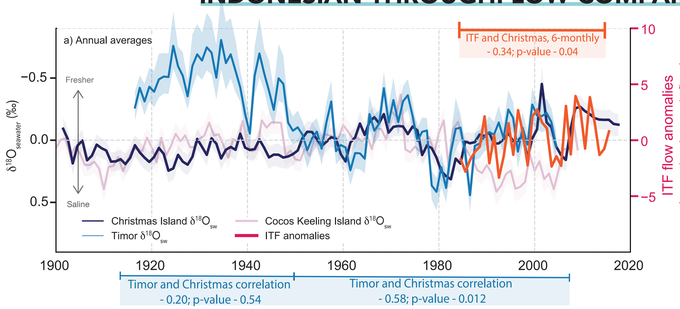


FIGURE 6.
Annual $\delta^{18}O_{sw}$ reconstructions for Christmas Island (dark purple), Cocos Keeling Island from Hennekam et al., (2018) (pink), Timor from Cahyarini et al., (2014) (blue) as well as the ITF observations from an XBT (orange) sourced from Feng et al., 2018.
Arrow on the left indicates the fresh vs saline conditions in the South East Tropical Indian Ocean.

KEY TAKEAWAYS

Corals from this region are reliable proxies for SST. Correlation between the coral $\delta^{18}O_{sw}$ reconstruction and SSS is not possible at monthly resolution, however at 6-monthly and annual resolution correlations are strong.

Coral $\delta^{18}O_{sw}$ reconstruction at this 6-monthly resolution reveals a strong relationship to ITF flow. Variability in ITF flow dominates the signal at Christmas Island with large increases in flow resulting in strong decreases in $\delta^{18}O_{sw}$ (indicative of freshened conditions).

Strong relationships and difference between records across Indian Ocean based coral $\delta^{18}O_{sw}$ reconstructions indicate there may be a mid-century shift in South East Tropical Indian Ocean hydroclimate.

REFERENCES

1 - Cahyarini, S.Y., Pfeiffer, M., Timm, O., Dullo, W.C. and Schönberg, D.G., 2008. Reconstructing seawater δ18O from paired coral δ18O and Sr/Ca ratios: Methods, error analysis and problems, with examples from Tahiti (French Polynesia) and Timor (Indonesia). Geochimica et Cosmochimica Acta, 72(12), pp.2841-2853.
2 - Hennekam, R., Zinke, J., van Sebille, E., ten Have, M., Brummer, G.J.A. and Reichart, G.J., 2018. Cocos (Keeling) corals reveal 200 years of multidecadal modulation of southeast Indian Ocean hydrology by Indonesian throughflow. Paleoceanography and Paleoclimatology, 33(1), pp.48-60.
3 - Cahyarini, S.Y., Pfeiffer, M., Nurhati, I.S., Aldrian, E., Dullo, W.C. and Hetzinger, S., 2014. Twentieth century sea surface temperature and salinity variations at Timor inferred from paired coral δ18O and Sr/Ca measurements. Journal of Geophysical Research: Oceans, 119(7), pp.4593-4604.
4 - Feng, M., Zhang, N., Liu, Q. and Wijffels, S., 2018. The Indonesian throughflow, its variability and centennial change. Geoscience Letters, 5(1), pp.1-10.